GLOBAL DISTRIBUTION OF OLIVINE EXPOSURES ON THE MOON REVEALED BY SELENE SPECTRAL PROFILER

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INTRODUCTION

Since the Moon has been considered to have an olivine-rich mantle, olivine exposure on the lunar surface is an important target for studying the entire composition and the evolution of the Moon. However, the discovery of olivine-exposure sites has been very limited to date. Earth-based telescopic observations have reported only two nearside craters, Copernicus and Aristarchus, with olivine-rich spectral features [1-3]. Whereas Earth-based observations produce continuous reflectance spectra, the observational points are sparse and limited to the lunar nearside. On the other hand, the Clementine UVVIS with five discrete bands provided the global data of the Moon; The Olivine Hill in the South-Pole Aitken (SPA) and the central peaks of the Theophilus, Langrenus, Keeler, Crookes, and Tsiolkovsky craters were identified as possible olivine-bearing sites by Clementine UVVIS [4, 5]. However, after a reexamination using data taken by Spectral Profiler (SP) onboard the Japanese explorer Kaguya, the central peak of the Tsiolkovsky crater was classified as a mixture of plagioclase and pyroxene, rather than as pure olivine [6]. This finding by SP demonstrated the importance of obtaining continuous reflectance spectra over the UV, visible, and NIR range covering the entire 1 μm band diagnostic of olivine and other silicates in identifying olivine exposure sites on the Moon.

SP has obtained continuous spectral reflectance data for $69,228,098$ points (0.5 by 0.5 km footprint) on the Moon over the wavelength range of $\lambda = 0.5$-2.6 μm and a spectral resolution of 6-8 nm during its mission period from November 2007 to June 2009. Here, we report the global distribution of olivine exposures on the Moon revealed by SP.

RESULTS

Analyzing the $69,228,098$ spectral data, we identified more than 200 observational points, which show clear olivine bands with wavelengths of 0.85, 1.05, and 1.25 μm as shown in Fig. 1 (hereinafter referred to as olivine-rich points). Since most of the olivine-rich points appear to be grouped into several local sites on the Moon, we divide and assigned those olivine-rich points to ~ 30 olivine-rich sites.

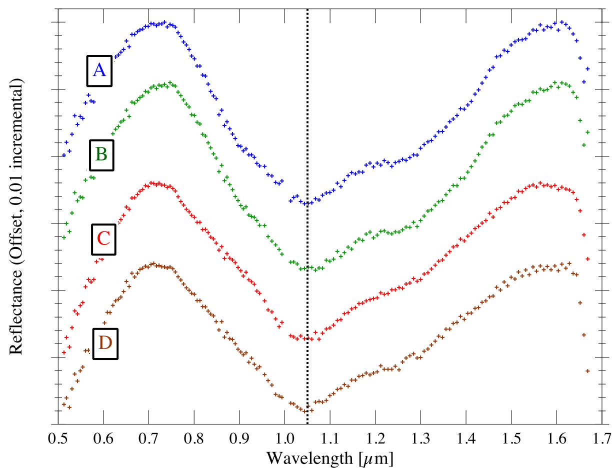

Figure 1: The continuum-removed reflectance spectra measured at SP observational points of A and B in Fig. 2, C in Fig. 3, and D in Fig. 4. The vertical lines indicate the location of olivine band of 1.05 μm. All spectra have been vertically offset for clarity, and the thick intervals of the vertical axes are 0.01.

Fig. 2 shows the close-up image of the olivine-rich site observed in Mare Frigoris. (The close-up images shown here were obtained by the Multiband Imager onboard on Kaguya [10].) The clear olivine spectra are observed at the crater rim, continuous ejecta, and the inside of an 1 km-sized, fresh crater in this mare. This suggests that the impact to form this crater excavated the olivine-rich materials just below this region. Fig. 3 shows the close-up image of the olivine-rich site near Mare Humorum. The olivine exposures are observed at the wall of an unnamed crater with diameter of ~ 10 km. We can see the streak-like features in the crater wall, where the clear olivine spectra are identified. On the other hand, we did not find the olivine exposures at the floor of this crater. The landslide on the crater wall may have exposed the olivine-rich materials. Fig. 4 shows the olivine-rich site at an outcrop near the Montes Alpes. SP identified the olivine spectral features at a small (100 m-sized) crater on this outcrop. Most of other olivine-rich sites were also observed at small, fresh craters or outcrops.

DISCUSSION

What mechanism produced the olivine exposures observed here? Previous studies have proposed the excavation of local plutons with olivine-bearing materials in the upper crust emplaced as an intrusion [e.g., 7]. This hypothesis was based on the olivine exposure at the central peaks of the Copernicus crater [1]. However, most of olivine exposures discovered by SP are observed at small craters with 0.1-10 km sized craters. This indicates that the olivine-rich materials at the olivine-rich sites are excavated from shallower regions with $<\sim 100$ m depth (up to $\sim$ 1 km). In addition, olivine exposure sites were also found at the crater wall of Copernicus and Aristarchus craters [e.g, 3, 8]. We consider that the olivine exposures observed here may be related to the crust thinning events by basin-forming events [3], because the regions with the olivine exposure sites, i.e., Mare Frigoris, Humorum, and Imbrium, are located in the thinner lunar crustal regions [9]. If so, the basin formation events in the early lunar history may have excavated the lunar upper mantle, exposing it to the lunar surface.

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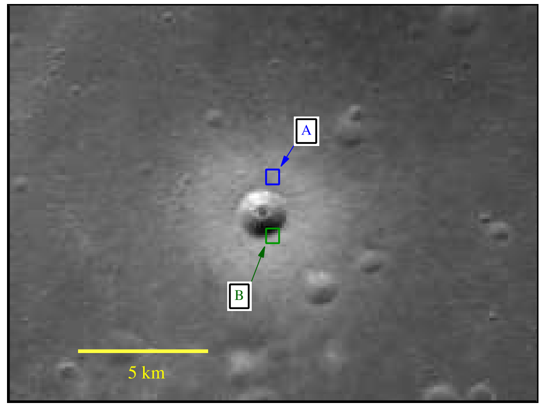

Figure 2: The close-up image of the olivine-rich site in Mare Frigoris.

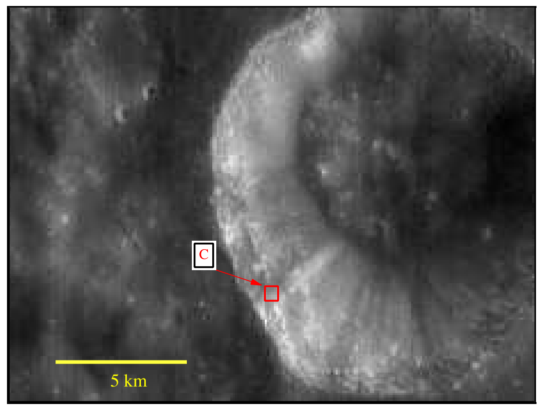

Figure 3: The close-up image of the olivine-rich site near Mare Humorum.

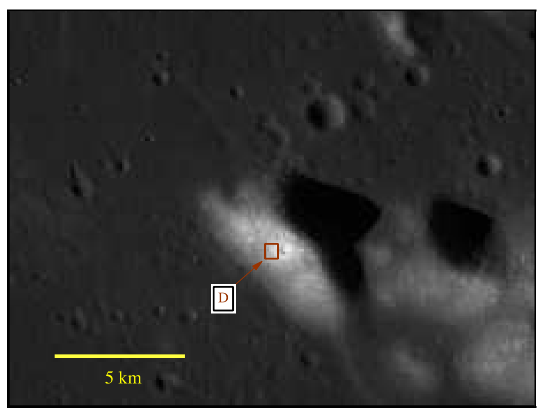

Figure 4: The close-up image of the olivine-rich site near the Montes Alpes in Mare Imbrium.