Quantitative analysis of high resolution isotope and concentration data from a toluene-pulse experiment by reactive transport modeling

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A major challenge in the application of compound-specific isotope analysis (CSIA) to quantify biodegradation at contaminated field sites is the separation of microbial- and physical-induced effects on the measured isotope signal. In contrast to simple analytical tools, as the Rayleigh equation, reactive transport models can account for the complex interaction of different fractionating processes.

In this study, we analyze the high resolution toluene concentration and isotope ratio ($\delta^{13}C$) data set of a large-scale laboratory toluene pulse experiment by reactive transport modeling. We uniquely quantify degradation and sorption properties of the system, estimate the contributions of reaction-induced, sorption-induced and transverse-dispersion-induced isotope fractionation to the overall isotope signal and quantify the error introduced by neglecting individual processes (e.g. fractionation by physical processes, Michaelis-Menten degradation kinetics) in the analysis of the data. Our results show that highly resolved data of both concentration and isotope ratios are needed for unique process identification of reactive transport facilitating reliable model calibration and that the combined analysis of these highly resolved data demands reactive transport models with sufficient complexity.

Mantle control on eruption style at Kīlauea Volcano, Hawai'i

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Ocean island volcanoes are associated with melting of a heterogeneous mantle source. Geochemical heterogeneity might be expected to influence the way in which melts ascend and are stored and erupted, with some melts inherently more enriched in incompatible trace elements, and hence volatiles, than others. Contrasts between effusive and explosive (fountaining) behaviour in basaltic magmas has previously been explained in terms of shallow melt-gas segregation, with little geochemical control. Here we present data from a suite of melt inclusions from 25 historical eruptions of Kīlauea Volcano over the last 500 years. The deposits were emplaced via a range of eruptive styles, from effusive lava flows, fissure eruptions, high fountains and transient subplinian (gas-rich) eruptions.

The data show that more explosive styles of eruption (high fountaining and fissure eruptions) are associated statistically with more enriched melts (with higher relative proportions of Light Rare Earth Elements) with higher volatile concentrations, which ascend faster, retain their primitive nature and interact only minimally with the summit magma reservoir. Effusive styles of eruption, on the other hand, are linked statistically with more depleted melts, with lower volatile concentrations, that tend to homogenise, cool and evolve in the summit magma reservoir before eruption.

The ranges in melt volatile concentrations between the “depleted” and “enriched” end member primary melts are approximately 0.28 to 0.87 wt% water respectively and 0.17 to 0.68 wt% carbon dioxide respectively. The more volatile-rich melts are considerably more buoyant, which has a dramatic effect on their transport, storage and eruption, owing to their higher vapour content at low pressure, increasing the likelihood of explosive high fountaining styles of volcanic activity. Over time, Kīlauea's style of eruption and magma supply rate are linked fundamentally to the geochemistry of primary melts: magma explosivity thus might be determined right at the point of separation from its mantle source region.

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