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Quantitative interpretation of multi-parameter constraints from marine geophysical experiments at active volcanoes

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Constraining magma reservoirs is important for understanding magma storage and ascent in the crust. The application of marine geophysical approaches to active volcanoes, involving the deployment of dense temporary seismometer networks to record the seismic waves generated by airgun sources, has opened the way to new inversion techniques, promising increased resolution and robustness. Geophysical imaging, however, is far from a silver bullet and has limitations arising mostly from non-uniqueness of geological interpretations. Physical properties, like seismic velocities and density, are affected by many factors (composition, porosity, temperature, melt content), therefore interpretation of seismic tomography models on their own can rarely provide accurate estimates on melt distribution and temperature in the crust. Joint inversion of independent geophysical data allows one to recover multiple parameters and reduce the non-uniqueness of interpretations. We developed a quantitative interpretation approach based on rock physics to analyse the relationship between Vp and density and their spatial variability. When multiple parameters, like Vp and density, are considered together, the effects of melt content can start to be disentangled from other factors since the Vp/density relationship is affected by melt content and by the melt inclusion geometry. These techniques have been applied on the Soufrière Hills Volcano, Montserrat, and are being tested at Santorini Volcano, Greece. Tomographic inversion of first-arrival P-wave traveltimes from a recent active source seismic experiment reveals multiple low-P-wave velocity volumes inside Santorini caldera. Quantitative interpretation allows us to distinguish high-porosity regions from partial melt. Future work will include the joint interpretation of seismic attenuation and Vs models. When considered together with ground deformation observations and seismicity distribution, these constraints will help better understand future volcanic eruptions and other magmatic unrest episodes.