VOLCANISM IN THE ORIENTALE BASIN: A COMPARISON TO OTHER NEARSIDE LUNAR BASINS. J. L. Whitten1 and J. W. Head2, M. Staid3, C.M. Pieters3 and the M3 Team, 1Brown Univ., Providence RI 02912, 2PSI, Tucson AZ; (jennifer_whitten@brown.edu).

Introduction: About 20% of the lunar surface is covered with mare deposits, including mare patches on the farside and limbs and larger more continuous deposits lying within and adjacent to the large impact basins on the nearside of the Moon [1, 2, 3, 4]. Investigating volcanic activity in lunar basins can help to constrain the thermal evolution of the Moon. In addition, careful study of volcanic features can assist researchers in further understanding the relationship between formation of basins and mare basalt petrogenesis.

Several individual mare patches are located in the Orientale basin, itself located on the western limb of the Moon. It is the youngest multi-ring basin on the lunar surface [2]. Unlike the other large lunar multi-ring basins Orientale is well preserved, being only partially filled with mare, making it very useful for understanding the interior structure of other lunar basins and their relationship to volcanic activity (Fig. 1).

Moon Mineralogy Mapper (M3) data [6,7] are used to characterize the volcanic features within the Orientale basin. Model ages, areas, volumes and volcanic features (e.g., sinuous rilles and domes) were mapped and measured. We compare our results for Orientale basin with work from other researchers to determine the similarities and differences between the various nearside lunar basins.

![Figure 1. LOLA topographic map of the Orientale basin. White arrows point to different topographic rings.](image)

Summary: Orientale Basin Volcanism: Orientale basin is dated to the beginning of the Upper Imbrian period at ~3.68 Ga [5]. It is approximately 930 km in diameter and covers an area of ~700,000 km² [8]. Since the basin interior has not been completely filled with mare, each of its three main mountain rings is still visible (Inner Rook, Outer Rook, Cordillera) [9]. The preservation of ring topography clearly separates all of the Orientale mare deposits and allows further investigation of their ages and modes of emplacement.

Mare basalt emplacement began in the center of the basin ~3.58 Ga, approximately a hundred million years after basin formation (~3.68 Ga), assuming this fill is the result of a single volcanic phase (Fig. 2). Mare Orientale, the central deposit, erupted as a flood basalt and was followed closely by later pulses of volcanism that produced the mare ponds in Lacus Veris and lastly those in Lacus Autumni [5]. Estimated flow unit volumes range from 30 to 7,700 km³, averaging between 590 and 940 km³ [5]. This time sequence correlates well with the concept that early flooding is dominated by larger deposit thicknesses over a smaller area, and later flooding is opposite in character, with shallower deposits that cover a larger area [10].

The youngest of these mare deposits occur along the edge of the basin in Lacus Autumni. Crater count model ages range from 3.47 to 1.66 Ga (Fig. 2). A few of the ponds in Lacus Veris have ages between this range as well. The abundance of sinuous channels and rilles in these two laci indicates a basaltic plains style volcanism, with both point sources and fissures [5,11].

Mare eruption locations are focused along the margins of the different basin rings, mostly in the form of vents and sinuous rilles. Most identified vents and all of the identified rilles are located on the eastern side of the Orientale basin [5]. No rilles exist on the southwestern side of Orientale, likely the result of a very thick crust that hindered both the propagation of dikes to the surface and the opening of vents and extrusion of significant quantities of mare basalt over a sustained time period. The sequence and timing of mare basalt deposits suggest that regional basin-related stresses exerted control on their distribution [e.g., 12-14]. Our analysis clearly shows that Orientale serves as an excellent example of the early stages of the filling of impact basins with mare basalt.

Comparison with Other Basins: The model age distribution of Orientale mare basalts, between ~3.50 and ~1.66 Ga [5], shows that they span nearly the entire range of nearside model ages (Fig. 2). Even the latest Orientale basalt patches are as young as some of the youngest basalt deposits on the lunar nearside. The majority of the mare ponds were deposited during the highest frequency of eruptions on the lunar nearside, centered around 3.5 Ga (Fig. 2) [15].
The similarity in the range of mare model ages indicates that the small amount of mare fill in Orientale is not due to early cessation of mare emplacement, but to limited volumes of extrusion during the entire period of nearside mare basalt volcanism. This suggests that nearside and farside volcanic source regions may be similar, but that other factors, such as thermal and crustal thickness barriers to magma ascent and eruption, may be determining the abundance of surface deposits on the limbs and farside.

Unlike Orientale, the sequence of filling is difficult to define for most of the nearside basins. The continuous high-volume eruptions have made the distinctions more difficult. Most of the younger mare deposits on the nearside are related to the Procellarum KREEP Terrain [15]. Previous research has indicated that the oldest deposits in Serenitatis and Crisium are located around the edge of the basins, opposite the situation in Orientale [15-17].

Several models dealing with different aspects of the infilling of lunar basins exist [e.g., 10,12-13,18]. One model suggests that the largest volume, but smallest area of mare fill occurs first in the center of the basin. The second stage of filling covers a much larger area, but also a smaller volume. This first stage would look similar to a circular plug, whereas the second stage would be more disk shaped [10]. Another model suggests that the infilling of basins is governed by local and global stresses. A central deposit creates a load great enough to produce local extensional stress at its edges which propagates outward over time due to a cooling thickening lithosphere [12].

The most obvious difference between Orientale and other nearside lunar basins is their volume of mare fill. Orientale mare ponds have comparatively low volumes, totaling \(-46,000 \text{ km}^3\) [3,5]. All of the other nearside lunar basins are filled with mare deposits. Therefore, calculated approximations for the total volume of the topographic depression of nearside basins on the Moon [18] can be used as estimates of the volume of mare fill. Serenitatis and Nectaris, two basins similar in size to Orientale, have total basin volumes of \(1 \times 10^6 \text{ km}^3\) and \(7 \times 10^7 \text{ km}^3\), respectively. The calculated basin volume for Orientale is \(7 \times 10^7 \text{ km}^3\). Therefore, Orientale has a volume that is typical for a lunar basin. Other studies have estimated basin diameters and depths based on \(d/D\) relationships, corroborating other estimates [19].

This estimated basin volume for Orientale indicates that there are \(-6.55 \times 10^7 \text{ km}^3\) that were not filled with mare, meaning the mare load in the center of Orientale basin is not as massive as the initial central loads in other lunar basins. A smaller central load suggests the load necessary to cause extensional stresses around the edge of the basin is smaller than initially expected [12,13].

The lack of mare fill in Orientale has also allowed researchers to investigate the ring structure of other lunar basins. Three different rings were estimated for the Serenitatis basin based on the spacing and morphology of the various rings in Orientale basin [20].

**Preliminary Conclusions and Future Work:** Investigating Orientale basin has brought to light the unique character of each of the lunar basins. They share many similarities, such as the presence of mare fill and predicted depths relative to diameter. However, they are also very different, having mare of different composition and age. Comparing Orientale and Serenitatis shows that one basin filled from the center outwards, while others appear to have filled from the outer rim inwards based on surface exposure of mare units. Future work will focus on analyzing the various volcanic features of each lunar basin and comparing them with one another.

![Figure 2. Histogram of the temporal distribution of crater count model ages for basalts in nearside and farside basins and craters (modified from Hiesinger et al., 2010). N=328 represents nearside basalt ages from Hiesinger et al. [2010]. N=16 represents the counts performed for Orientale basin in this study.](Image)