The Uniform K Distribution of the Mare Deposits in the Orientale Basin: Insights from Chang’E-2 Gamma-ray Spectrometer. M.-H. Zhu¹, J. Chang², M. G. Xie³, J. Fritz³, V. Fernandes⁴, W.-H. Ip⁵, T. Ma², and A. A. Xu⁶,
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Introduction: The Orientale center was covered by magma that erupted a few tens of million years after the basin-forming impact event (~3.8 Ga). These initial mare deposits are thought to have been attacked by a single volcanic event [1] and later was resurfaced (~2.9 Ga) by volcanic eruptions in its NW and SE portions. Chang’E-2 gamma ray spectrometer (CE-2 GRS) observed that these mare deposits have a notable K abundance with an average of 360 ppm. That is a factor of two higher than the surrounding areas [2]. A similar Th enhancement within Orientale Basin was also identified by the Lunar Prospector gamma ray spectrometer [3]. Since the chemical diversity (e.g., FeO, TiO₂, and radioactive elements) of the basaltic units can be related to the chemical and thermal evolution of the magma source regions, the eruptive sequence and chemical composition of the magma sources in the Orientale Basin therefore could be understood from the compositional distribution.

K Distribution in Orientale Basin: We divided the Mare Orientale into four different regions: Orientale North East (ONE), South East (OSE), South West (OSW) and North West (ONW) (see Fig. 1) based on the albedo and Clementine FeO data [4]. In the Mare Orientale relatively elevated K abundances with average values of ~550 ppm are identified in the mare regions ONW and OSE. The mare deposits within the ONE are thought to be contaminated by low K highland ejecta, but still show K abundance of ~100 to 300 ppm. The earliest mare deposits within OSW [5, 6] display K abundance of ~300 to 400 ppm. In contrast, the mare basalt in the southwest polygon area (~530 km²) corresponding to an eruption age of ~3.77 Ga is characterized by lower K abundance of ~200 ppm. This value is comparable to those identified in the mare regions of Lacus Verris and Lacus Autumni (~100 ppm).

Forward Modeling: However, due to the lower spatial resolution of CE-2 GRS (~150 km × 150 km), it is not possible to resolve the small features of the K distribution (i.e., Lacus Veris and Lacus Autumni) in the map because spatial mixing of gamma rays from these deposits and surrounding regions with depleted K abundance that may result in artificially low K abundances. In order to account for spatial mixing in the observation, we used the forward model [7] to estimate a more accurate K abundance for the mare deposit in the Orientale Basin. The modeled K abundance are 1210 ± 240 ppm for ONW, 900 ± 350 ppm for OSW, 1260 ± 182 ppm for OSE, 730 ± 410 ppm for Polygon area, 1090 ± 370 ppm for Lacus Verrris, and 1160 ± 440 ppm for Lacus Autumni. Fig. 2 displays the K distribution within the Orientale Basin while assigning the modeled K abundance to each mare deposit unit. All the enhanced values are comparable to the K abundances at the boundary of PKT with a value of ~900 ppm indicating that all the features may indeed have relatively high K abundances compared to the surrounding background region.

Fig. 1 K distribution map of the Orientale Basin observed by CE-2 GRS. The outlined boundaries of the mare deposits are based on the albedo and Clementine FeO data [4].

Melting Mechanism for the Resurfaced Mare Deposits: The Orientale Basin is located at the boundary of PKT and FHT, but the relatively high K abundance observed by CE-2 GRS in the resurfaced mare deposits (ONW and OSE) indicate that the KREEP layer extends or some part of it exists underneath the Orientale Basin [2]. The morphological and spectral investigations of the resurfaced mare basalts revealed similarities in the chemical compositions between Mare Orientale and those within the PKT region [8], including radioactive element signatures. The volcanic eruptions that formed the resurfaced mare deposits at ~2.9 Ga ago are contemporary with an episode of volcanic activity in the PKT region between 3.5 Ga and 1.5 Ga [9]. The resurfaced mare deposits in the Orientale Basin therefore might be formed by similar melt generating mechanism as those in the PKT region. That is by the voluminous heat release due to the decay of radioactive elements concentrated at the lower crust.
Mare deposits that erupted from a single magma source in the interior of the Moon should produce basaltic units with similar compositions (e.g., K, FeO, and TiO₂). The relatively high K values in the two resurfaced unit ONW and OSE advocate for melt generation due to heating released from the radioactive decay. The comparable concentrations of K, FeO, and TiO₂ and roughly the same eruption time (~2.9 Ga) [1, 6] for both resurfaced mare deposits suggest that they were fed by the same magma source within the lunar interior, and were emplaced onto the lunar surface during a brief eruptive phase at ~2.9 Ga [5, 6].

![K distribution map of the Orientale Basin](image)

Fig. 2 K distribution map of the Orientale Basin with the modeled K abundance assigned to each mare deposit unit.

**Homogeneous Magma Source for Orientale Mare Deposits:** The OSW mare basalt is one part of the earliest mare deposits erupted at ~3.77 Ga [1, 6] and ONW and OSE were later covered by the younger mare basalts. The initial OSW mare deposit is thought to erupt as a single volcanic event and was independent of the basin-forming impact [6]. Similar K concentration of OSW (~900 ppm) compared to the resurfaced basalts (1200 – 1260 ppm) derived from forward modeling and the very similar FeO concentration of these two regions (i.e., ~10 – 15 wt.% for OSW and ~10 – 18 wt.% for the resurfaced basalts [11]) indicates that these earlier mare basalts might be derived from the same melt generating mechanism as the younger resurfacing mare deposits. That is, the initial mare deposit was also generated by heat release from the radioactive decay. Previous studies of crater retention ages suggested that the early OSW mare basalts and the resurfaced mare deposits ONW and OSE represent either multiple eruptions from a relatively homogeneous source or multiple sources with subtle compositional differences [1]. A thorough comparison of these deposits would require more chemical and texture data, however, from the chemical compositions of the mare basalts and their eruption ages (~3.77 Ga for OSW and ~2.90 Ga for ONW and OSE [6, 9]), we argue in favor for a homogeneous source underneath the Orientale Basin.

Mare basalts in SW polygon area and Lacus Veris are to some degree contaminated by impact ejecta from the surrounding FeO and TiO₂ poor highlands [8]. Nevertheless, these two mare deposits display similar FeO and TiO₂ composition to the center of Mare Orientale [11]. The chronological investigation shows that the lava in SW polygon area (~3.77 Ga) and Lacus Veris (~3.4 – 3.6 Ga) were erupted early that are contemporaneous with the volcanic activity forming the initial mare deposit of OSW (~3.77 Ga). The high K abundances displayed in these two mare deposits (~730 ppm for polygon area and ~1090 ppm for Lacus Veris) after forward modeling are similar to those of OSW (~900 ppm). Additionally, these two mare units also have the similar abundances of FeO (~10 – 15 wt.% and TiO₂ (~3 – 6 wt.%) [11] to the OSW mare deposits. The chemical similarities in these three mare areas strongly suggest that partial melts feeding the early volcanism in Lacus Veris, SW polygon area, and OSW might originate from the same magma source within the lunar interior. For the younger lava of Lacus Autumni erupted at age of ~1.8 – 2.2 Ga ago, the high K abundance of ~1160 ppm after forward modeling is similar to those of the central Mare Orientale deposits. This suggests that the melt of Lacus Autumni was also generated by heating from the decay of radioactive elements. Furthermore, considering the high FeO (~9 – 15 wt.%) and TiO₂ (~3 – 5 wt.%) concentrations in Lacus Autumni, we argue that these basalts erupted from the same magma source as the central Mare Orientale. This indirectly implies that the mare units in the Orientale Basin were resulted from multiple eruptions of a relatively homogeneous and long-lived magma source during ~3.77 Ga to ~1.8 Ga ago.