Impact Crater and Basin Control of Igneous Processes on Mars

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Numerous martian impact craters have been heavily modified by processes restricted to the crater interior. A common expression of this modification is the presence of extensive fractures arranged in a concentric plan and typically forming moats that engulf the old crater wall. Although similar styles of modification occur on the moon, martian floor-fractured craters display a greater diversity in morphology. Such craters are closely associated with major regional features and provinces, such as the Vallis Marineris system, the fretted terrains, and the martian plains. The well-preserved record of this style of crater modification and its proximity to similarly preserved regional features imply that floor-fractured craters represent crater-controlled sites of a late-stage and widespread pulse of igneous activity. Heat from such activity may locally thaw ground ice, resulting in the observed diversity in style of crater modification. Theoretical calculations show that heat released by a mafic sill beneath the brecciated zone of an impact crater may thaw trapped water-ice at depth over periods on the order of 10^4–10^5 years. Thawed materials may gradually escape through peripheral fractures surrounding the crater floor. Alternatively, a metastable state of potential liquification can occur if the material is confined and the rate of thawing exceeds the rate of escape. This establishes conditions for catastrophic release of a warmed slurry which may produce the chaotic terrain and outflow channels as suggested by other investigators. Identified multiring basins associated with Margaritifer Sinus and the fretted terrains are proposed to represent broader scale control of igneous processes by old impact structures, in direct analogy with floor-fractured craters. Moreover, the arcuate pattern of Noctis Labyrinthus and a concentric arrangement of massifs identify a proposed Tharsis impact basin centered on Syria Planum.

INTRODUCTION

Impact craters on the moon have played a dominant role in controlling the surface expression of igneous activity as revealed by mare-filled craters and basins, floor-fractured craters, and basin-controlled vent location (e.g., see *Wilhelms and McCauley* [1971], *Schultz* [1976*a*, *b*], *Head* [1976]). Typically, the stage of igneous activity is temporally separate from the time of impact crater formation, as illustrated by the wide range in ages of craters and basins filled with basaltic plains. A record of a similar control of igneous activity by preexisting or concomitant impact craters appears to be present on Mars, but with the added complication of water/ice-bearing permafrost [*Schultz et al.*, 1973; *Schultz*, 1978].

The present study reviews the possible role of impact craters in controlling local martian endogenic activity and proposes a widespread influence of this process on major tectonic and volcanic provinces including the Tharsis region, the Valles Marineris system, and the chaotic and fretted terrains. First, we consider examples of martian impact craters that exhibit evidence for endogenic modification and survey the style of modification. Second, we examine the cooling history of a mafic body intruded beneath impact craters of different sizes which contain water-ice deposits and relate these results to modified martian craters. Third, we extend this analysis to basin-size structures and consider the evidence for impact basin control of major volcanic and tectonic provinces.

MARTIAN FLOOR-FRACTURED CRATERS

Igneous activity on the moon can be inferred from the occurrence of dark basaltic plains or volcano/tectonic modification of impact craters. Where volcanic constructs or flow fronts are absent on Mars, identification of volcanically derived plains units may be ambiguous owing to other plains-forming processes (eolian and perhaps fluvial deposition). The modification of crater interiors, however, provides many examples of endogenic (subsurface-controlled) and perhaps igneous processes.

From Mariner 9 images, over 80 craters with floor fractures could be identified [*Schultz*, 1978]. Although Viking images reveal this inventory as a gross underestimate, the general distribution revealed in the initial survey remains valid: martian floor-fractured craters are concentrated in the old cratered highlands along the margins of plains regions and within the lightly cratered plains near the Valles Marineris canyon system (see Figure 1). The close proximity to canyon systems and lava plains suggested that such craters record localized centers of regional endogenic activity. Moreover, *Schultz* [1978] proposed that modification of these craters contributed to regional processes. For example, coalescing modified craters contributed to the development of large areas of chaotic terrain. This process is in contrast to modification of craters that resulted from nearby regional processes. Specifically, modification may be a consequence of collapse due to weakening by surface erosion or regional groundwater movement.

The style of impact crater modification on Mars as revealed by Viking images is extremely diverse. This diversity generally reflects the degree of modification and the timing of modification (relative to the age of the impact crater) in direct analogy with lunar floor-fractured craters [*Schultz*, 1976*b*]. Figures 2–4 illustrate representative examples. Figure 2 shows two impact craters with vast differences in formation ages. The 100-km-diameter crater in Figure 2*a* occurs in the cratered highlands on the southwest border of Syrtis Major Planitia. The crater floor exhibits extensive fracturing approximately concentric around an intact central floor plate. In many respects, this crater resembles lunar floor-fractured craters in that a broad moatlike depression encircles the central floor and contains wall slump remnants. Secondary craters and fine-scale linear textures indicate a relatively well preserved state of the original impact crater.

Figure 2*b* illustrates a highly degraded impact structure found in the cratered plateau material mapped by *Scott and*

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