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Rapid magnetic localisation of pottery kilns

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The paper presents the posssibility of magnetic prospection in localisation of the remains of pottery kilns on an example of the survey made in 1989 and 1990 at the Early Christian site at Old Dongola in Sudan. Due to geophysical measurements it was possible to localise the remains of 11 pottery kilns. Localisation was confirmed by a trial trench in which two kilns were excavated at a depth of 1.8 m.

KEY-WORDS: geophysics, magnetometry, pottery kiln, Sudan

FIELDWORK REPORT

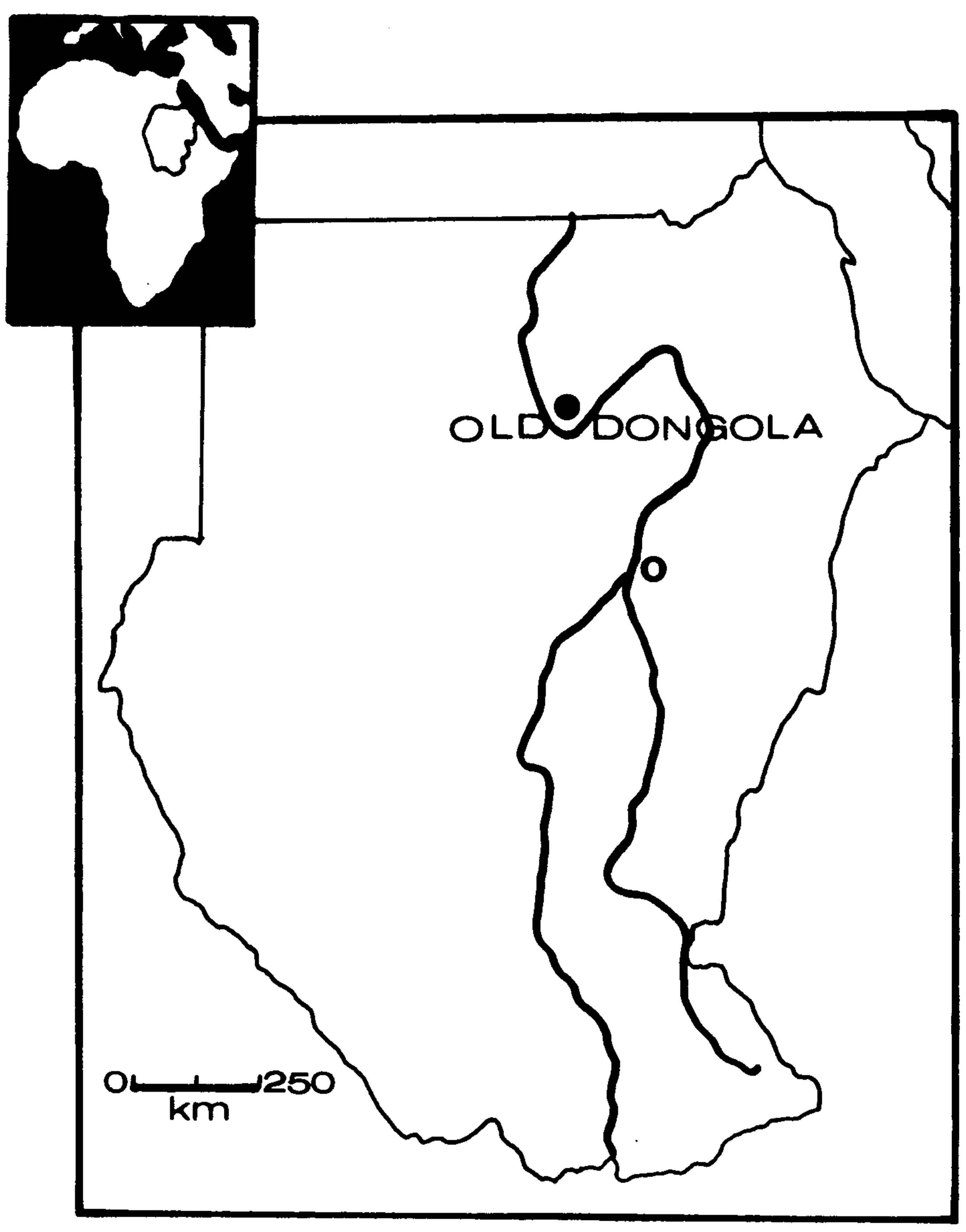

Fig. 1. Location of the site.

The method of a quick localisation of the remains of pottery kilns was used during the 12-week geophysical prospection of the Early Christian site (6th–12th cent. AD) at Old Dongola in Northern Sudan (Fig. 1) in the winter of 1989 and 1990. The site has been examined by the archaeological mission of the Polish Center of Mediterranean Archaeology in Cairo since 1966. There are different archaeological objects lying in the limits of Polish concession : the remains of defensive walls, foundations of houses, palaces, complexes of monasteries, cemeteries with rock and chamber tombs and remains of pottery kilns. Many problems can therefore be tackled by archaeological research.

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The geophysical survey involved at this site was done as a supplementary prospection of the area of excavations, as preliminary research before excavations and as an auxiliary method in the examination of cemeteries.

All archaeological structures on the site are covered by dry sand of very high resistivity; however, most of them are made of mud bricks — material containing particles producing high magnetic susceptibilities, the others were burnt and have properties typical for thermoremanent magnetization. There is also a strong contrast between features described above and the almost amagnetic surroundings. The measurement of intensity of the Earth's magnetic field seemed therefore to be the most effective solution for the geophysical prospection of this site.

We used three proton magnetometers. One (Polish construction PMP4) with sensivity of 1 nT and cycle time of 3 to 6 s — for preliminary survey, and two magnetometers PMP6 — having a sensivity of 0.1 nT and cycle time of 1.5 s with a possibility of automatic registration of the readings — for detailed prospection.

Sensitive magnetometers were necessary when the observed anomalies were not higher then 2—3 nT (for example in the cemeteries). Looking for the remains of pottery kilns we were interested in the other kind of anomalies (described below) but we also needed such magnetometers to avoid diurnal variation and false linear anomalies.

Before the prospection we had some knowledge about the features we were looking for. We even knew the position of two kilns — one partly excavated and the other still covered by sand. We could then make a test which gave us an idea about the anomalies produced by these remains and which was helpful for choosing the best method of prospection.

The field, suspected to be a center of pottery production was situated near the Nile, outside of the town and the other settlement complexes. All archaeological features in this part of the site were connected with the production and the storage of finished pottery ware. The pottery kilns were the most interesting for us. A typical structure of this kind was round with diameter ca. 2 m, 2—2.5 m high, had two chambers — a lower one for heating and an upper one for firing the pots. It was built of mud bricks baked, of course, during the process of firing. The internal walls of this construction were covered by slag sometimes containing metal particles. The kilns were built sometimes separately, sometimes in groups of two or three. Some of them were for single use, the others could be used several times. As mentioned above, we knew of two features in situ. One of them was partly destroyed during the process of firing but it contains a full load of pottery vessels, from the other only the lower part of inner chamber wall was preserved.

Looking for the remains of unknown pottery kilns we took measurements over an area 500 × 50-100 m along the Nile (Fig. 2). At the beginning of the prospection we made parallel traverses over the remains of kilns already known. During this operation we chose the optimal sensor height which was 1 m above the ground.

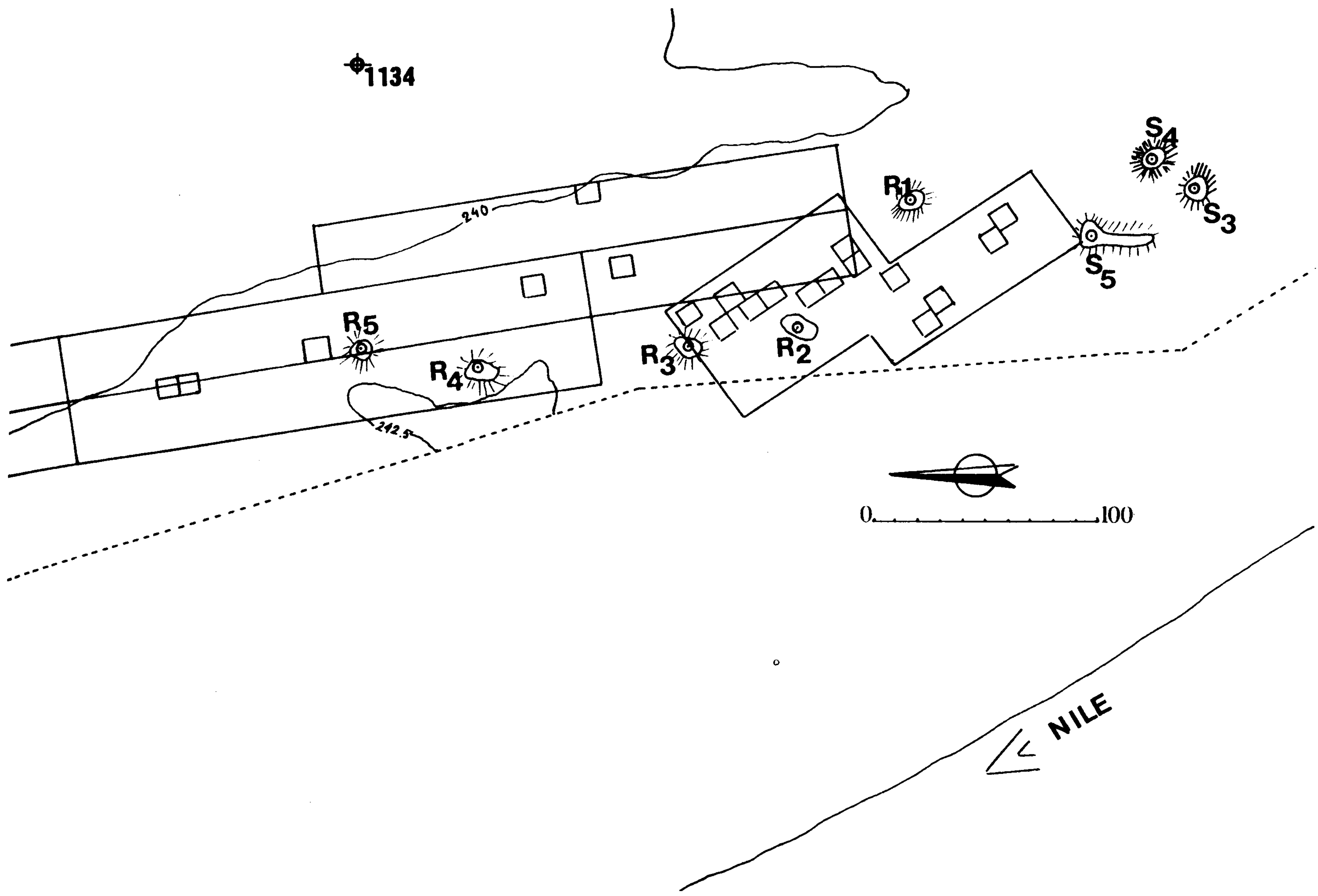
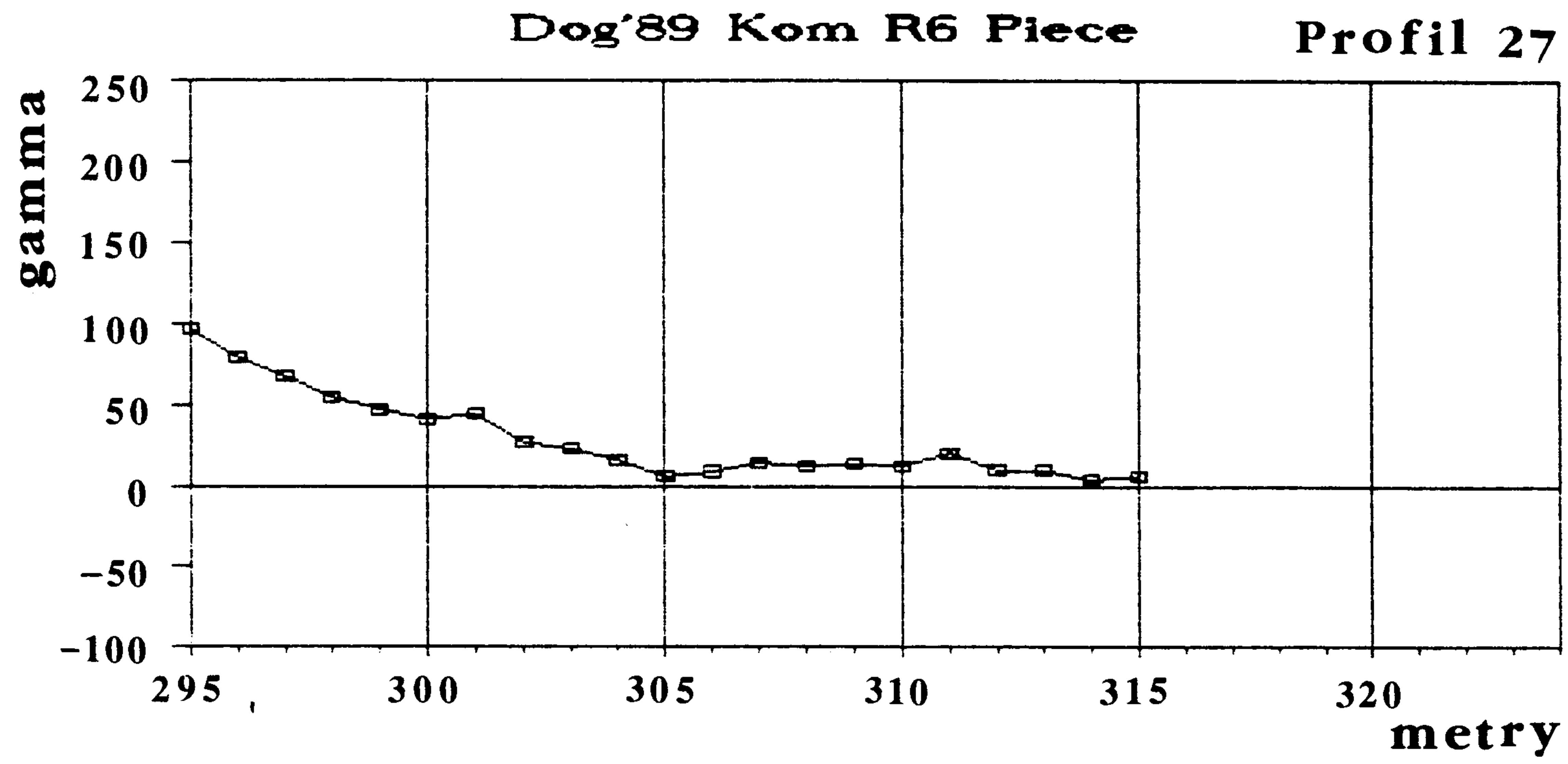


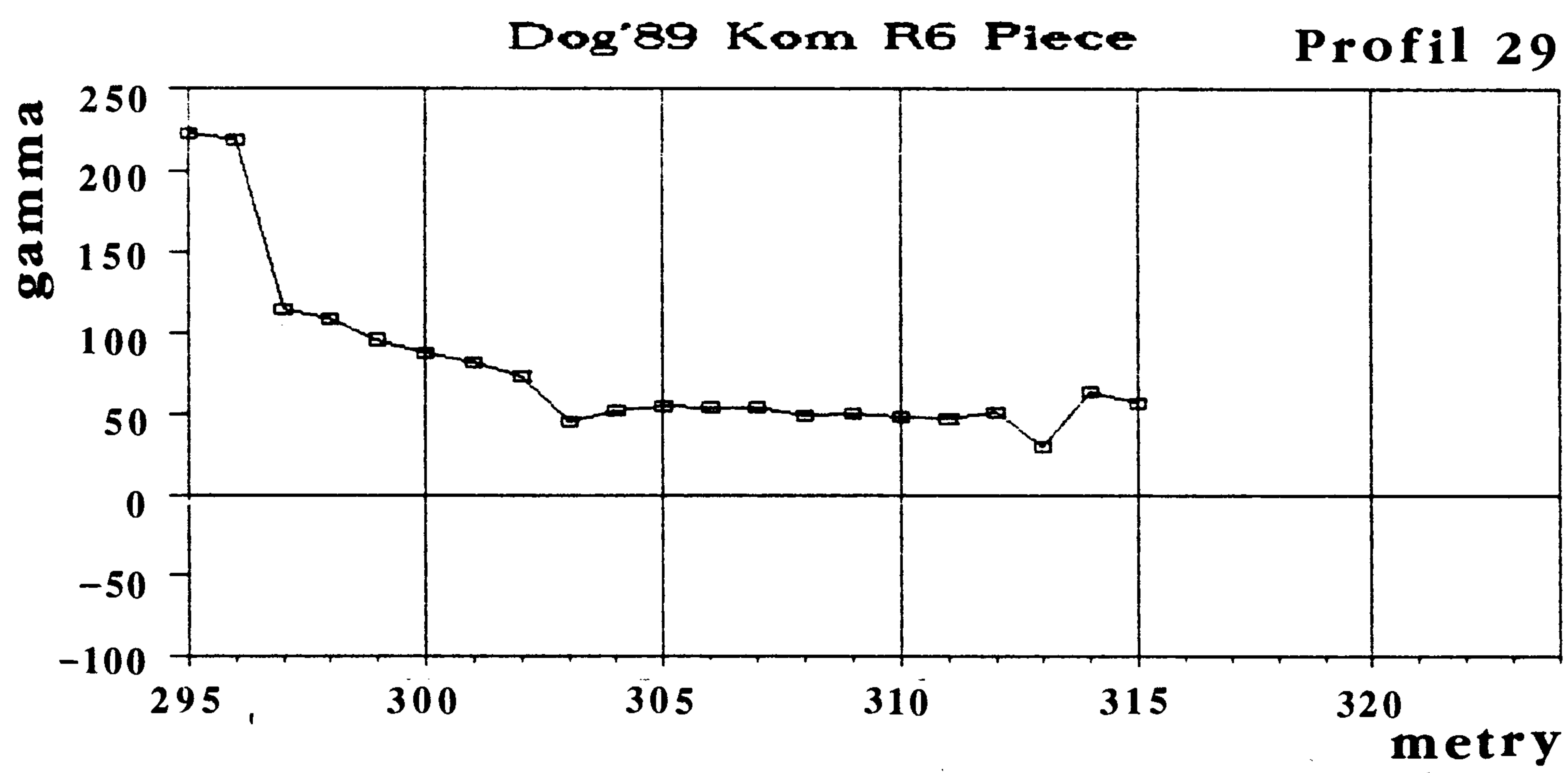
Fig. 2. Location of surveyed field.

We made tests with sensor heights in the range of 40 to 80 cm but in this range the soil surface irregularities had too strong an influence. The height of 1 m was then the most reasonable.

As the results of readings of values of the intensity of Earth's magnetic field on these south-north profiles we obtained dipole anomalies known as non-normal type (Weymouth 1986:344) characteristic for features with remanent magnetization. The diagrams of profiles show very sharp passing from low to high values on north-south line (Fig. 3) over short distance. For instance, the magnitude of anomaly could change from −30 nT to 50 nT over 4—5 m. The presence of a kiln produced rather large zones of disturbances in the intensity of the natural magnetic field easily detected even using one magnetometer, because the changes of values were bigger then those produced by diurnal variation. However one magnetometer was not sufficient for the detailed localization of the remains.

We decided then to prospect the site in two stages. First the preliminary survey was done with one magnetometer. At this stage we broke the prospected area down into 20 blocks — 25 × 50 m. We used alternative grid-profiles 1 m apart, the distance between readings — 2 m in even meters on even numbered profiles and odd meters on odd numbered profiles. We kept then the same interpolation grid





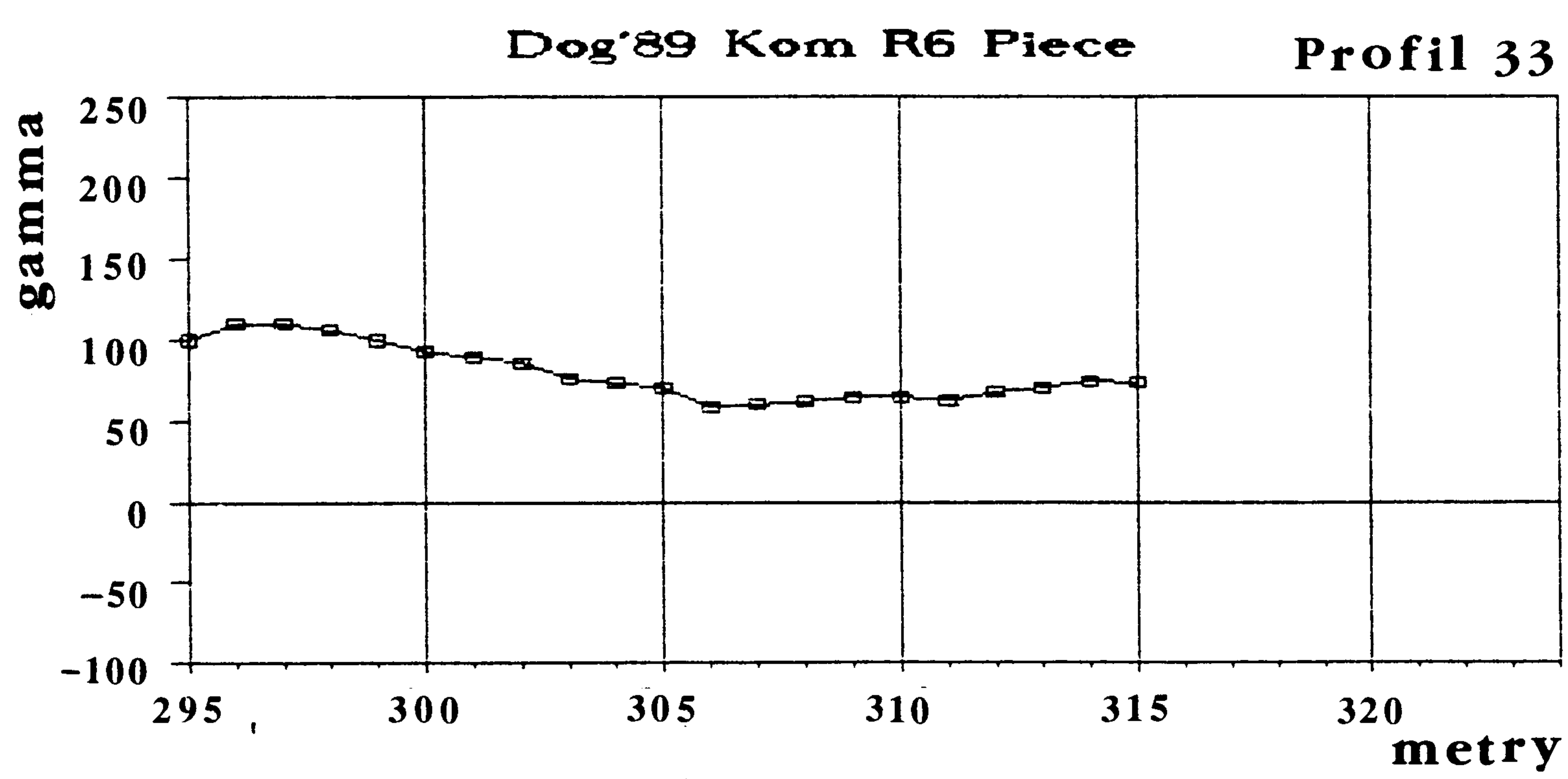


Fig. 3. Graphs of changes of intensity of magnetic field in surveyed areas.

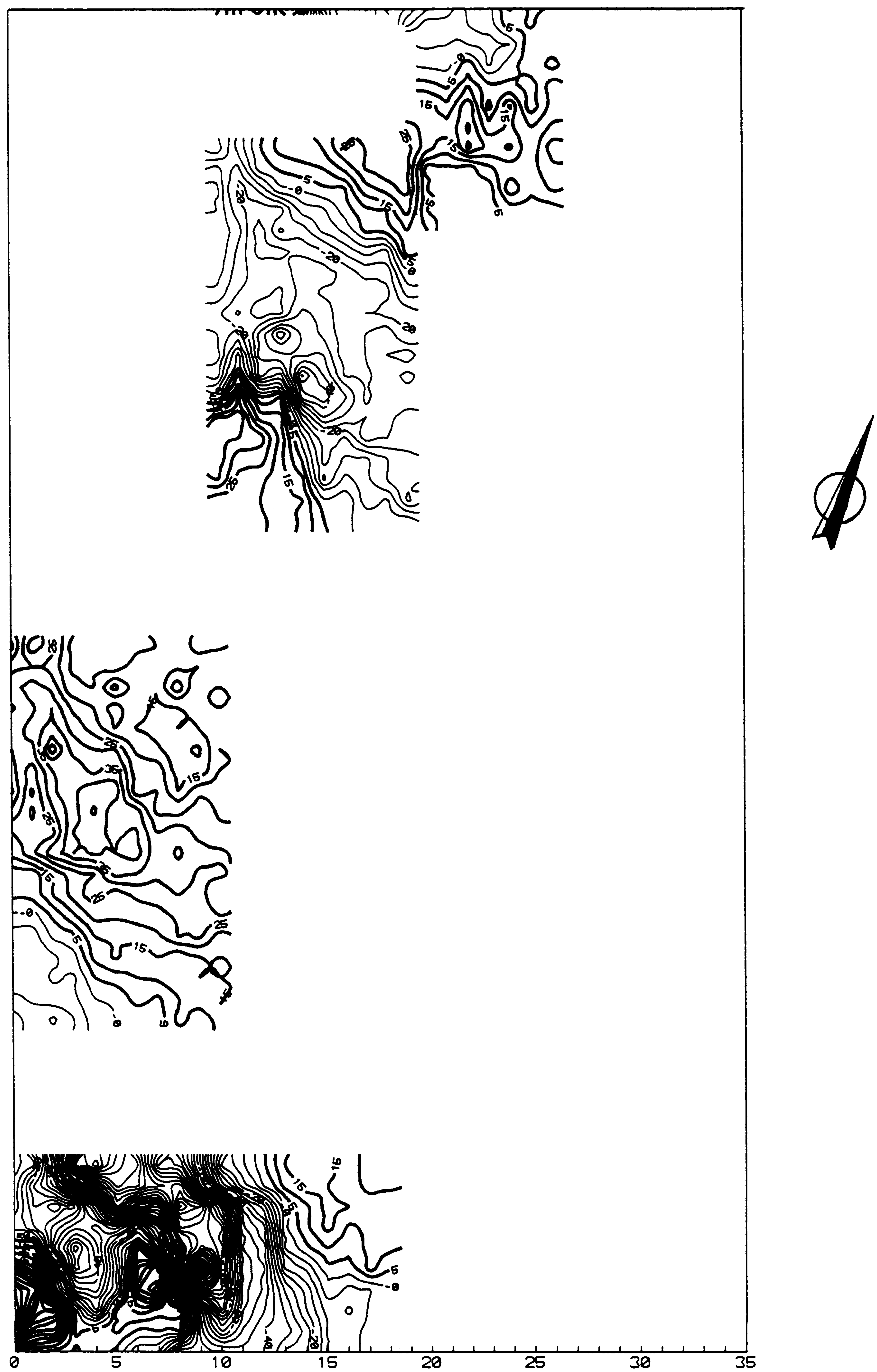


Fig. 4. Contour map of the changes in intensity of magnetic field. Set 1. Contour interval 5 nT.

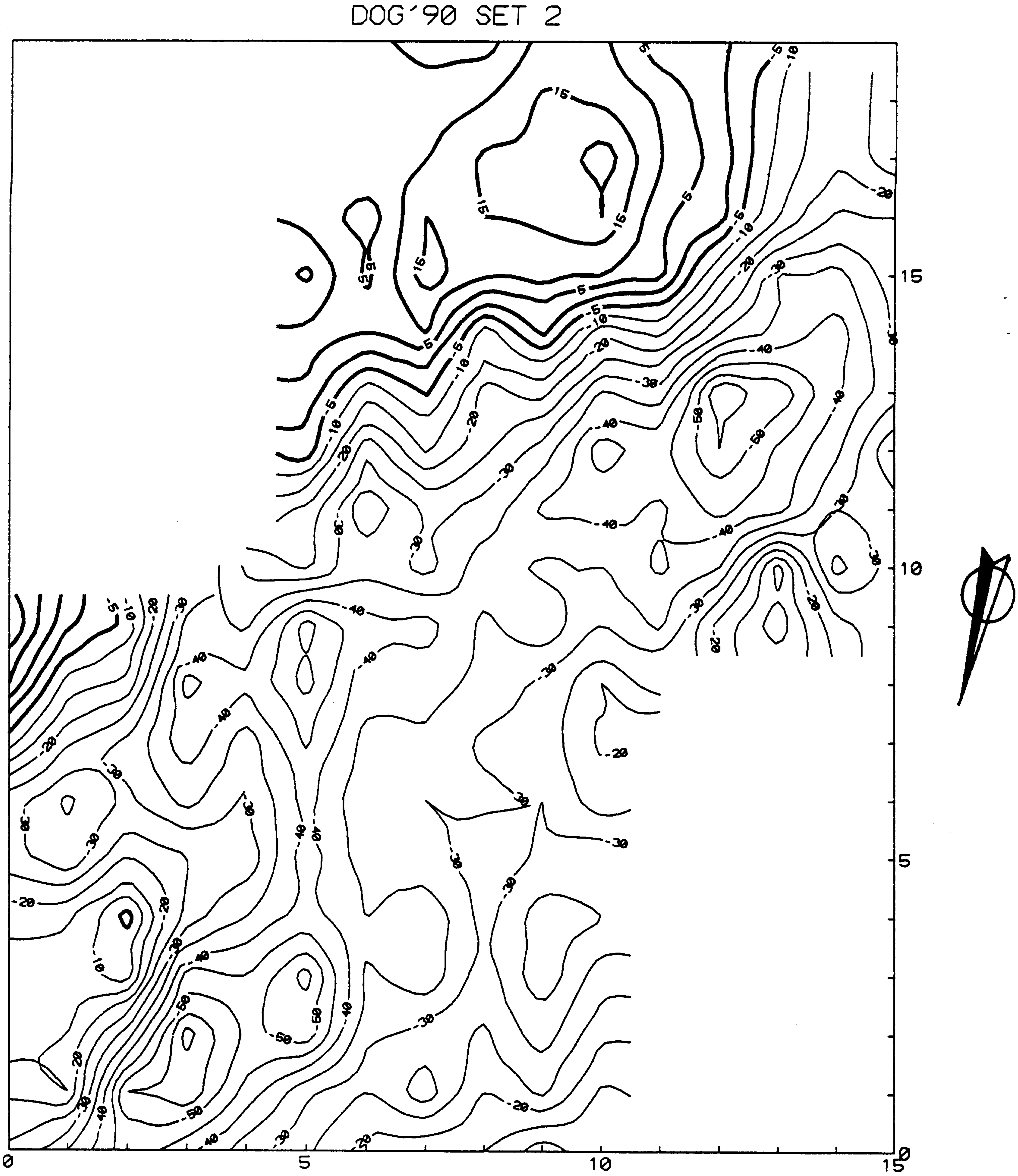


Fig. 5. Contour map of the changes in intensity of magnetic field. Set 2. Contour interval 5 nT.

distance as in the case of normal 1 m grid, but we made only one half of the measurements. As the result of this stage of prospection we obtained the location of anomalies characteristic for the remains of kilns. This preliminary survey took a crew of three people five days. Next we marked in the field 11 squares 10 × 10 m

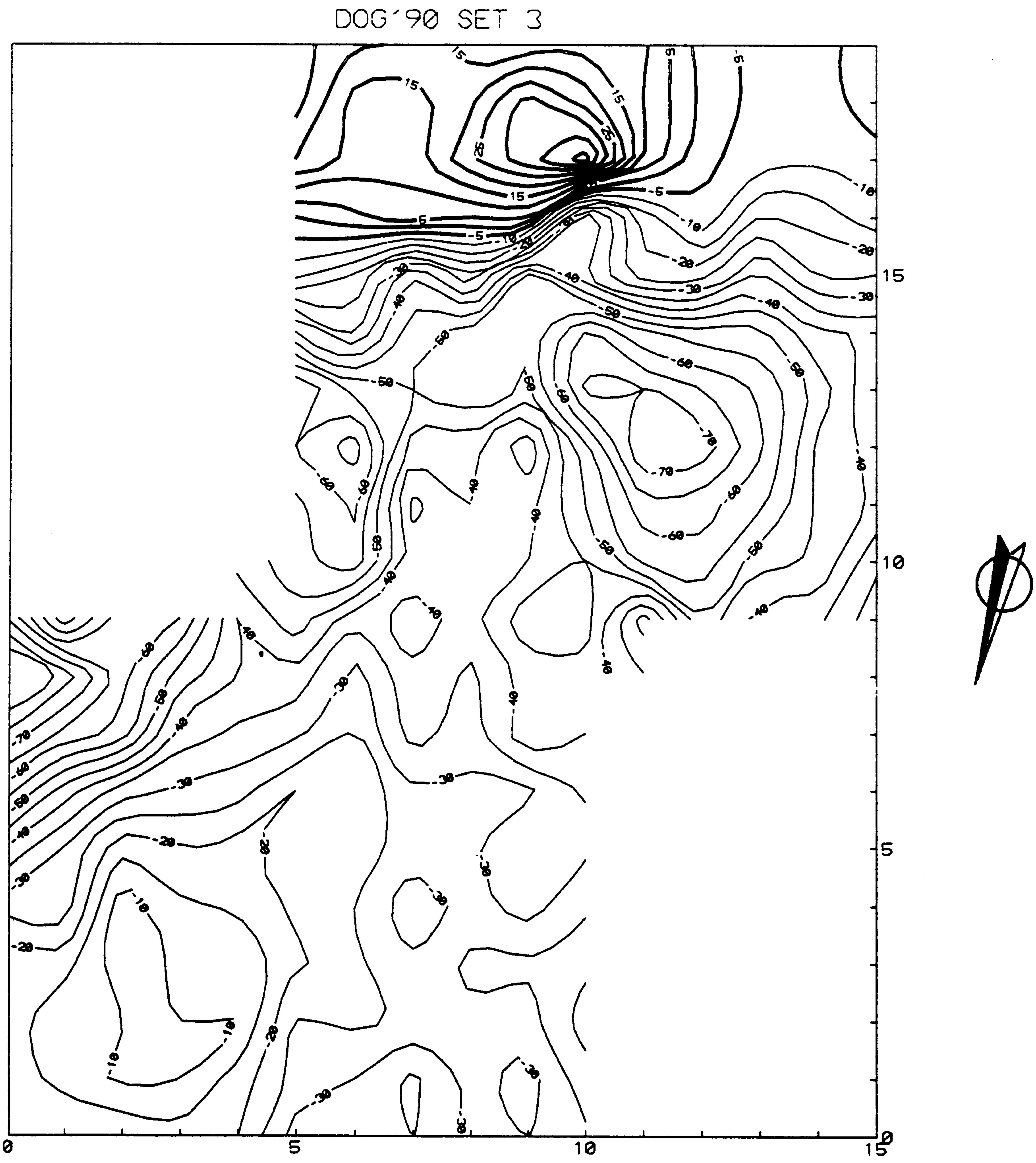


Fig. 6. Contour map of the changes in intensity of magnetic field. Set 3. Contour interval 5 nT.

which should be prospected using the difference mode of magnetical readings for detail localization of remains.

For this stage of prospection we used more sensitive magnetometers (0.1 nT) working in differentional mode. One magnetometer was operated at a fixed base station, located separately for each square, while the other was read at the grid points. It was possible to work with the base station magnetometer in automatic-repeating mode, but we have chosen the method of reading the reference magnetometer simultaneously, with the moving one for all readings. The reference values were subtracted from the corresponding grid-point values and the difference constituted the data to be plotted. Work in the field on this stage of survey took the same crew three days (including determination of measurement noise, setup and recalculating time for each prospected square).

The obtained data were grouped into 4 main sets. We used a computer to generate maps for each set for final presentation but in the field we had have to write numbers on gridded paper and to make hand-contoured maps as primary results of the readings. The final results of prospection were presented in a form of magnetic contour maps with a 10 nT contour interval (Figs 4–6) and as three dimensional plots.

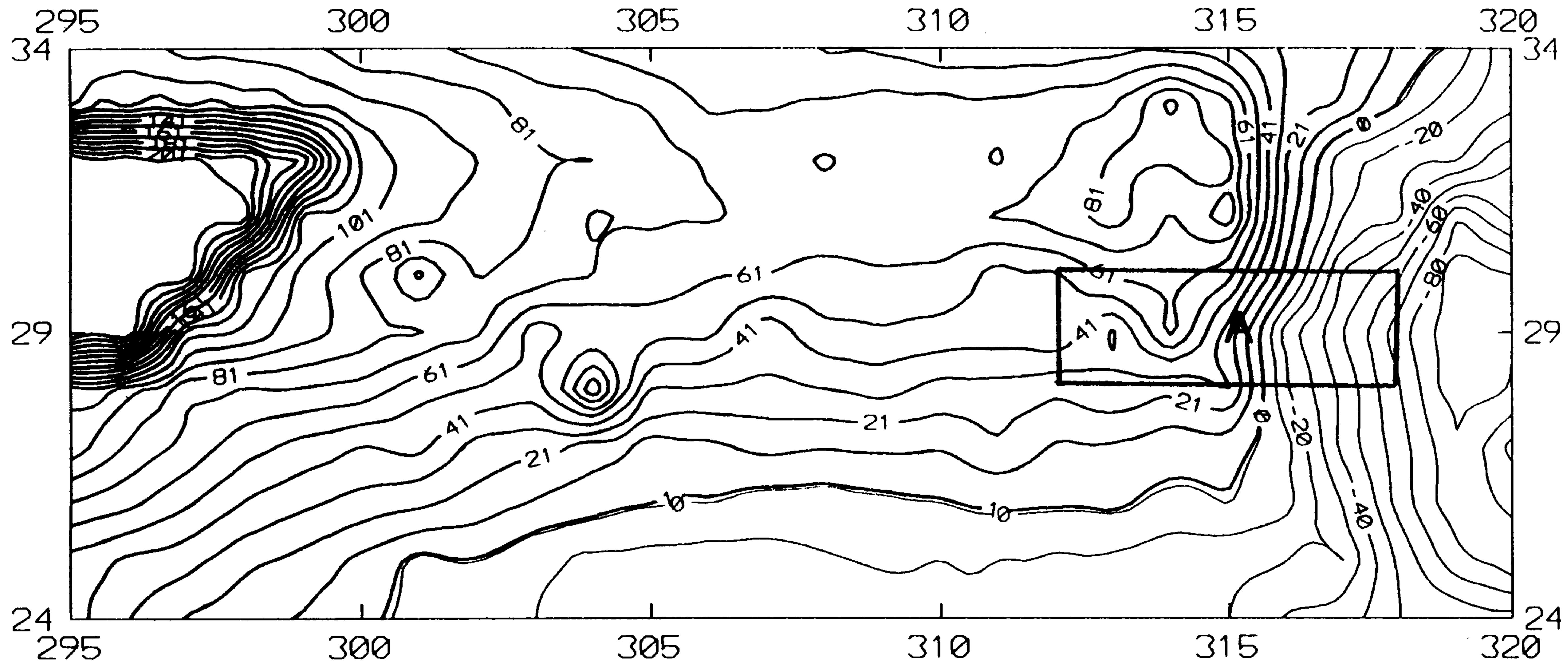


Fig. 7. Contour map of the changes in intensity of magnetic field. Set 4. Contour interval 10 nT. (with trial trench A).

Analysis of the disposition of intensity of the magnetic field allowed us to localise 11 anomalies similar to those caused by the presence of remains of pottery kilns already known. In the place of one of these characteristic anomalies (Fig. 7) a trial trench was dug to confirm our observation and to test the exact position of the remains. We chose specially the place where there were no traces of human activity on the ground surface. The upper part of two pottery kilns were excavated in this trench at a depth of 1.83 m.

CONCLUSIONS

The magnetic survey of the site at Old Dongola was made in very favorable conditions. We were looking for burned features which gave very good contrast between the surrounding soil which was almost completely amagnetic. The kilns were rather large and produced strong characteristic anomalies. Looking for these features we were not interested in the other anomalies caused or by the soil surface irregularities or in small archaeological features. This allowed us to make faster measurements in the field and also the analysis of the results was easier and did not require supplementary studies like data filtering, diurnal correction, theoretical model calculations, measuring of susceptibility values on soil samples usually necessary in magnetical prospection.

We had to find the solution for only two problems: to determine the depth of sources causing anomalies and to divide detected anomalies into those being the results of the presence of remains of one kiln from those caused by kiln groups.

The first problem was easier to solve, because we had only to differentiate between anomalies caused by shallow kilns (to 1 m) and those produced by deeper remains (over 1 m). The first group of anomalies usually were similar to classical dipole anomalies, had contours close together and rose rapidly to the maximum values (for a discussion of shapes of magnetic anomalies see Linington 1972). If remains of kilns lying close to the surface were heavily fired, they produced anomalies similar to these caused by the presence of metal (Bevan 1983). In the case of anomalies caused by deeper kilns, the passage from high to low values was gradual but still had a dipole character.

More complicated was separating single sources of anomalies from these produced by groups of kilns. If the remains were situated close to the ground surface, a group of kilns produced dipole anomalies with separate maximas and minimas. If they were deeper we could have two zones of minimal values and only one large zone of maximas. One could say that groups of deeper kilns usually produced larger anomalies. However these anomalies could be similar to disturbances in the magnetic field being of geological origin. This problem was very carefully examined and our trial pit was made in the place where we suspected the presence of remains of more then one kiln. The method of prospection involved on this site produced a satisfactory result and difficult conditions of occurrence of the remains of kilns allowed us to conclude that the method should be effective also on other similar archaeological sites.

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