SAMPLE RETURN FROM THE NECTARIS BASIN ON THE MOON. T. Morota, Y. Cho, H. Nagaoka, Y. Nakauchi, Y. Sato, H. Tabata, S. Sugita, M. Otake, K. Yogata, M. Aida, R. Sakai, K. Saiki, O. Mori, T. Yoshimitsu, and T. Saiki \(^1, \) The Univ. of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan (morota@eps.s.u-tokyo.ac.jp), \(^2\) Ritsumeikan Univ., 1-1-1 Noji-higashi, Kusatsu, Shiga 525-8577, Japan. \(^3\) The University of Aizu, Ikki Machi, Tsuruga, Aizu Wakamatsu City 965-8580, Japan. \(^4\) Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan.

**Introduction:** Lunar activities promoted by the ARTEMIS program give us the opportunity to advance key science on the Moon. We have been considering sample return mission from the Moon during the Artemis era and have developed compact in-situ analysis instruments for geologic surveys around the landing site and sample selection. Our scientific objectives are categorized into the following two:

1. Reconstruction of impact history in the early solar system and verification of the late heavy bombardment hypothesis associated with giant planet migration model [e.g., 1].

2. Constraints on lunar formation conditions and the crust-mantle differentiation process through determination of the bulk composition of refractory and volatile elements of the Moon.

In this paper, we focus on scientific objective (1) and introduce a proposed potential landing site and in-situ instruments. The specifics of scientific objective (2) are presented by Nagaoka et al. [2].

Lunar cratering records provide us with key information on the impact history in the solar system. Especially, formation ages of impact basins are important for understanding the bombardment history before 3.8 billion years ago [3]. While relative ages of impact basins have been determined based on the stratigraphic relationship, crater densities, and its topographic degradation states [4], the absolute ages are poorly constrained yet. This is principally due to the lack of rocks from most of the impact basins and difficulties in determination of the geologic origins of returned impact melt rock samples. The impact melt rocks generated by the basin-forming impact are expected to be cumulated in the floor inside the inner ring of impact basin [5]. For age determinations of impact basins, therefore, collecting basin floor rocks is required.

The Nectaris basin is located on the southeastern region of lunar nearside and its deposits have been used to subdivide lunar geologic history [4]. Additionally, previous studies of crater statistics and dynamical evolution of small bodies suggested that there may be a peak in impact flux after the Nectaris basin formation [6]. To determine the formation age of Nectaris may lead to identify whether the late heavy bombardment occurred and the magnitude if it has occurred.

**Potential Landing Site:** Most of the inner floor of Nectaris is covered by mare basalts, which have erupted after the basin formation. In this study, we investigated the geologic structure around the Nectaris basin and candidate exposures of floor materials of Nectaris to identify candidate sites for the future landing missions. To identify four lithologies, mare basalts, ejecta from the other basins, anorthosites originated from highland crust, and floor materials of Nectaris, we used multi-band image data and Digital Terrain Models (DTMs) acquired by Multiband Imager (MI) [7] and Terrain Camera (TC) [8] onboard Kaguya and high-resolution images obtained by Narrow Angle Camera onboard Lunar Reconnaissance Orbiter (LROC) [9].

Mare basalts were identified based on their high FeO and TiO\(_2\) contents [10, 11], which covers most of the inner floor of Nectaris. Spectral data of craters penetrating mare basalts suggest that the rocks underlying mare basalts have relatively high FeO content (> 10 wt%) and strong absorption of pyroxene, corresponding to Fe-rich noritic rocks (Fig. 1). The Fe-rich noritic rocks are expected to be ejecta from the other impact basins such as Imbrium, Serenitatis, and Crisium, because such basins were formed in the period between the Nectaris formation and the eruptions of mare basalts. Rocks exposed in regions excavated more than 1 km on the Nectaris inner ring have low FeO content (< 4 wt%) and a spectral absorption at 1250 nm, suggesting that the inner ring consists of anorthositic rocks originated from the highland crust.

Among four craters larger than 30 km in diameter inside the Nectaris inner ring, two craters (Fracastorius and Beaumont) have rims consist of norite with slightly low FeO content (5-10 wt%), interpreted as mixtures of upper (anorthosites) and lower crustal rocks (norites). This result suggests that the large craters excavated the inner floor materials of Nectaris before mare basalt eruptions and their rims are remained not buried by mare basalts. Small craters on the rims of these large craters excavated rock fragments originated from the inner floor materials of Nectaris (Fig. 2), unaffected by space weathering and various alterations, have the advantage of being fresh, making them potential targets for future sample return missions.
**In-situ Observation:** To determine the formation age of the Nectaris basin, a sample return from these rocks is necessary. We have been developing in-situ observational instruments mounted on a rover for geological surveys around the landing site and sample selection: microscopic infrared (IR) hyper imager, laser-induced breakdown spectroscopy (LIBS) [12, 13], and Raman spectrometer [14, 15]. Based on observation of detailed mineral texture by microscopic IR hyper imager and mineral and elemental measurements by LIBS and Raman spectrometer, we will investigate the occurrence of the rocks, identify rock types, and assess the degree of thermal and impact metamorphism in rocks.


Figure 1. FeO content map (A) and spectral absorption depth map (B) around the Nectaris inner ring calculated from Kaguya MI data. The spectral absorption depth map was generated by assigning the absorption depths at 950 nm to red, 1050 nm to green, and 1250 nm to blue [16, 17].

Figure 2. Potential landing site in the Nectaris basin. (A) DTM map around the Fracastorius crater on the inner ring of the Nectaris Basin. The northern rim of the crater has excavated material from the Nectaris floor, believed to consist of impact-melt rocks. (B) A fresh crater with a diameter of 600 m located to the northwest of the Fracastorius crater rim (LROC image: M1335129791LC). (C) Rock fragments excavated by the fresh crater (red arrow). These rock fragments are expected to originate from the Nectaris impact-melt rocks that make up the northwestern rim of the Fracastorius crater.