NORTH DAKOTA GEOLOGICAL SURVEY

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Geomagnetic Survey of Part of the East Edge of Williston Basin

By

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Introduction

This survey was made with the hope of showing the regional subsurface features of part of the eastern edge of the Williston Basin in North Dakota. There seem to be some definite trends occuring, but at the present time so little precise geologic information concerning the Pre-Cambrian is available on the eastern edge of the Basin that interpretation is difficult. Parts of Pierce, Benson, Wells and Sheridan counties were surveyed.

The field work was begun June 13, 1952 and continued through September 18, 1952. Two vertical intensity magnetometers were used. The first half of the survey was done with a much less sensitive instrument than the second half. The base station was located at Rugby.

This survey continues southward the magnetometer work done by N. N. Kohanowski during the summer of 1951 and published as Report of Investigation No. 6. During the past summer Miller Hansen, Geologist, North Dakota Geological Survey, investigated the adjoining area to the east of the area covered in this report. This report has been published as North Dakota Geological Survey Report of Investigation No. 9.

Instruments Used

During the course of the survey, two Schmidt type vertical intensity magnetometers were used. The first half of the survey (Townships 156 through 151 North, Ranges 69 through 74 West) was done with a Sprengnether instrument, serial number 1063. The remaining area (Townships 150 through 145 North, Ranges 69 through 74 West) was surveyed with an Askania instrument, serial number 92956.

Field Procedure

Rugby was chosen as the base station. The actual station was located a mile east of town so that extraneous magnetic forces would be at a minimum. The magnetic intensity of this station was determined from a station of known magnetic intensity near Leeds. Two round trips between Leeds and Rugby were made, using a Gulf Research magnetometer. Diurnal variations were plotted and corrected for each trip. The resulting readings were averaged.

The latitude adjustment of the Sprengnether instrument was set for the latitude of Rugby and the sensitivity screw adjusted, and the sensitivity was then determined with a Helmholtz coil. The sensitivity was found to be 321.4 gammas per scale division. After considerable use the instrument was taken apart and cleaned and the sensitivity again determined. This time it was found to be 326.4 gammas per scale division. This instrument was not equipped with a thermometer so no temperature corrections were made. This factor is bound to introduce some error.

After half the area was surveyed an Askania instrument was made available, and this was set for the latitude of Maddock. The sensitivity was found to be 35.6 gammas per scale division. The temperature coefficient of this instrument was 0.055 scale division per degree Centigrade. The auxiliary magnet was not needed in the area surveyed, but it was used when checking the instrument over the two known highs in the area to the east.

Corrections were made for latitude and longitude in order to offset the 10 gamma increase per mile north and 3 gamma increase per mile east that occurs in this part of North Dakota.[1]

The form used for calculating field notes was of the type in which plus and minus values of corrections for diurnal variations and latitude and longitude changes are entered directly.[2] The temperature readings were adjusted to 20° Centigrade.

When a distinct change in scale reading from the last station was noted, several check stations at 50 foot intervals were taken. Two instrument checks were made during the summer over known magnetic highs. The first of these was made near Ramsey, and both the Sprengnether and Askania instruments agreed with the anomaly. Later in the summer a second magnetic high near Fort Totten was used as an instrument check. This time only the Askania was checked, and the results were satisfactory.

Readings were taken at each mile around a township with two stations taken one male apart near the center of the township. After the traverse was completed the instrument was returned to the first station and checked. The diurnal variation was distributed to every station. North Dakota State Highway maps were used as base maps.

Surface Geology

The area lies in two physiographic provinces, the Central Lowlands and the Great Plains.[3] These provinces are divided by a drift-covered erosional escarpment which faces east and crosses the area approximately north 60° west from the southeast corner of Wells County. The Great Plains lie to the southwest of this escarpment whereas the Central Lowlands occur to the northeast. The largest part of the area is within the Western Lake Section of the Central Lowlands. The remainder of the area is included in the glaciated Missouri plateau section of the Great Plains province.

The Western Lake Section of the Central Lowlands province in North Dakota has been sub-divided into the Red River Valley, Drift Prairie, and Souris River Valley.[4] The Red River Valley is to the east of the area covered by this investigation, and the Souris River Valley comprises only a small part of northwestern Pierce County. The Souris River Valley is a relatively flat lake plain, formerly occupied by glacial Lake Souris, and here the Souris River drains to the north. The Drift Prairie is a gently rolling to hilly, drift-covered region in early topographic youth, which in the area mapped is drained mainly by the Sheyenne River flowing from west to east.

The glaciated Missouri Plateau is characterized by the knob-and kettle topography of end moraine deposits and has considerable relief. The end moraine lies on an escarpment probably underlain by Tertiary deposits.

The northwestern part of Pierce County extending almost to Rugby was covered by glacial Lake Souris.[5] The surface deposits in that area consist of beache ridges and lake sediments overlying the glacial drift. Three belts of end moraines cross the southern part of the county in a northwesterly direction. The northern part of Pierce County is covered by a recessional moraine. The drift is very thick and reaches a maximum of 300 feet in the moraine north of Pleasant Lake, which is just outside of the area covered by this report. The Pierre shale of Cretaceous age underlies the drift in most of the area. An outlier of probable Fox Hills occurs in a railroad cut west of Selz.[6]

According to Simpson, at least five recessional moraines occur in Benson County. The region shows striking knob-and kettle topography.[7] Outwash plains occur in several parts of the county on the south and west sides of the larger moraines. The drift in most places is underlain by Pierre Shale. Outcrops of the shale occur along the Sheyenne River and in the vicinity of Fort Totten Bay. These outcrops are east of the part of Benson County covered by this report.

That part of Wells County which is east of the escarpment is covered by gently rolling ground moraine.[8] The part west of the escarpment is also covered by drift but is characterized by roughly rolling end moraines. The Fort Union formation forms the bedrock in this area. The drift underlying Wells County reaches the maximum thickness of any place reported in North Dakota. Five hundred feet of drift was penetrated by a well in the SW¼ Sec. 28, T. 147N., R. 73W. The underlying bedrock is the Pierre shale with outliers of Fox Hills sandstone.[9] The Fox Hills sandstone has been noted in outcrops south of Harvey on the Sheyenne River.

The Missouri escarpment also extends across Sheridan County, and the area is everywhere covered with glacial drift.[10] No outcrops are known to exist in Sheridan County, but it is probable that the Fort Union formation underlies this section of the escarpment. To the east the area is mostly underlain by the Pierre shale.

Subsurface Geology

Only one deep hole has been drilled in the area mapped, so little subsurface information is available without referring to nearby oil tests. The Continental Lueth No. 1 was drilled in SE SE Sec. 27, T. 146N., R. 73W., near Hurdsfield in Wells County and bottomed in a granitic-type rock at a depth of 6020 feet or 4087 feet below sea level. [11] This well is reported to have penetrated 2736 feet of Paleozoic sediments. The remaining 3284 feet are mainly Mesozoic sediments with the exception of a few hundred feet of Tertiary Paleocene and glacial drift.

The Carter MacDiarmid well was drilled to the east of the map area in Ramsey County in NE NE Sec. 16, T. 154N., R. 65W. This test encountered Pre-Cambrian greenstone at a depth of 3728 feet or 2242 feet below sea level and is reported to have penetrated 1578 feet of Paleozoic sediments. The overlying Mesozoic sediments together with the glacial drift are 2150 feet thick.

Basement Complex

The Pre-Cambrian rocks so far recorded in North Dakota by deep tests show that there is considerable variation in lithology. Whereas many of the deep oil tests bottom in acidic rocks, such as granite and pink granitic gneiss, others of them encounter various basic greenstones.

The Pre-Cambrian rocks of a number of test wells in eastern North Dakota were examined and identified by the writer. The lithologic determinations are listed below: (Some of the granites may be gneiss).

NAME OF WELL	LOCATION	BASEMENT ROCK
Phillips-Carter, Dakota No. 1	NW Sec. 29-136N-81W	Hornblende Schist
Carter Oil Co. Semling No. 1	SE SE Sec. 18-141N-81W	Amphibolite with pyrite
California Co. Thompson No. 1	SW SE Sec. 31-160N-81W	Greenish-gray gneiss
Carter Oil Co. MacDiarmid No. 1	NE NE Sec. 16-154N-65W	Greenstone
Nome Water well	137N-56 or 57W	Reported green quartzite
Continental Oil Co. Lueth No. 1	NE NE Sec. 27-146N-73W	Pink granite with biotite
Rhodes, Murphy No. 1	NW NE Sec. 18-163N-65W	Biotite granite
Northern Natural Gas Producing Company Lee No. 1	NE NE Sec. 36-154N-63W	Pink granite
Glenfield Oil Co. No. 1	SE Sec. 18-146N-62W	Pink granite gneiss
Northern Ordnance Franklin Investment Company No. 1	NW NW Sec. 35-133N-75W	Pink granite
General Atlas Carbon Co. Barthal No. 1	SW NE Sec. 15-142N-65W	Pink granite
H. W. Snowden, Ruddy Bros. No. 1	NW SW Sec. 11-132N-48W	Biotite granite with pyrite
Barnett Drilling Inc. Gaier No. 1	NW NW Sec. 11-141N-67W	Biotite granite
Roeser-Pendleton, Weber No. 1	SE Sec. 35-133N-76W	Biotite granite
Magnolia Petroleum Co., Dakota A	NE Sec. 36-141N-73W	Pink granite
Grafton City water well	Sec. 13-157N-53W	Reported granite
Hamilton City water well	Sec. 35-162N-53W	Reported granite

A contour map was made of the elevation of the Pre-Cambrian surface. In the area surveyed only one deep test reached Pre-Cambrian. For this reason the basement depths of deep tests surrounding the area investigated were used in constructing a basement contour map. From this map, it is observed that the depths of the basement in the area covered by this investigation are as follows: northeast corner of the map area 3000-3200 feet, southeast corner 2800-3000 feet, southwest corner 4400-4600 feet, northwest corner 4600-4800 feet. The southeast corner of the area investigated should have the least depth to basement rocks, whereas the northwest corner should have the greatest depth to basement rocks.

Geologic Interpretation

There are several geologic conditions which can alter the regional magnetic gradient. The conditions that may cause magnetic intensity variance in the area mapped for this report are as follows:

1. Glacial deposits which vary in type and thickness.
2. Magnetic iron derived from the iron-bearing positive area in Minnesota or adjacent areas.
3. Structure manifested in the sedimentary section.
4. Relief on homogeneous basement rock surface.
5. Basic instrusions in a less basic basement with structure associated.
6. Granitic intrusions in a more basic basement with structure associated.

The known glacial features already discussed do not seem to effect the mapping to any noticeable extent. This is probably due to the coarse setting of the sensitivity of both insturments and the large magnetic contour interval used. A trial contouring at smaller magnetic intervals showed many small anomalies a few of which may be cause by variations of the type and thickness of glacial drift.

There is a possibility that the sedimentary rocks in certain areas are contaminated by iron derived from Pre-Cambrian deposits in Minnesota or adjacent areas. Pre-Cambrian rocks in North Dakota perhaps contain iron deposits similar to those of Minnesota, but, as yet none have been found.

If a sedimentary bed such as shale has a high magnetic susceptibility, then it would be possible to map structure contained in the sedimentary section. Because of the coarse setting of the magnetometers used in the field work for this report it is not thought that sedimentary structure alone was mapped, even if highly susceptible sedimentary beds exist. The influence of the sedimentary section alone is not considered in the interpretation of this magnetometer map.

Relief on a surface of homogeneous basement rocks can be mapped by vertical intensity magnetometers, because the magnetic intensity varies with the depth of the basement. In this case magnetic highs would correspond to ancient hills over which younger sediments were deposited.

In the area covered by this investigation there does not seem to be any relationship between basement depth and magnetic intensities. Vertical magnetic intensity ranges from a minimum of 4964 gammas in the northeast corner of the area to a maximum of 5662 gammas on the magnetic high in the southeast part of the map area south of Sykeston. According to a basement contour map constructed during this investigation, the magnetic low area in the northeastern part of the area should not have the greatest depth to the basement. There is considerable magnetic relief over the area which suggests that the basement rocks are heterogeneous.

Where little basement information is available, the highs of large magnetic intensity can be interpreted as intrusions into, or changes within, the basement rock, whereas the smaller magnetic highs most probably reflect areas of relief on the basement surface.[12 13 14 15] Further, the large magnetic contour interval used together with the coarse instrument setting would make it unlikely that basement relief on homogeneous rocks are shown on the map.

The magnetic susceptibilities of North Dakota basement rocks were not measured in laboratory experiments for this investigation. Published literature on the subject states that basic rocks have higher magnetic susceptiblities than acidic rocks.[16] Upon this assumption rests much of the interpretation of the magnetometer map prepared for this report.

The known basement rocks in North Dakota vary considerably as to lithology and presumably as to magnetic susceptibility. Basic instrusive bodies are much less common over the world than are acidic intrusives. After considering the many factors mentioned, it seems likely that the North Dakota basement complex, with the exception of a narrow area of granite adjoining the state of Minnesota, consists of various metamorphic greenstones intruded by acidic rocks as indicated by the table of basement rocks found in North Dakota deep tests.

More basic intrusions into the metamorphic greenstones would result in a large intensity magnetic anomaly. Some structural relief may be associated with these basin intrusions.

There are two strong magnetic highs mapped. One is in Range 68, 69W., Township 145N, and the other is located in Ranges 74, 75W, Townships 147, 148N. Both of these magnetic highs are on the edge of the map area so that closure was not accurately determined, but they both appear to have at least 250 gammas closure. These two strong mangetic highs are suggestive more of lithologic changes than basement relief. These two magnetic anomalies quite possibly are intrusives of a more basic type of rock. There is also a possibility of basement relief due to the effects of differential erosion upon the two lithologies.

The string of magnetic highs with a few associated lows in the southern part of the map may reflect a greenstone ridge intruded by granitic rocks. Over these structures the map would show magnetic highs except where the granitic intrusions form the Pre-Cambrian surface. Because of differential erosion the granitic areas should be structurally higher than the adjoining greenstone areas. This is perhaps the situation which exists beneath the Continental Lueth test which is located in the center of a small intensity low, and where an acidic granitic basement was encountered. The overlying sedimentary rocks could be affected by these basement structures. Therefore, the previously mentioned northeasterly-trending line of magnetic highs and lows could conceivably indicate a Pre-Cambrian ridge. As has been suggested by Laird[17] there is a possibility of such basement structures existing.

The 5400 gamma contour line which points eastward from the west edge of the map is the largest highly magnetic area. This area of high magnetic susceptibility may indicate a regional change in lithology.

Conclusions

A magnetometer survey in respect to oil exploration is a regional reconnaissance tool and, therefore, it is customary to check an interesting magnetic anomaly with a seismograph or gravimeter. An exception to this is found in micromagnetic surveys which, because of the detailed nature, may serve as a check on other types of geophysical surveying.[18]

The two large magnetic highs may be more basic areas in the basement rocks, and they may indicate structure. However, the large eastward-trending magnetic high area on the west side of the map area is quite pissibly due to a regional incerase in magnetic susceptibility caused by changes in lithology. The lower magnetic intensity highs and lows are more likely to reflect basement and possibly overlying sedimentary structure. These highs and lows form at least one northeasterly trend which may be an irregular basement ridge. A promising place to look for oil accumulation might then be on these lower intensity magnetic highs and lows, which may reflect both basement and the overlying sedimentary structures.

Because of the coarse sensitivity setting of the instruments used and the large magnetic interval used in contouring the map, the writer does not think that structural relief of a homogeneous body is generally indicated. Rather it is believed that changes in magnetic susceptibility were mapped. As has previously been discussed, these changes in lithology could affect the structure of the basement and possibly the sedimentary section. The writer thinks that magnetometer surveys in North Dakota made with a sensitive instrument setting can serve a definite purpose in outlining a structural prospect if the previously discussed geological and geophysical elements are kept in mind when interpeting the work.

References

[1] U. S. Magnetic Tables and Magnetic Charts for 1945, *U.S. Department of Commerce Publication*, Serial 667, 1945.

[2] Jakosky, J. J.: "Magnetic Methods", *Exploration Geophysics*, Trija Publishing Company, Los Angeles, pp. 152-153, 1950.

[3] Fenneman, N. M.: *Physiography of Western United States*, McGraw-Hill Book Company, New York, p. 3, 1931.

[4] Simpson, H. E.: Geology and Ground-Water Resources of North Dakota, *U.S. Geological Survey Water-Supply Paper 598*, pp. 4-11, 1920.

[5] Simpson, H. E.: *op. cit.* p. 187.

[6] Laird, W. M.: N. D. State Geologist, Grand Forks North Dakota, oral communication.

[7] Simpson, H. E.: *op. cit.* pp. 71-74.

[8] Simpson, H. E.: *op. cit.* pp. 262-263.

[9] Akin, P. D.: Engineer, U.S. Geological Survey, Grand Forks, North Dakota, oral communication.

[10] Simpson, H. E.: *op. cit.* p. 220.

[11] Well information from *Petroleum Information*, Rocky Mountain Report.

[12] Dobrin, M. B.: "Magnetic Prospecting," *The Oil and Gas Journal*, p. 142, March 24, 1952.

[13] Hoylman, H. W.: "Airborne Magnetic Profiles", *The Oil and Gas Journal*, p. 56, December 29, 1949.

[14] Nettleton, L. L.: "Interpretation of Aeromagnetic Survey in Western Canada", *Oil in Canada*, p. 15, July 17, 1950.

[15] Nettleton, L. L.: "Magnetic Calculations and Interpretation", *Geophysical Prospecting for Oil*, McGraw-Hill Book Company, New York, p. 203, 1940.

[16] Nettleton, L. L.: *op. cit.* p. 201.

[17] Laird, W. M.: "Geology of the Williston Basin," *World Petroleum*, p. 44, January, 1952.

[18] Jenny, W. P.: "Structural Correlation of Micromagnetic and Reflection Survey," *World Oil*, pp. 67-72, March, 1952.

GEOMAGNETIC MAP

OF

PART OF THE EAST EDGE OF WILLISTON BASIN

LEGEND

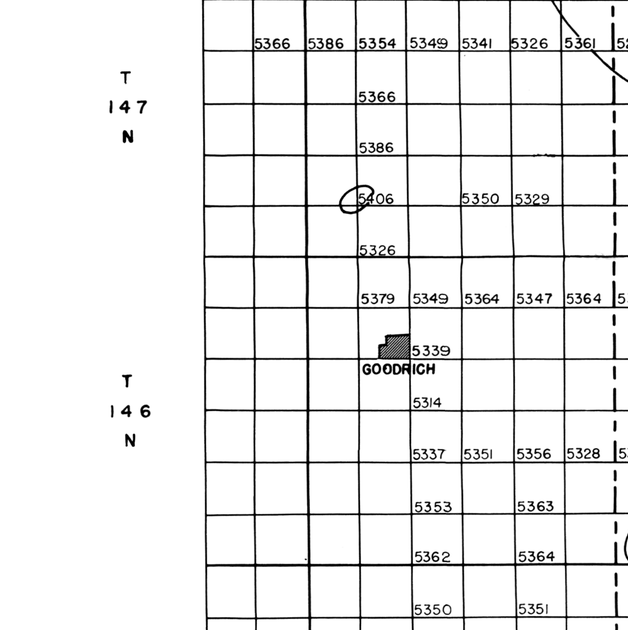
BASE STATION AT RUGBY 5107

VERTICAL MAGNETIC INTENSITY IN GAMMA 5107

CONTOUR INTERVAL 100 GAMMA, 50 GAMMA ON HIGHS

SCALE, 1 INCH = 2 MILES 0 1 2 3 4 5, DRY

GEOPHYSICS BY HARALD C. HARALDSON, 1952



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