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Is Submergence of the Saint Neophytos Basilica (Lake İznik, NW Turkey) Caused by AD740 Earthquake or Climate Change? Discussion of Geoelectrical Data

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Abstract: Aerial photograph surveys conducted in 2014 around Lake İznik lead to discover of the remains of underwater Byzantine basilica near the eastern shoreline of the lake. The base unit of this structure, which is about 20 meters off the shoreline at 2 meters water depth, is perfectly preserved up to the present. Archaeological research has argued that this structure has been collapsed due to the devastating AD740 earthquake. On the other hand, the existence of beachrock beds on the surveyed beach (near the protected area), which is just a few meters away from the basilica, makes an alternative interpretation possible. Beachrocks with broad distribution throughout the Lake İznik keep records of the climate changes in the late Holocene. Considering that the water level of the lake descended to 2 meters during arid periods, as supported by existing multiproxy data obtained from the sediment cores taken from the lake, existence of beachrock beds in the surveyed beach allows to think that beachrock may exists in the basilica area. In this case, if the basilica was built on beachrock beds, providing a hard and safe ground for the construction, then it may have been inundated due to rise of lake waters during the following rainy stage. This study was conducted to test the hypothesis briefly described above. Geoelectrical measurements were made using the Electrical Resistivity Tomography (ERT) method at the public beach located just 10 meters from the basilica. Beachrock beds (strike N10°E., dip 5°NW) crops in out in a limited area on the beach where the survey section was taken. ERT section was taken perpendicular to the shoreline to determine subsurface extension, thickness and the angle of dip of the buried beachrock beds as well as the existence of possible earthquake-related deformations. Our preliminary findings reveal that the measured values on resistivity values delineated the two distinct; beachrock units (>100ohm) and altered zones (100ohm<). The tomographic image shows that the beds which seem to have buried 50 cm below the surface have resistivity values over 120 ohm.m and have average dip at an angle of 10° towards the lake (i.e westward). The thickness of the buried sandstone is 1 meters. The fact that the beds are regularly inclined towards the lake, with no evidence for tectonic deformation, raise doubts about the impact of the AD740 earthquake on the collapse of the basilica. In addition, no significant deformation is observed in the underwater images of the basilica walls. In this case, if the geophysical surveys are conducted along the beach behind the basilica and if the beachrock beds are found below this underwater structure are determined, it is highly probable to obtain evidence confirming our hyphothesis.

Keywords: Electrical resistivity tomography, AD740 earthquake, St. Neophytos basilica, Lake İznik, Turkey

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1. Introduction

One of the distribution showed that the structure of the coastal environment beachrocks Turkey. There have been studies on the presence of beachrock on the coast of Mediterranean (Bener, 1974; Erol, 1983; Avşarcan, 1997; Desruelles et al., 2009; Çiner et al., 2009), the Sea of Marmara (Ertek et al., 2016), the Aegean Sea (Erol, 1972; Ertek and Erginal, 2003) and the Black Sea (Erginal et al., 2013). It is among the examples of the existence of the Yalta formation on the shores of the lake, e.g. Southeast of Lake Michigan (Binkley et al., 1980), Pyramid Lakes (USA) region (Benson, 1994), and Taupo Lake (Jones et al.) Are examples of the existence of the coastal lakes. Another recent example of beachrock is Lake İznik. İznik Lake, which has fresh water, is the only known example in the world about the formation of beachrocks in fresh water environment and it keeps the climatic records of the lake after the last ice age (Erginal et al., 2012., Öztürk et al., 2016).

The main scope of this study is located on the shores of Lake Iznik. It is an application of ERT in an area where seismic deformation records are kept in the seals around Neophytos Basilica. The fault causing the earthquake activity in the lake area is the segment that forms the northern part of the southern branch of the NAF. (Barka and Kadinsky-Cade, 1988). Numerous damaging and destructive earthquakes occurred both in historical and instrumental periods in the northern part of the southern branch in and around the study area. The earthquakes in the historical period are 29, 33, 69, 120, 368, 378, 715 and 1895 AD. Among these, the most important earthquake of AD715 is an IX magnitude earthquake and it was felt and damaged in other cities around Iznik (Ergin et al., 1967; Sosyal et al, 1981; Pınar Erdem and Lahn, 2001). Another aim of this study is to question the relationship of 1600 years determined from aerial photographs in 2014. Although there is no published scientific data, this Byzantine Basilica is thought to be sunken. The destructive earthquake of AD74 is discussed as a result of this earthquake or as a result of the rise of lake waters.

In this study, especially M.S. 740 and M.S. 715, three-dimensional modeling of the St Neophytos Basilica near the shore of Lake Iznik, using Electrical Resistivity Tomography (ERT) technology. In this way, it will be tried to reveal how the basilica, which is currently under water, is in this position.

2. Material and Method

The electrical resistivity method used in this study was first applied by Wenner in 1915, and in the 1920s, Schlumberger developed and obtained successful results in imaging the underground (Ward, 1988). With the development of technology, the devices used in geophysical methods have been developed and the underground structure has been evaluated in different dimensions. With this development, it was possible to eliminate the dependence on a single direction and to be in a uniform way and to make investigations with more realistic approaches (Berge, 2002; Drahor et al. 2004).

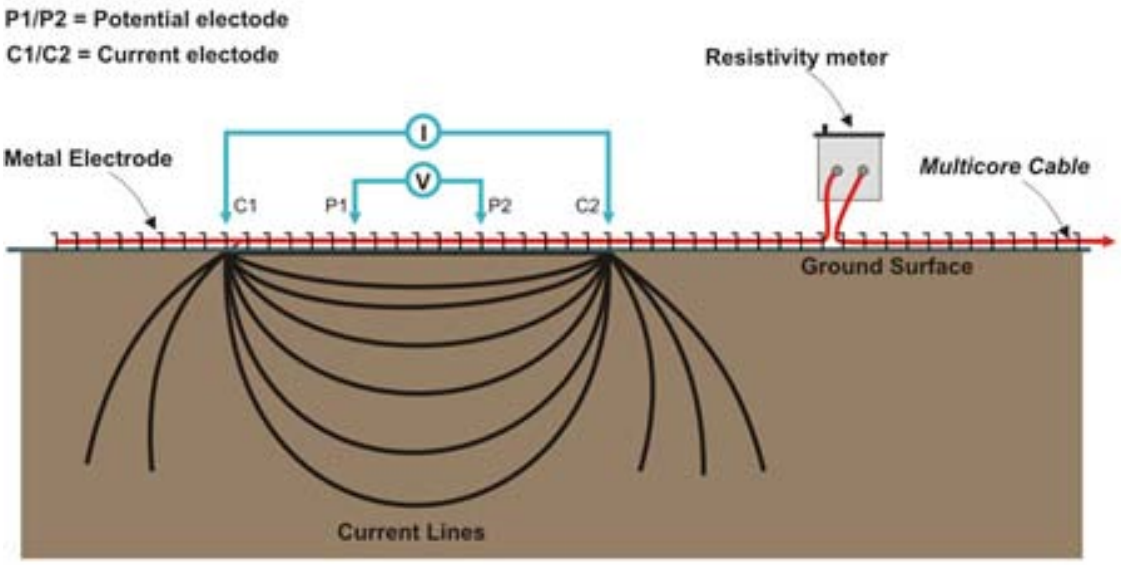


Figure 1. Electrical Resistivity method working principle in two dimensional representation: C1-C2 current electrodes P1-P2 potential electrodes versus current and voltage (voltage) lines formed in semi-infinite environment.

The current applied to the ground with the C1 and C2 electrodes creates a different voltage in the ground, and this difference is measured from the electrodes P1 and P2 (Figure 1). These voltage differences we measured vary according to the distance between the electrodes and the geological structure of the underground.

Resistivity values of geological units vary. The structure characteristics of these units may vary according to the water content in the environment and the temperature differences in the environment. Different resistivity values can be seen even in the same unit. It is not correct to define a unit with a single value. Resistivity values of geological materials are shown in Table 1.

Table 1. Resistivity values of geological materials

Geological material	Electrical resistivity Ωm
Wet excess clay soil	1-10
Wet excess silty soil and silty clay	< 10
Wet silty and sandy soil	10-100
Silt alternating sand and gravel	<1000
Coarse dry sand and gravel deposits	>1000
Very fractured rock with cracks filled with wet soil	100
Fractured rock with cracks filled with dry sand	<1000
Solid and robust rock	>1000

İznik Lake is located in the southeast of the Marmara region (Figure 2). From the west, it is bordered by the Paleozoic marbles and the Karsak Strait excavated in the Triassic metamorphic rocks. Iznik in the east and Orhangazi coastal plains to the west where the

maximum depth of the lake is 80 meters (Öztürk et al., 2009). Lake waters are warm-monomic (Franz et.al., 2006).

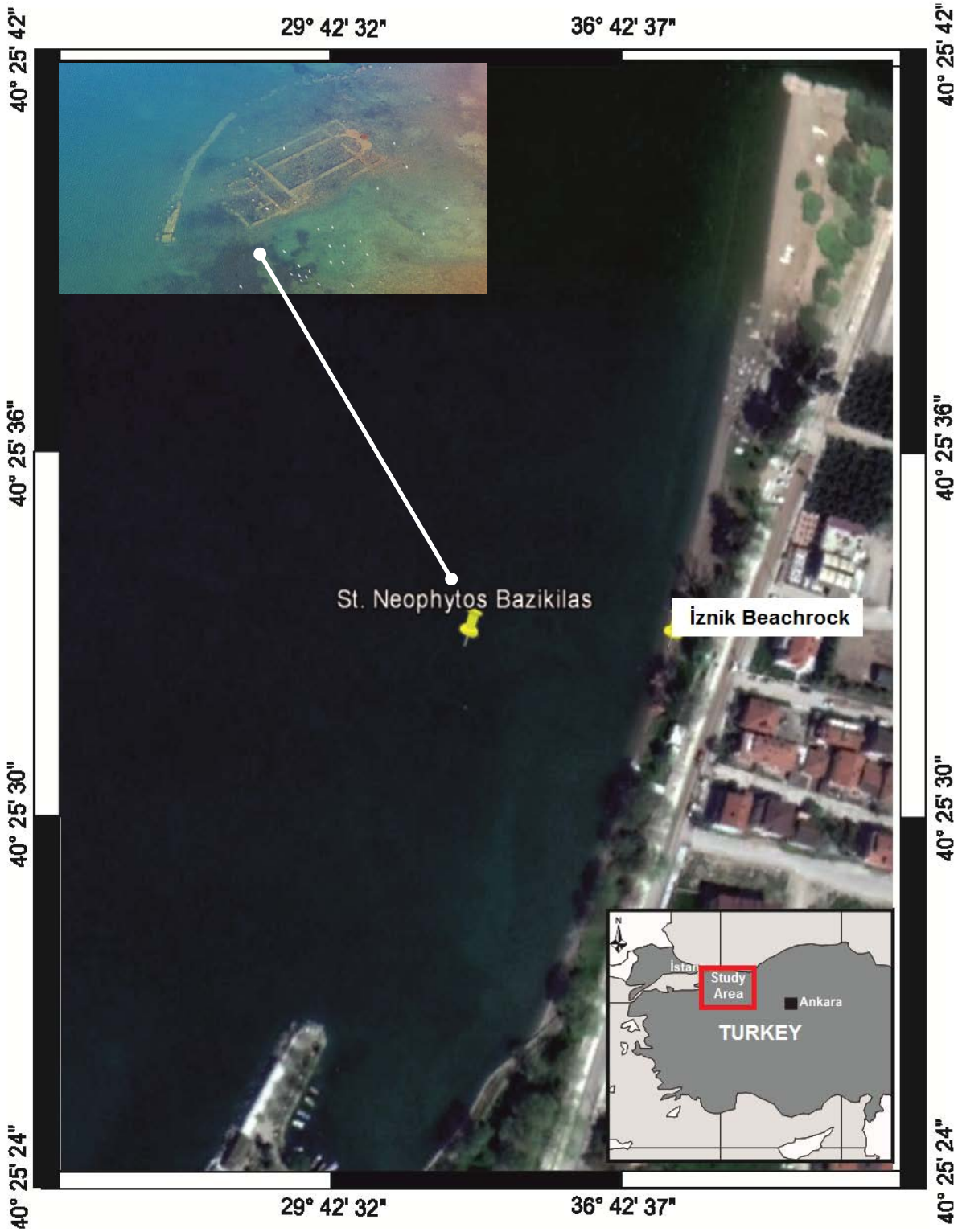


Figure 2. Satellite view and photo of the study area and its vicinity and location map (Google Earth, 2019. https:// earth.google.com / web / search, 26 May 2019..

Beachrocks are distributed in the southern, southwestern and northwestern parts of the lake. Tertiary units consist of Paleogene - Eocene flysch, Paleogene volcanics, Paleogene - volcanic alternating sedimentary rocks and Neogene sediments and these rock assemblages

are distributed in the south, southeast and northeast of the lake. Lastly, the alluvials forming the Orhangazi and İznik Plains of the Quaternary formations, especially the alluvial fan deposits in the southern part of the lake, travertine in the northern part and the coastal rocks observed in almost all coasts.

Within the scope of the field study, on 18.07.2019; it was studied in the beachrock area near the Basilica of Neophytos. In this context, firstly steel electrodes were installed in order to form two different profiles in the region. Steel electrodes have been installed quite easily since it is foreseen that the base stones are below the surface debris and the measurements are performed (Figures 3 and 4).



Figure 3. Beachrock study area and profiles near St. Neophytos Basilica.



Figure 4. ERT and GNSS measurements performed near St. Neophytos Basilica.

3. Results

In this study, the measurements of dipole-dipole electrode were performed on two different profiles in the electrical resistivity method. The measurements were made with geotronic resistivity instrument. The electrode spacing was measured by dipole-dipole alignment along the profile with a length of 1 m. After the apparent resistivity values were collected for each profile, the tomographic inversion solution program RES2DINV (Loke and Barker 1996) was used to obtain the ground electrical section. The land measurements taken were not included in the inverse solution by masking the program because of the variable values due to the difficult terrain. Due to some data which is noisy (showing high or low value according to the environment), the mistif values are in the range of 15-20%. However, sections obtained from both observational and theoretical data show similar structural changes. The results are presented in the same color range (Figures 5 and 6).

On 18.07.2019, in the studies carried out on the wall section next to the Basilica in the coastal part of İznik lake, Electrical Resistivity method which is one of the geophysical methods was used. In this method, measurements were taken using Dipole-Dipole sequence. 1 profile was laid along and 12 electrodes were laid at 1m intervals. The current is applied to the ground with C1 and C2 electrodes and the voltage of the ground is measured with P1 and P2 electrodes. In this study, multiple electrode box connected to resistivity instrument was measured.

In general, there are two separate units. These two units can be defined as Yalı stone (> 100ohmm) and alterated segments (<100ohmm) (Figure 5). As can be seen in the section taken at the base of the wall of the basilica, we can say that there is a structure which we call as high resistivity beachrock with a resistance of 121-153ohm m at a depth of 1m from the surface at 2-3m with high resistivity. Again, at a depth of about 2 m from the surface at a depth of 2 m 121-153ohm resistivity of the structure called high-resistivity beachrock can be seen. In general, in this section, the basalt and the altered surface are observed.

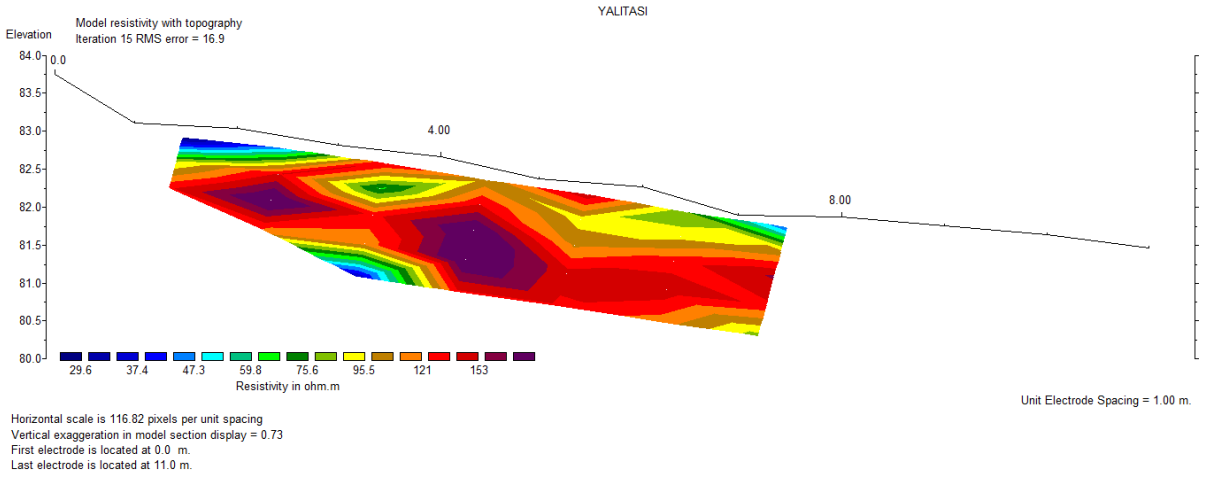


Figure 5. The electrical resistivity tomography model obtained as a result of the measurement carried out next to the Basilica in Iznik on 18.07.2019.

On 18.07.2019, in the works in front of the park in the part of the basilica on the coastal part of İznik lake, Electrical Resistivity method which is one of the geophysical methods was

used. In this selected profile, Dipole-Dipole arrangement and 12 electrodes with 1 meter spacing along 1 profile were used. The results are presented in the same color range. In general, there are two separate units. These two units can be defined as beachrock (> 100ohmm) and alterated sections (<100ohmm). When the cross-section in Figure 6 is looked at, it is seen that it has a high resistivity of 121-153ohm m at a depth of approximately 2m from the surface at 2m and it is described as beachrock.

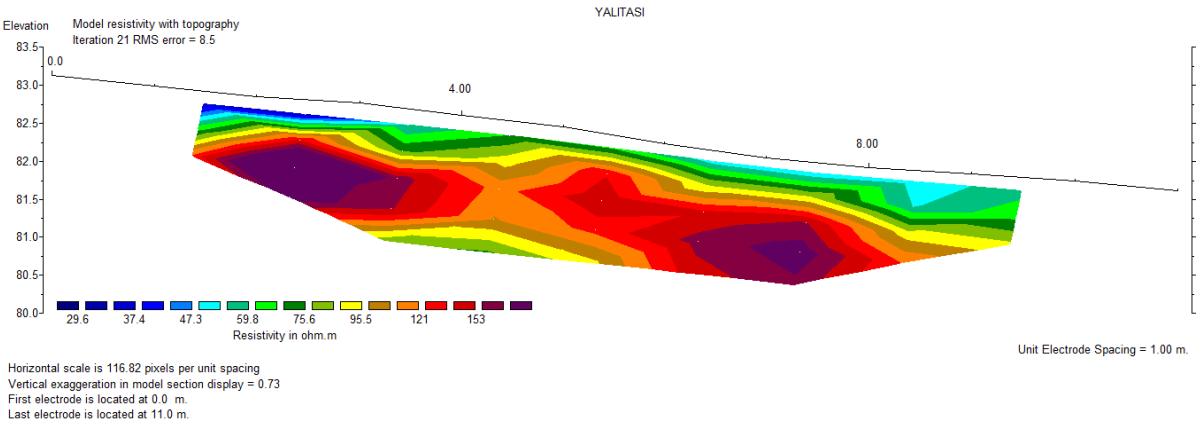


Figure 6. The electrical resistivity tomography model obtained as a result of the measurement performed in the central part of the park next to the Basilica in Iznik on 18.07.2019..

At the same time, there is still a high resistance to the depth of 3m (121-153ohm m) from the surface at a depth of 6-7m. In general, in this section, the beachrock is observed at the base and the altered section at the surface.

4. Discussion and Conclusions

This study was conducted to determine whether the 1600-year-old St Neophytos Basilica, which was first identified from aerial photographs in 2014, was submerged due to an earthquake or as a result of the rise of lake waters according to the relationships between the subsoil and superstructures. The most devastating earthquake in Lake Iznik and its vicinity is the IX severe AD 715 earthquake. It was felt in other cities around it. In this study, according to the results of the two electrical resistivity models produced in the Byzantine Basilica, which is described as submerged in Iznik, it was concluded that the Basilica of St Neophytos Basilica was built entirely on the surrounding beachrock formation. Therefore, the main reason why the basilica is submerged today is that the lake waters rise significantly over time.

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