Origin of water on the chondrite asteroids: Evidence from oxygen-isotope compositions of aqueously-formed minerals

A. N. KROT[1,2]*, P. M. DOYLE[1,2], K. NAGASHIMA[1], K. JOGO[3], S. WAKITA[3], F. J. CIESLA[4] AND I. HUTCHEON[5]

[1]HIGP, University of Hawai'i, Honolu, HI 96822, USA.
[2]Hawai'i NASA Astrobilogy Institute, University of Hawai'i
[3]Tohoku University, Sendai 980-8578, JAPAN
[4]University of Chicago, Chicago, IL 60637, USA
[5]Glenn Seaborg Institute, LLNL, Livermore, CA 94551, USA

Fayalite and magnetite in CV3.1 and CO3.1 carbonaceous chondrites (CCs) resulted from water-rock interaction on their parent asteroids at water/rock volume ratio of ~0.2 and temperatures of ~100–200°C [1,2]. The inferred ^{53}Mn/^{55}Mn ratios in fayalite in Asuka 881317 (CV) and MacAlpine Hills 88107 (CO-like) are (2.77±0.48)×10^{-6} and (2.45±0.33)×10^{-6} [3] The ^{53}Mn-^{53}Cr ages of the CV and CO fayalite formation anchored to D'Orbigny angrite [4,5] are 3.7 (+1.1/–0.9) and 4.4 (+0.9/–0.7) Ma after CV CAIs [3] having an absolute age of 4567.3±0.16 Ma [6]. These ages are indistinguishable from the ^{53}Mn-^{53}Cr ages of calcite in CMs [7] and dolomite in CMs and CIs [7,8]. The high peak metamorphic temperatures experienced by CVs and COs of petrologic type ≥ 3.6 (≥600°C) and the old formation ages of fayalite imply a rapid accretion of their parent asteroids after chondrule formation (~2–2.5 Ma after CV CAIs) followed by a short onset of aqueous alteration. The accretion of CVs and COs predated by ~ 1Ma accretion of the more extensively aqueously-altered, but less metamorphosed CMs and CIs [7,8]. Near terrestrial oxygen-isotope compositions of the CV and CO fayalite and magnetite (Δ^{17}O ~ –1‰), and CM and CI carbonates and magnetite (Δ^{17}O ~ +2‰ to –3‰) may indicate water in the CC parent asteroids had preferentially a local, inner Solar System origin, consistent with the inferred hydrogen-isotope composition of the CC asteroidal water [9]. The low influx of isotopically heavy (i.e., enriched in ^{17}O, ^{18}O, and D/H) water ices from the outer Solar System at the time of accretion of CC asteroids may be due to an early growth of Jupiter that could have prevented significant radial transport of dust and gas from outside its orbit.

[1] Krot A. N. *et al.* (1998) *MAPS* 33, 1065. [2] Zolotov M. Yu. *et al.* (2006) *MAPS* 41, 1775. [3] Doyle P. M. *et al.* (2013) *LPSC* 44, #1793. [4] Amelin Y. (2008) *GCA* 72, 221. [5] Glavin D. M. *et al.* (2004) *MAPS* 39, 693. [6] Connelly J. N. *et al.* (2012) *Science* 338, 651. [7] Fujiya W. *et al.* (2012) *Nature Commun.* 3, 1. [8] Fujiya W. *et al.* (2013) *EPSL* 362, 130. [9] Alexander C. M.O'D. *et al.* (2012) *Science* 337, 721.

Nucleosynthetic W isotope anomalies in CAI: Implications for Hf-W chronology

T.S. KRUIJER[1,2,]*, T. KLEINE[1], C. BURKHARDT[3] AND R. WIELER[2]

[1]Institute for Planetology, University of Münster, Germany
[2] Institute of Geochemistry and Petrology, ETH Zürich (*correspondence: thomas.kruijer@erdw.ethz.ch)
[3]Origins Laboratory, Department of the Geophysical Sciences, The University of Chicago

The application of the short-lived ^{182}Hf-^{182}W decay system to investigate the timing of early solar system processes requires knowledge of the initial Hf and W isotope compositions at the beginning of the solar system [1,2]. These can most directly be determined from Ca-Al-rich inclusions (CAI), which are the oldest yet dated objects that formed within the solar system [*e.g.*, 3,4]. However, the interpretation of W isotope data in CAI is complicated by the presence of nucleosynthetic W isotope anomalies [1], which may significantly bias the inferred initial ^{182}W/^{184}W of CAI [2]. The aim of this study is to explore the range of nucleosynthetic W isotope variations in CAI to better quantify the initial Hf and W isotope compositions of the solar system.

Here we report W isotope compositions for six bulk CAI (one type B, five type A) from the Allende CV3 chondrite. Tungsten isotope compositions of the CAI were measured on a Neptune *Plus* MC-ICPMS at the University of Münster and are reported as ε^{i}W (*i.e.*, 0.01 % deviations from terrestrial values). The investigated CAI display large variations in ε^{183}W, extending to much larger anomalies than previously observed [1,2] and indicating variable abundances of *s*- and *r*-process W isotopes in CAI. The CAI define a precise empirical correlation between ε^{183}W and initial ε^{182}W, which allows correction of measured ε^{182}W for nucleosynthetic heterogeneity. The corrected ε^{182}W *vs.* ^{180}Hf/^{184}W define a bulk CAI isochron (MWSD=1.5) with a precise initial ^{182}Hf/^{180}Hf of ≈1.0×10^{-4}, which when anchored to the angrite D'Orbigny [5] corresponds to an absolute age of CAI that is in good agreement with their Pb-Pb ages [3,4]. The bulk CAI isochron confirms the recently revised CAI initial of ε^{182}W ≈ –3.5 [2]. Relative to this value, magmatic iron meteorites have more radiogenic neutron capture-corrected ε^{182}W [6], corresponding to core formation timescales of ≈1-3 Ma after CAI formation and indicating a time gap of ≈ 0.5-1 Ma between the formation of the first solids and accretion of the oldest planetesimals.

[1] Burkhardt *et al.* (2008) *GCA* **72**, 6177-6197. [2] Burkhardt *et al.* (2012) *APJ Lett.* **753**, L6. [3] Amelin *et al.* (2010) *EPSL* **300**, 343-350. [4] Bouvier & Wadhwa (2010) *Nat. Geosci.* **3**, 637-641. [5] Kleine *et al.* (2012) *GCA* **84**, 186-203. [6] Kruijer *et al.* (2013) *EPSL* **361**, 162-172.

www.minersoc.org
DOI:10.1180/minmag.2013.077.5.11