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Magnetic enhancement over buried features in Kerkenes archaeological site, Yozgat, Turkey

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Abstract: *Kerkenes Mountain in Central North Tukey was a very large iron-age settlement of Persians. It is located at about 30 km south east of the town of Yozgat. Archaeogeophysical surveys have been carried out in the site along with the archaeological works since 1993. The site was surveyed by a Geoscan gradiometer almost throughout. However, some form of noise was introduced in the gradiometer measurements. In this paper, the noise introduced, was filtered out by designing a wavenumber filter. Filtered maps show improved images of the response of manmade structures.*

INTRODUCTION

Kerkenes site, described by Herodotus as a stronghold of Median Empire (Persian Empire) which was constructed around begining of the 6th century BC. This magnificent iron age city was destroyed by firing, by Lydians about half a century later because of its strategic location in central Turkey (Kerkenes News 2, 1999). The settlement has never been reconstructed again by any civilisation. The Kerkenes archaeological site captured the interest of the British Institute of Archaeology (BIA). The archaeological work was initiated by the BIA and the Middle East Technical University (METU) in 1993. Since then, a wide range of studies have been carried out, ranging from excavation to archaeometric investigations and geophysical surveys. Kerkenes Newsletters can be accessed by the WEB address (http:// www. metu. edu.tr/home/wwwkerk/)

The gradiometer survey of the Kerkenes site has been nearly completed. The gradiometer data were of good quality, but the images produced from these data were poor. It is thought that some form of noise mixed into the data which obscures the signal coming from man made constructions causing gradiometer anomalies. In this paper, gradiometer data of a sellected bit of land, shown in Fig.1, were filtered using frequency domain filters to remove the noise and enhance the quality of signal.

TOPOGRAPHIC MAP AND GEOMORPHOLOGICAL FEATURES

The topographic map of the Kerkenes mountain and its surroundings was taken from the Mineral Research and Exploration (MTA) of Turkey, produced by the general directorate of mapping of Turkey. The area extends in two sheets of 1:25000 scale. These two sheets were joined together and redrawn (Fig.1). The basement of the area, inferred by the regional geology, is consisted of granitic rocks. There is a steep-hill from south-east which gradually decreases towards the south-west. The highest topographic locations Kale (Castle) and Kiremitli Hills are in the east and south, respectively. The lowest topographic location is in the north-west outside of the city walls (Fig.1). Thus, water courses follow south-eastern and north western paths. There are two

small lakes which are also associated with the north-westerly water course.

THE METHOD

Filters can be designed both in space and wavenumber domains (Dean, 1958; Black and Scollar, 1969). Wavenumber filtering can be designed to transfer the spatial domain datasets into wavenumber domain. Spectrum analysis according to the method of Spector and Grant (1970) provides the bases of designing wavenumber filters. The method consists of plotting the spectrum against the wavenumber. A cut-off wavenumber is necessary to be assessed to design the appropriate wavenumber filter types listed below:

i. High-pass,
ii. Low-pass,
iii. Band-pass filters.

Any of these filters can be designed provided that the signal and noise levels of the data can be estimated. Thus, noise introduced into the data may be filtered out and consequently, the signal will be enhanced. If the noise level of the data cannot be easily predicted, it is better to start trying at first a low and then a high-pass filter. A band pass filter can isolate the signal at intermediate wavenumbers at the expense of both low and high wavenumber components which are supposed to be dominated by the noise.

GRADIOMETER SURVEYING

Gradiometer surveys in the Kerkenez archaeological site commenced in 1997 and since then the whole site has almost been covered. Measurements were taken using the FM36 instrument of GEOSCAN RESEARCH, stepwise at 0.25m intervals along profiles spaced 1m apart each from the other. Readings were stored in the data logger of the instrument for every 20×20 meter squares and then transfered to a computer via a RS232 cable.

The results of the gradiometer survey were produced as images using the Geoscan Research computer program and they are shown in the WEB site (http://www.metu.edu.tr/home/wwwkerk).

Referring to the bit of land used for testing, it is at the north part of the site seen in Figure 1. In Figure 2, a very pronounced, roughly oval shaped feature, with extensions in one side, is located near the central part of the map. The coordinate system of the map of Figure 1 is a local one. The data were gridded using the spacing of 0.664 metre along the X and 0.5 metre along the Y direction to establish a data matrix of 119 × 119. The image of Figure 2 is in grey scale. Although the structure can be discerned from the gradiometer image map and can easily be considered to be man made, its archaelogical interpretation seems to be difficult. The gradiometer image appears to be blured by some form of noise mixed with the data at unknown level.

FILTERING THE GRADIOMETER ANOMALIES

Gradiometer anomalies of the control region filtered succesfully by using low-high and band-pass filters. In order to have control over the filter, the log power spectrum plot was produced. It is well known that the power spectrums provided the base for filtering. The filtering process was carried out in the frequency domain and unwanted frequencies were removed from the data.

A low-pass filtered image is shown in Figure 3. The cut-off frequency of 0.15 cycles/m was used. Two-high-pass filtered images were produced using the cut-off frequencies of 0.15 and 0.2 cycles/m respectively (Figs. 4a and 4b). Two band-pass filtered image maps were also produced using the cut-off frequencies 0.2-0.45 (cycles / m) and 0.2-0.6 (cycles / m) respectively (Figs. 5a and 5b).

INTERPRETATION

The low-pass filtered map (Fig. 3) shows broad anomalies presumable caused by topographic features or the geological structure. On the contrary, the high-pass filtered anomalies show an enhanced image where wall ruins of the buried structures become clearer. Features resembling a canal-like structure and a fire hearth become visible. To enhance the

images further band-pass filter was employed which shows further improvement on the image map of the region. Hand-drawing of an interpretative plan of the region is given in Figure 6.

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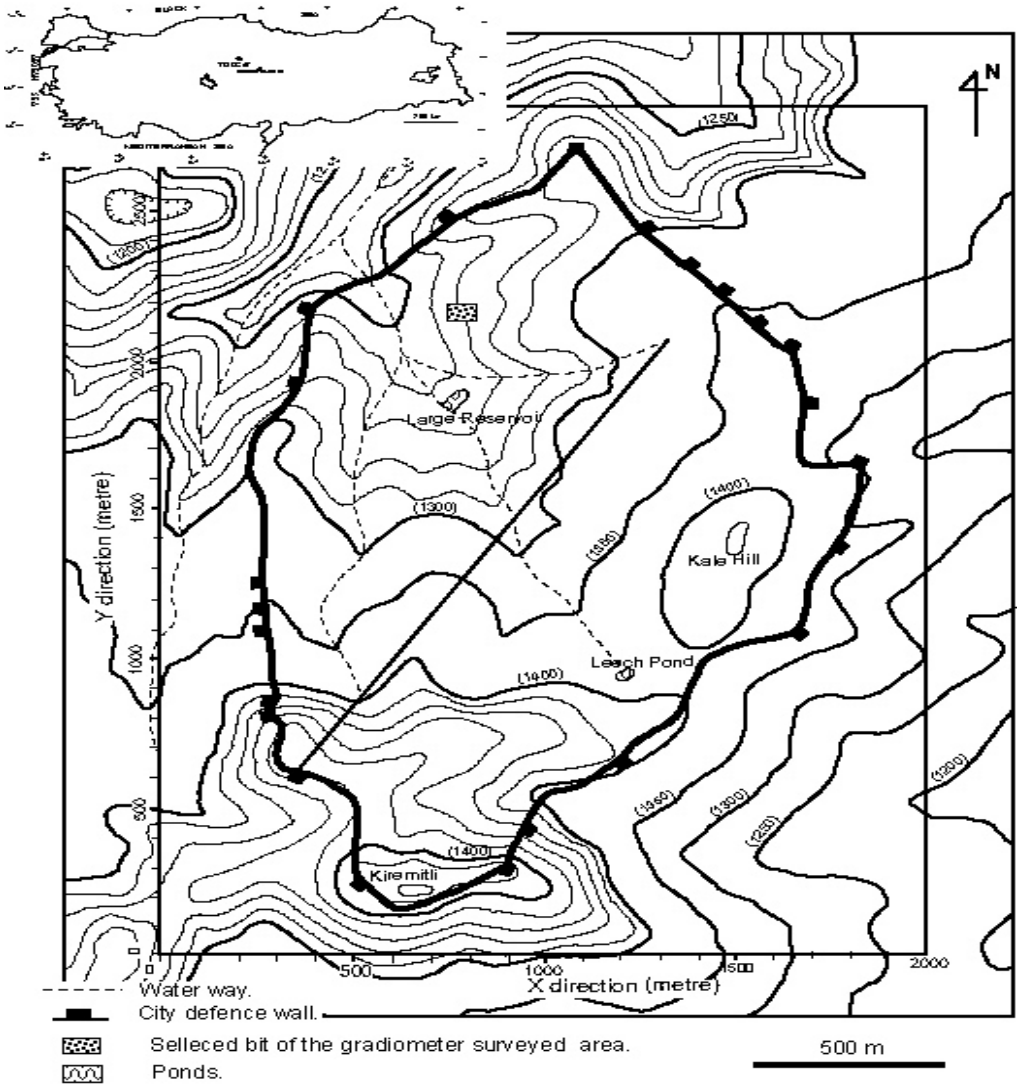

Fig. 1. Topographic map of the Kerkenes archaeological site. Numbers in brackets show absolute altitude from sea level. Thick lines denote the contours in 50 m intervals, between each other. The thin lines are in 10 m intervals. Inset map shows the location

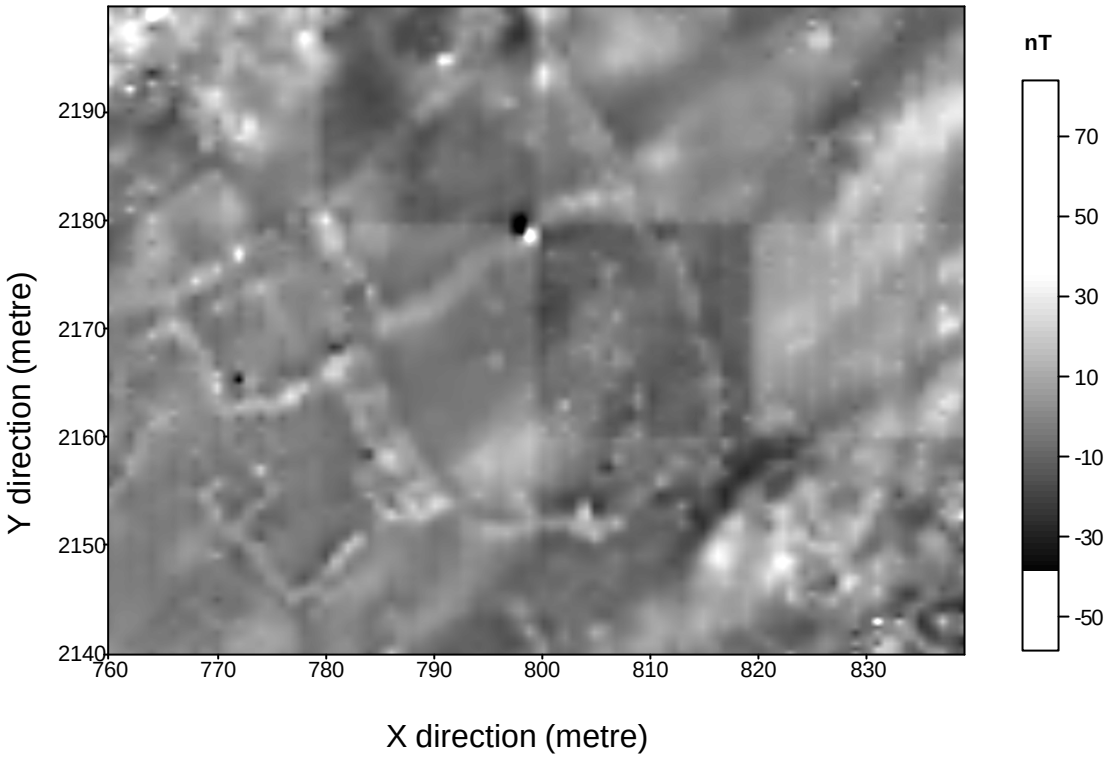

Fig. 2. Grey scale of the gradiometer data.

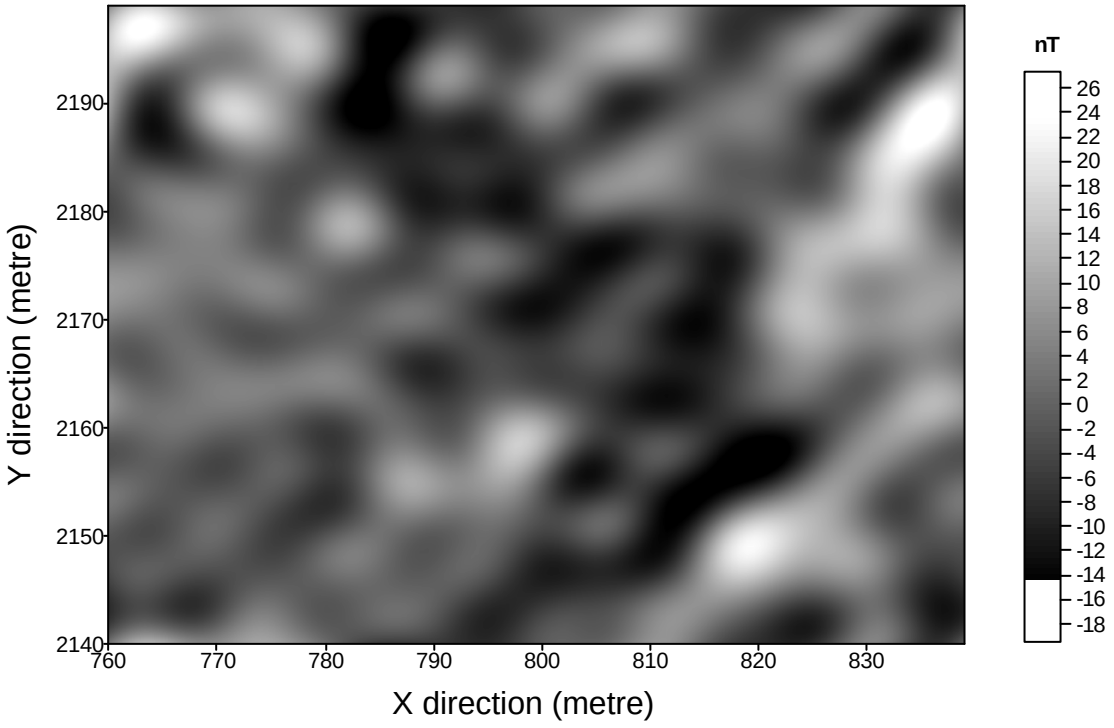

Fig. 3. Low-pass filtered image. Cut-off frequency is 0.15 cycles/m.

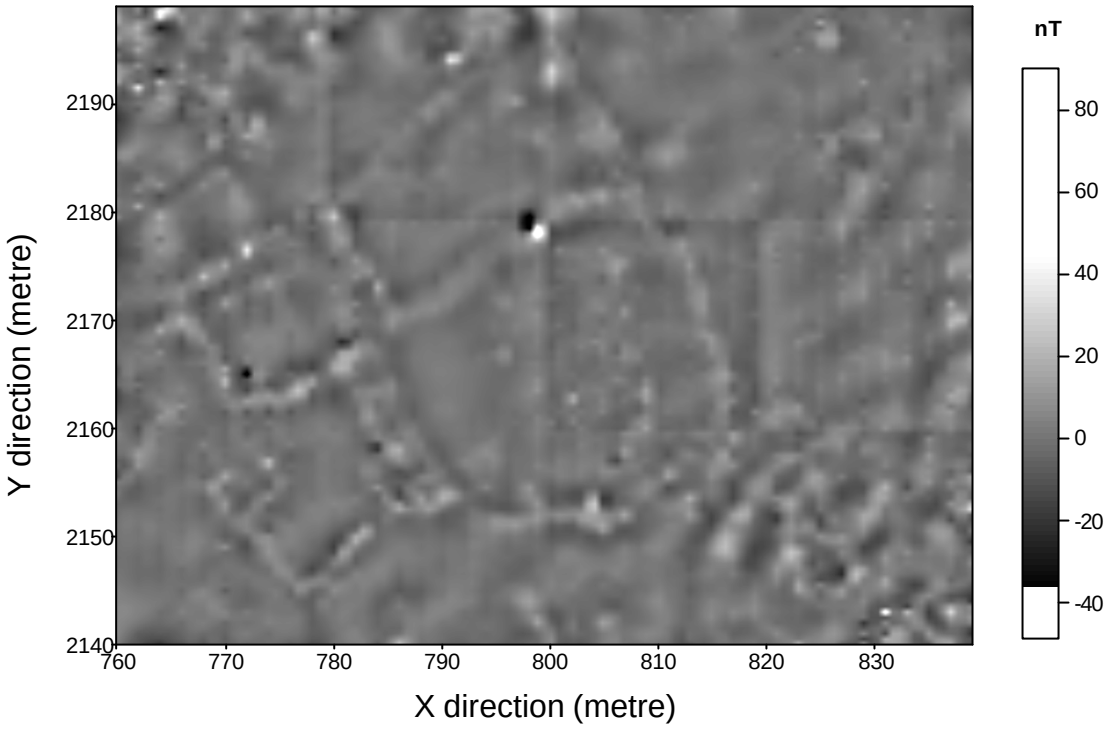

Fig. 4a High-pass filtered image. Cut-off frequency is 0.15 cycles/m.

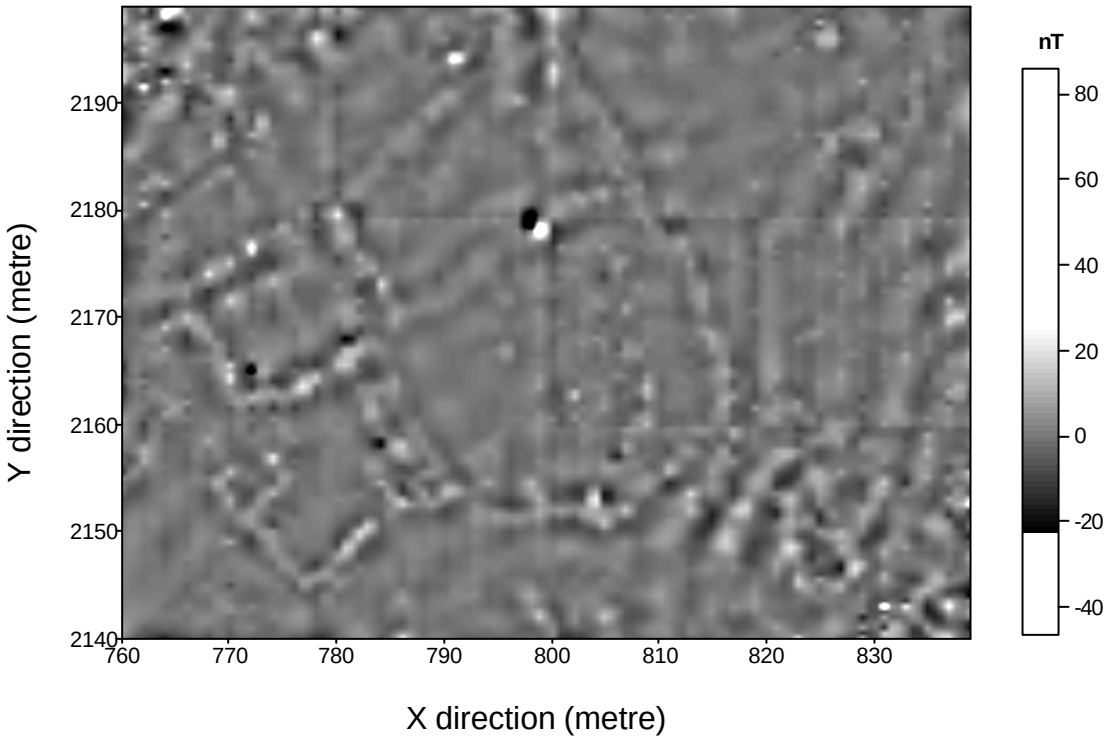

Fig. 4b High-pass filtered image. Cut-off frequency is 0.2 cycles/m.

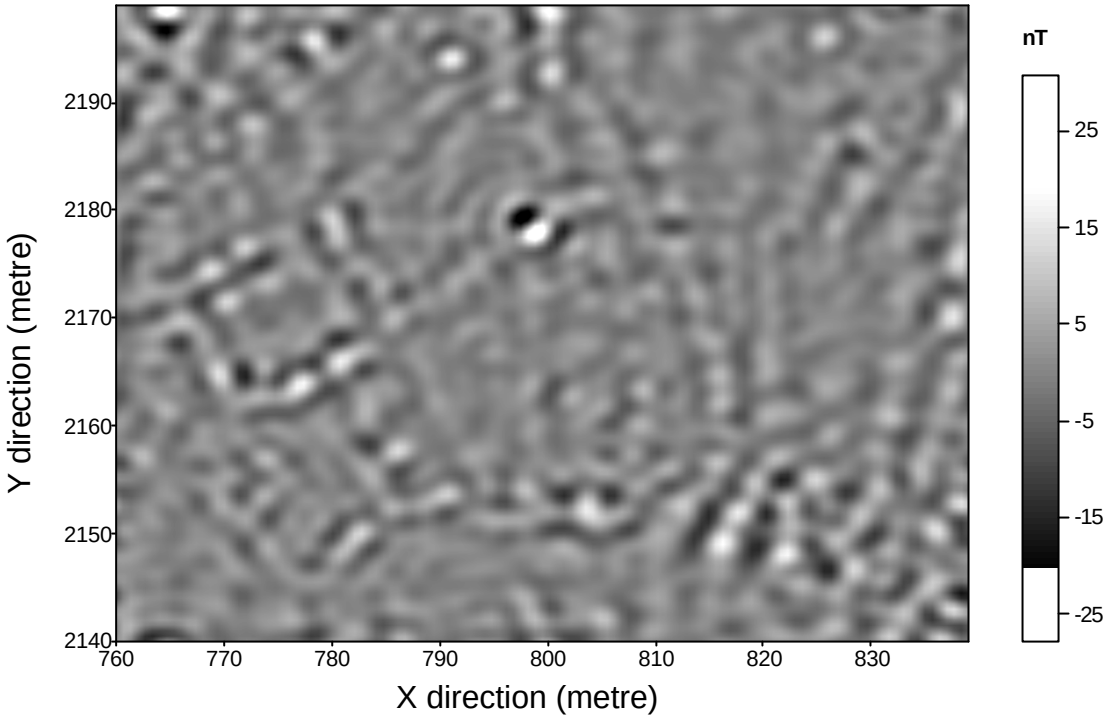

Fig 5a Band-pass filtered image.Cut-off frequencies are 0.2-0.45 cycles/m.

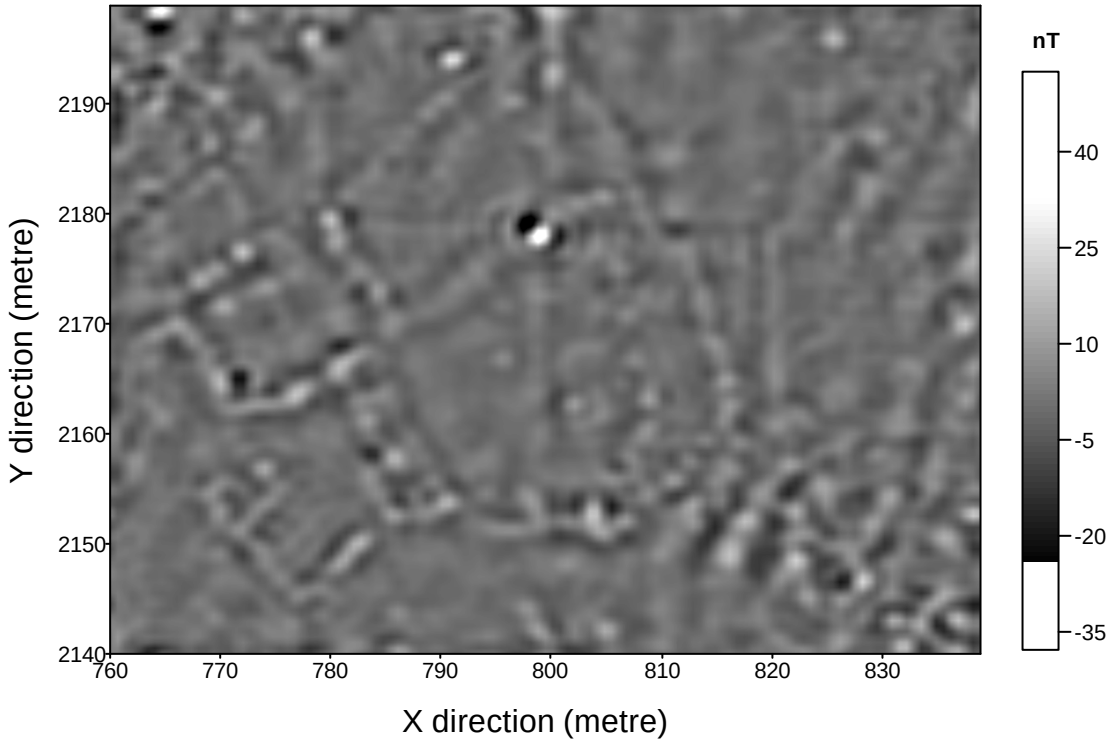

Fig 5b Band-pass filtered image. Cut-off frequencies are 0.2-0.6 cycles/m.

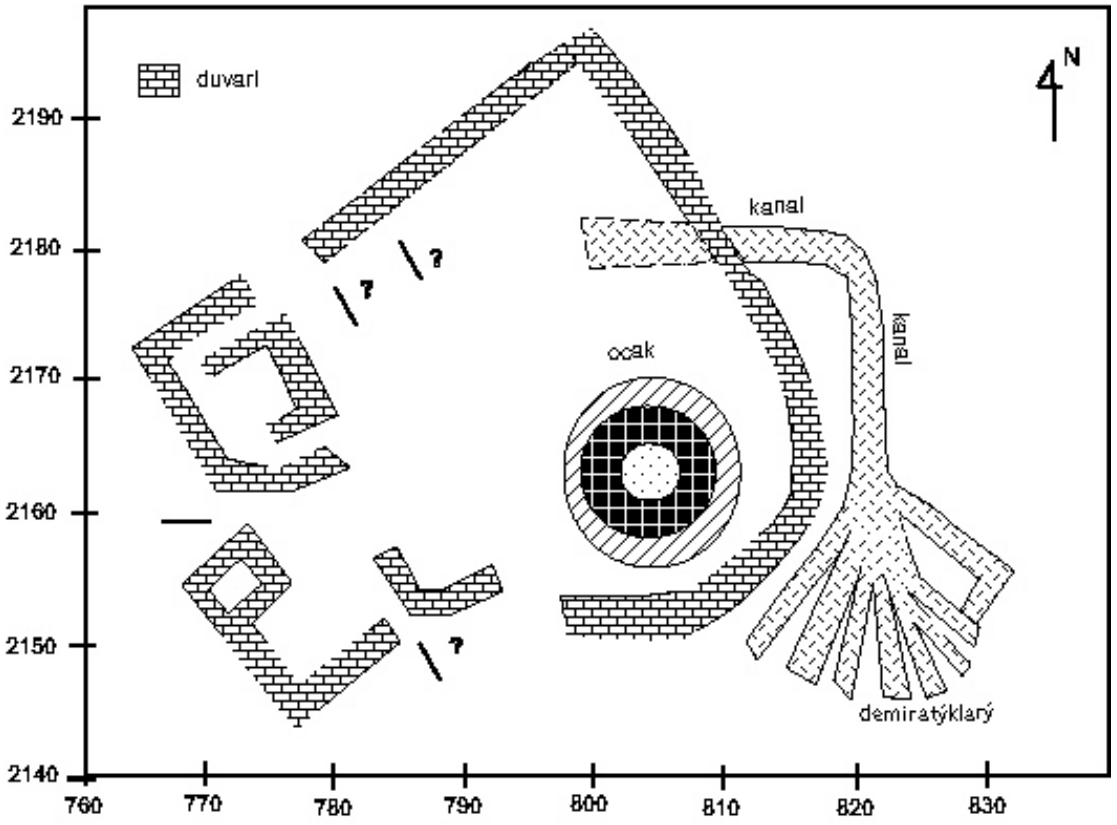

Fig. 6. Interpreted plan view over the bit of land used for the tests. Arrows and question marks show possible locations of gates of the building.

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