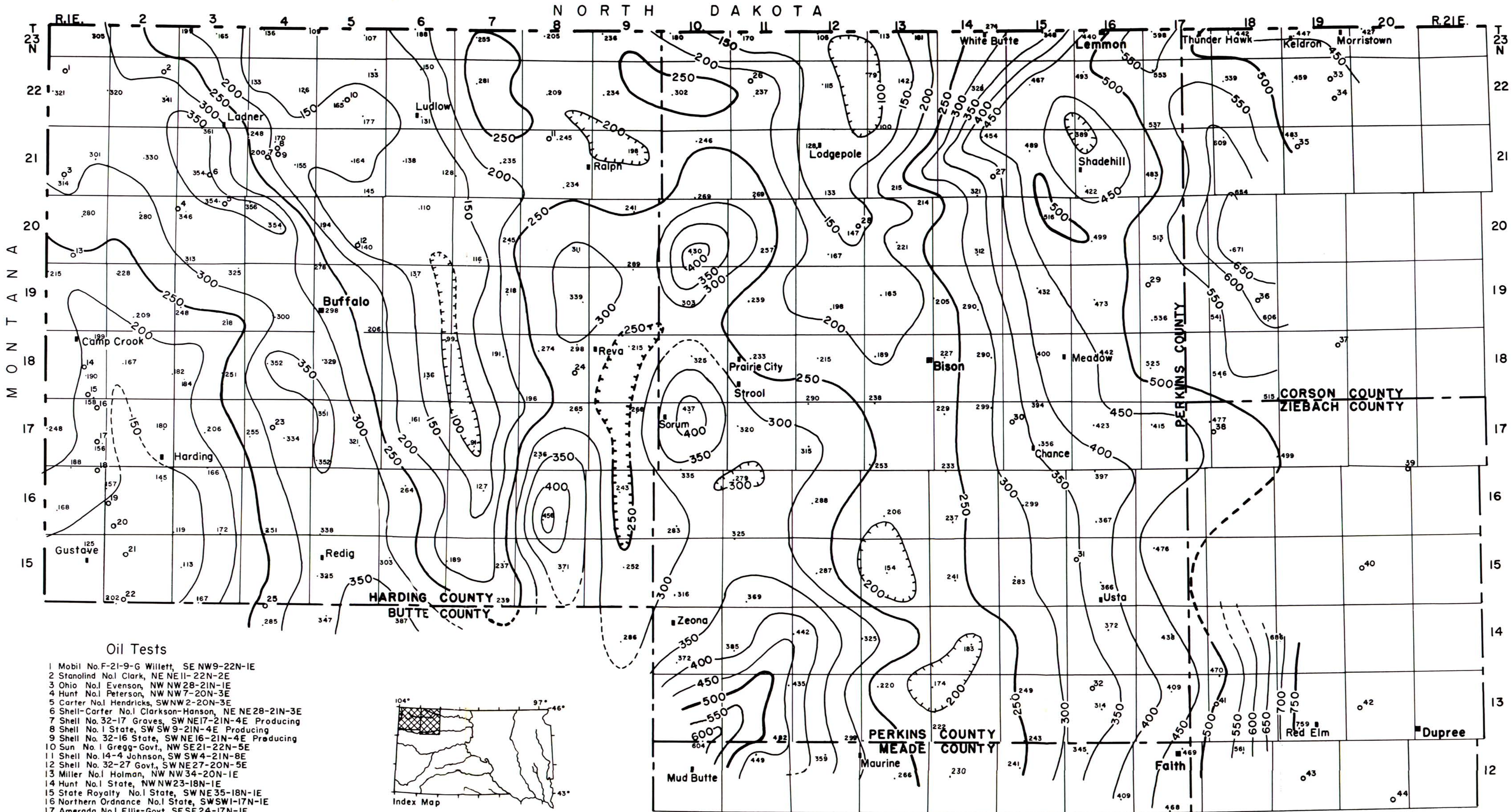
STATE OF SOUTH DAKOTA
JOE FOSS, GOVERNOR

SOUTH DAKOTA GEOLOGICAL SURVEY
ALLEN F. AGNEW, STATE GEOLOGIST



Oil Tests

1 Mobil No. F-21-9-G Willett, SE NW9-22N-1E
2 Stanolind No.1 Clark, NE NE11-22N-2E
3 Ohio No.1 Evenson, NW NW28-21N-1E
4 Hunt No.1 Peterson, NW NW7-20N-3E
5 Carter No.1 Hendricks, SWNW2-20N-3E
6 Shell-Carter No.1 Clarkson-Hanson, NE NE28-21N-3E
7 Shell No. 32-17 Graves, SW NE17-21N-4E Producing
8 Shell No. 1 State, SW SW9-21N-4E Producing
9 Shell No. 32-16 State, SW NE16-21N-4E Producing
10 Sun No. 1 Gregg-Govt., NW SE21-22N-5E
11 Shell No. 14-4 Johnson, SW SW4-21N-8E
12 Shell No. 32-27 Govt., SW NE27-20N-5E
13 Miller No.1 Holman, NW NW34-20N-1E
14 Hunt No.1 State, NW NW23-18N-1E
15 State Royalty No.1 State, SW NE35-18N-1E
16 Northern Ordnance No.1 State, SWSW1-17N-1E
17 Amerada No.1 Ellis-Govt., SE SE24-17N-1E
18 Amerada No.1 State "A", NE NE1-16N-1E
19 Amerada No.1 Short Pine Hills, SE NW19-16N-2E
20 Amerada No.2 Short Pine Hills, NENE 31-16N-2E
21 Amerada No.1 Govt.-Holland, SW SW8-15N-2E
22 Northern Ordnance No.1 Govt., SE SE32-15N-2E
23 Richfield No.1 State "A", SW SW16-17N-4E
24 Shell No. 41-23 State, NE NE23-18N-8E
25 Amerada No.1 State, NW NW4-14N-4E
26 Hunt No.1 Govt., NW SE8-22N-11E
27 Youngblood No.1 Andersen, NE NE26-21N-14E
28 Shell No.1 Homme, NW NW13-20N-12E
29 Youngblood No.1 Wheiner, SW SW7-19N-17E
30 Shell No.1 Veal, SESE7-17N-15E
31 Shell No.22-7 Bastian, SE NW7-15N-16E
32 Evans & Querbes No.1 Capp, NWNW9-13N-16E
33 Shell No.1 Winter, NWSW11-22N-19E
34 Youngblood No.1 Winter, SWSW23-22N-19E
35 Youngblood No.1 Macheel, SWSW8-21N-19E
36 Shell No.11-23 Govt., NWNW23-19N-18E
37 Shell No. 22-12 Evridge, SE NW12-18N-19E
38 Shell No. 14-18 Dreis, SWSW18-17N-18E
39 Herndon No.1 Young, NWNE1-16N-20E
40 Irish Creek Oil Test, SE17-15N-20E
41 Phillips No.1 Nelson, NW SE18-13N-18E
42 Kerr-McGee No.1 Brammer, SE NW20-13N-20E
43 Herndon No.1 Butler NENE21-12N-19E
44 Dayton No.1 Olsen-Rural Credit, NENE35-12N-20E

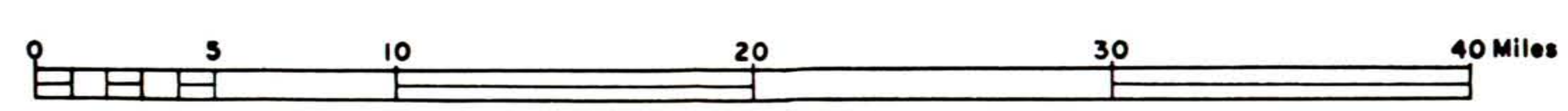
EXPLANATION

354 Vertical Magnetic Intensity in Gammas

o4 Oil Test Location

MAGNETOMETER MAP
of
Harding and Perkins Counties
South Dakota

By
Bruno C. Petsch
1958



INTRODUCTION

The magnetometer survey was made during the summer of 1957, in Harding and Perkins Counties. The survey was undertaken as a continuation of a magnetometer program which will eventually cover the entire State. About one-half of the State has been surveyed, and the results are published in four reports: Jordan and Rothrock (1940 a, b); Tullis (1942); Petsch and Carlson (1952). In addition, recent magnetic surveys made by the North Dakota Geological Survey in the Williston Basin have shown that a close agreement exists between magnetic anomalies and geologic structure (Opp, 1955). The project was carried out under the supervision of Dr. Allen F. Agnew, State Geologist.

TOPOGRAPHY

Harding and Perkins Counties lie in the extreme northwestern part of South Dakota. They are bounded on the north by North Dakota, and Harding County is bounded on the west by Montana. The Little Missouri River flows northward, draining the western part of Harding County; the remainder of the county and all of Perkins County are drained by the Grand and Moreau rivers, which flow eastward.

The area is in part of the northern Great Plains. The gently rolling plains are interrupted in the southwest by "Badland" areas which are locally known as the "Jump Off". Flat-topped mesas are common in Harding County, from one mile to as much as 20 miles long, the largest being the Slim Buttes; they rise about 600 feet above the surrounding plain. Rounded and pointed buttes dot the landscape in Perkins County.

The altitude of the land surface ranges from 2500 feet in the east to 3200 feet in the west, with mesas reaching above 3600 feet.

SURFACE GEOLOGY

The area lies in the southern part of the Williston Basin. About 1600 feet of Mesozoic and Cenozoic rock strata comprise the surface formations (see Table 1).

The Pierre and Fox Hills Formations are exposed in the southern part of the area. The Pierre (Curtiss, 1956) is drab to dark-gray soft crumbly bentonitic clay-shale. It contains clear crystals of selenite and dark-gray limestone concretions with geodic linings of golden calcite. The material weathers to a light-gray or brown "popcorn" surface. Although only the upper 75 feet is exposed, the total thickness of the Pierre is at least 2200 feet.

The Fox Hills is a buff-yellow fine-grained, friable sandstone. It is about 100 feet thick and thickens eastward. Locally it is exposed in steep cliffs.

The Hell Creek, known as the "somber beds", forms the surface over most of the area. It is about 400 feet thick and consists of dull light- to dark-gray or brown bentonitic clay or mudstone, interbedded with grayish-yellow silts and fine sands which have a bentonite bond. The bentonitic clay surfaces have a "popcorn" appearance. Dark-brown ironstone concretion layers are common. Huge lenses of yellowish-gray uncemented sandstone occur at random and they are marked in gently rolling topography by sand dunes. Peat-clay, carbonaceous shale and locally lignite are present. The landscape is dotted with "mud buttes" of Hell Creek. Badland topography is present in many places, and dinosaur bones are present.

The Ludlow Formation is the oldest of the Tertiary rocks; it contains many lignite beds. They range in thickness from less than a foot to as much as fifteen feet. Besides the lignite the Ludlow is made up of tan and buff soft sandstones, hard ledge-making sandstone, dark shale, carbonaceous shale, peat, and local red and pink "clinker". Petrified wood is common in some areas. Radioactive minerals are present in varying amounts in the formation.

The Tongue River Formation has the smallest extent of any of the surface rocks in the area, as it is confined to the higher altitudes in the northern part of the area. It is dominantly sandstone throughout and is characterized by two massive sandstones, separated by the Lodgepole lignite zone. The lower sandstone caps prominent buttes and mesas. Radioactive minerals are present in minor amounts in the sandstone, and commercial amounts are found in the lignite.

The White River Group is the most picturesque of the formations. It is divided into the Chadron Member below and the Brule above. The Chadron is a tan to gray hard silty clay at the base, overlain by a coarse dazzling white sandstone; its upper part is a pale-brown mottled bentonitic clay, which weathers to a "popcorn" surface. The sandstone locally contains a layer of vuggy limestone.

The Brule contains the Oreodon and Protoceras beds (Toepelman, 1923, p. 6); the former is a hard fine pale-green sandstone with alternate beds of hard pale brownish-gray bentonitic clays which on weathering cause a tread-and-riser effect. The outcrops are generally steep. The Protoceras beds are massive pink hard silty clays that stand in vertical outcrop. The White River Group is exposed in the buttes of southern Harding County, and in a few "white" hills in Perkins County.

The Arikaree is the youngest and uppermost group of rocks of the sedimentary column exposed in the area. It is limited in extent and forms the cap rock of the higher mesas in southern Harding County, the Short Pine Hills and the Slim Buttes. The lower part of the formation is a coarse sandstone with local conglomerate. The upper part is hard massive carved sandstone, calcareous in places with stalactite-like concretions. The formation contains much tuffaceous material which on weathering gives the vertical cliff a characteristic tannish-brown appearance. The forest cover of the buttes is generally confined to this formation.

TABLE 1

ERA	PERIOD	GROUP OR FORMATION
Cenozoic	Miocene	Arikaree ? Formation
	Oligocene	White River Group Brule Formation Chadron Formation
	Paleocene	Fort Union Tongue River Formation Ludlow Formation
Mesozoic	Cretaceous	Hell Creek Formation Fox Hills Formation Pierre Formation

SUBSURFACE GEOLOGY AND STRUCTURE

The southern edge of the Williston Basin is shown by altitudes on the Greenhorn Formation (fig. 1). The regional dip of the Greenhorn on the western flank, in Harding County, is about 28 feet per mile to the northeast. In Perkins County the regional dip is 14 feet per mile due north, and on the eastern flank it is 18 feet to the northwest.

In western Harding County the regional dip is interrupted by two anticlinal structures. The Cedar Creek anticline extends southward from Montana and North Dakota, and the Camp Crook anticline is possibly a northward extension of the Black Hills uplift; the axis of the Camp Crook anticline plunges northward at about 28 feet per mile.

The Precambrian surface is 9345 feet deep in north-central Perkins County, according to the data derived from the Shell #1 Homme oil test. This may be the maximum sedimentary section in South Dakota. It contains 320 feet of Tertiary sand, silt, and clay; 4175 feet of Cretaceous shale, sandstone, and limestone; 550 feet of Jurassic shale, sand, and limestone; 230 feet of Triassic red beds, with gypsum and anhydrite; and 4090 feet of Paleozoic rock that is about 80 percent limestone and dolomite. The thicknesses of the Cretaceous and the Paleozoic are almost equal. In the surveyed area the formations remain fairly uniform in character and thicken somewhat northward.

The Precambrian is penetrated by five oil tests: the Ohio #1 Evenson at 8836 feet depth, the Shell #1 Homme at 9345 feet, the Shell #1 Veal at 8292 feet, the Shell #1 Winter at 8433 feet, and the Evans and Querbes #1 Capp at 7300 feet. Contours on the Precambrian surface are similar to those on the Greenhorn (Petsch, 1953).

FIELD WORK

Observations with an Askania vertical component magnetometer were made at intervals of four to six miles. This network probably outlines the major magnetic features, which can be detailed later if desired.

In South Dakota the vertical magnetic intensity increases from 56,000 to 58,000 gammas, from southwest to northeast. In order to maintain a flat magnetic surface, a regional correction of 9 gammas was subtracted for each mile north and 3.2 gammas was subtracted for each mile east of the base stations. This survey and all previous surveys have been thus maintained on the same plane.

The magnetometer had a sensitivity value of 10.4-11.4 gammas per scale division. The magnet system has a zero temperature coefficient.

Diurnal variation was taken from a three-point curve and from daily magnetograms supplied by the Tucson magnetic observatory. The two curves agreed on many comparative days. Hence by using the magnetogram the noon check-in was eliminated. The result was that stations were reoccupied and gave check readings within 20 gammas, and many were within 10 gammas. All observations were made in fields or pastures, at least 100 yards from power lines, fences, buildings, machinery and other possibly magnetic objects.

MAGNETIC ANOMALIES

The total magnetic relief in the area is 680 gammas, which includes a low reading of 79 gammas in sec. 12, T. 22 N., R. 13 E., to a high reading of 759 gammas in sec. 29, T. 13 N., R. 19 E. The two extremes are 70 miles apart.

The major magnetic feature in Harding County as shown by the magnetic contours (isogams) is a long wide magnetic high, which extends in a southerly direction across the full length of the western part of the county and is here named the Hendriks-Redig high. It is outlined by the 300 gamma contour and connects with the Newell magnetic high (Petsch, Carlson, 1952) in Butte County. Two 350-gamma closed contours in Harding County and a 600-gamma closed contour in Butte County mark this high. The entire feature is more than a hundred miles long, and averages eight miles wide.

The Ludlow-Murchison magnetic low parallels it on the east and is shown by the 100-gamma closed contour and low intensity values. A magnetically low area in the southwestern part of Harding County adjoins the Hendriks-Redig high on the west.

Local magnetic anomalies of moderate intensity are in the eastern part of Harding and the western half of Perkins Counties.

In the eastern half of Perkins County a smooth magnetic slope trends north-south and rises eastward from 200 to 450 gammas, where it terminates or is the flank of a large magnetic high which extends from Lemmon southeastward to Red Elm. This high reaches 759 gammas and is the highest anomaly mapped during the present survey.

GEOLOGIC ANALYSIS

Vertical magnetic intensity is a composite of all conditions that influence the magnetic field emanating from the crust of the earth. Many geologic conditions are responsible for magnetic variables. The magnetic field as shown by the contours would be more pronounced except for the shielding effect of the more than 9000 feet of paramagnetic, nonmagnetic, and diamagnetic sedimentary rocks in the geologic column; this is in contrast with the area east of the Missouri River in South Dakota, where the sedimentary sequence is less than 3000 feet thick for the most part. There is apparently no relation between the depth to the Precambrian surface and the vertical magnetic intensity in the eastern part of this region. However, the magnetic configuration may indicate differences of rock type in the basement. The eastern part of Harding and the western half of Perkins County shows a combination of granite with basic intrusive bodies. The magnetic susceptibility changes caused by such a basement complex could result in local polarizations that are contoured as uneven, irregular magnetic lines.

A thick deep-seated Redbed section in the sedimentary column might have sufficient magnetic influence to indicate folded or faulted structure; however, the Redbeds of this area are not that thick.

The Hendriks-Redig magnetic high indicates a tectonic origin and in all probability shows the direction, magnitude and extent of the southern part of the Cedar Creek anticline as it extends into South Dakota from Montana and North Dakota (Calvert, 1910). The Fox Hills dome and the Gallup dome (Moulton, Bass, 1922) are structures superimposed on the Cedar Creek anticline, and lie within the 300-gamma contour. A comparison of this structure and the magnetic anomaly shows a marked coincidence. The linear design demonstrated by the magnetic contours suggests that the anomaly may be caused by structure rather than by susceptibility changes. The core of the magnetic high is possibly a buried granite ridge, although a granite ridge in high mountains or a granite ridge buried under sediments normally does not alone produce a magnetic high.

The long 100-gamma magnetic low paralleling the east side of T. 18-19 N., R. 6 E., indicates possibly a deep-seated fault.

The Camp Crook-Harding-Gustave area of southwestern Harding County is in a broad magnetic low. It is bisected by the Camp Crook anticline (fig 1), a structural high which is not reflected by a magnetic high. Apparently the susceptible material that causes the positive anomaly indicated by the Hendriks-Redig high is missing in this area. This broad magnetic low may contain uniformly light-colored acidic igneous rocks in the basement, and is an extension of the Precambrian of the Black Hills, which has low magnetic susceptibility.

In eastern Perkins County the smooth eastward rise of the magnetic intensity coincides with the structural rise of the sediments (figs. 2, 3). A terrace on the Precambrian surface could yield the same type of magnetic anomaly.

The magnetic intensity is not generally lower in the deeper part of the Williston Basin in Perkins County, but it is lower than on the extreme eastern flank of the basin in east-central South Dakota. A magnetic trough-like low west of Bison is in the lowest part of the Williston Basin in South Dakota.

The Shell-Carter #1 Clarkson-Hanson and the Carter #1 Hendriks oil tests are on a magnetic high, and the remainder of the oil tests are on regional lows or flanks of highs. It is assumed that all oil test borings were made on seismic highs, and many of them are structurally high.

CONCLUSIONS

Certain prominent anomalies that stand out in the regional magnetic configuration seem to coincide with the structure of the area. The Hendriks-Redig magnetic high and the Lemmon-Red Elm high have a tectonic origin; the magnetic low in southwestern Harding County is an extension of the Black Hills magnetic low. Local magnetic highs and lows in the central part of the area may indicate different Precambrian rock types.

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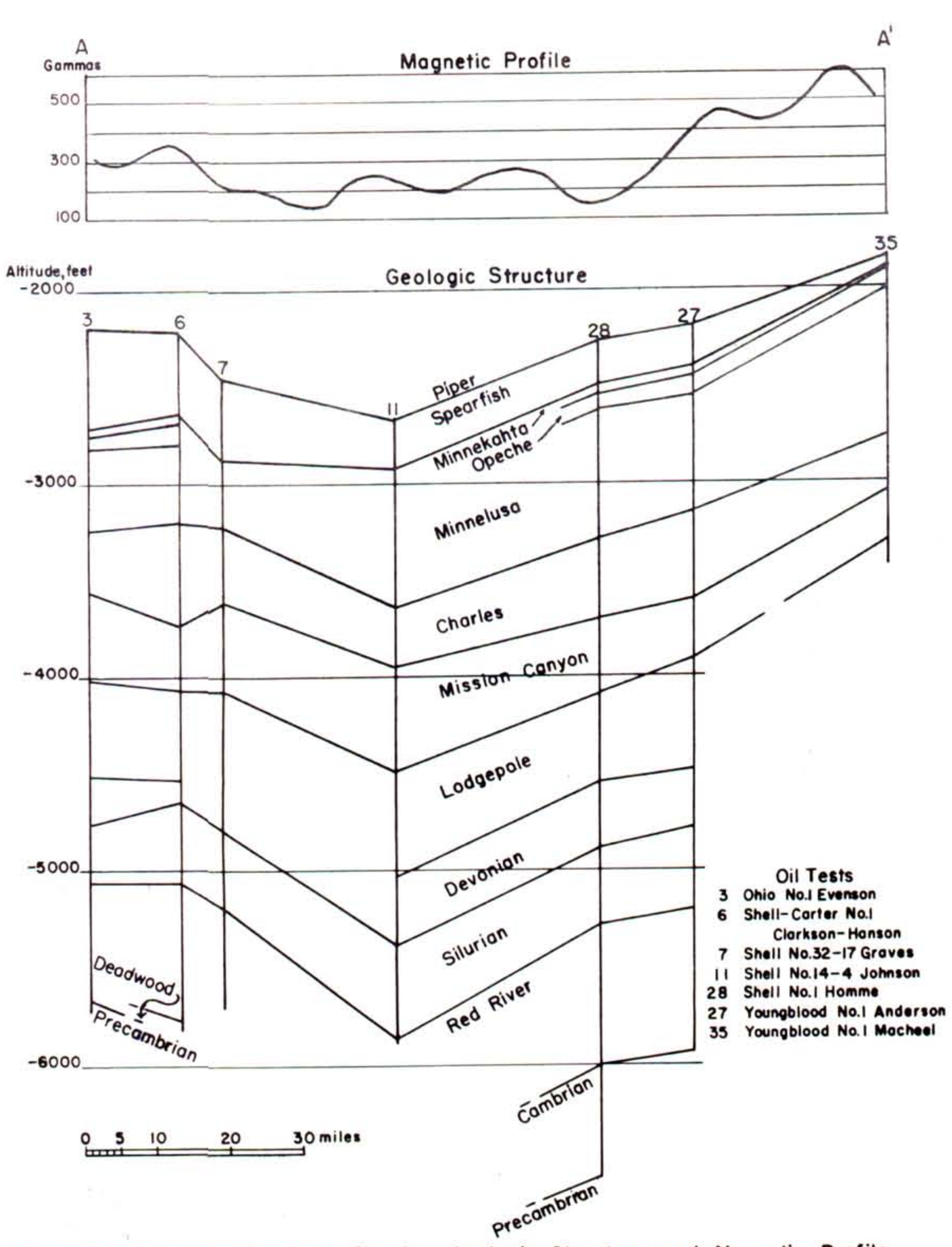

Figure 2. – Cross-section A-A', Showing Geologic Structure and Magnetic Profile.

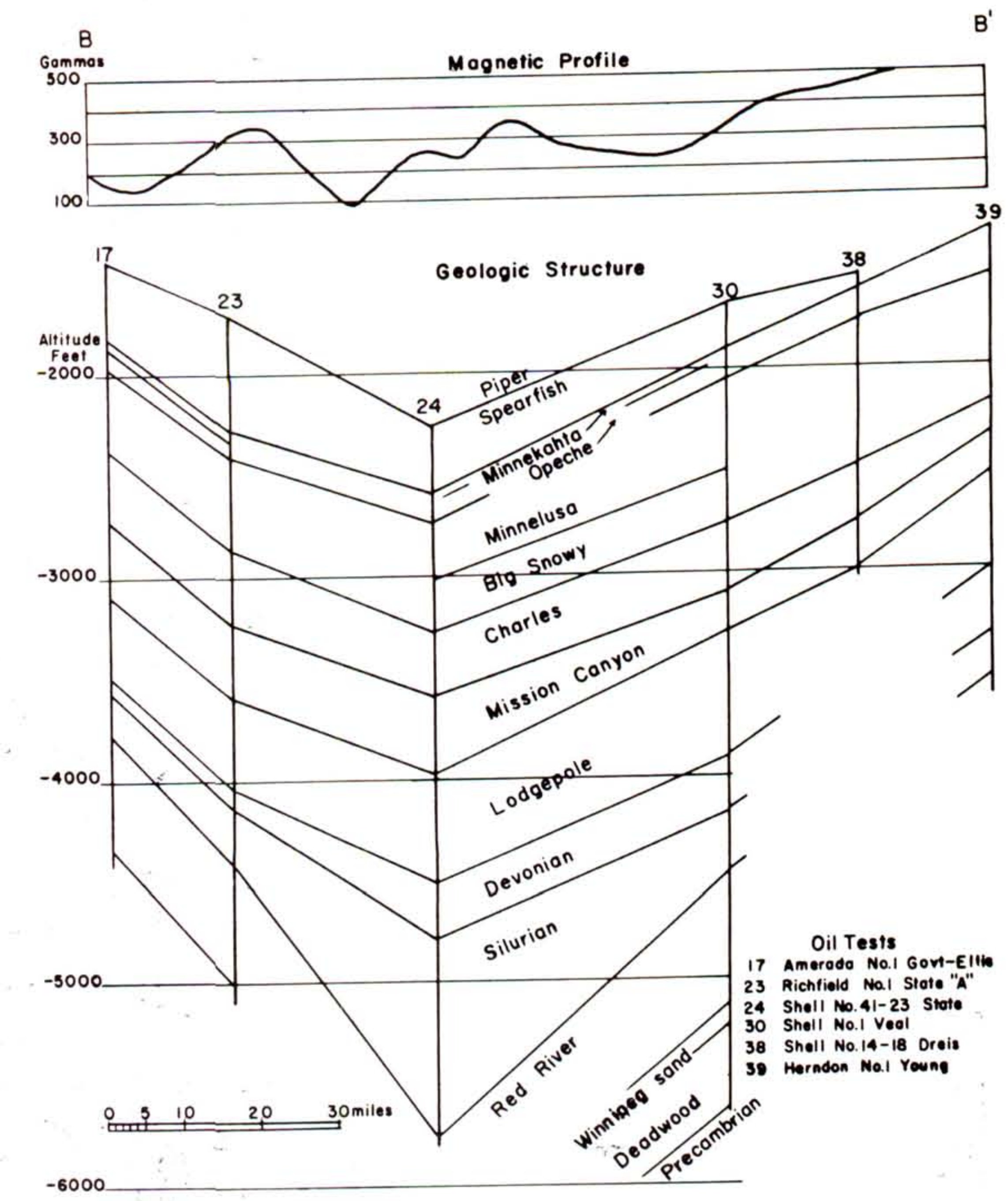

Figure 3. – Cross-section B-B', Showing Geologic Structure and Magnetic Profile.

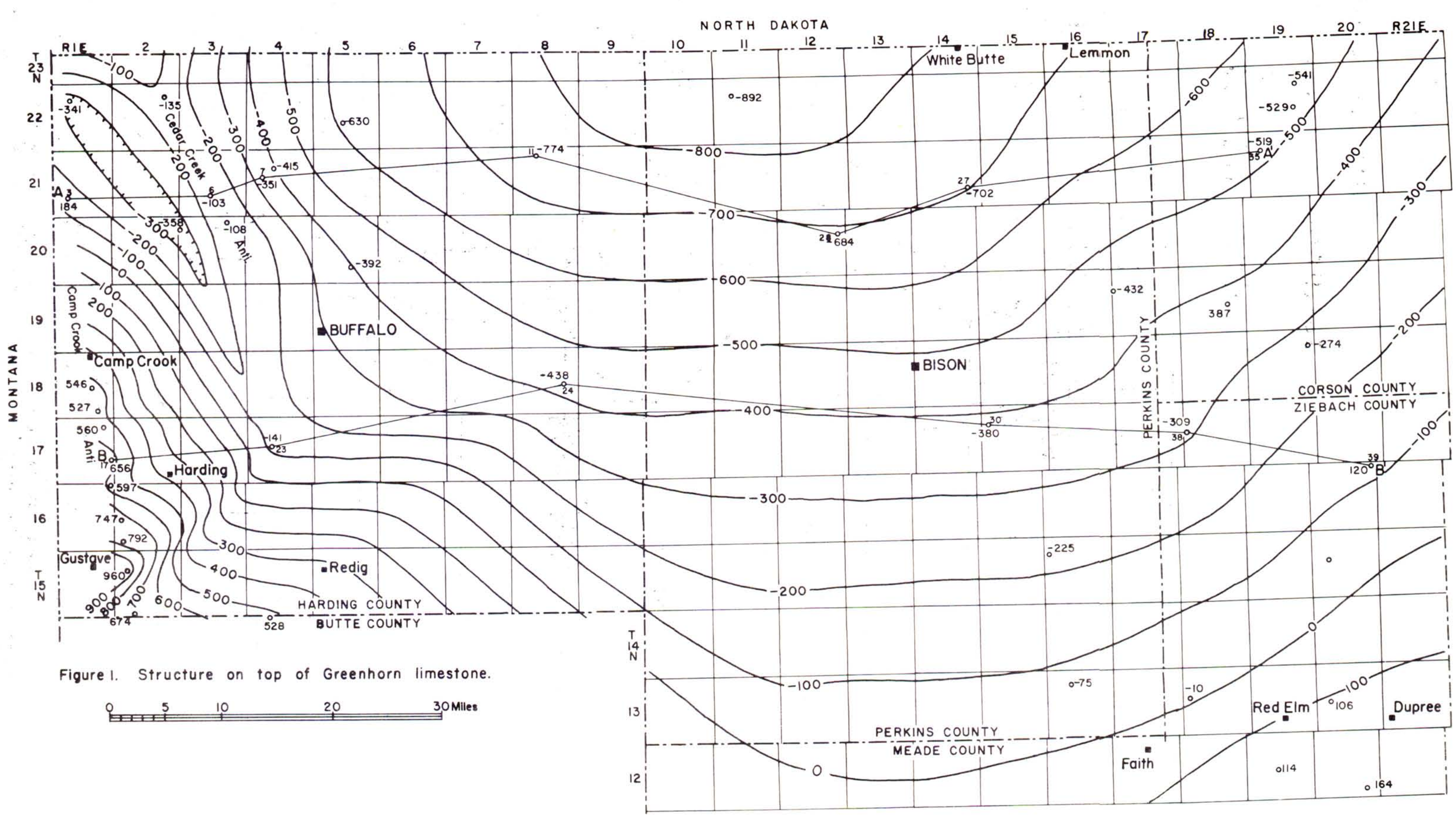

Figure I. Structure on top of Greenhorn limestone.

0 5 10 20 30 Miles