THE USGS ASTROGEOLOGY GEOLOGIC MATERIALS COLLECTION: TERRESTRIAL IMPACT CRATER SAMPLES FOR USE BY THE PLANETARY SCIENCE COMMUNITY.

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Introduction: The Astrogeology Geologic Materials Collection encompasses three individual sample collections (Meteor Crater, Flynn Creek crater, and Shoemaker) whose curation have been previously funded by NASA's PG&G program (2008-2016) or the USGS Data Preservation Program (2014-2016), in order to make these invaluable geologic samples available to the planetary science community. The geologic materials in these voluminous collections include impact crater drill cores and cuttings; unique and irreplaceable geologic hand samples, rock powders, thin sections and associated documentation, from locations of scientific interest around the world. These sample collections are an essential part of the legacies of Dr. David Roddy and Dr. Eugene Shoemaker, both world renowned USGS scientists who were at the forefront of investigations of impact and explosion cratering during the Apollo era and for decades after. The overall goal of this project is to continue curating these collections and provide the planetary science community access to the collections for fundamental research.

Recent advances in numerical modeling and sample analysis techniques have provided new opportunities for investigating materials from these collections, thus making it possible to obtain unprecedented information on issues such as the formation of complex impact crater morphology, impact melting of variable target rock lithologies, mineral shock metamorphism, and impact-induced hydrothermal activity at terrestrial impact craters. Such research on terrestrial samples that are analogues for planetary features is an integral part of planetary science, and these collections facilitate such investigations.

History of the USGS sample collections: *Meteor Crater.* Meteor Crater is a 1.2 km diameter, 180 m deep, bowl-shaped depression 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, approximately 30 m in diameter. The crater and surrounding rim have since experienced limited erosion, providing one of the best preserved, young impact craters on Earth. During the early 1970s, Dr. David J. Roddy led a program of rotary drilling on the rim and flanks of Meteor Crater. 161 drill holes were completed, and over 2,500 m of drill cuttings were collected. The drill 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 [4]. 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.

The Meteor Crater collection consists of 630 boxes of drill cuttings (from 161 drill holes in the ejecta blanket) and 30 boxes of drill core (from unshocked target rock).

Flynn Creek Crater. Flynn Creek crater is a ~3.8 km diameter, >200 m deep, flat-floored impact structure that formed ~360 Ma in what is now north central Tennessee [5-8]. Between 1967 and 1979, David Roddy conducted a drilling program at Flynn Creek crater. The drilling program produced more than 3.8 km of nearly continuous core from 18 separate bore holes [9]. Roddy's studies at Flynn Creek crater during the 1960's and 1970's laid the groundwork for understanding structural deformation during marine target impact crater formation, but the cores have remained inaccessible and unstudied since that time. These samples are now contained in 2,621 standard core storage boxes at the USGS in Flagstaff, Arizona.

Flynn Creek crater is of considerable scientific interest to planetary science because the impact-induced hydrothermal system at Flynn Creek crater may have implications for the origin and evolution of life on early Earth [10-11], and possibly on Mars [12-14]. At PCC 2017, Gullikson et al. [15] will present recent microthermometry results using samples from the Flynn Creek collection.

Shoemaker. The USGS Shoemaker Collection is an essential part of the legacy of Dr. Eugene Shoemaker, whose pioneering work in the 1960's established the new field of astrogeology, including shock metamorphism studies, impact crater modeling, and stratigraphic relations on other planetary bodies. Among his many other scientific accomplishments were the development of dating planetary surfaces using impact crater size distributions, training Apollo astronauts in geologic field methods at Meteor Crater, and co-discovering Comet Shoemaker-Levy 9, which impacted Jupiter in 1994.

The USGS Shoemaker Collection consists of unique and irreplaceable geologic hand samples, rock powders, thin sections and billets, and associated documentation, from locations of scientific interest around the world. These materials are currently housed in a variety of locations on the USGS Flagstaff Science Campus (FSC). Since Dr. Shoemaker's passing in 1997, these materials have been moved, separated from each other and their documentation, and stored in less than ideal conditions in metal shipping containers (i.e., seavans). We have begun a data rescue, preservation, and inventory project to move the samples into long-term appropriate storage facilities and compile a detailed database of the geologic materials for use by the scientific community. The Shoemaker collection, for which curation has only begun last year, consists of approximately 200 boxes with ~30 hand samples (or ~1 liter container of rock chips or powders) per box, for an approximate total of ~6,000 individual specimens. The samples are from a variety of locations. Impact crater rocks are from Meteor Crater (AZ), Flynn Creek Crater (AZ), Sierra Madera Crater (TX), Steinheim Crater (Germany), and several craters in Australia. Of special interest to planetary science are nine bags of fallback ejecta from the Meteor Crater interior. Also in the collection are igneous, sedimentary, and metamorphic rocks from the San Francisco Volcanic Field, the Colorado Plateau, Alabama, and other locations throughout the U.S. The scope of this project is to rescue these samples from their current inadequate storage, inventory and describe the samples in an electronic (Excel-based) database, photograph the most interesting specimens, and build a website that provides access to the samples.

Community Access: Given the modern financial and logistical difficulties inherent in conducting thorough sampling or drilling campaigns at impact craters and other terrestrial analogue sites, the continued curation of the Meteor Crater and Flynn Creek crater sample collections, as well as the rescue and curation of the Shoemaker materials, maximizes the prior financial and scientific investment of NASA and the USGS. We are providing access to the Astrogeology Geologic Materials Collection for the scientific community via our Astrogeolgy website, which has a web-based portal and online database for each collection. The electronic, searchable, publicly available websites and databases allow interested researchers to explore the variety of samples and data, and request samples for their own investigations. The websites feature interactive maps of Meteor Crater and Flynn Creek crater, with links to the drill core documentation and databases, a downloadable ArcGIS package, and sample request forms, such that researchers may identify, request, borrow, and utilize samples and data. The Shoemaker website is currently under construction.

The websites may be accessed using the following URLs:

http://astrogeology.usgs.gov/facilities/meteor-crater-sample-collection

https://astrogeology.usgs.gov/facilities/flynn-creek-crater-sample-collection

https://astrogeology.usgs.gov/facilities/shoemaker-sample-collection

References: [1] Shoemaker E.M., and Kieffer S.W. (1974) Guidebook to the geology of Meteor Crater, Arizona, Publ. 17, 66 pp; [2] Nishiizumi K., et al. (1991) Geochim. Cosmochim. Acta, 55, 2699; [3] Phillips F.M., et al. (1991) Geochim. Cosmochim. Acta, 55, 2695; [4] Roddy D.J., et al. (1975) Proceedings of the Sixth Lunar Science Conference, 3, 2621; [5] Roddy, D.J. (1977a) Impact and Explosion Cratering, Pergamon Press, New York, 125-161; [6] Roddy, D. J. (1977b) Impact and Explosion Cratering, Pergamon Press, New York, 277-308; [7] Evenick, J. C. (2006) Field Guide to the Flynn Creek Impact Structure. Knoxville: University of Tennessee. 22 pg; [8] Wilson, C.W., and Roddy, D.J. (1990), Geologic map and mineral resources summary of the Gainesboro quadrangle, Tennessee: Tennessee Division of Geology, GM 325-SW, Scale 1:24,000; [9] Roddy, D.J. (1979b) 10th LPSC, Abstract #1361. [10] Zahnle, K.J. and Sleep, N.H. (1997) Impacts and the early evolution of life, in Comets and the Origin and Evolution of Life, edited by P. J. Thomas et al., pp. 175-208, Springer-Verlag, New York; [11] Kring, D.A. (2000) GSA Today, 10(8), 1-7; [12] Newsom, H.E. et al. (1996) JGR, 101, 14951-14956; [13] Schwenzer, S.P. et al. (2012) EPSL, 335, 9-17; [14] Abramov, O. and Kring, D.A. (2005) JGR, 110, E12S09, doi:10.1029/2005JE002453; [15] Gullikson, et al. (2017) PCC abstract.