MULTI-DIMENSIONAL CHARACTERIZATION OF IMPACT EJECTA DEPOSITS FROM METEOR CRATER, AZ.

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Introduction: Meteor Crater is a 180 m deep, 1.2 km diameter, bowl-shaped depression on the southern edge of the Colorado Plateau, located in north-central Arizona [1]. This impact crater is thought to have formed ~50,000 years ago [2,3] by the impact of a 100,000 ton iron-nickel meteorite, roughly 30 m in diameter, which struck at a speed that has been estimated to be anywhere between 12 and 20 km/sec [4,5,6,7]. The crater and surrounding rim have since experienced limited erosion, providing one of the best preserved, young impact craters on Earth [8,9,10].

The impact ejecta blanket for Meteor Crater is thought to have formed when the iron-nickel impactor pierced the surface of the Moenkopi Formation to a depth approximately equal to the diameter of the impactor [11]. At Meteor Crater there are a variety of demonstrated subtleties induced by the ejecta emplacement process [12]. However, the most striking feature of the ejecta blanket is that it consists of a well-defined sequence of inverted target lithologies (e.g., Coconino Sandstone overlying Toroweap Limestone, overlying Kaibab Limestone, overlying units of the Moenkopi Formation [1,8,11]). The internal structure of the ejecta blanket consists of mainly blocky, fragmented beds that are continuous but lie in an inverted stratigraphic order [1]. The incredible continuity of the inverted strata led Roddy et al. [8] to use the term "overturned flap" to emphasize the well-ordered inversion. They used this term to include material outside of the continuous flap, extending out to ~3 crater radii from the center of the crater. Roddy et al. [8] also noted that the overturned flap, and much of the Moenkopi and Kaibab Formations surrounding the crater, were covered by a patchy veneer of fine-grained, Holocene- and Pleistocene-age alluvium, composed largely of reworked, fine-grained debris ejected from the crater.

Background: During the early 1970s, Dr. David J. Roddy led a program of rotary drilling on the rim and flanks of Meteor Crater. The preliminary results of the drilling program, conducted under the auspices of the USGS, are described in Roddy et al. [8] and show that 161 drill holes were completed, and over 2,500 m of drill cuttings were collected. The holes ranged in depth from a few meters to 50 m, and the drill cuttings were sampled on average every 0.3 m. Approximately 72% of those holes were drilled in the over-turned ejecta flap, with the remaining 28% drilled beyond the flap [8,13]. The existing collection, therefore, represents an invaluable source of material that provides geologic context for impact generated lithologies and spans the entire extent of the ejecta blanket.

Unresolved issues remain regarding the nature of Meteor Crater and the associated ejecta deposits, and some of these issues will be addressed through systematic documentation, curation, and dissemination of this unique sample suite, currently housed on the campus of the USGS Flagstaff Science Center.

Curation Effort: In consultation with the USGS Core Research Center and the USGS Geologic Materials Repository, we are in the process of properly curating the Meteor Crater sample collection in an effort to facilitate scientific utilization of, and the broadest possible access to, this invaluable collection. To enhance preservation while increasing access to the collection we are transferring the samples from their previous storage media to durable, long lasting media.

As of December 2010, we have transported all of the Meteor Crater samples into a climate controlled warehouse, obtained heavy duty shelving, created a sorting and display area, established curation procedures and policy, and have transferred approximately 65% of the sample collection to appropriate, long term storage media. In addition to describing the condition of the sample prior to transfer, we have documented each sample's geologic unit designation, the presence of metallic spherules and impact melt fragments, and identified the approximate contact between ejecta deposits and target rock for each curated drill hole.

In addition to our curation efforts, we are addressing specific questions regarding the nature of the Meteor Crater ejecta. We are investigating whether the contact between the ejected and in-situ Moenkopi Formation can be more precisely defined and identified than by Roddy et al. [8,14], who appear to have used the first contact with any Moenkopi material as the contact between the ejecta and the original surface, thus neglecting a portion of the ejecta in their initial volume estimates. Additionally, we are documenting the three-dimensional distribution and compositions of impact melts, metallic spherules, and meteoritic fragments. Detailed studies by Horz et al. [15] and See et al. [16] showed impact melts with a large range of compositions, chemically fractionated projectile-derived Fe-Ni metal alloys and sulfides, and variable olivine and pyroxene compositions. However, most of the previous analyses were conducted on samples that were randomly collected from Meteor Crater. Therefore, we will combine the previously collected data with new data collected from samples with known lateral and vertical context to map the three dimensional distribution of meteoritic components and their compositional variations.

Results: Initial results of our analysis of the vertical extent of the Meteor Crater ejecta deposit and thicknesses of individual units within it are similar to previous calculations; ejecta blanket thickness and average thicknesses of individual units are greatest in the south and southwest directions, and average thickness of the ejecta is approximately 18 m at ~670 m from the crater center. However, we find that the ejecta blanket is thicker in specific locations than has been previously documented.

We used detailed scanning electron microscope (SEM) examinations of thin sections from drill hole #27 to more precisely identify the contact between ejecta deposits and target rock (which we expected to find within the Moenkopi strata, given the "overturned flap" structure of the ejecta). We assessed compositional and textural differences between samples from this drill hole; specifically, the presence or absence of metallic spherules, meteorite fragments, and impact melt fragments within thin sections from ~0.3 m intervals. Meteoritic components are present in the *upper* few meters of this drill hole, as expected; surprisingly, no evidence of meteoritic material was found in any interval of Moenkopi-dominated lower ejecta. This may suggest that the presence or absence of impact melts, metallic spherules, and meteorite fragments cannot be used to precisely identify the contact between Moenkopi ejecta and Moekopi bedrock.

Preliminary SEM analysis of selected impact melt fragments show vesicular, irregular shapes (Figure 1) of variable color (dark brown to gray).

We will further assess textural characteristics and compositions of impact melts and metallic spherules by SEM and electron microprobe analyses, and obtain bulk rock siderophile element concentrations from ICP-MS analyses of representative samples from three drill holes along each transect. These data will be incorporated into a GIS package to create three dimensional compositional maps of the ejecta blanket and to evaluate the spatial effects of elemental fractionation and condensation.

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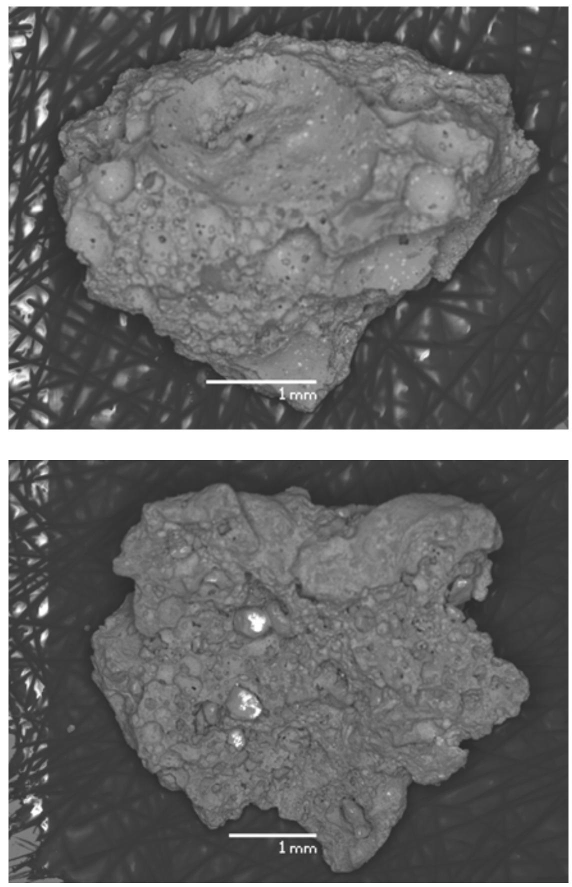

Figure 1. Vesicular, irregularly shaped impact melts from drill holes #63 and #94 .