Erosion of Ejecta at Meteor Crater, Arizona: Further Constraints from Ground Penetrating Radar; John A. Grant and Peter H. Schultz, Brown University, Geological Sciences, Providence, R.I. 02912.

Ground penetrating radar (GPR) is an effective, non-intrusive, and easily deployed tool for defining the shallow stratigraphy around a variety of landforms (1-3). At Meteor Crater, Arizona (35°1'30"N; 111°1'15"W), GPR can be used to measure the accumulation of erosional products and place limits on the relative planation of exposed and adjacent buried ejecta surfaces. Such information constrains the preservation state of the ejecta deposits surrounding the crater and helps to distinguish between morphology related to primary emplacement and subsequent erosion. Previous GPR studies at the crater using a variety of transducer frequencies provided penetration depths of several meters around (4-6) and tens of meters inside the crater (7). The present study used a continuously profiling GPR with a 500 Mhz transducer along transects through alluvial and *in situ* ejecta deposits outside the crater. Results demonstrate that the ejecta deposit remains relatively undissected and largely preserved, thereby supporting recent estimates of low erosion at the crater (8).

Data were collected and processed using a fully digital SIR-10a subsurface profiling radar and RADAN III software. Transects were completed through alluvial and ejecta deposits on the west, southwest, south, southeast, and northeast sides of the crater at ranges between 0.4-3.0R (0.25-1.8 km). Intentional variations in strike along transects yielded continuous data collection over distances of nearly 3 km. Sample pits and discrete reflectors at known depth established groundtruth for the radar transects including dielectric constants and corresponding radar pulse travel times. For ejecta dominated by fragments of the Permian Kaibab Formation, the dielectric constant is fairly uniform around the crater (ranging between 4.0-5.3). Corresponding one-way pulse travel times are 13.0-14.5 cm/ns. Dielectric constants in alluvium derived from the ejecta are slightly higher at 7.3 and 10 for deposits containing significant Kaibab and Coconino ejecta debris, respectively. The one-way pulse travel time in Kaibab alluvium is 11 cm/ns, whereas a travel time of 9 cm/ns characterizes the Coconino alluvium. Such values are typical of dry blocky and sandy/silty materials (9).

GPR profiles through alluvium delineate stratigraphic relationships between the deposits and the surrounding *in situ* ejecta to depths of 1-3 m. Interpretation of these data indicate that buried ejecta surfaces are largely unincised by drainages. Consequently, deposition of the alluvium was not preceded by significant fluvial dissection of the ejecta. This conclusion is consistent with gradients of ejecta surfaces that can be traced continuously beneath the alluvium, thereby indicating minimal vertical denudation following alluvial deposition. Where not impeded by calcic soil development and/or high soil moisture, the GPR confirms the generally superficial nature of the alluvium and can generally distinguish deposits mapped as being Holocene versus Pleistocene in age (10). Transects crossing small alluvial fans on the southwest crater flank (~0.4-0.55R) indicate that the alluvium is less than 2 meters thick. Sediments comprising these deposits reflect relatively minor erosion of up gradient Coconino ejecta exposures. Not only do alluvial grains derived from erosion and transport of the Coconino ejecta decrease rapidly down the drainage, but the preserved volume represents a significant fraction of the entire inventory of fluvially transported Coconino ejecta.

GPR data collected at greater range west and south of the crater delineates the distal margin of the continuous ejecta at a range beyond that defined by surficial surveys. When confirmed by excavation, these data reveal that continuous ejecta remain preserved beneath a relatively thin veneer of colluvium (~20-40 cm thick) at ranges exceeding 2.0R. Local ejecta sections are in excess of 1.5 m in thickness at this range and varies due to emplacement over pre-impact relief on the *in situ* bedrock (Fig. 1). Transects completed across low sub-radial ridges (up to 5 m relief) on the ejecta west of the crater delineates cores of *in situ* bedrock (Fig. 1). As such, the ridges reflect ejecta emplacement over the existing topography on the pre-impact surface and are not the result of erosion-derived debris flow deposits were shed off the crater rim. Total ejecta thickness decreases by less than a meter across the ridge crests (likely resulting from the combined effects of emplacement over the ridge and subsequent erosion; Fig. 1), but continues to completely drape their outline. Moreover, there is no evidence for fluvial incisement or locations where the ejecta is locally breached by deflation or colluviation.

All of these observations indicate that there has been minimal erosion of the majority of the ejecta beyond the steep near-rim of the crater (ranges greater than 0.25-0.5R from the rim). Recent estimates place average vertical denudation on the distal ejecta at less than 1 meter (8). GPR data yield results that not only support this estimate, but demonstrate that much of the ejecta surrounding the crater retains a pristine form. Hence, the ejecta deposits around Meteor Crater should preserve key information regarding the subtleties of ejecta emplacement processes, as well as signatures of incipient degradation by fluvial and eolian processes.

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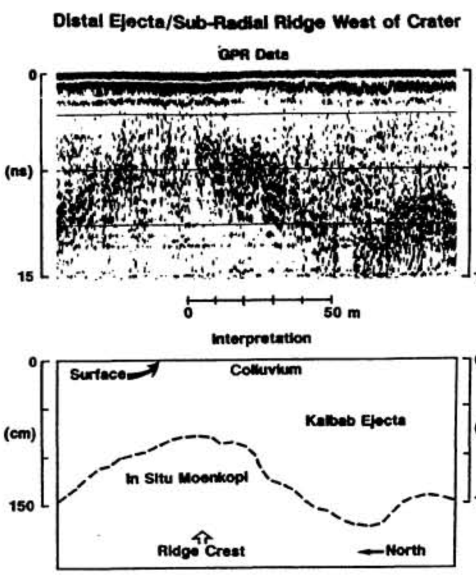

Figure 1 Portion of GPR transect and interpretation from north to south on Chavez Pass Road at just over 1R from the crater rim. Transect crosses low (<5 m relief) ridge that is sub-radial to the crater and trends ENE-WSW. GPR data combined with groundtruth demonstrates that this ridge reflects buried relief on the pre-impact Moenkopi surface. Ejecta thins over the crest of the ridge but has not been breached by erosion. Because the radar defines the changing depth to reflectors, the surface is defined as horizontal and does not reflect actual topography. Colluvial thicknesses vary little between exposed highs and swales and demonstrates minimal lateral transport of debris.