Brothers submarine arc volcano: gateway to the sub-arc mantle

Cornel E.J. de Ronde[1] and the Lisbon IODP Working Group

[1] *GNS Science: Dept. Marine Geosciences, Lower Hutt 5010, New Zealand*

cornel.deronde@gns.cri.nz

The GeoPRISMS Science Program includes two broadly integrated initiatives, distinguished by tectonic setting, with the "Subduction Cycles and Deformation" initiative taking a holistic approach to the deformation processes and *material cycles governed by subduction* (GeoPRISMS draft science plan, 2010). In particular, it studies the properties, mechanisms, and manifestations of strain build-up and release along plate boundaries, and the *transport and release of volatiles such as H_2O and CO_2 through the thrust zone and sub-arc mantle*. One of five Overarching Themes, "Fluids, Magmas and Their Interactions", serves as the basis for integrative studies, with a new focus on *volcanic systems* providing *potential linkages to mining and minerals.* Brothers volcano of the Kermadec Arc, New Zealand, affords an opportunity for such integrative studies.

Volcanic arcs are the surface expression of magmatic systems that result from the subduction of mostly oceanic lithosphere at convergent plate boundaries. Arcs with a submarine component include intraoceanic arcs and island arcs that span almost 22,000 km on Earth's surface, with the vast majority located in the Pacific region. Intraoceanic arcs total almost 7,000 km, thus ensuring a steady supply of dissolved gases and metals to the oceans, and the potential for the formation of polymetallic mineral deposits.

Most mineralization along intraoceanic arcs is dominated by mineral assemblages representing high-sulfidation conditions, including elemental sulfur, polymorphs of silica, alunite and lesser pyrite. This mineralizaton is typically associated with relatively low temperature (≤120°), diffuse, acidic (pH <3), metal-poor but gas-rich emissions from seafloor hydrothermal systems. Less common are focused, relatively high temperature (~300°C), metal-rich fluids where Fe-Cu-(±Au)-Zn sulfides and barite/anhydrite predominate. Both types of venting show evidence for contributions from magmatic sources. These two types of venting represent end-members of a continuum that spans magmatic-hydrothermal to water/rock dominated systems, respectively. More mature vent fields are better able to deliver and accumulate metals at the seafloor.

The ~1,220 km long Kermadec arc is host to ~40 large volcanoes of which 80% are hydrothermally active, making it the most active arc in the world. Hydrothermal activity associated with these arc volcanoes, including both caldera- and cone-types, is dominated by the discharge of magmatic volatiles. This hydrothermal magmatic signature(s), including high concentrations of S and C species gases together with high Fe contents, coupled with the shallow depths (~1800-120 m below sea level) of these volcanoes, greatly influences the chemistry of the venting fluids, the mineralization that results from these fluids, and more than likely has important consequences for the biota associated with these systems. Given the high metal contents and very acidic fluids, these hydrothermal systems are thought to be important analogues of the porphyry copper and epithermal gold rich deposits exploited on land today.

Brothers volcano of the Kermadec arc is host to a hydrothermal system unique among seafloor hydrothermal systems. It has two distinct vent fields, known as the NW Caldera and Cone sites, whose geology, permeability, vent fluid compositions, mineralogy and ore forming conditions are in stark contrast to each other. The NW Caldera site strikes for ~600 m in a SW-NE direction with chimneys occurring over a ~145 m depth interval, between ~1690 and 1545 m. At least 100 dead and active sulfide chimney spires up to 7 m tall occur in this field, whose ages fall broadly into three groups: < 4 years, 23 and 35 years old. Two main types of chimney predominate: Cu-rich (up to 28.5 wt.% Cu) and more commonly, Zn-rich (up to 43.8 wt.% Zn). Vent fluids here are focused, hot (≤302°C) and metal-rich, with moderate gas contents.

The Cone site comprises the Upper Cone site atop the summit of the recent (main) dacite cone, and the Lower Cone site that straddles the summit of an older, smaller, more degraded dacite cone on the NE flank of the main cone. Huge volumes of diffuse venting are seen at the Lower Cone site, in contrast to venting at both the Upper Cone and NW Caldera sites. Individual vents are marked by low relief (≤0.5 m) mounds comprised predominately of native sulfur with bacterial mats. Vent fluids are very acid (pH 1.9) and gas-rich, though metal-poor. The NW Caldera and Cone sites are considered to represent water/rock and magmatic-hydrothermal dominated end-members, respectively. Drilling Brothers would provide an exciting opportunity to understand subseafloor volcanic architecture, hydrology, polymetallic ore deposition formation and the deep biosphere of intraoceanic arc volcanoes associated with convergent plate margins.

References:

de Ronde, C.E.J., Massoth, G.J., Butterfield, D.A., Christenson, B.W., Ishibashi, J., Ditchburn, R.G., Hannington, M.D., Brathwaite, R.L., Lupton, J.E., Kamenetsky, V.S., Graham, I.J., Zellmer, G.F., Dziak, R.P., Embley, R.W., Dekov, V.M., Munnik, F., Lahr, J., Evans, L.J. and Takai, K., 2011, Submarine hydrothermal activity and gold-rich mineralization at Brothers volcano, Kermadec arc, New Zealand. Mineralium Deposita 46: 541-584, DOI 10.1007/s00126-011-0345-8.

GeoPRISMS Draft Science Plan, 2010, http://www.geoprisms.org/science-plan.html

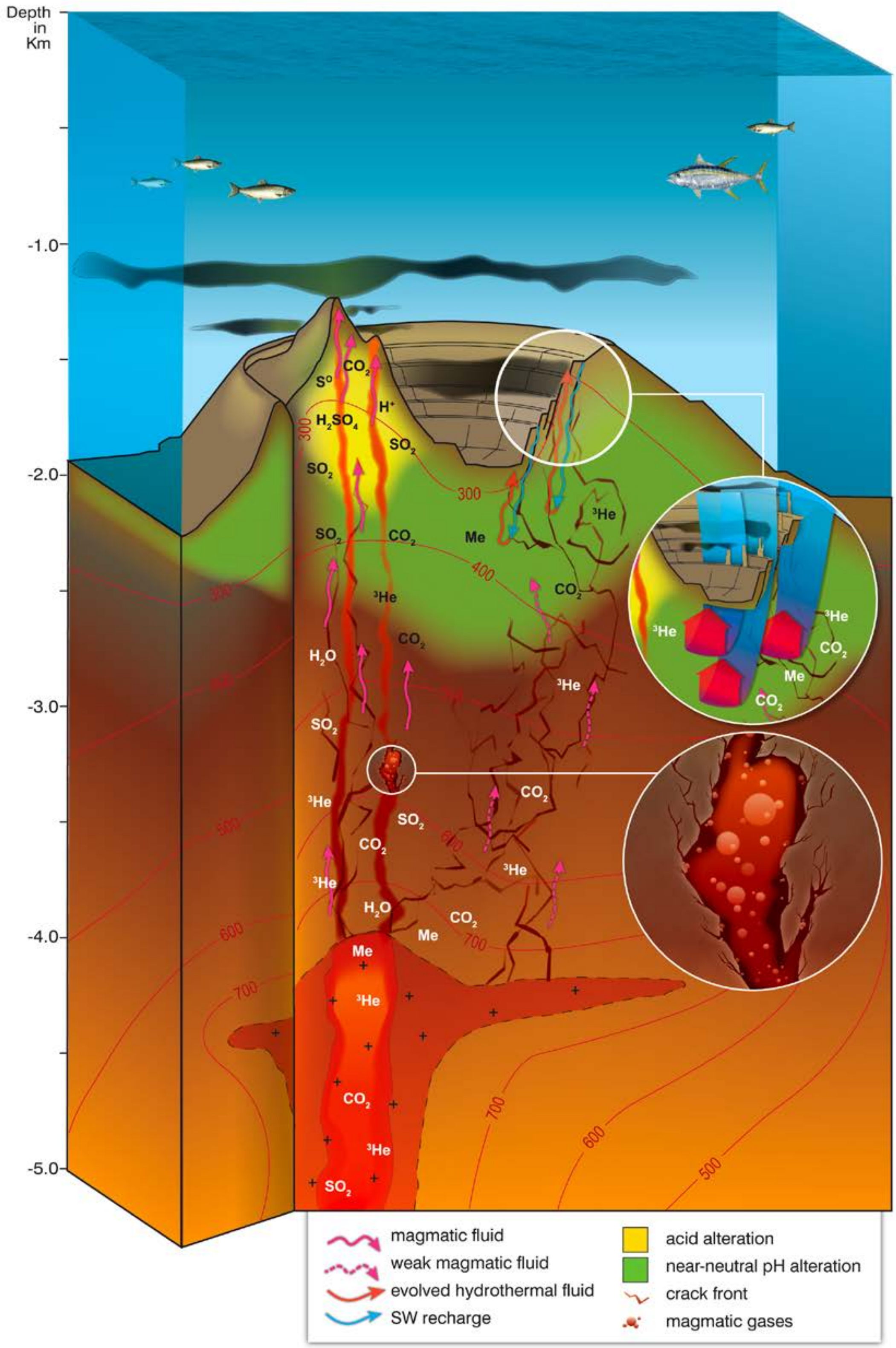

Figure 1. High resolution, AUV-derived data of seafloor geology, structure, geophysics and vent distribution, plus submersible sampling of rocks, mineralization, biology and vent fluids, has enabled a first-order model of the hydrothermal system at Brothers to be constructed (from de Ronde et al., 2011).