IMPACT MELT FROM THE LUNAR CRISIUM MULTI-RING BASIN. P.D. Spudis[1] and M.U. Sliz[1, 2] 1. Lunar and Planetary Institute, Houston TX 77058 (spudis@lpi.usra.edu); 2. School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester M13 9PL, UK

The formation of multi-ring impact basins on the Moon produces thousands of cubic kilometers of shock-created melt [e.g., 1]. This melt is largely concentrated inside the basin, although some is ejected along with the clastic materials that make up most of the continuous ejecta blanket that surrounds basins [1, 2]. Impact melt is important because it contains information on the crustal target for basins as well as being the most suitable material to date basin-forming events. Geological mapping of the Orientale [3] and Imbrium [4] impact basins have documented the presence of deposits of impact melt. We have completed new geological mapping of the Crisium basin [5] and have found likely remnants of the melt sheet from that basin impact as well. We document the occurrence of Crisium basin melts and estimate their composition and will use these results to better understand lunar crustal composition and the basin-forming process.

Morphological criteria for the recognition of impact melt deposits. Impact melts have distinct and well-defined morphologic features that permit their recognition from images [2,6]. Typically, melt is found on the floors of fresh craters, showing fissured, cracked and ponded surfaces. Melt deposits form pools and flows in the walls and rims of complex craters [6,7] and are sometimes found at large radial distances from the crater rim, where melt can make up flows that appear to have segregated from the clastic debris. The great age associated with impact basins means that most pristine morphologies have vanished from impact erosion and burial by subsequent units, but the youngest basins preserve portions of their original morphology [3, 4]. Exposed melt deposits in these features help us to interpret the nearly obliterated and buried melt deposits of Crisium. For each melt deposit, we have collected compositional data from Clementine multi-spectral images [8] and Lunar Prospector gamma-ray data [9], allowing us to estimate their chemical composition and assess any variability. These observations and compositional data were then evaluated against physical models for the generation of impact melts [6,7,10].

Orientale and Imbrium basins. The Orientale basin (930 km diameter) is well preserved and only partly flooded by later mare basalts. The basin interior melt sheet is represented by the Maunder Formation (Fig. 1), a smooth-to-cracked surface unit that covers the innermost basin ring [1-3]. The Maunder Fm. as is remarkably uniform in composition, with no evidence of any differentiation [3]. Portions of the Montes Rook Fm., defined primarily by its knobby texture, appears to have flowed in some locations [3] and may consist at least in part of a substantial amount of impact melt [11]. In addition, two localized deposits (each about 5-10 km in extent) appear overlying the Cordillera basin scarp. These deposits display cracked surface morphology and are likely ponds of impact melt.

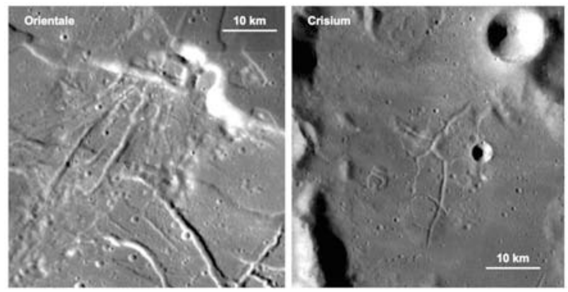

Figure 1. Comparison of surface texture of Orientale basin Maunder Fm. (left) and cracked and fissured floor deposits of the Crisium basin (right). The Crisium deposit is a highland kipuka, embayed by mare basalt on all sides, and have highlands spectral and chemical compositions.

The slightly larger (1160 km diameter) and older Imbrium basin is filled with mare basalt lava, concealing most of the basin floor. The Imbrium basin rim (Apennine ring) displays extensive slumping near Mons Bradley (20.8°N, 2.3°W) on top of which occur pools of fissured and cracked deposits. These features have been interpreted as Imbrium basin impact melt [2]. At one time, the planar Apennine Bench Fm. (26°N, 2.5°W) had been thought to be the Imbrium equivalent of the Orientale Maunder Fm., i.e., the impact melt sheet of the Imbrium basin [12]. However, pristine volcanic KREEP basalt found at the nearby Apollo 15 landing site are likely to be pieces of this material and thus, the Apennine bench Fm. is probably early volcanic infilling of the Imbrium basin [13].

Impact melt deposits of the Imbrium basin contrast strongly in composition with their Orientale counterparts, being more mafic (Fig. 2). Typical Imbrium melt has FeO between 8 and 10 wt.%, significantly higher than the 4-5 wt.% of Orientale Maunder Fm. and the small ejected melt ponds. The Imbrium basin melts fall broadly within the field defined by the Fra Mauro Fm., the predominantly clastic ejecta blanket of the basin. These results indicate that the target rocks for the Imbrium basin impact were distinctly different from those of the Orientale basin, consistent with its position within the Procellarum geochemical province.

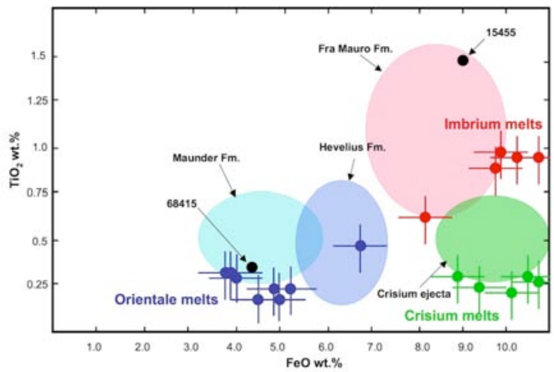

Figure 2. Composition of Orientale (blue), Imbrium (red), and Crisium (green) basin impact melt deposits (after [4]). Apollo impact melt samples [14,15] shown by black dots.

Crisium basin impact melt. During geological mapping of the basin [5], we identified a small deposit of fissured and cracked material at the base of the mare-bounding ring of Crisium at 15.2°N, 50.2°E (Fig. 1). Subsequent mapping identified additional exposures of this unit elsewhere within the basin (Fig. 3). The deposits are embayed on all sides by mare basalt, but are exposed at the surface, with little (if any) mare cover evident. They have moderately low FeO content (8-10 wt.%) and highland pyroxene compositions (opx, *not* cpx). On the basis of their morphological similarity to the fissured facies of the Maunder Fm. (Fig.1), we interpret this unit as exposed remnants of the Crisium basin impact melt sheet, presumed to lie beneath the basalts of Mare Crisium. All exposures occur in topographically high areas adjacent to the basin massifs. This relation suggests that a continuous melt sheet exists at depth within Crisium basin, covered by basalt and exposed only near the margins of the maria.

Chemical compositions of the newly identified Crisium basin melts and comparison with the previously mapped melt deposits for Orientale and Imbrium [4] are shown in Fig. 2. The impact melt within a given basin tends to be chemically similar and of broadly highland basaltic composition, although significant differences exist among the different basins. Crisium melt appears to be more mafic than Orientale basin melt, but not as Ti-rich as the impact melt from Imbrium basin. These data support the notion that basin impact melt sheets are (more or less) homogeneous from a single event, but may vary widely among basins, depending upon the regional composition of the basin crustal target.

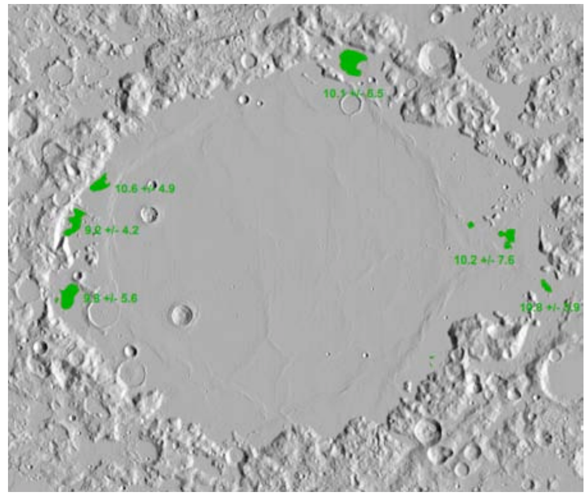

Figure 3. Map of the newly recognized impact melt deposits inside Crisium basin. Numbers are FeO content in wt.% from Clementine iron maps [8].

Conclusions. We have identified remnants of the impact melt sheet of the Crisium basin, a Nectarian age feature thought to have been completely buried by mare flooding. The melt from this impact is similar in composition around the basin but distinct from the melt deposits of both the Orientale and Imbrium impact basins, with Orientale being the most feldspathic (noritic anorthosite), Imbrium being more mafic and gabbroic (highland basalt) and Crisium having similar iron but less titanium than Imbrium. The identification of these melt features offer the possibility of obtaining basin impact melt samples of reasonably certain provenance by robotic sample return missions. Such samples could answer many questions about lunar composition, processes and cratering history.

References. [1] Spudis P.D. (1993) *Geology of Multi-Ring Basins*, Cambridge Univ. Press, 263 pp. [2] Wilhelms D.E. (1987) USGS **PP 1348**, 302 pp. [3] Spudis P.D. et al. (2014) *JGR* **199**, 1. [4] Spudis P.D. and Murl J.N. (2015) *LPS* **46**, 1853. [5] Sliz M.U. and Spudis P.D. (2016) this volume. [6] Howard K. and Wilshire H. (1975) *J. Res. USGS* **3**, 237 [7] Hawke B.R. and Head J.W. (1977) *Impact Explosion Cratering*, Pergamon, 815. [8] Lucey P. et al. (2000) *JGR* **105**, 20297. [9] Lawrence D. et al. (2007) *GRL* **34**, 3. [10] Phinney W. et al. (1977) *Impact Explosion Cratering*, Pergamon, 771. [11] McCauley J.F. (1977) *PEPI* **15**, 220. [12] McCauley J.F. et al. (1981) *Icarus* **47**, 184. [13] Spudis P.D. (1978) *PLPSC* **9**, 3379. [14] 68415 data sheet, JSC [15] Ryder G. and Bower J. (1977) *PLSC* **8**, 1895.