Using reactive transport modeling to characterize the record of climate change in deep vadose zones

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Studies of deep vadose zone pore waters that evaluate chloride mass balance, and stable (deuterium and ^{18}O) and radiogenic (^{3}H, ^{36}Cl) isotope systematics have concluded that variations in infiltration flux can account for the observed variations in abundance of these approximately conservative tracers. It can be inferred, on the basis of these observations and interpretations, that a climate change record is preserved in these vadose zone waters. In arid regions where thick (>100 m) vadose zones persist, it has been concluded that this record may extend back more than 100,000 years. Consideration of the mechanisms that control reactive transport led to the conclusion that such climate-driven effects will also be evident as chemical reactions involving dissolution and/or precipitation of mineral phases along the flow pathway. As a result, there should also be variations in the concentrations of non-conservative chemical species that correspond to changes in the concentrations of the conservative tracers. Simulations of this reactive transport, in a regime typical of the arid Southwest U.S., demonstrate that these changes can modify pore water chemistry by factors of up to 200%, but the changes take place slowly, requiring thousands of years to achieve steady state conditions. This suggests that a very rich archive of climate change history is preserved in this type of setting. However, extracting that history is currently hampered by inadequate data for relevant rock properties. This challenge may be overcome if coordinated efforts are undertaken that exploit the power of detailed studies of isotope systematics, micro-scale rock characterization, and high performance computing.

A search for extraterrestrial amino acids in Antarctic micrometeorites

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The delivery of amino acids by micrometeorites to the early Earth during the period of heavy bombardment could have been a significant source of the Earth's prebiotic organic inventory (Chyba and Sagan, 1992). However, one problem associated with the delivery of organic compounds by micrometeorites is that these grains can be heated to very high temperatures during atmospheric deceleration. Direct analyses of micrometeorite grains (200-400 μm) collected from Antarctic blue ice suggest peak heating temperatures from ~1000°C to 1500°C for several seconds during atmospheric entry (Toppani *et al.*, 2001). Since amino acids will begin to decompose in the solid state at temperatures in the range of 150°C to 600°C (Rodante, 1992), it is unclear whether these compounds could survive atmospheric entry on large micrometeorite grains.

In this study the acid-hydrolyzed, hot water extracts from a total of 455 Antarctic micrometeorite (AMM) grains were analyzed for the presence of amino acids by high performance liquid chromatography. Because AMMs have been found to be both petrologically and chemically similar to the CMs (Kurat *et al.*, 1994), a 5 mg sample of the CM meteorite Murchison was also analyzed. In the Murchison sample we found a high level (~3 ppm) of α-aminoisobutyric acid (AIB), a non-protein amino acid that is extremely rare on Earth, and is characteristic of amino acids of apparent extraterrestrial origin. In contrast, we were unable to detect any AIB in the AMMs above the 0.1 ppm level.

One possible explanation for the lack of extraterrestrial amino acids in AMMs, is that these compounds were completely destroyed and/or sublimed away from the grains during atmospheric heating. Sublimation has been proposed as a mechanism by which amino acids could survive atmospheric entry heating by vaporizing off the surface of micrometeorite grains at lower temperatures (~150°C) before they are pyrolyzed and destroyed (Basiuk and Douda, 1999). Although recent meteorite heating experiments indicate that most of the amino acids in micrometeorites are likely destroyed at temperatures >550°C, we found that the sublimation of glycine present in micrometeorite grains may provide a way for this amino acid to survive atmospheric entry heating (Glavin and Bada, 2001).

References

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