EXCHANGE BETWEEN THE ATMOSPHERE AND THE REGOLITH OF MARS: DISCUSSION OF OXYGEN AND SULFUR ISOTOPE EVIDENCE. J. Farquhar ESSIC and Department of Geology, University of Maryland, College Park, Maryland, 20742 (jfarquha@essic.umd.edu).

Introduction: Mass-independent fractionations for oxygen isotopes and sulfur isotopes between secondary phases and primary igneous phases in SNC meteorites have been interpreted to reflect a difference between surface and deep oxygen and sulfur reservoirs on Mars [1-6]. Several hypotheses have been proposed to explain this observation such as fractionation by escape processes (in the case of oxygen), addition of a late veneer of anomalous oxygen and sulfur, and mass-independent atmospheric chemistry [1, 4, 5, 7, 8]. The observation of a variable magnitude mass-independent oxygen isotope signature for carbonate and water among different meteorites, and for carbonate and sulfate from the same meteorite (Nakhla) is most consistent with the latter interpretation.

Narrowing the source of the sulfur isotope data is less straightforward but bears on the question atmosphere-surface oxygen exchange because it may reflect a similar process. The magnitude of the mass-independent fractionations for sulfate sulfur from Nakhla and for isolated grains in ALH84001 [1, 3] are larger than those seen for all analyses of whole rock sulfide and sulfate from other meteorite groups (e.g., [9-11]). This argues against an origin associated with addition of a late veneer of exotic sulfur. Experimental and theoretical evidence allows a gas-phase (atmospheric) origin for these mass-independent sulfur and oxygen isotope signals [12], and the observation of mass-independent sulfur isotope signatures in atmospheric and atmospheric-derived species on Earth [13] provides a consistency argument in favor of similar processes operating on Mars. Mass-independent oxygen and/or sulfur isotope signatures have been observed in terrestrial sulfate aerosols, ice core sulfate from stratosphere-piercing volcanic eruptions, and terrestrial rock samples older than 2.0-2.5 billion years old [3, 12, 14, 15]. For sulfur, these signatures are larger than the largest that have been identified in the meteoritic record and direct transfer of atmospheric sulfur species such as sulfate to the surface has been suggested as the source for the SNC signature. (Minor components of some carbonaceous chondrites have been shown to possess mass-independent signatures up to a few permil.)

The Earth-centered perspective also tells us that the exchange pathways and local reservoir sizes for oxygen and sulfur can play a significant role in the transfer and preservation of these signals in the rock record leading to the interpretation that the sulfur and oxygen isotope signature in sulfate sulfur may reflect direct transfer of the sulfate from the atmosphere to the surface, but that the oxygen isotope signatures for carbonate and water may reflect the transfer of oxygen from another species that itself acquired a mass-independent oxygen isotopic composition from the atmosphere.

Consideration of the amounts of oxygen in the carbonate and water, leads to the suggestion that the isotopic composition of both species was buffered by an oxidized species in the regolith that itself had a mass-independent oxygen isotopic composition. This oxidized species may have been directly deposited to the regolith, or formed by oxidation of another species by reaction with a mass-independent species like ozone. The signature would then be transferred from the water to the carbonate during carbonate formation. In the case of SNC carbonate, this interpretation would imply that the amounts of aqueous phase were limited, or at least comparable to the amounts of the phases in the regolith with which they exchanged oxygen. The significance of this observation for the Martian surface oxygen reservoirs is that suggests the absolute amounts of oxygen stored in liquid phase water may have been small, and that transfer of oxygen between phases in the regolith and the martian atmosphere is a common phenomenon. The observation of this signature in carbonate from ALH84001 suggests that the conditions required for the production and preservation of these signals in the SNC record extend were established early in Mars’s history.