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Enhancing PANGA for Seismic Risk Assessment: Collaborative Research Central Washington University, Oregon State University, and University of Washington.

PROJECT PLAN

Objectives

Seismic risk in the Pacific Northwest is concentrated in the populous fore-arc region, and realistic assessment of such risk hinges on understanding along-strike variation in subduction zone dynamics as well as the role of crustal faults in generating earthquakes. This objective requires an integrated view of the three-plate interaction zone, achieved by the overall PANGA network of permanent and campaign sites. The densified network proposed here is focused on the fore-arc region in the Puget Willamette lowland, including Seattle and Portland. In order to characterize these processes using GPS, we propose to: **(1)** integrate regional GPS campaign results into the PANGA velocity field, **(2)** densify the PANGA network by adding new high-precision campaign sites to directly address crustal faulting in the urban corridor, **(3)** enhance these regional studies through a coordination of the investigator community, and **(4)** assure the ongoing operation of the PANGA array; and **(5)** extend geologic and geophysical descriptions of Pacific Northwest kinematics and constrain the processes that drive deformation through modeling efforts. These collectively form the basis for characterizing seismic risk in densely populated regions of the Pacific Northwest.

This Report will address Objectives 2 and 4 which were conducted by OSU. Other objectives conducted by CWU and UW are included in separate reports by those investigators.

Objective 2: High-Precision Campaign Measurements

Portland Basin Seismotectonics

The Portland area lies in the Cascadia forearc, and is characterized by a number of northwest trending structures that offset Quaternary strata. The forearc block is rotating clockwise about a pole to the east as shown by both paleomagnetics and recent GPS observations (McCaffrey et al., 2000). The forearc block is under north-south compression (Ma et al., 1991), most likely due to collision with the more rigid northern Cascadia forearc. The Portland area structures are thus expected to have dextral transpressive sense of slip. The basin tectonics have been interpreted as a dextral pull-apart basin by Yelin and Patton, (1991). The Portland metropolitan area sits astride or adjacent to several significant crustal faults that have the potential to generate significant earthquakes at very short epicentral distances to the City of Portland and its suburbs. The Portland Hills fault is a striking lineament traversing the southwest quadrant of the city, and has a topographic scarp with more than 100 m elevation change. This structure is the main seismic hazard to Portland, and in recent hazard mapping produced by Wong et al. (2000), presents a seismic hazard that potentially overshadows that of the larger but more distant subduction zone. Peak ground acceleration from a M=6.8 scenario earthquake (at 0.2 second spectral g) was 2.7 g, but PGA from the subduction zone M=9 scenario was only 0.1-0.2 g. In addition, a number of other potentially active faults ring the Portland basin. The Frontal fault, East Bank Fault, Oatfield Fault, Mollalla-Canby Fault, Sandy River Fault, and several others trend northwest or north-northwest, sub-parallel to the Portland Hills Fault. (Figure 7). One common measure of fault activity is whether or not a fault has ruptured during the Holocene, the last 10,000 years. Faults in and around the Portland Basin have not yet been shown to meet these criteria in an unequivocal way, but evidence is mounting that these structures may be active. The difficulty in determination of youthful fault activity is in part due to the deep weathering that is pervasive in western Oregon and Washington. Another contributing factor in the Portland Basin and Willamette Valley is the scouring and subsequent deposition of loess during the Missoula flood events 13,000-14,000 years ago. These profound flood events shaped much of the physiography of the Columbia River and adjacent basins, including Portland. The recency of these catastrophic events means that active fault traces in the area have had relatively short time available to generate topographic expression, and many are buried by flood deposits.

Seismicity in the Portland area is diffuse, and does not sharply define known structures, though Blakely et al., (1995) report a tentative correlation between structures mapped using high-resolution aeromagnetics, and an alignment of events does suggest activity on the Portland Hills Fault. Ten significant earthquakes have occurred between 1877 and 1993. These events were intensity VI-VII for the earlier events, and M=5-5.5 for the recorded events, the most recent being the Scotts Mills earthquake on March 25, 1993. Pratt et al. (1999) conducted multichannel seismic reflection profiles in the Columbia and Willamette Rivers and along two land profiles looking for evidence of Holocene or Late Quaternary deformation. They report evidence of deformation of a Late Pleistocene unconformity (15 ka) with a vertical separation of ~5 meters on the East Bank Fault, and even larger separation on the Portland Hills Fault.

Wong et al. (2000) estimated slip rates and maximum magnitudes for Portland area faults in a probabalistic hazard assessment. These parameters were estimated in most cases where definitive geologic data are presently lacking. The methodology included distributing 4-7 mm/yr. of regional forearc shortening across the many structures considered in the study, as well as geologic constraints where available. The Portland Hills and East Bank Faults were assigned a slip rate of 0-0.4 mm/yr., with other faults in the area having somewhat lower rates. Maximum magnitudes were estimated to be 6.6-7.1 using segment rupture length estimates and the rupture length-magnitude relationships of Wells and Coppersmith (1994). Recurrence intervals for Portland area faults are unknown, but similar structures with comparable slip rates have recurrence times > 5000 yr. Nevertheless, the cumulative hazard to Portland is great due to the proximity of numerous sources. In a scenario 6.8 event on the Portland Hills fault modeled by Wong et al. (2000), the peak ground accelerations exceeded 1.0 g, from which severe damage would result.

Portland Area Deployments

The Portland region is a difficult area to assess seismotectonic hazards. While the Portland Hills fault is an obvious major tectonic feature, its slip rate is probably slow, and the recurrence interval for significant events is probably large. This makes investigation with both GPS and paleoseismic techniques difficult. Nevertheless, the potential damage resulting from a Mw~6 event in downtown Portland is sever, necessitating long-term efforts to assess this potential. GPS will not be able to resolve this issue in a few years, likely it will take 8-10 years. At the same time, the Portland basin has several factors in it's favor. A major factor in the suitability of the Portland area is the presence of numerous outcrops of the Columbia River Volcanics, Boring Lavas, and Goble volcanics. Rock sites are strongly preferred for the MOST and extended-occupation campaign sites, and such sites are abundant. The Boring lavas are preferred since they were erupted subsequent to the Missoula flood deposition, and are generally free of cover sediments. Columbia River Basalts are also prevalent, though many sites have a loess cover.

In 2000 and 2001 we established18 new sites in addition to the existing benchmark network to densify the Portland area. Most of these are rock pins to be used for extended campaign observations, and about half are MOST sites suitable for longer occupation. Sites proved much more difficult to find than anticipated, with security for MOST sites being the biggest problem. These sites were occupied with lengths averaging 17 hours per site. In addition 8 more sites were established in the Corvallis area, focusing on the Corvallis fault. Security was less of an issue, and these sites were easily established on private property with land owners cooperation and assistance. Average occupation times for these sites was 30 hours, with 4 sites occupied for more than one week. These sites were for the most part new sites, thus no velocities are available at this time.

In addition to the first occupations of the above sites, site reconnaissance was done for several new proposed permanent sites in the northern Willamette Valley and Portland Basin. This region is presently one of the larger holes in the permanent array, and is important for modeling the downdip extent of the Cascadia coupled zone. The eastern flank of the coast range in general is poorly resolved with the present array, prompting the interest in densifying this region. Sites with the required power, phone and security were very difficult to locate. Several sites were located in the McMinneville area with the assistance of Del Smith of Evergreen International, a major landowner in the area. The best site appears to be one on the McMinneville airport, which has power, phone security, and an excellent sky view. Negotiations were begun with the FAA, who operates a glideslope receiver at the proposed site. This site awaits proposed funding as of this writing.

Objective 4: Network Maintenance and Operation

CORV and NEWP Station Operation, Data Collection, Processing and Archiving

Two permanent stations on Oregon, at Newport and Corvallis were supported by NEHRP funding under this award. The two stations had normal maintenance including firmware upgrades of the receivers, and download software upgrades of the office computer used to download convert to RINEX format and quality check the incoming data. The data are and site logs are now available from the Active Tectonics web site at http://coas.activetectonics.oregonstate.edu as well as the CWU PANGA archives. The data are downloaded rinexed and archived daily, and are available to other institutions and the public 24 hours after collection.

The data are routinely downloaded by NOAA, NGS, other PANGA members, and by Unavco and Scripps, where they are also archived.

The results of 2001 operations of the two permanent stations operated under NEHRP funding were reported at the 2001 PANGA meeting in January, 2002, and at the San Francisco Fall AGU meeting. The CORS data were combined with campaign data and older USGS data to produce an updated and much more extensive (than in 1999) velocity field for the Pacific Northwest. Data processing was done by independently R. McCaffrey at RPI, and Dan Johnson and Meghan Miller at CWU.

The Newport site was reconfigured to log data at 1 Hz for June as part of a Scripps Seafloor Geodesy experiment by David Chadwell and John Hildebrandt. This ongoing experiment requires considerable attention to collect data at this high rate due to the relatively small memory capacity of the CORV and NEWP receivers. No publications of the results of this work are available as of this writing.

Publications resulting from this work or data produced by this work:

2001 Plate coupling along the southern Cascadia subduction zone, Geophysical Research Letters, v. 27, p. 3117- 3120. (McCaffrey, R., Long, M., Goldfinger C., Zwick, P., Johnson, C. K., and Smith, C. Nabelek, J.)

2001 GPS-determination of along-strike variation in Cascadia margin kinematics: Implications for relative plate motion, subduction zone coupling, and permanent deformation. Tectonics, v. 20, p. 161-176. (Miller, M., Johnson, D. Rubin, C.M., Dragert, H., and Wang, K. Qamar, A., Endo, E., and Goldfinger, C.)

2001 Modeling western U.S. Deformation from plate motions and elastic strain accumulation, EOS (Transactions of the American Geophysical Union), v. 82, p. F281. (Murray, M.)

2001 Inversions of geodetic data for rotation pole and deformation mechanism at subduction zones: Applications to Cascadia, Sumatra, and Alaska, EOS (Transactions of the American Geophysical Union), v. 82, p. F280. (Williams, C. and McCaffrey, R.)

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