A COMPARISON OF SOME LUNAR BASIN IMPACT MELT COMPOSITIONS. Paul D. Spudis, Lunar and Planetary Institute, USRA, Houston TX 77058

Large impacts create shock melted and vaporized material that later lines the cavity of the crater; after formation, this shock melt pools into a sheet of molten material that makes up the floors of large craters. The largest craters on the Moon, multi-ring basins, have melt sheets with volumes of hundreds to thousands of cubic kilometers [1,2]. Basin melt sheets are of interest because they are formed during the largest impacts and contain information about the composition of the pre-impact crustal targets and how they vary over regional distances. Additionally, it has been proposed that the melt bodies generated by the largest impacts may remain molten for a long time and differentiate into a layered complex [3]. To test some of these ideas, we have been re-mapping the deposits of some selected lunar basins around the Moon with the object of identifying their geological properties, including the distribution and composition of basin impact melt. Here, I report on some preliminary conclusions regarding the melt compositions of 7 basins on the Moon, distributed widely over the lunar surface and having a variety of sizes and ages.

Basin floors and melt deposits. Basin impact melt sheets have distinct morphology, as exemplified by the nearly unmodified Orientale basin [2]. However, Orientale is unique in that it is both the youngest major basin and is also only partly flooded by later mare basalts. Most basins are more difficult to interpret, being older and thus degraded in appearance and modified by later events, either flooding by mare basalt or overlain by deposits of other large craters and basins. It is widely assumed that basins initially possessed a floor lined with the impact melt produced during its formation [1,4-5]. The principal question is to what extent has that floor been obscured or modified by subsequent events. The basins studied here are all modified to some degree, but I mapped areas on the floors of these features that appear to be least affected by other geological units.

Based on morphology and position, remnants of the original melt sheet are exposed in the Orientale [6], Imbrium [7], and Crisium basins [8]; its presence is inferred at Nectaris [9]. For these features, new mapping has revealed the extent of likely melt sheet deposits and remote sensing data allow us to estimate their chemical make up. For other basins, distinct morphological textures are not evident and the assumed equivalence of basin floor to basin melt sheet is more problematical. Three lines of evidence suggest such an association is valid: 1) floor material can still be clearly distinguished from other units in the basins studied [10]; 2) these areas are unflooded by maria and appear to be unmodified by other regional units, such as crater ejecta or pyroclastic deposits [8]; 3) the materials occur within the basins studied at the same position, location and relation to other units at which a melt sheet is clearly visible at younger, unmodified basins, suggesting that a melt sheet provenance is likely [6,11]. However, given these uncertainties, conclusions are drawn with caution.

Results. Data for the composition of the floors/melt sheets of seven basins are given in Table 1 and Figure 1. Basin floors vary widely in composition from the very feldspathic (Humboldtianum, Nectaris, Orientale) to the relatively mafic (Imbrium, Moscoviense, Smythii). There is no obvious correlation with basin floor/melt sheet composition and geographic location on the Moon (e.g., inside or outside of the Procellarum geochemical province [12]). On the basis of the average compositions of their clastic (ejecta) deposits, basins occurring within feldspathic highlands terrane [12] such as Smythii and Moscoviense might be expected to possess relatively feldspathic ejecta and impact melt. As seen in Table 1 and Figure 1, both of these basins do display highly feldspathic exterior ejecta deposits, but relatively mafic floors, with FeO contents over twice that of the exterior ejecta. That this is not some generalized phenomena is shown by the compositional relations seen at both the Humboldtianum and Orientale basins, which have both feldspathic ejecta and floor deposits (Table 1; Fig. 1). In addition, both the Imbrium and Crisium basins have (more or less) matching mafic compositions to their ejecta and floor/melt sheet materials.

Discussion. Most large craters on the Moon display some degree of compositional homogeneity, except in areas where the impact targets possess extreme diversity (e.g., Aristarchus, [13]). As impact size increases, it is perhaps reasonable to expect more diversity in the composition of both ejecta and the feature's associated impact melt. Some basins appear to have very similar composition to both their clastic and melt components, whether both are dominantly feldspathic (e.g., Orientale) or dominantly mafic (e.g., Imbrium). Two of the studied basins appear to be different. Both the Moscoviense and Smythii basins seem to possess relatively mafic floors (and thus, probably mafic melt sheets) yet in both cases, their exterior deposits are quite low in FeO – in each case, their exterior ejecta are even more feldspathic than those of Orientale basin. Yet their floors are similar in composition to that of Imbrium melt (Fig. 1).

There is no obvious explanation for this relation, except possibly for one factor. In the case of both the Smythii and Moscoviense basins, recent gravity data from the GRAIL mission indicate that dense rocks, probably ultramafic rocks derived from the lunar mantle, are present at very shallow depths beneath each basin floor [14]. In fact, crustal thickness is estimated to be less than 1 km under the floor of the Moscoviense basin [14]. It is possible that a relatively feldspathic melt sheet has been mixed with underlying ultramafic rocks beneath the basin floor to produce a slightly mafic melt sheet. The crust beneath the Smythii basin is also very thin (less than 10 km), vertical mixing of a mafic sublayer might also explain that relation. However, in the case of both basins, extensive pyroclastic eruptions have occurred around the periphery of the basin, suggesting the discontinuous mixing of mafic volcanic glasses might instead be responsible for the elevated mafic content of the two basins.

A problem with both of these possible explanations is indicated by the relations seen in the unusual Humboldtianum basin [10]. Here, GRAIL data also suggest an extremely thin crust [14] but the basin floor is extremely feldspathic (~3.5 wt.% FeO). Moreover, significant pyroclastic activity is also present, associated with mare volcanism, occurring long after basin formation. If either the very thin crust or subsequent pyroclastic activity were good explanations for a mafic floor and feldspathic ejecta, one might expect to see a mafic floor in Humboldtianum, but such does not occur. The "normal" feldspathic composition of this basin indicates that post-basin, vertical impact mixing is not sufficient to create a mafic floor and that pyroclastic activity does not necessarily contaminate all nearby highland surfaces.

We are thus left without a good explanation for this enigmatic relation. Basins form during early planetary history and theory suggests that impact melt from them should represent an average mixture of the diverse compositions that make up the basin target [1,3-5]. There is no particular reason to expect basin melt and clastic ejecta to greatly differ in composition unless they are derived from completely different portions of the target. That is possible for basin-sized impacts and has been invoked previously as a possible explanation for the origin of low-K Fra Mauro basalt, a mafic composition that seems to be associated with large impacts [1]. Although several basins with mafic floors and feldspathic ejecta are now known, not a single case of the reverse relation has been identified. Work continues to understand the origin of this enigmatic compositional dichotomy.

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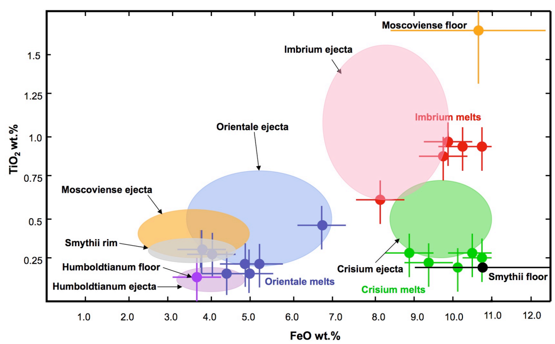

Figure 1. Composition of some selected lunar basin units. Both Moscoviense and Smythii have floors that are more mafic than their ejecta.

Table 1. Composition of the floor material of some lunar basins

Basin	Location	FeO (wt.%)	TiO_2 (wt.%)	Th (ppm)	Ref
Orientale	19°S, 95°W	4.4 ± 2.0	0.6 ± 0.3	0.9 ± 0.5	6
Imbrium	35°N, 17°W	10.0 ± 0.5	0.1 ± 0.2	4.5 ± 1.0	7
Nectaris	16°S, 34°E	5.6 ± 2.4	1.1 ± 2.8	1.5 ± 0.24	9
Crisium	18°N, 59°E	8.3 ± 0.9	0.25 ± 0.2	--	8
Humboldtianum	59°N, 82°E	3.6 ± 1.6	0.15 ± 0.1	1.7 ± 0.3	10
Moscoviense	26°N, 148°E	10.6 ± 3.0	1.9 ± 1.1	1.4 ± 0.5	11
Smythii	2°S, 87°E	10.6 ± 1.5	--	--	this study