CHEMICAL MIXING MODEL STUDIES OF THE ORIENTALE BASIN REGION, B. Ray Hawke and T.L. Jackowski, Hawaii Inst. of Geophysics, Univ.of Hawaii, Honolulu, HI 96822, P.D. Spudis, Dept. of Geology, Arizona State Univ., Tempe, AZ 85281, and A.E. Metzger, Jet Propulsion Lab., Calif. Inst. of Technology, Pasadena, CA 91103.

Introduction: Valuable insight concerning lateral and vertical changes in the chemical composition of the lunar crust can be provided by studies of material ejected from the lunar basins. These impacts have excavated material from a variety of depths and deposited this ejecta in a systematic manner. While studies of lunar samples thought to have been derived from basin deposits, notably Imbrium and Serenitatis, have yielded important information, there is a need to extrapolate the detailed chemical information for individual landing sites to much larger regions of the lunar surface. This has been possible largely through the use of the Apollo orbital geochemistry data (1-5). Chemical mixing model calculations have previously been performed on the remotely sensed chemical compositions of deposits related to the Crisium, Nectaris, Serenitatis, Imbrium, and Orientale basins in order to establish which chemically-defined rock types are likely to be present and to make quantitative estimates of their relative abundances (6-9). Recently, a wide variety of new orbital geochemical data have been presented for the Oriental region. The purpose of this study was to perform chemical mixing model calculations on the newly derived chemical compositions of the various subregions around Orientale basin and to assess the results in terms of the crustal stratigraphy of the western limb of the Moon.

Method: A least-square mixing model program was used to translate the chemical composition of each subregion into the best mixture of given endmembers (10). A new modification allows the automatic testing of all possible combinations of endmembers. Up to six elements (Fe, Ti, K, Th, Mg, and Al) were used. The chemical data for the subregions around Orientale are those presented by Metzger et al. (4), Davis (11), and Bielefeld et al. (2) together with new unpublished K values. Al abundances were estimated based on regression analysis of lunar Fe-Al data. Endmember compositions were selected from Taylor (13) and Ridley (14). The best solution obtained for selected subregions are presented in Table 1. The total anorthositic component is the sum of anorthosite and gabbroic anorthosite abundances. The mare basalt composition which generally yielded the best solutions was Apollo 17 high-Ti basalt.

Results and Discussion: Subregion 11A includes the entire Apollo 15 groundtrack in the Orientale region. The subregion is dominated by materials emplaced as a result of the Orientale impact event but also contains Orientale interior deposits, pre-Orientale terrain, and small amounts of mare basalt. The mixing model results show that the surface material in the subregion is composed largely of anorthosite, gabbroic anorthosite, and anorthositic gabbro. A very minor amount ($\lesssim$5%) of low-K Fra Mauro basalt (LKFMB) is present, as is a small mare basalt component. These results are in general agreement with previous mixing calculations based on early versions of the orbital geochemical data sets (7,8) which suggested that the Orientale region was composed of 40% gabbroic anorthosite and 60% anorthositic gabbro. The amounts of mare basalt modeled are in excess of the amounts which would be expected based on photogeologic mapping of the region (12). This suggests that small amounts of mare material may be present in a form difficult to recognize. The possibilities include the following: 1) Pre-Orientale mare basalts were ejected and emplaced by the Orientale impact event, 2) Magmas of mare composition were ejected and emplaced by Orientale, and 3) Highland material ejected by Orientale disrupted and mixed with pre-existing mare deposits in the more distant portions of the Orientale ejecta blanket. The mixing model results for subregion 11E also suggest that mare material is far more abundant in this subregion than would be expected. It is also possible that the Ti values are systematically high in these and adjacent subregions or that a poorly sampled class of Ti-rich lunar highland rocks exists in this portion of the lunar surface.

The results for subregions 11G, 11H, and 11I provide important clues for understanding the composition of Orientale primary ejecta and the pre-impact stratigraphy of the Orientale target site. Subregion 11G is located NNW of Orientale and the surface composition should be dominated by material emplaced as a result of the Orientale basin-forming impact. This subregion contains more anorthositic material than any other modeled in this study. Only very minor amounts of LKFMB and mare material are present. Subregion 11H is located just north of the Cordillera ring of Orientale and its surface composition should be dominated by Orientale primary ejecta from deeper portions of the lunar crust than that in subregion 11G. The anorthositic component comprises a slightly smaller percentage of the total highland material in the subregion than in 11G. The LKFMB component, though small, is more abundant than in 11G. Subregion 11I is located NNE of the Orientale outer ring and appears to be dominated by anorthositic gabbro. This subregion contains a larger mare component than 11G and 11H, consistent with the presence of post-Orientale mare deposits in the subregion (12)

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Subregion 31 is located north of the outer Rook ring and includes the northern Cordillera Mts., a portion of the Orientale interior deposits between the outer Rook ring and the Cordillera ring, and primary basin ejecta deposits. The southern portions of subregions 11H and 11I are included in subregion 31. Subregion 31 is dominated by anorthositic material but the amounts are not as great as in 11G. The small mare component is consistent with the presence of mare basalts mapped in the subregion.

Conclusion: 1) The surface composition of the Orientale region is dominated by anorthositic gabbro, gabbroic anorthosite, and anorthosite. 2) Only minor amounts of LKFMB are present in the region. If a LKFMB layer exists at a depth within the crust at the Orientale target site, very littl was excavated by the Orientale event. 3) No mafic material from the lunar mantle appears to be present in the Orientale region. Since the ejecta deposits are dominated by anorthositic material which is thought to be most abundant in the upper crust, constraints are placed on the maximum depth of Orientale basin excavation. 4) Slightly more mare basalt is modeled to be present in the region than would be expected from photogeologic studies.

This work was performed at the University of Hawaii, and, in part, at the Jet Propulsion Laboratory where it was partially supported under NASA contract NAS 7-1000.

Table 1. Mixing Model Results for the Orientale Region

Subregion	Approximate Location	Total Anorthositic Component	Anorthositic Gabbro	Low-K Fra Mauro Basalt	Mare Basalt
11A 15-total	86°W-120°W long 10°S-20°N lat	30	54	5	11
11C 15-North	86°W-120°W long 10°N-20°N lat	49	44	1	6
11E 15-West	104°W-120°W long 10°S-12°N lat	41	43	2	14
11G 16-West	106°W-120°W long 2°S-6°N lat	63	32	2	3
11H 16-Center	92°W-106°W long 4°S-4°N lat	51	40	4	5
11I 16-East	78°W-92°W long 6°S-2°N lat	26	60	4	10
31 Orientale Rings	76°W-104°W long 8°S-2°S lat	45	40	6	9

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