Gradiometer and Ground Penetrating Radar Survey
Akkerman Fortress, Bilhorod-Dnistrovsky, Ukraine
Summer 2008

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Abstract

Following the successful deployment of electrical resistance survey in 2007 the geophysical surveys team continued in 2008 with two further prospection techniques, gradiometry and ground penetrating radar (GPR). The application of the two geophysical survey methodologies, in addition to the resistivity of 2007, would, it was hoped, provide a more holistic approach to the investigation of the sub-surface remains at Akkerman. Gradiometry was used over a total area of 0.8ha within both the Garrison Yard and the Civil Yards. A number of ephemeral rectilinear anomalies could be observed along the base of the northwest section of the Civil Yard and the buildings, revealed during the 2007 resistivity survey, were also evident. Two circular anomalies in the north-western sector of the Civil Yard, probably representing well cappings, were also detected. Only further intrusive physical investigation would reveal whether these belong to antiquity or are reminders of a much more recent past. Several areas of Ground Penetrating Radar (GPR) survey were also undertaken both within the Civil Yard and outside the walls within the immediate environs of the fortress. Survey within the southwest corner of the Civil Yard confirmed the features revealed on the gradiometry and clearly demonstrated the artificial changes in level within the fortress. The survey of the area outside the fortress to the north of the Storeyed Tower revealed a palimpsest of features many of which are probably associated with the modern sewage and gas systems. A circular anomaly on the GPR to the south of the Wooden Tower, may hint at Greek activity beyond the area visible today. The application of these survey methods has gone some way towards a truly holistic cross-disciplinary application of research methodology but further retrogressive investigation of the cartographic evidence and its integration with an accurate combined GPS and Total Station survey of the fortress would enable greater value to be derived from the collected data.

Introduction

Survey location

Surveys were undertaken in Civil Yard using gradiometry and GPR, the Garrison Yard using gradiometry only and some areas outside the fortress on the Glacis were undertaken using GPR only (Figure 1-3). The choice of survey area was determined by a desire to compare the results of the two methodologies with those from the resistance survey of 2007 and logistical expediency. Due to the sensitivity of the gradiometer to the magnetic signature from the GPR any given survey area could only be occupied by one method at any given time. The division between gradiometry in the Garrison Yard and GPR outside the fortress was therefore one of practical necessity.

Survey conditions

Weather conditions were ideal for gradiometer and GPR surveys with the low level of moisture within the soil being particularly advantageous for radar, enabling good penetration of the radar signal through the ground. Conditions underfoot were variable and some of the survey areas, particularly in the Civil Yard, were difficult to negotiate. Survey within the Garrison Yard was hampered by the movement of people, particularly during the weekend tourist activities within the fort, but careful timing of survey location kept this to a minimum.

Survey methods

Gradiometry relies on the enhancement of magnetism within buried objects, from exposure either to high temperatures from burning or a firing process, as in the case of tile or pottery production. Changes in magnetism can additionally be caused by anthropogenic action, as in the case of a pit or a ditch containing decomposing organic material. GPR imparts an electro-magnetic pulse into the ground and measures the speed of the reflection of this signal from buried objects or the interfaces between archaeological horizons. Gradiometry is a passive technique and GPR an active one. Both survey techniques require the establishment of a site survey grid. To this end, for the gradiometer survey, parallel base lines at 20 metre intervals were laid out using tapes and sub-divided with survey pegs at 20 metre intervals. The first baseline was aligned to magnetic north and the second was orientated at 90 degrees to the first. The survey area was then divided into a series of 20 metre x 20 metres squares again using tapes. The survey grid for the GPR survey was more flexible but mainly consisted of a series of 50m x 20m rectangular survey areas. These were also laid using tapes and survey pegs. Readings were taken on a series of traverses 0.5m apart with a sample interval along each traverse of 0.2m. Both surveys employed some non-standard survey grid sizes but these were confined to areas with difficult terrain or limited access. The gradiometer survey was carried out using a Geoscan FM36 fluxgate gradiometer equipped with a ST1 sample trigger. Reading were taken at 0.5m intervals in both the traverse and sample directions. The GPR survey was carried out using a Mala RAMAC X3M with two laptop computers used for data storage and a 500 MHz antenna. Parallel traverses were surveyed at one-metre intervals using two parallel tapes for traverse measurement and sample readings were taken along each traverse at 0.25 metres intervals. Sample measurement was controlled by a calibrated measuring wheel attached to a rough terrain cart.

Data processing and presentation

Upon completion of the survey, the GPR data was transferred from the portable computer to a desktop PC and processed using Reflexw, Reflex3Dscan, Easy3D and ArcGIS 9.2. The gradiometer data was processed using Geoplot v3.0V and ArcGIS. Base maps were prepared using a combination of Google satellite imagery and georeferenced plans from published sources. Some margin of error was noticeable in the available cartographic sources and correction of this awaits the completion of the detailed survey of the fortress. Adobe Illustrator CS3, Adobe Acrobat and Word 2008 were used for report production. Data is presented as a series of combined plots with an accompanying annotated interpretation of the results. The final plot for each method is a combination of several plots derived from an examination of different levels of the underlying data. The GPR survey results presented here are limited to a single combined slice of the data at approximately 1.2 metres below the ground surface. Further examination of the geology and topology will be required before a firmer estimation of depth can be obtained. This could be established either by determining an accurate velocity estimate for the sites, either through on-site measurements (e.g. Common Mid-Point survey) or appropriate analysis of resulting data (e.g. estimation from hyperbolic diffraction tails), (Lynford 2006).

Ground Penetrating Radar (GPR)

Several areas of GPR survey were undertaken both within the Civil Yard and outside the walls within the immediate environs of the fortress. Although the outcomes of the surveys were mixed the addition of the additional dimension of depth provided a glimpse of the complexity of the build-up and destruction of archaeological stratigraphy within the fortress. The survey within the southwest corner of the Civil Yard confirmed the features revealed on the gradiometry but also clearly demonstrated the changes in level within the fortress, presumably due to levelling of parts of the interior in the Soviet era. Less affected by the presence of ferrous material, the sizes of the potential wells [Fig 6, 24] are more clearly defined. Outside the fortress to the north of the Storeyed Tower there appear to be a palimpsest of features. Unfortunately, many of these are probably associated with the modern sewage and gas systems. The latter obvious by the distinctive linear profile [Fig 7, 18] within the GPR traces and the former by the all too familiar odour when surveying in close proximity to exhaust vent from what is presumably an active septic tank. A circular anomaly on the GPR to the north of the exterior survey [Fig 7, 20], south of the Wooden Tower, may indicate that Greek activity was not limited to the area visible today. This was mirrored at the southeastern edge of the same area [Fig 7,23]. More intriguing were a series of rectilinear anomalies that were visible in the Civil Yard [Fig 6, 7/10/11] and to the south of area GPR7 [Fig 7, 19]. These may be the remains of structures but given the ephemeral nature of the response could equally represent divisions or plot boundaries within the fortress. A number of present day paths and the sub-surface remains of earlier trackways were also revealed [Fig 6, 1-6]. Examination of the satellite imagery, available from Google, reveals a myriad of such features throughout the fortress complex. The definition of the edge of the bank in area GPR7 is clearly shown in Fig 7, 15-16 but a faint anomaly, paralleled by a physical depression in the ground surface, may be the remains of a structure used to

span the moat [Fig 7, 14]. Fig 6, 8-9 and 13 are a series of curvilinear anomalies who purpose remains unclear but may represent simliar activity to [Fig 7, 20].

Gradiometer Survey

Gradiometry was used over a total area of 0.8ha within both the Garrison Yard and the Civil Yards. Although hampered by the presence of large quantities of, what is probably Soviet era, destruction debris, with a high ferrous content [Fig 8, 8-9], some results were discernable from the resultant plots. A number of ephemeral rectilinear anomalies could be observed along the base of the northwestern section of the Civil Yard some 10 to 30 metres southwest of the Water Gate where rectilinear anomalies were visible [Fig 8, 5]. The buildings, revealed during the 2007 resistivity survey, were also evident but, presumably because of their physical make-up, less pronounced in nature [Fig 8, 1]. Most striking were two circular anomalies that lay approximately 10 and 20 metres, respectively, from the northwestern wall of the Civil Yard and may represent well cappings [Fig 8, 6-7]. Only further intrusive physical investigation would reveal whether these belong to antiquity or are reminders of a much more recent past. A number of ephemeral curvilinear features were also revealed [Fig 8, 14-15] but given the disturbed nature of the ground within this area of the fortress may represent relatively recent activity. Two rectilinear alignment did provide a glimpse of the possible remains of structure [Fig 8, 10-11] but what there are is impossible to determine from the small sections of remains revealed. As with the GPR, pathways were also evident within the gradiometer data [Fig 8, 2/4/14]. Within the Garrison Yard some rectilinear features were evident as a lines of magnetic spikes [Fig 10, 19/21-22] as well as some less pronounced perpendicular linear arrangements [Fig 10, 15-16]. Given the current use of the area caution with the interpretation of such results must be countenanced. Two large ferrous spikes were also revealed [Fig 10, 17-18]. The area to the east of the present main entrance to the Garrison Yard also revealed parallel lines of magnetic spikes and probably represents the limits of the edges of the present path [Fig 9, 23-24]. The linear anomalies represented by [Fig 9, 25-26] are most likely associated with the mosque immediately to the south of the survey area.

Conclusions

The deployment of gradiometry and GPR in addition to the resistance survey carried out in 2007 has clearly demonstrated the usefulness of combining these techniques. Gradiometry, in particular, is however limited by the present use of the fortress and the levelling of the areas of the interior in the recent past. The results obtained from the limited resistance survey in 2007 have, to date, provided the more clearly interpretable results. Further use of this technique in combination with a GIS based map regression and thorough topographic survey would produce a body of data capable of more conclusive analysis.

Figures

Figure 1: Location of the Gradiometer survey: base map georeferenced to Google satellite imagery

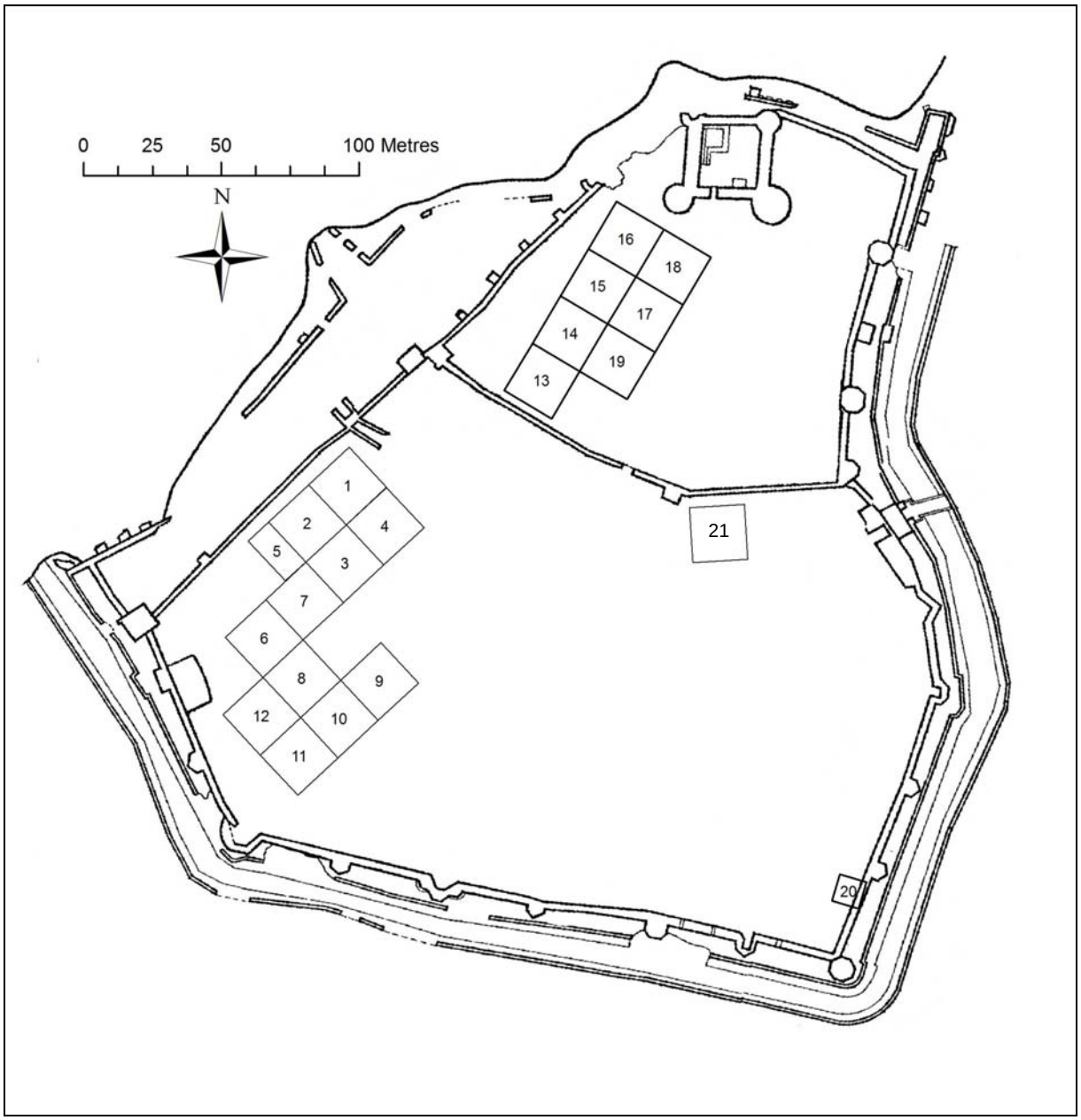


Figure 2: Location of the GPR survey: base map georeferenced to Google satellite imagery

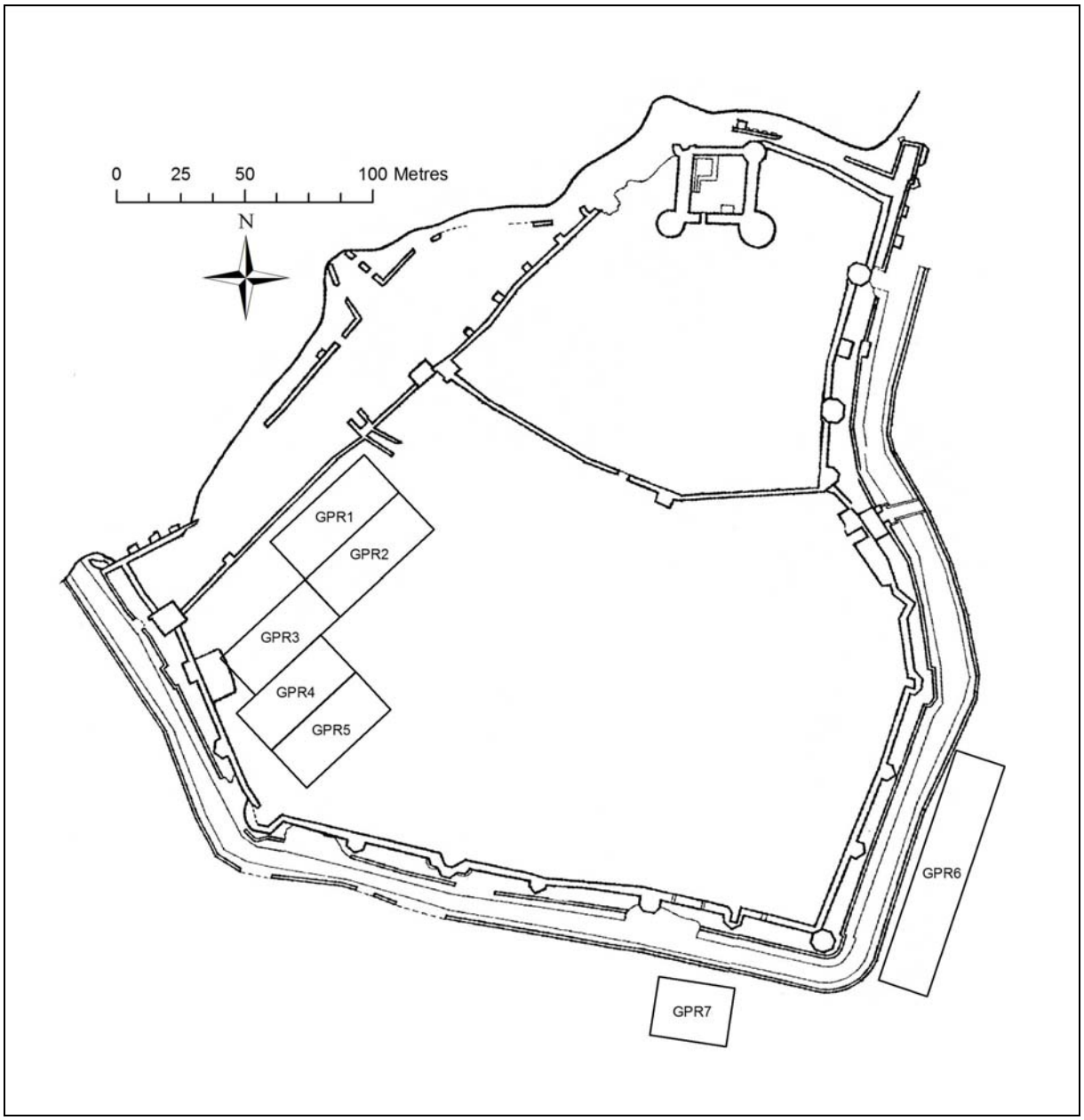


Figure 3: Location of the 2008 Gradiometer and GPR surveys in relation to the 2007 Resistance survey: base map georeferenced to Google satellite imagery.

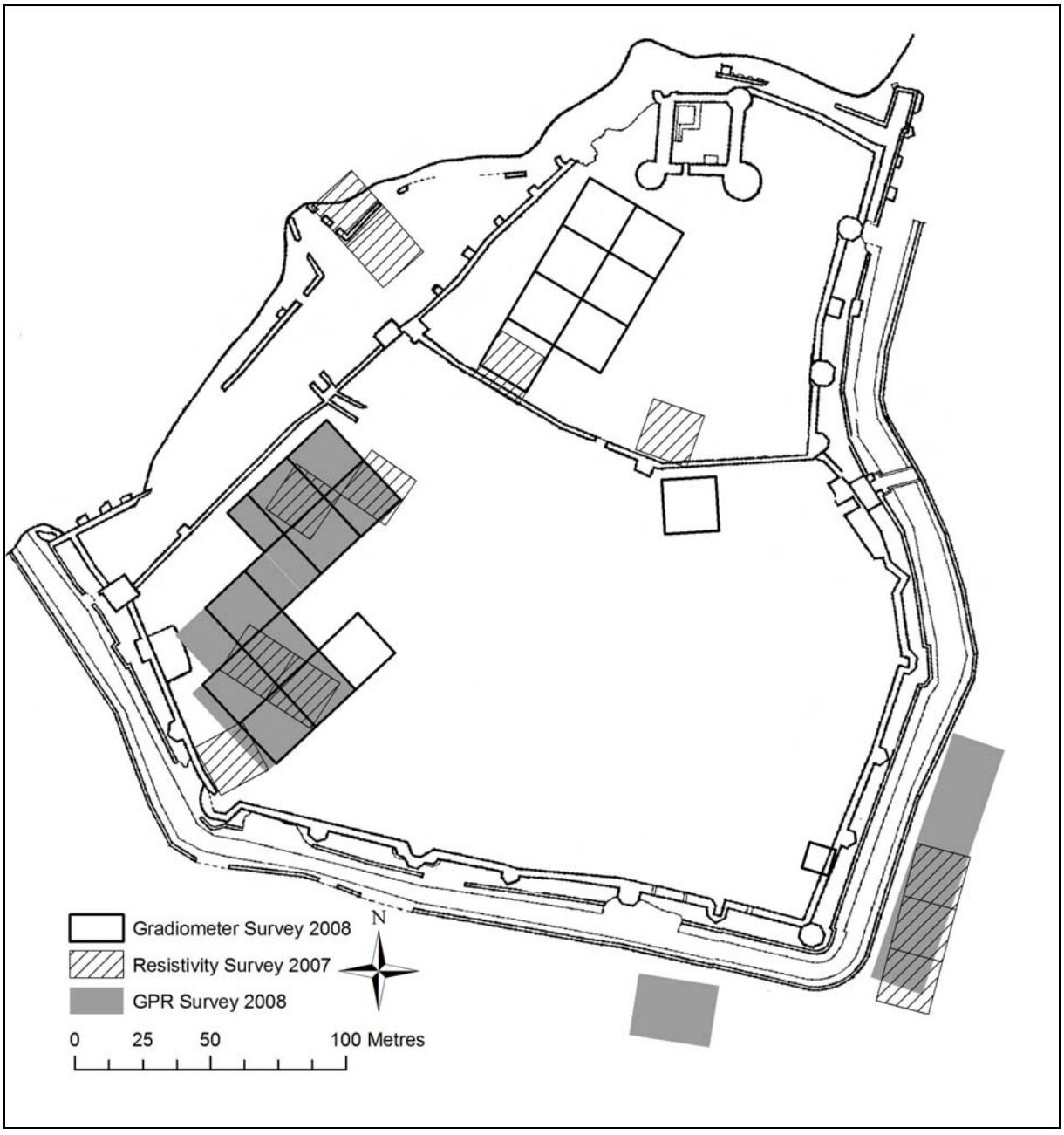


Figure 4: Composite plot of GPR survey results: base map georeferenced to Google satellite imagery.

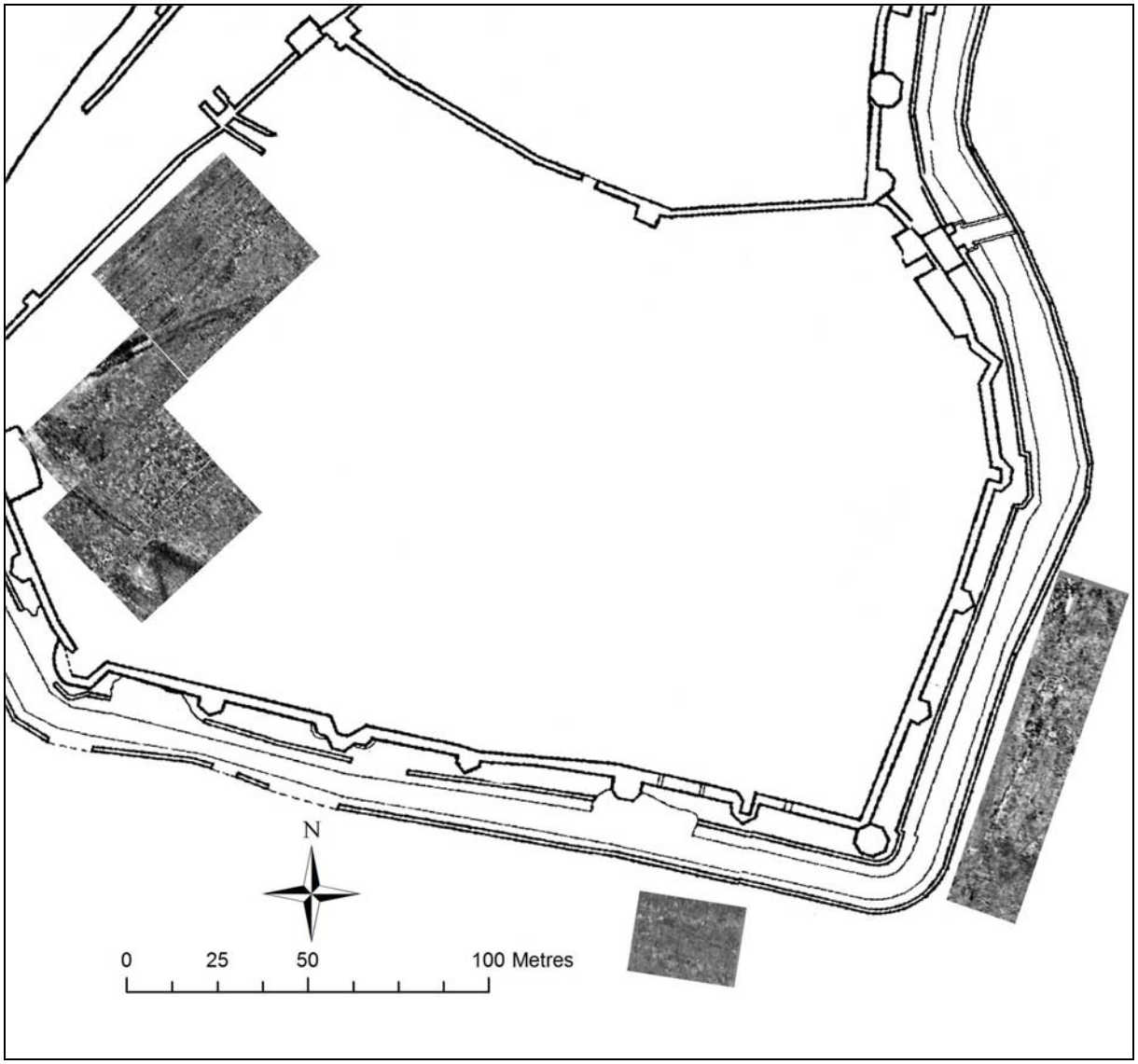


Figure 5: Composite plot of the gradiometer survey: base map georeferenced to Google satellite imagery.

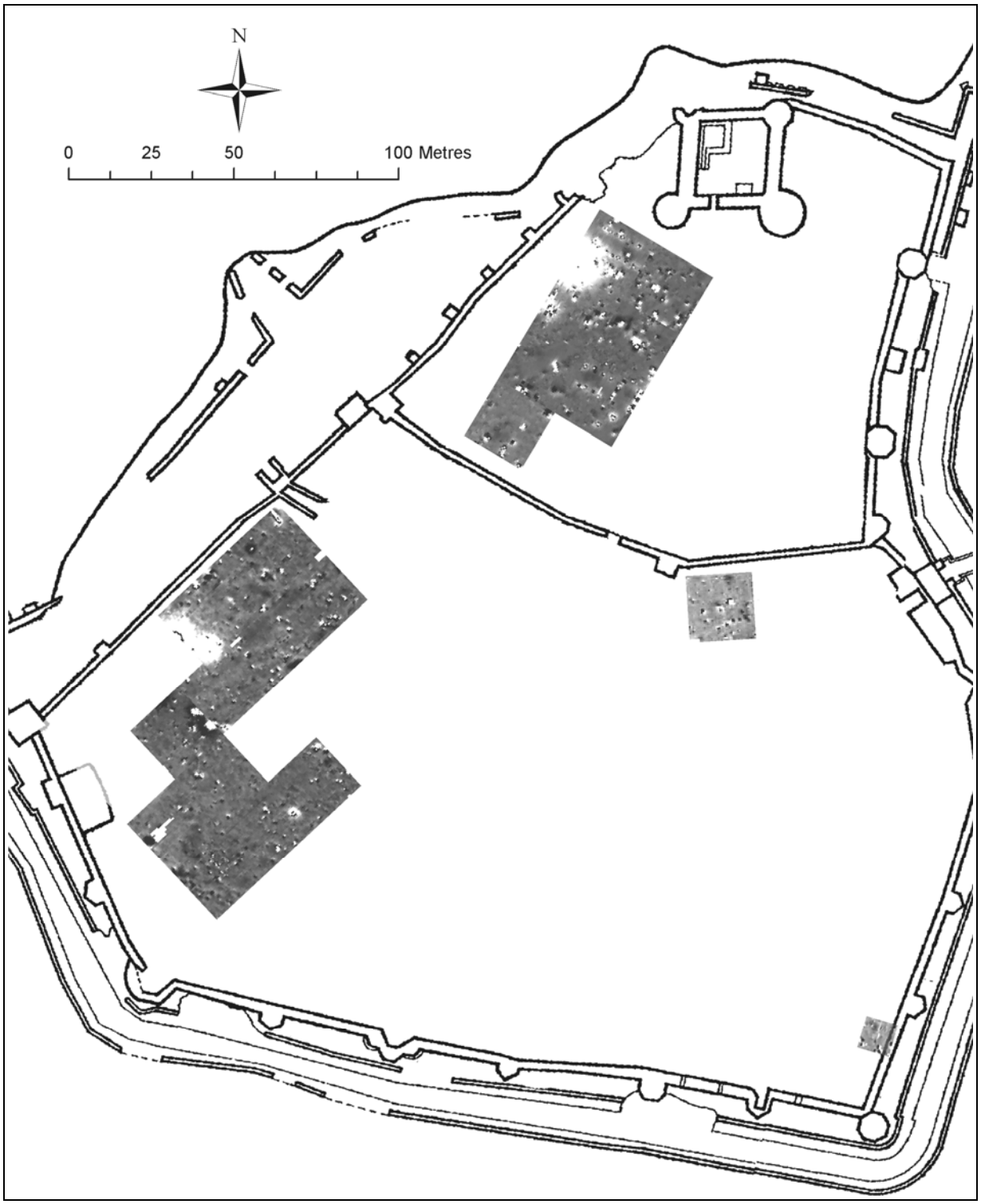


Figure 6: Interpretation of the GPR results: Grids 1-5, Civil Yard.

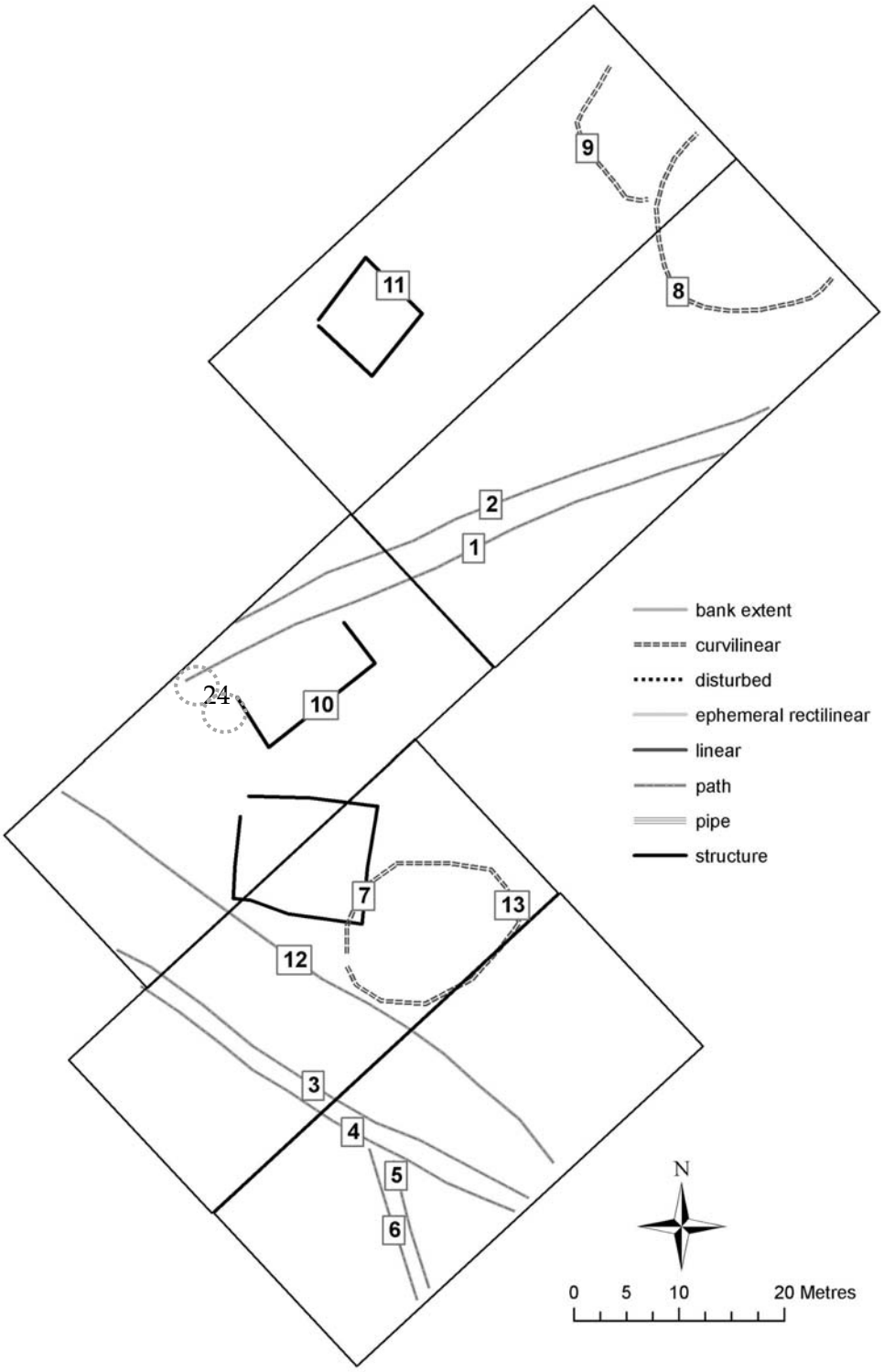


Figure 7: Interpretation of the GPR results:- Grids 6-7 (top) grid 8 (bottom), Glacis.

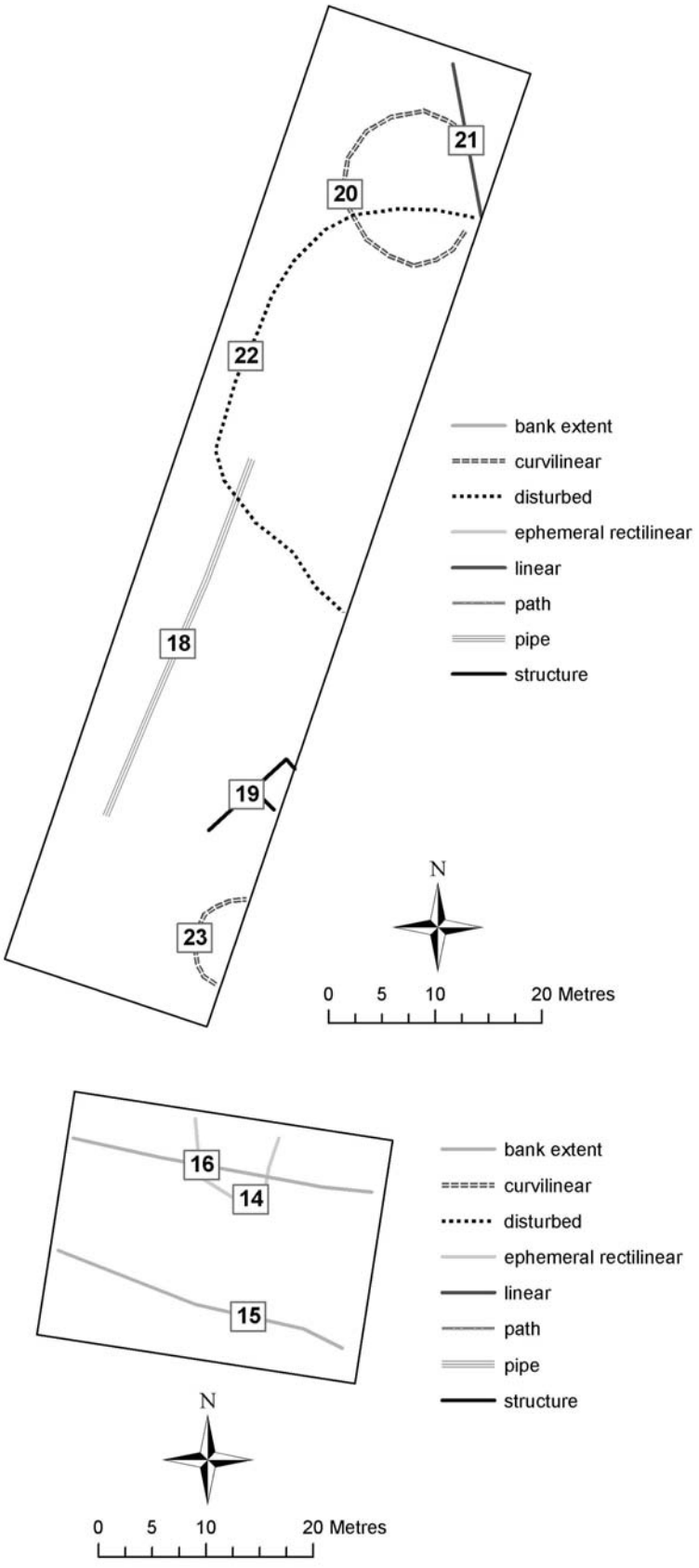


Figure 8: Interpretation of the gradiometer results: Grids 1-12, Civil Yard

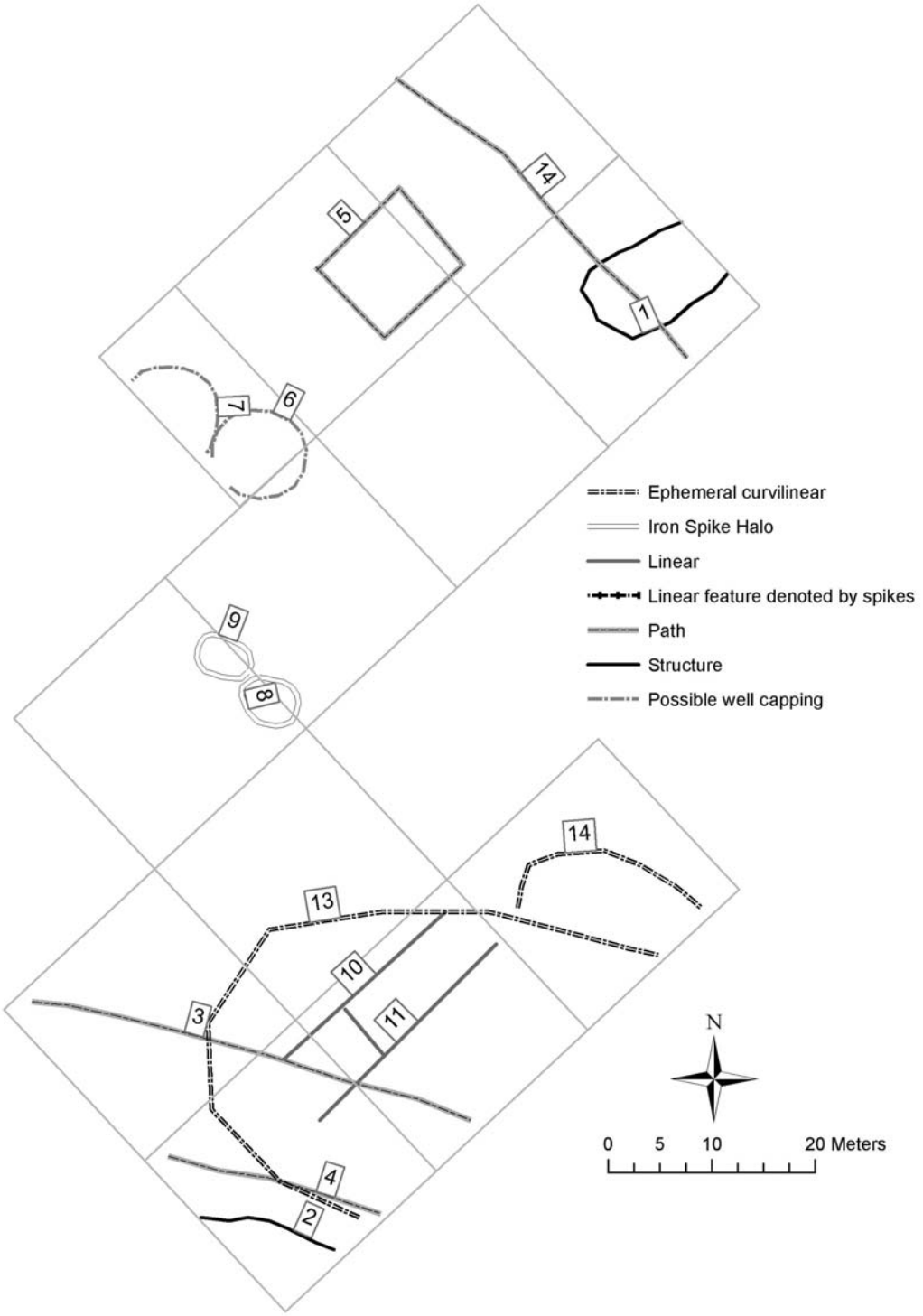


Figure 9: Interpretation of the gradiometer results: Grids 20 and 21, Civil Yard

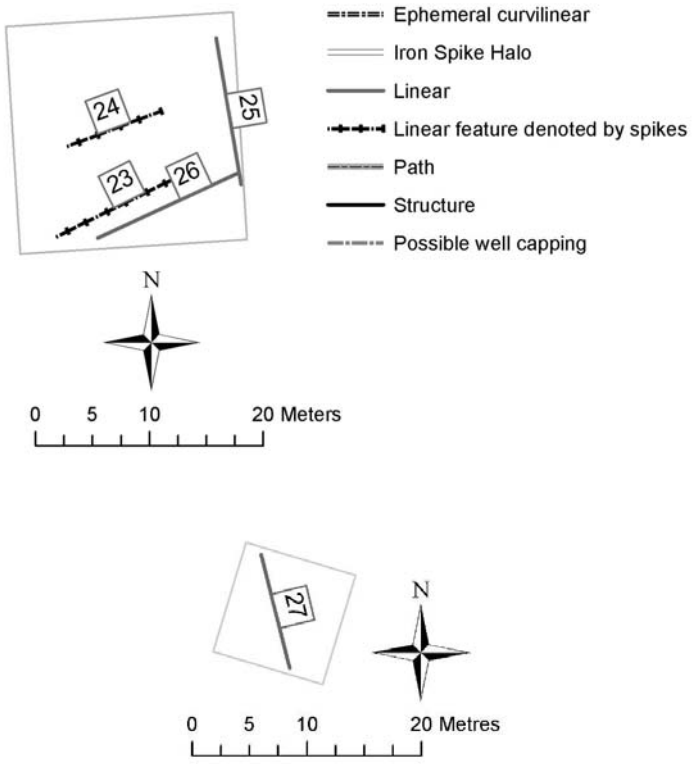
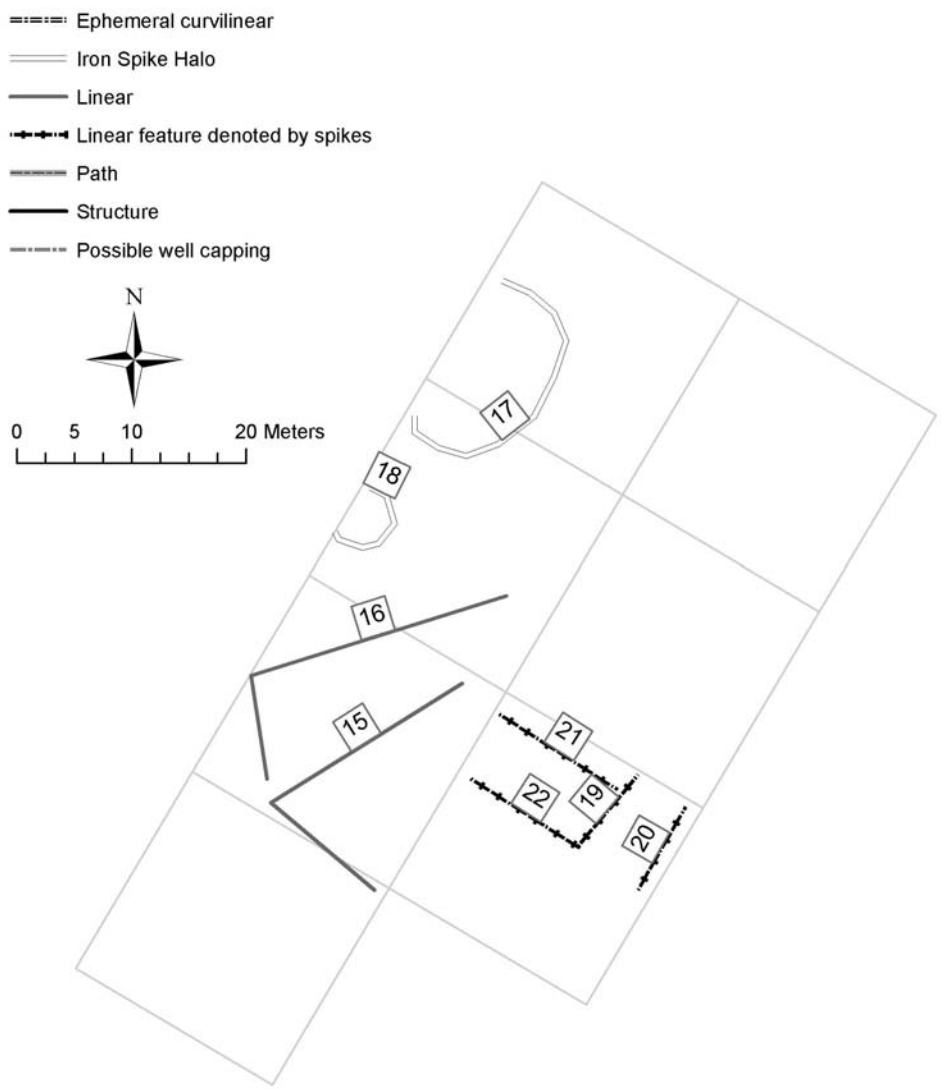


Figure 10: Interpretation of the gradiometer plot: Grid 13-19, Garrison Yard



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