CRYSTAL PROPERTIES AS BIO-MARKERS: A POTENTIAL MRSR EXPERIMENT

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Mineral crystals reflect the environment under which they are formed, that is, the temperature, pressure, chemical composition, redox potential, etc., that exists in their immediate vicinity, although owing to the unique properties involved in biological processing, these minerals may not always reflect equilibrium conditions. Minerals can be deposited biologically as well as abiotically. Biologically produced minerals reflect characteristics of the living system which formed them, for example, aragonite crystals in mollusk shells have their crystallographic C axes oriented perpendicular to the matrix surface (Mann, 1988). For this and other reasons, biologically produced minerals have been proposed as bio-markers (Schwartz and Mancinelli, 1989). Bio-markers are key morphological, chemical, and isotopic signatures of living systems that can be used to determine if life processes have occurred.

Physico-chemical processes that have occurred at varying stages of formation during mineral growth can be reflected in unusual textures, structures and inclusions in the minerals. Mineral formation seldom originates from a single process, but the characteristics of the most recent process, geological or biological in nature, are recorded in the mineral. Minerals that have crystallized from magma, that is, igneous minerals, will not be considered here since they reflect the chemistry and the physics of the melt and the cooling process. As exobiologists, our interests lie in understanding the properties of non-igneous minerals, those that result from weathering, reworking and biological processing.

The characteristics of a crystal, such as its structure, size, chemistry, morphology, etc., give us insight into the environment under which the crystal forms. Understanding the details of the crystallographic structure will allow us to determine whether a mineral was deposited via abiotic or biologic means. Examining abiotically produced crystals provides information regarding the characteristics of the local environment as previously described. Studying biologically produced minerals will also provide similar information about the environment, but this data will reflect the intra-, inter-, or extra-cellular characteristics of the microorganism responsible for the controlled mineral growth. More than 40 different minerals have been identified as being produced or reworked by an assortment of organisms (Mann, 1988). These minerals, such as calcite, aragonite, silica, and magnetite, serve a variety of different functions in different organisms. Independent of the functions they serve, these inorganic crystals are laid down in orderly arrays in association with a matrix of organic macromolecules.

How can we distinguish between abiotically and biologically produced minerals? Abiotically produced minerals grow to a range of different sizes at varying rates. They tend to have diversified morphologies depending on the conditions during growth, but they have distinctive crystal structures, symmetry classes, predictable variations in chemical structure, and usually contain a variety of impurities or inclusions. Biologically produced minerals are always a result of controlled crystallization. These minerals contain regular and limited quantities of impurities that are biologically determined. A diversity of mineral shapes can be biologically molded by cellularly constraining the space available to the growing mineral, and the grain sizes should be homogeneous for a given mineral produced by a given organism. Crystallographic properties reflect the location and orientation of macromolecule sites. The trace element and isotopic compositions of the minerals are controlled by the organism and therefore may be out of equilibrium with the environment (Lowenstam, 1981). Even after varying degrees of diagenesis, the structure and composition of the original mineral can be deduced, for example, the association of microdolomites with low magnesium calcites has been found to be stable products of the diagenetic alteration of original biogenetic high magnesium calcites (Blake, et al., 1982). The analytical capabilities for such determinations should be included on the Mars Rover.

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