MARS SAMPLE RETURN: 20+ YEARS AFTER THE FIRST MARS SAMPLE RETURN WORKSHOP

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Introduction: In the fall of 1987, a Mars sample return workshop was held in Houston, TX. It is fitting, therefore, to compare and contrast one's thinking after such a span of time. Either remarkably or infuriatingly, my own ideas on the subject have changed little, if at all, in those twenty years. Below, I will revisit a 1987 model in light of twenty years of progress in martian investigation.

A Retrospective: Because a keynote speaker had a medical emergency in his family, I was asked to replace him on short notice. My theme then was that we should land on a datable basaltic terrain and return a sample of that terrain, as well as samples of the atmosphere and windblown dust. This scheme had the advantage of simplicity; and simplicity should, in turn, translate into lower cost. Roving and *in situ* analytical capabilities were to be kept to a bare minimum. And the choice of these three sample sets would almost guarantee that good science could be accomplished upon their return to Earth.

My recollection is that other sampling schemes were more ambitious, one of which involved returning km-long drill cores under cryogenic conditions.

Basalt Revisited: The advantage of a moderately fresh basaltic rock over other types of rock or soil is that it's age can be determined fairly straightforwardly. With sedimentary and metamorphic rocks, this need not be true. The main scientific goal should have a high probability of being accomplished successfully. It ought to not be difficult to find a sample to return, either. Go to a basaltic terrain and grab almost anything that's lying around. The analytical instrumentation necessary to accomplish this might be as simple as a camera.

What do you get as scientific return from such a sample? If the terrain is chosen carefully, not only will you get the age of the returned basalt, but also the age of the terrain. A terrain that is large enough to have a well-defined crater count will then allow the calibration of the martian cratering record. Very old and very young terrains should be avoided. It is important to get a sample from a middle-aged terrain where the uncertainties in absolute ages are greatest. If successful, the returned sample will not only date its native terrain, but many other martian terrains as well.

In addition, it would be useful to land in an area that we have not visited before. This will add one more data point to our global martian experience.

What are the drawbacks of this plan? How can the mission fail? The simplest way for the mission to fail is if the basalts at this landing site are undatable. The MER experience has shown that many of the rocks that Spirit has encountered have been altered and/or weathered. To the extent that such alteration is pervasive, dating a basaltic crystallization age may not be possible. It is even possible that such alteration is the reason that there are so few old martian meteorites in our collections. One simple means of evaluating the pristinity of a basalt would be to have a RATing tool. If it RATs easily, it's altered.

Therefore, landing sites should be evaluated not only for age and landing safety; they should also be evaluated for the prisinity of their basalts. The presence of dust may make this difficult. Remember that Olympus Mons, the solar system's largest volcano, is invisible to the TESS and THEMIS instruments for just this reason.

To summarize, returning a basaltic sample from a basaltic terrain maximizes simplicity and, therefore, minimizes scientific risk. The successful dating of a rock from a particular terrain has immediate implications for the rest of the planet. Minimizing analytical and roving capabilities minimizes cost.

Windblown Dust Revisited: Based on two data points from Viking, in 1987 I surmised that windblown dust was nearly ubiquitous on Mars. With a few more data points 20 years later, this assumption seems to still be valid. On Earth, layers of dusty material (loess) have been used to estimate the chemical composition of the upper continental crust. In other words, a local sample may have global implications. This may also be true for Mars — perhaps even more so. The chemical compositions of dust or dusty soils at the Viking, Pathfinder, and MER sites were rather similar. It is possible that a returned sample of windblown dust would give a reasonable estimate of the composition of the martian crust.

How can this part of the mission fail? The easiest way would be for a local soil product to be confused with a global average. Morphological evidence should be able to sort these two out. Does it look like a drift? Then it probably is. Nevertheless, it is likely that any sample of windblown dust will have a local component.

To summarize, a windblown sample may well give a global average of the upper crust, and it may well be enriched in alteration/weathering products (e.g., sulfates). It should be easy to find at any landing site; we are five for five, so far. Much roving should not be necessary; and the necessary analytical instrumentation may consist of just a camera.

Atmosphere Revisited: Since the first workshop, two notable developments have occurred in refining the composition of the martian atmosphere and martian volatile reservoirs.

(i) It is now recognized that Chassigny contains noble gases that most likely reflect the signature of the martian mantle. For example, the Xe isotopic composition of Chassigny is not significantly different from solar. And, consequently, it is probable that the carbon and hydrogen isotopic compositions of Chassigny also reflect those of the martian mantle.

(ii) Bogard and coworkers have used analyses of martian meteorites to redefine both the $^{40}Ar/^{36}Ar$ and the $^{38}Ar/^{36}Ar$ ratios of the martian atmosphere. The $^{40}Ar/^{36}Ar$ ratio of ~1800 is significantly different than the Viking measurement of ~3000; and the $^{38}Ar/^{36}Ar$ ratio is fractionated from that of planetary Ar.

Another improvement in our knowledge of martian atmospheric composition will come from the analyses of the SAM instrument on the Mars Science Laboratory. We should be able to measure the isotopic composition of Ar *in situ*, as well as the oxygen and carbon isotopic composition of CO_2. We will not be able to measure ^{20}Ne.

It is difficult to envision that a remote analysis of the martain atmosphere will be as accurate or precise as a measurement in a terrestrial lab. Therefore, it seems prudent to return an atmospheric sample as a part of the sample return mission.

Impact of this Mission Design on Astrobiology: The search for martian life is an exciting aspect of the exploration of Mars; and the sample return mission described above seems to ignore that facet of martain research. However, that is not necessarily true. It is not much of an exaggeration to say that, prior to the MER missions, almost everything we knew about the atmosphere, hydrosphere, and biosphere of Mars came from the study of basaltic martian meteorites — the analysis of martian air by Viking being an obvious exception. Therefore, it is not out of the question that new biological insights will be gained from the return of a basaltic sample.

It may also be true that, if fossilized bacteria exist on Mars, examining windblown dust may be the easiest means of finding them. They are small enough to become windborne and the sampling, as argued above, is global. It is highly probable that the UV radiation environment would destroy any organics in the windblown dust, but that should not affect fossilized materials.

Admittedly, this mission design is not focused on Astrobiology. However, I believe that this is the best strategy. Even if Mars were teeming with life, it is not clear that we would find it on any given sample return mission. Therefore, a mission that focuses on Astrobiology has a diminished chance of scientific success. And as we have seen from the MER Spirit site (i.e., the "basaltic prison"), even a mission that focuses on Astrobiological environments can be risky.

A Recapitulation: Any martian sample return mission will be expensive and risky. A mission that returns a datable basalt, a sample of windblown dust, and a sample of the atmosphere minimizes risk, minimizes cost, and maximizes the scientific return.

We as a scientific community tend to be greedy. We want to return the perfect sample. And to accomplish that, we want to perform a lot of remote analyses and rove 10's of kilometers in search of that perfect sample. Sadly, the first returned sample will not be perfect. Therefore, we should accept that and simplify the first Mars Sample Return Mission in every way possible.