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Full-vector paleomagnetic secular variation records from latest quaternary sediments of Lake Malawi (10.0°S, 34.3°E)

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A B S T R A C T

We have conducted a paleomagnetic study of Late Quaternary sediments from Lake Malawi, East Africa, in order to develop a high-resolution record of paleomagnetic secular variation (PSV). This study has recovered PSV records from two cores (3P, 6P) in northern Lake Malawi (10.0°S, 34.3°E). The PSV appears to be recorded in fine-grained detrital magnetite/titanomagnetite grains. Detailed af demagnetization of the natural remanence (NRM) shows that a distinctive characteristic remanence (ChRM) is demagnetized from ~20 to 80 mT, which decreases simply toward the origin. The resulting directional PSV records for 3P and 6P are easily correlatable with 29 distinct inclination features and 29 declination features. The statistical character of the PSV in both cores is consistent with Holocene PSV noted at other Holocene equatorial sites. Radiocarbon dating of the cores is based on 18 independent radiocarbon dates and four dated stratigraphic horizons that can be correlated into each core. The final directional PSV time series cover the last 24,000 years with an average sediment accumulation rate of ~30 cm/kyr. We have also developed a relative paleointensity estimate for these PSV records based on normalizing the NRM (after 20 mT af demagnetization) by the SIRM (after 20 mT af demagnetization). Changing sedimentation patterns complicate any attempt to develop a single paleointensity record for the entire core lengths. We have developed a relative paleointensity record for the last 6000 years that has 14 correlatable features including 5 notable peaks in intensity. Three of these peaks are synchronous with paleointensity highs farther north in SE Europe/SW Asia/Egypt but two of the peaks are at times of low paleointensity farther north. We interpret this to indicate that Lake Malawi (10°S) is at least partly under the influence of a different flux-regeneration region of the outer-core dynamo. A relative paleointensity record was also developed for ~11,000–24,000 YBP; the general pattern appears to be consistent with other published records, but our confidence in the correlations is more limited.

1. Introduction

Our understanding of the prehistoric secular variation of the geomagnetic field requires a global distribution of high-resolution, well-dated paleomagnetic records. The Holocene (~0–12,000 ybp) is perhaps the only time interval with sufficient time control wherein we can hope to develop a global, high-resolution space/time pattern of geomagnetic field variability. To date, there are several regions where relatively little is known about Holocene field variability; the African continent is one of those regions. This study is the first in a series of new studies to carry out detailed paleomagnetic studies of lake sediments from the East African Rift Valley. The primary goal is to recover full-vector records (both field directions and intensity) of paleomagnetic secular variation (PSV) for Holocene time to help improve our understanding of the space/time pattern of PSV. The secondary goal is to develop a paleomagnetic chronostratigraphy in the lake sediments that can permit independent correlation and dating among the lakes on a regional scale both as an aid to improved PSV age dating and as an aid for regional paleoclimate studies.

1.1. Lake Malawi setting

Lake Malawi (Fig. 1) is a fault-bounded tectonic lake, the southernmost lake of the East African Rift Valley, which contains up to 4 km of Quaternary sediment (Scholz and Rosendahl, 1988). The

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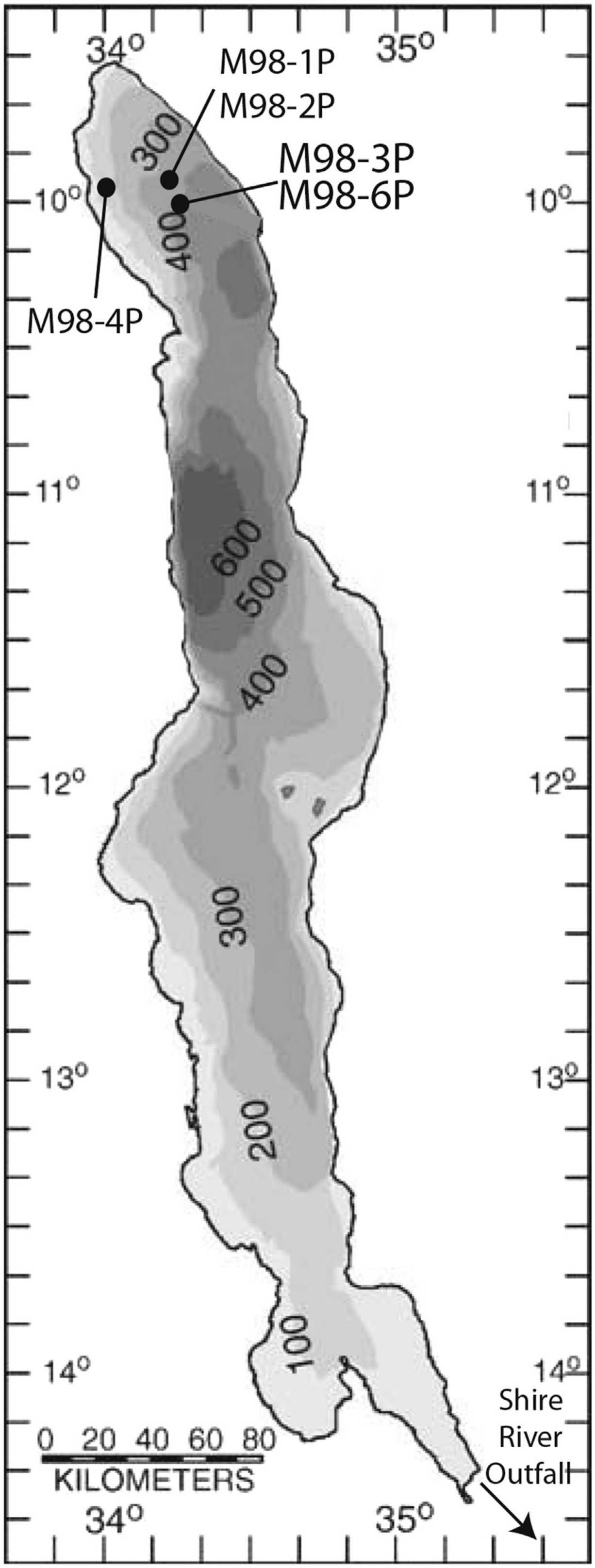

Fig. 1. Map of Lake Malawi showing the locations of cores M98-1P, M98-2P, M98-3P, M98-4P, and M98-6P (Modified from Barry et al., 2002.).

lake is ~570 km long, an average of ~40 km wide, and up to 700 m deep; it is the second largest of the East African Rift lakes by volume.

Lake Malawi receives significant clastic flux from a number of rivers along its margin; the highest clastic flux occurs in the north. This is because the northern part of the lake receives ~2500 mm/yr rainfall, associated with the African Monsoon, while the southern part of the lake receives only ~600 mm/yr rainfall (Eccles, 1974). The lake today drains to the south through the Shire River outfall (Fig. 1). Variable long-term rainfall, however, has intermittently lowered the lake level, stopped outfall, and made Malawi a closed-basin lake (Finney et al., 1996; Barry, 2001; Barry et al., 2002; Johnson et al., 2002).

The deep lake sediments are currently laminated due to seasonal variations between relatively high clastic flux versus high diatomaceous particle flux (Barry, 2001; Barry et al., 2002). The laminated sediments are currently being preserved due to almost permanent anoxia in lake water column below ~220 m (Eccles, 1974) preventing significant bottom sediment bioturbation. The clastic sediments in the deep basin average 3–4 μm in mean grain size (Barry, 2001). Previously, the deep sediments have intermittently been more homogenous suggesting more constant and higher proportion clastic flux, more oxygenated bottom water, and/or sediment bioturbation due to regular whole-lake overturn.

T. Johnson and colleagues (Barry, 2001; Barry et al., 2002) collected a series of cores from the north part of the lake in 1997/1998 for paleoclimate studies. This study uses two piston cores recovered from their Lake Malawi coring in 1998, MAL98-3 and MAL98-6. The two cores were collected within about 100 m of one another in ~390 m water depth (Fig. 1). MAL98-3P is 881 cm long; MAL98-6P is 901 cm long.

1.2. Magnetic measurements

Cores MAL98-3P (called 3P for simplicity hereafter) and MAL98-6P (called 6P hereafter) were u-channeled for our paleomagnetic and rock magnetic studies. The initial NRMs of the u-channels were measured and then the u-channels were step-wise demagnetized in alternating magnetic fields (af) at 10 mT, 20 mT, 30 mT and 40 mT and measured. Selected u-channels were then stepwise af demagnetized in 10 mT steps from 50 to 100 mT. The u-channels were then given an artificial anhysteretic remanence (ARM, 100 mT af, 0.05 mT steady field), which was measured and then stepwise af demagnetized at 10 mT, 20 mT, and 40 mT and measured. Finally, all u-channels were given a saturation isothermal remanence (SIRM, 1 T steady field), which was measured and then stepwise demagnetized at 10 mT, 20 mT, and 40 mT and measured. Selected u-channels also had their ARMs and SIRMs stepwise af demagnetized at 20 mT steps from 60 to 100 mT.

Fig. 2 shows the directional variation of selected samples under af demagnetization. It is clear that almost all samples have a single paleomagnetic direction that is demagnetized between 10 and 80 mT, which demagnetizes toward the origin. The ChRM of all samples was calculated in the 10–40 mT interval normally and in the 10–80 mT interval in u-channels that had been further demagnetized. The characteristic remanence (ChRM) typically has maximum angles of deviation (MAD) of less than 3° for samples in the 10–40 mT interval (most samples) and MAD angles of less than 4° in the 10–80 mT interval (selected u-channels). We see no evidence for significant directional differences depending on whether we used the 10–40 mT or 10–80 mT ChRMs. There is commonly a 'viscous' magnetic overprint, which is demagnetized by 10 mT, but on occasion, the overprint may extend to 20 mT. The simple characteristic remanence is associated normally with more than 70% of the total NRM.