The timing of the Earth's accretion and volatile loss: The Pd-Ag view

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The ^{107}Pd-^{107}Ag decay system (half-life = 6.5 Myr) is a powerful tool to study early solar system processes. It provides time constraints on accretion and subsequent chemical separation of planetary bodies in a similar way as the Hf-W system, because of different metal-silicate partitioning. In addition, due to the different volatility of Pd and Ag, it also tracks volatility-related processes. The Pd-Ag system was successfully applied to iron meteorites [1] and in combination with recent results from carbonaceous chondrites, the data indicate that the solar system started with an initial ^{107}Pd/^{108}Pd ratio in the range of ~ 6 x 10^{-5} [2]. This is an important parameter for accretion models based on Pd-Ag. Other necessary parameters such as ε^{107}Ag of bulk silicate Earth (BSE) and the precursor material are estimated from (1) a range of unaltered terrestrial basalts with an average ε^{107}Ag of -2.1 ± 0.6 relative to the NIST SRM 978a Ag standard and (2) the CV3 chondrite Allende with a ε^{107}Ag of -0.4 ± 0.5. Based on this, it is possible to model the Earth's accretion and core formation, assuming that the Earth accreted from material with similar volatile element depletion as CV3 chondrites and that Ag isotopes are not significantly affected by stable isotope fractionation. A simple two stage model suggests that the last complete metal-silicate equilibration occurred within the first 15 Myr of the solar system. However, the Hf-W system yields an age of 30 Myr for the same model. Several reasons for this discrepancy are discussed: (a) the Pd/Ag ratio of BSE is not well known. However, modeling shows that this ratio can be varied from 0 to 1, without significantly affecting the results. (b) Metal-silicate differentiation was incomplete and affected Hf-W and Pd-Ag differently. Applying the model of [3] suggests that this cannot reconcile the data. (c) The Earth accreted from volatile-rich (CI-like) material. Here the two-stage model provides a bounding limit on the time of core formation of later than 3 Myr after solar system formation.

[1] Chen & Wasserburg (1996) in *Earth Processes, Reading the Isotopic Code*, Geophysics Monograph '95, pp. 1-20. [2] Schönbächler *et al.* (2008) *GCA*, submitted. [3] Halliday (2004) *Nature*, **427**, 505.

Are we getting close to a mechanistic description of weathering in the field?

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The kinetics of mineral dissolution/precipitation plays an important role in various processes occurring at the Earth surface, including continental weathering that exerts a major control on the migration of major and trace elements in the critical zone, the chemistry of rivers, the regulation of ocean and atmosphere compositions, and ultimately the climatic evolution of the Earth surface. As a result, many efforts have been recently dedicated to the quantitative description of weathering at different scales based on reactive transport modeling approaches. The accuracy of such modeling depends heavily on the robustness of kinetic models and thermodynamic and kinetic parameters used for describing mineral-water reactivity, and it has been often argued that rate laws and parameters derived from laboratory experiments yield reaction rates several orders of magnitude faster than those measured in the field. Rigorous investigation of such possible discrepancies requires the use of full reactive transport modeling to compare natural and calculated weathering profiles and soil and river waters chemistries, and to test the impact of important physical, biological, and thermodynamic and kinetic parameters on weathering modeling outputs. For this purpose, a mechanistic numerical model of chemical weathering in soil horizons and underlying bedrock (WITCH) has been coupled to numerical model of water and carbon cycles (ASPECT, LPJ) and a global climate model (GENESIS) to compare observed and calculated soil profiles and water chemistries developed at different spatial and time scales and to quantify the sensitivity of calculated results. We demonstrate that the weathering processes are highly dependent on a large set of parameters: first of all, the kinetic and thermodynamic parameters. Then the water fluxes exert a very strong control on the weathering profile, and finally the species exchange with the living and dead biomass. The exact reactive surface, still a frontier research question, may appear as a calibration parameter.