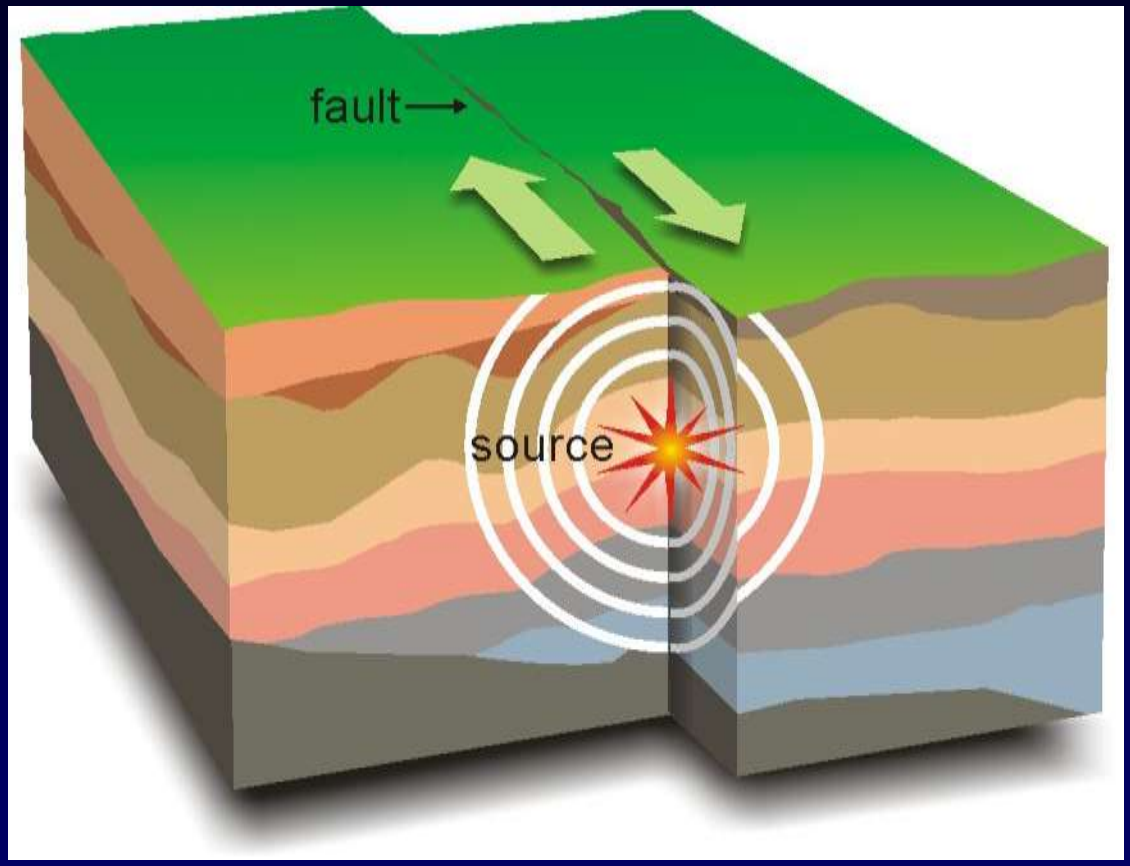
Magnitude 9!

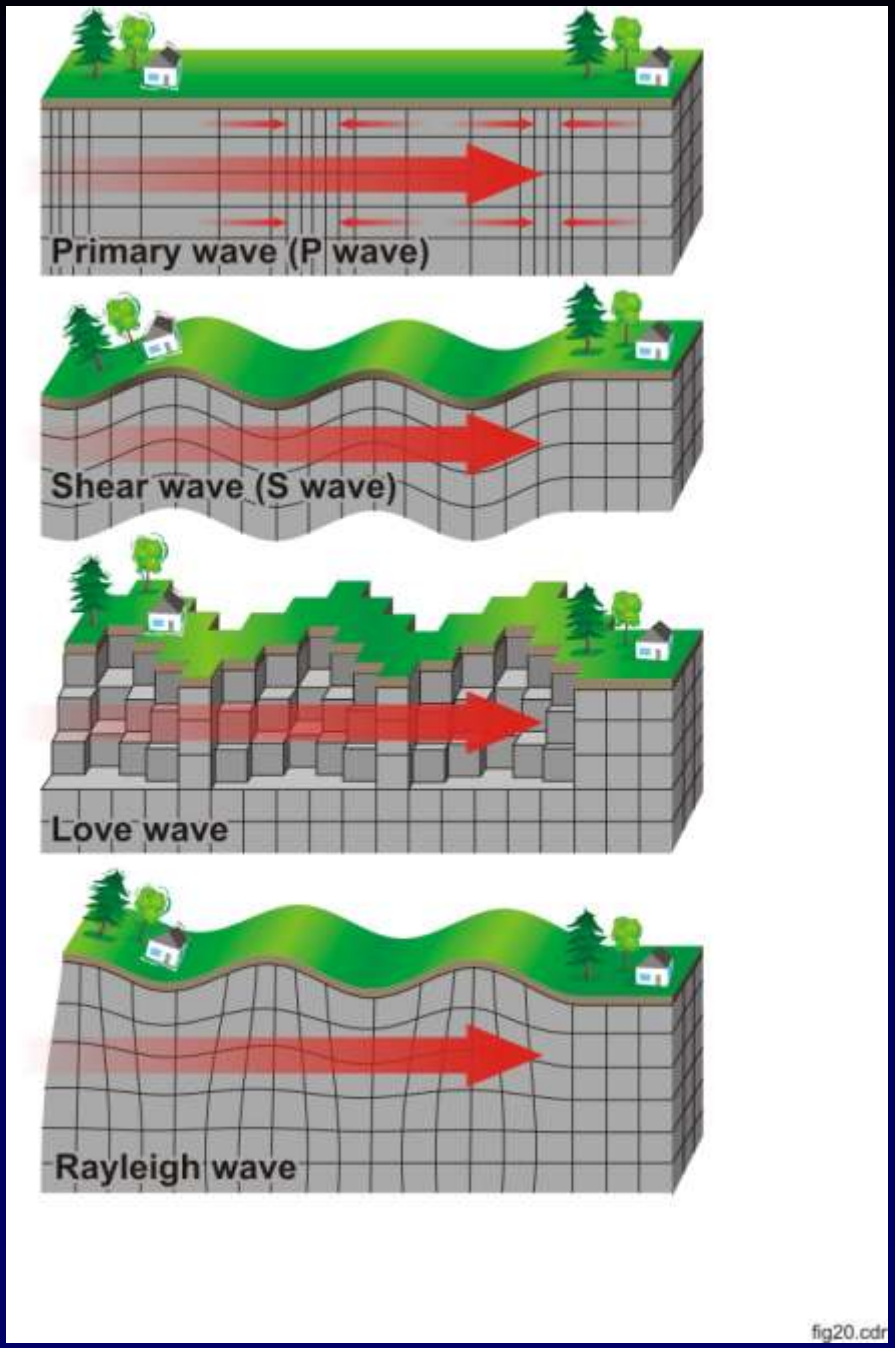
How We Learned That the Largest Earthquakes on Earth Happen in the Pacific Northwest

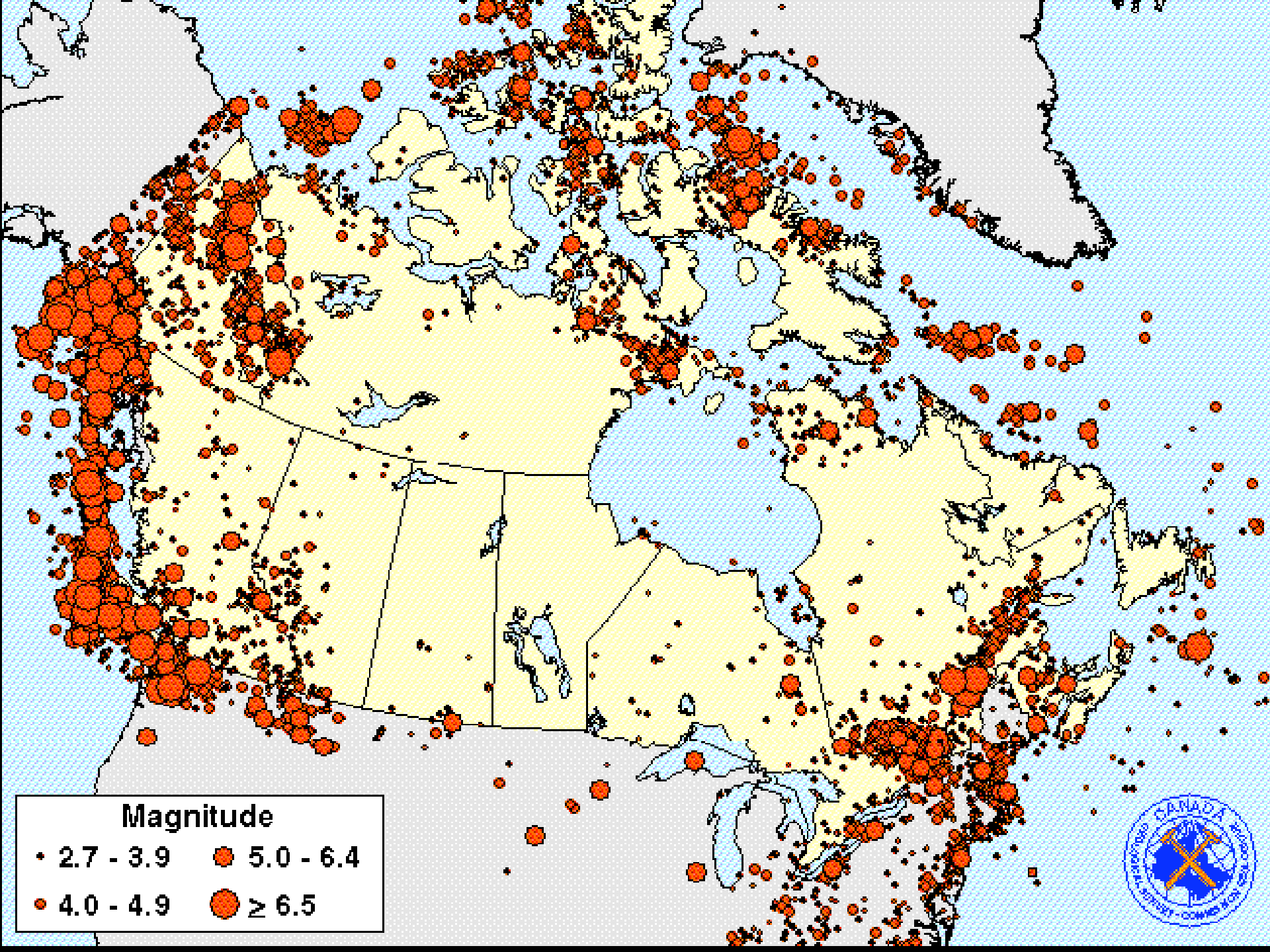
John J. Clague

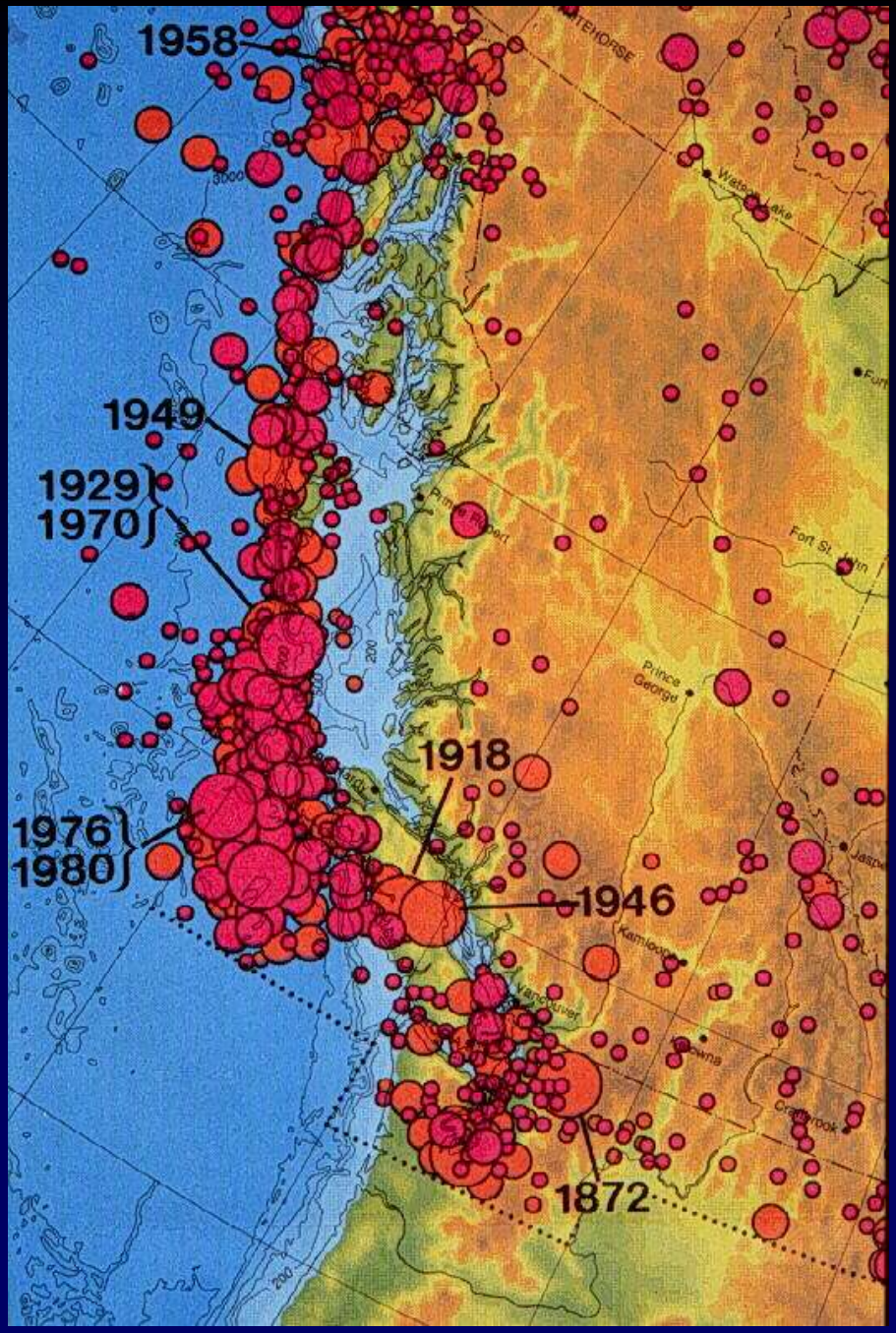
SFU Centre for Natural Hazard Research

What is an earthquake?




Primary wave (P wave)
Shear wave (S wave)
Love wave
Rayleigh wave
fig20.cdr


Magnitude
2.7 - 3.9
4.0 - 4.9
5.0 - 6.4
≥ 6.5


1958
1949
1929
1970
1976
1980
1918
1946
1872
Prince George
Vancouver

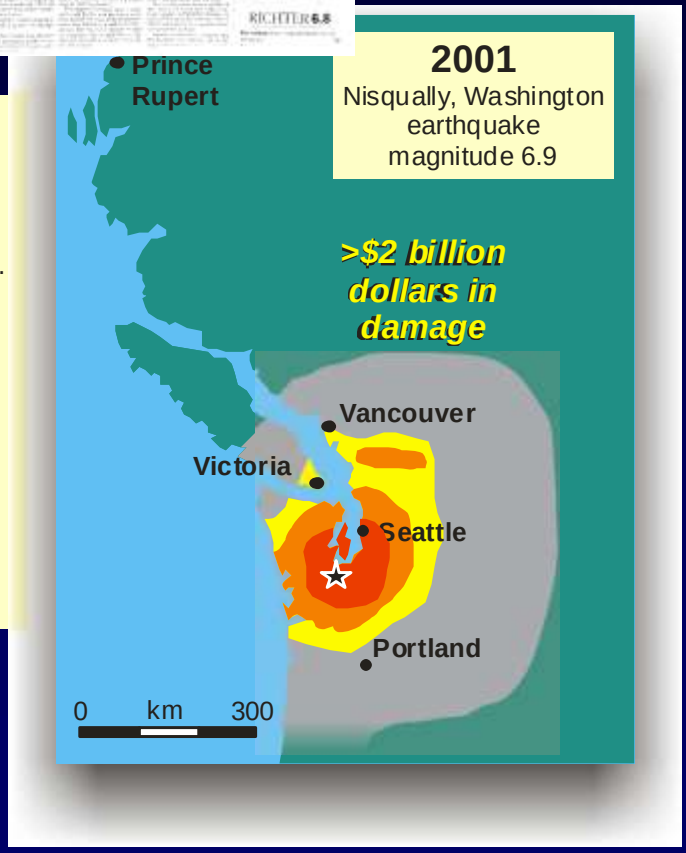

THE VANCOUVER SUN

Richter 6.8

"The magnitude of this quake is a wake-up call to B.C."

Shake maps (Mercali intensity)

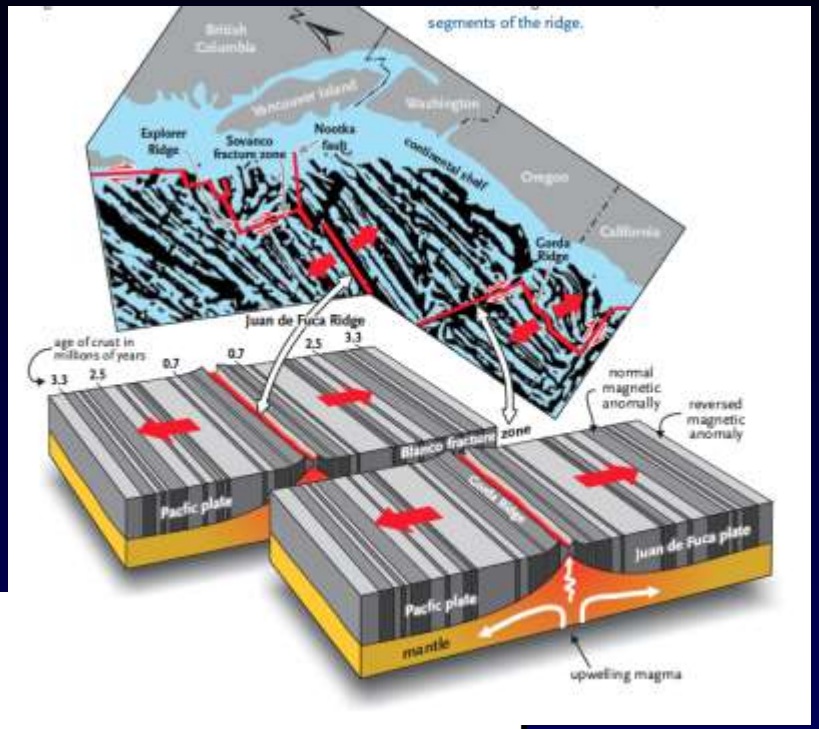
VII	General alarm. Difficult to stand. Damage to buildings.
VI	Felt by everyone. Difficult to walk. Objects fall.
V	Felt outdoors, Buildings sway.
IV	Felt by most people indoors.



How did we learn that giant earthquakes occur in the Pacific Northwest?

A 50-year odyssey marked by advances in scientific knowledge and technology

Early 1960s – The revolution in earth sciences



No. 4897 September 7, 1963 NATURE

MAGNETIC ANOMALIES OVER OCEANIC RIDGES

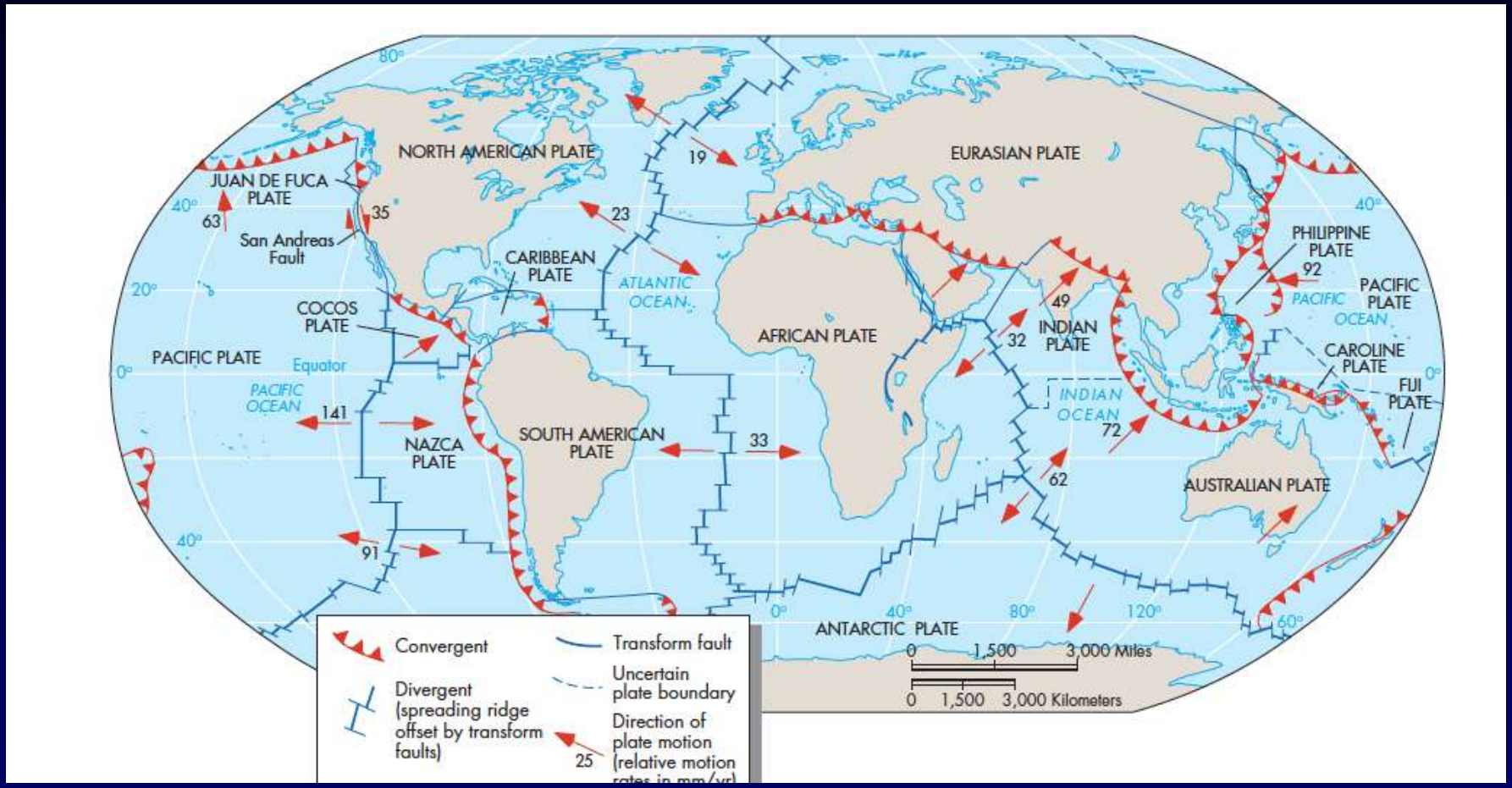
By F. J. VINE and Dr. D. H. MATTHEWS
Department of Geodesy and Geophysics, University of Cambridge

TYPICAL profiles showing bathymetry and the associated total magnetic field anomaly observed on crossing the North Atlantic and North-West Indian Oceans are shown in Fig. 1. They illustrate the essential features of magnetic anomalies over the oceanic ridges: (1) long-period anomalies over the exposed or buried foothills of the ridge; (2) shorter-period anomalies over the rugged flanks of the ridge; (3) a pronounced central anomaly. The positive anomalies correspond to mountains on either side of the valley.

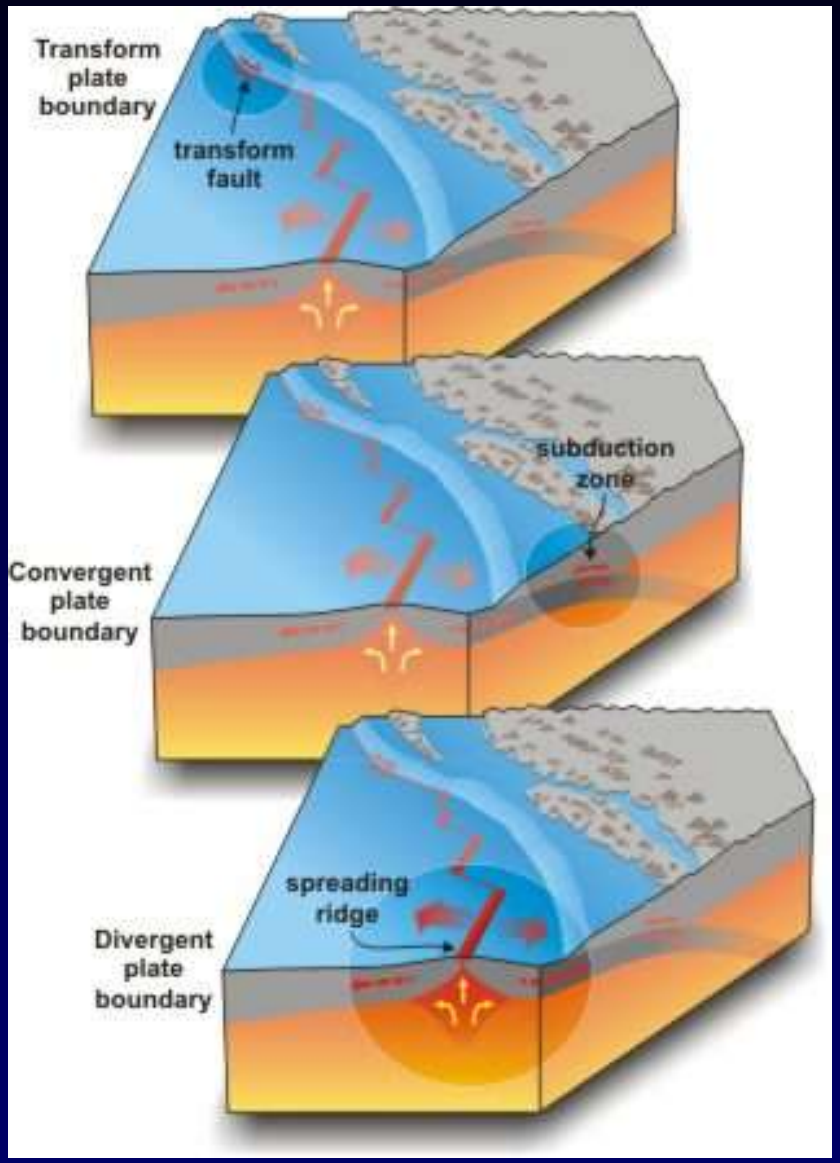
In this low magnetic latitude (inclination $-6°$) the effect of a body magnetized in the present direction of the Earth's field is to reduce the strength of the field above it, producing a negative anomaly over the body and a slight positive anomaly to the north. Here, over the centre of the Ridge, the bottom topography indicates the relief of

1963 - Drummond Mathewes and his PhD student Frederick Vine document magnetic striping on the seafloor

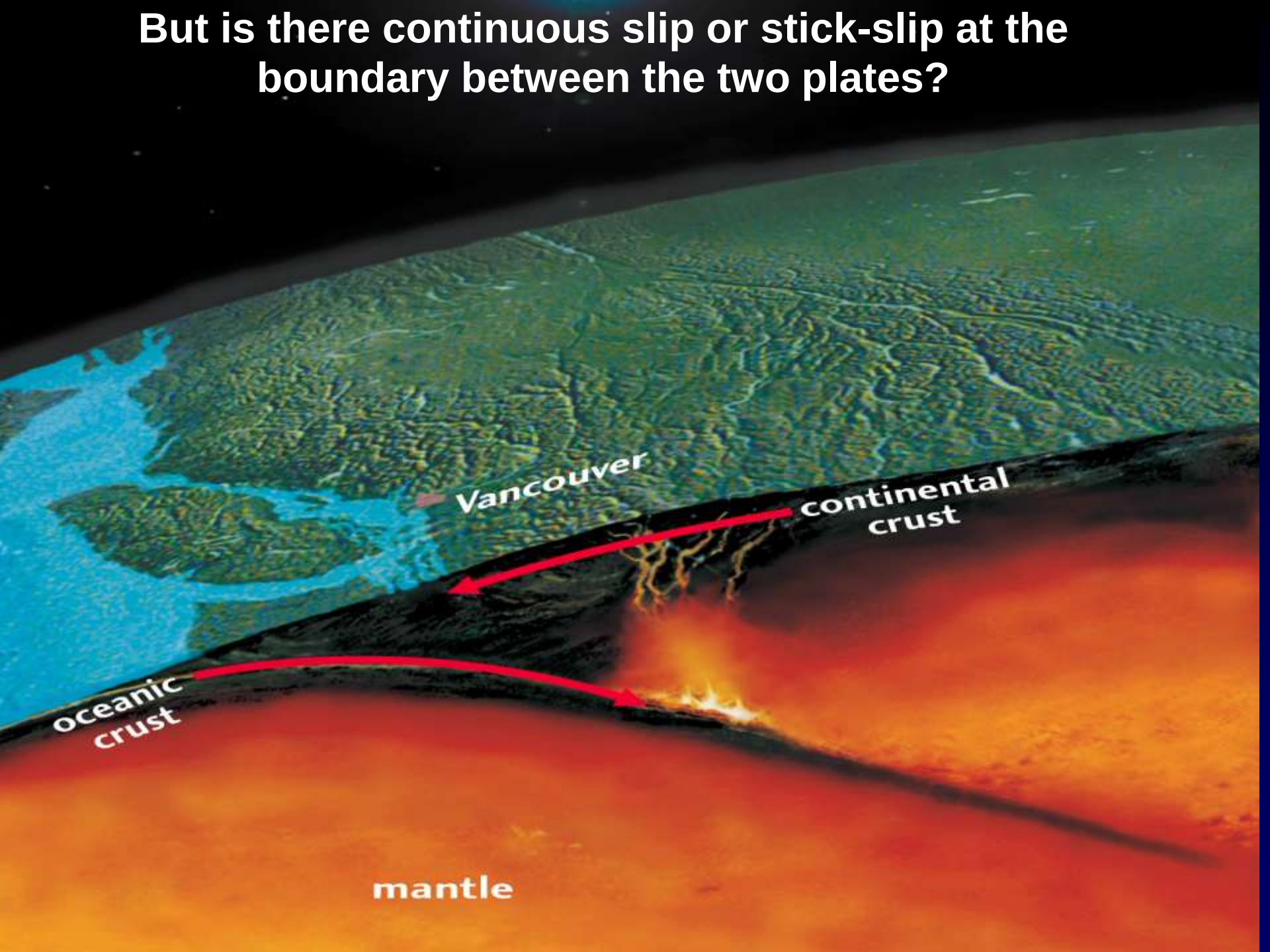
Earth's lithospheric plates



1970s – Recognition that there is a subduction zone off the coast of the Pacific Northwest …



But is there continuous slip or stick-slip at the boundary between the two plates?



1984 – Heaton and Kanamori ‘rock the boat’

Bulletin of the Seismological Society of America, Vol. 74, No. 3, pp. 933–941, June 1984

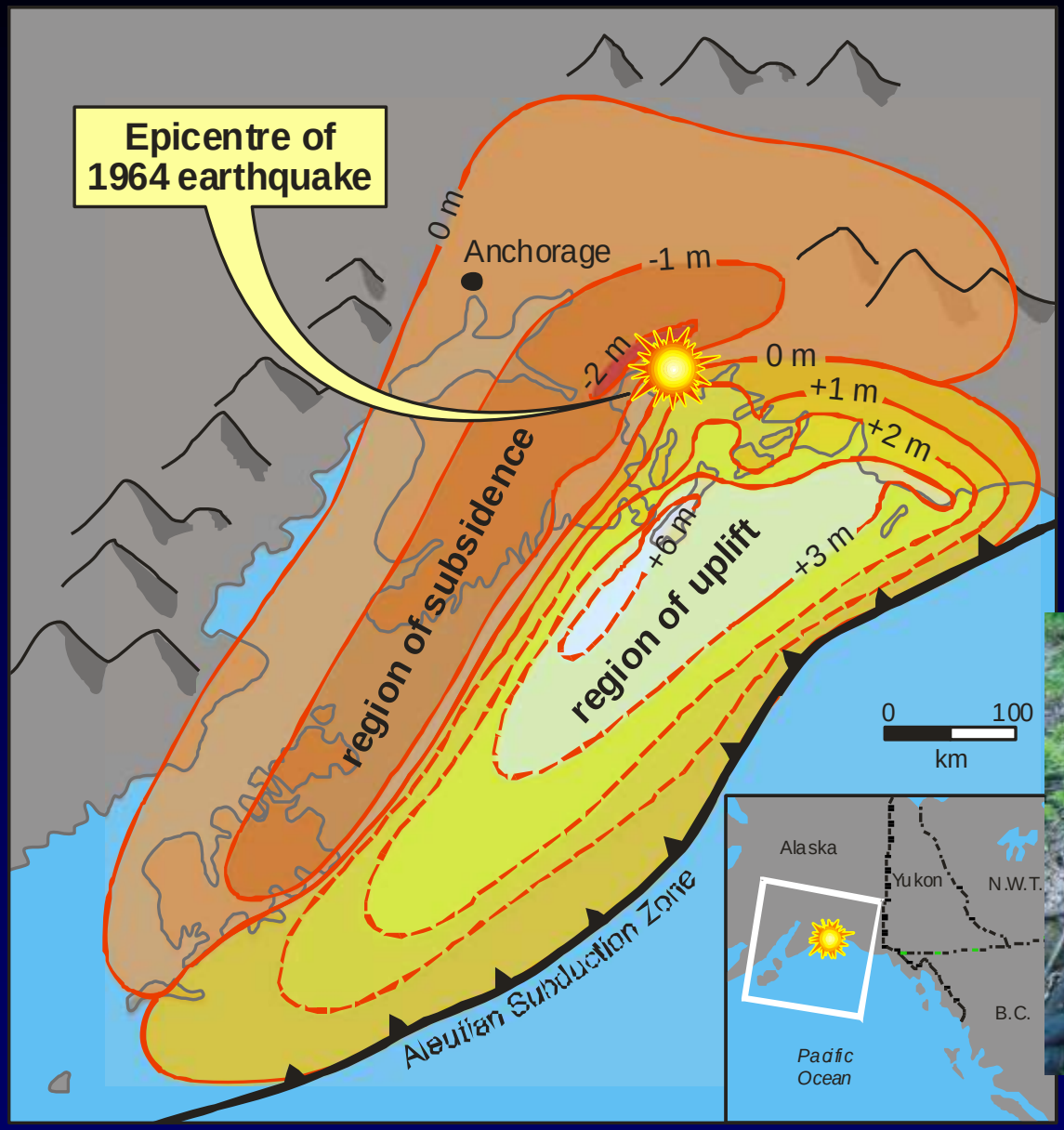
SEISMIC POTENTIAL ASSOCIATED WITH SUBDUCTION IN THE NORTHWESTERN UNITED STATES

BY THOMAS H. HEATON AND HIROO KANAMORI

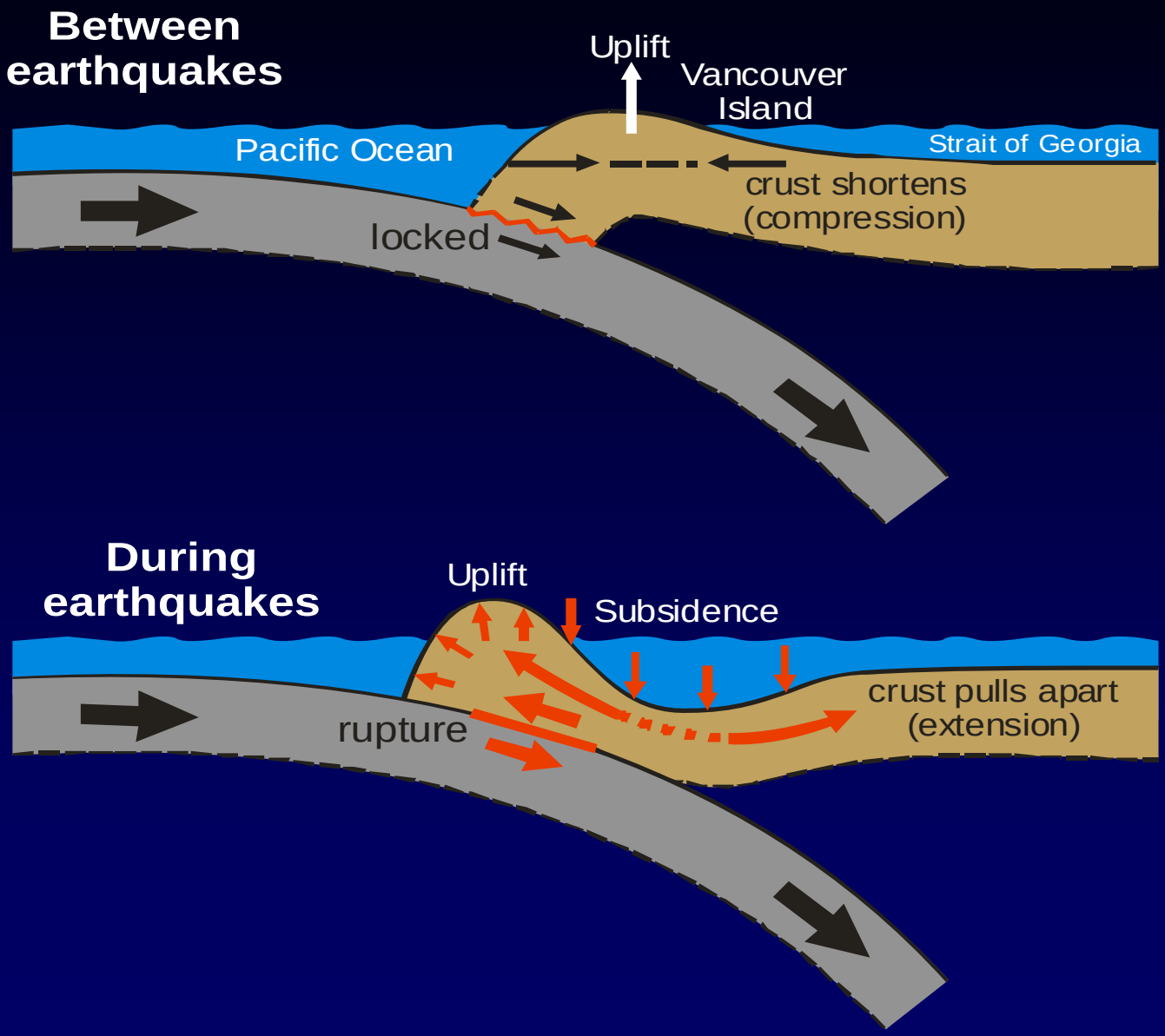
ABSTRACT

Despite good evidence of present-day convergence of the Juan de Fuca and North American plates, there has been remarkably little historical seismic activity along the shallow part of the Juan de Fuca subduction zone. Although we cannot completely rule out the possibility that the plate motion is being accommodated by aseismic creep, we find that the Juan de Fuca subduction zone shares many features with other subduction zones that have experienced great earthquakes.

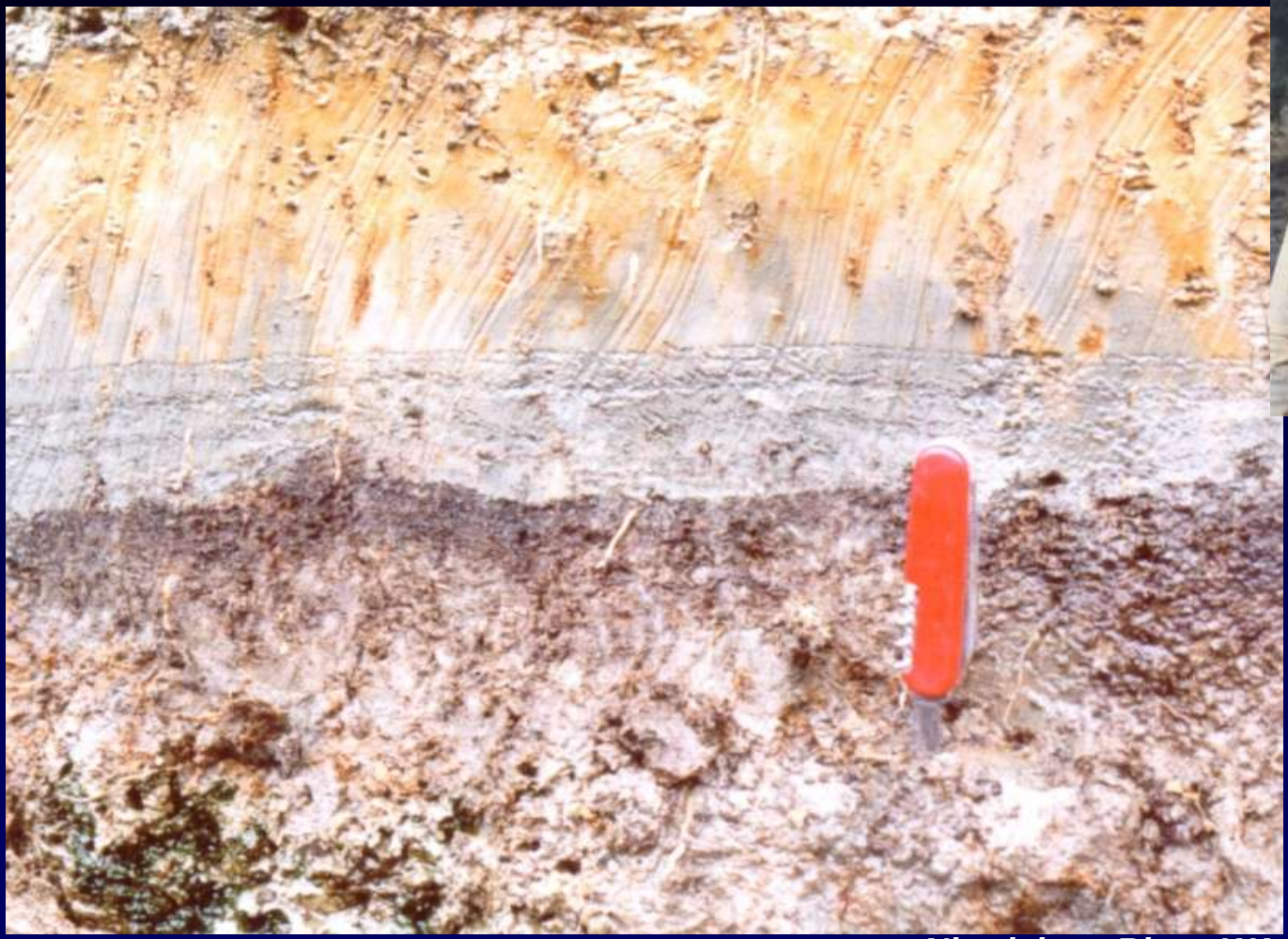
The story from other giant earthquakes



George Plafker

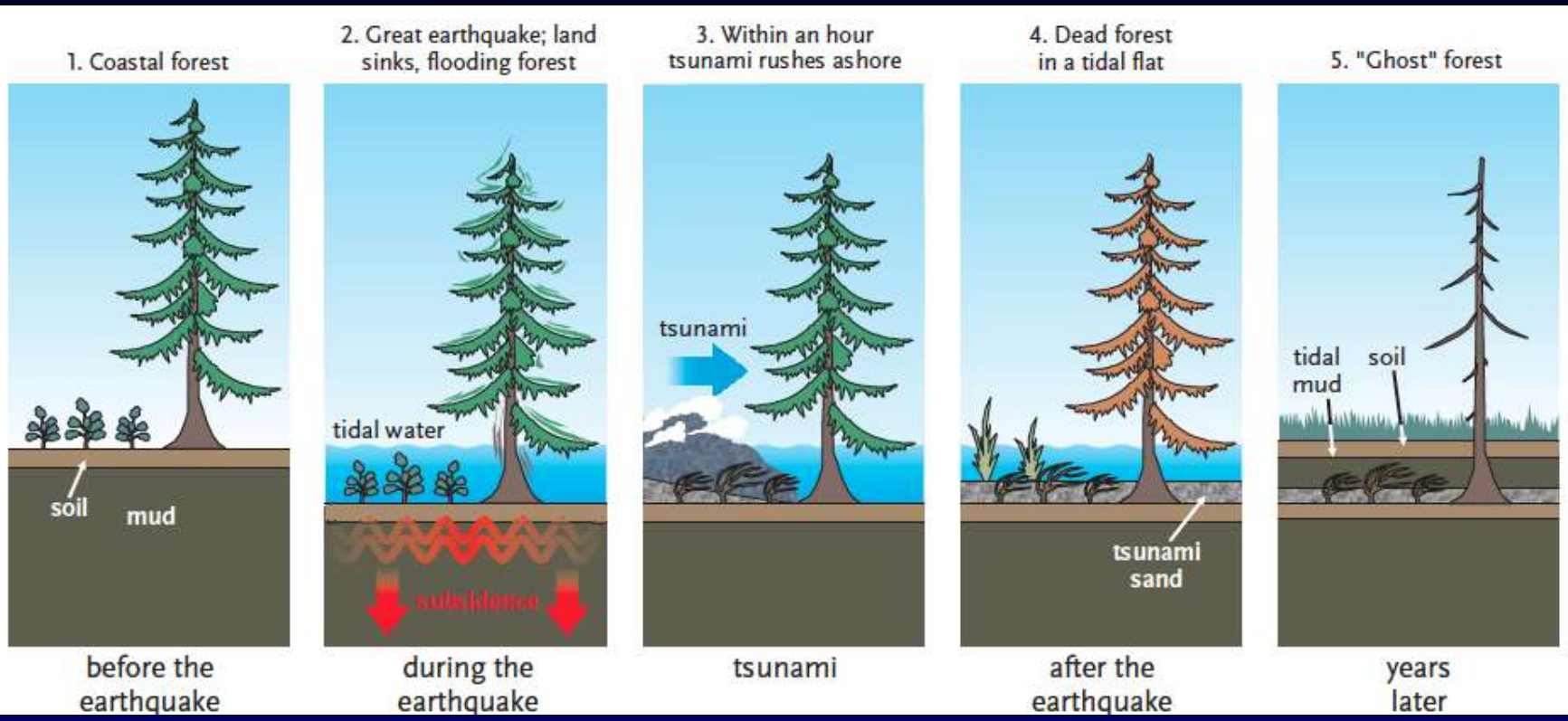

Between earthquakes
Uplift
Vancouver Island
Pacific Ocean
Strait of Georgia
crust shortens (compression)
locked
During earthquakes
Uplift
Subsidence
crust pulls apart (extension)
rupture

1987 - The “aha” moment

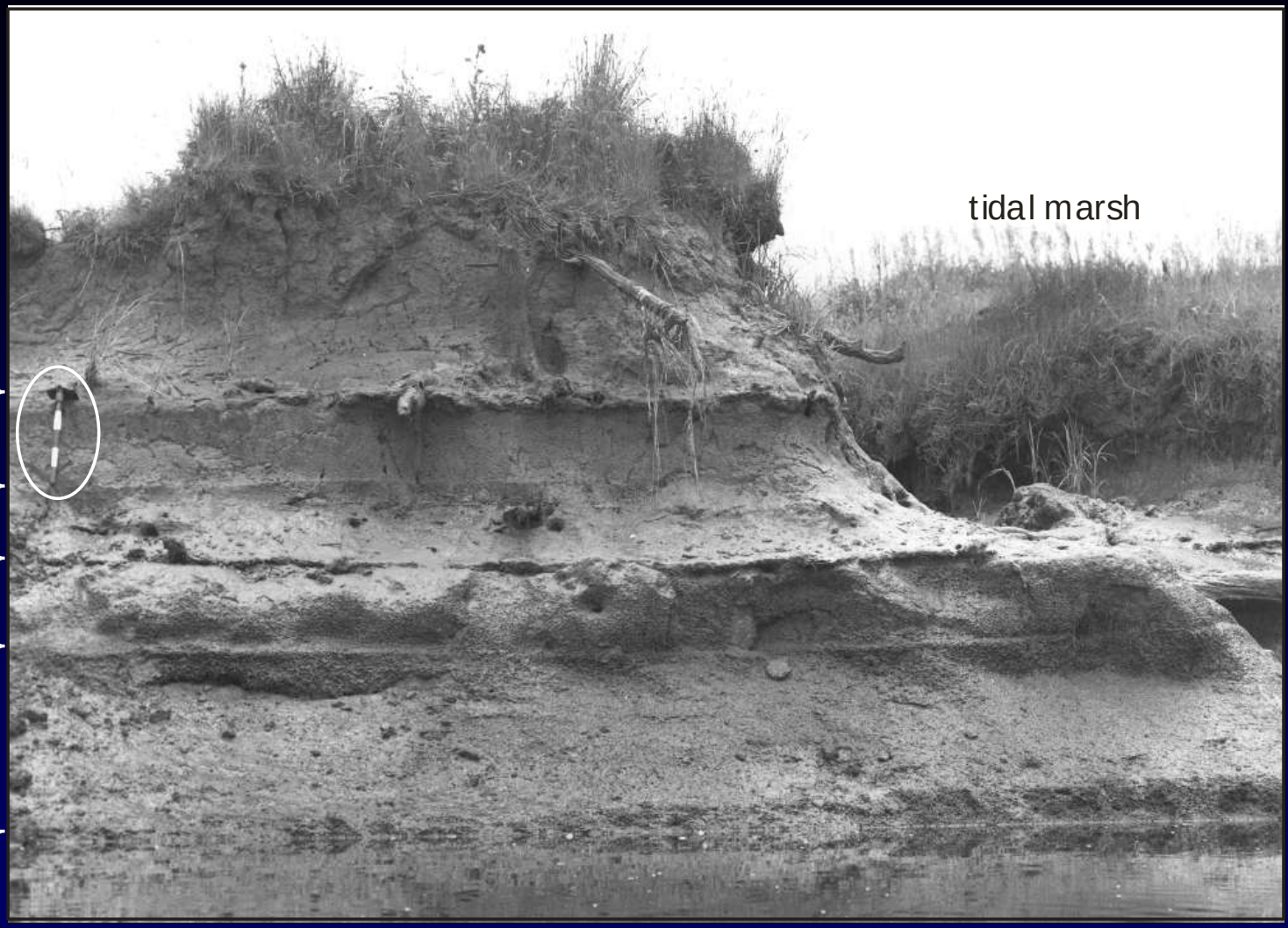


Niawiakum River, WA

Brian Atwater

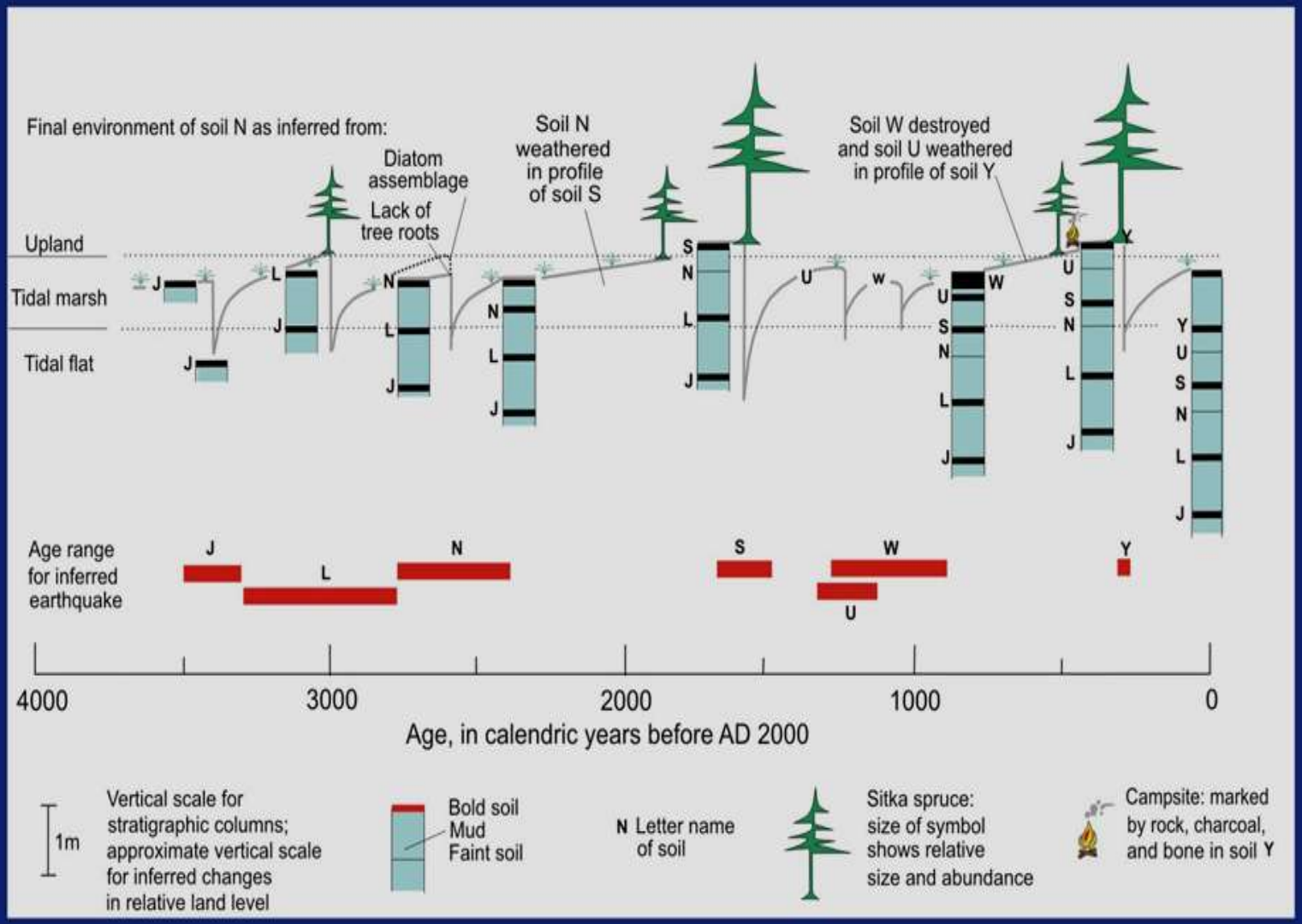

1. Coastal forest
soil
mud
before the earthquake
2. Great earthquake; land sinks, flooding forest
tidal water
subsidence
during the earthquake
3. Within an hour tsunami rushes ashore
tsunami
tsunami
4. Dead forest in a tidal flat
tsunami sand
after the earthquake
5. "Ghost" forest
tidal mud
soil
years later

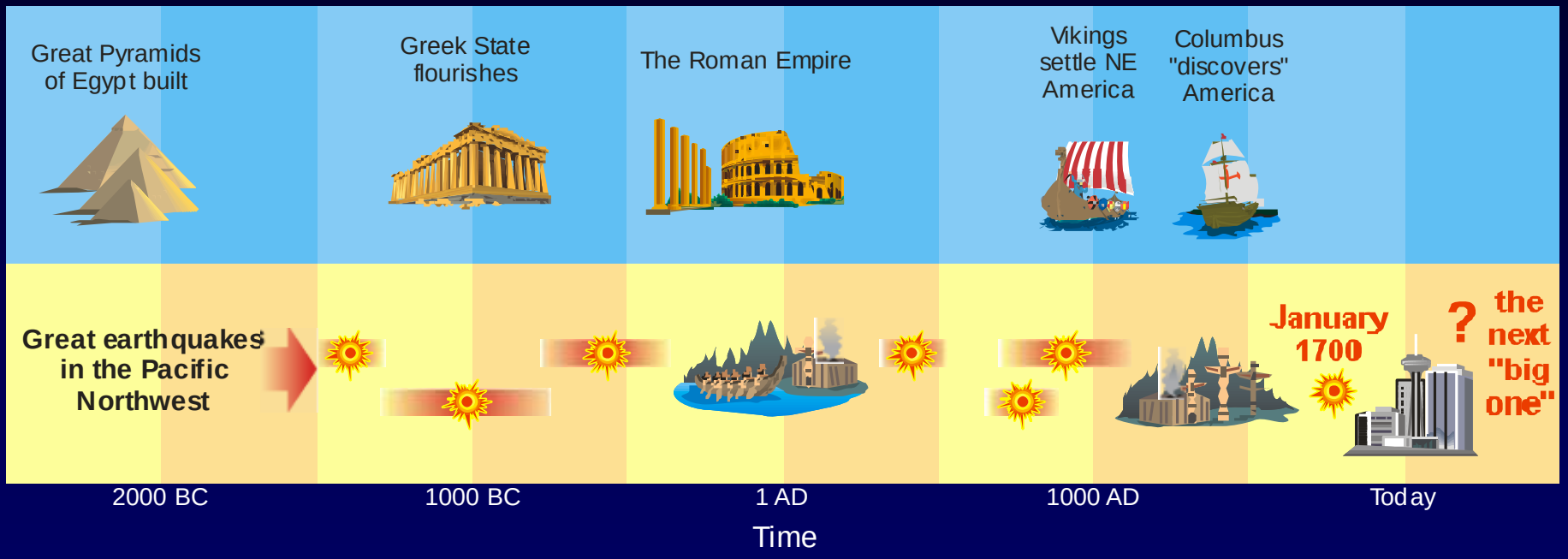
Copalis River, WA



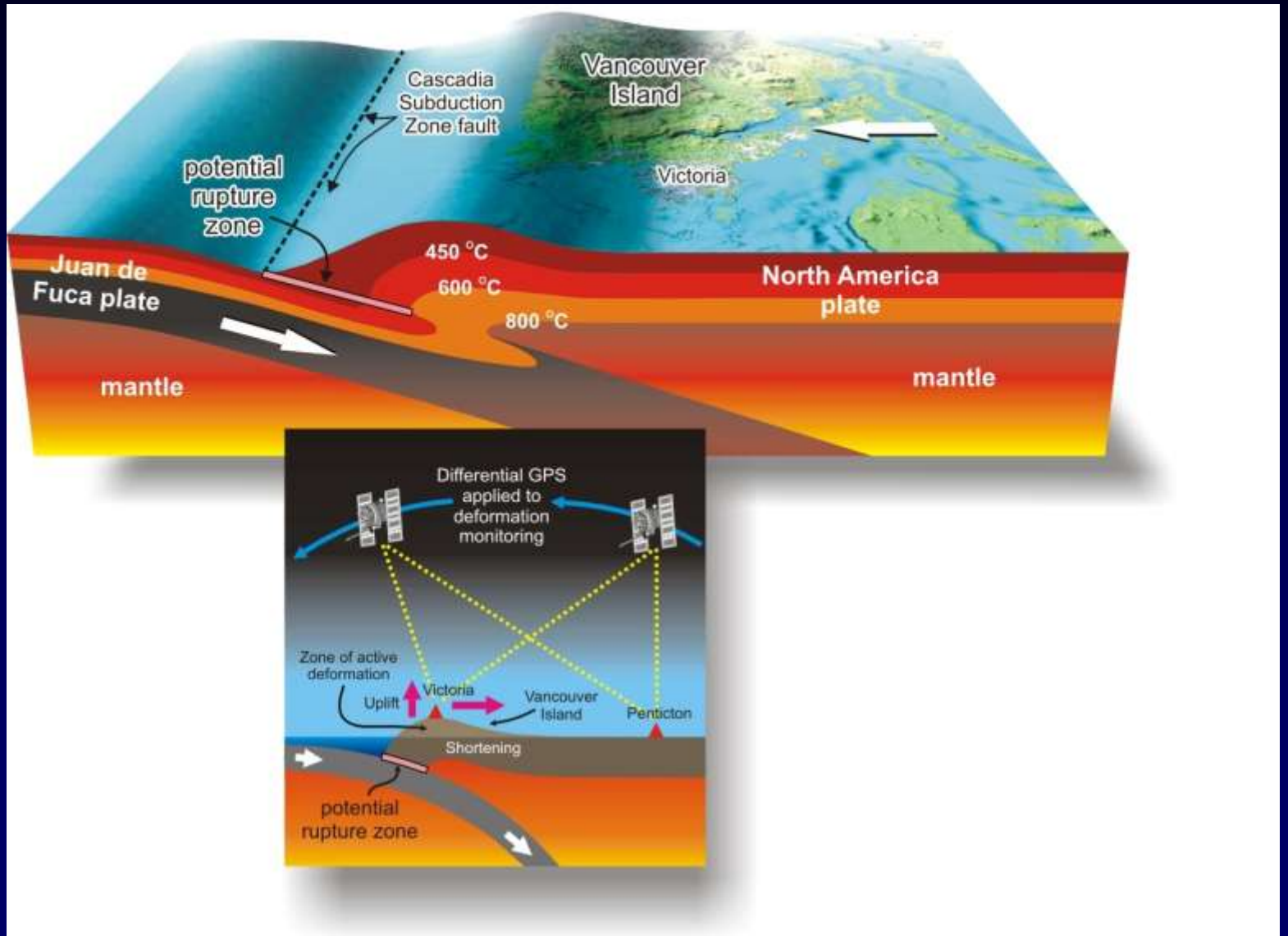
Niawiakum River, WA

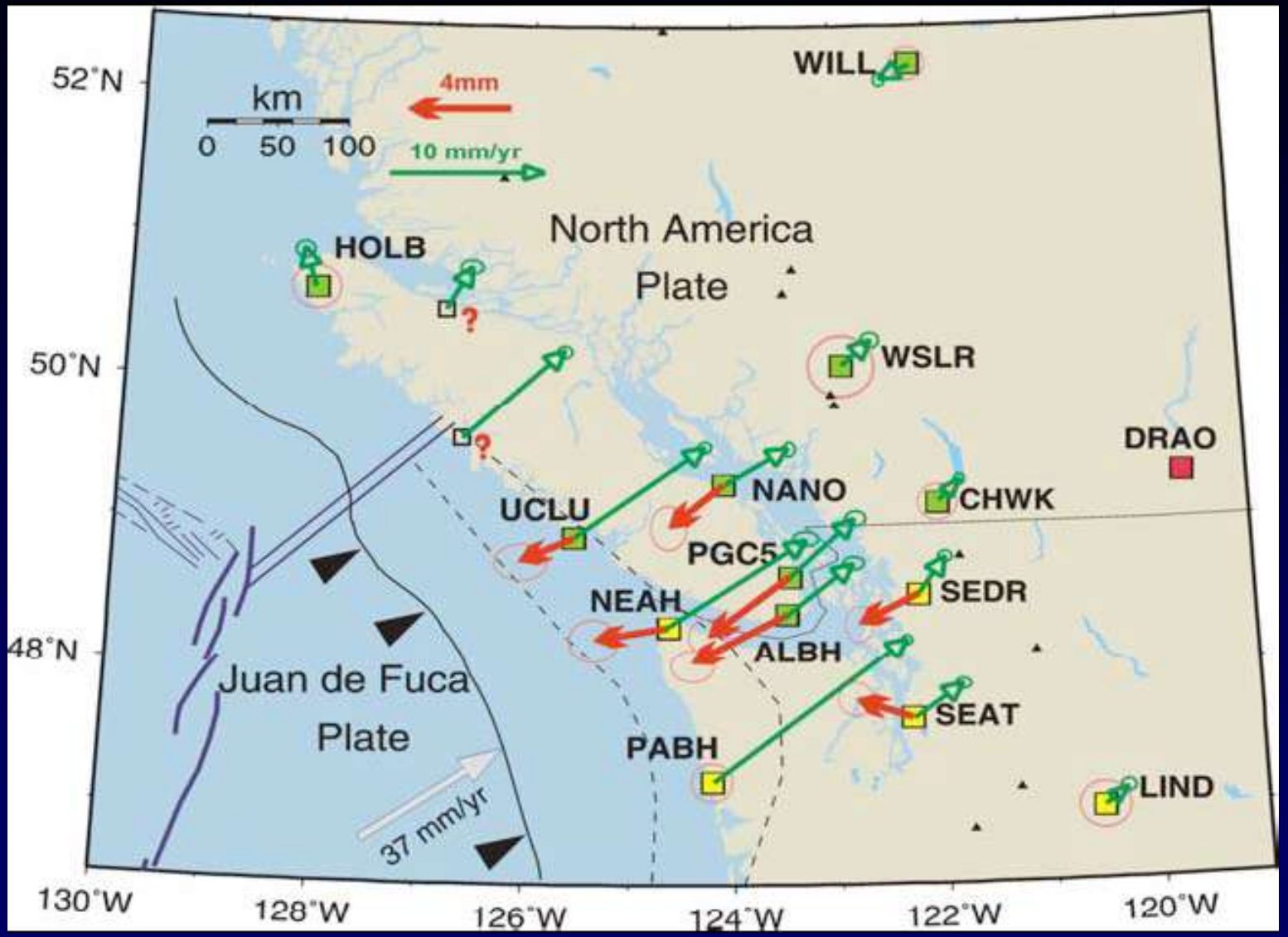
Recurrence


Final environment of soil N as inferred from:
Diatom assemblage
Lack of tree roots
Soil N weathered in profile of soil S
Soil W destroyed and soil U weathered in profile of soil Y
Upland
Tidal marsh
Tidal flat
Age range for inferred earthquake
J
L
N
S
W
U
Y
4000
3000
2000
1000
0
Age, in calendric years before AD 2000
1m
Vertical scale for stratigraphic columns; approximate vertical scale for inferred changes in relative land level
Bold soil
Mud
Faint soil
N Letter name of soil
Sitka spruce: size of symbol shows relative size and abundance
Campsite: marked by rock, charcoal, and bone in soil Y

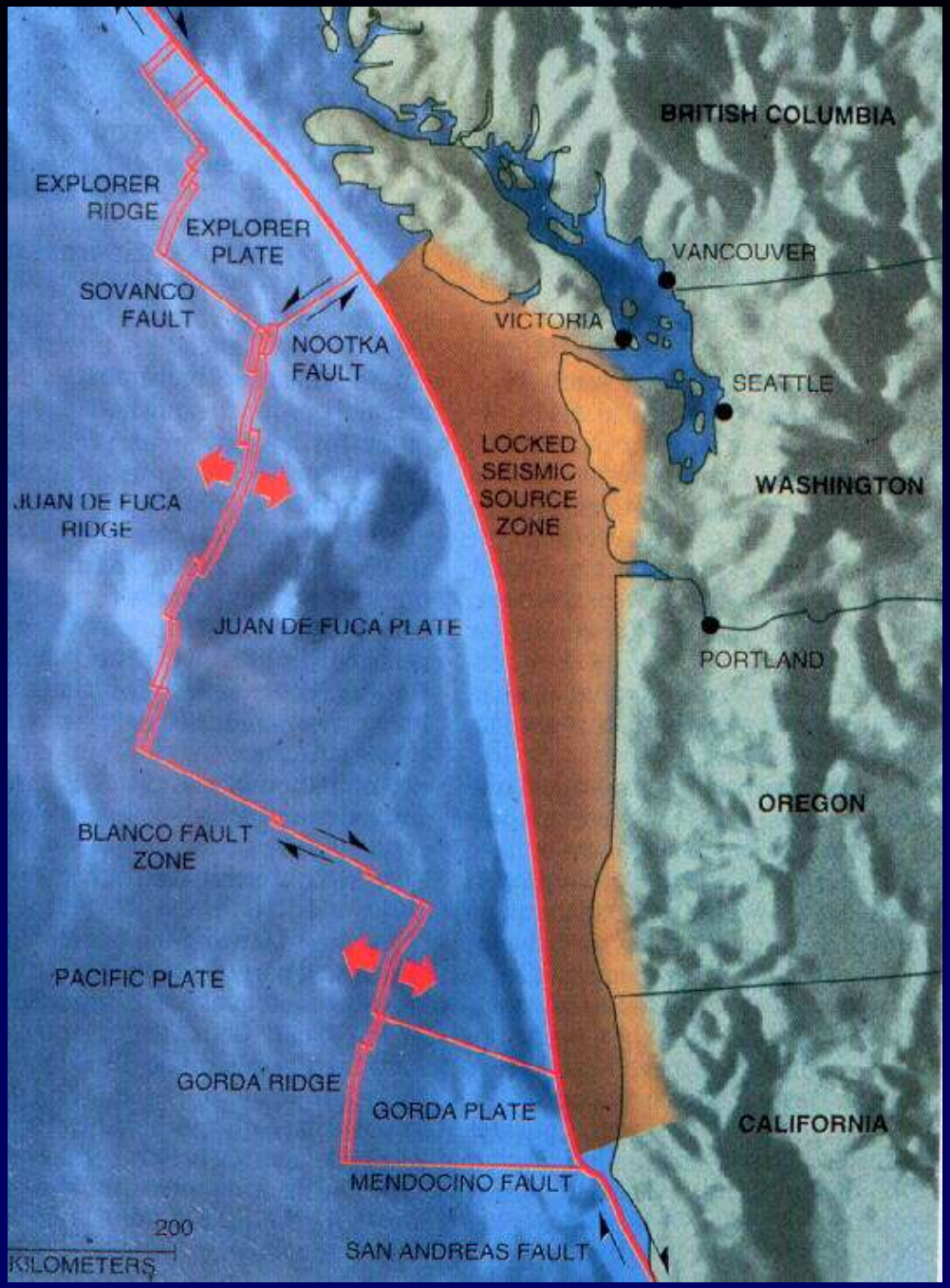

Great Pyramids of Egypt built
Greek State flourishes
The Roman Empire
Vikings settle NE America
Columbus "discovers" America
Great earthquakes in the Pacific Northwest
January 1700
?
the next "big one"
2000 BC
1000 BC
1 AD
1000 AD
Today
Time

1990s - Support from the geophysicists





Natural Resources Canada

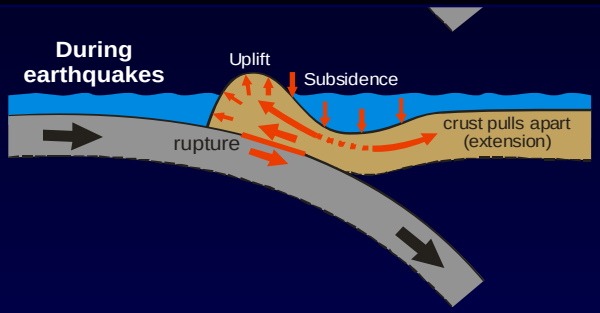


Roy Hyndman

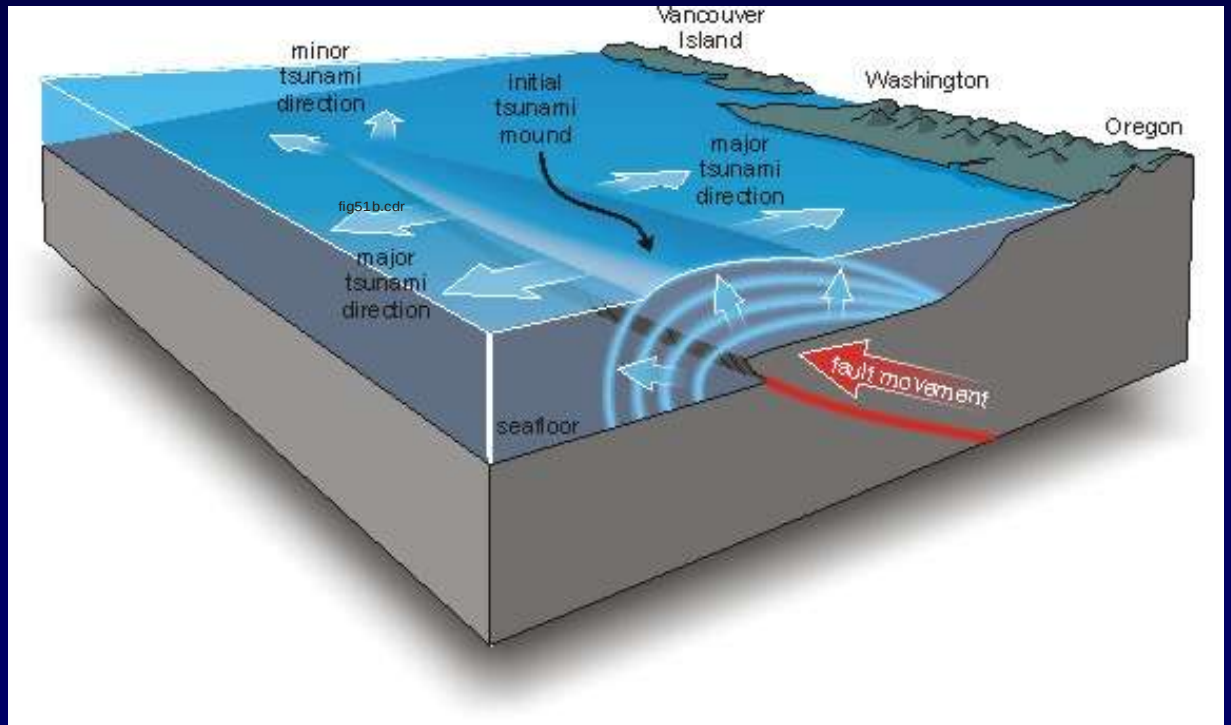
Kelin Wang

1990s to present –

Documenting the expected secondary effects



Tsunamis

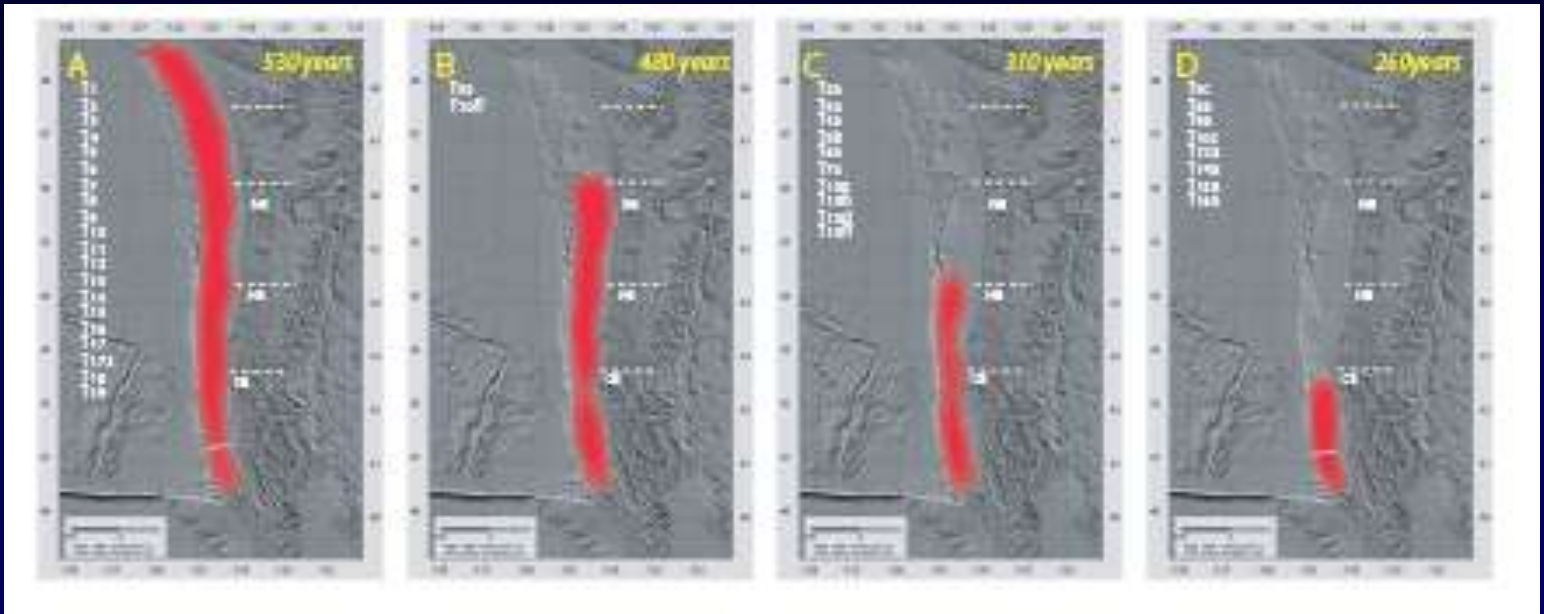



PhiPhi Island, Thailand

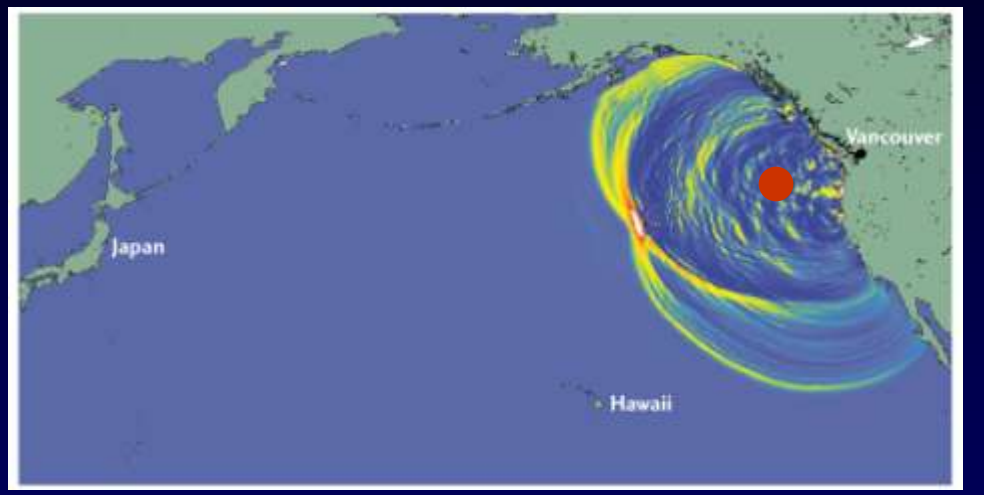
Tofino, BC

Chronologies

Twenty great earthquakes in the past 10,000 years



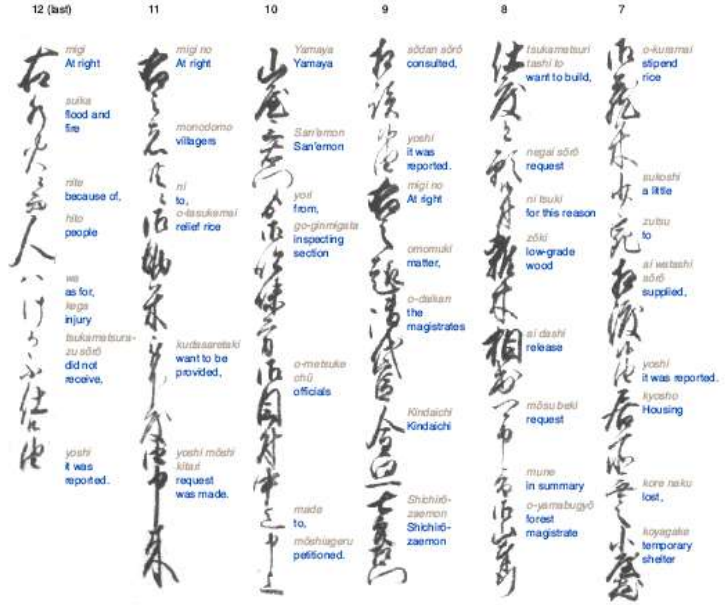
The orphan tsunami



Account in Morioka-han "Zassho" 盛岡藩『雑書』の記述

TWELVE CURSIVE COLUMNS in Morioka-han "Zassho" provide an official description of the 1700 tsunami and its aftermath in Kuwagasaki. The tsunami arrived at night (column 2). Villagers fled to high ground (2-3). The water destroyed 13 houses outright (4) and set off a fire that burned 20 more (3). In response, magistrates in nearby Miyako issued rice to 159 persons (6-7) and sought wood for shelters (8-9). They kept other officials informed of these emergency efforts (9-12).

The columns contain symbols of Chinese origin (*kanji*) and a few, simpler symbols from Japanese syllabaries (*kana*). The writer applied these symbols with a brush. In gray we



Formal language—*mōsu* (3, 5, 8), *sōrō* (4, 6-8), *mōshi* (11).

Liaisons—*doki* for *toki* (2), *domo* for *tomo* in *monodomo* (2), *nijūkken* for *nijū-ken* (3), *iasai* for *ishisai* (5), *gata* for *katain go-ginmigata* (10).

NOTES, LIKE THE COLUMNS, BEGIN AT RIGHT ON FACING PAGE.

9-10, *Kindaichi...San'emon*—During Genroku 12, the year of the 1700 tsunami (p. K7), four magistrates served in Miyako. Among them were Kindaichi Shichirōzaemon and Yamaya San'emon (Miyako-shi Kyōiku Iinkai, 1991, p. 554).

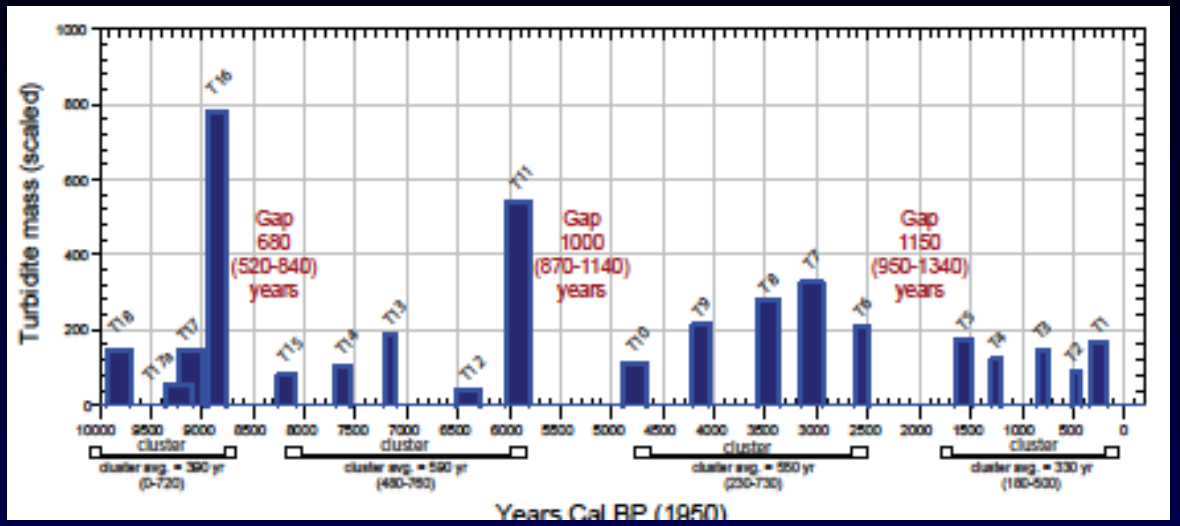
10, *go-ginmigata*—*go-*, honorific 御 like *o-* in column 1. *ginmi*, Chinese loan word for inspection.

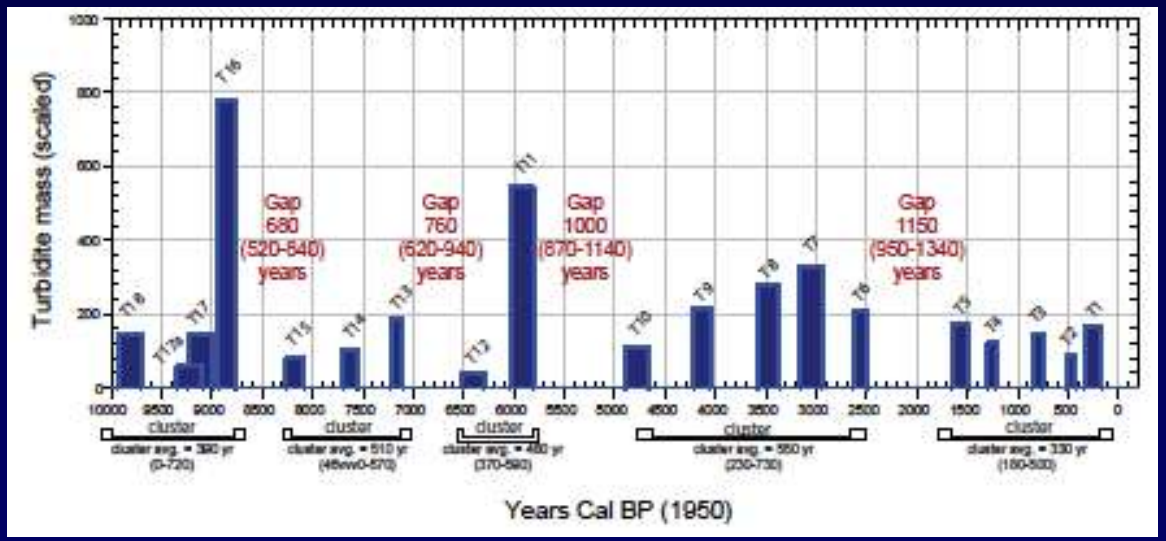
12, *kega tsukamatsura-zu sōrō*—Language reflects the villagers' status below that of the writer.

8, *zōki*—*zō*, miscellaneous; *ki*, tree or timber. Probably the writer would have used *mokuzai* had the wood been suitable for fine buildings and furniture.

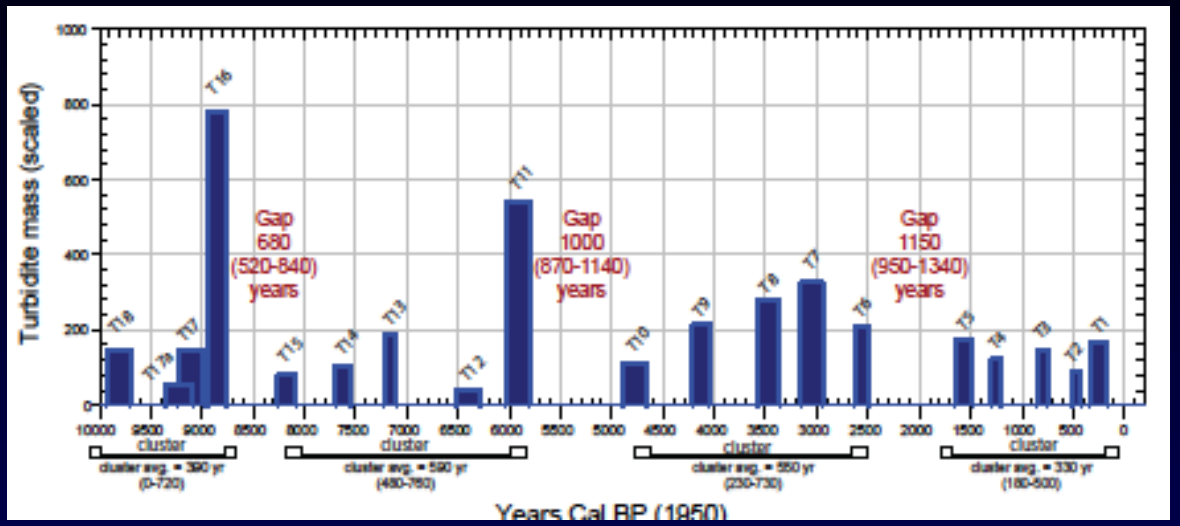
8, *o-yamabugyō*—Literally, person in charge (*bugyō*) of hills (*yamaa* as in column 2). In Edo period domains, senior forest officials called *yamabugyō* commonly worked in the finance office (*kanjōsho*) and reported directly to deputy governors (*karō*) (Totman, 1989, p. 91).

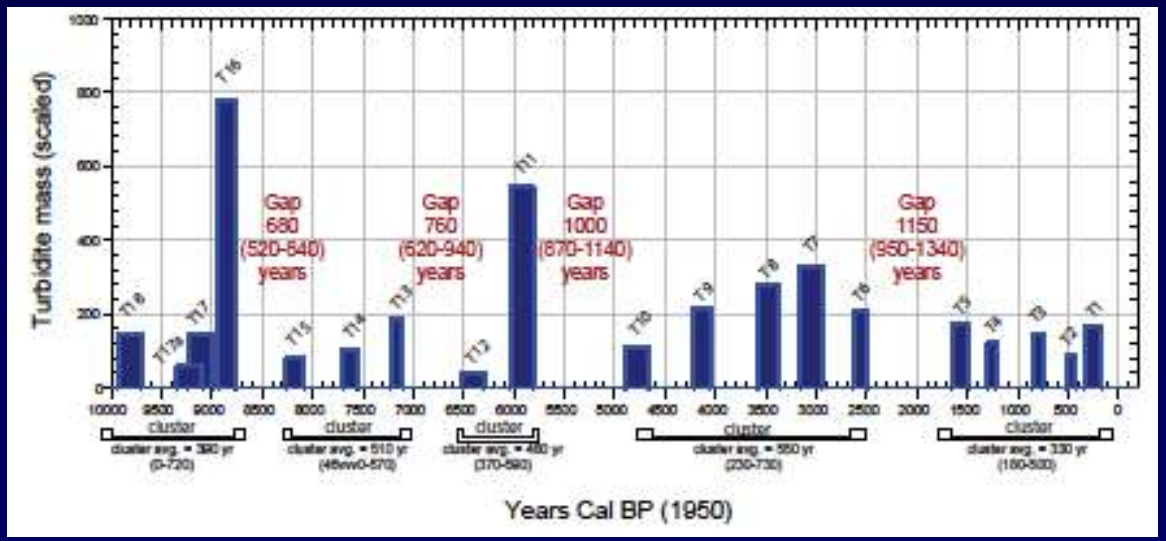
They occur in clusters





Are we in a cluster or in the interval between two clusters?





The future –

- Refined map of the locked zone
- Further refinements in the earthquake chronology
- Tackling the issue of segmentation
- Search for precursor signals

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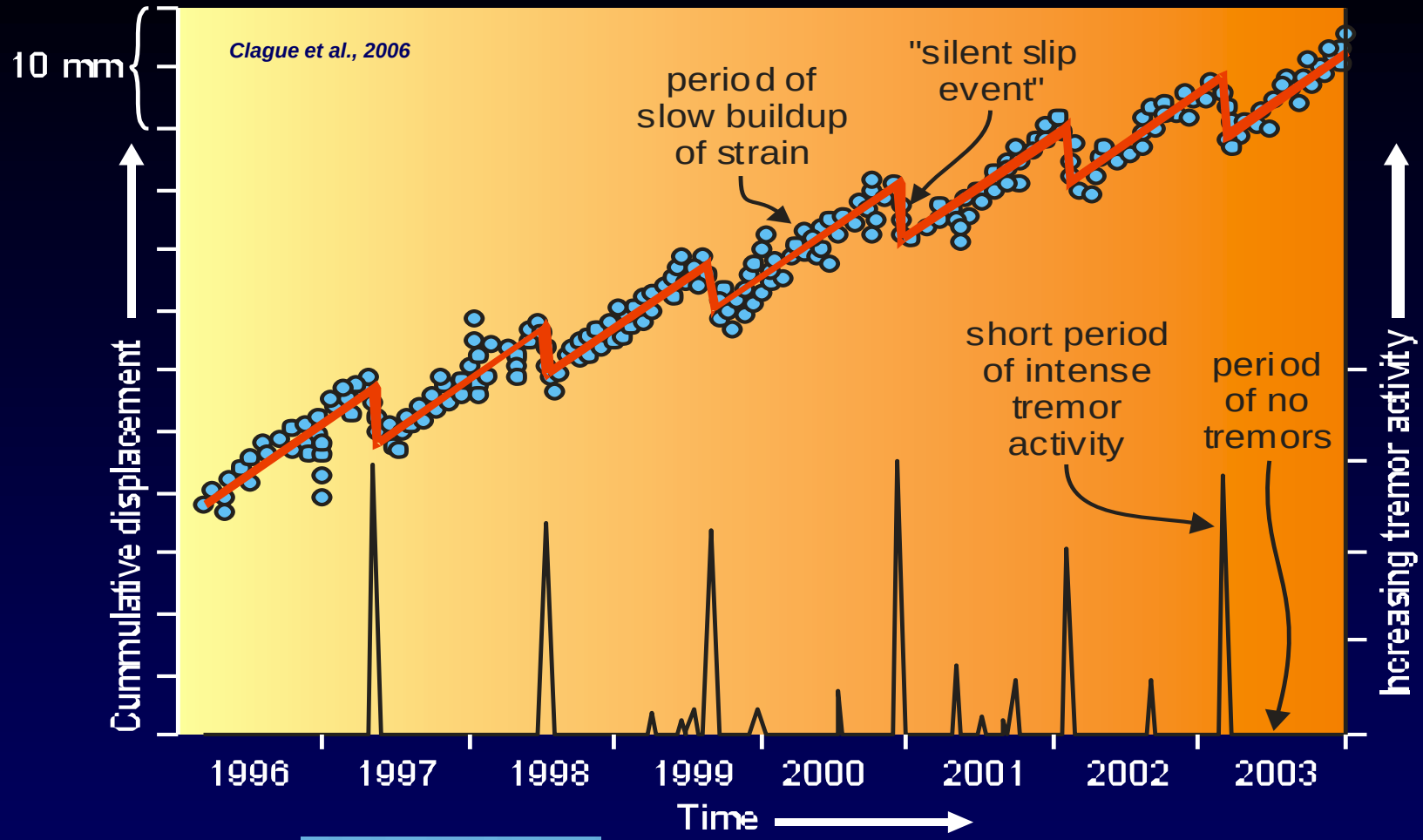
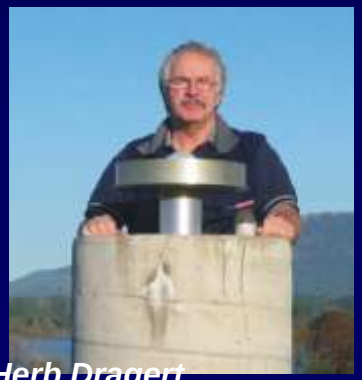
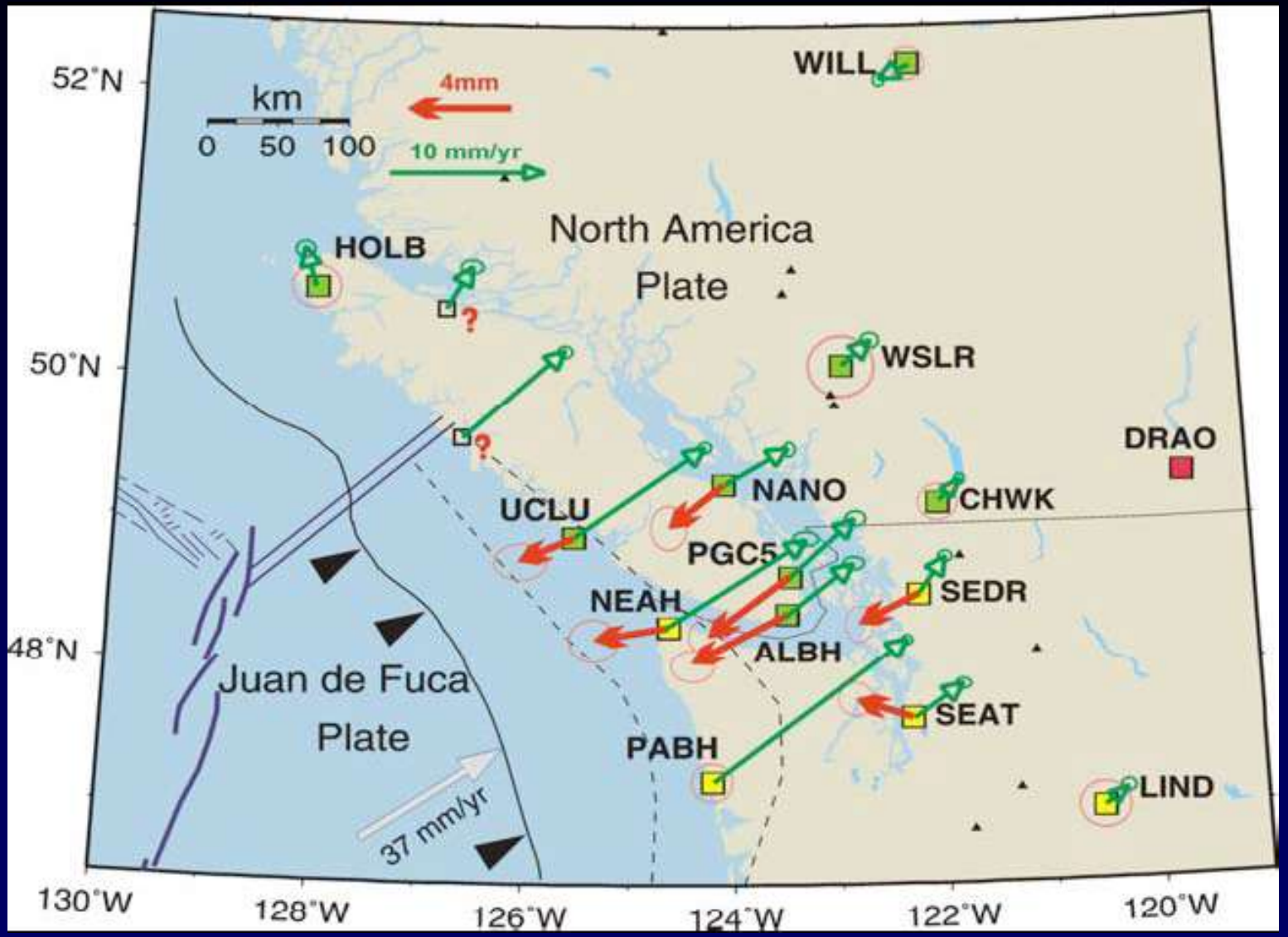


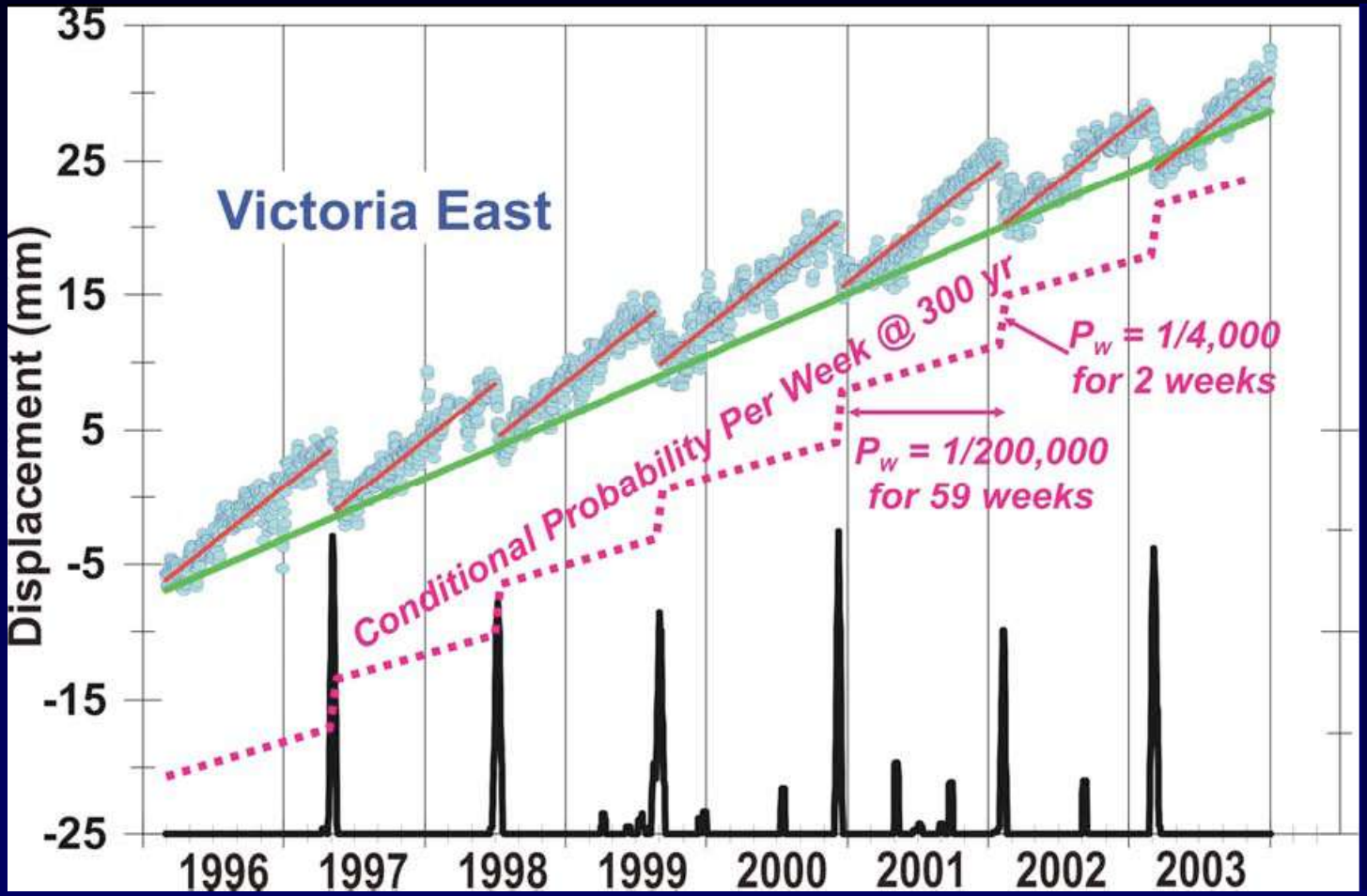


Herb Dragert

Garry Rogers



Natural Resources Canada



Herb Dragert, National Resources Canada

The End