Geophysical Survey at Yassıhöyük in 2011

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1. INTRODUCTION

Yassıhöyük is one of the largest mound-type sites in central Anatolia, with a diameter of more than 600 m. The Japanese Institute of Anatolian Archaeology (JIAA) has been conducting archaeological excavations at Yassıhöyük since 2009 to contribute to an understanding of ancient settlement and cultural features in central Anatolia (Omura 2011). The large size of Yassıhöyük highlights the importance of performing wide-ranging preliminary surveys prior to excavation. Our magnetic field gradient survey (called simply "magnetic survey" hereafter) provided information about buried architectural remains (Kumagai 2008), resulting in a set of initial excavation grids on the mound. However, magnetic survey is insufficient for a complete understanding of the site's buried remains because most of the surveyed area, except the present excavation grids, exhibited poor magnetic signatures and the resulting magnetic anomaly map principally contains little information on depth. Several structures excavated so far (Omura 2013) indicate that a survey depth of at least 3 m, deeper than that of the magnetic survey, is required. Thus it is possible that many remains having negligible magnetic contrast are distributed over the mound.

A ground penetrating radar (GPR) survey, based on the penetration and reflection of electromagnetic waves emitted from an antenna, has great advantages in probing objects at depth regardless of magnetism. GPR survey depth often exceeds 10 m, depending on the frequency of radio wave used and the site conditions. For example, we demonstrated at the site of Kültepe that a GPR survey with a 200 MHz antenna can reveal underground remains at depths of 3 m and more (Fukuda *et al.* 2004). This analytical performance is suitable for characterizing the distribution of buried remains at Yassıhöyük and may also allow an estimate of their chronology.

In this study, we report the distribution and depth of buried remains, including a city wall at the perimeter of the mound and traces of an ancient wall outside the mound, on the basis of GPR and magnetic surveys.

2. EXPERIMENT

2.1. Survey area

Fig. 1 shows a topographical map of Yassıhöyük (Omura 2008) with this season's survey areas indicated. Each rectangular survey grid is 40 m × 20 m and is identified by coordinates at its southwest corner: (N 60 m, E 0 m), (N 20 m, E 120 m), (N 40 m, E 140 m), and (S 460 m, E 60 m). These coordinates indicate the direction and the distance in meters from the standard point shown as a black triangle symbol on the map. The axis of the survey areas was set using magnetic north. At the beginning of this investigation, grids (N 60 m, E 0 m) and (N 20 m, E 120 m) on the mound were covered with tall grass and a large number of stones with a diameter of less than 30 cm. Prior to the geophysical survey, we carefully removed these obstacles to reduce the noise level and attain correct detection of the radar signals reflected from the surface. These grids except for (N 60 m, E 0 m) are used for agricultural cultivation at present.

2.2. GPR survey

The GPR survey was conducted using a Geophysical Survey System, Inc. (GSSI) radar system with a 200 MHz antenna and a hand-trigger. Taking into consideration topographical flatness and easy data handling, the survey areas were chosen. The

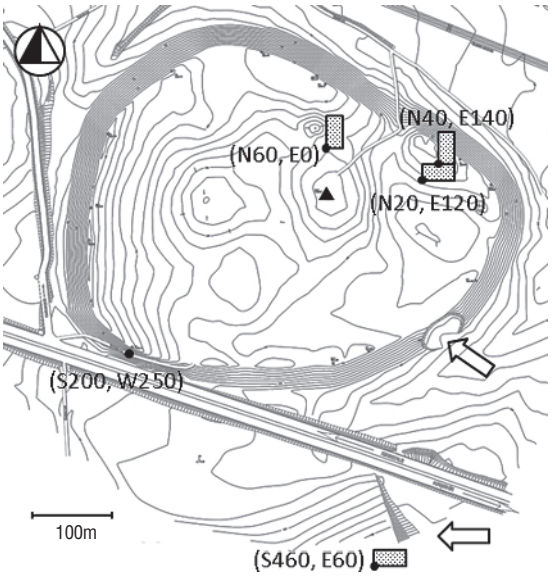

Fig. 1 Topographical map of Yassıhöyük. The four shaded portions indicate the areas surveyed in this study. The two large arrows indicate the direction of photographs taken of sections formed by road construction (see *Fig. 5*).

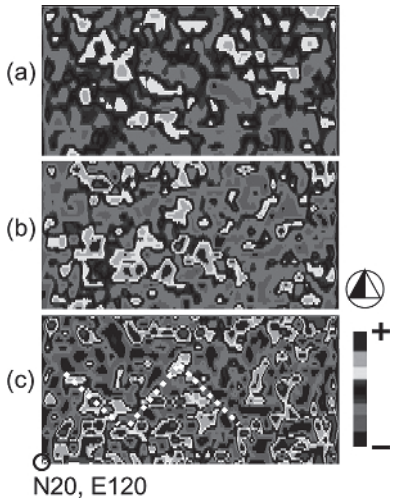

Fig. 2 2D maps of the GPR data at depths of (a) 0.6 m, (b) 1 m and (c) 2.5 m from the ground surface in survey grid (N 20 m, E 120 m).

dielectric constant of the target soil was estimated as 4.0 from a pre-survey of several stones exposed in the section walls of excavated grids and was used for calibration of the virtual depth of GPR signals. The amplitude of the electromagnetic wave was recorded in 16 bit code. The sampling number of the instrument was determined as 16 times/sec in the scanning direction. The antenna was pulled by hand. Digital markers indicating the position of the antenna during the survey were added to the GPR data by means of the hand-trigger. In principle, the emitted radar signal should be reflected by the ground surface at first, yielding a strong reflection, which was used as an indicator of the ground level, in individual radar profiles. These data were mathematically processed (smoothing and Fourier filter analysis) and displayed with RADAN 5.0 for Windows (GSSI). The individual wave forms which offer depth information at one point were united to make a GPR profile for one scan, i.e., section image. The resultant profiles were combined to create two-dimensional distribution (2D) maps of the radar reflections at various depths from the ground surface. Positive amplitude of the electromagnetic wave was especially emphasized in white to give a clear vision of buried objects.

2.3. Magnetic field gradient survey

Details of the magnetic survey system are described elsewhere (Fukuda *et al.* 2001, 2002). Briefly, the magnetic field gradient survey was performed with a Geoscan Research FM256 gradiometer. Data density was 8 points/m for the north-south direction and 1 point/m for the east-west direction. Magnetic resolution was set to 0.1 nT. Obtained raw data were processed with GEOPLOT 3.0 for Windows (Walker *et al.* 2005). In a magnetic anomaly map composed of the processed data, regions of large positive magnetic field gradient are expressed as dark gray to black, and those of large negative magnetic field gradient are white.

3. RESULTS AND DISCUSSION

3.1. Architectural distribution on the mound

One of the prominent features of Yassıhöyük is a great number of unnatural undulations on the mound, illustrated by closed contour lines in the topographical map (see *Fig. 1*). These may indicate the presence of buried remains close to the surface. In this study, two areas of undulating topography were investigated to understand the extent and depth of buried objects.

GPR maps of the northeast survey grid (N 20 m, E 120 m) obtained from various depths are displayed in *Fig. 2*. Note that the edges of the grid tend to exhibit ghost reflections as a result of the data analysis. As indicated by white and gray portions in *Fig. 2a*, four broken lines oriented northwest-southeast are observed at a depth between 0.6 m and 0.8 m. Their orientation seems to parallel the edge of the mound in this area. In addition, these lines observed

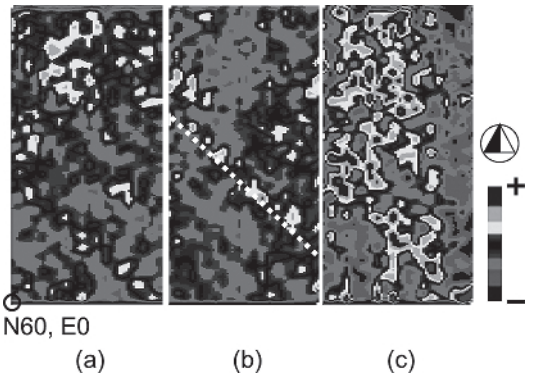

Fig. 3 2D maps of the GPR data at depths of (a) 0.5 m, (b) 0.9 m and (c) 2.6 m from the ground surface in survey grid (N 60 m, E 0 m).

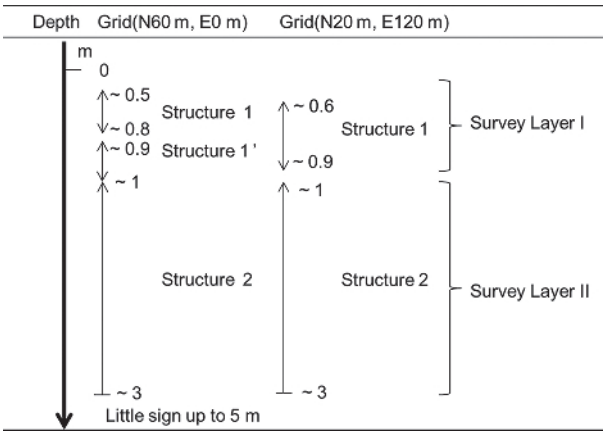

Table 1 Summary of the stratigraphic identification of the radar reflections detected on the mound

in *Fig. 2a* seem to form several right angles, which can be regarded as a sign of ancient architecture. The uniform and featureless signals observed at the depth of less than 0.5 m suggest that the layer between 0.6 m and 0.8 m can be interpreted as a first cultural period, named "Survey Layer I" in this study. At depths of 1 m and deeper, a 2D map having different radar contrast and position was acquired (see *Fig. 2b*). The contrast became most noticeable at the depth of 2.5 m, resulting in an easy identification of buried objects as indicated by the dotted line in *Fig. 2c*. The continuity of the same GPR pattern with depth is believed to reflect the presence of large buildings. Although it is difficult to identify the chronology of the buried features without excavation, the layer at the depth of approximately 1 to 3 m can be identified as a second cultural period, named "Survey Layer II" in this study. Importantly, the distribution of the observed radar signals in Survey Layer II partly overlaps that of Survey Layer I. A comparison of the distribution between them shows a common feature with respect to the architectural direction, implying a similarity in the city plan in each Survey Layer. At further depth (more than 3.5 m), no meaningful signal was observed even after emphasizing radar amplitudes in the data analysis. This may be explained by the existence of uniform layers beneath Survey Layer II. A thick layer of natural, undisturbed soil observed at the slope of the mound (see a point of (S 200 m, W 250 m) in *Fig. 1*) may support our results. Another explanation may be that Survey Layer II might reflect most of the incident electromagnetic waves and consequently trigger a tremendous reduction of the survey depth.

Fig. 3 shows 2D maps of the GPR data acquired from the north-central survey grid (N 60 m, E 0 m) at depths of (a) 0.5 m, (b) 0.9 m and (c) 2.6 m. A corner formed by two dotted radar signals at (N 80m, E 0 m), possibly the first building level in this area, begins to appear at a depth of 0.5 m. The 0.9 m depth shows a dotted line of radar spots, traced with a broken line in the figure. These radar features at 0.5 m and 0.9 m can be identified as belonging to the same layer because of similar spot shape and radar contrast between the buried objects and the background. Since these features are at approximately the same level as features observed at 0.6 m depth in the northeastern grid discussed previously, (N 20 m, E 120 m), we classify them as Survey Layer I in this study, pending further analysis. Both survey grid areas exhibit strong radar reflections at the depth ranging from ~ 1 m to ~ 3 m, indicating the presence of buried structures belonging to Survey Layer II. At further depth, most signals became very weak and finally disappeared.

These results suggest two main levels on the Yassıhöyük mound, Survey Layer I and II. Table 1 summarizes the stratigraphic identification of buried objects based on the GPR survey conducted this season. This shows that the levels of Survey Layer I and II are approximately comparable to the occupation levels Yassıhöyük I and II identified in excava-

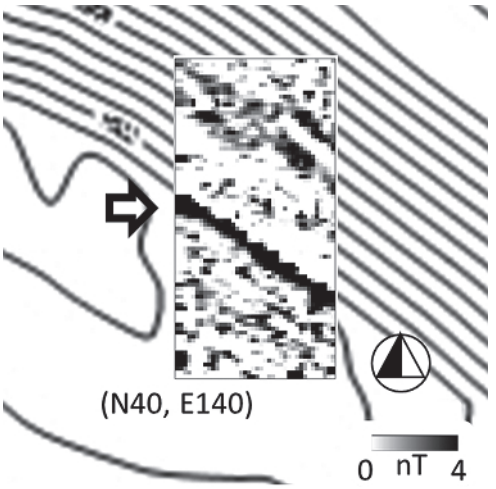

Fig. 4 A composite map consisting of the topographical map and the magnetic anomaly map obtained at the northeast edge of the mound in survey grid (N 40 m, E 140 m).

tion (Omura 2013). These GPR results contribute to understanding the chronology and distribution of Yassıhöyük remains.

3.2. City walls of Yassıhöyük mound

Investigations at the perimeter of a mound-type site can lead to discovery of archaeologically important remains such as city walls and gates. Generally speaking, remains at the mound slope tend to be less deeply buried compared to those in the central part of the mound, and therefore are easily revealed by magnetic survey (Fukuda *et al.* 2001). Our preliminary survey at Yassıhöyük found strong magnetic anomalies along the northwest edge of the mound (Kumagai 2008). These signals are considered to indicate the remains of a city wall, although a city wall has not been revealed by archaeological excavation, to date. Judging from the height of the mound, approximately 13 m, several city walls may remain undiscovered yet.

Fig. 4 shows a composite map consisting of contour lines and magnetic anomalies acquired from survey grid (N 40 m, E 140 m) on the northeast slope of the mound. On the mound surface (see the southern part of the grid), it is hard to identify meaningful signals except for several narrow lines of negligible magnetic anomalies which stem from the surface undulations of the agricultural field. The mound/slope edge indicated by the arrow exhibits a distinct line of positive magnetic anomalies. This is fairly consistent with our previous work at the west side of the mound, which supports the existence of a city wall at the mound edge. In the sloping area (the northern part of the grid), two parallel lines oriented northwest-southeast can be seen. They seem to have zigzag corners and dividing lines, indicative of a man-made structure. A large number of stones exposed at the eastern area of the mound in a cut formed by road construction may be evidence of the continuation of this wall structure (see *Fig. 5a)*.

These results suggest the existence of at least two city walls. The contour lines observed at the edge of the mound, at the higher level, may be associated with the first cultural period, i.e., Survey Layer I. On the other hand, the level of the anomaly features seen on the slope can be estimated to be about 4 m

(a) (b)

Fig. 5 Photographs of two areas on the eastern edge of the site cut by road construction: (a) the mound slope and (b) the agricultural field near survey grid (S 460 m, E 60 m). The arrows indicate several stones exposed in the sections.

from the top of the mound. Taking into consideration the inclination of geomagnetism in the northern hemisphere and the north-side slope, the origin of the anomalies is believed to be shallower than 4 m. On the basis of this estimation, the city wall observed on the slope may be identified as Survey Layer II. Interestingly, the shape of this magnetic anomaly resembles the saw-tooth wall discovered at Alişarhöyük in terms of architectural functionality, e.g., zigzag shape and row of small rooms (Von der Osten 1937). This similarity could pave the way for dating Survey Layer II.

3.3. Wall in the surrounding area of the mound

The surroundings of mound-type sites are of great interest in archaeological studies as they may be residential areas, as at Kültepe (Özgüç 2003), for example. At Kaman-Kalehöyük, there are a great number of magnetic anomalies that may originate from ancient structures in the surroundings of the mound (Fukuda *et al.* 2003, 2005; Kumagai *et al.* 2006). Thus, it is of interest to determine the extent of remains around the Yassıhöyük mound.

We investigated the distribution of surface sherds as an indicator of settlement areas and possible buried remains, in seeking an area that would be fruitful for survey using the GPR system. An area just southeast of the mound at (S 460 m, E 60 m) was carefully investigated this season. As can be seen in a manmade topography close to the grid in Figure 1, this area was disturbed during the construction of the national road running next to the mound. An exposed section in the area contains archaeological sediments including a line of several stones, at a depth of approximately 1 m, overlying the natural soil layer (see *Fig. 5b*). *Fig. 6* displays GPR maps acquired from this survey grid at depths of 0.8 and 1.1 m from the surface. In *Fig. 6a* (0.8 m), the white spots seem to form a broken line oriented southwest-northeast. The eastern end of this line disappears at 1.1 m. Instead, the western end becomes clearer, presumably because of a difference in elevation from the surface. A projection of this line intersects with the stone line exposed at the section in terms of both spatial position and level. The fact that the stone line overlies the natural layer should be responsible for little detection of the GPR signals from the depth of 1.2 m and deeper. Thus, the radar spots are likely to reflect a buried wall belonging to a first cultural period in this area. Dating this wall will be a subject of future study. Our findings strongly promote future archaeological investigation not only on the mound but also in the areas surrounding the mound.

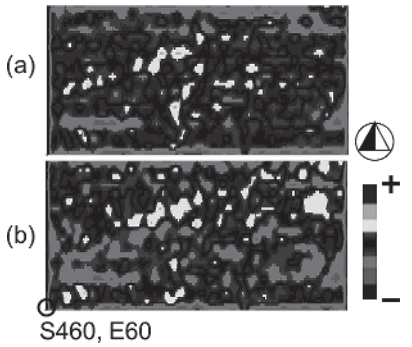

Fig. 6 2D maps of the GPR data at depths of (a) 0.6 m and (b) 1.1 m from the ground surface in survey grid (S 460 m, E 60 m).

4. CONCLUSION

We have succeeded in revealing the distribution and the level of several buried objects through the combined use of GPR and magnetic surveys. Our surveys on the mound revealed that there are two architectural layers, Survey Layer I and II, in the north and northeast areas of the mound. This is basically consistent with the results of ongoing archaeological excavation. Furthermore, it is found that the mound is surrounded by at least two city walls. One of them may be of the same period as the wall at Alişarhöyük, based on the topological comparison. The stone line discovered in the area to the south of the mound may indicate the existence of ancient suburbs around the mound.

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