Further Constraints on the Erosional Evolution of the Ejecta at Meteor Crater, Arizona, as Revealed by Ground Penetrating Radar; **John A. Grant, SUNY College at Buffalo, Earth Sciences, Buffalo, N.Y., 14222, and Peter H. Schultz, Brown University, Geological Sciences, Providence, R.I. 02912.**

Ground penetrating radar (GPR) provides an efficient, reliable means of defining the shallow stratigraphy around landforms (1-4), thereby minimizing the labor-intensive groundtruth required by more traditional methods. At Meteor Crater, Arizona (35°1'30"N; 111°1'15"W), GPR continues to be used to define the volume and distribution of erosional products outside the crater in order to constrain the average amount of erosion that has occurred (*e.g.*, 4-8). A consequence of this approach is the ability to distinguish between morphology related to primary emplacement of ejecta versus that evolved due to subsequent erosion (6). Prior GPR studies (*e.g.*, 5-8) emphasized results from the probing of ejecta and alluvium dominated by fragments of the Permian Kaibab formation to establish lateral and vertical stratigraphic relationships. The current effort targeted similar deposits and was expanded to include ejecta of predominantly Permian Coconino sandstone fragments, its erosional deposits, and more distal alluvium. Results continue to be consistent with the conclusion that only minor erosion of the ejecta has occurred beyond the steep near-rim (5).

Data were collected using a fully digital GSSI SIR-10a subsurface continuously profiling radar and processed using RADAN III software whenever possible. The GPR was configured using both 500 MHz and bi-static 100 MHz transducers and deployed along transects covering a total of ~10-11 km through *in situ* ejecta, alluvium, and eolian deposits outside the crater. Most transects were radial and located beyond the steep near-rim; however, additional transects crossed a downwind playa known as Mud Lake and located ~10 km east-northeast of the rim. Transects completed through alluvial and ejecta deposits on the west, southwest, south, southeast, and northeast sides of the crater covered ranges between 0.4-3.0R (0.25-1.8 km). Sample pits and burial of target reflectors at known depth along these transects established groundtruth for the radar pulse travel time and dielectric constant in the various deposits. The dielectric constant for each major ejecta type is fairly uniform around the crater and ranges between 4.0-5.3 for the Kaibab ejecta to ~3.0 for the Coconino ejecta deposits. Corresponding one-way pulse travel times for these substrates are 13.0-14.5 cm/ns and ~17 cm/ns, respectively. Dielectric constants in alluvium comprised of debris from mostly Kaibab and Coconino ejecta are 7.3 and 11, respectively. These values equate to one-way pulse travel times of 11 cm/ns in Kaibab alluvium and 9 cm/ns in the Coconino alluvium. The dielectric constant of the windstreak sediments east and northeast of the crater is between 4.0 and 7.7 and produces a one-way radar travel time of 11-15 cm/ns. The slightly higher travel times cited for the Coconino ejecta and range of values for the windstreak may reflect a slightly lower density for these materials, local mixtures of sediments deflated from upwind outcrops of both Kaibab and Coconino ejecta, and/or locally higher concentrations of salts in the subsurface.

GPR profiles through Kaibab alluvium southeast, northeast and northwest of the crater delineate stratigraphic relationships between the deposits and the surrounding *in situ* ejecta as described previously (5-7). Penetration to depths of 1-3 meters southeast of the crater confirms that alluvium filling a blocked northeast draining gully is less than ~1.3 meters thick. Moreover, gradients along the buried ejecta/alluvium contacts equate to those on adjacent exposed surfaces and the underlying ejecta remains largely unincised. Hence, deposition of the alluvium was preceded and followed by only minor vertical lowering/incisement. The floors of somewhat broader drainages northeast and northwest of the crater also appear unincised and possess maximum fill of ~1.0-1.5 meters, thereby confirming the superficial nature of the alluvium.

Transects completed across the nearby Mud Lake playa (~10 km east-northeast of the crater) focused on location of possible horizons related to formation or degradation of the crater. Since prevailing winds remain largely invariant since the time of crater formation (9) the stratigraphy in the playa may record the impact or subsequent accumulation of fines deflated from the ejecta surface. Unfortunately, achieved penetration depths were less than 1 meter for both the 500 and 100 MHz transducers and the underlying bedrock surface could only be traced slightly beyond the

current playa margin. Such difficulties undoubtedly relate to the ongoing deposition of fine-grained sediments and abundant salts as water ponds in the regional drainage and evaporates. Efforts are planned for the simultaneous use of the GPR and a shallow coring device to better groundtruth the system and refine more subtle horizons that may be present.

Data collected in the windstreak east and northeast of the crater confirm its occurrence as a variably thin veneer of sediments superposing the ejecta surface. Grain size analyses (5) of the windstreak sediments indicate its origin is due to deposition of saltating grains deflated from upwind outcrops of Kaibab ejecta (mostly northeast portions) and Coconino ejecta (mostly east and southeast portions). Most sections through the windstreak total 10-15 cm or less, especially those on topographic highs. Slightly thicker accumulations of up to 50-55 cm were mapped locally using the GPR downwind of relief and in shallow topographic swales on the ejecta surface (Fig. 1).

Additional GPR transects limit the extent of the preserved ejecta deposit and reveal the origin of relief on the deposit surface. Data collected across the distal margin of the continuous ejecta west, north, and east of the crater confirm its preservation to at least 2.0R. Much of this distal material occurs beneath shallow accumulations of colluvium and alluvium and would be difficult to identify via traditional field methods. Most of the relief on the surface of the distal ejecta is typically cored by pre-impact topography on the Moenkopi surface (6) and data collected across one low pre-impact ridge southwest of the crater document an increase in ejecta thickness on the crater-facing side. By contrast, data collected across a discontinuous arcuate ridge located ~0.5R south of the rim indicate that the ejecta deposit is at least 5 m thick. Walls of a nearby mine shaft through the ridge reveal an equally thick ejecta section and suggest this more proximal relief may not be cored by pre-crater topography.

Each of these observations lends further support to recent conclusions of only ~1 meter average vertical erosion over the bulk of the ejecta located outside of the steep near-rim (ranges greater than 0.25-0.5R from the rim, 5, 6). As a result of this minimal denudation, the styles of climate-controlled degradation remain quantifiable and many of the subtle variations in ejecta topography likely preserve key information regarding the subtleties of ejecta emplacement processes. For example, the thicker distal ejecta section on the crater-facing side of the ridge to the southwest and the possible absence of a pre-impact bedrock core beneath the arcuate ridge south of rim.

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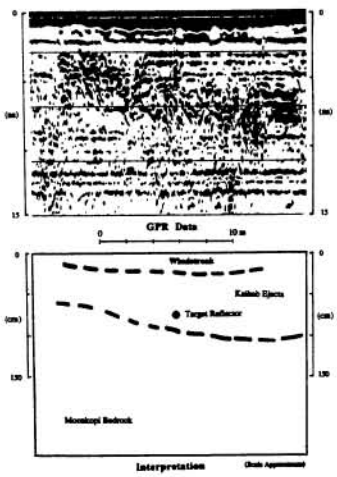

Figure 1 GPR transect and interpretation from within windstreak ~475 m east of the crater. When combined with groundtruth (parabolic reflector at 75 cm depth) the following sequence can be inferred: ~30 cm eolian sediment overlies ~50-60 cm of Kaibab ejecta that in-turn mantles the pre-impact Moenkopi bedrock. The transect is within a buried pre-crater drainage swale (10), thereby creating a sink for sediments saltating from upwind outcrops of Coconino sandstone (5). Such accumulations are local and comprise the thickest portions of the windstreak: most of the deposit is considerably thinner.