Relocation of earthquakes off the west coast of British Columbia, Canada using processing routines at the International Seismological Centre and various travel time tables

Alison Bird[1] & Dmitry Storchak[2]

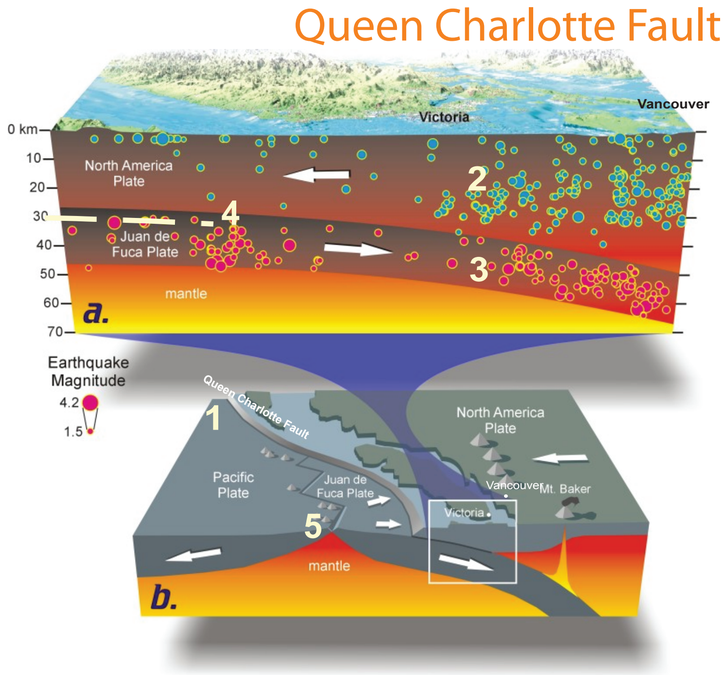
Abstract

As part of efforts by the International Seismological Centre to refine and modernize the location of earthquakes, it was decided that an updated, modern spherical Earth velocity model, with consistent travel-time tables for all major seismic phases, should be used. The AK135 velocity model was of particular interest in this procedure, replacing the out-dated Jeffreys-Bullen travel time tables. A comparison of test events world-wide included a selection of earthquakes along the west coast of British Columbia, Canada. This region has the benefit of accommodating all three major types of plate boundary. The highly active Queen Charlotte transform fault along the northern west coast is the location of Canada's largest instrumentally recorded earthquake (a magnitude 8.1 in 1949). The area to the west of Vancouver Island is the prime area of focus in this study. The Juan de Fuca Ridge experiences considerable seismicity, including that induced by sub-sea volcanism, and the 1000km-long Cascadia Subduction Zone, imme-diately west of Vancouver Island, is potentially the most seismically hazardous area in the country, including a history of megathrust earthquakes. As Canada does not yet operate ocean-bottom seismometers, all off-shore earthquakes are located via stations in a limited azimuthal range and, at times, at distances greater than 150km. Close examination of such events will be presented, with preliminary results supporting the conversion of the ISC's location process to that using AK135 travel time tables.

[1]albird@nrcan.gc.ca
www.earthquakescanada.ca
Geological Survey of Canada
9860 West Saanich Road
P.O.Box 6000, Sidney, B.C.
V8L 4B2, Canada
ph: +1-250-363-6432

[2]dmitry@isc.ac.uk
www.isc.ac.uk
International Seismological Centre
Pipers Lane, Thatcham, Berkshire
RG19 4NS, United Kingdom
ph: +44-1635-861022

Queen Charlotte Fault and Cascadia Subduction Zone: seismic and tectonic setting



1) transpressional earthquakes along the Queen Charlotte Fault, 2) crustal earthquakes within the North American Plate, 3) in-slab earthquakes, within the Juan de Fuca Plate, 4) subduction (mega-thrust) earthquakes along the interface of the two plates, and 5) smaller earthquakes induced by sub-sea ridge volcanics, adapted from Yorath et al. (2001).

The Queen Charlotte Fault (1), along the west coast of northern British Columbia, Canada is a transpress-ional margin between the Pacific and North America Plates, exhibiting intense strike-slip and some thrust activity. It is the location of Canada's largest instrumentally recorded earthquake (a M8.1 in 1949) and one of the highest seismic hazard regions in the country.

To the south, the Cascadia Subduction Zone lies off the west coast of British Columbia, Washington, Oregon and northern California, where the oceanic Juan de Fuca Plate subducts beneath the continental North American plate. This is an area of significant seismic hazard, from the sizeable earthquakes which occur shallow within the North American Crust (2) - e.g. M7.3 in 1946, in the Juan de Fuca slab (3) - e.g. M6.8 in 2001 and, most dramatically, due to the mega-thrust potential along the subduction interface (4) which last experienced an earthquake in 1700 of magnitude ~9. Major cities in this region include Vancouver and Victoria, British Columbia, and Seattle and Olympia, Washington.

Seismic activity along the Juan de Fuca Ridge (5), which separates the Pacific and Juan de Fuca Plates, is generally moderate in size and at a sufficient distance from land to pose no threat.

Several earthquakes throughout this region were part of a study, performed at the ISC with cooperation from the GSC, to study the effects of different location algorithms on location accuracies. Primarily, earthquake locations calculated using the hitherto standard Jeffreys-Bullen (JB) velocity model were compared to locations obtained using a modern spherical Earth model with consistent travel-time tables for all major seismic phases, namely the AK135 velocity model - considered the best candidate for this purpose. Results are presented below.

Comparison of earthquake locations

Circles on the map at right represent the difference between Jeffrey-Bullen and Ak135 locations. White circles indicate a difference of less than 10 km (reliable enough that such events will not be discussed), black circles indicate a 10 - 20 km difference, and blue 20 - 30 km.

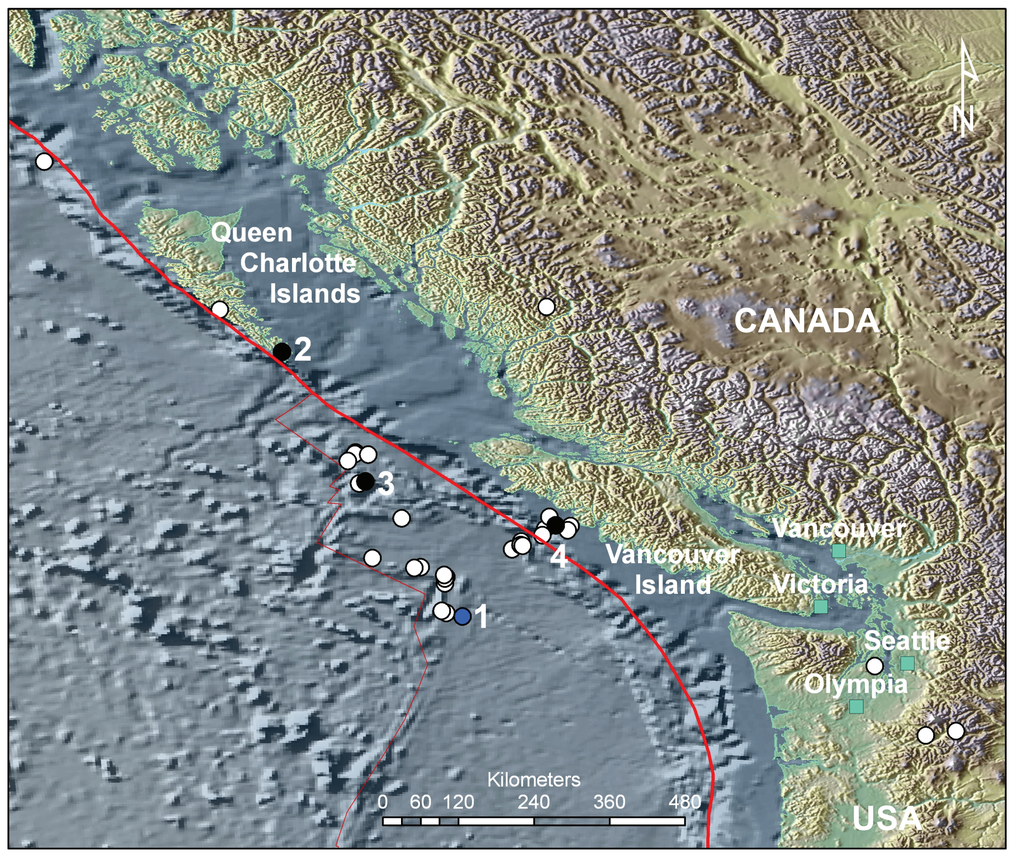
1: The lone blue dot (representing a 21 km difference between JB and AK locations) lies at the northern tip of the Juan de Fuca Ridge, a truly onerous region for earthquake location. This particular event was recorded by stations with an extremely narrow azimuthal coverage of 72° and at a considerable distance (>240 km); in addition, travel paths were impeded by low ridge velocities and the subduction boundary, causing phases to be emergent and noisy. This location would therefore be considered unreliable, regardless of the model used.

At JB-AK differences of 10 - 20 km, earthquakes labelled with black circles should also be addressed, and are done so from north to south:

2: The magnitude 4 earthquake located at the southern tip of Moresby Island, in the Queen Charlotte Islands, most likely occurred on the Queen Charlotte Fault, which runs along the west coast of the Island. Earthquakes to the north, along the coast of the islands, tend to locate reliably but, for earthquakes at the southern tip of Moresby Island, the closest stations (within 150km) all lie in a narrow band to the NNW. Contrary to standard GSC practices continental phases were, therefore, included in order to improve azimuthal coverage. Due to this awkward location a difference of 11 km is acceptable.

3: This earthquake to the west of northern Vancouver Island seems to have occurred on the Paul Revere Ridge. Seismic waves had to travel through both the Winona Ridge and Cascadia Subduction Margin in order to reach the stations; not surprisingly, they experienced timing issues. The azimuthal range was only 65° and stations were no closer than 158km. This combination of obstacles instils sufficient doubt in the location of any earthquake along the Revere Ridge; that the study found a difference of 12 km is reasonable.

4: Unlike the aforementioned earthquakes, the event located just south-west of Nootka Island, off the west coast of central Vancouver Island, is in an area where earthquakes are generally located accurately, primarily due to the close proximity to seismic stations on Vancouver Island (six within 100 km for this event) recording impulsive wave arrivals with at least 180° of azimuth covered. This event provided the one mystery for this study, which was eventually resolved by the discovery that both models used by the ISC downgraded the use of close stations in preference for regional stations. Due to this area's highly folded geology, the GSC prefers to restrict the use of stations to those within 100 km epicentral distance. It should be noted that the Ak135 provided closer results with those obtained by the GSC.



Earthquakes reviewed as part of this study. White circles show a difference between Jeffrey-Bullen and Ak135 locations of less than 10 km; black circles 10 - 20 km and blue 20 - 30 km.

Remarks

This initial study resulted in confidence that the Ak135 travel time tables would provide reliable results for the region off western Canada, consistent with the established century-long catalogue of earthquakes for this seismically active area. Further analysis of this model in comparison with that of Jeffrey-Bullen will occur before the ISC commits to adopting the new model.