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THE RECORD OF MARTIAN CLIMATIC HISTORY IN CORES AND ITS PRESERVATION

Zent, A. P., Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hi. 96822

Among the questions to be addressed by a Mars Sample Return Mission are the history of the martian climate and the mechanisms that control the volatile cycles. Unfortunately, the evidence that bears most strongly on those issues lies in the volatile distribution in, and physical configuration of, a very delicate and volatile system: the uppermost martian regolith. This study identifies some useful measurements to be made on returned samples of the regolith, and a few of the many critical considerations in ensuring the usefulness of returned samples.

Among the most difficult properties of the regolith to examine via returned sample are: the vertical distribution of ground ice, the vertical distribution of adsorbed H_2O, and the amount of adsorbed CO_2.

The ability of the martian regolith to transport H_2O is very limited; only ~ 1 - 10 g H_2O cm^{-2} can exchange with the regolith per obliquity cycle. Therefore the abundance and distribution of H_2O through the uppermost regolith is the product of an extensive history of H_2O migration. testing for the presence or absence of ground ice in the shallow, high-latitude regolith would provide a measure of our fundamental understanding of the martian H_2O cycle. If present, it would confirm our model of the high-latitude regolith as a sink for H_2O. The depth at which ground ice is found could be related to the thermal properties of the regolith, which control propagation of heat to the ice, and to the long-term average atmospheric partial pressure of H_2O. If absent, it would cause a re-examination of our models, and could lead to constraints on the erosion/deposition rates of the regolith.

Whether there is ground ice present or not, there is certain to be a finite amount of adsorbed H_2O. Diurnal, seasonal and long-term cycles of temperature and P_{H_2O} act to modify the abundance and distribution of the adsorbate. Because the depth to which each cycle acts is proportional to the square root of the cycle's period, the depth profile of H_2O adsorbate may be invertible to yield information on the history of the H_2O cycle. Further laboratory and numerical work is necessary to develop the possibility.

The largest portion of exchangeable CO_2 in the martian environment is physically adsorbed onto the regolith. Models suggest that at high obliquity, the regolith desorbs enough CO_2 to raise the atmospheric pressure by several millibars. We would like to measure the amount of CO_2 available for exchange with the atmosphere. One concern is the competition for adsorption sites by H_2O vapor. Another is the degree to which CO_2 is chemisorbed onto the particulate material, and how that might alter the soil's surface functional groups. For example, the difference between chemisorption onto inorganic hydroxyl groups and simple outer-sphere complexation on siloxane ditrigonal cavities would be substantial in terms of adsorptive exchange.

The interaction of the regolith and atmosphere is also controlled by the small-scale structure of the regolith. For example, the thermal conductivity of the regolith can depend upon the geometry of packing, the nature of grain boundaries, and the presence of intragrain bonding, which might allow conduction between grains to compete with gaseous conductivity. The pore size, in relation to the mean free path of a gas molecule determines the gas-phase conductivity, especially important in loose, unbonded material.

The pore size distribution determines the efficacy of volatile transport through the regolith, and the capacity of the regolith to buffer climate changes. If possible, we would like to measure the pore size distribution in a number of relatively undisturbed samples.

We conclude that there is a great deal to be learned from examination of the uppermost martian regolith if the chemical state and structure could be preserved.

Cores are the optimal method for retrieving and examining the material in the shallow martian regolith. A great deal of work has been done on core acquisition, although several aspects bear additional emphasis. One of the first is the extreme importance of using a minimum penetration rate, which is proportional to the temperature of the core at the bit during drilling. Because of the extreme volatility of physically adsorbed CO_2, the core must be kept at the minimum ambient temperature. The drill stem should be constructed of low thermal conductivity material to avoid transporting heat along the stem during drilling operations.

Preservation of the cores after drilling is must also be addressed. There should be rapid transfer from the drill stem to the storage container. The seasonal thermal profile is such that the temperature at the surface is different from the temperature at depth. Since the cores are to be no more than 1 - 2 cm in diameter, they will approach the surface temperature, which may differ from their original temperature by > 40 K, in a matter of minutes. There is the possibility of escape of gas at the margins of the core, and for migration of gas in response to the changing temperature profile. If possible, the transfer from core stem to storage should take place at night, although this will place constraints on our ability to inspect the core and to make go-nogo decisions on storage. In any event, the leisurely examination of the core in the full sunlight will cause an unacceptable loss of information, and should be absolutely disallowed.

The typical lifetime of the cores after extraction, and before examination, will be several hundred days, during which time significant alteration is possible. The optimal solution to this problem is to return subsamples of taken at pre-determined intervals along core. The subsamples should be stored and transported separately. In addition to preserving the gradients, albeit at degraded resolution, the subsampling technique would allow more sample to be returned, since returning the entire core is probably wasteful of mass. Our calculations suggest that the uncertainty in average P_{H_2O} associated with a 5 cm uncertainty in the position of the interface is only ~10%. A third reason for the return of small subsamples of the cores is the importance of preserving the pore size distribution of the regolith. Smaller samples place less load on contact points during acceleration, and are less likely to result in result in compaction.

If it proves prohibitively expensive or complex to implement adequate techniques for the acquisition and subsectioning of contiguous cores, then thought should be given to abandoning the coring tool altogether, and simply returning samples dredged from a variety of depths in adjacent excavations. In the absence of local variations in surface units, the volatile distribution in the subsurface should be sufficiently homogeneous to make all locations equally representative.

The samples should be continuously monitored after excavation, and provision should be made for cooling of the sample container should the temperature rise substantially above the temperature at the time of collection.

Finally, there should be no sterilization whatsoever on the core samples to be analyzed for the state and distribution of major volatiles. Even heating samples to room temperature is likely to result in wholesale chemical and physical redistribution of volatile species.

Cores should be collected from two well separated latitudes on the surface of the planet. The goal in so doing would be to establish a the latitudinal distribution in the volatile abundances of the regolith, both as an historical indicator of the past climate, and as an aid in understanding how the martian climate will respond to future insolation variations. The cores should be at least 1 m in depth, in order to sample volatile distributions that are indicative of both annual and longer term averages. Since only subsamples of the cores are logical for return, the option of drilling to 2 m might be explored, depending on the latitude at which drilling is to take place. One core should be from latitudes poleward of 40°, in order to sample the hard-frozen permafrost. A second lander/rover should be included in the mission for redundancy and targeted for the low-latitude regolith.

With these criteria and others, we have selected two options for landing sites for a lander-rover tandem. The additional criteria we have considered are as follows: Both landing sites should be in geologically complex areas, with the opportunity to visit a maximum number of terrains with total traverses of no more than 100 km; at least one of the rovers should be able to sample volcanic terrains. Our high-latitude site is at 316°W - 50°30' N. It is very near the boundary of the northern plains and cratered highlands. The rover should be able to example the stratigraphy of the boundary. The second site is at 61°30'N - 0°30'N. This site is in the ridged plains material, and very near the channel system that runs north from Juventae Chasma. The channel system forms a geologic boundary between the volcanic terrains on the west, and the heavily cratered terrain on the east.