Regional Seismic Monitoring in Western Washington

14-08-0001-21861 Oct 1, 1984 - Mar 31, 1985

R.S. Crosson and S.D. Malone
Geophysics Program
University of Washington
Seattle, WA 98195
(202) 543-8020

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 funded jointly with other contracts. The time period for this summary is the six months from October 1, 1984 through March 31, 1985. Data are provided for USGS contract 14-08-0001-21862 as well as for other research programs. Network calibration and data assembly efforts are closely related to and overlap objectives under contract 21862, also summarized in this volume. Publications are listed in the 21862 summary.

Results

Network operation for stations in western Washington continued normally. No unusual regional earthquake activity was recorded and the Mt. St. Helens region remained generally quiet. A new station (MEW) sited on McNeil Island in the south part of Puget Sound began operation in early 1985, improving coverage of the central Puget Sound region. A nearby station on the Kitsap Peninsula near Port Gamble is presently being installed, and should further enhance the network. Network coverage in the northeast part of the Puget Sound basin will improve with the installation and reinstallation of stations in the Skagit Valley. The telemetry link for these stations is now available, and one station in the Skagit Valley, BLS, is operational but noisy. Signal quality should be improved by a planned telemetry re-routing. Station RMW was restored in November, 1984 after an outage of several months. Stations APW (vandalized in late 1984) and STW (destroyed by machinery in July, 1984) were repaired in March, 1985. Stations RVW, NLO, and HDW ceased operation during the winter and are scheduled for repair. Loss of several stations is typical in winter months, and stations are restored as good weather permits. A skeletal network of calibrated stations is being installed, to improve our ability to study earthquake spectra, source parameters and transmission characteristics.

To improve the consistency of magnitude estimation, we are using our new automatic picking program to determine coda lengths by fitting an exponential curve to a derived amplitude envelope of trace data. These coda lengths are being calibrated to Wood-Anderson amplitudes for a suite of events.

We are working to establish a uniform base of arrival time data. This effort includes reformatting 'pickfiles' of arrival times and relocating events using an updated velocity model and a revised location routine. Western Washington data from 1970 through 1983 have been processed and checked and eastern Washington data are partially processed.

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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. Analysis and interpretation of Pn observations for both eastern and western Washington

2. Development and implementation of automated processing of seismic events using digital network data

3. Development of a revised crustal structure model for the greater Puget Sound Region

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

Results

1. Previously reported results from Pn analysis are being prepared for publication by C. Zervas and R. S. Crosson.

2. Our algorithm for automated phase and coda length picking is operating in a testing and verification mode. The routine performs well for events above a specific size. We anticipate that the autopicking will improve our network magnitude calibration by providing quantitative and consistent estimates of coda lengths. We are calibrating auto-processed coda duration measurements to Wood-Anderson amplitude measurements for the purpose of improving the consistency and accuracy of local magnitude determinations. Use of automatic processing in routine network data analysis appears feasible and we will begin trial implementation soon.

3. Using auto-picked digital data for 58 seismic events (48 earthquakes, 10 explosions), we inverted for a coupled P and S velocity model for the greater Puget Sound region. The final model, although similar to our previous model in the depth range from about 12 km to 30 km, has a thinner surface layer of velocity 5.4 km/sec and a slight velocity reversal in the interval 30-40 km. km. The constraint on the velocity in the 30-40 km depth range, an earthquake free zone, with our new model appears to be better than that previously obtained. This structure inversion effort is preliminary to undertaking a reexamination of deep earthquake seismicity.

4. Various studies of PNW focal mechanisms have been undertaken previously, but no system has been established to comprehensively compile and classify all available mechanisms. Therefore, we are creating a data base of events for which focal mechanisms have been determined and trace data checked. A search is also being made to identify other events for which focal mechanisms

can be determined and to compile a comparatively complete data base of focal mechanisms. To date, evidence from focal mechanisms is difficult to reconcile with regional stress; focal mechanism data seem to favor NS compression rather than the N70E direction predicted on the basis of geodetic strain measurements, or the N50E direction of plate convergence determined from ocean-floor magnetic anomalies. Focal mechanisms are observed that reflect stress orientations which contradict the expectation from locked subduction. If earthquakes occur on preexisting fractures which are planes of weakness, then the apparent stress direction from focal mechanisms does not necessarily define the true stress direction (McKenzie, 1969). McKenzie made the single assumption that the slip vector is always parallel to the direction of resolved shear stress in the fault plane. Using this assumption, for a particular ratio of principal stresses and a particular fault surface, all allowable orientations of true principal stress can be defined. In the extreme case, the actual axis of greatest principal stress may be as much as 90 degrees away from the apparent axis determined by the P axis of a focal mechanism. Recently, Gephart and Forsyth (1984) have devised a method of determining tectonic stress orientation, which also gives information about the ratio of principal stresses. This method depends on a statistical distribution of focal mechanisms and uses physical principles stated by McKenzie (1969) in addition to a 'minimum rotation' criteria. We have begun implementation of their analysis programs. This method, or a modification of it, promises to provide a powerful tool for extracting stress information from focal mechanism data; and may help resolve the question of tectonic stress in the Pacific Northwest margin area.

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Earthquake Hazard Investigations in the Pacific Northwest

14-08-0001-22007

R.S. Crosson
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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. Compiling a uniform data-base of all arrival time data available for Washington and northern Oregon from 1970 to the present.

2. Calibration of computer determined codas for magnitude determination.

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

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

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

6. Analysis and interpretation of Pn observations.

7. Study of three-dimensional seismic attenuation (Q) structure of the Puget Sound area (primarily funded under another project).

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 are complete, and are being used in research. Eastern Washington data from 1975-1979 have been reformatted, and are being checked for completeness.

2. We have completed calibration of our compute coda magnitude determination algorithm using 18 earthquakes for which M_L was available. Routine use of this procedure may improve the consistency of magnitude estimates.

3. We are investigating the feasibility of a tomographic inversion of arrival-time data to determine the velocity structure of the Puget Sound area using P and S-wave data recorded by the

University of Washington seismic network. We hope to use local events to determine crustal velocity structure shallower than about 40 km. We are presently exploring the effect of a non-isotropic data set, and calculating the approximate resolution which could be achieved with this method.

4. A data base of focal mechanisms is being established. We have plotted stereographic projections of first-arrival polarities for about 60 of the largest earthquakes in Washington. These projections are being checked against data traces, and focal mechanisms determined when possible. 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. Once completed, the data base will be used to determine the most probable set of regional tectonic stresses in western Washington.

5. Teleseismic residuals from the 1965 Puget Sound earthquake were interpreted by McKenzie and Julian (1971) to indicate a north-south striking slab dipping 50 degrees East. These residuals were calculated using the Jeffreys-Bullen travel-time tables. We are redoing these calculations using several travel-time models and additional earthquakes in an attempt to determine if slab effects are indeed detectable.

6. Previously reported results from Pn analysis have been submitted to the BSSA in an article by C. Zervas and R. S. Crosson.

7. Under another contract, we are undertaking an evaluation of seismic attenuation in western Washington. In cooperation with Dr. W.H.K. Lee of the USGS, we are using spectral estimates of coda waves to determine regional coda Q. A preliminary data set of fifty events has been processed, and results are being analyzed.

Articles

Ludwin, R.S., S.D. Malone, R.S. Crosson, 1985 (in press), Washington Earthquakes, 1983, National Earthquake Information Service

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Results

Network operation for stations in western Washington continued normally. No unusual regional earthquake activity was recorded. In late May and early June Mount St. Helens underwent a non-explosive eruptive phase accompanied by energetic seismicity. A new station (PGW) sited on the Kitsap Peninsula near Port Gamble began operation on April 12, 1985. This station, along with station MEW on McNeil Island, provide improved coverage of the central Puget Sound Basin. Station RPW in the Skagit Valley, lost in 1982, was reinstalled and began operation in September. An additional station in this region is being planned. A temporary station in the same area, BLS, was discontinued due to noise problems.

Since early 1982, some stations in the telemetered network have been calibrated so that recovery of absolute ground motion is possible. Figure 1 shows sites at which calibrated equipment is currently operating. Additional calibrated equipment will gradually be installed at selected stations as part of our program to upgrade data quality and increase operational reliability.

Equipment at each calibrated station consists of a Geotech S-13 seismometer and a Morrissey-Interface Technology amplifier/VCO package. Standard damping is 0.70 critical. Most calibrated stations use a Morrissey-Interface Technology discriminator, but some use Emtel discriminators which have similar response characteristics. The complete systems should all have similarly-shaped response curves differing only in absolute gain level. Figure 2 shows an approximate response curve for the whole system (with a 1-second seismometer free period) as recorded on the digital system at the University of Washington.

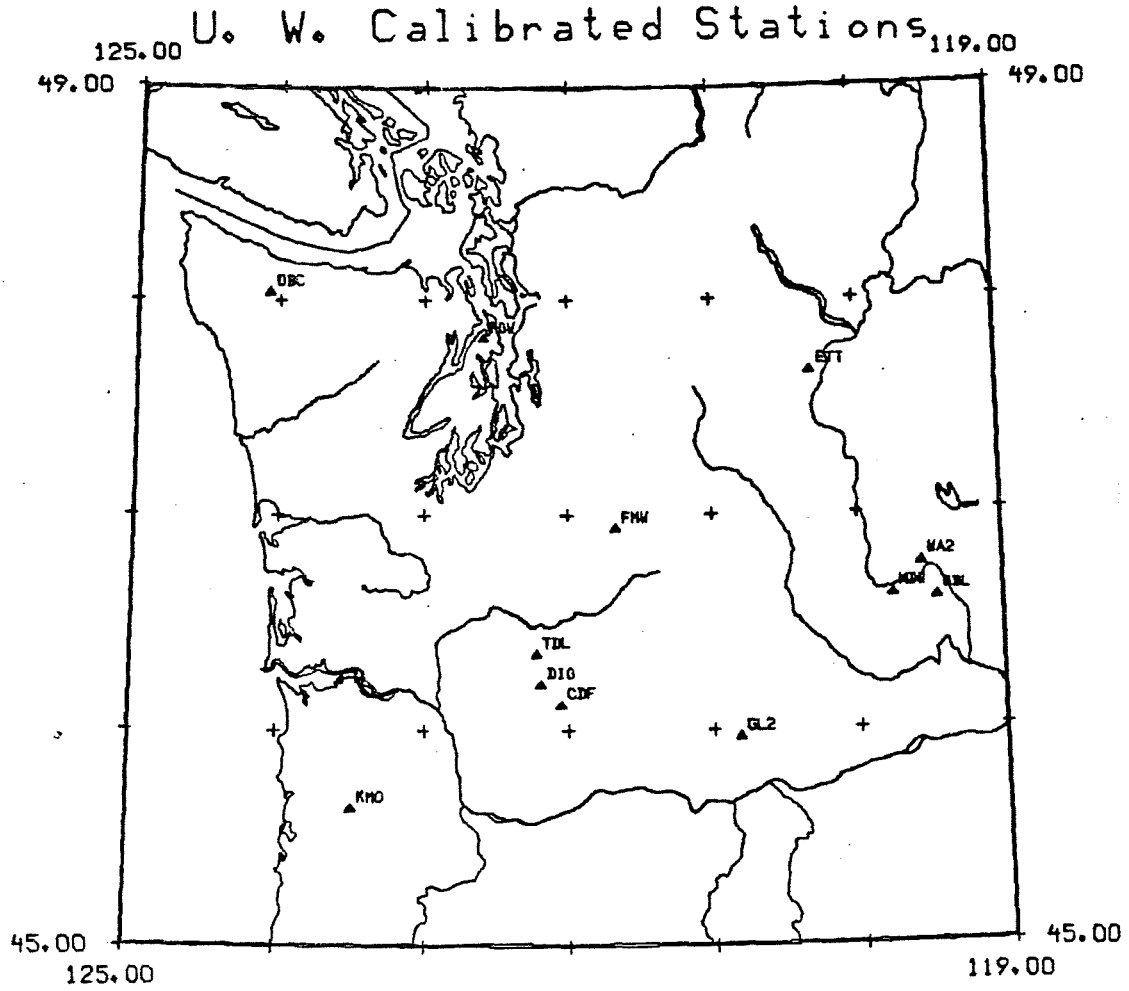

Figure 1. Calibrated stations currently in operation. Station DIG is a three component station. Other stations consist of one vertical S-13 seismometer, a "SLU" type VCO and use Emtel or Morrissey-Interface Technology discriminators.

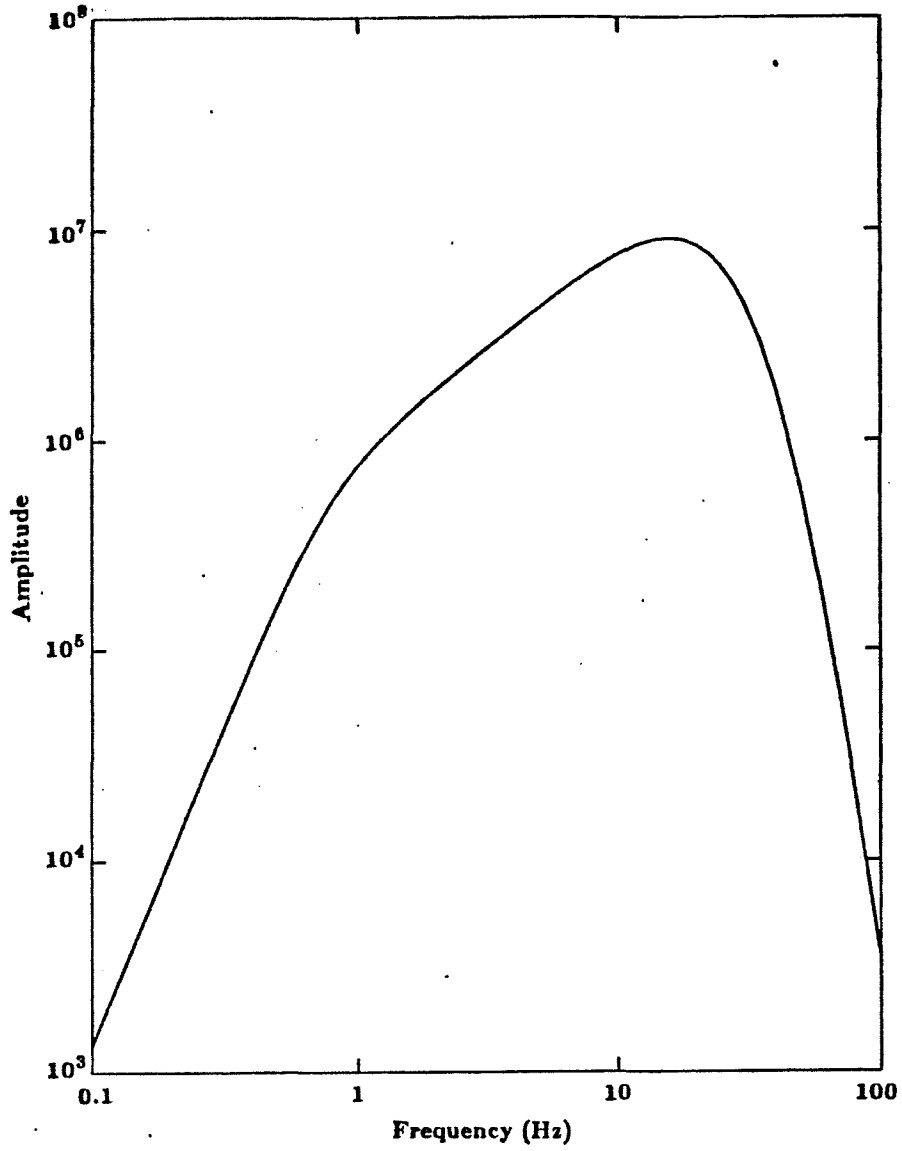

Figure 2. Approximate relative amplitude magnification curve for complete calibrated short-period system into online computer.

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University of Washington seismic network. We hope to use local events to determine crustal velocity structure shallower than about 40 km. We are presently exploring the effect of a non-isotropic data set, and calculating the approximate resolution which could be achieved with this method.

4. A data base of focal mechanisms is being established. We have plotted stereographic projections of first-arrival polarities for about 60 of the largest earthquakes in Washington. These projections are being checked against data traces, and focal mechanisms determined when possible. 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. Once completed, the data base will be used to determine the most probable set of regional tectonic stresses in western Washington.

5. Teleseismic residuals from the 1965 Puget Sound earthquake were interpreted by McKenzie and Julian (1971) to indicate a north-south striking slab dipping 50 degrees East. These residuals were calculated using the Jeffreys-Bullen travel-time tables. We are redoing these calculations using several travel-time models and additional earthquakes in an attempt to determine if slab effects are indeed detectable.

6. Previously reported results from Pn analysis have been submitted to the BSSA in an article by C. Zervas and R. S. Crosson.

7. Under another contract, we are undertaking an evaluation of seismic attenuation in western Washington. In cooperation with Dr. W.H.K. Lee of the USGS, we are using spectral estimates of coda waves to determine regional coda Q. A preliminary data set of fifty events has been processed, and results are being analyzed.

Articles

Ludwin, R.S., S.D. Malone, R.S. Crosson, 1985 (in press), Washington Earthquakes, 1983, National Earthquake Information Service

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Reports

Univ. of Wash. Geophysics Program, 1984, Quarterly Network Report 85-A on Seismicity of Washington and Northern Oregon

Univ. of Wash. Geophysics Program, 1984, Quarterly Network Report 85-B on Seismicity of Washington and Northern Oregon