CHAPTER 6

PROTON-MAGNETOMETER SURVEYS IN THE MAIN CITY

by

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6.1 Introduction

In the last volume of *Amarna Reports* I gave an account of two resistivity surveys carried out in 1987 and located within the Main City and Central City at Amarna (*AR* V: Chapter 7). During the following four seasons of fieldwork (1988–91) I continued remote-sensing surveys, first with the resistivity meter and then with a proton-magnetometer, concentrating exclusively on Kom el-Nana in order to complement the topographic survey and excavation then being undertaken there. A full report will appear in *Amarna Reports* VII, as part of a publication of the work conducted so far at Kom el-Nana. In 1992, at the invitation of Barry Kemp and the Egypt Exploration Society, and with the help and co-operation of the Egyptian Antiquities Organization and their inspectors, I returned to the Main City in order to resume the survey there, using the proton-magnetometer.

The rationale this time was to seek for kilns and ovens as part of the expedition's continuing research into ancient manufacturing. Two areas were selected for methodical survey, and at two further points spot-checks were carried out. Of the two main areas the first was the entire site of the building numbered Q48.4 where a small excavation in 1987 had led to the discovery of a pottery factory (*AR* V: Chapters 2–4); the second lay to the south of the Central City, not far from the edge of the cultivation, in the general area where, in 1892, Petrie had reported finding glass or glazing kilns.

6.2 Methodology

Magnetometry has been used in the field of archaeology since the early 1960s, when the method was used to locate Etruscan tombs in Italy. There are various types of instrument which lend themselves to archaeological field-searching: the flux-gate and gradient magnetometers, the single-sensor proton-magnetometer, and the double-sensor differential proton-magnetometer. All of them, by using the magnetic field of the earth as a base, attempt to measure modifications to the earth's surface static field caused by local ore bodies, metallic iron, or the small but measurable anomalies caused by ancient foundations, graves, pottery, kilns or ovens, hearths, cavities, or changes in the sub-surface materials. The searcher is fortunate that the magnetic field of the earth changes during the passage of time, and that the firing of clay or the destruction by fire of a site tends to freeze the magnetic field existing at the time of the event.

The magnetic field of the earth, though very weak, is easily measured, and averages about 50,000 gammas (or nanotesla - [nT] = 10^{-9} tesla [T] in the SI system), the international units for measurement of the earth's magnetic intensity. Diurnal changes can vary between very small amounts of 1 or 2 gammas to as much as 100 gammas during a solar magnetic storm which can last for several days.

For research work in Egypt, where structures can be at depths of up to ten metres, a double-sensor Liebhazet differential proton-magnetometer manufactured by M.L. Dalton Research of Dallas, Texas, U.S.A. was chosen. This instrument allows the calculated value of the earth's magnetic field intensity to be used as a calibration factor at the geographic position of the survey site. By fine-tuning the instrument, a difference of 0.5 of a gamma may be detected by using a beat frequency introduced into the decay sequence of the protons at the separate sensors. This enables the surveyor to field-walk to a grid pattern knowing that any anomaly will be indicated immediately by the audio beat, digital meter, or strip recorder.

For the survey of Q48.4 and the search for the Petrie kilns the instrument was calibrated at 42500 gammas and fine-tuned to maximum response at each portion of the site. An addition to the recording side of the survey was the purchase of a Model 142 strip-chart recorder, manufactured by Linear Inc., U.S.A., which enables permanent survey records to be kept of all anomalies found during the survey.

6.3 The survey of Q48.4

It will be recalled that, before the 1987 excavation, Q48.4 appeared as a series of very low undulations on the desert surface within a roughly rectangular space measuring approximately 80 x 45 m. A topographic contour-map was then prepared of about two-thirds of it which also extended across the site of a large well lying a short distance to the north. During the 1987 season a block of five-metre squares was excavated which covered the south-west corner. This seemed to show that the site was a rectangular walled enclosure with lightly constructed rooms built along the inside and much space left in the middle, and that it had seen a major change of use during its life. Of particular interest was that, in its initial phase, a pottery workshop with kilns had been situated in the area excavated. This had also contained smaller ovens or kilns which might (though this remains to be properly demonstrated) have been used for the manufacture of small items of faience jewellery.

No further excavation has taken place since the 1987 season in view of the continuing commitment to Kom el-Nana. Ancient manufacturing (the technology and the social context) has, however, become an important theme of the expedition's research programme. Dr. Paul Nicholson accordingly suggested a magnetometer survey of Q48.4 which would have the aim of establishing whether the enclosure contained any more pottery kilns.

The first step was to locate the site grid used in 1987, and this was done from a series of small painted wooden dowels which had been left in the ground at measured intervals. The grid was next extended to cover the likely area of interest, defined by the axes D2–D11, and D2–S2. The intersections of the five-metre grid acted as reference points for a further subdivision into intervals of one metre. In 1987 there had been insufficient time to complete the contour survey of the whole surface of Q48.4; about one-third of the site at the eastern end had been left unsurveyed. At the same time that the grid was laid out anew for the magnetometer survey Dr. Hans Barnard continued the conventional contour survey and brought it to completion (Figure 6.1).

The pottery kilns and smaller ovens had been reburied at the end of the 1987 season, and it was thus possible to run the magnetometer over their locations (specifically the kiln in square G4 and one of the ovens in F5) as a way of calibrating the equipment. Accordingly several beat-frequency measurements were taken with the proton-magnetometer over each of them in order to obtain a base signature signal to help with the interpretation of field data. It was found that the kilns gave a beat frequency of 5–7/8 beats per cycle, which is a strong clear signal, and the ovens 2–3 beats per cycle. The entire surface of Q48.4 was then surveyed with the magnetometer by observing two full cycles of measurement at each one-metre interval along traverses set at one metre apart, controlled by the five-metre grid intersections. The data obtained were computerised and a map showing the beat values was plotted. Figure 6.1 shows a simplified version of the results.

It seems reasonable to infer that there are no further pottery kilns present on site Q48.4, for no readings of the intensity found over the known kiln in square G4 were encountered. However, many readings within the range given by the small oven in square F5 were picked up, and could be taken to signify the presence of as many ovens or hearths.

6.4 Comments by B.J. Kemp and P. Nicholson

The higher readings from the magnetometer, calibrated at the start of the survey over the site of a known kiln and a known oven, form a pattern for which some interpretation is possible using the contours and surface appearance of the site. From the absence of further very high readings, equivalent to those from above the known kiln, we may conclude that the group of kilns found in 1987 was the only one present. The kilns were part of what looks to have been a corner

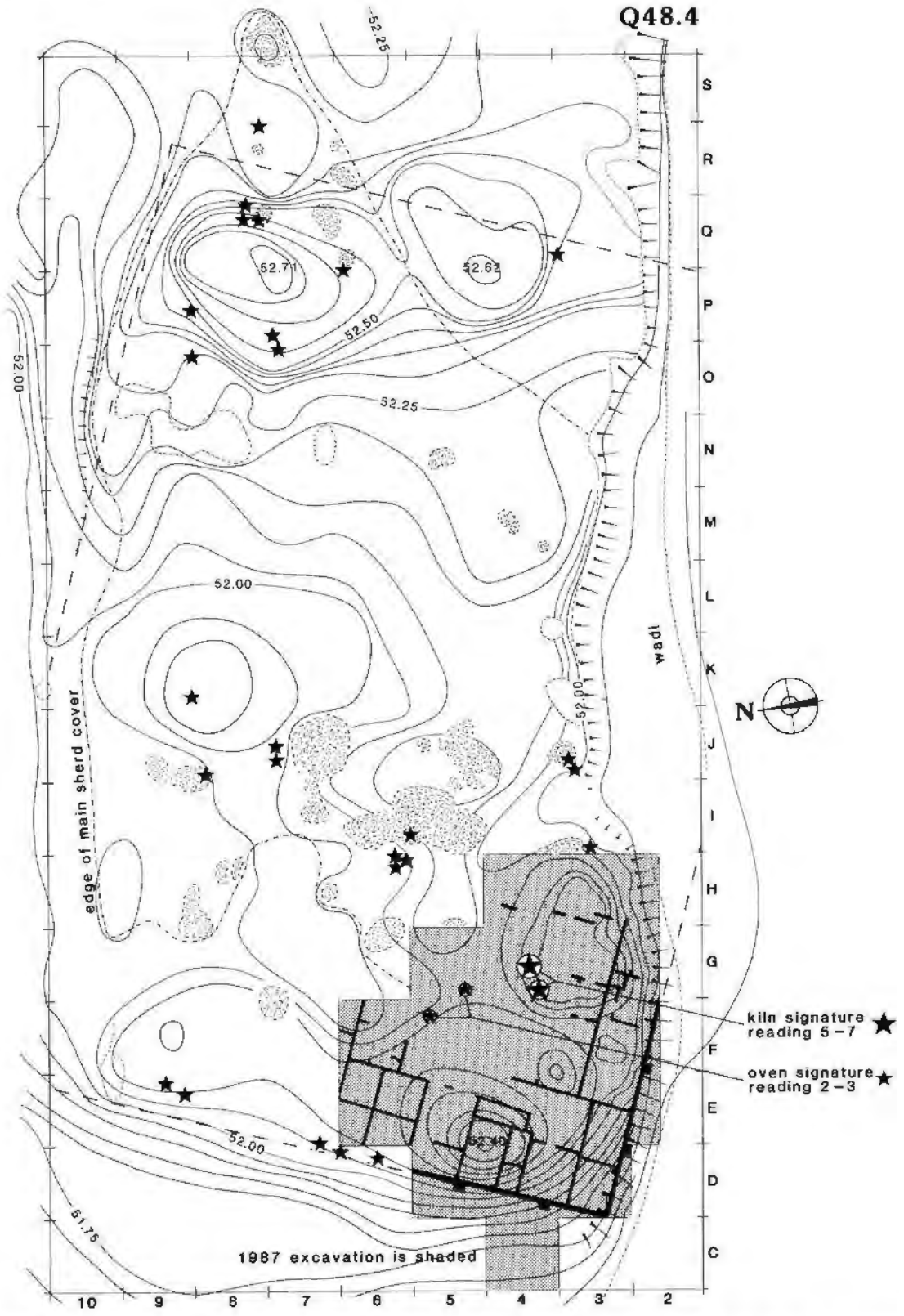

Figure 6.1. Contour map of site Q48.4 on which has been plotted the results of the proton-magnetometer survey.

subdivision of the enclosure marked off by small rooms on the north, south, and west, leaving the kilns (as well as some ovens) well out in the open space to the east. The evidence for pottery-making and for glazing was scattered around this area. Until more of the ground is excavated we cannot properly check the wider distribution of evidence of both kinds, but, for the present, it would seem that pottery-making was not the leading characteristic of the enclosure Q48.4, only of a part of it.

This is not the case for the moderately high readings which can be interpreted to signify the presence of ovens (or hearths), however. They are scattered in three widely spread groups and so help to characterize the site as a whole. They run along the inside of the west enclosure wall. Here, from what has already been excavated and from the character of the surface of the unexcavated ground, we can be fairly certain that they lie within small rooms built up against the enclosure wall. A second group forms a broad irregular spread from north to south across the middle of the site, somewhat to the west of the actual mid-line. Here the archaeological cover is quite thin though dense sherd layers are present, as shown by the material thrown up by modern illicit digging. If the higher readings do denote ovens then they must lie in open space, perhaps in little hollows in the ground as was the case with those excavated in squares F5 and G5. The third group occurs at the east end, where the surface is mounding up more, indicative of a group of small buildings, presumably built against the eastern enclosure wall. They cluster particularly in the north-east corner.

The range of uses to which small cylindrical clay ovens or those made from reused pottery storage jars were put is still not well defined. We know that they were commonly used for heating food (baking bread and probably simmering meat in vessels placed on top), and could have been used in manufacturing processes. It will be recalled that, in the course of the 1987 excavations at Q48.4, both a faience ring-bezel and the actual mould from which it was cast were found close to one another, implying proximity to the kiln in which the ring and its bezel were fired. The only heating-installation in the vicinity was one of the small circular ovens, about three metres away, which has to be seen as the likely kiln in question.

6.5 The search for Petrie's glass factory

Petrie's discovery of glass factories at Amarna during his 1891–2 season has remained a significant point of reference in the history of glass-making in Egypt despite the brevity of his description, which leaves even their location uncertain (Petrie 1894: 25–6). He begins by referring to his discovery of "the sites of three or four glass factories, and two large glazing works", evidently in a poor state of preservation, for "the actual work-rooms had almost vanished", although "the waste heaps were full of fragments which shewed the methods employed". Later, after describing the processes, he returns to field evidence: "Of the furnaces used for glass-making we have no example; but a furnace that was found near the great mould and glaze factory was apparently used for charcoal-burning, as a great quantity of charcoal was found in it, but no trace of pans, jars, or glass". Nowhere does he add further information on this "mould and glaze factory"; one is left to make for oneself the connection with a site marked on his tiny sketch map and labelled with the word "moulds" (Petrie 1894: Pl. XXXV). It should be noted that Howard Carter, working simultaneously but in his own area of the site, also seems to have uncovered a glazing factory. He later described this episode thus: "I was also fortunate enough to find the remains of obsolete glass-factories, which threw light upon the methods employed in that manufacture. In the same quarter I discovered a sculptor's workshop which contained interesting and fine examples of their experimental studies" (Reeves and Taylor 1992: 37; cf. James 1992: 35). He then continued with an account of work in "the town proper" and at the Great Aten Temple, implying that the factories lay separately. From the reference to a sculptor's workshop and from what we know generally of Carter's area of work, the most likely place is an industrial zone located a short distance in front of the Great Aten Temple, at or close to the position marked "ushabtis" on Petrie's map (Petrie 1894: Pl. XXXV, cf. pp. 17, 40; also *COA* III: 34, 80–1). The details of the find were presumably subsumed into Petrie's generalized comments.

If one transfers the position of the "moulds" site to a modern map it falls towards the boundary between squares N44 and O44, in an area which now lies beneath the modern cultivation or the ground inside the enclosure around the modern water tower. Pieces of slag

Figure 6.2. Building O45.1, south of the modern water tower, photographed in 1977 (cf. Kemp 1978: Pl. VI.1). The area of vitrified clay and of the magnetometer survey is where the two bundles of sugar-cane stalks are lying.

(vitrified clay is a better term) can still be found in the vicinity. During the course of the Amarna survey in 1977, however, an area where such pieces were scattered was noted just to the south of the water tower, on the edge of the building designated O45.1 (Figure 6.2; for location see also Figure 1.1). It lies well to the east of the place marked by Petrie. The most distinctive feature of this site is a low mound with a covering of fine white dust and small white fragments. In addition to pieces of vitrified clay, small pieces of fired clay, rich in straw and with a very rough green

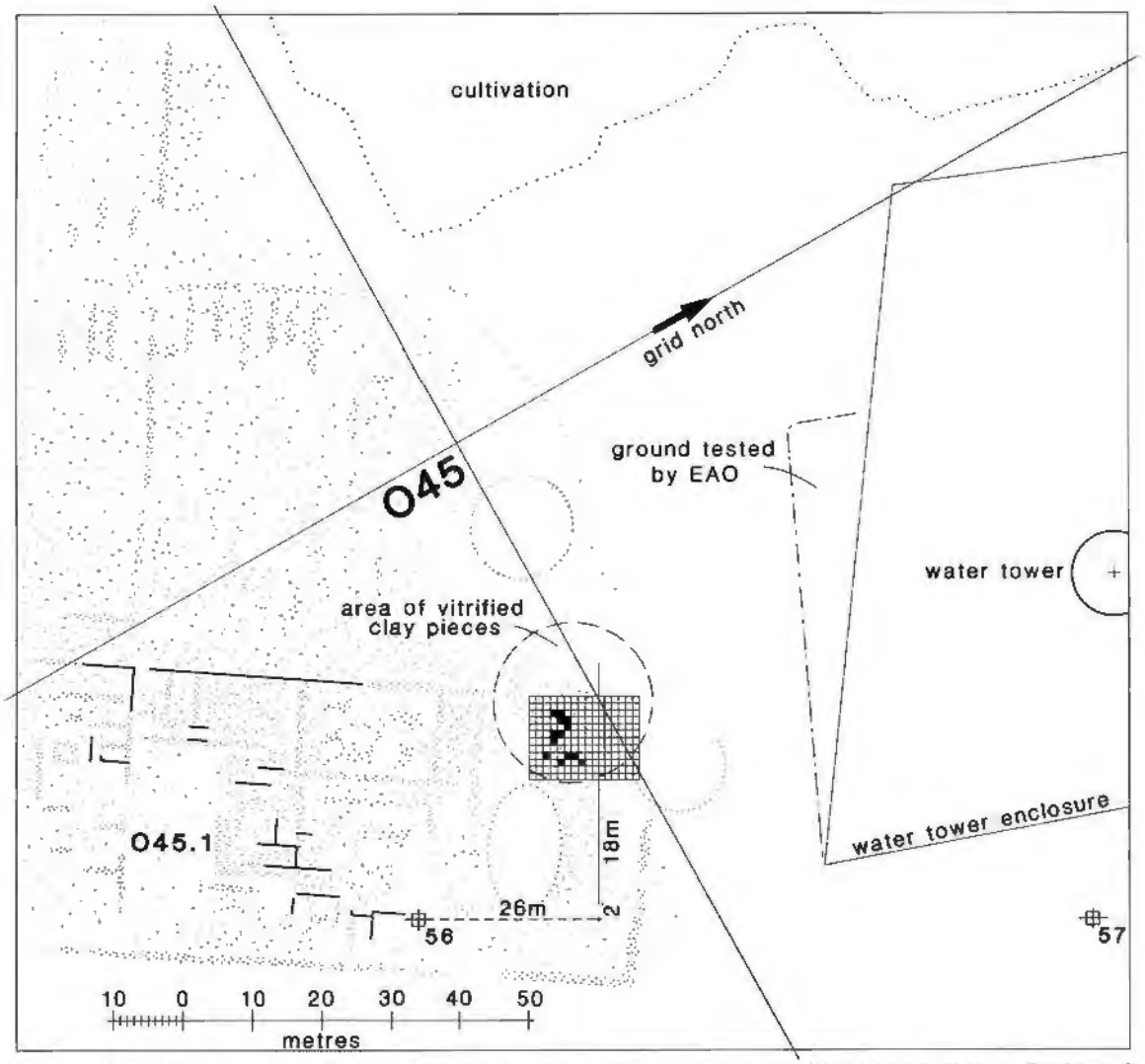

Figure 6.3. Map showing the location of the magnetometer survey grid within building O45.1 (cf. Figures 1.1a and 1.1b). Black squares are those with a beat-frequency of 10.

glaze coating on one or both sides, can be seen on the surface in the vicinity. One fragment of fritting-pan was also noted.

In March 1992 this area was made the object of a magnetometer survey (Figure 6.3). To begin with, a trial profile was run across. At a position some 15 m from the edge, extending to the 30 m mark and located within the fragment area, beat-frequency signals between 2 and 5 were observed, sufficient to justify intensifying the survey. Accordingly a 12 by 16 m grid was laid out to cover this area, and measurements were taken at each of the 1 m grid intersection points.

The recorded amplitudes are plotted as contours in Figure 6.4. Against a background of relatively low readings two adjacent islands of readings of up to 9 and 10 stand out clearly. Readings of this magnitude are likely to be of kilns, and so designate this site as worthy of further investigation in any programme to learn more about the glazing industry at Amarna.

In September 1993 Dr Nicholson returned and made a trial excavation in the ground where the highest readings had been obtained. The remains of substantial kilns were found to lie exactly where the magnetometer survey predicted they would. A further season of excavation, following a second magnetometer survey, was carried out in September 1994.

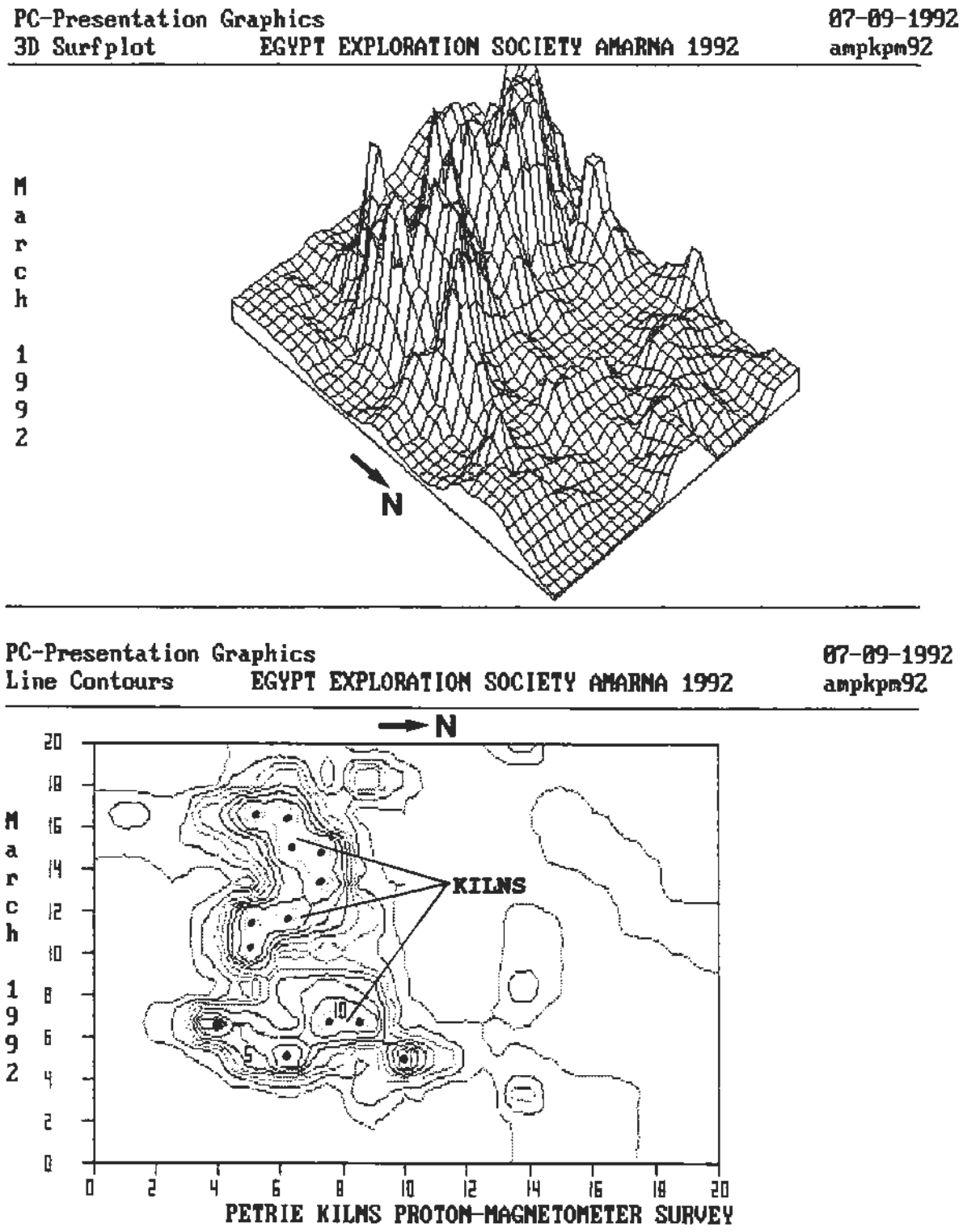

Figure 6.4. Magnetometer survey grid in building O45.1, and plots of the 1992 survey.

References

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