NORTH DAKOTA GEOLOGICAL SURVEY

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Mississippian Stratigraphic Studies

Bottineau County, North Dakota

by

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ABSTRACT

This report provides a study of the Mississippian Madison group in Bottineau County, North Dakota, as shown by wells drilled for oil and gas. The names and definitions, occurrence, lithology, thickness, and correlations of the Mississippian formations are given. Three electric and lithologic log cross sections and four maps are included.

ACKNOWLEDGEMENTS

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INTRODUCTION

GENERAL STATEMENT

Oil was first discovered in the Bottineau area on January 1 of 1953 in the Ward-Williston (Zach-Brooks) Berentson #1 Well, SW SE Sec. 21-163-80. Since then there have been a number of discoveries in the area, with oil now being produced from seven pools in Bottineau County and one in Renville County. The gravity of the oil produced in the area ranges from 31.2° at the Sohio Ritter well, SE NE Sec. 23-163-86, to 38° API at the Frazier-Conroy Ekrehaugen #1 well, NE SE Sec. 9-163-78, with an average gravity of 36° API.

LOCATION

The Bottineau area is located in the extreme north-central part of North Dakota, with the International Boundary forming the northern border. The area includes Townships 162, 163, and partial Township 164, Ranges 77, 78, 79, and 80 in Bottineau County. Information from the adjoining tier of townships in Manitoba has also been included in this investigaton.

The area is typical of the North Dakota prairies, with the surface consisting largely of ground moraine and glacial lake beds. Recessional moraine and associated deposits are found in the Turtle Mountains in the northeastern corner of Bottineau County. The mountains have a topographic relief of several hundred feet and stand sharply above the surrounding ground moraine plain. The bedrock of the Turtle Mountains is an erosional remnant of the Fort Union strata exposed in the Coteau du Missouri to the west. Most of the general area under consideration lies within the Souris Lake plain and the Drift prairie as shown by Roth and Zimmerman (1955).

PURPOSE OF THE REPORT

The purpose of this report is to provide stratigraphic data that will stimulate further exploration on the "East Side" of the Williston Basin. All of the oil that is being produced in Bottineau County at the present time is coming from the Mississippian Mission Canyon and Charles formations, with the exception of the Amerada Petroleum Corporation Beauchamp #1, SE SW 21-161-79, which is producing from the Triassic Spearfish formation. During the past year, three discoveries have been made in the Bottineau area. These are the Monsanto Chemical Company Skarphol #1, SE NW 33-164-77, which opened the North Souris pool and the Amerada Beauchamp #1, which opened the Newberg pool in Bottineau County and the Sohio Petroleum Corporation Ritter #1, SE NE 23-163-86, which was the discovery well in the Bluell field in neighboring Renville County.

METHOD OF STUDY

The logs on the cross sections show the general lithology and textures. Porosity is indicated on two of the cross sections (Fig. 2 and 3) by a set of numbers known as porosity numbers. Colors are indicated on the third cross section (Fig. 1). Color was determined by use of the 1948 Rock Color Chart distributed by the National Research Council.

Textural forms used are oolitic, fragmental, sugary and crystalline; these terms are indicated by appropriate symbols on the cross sections. Spherical to subspherical grains are termed oolitic without regard to internal structure. It is conceivable that some oolites may be algal in origin. Aggregates of rock or fossil fragments are termed fragmental. Non-interlocking aggregate crystals or angular fragments are termed sugary if no rounded grains or obvious rock or fossil fragments are found. Interlocking crystals usually having little or no intergranular porosity are termed crystalline.

Dilute 7:1 hydrochloric acid was used in determining limestone, dolomite or approximate combinations of the two. Oil production and oil shows are indicated by appropriate symbols.

Electric and radioactive logs were used to facilitate correlation.

The porosity numbers, one through six, were arbitrarily selected to indicate a relative percent of porosity in sample cuttings and cores. The amount of porosity increases with increase in number. The porosity numbers do not indicate the exact percent of porosity such as could be determined from porosity meters in a laboratory.

These numbers were determined by microscopic examination of sample cuttings and cores by one individual in order that a consistency of some degree could be maintained. Samples of ten foot intervals were studied and a porosity number, which best indicated the average porosity, was given for each interval.

The porosity map (Fig. 7) was prepared by adding the porosity numbers of each ten foot interval from the unconformity at the base of the Spearfish to a depth of 100 feet below the unconformity. The total of the porosity numbers for each well for the 100 foot interval noted above was plotted on the map and contours were drawn to indicate relative porosity zones.

The datum used for the Mission Canyon anhydrite structure map (Fig.5) is at the top of the anhydrite zone that occurs near the center of the Mission Canyon formation. This marker was chosem because it is consistent over the whole region. The datum occurs in the Mississippian section far enough below the pre-Triassic unconformity so that post-Mississippian erosion in this area could have had little, if any, effect on it.

STRATIGRAPHY

GENERAL DISCUSSION OF STRATIGRAPHY

The thickness of the stratigraphic section in the Bottineau area is governed mainly by regional thinning. The Mississippian Charles formation has been thinned by erosion, with the Mission Canyon having been thinned by erosion where the Charles has been removed.

This report deals primarily with the Mississippian system; however, there are a number of other good possibilities for the production of oil. They are notably the Ordovician Winnipeg sandstone and Red River formations, the Silurian Stonewall formation, the Devonian Winnipegosis, Duperow and Nisku formations.

ENGLEWOOD FORMATION

Name and Definition

The Englewood limestone was first described by N. H. Darton (1901).

In the Black Hills, Butler et al (1955) describe the Englewood as consisting of variecolored shales with intercalated beds of reddish brown limestone and buff colored dolomite underlying the Pahasapa limestone.

The Englewood equivalent has been termed the Bakken in North Dakota by the North Dakota Geological Society (1954) because of the excellent samples obtained in the Amerada H. O. Bakken #1 Well, SW NW 12-157-95, in the Tioga pool. In the opinion of the writers the Englewood in North Dakota correlates reasonably close to the Englewood of the type area. For this reason there is no apparent need now to introduce a new term, unless further study so demonstrates.

Occurrence and Lithologic Character

In most of Bottineau County as in the Amerada Bakken well, the Englewood consists of two dark gray to black, thin bedded, hard, carbonaceous shales, separated by any one of the following: a light gray siltstone, a very fine grained sandstone, or a thin limestone. A sandstone at the base of the formation known only in the Sanish area at the present is locally called the "Sanish sand." McCabe (1954) included the "Sanish sand" in the "Bakken" (herein called Englewood) and the authors agree with McCabe's interpretation. The formation unconformably overlies the Devonian Lyleton (McCabe 1954) and is overlain conformably by the Mississippian Lodgepole in North Dakota. However, in Montana on the Cedar Creek Anticline the Lodgepole is unconformable on the Bakken (N. Dak. Geol. Soc. 1954).

MADISON GROUP

The Madison group consists of three formations which are in ascending order, the Lodgepole, Mission Canyon, and Charles, all of which are present in the Bottineau area. The two upper formations produce oil in this area.

LODGEPOLE FORMATION

Name and Definition

The Lodgepole formation is the lower unit of the Madison group, which was first described by A. C. Peale (1893). A. J. Collier and S. H. Cathcart (1922) named the formation for exposures in Lodgepole Canyon in the Little Rocky Mountains of Eastern Montana, where, according to Collier and Cathcart, the Lodgepole consists of fossiliferous thin-bedded limestone and shales, having a thickness of 800 feet. Sloss and Hamblin (1942) state that the type section of the Madison group is near the town of Logan, on the Gallatin River, Gallatin County, Montana, Holland (1952) agrees with Sloss and Hamblin in this and states that the Lodgepole there has a thickness of 584 feet.

Occurrence and Lithologic Character

In the Bottineau area as in most of the North Dakota portion of the Williston Basin, the Lodgepole rests conformably on the Mississippian Englewood and is conformably overlain by the Mississippian Mission Canyon.

The Lodgepole in the Bottineau area has a thickness of approximately 600 feet and is composed of fragmental and fine-to-medium-grained granular limestone, and a little fine-grained dense limestone. The lower part of the formation is often argillaceous, in which case the argillaceous section generally occurs above a thin, basal cherty zone.

However, in a few wells a shaly section may occur immediately above the Englewood. The Englewood may then appear to be thicker than it actually is. The shaly Lodgepole is lighter in color and less radioactive than the Englewood.

The color varies from very light gray to medium gray to pale red and pale orange with an occasional small section of light olive gray or white. The section in the western part of the area ranges from very light gray to medium gray while the upper part of the section becomes increasingly pale reddish to pale orange toward the eastern part of the area.

The fragmental zones of the Lodgepole can be easily confused with the Mission Canyon in the extreme eastern part of the Bottineau area and the "East side" of the basin in general, where the Mission Canyon has been thinned or removed by erosion. Both formations have some color similarities on the "East side" as they may both be pale red or pale orange in color, however, they can be correlated quite readily on electric and radioactivity logs.

There is no production from the Lodgepole in the Bottineau area. However, the Lodgepole produces from a crinoidal zone northeast of Bottineau in the Lulu Lake and Virden areas of Manitoba.

MISSION CANYON FORMATION

Name and Definition

The Mission Canyon is the upper unit of the Madison limestone as it was first described by A. C. Peale (1893). The formation was named by Collier and Cathcart (1922) for exposures of 500 feet of massive white marine limestone in Mission Canyon in the Little Rocky Mountains.

Occurrence and Lithologic Character

In the western part of the area covered by this report the Mission Canyon conformably overlies the Mississippian Lodgepole and is conformably overlain by the Mississippian Charles. However, in the north-central and eastern parts of the area erosion has removed the Charles and the Mission Canyon is unconformably overlain by the Triassic Spearfish.

In the Bottineau area the Mission Canyon is approximately 280 feet thick and consists largely of oolitic and fragmental limestone with some granular and fine crystalline dense limestone. In the approximate center of the formation is a zone of anhydrite 20 to 30 feet thick. This zone provides an excellent marker on electric and radioactivity logs. However, when a well is drilled only into the top of the Mission Canyon, it is sometimes difficult to determine whether the anhydrite zone is part of the Charles, which has been greatly thinned, or the Mission Canyon Middle anhydrite, with the Charles and Upper Mission Canyon having been removed by erosion.

The color of the formation varies greatly in the area, ranging from white to yellow gray to yellow brown, and pale orange to pale red. The anhydrite zone is predominately light gray, varying to white and pale red in color.

In this report the Mission Canyon has been divided into three units, which are the Upper Mission Canyon, the Middle anhydrite zone and the Lower Mission Canyon. This division was made in order to show better the effects of erosion and structure on the Mission Canyon. Where the Charles has been eroded, the upper unit of the Mission Canyon has been thinned eastward by erosion. On the extreme eastern edge of the area and on the structure on which the Lion Oil Co. Erickson #1, NW NE 32-164-78, was drilled the upper zone has been completely removed. This erosion has produced some interesting pinch-outs, some of which are shown on cross section A-A′ (Fig. 1). Lion Oil Co's. (Monsanto Chemical Corp.) North Souris field appears to be producing from the Lower Mission Canyon, while the upper unit of the Mission Canyon produces oil in the N. E. Landa pool.

CHARLES FORMATION

Name and Definition

The Charles formation was first named by O. A. Seager (1942) from the Arro Oil and California Company's Charles #4 well, SE NW Sec. 21-15N-30E, Garfield County, Montana, where he described it as a sequence of limestone, anhydrite, brown to red shales and siltstones, and dolomite lying between the Kibbey and Mission Canyon limestone. Seager placed the Charles formation in the Big Snowy group, but he did not designate the interval. Nordquist (1953), however, placed the interval between the Kibbey limestone and the Mission Canyon, being from 3,195 to 3,800 feet in the type well. Also in the Report of Investigation No. 16 (Anderson, 1954) of the North Dakota Geological Survey, the Charles formation is placed in the Madison group. More recent studies suggest that the contact between the Charles and Mission Canyon is transitional.

Occurrence and Lithologic Character

In the Bottineau area the Charles consists mainly of a massive, bluish white, light gray, and pale red anhydrite, up to 260 feet thick. Some thin interbedded layers of dense, fine grained dolomite and limestone occur.

The lithology of the Charles formation exhibits a marked change from the Bottineau area westward to the Tioga area. In the Bottineau area the formation is composed predominately of anhydrite; in Renville County and eastern Burke County it contains a larger percentage of limestone, some of which is oolitic and fragmental, while in the Tioga area it is composed largely of salt and anhydrite with some limestone. Two new discoveries have been made during the past year in the limestone facies of the Charles, the Sohio-Ritter, SE NE 23-163-86, opening the Bluell field in Renville County and the Hunt Oil-Opseth, NE NW 28-161-90, which opened the Coteau field in Burke County.

The Charles lies conformably on the Mission Canyon and is overlain unconformably by the Triassic "Spearfish" formation. In the Bottineau area oil has been found near the pinchout of the Charles porosity zones, notably in the Westhope and North Westhope fields.

"SPEARFISH" FORMATION

Name and Definition

N. H. Darton first described and named the Spearfish formation in 1899 from exposures near Spearfish, South Dakota. The formation was placed in the Triassic System. Darton (1901) described the formation as consisting of from 350 to 500 feet of red sandy clays, with intercalated beds of gypsum which sometimes are 30 feet thick. Darton, however, included in the Spearfish formation (Imlay 1947) the "gypsiferous facies" of what was later termed the Jurassic Gypsum Springs formation.

As yet no faunal evidence has been found that will prove the age of the Spearfish. It may be Triassic or Jurassic or it may possibly even be upper Paleozoic in age.

Zeiglar (1955) divided the "Spearfish" in North Dakota into four units. They are in ascending order the Spearfish formation, Pine Salt, Saude formation, and Dunham salt. Beds referred to herein as Spearfish are equivalent to the Saude formation of Zeiglar.

Occurrence and Lithologic Character

The "Spearfish" formation is present in all of the Bottineau area. Jurassic Piper unconformably overlies the "Spearfish" and the "Spearfish" unconformably overlies the Mississippian Charles formation or Mission Canyon formation where the Charles has been eroded.

The "Spearfish" formation of the Bottineau area is a pale red to moderate reddish orange, sandy, anhydritic siltstone, ranging in thickness from 230 feet in the extreme southwestern parts of the area to 110 feet in the north central and extreme northeastern part of the area. At and near the contact of the formation with the basal unconformity, numerous quartz sand grains ranging up to medium size occur.

Good oil shows have been found in sample cuttings and cores. Cores from the "Spearfish" section of the Ward-Williston (Zach Brooks) Berentson #1 well, SW SE Sec. 21-163-80, were saturated with oil; however, the porosity and permeability needed to make a producing well were lacking. A recent discovery this past year, the Amerada Petroleum Corporation-Beauchamp #1 well, SE SW 21-161-79, opening the Newburg field, was completed in the "Spearfish" formation with an initial production of 73 BOPD which has since declined to a current production of 6 or 7 BOPD.

CROSS SECTIONS

Figure 1 is an east-west cross section (A-A′) in Bottineau County extending from the North Westhope field through the Northeast Landa and the North Souris fields to the Lion Oil Co. Magnusson #1 well, SW SE Sec. 2-163-77. This line of cross-sections was selected to show the structural relationships between the fields in Bottineau County. The wells selected for this cross-section include mainly the deeper tests.

The Lion Oil Co. Erickson #1 well, NW NE Sec. 32-164-78, is structurally higher than the wells on either side. The Upper Mission Canyon pinches out to the west of the Lion Erickson well. Pinch outs such as these, especially the pinch outs up dip, could provide excellent reservoirs for the entrapment of oil.

Since this cross section was completed Monsanto Chemical Corporation has completed a dry hole between the Calvert Exploration Co. Kornkven #1, NW SE Sec. 32-164-77, and the Lion Oil Co. Magnusson #1. The well is 143 feet higher structurally on the Lodgepole top than the Calvert Kornkven #1 and 58 feet higher than the Lion Magnusson. On this cross section little or no evidence is apparent that a structure exists between the two wells, a distance of only three miles. The data indicate that close control is needed to locate structures in the Bottineau area. These structures may possibly be due to basement faulting or draping over buried topographic "highs" but further drilling must be done in the Bottineau area before this can be determined.

Cross section B-B′ (Fig. 2) trends northeast and southwest. Because this cross section is perpendicular to the original strike of the beds, a true picture of the thinning of the beds toward the edge of the basin is shown. The combined distance between the first four wells (4.4 mi.) is .1 of a mile less than the distance between the last two wells. Consequently, the cross section gives an impression of rapid thinning and possible structure. It is interesting to note that most of the thinning is limited to the Charles formation, while the Mission Canyon zones retain approximately the same thickness.

Cross section C-A′ (Fig.3) is a northeast-southwest-trending cross section from the National Associated Pet. Corp. Sarah Newhouse #1 well, NE SE 3-162-79, to the Lion Magnusson #1 well, SW SE 2-163-77. This cross section shows the Charles formation pinching out between the Hunt Oil Co.-Olson #1 well, SW NW 18-163-77, and the Lion-Magnusson #1. Since this cross section was made, the Cardinal Skarphol #1 well, NW NW 10-163-78, has been completed as an offset to the Frazier-Conroy Ekrehaugen #1 well, NE SE 9-163-78, and was drilled into the Lodgepole formation. In this well the anhydrite just below the unconformity appears to be a part of the Upper Mission Canyon. If this is correct then the anhydrite in the Hunt Olson well is also Upper Mission Canyon and not Charles as shown on the cross section. This suggests that a facies change occurs in the Upper Mission Canyon. To the west where limestone occurs in the top portion of the Upper Mission Canyon the limestone is porous and oolitic. With the limestone changing to an anhydritic facies, there is the possibility that oil may accumulate in a stratigraphic trap somewhere near the line of facies change.

Moving west from the North Westhope field some of the Charles anhydrites appear to change to an oolitic limestone facies. The Sohio Ritter in Renville County was completed in a very porous and oolitic limestone, which may have formed a stratigraphic trap between the porous oolitic limestone and the anhydrite. However, Walter Johnson, division geologist for the Sohio Oil Co., stated at the hearing of case 81 (N. Dak. Industrial Comm. 1955) before the North Dakota State Industrial Commission that structure may play some part in this accumulation.

MAPS

Four maps have been prepared for this study, they are: (1) an isopach map of the Spearfish formation (Fig. 4), (2) a structure map on the Mission Canyon anhydrite (Fig. 5), (3) a contour map on the Paleozoic erosional surface (Fig. 6) and (4) a porosity map (Fig. 7).

The structure map, Figure 5, shows contours on the middle anhydrite zone of the Mission Canyon formation. The contours reflect little structural relief. Since it is evident that structure shows only in areas of close control, it should be noted that the structure of the area is undoubtedly a good deal more complex than is indicated on Figure 5. There are two northeast-southwest trending noses on the regional dip and one high area consisting of a single closed contour. It is probable that a structural high exists in the areas enclosed by the dashed contour line, but more control is necessary to establish this possibility.

Two small high areas on the map of the Paleozoic erosion surface (Figure 6, Sec. 36, T. 164N., R. 79W. and Sec. 31, T. 164N., R. 78W.) in the Northeast Landa Field reflect the minor relief of the structure map (Fig. 5). There is little on the map of the erosion surface (Fig. 6) to reflect the minor relief shown in and near Sec. 30, T. 163N., R. 78W. on the structure map (Fig. 5). Comparison of Figures 5 and 6 indicates that the ridge and the corresponding trough in T. 163N., R. 78W of the erosion surface map are apparently not structurally controlled.

The Spearfish isopach map, Figure 4, shows a constant northeastward rate of thinning in the southwestern part of the area. The rate of thinning changes abruptly to the east forming a broad shelf with thinning clearly shown in the area marked by minor relief on the structure map and higher elevations on the map of the erosion surface. As would be expected, the Spearfish thickens over the trough on the erosion surface map (Figures 4 and 6, T. 163N., R. 78W).

On the porosity map, Figure 7, the lines of higher porosity occur in and near the Northeast Landa field and within the eastern limits of the map where the North Souris field is located. These areas of high relative porosity have a greater percentage of oolitic limestone per 100 feet. Areas of low porosity have larger percentages of fragmental and sublithographic limestone. A fragmental to oolitic ratio map, which was prepared during the course of the study, but is not published with this report, calls attention to this fact.

The porosity seems to form a definite pattern in that both the Northeast Landa field and the North Souris field lie in the areas of highest porosity. This could mean that porosity may play a larger part in the accumulation of oil in the area than structure does.

From the evidence cited so far, it is apparent that factors other than structure have had something to do with oil accumulations in the Bottineau area.

With the exception of the Amerada Beauchamp #1 which produces oil from the Spearfish all the production from the Bottineau area is Mission Canyon or Charles and comes from below one of several anhydrite zones which may have sealed the production zones.

Evidence of anhydrite zones sealing accumulations of oil has been presented by Johnson (1956) who cites three ways in which anhydrite seals oil reservoirs in the northeastern Williston Basin. Secondary anhydrite along the unconformity at the top of the Madison is mentioned by Johnson as one of the ways in which anhydrite seals reservoirs. Anhydrite sealing at the same unconformity in the Alida-Nottingham area of Saskatchewan has been studied by Lill (1956).

An example of this type of seal is found in the Zach Brooks Drilling Co. Edwin Berentson #1. In the cross-section B-B' Figure 2 on the section of the Berentson well, production is shown from a depth of about 3345 feet, immediately below an anhydritic zone at the top of the unconformity.

In comparing the erosion surface map and the structure map with the porosity map Figure 7, which shows production in well 247 (Sec. 9, T. 163N, R. 78W) it is apparent that this well produces oil from a zone that is high on the old erosion surface but relatively low structurally. It seems reasonable to assume that this condition may well exist elsewhere in the area, and that other accumulations will be found associated with highs on the surface of the unconformity which have little or nothing to do with the structure.

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Figure 1

Cross Section A—A'

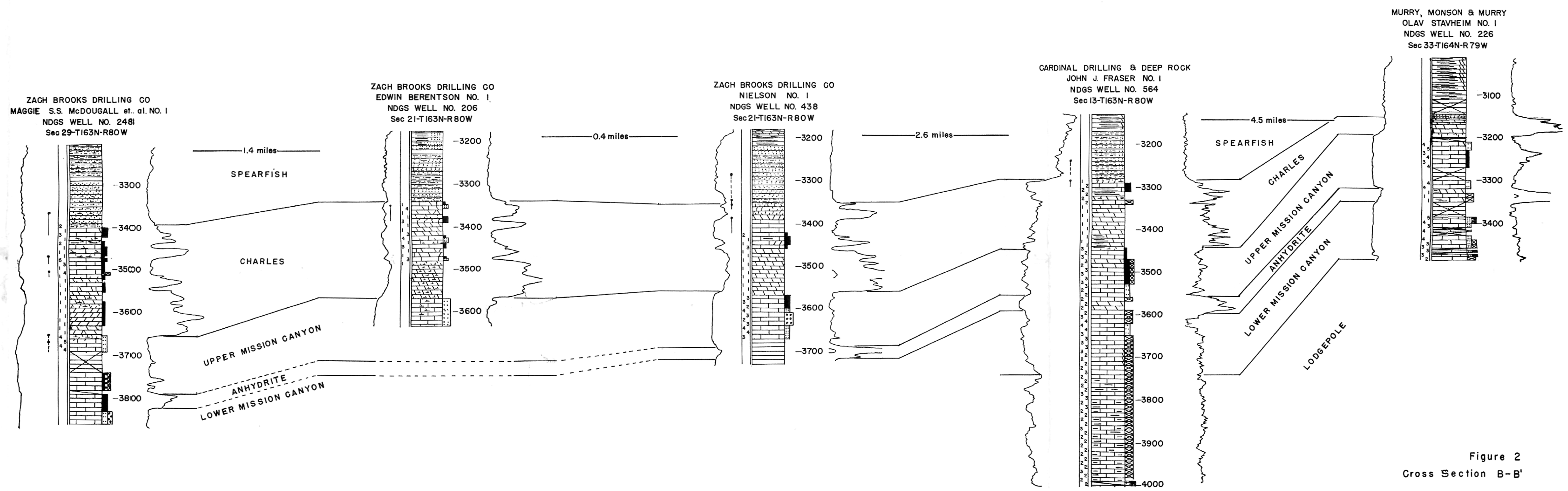


Figure 2

Cross Section B-B'

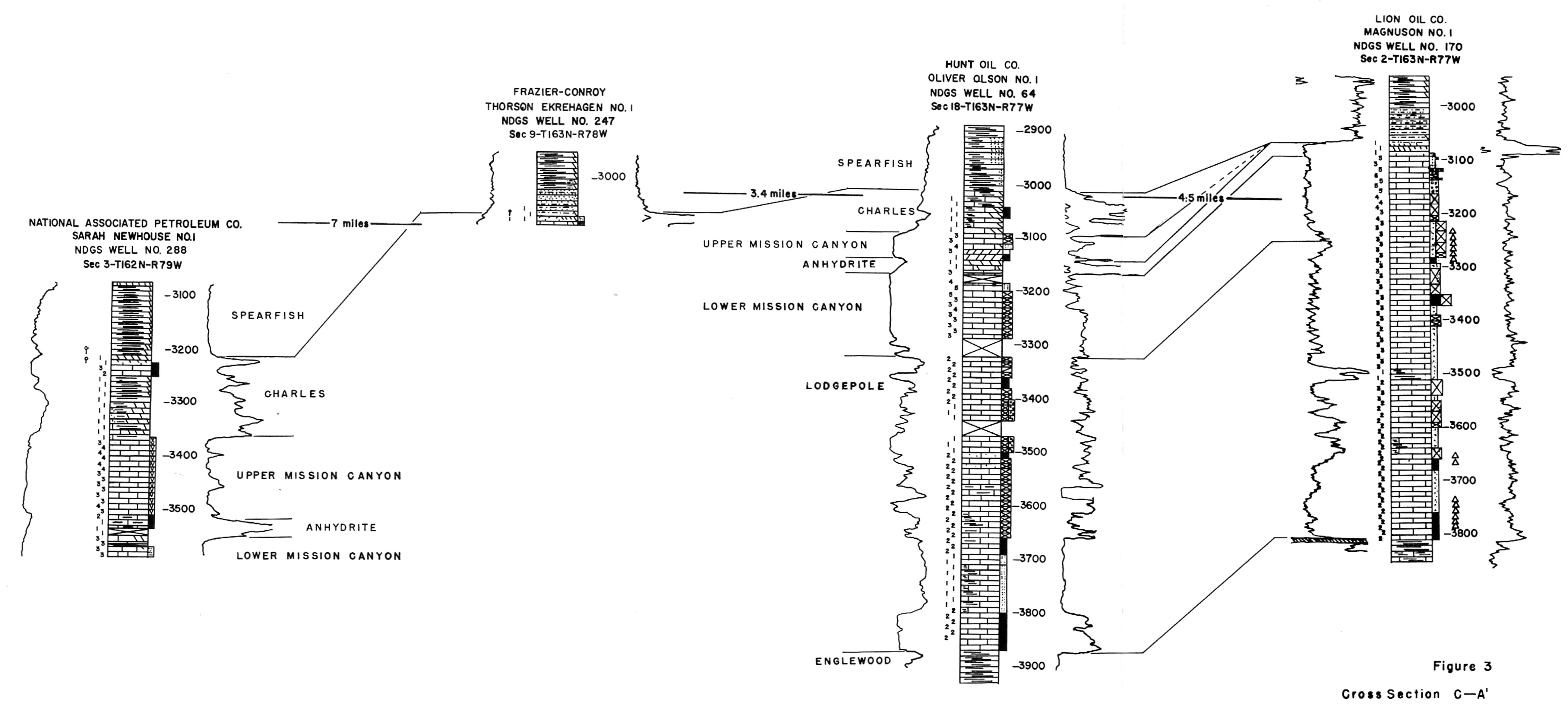
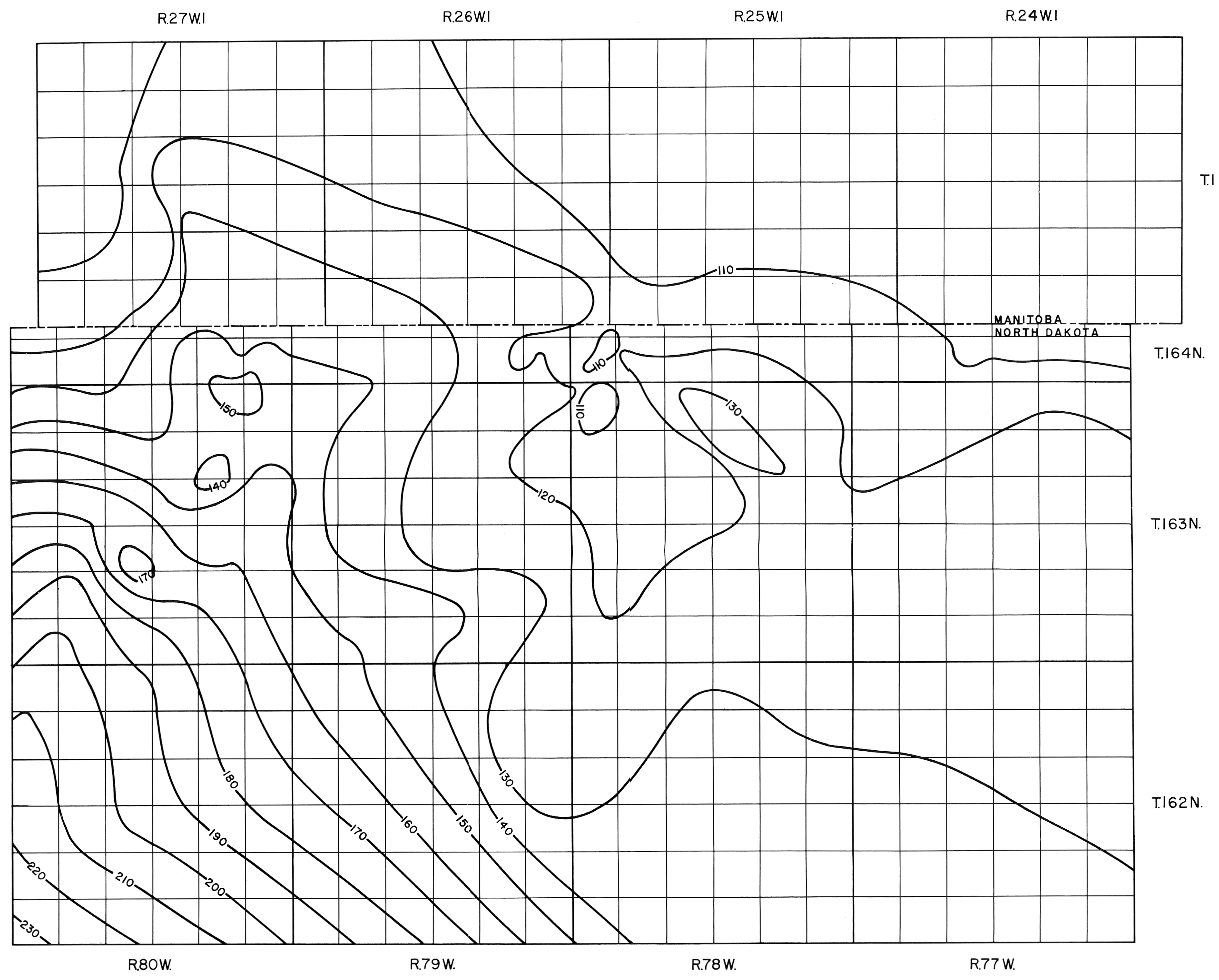


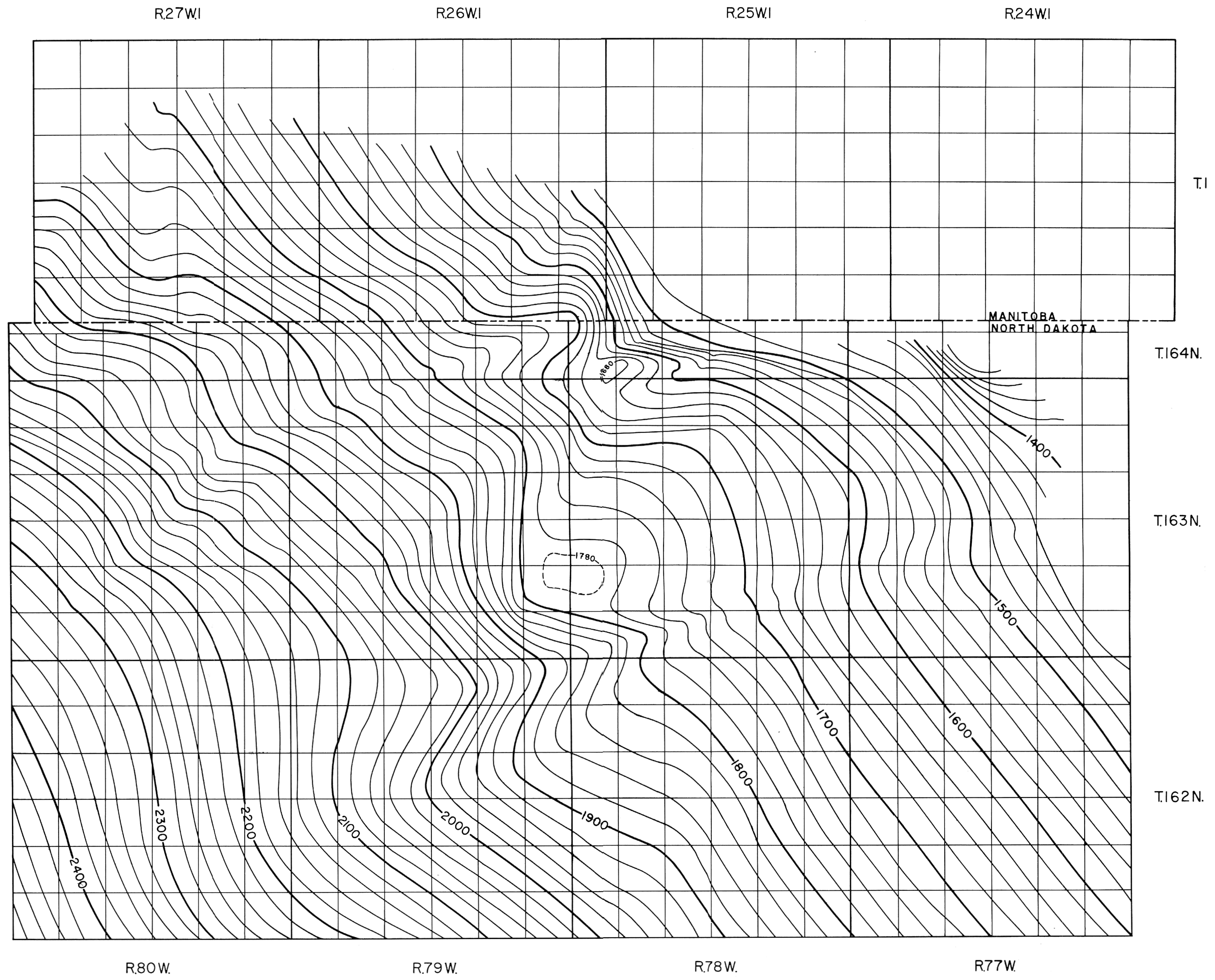
Figure 3

Cross Section C—A'



ISOPACH MAP
SPEARFISH FORMATION
CONTOUR INTERVAL 10 FEET

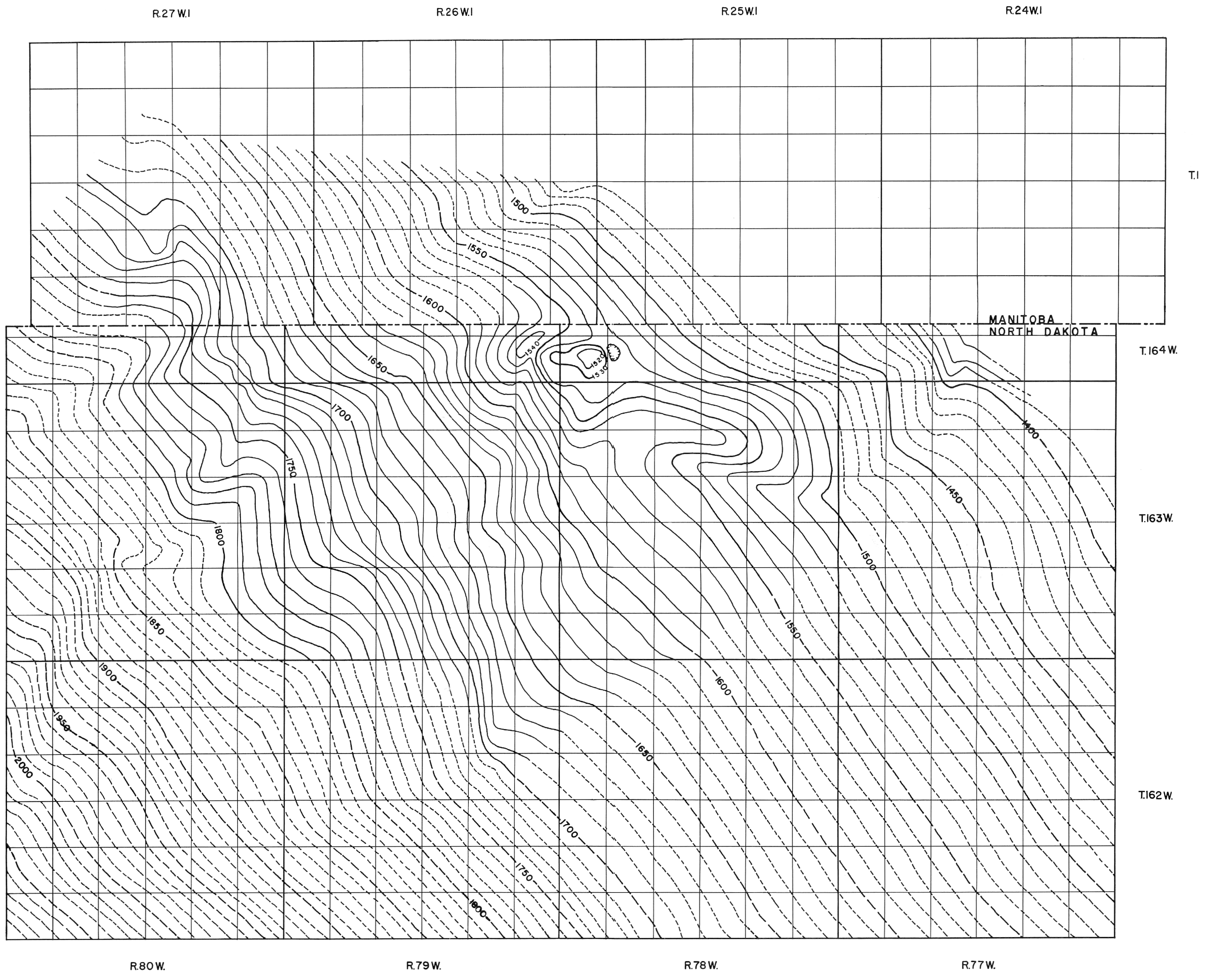
Figure 4



STRUCTURE CONTOUR MAP
MISSION CANYON FORMATION
TOP OF MIDDLE ANHYDRITE
CONTOUR INTERVAL 20 FEET

Elevations are below sea level

Figure 5

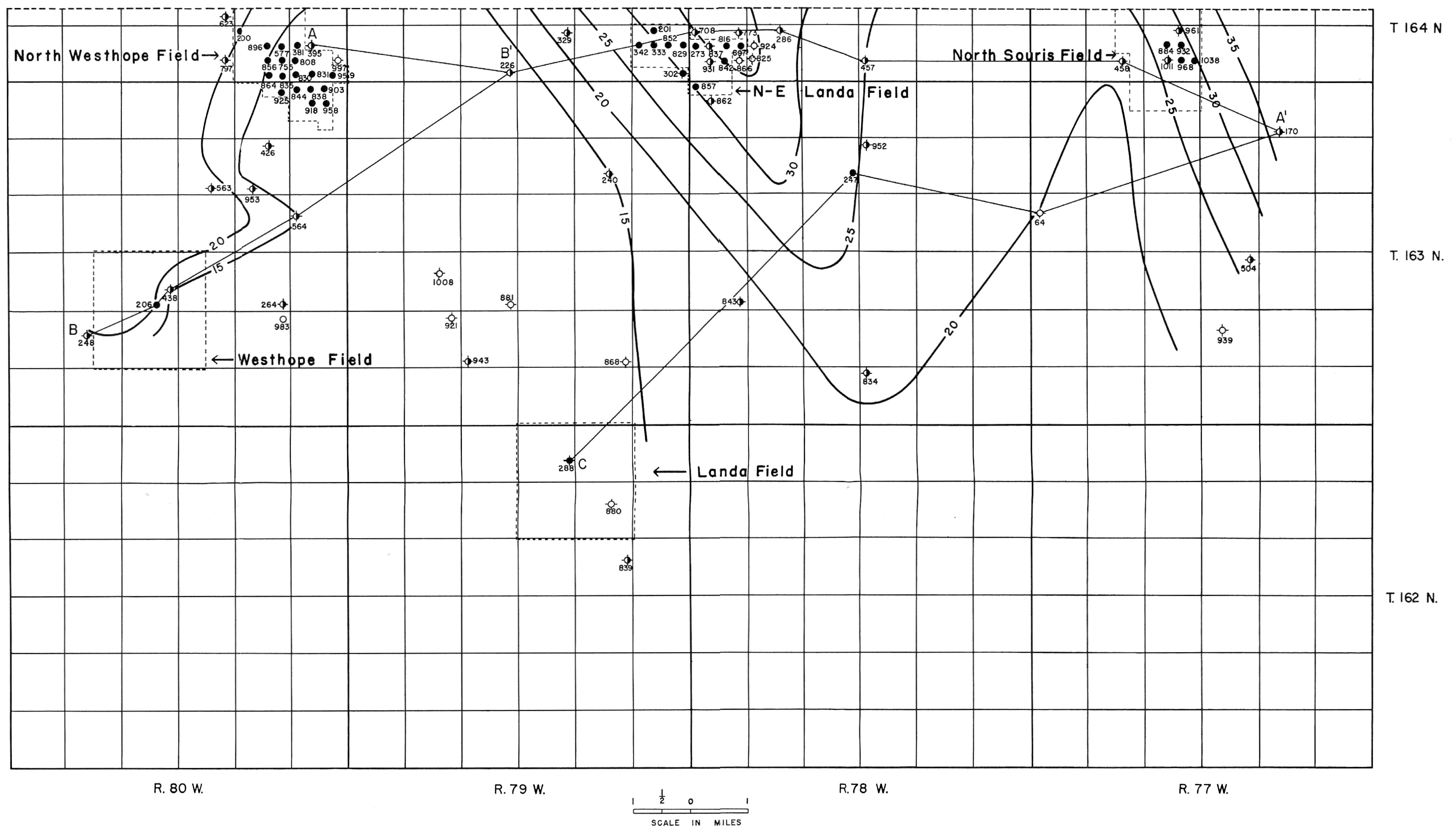


CONTOURS ON PALEOZOIC EROSIONAL SURFACE

Elevations are below sea level

CONTOUR INTERVAL 10 FEET

Figure 6



POROSITY MAP OF 100 FOOT INTERVAL BELOW POST MISSISSIPPIAN UNCONFORMITY

Contour Interval 5 Isopors — Higher numbers indicate better porosity

Figure 7