ACCRETION AND PRIMARY DIFFERENTIATION OF MARS. Michael J. Drake, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721, U.S.A.

Introduction: In collecting samples from Mars to address questions such as whether Mars accreted homogeneously or heterogeneously, how Mars segregated into a metallic core and silicate mantle, and whether Mars outgassed catastrophically coincident with accretion or more serenely on a longer timescale, we must be guided by our experience in addressing these questions for the Earth, Moon, and igneous meteorite parent bodies.

Accretion and Core Formation: A key measurement to be made on **any** sample returned from Mars is its oxygen isotopic composition. A single measurement will suffice to bind the SNC meteorites to Mars or demonstrate that they cannot be samples of that planet. A positive identification of Mars as the SNC parent planet will permit all that has been learned from the SNC meteorites to be applied to Mars with confidence. A negative result will perhaps be more exciting in forcing us to look for another object that has been geologically active in the recent past. If the oxygen isotopic composition of Earth and Mars are established to be distinct, accretion theory must provide for different compositions for two planets now separated by only 0.5 AU [1].

Tracing core formation and the homogeneous or heterogeneous nature of accretion can best be accomplished using siderophile and chalcophile elements. Siderophile elements which are compatible in silicate solids in the absence of metal are retained in mantle samples during magma genesis. Only on Earth have samples of known mantle origin been analyzed and interpreted in terms of core formation and accretion processes (e.g., [2, 3]). Interestingly, noble siderophile element abundances in these mantle samples are significantly higher than would be expected to be in equilibrium with a metallic core, based on known metal/silicate partition coefficients. This observation is open to various interpretations (e.g., heterogeneous accretion of the Earth and inefficient core formation - [4, 5]). Such samples would be of utmost importance to collect if they could be identified.

However, it is problematical that mantle samples can be identified and collected using a remote sensing roving vehicle on Mars. More probably, we will successfully collect basaltic materials. Siderophile elements which are incompatible in silicate solids in the absence of metal are concen- trated in basalts during melting of planetary mantles. The correlation of the abundances of moder- ately siderophile elements such as W, P, and Mo with a lithophile incompatible element of equiv- alent incompatibility has been used in concert with experimental measurements of metal/silicate partition coefficients to successfully recover details of core formation processes in the Earth, Moon, Eucrite Parent Body, and SNC Parent Planet (e.g., [6-13]). Figure 1 illustrates the principle of this method. One possible interpretation of these studies is that the Earth accreted heterogeneously [5] while the SNC Parent Planet accreted homogeneously [12, 13]. If the SNC meteorites are confirmed to be from Mars as a result of a Mars sample return mission, this interpretation raises the question of why two planets so closely associated in space should have accreted differently.

Atmospheric Outgassing: Allegre *et al.* [14] have argued plausibly that the isotopic composition of xenon in various Earth reservoirs is best interpreted in terms of early catastrophic outgassing of at least part of the atmosphere. Briefly, mid-ocean ridge basalts (MORB) have excess ^{129}Xe relative to the atmosphere and to ocean island basalts (OIB). MORB is thought to sample the upper mantle of the Earth, while OIB may sample a deeper reservoir. The excess ^{129}Xe is interpreted as the decay product of ^{129}I. The upper mantle is interpreted to have been efficiently outgassed while ^{129}I was still alive (halflife = 17 x 10^6 years), allowing more ^{129}Xe to be produced in a Xe deficient upper mantle. If similar events occurred on Mars, a sample of the atmosphere and of representative mantle reservoirs might also reveal the signature of early catastrophic outgassing. Whether such outgassing occurred on Mars is problematical, but one way to reconcile the possibility of a heterogeneously accreted Earth with a homogeneously accreted Mars as discussed above would be for Mars to accrete heterogeneously while simultaneously being very effectively homogenized. Such a postulated homogenization process would likely involve very energetic processes which might lead to efficient outgassing. Thus, probing the timing of outgassing might also provide evidence concerning the accretional and primary differentiation processes occurring on Mars.

Sampling Recommendations:

1. To confirm or disprove the link between the SNC meteorites and Mars, any sample with sufficient oxygen to permit precise measurement of ^{16}O, ^{17}O, and ^{18}O and which is substantially uncontaminated with exogenous material will suffice.
2. To address the major questions posed concerning the nature of accretion and the processes of core formation, the samples most likely to be accessible and collectible are fresh basalts. It will be necessary to collect various types in order to populate Figure 1.
3. To address the question of the abundances of compatible siderophile and chalcophile elements in Mars, with implications for accretion and core formation, a major target of opportunity would be the identification and collection of a mantle nodule or of exposed ultramafic terrain.
4. To address the question of the timing and nature of atmospheric outgassing, a sample of the atmosphere of sufficient mass to permit the determination of the abundances and isotopic composition of at least C, N, O, and the noble gases must be collected.
5. The most promising locations to collect samples to address these questions are in the northern plains, which contain the youngest volcanic units.
6. The masses of samples to be returned depends on grain size (excepting the atmosphere, of course) and probably exceeds 1g per sample.

References:

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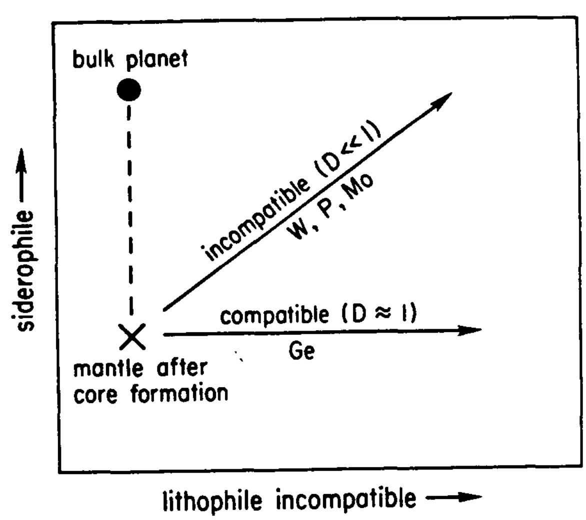

Figure Caption. Schematic diagram illustrating the evolution of elemental abundances of siderophile elements from bulk planet through core formation and subsequent igneous differentiation events over the planet's history. D is the mean mantle/magma partition coefficient of an element.