SURVEYING AND MAPPING USING MOBILE PHONE IN ARCHAEOLOGICAL SETTLEMENTS

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ABSTRACT:

Depending on the development of technology, the boundary concept between different disciplines became unclear today and it became necessary to work jointly depending on data sharing. Also Producing the maps is effected the development of the technology and positioning of desired area is become very fast. Today, instead of hand GPS, users can be obtained coordinate desired via programs which are compatible with mobile phone. CORS (Continuously Operation Reference System) GNSS (Global Navigation Satellite System) receivers which measure points coordinates (x, y, h) at all weather conditions, day and night will become compatible Mobil PC devices (Mobil Phone) via compatible software.

By means of this study, including the surveys of Ancient History and Archaeology sciences, different samples belonging to different periods have been evaluated. In this study, coordinates obtained with CORS-TR (Continuously Operation Reference System- TuRkey) and Asus Zenfone 6 in which Kocaman Pro Software was used at selected areas compare with each and the usage of Asus Zenfone 6 was investigated in term of easiness and accuracy in Archaeological Settlements. This study was carried out at the Hatıp Castle, Malas II and Campus ruins in Konya. Only horizontal accuracy (x, y) was investigated. The horizontal accuracy is higher in Malas II and Campus ruins than Hatıp Castle. This is due to the distance of the GSM networks to the application area.

Key-words: *Map, Coordinates, Measurement, Accuracy, Mobile Phone, Archaeological Settlement.*

1. INTRODUCTION

Today, parallel to the development of technology, the speed of access to information is increasing. As a result, the boundary concept between different disciplines became unclear and it became compulsory to collaborate according to data sharing. Today, the transformation of computers into mobile phones has also affected devices which are used to produce maps. So, via CORS (Continuously Operation Reference System) points coordinates has become to obtained at all weather conditions, day and night. Archaeological applications also need to get the coordinate information which is the main topic of Geomatics Engineering. Different disciplines are users of coordinate information. It does not expect to know by Archaeological applications that information about map

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projection (UTM 3 and UTM 6) and different coordinates systems (WGS84 and ED50) used by Geomatics Engineering.

Thanks to parallel developments in mobile phones and computer technology, users can obtain easier information about coordinates. In the last years, the purpose of the usage of mobile phone changed because of the development of mobile phone. As a result of the development of the mobile phone, other users in Archaeological applications, start to obtain coordinate via mobile phone instead of hand GPS. It has a great importance that the visual presentation of the obtained coordinates data via Google Earth Program etc. It is hoped that today's CORS-compliant GNSS devices will be compatible with Mobile PC devices (mobile phone, computer use), which will carry out the evolution of mobile phones and computers in the future and will have multiple functions.

In social areas such as Archeology, Art History and Ancient History, land studies are also important in addition to literature studies. In archaeological excavations and surface surveys, the coordinates of the studied ruins must be determined and transferred to the map. In order for these studies to be carried out in a healthy way, it is a necessity to make use of the possibilities provided by technology. In this sense, taking into consideration the interdisciplinary working principle, not only experts in the field of social sciences but also researchers in other disciplines should be involved in field studies.

Although access to information facilitated in this age, scientific study has not been done yet about Mobile phone surveying and mapping program to obtain coordinate information. Stauffer & Thale (2014) compares the coordinate data obtained with a tablet computer and a GNSS device. This study is the closest to this subject. Howard (2007), Flexner (2009), Di Giacomo et al. (2011), Barlindhaug (2012), Roosevelt (2014), Marcos-Sáiz & Fernández-Lomana (2015), Yumono & Susetyo (2015), Mira (2016) studied on the mapping of historical sites.

In this study, the usability of coordinates which were obtained by Kocaman Pro has been investigated in Archaeological applications. In the study, point coordinates (x, y) were determined by making Topcon Hiper V GNSS receiver and three epoch CORS RTK measurements at the points determined by the stakes. At the same points, before 1 April 2014 with Asus Zenfone 6 mobile phone, point coordinates were determined first by using Turkcell, Avea (Turk Telecom) and Vodafone GSM lines and then compared with CORS RTK coordinates. In the selection of places to be surveyed, different samples were taken into consideration both in the form of settlement and in the frame of archaeological surface researches carried out by the Ancient History and Archeology sciences. From these, Hatıp Castle B. C. II. A possible castle from the end of the millennium to the Hellenistic Age; Malas B. C. III. A thousand years and a Roman settlement on top of a hill or maybe a castle, Campus is a hillside settlement of the Hellenistic and Roman periods. The measurement locations are displayed in 3D mapping and in the Google Earth program. By comparing CORS-TR coordinates, which is the basic coordinate used in mapping, and coordinate data obtained by mobile phone surveying and mapping, it is aimed to investigate the possibilities of today's technology in terms of user convenience and accuracy in order to obtain coordinate data of users who need coordinates in different disciplines.

2. THE FIELDS OF APPLICATION

Konya is in the transition region between the Central and Western Anatolia. The earliest settlements of the region dates back to the Paleolithic Age (M.Ö. 1.000.000-10.000). Among the earliest settlements, there are Kürtini, Pınarbaşı, Boncuklu Mound. In

Neolithic Age the settlement is much Basin denser in Konya. Among the most well-known settlements of this age, we can name Suberde, Erbaba, Canhasan and Çatalhöyük. This density around Konya continues without decreasing even in the following ages. This situation results from the position of the region that is on the intersection point of the important historical and natural roads and has wide and fertile cultivated areas (Bahar et al, 1996). In the determination of our study, the position of the region has been regarded and within the scope of archeological surveys carried out by the sciences of Ancient History and Archeology, Hatıp Castle, Malas and Campus which are different samples in terms of both the way of settlement and the dating have been evaluated.

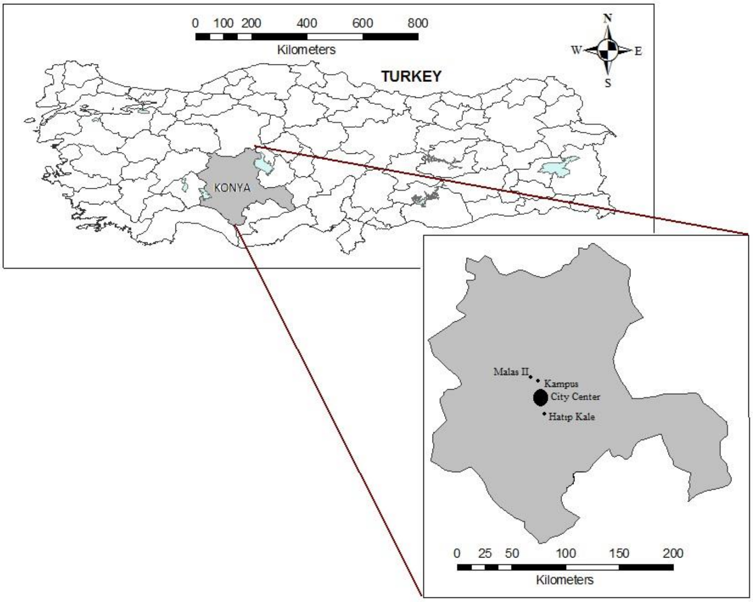

Fig. 1. View of the Study Field (Konya City).

2.1. Hatıp Castle

Hatıp is settlement of the Meram District in Konya City. Hatıp Castle situates in the south-west of city center and roughly in the west of Konya Plain. The elevations created by the cliffs nearby were chosen as a settlement area about 3000 years ago. This situation continued at intervals until the Roman Period. Even today, there are a great number of water springs around the cliff part. A god figurine and hieroglyphics dated back Hittite Period are located nearly 5 m. above these springs (Bahar et al, 1996; Bahar, 1996 a; Bahar, 1996 b; Bahar, 1996 c; Bahar, 1998; Bahar et al, 2007).

Hatıp Castle is roughly round-planned and in diameter of 40 m. It is possible to pursue the wall remains belonging to this castle whose only the foundation has come today (**Fig. 2a**). Around this area, the ceramics of Hellenistic- Roman Period mostly which belong to the Iron Age (Late Iron Age) (**Fig. 2b**). The springs in this area probably had an important effect in founding and developing the early settlements in the region. Thus, the findings obtained from Hatıp Mound, which is on the plain in the west of the cliffs prove that this neighborhood has a past dating the Bronze Age. In this field, not only the castle we study on and the reliefs dating the Hittite Period but also the spring rising from under the cliffs here show that this area is to be historically and naturally protected. Because of all these features, a nice touristic restaurant together with a trout production facility gives service here nowadays.

a b

Fig. 2. The View of Hatıp Castle (a) Sherds of Hatıp Castle (b).

2.2. Malas II Settlement

Malas II settlement situates in the north/northwest of Konya Plain and it is settlement on a hill that places on a natural cliff lying towards the highlands. Here is 4 km west of the Selcuk University Campus and takes place on the road of Malas (Ardıçlı) - Bilecik (Yükselen) (**Fig. 3**).

Fig. 3. The View of Malas II Settlement.

This area is the region of the animal husbandry, mining, limited agriculture, and viticulture. Moreover, it controls the springs (like Kestel) that water the fertile fields of the plain. This settlement that controls the east- west roads is the leading of the roads that open to the Pisidia Region. The location of the settlement provides to control a very large bottom land on the north-east. In the settlement, the findings of Early Bronze Age, Roman /Late Ancient Age are the most seen ones. Just like reflecting the properties of the highlands, EBA ceramics indicate the rough-hewn characteristics. The architectural remains on the surface give the properties of later periods more. A great number of samples belonging to not only the potteries and tripod pieces but also the pans have been seen here (**Fig. 4**). On the cover and potteries, there are lid sherds and lid handles (Bahar & Koçak, 2003; Bahar & Koçak, 2004).

Archeological data clearly indicates that this area dates about 4500 years ago before present day (in the middle of the 3000s B.C.). In this period called EBA (EB2) in literature, on the hill that is in Malas II site, there was a small village. This area was inhabited again about 2500 years later, in the period of Roman in Anatolia. In the Roman Period, one can see too many settlements and cemeteries not only in Malas II but also on the sides of the heights nearby. As in the following example, Campus is one of these settlements.

Fig. 4. Sherds of Malas II Settlement.

2.3. Campus Settlement

Campus Settlement is located in the north/northwest of Konya Plain and it is a part of a large Ancient Age archeological site that is on the slopes 2,8 km southeast of Malas II (**Fig. 5a**). This area was used for both inhabiting and cemetery (necropolis) in the Iron Age, Hellenistic and Roman Periods (**Fig. 5b)**. The big architectural blocks on the Campus settlement are regarded as the proof of the Roman housing here. This example is important in terms of evaluating the slope settlements. The fact that the Ancient Age locations had wide ranges makes it hard to determine these settlements. The example we have is a small slope that belongs to such a site. The observations we have made on the field show that this area lies towards the settlements and cemeteries especially on the north and west. The structure remains or architectural blocks and ceramics have been important materials to locate this archeological site.

a b

Fig. 5. The View of Campus Settlement (a) Sherds of Campus Settlement (b).

3. DETERMINATION OF POINT POSITIONS WITH NETWORK-RTK

Real Time Kinematic (RTK) is a technique used to enhance the precision of position data derived from satellite-based positioning systems (Global Navigation Satellite Systems, GNSS) such as GPS, GLONASS, Galileo, and BeiDou. It uses measurements of the phase of the signal's carrier wave, rather than the information content of the signal, and relies on a single reference station or interpolated virtual station to provide real-time corrections, providing up to centimeter-level accuracy. With reference to GPS in particular, the system is commonly referred to as Carrier-Phase Enhancement, or CPGPS. RTK technique is a Network RTK depending on shapes of application. In RTK technique, dual-frequency GNSS receivers are used in both the rover and reference receiver. In addition, this method includes a radio station that broadcasts phase measurement corrections calculated differently from the static and kinematic GNSS measurement methods used in point location, while the rover receiver has a radio receiver that receives these corrections.

In RTK application, the correction information calculated at a reference station is sent to the user. In order to avoid systematic errors (atmospheric effects, orbit error effects, etc.), the distance between the reference station and the rover receiver should not exceed 10 km (Rizos, 2002). The accuracy achieved with the RTK GPS technique in cm is sufficient for many Geomatics Engineering applications. In order to overcome the limitation of the RTK made by a single reference receiver, the world of science and technology has been constantly searching and the Network RTK method has been developed as a result of these searches.

In the Network RTK system, the dependence on a single reference station has ceased to exist, and atmospheric modeling of a specific region has been made possible by utilizing data belonging to a large number of reference stations and The power of GNSS observation techniques combined with the advantages of network structure (network adjustment) (Kahveci, 2009). The rover receiver in the network RTK system is connected to the server in one or two different ways (such as a radio modem, Global System for Mobile Communications (GSM), or the Internet). The rover receiver computes the position according to an appropriate algorithm without receiving real-time kinematic data. Different methods are used to transfer network data to rover receivers. These methods vary depending on the information to be sent, the data transfer protocol (format) and the data transferring environment (radio, GPRS, etc.) when the corrections are made at the reference station or at the rover receivers (Pektaş, 2010). As a result, Network RTK is a technique of real-time points positioning of cm-accuracy based on phase observations at longer base lengths (50-100 km) than the RTK technique.

With the network RTK, the point coordinates are determined in a single meaningful and homogeneous coordinate system, high quality results are obtained and the necessary corrections for the measurement point can be calculated by interpolation using the atmospheric model created for the entire network.

There are many networks in the world that work with the Network RTK technique. For examples of these,

- US NGS CORS Network (URL1, 2016)
- Germany SAPOS Network (URL2, 2016)
- Japan GEONET Network (URL3, 2016)

can be shown.

For this purpose, TUSAGA-Active (Turkish National Permanent GNSS Network-Active (CORS-TR)) network consisting of 146 points has been established in Turkey (**Fig. 6**). An active CORS approach has been adopted in the CORS-TR project. Here, the CORS stations covering the whole country are connected to a control center where the locations of stations and atmospheric corrections are continuously calculated. Thus, the atmosphere and positioning corrections can be modeled throughout the country. As a result, the clocks go down to the required GNSS measurement times, minutes and even seconds and base lengths also grow by about 10 times (Eren & Uzel, 2008). CORS-TR system is a paid system, correction is send rover receivers via internet so GSM is important at CORS-TR applications.

Fig. 6. TNPGN-Active point distributions.

4. APPLICATION AND RESULTS

In the study, determined coordinates were obtained with Topcon Hiper V GNSS receiver and Asus Zenfone 6 mobile phone using Kocaman Pro software.

4.1. Topcon Hiper V GNSS Receiver

It is a GNSS receiver manufactured by Topcon with 226 channel, capability to track GPS, GLONASS and GALELIO satellites (**Fig. 8a**). The receiver is configured with radio and GSM modem. The characteristics of the receiver are given in **Table 1**.

Table 1.

Technical characteristics of Topcon Hiper V GNSS receiver.

Tracking Capabilities	**Positioning Accuracy**	**Wireless Communication**
Number of Channels 226 Channels with Universal Tracking Technology Tracked Signal GPS L1 CA, L1/L2 P-code, L2C GLONASS L1/L2 CA, L1/L2 P-code SBAS WAAS, EGNOS, MSAS, QZSS	Static L1+L2 H: 3mm + 0.5ppm V: 5mm + 0.5ppm L1 only H: 3mm + 0.8ppm V: 4mm + 1ppm RTK, Kinematic L1+L2 H: 10mm + 1ppm V: 15mm + 1ppm DGPS <0.5 m	Bluetooth® V2.1 + EDR, Class 2, 115,200bps Radio UHF, Spread Spectrum, Cellular (options)
Environmental	**Physical**	**Power Supply**
Dust/ Water Protection IP67 Shock 6.56 ft. (2m) pole drop Operating Temperature External Power -40°F to +149°F (-40°C to +65°C) Battery -4°F to +149°F (-20°C to +65°C) Cellular -4° to +131°F (-20° to +55°C)	Enclosure Magnesium alloy Size 7.24" D x 3.74 "H Weight Hiper V receiver 2.20 lb. to 2.82 lb (1.0 kg to 1.28 kg) Battery (BDC70) 7.23 oz. (195 gr)	Standard Battery Detachable, Li-on rechargeable battery, 7.2V, 4.3 Ah Operating Time > 7.5 hours in static mode At 68°F (20°C) Bluetooth connection External Powers Input Voltage 6.7 - 18V DC

4.2. Asus Zenfone 6

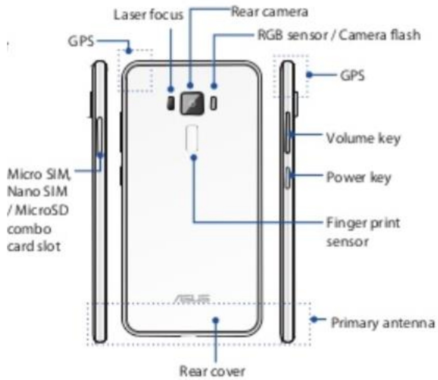

Fig. 7. Asus Zenfone 6 GPS chip.

The characteristics of Asus Zenfone 6 (**Fig. 8b**) which is used in the study are given at **Table 2**. Asus Zenfone 6 has GPS chip, and via GPS chip it can be calculated point coordinates (**Fig. 7**).

According to Kahveci & Yildiz (2012), there are Quad-helix and Patch antenna types in hand GPS. The Quad-helix antenna is the best result when held vertically, while the Patch is kept parallel to the ground.

Table 2.

The Characteristics of Asus Zenfone 6 (URL 5, 2017)

Platform	**Color**	**Dimensions**
Android OS, v4.3 (Jelly Bean)	Charcoal Black, Pearl White, Cherry Red, Champagne Gold	166.9 x 84.3 x 9.9 mm (UxGxY)
Weight	**Chipset**	**Memory**
196 g	Intel® Atom™ Z2560 (1.6 GHz)	2 GB LPDDR2 RAM
External Memory	**Card slot**	**COMMS**
16GB/32GB eMMC Flash 5GB ASUS Web Storage Cloud Storage	MicroSD card (64 GB)	WLAN 802.11 b/g/n Bluetooth V4.0+EDR +A2DP GPS (A-GPS) Dual Micro SIM card **
Network Standard	**Display**	**Battery**
UMTS/WCDMA DC-HSPA+ Upload: 5.76 Mbps Download: 42 Mbps 3G: UMTS 850/900/1900/2100 2G: EDGE/GPRS/GSM 850/900/1800/1900	6 inch, HD 1280x720, IPS LCD capacitive touch screen, Multi-touch	Non-removable Li-Po 3300 mAh battery (12 Wh)
browser	**E-Mail**	**Sensor**
Google Browser/IE Browser	Google Mail/Exchange/POP3	E-Compass/Gyroscope/ closeness

4.3. Kocaman Pro Software

Kocaman Pro software was developed as alternative to Kocaman 2.0 software. Kocaman 2.0 software is a free application. Kocaman Pro software are operating at mobile phone which use Android operating systems. The purpose of Kocaman Pro software is that it can be used at advanced Geomatics Engineering applications (URL 6, 2017).

The coordinates of desired point are obtained in different datum [ITRF96 (UTM3), ED50 (UTM3), ITRF96 (UTM6), ED50 (UTM6) and WGS84 Geographical)] with this program. Additionally, the program is made application, tacheometric surveying, base mathematical computation for Geomatics Engineering applications (horizontal angle, set out, curve applications vb.), 2D transformation (WGS84 Geographical/WGS84 UTM, WGS 84 UTM/WGS 84 Geographical, WGS 84 Geographical/ED 50 UTM, ED 50 UTM/WGS 84 Geographical) and calculation of section areas. Both obtained coordinate and calculated area is shown at program and they can be stored at Google Earth format (.klm). Main screen view of Kocaman Pro software at mobile phone is shown **Figure 8c**.

a b c

Fig. 8. Topcon Hiper V (a), Asus Zenfone 6 (b) ve main screen view of Kocaman Pro software (c) (URL 4, 2016; URL 5, 2017; URL 6, 2017).

4.4 Measurements and Evaluating

At the three different archaeological sites selected, 3*3*15 cm sized wooden piles were put in to reflect the characteristics of the study areas and measurements were made the center of wooden piles (**Fig. 9a**). In the study, Topcon Hiper V GNSS receiver and VRS corrections techniques which gives the best performance and fast connection were used and points positioning were determined with CORS-TR Network (**Fig. 9b**) (İnal et al, 2015).

Accuracy of the used GNSS receiver is 1 cm + 1 ppm at horizontal direction. The measurements were conduct at 1 sn record interval and 5 epochs. Coordinates obtained with Asus Zenfone 6 mobile phone, using different GSM operators, were compared with the coordinates obtained from CORS-TR Network (**Fig. 9c**).

a b c

Fig. 9. View of used wooden pile (a); view of measurement with Topcon Hiper V GNSS Receiver (b); View of measurement with Asus Zenfone 6 using Kocaman Pro Software (c).

On 15-18.03.2016, coordinates of 44 points about 10 arc area at Konya Hatıp Castle archaeological site, 34 points about 10 arc area at Campus ruins site and 33 points about 4 arc area at Konya Malas II archaeological site were obtained with Asus Zenfone 6 mobile phone. Base on the coordinates which were determined with CORS-TR, coordinate differences (v_x, v_y) are calculated via;

$$v_x = x_i - x_{CORS\text{-}TRi} \qquad v_y = y_i - y_{CORS\text{-}TRi} \qquad (1)$$

root mean square error is calculated via:

$$m_x = \pm\sqrt{\frac{(v_x v_x)}{n-1}} \qquad m_y = \pm\sqrt{\frac{(v_y v_y)}{n-1}} \tag{2}$$

In equations (1-2) show,

x_i, y_i, : coordinates which are obtained with mobile phone at i points,
$x_{CORS\text{-}TRi}$, $y_{CORS\text{-}TRi}$: coordinates which are obtained with mobile phone at i points,
m_y, m_x : root mean squares (rms) error of x, y directions respectively

Calculated measurements differences and rms are showed at **Table 3**. It has been tested whether the difference between calculated accuracy of points positioning (mk) is significant. Test value is calculated with

$$F = \frac{m_1^2}{m_2^2} \tag{3}$$

In the usage of equations (3), it is taken that m1>m2. Obtained test value was compared with the value of F distribution table which is $F_{0.95,\ f1,\ f2}$. In addition to the determination of the site areas, positioning of these sites in the 2 Dimensional (2D) map according to the intensity of the architectural and small finds in the working areas is also important archeological sites (grades I, II and III) (**Fig. 10**). The 3D-maps of the study areas are shown at **Figure 11.**

Table 3.

Measurement and positioning error of selected areas.

Area	Difference statistics	Avea		Turkcell		Vodafone	
		dy (cm)	dx (cm)	dy (cm)	dx (cm)	dy (cm)	dx (cm)
MALAS RUINS	max	28.3	52.0	81.4	72.8	71.8	75.1
	min	-40.9	-36.3	-60.2	-58.5	-60.4	-42.4
	average	5.5	12.3	1.7	12.7	-3.0	11.2
	m_y, m_x	14.1	24.7	31.7	34.3	30.5	32.0
	m_k	28.5		46.8		44.2	
CAMPUS RUINS	max	30.0	39.6	87.5	86.1	64.1	61.8
	min	-43.7	-51.9	-84.7	-116.4	-27.6	-28.1
	average	1.0	-1.7	6.1	7.3	-2.7	11.5
	m_y, m_x	15.5	21.6	37.9	42.9	20.8	21.7
	m_k	26.6		57.2		30.1	
HATIP CASTLE	max	362.7	606.9	308.7	501.3	476.9	253.5
	min	-343.5	-457.0	-323.4	-474.3	-325.4	-709.4
	average	-23.5	-5.6	-20.7	-72.1	97.1	-173.5
	m_y, m_x	157.8	229.3	152.2	173.1	211.7	253.2
	m_k	278.4		230.46		330.1	

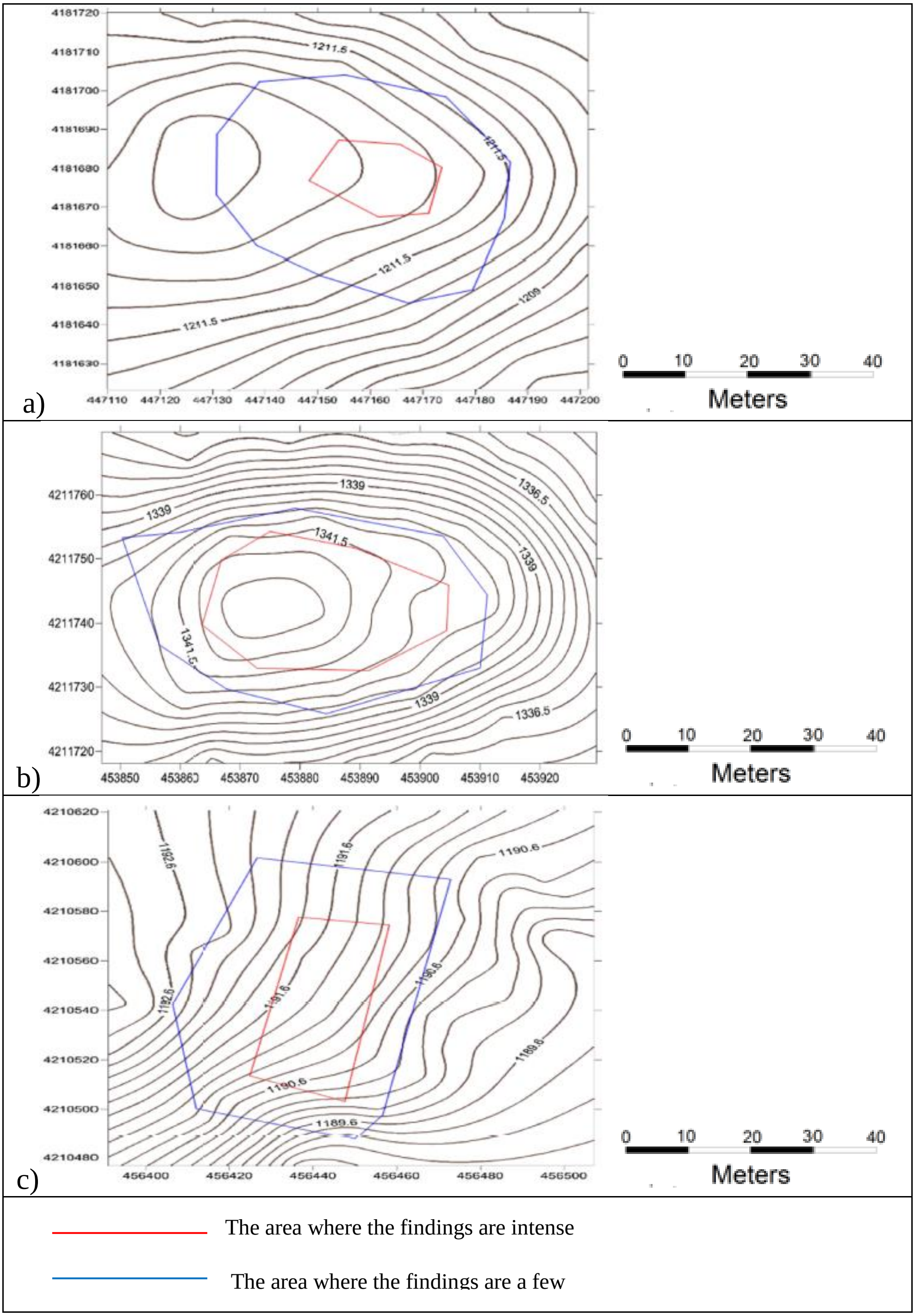

Fig. 10. The 2D maps of Hatıp Castle (a), Malas II Settlement (b) and Campus Ruins (c).

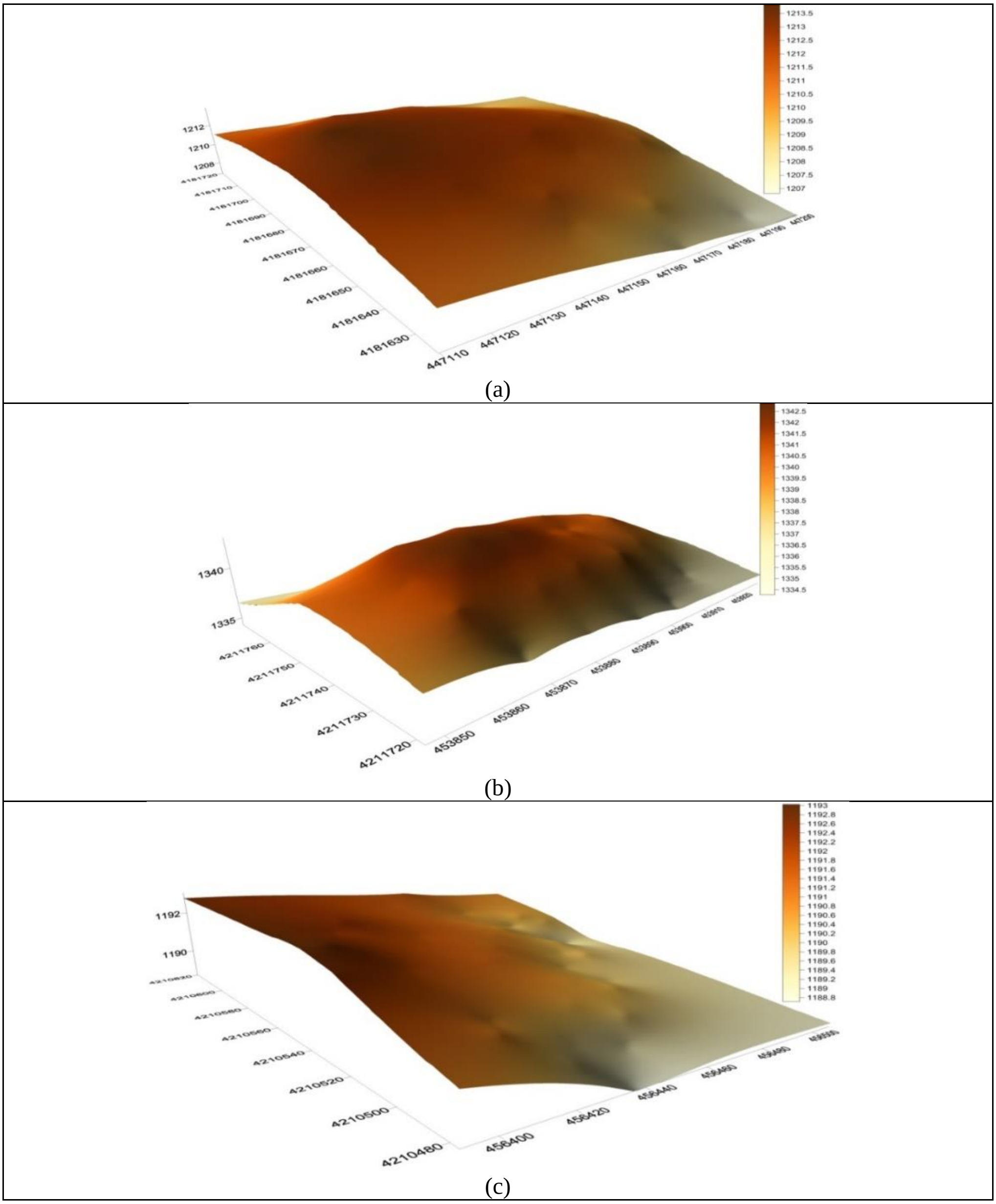

Fig. 11. The 3D maps of Hatıp Castle (a), Malas II (b) and Campus Ruins (c).

5. CONCLUSIONS

Anatolia is quite rich in terms of ancient artifacts. However, these artifacts cannot be evaluated properly. The most important problem is the lack of inventory. Also, this makes it hard to preserve and evaluate the artifacts. The first step for the studies on the ancient archaeological sites is that they have to be determined and documented. Then the scientific studies can be carried out in detail.

When determining the archaeological sites, the most important obstacle is to identify the area. This is quite hard job to do. The ones to work on this field should be able to do the survey and comment on it very well. The most important materials for the researchers are the archaeological ones identified on the surface. These are sometimes architectural materials, areas that became tumulus, gravestones, inscriptions, statues, terracotta potteries, loom weights and parts of stone materials. The new methods of determining the location and the area of archaeological sites spread are very important to preserve cultural heritage and to have them ready for the scientific studies. The new methods ahead should accelerate the processes of identification and documentation and also should minimize the margin of error. The borders of archaeological site should be well-determined for numerous reasons:

1- It provides data to the relevant institutions to preserve the sites.

2- It favours the area to be evaluated and commented.

3- It protects the rights of the owners of the land.

As a result of the comparison considering approximate square errors 2B spot positioning (horizontal accuracy) by means of GSM operators it is understood that: Avea (Turk Telecom) gives the best result in Malas Archaeological Sites, Turkcell and Vodafone follows equally correct results, Avea and Vodafone gives equally correct results in Campus archaeological area and then Turkcell follows; Turkcell gives the best result in Hatıp Castle, also Avea and Vodafone follows it respectively. It is compromised that the approximate errors in Campus and Malas II Region are close whereas the approximate error in Hatıp Castle is way different. It is understood that these problems stem from the distance between GSM Operators and the areas in question. Thus, when the place of the GSM Operators and the working areas are correlated this will clearly be seen.

When the results obtained from this study are examined, disciplines other than Geomatics Engineering can use android applications that are designed to find locations and coordinates in order to produce maps. Kocaman Pro software application is used in this study. It is understood that the location accuracy of GSM operators taken from Cell Towers is not more than 4 meters and this accuracy is enough for Archaeological usage. Therefore, the architectural structure and small findings (ceramics etc.) on Hatıp Castle, Malas II and Campus archaeological sites have been easy to position and show on the map. This will be the most important reference for the related institutions to determine whether the archaeological area should be protected. This study will also minimize the loss of the land owners.

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