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THE ROLE OF IMPACT CRATERING FOR MARS SAMPLE RETURN, P.H. Schultz, Dept. of Geological Sciences, Brown University, Providence, R.I. 02912

The impact process became a major focus of lunar studies during Apollo because it provided a context for understanding sample provenance, regolith evolution, smooth plains origin, the lunar time scale, magnetic field generation, lithospheric evolution, and crustal structure. Although Mars offers a much more complex geologic history (a contrasting style of volcanism/tectonism and active atmsophere/surface processes), the preserved cratering record indicates that impacts will play an important role in deciphering martian geologic history whether as a mechanism to modify the lithosphere and atmosphere or as a tool to sample the planet. Rather than reviewing lessons learned from Apollo in detail, the following discussion examines the various roles of impact cratering in adding a broader understanding of Mars through returned samples. Five broad roles include impact craters as: a.) a process in response to a different planetary impact environment; b.) a probe for excavating crustal/mantle materials; c.) a possible localizer of magmatic and hydrothermal processes; d.) a chronicle of changes in the volcanic, sedimentary, atmospheric, and cosmic influx history; and e.) a chronometer for extending the geologic time scale to unsampled regions. Three underlying philosophies are implicit. First, a limited sample return should provide the broadest range of materials and processes. Second, at least one reference time needs to be firmly established. And third, a strategy should explore what is known as well as attempt to confirm what is (believed to be) known.

Impact Process: Impact conditions at Mars differ from the Moon in three very fundamental ways: the presence of an atmosphere; presence of crustal volatiles (whether free or chemically bound); and lower impact velocities. Atmospheric density above Mars at 80 km matches the terrestrial value at 100 km; consequently, shielding of the surface from low mass impactors on the two planets is equally effective. Larger mass meteoroids will break–up due to aerodynamic forces and it has been estimated that craters smaller than 50 m would be prevented from forming (1). As a result, the martian regolith may contain a record of cosmic dust and broken meteorites unlike the lunar regolith. The presence of even the presently tenuous atmosphere also affects ejecta ballistics provided that: ejecta are small enough to be affected by air drag; the crater is large enough to eject material at high velocities; and the crater is small enough to be formed within a few atmospheric scale heights (2, 3, 4). On the basis of laboratory experiments and theoretical considerations, the present martian atmosphere may control the development of contiguous ejecta ramparts and ejecta lobes (3) as well as crater size (5). At large distances, ejecta re–entering the atmosphere develop dynamic pressures large enough (0.5 kb) to induce break–up and dispersal of weak ejecta, thereby reducing the role of secondary cratering. The addition of volatiles in the near surface result in enhanced fluidization of the ejecta (6, 7, 8), a strong precursor air blast that scours the surface to large distances (4, 9), and possibly increased crater collapse (6). Martian impactors are believed (10) to be dominated by asteroids with an impact velocity ranging from 8 to 15 km/s whereas lunar impactors may be a mix of asteroids (22 km/s) and periodic comets (40 km/s). This difference may be significant for the production of melt and vaporization (since partitioning increases as v^2) and crater aspect ratio (11).

Impact Probe: Impacts permit sampling buried materials through excavated ejecta and uplift of the crater interior. This principle was used as a rationale for Apollo landing site selection: Apollo 14 (Fra Mauro, Cone Crater); Apollo 15 (Imbrium rim); Apollo 16 (Cayley, North/South Ray); Apollo 17 (serenitatis rim). It may be even more important for Mars where a reworked or covered surface may prevent direct sampling of bedrock. The presence of an atmosphere and volatiles modifies simple ballistic emplacement and inverted stratigraphy unless smaller craters (< 1 km) are used. The atmosphere, however, could play a useful role by reducing the velocity of more distant ejecta such that primary ejecta can be sampled. With such a philosophy, an ideal site would provide a potpouri of martian processes through breccias from distant (4 crater radii) large craters, talus from an uplifted basin massif ring, debris ejected from a small crater, and surface materials reflecting a uniquely martian process (e.g., outflow channel). One possible candidate includes the base of the Isidis inner massif ring where channels weaving between massifs empty on the plains (12), where a thick transient volatile-rich debris layer once existed (13), and where small dark-haloed as well as larger impact craters insure sampling below more recent sediments. The deeply incised channels through the massif ring of Chryse provide an alternative setting and context.

Magmatic/Hydrothermal Centers: Impact basins and craters provided the primary pathways for lunar magmas. Similarly, the early volcanic history of Mars was localized by impact structures (14, 15). The addition of water, however, may have resulted in hydrothermal processes resembling the Sudbury structure on the Earth (16). Sampling this history on Mars is possible by extensive erosion and dissection of ancient impact basins along the contact between the ancient cratered uplands and northern plains. Possible candidates include craters and basins Deuteronilus Mensae where erosion has revealed roots of central uplifts and possible dikes expressed as dark linear extension of a now-missing basin ring.

Chronicle: The preservation of craters as landforms dating back to the first 0.5 by history of Mars contrasts with the Earth where the erosion rate can erase a 10 km crater in 200–300 my (17). Stable polar ice sheets, lakes, and oceanic basins are now providing a record of the terrestrial climate and cosmic flux over the last 30 my. The present plar layered terrains could provide an analogous sedimentary environment over the recent past (< 1 by) while the interiors of large (30–100 km) craters may provide a record over 3.0 by. The high rate of erosion and deposition on the Earth dilutes the cosmic flux unless a major event occurs (e.g., the putative K/T impact event). The possibly higher martian impact rate, the longer collection history, the more stable tectonic environment, the lower rate of resurfacing, and the effective atmospheric shielding all point to the possible use of isolated depositional traps as a chronicle of the martian cosmic flux. Estimates of this flux from the observed crater statistics indicate as much as 10^{21} g/100 my during the time following the Argyre impact and 10^{20} g/100 my during the emplacemnt of the ridged plains (18). A different but equally important chronicle of atmospheric conditions may be provided by the rate and style of weathering of ejecta from craters of different ages.

Chronometer: One of the most important goals of a sample-return mission is establishing a martian time-scale. Not only does this provide a time scale for geologic history but also a time scale for the impact flux on a different planet. The concept is simple but the application complex. The effects of substrate, volatiles, the atmosphere, and erosion all affect extrapolations from a single reference time; consequently, a priority must be given to different units or events, thereby limiting errors from interpolations while providing important information about cratering mechanics.

Summary: The evidence for Earth-like processes and very non-lunar styles of volcanism and tectonism may shift the emphasis of a sampling strategy away from equally (or more) fundamental issues including crustal composition, unit ages, and climate history. Impact cratering not only played an important active role in the early martian geologic history, it also provides an important tool for addressing such issues.

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