Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SVC51-01 Room:201A Time:May 20 16:15-16:30

Semi-Volcanic Low-Frequency Earthquakes and Stress Accumulation during Magma Cooling

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Deep low-frequency earthquakes (LFEs) are relatively small earthquakes that radiate low frequency seismic waves. While tectonic LFEs on plate boundaries are thought to be thrust events, the mechanisms of volcanic LFEs around the Moho beneath active volcanoes have not yet been firmly established. Recently, we examined a unique class of LFEs that occur far from active volcanoes but which are otherwise similar to volcanic LFEs [<i>Aso et al.</i>, 2011; 2013]. Since these 'semi-volcanic' LFEs occur far from active volcanoes, they may provide clues to generally explaining why LFEs occur.

We used waveform inversion to estimate focal mechanisms of semi-volcanic LFEs in eastern Shimane, where the second-most frequent (semi-) volcanic LFEs occur in a quiet region. The focal mechanisms and moment rate functions were estimated by grid search and a linear inversion, respectively. The moment rate functions determined from our inversions oscillate between positive and negative values. The focal mechanisms for many LFEs are found to be dominated by a CLVD component, with their symmetry axes parallel to the lineation formed by the source distribution.

Based on these observations, we tried to develop a physical source model of semi-volcanic LFEs. We suggest that the fundamental driving force of these LFEs is due to the rapid density change caused in a cooling process of magma. Our model involves three steps: stress accumulation, stress release, and oscillation excitation. First, we calculate the expected amount of accumulated stress and compare the speed of accumulation and that of diffusion. Next, we explain the reason why the brittle deformation prefers CLVD type of deformation to simple faulting. Finally, we evaluate a basic frequency and an attenuation factor of the resulting oscillation.

Keywords: Semi-Volcanic Low-Frequency Earthquakes, CLVD, Cooling Magma

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SELENE lunar mission reveals the formation history of the Marius Hills Plateau, the largest lunar volcanic complexes

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Lunar volcanic activity played a significant role in the geological evolution of the Moon. The Marius Hills Plateau (13.5N, 306E) of the Oceanus Procellarum is one of the largest volcanic complexes on the nearside of the Moon, presenting records of igneous activities such as numerous dome-like structures, rilles, cones, and lava flows [1]. To estimate the precise formation ages of the Marius Hills Plateau and understand the past lunar volcanism, we used the data from the Terrain Camera (TC) and the Multiband Imager (MI) installed on the Selenological and Engineering Explorer (SELENE).

The TC is a push-broom stereo-camera with two slant telescopes, +15 degrees forward looking and -15 degrees backward looking. It acquired 10 m spatial resolution image data from the SELENE nominal altitude of 100 km. The stereo pair images are used to produce digital terrain models (DTMs) with an elevational resolution of 20 m or better [2]. The MI is a multi-spectral imager with four and five color bands with 20 m (visible) and 62 m (near-infrared) spatial resolutions from the SELENE nominal altitude. The band assignments are 415 nm, 750 nm, 900 nm, 950 nm, and 1000 nm in the visible range and 1000 nm, 1050 nm, 1250 nm, and 1550 nm in the near-infrared range [2]. Based on the TC and MI data, we first morphologically and spectrally classified distinct basaltic lava flows on the Marius Hills Plateau as different geological units. We then estimated the crater retention ages of each geological unit using the TC data.

Crater counting is a well-established technique for deriving the model ages of planetary surfaces. We can infer the relative and absolute ages by measuring the Crater Size-Frequency Distribution (CSFD) with image data based on the simple idea that older surfaces accumulate more craters [3]. We counted craters and measured their diameters using the TC data and estimated the age based on CSFD measurements for each unit on the Marius Hills Plateau. We used the polynomial production function and the cratering chronology model proposed by Neukum and Ivanov (1994) [4] to obtain the absolute model age from the CSFD measurement [5]. Volcanic craters such as the top of the dome-like structures or cones may affect the counting results, so we eliminated what can be clearly distinguished from impact craters in the TC data.

The Marius Hills Plateau can be classified into about sixty geological units based on the MI color-composite maps. There are twice as many geological units on the Marius Hills Plateau than previously proposed by [6].

The measured crater retention age of each unit indicated that the youngest Marius Hills Plateau formation is ˜3.3 Ga, corresponding to the Early Imbrian Model Age, while some geological units exhibit greatest ages of ˜3.8 Ga. The Marius Hills Plateau is thus older than previously estimated. In our study, no classified geological unit exhibited young ages of 0.7?1.5 Ga, corresponding to the Late Eratosthenian Model Age and the Early Copernican Model Age reported by [7].

We found that almost all geological units of the high-calcium pyroxene plateau are significantly older than those of the olivine-rich basaltic lava areas, consistent with [8]. However, we note that some geological units of the high-calcium pyroxene plateau are apparently younger than those of the olivine-rich basaltic lava areas. The Marius Hills Plateau formation history is thus complex [9].

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Keywords: KAGUYA (SELENE), Terrain camera (TC), Multiband Imager (MI), Volcanic complexes, Marius Hills Plateau, Crater-counting

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Morphometry and morphology of lunar mare domes from SELENE terrain camera

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A number of smooth low domes with gentle convex-upward profiles are distributed in lunar maria. They are called lunar mare domes, and have long held the interest of the planetary and volcanological communities.

Lunar mare domes are characterized by circular to somewhat irregular outline, a generally convex shape, relatively low slopes (generally less than 10 degrees), and diameters ranging up to 30 km. Some show summit craters, and occur in groups on mare plains. Lunar mare domes have been detected during telescopic study of the Moon since 18 century. Previous studies were used Lunar Orbiter, Apollo, Clementine, and Lunar Reconnaissance Orbiter data, and almost agree that most lunar mare domes are volcanic origin. But the details of mare domes are still not well understood, because of shortages of spatial resolution, favorable light condition, and limited coverage of imaging area.

In this research, we use Terrain Camera (TC) data of SELENE. The TC carried on SELENE is a panchromatic push-broom imager with two optical heads (TC1 and TC2) to acquire stereo data for the entire surface of the Moon when the sun elevation is higher than 30 degrees. The slant angles of TC1 and TC2 are + 15 and -15 degrees, relative to the spacecraft flight direction for the nadir vector. Each head has a linear CCD sensor of 4096 pixels. They have 10-m cross- and along-track resolutions respectively, and 10-m vertical resolution at the SELENE nominal altitude of 100 km. The TC also acquired non-stereo data when the sun elevation was lower than 30 degrees. These low sun-elevation data is powerful tool to analyze mare domes with very low slopes.

We analyze the morphometry and morphology of mare domes in Hortensius, Milichius, Cauchy, and Arago areas by the TC data, and compare with terrestrial small shield volcanoes of Hawaii, Mexico, Iceland, and NW USA. We will discuss the formation of lunar mare domes.

Keywords: SELENE (KAGUYA), Moon, Shield volcanoes, Terrain camera, Mare domes

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SVC51-04 Room:201A Time:May 20 17:00-17:15

Lunar gigantic vertical holes: Possible skylights of lava tubes of the Moon?

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Japanese lunar explorer SELENE (Kaguya) discovered gigantic vertical holes of 100 m in diameters and depths. These holes are possibly skylights of underground large caverns such as lava tubes, magma chambers, or faults; they are probably related to lunar volcanic activities. In this presentation, we will introduce these lunar gigantic hole-structures based on remote-sensing data from recent lunar explores and discuss significance of the structures for the lunar volcanic studies.

Keywords: lava tube, vertical hole, moon, volcano, SELENE, Kaguya

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Unusually high-temperature andesitic magma erupted shortly before the Aso-2 pyroclastic flow from Aso caldera, Japan

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Aso Volcano, which is located in central Kyushu, southwestern Japan, is one of the largest caldera volcanoes in the world. The caldera (25 km north-south and 18 km east-west) was formed by four large pyroclastic flow eruptions: Aso-1 (270 ka), Aso-2 (14 ka), Aso-3 (12 ka) and Aso-4 (89 ka). Each pyroclastic flow deposit is divided into several flow units. In particular, the stratigraphy of Aso-2 eruption deposit is very complicated and the chemical compositions remarkably vary between subunits in the eruption cycle. Andesitic lava flows were generated shortly before the main Aso-2 eruption. Tamaraigawa lava distributed east of Aso caldera and Iwato, Akita and Togawa lavas distributed west. These lavas are nearly aphyric and display textural characteristics similar to pahoehoe lava flows.

Lava compositions, temperatures and viscosities have been investigated. All lavas are phenocryst-poor, consist of two pyroxene andesite and have 61 wt.% SiO2 except for Togawa lava (58 wt.% SiO2; Matsumoto, 1974). The magma temperatures were estimated using the two-pyroxene thermometer of Anderson et al. (1983). Five to seven coexisting pairs of pyroxenes were analyzed for each lava. The calculated magma temperatures are 1123+/-23 oC (Tamaraigawa lava), 1081+/-17 oC (Iwato lava), 1061+/-18 oC (Akita lava) and 1045+/-24 oC (Togawa lavas). We calculated the melt viscosity of the Tamaraigawa lava at 1123 oC (two-pyroxene temperature) using the model of Giordano et al. (2008). The results show that the Tamaraigawa lava has a viscosity lower than 10ˆ4.5 Pa s (dry case). Dissolution with water further decreases the melt viscosity to 10ˆ2.7 Pa s at 2 wt.% H2O.

In general, andesitic magmas have eruption temperatures of 900?1000 oC and viscosities around 10ˆ8˜9 Pa s. The andesitic lavas in this study, therefore, had unusually high temperature and low viscosity conditions similar to basaltic lavas. The data are consistent with the textural characteristics of pahoehoe lava flow.

Keywords: Aso caldera, presursory event, high-temperature andesitic magma, paahoehoe lava

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Reconstruction of Middle Miocene volcanism in Dewa Mountains in Sakata city, Yamagata Prefecture, northeast Japan

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In northeast Japan, many submarine volcanic rocks related to opening of the Japan Sea in the Early Miocene are widely distributed. The most of basaltic rocks among them can be found in the Japan Sea side of northeast Japan. They were thought to be related to back-arc rifting due to opening of the Japan Sea (Sato and Amano, 1991), and discussed about the magma genesis (Tsuchiya, 1988; Yagi et al. 2001). However, there is no detaile sedimentological study, and the exact volcanic edifices and volcanism could not know. In this study, we tried to reconstruct the detail volcanic edifices and volcanism based on the facies analysis of volcanics in Dewa Mountains in Sakata, Yamagata prefecture. The submarine volcanoes of basaltic rocks which are about several km in diameter and over one hundred km high can be reconstructed. These volcanoes are mainly composed of resedimented hyaloclastites including fluidal-clast breccias with minor massive and pillow lavas. Their characteristics were very similar to those of submarine fire fountain eruption and those deposits (Fujibayashi and Sakai, 2003; Head and Wilson, 2003; Simpson and McPhie, 2001). In this study area, many dikes that were feeders of these basaltic rocks intruded. The palaeostress field in this stage was tensional (Sato and Amano, 1991). Reconstructed submarine volcanoes were related to fissure eruptions at the Japan sea opening.

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Keywords: greentuff, subaqueous volcanism, fire-fountain, fissure-eruption, Dewa Mountains, Miocene