REPORT ACCOMPANYING GROUND MAGNETIC MAP OF HOMER AND SPRING ARBOR 15' QUADRANGLE, MICHIGAN

by

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INTRODUCTION

During the summer of 1980, a precision ground magnetic survey was made over the two 15' quadrangles which cross the central part of the Albion-Scipio oilfield in southern Michigan. The objective was to try to verify that basement faulting controlled the location of this long, narrow field, as had been suggested by earlier gravity work.(1) This research was done as a cooperative project involving the Michigan DNR - Geological Survey Division, Geology and Minerals Research Unit and the Dept. of Geology of Western Michigan University. Western Michigan University's efforts on the project were funded by a gift from the Hunt Energy Corporation.

DESCRIPTION OF AREA

The area is totally blanketed by gently rolling glacial moraine and outwash sediments which vary from tens to hundreds of feet in thickness. Approximately 5000 to 6000 feet of Paleozoic sediments lie beneath the glacial cover. Below the Paleozoic rocks, which here represent the southern edge of the Michigan Basin, lie poorly known and undifferentiated Precambrian igneous-metamorphic basement rocks. The Albion-Scipio field is one of the oldest and is the most productive in the Michigan Basin, producing from dolomitization porosity in the Ordovician Trenton-Black River limestones. Surface land use is primarily agricultural, with lesser amounts of land left to woodland or undrained marshes. Access is easy via a network of roads on a one-mile grid which is interrupted occasionally by wetlands.

SURVEY DESIGN AND SPECIFICATIONS

The nominal survey design was to occupy stations at 0.5 mile intervals along E-W roads, normally separated by 1.0 mile in the N-S direction. All readings were to be made by absolute, total-field proton-precession magnetometers with one gamma precision. The goal was to have sufficient confidence in station values to contour with 5 gamma or smaller contour intervals.

Four test sites were surveyed in nearby Kalamazoo County to examine the variability to be expected at a station site due to geologic "noise" and unnoticed cultural features while using a hand-held magnetometer. These data were used to determine the optimum number of readings and their spatial distribution around the station site required to produce a reliable magnetic value for that station. The test grid results are summarized in Table 1. Sites 1 and 3 are low-lying areas with homogeneous, relatively fine-grained soils chosen to be representative of good field conditions and show much less variation than sites 2 and 4, which are probably worst-case station sites. Site 2 had boulders of various lithologies at the surface, and site 4 probably had concealed boulders or soil remanent magnetization due to lightning strikes.

Table 1. Results of test grid measurements for determining local variability of magnetic field on typical glacial sediments.

Site	Description of site	Number of Readings	Grid Size	Length	Width	Range Gammas	Std. Dev. Gammas
1	Outwash plain	48	5' x 5'	75'	10'	15	2.78
2	Bouldery end moraine	48	5' x 5'	75'	10'	56	11.2
3	Valley bottom in moraine complex	105	3' x 3'	60'	12'	12	2.70
4	Hilltop in moraine complex (near site 3)	105	3' x 3'	60'	12'	51	12.0

SURVEY TECHNIQUES

One person was generally at the base station and two with the mobile magnetometer. All had matched, synchronized digital watches with 1 second displays to ensure simultaneity of base and mobile magnetometer readings. The magnetometer sensor and staff were clipped to a cartop carrier while traveling between stations. The driver maintained radio contact with the base operator and also marked station locations on a map. The field map had a one centimeter grid superposed and each station was assigned a north and east coordinate, to the nearest millimeter, by the driver. The operator wore the magnetometer console in a shoulder harness and had only to connect the sensing head when he left the car at each new station. The operator walked at least 100 feet from the road at a prospective station location (open field or woodland) and the driver called the base operator to inform him a series of readings was to start at the next minute. The mobile operator took a single reading, wrote it in a notebook, paced forward 5 steps, and exactly 20 sec. after the previous reading, started another magnetometer cycle. He continued until 16 readings were finished (200 - 225 linear feet) or until he aborted the series because of scatter or continuous steep gradients, in which case he searched for a more suitable site or abandoned the location entirely. This type of problem often occurred

while in the oil field, due to the buried pipelines and well casing.

Due to the 3 to 5 mile reliable range limit of the CB radios, the base station had to be moved whenever approximately 20-25 square miles has been covered. The mobile operator and driver selected a new base, usually several hundred feet from a road and in the shade. They verified that no steep gradients existed and then placed the sensing head in a marked location, usually against a tree. They called the base operator, who was still at the previous base, and initiated a series of ten readings taken simultaneously by both magnetometers without moving either one. Thus, datum was passed from the old base to a new one, and the base station operator then moved his car and equipment to the next base. The two magnetometers were normally checked against each other once per day at a base station by alternately placing one sensing head, then the other, at the same location, and repeating a number of times. The averaged readings always agreed to less than one gamma.

Data books were photocopied every few days. Mobile and base magnetometer data were entered with time and location data into a data file at the WMU Computer Center. Some of the data were entered on evenings or on rainy days via long distance telephone and a terminal located in the place of lodging of the field crew. The terminal or computer listings were used to verify the data, and also to check for single-station anomalies on a map which was hand contoured as the survey progressed. Repeat stations and some new stations were surveyed after the main phase of data gathering was completed. Also, at this time a different path was taken to independently re-connect all the base stations to improve the reliability of the base station values.

DATA REDUCTION

The raw data were added periodically to a disk file at the WMU computer center. A simple FORTRAN routine was made to take the difference between the 16 pairs of base and mobile magnetometer readings for a station to remove diurnal or other temporal effects. A mean and standard deviation for the base station readings were calculated. An initial mean and standard deviation of the mobile-base differences was then calculated. As a crude filter for erratic values at each station, any values deviating from the mean by more than two standard deviations were rejected. A second or new mean and standard deviation of the differences were calculated. Finally, the mean difference value for the station was added algebraicaly to the base station value to give the mobile or station magnetic reading. (There are better ways of excluding high or low readings, and they will be used in later reprocessing of the data.)

PRESENTATION OF RESULTS

The processed base and mobile station data were stored in an output file which is reproduced as Appendix I. Each line is the pertinent information for one station. An incremental computer-driven drum plotter was used to plot station symbols and the low-order three digits of the magnetic value from the output file onto a stable film base map for all stations. To determine if three gammas was a reasonable minimum contour interval, the "t" test was applied to find whether the magnetic value was within ±1.5 gammas of the true mean for the station with 95% confidence. An average of 15 usuable readings per station gave 14 degrees of freedom. From the "t" table $t_{0.975} = 2.145$. Since $tS\sqrt{N}$ must equal 1.5, we solved for the standard deviation, S : $S = 1.5\sqrt{15}/2.145 = 2.71$. Thus, with 95% confidence it can be said that the mean lies within ±1.5 gammas of the true value if the standard deviation is less than or equal to 2.71 gammas. Since 87% of the stations had a standard deviation less than 2.71 gammas, a contour interval of 3 gammas was determined to be reasonable.

The computer-plotted data were hand-contoured with 3 gamma intervals and 15 gamma intervals in areas of steep gradient. No regional field was removed from the data, but will be done in later reprocessing.

OBSERVATIONS AND PRELIMINARY INTERPRETATION

The contour map has a number of striking features. At the SW corner, a linear negative anomaly strikes approximately N50°W. This is part of a much (2) larger feature clearly visible on the Aeromagnetic Map of Michigan.[2] Its origin has been postulated by others to be a wide dike-like body of reversely magnetized mafic intrusive rock, probably of Keeweenawan age and satellite to the main mid-Michigan paleorift further to the NE. The vector of magnetization is probably directed upward and to the south, as the steeper gradient is on the NE edge of the "dike". The two oval highs on the NE side of the strong negative anomaly are at least partly related to the adjacent strong low due to the dipolar anomaly nature resulting from the non-vertical magnetization of that "dike"-like body. North of this pair of highs is a series of five lows aligned subparallel to the "dike". An axial line can be drawn connecting these lows, extending from near the west margin of the map to the vicinity of the Albion-Scipio trend, where it is truncated or turned abruptly to the north. This could be a low-susceptibility greenstone band or a much narrower reversely magnetized dike. At the NW corner of the map is a part of a broad magnetic high with a small sharp peak having much steeper gradients at its center. This central feature could be due to a pipe-like intrusive body. The combined magnetic relief is about 300 gammas. This high can be connected to an ESE trending magnetic ridge with two smaller maxima. This axial line also terminates against the Albion-Scipio trend, or is

shifted north to culminate in the broad high SE of Albion. To the SW of Albion is a strong low which also must have its origin in reversed remanent magnetization, because it does not lie to the north of a strong high as would be the case for magnetization by induction in the present field having inclination of 75°. This could be a stock or plug of material similar to the "dike" in the SW corner of the map. To the SE of Albion is a circular high with about 100 gammas amplitude. The form and moderate magnetization suggest an unmetamorphosed granitic pluton magnetized in the direction of the present field. This body is the only one on the east side of the Albion-Scipio trend which has significant magnetic expression, the remainder of the area having less than 60 gammas relief. A NE trending magnetic ridge at the south-center edge of the Spring Arbor Quadrangle is bent or offset to the NW as it crosses the Albion-Scipio field. There are no anomaly axes or trends which are not altered where they cross the Albion-Scipio trend.

CONCLUSIONS

The goal of making a precision ground magnetic map covering a large area has been met. In addition, there is now magnetic evidence for a significant structural break in the Precambrian basement directly beneath the Albion-Scipio oil field. At least 3 linear anomaly trends are either truncated or offset in a left-lateral sense with apparent displacement of nearly three miles. Magnetic relief is much less, with the exception of one anomaly, on the east side of the Albion-Scipio trend. This could imply that magnetic basement is somewhat deeper, or is different lithologically. Obviously, the major movement on this fault occurred prior to deposition of the Paleozoic sediments, with minor motion occurring until after deposition of the Trenton limestone. Dolomitization could then have been caused by circulating meteoric waters in the fault zone, or perhaps by hydrothermal fluids ascending in the fault zone.

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APPENDIX I

LISTING OF PRINCIPAL FACTS FOR MAGNETOMETER STATIONS,

Explanation:

Columns 1 and 2 give the coordinates of the magnetometer stations; "X" is in cm East and "Y" is in cm North of the origin, which was arbitrarily chosen at the SW corner of the survey area, at 42°N, 85°W.

Columns 3 and 4 are the correspnding locations of the base stations. All coordinate distances are on 1:62,500 map scale.

Columns 5, 6, and 7 give the date at which the station was occupied.

Columns 8 and 9 give the time in hours and minutes of the first reading at a station.

Column 10 gives the number of readings taken at the base station, all at intervals of exactly 20 seconds.

Column 11 is the standard deviation calculated for the series of readings at the base station.

Column 12 gives the number of readings used from the station site. These were normally spaced at 15 foot intervals along a linear, L-shaped, or T-shaped pattern. The erratic values, more than two standard deviations from the mean of the site, have been rejected.

Column 13 is the second standard deviation of the site magnetometer readings, calculated after the erratic values were rejected.

Column 14 is the mean station value which is plotted on the map.