Geophysical Research Abstracts
Vol. 21, EGU2019-8835-1, 2019
EGU General Assembly 2019

Noble gas isotopes at the Kermadec arc

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Primordial helium is one of the gases carried from the Earths' mantle into the ocean by hydrothermal fluids, thus hydrothermal fluids and plumes are highly enriched in helium, especially the isotope 3He. The isotopic signature, the 3He/4He ratio, of primordial helium is significantly different from the atmospheric ratio, and can be identified with high precision in water samples. Commonly used to describe the excess 3He is the parameter delta3He, that is defined by the isotopic ratio R = 3He/4He compared to the atmospheric ratio, RA (delta3He = 100[(R/RA)-1] in %). As a noble gas, the concentration of helium in the sea water is only altered by physical processes as mixing, not by biological and chemical reactions or processes. Therefore, the isotopic signature of helium can be used to identify and track the output of hydrothermal fields.

During an expedition with the RV Sonne ($SO_2$53, Dec 2016 — Jan 2107), we sampled the noble gas signature of several chemically diverse hydrothermal systems along the Kermadec arc (SW Pacific) , including Macauley, Rumble III, Haungaroa, and Brothers volcano. The 100+ samples come from the water column plumes of the systems taken with a CTD/water sampling system as well as from less diluted samples collected with an ROV based sampling device typically 1m above the vents. In addition to the noble gas samples, radium isotopes have been determined from the same samples.

Island arcs exhibit considerable more variability in fluid composition than mid-oceanic ridge systems. At the Kermadec arc, especially Brothers volcano, multiple expeditions over the past two decades have lead to a large data base with regard to the fluid composition and its temporal evolution, indicative of changes in the underlying hydrothermal systems. At Brothers volcano, we thus extended the existing time series of helium isotopes that have been intermittently sampled since the late 1990s.

The 3He/4He ratios at the volcanoes vary between 5. 8 and 6.5 Ra. The maximum observed delta3He at the non-buoyant plume level are for Rumble III 90%, Haungaroa 83%, Macauley Cone site 144%, Macauley Caldera site 16%, Brothers Cone site 56%, Brothers NW Caldera site 94%. Comparison with the previously existing data sets shows in addition to this variability between individual systems a considerable amount of temporal variability. While the systems at Brothers and the Macauley Caldera site appear to be relatively stable since the late 1990s/early 2000s, the delta3He at Macauley Cone has increased by a factor of 10 since the observations during the NZASRoF expedition in 2005. This site also showed the highest recorded delta3He of 445% in a weakly diluted sample (pH = 5.0) from rising plume, less than 1m above the vent.