N89-18328

SOME LESSONS FROM APOLLO FOR A SAMPLING STRATEGY ON MARS FOR UNDERSTANDING THE ORIGIN OF THE ANCIENT IGNEOUS CRUST AND THE COMPOSITION OF THE MANTLE.

Randy L. Korotev and Larry A. Haskin, Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130.

Proper site selection for sample collection is crucial to determining the nature and time scales of major events on Mars. From a comparative planetological standpoint, an important consideration in sampling Mars is to obtain samples of igneous rock from which, through the analysis of lithophile elements and their radiogenic isotopes, we can infer the compositional nature of the Martian crust, the processes that led to its formation, and the timing of its major evolutionary events. Analysis and interpretation of lunar samples acquired by the Apollo lunar missions provides valuable experience on the effects of site selection for this purpose. Lunar samples are our main source of information on the nature and history of formation of the Moon's crust.

"Typical" material. Igneous evolution of Mars produced three general types of crustal terrain: the ancient, cratered southern hemisphere, the younger northern hemisphere, and the still younger major plateaus with their stratovolcanoes. We need samples of igneous rock unambiguously characteristic of all three terrains. A serious problem in the interpretation of data for lunar samples is that only a small fraction of the samples come from prevalent types of lunar crust, as inferred from the results of various remote sensing techniques. Apollos 11 and 12 landed in mare basins at sites selected (sensibly) for reasons of safety, but selected without benefit of prior spectral mapping to determine representativity. Of the nine Apollo plus Luna sampling missions, seven were to maria or to mare-highlands interfaces; none was to a "typical" highlands site. Mare materials are important as indicators of time scale and as probes of mantle composition. In order to characterize the early lunar crust satisfactorily, we need samples from at least a few broadly typical regions of the highlands. The Fra Mauro highlands region (Apollo 14) was chosen as an interesting highlands area, but turned out to be geochemically very atypical. The Apollo 14 samples are very important, but it is still not clear how they relate to other parts of the lunar highlands. Data from the Mars Observer will help us discover prior to sampling whether a site is geochemically "typical" or not. Apollos 15 and 17 landed at interfaces between maria and the highlands and probably provided samples typical of neither. Many of the rocks and all of the soils from these two sites are mixtures of mare and nonmare material, which complicates our attempts to characterize the highland components [1,2]. Only Apollo 16 landed in a region remote from mare basins. Even samples collected there turned out not to be geochemically "typical;" Apollo 16 soils have concentrations of incompatible trace elements 2-3 times higher than the mean values for the highlands surface. The lunar meteorites discovered in Antarctica and the soil from Luna 20 more closely resemble the mean surface crust in composition than do any of the Apollo soils [3,4,5].

The temptation is great to sample areas expected to provide a diversity of sample types or that are regionally "interesting" based on photogeologic data. Nevertheless, it is imperative to our understanding of major evolutionary features of a planet that we obtain samples that unambiguously represent areas that, even if mundane, are typical. Sampling only at sites with interfaces between types of major terrain may not accomplish this.

Large vs. small samples. Primarily as a result of our experience with lunar samples, we can extract much information from small samples. In fact, with most types of sophisticated instrumentation for chemical and isotopic analysis of geologic materials, samples exceeding 0.1–1.0 g in mass cannot be analyzed directly but must be subsampled. This is so even for terrestrial samples, where the supply is often limitless. A 100 mg sample can easily be analyzed for concentrations of 30–40 chemical elements [e.g., 5]. Of course, 100 mg is too little to represent a hand specimen or an outcrop. For terrestrial rocks, kilogram-size hand samples are pulverized to assure that a subsample represents the hand sample, at least.

Although 49% of the mass of lunar material collected on the last three Apollo missions was rocks exceeding 1 kg in mass, none of these rocks has been (or should be) pulverized in its entirety to produce a representative subsample. Instead, several small chips are analyzed, providing information of the extent of heterogeneity as well as yielding an average that is more nearly representative than analysis of a single chip of equivalent mass. There is no compelling advantage to petrology, geochemistry, and geochronology in acquiring samples many times (e.g., 100+) larger than the largest subsample that can be analyzed in a single determination. A thousand 1 g pebbles can provide far more information than a single 1 kg rock because the former provide information on diversity totally lacking in the latter. A single 1 g pebble may not be representative of an important rock type; however, a single 1 kg rock may not either. Most of the problem of representativeness of small samples can be offset by collecting a large number of such samples. Thus, we suggest that for the types of studies discussed here, most samples need not exceed a few grams in mass.

Cores. At the expense of much time and effort, the Apollo astronauts collected 21 cores in 52 sections totalling about 15 meters in length, containing about 20 kg of regolith, and constituting about 5% of the mass of returned samples. The Apollo cores have been interesting; perhaps their most useful information relates to depth of gardening and how the lunar surface has interacted with the space environment, e.g., the effects of solar wind irradiation. However, the cores have not provided the kind of stratigraphic information that we might desire. In part, this problem is characteristic of the Moon and the chaotic process of lunar regolith formation. However, in large part the problem is characteristic of the coring process itself - only a small amount of useful stratigraphic information can be obtained from a single one-dimensional sample.

It is important to obtain samples from beneath the immediate surface of a planet, but coring is not necessarily the most efficient way to obtain them. Trenching, sampling of crater ejecta, or even blasting some holes can provide deep samples more easily. An effective coring device and the problem of transport and storage of cores complicate a sample acquisition mission. Thus, a coring device should not be used for collecting routine samples. Cores preserve stratigraphy; they should be obtained only when a sample containing an intact profile is specifically required to answer some scientific question. Even then, a core does not guarantee a useful sample if it is too short to include all of the feature of interest.

REFERENCES. [1] Korotev R.L., Haskin L.A., and Lindstrom M.M. [1980] *Proc. Lunar Planet. Sci. Conf. 11th,* 395–429. [2] Korotev R.L. [1987] *Proc. Lunar Planet. Sci. Conf. 17th,* in *J. Geophys. Res.* 92, E411–E431. [3] Korotev R.L., Lindstrom M.M., Lindstrom D.J., and Haskin L.A. [1983] *Geophys. Res. Lett.* **10,** 829–832. [4] Lindstrom M.M., Lindstrom D.J., Korotev R.L., and Haskin L.A. [1986] *Proc. 10th Symp. on Antarctic Meteorites 1985,* in *Mem. Nat. Inst. Polar Res., Spec. Iss.* 41 (Tokyo), 58–75. [5] Palme H., Spettel B., Weckwerth G., and Wänke H. (1983) *Geophys. Res. Lett.* **10,** 817–820.