White paper proposal for the Cascade region; MARGINS program

Illuminating the structure of the mid to lower crust in the Cascade region

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Summary:
In order to: (1) resolve major tectonic controls on volcanism along the Cascade arc, and (2) determine the extent and characteristics of highly crystalline magma bodies (crystal mushes; potential source zones for explosive silicic magmas), we propose to use a variety of high-resolution seismic and Magneto-Telluric (MT) methods to image the crust and upper mantle in strategic locations in Cascadia. Our first choice would be to focus data gathering efforts in the area from Mount Hood to Mount St. Helens as (a) both volcanoes have activity as recent as the 19th to 21st centuries, (b) the area is close to urban centers (Portland, Vancouver, Columbia River shipping), (c) the arc magmatic front shifts abruptly westward going N from Mt Hood to Mt St. Helens, (d) previous surveys using both seismic tomography and MT data have outlined interesting crustal structures that merit further investigation. We also suggest that detailed imaging of the Crater Lake system would be highly informative in constraining the geometry of magma bodies beneath large silicic centers in a tectonically simple region.

Project:
The origin of petrologic diversity in the Earth's crust and generation of viscous, highly explosive magma types (silicic magmas such as dacites and rhyolites) remains a fundamental challenge in the Earth Sciences. Over recent years, the synthesis of decades of geochemical data with the mechanics of magmatic differentiation has led to a model where (1) magmas are mostly stored within the crust as crystal mushes (mixture of crystal and silicate liquid whose mobility is inhibited by a high fraction of solid particles; [1-3]), (2) evolved magma compositions (i.e., dacite-rhyolite) are most efficiently produced by the extraction of interstitial melt from these large, long-lived mush zones ([4]).

According to this model, mush zones are expected beneath active volcanic areas producing silicic magmas. Seismic tomography and MT imaging have outlined areas of low density and high conductivity in the upper crust beneath large rhyolitic magmatic provinces, such as the Central Andes ([5, 6]), Yellowstone ([7]) and Taupo, New Zealand

([8, 9]). These observations imply the presence of extensive, highly crystalline bodies in the mid to upper crust. In the Cascade region, large eruptions of silicic magmas are rare ([10]), and evidence for extensive crustal-level mush bodies is conflicting. Evidence against large mush bodies comes from the abrupt changes in magma composition between successive eruptions, typically small eruptive volumes, and the eruption of distinctly more mafic magmas at radial distances of only ~7-10 km from the main andesite-dacite edifices. Evidence for mush bodies includes abundant Pleistocene zircons carried to the surface in substantially younger eruptions at Mt St. Helens [11], intermittent large volume silicic eruptions from Mt Mazama, Mt St. Helens, Glacier Peak, and the Pleistocene Kulshan caldera associated with Mt Baker, and MT surveys that reveal a highly conductive region in the crust of southern Washington that has been interpreted either as conductive sediments or as magma [11, 12]. Comparing the "magmatic structure" of the Cascade Arc, a subduction zone characterized by a young, hot slab and refractory crust with that of large silicic centers such as the Taupo Volcanic Zone (New Zealand) and Yellowstone is a major goal of this proposal.

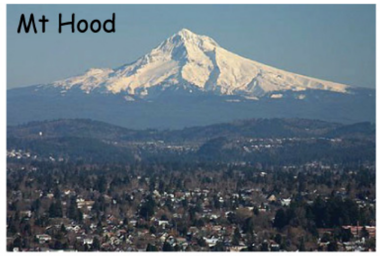
In addition to shedding new light on the extent and characteristics of crystal mushes in the crust, several outstanding problems related to the tectonic controls of some major features of the Cascade Arc remain unsolved. For example,

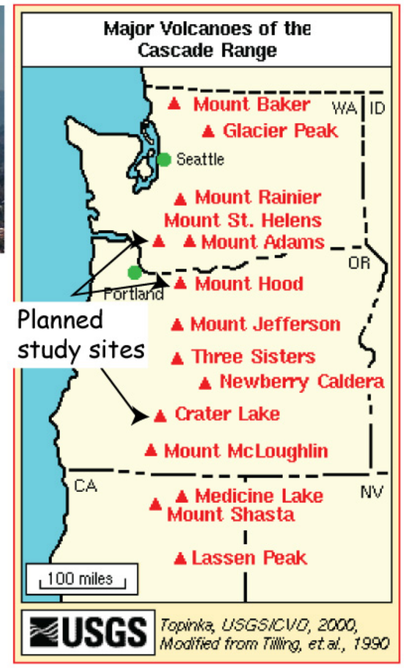
1. Why is the northern part of the arc (from Mt Garibaldi to the Washington – Oregon border) dominated by large, isolated stratovolcanoes while the south-central part (Oregon Cascades) has a nearly continuous close-set vent system (e.g., [10])? A switch from compressional to transtensional tectonics is possible.
2. Why does the arc magmatic front step to the west moving north across the Columbia River, including unusual forearc basaltic magmatism in the urban Portland area?
3. What controls the episodicity in magmatic activity and the longevity of magmatic centers?

Better definition of the structure and state of the crust and upper mantle in the Cascade region using geophysical imaging techniques is the most promising tool to link the tectonics, volcanology and large-scale structures of the complex active margin. We propose to use MT and active and passive seismic tomography and scattered wave imaging from dense grids around and along strategic areas to precisely outline the contours of geophysical anomalies, resolve their sources as due to magma versus buried low-density conductive sedimentary rocks (Vp/Vs contrasts), and thereby obtain accurate estimates of the amount of silicate melt present from the mid crust to the upper mantle.
The most promising area for such a deployment of geophysical instruments appears to be around the volcanic centers of **Mt St. Helens and Mt Hood**. This region is close to densely populated areas, making it an ideal target to study both because of good accessibility to install instruments and because of urban hazards. This area is also one of the most tectonically and volcanically active zone of the Cascade region. Preliminary geophysical information has already been gathered in N-S and E-W transects in the surroundings of these two volcanoes, providing background to guide further investigations.

We are proposing a combined active-passive seismic experiment to image the volcano system from the upper crust to the subducting slab. We propose deploying a large number of broadband seismometers and MT receivers in dense linear and areal arrays across both volcanoes, extending well beyond the volcanoes in both the E-W and N-S directions. The seismic data will be used for receiver function, noise-correlation tomography, shear wave splitting, and local earthquake and teleseismic body wave tomography analyses. A complementary active seismic tomography and scattered wave imaging experiment will illuminate the crustal structure and Moho details. We also suggest that lines connecting both volcanoes across the Columbia River would be important to better image the fundamental transition that occurs in the area.

Focusing on a second, tectonically more simple location would be beneficial in terms of isolating the geometries of magma bodies in the crust, particularly in an area producing large explosive eruptions. The **Crater Lake region** seems an obvious candidate for such an investigation, as it is one of the most active silicic centers in the Cascade Arc; it shows a long-lived history of erupting dacites to rhyodacites, requiring efficient intra-crustal differentiation (and therefore the presence of “magma chambers”). It also was the site of a large, caldera-forming eruption (~50 km^3 of erupted material) ~ 7700 BP ([12]).





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