Quaternary International xxx (2017) 1–6

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Palynology of Lake Arin (Eastern Anatolia, Turkey) deposits and its relation with water level change of Lake Van: Preliminary findings

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A R T I C L E I N F O

Article history:
Received 30 November 2016
Received in revised form
9 May 2017
Accepted 12 May 2017
Available online xxx

Keywords:
Lake Van
Lake Arin
Holocene
Lake level

A B S T R A C T

Palynological and lithological investigations of Lake Arin indicate mid-late Holocene lake level fluctuations both in Lake Arin and Lake Van. Pollen diagram and lithological features of sediments suggest unstable conditions during last 6 kyr BP for Lake Arin. Climatic changes and human impact have been both effective for destroying uppermost sediments of the lake. Semi-arid steppe vegetation dominance has been identified for Early Holocene around Lake Arin.

1. Introduction

Sensitive records of globally and locally climate change have been preserved in lake sediments. Water level and consequently shoreline geomorphology of lakes might change as a result of climate change. Climatic records of Eastern Mediterranean region have significant shifts from early to late Holocene which indicating multi-centennial wet-dry oscillations (Roberts et al., 2011). Investigations of ~50 globally distributed palaeoclimate records shows six periods of significant rapid climate change during the time periods 9000–8000, 6000–5000, 4200–3800, 3500–2500, 1200–1000, and 600–150 cal yr BP and characterized by polar cooling, tropical aridity, and major atmospheric circulation changes (Mayewski et al., 2004). Climate change periods of Holocene have been recorded at Anatolia and also closer area to the study site of this investigation such as Armenia and Lake Urmia (Ülgen et al., 2012; Eriş, 2013; Ocakoğlu et al., 2013; Dean et al., 2015; Talebi et al., 2016). In northwest Turkey, positive shifts in $\delta^{18}O$ of early Holocene indicate a mean summer temperature rise and increased aridity (Ocakoğlu et al., 2013) and deposits of Lake İznik points arid periods and lowered lake level for late Holocene at 4.2 and 3 ka BP (Ülgen et al., 2012). In Eastern Anatolia, Late Holocene level of Lake Hazar has been dropped about 3ka BP because of cold and dry conditions (Eriş, 2013).

Transgressive and regressive sequences of Lake Van have been identified as a result of water level changes from Pleistocene to the end of Holocene (Schweizer, 1975; Kempe and Degens, 1978; Valeton, 1978; Landmann et al., 1996a,b; Lemcke and Sturm, 1997; Kempe et al., 2002; Kuzucuoglu et al., 2010; Öğretmen and Çağatay, 2012; Çağatay et al., 2014; Çukur et al., 2014; Görür et al., 2015). Several depositional terraces deposited all around the Lake Van because of the changes of lake level (Schweizer, 1975; Valeton, 1978; Kempe et al., 2002; Kuzucuoglu et al., 2010). Schweizer (1975) has defined four sets of terraces at 12 m (1658 m above sea level (a.s.l)), 30 m (1676 m a.s.l.), 55 m (1701 m a.s.l.), 80 m (1725 m a.s.l.). Çağatay et al., 2014, has been defined a rapid transgression about 5-4 ka BP and after a general regression during 4-1 ka BP for Lake Van.

Palynological investigations in Lake Van Basin mainly have focused of the analysis of Lake Van and its terrace deposits (Wick et al., 2003; Litt et al., 2009, 2014; Kaplan, 2013). Previous studies indicate that the recent vegetation have been developed and extended from the Late Holocene to today by increasing human impact (van Zeist and Woldring, 1978; Wick et al., 2003; Litt et al., 2009; Kaplan and Örçen, 2012). Glacial and interglacial phases have been characterized by two main vegetation types of oak-steppe forest for past interglacial and dwarf-shrub steppe for glacial periods during Pleistocene (Litt et al., 2014).

Aims of this study are to define palynology of Lake Arin core samples and to determine the relation with the regressive periods of Lake Van, palaeoclimate, water level changes and human impact by using palaeoflora and palaeovegetation.

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http://dx.doi.org/10.1016/j.quaint.2017.05.020
1040-6182/

2. Study site

Lake Arin is located at the northern part of Lake Van with about 18 km^2 surface area and maximum 6.80 m water depth. Surrounding area of the lake covered with Plio-Quaternary pyroclastics and also Quaternary alluvial deposits contact with the pyroclastics at the eastern part of Lake (Fig. 1). Süphan Volcano is located at the north part of Lake Arin with about 10 km distance.

Lake water has dried completely at summer in past times (Lahn, 1951). In the past years, current events have reported that the lake water has frozen completely. Carbonate salt has been produced from Lake Arin according to the Ottoman Governmental Yearbooks (Şahin, 2015).

Study site is located in Irano-Turanian phytogeographic region which is characterized by steppe vegetation (Donner and Çolak, 2007). Surroundings is covered by East Anatolia lowlans steppe (Eken et al., 2006). *Limonium meyeri, Tamarix parviflora, Carex divisia, Typha latifolia, Salix alba, Hippophae rhamnoides, Plantago lanceolata, Prunella vulgaris, Polygonum bistorta, Ephedra distachia, Ephedra major* are the elements of lowland steppe of East Anatolia (Tatlı, 2004). Forest vegetation of Eastern Anatolia is represented mainly by *Pinus sylvestris, Quercus libani, Q. longipes*, *Q. brantii, Q. macranthera*, *Juniperus excelsa* and *Betula pendula* (Öztürk et al., 2015).

3. Material and methods

Measured maximum depth of Lake Arin is about 6.50 m. Five core samples have been collected using gravity corer from different water depths from 2 m to 6.50 m. Two core samples −A3 and A5- have been investigated stratigraphically and A3 also palynologically. 106 cm long A3 core was taken from 6.20 m water depth with the altitude of 1661 (±5) m above sea level and 44 cm long A5 was taken from 3.5 m water depth with the altitude of 1665 (±6) m above sea level (Fig. 2).

Samples for pollen analysis of A3 core have been taken 8–10 cm intervals of the sediments and have been prepared according to standard palynological sample preparation method treated with HCl, HF and $ZnCl_2$ (Ediger, 1986). 400–450 pollen grains have counted per each sample. Pollen descriptions, plates and illustration of Wodehouse (1935), Erdtman (1943), Faegri and Iversen (1989), Moore et al. (1991) and Beug (2004) have been used for pollen identifications and pollen diagrams were plotted using Tilia computer program (E. C. Grimm, Springfield, Ilinois, USA) (Figs. 3 and 4).

4. Results and discussion

A3 core content is more sufficient for palynological investigation of Lake Arin thus palaeoflora and reconstruction of palaeovegetation are based on pollen analysis of A3 core samples. Palynological analysis of A3 core samples represents high values of NAP (nonarboreal pollen) within the range of 80–90%. Poaceae, Chenopodiaceae and *Artemisia* were main elements of NAP palaeoflora (Fig. 3). Other NAP elements such as Compositeae *Tubuliflorea* type, Compositeae *Liguliflorea* type, *Carex* and Apiaceae pollen grains have been observed in every sample with a low values less than 5%. Deciduous *Quercus* and *Pinus* pollen grains represent main elements of AP (arboreal pollen) palaeoflora (Fig. 3). *Quercus* values in pollen diagram are under an average of 15% and *Pinus* has an amount of 5%. Other AP pollen grains have been identified only in a few samples such as *Juglans*, *Juniperus*, *Ulmus*, *Corylus*, *Carpinus*, *Olea*, *Tamarix* and *Pistacia*. AP/NAP rates of A3 core samples are ranging from 80% to 90% which means steppe vegetation dominance during deposition (Fig. 3). Steppe vegetation was characterized mainly by Poaceae, Chenopodiaceae and *Artemisia* elements. According to the palaeoflora changes, pollen diagram separated two subzones. At the bottom of the diagram, subzone 1b is characterized with maximum Chenopodiaceae and minimum *Quercus* values with 5% (Fig. 3). Aquatic taxa also have low values than upper levels in subzone 1b. Maximum Chenopodiaceae expansion up to 40% percent suggests halophytic conditions at the middle of the zone 1b and related with relatively high evaporation and lake level drop. Subzone 1b is represented by halophytic vegetation (Fig. 3). Boundary of subzone 1a and 1b is represented with maximum *Quercus* values up to 20% and during continued period as an effect of evaporation and rising level of ground water level *Carex* and *Cyperus* curve has been reached their maximum. While *Artemisia* reaches maximum value (about 30 cm depth of the core) in subzone 1a, aquatic taxa decreases minimum amount. Due to semi arid conditions might have been effective for maximum *Artemisia* expansion and minimum values of aquatic taxa. Subzone 1a is represented semi arid steppe vegetation (Fig. 3).

Steppe palaeoflora elements propagate naturally at the present time surrounding areas of Lake Arin. Also *Quercus* is an important forest vegetation element in Lake Van Region from Pleistocene to the present time. Lake Van palaeoflora is characterized by dominance of steppe vegetation for past glacial periods and steppe-forest vegetation during interglacials (Litt et al., 2014). Steppe vegetation is characterized by expansion of Poaceae, Chenopodiaceae and *Artemisia* and forest vegetation is characterized by expansion *Quercus* and *Pinus* for Lake Van region. Increase, decrease, maximum expansion and minimum ratios of those taxa can be associated with palaeoclimate changes before Holocene. An important AP element *Juglans* is cultivated at Adilcevaz-Ahlat region which is a close range to Lake Arin at the western part. Relatively abundance of *Juglans* pollen grains on pollen diagrams can be correlated with human impact in Lake Van Basin for Late Holocene. *Juglans* pollen grains have been observed just a few on pollen diagram of Late Pleistocene of Lake Van terrace deposits (Kaplan, 2013). Human impact in Van region is established for Late Holocene and last 600 years are important for clearing woodland by people (Wick et al., 2003). There is not an evidence for Early Holocene anhtopogenic impact in the area.

Preliminary palynological results of this study have been compared with previous studies from Lake Van Northern Basin (Kaplan and Örçen, 2012), Ahlat Ridge (Litt et al., 2009), Tatvan Basin (van Zeist and Woldring, 1978; van Zeist and Bottema, 1991; Wick et al., 2003). AP/NAP ratio has different values although palaeoflora has similarities between A3 core and Late Holocene palaeoflora of Lake Van Northern Basin. Therefore, Late Holocene vegetation is incomparable with the results of this study due to high amount of AP grains about 40% values. Lake Van AP/NAP values have been changed repetitively from Pleistocene to Late Holocene with the maximum 80% AP and less than 5% minimum ratio as known from previous palynological studies (Litt et al., 2014). Early Holocene pollen diagrams of Ahlat Ridge and Tatvan Basin are rather similar with Arin A3 pollen diagram both palaeoflora and AP/NAP raito (Fig. 4). AP/NAP ratio of all those two sites was approximately 80% between 8 and 10 ka BP as such on pollen diagram of A3 (Fig. 4) and *Quercus* was the main AP element while Poaceae, Chenopodiaceae and *Artemisia* were dominant in NAP palaeoflora. Lake Arin pollen diagram is comparable with the lower part of local pollen assemblage zone 3 of Lake Van Ahlat ridge (see Litt et al., 2009 for more). Dating approach of Lake Arin mainly base on correlation between pollen diagrams of this study and Lake Van Ahlat ridge according to the increase and decrease of AP/NAP values shown with red circles (Fig. 4) and indicator taxa for Lake Van region such as *Quercus*, Chenopodiaceae, *Artemisia* and Poaceae. It is believed that the sampled sediments in this study were deposited

Please cite this article in press as: Kamar, G., Palynology of Lake Arin (Eastern Anatolia, Turkey) deposits and its relation with water level change of Lake Van: Preliminary findings, Quaternary International (2017), http://dx.doi.org/10.1016/j.quaint.2017.05.020