# Chapter VI:

# Conclusions

(PART I)

The ability to simultaneously explain geophysical and geochemical observations is essential to demonstrate certain behaviors such as the development of boundary features along the slab-mantle interface, and is a primary reason for using a coupled scheme such as GyPSM-S. The development of the low-viscosity channel (LVC) is a consequence of the migration of slab-derived fluids into the mantle wedge and reaction with peridotite to produce hydrous phases and higher water contents in nominally anhydrous minerals (NAM). The spatial extent of the low-viscosity region of the wedge may be a large-scale volume extending from the slab-mantle interface to the back-arc [1] or a relatively thin, continuous channel defined by water-saturated NAM and hydrous phases along the slab-mantle interface, depending on changing subduction parameters (slab age, convergence velocity, slab dip angle). It is limited by the onset of melting, and its geometry is therefore dependent on the position of the water-saturated solidus, which changes spatial position within the wedge due to source depletion (prior melt extraction) and/or the thermal evolution of the wedge (latent heat of melting). The zone of active melting within the mantle wedge exists at the upper surface of the LVC, and is restricted in our models by assumptions of iterative near-fractional melt extraction and water transport via a hydrous fluid only (as opposed to a hydrous melt).

Despite changing subduction parameters, the geometry of the melting region is quite similar in all models: discontinuous lenses inclined to the slab surface and displaced from it by tens of kilometers, geometries in agreement with results from tomographic imaging [2, 3]. The persistence of the LVC would provide a mechanism by which hydrated slab-adjacent mantle material (consisting of a significant reservoir of water and potentially very low-degree mantle melts) is transported to the deep mantle without melting, providing a source for enriched OIB magmas. The LVC is also significant because of the effect it has on the large-scale flow field within the wedge, possibly leading to slab decoupling [1] and changes in slab dip [4].

Changing subduction parameters have significant impacts on the source lithology and intensity of fluids originating from the slab as a function of distance along the subducting slab. Modeling of fluid migration through the LVC provides evidence for a limited fluid-rock interaction, preserving the fluid-mobile trace element chemistry associated with the original slab lithology to the active melting region. This suggests the potential for either a rapid fluid transport scenario or a fluid-dominated trace element budget within the LVC. Comparison with interpretations of along-arc trends suggest that changing subduction parameters lead to a varying fluid flux and fluid chemistry reaching the active melting region, which can be manifested in erupted lavas. By comparison with interpretations of cross-arc [5-7] trends, we find that a simple melt migration scheme which preserves spatial heterogeneity of initial melts towards eruption is likely. Melts associated with low- to mid-pressure fluid release will erupt towards the volcanic front and melts associated with higher-pressure fluid release will erupt towards the rear-arc. Interpretations of these results lead to several potential mechanisms to explain hydrous inputs to back-arc source regions [8].

Inclusion of a localized low-viscosity, low-density zone in modeling the subduction zone wedge is required in order to match geophysical surface observations of dynamic topography and geoid and gravity anomalies [1, 9]. Coupled geochemical and geophysical modeling using GyPSM-S allows for a fluid-source-based approach to determining a particular low-viscosity geometry based on changing subduction parameters. Subsequent modeling of geophysical surface signals with inclusion of the particular low-viscosity geometry can then be performed and compared with observed values. For the northern Izu-Bonin (NIB) subduction system, comparison of computed signals with those observed results in the conclusion that fluid release from the slab occurs within the interval ~150-350 km depth, forming an extended low-viscosity channel (ELVC) ($\eta_{LV} = 3.3\times10^{19}$-$4.0\times10^{20}$ Pa s) with an associated density reduction within the ELVC of -10 kg/m$^3$ relative to the ambient nominally anhydrous mantle wedge, values in agreement with GyPSM-S results.

Thus, the development of a coupled geochemical and geodynamic model for subduction (GyPSM-S) results in a greater understanding of the role that changing subduction parameters (slab age, convergence velocity, slab dip angle) play in the hydration of the mantle wedge. The dominant control on fluid release into the wedge is the thermal state of the slab, defined primarily by slab age and secondarily by convergence velocity. As water transits the near-slab wedge, a water-saturated zone (LVC) emerges, composed of hydrated NAM and hydrous phases, and necessarily truncated by the crossing of the water-saturated peridotite solidus further into the wedge. Slab age and slab dip angle are the primary controls on the geometry of this hydrated slab-adjacent region. As water in NAM additionally has a water-weakening effect, this water-saturated zone has important consequences for the force balance within the wedge as well. The chemical composition of melts changes along the active melting region at the top of the LVC as a function of the fluid source lithology, fluid flux, and degree of prior depletion of the melt source region. At the surface, as demonstrated by comparison with datasets from the NIB and central Costa Rican (CCR) systems, geochemical and geophysical modeling can be used to strengthen the arguments for the existence of the particular low-viscosity geometries solved by GyPSM-S.

(PART II)

The evolution of color, including a naturally occurring greenish gray variety, in a particular zone of the Thunder Bay Amethyst Mine Panorama (TBAMP) system allows an examination of the chemical and kinetic factors acting during the early stages of quartz precipitation in the hydrothermal system. Interpretation of the color variations in quartz as environmental indicators stresses the importance of viewing color as a consequence of a system. We present a comprehensive series of spectroscopic analyses of the quartz color sequence, supplemented by additional analyses of a limited sample set from similar amethyst-bearing localities worldwide, noting the importance of incorporation of water as hydroxyl and molecular species on color development. The greenish gray coloration is not a secondary result of heating of pre-existing amethyst, but another radiation-induced color variant, which developed its particular color as a result of specific chemical constituents, exposure to radiation, and incorporation of molecular water both as nano-scale and micro- to macro-scale inclusions. Interpretation of color is an important factor in deriving the changing state of early stages of this system, as we use our data to confirm that the hydrothermal system experienced a gradual decrease in salinity and quartz growth rate as deposition proceeded.

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