Influence of volcanic ash in soils on Ca cycling in forest ecosystems - Using Sr isotopes to determine the contribution of volcanic ash to Sr and Ca in stream waters and plants in a granite watershed -

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Ca in soil serves as a neutralizer of acids and is an essential nutrient for plants. The supply of Ca from weathering of rocks and its subsequent cycling is a key factor that controls the tolerance of forest ecosystems to acid deposition. In studies of the Ca cycle, stable isotopes of Sr have been used to trace Ca, because the chemical and biological behaviors of Sr resemble those of Ca. The Sr isotope method has been successfully applied, not only to investigate Ca cycling in acid-impacted ecosystems, but also to evaluate soil development processes and water-rock interactions in groundwaters and surface waters.
Volcanic ash, composed of small grains and with a large specific surface area, is present as a tephra layer in soils in Japan; this ash releases base cations rapidly owing to relatively quick weathering. However, it is difficult to estimate the distribution of volcanic ash on steep slopes, because it blends into soil and cannot be visually identified easily. Sr isotopes may be used to detect volcanic ash blended with soil and volcanic ash-derived Sr in plants and stream waters, because the stable Sr isotope ratio of volcanic ash is, in most cases, different from the ratio of the parent materials.
The aim of this study was to examine the role of volcanic ash in the Ca cycle in Japanese forest ecosystems. Soils, plants, and stream waters from a ridge, slope, and a valley were collected in a granite watershed on Mt. Tsukuba, central Japan. Rocks and atmospheric precipitation were also collected to represent Ca sources in the watershed. The $^{87}Sr/^{86}Sr$ ratios and element compositions of samples were determined to support identification of the origins of Sr and Ca in plants and stream waters.
The $^{87}Sr/^{86}Sr$ ratios were determined using a thermal ionization mass spectrometer (TIMS) (Triton; Thermo Fisher Scientific) at the Research Institute for Humanity and Nature. Acid digests of soils and plants, and filtrates of stream waters and bulk precipitation, were transferred to Teflon vials, heated until dry, dissolved in 2 M HCl, purified by cation exchange (Na et al. 1995), and subjected to TIMS analysis.
The $^{87}Sr/^{86}Sr$ ratios of soils on steep slopes and the valley floor ranged from 0.7110 to 0.7139, which indicates that the major source of Sr was the granite substrate ($^{87}Sr/^{86}Sr$ ratio 0.7120–0.7131). Soils on a ridge had lower $^{87}Sr/^{86}Sr$ ratios (0.7068–0.7072), indicating that they were mainly composed of volcanic ash materials released around 30,000 years ago from Mt. Akagi (0.7069). The $^{87}Sr/^{86}Sr$ ratio decreased and the concentrations of Sr (and Ca) increased in stream water with increased elevation from the valley bottom to the ridge, indicating that volcanic ash was the dominant source of both cations in the upstream area. The contributions of volcanic ash-derived Sr to upstream and downstream water were 50 % and 0–1 %, respectively. The $^{87}Sr/^{86}Sr$ ratios of plants were between those of the soils in which the plants were growing and those of atmospheric precipitation (0.7100). More than 74 % of the Sr in plants on the ridge, but less than 17 % in plants in the valley bottom, was volcanic ash-derived. The origin of Sr (and thus Ca) in stream waters and plants varied depending on the volcanic ash content in soils, which was significantly influenced by the site elevation. These results confirm that information about the Sr isotopic composition is useful for determining the sources and contributions of Sr and Ca in stream waters and plants, even in complex systems containing volcanic ash and bedrock weathered products.

Keywords: Ca sources, Sr isotopes, Atmospheric precipitation, Soil, Plants, Stream water

