SURFACE MAGNETIC SURVEY
OF SOUTH - CENTRAL
PIKE COUNTY, OHIO

A Thesis

Presented in Partial Fulfillment of the Requirements
for the Degree Bachlor of Science

by

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The Ohio State University
1982

RESEARCH AWARD
1982

Approved by

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ACKNOWLEDGEMENTS

This list can in no way mention all of the people who helped with this survey, either technically, financially, or morally. Below are listed some of the people whose help is especially appreciated.

Thanks are extended to Dr. Hallan Noltimier who suggested the project and contributed his knowledge and time and who kept the survey going despite several equipment failures.

A very special thanks is extended to those who made this survey financially possible. My parents not only offered moral support but also most of the financial support. Thanks are also extended to the Friends of Orton Hall for their financial support as well.

Thanks to Karen Tyler for her help and advise on the drafting of the residual map. Thanks are also extended to Dave Little who donated both time and materials in photographically reducing the residual map.

Last but not least, a final thanks is extended to the residents of Pike County, Ohio, who for the most part, allowed me access to their property.

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Introduction

This surface magnetic study in south-central Pike County, Ohio was undertaken for the purpose of confirming in much greater detail the presence of several significant magnetic residuals observed during an aeromagnetic survey by Rhonda Patterson. (Patterson, 1980).

The survey covered approximately 130 square miles, essentially 13 miles south by 10 miles west of the town of Waverly, Ohio. Using a Barringer Precession Magnetometer, the total component of the earth's magnetic field was measured along a grid system in which stations were spaced approximately 1/2 minute of latitude by 1/2 minute of longitude. The grid system was subdivided further into 1/4 minute by 1/4 minute rectangles in areas where the readings were unusually high or low. Approximately 625 readings were taken.

Due to the daily diurnal changes in the amount of electric current in the upper atmosphere and changes this causes in the surface geomagnetic field, a centrally located base station was established in which three daily readings were taken. Each day's data was then adjusted for the diurnal variation and the data was then adjusted for changes which occured over the period of the survey.

A table for the IGRF values was calculated using the IGRF values from Patterson's survey. Each reading in this survey was assigned an IGRF value and that value was subtracted from the adjusted observed value to produce the residual values. A contour map was then constructed. The major northeast-southwest anomaly was modelled first assuming it was due to an intrusion, and secondly assuming it was due to faulting within the basement.

Survey Location

The survey area covered approximately 130 square miles in south-central Pike County, Ohio. (Fig. 1). The boundry lines for the survey area are from 38°57' to 39°07'30" North Latitude by 83° to 83°10'30" West Longitude. The area includes all of the Piketon Quadrangle, the nothern 1/3 of the Wakefield Quadrangle, the northeastern 1/8 of the Rarden Quadrangle, and the eastern 1/3 of the Latham Quadrangle.

The town of Waverly, Ohio is located in the northeastern corner; the town of Wakefield in the southeast; the town of Mt. Joy in the southwest; and the town of Idaho in the northwest corner of the survey area.

Grid System Layout

A grid system, 1/2 minute of latitude by 1/2 minute of longitude was laid out on the 7 1/2 minute quadrangle sheets, with projected station locations established at the intersection of the N-S and E-W lines of the grid system.

Several factors were considered when laying off the grid system. The density of the stations should be large enough to delineate the major anomalies. In addition, the grid system for this survey was intended to be on a scale which would be comparable with Patterson's 1980 survey. Her readings were taken every .4 km. or .24 miles. This spacing was along her flight lines. There was considerably greater separation than this between her different flight lines, however. (Fig. 2).

In this survey, the grid system was spaced so that readings were 1/2 minute of latitude by 1/2 minute of longitude. This corresponds to approximately 1/2 mile by 1/2 mile. After the survey was covered at this interval, the grid system was split

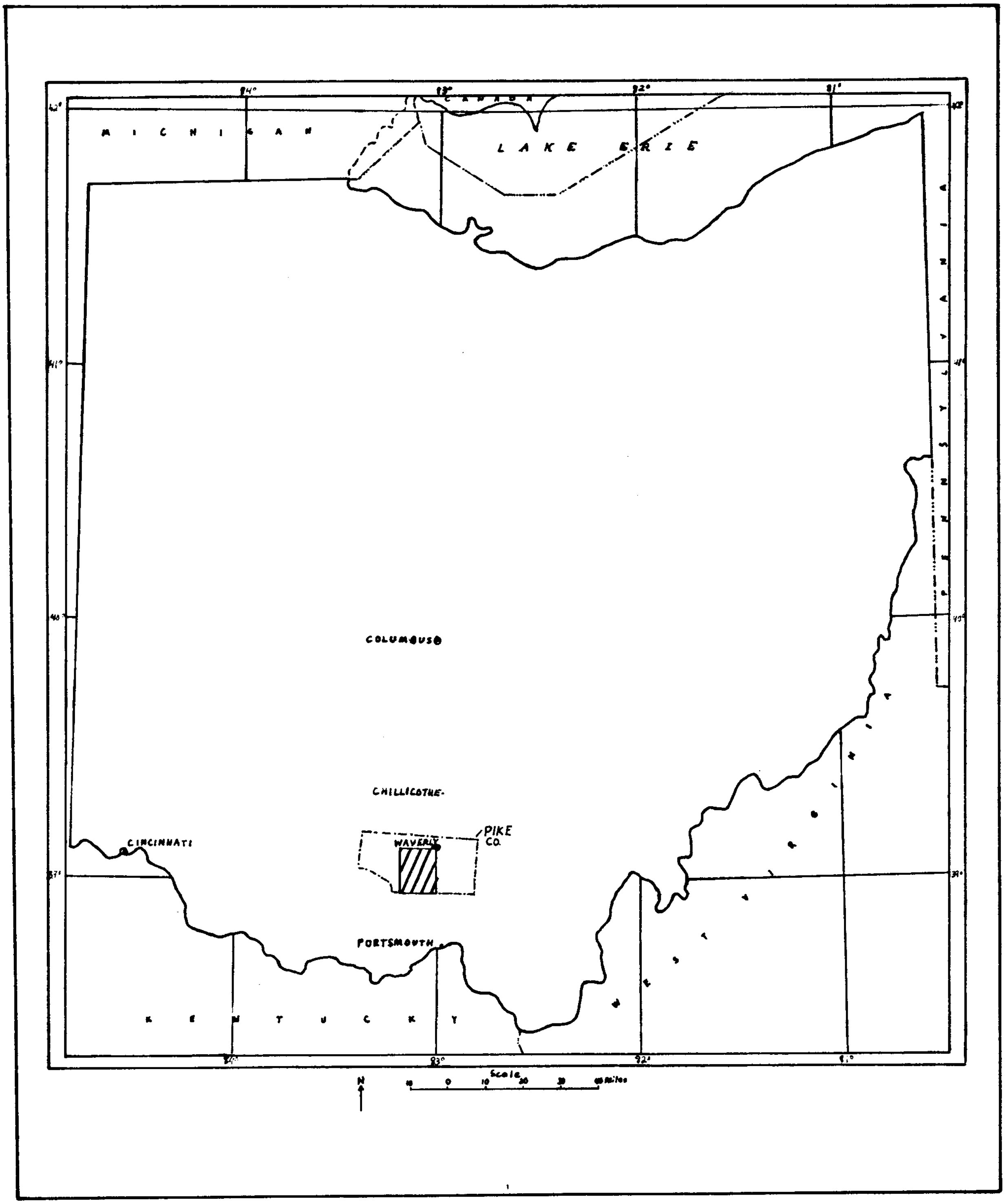


Figure 1. Survey Location.

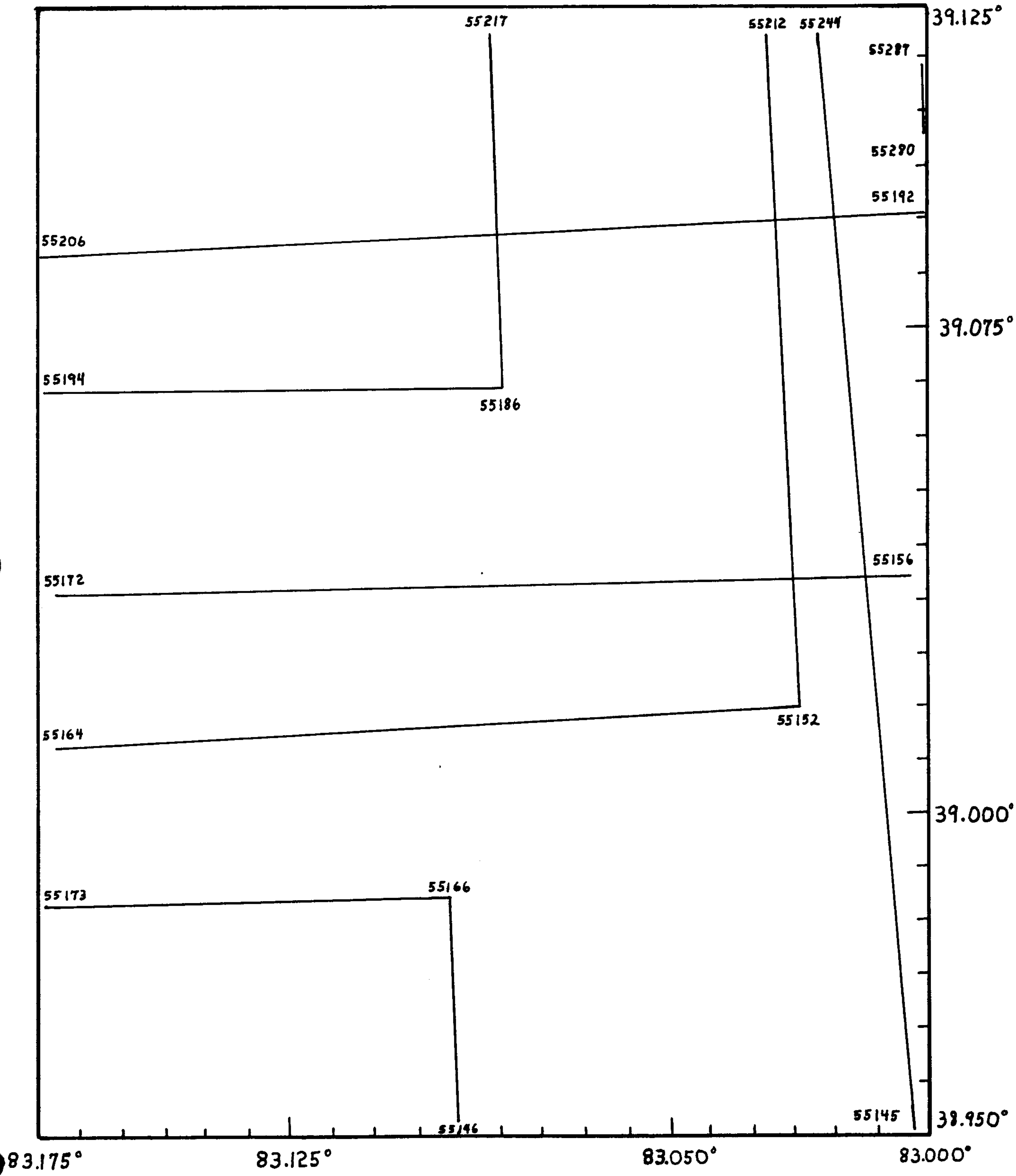


Figure 2. Patterson's 1980 aeromagnetic flight lines and IGRF values within this survey area.

up and readings were taken every 1/4 minute of latitude by 1/4 minute of longitude in those areas exhibiting high and low values.

One final factor for choosing this grid system pertains to the convenience in computing the value of the International Geomagnetic Reference Field (IGRF) for each station. Due to the lack of accessibility of certain areas, in part due to the rugged terrain, in part due to the lack of owner's consent, and in part due to time constraints, the corners of the grid system were obtained in only 15 to 20% of the cases.

465 out of a possible 484 readings were taken using the origional grid system with over 150 more readings taken when the grid system was split up. Most of those readings were taken along the eastern edge of the map where the field drops off and in the central and southwestern areas where the readings are higher.

Piketon Uranium Enrichment Plant and it's Effect on the Survey.

If one looks closely at the residual map (Fig. 3), there is a lack of stations on the eastern border of the map, especially in the central portion. This lack of stations is due to the Goodyear Atomic Corporation's Uranium Enrichment Plant in Piketon, Ohio. This plant is operated by the United States Department of Energy and the security there is very tight. Permission to obtain readings was sought from the Department of Energy and permission was given to obtain readings only around the access roads. This eliminated about 10 stations from my projected survey.

Another problem related to the plant stems from the large amount of electricity used in the enrichment process. Power lines come in from all directions into the plant with several substations around the perimeter of the plant near the access roads.

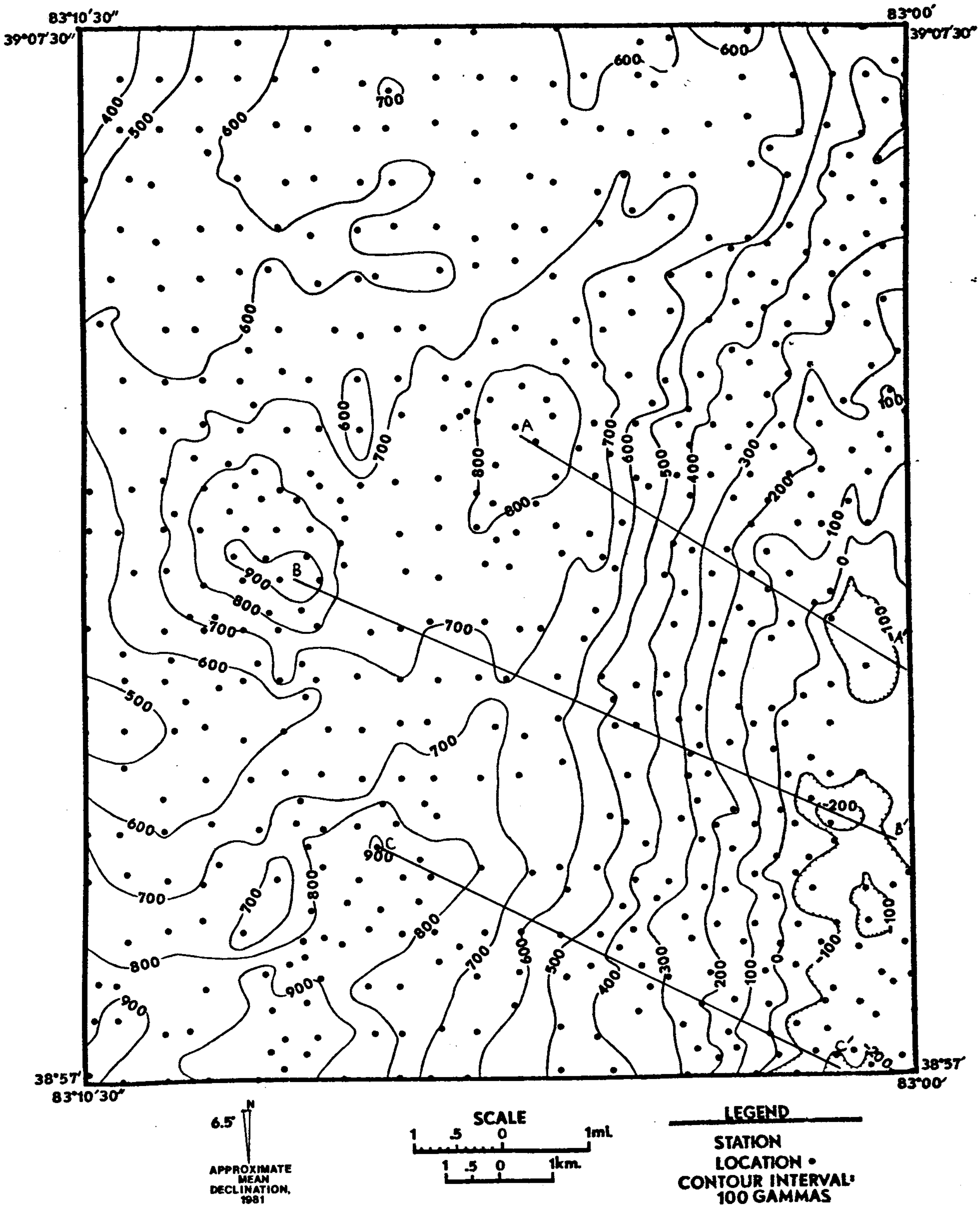


Figure 3. Surface magnetic residual map of south-central Pike County, Ohio. (Pennington, 1982).

The gradients set up by these lines were so great as to affect the magnetometer in distances of up to a 1/4 of a mile radius of the lines, making accurate measurement of the earth's field impossible. Many of these power lines extended out into the survey area and at times prevented accurate measurements in the vicinity of these lines.

The survey area, located in south-central Pike County, Ohio, is to the south of the glacial boundry in Ohio. The Scioto River and its floodplain dominates the eastern 1/3 of the area. The Scioto River Valley is the main drainage basin for central and southern Ohio, flowing into the Ohio River 20 miles to the south of the survey area. While Pike County was not glaciated, the Scioto floodplain contains a large amount of outwash gravels. This outwash was carried downstream and deposited when the discharge from melting glaciers to the north was greater during the Pliestocene. The gravels are being quarried extensively today. Within these gravels, there is a large amount of groundwater in storage. This groundwater is the main source of "cooling water" for the Uranium Enrichment Plant in Piketon.

Several smaller streams flow into the Scioto River within the survey area. (Fig. 4). To the north, Pee pee Creek, which has been dammed, forming Lake White, flows from the northwest to the east, while in the center of the area, Sunfish Creek flows from west to east and Beaver Creek from east to west, and to the south, Camp Creek, flowing from west to east, empties into the Scioto River. There are also many smaller intermitten streams within the survey area.

The western 2/3 of the survey area is a highly dissected plateau. Due to stream erosion, this plateau consists of low hills, whose elevations average about 1000 feet above sea level. These hills, at the present time, are in an active state of erosion. Over a dozen debris flows, of varing sizes were noticed during the survey, with most of these due to man's actions, mainly through road cuts and cutting of trees on hillsides. Several of these flows developed during the survey, while others appear

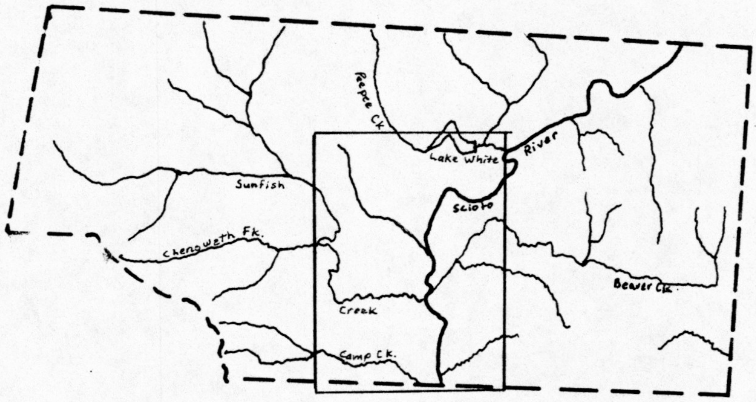


Figure 4. Stream drainage in Pike County, Ohio. (Adapted from Bownocker, 1920).

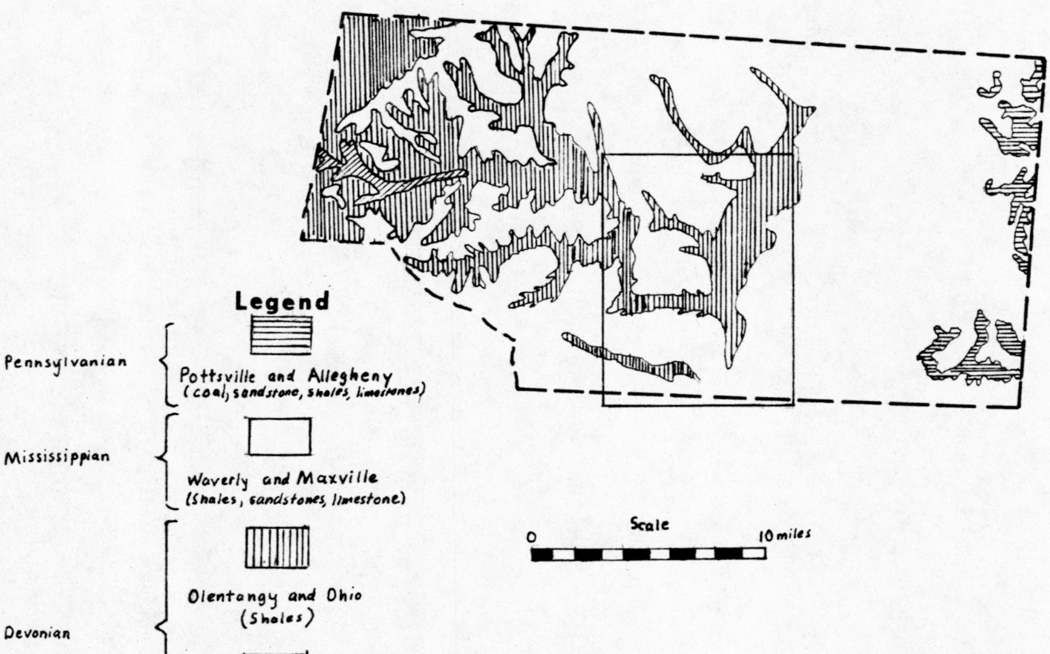


Figure 5. Bedrock geology in Pike County, Ohio. (Adapted from Bownocker, 1920).

to have moved periodically over the past several years, and several older flows, now grassed and treed over, were recognized.

The bedrock within the area is from two formations. The Ohio Shale, Devonian in age, is overlain by the Waverly Sandstone, which is Mississippian in age. The Ohio Shale located in this area is dark and contains kerogens. It is exposed where streams have eroded down through the Waverly Sandstone. (Fig. 5). In the past several years, test wells have been drilled in the area by North American Exploration.

Stratigraphy

The basement rock, Precambrian in age, consists of igneous, metamorphic, and sedimentary rock in Ohio. Within this survey area, the surface of the basement ranges from -3500 feet on the west to -4200 feet on the east. (Fig. 6)

The Paleozoic rocks on top of the basement are Cambrian through Mississippian in age. As was stated in the Surface Geology section, both Devonian and Mississippian rocks exposed in the area. The Ohio Shale, overlain by the Waverly Sandstone, is visible at the surface due to stream erosion.

The overall stratigraphy of the Paleozoic rocks consists of transgressive and regressive sequences of sandstone, shale, and limestone. (Fig. 7) Although the rocks appear to be flat-lying, they have been warped into gentle synclines, and anticlines by the Appalachian Orogeny. (Patterson, 1980).

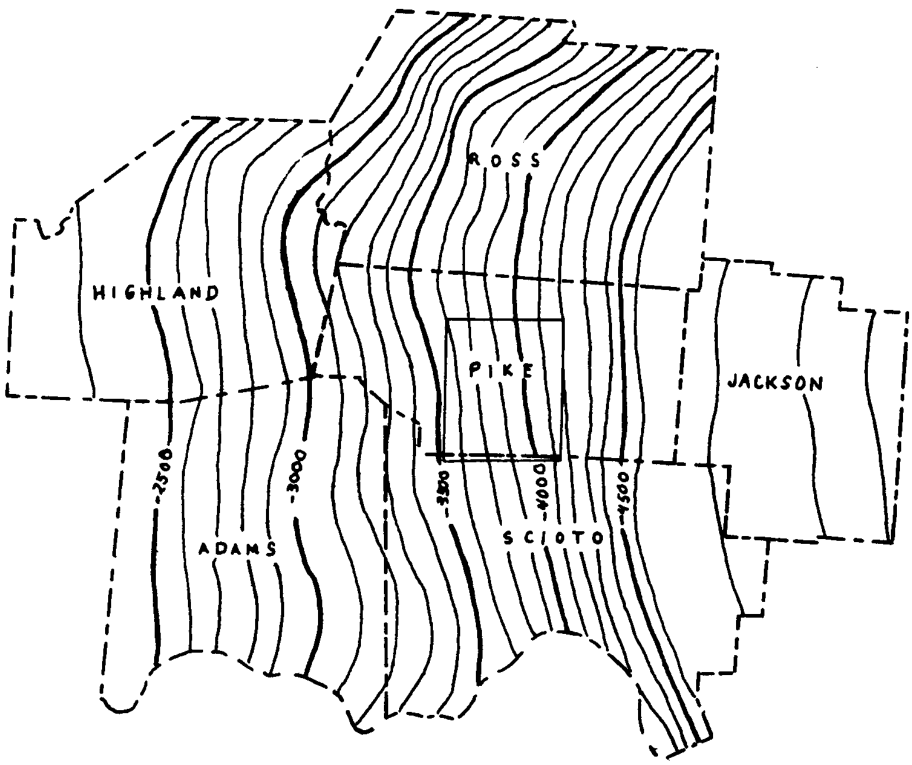


Figure 6. Depth to the Precambrian basement. (Adapted from Botoman, 1975)

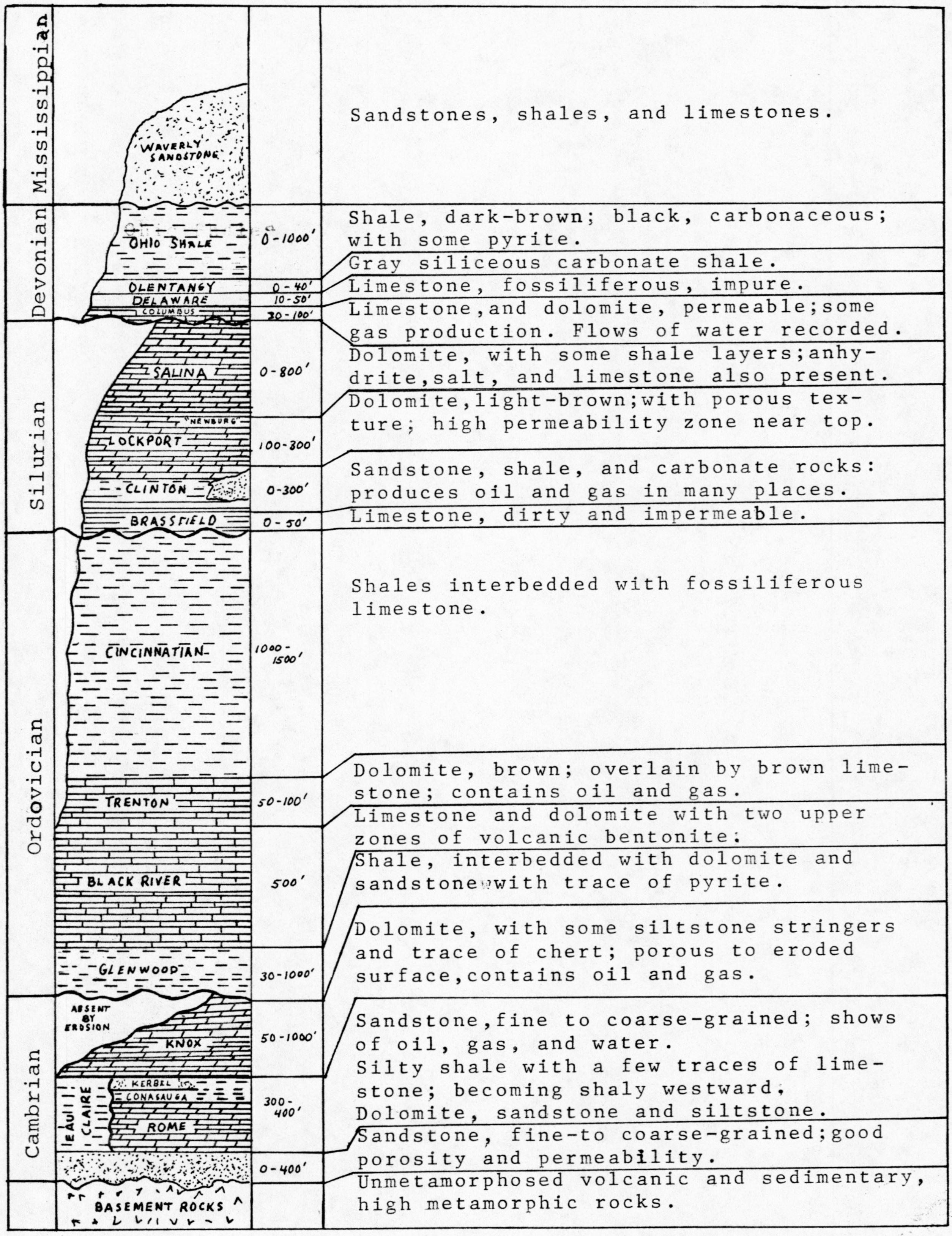


Figure 7. Generalized stratigraphy of western and central Ohio (Adapted from Botoman, 1975)

Most geophysical research in Ohio has been either gravity or aeromagnetic surveys and aeromagnetic studies have concentrated on determining basement structure and topography. The south-central portion of the state was surveyed by Patterson (1980), (Fig. 8). The central portion was covered by Zietz and others (1966). Bromery and McCaslin (1965) located the Greenville Front in northern Ohio by aeromagnetic survey.

Several gravity studies have been conducted in Ohio. Heiskanen and Uotila (1956) produced a bouger gravity map of the state. From a large gravity anomaly in Fayette County, Pincus (1960) suggests that the Paleozoic structure might be related to the basement structure which caused the anomaly. From Heiskanen and Uotila's gravity map, Batsche (1963) concluded that the gravity anomalies are related to variation in density and mineralogy of the basement rocks. He also stated that anomalies within the sedimentary sections, from such features as faults and facies changes would have only a minor influence on regional gravity.

Several seismic reflection studies have been conducted in nearby counties. Tobin (1961) included portions of Clinton, Fayette, Highland, Pike, and Ross Counties of Ohio. He concluded that topographic high exsists in the basement formed by erosion during the Late Precambrian or Early to Middle Cambrian time. He also noted an increase in the amount of dip to the east which he believes could mark the boundry between the Cincinnati Arch or Indiana-Ohio Plateform to the west and the Appalichian Basin to the east.

Mayhew (1969), conducted another reflection survey in portions of Champaign, Clark, Clinton, Fayette, Franklin, Green, Madison, Pickaway, and Ross Counties of Ohio. He found evidence

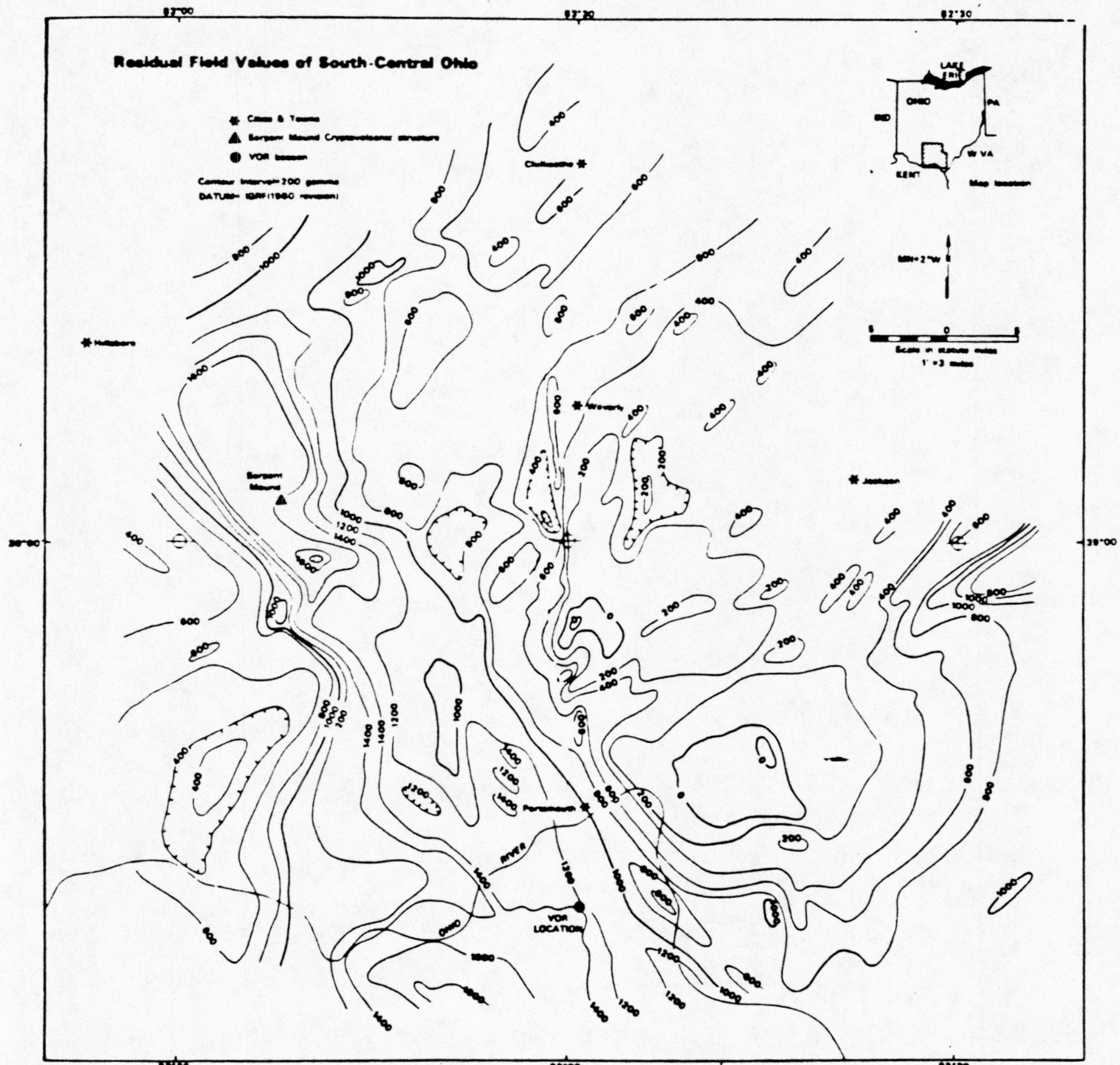


Figure 8. Aeromagnetic residual map of south-central Ohio. (Patterson, 1980).

for possible faulting which cut the Precambrian basement rock and the overlying Paleozoic rocks. Mayhew believes the faulting took place after deposition of the Trenton Formation with later periodic movement on the fault.

Serpent Mound Structural Area

The Serpent Mound Cryptovolcanic area, 15 miles west of this survey in Adams County and portions of the surrounding counties, was first mapped and given the term cryptovolcano by Bucher (1921). He believed its origin was due to deep seated explosive volcanic processes. In 1947, Dietz suggested the term cryptoexplosion structure, and believed the structure was caused by meteorite impact.

Several geophysical studies have been undertaken at Serpent Mound in order to better understand its nature and origin. Sappenfield (1950) did a surface magnetic survey of the area (Fig. 9). Sappenfield concluded from his survey that a basic magma was intruded into the upper part of the basement.

Bull, Corbato, and Zahn (1967) conducted a gravity survey of the Serpent Mound area. (Fig.10). Their positive anomalies corresponds to the negative magnetic anomalies of Sappenfield and vice-versa. It has been suggested by Noltimier (1982) that the magnetic poles were reversed when the material was intruded which would account for this.

Istok (1977) did a paleomagnetic survey of Serpent Mound. He concluded that there was two periods of activity, first deformation in the Carboniferous and then mineralization in the Jurassic.

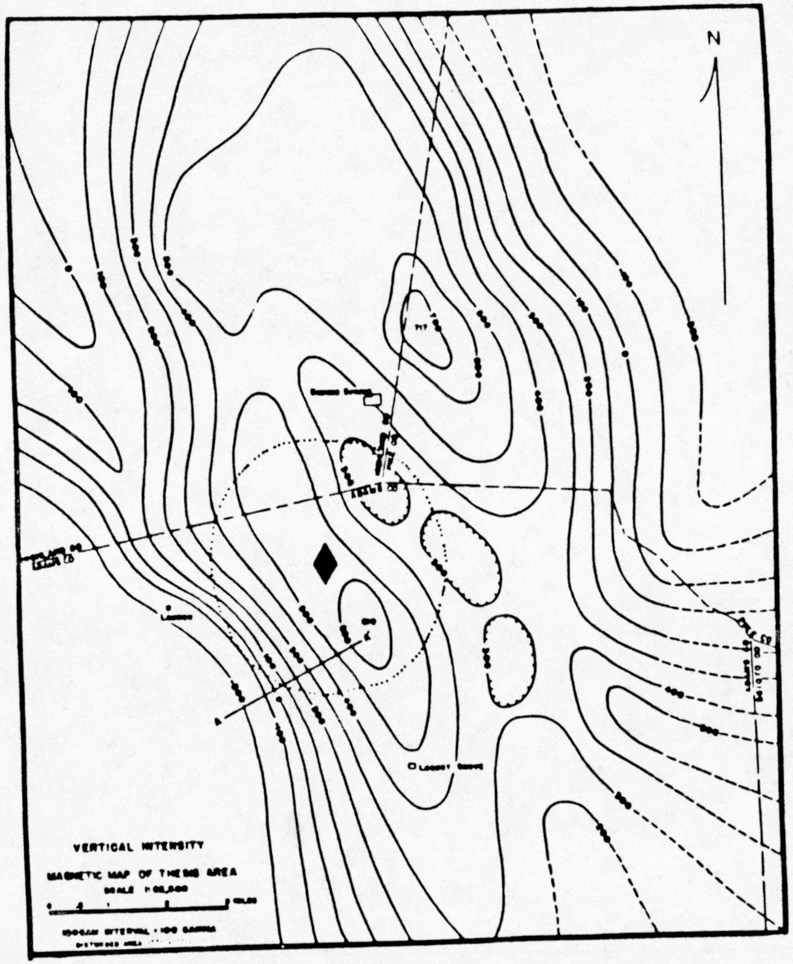


Figure 9. Surface magnetic survey map of the Serpent Mound Structural Area (Sappenfield, 1950).

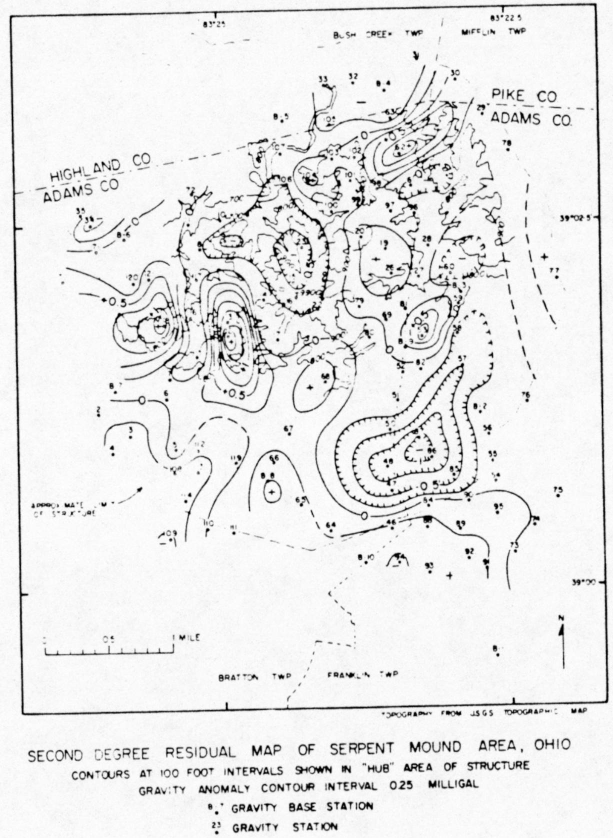


Figure 10. Gravity map of the Serpent Mound area (Bull et al, 1967).

The regional basement structure in the Midwest consists of arches and basins (Figs. 11&12). In Ohio, the Cincinnati Arch dominates the western half of the state while on the eastern half, the Appalachian Basin dominates. The Cincinnati Arch, with an approximate north-south axial trend, splits in western Ohio with the eastern branch, called the Finlay Arch, trending approximately N30E. The Finlay Arch continues into Canada where it is termed the Algonquin Arch. The western branch called the Kankakee Arch, has an axial trend of approximately N50W. It extends through northern Indiana and into Illinois. Many previous studies have been conducted on the Cincinnati Arch and several of the more important ones are listed below.

Locke (1838) was the first to propose that an arch exsisted, with an anticlinal axis in Ohio and Indiana. From studies of the thickness of Paleozoic rocks in Kentucky, Tennessee, and Indiana, Newberry (1863) also concluded that an anticlinal axis exists along the Cincinnati Arch.

The idea that the arch was formed on a Precambrian ridge was proposed by Wasson (1932), who based his evidence on two drill holes in Sandusky and Clark Counties, Ohio. This theory of a ridge was also supported by Lafferty (1941).

Another theory for the formation of the Cincinnati Arch was proposed by Stout (1941). He concluded that instead of the arch being uplifted, it remained relatively stable, and that subsidence due to deposition of sediments in adjacent basins led to the formation of the arch.

Subsidence of the granitic basement was proposed by Lockett (1947). He concluded that this resulted in the formation of the Chatam Sag at the north end of the Findlay Arch.

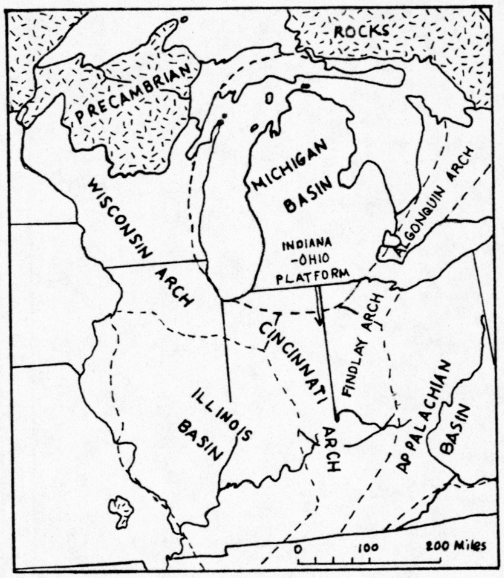


Figure 11. Structural setting of the Midwest. (After Rudman et al, 1965).

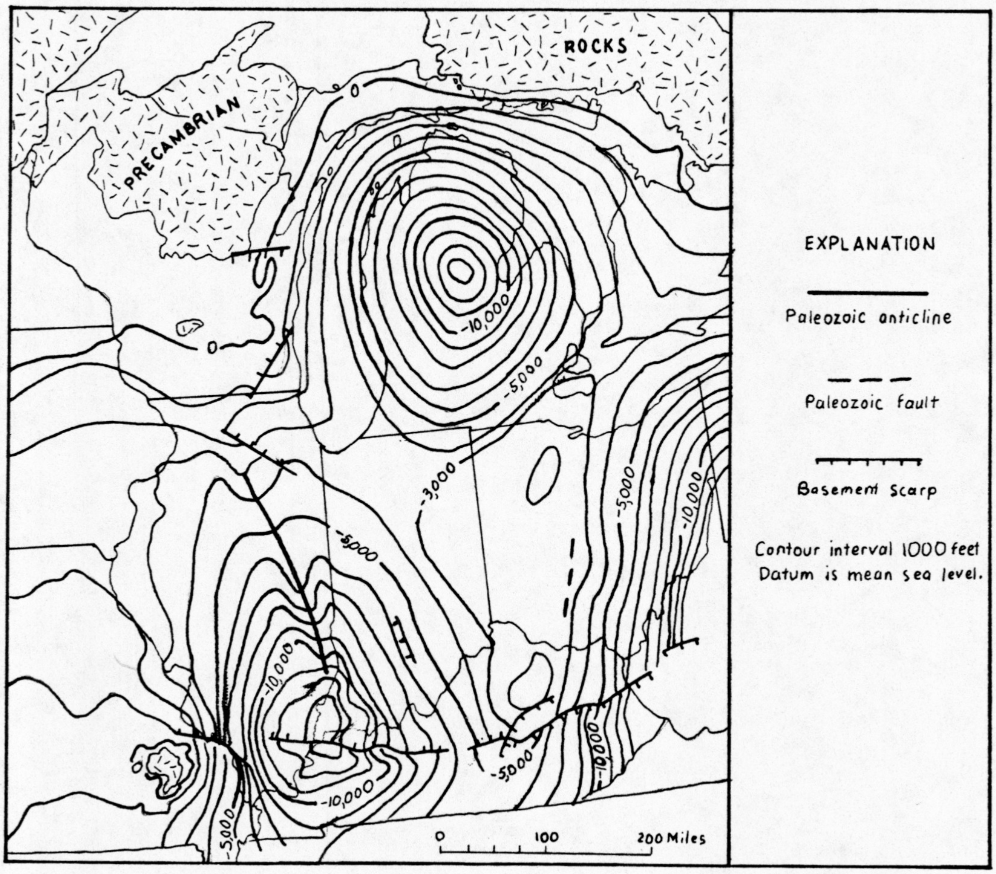


Figure 12. Depth to the Precambrian basement in the Midwest. (After Rudman et al, 1965).

Based on well logs, Green (1957) suggested that the structure of western Ohio was not an arch, but a broad relatively unwarped plateform which he labeled as the Indiana-Ohio Plateform.

In another study based on well logs, Woodward (1961) identified an anticlinal arch during the Palozoic which he named the Waverly Arch. The arch was located east of the Cincinnati Arch and trended north-south. It's width was 60 to 80 miles, with a north-south length of 300 miles, and an amplitude on the arch of about 750 feet. The arch was uplifted in Middle Cambrian and subsided in the Middle Ordovician. Woodward also disputed the existence of the Cincinnati Arch. Later work by Calvert (1974) disputed the existence of the Waverly Arch. Calvert suggested that instead of an anticline, an eroded river valley was actually the cause for the thinning of sediments which had first lead Woodward to describe the Waverly Arch. Existence of the arch was also disputed by Mayhew (1969) in a seismic reflection survey.

The Precambrian rocks of the basement have been dated in several studies. Bass (1960) determined from dating of the micas of metamorphic rocks that their ages ranged from 870 to 940 million years ago, which corresponds to the age of the Greenville rocks in Canada. From these dates he extended the boundry of the Greenville Front from Canada where it appears at the surface, south into Ohio where the basement rocks are covered by the Paleozoic section.

Rudman _et al._ (1965) also separted the basement rocks by age. Those rocks to the west of a line running from Lake Huron to western Kentucky with ages of 1.2 to 1.3 billion years were placed in the Superior Province. Those rocks to the east of this line, with ages of 870 to 940 million years were placed within the Grenville Province.

The Precambrian rocks were divided into two provinces based on lithology by McCormick (1961). Those rocks on the eastern side of a line through Sandusky, eastern Champaign, central Clark, and western Green Counties, consists of marble, horfels, amphibolite with gneiss and pegmatite; while rocks to the west consists of granite, volcanic rocks like syenite, latite, trachyite, and small amounts of biotite schists.

Botoman (1975) conducted a study on the Precambrian and Paleozoic stratigraphy and the potential for mineral deposition along the Cincinnati Arch.

Several studies have been conducted to determine the depth to the Precambrian basement in Ohio along with mapping the basement rock type distribution. These sutdies have relied primarily on the deep wells drilled into the basement in Ohio. Summerson (1962) produced a map of the basement contoured on the 500 foot level along with rock type distribution for the basement.

Botoman (1975) also produced a map of the Precambrian basement along with rock type distribution. His map was contoured on the 100 foot level with additional well data included.

These are some of the more important studies done on the structure in western and central Ohio. There were many more minor studies which are not included. In addition, there are other structural studies listed in the Previous Geophysical Studies section.

It is generally recognized that the earth's magnetic field consists of three parts:

(1) The main field, of internal origin, which varies slowly through time but can rapidly reverse polarity at irregular intervals. The main field is believed to be due to convective currents within the liquid outer core, which operates similar to Faraday's self-exciting disk dynamo. (Fig.13).

(2) The external field, originating outside the earth's surface, is only 5% of the main field. The external field varies rapidly and is partly random and partly cyclical. The effects of the external field on surveying will be discussed in a later section.

(3) Variations of the main field caused by local magnetic anomalies in the near surface crust and are usually constant in time and place. (Telford et al, 1976). There is a larger discussion of the anomalies encountered in this survey in the Modelling section.

Elements of the Main Field

The earth's magnetic field can be divided up into several components. F, is the magnitude of the field. I, is the inclination of the field as measured from the horizontal. D, is the declination or the angle of the field with respect to geographical north. (Fig.14). In this survey area, the declination is 6.5° as calculated for 1981 and the inclination is approximately 60° in Ohio.

The north magnetic pole, at the present time, is the source of south seeking flux or is a negative pole. The south magnetic

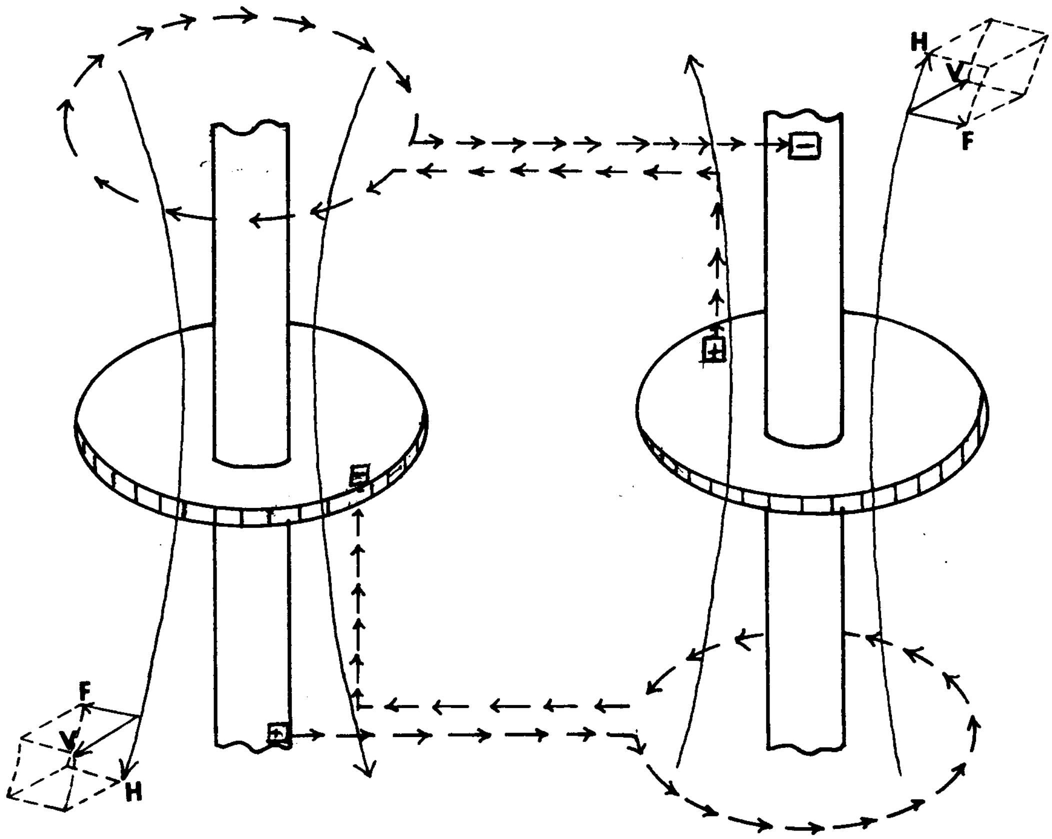
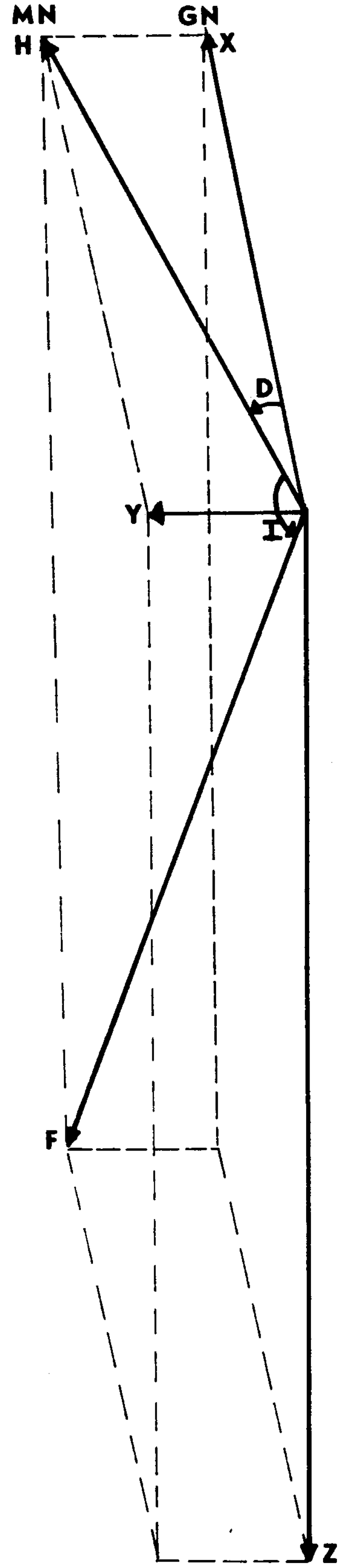


Figure 13. Faraday's Disk Dyanamo.



MN : Magnetic North
GN : Geographic North
D : Declination
I : Inclination
F : Magnitude Of Field
H : Horiz. Component Of Field
X : Comp. Of Horiz. Field (Pos. To N)
Y : Comp. Of Horiz. Field (Pos. To E)
Z : Vert Component Of Field (Pos. Downward)

Figure 14. Components of the Earth's Magnetic Field.

pole is the source of north seeking flux or is a positive pole. The lines of magnetic force emerge outward from the surface at the south magnetic pole while at the north pole their direction is inwards towards the surface. Inside the core, magnetic flux completes the circuit from north to south.

The geomagnetic field resembles a dipole whose south and north magnetic poles are located approximately at 78 1/2°N, 69°W and 78 1/2°S, 111°E, the axis being inclined 11 1/2° to the polar diameter, and its center displaced off axis 300 km. towards Indonesia. The dip poles, or the north and south magnetic poles are presently located at 75°N, 101° W and 67°S, 143°E. (Telford et al, 1976).

The magnitude of the field at the north magnetic pole is 0.6 oersteds, while at the south magnetic pole the field is 0.7 oersteds. The minimum value is about .25 oersted and occurs in the Pacific off the coast of northern Chile. The field is greater than 3 oersteds in several places due to near surface magnetic anomalies in the crust. The lines of zero inclination or where the field is horizontal lie within a range of 0° to 15° north and south of the equator. (Telford et al, 1976).

The external magnetic field which comprises less than 5% of the earth's total magnetic field, still must be taken into account when conducting a magnetic survey. The external field seen at the earth's surface is generated outside the earth by mainly the sun. Variations at the surface are caused by interactions of the solar wind with the ionosphere. The solar wind carries solar magnetic flux to the earth and distorts the earth's field. Listed below are several effects caused by the sun and moon along with a discussion of how each of these effects were adjusted for.

Increased sunspot activity, having an 11 year cycle, can disrupt a survey. According to Patterson (1980), we are supposedly just past a peak period of increased activity.

Another type of variation results from magnetic storms. Magnetic storms, associated with the aurora displays, occur erratically, sometimes involveing ambient field changes with amplititudes of 1000 gammas or more. (Telford _et al_, 1976). No magnetic storms were noticed during this survey.

Variations of lunar origin, caused by the moon's effect on the ionosphere, varies by about 2 gammas. This variation, having a period of 25 hours, is cyclical throughout the month. (Telford _et al_,1976). In careful gravity surveying, the moon's effect on the earth's gravity is large enough, (0.1 milligals), to be considered important. However, in magnetic surveying, the variation of 2 gammas is so small that it is regarded as unimportant, so that in this survey the lunar variation wasn't corrected for.

The main cause for variation in the earth's external field arises from diurnal variation due to the sun. This variation is caused by the sun's effect on the ionosphere. Simply put, at night, when the sun is on the other side of the earth, the ionosphere expands in the plane of the ecliptic because of the decrease of charged particles in the ionosphere on the dark side of the earth due to shielding by the earth. This results in a decrease of the total field values. During the day, the ionosphere is compressed in the plane of the ecliptic due to the bombardment of charged particles upon the earth's ionosphere. Consequently, the total field values increase. North and south of the ecliptic plane, the ionosphere behaves in an inverse manner and so does the field. We are at 40° (23° north inclination).

As was observed by Sappenfield (1950) and in this survey as well, the total field readings at the base station started out relatively higher during the morning and decreased during the morning until the values reached their lowest point around noon and began to rise again during the afternoon. A graph of the daily base station readings, when plotted, represents a U-shaped curve. (Fig.15). Sappenfield found the daily change ranged from 20 to 100 gammas depending on the season. In this survey the mean daily change from the morning readings until the midday readings was 14 gammas while the mean daily change from the midday reading to the final reading in the evening was 23 gammas.

In this survey, in order to correct for diurnal change, one base station was established and 3 readings a day were taken, one in the morning, one around noon, and one in the late afternoon. Based on these 3 readings, a curve of the diurnal change was plotted. All other readings taken during that day were then plotted on a graph. Each day's readings would then be adjusted downward to a straight line equal to the midday

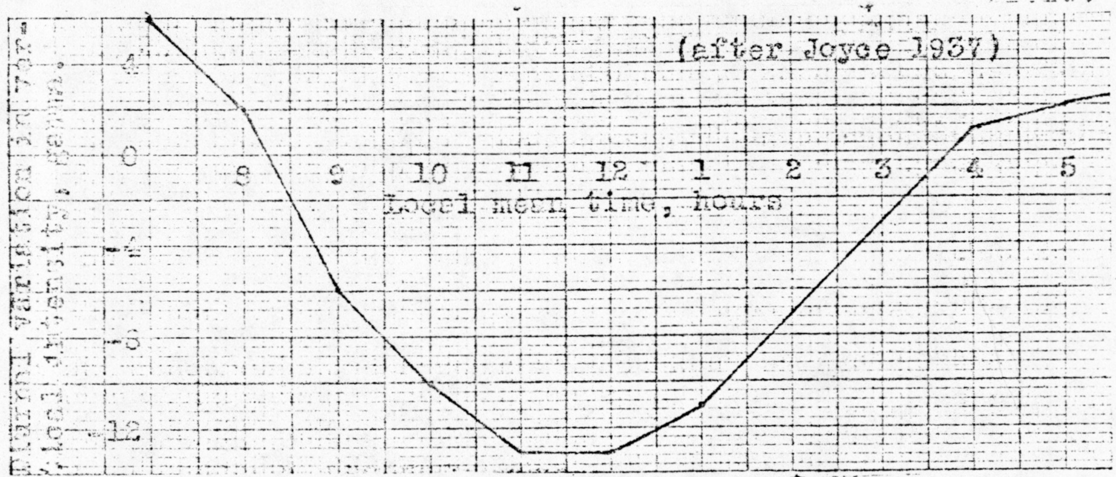
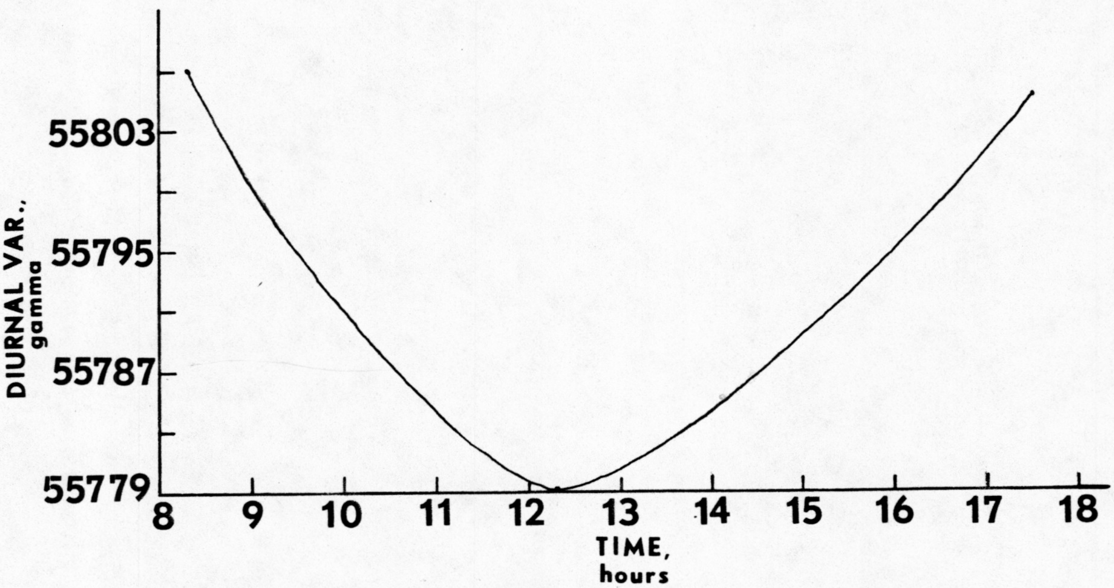


Fig. 1. Graph of diurnal variation in vertical intensity.

Sappenfield 1950



Pennington 1982

Figure 15. Comparison of diurnal variation between Sappenfield's 1950 survey and Pennington's 1982 survey.

base station low reading for that particular day.

Due to the size of the area, 130 square miles, the midday base station reading was not always taken at noon each day. In fact, the midday readings ranged from 10:30 am to 1:30 pm. Partially because of this, the daily low ranged from 55792 gammas to 55746 gammas, with the mean daily low of 55774 gammas and the standard deviation of $\pm$ 9 gammas. This wide time range for the midday readings may have masked any slight change in the field over the survey period. To correct for this large variation in midday readings, the mean low of 55774 gammas was chosen as a standard low against which all the readings were adjusted to. Consequently, on a day when the daily base station low was 55778 gammas, all data taken that day would be adjusted downward by 4 gammas. If a daily low was 55770 gammas, all readings for that day would be adjusted upward by 4 gammas (See appendix).

The IGRF Field

In 1965, the International Association of Geomagnetism and Aeronomy adopted an internationally accepted reference field. This was done to provide a uniform reference field for isolating local magnetic anomalies. This field is entirely internal in origin. (Zmuda, 1971).

The IGRF values in this survey were calculated from Patterson's 1980 survey. The IGRF field values change through time, but the change between the time of her survey and this survey is small and only a few gammas. Flight lines from Patterson's survey within the area bounded by this survey are shown in figure 2. There are approximately 3 values along each of the borders of the map, as well as two values near the center. From these values, the north-south gradient was calculated in the western, central, and eastern sections of the map. Also from these values, the east-west gradient was calculated for the northern, central, and southern portions of the survey area.

The north-south gradient on the western edge is 6 gammas/ minute of latitude, in the center, 7 gammas/ minute , and on the eastern edge 9.8 gammas/minute of latitude. The mean value is 7.6 gammas and the standard deviation is ± 9.5 gammas/minute of latitude.

The east-west gradient in the northern portion of the map is 1.3 gammas/minute of longitude, in the center, 1.6 gammas/ minute, and in the southern portion, 2.4 gammas/minute of longitude. The mean value is 1.7 gammas/minute and the standard deviation is ± 2.2 gammas/minute of longitude.

The north-south gradient value of 7 gammas/minute of latitude in the central portion of the map was chosen as the north-south gradient value for the whole map area. Likewise, the east-west gradient value of 1.6 gammas/minute of longitude, in the central portion of the map was chosen as the east-west gradient value for the entire map area. A table of the north-south and east-west gradient values were then calculated for each square of the grid system. (Table 1)

Overall, the IGRF field values decrease from north to south, and increase from east to west. Therefore, in the northeast quadrant, the N-S gradient values are positive while the E-W values are negative. In the southeast, the N-S and E-W gradient values are both negative. In the southwest, the N-S gradient values are negative while the E-W values are positive. Finally, in the northwest quadrant, the N-S and E-W gradient values are both positive.

Because the N-S gradient is larger than the east-west gradient, 7 gammas/minute of latitude to 1.6 gammas/minute of longitude, the IGRF value for the center of the map was chosen from the north-south gradient. This value is 55181 gammas. The N-S and E-W values for each square of the grid system in table 1 were added together. These values were then added to this value of 55181 gammas to compute the IGRF values for each square of the grid. (Table 2)

The observed values were assigned an IGRF value depending upon which square in the grid system a reading was taken in. Once the IGRF values were assigned to each station location, this value was then substracted from the observed value to produce the residual magnetic field value for each station. These residual field values are plotted in the appendix and on the residual map in the back of the thesis. (Plate 1)

+35 / +8	+35 / +7.2	+35 / +6.4	+35 / +5.6	+35 / +4.8	+35 / +4	+35 / +3.2	+35 / +2.4	+35 / +1.6	+35 / +.8	+35 / 0	+35 / -.8	+35 / -1.6	+35 / -2.4	+35 / -3.2	+35 / -4	+35 / -4.8	+35 / -5.6	+35 / -6.4	+35 / -7.2	+35 / -8
+31.5 / +8	+31.5 / +7.2	+31.5 / +6.4	+31.5 / +5.6	+31.5 / +4.8	+31.5 / +4	+31.5 / +3.2	+31.5 / +2.4	+31.5 / +1.6	+31.5 / +.8	+31.5 / 0	+31.5 / -.8	+31.5 / -1.6	+31.5 / -2.4	+31.5 / -3.2	+31.5 / -4	+31.5 / -4.8	+31.5 / -5.6	+31.5 / -6.4	+31.5 / -7.2	+31.5 / -8
+28 / +8	+28 / +7.2	+28 / +6.4	+28 / +5.6	+28 / +4.8	+28 / +4	+28 / +3.2	+28 / +2.4	+28 / +1.6	+28 / +.8	+28 / 0	+28 / -.8	+28 / -1.6	+28 / -2.4	+28 / -3.2	+28 / -4	+28 / -4.8	+28 / -5.6	+28 / -6.4	+28 / -7.2	+28 / -8
+24.5 / +8	+24.5 / +7.2	+24.5 / +6.4	+24.5 / +5.6	+24.5 / +4.8	+24.5 / +4	+24.5 / +3.2	+24.5 / +2.4	+24.5 / +1.6	+24.5 / +.8	+24.5 / 0	+24.5 / -.8	+24.5 / -1.6	+24.5 / -2.4	+24.5 / -3.2	+24.5 / -4	+24.5 / -4.8	+24.5 / -5.6	+24.5 / -6.4	+24.5 / -7.2	+24.5 / -8
+21 / +8	+21 / +7.2	+21 / +6.4	+21 / +5.6	+21 / +4.8	+21 / +4	+21 / +3.2	+21 / +2.4	+21 / +1.6	+21 / +.8	+21 / 0	+21 / -.8	+21 / -1.6	+21 / -2.4	+21 / -3.2	+21 / -4	+21 / -4.8	+21 / -5.6	+21 / -6.4	+21 / -7.2	+21 / -8
+17.5 / +8	+17.5 / +7.2	+17.5 / +6.4	+17.5 / +5.6	+17.5 / +4.8	+17.5 / +4	+17.5 / +3.2	+17.5 / +2.4	+17.5 / +1.6	+17.5 / +.8	+17.5 / 0	+17.5 / -.8	+17.5 / -1.6	+17.5 / -2.4	+17.5 / -3.2	+17.5 / -4	+17.5 / -4.8	+17.5 / -5.6	+17.5 / -6.4	+17.5 / -7.2	+17.5 / -8
+14 / +8	+14 / +7.2	+14 / +6.4	+14 / +5.6	+14 / +4.8	+14 / +4	+14 / +3.2	+14 / +2.4	+14 / +1.6	+14 / +.8	+14 / 0	+14 / -.8	+14 / -1.6	+14 / -2.4	+14 / -3.2	+14 / -4	+14 / -4.8	+14 / -5.6	+14 / -6.4	+14 / -7.2	+14 / -8
+10.5 / +8	+10.5 / +7.2	+10.5 / +6.4	+10.5 / +5.6	+10.5 / +4.8	+10.5 / +4	+10.5 / +3.2	+10.5 / +2.4	+10.5 / +1.6	+10.5 / +.8	+10.5 / 0	+10.5 / -.8	+10.5 / -1.6	+10.5 / -2.4	+10.5 / -3.2	+10.5 / -4	+10.5 / -4.8	+10.5 / -5.6	+10.5 / -6.4	+10.5 / -7.2	+10.5 / -8
+7 / +8	+7 / +7.2	+7 / +6.4	+7 / +5.6	+7 / +4.8	+7 / +4	+7 / +3.2	+7 / +2.4	+7 / +1.6	+7 / +.8	+7 / 0	+7 / -.8	+7 / -1.6	+7 / -2.4	+7 / -3.2	+7 / -4	+7 / -4.8	+7 / -5.6	+7 / -6.4	+7 / -7.2	+7 / -8
+3.5 / +8	+3.5 / +7.2	+3.5 / +6.4	+3.5 / +5.6	+3.5 / +4.8	+3.5 / +4	+3.5 / +3.2	+3.5 / +2.4	+3.5 / +1.6	+3.5 / +.8	+3.5 / 0	+3.5 / -.8	+3.5 / -1.6	+3.5 / -2.4	+3.5 / -3.2	+3.5 / -4	+3.5 / -4.8	+3.5 / -5.6	+3.5 / -6.4	+3.5 / -7.2	+3.5 / -8
0 / +8	0 / +7.2	0 / +6.4	0 / +5.6	0 / +4.8	0 / +4	0 / +3.2	0 / +2.4	0 / +1.6	0 / +.8	0 / 0	0 / -.8	0 / -1.6	0 / -2.4	0 / -3.2	0 / -4	0 / -4.8	0 / -5.6	0 / -6.4	0 / -7.2	0 / -8
-3.5 / +8	-3.5 / +7.2	-3.5 / +6.4	-3.5 / +5.6	-3.5 / +4.8	-3.5 / +4	-3.5 / +3.2	-3.5 / +2.4	-3.5 / +1.6	-3.5 / +.8	-3.5 / 0	-3.5 / -.8	-3.5 / -1.6	-3.5 / -2.4	-3.5 / -3.2	-3.5 / -4	-3.5 / -4.8	-3.5 / -5.6	-3.5 / -6.4	-3.5 / -7.2	-3.5 / -8
-7 / +8	-7 / +7.2	-7 / +6.4	-7 / +5.6	-7 / +4.8	-7 / +4	-7 / +3.2	-7 / +2.4	-7 / +1.6	-7 / +.8	-7 / 0	-7 / -.8	-7 / -1.6	-7 / -2.4	-7 / -3.2	-7 / -4	-7 / -4.8	-7 / -5.6	-7 / -6.4	-7 / -7.2	-7 / -8
-10.5 / +8	-10.5 / +7.2	-10.5 / +6.4	-10.5 / +5.6	-10.5 / +4.8	-10.5 / +4	-10.5 / +3.2	-10.5 / +2.4	-10.5 / +1.6	-10.5 / +.8	-10.5 / 0	-10.5 / -.8	-10.5 / -1.6	-10.5 / -2.4	-10.5 / -3.2	-10.5 / -4	-10.5 / -4.8	-10.5 / -5.6	-10.5 / -6.4	-10.5 / -7.2	-10.5 / -8
-14 / +8	-14 / +7.2	-14 / +6.4	-14 / +5.6	-14 / +4.8	-14 / +4	-14 / +3.2	-14 / +2.4	-14 / +1.6	-14 / +.8	-14 / 0	-14 / -.8	-14 / -1.6	-14 / -2.4	-14 / -3.2	-14 / -4	-14 / -4.8	-14 / -5.6	-14 / -6.4	-14 / -7.2	-14 / -8
-17.5 / +8	-17.5 / +7.2	-17.5 / +6.4	-17.5 / +5.6	-17.5 / +4.8	-17.5 / +4	-17.5 / +3.2	-17.5 / +2.4	-17.5 / +1.6	-17.5 / +.8	-17.5 / 0	-17.5 / -.8	-17.5 / -1.6	-17.5 / -2.4	-17.5 / -3.2	-17.5 / -4	-17.5 / -4.8	-17.5 / -5.6	-17.5 / -6.4	-17.5 / -7.2	-17.5 / -8
-21 / +8	-21 / +7.2	-21 / +6.4	-21 / +5.6	-21 / +4.8	-21 / +4	-21 / +3.2	-21 / +2.4	-21 / +1.6	-21 / +.8	-21 / 0	-21 / -.8	-21 / -1.6	-21 / -2.4	-21 / -3.2	-21 / -4	-21 / -4.8	-21 / -5.6	-21 / -6.4	-21 / -7.2	-21 / -8
-24.5 / +8	-24.5 / +7.2	-24.5 / +6.4	-24.5 / +5.6	-24.5 / +4.8	-24.5 / +4	-24.5 / +3.2	-24.5 / +2.4	-24.5 / +1.6	-24.5 / +.8	-24.5 / 0	-24.5 / -.8	-24.5 / -1.6	-24.5 / -2.4	-24.5 / -3.2	-24.5 / -4	-24.5 / -4.8	-24.5 / -5.6	-24.5 / -6.4	-24.5 / -7.2	-24.5 / -8
-28 / +8	-28 / +7.2	-28 / +6.4	-28 / +5.6	-28 / +4.8	-28 / +4	-28 / +3.2	-28 / +2.4	-28 / +1.6	-28 / +.8	-28 / 0	-28 / -.8	-28 / -1.6	-28 / -2.4	-28 / -3.2	-28 / -4	-28 / -4.8	-28 / -5.6	-28 / -6.4	-28 / -7.2	-28 / -8
-31.5 / +8	-31.5 / +7.2	-31.5 / +6.4	-31.5 / +5.6	-31.5 / +4.8	-31.5 / +4	-31.5 / +3.2	-31.5 / +2.4	-31.5 / +1.6	-31.5 / +.8	-31.5 / 0	-31.5 / -.8	-31.5 / -1.6	-31.5 / -2.4	-31.5 / -3.2	-31.5 / -4	-31.5 / -4.8	-31.5 / -5.6	-31.5 / -6.4	-31.5 / -7.2	-31.5 / -8
-35 / +8	-35 / +7.2	-35 / +6.4	-35 / +5.6	-35 / +4.8	-35 / +4	-35 / +3.2	-35 / +2.4	-35 / +1.6	-35 / +.8	-35 / 0	-35 / -.8	-35 / -1.6	-35 / -2.4	-35 / -3.2	-35 / -4	-35 / -4.8	-35 / -5.6	-35 / -6.4	-35 / -7.2	-35 / -8

Table 1. N-S and E-W IGRF Gradient Values.

IGRF VALUES
GAMMAS (55,___.)

224	223.2	222.4	221.6	220.8	220	219.2	218.4	217.6	216.8	216	215.2	214.4	213.6	212.8	212	211.2	210.4	209.6	208.8	208
220.5	219.7	218.9	218.1	217.3	216.5	215.7	214.9	214.1	213.3	212.5	211.7	210.9	210.1	209.3	208.5	207.7	206.9	206.1	205.3	204.5
217	216.2	215.4	214.6	213.8	213	212.2	211.4	210.6	209.8	209	208.2	207.4	206.6	205.8	205	204.2	203.4	202.6	201.8	201
213.5	212.7	211.9	211.1	210.3	209.5	208.7	207.9	207.1	206.3	205.5	204.7	203.9	203.1	202.3	201.5	200.7	199.9	199.1	198.3	197.5
210	209.2	208.4	207.6	206.8	206	205.2	204.4	203.6	202.8	202	201.2	200.4	199.6	198.8	198	197.2	196.4	195.6	194.8	194
206.5	205.7	204.9	204.1	203.3	202.5	201.7	200.9	200.1	199.3	198.5	197.7	196.9	196.1	195.3	194.5	193.7	192.9	192.1	191.3	190.5
203	202.2	201.4	200.6	199.8	199	198.2	197.4	196.6	195.8	195	194.2	193.4	192.6	191.8	191	190.2	189.4	188.6	187.8	187
199.5	198.7	197.9	197.1	196.3	195.5	194.7	193.9	193.1	192.3	191.5	190.7	189.9	189.1	188.3	187.5	186.7	185.9	185.1	184.3	183.5
196	195.2	194.4	193.6	192.8	192	191.2	190.4	189.6	188.8	188	187.2	186.4	185.6	184.8	184	183.2	182.4	181.6	180.8	180
192.5	191.7	190.9	190.1	189.3	188.5	187.7	186.9	186.1	185.3	184.5	183.7	182.9	182.1	181.3	180.5	179.7	178.9	178.1	177.3	176.5
189	188.2	187.4	186.6	185.8	185	184.2	183.4	182.6	181.8	181	180.2	179.4	178.6	177.8	177	176.2	175.4	174.6	173.8	173
185.5	184.7	183.9	183.1	182.3	181.5	180.7	179.9	179.1	178.3	177.5	176.7	175.9	175.1	174.3	173.5	172.7	171.9	171.1	170.3	169.5
182	181.2	180.4	179.6	178.8	178	177.2	176.4	175.6	174.8	174	173.2	172.4	171.6	170.8	170	169.2	168.4	167.6	166.8	166
178.5	177.7	176.9	176.1	175.3	174.5	173.7	172.9	172.1	171.3	170.5	169.7	168.9	168.1	167.3	166.5	165.7	164.9	164.1	163.3	162.5
175	174.2	173.4	172.6	171.8	171	170.2	169.4	168.6	167.8	167	166.2	165.4	164.6	163.8	163	162.2	161.4	160.6	159.8	159
171.5	170.7	169.9	169.1	168.3	167.5	166.7	165.9	165.1	164.3	163.5	162.7	161.9	161.1	160.3	159.5	158.7	157.9	157.1	156.3	155.5
168	167.2	166.4	165.6	164.8	164	163.2	162.4	161.6	160.8	160	159.2	158.4	157.6	156.8	156	155.2	154.4	153.6	152.8	152
164.5	163.7	162.9	162.1	161.3	160.5	159.7	158.9	158.1	157.3	156.5	155.7	154.9	154.1	153.3	152.5	151.7	150.9	150.1	149.3	148.5
161	160.2	159.4	158.6	157.8	157	156.2	155.4	154.6	153.8	153	152.2	151.4	150.6	149.8	149	148.2	147.4	146.6	145.8	145
157.5	156.7	155.9	155.1	154.3	153.5	152.7	151.9	151.1	150.3	149.5	148.7	147.9	147.1	146.3	145.5	144.7	143.9	143.1	142.3	141.5
154	153.2	152.4	151.6	150.8	150	149.2	148.4	147.6	146.8	146	145.2	144.4	143.6	142.8	142	141.2	140.4	139.6	138.8	138

Table 2. IGRF Values For Each Square Of The Grid System.

The magnetic field from a body or bodies of rock results from two sources, the induced field and the remanent magnetization of the rock. This relationship can be expressed in the following formula by,

$$J = Jr + KT$$

where J = the intensity of magnetization, or the magnetic moment per unit volume in e.m.u./cm^3; Jr = the remanent magnetization of a rock; K = the volume susceptibility which is defined as the magnetic moment aquirred by unit volume (1 cm^3) when placed in a field of one oersted; and T = the field strength in oersted. (Griffiths and King, 1965)

Induced Magnetization

The induced field is dependent upon two factors, the susceptibility (K) and the force of the earth's magnetic field (T). Several factors affect the susceptibility such as the type of ferromagnetic minerals, the size of the magnetic minerals, and their distribution within a rock. The susceptibility for igneous rocks is greater than that for metamorphic rocks and likewise the susceptibility for metamorphic rocks is greater than for sedimentary rocks. The susceptibility for the overlying sedimentary rocks in this survey area is so low that it is unimportant and can be ignored altogether. The volcanic, igneous and metamorphic basement rocks in south-central Ohio have susceptibilities ranging from 10^{-4} to 10^{-3}. (Patterson, 1980).

Remanant Magnetization

There are several different types of remanant magnetism. The main type in igneous rocks is thermoremanant magnetism (TRM). TRM results from the magnetic minerals orienting themselves in the same direction as the earth's geomagnetic field when cooled from a magma.

The polarization of the rocks in North America was determined by McElhinney (1973). The approximate age of the basement rocks in south-central Ohio is 1 billion years old. At that time, the latitude of the area ranged from 1° to 11°N, with the magnetic inclination ranging from 0° to 20°. Therefore the TRM of the basement rocks in Ohio is assumed to be 10° from the horizontal and near east-west in azimuth. (Patterson, 1980).

In an aeromagnetic study by Harvey (1980) in Elliott County, Kentucky, peridotite of Mesozoic age was intruded into the surrounding rock. The field was polarized horizontally to the north as opposed to the east-west polarization of the Precambrian basement rocks.

The major northeast-southwest anomaly (Fig. 3) has been modelled assuming first that it is caused by an intrusion and second, it is the result of faulting within the Precambrian basement

Intrusion

When modelling a magnetic anomaly, there is usually several unkown variables. This is especially true when a body which is producing an anomaly is buried below the earth's surface. This is the case in this survey where there are no known outcrops of highly magnetic material at the surface. One is left with a map of the residual values and must determine from that map the simplest geologically plausible explanation for the anomalies shown. Figure 16 lists some simplified models and their resulting profiles. From figure 16, case 2 seems to be the best simplified model for the anomaly whose cross-sections are shown in figures 17 through 19.

Several assumptions are made if the anomaly is modelled as an intrusion. The map is a total field map, however, the anomaly is modelled only on the vertical field. The vertical component of the total field comprises approximately 60% of the total field at this latitude. Therefore any changes in the vertical field will affect the total field.

If the anomaly is assummed to be caused by an intrusion similar to the Elliott County peridotite, it would have a susceptibility of 10^{-2}gauss/oersted. (Noltimier, personal communication). It's orientation is N10E to N15E in the long dimension and is horizontally magnetized northwest to southeast. The intrusion is believed to have been intruded in the Late

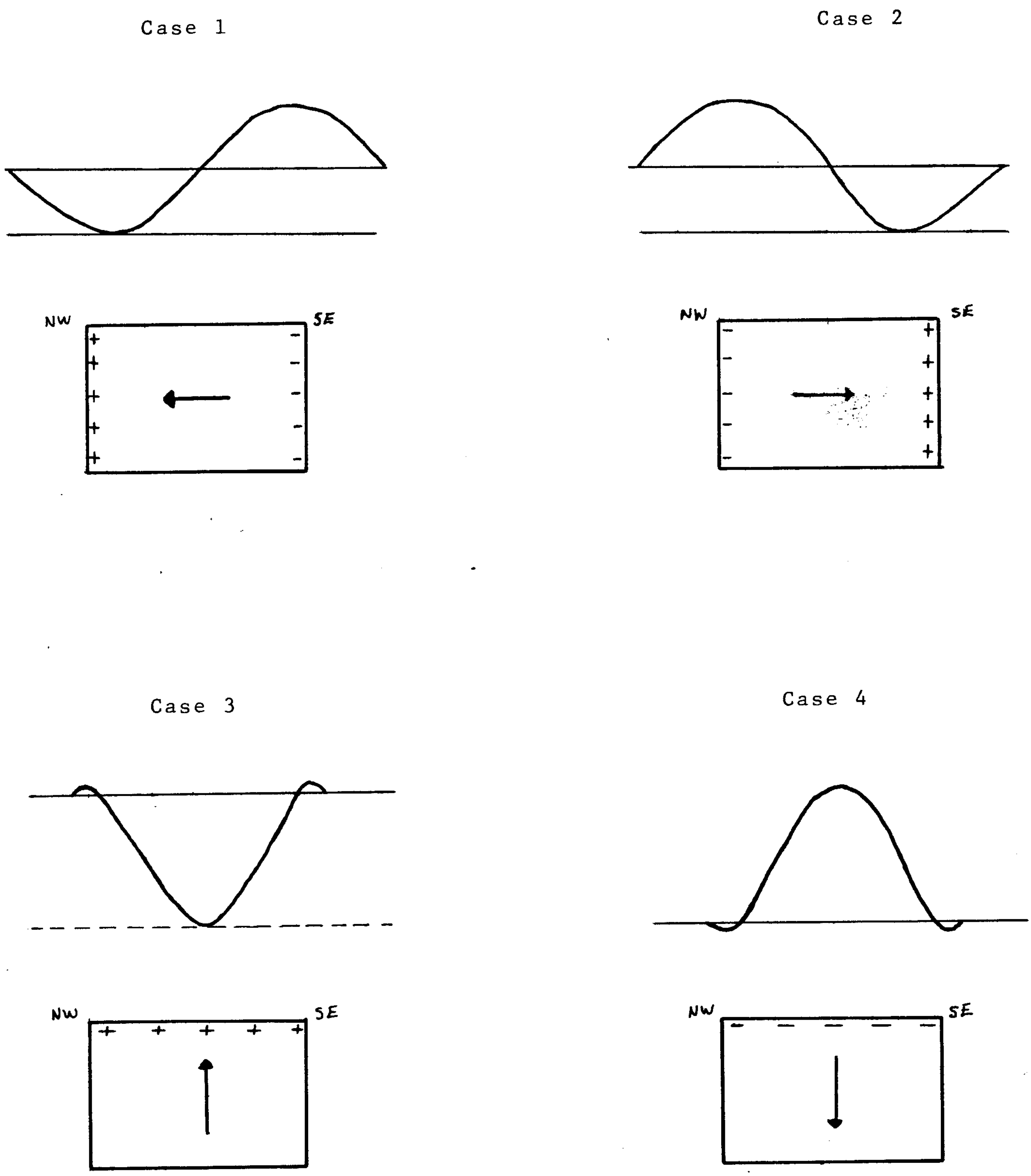


Figure 16. Possible theoritical cases used in modelling.

Paleozoic or Early Mesozoic which is similar to the Elliott County peridotite.

The anomaly was modelled as if it is a prism of finite length and thickness, similar to a dike, using the standard dipole formula, (Fig.20),

$$|\vec{H}| = \sqrt{\left(\frac{2M\cos\theta}{r^3}\right)^2 + \left(\frac{M\sin\theta}{r^3}\right)^2} \quad X\ 10^5 \text{ gammas}$$

where,

$|\vec{H}|$ = magnitude and direction of the total field strength in gammas.

M = the magnetic moment of the body = 2J(lwt).

J = magnetic susceptibility of the body.

2(lwt) = the volume of the body

l = 1/2 length, perpindicular to the long direction.

w = width in the long direction.

t = thickness of the body.

θ = tan Z/X

r = the radius away from the center of the body = $\sqrt{X^2 + Z^2}$

X = the horizontal distance away from the center of the body.

Z = the depth to the center of the body.

The anomaly was modelled using cross-section A-A (Fig. 17), at three different lications, 3 km. west of the center, 3 km. east of the center, and at the center, using the vertical magnetic field. The center is assumed to be 1/2 way between the high and low around the 350 gamma line on the residual map (Fig. 3).

The equation for the vertical magnetic field consists of,

$$Hv = H \cos\mu$$

where H = the total field, u = 90-(θ+α), and α = tan (1/2tanθ).

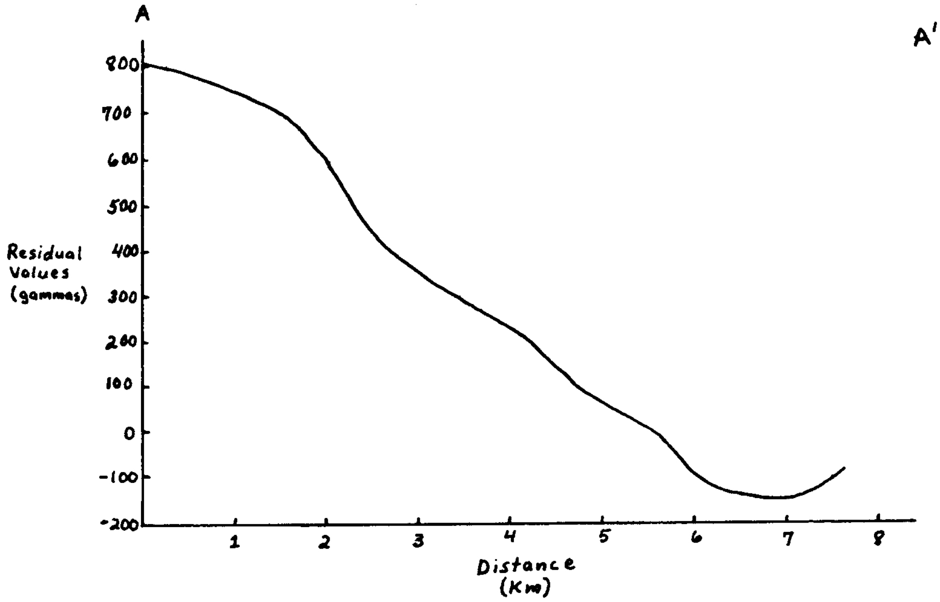


Figure 17. Cross-section A-A' of figure 3.

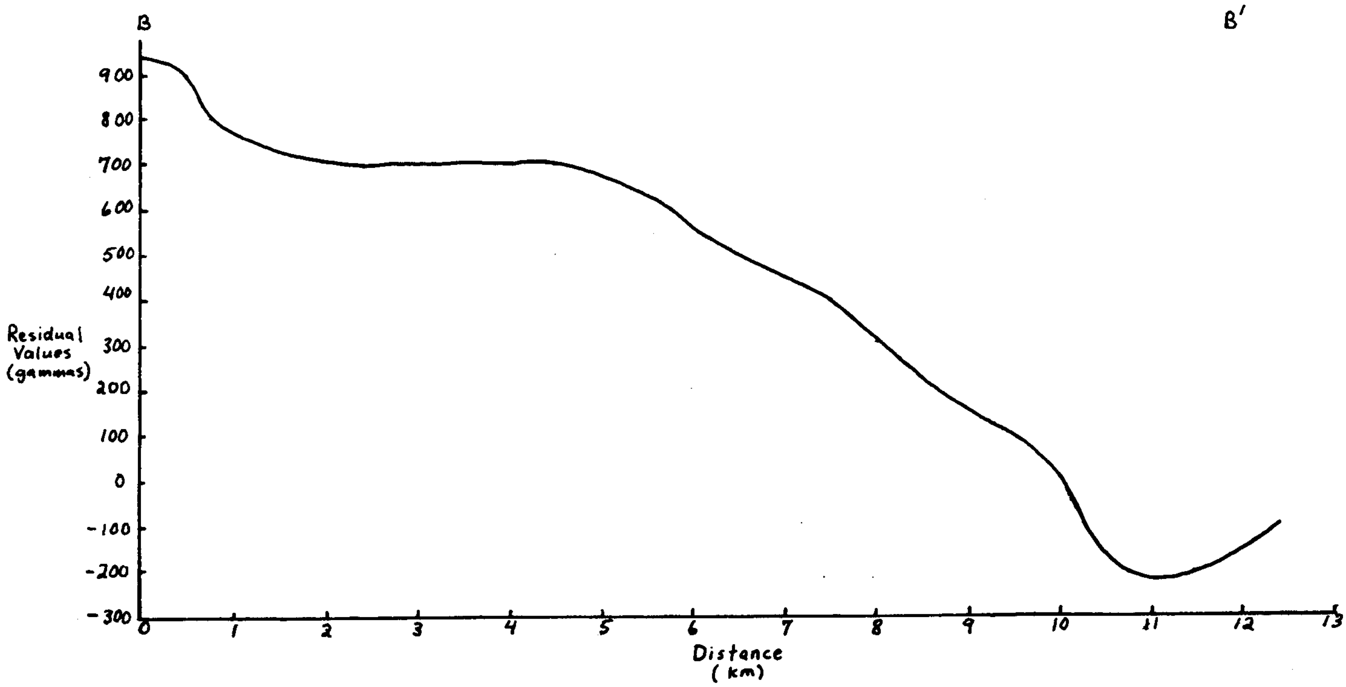


Figure 18. Cross-section B-B' of figure 3.

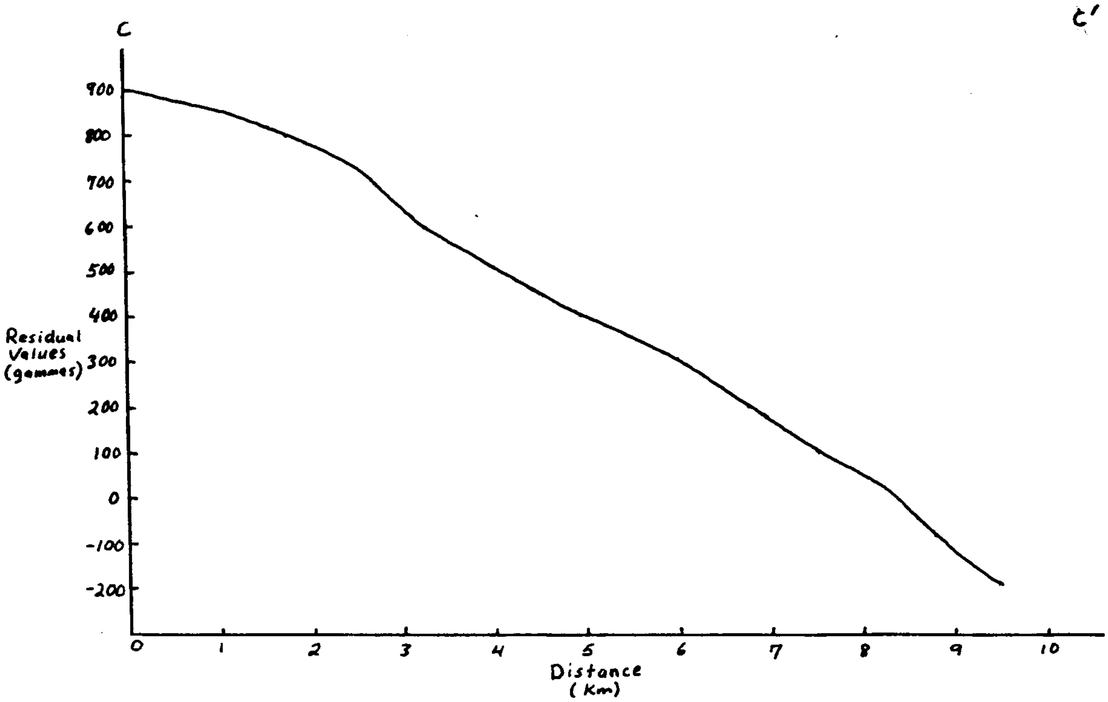


Figure 19. Cross-section C-C' of figure 3.

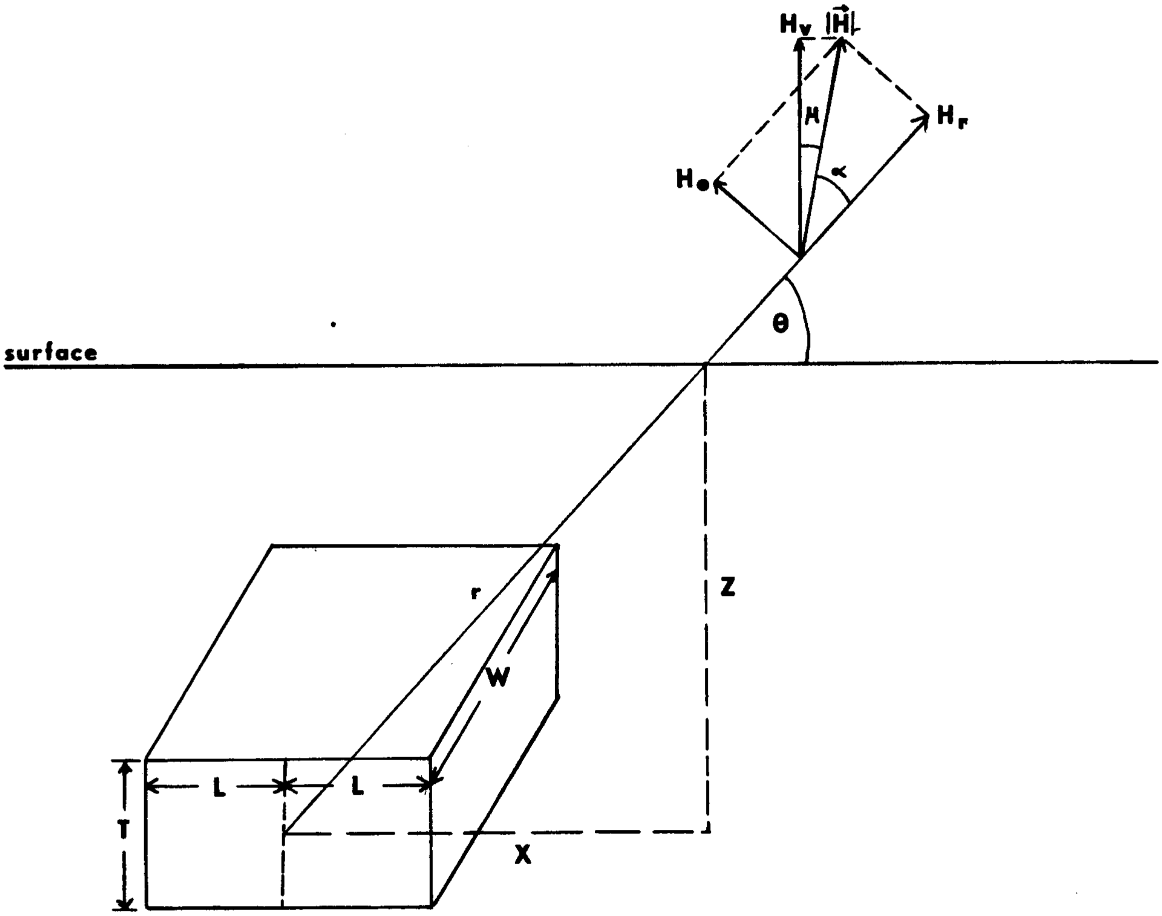


Figure 20. Components of the Dipole Formula.

When modelling this anomaly, several facts should be understood about the computed values from the dipole formula. The size of the anomaly is going to vary with the volume of the body producing it as well as the depth of the body below the ground surface. The values for the volume, (length, width, thickness), as well as the depth were arrived at through a process of trial and error. Different values for the volume and depth were plugged into the formula until values for the field were found which closely approximated the total change of the anomaly.

The values of θ and r will vary with the distance away from the center of the body as well as the depth, and is therefore dependent on the depth. Therefore, the values within the dipole formula, M, θ, and r are dependent upon the values chosen.

From the information given above,it would be foolish to state one volume and its corresponding depth and say that this is the absolute depth and volume. Therefore, figure 21 is a graph of depth verses magnetic moment which would produce a change of $\pm$ 450 gammas, or a 900 gamma total change. From the graph it should be noted that an intrusion, with a magnetic moment of 6.125×10^{13} gauss/cm^3 would be found .0625 km. or 205 feet below the earth's surface, which is probably too close to the surface. This implies, however, that the magnetic moment of the body is at least 6.125×10^{13} gauss/cm^3 with the likelihood that it is greater, since the intrusion is believed to be at a greater depth.

Possible Faulting

From Patterson's 1980 aeromagnetic survey, she believes that the Hickman-Bryan Station Fault zone, present at the sur-

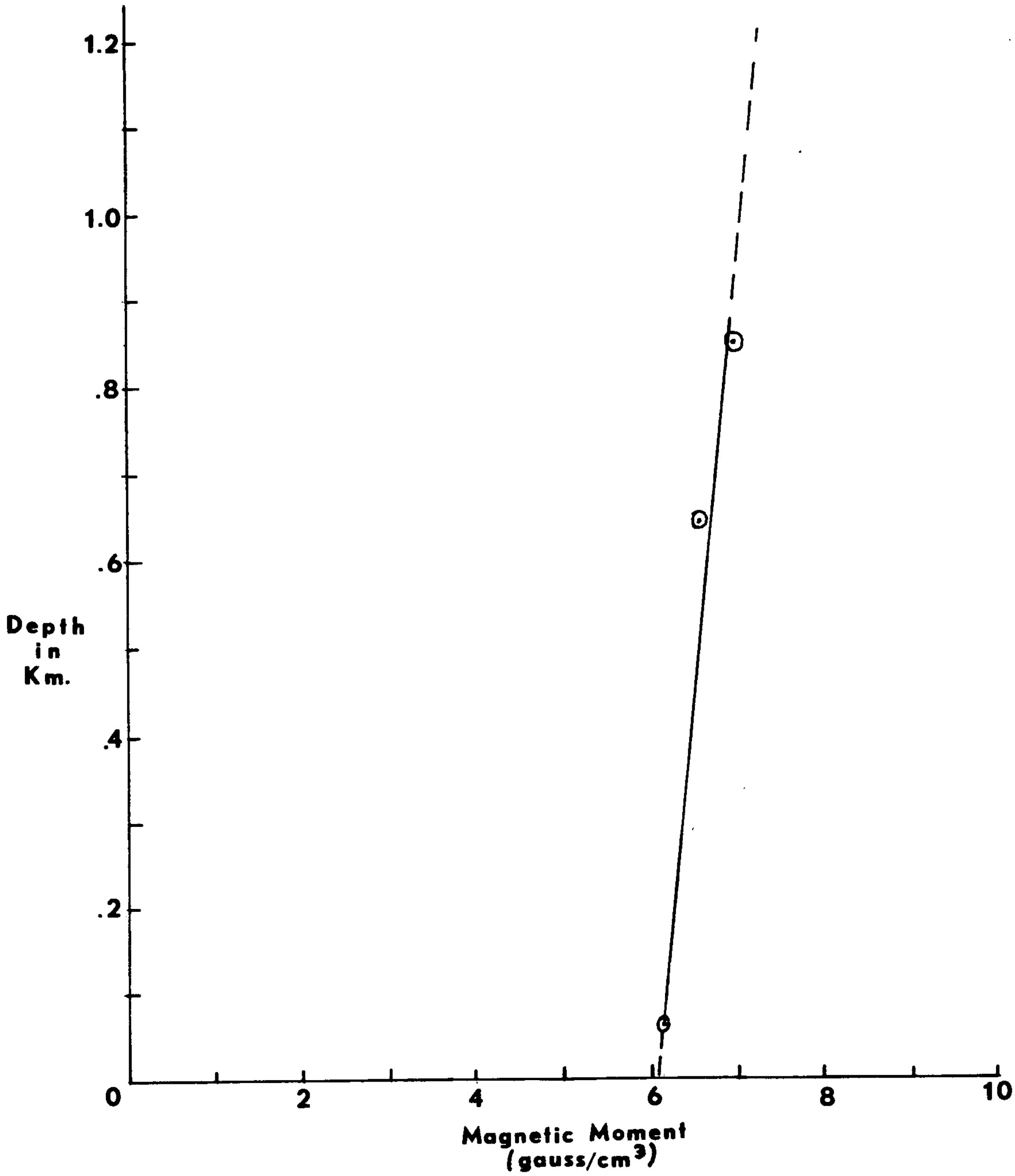


Figure 21. Graph of Magnetic Moment Verses Depth to Intrusion.

face in northern Kentucky, which abruptly ends at the Ohio River, may extend below the surface into southern Ohio.

If the anomaly in this survey is modelled assuming there is a fault in the Precambrian basement, the formula used is

$$\frac{\Delta Z}{2\pi(Jx)} = \frac{T}{D}$$

where Z = 1/2 the total change of the anomaly = 450 gammas; Jx = the intensity of magnetization = 565 gammas (Patterson, 1980); D = depth to the basement = 4000 feet; T = the throw on the fault.

$$4000' \quad \frac{450\gamma}{2\pi(565\gamma)} = T$$

The throw on the fault would be 507 feet.

Conclusions

From this surface magnetic survey, there could be at least two possible interpretations to explain the anomaly shown on the residual map. The anomaly could be the result of an intrusion of peridotite below the surface similar to the Elliott County peridotite exposed at the surface in Kentucky. This intrusion was Mesozoic in age and if there is an intrusion in Pike County, it would be similar in age. Another possible explanation is that the anomaly could be caused by subsurface faulting which cut the Precambrian igneous basement. Several studies which would support either explanation are listed below.

In an aeromagnetic study in Elliott County, Kentucky, Harvey (1980) studied a peridotite dike outcropping at the surface. From whole rock age dating and the direction of magnetization of the peridotite, she determined that the dike was between Middle Permian and Triassic in age. She believes that these dikes are part of a larger scale intercontinental tectonic system and that they were intruded along a major zone of crustal weakness.

A paleomagnetic survey of the Serpent Mound Structural area by Istok (1978), 15 miles west of this survey area, found evidence for chemical remanent alteration of two Silurian formations. He found two periods of activity at Serpent Mound, first during the Carboniferous when the structure formed and in the Upper Triassic when iron and zinc bearing fluids were intruded along existing fault planes.

Sappenfield (1950) concluded from his surface magnetic survey of Serpent Mound that the structure was the result of an intrusion of basic magma within the basement.

Supporting evidence which would indicate faulting can be cited from Patterson's 1980 aeromagnetic survey. She suggests that the Hickman-Bryan Station fault zone, which is at the surface in northern Kentucky and abruptly ends at the Ohio River, may extend below the surface into Ohio. She sites as supporting evidence the subcrop pattern of the Rose Run sandstone above the basement which follows the trend of her northeast-southwest anomalies. She believes that this depositional pattern may be controlled by faulting. (Figs. 22&23).

Mayhew (1969) found evidence for possible faulting which occured after deposition of the Trenton and which cut the basement, in a seismic reflection survey in portions of several counties northwest of this survey area.

What can be stated from this survey is that if there is an intrusion, the volume of the material would be at least 6.125×10^{15} cm^3 in size. If there is faulting within the basement, the throw on the fault would be approximately 507 feet. Further studies such as gravity and/or seismic could help determine the nature of the subsurface.

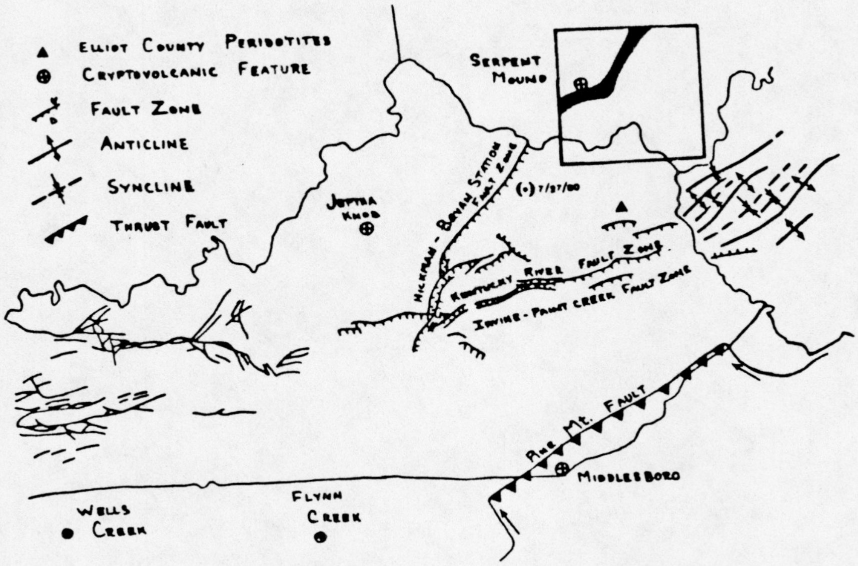


Figure 22. Structural features of Northeast Kentucky (Patterson, 1980).

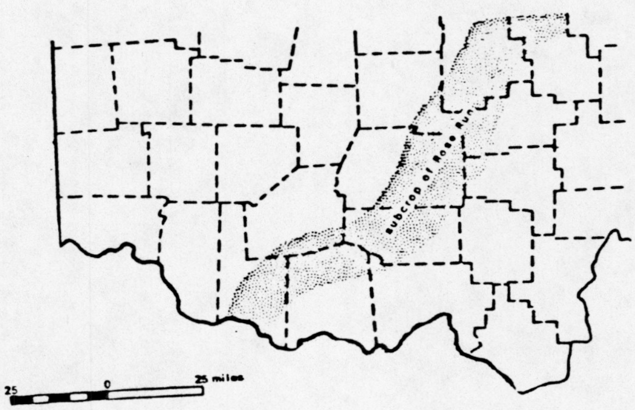


Figure 23. Subcrop of the Rose Run Sandstone (Patterson, 1980).

This survey cas carried out with the use of the Barringer Precession Magnetometer, (GM-122). The instrument measures the total field within a range of 20,000 to 99,999 gammas. It has an accuracy of ± 1 gamma. The poerating temperature range extends from -40°F up to 131°F. The magnetometer can withstand gradients of up to 600 gammas/foot. The readings are displayed on a 5 digit LED readout. When the gradient is too high, only the first two numbers are displayed. A switch within the unit can display readings every 3 seconds or every 6 seconds, depending on which cycle rate is desired. The instrument is portable and is powered by 12 "D" cell batteries (1.5 volts each). The magnetometer consists of a PVC sensing head containing 600 ml. of kerosene mounted on a 6 foot brushed aluminum pole. The sensing head is connected to the instrument "box", worn by the operator, and is connected by means of an insulated coiled wire. The total weight of the unit, including the batteries, is 11 pounds. (Barringer Operations Manuel)

Operating Principles of Total Field Magnetometers

The precession magnetometer was developed in 1954 by Packard and Varian. Their instrument was based on the original discovery in 1945, that some nuclei have a net magnetic moment, and when coupled with their spin cause the nuclei to precess about an axial magnetic field. (Telford et al, 1976)

The nuclear precession magnetometer measures the free-precession frequency of protons which have been polarized in a direction perpendicular to the direction of the earth's field. When the button on the instrument "box" is depressed, an electric current of one ampere is passed briefly through the coils located in the sensing head. This charge has the effect of polarizing the protons. This alignment lasts for about a second and the charge is then abruptly ended. As this polarizing field decays, the protons precess, like a spinning top, with the earth's field supplying the precessing force (Fig.24). The precession angular velocity (w), is related to the strength of the field by the equation,

$$4\pi f/Vp = F \qquad (2\pi f = w)$$

where Vp is the gyromagnetic ratio of the proton, and F is the force of the earth's field. A small emf is induced in the coils surrounding the fluid at the same frequency (f) as that of the precession. This signal is amplified, the precession frequency counted, and then displayed as a digital readout (Fig.25).

The precession magnetometer has the advantage over flux-gate, torsion, and vertical magnetometers in that it's sensitivity is approximately $\pm$ 1 gamma, without modifications it measures the total field, it has a large temperature range, and it requires no leveling. (Telford et al,1976). This means that the precession magnetometer doesn't require that the data be corrected for the temperature changes. During this survey, which was conducted during the autumn of 1981, the temperature range was from 15°F to 70°F.

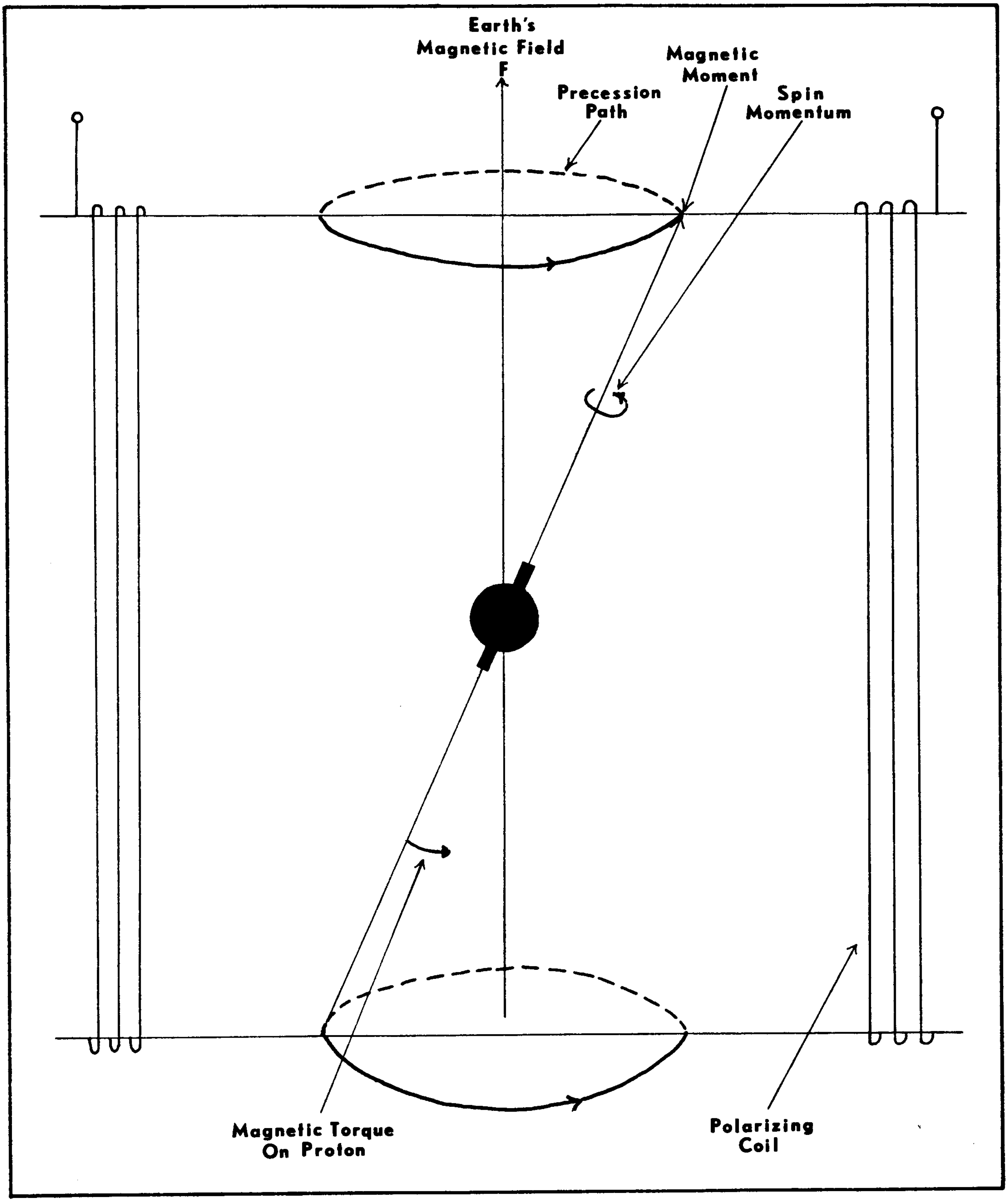


Figure 24. Proton Precession (Adapted from Telford et al, 1976).

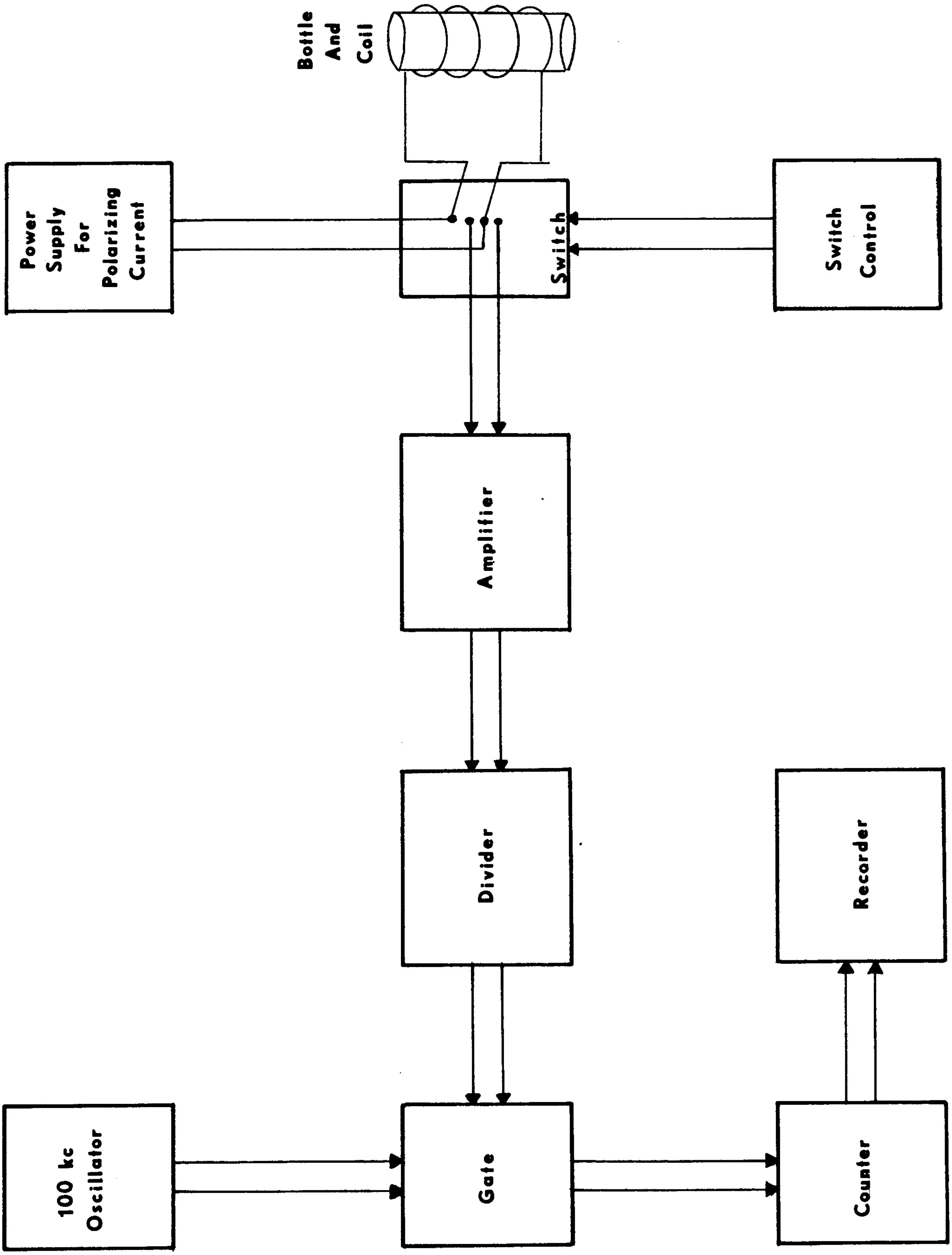


Figure 25. Block diagram of Proton Precession Magnetometers, (Griffiths and King, 1965).

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APPENDIX

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
09/26/81	12:10	010	39.05000	83.05833	55778	55778	55774	55184	590
09/26/81	12:55	A1	39.12500	83.17500	55584	55581	55576	55224	352
09/26/81	13:10	B1	39.12500	83.16667	55567	55563	55559	55224	335
09/26/81	13:30	C1	39.12500	83.15833	55689	55683	55679	55223	456
09/26/81	13:55	C2	39.11667	83.15833	55690	55681	55677	55222	455
09/26/81	14:20	B2	39.11667	83.16667	55606	55593	55589	55222	367
09/26/81	14:40	C3	39.10833	83.15833	55805	55789	55785	55218	567
09/26/81	15:20	A2	39.11667	83.17500	55655	55633	55629	55222	407
09/26/81	15:40	A3	39.10833	83.17500	55571	55545	55541	55219	322
09/26/81	16:05	B3	39.10833	83.16667	55692	55662	55658	55218	440
09/26/81	16:45	A4	39.10000	83.17429	55703	55667	55663	55215	448
09/26/81	17:05	A5	39.09167	83.17500	55757	55717	55713	55212	501
09/26/81	17:15	B5	39.09167	83.16667	55772	55730	55726	55211	515
09/26/81	17:45	010	39.05000	83.05833	55825	55778	55744	55184	590
09/27/81	8:20	010	39.05000	83.05833	55807	55779	55774	55184	590
09/27/81	8:45	B4	39.10000	83.16480	55782	55757	55752	55215	537
09/27/81	9:10	D5	39.09167	83.15000	55789	55768	55763	55210	553
09/27/81	9:20	E5	39.09167	83.14167	55782	55762	55757	55209	548
09/27/81	9:35	E4	39.10000	83.14193	55841	55823	55818	55213	605
09/27/81	9:55	D4	39.14502	83.14706	55832	55817	55812	55215	597
09/27/81	10:15	D3	39.10833	83.15000	55808	55795	55790	55217	573
09/27/81	10:35	D2	39.11667	83.15000	55758	55748	55743	55220	523
09/27/81	10:50	D1	39.12500	83.15000	55737	55729	55724	55222	502
09/27/81	11:05	E2	39.11667	83.14167	55733	55727	55722	55220	502
09/27/81	11:25	E1	39.12128	83.14167	55785	55782	55777	55221	556
09/27/81	11:55	F1	39.12500	83.13333	55816	55815	55810	55220	590
09/27/81	12:20	010	39.05000	83.05833	55779	55779	55774	55284	590
09/27/81	13:00	G2	39.11770	83.12500	55875	55874	55869	55220	649
09/27/81	13:20	F2	39.11667	83.13387	55828	55825	55820	55219	601
09/27/81	13:50	E3	39.11162	83.13792	55834	55829	55824	55217	607
09/27/81	14:25	F3	39.10899	83.13375	55851	55843	55838	55217	621
09/27/81	14:55	G3	39.10833	83.12606	55881	55870	55865	55215	650
09/27/81	15:25	G4	39.10000	83.12557	55884	55870	55865	55211	654
09/27/81	15:40	F4	39.09913	83.13108	55865	55849	55844	55210	634
09/27/81	16:10	G5	39.09046	83.12585	55774	55756	55751	55206	545 5
09/27/81	16:45	F5	39.09167	83.13333	55847	55825	55820	55208	612 5
09/27/81	17:30	010	39.05000	83.05833	55805	55779	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
09/28/81	8:25	010	39.05000	83.05833	55788	55781	55744	55184	590
09/28/81	8:45	D6	39.08333	83.15000	55799	55784	55787	55206	581
09/28/81	9:00	D7	39.07500	83.15092	55785	55771	55764	55203	561
09/28/81	9:15	C7	39.07500	83.15707	55759	55746	55739	55203	536
09/28/81	9:35	D8	39.06667	83.15000	55821	55809	55802	55199	603
09/28/81	9:55	C8	39.06667	83.15833	55823	55812	55805	55200	605
09/28/81	10:00	B8	39.06667	83.16667	55633	55623	55616	55201	415
09/28/81	10:15	A8	39.06667	83.17500	55817	55808	55801	55201	600
09/28/81	11:10	A7	39.07500	83.17500	55820	55815	55808	55205	603
09/28/81	11:25	A6	39.08060	83.17500	55810	55806	55799	55207	592
09/28/81	11:40	B6	39.08333	83.16893	55769	55766	55759	55208	551
09/28/81	12:05	B7	39.07622	83.17119	55830	55829	55822	55207	615
09/28/81	12:35	010	39.05000	83.05833	55781	55781	55774	55184	590
09/28/81	13:45	A9	39.05967	83.17500	55812	55804	55797	55200	597
09/28/81	14:10	B9	39.05833	83.16667	55847	55835	55828	55197	631
09/28/81	15:05	C10	39.05000	83.15833	55907	55887	55880	55193	687
09/28/81	15:55	B10	39.04858	83.16455	55854	55827	55820	55192	628
09/28/81	16:10	A10	39.04836	83.17388	55785	55756	55749	55192	557
09/28/81	16:20	B11	39.04167	83.16780	55813	55782	55775	55189	586
09/28/81	16:40	C11	39.04167	83.15833	55905	55871	55864	55191	673
09/28/81	16:55	D11	39.04167	83.15071	56050	56014	56007	55187	820
09/28/81	17:15	010	39.05000	83.05833	55820	55781	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
09/29/81	9:25	010	39.05000	83.05833	55801	55779	55774	55184	590
09/29/81	10:10	D10	39.04869	83.14930	56012	55995	55990	55190	800
09/29/81	10:20	E10	39.04858	83.14930	56069	56053	56048	55190	858
09/29/81	10:40	E9	39.05833	83.14209	55936	55922	55917	55195	722
09/29/81	12:10	E8	39.06667	83.14167	55853	55849	55844	55197	647
09/29/81	12:30	E7	39.07161	83.13983	55819	55817	55812	55200	612
09/29/81	13:05	010	39.05000	83.05833	55779	55779	55774	55184	590
09/29/81	13:45	D8.5	39.06063	83.14803	55907	55906	55901	55197	704
09/29/81	13:55	D9	39.05965	83.15000	55847	55845	55840	55197	643
09/29/81	14:25	C9	39.05833	83.15833	55859	55855	55850	55197	653
09/29/81	15:20	G9	39.05833	83.12500	55924	55916	55911	55193	718
09/29/81	15:40	F9	39.05833	83.13122	55980	55971	55966	55194	772
09/29/81	16:30	F8	39.06755	83.13263	55877	55864	55859	55199	660
09/29/81	16:40	G8	39.06667	83.12684	55904	55891	55886	55197	689
09/29/81	17:20	H9	39.05833	83.11667	55745	55729	55724	55193	531
09/29/81	17:40	F7	39.07500	83.13333	55848	55830	55825	55201	624
09/29/81	18:00	F10	39.04825	83.13333	56023	56004	55999	55189	810
09/29/81	18:10	010	39.05000	83.05833	55779	55779	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
10/13/81	8:45	010	39.05000	83.05833	55806	55793	55774	55184	590
10/13/81	9:00	H7	39.07336	83.11667	55876	55864	55845	55197	648
10/13/81	9:20	G6	39.08268	83.12500	55825	55814	55795	55202	593
10/13/81	9:45	H6	39.08333	83.11667	55834	55825	55806	55203	603
10/13/81	9:50	I6	39.08333	83.11271	55817	55808	55789	55204	585
10/13/81	10:10	H5	39.09142	83.11667	55840	55832	55813	55205	608
10/13/81	10:45	H3	39.10833	83.11667	55868	55862	55843	55214	629
10/13/81	11:15	I3	39.10833	83.11045	55875	55871	55852	55213	639
10/13/81	11:30	H2	39.11579	83.11554	55897	55894	55875	55215	660
10/13/81	12:00	J2	39.11667	83.10000	55867	55865	55846	55216	630
10/13/81	12:10	J3	39.10910	83.10000	55856	55855	55836	55214	622
10/13/81	12:20	J4	39.10066	83.10071	55831	55830	55811	55211	600
10/13/81	12:40	010	39.05000	83.05833	55793	55793	55774	55184	590
10/13/81	13:15	I7	39.07500	83.10833	55860	55859	55840	55199	641
10/13/81	13:40	G7	39.07500	83.12176	55842	55839	55820	55200	620
10/13/81	14:20	I5	39.09200	83.10890	55848	55843	55824	55208	616
10/13/81	15:00	H4	39.09935	83.11596	55868	55859	55840	55208	616
10/13/81	15:20	H1	39.12500	83.11667	55901	55891	55872	55219	653
10/13/81	15:45	I1	39.12391	83.10833	55917	55908	55889	55218	671
10/13/81	16:05	J1	39.12237	83.09930	55904	55894	55875	55217	658
10/13/81	16:20	K1	39.12347	83.09167	55934	55923	55904	55216	688
10/13/81	17:00	010	39.05000	83.05833	55806	55793	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
10/31/81	9:15	O10	39.05000	83.05833	55792	55770	55774	55184	590
10/31/81	9:30	J9	39.05833	83.09874	55984	55966	55970	55191	779
10/31/81	9:40	J10	39.05000	83.10000	55947	55931	55935	55187	748
10/31/81	9:50	J11	39.04167	83.10000	55936	55921	55925	55184	741
10/31/81	10:30	K10	39.04874	83.09167	55990	55980	55984	55185	799
10/31/81	10:50	K11	39.04167	83.09167	55998	55991	55995	55183	812
10/31/81	11:10	K12	39.03542	83.09115	55975	55969	55973	55181	792
10/31/81	11:20	L12	39.03498	83.08489	55953	55948	55952	55181	771
10/31/81	11:30	L11	39.04057	83.08333	55979	55975	55979	55181	798
10/31/81	11:50	K11.5	39.03934	83.08795	55960	55958	55962	55181	781
10/31/81	12:05	M10	39.05000	83.07500	56001	56000	56004	55185	819
10/31/81	12:25	O10	39.05000	83.05833	55770	55770	55774	55184	590
10/31/81	12:30	M9	39.05998	83.07571	56055	56055	56059	55191	868
10/31/81	12:45	K9	39.05932	83.09167	55990	55989	55993	55192	801
10/31/81	13:00	L9	39.05833	83.08390	56044	56042	56046	55190	856
10/31/81	13:15	K9.5	39.05593	83.08686	56055	56052	56056	55188	868
10/31/81	13:25	L10	39.05520	83.08754	56010	56006	56010	55188	822
10/31/81	13:55	O9	39.05833	83.05763	55725	55717	55721	55183	538
10/31/81	14:10	P8	39.06579	83.05141	55756	55746	55750	55183	567
10/31/81	14:20	O8.5	39.06206	83.05410	55767	55756	55760	55183	677
10/31/81	14:30	O8	39.06667	83.05918	55842	55830	55834	55191	643
10/31/81	14:40	N7	39.07424	83.06441	55857	55843	55847	55193	654
10/31/81	14:55	N6	39.08005	83.06441	55889	55873	55877	55196	681
10/31/81	15:20	O6	39.08191	83.05833	55890	55870	55874	55196	678
10/31/81	15:40	M6	39.08333	83.07500	55953	55930	55934	55200	734
10/31/81	15:50	L7	39.07500	83.08333	55993	55969	55973	55202	771
10/31/81	16:15	N9	39.05877	83.06667	55948	55920	55924	55190	734
10/31/81	16:40	O10	39.05000	83.05833	55804	55770	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/01/81	7:45	O10	39.05000	83.05833	55800	55776	55774	55184	590
11/01/81	8:10	Q10	39.05000	83.04167	55547	55526	55524	55182	342
11/01/81	8:35	S10	39.05000	83.02500	55413	55395	55393	55180	213
11/01/81	8:45	R10	39.05000	83.03333	55484	55467	55465	55181	284
11/01/81	8:55	P10	39.05000	83.04916	55667	55651	55649	55182	467
11/01/81	9:10	P9.5	39.05505	83.02105	55606	55592	55590	55184	406
11/01/81	9:30	Q9.5	39.05450	83.03771	55541	55529	55527	55183	344
11/01/81	9:35	Q9	39.05833	83.04108	55576	55564	55562	55185	377
11/01/81	9:45	R9	39.05833	83.03333	55515	55504	55502	55185	317
11/01/81	9:50	S9	39.05833	83.02656	55479	55468	55466	55184	282
11/01/81	10:00	R9.5	39.05450	83.02811	55444	55434	55432	55182	250
11/01/81	10:45	R11	39.04167	83.03333	55384	55378	55376	55178	198
11/01/81	11:15	P11.5	39.03750	83.04563	55511	55508	55506	55177	329
11/01/81	11:25	Q12	39.03333	83.04167	55444	55441	55339	55175	264
11/01/81	11:50	Q13	39.02500	83.04167	55446	55445	55443	55171	272
11/01/81	12:05	R12	39.03333	83.03333	55348	55348	55346	55174	172
11/01/81	12:20	O10	39.05000	83.05833	55776	55776	55774	55184	590
11/01/81	12:55	R13	39.02500	83.03333	55304	55303	55301	55171	130
11/01/81	13:20	R15	39.00833	83.03333	55254	55251	55249	55164	85
11/01/81	13:55	P15	39.00921	83.04916	55481	55475	55473	55167	306
11/01/81	14:25	Q14	39.01667	83.03983	55343	55335	55333	55168	165
11/01/81	14:55	S11	39.04167	83.02331	55322	55311	55309	55176	133
11/01/81	15:05	S12	39.03333	83.02571	55228	55216	55214	55174	40
11/01/81	15:10	S13	39.02500	83.02500	55263	55250	55248	55170	78
11/01/81	15:25	S15	39.00833	83.02698	55145	55131	55129	55163	-34
11/01/81	15:45	U10	39.05044	83.00833	55308	55291	55289	55181	108
11/01/81	15:50	V10	39.05198	83.00000	55300	55282	55280	55180	100
11/01/81	16:00	U9	39.05691	83.00580	55375	55356	55354	55180	174
11/01/81	16:10	T10	39.05066	83.01837	55345	55325	55323	55182	141
11/01/81	16:25	O10	39.05000	83.05833	55799	55776	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/02/81	7:40	010	39.05000	83.05833	55800	55768	55774	55184	590
11/02/81	7:50	V9	39.06031	83.00057	55373	55352	55358	55184	174
11/02/81	8:05	V8	39.06711	83.00000	55397	55368	55374	55187	187
11/02/81	8:55	U7	39.07500	83.00833	55462	55439	55445	55189	256
11/02/81	9:10	U6	39.08333	83.00833	55493	55472	55478	55193	285
11/02/81	9:30	T6	39.08333	83.01612	55515	55496	55502	55193	309
11/02/81	9:45	T7	39.07500	83.01667	55520	55503	55509	55190	319
11/02/81	10:00	S6	39.75658	83.02783	55636	55621	55627	55193	434
11/02/81	10:15	T5	39.08016	83.01667	55548	55535	55541	55195	345
11/02/81	10:25	U5	39.08977	83.00833	55512	55500	55506	55194	311
11/02/81	10:35	U4	39.09836	83.00664	55547	55536	55542	55198	344
11/02/81	10:55	V5	39.09080	83.00071	55432	55424	55430	55194	236
11/02/81	11:00	V6	39.08333	83.00000	55424	55416	55422	55192	230
11/02/81	11:20	T8	39.06667	83.01724	55709	55704	55710	55187	523
11/02/81	11:35	S7	39.07500	83.02500	55510	55507	55513	55191	322
11/02/81	11:45	R7	39.07500	83.03333	55641	55639	55645	55192	453
11/02/81	12:00	R8	39.06865	83.03333	55547	55546	55551	55190	361
11/02/81	12:10	S8	39.06667	83.02500	55498	55498	55504	55187	317
11/02/81	12:20	010	39.05000	83.05833	55768	55768	55774	55184	590
11/02/81	12:35	P9	39.05833	83.04803	55605	55604	55610	55186	424
11/02/81	12:45	Q8	39.06667	83.04351	55620	55618	55624	55189	435
11/02/81	13:00	R6	39.08333	83.03263	55663	55658	55664	55195	469
11/02/81	13:05	S5	39.09112	83.02459	55660	55654	55660	55196	464
11/02/81	13:20	Q6	39.08333	83.04167	55722	55713	55719	55196	523
11/02/81	13:35	Q7	39.07555	83.04167	55696	55684	55690	55194	496
11/02/81	14:20	U3	39.10680	83.09047	55623	55601	55607	55202	405
11/02/81	14:30	V2	39.11667	83.00000	55633	55609	55615	55206	409
11/02/81	14:40	U2	39.11667	83.00833	55565	55539	55545	55207	338
11/02/81	15:00	T4	39.10000	83.01554	55594	55563	55569	55200	369
11/02/81	15:10	V4	39.09825	83.00057	55537	55504	55510	55198	312
11/02/81	15:30	010	39.05000	83.05833	55806	55768	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/03/81	10:05	O10	39.05000	83.05833	55774	55764	55774	55184	590
11/03/81	10:15	P12	39.03333	83.05198	55606	55597	55607	55176	431
11/03/81	10:25	P13	39.02500	83.05000	55525	55516	55526	55172	354
11/03/81	10:30	P14	39.01667	83.05170	55541	55532	55542	55169	373
11/03/81	10:40	O15	39.00833	83.05833	55645	55637	55647	55166	481
11/03/81	11:00	O14	39.01491	83.05833	55611	55604	55614	55168	446
11/03/81	11:15	N14	39.01667	83.06540	55660	55654	55664	55170	494
11/03/81	11:40	M14	39.01667	83.07500	55821	55816	55826	55171	655
11/03/81	12:10	M13	39.02500	83.07853	55878	55875	55885	55173	712
11/03/81	12:20	L13	39.02446	83.08278	55905	55902	55912	55173	739
11/03/81	12:45	L14	39.01612	83.08559	55872	55870	55880	55171	709
11/03/81	12:55	K13	39.02566	83.09026	55872	55871	55881	55178	703
11/03/81	13:05	J12	39.03542	83.09102	55929	55929	55939	55181	758
11/03/81	13:20	O10	39.05000	83.05833	55764	55764	55774	55184	590
11/03/81	13:35	K14	39.01667	83.09167	55855	55853	55863	55175	688
11/03/81	13:45	J14	39.01667	83.10000	55831	55827	55837	55172	665
11/03/81	13:50	H14	39.01711	83.11724	55819	55814	55824	55177	647
11/03/81	14:00	J13	39.02588	83.10198	55879	55873	55883	55179	704
11/03/81	14:10	I13	39.02566	83.09025	55948	55940	55950	55178	772
11/03/81	14:40	I12	39.03440	83.10707	55943	55929	55939	55183	756
11/03/81	14:55	I11	39.04079	83.10833	55934	55917	55927	55183	744
11/03/81	15:05	H10	39.04880	83.11667	55931	55912	55922	55187	735
11/03/81	15:30	H15	39.00833	83.11667	55836	55813	55823	55172	651
11/03/81	15:35	I15	39.00932	83.10833	55883	55859	55869	55173	696
11/03/81	15:45	G15	39.00833	83.12360	55828	55802	55812	55172	640
11/03/81	15:50	G16	39.00549	83.12500	55840	55814	55824	55171	653
11/03/81	15:55	H16	39.00549	83.11667	55872	55844	55854	55168	686
11/03/81	16:05	I16	39.00000	83.10833	55926	55897	55907	55167	740
11/03/81	16:10	J16	39.00000	83.10000	55937	55907	55917	55167	750
11/03/81	16:15	L16	39.00529	83.08333	55866	55835	55845	55165	680
11/03/81	16:30	O10	39.05000	83.05833	55798	55764	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/04/81	7:55	010	39.05000	83.05833	55798	55774	55774	55184	590
11/04/81	8:10	S15	39.00833	83.02698	54962	54942	54942	55163	-221
11/04/81	8:15	S16	39.00000	83.02698	55145	55126	55126	55160	-34
11/04/81	8:25	S17	38.99167	83.02500	55153	55135	55135	55156	-21
11/04/81	8:35	S18	38.98333	83.02500	55078	55061	55061	55152	-91
11/04/81	8:40	R18	38.98333	83.03333	55192	55176	55176	55153	23
11/04/81	8:55	Q19	38.97500	83.04167	55348	55334	55334	55150	184
11/04/81	9:15	S19	38.97500	83.01540	55104	55092	55092	55147	-55
11/04/81	9:20	R19	38.97500	83.03333	55242	55231	55231	55150	81
11/04/81	9:35	S20	38.96780	83.02500	55082	55073	55073	55147	-74
11/04/81	9:45	R20	38.96711	83.03121	55194	55186	55186	55147	39
11/04/81	10:00	S21	38.95833	83.02500	55000	54993	54993	55141	-148
11/04/81	10:15	S22	38.95000	83.02500	54671	54665	54665	55140	-475
11/04/81	10:25	U22	38.95132	83.00933	54901	54896	54896	55139	-243
11/04/81	10:35	V22	38.95044	83.00000	54938	54934	54934	55138	-204
11/04/81	10:45	T22	38.95274	83.01667	54904	54901	54901	55139	-238
11/04/81	11:10	Q22	38.95285	83.04167	55369	55367	55367	55142	225
11/04/81	11:20	Q21	38.95680	83.03898	55264	55263	55263	55141	122
11/04/81	11:30	R21	38.95658	83.03037	55146	55145	55145	55140	5
11/04/81	11:35	R22	38.95000	83.03333	55169	55169	55169	55141	28
11/04/81	12:05	010	39.05000	83.05833	55774	55774	55774	55184	590
11/04/81	12:20	P16	39.00000	83.04718	55449	55449	55449	55161	288
11/04/81	12:25	Q17	38.98922	83.04464	55436	55435	55435	55157	278
11/04/81	12:30	Q18	38.98114	83.04407	55395	55394	55394	55153	241
11/04/81	12:35	Q20	38.96700	83.04336	55414	55413	55413	55149	264
11/04/81	12:50	P20	38.96661	83.05184	55442	55440	55440	55146	294
11/04/81	13:00	020	38.96820	83.05750	55510	55507	55507	55150	357
11/04/81	13:05	019	38.97412	83.05918	55475	55472	55472	55147	325
11/04/81	13:15	018	38.98234	83.05890	55543	55539	55539	55153	386
11/04/81	13:20	N18	38.98460	83.06667	55687	55683	55683	55158	525
11/04/81	13:35	N19	38.97324	83.06667	55622	55617	55617	55151	466
11/04/81	13:45	N20	38.96820	83.06808	55610	55604	55604	55151	453
11/04/81	13:55	M19	38.97325	83.07500	55695	55689	55689	55152	537
11/04/81	14:00	L19	38.97358	83.08333	55762	55755	55755	55153	602
11/04/81	14:05	K19	38.97390	83.09092	55912	55905	55905	55153	752
11/04/81	14:20	K20	38.96667	83.09252	55829	55820	55820	55152	668

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/04/81	14:25	H19	38.97500	83.11511	55992	55983	55983	55157	826
11/04/81	14:30	H18	38.98333	83.11738	56002	55992	55992	55162	830
11/04/81	14:40	G18	38.98604	83.12444	56020	56010	56010	56164	846
11/04/81	14:55	I17	38.99222	83.10960	55989	55977	55977	55166	811
11/04/81	15:15	N15	39.00833	83.06257	55637	55623	55623	55166	457
11/04/81	15:25	M15	39.01002	83.07500	55800	55785	55785	55169	616
11/04/81	15:35	010	39.05000	83.05833	55791	55774	55774	55184	590
11/05/81	7:30	010	39.05000	83.05833	55796	55768	55774	55184	590
11/05/81	7:45	R5	39.09110	83.03333	55823	55799	55805	55197	608
11/05/81	7:55	Q5	39.08859	83.04167	55610	55588	55594	55198	396
11/05/81	8:00	P5	39.09299	83.05000	55812	55791	55797	55202	777
11/05/81	8:05	05	39.09386	83.05777	55866	55846	55852	55202	650
11/05/81	8:10	04	39.10000	83.05974	55932	55912	55918	55205	713
11/05/81	8:35	T3	39.10833	83.01667	55690	55674	55680	55204	476
11/05/81	8:45	S3	39.10712	83.02260	55815	55801	55807	55199	608
11/05/81	8:55	S2	39.11667	83.02331	55821	55808	55814	55208	606
11/05/81	9:00	R2	39.11600	83.03418	55869	55856	55862	55208	654
11/05/81	9:05	Q3	39.10833	83.04167	55865	55853	55859	55206	653
11/05/81	9:10	P3	39.10702	83.05099	55886	55875	55881	55206	675
11/05/81	9:15	03	39.10658	83.05833	55816	55805	55811	55206	605
11/05/81	9:30	P2	39.11370	83.05268	55821	55812	55818	55209	609
11/05/81	9:40	02	39.11667	83.05508	55854	55846	55852	55211	641
11/05/81	9:45	01	39.12215	83.05635	55761	55754	55760	55213	547
11/05/81	9:55	P1	39.12204	83.05000	55790	55784	55790	55212	578
11/05/81	10:10	Q2	39.11524	83.04605	55830	55825	55831	55209	622
11/05/81	10:20	Q1	39.12500	83.03968	55973	55969	55975	55211	764
11/05/81	10:25	R1	39.12412	83.03333	55775	55772	55778	55211	567
11/05/81	10:45	R3	39.10986	83.03333	55873	55871	55877	55207	670
11/05/81	10:50	R3.5	39.10438	83.02585	55766	55765	55771	55203	568
11/05/81	11:05	010	39.05000	83.05833	55768	55768	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/08/81	10:40	O10	39.05000	83.05833	55777	55777	55774	55184	590
11/08/81	10:50	E12	39.03333	83.14167	56058	56058	56055	55185	870
11/08/81	11:00	E13	39.02500	83.14167	55885	55885	55882	55181	701
11/08/81	11:10	F13	39.02500	83.13333	55945	55944	55941	55181	760
11/08/81	11:20	F12	39.03333	83.13333	56116	56115	56112	55184	928
11/08/81	11:30	E11	39.04167	83.14081	56080	56079	56076	55188	888
11/08/81	11:40	E11.5	39.13630	83.12873	56086	56084	56081	55186	895
11/08/81	11:50	F11	39.04167	83.13404	56061	56059	56056	55188	868
11/08/81	12:05	E14	39.01667	83.14167	55762	55759	55756	55178	578
11/08/81	12:35	F14	39.01667	83.13333	55923	55920	55917	55177	740
11/08/81	13:10	D13	39.02500	83.15000	55844	55838	55835	55182	653
11/08/81	13:35	D12	39.03223	83.15000	55992	55985	55982	55184	798
11/08/81	14:00	C12	39.03467	83.15721	55907	55899	55896	55187	709
11/08/81	14:40	C13	39.02500	83.15833	55867	55857	55854	55183	671
11/08/81	14:55	A13	39.02533	83.17455	55767	55756	55753	55186	567
11/08/81	15:05	B13	39.02105	83.16667	55770	55758	55755	55182	573
11/08/81	15:10	C14	39.01667	83.15833	55707	55695	55692	55179	513
11/08/81	15:20	B14	39.01667	83.16667	55713	55700	55697	55180	517
11/08/81	15:35	A15	39.00833	83.17500	55651	55637	55634	55177	457
11/08/81	15:45	A14	39.01359	83.17500	55665	55650	55647	55179	468
11/08/81	16:00	B15	39.00833	83.16667	55611	55595	55592	55179	416
11/08/81	16:10	D15	39.00910	83.15000	55715	55698	55695	55177	518
11/08/81	16:20	D16	39.00000	83.15000	55722	55704	55701	55171	530
11/08/81	16:30	E16	39.00000	83.14025	55814	55795	55792	55170	622
11/08/81	16:35	F16	39.00110	83.13234	55826	55807	55804	55171	633
11/08/81	16:45	G14	39.01667	83.12585	55810	55790	55787	55176	611
11/08/81	17:05	O10	39.05000	83.05833	55800	55777	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/10/81	9:55	010	39.05000	83.05833	55778	55778	55774	55184	590
11/10/81	10:25	D17	38.99266	83.14929	55789	55789	55785	55169	616
11/10/81	10:35	E17	38.99167	83.13884	55845	55845	55841	55167	674
11/10/81	10:45	E18	38.98333	83.13460	55948	55948	55944	55166	778
11/10/81	11:05	F18	38.98585	83.14788	55840	55839	55835	55163	672
11/10/81	11:20	D18	38.98234	83.15099	55865	55864	55860	55159	701
11/10/81	11:45	C18	38.98333	83.15833	55830	55829	55825	55165	660
11/10/81	11:50	B17	38.99111	83.16823	55799	55798	55794	55168	626
11/10/81	12:00	A18	38.98333	83.17500	55900	55899	55894	55166	728
11/10/81	12:15	C19	38.97500	83.15833	55945	55943	55939	55162	777
11/10/81	12:25	B19	38.97314	83.16667	55947	55945	55941	55161	780
11/10/81	12:55	010	39.05000	83.05833	55781	55778	55774	55184	590
11/10/81	13:35	F19	38.97314	83.12952	55970	55963	55959	55157	802
11/10/81	13:55	G20	38.96667	83.12571	56064	56055	56051	55155	896
11/10/81	14:15	F21	38.95658	83.13333	56115	56103	56099	55150	949
11/10/81	14:25	E22	38.95000	83.13968	56138	56125	56121	55151	970
11/10/81	14:30	D22	38.95000	83.15000	56086	56072	56068	55152	916
11/10/81	14:40	C22	38.95000	83.15833	55971	55956	55952	55153	799
11/10/81	14:55	C21	38.95767	83.15904	56057	56041	56037	55153	884
11/10/81	15:00	D21	38.95833	83.15381	56011	55996	55992	55154	838
11/10/81	15:10	D20	38.96491	83.15071	55998	55980	55976	55156	820
11/10/81	15:30	B22	38.95000	83.16780	56041	56021	56017	55154	863
11/10/81	15:35	A22	38.95110	83.17500	56106	56085	56081	55154	927
11/10/81	15:45	A21	38.95997	83.17373	56058	56036	56032	55158	874
11/10/81	15:55	B20	38.96600	83.16907	55999	55976	55972	55158	814
11/10/81	16:05	A20	38.96590	83.17302	56021	55997	55993	55158	835
11/10/81	16:15	B21	38.95997	83.16879	56059	56034	56030	55158	872
11/10/81	16:25	F22	38.95186	83.13333	56089	56063	56059	55150	909
11/10/81	16:35	G19	38.97314	83.12500	56022	55994	55990	55157	833
11/10/81	16:55	010	39.05000	83.05833	55808	55778	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/11/81	7:30	010	39.05000	83.05833	55800	55772	55774	55184	590
11/11/81	7:55	U21	38.95943	83.00833	55008	54983	54985	55142	-157
11/11/81	8:05	T20	38.96403	83.01667	55005	54981	54983	55143	-160
11/11/81	8:10	U20	38.96667	83.00548	54970	54946	54948	55143	-195
11/11/81	8:25	V19	38.97171	83.00170	55016	54994	54996	55145	-149
11/11/81	8:40	V21	38.96030	83.00000	54984	54963	54965	55142	-177
11/11/81	8:50	V20	38.96622	83.00071	55024	55004	55006	55142	-136
11/11/81	9:05	T19	38.97500	83.01667	55067	55049	55051	55148	-97
11/11/81	9:25	U19	38.97547	83.00947	55115	55099	55101	55149	-48
11/11/81	9:30	V18	38.98333	83.00085	55052	55036	55038	55150	-112
11/11/81	9:50	V17	38.99045	83.00000	55115	55101	55103	55152	-49
11/11/81	10:30	T18	38.98881	83.01667	55085	55075	55077	55153	-76
11/11/81	10:45	T17	38.99167	83.01733	54925	54917	54919	55155	-236
11/11/81	11:00	T16	39.00000	83.01738	55123	55116	55118	55159	-41
11/11/81	11:10	T15	39.00833	83.01738	55110	55104	55106	55162	-56
11/11/81	11:35	T12	39.03048	83.01667	55227	55223	55225	55171	54
11/11/81	11:45	T13	39.02588	83.01667	55036	55033	55035	55171	-136
11/11/81	12:05	T11	39.04167	83.01851	55307	55305	55307	55176	131
11/11/81	12:25	U11	39.04167	83.00833	55279	55278	55280	55175	105
11/11/81	12:45	010	39.05000	83.05833	55772	55772	55774	55184	590
11/11/81	13:00	U8	39.06788	83.00720	55418	55418	55420	55184	236
11/11/81	13:10	V7	39.07336	83.00000	55311	55311	55313	55187	126
11/11/81	14:00	N3	39.10767	83.06483	55822	55820	55822	55207	615
11/11/81	14:15	M2	39.11502	83.07500	55847	55845	55847	55211	636
11/11/81	14:20	M1	39.12423	83.07401	55817	55815	55817	55214	603
11/11/81	14:30	N1	39.12500	83.06808	55774	55771	55773	55214	559
11/11/81	14:35	L1	39.12500	83.08079	55838	55835	55837	55215	622
11/11/81	14:50	L2	39.11600	83.08333	55848	55845	55847	55214	633
11/11/81	15:05	K2	39.11667	83.08968	55860	55856	55858	55214	644
11/11/81	15:25	M3	39.10988	83.07232	55829	55824	55826	55211	615
11/11/81	15:45	L4	39.10000	83.07980	55859	55853	55855	55207	648
11/11/81	15:55	M4	39.09901	83.07500	55819	55812	55814	55204	610
11/11/81	16:15	K4	39.09934	83.09095	55829	55821	55823	55206	617
11/11/81	16:25	L5	39.09167	83.08333	55847	55838	55840	55203	637
11/11/81	16:40	010	39.05000	83.05833	55782	55772	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/12/81	7:40	O10	39.05000	83.05833	55793	55790	55774	55184	590
11/12/81	8:05	K5	39.08503	83.09167	55804	55801	55785	55202	583
11/12/81	8:15	J6	39.08443	83.09944	55801	55798	55782	55203	579
11/12/81	8:30	I4	39.09945	83.10904	55737	55735	55719	55208	574
11/12/81	8:50	J5	39.09167	83.10000	55849	55847	55831	55205	626
11/12/81	9:25	N4	39.09748	83.06525	55899	55897	55881	55203	678
11/12/81	9:40	P4	39.10000	83.05071	55898	55896	55880	55204	676
11/12/81	10:20	Q4	39.10000	83.04534	55886	55885	55869	55203	666
11/12/81	11:05	M5	39.09067	83.07712	55872	55871	55855	55201	654
11/12/81	11:25	K6	39.08530	83.09167	55854	55853	55837	55202	635
11/12/81	11:55	L6	39.08574	83.08333	55856	55855	55839	55202	637
11/12/81	12:15	K7	39.07270	83.08757	55963	55963	55947	55195	752
11/12/81	12:35	O7	39.07708	83.05833	55836	55836	55820	55196	624
11/12/81	13:15	O10	39.05000	83.05833	55790	55790	55774	55184	590
11/12/81	13:35	C4	39.09901	83.15960	55732	55732	55716	55213	503
11/12/81	13:55	C6	39.08202	83.15777	55788	55787	55771	55205	566
11/12/81	14:15	A12	39.03410	83.17500	55736	55734	55718	55189	529
11/12/81	14:35	B12	39.03454	83.16271	55837	55833	55817	55188	629
11/12/81	15:00	O10	39.05000	83.05833	55797	55790	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/15/81	9:10	010	39.05000	83.05833	55785	55782	55774	55184	590
11/15/81	9:25	K8	39.06556	83.09336	55932	55929	55921	55192	729
11/15/81	9:35	J8	39.06667	83.09788	55959	55956	55948	55194	754
11/15/81	9:55	J7	39.07500	83.10311	55880	55878	55870	55198	672
11/15/81	10:55	H20	38.96524	83.11567	55926	55924	55916	55152	764
11/15/81	11:10	I20	38.96491	83.10904	55930	55929	55921	55152	769
11/15/81	11:25	I21	38.95734	83.10833	55929	55928	55920	55148	772
11/15/81	11:30	H21	38.95756	83.11412	56036	56036	55028	55148	880
11/15/81	11:55	J21	38.95833	83.10000	55853	55852	55844	55149	695
11/15/81	12:10	J22	38.95000	83.10268	55831	55830	55822	55147	675
11/15/81	12:20	K22	38.95000	83.10904	55774	55773	55765	55146	619
11/15/81	12:30	I22	38.95000	83.10904	55903	55902	55894	55148	746
11/15/81	12:45	H22	38.94923	83.11539	56028	56028	56020	55148	872
11/15/81	13:00	G22	38.95000	83.12076	56051	56051	56043	55149	894
11/15/81	13:10	G21	38.95680	83.12655	56106	56106	56098	55150	948
11/15/81	13:40	010	39.05000	83.05833	55782	55782	55774	55184	950
11/15/81	14:10	P22	38.95000	83.04817	55438	55437	55429	55142	287
11/15/81	14:20	P21	38.95833	83.04887	55427	55426	55418	55144	274
11/15/81	14:40	021	38.96052	83.05833	55532	55530	55522	55147	375
11/15/81	15:05	M20	38.96644	83.07345	55584	55580	55572	55150	422
11/15/81	15:40	M21	38.95833	83.07500	55653	55647	55639	55147	492
11/15/81	16:00	N21	38.95647	83.06738	55590	55582	55574	55144	403
11/15/81	16:10	N22	38.95110	83.06798	55589	55580	55572	55144	403
11/15/81	17:00	P11	39.03826	83.05000	55598	55584	55576	55177	399
11/15/81	17:10	010	39.05000	83.05833	55798	55782	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/16/81	7:30	O10	39.05000	83.05833	55798	55785	55774	55184	590
11/16/81	9:25	I18	38.98333	83.10833	56039	56030	56019	55160	859
11/16/81	9:40	J18	38.98333	83.10240	56010	56002	55991	55160	831
11/16/81	9:55	J17	38.99364	83.10085	55934	55926	55915	55165	750
11/16/81	10:15	G17	38.99167	83.12500	55967	55960	55949	55165	784
11/16/81	10:25	F17	38.99266	83.13093	55978	55971	55960	55168	792
11/16/81	11:00	E15	39.00658	83.14167	55738	55733	55722	55172	550
11/16/81	12:00	L15	39.00680	83.08178	55844	55841	55830	55166	664
11/16/81	12:15	O16	39.00000	83.06031	55637	55634	55623	55163	460
11/16/81	12:30	J15	39.00910	83.10282	55846	55844	55833	55172	661
11/16/81	12:55	I14	39.01667	83.10833	55882	55881	55870	55174	696
11/16/81	13:00	H13	39.02434	83.11440	55954	55953	55942	55176	766
11/16/81	13:30	G13	39.02544	83.12571	55996	55996	55985	55182	803
11/16/81	13:50	O10	39.05000	83.05833	55785	55785	55774	55184	590
11/16/81	14:10	G11	39.04167	83.12669	56030	56029	56018	55187	831
11/16/81	14:30	G12	39.03333	83.12500	56120	56117	55106	55183	923
11/16/81	15:00	C15	39.00888	83.15607	55700	55695	55684	55175	509
11/16/81	15:30	B16	39.00219	83.16667	55703	55695	55684	55175	509
11/16/81	16:00	B18	38.98443	83.16667	55867	55856	55845	55168	677
11/16/81	16:20	A17	38.99111	83.17500	55889	55876	55865	55168	697
11/16/81	16:50	O10	39.05000	83.05833	55801	55785	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/18/81	9:55	010	39.05000	83.05833	55775	55768	55774	55184	590
11/18/81	10:30	M11	39.04167	83.07500	55915	55910	55916	55182	734
11/18/81	10;55	N11	39.04103	83.06780	55947	55943	55949	55179	770
11/18/81	11:05	N12	39.03640	83.06483	55915	55912	55918	55179	739
11/18/81	11:25	012	39.03432	83.06228	55800	55798	55804	55179	625
11/18/81	12:00	M12	39.03717	83.07387	55913	55912	55918	55179	739
11/18/81	12:25	010	39.05000	83.05833	55768	55768	55774	55184	590
11/18/81	13:05	M18	38.98433	83.07500	55775	55773	55779	55159	620
11/18/81	13:15	L18	38.98388	83.08065	55844	55841	55847	55159	688
11/18/81	13:25	K18	38.98497	83.09167	55957	55953	55959	55160	799
11/18/81	14:00	I19	38.97390	83.10875	55975	55966	55972	55155	817
11/18/81	14:15	J20	38.96908	83.10057	55931	55921	55927	55160	767
11/18/81	14:30	J19	38.97379	83.10155	55942	55930	55936	55155	781
11/18/81	14:50	H17	38.99200	83.11780	56028	56013	56019	55167	852
11/18/81	15:25	F15	39.00723	83.13333	55780	55761	55767	55168	599
11/18/81	15:50	M16	39.00230	83.07429	55824	55802	55808	55165	643
11/18/81	16:20	F20	38.96908	83.13234	56026	56001	56007	55157	850
11/18/81	16:25	E20	38.96733	83.13771	56180	56154	56160	55158	948
11/18/81	17:00	K21	38.95745	83.09266	55811	55781	55787	55147	640
11/18/81	17:35	010	39.05000	83.05833	55802	55768	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/19/81	7:30	010	39.05000	83.05833	55792	55785	55774	55184	590
11/19/81	7:50	F6	39.08476	83.13545	55831	55825	55814	55207	607
11/19/81	8:05	E6	39.08421	83.14167	55808	55802	55791	55207	584
11/19/81	9:00	I2	39.11436	83.11002	55952	55947	55936	55215	721
11/19/81	9:10	G1	39.12500	83.12500	55878	55873	55862	55219	643
11/19/81	9:45	K3	39.10734	83.09167	55830	55826	55815	55209	606
11/19/81	9:55	L3	39.10833	83.08333	55833	55829	55818	55210	608
11/19/81	10:30	N5	39.09222	83.06511	55918	55915	55904	55203	701
11/19/81	11:10	P6	39.08333	83.05000	55799	55796	55785	55197	588
11/19/81	11:55	S1	39.12500	83.02754	55841	55839	55828	55210	618
11/19/81	12:20	T1	39.12401	83.01667	55659	55658	55647	55209	438
11/19/81	12:25	U1	39.12445	83.00904	55722	55721	55710	55209	501
11/19/81	12:30	V1	39.12500	83.00000	55650	55649	55638	55208	430
11/19/81	12:45	V3	39.10833	83.00000	55614	55613	55602	55203	399
11/19/81	13:10	T2	39.11667	83.01525	55717	55717	55706	55207	499
11/19/81	13:30	010	39.05000	83.05833	55785	55785	55774	55184	590
11/19/81	14:10	C5	39.08947	83.15890	55713	55711	55700	55209	561
11/19/81	14:50	A11	39.04167	83.17387	55753	55748	55737	55191	546
11/19/81	15:35	N13	39.02270	83.06907	55827	55819	55808	55172	636
11/19/81	15:55	013	39.02774	83.06667	55863	55853	55842	55175	667
11/19/81	17:05	R17	38.99167	83.03333	55301	55285	55274	55157	117
11/19/81	17:15	Q17	38.99167	83.04167	55377	55360	55349	55157	192
11/19/81	17:30	010	39.05000	83.05833	55803	55785	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/22/81	11:00	010	39.05000	83.05833	55776	55776	55774	55184	590
11/22/81	11:55	P17	38.99288	83.04873	55525	55523	55521	55160	361
11/22/81	12:20	017.5	38.98859	83.05650	55584	55581	55579	55157	422
11/22/81	12:40	P18	38.98212	83.05169	55520	55516	55514	55153	361
11/22/81	13:25	017	38.99255	83.06059	55659	55653	55651	55161	490
11/22/81	13:45	N17	38.99331	83.06426	55709	55702	55700	55161	539
11/22/81	14:45	P19	38.97621	83.04831	55402	55392	55390	55153	237
11/22/81	15:55	M22	38.95099	83.07500	55642	55630	55628	55145	483
11/22/81	16:55	010	39.05000	83.05833	55794	55776	55774	55184	590
11/25/81	9:30	010	39.05000	83.05833	55776	55773	55774	55184	590
11/25/81	9:55	M6.5	39.07601	83.07048	55950	55948	55949	55197	752
11/25/81	10:15	N8	39.06864	83.07429	55919	55917	55918	55193	725
11/25/81	10:25	M8	39.06919	83.07274	55963	55961	55962	55193	769
11/25/81	10:30	M7	39.07248	83.07500	55965	55963	55964	55194	770
11/25/81	11:05	L8	39.06535	83.08178	56030	56029	56030	55191	839
11/25/81	11:15	I9	39.06052	83.10748	55921	55921	55922	55193	729
11/25/81	11:35	G10	39.04858	83.12500	55916	55915	55916	55188	728
11/25/81	11:40	H11	39.04353	83.11964	55948	55947	55948	55188	760
11/25/81	12:00	I10	39.04945	83.10704	55917	55917	55918	55187	731
11/25/81	12:15	H12	39.03585	83.12020	55919	55919	55920	55184	736
11/25/81	12:40	010	39.05000	83.05833	55773	55773	55774	55184	590
11/25/81	12:55	N10	39.05000	83.06667	55935	55935	55936	55184	752
11/25/81	13:10	011	39.04222	83.06073	55843	55842	55843	55182	661
11/25/81	14:00	K15	39.00833	83.08813	55895	55888	55889	55169	720
11/25/81	14:40	022	38.94956	83.05748	55546	55534	55535	55143	392
11/25/81	15:15	L20	38.96722	83.08375	55813	55796	55797	55153	644
11/25/81	15:30	L21	38.96195	83.08474	55776	55757	55758	55150	608
11/25/81	16:25	Q16	39.00000	83.04294	55425	55399	55400	55161	239
11/25/81	16:40	010	39.05000	83.05833	55801	55773	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/26/81	7:30	010	39.05000	83.05833	55795	55782	55774	55184	590
11/26/81	7:40	T9	39.05833	83.01879	55249	55237	55229	55183	46
11/26/81	8:15	V12	39.03333	83.00000	54936	54925	54917	55173	-256
11/26/81	9:30	U18	38.98081	83.10165	55059	55061	55053	55149	-96
11/26/81	10:00	T21	38.95723	83.01815	55028	55021	55013	55140	-127
11/26/81	10:40	S4	39.10000	83.02500	55809	55804	55796	55201	595
11/26/81	10:50	R4	39.10164	83.03262	55864	55859	55851	55203	648
11/26/81	11:40	N2	39.11667	83.06893	55798	55796	55788	55213	575
11/26/81	12:20	P7	39.07730	83.05000	55836	55835	55827	55195	632
11/26/81	12:55	010	39.05000	83.05833	55782	55782	55774	55184	590
11/26/81	13:35	D19	38.97643	83.15099	55941	55938	55930	55153	777
11/26/81	13:50	E19	38.97423	83.14252	55808	55803	55795	55159	636
11/26/81	14:15	C17	38.99167	83.15904	55775	55767	55759	55169	590
11/26/81	14:30	C16	38.99682	83.15904	55727	55717	55709	55171	538
11/26/81	15:15	010	39.05000	83.05833	55797	55782	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/28/81	10:25	010	39.05000	83.05833	55770	55777	55774	55184	590
11/28/81	10:35	P10.5	39.04660	83.04591	55599	55599	55596	55181	415
11/28/81	10:45	Q10.5	39.04595	83.03672	55448	55448	55445	55180	265
11/28/81	10:50	R10.5	39.04551	83.02980	55387	55386	55383	55179	204
11/28/81	11:00	Q11.5	39.03750	83.03813	55411	55410	55407	55176	231
11/28/81	11:10	R11.5	39.03695	83.02994	55183	55182	55179	55175	4
11/28/81	11:15	R12.5	39.03059	83.02994	55288	55287	55284	55172	112
11/28/81	11:25	Q12.5	39.02730	83.03601	55320	55318	55315	55173	142
11/28/81	11:30	Q13.5	39.02226	83.03926	55347	55345	55342	55169	173
11/28/81	11:45	R13.5	39.02248	83.02938	55220	55218	55215	55168	47
11/28/81	11:55	R14.5	39.08574	83.02938	55189	55187	55184	55165	19
11/28/81	12:05	Q14.5	39.01118	83.03630	55176	55273	55270	55166	104
11/28/81	12:10	P14.5	39.01107	83.04492	55398	55395	55392	55167	225
11/28/81	12:20	P15.5	39.00482	83.04506	55396	55393	55390	55163	227
11/28/81	12:30	Q15.5	39.00526	83.03827	55312	55308	55305	55162	143
11/28/81	12:45	R15.5	39.00406	83.02924	55183	55179	55176	55161	15
11/28/81	13:00	010	39.05000	83.05833	55782	55777	55774	55184	590
11/28/81	13:05	N9.5	39.05362	83.06285	55888	55883	55880	55186	694
11/28/81	13:10	010.5	39.04803	83.05508	55759	55754	55751	55181	570
11/28/81	13:30	R16.5	38.99408	83.02782	55181	55175	55172	55158	14
11/28/81	13:45	R17.5	38.98629	83.02938	55172	55165	55162	55154	8
11/28/81	13:55	Q17.5	38.98750	83.03771	55318	55311	55308	55155	153
11/28/81	14:15	Q18.5	38.98048	83.03954	55345	55336	55333	55152	181
11/28/81	14:25	R18.5	38.97949	83.02881	55208	55199	55196	55151	45
11/28/81	14:30	R19.5	38.97160	83.02825	55176	55166	55163	55147	16
11/28/81	14:40	Q19.5	38.97171	83.03587	55287	55277	55274	55148	126
11/28/81	14:55	Q20.5	38.96239	83.03785	55296	55285	55282	55145	137
11/28/81	15:00	R20.5	38.96140	83.03065	55204	55193	55190	55144	46
11/28/81	15:10	R21.5	38.95296	83.02853	55153	55141	55138	55140	-2
11/28/81	15:20	Q21.5	38.95428	83.03742	55298	55285	55282	55141	141
11/28/81	15:35	S21.5	38.95351	83.02105	55007	54994	54991	55140	-149
11/28/81	15:45	T21.5	38.95373	83.01271	54992	54978	54975	55139	-164
11/28/81	15:55	U21.5	38.95274	83.00297	54980	54965	54962	55138	-176
11/28/81	16:20	T20.5	38.96184	83.01158	55016	55000	54997	55142	-145
11/28/81	16:40	S20.5	38.96195	83.01879	55061	55044	55041	55143	-102
11/28/81	16:50	S19.5	38.97160	83.01949	55105	55087	55084	55147	-63
11/28/81	17:05	010	39.05000	83.05833	55796	55777	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/29/81	7:45	010	39.05000	83.05833	55795	55773	55774	55184	590
11/29/81	8:05	U20.5	38.96491	83.00438	55002	54982	54983	55142	-159
11/29/81	8:10	T19.5	38.97084	83.01172	55034	55014	55015	55146	-131
11/29/81	8:15	U18.5	38.98103	83.00424	55045	55026	55027	55149	-122
11/29/81	8:25	S18.5	38.98081	83.02147	54983	54965	54966	55150	-184
11/29/81	8:30	S17.5	38.98604	83.02204	55099	55081	55082	55154	-72
11/29/81	8:35	S16.5	38.99605	83.02447	54988	54971	54972	55157	-185
11/29/81	8:45	S15.5	39.00252	83.02161	55129	55112	55113	44161	-48
11/29/81	9:00	S14.5	39.01271	83.02288	55169	55154	55155	55164	-9
11/29/81	9:10	S12.5	39.02851	83.02020	55197	55182	55183	55171	12
11/29/81	9:25	S11.5	39.03870	83.02161	55314	55301	55302	55175	127
11/29/82	9:40	T10.5	39.04529	83.01313	55282	55270	55271	55177	94
11/29/81	9:55	U9.5	39.05417	83.00409	55297	55286	55287	55180	107
11/29/81	10:00	T9.5	39.05384	83.01186	55346	55336	55337	55181	156
11/29/81	10:10	S10.5	39.04638	83.02076	55296	55287	55288	55178	110
11/29/81	10:20	S9.5	39.05351	83.02048	55446	55437	55438	55182	256
11/29/81	10:30	T8.5	39.06206	83.01370	55417	55409	55410	55184	226
11/29/81	10:40	U7.5	39.07029	83.00198	55391	55384	55385	55187	198
11/29/81	10:50	U8.5	39.06392	83.00353	55282	55276	55277	55184	93
11/29/81	11:00	T7.5	39.06985	83.01242	55838	55833	55834	55188	646
11/29/81	11:10	S8.5	39.06239	83.02048	55331	55327	55328	55185	143
11/29/81	11:15	S7.5	39.06831	83.02048	55400	55396	55397	55189	208
11/29/81	11:35	R7.5	39.07215	83.02782	55516	55514	55515	55189	326
11/29/81	11:50	R6.5	39.07785	83.02994	55601	55600	55601	55193	408
11/29/81	12:00	Q7.5	39.07062	83.03686	55560	55559	55560	55190	370
11/29/81	12:05	R8.5	39.06348	83.02952	55515	55515	55516	55186	330
11/29/81	12:15	Q8.5	39.06271	83.03757	55571	55571	55572	55187	385
11/29/81	12:30	010	39.05000	83.05833	55773	55773	55774	55184	590
11/29/81	12:40	U6.5	39.07884	83.00494	55371	55371	55372	55191	181
11/29/81	12:45	T6.5	39.07796	83.01206	55462	55461	55462	55191	271
11/29/81	12:55	S6.5	39.07928	83.02119	55545	55544	55545	55192	353
11/29/81	13:10	T5.5	39.08750	83.01327	55510	55507	55508	55195	313
11/29/81	13:15	U5.5	39.08782	83.00494	55491	55488	55489	55194	295
11/29/81	13:40	U4.5	39.09551	83.00480	55526	55519	55520	55198	322
11/29/81	13:50	T4.5	39.09584	83.01186	55571	55563	55564	55198	366
11/29/81	14:00	U3.5	39.10274	83.00607	55620	55611	55612	55201	411
11/29/81	14:20	U1.5	39.11875	83.00240	55671	55659	55660	55208	452

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
11/29/81	14:25	U2.5	39.11228	83.00395	55579	55567	55568	55205	363
11/29/81	14:30	T3.5	39.10296	83.01200	55503	55490	55491	55202	289
11/29/81	14:40	S5.5	39.08684	83.02105	55620	55606	55607	55196	411
11/29/81	14:50	S4.5	39.09584	83.01964	55632	55617	55618	55199	419
11/29/81	15:00	R5.5	39.08826	83.02909	55692	55676	55677	55196	481
11/29/81	15:10	Q5.5	39.08771	83.03686	55741	55723	55724	55197	527
11/29/81	15:20	Q6.5	39.07581	83.03601	55698	55679	55680	55194	486
11/29/81	15:30	P8.5	39.06096	83.04633	55701	55681	55682	55188	494
11/29/81	15:50	P12.5	39.03026	83.04746	55554	55532	55533	55174	359
11/29/81	16:10	014.5	39.01326	83.05339	55575	55550	55551	55167	384
11/29/81	16:25	N14.5	39.01261	83.06299	55701	55675	55676	55168	508
11/29/81	16:35	010	39.05000	83.05833	55801	55773	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
12/03/81	10:40	010	39.05000	83.05833	55766	55766	55774	55184	590
12/03/81	10:50	P15.5	39.00340	83.04704	55446	55446	55454	55163	291
12/03/81	10:55	P16.5	38.99551	83.04548	55418	55418	55426	55160	266
12/03/81	11:05	P20.5	38.96195	83.04506	55339	55338	55346	55146	200
12/03/81	11:10	P21.5	38.95384	83.04591	55390	55389	55397	55142	255
12/03/81	11:20	O20.5	38.96358	83.05565	55472	55471	55479	55146	333
12/03/81	11:25	N19.5	38.97127	83.06214	55498	55496	55504	55151	353
12/03/81	11:35	J19.5	38.97160	83.09633	55865	55863	55871	55150	721
12/03/81	11:45	I18.5	38.97917	83.10452	55996	55993	56001	55158	843
12/03/81	11:55	I17.5	38.98640	83.10424	56006	56002	56010	55162	848
12/03/81	12:10	I16.5	38.99562	83.10339	55940	55935	55943	55165	778
12/03/81	12:55	H18.5	38.97909	83.11299	56026	56018	56026	55159	867
12/03/81	13:35	H17.5	38.98848	83.11341	56068	56058	56066	55162	904
12/03/81	14:00	H16.5	38.99595	83.11214	55981	55969	55977	55166	811
12/03/81	14:15	F16.5	38.99638	83.12980	55879	55866	55874	55168	706
12/03/81	14:25	F17.5	38.98870	83.12825	55973	55959	55967	55164	803
12/03/81	14:45	G18.5	38.97928	83.11964	56018	56003	56011	55160	851
12/03/81	15:00	F18.5	38.97807	83.12754	55962	55946	55954	55161	793
12/03/81	15:05	G19.5	38.97215	83.12091	56022	56006	56014	55156	858
12/03/81	15:15	F19.5	38.97040	83.12909	56011	55994	56002	55157	845
12/03/81	15:20	F20.5	38.96271	83.12867	56102	56085	56093	55154	939
12/03/81	15:35	E20.5	38.96118	83.13658	56088	56070	56078	55154	924
12/03/81	15:45	F21.5	38.95417	83.12867	56026	56007	56015	55150	865
12/03/81	15:55	E21.5	38.95438	83.13686	56161	56142	56150	55151	999
12/03/81	16:25	C21.5	38.95241	83.15480	56080	56059	56067	55152	915
12/03/81	17:00	010	39.05000	83.05833	55790	55766	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
12/05/81	10:00	O10	39.05000	83.05833	55766	55759	55774	55184	590
12/05/81	10:25	G10.5	39.04649	83.12076	55913	55907	55922	55188	734
12/05/81	10:40	G11.5	39.03947	83.12091	55971	55966	55981	55184	797
12/05/81	10:55	F10.5	39.04649	83.12994	55997	55993	56008	55189	819
12/05/81	11:05	F11.5	39.03728	83.12782	56081	56077	56092	55185	907
12/05/81	11:10	F12.5	39.02818	83.12881	56063	56059	56074	55182	892
12/05/81	11:15	F13.5	39.01908	83.12867	55834	55831	55846	55178	668
12/05/81	11:25	F14.5	39.01425	83.12825	55750	55747	55762	55175	587
12/05/81	11:35	E14.5	39.01458	83.13757	55705	55702	55717	55175	542
12/05/81	11:45	E13.5	39.01941	83.13813	55787	55785	55800	55179	621
12/05/81	11:55	E12.5	39.02763	83.13545	56014	56012	56027	55182	845
12/05/81	12:15	D11.5	39.03128	83.14365	56091	56090	56105	55187	918
12/05/81	12:20	D10.5	39.04474	83.14421	56057	56056	56071	55190	881
12/05/81	12:25	E10.5	39.04660	83.13725	56030	56030	56045	55189	856
12/05/81	12:35	F9.5	39.05099	83.12684	55847	55847	55862	55192	670
12/05/81	12:45	O10	39.05000	83.05833	55759	55759	55774	55184	590
12/05/81	13:25	E9.5	39.05143	83.13855	56047	56040	56059	55193	866
12/05/81	13:35	D9.5	39.05339	83.14449	55959	55955	55970	55194	776
12/05/81	13:45	E8.5	39.06250	83.13855	55857	55851	55866	55196	670
12/05/81	14:25	C9.5	39.05340	83.15141	55964	55954	55969	55194	775
12/05/81	14:30	C10.5	39.04430	83.15438	55949	55937	55952	55191	761
12/05/81	15:00	D12.5	39.02768	83.14760	55968	55952	55967	55183	784
12/05/81	15:10	C12.5	39.02697	83.15282	55886	55869	55884	55184	700
12/05/81	15:20	C13.5	39.01952	83.15635	55763	55745	55760	55180	580
12/05/81	15:40	C14.5	39.01348	83.15367	55703	55682	55697	55177	520
12/05/81	15:45	D14	39.01567	83.14704	55740	55718	55733	55176	557
12/05/81	16:10	K8.5	39.06282	83.08884	56048	56023	56038	55192	846
12/05/81	16:15	J8.5	39.06030	83.09520	55956	55930	55945	55192	753
12/05/81	16:30	O10	39.05000	83.05833	55787	55759	55774	55184	590

DATE	HOUR & MINUTE	GRID POS.	LATITUDE	LONGITUDE	FIELD (GAMMAS) RAW OBS.	FIELD W/ DIURNAL CORR.	FIELD W/ MEAN LOW CORR.	IGRF FIELD	RESIDUAL FIELD
12/12/81	10:20	010	39.05000	83.05833	55747	55747	55774	55184	590
12/12/81	11:00	H8	39.06667	83.11709	55749	55748	55775	55197	578
12/12/81	11:40	M9.5	39.05449	83.07006	55953	55951	55978	55186	792
12/12/81	12:00	L9.5	39.05592	83.07924	56030	56027	56054	55187	867
12/12/81	12:15	L8.5	39.06271	83.07684	56027	56024	56051	55191	860
12/12/81	12:30	010	39.05000	83.05833	55752	55747	55774	55184	590
12/12/81	12:45	L10.5	39.04521	83.07909	55959	55952	55979	55184	795
12/12/81	13:10	K10.5	39.04573	83.08827	55985	55974	56001	55185	816
12/12/81	13:45	Q16.5	38.99441	83.03714	55370	55353	55380	55159	221
12/12/81	14:20	P19.5	38.97270	83.04704	55396	55373	55400	55159	241
12/12/81	14:35	018.5	38.97938	83.05494	55472	55447	55474	55154	320
12/12/81	14:55	M18.5	38.98103	83.07331	55751	55722	55749	55155	594
12/12/81	15:10	N18.5	38.97807	83.06172	55635	55604	55631	55154	477
12/12/81	15:30	010	39.05000	83.05833	55782	55747	55774	55184	590
12/16/81	10:35	010	39.05000	83.05833	55765	55765	55774	55184	590
12/16/81	11:40	V16	38.99616	83.00000	55092	55090	55099	55156	-57
12/16/81	11:45	U16	38.99584	83.00833	55050	55048	55057	55158	-101
12/16/81	12:05	T14	39.01447	83.01709	55119	55116	55125	55164	-39
12/16/81	12:20	U14	39.01799	83.00960	54997	54994	55003	55167	-164
12/16/81	12:30	U13.5	39.02215	83.00551	55039	55035	55044	55166	-122
12/16/81	12:35	V13	39.02336	83.00000	55115	55111	55120	55166	-46
12/16/81	12:45	V12.5	39.03125	82.99915	55168	55164	55173	55170	3
12/16/81	12:50	V11	39.04167	83.00000	55210	55205	55214	55175	39
12/16/81	13:15	010	39.05000	83.05833	55771	55765	55774	55184	590