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Isopach Maps and Discussion of the Ordovician and Devonian of Montana and Adjacent Areas

Arden F. Blair

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ISOPACH MAPS AND DISCUSSION OF THE ORDOVICIAN AND DEVONIAN OF MONTANA AND ADJACENT AREAS

by
Arden F. Blair

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BUTTE

A thesis
submitted to the Department of Geology
in partial fulfillment of the requirements
for the Degree of Bachelor of Science
in Geological Engineering

Montana School of Mines
Butte, Montana
May 15, 1947
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18957

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## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Ordovician Stratigraphy</strong></td>
<td>2</td>
</tr>
<tr>
<td>Formations.</td>
<td>2</td>
</tr>
<tr>
<td>Winnipeg and Lander</td>
<td>2</td>
</tr>
<tr>
<td>Big Horn</td>
<td>3</td>
</tr>
<tr>
<td>Whitewood</td>
<td>3</td>
</tr>
<tr>
<td>Lithology of the Sediments</td>
<td>4</td>
</tr>
<tr>
<td>Conditions of Deposition</td>
<td>6</td>
</tr>
<tr>
<td>Discussion of Isopach Map</td>
<td>6</td>
</tr>
<tr>
<td>Petroleum Possibilities</td>
<td>7</td>
</tr>
<tr>
<td>Summary.</td>
<td>7</td>
</tr>
<tr>
<td><strong>Devonian Stratigraphy</strong></td>
<td>8</td>
</tr>
<tr>
<td>Formations.</td>
<td>8</td>
</tr>
<tr>
<td>Basal Devonian Shales</td>
<td>10</td>
</tr>
<tr>
<td>Jefferson</td>
<td>10</td>
</tr>
<tr>
<td>Three Forks</td>
<td>12</td>
</tr>
<tr>
<td>Lithology of the Sediments</td>
<td>13</td>
</tr>
<tr>
<td>Conditions of Deposition</td>
<td>14</td>
</tr>
<tr>
<td>Discussion of the Isopach Map.</td>
<td>15</td>
</tr>
<tr>
<td>Petroleum Possibilities</td>
<td>15</td>
</tr>
<tr>
<td>Summary.</td>
<td>17</td>
</tr>
<tr>
<td>Description of Diagnostic Points on Isopach Maps</td>
<td>18</td>
</tr>
<tr>
<td>Bibliography.</td>
<td>21</td>
</tr>
</tbody>
</table>
ILLUSTRATIONS

Plate 1--Isopach Map of Ordovician in Montana and Adjacent Areas . . . . Inside back cover

Plate 2--Isopach Map of Devonian in Montana and Adjacent Areas . . . . Inside back cover
INTRODUCTION

The intensive postwar search for new petroleum horizons has resulted in widespread prospecting in the northern Great Plains. No commercial production has as yet been derived from Ordovician or Devonian rocks in Montana, but the relatively few tests that have penetrated to critical depths have disclosed encouraging conditions which merit further consideration, especially in Devonian strata. Ordovician and Devonian strata of Montana are definitely potential oil-bearing horizons, and as yet detailed information of distribution, thickness, and lithology has not been published.

In order that the depth of potential oil-bearing horizons may be predicted, it is important to the geologist to have in advance an estimate of the thickness of the strata to be drilled; this also aids in the interpretation of geologic horizons encountered. It is largely for these reasons that this problem has been chosen as the subject for an undergraduate thesis.

The area under consideration includes all the state of Montana and the margins of adjacent states. The information contained herein was obtained from various reports of State and Federal Surveys, from articles in technical journals, and from unpublished well logs on file at Montana School of...
Mines. The writer believes that the bringing together of these scattered bits of information on the Ordovician and Devonian strata is of much value, but that the main contribution is the presentation of isopach maps which are to be found nowhere in the literature.

The suggestions and help offered by Dr. E. S. Perry of the Department of Geology of Montana School of Mines have greatly aided the writer in preparing the isopach maps and presenting a brief related discussion, and the writer wishes to express his gratitude and appreciation.

ORDOVICIAN STRATIGRAPHY

Formations

Ordovician strata are believed to be present only in the eastern half of Montana. Throughout the region of the Sweetgrass arch in northern Montana and southwestward to the Idaho border Ordovician strata have not been recognized. The only outcrop of Ordovician in Montana are the exposures of the Big Horn dolomite in the Big Horn, Pryor and Beartooth mountains of the extreme south-central portion of the state, exposures near Livingston and Bozeman, and exposures in the Little Rocky Mountains. In Idaho the Ordovician thickens to 2500 feet or more, becomes clastic in character, and apparently represents a geosynclinal facies, the source of the clastics lying to the west.

Winnipeg and Lander

Oldest of Ordovician strata in the northern Great Plains is a sandstone and shale series, known as the Winnipeg for-
ation, which reaches southwestward from Manitoba; this series may underlie the Big Horn or its equivalent in the extreme eastern part of Montana. In central Wyoming the Big Horn dolomite rests conformably on the Lander sandstone, and perhaps grades downward into it. It is possible that the Lander and Winnipeg formations connect, but there has been no direct evidence yet presented to substantiate this view because these strata are hidden in the Powder River basin. According to Miller (3-p. 195 to 196) the Lander sandstone in Wyoming is believed to be Richmond in age, whereas the Winnipeg is considered to be Black River in age. If this is correct, these two sandstone formations are not the same.

**Big Horn**

The Big Horn dolomite has its type section in the Big Horn mountains of northern Wyoming and southern Montana.

The exact easternmost extent of the Big Horn dolomite is not known, but Seager (8-p. 1421 to 1422) has called 455 feet of Ordovician sediments penetrated by Carter Oil Company's Northern Pacific No. 1 in Fallon County, the eastern representative of the Big Horn dolomite. It is considered Richmond in age.

**Whitewood**

In the Black Hills region of South Dakota and northeastern Wyoming, strata similar to and partially equivalent to the Big Horn dolomite are known as the Whitewood formation. Seager (8-p. 1421 to 1422) has correlated 1135 feet of the sediments drilled in Carter Oil Company's Northern Pacific
No. 1 with the Whitewood formation of the Black Hills. Sloss and Laird (11) have suggested the possible presence of the Whitewood formation as far west as the Mosby dome in central Montana, but their observation was from study of cuttings in one well, and these cuttings might also be considered Big Horn.

Lithology of the Sediments

The Big Horn dolomite is persistently similar in its lithologic characteristics throughout its entire outcrop area in south-central Montana and northern Wyoming. Darton (2-p. 27), in his studies of the formation divides it into three members. The basal member, consisting of 25 to 30 feet of light-grey, moderately coarse grained sandstone, is overlain by a massive middle member of light-buff, sugary crystalline dolomite. The weathered surfaces of this massive middle member commonly show in relief a coarse mat or network of less soluble siliceous material, possibly representing fossilized algae remains.

The top member of the formation is composed of 75 to 100 feet of light-colored thin-bedded limestone. In some places this member contains a stratum that weathered in the same way as the massive middle member.

The greater part of the Big Horn dolomite yields but few fossils. Fragments of maclurinas and corals appear occasionally in the lower massive beds, and also the coralline limestone near the base of the upper member shows corals in most localities. The principal species is Halysites gracilis, a variety of chain coral which often occurs in great numbers.
Receptaculites oweni is a very good index fossil of the Big Horn dolomite when it can be found, but it is very scarce.

Information of lithology of the Ordovician in the Williston basin can be obtained only from a study of well cuttings. The rocks consist of a series of earthy and crystalline dolomites with some maroon shale seams in the lower third. The basal 18 feet is green calcareous shale with variegated maroon and green at the top, this unit is highly fossiliferous. The identification of representative upper Ordovician fauna (Rhynochotrema capax, Dalmanella meeki, and Strophomena planumbona) by members of the Carter Oil Company staff was confirmed by Dr. L. L. Sloss. It is this unit which Seager (8-p. 1421-1422) suggests is the eastern representative of the Big Horn dolomite.

The Whitewood formation as seen in outcrop is a massive pink to buff limestone with a thickness in the northern Black Hills of 60 to 80 feet. Of the Ordovician sediments penetrated by Carter's Northern Pacific No. 1, Seager (8-p. 1421 to 1422) has correlated 530 feet of principally gray massive granular crystalline limestone with the upper Whitewood of the Black Hills. Below that are 615 feet of interbedded green sandy to shaly limestone with the percent of sandstone increasing toward the base. On the basis of conodonts identified from the green shales, he suggests that this latter member is the probable age equivalent of the Winnipeg formation and the lower Whitewood formation of the Black Hills.
Conditions of Deposition

The sediments just described were laid down in a late Ordovician sea which was the coalescence of a sea extending down from the Arctic and one spreading northward from southern United States. Tomlinson (12-p. 390) suggests that the remnants of algea in the massive middle member of the Big Horn dolomite bear witness to the prevalent shallowness of the sea.

The persistent similarity in lithologic characteristics of the Big Horn formation from its type locality in the Big Horn Mountains to its western margin of distribution, and consequently the absence of any shoreline facies leads the writer to believe the original extent and thickness of the formation was probably greater than at present. The period of emergence which followed its deposition afforded ample opportunity for erosion.

Discussion of Isopach Map

An overall inspection of the isopach map reveals several outstanding features. First, there are two positive areas of this region, one in the western part which covers southern British Columbia, western Montana, and northeastern Idaho; and another in eastern Wyoming and southern South Dakota.

Second, there is the indication of a thickening of Ordovician sediments in the middle of the Williston basin which is centered on the Montana-North Dakota border. It is possible that the thickening of Ordovician sediments in this area is a manifestation of the subsurface joining of Lander
sandstone and the Winnipeg formation, although this must remain purely speculative until further subsurface data are available.

Attention is called to the fact that information pertaining to the thickness of Ordovician strata in eastern Montana and western North Dakota is very meager owing to the scarcity of outcrops, and in the course of time more subsurface information might very well change the isopach pattern in this area especially.

Petroleum Possibilities

Showings of oil were reported to have been observed in Ordovician strata in northwestern South Dakota, and in the Lander sandstone in central Wyoming. As yet no petrolierous Ordovician rocks have been penetrated by drilling in Montana. Any further statement regarding the petroleum possibilities of Ordovician strata would be merely conjecture, only time and deeper drilling may produce the desired information.

Summary

The Ordovician sediments in the area studied extend from southern Idaho across western and central Wyoming into the eastern half of Montana, southern Saskatchewan and Manitoba. The strata were deposited by a coalescence of Artic and southern United States seas in Upper Ordovician time. The sediments are dominantly a massive dolomite underlain at least in part of the area by a sandstone or a sandstone and shale series. Attention is called to the great increase in
thickness in the Williston basin zone, and also to the relatively sharp westward limit of distribution as shown on the isopach map. Although two showings of oil have been observed in Ordovician strata in this region, the commercial petroleum possibilities remain rather obscure at the present.

DEVONIAN STRATIGRAPHY

Formations

Devonian strata are present in all of Montana except the southeastern corner where Mississippian rocks directly overlie the Ordovician. Apparently only Upper Devonian strata are present in Montana, and Sloss (10) interprets Jefferson as equivalent to Senecan in age and Three Forks comparable to Chautauquan in age.

The eastern half of Wyoming is entirely lacking in representation of Devonian. From the Pryor and Big Horn Mountains eastward to the Black Hills, just lapping over into Montana, was the northern extent of a great positive area extending up from the south.

Moore (4–pp. 1154 to 1155) reports that the Devonian of southern Alberta compares closely in lithology and thickness with that of the Sweetgrass arch in northern Montana.

In the northeastern part of the area, in Montana, the nearest exposures of Devonian rocks are in the Lake Winnipeg area, and in the Little Rock Mountains of north-central Montana. It is assumed until further information is available that the Devonian of northeastern Montana and northwestern
North Dakota is similar to that described in the outcrop and in wells in Manitoba.

No Silurian strata have been recognized in outcrop in Montana, Wyoming, North Dakota and South Dakota; nor has it been identified in well cuttings in eastern Montana, South Dakota, or central and western North Dakota. While the reasons for the absence of Silurian strata in this area are controversial, the writer is in accord with Perry's (personal communication) suggestion that it is a hiatus of nondeposition rather than erosion. He advances the possibilities of the land area under discussion being practically at sea level during Silurian time, or perhaps that it was in the middle of a sea, too remote from a source of sediments to receive any deposition.

Devonian stratigraphy in Montana first received detailed attention by Peale (5-pp. 25 to 32) who described the type section for the area, near Logan. Peale divided the Devonian into the Jefferson and Three Forks formations, a terminology used later by Weed (13-pp. 287 to 289) in his work on the Little Belt Mountains; however Weed grouped both formations into the Monarch formation for purposes of mapping. The term Monarch is no longer used. Sloss and Laird (10) in their studies of Devonian strata west and south of Great Falls, recognized a three-fold division which they designated as unit DA, unit DB, and unit DC tentatively until more definite correlations could be made.
Basal Devonian Shales

In the mountains of northwestern Montana, shales at the base of the Devonian, termed unit DC by Sloss and Laird (10), rest with marked disconformity on a channeled surface cut in Upper Cambrian dolomite. In central Montana, however, red, green, brown, and yellow dolomitic shales and mudstones with interbedded sandy dolomite appear to be transitional with beds that are very similar in lithology to the Upper Cambrian Dry Creek shale. Because of upward transition into the limestone member of the Jefferson formation, and occurrence of similar shales at the base of the Devonian where Ordovician and Silurian strata would normally intervene above the Cambrian, Sloss and Laird (11) believe that a variable portion of the shale sequence is Devonian in age. They have assigned the glauconitic, micaceous, sandy shales associated with flat-pebble limestone conglomerates, bearing trilobite fragments and phosphatic brachiopods, to the Cambrian Dry Creek shale. The nonmicaceous and less fissile shales and mudstones interbedded with rocks like those of the Jefferson formation have been called basal Devonian. Between the definite Cambrian strata and the basal Devonian shales are beds which cannot be readily placed in either.

Jefferson

At its type locality near Logan, Montana, and elsewhere the Jefferson is divisible into an upper dolomite member and a lower limestone member according to Sloss and Laird (11).

The dolomite member of the Jefferson formation is the
most persistent and widespread of the Devonian rocks in Montana. Throughout most of the area it rests conformably on the limestone member of the Jefferson, the contact being sharp in some localities, and transitional in others. Eastward from the Little Belt Mountains the dolomite member successively overlaps the limestone member and the basal Devonian shales and lies with slight angular unconformity on Upper Cambrian in the Big Snowy Mountains. East of the uplift the member pinches out, apparently through nondeposition and is not present in the Mosby dome. The dolomite member of the Jefferson is considered equivalent to all except the extreme upper part of unit DA of the northwestern Montana section, and to the lower part of the Potlatch anhydrite formation of the Sweetgrass arch, described by Perry (6-pp. 6 to 7).

The limestone member of the Jefferson formation is transitional with underlying basal Devonian shales in central Montana. Distribution of the member was influenced by an east-west positive element that coincided with the axis of the Little Belt-Big Snowy-Porcupine uplift. Along the axis of the positive element the member is thin, very irregular in thickness, and may be missing or unrecognizable in some localities. It is readily recognizable in southwestern Montana.

By stratigraphic position, lithology and fauna, Sloss and Laird (11) correlate the limestone member with unit DB of northwestern Montana.
Three Forks

The Three Forks formation is transitional with the underlying dolomite of the Jefferson formation, the contact being placed at the base of the predominantly argillaceous sequence and the top of the massive dolomites.

The Three Forks formation is conformably overlain by the Lodgepole limestone (lower Mississippian) of the Madison group. Wherever the contact is well exposed, the basal black shale of the Lodgepole, bearing Kinderhook conodonts marks the contact.

Rocks to which the Three Forks formation may be logically applied can be traced throughout the Big Belt and Little Belt Mountains, and northeastward to the Little Rocky Mountains. Only a few feet assignable to the formation are present in the Judith and Big Snowy uplifts, near the eastern margin of Devonian deposition. On the Sweetgrass arch, green shales near the top of the Devonian sequence are almost certainly equivalent to part of the Three Forks, but these shales are closely interbedded with the evaporites and dolomites of the Potlatch anhydrite, so that delineation of the Three Forks is not possible. In northwestern Montana, the original lithologic character of the rocks equivalent to Three Forks has been obscured by brecciation and slumping caused by removal of evaporites, preventing recognition of the Three Forks (or Potlatch) formation in that area. Prominent evaporite-solution breccias in the Three Forks formation of the Big Belt and Little Belt Mountains, and thick anhydrites penetrated in wells drilled adjacent to these uplifts, indicate
a gradual transition between the predominantly clastic facies of the type locality in the Three Forks area and the Potlatch anhydrite facies to the north.

Lithology of the Sediments

The predominant rock type of the dolomite member of the Jefferson formation is a massive, saccharoidal dolomite, usually medium to dark brown in color, but all gradations from light buff to black may be found. It emits a strong fetid odor when struck by a hammer or freshly broken. At the type locality the upper portion of the member is characterized by prominent evaporite-solution breccias interbedded with red dolomitic shale. Similar breccias are present near the top of the member in many localities in the state, and subsurface samples from central Montana show anhydrite and anhydritic dolomite at this horizon.

The limestone member of the Jefferson formation is characterized by gray to dark-brown, very dense limestone and dolomitic limestone. A few beds of saccharoidal dolomite are present in most sections, and yellow-brown, argillaceous and saccharoidal limestone is common near the base. Stromatoporoids are the most frequently observed fossils, but tetracorals and brachiopods have been found by careful search in several localities.

Shenon (8-pp. 47 to 48) describes a relatively local "twiglike" zone at the base of the Jefferson formation in southwestern Montana. These "twiglike" bodies give the rock a peculiarly, distinctive, mottled appearance, and are thought
by Perry (personal communication) to be the remains of bryozoa.

Many lithologies are represented in the Three Forks formation. At its type locality the basal part is composed of dark-brown dolomitic shale and shaly dolomite, the middle part of green plastic shale interbedded with fossiliferous black limestone, and the upper part of yellow-weathering calcareous sandstone. This upper member was named the Sappington sandstone by Berry (1-pp. 14 to 16). It is limited to a small area around Three Forks, and is in sharp contact with the overlying basal Mississippian black shale. In southwestern Montana, within a radius of about 50 miles of Three Forks, the rocks of the Three Forks formation are essentially shaly as described above, but away from this area the shale grades into a gray earthy limestone. Perry (7-p. 5) states that where all strata of the Devonian are limestone and/or dolomite, a division into Three Forks formation and Jefferson formations may be difficult.

Conditions of Deposition

In late Devonian time the land was suppressed with apparent rapidity to allow sea water to impinge upon Montana and northern North Dakota as an arm extending eastward from the Cordilleran geosyncline. Deep sea conditions with clear water free from clastics persisted to allow thick and relatively uniform limestone deposition. Locally the Upper Devonian calcareous sediments were polluted by influxes of mud. The Three Forks formation comprises the resulting shales and
limestone along with a few arenaceous sediments. Further north the Potlatch anhydrite was thought to be deposited as the result of shoaling conditions to the extent of isolation of small embayments wherein thick beds of anhydrite were laid down.

Discussion of the Isopach Map

Two prominent features are disclosed upon examining the isopach map. One is the great thickness of Devonian strata extending along the western borders of Alberta, Montana, and Wyoming. These beds thicken very rapidly to the west, and were deposited in a deepening portion of the Cordilleran geosyncline.

Another feature of the map is the great positive emergent area extending up from the south across northern South Dakota, southern North Dakota, eastern Wyoming and into southeastern Montana.

Petroleum Possibilities

Sloss and Laird (11) in their recent study of the Devonian of central and northwestern Montana report that potential reservoir rocks appear to be confined to the dolomite member of the Jefferson formation; no true sandstone reservoirs being known. The member is abundantly petrolierous, and its saccharoidal dolomites have an intercrystalline porosity which is capable of development into appreciable porosity and permeability under proper conditions. Study of outcrop samples from wells which penetrate the member reveals that
in most cases the intercrystalline voids are occupied by either anhydrite or by solid hydrocarbons which do not yield to ordinary organic solvents.

The most promising area that has been noted is in the Big Snowy Mountains, near the southeast margin of Devonian deposition. Here the upper part of the dolomite member of the Jefferson includes highly porous and permeable masses of coralline debris, approaching reef facies, in zones and lenses up to 10 feet thick. Here, also, the saccharoidal dolomites are conspicuously lacking in interstitial hydrocarbon, suggesting the possibility that if the hydrocarbon were deposited as an original constituent of the sediment as in other areas, conditions were such as to permit migration. Nothing is known of Devonian sediments east of the Big Snowy Mountains, except that they pinch out, before reaching the Mosby dome.

Small showings of oil and gas in the dolomite member of the Jefferson formation have been reported in several localities in Montana. In the Kevin-Sunburst field (Texas-Pacific Rice No. 1) about one barrel per day of amber colored oil was reported at about 880 feet below the top of the Devonian; and also large volumes of carbon dioxide, hydrogen sulphide and combustible gas were encountered in this and other wells in Devonian strata, according to Perry (7-p. 5).

North of Montana in Canada oil in commercial quantities has been produced from Devonian strata in several widely separated areas. These Canadian occurrences are in part responsible for the recent interest in testing Devonian strata in Montana.
Summary

Within the region studied, Devonian sediments were deposited in southern Canada, northern North Dakota, all of Montana but the southeastern corner, northwestern Wyoming and southern Idaho. They were laid down by a sea extending easterly from the Cordilleran geosyncline in Upper Devonian time. The rocks are essentially limestone and dolomites overlain by a shale phase in southwestern Montana which grades into an anhydrite facies further north. The isopach map demonstrates the apparent geosynclinal facies in the west as indicated by the rapid thickening of sediments in western Montana and Idaho. The thickness affects cost in drilling, and a knowledge of thickness aids greatly in correlation of underlying strata. Another noteworthy feature is the great positive emergent area in the southeastern portion of the map.

Potential oil reservoir rocks appear to be confined to the dolomite member of the Jefferson formation from which showings of oil and gas have been reported in several localities. Attention has been called to a promising area in central Montana where this member includes lenses of highly porous and permeable coralline debris approaching reef facies. This is especially significant in view of the fact that considerable oil production in Canada has been from coral reef facies in the Jefferson formation.
DESCRIPTION OF DIAGNOSTIC POINTS ON ISOPACH MAPS

Although information on thickness of strata in many localities is obtainable, that for certain localities is more authentic or more accurate than others. Also information on certain parts of the maps is more diagnostic than on other parts. The following list contains descriptions of those points on the map which the writer feels are particularly important.

<table>
<thead>
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<th>No. on Maps</th>
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</tr>
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<td>1.</td>
<td>Flathead Range, Spotted Bear Mtn.</td>
<td>26-25N-13W Flathead</td>
<td>---</td>
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<td>24--2N--2E Gallatin</td>
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<td>Big Belt Mtns., Beaver Creek</td>
<td>32-13N--1W Lewis and Clark</td>
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<td>Little Belt Mtns., Newlon Creek</td>
<td>15-10N--6E Meagher</td>
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</tr>
<tr>
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<td>----------------</td>
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</tr>
<tr>
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<td>Little Belt Mtns., Yogo Creek</td>
<td>1-13N-10E</td>
<td>Judith Basin</td>
<td>400</td>
</tr>
<tr>
<td>14.</td>
<td>Little Rocky Mtns., Tin Cup and Lodgepole Creeks</td>
<td>10-25N-24E</td>
<td>Phillips</td>
<td>158 590</td>
</tr>
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</tr>
<tr>
<td>15.</td>
<td>Argenta District, Vicinity of Ermont Mine</td>
<td>35-6S-11E</td>
<td>Beaverhead</td>
<td>1486</td>
</tr>
<tr>
<td>16.</td>
<td>Rochester District, Camp Creek</td>
<td></td>
<td>Madison</td>
<td>1150</td>
</tr>
<tr>
<td>17.</td>
<td>Phillipsburg Quadrangle, South Boulder Creek</td>
<td></td>
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</tr>
<tr>
<td>18.</td>
<td>Elkhorn Mining District</td>
<td>6N-3W</td>
<td>Jefferson</td>
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<td>60</td>
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<tr>
<td>21.</td>
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<td>9S-14E</td>
<td>Park</td>
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<td>9-9N-4W</td>
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<td>Meagher</td>
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<td>Yellowstone Park, Antler Peak</td>
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<td>Teton Mtns., Survey Peak</td>
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<td>Cinnabar Mtn.</td>
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<td>Judith Mtns.</td>
<td>16N-19E</td>
<td>Fergus</td>
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<td>Pryor Mtns.</td>
<td>6S-25E</td>
<td>Big Horn</td>
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<td>Section, Township and Range</td>
<td>County</td>
<td>Thickness Ord. Dev.</td>
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<td>Wheatland</td>
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<td>19--4N-62E</td>
<td>Fallon</td>
<td>1590 ----</td>
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<td>36.</td>
<td>California Co., No. 1 Kamp</td>
<td>3-154N-96W</td>
<td>Williams (N. D.)</td>
<td>--- 656†</td>
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<td>State Royalty Petroleum Co., No. 1 State</td>
<td>35-18N--1E</td>
<td>Harding (S. D.)</td>
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</table>
BIBLIOGRAPHY

The bibliography contains the more important references from which material has been drawn. Thickness of sections for the isopach maps have been taken from many sources other than those listed.

9. Shenon, P.J., Geology and ore deposits of Bannock and


ISOPACH MAP OF ORDOVICIAN IN MONTANA AND ADJACENT AREAS

MONTANA SCHOOL OF MINES

1947

SCALE IN MILES

EXPLANATION

X Surface Section

Well Log Data

B.C.

ALBERTA

SASKATCHEWAN

N. DAK.

S. DAK.

WYOMING

MONTANA

GREAT FALLS

LENSTOWN

MISSOULA

HELENA

BUTTE

DILLON

WYOMING

GREAT FALLS

LENSTOWN

MISSOULA

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