Regional Seismic Monitoring in Western Washington

1988

14-08-0001-A0266

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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 through 1987. Final catalogs are available though 1986. These catalogs were funded jointly by this contract and others. The University of Washington operates approximately 80 stations west of 120.5°W. Twenty eight are funded under this contract.

Data are provided for USGS contract 14-08-0001-G1390 and other research programs. Efforts under this contract are closely related to and overlap objectives under contract G1390, also summarized in this volume. Publications are listed in the G1390 summary. This summary covers a six month period from April 1, 1988 through September 30, 1988.

We have updated our on-line seismic recording system. Since 1980 a DEC PDP-11/34 has recorded incoming digital data, and a DEC PDP-11/70 has been used for analysis. In April of this year a Masscomp-5600 minicomputer was acquired and installed by the U.S. Geological Survey in our lab to take the place of the DEC equipment. By June 1 we had software running on the Masscomp computer to to do both data acquisition and analysis tasks for the network. This software is a modified version of *RAVEN*, a specialized data acquisition system from NEWT Inc. We have a software agreement with NEWT Inc. for the development of a regional network recording version of this software called *HAWK*. By July the *HAWK* software running on the Masscomp computer had taken over all acquisition and analysis tasks and the DEC equipment was being phased out. The PDP-11/34 is still running as a backup system to the Masscomp; however, all recording, processing, and archiving are now routinely done on the Masscomp. The HAWK data acquisition system is a great advance over the PDP-11/34. It can record more channels of data and has a much greater capacity for recording unattended. Also, operating parameters can be changed while the system is running, data are recorded directly onto disk (instead of onto magnetic tape), and automatic post-recording processing begins as soon as the event is recorded. The automatic post-recording processing includes phase and coda-duration picking, and preliminary event location. An alarm system notifies seismologists when a sizable local earthquake occurs (includes a buzzer, and automatic telephone notification). Several other types of system emergencies (power outage, digitizer failure, disk full) are also identified, and initiate similar alerts. The automatic post-recording processing can quickly determine preliminary locations of both teleseisms and local events. For teleseisms, we are exploring the possibility of using the preliminary location to reactivate the recording system to record later phases which might not trigger the recording system on their own.

Excluding blasts, probable blasts, and earthquakes outside the U. W. network, 518 earthquakes west of 120.5°W were located during this period. 71 of these were located near Mount St. Helens, which has not erupted since October of 1986. The largest earthquake located in western Washington/northern Oregon between April 1 and September 30 was an M_c 4.1 earthquake on

July 29, 1988 which occurred at a depth of 12 km on the western flanks of Mount Rainier, Washington. An M_c 3.8 earthquake occurred in the same location an hour later. Both hypocenters were located approximately 12 km west of Mount Rainier's summit. Nearly two weeks later, on August 12, an M_c 3.0 earthquake with a similar location occurred. The July 29th earthquake is the largest earthquake to occur in the Mt. Rainier region since an M_c 4.7 shock on April 20, 1974.

Mount Rainier seismicity is high compared to other strato-volcanos of the central Cascade region, which (with the exception of Mount St. Helens) are seismically quiet. Figure 1 shows all earthquakes since 1969 in the Mount Rainier region. There is a north-south trend of seismicity just to the west of the mountain, as well as a cluster at the summit. Focal mechanism solutions for the three earthquakes in July and August of 1988 are very similar to solutions found for earthquakes in 1973 (Crosson and Frank, 1975) and 1974 (Crosson and Lin, 1975) in this region. Figure 1 shows focal mechanism solutions for selected events larger than M_c 3.0.

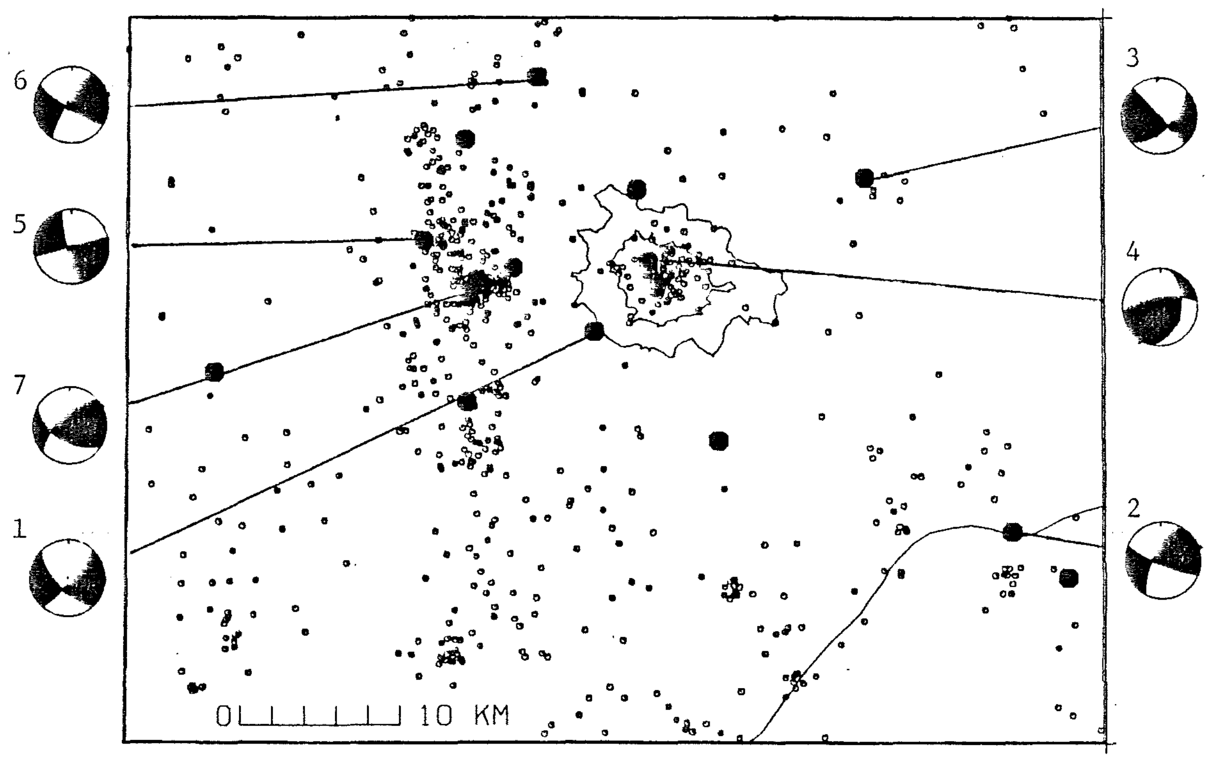

Figure 1. Earthquakes located in the vicinity of Mount Rainier from 1969 through August, 1988. The map includes the area from 121.4° to 122.2° west longitude and from 46.6° to 47° north latitude. The contours on the map represent the 7,500 ft. and 10,000 ft. contours of Mount Rainier. Two symbol sizes are used, the smaller for earthquakes with magnitude less than 3.0, and the larger for earthquakes greater than magnitude 3.0. Lower hemisphere, equal-area focal mechanisms for larger earthquakes are shown, and are numbered to correspond to the table below.

#	DATE	TIME	LAT	LON	DEPTH(KM)	MAG
1	73/07/18	21:58:06.01	46 49.54	121 49.03	6.94	3.9
2	74/04/20	03:00:09.38	46 42.95	121 28.54	5.55	4.7
3	75/04/18	04:57:56.62	46 54.68	121 35.83	5.05	3.9
4	76/11/11	05:28:28.43	46 51.86	121 46.38	0.56	3.1
5	85/01/01	19:15:00.80	46 52.57	121 57.39	11.31	3.1
6	85/12/27	19:12:00.81	46 58.02	121 51.91	7.02	3.0
7	88/07/29	04:59:47.27	46 51.27	121 54.82	11.83	4.1

Earthquake Hazard Investigations in the Pacific Northwest

14-08-0001-G1390 1988

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Investigations

The objective of this research is to investigate earthquake hazards in western Washington, including the possibility of a large subduction-style earthquake between the North American and Juan de Fuca plates. Improvement in our understanding of earthquake hazards is based on better understanding of the regional structure and tectonics. Current investigations by our research group focus on the configuration of the subducting Juan de Fuca plate, differences in characteristics of seismicity between the overlying North American and the subducting Juan de Fuca plates, determination of regional stresses through analysis of earthquake focal mechanisms, and modeling of lateral velocity variations in the shallow crust. Research during this contract period concentrated on the following topics:

1. Tomographic inversion of earthquake travel times to determine 3-D velocity structure in the Puget Sound Region.

2. A semi-automated method of determining accurate relative phase arrival times for teleseisms recorded on regional networks.

3. Modeling 3-D kinematic flow of the subducted slab.

Results

1. We are investigating the three dimensional seismic velocity structure of western Washington using tomographic techniques. Delay times of local earthquake phase arrivals at Washington Regional Seismographic Network stations are inverted to determine velocity structure. Approximately 30 thousand source-receiver pairs were used in the western-Washington inversion. Initial results indicate high velocity structures that correlate with the Crescent formation along the eastern flank of the Olympic Peninsula. A low velocity lineation beneath Puget Sound is evident down to 16 km depth, possibly reflecting sediment accumulation. The tomographic velocity inversion is part of the Ph.D. research of Jonathan Lees. An article detailing inversion results in the Mount St. Helens area has been submitted to the JGR.

2. We have developed a semi-automated method of determining accurate relative phase arrival times for teleseisms recorded on regional networks. Our analysis begins by obtaining preliminary arrival times with a single-trace phase picking algorithm. For each possible pair of traces we then perform a ''quick search'' for the maximum of their cross-correlation function in order to obtain

relative delay times. Best results are obtained by using the first 3-4 sec of the major energy pulse of the phase. The cross-correlation derived delay times are then used to generate an over-determined system of linear equations whose solution is an optimized set of relative arrival times. A least-squares criteria is used to solve for these times. This procedure is effective in eliminating cycle skipping through the re-evaluation of cross-correlation functions which yield high residuals. Quantitative estimates of timing uncertainty are obtained from the variance of the residuals associated with each trace.

Utilizing data from the Washington Regional Seismograph Network we have found that, for reasonably good events, the rms uncertainty in arrival time estimates is on the order of the sample interval (.01 sec). Reproducibility of delay anomalies is excellent for events from the same geographic locations despite differences in waveform and in frequency spectra. A paper on the use of this technique to study the deep velocity structure of the Cascadia subduction zone has been submitted to the BSSA. This work is part of the Ph.D. research of John VanDecar.

3. A wide variety of geophysical investigations including the accurate location of earthquakes, teleseismic receiver-function analyses, reflection profiling, tomographic inversion of teleseismic travel times and electromagnetic analyses are beginning to delineate the geometry of the subducting Cascadia slab. This task has proven difficult because only a small part of the slab is seismically active. This activity is concentrated beneath the Puget Sound region where it extends to a depth of 100 km. The slab appears to have a shallow dip (~10-12°) beneath the Olympic Peninsula and Puget Sound and a much steeper dip (~15-20°) to the north and south of this area forming an arch. Coincident with the latitude of the arch, the trench bends concave oceanward by 35°. We have constructed 3-D kinematic flow models of the subducting slab that minimize the in-plane strain rates associated with deforming the oceanic plate (spherical shell) into a predefined shape (observed slab geometry). Two important results have emerged: 1) The strain rates are smaller for the arch geometry than for a slab with a constant dip of 20° everywhere along the trench. 2) The strain rates reach a peak value of $2*10^{-16}$/s and are concentrated beneath the Olympic Peninsula and Puget Sound, coinciding with the region of seismic activity within the slab. Thus, to first order it appears that the slab shape and slab seismicity distribution are controlled by the in-plane strains associated with the atypical trench curvature. (Most trenches have the opposite sense of curvature.) In this analysis, we have specified the slab geometry a priori and have assumed the slab is infinitely thin, thus ignored bending strains. We are extending the analysis to include a slab with finite thickness. The new formulation will be used to determine the slab geometry that minimizes the the in-plane and bending strain rates, given the trench geometry and the slab geometry at two cross sections, say below Vancouver Island and Oregon. Similar calculations for the Aleutian slab explain the along-arc distribution of recent andesitic volcanism, seismicity cutoff depth, and the focal mechanisms and seismic moment release of intermediate-focus earthquakes [Boyd and Creager, 1988]. Three-dimensional kinematic flow calculations have the potential of explaining a wide variety of geophysical observations in the Cascadia subduction zone as well.

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