Thermal Structure of the Cascadia Subduction Zone on the Washington Margin

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Abstract: We will be conducting a 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. This study site overlaps geographically with the North Cascadia OBSIP array and the 2-D MCS survey of the R/V LANGSETH. The goal of this GeoPRISM/NSF funded study is to determine the temperature structure of the overlying accretionary prism sediments of the CSZ deformation zone with a transect of systematic heat flow and fluid flux profiles off the Washington Coast near Grays Canyon. The CSZ is a targeted Discovery Corridor within the new GeoPRISM Program, where an abundance of geophysical, geochemical, biological and physical oceanographic investigations are planned for the next decade. Temperature is a primary controlling factor of many subduction zone processes, particularly at active margins subject to large magnitude, megathrust earthquakes such as the CSZ offshore Washington State, and basic heat flow and fluid flux studies of the Cascadia Corridor are fundamental data required by the GeoPRISM Program.

Rationale: The Cascadia Subduction Zone has generated a large number of high-magnitude M_w9 earthquakes, and **poses the greatest single source of seismic hazard to the northwestern United States**. In spite of an intense scientific focus on the CSZ, there have been no systematic heat flow measurements on the margin over an along-strike distance of 800 km – from south of Vancouver Island to southern Oregon. Existing data demonstrate that while the 100 km along-strike section of the CSZ adjacent to Vancouver Island has densely-spaced heat flow profiles, MCS surveys and ODP/IODP drill holes, the segments of the CSZ off-shore WA and OR have only sparse heat flow stations made during programs focused on other scientific goals. We will acquire systematic profiles of heat flow and fluid flux data along a corridor of the accretionary prism on the Washington margin at 47°N, from west of the deformation front on the abyssal plain to just below the shelf edge at 500 m depth – in order to make the first quantitative estimates of the thermal structure of the 'locked zone' of the Cascadia megathrust.

Specific Questions Addressed by This Experiment:

1. *What is the temperature of the basement-sediment interface at the deformation front prior to entering the CSZ?* Prior data suggests a strong latitudinal gradient in basement temperatures in Cascadia Basin, from hot igneous basement beneath Vancouver Island to a cooler plate offshore Oregon. This N-S temperature gradient appears due to differences in sediment thickness and in exposure of basement outcrops on the incoming plate, but the processes are poorly understood.
2. *Is there a correlation between isotherms within the sediment column and the vertical position of the décollement at the up-dip limit of the mega-thrust fault interface?* If the décollement 'steps down' to basement depth as the CSZ deepens landward - as implied by MCS data elsewhere, is there a corresponding change in the temperature distribution of the overlying sediment column?
3. *What is the temperature at the up-dip limit of the seismogenic zone at the CSZ, and does it correlate with known diagenetic reactions and dehydration temperatures of primary clays?* Mineralogy exerts a first-order control on fault frictional properties, including strength and sliding stability. Temperature is a primary control on the seismogenic zone location, as the up-dip limit consistently occurs between 100°C to 150°C. These temperatures coincide with clay dehydration reactions important for controlling the up-dip limit, and the release of mineral-bound water reduces the shear

strength of faults by decreasing the effective stress. Authigenic minerals precipitating at these temperatures may have a higher coefficient of friction and exhibit velocity-weakening behavior, directly influencing the frictional behavior of the décollement.

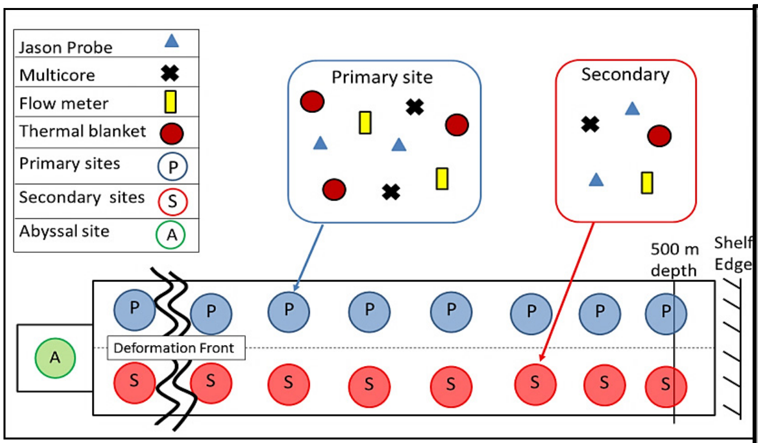
4. Prior CSZ models based on data from off-shore Vancouver Island suggest that subduction zone isotherms are correlated with slab dip, which is well-defined seismically (Hyndman and Wang, 1995; Wang et al, 1995; Oleskevich et al, 1999; McCrory et al, 2002). *However, on the Washington margin, there are only sparse terrestrial heat flow data, and almost no marine heat flow data along the entire WA/OR segments with which to test this model.*

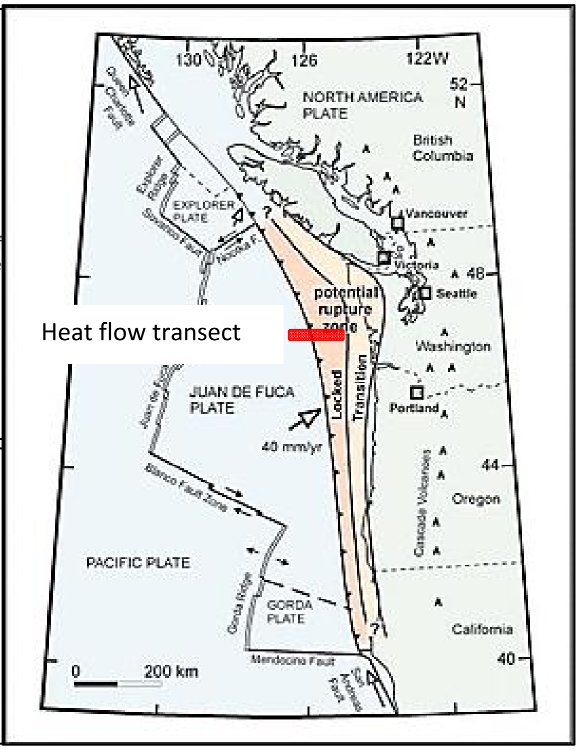
Methodology: For accurate estimates of heat flux from the challenging environment of the accretionary prism, we plan redundant methods of both thermal and fluid flux measurements along a 2.5-D profile of the margin at a single latitude. In this profile we would use thermal blankets suitable for impenetrable sub-stratum, continuous fluid flow meters, multi-core deployments for both pore fluid chemistry and thermal gradient data, and ROV heat flow probes, and concentrate our efforts at 10 equally-spaced depth intervals. Our proposed heat flow profile will coincide spatially with other large-scale NSF programs planned for the Washington corridor at 47°N, including the OBSIP (Ocean Bottom Seismometer) deployments, Endurance Array moorings for OOI, and two Open Access MCS programs (2-D in 2012, 3-D proposed for 2014) using the R/V LANGSETH. The mutual benefit of our proposed heat flow surveys to (and from) these existing programs/proposals in the same area would be substantial. The goal would be to obtain data of sufficient quality that downward projection of the surficial thermal gradients to the CSZ décollement and igneous basement could be done with reasonably high level of confidence.

Bottom water temperatures (BWT) vary seasonally, particularly in the shallower portions of the margin. This variability must be removed to extract the heat flow signal from the sub-surface, but can easily be accomplished if the BWT variations at the site are recorded over a sufficient period (i.e., >8 months; Hamamoto et al, 2005; 2011). The sub-surface variability of seasonal bottom water temperature changes on the WA margin will be determined by the addition of Antares temperature sensors externally to the OBSIP OBS instruments during their simultaneous 1-year deployment in 2012 (Andrew Barclay, pers. comm. 2011) and again during our proposed 2013 Grays Canyon field program. Further, historical CTD moorings and sea glider data on the Washington margin, deployed almost continuous since 1998, will provide additional constraints on bottom water temperatures.

Seafloor fluid flow meters are critical to assessing the presence and magnitude of upward fluid advection at the heat flow stations, and we will be deploying continuous fluid flow meters (Mosquitos) in the sediments at the same sites where heat flow measurements are made (Solomon et al., 2008). In addition, we will be estimating flow rates from sediment pore fluid profiles collected at each station, using the OSU multi-corer samples dedicated to fluid geochemistry. The sediment geochemical profiles provide redundancy with the Mosquito flow rates, information on fluid-rock reactions and the source of the fluids, and constraints on the spatial variability and mean values of flow at each station.

Data Access: The Open Data Access strategy recently adopted by the MCS community is the new paradigm of rapid release of data and cruise reports with both wide community and NSF support. Consistent with this policy, our ship-board data sets and cruise reports are planned to be available to the GeoPRISM community ~6 months post-cruise.





GeoPRISM Heat Flow Transect off Grays Canyon, WA in 2013. Our heat and fluid flow program will be a 2.5-D profile oriented orthogonal to the margin with multiple instrument deployments at 10 discrete water depths. E-W profile extends from west of the deformation front to 500 meters depth below the shelf edge.

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