GLOBAL DISTRIBUTION OF HIGH-Ca PYROXENE ON THE LUNAR HIGHLAND REVEALED BY SELENE SPECTRAL PROFILER

Satoru Yamamoto[1], Ryosuke Nakamura[2], Tsuneo Matsunaga[1], Yoshiko Ogawa[3], Yoshiaki Ishihara[4], Tomokatsu Morota[5], Naru Hirata[3], Makiko Ohtake[4], Takahiro Hiroi[6], Yasuhiro Yokota[1], and Junichi Haruyama[4], [1]National Institute for Environmental Studies, Japan (yamachan@gfd-dennou.org), [2]National Institute of Advanced Industrial Science and Technology, Japan, [3]The University of Aizu, Japan, [4]Japan Aerospace Exploration Agency, [5]Nagoya University, Japan, and [6]Brown University, USA.

INTRODUCTION

Although global distributions of exposure sites of the end-members of various lunar minerals have been revealed from the global survey using the data obtained by Spectral Profiler (SP) onboard SELENE/Kaguya [e.g, 1-4], the global distribution of high-Ca pyroxene (HCP)-rich sites has been unclear so far. In addition to mare region, which is dominated by HCP, it has been reported that several ray craters on highland regions show HCP-dominant spectra [5]. Thus, the global distribution of HCP-rich sites, especially for the lunar highland regions, would provide important information for the structure and evolution of the lunar crust and mantle. In this study, using the global data set of the SP, we conducted the global survey to find HCP-rich sites on the Moon, especially for the lunar highland regions.

METHOD

SP has obtained continuous spectral reflectance data for about 70 million points (0.5 by 0.5 km footprint) on the Moon in wavelength $\lambda = 0.5$-$2.6\,\mu$m and a spectral resolution of 6-8 nm [6,7]. Pyroxenes have absorption bands minima near both 1 and 2μm with central wavelength of both minima moving to longer λ with increasing Ca [8]. Analyzing the 70 million spectral data with the global survey algorithm used in [2,3,4], we pick up the spectra which show a clear $1.0\,\mu$m band diagnostic of HCP [5,8]. We then eliminated the spectra whose absorption depth ratio of $2\,\mu$m to $1\,\mu$m is smaller than 0.5 to distinguish between HCP and olivine-rich materials. In this case, more than 200 thousands points are selected (Fig. 1(a)). In order to select the HCP for the highland regions, we then choose the spectra with $R_{\rm p} \geq 0.1$ (hereafter, bright HCP or BHCP), where $R_{\rm p}$ is photometrically corrected reflectance at $\lambda = 0.75\,\mu$m (this is because the typical value of $R_{\rm p}$ for the highland regions is $R_{\rm p} >\sim 0.1$ [9]). Finally, 2,256 points are selected as BHCP points, as shown in Fig. 1(b). Fig. 1(c) shows example spectra of BHCP, which show a clear $1.0\,\mu$m band as well as $2\,\mu$m band.

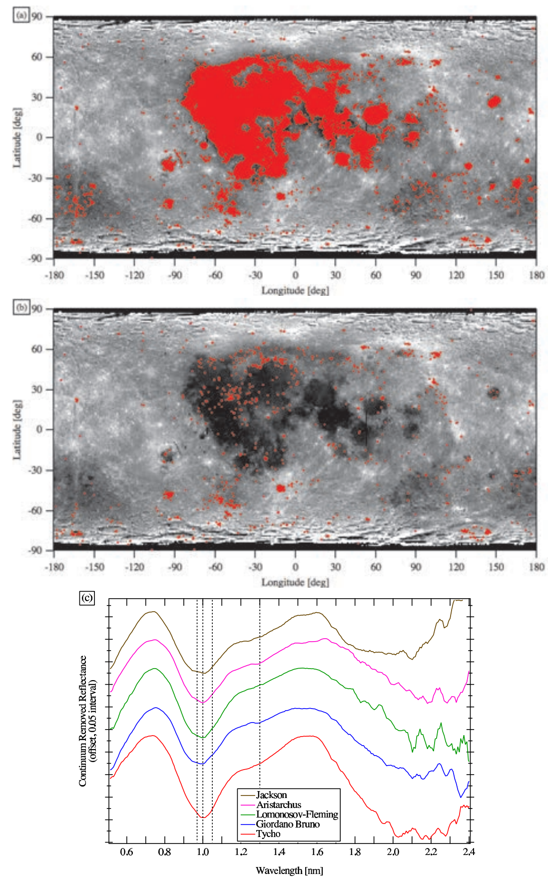

Figure 1: (a) The global distribution of HCP points. The background map is the albedo map based on $R_{\rm p}$ [9]. (b) The same as (a), but for BHCP with $R_{\rm p} \geq 0.1$. (c) The continuum-removed reflectance spectra measured at SP observational points in several BHCP points. All spectra have been vertically offset for clarity, and the tick intervals of the vertical axes are 0.05. Vertical lines are at 0.97, 1.00, 1.05, $1.30\,\mu$m, respectively.

RESULTS

Fig. 1(b) shows that many BHCP points are located around impact basins with mare basalts (e.g., Imbrium, Procellarum, Humorum, Nubium, Crisium, Humboldtianum, and Moscoviense). In these basins, most of BHCP points occur at elevated altitudes at the rim or peak rings of these basins, while the occurrence of BHCP points in the center region of mare is sporadic. In addition, we found that in the highland regions many BHCP points are grouped into several local craters (e.g., Tycho, Jackson, and Giordano Bruno craters). We can also see that many BHCP points are found in lunar suspected cryptomare deposits listed in [10] (e.g., Mendel-Rydberg, Schiller-Schickard, and Lomonosov-Fleming).

Fig. 2(a) shows the close-up image of Tycho crater, where BHCP points are distributed in the crater floor, rim, and ejecta region. On the other hand, there are few BHCP points outside the Tycho crater. Fig. 2(b) shows the close-up image of Giordano Bruno crater, where the BHCP points are mainly distributed over the ejecta region. This indicates that the BHCP-rich materials originate from a shallow region, which were excavated by the impact to form this crater. Fig. 2(c) shows the close-up image of BHCP points in Jackson crater. The BHCP spectra are found on the crater floor and terrace region, while they are not found at the central peaks where many purest Anorthosite (PAN) spectra are found [1,2]. For other several complex craters with the central peaks, BHCP points are mainly found outside the central peaks, while other lunar-major minerals such as PAN are mainly located at the central peaks. This indicates that the BHCP-rich materials existed above the layers of PAN before the formation of the complex craters. Fig. 2(d) shows the location of BHCP points in the cryptomare of Schiller-Schickard region, where BHCP points are found at small craters in the cryptomare.

In summary, most of BHCP points are found in the ejecta, rim, and floor of impact craters rather than the central peaks, suggesting that BHCP-rich materials originate from relatively shallower region in the lunar crust. This occurrence feature is different from the PAN, olivine-rich, and low Ca pyroxene-rich materials, which are thought to be originated from relatively deeper region below the uppermost mixed layer in the lunar crust [2,3,4].

DISCUSSION

There are several possible mechanisms to form the occurrence trend of BHCP-rich materials on the highland regions. The one of the important mechanisms is the cryptomare formation, because our survey detected many BHCP points in the cryptomaria listed in [10]. In addition, gabbroic pluton (≈ HCP + plagioclase) into the shallower region of the upper crust may be pervaded over the lunar highland regions, and impacts to form smaller, fresh craters could have exposed BHCP materials to the surface [11]. Furthermore, since BHCP points are always associated with fresh impact craters, we also propose an additional mechanism for the BHCP; the impacts melted the mixing layer composed of plagioclase and pyroxene, producing BHCP-rich materials in their crater floor, rim or ejecta regions. This is why many BHCP points originate from a shallower region, while PANs are mainly found at the central peaks. Although we need further investigations for their origins, our new data suggest that the top layer of the lunar crust in the highland regions is dominated by HCP-rich materials.

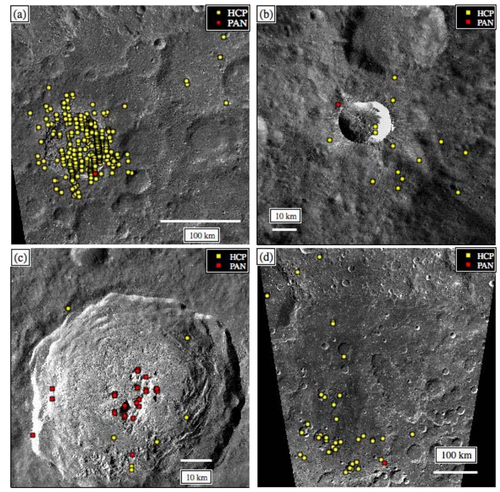

Figure 2: The close-up images of the BHCP points in (a) Tycho, (b) Giordano Bruno, (c) Jackson craters, and (d) Schiller-Schickard cryptomare. Yellow and red rectangles indicate the BHCP and PAN points, respectively [1,2].

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