Electromagnetic prospecting at two polish sites (Slonowice and Milanowek) with the SH3 Slingram device

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Electromagnetic prospecting at two Polish sites (Słonowice and Milanówek) with the SH_3 Slingram device

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Results of the geophysical research at two sites in Poland are presented: at a Neolithic defended settlement at Słonowice and an iron-smelting site in Milanówek—Falęcin. The electromagnetic method was the basic method applied; different versions of SH_3 instrument were used. Results of the magnetic survey, with the use of a proton magnetometer are also presented. The efficiency of these methods when applied to the research of the sites of the types mentioned above, is discussed. In the introduction, the concept of the Slingram instruments is briefly presented.

KEY-WORDS: geophysical methods, electromagnetic prospecting, magnetic prospecting, magnetic susceptibility, Neolithic, Iron Age.

1. INTRODUCTION

Experimental surveys which are presented in this paper result from active cooperation following a first contact within exchange agreements between the Centre National de la Recherche Scientifique (CNRS) and the Polish Academy of Sciences (PAN). The cooperation was initiated by the visit of A. Hesse in Poland

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and, throughout the duration of the experiments, efficiently managed by J. Przeniosło. The visit clearly demonstrated the potential interest of testing on Polish sites the electromagnetic Slingram instrument which was not available in Poland at the time when the first results started to be published and known through the experiments carried on in Centre de Recherches Géophysiques (CRG) in Garchy (Tabbagh 1984).

The project became a reality during a second French visit (AH) which took place in April 1986. Tests were conducted on two sites of very distinct type but which were both already well known from two points of view:
1. through previous geophysical investigations by magnetic and electrical methods;
2. through preliminary archaeological excavations.

A new prototype of the SH_3 device, which will be described below, was available in Garchy at that time: it had been designed with an increased sensitivity in order to meet the requirements of archaeological sites with low magnetic susceptibility contrast like these which can be encountered in countries where loess soils prevail (Scollar 1965). In addition, this prototype included a much lighter sensor than the previous one in order to facilitate transportation and operation in the field.

Since the interest of such instruments had been demonstrated just a little while before, for rapid investigation of metallurgic sites with large mesh grids (Hesse, Bossuet and Choquier 1986), we made an attempt to use the SH_3 at Milanówek —Falęcin. Unfortunately, but predictably we should say, the increased sensitivity turned against us on such a site where extremely high values of magnetic susceptibility are to be encountered. The instrument was entirely disturbed in the area of location of metallurgic remains: the in phase signal not only was overloaded but the quadrature component of magnetic susceptibility added to the conductivity signal and made of no use the data obtained on both measuring channels. It was only during a third campaign (AH and MD, June 1988) that we could obtain the satisfactory results which are described hereafter: in the meantime, the instrument had been provided with an appropriate selector of sensitivity range.

This was a brief historical account of a scientific experience and of international cooperation which took place in the development of electromagnetic survey methods applied to archaeology. This particularly concerns the Slingram concept which we think is worth now being presented here.

2. THE SLINGRAM INSTRUMENTS

This type of electromagnetic device was first used during the 1930s by Swedish surveyors who fixed its actual denomination. It consists of two coils: one is used

as a source which produces an alternating low frequency magnetic field (*i.e.*, between 200 Hz and 20 kHz) while the second, at a distance L, can measure different components of the magnetic field. The primary field transmitted by the source coil (transmitter) being variable with time, induced currents are produced in the ground which then generate a secondary field which is measured through the second coil (receiver). According to the relative orientation of coils, the receiver can measure either the secondary field or, more generally, the superposition of both primary and secondary fields. In this latter case, the primary field's influence must be compensated electronically.

Generally speaking, the response of the instrument is complex: the secondary field is not in phase with the primary field but its modulus increases with the conductivity of the ground which is the main intervening parameter. However it has been demonstrated (Tite and Mullins 1969; Tabbagh 1974) that an appropriate choice of frequency f and of the distance L between the coils makes it possible to satisfy the condition of "low induction number" where the term $\sigma\omega\mu L^2$ is very small compared to 1: σ being the conductivity, μ — the magnetic permeability of the ground and $\omega = 2\pi f$ — the angular frequency. Then the secondary field due to the electrical conductivity of the ground is in quadrature of phase with the primary field and directly proportional to this conductivity. The signal as well is weak enough to prevent the in phase secondary field produced by the magnetic susceptiblity of the ground from being masked. The presence of this field is a direct consequence of the magnetisation induced by the primary field at the frequency f: the main part of it is generally in phase but it may sometimes present a weak quadrature component originating from the magnetic viscosity of the ground.

It results from these considerations that such an instrument is able to provide not only an apparent electrical conductivity (which will be converted in usual resistivity in our actual results) but also an apparent magnetic susceptibility leading to a surveying method entirely different from that of one resulting from the measurement of the magnetic field of the Earth. It is particularly possible to measure at each point of the surface an absolute value of the magnetic susceptibility when only spatial variations can be observed with the magnetic method. Experimentally this method was revealed as very useful for archaeological surveying (Tabbagh 1984): it allows fast surveys by sampling the readings on large mesh grids (Hesse and Tabbagh 1981); shallow and flat lenticular features become detectable and the sensitivity to many sources of disturbance of the magnetic field is considerably reduced. All these abilities have been extensively tested on several different archaeological sites since the time of our surveys in Poland (Scollar *et al.* 1990).

The last stage of development of the SH_3 prototype in use at Słonowice and Milanówek had the following characteristics (Tab. 1):

Table I

frequency	f=8.04 KHz
distance between coils	L=1.5 m
configuration of the coils	PAR (parallel at 35 degrees from vertical)
height above ground	h=0.15 m

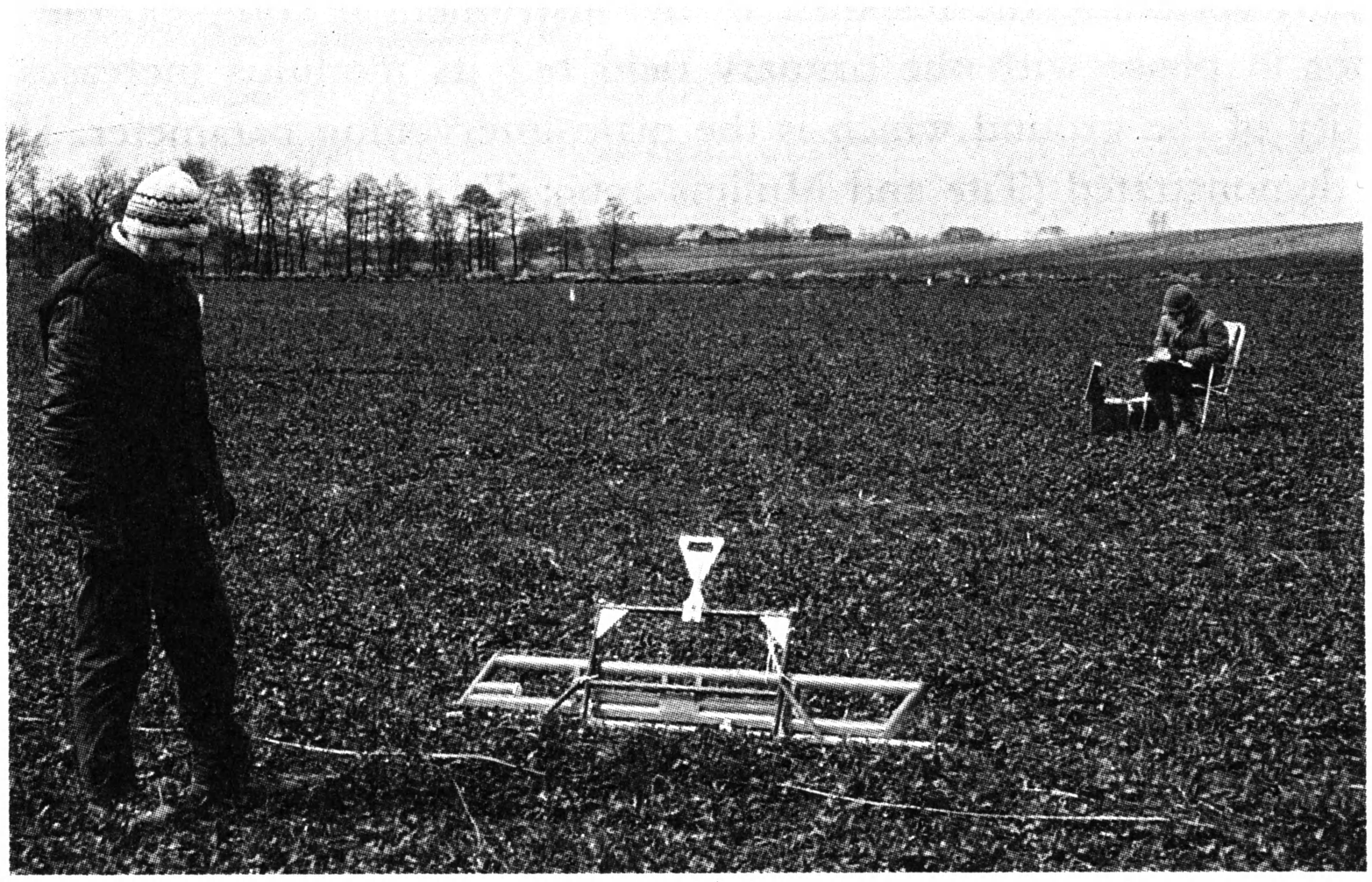

Fig. 1. The SH_3 device in operation at the Słonowice site.

3. THE SURVEY OF SŁONOWICE, SITE "G"

3.1. THE SITE

Słonowice lies on a loess upland in the western region of Little Poland, on a wide ridge sloping towards the Małoszówka river. The site has been shown to be of importance according to the excavations which have taken place there since 1979 (Tunia 1990). The geophysical location of some of the archaeological features had been shown before by magnetic and resistivity surveys (Herbich and Misiewicz 1990; Herbich 1993).

The remains mainly consist of back-filled ditches and pits excavated in the loess and of traces of a palisade. The extent of the defence complex is approximately 200 by 200 m in an open field levelled due to ploughing.

The site was first occupied during the Neolithic (the Funnel Beaker Culture) and ditches come only from this period. The site was reoccupied in the Early Bronze Age by people of the Trzciniec Culture. There is no trace of any defence system coming from this later period; pits are the only remains found. However, the pits are deep enough to reach the Neolithic levels.

The northern part of the site is horizontal; the southern end lies on a slope. This causes different sequences of layers:

In the northern part, under "modern" humus (topsoil) there is a layer formed during occupation of the site in the Early Bronze Age. Below lies a buried soil, being the topsoil during the Neolithic. Under the buried soil there is the loess (virgin soil). The pits, of different depths, start below modern humus, cut the buried soil and penetrate the loess. The ditches can be found only under the buried soil (Fig. 2).

In the southern part of the site, the modern humus and Trzciniec Culture layer have been eroded away. Here the buried soil became the top soil in contemporary use; the ditches, of different depths, are visible just under the modern humus. A significant number of Trzciniec Culture pits were also found: only their lowest parts were preserved, they sometimes reached greater depths than the ditches (Fig. 2).

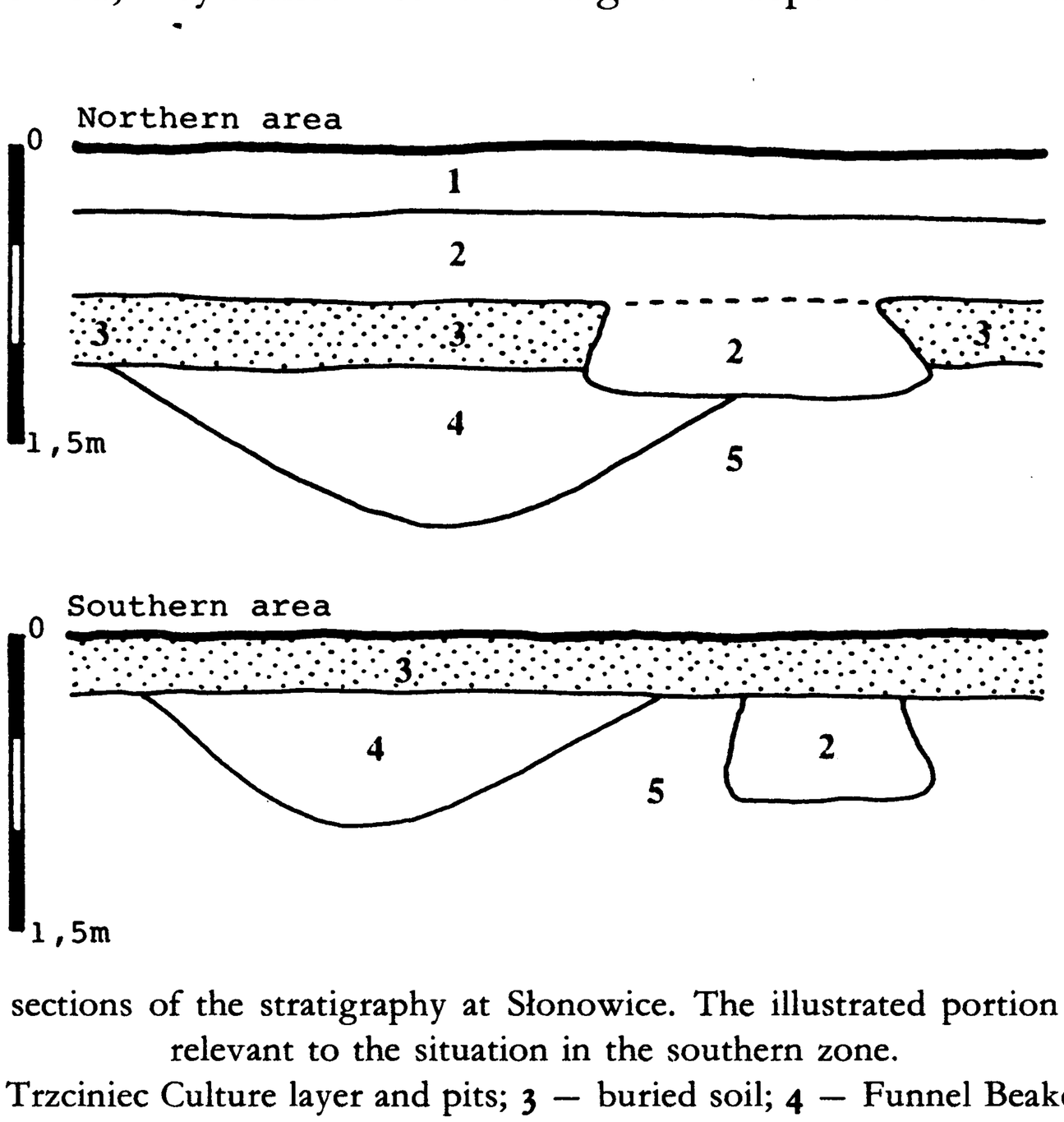

Fig. 2. Schematic sections of the stratigraphy at Słonowice. The illustrated portion is almost entirely relevant to the situation in the southern zone.
1 – topsoil; 2 – Trzciniec Culture layer and pits; 3 – buried soil; 4 – Funnel Beaker Culture ditches; 5 – loess.

3.2. RESULTS OF THE GEOPHYSICAL SURVEY

Our surveys were limited to the southern, sloping part of the site. Its simpler stratigraphical situation and the relatively shallow depth of the features actually cut into the loess were expected to allow an easier interpretation of the anomalies (Fig. 3). Such a case of back-filled ditches with very shallow profiles is generally not in favour of the magnetic method: 6 to 7 nT of anomaly only were obtained during our first tests (TH and KM) in the field; we could now expect better results since the features searched-for were thought to meet the abilities of the SH_3.

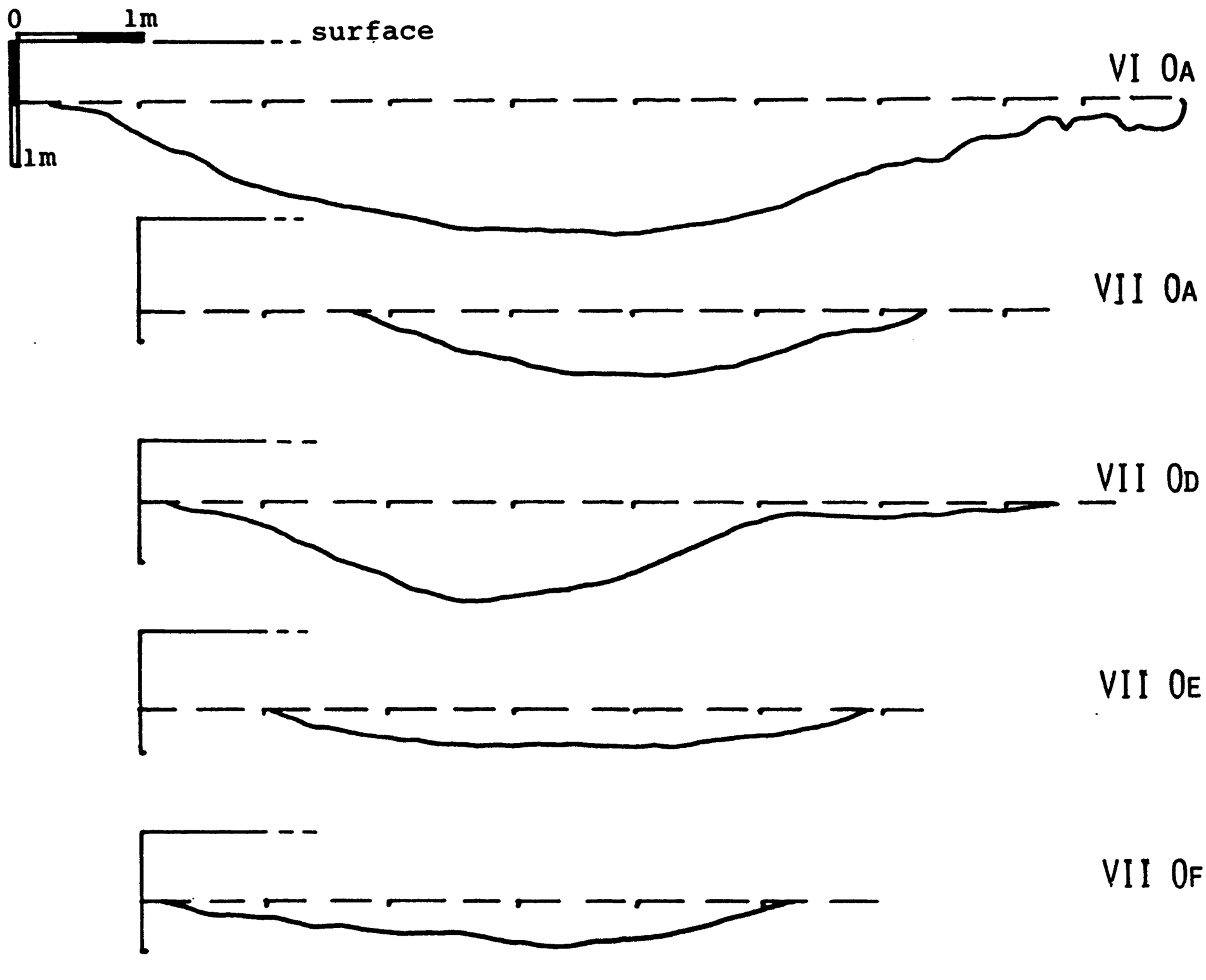

Fig. 3. Słonowice. Different aspects of ditch sections in the southern zone.

Some samples of soil were collected during the archaeological excavations and their magnetic susceptibility was measured in Garchy (ELSEC magnetic susceptibility meter, type 780):

Table II

I	humus, depth 0.25 m	98.0 10^{-5} USI
II	humus, depth 0..25 m	106.0 10^{-5} USI
III	loess, virgin soil, 0.70 m	29.1 10^{-5} USI
IV	loess, virgin soil, 1.00 m	25.5 10^{-5} USI
V	filling of ditch O_A/ VII, depth 0.95 — 1.00 m	108.0 10^{-5} USI

An appropriate contrast between the filling of a ditch and the virgin soil can be observed. Unfortunately, the susceptibility of the topsoil (samples I and II) almost reaches the values obtained in the ditch (sample V). This could be due to its being a complex mixture of different humus materials including some more magnetic layers, back-fills or different artefacts. This results in possible disturbances in the pattern of geophysical readings in the field.

The survey was conducted in two parts: zone A and zone B (Fig. 4), respectively located at the east and at the west side of trench VI in order to try and recognize the continuation of the two ditches O_A and O_D which could not be identified towards the east in trench X (at that time trenches XII, XIII, XIV had not been yet excavated). The technical conditions of the survey were not ideal and the instrument suffered from relatively large drifts which were not satisfactorily compensated by our regular checks at a reference station. However a first presentation of the work was made (Herbich and Misiewicz 1990) in order to set up only the efficiency of different computer systems and programs in displaying geophysical data obtained on archaeological sites.

Different data treatments (Hesse *et al.* 1992) were necessary here in order to achieve archaeologically readable maps: destriping for zone A only, median filtering on a small 3x3 readings window for both zones. This results in several physical defects of the results. We must mainly pay attention to the large difference between the average values of susceptibility for both maps, and in comparison with the samples: they look satisfactory in zone B but abnormaly high in zone A and this cannot be explained by their position on the slope which is relatively similar. For all these reasons we shall only consider the spatial relative variation of susceptibility on each map separately.

On the zone B map, the susceptibility values are already higher than expected from the measurements on the samples. However they fit their order of magnitude and the anomalies look rather clear: average values on the north edge of the map could correspond to the ditch found in trenches VII/O_A, II and the northern part of VI as stated by the excavator (Tunia 1990). A very strong anomaly appears in the center of the map and could mark the continuation of ditch VII/O_D (detecting

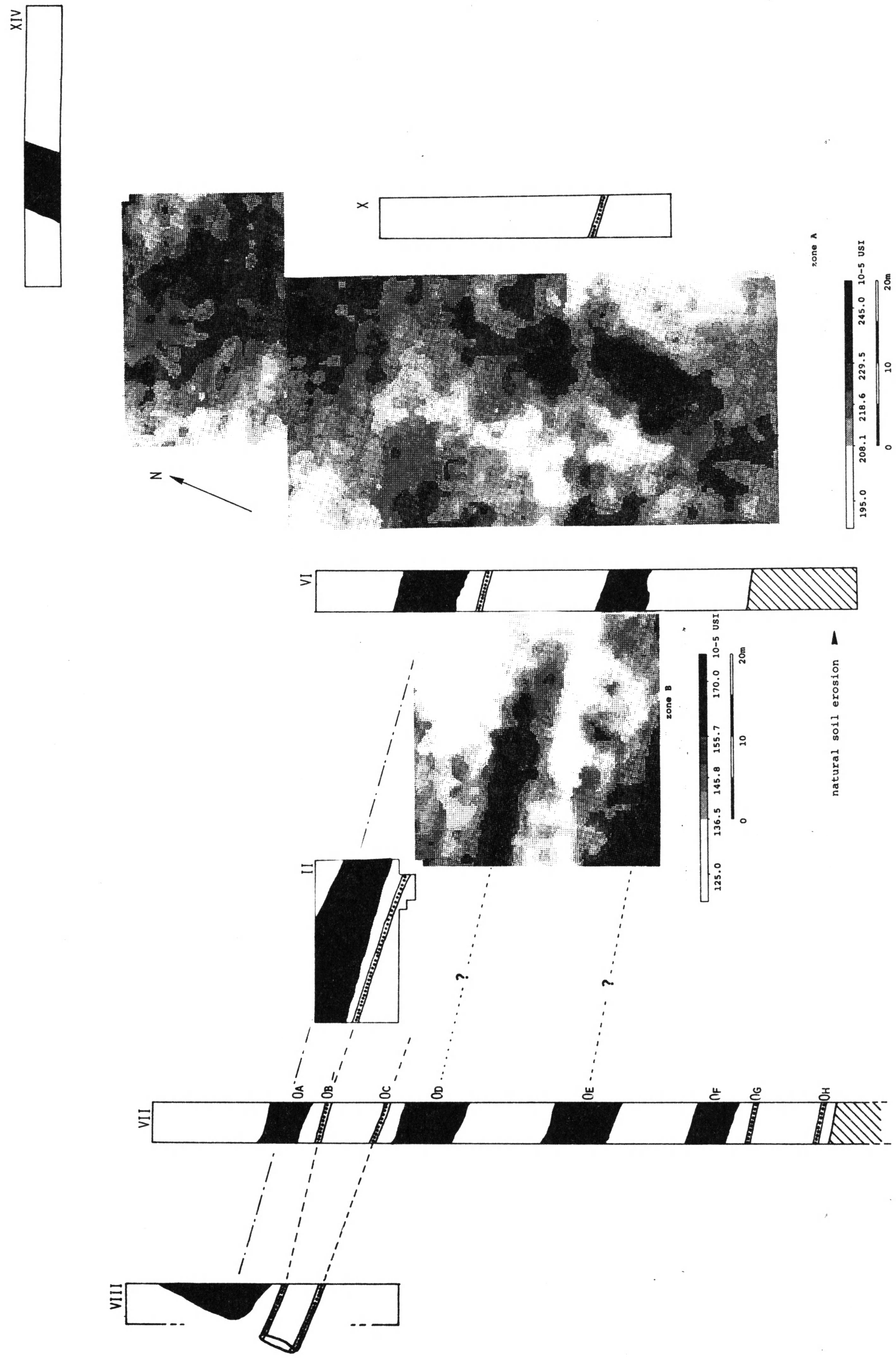

Fig. 4. Słonowice. General map of the SH_3 apparent magnetic susceptibility survey and of the excavated archaeological features.

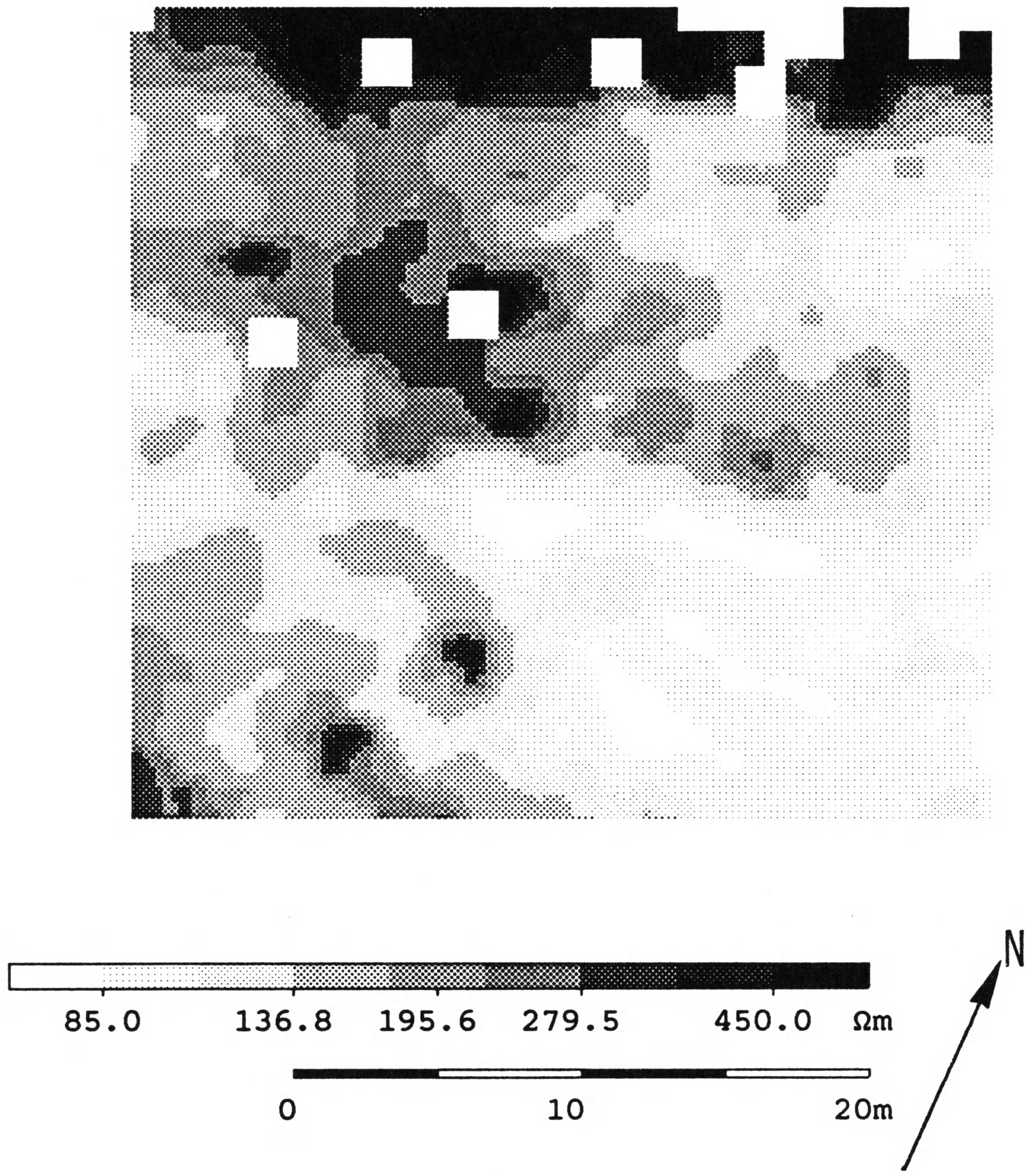

Fig. 5. Słonowice. Detail of the SH3 resistivity survey. Zone B.

the traces of the palisade was entirely unexpected in as much as O_C in VI and X and even O_B in later XII and XIII trenches could not be recognized by excavation). The main problem comes from the fading of this anomaly towards the east and from its orientation which does not fit the slightly discordant direction suggested by the archaeological data towards the southern ditch of trench VI. Otherwise this ditch corresponds to some high values of susceptibility in the south-east of the map. No clear relation can be imagined with the strong south-west anomaly which might be considered as a rectilinear continuation of ditch VII/O_E.

On the zone A map also, no significant continuation of trench VI ditches can be observed: two limited anomalies correspond to their termination as confirmed *later by trenches XII and XIII (Fig. 5). Then, according to maps A and B, the southern feature excavated in trench VI could better be considered as an east-west* elongated pit rather than a ditch.

Anyway, we should not forget the possible disturbing effects of erosion in the complex actual aspect and magnetic signature of the features. This is particularly true when considering the map in zone A: as has been explained before, it results from a strong computer cleaning of the data, but this should not have affected (nor created) the long north-south directions which clearly appear in the pattern of the low (white) and high (black) values of susceptibility readings. Nothing exactly fits the ditch encountered in trench XIV but the orientation is coherent. This square angle left turn of the ditches was expected of course, accordingly with the absence of such features in trench X.

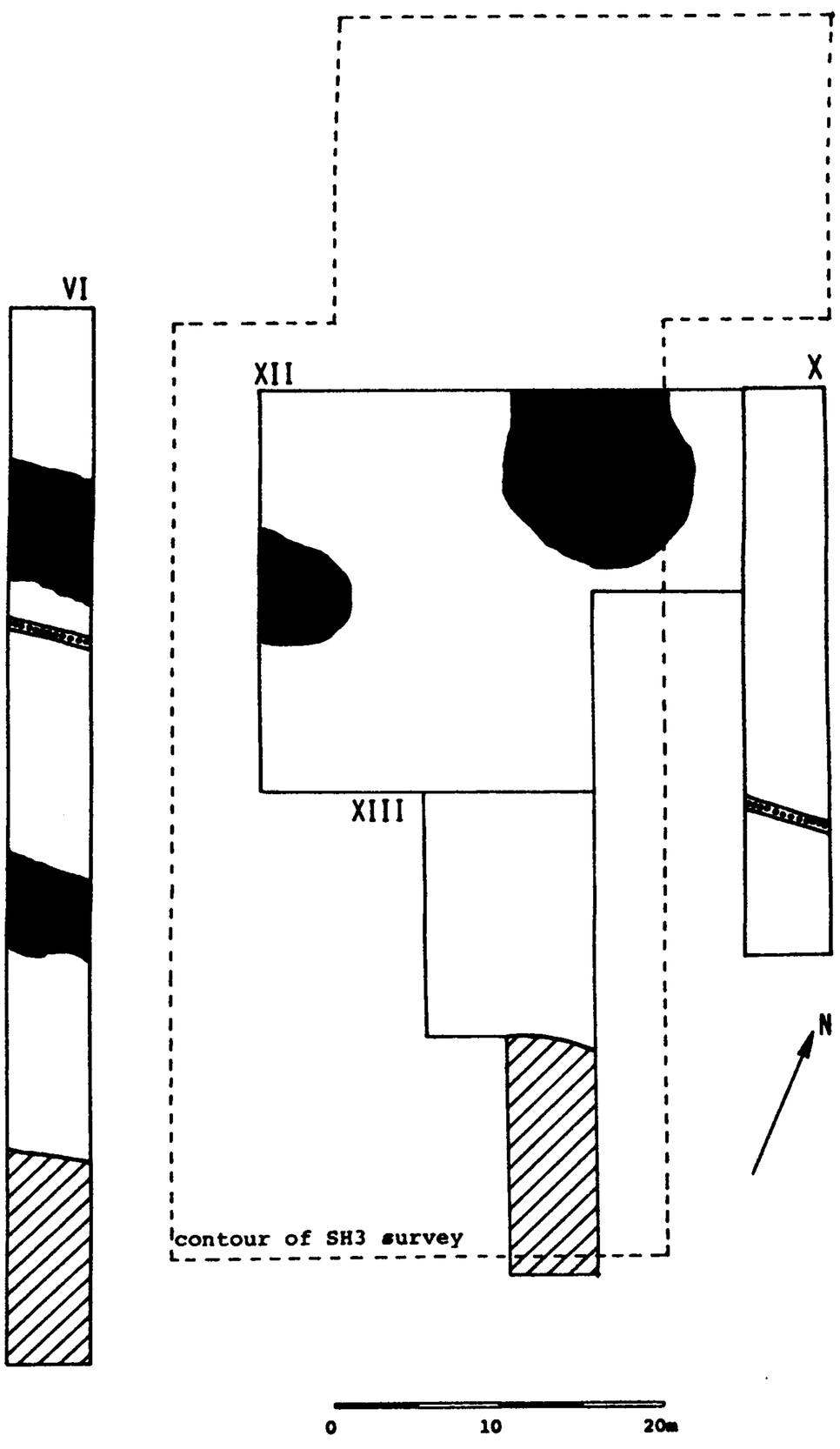

Fig. 6. Słonowice. Map of excavated features in zone A of the SH_3 survey.

The most surprising result comes from two highly reliable anomalies in the southern part of the map: they appear on several contiguous profiles, they are strong enough and perfectly orientated in the north-south direction. The problem consists of the absence of any archaeological confirmation in trench XIII (Fig. 6). Among the possible explanations for this discordance we imagine the anomaly as a possible phantom of a magnetic back-fill which could have survived erosion in the topsoil layers and have been removed at the beginning of the excavations.

A few words must be added about the quadrature of phase maps. As expected on loess, the resistivity level and contrast are very low: between 39 and 54 ohm-m on map A, with a few faint north-south and east-west anomalies not worth being published. Map B is a little clearer (Fig. 6) but in the range 85 to 450 ohm-m. Such high values are unrealistic and correspond to disturbed profiles in which some values of resistivity even

could not be calculated (square white dots on the map). If we discard data from this area, the results are coherent with the susceptibility results. The weak but unusual maximum anomaly over the central ditch confirms our previous experiments on this site (TH and KM) with an ordinary resistivity-meter which gave a clear 15 percent anomaly.

3.3. CONCLUSION

In any case, it seems certain that the conditions of erosion and redeposition of the different cultural layers and back-fills have strongly affected this site from an archaeological as well as from a geophysical point of view. It is clear that long features (ditches) have at one time existed here. This survey as well as the results of the excavation (determining the orientation of a ditch without sharp edges in a narrow trench is evidently difficult) show that actual reality is probably different or at least slightly more complex. Then some of the dotted lines proposed by the excavator (Tunia 1990) should probably be treated for the moment as hypothetical.

4. THE SURVEY AT MILANÓWEK—FALĘCIN

4.1. THE SITE

The site of Milanówek—Falęcin is situated thirty kilometers west of Warsaw and belongs to a complex of Mazovian iron smelting sites, dating to the Period of Roman Influences. Since the discovery of the first iron-smelting site in this region in 1967, more than seventy sites have been found (the discovery of the Mazovian center followed research for many years of the smelting sites complex in the Holy Cross [Świętokrzyskie] Mountains, central-southern Poland [Bielenin 1974] — this work also included geophysical fieldwork: the magnetic method was applied). The first geophysical survey in Mazovian centre was done in 1973 (Jarzyna *et al.* 1975); excavations were started in 1974. The magnetic survey at Milanówek—Falęcin allowed to limit the extent of the site: the excavation showed a coincidence of the limits of the iron smelting zone with the results of magnetic survey (Woyda 1977).

4.2. THE GEOPHYSICAL SURVEY

The site of Milanówek was surveyed mainly with methods using the Earth's magnetic field because of very favourable conditions: a highly magnetically uniform medium (loess), the shallow depth of archaeological remains (typically 0.25

to 0.5 m), the existence of fired structures (furnaces) which results in a high thermo-remanent magnetisation, and magnetic artefacts (slags blocks, iron blooms, *etc.*). As a consequence, a proton magnetometer was very useful for delimiting the extent of the sites. This approach is developed in section 4.2.1.

In section 4.2.2 we explain the geophysical method we used for that site in 1988. Following our experience on similar sites in France (Dabas, Hesse and Jolivet 1989; Dabas 1989), we had noticed that it was very difficult, and often impossible in the case of complex sites, to delimit internal structures within the extent of a site. Except the particular case of a site with a single furnace and on which slags are concentrated, it is impossible by means of a magnetic survey to find the exact location of a furnace. As a consequence, we used the SH_3 after some modifications for those particular sites (high magnetic susceptibility), as was explained above.

4.2.1. RESULTS OF THE MAGNETIC SURVEY

The magnetic survey (Fig. 7) clearly shows a high amplitude anomaly (100 nT) and orientated nearly in the north-south direction (angle of 6° to the west from point 927 to the south to point 923 to the north). The external limit of this anomaly is very linear in the west direction for more than 300 metres with a sharp gradient (up to 50 nT/m). The east border is more sinuous and is situated approximately 20 m from the first one. The anomalous zone extends over 1800 m^2.

The total anomaly amplitude is 100 nT. In Figure 7 the surface above 60 nT is hachured. The reference basis (0 nT) is chosen arbitrarily. In the area we have surveyed (Figs 9 and 10), the maxima are clearly visible specially at point 1070/925 or 1078/925. We will be able to compare the magnetic anomalies to the ones found with the SH_3 only within a zone situated to the north (1060 to 1090) and 900 to 930, together with a zone situated from 1030 to 1060 and from 900 to 917, because the area to the south (918 to 930) was excavated between the two surveys.

In Figure 7, to the west of the high gradient zone, we have represented with dots a zone, the amplitude of which is negative (referred to the base station used) and is low (less than 10 nT). This zone is narrower than the high amplitude zone (5 to 10 m).

It is interesting to superpose the magnetic map with the results of the excavation undertaken after the surveys (represented as dots on Figure 10; in order to be readable, the totality of the findings have only been represented on this Figure). To the west of line "923", the density of slag blocks is low (0.7 per square metre). The magnetic anomaly is also low (10 nT). To the east of line "923", the

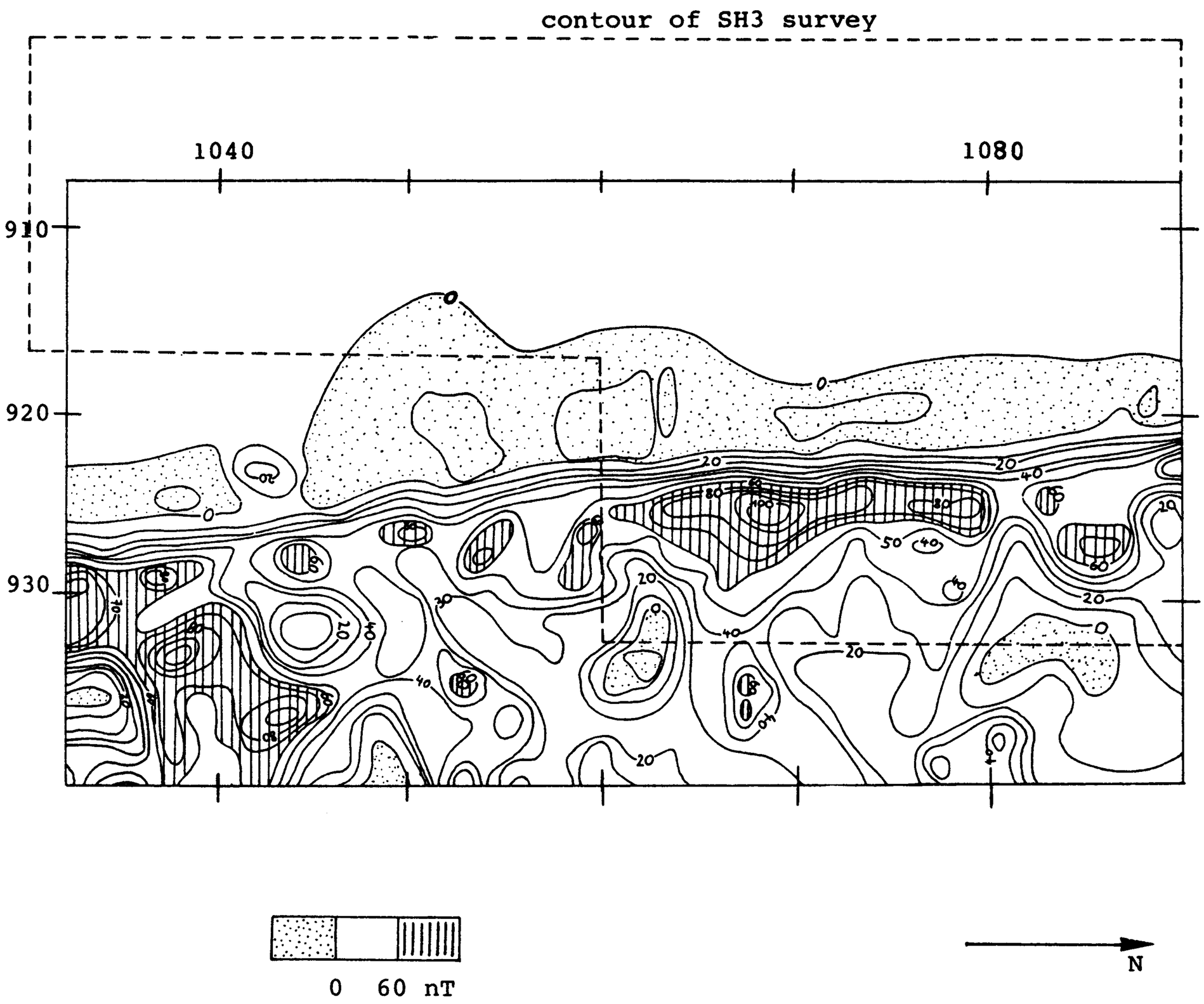

Fig. 7. Milanówek—Falęcin. Map of total magnetic field (arbitrary reference).

density of slag blocks becomes higher: more than 3.5 per square metre. The limit observed in the excavation is coincident with this limit of slag density. The geophysical limit corresponding to this change in the density of slags is consequently extrapolable outside the actual extension of the excavated area. We should point out that the increase in the slag density is of the order of 9 (0.4 to 3.5) which is of the same order for the increase of the magnetic anomaly (—10 to 80 nT). We think that one can extrapolate with some restrictions this result to correlate the slag surfacial density (Dsl) to the corresponding magnetic anomaly (A). The restrictions come from the fact that we have no sound physical explanation why the ratio of Dsl to A should remain constant (*i.e.*, why a linear relationship between A and Dsl exists). We lack intermediate data to test this model with values of slag density in between the two extrema quoted. This computation also

takes for granted that the slags have approximately the same volume and are situated at the same depth. With these restrictions in mind, we can compute that a unit slag density (1 slag per square metre) corresponds to an anomaly of 23 nT. Consequently, it is posssible to transform the magnetic map into a map of apparent density of slags. But this map would be very smooth and could not picture local variation of the density of slags as will be shown in section 4.2.2.1.

4.2.2. RESULTS OF THE ELECTROMAGNETIC SURVEY

As was explained above, we have used the SH_3 (Parchas and Tabbagh 1978) which is able to measure simultaneously the electrical conductivity (proportional to the quadrature component of the transmitted field) and the magnetic susceptibility proportionnal to the in-phase component.

Preliminary field trials have shown that we have to lower the sensitivity of the device by a factor of ten in order to enhance its dynamic range which permits the survey of metallurgical sites where high magnetic contrast could occur.

In Figure 8, we have illustrated this problem for a selected profile (profile 1080 from 900 to 930 indicated in Figure 9). The broken line with squares represents the in-phase measurement of SH_3 before its modification. Starting at 918 metres, no more data can be collected, due to saturation. After the decrease of the sensitivity of SH_3, the whole curve can be drawn until point 930. The in-phase component (magnetic susceptibility) has been shown with squares and the quadrature component (electrical resistivity) with triangles. Figure 8 shows successively: a slow rising of both components from 900 to 921 m, a sharp rise in less than one metre and finally a high amplitude zone with large fluctuations. The positive correlation between conductivity and susceptibility is evident. Furnaces or slags should normally have electrical resistivities higher than those of the loess subsoil. Our apparatus observed the opposite. This is a consequence of two factors:

1. The separation between the in-phase and the quadrature component is not electronically perfect: a certain amount of the in-phase component is mixed with the quadrature component (a few percent). This instrumental effect is of course more visible when very high susceptibilities are encountered (for example between 921 and 930).
2. Theoretically, the quadrature component is solely a function of electrical conductivity when another phenomena, known as magnetic trainage (Leborgne 1960) can be neglected. Physically, the existence of this trainage

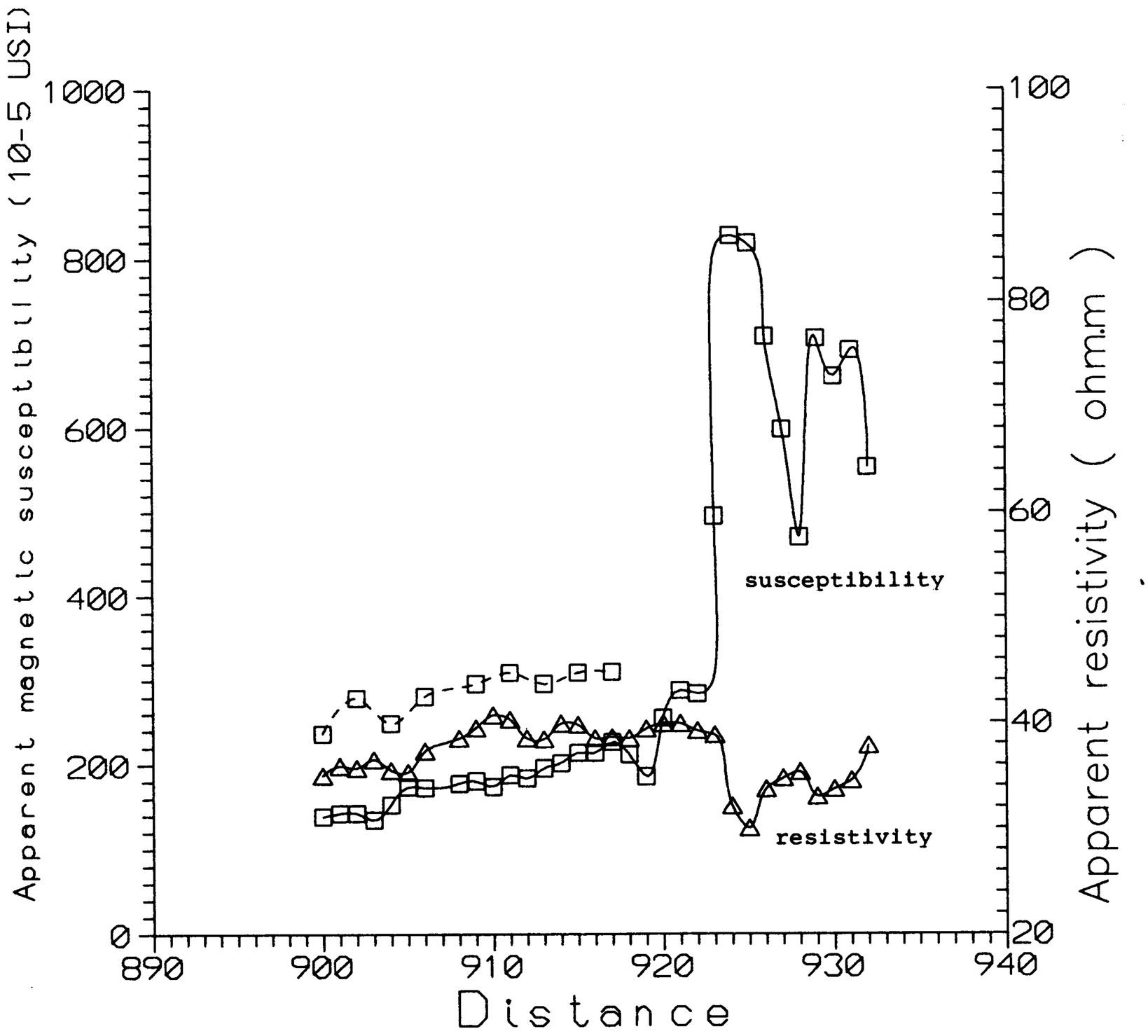

Fig. 8. Milanówek—Falęcin. Measurements obtained on profile 1080 with two different sensitivity ranges; broken line — high sensitivity; continuous line — low sensitivity.

means that the magnetic susceptibility is a complex number. If we do not neglect it, this signal superposes to the one due to the electrical conductivity. In most instance, trainage can be neglected being only a few percent of the magnetic susceptibility, percentages of the same order as the one quoted in (1). But if magnetic susceptibility becomes very high as in the case of the site of Milanówek, the signal originating from trainage becomes non-negligeable compared to the conductivity signal and as a consequence, lowers the apparent electrical resistivity over the highly magnetic areas.

It is not possible for the moment to make the distinction between these two factors. We shall avoid interpreting quantitatively the results obtained in the high magnetic area (to the east of line "914").

Keeping this point in mind, the modified SH_3 has a sufficient wide dynamic range for surveying the site at Milanówek.

4.2.2.1. *Apparent magnetic susceptibility*

In Figure 9, apparent magnetic susceptibility (further quoted as K) together with the slags are depicted (dots). This map has a better spatial resolution (less smooth, smaller wavelengths) than the magnetic map of Figure 7.

Three areas can be defined:

1) a magnetic quiet area (less than 200 10^{-5} USI),

2) an intermediate area between 200 and 300 10^{-5} USI, and

3) a high magnetic area (from 300 to more than 800 10^{-5} USI).

When considering the distribution of slags in the excavated area, one can notice that slags appear only for values of *K of more than 200 10^{-5} USI. We* can consider that the surrounding area (loess) has a susceptibility ranging from 100 to 200 10^{-5} USI.

The area between 200 and 300 10^{-5} USI corresponds to a density of slags of 0.4 per square metre. It is interesting to highlight the coincidence between the point "b" in Figure 9 with two slag blocks or in "a" or "c" with single large slag blocks. We should compare this with Figure 7, where on the magnetic map no detail could be seen. The cartography of K brings us more details and specially within the third zone in which magnetic susceptibility is higher than 300 10^{-5} USI.

If a superposition of the magnetic and electromagnetic map is attempted, we can notice the good correlation between zones of magnetic amplitude higher than 50 nT and zones the susceptibility of which is higher than 600 10^{-5} USI. It is certain that in such a zone where the density of slags is higher than 3 per square metre, the resulting anomalies overlap in a single anomaly. But it is posssible to make the distinction between numerous regions limited in space (1 to 5 sq. metre) and associated with a higher density of slags and furnaces. These zones (tested by excavation), can reach more than 800 10^{-5} USI and have a slag density of more than 3 blocks per metre.

It is also interesting to note that the very linear limit on the magnetic map is now more irregular on the susceptibility map specially to the north where it bends towards the east and decreases in amplitude.

All the anomalies in the third zone are aligned N—S except anomaly "d" which has a clear L shape. Does this shape originate in two orthogonal directions of kilns or in a building which can be detected by its high magnetic filling?

4.2.2.2. *Apparent electrical resistivity*

The resistivity measurements (Fig. 10), simultaneously acquired with the susceptibility, supply very different information. The variation in resistivity is not wide-spread: 13 ohm-m. But, despite this low number, several features are clearly visible. The map can be separated into two zones: to the south of line AB, the apparent electrical resistivities are higher than 40 ohm-m, and to the north of AB, the electrical resistivities lie between 32 and 40 ohm-m. These two zones are diagonally cut by a linear feature C–D. This is also the case for the low resistivity zone: the east-west linear feature E–F.

The reason for the higher resistivities in the south is not evident. We could, by invoking the existence of a fault, explain this anomaly by a greater depth of loess in the north compared to the south. We could also, but it seems less probable, invoke the drying of the land as a consequence of the excavation. In that case, we could not clearly explain the direction of AB. Anyway, we think that this partition has no human origin. But the linear anomalies C–D and E–F are anthropogenic. These two structures are conductive. The E–F anomaly is less visible than C–D because E–F lies in the most conductive area and consequently the contrast is less. These two structures could be an infilled ditch or an ancient lane. The E–F structure seems to stop at the magnetic zone, but C–D crosses this area. Magnetically, E–F can be seen as a lower magnetic structure compared to its surrounding (see for example at the NW angle of the excavation). We had noticed that the loess get a lower susceptibility than the other materials. These two facts corroborate the hypothesis of a loess-filled ditch.

4.3. CONCLUSION

The use of electromagnetic survey for the comprehension of the Milanówek site has enabled us to detect a single mass of big slag blocks. It has also been possible with this method and with a calibration through an excavated area to predict the density of slag blocks. Comparison with the magnetic survey gives a map more precise for the localization of very magnetic zones. The use of both electrical conductivity and magnetic susceptibility bring very different results which revise the interpretation and comprehension of the anomalies.

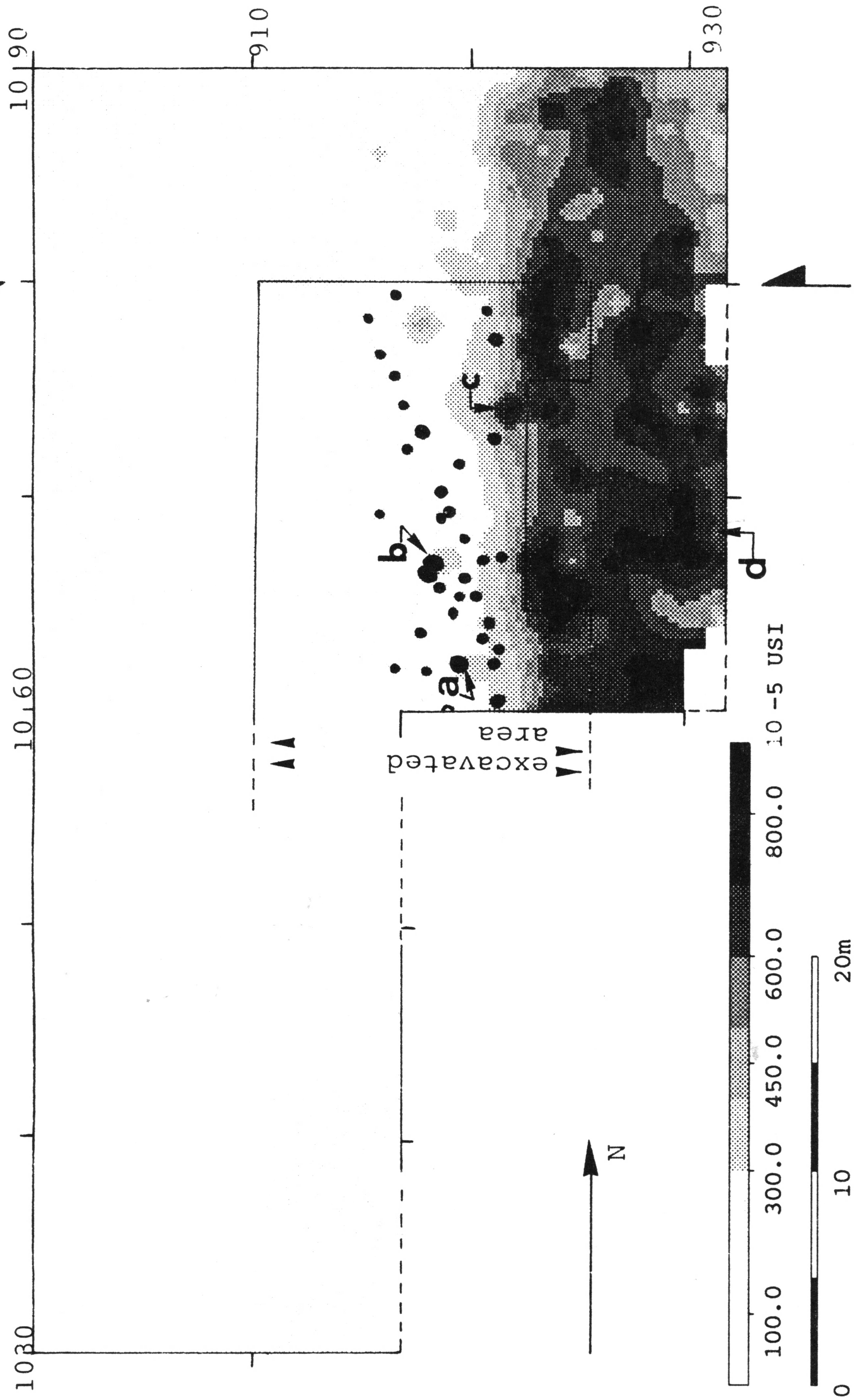

Fig. 9. Milanówek—Falęcin. The SH_3 apparent magnetic susceptibility map with results of subsequent excavations.

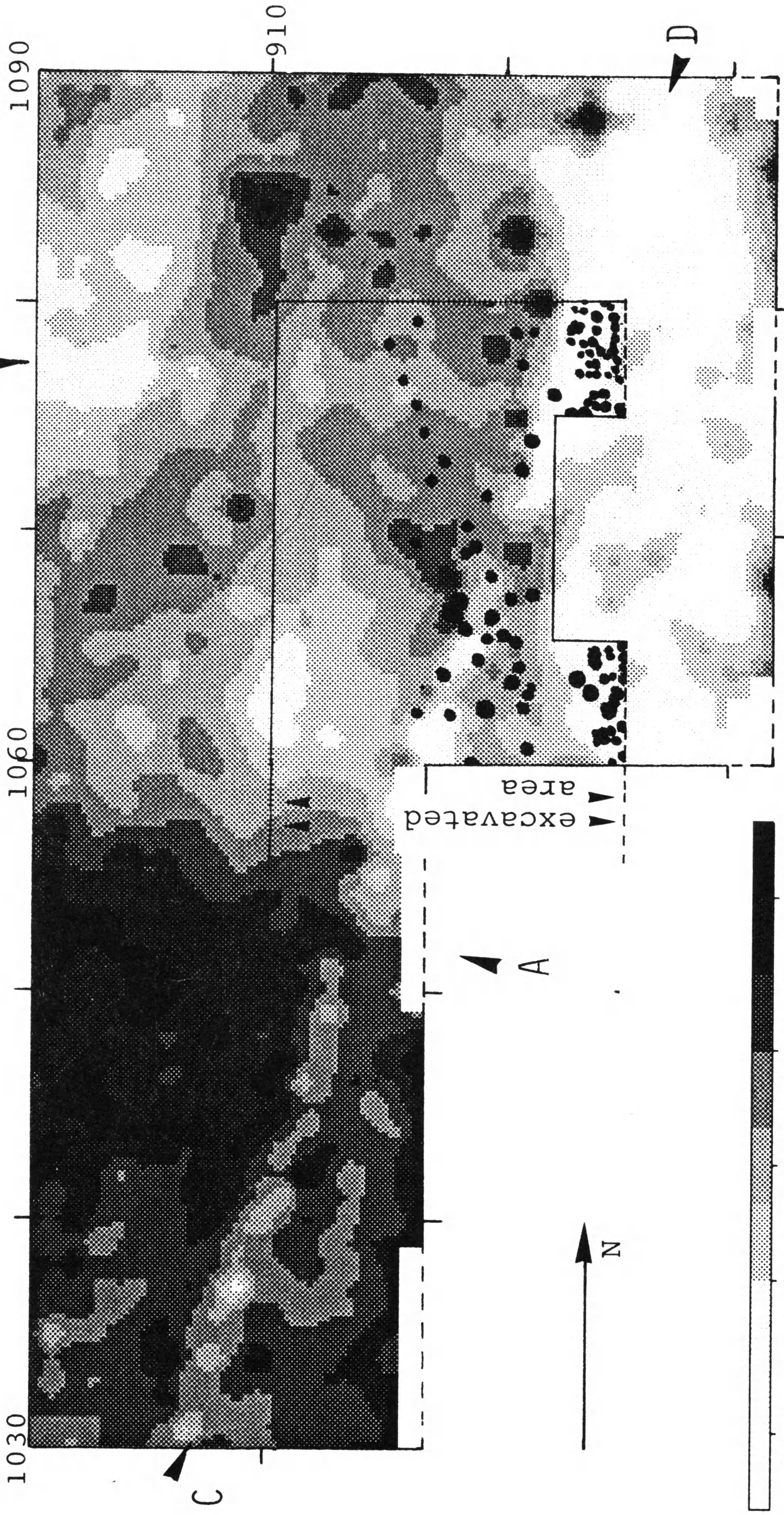

Fig. 10. Milanówek—Falęcin. The SH_3 apparent electrical resistivity map with results of subsequent excavations.

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