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The Structure and Evolution of Ancient Impact Basins on Mars

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The number of Martian impact basins, once thought deficient owing to a low number of impactors, has been significantly increased through the identification of structural imprints that remain even after nearly complete erasure of basin massifs. Five ancient multiringed impact basins were selected for detailed study and exhibit a systematic pattern of rejuvenation of the multiring plan through endogenic modification. Concentric zones of unstable terrain are believed to reflect deep-seated, impact-related fractures that have localized regional igneous processes in a manner analogous with the basin-controlled distribution of basalts on the moon. Most Martian outflow channels were found to originate along the unstable ring zones. Hydrothermal melting and temporary confinement of channel source materials at sites analogous to lunar sinuous rille source regions are proposed to play an important role in the distribution of Martian outflow channels. Ancient basins also can be delineated by the concentric pattern of topographically and structurally controlled narrow valley networks that are particularly abundant along the outer rings where basin ejecta deposits occur. Remnant massifs and scarps commonly exhibit extensive furrowing by narrow valley networks, perhaps due to a different paleoclimate or sapping during a period of geothermal melting of trapped ices. The systematic patterns of valley networks, stable and unstable annuli, scarps, and massifs provide bases for interpreting impact structure in general and for recognizing multiringed structures elsewhere. The Chryse basin, in particular, is proposed to represent a major multiringed structure that controlled the formation and distribution of eastern Valles Marineris and the chaotic terrains of Margaritifer Sinus in response to volcanism/tectonism related to Tharsis. We conclude that (1) Mars is probably not deficient in large-body impactors; (2) the multiring patterns of basins represent deep-seated fracture zones that can be reexposed through subsequent volcanism, hydrothermal activity, sapping, and differential erosion; (3) many Martian terrains and features (e.g., chaotic terrains and outflow channels) are controlled by ancient basins; and (4) the resurrection and destruction of impact basins reveal an important third dimension (depth) for interpreting impact basin formation.

INTRODUCTION

The record of impact basins on Mars has generally been regarded as notably deficient relative to Mercury and the moon [*Wilhelms*, 1973; *Mutch et al.*, 1976; *Malin*, 1976; *Wood and Head*, 1976]. *Wood and Head* [1976] suggested that this relative deficiency indicates a fundamental difference in the production rate of impact basins, whereas *Malin* [1976] offers an additional process of planetary resurfacing thereby removing the early episodic/cataclysmic record. *Schultz and Glicken* [1979] and *Schultz and Schultz* [1980] identified several extremely subdued impact basins whose multiringed pattern has been resurrected by endogenic processes related to the formation of chaotic and fretted terrains. This raises the possibility that the early basin-forming impacts on Mars were only obscured, but their deep-seated fracture zones persisted throughout Martian geologic history. Characteristic styles of degradation and modification of obvious Martian basins permit recognizing more subtle expressions. This approach not only adds additional basins to the existing inventory but also provides fundamental clues for initial impact basin structure and stratigraphy. Moreover it reveals the long-lasting influence of basin formation on the crust of Mars in spite of extensive erosion and resurfacing.

We first consider five clear examples of modified impact basins and delineate regions around each that have undergone similar processes such as fracturing, collapse, and channeling. Second, we compare these processes among the different basins and correlate similar zones of modification with concentric basin rings. Third, we consider the implications of these observations for current models of basin formation and the role of impact basins in controlling regional tectonics. The results suggest that large multiring impact scars leave a major but sometimes subtle imprint on the geologic structure of stable crustal regions on Mars. We feel that similar but as yet unappreciated imprints are manifested on most other planets as well—including the stable cratons of the earth.

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SELECTED EXAMPLES

Ladon Basin. Ladon basin (Figure 1, Table 1) was first recognized in earth-based radar profiles [*Saunders et al.*, 1978] but its full dimensions and relation to the distribution of nearby chaotic terrains, outflow channels, and narrow valleys were not recognized until later [*Schultz and Glicken*, 1979]. Figure 2 shows the distribution of selected terrains, structure, and remnant basin massifs. Ladon has three well-defined concentric rings. The innermost ring (270 km in diameter) is poorly defined but corresponds to a subtle scarp crossing the interior plains. The second ring (580 km diameter) is expressed by massifs, scarp segments, narrow valleys, and clustering of floor-fractured craters. The massifs form two closely spaced concentric rings, perhaps in analogy with the Inner and Outer Rook Mountains of the Orientale Basin on the moon. Numerous narrow curvilinear valleys of the type discussed by *Pieri* [1980] and *Carr* [1981] typically cross this zone toward the central low-lying basin. Topographic and structural control is also clearly expressed by valleys diverted by massifs and paralleling the concentric massif plan. In general, the valleys narrow and