Composition of olivine-bearing rocks and their estimated origin

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Introduction: Remote sensing data obtained by the SELENE (Kaguya) Spectral Profiler (SP) found exposures with olivine-rich spectral features, globally distributed on the lunar surface[1], and it was suggested that they are possibly originated from the mantle.
Previous studies of returned lunar samples and the lunar magma ocean differentiation model indicate that olivine-rich rocks have the following three major origins: 1) mantle material, 2) volcanic material with olivine-rich composition, and 3) crustal material including rocks intruding into the crust (troctorite) [2]. Though most of the olivine exposures identified in [1] were located near basin rings, the origins of individual olivine sites may not be the same. Furthermore, no mantle material and only a small number of olivine-rich mare materials are available in the lunar sample collection. Therefore, understanding the origin of individual olivine exposures and advancing our knowledge about the distribution and composition of the three types of olivine-rich materials are important for understanding the composition and evolution of the lunar interior.
To address these issues, we geologically and morphologically investigated all of the identified olivine exposures in detail to assess the origin of each site in this study.
Methods: All of the 70 million latest calibrated reflectance spectra obtained by Kaguya SP [3] were used to re-identify olivine-rich exposures on the lunar surface by finding diagnostic absorption features of olivine around 1050 nm as described in [1]. Data of the Kaguya Multiband imager (MI) [4], Lunar Reconnaissance Orbiter Camera (LROC) [5], and SLDEM2013 (digital elevation model generated using the Kaguya Terrain Camera [6], MI, and Lunar Orbiter Laser Altimeter aboard LRO) of each of the identified olivine sites were used to evaluate reflectance, space weathering, geologic context, distribution and size of the exposures, composition, surface texture, and local slopes.
Results: About 150 SP reflectance spectra were re-identified as having unambiguous olivine-rich absorption features. Locations of the spectra were grouped into 50 sites located within the same latitude and longitude. We also evaluated the origin of all grouped sites. Note that we identified the clearest olivine-rich spectra among SP datasets, therefore olivine-rich material with less clear spectra may be present at other areas. We categorized their origins as likely mantle, volcanic, crustal, and “unclear”. About 60% of the sites are estimated to be mantle origin, and 5% are volcanic, 30% are crustal, and 5% are of unclear origin respectively. Mantle origin sites surround large basins whereas volcanic origin sites are within mare, and crustal origin sites are either surround or far from large basins.
Discussion: Though the percentage of each origin is not necessarily proportional to the volumes (surface area) of each category, at least there are many olivine sites of mantle origin around Crisium, Imbrium, and Nectaris. Estimation of excavation depth of these basins indicates it is likely they reach the mantle, which is consistent with the estimation of mantle origin for these olivine sites. We also identified volcanic olivine-rich sites, which have not been reported previously.
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