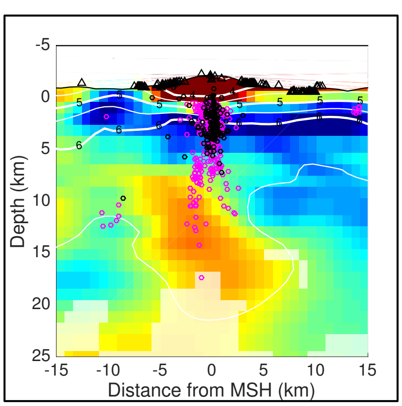
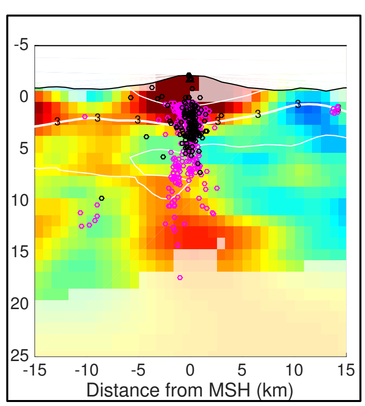
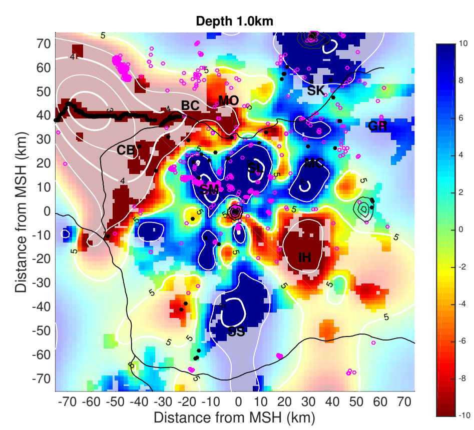
Imaging seismic zones and magma beneath Mount St. Helens with the iMUSH broadband array

Ken Creager, Carl Ulberg, Kayla Crosbie, Robert Crosson, Eric Kiser, Alan Levander, Brandon Schmandt, Steven Hansen, Olivier Bachmann

We deployed 70 broadband seismometers from 2014 to 2016 to image the seismic velocity structure beneath Mount St. Helens (MSH), Washington, as part of the collaborative imaging Magma Under St. Helens (iMUSH) project. The broadband array had a 100 km diameter and a10-km station spacing, augmented by dozens of permanent stations. More than 400 local earthquakes M>0.5 occurred during the deployment, providing over 12,000 P-wave and 6,000 S-wave arrival times. We recorded P-wave arrival times from 23 explosions from the active-source component of iMUSH, and incorporated additional P-picks from the permanent network. We used the program struct3DP to invert travel times to obtain a 3-D seismic velocity model for Vp and Vs including relocated hypocenters. Travel times were computed using a 3-D eikonal-equation solver. Principal features of our 3-D models include: (1) Low P- and S-wave velocities along the St. Helens seismic Zone (SHZ), striking NNW-SSE north of MSH from near the surface to where we lose resolution at 15–20 km depth. This anomaly corresponds to high conductivity as imaged by iMUSH magnetotelluric studies. The SHZ also coincides with a sharp boundary in continental Moho reflectivity that has been interpreted as the eastern boundary of a serpentinized mantle wedge (Hansen et al, 2016). We speculate that the SHZ and low velocities are related to fluids rising from the eastern boundary of the wedge; (2) A 4-5% negative P- and S-wave velocity anomaly beneath MSH at depths of 6-15 km with a quasi-cylindrical geometry and a diameter of 5 km, probably indicating a magma storage region. Based on resolution testing of similar-sized features, it is possible that the velocity anomaly we see underneath MSH is narrower and higher (i.e., more negative) amplitude. Assuming approximately 1% partial melt per % velocity variation, this region could contain up to 5-10 km^3 of partial melt; (3) A broad, high-amplitude, low P-wave velocity region below 10-km depth extending between Mount Adams and Mount Rainier along and to the east of the main Cascade arc, which is likely due to high-temperature arc crust and possible presence of melt; (4) Several anomalies associated with surface-mapped features, including high-velocity igneous units such as the Spud Mountain, Spirit Lake, McCoy Creek, Silver Star, and Tatoosh plutons and low velocities in the Chehalis sedimentary basin and the Indian Heaven volcanic field.







V_P W-E cross section

V_S W-E cross section
% velocity anomaly

V_P map slice at 1 km depth