Opportunities for Seismology and Geodynamics in NEPTUNE

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Abstract. The NEPTUNE project will provide an opportunity to deploy a long-term regional ocean seismic network on the Juan de Fuca plate. Together with land arrays and seafloor geodetic measurements, a NEPTUNE seismic network can address many important scientific problems. Great earthquakes occur along the Cascadia subduction zone and there is considerable interest in understanding of subduction zone seismogenesis and hazard. On the Juan de Fuca ridge, the network will be part of multidisciplinary experiments to monitor seafloor volcanism and hydrothermal circulation. Observations on the Blanco transform fault will contribute to studies of the physics of earthquake rupture. At the plate-scale, the network will constrain the coupling of forces across plate boundaries, the variations in stress across the plate, and the characteristics of intra-plate earthquakes. It will contribute to studies of mantle melting, the coupling of the mantle to the lithosphere, the pattern of return flow from trench to ridge, the nature of mantle flow near plate boundaries, and the rheology of the mantle. The seismic network might comprise 30-70 broadband seismometers and local networks of intermediate band instruments. NEPTUNE is still in the early stages of development and considerable community input will be required to fully define the scientific objectives and priorities of the seismic and geodetic experiments.

1 Introduction

The NEPTUNE project (http://www.neptune .washington.edu) is an ambitious plan to deploy a submarine fiber-optic network on the Juan de Fuca Plate off the coast of the Pacific Northwest. The network would host scientific instrumentation to study a wide variety of geological, oceanographic, and ecological processes. A conceptual design and feasibility study was recently completed and demonstrates that there are no insurmountable technical obstacles. It is envisioned that the backbone would comprise 3000 km of cable connecting about 30 evenly distributed primary nodes. Secondary branch cables could extend to any location on the plate. At each node a junction box would provide standard power and communication interfaces for scientific instruments. The complete network could carry 10 GB/s of data and deliver up to 100 kW of power and would have an operational life span of at least 30 years.

In parallel with the conceptual design and feasibility study, a number of small ad hoc working groups met to explore the scientific opportunities that would be provided by NEPTUNE. The seismology and geodynamics working group met in Seattle in June 1999. This abstract is based on the deliberations of this meeting and the contributions of several scientists who did not attend (a full report can be viewed on-line at http://gore.ocean.washington.edu/neptune).

2 Juan de Fuca Plate

The movement and interaction of lithospheric plates gives rise to many of the Earth's most dramatic and hazardous geologic features. In the Pacific Northwest, the processes accompanying the creation of the oceanic Juan de Fuca plate and its eventual subduction beneath North America result in mountain building, damaging earthquakes and explosive volcanism. Understanding the causes of such geologic hazards, as well as the processes responsible for the formation, evolution, interaction, and destruction of tectonic plates is a central goal of the geosciences.

The Juan de Fuca / Explorer / Gorda plate system (Fig. 1) represents a natural laboratory for addressing many questions related to this goal since it incorporates a remarkable array of plate tectonic features within a relatively small area.

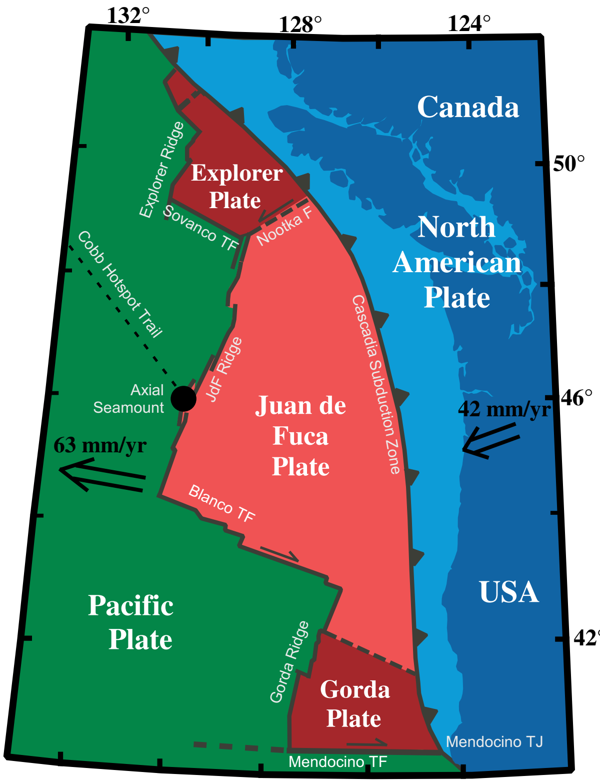

Fig. 1. Location of plates and plate boundaries in the Pacific Northwest. The velocities of the Pacific and North American plates are shown relative to the Juan de Fuca Plate. Acronyms are as follows: JdF - Juan de Fuca; TF - transform fault; TJ - Triple Junction; and F - fault.

In western North America, large regional land seismic networks have been in operation for about 30 years and are in the process of being upgraded. Long-term observations have provided a comprehensive view of the distribution and style of continental seismicity and of the seismic structure of the continental lithosphere. In the past decade, geodetic networks that utilize GPS have also been deployed and as they grow, they are providing an increasingly detailed and complementary picture of crustal strain rates. However, in the Pacific Northwest much of the seismicity and deformation associated with the Pacific / Juan de Fuca / North America plate boundary system occurs offshore (Fig. 2). Over most of the plate, SOSUS hydrophone network has a lower detection threshold and smaller epicentral errors (Fig. 3). However, seafloor seismic observations are necessary to obtain accurate hypocenters and focal mechanisms.

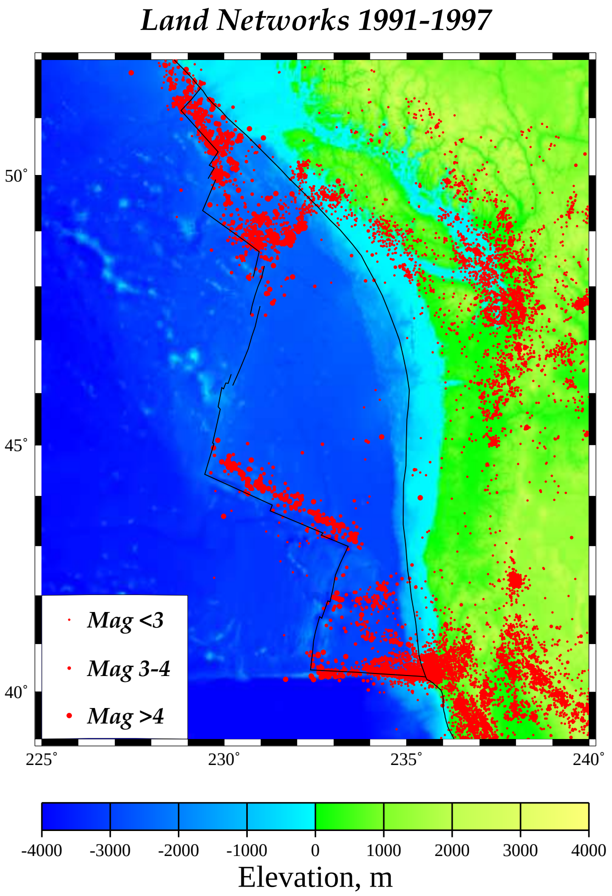

Fig. 2. Earthquakes epicenters for the period August 29, 1991 - December 31, 1997 determined using land seismograph data from the Pacific Northwest Seismograph Network, Canadian National Seismograph Network, and the Northern California Seismic Network.

3 Scientific Issues

The last great earthquake along the Cascadia subduction zone occurred three centuries ago and there is considerable interest in improving our understanding of subduction zone seismogenesis and hazard. Seafloor seismometers and geodetic observations will lead to improved constraints on the earthquake cycle, the width of the locked zone and its variations along the margin and can also contribute to an improved understanding of deep intraslab earthquakes. Long-term observations are required for multidisciplinary experiments to understand the relationships between earthquakes, fluid flow in the accretionary prism, and catastrophic sediment transport events.

At the Juan de Fuca and Gorda mid-ocean ridge, seafloor seismic observations are essential for understanding the relationship of seismicity to magmatism and hydrothermalism. Both seismic and geodetic measurements will be an important part of the

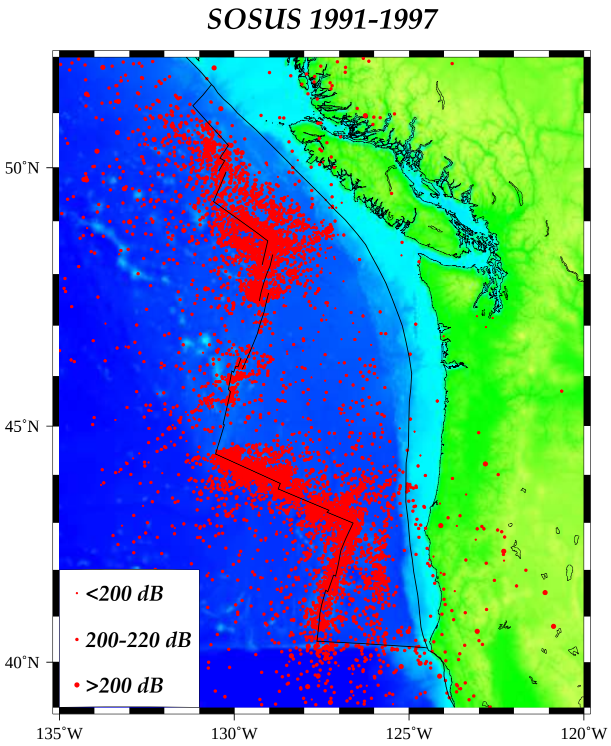

Fig. 3. Preliminary earthquakes epicenters for the period August 29, 1991 - December 31, 1997 determined using T-phases recorded by underwater hydrophones in the U.S. Navy's SOund SUrveillance System (SOSUS) and analyzed by NOAA/PMEL. Locations were determined from three or more SOSUS arrays (reanalyzed epicenters are available at http://www.pmel.noaa.gov/vents/oceanseis.html).

long-term observatories that have been envisioned for the Juan de Fuca Ridge. At present, our understanding of tectonism and deformation on oceanic transform faults is also limited. This setting may be particularly important for studies of earthquake physics since many earthquakes on transforms appear to have anomalously slow rupture characteristics.

At the plate-scale, observations of seismicity and deformation will constrain many important processes including the nature and causes of variations of stress with time across the plate, the styles and causes of intra-plate earthquakes, and the coupling of forces across plate boundaries. A plate-scale seismic array will also facilitate studies of the structure and evolution of the lithosphere-asthenosphere system. Such work would contribute to our understanding of mantle melting, the coupling of the mantle to the lithosphere, the pattern of return flow from trench to ridge, the nature of mantle flow near plate boundaries, and the rheology of the mantle.

4 Network Design

Because many of the problems of interest require observations at the plate scale, the ad hoc working group concluded that the first priority for a seismic network is to deploy a fiber-optic backbone across the entire Juan de Fuca / Gorda / Explorer plate system. This would be instrumented with 30 broadband seismometers spaced about 100 km apart at each primary junction box (Fig. 4). In order to develop a fully two-dimensional network that spans the plate boundaries, 30-40 additional broadband sensors will eventually be required at distances of 50-100 km from the nearest primary junction box. Hydrophones and strong motion accelerometers should also be included at most installations. In selected areas of seismic interest, local networks of intermediate band seismometers should be deployed to supplement the regional network.

There are a variety of seafloor geodetic techniques at various stages of development that can be used to study motions near plate boundaries and plate scale deformation. Such observations will complement the seismic network and should be an important component of NEPTUNE.

5 Future Plans

NEPTUNE is still in the early stages of planning. Upon completion of the conceptual design and feasibility study in mid-2000, NEPTUNE commenced a phase of detailed design that will lead to deployment as early as 2005. A consortium of five partners (University of Washington, Jet Propulsion Laboratory, Monterrey Bay Research Institute, Woods Hole Oceanographic Institution, Institute of Pacific Ocean Science and Technology - Canada) is leading the effort to design and prototype the power, communications, and data management systems. Test beds will be developed to evaluate the system performance and scientific instrumentation.

As part of the design phase about ten specialized scientific working groups with members drawn from the whole community will be established and open workshops will be held. The workshops will further develop the scientific rationale and will establish the scientific priorities for NEPTUNE. The deliberations will guide the system design and each working group will be responsible for the implementation of community experiments in their field of expertise. It is expected that a NEPTUNE Seismology and Geodynamics workshop will be held in 2001.

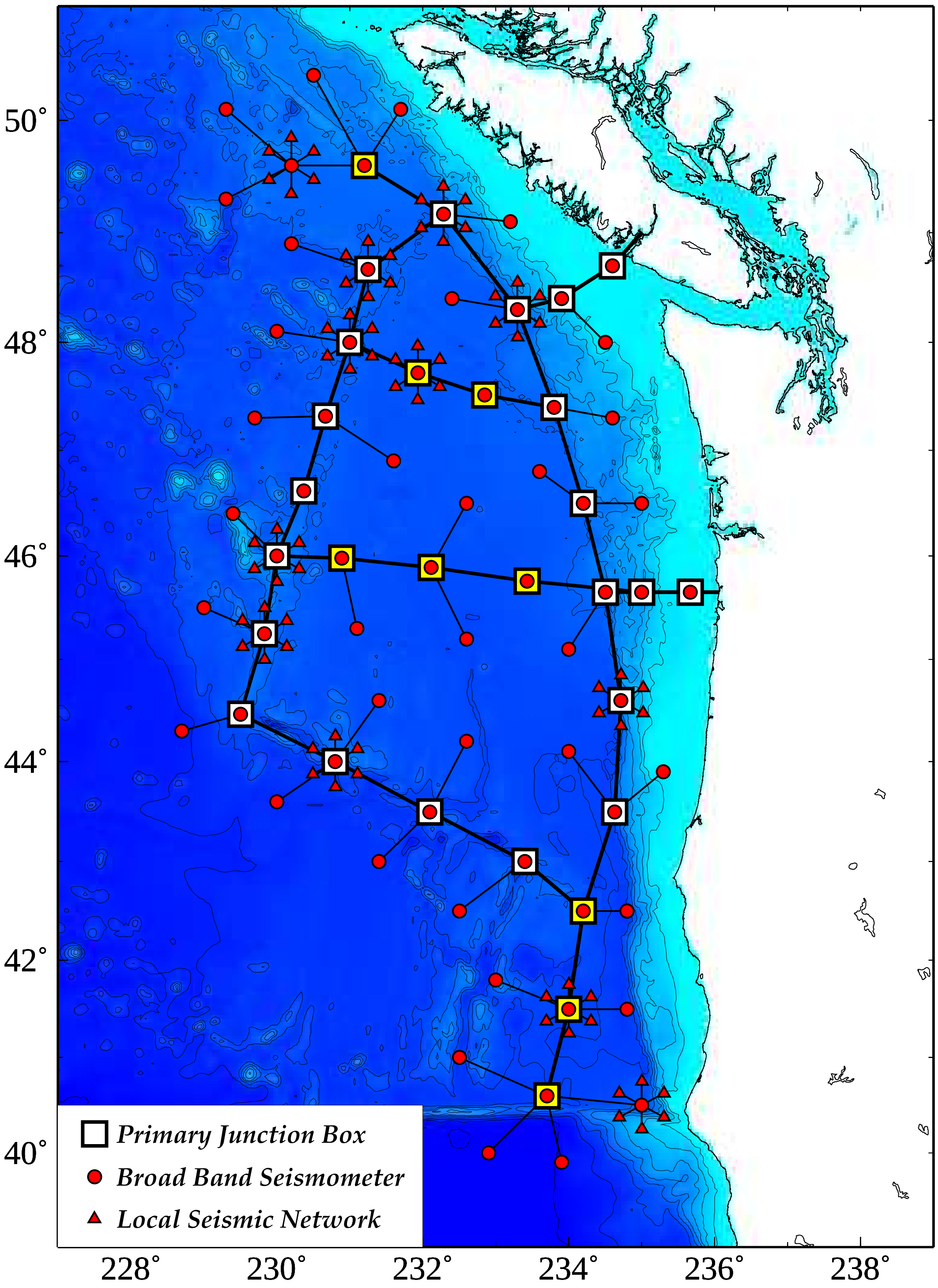

Fig. 4. Possible seismic network design based on a configuration used for the conceptual design and engineering feasibility study (yellow symbols show junction boxes that have been modified from that study). The first priority is the deployment of a broadband seismometer (red circles) at primary junction boxes (open squares) spaced about 100 km apart and covering the Juan de Fuca, Explorer, and Gorda plates. A fully two-dimensional plate-scale network, which spans the plate boundaries, will require the deployment of additional broadband stations at distances of 50-100 km from the primary junction boxes. High-resolution local networks comprising 10 or more closely spaced intermediate period sensors (red triangles) will be installed around primary nodes in regions of particular scientific interest.