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Geochemistry of Marmara Lake sediments - Implications for Holocene environmental changes in Western Turkey

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ABSTRACT

Beginning from the Early Holocene marked environmental changes have been revealed by a multi-proxy study of two radiocarbon-dated sediment cores from Lake Marmara. Both cores are composed of fine clastic sediments deposited over the last 1845 years. The core taken from the western depocentre supplementary consists of a 20 cm thick interval which represents a time period of 10.28 to 8.28ka yrBP. A desiccation event caused 6435 year hiatus in the sedimentary record. The lake was established again at 1.85ka yrBP. After a transitional humid phase at the beginning of the Late Holocene, overall arid conditions were continuously effective.

Especially the difference between the geochemical composition of Early and Late Holocene sediments indicates distinctive environmental conditions. Respective humid phases took place in between 10.28 and 8.28ka yrBP (Early Holocene) and 1.85 to 1.72ka yrBP (Late Holocene). The Early Holocene phase is characterized by higher fluvial activity controlled by the humid climate and active tectonics. Right after the Middle Holocene droughts, a short-termed tendency to relatively fresh and oxic conditions prevailed. However, the small surface area of the lake and its shallow conditions caused fast variations of hydrology, oxidation level, salinity and organic productivity during the last 1850 years. We suggest that a combination of the instability of the Eastern Mediterranean climate and local conditions is the main control on the changing paleo-environment during the study period.

1. Introduction

Extensive paleoclimatic studies have provided evidence that the Holocene is characterized by marked sub-millennial to multi-centennial climatic fluctuations and rapid shifts worldwide (e.g. Bond et al., 2001; Mayewski et al., 2004; Arz et al., 2006; Lamy et al., 2006; Wanner et al., 2008; Magny et al., 2009; Ülgen et al., 2012). Previously, it has been reported based on studies of lacustrine, marine and fluviatile deposits that the coastal area of Turkey has responded sensitively to these climate changes (Kayan, 1988; Ergin et al, 2007; Leng et al., 1999; Roberts et al., 2010; Doğan, 2010). Various lake systems in Turkey have been studied, however, most of these are located in the eastern and central parts of the country, such as Lakes Van, Acıgöl, Akgöl, Nar, Bafa etc. (Bottema, 1995; Leng et al., 1999; Wick et al., 2003; Roberts et al., 2001, 2008; Roberts and Jones, 2002; Jones et al., 2006; Woodbridge and Roberts, 2010; Bruckner et al., 2002, 2006; Mullenhoff et al., 2004, 2005; Knipping et al., 2008; Litt et al., 2014).

In contrast, we identify a significant gap in paleoclimate research addressing the central parts of Western Turkey. A limited number of the lake repositories (Gölcük, Köyceğiz, Gölhisar) has been studied so far with a main focus on the Late Holocene period only (Sullivan, 1988, 1990; Jones et al., 2002; Eastwood et al., 1999, 2007a,b). Here, we demonstrate that one of the rare surviving Holocene Lake system - Lake Marmara - in central Western Turkey may be suitable to overcome this deficiency. In a previous study, deposits of Lake Marmara have been investigated by Besonen and Roosevelt (2009) in a geoarcheological context. Our research takes into consideration that Lake Marmara exhibits a complex evolution mainly controlled by intense tectonic periods and that the lake is formed in topographic depression in the northern part of the Gediz basin (Hakyemez et al., 1999).

We propose that, the sedimentary record of Lake Marmara provides a suitable geological archive for understanding the Holocene and particularly the Early and Late Holocene environmental

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changes in this climate sensitive coastal area. The work reported here is predominantly focused on lithological observations, inorganic parameters and basic organic matter characteristics. The field work started in 2003 when two approximately 1.5m long cores were collected from the western (core:H3) and eastern (core:H5) depo-centers of the lake. We have applied various geochemical proxy methods including AMS radiocarbon dating, Rock-Eval pyrolysis and X-ray fluorescence (XRF) core scanner (μ-XRF) analysis of the sediment cores. The latter technique has been used to obtain high-resolution geochemical profiles, which are interpreted to identify local climate signals, distinguish internal and external effects on the lake environment such as physical dynamics, chemical characteristics of the water column and bioproductivity. This study also aims to analyse the effect of main global climate trends on the environment of Lake Marmara such as the Early Holocene humid phase, the Middle Holocene dry conditions and various Late Holocene events including organic matter rich sedimentation (ORS), Medieval Warm Period (MWP) and Little Ice Age (LIA). We propose that the study of the sedimentary record of Lake Marmara would help us to understand such climatic and environmental changes for the central part of Western Turkey, as it is the most significant surviving lake ecosystem in this area during the Holocene.

2. Regional setting

The study area is located in a complex horst-graben system, formed on the northern margin of the Menderes Massive, one of the main tectonic units of Turkey (Fig. 1). Metamorphic rocks of the Menderes Massive are present in the northern part of the lake's drainage area. Furthermore, Plio-Quaternary formations are also present at the southern margin of the lake. These units contain fluvial sediments at the bottom and lacustrine carbonates on the top. The Quaternary sediments exhibit mainly fluvial character, but some young paleo-soils were also observed along the southern coast of the lake. Formation of Lake Marmara is probably controlled at the beginning by the regional uplift and flow regime of the Gediz River (Hakyemez et al., 1999). Regional uplift probably caused a fan shaped barrier establishment in front of the tributary which had reached the Gediz River in south-western boundary of Lake Marmara (the east of Bintepeler to the north of Salihli) at the beginning of the Holocene. Therefore, Lake Marmara was formed by the obstruction of the stream coming from nearby northern areas (Hakyemez et al., 1999). While the lake was originally a natural one, the Turkish General Directorate for State Hydraulic Works (DSI) transformed it into a reservoir by a dam construction in 1953.

Turkish shallow lakes, mostly influenced by Mediterranean climatic conditions, fluctuate annually from less than 1 m to over 3 m (Beklioğlu et al., 2001). The amplitudes depend on local climatic conditions; however, human water abstraction should also be taken into account. Considering temperature and precipitation data, this lake is located in the Aegean climatic zone. Thus, the semi-arid climate of the area is characterized by hot and dry summers and warm and wet winters. Average minimum and maximum temperatures over the period of 1951–1998 were 4 °C and 27.6 °C, respectively, with a mean of 15.4 °C and a standard deviation of 3.2, 2.0, 2.5 °C, respectively. Average annual precipitation was 682 mm with a standard deviation of 1.5 mm (Ünal et al., 2003). The modern condition is eutrophic in the lake column (Balık et al., 1991; Ahnelt et al., 1995; Özcan, 2009; Beklioğlu et. al., 2006). Geographical, hydrological and physical features and the modern biological and basic limnological properties of the lake have been investigated in previous studies (Balık et al., 1991; Ahnelt et al., 1995; Tan and Beklioğlu, 2006; Özcan, 2009), as summarized in Table 1.

3. Materials and methods

This study represents the sedimentary, geochemical and radiocarbon investigations of selected two cores, namely H3 and H5,

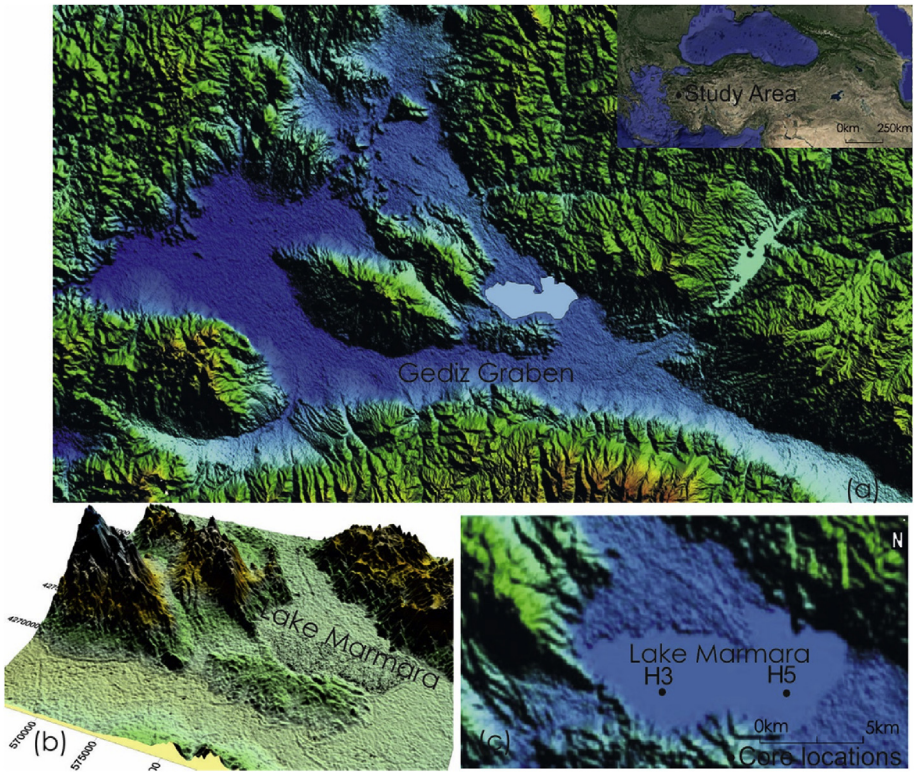

Fig. 1. a. Map of Turkey with study location of Lake Marmara shown in satellite image and relief map. b. 3D block diagram. c. Core locations.