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Comment on Mark et al. (2017): High-precision $^{40}Ar/^{39}Ar$ dating of Pleistocene tuffs and temporal anchoring of the Matuyama-Brunhes boundary. *Quaternary Geochronology*, 39, 1–23

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Mark et al. (2017) utilized data from Ocean Drilling Program (ODP) Site 758 (NE Ninetyeast Ridge, Indian Ocean) to draw conclusions regarding the age of the Matuyama-Brunhes boundary (MBB). $^{40}Ar/^{39}Ar$ ages from the Toba tuffs on Sumatra were used to provide ages for correlative ash layers at ODP Site 758 where the MBB has been recorded. Note that the MBB transition, and other polarity transitions, are not instantaneous having durations of several kyr characterized by magnetization directions of intermediate polarity, and the duration of the polarity transition would be expected to increase with increasing site latitude. The Mark et al. (2017) age for the MBB (783.4 ± 0.6 ka) is interesting because it is ~10 kyr older than the ages that have been acquired from North Atlantic deep-sea cores (Channell et al., 2010; Channell, 2017) and from some cores from the equatorial Indian Ocean (Valet et al., 2014).

Mark et al. (2017) speculate that their result may imply diachroneity of the MBB between the North Atlantic and the Indian Ocean. In addition, the MBB at Site 758 apparently correlates with the deglaciation from MIS 20 to 19 (Termination IX) or the *early* part of marine isotope stage (MIS) 19c, rather than with millennial events that occurred during the glacial inception from MIS 19 to 18 as seen in the North Atlantic (Channell et al., 2010; Channell, 2017), and the equatorial Indian Ocean (Valet et al., 2014). Increases in ^{10}Be fluxin the EPICA Dome C ice core (Raisbeck et al., 2006; Dreyfus et al., 2008), and $^{10}Be/^{9}Be$ accumulation in marine sediments from Montalbano Jonico in Italy (Simon et al., 2017) and the Indian Ocean (Valet et al., 2014) also suggest that the MBB occurred at the end of MIS 19c and early MIS 19b associated with Antarctic Isotope Maxima B and C (Pol et al., 2010). Although ^{10}Be flux is susceptible to processes other than atmospheric ^{10}Be production and geomagnetic field strength, it is immune to lock-in depth issues associated with magnetostratigraphy. Mark et al. (2017) speculate that the association of MBB with Termination IX at Site 758 may be attributed to diachroneity among major oceans in the $\delta^{18}O$ increase associated with deglaciation (see Skinner and Shackleton, 2005; Lisiecki and Raymo, 2009).

Rather than pursuing these speculations, we focus here on issues associated with the paleomagnetic and oxygen isotope records at ODP Site 758. Firstly, the paleomagnetic data in the vicinity of the MBB at Site 758 were acquired from half cores using the shipboard pass-through cryogenic magnetometer, and the measurements were carried out using a single (9 mT) peak alternating demagnetization field (Shipboard Scientific Party, 1989; Farrell and Janecek, 1991). Shipboard measurements were carried out at 10-cm spacing and each adjacent measurement is not independent at this spacing due to the finite width (~15-cm at half-height) of the Guassian-shaped magnetometer response function (see Oda and Shibuya, 1996). The single (9 mT) demagnetization step does not allow recognition of magnetization components. The paleomagnetic data are important for the definition of the Pliocene-Pleistocene polarity stratigraphy at the site (Farrell and Janecek, 1991), but should not be used to define the precise position of the MBB or other polarity reversals because of the low mean sedimentation rates at this site, and the likely presence of unresolved magnetic overprints in the immediate vicinity of the recorded reversal, as a result of the abbreviated demagnetization treatment. Multiple magnetization components are likely to be present close to the polarity transition due to non-instantaneous acquisition of detrital remanent magnetization (DRM) and the possible presence of viscous remanent magnetization (VRM) affecting the uppermost part of the Matuyama Chronozone.

This likelihood of temporally significant downward displacement (delayed lock-in) of the MBB at Site 758 is exacerbated by the low sedimentation rates. The thickness of the Brunhes Chronozone at Site 758 (10.75 m) leads to a mean Brunhes sedimentation rate of 1.4 cm/kyr. This mean sedimentation rate is an order of magnitude lower than many of the North Atlantic cores that have been used to study the MBB (Channell et al., 2010; Channell, 2017), and lower than other cores that have been used to study the MBB in the Indian Ocean (Valet et al., 2014; Bassinot et al., 1994). Lock-in delay in remanence acquisition is dependent on the thickness of the sediment-surface bioturbated layer, and the thickness of the bioturbated layer in pelagic sediments from radioisotopic measurements, often ~10 cm, is apparently *not* a function of sedimentation rate (Boudreau, 1994, 1998). For this reason, lock-in delay in remanence acquisition has far greater temporal significance in low sedimentation rate cores than in than in high sedimentation rate cores. Note that ash layers (including Ash D) at Site 758 show sharp bases and obviously bioturbated tops, emphasizing the presence of a bioturbated sediment at this site.

The MBB boundary was placed at 10.75 m below seafloor (mbsf) at Hole 758A (Farrell and Janecek, 1991), and this designation was utilized by Mark et al. (2017). At Hole 758A, remanence declinations

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and inclinations are scattered over a ~50 cm in the vicinity of the MBB (Fig. 1). Note that remanence inclinations are not definitive for polarity at the equatorial latitude (5.38°N) of Site 758. Ash D at Site 758 (deemed equivalent to Old Toba Tuff B, OTTB, on Sumatra) was observed in Hole 758A over a 13–cm interval at 10.80–10.93 mbsf (Dehn et al., 1991), with the top of Ash D located 5 cm below the designated MBB (Fig. 1). Ash D was not observed in Hole 758B (Dehn et al., 1991), but can be associated with a susceptibility peak (Fig. 2) that again occurs just below the declination change associated with the MBB. Note that the position of the MBB at Hole 758B was not tabulated by Farrell and Janecek (1991), possibly because the MBB transition at this hole, as defined by declination measurements after 9 mT peak field demagnetization, is not abrupt but occurs over about 20–25 cm of core, again immediately above the susceptibility peak associated with Ash D (Fig. 2).

Both planktic and benthic oxygen isotope data are available for Hole 758A back into the Pliocene (Farrell and Janecek, 1991; Chen et al., 1995). The sample spacing in the vicinity of the MBB is 10 cm, equivalent to a ~7 kyr sampling resolution assuming a constant (1.4 cm/kyr) sedimentation rate across the MBB. As a result of the low mean sedimentation rate, the $\delta^{18}O$ record, inevitably, has low resolution relative to many $\delta^{18}O$ records across the MBB. MIS 19 is represented by a single point in the benthic $\delta^{18}O$ record and three points in planktic $\delta^{18}O$, which is not ideal for determining the relationship of the MBB to oxygen isotope stratigraphy, given the low sedimentation rates and the likely bioturbation/mixing of foraminifera from different levels.

As pointed out by Mark et al. (2017), the MBB recorded in Hole 758A at 10.75 mbsf corresponds to Termination IX or the early part of MIS 19 (Fig. 1). This correlation is at odds with all correlations of the MBB with oxygen isotope data from North Atlantic cores with high sedimentation rate (Channell et al., 2010; Channell, 2017), as well as with cores with mean Brunhes sedimentation rates of ~4.8 cm/kyr from the equatorial Indian Ocean (Valet et al., 2014). It is also at odds with the position of the peak ^{10}Be flux, associated with the MBB, in the EPICA (Antarctic) ice core and in the Montalbno Jonico (Italy) section, relative to stable isotope stratigraphy in those archives (Raisbeck et al., 2006; Dreyfus et al., 2008; Channell et al., 2010; Simon et al., 2017). If all higher sedimentation

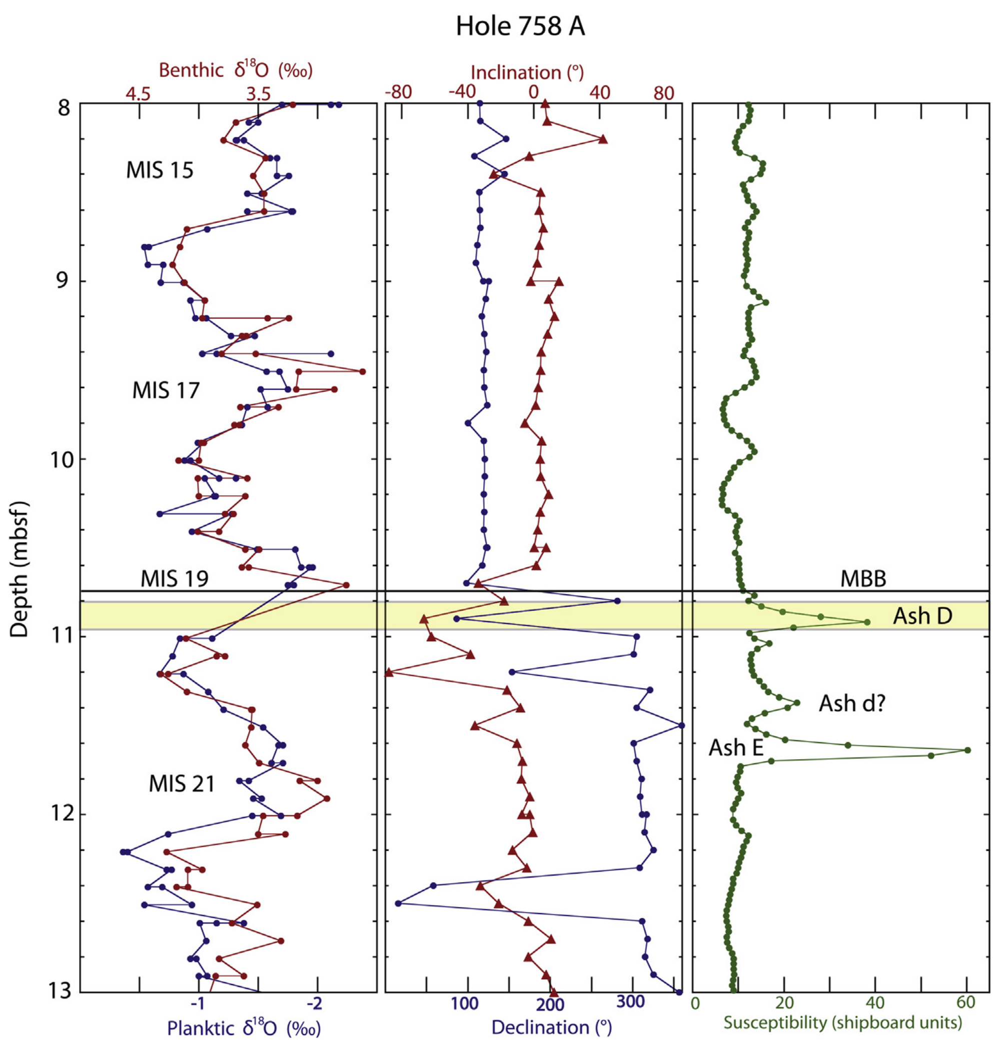

Fig. 1. Hole 758A: Planktic (blue) and benthic (red) oxygen isotope data with marine isotopic stage (MIS) interpretation (Farrell and Janecek, 1991; Chen et al., 1995), shipboard magnetic declination (blue) and inclination (red triangles) from half-cores after 9 mT peak field demagnetization (Shipboard Scientific Party, 1989; Farrell and Janecek, 1991) and shipboard magnetic susceptibility (green) (Shipboard Scientific Party, 1989) in the vicinity of the Matuyama-Brunhes (MBB) boundary. Thick black line indicates position of the MBB (10.75 mbsf) according to Farrell and Janecek (1991). Yellow shaded interval indicates the visual location of Ash D (Dehn et al., 1991) corresponding to a clear susceptibility peak. Depth of Ash E (from Dehn et al., 1991) corresponds to a susceptibility peak. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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