GeoPRISMS - EarthScope Science Workshop for Cascadia Report
(Portland, OR, April 4-6 2012)

1. Background and Motivations

1.1 Why Cascadia

The Cascadia subduction zone, which cuts through three US states and western Canada (Figure 1), is the only region of the lower 48 states that is capable of producing a M_w 9 earthquake and has the greatest potential for volcanic eruptions in the conterminous US. A trove of new geological, geodynamic, and geophysical data has recently been collected and more will be forthcoming in the next several years thanks in part to NSF investments in EarthScope and the onshore/offshore ARRA-funded Amphibious Array Facility (AAF) of the Cascadia Initiative (CI). The first phase of the CI Amphibious Array observations, including both the offshore and onshore deployments, was completed in 2011. Data from the onshore deployment are becoming available to the community and those from offshore should become available in mid-2012. The Cascadia margin was also chosen as a Primary Site of the NSF GeoPRISMS program during the Subduction Cycles and Deformation (SCD) Initiative Implementation Workshop in 2011, and is thus recognized as a focal point of interest to a broad base of scientific communities. With so many other onshore and offshore research efforts in process or planning stages, the time was right to hold a science workshop to build synergies among communities, disciplines, and agencies with scientific interests in the area. Ongoing/future scientific efforts in Cascadia will benefit greatly from communication and coordination among these diverse groups.

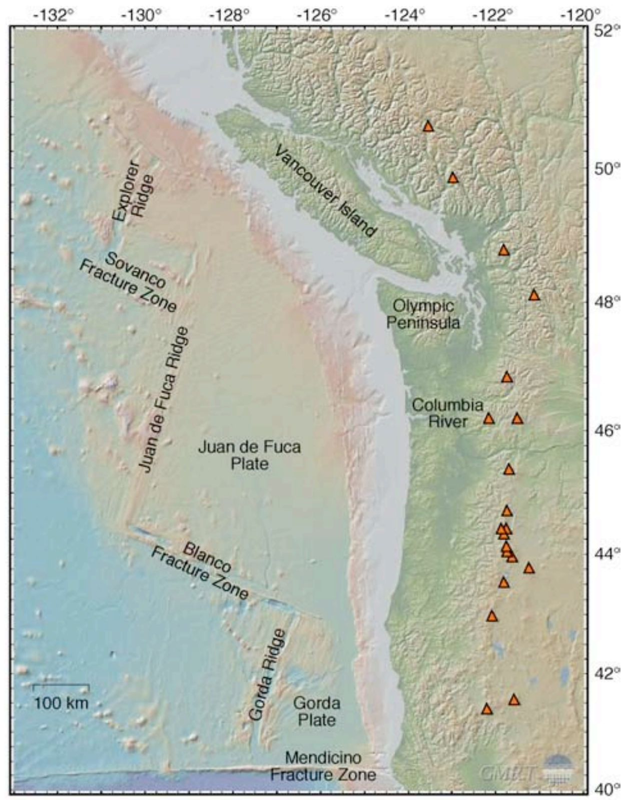

Figure 1. Bathymetry & topography of the Cascadia margin and associated tectonic elements. Significant arc volcanoes indicated by orange triangles. Map generated using GeoMapApp.

1.2 Workshop Objectives

GeoPRISMS and EarthScope co-sponsored a workshop, held April 4-6, 2012 at the World Trade Center in Portland, OR (http://www.geoprisms.org/past-meetings/207-cascadia-apr2012.html), as a joint effort to foster communication and collaboration among researchers with diverse interests in Cascadia, and with the broader goal of informing and revising guiding documents for both communities. The workshop offered a program relevant to both the EarthScope and GeoPRISMS communities. The EarthScope program, through its ongoing series of EarthScope Institutes, provides reviews and synthesis of broad themes with transformative potential. This workshop serves such a purpose for EarthScope. The GeoPRISMS program requires an updated implementation plan for the Cascadia Primary Site, developed through community discussion and input. The outcomes of breakout and plenary discussions, in the light of overview talks by experts in a range of fields, will be incorporated into an updated Cascadia Implementation Plan that will serve as the guiding document for researchers intending to submit Cascadia-related proposals to the GeoPRISMS program.

This workshop took as its starting point the Cascadia SCD portion of the GeoPRISMS Science and Implementation Plans (http://www.geoprisms.org/science-plan.html) and the Earthscope Science Plan (http://www.earthscope.org/ESSP). The primary goals of the workshop were to: (i) to clarify common research objectives within Cascadia; (ii) to address the range of interacting tectonic, magmatic, and surficial processes acting along the convergent margin; and (iii) to update implementation plans and timelines for GeoPRISMS and EarthScope research, considering available resources and infrastructure.

The specific objectives included:

- Informing the broader geoscience community about the status of community experiments and new science activities and opportunities in the Cascadia area
- Enhancing interdisciplinary interactions and collaborations in Cascadia
- Encouraging new proponent teams to organize in advance of upcoming proposal deadlines
- Providing input to update the GeoPRISMS implementation plan for Cascadia, including thematic aspects of SCD science
- Clarifying broader impacts and education opportunities associated with Cascadia research

A key additional goal of the workshop was to tap a broad cross-section of researchers working in Cascadia, or interested in future opportunities, and to foster interaction and discussions leading to new collaborations and understanding. This specifically included entraining early-career scientists (students, postdocs, and new faculty) interested in furthering Cascadia science.

2. Workshop Overview

2.1 General scope and structure of workshop

The workshop was attended by nearly 180 participants (Figure 2), including ~60 graduate students and post-docs, for two days of talks and discussion in Portland, OR. The workshop aimed to provide a platform for review and synthesis of the current state of Cascadia science, involving a wide range of topics from tectonics to geophysics/geochemistry to sedimentation and beyond, and an open forum for discussion of the future directions of scientific research in Cascadia. A student symposium took place on the day before the workshop, introducing graduate students and post-docs to the Cascadia system through a series of talks and a regional field trip. The 2-day workshop was organized into a series of broad plenary talks to provide an overview of the Cascadia subduction system, interleaved with topical break-out sessions, short presentations on hot-topic science, poster sessions, and plenary discussions.

Figure 2. Participants at the GeoPRISMS-EarthScope Cascadia Workshop in Portland, April 2012.

The first day opened with plenary presentations on the tectonics, volcanism, faulting, and deep structure of the Cascadia subduction system, followed by updates on the current major projects ongoing in the Cascadia region. A set of evening discussion sessions (Special Interest Groups, or SIGs), focused on these major projects, providing opportunities for informal discussions of the details of each project, and helped define pathways for future research to link in to these efforts. The second day of the workshop opened with a plenary session on sedimentary processes in Cascadia, followed by two sets of special interest group (SIG) break-out discussions targeted at communities with interests in particular scientific questions or processes relevant to Cascadia. These discussions were followed by shorter plenary presentations on the geohazards specific to the Cascadia margin, and reports by each of the breakout groups summarizing the main discussion points in each session. The workshop wrapped up with a presentation from the student participants in the workshop, and an open plenary discussion outlining a "roadmap" to the future of Cascadia science.

2.2 GeoPRISMS Science and Implementation Plan

For the GeoPRISMS community, one of the key objectives of the Cascadia workshop was to obtain input to refine the directions of GeoPRISMS research in Cascadia. In particular, the outcomes of the breakout and plenary discussions at the workshop will be incorporated into an updated version of the GeoPRISMS Implementation Plan (IP) for the Cascadia Primary Site (e.g., http://geoprisms.org/science-plan.html). This document provides guidance to principal investigators interested in submitting proposals for funding under the NSF GeoPRISMS Program. Although proposals for research in Cascadia have been accepted under the GeoPRISMS solicitation since 2010, input from the community to clarify the research priorities for GeoPRISMS in Cascadia has been limited (see Appendix 3: Related Workshops), with a strong emphasis on projects linked to the Cascadia Initiative. Thus, a main goal of this workshop was to open an interdisciplinary dialog that would enable an integrated view of the Cascadia subduction zone, to solicit and incorporate feedback on science implementation in Cascadia from a broad-based community, and to provide focus and guidance for subsequent GeoPRISMS proposal solicitations.

2.3 EarthScope Science Plan

For the EarthScope community, this workshop provided an integrative scientific dialogue building on the transformative observations from its augmented geodetic, magnetotelluric, and seismological facilities in Cascadia. Numerous science targets identified in the EarthScope Science Plan (http://www.earthscope.org/ESSP) were illuminated in the presentations and discussions from the workshop. Initial research results from jointly NSF-funded EarthScope and GeoPrisms projects were presented and momentum for additional joint proposals was evident and encouraged. In addition, IRIS and UNAVCO as the respective managers of the seismological and geodetic facilities of EarthScope are currently developing proposals for 2013-2018 operations and maintenance. The community discussions about science targets, priorities, and opportunities for coordination with other programs such as GeoPrisms provide essential fodder for these necessarily integrative proposals.

Figure 3. Student Symposium attendees engaged in discussion about paleoseismic methods with speaker Harvey Kelsey, Portland, April 2012.

2.4 Student Symposium

An important aspect of any scientific meeting is the engagement, preparation, and inspiration of the next generation of scientists and leaders (Figure 3). The student symposium, attended by thirty-three students and two postdocs from thirteen universities, brought together representatives from this vital demographic. The symposium was organized by the GeoPRISMS Education Advisory Committee (GEAC) and led by Andrew Goodliffe (University of Alabama) with help from the GeoPRISMS Office and several workshop conveners and participants. Students and postdocs arrived a day early for this event on April 4, 2012. Juli Morgan (GeoPRISMS chair, Rice University) kicked off the morning agenda with an introduction to the GeoPRISMS program with particular emphasis on the SCD initiative. Ramon Arrowsmith (EarthScope Steering Committee Chair, Arizona State University) followed with an outline of the EarthScope program. An overview of the geology and geophysics of the Cascadia region was provided by Anne Trehu (Oregon State University). Harvey Kelsey (Humboldt State University) led the attendees though the paleoseismicity of the region with emphasis on the coastal record left behind by ancient tsunamis. Karl Wegmann (North Carolina State University) introduced the participants to the geomorphological aspects of the region, including evidence of how the landscapes responded to tectonic (and climatic) forcing. Adam Kent (Oregon State University) introduced the participants to the volcanic and geochemical processes at work in the Cascadia region. The students and postdocs then took over the stage, giving one-slide descriptions of their research. Those presenting posters had an opportunity to highlight the work that they would be presenting later in the meeting.

In the afternoon, Ray Wells (USGS) and Ian Madin (Oregon Department of Geology and Mineral Industries) led a fieldtrip through the Portland metropolitan area. Participants got to see a spectacular Columbia River Basalt outcrop, evidence of mass wasting, a panorama of the Portland Basin and rocks form the Boring volcanic field flow. The field trip ended at the Zoo station of the Portland MAX light rail system where a spectacular core (recovered during the construction of the 3-mile-long tunnel) is displayed.

In the evening, following the icebreaker for the Cascadia workshop, symposium participants participated in a lively group dinner at Kell's Irish Pub. Several workshop scientists joined the group and shared insights about their career path and the GeoPRISMS/EarthScope programs. These scientists included Mark Reagan (University of Iowa), Jenn Wade (NSF-EAR), Charles Bopp (GeoPRISMS Office, Rice University), and Karl Wegmann (North Carolina State University).

3. Scientific Program

3.1 Cascadia Crustal Evolution and Deformation

This session highlighted the geological development of the crust in the Cascadia region, focusing on the geologic record and the history of magmatism and volcanism. Three presentations were made: Ray Wells discussed the geologic evolution of the Cascadia margin; Anita Grunder presented on the pre-Quaternary magmatic history of Cascadia; and Kathy Cashman spoke about recent magmatic history and volcanism.

Figure 4. Ray Wells demonstrates present-day Cascadia plate motions.

Ray Wells focused on the processes that built the Cascadia margin and how this history affects modern deformation, seismicity and magmatism (Figure 4). The talk started with the origin and collision of the Siletzia Terrane to form the basement of the modern arc, followed by post collisional re-organization, establishment of the volcanic arc and rotation/shear overprinting of this within the modern subduction regime.

New geochronology shows that Siletzia accreted at 51 Ma, after origin as an oceanic plateau, rather than in a slab window. The age of the Siletz lavas varies from 49 Ma in the south to 56 Ma in the north. Collision resulted in fold and thrust belt style deformation and some renewed magmatism. The postulated relation to the Yellowstone hotspot remains unclear, but there may be a link. After accretion renewed magmatism occurred sporadically from 48-30 Ma, including basaltic sequences and rift-related dyke suites in structures related to margin-parallel extension. This phase was coeval with start up of volcanism along the Cascade arc.

Paleomagnetic and GPS data indicates significant clockwise motion of the Oregon coast block occurred post accretion, and Ray argued this results from transpressional shear along the subducted margin. Collision of this block with southern Washington also produced compressional fold and thrusting in the Yakima belt and extension to the east of the arc. The response of the volcanic arc to this motion was a net migration, resulting in the current location of the modern High Cascades to the east of the older western Cascades, although there is the possibility of this also reflecting changes in slab dip.

Ray was also the first of several presenters who addressed the segmentation of the arc. Segmentation is apparent in a number of datasets – including gravity, the distribution of volcanoes and faults, chemistry of volcanic rocks, and seismicity, and discussion of this topic recurred throughout the meeting. Important questions remain regarding the origin of segmentation and the relation between segmentation defined using different datasets.

Anita Grunder discussed the pre-Quaternary magmatic history of Cascadia. The pre-Quaternary magmatic suites that are relatively abundant in Cascadia are a relatively untapped source of information (compared to modern volcanism) and provide some of the key insights into the changes in the nature of the arc and subduction through time. Important unresolved questions are the nature of contributions from a potpourri of mantle sources through time, the effect of older episodes of earlier subduction on the current mantle source, and the role of subduction magmatic processes in creating and differentiating North American continental crust. Anita also emphasized the segmentation evident in the arc – particularly with respect to isotope compositions of volcanic rocks. In this case Anita suggested segmentation appears related to the nature of the crustal blocks that form the basement along the arc, and the mantle located beneath these. Variations in the style of magmatism – from central volcanoes to dispersed monogenetic magmatism are also important parts of this segmentation.

A major control on Cascade volcanism through time is the obliquity of convergence (Figure 5). In the Oregon Cascades, where erupted volumes are well documented, the first order effect of this appears to be decreasing magmatic output with progressively more oblique subduction through the Cenozoic. There are also second order variations on this as well – for example, apparent increases in productivity are evident after the switch to the High Cascades and the started of on-arc rifting. Change in proportions of basalt, andesite and rhyolite suggests that differences in crustal processing of magmas also reflect changes in crustal structure and magma flux. Anita also addressed the issue of the apparent migration of the arc through time (discussed by Ray Wells above) – and asked whether this is a true migration or a focusing of the arc from dispersed earlier magmatism to the current localized arc.

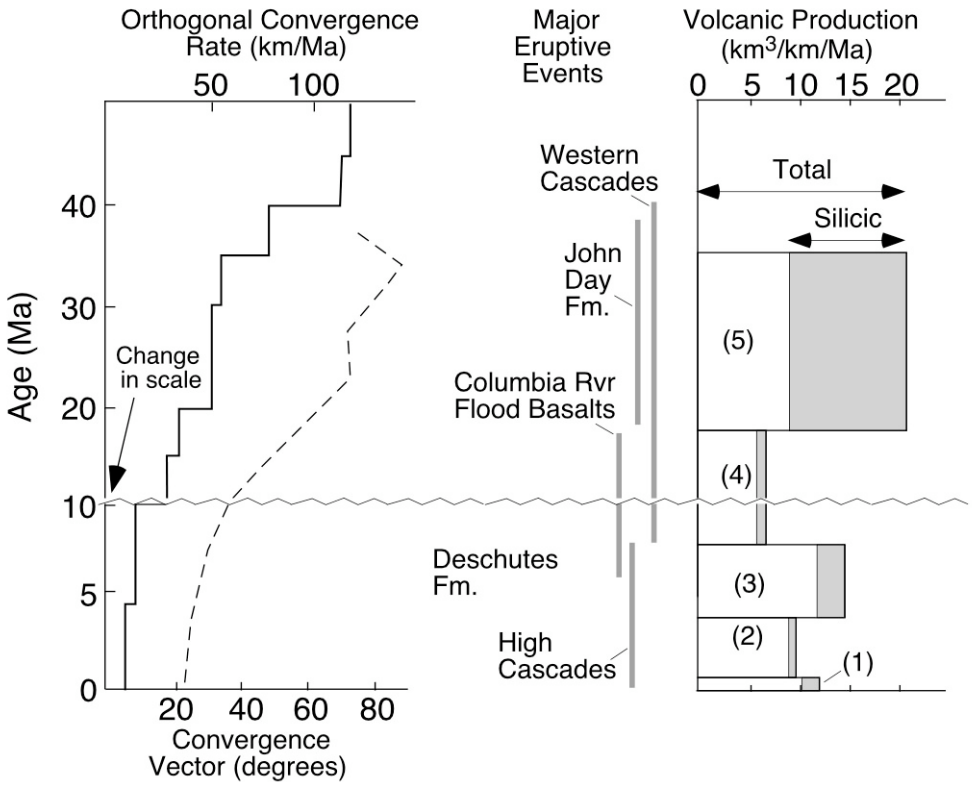

Figure 5. Comparison of orthogonal convergence rate and convergence vector with magma production rates for the Central Oregon Cascades over the previous 40 million years. Figure modified from Priest (1990), convergence rates (solid line) and vector (dashed line) are from Verplank and Duncan (1987). The intervals representing major eruptive episodes on the arc and nearby are shown. Numbers 1-5 show the eruptive episodes defined by Priest (1990) and represent: (1) 0.730-0 Ma; (2) 0.731-3.9 Ma; (3) 4.0 - 7.4 Ma; (4) 7.5-16.9 Ma and (5) 17.5-43.2 Ma.

The nature of the parental magmas to Cascadia magmas is also a longstanding question in Cascadia. Contributions from different chemical types of mantle (tholeiites, high field strength enriched, calc-alkaline etc.) are well known from studies in a number of locations – however the exact nature and ultimate origin of these various mantle sources are still uncertain.

Kathy Cashman presented the final talk in the session on Holocene and recent volcanism. Kathy started by discussing the distribution of volcanism from post Quaternary times and pointing out some key features, based on the recent summary published by Wes Hildreth. Firstly, in comparison to some other arcs the Cascades appear highly variable – with a diffuse volcanic front and irregularly spaced central volcanoes. In addition the segmentation of the arc evident in other data sets is also seen clearly in terms of post-Quaternary eruption volumes. In particular the Garibaldi, Washington and California segments have significantly larger proportions of erupted volumes of magma derived from long-lived central volcanoes (75-90%), whereas along the Oregon portion this is only 12%. Kathy also highlighted the location of volcanic “gaps” where little or no volcanism occurs, and noted that these often define segment boundaries. In addition, there is a lack of back-arc volcanism, with the only locations being Medicine Lake, Newberry and Simcoe. She suggested that this might, in some way, reflect difficulty in magma traversing the lithosphere.

Studies of localized volcanism, particularly from smaller "monogenetic" type volcanoes, are less common than studies of larger central volcanoes but represent a key data source. At present the controls on this style of magmatism are not well known, but may reflect lower time integrated magma flux from the mantle, together with an important control from crustal structure. One interesting recent result is that even monogenetic systems – which have much shorter lifetimes and less indications of crustal differentiation than central volcanoes – appear to "stage" within the upper crust, and to form from multiple batches of different composition magma. The ultimate controls on dispersed vs. central magmatism, and why these are prevalent in some areas along the arc, are seen as key issues for further studies of Cascadia volcanism. Tectonic events may be very important for initiating eruptions, serving to link structural and volcanic studies to hazard assessments.

Kathy finished by discussing the key role of the lithosphere in volcanism, and suggested that it has an important role in determining the rates and volumes of magma transfer, focusing of magma transport, the composition of magma batched and to the longevity of individual volcanic centers. Although many of these processes are not fully understood at Cascadia and elsewhere, Cascadia is seen as an ideal location for multidisciplinary study of these issues.

3.2 Earthquakes and Other Faulting Processes

A primary focus of both EarthScope and GeoPRISMS at Cascadia is what controls earthquakes and other types of fault slip. In this session, this topic was addressed from three different perspectives.

Shuichi Kodaira (JAMSTEC) briefly reviewed new observations from the recent Tohoku earthquake and the ongoing and planned research and monitoring work at both the Japan Trench and Nankai subduction zones. The Japan Trench shows the greatest contrast with Cascadia in terms of the thermal structure and related petrologic and mechanical processes, but Nankai is similar in a number of ways. Seafloor geodesy, repeated bathymetric surveys, and repeated high-resolution seismic profiling, in conjunction with traditional seismic and geodetic methods, showed very large rupture (~50 m) near or at the trench and very large along-strike variations in slip distribution in the Tohoku earthquake. The IODP NanTroSeize project at Nankai has yielded useful information. For example, drilling combined with regional geophysical site surveys has elucidated the importance of splay faults in megathrust rupture and tsunamigenesis.

Rob Witter (USGS) reviewed paleoseismic studies of past megathrust earthquakes along the Cascadia margin. Various lines of evidence for sudden coastal subsidence and tsunami deposits were instrumental in establishing that Cascadia is capable of producing giant earthquakes and tsunamis. Microfossil data, especially foraminifera, provide the best constraints for the amount of coseismic elevation change and have begun to shed light on along-strike variations of megathrust slip in the great Cascadia earthquake of 1700, but there are pronounced data gaps, especially at the northern and southern ends of the Cascadia subduction zone. Analyses of offshore turbidity deposits have allowed the construction of a long history of Cascadia megathrust earthquakes that cannot be accomplished with other methods, although many of the technical details of the turbidite analyses await further validation and improvement.

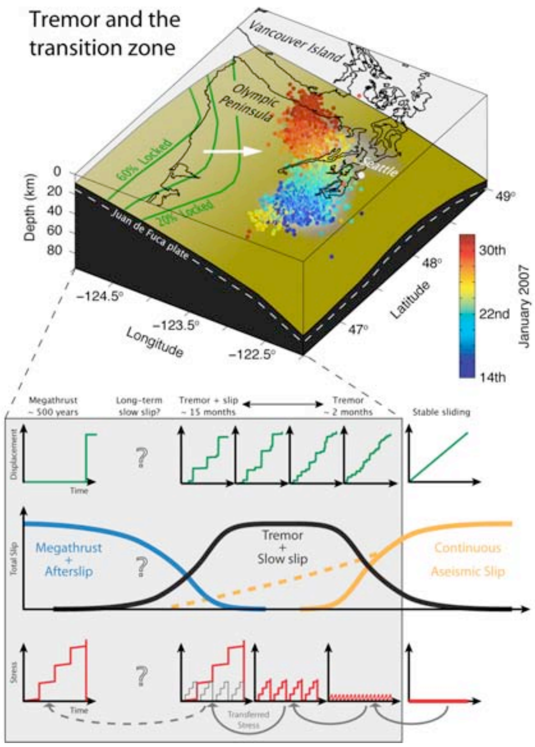

Figure 6. Top (from Forsyth et al., 2009): The Juan de Fuca plate subducts beneath the North America plate with convergence direction shown by the white arrow. The plates are locked along part of their interface (khaki-colored surface) by varying degrees; the locking model here shows the fraction of relative plate motion that isn't occurring, increasing downdip from 60% to 20% (green contours) (from McCaffrey et al., 2007). Inland of the locked zone, tremor epicenters projected onto the plate interface (circles) overlie the area that experienced slow slip (gray area on plate interface) during January 2007. Color shading of tremor epicenters shows its temporal migration. Bottom (from Wech et al., 2011): Top panel shows a profile of displacement timelines from the locked zone to stable sliding. Middle panel shows a schematic profile of how the different regions accommodate plate convergence. Lower panels shows a schematic profile of stress timelines, illustrating a stress transfer model in which stable sliding loads the downdip weakly coupled tremor region, which slips easily and transfers stress updip to stronger portions of the fault.

Ken Creager (U Washington) synthesized seismicity and tremor activity along the Cascadia margin. There is an eerie lack of modern megathrust seismicity except for a few small events off Oregon and northern California. Upper plate and intraslab earthquakes primarily occur beneath Puget Sound and Vancouver Island and in the Mendocino Triple Junction area. Mechanical and petrologic reasons for the spatial distribution of modern seismicity remain subjects of investigation. Cascadia has seen a recent explosion of information on episodic slow slip and non-volcanic tremor (ETS). In major ETS episodes, the overall along-strike migration of tremor pattern is seen to be in pace with the propagation of slow slip in the same direction as constrained by GPS and strainmeter observations, but in detail the tremor migration exhibits a rich variety of migration directions and speeds (Figure 6). Tremors located in the more seaward side of the tremor zone appear to occur more coherently in large clusters, and those more landward appear to be more sporadic and less organized. Cascadia slow slip and tremor are very similar to those at the Nankai subduction zone, but some of the phenomena reported from Nankai have not been seen or clearly resolved at Cascadia, such as long-duration (months to a few years) slow slip that appears to occur just updip of the ETS zone, very-low-frequency earthquakes within the ETS zone and in the accretionary prism, and tremor around the updip edge of the megathrust. The difference may be partly due to different detection thresholds, especially in the offshore area, and partly due to the fact that the two subduction zones are presently at different stages of their earthquake-cycle evolution. Further comparative studies are needed. Various hypotheses have been proposed to explain the physical mechanism of ETS (Figure 6), linking it to friction properties, pore fluid pressure, and petrology, but a major conceptual breakthrough has yet to happen. Such a breakthrough will also answer questions about the relation between ETS and megathrust earthquakes.

3.3 Large-scale and Deep Processes

This session focused on the large-scale processes that control subduction system dynamics, with an emphasis on those processes that occur deep with the subduction system. Three presentations were made: Ikuko Wada discussed the thermal-petrologic-fluid flow structure and dynamics of subduction zones; Gene Humphreys described the geodynamic framework of the Pacific Northwest; and Tom Sisson talked about generation of magmas in Cascadia.

Ikuko started by outlining the key factors controlling the thermal structure and fluid flow regimes of subduction zones in general and Cascadia in particular, showing the importance of the age and structure of the slab and the nature of flow within the mantle wedge and backarc region. She also emphasized the datasets that could be used to constrain models of thermal structure, including heat flow observations across the arc and seismic observations regarding the maximum depth of decoupling (MDD) of the downgoing slab. For Cascadia in the region of Puget Sound a MDD of 70-80 km (a common value for many subduction zones) satisfies lower forearc and higher arc heat flow observations and in changes in seismic attenuation. The MDD depth is effected by a number of factors, including the temperature dependence of rheologies, dehydration reactions, fluid and melt constraints, grain size and mantle dynamics within the backarc. The complexity and importance of slab-driven flow within the backarc is also a key factor for Cascadia and remains unconstrained.

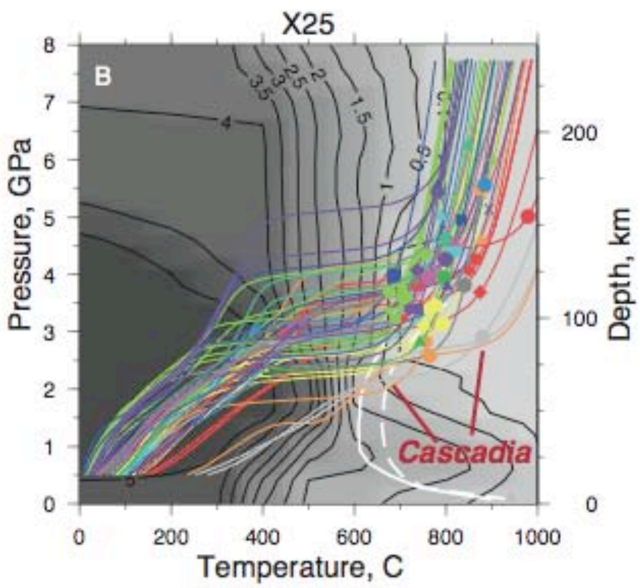

Figure 7. Calculated slab surface temperature-pressure paths (colored) for worldwide subduction zones, super-imposed on plot of structurally bound H_2O retained in metabasalt (grayscale). Note that Cascadia slab models define the high-T at low-P endmember of subduction systems, and that the basaltic slab would be expected to be nearly anhydrous by ~3 GPa, typical of slab depths beneath active arcs (modified from Syracuse et al., 2010 PEPI).

A comparison of the thermal structure of Cascadia (hot subduction zone) and NE Japan (cold) also provided insight, with the hotter temperatures within the Juan de Fuca plate resulting in peak dehydration at a shallower level and a thinner zone of serpentinite stability (Figure 7). This is also broadly consistent with existing seismic velocity models. Ikuko presented calculations of fluid release from the slab, that again suggest early dehydration of the slab – particularly when the realistic scenario of localized dehydration is considered. This should have an important effect of the volatile budget of the forearc and on magma generation, although rehydration can have a moderating effect. Ikuko showed that grainsize and other localized factors within the slab would also have an important effect. Overall this emphasizes the importance of the physical and structural state of the incoming plate and the strong control that this will have on dehydration, fluid flow and fluid migration. The work supports efforts to characterize the incoming plate in greater detail.

Gene Humphreys discussed the geodynamic development of the Pacific Northwest in light of new data obtained from seismic tomography and other sources. Gene initially highlighted the importance of reconciling known plate stresses and velocities with the modeled loads on the plates from gravitational forces, basal traction and plate margins loads. One key question is the fate of the subducted Juan de Fuca slab, which appears difficult to image using current tomographic methods.

Tom Sisson discussed magmatism and magma generation in Cascadia. As background information he showed the current estimates of the productivity of the arc over the range of erupted compositions, which are primary constraints on magma generation and differentiation processes. There is considerable variation in production rate and composition of magmas throughout the arc, and the reasons for this remain largely unknown. Tom noted that the mean volcanic rock composition, weighted approximately for edifice size, is relatively primitive (~55 wt.% SiO_2). This is dominated by the central Oregon region, considering central volcanoes alone gives a mean composition of ~62 wt.% SiO_2 – implying greater extent of crustal processing in these systems, although highly evolved magmas such as rhyolites are relatively rare. The hot slab geotherms for Cascadia (Figure 7) also raise the possibility of the slab melting, although geochemistry suggests that this is probably uncommon (with the exception of Mount Shasta). This observation emphasizes the potential influence of the structure of the incoming slab, as the projection of the Blanco Fracture Zone is located beneath Shasta. Tom also raised the long standing question of why Cascade magmas appear relatively wet and do not show widespread evidence for slab melting, as might be expected for thermal considerations. As Tom put it – for a hot dry slab why are the magmas produced so ordinary?

Crustal level differentiation also plays an important role in Cascadia, although the controls on this remain uncertain. Individual volcanic centers show distinctly different differentiation trends, suggest highly localized controls on differentiation processes. Tom argued that local assimilation of earlier magmatic products in magma transport systems might have an important influence, although this model does not work for all systems. Zircon age dating – a relatively new technique for young volcanic rocks, also provides compelling evidence that erupted magmas contained a spectrum of contributions from within the volcanic transport system. The nature of magma fluxes, and the ultimate effects of this are also an outstanding issue. Magma supply appears to be discontinuous through the growth phases of the larger volcanoes, with periods of rapid growth separated by periods of quiescence. Magma supply may also dictate whether magmatism occurs at a central volcano or in dispersed monogenetic fields. The exact controls on this are unclear but suggest a role for the lower crust and/or mantle flux.

3.4 Sediment Transport, Accretion, and Subduction

The purpose of this session, with three plenary speakers, was to focus on the Cascadia forearc as a setting for the transport of sediment from the Coast Ranges through the estuaries offshore to the accretionary prism and the abyssal plain. Topics ranged from the driving forces for erosion initiated through wedge dynamics to deformation of sediment in the offshore accretionary wedge to the mechanisms and processes of delivery of sediment to the continental slope and abyssal plain by turbidites. Mark Brandon (Yale) discussed how deformation of the accretionary wedge generates relief, and how dated flights of strath terraces along rivers eroding the uplifted accretionary wedge can trace variation in uplift rates across the subaerially exposed forearc. Lisa McNeill (National Oceanography Centre, Southhampton) discussed a range of accretionary prism deformation styles in the Makran, Sumatran and Cascadia subduction zones, and David Piper (Geological Survey of Canada, Halifax) discussed turbidite processes in both passive and active margins and then addressed some of the unique challenges to interpreting some aspects of the turbidite record in Cascadia. The potential role of sediment in modulating dynamics of tectonic and volcanic processes in Cascadia emerged during several talks in the other sessions and highlighted the need to document along-margin variations in sediment yield, sediment composition, and offshore sediment redistribution. The dominant pattern of sediment yield along the Cascadia margin features high fluxes at the northern and southern edges of the Subduction zone with relatively low rates through the central Cascadia margin coincident with Siletzia basement rocks. Marine sedimentary records have not been broadly exploited to characterize how spatial and temporal variations in terrestrial fluxes manifest along the accretionary prism.

3.5 Poster presentations

In addition the plenary and other sessions detailed above attendees were also given the opportunity to display posters summarizing their own research based on Cascadia and related topics (Figure 8). Time for viewing posters was included during both days of the meeting schedule, and posters were well attended during these times, as well as at other times during the meeting. A large number of posters (~80) were on display and highlighted the diverse array of Cascadia geoscience research that occurs within the GeoPRISMS and EarthScope communities.

Figure 8. Attendees participated in animated conversations during poster sessions.

During the Cascadia workshop, volunteers served as judges for the excellent posters that many of the students and postdocs presented. Although all of the presentations were of the highest quality, three posters rose to the top. These were: Allison Koleszar (postdoc, Oregon State University); Jason Patton (Ph.D. candidate, Oregon State University); and Wanda Vargas (M.S. student, Cornell University). Each student received a copy of the book “In Search of Ancient Oregon: A Geological and Natural History”, by Ellen Morris Bishop.

4. Special Interest Group Summaries

4.1 Deep Subduction Zone Structure

The Special Interest Group (SIG), led by Anne Sheehan and Doug Toomey, with Rob Porritt as scribe, was set up to discuss large-scale structural questions associated with deeper parts of the subduction system. This SIG group shares many common interests with the Implementation Interest Group Cascadia Initiative & Amphibious Arrays (Section 5.1). Several important themes were discussed. (1) Deep composition and structure of the overriding plate. Specific issues include the depth of Moho in the forearc and whether the lower crust at the Olympic Peninsula consists of Siletzia rocks or underplated sediments. (2) Constraining the hydration and dehydration processes of the young and hot Juan de Fuca plate. Specific issues include seismic mantle hydration in the incoming plate, faulting structure that facilitates downward migration of fluids in the incoming plate, spatial distribution of high Vp/Vs areas that are interpreted to indicate high pore fluid pressure, and the seismic signature of various mineralogical changes of the downgoing slab. (3) Geometry and structure of the slab. Specific issues include resolving the highly controversial depth location of the slab beneath southern Vancouver Island and Puget Sound (several models currently exist), the possibility of slab tear, gap (or “hole”), and detachment in a number of places as suggested by USArray data interpretation, and the fate of the deep slab. (4) Geophysical imaging to constrain thermal and petrologic states of the mantle wedge and asthenospheric back arc. Specific issues include flux vs. decompression melting, magma migration, mechanisms for seismic anisotropy, evidence for small-scale convection in the back arc, and related transition from slab-driven flow in the forearc to buoyancy-driven flow in the back arc.

What more is needed in addition to USArray and Cascadia Initiative? Suggestions included broader regional coverage of heat flow data, joint interpretation of seismic and MT imaging, and, more specifically for resolving the depth of the slab, combined analyses of wide angle reflection data, passive (RF) seismic data, earthquake locations, tremor locations, and resistivity imaging. It is recognized that there is strong need for laboratory experiments simulating in situ conditions that will allows us to infer fluid content, fluid pressure, and petrology from geophysical signatures. These may include, but by no means are limited to, in situ physical properties of aqueous fluid, melt, and (antigorite) serpentinite. There is also ongoing need to improve observational and analytical methods to improve resolution of imaging at depths.

4.2 Megathrust Structure and Processes

This SIG, entitled "Faulting Processes I", was co-led by David Schmidt and Harmony Colella, with Abhi Ghosh serving as scribe. This session was charged with discussing megathrust processes, properties and behaviors and identified a number of outstanding questions, which were boiled down to a smaller number of knowledge gaps. They also proposed strategies for filling these knowledge gaps. For a complete list of questions, see the SIG summary on the meeting web site. The primary knowledge gaps identified related to (1) the actual position of the currently active plate boundary at depths greater than ~10 km beneath the seafloor, which remains suprisingly poorly constrained and (2) the nature of the material immediately above and below the active plate boundary, a region sometimes referred to as the "subduction channel," in which permeability, internal structure, frictional heats and other properties are poorly known; and (3) whether there is currrently interseismic deformation offshore. Filling these knowledge gaps will require technical advances in techniques to image velocity and electrical conductivity structure, measure offshore deformation, and develop more realistic numerical models. Other strategies proposed to advance understanding of these issues include detailed multidisciplinary studies at carefully selected sites; PI-driven piggy-back experiments developed to take advantage of facilities mobilized for large community experiments; ambitious PI-driven transects along and across strike; and community workshops to facilitate synthesis of multiple datasets, ideas and model and development of new PI-driven and community proposals.

4.3 Outer Forearc Structure and Segmentation

This SIG was the focus of two discussion groups, which merged given the considerable overlap between their charges. The discussion group on "Megathrust processes II," led by Rick Blakely and Sue Bilek merged with the discussion group on "Shallow forearc structure," led by Tom Pratt and Helene Carton. A major topic of discussion was observations of along-strike segmentation of many processes in Cascadia, including ETS recurrence time, the composition and volume of Quaternary volcanic output, and both upper and lower plate seismicity. Proposed causes for this segmentation included structures of the incoming plate (e.g., pseudofaults, subducting seamounts), inherited upper plate crustal structure, and along strike variations in sediment input to the subduction zone. Other key science targets included better understanding of kinematic links between the forearc and backarc and the relationship between upper crustal faults and the megathrust earthquake cycle. Some techniques proposed to address these questions included along-strike seismic imaging surveys, densification of paleoseismic data, maintenance and enhancement of seismic and geodetic networks (especially in Oregon), development of community databases, and community modeling efforts using high-performance computers. The importance of cooperation across the US/Canada international border for addressing these problems was emphasized. For more details, see the discussion group summary on the workshop web site.

4.4 Geodetic Processes

This SIG was chaired by Herb Dragert and Spahr Webb, with Jay Patton as scribe. The discussion began by reviewing existing infrastructure for geodetic studies of Cascadia geodynamics:

Onshore: With PBO, PANGA, and Western Canada Deformation Array, Cascadia has one of the world's densest land-based GPS networks, with most stations streaming data at high rate and in real time. There are 45 PBO borehole strainmeters and some other types of strainmeters. Absolute gravity surveys are regularly taking place in northern Cascadia, and there is potential to expand this work.

Offshore: There is one borehole observatory (CORK) in the subduction zone continuously monitoring formation fluid pressure as proxy for volumetric strain, which will soon be connected to the NEPTUNE Canada cable observatory system; funding has been approved to install a borehole tiltmeter and to deploy an array of eight autonomous seafloor pressure gauges in the same area. CORK systems also exist farther offshore. Two seafloor GPS-acoustic (among the world's earliest) stations have been surveyed in the past, but not since 2004.

A number of knowledge gaps were identified during the discussion, which must be addressed through integration of geodetic data with other data. They include: the true state of interseismic locking of Cascadia megathrust, which requires near-source (offshore) monitoring; the relationship between megathrust rupture and the ETS zone; the relationship between slow slip and nonvolcanic tremor; and the possibility of offshore tremor, low frequency earthquakes, and slow slip events.

There was strong consensus that new advances are needed in seafloor geodesy to achieve breakthroughs in understanding. David Chadwell summarized new seafloor GPS-acoustic observations during the Tohoku earthquake and Japan's plans to further strengthen this work. He pointed out that cost reduction through innovative use of technology is critical for realistic development of seafloor GPS in Cascadia. The use of "wave gliders" may do away with the requirement for expensive ship time, and a new design of permanent benchmarks will allow a small number of seafloor transponders to be economically used for many sites. These technologies are being developed and may be put to test in Cascadia in the next couple of years. Evelyn Roeloffs emphasized the value of borehole strainmeters and the need to train the new generation of scientists to carry out research in this field. CORK observations at the Nankai subduction zone from Earl Davis (presented by Herb Dragert) potentially indicate local fault slip remotely triggered by the Tohoku earthquake ~900 km away, and illustrate the value of continuous seafloor or sub-seafloor monitoring.

Although the use of real-time GPS and other geodetic systems for earthquake early warning is another important new geodetic development, it was not discussed in detail by this group; however, it was addressed under Cascadia Geohazards (see Section 5.3 of this report). The need to develop more powerful modeling tools was also discussed, but there was a general recognition that a strong conceptual understanding of the underlying physical processes is critical for linking data to computer models.

4.5 Magmatism and Volcanic Processes

This SIG recognized the unique nature of Cascadia where access to a ~50 million year record of magmatism provides the opportunity to study the evolution of an arc through time. If we include Cretaceous plutonic rocks of the north Cascades, this record is even longer. To do this requires further work, including improved geochronology and geochemistry, an understanding of slab fluxes through time and also improved knowledge of the tectonic history of the overlying plate (including Basin and Range extension etc.). Additional studies of volcanic centers would provide the ability to compare arc evolution through time along strike, and further work on volatile fluxes would constrain the role of slab devolatilization in magma generation.

Existing knowledge of the volcanic record also raises some key issues, such as what are the controls on the localization of individual volcanic centers, and why are these so long lived in several places? In addition the question of why some locations see focused magmatic output (central volcanoes) and others see more dispersed and more primitive volcanism (central Oregon) is a key issue. The role of magma focusing on crustal magma processing was also considered important. There was also discussion regarding the presence and potential role for lithosphere in magma transport and modulation of magmatic signals.

Ongoing studies of the downgoing plate were also highlighted as useful for understanding the volcanic record. Key issues are the role of along-strike changes in thermal state, plate structure and sediment load, as well as chemistry and alteration of the oceanic crust being subducted. Questions remain about whether the oceanic plate melts and where this might occur, and these would have important ramifications for thermal structure.

It was also recognized that there is an important role for comparative studies between Cascadia and other well-studied subduction systems. This provides an avenue to link to MARGINS focus sites (Central America, Izu Bonin-Marianas) as well as the other GeoPRISMS primary sites. Although the Cascades are a "hot and dry" system it is unclear how this is manifest in magmatic outputs, as many volcanic rocks have "normal" arc-like water contents and chemically are quite comparable to other arcs. The large datasets that will become available through GeoPRISMS will be powerful ways to address these issues.

There was also a discussion about data sharing, revolving around access to the large amounts of "grey" literature that are available on the Cascades and how to get these into large internet databases. Possibly GeoPRISMS could provide a portal for this, unless existing databases (e.g., GEOROC) are sufficient.

4.6 Volatile Processes and Cycles

Volatiles play important roles in subduction zone processes. This SIG focused on the key questions of the effect of volatile release and transfer on the rheology and dynamics of the plate interface, from the incoming plate and trench through to the arc and backarc, and how released volatiles, fluids, and melts are stored, transferred, and released through the subduction system.

One key issue For Cascadia is to improve understanding of the volatile budget and thermal state of the incoming plate, including the degree of serpentinization. It is clear that this could be better characterized by seismic or other geophysical studies, and also potentially by drilling the plate. It was also pointed out that in some respects (but not all) there is an analogue for older crust being subducted in the oceanic crust to the west of the Juan de Fuca Ridge.

Conversation also revolved around the nature of devolatilization processes within the subduction zone. Although it is predicted that the Cascades should be a relatively hot and dry subduction system, as pointed out already this is at odds from petrological studies – which show water contents of melts that are comparable to other arc systems. It was recognized that improved efforts to model the mineralogy and thermal state of the downgoing slab is critical to understanding devolatilization processes, and how this should relate to slab fluxes and to magmatism. Further geophysical work may help to address this question. There is also considerable uncertainty regarding forearc and subarc volatile releases and integrating observations with numerical and experimental studies is a key for progress on this issue. The role of this release on detachment and mantle wedge physical properties is also seen as a critical area for future work.

A further role for petrologic and other studies aimed at understanding the volatile outputs of the arc system is also seen as essential. This includes further melt inclusion studies to look at changes in volatile budgets across space and time and the relation between these and magma compositions and fluxes. Additional petrological, experimental and geophysical studies could also help constrain these processes. The relation of volatile budgets to more evolved magmatism and to volcanic hazards also remains unclear. These processes have important control over crustal volatile fluxes and within the lower crust these remain largely unknown. Resolving this will require additional experimental work, but will require access to deep crustal sections that are largely absent in Cascadia.

4.7 Sedimentary Processes

The SIG on sedimentary process had a primary interest in tracing the movement of sediment, including carbon and other bio-markers, through the subaerially exposed forearc to estuaries. The group discussed strategies for assessing the impact of infrequent subduction zone earthquakes on erosion processes. Of particular interest were earthquake-triggered landsides and the subsequent fate of landslide-generated sediment. An important research tool with regards to assessing the effect of earthquake-generated regional sediment yield is the coring of lake sediments to investigate sediment archives of erosion to lake basins. For instance, regional shaking during major earthquakes would generate landslides of all sizes; and landslide-generated deposits would accumulate in lakes as a consequence. Logistically, there was discussion of a repository or consortium for lake and marsh coring equipment that would have an inventory of a range of coring equipment for use by research groups, not dissimilar to UNAVCO’s role as a resource for borrowing geodetic equipment. Additionally, the sediment mass balance analysis performed by Mark Brandon and colleagues in the Olympic Mountains has not been exported elsewhere along the margin. That work demonstrates that the accretionary flux is balanced by the erosional flux coming off the Olympic Mountains, constituting a flux steady state. Those results are consistent with accretionary wedge models that provide a mechanical basis for orogeny and landscape evolution along the forearc. Sediment accretion and sediment yield data along the remainder of the margin along with a more generalized modeling framework that accounts for diverse crustal architecture of the forearc can be conjunctively employed in order to assess sediment mass balances more broadly in Cascadia.

5. Implementation Interest Group Summaries

5.1 Cascadia Initiative & Amphibious Arrays

Doug Toomey presented an update on the status of the NSF-funded Cascadia Initiative Ocean Bottom Seismometer (CI-OBS) experiment. The CI-OBS experiment (Figure 9) is an ambitious experiment to extend the US-Array transportable array concept (www.earthscope.org) to the Juan de Fuca plate offshore the Pacific Northwest. The first set of instruments was deployed over the northern Juan de Fuca/Gorda plate system during summer and fall 2011 and will be retrieved and redeployed on the southern part of the Juan de Fuca plate in 2012. Each year's deployment includes a handful of backbone sites that span the entire Juan de Fuca plate and its boundaries, a grid of instruments spaced ~50 m on either the northern or southern half of the system, and a focused array with dense instrument spacing somewhere along the subduction boundary. Six cruises are planned for summer 2012 to recover and redeploy the instruments. Scientists and students interested in participating in one of these cruises can contact the CIET team to see if there are berths available. Data from this experiment will be released to the community as soon as it is available. For more details, please see their web site (http://cascadia.uoregon.edu/CIET).

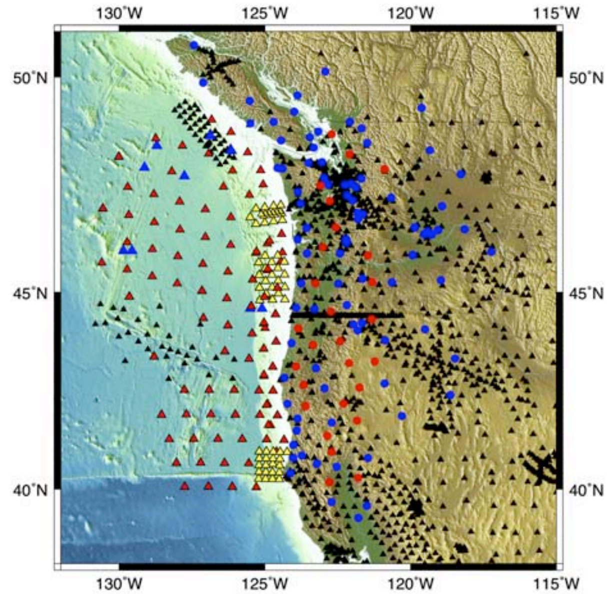

Figure 9. Stations that will have publicly available seismic data as of 2015. Offshore triangles show data to be collected over the 4 years of the Cascadia initiative. Circles on land show locations of USArray stations that will be deployed until 2013 as part of the Cascadia Initative. Black triangles on land show data from past PASSCAL and Earthscope Flexible Array deployments. More than 200 high-rate GPS stations that are part of the Cascadia initiative (not shown) will be available through 2018.

The onshore component of this amphibious project was presented by Geoff Abers, incoming chair of the AASC (Amphibious Array Steering Committee). This component of includes reoccupation of a number of former US-Array sites in the Oregon and Washington Coast Range and upgrading of many EarthScope PBO GPS sites to higher data rates and real-time processing.

5.2 Volcano Imaging

In the plenary session, Olivier Bachmann provided a brief overview of the Mt. St. Helens volcano imaging project, which is a collaborative, PI-driven project jointly funded by GeoPRISMS and EarthScope, and with collaborative links to the US Geological Survey and the Cascades Volcano Observatory. Mt. St. Helens was chosen by the PI group as a focus for detailed geophysical imaging of a Cascades volcano because of its extensive history of activity, a wealth of existing data, and accessibility for installing instrumentation. The goal of the project is to develop a geophysical image of unprecedented spatial resolution (using passive and active seismic and magnetotelluric techniques) of the crust and mantle structure beneath Mt. St. Helens, from the slab to the surface, to be integrated with petrological data from eruptive products. A group of about 25-30 people also attended the evening SIG discussion related to this project, and discussions largely centered on how researchers outside of the project-specific PI group could link in to this effort. The project itself will supplement existing geophysical infrastructure in the region, which presently consists of 67 seismometers (most vertical component only), a small GPS network on select Cascades volcanoes (Shasta, Helens, Rainier), industrial MT studies away from volcanoes, and a strain meter array on Mt. St. Helens. Opportunities to build upon the planned work are particularly strong in the petrology/geochemistry/mineral physics fields, including improving characterization of material responses to wave speed and conductivity, characterizing the eruptive products and crustal composition of the Mt. St. Helens region, assessing roles for petrologic processes such as fractional crystallization and crustal assimilation beneath Mt. St. Helens, and determining a detailed chronology of the eruptive history of the volcano. The products of the MSH project may also be important for interpreting similar, but smaller-scale, studies of different types of volcanoes (e.g., Newberry or Three Sisters), and for interpreting the future behavior of the MSH system. The USGS houses a wealth of existing samples from the MSH region, and these are available for public access for further study. The discussion also noted that rapid response efforts by non-USGS scientists on any Cascades volcanoes need to be closely coordinated with the USGS, and that formal procedures within NSF for rapid-response funding of on-land activities should be developed and incorporated into the GeoPRISMS Implementation Plan for Cascadia.

5.3 Cascadia Geohazards

Plenary presentations given earlier in the workshop set the stage for brainstorming discussions of implementation plans by a large group, with discussions coordinated by Roy Hyndman and Brian Sherrod. The presentations and the ensuing discussions addressed the important and diverse topic of Cascadia Geohazards, including those related to earthquakes, tsunamis and volcanoes. They also addressed the major new direction of earthquake early warning.

The earthquake hazard assessments with the greatest societal impact nationwide are the USGS national seismic hazard maps, which are used in building codes, to set insurance rates, for planning and other purposes. Art Frankel described the ingredients of these maps, which include models of earthquake sources (recurrence, size, location, etc.) and ground motion attenuation. These derive from seismicity records, fault mapping and paleo-earthquake chronologies, ground motion data, and most recently geodetic observations. Additional validation is needed for inferences from turbidite-based chronologies, extrapolations of ground motion attenuation from great earthquakes elsewhere to Cascadia, and locking-models and their implications for coseismic slip. The surprisingly large amplitude and impacts of the tsunami generated by the Tohoku earthquake has provided new impetus to understand local tsunami hazard.

George Priest summarized local tsunami hazard assessments, with hazard characterized by run-up and inundation. Predictions of local tsunami hazards appear to be most sensitive to source models, rather than hydrodynamic assumptions. Because run-up and inundation both may scale linearly with peak surface slip, understanding of processes including the frictional behavior during rupture, small-scale wedge deformation, and splay faulting is key. The development of probabilistic tsunami hazard maps is now underway. .

Seth Moran presented an overview of volcano hazards in the Cascades, noting that characterization involves determination of an eruption's duration, areal extent, flow type (e.g. lahar, pyroclastic, etc.), and evolution. New information from the last decade, primarily geologic mapping, have changed assessments of the past eruptive behaviors and shown St. Helens, Rainier and Glacier Peak to be the three most active Cascade volcanoes in the last 4000 years. Volcano hazard assessments also rely heavily on models of magmatic systems, and are quantified in terms of 'threat scores'.

Ingrid Johanson reviewed the philosophy and methodology of earthquake early warning - notification that strong shaking will occur at the notification site within seconds to tens of seconds – and the broader issue of rapid characterization of earthquake rupture. A few systems based on the detection of P-wave arrivals are presently operational in several parts of the world, but experience from the recent Tohoku earthquake shows the inherent limitations of these systems in responding to very large earthquakes. A new 'Shake Alert' early warning system for the continental western US, building on a seismic data-based prototype being run in California, is now being developed. In Cascadia, its inclusion of high-rate, real-time GPS data from more than 230 PBO and 220 PANGA sites, in addition to seismic P-wave measurements, enhances its design performance for very large events, such as a great Cascadia subduction earthquake. For areas far away from the coast, it may provide warning before the arrival of destructive surface waves. For coastal areas, it will provide rapid determination of rupture size and propagation characteristics for effective tsunami early warning.

5.4 Energy & Mineral Potential

The focus of the discussion for mineral and energy resources was predominantly related to geothermal prospects. This was deemed the topic most related and accessible by the GeoPRISMS community. Mineral resources within the Cascades are minor and isolated, although the lack of large mineral deposits in Cascadia is interesting in itself. Overall the broad focus of GeoPRISMS will improve the understanding of the geologic structure of Cascadia, and this could be then used to framework and mechanisms for mineral and energy exploration.

Discussion concerning infrastructure focused on unrealized potential for geothermal exploration that exists in the Cascades and how GeoPRISMS might be able to assist with this. It was recognized that large-scale geothermal projects are unlikely to fall within GeoPRISMS but that opportunities exist for piggybacking on research programs funded under GeoPRISMS could be useful – measuring heatflow in locations used for seismic and other experiments is one example. In addition REU supplements to GeoPRISMS grants could be used to fund undergraduate projects with a geothermal emphasis. There are also multiple opportunities to coordinate research in this field with other government agencies (DOE) as well as state and commercial organizations. The State of Washington has a mandate for renewable energy that could also be integrated into GeoPRISMS studies.

Monitoring activities around active volcanic systems could also be useful for geothermal research, particularly where new measurements, such as sampling of water or heat flow could be used to constrain geothermal potential. Another concrete contribution from GeoPRISMS could be to further the acquisition and release of LIDAR data for basic geothermal exploration, geologic mapping and structural assessment. This is particularly useful in heavily vegetated areas like the Western Cascades. Aeromagnetic surveys would also be beneficial to the larger GeoPRISMS community and could be utilized to identify potential geothermal anomalies.

Opportunities also potentially exist for academic-industry partnerships related to geothermal studies. Many existing geothermal projects come with money already dedicated to student participation. GeoPRISMS could provide further mechanisms for this type of collaboration.

5.5 Education & Outreach

The integrated scientific research and monitoring at Cascadia present, and can be enriched by, substantial education and outreach opportunities. At the workshop, this was manifest in the student and postdoc symposium (see above) and in the student involvement throughout the workshop and their final presentation during the wrap up period. This enhanced effort to introduce young scientists to the science and planning processes was led by Andrew Goodliffe on behalf of the GeoPRISMS Education and Outreach committee. In addition, Ellen Morris Bishop (a prominent science educator and author in the region) presented a motivating evening talk about engaging communities about science.

A wide-ranging discussion about education and outreach opportunities provided by a scientific focus on Cascadia took place during the Thursday evening break-out sessions, co-led by Bob Butler and Ellen Morris Bishop. Examples include:

- Development of Cascadia-themed mini-lessons to further build the existing MARGINS mini-lesson collection housed at SERC (http://www.geoprisms.org/mini-lessons.html). These mini-lessons could serve both undergraduate and K-12 audiences.
- Updating and expanding the Active Earth Kiosk content on Cascadia.
- Identifying and announcing REU opportunities associated with ongoing Cascadia research, to draw undergraduates into the research community.
- Hosting regular student symposia on GeoPRISMS-EarthScope Cascadia research, with associated field trips, to keep students and post-docs engaged, and to enhance interaction, communication, and collaboration.
- Offering teacher education programs, possibly including research and field components (e.g., NSF Research Experience for Teachers).
- Further developing accessible web content about ongoing Cascadia projects, for students, educators, policy makers, and the public. GeoPRISMS and EarthScope sites can offer some parallel content, as well as community-specific materials.

Emphasis was placed on leveraging existing, well-respected E&O efforts, such as those managed by IRIS, and also on reducing redundancy among different organizations. This would allow individual organizations to concentrate on their strengths, jointly contributing to a coherent E&O package. Coordination of EarthScope and GeoPRISMS efforts in Cascadia is sensible at this stage, and is facilitated by ongoing efforts to coordinate web content.

Cascadia is ripe for new E&O products, activities, and efforts, because of the increasing awareness of North American geohazards, the large population centers that would be impacted by hazardous events in the region, the growing concentration of scientific and infrastructure resources in Cascadia, and the large pool of experts within the scientific community who can contribute to such efforts. Logically, outreach efforts, particularly relating to geohazards, should be coordinated with the U.S. Geological Survey, which takes primary responsibility for event response and communication, and similarly, with its Canadian counterpart, the Natural Resources Council (NRC).

6. Student Activities and Perspective

Figure 10. The students shared their perspectives and experiences during the workshop.

Throughout the workshop, the students participated in the plenary and breakout sessions, enthusiastically contributing to discussions. During lunches and in the evening, when most workshop participants had long since left the convention center, the symposium participants were often found discussing Cascadia science. During these discussions, the students and postdocs developed a consensus statement that emphasized what they determined to be the key aspects of the Cascadia system and where they thought that the important scientific breakthroughs would come (Figure 10). The students and postdocs split their comments into four main categories. In the category of Cascadia crustal evolution they determined that key questions remained regarding the temporal evolution of magmas, the origin of silicic bodies, and why silicic magmas generally stall and form plutons while mafic magmas erupt at the surface. In the category of earthquakes and other faulting processes, the symposium participants felt that the scientific community would benefit from a greater understanding of the correlation between turbidites and coastal paleoseismicity records. They also felt that there were major gaps in our knowledge of upper plate faulting and ETS process. The participants recognized a need for more hazard maps for urban centers. In the third category, large scale and deep processes, the symposium participants identified a need for better understanding of subduction initiation, particularly with respect to the westward trench jump after Siletzia accretion. Another area of focus should be the effect of slab geometry on features such as volcanism, mantle flow, and seismicity. In the fourth category, sediment feedbacks across space and time, the participants determined that more resources could be focused on the question of how sediment erosion and flux affects tectonic processes.

7. Roadmap to the Future – Science Implementation at Cascadia

Throughout the meeting several key issues emerged from the presentation and discussions. A selection of these is provided below, and collectively they constitute a roadmap for refining the Cascadia science implementation plan. In most cases these issues cross traditional discipline boundaries, and our understanding of them is impacted by multiple datasets.

- *The nature of segmentation along the subduction zone.* A number of diverse data sets (geophysics, seismicity, volcano age and distribution, geochemistry, geodesy and paleogeodesy, etc.) reveal that the subduction zone is segmented along strike. Key uncertainties remain. Is the segmentation the same for different data sets? What are the ultimate controls of segmentation evident in different data? What is the influence of the incoming plate on segmentation? What is the influence of the inherited crustal structure and composition of the upper plate?

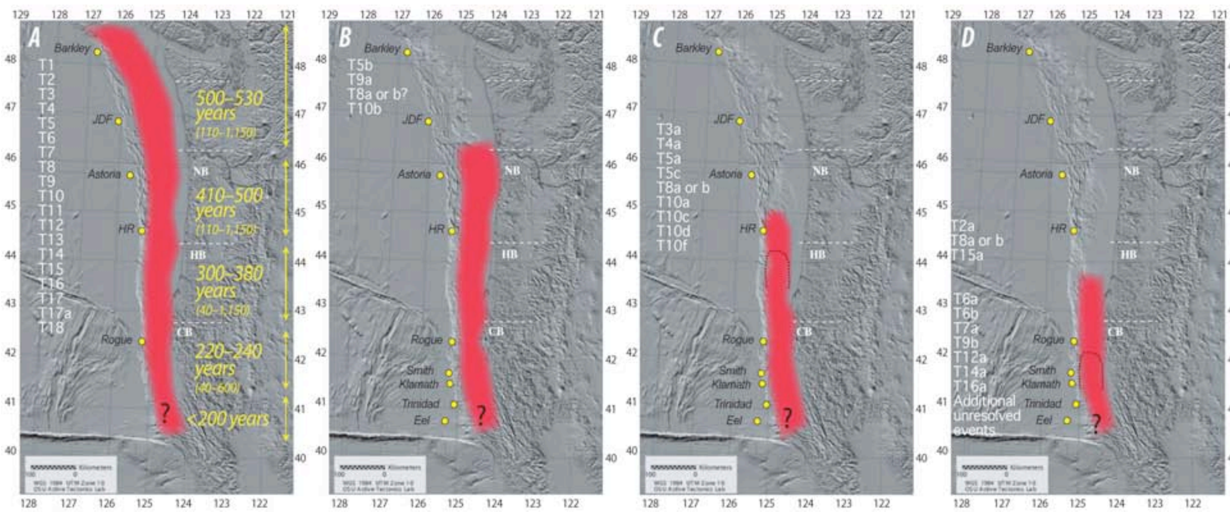

Figure 11. Holocene rupture lengths of Cascadia great earthquakes based on marine and onshore paleoseismology. Four images showing rupture modes inferred from turbidite stratigraphic/14C correlation, supported by onshore radiocarbon data. Marine core sites controlling rupture-length estimates are shown as yellow dots. A, Full or nearly full rupture, represented at most sites by 19 events. B, Mid-southern rupture, represented by 3–4 events. C, Southern rupture from central Oregon southward represented by 10–12 events. D, Southern Oregon/northern California events, represented by a minimum of 7–8 events. Recurrence intervals for each segment are shown in A. Rupture terminations are located approximately between three forearc structural uplifts, Nehalem Bank (NB), Heceta Bank (HB) and Coquille Bank (CB). Paleoseismic segmentation shown also is compatible with latitudinal boundaries of episodic tremor and slip (ETS) events proposed for the downdip subduction interface (Brudzinski and Allen, 2007) and shown by white dashed lines. A northern segment proposed from ETS data at approximately lat 48° N. does not appear to have a paleoseismic equivalent. (Figure from Goldfinger et al., 2012; see for more details).

- *Earthquakes and the turbidite record.* Inferences have been drawn from turbidite records that earthquakes rupture only part of plate boundary (M>~8 events) have regularly occurred in southern Cascadia with the northern portion rupturing only in entire-boundary, M9 earthquakes (Figure 11). These suggestions warrant further study as they have important impacts on hazard estimates and our basic understanding of the earthquake cycle along the plate boundary. A promising 'amphibious' approach to testing these inferences involves correlation of offshore results with those from onshore studies of paleo-landslides in lakes. Other 'amphibious' (in both marine and onshore environments) and multi-disciplinary studies can also provide constraints on plausible variations in key sedimentation and failure processes, and further studies of the overall linkages between earthquakes and turbidites are also warranted.

- *The hot and dry slab paradox*. Uncertainty remains in reconciling the geochemical and petrological estimates of volatile fluxes in Cascadia with thermal models that predict a hot and dry subduction system? At present, measurements of pre-eruptive water contents seem relatively normal (compared to other arcs) in Cascadia basalts, however thermal models predict early dehydration and devolatilization. This remains an enigma for Cascadia. The relationship between timing of dehydration, extent of dehydration and the role of volatile fluxes in magmatism remains unclear.

- *Distribution of volcanism.* There remains uncertainty over the ultimate the controls on the distribution of volcanism in Cascadia? Specifically, what parameters influence the formation of large central volcanoes that occur along the arc versus the more dispersed monogenetic volcanism that characterizes the regions between the larger volcanoes? Can this distribution be linked to the slab, structures in the mantle wedge, or in the upper plate? How do the relatively localized back-arc volcanic complexes (Simcoe, Newberry, Medicine Lake) relate to the arc system? What are the roles of mantle fluxes, solid/fluid flow vectors, and crustal magma processing?

- *Role of surrounding regions.* Cascadia did not develop in isolation, and important questions remain regarding the evolution of Cascadia in relation to surrounding geologic provinces? These include the Yakima fold and thrust belt, the Basin and Range, The High Lava Plains, Klamath/Sierra block, the Yellowstone hot spot trail and the Juan de Fuca ridge. How have the interactions between these geologic provinces changes through time to influence the formation and evolution of the North American continent?

- *Imaging the physical properties deep within the crust and upper mantle.* Different models of subduction processes, including the transition from stick-slip to stable sliding along the megathrust and the migration of magma through the crust, are difficult to image geophysically. How can traditional techniques for imaging subsurface seismic velocity and electrical conductivity be improved to better image these processes? How can better images be integrated with other geophysical and geochemical observations?

- *Sediment transport*. The transport of sediment from the subaerial forearc to offshore not only is a response to tectonic processes but also the sediment records of such transport provides insight to the past tectonic events. Specific questions include, what is the role of subduction zone earthquakes in initiating landslides, in creating readily mobilized sediment sources and in modulating estuaries as sediment storage compartment or as conduits for sediment delivery to the offshore. Can records from lakes, especially landslide-dammed lakes, be valuable archives of erosion history in the Coast Ranges? How effective are carbon and other biomarkers in tracing sediment through watersheds to the offshore and can these methods, along the sediment transport data, be applied to determine sediment mass balances for Coast Range watersheds located at different latitudes along the Cascadia margin?

9. References

Forsyth, D.W., Lay, T., Aster, R.C., and Romanowicz, B., 2009, Grand challenges for seismology: Eos (Transactions, American Geophysical Union), v. 90, p. 361– 362, doi: 10.1029/2009EO410001.

Goldfinger, C., Nelson, C.H., Morey, A.E., Johnson, J.E., Patton, J.R., Karabanov, E., Gutiérrez-Pastor, J., Eriksson, A.T., Gràcia, E., Dunhill, G., Enkin, R.J., Dallimore, A., and Vallier, T., 2012, Turbidite event history—Methods and implications for Holocene paleoseismicity of the Cascadia subduction zone: U.S. Geological Survey Professional Paper 1661–F, 170 p. (Available at http://pubs.usgs.gov/pp/pp1661f/).

McCaffrey, R., Qamar, A., King, R.W., Wells, R.W., Khazaradze, G., and Williams, C., 2007, Deformation in the Pacifi c Northwest: Geophysical Journal International, v. 169, p. 1315–1340, doi: 10.1111/j.1365-246X.2007.03371.x.

Priest, G.R., 1990, Volcanic and tectonic evolution of the Cascade volcanic arc, Central Oregon, J. Geophysical Research, 95, B12, 19,583-19,599.

Syracuse, E.M, van Keken, P.E. and Abers, G.A., 2010, The global range of subduction zone thermal models, Physics Earth Planetary Interiors, doi:10.1016/j.pepi.2010.1002.1004.

Verplank, E.P., and Duncan, R.A., 1987, Temporal variations in plate convergence and eruption rates in the Western Cascades, Oregon, Tectonics, 6, 2, 197-209.

Wech, A.G., & Creager, K.C. (2011). A continuum of stress, strength, and slip in the Cascadia subduction zone. *Nature Geoscience, 4,* 624-628.

Appendix 1: Workshop Agenda

Wednesday, April 4 – Registration (and Student Symposium)

5:30 PM Registration and Ice Breaker (at Marriott Waterfront)

Thursday, April 5 – Workshop Day 1

7:30 AM Breakfast (at World Trade Center)

Moderators: Adam Kent, Katie Kelley

8:30 AM Welcome from the conveners (TBA), logistics, goals for the workshop
8:45 AM Comments from NSF representatives
9:00 AM Cascadia Crustal Evolution and Deformation
*9:00 Evolution of Cascadia backarc & forearc - **Ray Wells***
*9:30 Cascadia pre-quaternary geologic context - **Anita Grunder***
*9:50 Controls on Holocene and recent volcanism in the Cascades – **Kathy Cashman***
10:10 Discussion

10:30 AM COFFEE BREAK

Moderators: Anne Trehu, Kelin Wang

11:00 AM Earthquakes and Other Faulting Processes
*11:00 Learning from Tohoku Earthquake, NanTroSEIZE, and related - **Shu-ichi Kodaira***
*11:30 Paleoseismic history of Cascadia from onshore and offshore record - **Rob Witter***
*11:50 Seismic and aseismic processes from the modern record - **Ken Creager***
12:10 Discussion

12:30-1:30 LUNCH

Moderators: Geoff Abers, Adam Kent

1:30 PM Large-scale and Deep Processes
*1:30 Thermal-petrologic-fluid flow structure and dynamics of the subduction zones - **Ikuko Wada***
*2:00 Geodynamic framework of the Pacific NW - **Gene Humphreys***
*2:30 Structure, composition, and evolution of the incoming plate, and effects on subduction – **Suzanne Carbotte***
*3:00 Generation of magmas in Cascadia - **Tom Sisson***
3:30 Discussion

Moderators: Joan Gomberg, Anne Trehu

3:50 PM Project Summaries: Ongoing studies in Cascadia and elsewhere (5 min each)

- *Cascadia Initiative – offshore update - **Doug Toomey***
- *Cascadia Initiative - onshore update - **Richard Allen***
- *IODP studies - **Rob Harris***
- *Cabled observatories, Canada – **Martin Heesemann***
- *Cabled observatories, US - **William Wilcock***
- *Offshore GPS - **Dave Chadwell***
- *Mount St. Helens project - **Alan Levander***
- *Langseth project to study forearc deformation - **Katie Keranen***
- *Mocha Project – **Adam Schultz***
- *GeoPRISMS Portal and MGDS - **Andrew Goodwillie***

4:40 PM **Poster Session**

6:30 PM CONFERENCE DINNER (at World Trade Center)

- *Earth to Humans: The importance of connecting people with their planet – **Ellen Morris Bishop***

8:00 PM Poster Session w/ CASH BAR

8:00 PM Projects and Implementation Discussions

Objective: Break-out groups to discuss existing and planned projects, activities, opportunities and future directions (90 minutes). Reports will guide closing discussions on Day 2.

- *What infrastructure exists for Cascadia; what are associated opportunities?*
- *What major research products and data streams will be available?*
- *What gaps remain to be filled; what are future directions?*
- *What challenges exist, and how can they be overcome?*

(a) Cascadia Initiative & Amphibious Arrays – ***Richard Allen, Doug Toomey***
(b) Volcano Imaging – ***Ken Creager, Olivier Bachman***
(c) Cascadia Geohazards – ***Brian Sherrod, Roy Hyndman***
(d) Energy & Mineral Potential – ***Andrew Meigs, Michael Rowe***
(e) Education & Outreach – ***Bob Butler, Ellen Bishop***
(f) GeoPRISMS Portal and MGDS - ***Andrew Goodwillie***

Friday, April 6 – Workshop Day 2

7:30 AM Breakfast (at World Trade Center)

8:30 AM Introduction to Day 2

Moderators: Josh Roering, Harvey Kelsey

8:40 PM Sediment Transport, Accretion, and Subduction

*8:40 Mass Balance and terrestrial surface processes - **Mark Brandon***
*9:10 Accretionary prism processes, comparison with other subduction zones - **Lisa McNeil***
*9:40 Understanding turbidite record: genesis, transport, and preservation – **David Piper***
10:10 Discussion

10:30 AM COFFEE BREAK

11:00 PM Special Interest Groups (Mini-Sessions)

Objective: *Break-out groups to discuss scientific topics, targets, and research approaches, (2 sessions, 45 minutes each). Reports will guide closing discussions on Day 2.*

- *What are the key exciting scientific questions that can be addressed in Cascadia?*
- *What infrastructure exists in Cascadia research to address them?*
- *What knowledge gaps remain to be filled; what are future research directions?*
- *What challenges exist, and how can they be overcome?*

11:00-11:45 AM - Session 1

(a) Subduction Zone Structure I – ***Anne Sheehan, Gary Egbert (Scribe: Rob Porritt)***
Deep geophysical imaging (e.g., mantle wedge, slab), passive seismic, resistivity

(b) Faulting Processes I – ***David Schmidt, Harmony Colella (Scribe: Abhi Ghosh)***
Megathrust processes, properties, and behaviors

(c) Sedimentary Processes – ***Chris Goldfinger, Becky Dorsey (Scribe: Karl Wegmann)***
Sediment transport, linkages among hillslopes, estuaries, turbidite processes, preservation of extreme events (flooding, landslides, earthquakes)

(d) Volcanism and Volcanic Processes – ***Sue de Bari, TBA (Scribe: Alison Koleszar)***
Distribution, composition, and output through time and space, correlations with seismic record, imaging and monitoring

11:45-12:30 PM - Session 2

(a) Subduction Zone Structure II – ***Tom Pratt, Helene Carton (Scribe: Lee Liberty)***
Shallow imaging (forearc structure), active source, potential fields, resistivity

(b) Faulting Processes II – ***Rick Blakely, Sue Bilek (Scribe: TBA)***
Margin segmentation from modern, paleoseismologic and paleogeodetic perspectives, forearc and backarc deformation, intraplate faults

(c) Geodetic studies **–** ***Spahr Webb, Herb Dragert (Scribe: Jason Patton)***
Present-day ground motions, on- and off- shore, causes and consequences

(d) Volatile Processes and Cycles – ***Glen Spinelli, Stacia Gordon (Scribe: Dan Ruscitto)***
Fluids and melting, from trench to arc

12:30-1:30 PM LUNCH

Moderators: Kelin Wang, Joan Gomberg

1:30 PM Cascadia Hazards Plenary Presentations

1:30 Implications for the built environment – hazard mapping - ***Art Frankel***
1:45 Tsunami potential and modeling - ***George Priest***
2:00 Volcanic Hazards - ***Seth Moran***
2:15 Early Warning - ***Ingrid Johanson***

2:30 PM Special Interest Groups Reports (5 mins each)

3:00 PM COFFEE BREAK

Moderators: Katie Kelley, Josh Roering

3:30 PM Student Perspective & Follow-up Discussion

4:00 PM Implementation Discussion and Roadmap to the Future

4:00 Implementation Discussion Summaries (5-10 mins each), setting stage for

4:30 Future Research Directions and Opportunities, e.g.,

- *What are the key exciting scientific questions that can be addressed in Cascadia?*
- *What infrastructure exists for Cascadia; what are associated opportunities?*
- *What major research products and data streams will be available?*
- *What gaps remain to be filled; what are future directions?*
- *What interdisciplinary activities / collaborations will advance understanding of Cascadia?*
- *What challenges exist, and how can they be overcome?*

5:30 PM Wrap-up and Closure

6:30 PM DINNER ON YOUR OWN

GeoPRISMS-EarthScope Cascadia Workshop
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Appendix 3: Related Meetings and Websites

GeoPRISMS Subduction Cycles and Deformation Implementation Workshop
(Bastrop, TX, Jan 5-7, 2011)
http://www.geoprisms.org/past-meetings/43-scd2011.html

Cascadia Initiative Expedition Team
http://cascadia.uoregon.edu/CIET/cascadia-initiative

NSF Cascadia Initiative Workshop
(Portland, OR, Oct 15-16, 2010)
http://www.oceanleadership.org/2010/nsf-cascadia-initiative-workshop

Joint MARGINS - EarthScope Cascadia Amphibious Facility Planning Group meeting
(Lamont-Doherty Earth Observatory, June 29-July 1, 2009)
http://www.nsf-margins.org/Cascadia/09meeting

GeoPRISMS Program
http://www.geoprisms.org

EarthScope Program
http://www.earthscope.org

IRIS – Incorporated Research Institutions for Seismology
http://www.iris.edu/hq

OBSIP - National Ocean Bottom Seismograph Instrument Pool
http://www.obsip.org

U.S. Geological Survey, Pacific Northwest
http://earthquake.usgs.gov/regional/pacnw

Pacific Northwest Seismic Network
http://www.pnsn.org

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