MAGNETIC SURVEY OVER BRICK KILN REMNANTS AT VELDBÆK NEAR ESBJERG (DENMARK)

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Abstract

Detailed magnetic total field and gradient measurements over remnants of a tile kiln at Veldbæk (55.46°N, 8.50°E) near Esbjerg in SW-Jutland (Denmark) have showed marked magnetic anomalies of up to 200 nT, revealing the rectangular shape of the kiln as well as specifically depicting the heating channels. The bulk susceptibility also showed markedly increased values of the kiln-area as compared to the surrounding unheated smelt-water sands.

Introduction

In relation to new roadworks in 1995 Esbjerg Museum excavated remnants of an old brick kiln at Veldbæk ca. 3 km east of Esbjerg. Only part of the kiln floor and minor parts of the walls were preserved. The age was unknown, but luminescent and magnetic datings suggest the age of the kiln to be around 1790 AD (Mejdahl 1996, Abrahamsen et al. 1997). During the archaeological excavation, magnetic mapping using the total magnetic field as well as the surface susceptibility were also made with the purpose of evaluating the potentials of the magnetic methods in relation to other archaeological brick structures.

Magnetic survey

Magnetic anomalies at the Earth's surface are generated by a complex interplay between the Earth's magnetic field, the magnetic remanence and the magnetic susceptibility of the nearby anomalous materials (*in casu* the kiln), and the geometric shape of these materials.

The magnetic susceptibility was measured directly at the cleaned surface of the excavation (after having removed the soil) by a kappameter (Geofyzika Brno Model KT-5), whereas the magnetic survey was made by a proton gradient magnetometer (Geometrics G856), using two sensors on a vertical rod (Fig. 1). The lower sensor was situated 0.3 m above the surface of the excavation (the exposed surface of the kiln floor), and the top sensor was at 1.4 m above the bottom sensor (separation length 1.4 m). Measurements were automatically stored and later corrected for daily variations by means of repeated measurements on a local base station.

Fig. 1: Oblique view from WSW of the exposed remnants of the kiln floor. The proton-magnetometer with the two sensors is situated at the coordinate (7m E, 11m N), c.f. Figs. 2–5.

Magnetic anomaly map

Measurements were made along profiles directed towards the North in a grid of 0.5 m x 0.5 m. An area of 16m x 12 m was surveyed (Figs. 2 & 3). The total magnetic field T_t at the top sensor is shown in Fig. 2 (aequidistance 5 nT), the sensor elevation being 1.7 m above the floor. Even at this height the area of burned stones are well depicted; the rectangular shape of the kiln is also detectable, but no detailed structures are seen from this elevation.

The total magnetic field T_b at the bottom sensor is shown in Fig. 3 (aequidistance 4 nT). At this close distance from the magnetic sources the rectangular shape of the remaining kiln floor is very well recorded, and by comparisons with the plan of excavation there is a good correspondence between excavated structures and the local magnetic anomalies. Especially the northernmost (best preserved) heating funnel and the funnel openings are well marked, these parts being the best preserved parts of the structure.

The magnetic gradient (or more correct "vertical difference", cf. Koppelt et al. 1996) $\Delta T = (T_b - T_t)/\text{length}$ is shown in Fig. 4. The resolution of details are the same as for the bottom sensor, but possible uncertainties which might have been caused by rapid daily variations would have been eliminated even without control by the base station.

Magnetic susceptibility

The magnetic susceptibility k was measured with the kappameter along 5 profiles in a grid of $^1/_4$ m · 1m across the structure (Fig. 5). It appears that the contrast in susceptibility between the kiln remnants and the magnetically neutral soil (consisting of smelt-

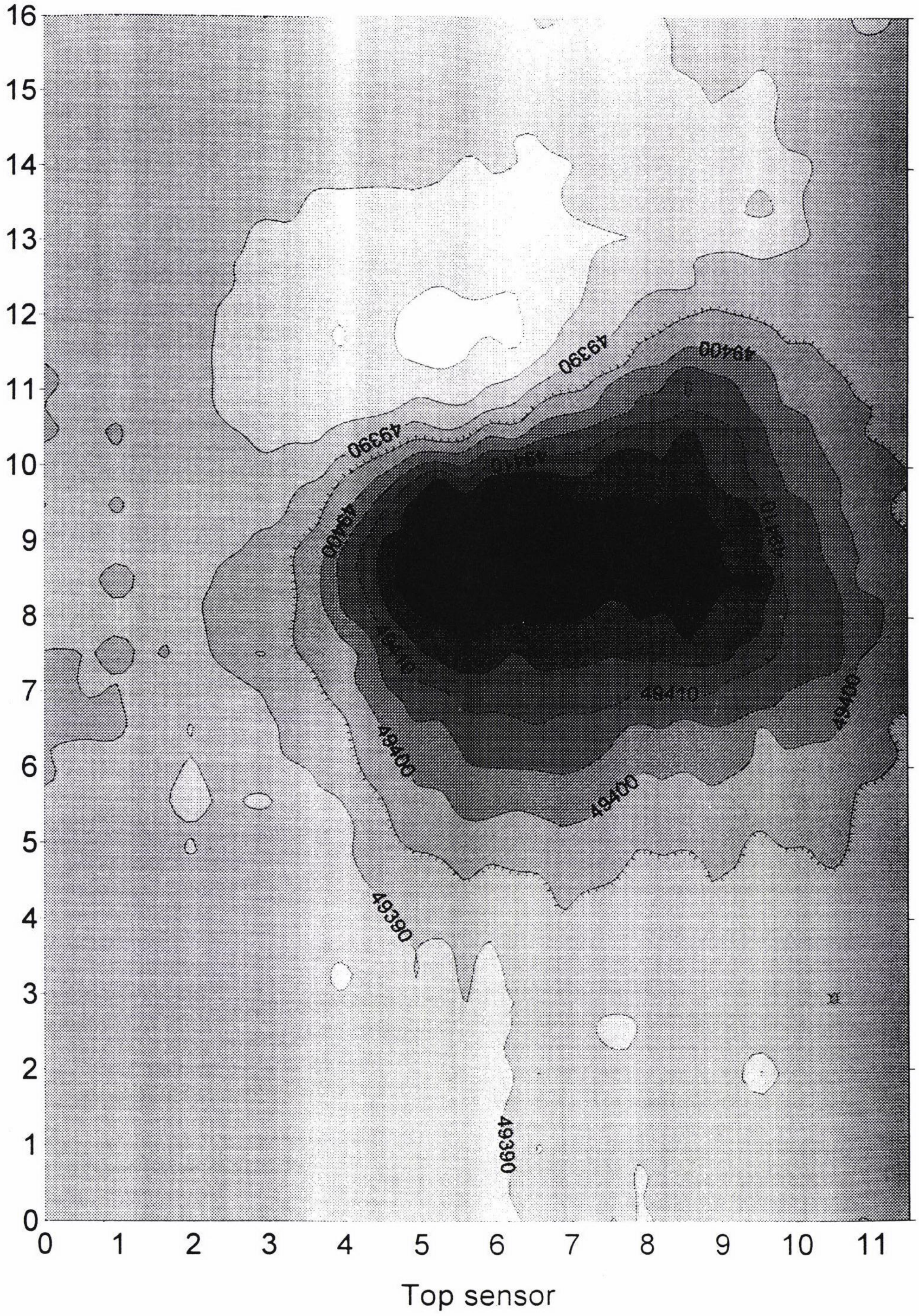

Fig. 2. Magnetic total field anomalies T_t (top sensor, equidistance 5 nT).

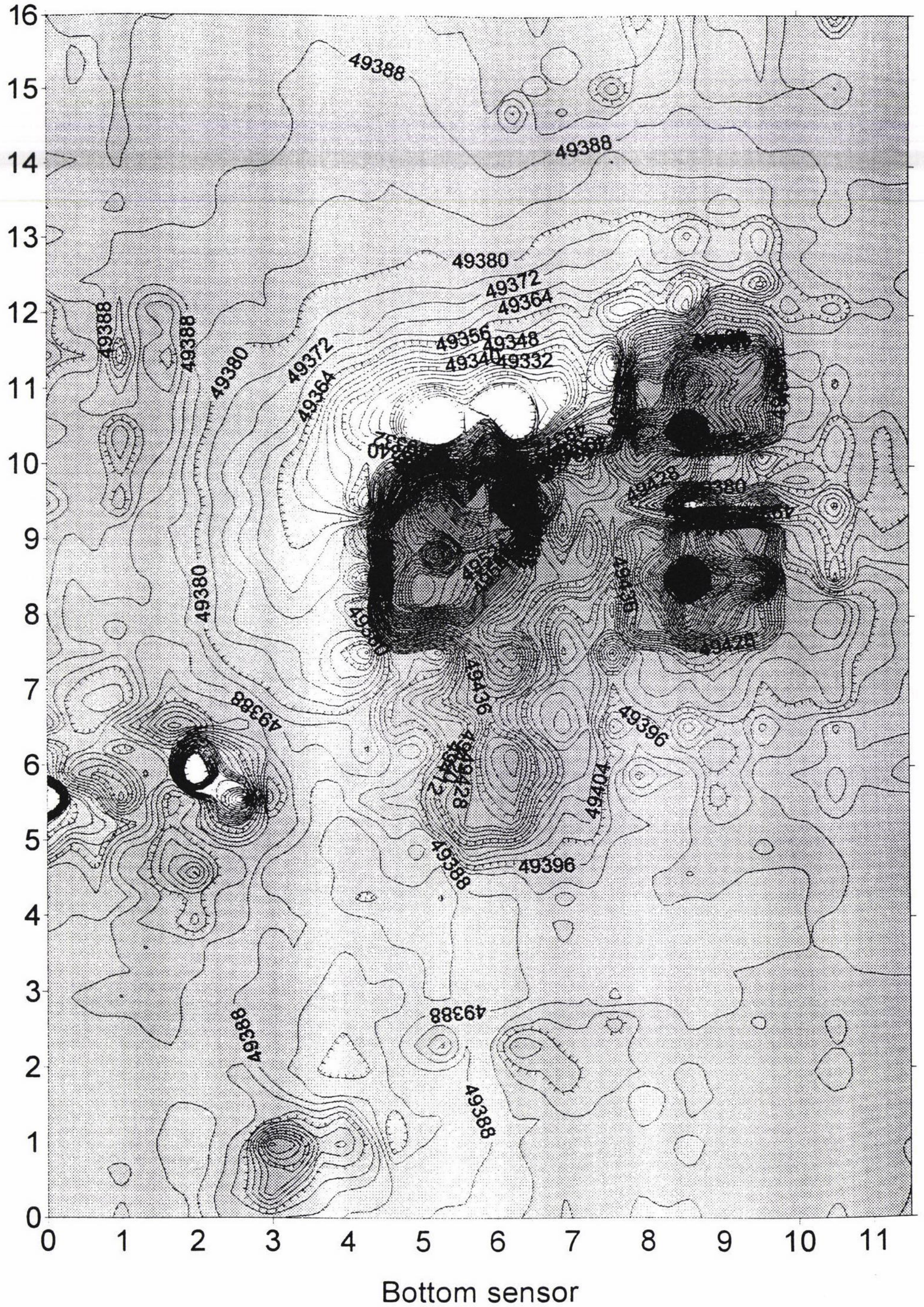

Fig. 3. Magnetic total field anomalies T_b (bottom sensor, equidistance 4 nT).

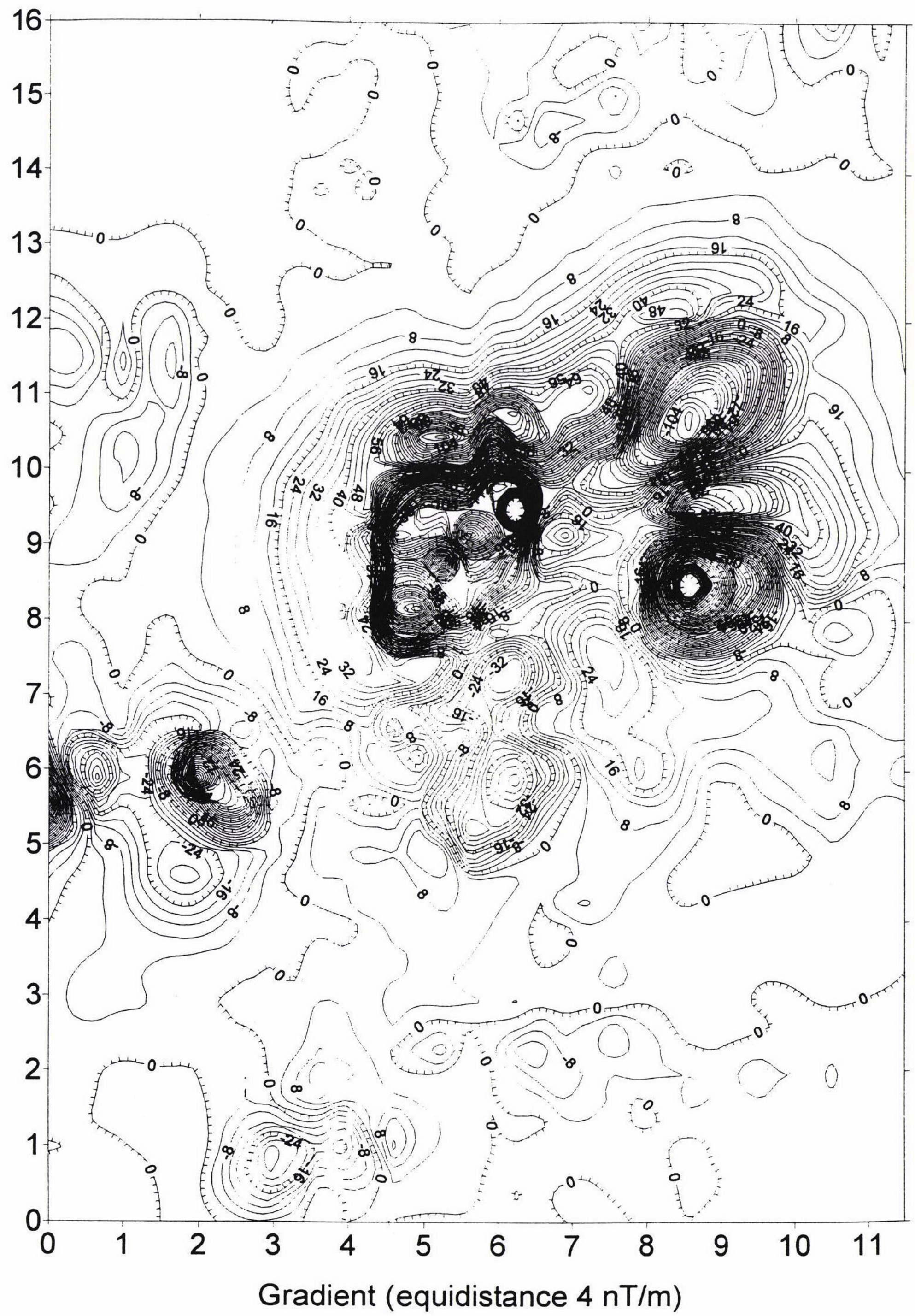

Fig. 4. Magnetic gradient anomalies $\Delta T = (T_b - T_t)/l$ (equidistance 4 nT/m).

water quartz sand whith very low susceptibility) roughly varies as the magnetic anomalies from the previously heated kiln material.

Magnetic properties of the kiln bricks

Magnetic properties of ferromagnetic materials such as baked clays may be described by the intensity of the natural remanent magnetization (NRM) and the magnetic bulk susceptibility k. The ratio between the NRM and the induced magnetization $J_i = k \cdot T$ is the so-called Q-ratio, $Q = NRM/J_i$, T being the total geomagnetic field. If Q is high, the magnetic remanence (the magnetic memory) is likely to be more stable, and the material likely to be suitable for magnetic dating (Abrahamsen 1984).

The susceptibility, measured on cored specimens from the kiln, varied between 0.1 and $2.6 \cdot 10^{-3}$ SI, with an average 1.1 ± 0.7 SI, while the NRM intensity varied between 0.3 and 16 A/m, with an average of 5.4 ± 2.6 A/m. The Q-ratio was found to vary between 3.6 and 25, with an average value of 10, and thus the NRM is strongly dominating over the susceptibility; demagnetization experiments (Abrahamsen et al. 1997, Fig. 5) also showed the direction of the remanence to be very stable. Thermal demagnetizations of the specimens show Curie-points close to 580° C, indicating the dominant magnetic carrier to be pure magnetite, which is also evidenced by the bell-shaped decay-curve by AF demagnetization, the median destructive field being around 40 mT.

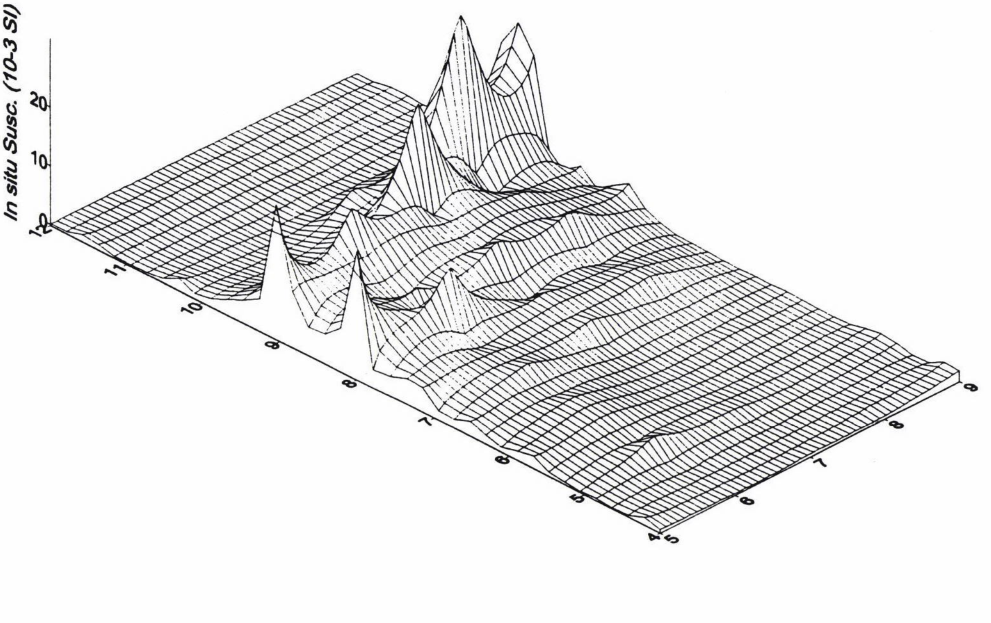

Fig. 5. Map of the magnetic susceptibility k (10^{-3} SI), measured at the exposed surface of the excavation (numbers on grid in m).

Conclusions

Due to the fairly strong magnetic properties of the kiln materials, it may be concluded, that magnetic measurements (total field surveying over the structure, as well as susceptibility measurements directly on the ground surface) are useful tools for detecting and mapping archaeological structures, which contain baked clays, stones, slags and other magnetic objects.

To optimise the time necessary for performing a planned magnetic survey it is furthermore important carefully to consider the choice of the grid spacing and also to choose the magnetic sensors to be suitably arranged, in accordance with the expected dimensions and depth of the magnetic target (e.g. Abrahamsen et al. 1996, Koppelt et al. 1996).

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