Revised Hf-W ages for core formation in planetary bodies

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The extinct ^{182}Hf-^{182}W isotope system has been widely applied to date core formation in planetary bodies [e.g., 1]. Recent studies report a ^{182}W anomaly of about -2 ε units for the carbonaceous chondrite Allende relative to the terrestrial value [2] which significantly differs from the previously accepted value of 0 ε units [1]. Based on this finding, a solar system initial ^{182}Hf/^{180}Hf ratio of ~1x10^{-4} has been suggested [2] which is in stark contrast to the previously accepted value of 2.75x10^{-4} [3]. To address these issues, we obtained W isotope compositions for seven carbonaceous chondrites (CC) and a four point Hf-W internal isochron for the H chondrite Ste. Marguerite which is well dated with U-Pb (4.5627±0.0006 Ga). Using the MC-ICPMS at Münster, ^{182}W/^{184}W can be measured with an external reproducibility of ±0.5 ε units (2σ). Hf/W ratios were measured using a ^{180}Hf-^{183}W tracer that was calibrated against pure metals.

The seven CC Orgueil, Allende, Axtell, Murchison, Cold Bokkeveld, Nogoya and Karoonda exhibit uniform W isotope compositions with a mean of -1.9±0.2 ε units relative to the terrestrial standard. This value is consistent with the result from [2] and with Hf-W data on E chondrites. Most importantly, terrestrial samples now show a ^{182}W anomaly of ca. +2 ε units relative to the newly defined chondritic value, which allows precise dating of terrestrial core formation. An internal Hf-W isochron for Ste. Marguerite defines the solar system initial ^{182}Hf/^{180}Hf as 1.1±0.1x10^{-4} (2σ), which is significantly lower than the currently accepted value of 2.75x10^{-4} [3], but in remarkable agreement with previously suggested values of 0.8±0.2x10^{-4} [4] and ~1x10^{-4} [2].

The redefinition of both the chondritic ^{182}W/^{184}W and the solar system initial ^{182}Hf/^{180}Hf requires the re-evaluation of published Hf-W ages for core formation. Assuming Hf/W = 34.6 for the HED mantle, 6.2 for the Martian mantle and 17.7 for the bulk silicate Earth, Hf-W model ages (after formation of CAIs) of ~4 m.y. for the HED parent body, ~16 m.y. for Mars, and ~30 m.y. for Earth can be calculated if our newly defined parameters are used. The Hf-W model age for the HED parent body is now consistent with results from the ^{53}Mn-^{53}Cr and ^{26}Al-^{26}Mg systems, which suggest HED mantle differentiation within the first ~3 m.y. after condensation of CAIs. The Hf-W model ages obtained for Mars and Earth are in excellent agreement with Wetherill-type models for planetary accretion that suggest a timescale of tens of m.y. for the formation of the terrestrial planets.

[1] Lee and Halliday, (1995), *Nature* 378, 771-774 [2] Yin et al., (2002), *LPS* XXXIII, 1700.pdf [3] Lee and Halliday, (2000), *Chem. Geol.* 169, 35-43 [4] Ireland et al., (2000), *LPS* XXXI, 1540.pdf

H_2O in the mantle drives secular change in continental petrology

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A model for Archaean granitoid magmatism is presented, which reconciles the geochemical similarities and differences between TTG and potassic granitoids. The model was developed with a sample suite from Barberton Mountain Land, South Africa. Since both investigated rock types share the typical trace element signature for arc magmatism (overabundance in fluid-sensitive elements; HFSE depletion) it follows that both granitoid types are derived from refertilised mantle above subduction zones (s.l.), where melting is triggered by fluids derived from slab dehydration. As parental melts hydrous basalts are envisaged, which underwent extensive fractional crystallisation. Experiments demonstrate that depending on initial water content of the melt, remarkably different fractionating assemblages crystallise (e.g. Sisson and Grove, 1993; Müntener et al. 2001). Importantly for TTG, high-H_2O basaltic melts crystallise extensive garnet and/or amphibole whereas plagioclase and olivine crystallisation is suppressed. Such a fractionating assemblage ultimately leads to tonalitic derivative melts with (i) high LREE/HREE ratios; low HREE contents, (ii) absence of Eu-anomaly, (iii) low K/Na ratios and (iv) high abundances of highly compatible elements. While intermediate H_2O-melts still crystallise garnet and/or amphibole, plagioclase and olivine are, in contrast, not suppressed. This results in derivative liquids with (i) high LREE/HREE ratios; low HREE contents, (ii) presence of Eu-anomaly, (iii) high K/Na ratios and (iv) low abundances of highly compatible elements. These characteristics are found in Archaean potassic granitoids. Low H_2O-melts do not crystallise garnet and amphibole, but olivine and plagioclase resulting in 'classical' post-Archaean granites with (i) relatively low LREE/HREE ratios; high HREE contents, (ii) presence of Eu-anomaly, (iii) high K/Na ratios and (iv) low contents of highly compatible elements.

We identify the initial water content of the parental melt as the key parameter to explain the secular change in continental petrology. The disappearance of TTG between 2.5-2.0 Ga and emergence of 'classical K-granites' is thus explained with secular decrease of aqueous fluid transport into the supra-subduction zone and/or efficiency of deep fluid release from subducted slabs.

Müntener O, Kelemen PB and Grove TL (2001), Contrib Mineral Petrol 141, 643-658.
Sisson TW and Grove TL (1993), Contrib Mineral Petrol 113, 143-166.