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Seafloor Seismometers Monitor Northern Cascadia Earthquakes

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The M_w = 9.0 earthquake of 11 March 2011 at the Japan Trench and its devastating tsunami underscore the importance of understanding seismogenic behavior of subduction faults and realistically estimating the potential size of future earthquakes and tsunamis. For the Cascadia subduction zone (Figure 1a), a critical knowledge gap is the level of microseismicity offshore, especially near the megathrust, needed to better understand the state of the locked zone. In 2010 the first detailed seafloor earthquake monitoring campaign along the northern Cascadia subduction zone recorded nearby earthquakes in the local magnitude (M_L) range from possibly around zero to 3.8 (Figures 1b and 1c) and larger earthquakes from outside this region.

Preliminary analyses indicate that the network appears to have yielded a fairly complete catalog for events with M_L > 1.2. Only a few tens of these events occurred beneath the continental shelf and slope (Figure 1a). The majority of the earthquakes were located along the margin-perpendicular Nootka fault zone. The relatively low seismicity away from the Nootka fault is consistent with a fully locked megathrust. Land-based GPS measurements cannot resolve the question of whether the offshore part of the megathrust seismogenic zone is narrow and fully locked or wider and only partially locked (slowly creeping). If it were only partially locked, the seafloor seismometer data should show many more small earthquakes along the interface than were actually detected.

The SeaJade Project

The Seafloor Earthquake Array–Japan-Canada Cascadia Experiment (SeaJade) is a multiyear, two-phase collaboration involving the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), University of Victoria, Geological Survey of Canada (GSC), and Woods Hole Oceanographic Institution (WHOI). The first phase of SeaJade consists of the successful deployment of 32 short-period ocean bottom seismometers (OBSs) from JAMSTEC and 10 broadband instruments from WHOI, plus the use of the permanent broadband seismometers of the North-East Pacific Time-series Undersea Networked Experiments (NEPTUNE) Canada cabled seafloor observatory (http://www.neptunecanada.ca).

The array is located mostly on the continental slope (Figure 1a). The short-period OBSs detected more than 1500 earthquakes from July to October 2010. Data from the broadband OBSs, deployed from July 2010 to July 2011, are being processed. The next SeaJade deployment of OBSs is planned for 2013.

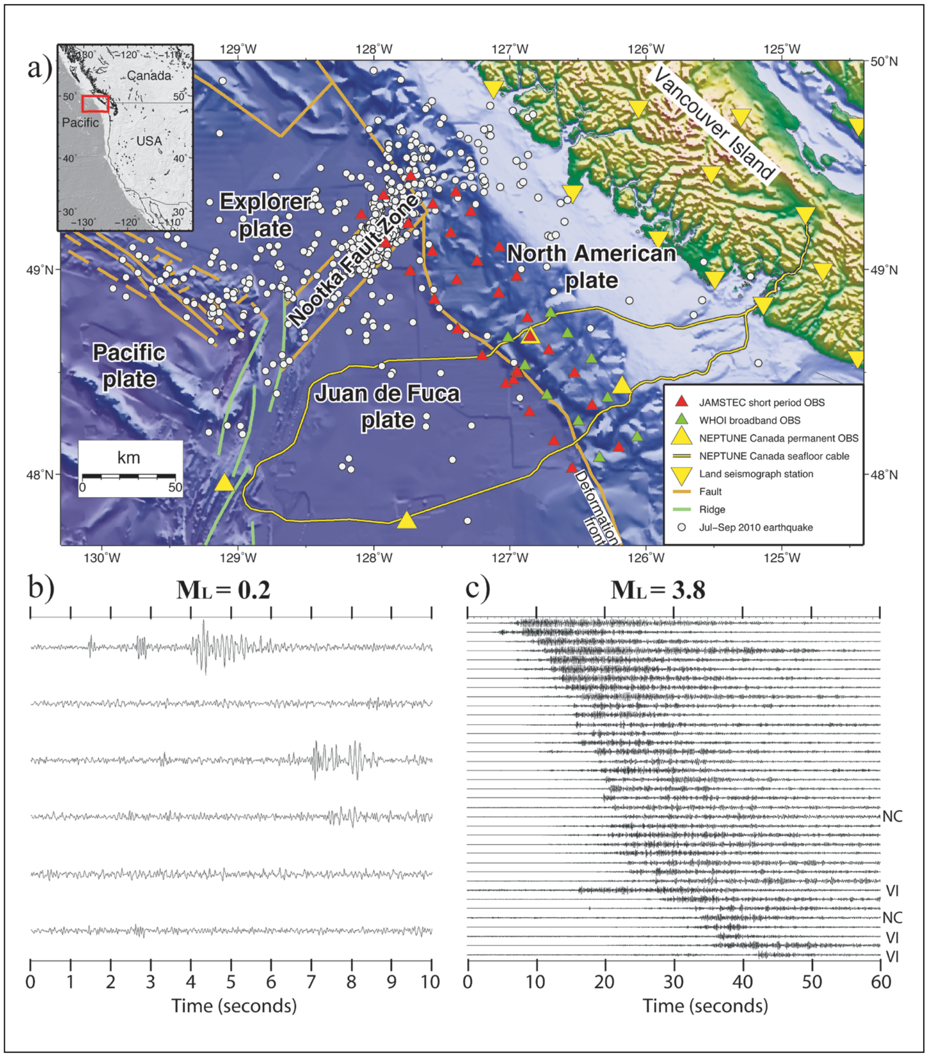

Fig. 1. (a) Map showing the Seafloor Earthquake Array–Japan-Canada Cascadia Experiment (SeaJade) monitoring area at the northern Cascadia margin, seismometer stations at the seafloor and on Vancouver Island, and preliminary earthquake epicenters from the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) short-period ocean bottom seismometer (OBS) array. (b) Example of a small earthquake (M_L = 0.2) shown on the six JAMSTEC OBSs nearest this earthquake. (c) Example of a larger earthquake (M_L = 3.8) shown on all 32 JAMSTEC OBSs, the two North-East Pacific Time-series Undersea Networked Experiments (NEPTUNE) Canada (NC) OBSs located on the continental slope, and the three seismometers on Vancouver Island (VI) closest to this earthquake.

SeaJade Targets

Future analyses in this project will include a comparative study of Japan's Nankai subduction zone. The Cascadia margin is similar to Nankai in many ways, including the young age of the subducting plate, a moderate convergence rate, ample trench sediments, a large accretionary sediment prism, and the occurrence of episodic tremor and slip (ETS). A large amount of information has been gathered through OBS monitoring at Nankai, including numerous small earthquakes previously undetected by land-based networks, very low frequency (VLF) earthquakes likely occurring in the accretionary prism, and shallow subseafloor seismic tremor [e.g., *Obana et al.,* 2006; *Obana and Kodaira,* 2009]. To better understand the seismogenic behavior of convergent margins, it is important to know whether similar phenomena are present at Cascadia.

A clear difference between the Cascadia and Nankai margins is that many more earthquakes, mainly in the downgoing plate, are recorded in similar monitoring campaigns at the fully locked Nankai subduction zone [e.g., *Obana et al.,* 2006] than at Cascadia. This may reflect different states of stress relaxation due to the different elapsed times since the previous great earthquakes, which occurred only 6 decades ago at Nankai but 3 centuries ago at Cascadia. This explanation is consistent with geodetically determined upper plate deformation where strain rates due to fault locking are larger at Nankai [*Wang,* 2007]. For understanding subduction earthquake processes, differences between the two margins are as important as their similarities. Another difference, not detailed in this report, is the role of the Nootka fault as a major shear zone in the subducting plate.

A fortuitous aspect of the first SeaJade deployment is that the August–September 2010 Cascadia ETS occurred during the OBS recording. Although the ETS sources are landward of the locked seismogenic zone, a pertinent question is whether there are accompanying seismic signals offshore. Some tremor-like signals were noticed in the OBS records, but the nature of these signals requires more thorough analyses.

On the Cascadia margin, there has not been an extensive search for VLF events and offshore tremor, although some evidence for a VLF event has been found using seismograms of the land-based network [*Kao et al.,* 2008]. Detection of VLF events is a primary target in the analysis of the 10 broadband OBSs from WHOI.

Several margin-wide deep seismic surveys and offshore drilling legs also contribute to the seismic characterization of the northern Cascadia margin. For example, a borehole observatory on the continental slope, newly installed under the Integrated Ocean Drilling Program and soon to be connected to NEPTUNE Canada, has enabled long-term monitoring of pore fluid pressure variations associated with seismic and aseismic strain [*Davis and Petronotis,* 2010]. An integrated analysis of events recorded by land-based networks, NEPTUNE Canada, and SeaJade will significantly improve understanding of seismicity in northern Cascadia.

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