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Mid- to late-Holocene paleovegetation change in vicinity of Lake Tuzla (Kayseri), Central Anatolia, Turkey

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ABSTRACT

This study carried out in Lake Tuzla in northeast Cappadocia (Central Anatolia-Kayseri-Palas Plain) aimed primarily to determine changes in paleovegetation of mid- to late-Holocene in the vicinity of Lake Tuzla and factors affecting these changes. A secondary objective was to determine paleoenvironmental conditions during the settlement period of Kültepe (Karum-Kanis), an important archaeological site in the region. Fossil pollen analysis was carried out on a sediment core 337 cm long representing the period from the present day extending back to 5080 ± 30 years. Changes in paleoclimatic conditions and paleovegetation were identified. From changes in the vegetation, the climatic changes determined were dry in the periods 3200-3000 BP, 2050-1450 BP, and 1120-850 BP; and humidity in the periods 1400-1115 BP and 1400-1700 BP. Alterations to the vegetation structure between 3230 and 1155 BP reveal the effects of the Beyşehir Occupation Phase (BOP). According to Lake Tuzla data, the effect of BOP was relatively less than that of Lake Nar. After the end of BOP, pine forests grew in the area around Lake Tuzla. The vegetation consisted of *Pinus* and *Quercus* in AP (arboreal pollen) and *Artemisia*, Amaranthaceae and Poaceae in NAP (non-arboreal pollen). The density of *Artemisia*, Amaranthaceae and Poaceae taxa suggests that steppe vegetation was dominant in the surroundings of Lake Tuzla.

Keywords: Lake Tuzla, Cappadocia, Kültepe, fossil pollen, vegetation and climate change.

1. Introduction

Anatolia is characterized by human-induced vegetation change and a complex climatic history (Bottema and Woldring, 1990; Kaniewski, 2007; Riehl and Marinova, 2008; Bakker et al., 2013). Pollen analysis is the most useful method for evaluating human-induced vegetation change and the climatic history of Anatolia from the temporal perspective and on a spatial scale (Behre, 1990; Eastwood, 1997; Vermoere, 2004; England, 2006; Şenkul, 2014). The formation of vegetation in Anatolia revealed by pollen analysis, and factors such as human impact and climate affecting these changes, enable the reinterpretation of environmental conditions (Bakker et al., 2011). Furthermore, the climatic and human impacts effective on vegetation also help us to understand changes occurring in the socio-cultural structure (Allcock, 2017).

The extent, nature and duration of climatic changes affecting natural environmental conditions vary from region to region (Miebach, 2016). Notably, the 4200, 2800, 1400 BP Cold Climate periods and the Little Ice Age (Bond et al., 1997) occurring in Holocene, together with the climatic cycles termed the Roman and Medieval Warm periods (Free and Robock, 1999; Crowley and Lowery, 2000; Luterbacher et al., 2001; Mann, 2002; Bradley, 2003; Cronin et al., 2003; Bakker et al., 2011; Wang et al., 2012), were all effective on the natural environment, inhabitants and human activity.

Kültepe (Kaniş Karum), the most important ancient settlement in Cappadocia, is the largest Early Bronze Age settlement in Anatolia (Kulakoğlu et al., 2013). This settlement became an important trade and cultural center in the period of the Assyrian Trade Colonies (1950-1700 BC), during which commercial and cultural relations with Mesopotamia developed (Uğuryol and Kulakoğlu, 2013). Kültepe, important historically and for its strategic location in Cappadocia, is of particular significance since it is situated close to the Lake Tuzla (23 km to the northeast).

Regarding Cappadocia as a whole, several fossil pollen studies have included Lake Tuzla (Bottema et al., 1993-1994; Woldring, 2001; Roberts et al., 2001; England, 2006; Roberts et al., 2016; Doğan, 2017). However, the exact age-based chronology of fossil pollen data from Lake Tuzla, representing the northeast of the region, has not yet been revealed in detail (Bottema et al., 1993-1994). In order to gain a holistic view of the fossil pollen record of Cappadocia region, it is difficult to use data from Lake Tuzla due to the lack of information about its age. Therefore, this study aimed to solve the problem of chronology by examining the record of Lake Tuzla in the north-east of Kayseri-Palas Plain (Memiş, 2017). Thus, a data set was compiled reflecting the Holocene paleoenvironmental history of the Cappadocia region.

This study is important in terms of perceiving the effect of changes in paleovegetation and palaeoclimate on human activity during the settlement period of Kültepe and the influence of mankind on the environment. For this reason, the aim of this study was to determine the paleovegetation changes of the Lake Tuzla environment and the factors affecting these changes in the light of fossil pollen analysis. Fossil pollen data were used as the data record, making a significant contribution to the construction of paleoecology in Cappadocia and revealing the environmental factors affecting the paleoenvironment of the Kültepe settlement.

2. Study Area

Lake Tuzla (1130 masl) is included in a closed basin located to the southeast of Kızılırmak valley between Mt. Akdağlar to the north and Mt. Korumaz (1907 masl) to the south in Central Anatolia (Fig. 1). The rocks exposed around Lake Tuzla, from oldest to youngest, are metamorphic rocks of Paleozoic age, ophiolitic mélange, sedimentary (clastic, carbonate) and plutonic rocks of Mesozoic age, lacustrine carbonate and volcanic rocks of Cenozoic age, and alluvial deposits of Quaternary age (Fig. 2). Most of these rock groups (except the Paleozoic metamorphics) are exposed in the catchment area of Lake Tuzla.

The closed basin developed in the Central Anatolian Fault System (Koçyiğit and Beyhan, 1998). The Central Anatolian Fault System is approximately 730 km long and 2–80 km wide, a northeast–trending neotectonic structure in the nature of sinistral strike-slip faulting (Koçyiğit and Beyhan, 1998; Koçyiğit and Erol, 2001; Koçyiğit and Doğan, 2016). It resulted from the reactivation and propagation of an older paleotectonic structure, the so-called “Ecemiş corridor” (Blumenthal, 1941), running both north-northeast and southwest across the Inner Tauride Suture during Quaternary (Koçyiğit and Doğan, 2016). Therefore, the study area has been affected by a strike-slip neotectonic regime during Quaternary (Koçyiğit and Beyhan, 1998; Koçyiğit and Erol, 2001; Koçyiğit and Doğan, 2016). Consequently, Lake Tuzla closed basin formed as a pull-apart basin within the Central Anatolian Fault System (Koçyiğit and Beyhan, 1998; Koçyiğit and Doğan, 2016). As a result, strike-slip and normal faults are found around Lake Tuzla (Fig. 2). Ion concentration in Lake Tuzla is twice (84 g/l) that of sea water (Shekkerman and van Roomen, 1993).

Fig. 1. Location map of study area.

Fig. 2. Geological map of study area, (active faults and 1/500.000 scale geology map taken from MTA, active faults modified from MTA).

3. Modern climate

Lake Tuzla and its surroundings (Kayseri province) in Cappadocia possess the most extreme terrestrial climate features in the region in terms of high-temperature variability and long-term low temperatures (Türkeş, 2005). The average temperature in January is -9ºC and the average July temperature is 21ºC. Average rainfall ranges from 510 mm to 390 mm (http://worldclim.org/current; http://worldclim.org/bioclim). According to Thornthwaite climate classification, this area is within the arid-sub-humid climate class (Yılmaz and Çiçek, 2016).

4. Modern vegetation

The study area is located in the Irano-Turanian flora region and xerophytic plants constitute the majority of the region's flora (Çetik, 1985; Avcı, 1993; 2013). The steppes in Central Anatolia have an anthropogenic character (Avcı, 2013). The steppe forests in the region were destroyed due to climatic conditions (gradual aridification) and anthropogenic factors. Indeed, *Amygdalus arabica oliv.*, *Cedrus*, *Crataegus azarolus*, *Juniperus*, *Quercus*, *Pinus nigr*a and *Purunus domestica* are present in a mixed manner in the degraded forestlands. Plant types belonging to a steppe climate zone have developed in the Lake Tuzla surroundings. Plant groups of *Eleocharis potustris* are found in the brackish marsh in the southern and western parts of the lake, and *Juncus inflexus* on dry soils (Seçmen and Leblebici, 1987).

5. Materials and Method

5.1. Sampling of the Core

In 2016, a sediment core of 337 cm in length (TZL 16-01) was taken from the bottom sediment of Lake Tuzla at 4 m water depth with the aid of a Livingstone drilling rig. The sediment core was wrapped with stretch film and placed in hard plastic pipes then packed in codes. Fossil pollen analysis was carried out by taking sediment samples from 21 levels, each 16 cm long, on the 337 cm-long sediment core. The lithology of the whole sediment cores forms gray clay.

5.2. Palynological Analyses

During the pollen analysis, sediment samples were subjected to the traditional method (Faegri and Iversen, 1989; Moore et al., 1991; Seppa, 2007) and a *Lycopodium* spore tablet was added to each sample to determine pollen density (Stockmarr, 1971). The pollen was made into a solution using silicone oil so that it could be analyzed under a microscope. The detection and counting of pollen and *Lycopodium* were carried out using a x40 and x100 immersion lens in a computer-assisted light microscope. At least 350 black pollen spores were counted in each sample to determine the amount of pollen. Paleomorphological keys and photographs were used for the identification of pollen during the identification and counting stages, as per Moore et al. (1991) and Reille (1998; 1999). After the pollen identification and counting, cluster analysis was carried out in Tilia 2.0.41 program and a pollen diagram was created (Grimm, 2015).

6. Results

6.1. Radiocarbon Ages and Age Depth Model

Samples from two different points (187 cm to 325 cm) on the sediment core were taken and dated to ages of 3110 ± 30 BP and 5080 ± 30 BP, respectively (Table 1). The age depth profile for Lake Tuzla was established with the obtained age data (Fig. 3). Based on radiocarbon ages, the chronology of all sediment series was constructed by linear interpolation using Tilia 2.0.41 software. According to this, the base age of the sediments is 5160 BP. This chronology was integrated into the pollen diagram and changes are presented in the temporal frame.

Table 1. Radiocarbon/AMS ^{14}C ages from Lake Tuzla (TZL 16-01) sediment core.

Fig. 3. Age-depth profile for Lake Tuzla (Core TZL 16-01).

6.2. Pollen Analysis

Five main LPAZs (Local Pollen Assemblage Zone) were determined in the summary diagram obtained from the pollen analyses. These LPAZs were named Lake Tuzla Zone I (TZL-I), TZL-II, TZL-III, TZL-IV and TZL-V (Fig. 4).

6.2.1. TZL-I (between 5160 and 4600 BP)

In this zone, the *Pinus* values were reduced up to 25% at the end of the zone by consistently decreasing. The *Quercus* values reached their highest level (21.5%) in the year 4600 BP, during which *Pinus* decreased to its lowest level (Fig. 4). The AP value varied between 47% and 53%. This zone is characterized by *Artemisia* and Amaranthaceae, which are among the NAP. *Artemisia*, which reached its highest level of 30% at the beginning of the zone, decreased to 23.5% at the end of the zone. For Amaranthaceae, the value of 3.7% at the beginning reached 10% at the end of the zone.

6.2.2. TZL-II (between 4600 and 3230 BP)

This zone is divided into two sub-zones. TZL-IIa represents the years 4600-3916 BP, and TZL-IIb represents the years 3916-3230 BP. The *Pinus* values that were 25% at the end of TZL-I (during 4600s BP) increased to 51.2% at the beginning of TZL-II (4600 BP) and decreased to 36% at the end of the zone (3916 BP). Among the NAP, the ratio of *Artemisia*, which decreased to 23.5% at the end of TZL-I, continued to decrease (from 16.6%) at the beginning of TZL-IIa but increased to 27.2% at the end of the zone. The ratio of *Pinus* decreased to 36% in TZL-IIa then increased to 42% at the beginning of TZL-IIb and decreased to 38.2% at the end of the zone. In TZL-IIb, *Artemisia*, Ranunculaceae and Brassicaceae increased by 5.4%, 4.8% and 4%, respectively, while Amaranthaceae and Rosaceae decreased by 4.4% and 2.3%, respectively.

6.2.3. TZL-III (between 3230 and 1115 BP)

In the pollen diagram, the change in the ratios of NAP and AP in TZL-III is striking. It is observed that there is an overall increase in the ratio of AP. It is remarkable that *Artemisia* values suddenly decrease in NAP. The increase in Ranunculaceae values during the transition period from TZL-II to TZL-III indicates that a humid period was experienced. This zone was divided into three sub-zones as TZL-IIIa (3230-2710 BP), TZL-IIIb (2710-1912 BP) and TZL-IIIc (1910-1115 BP) (Figure 4). In TZL-IIIa, *Artemisia* values showed a tendency to decrease continuously, and these values decreased to 5.1% at the end of the zone. The fact that the *Pinus* and Ranunculaceae values decreased while the *Artemisia* and Amaranthaceae values increased in TZL-IIIb indicates that an arid period occurred. The increase in *Pinus* values in TZL-IIIc and the presence of Ranunculaceae indicate that a humid period dominated.

6.2.4. TZL-IV (between 1115 and 600 BP)

The *Pinus* value in TZL-IV decreased to 41.4%. Among NAP, Amaranthaceae and Lactuaceae reached the highest levels of 14% and 3.5%, respectively. The value of *Artemisia* increased to 7.7% and started to rise, as of this period. The fact that *Pinus* values decreased and *Artemisia* and Amaranthaceae values started to increase indicates that open steppe vegetation was dominant in Lake Tuzla and its surroundings between 1115 and 600 BP. The decrease in *Plantago lanceolata* and *Sanguisorba* values compared to TZL-III indicates that animal husbandry activity on the vegetation decreased. In this zone, the AP and NAP values are 60.5% and 39.2%, respectively.

6.2.5. TZL-V (between 600 and 83 BP)

In 332 BP, *Pinus* reached its highest level in the pollen diagram with 68.2%. The increasing ratio of *Pinus* indicates that forested land expanded. Among the NAP, *Artemisia*, Amaranthaceae and Brassicaceae increased to 18.7%, 8% and 3%, respectively. Rosaceae increased by 2.3% compared to TZL-IV. The ratio representing cereals reached its highest level, with 2.8% (Fig. 4). This increase indicates that agricultural activity was performed.

Fig. 4. Summary pollen percent diagram of Lake Tuzla.

7. Discussion

Results obtained from fossil pollen analysis carried out at Lake Tuzla include studies by Bottema et al., 1993-1994 (Lake Tuzla I), Roberts et al., 2001; Woldring, 2001 (Lake Eski Acıgöl), England, 2006 (Lake Nar) and Kuzucuoğlu, 2011 (Lake Tecer). *Pinus*, *Quercus*, Amaranthaceae and *Artemisia* pollen, which are dominant in the fossil pollen diagram of Lake Tuzla I (Bottema et al., 1993-1994) and Lake Tuzla II (Memiş, 2017), show that the vegetation structure overlaps in both studies. However, it is not possible to make a chronological comparison since the Lake Tuzla I study of Bottema et al., (1993-1994) is not age-dependent. *Pinus* and *Quercus* in AP and *Artemisia*, Amaranthaceae, and Liguliflorae in NAP form the most common plant taxa in a previous fossil pollen study (Bottema et al., 1993-1994) conducted at Lake Tuzla. In the diagram of zone 1, the taxa of *Alnus*, *Cedrus*, *Betula*, *Corylus*, *Ostrya*, and *Abies* in AP indicate that it was a significant period. It is seen that NAP values increased most in zone 2. The increase in Liguliflorae values, particularly in NAP, suggests significant changes in the lake environment. These changes may be due to the effect of summer temperatures, basin fill, or sediment properties. It is seen that the AP values increased most at zone 3. The preponderance of *Pinus* is especially due to the low production of pollen in the local area and that *Pinus* pollens were transported from distant places to the study area.

Plant taxa and vegetation structure in IIIb, IV and V pollen zones dated to mid- to late-Holocene in the fossil pollen diagram of Lake Eski Acıgöl when compared with the Lake Tuzla fossil pollen diagram of mid- to late-Holocene. In the IIIb pollen zone of the diagram, *Quercus robur* type, the dominant woody taxon, takes its place at the end of the zone. The predominant woody taxon in the IV and V zones is *Pinus*. This is thought to be caused by excessive grazing, the cutting down of trees for timber and heating, a reduction in the production of woody pollen in the lake basin; and the *Pinus* pollen is believed to have been transported from long distances (Roberts et al., 2001). When the pollen diagram of Lake Tuzla II is compared between the periods of mid- to late-Holocene and the pollen diagram of Lake Eski Acıgöl, it is seen that the vegetation structure overlaps on a large scale. In fact, in the mid- to late-Holocene, the plant taxa dominant in the pollen diagram of Lake Tuzla II and Lake Eski Acıgöl are *Pinus* and *Quercus*; while within N it is formed of *Artemisia*, Amaranthaceae and Poaceae.

Lake Tuzla II is an important indicator of the presence of forests in the pollen diagram of *Pinus*, while *Quercus* seems to have found a wide distribution area as a secondary forest product, which fell to its lowest level in 4600 years. The high ratio of *Artemisia*, Amaranthaceae, and Poaceae in the diagram indicates that steppe vegetation around the lake was dominant.

The ancient settlement of Kültepe in Cappadocia gained importance in the early years of 3218 BP when Anatolia entered the historical era (Yiğit, 2003). Kültepe is an area where Assyrian merchants settled and developed Kültepe-based trade networks covering most of Anatolia. The Hittites dominated a wide area in Anatolia between 3868 and 3218 BP and greatly affected the social and economic activity of the region (Gümüşçü et al., 2013; Macqueen 1996; Table 2). The economy of the Hittite state was based on agriculture and animal husbandry. *Plantago lanceolata*, which is seen in the vegetation structure of the land in these years in the diagram, shows that animal husbandry was carried out in and around Lake Tuzla during the Hittite period.

The existence of agricultural crops in the pollen diagram of Lake Beyşehir, indicating breaks in forestation, points to a period in which humans had an effect on vegetation (van Zeist et al., 1975, Bottema and Woldring, 1984, van Zeist and Bottema, 1991). In fossil pollen studies, this period showing the effect of humans on vegetation in mid- to late-Holocene is called the Beyşehir Occupation Phase (BOP) (Bottema and Woldring, 1984; Eastwood et al., 1998). *Castanea*, *Fraxinus ornus*, *Olea europaea*, *Juglans*, *Vitis*, *Plantago lanceolata* and *Sanguisorba* taxa, observed in the pollen diagrams of many fossil pollen studies in Southwestern Anatolia and Central Anatolia, are evidence of the BOP (England, 2006; England et al. 2008; Şenkul, 2018). The effect of BOP on the pollen diagram of Lake Tuzla is seen between 3230 BP and 1115 BP. The increase in the rate of *Plantago lanceolata* and *Sanguisorba* during these years indicates that livestock activity was carried out (Eastwood et al., 1998; Gaillard, 2007). The absence of primary indicator species (*Olea*, *Juglans regia* and *Vitis*) reflecting BOP during this period, but the presence of several secondary indicator species (*Plantago lanceolata*, *Sanguisorba*), suggest that the effect of human-grown vegetation on Lake Nar and its surroundings (England et al., 2008) was more limited around Lake Tuzla. According to the Lake Tuzla data, the event that ended BOP in the study area around ~ 1150 to 1400 BP (England et al., 2008) was Arab invasions in Anatolia. Arab raids disrupted the balance of social life in Central Anatolia and caused the land to be abandoned. During the Arab invasions, Anatolian rural dwellings and cities were severely damaged, social and economic life collapsed, leaving the villages and agricultural land empty (Gümüşçü et al., 2013). According to the Tuzla data, significant changes were identified in the vegetation structure during this time. The decrease in *Pinus* values indicates that forest areas were destroyed and that the increase in *Artemisia*, Amaranthaceae and Poaceae was not on arable land (Gaillard, 2007). The increase in *Pinus* values along with the end of the Arab raids, in accordance with the pollen data of Lake Nar (England et al., 2008), indicates that forested areas were again spreading. The presence of cereals in the diagram indicates that agriculture was carried out in the Roman-Byzantine-Seljuk and Ottoman periods around Lake Tuzla (Table 2).

Table 2. States ruling Central Anatolia, archaeological periods, climatic events and changes in vegetation (Akurgal, 2014 [1], Bond et al., 1997 [2], Crowley and Lowery, 2000 [3], England et al., 2008 [4], Gümüşçü et al., 2013 [5], Wanner et al., 2008 [6], Wang et al., 2013 [7]).

The effects of global climate change are also seen on the vegetation structure of the Lake Tuzla periphery. At 4.2 ka BP, a 450-year drought was experienced in Lake Tecer; then the 4.3 ka BP event started. With the long-lasting drought at 4.3 BP, repeated drought periods began in the Near East (Kuzucuoğlu et al., 2011). The 4.2 ka BP climatic period, in which marine coral-dolomite dust from the Gulf of Oman shows a sharp peak (Migowski et al., 2006), and a sharp decline in the level of the Dead Sea, have been interpreted as a sudden drought in the eastern Mediterranean (Cullen et al., 2000). The effects of this arid period were also recorded in the Lake Tuzla data. The decrease in the number of woody taxa in Tuzla data, which is compatible with Lake Tecer and Lake Nar, suggests that the climate of this period was dry around the lake.

Pollen data show that the climatic regime varied significantly during the Iron Age, when a humid climate once again predominated, and during this period at 2.8 ka BP (Bond et al., 1997; Issar and Zohar, 2007). Between 3.2 and 3.0 ka BP, an event in the IRD curve occurred (Bond et al., 1997), and a drought in Lake Eski Acıgöl sediments in Central Anatolia emerges from isotopes between 3.1 and 2.7 ka BP (Roberts et al., 2001). However, at 3.3 and 3.0 ka BP in the Dead Sea (Migowski et al., 2006), the water level declines while the Eastern

Mediterranean is recorded at 2.8 ka BP (Kuzucuoğlu et al., 2011). The effects of an arid climate were observed in the period between 3.2 and 3.0 ka BP in Lake Tuzla data.

The optimum climatic effects of Roman reflected in the data were recorded between 2020-1450 BP. The drought recorded in Lake Tecer is thought to be related to a decrease in precipitation and increase in evaporation during the Mediterranean summer. The effects of the arid period recorded between 2050 and 1450 BP in Tuzla data are reflected in the vegetation. An increase in herbaceous taxa during this period indicates the effect of a dry period.

1400-1115 BP corresponds to a significant turning point. This moist period determined in the diagram is compatible with the moist period recorded between 1440-1200 BP in Lake Nar (Jones et al., 2006) and between 1500-1180 BP in Lake Tecer (Kuzucuoğlu et al., 2011). A decrease in the values of *Artemisia* and Amaranthaceae while values of *Pinus*, *Corylus* and *Alnus* increased tell us that at 1.4 ka BP (Bond et al., 1997), the climate was humid in around Lake Tuzla.

Differences in temperature observed on a global scale in the Medieval Climatic Anomaly (MCA) are related to changes in the North Atlantic thermohaline circulation (Crowley and Lowery, 2000, Broecker, 2001, Cronin et al., 2003, Hunt, 2006). The MCA, Lake Tecer and Lake Nar from 1150 to 920 BP were recorded as arid due to the increase in summer temperatures (Jones et al., 2006; Kuzucuoğlu et al., 2011). At Lake Tuzla, a dry period was recorded between 1120-850 BP which is compatible with figures from lakes Tecer and Nar.

The effects of the Little Ice Age (Hass, 1996, Free and Robock, 1999, Luterbacher et al., 2001; Mann, 2002; Bradley, 2003; Cronin et al., 2003; Wanner et al., 2008) are also seen around Lake Tuzla. The overall woody taxon density in the diagram reached its highest level in this period. The period between 1400-1700 BP is compatible with the period recorded in Lake Tecer between 1570-1750 BP (Kuzucuoğlu et al., 2011). However, contrary to the Lake Tecer data, the Lake Nar data are characterized by more arid conditions between 1400 and 1960 BP (Jones et al., 2006).

Changes in the climatic conditions of the Little Ice Age (end of 16th century to beginning of 17th century) adversely affected the social and economic life of the Ottoman Empire. Cold, dry winters became increasingly frequent and hardened with the beginning of irregular climate oscillations in the Little Ice Age at the end of the 16th century; this adversely affected regional agriculture (White, 2011). The negative effect of the Little Ice Age on agriculture also affected social life, this is one of the reasons the Celali Rebellion in Central Anatolia revolted against the Ottoman Empire. Due to the turmoil created by the Celali

Rebellion, villagers abandoned the areas where they had carried out agriculture (Akdağ, 1975; Erlat, 2013).

8. Conclusion

This study examined changes during the last 5000 years of paleovegetation around Lake Tuzla near Kültepe based on fossil pollen analysis and reveals the factors that influenced those changes. Determination of the factors affecting paleovegetation change sheds light on the paleogeography of Kültepe and Lake Tuzla. It is seen that the effects of the BOP, when agriculture was carried out intensively in the vicinity of Lake Nar, are weaker around Lake Tuzla. Cereals, *Plantago lanceolata*, *Polygonum aviculare*, *Centaurea solstitialis* and *Sanguisorba* are among the secondary indicator species that indicate human influence on the vegetation of the Lake Tuzla surroundings. *Plantago lanceolata* and *Sanguisorba* taxa in the BOP revealed that in the study area, inhabitants were influenced by the vegetation structure. The human effect on vegetation is clearly seen between TZL-IIb and TZL-IIIc in the diagram. After the end of BOP, the increase in *Pinus* values shows that the pine forests around Lake Tuzla developed again. Tuzla data and paleoclimatic data in Anatolia and the Eastern Mediterranean are compatible with each other. The dry/humid periods identified in the Tuzla data for the last two thousand years correspond to climatic periods such as the Roman Climatic Optimum, Medieval Climatic Anomaly, and Little Ice Age. The most prominent effects of the Little Ice Age are seen; the very low NAP value of the AP value in 332 BP indicates that this change in the climate had a significant effect on the study area. The high values of *Artemisia* and Amaranthaceae pollen in the period 5000-3230 BP indicate that the vegetation of Lake Tuzla and its surroundings was dominated by steppe vegetation.

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Table 1. Radiocarbon/AMS ^{14}C ages from Lake Tuzla (TZL 16-01) sediment core.

Lab codes	Depth (cm)	Measured age	Conventional age	95%	68%
Beta-450113	187	3080 ± 30 BP	3110 ± 30 BP	3385-3240	3370-3335 / 3290-3265
Beta-450114	325	5020 ± 30 BP	5080 ± 30 BP	5910-5745	5905-5860 / 5825-5750

Table 2. States ruling Central Anatolia, archaeological periods, climatic events and changes in vegetation (Akurgal, 2014 [1], Bond et al., 1997 [2], Crowley and Lowery, 2000 [3], England et al., 2008 [4], Gümüşçü et al., 2013 [5], Wanner et al., 2008 [6], Wang et al., 2013 [7]).

<table>
<tr><th colspan="2">Archaeological/Historical Periods</th><th>Climatic Events</th><th>Changes in the Vegetation</th></tr>
<tr><td colspan="2">Republic of Turkey (1923) [1]</td><td rowspan="2">Little Ice Age (1300-1850 AD) [6]</td><td rowspan="2">In the 332s BP, the AP was 73% and the NAP was 27%. Within the AP, *Pinus* (68.2%) has increased. *Artemisia* (18,7%) and Amaranthaceae (8,1%) values increased in NAP. Cereals reached the highest value (2.8%). In TZL-V the vegetation structure is pine forests.</td></tr>
<tr><td colspan="2">Ottoman Empire (1299-1923 AD) [1]</td></tr>
<tr><td>Seljuk Period (1071-1300 AD) [1]</td><td rowspan="2">Byzantine Empire (395-1453 AD) [1]</td><td>Medieval climatic Anomaly [2-3]</td><td>In the 850s BP, AP was 60.5% and NAP was 39.2%. *Pinus* decreased in AP (41.4%) and *Quercus* (16.9%) increased. *Artemisia* (7.7%) and Amaranthaceae (13.9%) increased in NAP. *Pinus* and *Quercus* forests are predominant in the vegetation structure although the rate of *Pinus* is decreasing in TZL-IV.</td></tr>
<tr><td>Arab invasions (670-950 AD) [4]</td><td>1.4 ka BP event [2]</td><td>In the 1380s BP, AP was 69.2% and NAP was 30.8%. *Artemisia* (4,8%) and Amaranthaceae (5,1%) decreased in NAP while *Pinus* was increased in AP (56,3%). The predominant vegetation structure in TZL-IIIc is pine and oak forests.</td></tr>
<tr><td>Hellenistic Period (330-30 BC) [5]</td><td rowspan="2">Roman Empire (30 BC-395 AD) [1]</td><td rowspan="2">Roman climatic optimum [7]</td><td rowspan="2">In 1910 BP the AP value was 57.2% and the NAP value was 42.5%. In the AP, *Pinus* is 43,7% and *Quercus* is 9%. In NAP, *Artemisia* is 8,5% and Amaranthaceae is 8,2%. In the TZL-IIIb, pine forests dominate the vegetation structure.</td></tr>
<tr><td>Alexander Empire (336-323 BC) [5]</td></tr>
<tr><td>Persians (559-330 BC) [5]</td><td rowspan="2">Iron Age (1200-330 BC) [5]</td><td rowspan="2">2.8 ka BP event [2]</td><td rowspan="2">In 2910 BP, AP value is 54.8% and NAP value is 44.4%. In the AP, *Pinus* decreased (36,8%), *Quercus* (12,6%), and *Ostrya carpinifolia* (2,2%). Within the NAP, *Artemisia* (11,8%) decreased, Amaranthaceae (6,2%) and Ranunculaceae (8,4%) increased. In TZL-IIIa the vegetation structure dominates the forested areas.</td></tr>
<tr><td>Late Hittite Period (1200-650 BC) [1]</td></tr>
<tr><td>Hittites (1850-1200 BC) [5]</td><td rowspan="3">Bronze Age (3000-1200 BC) [5]</td><td rowspan="3">4.2 ka BP event [2]</td><td rowspan="3">In 4373 BP, AP was 63.1% and NAP was 36.9%. A sudden increase (51.2%) in the *Pinus* value was observed in AP, whereas a decrease in *Artemisia* value (16.6%) was observed in NAP. In TZL-I, the vegetation structure is in competition with the forested areas and step vegetation structure. In TZL-II 4100-3400 BP, the steppe vegetation structure is dominant.</td></tr>
<tr><td>Assyrians (2000-1750 BC) [5]</td></tr>
<tr><td>Hattians (2500-2000 BC) [1]</td></tr>
</table>

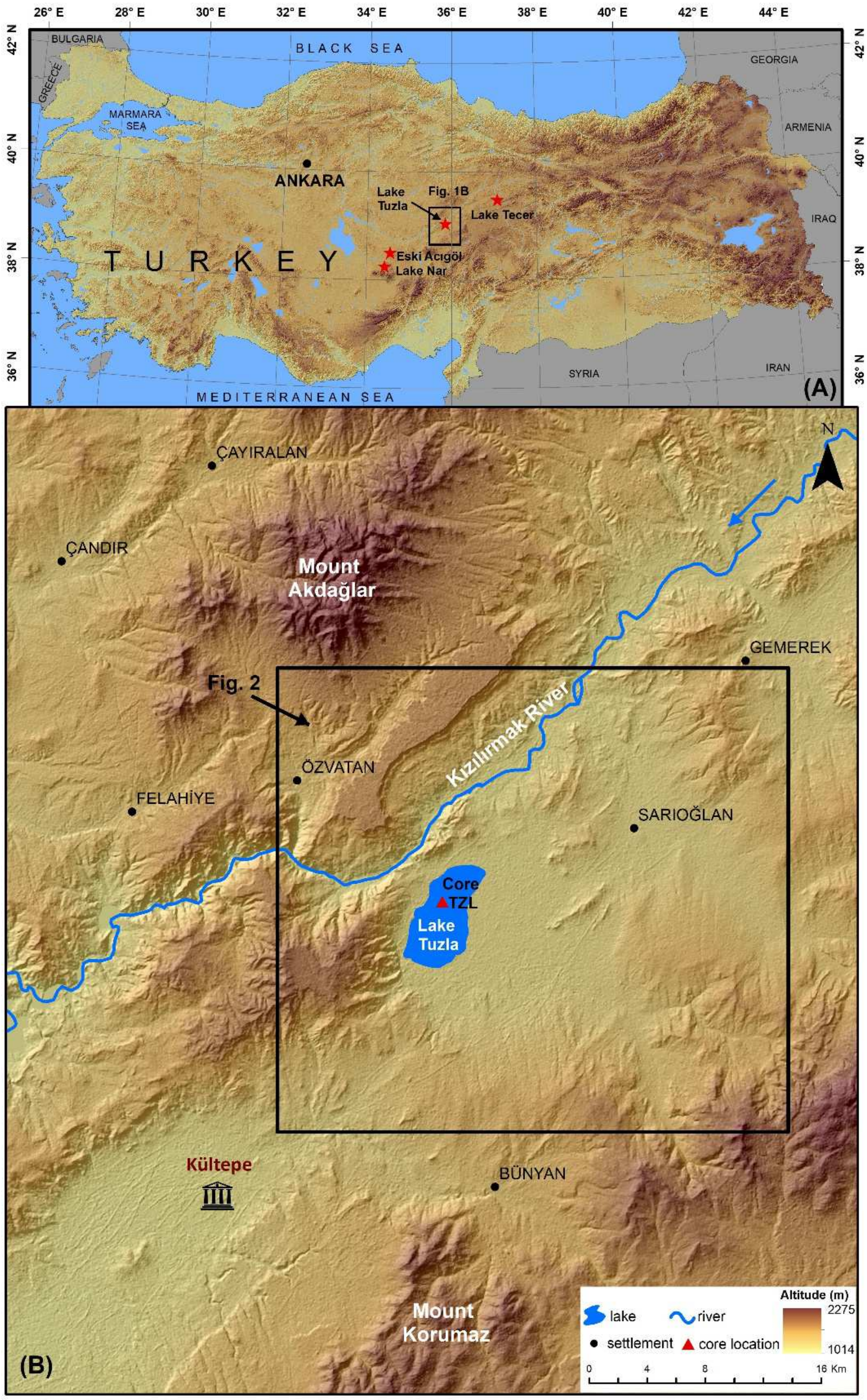

Fig. 1. Location map of study area

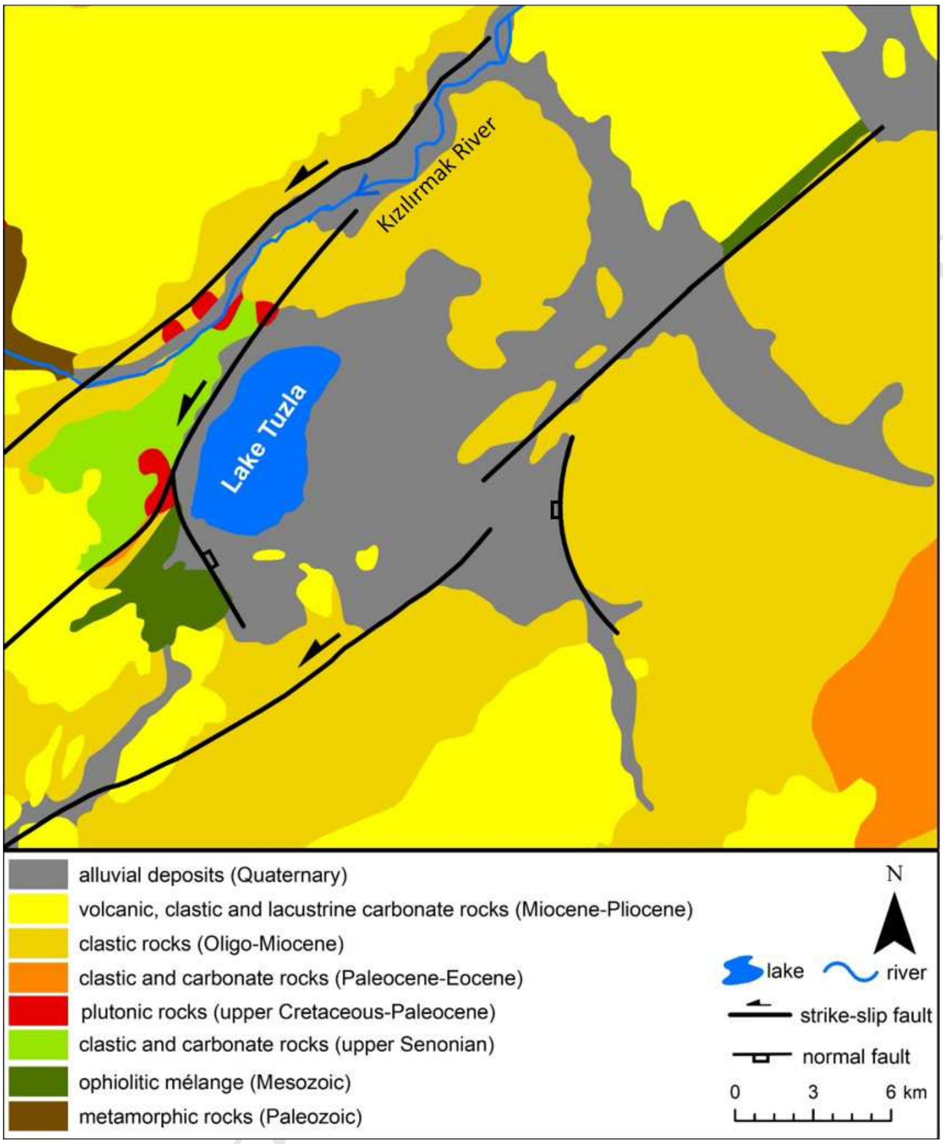

Fig. 2. Geological map of study area, (active faults and 1/500.000 scale geology map taken from MTA, active faults modified from MTA).

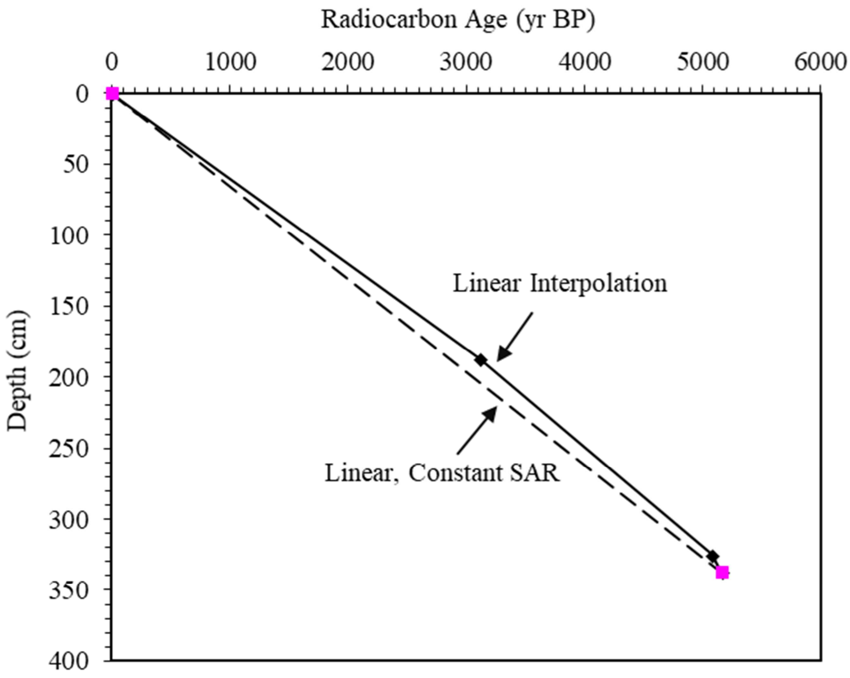

Fig. 3. Age-depth profile for Lake Tuzla (Core TZL 16-01).

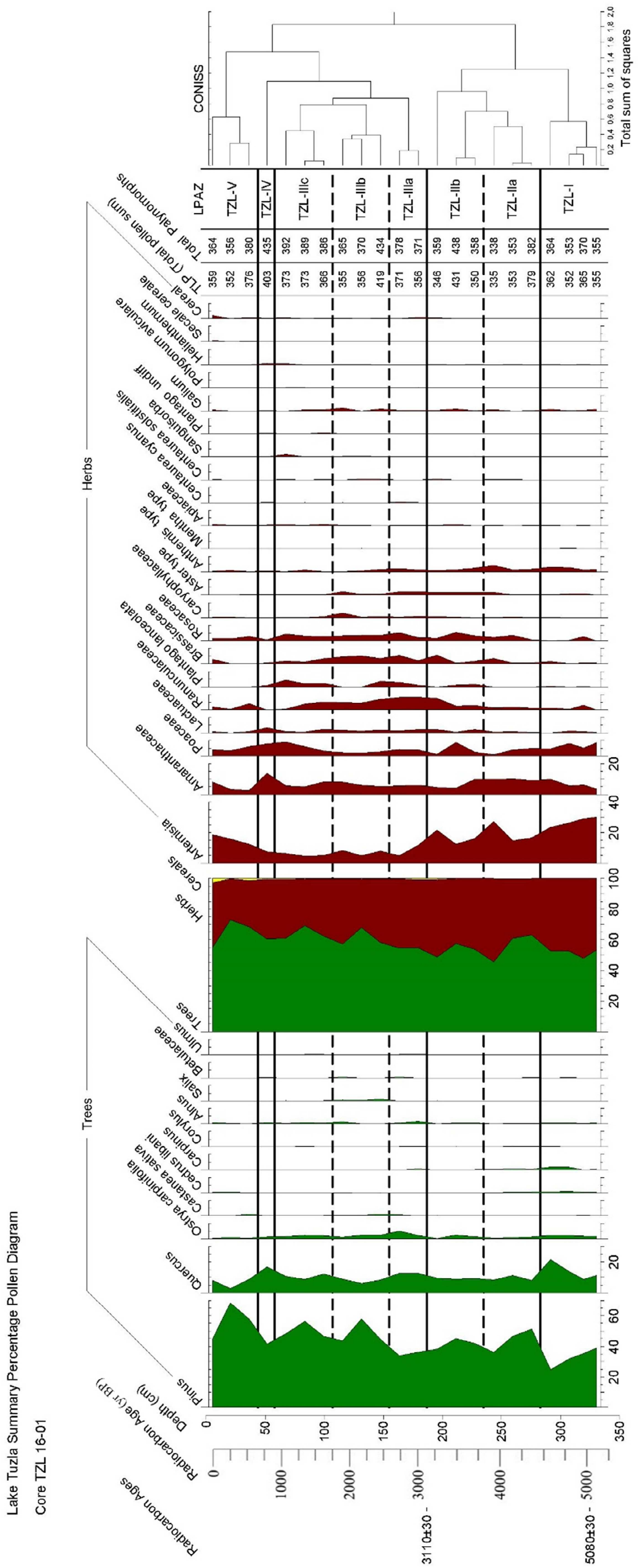

Fig. 4. Summary pollen percent diagram of Lake Tuzla.