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Paleoclimate of Eastern Black Sea Region in Turkey and The Importance of Glacial Lakes and Their Sediment Record

Türkiye'de Doğu Karadeniz Bölgesinin Paleoiklimi ve Buzul Göllerinin ve Sedimanlarının Önemi

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Abstract: *To be able to make sustainable management plans we should know previous conditions of any region. Natural archives and their preserved proxies are used to track past environmental and climatic changes in time scales longer than instrumental records. Most of the natural archives that have been used to reveal the past are coming from the central, south central and northwestern Anatolia. However, glacial lakes and their sediment in the northeastern part of Turkey are untapped source of information. Here, I will discuss existing knowledge from different natural archives in Anatolia, and in southern Black Sea coast since the Late Glacial and possible future research questions in northeastern part of Turkey.*
Key words*: Glacial lakes, paleoclimate, paleolimnology, the Black Sea.*

Özet: *Sürdürülebilir yönetim planları yapabilmek için herhangi bir bölgenin referans koşullarını bilmemiz gerekir. Doğal arşivler ve onların korunan indikatörleri geçmiş çevresel ve iklimsel değişiklikleri, ölçülen kayıtlardan daha uzun zaman ölçeğinde takip etmede kullanılırlar. Geçmişi ortaya çıkarmakta kullanılan doğal arşivlerin çoğu iç, güney ve kuzey-batı Anadolu'dan gelmektedir. Buna rağmen, Türkiye'nin kuzey-doğu bölümündeki buzul gölleri ve onların sedimanları kullanılmayan bilgi kaynağıdırlar. Burada, Anadolu'da ve Karadeniz'in güneyindeki kıyılarda Geç Buzul döneminden beri, farklı doğal arşivlerden var olan bilgileri ve Türkiye'nin kuzey-doğusunda olası gelecek araştırma sorularını tartışacağım.*
Anahtar kelimeler*: Buzul göller, paleoiklim, paleolimnoloji, Karadeniz.*

1. Introduction

For effective ecosystem management, we need to know reference (background) conditions prior to human disturbances, the range of natural variability, and the time and level of occurring disturbances (Smol, 1992). Long term ecological and environmental monitoring data would be helpful to get this information. However, it is usually not easy to collect long term monitoring data, which is based on field works for ecologists. Usually they rarely exceed three years, which is a typical duration to collect samples for PhD students suggested via many universities in the world (Smol, 2008). Even, to obtain last fifty years of environmental monitoring data for either an aquatic or terrestrial ecosystem is almost impossible. Then, it becomes difficult or impossible to determine the nature and timing of changes in the ecosystem, which is essential for effective ecosystem managements, with these short term

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environmental datasets (Smol, 2019). On the other hand, we know that at least within the last century, which we can also call this period as an Anthropocene, natural ecosystems have been densely effected by anthropogenic impacts (Corlett, 2015). Most of the ecosystems are far from their reference conditions now. Plus, current warming climate is a global trend (Neukom et al., 2019).

Even though, people are not able to monitor these systems for long term periods, there are natural archives collecting information about them. Natural archives are diverse, such as marine and lake sediments, cave deposits, tree rings (Bradley, 1985, pp.6-7). And, usually, one should be chosen according to your environmental question, time interval, and resolution that you are interested in. Mostly lake sediments are the common one to track century to decadal changes since the Late Glacial (Bradley, 1985, pp. 6-7; Jones et al., 2006). If varve deposition occurs in a lake, then they also provide annual and even seasonal dating by means of counting varves (Zolitschka et al., 2015). In Turkey, Lake Van has continuous varves (Wick et al., 2003), and Nar lake and Eski Acı Göl (Old Bitter Lake) has discrete varve occurrence (Roberts et al., 2001; Roberts et al., 2016) in their sediment records.

To study same contemporary limnological problems using primarily lake sediments is called as paleolimnology (Smol, 2008). Those problems could be acidification (Charles ve Smol, 1990; Battarbee, 1994), eutrophication (Bennion, 1994), salinity change (Fritz, 1991; Frenzel and Boomer, 2005), water level fluctuations (Fritz, 1991), and lake water temperature changes (Korhola, 1999; Leng and Marshall, 2004). Those are within the lake problems and they can be tracked via autochthonous proxies preserved in the lake sediments, such as diatoms, Cladocera, Chrinomidae, Ostracoda, stable oxygen isotopes, etc. Also allochthonous proxies from the lake's catchment or air can be deposited in the lake sediments which enables to track past vegetation change (Bottema, 1995), and pollution (Rose, 2001). Except the lakes forming varves, chronology of the lake sediment usually based on ^{210}Pb and ^{135}Cs dating techniques for short cores (Appleyby, 2001) and ^{14}C dating technique for the long cores (Björck and Wohlfart, 2001).

2. Paleoclimate of The Region

Both Soreq Cave record in southern Levant, in Israel (Bar-Mathews et al., 2000) and Sofular Cave record in southern Black Sea coast, in Turkey (Fleitmann et al., 2009; Göktürk et al., 2011) are well dated, high resolution archives revealing past climate of Eastern Mediterranean region. Soreq Cave record include number of low d^{18}O values, which is interpreted as increase in annual rainfall, during last 140 kyr (thousand years) in Eastern Mediterranean (Bar-Mathews et al., 2000). The last one was occurred from 8,5 to 7 kyr (Bar-Mathews et al., 2000). Sofular Cave is located in northwestern Turkey, on the Black Sea coast. According to their isotope records precipitation was increased during the early Holocene both in the southern Black Sea coast (Göktürk et al., 2011) and in the Mediterranean coast (Bar-Mathews et al., 2000). Sofular Cave data is well compatible with Greenland Interstadials (Fleitmann et al., 2009) and Soreq Cave record matches sapropel formations in the Mediterranean Sea (Bar-Mathews et al., 2000).

Lake sediments give information from south (Eastwood et al., 1999), central (Roberts et al., 2001; Roberts et al., 2011; Roberts et al., 2016), north-western (Miebach et al., 2016) and eastern Anatolia (Wick et al., 2003) and they are mostly located in lowlands of Anatolia under the human impact (Woldring and Bottema, 2003; England et al., 2008).

As elsewhere, the Late Glacial Maximum, was a cold and dry period both in the Levant (Bar-Mathews et al., 2000; Bartov, et al., 2002; Bar-Yosef, 2011) and in Anatolia (Fleitmann et al., 2009; Göktürk et al., 2011; Miebach et al., 2016). YD (Younger Dryas) was dry too (Wick et al., 2003; Göktürk et al., 2011; Dean et al., 2015; Miebach et al., 2016). Early Holocene was wetter according to the oxygen isotope data (Bar-Mathews et al., 2000; Fleitmann et al., 2009; Göktürk et al., 2011; Dean et al., 2015) and pollen records (Woldring and Bottema, 2003; Wick et al., 2003; Miebach et al., 2016). Increase in the lake water level due to high precipitation was also observed from lacustrine archive in central Anatolia during this time (Roberts et al., 2001), however, the mid Holocene was drier (Roberts et al., 2011). The last 600 years until the 20th century have been driest period during the Holocene in northern

Anatolia according to the Sofular Cave record (Göktürk et al., 2011). Despite of relatively stable Holocene climate worldwide, there have been also a few rapid climate changes (RCC) during the Holocene (Bond et al., 1997; deMenocal et al., 2000). During these RCC (9.3, 8.2, 4.2 ka events), the climate was colder and drier with less precipitation in Anatolia (Dean et al., 2015).

An abrupt change in Black Sea faunal composition at around 7500 cal yr BP has been revealed from Black Sea sediment records (Ryan et al., 1997; Williams et al., 2018). However, that change was gradual according to Ivanova et al. (2015). That is also corresponding to the increased annual precipitation over the Eastern Mediterranean according to the speleothem records from the caves (Bar-Mathews et al., 2000; Göktürk et al., 2011). There are also, palaeolimnological studies from marginal marine environments (Berndt et al., 2019), and coastal lakes on the Black Sea shore, in Turkey (Sekeryapan, 2011), revealing past environmental changes during the Holocene/mid-late Holocene.

Human's respond to these rapid climate changes during the Holocene is still a subject of question however there are also some studies revealing that it was less strong than the one during the Late glacial and the Early Holocene transition (Bar-Yosef, 2011; Floh et al., 2015). During the late Glacial and early Holocene human's respond must have been high (Bar-Yosef, 2011), whereas during the rapid climate changes of the Holocene (during 8.2 ka, 9.8 ka events) people was resilient to it anymore (Floh et al., 2015).

Despite of its mid- latitudes Turkey has several mountain glacials (recent and Pleistocene) (Çiner, 2004) and also glacial lakes due to its diverse topography. Some of them are located in the northeaster Turkey (Çiner, 2004), on the Black Sea coast. There have been several glacial lakes located on these mountains. Their sediment records are untapped source of information both in terms of past climate and environmental change about this area. There have only been a few publications about species composition in these lakes (Aygen et al., 2012). Since they are located in high mountains, remote from human influence, they might be perfect source of information to track past global climate changes, too.

3. Glacial Lakes and Their Paleolimnology

When you want to reconstruct past climate change using the lake sediments, you usually need to differentiate human effect and climate effect in your data. Because if you use water level fluctuations depending on past precipitation and evaporation rations to reveal past climate change in an endorheic lake, you should give some evidences that there were no human influence effecting water level changes in that lake. That is especially important in an area like Anatolia that highly inhabited since almost the 9 000 BP via human societies (Hodder, 2010), and anthropogenic impacts have been observed since the 7^{th} millennium BP (Woldring and Bottema, 2003). Usually remote alpine lakes are directly affected via climate changes and their sediment archives are used to reconstruct regional and global climate changes (Catalan et al., 2013; Moser et al., 2019).

Alpine lakes are sensitive, remote, freshwater ecosystems, mostly composed of glacial or volcanic lakes. They endure environmental conditions including at least 8 month's ice cover in a year and high UV radiation. Those conditions in turn determine their ecosystem function and species diversity (Moser et al., 2019). They are mostly small, and dilute (oligotrophic) freshwater lakes. They are also important freshwater sources. Since they are located mostly in pristine, protected area, they are called as sentinels of global environmental changes (Moser et al., 2019).

3.1. Glacial lakes in northeastern Anatolia

Despite it is located in mid- latitudes, Anatolia has several glacials and also glacial lakes because of its diverse topography (Çiner, 2004). However, those lakes are untapped source of information except a few publications about their species composition (Aygen et al., 2012). In the northeastern part of Turkey, there are recent and Pleistocene glacials on the Kaçkar Mountain (Çiner, 2004). Northern hillsides of this mountain includes several glacial lakes; most probably among Pleistocene glacials (Çiner, 2004). Glacial lakes are far from human impact and were not altered directly by human. Yet, current tourism in the region may affect them. Their remote location in pristine areas makes them the sentinels of these mountains and both regional and global climate changes. Alpine lakes are sensible to

climate change and it is easy to track climate change in the absence of anthropogenic impacts. Moreover, glacial lakes may deposit varves, which provide annual dating opportunity via counting them (Ojala et al., 2012; Zolitschka et al., 2015). However, their sediments are untapped source of information for the past climate of this region in Anatolia. Even, their contemporary limnological monitoring is very scarce (Aygen et al., 2012).

3.2. Paleolimnological studies in glacial lakes and its possible application to the ones in North East Anatolian region: What they can tell us about the past environment and climate of the region?

Glacial lakes can record both past environmental changes both within the lake and in its surrounding area. Their sediments can contain products of glacial erosion, biological and chemical remains within lake, and from its catchment (Hodgson and Smol, 2008). Their sediments can be used for reconstruction of deglaciation (e.g. in glacial lakes, deglaciation can be seen as a transition from siliciclastic glacial to organic non-glacial sediments) (Hudgson & Smol, 2008). Together with ^{14}C chronologies we can know when the land became ice free. Glacials all around the world are retreating in 21st century (Zemp, et al., 2015). And, we know that current glacials in Turkey are also retreating since the 20th century (Çiner, 2004). Mountains are the first locations effected by the global climate change (Beniston, 2003), and alpine lake's sediment can archive those global changes (Catalan et al., 2013; Moser et al., 2019). Their sediment can be used for the studies related with the climate and ecosystem change and human impacts (Hudgson and Smol, 2008).

4. Conclusion

The glaciers in the Kaçkar Mts. were maximum in the Last Glacial Maximum (LGM), and younger glacial advance took place during the Late Glacial (Sarıkaya et al., 2011). From the data of lake sediments in the south, central, north-western and eastern Anatolia we know that past climate of these regions was including some alterations between wet and dry periods since the Late Glacial (Roberts et al., 2001; Wick et al., 2003; Roberts et al., 2011; Roberts et al., 2016). During the late glacial the climate was cold and dry (Wick et al., 2003) and it was even colder and drier during the YD (Wick et al., 2003). However, lacustrine records from the other parts of Anatolia might be limited to reveal past climate change in the south eastern Black Sea coast where we know that current climate and climate dynamics are quite distinct from the other parts of Anatolia (Türkeş, 1996; Türkeş and Erlat, 2003).

Sofular Cave record from the south-west Black Sea coast also reveals wetter early Holocene conditions with an interruptions of an abrupt dry phase (around 8.2 ka event) and more drought during the last 600 years until the 20th century (Göktürk et al., 2011), despite of its dry and cold late Glacial conditions (Fleitmann et al., 2009; Göktürk et al., 2011).

Sofular Cave is in the same present-day climate with the eastern Black Sea region in Turkey according to Türkeş (1996), so that it can give us a general perspective of the past climate of the region (especially during the Holocene). However, we still can get the benefits of high resolution glacial lacustrine sediments in the south east Black Sea coasts to reveal past climate change of this region. It has been well known that lake sediments are excellent archive revealing past environmental and climate changes. Although most of the paleolimnological studies in Anatolia have been carried out in the lowland lakes close to the archaeological sites, alpine lakes can give us direct results for the past climate change without obscuring past human effect to these ecosystems.

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