Characteristics of Ejecta and Alluvial Deposits at Meteor Crater, Arizona and Odessa Craters, Texas: Results from Ground Penetrating Radar; J.A. Grant and P.H. Schultz, Brown University, Providence, RI 02912.

Purpose: Previous ground penetrating radar (GPR) studies (1) around the 50,000 year old Meteor Crater revealed the potential for rapid, inexpensive, and non-destructive sub-surface investigations for deep reflectors (generally greater than 10 m). The present study summarizes new GPR results focusing on the shallow subsurface (1–2 m) around Meteor Crater and the main crater at Odessa and reveal: A) the thickness, distribution and nature of the contact between surrounding alluvial deposits and distal ejecta; and B) stratigraphic relationships between both the ejecta and alluvium derived from both pre and post crater drainages. These results support previous conclusions indicating limited vertical lowering (<1 m) of the distal ejecta at Meteor Crater (2,3) and allow initial assessment of the gradational state of the Odessa craters.

Approach: A SIR–3 GPR system manufactured by Geophysical Survey Sytems, Inc., was used for all data collection. The present work differs significantly from previous GPR studies at Meteor Crater (1) in that both a bi-static 100 Mhz and 500 Mhz transducer was used, thereby allowing high-resolution probing of the uppermost few meters of the subsurface. Initial GPR deployment around the 1.2 km diameter Meteor Crater followed previously sampled transects crossing distal ejecta and distal diffuse drainage alluvial deposits (2,3). A metal plate was buried along several transects at variable depths to allow calculation of the dielectic constant and pulse travel time in the ejecta and alluvium. Calculated dielectric constants are 4.0–4.8 and ~7.3 and pulse travel times are 14.5 cm/ns and 11 cm/ns for the ejecta and alluvium, respectively. These values are slightly less than those derived for material beneath the crater floor (1). Subsequent transects crossed diffuse drainages west and south of the crater, portions of the distal continuous ejecta north and south of the crater, and low semi-concentric ejecta ridges 1.0R north and 0.5R south of the crater rim.

Results: Preliminary analysis of GPR data from transects through diffuse drainage deposits frequently revealed the presence of a very shallow, discontinuous reflector at depths of only ~30–45 cm. Based on stratigraphic information provided by pits excavated along the transects, this uppermost reflector probably marks the depth of discontinuous carbonate laminae in soils (Bk horizon) formed in most deposits. Variability in the depth of these characteristic soil horizons can be used to constrain local stability of the ejecta surface. The base of the alluvium in contact with the underlying ejecta was also detected as a distinct reflector in many locations despite the relatively high conductivity of these overlying calcic soil horizons. Deposit thicknesses derived from GPR data corroborate previous conclusions that where present, the alluvium forms only a 1–2 m thick veneer over the distal ejecta (4,1). In additon, GPR transects demonstrate that gradients along subsurface ejecta/alluvium interfaces are generaly concordant with those on exposed ejecta surfaces emerging from beneath the deposits. Hence, there has been minimal vertical erosion of exposed ejecta during and following the emplacement of the adjacent alluvial deposits that were studied. Because many alluvial deposits appear to be latest Pleistocene in age (5,1), this statement supports our previous estimates of low erosion on the more distal ejecta (1,2). The relatively low variability, low relief nature of the buried alluvium/ejecta contact observed in the GPR transects approximates relief on the exposed ejecta and implies occurrence or little pre-deposit fluvial incisement of the ejecta at least in the locations studied to date. Therefore, most of the investigated alluvial deposits occur as a depositional mantle filling topographic depressions on the ejecta created during primary ejecta emplacement. Identification of the nature of these deposits highlights the importance of depositional processes in reducing erosion of the distal ejecta.

Transects across exposed ejecta surfaces with the GPR did not reveal near-surface well-defined continuous reflectors. However, numerous local reflectors were observed at varying depths that mark the location of buried ejecta blocks (>20–30 cm in diameter). Despite scattering and attenuation of the radar pulse by both these buried ejecta blocks and calcic soils, the bi-static 100 Mhz transducer revealed a strong, continuous reflector at depths close to those expected for the ejecta/country rock contact. Tracing the reflector beyond the edge of the continuous ejecta identified it as the contact between the upper Moqui and lower Waputki members of the Triassic Moenkopi Formation that lies beneath the ejecta (4). It is possible that similarities between the dielectric properties of the Moqui member of the Moenkopi Formation and the immediately overlying ejecta (perhaps dominated by ejected Moenkopi fragments; 4,5) precludes identification of the exact ejecta/country rock contact. Nevertheless, the Moqui/Waputki contact provides a widespread, approximate marker (generally with 1–3 m, but less in distal thin ejecta) that can be used to distinguish subtle variability (10's of cm) in primary emplacement morphology of the shallow, distal ejecta (6).

Transects crossing a low ridge north of the crater revealed a bedrock core rising to within 1 m of the surface. This conclusion is consistent with inferences drawn from previous maps of ejecta in the area (5,7) and indicates ejecta draping over pre-impact topography in the country rocks. However, a comparable bedrock core is not found within 1.5–2.0 m of the surface in transects across a segmented ridge south of the crater: either pre-crater topography is more deeply mantled by ejecta or the ridge reflects primary emplacement morphology.

The more advanced state of human modification and stage of calcic soil development around the 0.17 km diameter main crater at Odessa made GPR data collection more difficult than at Meteor Crater. A total of 28 radial and partially concentric transects around the main crater revealed that the dielectric constant of the ejecta (as determined by methods similar to those described at Meteor Crater) is ~12, whereas the radar pulse travel time is ~8–9 cm/ns. Differences between values noted at Meteor Crater may reflect the greater lithologic diversity at Odessa. These values were used to confirm ejecta thicknesses along radial trenches through the rim and near-rim ejecta (8). In addition, transects identified the extensive superposition of alluvial/eolian deposits on ejecta that are located much closer to the rim-crest than at Meteor Crater. Initial results demonstate the potential for differentiation between artificial fill, alluvium, and ejecta and confirms the feasability of future GPR studies to constrain the erosional history.

Summary: Preliminary GPR results from various transects at Meteor Crater and the Odessa Craters demonstrate the potential for high resolution, non-destructive evaluation of the shallow subsurface around impact craters. Transects across alluvial and distal ejecta deposits at Meteor Crater provide additional evidence supporting both the low estimates of vertical erosion and conclusions regarding the remarkably pristine preserved state. Studies at Odessa allow correlation between radar transects and stratigraphy exposed in trenches through the rim/near-rim ejecta and reveal patterns of alluvial/eolian deposition on the ejecta that are considerably different than those observed at Meteor Crater. Future GPR studies are planned to examine relationships between the timing of alluvial deposition and variations in the history of climate controlled erosion at both craters.

References: **(1)** Pilon, J., Grieve, R.A.F., Sharpton, V.L., Kennedy, J. and Coderre, J., 1989: p. 852–853, in Lunar and Planet. Sci. XX (abstracts), Lunar and Planetary Institute, Houston, Texas. **(2)** Grant, J.A. and Schultz, P.H., 1990: p. 433–434, in Lunar and Planet. Sci. XXI (abstracts), Lunar and Planetary Institute, Houston, Texas. **(3)** Grant, J. A., 1990: Ph.D. Dissertation: Geology, Brown University, Providence, Rhode Island, 401p. **(4)** Roddy, D.J., Boyce, J.M., Colton, G.W. and Dial, A.L., Jr., 1975: *Proc. Lunar and Planet. Sci. Conf.*, v. 6, p. 2621–2644. **(5)** Shoemaker, E.M. and Kieffer, S.E. 1974: Arizona State University Center for Meteorite Studies Pulication 17, Tempe, AZ., 66p. **(6)** Schultz, P.H. and Grant, J.A., 1989, Styles of ejecta emplacement, Meteor Crater: p. 972–973, in Lunar and Planet. Sci. XX (abstracts), Lunar and Planetary Institute, Houston, Texas. **(7)** Shoemaker, E.M., 1960: PhD Dissertation, Geology, Princeton Univ., Princeton, N.J., 55p. **(8)** Evans, G.L., 1961: in Proc. Geophys. Lab./Lawrence Rad. Lab. Cratering Symp. (M.D. Nordyke, ed.), pt. 1, paper D, 11p., Livermore, Calif., Univ. Calif. Livermore Rad. Lab. Rept. UCRL-6438.