PROJECTILE DISSEMINATION IN IMPACT MELTS FROM METEOR CRATER, ARIZONA. D.W. Mittlefehldt, T.H. See, C23, Lockheed ESC, 2400 NASA Rd 1, Houston, TX 77058; and F. Hörz, SN2/Planetary Sciences Branch, NASA/Johnson Space Center, Houston, TX 77058

Siderophile element abundances of impact melts have been used to identify the impactors responsible for terrestrial impact craters [1] and lunar basins [2]. However, little is known about elemental fractionations that might occur as a result of the extreme transient pressures and temperatures achieved during impact processes. At several young terrestrial craters, both impact glass and meteoritic debris can be collected, allowing detailed geochemical and petrologic study of target, impactor and impact melt. We have previously applied petrologic and geochemical techniques to the study of materials from the 90 m diameter Wabar Crater [3]. Here, we extend these studies to target rocks and impact glasses from the 1200 m diameter Meteor Crater, Arizona. Special emphasis was placed on genuine impact melts by selecting apparent holohyaline, irregular fragments or spherical beads a few mm across (courtesy of C.B. Moore, Center for Meteorite Studies, Arizona State University). Such melts, especially aerodynamically shaped beads, contained the highest concentrations of elements derived from the impactor at Wabar [3]. Genuine impact melts seem relatively rare in the ejecta of Meteor Crater, as opposed to highly shocked, melt-rich clasts of target rock [4]. In addition, we obtained unshocked samples of Kaibab limestone and Coconino sandstone, and a shocked Coconino clast. This is a preliminary report, as all analyses have not yet been completed.

**Meteor Crater.** Meteor Crater was formed ~49,000 years ago [5] by the impact of the Canyon Diablo IA iron meteorite. The stratigraphy at Meteor Crater [6] is, from top down, Moenkopi Formation (<20 m, sandstone, siltstone), Kaibab Formation (80-95 m, sandy dolomite, dolomitic limestone), Toroweap Formation (2-3 m, calcareous sandstone, siltstone), and Coconino Formation (220 m, sandstone). The crater may or may not have bottomed in the upper few meters of the Supai Group (argillaceous sandstone, siltstone) [7].

**Sample Description.** The irregular melt fragments are brown to black, highly vesicular glass particles ~10x20 mm in size which contain a few mm-sized clasts. The spherical beads are brown to black vesicular glass ~5 mm in diameter. The spherical beads are hollow, with central cavities up to about half the diameter of the sphere. Fine-grained "weathering products" occur throughout the particles in vesicles. This material was ubiquitous throughout the glass, and we were unable to rigorously exclude it from the analyzed samples. We have not yet determined the nature or origin of this material.

**Petrology.** In thin section, all melt samples possess schlieren, clasts of highly variable sizes, and numerous opaque droplets of disseminated projectile material. The latter are in unexpectedly high concentrations compared to other impact melts [8]. To date, only a limited number of electron microprobe analyses have been performed on irregular melt specimens. These melts consist predominantly of SiO₂ (39.5 wt%), FeO (27.5%), CaO (15.5%), MgO (10%), Al₂O₃ (2.5%) and Ni (1.7%), while Na₂O, K₂O, TiO₂, Cr₂O₃ and MnO occur in concentrations of <1 wt % combined. These limited data are suggestive of considerable meteoritic contamination or mixing of the Fe-Ni projectile with the various rock types present in the target stratigraphy. The high CaO and MgO values indicate a considerable contribution from the dolomitic Kaibab Formation, and possibly the calcareous Toroweap Formation, while the SiO₂ content establishes the contribution of the siliceous Moenkopi and Coconino Formations. Following major- and minor-element analyses of the target rocks and other Meteor Crater melt specimens we will attempt to determine the contributions of various components via mixing models.

**Geochemistry.** Two samples of unshocked Coconino, one shocked Coconino, three irregular melts and one spherical bead have been analyzed to date by instrumental neutron activation analysis for a suite of lithophile and siderophile elements. Most lithophile elements are enriched in the impact melts relative to unshocked Coconino by 2-3x. The most glaring exception is CaO, which is enriched ~130x in the melts compared to unshocked Coconino. The high CaO contents of all bulk impact glasses (~7-13 wt%) support our limited electron microprobe data indicating mixing of the calcareous members of the target stratigraphy in the melts. This may be the source of generally elevated lithophile elements as well.

As expected, siderophile elements in the impact glasses are enriched over those in the Coconino sandstone. (Analysis of Kaibab limestone is in progress). Coconino sandstone contributes <1% of the Fe, Co, Ni and Ir in irregular melts and spherical beads. About 2% of the Au in irregular melts can be derived from Coconino, and about 9% of the Au in the spherical bead. Coconino can contribute 8-16% of the As and between 40-60% of the Sb and W. Because of variability of As, Sb and W in Coconino, and their unknown concentrations in other target lithologies, the contributions of the target to these elements in the impact glasses...
are uncertain. It is likely that Fe, Co, Ni, Ir and Au are dominated by the impactor. Based on the INAA data and mean Canyon Diablo meteorite [9], average irregular melts contains ~19% meteoritic material, while the spherical bead contains ~24%. These are unusually high concentrations of projectile material for impact melts [1,2] and higher than the extreme enrichment of 17% estimated for a Wabar melt bead which we deemed exceptional [3].

**Discussion.** The levels of meteoritic material in glasses from Meteor Crater are considerably greater than observed at other craters. The average of Wabar small beads indicates about 11% meteoritic material based on Fe and Co [3]. At Wolfe Creek Crater, the maximum meteoritic component in "impactites" is ~11%, while at Henbury Crater, the meteoritic component is <1% [10]. Only relatively few "impactites" have been analyzed at these latter two craters and descriptions of the "impactites" are not given.

Figure 1 compares the siderophile element patterns normalized to the impactor for Meteor Crater and Wabar Crater impact glasses. For W, Au, Sb and As, corrections have been made for contributions from the target rock. Meteor Crater glasses exhibit a siderophile element pattern distinct from those of Wabar Crater samples. At Wabar Crater, those siderophiles that are negligibly contributed by the target rock show a distinctly fractionated pattern with Ni, Au and Ir depleted relative to Fe and Co ([3] and Fig. 1). In contrast, the Meteor Crater samples have an unfractonated pattern, except for depletion in Au (Fig. 1). The Au depletion at Meteor Crater cannot be due to uncertainty in the Au content of the target rock. This indicates that Au is selectively fractionated relative to the other siderophiles at Meteor Crater. The variable enrichments and depletions of W, Sb and As in the Meteor Crater samples may potentially be due to uncertainties in corrections for indigenous contribution. We will only be able to evaluate this after further measurements of target rocks.

**Conclusions.** We find substantial differences in the fractionation trends of siderophile elements in impact melts from Wabar and Meteor craters. Both were caused by iron meteorites impacting sandstone dominated targets, although Meteor Crater contains a substantial carbonate component as well. It is tempting and plausible, yet nevertheless speculative, to postulate that different impact velocities could be the cause. Regardless, our results indicate that great care is needed in properly interpreting impactor properties from siderophile element abundances in impact melts, or in suggesting that a single, simple, mechanism may dominate fractionation processes during hypervelocity impact.