A NEW REPOSITORY FOR DRILL HOLE SAMPLES AND REMOTE SENSING DATA 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.

Many unresolved issues remain regarding the nature of Meteor Crater and the associated ejecta deposits. Some of these issues can be addressed through analyses of a unique sample suite that provides geologic context for impact generated lithologies and spans the entire extent of the ejecta blanket. This sample suite is currently housed on the campus of the USGS Flagstaff Science Center.

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 (Figure 1) and over 2,500 m of drill cuttings were collected. The cuttings were sampled on average every 0.3 m and placed in sandwich-sized plastic bags that also contain paper slips recording drilling information (depth, hardness, losses) and sample notes. These bags were placed in core boxes that were labeled with the drill-hole number and footage interval. The holes ranged in depth from a few meters to 50 m. Approximately 72% of those holes were drilled in the over-turned ejecta flap, with the remaining 28% drilled beyond the flap (Figure 1) [8,13]. The existing collection, therefore, represents an invaluable source of material (i.e., a unique suite of samples that span the entire extent of the Meteor Crater ejecta blanket) and warrants systematic documentation, curation, and dissemination.

Curation Effort: In consultation with the USGS Core Research Center (CRC) and the USGS Geologic Materials Repository (GMR), 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 part of our sample transfer process, we begin by assessing the quality of the boxes and each of the bags within the box. If each baggie is capable of being picked up without breaking, we remove the bag from the box, open it, and remove the paper slip documenting the drill number, depth, and any drilling notes. We record the pertinent information and document the condition of the sample. If the bag cannot be transferred without breaking, or has already broken, we remove the sample in-situ and do not retain any portion of the sample that has fallen out of the bag or has mixed with other materials in the box.

After recording the sample condition, we obtain a teaspoon worth of representative material for an archival sample set that is stored in a separate building. The archival sample is first placed in a 4 mil polyethylene bag that is labeled with the drill hole number and depth. This bag is then placed in a protective manila coin envelop that is also labeled with the drill hole and depth. The remaining sample from the initial bag is then transferred to larger 4 mil polyethylene bags that have been labeled with the drill hole and depth. We then record the volume of the sample that is contained within each of the polyethylene bags. The bags are placed in new, more durable storage boxes that are labeled with the drill hole and depth interval. All sampling utensils are cleaned with 91% isopropyl alcohol, are dried, and the process starts again.

As of December 2009, 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 15% of the sample collection to appropriate, long term storage media.

Additional Efforts: Upon the completion of our curation effort, we will input all of the inventory information into an electronic, searchable, publicly available database. The information from each georeferenced drill hole, including all documentation and sample data, will then be integrated into a GIS-based digital elevation model (DEM) of Meteor Crater. End-users will be able to click on any geo-referenced drill hole to obtain sample descriptions, photographs, and analytical data for any samples within that drill hole. Users will then be able to submit a sample request via a web based interface. However, we will also make it possible for researchers to come to the Flagstaff Science Center to view the Meteor Crater sample collection. To facilitate access, we will provide a layout table, a dissecting microscope, and sorting supplies, such that guests can view the sample collection and select samples of interest. In the event that a researcher wishes to borrow or analyze a sample, we will use the established methods and rules of the USGS CRC and GMR sampling policy regarding checkout and return of the curated sample. All data collected from the analysis of borrowed samples will be returned to the USGS in electronic form and the data will be subsequently included in a searchable database.

A first generation webpage will be developed that will include the searchable and sortable database, the various GIS layers of Meteor Crater, photographs of each sample box, and a sample request page. Interested researchers will be able to know where their requested samples occur within the ejecta blanket, what sample data are available, and if there is an available thin section or billet to request. This first generation webpage will also include available remote sensing data (e.g., [14]), as well as DEMs, areal photos, topographic contour maps, isopach maps, and the final digitized geologic map of Dr. Eugene Shoemaker. All layers will be viewable through an on-line viewer as well as available for download for further analysis in open and common GIS formats.

Finally, we will leverage the creation of an expansive, searchable, geo-referenced database, currently being created by the USGS Astrogeology Science Center, to make the Meteor Crater inventory searchable and amendable. This will include historical imagery that may be of scientific value as well. For example, after passing through a data review process, external users will be able to post sample and remote sensing data to the database, which will give users point-and-click access to common repository of integrated data for Meteor Crater, AZ.

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Figure 1. Locations of drill holes drilled by Roddy et al. [8] as part of a USGS rotary drilling program. High resolution image courtesy of the Department of Agriculture.