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Migration of trace elements from basalt substrate to co-located vegetation (lichens and mosses) at the Wudalianchi volcanos, Northeast China

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ABSTRACT

Vegetation (e.g., lichens and mosses) living on the basalt substrate have potential to accumulate trace elements in their tissues. Here, we analyze the trace elements in basalt (collected from major volcanic center to jet plate places, representing four different eruption phases) and adjacent lichens and mosses to assess their elemental source–receptor relation. The results indicate that As, Sr, Mo, Cd, and Ba are enriched in basalt, and depleted in lichens and mosses. However, Zn, Hg, and Pb are enriched in lichens and mosses and depleted in basalt. Moreover, with the increase of basalt age, Cr, Mn, Fe, Ni, and Cu are gradually enriched in lichen and moss, but gradually depleted in basalt. Compared with transition metals, large ion lithophiles, the platinum group, and rare earth elements, Cr, Co, Cu, Zn, and Os are more easily absorbed by No. 1 lichen. Specifically, S is highly assimilated in vegetation, with a highest value of 166, followed by I, C, Pb, Zn, and Hg. In addition, the hydrogen and oxygen isotopic compositions of water samples suggest that the surface water in the Wenbo area came from meteoric waters in summer with a high humidity, while the underground water in the Beiyaoquan area came from meteoric waters in winter with a low humidity.

1. Introduction

The Wudalianchi volcanos, located in the Heilongjiang province of Northeast China, formed during the Cenozoic age through the upwelling of a mantle plume sourced from sub-continental lithospheric mantle and the mantle transition zone (410–660 km; Xiao and Wang, 2009; Mao et al., 2010; Kuritani et al., 2013; Xu et al., 2013). Wudalianchi volcanic rocks are mainly composed of basalts (also named Shilonggite due to their dragon shape) with potassium-rich picrite-leucitite, olivine-leucite, and leucite (Qiu et al., 1988; Fan et al., 2001). Besides the lithology, previous studies have focused on the eruption history (Xiao and Wang, 1994; Mao et al., 2010), tectonic structure (Zhao and Liu, 2010; Zhao et al., 2014) and geochemistry of volcanos' trace elements (Wang et al., 1988; Hsu and Chen, 1998; Fan et al., 2001). However, scholars have conducted little research on the relation between rock weathering and vegetation absorption of trace elements.

Nowadays, vegetation (e.g., lichens and mosses) grows abundantly on basalt substrate (Fig. 1b). The highest density of lichens and mosses appears in crevices of flower-like and pahoehoe lava. Moss coverage on the rock surface is estimated to fall between 43% and 70% (Feng, 2013). Therefore, the lichens and mosses living on rock substrates have the potential to take up elements from weathering.

In this study, we collected basalt, lichen and moss samples and then measured the content of trace elements to study the migration of trace elements from the basalt to the vegetation. Results from this study could promote our understanding of rock-vegetation elemental interactions and help us to identify a favorable environment for the presence of lower vegetation.

2. Geological setting and sample testing

2.1. Geological setting

The Wudalianchi volcanos lie at the junction site between the Lesser Khingan Mountains uplift and the Songliao rift zone (Qiu et al., 1989). The main outcrop strata are Carboniferous phyllite

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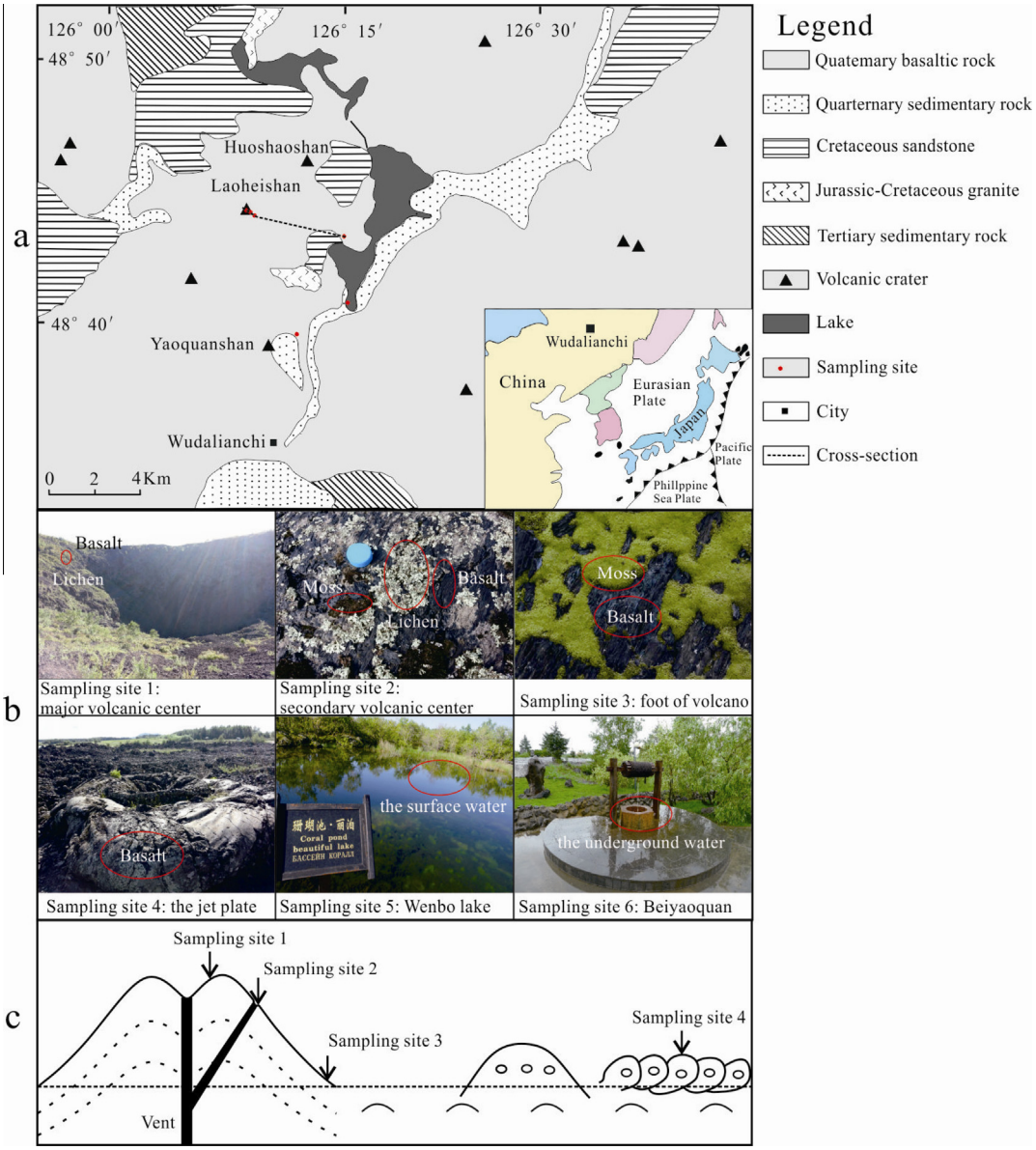

Fig. 1. Geological map (modified after Du et al. (1999) and Xu et al. (2013)) showing the sampling points of the Wudalianchi volcanic field. The six images listed on the right show the landforms where six kinds of samples were collected.

and schist, Cretaceous sandy shale, and Quaternary basalt. The granite intrusions that occurred during the Hercynian and Yanshan tectonic periods are only visible in a limited area (Xiao and Wang, 1994; Fig. 1a). The Huoshaoshan and Laoheishan volcanos, erupted in the early 18th century, are the youngest volcanos among the 14 volcanos composing the field (Zhang, 1984; Feng and Whitford-Stark, 1986; Mao et al., 2010).

Field observation proves that weathering and leaching are evident at the rocks' surface. Lichens and mosses cover most of the volcanic area, with woody plants, such as shrubs, arbors, and birch trees, growing in heavily weathered areas.

2.2. Sampling and measurement

Four basalt samples were collected from the Laoheishan volcano (166 m) according to different volcanic eruption phases. Along the lava's flow direction, basalts and co-located vegetation samples were systematically collected at four different positions: major volcanic center (sampling site 1, located at 126°07′57.7″E and 48°43′26.8″N), secondary volcanic center (sampling site 2, located at 126°08′46.3″E and 48°43′25.2″N), foot of volcano (sampling site 3, located at 126°09′31.6″E and 48°43′16.5″N), and the jet plate 4 km away from the Laoheishan volcano (sampling site 4, located at 126°14′51.0″E and 48°43′8.9″N). Fig. 1 shows the sampling sites in plane and vertical views. The massive basalt samples were collected on the weathered and partly weathered surface of exposed rocks. Each basalt comprises three subsamples gathered in a 1 m diameter circle. The collected basalt and vegetation samples were preserved in sealed bags. In addition, one surface water (sampling site 5, located at 126°15′43.7″E and 48°41′5.3″N) and one underground water (sampling site 6, located at 126°11′41.7″E and 48°39′44.1″N) samples were collected in two 500 ml glass bottles. Upon collection, all the samples were transported to the laboratory and preserved in a 4 °C refrigerator.

The basalt and vegetation samples were performed acid digestion using a Microwave Digestion Instrument (Anton Paar MW3000) before element measurement using Inductively Coupled Plasma Mass Spectrometry (Agilent 7500ce). Approximately 0.2 g