

Discovery of lunar foramen (hole) structure by SELENE (Kaguya) Cameras ~Extraterrestrial Lava Tube Exploration Proposal~

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In the SELENE camera (Terrain Camera and Multiband Imager) data, we have found three vertical holes, "foramen" structure, on the Moon which probably associate with underlying caves such as lava tubes.

First discovery of the foramen structure is at 303.3E, 14.2N, in a long rille (50 km) of the Marius Hills region in Oceanus Procellarum on the near side of the Moon [Haruyama et al., 2009]. The Marius Hills is a prominent volcanic province on the Moon where a lot of volcanic features such as lava flows, domes, and rills are seen [Greerely, 1971]. The Marius Hills hole (MHH) is nearly circular of 65 m diameter. The depth was estimated to be 80 - 90 m by shadow measurements. There is no pyrocrastic ejecta around the hole. We concluded the MHH is a possible skylight. The SELENE TC and MI successfully imaged the entire surface of the Moon during the twenty-one month SELENE mission. Therefore, we tried to find foramen structure similar to MHH by extracting darker spots in the images of higher solar elevation angles (SEAs) of > 40deg in the global TC data set. Because TC's sensitivity is very high as it could observe even permanent shadowed areas on the lunar polar regions [Haruyama et al., 2008], it could be possible the dark spots associating with foramen structures are recognized. As a result, two new holes were discovered in Mare Tranquillitatis and Mare Ingenii [Haruyama et al., 2010]

These newly discovered holes are twice large as MHH. The internal temperature are probably nearly 0degC or higher when we assume the temperature are determined by the radiative valance of solar illumination and radiation from the surface. The total amounts of solar wind protons in the discovered foramen would be more than 1 metric tons if the holes were formed simultaneously with or just after the formation of their surrounding areas.

The foramen structures and possibly associating caves, lava tubes, are scientifically very interesting from the geologic view points: formation mechanism with similarity and difference between the cases on the Moon and the Earth, the significant roles on the lunar mare formation, volatile behaviors on the lunar surface and subsurface, and so on. On the Mars, similar holes have been already discovered [Cushing et al., 2007]. The Martian holes and associating caves might be a good cradle for the organic matters. The extraterrestrial foramen structure should be one of the most important targets for future explorations.

The foramen and subsurface caves will be good shelters for future unmanned and manned activities. In particularly, lunar caves are very significant because they are good evacuations while the lunar surface is very severe environment. Inside foramen and underlying caves are very safe. In future, we will establish lunar bases in the lunar holes and caves, where a lot of scientifically important activities are expected such as long-term observations of moonquakes and internal heat flows to understand the internal structure of the Moon in addition to astronomical observations, and first documentations and permanent storages of extraterrestrial samples.

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