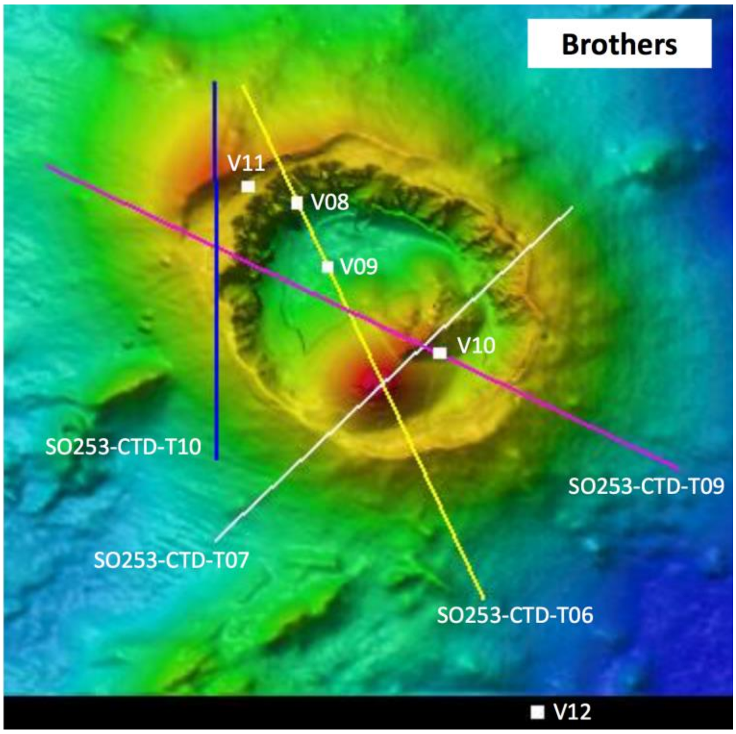
SO253 4. Weekly Report 10.– 16.01.2017

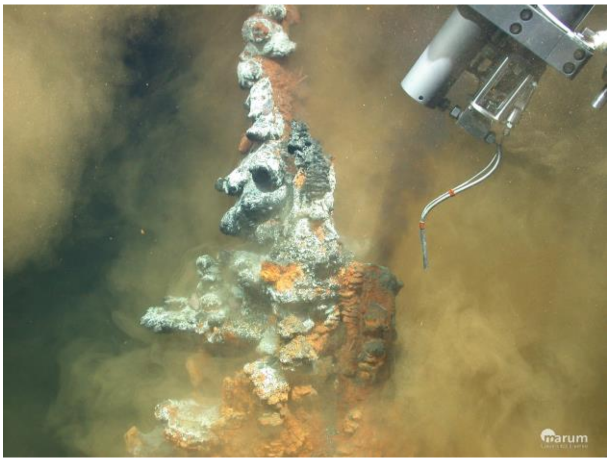
This whole week was fully dedicated to our third working area, Brothers volcano. Although ROV deployments and sampling turned out to be a challenge because of the slightly rough weather and strong currents, we were still able to carry out 7 ROV dives, 4 tow-yos and 5 vertical CTD stations (see map below), 4 in-situ pumps, 3 trace-metal rosette deployments and several echosounder and gravimeter survey tracks.



Brothers volcano is perhaps the most hydrothermally active of all volcanoes along the Kermadec Arc. It forms an elongate edifice 13 km long by 8 km across that strikes northwest-southeast. Brothers Volcano is host to a 3x5 km large caldera with a floor at 1,850 m below sea level, surrounded by 290 to 530 m high walls. Heat flow measurements recorded the highest values ever measured for heat flow from a submarine hydrothermal system. A conical volcanic peak rises 350 m from the southern caldera floor (Upper Cone), and a smaller, more rugged one (Lower Cone) outcrops immediately northeast of the Upper Cone. The Lower Cone consists of very fresh and extremely steep felsic volcanic necks/dikes and steep-sided flows. Fluids sampled on the steep, south-eastern flank of the Lower Cone were gassy (rich in CO_2), but had very low concentrations of H_2 and CH_4 and were low in Fe; chlorinity was close to seawater and the pH around 4. The main crater of the Upper Cone was hydrothermally inactive, but in a smaller depression immediately to the south, abundant hydrothermal venting of white smoke was detected. This was not seen during previous dives in 2005 and 2009. Sampling recorded acidic fluids with similar gas compositions as the Lower Cone.

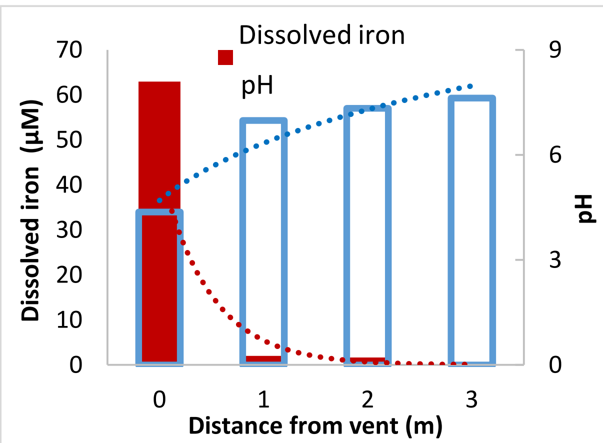
The northwestern wall of the caldera hosts abundant hydrothermal vents with Cu-Fe-Zn-Ba-rich chimneys that vent fluids with highly variable gas contents. Also spectacular beehive chimneys and obviously high-temperature alteration mark this NW Caldera site. Many of these chimneys are actively venting black smoke into the water column. A previously unrecognized site of hydrothermal venting from 20-m tall chimneys was discovered northwest of the main hydrothermal field, on the southeastern flank of the upper caldera wall. Many huge chimneys had fallen downslope like logged trees. The 311°C hot fluid sampled there sets a new vent temperature record for the Kermadec arc. The summit of the upper caldera wall is hydrothermally inactive, although minor Fe-oxide mounds are present.

The chemical composition of fluids from the NW Caldera site differed from our previously sampled vent sites at Macauley and Haungaroa. That is, concentrations of dissolved sulphide in the hot fluids yielded a maximum value of 2.3 mM which is within the range of previously

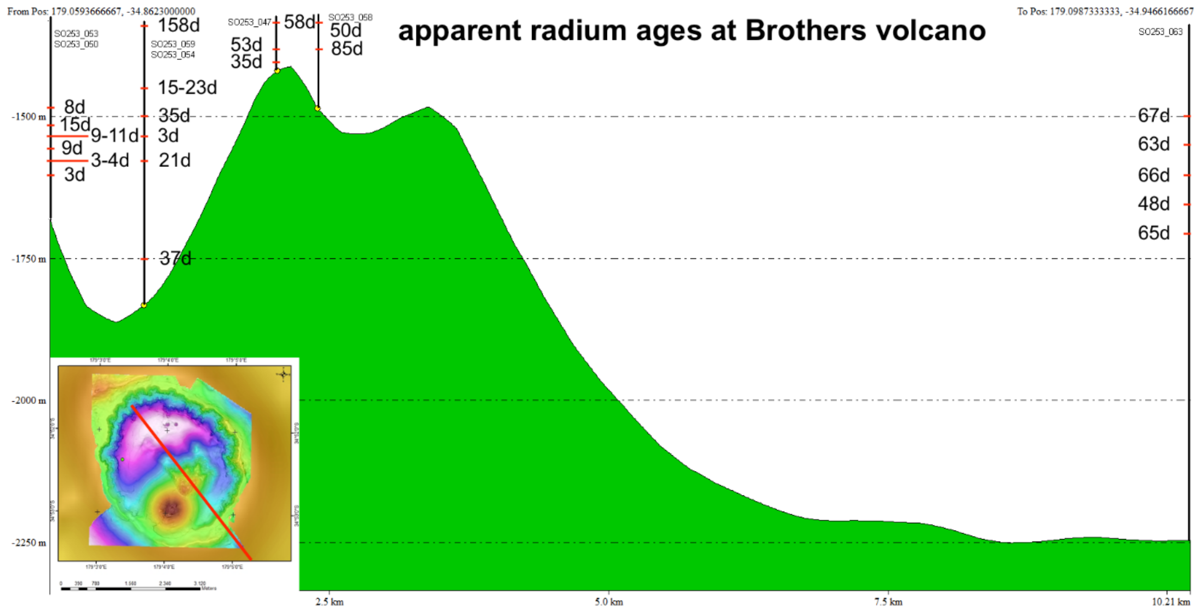


reported sulphide concentrations in fluids at Brothers volcano. Concentrations of H_2 and CH_4 were moderate and Mg concentrations typically depleted. Fluids with chlorinity above seawater (brine fluids) had more than 10 mM Fe (with most of it being Fe^{2+} but also with significant concentrations of Fe^{3+}) which is among the highest Fe concentrations of all known hydrothermal sites. Even in fluid samples with depleted chlorinity (i.e. vapor-type fluids) Fe was around 4 mM. Hence, this area is of major importance for our study on hydrothermal Fe flux into the ocean and its potential contribution to biogeochemical cycles.

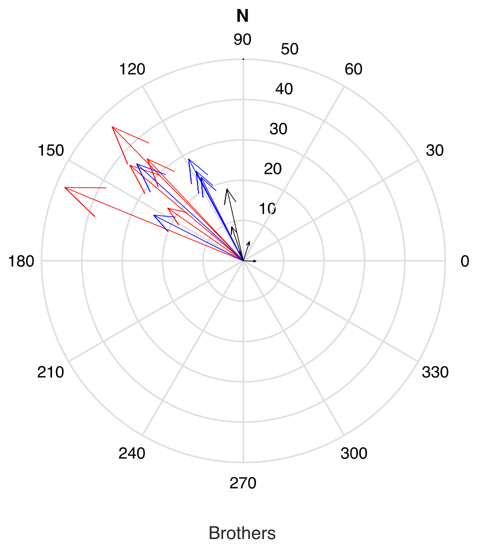
Four in-situ particle pump stations and three trace metal rosettes were deployed in the Brothers volcano area. The samples taken will be used to define the size and age of the plume, especially the distal plume, which is impossible to distinguish from background for the in-situ sensors on the CTD. We were able to track the iron plume at 1250m depth for more than 10km to the north-east of the cone, the suspected source of this plume. Our on-board iron-FIA analysis has been running samples from CTD and trace metal rosette deployments, as well as samples from ROV dives that were too low to be detected by colorimetric determination. The figure below shows a gradient of iron concentrations and pH with distance from a low temperature hydrothermal vent (see photo) at the Lower Cone.



Plume ages at Brothers have been determined based on the measurement of the two short-lived radium isotopes, 224Ra and 223Ra, along the NW-SE main current using data based on high volumes of water (20-400 L) sampled by in-situ pumps and vertical CTD rosette samplers (see figure). We use the term "apparent ages" as these preliminary results are not corrected



for radioactive decay between sampling and measurement, thus the final age may be slightly lower. The age structure of plumes at Brothers is much more complicated than those of Macauley and Haungaroa. The reason for the apparent disorder in the water column around the cones and the caldera is related to the occurrence of multiple active vents, the resulting plumes and the role of the currents. Nevertheless, at all three volcanoes investigated so far during the cruise there is a general trend with the lowest ages in the plume maximum and higher ages further away in both a vertical sense as well as in a horizontal direction, confirming that onboard determination of short-lived radium isotopes is a useful strategy to support planning of stations during the cruise.



Current measurements of 5 vertical casts at Brothers volcano showed strong currents in the upper part of the ocean between the summit at approximately 1200 m and the surface. The current velocities were on average between 20 and 40 cm/s in south-easterly direction, intensifying towards the surface to 50 cm/s. In the caldera of the volcano, the currents were impeded by the crater rim and decreased. This results in an accumulation of plume material below the crater rim as was evident from an increase in turbidity in the water in this depth range.

Hydrothermal fauna at Brothers was much scarcer than at the previous two volcanoes. Nevertheless, huge numbers of long-necked (stalked) barnacles at the Lower Cone site were found flourishing in the diffuse fluids. We also found the first live mussels ever recovered from Brothers: *Vulcanidas* mussels were collected in 1580 m water depth on the northern slope of the NW Caldera site. After the recovery of these mussels from Haungaroa, this collection at Brothers represents another depth record for these mussels which were formerly only known from sites shallower than 500 m at Macauley and Giggenbach. *Vulcanidas* mussels are phylogenetically basal to the clade of chemosynthetic bathymodiolin mussels from hydrothermal vents, cold seeps and wood falls in the deep sea. Genetic analysis in shore-based laboratories will show if the Brothers mussels belong to the same species *V. insolatus* that was named after its shallow occurrence (insolatus = in the sunshine). If so, previous hypothesis based on shallow habitats being primary for this species, may be questioned.

In short, we have confirmed with our work what had been discovered previously in some places and can now assess temporal variations. However, we also acquired a lot of additional information in other places, especially the Upper Caldera site that was previously unknown.

On 15 January, we arrived in our fourth and last working area, Rumble III, which is a large shallow volcanic edifice characterized by very recent volcanic activity. No dives have been carried out before in this area. We are presently exploring this new place using seafloor and water column mapping, CTD stations and our ROV Quest. In addition to the scientific work, preparations for the arrival in Auckland on 21 January have been ongoing for quite some time already.

With best regards from board RV Sonne on behalf of the whole science team of cruise SO253

Andrea Koschinsky (chief scientist SO253)