ORIENTALE BASIN EJECTA: DEPTHS OF DERIVATION AND IMPLICATIONS FOR THE BASIN-FORMING PROCESS.

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Introduction. Lunar basin ejecta has been recognized from several Apollo highland landing sites. Detailed petrologic, chemical and mineralogic studies of these samples have given a reasonable understanding of the gross composition of the lunar crust and has helped constrain the depth of origin of basin ejecta. These rocks are complex polymict breccias that appear to have been primarily derived from crustal regions (1), and to consist of ANT suite, KREEP and mare volcanic components. Moreover,studies of petrologic mixing in lunar highland regions overflown by orbital geochemical instruments indicate the highlands are complex and regionally heterogeneous (2,3).

This study utilizes photogeological, geophysical, orbital geochemical and Apollo site geological data to attempt to address the problem of depth of origin for lunar basin ejecta. These results place constraints on the probable size of the original basin cavity as well as the origin of basin ring structures.

Orientale Impact Target. The Orientale impact occurred in rugged highlands on the southwestern limb of the Moon. Crustal thickness maps derived from the gravity data (4) suggest the thicknesses of the crust in this region of the Moon are greater than average, ranging from 70 to 110 km. These estimates are substantiated by study of the Apollo gamma-ray data (5). Orientale is the youngest major lunar basin and thermal models (e.g.6) suggest the impact occurred into a thick, rigid lithosphere. Orbital geochemical data and mixing studies (3,7) indicate Orientale basin ejecta is extremely anorthositic and KREEP levels in this region are some of the lowest observed within the lunar highlands (8).

The latest mixing model results (3) suggest anorthositic material constitutes greater than 60 percent of the total basin ejecta with the balance composed primarily of a slightly more mafic anorthositic gabbro and minor mare basalt. These results are in striking contrast to mixing model results from other lunar basin ejecta blankets like Nectaris (2) where anorthosite is subordinate to mafic norite and KREEP. Orientale is approximately the same size as Nectaris, but the average crustal thickness in the Nectaris region appears to be significantly thinner -70 km (4). Thus, there is no reason to suppose that the depth of excavation of these two basins was significantly different, and the Nectaris event sampled slightly deeper crustal levels because the crust was thinner in this region. In contrast, Orientale appears to have sampled only upper anorthosite-rich crustal levels .

Depths of Basin Ejecta Derivation. Many attempts have been made to estimate the depths to which basin-sized impacts excavate. Estimates range from very deep ,d/D=0.3 (9) to extremely shallow, d/D less than 0.01 (10). Recently, application of a theoretical cratering flow model (11) to the basin excavation stage suggests basins effectively excavate to depths of approximately one-tenth the diameter of the original crater (12). Thus, if the original crater can be identified, a model can be produced that predicts depths of origin for ejecta. Although there is considerable disagreement regarding the dimensions of the original basin cavity (cf.9,13), certain geologic observations can be used to constrain possible solutions to this problem.

Several workers (14,15,16) have previously noted the preservation of pre-basin topography and structure located within the outer (Cordillera) ring and possibly within the intermediate (Outer Rook) ring (16). If correct, these observations constrain the maximum size of the Orientale transient cavity to be less than 650 km, but probably greater than 500 km in diameter (the diameter of the innermost massif-like ring). This suggests maximum excavation depths of 50-65 km, indicating that Orientale ejecta should consist entirely of crustal lithologies.

The exact shape of the basin transient cavity is not known, but the z-model (11,12) suggests a spherical cap segment with height equivalent to the maximum depth of excavation is a good approximation (17). When this geometry is applied to a spherical Moon, a convex lens-shaped body of excavation is produced. Analysis of this geometric figure suggests that 90 percent of the ejecta produced by the Orientale impact is derived from depths shallower than 30 to 40 km. Thus, for an Orientale-sized impact in this region of the Moon, most ejecta will be derived solely from upper crustal levels. This model is in close agreement with the observed compositiom of Orientale basin ejecta, since a mafic-KREEP component is almost totally absent.

Implications for the Basin-forming Process. The results of this study suggest that the transient cavity of lunar basins was smaller than the current main topographic ring. The exact position of this feature cannot be located with complete confidence, but results obtained here suggest that it probably lies within the intermediate ring (Outer Rook ring at Orientale). Thus, the outer rings of lunar basins are probably of structural (megaterrace) origin (9,14,18), and were formed by gravity enlargement and adjustment to an initially smaller transient cavity. This idea is further supported by the results of a study of the Imbrium basin Apennine scarp, which indicated that an extensive section of pre-Imbrium basin rocks are structurally exposed within the Apennine front (19). At Orientale, the outer (Cordillera) ring appears to cut several pre-existing craters (14) suggesting it is also structurally produced. Inner rings may be produced either as a single central uplift, analogous to crater central peaks (14,20) or by an oscillatory mechanism resulting from fluidization of the crustal target (21,22); either mechanism is compatible with the observed relations. Future work will apply this analysis to other lunar basins to obtain better understanding of the complex lunar basin-forming process.

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