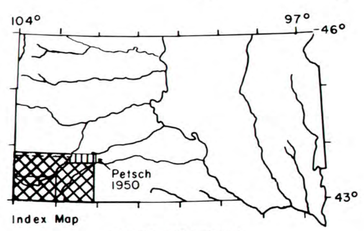
SOUTH DAKOTA GEOLOGICAL SURVEY
ALLEN F. AGNEW, STATE GEOLOGIST

STATE OF SOUTH DAKOTA
RALPH HERSETH, GOVERNOR

OIL and GAS INVESTIGAGTIONS
MAP 9



EXPLANATION

237 Vertical Magnetic Intensity in Gammas

ϕ^2 Oil test or water well drilled to Precambrian rocks

MAGNETOMETER MAP
of
Custer, Fall River and Shannon Counties
South Dakota

By
Bruno C. Petsch

1960

0 5 10 20 30 40 Miles

MAGNETOMETER MAP OF CUSTER, FALL RIVER AND SHANNON COUNTIES

by
BRUNO C. PETSCH

INTRODUCTION

A ground magnetometer survey was made during the summer of 1959 in Custer, Fall River, and Shannon Counties. The Survey was undertaken as a continuation of the magnetometer program of the Geological Survey under the direction of Dr. Allen F. Agnew, State Geologist; magnetometer maps will eventually be prepared for the entire State. About two-thirds of South Dakota has been surveyed, and the results are published in six separate reports: Jordan and Rothrock (1940 a, b), Tullis (1942), Petsch and Carlson (1952), and Petsch (1958, 1959).

The writer was assisted by Nathaniel Lufkin.

TOPOGRAPHY

Custer, Fall River and Shannon Counties lie in the southwestern corner of South Dakota. The area is bounded on the west by Wyoming and on the south by Nebraska. Custer and Fall River Counties are drained by the Cheyenne River, and Shannon County is drained by it and the White River.

Most of Custer County and the northern part of Fall River County are in the Black Hills, and are very hilly, with deep canyons, hog-back ridges and rolling foot-hills. Several well-known mountain peaks are in this part of the area, which is heavily forested.

The rest of the area lies in the Great Plains. The topography of the plains country is gently rolling in Fall River County, and in Shannon County it is rugged for the most part. In the northwestern part of Shannon County are impassable "Badlands". Pointed buttes and flat-topped mesas are common in the plains country.

The altitude of the land surface ranges from 2600 feet along the Cheyenne River valley to almost 7000 feet above sea-level in the mountains. Some of the buttes on the plains rise more than 200 feet above the land surface, and some mountain peaks rise at least 1000 feet above the mountain valleys.

STRATIGRAPHY AND STRUCTURE

The area lies in four distinct structural provinces: an area of anticlines bordering the Denver-Julesburg Basin, a Precambrian buried ridge known as the Cambridge Arch, the uplifted Black Hills, and the Plains.

Anticlines Bordering the Denver-Julesburg Basin

Fall River County lies in an area that is replete with outstanding geologic features. The northern end of the Denver-Julesburg sedimentary basin underlies the western part of Fall River County. Three anticlines (fig. 1) plunge southward from the Black Hills uplift into the basin. The steeply dipping calcareous layers of the Greenhorn Formation mark the limits of these anticlines.

The most prominent is the Cascade anticline, which passes due south beneath the abandoned village of Cascade Springs. In T. 10 S., R. 5 E. the anticlinal axis appears to join an east-trending one, probably joining the Chadron Dome in southwestern Shannon County (fig. 1).

The prominent Chilson anticline extends from Minnekahta due south through Ardmore. The third or Cottonwood anticline is less prominent, and trends southwest from Edgemont. These structural features are related to the upheaval of Black Hills and probably have Precambrian cores.

The surface rocks of the Chilson and Cottonwood anticlines are Cretaceous in age, ranging from the Pierre shale down to the Lakota sandstone and shale along the axis. The surface rocks over much of the Cascade anticline are Jurassic to Permian in age, including the Morrison and Sundance shale and sandstone, and the Spearfish shale and gypsum; much of the axis is covered by the Minnekahta limestone.

In these anticlines the Precambrian rocks are overlain by Pennsylvanian or Mississippian strata, marking a significant unconformity.

Chadron Dome

A buried Precambrian ridge which begins in western Kansas as the Central Kansas Uplift, and crosses western Nebraska as the northwest-trending Cambridge Arch, is marked at the extreme northern end by the Chadron Dome which enters South Dakota in southwestern Shannon County. The Amerada #1 Red Eagle oil test, in Sec. 25, T. 36 N., R. 48 W., penetrated the Precambrian granite at an altitude of -14 feet, whereas an oil test in Dawes County Nebraska (Sec. 4, T. 34 N., R. 47 W.) 8 miles to the south, penetrated the Precambrian granite at 509 feet above sea-level on the arch (Reed and Svoboda, 1957 a, b). On the crest of this arch the Precambrian rocks are overlain by the Pennsylvanian Minneluss Formation, and the older Paleozoic rocks are present only on the flanks.

Black Hills Uplift

The Black Hills are an isolated elongate dome-shaped uplift in western South Dakota and eastern Wyoming. Most of Custer County is part of the uplift, and the Precambrian core consists of schist, slate, quartzite, granite and pegmatite. Outcrops of outward-dipping Paleozoic and Mesozoic rocks encircle this core. Oil tests several miles downdip to the east show more than 5000 feet of these later rocks above the Precambrian.

Plains

The eastern part of Custer and Fall River Counties, and all of Shannon County are in the plains region. In the former the Pierre Formation is at the surface. In almost all of Shannon County the surface is made up of the White River and Arikaree sediments, except along White Clay Creek in T. 35 N., R. 45 W., where the Pierre and Niobrara Formations are present.

The Pierre shale has a regional dip to the east of 75 feet per mile. It is about 1200 feet thick.

The White River Group covers the northern half of Shannon County. It contains poorly cemented sandstone, bentonitic clays, and siltstone, and is as much as 620 feet thick (Bump, 1951).

The Arikaree Group covers the southeastern part of Shannon County. It is composed of sand and sandstone and volcanic ash, and is as much as 700 feet thick.

FIELD WORK

Observations were made with an Askania Vertical Ground Magnetometer at intervals of four to six miles. This network probably outlines the major magnetic features outside the area of Precambrian exposures. Observations were made at two- to three-mile intervals in the latter area, because of the small areal extent of the different Precambrian lithologies and the rough topography.

In South Dakota the vertical magnetic intensity increases from 56,000 to 58,000 gammas, from southwest to northeast (Deel and Howe, 1948, Map 4). This regional variation was compensated for by subtracting 8.9 gammas per mile northward and 3.5 gammas per mile eastward from base stations, in order to maintain a flat magnetic surface. This correction is sometimes removed from regional surveys for interpretation purposes, and is not applied to local surveys.

Diurnal variation was taken from repeated observations at base stations and from daily magnetograms supplied by the Tucson Magnetic Observatory of the U. S. Coast and Geodetic Survey. All magnetic observations were made in fields or pastures away from power lines, fences and other possibly magnetic objects.

MAGNETIC ANOMALIES

The manner in which magnetic surveys reveal the general structure of a portion of the Earth's crust is illustrated by contour maps and profile drawings. From these, reasonable conclusions can be made about the geologic environment which causes the variations in the earth's magnetic field.

A cursory examination of the magnetic field, illustrated by the isogam contours, shows that 300 gammas is about the medium magnetic intensity for the area. Anomalies above this value are magnetometer highs, whereas those below are lows. Most of Shannon County is above 300 gammas.

There are nine magnetometer highs which are separated arbitrarily into two catagories (Table 1). Five have higher intensity and the other four, lesser intensity; the latter are larger in areal extent. The Imlay-Kyle-Chimney Butte region in the northeastern part of the area has a broad high anomaly with three summits.

Table 1. --Magnetometer Highs

Name	Location	value (Gammas)
Oglala	T. 37 N., R. 46 W.	1175
Chimney Butte	T. 40 N., R. 40 W.	946
Kyle	T. 40 N., R. 41 W.	874
Mayo	T. 4 S., R. 4 E.	808
Imlay	T. 4 S., R. 14 E.	744
South East	T. 35 N., R. 42 W.	547
Custer	T. 3 S., R. 4 E.	528
Buffalo Gap	T. 6 S., R. 8 E.	457
Rumford	T. 11 S., R. 3 E.	408

The 300-gamma range which separates the high and the low anomalies, covers a large part of the area. The amplitude of the magnetometer lows is not as great, and they are more irregular in design than the highs.

The Smithwick-Porcupine low separates the Oglala and the Chimney Butte-Kyle highs, and reaches a low of 80 gammas (Sec. 25, T. 35 N., R. 41 W.)

An irregular low west of Custer has a low reading of 61 gammas, (Sec. 15, T. 3 S., R. 4 E.). The Red Shirt and Stirk Table lows are somewhat twinned and may join a broad low at Fairburn. The entire western part of Fall River County and the southwestern part of Custer are characterized by a smooth low.

GEOLOGIC ANALYSIS

In the practical application of magnetic measurements to the solution of subsurface problems of economic geology, it is advantageous to carry out magnetic studies over known geologic features. In this respect the present magnetometer survey covered a large part of an area where the general geology is well known. The structural provinces have been described under stratigraphy and structure.

Possible causes of magnetic features are: (1) large-scale heterogeneity of Precambrian basement rocks; magnetic maps suggest the presence of boundaries between rocks of contrasting magnetic properties; (2) orogenic and major structural provinces, which seem to be concordant with magnetic features; (3) topography of the Precambrian surface; (4) deep-seated iron body in magma; (5) concentrations of magnetic material in granite wash; (6) basal conglomerate on a Precambrian surface; (7) concentrations of magnetic minerals in Paleozoic and Mesozoic rocks; (8) changes in thickness of the Redbed section; and (9) pegmatite intrusions in Precambrian metamorphic rocks.

The interpretation of a magnetometer map is greatly aided when its features are compared with similar maps that have been correlated with geologic features.

In areas where sedimentary formations are thick, effective magnetic members such as ferruginous shales, sandstones, volcanic tuffs, and conglomerates yield magnetic highs over anticlines. Erosion of magnetic formations from the crest of an anticline yields a magnetic low, with magnetic highs somewhat surrounding it. A fault in sedimentary formations is indicated by an abrupt drop of a few hundred gammas, especially if the basement rocks are affected. If the axis of an anticline has been shifted, the concordant magnetic high is directly above the Precambrian granite core at depth and to one side of the structure at the surface. A magnetic high over an anticline is long and narrow and of moderate intensity, as compared to a high over a basic igneous body which is irregular in design and of abnormal magnetic intensity.

In regard to these factors, the present magnetometer survey yielded comparisons between the structure of the area and the earth's magnetic field which will justify certain conclusions.

A synclinal lobe of the Williston Basin (fig. 1) trending northeast-southwest in the northeastern part of Fall River County, is situated between the Black Hills Uplift and the Chadron Dome. It is concordant with a magnetic low that lies north of Oelrichs, between it and the Cheyenne River. A Bouguer Gravity low (Woollard, 1955) trends northward from Nebraska into this area.

Although the structure of the Cascade Anticline is well defined by high-angle dips of the Cretaceous formation for a distance of many miles especially on the west flank, it is not indicated by magnetic anomalies. The Chilson and Cottonwood anticlines are also not indicated by magnetic anomalies or outlined by isogam contours. A magnetic high at Rumford lies to the west of the Chilson axis. A magnetic low at Cascade Springs is concordant with the synclinal structure between the Cascade and Chilson anticlines. A magnetic low is likewise present in the syncline between the Cottonwood and Chilson anticlines. The magnetic intensity is below normal, and does not vary more than 180 gammas over this structural province. The region apparently contains uniformly light-colored acidic igneous rocks in the Precambrian basement, and the Paleozoic and Mesozoic formations do not contain an unusual amount of magnetic minerals.

A broad uniform magnetic low in east-central Custer County includes the eastern part of the Central Black Hills crystalline area and the east-dipping outcrops of the Paleozoic and Mesozoic rocks. The Precambrian surface slopes about 200 feet per mile eastward, and the regional dip of the sedimentary formations is also to the east at about 100 feet per mile (fig. 4); this indicates that the magnetic anomaly is not caused by structure. The low magnetic anomaly is flat and does not vary more than 40 gammas. The low underlies the general region of outliers of Tertiary sediments. A basin in the Precambrian surface filled with placer gravels could yield a magnetic low of this type (Heiland, 1940). The small Fairburn anticline lies in the center of the low anomaly. The depth to the Precambrian is estimated at 4000 feet under the anticline. The aforementioned Bouguer Gravity low crosses the magnetic low.

The Custer and Mayo magnetic highs are probably caused by pegmatite dikes and sills in the Precambrian schists, slates, and quartzite.

A major geologic feature in the northern Great Plains is the Cambridge Arch of Nebraska, which is reflected as a magnetic high in northern Kansas (Merriam, Hambleton, 1959) and in Red Willow County, Nebraska.

The large Oglala magnetometer high in southwestern Shannon County seems to lie along the northern side of, and to coincide with the Chadron Dome. The surface expression of the dome is indicated by extensive outcrops of the Niobrara Formation.

The Chadron Dome trends northwest-southeast and appears as a broad rounded dome. A long narrow anticlinal axis extends from the dome northwestward between Slim Buttes and Oelrichs (Darton, 1918); this coincides with the western part of the Oglala magnetic high. The magnetic intensity may be caused by the Precambrian granite core at a depth of 2800 to 3400 feet.

The Oglala magnetic high may be connected through a series of moderately high magnetic readings to the Mayo and Custer highs. This suggests a connection between the core of the Black Hills Uplift and the Chadron Dome-Cambridge Arch.

An important feature of the map is a magnetometer high in northeastern Shannon County. The triangular design of its three peaks may indicate differences of basement rock type, because magnetic susceptibility changes caused by different basement rocks can result in local polarization of irregular design. On the other hand, an extended Precambrian buried ridge should result in a linear magnetic high.

The lack of magnetic features and the general low range of magnetic intensities in the outcrop area of the lower Mesozoic rocks and all the Paleozoic formations, indicates that there is no significant concentration of magnetic minerals in these beds.

The Precambrian surface north of Custer is about 6500 feet above sea-level, and is 1325 feet below sea-level in the Amerada #1 Moody oil test (Sec. 8, T. 12 S., R. 6 E.). The difference of 7825 feet in 60 miles shows a slope of 130 feet per mile southward. The difference of the general magnetic intensity as measured, not including the Custer and Mayo magnetic highs, is about 600 gammas sloping in the same direction. The thinning of the sedimentary rock section from south to north, coupled with the topographic difference possibly explains the magnetic gradient.

Table 2. --Borings Which Penetrated the Precambrian Basement

Fall River County

No.	Company	Farm	Loc.	S	T	R	Alt.	Depth Pre-€	Alt. Pre-€	T.D.	Boring
2	Amerada #1	Moody	NW¼NE¼	8	12 S.	6 E.	3650	4775	-1325	4980	Oil Test
9	Amerada #1	Voorhees	NE¼SW¼	25	10	8	3332	4132	-800	4142	Oil Test
74	Black Hills Ordn. Dep.		SE¼SE¼	3	10	2	3064	3915	-251	3999	Water Well

Shannon County

1	Amerada #1	Red Eagle	NW¼NW¼	25	36 N.	48 W.	3344	3358	-14	3367	Oil Test

The Precambrian rocks were penetrated in three oil test borings and one water well (Table 2), all located in the southern part of the area. The rocks were all granite. The Black Hills Ordnance Depot water well and the Amerada #1 Moody oil test (fig. 3) found the Mississippian Pahasapa formation lying on the granite surface. The Amerada #1 Voorhees and the #1 Red Eagle (fig. 2) found the Pennsylvanian Minnelusa lying on the granite.

CONCLUSIONS

The regional magnetometer map of Custer, Fall River, and Shannon Counties has a normal magnetic intensity of 300 gammas, which divides the area into two general patterns. The eastern half is generally higher than normal, indicated by four magnetic highs, and the western half is generally normal or lower in magnetic intensity except for the Mayo and Custer highs.

There is no agreement between magnetic anomalies and geologic structure in Custer and Fall River Counties. A large magnetometer high corresponds with the Chadron Dome which is a buried Precambrian ridge, indicating its possible connection with the Black Hills Uplift. The triple magnetometer high in northeastern Shannon County indicates changes in Precambrian rock type.

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CUSTER COUNTY

No.	Company	#	Well	Location	Sec.	Twp.	Rge.	Altitude	Greenhorn Depth	Greenhorn Alt.	Total Depth
8	Continental	1	Harrison	SW¼SE¼	24	3	8	3208 Kb.	655	2553	1545
13	Gary	1	Bohling	SE¼NE¼	2	3	10	2864	1559	1305	2500
14	Gary	1	O'Neill	SW¼NW¼	23	3	11	2804 Kb.	1656	1148	2561
15	Gary	1	Wilsey	NW¼SW¼	33	3	10	3017 Kb.	1619	1398	2530
16	Gary	1	Young	SE¼NW¼	21	4	8	3465 Kb.	660	2805	1605
30	Phillips	1	Govt.-Williams	SE¼NW¼	26	3	10	3025 Kb.	1727	1298	2667
31	Pure	1	Ashmore	NE¼NE¼	5	6	8	3142	1152	1990	1891
32	Pure	1	Bergmeyer	SW¼NE¼	26	3	9	3033	1458	1575	2148
33	Pure	1	Carey	NW¼NW¼	35	4	8	3234	1080	2154	1821
34	Pure	1	Govt. A	SW¼SW¼	14	4	10	2896	1685	1211	2347
35	Pure	1	Govt. B	NW¼SE¼	20	5	9	2976	1586	1390	2183
36	Pure	1	Kellher	NW¼SW¼	33	2	10	2919	1400	1519	2124
37	Pure	1	Stabelfeldt	SE¼NE¼	26	2	8	3408	675	2733	1425
39	Shell	1	Engelbrecht	SW¼SW¼	24	6	8	3036	1675	1361	2880
40	Shell	1	Evans	NE¼NE¼	35	2	9	3091	1403	1688	2603
41	Shell	1	Flier	SE¼	5	3	11	2864	1650	1215	2893

FALL RIVER COUNTY

No.	Company	#	Well	Location	Sec.	Twp.	Rge.	Altitude	Depth Kg.	Altitude Kg.	T. D.
1	Amerada	1	Manders	NE¼SE¼	30	10	8	3379 Kf.	1145	2232	1827
2	Amerada	1	Moody	NW¼NE¼	8	12	6	3650	1698	1952	4980
3	Amerada	1	St. Col.	SW¼SE¼	27	8	7	3366 Gl.	1310	2056	4548
4	Amerada	1	Strat.	NW¼NW¼	29	9	7	3314 Df.	940	2374	1596
5	Amerada	43	Strat.	SE¼NW¼	34	10	8	3291 Df.	1059	2230	1665
6	Amerada	45	Strat.	SW¼SW¼	11	10	6	3478 Df.	1210	2266	1868
7	Amerada	81	Strat.	NE¼NE¼	28	10	7	3507 Df.	1120	2387	2011
8	Amerada	85	Strat.	NE¼SE¼	13	10	6	3383 Df.	1217	2164	2113
9	Amerada	1	Voorhees	NE¼SW¼	25	10	8	3332 Df.	1070	2262	4143
12	Barrows	1	Govt.	NE¼SW¼	1	10	2	3759	335	3424	1314
16	Gary	1	Kimblom	NW¼NE¼	2	12	8	3413Kb.	2339	1274	3105
17	Gary	1	Lounsberry	SW¼NE¼	28	11	6	3753	1864	1889	2803
18	Gary	1	Pettegrew	SW¼SE¼	30	11	7	3560	2261	1299	3161
19	Gary	1	Rasmussen	NE¼NE¼	21	8	8	3242	1694	1548	2566
20	Gary	1	State	SE¼SE¼	25	10	5	3772 Kb.	1505	2267	4782
21	Gary	1	White	NE¼NW¼	3	10	9	3071 Kb.	1264	1807	2180
27	Kunde	1	Shiloh	NE¼NE¼	1	11	3	3525	425	3100	1562
29	Lakota	1	Houghton	SW¼NE¼	34	9	5	3625	-	-	2529
32	Ohio	1	Hedrick	SE¼NE¼	25	9	7	3413 Gl.	1470	1960	4162
33	Osage-Trust	1	Moody	NE¼SW¼	6	12	6	-	16307	-	2840
35	Pacific-Western	1	Chris.-G.	NW¼SW¼	10	11	1	4115 Df.	615	3500	4080
36	Phillips	1	Govt. A	SE¼NW¼	20	7	9	3234 Kb.	1717	1517	2657
37	Phillips	1	Govt. B	SW¼SW¼	5	11	2	4082 Df.	1000	3082	1935
38	Phillips	1	Madsen	SE¼NW¼	21	11	4	3483 Gl.	117	3366	1140
39	Provo	1	Soske	NE¼SW¼	24	10	2	3647	220	3427	3072
40	Pure	1	Barta	NW¼SW¼	4	8	9	3256	1710	1546	2370
41	Pure	1	Govt. C	SE¼SE¼	3	7	9	3150	1655	1495	2352
42	Pure	1	Govt. D	NW¼SE¼	3	11	2	3901	905	2996	1630
43	Pure	1	Govt. E	NE¼NE¼	10	12	4	3659	1070	2589	1747
44	Pure	1	Landers	SE¼NW¼	24	10	4	3483	442	3041	1162
45	Pure	1	Peters	SW¼NW¼	23	9	6	3306	497	2809	1220
47	Pure	1	State	SE¼NW¼	35	9	7	3373	1698	1675	2360
48	Pure	1	Whetstone	NE¼NE¼	6	10	7	3395	1233	2162	1927
49	Raymond	1	Goodnick	NW¼SW¼	23	11	9	3328 Gl.	1074	2254	1740
50	Raymond	1	Govt.-Mitchell	SW¼SW¼	28	11	1	4005 Gl.	740	3265	1510
51	Shell	1	Sides	SE¼NW¼	32	8	9	3241 Kb.	1640	1601	2735
52	Shell	1	Thompson	SW¼NE¼	2	8	8	3142 Kb.	1640	1502	2720
60	Woodward	1	Eckard	SW¼SE¼	21	11	4	3493 USGS	300	3193	835
62	Woodward	1	Hill	SE¼SW¼	23	11	4	3528	295	3233	930
64	Woodward	1	Schmidt	SW¼SW¼	4	12	4	3550	495	3055	1315
65	Woodward	2	Schmidt	SW¼NW¼	4	12	4	3536	435	3101	1315
66	Woodward	3	Schmidt	NW¼NW¼	9	12	4	3550	530	3020	1145
67	Woodward	4	Schmidt	NE¼NW¼	4	12	4	3525USGS	440USGS	3085	3175
68	Woodward	5	Schmidt	SE¼NW¼	4	12	4	3568	470	3093	1860
69	Woodward	1	Benson	SW¼SE¼	14	8	6	3215	830	2385	1656
73	Wright			SE¼SE¼	3	10	2	3655	200	3455	3999
74	Blk. Hls. Ordn.	1		NE¼NE¼	24	8	6	3280	1195	2085	1729
75	Drkamont	1	Burg								

SHANNON COUNTY

No.	Company	#	Well	Location	Sec.	Twp.	Rge.	Altitude	Depth Kg.	Altitude Kg.	T. D.
1	Amerada	1	Red Eagle	NW¼NW¼	25	36 N.	48 W.	3358	415	2929	3367

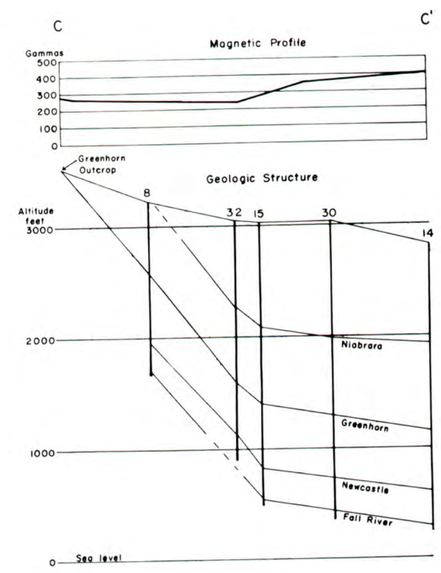

Figure 4. — Cross-section C-C', Showing Geologic Structure and Magnetic Profile.

5 0 5 10 15 MILES

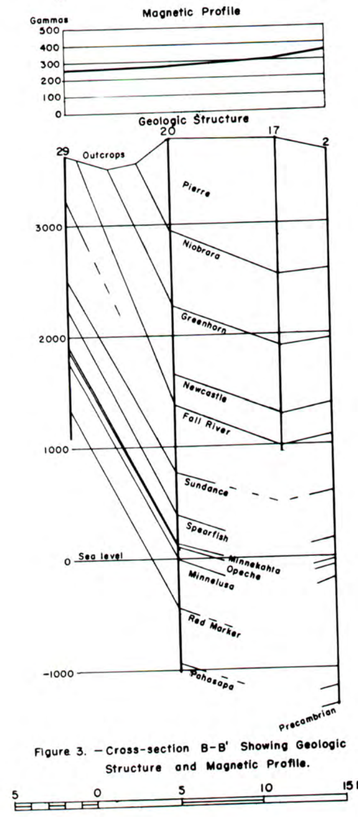

Figure 3. — Cross-section B-B' Showing Geologic Structure and Magnetic Profile.

5 0 5 10 15 MILES

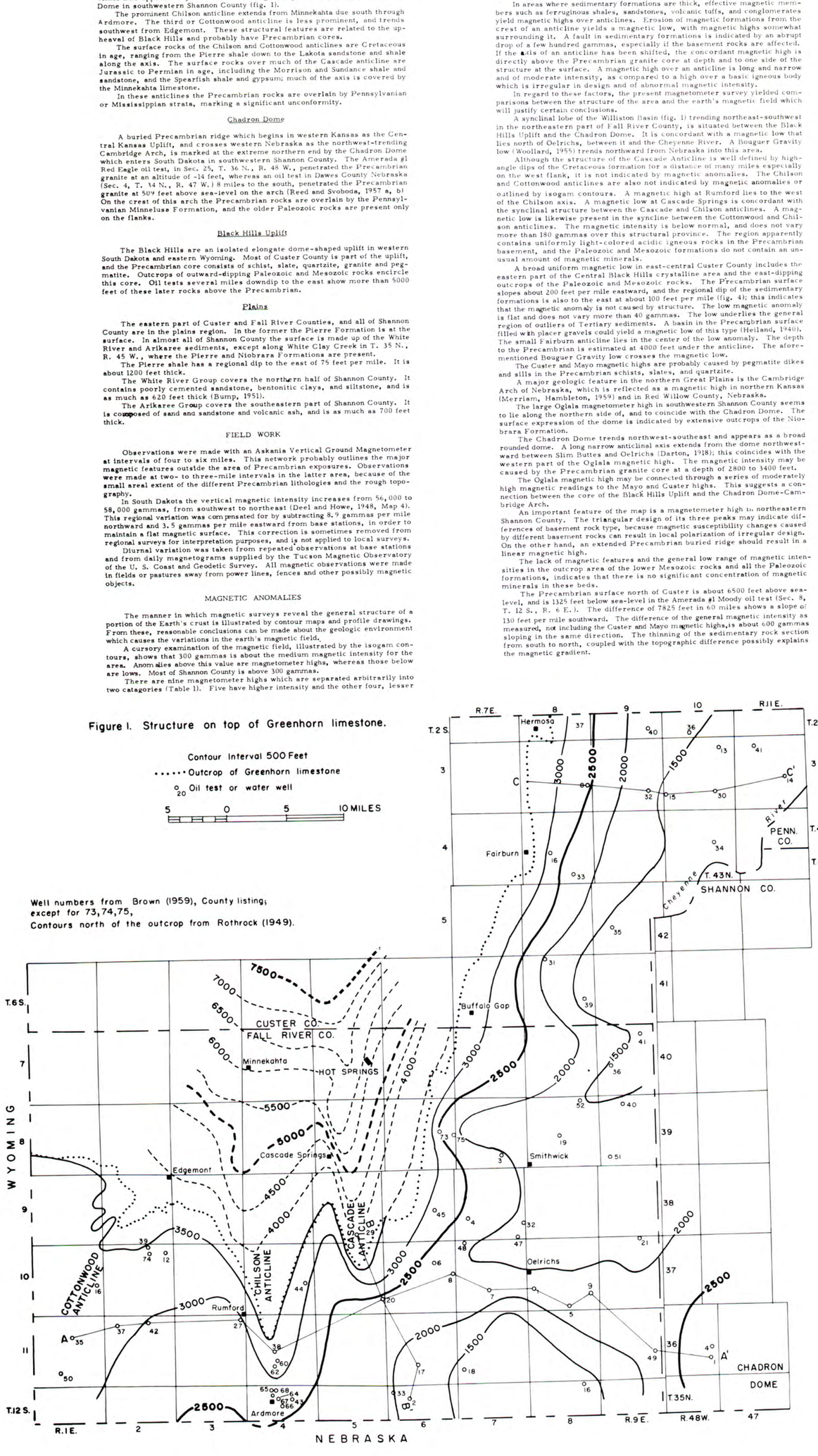

Figure 1. Structure on top of Greenhorn limestone.

Contour Interval 500 Feet

Outcrop of Greenhorn limestone

Oil test or water well

5 0 5 10 MILES

Well numbers from Brown (1959), County listing, except for 73, 74, 75.

Contours north of the outcrop from Rothrock (1949).

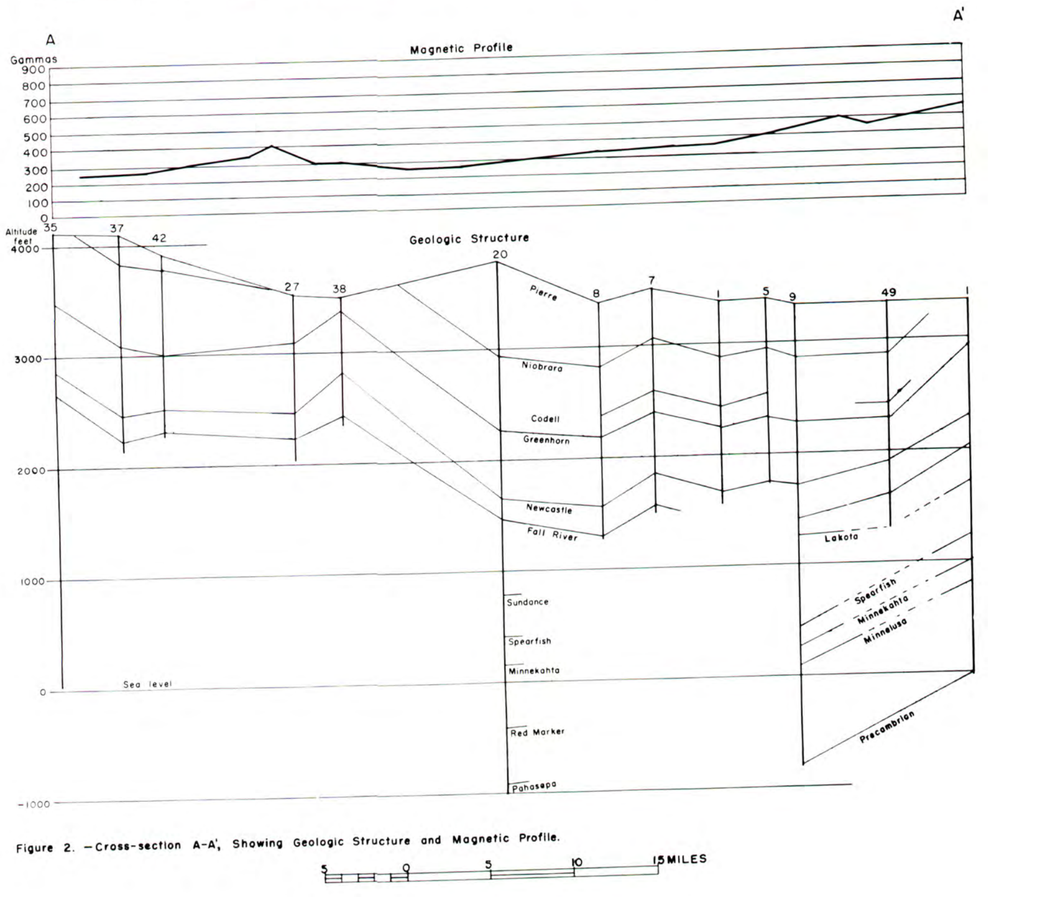

Figure 2. — Cross-section A-A', Showing Geologic Structure and Magnetic Profile.

5 0 5 10 15 MILES