**LITHOSTRATIGRAPHIC ANALYSIS OF THE METEOR CRATER EJECTA BLANKET.** A. L. Gullikson[1], T. A. Gaither[1], K. A. Villarreal[2], and J. J. Hagerty[1], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001, [2]Northern Arizona University, 625 S. Knoles Drive, Flagstaff, AZ 86011.

**Introduction:** Meteor Crater is a bowl-shaped depression [1] located in north-central Arizona, thought to have formed ~50,000 years ago [2,3] by the impact of the ~100,000 ton iron-nickel Canyon Diablo meteorite. Recent sample analyses and numerical models [e.g., 4-11] indicate that the formation of Meteor Crater was much more complex than previously thought. Current models are insufficient for explaining certain processes, including impact melting, target rock-projectile mixing, siderophile element fractionation trends, and ejecta blanket formation. These issues are being investigated through the use of the USGS Meteor Crater Sample Collection. Our work utilizes these samples to study the composition and spatial distribution of impact-generated materials associated with the ejecta blanket, in an effort to better understand the complexity of cratering processes.

**Lithostratigraphic Analysis:** We are formulating a detailed, field-based model for crater excavation and ejecta emplacement processes through a lithostratigraphic analysis of the internal structure of the ejecta blanket. The extent of lithologic mixing within the ejecta blanket is being quantified by identifying ejecta facies that represent mixtures of target rock lithologies, impact melts, and lechatelierite (shock-melted Coconino sandstone). This study will provide a representation of the complete ejecta blanket, including possible internal structures and lateral and vertical variations in lithologic composition. Results will be ingested into the project database and will be used to inform new models for the excavation/transient crater stage of the impact process.

**Methods:** Drill cuttings from several drill holes along four transects, as well as several drill holes south of the crater, were analyzed as part of this investigation. These transects, consisting of 4 – 6 drill holes per transect, extend from the crater rim in a northwest, northeast, southwest, and southeast fashion (**Figure 1**). Drill holes typically range in depth from several meters to 50 meters [10], with cuttings collected at 0.3 m intervals. For our lithostratigraphic analysis, drill cuttings were sampled every 1.2 m until Moenkopi bedrock was reached. Sample aliquots for each depth interval ranged from 100 - 200 g. In order to obtain representative splits for analysis, samples for each depth interval were first rehomogenized, and then subsampled using the cone-and-quarter method [12]. Representative splits were dry sieved and separated into seven particle size fractions (e.g., U.S. Standard sizes 3 ½ - 140). The four largest particle size fractions were rinsed thoroughly with deionized water, dried under a heat lamp, and re-sieved to remove a fine powder that coats many of the clasts [8,9].

We sorted clasts into their respective lithologies: Coconino sandstone, Kaibab (dolomite, dolomitic limestone, and sandstone), Moenkopi (red siltstone and sandstone), as well as separated lechatelierite fragments from lesser-shocked Coconino sandstone. Modal percentages for each lithology were estimated for the largest sand size particles (i.e., 35). Particles smaller than size 35 were included in calculating the ratio of sand to clasts for each depth interval, however, did not contribute to the ejecta facies. Because particles < size 35 are no longer clasts of rock, but rather individual mineral grains (e.g., quartz grains), there is difficultly in determining their source lithology. Volume measurements for sand were made with dry samples, and clasts were measured through water displacement to account for void spaces.

Ejecta facies are therefore defined based on varying volume percentages of Coconino, Kaibab, Moenkopi, lechatelierite, and impact melt. To be included in a facies unit, lithologies must make up at least 10 vol% of the sample; anything below this value were noted to be present as minor or trace amounts.

**Results:** Using RockWorks software, we generated lithostratigraphic columns and cross sections of the transects (e.g., **Figure 2**). These results will be accessible on the USGS Meteor Crater Sample Collection website:
**http://astrogeology.usgs.gov/facilities/meteor-crater-sample-collection.**

**Discussion:** The southern portion of the ejecta blanket (i.e., southeast and southwest transects, and drill holes 94 and 95) has the highest amount of both impact melt and lechatelierite. Drill hole 45 (southwest of the crater) from 2.4 - 4.4 m depth, comprises ~35 vol% impact melt. Excluding this unique zone, impact melt within this area averages ~1.4 vol% and lechatelierite averages ~0.9 vol% of the analyzed samples. The northern portion of the ejecta blanket, however, has negligible amounts of both impact melt and lechatelierite.

There is mixing of Kaibab and Moenkopi ejecta throughout the majority of the transects. Apart from the southwest transect (from the crater rim to a distance <260 m, there is no mixing observed between these two units), all transects have this zone of mixing, which ranges in thickness from ~1 to 4.3 m. The southwest transect is unique in that it has two zones of mixing, a deeper unit that is similar to the other transects, and a shallow lens. Drill holes that have a shallow lens are located in local depressions, and likely formed as water-laid deposits of material eroded from higher elevations [13].

Drill hole 94 and 95 (south of the crater) have areas of mixing that include all the target lithologies (Kaibab, Moenkopi, and Coconino). Both drill holes have two layers of mixing comprised of all the target rock types, and are separated by a mixing unit of Kaibab and Moenkopi, with <10 vol% Coconino. Coconino fragments present in these two drill holes exhibit textures that represent various shock levels, ranging from coarse-grained and saccharoidal in texture (minimally shocked), to bright white and fine-grained (moderately to strongly shocked).

**Conclusion:** Lithostratigraphic analysis of the drill cuttings has enabled us to begin quantifying the extent of mixing between ejected and minimally to strongly shocked target rocks, impact melt particles, and lechatelierite. The resulting lithologic facies complement the surficial geologic units established by [14] and provide a third dimension to our understanding of the distribution of impact generated materials. Initial results suggest that while the "overturned flap" characterization [15] is appropriate at the >1 m scale for proximal ejecta, the mixed facies (i.e., mixing of impact melt particles, lechatelierite, and minimally shocked material) indicate more complex crater excavation and ejecta emplacement processes for more distal ejecta. These mixed facies are better described as "chaotic" deposits, consisting of material showing a wide range of shock effects, resulting from the interplay of the excavation flow lines of ejected particles with the originally hemispherical shock pressure zones [16,17]. Continuing work includes combining these results with impact melt particle compositions, and assessment of erosion on the internal structure of the ejecta.

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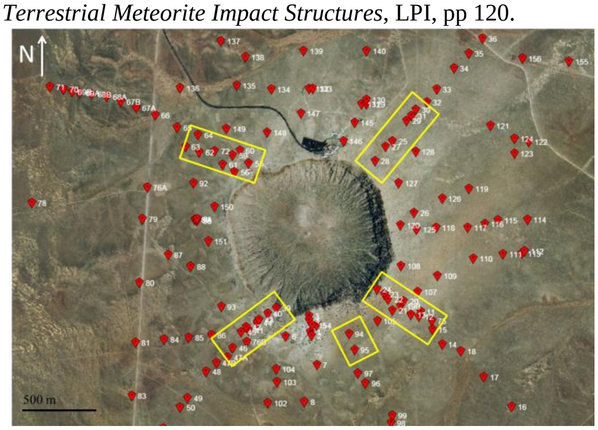


**Figure 1**. Map view of Meteor Crater. Red points show all drill holes. Yellow boxes highlight transects and additional drill holes chosen for study, though not all drill holes within the highlighted transect sections are used for the lithostratigraphic analysis.

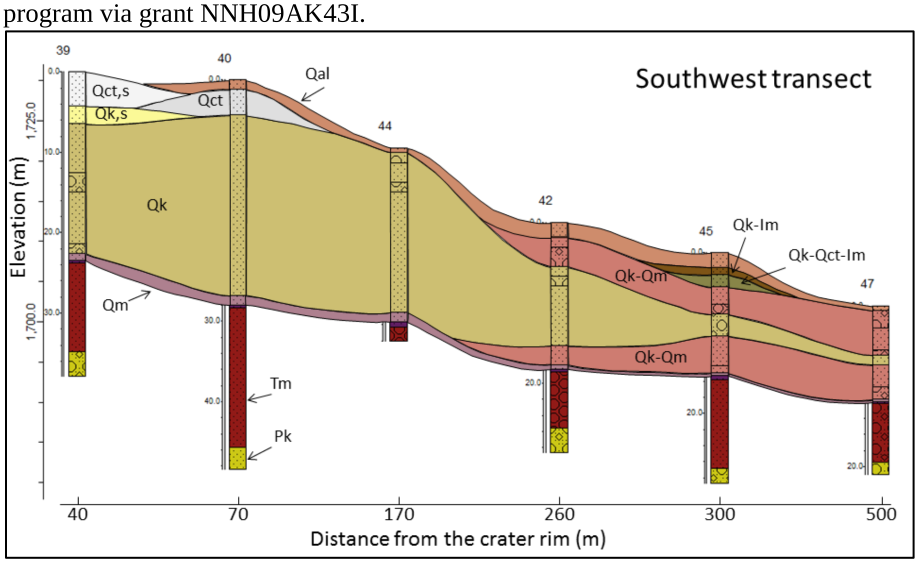


**Figure 2.** Cross section of the southwest transect. Drill hole numbers are located above each individual stratigraphic column. Abbreviations represent facies: Qal = alluvium, Qct,s = strongly shocked Coconino, Qct = ejected Coconino, Qk,s = strongly shocked Kaibab, Qk = ejected Kaibab, Qm = ejected Moenkopi, Im = Impact melt, Tm = Triassic Moenkopi, Pk = Permian Kaibab.