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Dynamics of magma reservoir before and after volcanic eruptions at Axial Volcano in the Eastern Pacific using time-lapse seismic imaging method

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Unraveling the nature (physical state) of magma reservoirs beneath active volcanoes is essential to understand their eruption potential. Magma can be in a pure melt state and hence it is more likely to erupt if supplied by fresh melt from below, or in a mush state that is less likely to erupt. However, imaging magma reservoirs on land and deciphering their physical properties is inherently difficult, but the submarine environment offers more favorable conditions, as exemplified by the fact that magma reservoirs have been commonly imaged beneath fast and intermediate spreading centers. Moreover, when several collocated high-quality seismic datasets are available at different times, time-lapse seismic analysis, commonly used in industry, could be applied to study the evolution of the reservoir through multiple eruptions cycles.

The Axial Volcano is a large submarine volcano at the intersection of the Juan de Fuca Ridge and Cobb hotspot that hosts many hydrothermal vent fields and has erupted three times (1998, 2011 and 2015) in recent years. The volcano was the site of a seismic reflection survey in 2002 and some lines were reshot after the 2011 and 2015 eruptions, respectively in 2012 and in 2019. In this study, we focus on one NW-SE oriented profile and apply time-lapse techniques to investigate changes in the magma reservoir before and after the 2011 and 2015 eruptions. Time-lapse signals could be due to the change in depth of the top of magma reservoir and/or a change in the state (melt versus mush) of the magma. The three data vintages were first processed to remove the effect of the data acquisition footprint, which included deghosting, wavelet shaping, and matching filter application. Dynamic time warping was applied to measure time shifts on stacked images, and amplitude energy changes (reflecting impedance contrast variations) were subsequently computed. In addition, absolute reflection coefficients were calculated to obtain indications on melt fraction evolution through time.

The time-lapse results reveal uplift and subsidence of the magma lens before and after eruptions on the scale of 4ms to 20ms. In comparison with 2002, one year after the 2011 eruption, the southeast portion of the magma lens outside the caldera shows uplift, while the portion beneath the 2011 lava flow inside the caldera exhibits subsidence. Interestingly, the melt percentage has decreased everywhere. Then 4 years after the 2015 eruption, in comparison with 2012, the portion of the magma lens beneath the 2011 lava flow southeast of the caldera show subsidence, whereas the portion beneath the 2015 lava flow inside the caldera has continued to undergo slight uplift, with melt fraction increasing in both regions. The contrasting time shift patterns inside versus outside of the caldera could indicate that different magmatic processes are at play in these regions before and after eruptions.

In this contribution, we will present the details of our time-lapse methodology and insights gained about magma dynamics at Axial Volcano using our methodology.

Speaker information

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