Boron isotope based CO_2 record during retreat of the Antarctic ice sheet

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Large ice sheets have existed on Antarctica since the Eocene-Oligocene transition (~34 Ma) when atmospheric CO_2 dropped below around 750 ppm. Results of ice sheet modelling experiments suggest that once the land based East Antarctic ice sheets had grown, a powerful hysteresis effect should have acted to make them inherently stable necessitating high CO_2 levels >> 750 ppm to initiate deglaciation [1]. However, the deep sea oxygen isotope record [2] and results of proximal ice drilling [3] suggest that there has been large fluctuation in Antarctic ice sheet volume, while existing CO_2 records appear to have remained relatively low and constant [2].

Here, we explore this hysteresis effect using boron isotopes, measured by MC-ICPMS, to produce high-resolution CO_2 records during the warming into the Mid-Miocene Climatic Optimum, a time interval associated with significant retreat of the Antarctic Ice Sheet [3]. A high-resolution boron isotope record has been produced for the time period between 15.5 and 17 Ma at ODP Site 761 (16°44.23′S, 115°32.10′E 2179 m). Our results show relative changes in atmospheric CO_2 across this time interval. By combining this new record with records of proxy ice volume change we shed new light on our understanding of CO_2 driven retreats of the Antarctic ice sheet.

[1] Pollard & DeConto (2005) *Global and Planetary Change* **45**(1-3), 9-21[2] Zachos *et al.* (2008) *Nature* **451**(7176), 279-283 [3] Passchier *et al.* (2011) *Geol Soc Am Bull, **123***(11-12), 2352-2365.

Water in the Moon: D/H and high volatile abundances of lunar apatite

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In order to study ^1H and D distributions in individual apatite grains $\{Ca_5(PO_4)_3(F,Cl,OH)\}$ in a range of lunar rocks collected during the Apollo program, we have been using a new ion microprobe technique that combines quantitative spot analyses with semi-quantitative 2-D ion imaging. We find the Moon has abundant water and a distinct range of D/H compared to known water sources in the solar system [1]. Since our publication, we have measured D/H and OH in lunar apatite in five more samples. New samples include mare basalts 10047 and 12064 that both have high δD, but moderate water contents (<2000 ppmw OH) in comparison to other mare basalts that we have measured. New analyses of mare basalt 12039 have been performed, a rock from which a significant portion of our pubished data was derived. These new analyses of 12039 suggest less variability in D/H than reported for this sample.

We continue to see that the mare basalts have significant hydroxyl in their apatite grains (with the exception of olivine basalt 12040). Estimates for the lunar-mantle water content from apatite grains are fraught with assumptions. However, with some assumptions, we can estimate the H_2O content of the lunar mantle that produced 12039. For 3-5% partial melting, and assuming no assimilation of volatile-bearing material by the magma, a mean partition coefficient of 0.4 for OH between apatite and melt (e.g. [2]), and that apatite is the only OH-mineral crystallizing from the magma, and no degassing of H_2 or H_2O, and, finally, that our highest water content apatite represents 99% crystallization of the magma, we estimate 5-8 ppm H_2O for the 12039 source region.

[1] Greenwood J. P. et al. (2011) *Nature Geosci.,* **4**, 79-82. [2] Boyce J. W. et al. (2010) *Nature* **466***,* 466-469.