'Atiqot 83, 2015

Magnetic Prospecting of Archaeological Targets at Ḥorbat Be'er Shema'

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Introduction

Geophysical prospecting is a reliable tool for revealing and mapping buried archaeological sites. It is the most widely used method for investigation of archaeological remains used worldwide and is a fast, low-cost and non-invasive method compared to excavation (Aitken 1974; Wynn 1986; Clark 1990). The increasing sensitivity of magnetometers, the rising accuracy, the high resolution and the reliability of magnetic measurements in recent years have led to wide application of the magnetic method in archaeology (Heimmer and De Vore 1995; Hansen 2001; Kvamme 2001). Magnetic prospecting cannot substitute for direct examination of ancient remains by excavation, but it is helpful in providing preliminary outlines of major targets prior to excavation, thus leading to much more efficient and cost-effective excavations.

At the site of Be'er Shema', a large feature in the north of the site, referred to as a 'reservoir' although its actual function is unknown (see Erickson-Gini, Dolinka and Shilov, this volume), was surveyed in order to ascertain the existence of subsurface construction.

Determination of Magnetic Susceptibility and Evaluation of the Potential of the Magnetic Survey

Magnetic prospecting of archaeological sites is based on the magnetic contrast between archaeological remains and the surrounding soil. The feasibility of the detection of remains at Be'er Shema' by magnetic prospecting was evaluated in the field by measuring the magnetic susceptibility (κ) of the surrounding soil and the stones making up walls. This test revealed weak magnetic contrast between mud-brick and limestone walls and the hosting soil, ranging in the interval of 60–80 × 10^{-5} units SI.

Near-surface archaeological targets, despite their wide diversity, can be classified into groups of similar shapes and approximated by simple geometrical models at the initial stage of interpretation. A simple model of a wall was developed, based on geometrical parameters, typical of archaeological sites in the vicinity of Be'er Shema'. The pattern and amplitude of magnetic anomalies are determined by both the geometrical parameters (shape, depth, orientation) and the magnetic contrast (Δκ) between the anticipated target and the host medium (Itkis 2006). Preliminary modeling using TM-2 software (Bulychev and Zaytzev 2001) was performed to evaluate the amplitude of magnetic anomalies over anticipated targets.

Figure 1 demonstrates the result of forward modeling. In the model, a mud-brick wall in a non-magnetic soil environment was represented by a thick vertical slab measuring 1 m wide and 0.6 m high at a depth of 0.6 m (Fig. 1:b). The magnetic contrast (Δκ) between the slab and soil was taken as 80 × 10^{-5} units SI. The model produced a narrow bipolar magnetic anomaly (Fig. 1:a) that has an extremely weak minimum of 0.7 nanoTesla (nT) displaced northward, and a weak maximum of 2.2 nT displaced southward, with respect to the model's center, due to the strong inclination (~45º) of the magnetization vector in the eastern Mediterranean (Itkis 2006). It was clear that the detection of similar

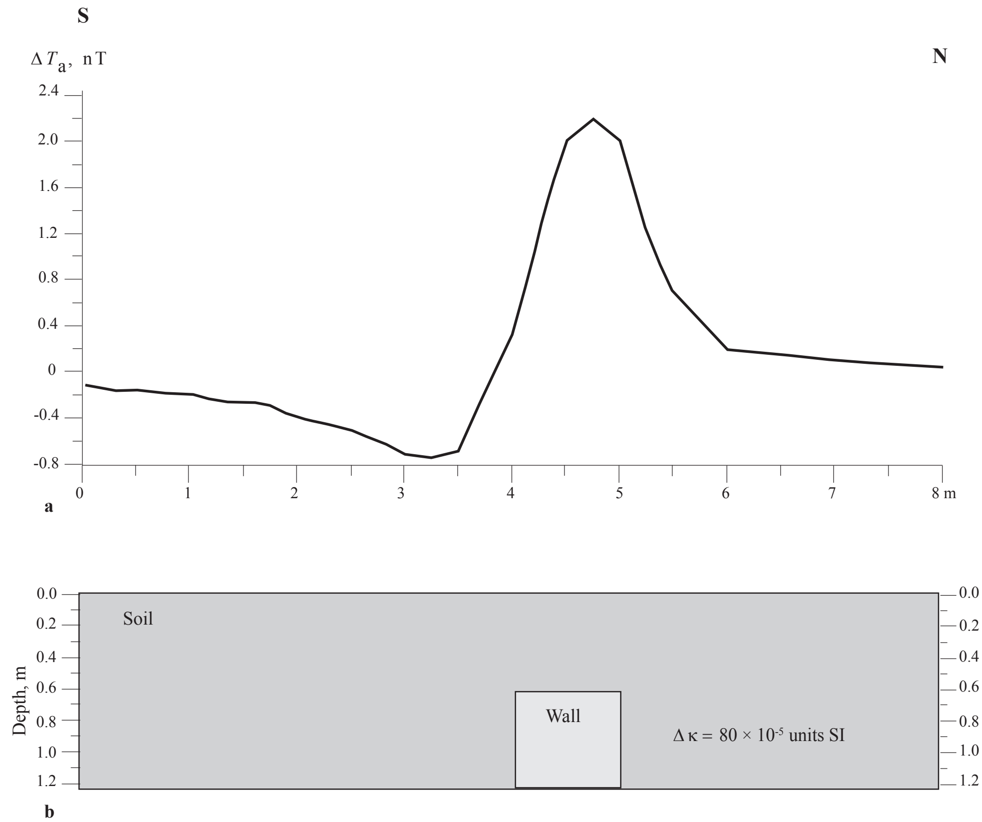

Fig. 1. Modeling of magnetic effect over a wall in non-magnetic soil: (a) calculated magnetic anomaly over a thick vertical slab for $\Delta\kappa$ of 80×10^{-5} units SI; (b) section of the model.

weak magnetic effects requires the highest accuracy of the magnetic survey (Itkis 2005). Moreover, targets of this type located at a greater depth would seem to be undetectable. The 2–3 m width of the anomaly allowed us to select a routine survey grid of 1×1 m without fear of missing an anticipated target.

The survey was performed within a rectangular area of 13 × 20 m (260 sq m) along west–east oriented profiles. The total magnetic field (T) was measured by proton magnetometer MMP-203.[2] According to the feasibility test, we expected extremely weak magnetic anomalies; therefore, the sensor was held close to the ground surface at a height of 0.1 m. The measured magnetic field includes both the signals related to the desired targets and noise effects. Noise is defined as the sum of the undesired natural and artificial magnetic signals. Among the most significant factors affecting high-resolution magnetic prospecting are diurnal variations in the earth's magnetic field and industrial disturbances (Itkis 2006). The effect of diurnal variations was eliminated using the repeatable measurements at the base point located within the area (profile 6, picket 9) every 2–3 minutes. Then, magnetic field values measured at grid points were corrected using a conventional scheme (Parasnis 1986).

The magnetic effect of iron disturbances—such as fences, signs, reinforced concrete, stakes or accumulated pieces of iron refuse, which are common at archaeological sites or in adjacent areas—depends on their 'magnetic mass'

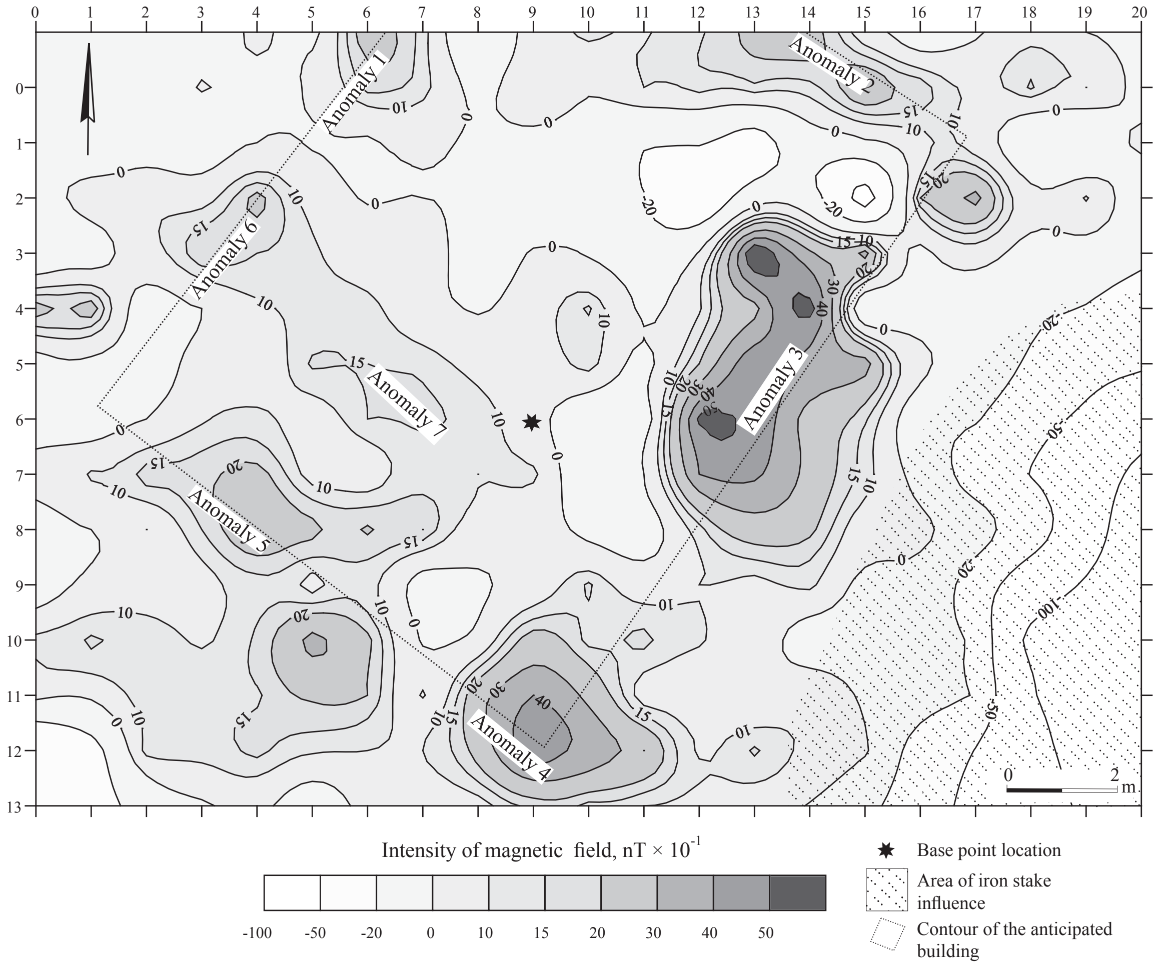

Fig. 2. Magnetic anomaly map.

(magnetization vector multiplied by volume) and the distance between the disturbance and the point of measurement. The disturbing effect is significantly stronger than that of the relatively small archaeological targets, which can be undetectable against the background of the disturbance. One can see an example of such influence in the magnetic anomaly map (Fig. 2). The strong magnetic anomaly produced by an iron stake, located a few meters southeast of the survey area, overlaps the southeastern part of the map, obscuring signals produced by archaeological features.

Measured T data are characterized by weak values of 1–4 nT, with the exception of the southeastern area described above. In order to display weak anomalies, the contours of the intensity of the magnetic field in the map were designed in nT × 10^{-1}.

RESULTS

The magnetic study revealed a complex anomaly composed of a number of elongated positive anomalies with dominant orientations of NNE–SSW and WNW–ESE (Anomalies 1, 3, 6 and 2, 5 respectively). The amplitudes of the anomalies are in a narrow interval from 1.5 to 4 nT. In plan view, these anomalies, with the exception of Anomaly 7, form a rectangular shape of 9 × 13 m (dashed rectangle in Fig. 2). The contours of Anomaly 4, which is located in the southern corner of the rectangle, extend in both NNE–SSW and WNW–ESE directions.

According to forward modeling performed prior to the magnetic survey (Fig. 1), it seems to be justified to interpret the results as depicting the plan of a rectangular building. Anomalies 1–6 indicate the location of outer walls, whereas Anomaly 7 is probably the location of an inner wall. The difference in amplitude of anomalies could be explained by different degrees of preservation, or by different depth, or a combination of both these factors (compare Anomalies 2 and 3).

RECOMMENDATIONS

The map obtained shows dense and persistent distribution of magnetic anomalies in the whole area investigated, with the exception of the southeastern corner affected by the disturbing object. Objects that should be examined first are Anomalies 2, 3 and 4.

It seems reasonable to extend the area of the magnetic survey to the north, to locate the northern corner of the anticipated building, and to perform measurements further east, at a distance from the disturbance of the iron stake.

For a successful test excavation, it is necessary to take into account displacement of magnetic anomalies due to oblique magnetization to the south relative to their source location. Therefore, the location of the test excavation should be chosen with close collaboration between archaeologist and geophysicist.

NOTES

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[2] Manufactured by 'Geologorazvedka', St. Petersburg, Russia.

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