Nano-scale observation of interface between lichen and basaltic lava by TEM and STXM

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Introduction: Lava extruded during a volcanic eruption moves downslope and covers huge areas. Living plants are destroyed by the lava flow over a wide area. The surface lava has been exposed to the weathering and erosion at the Earth's surface for a long time, which is responsible for the formation of soils. Recently, lichens as the earliest colonizers of terrestrial habitats are recognized to accelerate the degradation of minerals. Much interest has been therefore devoted in recent years to the weathering induced by the lichen colonization. Here, we report the nano-scale observation of the interface between lichen and basaltic lava by TEM and STXM techniques.

Materials and Methods: Basaltic lavas totally covered by lichens were collected from the 1986 lava flows on the northwest part of Izu-Oshima volcano, Japan. To prepare specimens for the nano-scale observation, we utilized the focused ion beam (FIB) system (JEOL: FIB-4000; JEOL: JEM-9320FIB) at National Institute for Materials Science (NIMS), Tsukuba, Japan. The specimens were thoroughly investigated by TEM (JEOL: JEM 2100F) equipped with energy-dispersive X-ray spectroscopy (EDX) at NIMS. Chemical components and chemical heterogeneity at the interface were observed by synchrotron scanning transmission X-ray microscopy (STXM) at Advanced Light Source (ALS) branch line 5.3.2.2.

Results and Discussion: The collected lava is augite-pigeonite-bronzite basalt, with 6 to 8% plagioclase phenocrysts. Mafic phenocrysts, orthopyroxene, clinopyroxene, and titano-magnetite, are less than 1%. The basaltic lava can be characterized to be chemically homogeneous with 52.2 to 52.5% SiO_2 and 15.2 to 15.6% Al_2O_3. Species of the lichens adhering to the lava was mainly *S. vesuvianum*, fruticose lichen, which are widespread over the area of investigation. The STEM-EDX observations for all the lichen-lava interfaces showed there are numerous small particles of amorphous alumino-silicate, goethite (α-FeOOH), and α-quartz within micrometer size. Since no α-quartz was observed in the collected basaltic lava, it is of exogenous origin. A small amount of Mg, Fe, and K are detected from the amorphous alumino-silicate. Poorly ordered alumino-silicates, iron oxides, and iron hydroxides have been already observed as biological weathering products (Adamo and Violante 2000). It is therefore certain that the small particles at the interface between the *S. vesuvianum* and basaltic lava were produced by the biological weathering process. Taking into consideration that the *S. vesuvianum* can readily produce organic compounds such as fatty acids, phenolics and carotenes, the amorphous alumino-silicate and goethite observed at the interface were produced by dissolution of plagioclase, augite, and pegionite.

Keywords: lichen-rock interaction, TEM, STXM, nano-scale

