Field Studies Target 2012 Haida Gwaii Earthquake

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At 8:04 P.M. Pacific daylight time (PDT) on 27 October 2012 (03:04 universal time (UT), 28 October), Canada's second largest instrumentally recorded earthquake rocked Haida Gwaii (formerly Queen Charlotte Islands) and the mainland coast of British Columbia. The *M* 7.7 event off the west coast of Moresby Island caused a tsunami with local runup of more than 7 meters and amplitudes up to 0.8 meter on tide gauges 4000 kilometers away in Hawaii. Shaking was felt as far away as the Yukon, Alberta, Washington, and Montana, up to 1500 kilometers away. Little damage was caused, as the immediate region is an uninhabited National Park Reserve. The closest point of the rupture zone, as defined by aftershocks (Figures 1a and 1c), was 50 kilometers from the nearest community, Queen Charlotte, where damage was confined to a few chimneys and slumped roads.

The seismic waveforms, the pattern of aftershocks, and the coseismic motion determined from Global Positioning System (GPS) measurements indicate a low-angle thrust earthquake with motion significantly different from the relative plate motion and almost perpendicular to the margin (Figures 1a and 1b). The epicenter is close to that of the 2001 *M* 6.1 thrust earthquake, which caused a small tsunami recorded on west coast tide gauges [*Rabinovich et al.*, 2008]. New data from instruments deployed shortly after the earthquake are helping scientists learn more about the earthquake and tsunami hazard of the region.

Tectonic Setting of the Earthquake

The earthquake occurred off Moresby Island adjacent to the Queen Charlotte fault (the mainly transcurrent boundary between the Pacific and North American plates), which extends from the triple junction where the Pacific Plate, the North American Plate, and the Explorer Plate meet just north of Vancouver Island to southern Alaska [e.g., *Szeliga*, 2013]. To the north of Haida Gwaii, the margin is predominantly strike slip. In 1949, an *M* 8.1 strike-slip earthquake initiated to the north of the recent event and ruptured in both directions. It propagated northward to the area where a recent (4 January 2013) *M* 7.5 strike-slip event occurred in southeast Alaska and propagated southward into the region of the 27 October 2012 earthquake. Before the 27 October event, no major earthquake west of Moresby Island had been recorded since the Canadian federal government established a seismograph in Victoria, British Columbia, in 1898.

Although the Queen Charlotte fault to the north is mainly strike slip, off Moresby Island the orientation of the fault differs from the Pacific–North American plate motion by about 20 degrees (Figure 1a). This implies that in addition to sliding horizontally past each other, the plates are converging at a rate of about 15 millimeters per year [e.g., *Hyndman and Hamilton,* 1993]. Zooming in on the plate boundary near southern Haida Gwaii, the relative plate motion appears to be partitioned onto a shallowly dipping thrust fault and the steeply dipping strike-slip Queen Charlotte fault near the coast (Figure 1b). A similar slip-partitioning model was described by *Fitch* [1972] for the Sumatra region, but the scale is different in Sumatra, where the strike-slip fault is nearly 300 kilometers inland. Some of the compression on the Queen Charlotte fault near the Haida Gwaii margin may also be accommodated through internal deformation in both plates [*Rohr et al.,* 2000].

The October earthquake likely ruptured a thrust fault underlying the 30-kilometer-wide tectonic sliver called the Queen Charlotte Terrace, which may be an accretionary sedimentary prism. The convergence and underthrusting have resulted in down bowing of the oceanic plate into a "trench" (the Queen Charlotte Trough) and have uplifted the west coast of the islands. The oblique convergence began about 8 million years ago, and its duration has been too short for a volcanic arc to form. Receiver-function structure studies of teleseismic earthquakes define a downgoing plate [*Bustin et al.,* 2007].

Field Response to the Earthquake

In the weeks following the earthquake, the Geological Survey of Canada conducted surveys to assess the effects of the earthquake and tsunami and deployed instruments to record aftershocks and ground motion (Figure 1a). The efforts were complemented by a survey to map landslides conducted by British Columbia's Ministry of Forests.

Late fall and winter field work is difficult in Haida Gwaii. The rugged terrain, high precipitation, low cloud cover, strong winds, and short working days combined to make field conditions demanding. Most sites are accessible only by helicopter. Starting in early November, seven GPS instruments, three broadband seismographs, and four short-period seismographs were deployed on southern Haida Gwaii, supplementing the one existing continuous GPS site and four seismographs in the area. GPS instruments were deployed at three previous campaign sites and at three new locations. A tsunami runup

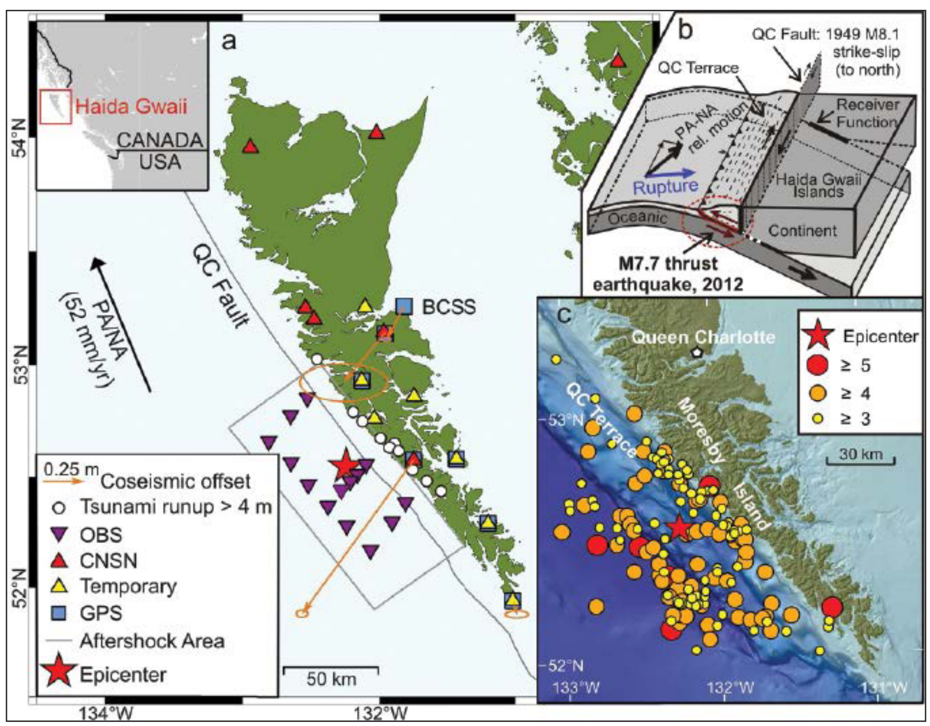

Fig. 1. (a) Map showing locations of Global Positioning System (GPS) and seismic instruments deployed since the 2012 Haida Gwaii earthquake, as well as GPS coseismic offsets and sites with substantial tsunami runup. OBS are ocean bottom seismometers; CNSN is the Canadian National Seismograph Network. BCSS is a continuous GPS site operated by the government of British Columbia; other GPS sites are campaign sites occupied for this study. (b) Tectonic block model (modified from Hyndman and Hamilton *[1993]). The earthquake rupture likely occurred on a shallow dipping thrust fault beneath the Queen Charlotte Terrace with motion almost perpendicular to the margin. QC is Queen Charlotte. PA is the Pacific Plate; NA is the North American Plate. (c) Map showing locations of the main shock (star) and well-located aftershocks from 28 October to 31 December 2012.*

survey was carried out along the west coast of Moresby Island, focusing on the heads of inlets, for comparison with numerical tsunami models. Offshore, 14 ocean bottom seismometers (OBS) were deployed in early December with retrieval in early January 2013, and an air gun survey was completed to determine the structure in the aftershock region. Field work to renew batteries, download data, and upgrade some sites is ongoing.

Data are being retrieved and analyzed from the instrument deployments and surveys. Early GPS data indicate more than a meter of coseismic displacement toward the rupture at a site just landward of the rupture, followed by postseismic motions exceeding 1 millimeter per day at some sites. The aftershocks form a halo around the epicenter of the main shock (Figure 1c); several large aftershocks seaward of the Queen Charlotte Terrace appear to represent normal faulting. Numerous $M > 3$ aftershocks occurred during the OBS deployment, and prospects are excellent for better discernment of the rupture area and regional crustal properties and structure.

Improving Hazard Assessment

Megathrust earthquakes, up to M 9, can occur in the Cascadia subduction zone offshore southern British Columbia (Vancouver Island), Washington, Oregon, and northern California. Similar to the Haida Gwaii thrust event, Cascadia megathrust earthquakes occur offshore, generate tsunamis, and cause significant shaking on land. Analyses of data from the Haida Gwaii earthquake will provide a valuable opportunity to calibrate modeling methods for estimating the much larger earthquake ground motions and tsunami amplitudes resulting from megathrust earthquakes. This will lead to better assessment of earthquake and tsunami hazards in coastal British Columbia, the Pacific Northwest, and elsewhere where large thrust earthquakes occur in coastal settings.

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