Prompt recognition of submarine volcanic activity based on detection of mantle-derived volatiles in seawater collected using a flying boat

*Hirochika Sumino[1], Urumu Tsunogai[2], Takanori Kagoshima[3], Kaori Kawana[1], Toshiya Mori[4], Takeshi Ohba[5]

1. Department of Basic Science, Graduate School of Arts and Sciences, The University of Tokyo, 2. Graduate School of Environmental Studies, Nagoya University, 3. AORI, The University of Tokyo, 4. Geochemical Research Center, Graduate School of Science, The University of Tokyo, 5. Department of Chemistry, School of Science, Tokai University

The submarine volcanic eruption may cause significant damage to inhabitants of nearby islands and ships traveling in the vicinity. Even during relatively quiescent periods, some submarine volcanoes regularly emit hydrothermal fluids together with gas plumes that reach the ocean's surface [1]. The release of such fluids from the earth’ s interior is thought to have a great impact on the ocean environment. Therefore, understanding submarine volcanic activity is necessary not only for the earth sciences but also for disaster prevention. However, while the large-scale emission of hydrothermal fluids from a submarine volcano can be observed via discoloration of surface seawater, what is actually going on on the ocean floor is difficult to be inferred from the surface. Therefore, it is desirable to find a new method of collecting samples from submarine volcanoes quickly and safely, and evaluating submarine volcanic activity.
The volatile components, particularly helium emitted from submarine volcanoes are observed diffused into upper seawater. Above mid-ocean ridges, for example, dispersions of mantle helium over a wide range extending over 1,000 km have been detected [2]. The amount of helium degassed from the earth’ interior has been estimated from the mantle helium distribution in the ocean [3]. Furthermore, the mantle helium emission can also be used to place limits on the amount degassed of other volatiles [4]. Helium is chemically inert, so its isotope ratio ($^3He/^4He$) is unaffected by the physical and chemical conditions such as temperature, pressure, and pH and the isotope ratio of mantle helium differs by an order of magnitude from that of ambient seawater, which is almost atmospheric in composition. These features make helium an extremely sensitive and highly reliable geochemical tracer for oceanic hydrothermal fluid emissions.
In this presentation we will propose the use of a flying boat to conduct seawater sampling and the use of $^3He/^4He$ ratio analysis for the prompt detection of submarine volcanic activity. Sampling at depths of 100 m or more is routinely conducted with a Niskin water sampler [5] or hosepipe [6], so a flying boat could be promptly dispatched to areas where discoloration or foaming has been observed at the ocean surface, where quick multipoint sampling at depth would be conducted. Using the maneuverability of the flying boats, $^3He/^4He$ isotope ratio analysis could be conducted at the laboratory the next day to make it clear whether or not new hydrothermal fluids are being emitted. If the flying boat could remain for a relatively long period of time in the target area, depth profiles at multiple locations would be taken to obtain a three-dimensional profile of the distribution of mantle helium, and to estimate scale of the magma responsible for the degassing from the overall amount of emissions.
Besides helium, carbon isotope ratios of carbon dioxide and methane as well as nitrogen isotope ratios can provide important limits regarding the origin of dissolved volatiles in seawater [1, 5, 6]. We are promoting the development of method to collect and analyze bottom water in the vicinity of submarine volcanoes and of on-site isotope ratio analysis techniques using portable mass spectrometers [7] and laser-based isotope ratio spectrometers [8]. Through combining these new technologies with prompt sampling using flying boats, we would like not only to further our understanding of the degassing history of the earth and the primary causes of changes in ocean environments, but also to contribute to disaster prevention by providing prompt detection of submarine volcanic activity.

[1] Wen *et al.*, *Sci. Rep.* 2016. [2] Lupton & Craig, *Science* 1981. [3] Bianchi *et al.*, *EPSL* 2010. [4] Kagoshima *et al.*, *Geochem. J.* 2012. [5] Nishimura *et al.*, *Geochem. J.* 1999. [6] Notsu *et al.*, *JVGR* 2014. [7] Jensen *et al.*, JpGU-AGU Joint Meeting 2017. [8] Rizzo *et al.*, *GRL* 2014.

Keywords: isotope, helium, submarine volcano, flying boat, volatile elements

