Global and Planetary Change 71 (2010) 183–192

Contents lists available at ScienceDirect

Global and Planetary Change

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

Natural and human-induced environmental change in southern Albania for the last 300 years — Constraints from the Lake Butrint sedimentary record

D. Ariztegui [a,*], F.S. Anselmetti [b], J.-M. Robbiani [a], S.M. Bernasconi [c], E. Brati [d], A. Gilli [c], M.F. Lehmann [e]

[a] Section of Earth and Environmental Sciences, University of Geneva, 13 Rue des Maraichers, 1205 Geneva, Switzerland
[b] Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department of Surface Waters, Überlandstrasse 133, 8600 Dübendorf, Switzerland
[c] Geological Institute, ETH Zurich, Sonneggstr. 5, 8092 Zurich, Switzerland
[d] Department of Geology, University of Toronto, Toronto, Ontario, Canada
[e] Institute of Environmental Geosciences, Bernoullistrasse 30, 4056 Basel, Switzerland

ARTICLE INFO

Article history:
Accepted 27 November 2009
Available online 6 January 2010

Keywords:
Mediterranean Sea
coastal lake
varves
stable isotopes
anthropogenic influence
NAO
UNESCO world heritage site

ABSTRACT

A sediment core from Lake Butrint in southwestern Albania contains an annually-layered sequence covering the last ~300 years. It provides thus an exceptionally well-dated time series to study past climate-driven environmental changes, as well as anthropogenic perturbations along the coast of the Ionian Sea. The varves are composed of organic-rich carbonate couplets and detritus-dominated clay layers. The first are deposited during spring-to-fall, and reflect the chemistry of the lake, which, in turn, is sensitive to 1) the relative importance of marine versus freshwater inputs, 2) relative evaporation rates, and 3) the productivity cycle within the lake. The detrital laminae are deposited during winter, reflecting precipitation and runoff conditions during the wet season. A 2–3‰ stable carbon isotope ratio shift in both bulk organics and authigenic carbonates was attributed to increasing eutrophication towards the end of the 20th century, and validated by historical and instrumental data. An increase in the $\delta^{18}O$ of authigenic carbonates by more than 8‰ indicates the progressive salinization of the lake, which can primarily be attributed to man-made perturbations that reduced the freshwater input to the lake and/or enhanced the exchange with seawater from the nearby Ionian Sea. A recent increase in the relative evaporation versus precipitation rates may have additionally contributed to the observed ^{18}O enrichment in the Lake Butrint carbonates. The interdecadal cyclicity in the thickness of the detrital laminae seems to be at least partially controlled by NAO and/or ENSO-like phenomena that modulate precipitation patterns in the eastern Mediterranean. Thus, this study demonstrates the potential of combining microstratigraphic and stable isotopic tools to disentangle anthropogenic and natural environmental changes in Lake Butrint, validated by historical records.

1. Introduction

The identification and separation of climatic and human impacts on the environment represent one of the main challenges in present paleoenvironmental research. As an example, coastal areas in the Mediterranean realm have been clearly modified by anthropogenic activities (e.g., Vita-Finzi, 1969; Chester and James, 1991; Hounslow and Chepstow-Lusty, 2004a and references therein). Often, observed changes in the geomorphology were initially related to regional climate change (Vita-Finzi, 1969), although, more detailed studies combined with improved chronologies, have subsequently shown that human contributions to these changes must have been significant (e.g., Davidson, 1980; Lewin et al., 1991; Billi and Rinaldi, 1997). Whether climate has been the forcing, and perhaps the trigger, behind many of the observed human modifications in the environment remains also a controversial issue. The deconvolution of natural and anthropogenic influences on the environment is even more complex in regions affected by substantial tectonic activity such as the eastern Mediterranean (Meco and Aliaj, 2000). The Balkan region in particular has been affected by many historically-recorded earthquakes (Papazachos et al., 2001), which have induced geomorphologic and sedimentological modifications of the landscape.

Lake sediments provide ideal records of environmental changes, not only within the basins themselves but also of their catchments (e.g., Chondrogianni et al., 1996; Watts et al., 1996; Ariztegui et al., 2001; Anselmetti et al., 2007). Thus, lacustrine sediment archives, in particular when combined with good chronological constraints can be instrumental in separating climate, human and tectonic influences on the environment (e.g., Leroy et al., 2002).

Lake Butrint, located in southwestern Albania near the Greek border (Fig. 1), contains an exceptional archive of past and present natural and human-induced environmental changes occurring along the land–sea interface. On its shore, the antique city of Butrint, an UNESCO world heritage site, is a unique archaeological example

* Corresponding author.
E-mail address: daniel.ariztegui@unige.ch (D. Ariztegui).

0921-8181/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.gloplacha.2009.11.016

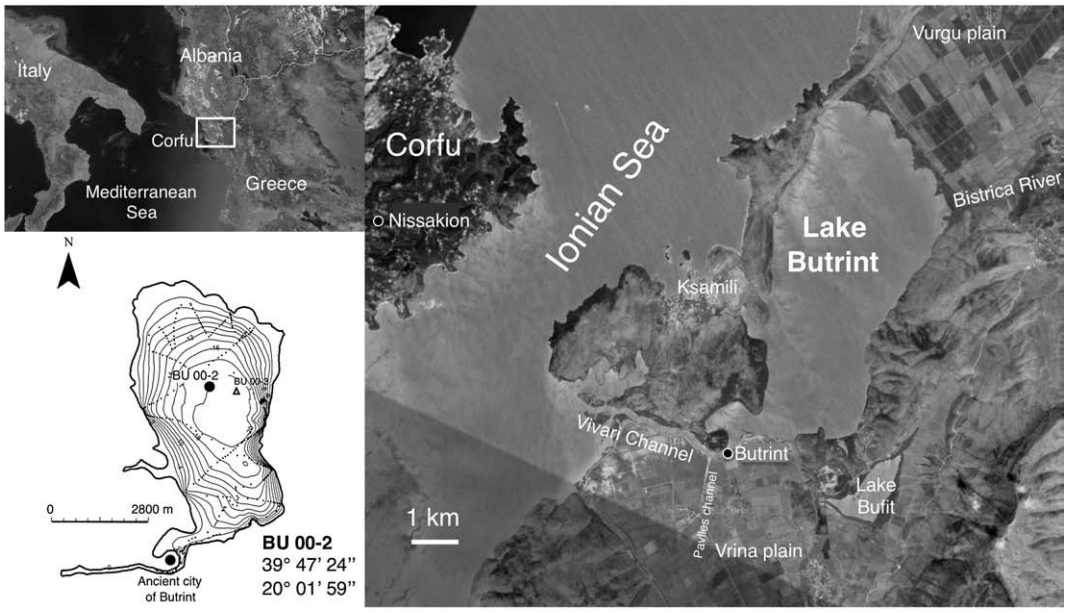

Fig. 1. Satellite image of the Mediterranean area showing the location of Lake Butrint in southern Albania. The close-up view of the study region shows in detail the lake and how the Vivari Channel connects it to the Ionian Sea. Notice the intensive agriculture at both Vurgu and Vrina plains located north and south of the lake, respectively. The bathymetric map shows the location of the two sedimentary cores.

representing a microcosm of Mediterranean history from the archaic Greek until the Venetian cultures, providing an unusual source of continuous documentary data (Hounslow and Chepstow-Lusty, 2004a,b). Although previous archaeological studies have acknowledged environmental (and cultural) change in the Lake Butrint area, the detailed timing and nature of geomorphologic and vegetational changes, for example, are not yet well understood.

Here we present a multi-proxy study of Lake Butrint sediments spanning the last ~300 years. We provide a first comprehensive description of sedimentation patterns and varve formation in the lake. As we will describe in more detail elsewhere (Anselmetti et al. in prep), the lake Butrint sediments represent a sensitive recorder of documented regional seismic activity, a fact that permits the precise dating of distinct sediment layers and thus the establishment of a robust age model. We demonstrate that the sediment archive of Lake Butrint records changes in Mediterranean climate, as well as the anthropogenic impact on both the trophic state and the hydrology of the lake during the last ~300 years. We anticipate that the results from this study yield valuable information that may provide the basis for paleolimnological extrapolation in future studies of longer sediment cores from Lake Butrint.

2. Regional setting

2.1. Geology and tectonics

The territory of Albania has been strongly affected by tectonic movements related to the Alpine/Mediterranean orogenesis. Lake Butrint's origin is a N–S extending graben structure formed during the Pleistocene, which continued to subside during the Quaternary (Aliaj et al., 2001). Submerged Roman and later levels in the archaeological site of Butrint below the current water table indicate some subsidence of unknown origin and lateral extent in the more recent centuries (Lane, 2004).

Albania is located in one of the most tectonically active areas in Europe generating a large number of earthquakes of variable magnitude. Most of them originate along the Adriatic–Ionian zone coinciding with the European plate–Adriatic microplate boundary (Meco and Aliaj, 2000). Moreover, recurrence rates of seismic events have been documented for the 20th century (Muco, 1994).

2.2. Present geography and climate

Mountains cover almost 80% of the surface of Albania whereas the remaining territory corresponds to relatively small and flat areas. The western littoral region at the Mediterranean coast is humid, hosting several coastal lagoons and lakes often separated by sand bars from the Adriatic Sea in the North and the Ionian Sea in the South (Fig. 1). Lake Butrint is the largest of a series of lagoons along the southernmost part of the coast and is the only Albanian lake connected to the Ionian Sea. According to Negroni (2001) the present lake's morphology is of tectonic origin and was invaded by Mediterranean waters during the Holocene transgression. Archeological data further indicate that during Roman times only the NE and the SW portions of the Vrina plain (Fig. 1) were emersed above sea level (Martin, 2004).

The Albanian climate is typical for the south Mediterranean (Meco and Aliaj, 2000). Mean annual precipitation ranges from 1000 to 1400 mm mostly occurring between November and March. These rainy winters are, however, relatively mild with an average temperature of 11 °C, whereas the summer season is generally dry and hot (Lane, 2004). Southern winds dominate during winter and fall whereas North winds prevail during spring and summer. As for other sectors of the Mediterranean, this general pattern has undergone significant temporal variations, most likely in association with the North Atlantic Oscillation (NAO; Luterbacher et al., 1999).

2.3. Modern hydrology and limnology

Today Lake Butrint is a saline lake with an average salinity of 25 PSU (practical salinity units). The hydrology of the catchment area of Lake Butrint comprises the Lake Bufi, the Bistrica River, the Pavlles channel, and a series of irrigation channels in the Vurgu and Vrina planes located in the north and south of the lake, respectively (Fig. 2A). According to Negroni (2001), there is an additional input of freshwater to the lake through groundwater from the East as well as from the towns located close to the basin (e.g., Ksamili). The whole area is presently under microtidal influence with a tidal range of 30 cm (Negroni 2001; Hounslow and Chepstow-Lusty, 2004a). Mediterranean saline waters can occasionally reach the lake through the Vivari Channel (Fig. 1) during intervals of particularly high tides. Episodic inflow of marine waters through the peninsula along the