Planetary geochemistry: Searching for generalities

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Planets and large asteroids seem to have followed their own muse in creating and modifying their crusts. The list of processes ([1] with some additions by me) affecting crustal compositions includes the abundance of ^{26}Al in planetesitmals; mixing during planetary accretion; effects of large impacts on primary differentiation and early crustal evolution; the style of primary differentiation (magma oceans and processes in them); planet size, mass, and composition; extent of volatile element depletion compared to CI chondrites; oxygen fugacity; H_2O content; and atmosphere-crust interactions. The stochastic interactions among these factors produces a baffling array of compositional variations.

We can, however, identify some general trends. *Depletion of moderately-volatile elements*: K/Th is a useful parameter because we have or will have global measurements for K/Th for the Moon, Mars, Vesta, and Mercury. K/Th values are: Earth and (probably)Venus, 2900; the Moon, 360; Mars, 5000; Vesta (HED meteorites), 1050; CI chondrites, 19,000. (The uniform depletion of volatiles in the Moon suggests that loss when the Moon formed by a giant impact was not driven by simple evaporation followed by fractional condensation [2]. It seems likely that the Moon inherited its volatiles from the impactor.) The planetesimal population that fed the terrestrial planets, the Moon-forming impactor, and Vesta accreted while ^{26}Al was still present and at relatively high temperatures (causing volatile depletion). Planetesimals that formed later were cooler and did not heat as much, forming chondrites and partial melts from them (e.g., GRA 06128/9, which is not depleted in volatiles [3]). *Basaltic magmatism:* Basaltic crusts are abundant on Earth and Venus (alkalic and tholeiitic), the Moon (FeO-rich mare basalts and terrestrial-like KREEP basalt), Mars (tholeiite and alkalic), and Vesta (similar to aluminous mare basalts). *Tertiary crusts are rare*: Evolved crust is present in significant amounts only on Earth. *Weathering styles*: Surface-atmosphere interactions are highly variable, but reflect the abundance of water in each body. Only Earth and Mars show evidence of aqueous weathering, with weathering on Mars at much lower pH and water/rock than on Earth.

[1] Taylor & McLennan (2009) *Planetary Crusts.* Cambridge. [2] Taylor *et al.* (2006) *GCA* **70**, 5904-5918. [3] Day *et al.* (2009) *Nature* **457**, 179-183.

Mycorrhizal evolution, biological weathering and the long-term carbon cycle

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Evolution of Plants, Mycorrhizas and Weathering

Two axes of plant evolution have been implicated in enhanced weathering of silicate minerals leading to drawdown of atmospheric CO_2 during the Phanerozoic aeon: the advance of forests in the Devonian, and the rise of angiosperms beginning in the Cretaceous [1]. This paradigm overlooks the co-evolution of roots with the major groups of symbiotic fungal partners that have dominated terrestrial ecosystems throughout the Phanerozoic. The evolution of arbuscular mycorrhizas (AM) was coincident with the colonisation of land by plants in the Devonian, whilst the Cretaceous witnessed the rise of ectomycorrhizas (EM) that associate with some gymnosperm and angiosperm trees. Modern evidence for the influence of AM and EM on mineral weathering reveals that the key processes underpinning the current paradigm and ascribed to plants are actually driven by the combined activities of roots and mycorrhizal fungi [2].

Mycorrhizal Weathering

Emerging evidence suggests that ancestral AM fungi may promote weathering by locally acidifying the soil solution. Later evolving EM, which are now common in trees of families Pinaceae, Dipterocarpaceae, Fagaceae and Betulaceae, often aggressively weather minerals both by acidifying the soil solution and releasing low molecular weight organic chelators. Although it may not be possible to attribute CO_2 drawdown to a single mechanism, the advance of ectomycorrhizal trees is more likely to have increased weathering than the rise of angiosperms. Field and laboratory studies must distinguish between AM and EM gymnosperms and angiosperms to better understand the relative weathering effects of trees and their mycorrhizas through the Phanerozoic.

[1] Berner (2004) *The Phanerozoic carbon cycle. CO_2 and O_2.* Oxford University Press, Oxford. [2] Taylor *et al.* (2009) *Geobiology* (in press).