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Holocene lacustrine fluctuations and deep CO_2 degassing in the northeastern Lake Langano Basin (Main Ethiopian Rift)

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ABSTRACT

This work reports the results of an integrated investigation on Holocene faulted deposits exposed on the northeastern Lake Langano in the central sector of the Main Ethiopian Rift (MER). The Lake Langano is part of a closed basin and thus it is highly sensitive to climate fluctuations. The present study explored the foot of the Haroresa escarpment, where coarse-grained slope deposits interbedded with thin lake shore shell-rich coarse sands are well exposed. Stratigraphical analysis of these deposits, integrated with radiocarbon dating carried out on lacustrine gastropod *Melanoides tubercolata* shells, points to significant lake level fluctuations forced mainly by climate oscillations. These have been interplaying during the early and middle Holocene with a structurally-controlled threshold separating an embayment of the Lake Langano to the south, from the small perched Lake Haro Bu-a basin to the north. Significant differences in the $^{13}C/^{12}C$ isotopic ratio have been identified in the *M. tubercolata* shells collected on the opposite sides of such a threshold. The time-space variations of the isotopic signature of the shells are referred to the mutual relationships between the two main different CO_2 sources (i.e., microbial activity and deep mantle degassing) dissolved in the lake water.

1. Introduction

Researches on the Late Pleistocene–Holocene evolution of the Lakes Region in the Main Ethiopian Rift (Ethiopia), have concurred to update regional models of hydrologic responses to global climatic changes, providing a reference for the late Quaternary palaeoclimatology of the tropics (Street-Perrott and Perrott, 1990; Gasse and Van Campo, 1994). Along with such a palaeoclimatic relevance, the MER is also a zone characterized by active tectonic processes and intense hydrothermal activity (Gianelli and Teklemariam, 1993; Chernet, 2011). In such a dynamic setting, climatic, tectonic and magmatic-related processes may have exerted a concurrent and complex control on the Late Quaternary geomorphic and depositional dynamics. We focus on the northern coast of Lake Langano where lacustrine shells-bearing deposits and their radiogenic and stable carbon isotopic signature record Holocene, climate-driven, lake level fluctuations in the frame of a local active tectonic setting.

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2. Hydrologic evolution of the Lakes Region

The Lakes Region includes lakes Ziway, Langano, Abiyata and Shala that developed since the Late Pleistocene (Street, 1979; Benvenuti et al., 2002) within the fault-controlled Main Ethiopian Rift depression (Fig. 1). Classically, the Holocene Ziway–Shala lake fluctuations (Street, 1979; Gasse and Street, 1978; Gillespie et al., 1983; Alessio et al., 1996; Fig. 2) have been considered a suitable proxy for the switching off and on of the monsoonal regime, as a regional response to global cooling and warming trends (Street-Perrott and Perrott, 1990; Gasse and Van Campo, 1994). Between 10 and 5 ky (conventional ^{14}C ages), the lakes experienced an overall high-level status abruptly interrupted by short arid pulses. The early-middle Holocene (5–10 ky) wetter period coincides in the subarid tropics with a climatic *optimum* attesting to a relatively stable monsoonal circulation over East Africa. Short-lived arid pulses are related to a weakened monsoonal circulation which, in some cases, correlated quite well with global cooling events (Benvenuti et al., 2002). Since 5 ky to Present, the lakes progressively reduced in size due to increasing aridity. The progressive hydrological deficit over the Lakes Region during the late Holocene (post-5 ky) may be related to increasing warming over the last 1000 years. Despite the evolution of the Ziway–Shala lacustrine system has been generally referred to a dominant climatic control,

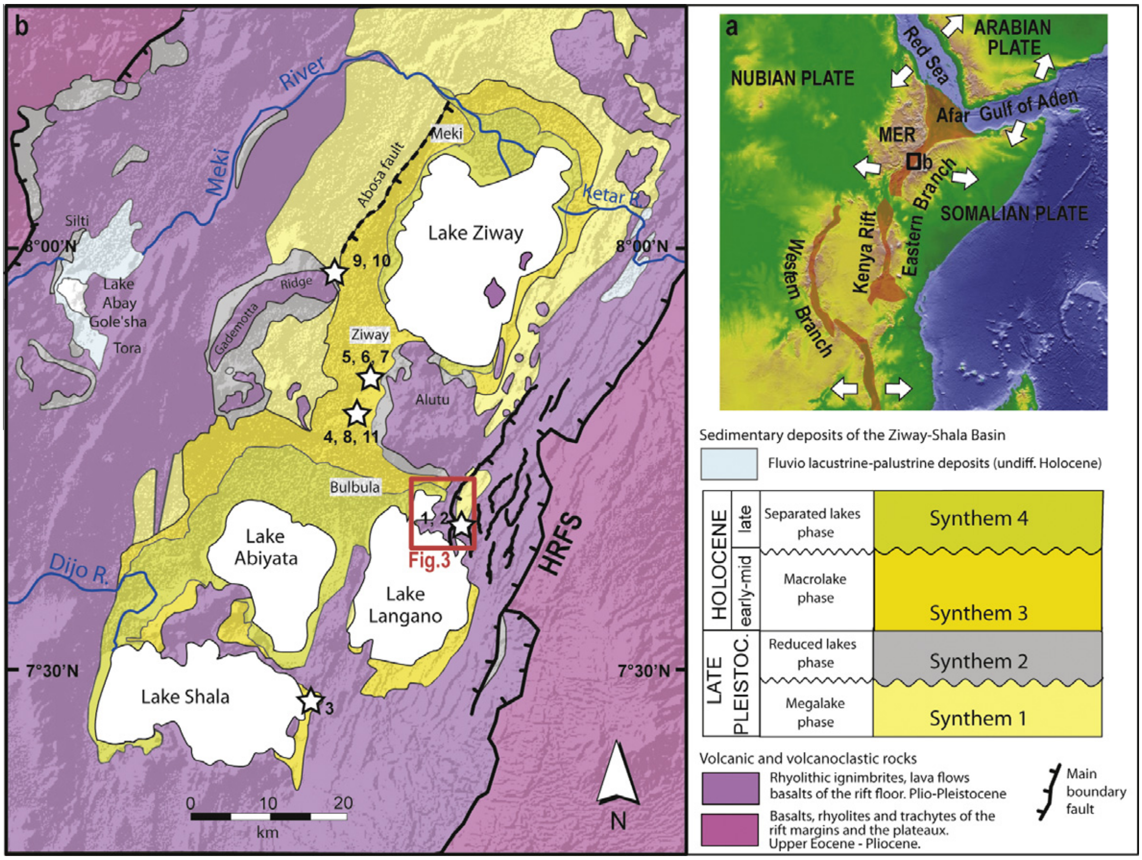

Fig. 1. Regional setting of the Lakes Region of the Main Ethiopian Rift. (a) Schematic tectonics setting of the East African Rift System; MER: Main Ethiopian Rift. (b) Detail of the Lakes Region in the central MER, showing the main Late Pleistocene–Holocene depositional units and their volcanic bedrock (after Benvenuti et al. (2002)). HRFS: Haroresa Rhomboid Fault System. Stars and related numbers refer to the location of lacustrine shell samples in Table 1.

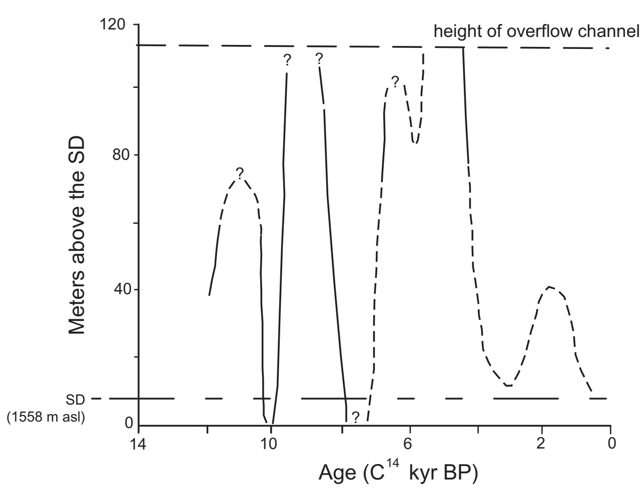

Fig. 2. Lake level fluctuations in the Lakes Regions (after Gillespie et al. (1983)). SD: Lake Shala datum ≈ 1558 m. a.s.l (1970s gauge data).

the tectonic setting of an active continental rift has played a significant role in controlling the surface hydrology as suggested for other lakes within the East African Rift System (e.g., Bergner et al., 2009). Around the Pleistocene–Holocene boundary, tectonically-driven stream piracy cut down a significant water budget to the lakes that was supplied by the northern catchments of paleo-Awash and paleo-Mojo rivers (Sagri et al., 2008). This determined a lake system less extended in the Holocene than in the Late Pleistocene, despite the early-middle Holocene climate was wetter than the last glacial (Benvenuti et al., 2002; Sagri et al., 2008).

3. Tectonic setting

The Main Ethiopian Rift (MER) is part of the largest East African Rift System, and extends between the Afar depression to the North and the Kenya Rift to the South (Fig. 1a). The MER is characterized by a roughly NE-trending rift valley striking close to N–S in its southern sector which has been developing discontinuously since the Late Miocene in response to the extensional stress produced by Nubia–Somalia movement (e.g., Corti, 2009). The resulting fault pattern consists of two main fault systems: (1) a border fault set, and (2) a set of internal faults commonly referred to as Wonji Fault Belt (WFB; Mohr, 1962) that are best expressed in the northern MER. In the central MER, the border faults formed at 6–8 Ma (WoldeGabriel et al., 1990; Bonini et al., 2005), while the WFB faults started developing since about 2 Ma (Boccaletti et al., 1998; Ebinger and Casey, 2001), and are still in an incipient stage (Agostini et al., 2011). By controlling the rift floor morphology, the WFB activity gave rise to an interplay between climatic-forced lake level fluctuations and tectonics (e.g., Benvenuti et al., 2002).

The northeastern Lake Langano, which is the focus of this paper, is adjacent to the eastern rift margin, which is typically characterized by a peculiar rhomboidal arrangement of faults with characteristic zigzag geometry, referred to as Haroresa Rhomboid Fault System (e.g., Le Turdu et al., 1999). This system essentially affects the Pliocene rift floor ignimbrites and locally the Middle Pleistocene–Holocene colluvial–alluvial deposits and pyroclastics (Dainelli et al., 2001). Such a recent fault activity probably