Quaternary International xxx (2015) 1–9

Contents lists available at ScienceDirect

Quaternary International

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

Records of repeated drought stages during the Holocene, Lake Iznik (Turkey) with reference to beachrock

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A R T I C L E I N F O

Article history:
Available online xxx

Keywords:
Beachrock
Cementation
Late Holocene
OSL
Lake Iznik

A B S T R A C T

The cement fabrics, subsurface nature and optically stimulated luminescence age of beachrocks along the shores of Lake Iznik in NW Turkey were studied within the context of Holocene lake level changes. With a maximum thickness of 1.5 m, the low-angle (average 5–10°) beds are composed of coarse grains and small gravels and extend up to 5 m offshore at their most lakeward extremities. Cement textures on and around the poorly-rounded grains are made up of micrite envelopes and meniscus bridges as well as acicular aragonite rims. Geoelectrical resistivity sections taken from a representative location along the beach where the beds have maximum thickness showed that the sand-buried beds are followed up to about 24 m landward. Based on the OSL ages of 33 samples, the cemented beds occurred at four drier periods of the following: Pre- and Early Holocene (dated to 15–9 ka), Holocene Climatic Optimum (7.9–5.6 ka), Middle Holocene (4.9 ka–2.8 ka) and Late Holocene (2.0 ka–0.9 ka).

1. Introduction

As a dependable marker of environmental change, temporal variations in lake levels leave a record of changes in hydrological cycle and climate during the Late Quaternary (Street-Perrott and Harrison, 1984). The amounts of precipitation and evaporation as well as input by runoff are among the primary factors controlling the water level in lakes. Temporal changes in lake levels can be reconstructed using geomorphic and sedimentological methods (Harrison and Digerfeldt, 1993).

Precipitating from sea or lake waters, the connective carbonate cements of beachrocks, consisting of mainly aragonite and high-Mg calcite, bear a record of paleo-climatic changes favoured mostly by increased evaporation under dry climatic conditions. Beachrock has been mostly attributed to intertidal environments along tropical and subtropical coasts (Vousdoukas et al., 2007). There has been a common belief in its intertidal origin since early studies (Ginsburg, 1953; Bernier and Dalongeville, 1996; Neumeier, 1998), as opposed to other studies underlining the importance of upper subtidal (Alexandersson, 1972) or supratidal zones (Kelletat, 2006). Given that intertidal cementation makes beachrock favourable for determining sea-level changes (Hopley, 1986; Desruelles et al., 2009; Mourtzas, 2012; Mourtzas and Kolaiti, 2014), which can be confirmed by the stable isotope composition and petrography of the connective cements (Vieira and Ros, 2006), it can be envisioned that the beachrock on lake shorelines also provides substantial hints inferring the paleo-climatic changes that have prevailed in the lake environment.

Knowledge of the existence of beachrock on lake shorelines is limited to just a few studies, as suggested by Binkley et al. (1980) and Jones et al. (1997). These authors demonstrated that beachrock cements precipitated from the low magnesian-calcite-dominated waters of Marl Lake in Michigan, USA and the silica-rich waters of Lake Taupo in New Zealand. Recent publications concerning Lake Iznik, NW Turkey (Erginal et al., 2012a,b) showed its presence along the fresh-water lake shorelines. In this paper, on the basis of cementation fabrics, subsurface geometry and optical luminescence ages, we discuss the implications of beachrocks on

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http://dx.doi.org/10.1016/j.quaint.2015.08.077
1040-6182/

the shores of Lake Iznik with regard to Holocene climatic and lake level changes.

2. Study area

Lake Iznik is the fifth largest lake in Turkey, lying at 40°30′–40°22′ N and 29°20′–29°42′ E in the eastern part of the Marmara Region, NW Turkey (Fig. 1a, b). It is roughly rectangular (32 km long, 12 km wide; Fig. 1c), and has a maximum depth of 80 m. Found at a level of about 85 m above the present sea-level, the mean annual variation in lake level is ~50 cm (Ülgen et al., 2012), influenced by anthropogenic water usage, evaporation and seasonal changes in precipitation. The lake has a surface area of 313 km^2 (Ozturk et al., 2009) and occupies an east-west-aligned depression formed by the middle segment of the North Anatolian Fault. Its present connection with the Sea of Marmara to the west is through the Garsak Gorge, carved deeply (up to 400 m) in Paleozoic and Triassic metamorphic rocks. This valley is at present crossed by the Garsak Stream that flows into the Gulf of Gemlik (Fig. 1c). A Mediterranean climate prevails in the study area, characterized by arid and semiarid conditions from May to October. According to Viehberg et al. (2012), it is a warm monomictic lake. The lake area receives an average total precipitation of 737.9 mm. The average annual air and water temperatures are 15.1 and 20 °C, respectively. High evaporation occurs when maximum temperatures reach 45 °C during the summer months.

3. Methods

A total of 33 samples of beachrock were collected from 8 different sites (L1-L8) along the southern, northern and western shores of Lake Iznik for petrographic and electron microscopy analysis as well as luminescence dating. The micro-fabrics and elemental composition of samples were examined using Scanning Electron Microscopy (SEM-ZEISS EVO 50 EP) coupled with Energy Dispersive Spectroscopy (EDX-Bruker AXS XFlash). The precipitated carbonate minerals were determined using X-ray diffractometry (XRD). Using a Scheibler calcimeter, CaCO3 content (%) was measured after extracting particles larger in size than 2 mm. The U, Th and K concentrations were analyzed using Inductively Coupled Atomic Mass Spectroscopy (ICP-MS).

3.1. Geoelectrical imaging survey

An ERT (Electrical Resistivity Tomography) survey, which has been widely used to describe the subsurface nature of cemented coastal deposits (David et al., 2009; Erginal et al., 2012c, 2013a, 2013b, 2013c; Ertek et al., 2015), was carried out on one of the studied beaches where the beds have maximum thickness (Fig. 1c). Thereby, we aimed at both determining the thickness of the cemented beds vertically and also perceiving their contact relationship with the underlying unit. For this purpose, a total of 11 depth levels on three ERT lines oriented perpendicular to the lake shoreline were measured using dipole–dipole electrode configuration with electrodes spaced every 1 m. Apparent resistivity measurements were carried out via the GF ARES multi-electrode resistivity-meter system. Due to the limited width of the shoreline, the lengths of profiles were selected as 24, 21 and 33 m for Line-1, Line-2 and Line-3, respectively (Fig. 1d). The measured apparent resistivities were then inverted to true resistivities using the tomographic inversion software package RES2DINV, which is based on smoothness-constrained least-squares (Sasaki, 1992) implemented by a quasi-Newton optimization technique (Loke and Barker, 1996). Significant topographical relief data obtained by optical levelling were also incorporated into the inversion procedure to achieve more accurate results.

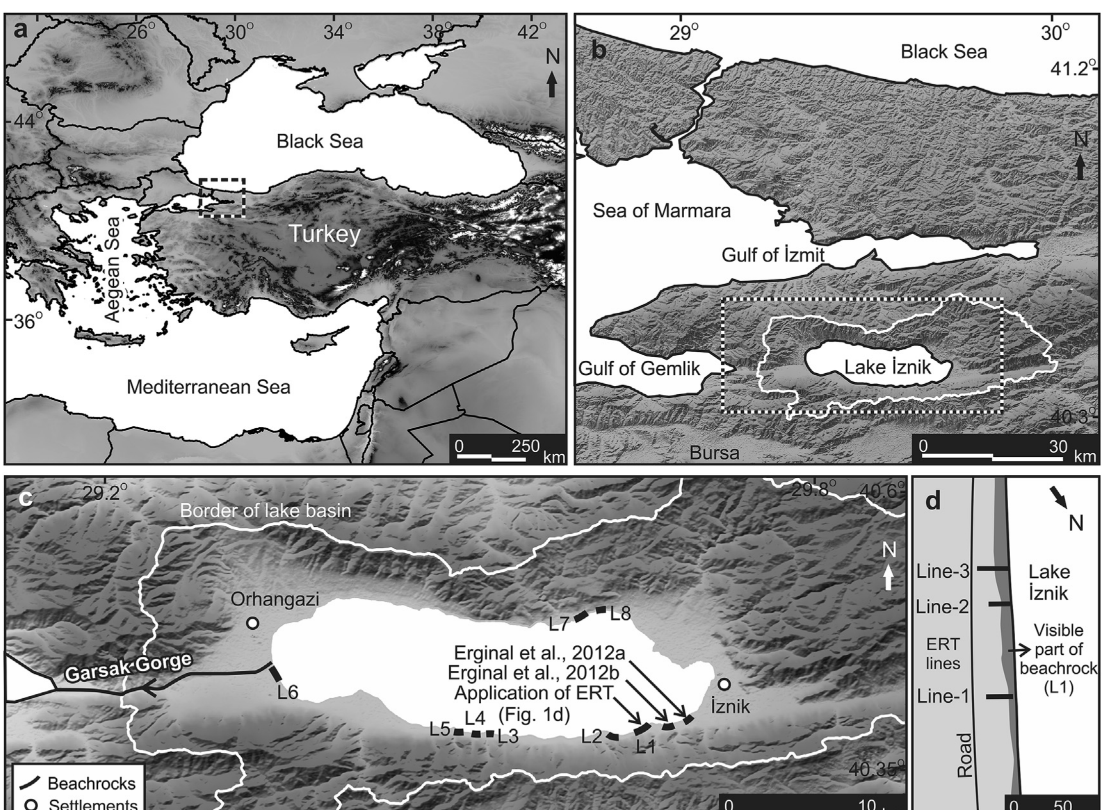

Fig. 1. (a, b) Location of Iznik Lake, (c) Beachrock localities, (d) ERT lines.

Please cite this article in press as: Ozturk, M.Z., et al., Records of repeated drought stages during the Holocene, Lake Iznik (Turkey) with reference to beachrock, Quaternary International (2015), http://dx.doi.org/10.1016/j.quaint.2015.08.077