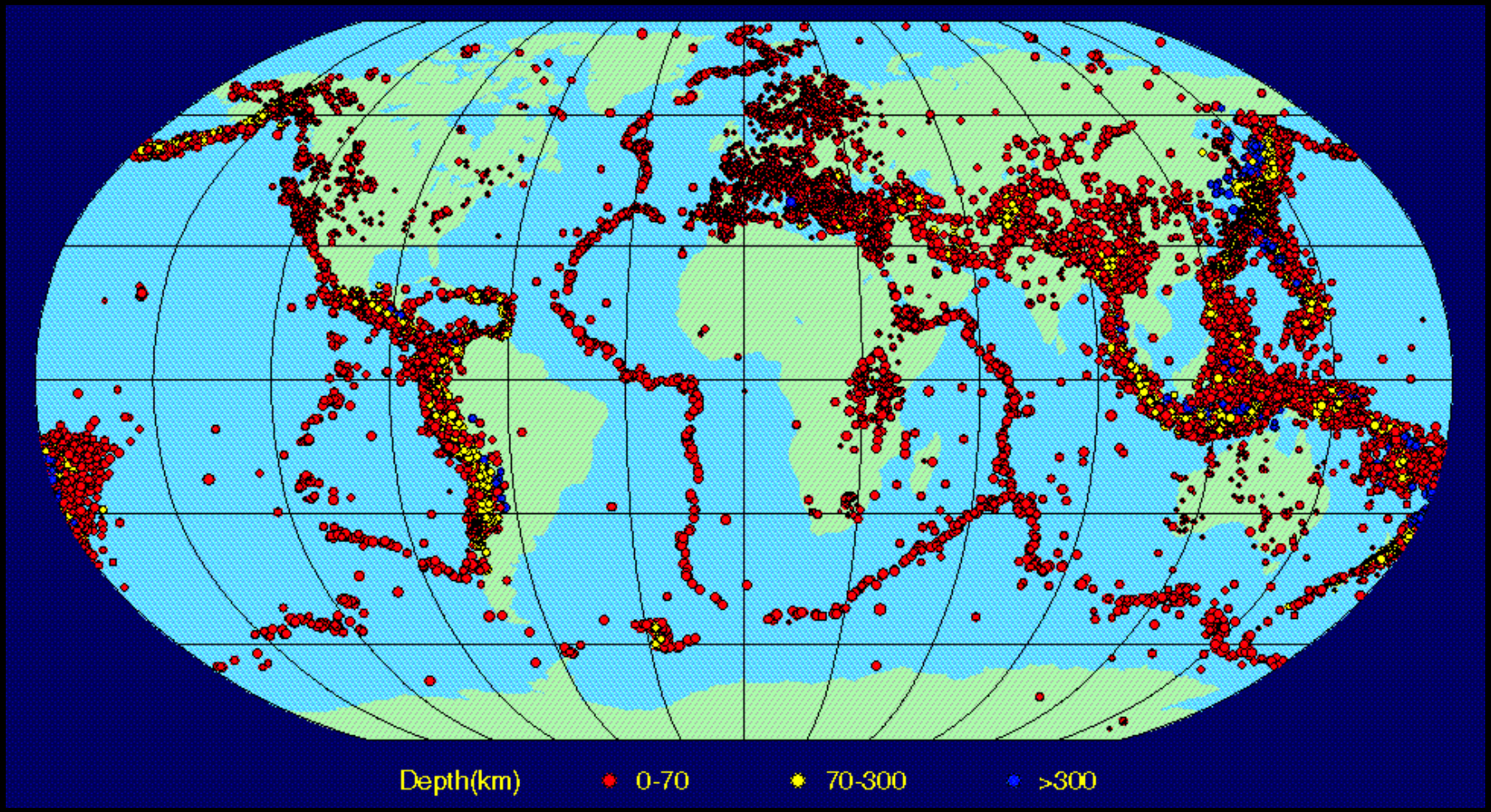
Recent earthquakes that Canada can learn from

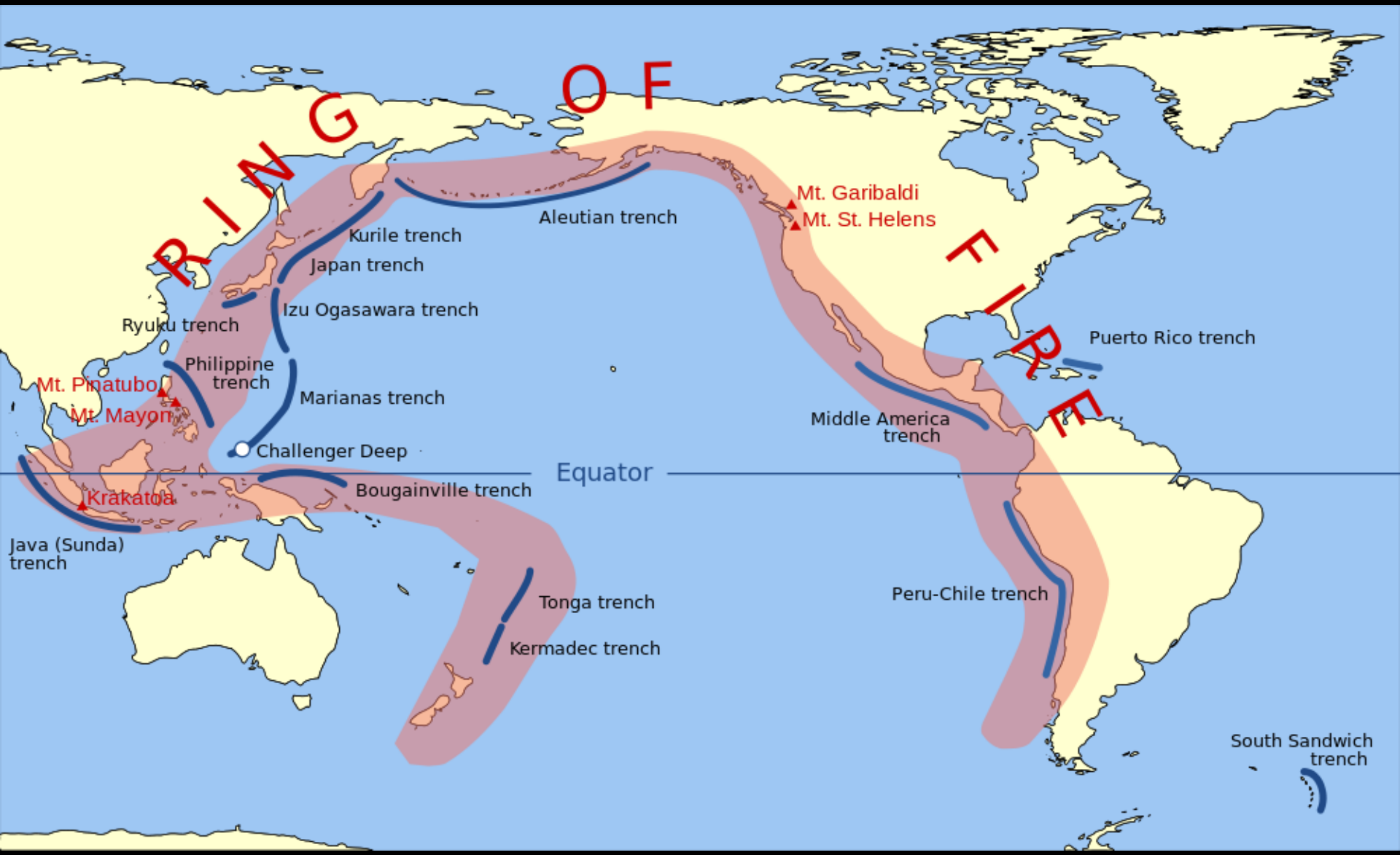
Garry Rogers

Geological Survey of Canada

Global earthquake activity

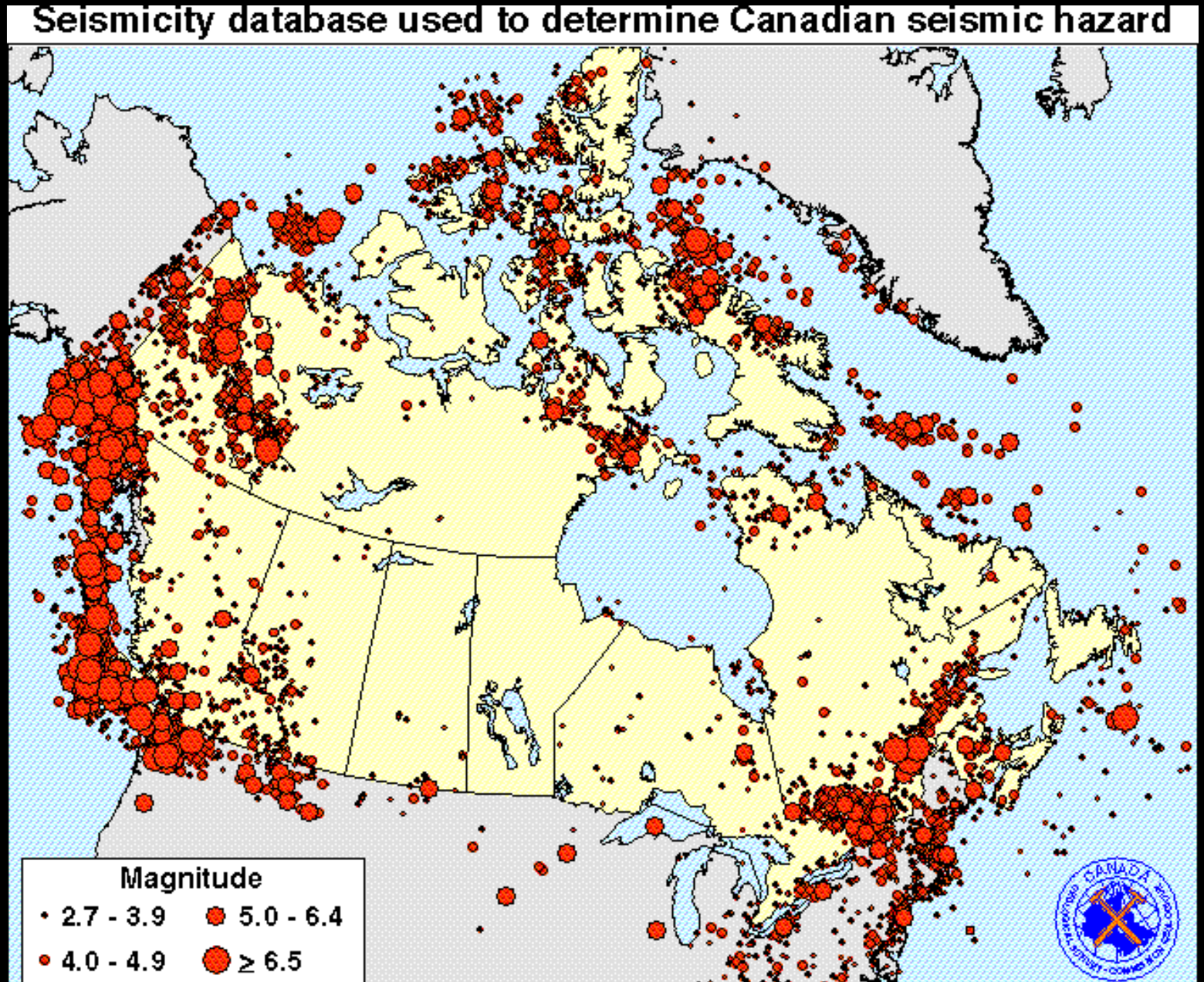


ISC

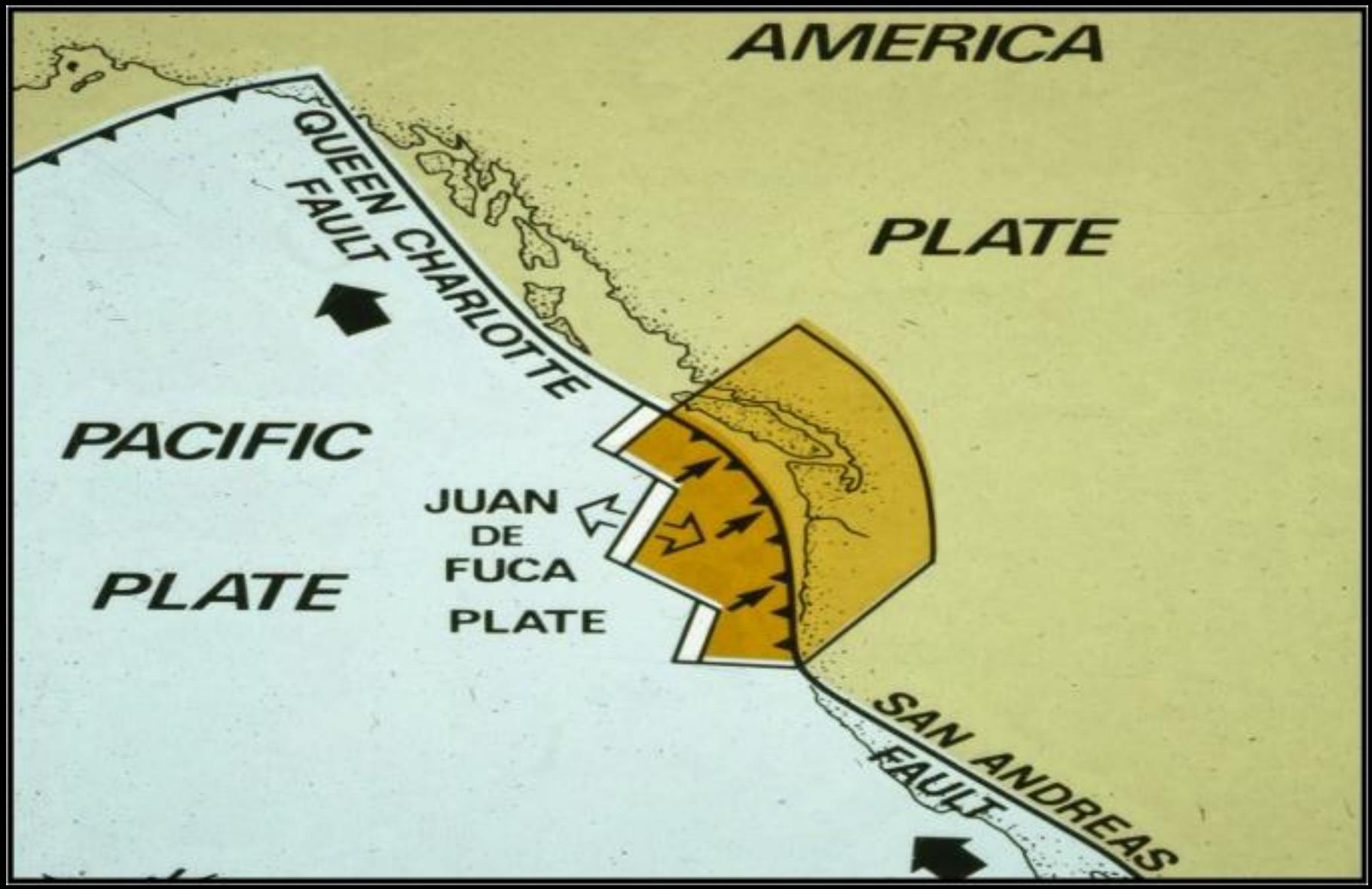

RING OF FIRE
Aleutian trench
Mt. Garibaldi
Mt. St. Helens
Kurile trench
Japan trench
Izu Ogasawara trench
Ryuku trench
Philippine trench
Mt. Pinatubo
Mt. Mayon
Marianas trench
Challenger Deep
Equator
Bougainville trench
Krakatoa
Java (Sunda) trench
Tonga trench
Kermadec trench
Puerto Rico trench
Middle America trench
Peru-Chile trench
South Sandwich trench

Wikipedia

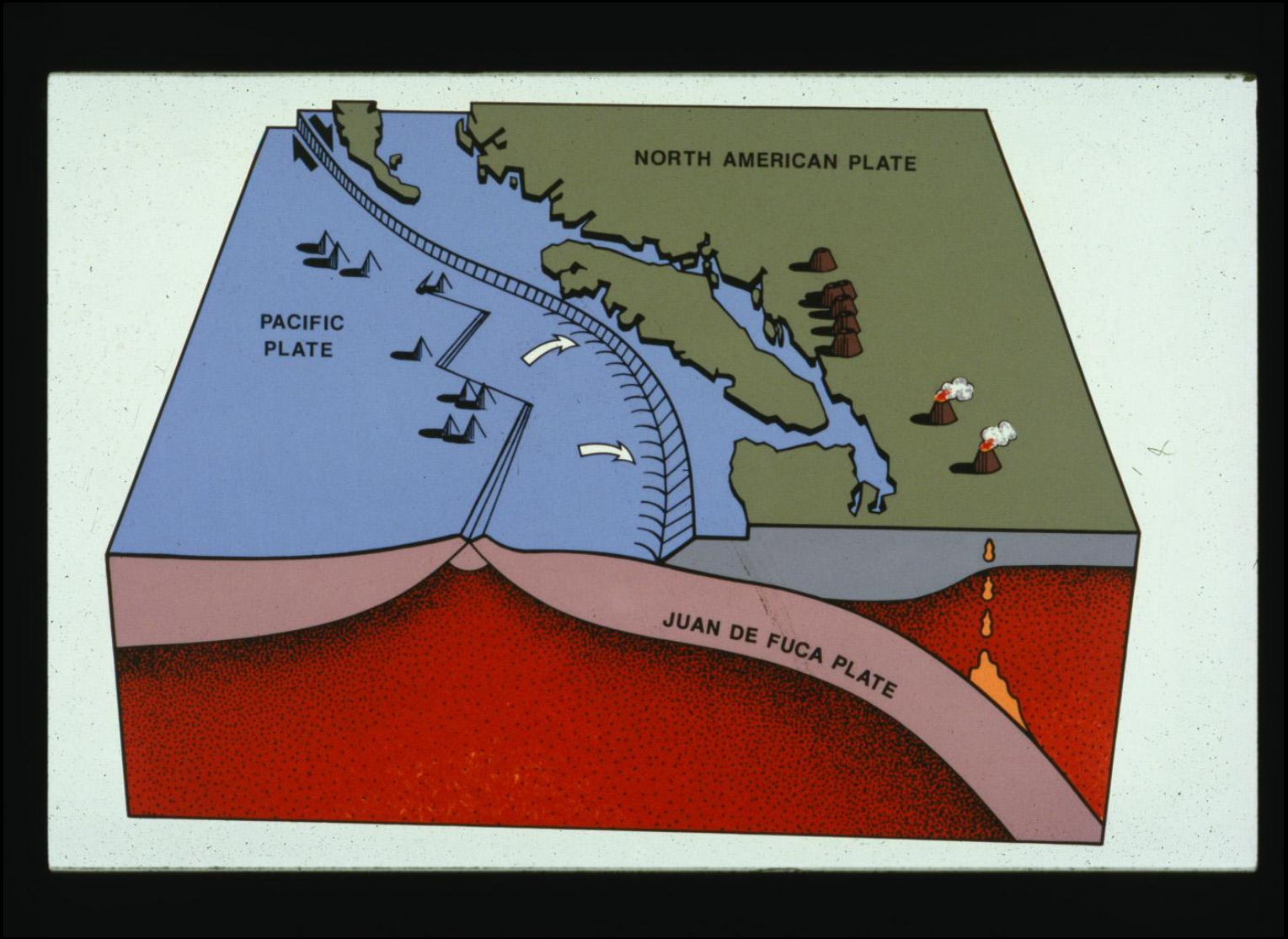
Earthquakes in Canada



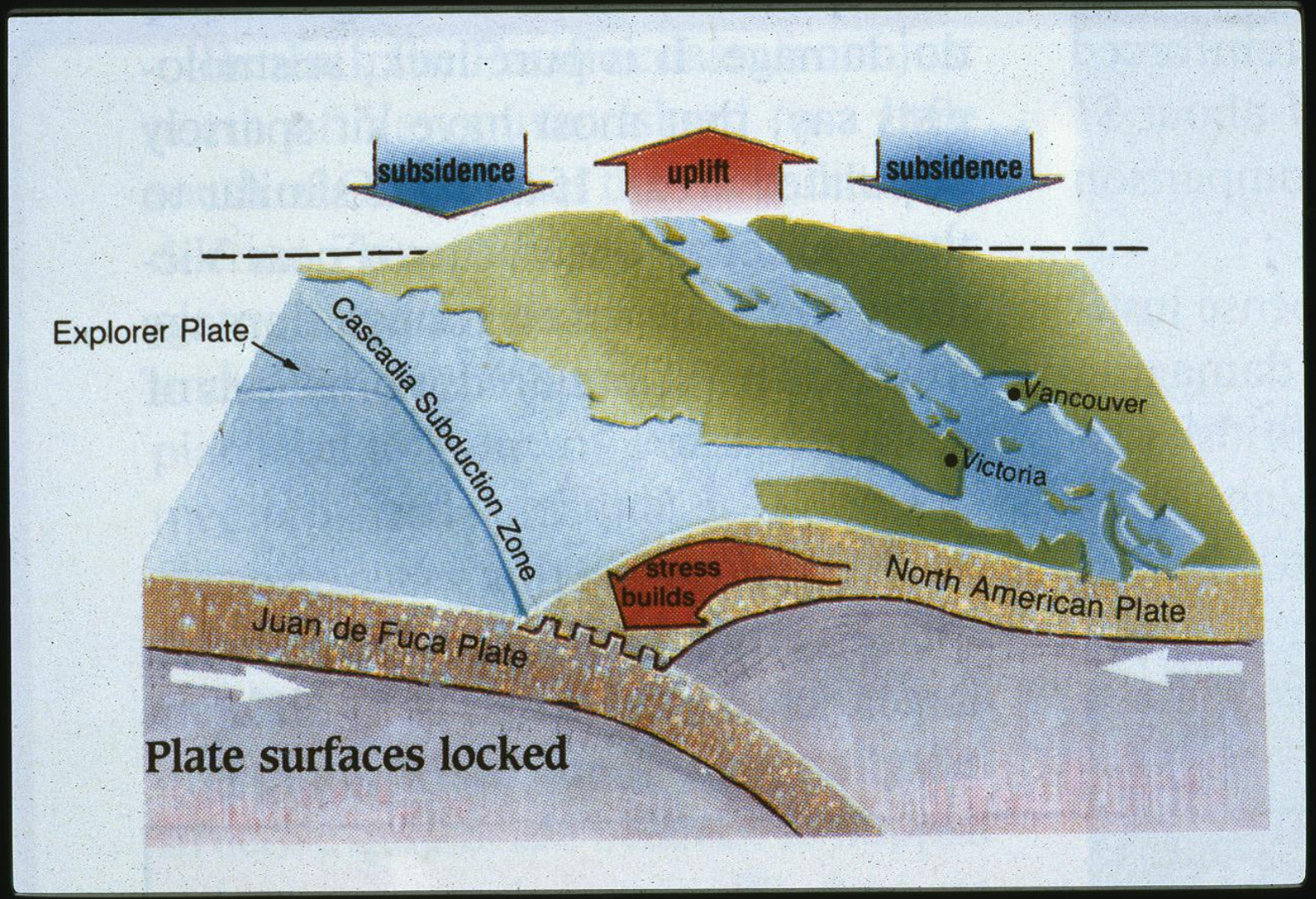
West Coast Plate Motions



Cascadia Subduction Zone

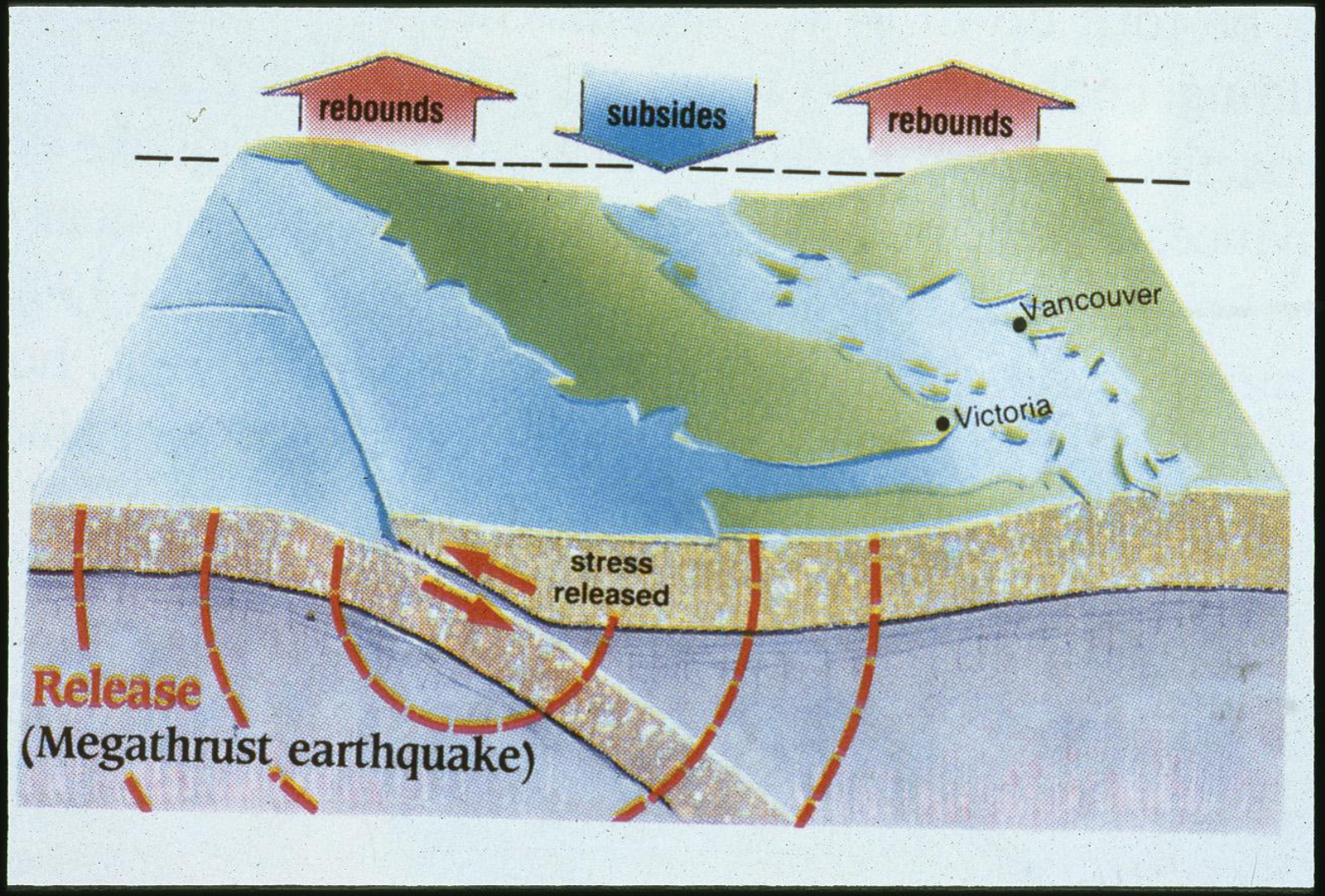


Strain Build-up: Centuries



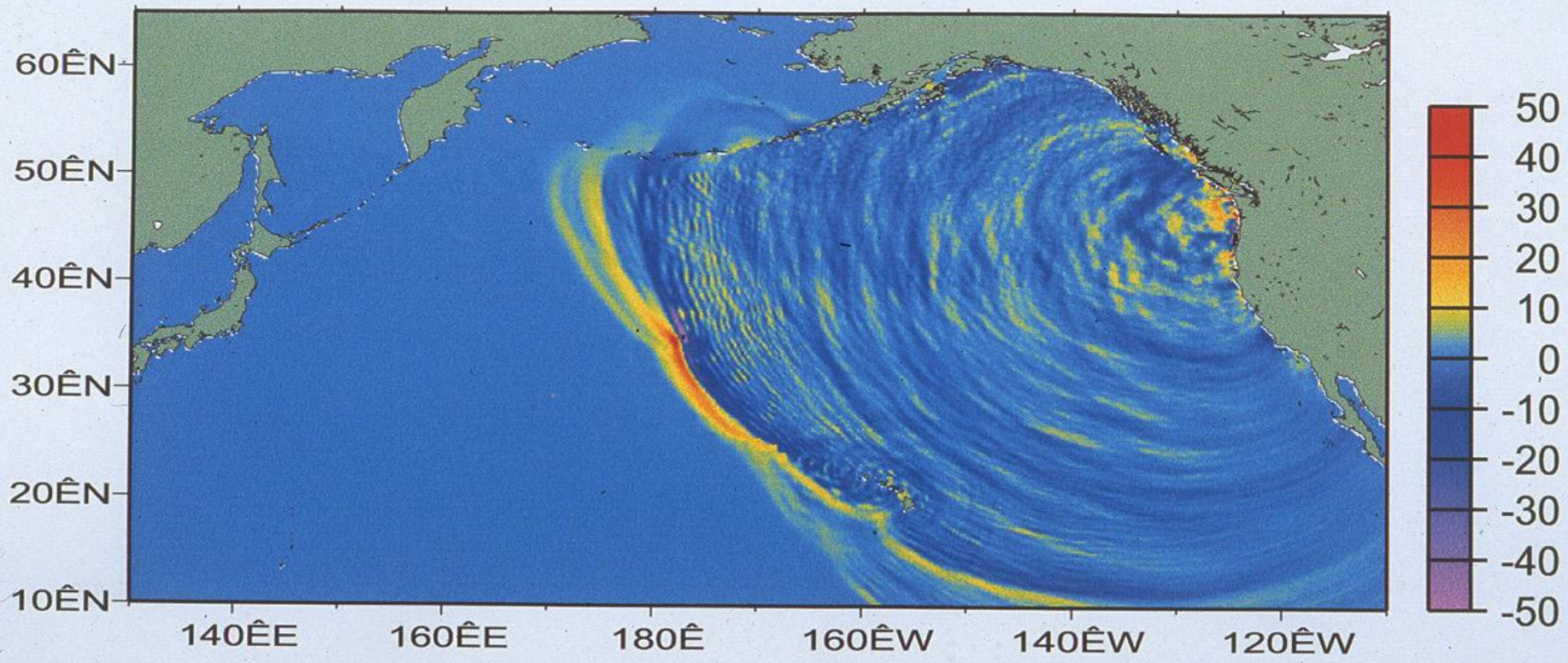
Canadian Geographic

Strain Release: Minutes

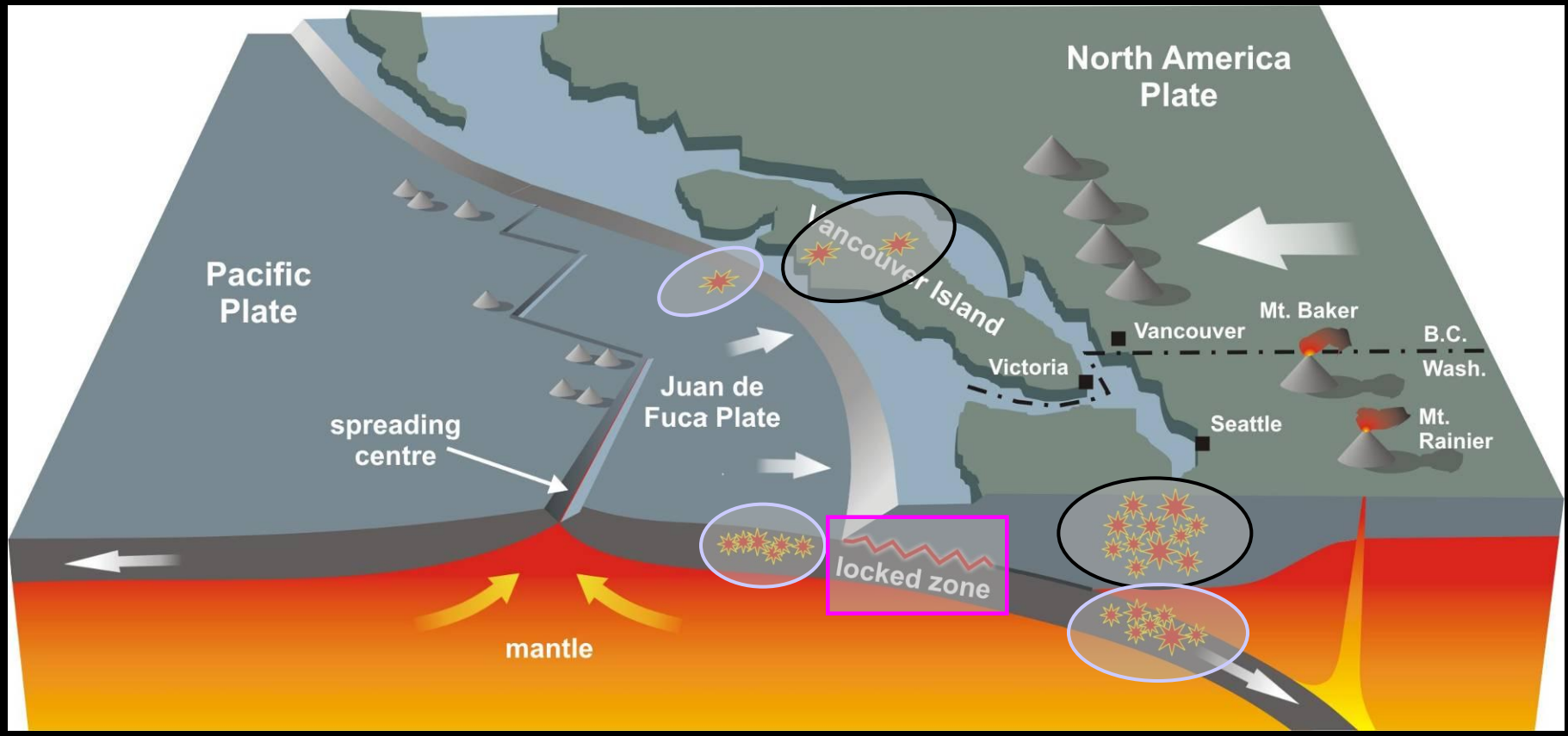


Canadian Geographic

Tsunami of January 26, 1700



Large Earthquakes on the Cascadia Subduction Zone



Megathrust Earthquakes

Crustal Earthquakes

In-Slab (Ocean Plate) Earthquakes

Slide: Herb Dragert, GSC

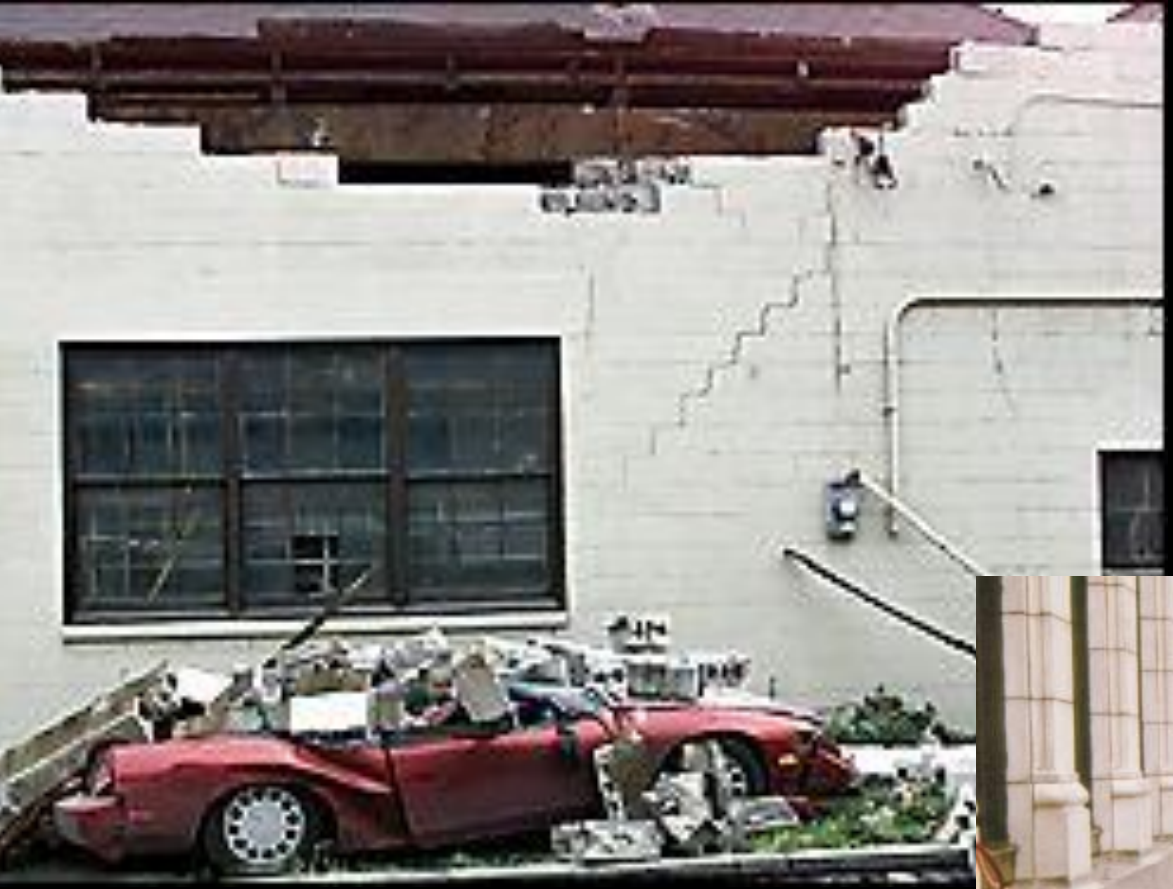
Deep earthquakes

Restricted to the west coast. Most common type of damaging earthquake in the Cascadia region in the last century

Example: Seattle 2001, M=6.8

Damage ~$3.5B

Unreinforced masonry damage



Nisqually 2001

Seattle Times

Slumping failure

Nisqually 2001

Seattle Times

Liquefaction damage

Nisqually 2001

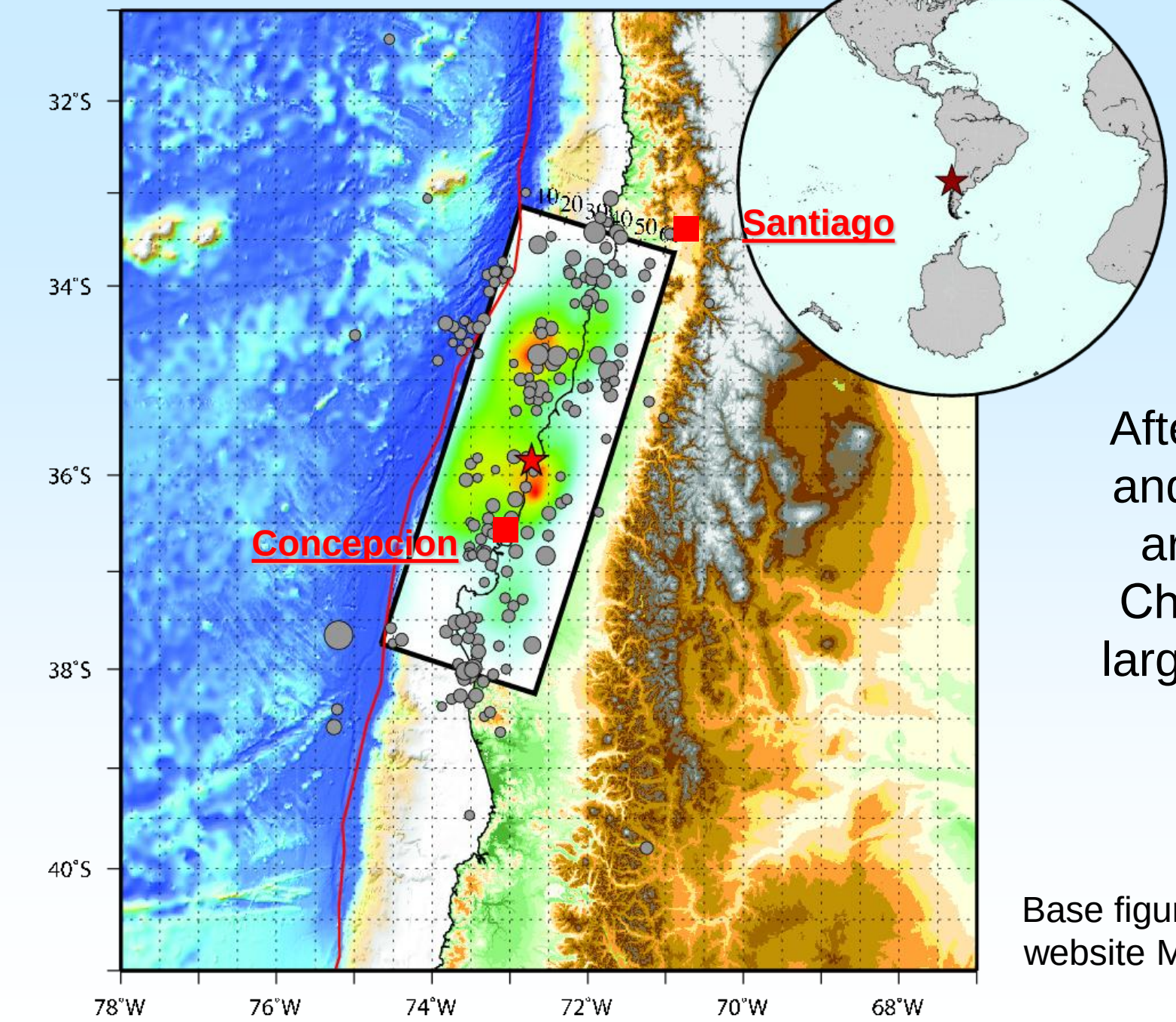
Great Subduction Earthquakes

This kind of earthquake has the most widespread shaking damage and a tsunami is generated

Chile 2010, M=8.8

Chile 2010 Mw=8.8

- $40B damage
- 562 deaths
- Several minutes of strong shaking
- Significant tsunami



Aftershocks and rupture area and Chile's two largest cities

Base figure from USGS website March 26, 2010

Only one high-rise collapse, but many damaged: Building Codes work!

Small wood-frame structures performed well

John Cassidy

Tsunami damage

John Cassidy

Chile 2010 Mw=8.8 random observations

- Damage very widespread
- Public tsunami education worked very well
- **Unreinforced masonry** a problem (esp. adobe)
- Retrofitted URM did well
- Earthquake science understanding was good
- Building codes work!
- Internet survived very well

Shallow earthquakes

The most damaging type of earthquake:
very strong shaking close to the source

Can occur in **any** earthquake region of Canada

- Christchurch, 2011 M=6.1

Christchurch Mw=6.1

- 12:51 pm, sunny day, summer
- 10 seconds of VERY strong shaking
- Within 5km of downtown, very shallow
- $20B damage
- 182 dead
- Population ~370,000 (Victoria ~350,000)
- Similar building codes

Christchurch Central Business District (CBD)

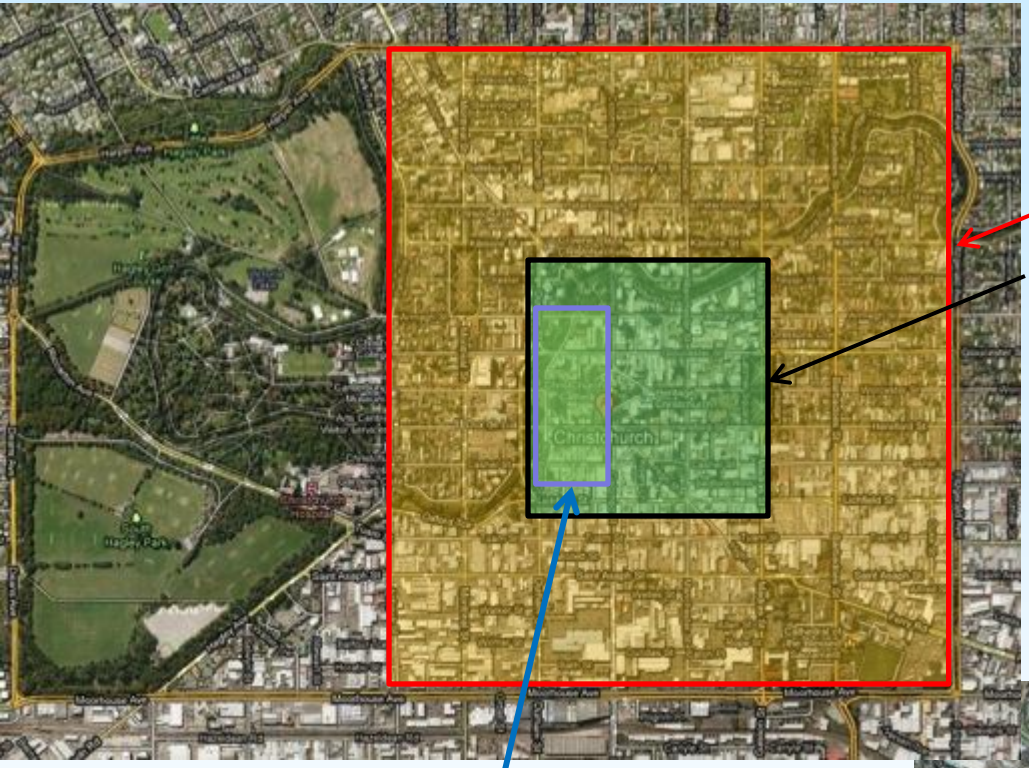
Christchurch:

- Pop. = 370,000
- 2nd largest in NZ

CBD:

- Approx. 6,000 companies or institutions with over 50,000 employees.
- 25% of the total employment in the city.

CBD – Cordon (114 Square Blocks)



Cordon in February 2011

Cordon in one year later

Cordon April 2013

Cordon Finally lifted
June 28, 2013

After 2 ½ years!


Christchurch: dust from collapsing buildings
Gillian Needham


connect.in.com


ester St

About 40 high-rise buildings have serious structural problems


Pyne Gould (1963)
Connect.in.com


FED338


KATO
LUND
POLICE
POLICE
30
OXFORD
TERRAC

Liquefaction / Differential Settlement

- Structure okay, but…
- Can it be fixed?
- How?


CJH942

Building contents damage


Debris: what to do with it?

Christchurch Mw=6.1 random observations

- Serious damage very localized
- Shaking exceeded probabilistic design levels
- **Unreinforced masonry** a problem
- Retrofitted URM did well
- Building codes work!
- Near surface liquefaction can be very costly
- Access to downtown **absolutely** denied for weeks
- Internet survived very well

Selected Impacts

- 182 deaths
- >6500 injuries
- Loss of ~70% heritage structures
- ~50% of downtown buildings to be demolished
- Close of downtown core for two and one half years
- >7500 homes to be demolished, neighborhoods eliminated
- Over 4.5M tons of demolition debris & liquefaction ejecta
- Outmigration (>9,000 permanent?)
- ~$20 Billion in losses → ~10% of GDP

Haida Gwaii 2012
M = 7.7

- Minimal damage (low-rise wood frame structures- closest 50km)
- No deaths, no injuries
- Significant tsunami localized to the west coast

Haida Gwaii

(Islands of the people)

Formerly the Queen Charlotte Islands

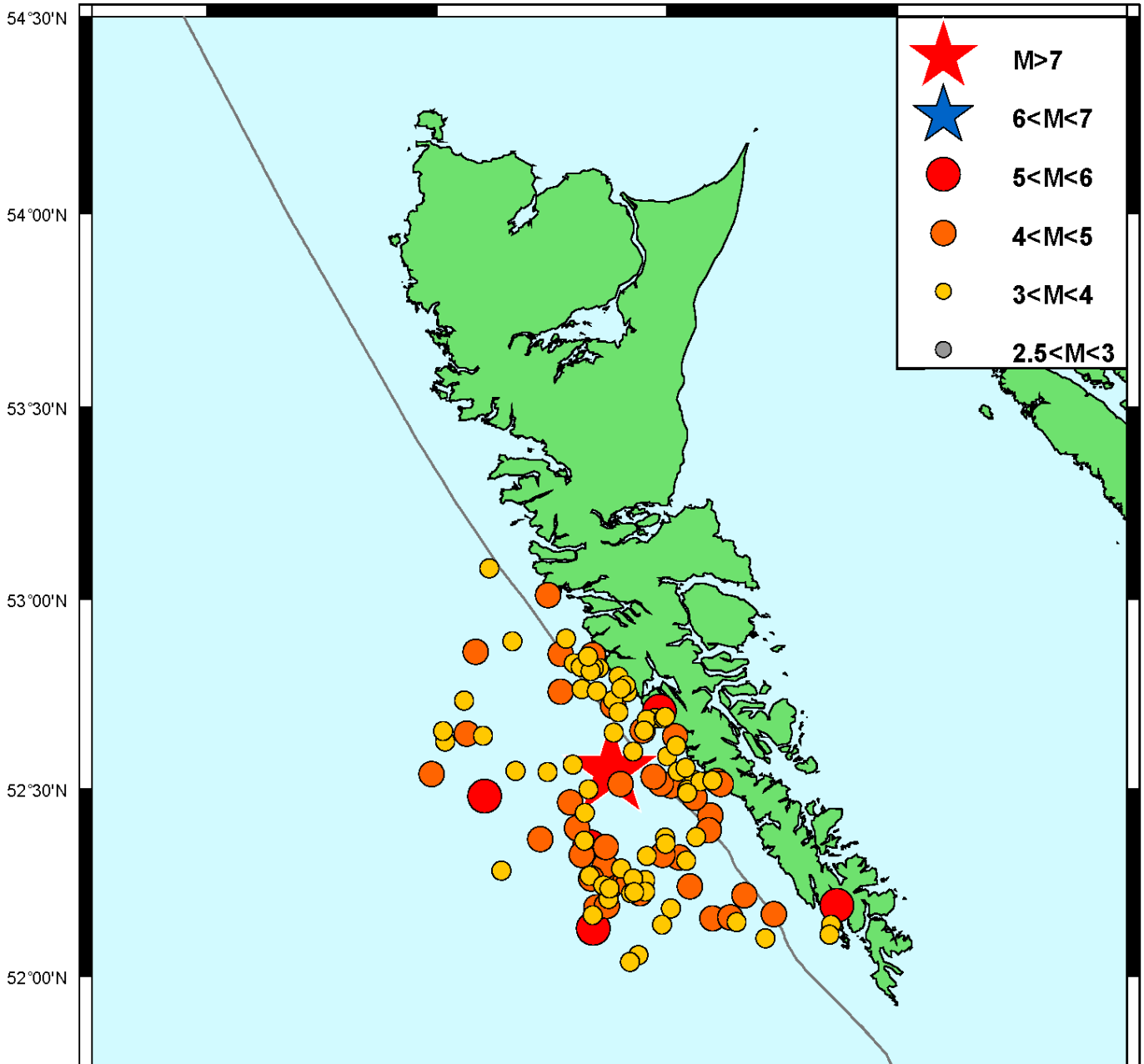
Population ~4000

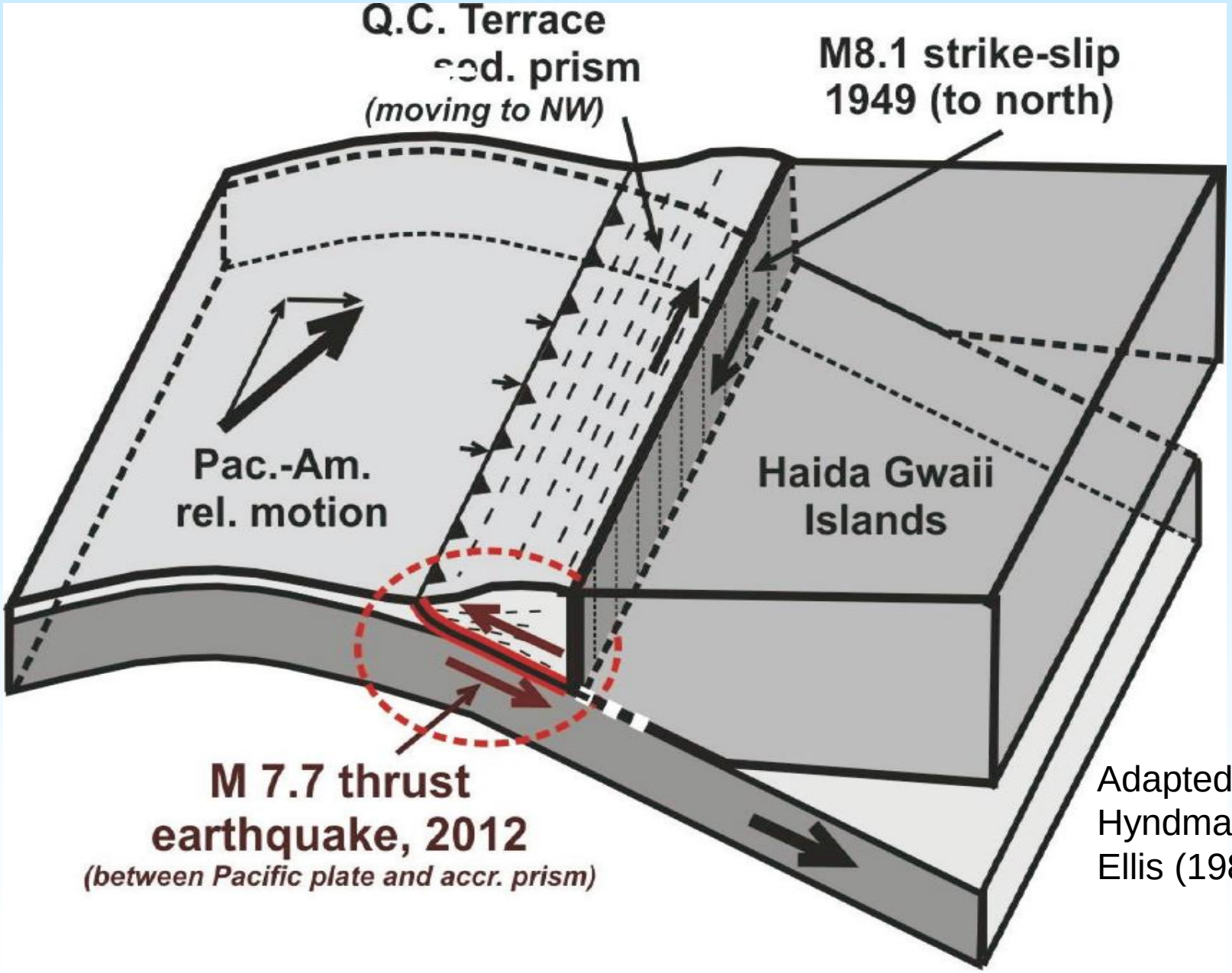
Mostly on Graham Island

Moresby Island unpopulated except for Sandspit – southern half is National Park Reserve

Canada

October 28 – December 31, 2012 M3.0+ Analyst Located HG Aftershocks

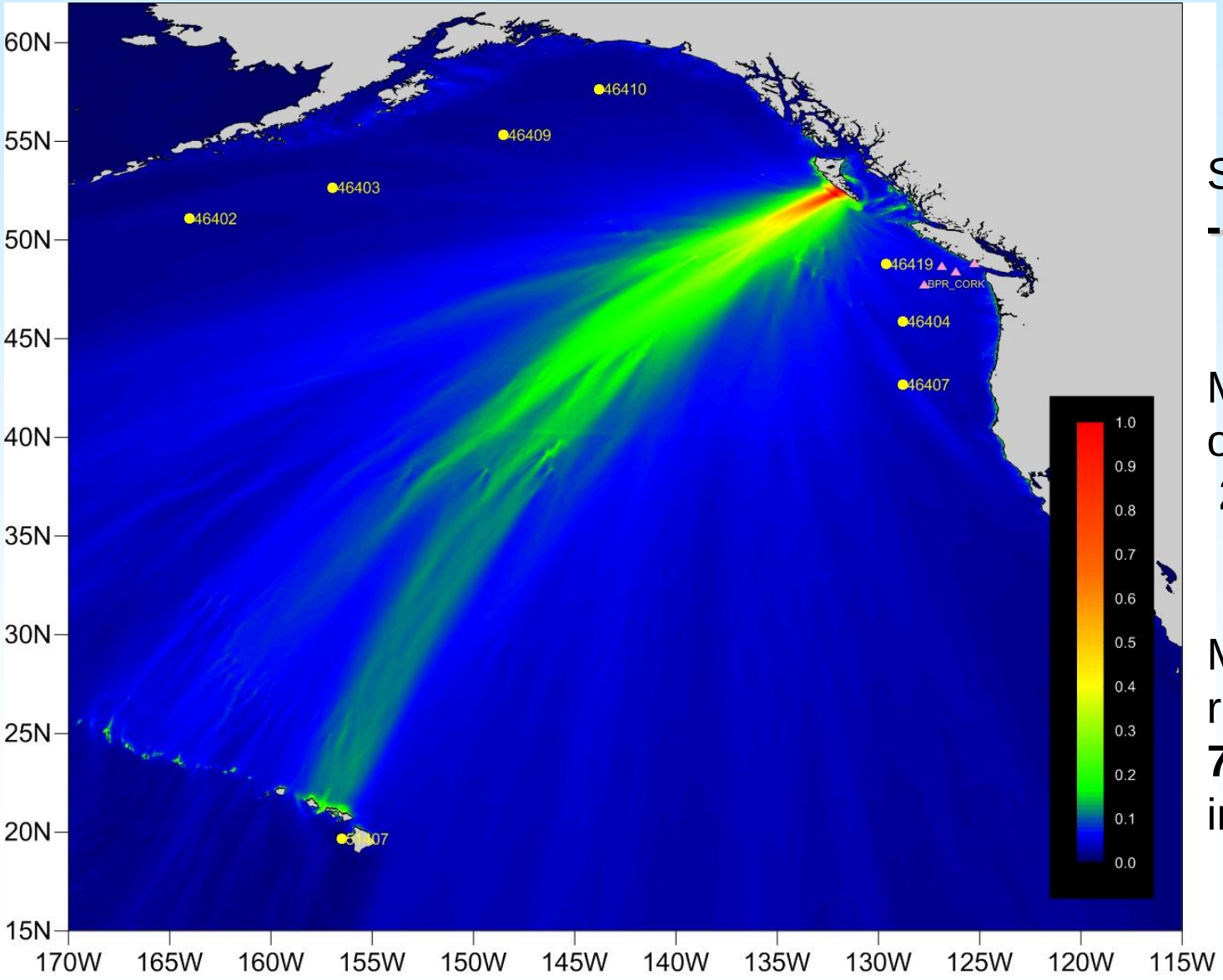




Adapted from Hyndman and Ellis (1986)

Oblique convergence is partitioned into thrust and strike-slip faults

Tsunami Model (by Issac Fine at Institute of Ocean Sciences, DFO)



State of the tide
-2m

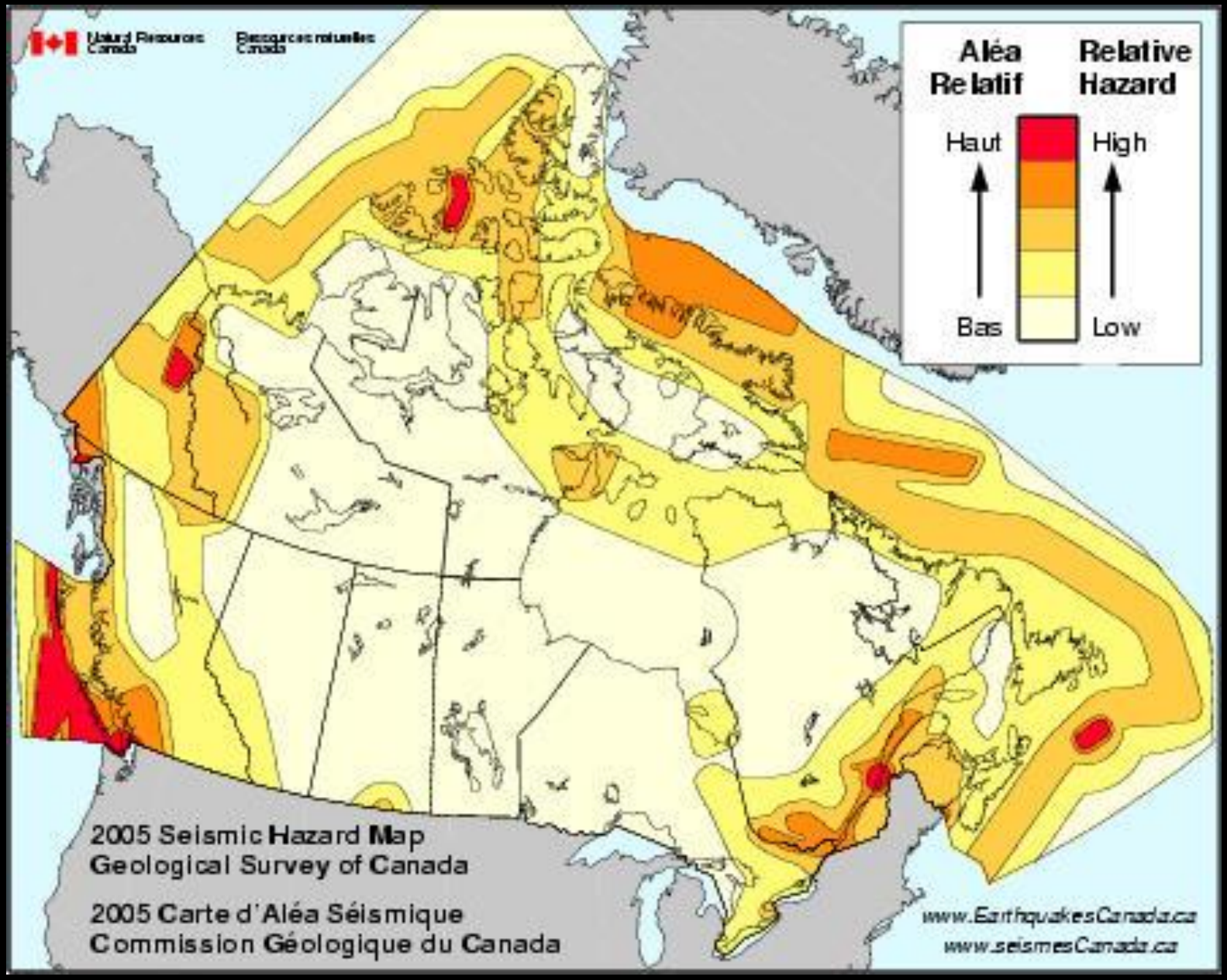
Modelled wave on outer shore
2-3m

Measured run-up
7m+ in some inlets

Haida Gwaii October 27, 2012
M = 7.7

- Minimal damage (low-rise wood frame structures- closest 50km)
- No deaths, no injuries
- **Significant** tsunami localized to the west coast of Haida Gwaii. 7meters in many places,m aximum 13meters.

Building Code Seismic Hazard Map: 2010



2015 hazard map nearing completion