CONCEPTUAL DIFFERENCES BETWEEN THE PACIFIC, ATLANTIC AND ARCTIC TSUNAMI WARNING SYSTEMS FOR CANADA

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ABSTRACT

Canada has coastlines on three of the four oceans on the globe, namely, the Pacific, Atlantic and Arctic oceans. The Pacific and Atlantic oceans are connected to the Arctic Ocean in the north, but still they are three distinct oceans, and need three individual tsunami warning systems. Tsunamis in the Arctic Ocean are not as well documented as in the Pacific and Atlantic oceans. From what is known, tsunamis in the Arctic Ocean are rare and probably are small in amplitude. Because of very low population density, around the Canadian Arctic, at present, there is no priority for a tsunami warning system for Arctic Canada. For the Pacific Ocean, a tsunami warning system is in existence since 1948. In at least one sense, the warning aspects of the tsunami warning system for the Pacific coast of Canada, is relatively simple and straight forward, because it involves only the federal government (PSEPC) and the provincial government of British Columbia (PEP). For the Atlantic Ocean, A tsunami warning system is now being established. The warning aspects will be some what more complex for eastern Canada, since it not only involves the federal government, but also five provinces, namely, Newfoundland and Labrador, Nova Scotia, New Brunswick, Prince Edward Island and Quebec. The Alaska tsunami warning center (ATWC) in Palmer, Alaska, provides tsunami warnings for both Pacific and Atlantic Canada.

1. INTRODUCTION

Canada is bordered by three oceans (figure 1), namely the Pacific to its west, the Atlantic to its east, the Arctic to its north and the USA to its south. The Pacific and Atlantic oceans, more or less stretch from the high latitudes of the southern hemisphere to the high latitudes of the northern hemisphere, whereas the Arctic Ocean lies only in the high latitudes of the northern hemisphere.. In principle, Canada needs three separate tsunami warning systems, because, tsunami characteristics are quite different in these three oceans. Moreover, for a tsunami warning system to function effectively in real time, all the nations bordering a given ocean, should share seismic and tsunami data in real time, which calls cooperation through various protocols. The only operational tsunami warning system, at present, namely the Pacific tsunami warning system is in existence since 1948 and is being coordinated since 1965 by the I.O.C. (Inter-governmental Oceanographic Commission) of UNESCO in Paris. It is expected that IOC will also be coordinating the Atlantic Ocean tsunami warning system and the Indian Ocean tsunami warning system, that are being established at present, in addition to some regional tsunami warning systems, such as for the Caribbean and Mediterranean seas.

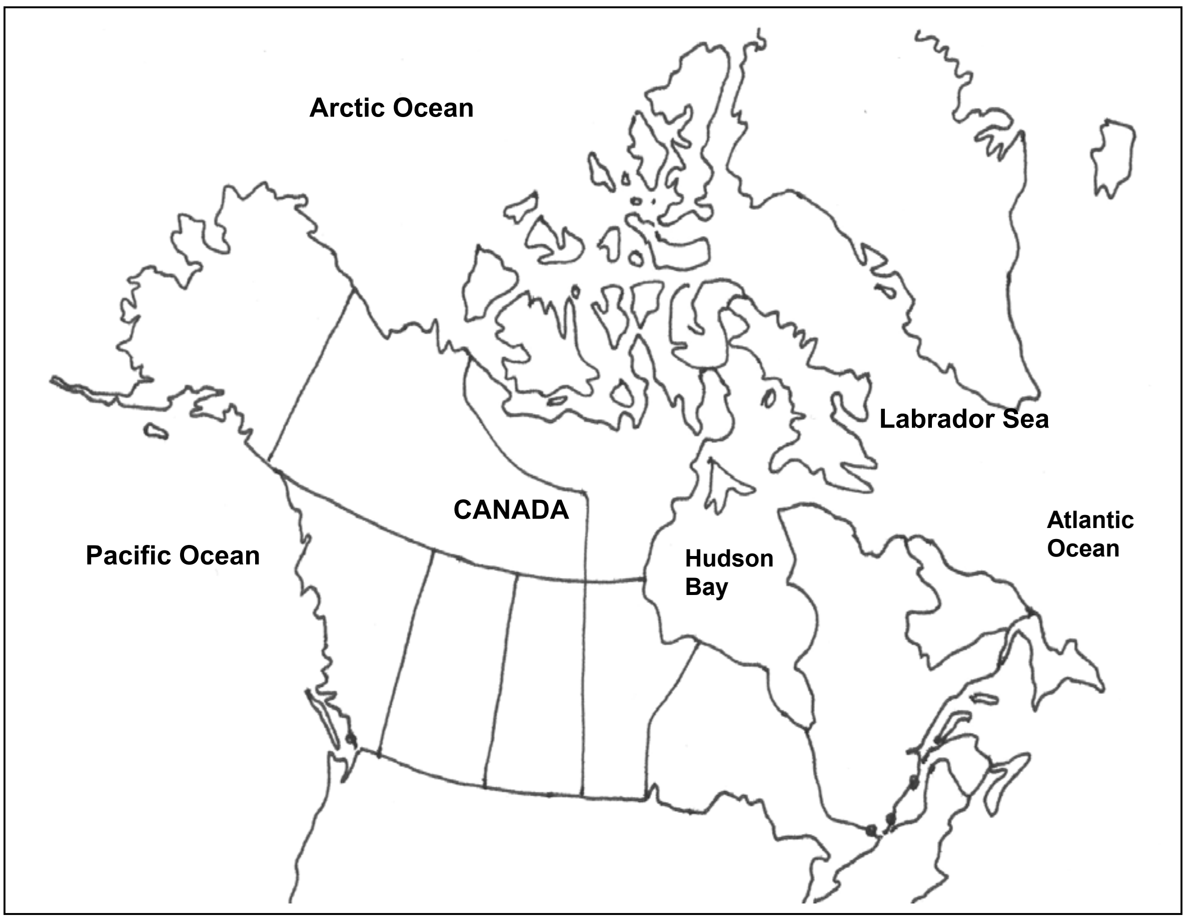

Figure 1: Canada's coastlines with Pacific, Atlantic, and Arctic oceans

1. TSUNAMI WARNING SYSTEM FOR ARCTIC CANADA

Figure 2 shows the earthquake distribution in Canada. Tsunamis in the Arctic Ocean are poorly documented and there are no reports of major ocean-wide tsunamis in historical time in the Arctic. What little evidence is there, seem to suggest that tsunami amplitudes in the Arctic Ocean probably will be small (Murty, 1977).

The following nations border the Arctic Ocean: Canada, USA (Alaska), Baffin Island, Greenland, Norway, and Russia (Siberia). In principle, all these nations should cooperate under the auspices of the IOC and share seismological and oceanographical data in real time, for an efficient tsunami warning system to function. Since the density of population around the rim of the Arctic Ocean is low at present, there is neither an incentive, nor any priority for an Arctic Ocean tsunami warning system.

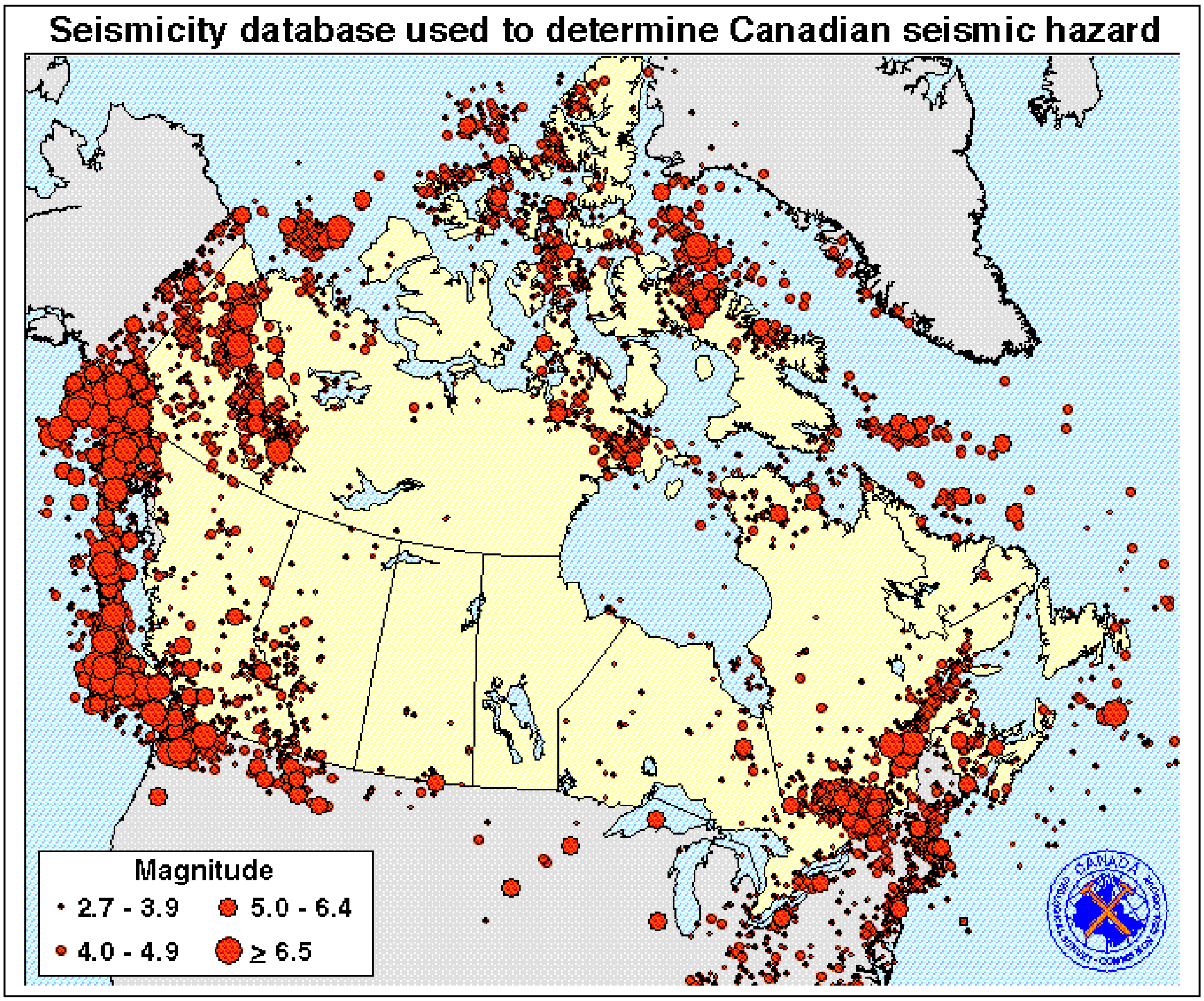

Figure 2: Earthquake distribution in Canada
(http://www.civil.bcit.ca/courses/4167/unit1_02.htm#seiz_BC)

2. TSUNAMI WARNING SYSTEM FOR PACIFIC CANADA

Figure 3 shows the major tectonic plates in the world and Figure 4 shows the tectonic faults in western Canada. Following the disastrous Aleutian earthquake tsunami of 1 April 1946, the USA established the Pacific tsunami warning center (PTWC) in Ewa Beach on Oahu Island of Hawaii. In 1965 the IOC started coordinating the activities of the Pacific tsunami warning system for some 26 nations around the rim of the Pacific Ocean, including Canada.

After the disastrous Alaska earthquake tsunami of 28 March 1964, the USA established the Alaska tsunami warning center (ATWC) in Palmer, Alaska, in 1967. The Pacific coast of Canada receives tsunami warning from the Palmer center.

In terms of logistics, the warning aspects of this system for Canada are relatively straightforward, as it involves only the federal government, through the PSEPC (Public Safety & Emergency Preparedness, Canada) and only the provincial government of British Columbia, through the PEP (Provincial Emergency Program).

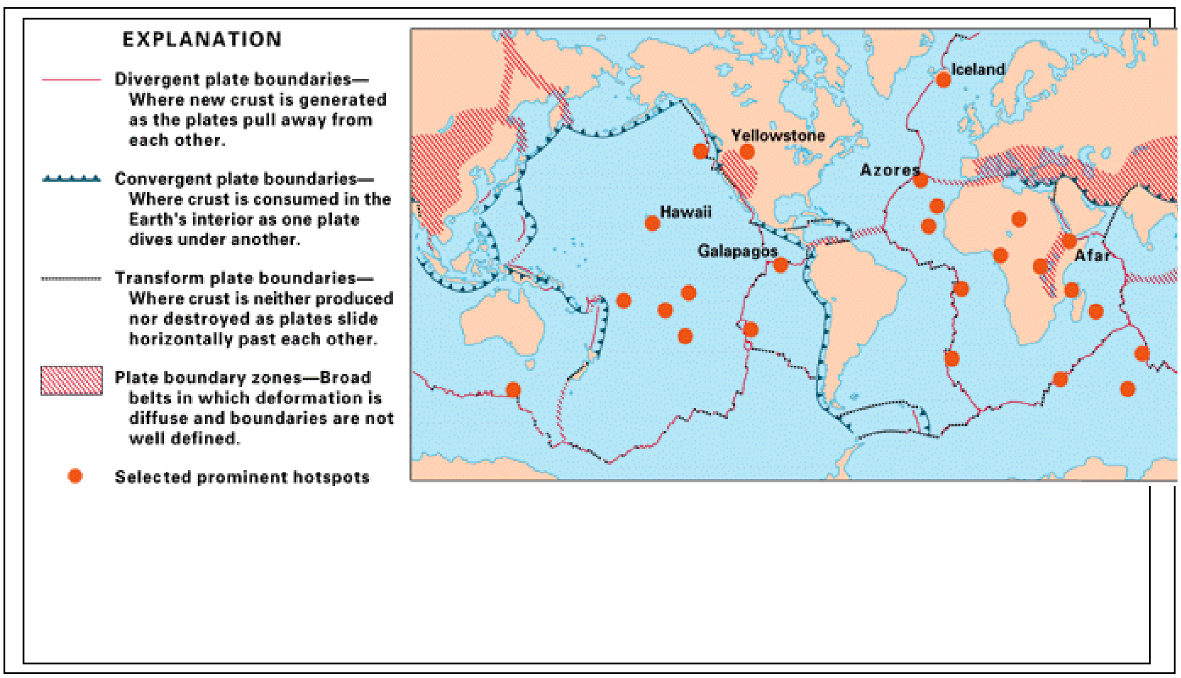

Figure 3: Major tectonic plates on the globe (Source: http://pubs.usgs.gov/publications/text/world_map.html)

In terms of scientific issues, it may be noted that, during the Alaska earthquake tsunami of March 1964, outside of Alaska, the greatest tsunami amplitude occurred, not at the open coast, but at Port Alberni, located at the head of the Alberni inlet, on Vancouver Island. Murty (1977) showed that, the tsunami from the Pacific Ocean, with amplitude of about 0.5 m was amplified to 5.2 m at Port Alberni through quarter wave resonance.

While it is somewhat unlikely that the Alberni inlet can amplify tsunamis coming from the south Pacific (for example, the Chilean earthquake tsunami of 22 May 1960), its geographical orientation and geometry is such that, it can magnify tsunamis from Alaska and the Aleutians.

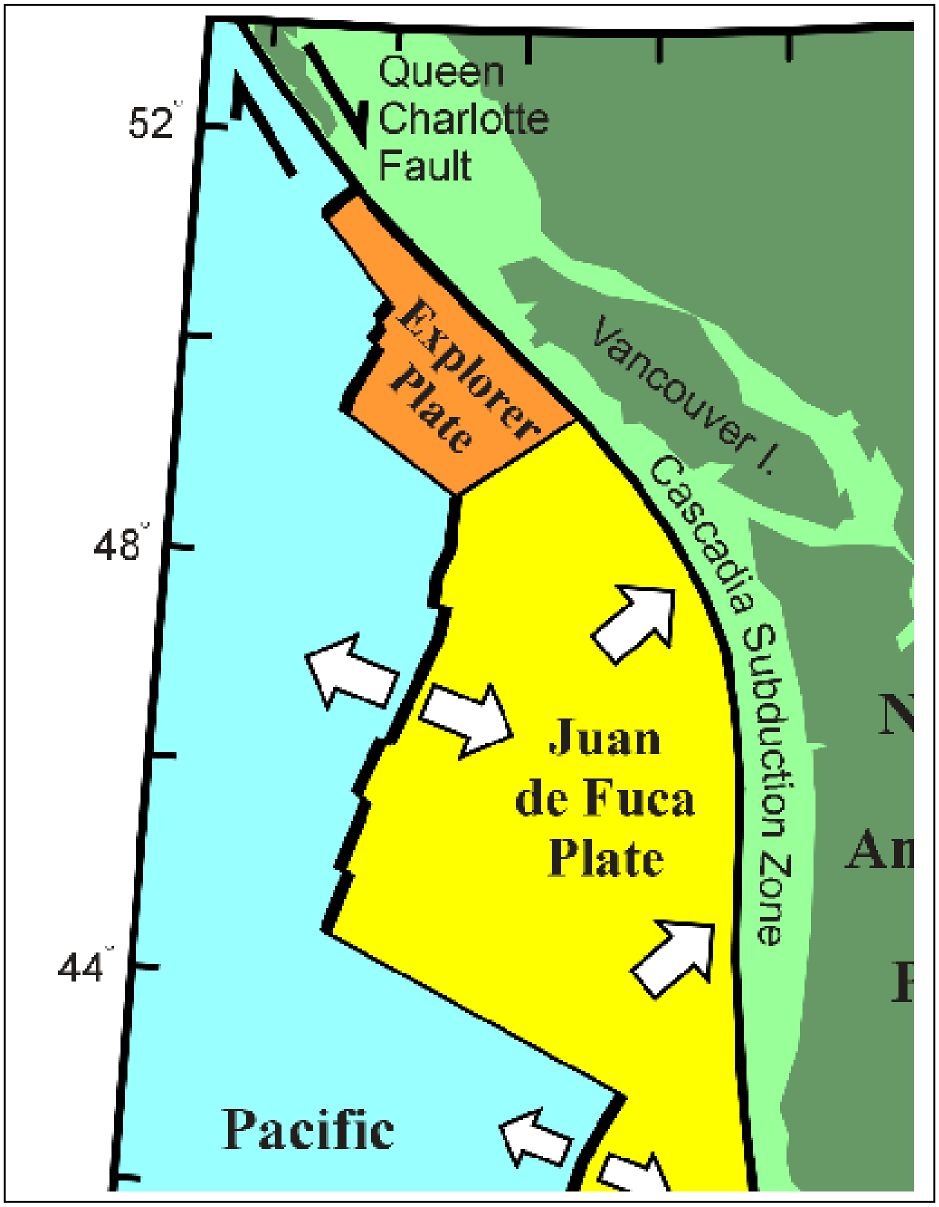

Figure 4: Western Canada tectonic faults in the Pacific Ocean (http://www.civil.bcit.ca/courses/4167/unit1_02.htm#seiz_BC)

3. TSUNAMI WARNING SYSTEM FOR EASTERN CANADA

Figure 5 shows that Atlantic Ocean and the mid-Atlantic ridge, which is a divergent plate boundary, and hence does not give rise to tsunamigenic earthquakes. Usually there are no ocean-wide tsunamis in the Atlantic, and most tsunamis are local, for example, the Caribbean Sea. The Lisbon earthquake tsunami of 1755 was supposed to have had several meters of amplitude in the Caribbean, but was not significant in the western Atlantic.

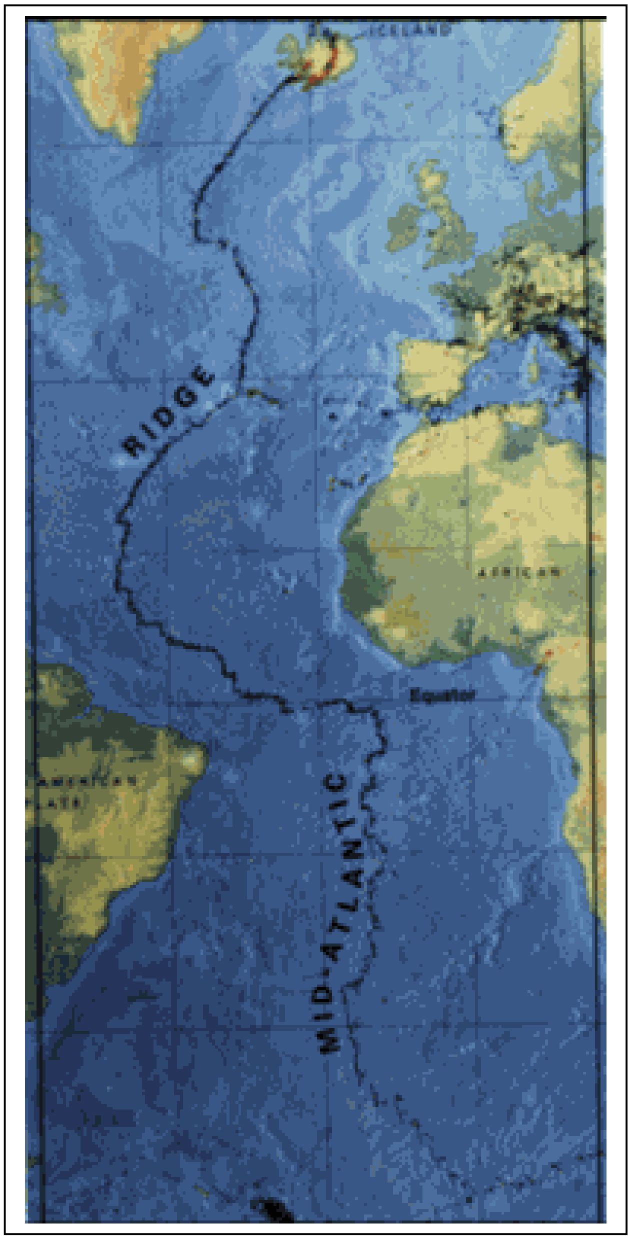

Figure 5: Atlantic Ocean and mid-Atlantic Ridge

We will briefly discuss three tsunamis that were generated in Canada and impacted mostly Canada only. In addition we well briefly mention the tsunami potential in the St. Lawrence estuary. Figure 6 shows the travel time contours of the Grand Banks earthquake tsunami of 18 November 1929 that was reported to have killed 28 people. Quarter wave resonance amplification played a major role in amplifying the tsunami in some of the bays and gulfs on the south coast of Newfoundland. It can be seen from Figure 6 that the tsunami energy could not propagate towards Nova Scotia, mainly because of extensive sand banks in between.

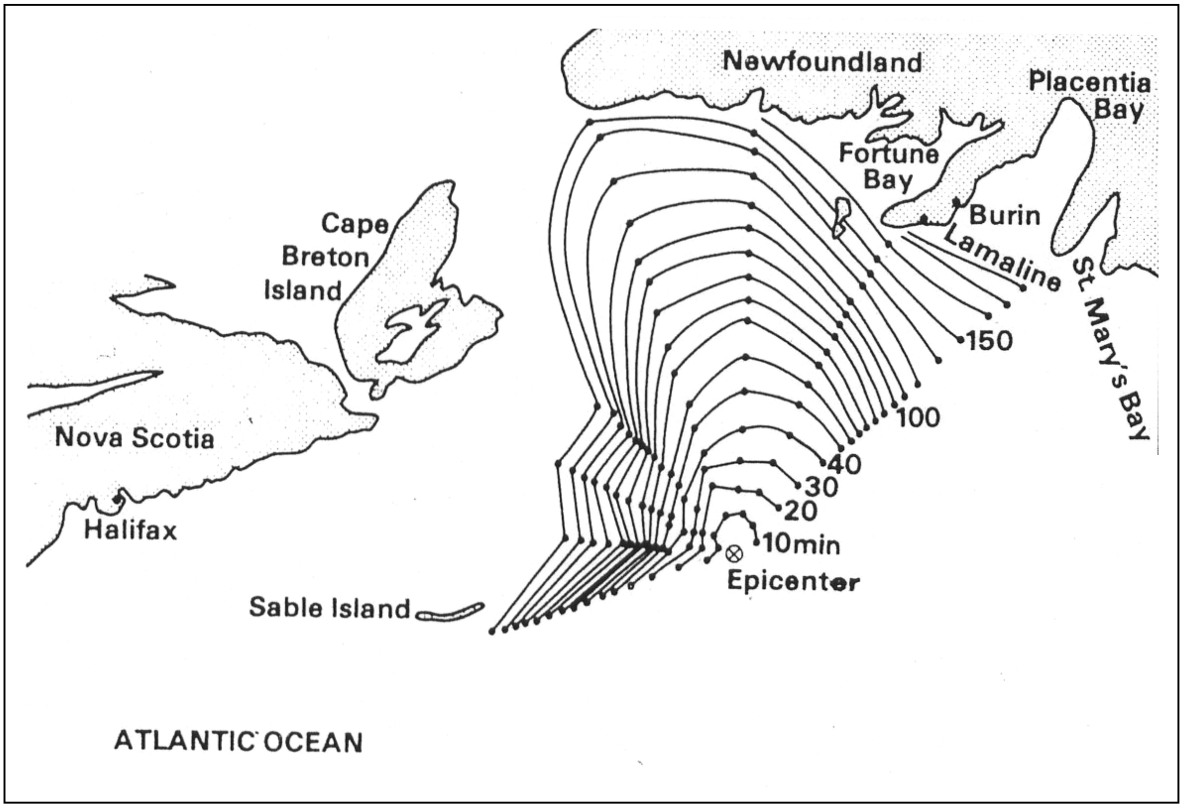

Figure 6: Travel time contours of Grand Banks earthquake tsunami (in minutes)

Greenberg et al. (1993, 1994) and Ruffman et al. (1995) numerically modelled the tsunami in the Halifax harbour, due to a large chemical explosion on 6 December 1917. It is not clear how many people died from the tsunami, as opposed to the explosion itself. Figure 7a shows the tsunami travel times and Figure 7b shows the travel time contours. Figure 8 shoes the tsunami amplitudes. It can be seen that in the Halifax harbour narrows, the tsunami achieved amplitudes of up to 14 m. However, the tsunami quickly dissipated as soon as it entered the Atlantic Ocean.

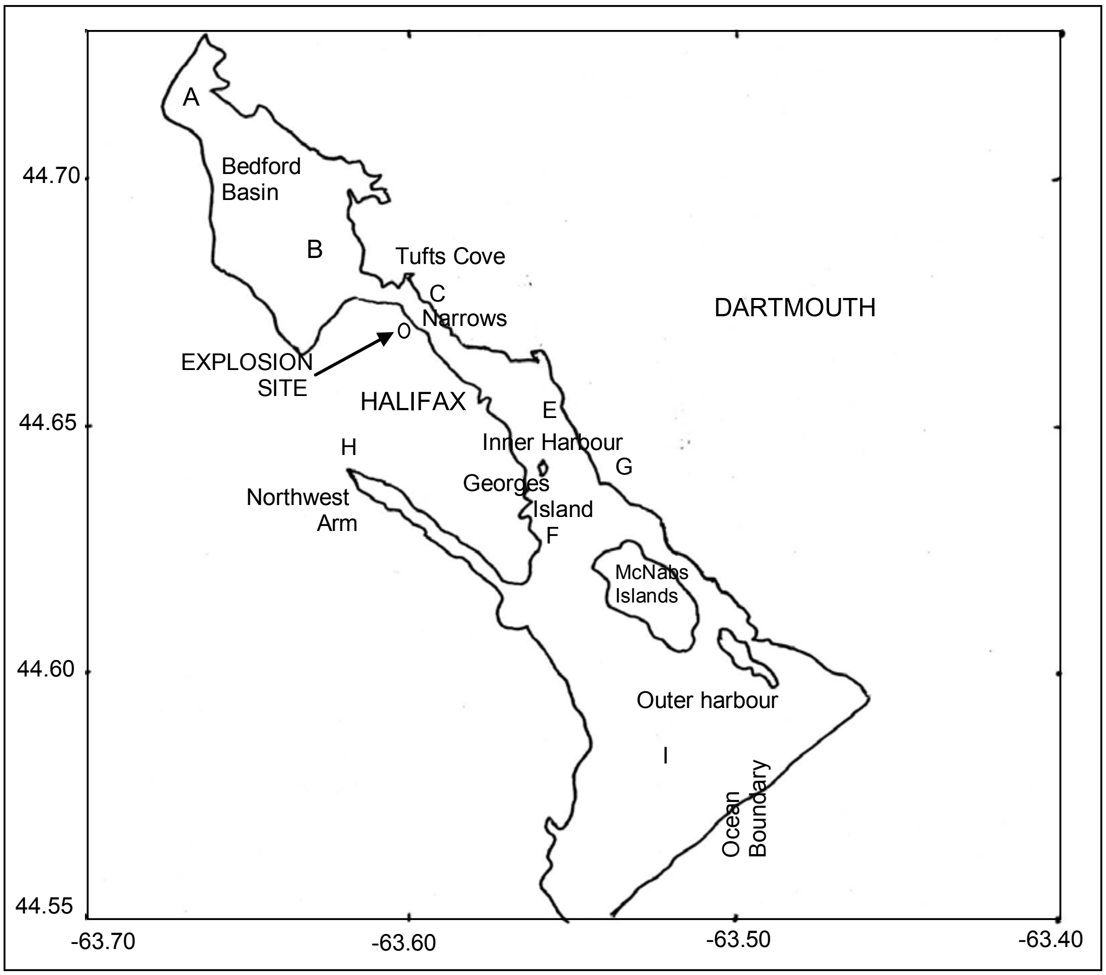

Figure 7a: Halifax Harbour location map. The letters refer to place names where the tsunami amplitude is shown in Figure 8 (Greenberg et al., 1993, 1994)

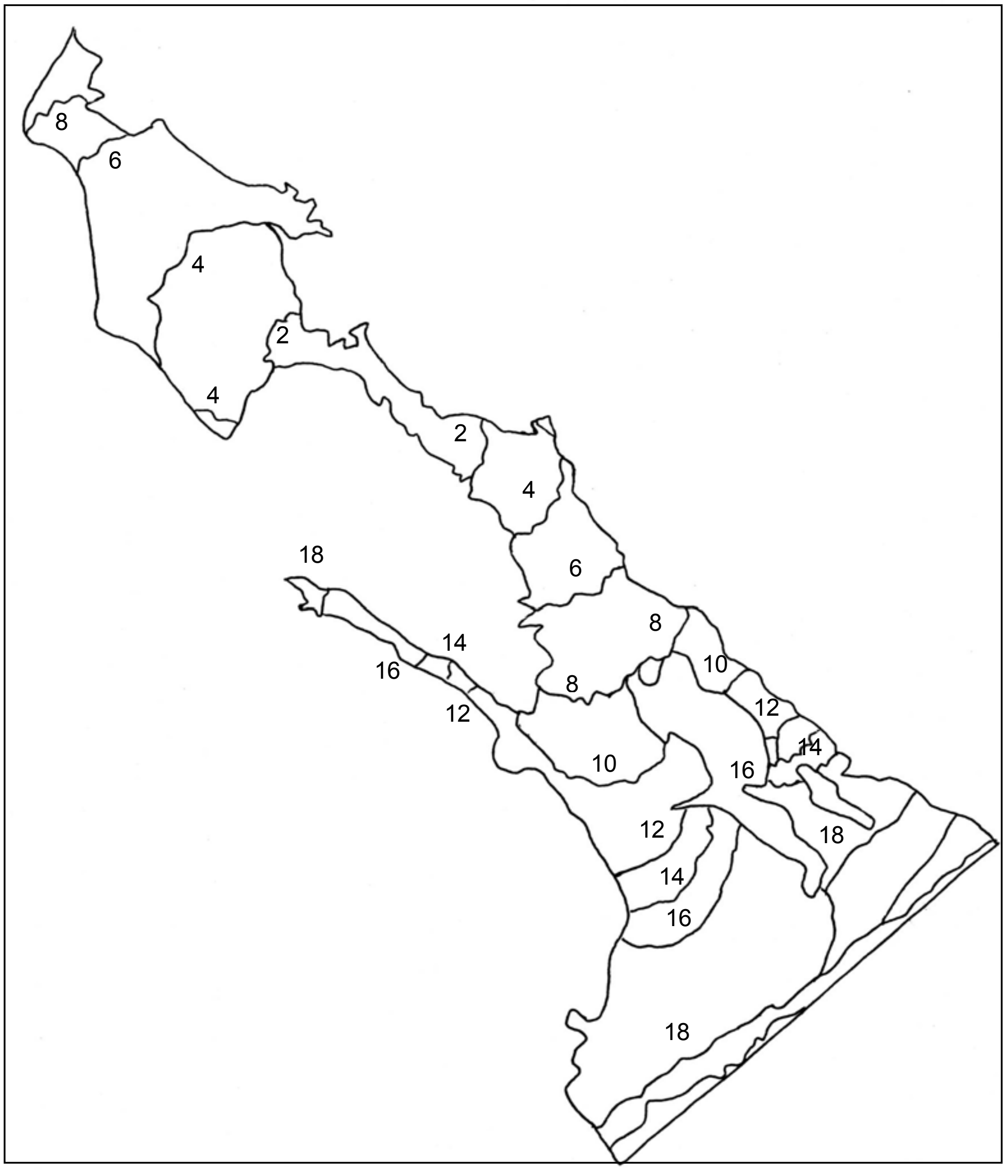

Figure 7b: Travel time contours (in minutes) of the tsunami (from Greenberg et al., 1993, 1994)

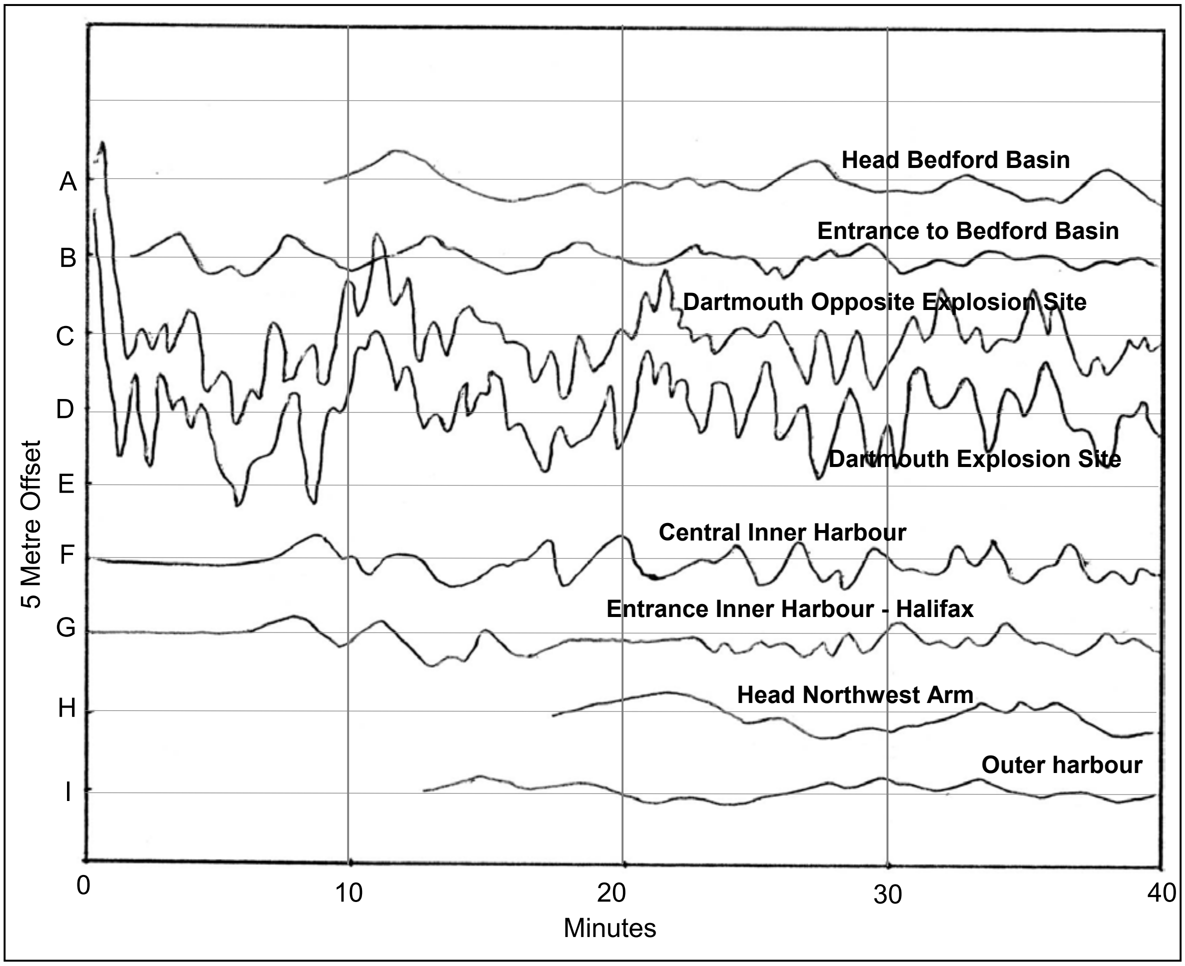

Figure 8: Maximum tsunami amplitudes (in m) at various locations identified in Figure 7a (from Greenberg et al., 1993, 1994)

Figure 9 shows the earthquake distribution in the St. Lawrence estuary. Tsunamis can be generated here from earthquakes and landslides also. Some 8,400 years B.P., at the end of the last glaciation, there was a large discharge of glacial melt water (Teller et al., 2005) from the huge glacial Lake Agassiz into the Labrador Sea through the Hudson Strait. Figure 10 shows the possible location of sand deposits today from this tsunami, which could have achieved amplitudes between 2 to 5 m.

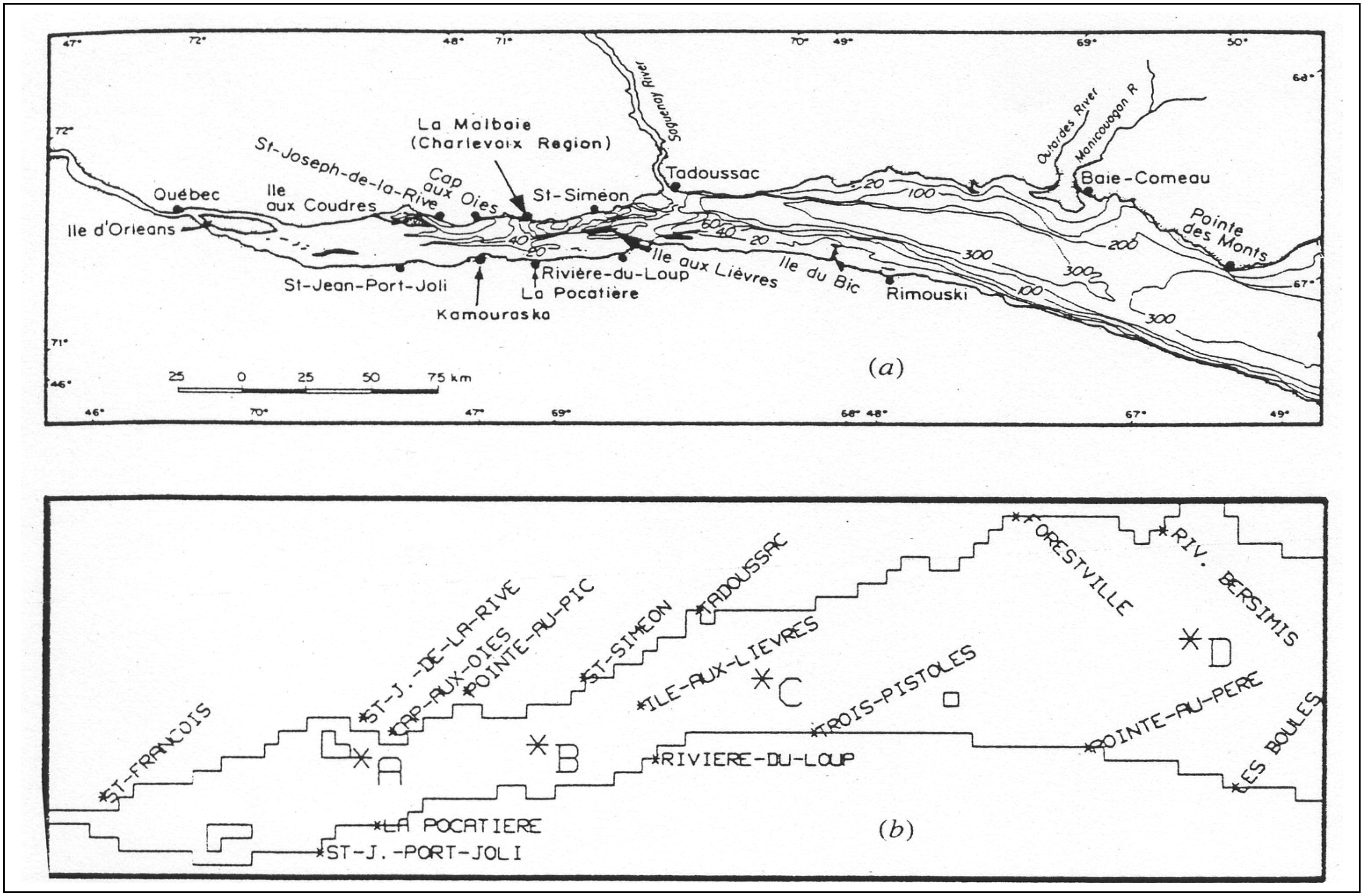

Figure 9: (a) Map of St. Lawrence Estuary in eastern Canada, and (b) The four hypothetical earthquake epicenters used in numerical simulation (from Chasse et al., 1993)

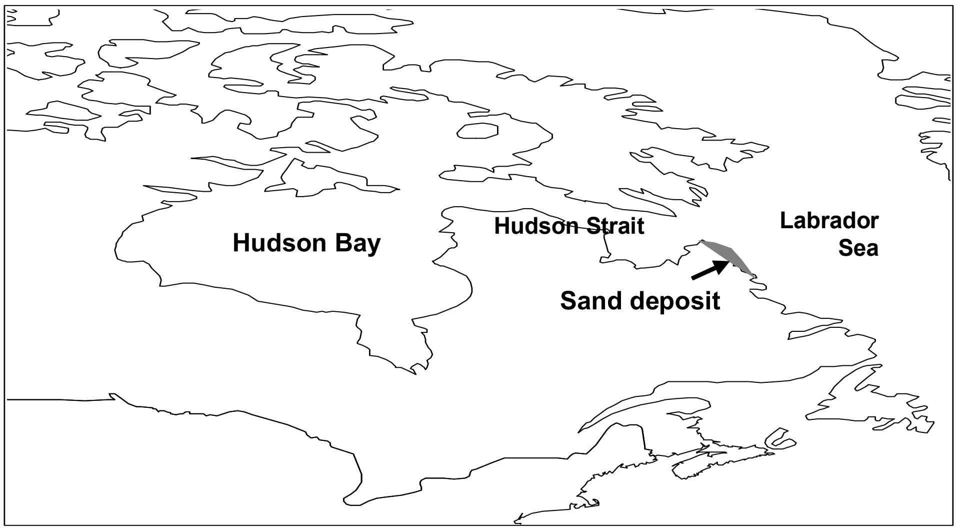

Figure 10: Location of possible sand deposits in the Labrador Sea from a tsunami, some 8,400 years B.P.

4. CONCLUSIONS

Because of low population density, at present, there is no priority for a tsunami warning system for Arctic Canada. The Pacific tsunami warning system is in existence since 1948 and functions reasonably well from a scientific point of view. As for the warning aspects for the Pacific coast of Canada, the logistics are relatively simple, because only the federal government and the province of British Columbia are involved.

For the Atlantic Ocean, a tsunami warning system is now being established the scientific as well as the logistical issues for this system have to be quite different from the Pacific system, for the following reasons. Since tsunamis that impact eastern Canada are of local origin, we cannot count on other countries to provide a tsunami warning to Canada. We have to rely more on our own efforts and systems. Second, for eastern Canada, even the logistics have to be more complicated because, not only the federal government, but five provinces (Newfoundland and Labrador, Nova Scotia, New Brunswick, and Quebec) need to be involved

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