

A continuum of aqueous alteration among carbonaceous chondrites

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Carbonaceous chondrite (CC) aqueous alteration appears to have been largely isochemical. Isochemical alteration, in turn, is sometimes used as evidence that hydrothermal activity in the CC parent bodies did not exist. Instead, it is asserted that fluids did not flow despite fluid/rock ratios >1 , the presence of forces that should have induced flow, and oxygen isotopic evidence for extensive down-temperature fluid flow [1]. The underlying assumption is that fluid flow requires dramatic chemical alteration. Several lines of evidence call into question this assumption.

Low-temperature aqueous alteration of many basalts in Gusev crater on Mars was nearly isochemical, with little or no deviations from the feldspar-olivine compositional join [2]. Analog studies of low-temperature aqueous alteration of Icelandic basalts by flowing fluids also demonstrate nearly isochemical alteration resulting in phyllosilicate-rich lithologies [3].

A recent analysis of permeabilities in carbonaceous chondrites suggests that permeabilities are likely to have been high enough to permit water flow [4]. Flow is also suggested by the likelihood for capillary flow along grain boundaries and new experiments on Murchison suggesting substantial H₂O permeability.

We are carrying out numerical simulations for fluid-rock interactions that constrain the conditions for chemical alteration. Results show that significant changes in mineralogy with relatively restricted changes in elemental ratios are characteristic of moderate flow rates.

Fluid flow on meteorite parent bodies would lead to heterogeneities in mineralogy that are similar to the variations exhibited among carbonaceous chondrites. The implication is that the parent body asteroids and/or comets of carbonaceous chondrites were geologically diverse. This diversity is a likely corollary of water-rock differentiation such as that evidenced by the Dawn observations of Ceres.

References: [1] Young E.D. et al. 1999. *Science* 286, 1331-1335. [2] Ming D.W. et al., 2008. in *The Martian Surface: Composition, Mineralogy, and Physical Properties*, J.V. Bell III, Ed., Cambridge University Press. [3] Ehlmann B.L. et al. 2012. *Journal of Geophysical Research* 117, E00J16. [4] Fu R.R. et al. 2015. Lunar and Planetary Science Conference. 1832, p. 1591.