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THE HISTORY OF MARE VOLCANISM IN THE ORIENTALE BASIN: MARE DEPOSIT AGES, COMPOSITIONS AND MORPHOLOGIES S.D. Kadel and R. Greeley, *Department of Geology, Arizona State University, Tempe, Arizona 85287*; G. Neukum and R. Wagner, *German Aerospace Research Establishment (DLR), Institute for Planetary Exploration, Berlin/Oberpfaffenhofen, Germany.*

The eruptive history of mare basalts in the Orientale Basin has been studied, using Lunar Orbiter IV high-resolution photographs, Zond 8 photographs, and recently acquired Galileo EM-1 multispectral images [1,2]. This work represents a refined set of compositional data, incorporating the use of a linear mixing model for mare compositions, crater count data, and a comprehensive morphologic analysis of Orientale Basin mare deposits. Evidence for multiple eruptive episodes has been found, with compositions ranging from medium- to high-Ti basalt (<4 to >6 wt. % TiO_2). Eruptive styles included flood, rille-forming and shield-forming eruptions. Impact crater densities of mare units in the Orientale Basin enable determination of the ages of these deposits, using the method of Neukum et al. [3]. Earliest eruptions of mare basalt in the basin occurred at ≥3.70 Ga and the latest eruptions occurred at about 2.3-2.5 Ga. Hence, mare volcanism occurred over a period of nearly 1.5 Ga.

The spectral slope between 0.40 μm and 0.56 μm can be used to obtain estimates of the Ti content (expressed as wt. % TiO_2) of mature mare soils [4,5]. Galileo 0.41/O.56 μm spectral reflectance ratio images indicate that medium-Ti (<4 wt. % TiO_2) basalt signatures are present in the northern and west-central regions of Mare Orientale, in a narrow bench around its southern and western margins, and in a mare patch just offshore to the southwest. Medium-high-Ti (3-7 wt. % TiO_2) basalt signatures are present throughout most of southern and eastern Mare Orientale. Small areas of high-Ti (>6 wt. % TiO_2) basalt are present in southeastern Mare Orientale, although these deposits do not approach the TiO_2.contents (>10 wt. %) of the high-Ti Apollo 11 or Apollo 17 basalts. Medium-Ti (<4 wt. % TiO_2) basalt signatures are present in the northern and northeastern mare deposits of Lacus Veris, whereas medium-high-Ti (3-7 wt. % TiO_2) signatures dominate the central and southern deposits. Medium-high-Ti (3-7 wt. % TiO_2) signatures are observed for the northern mare deposit of Lacus Autumni, and medium-Ti (<4 wt. % TiO_2) signatures are present in the central and southern Lacus Autumni mare deposits.

In order to distinguish between medium-Ti mare and medium-high-Ti mare contaminated with Ti-poor highlands material, it is necessary to "unmix" the components present in the mare surface soils. A three-component linear mixing model has been applied to the Galileo spectral reflectance data for the Orientale Basin. The resulting endmember fraction data, when combined with a survey of possible sources of contamination, suggest that the medium-Ti signatures in northern Mare Orientale and northern Lacus Veris are a result of contamination of medium-high-Ti basalt with highland ejecta from craters Maunder and Lowell. In addition, there are localized areas of contamination caused by smaller fresh highland craters adjacent to southeastern Lacus Veris and northwestern Mare Orientale. The medium-Ti signatures in west-central Mare Orientale, the nearby mare bench, the offshore mare patch to the southwest, northeastern Lacus Veris, and central Lacus Autumni represent uncontaminated medium-Ti basalt compositions for these mare deposits.

A morphologic survey of mare deposits in the Orientale Basin gives an indication of the styles of volcanism involved during their emplacement, as the surface features of lava flows are related to eruptive style [6,7]. Mare Orientale was emplaced primarily by flood eruptions, as evidenced by the presence of several large collapse depressions and a paucity of sinuous rilles. Lacus Veris was emplaced primarily by moderate effusion rate eruptions, as sinuous rilles are abundant. The most recent eruptions in central Lacus Veris were of low effusion rate, producing numerous mare domes. Northern and southern Lacus Autumni were emplaced at moderate effusion rates, as evidenced by prominent sinuous rilles, and the northern mare deposit lavas (which are very thin and have small dark-mantle-like deposits associated with them) appear to have had a higher volatile content than others in the basin. Central Lacus Autumni was emplaced as a flood basalt, as indicated by numerous small collapse features.

Synthesis of all the above information suggests the following emplacement and modification history of mare deposits in the Orientale Basin:

1) Medium-Ti basalt flood eruptions fill much of the center of the Orientale Basin (≥3.70 Ga).
2) Initial eruptions occur in northeastern Lacus Veris, and are medium-Ti basalts emplaced at moderate effusion rates (3.58 + 0.05/-0.06 Ga).
3) Northern Lacus Veris is emplaced as rille-forming eruptions of medium-high-Ti basalt (~3.45 Ga).
4) Much of Mare Orientale is again flooded (≤3.45 Ga), this time with medium-high-Ti basalts. Subsidence of Mare Orientale occurs before, during and after emplacement of this basalt, leaving the older medium-Ti basalt exposed only in west-central Mare Orientale and as a shelf along its southern and western margins. The last eruptions in southeastern Mare Orientale are of Ti-rich basalts.
5) Thin northern Lacus Autumni unit is emplaced (~3.40 Ga) by volatile-rich, rille-forming eruptions of medium-high-Ti basalt. Southern Lacus Autumni mare patches are emplaced as rille-forming eruptions at about the same time.
6) Central Lacus Autumni is emplaced (2.85 +0.28/-0.57 Ga) as flood eruptions of medium-Ti basalt.
7) Central Lacus Veris is emplaced (2.29 +0.51/-0.55 Ga) as rille-forming eruptions of medium-high-Ti basalts. Late-stage eruptions have sufficiently low effusion rates to produce numerous mare domes.
8) Craters Lowell and Maunder are formed, blanketing northern Lacus Veris and northern Mare Orientale with extensive amounts of highland ejecta.
9) Various small Copernican impact craters form in highlands adjacent to mare deposits causing localized contamination of mare surfaces with highlands materials.

A more refined compositional study of the Orientale mare deposits will be possible as a result of a high-resolution (both spectral and spatial) Lunar Scout mission. However, more precise dating of the eruptive events will have to await direct analysis of sample materials from the mare deposits.

[1] M.J.S. Belton et al. (1992) *Science, 255*, 570-576. [2] S.D. Kadel and R. Greeley, (1992) *LPSC XXIII*, 647-648. [3] G. Neukum et al. (1975) *The Moon, 12*, 201-229. [4] C.M. Pieters (1978) *Proc. Lunar Planet. Sci. Conf., 9th*, 2825-2849. [5] M.P. Charette et al. (1974) *J. Geophys. Res., 79*, 1605-1613. [6] R. Greeley (1976) *Proc. Lunar Planet. Sci. Conf., 7th*, 2747-2759. [7] J.W. Head et al. (1981) *BVSP*, 753.