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Lake Ohrid, Albania, provides an exceptional multi-proxy record of environmental changes during the last glacial–interglacial cycle

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A B S T R A C T

Multi-proxy analyses on core JO2004-1 recovered from Lake Ohrid (40°55.000 N, 20°40.297E, 705 m a.s.l.) provide the first environmental and climate reconstruction in a mountainous area in Southern Europe over the last 140,000 years. The response of both lacustrine and terrestrial environments to climate change has been amplified by the peculiar geomorphological and hydrological setting, with a steep altitudinal gradient in the catchment and a karstic system feeding the lake. The karstic system was active during interglacials, leading to high carbonate production in the lake, and blocked during glacials as a result of extremely cold climate conditions with permafrost in the mountains. At the Riss–Eemian transition (Termination 2) the increase in lacustrine productivity predated forest expansion by about 10,000 years. In contrast, the Late Glacial–Holocene transition (Termination 1) was characterized by the dramatic impact of the Younger Dryas, which initially prevented interglacial carbonate production and delayed its maximum until the mid-Holocene. In contrast, forest expansion was progressive, starting as early as ca. 38,000 ago. The proximity of high mountains and the probable moderating lake effect on local climate conditions promoted forest expansion, and contributed to make the surroundings of Lake Ohrid favourable to forest refugia during the last glacial, usually steppic, period. Our study of sedimentology, mineralogy, geochemistry, magnetics, palynology and isotopes illustrates the non-linear response of terrestrial and lacustrine ecosystems to similar climate events, and demonstrates the potential of Lake Ohrid as an excellent paleoclimatic archive during the Quaternary.

1. Introduction

Lake Ohrid, Albania, is an exceptional site for reconstruction of regional climate history over repeated glacial–interglacial fluctuations and its impact on terrestrial and lacustrine ecosystems. Not only the largest southern-European freshwater body (358 km^2, 289 m depth), it is likely the oldest in Europe and is renowned for a high level of endemism, with at least 200 lacustrine species described (Stankovic, 1960). The exceptional thickness of sedimentary deposits (Dumurdzanov et al., 2005) makes it directly comparable to the Mediterranean lowland site of Tenaghi Philippon in NE Greece which provides a continuous 1.35-million-year pollen record (Tzedakis et al., 2006). Its location at middle altitudes in a rift basin surrounded by high escarpments, within a key area at the confluence of central-European and Mediterranean climatic influences, provides a unique opportunity to study the impact of climate changes on middle- to high-altitude forest ecosystems. Particularly, Lake Ohrid is on exceptional location which allows testing of the “glacial refugia” hypothesis for southern Europe bordering the Mediterranean (e.g., Denèfle et al., 2000; Tzedakis et al., 2002a). Previous studies of the Lake Ohrid sediment record focussed on paleolimnological and sedimentological aspects during a 40,000 years period (Roelofs and Kilham, 1983; Wagner et al., 2008a,b). Here we present for the first time a record of

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environmental and climate change over the last 140,000 years. Attention is paid to selected proxies to discuss the influence of climate change on the karstic system and lake hydrology, as well as on regional vegetation response to glacial–interglacial variations.

2. Modern setting

Lake Ohrid lies in a strongly asymmetric, N–S oriented half-graben at the Macedonia–Albania border. It is bounded by faults running N to NNE which affect, to the north and east, carbonate rocks of Triassic and Jurassic age, and ophiolitic rocks of Jurassic age to the south-west (Fig. 1). The southern end of the basin connects with a small graben filled by Pliocene continental mudstones and sandstones, overlain by fluvio-lacustrine sediments of Holocene age (Nicot and Chardon, 1983). The basin is filled by several hundred meters of sediments deposited since around 8.5 Ma (Dumurdzanov et al., 2005). The modern lake is holomictic. Today roughly half of its water is derived from a number of springs located in the SE part of the lake, draining a karstic system which, in turn, is fed by water from nearby Lake Prespa and infiltration of rainwater (700 mm/yr on average) in the Galicica mountain range. The remaining water comes from rivers (e.g., the Sateska River to the north) and direct precipitation. A single outlet (the Black Drin River) to the

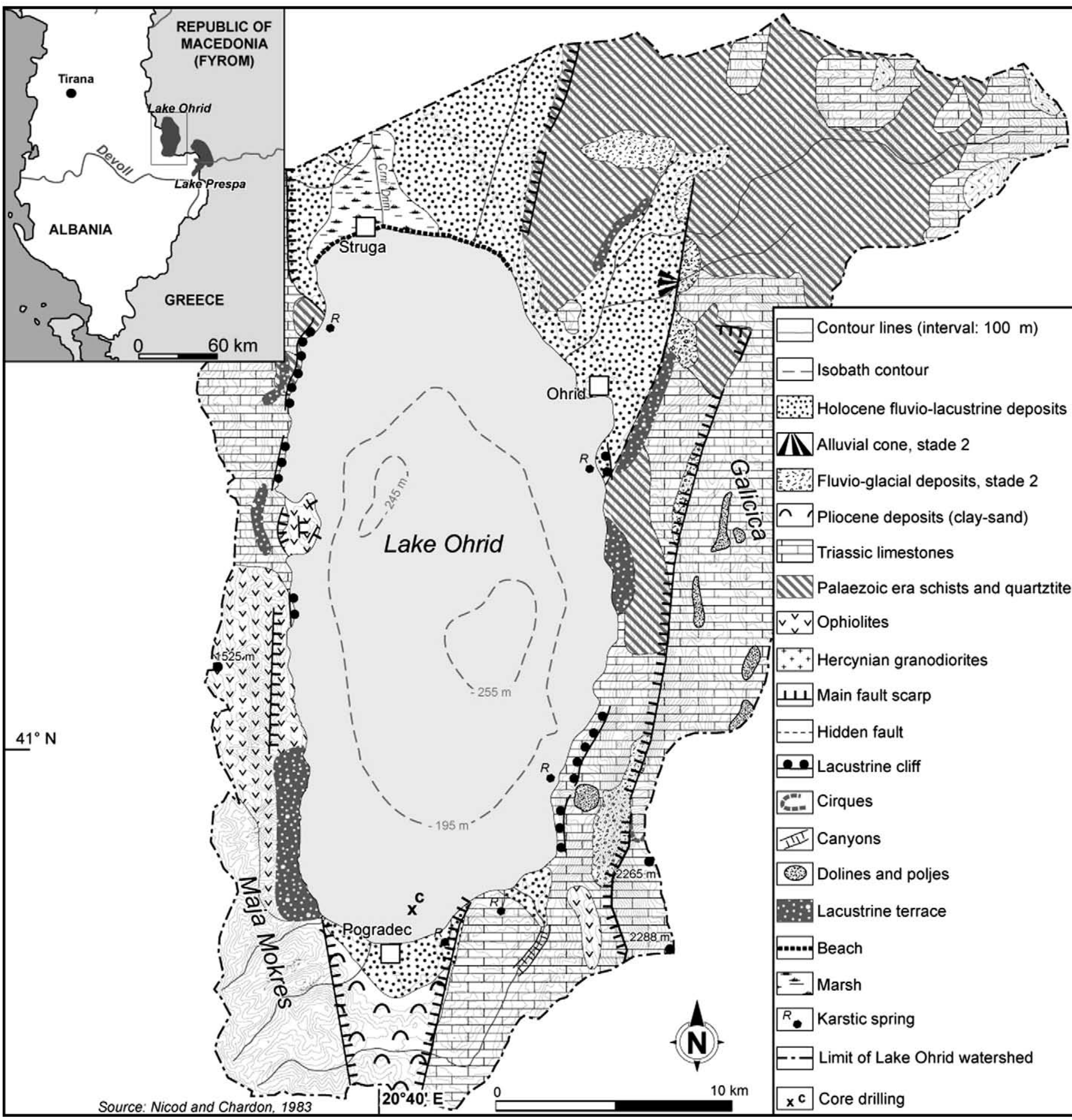

Fig. 1. Geological/geomorphological map of the Lake Ohrid basin, southern Balkan, showing the location of the core site.