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Impact fracturing and structural modification of sedimentary rocks at Meteor Crater, Arizona

P. Senthil Kumar[1,2] and David A. Kring[3]

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[1] Meteor Crater provides a rare opportunity to study impact deformation of sedimentary target rocks and isolate those features from preexisting tectonic deformation and impact-generated reactivation of preexisting tectonic features. This study reports over 2500 new measurements of orientations of bedding, faults, and fractures in crater walls and in surrounding bedrock. Target rocks are characterized by horizontal bedding planes that are cut by at least three prominent sets of preimpact tectonic fracture systems. The crater rim is also cut by three distinct groups of fractures: radial, concentric, and conical fractures. When the crater rim is restored to preimpact condition, the radial and concentric fractures resemble preimpact fracture populations, indicating that crater wall deformation and rim uplift were partly accommodated by activation of preexisting fractures. In contrast, the conical fractures are dissimilar to the preimpact fractures and apparently formed as a direct result of impact deformation. Some of the preimpact fractures were transformed into tear faults during the impact event, and motion along those faults appears to have controlled the geometry of the impact deformational features. The crater rim is, thus, square in plan view rather than circular. Faults occurring in the crater diagonals are prominent ones, allowing greater vertical displacement. The deformation pattern of Meteor Crater is different from that at Lonar Crater, which was excavated in basalt with fewer preimpact fractures. The differences between deformation at Meteor Crater and Lonar Crater may reflect the same disparities seen in simple craters produced in different target lithologies on Mars and other planetary surfaces.

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1. Introduction

[2] One of the most important characteristics of meteorite impact is the deformation of target rocks, which produces an excavated cavity, uplifted rim, and stratigraphically overturned ejecta blanket. The deformation occurs in a catastrophic burst of energy that fractures, melts, and vaporizes material in a few seconds to a few minutes, depending on the size of the impact event. Deformational stresses are at least 10^3 to 10^4 greater than material strength and strain rates are often 10^4 to 10^6/s, which are 7 to 12 orders of magnitude greater than that of other geologic processes [*Gault et al.*, 1968; *French*, 1998]. When an asteroid or comet hits a planetary surface, a shock wave radiates into the crust, compressing target lithologies in an expanding semihemispherical volume of rock. With increasing distance from the point of impact the shock wave weakens. A rarefaction or release wave follows the shock wave. The combined effect of these waves is to create a flow of material that initially moves downward, then outward and upward, excavating and ejecting material to form the crater cavity. The crater wall represents the limit where the flow is unable to eject material, although wall rock is still uplifted to produce a ring syncline with an axial trace beyond the crater rim. Furthermore, some of the ejected components remain stratigraphically coherent and are structurally overturned and redeposited on the uplifted crater rim. Deformation is not limited to excavated components, but also occurs at greater radial distances from the point of impact where shock waves permeate the crater walls and surrounding bedrock. Rock is displaced to a depth about 3 times greater than the excavated depth, defining a transient crater that is partially filled with deformed rock, impact breccias, and, in large events, impact melt [*Dence et al.*, 1977; *Grieve et al.*, 1977]. Although the energy of the impact event is accommodated by or dissipated within a large volume of fractured rock beyond the crater walls, this deformation is still poorly understood.

[3] Few simple craters on Earth are sufficiently well preserved to lend themselves to a structural analysis of deformation within crater walls. One of the most interesting examples is the ∼220 ka Tswaing impact crater. Formerly known as the Pretoria Saltpan crater, this structure is ∼1 km in diameter and carved from granite and a thin veneer of

[1]National Geophysical Research Institute, Council of Scientific and Industrial Research, Hyderabad, India.
[2]Department of Geological Sciences, Brown University, Providence, Rhode Island, USA.
[3]Lunar and Planetary Institute, Universities Space Research Association, Houston, Texas, USA.

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