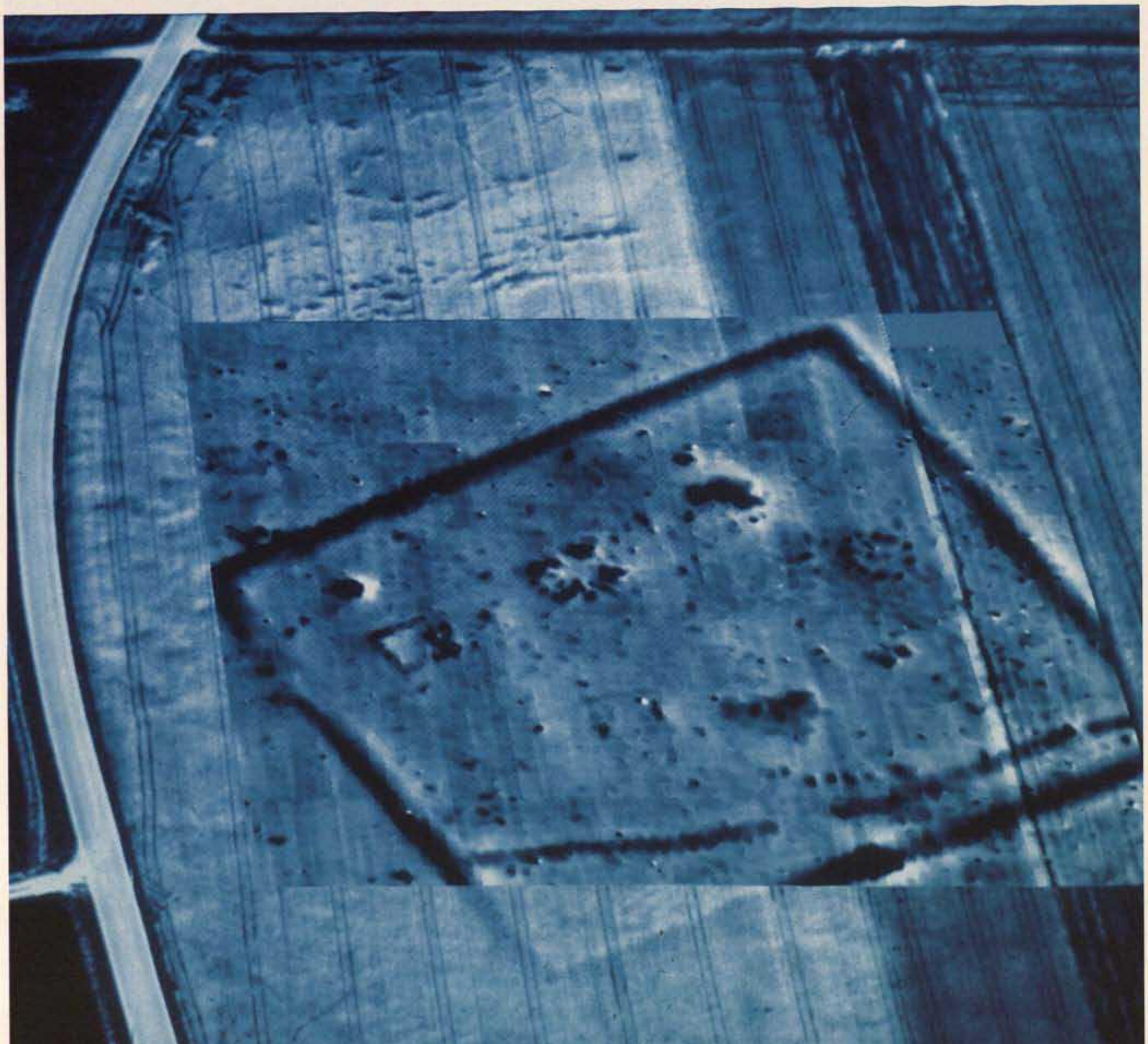


J. W. E. Fassbinder, W. E. Irlinger

Combining Magnetometry and Archaeological Interpretation: A Square Enclosure in Bavaria

Here we present the results obtained by high-resolution caesium magnetometry on a square enclosure of the Celtic period (300–100 B. C.) in Southern Bavaria.

Integration of the geophysical data with archaeological knowledge delivers the crucial information for a detailed plan, for classification and for a description of the archaeological finding.

Introduction

Magnetometry has been used for achaeological prospection for more then 40 years (Belshé 1957; Aitken 1958). However, most results obtained by proton and fluxgate magnetometers reveal only magnetic anomalies greater than 0.1 Nanotesla. Progress in this prospection technique was made by the introduction of digital image processing of the data (Scollar & Lander 1972). The modification of the cesium magnetometer for archaeological prospection (Becker 1982) and the availability of an instrument with a magnetic sensitivity of ± 0.01 Nanotesla (Becker 1995) was a major step in the development (Aveling 1997). We measured the apparent magnetic anomalies of the total earth magnetic field 0.3 meter above the ground in a sampling point density of 0.5 x 0.25 meter. Digital image processing and its representation as a 256 grayscale picture enables a detailed view beneath the soil.

Soil magnetism

Enrichment of ferrimagnetic minerals in topsoil (Le Borgne 1955; Tite & Mullins 1971; Mullins 1977) is frequently observed. The enhancement is due to the formation of maghemite or magnetite by different processes (Mullins 1977; Lovley et al. 1987; Maher & Taylor 1989; Fassbinder et al. 1990). Any intervention in soil produces a magnetic anomaly which can be measured above ground. The contrast in magnetic susceptibilty and remanent magnetization between the structure and the adjacent undisturbed soil enables the detection of single posts and palisades, stone structures, ditches, pits, kilns and fireplaces. Depending on the type of soil, the enrichment of magnetic minerals in a trace of a post or palisade may enhance the magnetic susceptibility by 2–50 times and increase the magnetic remanence by 5–20 times (Fassbinder & Stanjek 1993). Man made fire or natural fire may produce a much higher increase.

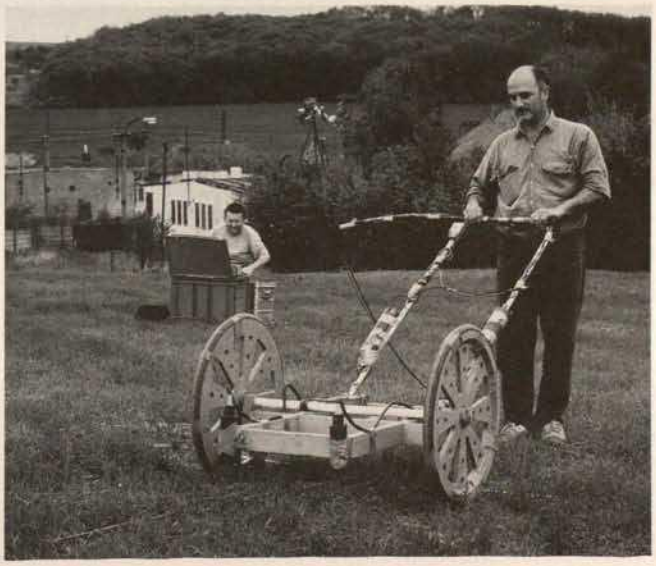
The cesium magnetometer enables the detection of anomalies caused by each single post in the adjacent loess soil. But the detectability of an archaeological anomaly is a rather complicated function of the sensitivity of the instrument, sampling density, and a function of soil noise which surrounds it (Graham & Scollar 1976). Therefore the magnetic prospection was done on bare soil before planting. The ploughing and the harrowing of topsoil is equal to a mechanical demagnetization and provides ideal conditions for magnetometry.

◁ Fig. 1. Egweil from the air. The magnetic map of the site has been cut in to the oblique aerial photograph of the site

Magnetometry

The principle of the magnetic prospection technique with the cesium magnetometer is based on the measurement of the total magnetic field. For magnetometry we used a high resolution total field cesium magnetometer (Scintrex CS2) with a sensitivity of ± 0.01 Nanotesla (the intensity of the total earth magnetic field in Europe ranges from about 45,000 to 49,000 Nanotesla, the diurnual variations are in the range of 10–30 Nanotesla, and is furthermore depending upon the sun activity). For the field survey we chose the so-called "duo-sensor" configuration in order to have a maximum speed of prospection combined with a high possible sensivity (Becker 1997). A wheel-devised equipment provides a constant distance between magnetometer and topsoil (Fig. 2). In this configuration two sensors are moved in a zigzag-mode 0.3 meter above ground. The sampling speed of the magnetometer (10 readings a second) allows us to measure a 20 meter profile of the grid (20 x 20 meter) in less than 15 seconds. A bandpass filter in the hardware of the magnetometer processor is used to cancel the natural micro-pulsations of the magnetic field. The slower changes in the daily variation of the geomag-

Fig. 2. Magnetic prospection with a Scintrex CS2 caesium magnetometer with the duo sensor configuration



netic field is reduced to the mean value of the 20 meter sampling profile and alternatively to the mean value of all data of a 20 meter grid. This compares to a difference between the measurement of both magnetometer probes and the calculated value of the earths magnetic field. This difference, the apparent magnetic anomaly, is then influenced by the archaeological structure respectivly by the magnetic properties of the soil and the geology.

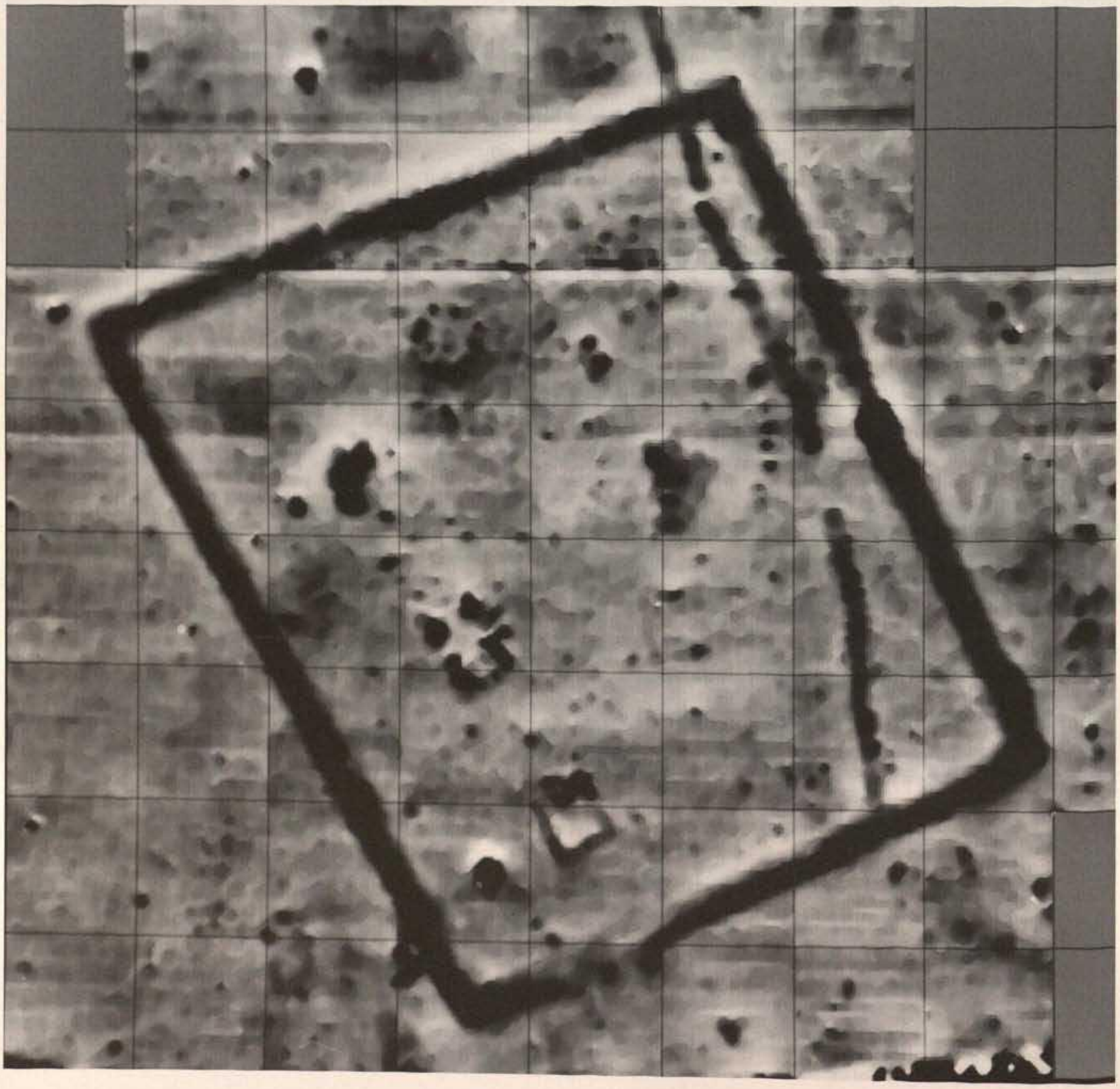
Ninety seven percent of the magnetometer data in a 20 m grid varies in the range of -4.5 to +4.5 Nanotesla from the mean value of the earths magnetic field. All of the stronger anomalies can be ascribed to burned structures or to pieces of iron rubbish. In situ burning is easily distinguishable from iron pieces by the direction of their erratic dipole directions. For image processing the magnetometer readings were converted into gray values ranging from 0 = white to 255 = black. Therefore each gray value compares to a magnetometer value of 0.035 Nanotesla.

Archaeological background

Iron age enclosures are widespread earthworks and occur mostly in Southern Germany (Bavaria, Baden-Württemberg), France, England and the Czech Republic (Bittel et al. 1990; Decker & Scollar 1962). These earthworks are characterized by earthen walls with uninterrupted steep side ditches and a single narrow entry mostly at the east side (Schwarz 1959; Murray 1995).

The square enclosure of Egweil, located at Southern Bavaria, was discovered in 1982 by the aerial archaeologist Otto Braasch. However the photographs show only the ditches as crop marks. The typical form with the uninterupted ditch and the size of the enclosure as it was shown by the aerial picture allows a rough interpretation as a Celtic site (Braasch 1990; Irlinger 1994, 1996a).

Fig. 3. Egweil. Magnetic plan of the iron age Viereckschanze at Egweil. Magnetogram in the digital image processing technique, CS-2 caesium magnetometer (Scintrex) and read out unit (Picodas), sensitivity (0.01 Nanotestla, duo sensor configuration, dynamics – 4.5 to +4.5 Nanotesla in 256 grayscales, sampling rate 0.5 x 0.25 meter, grid 20 x 20 meter



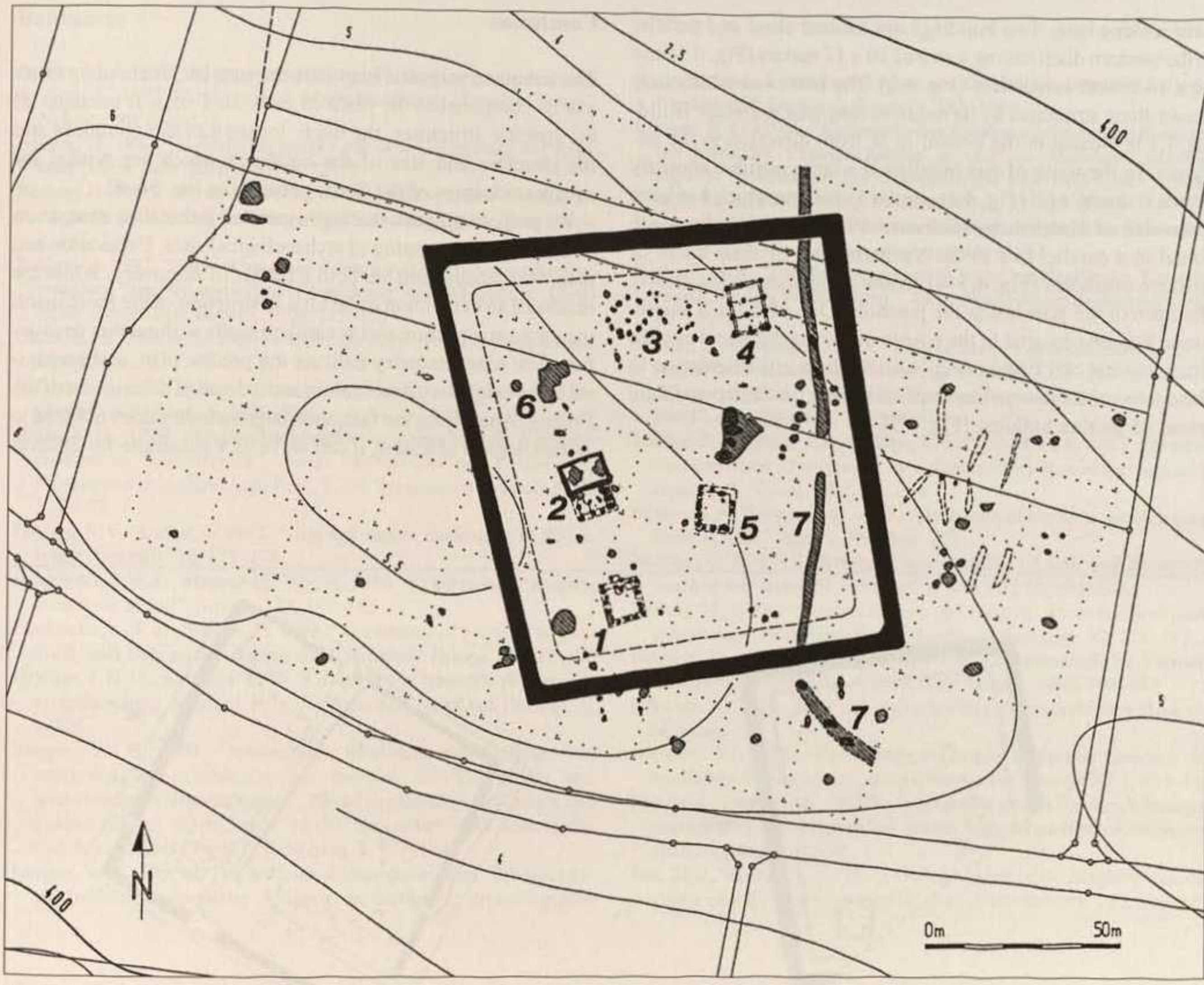


Fig. 4. Egweil. Graphic plan on the basis of the digital image processing of the magnetic picture. Drawn as an overlay from the computer and plotted together with the geographical card

Most of them are rarely visible from the air except when occurring for some days as a crop mark, soil mark or for some hours as snow mark. Although in Bavaria there are 162 enclosures visible above ground by their upstanding earthwalls and ditches, some additional 120 were discovered by aerial archaeology during the last 20 years (Irlinger 1996b).

Information from the inner structure of the monument are known for only 24 enclosures in Southern Germany. The function of these enclosures can actually only be discussed controversially. The lack of information on square enclosures yields to contradictory explanations, such as the use of these monuments as animal enclosures or for religious purpose.

Combining archaeological knowledge with geophysical interpretation of the data

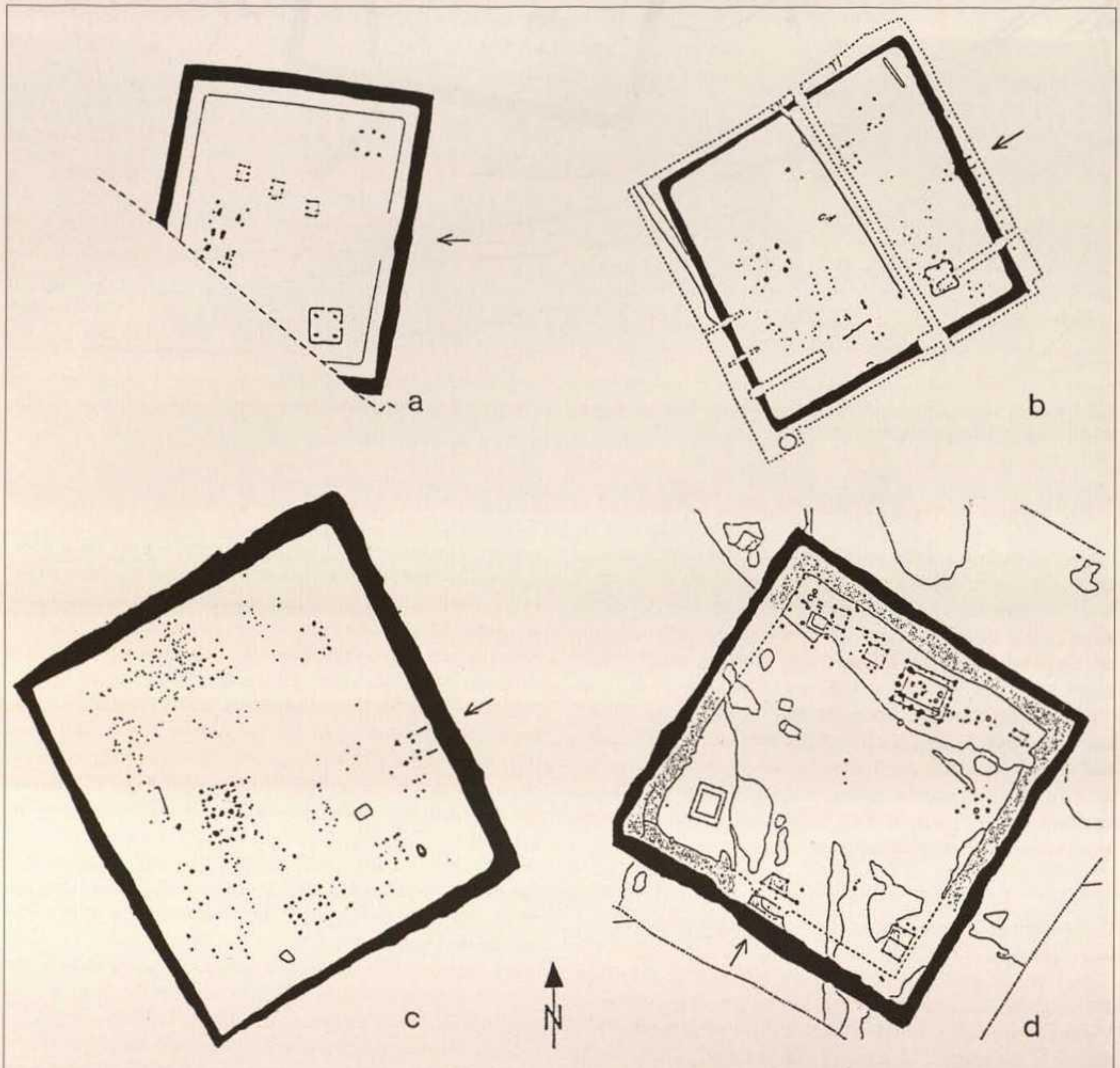
The magnetic measurement reveals all the typical elements of a Viereckschanze (Fig. 3). The inner side of the ditch measures 90 meters in the south, 112 meters in the west, 97 meters in the north and 105 meters in the east respectivly. Characteristic is the difference in the length of the sides as well as in the angles of the corners. The two sides of the south-eastern corner make a rectangle. The others show deviations from the rectangular with 96° in the south-west, 83° in the noth-west and 85° in the north-eastern angle. This finding is one of the peculiarities of Celtic Viereckschanzen. The totally destroyed rampart inside the ditch is indicated by slightly lighter grayshade with a broadness of 6 to 7 meters. Therefore the enclosed area covers estimatly 0.8 hectares, and compares to an average size for a Viereckschanze (Fig. 4), (Bittel et al. 1990; Schwarz 1959). The entry to the enclosure is vague, but is indicated by single posts of a former bridge inside and outside the ditch nearly in the middle of the east ditch. This bridge is broken into the ditch and makes it slightly smaller. Further indication for the entry is the configuration of the buildings inside. This can be compared to excavated examples (e. g. Fig. 5b–d). The location of the entry to the eastern (and to the north-east, see Fig. 5a–c) has been found on many square enclosures. Nearby and parallel to the eastern part of the enclosure, a ditch runs from the north to the south, but belongs to a Neolithic earthwork (Kaufmann 1997) (see Fig. 4,7).

Inside the enclosure we detected clearly the structures of five buildings. These buildings are visible by traces of posts and small ditches (see Fig. 4,1–5). One of them (Fig. 4, 2) seems to have a stone base. Two buildings are located close and parallel to the western ditch having a size of 10 x 12 meters (Fig. 4,1) and 10 x 14 meters respectivly (Fig. 4,2). The latter one additionaly shows stone structures by its negative magnetic anomaly. Building 4,3 is located in the central or in front direction to the entrance. To the north of this building is a large positive anomaly which is due to a pit (Fig. 4,6) similar to the one which has been excavated at Holzhausen (Schwarz 1975). Two buildings are found in a parallel line to the northern ditch by their traces of massive postholes (Fig. 4,3–4). Some anomalies shows clearly the trace of the post inside the posthole. One of them, a single-phase building located in the corner of the northern and eastern ditch, consist of 12 posts (Fig. 4,4). Without any orientation to the ditches and a few meters south-east from the center we found traces of another building (Fig. 4,5).

Conclusion

The complete magnetic map of the square enclosure in its result can be compared to the plans of excavated sites. It contains all the specific structures, the ditch, location of the entrances and the structure and size of the buildings which are typical for square enclosures of the Celtic period (see Fig. 5a–d).

We propose magnetometer prospection rather than excavation as a tool for the mapping of archaeological sites. Excavation and magnetic prospection are both a matter of discovery. While the results of an excavation is the total destruction of the monument, magnetic prospection yields similar results without this destruction. The magnetometry delivers the precise plan, archaeological knowledge the classification and a detailed description of the finding. Apart from the fact, that magnetometry does not lead to archaeological artefacts, it can serve as a substitute for excavation.



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◁ Fig. 5. Examples of four excavated square enclosures at Southern Germany, comparable in their extensions and structures to the result of magnetometry. The arrow marks the entry.
a) from Bopfingen-Flochberg (Krause & Wieland 1993) at Baden-Württemberg (Germany).
b) from Ehingen (Bittel at al. 1990) at Baden-Württemberg (Germany);
c) from Riedlingen (Klein 1996) Baden-Württemberg (Germany);
d) from Pocking-Hartkirchen (Schaich 1997) Bavaria (Germany)