Breakout 1b: Science Targets for Volcanic Processes
Summary by Bill Chadwick and James Foster

The discussion in this breakout session was wide-ranging but also guided by three broad questions:

- **What big science questions can be better/only addressed with seafloor geodesy?**

Learning about active volcanic processes is maximized by long-term geodetic monitoring that can capture dynamic processes of interest. On the seafloor this could include, for example, seafloor spreading processes at mid-ocean ridges - which might involve magma accumulation and inflation, diking, faulting, and eruptions of lava onto the seafloor. Geodesy can help address questions such as: the relative roles of diking and faulting in plate boundary extension. Or: determining the width of the zone where extensional strain is accommodated and the implications for the rheology of the ocean crust and upper mantle. Or: whether the temporal and spatial variations observed in seismicity and hydrothermal activity are linked to magma movements.

It was noted that sites that include monitoring of multiple geophysical observables (seismicity and deformation, for example) provide much more information for interpreting active processes than sites with more limited observations. For example, at intermediate and fast spreading ridges only a small percent of the extension is accommodated seismically. Geodesy can confirm major subsurface magma movements such as inflation/deflation from magma accumulation or withdrawal, extension from dike intrusion and faulting, and can quantify magma volumes and supply rates from modeling. The deformation of unstable submarine flanks of some island volcanoes are similar to subduction zones in that on-land monitoring provides critical information, but also misses important details of the process located offshore, and can only weakly constrain models without seafloor geodetic observations. Thus, there may be "more bang for the buck" in adding seafloor geodesy capabilities in places that are already instrumented in other ways.

- **What deployment strategies are needed to adequately measure these signals?**

We also had some discussion on the subject of the stability of benchmarks on the seafloor and the specific needs of different applications that included re-occupation of benchmarks. For example, there may be a need to study the repeatability of measurements before and after swapping instruments. For some applications, it may be preferred to leave the transducer fixed on the benchmark and only swap the batteries and electronics. At some sites, it may be important to position benchmarks with an ROV during the initial deployment to ensure site stability, or to push down benchmarks into sediment to prevent later settling. It was noted that "structure from motion" photographic techniques have been used to confirm benchmark stability relative to nearby calibrated marker posts. Our industry friends helpfully remarked that benchmarks that weigh thousands of tons tend to be very stable (!). The amount of attention needed to be focused on site stability obviously depends on the size of anticipated signals at any particular site and the character of the seafloor.

We also noted that a strategy that might make sense for some projects where the frequency of events is unknown might be to deploy a group of GNSS-A sites with seafloor benchmarks, make the first measurements, then recover the transponders so they can be used elsewhere. After an event of interest occurs then the transponders would be re-deployed on the benchmarks to document post-event changes. This would require the use of an ROV. Another unconventional strategy worth exploring is the idea of having one transponder on the seafloor interrogated by three wave gliders at the surface. This would likely increase the position errors, but would increase the number of monitored points on the seafloor by 3, so could be useful in areas where large displacements are expected.

It was recognized that for many signals of interest APGs or direct-path acoustic ranging might be a better solution than GNSS-A. Particularly in the case of APGs it was noted that many of these lower-cost sensors could be deployed quickly and provide important spatial coverage with adequate signal resolution in response to events of interest.

Overall, high-priority science goals included sites where poorly understood submarine processes could be illuminated: mid ocean ridge seafloor spreading dynamics; volcano flank dynamics at Kilauea; and the eruption cycle at Axial Seamount - where the juxtaposition of a hotspot volcano on thin oceanic crust allows a clearer view of the underlying processes. Sites with other marine infrastructure and complementary datasets are particularly appealing, such as at Axial Seamount where the OOI-Cabled Observatory monitoring network, high-resolution bathymetry, and 3D multichannel seismic datasets exist.

- **Are these questions best answered through PI-driven or community Projects?**

There was some discussion of whether seafloor geodesy projects focused on Volcanic Process targets would likely be PI-driven or Community-Driven.   The consensus was that it depended on the scale of a given project. For example, at the scale of a single volcano, it's not clear that there would be sufficient scope to support a community effort. On the other hand, a larger and more ambitious project like monitoring multiple segments of a mid-ocean ridge could potentially be a larger community project. There could also be multi-disciplinary projects that combine geodesy with another field like seismology, vent fluid chemistry, or physical oceanography, for example. The OOI Cabled Observatory is an example of a community project that includes geodesy components, but also many others, with all the data open to the community. This model has fostered a lot of interdisciplinary communication and collaboration.

Finally, we learned that IFREMER in France has recently funded the creation of a new cabled observatory offshore the island of Mayotte where an extraordinary and enigmatic eruption has been going on since 2018. The observatory will include 8 GNSS-A instruments, an autonomous surface vehicle, and 10-15 APGs. US and other international contributions to this effort are welcome and encouraged. This could serve as a potential template for ways in which modest contributions from the US instrument pool could be leveraged as part of a larger collaboration/consortium to achieve more ambitious science goals than would be possible otherwise, and without committing all the pool resources to a single community project.