Full-waveform inversion at Santorini volcano

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Detailed knowledge about geometry and physical properties of magmatic systems at arc volcanoes promises to better constrain models of magma differentiation, transit and storage in the crust, and to help assess volcanic hazard.

Unfortunately, low-velocity zones associated with melt accumulation are particularly difficult to image by conventional travel-time tomography due to its limited resolving power, resulting in blurred boundaries and underestimated velocity contrasts.

Here we alleviate these issues by applying full-waveform inversion (FWI) to study a magmatic system of Santorini - an active, semi-submerged volcano with a known record of large, caldera-forming eruptions.

We use a 3D wide-angle, multi-azimuth seismic dataset from the recent PROTEUS experiment acquired with ca. 150 ocean-bottom/land seismic stations and ca. 14,000 air-gun shots. We implement a finite-difference immersed boundary method to simulate reflections off the caldera’s irregular topography, and pressure-velocity conversion to take full advantage of the multi-component data. We perform inversion with careful data-selection, increasing frequency up to 6 Hz, and extensive quality-control based on a phase spatial-continuity criterion.

A final P-wave velocity model of the upper crust offers a high-resolution image of Santorini magmatic and hydrothermal systems with pronounced low-velocity zones due to a high melt and water content respectively. The features are better resolved and the velocity contrasts distinctly sharper than in the starting model obtained with travel-time tomography. We also recover a previously undetected low velocity anomaly of >40% beneath Kolumbo - a submarine volcanic cone to the NE of Santorini caldera. We interpret this anomaly as a magmatic sill.
