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Ries and Chicxulub: Impact craters on Earth provide insights for Martian ejecta blankets

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Abstract–Terrestrial impact structures provide field evidence for cratering processes on planetary bodies that have an atmosphere and volatiles in the target rocks. Here we discuss two examples that may yield implications for Martian craters:

1. Recent field analysis of the Ries crater has revealed the existence of subhorizontal shear planes (detachments) in the periphery of the crater beneath the ejecta blanket at 0.9–1.8 crater radii distance. Their formation and associated radial outward shearing was caused by weak spallation and subsequent dragging during deposition of the ejecta curtain. Both processes are enhanced in rheologically layered targets and in the presence of fluids. Detachment faulting may also occur in the periphery of Martian impacts and could be responsible for the formation of lobe-parallel ridges and furrows in the inner layer of double-layer and multiple-layer ejecta craters.
2. The ejecta blanket of the Chicxulub crater was identified on the southeastern Yucatán Peninsula at distances of 3.0–5.0 crater radii from the impact center. Abundance of glide planes within the ejecta and particle abrasion both rise with crater distance, which implies a ground-hugging, erosive, and cohesive secondary ejecta flow. Systematic measurement of motion indicators revealed that the flow was deviated by a preexisting karst relief. In analogy with Martian fluidized ejecta blankets, it is suggested that the large runout was related to subsurface volatiles and the presence of basal glide planes, and was influenced by eroded bedrock lithologies. It is proposed that ramparts may result from enhanced shear localization and a stacking of ejecta material along internal glide planes at decreasing flow rates when the flow begins to freeze below a certain yield stress.

INTRODUCTION

Martian impact craters reveal morphological characteristics such as fluidized ejecta with ramparts that differ from those of other planetary bodies. Ejecta morphologies such as single-layer ejecta, double-layer ejecta, and multiple-layer ejecta (Barlow et al. 2000) depend on crater size, geographic location, altitude, terrain, and time of formation (Mouginis-Mark 1979; Costard 1989; Barlow and Bradley 1990; Barlow 2005; Reiss et al. 2005). These characteristics have been explained by models that emphasize the role of either subsurface ice and water ("subsurface volatile model") (Carr et al. 1977; Wohletz and Sheridan 1983; Mouginis-Mark 1987; Clifford 1993) or atmospheric turbulence during the cratering process ("ring vortex model") (Schultz and Gault 1979; Schultz 1992; Barnouin-Jha and Schultz 1996, 1998). The existence of a critical and latitude-dependent onset diameter for which fluidized layered ejecta occur suggests that subsurface volatiles play a dominant role in the fluidization of ejecta blankets. The relationship between the ejecta type and the subsurface water/ice content and its variation with depth (Wohletz and Sheridan 1983; Mouginis-Mark 1987; Costard 1989; Barlow and Bradley 1990) is currently debated. It critically depends on the rheology of ice and water-bearing rocks and their behavior under shock (Stewart and Ahrens 2003; Ivanov 2005; Ivanov et al. 2005).

On Earth, impact craters also formed in the presence of an atmosphere and subsurface volatiles. This analogy underscores the significance of comparative crater studies, all the more so as the analysis of craters on Mars and Earth yields complementary information on the cratering process. Most of our knowledge of Martian craters is derived from remote sensing data. In contrast, analyses of terrestrial craters comprise a wide spectra of techniques whose applications benefit from easy accessibility and the opportunity of direct