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## Investigation on geoarchaeological structure of ancient ports in the Lycia Region

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### ABSTRACT

The effects of geological events that occurred in ancient times, on ancient cities are undeniably great, so geoarchaeology has become an important multidisciplinary science. Using geological methods in archaeological researches offers a much more comprehensive understanding for history. Today, the methods of remote sensing and geographical information systems have facilitated archaeological researches to a greater extent than before. In this study, Phaselis, Andriake and Patara ancient cities were investigated. In the research, help was obtained from satellite images as a method. By comparing the ancient coast line and the modern coast line, it is tried to be understood to what extent the sea level change occurred.

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## 1. Introduction

Archeology and geology have important places in the world cultural heritage. These two sciences work together to provide a wider perspective and provide access to get more information. Geoarchaeology is a bridge between human history and the history of the world. This allows us to better understand our planet.

One of the most important reasons for these changes at sea level is the plate movements. The Teke Peninsula, which is the focus region of this research, were highly affected by the changes in the sea level.

Also local differences in sediment structure and coastal dynamics had caused different coastline curves (Brückner et al., 2010).

Most extensive coastal changes in history have been observed in the delta regions of the Major

coastal changes were observed in the coastal delta bay of the Mediterranean Sea. On the other hand, earthquakes and other natural phenomenas had effects on delta formations. (Brückner et al., 2005). Also, the river valleys always formed along weak structural lines or in depressions, grabens, and half-grabens (Kayan, 1999).

Many historical harbors were affected by the sea level changes in Anatolia in the ancient period. Troy, Ephesus, Miletus, Priene, Patara, Seleukeia Pieria are important ones among these ports (Erol and Pirazzoli, 1992). Some of these historical harbors have been flooded due to the rise of the sea level. On the other hand some historical harbors had been covered with alluviums. The most famous example is the Ephesus Ancient Port which is 8 km away from the coastline today. Strabon states that Priene was originally on the shore but it is about 6.5 km far from the sea shore today.

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Santorini volcanic eruption (Thera eruption) has affected the eastern Mediterranean for over 1000 years during the Bronze Age. Probably volcanic eruptions are the reasons of these severe earthquakes and tsunamis which have caused the disappearance of the Minoan civilization (Özdemir, 2004). Also, Thera eruption and following tsunami affected the western Turkey and Crete coasts (Minoura et al., 2000) (Figure 1).

It has been determined that there have been different descending and ascending event sequences in close regions. For example while rises at the sea level are observed in the Mediterranean coasts, large decreases at the sea level are observed in Londos at the island of Rhodes.

In Lycia Region, earthquakes are the most important reasons of sea level changes. A few earthquakes which are known to have affected the region are listed at the below table (Table 1) (Guidoboni et al., 1994).

Table 1- Important earthquakes in Lycia region.

Date	Center
2nd Millenium BC	Santorini (Volcanic Eruption)
199-198 BC	Rhodes
227 BC	Rhodes
23	Cibyra
68	Myra
142	Rhodes
344	Rhodes
417	Cibyra
474-478	Rhodes
515	Rhodes
530	Myra

## 2. Material Method

In this study, Lycian Region was investigated by using archaeological, geoarchaeological and geological data. In this direction, surface surveys were carried out in Phaselis, Patara and Andriake ancient cities. Using Global Positioning System (GPS), contemporary coastlines and possible coastlines of

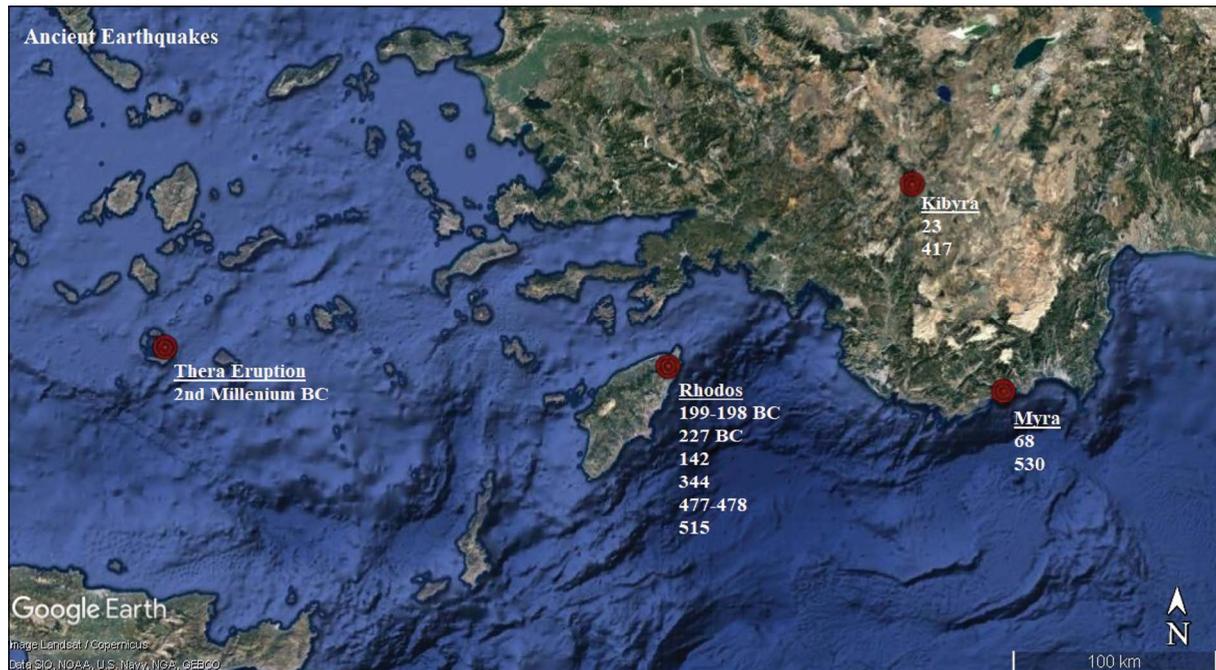


Figure 1- Important ancient earthquakes.

ancient times have been documented. During these surface investigations, the drone was flown above Phaselis and aerial photographs were taken. At the same time, a detailed underwater survey was conducted in the Phaselis coastline and many underwater parts of the buildings were photographed and documented.

The structure of the region has been studied in detail with the help of satellite images and geological maps and the desired result has been achieved by using GIS programs (QGIS and ArcGIS).

Firstly, research was carried out in the ancient city of Patara. In this research, it is aimed to determine the effects of the earthquakes that have occurred in the region. Moreover, it has been observed that alluviums carried by the Eşen River closed the port of the city. Much of the later work is concentrated in the Phaselis Ancient City. It was investigated how much Phaselis harbor was affected by earthquakes. During studies mainly it was concentrated to the underwater works. Photographs taken with underwater camera has a greater effect on the scope of the project.

The Andriake Ancient City, the port of Myra, also exposed the effects of the earthquakes. The research conducted around this region concentrates on the port which is in a swampy situation.

The data obtained from field studies conducted in ancient cities are compared with each other. The photographs were rearranged considering the geological structure of the region.

Territories, that could not be reached because of the land structure, were surveyed via satellite images. The geographical structure mentioned in ancient literatures and the present geography were compared.

### 3. Results

#### 3.1. Patara

Patara Ancient City in Kaş, Antalya, is located on the southeast of the delta flood plain formed by the Eşen Stream (Xanthos). The north-south tectonic groove bordered by 100-120 meters and 300 meters high hills to the west is located in the estuary, which is 2 kilometers from the sea. This estuary determines the borders of Patara harbor bay. In Patara, epigraphic datas from 13th Century BC, proved that the city had

been settled much earlier. The pottery of the Tepecik Acropolis located at the north of the settlement area and the finds of the mother goddess figurine as baked clay proves the existence of the settlement at the last phase of the Early Bronze Age (İşkan and Şahin, 2018).

Patara, which is the port of the famous Xanthos Ancient City, is also the biggest port of Lycia Region. Patara, the Ancient City port is now covered with alluviums. However, it is known that this region is the harbor of ancient times. Alluviums carried by the Eşen River have made the remaining part of the harbor a swamp. Nowadays, the area near the sea has been covered with alluviums. The sands of Patara beach are fine and smooth. This unique structure of the sand is due to the sandstone and limestone of the geological formation of the region. Patara Port was used 2500-3000 years ago from today. In this period, Eşen Bay was filled with sediments but Patara Bay was in a very convenient position to be a port. As Eşen Stream continued to carry sediments, it continued to be filled with sediments in Patara Bay continued to be filled with sediments. Thus, Patara Port was completely covered with alluvium (Öner, 2001).

According to Strabon ± 2000 years ago, Letoon was reached 10 stadion (1,8 km) from Eşen Creek. Today, this distance has increased to 4 km (Strabon, 2000).

It is mentioned in the historical literature that the ships could enter the port of Patara 15th century. In the following period, the port has become a marsh. In the same way, the lagoon in the eastern part of the Eşen Plain has also been a marsh. If we accept that these developments continue in the future, it will be possible for the eastern Kalkan Bay to turn into a lagoon and then a swamp in time (Öner, 2001).

In figure 2b, Patara and the geological formation of the region were taken into consideration to redraw the ancient port boundaries of the region with the help of the Adobe Photoshop program and Google Earth.

#### 3.2. Phaselis

Phaselis Ancient city is located in Kemer, Çamyuva district. In figure 3, the location of Phaselis in the Mediterranean Sea can be observed. Phaselis



Figure 2- a) Patara shore line in today, b) Patara shore line in ancient times (Google Earth 2017 map based).

Ancient City was founded on the west coast of the Gulf of Pamphylia under the leadership of Lindos in around 691/690 BC (Tüner-Önen, 2012). From the 7th century BC to the mid-2nd century BC, Phaselis, mainly governed through democracy, managed to maintain its autonomy during the period of Persian hegemony in Anatolia in the Classical Period and, at times, during the Hellenistic Period (Arslan and Önen, 2016).

In Phaselis some of the harbor structures are underwater. Destructive earthquakes caused the buildings in Phaselis to be destroyed and the city to be flooded. In addition, cracks were observed on the ground under the sea in the coastal region of Phaselis.

It is not clear when and for what reason these cracks were formed, and more information is needed to obtain by paleoseismological examinations in the region. Destructive earthquakes caused the buildings in Phaselis to be destroyed and the city to be flooded. In addition, cracks were observed on the ground under the sea in the coastal region of Phaselis. It is not clear when and for what reason these cracks were formed, and more information is needed to obtain by paleoseismological examinations in the region.

In the images which were taken by a drone over Phaselis, the remains of underwater structures of the ancient Breakwater are clearly visible (Figure 4,5).

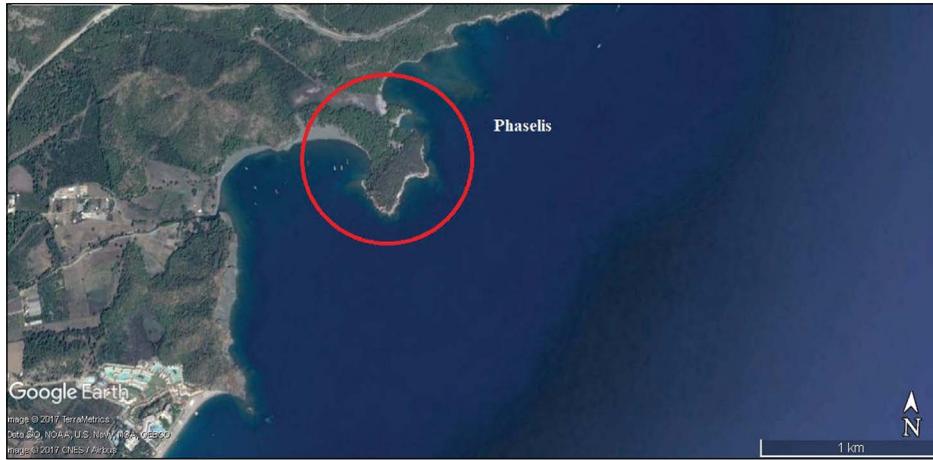


Figure 3- Phaselis (today) (Google Earth 2017 map based).



Figure 4- Location of the Phaselis breakwater.



Figure 5- Air photo of Phaselis breakwater (17.07.2016).

In Phaselis, there are many building remains under water (Figure 6). Above mentioned underwater fractures observed in Phaselis Shores are seen in Figure 7. It is not well known which earthquakes caused these fractures observed on the Phaselis coast. In order to have a certain knowledge, paleoseismological researches have to be carried out in the region.

### 3.3.Andriake

Andriake is located 4,7 km southwest of Myra. It lies between Kumdağ Tepe and Bozdağ Tepe. 3000-2000 years ago, the alluvials brought by Myros Stream filled the Myra River Delta by the time and turned it into a suitable plain for settlement (Çevik, 2015). It was one of the most active harbors in the region since the Hellenistic period. The defense system comprised



Figure 6- Building remains in underwater in Phaselis.



Figure 7- Underwater fracture in Phaselis.

of towers on the hills at the south side of the harbor settlement is dated to the Hellenistic period and was used in the Roman and Byzantine periods with some modifications (Akyürek, 2016).

The ancient city of Andriake was settled along a bay in the past, and around this bay was the ancient port of Andriake. Today, however, this port is in a swamp. Underneath this swamp a part of the harbor structures exists.

In figure 8, the result of the site surveys in Andriake and the studies about the geological formation of the region were provided basis to redraw the ancient port boundaries of the region with the help of the Adobe

Photoshop program and Google Earth. In figure 9 we can see the shoreline of Andriake in today.

The geological basement of the region consists of limestone. Because of this, there is no river to carry sediments to Andriake harbor. It can be assumed that the sediments of Demre River reached to the harbor were carried from here by the coastal currents (Öner, 1998).

#### 4. Discussion

Visible changes have been observed at the sea level in the research conducted in the Lycia Region.

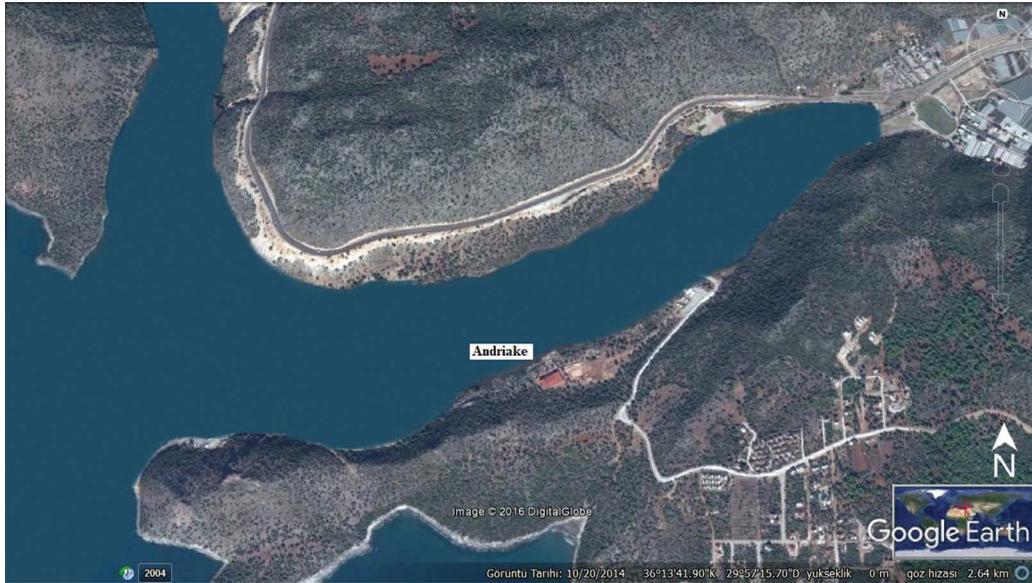


Figure 8- Estimated shore line in ancient times (Google Earth 2017 map based).



Figure 9- Andriake shore line in today. (Google Earth 2017 map based).

However, these changes are not the same everywhere. While the ports of cities such as Kekova and Phaselis are underwater as a result of the sea level rise, the ports of the Andriake and Patara cities are now filled with alluvial deposits and are quite inland. The most important reason why the port structures remain underwater is earthquake. In Phaselis, underwater fractures may have been caused by earthquakes that left the harbor structures underwater. Although it is not possible to say anything definite about this issue, it is possible to trace the earthquake traces in the major structures.

## 5. Conclusion

Lycia Region, today's Teke Peninsula, has hosted various civilizations throughout history. The geographical and geological characteristics of the region are the most important reasons for this. The region has always maintained its popularity due to the fertile lands, the sea and the sheltered location of the bays. However, like everywhere else, it was greatly influenced by the earthquakes in Lycia. We can see the effects of these earthquakes from the ancient literatures and the remains of ancient buildings.

It can be easily estimated that the earthquake is a great disaster for ancient civilizations. However, because of the earthquakes the strength of the structures built afterwards had been increased. The important buildings (theater, parliament building (bouleuterion), bathhouse etc.) were more solid than the others. Today, we see that most of these important structures are still standing.

Due to the earthquakes, the changes in the landforms in the Lycian region were much faster than expected.

The impact of rapid changes in ground patterns in the Lycian Region is most commonly observed in coastal areas. These changes on the coasts affected sea level directly. These visible changes in the sea level are evidences of tectonic mobility. For this reason, we can say that some changes in the sea level in the Lycian Region for example in Kekova and Phaselis, are tectonic rather than eustatic.

Apart from the direct effect of earthquakes, plate movements and climate change also affect the sea level changes. However, these effects occur over a

much longer period of time and this change is not visible and takes thousands of years. However, large climatic events accelerate this process. For example, climatic events, such as global warming, the ice age of the earth, which completely affect the fate of the earth, can cause great changes in sea level in a few years. Sudden and large changes in climate will affect sea level definitely.

Although the tides provide a significant change, they do not have much impact on the average sea level as they do not change the existing water volume and are merely gravitational events. However, the change in the volume of water and the change in sea level, can modify the magnitude of the tides. Sea level changes after the ice age have had significant impacts on the tides (Kayan, 2012).

Alluviums carried by rivers have a great effect on sea level changes. We have seen examples of this in Patara and Andriake, as previously mentioned. As the alluvium carried by the Eşen Stream collided with the waves coming from the sea, Patara Bay was completely occupied with marshes and the ancient port was filled with sand dunes and became a marsh. The existence of various building remains under this swamp in Andriake may indicate that water has risen and then filled with alluviums. However, it is not possible to reach a definite result without detailed research.

As a result of surface and underwater research in the Lycian Region, satisfactory results were produced in Phaselis, Andriake and Patara.

Particular, building blocks found in Phaselis under the sea, revealed the destructive effects of the earthquakes in the region. In addition, Phaselis's northern port is underwater and some cracks can be observed under the sea, extending to the main basement rock of the city. The block fragments belonging to the Breakwater in the northern port are observed under water. A Sarcophagus located on the shore of the Necropolis can be observed from the surface. The flooded block fragments of the city's ancient military port were documented with aerial photographs.

In Patara, earthquake traces were determined on ancient building remains. The ancient Patara coastline is now 2,30 km from away the sea and the ancient lighthouse is 573 m from away the coast. The ancient

port was filled with alluviums by the time and today there are only small ponds left from the port.

Andriake Port is covered with alluvium like the port of Patara. The harbor, which has become a swamp, is a home to various species of birds today.

In the light of all these data, it can be said that there has been a significant change in the coastal line from the ancient period to the present day. Considering the geological origin of the world, this change was experienced in a short period of time as nearly 2000 years. It will continue to change thereafter. On the basis of all these data, we can easily say that the coastal line changes in the Lycian Region are faster than normal. The reason for this is that there are continual earthquakes in the region.

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