Towards an Integrated Geomagnetic Polarity Reversal Timescale for the Pleistocene

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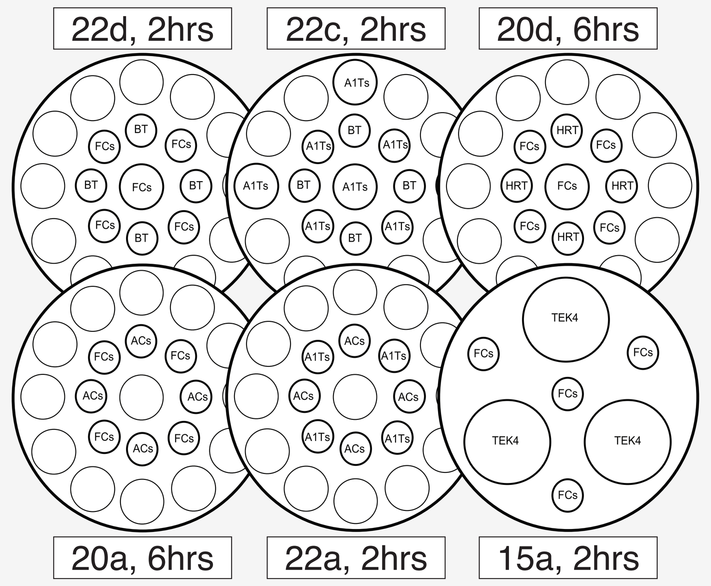
Abstract

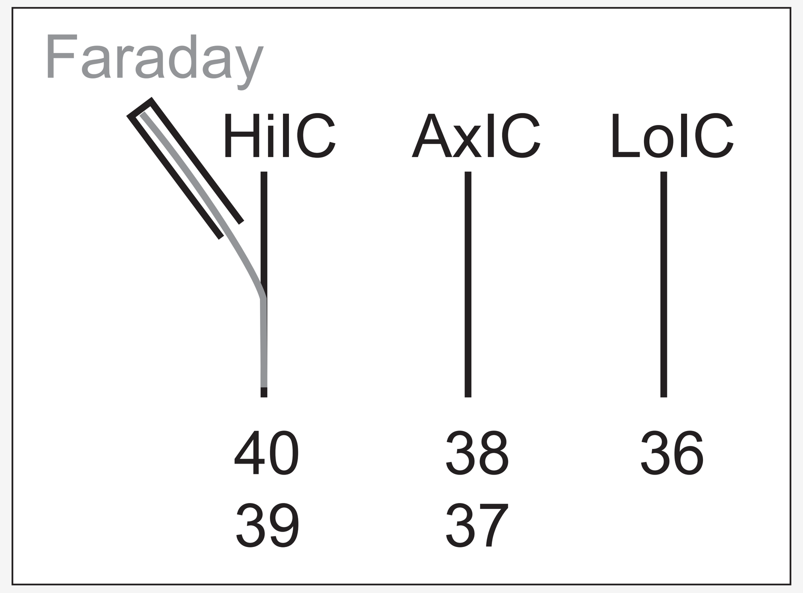
The development of the geomagnetic polarity timescale (GPTS) in the mid 20th century led to the greater understanding of seafloor spreading and plate tectonics (Heirtzler et al., 1968). Over 40 years later, the GPTS continues to be refined, particularly in terms of integrating multiple dating techniques to improve precision of such events, or to resolve the duration of geomagnetic transitions. Recent advancements in integrating astronomical and $^{40}Ar/^{39}Ar$ dating techniques, and improving upon the precision of neutron fluence monitors, necessitate re-evaluation of the accuracy and precision of various geologic events. Here, we review the ages of three Pleistocene geomagnetic polarity reversals: the Matuyama-Brunhes (ca. 0.78 Ma), the Cobb Mountain (ca. 1.2 Ma), and the Reunion (ca. 2.1 Ma) events. High-precision astronomically calibrated $^{40}Ar/^{39}Ar$ ages have been obtained via a Noblesse multi-collector noble gas mass spectrometer on volcanic and other datable materials related to each event. The ages were derived by single- or multi-crystal total fusion and/or step heating experiments, using the astronomically calibrated Fish Canyon sanidine and/or the astronomically tuned A1 sanidine as monitor minerals. Each of these ages is then compared to independent astronomical ages for the events in order to define tie-points for constructing a Pleistocene a multi-chronometer GPTS. Although only three reversals are addressed here, the methodology applied shows promise to refining short-lived excursions to enable further understanding of the wavering magnetic field.

Methods: $^{40}Ar/^{39}Ar$ technique

Irradiation

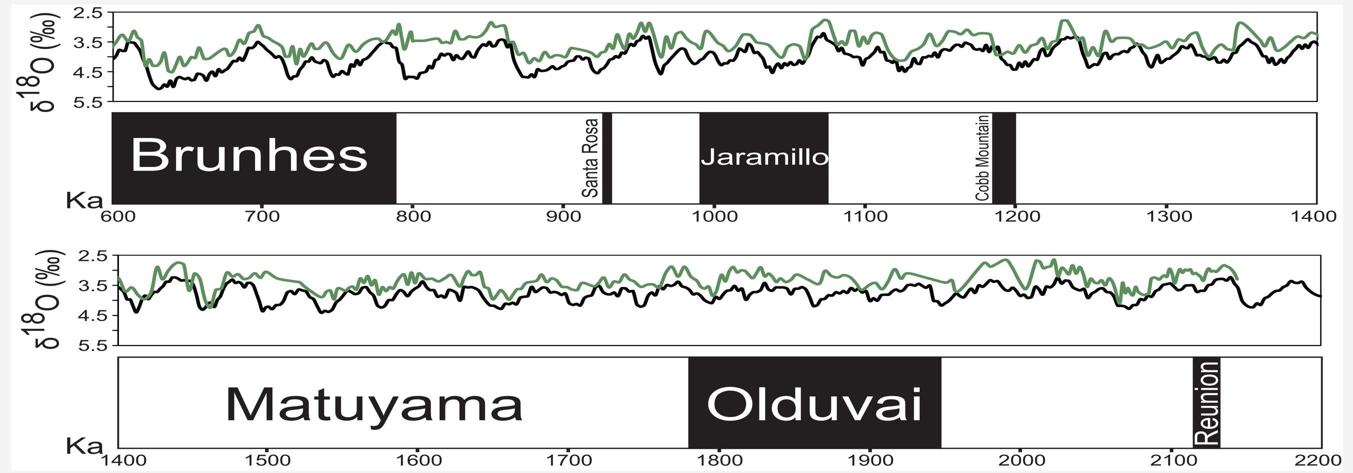


Noblesse Configuration



Methods: astronomical tunings

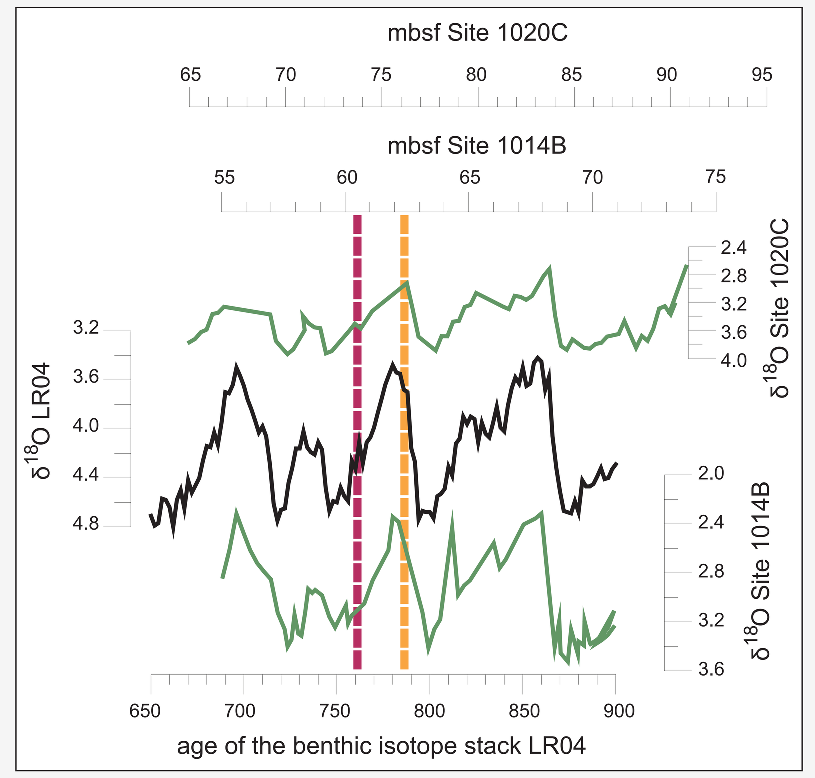
MD972143, Philippine Sea (after Horng et al., 2002)



$\delta^{18}O$ record from drill cores (green) matched to the Lisiecki and Raymo global stack (black), coupled to magnetostratigraphy (ODP record from core 1020C). The positions of the Bishop Tuff (red) and M-B reversal (orange) in the ODP cores were determined by depth in core. ***Bishop Tuff confirmed through EMP analyses***

All astronomically-derived ages incur a minimum of ± 1 ka uncertainty for inaccuracies in the tuning; ages < 1 Ma incur an additional ± 4 ka and ages between 1 and 3 Ma incur an additional ± 6 ka for uncertainties in LR04 (Lisiecki and Raymo, 2005)

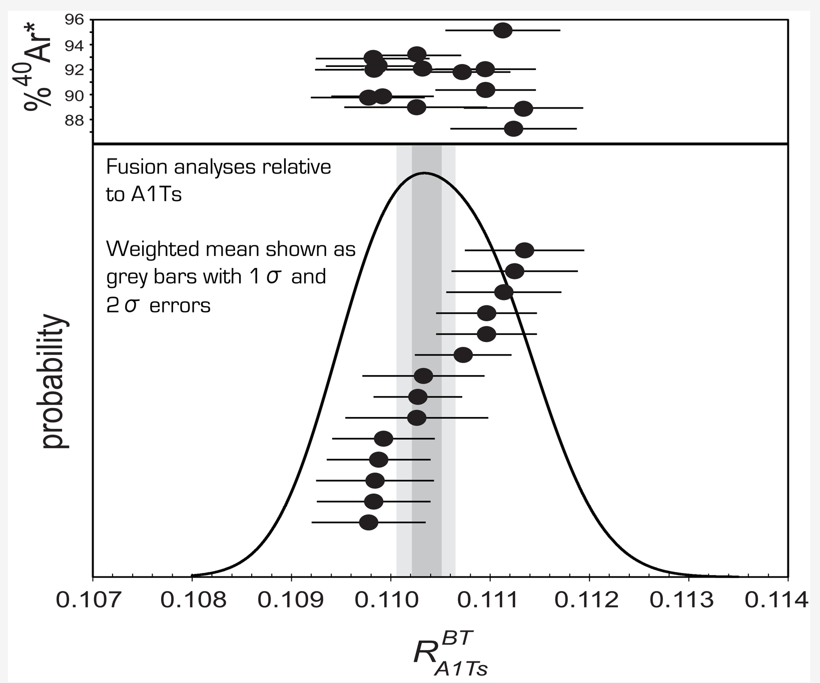
ODP Leg 167, California Margin



ODP $\delta^{18}O$ data from deMenocal & Baker, 2000

Setting Multi-isotopic Anchors for the Pleistocene GPTS

1 *Bishop Tuff, California*
Normal polarity, Brunhes chron
Matuyama-Brunhes reversal

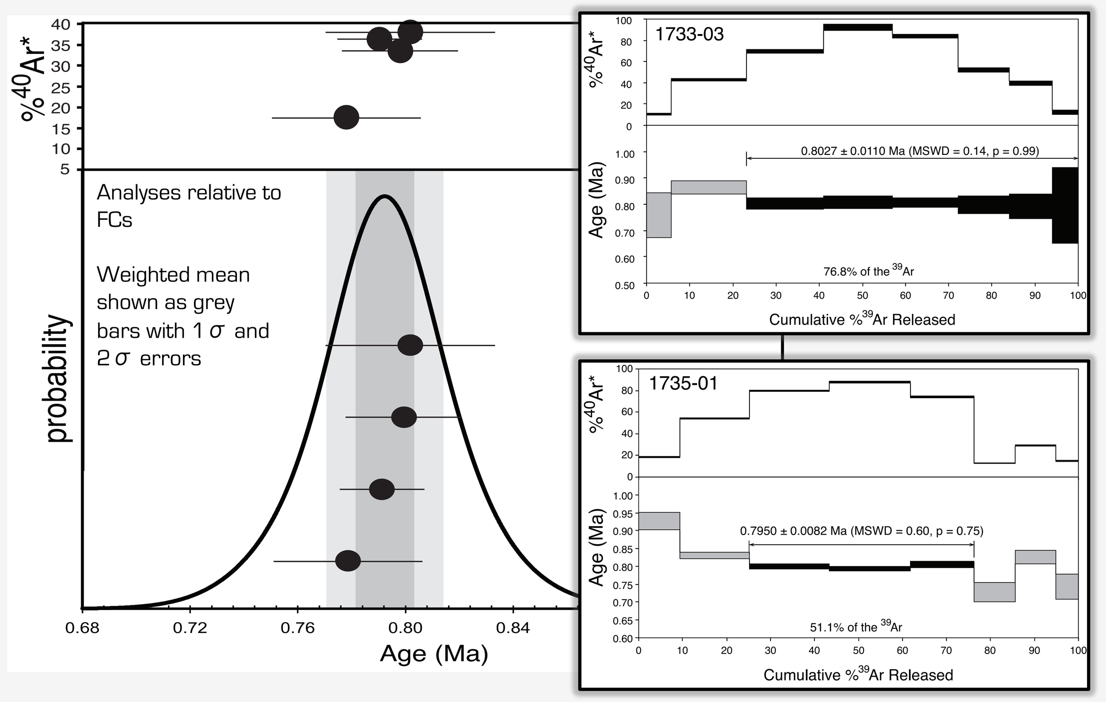


$^{40}Ar/^{39}Ar$ Age of 0.7674 ± 0.0022 Ma
0.29%, 2σ, MSWD = 1.09, n = 14
A1Ts = 6.943 ± 0.005 Ma, Rivera et al., 2011

Astronomical Age of 0.765 ± 0.005 Ma
Derived from ODP core tuning

U-Pb Age of 0.7671 ± 0.0019 Ma
Crowley et al., 2007

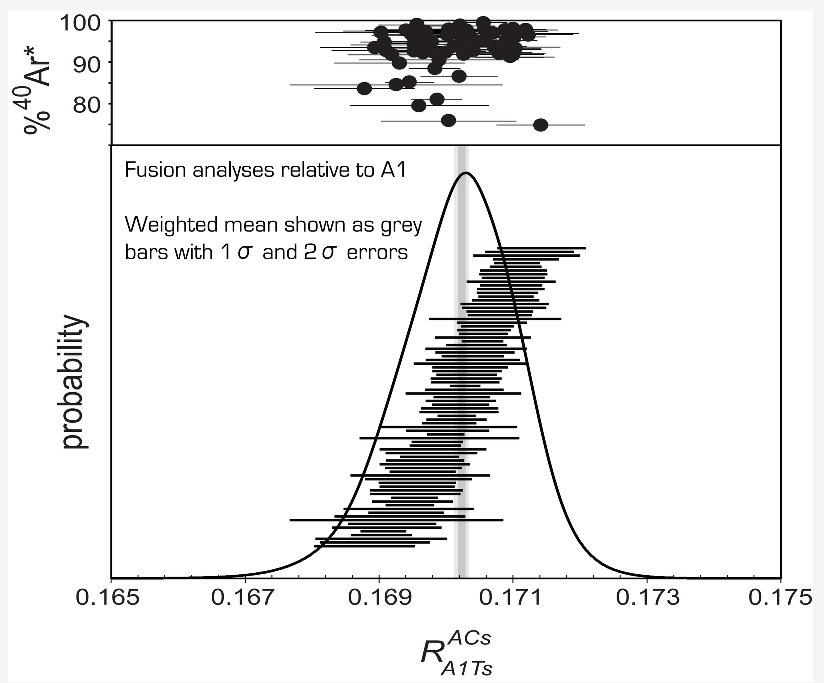
2 *Australasian Tektite, Thailand*
Reverse polarity, Matuyama chron
Matuyama-Brunhes reversal



$^{40}Ar/^{39}Ar$ Age of 0.7973 ± 0.0062 Ma
0.32%, 2σ, MSWD = 0.32, n = 13/20
FCs = 28.172 ± 0.018 Ma, Rivera et al., 2011

Astronomical Age of 0.798 ± 0.005 Ma
Derived from MD core tuning

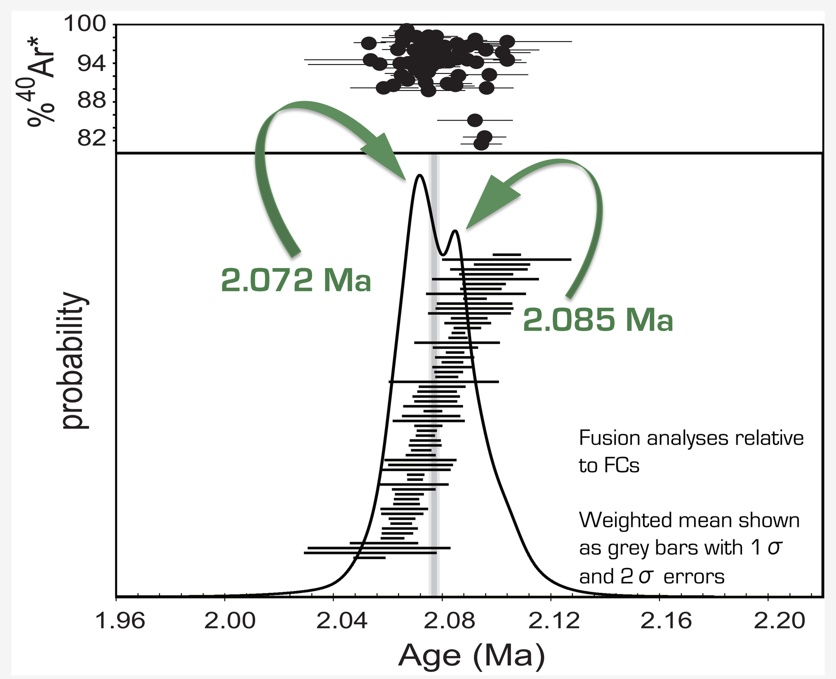
3 *Alder Creek Rhyolite, California*
Normal polarity, Matuyama chron
Cobb Mountain excursion



$^{40}Ar/^{39}Ar$ Age of 1.1839 ± 0.0012 Ma
0.10%, 2σ, MSWD = 1.38, n = 81/89
A1Ts = 6.943 ± 0.005 Ma, Rivera et al., 2011

Astronomical Age of 1.187 ± 0.007 Ma to 1.199 ± 0.007 Ma
Derived from MD core tuning

4 *Huckleberry Ridge Tuff, Idaho*
Normal polarity, Matuyama chron
Reunion excursion



$^{40}Ar/^{39}Ar$ Age of 2.0771 ± 0.0020 Ma
0.10%, 2σ, MSWD = 3.17, n = 63/73
FCs = 28.172 ± 0.018 Ma, Rivera et al., 2011

K-Ar Age of 2.04 ± 0.02 Ma
Derived from groundmass analyses of Reunion basalt samples, Guidelleur et al., 2010

Matuyama-Brunhes reversal in the Pacific

- *Astronomical age of 0.787 ± 0.005 Ma (MD core)*
- *Astronomical age of 0.785 – 0.789 ± 0.008 Ma (ODP core)*
- *Astronomical age of 0.773 for Atlantic sites (Channell et al., 2010)*
- *Δ T between reversal and Bishop Tuff averages 0.020 ± 0.003 Ma (based on sedimentation rates determined in this study)*
- *Δ T between reversal and Tektite is 0.0110 ± 0.0085 Ma (this study)*

Integrated ($^{40}Ar/^{39}Ar$, U-Pb) Age of 0.787 ± 0.004 Ma

Cobb Mountain excursion

$^{40}Ar/^{39}Ar$ Age of 1.184 ± 0.001 Ma

Reunion excursion(s)

- *Reunion I astronomical age of 2.115-2.131 Ma (MD core)*

Integrated ($^{40}Ar/^{39}Ar$, K-Ar) Age of 2.0767 ± 0.0020 Ma

- *Supports notion of 2 distinguishable Reunion events?*
- *Or dating younger Member C with antecrystic inheritance?*

[see Ellis et al., poster V53B-2610, Friday afternoon]

References and Acknowledgements

Channell et al., 2010 G-Cubed; Crowley et al., Geology 2007; deMenocal & Baker, Proc ODP Sci Res 2000; Heirtzler et al., JGR 1968; Horng et al., EPS 2002; Lisiecki & Raymo, Paleocean. 2005; Quidelleur et al., Geophys. J. Int. 2010; Rivera et al., EPSL 2011.
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