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Earthquake Hazard Research in the Pacific Northwest using Pacific Northwest Seismograph Network data

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Investigations

This research focuses on regional earthquake hazards in the Pacific Northwest, including effects of large scale plate interactions, through the study of regional structure, earthquake sources, and tectonics. Investigations include a cross-Cascade "refraction" profile using reflected and refracted rays from earthquake sources, investigations of P-wave reverberations from teleseismic observations, investigation of the Scotts Mills earthquake sequence in northwestern Oregon, and initiation of a project to reexamine earthquake location and 3-D structure effects in the Puget Sound region of western Washington in light of recently postulated tectonic models.

Results

East-west cross-Cascades structural profile

This project was completed in the previous contract period, and reported in a paper delivered at the Fall 1993 AGU meeting (Schultz and Crosson, 1993) and a thesis entitled: "A 2-D Velocity Structure for a Cross-Cascades Profile using Earthquake Sources with Application of Reflectivity Synthetic Modeling" by Andreas Schultz. The research used direct P, PmP, and Pn arrivals recorded on the PNSN regional network to infer the structure across the central Cascade Range of Washington. The final model indicates a depressed Moho beneath the central Cascades, with a relief of about 12 km from west to east. An article is currently in preparation for journal publication. This study indicates the feasibility of using earthquakes as sources for conventional refraction interpretation, and should complement the current emphasis on active source seismic experiments in the Pacific Northwest.

Crust and Upper Mantle Structure

In this continuing study, we have been using seismic signals (mainly direct P) from distant earthquakes to search for structure markers produced by P and S wave reverberations in the lithosphere. Using more conventional deconvolution methods, we have found that "receiver functions" can be constructed from vertical component, short-period data alone, but that these receiver functions vary significantly from station to station indicating rapid lateral variation of structure that produces strong scattering and rapid lateral loss of signal coherence. We are presently completing the characterization of the spatial variation of receiver functions and their implications for structure variations. Preliminary results of these investigation was presented at the 1993 Fall AGU meeting (Dewberry and Crosson, 1993).

In a related recent development, we are working on a new deconvolution method which may enhance our ability to detect and interpret crustal reverberations. The method uses joint deconvolution for many sources and many receivers in the Cepstral transform domain. It has the potential to greatly increase the quality of the deconvolution process and thus provide higher quality receiver functions for structure interpretation. The method is still under investigation and active development.

Scotts Mills Earthquake of 25 March, 1993

The Scotts Mills earthquake (M 5.6) was the largest earthquake in the crust of western Oregon's Willamette Valley region in recent time. With excellent aftershock data from portable instrument deployment, it offers a unique opportunity fo investigate the structure and tectonics of this region. The mainshock and aftershock sequence are consistent with a mid-crustal fault plane that strikes west-northwest, and dips about 60 degrees to the northeast. The mainshock appears to have involved oblique reverse or thrust motion in response to north-south tectonic stress. This stress is consistent with other evidence from earthquake and well data. A paper given at the 1993 Fall AGU meeting (Thomas, et al., 1993) presented the preliminary results of our aftershock analysis. An article containing these results is currently being prepared for journal publication.

Additional Activities

We have submitted an article on a new method of moment/magnitude estimation using short period regional network coda amplitude data. Another article by Ma et al. on focal mechanism and stress analysis in western Washington is in the final stages of publication in a USGS Professional Paper.

Recently, USGS investigators (Pratt and others, 1994) have proposed a very specific tectonic model for the Puget Sound region primarily based on industry seismic reflection data. These models elucidate the thrust nature of the "Seattle Fault" and include a decollement at approximately 15 km depth. Most central Puget Sound earthquakes appear to lie deeper than the proposed decollement and questions have been raised about the depth uncertainties of the mid-crustal Puget Sound earthquakes in light of these models. For example, could lack of depth control cause an apparent vertical smearing of hypocenters that are actually on the decollement surface? To address such questions, we are beginning a project to use a true 3-D structure for studying the location uncertainties of western Washington earthquakes.

References

Pratt, T.L., S.Y. Johnson, C.J. Potter, and W.J. Stephenson, 1994 (abstract), The Puget Lowland Thrust Sheet, EOS, V. 75, No. 44, p. 621.

Publications

Articles

Chiao, L.-Y., and K. C. Creager (in preparation) Geometry and lateral membrane rate of the subducting Cascadia slab, to be submitted to JGR

Dewberry, S.R. and R.S. Crosson, (submitted), Source scaling and moment estimation for the Washington Regional Seismograph Network using coda amplitudes, submitted to BSSA.

Ma, L., R.S. Crosson, and R.S. Ludwin, (in press), Focal Mechanisms of western Washington earthquakes and their relationship to regional tectonic stress, $roman {in} under$: USGS Professional Paper "Assessing and Reducing Earthquake Hazards in the Pacific Northwest")

VanDecar, J.C., M.G. Bostock, R.S. Crosson, K.C. Creager, (in preparation), How does subduction cease?: Reconciling the dynamic and kinematic observations of Cascadia tectonic evolution, (to be submitted to Science).

VanDecar, J.C., R.S. Crosson, and K.C. Creager, (in preparation), Nonlinear traveltime inversion for subduction zone structure: The upper-mantle beneath Cascadia, (to be submitted to J. Geophys. Res.).

Abstracts

Dewberry, S.R., and R.S. Crosson, 1994, Comparison of stacking and cepstral deconvolution in estimation of receiver functions from short-period regional network teleseismic data, EOS, V. 75, No. 44, p. 485.

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VanDecar, J.C., Bostock, M.G., R.S. Crosson, and K.C. Creager, 1993, How does a subduction zone die?: Reconciling the dynamic and kinematic observations of Cascadia tectonic evolution, EOS, V. 74, N. 43, p. 92.

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The Pacific Northwest is a region where earthquake, volcanic, and other geologic hazards exist. Large earthquakes have occurred in the past and will certainly occur in the future. In order to more fully understand the risks that earthquakes present to major population centers in both western Washington and Oregon, we are using data from the Pacific Northwest Seismograph Network (formerly known as the Washington Regional Seismographic Network) to study the earth's structure and the occurrence patterns and characteristics of small earthquakes. We are using the signals of small earthquakes and those from distant earthquakes to map and understand structures in the earth that will improve our knowledge of earthquake hazards. Such knowledge provides a basis for deciding how to minimize the damage from large earthquakes

Recent projects include an east-west structural profile across the Cascade Range, development of a new method of moment-magnitude estimation, a study on focal mechanisms and stress analysis in western Washington, a study of the March 25, 1993 Scotts Mills Oregon earthquake (M 5.6), and a study of crust and upper mantle structure using wave arrivals from distant earthquakes.