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COSMOGENIC NUCLIDES IN THE MARTIAN SURFACE: CONSTRAINTS FOR SAMPLE RECOVERY AND TRANSPORT

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Stable and radioactive cosmogenic nuclides and radiation damage effects such as cosmic ray tracks can provide information on the surface history of Mars. A recent overview on developments in cosmogenic nuclide research for historical studies of predominantly extraterrestrial materials is given in [1].

The information content of cosmogenic nuclides and radiation damage effects produced in the Martian surface is based on the different ways of interaction of the primary galactic- and solar cosmic radiation (GCR, SCR) and the secondary particle cascade. Generally the kind and extent of interactions as seen in the products depend on the following factors: 1. Composition, energy and intensity of the primary SCR and GCR. 2. Composition, energy and intensity of the GCR-induced cascade of secondary particles. 3. The target geometry, i.e. the spatial parameters of Martian surface features with respect to the primary radiation source. 4. The target chemistry, i.e. the chemical composition of the Martian surface at the sampling location down to the minor element level or lower. 5. Duration of the exposure. These factors are not independent of each other and have a major influence on sample taking strategies and techniques.

For stable and radioactive cosmogenic nuclides with half-lives exceeding several thousand years the composition and fluxes of primary GCR and SCR can be considered constant. The composition, energy and intensity of the secondary particle cascade depends on that of the primary radiation, but more so on the composition and geometry of the surface area sampled.

It is therefore important to determine the chemical composition and density of the sampling site. A major factor for the built up and energy distribution of secondary neutrons, the most effective nuclear interactive secondary particles in planetary surfaces exposed to GCR, is the volatile concentration (H_2O, CO_2) of the surface which can vary significantly [2,3]. Especially for core samples, information on the volatile concentration should be preserved in the returned sample throughout all sampling procedures envisioned, or by determination in situ before any volatile expelling procedures (heating) have been applied. Heating, though to a certain extent tolerable, may cause the loss of information from radiation damage effects and some volatile cosmic ray products.

The target geometry places even stronger constraints on sampling strategies and techniques. The built up of the secondary particle cascade in a target and consequently the production rates of cosmogenic nuclides and radiation damage effects are depth and size dependent [2,3]. Therefore, the geometry of any sample taken for cosmogenic nuclide research from the Martian surface has to be preserved and/or documented as precisely as possible. With respect to the thin atmosphere sampling altitude is also an important parameter to account for SCR contributions. Further documentation could consist of in situ measurements of radiation and other parameters of the sampling site such as a neutron depth profile at a core-sampling location, the neutron environment of other sampling locations and the bulk chemical composition and density by means of a gamma-ray survey or other techniques. Additional information on the direct environment of the sample such as the ruggedness of the surface, boulders in close distance, and slopes of the terrain is important.

Another aspect of target geometry has to be seriously considered, if short-lived radioisotopes such as ^{22}Na, ^{60}Co, and ^{3}He will be measured. The circumstances of the Mars-Sample-Return-Scenario include two possible geometry and radiation environment changes, which may influence the information content of short-lived radioisotopes considerably: Sampling and storage in the transportation vehicle and return flight to earth. The constraints derived therefrom are: 1. Samples for cosmogenic nuclide studies shall be taken as late as possible out of their last Martian geometry, i.e. as close as possible to launch date. 2. Samples should be stored in a controlled radiation environment, i.e. active monitoring of the radiation at the sample storage location should be required. 3. Best storage of cosmogenic nuclide samples could be achieved in a container that shields off SCR, but is thin enough not to cause serious built up of cosmic ray secondaries; therefore, this container should be stored away from the spacecraft on passage to earth.

Considering the production mechanisms, samples that provide abundant time information from cosmogenic nuclide studies are cores into soil and dust: maturity and turn over rates can be obtained over short and long time scales. Drill cores into rock, as well as small surface rocks , and top and lateral chips of large boulders give clues on surface exposure and especially on erosion rates. In principle, no surface sample is without time information. As sample geometry is one of the most important factors core samples have to be taken and handled without perturbation of the stratigraphy especially of the top few centimeters until subdivided in a laboartory.

Sample size for a complete consortium study of cosmogenic nuclides and other radiation exposure effects is estimated to be in the few gram range per sample for non-destructive determination of short-lived isotopes; reqirements for destructive analyses are much lower and depend significantly on the extent of the cosmogenic nuclide studies planned. Both, conventional mass spectrometry and especially accelerator mass spectrometry have lowered the limits of detection significantly during the last few years [1]. It can be anticipated that samples of every centimeter from drill cores would be requested at shallow depths, i.e. where major disturbances by aeolian activity are expected, and from every third to fifth centimeter from deeper locations.

References: [1] Reedy R.C. and Englert P. (1986), LPI Tech. Rpt. 86-06, Lunar and Planetary Institute, Houston, 80 pp. [2] Reedy R.C., Drake D., and Feldman W.C. (1987) In: Mars Sample Return Science Workshop. [3] Englert P.A.J., Reedy R.C., and Arnold J.R. (1987), Nucl. Instr. Meth., in press.