Composition of the Deposits of the Lunar Orientale Basin P.D. Spudis[1] and D.J.P. Martin[2] 1. Lunar and Planetary Institute, Houston TX 77058 spudis@lpi.usra.edu 2. School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester, United Kingdom, M13 9PL

Introduction. Orientale is the youngest and best-preserved multi-ring impact basin on the Moon and has long been studied for clues to the processes and histories of older, more degraded features [1-4]. We have recently completed a new geological map derived from LRO image and topographic data that show the distribution and relations of the geological units of the basin [5]. Using this new map as template, we can isolate individual basin units and study their composition to the exclusion of adjacent and overlying units [6]. Using this approach, we have studied the impact melt sheet of the Orientale basin and concluded that it has not been differentiated [6] as had been proposed [7]. Taking this same method, we have now compiled data for each ejecta unit of the Orientale basin, including both inner and outer basin units [5]. We use this compositional information to make inferences about the nature of the lunar crust, the depth of excavation of the Orientale impact and comparison with the composition of other basins of similar size and geological setting.

Method. Templates were created using the unit boundaries of the new geologic map. These templates were then used to isolate pixels on compositional maps of FeO and TiO_2 derived from Clementine data [6, 8]. These data were analyzed statistically to determine their characteristics and means. Spectral information from Clementine and M^3 were used to characterize the dominant mineralogy of the deposits. In total, this information allows us to characterize the units in terms of known rock types and compositions, which facilitate comparison between the ejecta deposits of different basins.

Results. The Fe and Ti concentrations of Orientale basin deposits are summarized in Table 1. With the exception of the mare deposits in the central inner basin and some of the basin ring massifs, most of the units have broadly similar compositions, i.e., feldspathic highlands. The basin impact melt sheet (Maunder Fm.) is strikingly uniform in composition; moreover, this uniformity extends to depths of at least 2-3 km [6]. These observations suggest that while constituting a very large volume of silicate melt (on the order of 1million km^3; [6,7]), the Orientale basin melt sheet probably did not differentiate [6].

The mare deposits of the inner basin offer a striking contrast to the feldspathic composition of the basin ejecta units. These mare basalts appear to be relatively high in Ti (~2.3 wt.% TiO_2), unusual for far side maria, which are largely very low in Ti [8]. Although largely restricted inside the innermost basin ring, mare basalts must constitute some fraction of the subsurface materials of the inner basin as their presence is evident as a mixing component in the ejecta of Maunder crater, the largest post-basin impact crater within Orientale. These basalts probably make up feeder dikes and vent deposits associated with the emplacement of Mare Orientale. The other significant departure from the feldspathic highlands composition comes in the form of numerous basin ring massifs that appear to be composed of pure anorthosite [9, 10]. Anorthosite massifs are most abundant in the Inner Rook ring, suggesting the presence of a regionally contiguous sub-layer of nearly pure anorthosite below a slightly more mafic upper crustal layer.

Although most Orientale ejecta deposits appear to be nearly the same composition, there do appear to be distinct differences between deposits inside and outside the main rim of the basin (Cordillera ring, 930 km diameter [1-4].) Both facies of the exterior textured ejecta (Hevelius Fm.) have mean FeO contents about 1.5 wt.% higher than the inner basin Montes Rook and Maunder Formations. This difference appears to be real and significant, even though error bars overlap. Assuming that the Hevelius Fm. represents ejecta primarily from the upper portions of the basin target and the inner Montes Rook Fm. come from lower depths [3, 4], it suggests a grossly stratified target for the Orientale basin-forming impact, with slightly more mafic highlands megaregolith (anorthositic norite) overlying a more feldspathic zone (noritic anorthosite and pure anorthosite) that makes up middle crustal levels.

There is little evidence for mafic highlands within or around the Orientale basin; some small deposits of norite are found in the central peak of the crater Maunder [6], but no ring massifs or exterior ejecta have any composition more mafic than anorthositic norite. Additionally, the smooth plains that make up some of the distal portions of the basin continuous deposits show a considerably more mafic composition than does the rest of the exterior ejecta. This may be at least in part a result of the presence of significant amounts of ancient mare basalt, buried by Orientale smooth plains ejecta within the Schiller-Schickard basin [11].

Comparison with other basins. The ejecta from the Orientale basin appear remarkably uniform. Although the basin subtends almost 1000 km and its ejecta cover half again as much terrain, the basin deposits display minimal variation over many hundreds of kilometers extent. In contrast, other basins of comparable sizes display great variety of ejecta composition; for example, Imbrium (1160 km diameter) ejecta contains anorthosite, norite, KREEP basalts and granites and some olivine-rich, ultramafic components, virtually the entire spectrum of lunar compositions [12]. The Nectaris basin (860 km diameter) has compositional diversity similar to Orientale, with feldspathic material ranging from anorthositic norite to anorthosite, but its (very sparsely preserved) impact melt appears to be slightly more mafic than Orientale [13]. The ejecta of the Serenitatis basin (900 km diameter) is much more mafic, with basaltic compositions dominating and feldspathic components essentially absent [14]. Finally, although the remnant highlands that are probably composed of South Pole-Aitken basin (2600 km diameter) ejecta are very feldspathic, the floor of SPA suggests that a deep lower crust or upper mantle might be significantly more mafic than the crustal columns sampled by most of the other large basins [15]. These results suggest that basins on the Moon are sampling significant lateral heterogeneity within the upper lunar crust and that, to first order, a uniformly layered crust is absent.

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Table 1. FeO and TiO_2 concentrations for Orientale basin units.

Geologic unit	FeO wt. %	TiO_2 wt. %
maria	11.0 ± 3.3	2.3 ± 1.4
Maunder Fm. (smooth member)	4.5 ± 1.9	0.6 ± 0.3
Maunder Fm. (rough member)	4.4 ± 2.0	0.6 ± 0.3
Montes Rook Fm. (knobby member)	4.6 ± 1.1	0.5 ± 0.1
Montes Rook Fm. (smooth member)	5.1 ± 1.1	0.5 ± 0.1
massifs (average)	4.1 ± 1.6	0.5 ± 0.2
massifs (anorthosite, average of eight)	0.6 ± 0.5	0.3 ± 0.8
Hevelius Fm. (transverse member)	5.9 ± 1.5	0.4 ± 0.1
Hevelius Fm. (radial member)	6.1 ± 1.3	0.4 ± 0.3
Smooth plains	7.0 ± 2.2	0.4 ± 0.2