WERE CARBONATE IMPACT MELTS PRODUCED FROM THE CARBONATE-RICH TARGET LITHOLOGIES AT METEOR CRATER, ARIZONA? Ana Cernok[1] and David A. Kring[2], [1]Dept. Lithospheric Research, University of Vienna, Vienna, Austria (ana.cernok@gmail.com), [2]USRA-Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (kring@lpi.usra.edu).

Introduction: In simple impact craters like Barringer Meteorite Crater (aka Meteor Crater), very little molten material was generated. There are no detectable melt ponds within the breccia lens or any significant melt pools on the crater walls or in the ejecta blanket. There was either an insufficient volume of melt produced by the impact event and/or it was too finely disseminated, possibly because the relatively high volatile content of the target rocks dispersed the melt as ash [1]. The target sequence is composed of sandy carbonates (Kaibab Fm.) and carbonate-bearing siltstones (Moenkopi Fm.) and sandstones (Toroweap and Coconino Fms.). Previous work by Hörz and others [2] demonstrated that melting occurred dominantly in the sandy carbonate portion of the section, producing siliciate melts that were thoroughly degassed of CO_2. On the other hand, two more recent, albeit preliminary, reports suggest carbonate melts were produced [3,4]. To test the concept of carbonate impact melts and to assess their abundance at Meteor Crater, we analyzed two suites of samples: (i) the ashy matrix of fall-back breccia from inside the crater and (ii) cm-scale melt particles that were ejected from the crater.

Methods: Standard optical microscope technieques were used to establish petrographic relationships. The fine-grained matrix of fallback breccia was examined with imaging and EDS capabilities of a JOEL 50 SEM, while ejected melt particles were examined with imaging and WDS capabilities of a CAMECA SX-100 electron microprobe. Both instruments are at NASA JSC.

Interior Crater Breccia: The interior breccia lens of the crater is composed of an allogenic breccia and an overlying fall-back breccia [5]. We sampled the latter, because it contains the airborne ejecta that may have entrained any ashy carbonate melt. This unit contains all of the target lithologies, including shocked varieties like lechatellierite, and meteoritic debris. We sampled a classic outcrop exposed on the north crater wall (Fig. 15.4 of [4]). The fine-grained matrix is dominantly less than 5 µm in size (Fig. 1a and b). It is composed of angular to sub-rounded quartz grains (Fig. 1c) and minor K-feldspar and calcite. The only hints of melt are rare shards of silica that are either fractured quartz or glass (Fig. 1d), but not carbonate.

Exterior Crater Ejecta: We re-examined a pair of melt particles briefly described by [4] that are 0.9 and 0.7 cm in size. Like the melts of [2], these two particles cooled quickly, producing an aphanitic assemblage of olivine (Fo_{48}) and pyroxene ($Wo_{40}En_{25}Fs_{35}$). The melts entrain a few relict quartz grains and are perforated by vesicles ranging from less than 100 µm to 1 mm as a result of complete CO_2 degassing.

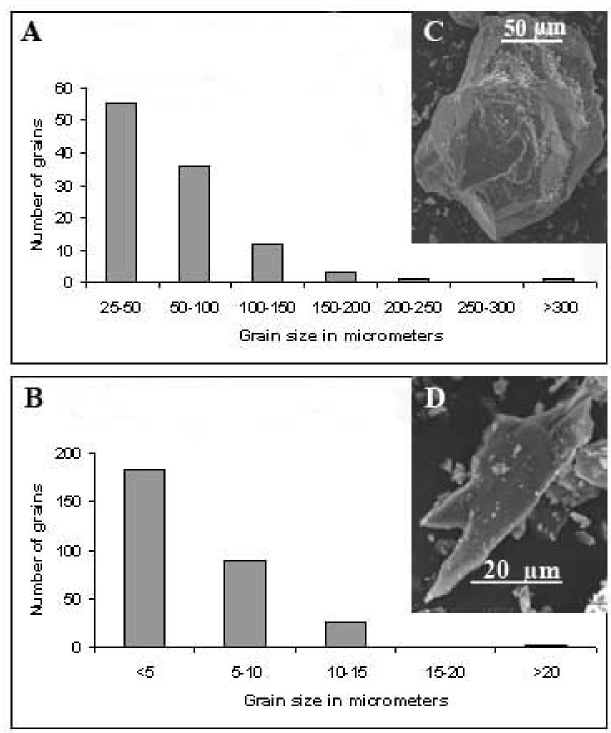

Figure 1: Grain size distribution of breccia matrix. A) Grain size distribution on 500 µm scale; B) Grain size distribution on 20 µm scale; C) SEM image of dominating sub-rounded quartz crystal; D) SEM image of irregular silica shard.

In the case of particle MC-Hxx4, a smoothly shaped edge of the silicate melt is coated with a 3 mm long and 1 mm wide carbonate phase (Fig. 2). No distinct oxidation rim is recognizable on this silicate edge. The carbonate–silicate contact is sharp and fine-grained pyroxene crystals do not show any change in shape or size near the contact with the carbonate rind. A distinct 250 µm width zone can be observed on the carbonate side of silicate–carbonate contact. This zone incorporates very fine calcite crystals, dolomite, melt particles, sub-rounded quartz, and a few grains of K-feldspar. The MC-Hxx7 particle is coated on one side with a 7 mm-long and 1 mm-wide carbonate layer.

In both samples, quartz is more abundant in the carbonate coating than in the mafic silicate melt. Its appearance, however, does not vary in these two phases. Quartz is about 100 µm long, sub-rounded, spherical to elongated, very fresh, and has mostly undulatory extinction. No cracks, mosaicism, planar fractures, planar deformation features, or other shock indicating patterns were observed. In the case of MC-Hxx4, quartz grains are more abundant closer to the carbonate–silicate contact than in the rest of the carbonate phase. In general, quartz is much more abundant in the MC-Hxx7 carbonate phase. A few fresh, subhedral and sub-rounded grains of K-feldspar were found in the carbonate phase of both samples. These grains do not contain any shock indicators either. No K-feldspar grains were found in the silicate melt. Calcitic material varies in size significantly. Sometimes it forms fine-grained rosettes, but isolated grains of dolomite and calcite, usually anhedral and ~40 µm in size, are distributed throughout the layers.

Comparison to Caliche. At Meteor Crater and other nearby geologic localities, carbonate caliche sometimes coats lithologies. To determine if the features described above could be caliche rather than melt, we conducted a comparative study of caliche on target sandstone and red siltstone. Cobbles were collected from the ejecta blanket. Caliche (300 to 500 µm thick) on sandstone is composed of a zone of quartz with calcite rims adjacent to the sandstone, beyond which is an outer zone of quartz grains embedded in fine-grained porous calcite. Caliche on carbonate-bearing siltstone is composed of a few-micron-wide irregular layer of pure calcite, followed by a wide (~300 µm) zone of porous calcite mixed with phyllosilicates that entrain isolated grains of quartz and calcite (like that in the underlying siltstone). Neither resemble the unit seen in Fig. 2.

We also examined caliche on the nearby Basalt of Lava Point, because the underlying protolith more closely resembles impact melt particles. In this case, calcite forms thick rims around quartz and K-feldspar particles and penetrates fractures into the basalt. In one location the calcite forms rosettes, reminescent of those in MC-Hxx4, but the overall texture is unlike that on the impact melt particles.

Discussion: Smoothly-shaped and vesicle-free edges of the silicate impact melts that are in contact with the carbonate coatings indicate that no vesicles were formed in that contact zone and that two phases, mafic silicate and carbonate, quenched at the same time. Also, quartz grains that are incorporated inside both the carbonate phase and the mafic melt suggest coeval origin of the two phases. The appearance of fresh and not-well-rounded quartz grains implies that no intensive erosion or transport had taken place before these grains were incorporated into the melt matrix. Collectively, these are unique textures not produced by other processes like caliche formation.

Conclusions: The work of Hörz et al. [2] imply that sandy carbonate in the target rocks was melted and that CO_2 was largely degassed. The lack of any carbonate melt particles in the ashy matrix of fall-back breccia support this conclusion. However, rare examples of carbonate melt appear to coat some degassed melt particles in ejecta. The carbonate-dominated melt coatings apparently just reached melting conditions and was quenched before CO_2 could be degassed. Thus far, there is no evidence to suggest large volumes of this type of CO_2-bearing melt exists at the crater, implying that the bulk of the melted target carbonate was degassed and quenched to mafic silicate melts.

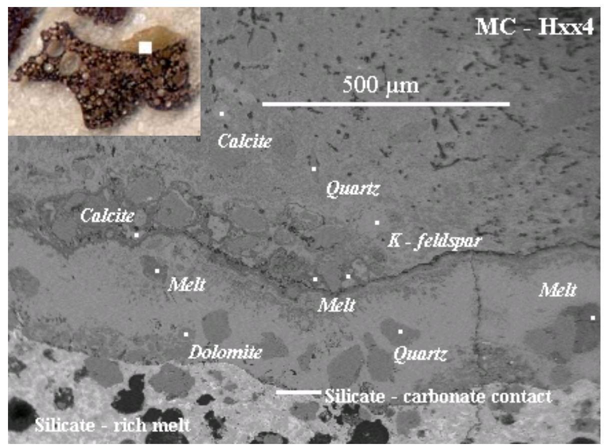

Figure 2. Backscattered electron image of the carbonate-rich coating (bulk of image) on a silicate melt particle (bright unit along bottom of image) on particle MC-Hxx4. The inset shows a plane-light view of the entire particle.

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