

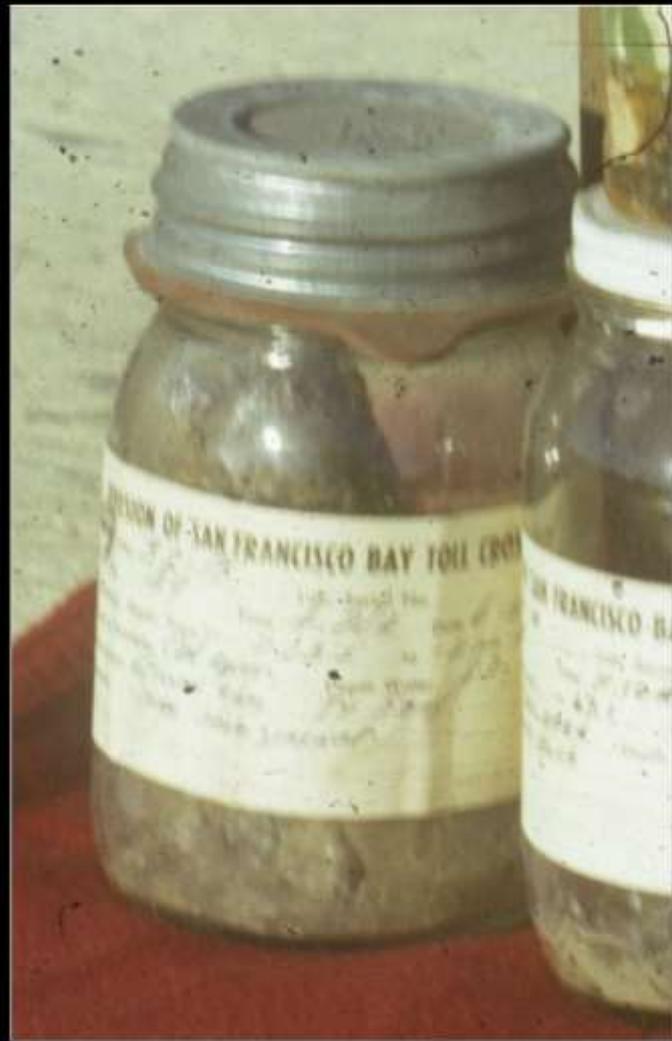


Helen and Ted Halsey, Jersey Island, 17 January 1980





Jersey Point, 1979



1974

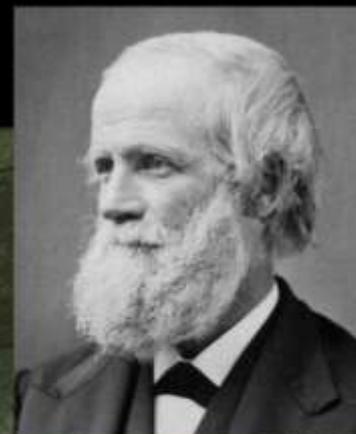


Bradford Island, 1978



Scirpus acutus

The Delta is a Mudge marsh



100 m

To Boston, 5 miles



PROCEEDINGS

OF THE

ESSEX INSTITUTE.

VOLUME II.

1856 to 1860.

SALEM:

PRINTED FOR THE INSTITUTE,

BY T. J. HUTCHINSON, PRINTER.

1862.

“Through the whole depth of the brown soil of the marsh the roots of the saline grasses as intermingled in the same manner as when living.

“The saline grasses grow only above ordinary high water mark, and as the roots in the lowest part of the soil, even eight or more feet below the surface, are in their natural position, we must conclude that their *situs* was above the high water line, and that the subsidence has been so gradual that the growth of the plants has never been interrupted.”

— Benjamin Franklin Mudge (1856)
The salt marsh formations of Lynn



“Pepper Island, Bolinas Lagoon. The line of the earthquake fault was between the pool and Professor Jepson. April 1907”



G.K. Gilbert photo 3055



Pepper Island

Bolinas

↓ ~30 cm

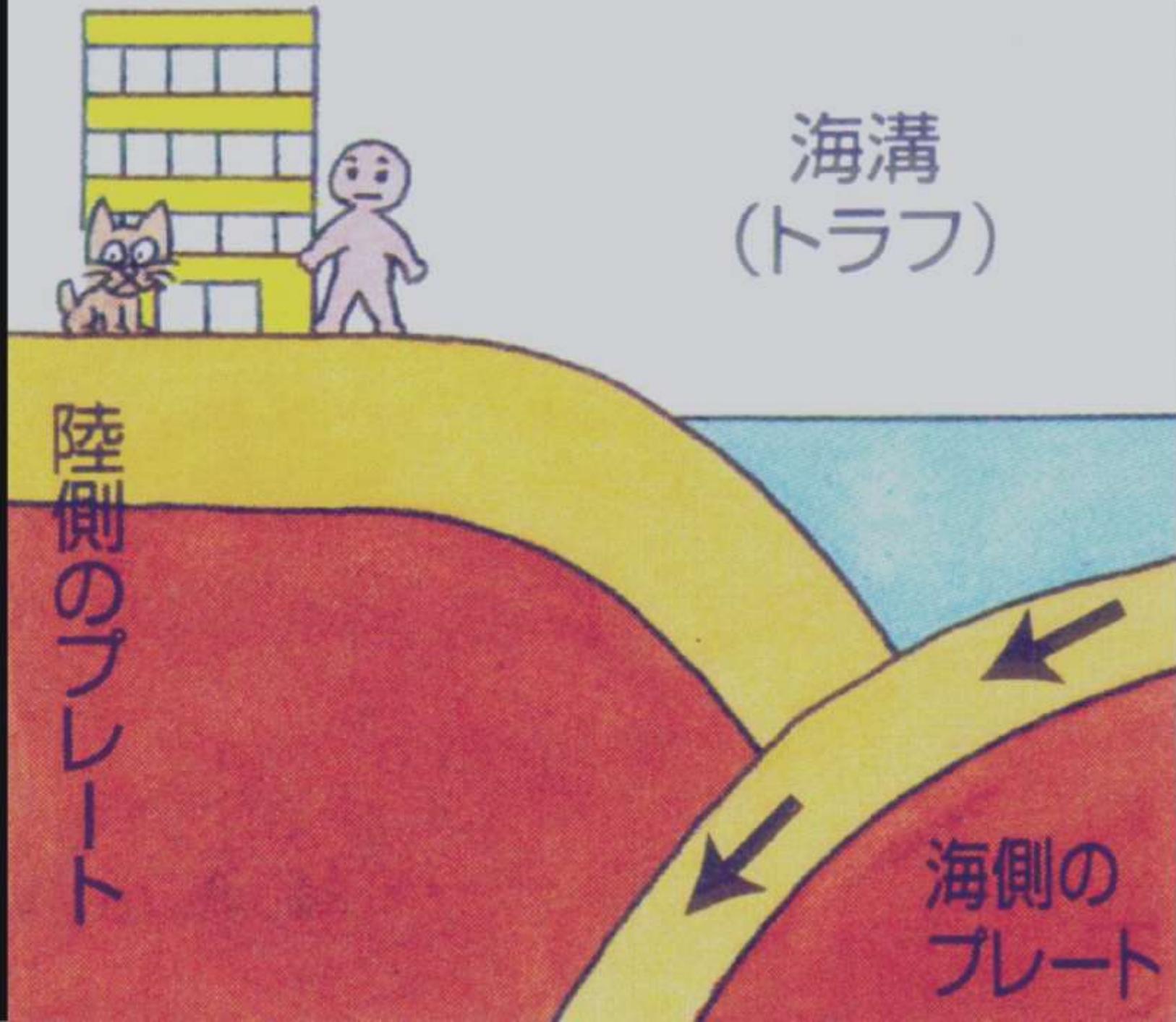
G.K. Gilbert photo 3050

Graben: J.R. Bergquist
[http://pubs.er.usgs.gov/
publication/ofr78802](http://pubs.er.usgs.gov/publication/ofr78802)

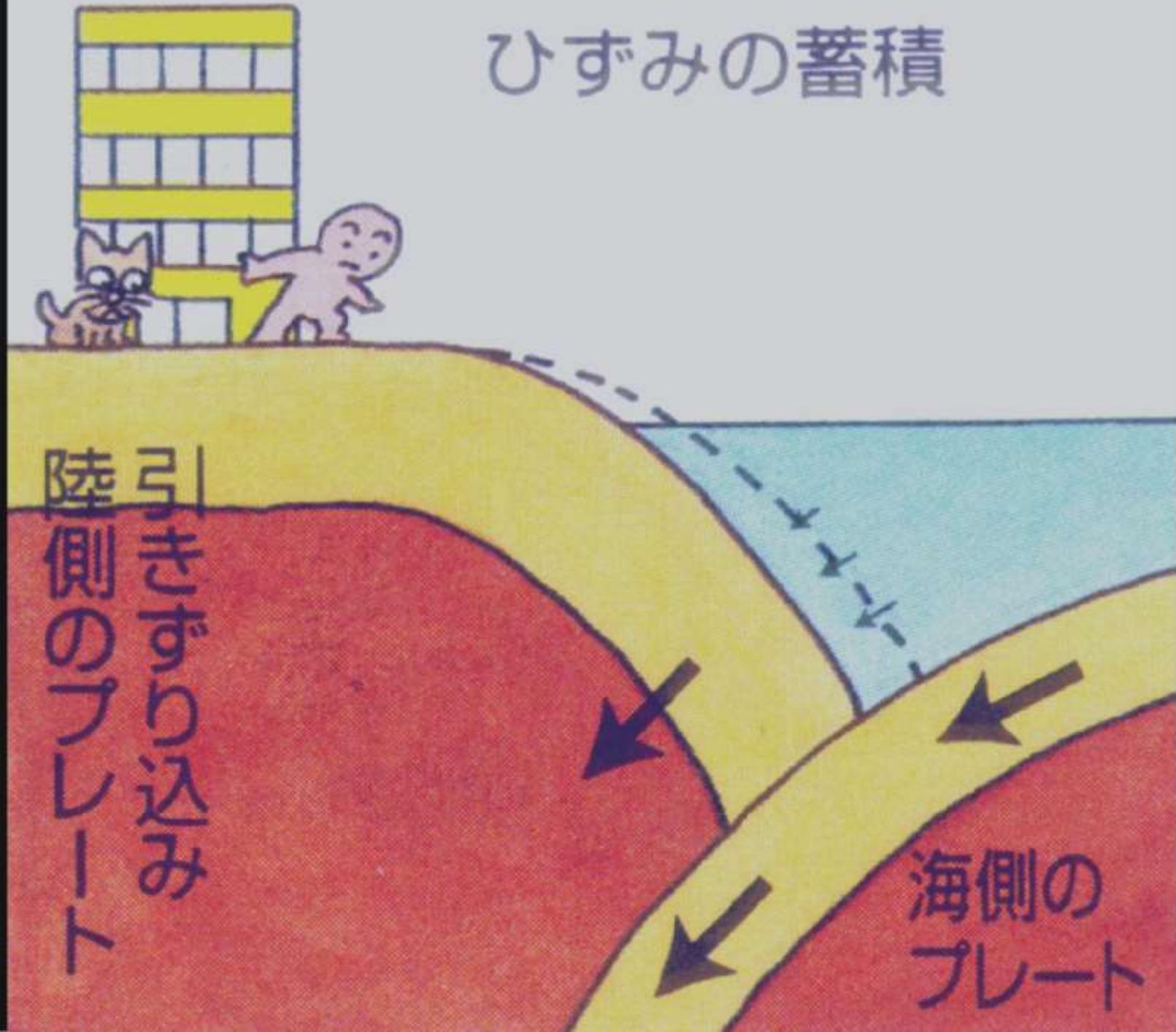
海溝
(トラフ)

陸側のプレート

海側のプレート



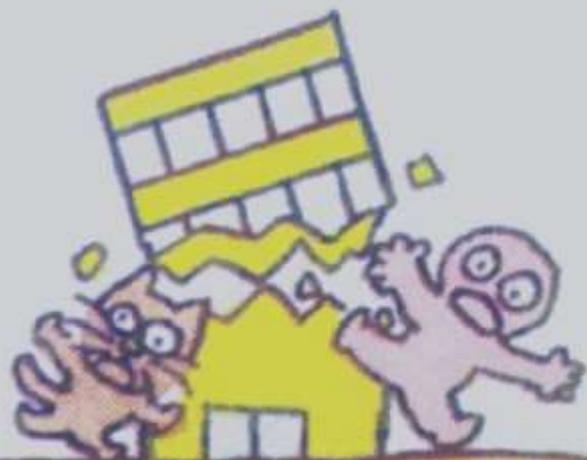
ひずみの蓄積



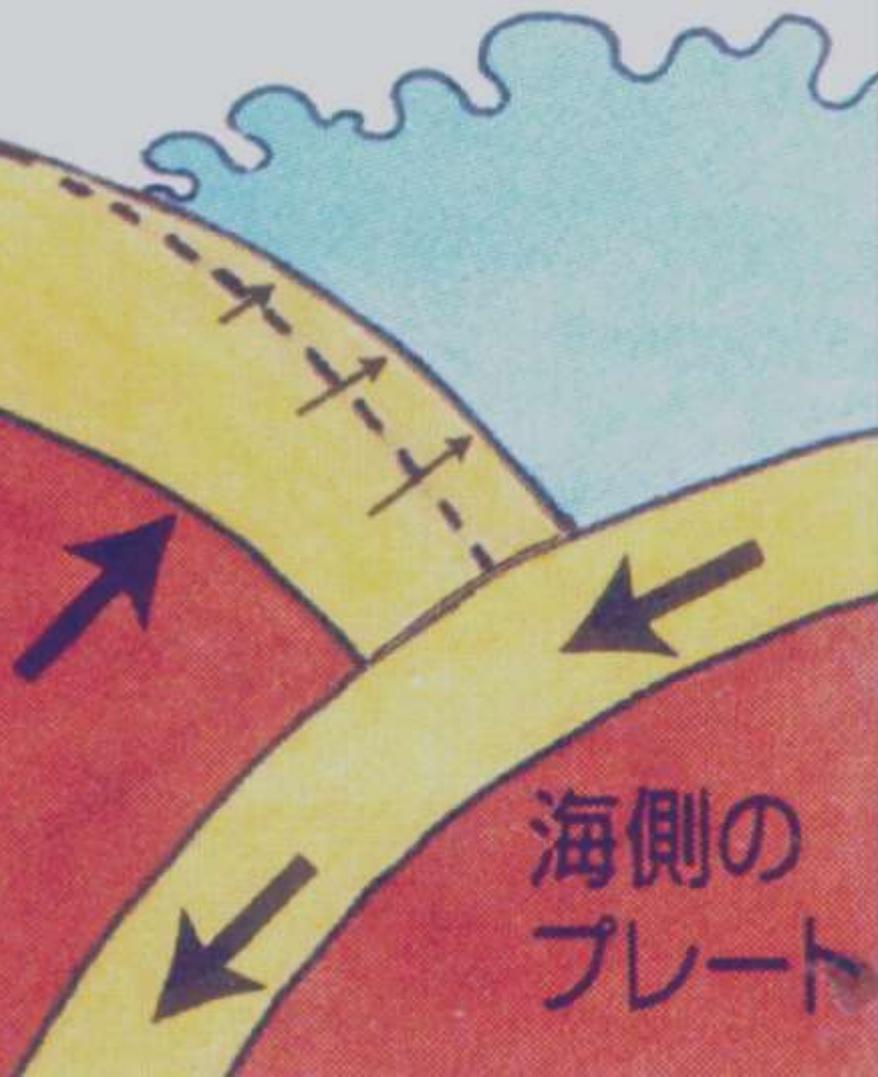
引きずり込み
陸側のプレート

海側のプレート

地震と津波の発生



陸側のプレート
跳ね上がり



海側のプレート

LARGEST THRUST EARTHQUAKE known as of April 2011

9.5

9.0

8.5

8.0

7.0



Linear by seismic moment

Stein & Okal (2007)

McCaffrey (2008)

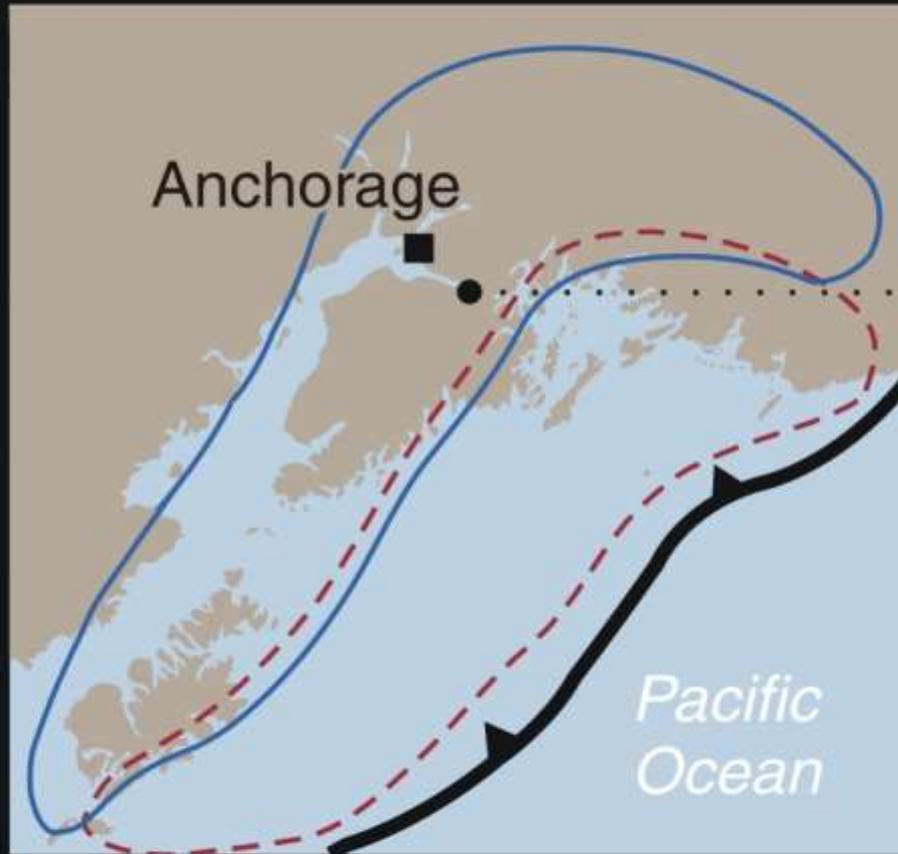
Muir-Wood & Mignan (2009)

1964 Alaska earthquake



North
America
plate

Pacific
plate



Lowered

Portage

Ruptured

*Pacific
Ocean*

0

500 km



Rising tide, April 1964



PORTAGE GARAGE

NEED



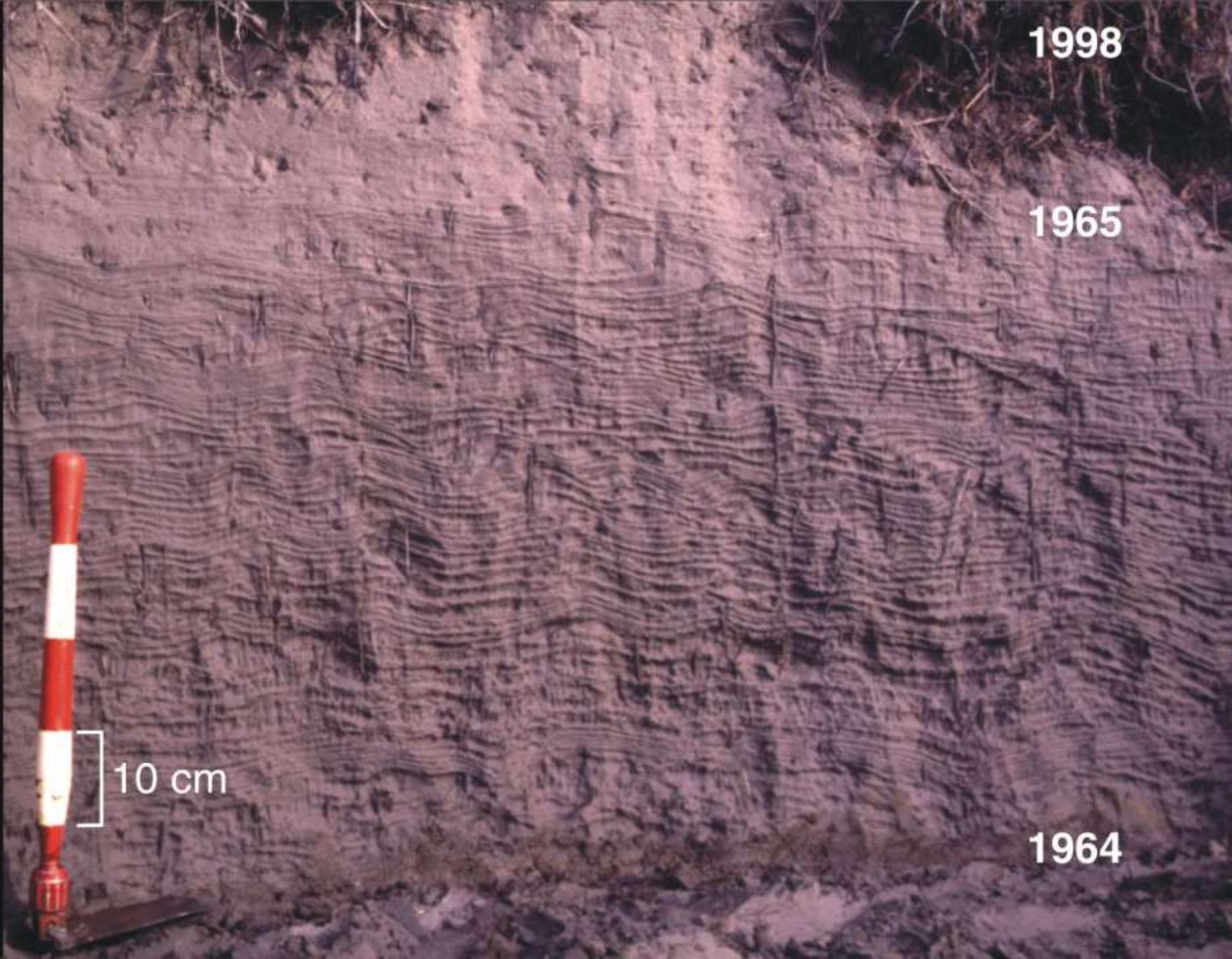


1998

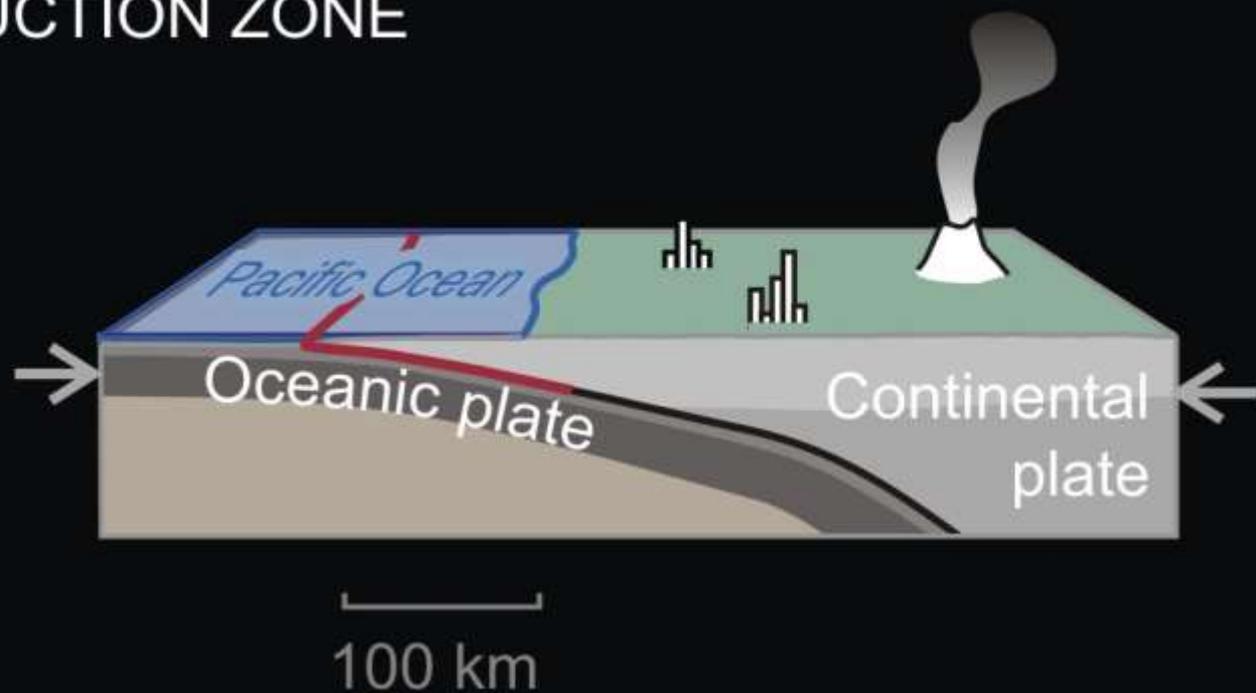
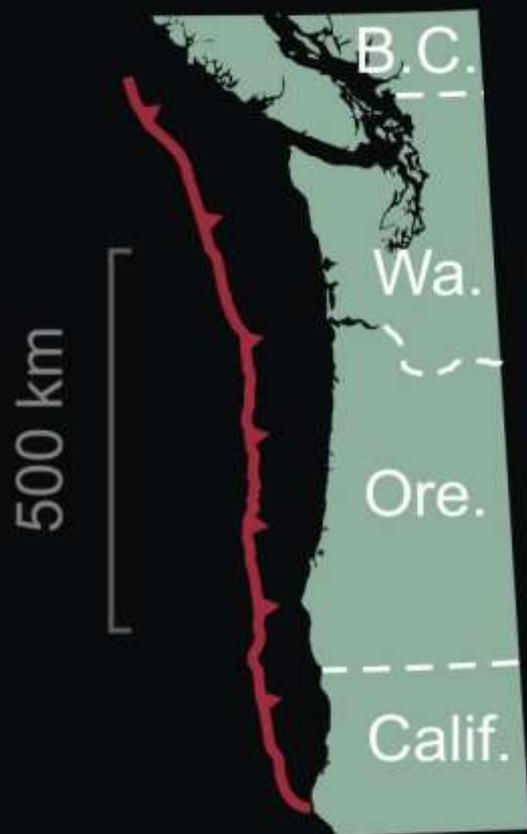
1965

1964

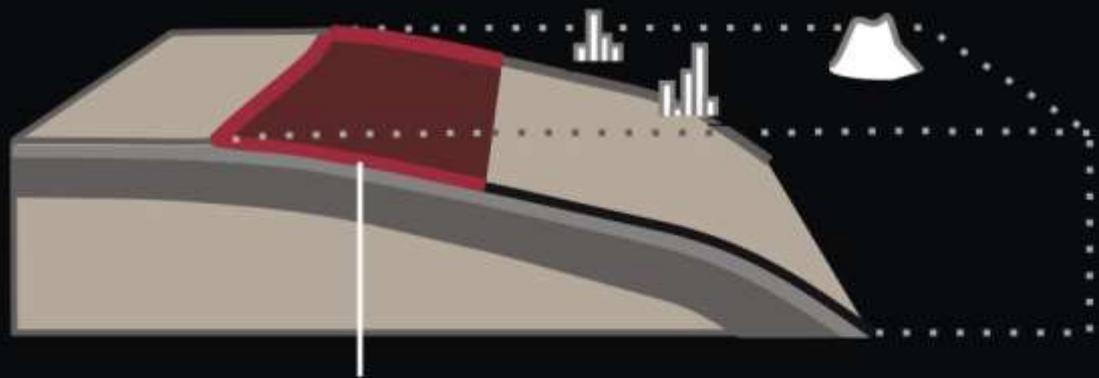
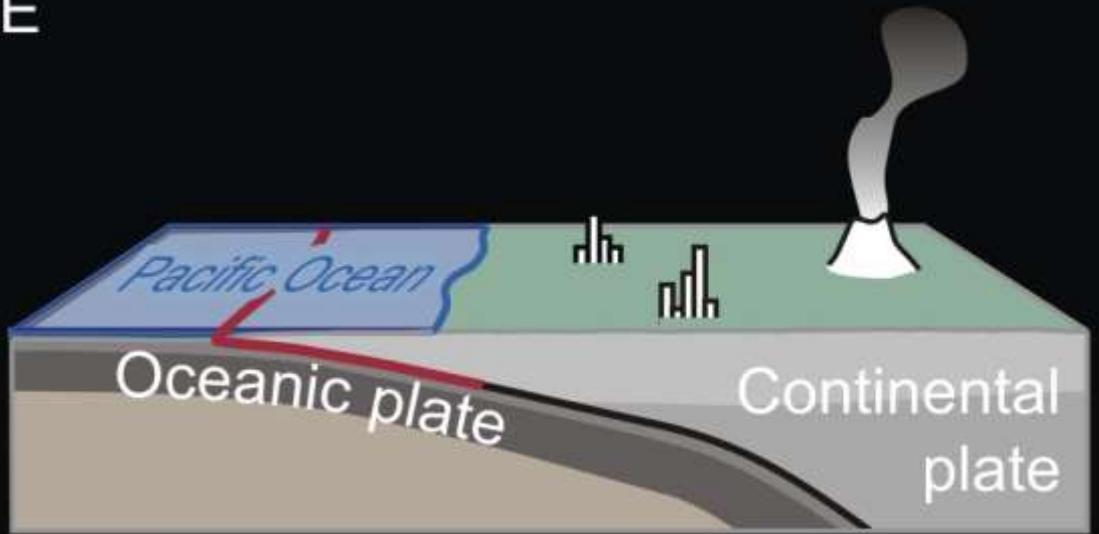
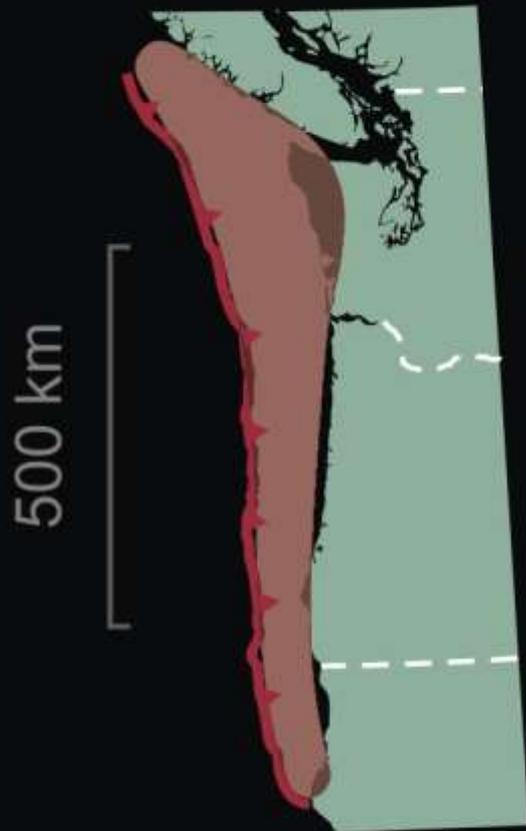
10 cm



CASCADIA SUBDUCTION ZONE



REAGAN-ERA PUZZLE



Sliding smoothly? Stuck dangerously?

100 km

RECORDING AN EARTHQUAKE

Before
earthquake

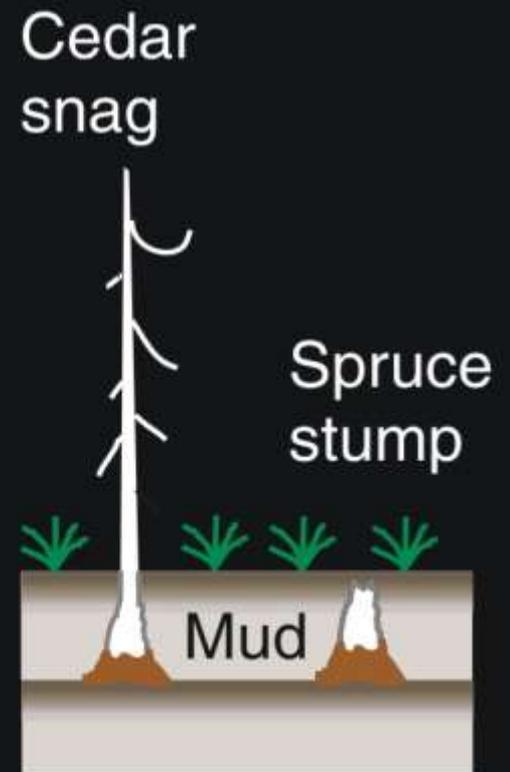


One year after
earthquake

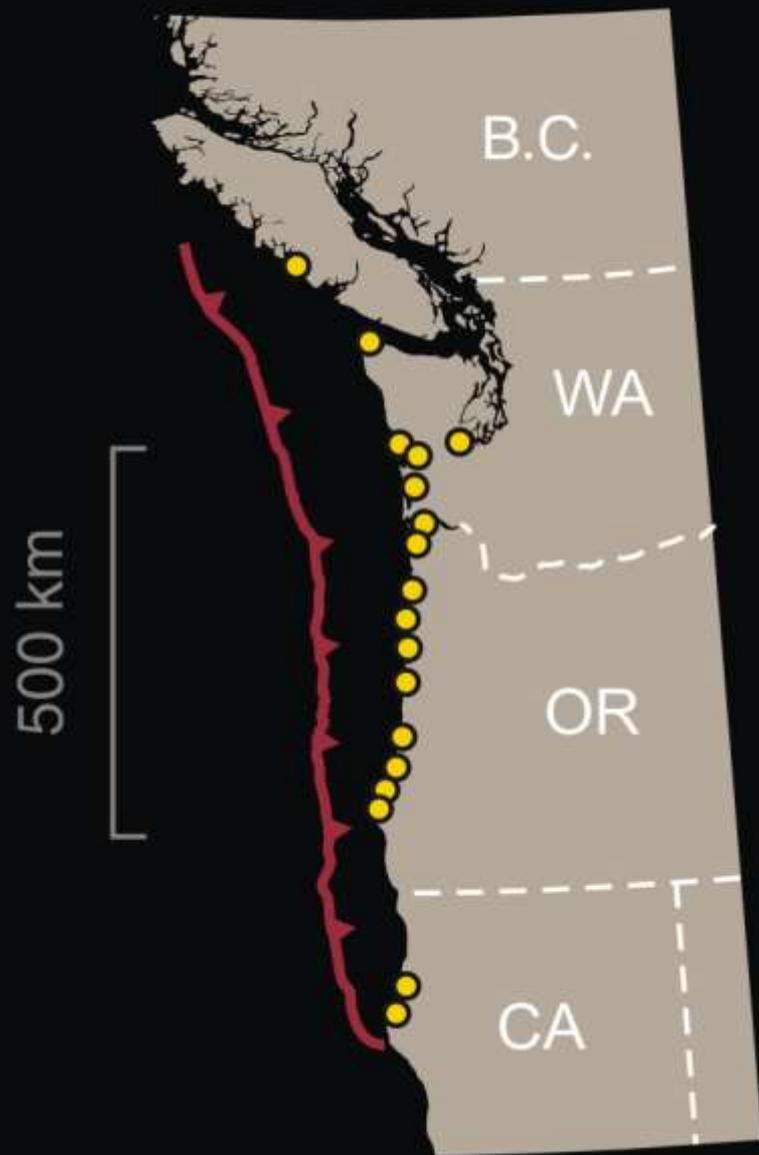
Land subsides
during earthquake



Decades to
centuries later



LAND LOWERED SUDDENLY



Copalis River, WA

BURIED SPRUCE-SWAMP SOILS



Tidal marsh

A.D.
1700

~400

Low tide in arm of Willapa Bay

RECURRENCE

Forest

Marsh

Mudflat



1000

BC | AD

1000

2000

Time →

SW Washington estuaries
Ranges at >95% confidence



TSUNAMI RECORDER

Before
earthquake

Tidal marsh

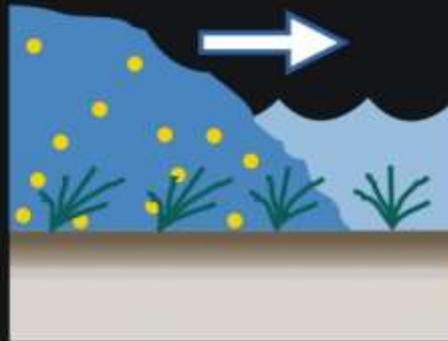


Minutes after
earthquake

Land subsides
during earthquake

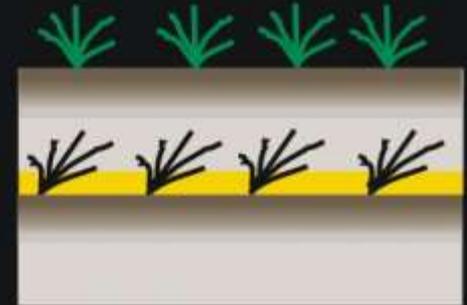


Tsunami



Decades to
centuries later

Sand sheet



FLOPOVERS



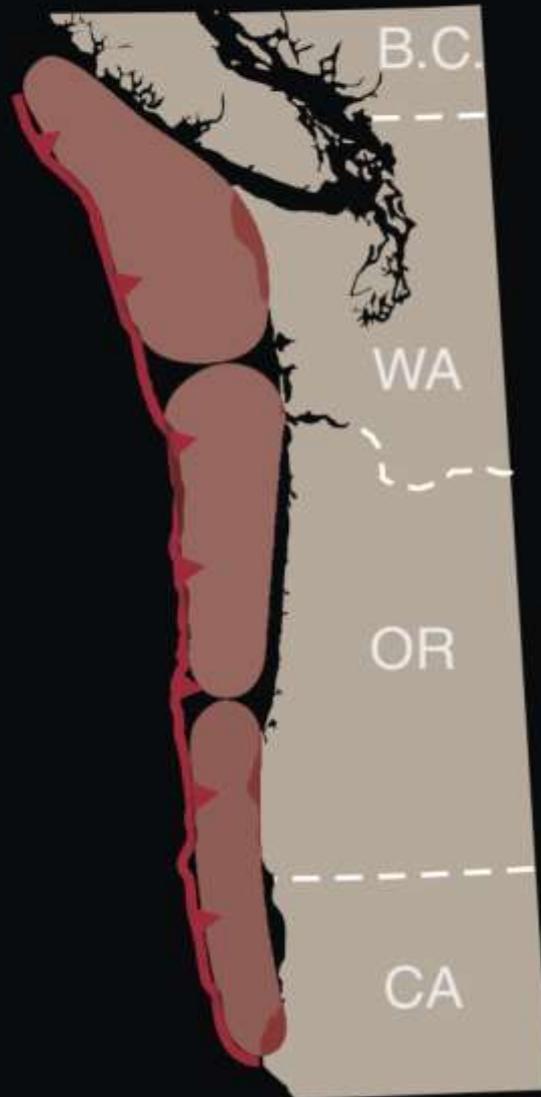
Willapa Bay



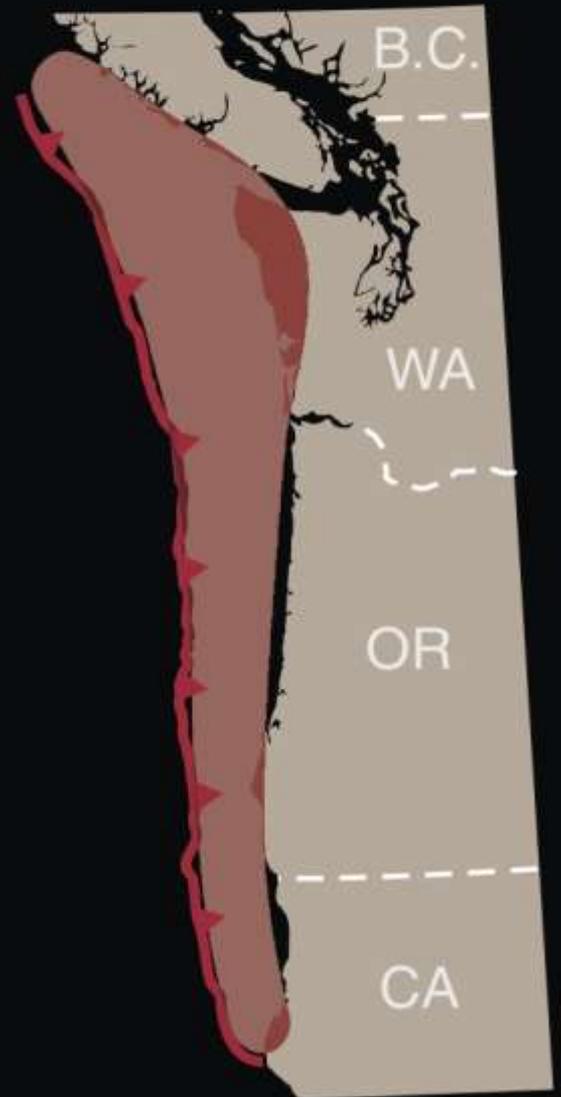


SEISMOLOGICAL MENU IN 1995

Breakfast links

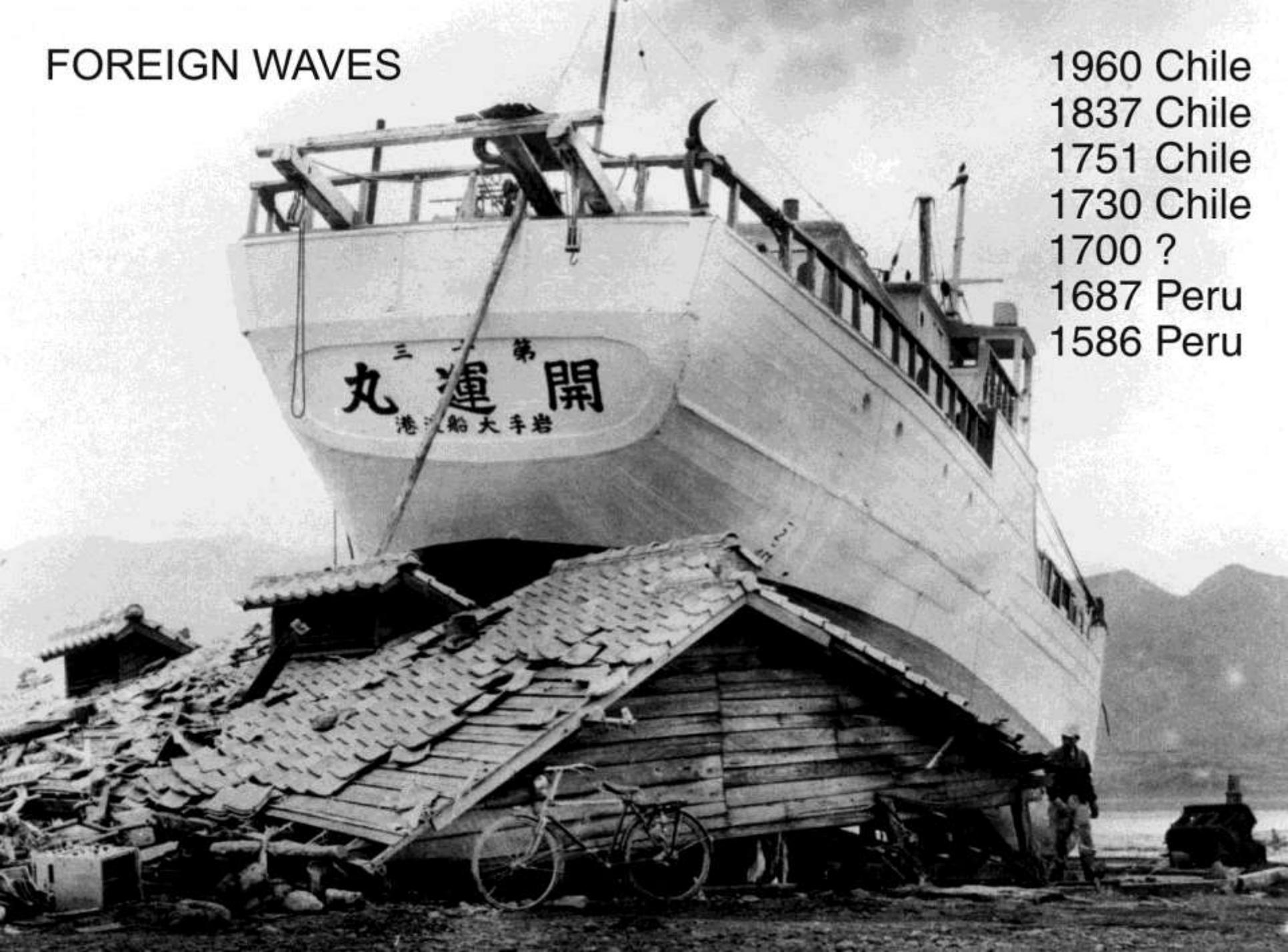


Dinner sausage



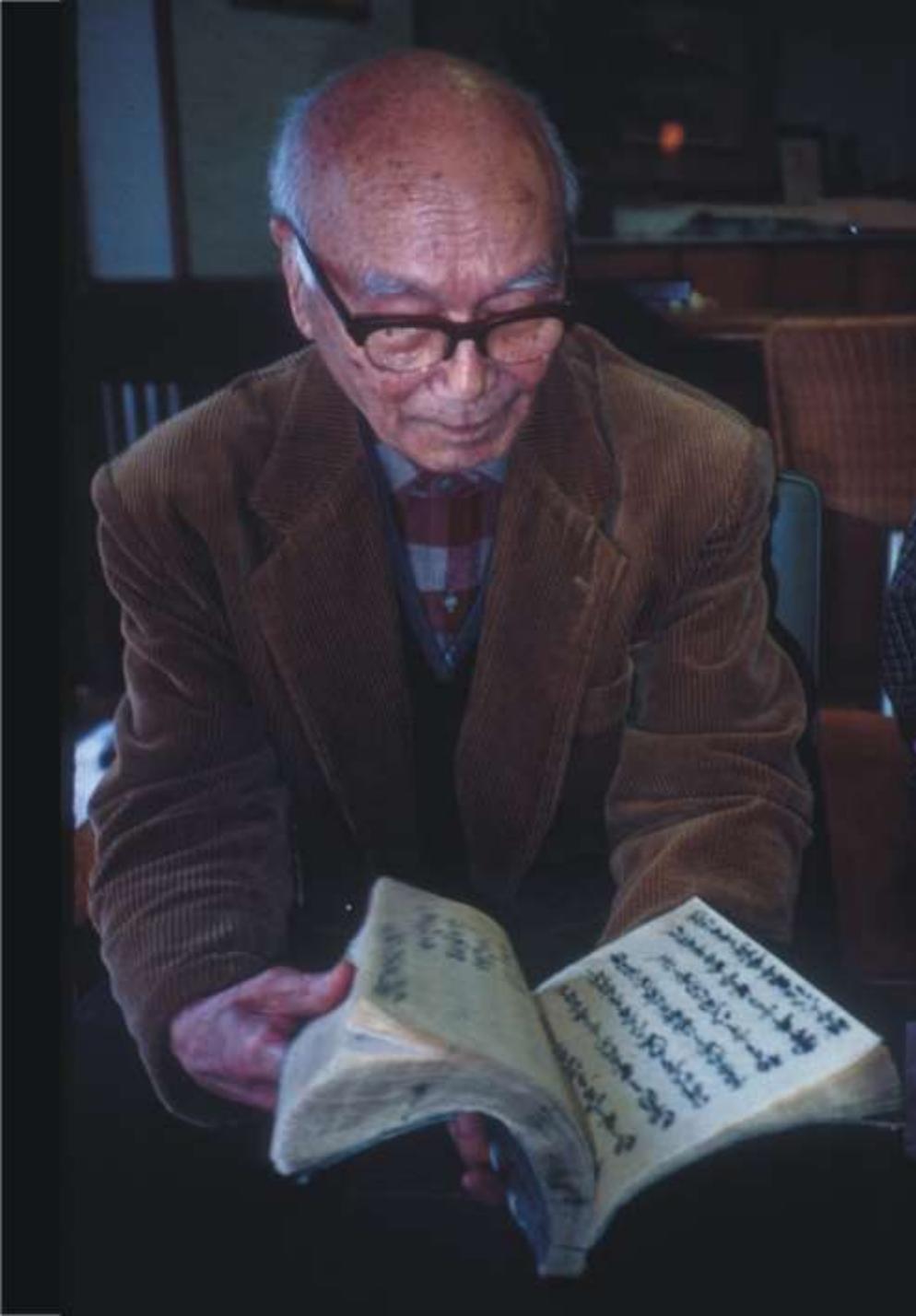
FOREIGN WAVES

1960 Chile
1837 Chile
1751 Chile
1730 Chile
1700 ?
1687 Peru
1586 Peru









“MIHO-MURA YŌJI OBOE”

Held by its possessor in
1999, Endō Kunio





くらりりり

くらりりり

ふはる

三條

くらりりり

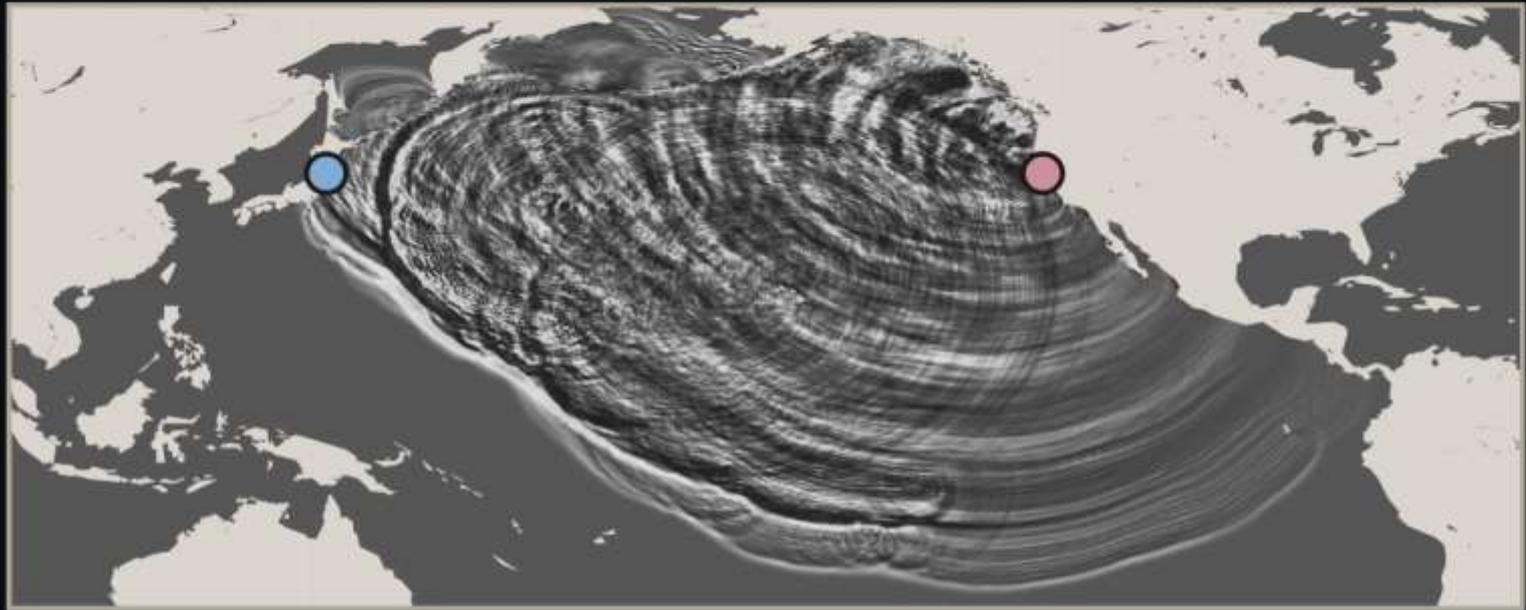
くらりりり

くらりりり

EARTHQUAKE DATING

Tsunami noticed

Tsunami departs



● ← ~10 hours → ●

Year

Genroku 12

A.D. 1700

Month

12

January

Day

8

26 Gregorian

Hour

"hour of nine"

evening

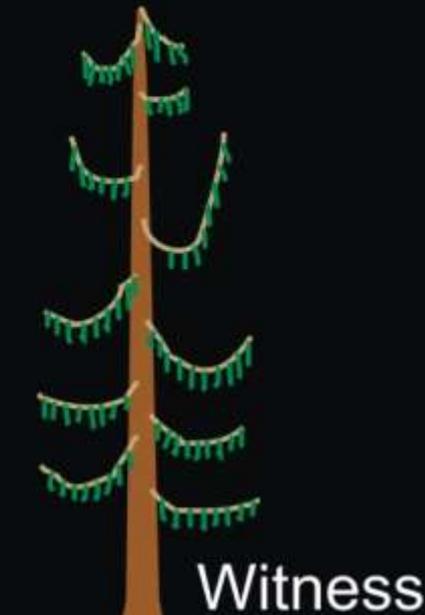
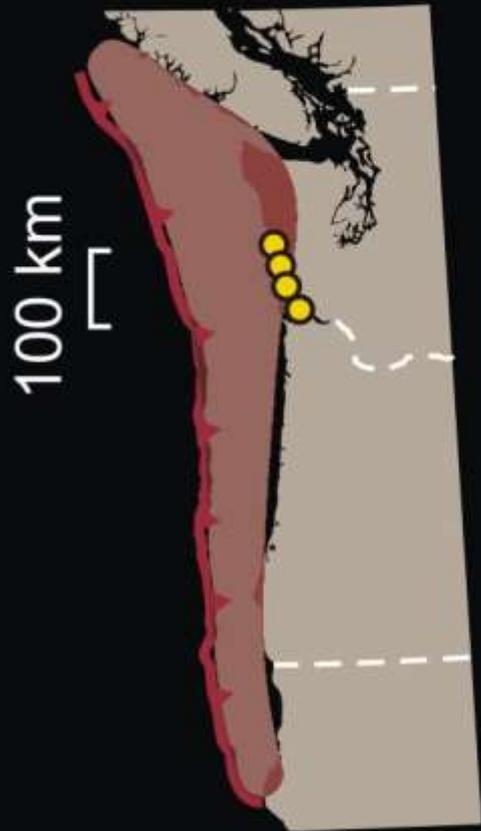
TREE DEATH IN JANUARY 1700?

David Yamaguchi



Photo by
Michael Clapp

TREE-RING TEST



Dendrochronology by
David Yamaguchi
Gordon Jacoby

Victim

Salt marsh

Bark



EVACUATION SIGN, Christmas 2004



Hoquiam, Washington; photo by Brian Smale

Widespread contributor to shaking hazards



Leading source of earthquake hazard to tall buildings

 Cascadia M 8 or 9

 Lesser quake on other fault

Shaking at 1 cycle per second
Probability 2% in 50 years

Harmsen, Frankel, & Peterson,
USGS OFR 03-440

“NIHON SANDAI
JITSUROKU”

“True history of
three reigns of
Japan”

50 volumes
completed AD 901,
covering 858-887

Except of copy
from 1614,
courtesy of
Yuki Sawai

野朝臣仿世為次侍從五月戊午朔五日壬
戌停端午之節廿六日祭未陸奧四地大震
動流克如晝隱映頃久人民叫呼伏不能起
或屋仆壓死或地裂埋殮馬牛駭奔或相屏
踏城郭倉庫門櫓墻壁頽落顛覆不知其數
海口哮吼声似雷霆發濤涌湖汙迴漲長忽
至城下去海數十百里浩々不辨其涯溪原
野道路惣為滄溟垂舩不遑登山難及溺死
者千計資產苗稼殆無子遺享六月亥朔十

Fifth month, 26th day, province of Mutsu

Ground large quake

Light like day shown briefly

People screamed lying could not stand

Houses collapsed crushed to death, ground opened buried to death

Horses and cattle ran with fright trampled

Castle storehouse scaffold wall collapsed, too many to count

River mouth sound like thunder, waves came up ran round strong

Soon arrived near castle

Along coast for tens or hundreds of *ri*, too far to see end

Wilderness road became sea

Taking boat impossible, clambering up hills difficult

Drowned people about 1,000, property and seedlings mostly lost

Yoshida, T. Jogan ju'uichi nen Mutsu fujou no shindou kouitsu [Quake and flood in Mutsu 11th year of Jogan era] *Rekishi Chiri* **8**, 1033-1040 (1906).

Imamura, A. Past tsunamis of the Sanriku coast. *Japanese Journal of Astronomy Geophysics* **11**, 79-93 (1934)

ISHI-
NO-
MAKI

10 cm

Masanobu
Shishikura,
AIST



2011
sand and mud

915 volc. ash

869 sand

TOHOKU HINDSIGHT

Sawai, Y., Namegaya, Y., Okamura, Y., Satake, K., and Shishikura, M., 2012, Challenges of anticipating the 2011 Tohoku earthquake and tsunami using coastal geology: *Geophysical Research Letters*, v. 29, no. 21, L2130, doi:10.1029/2012GL053692.



Sugawara, D., **Goto, K.**, Imamura, F., Matsumoto, H., and Minoura, K., 2012, Assessing the magnitude of the 869 Jogan tsunami using sedimentary deposits: prediction and consequence of the 2011 Tohoku-oki tsunami: *Sedimentary Geology*, v. 282, p. 14-26, doi:10.1016/j.sedgeo.2012.08.001.

