CONODONT BIOSTRATIGRAPHY OF THE BAKKEN AND LOWER LODGEPOLE

FORMATIONS (DEVONIAN AND MISSISSIPPIAN),

WILLISTON BASIN, NORTH DAKOTA

by
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This thesis submitted by Timothy P. Huber in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

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This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School at the University of North Dakota and is hereby approved.

Dean of tKri Graduate School

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ABSTRACT

Fourteen cores were sampled and processed, and conodonts obtained were used in the biozonation of the Bakken and basal Lodgepole Formations in the Williston Basin in North Dakota. The Bakken Formation of Devonian and Mississippian age and the Lodgepole Formation, entirely of Mississippian age, are subsurface units in North Dakota. The Bakken Formation (44 metres thick) consists of, in ascending order: a lower, dark, organic shale; a middle calcareous siltstone that is divisible into three lithic units; and an upper, dark, indurated, organic shale. The Lodgepole Formation (160 to 260 metres thick) is an argillaceous, fossiliferous limestone near the Basin center that varies to oolitic and skeletal limestone near the Basin margins.

Conodonts were recovered from the three members of the Bakken, by oxidizing in household bleach, and from the basal 15.5 metres of the Lodgepole, by treatment in acetic acid, in 10 of the 14 cores sampled. The 1963 discrete elements recovered were placed in 95 species-level form-taxa assignable to 22 form-genera: 15 percent (289) from the lower member of the Bakken, less than 1 percent (3) from the middle member of the Bakken, 47 percent (930) from the upper member of the Bakken, and 37 percent (741) from the basal Lodgepole. Twenty-five Bakken Formation form-taxa and all 61 Lodgepole Formation form-taxa are reported for the first time. Three-fourths (919) of the Bakken specimens were obtained from three, separate, thin, lag zones, one in the lower member of the Bakken and two in the upper member of the Bakken. No lag zones were observed in the Lodgepole. Lags may have resulted from accumulation of

coarse-grained fossil and inorganic debris under sediment-starved conditions, winnowing out of fine-grained elastics and organic material during deposition that concentrated coarse-grained fossils and inorganic material, and selective winnowing of partially lithified sediment by evanescent currents. Lags are important stratigraphically but are of little value in recognizing specific conodont biozones.

At least one Famennian (Lower Palmatolepis gracilis expansa) and possibly five Kinderhookian (siphonodellld) conodont biozones were recognized in the Bakken and basal Lodgepole Formations, Thirty-eight biostratigraphically useful form-species were used for recognition of the biozones. Form-genera recovered include, in order of decreasing abundance (species-level form-taxa listed in parentheses): Siphonodella (9), Polygnathus (9), Pseudopolygnathus (5), "Spathognathodus" (5), Palmatolepis (3), Bispathodus (3), Dinodus (2), Branmehla (1), and Elictognathus (1). Conodonts obtained from the lower member of the Bakken suggest the presence of the palmatolepid-polygnathid biofacies indicative of an outer shelf environment.

Siphonodella sulcata, from the upper member of the Bakken, suggests that this member may be as old *as* earliest Kinderhookian, but because of its association in lag zones with conodonts representative of younger biozones, its stratigraphic significance is diminished. Due to the paucity of conodonts in the middle member, further refinement of the Devonian-Mississippian systemic boundary was not possible. The conodont fauna supports the concept of continuous sedimentation from the Bakken Formation into the Lodgepole Formation.

INTRODUCTION

General Statement

        This study is a continuation of a number of recent studies that
have been undertaken to gain insight into the paleontology,
biostratigraphy, and petroleum geology of the Bakken and Lodgepole
Formations in the Williston Basin of North Dakota. In general, the
purpose of this study is to evaluate the conodont fauna recovered from
the Bakken Formation of Devonian and Mississippian age and from the
basal 15 metres of the Lodgepole Formation of Mississippian age.
Specifically, conodonts are used to expand the present collection of
Williston Basin elements used for correlation of North Dakota strata
with similar stratigraphic units in areas adjacent to the Williston
Basin. In addition, the strata that contain the conodonts are fitted
into the worldwide conodont zonation scheme recognized for late Devonian
and early Mississippian strata. Finally, numerous conodonts were
recovered from "lag zones" within the upper and lower shale members of
the Bakken Formation. The distribution and significance of these lags
is discussed.

Geologic Setting of the Williston Basin

        The regional geology of western North Dakota, northwestern South
Dakota, eastern Montana, southeastern Saskatchewan, and southwestern
Manitoba is dominated by an intracratonic structure known as the
Williston Basin. The Williston Basin encompasses more than 93,000
square kilometres and contains a vertical section of sedimentary rock

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slightly more than 4,880 metres in thickness with units representative of every Phanerozolc system. The Williston Basin, during the Paleozoic and early Mesozolc, was a shallow depression or broad cratonic area bordered on the west by Cordilleran miogeocline sediments, derived from orogenic uplift farther to the west, and on the east by the Precambrian shield of the North American craton (Sandberg, 1962). Gerhard and others (1982, p. 991) reported that seismic data indicate a relation between a change in the trend of the central Rocky Mountains and the structural grain of the Williston Basin.

Ballard (1963) mapped a number of structural elements present within the Williston Basin; he showed a north-south trending division that separates at least two major provinces of Precambrian rock as a hingeline that also separates his eastern shelf area from the western Basin proper. Ballard (1963), Laird (1964), and Gerhard and others (1982) have considered this hingeline a significant part of the Williston Basin's growth and development, especially as a prominent variable in the type of sedimentation and thickness of accumulation that occurred during the Paleozoic and early Mesozolc. More recently, Green and others (1985), Sims and Peterman (1986), and Bickford and others (1986) have shown that the Precambrian crystalline rocks that underlie the Phanerozolc section of sedimentary rock in the northern midcontinent have undergone a more complex tectonic history during the Cryptozoic than was understood by earlier workers. The outline of the Williston Basin and major structures in the Basin are shown in Figure 1.

Previous Work

Early Stratigraphy and Nomenclature

Prior to the ready availability of subsurface data from the
Williston Basin, much of what was known of the stratigraphy,
specifically of Devonian and Mississippian strata, of the northern Great
Plains was inferred from outcrops in Montana, Wyoming, Utah, Idaho, and
Alberta.

Stratlgraphlc analysis of Devonian and Mississippian strata in this
region was initiated by Peale (1893) in the Three Forks area of
Montana. He proposed (p. 32) two formations, of Devonian age, the
Jefferson and the overlying Three Forks, and two "Carboniferous"
formations, the Madison and overlying Quadrant. Peale divided (p. 32)
the Madison into three distinct lithologic units: lowermost "Laminated
limestones," middle "Massive limestones," and uppermost "Jaspery
limestones." Although Peale provided lithologic descriptions, faunal
lists, and a number of detailed cross sections and surface maps, he
failed to designate type sections for any of his "formations." Weed
(1899) compiled stratlgraphlc descriptions of Devonian and Mississippian
rocks in the Little Belt Mountains of Montana. He (p. 290) recognized
"three lithologically distinct horizons" in what today would be called
the Madison Group: "Paine shales," "Woodhurst limestone," and "Castle
limestone."

Collier and Cathcart (1922) were the first workers to employ
terminology and descriptions that considered the Madison limestones as a
true group. They studied (p. 173) stratlgraphlc sections in the Little
Rocky Mountains and determined that the Madison limestones become a

group that is divisible into two formations: the basal Lodgepole Limestone and the overlying Mission Canyon Limestone. Sloss and Hamblin (1942, p. 314, 315) stated that, on the basis of lithologic and faunal elements, Weed's (1899) "Castle limestone" is identical to Collier and Cathcart's (1922) Mission Canyon Limestone. Further, Sloss and Hamblin (p. 315) proposed "that Weed's lower divisions of the Madison, Paine and Woodhurst be treated as members of the Lodgepole limestone" and the terms be used as such throughout Wyoming and Montana. However, Sando (1967, p. D31) reported that the Lodgepole and Mission Canyon Formations are not distinguishable as distinct lithic units in Wyoming except in the westernmost part. Where the Madison cannot be subdivided it is treated as a formation, the Madison Limestone. Figure 2 summarizes the nomenclature of the Madison Group.

Although progress had thus been made toward understanding the Devonian and Mississippian stratigraphy of Montana and Wyoming* a type section for the Madison had not been designated or defined. Sloss and Hamblin (1942, p. 313) suggested that a type section for the Madison might be considered along the Gallatin River at Logan, Montana. Holland (1952, p. 1703) agreed with Sloss and Hamblin[1]s location for the type section and proposed a locality. Sando and Dutro agreed (p. 4) with Holland (1952) that the type section for the Madison Group is on the Gallatin River; however, they further defined the Madison type locality and provided a detailed stratigraphic section with accompanying paleontological information as well as gave stratigraphic descriptions of the type localities of the subdivisions of the Madison.

Seager and others (1942, p. 1420, 1421) suggested that the terms

Lodgepole, Mission Canyon and the newly named evaporite unit, the Charles Formation (Seager, 1942, p. 864), be used for Madison units in the Williston Basin (Fig. 3). The lithology of the Madison Group is quite variable in the subsurface and formational contacts are gradational. This has resulted in much discussion regarding units and formational contacts within the Williston Basin.

Overview of the Madison Group in the Williston Basin, North Dakota

The Madison Group in the Williston Basin is a succession of carbonates and evaporites approximately 600 metres thick. The group is composed of three formations, in ascending order, the Lodgepole Formation, Mission Canyon Formation, and Charles Formation (Fig. 3).

The Lodgepole Formation is up to 275 metres thick in the central Williston Basin. It is composed of fossiliferous, shaly, or cherty argillaceous limestone in the Basin center that varies to a grain-supported, oolitic, and skeletal limestone toward the Basin margins (Sandberg, 1962, p. 59).

The Mission Canyon Formation varies from a dark, argillaceous, skeletal limestone that is very similar to the underlying Lodgepole, to a lighter-colored, skeletal, and oolitic limestone that grades into evaporites toward the top. The Mission Canyon Formation is up to 236 metres thick in the central Williston Basin (Sandberg, 1962, p. 60).

The Charles Formation ranges up to 220 metres thick and consists of interbedded limestone, dolostone, and evaporites, primarily anhydrite and halite (Sandberg, 1962, p. 61).

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Because of the difficulty in establishing reliable and consistent
formational contacts between the three subsurface formations of the
Madison Group in the Williston Basin, stratigraphic intervals bounded by
unique, geophysical, log deflections were established for correlation of
units within the Basin. Ower (1953), Thomas (1954), and Fuller (1956)
were among the first workers to employ this marker-based stratigraphic
subdivision.

The Saskatchewan Geological Society, meeting in 1956 to discuss the
establishment of Mississippian subsurface nomenclature and correlation,
recognized Fuller's concepts but revised and proposed clearer, log-
defined, marker-bounded intervals for the Madison Group. They were, in
ascending order, the Souris Valley Beds, Tilston Beds, Frobisher-Alida
Beds, Middle Beds, Ratcliffe Beds, and Poplar Beds (see Waters, 1984,
p. 17-21 for complete discussion). Fuzesy (1960) implemented the
nomenclature proposed by the Saskatchewan Geological Society, as well as
discussed smaller subdivisions he created, as it applied to
Mississippian strata in southern Saskatchewan. Smith (1960) reevaluated
the proposals of the Saskatchewan Geological Society. Because Smith's
complete report was never published, Anderson and others (1960) and
Carlson and Anderson (1966) discussed Smith's redefinitions. Although
Figure 4 summarizes the subsurface nomenclature of the Madison Group in
the Williston Basin, not all of the units of the Madison are discussed
here—only those, in the order in which they were named, that are
germane to this study.

Lodgepole Formation

Knechtel and others (1954, p. 2397, 2399) proposed that the type locality of the Lodgepole Limestone be at a section exposed in the Little Chief Canyon of Lodgepole Creek in the Little Rocky Mountains of Montana. Sando and Dutro (1974, p. 17) agreed with Knechtel and others and further defined the locality, description, and thickness of the Lodgepole type section. Sando and Dutro (1974, p. 4) also suggested that Weed's (1899) terms "Paine shales" and "Woodhurst limestone" be revised to the Paine Member and the Woodhurst Member of the Lodgepole Formation to reflect the appropriate subdivision of this formation.

In discussing the Lodgepole Formation at its type locality at Little Chief Canyon in Montana, Knechtel and others (1954, p. 2395) recognized a "thin conodont bearing black shale unit" at the its base. They named this unit the Little Chief Canyon Member of the Lodgepole Limestone. Later, Klapper (1966), Sandberg and Mapel (1967), and Sandberg and Klapper (1967) reported that the dark shale unit at Little Chief Canyon is the only outcrop of the upper member of the Bakken Formation (named as a subsurface unit in North Dakota by Nordquist, 1953). Further, the shale unit identified by Knechtel and others (1954) at Logan, Montana, was referred by Sando and Dutro (1974, p. 3) to the Cottonwood Canyon Member of the Lodgepole; and they, therefore, said that, "Such usage obviates the necessity for the term Little Chief Canyon Member," which was abandoned. The Cottonwood Canyon Member of the Madison Limestone (or Lodgepole Limestone where present) was named by Sandberg and Klapper (1967) for exposures of what Sandberg (1963, 1965) had previously called a pervasive "dark shale unit" in northern

Wyoming and southern Montana. Sandberg and Klapper (1967, p. B33) recognized two tongues of the member that are separated by an unconformity and laterally divided into an eastern dolomitic llthofacies and a western dark, organic-rich, shale llthofacies. Sando and Dutro (1974, p. 21) concluded that the Lodgepole at its type locality is 555 feet (169 m) thick and consists of two members, in ascending order: Paine Member and Woodhurst Member. Although Sando and Dutro (1974, p. 1) recognized the Cottonwood Canyon Member of the Lodgepole in the two Montana sections they evaluated, they did not fully describe it. Thus, the Lodgepole is composed of three members, in ascending order: Cottonwood Canyon Member, Paine Member, and Woodhurst Member.

The term Lodgepole Formation was introduced into the Williston Basin by Seager and others (1942, p. 1420, 1421) for strata that are nearly identical to the lithologies of the type section in Montana. Stanton (1956) proposed intraformational terminology for the Lodgepole Formation in Manitoba with application in northern North Dakota. He proposed (p. 79) subdivision of Lodgepole strata in the Virden, Manitoba area into units considered to be of member rank based on well-developed log deflections that occur within the Lodgepole Formation toward the margins of the Basin. These units were, in ascending order, the Scallion, Virden (Upper and Lower), and Whitewater Lake "members." Additionally, Stanton recognized a succession of younger strata conformably overlying the Whitewater Lake "member." McCabe (1963, p. 17) proposed the name "Flossie Lake member" for these unnamed strata.

Carlson and Anderson (1966) divided the "lower Madison" in the center of the Basin Into three subintervals, in ascending order: LI,

L2, and L3. Carlson and Anderson's subdivision of the "lower Madison" (here taken as essentially the Bottineau interval) was based on additional gamma-ray well-log deflections that are not the same as those recognized at the Basin margins. Heck (1978, 1979) studied the Lodgepole Formation in North Dakota and implemented the nomenclature of Stanton (1956), Smith (1960), and McCabe (1963). LeFever and Anderson (1984) discussed the petroleum potential and reservoir characteristics of the "carbonate unit (L2) subinterval" of the Lodgepole in the "central basin fades" in northwestern North Dakota. Figure 5 summarizes the terminology that has been used for the Lodgepole Formation or the Bottineau interval in the Williston Basin, North Dakota. Some interpretation is here made in Carlson and Anderson's (1966) column in Figure 5 in that correlation of Lodgepole subdivisions from Basin center to Basin margin is not completely understood because of a lack of traceable log-markers and a lack of occurrence of stratigraphically diagnostic fossils crossing the two areas.

During this study, the Lodgepole has been considered as a formation of the Madison Group, and this report is primarily concerned with the basal 10 to 15 metres of the formation. As will be shown, conodont occurrence and abundance decrease abruptly up section within the Lodgepole and, therefore, the relation of conodont biostratigraphy to log-defined intervals is not definitely discernable. It is presumed that all of the conodonts obtained in this study are from the LI subinterval of the Bottineau interval. The portion of the Lodgepole germane to this study is the basal part of the Lodgepole Formation and this will hereafter be referred to as the basal Lodgepole.

Bakken Formation

Nordquist (1953, p. 72) named the Bakken Formation and recognized it as a "thin clastic zone" lying between the Madison Group and Upper Devonian rocks throughout the Williston Basin (Fig. 3). Nordquist (1953, p. 72) defined the Bakken as the strata that lie between 9615 and 9720 feet (Fig. 6) in the Amerada Petroleum Corporation, H. 0. Bakken No. 1 well, Williams County, North Dakota (NDGS Well No. 32). Whereas the type section of the Bakken is 105 feet thick, Webster (1982, p. 18) stated that the Bakken attains a maximum thickness of 145 feet just east of the Nesson anticline in western Mountrail County, North Dakota.

Nordquist (1953) assigned an early Mississippian (Kinderhookian) age to the Bakken Formation in North Dakota. He also recognized (p. 74) the stratigraphic equivalence of the Exshaw shale in Canada with the Bakken saying that Crickmay (1952) had repudiated the Devonian age of the Exshaw Formation and had assigned a Kinderhookian age to it.

Sandberg and Hammond (1958, p. 2326, 2328), as a part of their summary article on the Devonian System in the Williston Basin, suggested that the Bakken is not entirely of Mississippian age. Penner (1958, p. 264) proposed that strata exhibiting lithic and stratigraphic continuity with the typical Bakken section in the subsurface of southeastern Alberta also be called Bakken.

Kume (1963) presented stratigraphic descriptions, isopach maps, and cross sections in attempting to determine the relation between outcrops of the Englewood Formation in South Dakota and the Bakken Formation in North Dakota. Ballard (1963, p. v), using mechanical well logs, determined the thickness and areal extent of Paleozoic rock units in the

Figure 6.   Type section of the Bakken Formation.   Amerada Petroleum
            Company, H. O. Bakken No. 1 Well (NDGS Well No. 32).
            From Kume (1963, p. 30).

North Dakota portion of the Williston Basin. He used (p. 18) Kume's (1963) data and agreed with Kume's conclusions. Both of these workers, based on paleontologlc work compiled by others, placed the Bakken as the basal formation in the Mississippian System.

The potential for petroleum production from the Bakken Formation in the Williston Basin has long been recognized. Many studies have contributed to the petroleum geology of the Bakken. Murray (1968) discussed oil production and fracturing of the "Sanish sandstone" at the top of the Three Forks Formation. He stated (p. 65) that the shales of the Bakken are "supercharged oil shales" and the immediate source for oil in the Sanish pool of the Antelope field. Williams (1974) discussed the types of oil that have been generated in the Williston Basin. He recognized and correlated oil types based on carbon-isotope ratios. He reported that most oil found in Mississippian reservoirs is Type II oil and was probably generated from the Bakken shales. Dow (1974) followed Williams' (1974) report by presenting a discussion of Bakken oil, oil migration, and recognition in adjacent rock units. Meissner (1978) presented a synthesis of the petroleum geology of the Bakken including reservoir properties, source-rock properties, well-log characteristics, fracturing, and petroleum potential. Thode (1981), using sulfur isotope ratios, reproduced Williams' (1974) results in distinguishing between the three oil types present within the Williston Basin. Webster (1982, 1984) used a variety of geochemical techniques (organic carbon measurements, pyrolysis, vitrinite reflectance) to evaluate the organic-rich shales of the Bakken as petroleum source rocks. Hester and Schmoker (1983) produced preliminary log-derived maps of the Bakken

Formation, including formation density and organic-carbon content, that

they later (Hester and Schmoker, 1985) expanded and made more complete

for the United States portion of the Williston Basin. Schmoker and

Hester (1983) determined the approximate organic-carbon content of the

Bakken shales and also estimated the volume of hydrocarbons released by

the Bakken in the southern half of the Williston Basin. Wilson (1983)

reported on aspects of the petroleum geology and cumulative (to April,

1982) petroleum production of the Bakken Formation in North Dakota.

Hayes (1984) discussed the thermal maturation of the Bakken based on

conodont alteration indices (CAI) established by Epstein and

others (1977) and further discussed by Harris (1981).

Regional Stratigraphy and Correlation

Stratigraphy

The Bakken Formation in North Dakota, Manitoba, Saskatchewan, and

eastern Alberta is composed of a lower, dark, organic-rich shale member,

a middle calcareous siltstone member, and an upper organic-rich shale

member of a character similar to that of the lower member. This

particular succession of lithologies is represented in the northern and

western midcontinent by the Leatham Member of the Pilot Shale and the

upper member of the Pilot Shale in Utah, the Leatham Formation in

northern Utah, the Sappington Member of the Three Forks Formation in

west-central Montana, and the Exshaw Formation in southern Alberta. In

addition, a significant portion of the Englewood Formation and the

Cottonwood Canyon Member of the Madison also occur at the same

approximate stratigraphic level as the Bakken, and although the

lithologies of the Cottonwood Canyon and Englewood are different from those of the Bakken, the conodont faunas recovered from them establish equivalent age relation. Figure 7 summarizes the correlation of these and the overlying units based primarily on reported conodont occurrence. The western Alberta column presented in Figure 7 is slightly modified from that presented by Hacqueen and Sandberg (1970, fig. 4) in that they diagrammed their siltstone unit extending into the Upper Devonian. However, they stated (p. 53) that, based on the occurrence of broken specimens of Siphonodella from the basal siltstone unit and upper part of the dark shale unit, both units are Kinderhookian. For this reason, 1 have recognized the potential facies relationship and definitive Kinderhookian age for the siltstone unit.

Stratigraphic details of the Bakken Formation in southern Saskatchewan have been discussed by a number of Canadian workers. Reasoner and Hunt (1954, p. 1539) recognized the Bakken in the subsurface of Saskatchewan and termed the middle member of the Bakken the "Coleville Sand." However, Kume (1963, p. 41, 42) stated that this usage should not be continued, even informally. Fuller (1956) discussed aspects of the Bakken and noted its usefulness as one of the most important subsurface markers in the Williston Basin. McCabe (1959) and Rents (1959) reported on the lithologic character and stratigraphic relationship of the Bakken to adjacent units in the subsurface in Manitoba and Saskatchewan, respectively. Christopher (1961, 1962) discussed the areal extent, lithology, structure, deposition, and petroleum potential of the Bakken and adjacent units in Saskatchewan. Macauley and others (1964) summarized the surface and subsurface

Figure 7. Correlation chart of the Bakken and Lodgepole Formations and
their equivalents in the northern and western midcontinent.
Conodont biozones are from Sandberg (1979) and Ziegler and
Sandberg (1984). Biozone abbreviations are (U) Upper, (M)
Middle, and (L) Lower. Sources of information for each
column correspond to numbers enclosed in parenthesis and are
as follows: (1) Gutschlck and Rodriguez (1979); (2) Sandberg
and others (1980); (3) Sandberg and Gutschlck (1969);
(4) Sandberg and Poole (1977); (5) Sandberg and Gutschick
(1979); (6) Sandberg and others (1972); (7) Gutschick and
others (1962); (8) Sandberg (1965); (9) Sandberg and Klapper
(1967); (10) Sando (1967); (11) Macqueen and Sandberg (1970);
(12) Klapper and Furnish (1962); (13) Klapper (1966);
(14) Hayes (1985); (15) Thrasher (1985); and (16) Huber (this
study). Break lines at the top of each column and at the
base of certain columns indicate that the particular unit
extends beyond the confines of this figure.

stratigraphic data presented by other Canadian workers for the Bakken
and Lodgepole, or their equivalents, in western Canada.

In the only study to report the conodont fauna of the Bakken
Formation in the North Dakota portion of the Williston Basin, Hayes
(1984, 1985) determined that the Bakken Formation in North Dakota was,
indeed, Devonian and Mississippian in age. Thrasher (1985), who
recognized three stratigraphic units in the middle member of the Bakken
and with brachiopods correlated them with units in the upper Mississippi
Valley, placed the position of the systemic boundary at the base of his
unit 2.

Although the Englewood Formation in western South Dakota is not
traceable into North Dakota, it is stratigraphically and faunally
equivalent to the Bakken. Based on conodonts collected from exposed
sections of the Englewood, Klapper and Furnish (1962), and later Klapper
(1966), assigned a Devonian and Mississippian age to the Englewood.

Sandberg and Mapel (1967, p. 871) presented an isopach map of Upper
Devonian and Lower Mississippian units in the northern midcontinent.
They suggested (p. 872) that there may have been a connection between
the Bakken Formation in North Dakota, the Englewood Formation in South
Dakota, and the Cottonwood Canyon Member of the Lodgepole Formation in
Wyoming.

Sandberg and Poole (1977, p. 166) suggested that the lower shale
members of the Sappington Member of the Three Forks Formation, the
Leatham Formation, and the lower Leatham Member of the Pilot Shale
originally formed part of the same depositional complex, an idea that
was also supported by Gutschick and Rodriguez (1979, p. 38) and Sandberg

and others (1980, p. 72). Sandberg and others (1983) discussed Middle
Devonian to Late Mississippian geologic history of the Great Basin,
Rocky Mountains, and Overthrust belt region. They developed (p. 696) a
model containing a series of interpreted sea-level fluctuations and
tectonic events that resulted in deposition of the members of the Pilot
Shale and its lithic equivalents. They based the times of the events
they described on the phyletic evolution of conodonts (p. 695).

        Sandberg and Klapper (1967, p. Bl) reported that the Cottonwood
Canyon Member of the Madison Limestone (or Lodgepole Limestone where
present) has basal, coarse-grained lag zones that contain, among other
fossil and inorganic debris, abundant conodonts at the base of the upper
and lower tongue. Based on conodont collections recovered primarily
from the lags, they stated (p. B38, B39) that the lower tongue of the
Cottonwood Canyon Member is of late or latest Devonian age and the upper
tongue contains "three successive Early Mississippian conodont faunas."

Correlation

        Correlation of upper Devonian and lowest Mississippian units in the
northern Rocky Mountain region is based on faunal, lithic, and
stratigraphic similarities. Although the dark shale units may not have
been continuously connected, uniqueness of the depositional processes
and faunal environment produced components that make for remarkably
correlatable units (Fig, 7). Holland (1952) initially proposed the
equivalency of the Leatham Formation and what is now known as the
Sappington Member of the Three Forks Formation. Sandberg and others
(1972, p. 179) reported similar conodont faunas from uppermost Devonian

beds of the Sappington Member and its correlative, the Leatham

Formation. Sandberg and Mapel (1967, p. 872) stated that the Sappington

Member is continuous beneath the Snake River flexure in eastern Idaho

and that the lithologically and faunally identical rocks in southeastern

Idaho and northeastern Utah, known as the Leatham Formation, are the

southern extension of the Sappington Member. Sandberg and Poole (1970)

and later Sandberg and others (1972, p. 186) reported that the Leatham

Member of the Pilot Shale was the lithologic and faunal equivalent of

the Leatham Formation and the Sappington Member of the Three Forks

Formation.

Sandberg (1965, p. N16) reported that the Sappington Member of the

Three Forks Formation had been traced through the subsurface of

northeastern Montana and southern Alberta and is equivalent to the

Exshaw Formation; the lower shales are continuous and the siltstone beds

are nearly continuous except for a short interval of erosional thinning

in Montana. Further, Sandberg (1965, p. N17) stated that the Exshaw

Formation is continuous with the Bakken Formation in Alberta and

Saskatchewan. Sandberg, therefore, concluded (p. N17) that at least the

basal dark shale of the Sappington Member was continuous with the lower

member of the Bakken Formation in the Williston Basin, an idea

originally proposed by Sandberg and Hammond (1958, p. 2326). To the

north, Macqueen and Sandberg (1970, p. 32, 41, 47) said that the Exshaw

Formation was a correlative of the lower two members of the Bakken

Formation in Alberta and Saskatchewan and that this depositional complex

was equivalent to the Sappington Member of the Three Forks in Montana.

Sandberg and Hammond (1958) suggested (p. 2326) that strata at the

eastern and southern margins of the Williston Basin in North Dakota are direct correlatives of the Englewood Formation In South Dakota. Klapper (1966) discussed the similarity of the conodont faunas within the Englewood and the Cottonwood Canyon Member of the Madison Limestone. Sandberg and Klapper (1967) reported (p. B37) that the Cottonwood Canyon Member of the Madison Limestone is equivalent to the Englewood Formation. Further, they suggested (p. B37) that these two rock bodies may have been connected briefly during the earliest Misslssippian. Sandberg and Klapper (1967) discussed (p. B38, B39) the late Devonian-early Misslssippian deposltional complex composed of most of the Cottonwood Canyon Member, the Bakken Formation, the Exshaw Formation, and the Sappington Member.

Hayes (1984, p. 80; 1985, p. 71, 76), based on recovered conodont faunas, demonstrated the time equivalence of the Bakken with units to the north and west. He stated,'

> The Bakken Formation [In North Dakota] was deposited
> penecontemporaneously with thin, predominately clastic,
> units that Include the Exshaw Formation, Sappington Member
> of the Three Forks Formation, Leatham Formation, middle
> member (Leatham Member) of the Pilot Shale, Cottonwood
> Canyon Member of the Lodgepole Limestone, and Englewood
> Formation in the Northern Rocky Mountain region.

Figure 8 summarizes the areal distribution of the Bakken Formation and its time equivalents in the northern Rocky Mountain region and northern mldcontlnent.

Late Devonian and earliest Misslssippian deposition in the northern mldcontlnent and northern Rocky Mountains is characterized by formation of two dark marine shales with calcareous siltstones typically separating the dark shales. Overlying units of early Misslssippian age

Figure 8. Approximate regional distribution of the Bakken Formation
           (upper Famennian to lower Kinderhooklan) and partial time or
           lithic equivalents in the northern and western midcontinent.
           Slightly modified from Hayes (1984). Sources include
           Christopher (1961), Sandberg and Klapper (1967), Sandberg
           and Mapel (1967), Macqueen and Sandberg (1970), Sandberg and
           Poole (1977), Meissner (1978), and Gutschick and Rodriguez
           (1979).

N

Exshaw
Formation

Bakken Formation

ALBERTA

SASKATCHEWAN

MONTANA

NORTH DAKOTA

Sappington Member,
Three Forks Fm.

Cottonwood Canyon
Mem., Lodgepole Ls.
or Madison Ls.

Englewood

Formation

(part)

SOUTH DAKOTA

IDAHO

NEVADA

WYOMING

Leatham
Formation

Leatham Mem. &
upper mem.,
Pilot Sh.

UTAH

0   100
0   200 km

Approximate extant of unita   — — — —
Formation arbitrary eut-off   . . . .
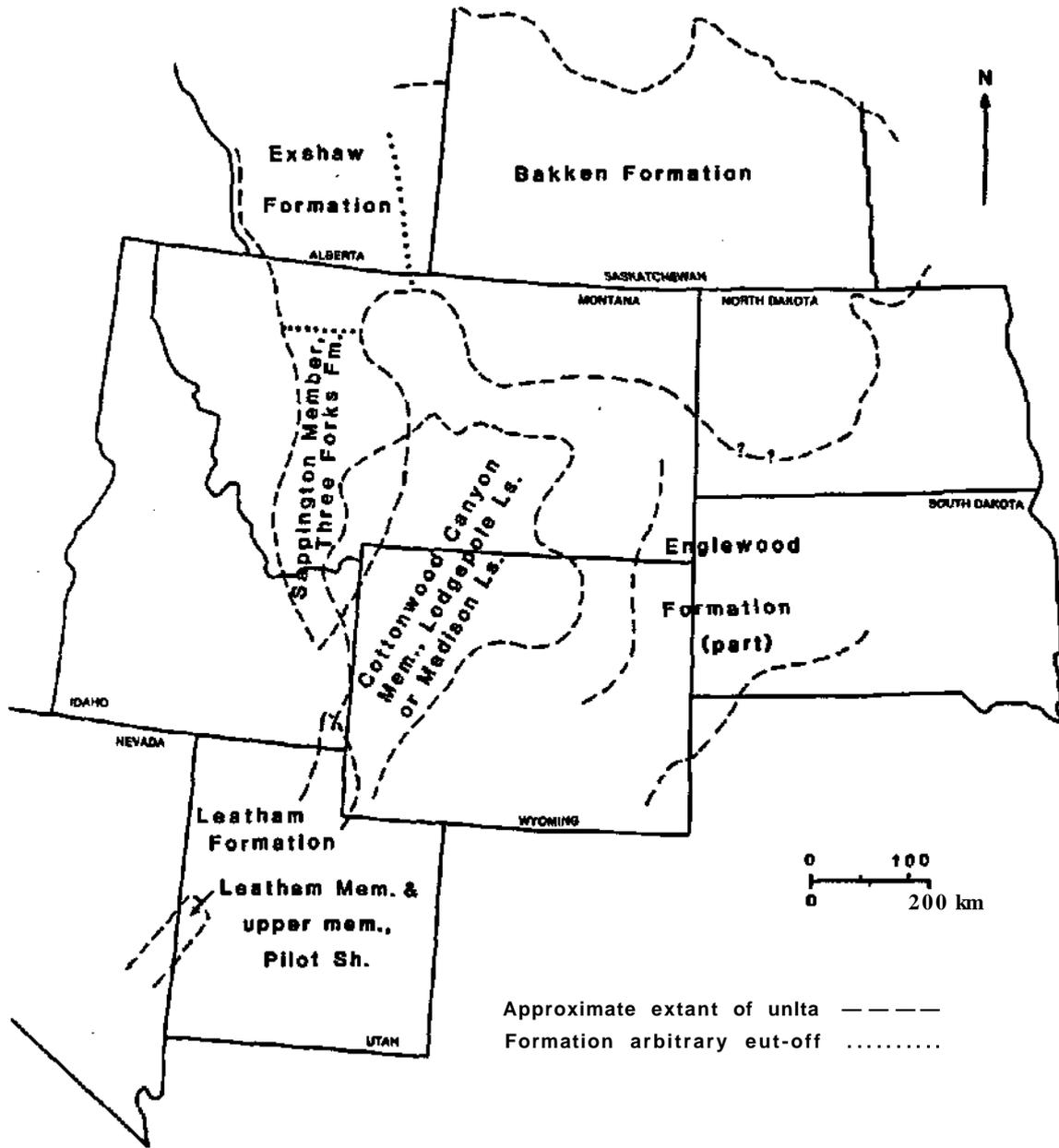
are characterized by beds of carbonate material (bloclastlc limestone or dolostone with varying amounts of argillaceous material) deposited from Klnderhookian seas that covered the entire region. Early Mississippian (but not earliest Mississippian) units occurring in the northern and western portion of North America include: Lodgepole Formation of the Madison Group in North Dakota, Montana, western Wyoming, central Utah, and the provinces of Manitoba, Saskatchewan, and Alberta in Canada; lower part of the Madison Limestone which is restricted to most of Wyoming and southeastern Montana; portions of the Englewood and Pahasapa Formations In South Dakota; and the Banff Formation in Alberta, Canada (Fig. 7). Regional dark shale units occurring near the base of the Lodgepole Include the Cottonwood Canyon Member of the Lodgepole Limestone, the Carrington shale lithofacies and Canadian equivalent Routledge shale of the Lodgepole Formation in southern Saskatchewan, Manitoba, and north-central North Dakota. Figure 9 presents the approximate regional distribution and areal extent of the Lodgepole Formation and stratigraphic equivalents.

   The Lodgepole Formation in the Williston Basin of North Dakota was reported (Heck, 1979, p. 24) to be composed of varying carbonate lithologies representing six lithofacies. Bjorlie (1979), Heck (1979), and Webster (1982) reported "a distinct lithologic unit" (Bjorlie, 1979, p. 10) occurring near the base of the Lodgepole Formation in the Williston Basin. This unit, known as the Carrington shale lithofacies, consists of green, mottled, dark-gray to red-brown shale with trace amounts of sand. It occurs in central North Dakota near the depositlonal limit of the Lodgepole. McCabe (1959) discussed (p. 26) a

Figure 9.   Approximate regional distribution of the Lodgepole Formation
            (middle Kinderhookian) and equivalents in the northern and
            western midcontinent. Sources include: McCabe (1963),
            Sandberg and Klapper (1967), Procter and Macauley (1968),
            Sandberg and others (1978), Heck (1979), Bjorlie (1979),
            Gutschick and others (1980), Sandberg and others (1983).
            Diagonally-ruled area Indicates distribution of isolated and
            poorly exposed outcrops of several units, for example, the
            Allan Mountain Limestone, Slope Limestone, McGowen Creek
            Formation, and Eleana Formation (adapted from Sandberg and
            others, 1983, p. 708).

similar lithology and stratigraphic position of two shale bodies in southwestern Manitoba and north-central North Dakota. McCabe proposed that these strata be named the Routledge shale and concluded that these shales were a lithofacies of the Lodgepole in Canada.

Procter and Macauley (1968) demonstrated the extensiveness of the Lodgepole Formation and overlying carbonate and evaporite units in western Canada and the Williston Basin. McCabe (1959) discussed aspects of Madison Group lithology, stratigraphy, and correlation in southern Manitoba. MacDonald (1956) and Fuller (1956) discussed similar characteristics of the Lodgepole in Saskatchewan and Penner (1958) detailed Mississippian subsurface stratigraphy and its relation to adjacent units in southern Alberta.

The limestone and shale of the Madison Group, and specifically the Lodgepole Formation, have been traced, almost continuously, in subsurface cores and exposed sections from North Dakota into Montana, Wyoming, Utah, Nevada, and north and west across the Canadian provinces of Manitoba, Saskatchewan, and Alberta. This succession of carbonate rock is one of the most widespread units in North America. Faunal and floral elements that are used for correlation include: conodonts, foraminiferides, algae, spores, corals, and brachiopods (Sando and others, 1969, p. El; Gutschick and others, 1980, p. Ill; and Sandberg and others, 1983, p. 707). Muller (1962b), Klapper (1966), and Sandberg and Klapper (1967) have demonstrated, with regional conodont studies, that the Lodgepole Limestone (Madison Limestone in Wyoming), or its exact equivalents, are Kinderhookian in age. The Cottonwood Canyon Member has been determined by Sandberg and Klapper (1967) to be of late

Devonian to early Mississippian (through the _Siphonodella sandbergi_

Biozone) age. The Routledge and Carrington shales in southern Manitoba

and North Dakota occupy the same approximate stratigraphic position as

the upper tongue of the Cottonwood Canyon Member; however, no diagnostic

fossils have been reported from these shale units. Klapper and Furnish

(1962) and Klapper (1966) have reported conodont faunas from the upper

Englewood and lower Pahasapa Formations in South Dakota that are the

same age as those recovered from the Lodgepole Formation at its type

locality and from the basal Banff Formation in Canada. Macqueen and

Sandberg (1970, p. 54) demonstrated that the conodont fauna recovered

from the basal Banff Formation is of Klnderhookian age and, therefore,

equivalent to a position low in the Paine Member of the Lodgepole

Formation in Montana.

Late Devonian-Early Mississippian

Conodont Blostratigraphy

In establishing the stratigraphic position and accuracy of

correlation of late Devonian-early Mississippian formations, workers

sought a common link by which these stratigraphic units could be

compared. Conodont elements provided this link; they are numerous,

widespread, and evolved rapidly, making them one of the best

stratigraphic index fossils of Paleozoic strata worldwide.

Knechtel and Hass (1938) were among the first to document the

presence of Klnderhookian conodonts in the northern midcontinent. They

extracted specimens from a thin black, fossiliferous shale at the base

of the Lodgepole Formation in the Little Rocky Mountains, Montana and

attributed a Kinderhookian age to the strata based on comparison with faunal collections in Missouri. Included in their faunal list (p. 519) are specimens of the form-genus Palmatolepis that were recognized as being indicative of Devonian strata by Branson and Mehl (1933b) from collections they made in Missouri. Hass (1943) addressed these apparently anomalous specimens of Palmatolepis by suggesting that their presence may have been the result of stratigraphic admixture. Hass (1943) also reviewed and revised assignment of specimens in the Little Rocky Mountain collection of conodonts made by Knechtel and Hass (1938).

Cooper and Sloss (1943) expanded the number of specimens collected from, and localities of occurrence for, a Lower Mississippian black shale. They also suggested (p. 168) that the exposed shale be correlated with a similar subsurface black shale ("Exshaw") in eastern Alberta. Raasch (1956) conducted a biostratigraphic study on a core from Alberta. He presented (p. 113, 114) a list of conodonts recovered from the Exshaw, but did not assign a definite age to this interval of core. Muller (1962b) recovered and identified a small conodont fauna from the basal Banff Formation in western Canada. Achauer (1959) collected a number of conodonts and fossil spores from the "Sappington Formation" in southwestern Montana. Sandberg and Klapper (1967, p. BIO, Bll) suggested that conodonts collected from all thin beds at the top of the Sappington Member of the Three Forks Formation may be more logically referred to the Cottonwood Canyon Member of the Lodgepole as similar conodonts have been recovered from a thin basal lag deposit in the Cottonwood Canyon Member.

Sandberg and Mapel (1967) presented a regional correlation chart

(p. 846, 847) for Upper Devonian and Lower Mississippian units in the northern and western midcontinent. They used conodont, brachiopod, and ammonoid zonation to fit rocks close to the Devonian-Mississippian systemic boundary into a time-stratigraphic framework.

Conodonts recovered from the Pilot Shale have substantiated the age and correlation of the Pilot with other stratigraphically or lithologically similar units. Clark and Ethington (1967) obtained an extensive fauna from the Pilot and adjacent units. They recognized (p. 3) twelve conodont biozones in the Great Basin that corresponded "in sequence and important faunal elements to the zones defined in the Upper Devonian of Germany" (Ziegler, 1962). Sandberg and Ziegler (1973) made a more complete survey of the conodonts to refine the zonation of Clark and Ethington, making the conodont zonation more useful outside of the Great Basin.

Holland (1952), based largely on recovered brachiopods, assigned a Kinderhookian age to the Leatham Formation. Sandberg and Gutschick (1969), Sandberg and others (1972), and Sandberg and Gutschick (1979) discussed the ages of the seven units of the Leatham based on recovered conodont faunas. Units 1, 2, and 3 of the Leatham contain conodonts representing the Lower Palmatolepis gracilis expansa Biozone of Ziegler and Sandberg (1984) (Upper Polygnathus styriacus Biozone sensu Sandberg, 1979, p. 91). An unconformity separates unit 3 of the Leatham Formation and a thin lag sandstone at the base of unit 4; unit 4 is characterized by having conodonts of the Upper Palmatolepis gracilis expansa Biozone of Ziegler and Sandberg (1984) (lower Middle Bispathodus costatus Biozone as presented by Sandberg, 1979, p. 91). Unit 5 and part of unit

6 of the Leatham Formation contain conodonts of the Siphonodella
praesulcata biozones. The remaining portion of unit 6 and unit 7 of the
Leatham Formation are devoid of fossils; and because of a Devonian fauna
below unit 6 and Mississippian conodonts of the upper tongue of the
Cottonwood Canyon Member above unit 7, it was said that a portion of
unit 6 and all of unit 7 of the Leatham Formation is Mississippian.

Based on collected conodont faunas, Sandberg and others (1972)
assigned a Late Devonian age to the Sappington Member of the Three Forks
Formation. Basal lag zones in unit 1 (units A-D of Gutschick and
others, 1962) were said to contain conodonts indicative of the Lower
Palmatolepis gracilis expansa Biozone of Ziegler and Sandberg (1984)
(Upper Polygnathus styriacus Biozone sensu Sandberg, 1979, p. 91) and
unit 5 (unit H of Gutschick and others, 1962) and unit 6 to contain
conodonts of the Siphonodella praesulcata Biozones. Gutschick and
others (1976) summarized the Upper Devonian and Lower Mississippian
biostratigraphy of western Montana. They discussed (p. 101-104) the
units of Gutschick and others (1962) and stated that because of the
presence of Kinderhookian conodonts, the uppermost unit, unit I, is
better placed in the Cottonwood Canyon Member of the Lodgepole
Limestone.

Macqueen and Sandberg (1970, p. 50) presented conodont evidence
from the Exshaw Formation, and circumstantial conodont and spore
evidence from the Sappington Member of the Three Forks Formation and the
Bakken Formation in Alberta, to suggest that the Exshaw Formation is
both Devonian and Mississippian in age. Conodont distribution is nearly
identical in all three of these units and provides the basis for

correlation; Upper Devonian strata are characterized by conodonts of the Lower _Palmatolepis gracilis expansa_ Biozone of Ziegler and Sandberg (1984) (Upper _Polygnathus styriacus_ Biozone in the sense of Sandberg, 1979, p. 91) and Lower Mississippian strata are characterized by conodonts of the Kinderhookian siphonodellid biozones. Macqueen and Sandberg (1970) stated (p. 32) that the Devonian-Mississippian "systemic boundary is probably positioned near the middle of the black shale unit" in the Exshaw Formation.

Using an extensive conodont collection recovered from the Cottonwood Canyon Member of the Madison, Sandberg and Klapper (1967) assigned a Late Devonian age for the lower tongue (Lower _Palmatolepis gracilis expansa_ Biozone of Ziegler and Sandberg, 1984; or Upper _Polygnathus styriacus_ Biozone as presented by Sandberg, 1979) and a tentative early Mississippian age for the upper tongue because of the uncertainties in the ranges of siphonodellid conodonts recovered at that time.

As the number of localities and diversity of conodont faunas recovered in the northern Rocky Mountains and northern midcontinent expanded, the need for developing a zonation compatible with particular aspects of North American occurrences and the conodont succession documented in Europe and Germany became necessary. Standard Upper Devonian conodont biozonation was proposed by Ziegler (1962) and has remained essentially unaltered except for minor emendations made by Ethington and Clark (1967), Ziegler (1971), Sandberg and Ziegler (1973, 1979), and Klapper and Ziegler (1979). Through the efforts of these workers, and numerous other European and North American workers, the

conodont zonation presented is applicable on a global scale.

Conodont biozonation of the Lower Mississippian has evolved slower than has the Upper Devonian scheme. Colllnson and others (1962) established the first attempt at synthesizing important ranges of diagnostic Mississippian conodont taxa from conodont occurrences in the upper Mississippi Valley and the North American midcontinent. Colllnson and others (1971) discussed the history of North American conodont zonation of the Mississippian and provided more defined ranges for key conodont taxa.

Through regional work that had already been compiled and projects that were on-going, Klapper (1966) produced the first attempt in creating an Upper Devonian and Lower Mississippian conodont biozonation scheme for like-aged strata in Montana, Wyoming, and South Dakota. He recognized three biozones regionally, one Upper Devonian and two Lower Mississippian. For the first time, a faunally based correlation was published that correlated the regionally recognized "dark shale units," Sappington Member of the Three Forks Formation, Englewood, basal Lodgepole and Pahasapa, and Madison limestones. In addition, 34 species-level conodont form-taxa used to establish regional biozonation were illustrated and discussed by Klapper (1966).

Sandberg and others (1972) reviewed the conodont biozonation and spore occurrence on both sides of the Devonian-Mississippian systemic boundary in the western and central United States and in Europe. A new conodont form-species, _Siphonodella praesulcata_, was collected, described, and illustrated from "very high Devonian beds" (unit 6) in the Sappington Member of the Three Forks Formation in Montana and the

Leatham Formation in Utah and recognized as a previously incorrectly described form found in other youngest Devonian strata in other parts of the world. Based on reevaluation and redescription of two diagnostic conodonts and spore assemblages, the highest part of the Devonian is recognized, in part, by Siphonodella praesulcata and diagnostic spores, including Hymenozonotriletes lepidophytus. Sandberg and others (1972, p. 179) also stated that the "Siphonodella sulcata Zone marks the base of the Carboniferous in North America and Europe."

Using a significant number of elements, representing nine important form-genera, from the regionally pervasive Upper Polygnathus stvriacus Biozone (Lower Palmatolepis gracilis expansa Biozone of Ziegler and Sandberg, 1984) in the Rocky Mountains and Great Basin of the western United States, Sandberg (1976) recognized five, major, conodont biofacies in paleotectonic settings ranging from continental rise to offshore bank and lagoon.

Sandberg and Poole (1977) synthesized knowledge of the Upper Devonian conodont succession and its relation to depositional packages that approximated their ideas of depositional environments in the western United States. In addition, Sandberg and Poole (1977), and later Sandberg and others (1983), used assumed durations for conodont biozones and calculated rates of sedimentation for stratigraphic units in the western United States.

Sandberg and others (1978) discussed the phylogeny, morphologic features, and the sequence of occurrence of the form-taxon Siphonodella. Based on detailed discrimination of oral surface ornamentation, these workers were able to define further the stratigraphic occurrence and

bio-utility of these predominantly Kinderhookian elements. A large number of articles dealing with siphonodellid zonation, presented after their article was published, are based on many of the ideas formulated by Sandberg and others (1978).

Sandberg and Zlegler (1979) presented the taxonomy, ranges, and phylogeny of biostratigraphically important conodonts from the Upper Devonian <u>Polygnathus stvriacus</u> Biozones (Lower and Upper <u>Palmatolepis perlobata postera</u> Biozones and Lower P. <u>gracilis expansa</u> Biozone of Zlegler and Sandberg, 1984). They emphasized biofacies application of specimens representative of these biozones. Using Sandberg*s (1976) outline, Sandberg and Zlegler (1979) further defined lateral mixing of Sandberg[r]s (1976) five biofacies. Sandberg (1979) presented a summary conodont biozonation for the Great Basin and Rocky Mountains. He presented long listings of zone-defining form-taxa as well as associated form-taxa. He stated (p. 87) that a total of 36 Upper Devonian and Lower Mississippian biozones are recognized and only four of these biozones had not been located in the western United States. Later, Sandberg and others (1983, p. 694) reported the occurrence of one of the missing biozones so that only three had not been recognized in the western United States. Ziegler and Sandberg (1984) revised the standard Late Devonian conodont biozonation eliminating four zonal groups and replacing them with <u>Palmatolepis</u>-based biozones. Sandberg and Dreesen (1984) developed a shallow-water, Upper Devonian, conodont biozonation to complement the revised deeper-water zonation of Ziegler and Sandberg (1984). Lane and others (1980) described and illustrated six form-genera and six biozones that are important constituents of global post-

Siphonodella zonation. Figure 10 summarizes the cumulative zonation
scheme used herein. Hayes (1984, 1985) recognized conodonts of the
Lower _Palmatolepis gracilis expansa_ Biozone of Ziegler and Sandberg
(1984) (Upper _Polygnathus styriacus_ Biozone) in the lower shale member
of the Bakken Formation in North Dakota and a limited siphonodellid
fauna indicative of Mississippian strata in the upper shale member of
the Bakken. Unfortunately, no conodonts of stratigraphic significance
were recovered from the calcareous middle member of the Bakken; and
Hayes, therefore, placed the Devonian-Mlsslssippian systemic boundary at
the base of the upper shale member of the Bakken. His study, while a
relatively recent work, was not able to incorporate the revised Upper
Devonian zonation of Ziegler and Sandberg (1984). For that reason,
Figure 10 lists both the former (as presented by Sandberg, 1979) and
present (Ziegler and Sandberg, 1984) zonation schemes to provide
continuity between Hayes' study and this one.

Paleontology of the Bakken and Lodgepole Formations

In the Williston Basin

    Studies that discuss the faunal and floral constituents of the
Bakken and Lodgepole Formations in the Williston Basin, with the
exception of two recent reports, are nearly nonexistent. Except for
passing remarks in peripheral studies, the Bakken was thought to be
largely unfosslllferous. Recent studies, including this one, undertaken
at the University of North Dakota have removed doubt as to the abundance
and diversity of fauna in the Bakken Formation

    MacDonald (1956) remarked (p. 13) that the Canadian equivalent of

the Bakken, the Exshaw Formation, is remarkably unfossiliferous in southeastern Saskatchewan. MacDonald found no identifiable macrofossils in the Exshaw and only a small brachlopod and conodont fauna from the basal beds of the Lodgepole in Saskatchewan. Fuller (1956, p. 18) reported the presence of the brachlopod Lingula. abundant "spore" cases and conodonts from the lower shale of the Bakken and a "scanty fauna [of] heavily pyrltized, finely ribbed brachlopods, Lingula and occasional crinoid ossicles." Rents (1959, p. 16) noted the presence of "amber coloured, flattened spore cases and pyritized organic remains" In the lower member of the Bakken ("Exshaw Shale Member") and numerous (p. 19) conodont fragments in the middle member ("Coleville Sandstone Member").

Brindle (1960) was the first worker to evaluate the macrofossils of the Bakken Formation in Saskatchewan. He reported (p. 15, 16) a small brachlopod fauna from the Bakken that increased in diversity up-section. Christopher (1961), however, reported a correction to Brindle's (1960) faunal list. A single brachlopod, Rhipidomella missouriensis. was collected from the middle member rather than the lower shale as reported by Brindle. Christopher (1961, p. 19), therefore, presented the question of an uncertain age for the lower shale member until such time as more stratigraphically diagnostic fossils were recovered.

Christopher (1961, p. 46; 1962) recorded calcitic brachlopods in the lower part of the middle member of the Bakken. He also stated (p. 48) that the upper shale member of the Bakken "is generally more fossiliferous, in that conodont remains and stunted chonetid brachlopods shells" were observed at more localities.

Kume (1963) reported (p. 46) fossils to be rare in the Bakken shales in North Dakota, except for an abundant conodont fauna. Kume also recorded one specimen of Conularia and numerous ichthyoliths from one well in Wells County, North Dakota. However, both Bjorlie (1979) and Webster (1982) regarded strata from which this specimen was recovered as within the Carrington shale lithofacies of the Lodgepole Formation. The calcareous middle member was reported (p. 46, 47) by Kume to contain more fossils, specifically three species of brachlopods. Ballard (1963) reported (p. 18) pyritized brachlopods from the middle member of the Bakken.

Bjorlie (1979) reported that the Carrington shale lithofacies of the Lodgepole Formation contained a macrofaunal assemblage including bryozoans and brachlopods. Fuller (1956, p. 26) reported a Lingula-conodont fauna occurring in the Routledge shale in southwestern Manitoba that is similar to the fauna found in the shales of the Bakken Formation. McCabe (1959, p. 26) mentioned fossils occurring within the Seallion subinterval (lower Lodgepole) to include bryozoans, brachlopods, and spinose material from brachlopods or echinoids. Heck (1979) recognized that Lodgepole strata are rich in pelmatozoan material.

Webster (1982, p. 28) noted the presence of abundant conodonts and plant material from cores of the Bakken. Hayes (1984, 1985) collected, described, and illustrated the first conodont fauna recovered from the Bakken in North Dakota. He identified more than 650 elements that he assigned to 48 form-taxa and 17 form-genera. Thrasher (1985) obtained more than 500 macrofossils representing 50 taxa from the Bakken

Formation in North Dakota. Brachiopods, the most common fossil, were represented by 17 genera. Nonbrachiopod fossils included: several genera of gastropods and pelecypods, straight and coiled cephalopods, a trilobite, conchostracans, a syringoporid coral, trace fossils, and a number of plant fragments including the alga <u>Foerstia</u>. Thrasher[1]s study was the first thorough report to discuss the occurrence and distribution of macrofossils in the Bakken Formation.

Purpose and Methodology

Purpose

Initially, the purpose of this study was to collect conodonts from the Lodgepole Formation. After one summer's reconnaissance and use of many litres of acid, no conodonts were recovered and attention was then focused on further sampling of the members of the Bakken while processing the remaining Lodgepole samples that had initially been collected. Eventually, conodonts were recovered from the lower part of the Lodgepole, as well as the Bakken, and the basal 15 metres of the Lodgepole was further sampled.

Objectives of this study are:

1. To add breadth and completeness to the Bakken collection established by Hayes and assemble the first collection of conodonts from the Lodgepole Formation in the North Dakota portion of the Williston Basin.

2. To place the Bakken and Lodgepole strata into the worldwide Late Devonian-Early Mississippian conodont biozonation scheme based on the collected conodont faunas.

3. To define the lateral and stratigraphic distribution of lag deposits which, when located, produce abundant conodont elements in the Bakken Formation.

4. To determine if paleontological evidence supports depositional continuity from Bakken to Lodgepole time as has been indicated by lithologic studies.

5. To attempt definition of the position of the Devonian-Mississippian systemic boundary by closer sampling in the middle member of the Bakken.

Materials and Methods

Materials

Cores, housed at the Wilson M. Laird Core and Sample Library at the University of North Dakota, supplied the bulk material necessary for data collection. Data were also obtained through the use of geophysical logs and thin sections provided by the North Dakota Geological Survey. The logs afforded a means of identifying member boundaries within the Bakken Formation and indicated a relative depth in the search for cores that might be of sampling interest. Unfortunately, the footage labeled on a core box is commonly six to twenty feet above or below the corresponding log depth. All footages presented herein are those of core-box depth. Thin sections prepared by previous workers were examined in transmitted and reflected light. Six thin sections were examined in the scanning electron microscope/electron probe. The high-power microscopy was done to gain insight into small-scale bedding features, contacts, bulk chemistry, and other small detail not

observable under scrutiny of the handlens or binocular microscope.

Cores from fourteen wells were used in this study. Figure 11 gives the well locations and symbols indicating the formation(s) of primary interest. Core diameter ranges from 2 inches (5 cm) to approximately 5 inches (13 cm) and cores are in poor to very good condition. Many of the cores have been previously sampled and, or, slabbed. Infrequently, one may encounter 12 to 18 feet (4 to 6 m) of slabbed core in one, three-foot core box. This makes for tentative footage determinations. Therefore, the level of accuracy of core depth given is not greater than to the nearest foot. Appendix A lists the locations of the wells used in this study and formation(s) from which samples were taken. Appendices C and D list the sampled core-box intervals and the number and condition of conodonts in the Bakken and Lodgepole Formations, respectively, collected during this study.

Methods

Critical observation of the cores included describing general condition of the core, overall rock recovery to labeled footage, bedding features, lithology, fossiliferous units, fossil types and preservation, and notable conodont occurrences. This was accomplished through the use of handlens and binocular microscope. Color determinations were made following the scheme presented by Goddard and others (1948).

Sampling of the cores was done in a nonrandom, preselective fashion. Two sampling methods were used in response to the availability of core, conodont distribution, and processing time. Due to the paucity of conodonts in the Lodgepole, the available core intervals were sawed

Figure 11. Location of wells used in this study and approximate extent
            of the members of the Bakken and Lodgepole Formations in
            North Dakota (limits of Bakken taken from Webster, 1982,
            p. 11; limit of Lodgepole taken from Heck, 1979, p. 2).
            Well numbers are those of the North Dakota Geological
            Survey. More complete locatlonal information Is listed in
            Appendix A.

lengthwise to remove one-third of the core for processing. These rocker

slabs of core were condensed into sample intervals corresponding to

labeled core box depth. For example, NDGS Well No. 607 has 27 feet

(8 m) of Lodgepole directly overlying the Bakken. A rocker slab was cut

from the entire section of core and the slab was then condensed into

five separate sample intervals (see Appendix D, Table 1) corresponding

to the five core boxes that contain the 27 feet of core.

Cores from the upper and lower organic-rich shales of the Bakken

were examined and samples taken if a bedding plane or lag zone had more

than five conodonts visible on a bedding plane fracture. Core pieces

containing such bedding planes were trimmed so that a minimum of core

was permanently removed from the core repository. The calcareous

siltstone of the middle member of the Bakken was sampled and prepared in

the same manner as the Lodgepole cores. Thrasher (1985) discussed three

stratigraphic units of the middle member that he based on lithic and

faunal change within the member. Sampling for this study recognized the

informal units established by Thrasher in an attempt to preserve any

microfossil discontinuity that might exist across the unit boundaries

and thus aid in narrowing the stratigraphic position of the Devonian-

Mississippian systemic boundary.

Once the core samples were obtained, they were crushed to a size of

approximately 2.5 cubic cm or cleaved to increase surface area, in the

case of core pieces from the "black" shale, weighed, and immersed in

appropriate solutions for processing. The organic shales of the Bakken

required an oxidizing solution originally described by Hoffmeister

(1960) and more recently presented by Duffield and Warshauer (1979).

Their technique utilizes a 4-6 percent sodium hypochlorite (household bleach) solution that slowly oxidizes the organic binding material in the dark, highly indurated shales, thereby releasing the conodonts. One-hundred grams of sodium hydroxide beads were added to 1 gallon (4 litres) of bleach to increase and enhance the oxidation reaction. The carbonate material of the Bakken middle member and basal Lodgepole was dissolved following the mass-preparation acidizing methods described by Collinson (1963). These samples were crushed to a mean size of 2.5 cubic cm and placed in an 8-10 percent solution of acetic acid. An 8-10 percent solution of formic acid was used on a trial basis, but I was told (W. J. Sando, personal communication) that formic acid has a tendency to etch conodont elements. Soaking in Stoddard's solvent was tried, without success, on the non-calcareous shale portions of the Bakken and Lodgepole after an initial treatment in acid or bleach. Average duration of acidizing for the middle member of the Bakken and Lodgepole was 18 weeks. Average processing time for the shale members of the Bakken was 18 weeks, although the samples were not completely disaggregated in this time. However, rich, conodont-bearing zones were left in the bleach and sodium hydroxide solution up to 35 weeks.

Jeppsson and others (1985) announced a warning that acetic acid harms phosphatic fossils. Throughout the course of this study, no significant damage was noted; although some whitening on the edges of platform elements was observed infrequently, nothing as severe as that reported by Jeppsson and others was recorded. An explanation may be that the percentage of carbonate material, with respect to the volume (3 liters) and the concentration (8-10 percent) of the acid bath, may

have been high enough to act as a buffer so that partial or complete destruction of elements did not occur.

The use of sodium hypochlorite and acetic acid is effective in releasing conodonts from most rock material used in this study; however, these are time-consuming (8-35 weeks) processes that require large volumes of the bleach or acid. Figure 12 summarizes, in a flow chart, the core-sample processing and the preparation of conodont specimens.

As the reactions in either bath proceeded, water was periodically added to offset evaporation. Frequent cleaning of the greater than -0.25-phi fraction was required as an argillaceous coating enveloped the fragments and greatly reduced the effectiveness of the reactions. To clean, the contents of the containers were emptied onto nested -0.25 phi and 3.75 phi U. S. Standard Sieves and thoroughly washed through the sieves with tap water. The less than 3.75-phi fraction was initially caught, but yielded no usable conodont elements, even in the zones of greatest conodont concentration and was thereafter discarded. After thorough washing, the -0.25 to 3.75-phi fraction was emptied onto a paper towel to dry. The fraction larger than -0.25 phi was replaced in the container and restarted in the appropriate solution. Once the -0.25 to 3.75-phi fraction was dry, it was examined under a binocular microscope and any conodont elements removed ("picked") for further cleaning, mounting, identification, and photographing.

Manually "picking" the residue is a tedious and time-consuming task. Two reported methods of quicker conodont separation from residue were attempted, but both met with unsatisfactory results. The first method utilized the Frantz Isodynamic Magnetic Separator and a procedure

Figure 12. Flow chart of sample processing and conodont specimen
           preparation.

outlined by Dow (1960). The most significant drawback to this method was the large amount of time it took to process the residue. Considering that the number of conodont elements present in each sample was small in comparison to the volume of residue, a visual check of the samples processed with the magnetic separator was necessary to be sure that no conodont element remained in the sample.

A second procedure to expedite the removal of conodonts from residue was described by Merrill (1985). He proposed (p. 481) a safe, economical, and reliable alternative to dangerous heavy liquid separation. Merrill outlined a procedure whereby an interface is established between an oil solvent, a detergent emulsifier and surfactant, and a substrate of paraffin wax. Merrill reported (p. 480, 481) a high efficiency in the effectiveness of separation of conodonts from residue; however, I had absolutely no success in implementing this procedure.

After the "fine" fraction of the residue had dried, it was examined under a binocular microscope. Conodont elements that showed promise for identification were extracted with a No. 00 sable brush and placed on micropaleontological slides that had been coated with gum tragacanth. The individual elements were sorted, further cleaned, if necessary, identified, and selected specimens were prepared for photography in the scanning electron microscope.

The JEOL 35C Scanning Electron Microscope/Electron Probe (SEM), housed in the Natural Materials Analytical Laboratory in the Department of Geology and Geological Engineering at the University of North Dakota under the direction of Dr. Robert J. Stevenson, was used for all

specimen photography. The SEM is outfitted with a Polaroid 545 Land camera that utilizes type 55 Positive/Negative 4 by 5 inch (10 by 13 cm) film. Specimens selected for illustration were mounted on a punched-out circle of a micropaleontological slide that had been saturated with gum tragacanth. The slide circle was attached to an aluminum plug with double-sided tape and sputter coated with gold. The advantage of mounting specimens on the slide circle, rather than directly to the aluminum plug with double-sided tape, is that the specimens can be repositioned and recoated, if necessary, for multiple shots of the same specimen with no contamination of the specimen surface with organic residue left by the tape. SEM photographs of the specimens were taken, cut out, and mounted on tag board, and then rephotographed and reduced for the final plates.

Specimens are housed In the paleontological collection of the Department of Geology and Geological Engineering at the University of North Dakota. All conodonts collected from an individual well were assigned an UND accession number (preceded by an "A"). Intervals sampled in each well were further identified by adding a decimal point and a number to the accession number. Specimens that have the same accession number and numeric extension are from the same horizon or interval within a particular well. Each accession card lists the stratlgraphic unit from which the conodont specimens were collected, the NDGS well number, and the core-box depth from which the specimens were obtained In accordance with UND paleontological accession practice. The accession number is given for all specimens on Plate 4. Illustrated specimens (chirohypotypes) have been assigned a four-digit catalog

number used in the curation of identified specimens in the UND

paleontological collection. Other specimens in each form-taxon, from a

particular sample interval and well, were assigned another four-digit

number and their catalog cards (alphabetical and numerical) bear, in the

upper right corner, the number of specimens present on the slide of that

form-taxon, horizon or interval, and locality.

STRATIGRAPHY

Bakken Formation

Areal Extent

The Bakken Formation occurs in all but the South Dakota portion of
the Williston Basin. The Bakken, overall, represents rock units
initially deposited as transgressive sediments; and, as such, the lower
shale member is overstepped by the middle member that, in turn, is
overstepped by the upper shale member (Fig. 11). The southern and
eastern limits of the Bakken in North Dakota may be erosional,
depositional, or both. Unfortunately, subsurface control in these areas
is poor and distinguishing between members of the Bakken is not easy at
the margins of the Williston Basin. Christopher (1961, p. 42), however,
reported that the Bakken and Exshaw Formations in Canada contained
erosional features such as clasts of "black" shale, oxidized shale, and
possible mud-filled desiccation cracks at the base of the middle member.
Hayes (1985, p. 67) reported one well (NDGS Well No. 7579), near the
limit of the Bakken in Billings County, North Dakota, to have "an
irregular surface covered with pyritized clasts and fragmentary
conodonts" at the top of the middle member of the Bakken. Hayes*
reported occurrence of an irregular surface separating the middle member
and upper member ("paracontinuity" in the sense of Conkin and Conkin,
1973, 1975) seems to correspond to Macqueen and Sandberg's (1970, p. 50)
report of a regional unconformity existing between the middle and upper
members of the Bakken in southeastern Alberta; however, the North Dakota
Bakken occurrence may be an isolated case in that no cores observed in

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this study showed such features. Figure 11 gives the approximate
distribution and areal extent of the members of the Bakken Formation in
North Dakota.

Thickness

Webster (1982) constructed structure contour and isopach maps of
the Bakken Formation in North Dakota. He reported (p. 19) the maximum
thickness of the lower, middle, and upper members of the Bakken 50, 85,
and 23 feet (15, 26, and 7 m), respectively. The maximum thickness of
the Bakken is 44 metres in western Mountrail County, North Dakota. Each
member thins to the south and east of its respective depocenter.

Well-Log Characteristics

The Bakken Formation is one of the most stratigraphically
diagnostic intervals in the Williston Basin. The two shale members
contain a relatively large amount of natural radioactivity and this
signature is recorded on gamma-ray logs as a reading that generally
exceeds 200 API units. Meissner (1978, p. 212) also noted that the
Bakken shales exhibit "anomalously low, but highly variable sonic
velocity (high transit time)" that he attributed to, mostly, the high
content of "low-velocity organic material." Additionally, Meissner
(1978, p. 212) pointed out that the extreme variation seen in
resistivity readings was primarily due to "the basic conductivity of
most shale and clay" and "their relatively high porosity" filled with
water at lesser depths (< 2000 m) and hydrocarbons at depths greater
than 2000 metres. The geophysical well-log response for the calcareous

middle member Is that of well-cemented carbonate and thoroughly
cemented, fine-grained elastics. Figure 6 illustrates the log response
from the type section of the Bakken in Williams County, North Dakota,
and Figure 13 illustrates a similar log response from NDGS Well No. 607
in Dunn County, North Dakota.

Lithology

The upper and lower members of the Bakken are hard, fissile,
brownish gray (5 YR 4/1) to medium dark gray (N4) to black (Nl),
organic-rich shale. Within the shales are thin lenses, or single-grain
layers, of quartz, disseminated lenses or large nodules of pyrite, and
phosphatic pellets and nodules. Phosphatic and silica cements are
pervasive but not prominent due to the small grain size of the clastic
material and high degree of induration. Biotic components include an
average of 11.3 weight percent organic carbon (Webster, 1984, p. 62),
sparse, thin-shelled brachiopods and conchostracans, abundant spore
material, the alga Foerstia, fish bones and teeth, and numerous conodont
elements. The shales, locally, are vertically fractured and may be
"healed" with calcite or calcite and pyrite. The shales tend to break
with irregular or concholdal fracture that is due to the large amount of
fine-grained quartz present (Webster, 1984, p. 62).

With the exception of differences in the contained conodont fauna
and an apparently smaller number of palynomorphs in the lower member,
the lower shale is seemingly identical to the upper shale member.
However, no detailed petrographic study has examined the specific
constituents of the upper and lower members of the Bakken.

Figure 13. Gamma-ray and neutron well-log response and generalized lithology of the Bakken Formation and a portion of the underlying Three Forks Formation and overlying Lodgepole Formation in NDGS Well No. 607, Dunn County, North Dakota. Depths are in feet below the Kelly Bushing. Solid circles indicate approximate position of conodont collection and "i/s" indicate position of lag zones from this well.

The middle member of the Bakken is a hard, slightly to very calcareous siltstone or argillaceous, fine-grained sandstone. Color varies from dark gray (N3) to light gray (N7) to greenish gray (5 G 6/1). Color variation is due to the degree of argillaceous material and pyrite and the lesser amount of organic material present within the member. The calcareous cementing material, as shown by thin section analysis and scanning electron microprobe observation, is composed of calcite and dolomite. The middle member is well cemented and tightly packed with very little observable porosity. Whereas the upper and lower dark shale members exhibit bedding of thin, sheety laminae, the middle member exhibits a wide variety of sedimentary structures; these include small-scale, trough, cross bedding, planar cross bedding, ripple cross laminations, scour-and-fill structures, and structures resulting from soft-sediment deformation. Post-depositional adjustments made within the middle member consist of vertical microfaults and vertical joints. Faunal and floral components of the middle member consist of an extensive macrofauna composed of primarily brachiopods (Thrasher, 1985), spores, and a sparse and fragmented conodont fauna.

Thrasher (1985) divided the middle member of the Bakken Formation into three, informal units, which he numbered in ascending order (Fig. 7). He based these subdivisions on faunal and lithic variation within the member. Thrasher's unit 1 is up to 10 metres thick and consists of a light gray to dark greenish gray, fossiliferous siltstone that may be very calcareous and cemented to the point of being confused with a limestone. Bedding features in unit 1 are rare except for minor bioturbation, and the fauna is dominated by Devonian brachiopods,

especially <u>Rhinidomella missouriensis</u>. Unit 2 is also up to 10 metres
in thickness and is largely unfossiliferous. Nearly all bedding
structures previously mentioned are restricted to unit 2. The unit
consists of thin, alternating beds of siliceous shale and slightly
calcareous siltstone or fine-grained sandstone. Fossils are sparse, but
are represented by the presence of "blade-like leaves" and a
syringoporid coral near the base of the unit. The boundary separating
units 1 and 2 is obscure and difficult to distinguish. In cases where
the boundary is not apparent, Thrasher (1985, p. 70) arbitrarily picked
the boundary at the lowest occurrence of well-defined bedding, or, in
cases where fossils occur within the well-bedded unit, at the lowest
occurrence of fossils.

Unit 3 is up to 3 metres thick and consists of massive, medium
gray, calcareous, bioturbated, fossiliferous siltstone that contains a
numerous and diverse brachlopod fauna that Thrasher (1985) determined to
be Hississippian in age. Bedding features found in unit 2 may be
transitional with the lower portion of unit 3, or the features may
extend to near the top of the middle member. In the absence of the type
of bedding of unit 2 in unit 3, and in lithology and texture, unit 3 is
similar to unit 1. The boundary between unit 2 and unit 3 is just below
the lowest occurrence of abundant fossils that Thrasher (1985, p. 71)
said was "always within the top eight feet of the middle member."

Within the upper shale member of the Bakken, and to a lesser extent
in the lower shale member, are thin (<1 cm), coarse-grained intervals of
quartz, phosphatic pellets, ichthyoliths, pyrite, and abundant spores
and conodonts. Gutschick and Moreman (1967, p. 1015) reported that

within similar Devonian and Mississlppian dark shale units present at the margin of the North American craton are sandstone "bone beds" representing "winnowed lag deposits of a shallow water littoral deposit." Sandberg and Klapper (1967, p. B8) reported a "transgressive sandstone" or "conglomeratic lag deposit" at the base of the Sappington Member of the Three Forks Formation that was very similar in thickness and components to thin lags in the upper tongue of the Cottonwood Canyon Member of the Lodgepole Limestone (p. B29). Sandberg and others (1972, p. 184) stated that the Sappington Member lags were 2.5 to 10 cm thick and Gutschick and others (1976, p. 94) diagrammed the occurrence of similar lags occurring in the same units. Sandberg and Gutschick (1969, p. 70) reported a basal conodont-bearing lag sandstone in the Leatham Formation. Macqueen and Sandberg (1970, p. 37, 38) reported a thin "phosphatic quartzose sandstone bed" occurring at the base of the Exshaw Formation. Fuller (1956, p. 23) reported a "pebble bed" at the base of the Bakken Formation in Saskatchewan and Hayes (1984, p. 56, 59; 1985, p. 70) briefly discussed lag occurrence in the upper shale of the Bakken in North Dakota.

Three lags were observed during the course of this study: one from the lower shale member (NDGS Well No. 607, 10,595 ft.), and two from the upper shale member (NDGS Well No. 607, 10,520 ft., and NDGS Well No. 4958, 7,578 ft.). Figure 13 is a representative section of NDGS Well No. 607 that was the most completely sampled core in this study. Shown are the positions of conodont collection levels or intervals and the positions of lag zones within this well. As with other reported lag occurrences, the Bakken Formation lags consist of phosphatic fossil

debris, pyrite, fish bones and teeth, quartz grains, fragments of plant
material and abundant spores, and conodonts. Figure 14 is a photograph
of a bleach-treated surface of shale from the upper member on which
these features are present. The greatest thickness of any of the
observed Bakken lags was 1.5 cm and the thinnest was two or three quartz
grains thick. Figure 15 is a photomicrograph of a vertical section
through a lag zone. These lags are of similar character in the upper
and lower shale members and apparently differ only in the conodonts
recovered from them. Lag formation and occurrence appears to be limited
to the shale members of the Bakken; none was found in the middle member
or in the overlying Lodgepole Formation. In addition to the
conglomeratic lags, lenses of disseminated pyrite in the core have the
same thickness and appearance as the fossiliferous lags; however, the
pyritic lenses or laminae contain no fossil material. The conodont-
bearing lags in the dark shales of the Bakken will be discussed below.

Lodgepole Formation

Areal Extent

The Lodgepole Formation is represented over the entire area of the
North Dakota portion of the Williston Basin, or the western two-thirds
of North Dakota. The Lodgepole conformably overlies the Bakken
Formation in the central Basin area and extends beyond the Bakken to lie
unconformably on the Three Forks Formation, Birdbear Formation, and
Duperow Formation, all of Devonian age, and, in the southeastern subcrop
area, the Red River Formation of Ordovician age. Figure 11 gives the
approximate distribution and areal extent of the Lodgepole Formation in

Figure 14. Photograph of an oxidized lag bedding-plane surface of core
from NDGS Well No. 4958, 7,578 feet, Burke County, North
Dakota. Features on the photograph are denoted as follows:
(C) conodont, (F) fish fragment or tooth, (P) phosphatic
nodule, (Q) quartz grains. Scale bar *is* 3 mm.

Figure 15. Photomicrograph through a vertical section of a lag from the
upper member of the Bakken in NDGS Well No. 4958, 7,578 feet,
Burke County, North Dakota. Letters on the photomicrograph
indicate the same features as in the photograph above. Large
oval feature near the center of the photomicrograph is probably
a palynomorph (PI). Black areas are mostly organic material
and pyrite. Scale bar is 0.5 mm.

North Dakota.

Thickness

Heck (1979, p. 13) reported the thickness of rocks in the Bottineau interval (the part of the Lodgepole Formation studied for this report) as 275 metres in the central Williston Basin, thinning to an erosional edge in eastern North Dakota. He (1979, p. 13, 14) suggested that variation in thickness is due, in part, to post-Mississippian erosion, and in part to salt dissolution in the Prairie Formation of Middle Devonian age, as well as to variation in the rates of Basin subsidence and sedimentation.

Well-Log Characteristics

The geophysical response of the Lodgepole Formation is not as readily recognizable as that of the Bakken Formation. The gamma ray response generally averages about 100 API units (Figs. 6 and 13); however, toward the base of the Lodgepole, a stronger gamma-ray response may indicate the position of the Carrington shale lithofacies (Bjorlie, 1979) or possibly an eastern extension of the upper tongue of the Cottonwood Canyon Member. But neither of these stratlgraphic relations has ever been demonstrated in core from the Williston Basin. Resistivity is characteristically low and non-descript throughout the Lodgepole section. LeFever and Anderson (1984, p. 31) reported that in the central portion of the Basin "similarities in log characteristics make the Lodgepole-Mission Canyon cantact [sic] almost impossible to identify."

Lithology

The Lodgepole Formation exhibits a wide variety of lithologies that become progressively less argillaceous, less cherty, and less dense up section. The lower 10 to 15 metres of the Lodgepole (the interval of concern in this study) is generally a medium light gray (N6) to brownish black (5 YR 2/1), finely crystalline, argillaceous, and dense limestone. Irregular intervals have been chertified (mostly burrows and narrow tubes), and stylolitic stringers and pressure solution features are common. Faunal components include a large amount of pelmatozoan material, gastropods, brachiopods, ostracods, scolecodonts, and conodonts. Glauconitic steinkerns of small gastropods, ostracods, and brachiopods recovered from acetic acid-bath residue are common. Sandberg and Klapper (1967, p. B42) reported the basal three metres of the Lodgepole at outcrop localities to contain abundant glauconite that can be used as a distinctive stratigraphic marker interval. The glauconite observed in thin section and core in this study is not readily distinguishable with an unaided eye; however, where glauconite is observed, it is typically within the basal 5 to 10 metres of the Lodgepole in North Dakota.

Nordquist (1953, p. 75) reported that the limestone of the Lodgepole becomes a lighter-colored fragmental limestone on the Basin shelves, rather than the darker-colored argillaceous limestone present toward the center of the Basin. The conodonts become quite sparse upward and by 15 metres above the top of the Bakken Formation are essentially nonexistent. This observation is consistent with the conodont collections made at exposed sections of the Lodgepole by

Klapper (1966) and Sandberg and Klapper (1967).

No sedimentary structures, other than minor bioturbation, are present in the basal Lodgepole. The limestone is hard and dense, but does not exhibit the fracturing that is present in the shales of the Bakken. Microprobe and optical microscope observations of Lodgepole thin sections show that calcite, chert, and minor dolomite are the cementing agents. The argillaceous content of the basal Lodgepole is high, but no X-ray diffraction was done to determine the clay minerals present.

CONODONT FAUNA

Abundance and Distribution of Conodonts

A total of 1963 elements were collected from the Bakken and
Lodgepole Formations in the Williston Basin of North Dakota. Ninety-
five species-level form-taxa were identified, assignable to 22 form-
genera. Thirty-four species-level form-taxa recovered from the Bakken
and 61 species-level form-taxa obtained from the Lodgepole are reported
for the first time from North Dakota.

The collection is composed mostly of pectiniform (platform)
elements; however, the ramiform (barlike) elements are quite numerous.
The coniform (conelike) elements are the least abundant with only two,
mostly complete, specimens recovered in this study. Important
stratigraphically diagnostic genera include, in order of decreasing
abundance (with the number of species-level form-taxa listed in
parentheses): Siphonodella (9), Polygnathus (9), Pseudopolygnathus (5),
"Spathognathodus" (5), Palmatolepis (3), Bispathodus (3), Dinodus (2),
Branmehla (1) and Elictognathus (1). Thirty-five -biostratigraphically
important form-species of these form-genera were identified. No natural
assemblages or fused clusters were identified on bedding planes or in
acid residues. Plate 4 (pocket) summarizes the abundance and
distribution of conodonts recovered in this study.

Conodonts were recovered from both the Bakken and Lodgepole
Formations. Although conodonts were recovered from all three members of
the Bakken, the middle member is nearly barren of conodonts; only three
elements, one each from three of the eleven samples taken from the

middle member, were collected. Conodont distribution in the two shale members of the Bakken was typically of two types. The elements were either rather unevenly distributed through the rock, with concentrations of five to ten elements on fracture or bedding surfaces, or they were concentrated within thin, sandstone and siltstone, lag zones that contain abundant fossil and inorganic debris. The lags were identified in both the lower and upper members of the Bakken, but more occur in the upper member.

Fourteen wells were sampled in the study; ten wells produced conodonts. Ninety-one condensed sample intervals or selected bedding surfaces were sampled, 38 from the three members of the Bakken and 53 from the Lodgepole. Twenty-four intervals, or 63 percent, of the Bakken samples produced conodonts. Twenty-seven intervals, or 50 percent of those sampled, of the Lodgepole samples produced conodonts.

Although the collection numbers 1963 specimens, 855 of the elements (44 percent) are so fragmented that assignment, even at the generic level, is questioned. If the indeterminate elements are eliminated, the distribution of conodonts recovered from the Bakken and Lodgepole intervals or bedding surfaces sampled is relatively even. The smaller, yet diverse, collection from the lower shale is a result of lesser sampling within this member.

A total of 289 elements, or 15 percent of the collection, was recovered from the lower member of the Bakken. Many of the larger specimens are, in general, in poor condition. The lower member assemblage of form-genera consists of, listed in order of decreasing abundance: Polygnathus. Pseudopolygnathus. "Spathognathodus,"

Palmatolepis. Bispathodus, and Branmehla. The palmatolepid elements and

four species-level form-taxa of Polygnathus were recovered from the

lower member only. Twenty-two palmatolepid elements were assigned to

three form-subspecies; 53 palmatolepid elements were recovered from the

lower member that were only diagnostic at the generic level. The

discrete element Polygnathus perplexus was the most abundant form-

species recorded from the lower member. The samples of the lower member

that produced conodonts averaged the equivalent of 379 conodonts per

kilogram of rock material processed. However, one lag zone (NDGS Well

No. 607, 10,595 feet) is included in this average. The lag sample

produced 1622 conodonts/kg and, if this sample is excluded from the

others, there is a 30 percent decrease in the ratio to 266 conodonts/kg.

A disappointing number of conodonts, or even conodont fragments,

were obtained from the middle member of the Bakken. One complete

specimen of Polygnathus communis communis, one hindeodellan element, and

one indeterminate ramiform element, or less than 1 percent of the total

collection, constitute the middle member collection of conodonts. Based

on the three samples that individually produced one conodont each, the

conodont/kg ratio averages 3.

The upper member of the Bakken yielded 930 elements, or 47 percent

of the total collection, and were assigned to 13 form-genera. Slightly

more than three-fourths of the upper member collection was obtained from

three lags zones. Most of the conodonts recovered from the upper member

are broken; however, the amount of breakage is not quite as great as was

observed in the lower member of the Bakken. The majority of the upper

member assemblage is composed of the following form-genera, listed in

order of decreasing abundance: _Slphonodella_. _Polygnathus_,
Pseudopolygnathus. "_Spathognathodus_." and _Bispathodus_. The lowest
occurrence of _Slphonodella sulcata_ in the Bakken is low in the upper
member. The occurrence of this form-species has not been previously
reported from the North Dakota portion of the Williston Basin.
Polygnathus communis communis was the most abundant element (55)
recorded from the upper member; it is closely followed by the discrete
elements _Slphonodella duplicata_ (49) and _Pseudopolygnathus primus_ (40).
To cite the number of 930 elements recovered from the upper member is
somewhat misleading in that the greatest number of specimens recovered
(575) were indeterminate ramiform elements in this member, too. The
large amount of fragmented material was, as in the case of the greater
number of diagnostic elements collected, recovered from the three lag
zones. Seventy-nine percent of the indeterminate forms were recovered
from one well (NDGS Well No. 4958) bearing a lag. The sampled intervals
of the upper member that produced conodonts averaged the equivalent of
688 conodonts per kilogram of rock processed to completion. This number
is highly skewed, as it is in the lower member, by the presence of two
sampled lag zones. NDGS Well No. 607 at 10,520 feet produced the
equivalent of 2430 conodonts/kg and NDGS Well No. 4958 at 7,578 feet
produced 1595 conodonts/kg. If the lag zones are excluded, the average
is cut slightly more than one-half, to 309 conodonts/kg.

The part of the Lodgepole Formation studied yielded 741 elements,
or 38 percent of the collection, which were assigned to 19 form-genera.
The diversity and preservation of collected elements is much greater in
the Lodgepole intervals than in the Bakken samples. In each Lodgepole

well sampled, the diversity and number of elements recorded dropped off

dramatically upward so that, on average, 25 feet above the top of the

Bakken, the samples from any given cored interval produced few

conodonts. Figure 16 is a graphic representation of the trend of

decreasing number of conodonts recovered up section in the Lodgepole.

Samples collected 60 feet above the top of the Bakken Formation produced

no conodonts. The Lodgepole collection of conodonts is dominated by, in

order of decreasing abundance: Siphonodella cooperi. Siphonodella

crenulata, Siphonodella quadruplicate. Polygnathus communis communis,

and Polygnathus inornatus. The number of indeterminate fragments

recovered from the Lodgepole Formation is much reduced, as the overall

quality of preservation is much better in the Lodgepole than in the

Bakken. Lodgepole samples that produced conodonts averaged 25 conodonts

per kilogram of material processed; however, this average is dependent

on where in the section the sample is taken (Fig. 16). No lags were

observed in the Lodgepole section. Whereas the conodont/kg ratio of the

shale members of the Bakken are an order of magnitude greater than the

basal Lodgepole ratios, the quality of specimens recovered from the

basal Lodgepole is by far superior.

Preservation

Conodont specimens on bedding or fractured surfaces of the Bakken

shale members have the appearance of being complete, or nearly so. But

microscopic observation of undisturbed elements on bedding planes

revealed numerous, non-displacive microfractures through them. Upon

processing, by removal of the binding organic material, the conodonts

Figure 16. Scatter diagram showing the upward decline In abundance of
            conodonts In the basal Lodgepole Formation from cores
            processed during this study. Except for NDGS Well No. 793,
            the highest point plotted indicates the top of core; no
            conodonts were obtained from core of NDGS Well No. 793
            higher than 54 feet above the top of the Bakken Formation.

are released. However, the bleaching and further processing resulted in breakage of many Bakken shale specimens.

Conodont specimens recovered from the middle member were generally fragmented and showed signs of abrasion; this indicated some degree of transport and deterioration of the elements. The paucity of elements in the middle member may be due, in part, to physical elimination of the fragile conodont elements during deposition of the middle member.

Specimens recovered from the basal Lodgepole are remarkably well preserved. Whereas finely denticulate elements removed from the Bakken shale members are missing a large number of their denticles and processes, the Lodgepole specimens have retained nearly all components of their morphologies. A large percentage of the figured specimens are Lodgepole specimens, because, even if respective specimens were more abundant in the Bakken, the preservation of Lodgepole specimens was far superior. Upward, the quality of preservation decreases, paralleling the decrease in vertical abundance, so that 10 to 15 metres above the base of the Lodgepole, extracted specimens were more fragmented and worn in appearance than those occurring lower in the section. Little is known of the distribution and preservation of conodonts higher in the Lodgepole Formation. The more worn appearance of these elements may be due to minor reworking of Lodgepole sediment during a lessened rate of deposition.

DISCUSSION OF RESULTS

Conodont Biostratigraphy

Lag Deposits and Conodont Occurrence

Depositional processes resulting in dark, organic-rich rock such as the fiakken shales is not fully understood, although a number of workers have considered this question. Twenhofel (1939) was among the first to discuss the depositional requirements and processes that would yield "black" shales (the term "black" shale is somewhat of a misnomer in that the shales may range in color from brownish black [5 YR 2/1] to grayish black [N2] to black [Nl] so that a more appropriate term might be either dark shale or organic-rich shale or carbonaceous shale). Kohlberger (1983) summarized the major items of confusion surrounding dark shales; foremost seems to be the question of water depth. Kohlberger (p. 9) said, "The failure of workers to distinguish relative depth of sediment in the facies sequence from absolute depth in appropriate numbers of feet or meters may be responsible for 90% of the debate on this question." For example, McCabe (1959, p. 44) suggested that organic-rich, dark shale, such as the Bakken, could form "under conditions varying from deep-water marine to terrestrial swamp." Likewise, Zangerl and Richardson (1963) presented a unique case for their suggestion that deposition of some dark shale could take place in very shallow, marginal, marine environments. They called on a "flotant" of vegetation (possibly algal) that would provide the abundance of organic material necessary and dampen wave energy, effectively reducing water circulation and limiting oxygenation of the upper portions of the water column. The

organic-rich sediment would be deposited in a current-inhibited, reducing environment that seems to be characteristic of dark-shale depositional environments.

Rich (1951) discussed dark shale units east of the Mississippi River. He presented evidence that suggested deposition of eastern dark shales was from "toxic water in the deeper, unaerated parts of an extensive marine basin into which sediment was coming only very slowly and where the water was deep enough for the bottom to be entirely below the level of effective wave action" (Rich, 1951, p. 2018). Rich termed deposits thus forming on the floor of a water body "fondoform deposits." Heckel (1977) and Byers (1977) have discussed marine conditions that allow for maximum organic production and preservation as well as concentration of phosphorite that is common in dark shale deposits. Demaison and Moore (1980) presented a discussion of four anoxic environments that have been shown to be responsible for deposition of dark shale units. Ettensohn and Barron (1981) discussed late Devonian-early Mississippian dark shale deposition and they established a depositional model applicable to North America. They considered (p. 344) dark shales to represent deposits of "low clastic input, high organic productivity, and anaerobic conditions in a stratified inland equatorial sea" in water that was a minimum of 230 metres deep.

Fuller (1956), and later McCabe (1959), suggested that the Bakken shale members were deposited in a vast swamp from sediments derived from mild orogenic uplift at the periphery of the Williston Basin. Raasch (1956) believed that the dark shale of the Exshaw Formation was deposited in a lagoonal setting adjacent to the main marine body of the

Canadian portion of the Williston Basin. MacDonald (1956) thought a deep-water, marine environment (60 to 180 metres) and deposition of organic-rich sediments below effective wave base were responsible for the shales of the Bakken. Using paleogeographic reconstructions during the late Devonian and early Mississippian, very similar to those presented by Heckel and Witzke (1979), Parrish (1982) predicted deposition of the Bakken shales based on late Devonian-early Mississippian interregional upwelling patterns. Lineback and Davidson (1982) suggested that the shale members of the Bakken were deposited in an extension and deepening of anaerobic waters in the Williston Basin. Further, Lineback and Davidson reported that, based on electric log correlation, the Bakken shale members represent anaerobic basin-center deposits, the middle member and Three Forks Formation represent shallower-water deposits within the dysaerobic portion of the water column, and the Lodgepole Formation represents very shallow-water deposits in well-lighted and well-oxygenated water ringing the margin of the Williston Basin. There is no conodont evidence from the Three Forks Formation or from the middle member of the Bakken Formation in North Dakota available yet to support or refute Lineback and Davidson's contention; however, Thrasher (1985, p. 110-112) discussed macrofossil evidence to suggest that the Three Forks Formation, Bakken Formation, and Lodgepole Formation were never deposited contemporaneously* Based on the type of organic constituents observed in the shales of the Bakken, Webster (1982, p. 33) reported that the "great predominance of amorphous-sapropelic organic matter (probable algal or phytoplankton origin) over terrestrial (woody or humic) material suggests an offshore

marine depositional environment." Both Hayes (1984, 1985) and Thrasher (1985) used recovered Bakken fossils to support Webster's conclusions.

The presence of lag deposits in time or lithic equivalents of the Bakken Formation is well documented (Gutschick and others, 1962; Gutschick and Moreman, 1967; Sandberg and Klapper, 1967; Sandberg and others, 1972); however, the significance of these lags in terms of biozonation and paleoecologic or depositional processes has, unfortunately, been neglected. A number of observations can be made regarding Bakken Formation lags from those sampled and processed in this study. First, the lags are not prominent features; they are inconspicuous and thin where present at all. Second, when isolated, they produce many times more conodonts per kilogram than adjacent surfaces or comparable intervals lacking lags. Third, the coarser material in the lags is present throughout the dark shale section, but in a much diluted state; in other words, the coarse-grained material in lags is concentrated with a lesser amount of fine-grained organic and clastic material. Fourth, although the number of lags observed and sampled is small, they do not appear to be pervasive features; rather, they are relatively isolated or local features, at least within the scope of the well spacing and core availability. Fifth, whereas the lags appear to be local features, it appears that widely separated lag occurrences may be present at the same approximate stratigraphic position within the Bakken shales possibly indicating an overall depositional or paleotectonic controlling factor.

These initial observations have lead to preliminary suggestions regarding depositional processes that may be responsible for their

occurrence. No attempt has been made; however, to suggest the relation

the lags represent in the development of lithologies or overall

sedimentation patterns in the Villiston Basin. Three lag zones have

been identified in the upper member of the Bakken, two during this study

and one by Hayes (1984). Two lag zones have been observed in the lower

member of the Bakken, one during this study and one by Hayes (1984).

Comments concerning the lags will be restricted to those in the upper

member because their occurrence and distribution were sought to a

greater degree, although in all likelihood the same conclusions would be

applicable for those in the lower member.

A single lag was observed in NDGS Well No. 4958. The two other

upper member lags (NDGS Well No. 607 and NDGS Well No. 793) are in the

same county and separated by about 15 kilometres. These two wells and

NDGS Well No. 4958 are separated by about 120 kilometres. No wells

having core from the upper member of the Bakken are present between NDGS

Well Nos. 607 and 793, but two wells with core of the upper member were

sampled in a line with NDGS Well No. 4958 and the southern lag-bearing

wells. The core from the two wells in between do not contain lag zones

in the upper member. In addition, the upper member maintains a

relatively consistent 7-metre thickness throughout its occurrence.

There is no evidence, either physical or faunal, to suggest pre-

Lodgepole erosion, so it appears that there has been no loss of

stratigraphic section from one well to another, regardless of the

presence of lags. It would seem that the lags represent coarse-grained

accumulations of material that collected in shallow, broad depressions

or on protected sides of broad, low relief obstructions under the

influence of gentle currents.

McGugan (1965, p. 127) discussed lag deposits and said that they are the result of very slow deposition and accompanying reworking and winnowing of fine-grained sediment to produce a stratigraphlc concentrate representing a great increment of time with no loss of section. Sandberg and Poole (1977), Sandberg and Gutschick (1979), and Sandberg and others (1983) used conodont evolution and occurrence to determine rates of sedimentation in stratigraphlc and lithic equivalents of the Bakken. Whereas this type of determination was not possible in the Bakken due to lack of boundary-defining conodonts, rates of sedimentation of about 1-3 metres/million years have been suggested for similar units. Because of the stratigraphlc, lithic, and faunal similarity of dark shale units adjacent to the Williston Basin, very slow rates of sedimentation for the organic-rich shales of the Bakken are also implied.

Conodont and phosphatic-debris concentrations in the shale members of the Bakken Formation are, at this time, thought to be the result of three similar, separate (yet perhaps interactive) processes, situations, or combinations of processes: coarse-grained accumulation of fossil and inorganic debris in sediment-starved conditions; winnowing of fine-grained siliciclastics and organic material during deposition that enhances coarse-grained deposition of fossils and inorganic material; and selective winnowing of partially lithified sediment and contained conodonts by evanescent currents. In each case a hypothetical column of water, in a reduced-circulation setting, has environmental components conducive to the formation of dark shale.

In the first scenario, the clay-sized, fine-grained elastics and unoxidized organic material may well stay an ooze until deposition of more of the same material causes compaction and dewatering. Because of the relatively high specific gravity of francolite (2.84-3.10), the primary mineral phase present in conodonts (Ziegler and Lindstrom, 1981, p. W53), these phosphatic elements, fish fragments, and other phosphate-rich debris may have settled to the general level of the sediment-water interface. If considerable time passed with little addition of clay or coarser siliciclastic sediment, abundant conodonts, ichthyoliths, and inorganic debris would become concentrated at the general sediment-water interface. Dark shale strata, to either side of the area of the concentrate zone but in a diluted state in relation to the number of conodonts, may represent a slightly greater rate of sedimentation under the influence of orogenic pulses of the Antler Highlands, increased organic productivity, or decreased abundance of conodont-bearing organisms than that occurring at the place or location of the concentrate formation.

In the second case, gentle currents continually remove the clay-sized, fine-grained elastics and organic material settling into the suspensive ooze and underlying, slightly compacted sediment that has achieved a slightly lithified state. Current winnowing of fine-grained material would leave coarse-grained fossil and inorganic debris to accumulate as a lag on the partially lithified surface of dark shale not affected by the currents. Current energy must have been low in this system, however, as conodonts are relatively fragile; and even though most of the elements from the dark shale are broken because of post-

deposltional compaction, it does not appear that the elements were transported far or under even moderate energy conditions.

While there is little water circulation in anoxic environments, it seems likely that slight water movement may occur in response to density currents, or that slight topographic channels, whose constrictions may cause a local increase in velocity of the water, may form. The third interpretation of lag formation is based on this model. These current-controlling factors may shift In location so that in one local area, area A, fine-grained sediment and lighter suspended material may be removed and deposited a short distance away. The coarser-grained material that remains behind is concentrated, or slightly reworked to form a lag. At a later time, another area, area B, adjacent to the first, experiences the influence of the evanescent currents and the removed light sediment and organic material, depleted In the coarse-grained debris left at area B, comes to overlie the first lag concentrate at area A. This method of sporadic removal of fine-grained material and concentration of coarse-grained material would explain both the lesser relative abundance of conodonts in the dark shale at the same approximate stratigraphic Interval that lags are found and the complete lack of lags in some wells (perhaps the only situation where the word lag, as such, is truly appropriate).

It has been suggested by Sandberg and Klapper (1967) and GutSchick and others (1976) that lags are the result of renewed transgression, related to activity in the Antler orogeny, subsidence of the basin of sedimentation, or possibly movement of structural elements within the confines of the basin. These suggestions, or factors, may also be of

importance and could fit into the outline presented above for conditions within the Villiston Basin.

Evidence to suggest that a single process is responsible for the formation of lags or coarse-grained concentrates has not been isolated, but the result of preferential settling, winnowing, or slight reworking in terms of conodont biozone distribution is presented in Figure 17. The distribution of Kinderhookian conodont biozones is represented by phyletic evolution within the form-genus Siphonodella. In a complete section of the upper member, that is a section representing continuous, even deposition during the increment of time in question, the conodont biozones should be evenly distributed in a sequential manner throughout the section. In a lag zone, however, there may be a condensing of biozones into a very thin interval of the total section. Within this lag zone, conodonts representative of two (or even more?) biozones may be found together.

<div align="center">Conodont Biozonation</div>

Study of the phyletic evolution of platform elements in late Devonian and early Mississippian strata in Europe and North America has provided the basis for a zonation scheme that is applicable on a worldwide scale. Sandberg (1979) listed important late Devonian and early Mississippian conodont taxa and their ranges. Late Devonian conodont biozones are based on occurrence of subspecies of the form-genus Palmatolepis and the first member of the siphonodellid lineage, Siphonodella praesulcata. Ziegler and Sandberg (1984) reevaluated and refined the occurrence and lineages of important palmatolepid elements

Figure 17. Schematic representation of a lag zone in the upper member of the Bakken Formation in North Dakota.

and suggested that these biozones are representative of "deep-water" deposits. Sandberg and Dreesen (1984) developed an accompanying conodont zonation scheme for "shallow-water" deposits of late Devonian strata. For younger strata, early Mlsslssippian conodont biozonation is based on the occurrence of form-species of the form-genus Siphonodella. Osagean biozonation was discussed by Lane and others (1980).

Lower member of the Bakken Formation

Hayes (1984, 1985) recovered conodonts from the lower member of the Bakken that he collectively considered to be of the Upper Polygnathus stvriacus Biozone (Lower Palmatolepis gracilis expansa Biozone of Ziegler and Sandberg, 1984). Conodont elements identified by Hayes (1984) from the lower member, but not recovered in this study include: Palmatolepis gracilis sigmoidalis. Polygnathus distortus, and Polygnathus cf. P. nodocostatus. Hayes (1984) recovered lower member conodonts from five horizons no higher than the middle of the lower member, and the collection from one well (NDGS Well No. 9351, Billings County) was from a lag. Even with the additional elements collected in this study, biostratigraphic control is not complete and due to the presence of lag zones, the discussion of biozonation deals with all samples of the lower member collectively. It may be possible, by detailed collection, to delineate biozone boundaries on a more discriminating scale.

Zone-defining conodonts recovered from the lower shale during this study were obtained from two wells: the lower six feet (2 m) of NDGS Well No. 607 and the lower three feet (1 m) of NDGS Well No. 5088.

Hayes (1984) sampled NDGS Well No. 5088 in an interval slightly above
the interval sampled in this study. Based on the collection of lower
member conodonts, considered collectively, the lower part of the lower
member of the Bakken is of the Lower Palmatolepis gracilis expansa
Biozone of Ziegler and Sandberg (1984). This biozone is equivalent to
all of the former Upper Polygnathus styriacus Biozone and the basal part
of the Lower Blspathodus costatus Biozone (Fig. 10). The lower boundary
of the Lower P. g. expansa Biozone is defined by the lowest occurrence
of P. g. expansa and the upper boundary by the lowest occurrence of
Blspathodus aculeatus aculeatus. Palmatolepis gracilis expansa was not
recovered in this study and the lowest that B. aculeatus aculeatus was
found was well up into the Kinderhookian Siphonodella biozones. In the
absence of the name bearer for a particular biozone, faunal associations
are used to recognize the various biozones. Pertinent taxa that occur
within the Lower P. £. expansa Biozone and were recovered in this study
include Polygnathus experplexus that is essentially confined to this
biozone, Polygnathus granulosus that becomes extinct within this
biozone, and Blspathodus jugosus that first appears within this biozone.
Other conodont form-taxa collected in this study that occur in this
biozone include: Palmatolepis rugosa ampla, P. perlobata postera, P.
perlobata schindewolfi. Polygnathus homoirregularis. P. perplexus, and
Branmehla inornata. In addition, Hayes (1984) identified Palmatolepis
gracilis sigmoidalis that is also an important constituent of the Lower
Palmatolepis gracilis expansa Biozone.

Because of the large, diverse, and distinct conodont fauna
recovered from the lower member, the Lower Palmatolepis gracilis expansa

Biozone is recognized with some confidence; however, portions of the biozones just above and below this biozone may also be represented in the lower member of the Bakken. Figure 18 shows literature-reported ranges of 23 form-taxa recovered in this study and <u>Palmatolepis gracilis sigmoidalis</u> obtained by Hayes (1984). For example, Ziegler and Sandberg (1984, p. 184) reported that <u>Palmatolepis rugosa ampla</u> and <u>Polygnathus homoirregularis</u> are common in the <u>Palmatolepis perlobata postera</u> Biozones and a number of other form-taxa (<u>Palmatolepis perlobata schindewolfi</u>, <u>Branmehla inornata</u>. <u>Polygnathus granulosus</u>. <u>Polygnathus perplexus</u>) range through these biozones. In addition, a portion of the Middle <u>Palmatolepis gracilis expansa</u> Biozone may be represented by forms that range through the Lower P. £. <u>expansa</u> Biozone and are present within the lag zone.

As mentioned previously, the origin of the lag deposits, from which the majority of these lower-member conodonts were recovered, are poorly understood; thus the distribution and stratigraphic occurrence (or condensation) of conodont biozones within lags or concentrates can only be speculated upon. Based on the occurrence of at least 10 associated form-taxa, the lower part of the lower member of the Bakken can be assigned to the Lower <u>Palmatolepis gracilis expansa</u> Biozone, but it may also include one or more of the <u>Palmatolepis perlobata postera</u> Biozones and a portion of the overlying Middle <u>Palmatolepis gracilis expansa</u> Biozone.

No stratigraphically diagnostic conodonts were recovered from the upper portion of the lower member of the Bakken. The presence of form-taxa collected in this study (Fig. 18) that have been shown by other

Figure 18. Reported ranges of 24 conodont form-taxa recovered from the
the Bakken and Lodgepole Formations and the biozones
represented by the entire conodont fauna. <u>Palmatolepis</u>
<u>gracilis sigmoidalis</u> was collected by Hayes (1984). Sources
for the conodont ranges include: Ziegler (1971), Sandberg
(1979), Lane and others (1980), and Ziegler and Sandberg
(1984). Zonation scheme is from Ziegler and Sandberg (1984).
Taxon abbreviations are as follows: (B.) <u>Bispathodus</u>, (Po.)
<u>Polygnathus</u>, (Pa.) <u>Palmatolepis</u>, (Br.) <u>Branroehla</u>, and (S.)
<u>Siphonodella</u>. Unit abbreviations are as follows: (OS.)
Osagean, (Bis) lower member, Bakken Formation, (Bmm) middle
member, Bakken Formation, (Bus) upper member, Bakken
Formation, (Lp) Lodgepole Formation.

conodont workers to range above the Lower P. g. expansa Biozone suggests

that a portion of the Middle and Upper P. g. expansa Biozones may be

present within the lower member of the Bakken. Likewise, the

Siphonodella praesulcata Biozones were not recorded from the lower

member; however, the possibility of the presence of the lowest of these

biozones cannot be overlooked.

Middle member of the Bakken Formation

Only one identifiable conodont, Polygnathus communis communis, and

two unidentifiable fragments were recovered from the middle member of

the Bakken. As is shown on Figure 18, P. communis communis is a very

long-ranging element found in many Upper Devonian and Lower

Mississippian conodont biozones. Thrasher's (1985) study of the Bakken

Formation macrofossils indicated that the Devonian-Mississippian

systemic boundary is positioned at the top of his unit 1.

Unfortunately, no conodonts diagnostic of the uppermost Devonian

(Siphonodella praesulcata Biozones) have been recovered from the Bakken.

Because of the paucity of middle member conodonts recovered in this

study, and similar results obtained by Hayes (1984), Thrasher's

placement of the systemic boundary is followed until such time as

conodonts from the middle member are found to refute this. Placement of

the middle member as being largely within the S. praesulcata Biozones is

interpretative and based primarily on conodont occurrence above and

below this member (Fig. 7 and 18).

Upper member of the Bakken Format ion

Hayes (1984, 1985) tentatively recognized the Lower Siphonodella crenulata Biozone in the upper member of the Bakken on the basis of a limited collection of siphonodellid elements. The base of this Kinderhookian biozone is recognized by the lowest occurrence of Gnathodus delicatus, or in its absence, by the first occurrence of Siphonodella crenulata. Sandberg (1979, p. 100) said that the siphonodellids attained their maximum speciation in the middle of this biozone. Form-taxa recovered from the upper member and present within this biozone include: Siphonodella crenulata, S. cooperi, S. quadruplicate, S. obsolete, Pseudopolygnathus primus (= P. dentilineatus), Polygnathus communis communis, P. inornatus, P. longiposticus. "Spathognathodus" crassidentatus, Bispathodus stabilis. B. aculeatus aculeatus, and Elictognathus laceratus. In addition, Siphonodella sulcata, S. duplicate, and S. sandbergi become extinct within this biozone. The large number of form-taxa obtained in this study confirms the presence of the Lower Siphonodella crenulata Biozone; however, biozones occurring beneath it may also be present, at least in part, in the upper member of the Bakken.

Sandberg (1979, p. 98) stated that the "base of the Mississippian in North America and the base of the Carboniferous worldwide" can be recognized by the lowest occurrence of Siphonodella sulcata in the presence of Siphonodella praesulcata. Siphonodella sulcata was recovered from three cores of the upper member but had not been reported in North Dakota prior to my study. While earliest Mississippian strata cannot be unequivocally recognized merely on the presence of S. sulcata,

and especially because of Its association in the Willisten Basin In lag zones with conodonts representative of Kinderhookian biozones younger than the S. sulcata Blozone, only further sampling and processing of the upper member and unit 3 of the middle member may reveal the unqualified presence of the S. sulcata Blozone.

The Sjphonodella sandbergi Blozone is stratigraphically lower than the Lower Sjphonodella crenulata Blozone and the faunal components of these two biozones are nearly identical. According to Sandberg (1979, p. 100), the base of the Sjphonodella sandbergi Blozone is defined by the lowest occurrence of S. sandbergi and the upper boundary can be defined by the lowest occurrence of S. crenulata. Conodont elements associated with this blozone are the same as those for the Lower S. crenulata Blozone. Only one bedding surface in the upper member of the Bakken that was sampled in this study contains S. sandbergi in the absence of S. crenulata. Confidence in the presence of the S. sandbergi Blozone could be strengthened by the presence of the Sjphonodella duplicata Biozones below it.

The base of the Lower Sjphonodella duplicata Blozone is recognized by the lowest occurrence of S. duplicata morphotype 1 and the upper boundary of the Upper S. duplicata Blozone is recognized by the lowest occurrence of S. sandbergi. Associated elements present in these biozones, and recovered in this study, include: Sjphonodella sulcata. S. duplicata, Bispathodus aculeatus aculeatus, B. stabilis, Pseudopolygnathus primus. Polygnathus communis communis, P. inornata, and P. longiposticus. One of the lag-containing wells, NDGS Well No. 4958, contains S. sulcata and a number of morphologic varieties of S.

duplicata in the absence of conodonts indicative of stratigraphlcally
higher conodont biozones. Determination of the specific biozone within
the limits of the two S. duplicata Biozones was not possible because of
the difficulty of recognizing distinct morphotypes of S. duplicata and
S. cooper1. which define the particular boundaries, and because of the
occurrence of many morphologies of these form-species together in two
separate lags.

In summary, the upper member definitely contains conodonts of the
Lower Siphonodella crenulata Biozone and there are indications of the
presence of the Siphonodella sandbergi and Siphonodella duplicata
Biozones in this member. In addition, whereas Siphonodella sulcata is
present within this member, its association in lags or concentrates with
conodonts indicative of stratigraphlcally higher biozones does not allow
for the unquestioned presence of the Siphonodella sulcata Biozone.
However, further sampling in upper member cores devoid of lags may
substantiate the presence of this biozone.

Lodgepole Formation

The change in lithology observed in the overlying Lodgepole
Formation represents a change in depositional processes from that of the
Bakken Formation; however, there appears to be a continuous record of
siphonodellid elements to record the transition from anoxic into more
nearly normal, marine conditions. The same conodonts of the Lower
Siphonodella crenulata Biozone found in the upper member of the Bakken
are also present in the basal Lodgepole (except S. sulcata); but, in
addition, the fauna includes the entry in the basal Lodgepole of S.

obsoleta, S. cf. S. isosticha, and the lowest occurrence of

Ps eudopolygnathus marginatus and P. triangulus. Sandberg (1979, p. 100)

reported that these pseudopolygnathid elements help to differentiate the

Lower S. crenulata Biozone, in the absence of the nominal taxon, from

the S. sandbergi Biozone.

The uppermost Kinderhookian conodont biozone is the Siphonodella

isosticha—Upper Siphonodella crenulata Biozone. This biozone is

defined at its base by the latest occurrence of Gnathodus delicatus and

by the last occurrence of the form-genus Siphonodella. Sandberg (1979,

p. 100) said that S. isosticha ranges throughout this biozone and S.

crenulata becomes extinct within it. Other associated conodont taxa

recovered in this study and of importance in this biozone include:

Siphonodella isosticha, S. cooperi. S. cf. S. isosticha. Polygnathus

communis communis, P. inornatus, P. longiposticus, Bispathodus stabilis,

Dinodus fragosus, D. youngquisti, and Elictognathus laceratus.

In summary, the basal Lodgepole Formation contains conodonts

representing the Lower Siphonodella crenulata Biozone and, based on

identification of S. isosticha. at least a portion of the Upper

Siphonodella crenulata--Siphonodella isosticha Biozone may well be

represented in these strata. The highest occurrence of a siphonodellid

element was recorded from an interval between 29 and 35 feet above the

top of the Bakken. Shortly above this, conodonts became conspicuously

absent. Thus, the upper boundary of the uppermost Kinderhookian biozone

and the appearance of Osagean conodonts was not recognized in this

study.

<u>Conodont Biofacies</u> in <u>the Williston Basin</u>

Sandberg (1976) used conodont faunas of the Upper <u>Polygnathus</u>

<u>stvriacus</u> Biozone (= Lower <u>Palmatolepis gracilis expansa</u> Biozone of

Ziegler and Sandberg, 1984) from the Rocky Mountain and Great Basin

regions to develop a pattern of conodont biofacies from "paleotectonic

settings ranging from continental rise to offshore bank and lagoon."

Sandberg (1976) used over 8,800 specimens from 38 collections at 19

localities. Sandberg (1976) based identification of a particular

biofacies on percentages of particular platform genera present within a

specific conodont collection. For example, the palmatolepid-bispathodid

biofacies, interpreted by Sandberg to be deposited on a continental rise

or slope (the clino environment of Rich, 1951), contains 47 percent

<u>Palmatolepis</u>, 39 percent <u>Bispathodus</u>. and 3 percent B. <u>iugosus</u>. In

addition, Sandberg said (p. 171) that this biofacies is almost devoid of

<u>Polygnathus</u>. <u>Pseudopolvgnathus</u>, and <u>Icriodus</u>. The palmatolepid-

polygnathid biofacies, deposited in a continental shelf (unda) setting,

is composed of 35 percent <u>Palmatolepis</u>. 49 percent <u>Polygnathus</u>, and 8

percent <u>Bispathodus stabilis</u>. <u>Bispathodus Iugosus</u>. <u>Pseudopolvgnathus</u>.

"<u>Spathognathodus</u>." <u>Icriodus</u> and similar shallow-water forms comprise the

remaining 8 percent. Hayes (1984, p. 84) used 80 platform elements of 5

form-genera recovered from the lower member of the Bakken and calculated

approximately 23 percent <u>Palmatolepis</u>. 21 percent <u>Polygnathus</u>, 11

percent <u>Bispathodus</u>, and about 45 percent "<u>Spathognathodus</u>" and

<u>Branmehla</u>. Except for the high percentage of "<u>Spathognathodus</u>" and

<u>Branmehla</u> and the polygnathld elements, Hayes concluded (p. 85) that the

lower member conodonts most closely matched that of the palmatolepid-

bispathodid (slope) biofacies. In comparison, 150 platform elements

recovered in this study from the Lower <u>Palmatolepls gracilis expansa</u>

Biozone were used and the following percentages arrived at: 51 percent

<u>Palmatolepis</u>. 26 percent <u>Polygnathus</u>, 22 percent "<u>Spathognathodus</u>" and

Branmehla, and 1 percent <u>Bispathodus</u>. It appears that in Hayes[1] study

of the Bakken and in mine that the palmatolepid-polygnathid biofacies,

representing the shelf pr unda environment, is more appropriately

represented; however, the percentage of "<u>Spathognathodus</u>" and <u>Branmehla</u>

remains higher than results obtained by Sandberg (1976) and the exact

paleotectonic setting or mixing of biofacies has not been fully explored

for the Bakken Formation. Sandberg (1976, p. 175), however, did diagram

the palmatolepis-polygnathid biofacies as encompassing the Leatham

Member of the Pilot Shale, the Leatham Formation, the Sappington Member

of the Three Forks Formation, and the Exshaw Formation.

Platform conodonts obtained from the upper member of the Bakken and

basal Lodgepole consist mostly of <u>Siphonodella</u>. <u>Polygnathus</u>,

<u>Pseudopolygnathus</u>, and to a lesser extent "<u>spathognathodus</u>" and

<u>Bispathodus</u>. Whereas the biofacies patterns in the Lower <u>Palmatolepis</u>

<u>gracilis expansa</u> Biozone are well documented and widely recognized, the

biofacies of uppermost Devonian and lower Mississippian strata are not

as well known. Clark (1981, p. W88) said that, generally, lower

Mississippian strata contain a deeper-water fauna of <u>Siphonodella</u> and

<u>Pseudopolygnathus</u>. and in shallower water, a "<u>Spathognathodus</u>."

<u>Polygnathus</u>, and <u>Clydagnathus</u> fauna. Sandberg and Gutschick (1983,

p. 221) reported that strata containing the Lower <u>Siphonodella crenulata</u>

Biozone were deposited at a high stand of the Kinderhookian seas and

that the presence of Siphonodella indicates a pelagic conodont

biofacies. The predominant Siphonodella and Pseudopolygnathus fauna,

and the reduced Polygnathus and "Spathognathodus" collection, recovered

from the upper member of the Bakken and basal Lodgepole, indicates that

these units were deposited in "deeper water" of the Kinderhookian seas.

Age

Nordquist (1953) considered the Bakken Formation in North Dakota to

be wholly Mississlppian in age. Sandberg and Hammond (1958) suggested

that the Bakken might be both Devonian and Mississlppian in age. Based

on faunal studies, Christopher (1961), Sandberg and Klapper (1967), and

Macqueen and Sandberg (1970), reported that the age of the Bakken was

both Devonian and Mississlppian. Not until Hayes (1984) extracted

conodonts from the Bakken was a dual age for the Bakken documented in

North Dakota. However, in spite of 25 years of research, the original

concept of Nordquist is still used (see Leenheer, 1984).

Hayes (1984, p. 79) used a "small, but biostratigraphically useful

conodont fauna from the lower shale, and an abundant fauna from the

upper shale," to determine that the Bakken Formation was both Late

Devonian (Famennian) and Early Mississlppian (Kinderhookian) in age.

Hayes recognized Famennian conodonts (dominated by Palmatolepis) in the

lower member of the Bakken and Kinderhookian conodonts (dominated by

Siphonodella) in the upper member of the Bakken. The middle member

produced no stratlgraphlcally diagnostic conodonts. Hayes (1984, p. 79)

determined that the position of the Devonian-Mississippian systemic

boundary in North Dakota was unclear, "but paleontological evidence

suggests that it occurs at, or near, the contact between the middle member and the upper shale of the Bakken."

Thrasher (1985) also recognized that the Bakken was of Devonian and Hississippian age and, based on an extensive macrofossil collection, was able further to define the position of the systemic boundary within the middle member of the Bakken. Thrasher (1985, p. 67) recognized a distinctly Devonian assemblage of macrofosslls, dominated by the brachiopod Rhipidomella missouriensis and other brachiopods that resemble the Svringothvris fauna of the Sappington Member of the Three Forks Formation in his unit 1, and a distinctly Mississippian assemblage of macrofosslls, dominated by a number of brachiopods that have been reported from the McCraney Limestone and the siltstone unit of the Exshaw Formation, in his unit 3. Circumstantial paleontologic evidence lead him to conclude that the position of the Devonian-Mississippian systemic boundary was situated between his units 1 and 2 in the middle member of the Bakken.

The general age determinations of Hayes (1984), that the Bakken Formation is both Devonian and Mississippian in age, are supported in this study, but are more firmly established in terms of biozonation and position within the respective stages. The presence of three new recognized form-taxa of Palmatolepis and associated polygnathid elements suggests that the Lower Palmatolepls gracilis expanse Biozone is present within the lower part of the lower member of the Bakken in the Williston Basin. Further study of the lower member, and associated lags, may confirm the presence of one or more of the Palmatolepls perlobata postera biozones below, and the Middle Palmatolepls gracilis expansa

Biozone above the Lower P. g. expansa Biozone; but at this time, recognition of more than the latter biozones in the lower member in the Williston Basin must be considered as tentative (Figs. 7 and 18).

Biostratigraphic units for the middle member of the Bakken Formation remain unknown; however, Thrasher's (1985) position of the systemic boundary is accepted. Thus, unit 1 of the middle member may well be of latest Devonian (one or more of the Siphonodella praesulcata Biozones) age and units 2 and 3 of the middle member may be of earliest Mississippian (Siphonodella sulcata Biozone) age.

The upper member of the Bakken Formation and the basal Lodgepole Formation are Kinderhooklan in age. The presence of Siphonodella sulcata indicates that the upper member may be as old as the S. sulcata Biozone; however, in the absence of S. praesulcata and because the associated siphonodellid elements recovered with S. sulcata may range into the middle Kinderhooklan, the upper member may be no older than the Lower Siphonodella crenulata Biozone as suggested by Hayes (1984, 1985). This question will not be definitely answered until the character and depositional significance of the thin, coarse-grained, lag deposits are ascertained. For example, if the lag zones do represent gentle, current-winnowed removal of fine-grained elastics and organic material over a significant period of time, then the conodonts present in a lag deposit might represent a continuum of conodont biozones that have been placed together by removal of sediment. Alternatively, the lag deposits may represent a short burst of sediment removal and conodont concentration that occurred in the lower part of the Lower Siphonodella crenulata Biozone when, according to Sandberg (1979), all the name-

bearing zonal conodonts were in existence.

The basal Lodgepole Formation contains Kinderhookian conodonts that are representative of the upper part of the Lower Siphonodella crenulata Biozone and the lower part of the Siphonodella isosticha—Upper Siphonodella crenulata Biozone. The upper biostratigraphic limit of Kinderhookian rocks within the Lodgepole cannot be determined due to lack of core and a dwindling number of conodonts (Fig. 16). The lithologies of the Bakken and overlying Lodgepole are distinctly different and easily differentiated; however, conodonts perhaps representing an unbroken succession of conodont biozones are present in these units. The Lower Siphonodella crenulata Biozone is represented in both the upper member of the Bakken and the basal Lodgepole (Figs. 7 and 18) and, therefore, deposition across this formational boundary also appears to have been unbroken. No stratigraphically diagnostic conodonts that define the Kinderhookian-Osagean series boundary were recovered, but the upper Lodgepole in North Dakota may be as young as Osagean.

Regional Correlation

Conodonts recovered from the Bakken Formation in North Dakota are similar to conodont faunas obtained from Bakken stratigraphic or lithic equivalents outside of the Williston Basin. The Lower Palmatolepis gracilis expansa Biozone, found in the lower member of the Bakken, has been recorded in similar basal, dark shale units in the Leatham Member of the Pilot Shale, the Leatham Formation, the Sappington Member of the Three Forks Formation, and the Exshaw Formation. Thus these units were

deposited contemporaneously during the Lower Palmatolepis gracilis expansa Biozone. Conodont evidence collected in this study and similar evidence reported by Macqueen and Sandberg (1970) shows that the lower and upper boundaries of these units may be slightly older, or younger (respectively), than the biozone represented because of earlier initiation of deposition or, in the case of the Exshaw Formation, a lingering continuation of depositional conditions into the Early Mississippian.

The middle member of the Bakken is considered likely to be mostly of the Siphonodella praesulcata Biozones, intimated by macrofossil evidence collected by Thrasher (1985) and conodont evidence collected in this study in the members above and below it (Fig. 7). However, unit 1 of the middle member may be as old as the Middle Palmatolepis gracilis expansa Biozone and unit 3 may include a portion of the Siphonodella sulcata Biozone. Therefore, the middle member is tentatively considered to be equivalent to the siltstone unit of the Leatham Member of the Pilot and possibly the basal portion of the upper member of the Pilot Shale, units 4-7 of the Leatham Formation, units 2-6 (units E-H) of the Sappington Member of the Three Forks Formation, part of the black shale unit of the Exshaw Formation, and the lower part of the Englewood Formation.

The upper member of the Bakken contains conodonts that have been recovered from the upper member of the Pilot Shale, the upper tongue of the Cottonwood Canyon Member of the Lodgepole (or Madison) in central Wyoming, and the upper part of the Englewood Formation.

Not surprisingly, the conodonts obtained from the Lodgepole

Formation in North Dakota are the same as conodonts recovered from the

Lodgepole Limestone in the Little Belt and Little Rocky Mountains in

Montana. In addition, the conodont fauna is the same as that recovered

from the upper Englewood Formation and basal Pahasapa Formation in the

Black Hills, the lower part of the Madison Limestone in central Wyoming,

the Joana Limestone, and the Banff Formation.

Depositional Summary

Summaries of the depositional conditions of the Bakken Formation in

North Dakota have been recently presented by Webster (1982, 1984), Hayes

(1984, 1985), and Thrasher (1985). The main thrust of this study was to

extract, describe, and determine the biozonation of conodonts obtained

from the Bakken and basal Lodgepole Formations. Sandberg and others

(1983) have provided a very complete synthesis of depositional events

with regard to conodont biozone distribution. Their article does not

discuss specific aspects of Bakken deposition and conodont

biostratigraphy, but from the close similarities reported in equivalent

units and evidence observed during this study, their conclusions have

direct application to the Bakken and the basal Lodgepole Formation.

Sandberg and others (1983, p. 704) stated that the dark shale unit

of the Leatham Member of the Pilot Shale, units 1-3 of the Leatham

Formation, and units A-D (or unit 1) of the Sappington Member of the

Three Forks Formations were deposited during the initiation of a brief

transgression during the time of the Lower Palmatolepis gracilis expansa

Biozone. Sandberg and others (1983, p. 704) and Sandberg (1976) have

suggested that these units are deep-water deposits. Sandberg and others

(1983, p. 704) stated that the:

> . . . widespread distribution of different conodont
> faunas of this complex probably resulted from the
> rapidity of the transgressive pulse, which was
> accompanied by eustatic deepening and (or) crustal
> downwarping. These factors permitted relatively
> deep-water rocks, such as the lower black shale of
> the Sappington Member of the Three Forks Formation
> to be deposited far onto the craton. Under these
> conditions, aeration, food supply, and other life
> sustaining factors were ideal for the development
> of large, highly diversified conodont faunas.

As was discussed previously, the Sappington Member of the Three Forks,
the Leatham Member of the Pilot Shale, the Leatham Formation, the Exshaw
Formation, and the Bakken Formation were once part of the same
depositional complex. Conodonts recovered from the lower member of the
Bakken establish a fauna1 link, thus supporting the contention that it
too was part of this late Famennian transgressive pulse.

Towards the end of the time of the Lower <u>Palmatolepis gracilis</u>
<u>expansa</u> Biozone, regression of the late Devonian seas began and
continued until the end of the Devonian. Sandberg and others (1983,
p. 707) said that shallowing of these Famennian seas is shown by the
shallow-water biota, ichnofossils, and change in lithologic character of
the sediments deposited. The dark, thinly laminated shales abruptly
give way to calcareous siltstones, mudstones, and sandstones. The upper
portions of the Leatham Member of the Pilot Shale, Leatham Formation,
and Sappington Member of the Three Forks Formation all reflect the
change in depositional setting and unit 1 of the middle member of the
Bakken is the reflection of this change in the Williston Basin.

At the start of the Mississippian, sea level in the tnidcontinent
was still at a low stand. With the reduced water bodies and connective

seaways, the Siphonodella sulcata Biozone has only been recorded from

the central-most part of the depositional complex (Sandberg and others,

1983, p. 707). With increased activity in the Antler Highlands, early

Mississippian seaways became consolidated so that the Siphonodella

duplicata and Siphonodella sandbergi Biozones represent a return to

deeper-water and anoxic deposition and are represented by the upper

member of the Pilot Shale, the upper tongue of the Cottonwood Canyon

Member of the Lodgepole Limestone, and the upper member of the Bakken

Formation in North Dakota (although none of these three biozones has

definitely been identified in North Dakota).

The Lower Siphonodella crenulata Biozone represents a time of rapid

transgression onto the North American craton. As sea level continued to

rise and water spread eastward onto the shelves of the Williston Basin,

anoxic conditions gave way to more normal marine conditions as

represented by the basal Lodgepole Formation. The last part of the

Lower Siphonodella crenulata Biozone and the lower part of the

Siphonodella isosticha—Upper Siphonodella crenulata Biozone are

represented in the Lodgepole or Lodgepole equivalents from North Dakota

into Canada and south to Nevada as the Kinderhookian seas attained their

maximum areal extent.

In sum, the Bakken Formation was deposited at approximately the

same time and under similar conditions as dark shale and siltstone units

adjacent to the Williston Basin. The upper and lower members of the

Bakken seem to have been deposited under conditions similar to other

dark shale units. Thin laminae, dark color, high total organic carbon,

abundant pyrite, and a limited and tolerant benthic fauna suggest

deposition in an offshore, anoxic, marine environment with limited or
sporadic water circulation patterns. Varying salinities are evidenced
by the presence of thin-shelled conchostracans that GutSchick and
Rodriguez (1979, p. 44) said may indicate reduced salinity or brackish-
water conditions. Following the outline of depositional events
presented by Sandberg and others (1983), the shale members of the Bakken
were deposited during separate periods of transgression of late Devonian
and early Mississippian seas. The onlapping relationship between the
members of the Bakken indicate that these seas, conducive to the
formation of dark shale, had achieved their near maximum areal extent at
the time of deposition of the upper member.

The calcareous middle member of the Bakken indicates deposition
under slightly dysaerobic or mostly aerobic conditions with increased
water circulation and current activity under the influence of increased
sediment accumulation. The abundant benthie macrofossil assemblage is
suggestive of a change in habitat that was more suitable to benthic life
(normal salinities, water temperatures, and organic productivity, and
shallower water). No conodonts were recovered from the middle member to
determine a position within Sandberg[1]s (1976) conodont biofacies-
determined environments; however, Thrasher (1985, p. 118) concluded that
unit 1 was deposited during a Late Devonian regression, whereas units 2
and 3 of the middle member are the result of renewed transgression
within the Williston Basin that continued into the late Kinderhookian.

With rising sea levels in the Kinderhookian, deposition in the
Williston Basin turned to a more normal, carbonate-producing, marine
environment. Lithologies developed in the Lodgepole Formation suggest a

wide variety of environments ranging from relatively deep water deposits
in the central Basin to shallow-shelf deposits at the Basin margins
(Heck, 1978, p. 198). Sea levels then began to recede so that by the
close of Lodgepole deposition, shallow margin deposits were occurring
over the deeper-water, central-Basin lithologies.

SUMMARY OF CONCLUSIONS

1. Nearly 2000 individual conodont elements were identified from the
    Bakken and basal Lodgepole Formations in the Williston Basin, North
    Dakota. Twenty-five species-level form-taxa recovered from the
    Bakken and 61 species-level form-taxa recovered from the basal
    Lodgepole Formation are here reported for the first time.

2. The existence of one Famennian conodont biozone (Lower Palmatolepis
    gracilis expansa) was confirmed and the possibility of a portion of
    three other biozones (Lower and Middle Palmatolepis perlobata
    postera and the Middle Palmatolepis gracilis expansa) was
    recognized, for the first time, in the lower part of the lower
    member of the Bakken.

3. No stratigraphically diagnostic conodonts were obtained from the
    middle member of the Bakken; however, based on the conodont-bearing
    units above and below the middle member and macrofossil collections
    made by Thrasher (1985), the middle member is tentatively
    considered to have been deposited during the time of the upper
    Devonian Siphonodella praesulcata Biozones and the lower part of
    the Mississippian Siphonodella sulcata Biozone.

4. Based on the collected conodont fauna, at least one (Lower
    Siphonodella crenulata), and possibly five (Lower and Upper
    Siphonodella duplicate. S. sandbergi. Lower S. crenulata, and
    S. isosticha--Upper S. crenulata) of the six Kinderhookian conodont
    biozones were recognized in the upper member of the Bakken and the
    basal Lodgepole.

5. Lag zones produce abundant conodonts where Identified In the core.
    They may result from accumulation of coarse-grained fossil and
    inorganic debris in sediment-starved conditions; winnowing out of
    fine-grained siliciclastics and organic material during deposition
    that enhanced deposition of coarse-grained fossils and inorganic
    material; and selective winnowing of partially lithified sediment
    by evanescent currents. Unfortunately, conodonts recovered from
    lag zones contributed little to biostratigraphic zonation.

6. The collected conodont fauna supports the concept of continuous
    sedimentation from the Bakken Formation into the Lodgepole
    Formation as has been indicated by previous lithologic studies.

7. Conodonts recovered from the Bakken Formation in North Dakota
    support the established equivalence of the Bakken to the Leatham
    Member of the Pilot Shale, the Leatham Formation, the Sappington
    Member of the Three Forks Formation, the basal Exshaw Formation and
    the lower part of the Englewood Formation.

8. Conodonts recovered from the basal Lodgepole Formation are better
    preserved than those obtained in the Bakken Formation. Form-taxa
    diversity is greater In the Lodgepole; however, this relation may
    be clouded by the better preservational quality in the Lodgepole
    and greater number of indistinguishable fragments recovered from
    the Bakken.

9. The conodont fauna recovered from the basal Lodgepole Formation is
    taxonomically similar to other Lodgepole conodont collections made
    from outcrop. Llthologically and faunally, the Lodgepole Formation
    in North Dakota is equivalent to the Joana Limestone of Nevada, the
    Lodgepole Limestone of Montana and western Wyoming, the lower part

of the Madison Limestone in central Wyoming, the Banff Formation in Alberta, and the upper part of the Englewood Formation and the basal part of the Fahasapa Formation in South Dakota.

10. As the Bakken and Lodgepole Formations contain abundant and diverse conodont faunas, these could well furnish the basis for future study. Such studies might include: systematic and detailed sampling of the Bakken, particularly in the upper part of the lower member, the whole of the middle and upper members; quantitative analysis of the late Devonian and early Mississippian conodont fauna in the Williston Basin followed by paleobiogeographic analysis and interpretation, as well as comparison to similar faunas recovered from like-aged units outside of North Dakota; and further sampling and processing of samples in the Lodgepole, especially higher in the section where the distribution of conodonts dwindles.

11. Identification of conodonts and conodont biozones from the Three Forks Formation, subjacent to the Bakken, would help to define sedimentational patterns across this formational contact.

12. Detailed petrographic and geochemical study of the shales of the Bakken may be helpful in determining depositional processes and characteristics of dark shale deposition. Finally, the abundance of sedimentological information in the middle member of the Bakken deserves study. Examination of the variety of sedimentary structures of this member, paleoecologic implications of its abundant benthic fauna, and lithologic differences from the dark shales that surround it would help to clarify changes in depositional patterns that produced these varied lithologies.

SYSTEMATIC PALEONTOLOGY

To provide a relatively complete discussion of the form-taxa
collected in this study, many older, as well as recent references, were
utilized. Because of the relatively rapid evolution of conodont study,
terminology used in the older literature may differ slightly from more
modern usage. Many of the original sources were included if the
original description of a particular taxon, for example, is still valid
and completely accurate. In places where older terminology may be made
more clear, bracketed parenthetical statements or modern terms have been
inserted. A complete list of conodont morphologic and structural terms
were given in a glossary prepared by Sweet (1981b, p. W60-W68).
Although the list of references for the current study is extensive, many
sources (especially the older references) have limited descriptions or
less than adequate illustrations. As more recent workers have given
synonymies, in some cases adding their own questioned assignment, and as
it became apparent during this study that questioned or comparative
assignments were necessary, the suggestions regarding open nomenclature
in systematics and synonymy made by Matthews (1973) were implemented.
The lists of synonymy presented herein are not complete; they represent
the major taxonomic revisions or good illustrations or direct the reader
to a complete earlier synonymy.

Individual elements have traditionally been designated as
individual taxonomic units even though it was recognized by Pander
(Sweet and Bergstrom, 1970, p. 157) that taxonomic units of conodonts
should perhaps contain more than one element. With the explosion of

conodont research in this century, a number of workers have identified

naturally occurring groups (for example, Scott, 1942; Rhodes, 1952;

Puchkov and others, 1982 [1981]) or statistically reconstructed (Kohut,

1969) multielement assemblages; these assemblages are taken to represent

one taxonomic unit of the conodont animal. Because the total number of

individual elements collected in this study is not statistically

significant for mathematical grouping, and because no fused clusters nor

natural assemblages were found, a form-taxa approach was used in this

study. The conodont elements described and illustrated in this report

are arranged alphabetically by form-genera. In recognizing the

appropriateness of multielement taxonomy, the form-genera "Hindeodella".

"Neoprioniodus". and "Spathognathodus" are enclosed in quotation marks

as these names (Hindeodella. Neoprioniodus, and Spathognathodus) are now

used to denote multielement genera. Klapper and Philip (1971) and Sweet

(1981a), as well as other workers, have devised various schemes of

notation to mark location or position of discrete elements in

multielement apparatuses. Sweet (1981a, p. W18, W19) recommended a

scheme based on a symmetrical, seximembrate apparatus that is separated

into three position catagories. P, M, and S, variously modified with

subscripts, designate position within the apparatus. Klapper and Philip

(1971), using statistically reconstructed Devonian apparatuses, devised

a similar notation scheme. Element types within the particular

apparatus were symbolized with the letters P, 0, N, A, and B.

Subscripts were used to denote the symmetry transition in long-ranging

elements (A and B types) or distinct morphologic dissimilarities

(0 types) within each apparatus and for homological comparisons of other

reconstructions. These two positional notation schemes are made note of, wherever possible herein, in recognition of the appropriateness of multielement notation and, ultimately, biological classification.

Phylum CONODONTA Eichenberg, 1930

Class CONODONTA Eichenberg, 1930

Order CONODONTOPHORIDA Eichenberg, 1930

Form-genus Angulodus Huddle, 1934

Angulodus Huddle, 1934, p. 76. Austin and others, 1981, p. W172.

Type species: Angulodus demissus Huddle, 1934.

Diagnosis: "Bar heavy, rounded, with both the anterior and posterior ends deflected downward; anterior end curved laterally. Cusp subcentral, rounded and straight or slightly curved; denticles closely spaced, rounded and apparently inserted; a few denticles at the posterior end of the bar point straight backward . . . " (Huddle, 1934, p. 76).

Remarks: Huddle (1934, p. 76) stated that Angulodus differs from Metaprioniodus in that the denticles of the former are closely spaced, appressed, and the position of the cusp is subcentral. Angulodus differs from Bryantodus in the lack of lateral ridges and downward deflection of the posterior bar. Austin and others (1981, p. W172) referred this form-genus to Sb elements of multielement nomenclature. Klapper and Philip (1971) assigned angulodontan elements to A-type elements in at least three reconstructed apparatuses.

Angulodus cf. A. demissus Huddle

PI. 3, fig. 1

Diagnosis: Heavy bar, rounded with oral shoulder on inner side posterior of large, subcentral cusp. Anterior deflected downward and bowed inward. Cusp rounded, widened at base. Denticles rounded, closely

spaced, and number 15; posterior denticles directed posteriorly, larger than cusp. Basal pit indistinguishable.

Remarks: Huddle (1934, p. 77) described Angulodus demissus as follows:

> Bar heavy, rounded, with oral shoulder on concave
> [inner] side posterior to the cusp, anterior portion
> deflected downward and slightly bowed laterally;
> posterior projection small. Cusp rounded, length
> unknown; denticles rounded, closely spaced, and
> apparently inserted.

Specimens collected in this study are similar to that illustrated by Huddle (1934, pi. 10, fig. 15) in that both specimens exhibit posterior and anterior deflections, an oral shoulder on the inner side, and a subcentral position of the cusp. However, two major differences do not allow for confident assignment to A. demissus• First, the specimens of this study have many fewer (15) bar denticles than Huddle's specimen (28); and, although the posterior denticles are directed posteriorly, none appears to be any longer than the other; whereas, in the Lodgepole specimens two prominent posterior denticles are longer than the cusp and other bar denticles.

Material: Two complete specimens and one broken specimen were collected from the basal Lodgepole.

Form-genus Bispatnodus Muller, 1962

Spathodus (Bispathodus) Muller, 1962a, p. 114.

Bispathodus Muller, Ziegler, Sandberg, and Austin, 1974, p. 100.

Ziegler, 1975, p. 13-15. Klapper and others, 1981, p. W164.

Type species: Spathodus spinulicostatus Branson, 1934.

Diagnosis: Compound "element characterized by one or more accessory (clearly separated) or satellite (barely split) denticles on right side of the blade. Where the side denticles are clearly separated, they may occur as round peg-like nodes, transverly [sic] elongate ridge-like nodes, nodes connected to the main blade by ridges, or sharp transverse ridges. The basal cavity, which is expanded laterally beyond the vertical sides of the blade, is either centered approximately below the midpoint of the blade or extended from there to the posterior tip. Left-side denticles may be present in the posterior part of the blade, but they do not occur to the exclusion of right-side denticles nor do they advance anteriorward of the basal cavity" (Ziegler and others, 1974, p. 100).

Remarks: Ziegler and others (1974) believed Bispathodus to be a P element in the apparatus reconstructions of Klapper and Philip (1971); however, Klapper and others (1981, p. W164) pointed out that only the P element is recognized. Bispathodus ranges from the Upper Devonian into the Lower Mississippian and contains many biostratigraphically unique elements. Bispathodus gave rise to several related genera, most notably the pseudopolygnathids.

Bispathodus aculeatus (Branson and Mehl)

partim Spathodus aculeatus Branson and Mehl, 1934a, p. 186, 187, pi. 17,
        figs. 11, 14.

partim Spathognathodus aculeatus (Branson and Mehl). Ziegler, Sandberg,
        and Austin, 1974, p. 101, pi. 1, fig. 5; pi. 2, figs. 1-8.
        Ziegler, 1975, p. 19-21, pi. 1, figs. 1-4. Hayes, 1985, pi. 2,

figs. 13, 14, 19, 20.

Diagnosis: " . . . one or more lateral nodes or transverse ridges
on the right side of the blade in a central position, more or less above
the basal cavity and not extending to the posterior tip of the blade. In
some specimens the side denticles may be only slightly split from the
main blade denticles.

"On the left side, a node, denticles, or nodose ridge may be
present on the upper surface of the basal cavity or on the blade above
it" (Ziegler and others, 1974, p. 100).

Remarks: Subspecific assignment within the form-species
Bispathodus aculeatus is based on the degree of anterior development of
the blade and the position and number of side denticles. Distinctions
are difficult to observe because of many intergradational forms. The
range (Ziegler, 1975, p. 18) of B. aculeatus is from the upper Middle and
Upper Palmatolepis gracilis expanse Biozones (Ziegler and Sandberg, 1984,
p. 180) (upper part of the Lower Bispathodus costatus Biozone sensu
Sandberg, 1979, p. 91) through the Lower Siphonodella crenulata Biozone.

Bispathodus aculeatus aculeatus (Branson and Mehl)

PI. 1, fig. 29

Bispathodus aculeatus aculeatus (Branson and Mehl). Ziegler, Sandberg,
        and Austin, 1974, p. 101, pi. 1, fig. 5; pi. 2, figs. 1-8.
        Ziegler, 1975, p. 19-21, pi. 1, figs. 1-4. Hayes, 1985, pi. 2,
        figs. 13, 14, 19, 20.

Diagnosis: " . . . anterior part of blade is even-topped, or
highest at the center or anterior to the center. One or more accessory

denticles are present above the basal cavity on the right side of the blade" (Ziegler and others, 1974, p. 101).

Remarks: These elements are distinguished by the presence of the few accessory denticles on the right side of the blade. Bispathodus aculeatus aculeatus is distinguished from other subspecies of B. aculeatus by lacking the single prominent, anterior, offset denticle that B. a. anteposicornis (Scott) has, and by lack of a plume-like anterior projection on the blade as exhibited by B. a. plumulus (Rhodes, Austin, and Druce). Ziegler and others (1974, p. 101) reported that some specimens of B. a. aculeatus that exhibit more than one node, denticle, ridge, or smooth bulge on the left side of the blade may be mistaken for Pseudopolygnathus primus fPseudopolygnathus dentilineatus sensu Klapper, 1966]. In this report, the distinction between these two elements was based strictly on the configuration of the basal cavity; P. primus has a typically circular cavity, whereas B. a. aculeatus may have a subcircular, oval, to sagitate cavity. The range of B. a. aculeatus is from the Middle Palmatolepis gracilis expanse Biozone of Ziegler and Sandberg (1984, p. 180) (or the upper part of the Lower Bispathodus costatus Biozone sensu Ziegler and others, 1974) through the Lower Siphonodella crenulata Biozone (Ziegler and others, 1974, p. 101).

Material: A collection of 19 elements was obtained from the upper member of the Bakken. The collection consists of nine mostly complete and ten broken elements representing a wide range of morphologic variability in the position and prominence of the lateral denticles.

Bispathodus jugosus (Branson and Mehl)

PI. 1, fig. 17

Spathodus jugosus Branson and Mehl, 1934a, p. 190, 191, pi. 17, figs. 19,
22(?).

Spathognathodus lugosus (Branson and Mehl). Ziegler, 1962, p. 110,
pi. 13, figs. 17-19.

Bispathodus jugosus (Branson and Mehl). Ziegler, Sandberg, and Austin,
1974, p. 103, pi. 1, figs. 3, 4; pi. 3, figs. 19, 23, 26.
Ziegler, 1975, p. 37-39, pi. 3, figs. 1-4. Hayes, 1985, pi. 2,
fig. 15.

Diagnosis: Straight to slightly curved row of main-blade
denticles paralleled by row of accessory denticles on right side;
accessory denticles continue anteriorly on blade farther than for any
other of form-species. Basal cavity rather large and asymmetrical,
extending to posterior end or close to it (modified from Ziegler and
others, 1974, p. 103).

Remarks: Bispathodus jugosus is an Upper Devonian element that
ranges (Ziegler and others, 1974, p. 103) throughout the Lower, Middle,
and Upper Palmatolepis gracilis expanse Biozones (Ziegler and Sandberg,
1984, p. 180) (middle of the Upper Polygnathus styriacus Biozone into the
lower part of the Middle Bispathodus costatus Biozone sensu Sandberg,
1979, p. 91).

Material: One nearly complete specimen with a large, asymmetrical
basal cavity and one broken specimen were collected from the lower member
of the Bakken.

<u>Bispathodus stabilis</u> (Branson and Mehl)

PI. 1, fig. 14

<u>Spathodus stabilis</u> Branson and Mehl, 1934a, p. 188, 189, pi. 17, fig. 20.

<u>Spathognathodus stabilis</u> (Branson and Mehl). Klapper, 1966, p. 23

(further synonymy), pi. 5, fig. 6 only.

<u>Spathognathodus crassidentatus</u> (Branson and Mehl). Rhodes, Austin, and

Druce, 1969, pi. 3, figs. 1-4.

<u>Bispathodus stabilis</u> (Branson and Mehl). Ziegler, Sandberg, and Austin,

1974, p. 103, 104, pi. 1, fig. 10; pi. 3, figs. 1-3. Ziegler,

1975, p. 47-49, pi. 2, figs. 9-12. Hayes, 1985, pi. 2, fig. 12.

<u>Diagnosis</u>: "Single-rowed, straight to slightly incurved. Unit
arched, especially from anterior end of basal cavity to posterior end of
blade. Denticles usually 20 or more in large specimens, commonly many
germ [suppressed] denticles. Symmetrical basal cavity widest anteriorly,
usually extending to near posterior end" (Klapper, 1966, p. 23).

Remarks: Klapper (1966, p. 23) reported that most of the
specimens reported in the literature as <u>Spathognathodus</u>
f"<u>Spathognathodus</u>"1 <u>crass identatus</u> do not exhibit specific characters
related to that element. Further, he suggested that many of those
incorrectly placed specimens should be referred to <u>Bispathodus stabilis</u>
although the basal cavity may not extend as posterior as originally
described.

Ziegler and others (1974, p. 97) stated, "<u>Bispathodus stabilis</u> is
the only species [form-species] of <u>Bispathodus</u> that does not have
accessory denticles on the right side of the blade. Its relationship to
the double-rowed members of the <u>Bispathodus</u> group is clearly evidenced,

however, by its tendency to develop widened or barely split (satellite) denticles at several different stages during its evolution." These authors also recognized two distinct morphotypes that are based on basal cavity configurations. The morphologies are significant in determining phylogenetic considerations, but are not considered to be diagnostically significant in this report. Bispathodus stabilis was said by Ziegler (1975, p. 48) to range from the Upper Palroatolepis marginifera marginifera Biozone into the Upper Siphonodella crenulata Biozone, but Lane and others (1980, p. 121) extended the upper range of B. stabilis into the Gnathodus texanus Biozone.

Material: One specimen with both anterior and posterior bars missing, and nine mostly complete specimens were recovered from the basal Lodgepole.

Bispathodus sp. indeterminate

Material: Five fragmented specimens, distinguishable from the single-rowed spathognathodids, were recovered from the upper member of the Bakken; but because of encrusting silt or fragmentation, they are recognizable at only the generic level.

Form-genus Branmehla Hass, 1959

Branmehla Hass, 1959, p. 381. Austin and others, 1981, p. W172.

Type species: Spathodus inornatus Branson and Mehl, 1934a.

Diagnosis: Element bladelike; basal cavity near posterior end of blade. Cusp indistinct; denticles fused with only apices free and closely set on blade. Posterior end may be flexed inward. Aboral edge

narrow; lips on basal cavity may be prominent (modified from Hass, 1959, p. 381).

Remarks: Distinction between "Spathognathodus" and Branmehla is difficult to establish when the elements are fragmented. Many conodont workers have considered Branmehla synonymous with "Spathognathodus." Hass (1959, p. 381) distinguished Branmehla on the position of the basal cavity, which is restricted to the posterior end of the element rather than at its center in the form-genus "Spathognathodus." Austin and others (1981, p. V172) considered Branmehla a Pa element of an apparatus of unknown affinities. Hass (1959) reported Branmehla ranging from the upper Devonian into the lowermost Mississippian; however, Ziegler and Sandberg (1984, p. 183) showed Branmehla extending only to the Middle Siphonodella praesulcata Biozone.

Branmehla inornata Hass, 1959

PI. 1, fig. 13

Spathodus inornatus Branson and Mehl, 1934a, p. 185, pi. 17, fig. 23.

Spathodus flexus Thomas, 1949, p. 429, pi. 2, fig. 20.

Spathognathodus inornatus (Branson and Mehl). Rexroad, 1969, p. 47,
    pi. 6, figs. 1, 2. Wang and Ziegler, 1982, pi. 1, fig. 9.

Branmehla inornata (Branson and Mehl). Hass, 1959, p. 381, pi. 50,
    fig. 3. Hayes, 1985, pi. 2, figs. 1, 2.

Diagnosis: Element laterally compressed and bladelike; slightly bowed inward. Anterior blade three times longer than posterior blade; denticles laterally compressed and sharp, biconvex in cross section. Basal cavity relatively large; lips semi-circular and smooth; outer lip

tends to be larger than inner. Narrow groove extends along length of
aboral edge (modified from Hass, 1959, p. 382).

Remarks: Hass (1959) believed B. inornata to be a "high Upper
Devonian to lowermost Mississippian" element. Ziegler and Sandberg
(1984, p. 183) illustrated the range of Branmehla inornata as sporadic in
the Upper Palmatolepls marginifera marginifera Biozone and extending into
the Middle Siphonodella praesulcata Biozone.

Material: Five complete or nearly complete specimens were
recovered from the lower member of the Bakken.

Form-genus Bryantodus Bassler, 1925

Bryantodus Bassler, 1925, p. 219. Ulrich and Bassler, 1926, p. 21.

Huddle, 1968, p. 9. Austin and others, 1981, p. W172.

Type species: Bryantodus typicus Bassler, 1925.

Diagnosis: "Conodont with more or less arched and bowed
triangular bars that are broad or flanged orally and thinner along the
aboral midline. Distinct cusp and basal cavity with or without lips in
the central third of the bar; denticles closely spaced" (Huddle, 1968,
p.9).

Remarks: Bryantodus is distinguished from the form-genus
Ozarkodina by having more massive bars, a distinct cusp and, on
infrequent specimens, a downward projecting apical lip at the position of
the basal cavity (Austin and others, 1981, p. W172). Bryantodus is
considered by Austin and others to be a P element of an unknown
apparatus. Huddle (1968, p. 9) reported the range of Bryantodus Middle
Silurian to Middle Pennsylvanian.

Bryantodus planirostris Branson, 1934

PI. 1, fig. 30

Bryantodus planirostris Branson, 1934, p. 326, pi. 28, fig. 31.

Diagnosis: "Bar thick at mid-height particularly in the front limb, nearly straight laterally, regularly curved into a low arch with the limbs about equal. Denticles of the back limb about eight, wide, long, laterally compressed, with discrete rounded tips, aboral and oral margins subparallel, all inclined slightly posteriorly. Apical denticle about three times as wide and twice as long as the largest of the limb denticles, fairly thick, with sharp edges and tip. Denticles of front limb about seven, very short, coalesced to near their tips, thick, with rounded edges and tips, irregular in size with an increase from the front toward the apical denticle. Aboral edge of the bar sharp. Apical [basal] pit very small, circular in outline" (Branson, 1934, p. 326).

Remarks: The thickness of the element at mid-height and aboral tapering results in a triangular cross section of the bar. Denticle size is distinctly different from the anterior to posterior bars. TVo broken specimens have been hesitantly assigned to this form-species based on the triangular cross section of the bar and similarity of the remaining part of the denticles with Branson*s (1934) description.

Material: Three mostly complete specimens were recovered from the basal Lodgepole.

Bryantodus planus Branson and Mehl, 1934

PI. 1, fig. 18

Bryantodus planus Branson and Mehl, 1934b, p. 284, pi. 23, fig. 8.

　　　Cooper, 1939, p. 385, pi. 43, figs. 29, 39. Canis, 1968,

　　　p. 534, 535, pi. 73, fig. 24.

non Bryantodus planus Huddle, 1934, p. 75, 76, pi. 10, fig. 8.

　　　Diagnosis: Bar moderately thick, blade-like, slightly arched laterally and concave inward. Anterior denticles about seven, relatively large, subequal, laterally compressed, posteriorly directed, and fused so that only apices free. Cusp large, twice the length and twice the width of bar denticles, laterally compressed, sharp edged, and inclined posteriorly. Posterior denticles about ten, similar to anterior denticles but smaller. Aboral edge sharp, basal pit circular, small (modified from Branson and Mehl, 1934b, p. 284).

　　　Remarks: Bryantodus planus is somewhat atypical of the other bryantodid elements. Widened development of the bar at mid-height is much suppressed on 13. planus and may be confused with ozarkodinan elements; however, it is distinguished by the generic characters of a prominent cusp and indistinct basal pit.

　　　Material: Two complete specimens were collected from the upper member of the Bakken.

Bryantodus typicus Bassler, 1925

Pl. 1, fig. 19

Bryantodus typicus Bassler, 1925, p. 219. Ulrich and Bassler, 1926,

      p. 21, 22, pi. 6, figs. 11, 12. Huddle, 1968, p. 11 (further

      synonymy), pi. 3, figs. 1-15; pi. 4, figs. 12-15.

Diagnosis: "Bar-type conodont more or less bowed inward and
arched upward. In young specimens the bar is triangular in cross
section, sharp aborally, and thickened at top or in the center. In
mature and older individuals the bar is flattened, broad or shelved, oval
in cross section, or nearly flat aborally. Bar denticles compressed,
biconvex in cross section, and commonly fused. There are four to eight
anterior denticles and three to ten posterior denticles. Cusp broad and
much larger than the denticles and includes in its base one or more
suppressed denticles, especially on the anterior side. Basal cavity
round, small, and below cusp in the central third of the bar and
flattened on the outside by projection or lip extending down from the
cusp" (Huddle, 1968, p. 11).

Remarks: The presence of a projection or lip-like extension
beneath the cusp distinguishes *Bryantodus typicus* from *Bryantodus*
planirostris. Other characters of these two taxa are strikingly similar.
The illustration of B. *typicus* (Pl. 1, fig. 19) does not reveal the
distinct apical flap. This is due to the orientation of the figured
specimen rather than lack of this character.

Material: One complete specimen was collected from the basal
Lodgepole.

Bryantodus sp. indeterminate

Material: Eleven fragmented specimens recovered from the upper
member of the Bakken and the basal Lodgepole were distinguishable at the
generic level but fragmented to the point of unrecognizable specific
characteristics.

Form-genus Dinodus Cooper, 1939

Dinodus Cooper, 1939, p. 386. Klapper, 1966, p. 24, 25. Austin and
        Rhodes, 1981, p. W170.

        Type species: Dinodus leptus Cooper, 1939.

        Diagnosis: "Highly arched, strongly compressed blades composed of
extremely thin, high denticles fused nearly to their tips and lacking
distinct main cusp. Unit asymmetrical or nearly symmetrical consisting
of either 2 or 3 processes. Surface covered with small pits.
Conspicuous flange near lower margin" (Klapper, 1966, p. 24).

        Remarks: Klapper (1966, p. 25) stated that Dinodus is a Lower
Mississippian (Kinderhookian) form-taxon.

Dinodus youngquisti Klapper, 1966

PI. 3, fig. 6

Scutula cf. S. venusta Sannemann. Voges, 1959, p. 306, pi. 35,
        figs. 14-18.

Dinodus youngquisti Klapper, 1966, p. 25, pi. 5, figs. 2, 3.

        Diagnosis: "Composed of posterior process and arch formed by 2
lateral processes. Unit nearly symmetrical, one side of arch slightly
more developed than other. Median posterior process projects through

flange developed near lower margin; basal cavity developed under posterior process where it intersects flange, which has sharp keel on its lower side" (Klapper, 1966, p. 25).

Remarks: This unique specimen has high, tightly fused denticles. Voges' (1959, pi. 35, figs. 14-18) illustrated specimens are of questionable value, but Klapper (1966, p. 25) felt very strongly about the affinity of Dinodus youngquisti and Scutula cf. S. venusta. I have no reason to question Klapper[f]s remarks on specimens he studied and, therefore, agree with him. Klapper collected many of these elements from the basal Lodgepole in Montana.

Material: One complete specimen and one broken specimen were collected from the basal Lodgepole.

Dinodus aff. D. fragosus (Branson)

Palmatodella fragosa Branson, 1934, p. 333, pi. 27, figs. 2, 4-6,

Dinodus fragosus (Branson). Hass, 1959, pi. 49, figs. 16, 23. Scott and
    Collinson, 1961, p. 122, pi. 2, fig. 21. Rexroad, 1969, p. 13,
    pi. 9, figs. 8, 9.

Diagnosis: Blade thin, surface granular. Thin anterior bar directed downward and backward; tapered to a point, very finely denticulated on anterior edge and grooved on posterior edge. Posterior bar laterally compressed with many tightly fused denticles; broadest near bottom margin; cusp indistinct and basal pit small. Angle between posterior bar and anterior projection approximately 50 degrees.

Remarks: Four of the five specimens recovered from the Lodgepole are fragmented so that a large portion of the posterior bar is missing.

Assignment Is based on characters of the anterior fragments, granular surface, and grooved ridge on the posterior side; but because of breakage, placement of these specimens Is tentative.

Material: Five broken or fragmented specimens were obtained from the basal Lodgepole.

Form-genus Dlplododella Bassler, 1925

Diplododella Bassler, 1925, p. 219. Ulrlch and Bassler, 1926, p. 41.

Huddle, 1968, p. 11, 12 (further synonymy). Austin and others, 1981, p. W175.

Type species: Diplododella bilateralis Bassler, 1925.

Diagnosis: "Typically with thin, flattened, bladelike bars in the anterior arch and a posterior bar perpendicular to anterior arch. Cusp at top of arch; denticles compressed, closely spaced or fused, and inserted. Basal cavity [pit] tiny or absent" (Huddle, 1968, p. 12).

Remarks: Huddle reported the form-genus Diplododella to be transitional with the form-genus Hibbardella but different in having bladelike bars with closely spaced and multlslzed denticles and a minute or nonexistent basal cavity. The range of Diplododella is Ordovician to Triassic.

Diplododella bilateralis Bassler, 1925

PI. 3, fig. 9

Diplododella bilateralis Bassler, 1925, p. 219. Ulrich and Bassler,

1926, p. 41, text-fig. 4, no. 21. Huddle, 1968, p. 12, pi. 7, fig. 8.

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Diagnosis: "Conodont consisting of a symmetrical denticulated anterior arch and a denticulated posterior bar. Denticles on anterior arch closely spaced and alternate with two small denticles between the larger denticles. Cusp flattened and curved backwards. Aboral edge of the anterior arch sharp; basal cavity a small triangular pit" (Huddle, 1968, p. 12).

Material: Two specimens, one mostly complete and one broken, were collected from the basal Lodgepole.

Diplododella cf. D. divergens (Huddle)

PI. 3, fig. 2

Hibbardella? diyergens Huddle, 1934, p. 81, pl. 10, fig. 6.

sic Trichognathus breviatata Branson and Mehl. Cooper, 1939, p. 421,
     pl. 46, fig. 48.

Trichognathus separata Branson and Mehl. Cooper, 1939, p. 422, pl. 46,
     figs. 45, 49.

Hibbardella cf. H.? diyergens Huddle. Rexroad, 1969, p. 22, pl. 5,
     figs. 3-5.

Diagnosis: Posterior bar long, thin, bearing deeply appressed denticles of the same thickness as the bar; lateral processes arched to form a flaring V, open aborally. Aboral edge sharp except at anterior end where shallow medial groove extends toward the posterior from extremely minute basal pit. Cusp erect to slightly recurved and of two major cross sections; one morphotype with triangular cross section and flat anterior margin, the other type with oval cross section (modified from Rexroad, 1969, p. 22).

Remarks: The specimen collected in this study is closely allied
with that described and illustrated by Rexroad (1969); however, the
questionable assignment to the form-species D. divergens is based on the
nearly complete, posterior lateral processes. The specimens (Hibbardella
cf. H.? divergens) illustrated by Rexroad (1969, pi. 5, figs. 3-5) show
lateral processes that have an upward sweeping of the aboral edges. The
specimen (H.? diyergens) illustrated by Huddle (pi. 10, fig. 6) shows a
projection of the lateral processes so that they extend farther below the
medial line than Rexroad*s specimen. The specimen collected in this
study is strongly arched with the posterior bar laterally compressed and
denticulate. The lateral processes flare to form a V that opens aborally
and the cusp has a triangular cross section. The major difference
between the elements previously illustrated and the specimen of this
study is in the lateral processes. The specimen illustrated herein
exhibits low, projecting processes that have sharp aboral edges, but lack
the upturning of the oral edges. The process that is best preserved
tapers to a sharp point at its lowest position beneath the medial line
and is curved posteriorly. Although the denticles have been broken, the
bases remain and reveal that 8 to 10 discrete denticles probably occupied
the oral edge of the processes. The assignment of this element to
Diplododella. rather than in the form-genus Hibbardella, is based on the
lack of a basal pit and blade-like, not bar-like, lateral processes.

Material: One nearly complete specimen was collected from the
basal Lodgepole.

<u>Diplododella</u> sp. A

PI. 3, figs. 20, 25

<u>Description</u>: Posterior bar rounded, thin, and denticulate. Cusp prominent, rounded in cross section, straight and directed toward posterior. Lateral processes positioned anterior of cusp; short, flaring, and inclined at nearly same angle as cusp. Each process has two rounded, separated denticles. Basal pit indistinct.

<u>Remarks</u>: <u>Diplododella</u> sp. A differs from all others of the form-genus <u>Diplododella</u> by the short, broad, and inclined posterior processes that have only two denticles. D. <u>bilateralis</u> and D. cf. D. <u>divergens</u> have blade-like posterior processes, but are of greater length and have a greater number of denticles than D. sp. A. The posterior bar of the collected specimen is broken and, therefore, largely unknown. Assignment to <u>Diplododella</u> is based on the lack of a basal pit and hint of denticulation on the posterior process.

<u>Material</u>: One specimen, missing the majority of its posterior bar, was collected from the basal Lodgepole.

Form-genus <u>Elictognathus</u> Cooper, 1939

<u>non Solenognathus</u> Agassiz, 1846. Branson and Mehl, 1934b, p. 270, 271

    (fide Klapper, 1966, p. 25).

<u>Elictognathus</u> Cooper, 1939, p. 386, 387. Klapper, 1966, p. 25 (further

    synonymy). Austin and Rhodes, 1981, p. W170.

<u>Solenodella</u> Branson and Mehl, 1944, in Shimer and Shrock, p. 244.

    <u>Type species</u>: <u>Solenognathus bialata</u> Branson and Mehl, 1934b.

    <u>Diagnosis</u>: "Element slightly arched; basal part of posterior

extremity flexed inward in some; inner side near lower margin in some with narrow platform and denticulate parapet, or 2 or 3 prominent denticles; basal cavity elongate and small, keel distinct" (Austin and Rhodes, p. W170).

Remarks: Klapper (1966, p. 25) stated that this form-genus is restricted to Toumaisian equivalents in North America, thus imposing a singularly Kinderhookian age on these elements.

Elictognathus laceratus (Branson and Mehl)

PI. 1, figs. 3, 4

Solenognathus lacerata Branson and Mehl, 1934b, p. 271, pi. 22, figs. 5, 6.

Solenognathus tabulata Branson and Mehl, 1934b, p. 271, 272, pi. 22, fig, 7. Cooper, 1939, p. 412, pi. 44, figs. 64-66.

Solenognathus costata Branson, 1934, p. 332, pi. 27, fig. 7. Cooper, 1939, p. 410, 411, pi. 44, figs. 33-35.

Solenognathus tabulata Branson and Mehl, 1934b, p. 271, 272, pi. 22, fig. 7. Cooper, 1939, p. 412, pi. 44, figs. 64-66.

Elictognathus lacerata (Branson and Mehl). Hass, 1959, p. 386, 387, pi. 49, figs. 1-8, 12. Voges, 1959, p. 278, 279, pi. 33, fig. 20. Rexroad and Scott, 1964, p. 26, 27, pi. 3, figs. 18-20. Klapper, 1966, p. 26, pi. 5, figs. 18-21.

Elictognathus costata (Branson). Rexroad and Scott, 1964, p. 25, 26, pi. 3, fig. 24.

Elictognathus costatus (Branson). Rexroad, 1969, p. 14, 15, pi. 1, figs. 6-8.

Elictoenathus laceratus (Branson and Mehl). Rexroad, 1969, p. 15-17,

      pi. 1» figs. 15-19. Thompson and Fellows, 1970, p. 81-83 (further

      synonymy), pi. 5, figs. 20, 21. Hayes, 1985, pi. 3, figs. 11, 16.

      Diagnosis: Blade widens toward base. Posterior end may be bowed

and flexed inward. Lateral ridges prominent near base; inner ridge may

be developed into a shelf as outer ridge remains narrow. Denticles

generally discrete and cusp may be prominent. Basal cavity elliptical

and somewhat elongate in plane of blade (modified from Klapper, 1966,

p. 26).

      Remarks: The extensive list of forms in synonymy indicates that

there is much variation in this elictognathid element. Branson and Mehl

(1934b, p. 271) and Hass (1959, p. 387) both stressed this variability.

Typically, designations have been based primarily on denticulation.

Rexroad and Scott (1964, p. 25) and Rexroad (1969, p. 15) considered the

lack of prominent anterior denticles significant enough to warrant the

creation of a separate form-species, Elictognathus costatus. Klapper

(1966, p. 26, 27) and Thompson and Fellows (1970, p. 83) suggested that

the significance attached by other workers to the lack of anterior

denticulation in E. costatus is within the morphologic variation of

E. laceratus. I accept Klapper's and Thompson and Fellows' opinion and

consider E. costatus synonymous with E. laceratus. Klapper (1966, p. 26,

27) briefly discussed morphologic variation in the aboral ridges of

elictognathids, a range that varies from a narrow ridge to a prominent

shelf on the inner side of the blade near the lower margin. He collected

a complete range of such morphologic variants from the basal 5 feet

(1.5 m) of the Lodgepole in Montana. Klapper suggested that the end

members of such a series, E. laceratus and E. tabulatus, are not separate

taxonomic entities, but rather, morphologic variants of one form-

species. Klapper concluded that E. tabulatus should be suppressed. Both

end members of this series were collected in this study and are

illustrated (PI. 1, figs. 3, 4).

   Material: A total of 20 specimens were collected from the upper

member of the Bakken and the basal Lodgepole. The majority of specimens

of this form-taxon are remarkably well preserved.

   Elictognathus sp. indeterminate

   Material: Two specimens collected from the basal Lodgepole,

though highly fragmented, still retained characters that allowed for

generic assignment. Specific characters of these discrete elements,

however, were indistinguishable.

   Form ~genus Hibbardella Bassler, 1925

Hibbardella Bassler, 1925, p. 219.

Hibbardella Bassler. Ulrich and Bassler, 1926, p. 37. Huddle, 1968,

   p. 12-14. Klapper and Bergstrom, 1981, p. W149.

   Type species: Prioniodus angulatus Hinde, 1879.

   Diagnosis: Anterior arch symmetrical; posterior bar denticulate;

with terminal cusp. Bars thick and round with denticles widely spaced

and rounded; cusp round, oval, or triangular in cross section. Basal pit

small or a relatively large excavation that tapers toward posterior

(modified from Huddle, 1968, p. 13).

Remarks: The form-genus Hlbbardella is similar to the form-genus Diplododella in outline and denticulation of the posterior bar, but differs by a larger basal pit and a symmetrical anterior arch that is more barlike than bladelike. Klapper and Bergstrom (1981, p. W149) designated the form-genus Hlbbardella an Sa element in a qujLnquimembrate or seximembrate apparatus. Klapper and Philip's (1971) reconstruction of Devonian conodont apparatuses indicated that the form-genus Hlbbardella is a B-type element in at least two apparatus reconstructions. Hlbbardella is a long ranging element that Huddle (1968, p. 13) reported as ranging from Ordovician to Triassic; however, Klapper and Bergstrom (1981, p. 149) reported a restricted range (Middle Devonian into the Upper Devonian) for the multielement-genus Hlbbardella.

Hlbbardella angulata (Hinde)

PI. 3, fig. 23

Prioniodus angulatus Hinde, 1879, p. 360, pi. 15, fig. 17.

Hlbbardella angulata (Hinde). Ulrich and Bassler, 1926, p. 37, pi. 3,
     figs. 1-4. Branson and Mehl, 1933b, p. 141, 142, pi. 11,
     fig. 16. Huddle, 1968, p. 14 (further synonymy), pi. 8, figs. 2,
     7; pi. 9, fig. 3.

Diagnosis: "Bar rounded and arched 80 to 90 degrees at the median point; cusp central, erect, rounded, sides nearly parallel; denticles well separated, usually five on either side of the cusp" (Huddle, 1934, p. 79). Basal pit excavated beneath cusp; pit rounded anteriorly and sharply tapered posteriorly.

Remarks: Huddle (1968, p. 14) reported that the posterior edge of the cusp and the aboral edges of the lateral processes are grooved. The specimen illustrated herein has no groove on the cusp and is only slightly grooved on the lateral processes. Nevertheless, the other characters of this form-taxon are present and the differences may represent morphologic variation.

Material: One complete specimen was collected from the basal Lodgepole.

Hibbardella cf. H. separata (Branson and Mehl)

PI. 3, fig. 19

Trichognathus separata Branson and Mehl, 1934b, p. 290, 291, pi. 23,
    fig. 30. Branson and Mehl, 1938, pi. 1, fig. 42.

Trichognathus curvidens Branson, 1934, p. 329, pi. 28, fig. 4.

Trichognathus sp. Branson, 1934, pi. 28, fig. 3.

Hibbardella? insignis Huddle, 1934, p. 80, 81, pi. 3, fig. 15.

Trichognathus micra Cooper, 1939, p. 422, pi. 46, fig. 47.

Hibbardella separata (Branson and Mehl). Rexroad, 1969, p. 21, 22,
    pi. 5, fig. 6. Wang and Ziegler, 1982, pi. 2, fig. 37.

Diagnosis: "Anterior arch broadly rounded on the oral edge, sharply flexed at the apex on the aboral edge; limbs [lateral processes] short, equal, blade-like with straight aboral edges;[11] cusp long, slender laterally compressed. Posterior bar short and slender with widely spaced discrete denticles; basal pit a longitudinal excavation, which is widest and deepest beneath the cusp and tapering toward the posterior (modified from Branson and Mehl, 1934b, p. 290).

Remarks: The single specimen referred to Hibbardella cf. H. separata is broken. Assignment is based on the longitudinal basal excavation, denticle bases indicating widely spaced and discrete denticles, inferred arching of the anterior bars, and the straight, sharp aboral edge on the intact lateral process.

Material: One broken specimen was recovered from the basal Lodgepole.

Hibbardella sp. A

PI. 3, figs. 22, 27

Description: Posterior bar thin, compressed laterally, probably having numerous denticles of at least two sizes. Element inferred to be slightly arched with the anterior processes positioned somewhat below posterior bar. Cusp large, compressed laterally, oval in cross section, moderately recurved. Lateral processes short, wing-like expansions having one denticle that tapers to sharp point from expanded base. Element bilaterally symmetrical. Basal pit small excavated area, widest beneath cusp, tapers posteriorly.

Remarks: This specimen is referred to the form-genus Hibbardella on the basis of the excavated basal pit. Due to breakage, much of the posterior bar is missing.

Material: One nearly complete specimen was recovered from the basal Lodgepole.

Hibbardella sp. indeterminate

Material: Eleven fragmented specimens were recovered from the
upper member of the Bakken and the basal Lodgepole. Only those fragments
retaining, at a minimum, a portion of the basal pit or cavity were
included here. Many indeterminate ramiform elements may be posterior
bars of Hibbardella.

Form-genus "Hindeodella" Bassler, 1925

Hindeodella Bassler, 1925, p. 219. Ulrich and Bassler, 1926, p. 38, 39.
        Huddle, 1968, p. 15.

Hindeodella Ulrich and Bassler. Branson and Mehl, 1934a, p. 194, 195.

        Type Species: Hindeodella subtilis Bassler, 1925.

        Diagnosis: "Long bar—or somewhat blade-like piece—straight or
slightly curved laterally, or arched, or both. Anterior end broadly
flexed or sharply curved inward in the horizontal plane or slightly bent
downward. Posterior end tapered, spatulate, slightly down-curved or
recurved beneath the bar. Denticulation consisting of a fang [cusp] of
large size at or somewhat behind the anterior curvature, and closely
spaced to articulating, more or less sheathed denticles of appreciably
smaller size in front and back of the fang [cusp]. The smaller denticles
usually alternate in size regularly or irregularly with one to several
minute denticles between the larger" (Branson and Mehl, 1934a, p. 194).

        Remarks: Hindeodellan elements exhibit a large degree of
morphologic variability and are long-ranging. Distinguishing specific
features include the morphology of the anterior bar, presence or absence
of posterior bar deflections, and the size and spacing of denticles on

the anterior and posterior bars. Huddle (1968, p. 15) stated that
complete specimens recovered from acetic acid residues are rare because
the long fragile posterior bars commonly break when the residue is
prepared for examination. Upon reviewing the synonymy presented by
Huddle (1968, p. 16, 17) for the type form-species, it is not surprising
that, because of the poor recoverability of complete specimens, the
"validity of many species referred to Hindeodella is in doubt."
Hlndeodellan elements are abundant, cosmopolitan, long ranging, and occur
in a number of apparatus reconstructions. Klapper and Philip (1971)
hesitantly proposed the synonymy of the form-genus Hindeodella with the
multielement-genus Polygnathus: hlndeodellan elements are considered S
elements of multielement taxonomy as discussed by Sweet (1981a), and as
A-type elements by Klapper and Philip (1971) in at least two
reconstructed apparatuses. Klapper and others (1981, p. W162, W163)
formally established the synonymy of Hindeodella with Polygnathus.
recognizing the importance and validity of hlndeodellan elements as
components in multielement apparatuses. Hindeodella. as applied to
individual elements is, therefore, considered an invalid name and is
placed in quotes. Many of the indeterminate ramiform fragments in the
collection are likely posterior bars of "Hindeodella."

"Hindeodella" subtilis Bassler, 1925

PI. 3, fig. 32

Hindeodella subtilis Bassler. Ulrich and Bassler, 1926, p. 39, pi. 8,
      figs. 17-19. Huddle, 1968, p. 16-18 (further synonymy to 1965),
      pi. 5, figs. 5, 7, 8, 10-15.

Hlndeodella subtilis Ulrich and Bassler. Wang and Ziegler, 1982, pi. 2,

     fig. 22.

"*Hlndeodella*" cf. "*H.*" *subtilis* Ulrich and Bassler. Hayes, 1985, pi. 3,

     fig. 17.

Diagnosis: "Posterior bar long, thin with thickest part near the
upper edge; bears larger denticles separated by two to four smaller
denticles. Anterior bar short, strongly curved inward and projects
slightly below posterior bar, bearing 10-14 denticles of two sizes. Cusp
distinct, curved posteriorly and inward slightly, slightly flattened
laterally or rounded as are the denticles. Aboral side tends to be sharp
edged and thin near the posterior end" (Huddle, 1968, p. 17).

Remarks: Nearly complete specimens, and a large number of
posterior-bar fragments likely belonging to this form-species were
collected from both the upper and lower members of the Bakken. Complete
and well-preserved specimens were recovered from the basal Lodgepole.
Hayes (1984, p. 113, pi. 3, fig. 17) described and illustrated a specimen
that he considered comparable to "*Hlndeodella*" subtilis, but because of a
lack of complete specimens felt that unquestioned assignment was not
wise. In comparing complete Lodgepole specimens collected in this study
with the specimen illustrated by Hayes, I consider the specimens
equivalent.

Material: Twenty-six complete or nearly complete specimens were
recovered from the upper and lower members of the Bakken and the basal
Lodgepole. Although a large number of indeterminate ramiform elements
are probably posterior bars of this form-species, I am not confident of
their assignment; therefore, these fragments are not included as material

assigned to "Hindeodella" subtilis.

"Hindeodella" sp. A

PI. 3, fig. 26

Description: Posterior bar thin, laterally compressed, becoming spatulate posteriorly. Posterior two-thirds of aboral edge keeled and sharp, becoming indistinguishable from spatulate termination. Aboral side of posterior bar has denticles of two subequal sizes; larger denticles laterally compressed, terminating in sharp point from widened base on posterior bar, becoming larger and more posteriorly directed away from cusp; two, three, or four smaller, subequal denticles alternate with larger denticles. Denticles approximately 21. Cusp prominent, somewhat compressed with oval cross section, and evenly tapering to sharp point. Anterior projection short, directed downward and slightly inward, having eight denticles of similar character to smaller denticles on posterior bar. Process spatulate, expanding distally from narrow junction at base of cusp. Basal pit small and shallow with thin, narrow groove extending posteriorly.

Remarks: This element differs from other hindeodellan elements in the overall lateral compression, more massive posterior bar and denticulation, and the character of the anterior projection.

Material: One well preserved specimen was recovered from the basal Lodgepole.

"Hlndeodella" sp. indeterminate

Material: Fourteen fragmented elements were recovered from both
shale members of the Bakken and the basal Lodgepole. Assignment is based
on fragments that retain a majority of the posterior bar and a portion of
the anterior process. These fragments have more characteristics of
"Hindeodella" than fragments called merely "indeterminate ramiform
elements."

Form-genus Hindeodelloides Huddle, 1934

Hindeodelloides Huddle, 1934, p. 48. Austin and others, 1981, p. W175.

Type species: Hindeodelloides bicristatus Huddle, 1934.

Diagnosis: Posterior bar compressed laterally, straight or gently
curved downward; denticles of two alternating sizes, laterally compressed
and somewhat appressed. Anterior process short, flat, directed slightly
downward, usually inclined at some angle to plane of posterior bar and
cusp; denticles few, varying in length, and may alternate in size
(modified from Huddle, 1934, p. 48).

Remarks: Hindeodelloides differs from Hindeodina in possessing an
anterior process that is more developed with larger discrete denticles.
The posterior bar is thin and may be gently curved and the cusp is
prominent.

Hindeodelloides bicristatus Huddle, 1934

PI. 3, fig. 5

Hindeodelloides bicristatus Huddle, 1934, p. 48, 49, pi. 7, figs. 2, 3;
    pi. 12, fig. 6.

Diagnosis: Posterior bar laterally compressed, broadening posteriorly from the cusp in plane of posterior bar; denticles compressed, pointed, directed posteriorly, and alternating in size; commonly with two or three small denticles between large ones. Anterior process short, flattened, directed outward from plane of posterior bar and cusp; denticles approximately six, larger and more discrete than on posterior bar; larger denticles may be separated by one or more closely spaced and appressed small denticles. Cusp flattened, slightly curved with sharp edges. Basal pit indistinguishable.

Material: One nearly complete specimen was collected from the lower member of the Bakken and four well-preserved specimens were collected from the basal Lodgepole.

Form-genus Hindeodina Hass, 1959

Hindeodlna Hass, 1959, p. 382.

Type species: Hindeodina simplaria Hass, 1959.

Diagnosis: "Elongate bladelike or barlike unit; anterior bar may be flexed inward. Main cusp aborted, indistinct, distinguished from bar denticles only through position above pulp cavity [basal pit]. Bar denticles may be of more than one size. Greater part of aboral side sharp edged. Lips of pulp cavity [basal pit] either absent or extremely small" (Hass, 1959, p. 382).

Remarks: Hass (p. 382) noted that Hindeodina differs from "Hindeodella" in having a very reduced or aborted cusp rather than a large well-developed one. Austin and others (1981, p. W175) reported the range of Hindeodina as Upper Devonian to Upper Mississippian.

<u>Hindeodina uncata</u> Hass, 1959

PI. 3, fig. 30

<u>Hindeodina uncata</u> Hass, 1959, p. 383, pi. 47, fig. 6.

   <u>Diagnosis</u>: Element barlike, with anterior projection angled
inward at approximately 90 degrees. Posterior bar may be five times
length of anterior, straight, slightly bowed inward, increasingly
compressed posteriorly. Posterior denticles closely spaced, directed
posteriorly, of two sizes; large denticles irregularly separated by
several smaller denticles. Cusp aborted. Anterior bar denticles may be
directed toward distal end of anterior bar, but otherwise resembling
posterior denticles. Aboral edge tapered to sharp edge except at basal
pit; pit small and may be grooved (modified from Hass, 1959, p. 383).

   <u>Remarks</u>: Hass (1959, p. 383) stated, "The aborted main cusp
distinguishes <u>Hindeodina uncata</u> from those species of <u>Hindeodella</u>
["<u>Hindeodella</u>"! whose anterior bar is angled inward approximately 90*."

   <u>Material</u>: Three complete specimens were recovered from the basal
Lodgepole.

<u>Hindeodina</u> sp. A

PI. 3, fig. 33

   <u>Description</u>: Posterior bar compressed; approximately four times
as long as anterior bar; broadest near basal pit, tapering to compressed
posterior end. Anterior bar angled inward at approximately 90 degrees
and tilted posteriorly. Denticles of two sizes; several smaller
denticles separate larger denticles. Larger denticles with oval cross
section, and generally directed inward and posteriorly so that

posteriormost denticles are nearly aligned with the aboral edge.
Anterior denticles of greatest height and massiveness with larger cross
section than that of posterior denticles. Innermost denticles may be
directed toward distal end of anterior projection. Main cusp aborted.
Aboral edge of posterior bar nearly straight and thickened. Basal pit
poorly developed with groove tapering to extinction posteriorly. Aboral
edge of anterior part of bar sharp and thinner than oral edge. Oral edge
of anterior bar slightly arched so that innermost portion of bar forms
downwardly directed, widened flange. Overall height of flange and
denticles half again the height of posterior bar and denticles.

Remarks: This specimen is similar to Hindeodina uncata. but
differs in that the anterior bar is more developed and angled inward.
The widening and downward development of the flange seems most
significant.

Material: One complete specimen was collected from the basal
Lodgepole.

Form-genus Ligonodina Bassler, 1925

Ligonodina Bassler, 1925, p. 218. Ulrich and Bassler, 1926, p. 12, 13.

Huddle, 1968, p. 18 (further synonymy). Austin and others, 1981,

p. W177.

Neocordylodus Cooper, 1939, p. 396.

Type speciest Ligonodina pectinate Bassler, 1925.

Diagnosis: "A pick-shaped conodont [element] with a large cusp
and denticulated posterior bar and anticusp. The denticles on the
anticusp point inward about at right angles to the plane of the bar and

cusp. Aboral side of the posterior bar and anticusp usually grooved along midline" (Huddle, 1968, p. 18).

Remarks: Ligonodina ranges from the Middle Ordovician to Middle Triassic (Huddle, 1968, p. 15). Austin and others (1981, p. W177) stated that these elements carry the designation Sc in multielement taxonomy. Klapper and Philip (1971) have designated ligonodinan elements as B-type elements in at least four reconstructed apparatuses. The form-genus Ligonodina differs from the form-genus Synp r ion iod ina in the orientation of the denticles on the anticusp (Huddle, 1968, p. 18).

Ligonodina conidens Huddle, 1934

PI. 3, fig. 17

Ligonodina conidens Huddle, 1934, p. 63, pi. 12, figs. 18, 19.

non Ligonodina conidens Huddle. Cooper, 1939, p. 390, pi. 45, fig. 45.

Diagnosis: Posterior bar somewhat rounded and laterally compressed though rarely complete. Cusp rounded in cross section and slightly recurved. Anterior process deflected at approximately 90 degrees to plane of bar and cusp; typically having 4 or 5 short, closely spaced denticles (modified from Huddle, 1934, p. 63).

Remarks: This form-species is characterized by discrete, separated denticles of uniform size on the posterior bar. Anterior deflection is prominent and typically lacks the denticle proper.

Material: Seven specimens were recovered from the basal Lodgepole; two are well-preserved and five are broken.

Ligonodina delicata Branson and Mehl, 1934

PI. 1, fig. 6

Ligonodina delicata Branson and Mehl, 1934a, p. 199, pi. 14, figs. 22, 23.

Ligonodina conidens Huddle. Cooper, 1939, p. 390, pi. 45, fig. 45.

Diagnosis: Cusp long, laterally compressed, and gently recurved. Faint anterior and posterior keels on cusp (Branson and Mehl, 1934a, p. 199). Anterior bar long and projected down and back so that outline of curve defined by cusp continuous. Denticles of anterior projection about five, with circular cross sections, and directed very slightly to posterior. Outer side of anterior projection marked by medial longitudinal groove that extends to bottom of projection. Basal pit small and may have tapering groove extending posteriorly.

Remarks: Ligonodina delicata Branson and Mehl differs from Ligonodina tenera Cooper in having a greatly extended anterior process that typically carries a greater number of denticles.

Material: Three specimens were collected, two from the lower member of the Bakken and one from the basal Lodgepole.

Ligonodina panderi (Hinde)

PI. 3, fig. 8

Prioniodus panderi Hinde, 1879, p. 361, pi. 16, fig. 4.

Ligonodina panderi (Hinde). Huddle, 1968, p. 19, 20 (further synonymy), pi. 9, fig. 11; pi. 10, figs. 1-8, 11. Wang and Ziegler, 1982, pi. 2, figs. 9, 23.

Ligonodina cf. L. panderi (Hinde). Hayes, 1985, pi. 3, fig. 3.

Diagnosis: "Bar heavy, rounded, with a flat base grooved along the midline. Denticles rounded and inclined toward the posterior end of the bar, usually 10 or fewer in number. Cusp large, curved toward the rear, rounded, or with a ridge and a groove along the inside anterior edge. Anticusp heavy, not offset, strongly curved backward under the posterior bar, grooved on the outside and bearing four to five denticles on the inside. Basal cavity a small pit" (Huddle, 1968, p. 19).

Remarks: The illustrated specimens of Huddle (1968) and Wang and Ziegler (1982) show features that are not completely consistent with Huddle's description of Ligonodina panderi. First, although the anticusp is curved under the posterior bar, there is some variability in how strong the flexure is. Secondly, the basal pit was only illustrated by Huddle on one specimen (Plate 10, fig. 11), and it appears that the pit is, indeed, small but also somewhat excavated with a tapering groove extending toward the posterior. Hayes (1984, p. 114) compared his specimens collected from the lower member of the Bakken to L. panderi citing the lack of flexure of the anticusp as reason for hesitance in assigning them to L. panderi. However, specimens collected from the basal Lodgepole exhibit a varying degree of anticusp flexure. Therefore, I have considered all of these specimens to be of L. panderi with a considerable degree of morphologic variation.

Ligonodina panderi differs from L. tenera in having a lesser number of alternating denticles on the posterior bar and an anticusp that is not directed away from the cusp in a horizontal plane nearly even with the posterior bar as in L. tenera. A number of broken specimens have been assigned to L. panderi with features that suggest it, but not

without question.

Material: Twenty-one specimens of Ligonodina pander! were obtained from the basal Lodgepole. Twelve of these elements are in varying degrees of completeness and the other nine are nearly complete.

Ligonodina platys Cooper, 1939

PI. 3, fig. 7

Ligonodina platvs Cooper, 1939, p. 391, pi. 45, fig. 47. Rexroad, 1969,

    p. 24. pi. 9, figs. 19, 20.

Ligonodina sp. indeterminate Hayes, 1985, pi. 3, fig. 4.

Diagnosis: Element with short, inner, lateral process bearing one or two denticles. Cusp thin, recurved, and nearly oval in cross section. Infrequent specimens may have sharp-edged, anterior margin that may be twisted off center near base of cusp and continue as inconspicuous ridge continuous with lateral process. Aboral side not fully developed in immature specimens; in mature specimens base diagnostically wedge-shaped with small groove along flat, aboral edge (modified from Rexroad, 1969,p. 24).

Remarks: The wedge-shaped base is characteristic and allows recognition of this form-species easily. The posterior bar is frequently broken off and, therefore, Cooper (1939) described the posterior bar as short. Rexroad (1969) stated that, when present, the posterior bar is long and may have as many as 12 long and short alternating denticles. Fragments, not illustrated but present in the faunal collection, by themselves would not be useful in specific determinations, but when compared to the nearly complete specimens, assignment can be made with

some degree of confidence.

Material: Seven mostly complete specimens were recovered from the basal Lodgepole.

Ligonodina tenera Cooper, 1943

PI. 3, fig. 10

Ligonodina delicata Branson, 1934, p. 328, pi. 27, fig. 3.

sic Ligonodina delicatula Branson and Mehl. Cooper, 1939, p. 145,

    figs. 50, 60, 61.

Ligonodina tenera Cooper, in Cooper and Sloss, 1943, p. 174, pi. 29,

    fig. 29.

Ligonodina sp. A Hayes, 1985, pi. 3, fig. 2.

Diagnosis: "Bar thin, flat on aboral side; cusp large, long, moderately curved, circular to lenticular in section; denticles alternating, becoming longer, heavier toward posterior end, sparse or wanting just back of the cusp; projection [anterior process] short, thin, with two to four small round denticles" (Cooper and Sloss, 1943, p. 174).

Remarks: Cooper and Sloss (1943, p. 174) remarked that Ligonodina tenera is different from, Ligonodina delicata Branson and Mehl, in the smaller size of the anterior projection. Ligonodina tenera differs from Ligonodina platys Cooper in having roughly double the number of discrete denticles on the anterior projection.

Material: Three slightly broken specimens were collected from the basal Lodgepole.

<u>Ligonodina</u> cf. L. <u>conidens</u> Huddle

<u>Ligonodina</u> cf. L. <u>conidens</u> Huddle. Rexroad, 1969, p. 24, 25, pi. 9,

   figs. 15, 18.

   <u>Diagnosis</u>: Denticles like those in <u>Ligonodina conidens</u> Huddle in

position, orientation, and cross sectional configuration but large

discrete denticles on posterior bar may be separated by smaller, discrete

denticles (<u>fide</u> Rexroad, 1969, p. 25).

   <u>Remarks</u>: Rexroad (1969, p. 25) stated that the alternation of

large and small denticles on the posterior bar distinguishes his

specimens from Huddle's holotype; all other characters are represented

equally. I will follow Rexroad*s lead in distinguishing the two elements

even though it may eventually be shown that the alternating sequence is

within the morphologic range of variation for the form-species.

   <u>Material</u>: One broken specimen was collected from the upper member

of the Bakken and one small, nearly complete specimen was recovered from

the basal Lodgepole.

   Form-genus <u>Lonchodina</u> Bassler, 1925

<u>Lonchodina</u> Bassler, 1925, p. 219. Ulrich and Bassler, 1926, p. 30, 31.

   Huddle, 1968, p. 21. Austin and others, 1981, p. W177.

   <u>Type species</u>: <u>Lonchodina typicalis</u> Bassler, 1925.

   <u>Diagnosis</u>: "Bar thick, rounded, or triangular in cross section

with wide attachment area; basal [aboral] side grooved in many species;

basal cavity a small pit. Cusp in central third of the bar or

indistinguishable. Denticles rounded or flattened, generally discrete,

and widely spaced. The bar is arched upward, laterally bowed, or with

sharp inward flexure. Generally nonsymmetrical" (Huddle, 1968, p. 21).

Remarks: Huddle (1968, p. 21) discussed the similarity of the
form-genera Lonchodlna and Prlonlodina. If specimens show lateral bowing
of the element or sharp inward flexure, an overall lack of symmetry, and
an irregular arrangement of large and small denticles, they should be
assigned to Lonchodlna. The cusp of lonchodinan elements is also
commonly twisted off center. Huddle (1968, p. 21) reported that the
range of Lonchodlna as Silurian to Triassic. Austin and others (1981,
p. W177) considered this form-genus an Sc element in multielement
taxonomy. Klapper and Philip (1971) have designated Lonchodlna as a
B-type element in at least four reconstructed apparatuses.

Lonchodlna arcuata Ulrich and Bassler, 1926

PI. 3, figs. 11, 31

Lonchodlna arcuata Ulrich and Bassler, 1926, p. 32, pi. 5, fig. 15.

Huddle, 1968, p. 21, 22 (further synonymy), pi. 11, figs. 5-13.

Prlonlodina curvata Branson and Mehl, 1934a, p. 214, pi. 14, fig. 17.

Lonchodlna curvata (Branson and Mehl). Wang and Ziegler, 1982, pi. 2,
figs. 31-33.

Diagnosis: "Bar heavy, thickest above, thins below and towards
the ends; base wide and flat near center of bar, strongly arched,
slightly bowed; anterior and posterior bars slightly twisted Inward at
tips. Cusp and denticles oval in cross section and become sharp edged In
mature specimens. Anterior bar has 5-10 denticles spaced about one-half
the width of the denticle apart, and the posterior bar has 5-7
denticles. Basal cavity a deep elongate pit" (Huddle, 1968, p. 22).

Remarks: Huddle (1968, p. 22) reported a great variability in the lateral bowing of the element, twisting of the bars and cusp, and number of denticles. This variety is reflected in the recovered collection of Lodgepole elements, two of which are illustrated herein (PI. 3, figs. 11, 31).

Material: Three nearly complete specimens were recovered from the upper member of the Bakken. Six complete, or nearly complete, specimens were collected from the basal Lodgepole.

<p style="text-align:center">Lonchodina brevipennata Branson and Mehl, 1934</p>

<p style="text-align:center">PI. 3, fig. 21</p>

Lonchodina brevipennata Branson and Mehl, 1934a, p. 212, pi. 15,

fig. 13. Wang and Ziegler, 1982, pi. 1, fig. 24; pi. 2, fig. 35.

Diagnosis: Base sharply arched and turned upward. Anterior and posterior bars nearly form a right angle. Anterior bar about twice as long as posterior, thick, rounded, carrying approximately six denticles. Posterior denticles number two or more. Cusp long, pointed, and compressed laterally. Basal pit relatively large opening inward, with thin grooves extending out from pit (modified from Branson and Mehl, 1934a, p. 212).

Remarks: The identification of specimens of Lonchodina brevipennata collected in this study was based on four elements in varying degrees of completeness. They were distinguished from others of the form-genus by the large, upturned basal pit. Although fragments of denticles or denticle bases are present, the character or number of bar denticles, and the cusp is unknown. One specimen, tentatively referred

to L. brevipennata. exhibits a strongly recurved cusp. This feature is
not present, nor can it even be inferred, on the other elements
collected; however, the recurved specimen does have an upturned, inwardly
opening basal pit. The specimens collected in this study are more
similar to those illustrated by Wang and Ziegler (1982, pi. 1, fig. 24;
pi. 2, fig. 35) than that illustrated by Branson and Mehl (1934a, pi. 15,
fig. 13).

Material: Four specimens were recovered from the basal Lodgepole.

Lonchodina dubia (Thomas)

PI. 3, fig. 16

Ligonodina dubia Thomas, 1949, p. 423, pi. 4, figs. 23, 24.

Lonchodina dubia (Thomas). Rexroad, 1969, p. 25 (further synonymy),

pi. 7, fig. 2 only.

Diagnosis: Element only slightly arched; cusp centrally
situated. Denticles and cusp oval in cross section and separated, about
two on anterior bar and three to five on posterior bar. Cusp recurved,
directed slightly inward. Basal cavity small with inner flare in line
with cusp; thin grooves extend distally on each bar from basal pit.

Remarks: Lonchodina dubia differs from Lonchodina torta in being
less arched and having fewer denticles on each of the bars. The twisting
of the two bars is less prominent in L. dubia.

Material: One nearly complete specimen was recovered from the
basal Lodgepole.

<u>Lonchodlna torta</u> Huddle, 1934

PI. 3, fig. 12

<u>Lonchodlna torta</u> Huddle, 1934, p. 86, pl. 10, fig. 4.

<u>Diagnosis</u>: "Bar heavy, rounded, strongly arched, laterally bowed and twisted near the cusp so that the two ends of the bar are not in the same plane. Cusp rounded, slender and gradually tapering; denticles similar to the cusp in shape, and separated" (Huddle, 1934, p. 86). Basal pit small excavation with short, tapering grooves extending both directions from it.

<u>Remarks</u>: Huddle (1934, p. 86) reported that the distinguishing characters of <u>Lonchodlna torta</u> are the large size of the cusp and denticles, and the twisting of the anterior and posterior bars into two different planes. Rexroad (1969, p. 26) suggested a similarity between <u>Lonchodlna dubia</u> (Thomas) and <u>Lonchodlna torta</u>. He reported that Huddle's holotype of L. <u>torta</u> has been lost, and because of the apparent similarity between the illustrated specimens of L. <u>torta</u> by Huddle (pl. 10, fig. 4) and <u>Llgonodlna dubia</u> by Thomas (1949, pl. 4, figs. 23, 24), suggested that L. <u>torta</u> should be considered <u>nomen</u> dubium. After reviewing the illustrations and descriptions of both Huddle and Thomas, I consider that L. <u>torta</u> exhibits enough unique morphologic characters that it should remain a distinct form-species.

<u>Material</u>: One complete specimen was collected from the basal Lodgepole.

<u>Lonchodina typicalis</u> Bassler, 1925

PI. 3, fig. 14

<u>Lonchodina typicalis</u> Bassler, 1925, p. 219. Ulrich and Bassler, p. 31,

pi. 5, figs. 1, 2. Huddle, 1968, p. 23, 24 (further synonymy),

pi. 12, figs. 14-22.

<u>Diagnosis</u>: "Bar heavy, bowed and arched, thickened above,

tapering below, with wide lateral attachment area on large specimens.

Posterior bar shorter than anterior . . . " (Huddle, 1968, p. 24). Cusp

at apex of arch; large, round or oval in cross section. Denticles number

10 to 14, evenly distributed and discrete around cusp. One or two

posterior denticles may be larger than cusp.

<u>Remarks</u>: <u>Lonchodina typicalis</u> displays somewhat atypical

morphology in comparison to others of the form-genus. The bar of L.

<u>typicalis</u> is more prominent than in others and the position and

development of bar denticles makes it difficult to distinguish between

anterior and posterior. Nevertheless, position of the cusp and

denticles, number of denticles, and character of the bar distinguish L.

<u>typicalis</u> from all others.

<u>Material</u>: Three complete, or nearly complete, specimens were

recovered from the basal Lodgepole.

Form-genus <u>Metaprioniodus</u> Huddle, 1934

<u>Metaprioniodus</u> Huddle, 1934, p. 57. Austin and others, 1981, p. W177.

<u>Type species</u>: <u>Metaprioniodus biangulatus</u> Huddle, 1934.

<u>Diagnosis</u>: "Bar heavy, rounded, usually with a distinct oral

shoulder posterior to the cusp on the concave [inner] side; anterior

portion deflected downward and curved laterally; posterior downward deflection always present. Cusp large, rounded, straight or slightly curved, and situated near the anterior end of the bar. Denticles separated and rounded with a few at the posterior end of the bar inclined nearly straight backward" (Huddle, 1934, p. 57). Basal pit small with a groove extending both directions a short distance in plane of element.

Remarks: Austin and others (1961, p. W177) reported this form-genus to range from the Upper Devonian into the Lower Mississippian (Kinderhookian).

Metaprioniodus biangulatus Huddle, 1934

PI. 3, fig. 18

Metaprioniodus biangulatus Huddle, 1934, p. 57, 58, pi. 11, figs. 12,

13. Hayes, 1985, pi. 3, fig. 10.

Diagnosis: "Bar heavy, anterior portion bowed and deflected downward, posterior portion smoothly rounded on the convex [outer] side, and with a distinct oral shoulder on the concave [inner] side; posterior downward projection large and thinner than the rest of the bar" (Huddle, 1934, p. 57, 58). Cusp relatively large and, as with denticles, laterally compressed and tapered to sharp point. Denticles tend to increase in size from cusp to posterior deflection.

Remarks: This element is distinguished from all others of the form-genus by the downward deflection of the posterior projection accompanied by the larger denticles on the aboral surface.

Material: One well-preserved specimen was recovered from the basal Lodgepole.

Metaprioniodus sp. A

PI. 3, fig. 4

Description: Posterior bar thick, deflected downward at posterior
end; rounded oral surface and nearly flat aboral surface, tapering to
point at downward deflection. Denticles on posterior bar number six,
rounded, becoming larger toward posterior end. Cusp rounded in cross
section, subcentrally located and slightly smaller than posteriormost
denticles. Anterior projection continuous with rest of bar, directed
downward and slightly inward. Denticles number six and of same character
as cusp and posterior denticles. Distal end of projection tapers to
sharp edge. Basal pit small and indistinct in flat aboral surface, thin
groove extends short distance posteriorly.

Remarks: This form-species is distinguished from others of the
form-genus by the distribution and position of the denticles and the
anterior and posterior deflections are developed to a lesser degree in
Metaprioniodus sp. A than in M. biangulatus. Likewise, M. sp. A exhibits
a less bar arch and lateral compression, and the oral surface is flatter
and broader with a small basal pit.

Material: One complete specimen was recovered from the basal
Lodgepole.

Form-genus "Neoprioniodus" Rhodes and Muller, 1956

Prioniodus Pander. Ulrich and Bassler, 1926, p. 8, 9. Branson and Mehl,
      1933b, p. 129, 130.

Neoprioniodus Rhodes and Muller, 1956, p. 698, 699. Huddle, 1968, p. 24,
      25.

Type species: Prioniodus conjuctus Gunnell, 1933.

Diagnosis: Posterior bar straight or slightly arched; denticles may be separated and discrete, but more commonly closely spaced and discrete to nearly fused. Cusp well developed and terminal, centered over basal pit; anticusp short, sharp, below and slightly anterior of cusp. Anticusp most commonly nondentlculate (modified from Huddle, 1968, p. 24, 25).

Remarks: Overall appearance of "Neoprioniodus" is pick-like; it is distinguished from the form-genus Synprioniodina by the nondenticulated anticusp. Huddle (1968, p. 24) reported the range of "Neoprioniodus" as Early Silurian to Middle Permian. Klapper and Philip (1971) stated that neoprioniodontan elements are common constituents of reconstructed apparatuses. They are symbolized as N-type elements and appear in at least three reconstructed apparatuses.

"Neoprioniodus" alatus (Hinde)

PI. 3, fig. 3

Prioniodus? alatus Hinde, 1879, p. 361, pi. 16, fig. 5.

Prioniodus alatus Hinde. Ulrich and Bassler, 1926, p. 11, pi. 1,
        figs. 25, 26. Branson and Mehl, 1933b, p. 134, pi. 11, fig. 13.
        Huddle, 1934, p. 37, pi. 1, figs. 1-3.

Prioniodus cf. Prioniodus lata Bischoff, 1957, p. 47, pi. 5, figs. 38,
        39.

Neoprioniodus alatus (Hinde). Huddle, 1968, p. 25 (further synonymy),
        pi. 6, figs. 1, 2.

sic Neoprioniodus cf. Neoprioniodinus latus (Bischoff). Rexroad, 1969,

p. 29, 30, pi. 7, figs. 15-17.

"Neoprioniodus" alatus (Hinde). Hayes, 1985, pi. 3, fig. 5.

Diagnosis: "Bar short, heavy, and straight; cusp large, laterally
compressed, sharp edged and forming a straight anterior line with the
large anticusp; denticles decreasing in size from the cusp toward the
posterior end of the bar, closely appressed, free at tips only, and
apparently inserted" (Huddle, 1934, p. 37). ". . . posterior edge is
wedge shaped and bears a faint groove extending from the tiny pit, which
is no more than a slight widening and deepening of the groove" (Rexroad,
1969, p. 29).

Remarks: "Neoprioniodus" alatus differs from "Neoprioniodus"
barbatus in the smaller volume of the basal pit and reduced or lacking
inner lateral flare.

Material: Four specimens were collected from the upper member of
the Bakken and the basal Lodgepole.

"Neoprioniodus" barbatus (Branson and Mehl)

PI. 3, fig. 15

Prioniodus barbatus Branson and Mehl, 1934b, p. 288, 289, pi. 23,

figs. 19, 20. Branson and Mehl, 1938, p. 144, pi. 33, fig. 38;

pi. 34, figs. 28, 32. Thomas, 1949, pi. 4, fig. 26.

Prioniodus corniger Branson, 1934, p. 329, pi. 28, fig. 2. Branson and

Mehl, 1938, pi. 33, fig. 21.

Prioniodus corniger Branson ? Branson and Mehl, 1938, p. 143, pi. 34,

fig. 19.

Prioniodus alatoideus Cooper, 1931, p. 232, pi. 28, fig. 1. Huddle,

     1934, p. 37, 38, pi. 1, figs. 4, 5.

Neoprioniodus barbatus (Branson and Mehl). Rexroad, 1969, p. 27, pi. 7,

     figs. 11-14.

     Diagnosis: Posterior bar short and straight; denticles numerous, most commonly appressed so just apices free; denticles shorter anteriorly. Cusp prominent, laterally compressed with sharp edges and slightly bowed inward. Anticusp moderately long, thick, and sharply pointed; outside margin concave without lateral flare, inner margin convex with lateral flare. Basal pit large and deeply excavated with a small groove extending posteriorly (slightly modified from Branson and Mehl, 1934b, p. 288, 289).

     Remarks: "Neoprioniodus" barbatus is distinguished on the basis of the large, excavated basal cavity, the anticusp terminating in a sharp point, and the inner lateral flare of the anticusp. "N." barbatus is distinguished from "N." alatus by the shorter, thicker anticusp, large excavated basal cavity, and cusp that is inclined anteriorly in "N." barbatus. One specimen collected from the basal Lodgepole is tentatively assigned to "N." barbatus as it is small and may be a juvenile form that only has the beginnings of a prominent lateral flare and deeply excavated basal cavity.

     Material: "Neoprioniodus" barbatus is the most common neoprioniodid element of the collection. Twenty mostly complete specimens were recovered from the upper member of the Bakken and the basal Lodgepole.

"Neoprioniodus" aff. "N." barbatus (Branson and Mehl)

PI. 1, fig. 8

"Neoprioniodus" cf. "N." barbatus (Branson and Mehl). Hayes, 1985,

   pi. 3, fig. 1.

   Diagnosis: Basal cavity large and excavated, inner lateral flare
moderately developed. Posterior bar denticles nearly fused with only
apices free. Cusp large, straight, and continuous with non-denticulate
antlcusp.

   Remarks: Hayes (1984, p. 117) described and illustrated (1984,
1985, pi. 3, fig. 1) a single Bakken specimen to be compared with "N."
barbatus. Another Bakken specimen was collected during my study and and
both were compared with nearly complete specimens of "N." barbatus from
the basal Lodgepole. Gross element morphology and outline are very
similar between the Bakken and Lodgepole specimens. The Bakken specimens
differ from those from the Lodgepole in that the basal cavity of "N."
aff. "N." barbatus is smaller and compressed laterally, and the tip of
the anticusp is short and not drawn downward to a sharp point. The sides
of the anticusp follow the contour of the cusp and posterior bar
resulting in a comparatively smaller volume of the basal cavity in "N."
aff. "N." barbatus.

   Material: One nearly complete specimen was collected from the
lower member of the Bakken.

"Neoprioniodus" sp. A

PI. 3, fig. 13

Description: Posterior bar long; one and one-half times length of cusp-anticusp complex, distinctly sinuous with posterior bar and anterior cusp-bar junction bowed Inward and middle posterior bar and outer anterior side of cusp bowed outward. Denticles on bar number approximately 20, appressed with only apices discrete, becoming larger, longer and more anteriorly directed towards anterior of bar. Denticles slightly compressed laterally. Anteriorly directed cusp prominent, bowed outward, distinctly compressed with elliptical cross section and sharp anterior and posterior edges, outer side more convex than inner side. Anticusp small continuation of cusp, terminating in a point. Basal cavity of moderate size, flared slightly on inner side and flat to slightly concave on outer side. Aboral side of bar flattened with a basal groove that develops from a narrowing of basal cavity. Tapering of groove continues to extinction posteriorly with finely developed lips marking edge of the groove on aboral side.

Remarks: "Neoprioniodus" sp. A differs from [M]N." barbatus in that the inner lateral flare is much less developed, the cusp is less massive, and the posterior bar is longer. '[f]N." alatus differs in having a small basal cavity, no inner lateral flaring, a shorter posterior bar, and a cusp-anticusp complex that is nearly perpendicular to the posterior bar. "N." sp. A is distinguished from "N." aff. "N." barbatus in that the former has its anticusp drawn downward to a point; however, the volume of the basal cavity remains considerable. The posterior bar on "N." sp. A seems to be thinner and longer than that of [M]N." aff. "N." barbatus.

Material: One broken specimen was recovered from the upper member of the Bakken and two well-preserved specimens were recovered from the basal Lodgepole.

"Neoprioniodus" sp. indeterminate

Material: Six fragmented specimens were collected from the basal Lodgepole. The fragments were assigned to this form-genus without question, but due to the incompleteness of the specimens specific identification was not possible.

Form-genus Ozarkodina Branson and Mehl, 1933

Ozarkodina Branson and Mehl, 1933a, p. 51.

Type species: Ozarkodina typica Branson and Mehl, 1933a.

Diagnosis: Thin, bladelike, denticulated arched bar; cusp much reduced and typically present as denticle slightly larger, but of same character as bar denticles to either side. Denticles subequal, laterally compressed, sharp, and generally appressed, approximately equal number to either side of main denticle. Basal cavity beneath main denticle (modified from Branson and Mehl, 1933a, p. 51).

Remarks: The diagnosis for Ozarkodina is based on that of Branson and Mehl. Klapper and Philip (1971) have emended this diagnosis and now consider a seximembrate apparatus comprised of a P, 0, N, and three A-type elements in a symmetry transition to bear the name Ozarkodina. Ozarkodinan elements are very common constituents of reconstructed apparatuses. The multielement apparatus ranges from the Silurian to the Devonian (Klapper, 1973a, p. 212). The form-genus Ozarkodina, as used

herein, refers to the single element as diagnosed by Branson and Mehl and is distinguished from <u>Bryantodus</u> by having a thinner blade and much reduced cusp.

<u>Ozarkodina macer</u> (Branson and Mehl)

PI. 1, fig. 2

<u>Bryantodus macer</u> Branson and Mehl, 1934b, p. 283, pi. 23, fig. 4.

<u>Ozarkodina macer</u> (Branson and Mehl). Rhodes, Austin, and Druce, 1969,

p. 173, 174 (further synonymy), pi. 27, figs. 7, 8.

<u>Diagnosis</u>: Gently arched bar with subequal blade-like limbs. Anterior blade has five to seven posteriorly directed denticles. Denticles on both bars laterally compressed, free at apices only, and sharply pointed. Cusp straight, posteriorly inclined, and higher and wider than blade denticles. Basal pit small, located beneath cusp. Aboral edge sharp (modified from Rhodes and others, 1969, p. 173).

<u>Remarks</u>: This ozarkodinan element is characterized by the subequal anterior and posterior bars. The specimens collected in this study, while not complete, exhibit characters of the form-species and placement is made with some confidence.

<u>Material</u>: Two nearly complete specimens were recovered from the upper member of the Bakken and one nearly complete specimen was collected from the basal Lodgepole.

Ozarkodlna radians (Branson and Mehl)

PI. 1, fig. 15

Subbrvantodus radians Branson and Mehl, 1938, p. 141, pi. 34, figs. 22,

23. Hass, 1959, p. 385, 386, pi. 48, figs. 25, 29.

Ozarkodlna radians (Branson and Mehl). Canis, 1968, p. 542, pi. 73,

figs. 3, 4.

Diagnosis: Bar short, thickened, sharply arched. Anterior limb denticles about five, large, subequal, sharp edged and pointed. Posterior denticles about six, smaller, pointed and sharp edged. Cusp larger than, but otherwise similar to, bar denticles. Basal pit of moderate size, deep, elongate, with distally directed and tapering grooves (modified from Branson and Mehl, 1938, p. 141).

Remarks: This ozarkodinan element is easily recognized. The large cusp and few partially fused bar denticles are most characteristic of this discrete element. It is distinguished from bryantodld elements by the lack of mid-height development of the bar.

Material: Four complete, or nearly complete, specimens were recovered from the upper member of the Bakken and the basal Lodgepole.

Ozarkodlna sp. A

PI. 1, fig. 7

Description: Bar thin, strongly arched, slightly curved inward. Anterior bar with approximately eight partially fused, laterally compressed, and sharply-pointed denticles. Posterior bar with ten to twelve smaller, rounded, tightly fused, posteriorly directed denticles. Cusp slightly larger than bar denticles and of same character as

posterior bar denticles. Bar tapers posteriorly. Aboral edge sharp
except for small circular basal pit beneath cusp with thin groove
extending posteriorly from pit.

Remarks: The strongly arching, numerous denticles, and reduced
cusp distinguish this element as an ozarkodinan. Ozarkodina sp. A
differs from others of the form-genus by the strong, high arching of the
bar and in the number and character of the bar denticles.

Material: Three mostly complete specimens were obtained from the
basal Lodgepole.

Form-genus Palmatolepis Ulrich and Bassler, 1926
Palmatolepis Ulrich and Bassler, 1926, p. 49. Huddle, 1968, p. 28, 29.

Ziegler, 1973a, p. 253-256. Klapper and others, 1981, p. W165.

Type species: Palmatolepis perlobata Ulrich and Bassler, 1926.

Diagnosis: "Palmatolepis is a platform-type conodont with a
prominent central node, a sigmoidally curved carina, and a tendency to
develop an inner [outer] lobe. Oral surface is variously ornamented.
The blade is highest at the anterior end, and the denticles decrease in
size toward the rear. The denticles are suppressed and indistinct, but
they are generally separate at the tips. Species with well-developed
inner lateral lobes may have secondary carina. Aboral surface is marked
by growth lines in the central portion, but growth lines are generally
absent in a narrow shiny rim, the crimp, at the margin of the platform.
The keel is highest at ends of the plate and may be absent in the
middle. Basal cavity generally absent but may be represented by a pit
below the central node" (Huddle, 1968, p. 28).

Remarks: Form-species within the form-genus _Palmatolepis_ are
determined from platform outline, upper surface sculpture, and position
and character of lateral lobes. Palmatolepid elements are one of the
most important element groups used in stratigraphlc zonation of the Upper
Devonian (modified from Ziegler, 1973a, p. 254). Klapper and
others (1981, p. W165) and Puchkov et al. (1981) [1982] have considered
Palmatolepis to be a Pa element in a seximembrate apparatus.

Palmatolepis perlobata Ulrich and Bassler, 1926

Palmatolepis perlobata Ulrich and Bassler, 1926, p. 49, 50, pi. 7, figs.

  19-22. Branson and Mehl, 1934a, p. 234, pi. 18, figs. 12, 23-25.

  Huddle, 1968, p. 32, 33, pi. 15, figs. 5, 8 only. Ziegler, 1977,

  p. 349, 350 (further synonymy).

Diagnosis: Scalloped blade and platform flexed upward posterior
of central node (modified from Sandberg and Ziegler, 1979, p. 179).

Remarks: Ziegler (1977, p. 348) reported that seven subspecies
are recognized. Discrimination of subspecies is based on overall
platform outline, curvature of blade and carina, and presence and degree
of development or absence of a lateral lobe. The range of the form-
species P. _perlobata_ is from the Upper _Palmatolepis triangularis_ Biozone
(Ziegler, 1977, p. 348) into the Upper _Palmatolepis gracilis expansa_
Biozone of Ziegler and Sandberg (1984, p. 180) (Middle _Bispathodus_
costatus Biozone _sensu_ Sandberg, 1979, p. 91).

<u>Palmatolepis perlobata postera</u> Ziegler ?, 1969

PI. 1, figs. 26, 27

<u>Palmatolepis perlobata postera</u> Ziegler. Sandberg and Ziegler, 1979,

      p. 180 (further synonymy), pi. 2, figs. 1-4.

      <u>Diagnosis</u>: Element "characterized by a broad platform that is slightly to moderately flexed upward posterior to the central node. The outer lobe is either weak or entirely lacking. The posterior half of the outer platform is ornamented by nodes that are arranged in rows parallel to the platform margin. The inner platform is ornamented by random nodes that are coarser on the rounded parapet that diverges slightly anteriorward from the blade" (Sandberg and Ziegler, 1979, p. 180).

      <u>Remarks</u>: <u>Palmatolepis perlobata postera</u> is distinguished from the other subspecies by the reduced development of an outer lobe. The three broken specimens collected from the lower member of the Bakken are tentatively referred to P. p. <u>postera</u> on the basis of anterior ornamentation. The size, spacing, and position of the nodes on each specimen vary, but exhibit characters similar to those illustrated for P. p. <u>postera</u> by Sandberg and Ziegler (1979, pi. 2, figs. 1-4). The Bakken specimens of P. p. <u>postera</u> are distinguished from the discrete element <u>Palmatolepis rugosa ampla</u> by weaker, anterior, nodose ornamentation. The range (Sandberg and Ziegler, 1979, p. 180) of <u>Palmatolepis perlobata postera</u> is from slightly above the base of the Lower <u>Palmatolepis perlobata postera</u> Biozone into the Middle <u>Palmatolepis gracilis expansa</u> Biozone of Ziegler and Sandberg (1984, p. 180) (slightly above the base of the Lower <u>Polygnathus styriacus</u> Biozone into the Lower <u>Bispathodus costatus</u> Biozone as presented by Sandberg, 1979, p. 91).

Material: Five posterior fragments and two mostly complete
anterior fragments were obtained from the lower member of the Bakken.

Palmatolepis perlobata schindewolfi Muller ?, 1956

PI. 1, figs. 28, 32

Palmatolepis perlobata schindewolfi Muller. Ziegler, 1977, p. 361-364

(further synonymy), pi. 11, figs. 1-7. Sandberg and Ziegler,

1979, p. 180, pi. 1, figs. 22-24; pi. 2, fig. 13.

Diagnosis: Element has large, elongate, strongly undulating
platform with finely nodose or shagreen ornamentation. Greatest width of
platform just anterior of central node. Outer lobe relatively large,
though not prominent. Secondary carina absent. Crimp moderately wide
and secondary keel most strongly developed near margin (modified from
Ziegler, 1977, p. 361).

Remarks: Palmatolepis perlobata schindewolfi is distinguished
from the nominate form-species by the finer platform ornamentation and
less developed outer lobe. Ziegler (1977) reported (p. 361) a wide
morphologic variety in P. perlobata schindewolfi. P. p_. schindewolfi
evolved from and is, in many cases, transitional with P. 2* perlobata.
The latter is distinguished primarily by its large platform and coarser
ornamentation. It may be difficult to distinguish these two palmatolepid
elements particularly when they occur in the same stratigraphic interval
(about the Upper Palmatolepis crepida Biozone) (modified from Ziegler,
1977, p. 349). The range of P. p_. perlobata is from the Lower
Palmatolepis triangulus Biozone through the Upper P. crepida Biozone;
however, Sandberg and Ziegler (1973, p. 108) have reported a few forms

from the Lower Palmatolepis marginifera marginifera Biozone (Ziegler,
1977, p. 350). The broken specimens collected from the lower member of
the Bakken are not complete enough to allow for unquestioned assignment.
In a few cases, specimens of P. perlobata schindewolfi collected in this
study may be transitional with P. p. perlobata; however, the platform
outline, ornamentation, and carina suggest a stronger relationship to
P. p. schindewolfi. P. p. schindewolfi is distinguished from P. p..
postera by having a much narrower platform and a wider parapet area and a
characteristic bulge that is absent on P. p. postera. The range
(Sandberg and Ziegler, 1979, p. 180) of P. p. schindewolfi is from the
Upper Palmatolepis crepida Biozone through the Upper Palmatolepis
gracilis expansa Biozone of Ziegler and Sandberg (1984, p. 180) (into the
Middle Bispathodus costatus Biozone sensu Sandberg, 1979, p. 91).

Material: Eight posterior fragments and four anterior fragments
were collected from the lower member of the Bakken.

Palmatolepis rugosa Branson and Mehl, 1934

Palmatolepis rugosa Branson and Mehl, 1934a, p. 236, pi. 18, figs. 15,

16, 18, 19. Ziegler, 1977, p. 397 (further synonymy).

Diagnosis: "Palmatolepis rugosa is , . . characterized by a
moderately to very coarsely ornamented platform that is broadly expanded
to form a semicircular arc on the outer side between the central node and
the posterior tip and a narrow parapet area that parallels the carina.
The platform is generally flat posterior to the central node. The blade
has a sharp crest that generally does not show the tips of fused
denticles in side view. The secondary carina is weak or its position may

even be represented by a depression, but a strong ridge generally extends across the anterior part of the outer lobe toward the blade, invariably anterior to the central node" (Sandberg and Ziegler, 1979, p. 180).

Palmatolepis rugosa ampla Muller ?, 1956

PI. 1, fig. 23

Palmatolepis rugosa ampla Muller. Ziegler, 1977, p. 401-403 (further

synonymy), pi. 13, figs. 6-8. Sandberg and Ziegler, 1979, p. 181,

pi. 2, figs. 10, 11.

Diagnosis: Element "characterized by many small nodes or many weak cross ridges formed by rows of three or more nodes in the parapet area and by a longitudinal row of larger nodes in the anterior part of the outer platform" (Sandberg and Ziegler, 1979, p. 181).

Remarks: The three anterior fragments and one mostly complete specimen collected from the lower member of the Bakken are hesitantly assigned to P. rugosa ampla based on a row of prominent nodes in the parapet area of the anterior platform; this feature is well illustrated by Sandberg and Ziegler (1979, pi. 2, figs. 10, 11). The anterior row of prominent nodes also serves to distinguish this subspecies from P. rugosa cf. ampla Ziegler which, according to Sandberg and Ziegler (1979, p. 181), is a stratigraphically older element and less coarsely ornamented anteriorly. The range (Sandberg and Ziegler, 1979, p. 181) of £• rugosa ampla is from the Lower Palmatolepis perlobata postera Biozone to just into the Upper Palmatolepis gracilis expanse Biozone of Ziegler and Sandberg (1984, p. 180) (upper part of the Lower Polygnathus styriacus Biozone through the Lower Bispathodus costatus Biozone in the

sense of Sandberg, 1979, p. 91).

Material: Three anterior fragments and one nearly complete specimen were collected from the lower member of the Bakken.

Palmatolepis sp. indeterminate

Pl. 1, fig. 33

Material: Fifty-two fragmented specimens were recovered from the lower member of the Bakken. A small number of specimens are largely complete but lack diagnostic characters that are necessary to establish confidence in species-level assignment.

Form-genus Polygnathus Hinde, 1879

Polygnathus Hinde, 1879, p. 361, 362. Huddle, 1934, p. 94, 95. Branson
        and Mehl, 1944, in Shimer and Shrock, p. 245. Rexroad and Scott,
        1964, p. 32, 33. Klapper, 1966, p. 19. Thompson and Fellows,
        1970, p. 92. Klapper and Ziegler, 1973, p. 333, 334. Klapper and
        others, 1981, p. W162-W164.

Type species: Polygnathus dubia Hinde, 1879.

Diagnosis: Compound element composed of posterior platform and most commonly an anterior free blade. Posterior characteristically lanceolate, tapering posteriorly. Aboral side typically with raised medial keel and small circular basal pit. Secondary ornamentation frequently lacking (modified from Rexroad and Scott, 1964, p. 32).

Remarks: Polygnathid elements are among the most common in Upper Devonian and Lower Mississippian strata. Several polygnathid elements have biostratigraphic importance and are directly ancestoral to other

stratlgraphically unique Mississippian platform form-genera. Rexroad and

Scott (1964, p. 32) divided polygnathids into three informal

ornamentational groups: those with smooth platforms, those with nodose

platforms, and those ornamented by transverse ridges on the platform.

Specific determinations of polygnathids are based on general platform

shape, type of platform ornamentation, length of free blade, and

characters of the aboral surface (Rexroad and Scott, 1964, p. 32, 33).

Klapper and others (1981, p. W162) followed Klapper and Philip's (1971)

designation of polygnathid elements being P-type elements occurring in a

wide variety of apparatuses.

Polygnathus communis Branson and Mehl, 1934

partim Polygnathus communis Branson and Mehl, 1934b, p. 293, pi. 24,

figs. 1-4. Branson, 1934, p. 308, pi. 25, figs. 5, 6. Rexroad

and Scott, 1964, p. 33. Klapper, 1966, p. 21 (further synonymy),

pi. 6, figs. 6, 11. Thompson and Fellows, 1970, p. 92.

Diagnosis: "Small, narrow platform, pointed to bluntly rounded at

posterior end, generally unomamented; occasionally possessing low

transverse ridges on anterior portion. Basal cavity small, located on

low, narrow keel" (Thompson and Fellows, 1970, p. 92).

Remarks: Rexroad and Scott (1964, p. 33) reported that

Polygnathus communis is the most common and longest ranging polygnathid

(late Devonian to early Osagean; Thompson and Fellows, 1970, p. 92). A

number of subspecies have been recognized on the basis of ornamentation.

Only the nominate subspecies of P. communis was recovered in this study.

Polygnathus communis communis Branson and Mehl, 1934

PI. 2, figs. 6, 13, 22

Polygnathus communis communis Branson and Mehl. Rexroad and Scott, 1964,

      p. 33, 34, pi. 2, figs. 17, 18. Canis, 1968, p. 543, 544, pi. 72,

      figs. 12, 14-17. Rexroad, 1969, p. 33, 34, pi. 5, figs. 7-10.

      Thompson and Fellows, 1970, p. 93. Norris, 1981, p. 1280, pi. 1,

      figs. 1, 2; pi. 2, figs. 11, 12. Wang and Ziegler, 1982, pi. 1,

      figs. 2, 3. Hayes, 1985, pi. 2, figs. 9-11.

      Diagnosis: Ovate to lanceolate platform lacking ornamentation;
carina composed of three to four medial nodes with paralleling adcarinal
troughs. Free blade, when present, approximately same length as
platform, having a variable number of fused denticles. Basal pit small,
at anterior of platform. Thin, narrow keel extends from basal pit to
posterior tip of blade (modified from Norris, 1981, p. 1280).

      Remarks: Polygnathus communis communis is the most common and
typically the best preserved polygnathld of the collected taxa. Sandberg
and Ziegler (1979, p. 188) reported the range of this subspecies as from
within the Devonian Palmatolepis crepida Biozones into the Mississipplan
Doliognathus latus Biozone; however, Lane and others (1980, p. 121)
illustrated the range extending into the Gnathodus texanus Biozone. A
wide variety of platform outlines were collected from the Bakken and
Lodgepole Formations. Forms with ovate (PI. 2, fig. 13) and lanceolate
(PI. 2, fig. 22) outlines have been illustrated herein.

      Material: This was the most abundant polygnathld element
recovered; 84 elements were recovered from the three members of the
Bakken and the basal Lodgepole. The single complete element collected

from the middle member of the Bakken Formation was of this form-taxon.

Polygnathus experplexus Sandberg and Ziegler, 1979

PI. 1, fig. 20

Polygnathus experplexus Sandberg and Ziegler, 1979, p. 185, 186, pi. 4,

figs. 2-6. Ziegler, 1981, p. 295-297, pi. 12, figs. 1-3.

Diagnosis: "A species of _Polygnathus_ that has a broadly expanded

inner rostral trough between the blade and an inner rostral ridge or

frill that diverges strongly from the blade anterlorward. The moderately

to strongly curved platform is ornamented by nodes arranged to suggest

weak transverse ridges" (Sandberg and Ziegler, 1979, p. 185).

Remarks: _Polygnathus experplexus_ is very similar to _Polygnathus_

perplexus except that the former is ornamented with nodes that resemble

transverse ridges and there is a stronger divergence of the rostral

frill. The range (Sandberg and Ziegler, 1979, p. 186) of P. _experplexus_

is from the Lower _Palmatolepis gracilis expansa_ Biozone into the Middle

Palmatolepis gracilis expansa Biozone of Ziegler and Sandberg (1984,

p. 180) (Upper _Polygnathus styriacus_ Biozone into the Lower _Bispathodus_

costatus Biozone as presented by Sandberg, 1979, p. 91).

Material: Four specimens, three complete and one nearly complete,

were collected from the lower member of the Bakken.

Polygnathus granulosus Branson and Mehl, 1934

PI. 1. figs. 25, 31

Polygnathus granulosa Branson and Mehl, 1934a, p. 246, pi. 20, figs. 21,

23. Thomas, 1949, pi. 1, fig. 33 only.

Polygnathus granulosus Branson and Mehl. 2iegler, 1973b, p. 361, 362

(further synonymy), pi. 3, figs. 6, 7.

Diagnosis: Platform thick, margins sinuous. Carina low,

irregular in height, composed of nodes fused and coalesced to an

irregular ridge that may or may not extend to posterior end of platform.

Carina rises to form a short free blade of three or four fused

denticles. Oral surface nearly flat and ornamented by random, variable

patterns of nodes. Aboral surface smooth, separated by thin, sharp

keel. Basal pit indistinct (modified from Branson and Mehl, 1934a,

p. 246).

Remarks: *Polygnathus granulosus* differs from *Polygnathus*

perplexus in that the former is less arched, nodose ornamentation is

developed to a greater degree, and the platform is much broader. Rostral

frills may be present in P. *granulosus*. but are not developed to the

point of confusion with P. *perplexus* or P. *experplexus*. The range

(Ziegler, 1971, Chart 6) of P. *granulosus* extends from the Upper

Palmatolepis rugosa trachytera Biozone into the Lower *Palmatolepis*

perlobata postera Biozone of Ziegler and Sandberg (1984, p. 180) (Upper

Scaphignathus velifer Biozone into the Lower *Polygnathus stvriacus*

Biozone *sensu* Sandberg, 1979, p. 91).

Material: Five specimens, four well-preserved and one broken,

were obtained from the lower member of the Bakken.

Polygnathus homoirregularis Ziegler, 1971

PI. 1, fig. 21

Palmatolepls? irregularis Thomas, 1949, pi. 2, fig. 27.

Polygnathus granulosa (Branson and Mehl). Thomas, 1949, pi. 1, fig. 34

      only.

Polygnathus homoirregularis Ziegler, 1971, p. 269, 270. Ziegler, 1973c,

      p. 365-367, pi. 3, figs. 4, 10 only. Sandberg and Ziegler, 1979,

      p. 186, pi. 4, figs. 7, 8.

    Diagnosis: Platform broad and relatively large. Oral surface
ornamentation of irregular nodes with tendency toward concentric ridges.
Adcarinal row of nodes form collar at anterior end of platform. Most
diagnostic is irregularity of carina that may consist of a large node,
sigmoidal bend, or sharp outward deflection. In specimens where carina
does not extend beyond midlength, only single node is present. Aboral
surface smooth except for sharp, kinked keel and small basal pit anterior
of kink (modified from Helms, 1961, in Ziegler, 1973c, p. 366).

    Remarks: Presence of single, isolated node makes this element
easy to confuse with the discrete element Palmatolepls. Polygnathus
homoirregularis may have evolved from P. perplexus (Ziegler, 1973c,
p. 366). Ziegler (1971, Chart 6) reported the range of
P. homoirregularis (listed as Po. irregularis) as from the Lower
Polygnathus styriacus Biozone into the Upper P. styriacus Biozone.
However, the range of P. homoirregularis (Sandberg and Ziegler, 1979,
p. 186) was later revised so that it extends from the Upper Palmatolepls
rugosa trachytera Biozone into the Middle Palmatolepls gracilis expansa
Biozone of Ziegler and Sandberg (1984, p. 180) (Upper Scaphignathus

velifer Biozone into the Lower Bispathodus costatus Biozone as presented by Sandberg, 1979, p. 91).

Material: Two complete specimens and one nearly complete specimen was recovered from the lower member of the Bakken.

Polygnathus inornatus Branson, 1934

PI. 2, figs. 28, 29

Polygnathus inornata Branson, 1934, p. 309, pi. 25, figs. 8, 26.

    Klapper, 1966, p. 19, 20, pi. 1, figs. 9, 10, 13, 14 only. Canis,

    1968, p. 544, pi. 72, fig. 25.

Polygnathus lobata Branson and Mehl, 1938, p. 146, 147, pi. 34,

    figs. 44-47. Rexroad and Scott, 1964, p. 35, 36, pi. 2, figs. 15,

    16. Canis, 1968, p. 544, 545, pi. 72, fig. 8.

Polygnathus inornatus Branson. Klapper, 1975a, p. 293-297 (further

    synonymy), pi. 4, figs. 1, 2, 4. Wang and Ziegler, 1982, pi. 1,

    fig. 21. Hayes, 1985, pi. 1, figs. 1, 2.

Diagnosis: "Lanceolate, with short, high blade; nearly straight to strongly incurved carina. Posterior end may be attenuate and sharply pointed or rounded. Lateral margins of anterior part of platform strongly upturned, usually to above level of carina. One anterolateral margin in many cases higher than other. 'Rostral ridges' may be present. Basal cavity relatively large, circular to ovate, usually with prominent lips" (Klapper, 1966, p. 20).

Remarks: Polygnathus inornatus is distinguished from all other polygnathids by the strong upturning of the lateral margins above the level of the carina; one always greater than the other. Some authors

(Rexroad, 1969; Rhodes and others, 1969; Thompson and Fellows, 1970)
recognized subspecies of P. inornatus. A lobe of the higher margin may
be present and has been used to distinguish this form from those with
non-lobed margins. Klapper (1975a, p. 294) included all forms with
subspecific determinations as variations of P. inornatus as originally
described by Branson; he determined that the elements exhibited a wide
range of morphologic variation. Two morphotypes of this form-taxon are
illustrated. Plate 2, fig. 29 illustrates the non-lobed form, and Plate
2, fig. 28 illustrates the lobed form. P. inornatus is a Kinderhookian
element (Klapper, 1975a, p. 295).

Material: One broken specimen, tentatively assigned to this form-
species, was recovered from the upper member of the Bakken and 21
complete, or nearly complete, specimens were collected from the basal
Lodgepole.

Polygnathus longiposticus Branson and Mehl, 1934

PI. 2, figs. 34, 37

Polygnathus longipostica Branson and Mehl, 1934b, p. 294, pi. 24,
        figs. 8-11. Rexroad and Scott, 1964, p. 36, 37, pi. 2, fig. 26.
        Klapper, 1966, p. 20, 21, pi. 4, figs. 1, 5. Ganis, 1968, p. 545
        (further synonymy), pi. 72, fig. 26.
Polygnathus longiposticus Branson and Mehl. Rexroad, 1969, p. 35, 36,
        pi. 5, figs. 11, 12. Thompson and Fellows, 1970, p. 95, 96
        (further synonymy), pi. 4, figs. 4, 16, 19. Klapper, 1975a,
        p. 303-306, pi. 6, fig. 1. Hayes, 1985, pi. 1, figs. 3, 4.

Diagnosis: Element symmetrical, median line straight to slightly
sinuous and strongly arched; oral ornamentation composed of transverse
ridges normal to carina. Carina made up of numerous fused nodes and
extending beyond posterior termination of plate; posteriormost node on
carina large and prominent. Aboral keel narrow, sharp, and reduced in
height posteriorly. Basal pit exceptionally large for the form-genus
(modified from Branson and Mehl, 1934b, p. 294).

Remarks: The distinction between Polygnathus longiposticus and
Polygnathus symmetricus is not clear. Klapper (1975a, p. 303) said that
the aboral surfaces of these two species are identical and "it is quite
possible that they should be synonymized." Nevertheless, separation of
these form-species is based on the attenuation of the blade, presence of
a prominent posterior node, and the posterior extension of the carina in
P. longiposticus. Lane and others (1980, p. 121) reported the range of
P. longiposticus as from the Siphonodella sulcata Biozone into the Lower
Gnathodus typicus Biozone.

Material: Seventeen complete, or nearly complete, specimens were
recovered from the upper member of the Bakken and the basal Lodgepole.

Polygnathus perplexus Thomas

PI. 1, fig. 11

Polygnathus? perplexa Thomas, 1949, p. 418, pi. 2, fig. 23.

Polygnathus perplexus Thomas. Sandberg and Ziegler, 1979, p. 185,

    pi. 4, fig. 1.

Diagnosis: Generally lanceolate with sharply pointed posterior
tip, perhaps with some expansion of platform at midlength. Element

moderately arched and curved inwards. Oral surface ornament nodose to granulose; carina subdued, increasing in height anteriorly. Anterior third of platform upturned to develop a broad trough between free blade and anterior margins. Rostral ridge present within anterior trough and anteriorly divergent from carina. Aboral surface smooth and upswept to a thin, sharp keel; basal cavity insignificant.

Remarks: Polygnathus perplexus differs from P. experplexus in having coarser oral ornamentation and less developed rostral frills. The range (Sandberg and Ziegler, 1979, p. 185) of Polygnathus perplexus is from the Lower to Upper Palmatolepls rugosa trachytera Biozones into the Upper Palmatolepls gracilis expanse Biozone of Ziegler and Sandberg (1984, p. 180) (Middle to Upper Scaphignathus velifer Biozones through the Lower Bispathodus costatus Biozone as presented by Sandberg, 1979, p. 91).

Material: Eighteen specimens, 12 well-preserved and 6 broken or partially obscured by silt, were collected from the lower member of the Bakken.

<p style="text-align:center">Polygnathus spicatus Branson, 1934</p>

<p style="text-align:center">PI. 2, figs. 5, 15</p>

Polygnathus spicata Branson, 1934, p. 312, 313, pi. 25, fig. 20.

Polygnathus anIda Cooper, 1939, p. 399, pi. 39, figs. 39, 40. Thomas, 1949, pi. 3, figs. 10, 12.

Polygnathus spicatus Branson. Klapper, 1975a, p. 321-323 (further synonymy), pi. 6, fig. 6.

Diagnosis: Lanceolate; long, thin blade with slightly curved carina and upturned anterolateral margins. Carina broadly nodose, greatest height and width at midlength. Aboral surface smooth, broken by large basal cavity with prominent lips that encircle basal cavity and narrow to point posteriorly (reminiscent of a pseudokeel as described by Sandberg and others, 1972). Posterior ridge on aboral surface split by thin groove.

Remarks: The aboral surface of Polygnathus spicatus is similar to those of specimens referred to P. symmetricus: however, the area around the basal cavity of P. symmetricus is inverted in contrast to P. spicatus in which the area is flat around the basal cavity. P. spicatus is of Kinderhookian age in North America (Klapper, 1975a, p. 321, 322).

Material: One complete and well-preserved specimen was obtained from the basal Lodgepole.

Polygnathus symmetricus Branson, 1934

PI. 2, fig. 14

Polygnathus symmetrica Branson, 1934, p. 310, pi. 25, fig. 11. Branson
    and Mehl, 1938, p. 146, pi. 33, fig. 11; pi. 34, fig. 33.
    Klapper, 1966, p. 21 (further synonymy), pi. 4, figs. 7, 9;
    pi. 6, figs. 1, 5.

Polygnathus symmetricus Branson. Thompson and Fellows, 1970, p. 97
    (further synonymy), pi. 4, figs. 17, 18. Klapper, 1975a, p. 325,
    326, pi. 6, fig. 7.

Diagnosis: "Lanceolate, with relatively long free blade and straight carina; unit only slightly arched. Anterolateral margins of platform somewhat upturned. Both sides of platform about equally

developed. Basal cavity usually deep and ovate but with groove

projecting short distance posteriorly as slit in keel. Basal cavity

usually without lips, because cavity is set deep into platform" (Klapper,

1966, p. 21).

Remarks: Klapper (1975a, p. 303) stated that Polygnathus

svmmetricus is very similar to P. longiposticus. so similar that it is

possible they should be synonymized. Klapper (1966, p. 21) reported that

the attenuation and upturning of the anterolateral margins are typically

better developed in P. longiposticus than in P. svmmetricus. For my

study, P. svmmetricus was distinguished from P. longiposticus by the lack

of posterior extension of the carina beyond the platform as well as by

the size and prominence of the posteriormost carinal node. Klapper

(1975a, p. 326) reported that P. symmetricus is essentially a

Kinderhookian element, but like P. longiposticus. it may range into

Osagean strata (Lane and others, 1980).

Material: Twenty mostly complete specimens were collected from

the upper member of the Bakken and the basal Lodgepole.

Form-genus Pseudopolygnathus Branson and Mehl, 1934

Pseudopolygnathus Branson and Mehl, 1934b, p. 297, 298. Rexroad and

　　　　Scott, 1964, p. 37, 38. Klapper, 1981, p. 355, 356. Klapper and

　　　　others, 1981, p. W166.

Type species: Pseudopolygnathus prima Branson and Mehl, 1934b.

Diagnosis: "Pectiniform element scaphate with free medial blade

half to one-third element length; platform symmetrical or asymmetrical

with nodes or sturdy ridges, carina distinct; basal cavity usually

prominent with longer dimension generally transverse to element axis, small basal pit rare" (Klapper and others, 1981, p. W166).

Remarks: The prominent basal cavity of the form-genus Ps eudopolvenathus is used to distinguish pseudopolygnathid elements from polygnathid elements. Klapper and others (1981, p. W166) reported unknown apparatus affinities for Pseudopolygnathus, but they have assigned them to P elements in multielement taxonomy. The range of Ps eudopolygnathus is from the Upper Palmatolepis rugosa trachytera Biozone of Ziegler and Sandberg (1984, p. 180) (Upper Scaphignathus velifer Biozone sensu Sandberg, 1979, p. 91) into strata of Early Osagean age (Klapper and others, 1981, p. 356).

Ps eudopolygnathus fusiformis Branson and Mehl, 1934

PI. 2, fig. 12

Ps eudopolygnathus fusiformis Branson and Mehl, 1934b, p. 298, 299,
    pi. 23, figs. 1-3. Klapper, 1981, p. 365-368 (further synonymy),
    pi. 3, fig. 2.

Diagnosis: "Plate narrow, subsymmetrical, tapering to both ends, both margins gently convex. Carina increasing gradually in height forward, made up of denticles all of which are distinct; no sharp distinction between carina and blade; blade nearly as long as the plate. Margins of plate low, denticulate. Aboral sides sharply beveled from keel and bottom of blade. Naval [basal pit] fusiform, longest axis in the greatest length of the plate" (Branson and Mehl, 1934b, p. 298, 299).

Remarks: Ps eudopolygnathus fusiformis is a Kinderhookian element (Klapper, 1981, p. 367).

Material: Six mostly complete specimens were recovered from the upper member of the Bakken.

Pseudopolygnathus marginatus (Branson and Mehl)

PI. 2, fig. 36

Polygnathus marginata Branson and Mehl, 1934b, p. 294, 295, pi. 23,

    figs. 25-27. Rexroad and Scott, 1964, p. 37, pi. 2, fig. 29.

Pseudopolygnathus marginata (Branson and Mehl). Klapper, 1966, p. 13,

    pi. 1, figs. 1-6.

Pseudopolygnathus marginatus (Branson and Mehl). Rexroad, 1969, p. 39,

    pi. 4, figs. 11-13. Klapper, 1981, p. 387-389 (further synonymy),

    pi. 3, figs. 4, 5. Hayes, 1985, pi. 2, fig. 8.

Diagnosis: "Lanceolate with platform equally developed on both sides. Platform bears transverse ridges; unit slightly arched. Raised keel present throughout length, interrupted only by basal cavity. Narrow groove, continuous with keel, traverses basal cavity. Basal cavity nearly symmetrical with characteristic sinus in it flared margins, on both sides, near posterior termination of cavity. Crimp is broad in mature specimens" (Klapper, 1966, p. 13).

Remarks: The platform of Ps eudopolygnathus marginatus may or may not reach the posterior tip. The carina is straight or may be slightly incurved. Klapper (1981, p. 388) reported P. marginatus as a Kinderhookian element in North America.

Material: IVo mostly complete specimens were collected from the upper member of the Bakken and six well-preserved specimens were recovered from the basal Lodgepole.

<u>Pseudopolygnathus nodomargInatus</u> (Branson)

PI. 2, figs. 27, 35

<u>Polygnathus nodomarginata</u> Branson, 1934, p. 310, pi. 25, fig. 10.

<u>non Pseudopolygnathus nodomarginatus</u> (Branson). Rhodes, Austin, and

      Druce, 1969, p. 212, 213, pi. 9, figs. 1-4; pi. 12, figs. 6-8, 10.

<u>Pseudopolygnathus nodomarginatus</u> (Branson). Klapper, 1981, p. 397, 398,

      pi. 3, fig. 8.

      <u>Diagnosis</u>: Element nearly bilaterally symmetrical; plate long and

thick, tapering posterior to sharp point. Margins of blade have about

seven low, rounded nodes; adcarinal troughs separate nodes and carina.

Carina low, narrow, and of regular height from anterior to posterior

ends. Aboral surface smooth with large basal cavity and thick lips near

anterior end of plate; deep median groove extends both anteriorly and

posteriorly from basal pit (modified from Branson, 1934, p. 310).

      <u>Remarks</u>: Ps eudopolygnathus nodomarginatus differs from

P. <u>marginatus</u> In having round, isolated marginal nodes rather than

transverse ridges on the oral surface and a much larger, thicker

basal cavity. The specimens illustrated by Rhodes and others (1969) may

be more accurately assigned to the discrete element <u>Polygnathus mehli</u> as

discussed by Klapper (1981, p. 397, 398).

      <u>Material</u>: Two nearly complete specimens were recovered from the

upper member of the Bakken.

Pseudopolygnathus primus Branson and Mehl, 1934

PI. 2, figs. 11, 26, 38

Pseudopolygnathus prima Branson and Mehl, 1934b, p. 298, pi. 24, figs.

  24, 25. Klapper, 1966, p. 14, pi. 4, fig. 8.

Pseudopolygnathus dentilineata Branson, 1934, p. 317, pi. 26, fig. 22.

  Klapper, 1966, p. 14, 15, pi. 5, figs. 10, 11.

Pseudopolygnathus primus Branson and Mehl. Klapper, 1981, p. 401-408

  (further synonymy), pi. 3, figs. 1, 3; pi. 4, figs. 1, 5-7; pi. 5,

  figs. 1-5. Hayes, 1985, pi. 2, figs. 2-5.

  Diagnosis: Element relatively thick, asymmetrical, subtriangular
to lanceolate. Oral surface ornamentation variable; irregular, thick
transverse ridges on both sides, to transverse ridges or nodes weakly
developed on one side and strong on other. Carina straight, of numerous
fused nodes, rising abruptly anteriorly into free blade. Right side of
platform extends further toward anterior. Aboral surface smooth, rising
to high narrow keel. Basal cavity may be irregular, asymmetric, deep,
shallow, somewhat depressed, to above aboral surface with flared lips.
Basal cavity may be as wide as platform.

  Remarks: Klapper (1966, p. 14, 15) based the assignment of
elements to P. primus and P. dentilineatus on the basal cavity diameter.
Later, he (1981, p. 401, 402) reported that this distinction was
arbitrary and after study of many specimens, concluded that
P. dentilineatus was within the range of morphologic variation of
P* Primus; therefore, he suppressed P. dentilineatus. Plate 2, fig. 11,
26 illustrates two elements of typical P. primus and Plate 2, fig. 38
illustrates the former "P. dentilineatus" morphology. P. primus is a

Kinderhookian element.

Material: Twenty-five well-preserved specimens and seventeen broken specimens were collected from the upper member of the Bakken and the basal Lodgepole.

Pseudopolygnathus triangulus Voges, 1959

PI. 2, figs. 19-21, 25

Ps eudopolygnathus triangula triangula Voges, 1959, p. 304, 305, pi. 35,

figs. 7-13. Klapper, 1966, p. 13, pi. 1, figs. 15-22.

Diagnosis: Compound element with subtriangular outline; anterior margin straight to slightly convex. Oral side ornamented with transverse ridges nearly perpendicular to, but not continuous to, carina. Carina slightly incurved, composed of 10-13 circular and moundlike nodes. Anterior edge of platform may be deflected downward. Free blade straight and short with same number of denticles as nodes on carina. Aboral surface smooth, arched with small basal cavity that may have raised lips that continue posteriorly as narrow keel.

Remarks: Pseudopolygnathus triangulus has a more triangular platform outline than the related form-species P. pinnatus Voges and, overall, is a more fragile element. The basal cavity of P. triangulus is small for the form-genus. Klapper (1966, p. 13) reported the range of P. triangulus as within the Lower Siphonodella crenulata Biozone of Germany.

Material: Four complete and nine nearly complete specimens were recovered from the basal Lodgepole.

Pseudopolygnathus sp. indeterminate

Material: Thirteen fragmented specimens retaining a portion of
the basal cavity were collected from the lower and upper members of the
Bakken and the basal Lodgepole.

Form-genus Siphonodella Branson and Mehl, 1944

Siphonognathus Branson and Mehl, 1934b, p. 295.

Siphonodella Branson and Mehl, 1944, in Shimer and Shrock, p. 245.

> Rexroad and Scott, 1964, p. 42, 43. Klapper, 1966, p. 15, 16.
> Thompson and Fellows, 1970, p. 103, 104. Klapper, 1973b, p. 451,
> 452. Klapper and others, 1981, p. W166.

Type species: Siphonognathus duplicata Branson and Mehl, 1934b.

Diagnosis: "Lanceolate, asymmetrical platform highly arched with
apex at or near position of basal cavity. Anterior rostral or spoutlike
extension of platform well developed in all but earliest species.
Rostrum arched downward anteriorly and at least slightly incurved. It
bears longitudinal (rostral) ridges on the upper [oral] side. Outer side
of platform at least as wide as inner side, and may be more than twice
that width. Carina well developed on the platform, extending anteriorly
as a fixed free blade.

"Raised keel present on lowed [sic] side in front of basal
cavity. This anterior portion of keel generally bears median groove
throughout its length. Basal cavity narrow expansion of median groove in
keel. Cavity in mature specimens small and slitlike, without lips. Keel
either absent or represented only by thin groove behind basal cavity,
except near posterior end where it is raised. Area immediately behind

basal cavity characteristically flattened or beveled" (Klapper, 1966, p. 15).

Remarks: Siphonodellids are "distinctive, short ranging, and of world-wide occurrence" (Collinson and others, 1962, p. 6); this makes these elements among the most important Kinderhookian index fossils. Siphonodellld elements are the most common element in the upper member of the Bakken and the basal Lodgepole. Klapper and others (1981, p. W166) reported Slphonodella elements to be Pa elements in an apparatus of unknown affinities. Slphonodella elements are distinguished from those of the form-genus Polygnathus by having a greatly reduced or nonexistent keel and the presence, or greater development, of rostral ridges on the oral surface. Klapper (1973b, p. 452) reported the age and range of Siphonodella to be Lower Carboniferous no higher than the Scaliognathus anchoralis Biozone; however, the Slphonodella praesulcata Biozones are representative of uppermost Devonian strata as reported by Sandberg and Ziegler (1973), Sandberg (1976), and Ziegler and Sandberg (1984).

<center>Slphonodella cooperi Hass, 1959</center>

<center>PI. 2, figs. 1, 7, 8</center>

Siphonognathus quadruplicate Branson and Mehl, 1934b, p. 295, 296,
    pi. 24, fig. 21 only.

Slphonodella cooperi Hass. 1959, p. 392, pi. 48, figs. 35, 36. Scott and
    Collinson, 1961, p. 131, pi. 2, figs. 31, 33 only. Rexroad and
    Scott, 1964, p. 43, 44, pi. 3, figs. 27-29. Klapper, 1966, p. 16,
    pi. 2, figs. 10, 11; pi. 3, figs. 1-4. Rexroad, 1969, p. 41, 42,

pi. 3, figs. 10, 11, 13 only. Klapper, 1971, p. 10, pi. 1,

figs. 13-15, 21; pi. 2, figs. 1-3. Klapper, 1975b, p. 345, 346

(further synonymy), pi. 2, figs. 4, 5. Sandberg and others, 1978,

p. 107, 108.

Siphonodella cooper1 cooper! Hass. Thompson and Fellows, 1970, p. 104,

105, pi. 6, fig. 16 only.

Diagnosis: Compound element having two or three rostral ridges on
oral surface; curved rostral ridge of outer platform may terminate on
outer margin near midlength or form outer margin, becoming subdued
posteriorly. Oral side adorned with transverse ridges on outer platform
and nodose ornamentation on inner platform. Aboral surface with slightly
raised and flattened pseudokeel posterior of minute basal pit and
slightly raised thin ridge anterior of pit; anterior ridge becomes
indistinguishable from the aboral edge of free blade (adapted from
Klapper, 1966, p. 16).

Remarks: Until Hass (1959) described the new discrete element
species Siphonodella cooperi and Siphonodella obsoleta. most
siphonodellid elements were assigned to S. duplicata (Branson and Mehl).
S. cooper! differs from S. duplicata by the latter having transverse
ridges on both sides of the carina, and a significantly shorter outer
rostral ridge. S. cooper1 may infrequently carry three rostral ridges
and, therefore, is commonly confused with S. quadrupllcata. which carries
between three and five rostral ridges. S. cooper! is distinguished by
having a raised outer margin and a rostral ridge that terminates
posteriorly of any on S. quadrupllcata.

Sandberg and others (1978, p. 107, 108) recognized two morphotypes

of S. cooperi. Morphotype 1 of S. cooperi has rostral ridges, one or
more on each side of the carina, that extend along both margins of the
posterior platform as wide rims. Sandberg and others (1978, p. 109)
stated that S. cooperi morphotype 1 evolved from *S.* duplicata morphotype
2. S. cooperi morphotype 2 is younger than morphotype 1 and has only one
rostral ridge extending along the outer margin of the platform. S.
cooperi morphotype 2 evolved from S. duplicata sensu Hass according to
Sandberg and others (1978, p. 108). These two morphotypes of S. cooperi
aid in deciphering phylogenetic position, and, ultimately, stratigraphic
age determination, but are used herein as one form-species of variable
character.

Thompson and Fellows (1970, p. 104, 105) felt that Hass' (1959)
description of Siphonodella cooperi was to broad and they, therefore,
recognized two subspecies of S. cooperi: the nominate subspecies,
.*S** cooperi cooperi, and a new subspecies S. cooperi hassi that was
distinguished by reduced development of transverse ridges on the outer
platform and an outer rostral ridge that joins the outer margin rather
than forming it as in S. cooperi cooperi. Having reviewed their
illustrations, it is not clear to me that the creation of a new
subspecies was warranted. Klapper (1971, p. 10, 12) placed Thompson and
Fellows' specimens of S. cooperi cooperi and S. cooperi hassi in two
separate form-species (S. isosticha and S. obsoleta). Specimens
recovered from the upper member of the Bakken and the basal Lodgepole
Formations exhibit variation in degree of rostral development, but it is
well within the range of morphologic variation for the form-species.
Therefore, Thompson and Fellows' form-subspecies are not recognized in

this report.

Klapper (1975b, p. 346) reported the range of S. cooper1 as from the S. sandbergi—S. duplicata Biozones to the Lower S. crenulata Biozone, and Sandberg and others (1978, p. 107, 108) stated that the range of S. cooper! extends from near the base of the Upper S. duplicata Biozone into the S. isosticha—Upper S. crenulata Biozone.

Material: S. cooper1 was the most common siphonodellid collected in this study; 71 mostly complete specimens were collected from the basal Lodgepole and three specimens were recovered from the upper member of the Bakken.

Siphonodella crenulata (Cooper)

PI. 2, figs. 9, 10

Siphonognathus crenulata Cooper, 1939, p. 409, pi. 41, figs. 1, 2.
Siphonodella crenulata (Cooper). Voges, 1959, p. 307, 308, pi. 35, figs. 23-30. Klapper, 1966, p. 18, pi. 3, figs. 5-8. Thompson and Fellows, 1970, p. 105, 106, pi. 6, figs. 7, 10. Klapper, 1971, p. 10 (further synonymy), pi. 2, figs. 4-14. Klapper, 1973b, p. 455, 456, pi. 1, fig. 2. Sandberg and others, 1978, p. 110, 111. Hayes, 1985, pi. 1, figs. 15, 16.

Diagnosis: "Representative specimens of Siphonodella crenulata have a markedly asymmetrical platform outline. Outer margin characteristically crenulate, inner margin may have a sharp angular bend at midlength. TVo short rostral ridges; only exceptionally are there three. In mature specimens, outer posterior platform bears weak transverse ridges, inner platform is nodose" (Klapper, 1971, p. 10).

Rostral ridges may converge on carina and appear to join it at or near
midlength. Aboral surface smooth with characteristically depressed
posterior keel.

Remarks: Siphonodella crenulata is distinguished from all others
of the form-genus by its slightly lobate and crenulate outer platform
outline and depressed keel. Sandberg and others (1978, p. 110, 111)
distinguished two morphotypes of S. crenulata; the majority of the
collected specimens appear to have the platform outline and oral
ornamentation suggestive of morphotype 1. Sandberg and others (p. Ill)
reported the range of S. crenulata as from the base of the Lower
S. crenulata Biozone into the S. isosticha--Upper S. crenulata Biozone.

Material: Six complete or nearly complete specimens were
recovered from the upper member of the Bakken. Thirty-nine specimens, 35
well-preserved and four broken, were collected from the basal Lodgepole.

Siphonodella duplicata (Branson and Mehl)

PI. 2, figs. 3, 18

Siphonognathus duplicata Branson and Mehl, 1934b, p. 296, 297, pi. 24,
        figs. 16, 17. Branson, 1934, p. 315, pi. 25, fig. 16 only.

Polygnathus plana Huddle, 1934, p. 103, 104, pi. 8, figs. 39-43.

Siphonodella duplicata (Branson and Mehl). Hass, 1959, pi. 49, fig. 25
        only (figs. 17, 18, S. duplicata sensu Hass; Sandberg and others,
        1978, p. 107). Klapper, 1966, p. 18, pi. 4, fig. 13. Thompson
        and Fellows, 1970, p. 106, pi. 7, figs. 1, 3, 5. Klapper, 1975b,
        p. 349-351, pi. 2, fig. 6. Sandberg and others, 1978, p. 105-107.
        Hayes, 1985, pi. 1, figs. 5, 6.

Siphonodella cf. S. duplicata (Branson and Mehl). Hayes, 1985, pi. 1,

    fig. 12.

    Diagnosis: "Transverse ridges on both sides of [a slightly

asymmetrical] platform. Two rostral ridges usually form margins of

well-developed rostrum. Outer lateral lobe not developed" (Klapper,

1966, p. 18).

    Remarks: Hayes (1984, p. 134) said that S. duplicata was the most

abundant Siphonodella collected during his study. It is certainly the

most abundant Siphonodella in the upper member of the Bakken, but I found

relatively few in the Lodgepole. Sandberg and others (1978, p. 105-108)

recognized two morphotypes of S. duplicata. Morphotype 1 evolved from

S- sulcata by development of a complete rostrum; it is distinguished by

strong transverse ridges on both sides of the carina and a pseudokeel

rather than a true keel. Morphotype 2 evolved from morphotype 1 by

reduction of the pseudokeel into a true keel and is distinguished from

morphotype 1 by transverse ridges on both sides of the carina and full

development of the rostrum. Sandberg and others (1978) regarded

particular specimens illustrated by Hass (1959, pi. 49, figs. 17, 18

only) as of a separate and distinct species. They stated (p. 107),

"S. duplicata sensu Hass evolved from S. duplicata Morphotype 2 by a

greater disarrangement of the nodes on the inner platform and by an

increased posterior convergence of the two rostral ridges." Specimens of

both morphotypes of S. duplicata (Branson and Mehl) and specimens of

£• duplicata sensu Hass were collected from the upper shale of the Bakken

and from the basal Lodgepole. These three entities, while perhaps

important as separate taxa for phylogenetic considerations, are used

herein as one species, S. duplicata, of variable character. Sandberg and others (1978, p. 107) reported S. duplicata to range from the Lower Siphonodella duplicata Biozone into the Lower Siphonodella crenulata Biozone.

Material: Fifty-seven mostly complete specimens were collected from the upper member of the Bakken and eight complete or broken specimens were recovered from the basal Lodgepole.

Siphonodella isosticha (Cooper)

PI. 2, fig. 23

Siphonognathus isosticha Cooper, 1939, p. 409, pi. 41, figs. 9, 10.

Siphonodella obsoleta Hass. Klapper, 1966, p. 17, pi. 2, figs. 9, 12
        only.

Siphonodella isosticha (Cooper). Rexroad, 1969, p. 43, pi. 3, fig. 1
        only. Klapper, 1971, p. 10, pi. 1, fig. 16. Klapper, 1973b,
        p. 459, 460, pi. 1, fig. 3.

Siphonodella cooperi hassi Thompson and Fellows, 1970, p. 105, pi, 6,
        figs. 1, 3, 5 only.

Diagnosis: "in representative specimens of Siphonodella isosticha the posterior termination of the longest rostral ridge is at the outer platform margin, opposite the position where the carina begins to incurve. Outer posterior platform smooth to weakly nodose, inner platform nodose" (Klapper, 1971, p. 10).

Remarks: This element is characterized by the termination of the longest rostral ridge on the outer platform margin. Siphonodella isosticha differs from Siphonodella cf. S. isosticha in that there is

extension of a rostral ridge to the outer margin and weaker, or lack of>

nodose ornamentation on the inner side of the platform. The collected

specimen figured herein (PI. 2, fig. 23) is broken anteriorly so that at

least a portion of the rostral ridges would still be present if they

terminated in the posterior portion of the blade as in S. cf. S,

isostlcha. This ornamentational feature is absent and the weakly nodose

ornament on the inner platform of the illustrated specimen is most

typical of S. isostlcha. Therefore, the assignment of the single element

collected from the Lodgepole to S. isostlcha is made with some

confidence.

Sandberg and others (1978, p. 106) reported the range of

S. isostlcha as from within the Lower S. crenulata Biozone to the top of

the S. isostlcha--Upper S. crenulata Biozone.

Material: A single specimen, missing the free blade, was

collected from the basal Lodgepole.

Siphonodella obsoleta Hass, 1959

PI. 2, fig. 17

Siphonodella obsoleta Hass, 1959, p. 392, 393, pi. 47, figs. 1, 2.

Voges, 1959, p. 309, 310, pi. 35, figs. 40-47 only. Klapper,

1966, p. 17, pi. 4, figs. 17, 19 only. Thompson and Fellows,

1970, p. 107, 108, pi. 7, fig. 10; pi. 8, figs. 8, 9. Rexroad,

1969, p. 44, pi. 3, fig. 6 only. Klapper, 1971, p. 12, pi. 1,

fig. 25. Klapper, 1973b, p. 463, 464, pi. 1, fig. 7. Sandberg,

1978, p. 108, 109. Hayes, 1985, pi. 1, fig. 11.

Siphonodella cooperi hassi Thompson and Fellows, 1970, p. 105, pi. 6,

figs. 2, 4 only.

Diagnosis: "Representative specimens of Siphonodella obsoleta
have a long rostral ridge that extends to near the posterior end of the
outer platform. Outer posterior platform weakly ornamented or smooth
between the long rostral ridge and carina. Rostral ridges vary from two
to four in number; platform is long and relatively narrow" (Klapper,
1971, p. 12). Inner platform nodose; outer platform ornamentation varies
from smooth, to grami lose, to faintly ridged.

Remarks: Siphonodella obsoleta differs from Siphonodella cooper!
in having only weak, smooth to grami lose ornamentation between the outer
margin and the carina, whereas S. cooperi has numerous well-developed
ridges across this area. S. obsoleta may have 2, 3 or 4 rostral ridges.
In cases where there are two or three rostral ridges and moderate
ornamentation, the distinction between S. obsoleta and S. cooperi becomes
hazed. Sandberg and others (1978, p. 108) reported a morphologic melding
of characters between S. obsoleta and S. cooper! within the S. sandberg!
Biozone. Ten specimens were collected that have three rostral ridges
where the innermost ridge on the outer margin extends to near the
posterior end as in S. obsoleta, but these elements have strong
transverse ridges on the outer margin; these specimens have been assigned
[to] S. cooper! based on the presence of the transverse ridges. Plate 2,
figs. 1, '7, 8, and 17 illustrate much of this morphologic variation:
fig. 17 shows S. obsoleta with the innermost rostral ridge extending
toward the posterior and reduced oral surface ornamentation; figs. 1 and
8 illustrate S. cooper! with strong transverse ridges on the outer
platform; fig. 7 shows the transitional form, here assigned to S.

cooper!. with rostral components of S. obsoleta and the posterior
ornamentation of *S.* cooper!. The range of S. obsoleta is from within the
Upper *S.* duplicata Biozone to nearly the end of the S. sandbergi Biozone
(Sandberg and others, 1978, p. 109).

Material: Fifteen well-preserved specimens and one broken
specimen were collected from the basal Lodgepole.

Siphonodella quadruplicata (Branson and Mehl)

PI. 2, figs. 2, 4, 24, 30

Siphonognathus quadruplicata Branson and Mehl, 1934b, p. 295, 296,
    pi. 24, figs. 18-20 only.

Siphonodella quadruplicata (Branson and Mehl). Miiller, 1962b, p. 1388,
    text fig. 5. Klapper, 1966, p. 17, 18, pi. 2, figs. 5-8; pi. 3,
    figs. 9-12; pi. 4, figs. 16, 20. Rexroad, 1969, p. 44, 45, pi. 2,
    figs. 11, 12. Thompson and Fellows, 1970, p. 108, 109, pi. 8,
    figs. 3-7. Klapper, 1971, p. 12 (further synonymy), pi. 1,
    figs. 22-24. Klapper, 1973b, p. 465, 466, pi. 1, fig. 6.
    Sandberg and others, 1978, p. 109, 110. Hayes, 1985, pi. 1,
    figs. 8-10, 17.

Siphonodella crenulata (Cooper). Rexroad and Scott, 1964, p. 44, pi. 3,
    fig. 26.

Siphonodella cooperi cooperi Hass. Thompson and Fellows, 1970, p. 104,
    105, pi. 6, figs. 15, 17 only.

Siphonodella cooperi Hass. Hayes, 1985, pi. 1, fig. 7.

Diagnosis: "in representative specimens of Siphonodella
quadruplicata the posterior termination of the innermost rostral ridge on

the outer platform is adjacent to the position where the carina begins to incurve and between the margin and carina. Number of rostral ridges varies from three to five. Outer posterior platform bears transverse ridges, inner platform is nodose" (Klapper, 1971, p. 12).

Remarks: Klapper (1973b, p. 465) stated that the distinction between Siphonodella quadruplicata and Siphonodella cooperi can be made based on the termination of the innermost rostral ridge on the outside of the platform. The ridge in S. quadruplicata terminates near the bend of the carina and halfway between the carina and outer margin; in S. cooperi the rostral ridge may terminate on the outer margin or form the outer platform margin. Sandberg and others (1978, p. 108) reported that S. cooperi morphotype 2 (single rostral ridge) may be transitional with S. quadruplicata and S. obsoleta. This field of transition was not recognized in this study but, in examining the three types of elements, seems a natural transition.

Plate 2, figs. 2, and 4 illustrate a mostly complete specimen that has been assigned to S. quadruplicata. This specimen, in addition to having the characters diagnostic of this form-species, possesses a sharp flare at the anterior of the outer portion of the blade. While this specific character has not been illustrated by other conodont workers, I believe that the flare is a stronger development of a slight protrusion present on many other specimens of S. quadruplicata (Pl. 2, fig. 24, for example). Sandberg and others (1978, p. 110) reported the range of S. quadruplicata as from within the S. sandbergi Blozone into the S. isosticha—Upper S. crenulata Biozone.

Material: Seven mostly complete specimens were recovered from the

upper member of the Bakken. Thirty-four specimens, 18 complete and 16 broken, were obtained from the basal Lodgepole.

Siphonodella sandbergi Klapper, 1966

PI. 2, fig. 16

Siphonodella sandbergi Klapper, 1966, p. 19, pi. 4, figs. 6, 10-12, 14,

    15. Thompson and Fellows, 1970, p. 109, pi. 7, figs. 9, 11-13.

    Klapper, 1973b, p. 467, 468, pi. 1, fig. 5. Sandberg and others,

    1978, p. 109. Hayes, 1985, pi. 1, fig. 18.

    Diagnosis: "Broad, short, with nodes on inner side of platform. On outer side, at least one rostral ridge (usually the innermost) extends to near posterior end. Ornament weak to absent between this ridge and carina. Five to six rostral ridges present" (Klapper, 1966, p. 19).

    Remarks: Klapper (1973b, p. 467) stated that Siphonodella sandbergi is comparable to Siphonodella obsolete in that each typically has the innermost rostral ridge extending to the posterior end of the blade. However, S. obsoleta is a narrow element with a prominent free blade, is more elongate in outline, and has fewer rostral ridges than does S. sandbergi.

    In addition to the material listed here, two unfigured anterior fragments, one from the basal Lodgepole and one from the upper member of the Bakken, have tentatively been assigned to S. sandbergi. The number of rostral ridges, lack of interrostral ornamentation, and apparent similarity of features in comparison to the complete specimen of 15. sandbergi collected from the basal Lodgepole were the criteria used to make the taxonomic placement of the broken specimens.

Sandberg and others (1978, p. 109) reported the range of
S. sandbergi as from the base of the S. sandbergi Biozone Into the Lower
S. crenulata Biozone.

Material: One rostral fragment was collected from the upper
member of the Bakken and two specimens, one complete and one broken, were
recovered from the basal Lodgepole.

Siphonodella sulcata (Huddle)

PI. 2, figs. 31, 32

Polygnathus sulcata Huddle, 1934, p. 101, pi. 8, figs. 22, 23.

Siphonodella sulcata (Huddle). Collinson, Scott, and Rexroad, 1962,
> p. 7, chart 2. Sandberg, in Sandberg, Streel, and Scott, 1972,
> p. 191, pi. 2, figs. 1-9. Klapper, 1975b, p. 357, 358, pi. 2,
> figs. 2, 3. Sandberg and others, 1978, p. 104, 105.

Siphonodella duplicata (Branson and Mehl). Rexroad, 1969, p. 43, pi. 2,
> fig. 13.

Diagnosis: "Slightly asymmetrical, arched platform is ornamented
on both sides by transverse ridges, which are separated from the strongly
curved, nodose carina by narrow adcarinal grooves. The strongly curved
basal cavity is in juvenile specimens completely open, but in mature
specimens it is partly inverted to form a raised, flat area (herein
termed a pseudokeel) that contains a deep pit near its anterior end. The
free blade is short and low" (Sandberg and others, 1972, p. 191).

Remarks: Siphonodella sulcata is similar to Siphonodella
duplicata except that S. sulcata has a shorter rostrum, the adcarinal
grooves are always present to some degree, and in some specimens of

ȷ>. duplicata there is a breakdown of the transverse ridges into a nodose

pattern. Character of the aboral surface is also diagnostic; S. sulcata

exhibits a raised, narrow pseudokeel that encloses an inverted basal

cavity, whereas S. duplicata exhibits a low, broad cavity that surrounds

the pit.

Sandberg and others (1972, p. 104, 105) suggested that S. sulcata

evolved from S. praesulcata and that there are a large number of

morphologic variations so that a specimen may show a tendency toward

either S. duplicata, S. cooperi, or S. crenulata. The range of

S. sulcata, as reported by Klapper (1975b, p. 358), is from the base of

the S. sulcata Biozone into the lowest part of the

S. sandbergi—S. duplicata Biozones; however, Sandberg and others (1978,

p. 105) revised the upper range to include the Lower Siphonodella

crenulata Biozone. Siphonodella sulcata is the earliest of the

Kinderhookian siphonodellids.

Material: Eight complete or nearly complete specimens were

collected from the upper member of the Bakken.

Siphonodella cf. S. isosticha (Cooper)

PI. 2, fig. 33

Siphonodella obsoleta Hass. Voges, 1959, p. 309, 310, pi. 35,

figs. 48-50 only.

Siphonodella isosticha (Cooper). Rexroad and Scott, 1964, p. 44, pi. 3,

figs. 21, 23 only. Rexroad, 1969, p. 43, pi. 3, fig. 3 only.

Thompson and Fellows, 1970, p. 106, 107, pi. 6, figs. 8, 9, 13,

14.

Siphonodella cf. S. isosticha (Cooper). Klapper, 1971, p. 12,

figs. 17-20. Sandberg and others, 1978, p. 105, 106.

Diagnosis: "In representative specimens of Siphonodella cf.
S. isosticha the posterior termination of the longest rostral ridge on
the outer platform is adjacent to the position where the carina begins to
incurve and midway between the margin and the carina. Long rostral ridge
on inner side terminates at a comparable position. Posterior platform
ornament weakly nodose on both sides, but somewhat stronger on the inner
side" (Klapper, 1971, p. 12).

Remarks: Klapper (1971, p. 12) remarked that this designation is
made for assignment of specimens, formerly assigned to S. isosticha.
which have a centrally terminating rostral ridge or ridges. Sandberg and
others (1978, p. 106) reported the range of Siphonodella cf. S. isosticha
as from within the S. sandbergi Biozone into the lower part of the S.
isosticha—Upper S. crenulata Biozone.

Material: Seven complete to nearly complete specimens were
collected from of the basal Lodgepole.

Siphonodella sp. indeterminate

Material: Forty-eight specimens, 14 from the upper member of the
Bakken and 34 from the basal Lodgepole, were obtained. Included are free
rostral fragments, specimens partly obscured by silt, and a small number
of juvenile specimens; none of these was recognizable to the form-
species level but all clearly showed characteristics of the form-genus.

Form-genus "Spathognathodus" Branson and Mehl, 1941

Spathodus Branson and Mehl, 1933a, p. 46.

Spathognathodus Branson and Mehl, 1941, p. 98. Rexroad and Scott, 1964,

p. 46. Thompson and Fellows, 1970, p. 110.

partim Branmehla Hass. Rexroad and Scott, 1964, p. 46. Klapper, 1966,

p. 22.

Type species: Spathodus primus Branson and Mehl, 1933a.

Diagnosis: Laterally compressed, bladelike element with basal

cavity occupying middle one-third. Basal cavity generally small, but may

have expanded lips. Element may be slightly flexed inward and arched

(modified from Rexroad and Scott, 1964, p. 46).

Remarks: Rexroad and Scott (1964, p. 46) and Klapper (1966,

p. 22) considered Branmehla Hass to be synonymous with

"Spathognathodus." I consider Branmehla a distinct form-genus based on

the posteriorly directed basal cavity that differs from spathognathodid

elements that have a subcentrally located basal cavity.

"Spathognathodus" and Branmehla differ from the bispathodid elements

that, for the most part, are double-rowed permutations of the

spathognathodids.

Rexroad and Scott (1964, p. 46) have reported the range of

"Spathognathodus" as Silurian to Triassic. Spathognathodid elements are

considered by Klapper and Philip (1971, p. 443) to be P-type elements in

the multielement-genus Ozarkodina. a Type 1 apparatus as redefined by

Klapper and Philip. In addition, they said (p. 443) that, "the majority

of Silurian and Devonian platform elements Identified in the literature

as Spathognathodus f"Spathognathodus"! occur in a Type 1 apparatus."

"Spathognathodus" abnormis (Branson and Mehl)

PI. 1, fig. 24

Spathodus abnormis Branson and Mehl, 1934b, p. 277, pi. 22, fig. 20.

      Branson and Mehl, 1938, p. 138, pi. 33, figs. 3, 40 (?); pi. 34,

      fig. 11.

Spathognathodus abnormis (Branson and Mehl). Klapper, 1966, p. 22,

      pi. 5, figs. 5, 12, 13. Canis, 1968, p. 551, pi. 74, fig. 25.

      Thompson and Fellows, 1970, p. 110, pi. 4, fig. 13.

      Diagnosis: "Spathognathodus" abnormis is "characterized by a
straight to slightly arched bar and an apical denticle that is only
slightly larger than the other denticles. The basal cavity is large and
conspicuous and has flaring edges. The number of denticles varies"
(Canis, 1968, p. 551).

      Remarks: "Spathognathodus" abnormis is distinguished from others
of the form-genus by the straight oral outline, small apical denticle,
and conspicuous circular, centrally located, basal cavity. Thompson and
Fellows (1970, p. 110) and Klapper (1966, p. 22) reported the basal
cavity to be small. Specimens collected in this study exhibit a wide
range of basal cavity sizes. The presence of an apical denticle is
difficult to distinguish from the other bar denticles in the small number
of specimens assigned here; the assignment, therfore, is somewhat
tentative. Klapper (1966, p. 23) reported that "S." abnormis is a
Kinderhookian element.

      Material: A total of six mostly complete specimens were recovered
from the lower and upper members of the Bakken and the basal Lodgepole.

"Spathognathodus" crassidentatus (Branson and Mehl)

PI. 1, fig. 9

Spathodus crassidentatus Branson and Mehl, 1934b, p. 276, pi. 22, figs.
     17, 18 (?).

Spathodus regularis Branson and Mehl, 1938, p. 137, pi. 34, figs. 1-3,
     10.

Spathognathodus crassidentatus (Branson and Mehl). Klapper, 1966, p. 23,
     pi. 5, figs. 15-17. Canis, 1968, p. 552, 553, pi. 74, fig. 29.
     Rhodes, Austin and Druce, 1969, p. 226, 227, pi. 3, figs. 1-4.
     Thompson and Fellows, 1970, p. Ill, 112, pi. 7, figs. 8, 14.

[11] Spathognathodus" crassidentatus (Branson and Mehl). Hayes, 1985, pi. 2,
     fig. 21.

     Diagnosis: "Single-rowed, straight to incurved, and slightly
arched. Two main denticles, markedly higher and wider than the others,
located at anterior end of blade. Denticles form convex arc from
position above basal cavity to posterior tip. Denticles usually 10 to
15, few germ [suppressed] denticles. Basal cavity extends from somewhat
in front of midlength to near posterior end. Nearly symmetrical cavity
rounded anteriorly tapering sharply toward posterior end" (Klapper, 1966,
P. 23).

     Remarks: "Spathognathodus" crassidentatus is most similar to the
only single-rowed bispathodid, Bispathodus stabilis; however, "S."
crassidentatus has two prominent anterior bar denticles and a basal
cavity that is neither as wide nor rounded anteriorly. "S."
crassidentatus differs from "S." abnonnis in that the former is lacking
the larger apical denticle. Klapper (1966, p. 23) reported "S."

crassidentatus to be a Kinderhookian element in North America.

Material: Fifteen mostly complete specimens were collected from the upper member of the Bakken and the basal Lodgepole.

"Spathognathodus" macer (Branson and Mehl)

PI. 1, fig. 1

Spathodus macer Branson and Mehl, 1934b, p. 276, pi. 22, fig. 19.

Spathognathodus macer (Branson and Mehl). Canis, 1968, p. 553 (further
synonymy), pi. 74, fig. 32. Rexroad, 1969, p. 47, 48, pi. 6,
figs. 9-11.

Diagnosis: "Spathognathodus f"Spathognathodus"! macer is characterized by its undulating oral margin [lateral view] that is due to variation in the size of the denticles. The basal cavity is subcentral, oval, and has moderately flaring lips" (Canis, 1968, p. 553).

Remarks: Rexroad (1969, p. 48) reported that "Spathognathodus" macer is similar to both "S." strigosus and "S." [= Bispathodus] stabilis. The greatest difference between these three form-taxa is in the lateral view of the oral margin. The outline of B. stabilis is nearly straight, "S." macer is undulating. Like B. stabilis, "S." strigosus also has a straight outline, but carries finer and more deeply inserted denticles. Many of the spathognathodid specimens collected from the upper and lower members of the Bakken and the basal Lodgepole are broken to some degree. It is difficult to infer denticle height on these specimens so that some of the less complete specimens assigned to S. strigosus may actually belong to "S." macer but are placed in "S." strigosus on the basis of a small posteriorly located basal cavity and

greater number of denticles.

Material: Three nearly complete specimens were recovered from the upper member of the Bakken.

"Spathognathodus" strigosus (Branson and Mehl)

PI. 1, fig. 5

Spathodus strigosus Branson and Mehl, 1934a, p. 187, pi. 17, fig. 17.

Spathognathodus strigosus (Branson and Mehl). Rexroad, 1969, p. 48, 49

    (further synonymy), pi. 6, fig. 3. Wang and Ziegler, 1982, pi. 2,

    figs. 11-16.

"Spathognathodus" strigosus (Branson and Mehl). Hayes, 1985, pi. 2,

    fig- 7.

Diagnosis: Blade thin, slightly incurved laterally. Aboral outline anteriorly straight, slightly arched posteriorly. Posteriorly set basal cavity symmetrical, small, narrow, tapering posteriorly with only faint lips developed. Oral lateral outline nearly straight to near posterior end where it curves downward sharply to aboral margin. Denticles about 24; sharp, laterally compressed edges. Larger denticles typically on anterior third of blade; abundant suppressed denticles at midlength of blade (modified from Branson and Mehl, 1934a, p. 187).

Remarks: "Spathognathodus" strigosus is characterized by the numerous denticles and small basal cavity. Although Branson and Mehl (1934a, p. 187) described the basal pit as narrow with little hint of lips, Rexroad (1969, pi. 6, fig. 3) illustrated a specimen whose basal cavity shows greater development of lateral lips and more central positioning. As other characters of Rexroad*s specimen correspond to the

characters of the form-species, it has been included as an element with slightly different morphologic variation. Four broken specimens from the Bakken exhibit the flared basal cavity lips as illustrated by Rexroad (1969).

Material: Twenty-five nearly complete and broken specimens were collected from the upper and lower members of the Bakken and the basal Lodgepole.

"Spathognathodus" cf. "S." planiconvexus

Wang and Ziegler

PI. 1, figs. 16, 22

Spathognathodus planiconvexus Wang and Ziegler, 1982, p. 155, pi. 1,

figs. 26-29.

Diagnosis: "The basal cavity is in mid-length. It is shallow and nearly symmetrical and in central position. The denticles of the inner side of the unit have a characteristically flat side surface. Their outer is rounded" (Wang and Ziegler, 1982, p. 155).

Remarks: The specimens collected from the lower member of the Bakken are nearly identical to those illustrated by Wang and Ziegler. The only exception is that their figured specimen illustrating the aboral surface (pi. 1, fig. 29c) exhibits a basal cavity that is relatively large, shallow, and circular. Specimens recovered in this study are fragmented in such a way that the flaring of the basal cavity is missing. Even so, it appears that the inferred diameter of the cavity would not attain the dimension of Wang and Ziegler's illustration. While this may seem a negligible feature, more specimens are needed to

determine morphologic variation and unquestioned assignment. Thus, the Bakken specimens can only be compared to the specimens of "S." planiconvexus illustrated by Wang and Ziegler. "S." planiconvexus is most similar to "S." strigosus but is distinguished by having thick denticles with two distinct lateral faces, one flat and one rounded.

Wang and Ziegler (Table 1, p. 154) showed "S." planiconvexus (non "S." planoconvexus) ranging to uppermost Devonian strata in China, but not into lowest Mississippian strata. Lindstrom informed Wang and Ziegler (p. 156) that similar if not identical elements are known from the Bushberg sandstone (basal Kinderhookian) of Missouri.

Material: Seven complete, or nearly complete, specimens were collected from the lower member of the Bakken.

"Spathognathodus" sp. A

PI. 1, fig. 12

Description: Small, thin, straight blade having 12 discrete denticles. Denticles oval In cross section and tapered to sharp point, largest above basal cavity; denticles on both sides of largest decrease in height at even rate. Oral lateral outline concave; posterior deflected downward to a greater degree than anterior. Aboral lateral outline nearly straight. Basal cavity widest at midlength, tapering to point posteriorly and rounded taper anteriorly. Basal pit shallow and two-thirds length of entire blade.

Remarks: "Spathognathodus" sp. A differs from others of the form-genus by having a small number of very discrete bar denticles with nearly equal distribution of the denticles to either side of the basal cavity.

Material: One well-preserved specimen was collected from the basal Lodgepole.

"Spathognathodus" sp. B

PI. 1, fig. 10

Description: Blade long, thin, having 13 to 15 widely-spaced denticles. Denticles circular in cross section, short, quickly tapering to sharp point; largest denticle centrally located above basal pit. Oral lateral outline gently concave. Aboral lateral outline straight in anterior one-half and concave in posterior half. Basal pit small, symmetrical, at apex of posterior arch; pit tapers toward posterior with thin groove extending toward anterior.

Remarks: "Spathognathodus" sp. B is recognized from others of the form-genus by having a small number of widely-spaced denticles on an elongate bar. "S." sp. B differs from "S." sp. A by having a small basal pit and a posteriorly directed cusp that is slightly larger than the surrounding denticles.

Material: One complete specimen was obtained from the lower member of the Bakken.

"Spathognathodus" sp. indeterminate

Material: Thirty-one mostly fragmented specimens with characters of the form-genus were collected from the lower and upper members of the Bakken and the basal Lodgepole. Many of the elements placed here are anterior or posterior portions of bars with or without denticles and most are missing the basal pit or cavity.

Form-genus <u>Synprioniodina</u> Bassler, 1925

<u>Svnprioniodina</u> Bassler, 1925, p. 219. Ulrich and Bassler, 1926, p. 42.

Huddle, 1934, p. 53, 54. Huddle, 1968, p. 45.

<u>Euprioniodina</u> Bassler, 1925, p. 219. Ulrich and Bassler, 1926, p. 29.

<u>Type species</u>: <u>Synpr ion iod ina alternata</u> Bassler, 1925.

<u>Diagnosis</u>: "Posterior bar arched and bowed with anteriorly
directed, closely spaced, discrete or fused denticles; terminal cusp and
denticulated anticusp. The posterior bar and anticusp form an acute
aboral angle in most species. Basal cavity beneath the cusp expanded on
the inner side. Denticles apparently inserted, and suppressed denticles
are common" (Huddle, 1968, p. 45).

<u>Remarks</u>: <u>Synprioniodina</u> is similar to "<u>Neoprioniodus</u>" except that
the latter characteristically has a non-denticulate anticusp. Huddle
(1968, p. 45) reported the range of <u>Synprioniodina</u> as Silurian to
Mississippian. Austin and others (1981, p. W179) stated that
<u>Synprioniodina</u> is a M element in multielement terminology. Klapper and
Philip (1971) designated synprioniodinan elements as N-types, occurring
in apparatuses that do not include neoprioniodontan elements.

<u>Synprioniodina alternata</u> Bassler, 1925

PI. 3, fig. 28

<u>Svnprioniodina alternata</u> Bassler, 1925, p. 219. Ulrich and Bassler,
1926, p. 42, text-fig. 4, no. 22, p. 16. Huddle, 1968, p. 45, 46
(further synonymy), pi. 6, figs. 3-5, 12. Wang and Ziegler, 1982,
pi. 2, fig. 25.

<u>Svnprioniodina decurrens</u> Huddle, 1934, p. 55, pi. 11, fig. 11.

Synprioniodina alternata Ulrich and Bassler. Cooper, 1939, p. 417,

>pi. 47, figs. 18, 19.

Diagnosis: Posterior bar heavy, slightly bowed and arched. Cusp prominent and somewhat compressed laterally. Anticusp flat on outside and deflected outward; sparsely denticulated with few denticles breaking aboral surface of anticusp. Denticles on posterior bar slender, rounded, and alternating in size. Basal pit located beneath cusp; relatively small with inner lip that is somewhat flared (modified from Huddle, 1968, p.46).

Remarks: *Synprioniodina alternata* differs from *Synprioniodina prona* (Huddle) in the lesser inclination of the cusp, greater bowing of the posterior bar, presence of a flat area at the base of the cusp, and a lesser outward deflection of the anticusp.

Material: One small, complete specimen was collected from the basal Lodgepole.

Synprioniodina delicatula Branson and Mehl, 1934

PI. 3, fig. 24

Synprioniodina? *delicatula* Branson and Mehl, 1934b, p. 292, pi. 23,

>figs. 23, 24.

Synprioniodina delicatula Branson and Mehl. Rexroad, 1969, pi. 8, figs.

>1, 3, and 4 only.

Diagnosis: Posterior bar compressed; sharp aboral edge; denticles small, slender, nearly fused with apices free, increasing length anteriorly. Cusp prominent, laterally compressed with sharp edges, directed upwards. Basal pit somewhat excavated with inner lip-like flare

that continues down inner part of anticusp as narrow flange (modified from Branson and Mehl, 1934b, p. 292).

Remarks: Synprionlodina delicatula differs from S. alternata in having a more developed lip on the basal pit and tightly fused denticles that are relatively uniform in size than in S. alternata. S. delicatula differs from S. prona by having relatively large, discrete denticles of uniform size on the posterior bar and an anticusp that may be deflected backward to a greater degree.

Material: A total of nine mostly complete specimens were collected from the upper member of the Bakken and the basal Lodgepole.

Synprioniodina prona (Huddle)

PI. 3, fig. 29

Euprioniodina prona Huddle, 1934, p. 52, pi. 6, fig. 9; pi. 11, fig. 8.

Euprioniodina regularis Branson, 1934, p. 330, pi. 28, fig. 1.

Prioniodina alternata Ulrich and Bassler. Helms, 1959, p. 652, 653,
     pi. 2, fig. 15; pi. 4, fig. 29 (?).

Synprioniodina prona (Huddle). Huddle, 1968, p. 46 (by reference only).
     Wang and Ziegler, 1982, pi. 2, fig. 24.

Synprioniodina regularis regularis (Branson). Rexroad, 1969, p. 50,
     pi. 8, fig. 8 only.

Diagnosis: Posterior bar thins posteriorly, strongly curved laterally; denticles 20 or more, closely spaced but conspicuously discrete with some variation in size. Cusp short, sharp edged, bluntly pointed, and anteriorly directed. Anticusp twisted backward with approximately five faintly discrete denticles. Basal pit relatively

large with inner flaring lip that may continue as flange to anterior bar
(modified from Huddle, 1934, p. 52; Branson, 1934, p. 320).

Remarks: Synprioniodina prona is a more massive element than S.
alternata and S. delicatula. Denticles are distinctly discrete and of
regular size in S. prona. The anticusp is short and the inner lip is
more developed in S. prona than in S. alternata. Huddle (1968, p. 46)
stated that S. alternata appears earlier in the Upper Devonian and Lower
Mississippian dark shales of the central United States than S. prona and
also disappears earlier.

Material: One broken specimen was recovered from the lower member
of the Bakken and six complete, or nearly complete, specimens were
obtained from the basal Lodgepole.

Synprioniodina sp. indeterminate

Material: Five fragmented elements displaying characteristics of
the form-genus, but lacking specific character identity, were collected
from the upper member of the Bakken.

coniform sp. indeterminate

Material: Two nearly complete, and unfigured, specimens were
obtained from the lower member of the Bakken.

ramiform sp. indeterminate

Material: A total of 857 fragmented and obscured specimens were
recovered from the three members of the Bakken and the basal Lodgepole.

Remarks: A large number of these fragments are probably assignable to three or four form-genera ("Hlndeodella". Hibbardella, Lonchodina. Ligonodina), but because of lacking diagnostic features, little confidence can be attached to any detailed placement.

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EXPLANATION OF PLATE 1

Figure

1   "spathognathodus" macer (Branson and Mehl). X38, lateral
        view, lower shale of Bakken, NDGS Well No. 607, UND A2605.9,
        UND 4411.

2   Ozarkodina macer (Branson and Mehl). X18, lateral view,
        upper shale of Bakken, NDGS Well No. 4958, UND A2609.1,
        UND 4412.

3, 4   Elictognathus laceratus (Branson and Mehl). 3. X25, lateral
        view; typical morphotype, basal Lodgepole, NDGS Well No.
        607, UND A2605.3, UND 4413. 4. X25, lateral view;
        development of shelf on aboral margin, basal Lodgepole, NDGS
        Well No. 607, UND A2605.5, UND 4414.

5   "Spathognathodus" strigosus (Branson and Mehl). X38, lateral
        view, basal Lodgepole, NDGS Well No. 793, UND A2606.ll,
        UND 4415.

6   Ligonodina delicata Branson and Mehl. X25, inner lateral
        view, lower shale of Bakken, NDGS Well No. 607, UND A2605.16,
        UND 4416.

7   Ozarkodina sp. A. X25, inner lateral view, basal Lodgepole,
        NDGS Well No. 607, UND A2605.5, UND 4417.

8   "Neoprioniodus" aff. "N." barbatus (Branson and Mehl). X38,
        lateral view, lower shale of Bakken, NDGS Well No. 607,
        UND A2605.16, UND 4418.

9   "Spathognathodus" crassidentatus (Branson and Mehl). X25,
        lateral view, upper shale of Bakken, NDGS Well No. 607,
        UND A2605.9, UND 4419.

10   "Soathognathodus" sp. B. X38, lateral view, lower shale of
        Bakken, NDGS Well No. 607, UND A2605.ll, UND 4420.

11   Polygnathus perplexus (Thomas). X38, lateral view, lower
        shale of Bakken, NDGS Well No. 607, UND A2605.16, UND 4421.

12   "Spathognathodus" sp. A. X38, lateral view, basal Lodgepole,
        UND Well No. 793, UND A2606.12, UND 4422.

13   Branmehla inornata Hass. X38, lateral view, lower shale of
        Bakken, NDGS Well No. 607, UND A2605.15, UND 4423.

14   Bispathodus stabilis (Branson and Mehl). X25, oral view,
        basal Lodgepole, NDGS Well No. 793, UND A2606.9, UND 4424.

15   *Ozarkodina radians* (Branson and Mehl). X38, lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4425.

16, 22 "*Spathognathodus*" cf. "*S.*" *planiconvexus* Wang and Ziegler. 16. X25, outer lateral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.ll, UND 4426. 22. X38, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.ll, UND 4426.

17   *Bispathodus jueoaus* (Branson and Mehl). X25, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2650.16, UND 4427.

18   *Bryantodus planus* Branson and Mehl. X25, lateral view, upper shale of Bakken, NDGS Well No. 4958, UND A2609.1, UND 4428.

19   *Bryantodus typicus* Bassler. X25, lateral view, basal Lodgepole, NDGS Well No. 5088, UND A2610.4, UND 4429.

20   *Polygnathus experplexus* Sandberg and Ziegler. X38, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.16, UND 4430.

21   *Polygnathus homoirregularis* Ziegler. X25, oral view, lower shale of Bakken, NDGS Well No. 607, A2605.16, UND 4431.

23   *Palmatolepis rugosa amp la* Miiller ? X38, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.16, UND 4432.

24   "*Spathognathodus*" *abnormis* (Branson and Mehl). X25, lateral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.ll, UND 4433.

25, 31 *Polygnathus granulosus* Branson and Mehl. 25. X25, aboral view, basal Lodgepole, NDGS Well No. 793, UND A2606.7, UND 4434. 31. X25, oral view, basal Lodgepole, NDGS Well No. 793, UND A2606.7, UND 4435.

26, 27 *Palmatolepis perlobata postera* Ziegler ? 26. X25, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.16, UND 4436. 27. X25, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.16, UND 4437.

28, 32 *Palmatolepis perlobata schindewolfi* Muller ? 28. X25, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.18, UND 4438. 32. X25, oral view, lower shale of Bakken, NDGS Well No. 5088, UND A2610.7, UND 4439.

29   Bispathodus aculeatus aculeatus (Branson and Mehl). X18, lateral view, upper shale of Bakken, NDGS Well No. 4958, UND A2609.1, UND 4440.

30   Bryantodus planirostris Branson. X25, lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4441.

33   Palmatolepis sp. indeterminate. X18, oral view, lower shale of Bakken, NDGS Well No. 607, UND A2605.16, UND 4442.
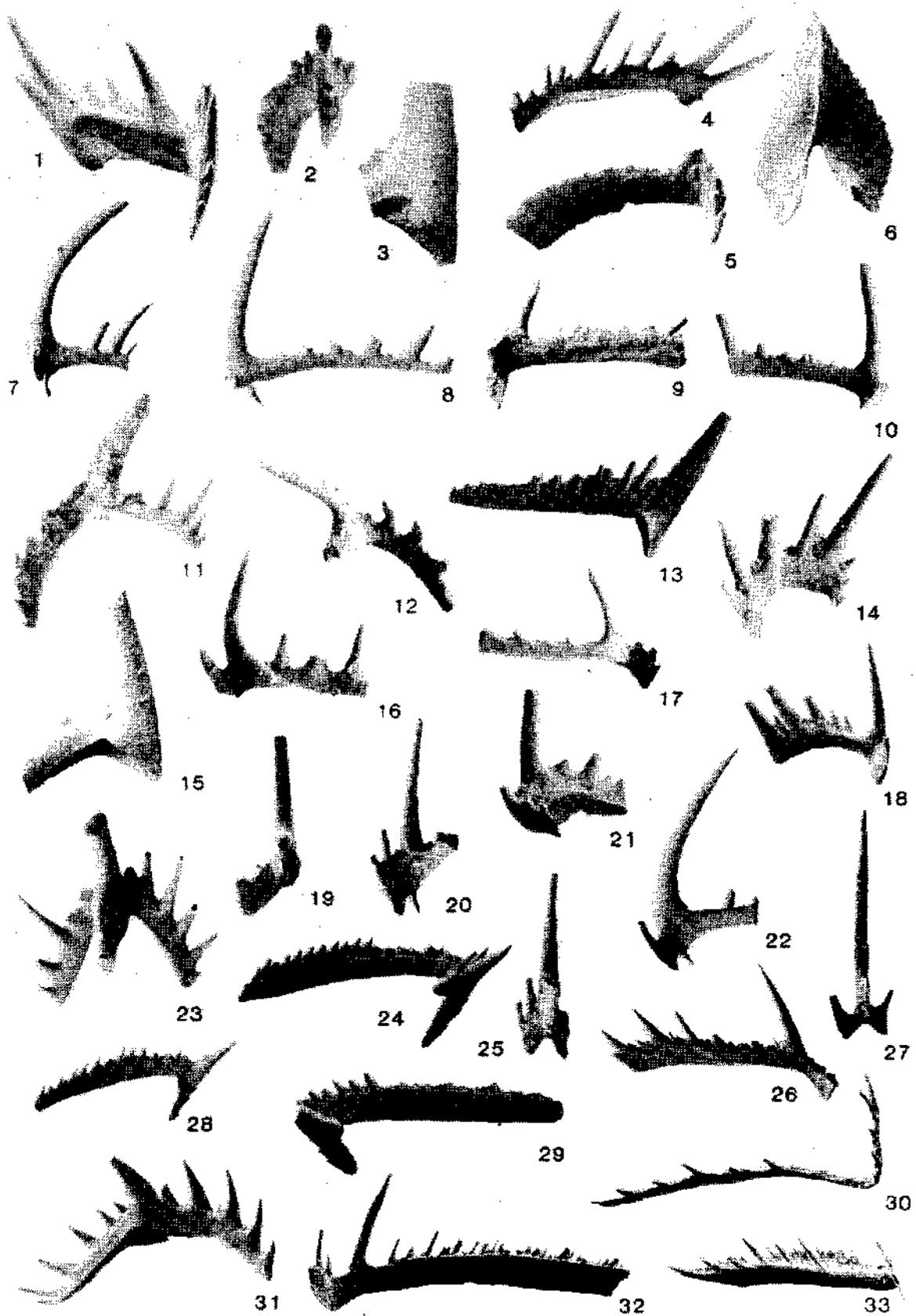
EXPLANATION OF PLATE 2

Figure

1, 7,   <u>Siphonodella cooperi</u> Hass. *l*. X25, oral view, basal
8   Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4443. 7.
         X25, oral view of specimen considered to be transitional with
         S. <u>obsoleta</u>. basal Lodgepole, NDGS Well No. 607, UND A2605.5,
         UND 4444. 8. X25, oral view, basal Lodgepole, NDGS Well No.
         8474, UND A2613.5, UND 4445.

3, 18   <u>Siphonodella duplicata</u> Branson and Mehl. 3. X25, oral
         view of posterior portion of blade, basal Lodgepole, NDGS
         Well No. 5088, UND A2610.3, UND 4447. 18. X25, oral view,
         upper shale of Bakken, NDGS Well No. 607, UND A2605.9, UND
         4448.

5, 15   <u>Polygnathus spicatus</u> Branson. X38, basal Lodgepole, NDGS
         Well No. 793,. <u>UND.A2606.il</u>, UND 4449. 5. Oral view of
         UND 4449. 15. Aboral view of UND 4449.

6, 13,   <u>Polygnathus communis communis</u> Branson and Mehl. 6. X25,
22   oral view, upper shale of Bakken, NDGS Well No. 607, UND
         A2605.9, UND 4450. 13. X38, oral view, basal Lodgepole,
         NDGS Well No. 793, UND <u>A2606.ll</u>, UND 4451. 22. X38, aboral
         view, upper shale^of Bakken, NDGS Well No. 4958, UND A2609.1,
         UND 4452.

9, 10   <u>Siphonodella crenulata</u> (Cooper). 9. X25, oral view, basal
         Lodgepole, NDGS .−Well No. 8474, UND A2613.5, UND 4453. 10.
         X25, oral view, basal Lodgepole, NDGS Well No. 607, UND
         A2605.5, UND 4454.

11, 26, <u>Pseudopolygnathus primus</u> Branson and Mehl. *!!*• X25, oral
38   view, upper shale of Bakken, NDGS Well No. 4958, UND
         A2609.1, UND 4455. 26. X25, oral view, basal Lodgepole,
         NDGS Well No. 793, UND.A2606.4, UND 4456. 38. X38, oral
         view, upper shale of Bakken, NDGS Well No. 607, UND A2605.9,
         UND 4457.

12   <u>Pseudopolygnathus fusiformis</u> Branson and Mehl. X38, oral
         view, upper shale of Bakken, NDGS Well No. 1202, UND
         A2607.1, UND 4458.

14   <u>Polygnathus symmetricus</u> Branson. X38, oral view, basal
         Lodgepole, NDGS Well No. 793, UND A2606.12, UND 4459.

16   <u>Siphonodella sandbergi</u> Klapper. X25, oral view, basal
         Lodgepole, NDGS Well No.. 607, UND A2605.5, UND 4460.

17   <u>Siphonodella obsoleta</u> Hass. X38, oral view, basal
         Lodgepole, NDGS Well No. 5088, UND A2610.2, UND 4461.

19-21, 25   Pseudopolygnathus triangulus Voges. .19. X25, aboral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4462. 25. X25, oral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4462. 20. X25, oral view, basal Lodgepole, NDGS Well No. 607, UND A2605.4, UND 4463. 21. X25, aboral view, basal Lodgepole, UND Well No. 607, UND A2605.4, UND 4463.

23   Slphonodella isosticha (Cooper). X38, oral view, basal Lodgepole, NDGS Well No. 793, UND A2606.8, UND 4464.

2, 4 24, 30   Slphonodella quadruplicata (Branson and Mehl). 2. X18, oral view, basal Lodgepole, NDGS Well No. 8474, UND A2613.2, UND 4446. 4. X18, aboral view, basal Lodgepole, NDGS Well No. 8474, A2613.2, UND 4446. 24. X25, oral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4465. 30. X38, oral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4466.

27, 35   Pseudopolygnathus nodomarglnatus (Branson). X38, upper shale of Bakken, NDGS Well No. 4958, UND A2609.1, UND 4467. 27. Aboral view of UND 4467. 35. Oral view of UND 4467.

28, 29   Polygnathus inornatus Branson. 28. X25, oral view, basal Lodgepole, NDGS Well No. 793, UND A2606.12, UND 4468. 29. X25, oral view, basal Lodgepole, NDGS Well No. 607, UND A2605.4, UND 4469.

31, 32   Slphonodella sulcata (Huddle). 31. X38, oral view, upper shale of Bakken, NDGS Well No. 4958, UND A2609.1, UND 4470. 32. X38, aboral view, upper shale of Bakken, NDGS Well No. 4958, UND A2609.1, UND 4471.

33   Slphonodella cf. S. isosticha (Cooper). X38, oral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4472.

34, 37   Polygnathus longiposticus Branson and Mehl. X25, basal Lodgepole, NDGS Well No. 607, UND A2605.2, UND 4473. 34. Oral view of UND 4473. 37. Semi-lateral view of UND 4473.

36   Pseudopolygnathus marginatus (Branson and Mehl). X38, oral view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4474.

EXPLANATION OF PLATE 3

Figure

1   Angulodus cf. A. demissus Huddle. X25, inner lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.2, UND 4475.

2   Diplododella cf. D. divergens (Huddle). X25, posterior view, basal Lodgepole, NDGS Well No. 607, UND A2605.4, UND 4476.

3   "Neoprioniodus" alatus (Hinde). X25, lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4477.

4   Metaprioniodus sp. A. X38, inner lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4478.

5   Hindeodelloides bicristatus Huddle. X25, inner lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.2, UND 4479.

6   Dinodus voungquisti Klapper. X25, posterior view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4480.

7   Ligonodina platys Cooper. X25, lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4481,

8   Ligonodina panderi (Hinde). X25, lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4482.

9   Diplododella bilateralis Bassler. X25, lateral view, basal Lodgepole, NDGS Well No. 5088, UND A2610.4, UND 4483.

10   Ligonodina tenera Cooper. X25, lateral view, basal Lodgepole, NDGS Well No. 793, UND A2606.ll, UND 4484.

11, 31   Lonchodina arcuata Ulrich and Bassler. JJL. [x]38» inner lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.4, UND 4485. 31. X38, inner lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.1, UND 4486.

12   Lonchodina torta Huddle. X38, inner lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4487.

13   "Neoprioniodus" sp. A. X38, lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4488.

14   Lonchodina typicalis Bassler. X25, inner lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.4, UND 4489.

15   "Neoprioniodus" barbatus (Branson and Mehl). X38, lateral view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4490.

16   Lonehodina dubia (Thomas). X38, inner lateral view, basal
     Lodgepole, NDGS Well No. 505, UND A2604, UND 4491.

17   Ligonodina conidens Huddle. X25, inner lateral view, basal
     Lodgepole, NDGS Well No. 607, UND A2605. 3, UND 4492.

18   Metaprioniodus biangulatus Huddle. X25, inner lateral view,
     basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4493.

19   Hibbardella cf. H. separata (Branson and Mehl). X25, inner
     lateral view, basal Lodgepole, NDGS Well No. 8474, UND
     A2613.2, UND 4494.

20, 25 Dlplododella sp. A. X38, basal Lodgepole, NDGS Well No. 607,
     UND A2605.5, UND 4495. 20. Lateral view of UND 4495. 25.
     Posterior view of UND 4495.

21   Lonchodina brevipennata Branson and Mehl. X38, inner lateral
     view, basal Lodgepole, NDGS Well No. 607, UND A2605.3, UND
     4496.

22, 27 Hibbardella sp. A. X38, basal Lodgepole, NDGS Well No. 607,
     UND A2605.5, UND 4497. 22. Lateral view of UND 4497. 27.
     Posterior view of UND 4497.

23   Hibbardella angulata (Hinde). X38, posterior view, basal
     Lodgepole, NDGS Well No. 793, UND A2606.9, UND 4498.

24   Synprioniodina delicatula Branson and Mehl. X25, inner
     lateral view, basal Lodgepole, NDGS Well No. 607, UND
     A2605.3, UND 4499.

26   "Hindeodella" sp. A. X25, inner lateral view, basal
     Lodgepole, NDGS Well No. 607, UND A2605.3, UND 4500.

28   Synprioniodina alternate Bassler. X25, inner lateral view,
     basal Lodgepole, NDGS Well No. 607, UND A2605. 5, UND 4501.

29   Synprioniodina prona (Huddle). X25, inner lateral view,
     basal Lodgepole, NDGS Well No. 793, UND A2606.12, UND 4502.

30   Hindeodina uncata Hass. X38, oral view, basal Lodgepole,
     NDGS Well No. 607, UND A2605.5, UND 4503.

32   "Hindeodella" subtilis Bassler. X25, inner lateral view,
     basal Lodgepole, NDGS Well No. 607, UND A2605.5, UND 4504.

33   Hindeodina sp. A. X25, inner lateral view, basal Lodgepole,
     NDGS Well No. 607, UND A2605.5, UND 4505.
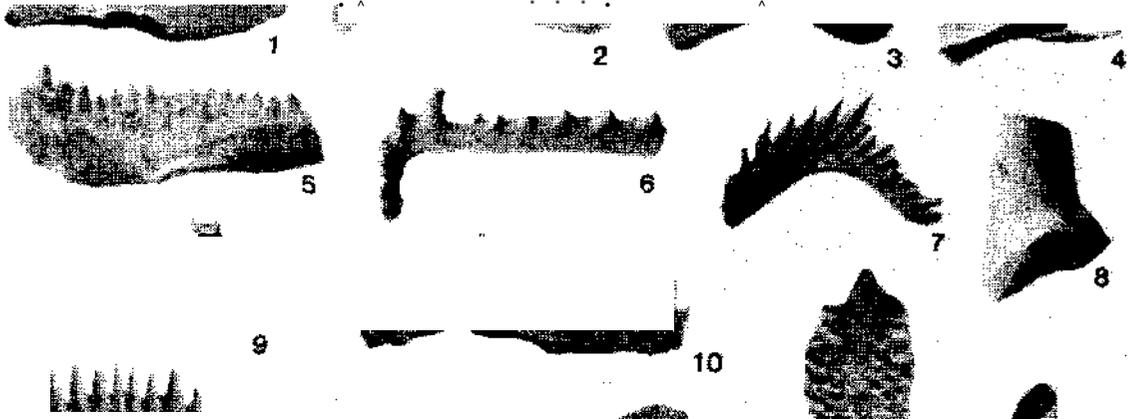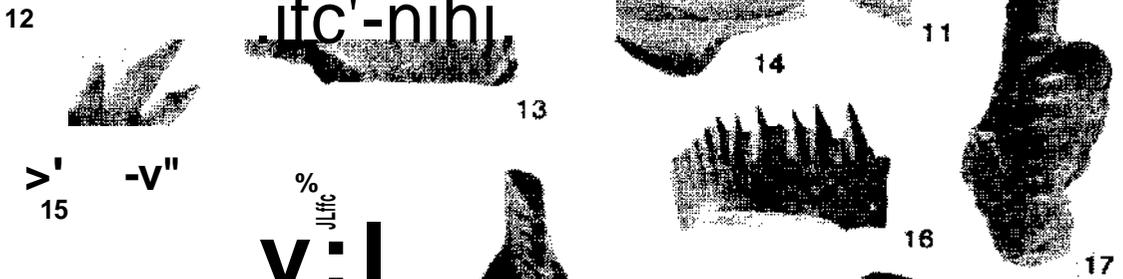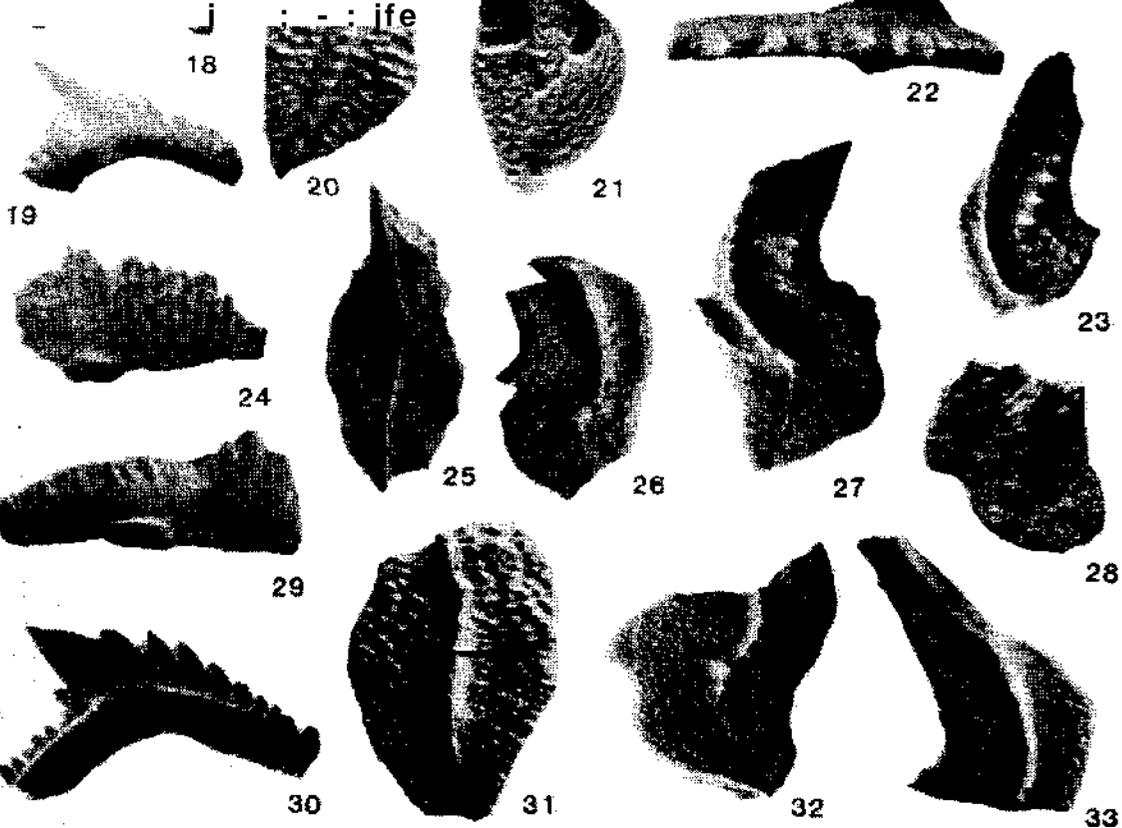
APPENDICES

APPENDIX A

LEGAL LOCATION OF WELLS USED IN THIS STUDY

LEGAL LOCATION OF WELLS USED IN THIS STUDY

Well numbers listed in the far left column of Table 4 are those of the North Dakota Geological Survey. Locations are based on the standard Land Office Grid System. Under the location heading, QQ stands for the first and second quarter of section; S, T, and R stand for section, township, and range, respectively. All townships in North Dakota are north and all ranges are west of the principal baseline and meridian. Unit abbreviations are as follows: (L) Lodgepole Formation, (B) Bakken Formation. Well names and operators are those currently listed by the North Dakota Geological Survey.

TABLE 1
CORES USED IN THIS STUDY

NDGS WELL NO.	OPERATOR	WELL NAME	LOCATION QQ	LOCATION S-T-R	COUNTY	UNIT SAMPLED
505	Socony-Vacuum Oil Co.	C. Dvorack #1	SENE	6-141-94	Dunn	L
511	Socony-Vacuum Oil Co.	Clarence and M. Jacobs	SWSW	24-134-96	Hettinger	L
527	California Oil Co.	Rough Creek Unit #1	NWNE	13-148-98	McKenzie	L
607	Mobil Producing Co.	Kennedy #F-32-24-P	SWNE	24-149-93	Dunn	L & B
793	Mobil Producing Co.	Soloman Bird Bear #1	SENW	22-149-91	Dunn	L
1202	Amerada Petroleum Corp.	Jens Strand #1	SENW	6-152-94	Mckenzie	B
2172	Amerada Petroleum Corp.	D. A. Nelson T-l #1	SWSW	5-152-94	Mckenzie	L
3007	Dallea Petroleum Corp.	Hamlet Unit #2	NE	30-159-95	Williams	B
4340	Pan American Petro. Corp.	Clifford Marmon #1	SWSW	2-154-95	Williams	B
4958	J.B. Hawley, Jr. Trust #1	F. M. Ingerson #2	SWNE	2-161-91	Burke	B
5088	Shell Oil Co.	Shell-Texel #21-35	NENW	35-156-93	Mountrail	L & B
7579	Shell Oil Co.	U. S. A. #42-24A	SENE	24-145-104	Mckenzie	L
8069	Marathon Oil Co.	Jensen #12-44	SESE	12-154-90	Mountrail	B
8474	Tenneco Oil Co.	Graham U. S. A. #1-15	NESW	15-144-102	Billings	L

APPENDIX B

FORMATION AND MEMBER TOPS

FORMATION AND MEMBER TOPS

    All elevations are In feet below the Kelly Bushing (KB) as
determined from picks made on geophysical logs. Well numbers are those
of the North Dakota Geological Survey. Stratigraphic unit abbreviations
are as follows: (L) top of the Lodgepole Formation, (Bu) top of the
upper member of the Bakken Formation, (Bm) top of the middle member of
the Bakken Formation, (Bl) top of the lower member of the Bakken
Formation, (TF) top of the Three Forks Formation. An asterisk denotes
the absence of that unit within a section.

TABLE 2

NDGS Well No.	KB	L	Bu	Bm	Bl	TF
505	2,296	9,250	10,010	*	*	10,080
511	2,614	8,150	*	*	*	8,785
527	2,472	10,345	11,197	11,214	11,254	11,286
607	2,149	9,658	10,510	10,535	10,583	10,615
793	2,092	9,158	9,994	10,014	10,046	10,076
1202	2,129	9,480	10,267	10,287	10,331	10,356
2172	2,098	9,727	10,520	10,544	10,591	10,630
3007	2,372	8,839	9,402	9,412	9,476	9,506
4340	1,972	9,178	9,895	9,916	9,978	10,015
4958	1,973	7,044	7,570	7,580	7,623	7,652
5088	2,409	9,487	10,161	10,177	10,243	10,292
7579	2,665	10,080	10,852	10,857	*	10,864
8069	2,213	8,409	9,157	9,174	9,207	9,236
8474	2,173	9,580	10,366	10,374	10,378	10,379

APPENDIX C

SAMPLED CORE BOX INTERVALS IN THE BAKKEN FORMATION

SAMPLED CORE BOX INTERVALS IN THE BAKKEN FORMATION

Wells listed in the far left column are those of the North Dakota
Geological Survey. Abbreviations for units of the Bakken Formation are
as follows: (Bu) upper member of the Bakken, (Bm) middle member of the
Bakken, (Bl) lower member of the Bakken. Depths listed in the third
column are in feet below the Kelly Bushing as labeled on the outside of
the core boxes. Number and condition refers to the completeness of the
specimens (le. complete or nearly complete [c]; broken, yet identifiable
to at least a generic level [bj; fragments that were not assignable at
any taxonomic level [fi]) and the number of each that were collected
from the listed depth or interval.

TABLE 3

NDGS WELL NO.	MEMBER	CORE BOX DEPTH	NUMBER AND CONDITION
607	Bu	10,510	3c, 2b
607	Bu	10,511	NONE
607	Bu	10,513	lc, lb
607	Bu	10,514	3c, 5b, 2fi
607	Bu	10,517	NONE
607	Bu	10,520	85c, 62b, 96fi
607	Bu	10,521	7c, 3b, 5fi
607	Bu	10,522	NONE
607	Bm	10,574	NONE
607	Bl	10,574	NONE
607	Bl	10,577	9c, 4b, 27fi
607	Bl	10,581	2b, 5fi
607	Bl	10,583	lc, 2b, 7fi
607	Bl	10,589	lc, 5fi
607	Bl	10,594	7c, lb, 45fi
607	Bl	10,595	20c, 50b, 3fi
607	Bl	10,598	2b
607	Bl	10,599	3c, 22b, 12fi
1202	Bu	10,271	NONE
1202	Bu	10,275	lie, 14b, 6fi
1202	Bu	10,276	3b, 3fi
1202	Bu	10,277	6c, 3b, 7fi
1202	Bm	10,277	NONE
1202	Bm	10,282-10,286	NONE
1202	Bm	10,300-10,302	NONE
1202	Bl	10,339	NONE
3007	Bm	9,418-9,419	NONE
4340	Bl	9,900	lc, 3fi

Table 3 -- <u>Continued</u>

NDGS WELL NO.	BAKKEN UNIT	CORE BOX DEPTH	NUMBER AND CONDITION
4958	Bu	7,578	77c, 69b, 456fi
4958	Bm	7,579-7,580	NONE
4958	fim	7,585-7,586	NONE
4958	Bm	7,602-7,603	lb
4958	Bm	7,624	lfi
5088	Bm	10,170	NONE
5088	Bl	10,288	7c, 2b
5088	Bl	10,289	lc, 6b, 2fi
5088	Bl	10,290	10c, 19b, 7fi
8069	Bm	9,171	lc

APPENDIX D

SAMPLED CORE BOX INTERVALS OF THE LODGEPOLE FORMATION

SAMPLED CORE BOX INTERVALS IN THE LODGEPOLE FORMATION

Wells listed in the far left column are those of the North Dakota
Geological Survey. Depths are in feet below the Kelly Bushing as
labeled on the outside of the core boxes. Number and condition refers
to the completeness of the specimens (ie. complete or nearly complete
[c]; broken, yet identifiable to at least a generic level [b]; fragments
that were not assignable at any taxonomic level [fi]) and the number of
each that were collected from the listed depth or interval.

TABLE 4

NDGS WELL NO.	CORE BOX DEPTH	NUMBER AND CONDITION
505	9,591–9,607; 9,609–9,640	NONE
505	9,802–9,860	NONE
505	9,991–10,000	3c
511	8,402–8,414	NONE
511	8,493–8,507	NONE
511	8,598–8,654	NONE
527	10,490–10,493	NONE
607	10,483–10,489	1ie, 4b, 2fi
607	10,489–10,496	1ie, 7b, 12fi
607	10,496–10,502	57c, 42b, 9fi
607	10,502–10,505	48c, 20b, 20fi
607	10,505–10,510	83c, 32b, 62fi
793	9,940–9,943	NONE
793	9,943–9,946	1fi
793	9,946–9,949	1c, 2b, 2fi
793	9,949–9,952	NONE
793	9,952–9,955	NONE
793	9,955–9,958	NONE
793	9,958–9,964	2b
793	9,964–9,970	2c, 2b
793	9,970–9,973	NONE
793	9,973–9,976	10c, 3b
793	9,976–9,979	2fi
793	9,979–9,982	3c, 5b, 2fi
793	9,982–9,985	7c, 4b, 8fi
793	9,985–9,988	1c, 2b, 3fi
793	9,988–9,991	21c, 16b, 4fi
793	9,991–9,993	37c, 14b, 5fi

APPENDIX E

RESULTS OF SAMPLE PROCESSING

RESULTS OF SAMPLE PROCESSING

Well numbers listed in the far left column are those of the North Dakota
Geological Survey. Unit abbreviations are as follows: (L) Lodgepole
Formation, (Bu) upper member of the Bakken Formation, (Bin) middle
member of the Bakken Formation, (Bl) lower member of the Bakken
Formation. Depths are in feet below the Kelly Bushing as recorded on
the outside of the core boxes. Solution components are explained in the
text; abbreviations are as follows: (ac) acetic acid, (fo) formic acid,
(bl) household bleach. All weights are in grams. Percent processed
refers to the amount of material removed from the original sample during
the course of sample processing.

TABLE 5

NDGS WELL NO.	UNIT	CORE BOX DEPTH	SOLN.	DURATION (weeks)	BEG. WT.	END WT.	PERCENT PROCESSED
505	L	9,591–9,607; 9,609–40	ac	16	5,342	1,915	64
505	L	9,802–60	ac	16	2,562	1,193	53
505	L	9,991–10,000	ac	21	6,243	1,800	71
511	L	8,402–14	ac	16	1,048	105	90
511	L	8,493–8,507	ac	4	4,772	4,147	13
511	L	8,598–8,618	ac	12	5,702	4,171	27
511	L	8,618–31	ac	12	4,843	3,348	31
511	L	8,631–43	ac	10	4,184	2,938	30
511	L	8,643–54	ac	10	4,219	2,856	32
527	L	10,490–493	ac	4	281	4	99
607	L	10,483–489	ac	20	3,398	1,687	50
607	L	10,489–496	ac	20	3,509	1,511	56
607	L	10,496–502	ac	20	3,055	1,153	62
607	L	10,502–505	ac	16	1,856	429	77
607	L	10,505–510	ac	16	2,244	126	94
607	Bu	10,510	bl	30	225	123	45
607	Bu	10,511	bl	9	237	129	46
607	Bu	10,513	bl	30	313	225	28
607	Bu	10,514	bl	30	360	234	35
607	Bu	10,517	bl	9	252	196	22
607	Bu	10,520	bl	32	201	101	50
607	Bu	10,521	bl	22	62	26	58
607	Bu	10,522	bl	30	94	16	83
607	Bm	10,574	ac	16	206	85	59
607	Bl	10,574	bl	9	52	27	48
607	Bl	10,577	bl	20	231	164	29
607	Bl	10,581	bl	21	150	86	43

TABLE 5 -- <u>Continued</u>

NDGS WELL NO.	UNIT	CORE BOX DEPTH	SOLN.	DURATION (weeks)	BEG. WT.	END WT.	PERCENT PROCESSED
607	Bl	10,583	bl	30	167	93	44
607	Bl	10,589	bl	23	126	87	31
607	Bl	10,594	bl	23	116	53	54
607	Bl	10,595	bl	21	100	55	45
607	Bl	10,598	bl	30	293	172	41
607	Bl	10,599	bl	30	136	35	74
793	L	9,940-43	ac	23	1,425	861	40
793	L	9,943-46	ac	28	1,398	927	34
793	L	9,946-49	ac	28	1,449	548	62
793	L	9,949-52	ac	20	1,068	595	44
793	L	9,952-55	ac	20	1,397	1,042	25
793	L	9,955-58	ac	20	1,388	781	44
793	L	9,958-64	ac	23	2,577	1,335	48
793	L	9,964-70	ac	28	2,378	821	65
793	L	9,970-73	ac	20	1,302	723	45
793	L	9,973-76	ac	28	1,144	369	68
793	L	9,976-79	ac	23	1,337	947	29
793	L	9,979-82	ac	28	917	660	28
793	L	9,982-85	ac	29	1,091	457	58
793	L	9,985-88	ac	29	1,710	828	52
793	L	9,988-91	ac	29	1,843	571	69
793	L	9,991-93	ac	29	1,217	82	93
1202	Bu	10,271	bl	22	50	46	8
1202	Bu	10,275	bl	22	89	74	17
1202	Bu	10,276	bl	22	61	43	30
1202	Bu	10,277	bl	22	52	31	40
1202	Bm	10,277	ac	22	95	40	58
1202	Bm	10,282-286	ac	22	294	146	50
1202	Bm	10,300-302	ac	21	504	365	28
1202	Bl	10,339	bl	22	17	8	53
2172	L	10,098-110	ac	10	1,247	121	90
2172	L	10,110-124	ac	10	1,463	273	81
2172	L	10,124-134	ac	5	934	147	84
2172	L	10,134-145	ac	10	1,280	188	85
2172	L	10,098-145	fo	18	4,098	879	79
3007	Bm	9,418-19	ac	9	1,721	1,201	30
4340	Bl	9,900	bl	35	64	24	63
4958	Bu	7,578	bl	35	1,114	736	34
4958	Bm	7,579-80	ac	20	196	141	28
4958	Bm	7,585-86	ac	20	968	538	44
4958	Bm	7,602-03	ac	20	791	382	52
4958	Bm	7,624	ac	20	746	412	45

TABLE 5 -- <u>Continued</u>

NDGS WELL NO.	UNIT	CORE BOX DEPTH	SOLN.	DURATION (weeks)	BEG. WT.	END WT.	PERCENT PROCESSED
5088	L	10,145-147	ac	24	3,445	1,805	48
5088	L	10,147-150	ac	24	3,909	2,130	46
5088	L	10,150-153	ac	24	2,464	969	61
5088	L	10,157	ac	14	602	97	84
5088	Bm	10,170	ac	19	459	90	81
5088	Bl	10,288	bl	30	384	135	65
5088	Bl	10,289	bl	30	141	46	68
5088	Bl	10,290	bl	30	362	137	62
7579	L	10,830-832	ac	16	152	71	53
7579	L	10,832-835	ac	16	214	93	57
7579	L	10,835-838	ac	16	209	111	47
7579	L	10,838-840	ac	16	243	110	55
7579	L	10,855	ac	9	19	3	84
8069	Bm	9,171	ac	5	469	274	58
8474	L	10,331-333	ac	20	2,087	1,696	19
8474	L	333-334.5	ac	20	1,442	1,020	29
8474	L	334.5-337.5	ac	20	2,480	1,744	30
8474	L	337.5-339.5	ac	20	1,731	1,405	19
8474	L	339.5-342.5	ac	20	2,181	1,749	20
8474	L	342.5-344.5	ac	20	1,493	1,153	23
8474	L	344.5-347.5	ac	20	1,265	996	21
8474	L	347.5-349.5	ac	20	1,682	1,337	21
8474	L	349.5-352.5	ac	25	2,113	1,496	29
8474	L	352.5-354.5	ac	25	1,814	1,071	41
8474	L	354.5-356.5	ac	25	2,020	1,107	45
8474	L	356.5-359.5	ac	25	2,367	1,176	50
8474	L	359.5-361	ac	25	1,093	157	86

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