Tracking carbon from subduction to outgassing along the Aleutian Subduction Zone

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Volatile cycling among Earth's mantle, crust, and surface reservoirs is an important process for magma generation, volcanism, and the long-term evolution and habitability of Earth. Volatile migration among Earth's reservoirs can be estimated by mass balance, using a volatile tracer such as carbon (C), whose chemical composition and flux can be measured or estimated both for the various source inputs and volcanic outputs. This project aimed to use new and existing measurements of volcanic gases from remote volcanoes within the Alaska-Aleutian arc, along with constraints on the composition and thickness of sediments presumed to be subducted into the Aleutian trench, to compare subduction inputs with volcanic outputs and ultimately characterize volatile cycling within this region. The composition of volcanic gas outputs and sediment inputs were used with two mixing models to constrain the proportions of C supplied from the three main subduction-zone C sources: subducted (altered) oceanic crust (AOC), subducted sediment, and mantle. These results were then combined with published constraints on the C flux from Aleutian volcanoes to estimate the amount of C supplied to volcanic outputs from each source within the Aleutian subduction zone.

Through this work we find that C source proportions vary significantly along the length of the Aleutian Arc, with Western Aleutian (WA) volcanoes having primarily mantle and AOC derived C, Central Aleutian (CA) volcanoes having primarily subducted sediment derived C, and Eastern Aleutian (EA) volcanoes having variable C inputs from all three sources. These along-arc variations can be explained in part by differences in sediment subduction vs. accretion, likely contributions of crustal C to EA volcanic emissions, and potentially greater slab AOC devolatilization in the EA and WA segments near slab edges. When volatile source proportions are averaged over the full arc, we find nearly equal proportions of volcanic C are supplied from mantle (~32%), AOC (~30%), and sediment (~38%) sources. When combined with published estimates of an Aleutian Arc volatile flux, we find that on an arc-wide scale only ~15% of trench sediments are recycled back to the atmosphere through volcanism. This may support previous studies of arc systems that indicate that the majority of C found in trench sediments is accreted to the overriding plate, subducted to the deep mantle, and/or stored in the overriding crust. Alternatively, this may reflect the previous subduction cycle before the Pliocene glaciation, when sedimentation rates were lower. This lower trench sedimentation input may have manifested as low sediment signals in present-day volcanic C output. These findings show that C contribution to the atmosphere from the Aleutians includes lower proportions of subducted sediment and crustal C, and higher proportions of AOC and mantle C, relative to other arcs. The dominance of AOC suggests that it may be a more globally significant input to atmospheric C than previously thought, especially in arcs where crustal C sources are minor. These combined findings have implications for the global C budget over Earth's history, and in turn the evolution of Earth's climate and suitability for life on Earth. ■

Reference

Sano, Y., B. Marty (1995). Origin of carbon in fumarolic gas from island arcs. Chem Geol, 119, 265-274

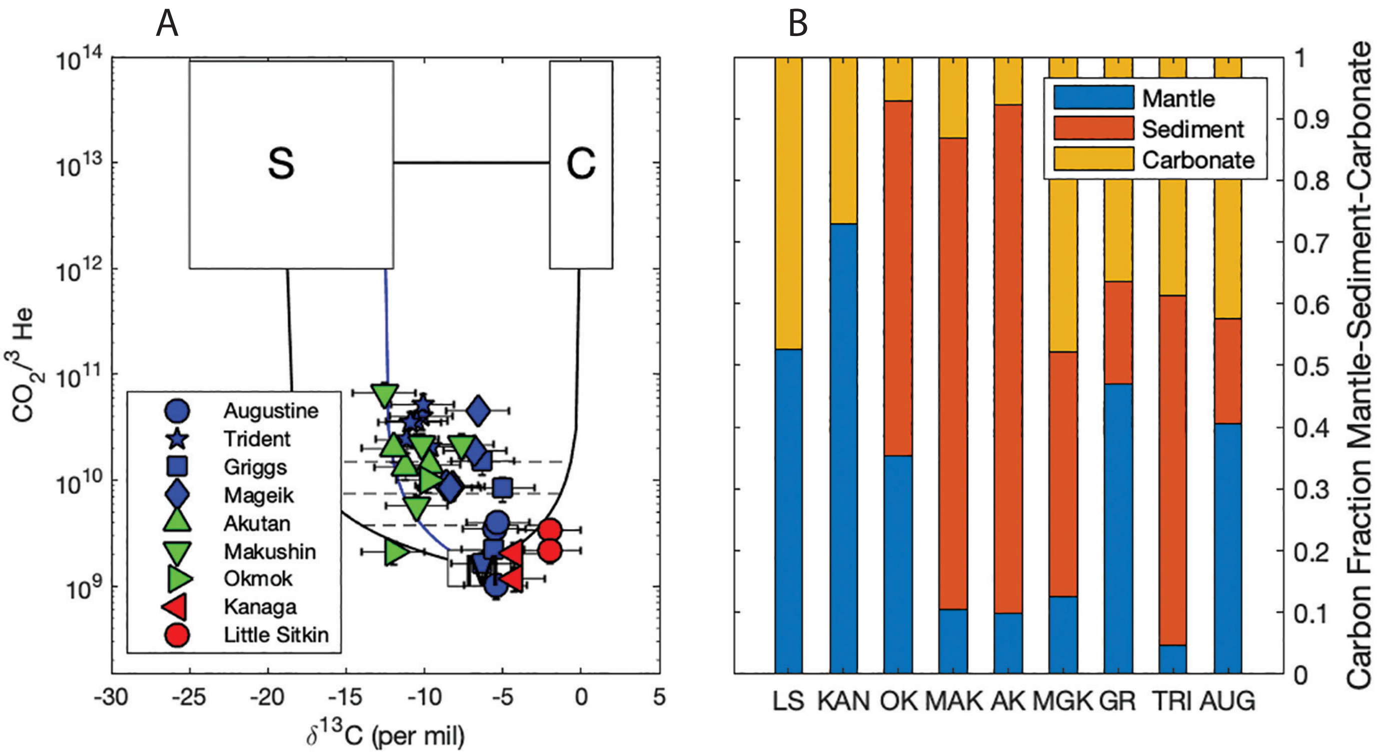

Figure 1. A. C-He three component mixing model results for the Aleutian Arc, following the methods of Sano and Marty (1995). This figure shows the volcanic gas compositions relative to those of end-member C sources of bulk sediment (S), carbonate (C) and Mid Ocean Ridge Basalt (MORB; M), used here as a proxy for upper mantle. Volcanoes within the different arc segments are colored, where blue, green, and red correspond with the eastern, central, and western Aleutian Arc segments, respectively. The M-S black line shows the mantle-sediment mixing line for the arc-minimum bulk sediment $\delta^{13}C$ value (-18.7), while the blue line shows the minimum bulk sediment $\delta^{13}C$ value (-12.6) seen in the Central Aleutians; B. Normalized mean proportions of sediment, carbonate and mantle C sources based on calculation results shown at left for Aleutian Arc volcanoes from West to East: Little Sitkin (LS), Kanaga (KAN), Okmok (OK), Makushin (MAK), Akutan (AK), Mageik (MGK), Griggs (GR), Trident (TRI) and Augustine (AUG). Mixing proportions were calculated using the minimum bulk sediment $\delta^{13}C$ value observed for each arc segment (-18.4 for EA, -12.6 for CA, and -18.7 for WA).

THE ALASKA & ALEUTIAN PRIMARY SITE defines the most tectonically active region in North America. It is the ideal location to study arc magmatism, structure and the contributions of arc volcanism to the development of continental crust. The Alaska and Aleutian subduction zone is also ideal for the study of earthquake processes and seismic cycle.

The Alaska and Aleutian subduction zone offered important opportunities to leverage onshore and offshore infrastructure associated with the EarthScope's Plate Boundary Observatory and the deployment of the US Transportable Array. GeoPRISMS investigations in Alaska faced logistical challenges due to remote locations of field work and required significant advance planning.