A STRATEGY FOR *IN SITU* ANALYSIS OF THE MARTIAN SURFACE;

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It is proposed that for future exploration of the martian surface with roving vehicles, surface-analytical (as opposed to meteorological or seismological) instruments on-board should aim, whenever possible, for a dual capability for both cursory and intense interrogation of sample materials. At the very least, the explorational platform itself should embody this capability within the suite of on-board instruments. The development of analytical instrumentation for planetary exploration commonly does not follow this philosophy. In essence, a roving vehicle's scientific payload should act as a surrogate geologist who has the capacity for site reconnaissance, but who also has a well-equipped backpack for conducting *in situ* analyses as desired. We are developing a field-deployable x-ray diffraction-fluorescence instrument that can perform the dual role required of the surrogate geologist.

The need for a hierarchical explorational capability can be illustrated by the example of the geologist in the field. Before taking hammer to rock, the geologist visually surveys the landscape and decides which outcrop should be examined first. In this preliminary survey, the geologist has scanned perhaps several hundred million tons of rock that will not be examined. This defines a first step: practising the art of rejection -- virtually all that is observed will neither be examined, nor collected. Having selected an area for more intense study, the geologist may use a hand lens and geological hammer as a means of deciphering the nature of the outcrop. This defines a second step, site inspection. Identification of samples that warrant further analysis back at the laboratory defines a third step, sample selection/collection.

Successful rover operations on a planetary surface will require some approximation to this "rejection-inspection-selection" scenario. How would a rover achieve this operational capability? Ideally, it would be equipped with telescopic vision (as opposed to just cameras for guidance), and telescopically-ranging spectroscopic instruments (e.g., IR spectrometers) that can identify broad areas of interest at the hillside, cliff-face, lake bed, or lava flow scale of landscape. This satisfies the need to "reject" many sites, and leads to the choice of a particular terrain for more intense study. When a particular site is chosen for inspection, other on-board instruments are then applied to site interrogation. What type of instruments are needed, and what should be their interrogation strategy? The answer to the first part of this question depends on the scientific quest at hand, but in general, the instrument should have the ability to conduct meaningful cursory or reconnaissance analyses that are economical in terms of time or resource utilization, and it should be able to conduct multiple analyses. This satisfies the mission's "inspection" step and defines the first level of an instrument's dual analytical capability.

Why is this cursory or "quick-look" mode needed for an instrument? The answer is that we know virtually nothing about the detailed geochemistry or mineralogy of Mars. Viking Landers have provided very detailed descriptions of a couple of samples of windblown dust, and with the exception of some remote spectroscopic speculation and geochemical inferences from orbitally-imaged geomorphic features, we have little else to go on. We should not conduct a rover mission that provides very intense study of a very limited number of samples. Although in some sense, we could never analyze a statistically meaningful number of samples on Mars, there should at least be the attempt to acquire a broad picture that places samples in context.

This brings us to the type of scientific questions that should be posed for the martian surface and an appropriate explorational strategy. Because we know so little about Mars, as a first step in the interrogation of a particular site, it seems inappropriate to try and determine, for example, if a particular sample has 5% illite in it, or 10% illite, and if it is "this type" or "that type" of illite. This level of analytical precision would be an unwise use of resources unless the proportions of the mineral were known for the adjacent sample one meter away, or for the proximal sample ten meters away, or if indeed they contained the same mineral at all. Without this calibration, it is difficult to attach significance to the percentages. As a first step, it seems more appropriate to be able to say, for example, simply that a sample contains clay (for Mars, an important statement), and that it is roughly similar to other soil samples in the region, but that it is totally different from the material at 50 cm depth and again totally different from the rocks

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embedded in the soil. Thus we derive an explorational strategy: determine sub-regional homogeneity-heterogeneity of materials, i.e., rough estimates of similarities and differences between samples of any one type of material (e.g. soil), comparison of rock composition versus soil composition, and both spatial and vertical comparisons of materials.

When a rover arrives on the surface of Mars, it needs to ask "top level" questions first, such as "Is this a lake bed or a lava bed?" -- rather than the type of question posed above concerning the illite. If the rover has the capability of determining that the samples are predominantly silicate minerals (without necessarily determining precise mineral species or their relative proportions in a sample), but it is searching for ancient evaporites, then it can quickly move on to another area to continue its search. If it finds a lake bed by cursory recognition of non-silicate minerals, several samples should be analyzed to get a rough feel for the extent and heterogeneity of the sample field. After this, more intense analyses can be conducted. And this brings us to the second part of the instrument's dual analytical capability. Very thorough, exhaustive, and if necessary, time-consuming analyses are now needed for a few select samples. The data so obtained have already been calibrated and placed in context by the precursory and exploratory analyses that led to the sample find.

If the instrument had only the capability for this second (intense) level of analysis, the sample might never have been discovered in the first place. Thus, it is important to consider the way in which the sample and the instrument are brought together. The recognition that a laboratory instrument has the capability for conducting certain types of analyses appropriate to the science at hand does not necessarily mean that a flight version of this instrument should be made without further consideration. The problem with this direct science-to-instrument philosophy is that it assumes that only detailed science questions need answering; "top-level" analytical perspectives are demoted in such a scheme. Implicitly, it omits the scientific step that made it a useful laboratory instrument to begin with -- the step of screening the samples in the field -- the selection process conducted by the geologist. And of course, the technological derivative of this might be the development of an instrument that has a non-versatile, single-level analytical capability.

Not all instruments can accommodate a dual functional role; their data must be at an already high level of resolution to be discernable at all. If such instruments are to be deployed on a rover, they should be coupled with other "quick-look" instruments that can provide the precursor site "inspection" role defined above. This second instrument would provide rough evaluations of sample type without the need for acquisition and on-board processing of the sample; complex and power-consuming operations such as rock chipping, crushing, sieving, etc. should be reserved for when the detailed analyses are to be conducted.

A description can be found in this volume of an x-ray diffractometer-spectrometer that we are currently developing with a dual analytical capacity which is achieved by combining variable-speed operating mechanisms (trading resolution for rapidity) with special analytical techniques that recognize environmentally diagnostic diffractometric-spectroscopic signatures or rock "fingerprints". The device has an x-ray geometry that permits it to identify specific minerals and specific elements by simply contacting a sample surface -- no sample acquisition or preparation are required. Diffraction data have already been acquired with the device deployed on the end of the Marsokhod rover manipulator arm during field trials at NASA Ames Research Center.

Even though an XRD-XRF instrument can function in a quick-look mode, it can also be operated in the XRF mode only, in order to provide first-order geochemical fingerprinting as a pre-diffraction screening procedure. An XRD-XRF could also be profitably coupled with NIR or TIR techniques for the provision of quick-look sample screening and general site inspection. It almost goes without saying that any suite of instruments should include a miniature camera with close-up color-imaging capability that is equivalent to the geologist's hand lens. This provides important information about surface texture, sample porosity, grain size, and other properties not discernable with most rock analysis techniques.