LITHOSTRATIGRAPHIC ANALYSIS OF THE METEOR CRATER EJECTA BLANKET. A. L. Gullikson[1], T. A. Gaither[1], K. A. Villareal[2], and J. J. Hagerty[1], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001, email: agullikson@usgs.gov; [2]School of Earth Science and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ.

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 aspects of the impact melting process, target rock-projectile mixing, siderophile element fractionation trends, and ejecta blanket formation processes, and require further investigation to understand newly identified complexities. 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 contrasting mixture of target rock lithologies, impact melts, and lechatelierite. 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.

Method: Drill cuttings from several drill holes along four transects, as well as a few drill holes south of the crater, are being analyzed. 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 1 ft intervals. For our lithostratigraphic analysis, drill cuttings were sampled every 4 ft 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 size fractions (U.S. Standard sizes 3 ½ - 140). The four largest size fractions were rinsed thoroughly with deionized water, dried under a heat lamp, and re-sieved, due to a fine powder that coats many of the clasts [8,9].

We sorted clasts into their respective lithologies: Coconino, Kaibab, Moenkopi, as well as separated lechatelierite fragments from minimally-shocked Coconino. Modal percentages for each lithology were estimated for the largest sand size particles (i.e., 35). Since particles smaller than size 35 are no longer clasts of rock, but rather individual mineral grains (e.g., quartz grains), we approximated the modal percentages for each size fraction <35 based on the modality of size fraction 35. 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, based on contrasting volume percentages of Coconino, Kaibab, Moenkopi, lechatelierite, and impact melt.

Results: The northwest, southwest, two drill holes from the southeast transect, and two additional drill holes south of the crater (i.e., 94, 95) have been completed. **Table 1** summarizes all the completed drill holes within each transect, highlighting their distance from the crater, as well as ejecta facies within each drill hole and their unit thickness.

Using RockWorks software, we generated lithostratigraphic columns and fence diagrams of the transects that have been completed. Currently, results from the northwest and southwest transects are accessible on the USGS Meteor Crater Sample Collection website.

Discussion: The southwest transect and drill holes 94 and 95 show the highest amount of impact melt and lechatelierite present at an average distance of ~ 300 – 450 m from the crater rim. Impact melt is typically found within the first 5 m of the drill holes and lechatelierite is found down to a depth of 11 m, ~300 m from the rim, and become shallower further from the crater. Drill hole 94 has the largest volume of both impact melt and lechatelierite observed thus far; from 0.5 – 2 m depth there is 8 vol% impact melt and 40 vol% lechatelierite present. At ~4 m, the rock unit comprises 54 vol% minimally shocked Kaibab, 32 vol% impact melt, 12 vol% lechatelierite, and minor amounts of Moenkopi. The northwest transect and the first two drill holes completed for the southeast transect have little to no impact melt or lechatelierite observed.

There is mixing of Kaibab and Moenkopi throughout the majority of the drill holes. The southwest and southeast transects show an average depth of mixing from ~17 – 21 m at a distance of <300 m from the crater. The southwest transect also has a shallow lens of mixing ranging from a depth of 2 – 8 m, >170 m from the crater. At distance of >300 m, the southwest transect and drill holes 94 and 95 have a similar overall unit thickness of Kaibab-Moenkopi; however, 94 and 95 displays a uniform thickness and not two separate lenses. The northwest transect averages 2 – 4 m thick of the Kaibab-Moenkopi unit that begins ~ 13 m deep and ~ 80 m from the rim, and becomes shallower further from the crater.

Conclusion: The LSA of the drill cuttings has enabled us to begin quantification of the extent of mixing between ejected and minimally to highly shocked target rocks, impact melt particles, and lechatelierite. The resulting lithologic facies complement the surficial geologic units established by [13] and provide a third dimension to our understanding of the distribution of impact generated materials. Initial results suggest that while the "overturned flap" characterization [14] is appropriate at the >1 m scale for proximal ejecta, the mixed facies (i.e., mixing of impact melt particles and lechatelierite with 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 [15,16]. Continuing work includes analysis of the SE and NE transects, combining the LSA results with impact melt particle compositions, and assessment of erosion on the internal structure of the ejecta.

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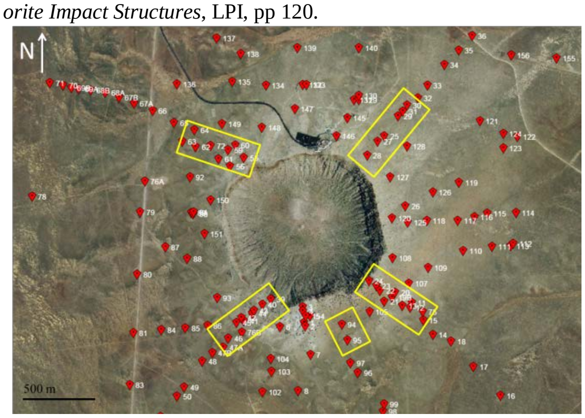

Figure 1. Map view of Meteor Crater. Red points show all drill holes. Yellow boxes highlight transects and additional drill holes chosen for study, though not all drill holes within the highlighted transect sections are used for the lithostratigraphic analysis.

Table 1. Summary table of completed drill holes within each transect.

Transects	Northwest				Southwest						Southeast		Drill holes 94 and 95	
Drill holes	56	60	62	64	39	40	44	42	45	47	24	23	94	95
Distance from the crater rim (m)	80	180	350	450	40	70	170	260	300	500	45	100	300	420
Facies and unit thickness (m)	Qk,s 7.9 Qk 4.5 Qk/Qm 1.2 Qm	Qal 0.3 Qk 0.9 Qk/Qm 4.5 Qm	Qal 0.3 Qk/Qm 4.5 Qm	Qal 0.3 Qk 2.7 Qk/Qm 1.2 Qm	Qct,s 4.3 Qk,s 2 Qk 16 Qm	Qal 1.2 Qct 3.0 Qk 22.5 Qm	Qal 0.6 Qk 20 Qm	Qal 1.8 Qk/Qm 3.7 Qk 10 Qk/Qm 2.4 Qm	Qal 1.8 Qk/IM 0.9 Qk/IM/Lech 1.5 Qk/Qm 3.3 Qk 2.7 Qk/Qm 4.6 Qm	Qal 0.6 Qk/Qm 5.5 Qk 1.2 Qk/Qm 4.3 Qm	Qal 0.9 Qct 5.2 Qk/Qct 4.3 Qk 5.8 Qk/Qm 5.1 Qm	Qal 1.5 Qk 16m Qk/Qm 3.0 Qm	Qal 0.6 Qk/Qm/Lech 7.2 Qk/Qm/Lech/Qct 2.4 Qk/Qm/Qct 1.8 Qk 2.0 Qk/Qm 1.8 Qm	Qal 0.3 Qk/Qm/Lech/Qct 2.4 Qk/Qm 7.9

Qal = alluvium, Qct = Coconino, Qct,s = heavily shocked Coconino, Qk = Kaibab, Qk,s = heavily shocked Kaibab, Qm = Moenkopi, Lech = lechatelierite, IM = Impact Melt, Slash symbol denotes mixture between two or more lithologies.