TESTING FOR GRAVES AT WYUKA CEMETERY, LINCOLN, NEBRASKA, USING THREE GEOPHYSICAL METHODS

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ABSTRACT

We used three geophysical methods to examine graves at Wyuka Cemetery in Lincoln, Nebraska. The methods were: fluxgate magnetic gradiometer, cesium magnetic gradiometer and soil resistance meter. We examined two different regions of the cemetery, one with graves dating to around 1905 the other with internments within the last decade. In general the magnetic methods gave similar results but the resistance data were not very useful, probably because of recent rains. Some graves were very visible but a number gave very weak or no anomalies. With the generous help of the cemetery director we examined the records of some of the graves that we could identify in the geophysical results and attempted to relate the visibility of the geophysical results with the physical nature of the internments. This was only partially successful.

INTRODUCTION

The initial purpose of this study was to see if it was possible to locate unmarked graves using geophysical methods. Sites were chosen in a local cemetery that had only a few graves marked with stones. Maps were obtained using three geophysical methods. Results were then compared with cemetery records. After most of the data were obtained it was realized that all of the grave plots were marked with a small cement numbered marker most of which were not visible, having sunk into the ground. We attempted to locate the markers on our maps. However small errors in our positional location of the markers and some ambiguity in the exact position of the plots obtained from plot maps provided by the cemetery prevented unambiguous one-to-one correlation between geophysical anomalies and identified graves. In some cases possible identifications were made. In one area a series of large anomalies lead to an unexpected interpretation of grave vaults.

PREVIOUS STUDIES

Much of the articles on geophysical testing of cemeteries occurs in the "gray" or report literature.

In the mid-1980's, geophysical investigations were reported regarding cemeteries in the Santa Ana river project area in California (Mason et al. 1987). Cemeteries and isolated graves were investigated in the Prado flood control basin and one grave site in the upper Santa Ana canyon. The results were used to evaluate the cemeteries and grave sites for eligibility for the National Register of Historic Places. The possible location of graves within the cemeteries was based on results of geophysical surveys using the Subsurface Interface Radar System-8 manufactured by Geophysical Survey System, Inc., proton magnetometers, an EM-38 meter, and the EM-31DL (both conductivity meters) manufactured by Geonics, Limited The identification of potential graves was based primarily on the magnetic results. Anomalies were given priorities based on shapes and amplitudes relative to a test program using backhoe dug and back filled trenches and the results of two excavated and verified graves. Geophysical investigations were performed on three reported cemeteries and one confirmed cemetery Several anomalies with the signature of burial shafts were identified on three sites The high priority anomalies ranged from 12% to 32% of the total number of anomalies. However, geophysical testing on one site was hampered by unknown subsurface features which caused extreme variations in magnetometer readings. As a result, no anomalies were identified in this region.

From 1984 to 1986, proton magnetometer data was acquired at Rincon Cemetery, near Corona, California (Brock, 1987). This cemetery is unmarked and dates from the late 19th/early 20th centuries. Archival sources indicate at least 91 interments. Magnetic anomalies representing possible graves numbered 82. This report covers one of the sites reported by Mason et al. (1987) and provides an interesting comparison of methods.

Geophysical surveys were conducted on Guam and Saipan in 1990 to locate burials and to identify the boundaries of burial sites on Guam and Saipan (Doolittle & Kaschko, 1990). Ground-penetrating radar and soil conductivity techniques were used. The soil conductivity survey located the boundaries of a mass grave. The radar survey was not as successful because of the size of buried artifact and the presence of scattering bodies within the soil. Examples of scattering bodies would be stratified soil, layers of stones, or tree roots. The location of graves was based on results using the Subsurface Interface Radar System-8 manufactured by Geophysical Survey System, Inc., proton magnetometers an EM-38 meter, and the EM-31DL (both conductivity meters) manufactured by Geonics, Limited.

In a paper by Bevan (1991) (this one is in the reviewed literature) graves were examined at three sites in Maryland, near Washington's grave and in Ohio. A radar survey examined grave sites at an historical house in Annapolis, Maryland. A radar profile crossed 14 marked graves, but only detected 6 of them. The graves that were detected were from the period 1954-1975, while graves containing reburials of bones from a century earlier could not be detected. Another radar survey was conducted at a 19th century cemetery in Maryland with 33 marked graves. When the radar passed over four marked graves, two were detected, along with three additional reflections that could be unmarked graves. A pauper's cemetery in Rockville, Maryland has graves dating back as early as 1789, all of which are unmarked. A radar profile of the area suggested the location of a grave, but excavation showed the cause to be a natural change in the complex soil strata. A radar survey was conducted near George Washington's tomb where historical records suggests the location of the graves of slaves. The survey may have located 50 unmarked graves. This is only a possibility since natural changes can cause radar reflections. A conductivity survey was carried out with a Geonics EM38 conductivity meter at a 19th century Shaker cemetery in Kettering, Ohio. In areas where no burials could be seen 25-50 anomalies were found. Six of these anomalies were tested by shallow excavations and five graves were partially exposed at depths of less than 1 m.

Other geophysical surveys in search of unknown grave sites have had mixed success. Sometimes evidence suggested that there was a grave where there was none. Other times known graves have not been obvious in the surveys. However, some surveys have proved successful.

THE CEMETERY

The surveys for this study were conducted in the Wyuka Cemetery, Lincoln, Nebraska. Wyuka was created by the Nebraska State Legislature in 1869, the only such designated cemetery in the state. Wyuka is now on the National Register of Historic Places. Since it is a state chartered cemetery it is a location for indigent burials, many of which do not have tombstones. The director of the cemetery very generously helped us locate our sites and examine the records.

The first site chosen in the cemetery was in an area of recent burials, from about 1956 to the present, with some of the graves not marked with stones. Block A, a 20 m square, was laid out here. The second site was in an area of mostly infant burials around the turn of the century, again with only a few stones marking the graves. Two contiguous 20 m squares, Blocks C and D, were laid out here. Figure 1 is a map of the cemetery with the blocks marked on it

METHODS

Three geophysical instruments were used, the Geometric G858 Cesium Magnetometer, the Geoscan FM36 Fluxgate Gradiometer and the Geoscan FMI5 Resistance Meter. All readings with the three instruments were taken on 1/2 m intervals on traverses spaced 1/2 m apart.

The G858 was used in the gradiometer mode. The manual suggests a configuration in which one operator carries the whole instrument. The operator has the electronics and battery pack on his waist and is strapped to an horizontal rod with a vertical rod, T-shaped, at the front end on which the two sensors are mounted (Figure 2). We have found this arrangement very awkward and it is difficult to maintain a constant height above the ground, which is critical for high precision work. We have reconfigured the instrument as a two person operation sketched in figure 3. The lower sensor was 30 cm above the ground and the upper sensor 150 cm above the lower sensor. In this configuration the difference between the two sensor readings is essentially a total field reading with a long wave-length trend subtraction and of course an exact diurnal correction. Each 20 m block, 41 by 41 or 1681 readings per block, took about I hour and 50 minutes.

The FM36 Fluxgate Gradiometer was carried with the lower sensor about 40 cm from the ground and the top sensor 50 cm above the lower. The gradiometer was operated in the continuous mode the (single) operator carrying the gradiometer at a pace such that it fired every 1/2 m. Traverses were separated 1/2 m. A single block, 19.5 m, 40 by 40 or 1600 readings, took about 40 minutes.

The FMI5 Resistivity Meter was operated in the automatic twin probe mode with one current-potential probe pair about 30 m away from the mobile pair. When the mobile probes are inserted into the ground a reading is automatically taken and recorded. The mobile probe separation was 50 cm. One 19.5 m block, 40 by 40 or 1600 readings, took about 1 hour 45 minutes. In the case of the resistance measurements rain preceding the surveys apparently reduced the amount of visible detail in the resulting maps.

RESULTS

Block A

Figure 4 is a map of the gravestones that had been placed on the graves in Block A. Burials proceeded in time from the west edge to the east edge. It can be seen that the west half has only a few stones, but we were told that all burial plots were filled.

Figure 5 is a cesium gradiometer map, Figure 6 is a fluxgate gradiometer map and Figure 7 is a resistance map of Block A. In comparing the cesium and fluxgate maps it can be seen that the fluxgate with a 50 cm separation of sensors gives better resolution or separation of parts of an anomaly that the cesium with a 150 cm separation of sensors but at the same time it should be noted that the fluxgate has a smaller dynamic range. In order for the fluxgate to record small anomalies by setting the sensitivity to the highest setting, the maximum gradient that it can tolerate is about 200 nT/m. Over that it gives a dummy reading which must be removed in plotting the data. Of course the cesium with a 50 cm separation of sensors would give the same resolution as the fluxgate. We will concentrate on using the cesium maps for interpretation. The resistance map lacks considerable detail, presumably because of the rain previous to the survey, and will not be further discussed

For purposes of interpretation the cesium data has been plotted in Figure 8 with an interval of 15 nT/m, clipped at +/- 500 nT/m. In addition lines have been drawn through linear alignments of anomalies. These lines show that the layout of the burial plots are not quite in alignment with the survey grid. The separation of the vertical (north-south) lines is about 9 feet which is in approximate agreement with the length of the burial plots. This Figure does not bring out very well the weaker anomalies. This is done in Figure 9 plotted with non-linear contour intervals (1.25,2.5,5,10,etc. nT/m about the mid value).

Several comments can be made about the magnetic data of Block A. First of all it needs to be pointed out that in some cases very strong anomalies arise from the presence of metal bases uses to support flower vases. East of about E I2 there are *many* larger anomalies which arise from concrete vaults in burials from about 1985 on. This is even reflected in the resistance map, though nothing much else is. West of this line the earlier burials did not have concrete vaults. These earlier burials were mostly wooden coffins. The strong negative anomaly at E2,N4 may be associated with an aluminum vault that the records indicate to be here. If the vault did not collapse then the void could give a negative anomaly. This, however, may be the negative part of the strong positive anomaly to the south. The weak anomalies in the central west region, see Figure 9, must all be due to wooden coffins For instance there is a weak anomaly of about 10 nT/m centered at NI5,E9.

Blocks B and C

Turning to the earlier burials in blocks B and C, we first show the distribution of standing grave stones in Figure 10. Figures 11, 12 and 13 are cesium, fluxgate and resistance maps. It can be seen that there are no stones west of about E6. That is because there once was a road west of this line. This is reflected in all three geophysical maps. There does not seem to be any other correlation with graves in the resistance map and will not be discussed further. One other fact about these blocks that should be noted. Most of these burials are for infants. The burial containers were about two and a half feet cubes with two to a burial plot.

There is a series of strong anomalies along the east side, see figure 11. Figure 14 is a north-south profile of the cesium data along E17. These anomalies are strong, some 100 to 160 nT/m. This puzzled us because this was well before cement vaults were required. In going through the records it was not possible to determine the exact burial conditions because of the age of these burials but we did run across an oblique reference to brick vaults. The city of Lincoln has long had a very productive brick works, some of the streets were once paved with bricks, so it would make sense to use bricks for a burial. This would be a very plausible explanation since bricks are quite magnetic. Apparently for a period of time around 1906 or 1907 a number of infants were buried in small brick vaults.

It is of interest to see what detail the geophysical data can reveal about an individual grave. Figure 15 is the cesium gradiometer record of such an individual grave. This grave could be clearly identified because of the gravestone. The person buried here was born in 1831 and died in 1906. However we were not able to determine the nature of the coffin or if there was a vault. Not all graves are this clear, a few are, many are not. It depends on a number of different burial conditions, the nature of the coffin, whether there is a vault, how the shaft was dug, how the dirt was back filled and so forth.

Some of the grave anomalies were very weak. Figure 16 is from an area of weak anomalies but which are most certainly associated with graves. The map is from the cesium gradiometer data with no interpolation between the data points Figure 17 is a profile along E7.5. A series of regularly space maxima can be seen with magnitudes from about 2 nT/m to about 10 nT/m. Thus it can be seen that to make a careful analysis of such a cemetery site it is necessary to look for anomalies over a large range in sizes from 2 nT (just above noise level) to several hundred nT.

CONCLUSIONS

In this survey the resistance measurements did not contribute much of value. This does not mean that resistance should not be used, just that the soil moisture conditions were not favorable. Our conclusion would be that a small resistance test should be run first to see if such data could be useful

Both magnetic methods, cesium and fluxgate gradiometer, gave similar results. The fluxgate gradiometer is faster but has a limited dynamic range The cesium gradiometer is slower but has the versatility of offering a range of inter-sensor distances. We did not try the so-called "walking" mode which has the potential of being almost as fast as the fluxgate gradiometer.

We have learned that it is very important to carefully measure the position of all visible plot markers if the aim is to make a careful comparison between the extant records and the geophysical record. The significant anomalies cover a wide range of magnitudes. Thus it is important to control carefully the height and placement of the magnetometer in order to minimize the operational noise and positional errors. In some cases the geophysical data must be examined point by point (pixel by pixel) to draw correct conclusions about the existence and placement of graves.

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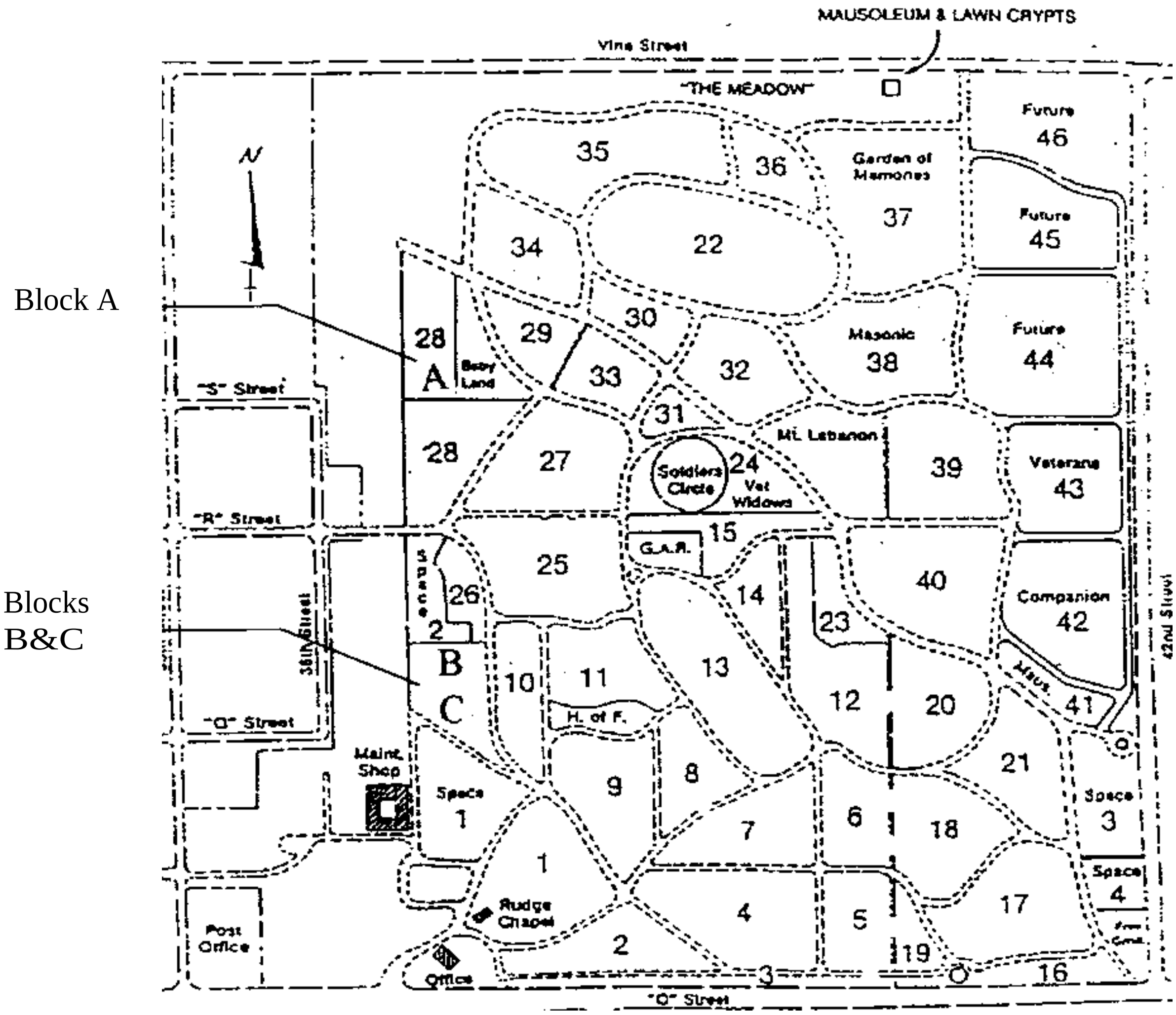

WYUKA CEMETERY

Figure I Map of Wyuka Cemetery, Lincoln, Nebraska with survey blocks marked.

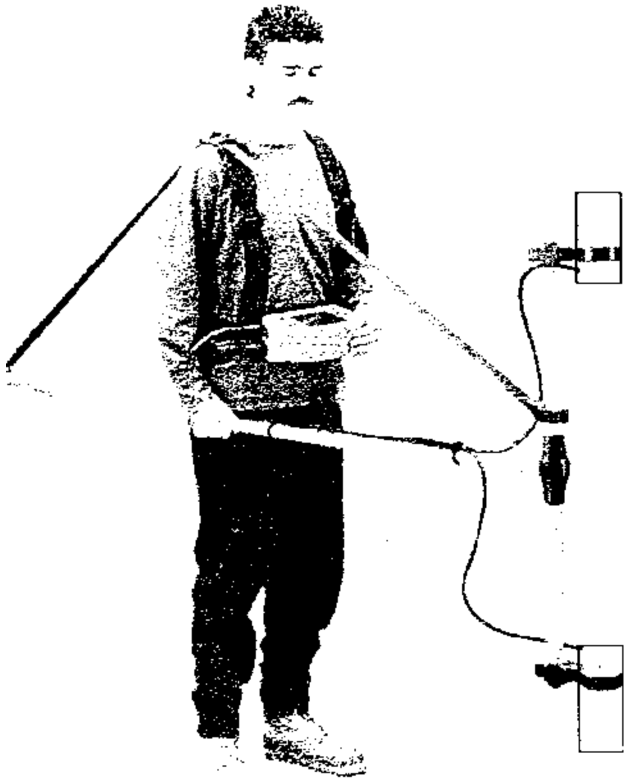

Figure 2: G858 Gradiometer - Geometric configuration

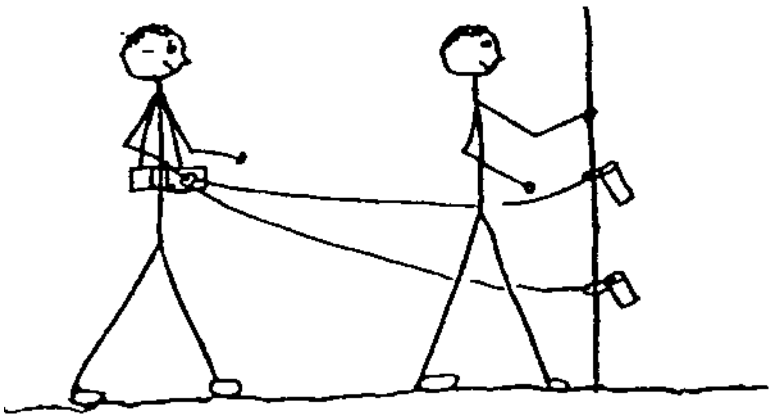

Figure 3: G858 Gradiometer - our configuration

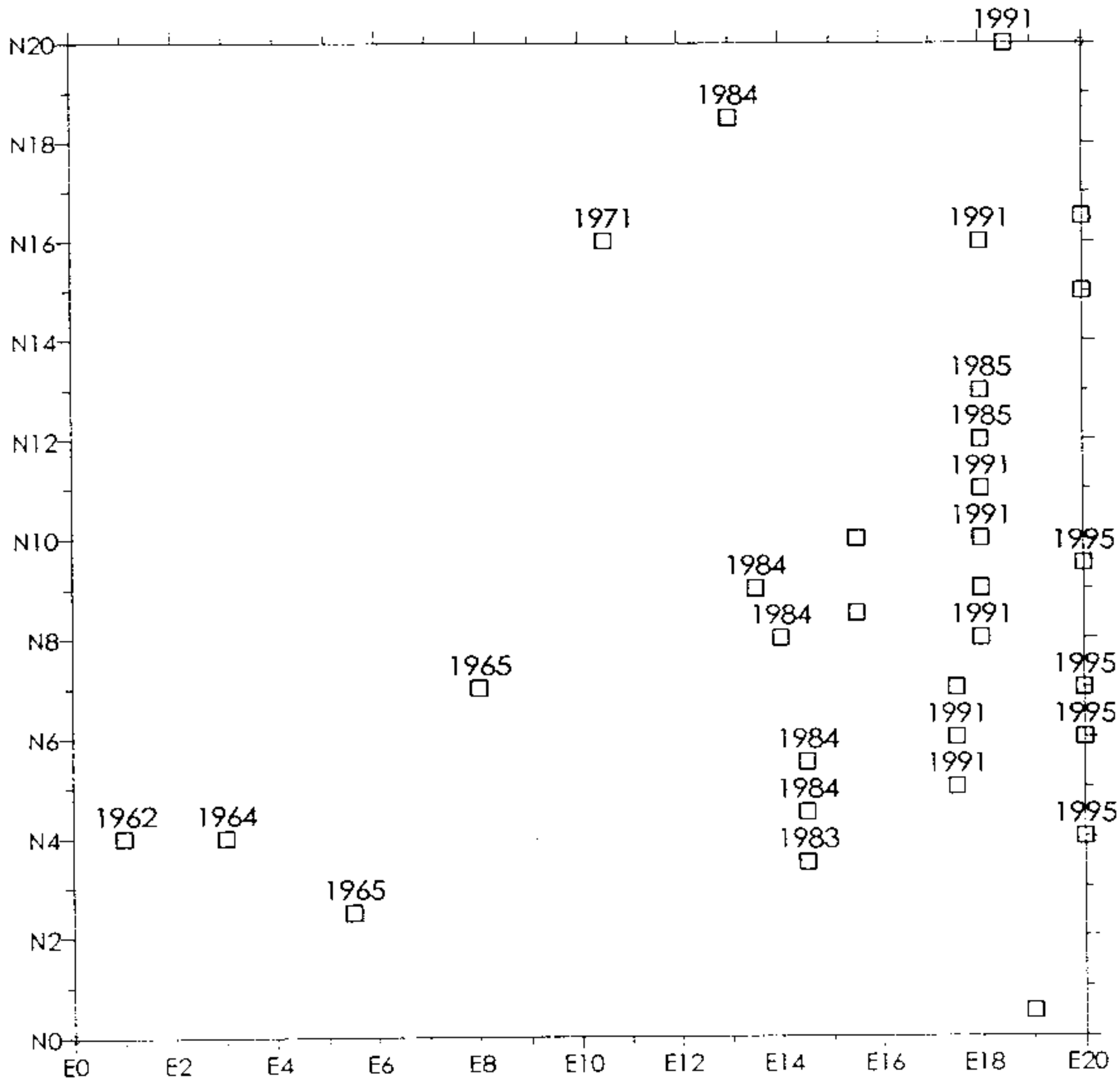

Figure 4. Block A gravestones

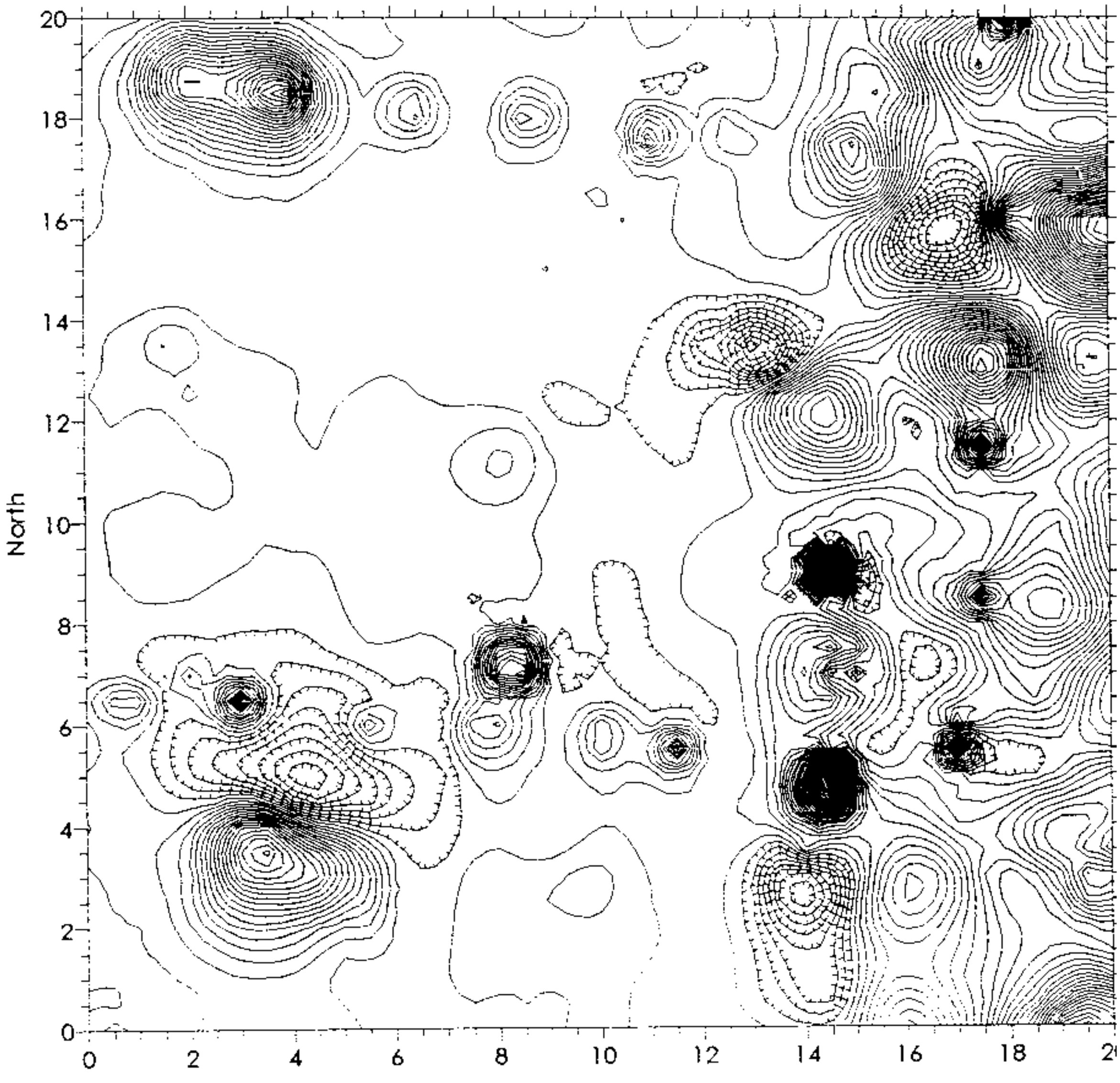

Figure 5: Contour map of block A cesium gradiometer data, contour interval 25 nT/m

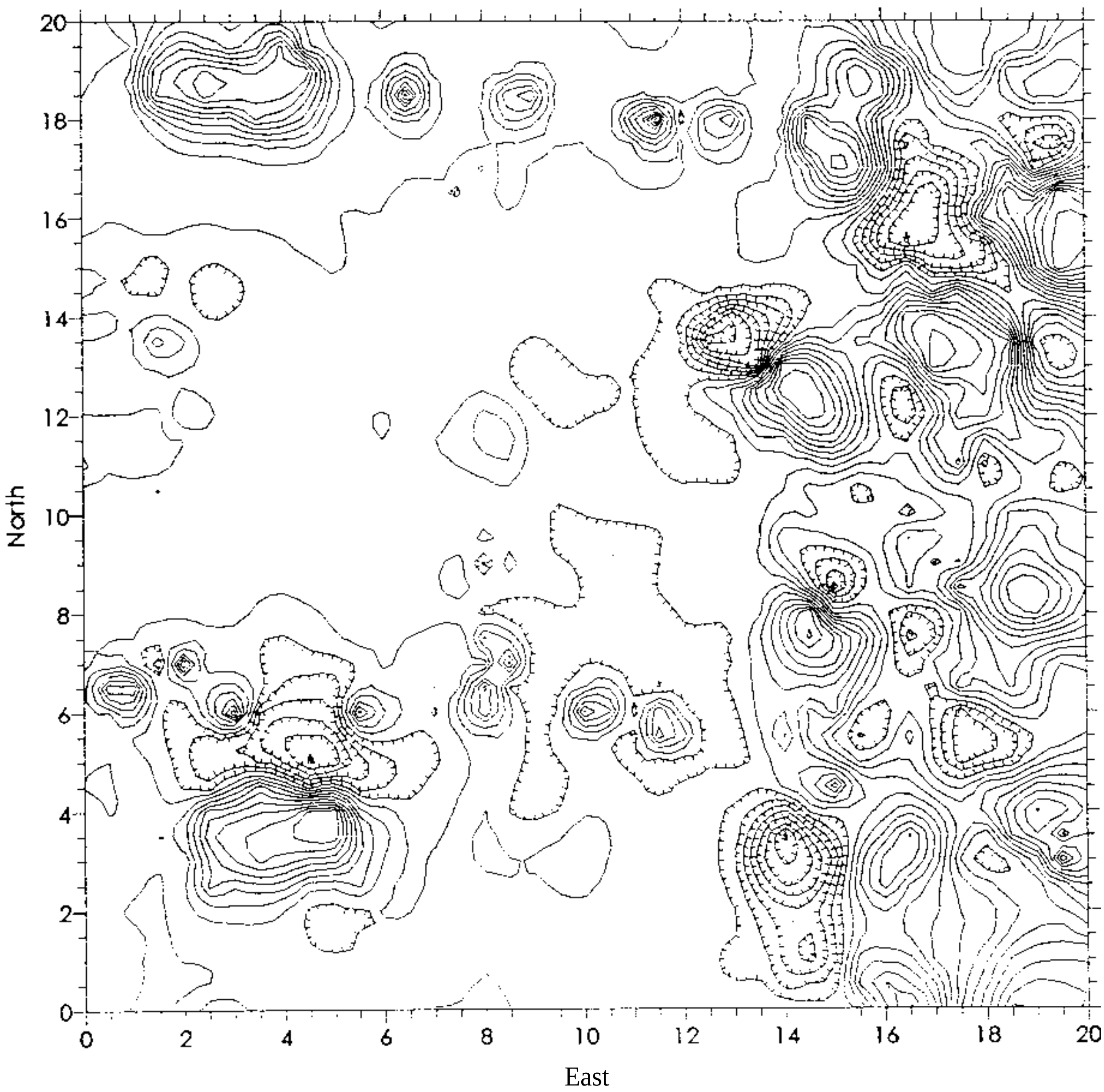

Figure 6: Contour map of Block A Fluxgate Gradiometer data, contour interval 25 nT/m

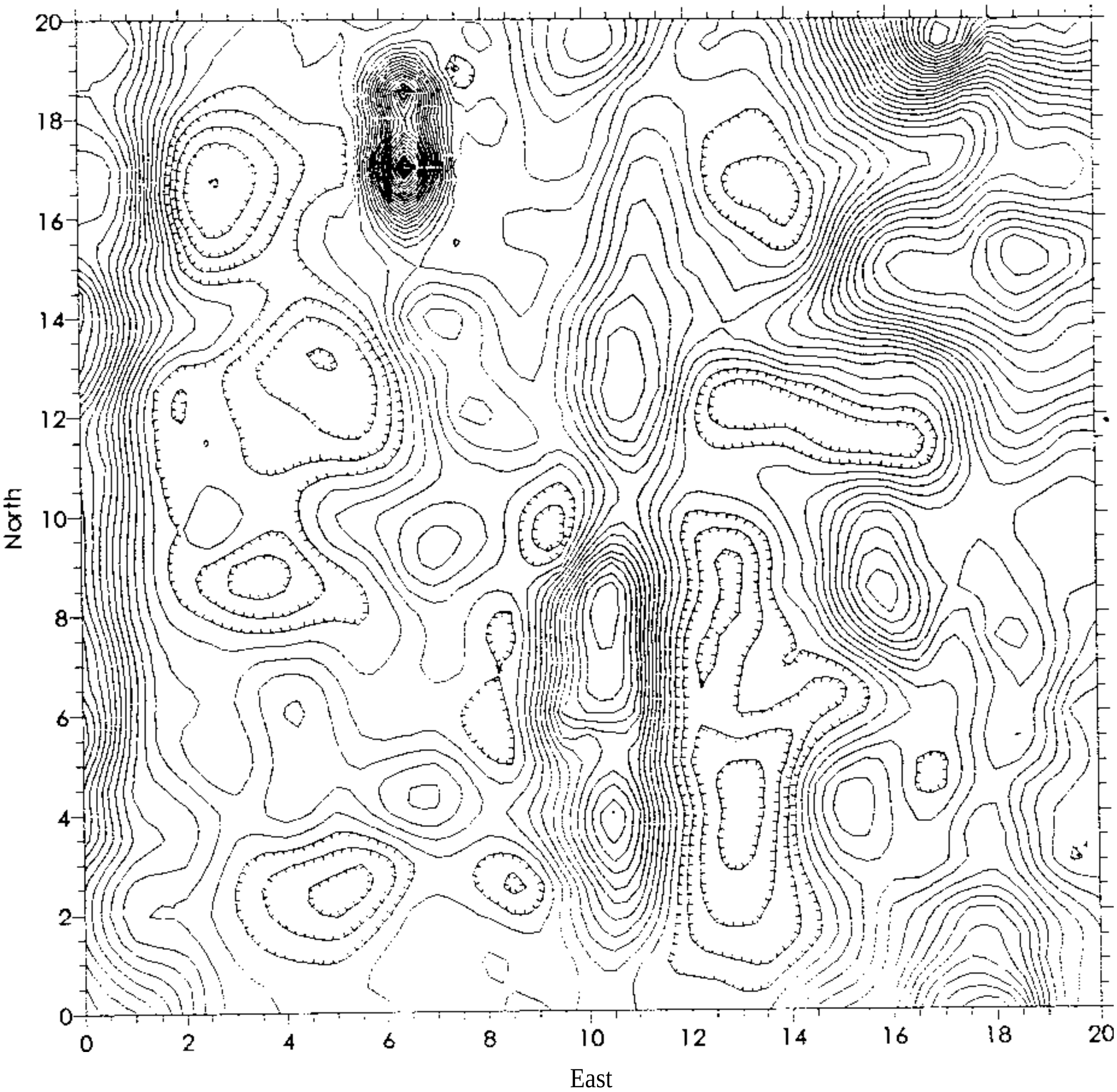

Figure 7: Contour map of Block A resistance data, contour interval 0.5 Ohms.

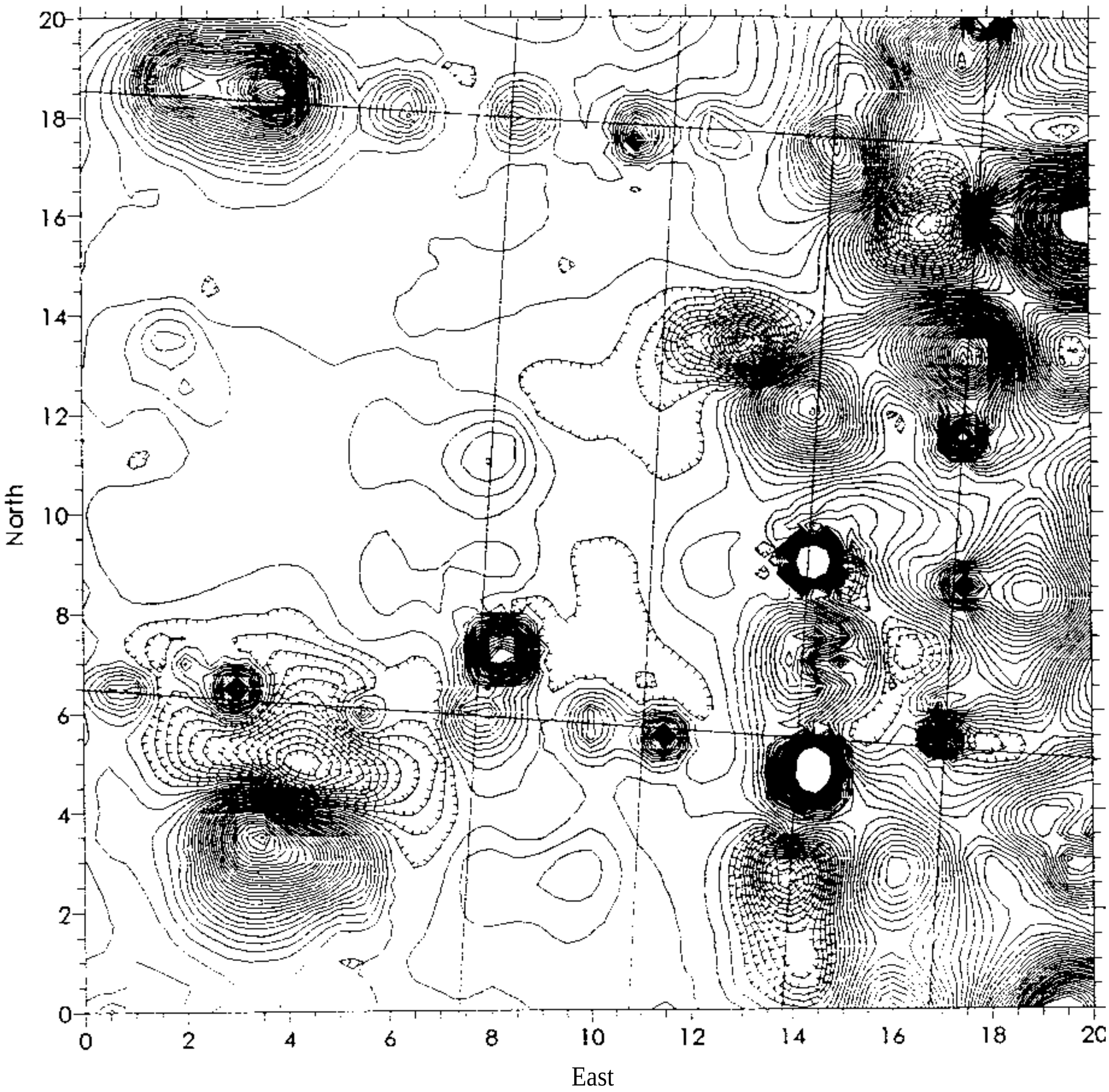

Figure 8: Contour map of Block A cesium gradiometer data, contour interval 15 nT/m with linear alignments of anomalies marked

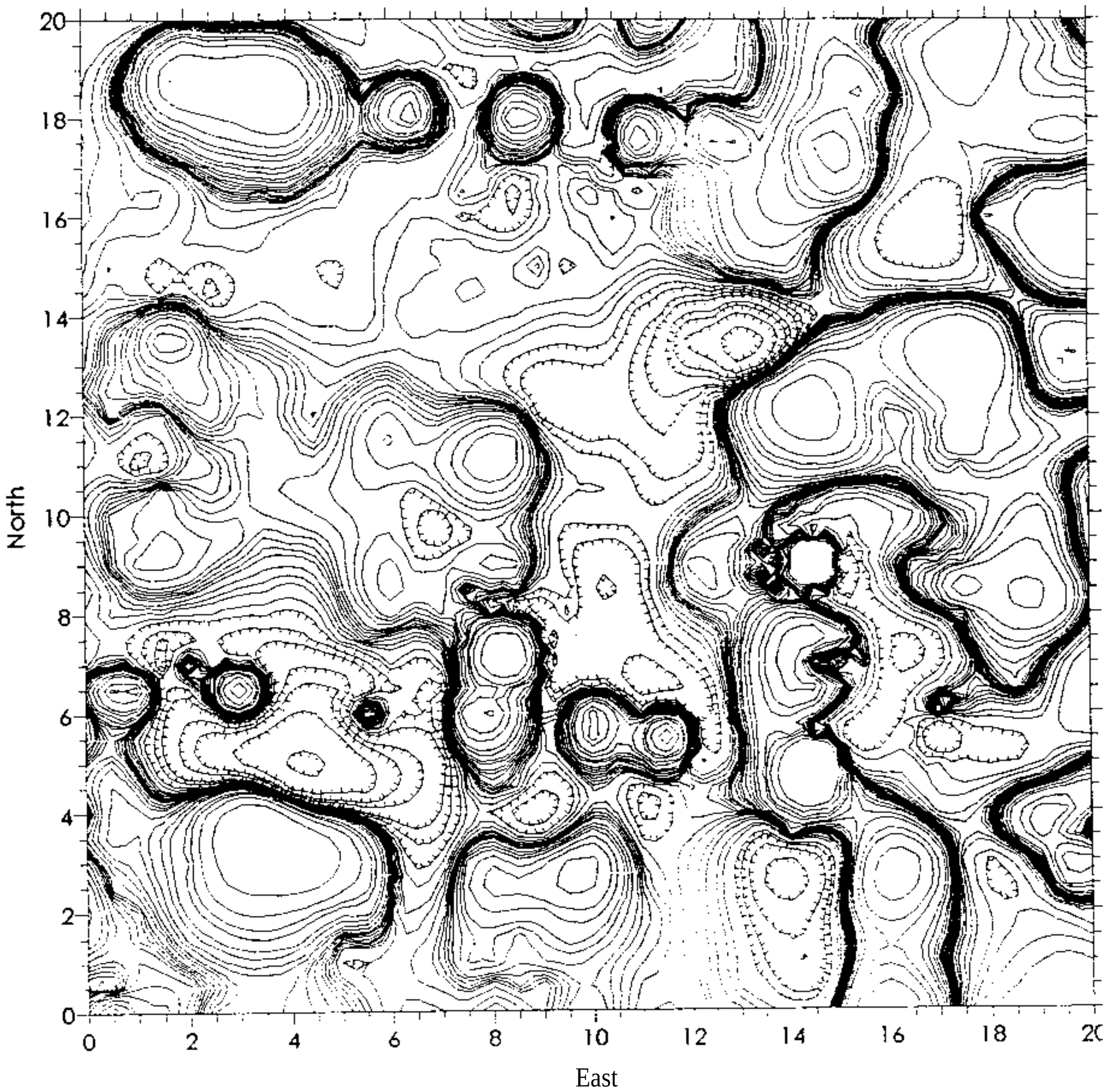

Figure 9-. Contour map of blocks A cesium gradiometer data, non-linear intervals with 1.25, 2.5, and 5 nT/m levels about mid-values.

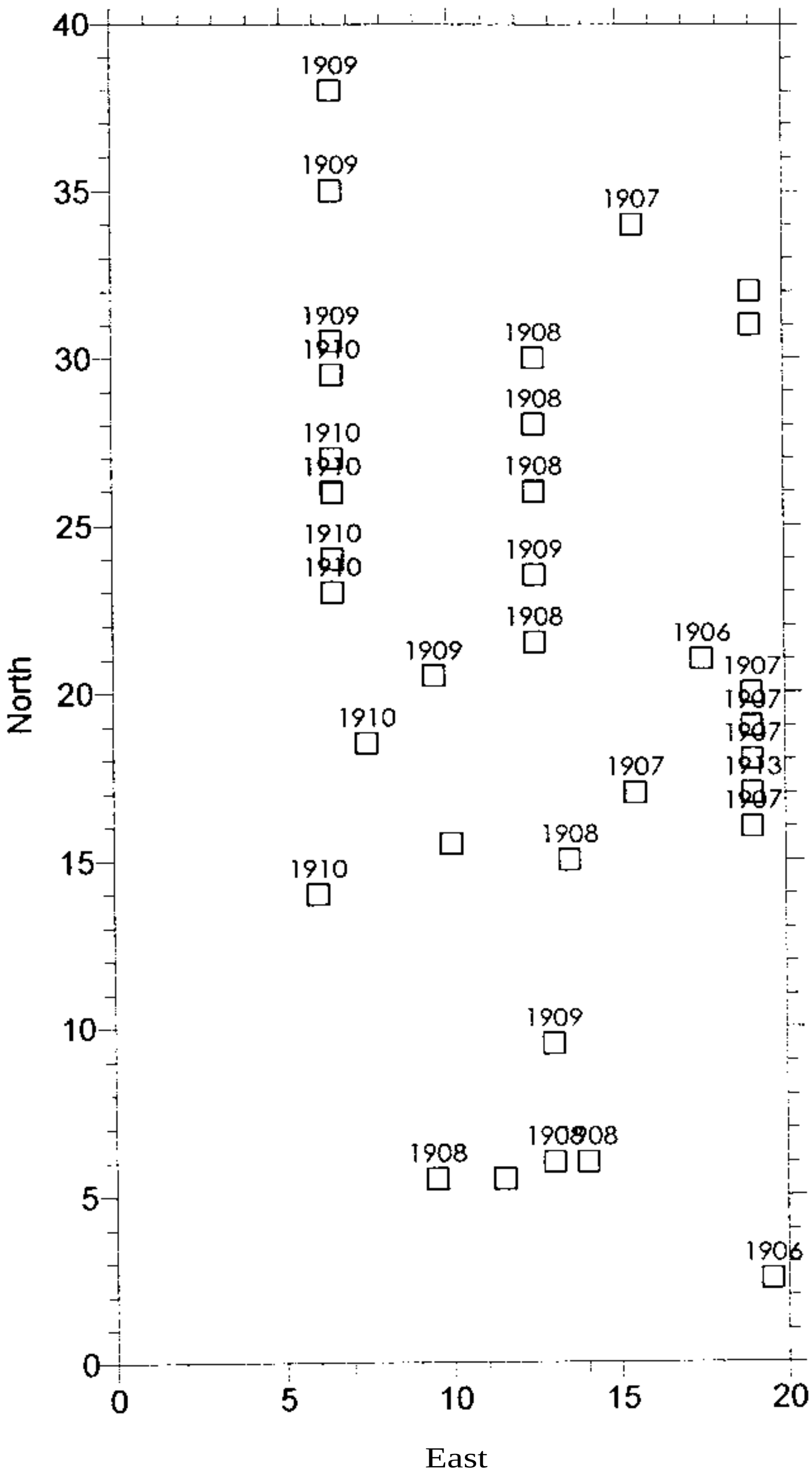

Figure 10: Blocks B and C with gravestones.

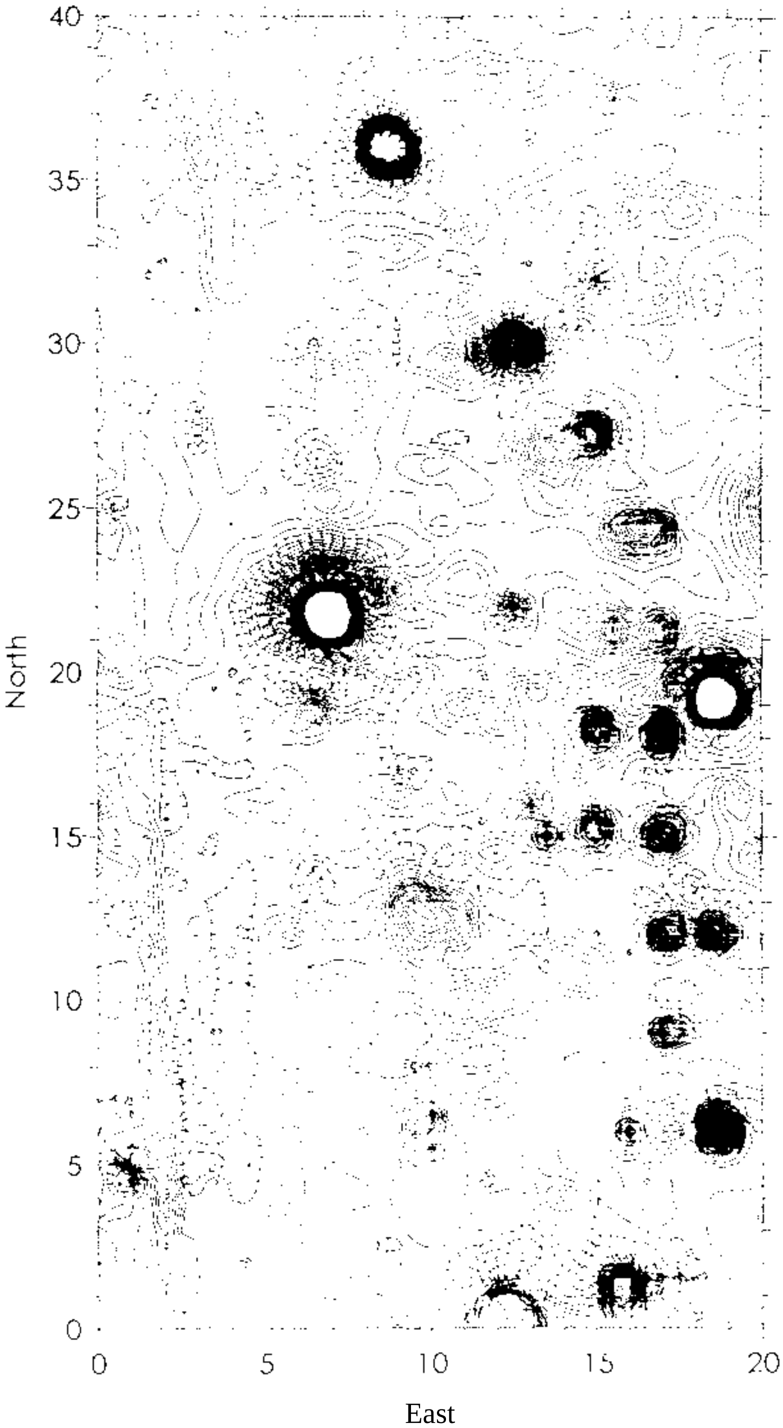

Figure I I. Blocks 13 and C cesium gradiomter data,
contour interval 5 nT/m clipped at +/

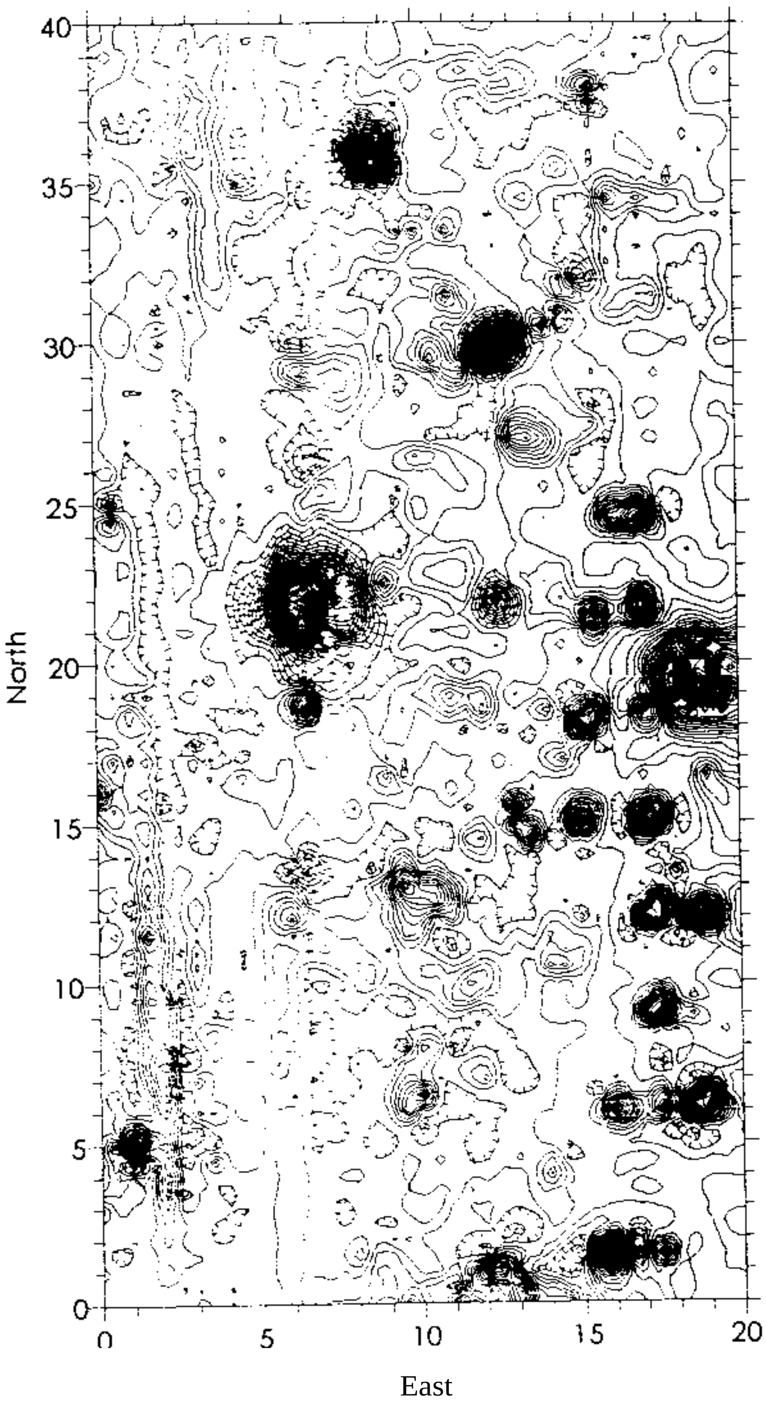

Figure 12. Blocks B and C fluxgate gradiometer data,
contour interval 5 nT/m clipped at +/- 200

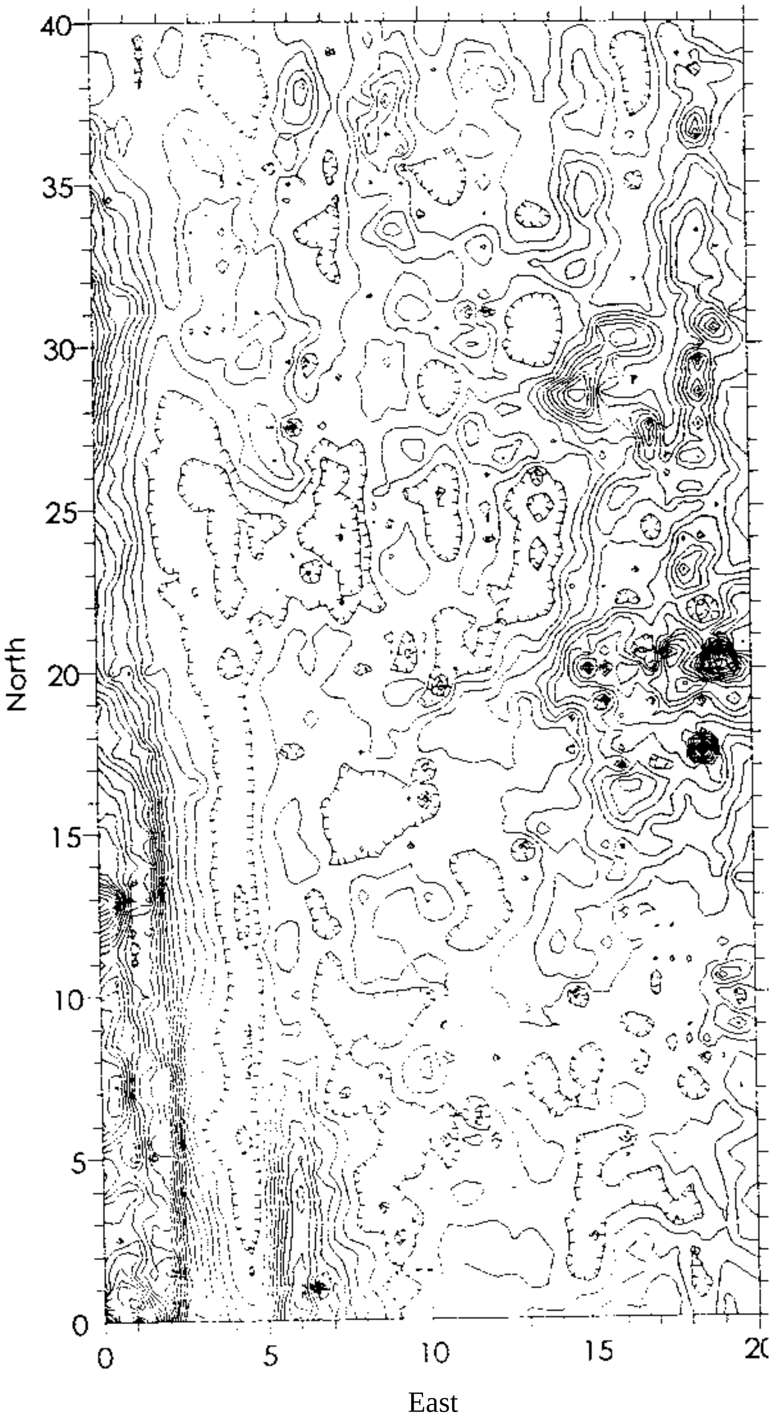

Figure 13. Blocks B and C resistance data, contour interval 2 Ohms.

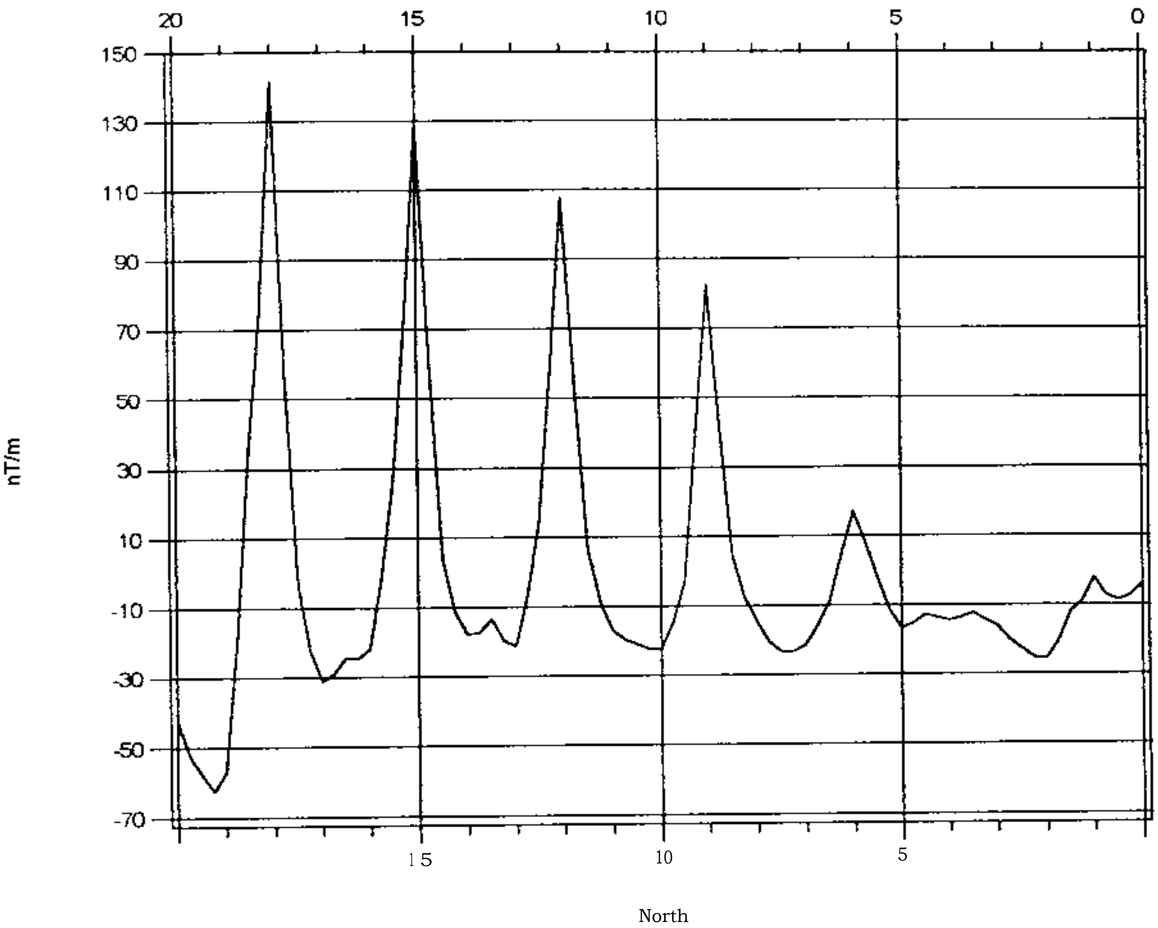

Figure 14. Block C cesium gradiometer profile along E17.

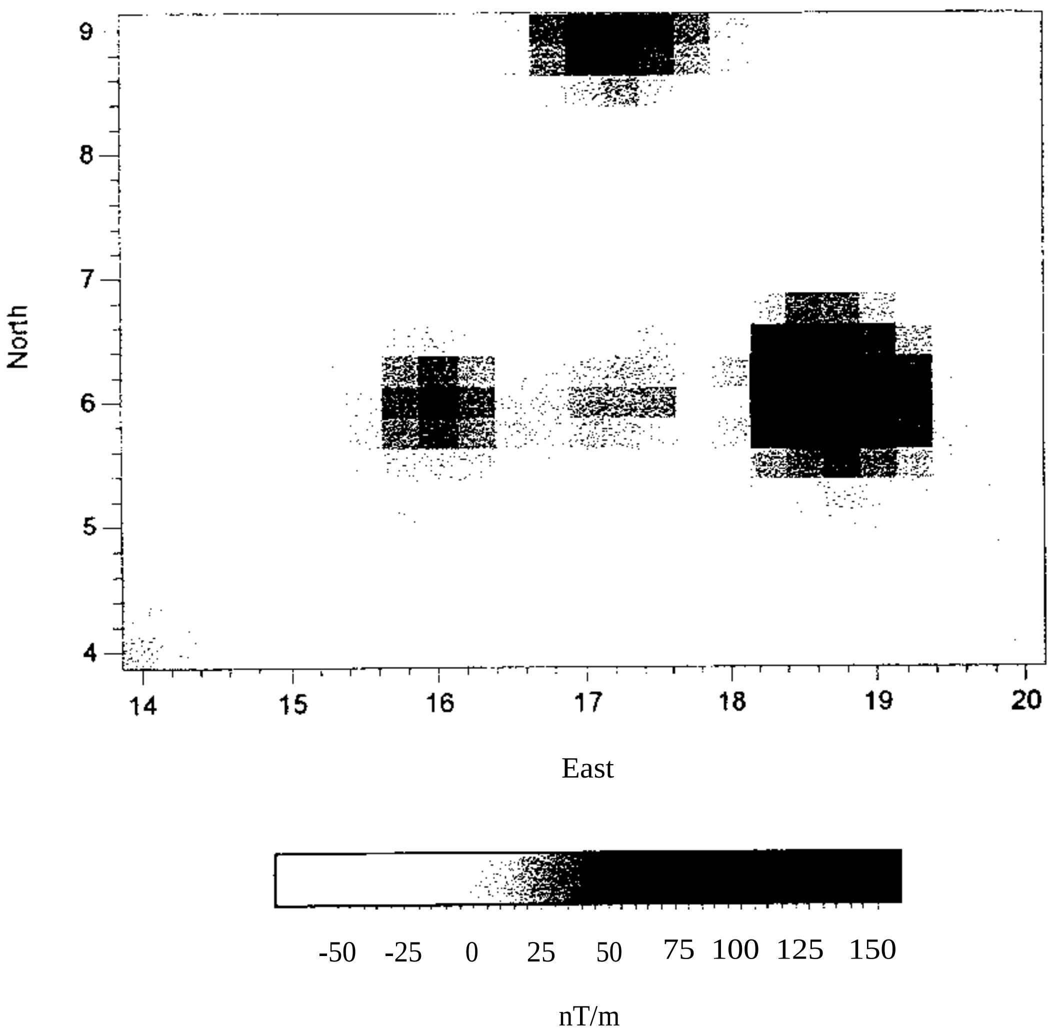

Figure 15 Single grave in south-east corner of Block C, cesium gradiometer data

Figure 16 Block C south-west corner cesium gradiometer data.

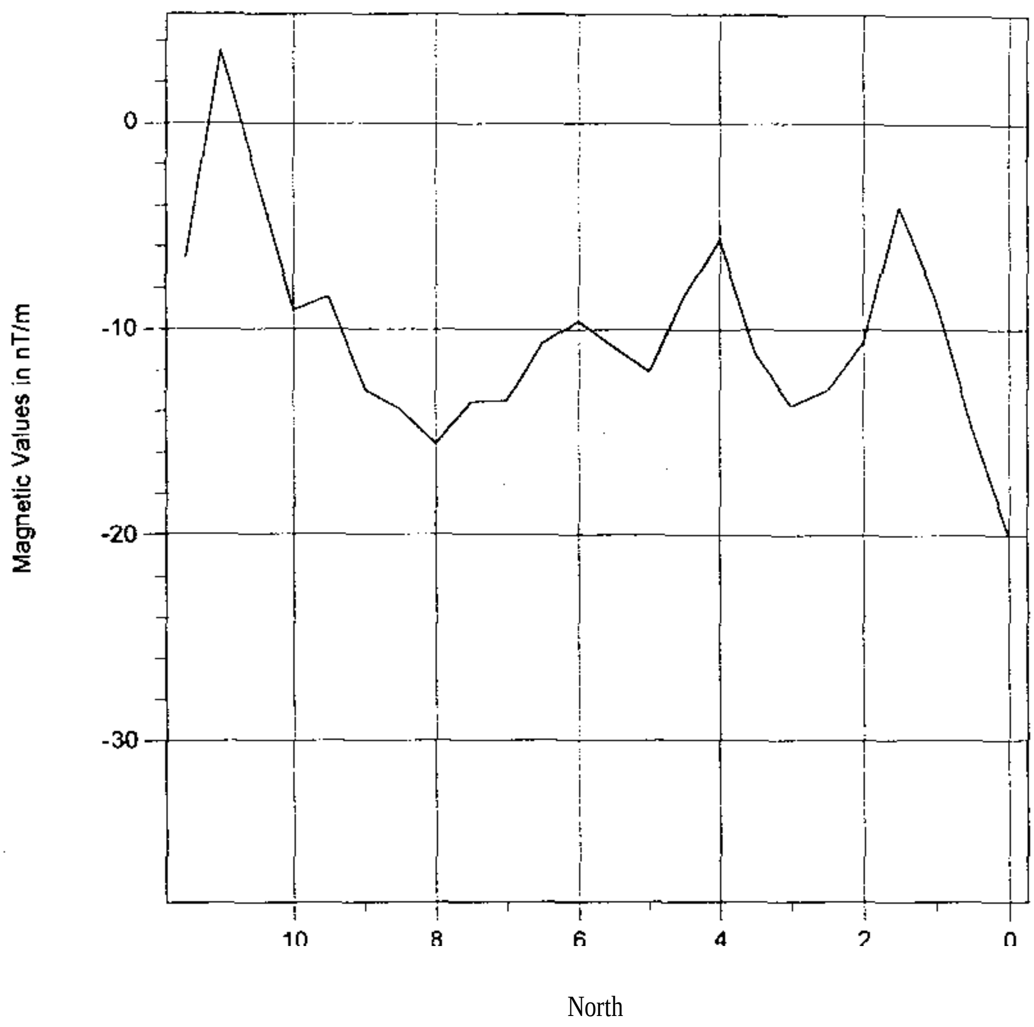

Figure 17: Block S south-west corner cesium gradiometer profile along E7.5