

Isotopic constraints on heterogeneous accretion of the Earth

M. SCHÖNBÄCHLER^{1,2*}, R.W. CARLSON², M.F. HORAN²,
T.D. MOCK² AND E.H. HAURI²

¹SEAES, The University of Manchester, M13 9PL, UK

(*correspondence: m.schonbachler@manchester.ac.uk)

²Dept. of Terrestrial Magnetism, Carnegie Institution of
Washington, Washington, DC 20015, USA

Planetary accretion, core formation and the loss of volatile elements are important processes in the early history of the Earth. New high-precision Pd-Ag isotope data define an Earth's mantle that is identical in Ag isotope composition to CI chondrites [1]. This indicates that the Earth accreted a significant amount of material with high contents of moderately volatile elements. The Mn-Cr and Rb-Sr decay systems, however, suggest the opposite i.e. the accretion of volatile-depleted material [2, 3]. A solution to this paradox is heterogeneous accretion [4].

Heterogeneous accretion implies that the composition of the material from which the Earth accreted changed over time. We performed combined Pd-Ag, Mn-Cr and Hf-W modeling applying the continuous core formation model of [5]. Reconciling the different chronometers requires that the Earth accreted heterogeneously from dominantly volatile-depleted material in the beginning and more volatile-rich material towards the end of accretion. The moon-forming giant impact also likely involved a collision with a Mars-like protoplanet that possessed an oxidized mantle enriched in moderately volatile elements.

The model results are in good agreement with recent dynamic models of accretion and planet formation [e.g. 6], which independently conclude that volatile-rich material was delivered towards the end of terrestrial accretion. Our model is also consistent with the early suggestion that accretion of reduced and volatile-depleted material was followed by accretion of oxidized and volatile-rich material based on elemental abundance patterns in the bulk silicate Earth [4]. Such an accretion sequence is furthermore supported by more recent studies of the partitioning behavior of V, Cr and Nb (e.g. [7]) that require an increase in oxygen fugacity during accretion.

[1] Schönbachler *et al.* (2008) *GCA* **71**, Suppl. A904.
[2] Carlson & Lugmair (1988) *Earth Planet Sci. Lett.* **90**, 119.
[3] Qin *et al.* (2009) *GCA* **74**, 1122. [4] Wänke *et al.* (1984) *in* *Archaen Geochemistry*, pp. 1–24. [5] Halliday (2004) *Nature*, **427**, 505. [6] O'Brien *et al.* (2006) *Icarus* **184**, 36. [7] Wood *et al.* (2008) *GCA* **72**, 1415.

Bicarbonate fluxes from rivers draining ophiolites and volcanoes, Luzon, Philippines

H.H. SCHOPKA¹, L.A. DERRY¹ AND C.A. ARCILLA²

¹Department of Earth and Atmospheric Sciences, Cornell
University, Ithaca, NY 14853, USA

²National Institute of Geological Sciences, University of the
Philippines, Diliman, Quezon City 1101 Philippines

We investigated fluxes of bicarbonate from rivers draining volcanic and ophiolitic areas in Luzon, the Philippines. Area-normalized average bicarbonate yield is higher in ophiolitic watersheds ($6.1 \cdot 10^6$ mol/km²/yr and $3.9 \cdot 10^6$ mol/km²/yr in ophiolite vs. volcanic regions, respectively) and in both cases, they are much higher than the global basalt area-normalized average of $0.6 \cdot 10^6$ mol/km²/yr (calculated using data in [1]). Theoretically, any 2 moles of bicarbonate fixed in river water by silicate weathering can only yield one mole of permanently sequestered C, since the other mole of C is released back to the atmosphere upon precipitation of calcite. Weathering studies often ignore this fact and equate bicarbonate fluxes with atmospheric C consumption. We tested two methods of calculating atmospheric C consumption, E&H [2] and FL&D [3] on our dataset. The E&H method overestimated C consumption relative to the FL&D method by up to a factor of 4 and in 17% of cases predicted C consumption larger than the total bicarbonate flux. In most cases the FL&D method yielded atmospheric C consumption values close to half the observed bicarbonate flux. Our results highlight the difficulties in comparing results from different weathering studies because of different methods used to calculate fluxes and atmospheric C consumption by silicate weathering.

Regardless of the exact manner in which these data are presented, the observed HCO₃ fluxes/atmospheric C consumption are among the highest reported anywhere in the world. This is a very interesting result because while volcanic regions have lately been recognized as the most efficient consumers of atmospheric CO₂ of all lithologies (e.g. Dessert *et al.* [1]), ophiolites have not been studied in this context before to the authors' best knowledge.

[1] Dessert *et al.* (2003) *Chemical Geology* **202**, 257–273.
[2] Edmond & Huh (1997) *in Tectonic Uplift & Climate Change*, pp.329–351. [3] France-Lanord & Derry (1997) *Nature* **390**, 65–67.