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GEO-ARCHAEOLOGICAL AND GEOPHYSICAL INVESTIGATION ON THE EARLY BRONZE AGE LAYERS OF TAVŞANLI HÖYÜK (INLAND WESTERN ANATOLIA)

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ABSTRACT

The objective of the project entitled "Prehistoric Periods Survey of Eskişehir and Kütahya Provinces (EKAR)", which is ongoing since 2017, is to conduct comprehensive research using modern techniques on large settlements aiming to achieve results that can contribute to clarify certain archaeological problems and fill in the chronological gaps regarding the prehistorical periods of the region. In this context, geo-archaeological and geophysical methods are applied alongside with traditional archaeological research methods. This paper discusses the results of the geophysical studies along with the contribution of geo-archaeological drills to these results in Tavşanlı Höyük located within the borders of Kütahya Province in Inland Northwest Anatolia within the scope of the mentioned surveys. Studies carried out on an area of 100 x 55 meters have shown that the seite featured a settlement pattern of houses surrounded by streets and alleys during the Early Bronze Age II (2700-2400 BC) and revealed a strong evidence that, at least for the area studied, it was not settled in again following a great fire outbreak during the Early Bronze Age III period.

KEYWORDS: Geo-Archaeology, Georadar, Early Bronze Age, Western Anatolia, Tavşanlı Höyük

1. INTRODUCTION

"The Prehistoric Periods Survey of Eskişehir and Kütahya Provinces" project, in short EKAR, is conducted in Inland Northwest Anatolia under the direction of the author since 2017 and focuses on large-scale Bronze Age mounds in the region. Tavşanlı Höyük is the largest mound in the region which spreads over an area of more than 40 hectares. The mound is located in the centre of the Tavşanlı Plain, approximately 2 km from the Tavşanlı District of Kütahya Province (Fig. 1-2). The Orhaneli Stream passing right by the settlement is the largest river in the plain. Traces of the Neolithic Period have also been identified during our research. If the inadequate information on the Neolithic period is left asidethe mound is primarily dated to the Bronze Age. The C-14 dates and intensive survey data obtained from the geo-archaeological drills indicate that the mound contains remains from Middle Bronze Age (MBA) & Late Bronze Age (LBA), and Early Iron Age. The survey data show that Early Bronze Age (EBA) pottery is mostly concentrated on the eastern and north-eastern parts of the mound.

Geophysical work has been carried out on 2 hectares in total in Tavşanlı Höyük. The 1.5-hectare study was carried out on the mound and the 0.5-hectare study was conducted to the northeast of the mound. The focus of this article is the studies carried out in an area of 100 x 55 meters to the northeast of the mound dated to the second half of the EBA. The results obtained are also supported by the geo-archaeological drills gathered from the area in question.

Figure 1. The location of Tavşanlı Höyük and the settlements mentioned in the article

Figure 2. Tavşanlı Höyük aerial view

2. METHODOLOGY

2.1 Geo-archaeological research

The drills were carried out using a manually operated Atlas Copco drilling equipment and sediment samples of alluvial fillings were collected by means of pipes with 5 cm inner diameter and 1.10 cm length (Fig. 3). Relevant physical properties of the sediment samples, such as the grain size and colour were noted for later analyses. The archaeological materials found within the auger heads (e.g. pieces of brick and ceramic) and datable organic materials (such as charcoal and plant remains) were placed in separate containers.

2.2 Geophysical research (GPR / Ground Penetration Radar)

The main technique used in this study is GPR (Ground Penetration Radar). GPR is a geophysical survey method that works by sending electromagnetic waves of different frequencies to the surface and recording the waves that bounce back either directly, reflected, or refracted. These recordings constitute an image called radagram. The collected signals are interpreted by subjecting the radagram to a special data processing program. GPR consists of two parts: a system (recorder) and an antenna. Antennas of different frequencies are used for studies with different purposes. Compared to many other geophysical survey methods this is known as a restrictive method in terms of depth, but it delivers high resolution results due to its method of operation using high frequency signals. A Swedish- "Geoscanners AB" brand Akula 9000B System was utilized as well as a 300MHz antenna and a GC - 1 Cart, GPR during the research carried out in Tavşanlı Höyük (Fig. 4) (see Appendix for technical data).

Figure 3. Geo-archaeological drills

Figure 4. Geo-radar studies

3. APPLICATION AND DATA

Two drills were performed at 50 meter intervals to the northeast of Tavşanlı Höyük in an area covering 100 x 55 m that was entirely scanned with the geo-radar (Fig. 5-6).

Figure. 5. Detailed view of the geo-radar areas and walking directions. (Early Bronze Age studies were conducted in "alan 8" marked with a red line)

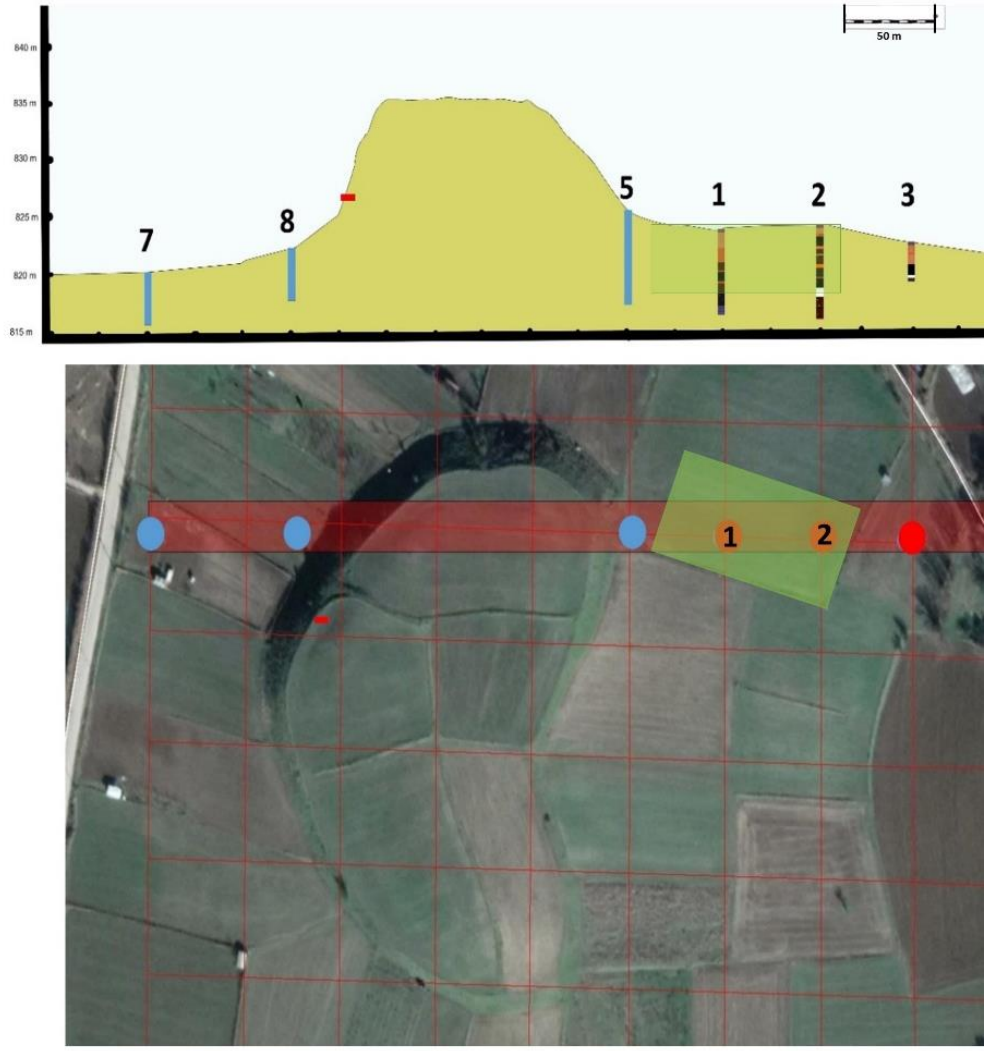

Figure 6. Tavşanlı Höyük, east-west section and areas where geo-archaeological drills and geo-radar studies are performed

3.1 Geo-archaeological Drills

A total of 2 geo-archaeological drills were performed in this area, and sediment samples were dated using C-14 method at various levels from the 8-meter drill identified by Nr. 2 (Fidan et al. in print). The traces of the Neolithic Period, known only from a few settlements in the region, were captured at a depth of about 7.5 meters. The radiocarbon results from the same level with a dark-faced pottery indicate to a date of 6000 BC. Here, periods EBA I and EBA II were identified from 3000 to 2400 BC after a 3000-years gap (Fig. 7).

The sediment characteristics obtained from geo-archaeological drills show that there was a back-marsh-lake environment in the immediate vicinity of the settlement when it was first established, and that the Neolithic settlement was probably built also in proximity of this watery environment. However, it seems that, later the swamp took over and a new settlement was not established for about 3000 years. During the drills, a thick anthropogenic filling of sandstone fragments between 5 and 7 meters down from the surface was encountered, which suggests that this back-marsh coast was filled by humans. C-14 results show that the filling of the marsh was started at the beginning of the EBA I, that is, around 3000 BC. It can be deduced that new settlers came here during the EBA I who made an effort to dry out the swamp and that they were successful. This deduction is based on the fact that, this back-marsh-lake environment left its place to a cultural layer containing abundant archaeological materials and burnt layers starting from deeper than 4 m of the present surface. Carbon 14 dates also confirm that this happened around 2700 BC, during the EBA II. It is understood that the 3-meter EBA II embankment was settled on for 300 years and this settlement suffered at least two fire outbreaks over the area under investigation (Fig. 7, 8).

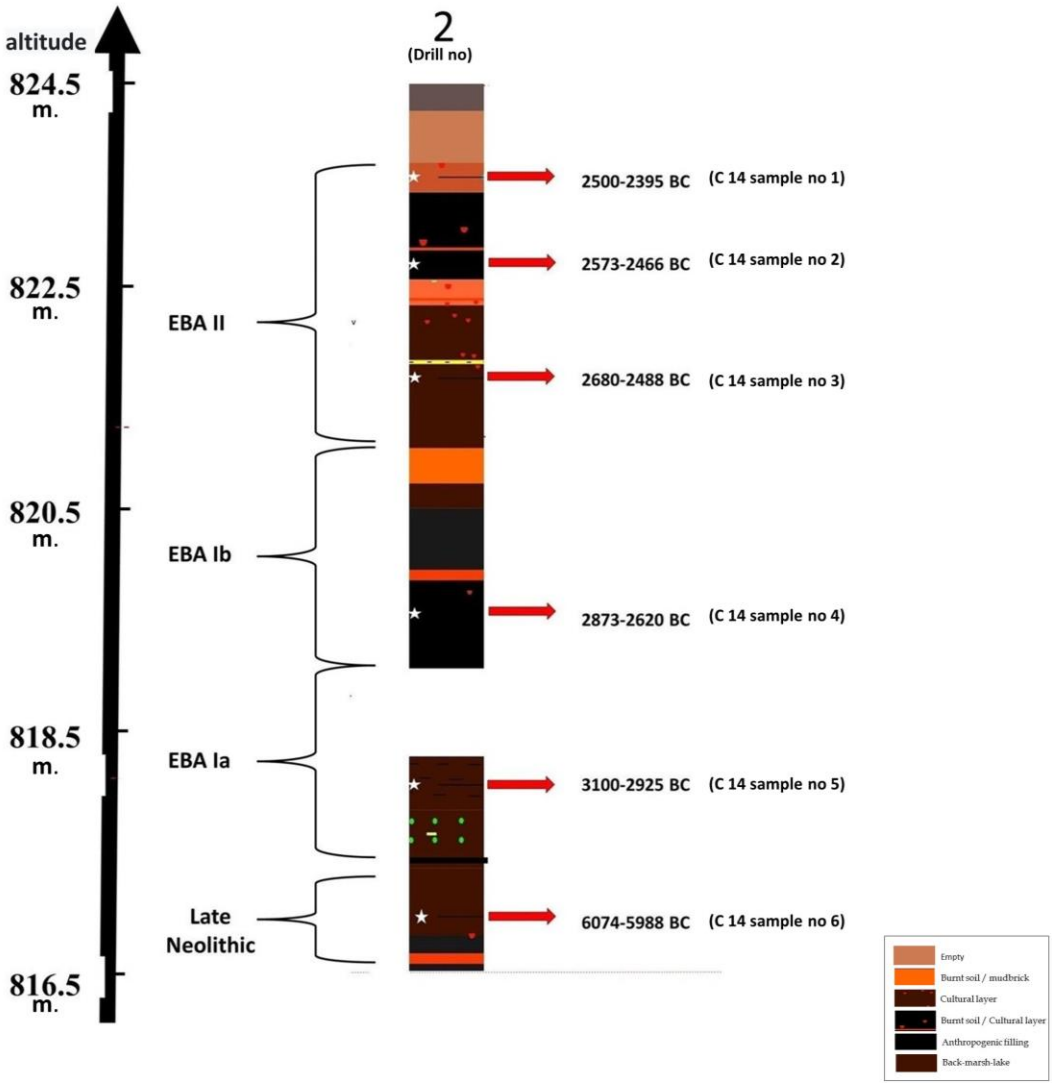

Figure 7. The geo-archaeological drill Number 2 and its radiocarbon dates

Sample No	TÜBİTAK Date	Calibrated Date	TÜBİTAK Sample No
1	3941 ± 43	2388 - 2395	TÜBİTAK - 0698
2	3987 ± 28	2573 - 2466	TÜBİTAK - 0496
3	4065 ± 30	2680 - 2488	TÜBİTAK - 0497
4	4136 ± 29	2873 - 2620	TÜBİTAK - 0498
5	4434 ± 36	3126 - 2925	TÜBİTAK - 0699
6	7161 ± 33	6074 - 5988	TÜBİTAK - 0499

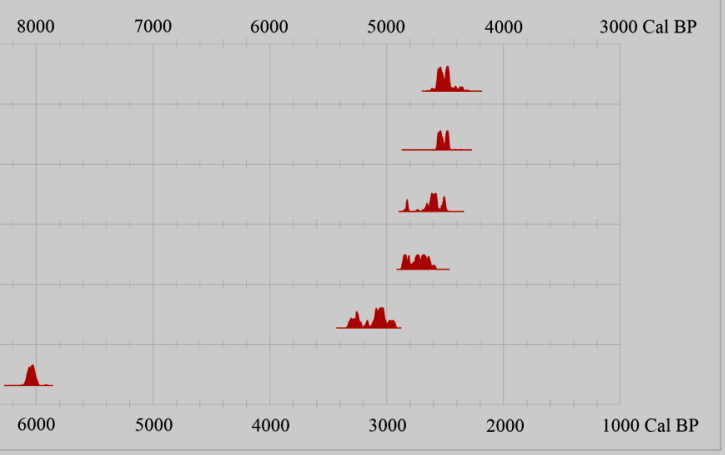

Figure 8. Radiocarbon dates of Drill 2

3.2 Geo-radar

Geo-radar studies have focused on a depth of 5 meters from the surface and 2 dimensional images were captured every 0.25 meters. The C-14 results provided us a chance to date the layers using the burnt wood pieces obtained from the geo-archaeological drills described earlier, which were between 819.5 and 824.5 meters above sea level.

The images of 5 to 3 m from the surface show that the area is archaeologically empty, in other words, there are no architectural features and it is not settled. According to the C-14 results, both of these two levels belong to the EBA I Period. As the geo-archaeological data also emphasized, it was not settled yet here during the EBA I Period (Fig. 9).

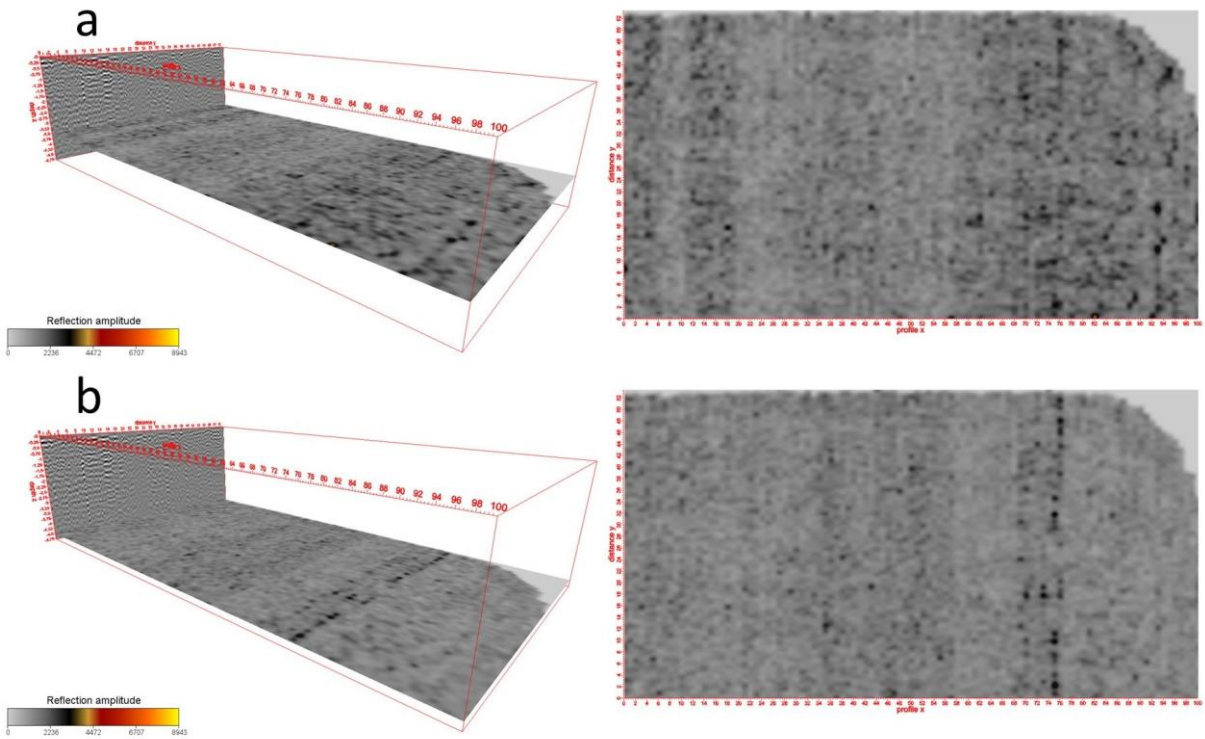

Figure 9. Geo-radar images from EBA I levels based on radiocarbon dates

a- 3.5 meters depth from the surface

b- 4.0 meters depth from the surface

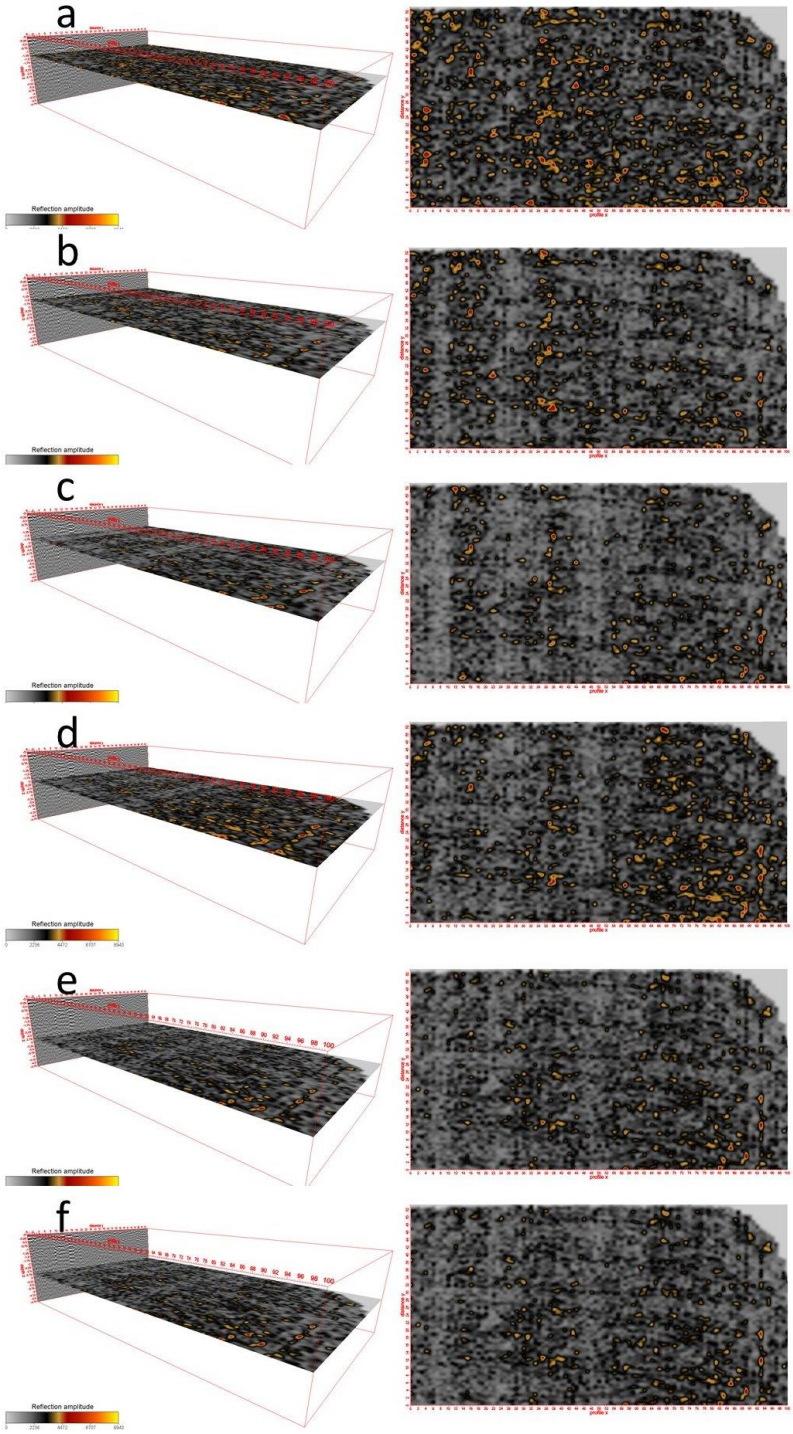

Figure 10. Geo-radar images from EBA II levels based on radiocarbon dates

a- 1.25 meters depth from the surface **b-** 1.50 meters depth from the surface

c- 1.75 meters depth from the surface **d-** 2.00 meters depth from the surface

e- 2.25 meters depth from the surface **f-** 2.75 meters depth from the surface

The images obtained at 3 meters deep from the surface point to some wall fragments for the first time. Architectural remains become more evident in the scans from 2.75 m. Calibrated C-14 result from this level, where the fire layer started, indicates their date as 2680-2500 BC, in other words, the beginning of the EBA II according to the Anatolian Chronology (Fig.

10f). Rows of walls extending in an east-west direction are observed here, where probably a long street exists between rows of walls. Based on the images observed at a depth of 2.5 m from the surface, it can be asserted that the population density has shifted to the western side, and that there are also empty areas extending in the north-south direction that could be interpreted as streets. Clearer images from 2.25 m deep also support this point of view (Fig. 10e).

At this level, where the fire layer continues at 2 m deep, at 823.5 m above the sea level- architectural features are observed to continue in the same way. The street in the north-south direction, which corresponds to the centre of the research area, is much more clearly visible. A northwest-southeast street connecting to the main street is visible among the wall remains that are apparent on the western side. The building clusters between these spaces should be structures placed in the form of insulae. The C-14 results from this layer are dated to 2573-2466 BC, that is to the middle of the EBA II (Fig. 10d).

The best images are obtained from above, i.e. from 1.75 m, and especially from 1.5 m deep. Here are traces of rectangular structures lined side by side between the streets/alleys extending in north-south and northwest-southeast directions (Fig. 10b-c, fig. 11). The upper layer is 1.25 deep from the surface. C-14 results dated to the end of the EBA II indicate an interval of 2500 and 2395 BC. The sediment samples taken at this level indicate a strong fire. Geo-radar images also show that the architecture is highly dispersed, unlike other previous images. This suggests that the settlement in the area surveyed ended with a great fire at the end of the EBA II (Fig. 10a). Hence, very scarce architectural traces have been detected just above this destruction layer. No architectural elements were detected at 1 m deep between these layers and the surface soil. This interval is completely empty; which is a fact that indicates that this area was not settled in the EBA III after this great destruction (Fig. 12).

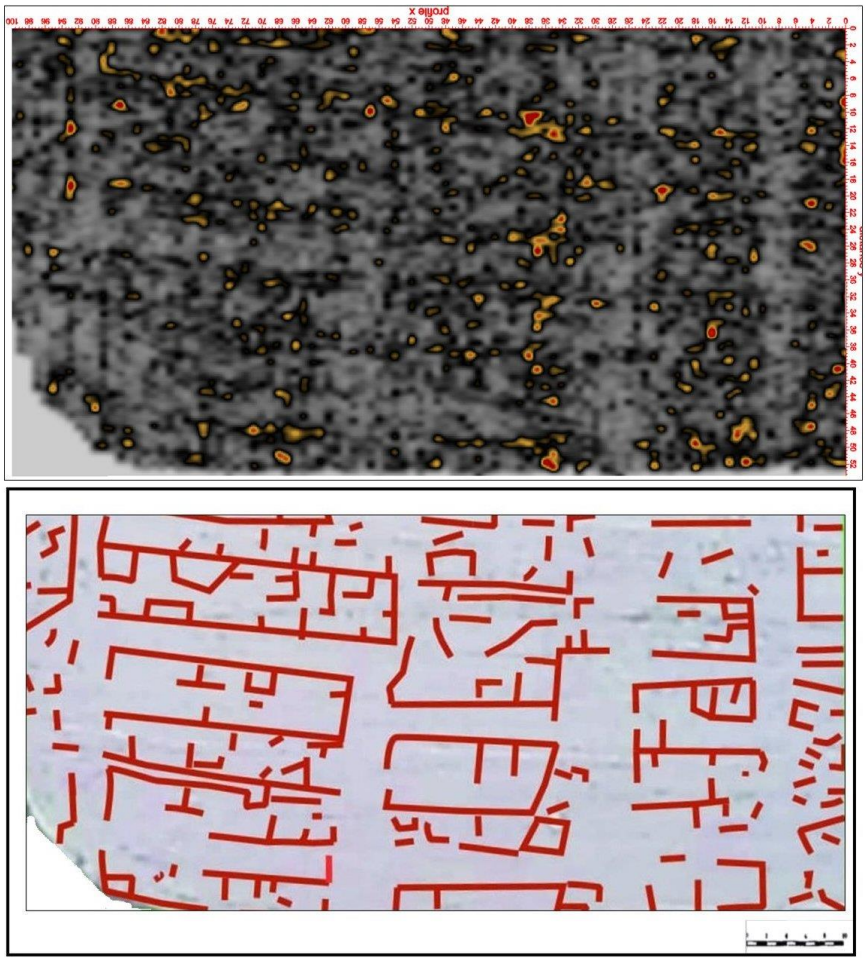

Figure 11. Geo-radar view from the EBA II layer and a restitution attempt of settlement layout

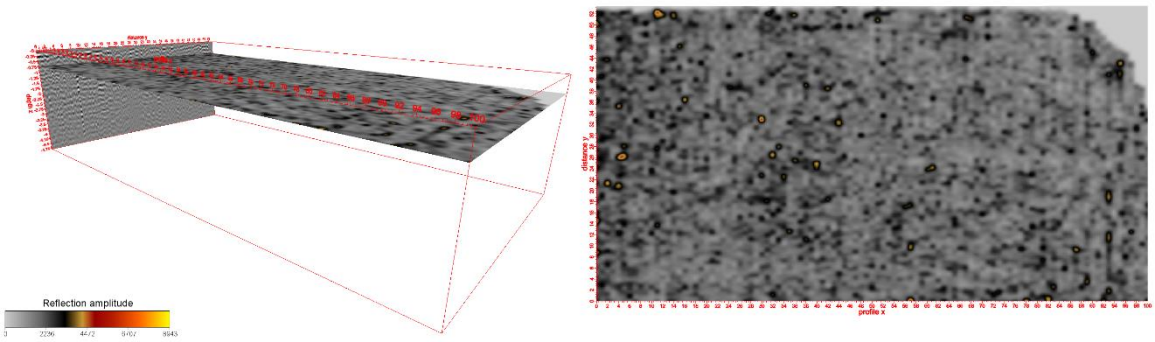

Figure 12. Geo-radar images from EBA III levels based on radiocarbon dates (0.75 meters depth from the surface)

4. DISCUSSION

Today, it is generally accepted that two different settlement patterns existed in Western Anatolia during the Early Bronze Age. The first was defined by M. Korfmann as the "Anatolian Settlement Plan" and referred to by the author as the "Inland Western Anatolian Settlement Model." However, as it is pointed out by new excavations in recent years this plan primarily dominated the inner parts of Western Anatolia (Korfmann, 1983: 222; Fidan 2013: 113-125; Fidan et al. 2015: 60-88). This is an enclosed system where the houses open to a common courtyard facing each other, or where the backsides of the houses function as an enclosure wall. This system, known in Inland Western Anatolia since the Chalcolithic Period, was applied in Hacılar, Ilıpınar, and Aktopraklık during the mentioned period. This system was known in almost all centres excavated in Inland Western Anatolia settled during the Early Bronze Age (Mellaart 1970; Cookson 2008: 149-203; Karul 2009: 1-7). Demircihöyük, Seyitömer, Küllüoba, Keçiçayırı, Çiledir (Türktüzün et al. 2014) Karaoğlan, Karataş Semayük, Hacılar Büyük Höyük, Bademağacı, and Kandilkırı are among the most important examples of these settlements (Korfmann 1983a: 179-222; Bilgen 2010: 265; Fidan 2012: 1-14); Fidan 2016: 87-99; Topbaş et al. 1998: 21-94; Mellink 1974: 351-359; Duru, Umurtak 2013: 1-22; Duru, Umurtak 2010: 261-268; Oğuzhanoğlu-Akay 2019: 239-252). However, the dimensions of these settlements are not quite large. Even the largest one of these, the Küllüoba EBA settlement does not spread over 5 hectares (Fig. 13).

Compared to Inland Western Anatolia a different system existed in the coastal zone of Western Anatolia and in the Aegean Islands. Most of the settlements in these regions are in the form of clusters of houses (insulae) around the streets and alleys (Fig. 12). This system does not feature a common courtyard to where the surrounding houses are facing and is observed in the settlements of Liman Tepe, Bakla Tepe, Troia, Yenibademli, Thermi, Samos, Poliochni, and the Cyclades (Erkanal et al. 2003: 423-437; Erkanal, Özkan 1996: 261-280; Mellaart 1959: 131-162; Ünlüsoy 2006: 133-137; Hüryılmaz 1998: 357-377; Lamb 1936: 291; Milojčić 1961: 96; Theochari, Parlama 1997: 344-356; Watrous 1994: 695-753).

Tavşanlı Höyük, where geo-radar studies have been carried out, is geographically located in between of this two systems, although it is closer to Inland Western Anatolia. In addition, unlike other Inland Western Anatolian settlements excavated so far, surveys show that Tavşanlı Höyük was occupying an area larger than 40 hectares during the Bronze Age. The images observed by the geo-radar studies clearly show the buildings and building groups that were built quite orderly and separated by the streets. The settlement model is similar to those settlements from coastal area and the Aegean islands which is surprisingly very similar to Thermi settlement on Lesbos Island in the North Aegean (Fig. 14). This settlement model, which consists of streets and alleys and surrounding structures, has been encountered for the first time in Inland Western Anatolia, perhaps not a surprise considering the huge size of Tavşanlı settlement compared to other excavated settlements. Due to its features such as these, it is deducted that Tavşanlı Höyük was a large settlement housing a large population during the EBA II Period, and possibly, was an important centre for the region.[1]

[1] Also Beycesultan Höyük is one of the largest mounds in Inland Western Anatolia. The Early Bronze Age layers have not been reached in this settlement in a large area yet, while its excavation is ongoing since 2006 by Prof. Dr. Eşref Abay, a member of Ege University Faculty of Letters Department of Archaeology.

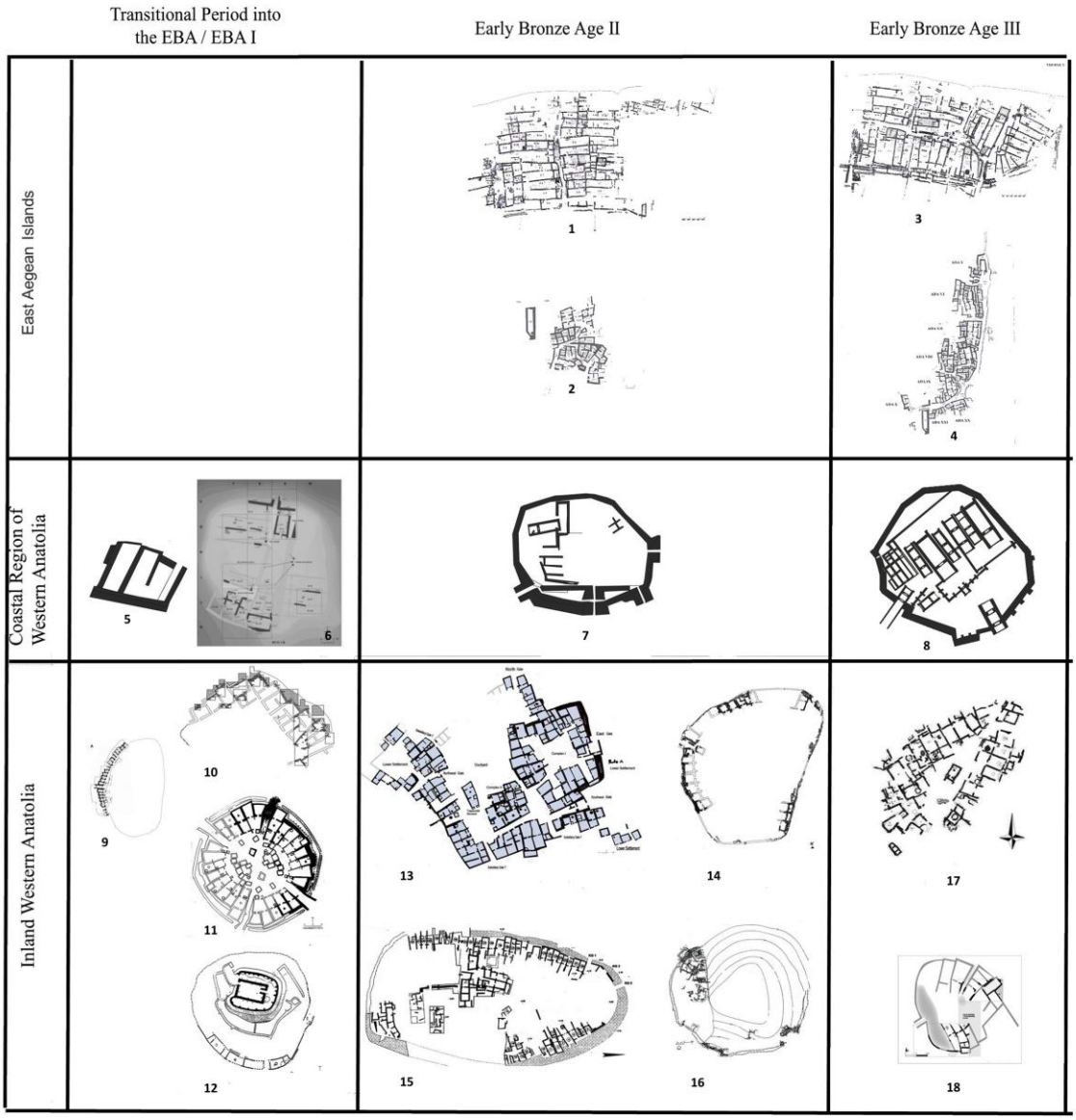

Figure 13. Early Bronze Age settlement plans in Western Anatolia and East Aegean Islands [1. Thermi: Lamb 1936, Fig 5; 2. Poliochni: Bernabò-Brea 1964, Fig. 24; 3. Thermi: Lamb 1936, Fig. 6; 4. Poliochni: Bernabò-Brea 1964, Fig. 25; 5. Liman Tepe: Kouka 2010, fig 3; 6. Bakla Tepe: Gündoğan 2020; fig. 5; 7. Troia: Mellaart 1959: fig. 2;, 8. Troia: Mellaart 1959: fig. 6; 9. Hacılar Büyük Höyük: Umurtak 2015: Fig. 3; 10. Küllüoba: Fidan 2012; Fig. 8; 11. Demircihöyük: Korfmann 1983, abb. 343; 12. Karataş-Semayük: Mellink 1974, fig. 1; 13. Küllüoba; Fidan 2018, Fig. 4; 14. Keçiçayırı: Fidan 2016, Fig. 5; 15. Bademağacı Duru & Umurtak 2010, fig. 2; 16. Karaoğlan Mevkii: Topbaş et al.1998, fig. 2; 17. Seyitömer: Bilgen 2010, 565; 18. Kandilkırı: Oğuzhanoğlu Akay, 2019, Fig. 7].

In addition, our research shows that the Tavşanlı Höyük EBA II settlement (2700-2400 BC) ended with a great fire and was not reoccupied at least in the large area explored. On the other hand, sherds from the EBA III Period (2400-2200 BC) were collected during the comprehensive survey around the mound, but it is very difficult to suggest anything about the size and extension of the EBA III settlement with the available data at the moment. As known, the interval between EBA II and EBA III is a breaking point in Western Anatolia. Many studies conducted in Western Anatolia have emphasized that the number of settlements decreased sharply during the EBA III Period (Dedeoğlu 2014: 20-42). The situation at the end of the EBA II period in Tavşanlı Höyük, whose settlement type was identified, and the fire layers were dated by geo-archaeological drills, may have resulted from the conflict between opposite rulers who were seeking to gain the political dominance in the region, as stated by many researchers who were previously interested on this subject (Efe 2004: 15-29).

Figure 14. Comparison of the EBA II period Thermi and Tavşanlı Höyük settlement layouts in terms of architectural plans

5. CONCLUSION

The studies carried out in Tavşanlı Höyük showed that the results obtained by using archaeometrical techniques in a survey could deliver important results without an actual excavation (Liritzis and Korka 2019, Liritzis et. al. 2020). However, it should not be forgotten that excavation is the most important tool for collecting information. On the other hand, this study once again shows the importance of applying such archaeometrical survey techniques prior to actual excavations (For the similar efforts with past activities: De Man et. al. 2017, Thomas et. al. 2018, Levy et. al. 2018, Jean-Candon and Jimenez-Hernandez 2019, Aydıngün v.d. 2020). As a result, extensive surveys carried out in Tavşanlı Höyük, one of the largest mounds of Inland Western Anatolia, have provided novel information regarding the Bronze Age of the region. Especially the images provided by the geo-radar show that there is a settlement system with streets and alleys. The C-14 dates obtained by geo-archaeological drills have provided absolute dates for these layers. The results indicate that valuable information will be obtained from this settlement in case future excavations are carried out in Tavşanlı Höyük.

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APPENDIX

The Features of the GPR System:

Mechanical and Environmental Specifications:

Dimensions LxWxD (mm)	380x295x160
Weight (kg)	2.6
Fastening points LxW (mm)	210x160
Ingress Protection	IP65
Operating Temperature (°C)	-25°C up to +40°C
Relative Humidity (%)	99 (NC)

Electrical Specifications:

Antenna Type	Quarter Wavelength Bowtie
Shield Type	Top and Side Shield
Distance Between the TX and RX	140 mm
Feed point impedance	328 Ω
Transmitted Pulse Amplitude (Volts)	100 V
Receiver Sensitivity	14 µV
Dynamic Range	137dB
Antenna Bandwidth (at 10dB)	99%
Antenna Center frequency at 10dB BW	307 MHz
Survey Wheel Output Voltage	5.01 V

Recommended Specifications:

Pulse Repetition Frequency, PRF	≥50 kHz
Scan Rate	100 Traces/Second
Range (depending on soil penetration)	32-128 ns
Low Pass Filter Cut-Off Frequency	600 MHz
High Pass Filter Cut-Off Frequency	150 MHz
Gain	Adjust to 75% Swing

After the preliminary examination, data collection was initiated in selected areas in parallel with a maximum interval of 100 cm. Data collecting activity was handled with the GAS application.

The attributes of collected data are as follows:

Scan type; 110 ns Trace frequency; 54 trace/m.

Scan frequency; 512 sample/scan

Data gain; Start 5dB – End 15dB Signal Position; 5ns

Data output; 16bit digital raw data

The size of the scanned area is approximately 50 x 100 m and 101 GPR profiles are collected in total. In this study, the following data processing steps were applied to the data obtained with 110 ns scan type using the GPRSoft PRO & 3D off-the-shelf data processing application.

Static correction; 10ns, DC Shift,

Dewow (1D filter); 7 – 8 ns Custom gain; 8 dots (Linear)

1. :-9dB
2. : 9dB
3. : 15dB
4. : 15dB
5. : 15dB
6. : 15dB
7. : 17dB
8. : 17dB
9. : 17dB
10. : 17dB

2D filter, FIR HP 100 MHz – LP 700 MHz,

Background Removal; Index ;100, Start; 0ns – 100 ns

Custom Gain; 8 dots (Linear)

1. : 9dB
2. : 9dB
3. : 9dB
4. : 9dB
5. : 9dB
6. : 8dB
7. : 8dB
8. : 8dB

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