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Earthquake Hazard Investigations in the Pacific Northwest

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1986

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Investigations

The objectives of this research are to provide fundamental data and interpretations for earthquake hazard investigations. Currently, we are focusing on seismicity, structure, and tectonic questions related to the possibility of a major subduction earthquake on the Juan de Fuca - North American plate boundary. Specific tasks which we have worked on in this contract period are:

1. Tomographic inversion of travel times to determine three-dimensional earth structure.

2. Locations, focal mechanisms and occurrence characteristics of crustal and subcrustal earthquakes beneath western Washington and their relationship to subduction processes.

3. Development of new network analysis programs.

4. Investigation of offshore earthquakes.

Results

1. A study of crustal velocity in western Washington is being done using tomographic techniques. The study area is divided into a grid of blocks, and travel times from the U. W. network data base are compared to travel-times computed from a starting velocity model. We are applying direct conjugate gradient techniques to the model inversion, and initial tests have been made using successive layers with 2-D inversion in each layer. Extension to full 3-D structure is planned as a final step.

2. A data base of focal mechanisms is being established. The objective is to determine the most probable regional tectonic stress in western Washington. Focal mechanisms have been determined for about 275 earthquakes in western Washington. All western Washington earthquakes which had ten or more polarities read in routine processing from 1982 through 1985 were examined. Since the suite of events deeper than 30 km is of particular interest, a special effort was made to include all possible deep events. Trace data were examined for all earthquakes from 1980 through 1985 which were deeper than 30 km and had ten or more P arrivals read. For earthquakes with valid focal mechanisms, software was developed to check orthogonality of P and T axes, to select events by focal mechanism type, and to make stereographic plots of nodal planes and stress axes, singly or in composite. We are working on a grading scheme to indicate quality of the focal mechanism solution by considering the possible range of focal mechanisms, the degree of constraint imposed by the polarity information, and inconsistent or ambiguous arrivals.

Examination of 121 focal mechanisms in the Puget Sound area indicates that systematic differences exist between shallow and deep earthquakes in the Puget Sound region. About half of both shallow and deep earthquakes have strike slip mechanisms, but many more normal

mechanisms occur in the deep suite than in the shallow; while thrust events are more common in the shallow suite. The table below shows how the three types of focal mechanisms are distributed in the shallow and deep suites.

The shallow and deep suites also show significantly different distributions of P and T axes. P axes for shallow events are clustered around the North-South direction, while P axes for deep earthquakes scatter in a broad girdle roughly about the E-W equatorial plane.

Distribution of Focal Mechanism Type by Depth Range

	Total	Strike-slip	Normal	Thrust
		P plunge $\leq 45°$ T plunge $\leq 45°$	P plunge $> 45°$ T plunge $\leq 45°$	P plunge $\leq 45°$ T plunge $> 45°$
Shallow ≤ 30 km	71	39 (55%)	6 (8%)	26 (37%)
Deep > 30 km	50	23 (46%)	19 (38%)	8 (16%)

3. Updated software which combines automatic picking of arrival times with interactive seismic processing has been developed to run on a Ridge 32C computer. Current network data collection and analysis are being carried out on a PDP 11/34 and a PDP 11/70, which need to be replaced within a few years. Software now being developed may by used in the next generation of network processing, and could be transferred to many 32 bit machines. Combining automated picking with interactive pick editing also enhances development and refinement of phase picking, polarity picking, and location routines, by making the data more immediately accessible for research use. Programs for picking, displaying and editing the regional network data are a part of this effort. Special utilities to handle local, regional and teleseismic data have been constructed and tested.

4. We have initiated a study of earthquakes occurring off the coast of Washington and Oregon. In the past digital data for these events were kept, but the events were not located. Since these events are both sizable and fairly frequent, we are exploring this data source. These earthquakes are generally shallow, and most of them are located on the Blanco Fracture Zone.

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Ma, Li, and R.S. Ludwin, 1986, Can Focal Mechanisms be used to Separate Subduction Zone from Intra-plate Earthquakes in Western Washington, Pacific Northwest AGU 1986

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Ludwin, R.S., L.L. Noson, A.I. Qamar, R.S. Crosson, C.S. Weaver, S.D. Malone, W.C. Grant, T.S. Yelin, Seismicity in the Northwestern U.S., submitted for AGU Fall 1986.

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Regional Seismic Monitoring in Western Washington

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Investigations

Operation of the western Washington regional seismograph network and routine preliminary analysis of earthquakes in western Washington are carried out under this contract. Quarterly catalogs of seismic activity in Washington and Northern Oregon are available for 1984 and 1985, and are funded jointly by this contract and others. The University of Washington operates a total of 79 stations west of 120.5 ° W. Twenty seven are funded under this contract. A new station will be installed in the Skagit Valley. A site has been selected and equipment will be installed as soon as weather permits.

This contract provides data for USGS contract 14-08-0001-G1080 and other research programs. Efforts under this contract are closely related to and overlap objectives under contract G1080, also summarized in this volume. Publications are listed in the G1080 summary.

This summary covers a six month period from October 1, 1985 through March 31, 1986. During this period the U.W. seismic network located 415 events west of 120.5 ° W. The largest earthquake, M_C 3.9, occurred on February 10, 1986 west of Rockport, Washington. This event was part of a sequence of 11 events larger than magnitude 1.0, including another felt event of magnitude 3.6 on the same day. Four other felt events were located in a similar cluster 20 km to the southeast.

The U.W. runs a statewide sub-network of calibrated stations. Each calibrated station consists of a Geotech S-13 seismometer and a Morrissey-Interface Technology amplifier/VCO package. The calibration curve for this system was given in the previous semi-annual summary. This contract funds two of these S-13 stations. In addition, most of the other stations funded under this contract may also be considered calibrated since the instruments have known response characteristics.

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Earthquake Hazard Investigations in the Pacific Northwest

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Investigations

The objectives of this research are to provide fundamental data and interpretations for earthquake hazard investigations. Currently, we are focusing on seismicity, structure, and tectonic questions related to the occurrence of a hypothetical major subduction earthquake on the Juan de Fuca - North American plate boundary. Specific tasks which we have worked on in this contract period are:

1. Assembling a uniform data-base of all arrival time data available for Washington and northern Oregon from 1970 to the present.

2. Initial studies of tomographic inversion of travel times to determine three-dimensional earth structure.

3. Locations, focal mechanisms and occurrence characteristics of crustal and subcrustal earthquakes beneath western Washington and their relationship to subduction processes.

4. Re-examination of teleseismic travel-times of large events in the Pacific Northwest for evidence of slab location and orientation.

Results

1. We are establishing a uniform base of arrival time data for all network data from 1970 to the present. From 1970 through 1979, data were archived in several different formats, at several sites. 'Pickfiles' of arrival times have been reformatted and events relocated using updated velocity models and location routines. The western Washington data from 1970-1979 and eastern Washington data from mid-1975 through 1979 are complete, and available for research. Eastern Washington data from 1970 through mid-1975 have been retrieved and are being processed.

2. We are beginning to use tomographic inversion of arrival-time data to determine the lateral velocity structure of the Puget Sound area using P and S-wave data recorded by the University of Washington seismic network. We will use local events to determine velocity structure shallower than about 60 km.

At present we are investigating several inversion procedures including simple and multiple interation back projection, direct conjugate-gradient least squares, a Fourier series smoothing method, and convolution techniques. We are investigating three dimensional modeling and the effects of errors and incomplete coverage in the data.

3. A data base of focal mechanisms is being established. The objective of compiling this data base is to use the information to determine the most probable regional tectonic stress in western Washington.

Focal projections of first-arrival polarities have been plotted for more than 400 earthquakes which had ten or more polarities read in routine processing. Focal mechanisms are being determined where possible. Azimuth and plunge of P and T axes must be read from the plots and axes checked to ensure orthogonality. A grading scheme will be implemented to indicate the quality of focal mechanism solutions. Such a grading scheme will consider inconsistent or ambiguous arrivals, and the range of feasible focal mechanisms.

4. Teleseismic residuals from the 1965 Puget Sound earthquake (depth = 60 km) were interpreted by McKenzie and Julian (1971) as evidence of a north-south striking slab dipping 50 degrees east. We recalculated these residuals using both Jeffreys-Bullen and Herrin travel-time tables, and determined that the anomaly is independent of choice of travel-time table. Two other earthquakes of comparable depth, in 1949 (Puget Sound) and 1976 (Pender Island) have similar residual patterns. Several shallow earthquakes in the Pacific Northwest were also analyzed and do not show a consistent distribution.

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Crosson, R.S., 1986, Where is the Subducted Slab beneath the Pacific Northwest?, Earthquake Notes, Vol. 57, no.1, p. 10.