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Paleomagnetism of Lake Van sediments: chronology and paleoenvironment since 350 ka

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ABSTRACT

In the framework of the PALEOVAN project, a high-resolution paleomagnetic and rock magnetic study was carried out on a 149 m sedimentary sequence recovered from Ahlat Ridge in the deepest part of the Lake Van (Eastern Turkey; ICDP Site 5034-2). High sedimentation rates (average ~30 cm/ka) allow high-resolution measurements of natural remanent magnetization (NRM), magnetic susceptibility (κ), anhysteretic remanence (ARM) and hence of anhysteretic susceptibility (κ_{ARM}) over the last 350 ka. The carrier of the remanence is detrital titanomagnetite largely from volcanic sources, based on the similarity of magnetite grain size of tephra layers and the other lacustrine lithologies observed in a plot of the κ versus κ_{ARM}. Bulk magnetic parameters often covary with paleoclimatic signals in the Lake Van sediments. A correlation exists between variations of κ and ARM intensity and glacial-interglacial marine isotopic stages, as well as dust flux and temperatures observed in ice cores from Greenland and Antarctica. The quality of the paleomagnetic record is compromised by weak NRM intensities, as well as by the presence of tephra and turbidites throughout the sequence. Nonetheless, a correlation is observed between the relative paleointensity (RPI) record, based on NRM/ARM, and the calibrated PISO RPI stack, that supports the independently derived age model for the site.

1. Introduction

Lacustrine sediments are a natural archive of past environmental change. Closed-basin lakes are particularly useful, as their lake levels are governed by evaporation, precipitation and river inflow, which strongly affect physical and geochemical processes influencing sedimentation. The accumulation of lake sediments is often controlled predominantly by climate, and Lake Van in eastern Anatolia (Turkey) represents an ideal site to investigate the evolution of Quaternary climate in the Near East as it is located in a transition zone between major atmospheric circulation systems (Reiter, 1975; Akcar and Schluchter, 2005).

The potential for long continental records covering several glacial-interglacial cycles was the motivation for the PALEOVAN project carried out in the framework of the International Continental Scientific Drilling Program (ICDP) (Litt et al., 2009, 2011, 2012). The primary drill site 'Ahlat Ridge' (AR, ICDP Site 5034-2; hereafter referred to as AR5034-2) is located in 360 m water depth (relative to present lake level at 1648 m above sea level) on a morphological ridge at the northern edge of the 440-m-deep Tatvan Basin (Fig. 1). Seven holes drilled at AR5034-2 in summer 2010 (Litt et al., 2012) were used to establish a composite section with a total length of 219 m, representing one of the longest continental sediment records recovered in the Near East. The lithostratigraphy showed that sedimentation were controlled by lake level variations and that they were linked to global climate change over several glacial/interglacial cycles back to marine isotope stage (MIS) 15 (Stockhecke et al., 2014b).

Magnetic measurements are of great value in understanding environmental conditions in the past, particularly in lacustrine sediments (Thompson and Oldfield, 1986; King and Channell, 1991; Vlag et al., 1997; Maher and Thompson, 1999; Evans and Heller, 2003; Rolph et al., 2004; Rosenbaum and Reynolds, 2004; Heil et al., 2009; Vigliotti et al., 2011). Variations in magnetic parameters in lake sediments may reflect variations in climate via changes in the source, rates of detrital input, production of diagenetic/authigenic/biogenic phases, and destruction of primary magnetic minerals (e.g., via reduction diagenesis) arising from changing

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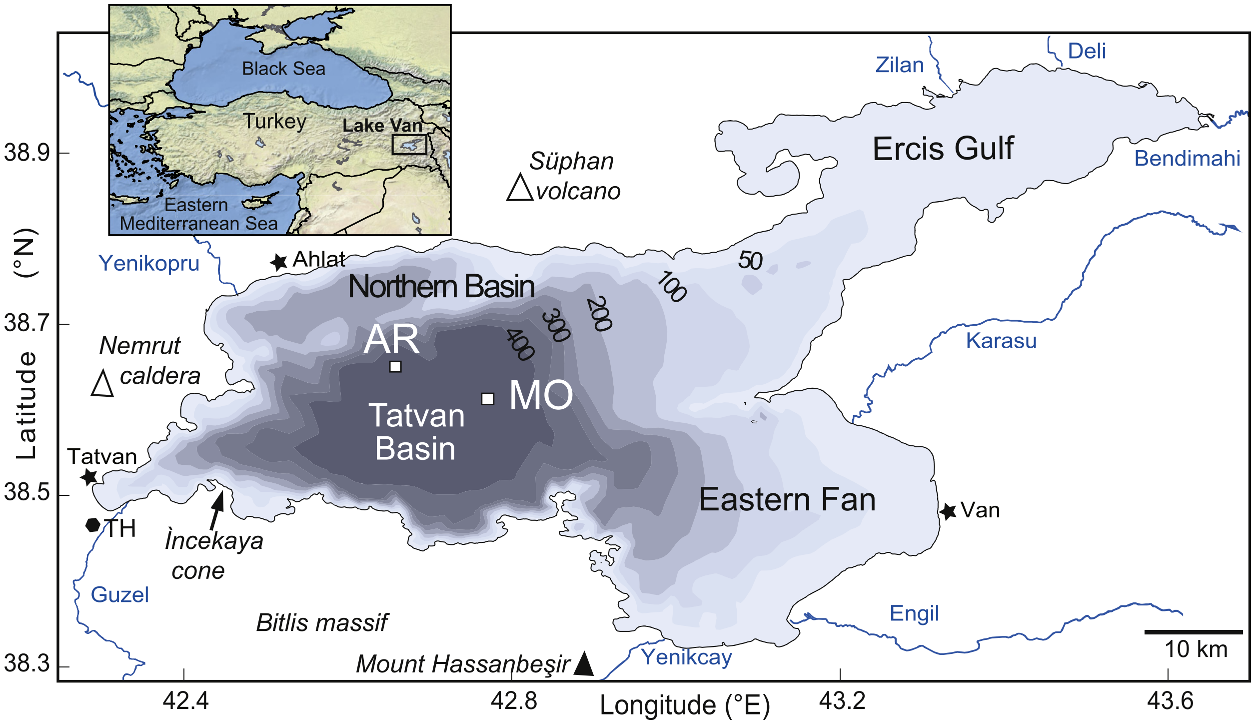

Fig. 1. Map of Lake Van showing the position of the studied ICDP drilling site (AR5034-2) on Ahlat Ridge (AR) and the position of the trap sediments collected by a mooring (MO) in the Tatvan Basin. Bathymetric contours are in meters.

climate conditions. Magnetic minerals within sediments may be a product of erosion of the catchment substrata or soils, transported by surface/ground water and wind, or created in situ (Oldfield and Richardson, 1990; Bloemendal et al., 1992; Thouveny et al., 1994; Rolph et al., 1996, 2004; Williamson et al., 1998). Anoxic conditions due to water stratification are often a feature of closed basins. In anoxic environments, detrital iron oxides are often progressively dissolved and/or transformed into authigenic iron sulphides. The result of such processes is a progressive down-core decrease in the intensity of both natural and laboratory-induced remanent magnetizations, reflecting magnetite dissolution and coarsening of the magnetic fraction as fine-grains preferrentially undergo dissolution (Karlin and Levi, 1983, 1985; Canfield and Berner, 1987; Leslie et al., 1990; Vigliotti, 1997; Vigliotti et al., 1999; Demory et al., 2005; Ortega et al., 2006; Ao et al., 2010). If reduction diagenesis does not predominant, the magnetic record may provide support for the chronology through records of palaeosecular variation (PSV) (Thompson and Turner, 1979; Rolph et al., 2004; Vigliotti, 2006; Olafsdottir et al., 2013) and relative paleointensity (RPI) of the geomagnetic field (Levi and Banerjee, 1976; Tauxe, 1993; Peck et al., 1996). Several paleointensity (RPI) stacks have been published over different time intervals ranging from the last 75 ka (NAPIS, Laj et al., 2000; SAPIS, Stoner et al., 2002; GLOPIS, Laj et al., 2004) to longer timescales (800–2000 ka) such as Sint-800, Sint-2000 (Guyodo and Valet, 1999; Valet et al., 2005), PADM2M (Ziegler et al., 2011) and PISO-1500 (Channell et al., 2009). The results have established that RPI, when recorded by marine sediments at pelagic sedimentation rates, is a global signal and therefore an important stratigraphic tool.

Here we present the paleomagnetic and environmental magnetic record of the upper 149 m of sediments recovered at Site AR5034-2 which represents an almost continuous record of the last 350 ka (back to MIS 10). The Lake Van sediments have potential for providing high resolution records of late Pleistocene geomagnetic field behavior and for investigating the response of magnetic proxies to climatic and environmental change. Such relationships are investigated by comparing concentration-related rock magnetic parameters, susceptibility (κ) and anhysteretic remanence (ARM), and an interparametric ratio sensitive to magnetic grain size, anhysteretic susceptibility divided by susceptibility (κ_{ARM}/κ), with proxy records of past global change (e.g., marine $\delta^{18}O$ records; Antarctic (EPICA) ice-core dust flux, and Greenland $\delta^{18}O$ records).

2. Geological setting and sedimentation

Lake Van (42°45' E, 38°8' N) is a deep terminal lake (max. depth 460 m) on the eastern Anatolian Plateau situated at 1647 m above mean sea level and enclosed within the Euphrates, Tigris and Arax basins (Fig. 1). It is the largest soda lake in the world, with a salinity of 21.7‰ and a pH of 9.7 (Degens and Kurtman, 1978). The southern border of the lake corresponds to a regional thrust fault caused by the collision between the Arabian and Eurasian plates (Sengor et al., 2008). The area is characterized by active volcanism with several volcanic edifices aligned along the northern side of the lake including the historically active Nemrut volcano (height 2948 m) and the dormant Süphan volcano (height 4158 m). The origin of the lake can be explained by a combination of tectonic extension and volcanic activity (Wong and Finchk, 1978; Sumita and Schmincke, 2013). Recent data suggest that the present lake developed over fluvial deposits, in the basal section of the core, around 600 ka (Stockhecke et al., 2014b). The lake has four main inputs: the rivers Engil, Karasu, Bendimahi and Zilan, plus a subsidiary input along the southeastern margin, the Kotum–Kucuksu. The river input occurs mostly during spring, and the lake level varies both seasonally and inter-annually following precipitation and snowmelt (Stockhecke et al., 2012). Lacustrine paleo-shorelines, reflecting up to a hundred meters of lake-level variation, were already described in the 1970s (Degens and Kurtmann, 1978;

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