Earthquake Risk in Canada and the National Building Code

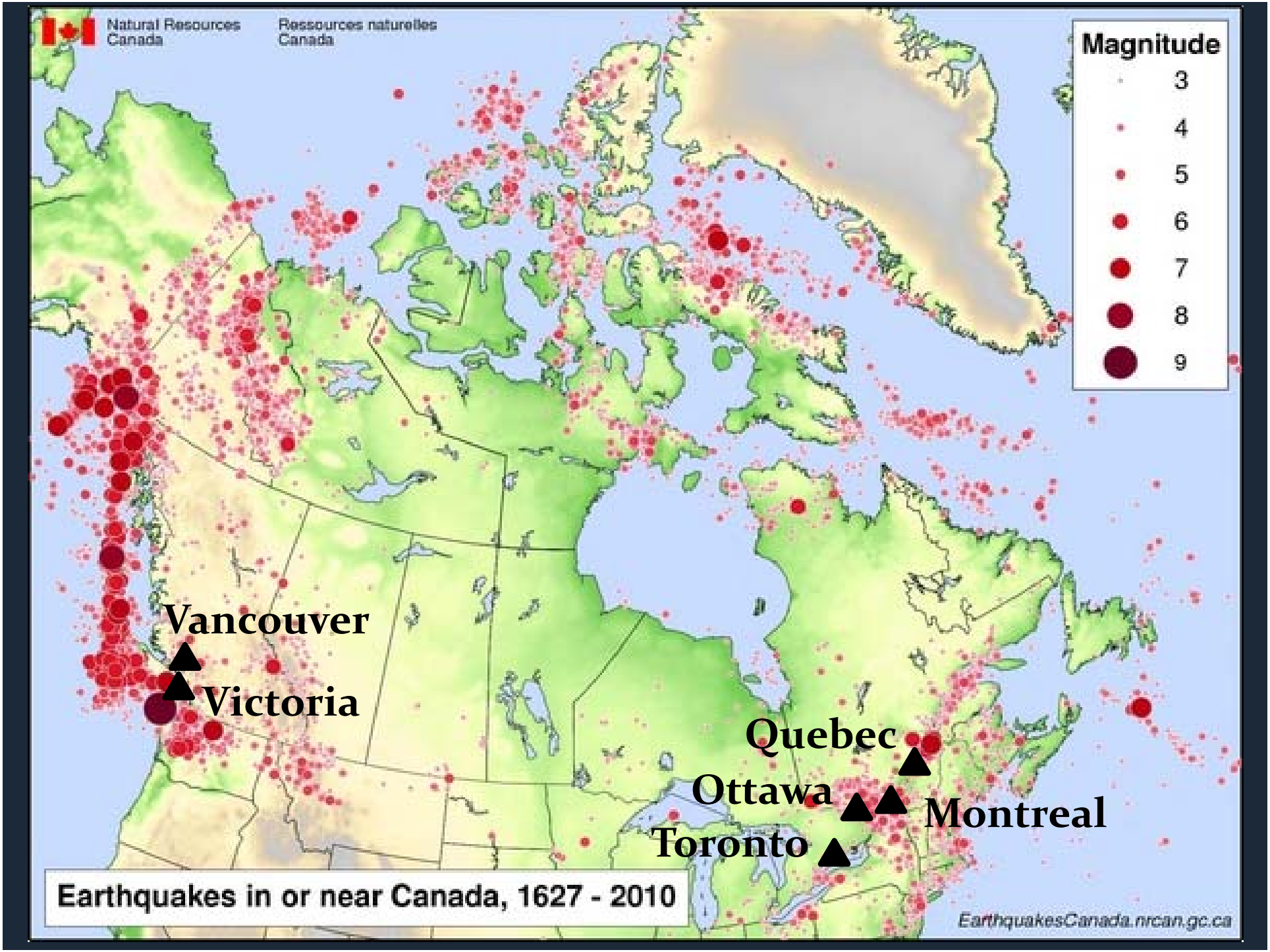
Tuna Onur, Ph.D.

Catastrophe Risk Consultant

ICLR, Toronto, ON
20 January 2012

Outline

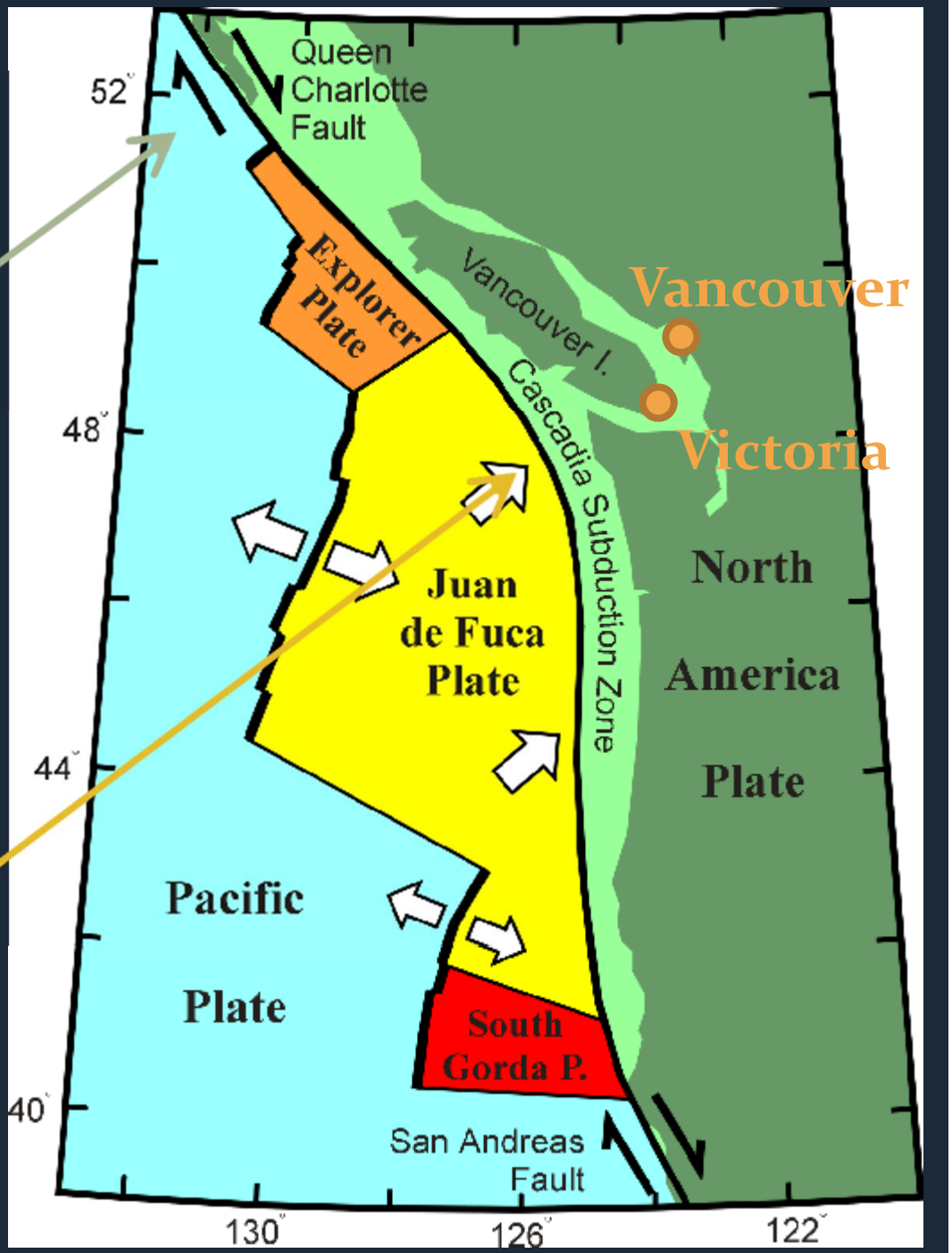
- Earthquake risk in Canada
- Uncertainties in risk models
- Seismic provisions of the National Building Code of Canada
- Recent earthquakes around the world


Natural Resources Canada
Ressources naturelles Canada
Magnitude
3
4
5
6
7
8
9
Vancouver
Victoria
Quebec
Ottawa
Montreal
Toronto
Earthquakes in or near Canada, 1627 - 2010
EarthquakesCanada.nrcan.gc.ca

Western Canada: Identified Faults

Queen Charlotte Fault

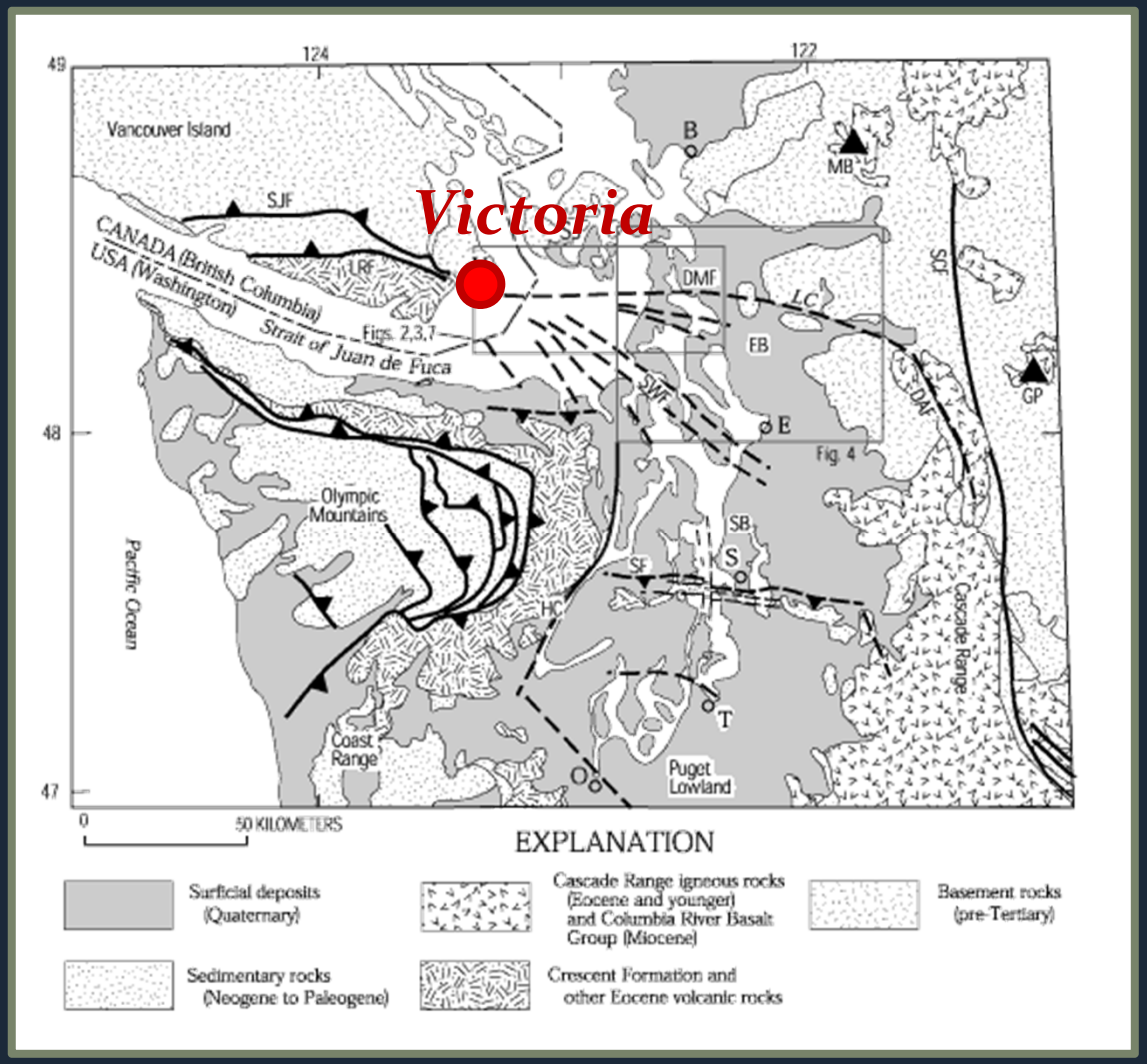
Cascadia Subduction Zone



Source: http://earthquakescanada.nrcan.gc.ca

Other Crustal Faults?

- We don't know!



U.S. Geological Survey Professional Paper 1643

To include a fault in risk models…

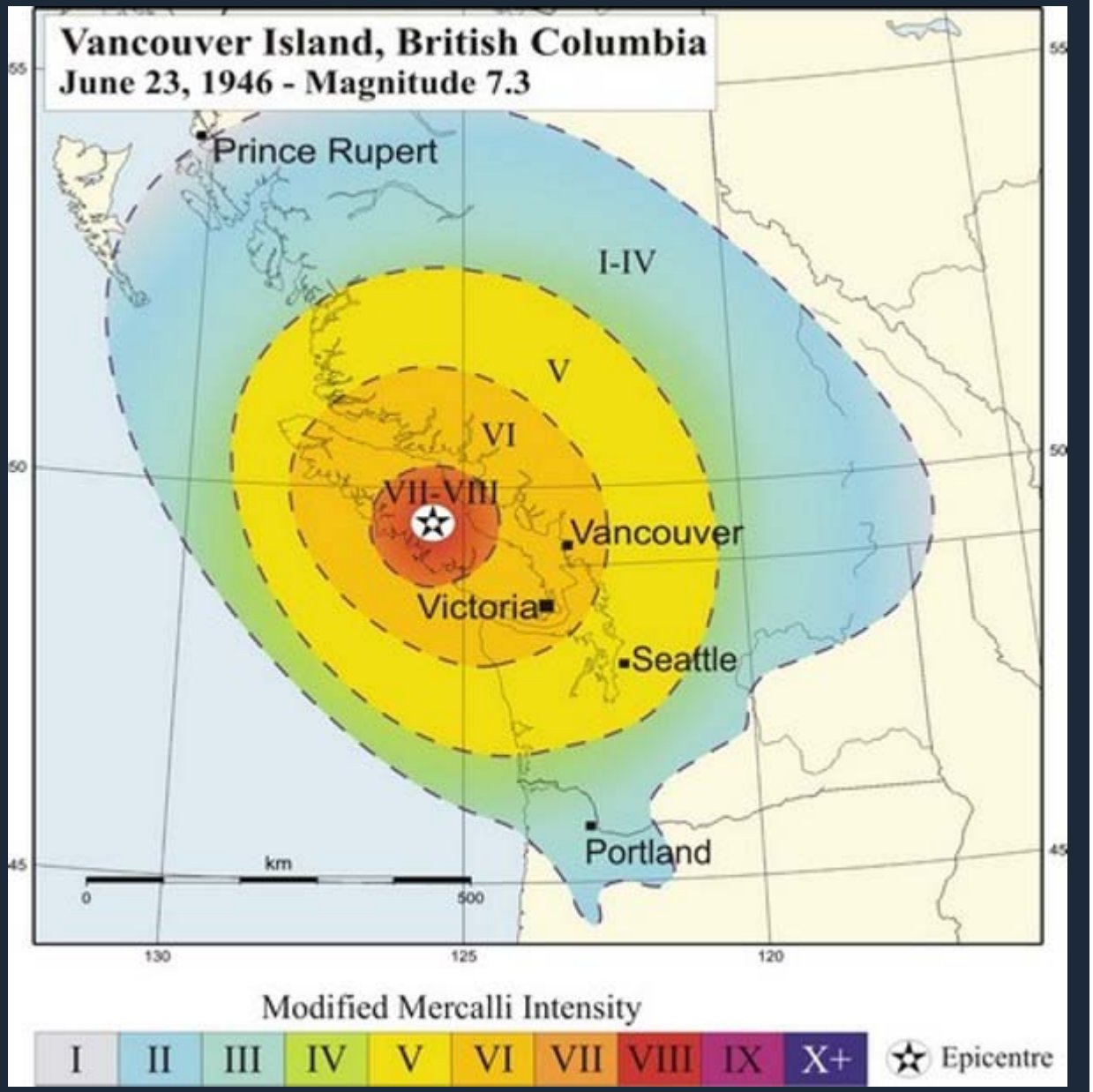
We need to know:

1. Geographic location and geometry of the fault
2. Whether it is active
3. Recurrence rate of earthquakes on the fault

1946 Vancouver Island Earthquake, M7.3

MMI VI

- Damage slight in poorly built buildings.
- Fall of plaster in small amount.
- Fine cracks in chimneys in some instances.
- Broken dishes, glassware in considerable quantity, also some windows.



Source: http://earthquakescanada.nrcan.gc.ca

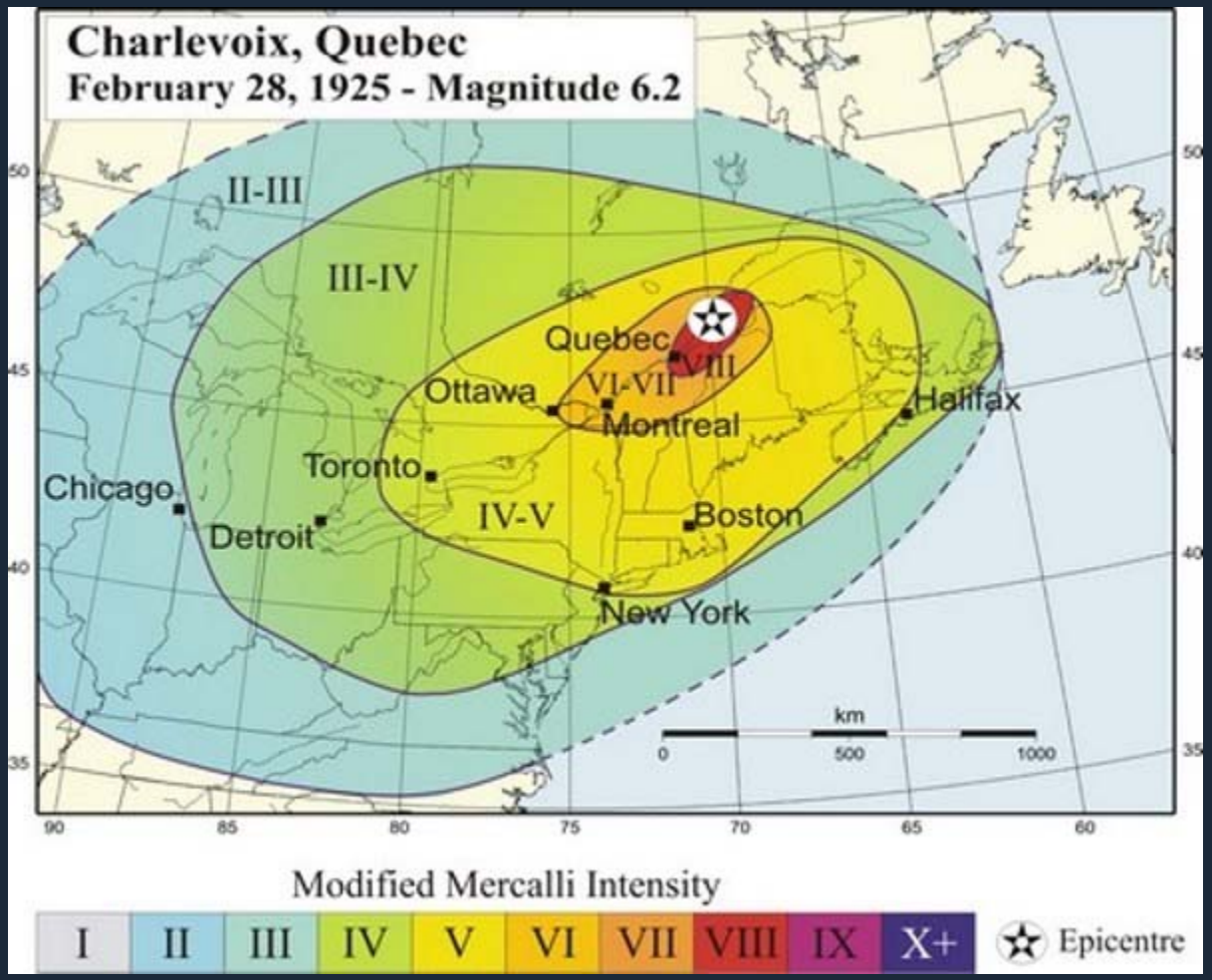
Eastern Canada:
Not near a plate boundary, BUT...

- 1663 M7 Charlevoix Earthquake:
  - Damage in Quebec City and Montreal
- 1732 M5.8 Montreal Earthquake:
  - Considerable damage in Montreal
  - ~300 buildings damaged, ~185 dwellings destroyed by fire following the earthquake
- 1925 M6.2 Charlevoix Earthquake:
  - Damage in Quebec City, including port facilities
- 1988 M5.9 Saguenay Earthquake:
  - Damage in Quebec City and Montreal-East.

1925 Charlevoix Earthquake, M6.2

MMI VII

- Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings
- Cracked chimneys to considerable extent, walls to some extent.



http://earthquakescanada.nrcan.gc.ca/historic-historique/events/19250301-intsi-eng.php

Earthquake Hazard (1)

1. Earthquake occurrence (source model)
   - Where?
   - How big?
   - How often?

Completeness

Faults
- Slip rates

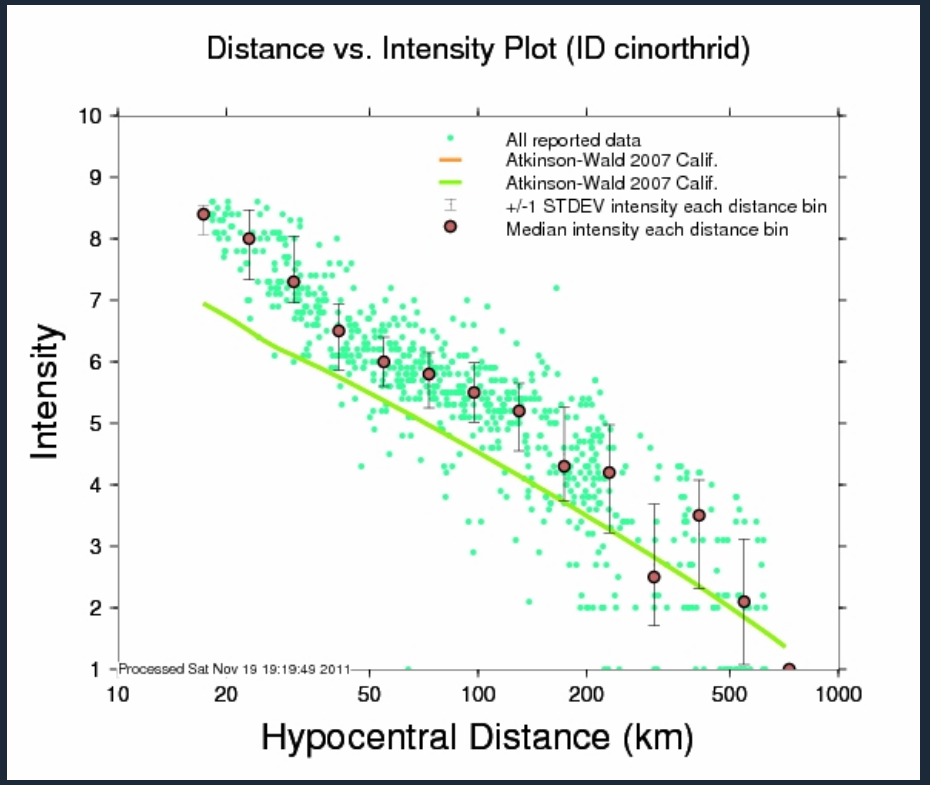
Seismic Catalogues
- Instrumental (~1900)
- Historical (~1600)

Paleoseismology

Earthquake Hazard (2)

2. How seismic waves propagate to sites of interest (ground motion attenuation)
   - Magnitude
   - Distance
   - Fault type
   - Site conditions

Scatter in data



Near-surface Geology

- Soil amplification
  - Amplitude
    - Frequency content
- Liquefaction
- Landslides

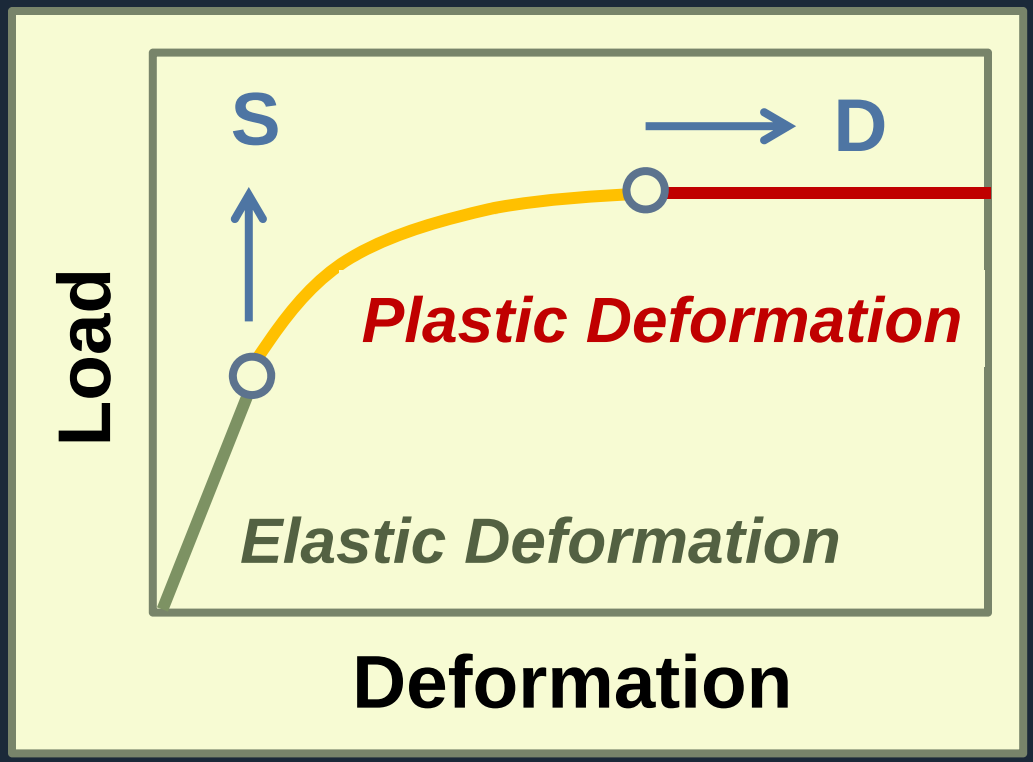
What is under the surface?

Source: Turner et al. (1996). Geoscape Vancouver. Geological Survey of Canada Open File 3309.

Building characteristics (1)

- What is it made of? Concrete, wood, etc.
- Load bearing system? Frame, wall, etc.
- How tall?

- Strength
- Ductility
- Natural Period (or Frequency) of Vibration



Building Characteristics (2)

- How old?
  - Building codes
    - Seismic provisions?
    - Strength
    - Ductility
  - Construction practices
    - Techniques and equipment used in construction
    - Quality of detailing
  - Deterioration
    - Maintenance?

Building characteristics (3)

- Soft storey?
- Seismically retrofitted?
- Base isolation or any other passive or active vibration control systems?
- Primary use? Commercial, residential, industrial, etc.
- Pounding?
- Shape?

Large variability
in building response

Which Uncertainty?

Aleatory?

Primary?

Epistemic?

Secondary?

How about by peril?

"Earthquake dominates in the west and weather perils in the east"

Yes, if you consider mean loss at short return periods with secondary uncertainty.
How about primary uncertainty?

Further Considerations

- Damage to non-structural elements (~75% of bldg cost)
- Damage to contents and time-element losses
- Indirect and non-modeled losses
- Treatment of uncertainty
- Correlation

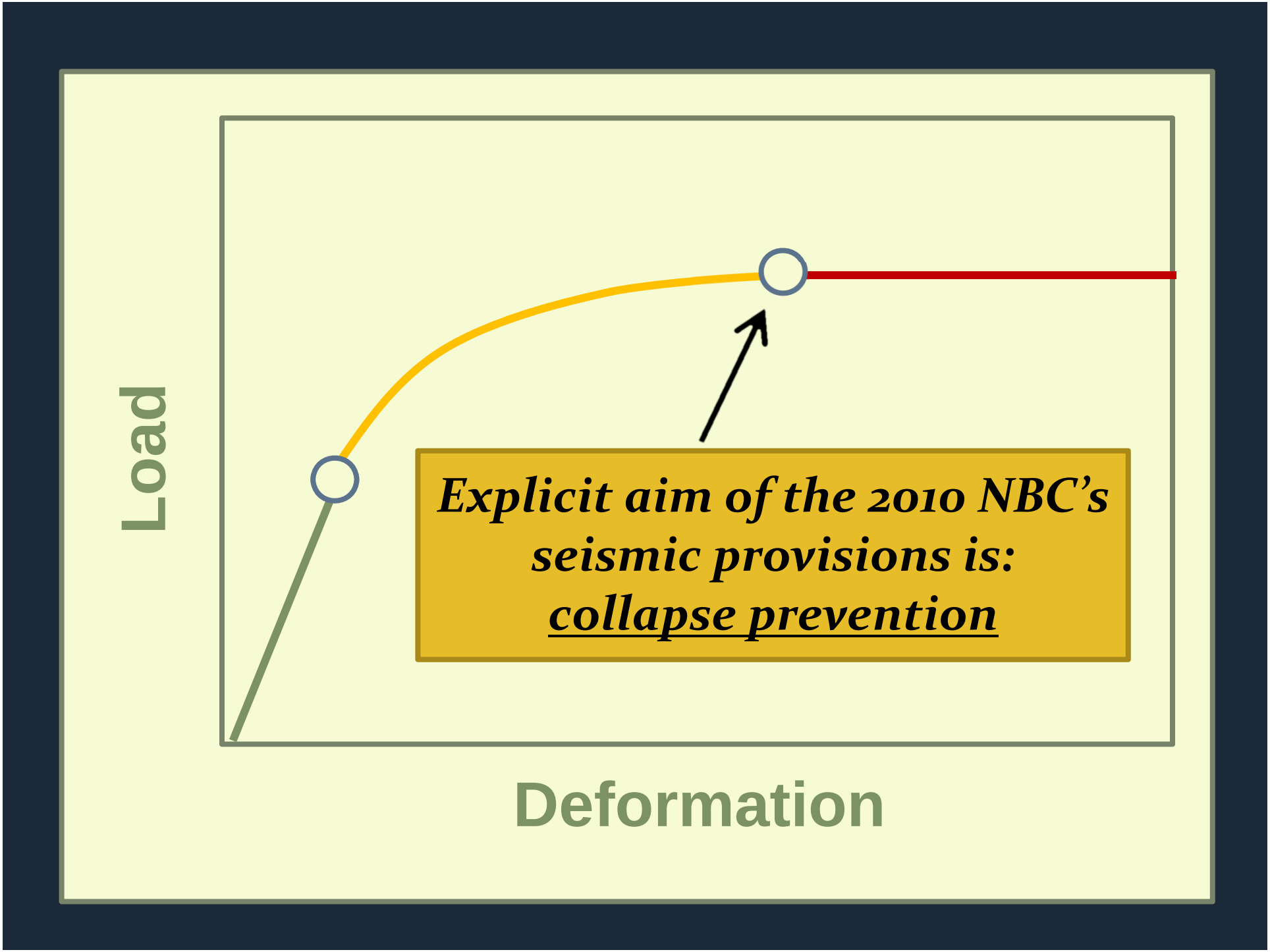
Building Codes in Canada

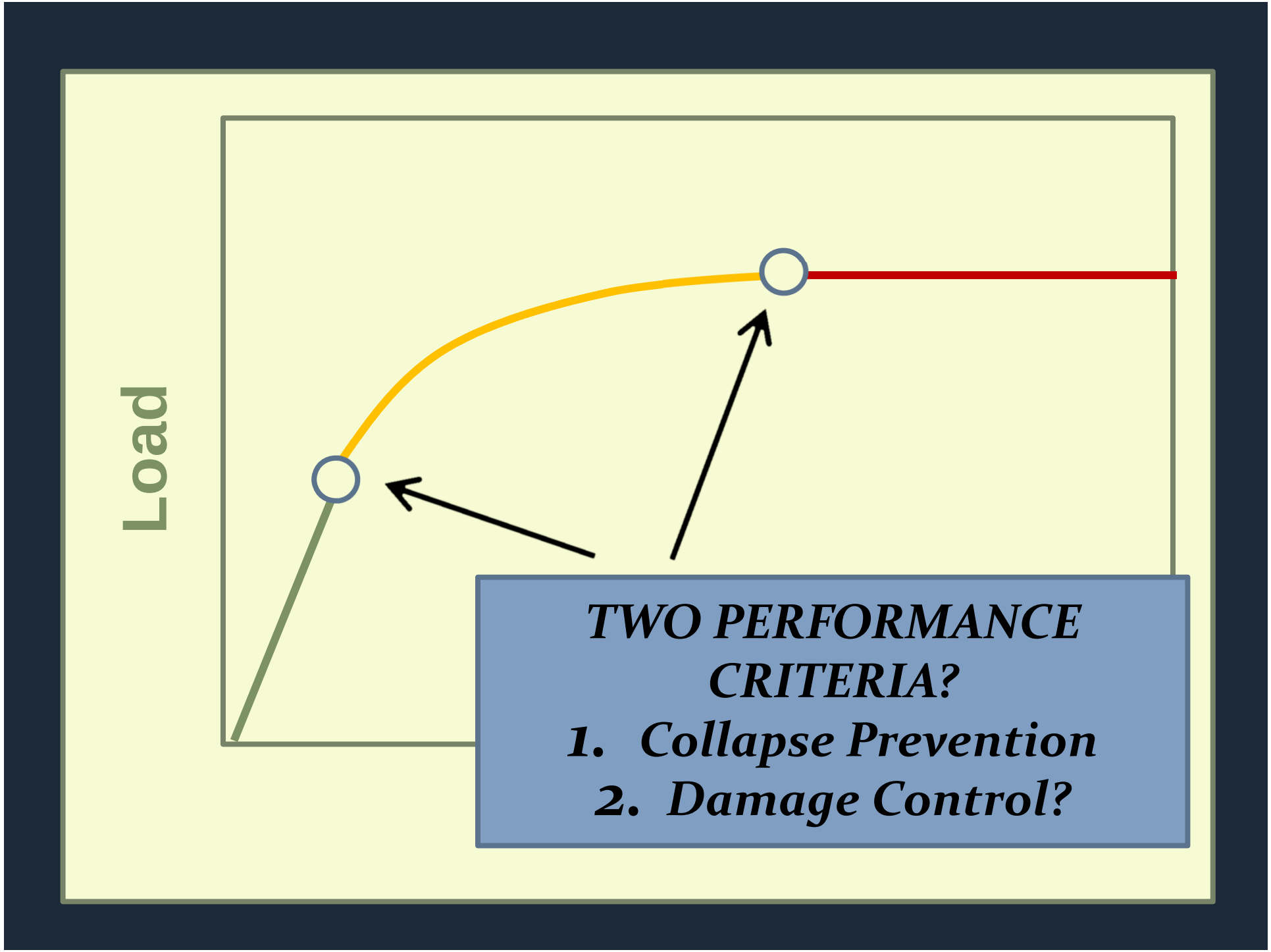
- **National Building Code (NBC) of Canada** is a "model building code"
  - Issued by the National Research Council of Canada
  - Each province in Canada either uses it as a base or adopts with modifications or supplementary requirements

NBC (2005)

BCBC (2006)

VBBL (2007)


Load
Deformation
Explicit aim of the 2010 NBC's seismic provisions is:
collapse prevention


Load
TWO PERFORMANCE CRITERIA?
1. Collapse Prevention
2. Damage Control?

Wood-frame Construction in Canada

- Seismic provisions are **NOT** mandatory for wood-frame buildings that are 3 storeys or lower and have footprint area less than 600 m^2
  - Majority of single-family homes
  - Significant portion of multi-family apartment buildings

Single-family wood-frame

- Common practice: Use of horizontal boards from concrete foundation formwork as first-storey walls
- Many not anchored to their foundations

Photos courtesy of World Housing Encyclopedia and Dr. G. Taylor

Multi-family wood-frame

- Multi-family apartment buildings that are 3 storeys or lower and have footprint area less than 600 m^2
- “Tuck-under” parking on the ground floor


1994 Northridge Earthquake

1989 Loma Prieta Earthquake

1989 Loma Prieta Earthquake

High-rise Construction in Canada

- Coupled shear walls
  - Pioneered by engineers in New Zealand; particularly common in western Canada
  - Significant proportion of high-rises in Vancouver
  - Superior performance when detailed properly

Design Aspects of Shear Walls for Seismic Areas[1]

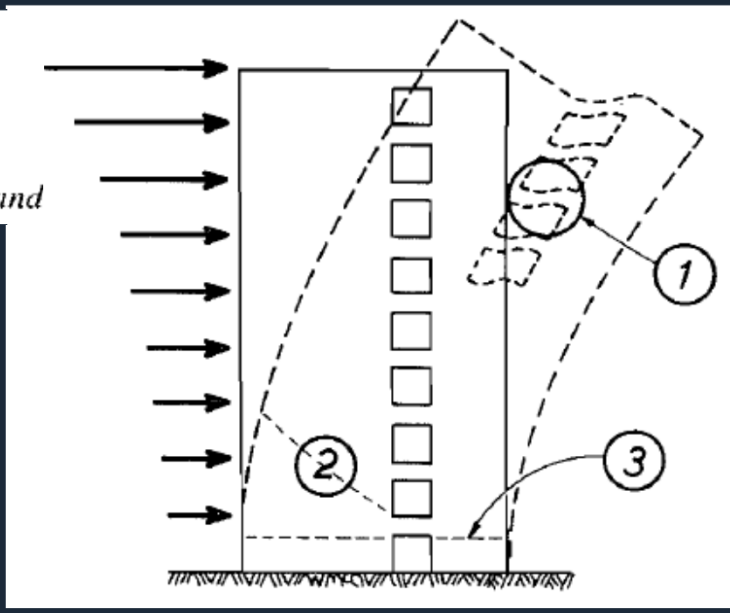
THOMAS PAULAY[2]

Department of Civil Engineering, University of Canterbury, Christchurch, New Zealand

[1]Presented at the 2nd Canadian Conference on Earthquake Engineering, McMaster University, Hamilton, Ontario, June 5–6, 1975.

[2]Visiting Professor, University of Toronto, Toronto, Ontario.

Can. J. Civ. Eng., **2**, 321 (1975)

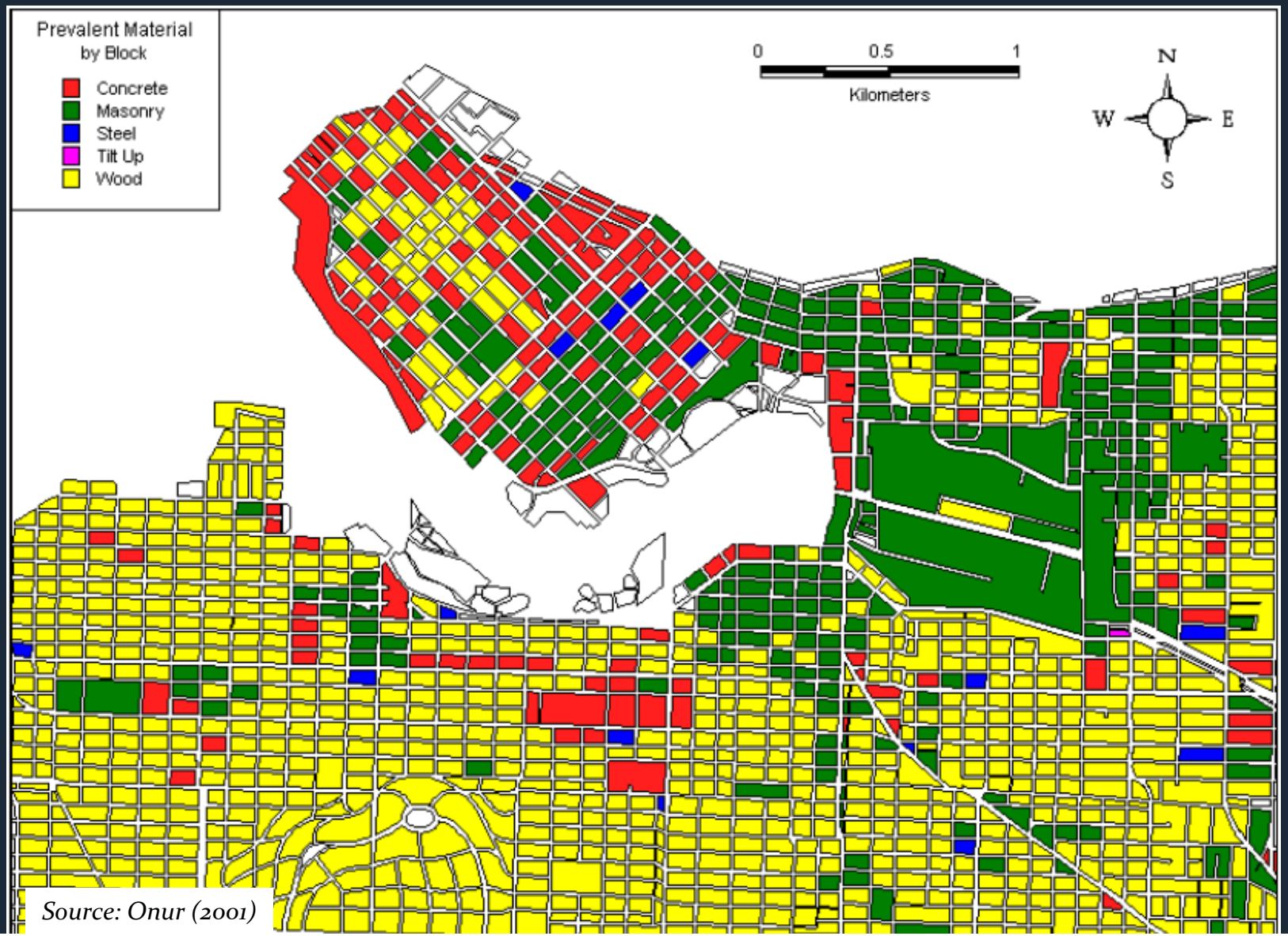


Unreinforced Masonry

- In the west, particularly prevalent in downtown Victoria, but also found in older parts of Vancouver
- Prevalent in most major cities in the east, particularly in Montreal, Quebec City, Ottawa

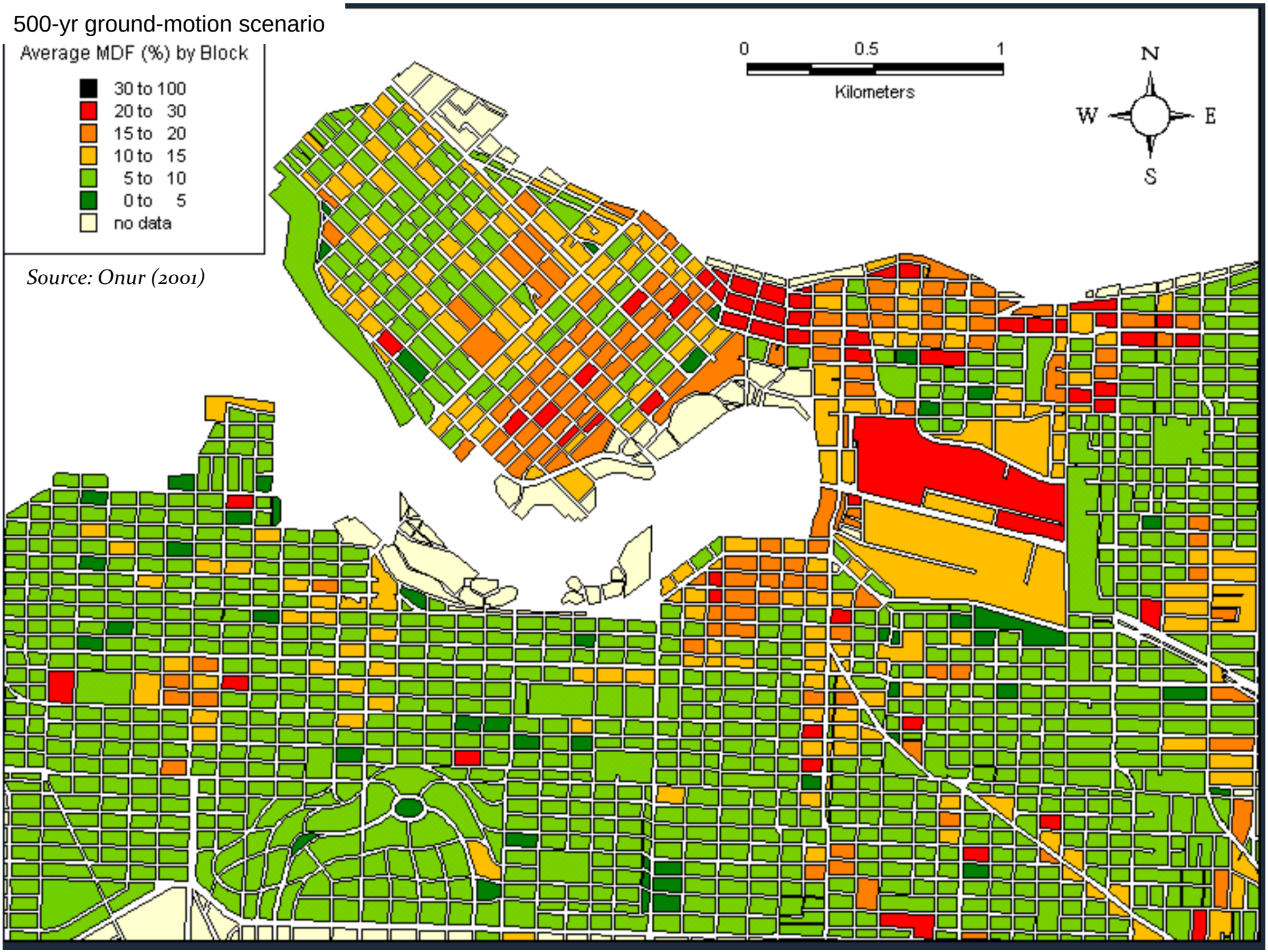
Photos: T. Onur, 2011

Vancouver Buildings by Material



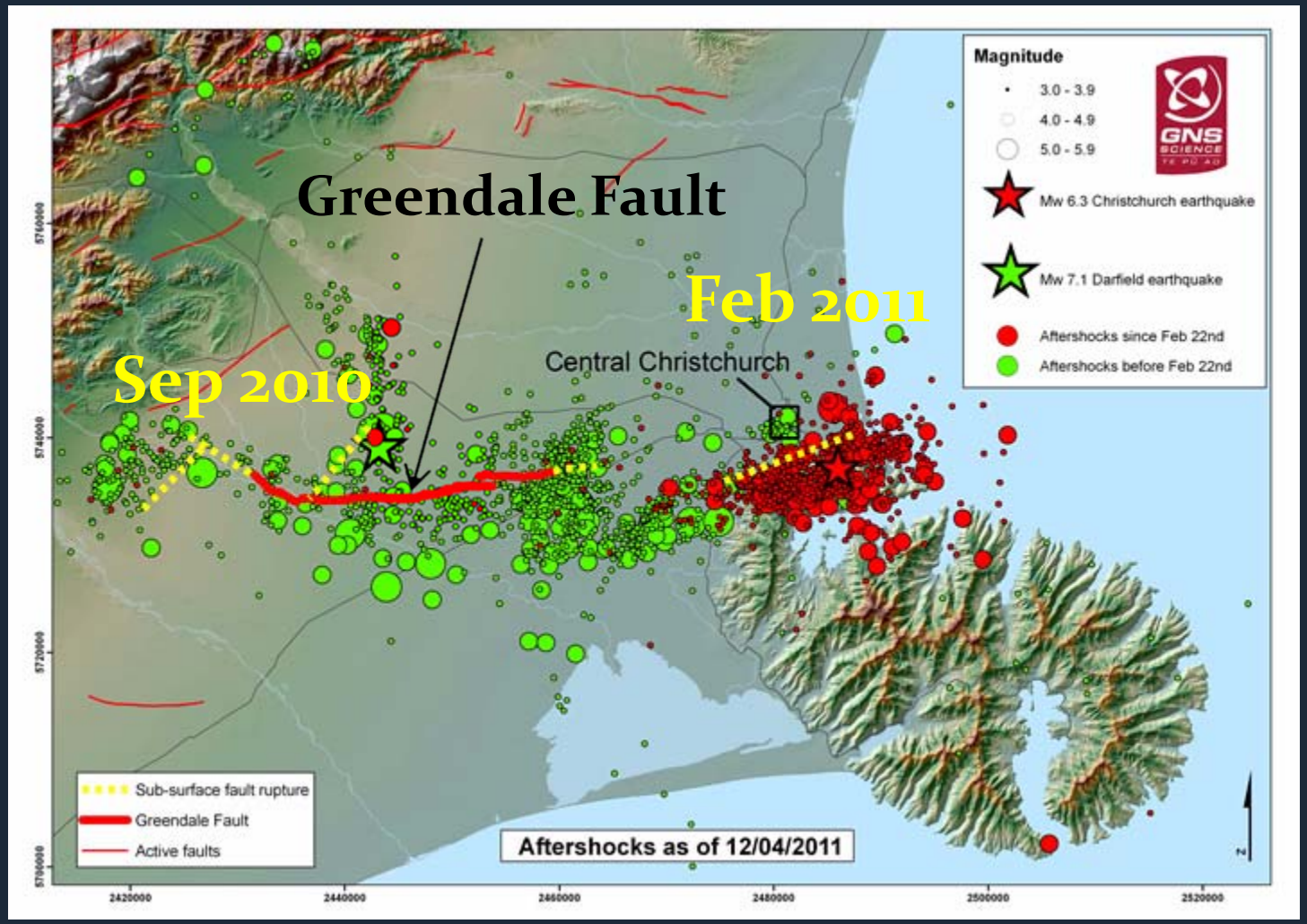
Source: Onur (2001)

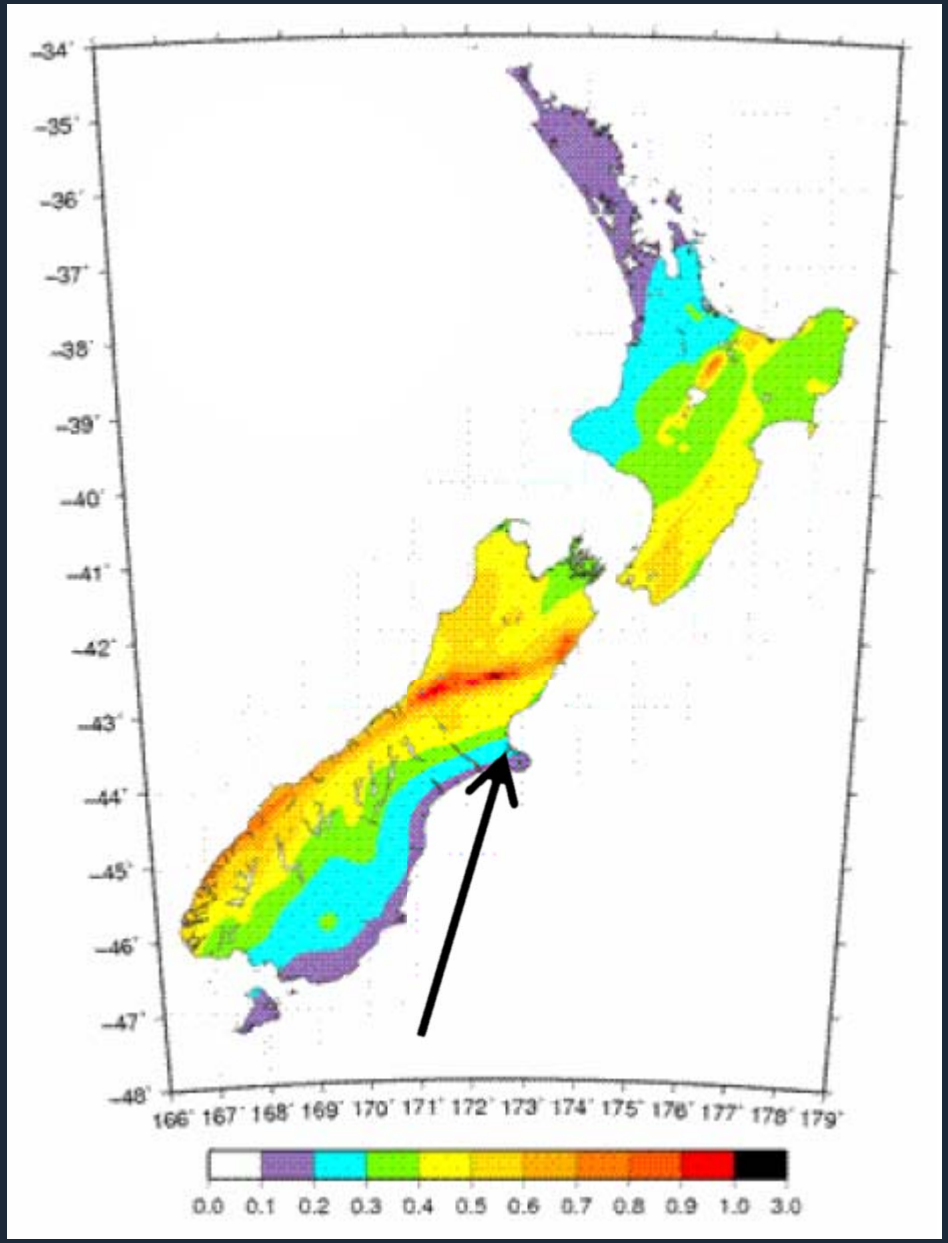
500-yr ground-motion scenario



Source: Onur (2001)

New Zealand Sep 2010 / Feb 2011





2002 National Seismic Hazard Map for New Zealand

Stirling et al. (2011) from the Proceedings of the Ninth Pacific Conference on Earthquake Engineering

M6.3 Christchurch Earthquake Feb 2011

- High stress-drop event
- Mainly URM damage
- Poor performance of a few reinforced concrete buildings (most of the casualties)
- Wide-spread liquefaction

Collapsed Pyne Gould Guiness Building in Central Christchurch

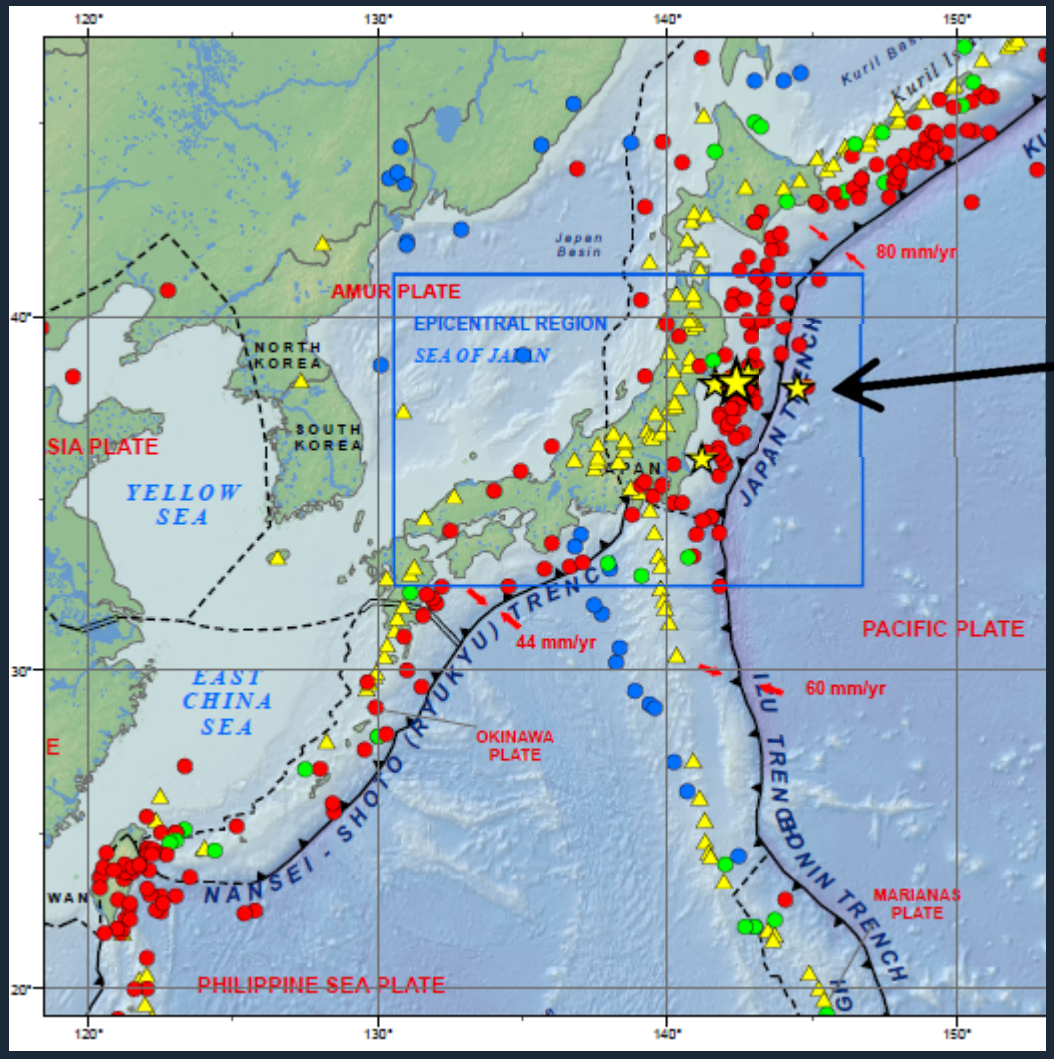
Photo Credit: AP

Damage and Rescue Efforts in Central Christchurch

URM Damage in Christchurch

Liquefaction in Suburbs of Christchurch

Japan Mar 2011



Mmax 8.2?

Source: USGS Poster on Tohoku Earthquake

Tsunami Damage in Sendai

M9.0 Tohoku (Japan) Earthquake March 2011

- Subduction earthquake
  - How does it compare to Cascadia?
- Extensive tsunami damage
- Long-duration strong shaking
- Foreshocks and aftershocks

Final Remarks

- There will always be another surprise earthquake
- Critical to:
  - know where and what your risks are
  - take into account uncertainties in risk models
- Building code matters!

Thank You!

onur.osc@gmail.com