Constraining Fluid Sources and Fluxes Through the Cascadia Accretionary Prism - Impact on Volatile Cycling, Physical State, and Microbiology

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This white paper addresses aspects of the GeoPRISMS SCD questions, in particular, what are the connections between thermal structure, fault zone composition, metamorphic dehydration, pore-pressure, fault strength, and fault slip behavior; and what is the cycling of volatiles in a young and hot subduction zone. It also addresses the 3rd SCD process-based theme on "Fore-arc to Back-arc Volatile Fluxes.

Fluid flow and fluid pressure in subduction zones have a profound impact on the shallow thermal structure and fluid content of the subducting plate and upper plate (e.g. Hyndman and Wang, 1993; Langseth and Silver, 1996; Spinelli and Saffer, 2004; Harris et al., 2010), fault zone stability and seismogenesis (e.g. Hubert and Rubey, 1959; Davis et al., 1983; Scholz, 1998), and the transfer of elements and isotopes to the oceans, volcanic arc, and mantle (e.g. Moore and Vrolijk, 1992; Martin et al., 1996; Fryer et al., 1999; Chan and Kastner, 2000; Solomon and Kastner, 2011). The cycling of solutes and volatiles in the forearc of subduction zones (SZs) supports a deep biosphere and should have a profound impact on global chemical and isotopic budgets, affecting the chemistry of seawater, arc and back-arc volcanoes, mantle, and the atmosphere.

At the Cascadia SZ, which represents an extreme thermal end-member SZ, fluid expulsion occurs at non-uniform rates from the deformation front to the arc, and, as observed on the IODP Expedition 311, produces variable fluid geochemical signatures along the W-E transect (e.g. Riedel et al., 2010). At sites near the deformation front, the pore fluids are primarily influenced by *in situ* reactions and porosity reduction, whereas the landward, more mature portion of the margin is influenced by advection/diffusion of diluted fluids generated at depth by mineral dehydration reactions (Riedel et al., 2010).

Changes in physical and mineralogical properties with depth and the associated evolution of fluids in SZs are intimately linked to the transition from aseismic to seismic slip along the plate boundary (e.g. Moore and Saffer, 2001). Fluids advected along fault zones, at the plate boundary, and in the upper plate may record mineral reactions occurring at depths marking the onset of seismogenesis (e.g. You et al., 1996; Moore and Saffer, 2001; James et al., 2003; Hensen et al., 2004). Fluid chemistry is predictably altered with increasing temperature and pressure, assuming fluid-rock equilibrium at various temperatures and knowledge of the mineralogy-lithology of the subducted and accreted materials. Thus, the chemistry and isotopic compositions of the fluids provide information on the fluid origin at depth, the temperature at the source, as well as the role of in situ diagenetic versus deeper-sourced reactions in the fluid production. Some of these diagenetic and low-grade metamorphic reactions release fluid, change the rocks frictional characteristics, and could alter fault zone rheology. Fluid pressure and fluid advection may affect localization of faulting and locking at subduction zones, and return flow in the subducting oceanic basement also influences pore fluid pressures and temperatures deeper within the subduction zone.

At higher temperatures and pressures within the seismogenic zone, a new suite of hydrous minerals forms as others break-down, inducing fluid recycling within the system, that leads to the formation of hydrous phases such as chlorite, serpentine, and amphiboles. Ultimately fluids are released, further altering both the pore fluids and solid geochemistry. Constraining the interplay between the key dehydration reactions at depth, including retrograde reactions during fluid ascent, along the plate boundary and other faults, and microbiological overprinting in the upper sediment column, is crucial for interpreting the chemical anomalies found in fault zones and other flow pathways in SZs. These reactions also impact the delivery of fluid-soluble elements and volatiles to greater depths in the SZ with implications for fluxes beneath the volcanic arc.

The key fluid-rock reactions and mineralogical changes impacting the fluid chemistry at Cascadia can be constrained through sampling of fluids at a predetermined array of sites that will be chosen based on existing and new geophysical surveys, and on a synthesis of results from the three Cascadia scientific drilling expeditions (ODP Legs 146 and 204; IODP Exp. 311). These chemical and isotopic compositions will aid in understanding the evolution of fluid rock reactions deeper within the subduction zone, as discussed above.

Hence, through detailed geochemical fingerprinting and numerical modeling of the chemical and isotope profiles, it will be possible to:

1. Characterize the fluid-rock reactions, fluid sources, and flow rates in fault zones and other fluid flow horizons in the Cascadia accretionary prism.
2. Constrain the temperatures at the fluid sources, how they relate to the up-dip limit of seismicity, and whether they differ from those at erosional margins.
3. Trace key diagenetic and low-grade metamorphic hydration/dehydration reactions that may be responsible for seismic behavior along the plate boundary.
4. Construct mass balance models to estimate the flux of fluids, solutes, and isotopes back to the ocean, and the residual flux to greater depths within the subduction zone.

These objectives could be achieved by:

1. Additional drilling, coring and logging. The new sites will be determined through synthesis of the data from the existing Cascadia prism sites
2. Long-term monitoring and connection to NEPTUNE-Canada and the future OOI-RSN cable system will allow co-documentation and understanding of the relationships between between tectonics, hydrogeology, geochemistry, and microbiology at an accretionary margin.

For all the above, the incoming sediments must as well be fully characterized along-strike at representative sites that reflect the main variations in sedimentology-lithology (both composition and thickness) and the thermal regimes.

If sampling is focused offshore Grays Canyon, it would coincide spatially with other large-scale NSF programs planned for the Washington corridor at 47°N, including the OBSIP (Ocean Bottom Seismometer) focused deployment site, Endurance Array moorings for OOI, high resolution EM302 bathymetry surveys, two Open Access MCS programs (2-D in 2012, 3-D proposed for 2014) using the R/V LANGSETH, and a proposed comprehensive study of the thermal environment of the Cascadia Subduction Zone (CSZ) off the Washington margin in 2013 during a 24-day field program with Jason II (Johnson, Solomon, Salmi white paper).

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