WHO NEEDS A FEW MORE MARS SAMPLES WHEN WE ALREADY HAVE THE SNCs?

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A spacecraft mission to return samples from Mars has been a long-standing goal of planetary exploration. Recently, the need for sample return has been questioned because some meteorites, the SNCs, are almost certainly from Mars. However, many important uncertainties about Mars require detailed analysis of documented samples, and cannot be resolved by continued investigation of the SNCs and/or robotic spacecraft missions. These uncertainties include: whether the SNC meteorites really are from Mars (requiring trace element and oxygen isotope analyses); absolute age calibration of the martian crater chronology (requiring isotopic analyses of rocks from known locations); and the composition and origin of the highlands and other unsampled units (requiring trace element analyses).

INTRODUCTION Engineers and scientists at the Johnson Space Center are currently studying a relatively simple and inexpensive Mars sample return mission known as MISR (1). The concept includes a lander supporting one or two small rovers (Fig. 1). Rock, soil, and atmosphere samples of ~2.5 kg total mass would be collected from the vicinity of the lander. Sample selection would be controlled from Earth, with a major goal of collecting igneous rocks with unweathered interiors. The samples would be documented, stored separately, preserved at or below Mars ambient temperature, and shielded from ionizing radiation. The samples would be returned to Earth for analysis.

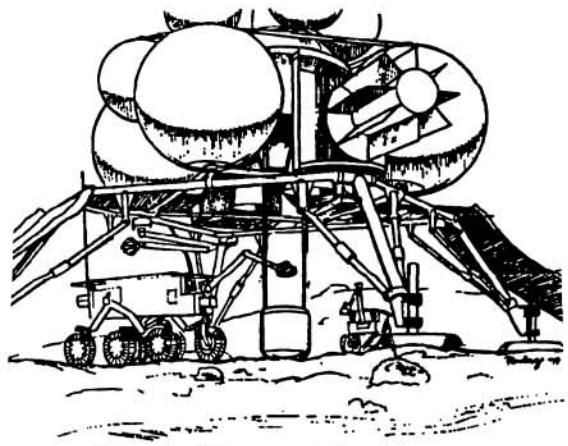

Fig.1 MISR sample loading concept

How can a Mars sample return mission be justified, since we already have ten supposed martian rocks (the SNC meteorites) to analyze? What is the 'value added' from bringing back a few more samples from a single location on Mars? These are legitimate questions for debate, both in scientific and public forums. We feel that sample return is among the most productive approaches to Mars science; it permits a synergism between the wealth of photogeologic and remote-sensing data on Mars and the extensive analytical capabilities available in laboratories on Earth. We feel that documented samples from a single site, complemented by continued study of the SNC meteorites, can provide solutions to some of the fundamental problems in Mars science, including: proof or disproof that the SNC meteorites are from Mars; the absolute (not relative) ages of surfaces on Mars; and the natures and origins of the martian highlands and other poorly-understood geologic provinces.

SNC METEORITES FROM MARS? Much of the current understanding of martian geology, geophysics, and evolution is based on the SNC meteorites. As compiled by McSween (2) the SNCs have been used to constrain: planetary differentiation; outgassing and water abundance; isotopic composition of the mantle; hydrosphere-lithosphere interactions; core composition and possible early dynamo; atmospheric loss processes; composition and mineralogy of surface units; weathering and alteration; magma rheology; and impact physics.

The connection between Mars and the SNC meteorites could be 'proved' or disproved by the return of documented samples. All of the SNCs share oxygen isotope abundances which define a fractionation trend unique from the Earth-Moon or asteroid trends. The SNCs also possess distinctive ratios of those major, minor, and trace elements which do not undergo fractionation. These isotopic and elemental systematics are thought to be unique to the planet of origin. If the SNCs are from Mars, any pristine igneous sample from Mars should exhibit these same geochemical characteristics. If the isotope and element ratios do not match, much of what we 'know' about Mars, the SNCs, and planetary geochemistry in general will require serious reevaluation.

MARS SAMPLES AND SNCs: Allen C.C. and Treiman A.H.

HOW OLD ARE MARTIAN SURFACES? The ages of surfaces on Mars are poorly known; relative dating by crater count statistics is quite accurate, but absolute age calibration relies on uncertain extrapolations from the sample-calibrated lunar crater counts. The leading models for Mars (3,4) differ dramatically in their recommended ages for many surfaces. For instance, the central shield of Arsia Mons could be as old as 3.4 Ga or as young as 0.6 Ga. Nor do we know when the highlands formed, though the model ages are in closer agreement (3.5 - 4.5 Ga). This age uncertainty translates into uncertainty in almost every quantitative aspect of martian evolution: heat flow; mantle convection; duration of volcanism; sources, sinks, and abundances of volatiles; volatile loss mechanisms; and the persistence of environments suitable for life.

The SNC meteorites are not helpful here. Although their crystallization ages are known (1.3 Ga for the nakhlites and Chassigny, 180 ma for the shergottites), their site(s) of origin on Mars are still uncertain (5,6). To calibrate martian crater count chronologies, to put absolute ages on martian surfaces, samples must be returned from surfaces for which statistically meaningful crater counts have been derived. Unweathered igneous rocks will provide the most reliable dates, and the samples must be unambiguously tied to the geologic unit to be dated. These criteria argue for selection of a simple landing site characterized by a small number of rock types. Middle- to early-Amazonian surfaces provide the highest degree of differentiation between the two leading models. If the sampling site is to be optimized for dating, a large Amazonian lava plain would be recommended.

THE REST OF MARS? The ten SNC meteorites are all basaltic igneous rocks, either eruptive or intrusive. Given the geological complexity of Mars, this is a distinctly incomplete subset of surface materials. The highlands, Mars' major physiographic province, are either totally unknown or only represented by the orthopyroxenite ALH84001 (7). In effect, we have no clue as to the composition of 2/3 of the planet's surface. Knowledge of the highlands composition is critical to any understanding of martian geologic evolution. One derives entirely different histories for Mars if the highlands are anorthosite, gabbro, or granite.

The SNC collection contains no sedimentary rocks or evaporites, despite evidence for widespread fluvial activity in the past. If life ever existed on Mars, fossils in such rocks may provide our only evidence. The compositions of dune sands and the polar deposits are totally unknown. We have no samples of the duricrust discovered at both Viking landing sites. Finally, the ubiquitous soil and dust which dominated the Viking geochemical analyses remain poorly understood due to lack of samples.

SAMPLE RETURN MISSION A sample return mission will address some, and perhaps many, of these unknowns. Landing at a geologically simple site, perhaps optimized for chronology, will yield samples of the local bedrock, plus soil, windblown dust, and probably duricrust. A single such mission could characterize and date a major geologic province as well as elucidate the planet-wide weathering and alteration environment.

An alternate strategy, adopted by the Pathfinder mission, is to target a complex site, namely the mouth of a large channel system. This site allows analysis of a wide variety of rock types from locations upstream. A sampling mission to a carefully chosen channel could return representatives of many of the planet's major rock units. Diversity would be maximized at the expense of confidence in bedrock location and rock unit ages. The MISR mission is being designed with sufficient flexibility and discrimination to deal with either a simple or a complex site.

REFERENCES (1) Kaplan, 1995, *LPS XXVI* (this volume) (2) McSween, 1994, *Meteoritics, 29*, 757 (3) Neukum and Hiller, 1981, *JGR, 86*, 3097 (4) Tanaka et al., 1991, in *Mars*, 345 (5) Mouginis-Mark et al., 1992, *JGR, 97*, 10,213 (6) Treiman, 1995, *JGR* in press (7) Treiman, 1995, submitted to *Meteoritics*