Groundwater and Coastal Phenomena Preceding the 1944 Tsunami (Tonankai Earthquake)

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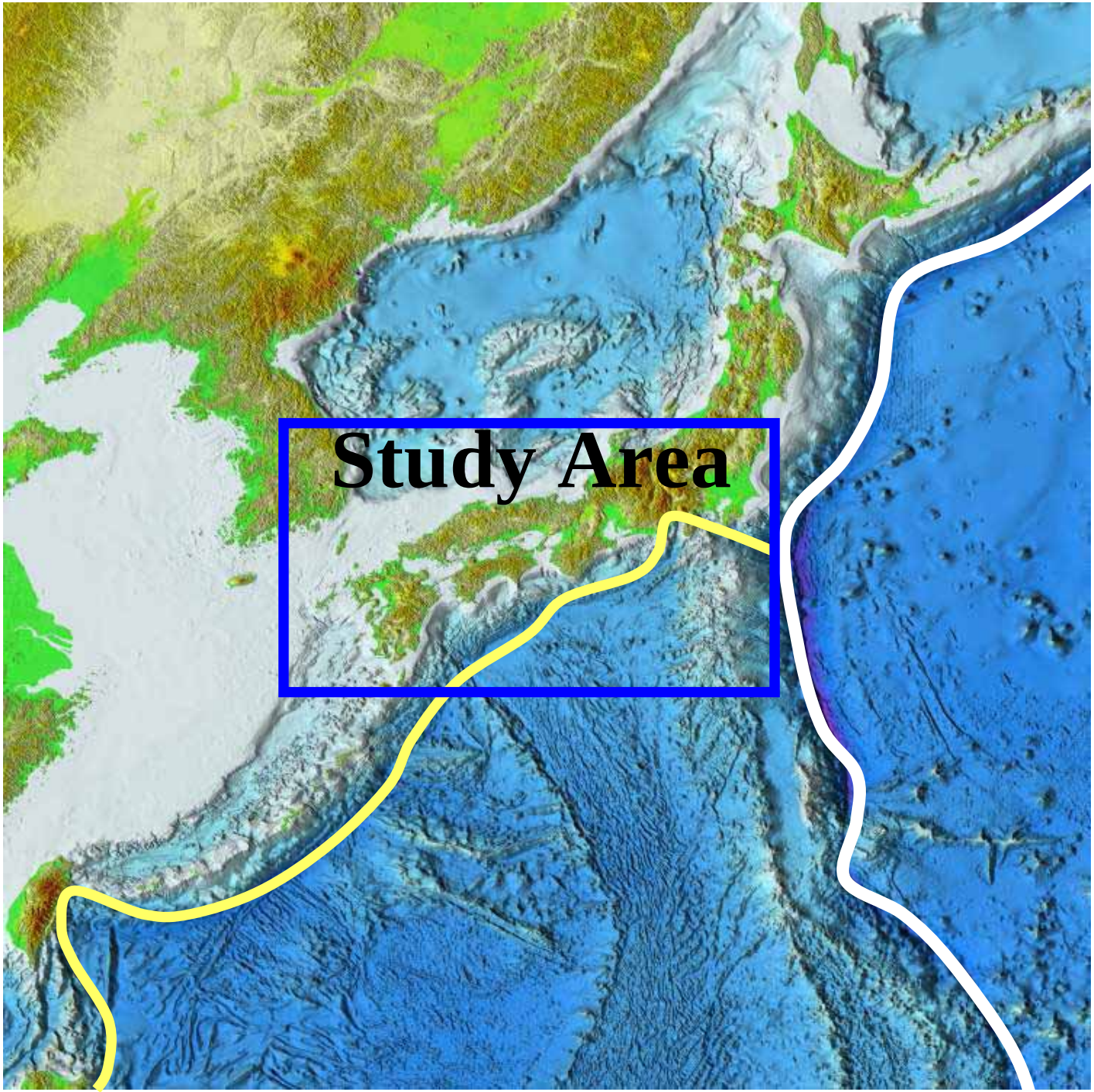
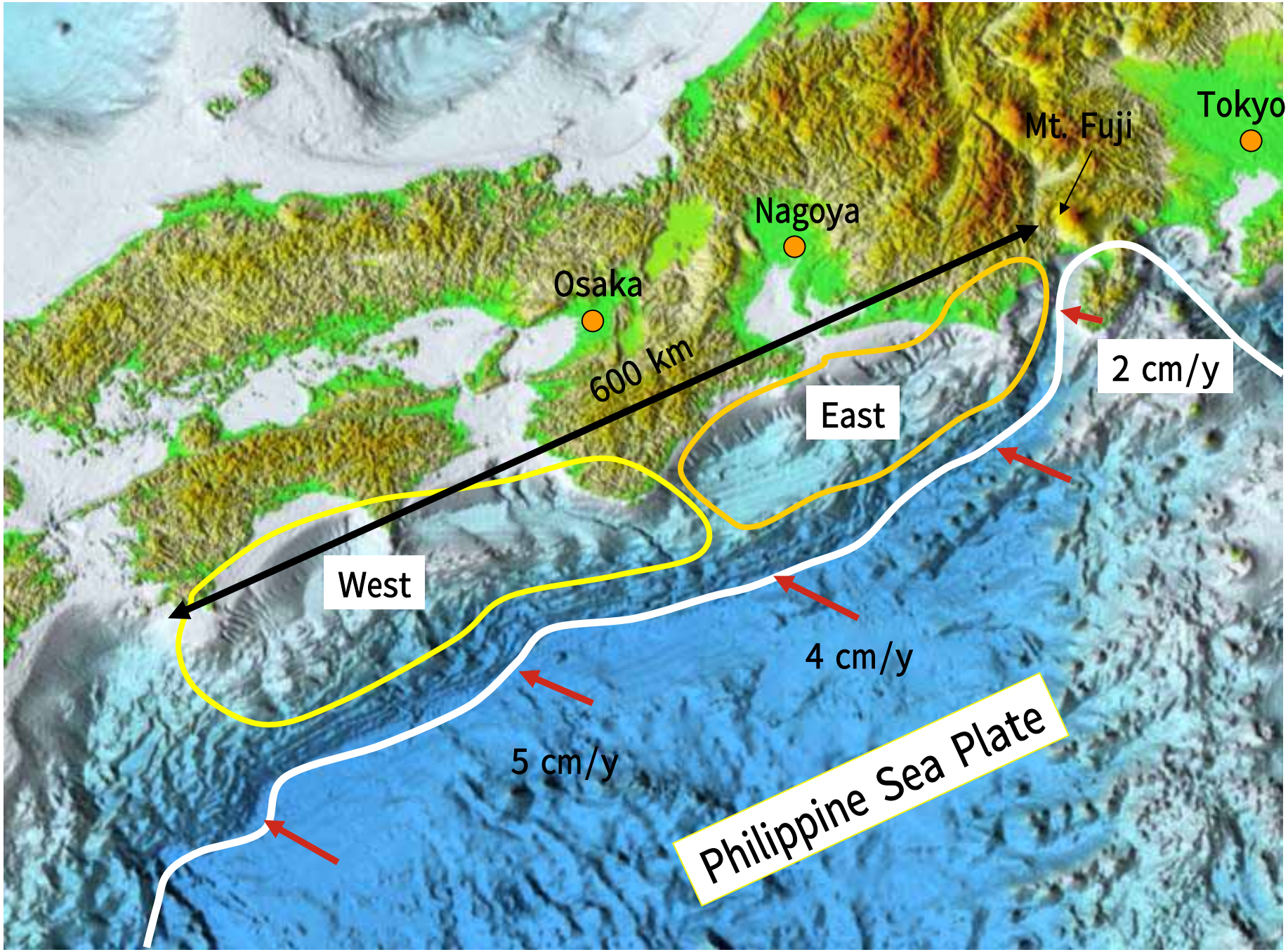
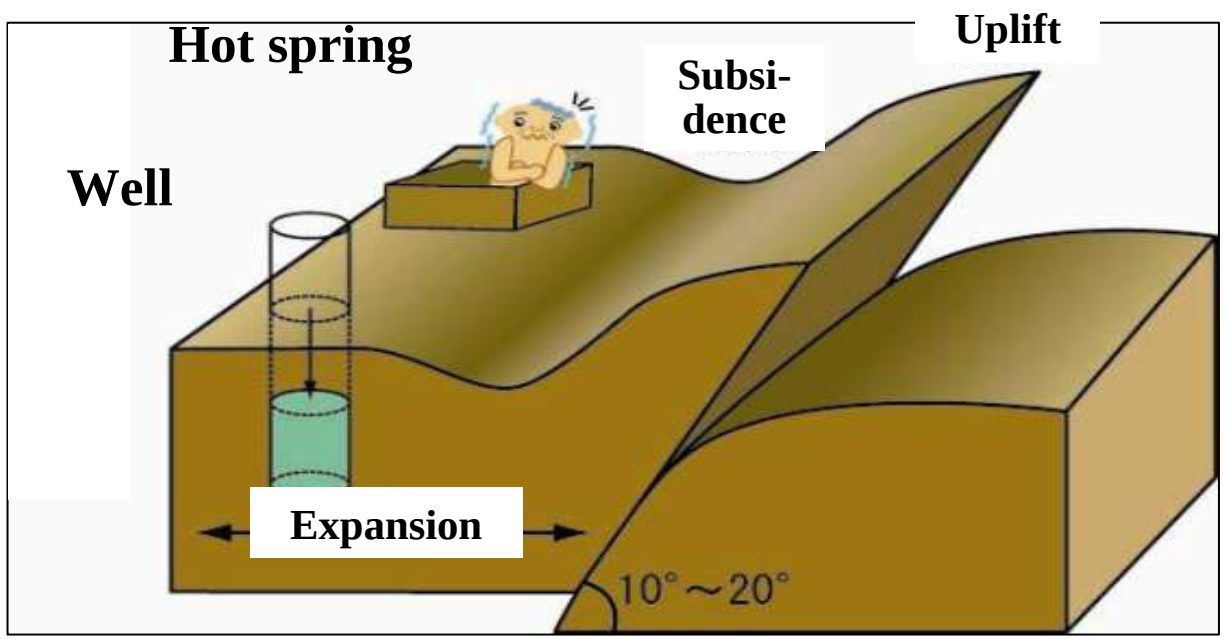

Study Area


Tokyo
Mt. Fuji
Nagoya
Osaka
600 km
East
West
2 cm/y
4 cm/y
5 cm/y
Philippine Sea Plate

Characteristics of large earthquakes along the Nankai trough

1. Strong ground motions in a large region
2. Tsunami damages in a large region
3. Groundwater level changes at hot springs

*4. Crustal deformation (not always documented)

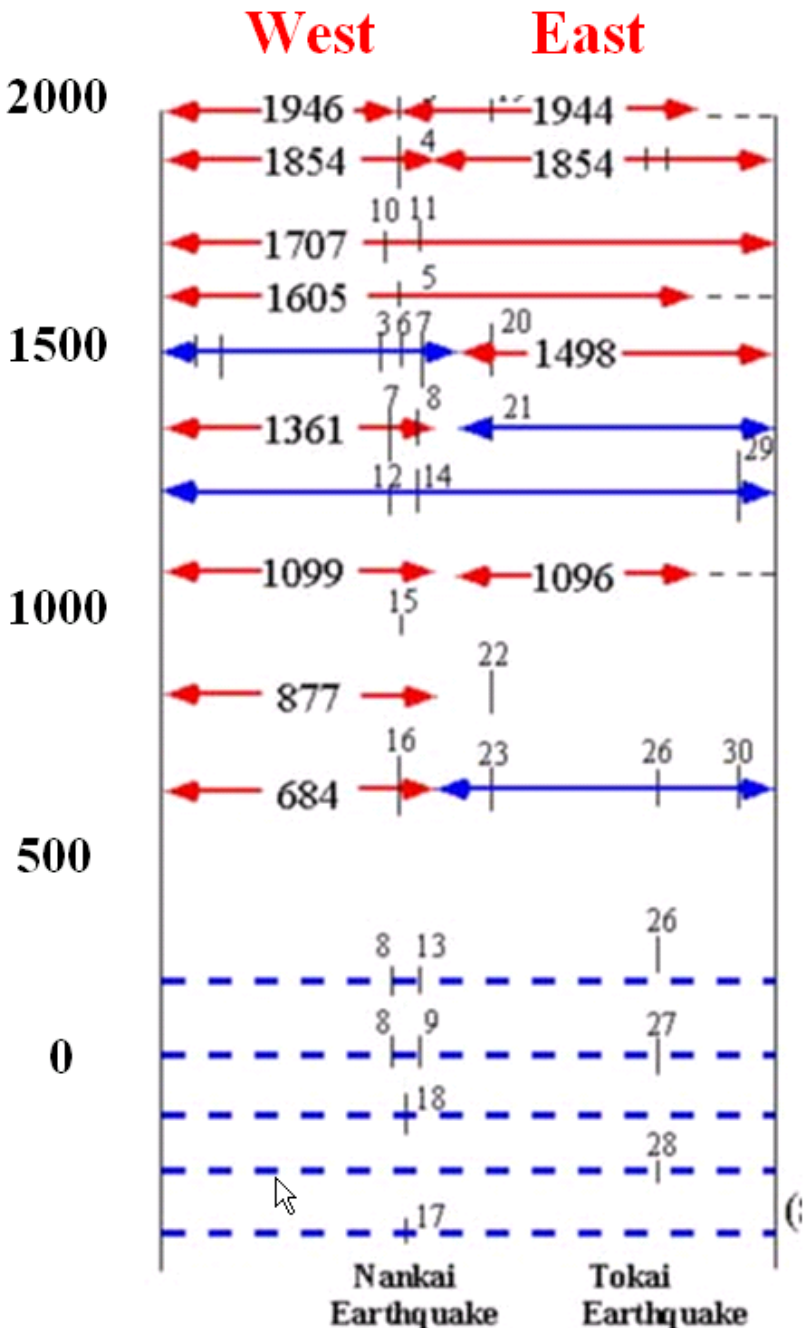


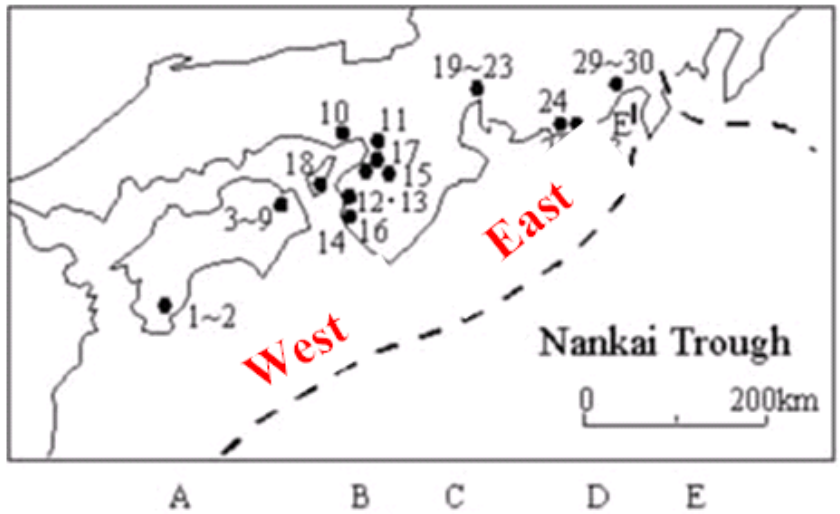
Documented Oldest Nankai Trough Earthquake, 684 A.D.

- Documented only with about 100 characters in an official document (“Nihon Shoki”),
- But this information is sufficient to identify the event as a large subduction earthquake along Nankai trough since it describes three following key words:

1) Regional strong shaking
2) Regional large tsunami
3) Groundwater level changes

Large Earthquakes along the Nankai Trough





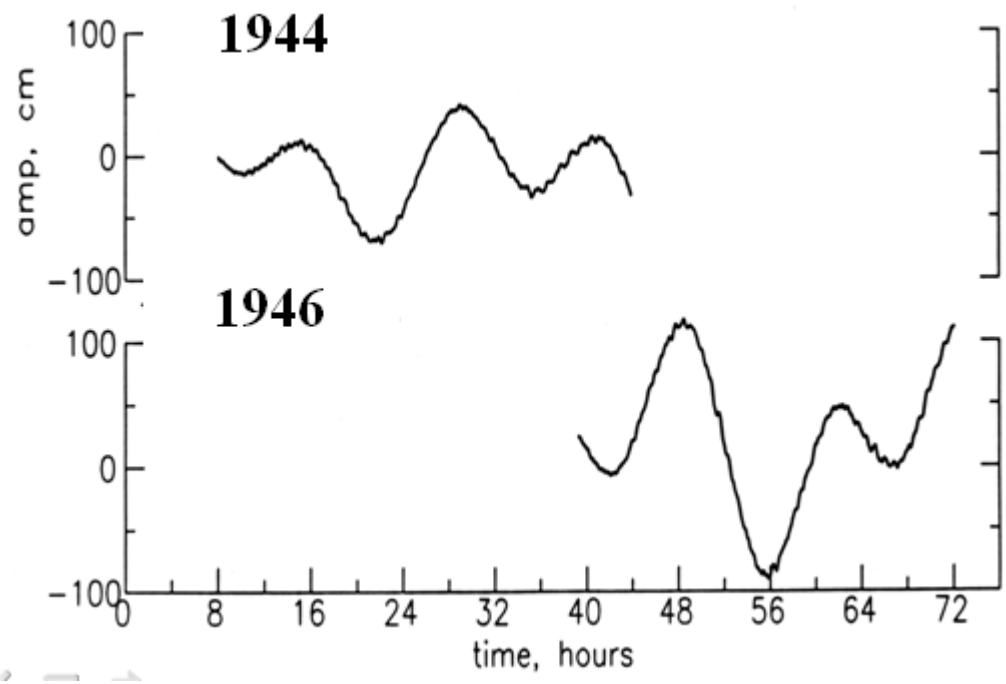
Historical Documents

Archeological Data

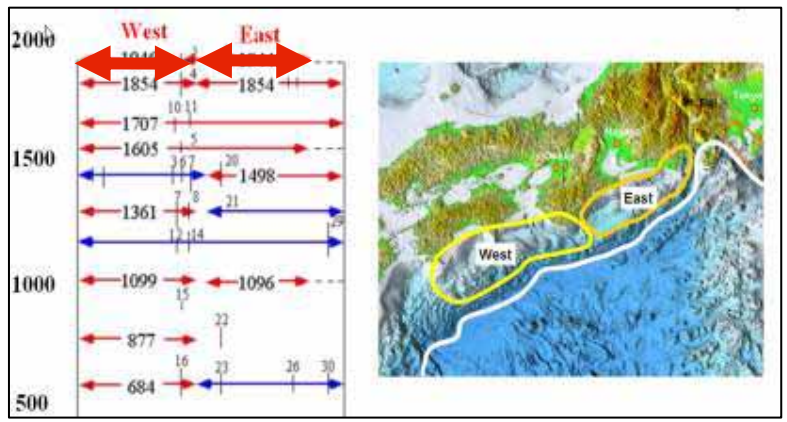
Modified from Sangawa (1992)

1944 and 1946 Events
(Tonankai and Nankai)

Tide gage records at San Diego

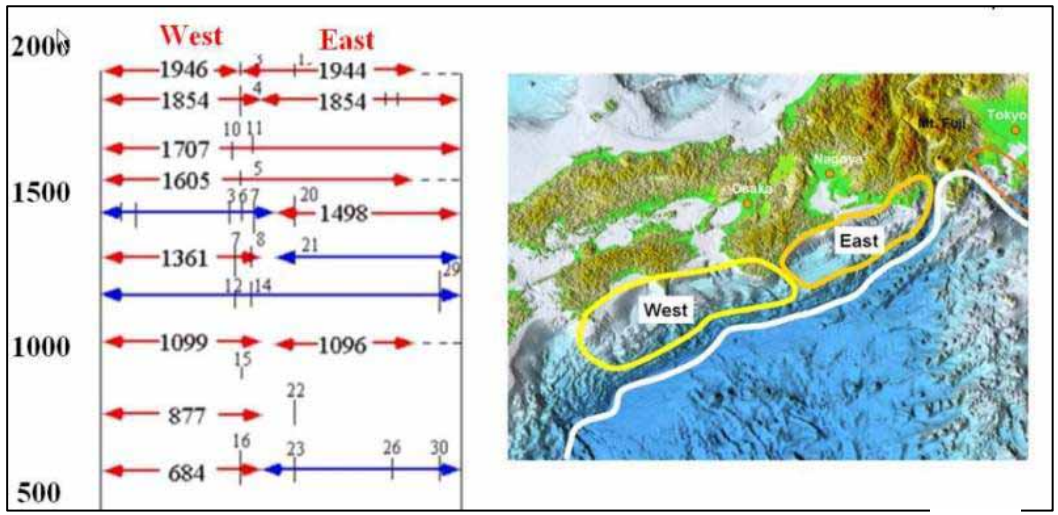


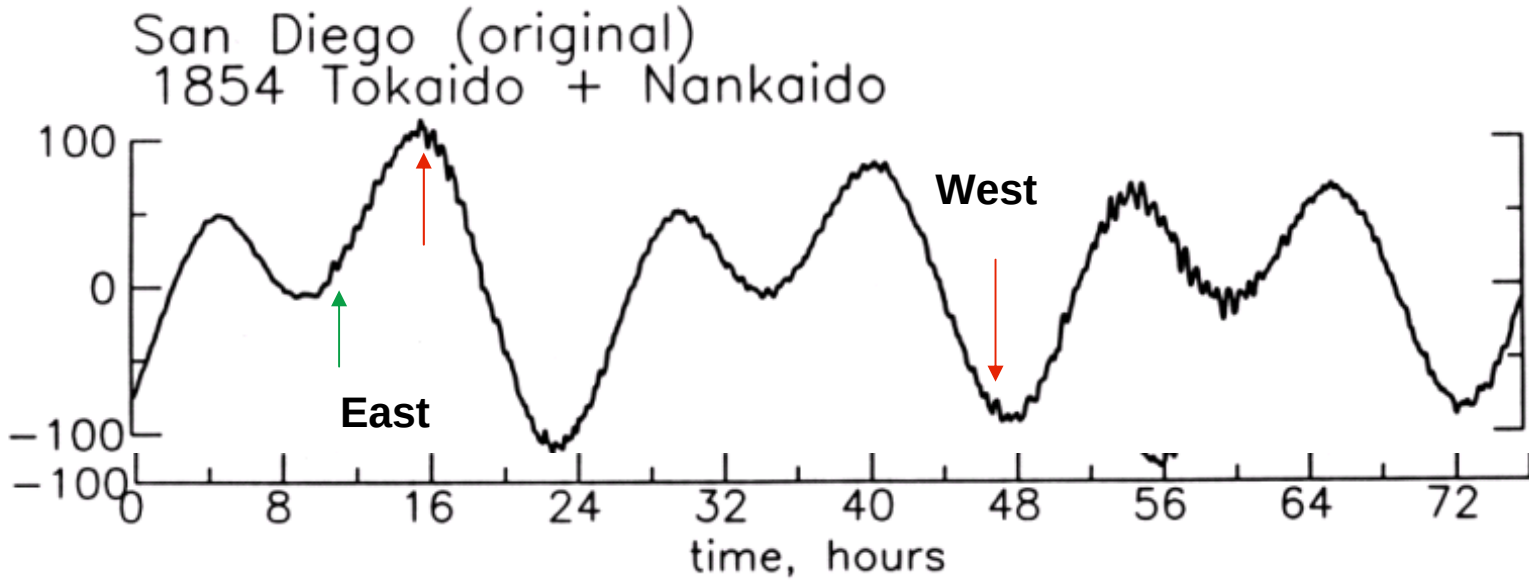
(Tanioka and Satake, 1993)



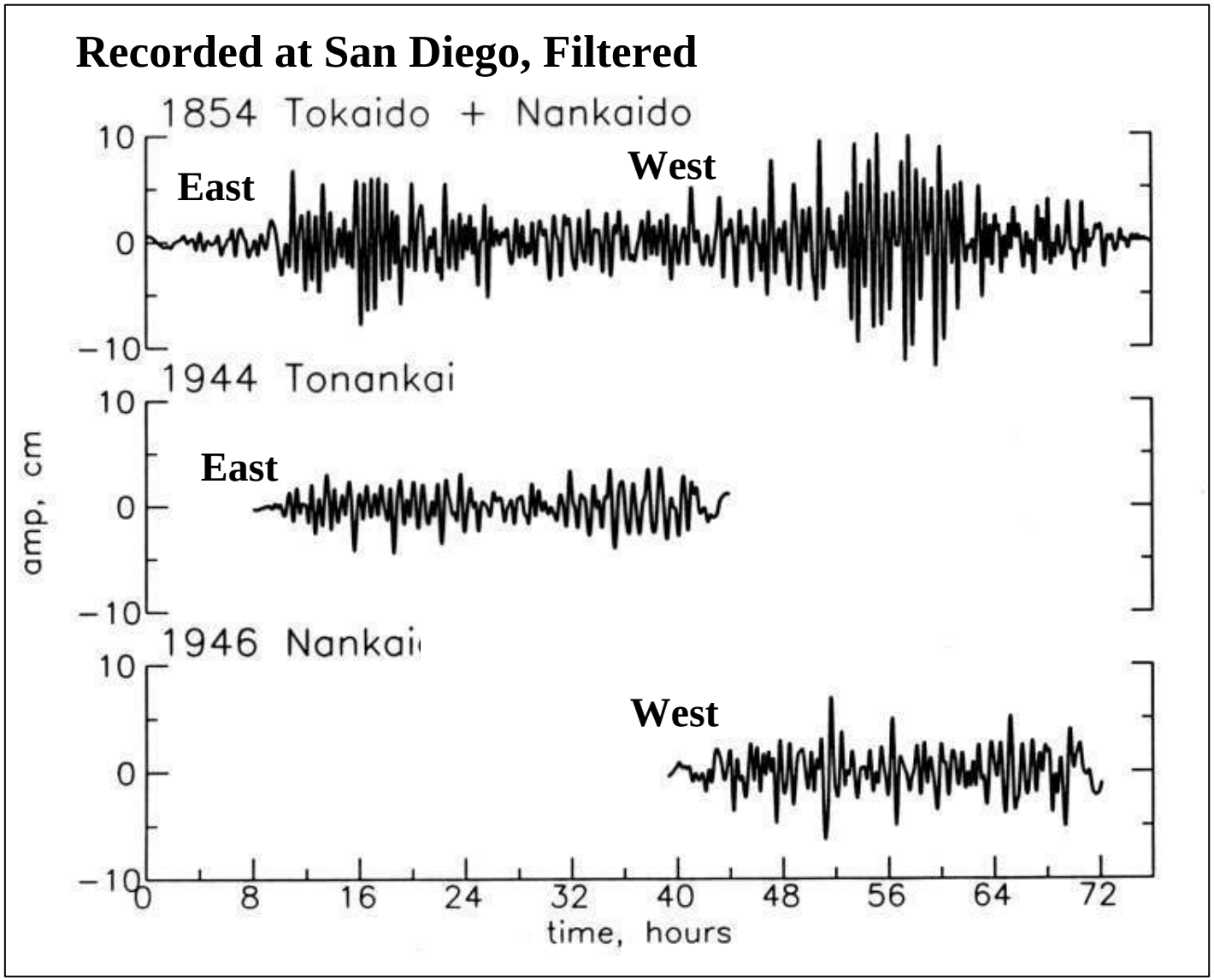
1854 Two Earthquakes (Ansei)
32 hours time difference

Two tsunamis recorded at San Diego



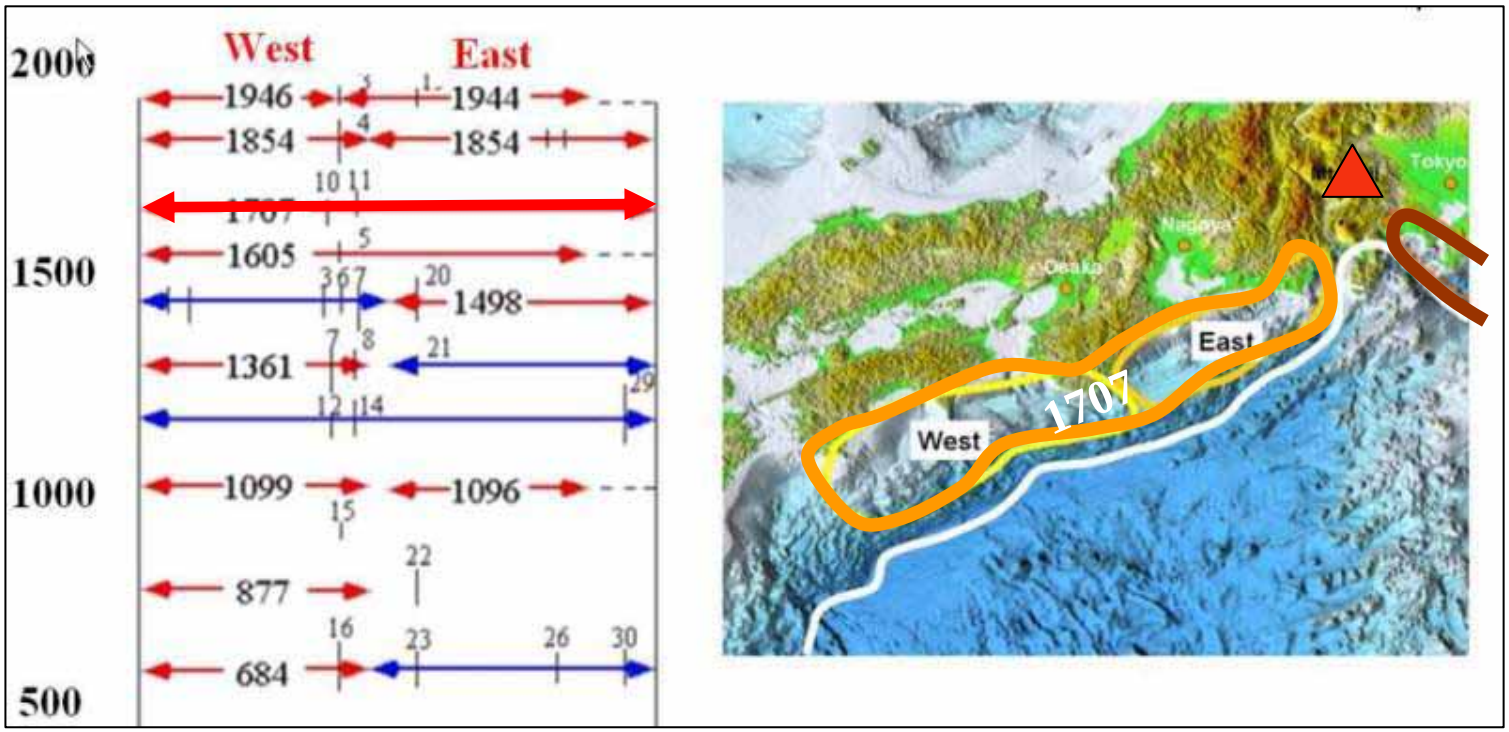


1944 and 1946 events, 1/2 –1/3 of 1854 events



(Tanioka and Satake, 1993)

1707 Earthquake (Hoei)



Casualties	5,049 + (10,000 in Osaka?)
Injured	1,430
Lost houses by tsunamis	18,025
Collapsed houses	59,272
Wrecked ships	3,915

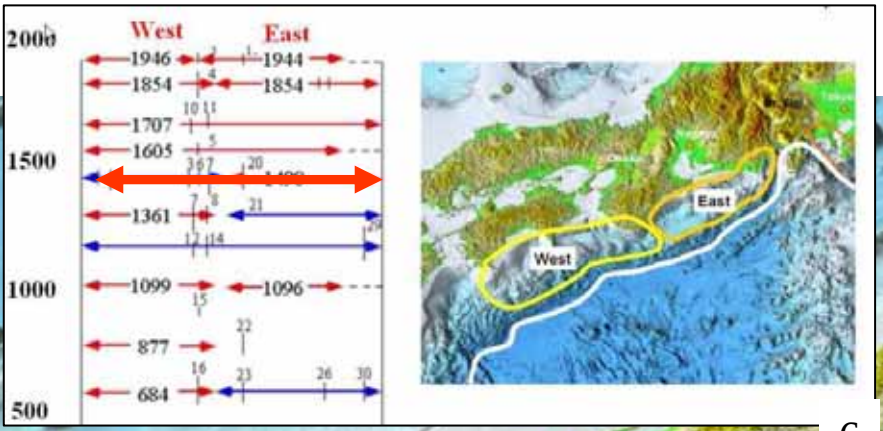
1605 earthquake (Keicho)

- **Only slight damage by strong ground motions**
- **Extensive tsunami damage over West Japan**
- **No Groundwater level change at hot springs**

- What is the mechanism of 1605 earthquake?
- Is this really a Nankai trough earthquake?

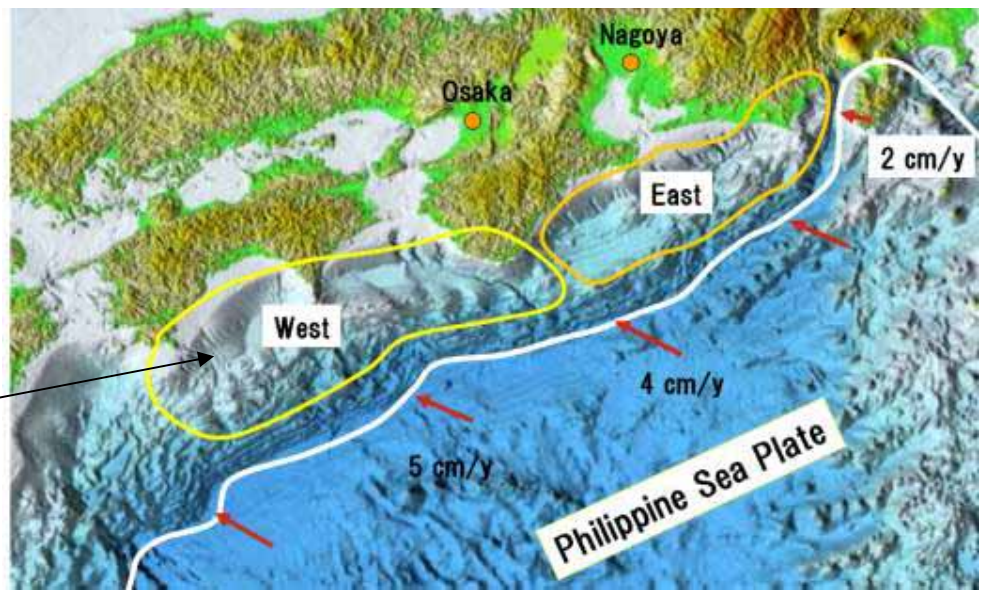
In 1603 Tokugawa Shogunate was established but the center of culture was still Kyoto.

1605 Tsunami Inundation Height (m)

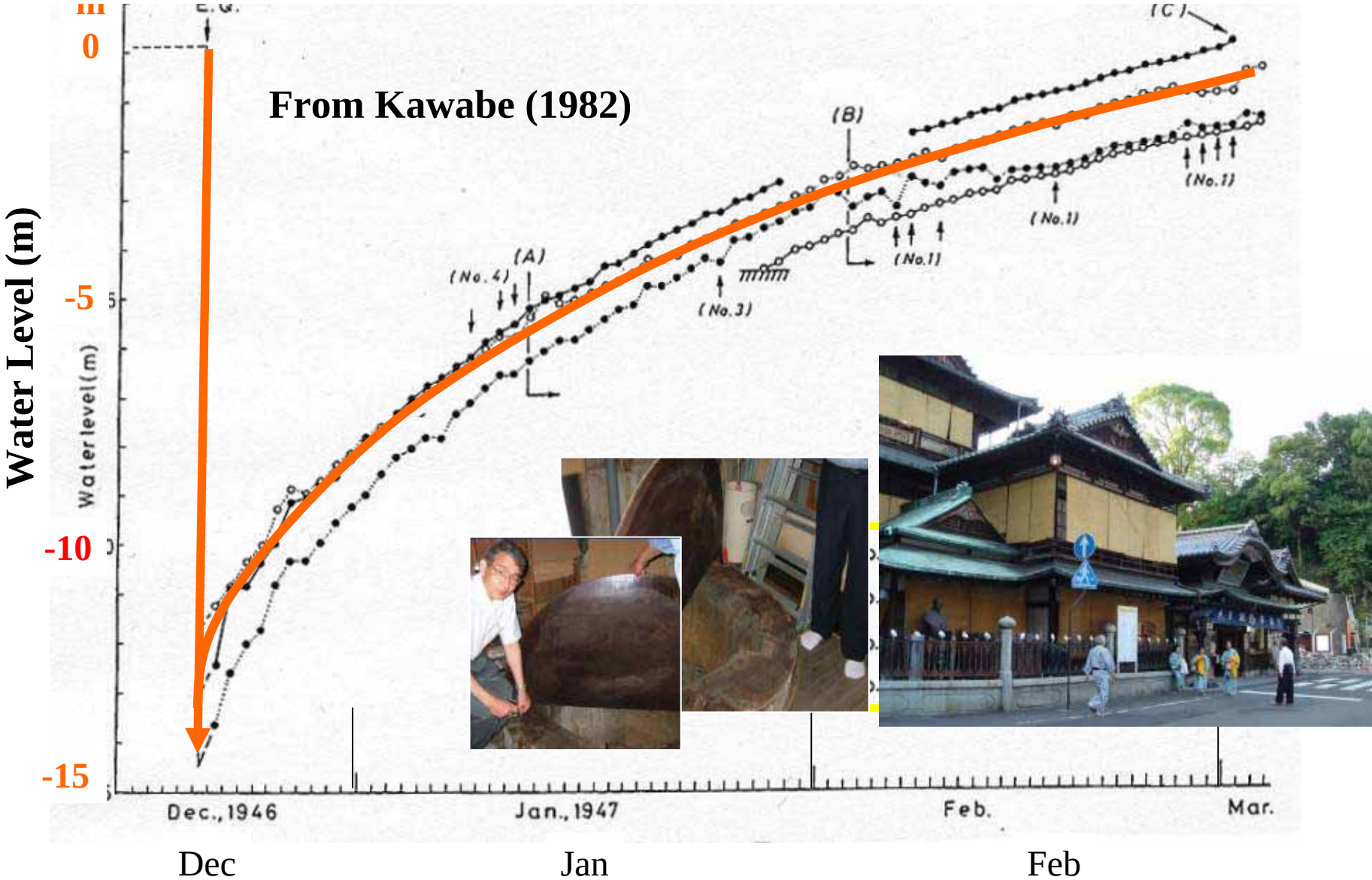


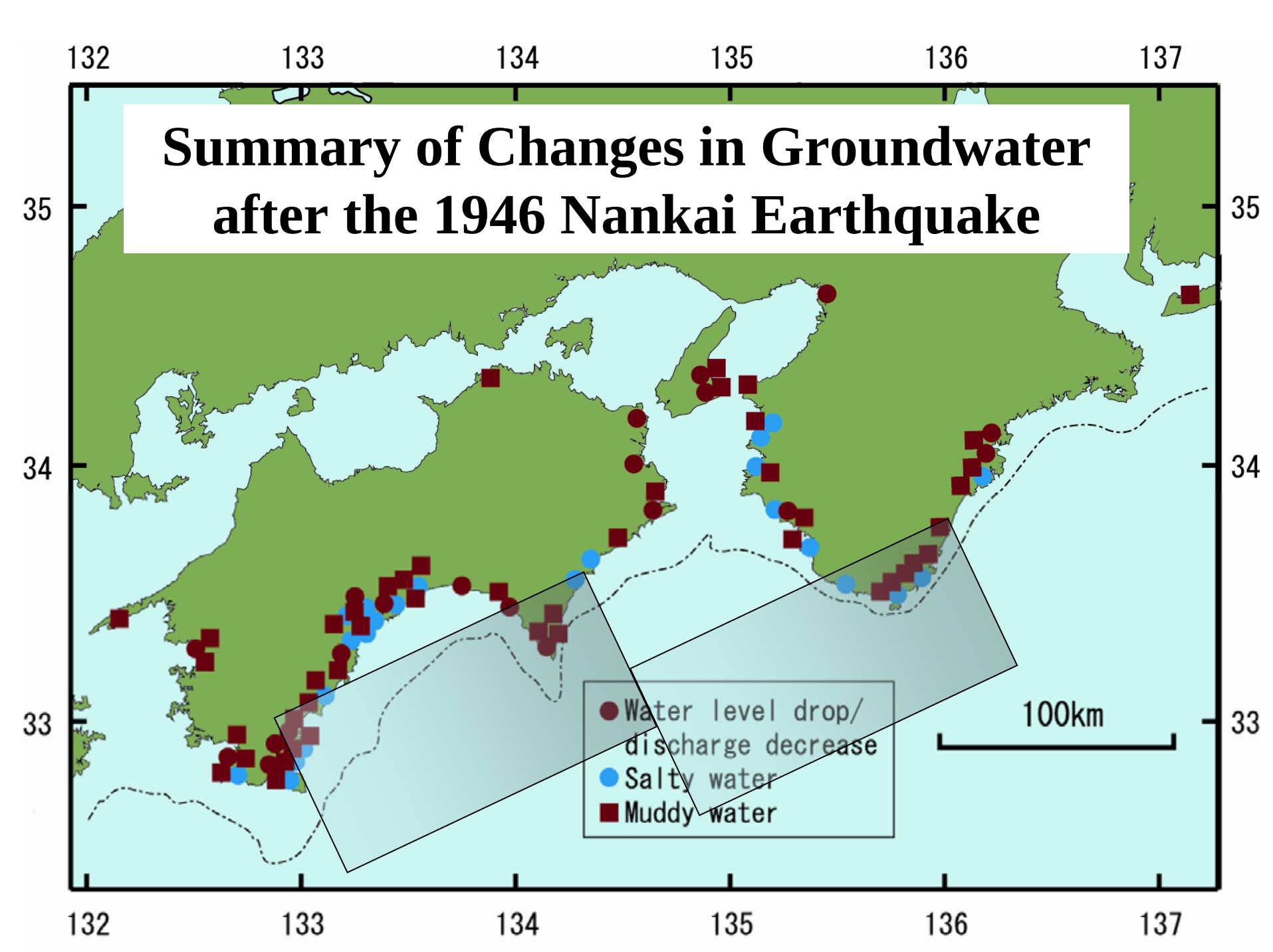
Groundwater level changes with 1946 Nankai Earthquake

- Extensive coseismic well water changes in water level, salinity and muddiness
- Extensive preseimic well water level changes

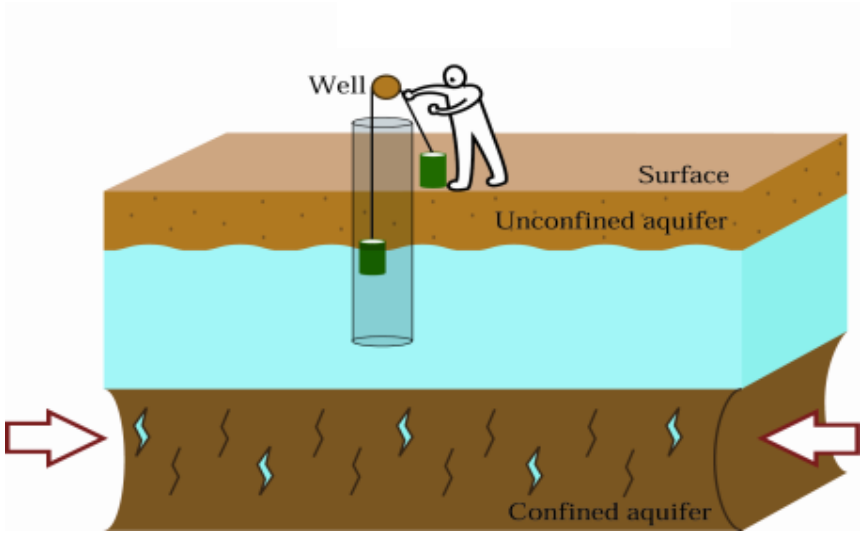


Well water levels at Dogo Spa after 1946 Earthquake

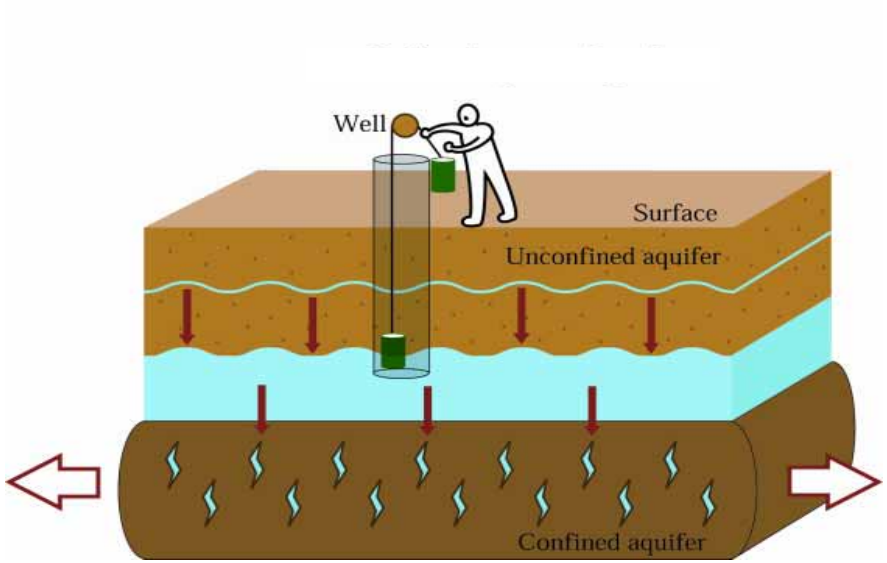



Summary of Changes in Groundwater after the 1946 Nankai Earthquake
132
133
134
135
136
137
35
34
33
Water level drop/ discharge decrease
Salty water
Muddy water
100km

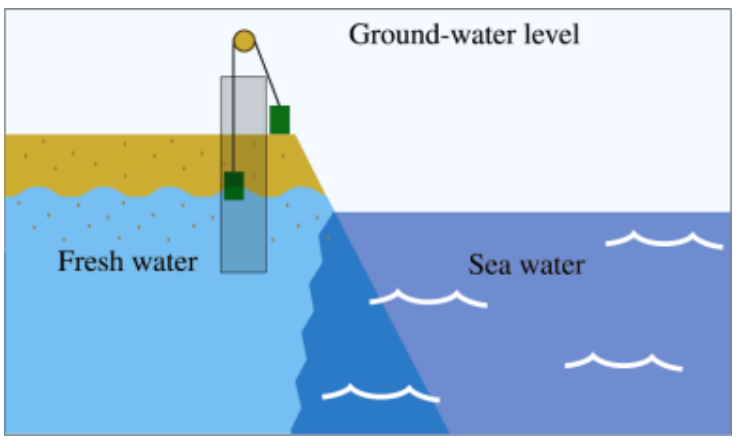
Before earthquake



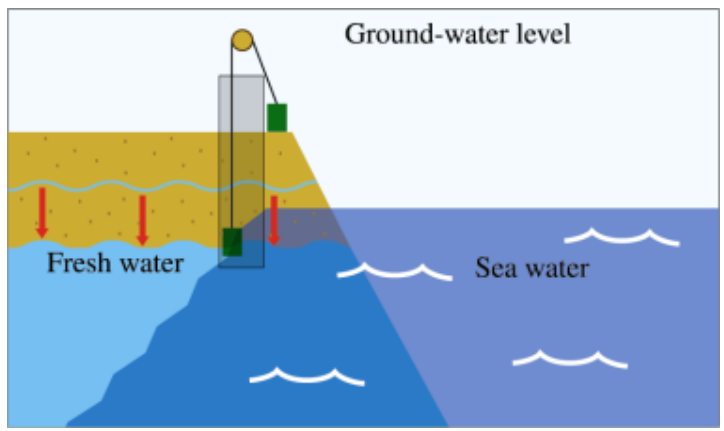
After earthquake



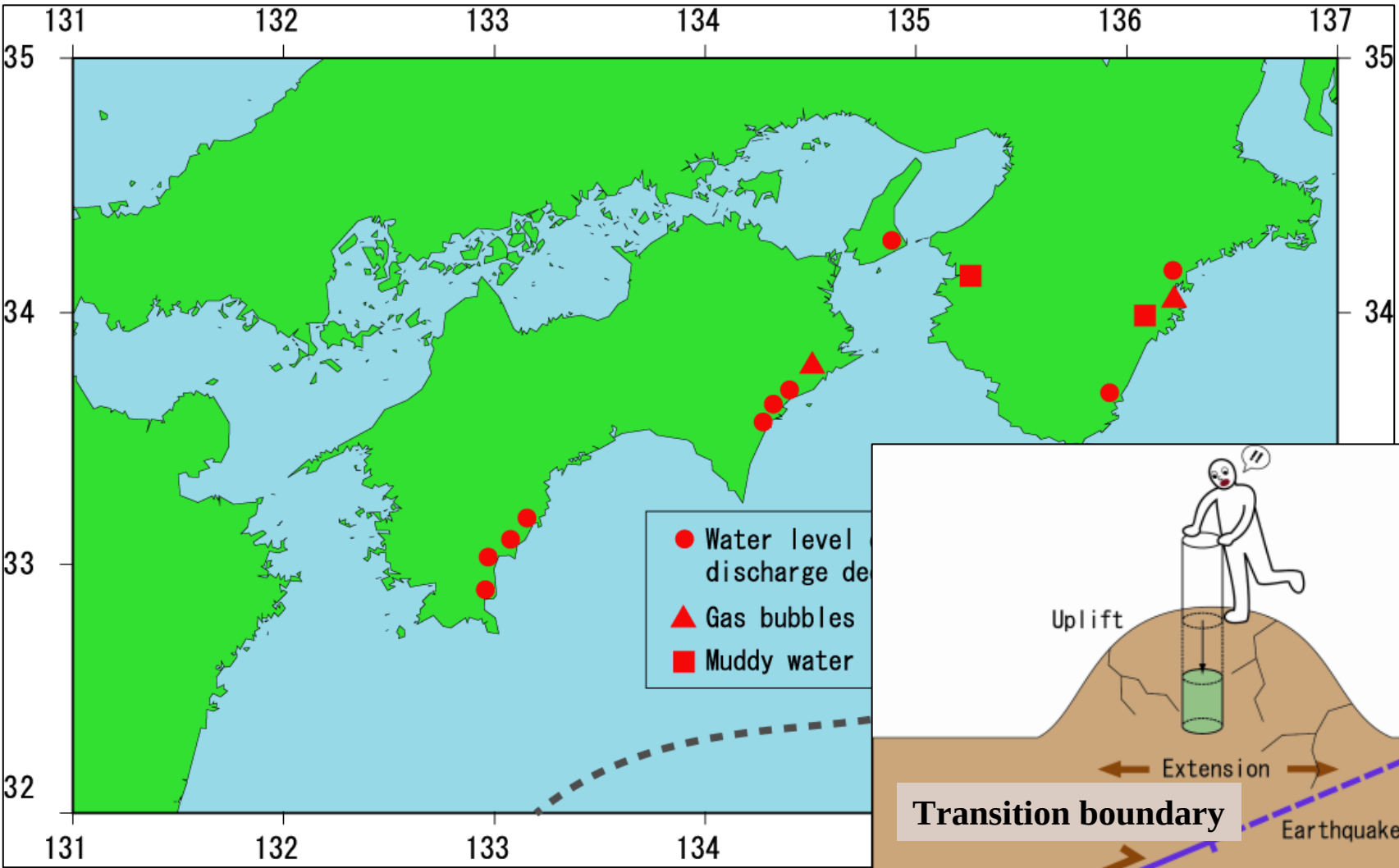
Fresh water



Salty water mixed

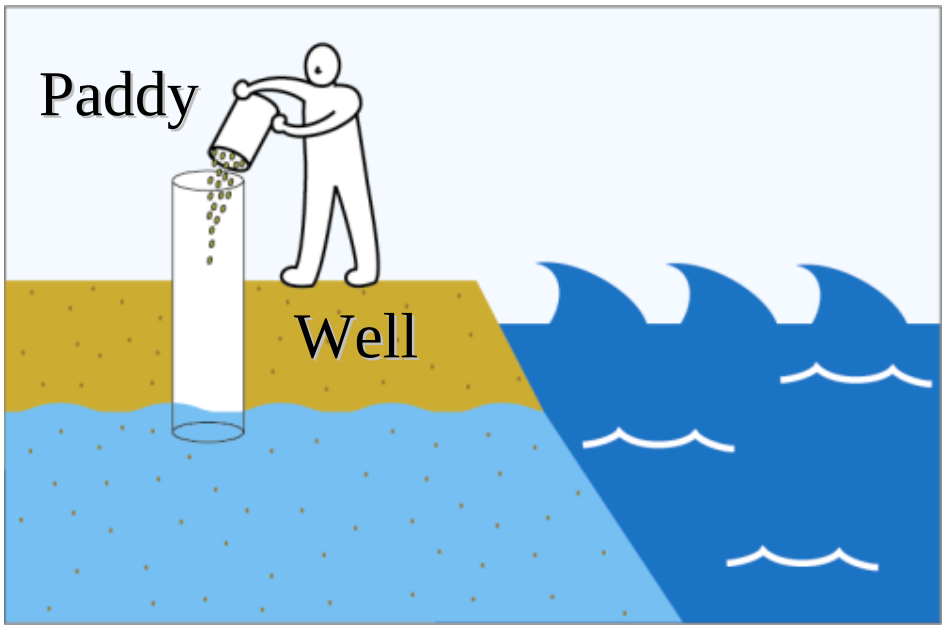


Preseismic changes in groundwater

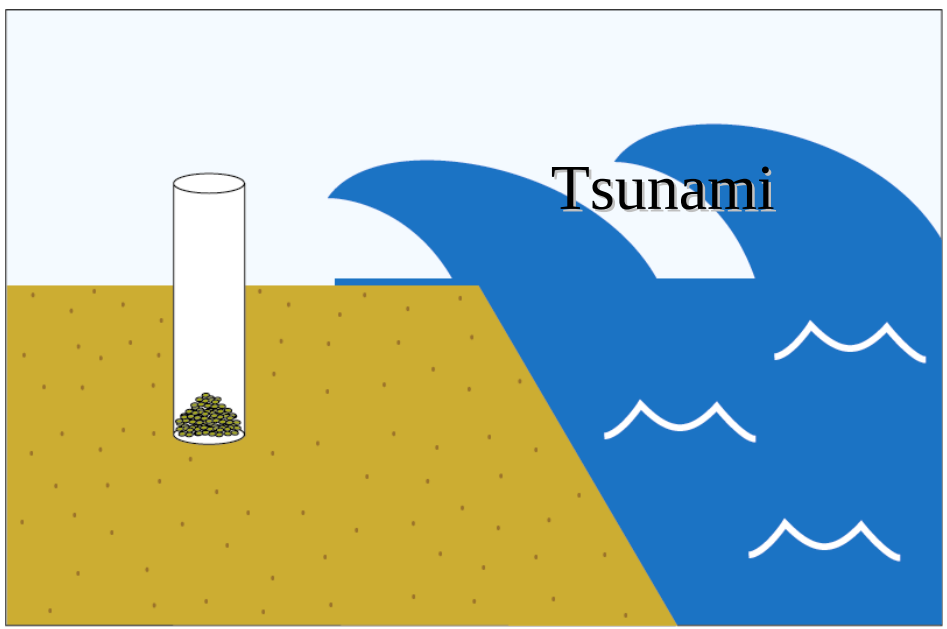


Changes in groundwater started about a week before the earthquake

Legend “A millionaire’s well”

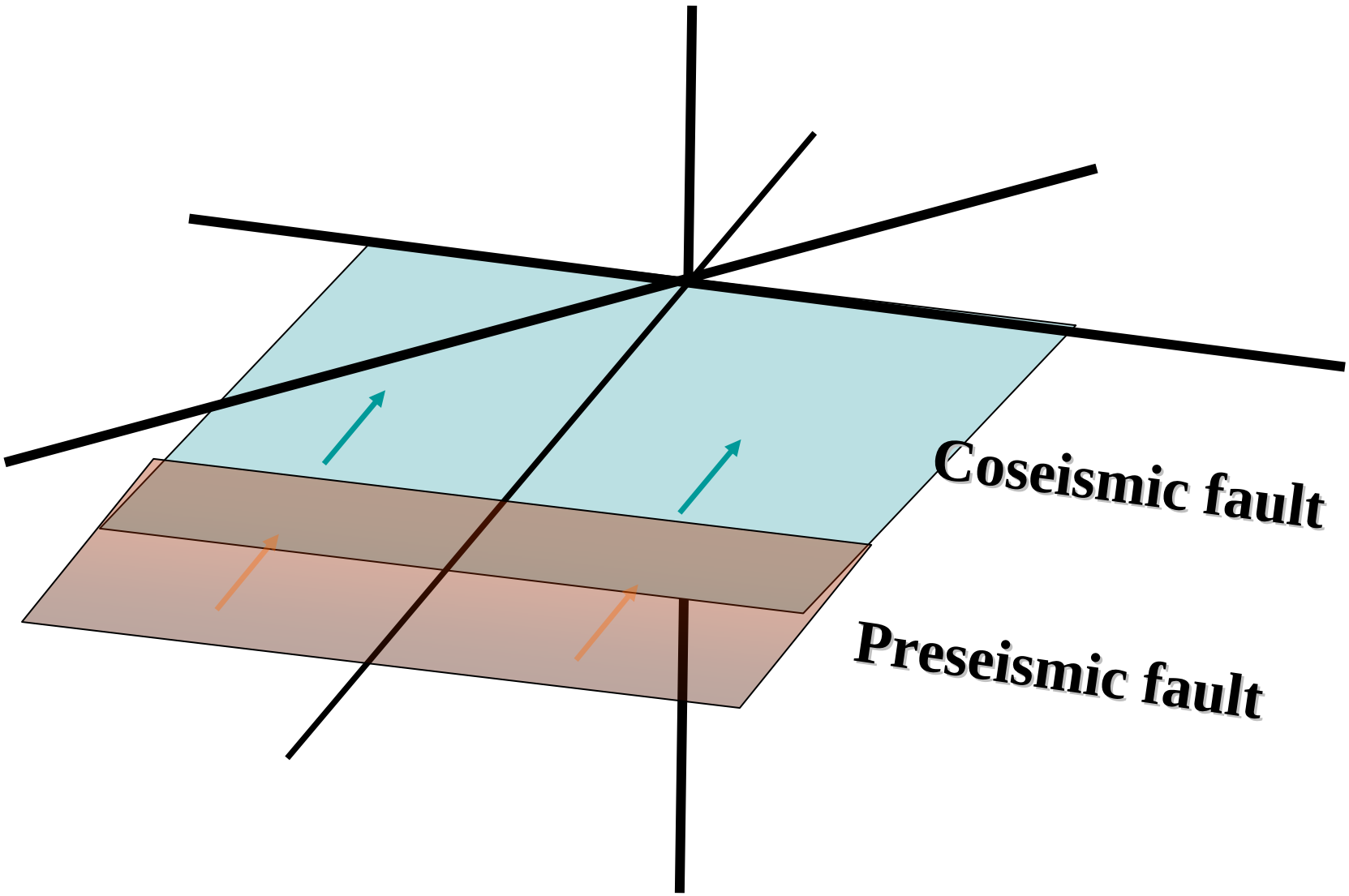


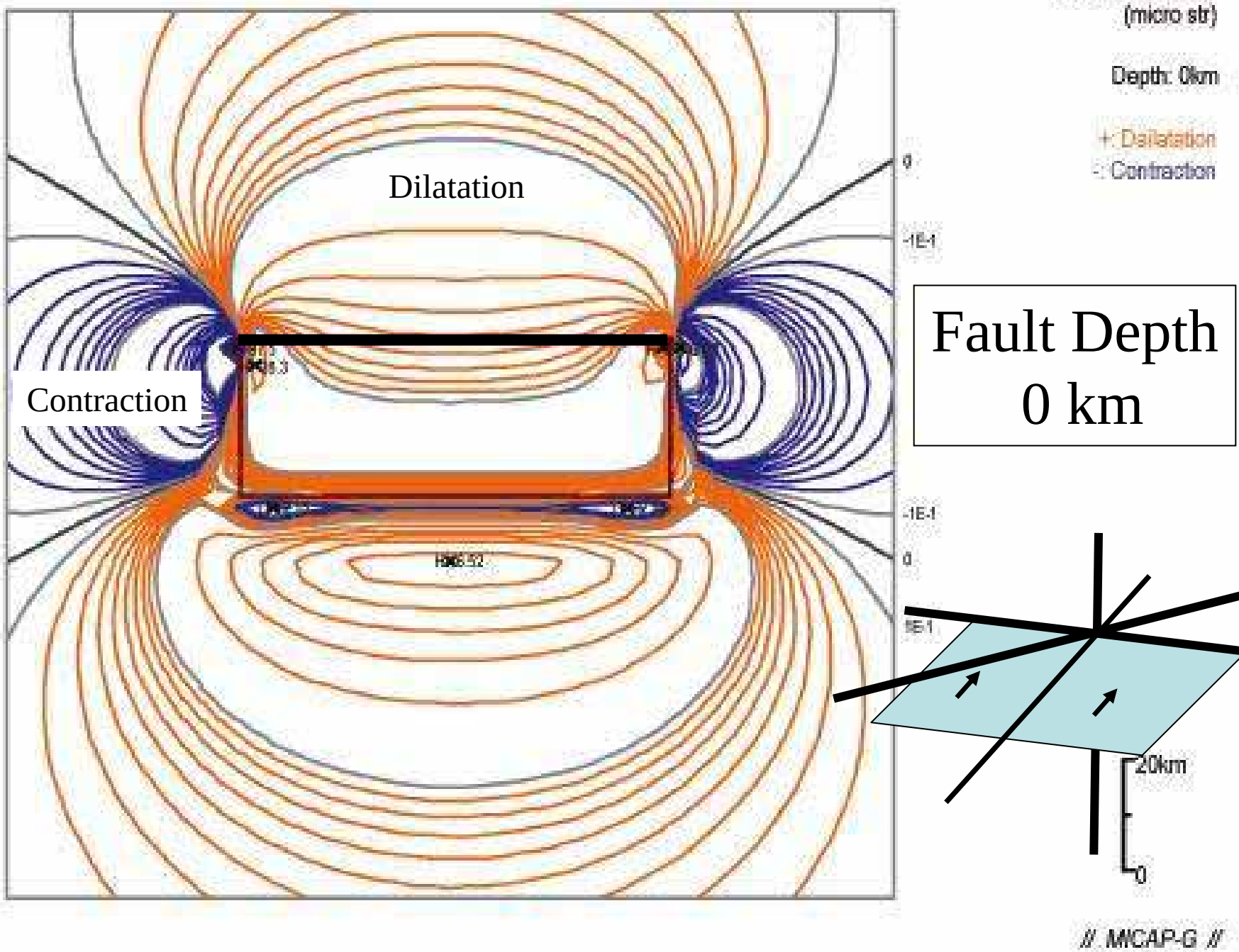
If a well is dried , one should store paddy in the well.



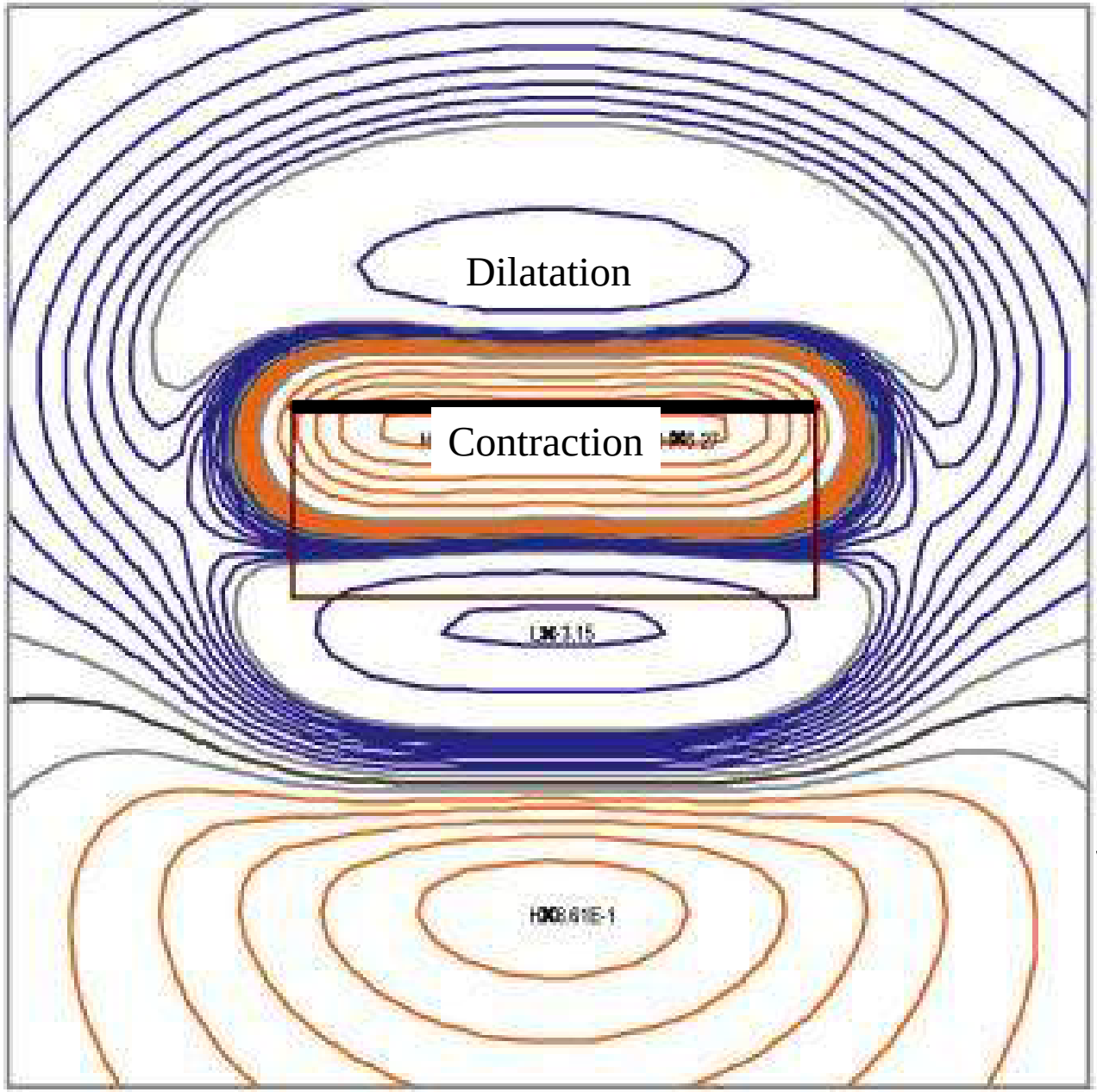
The paddy in the well makes him a millionaire.

Fault Model of the 1946 Nankai Earthquake

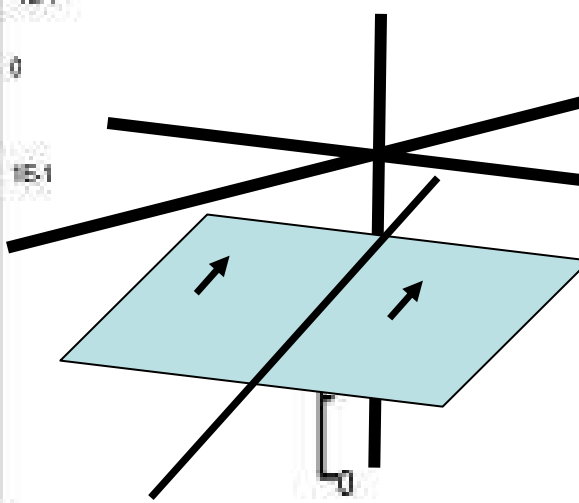




Fault Depth
0 km



Fault Depth
20 km



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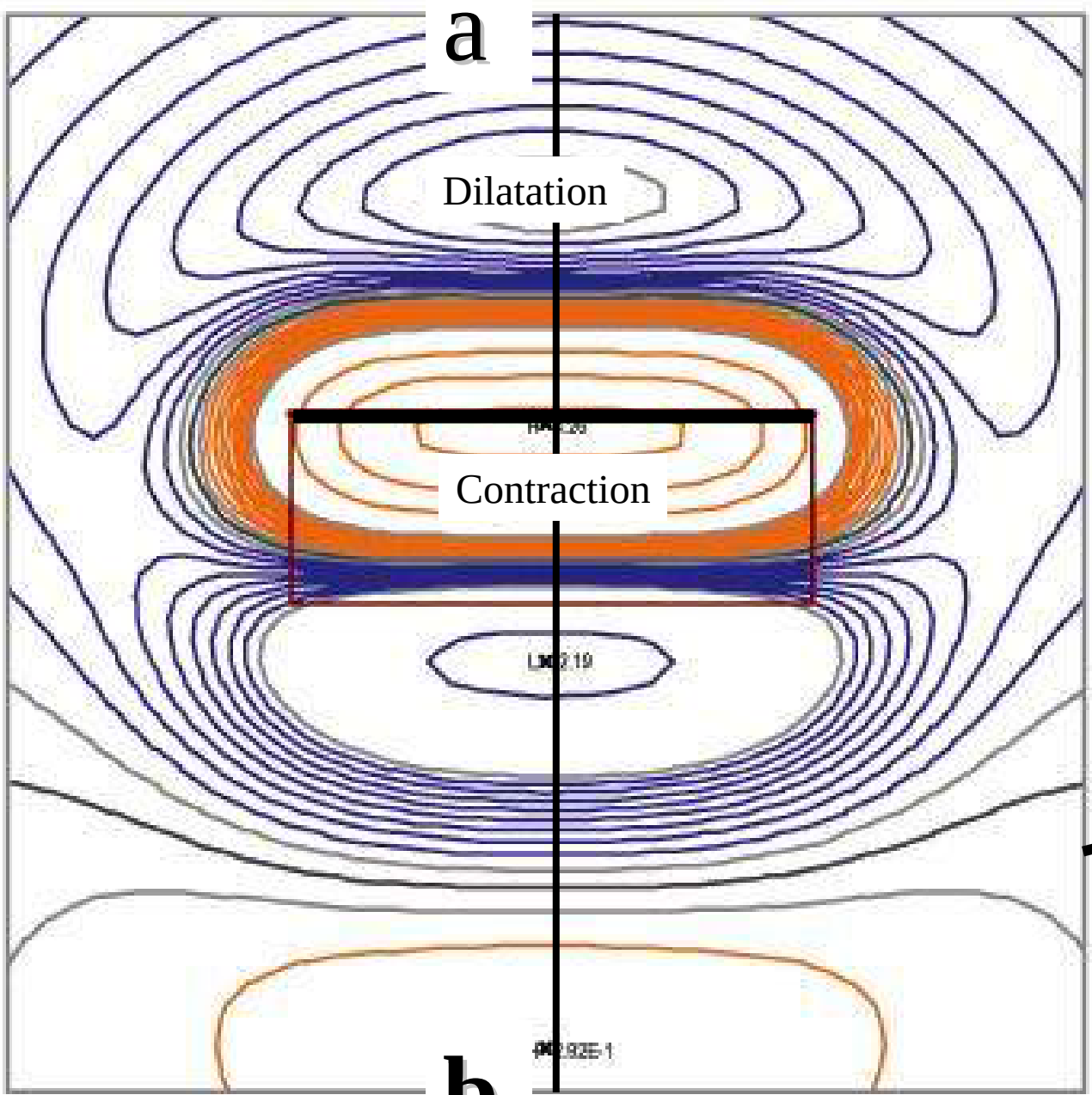
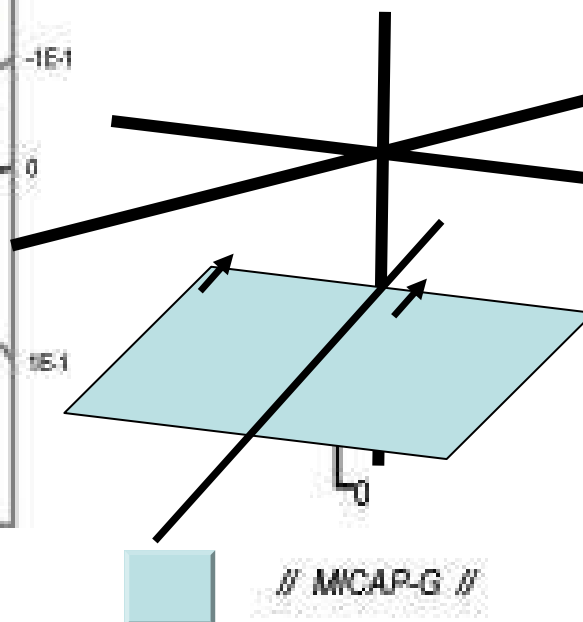


Volumetric Strain
(micro str)

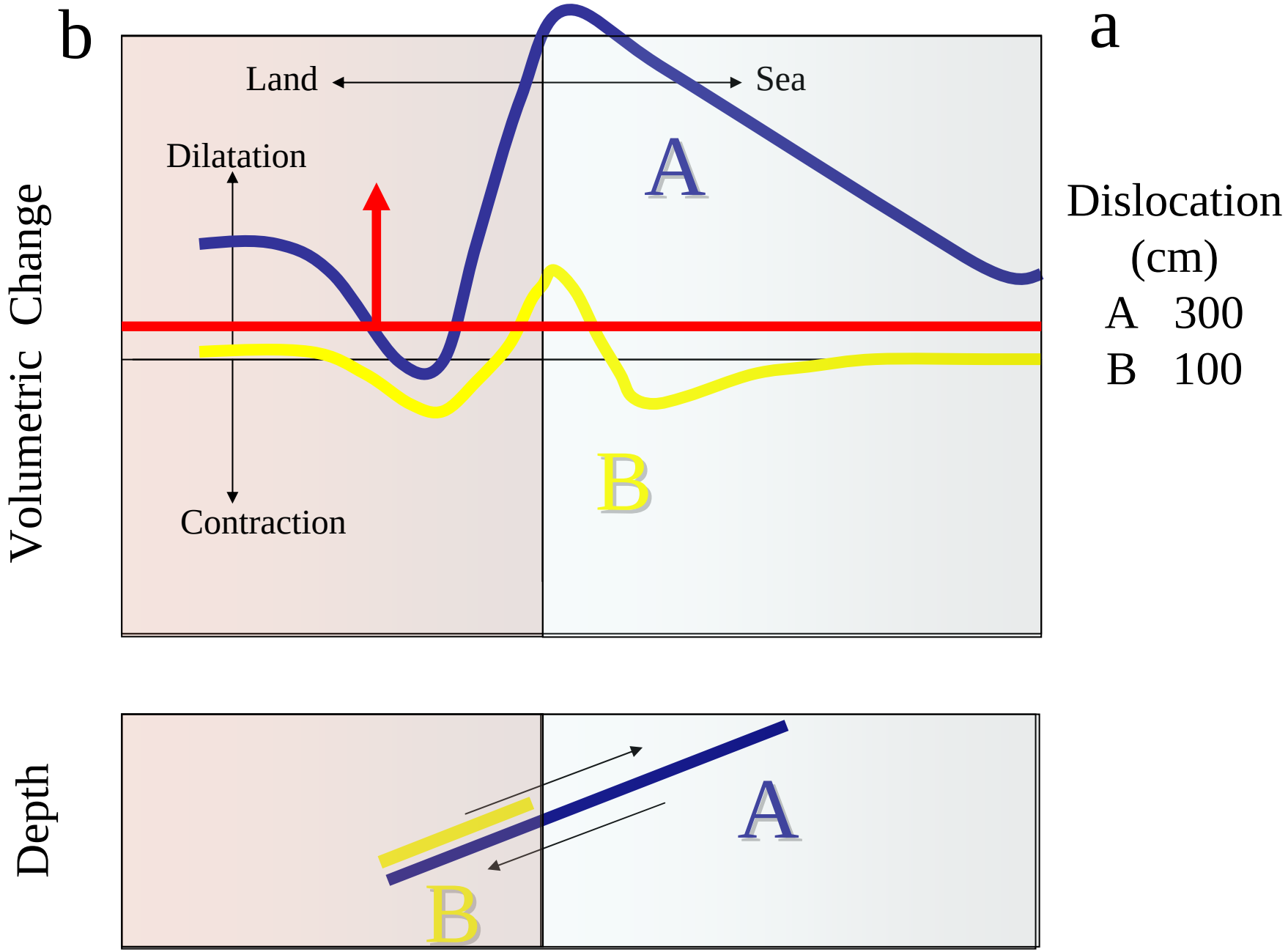
Depth: 0km

+: Dilatation
-: Contraction

Fault Depth
30 km

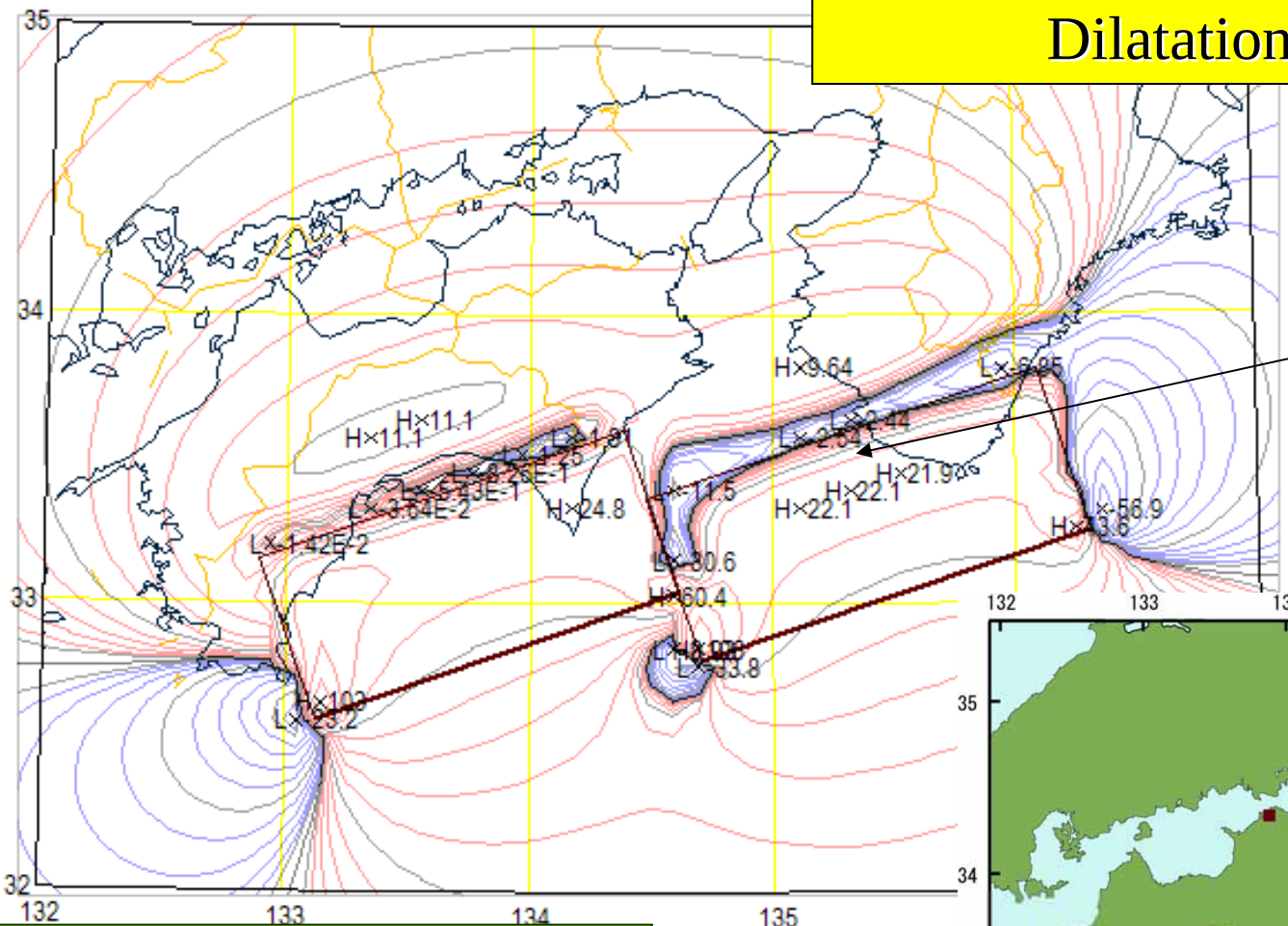


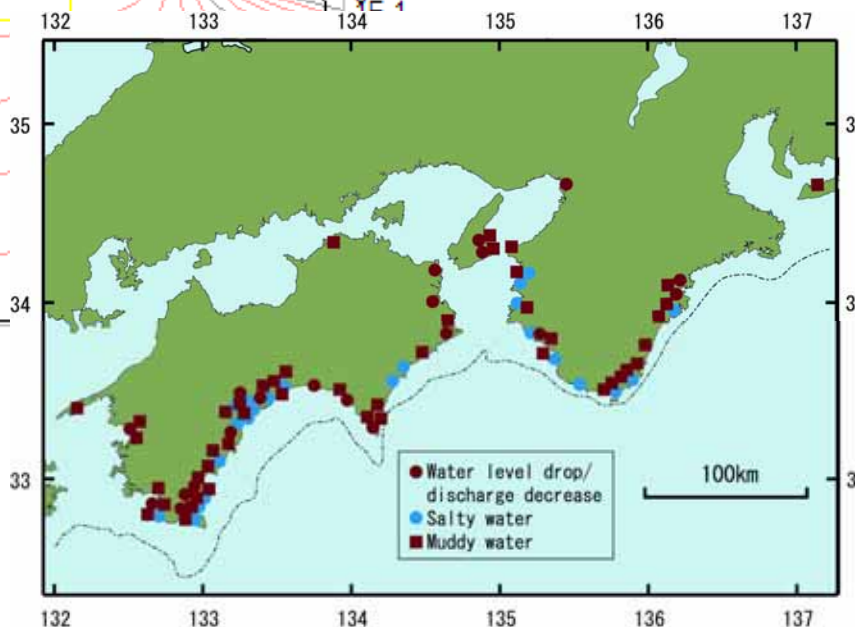
// MMCAP-G //


b
a
Land
Sea
Dilatation
Contraction
Volumetric Change
A
B
Dislocation
(cm)
A 300
B 100
Depth
A
B

Coseismic Volumetric Change

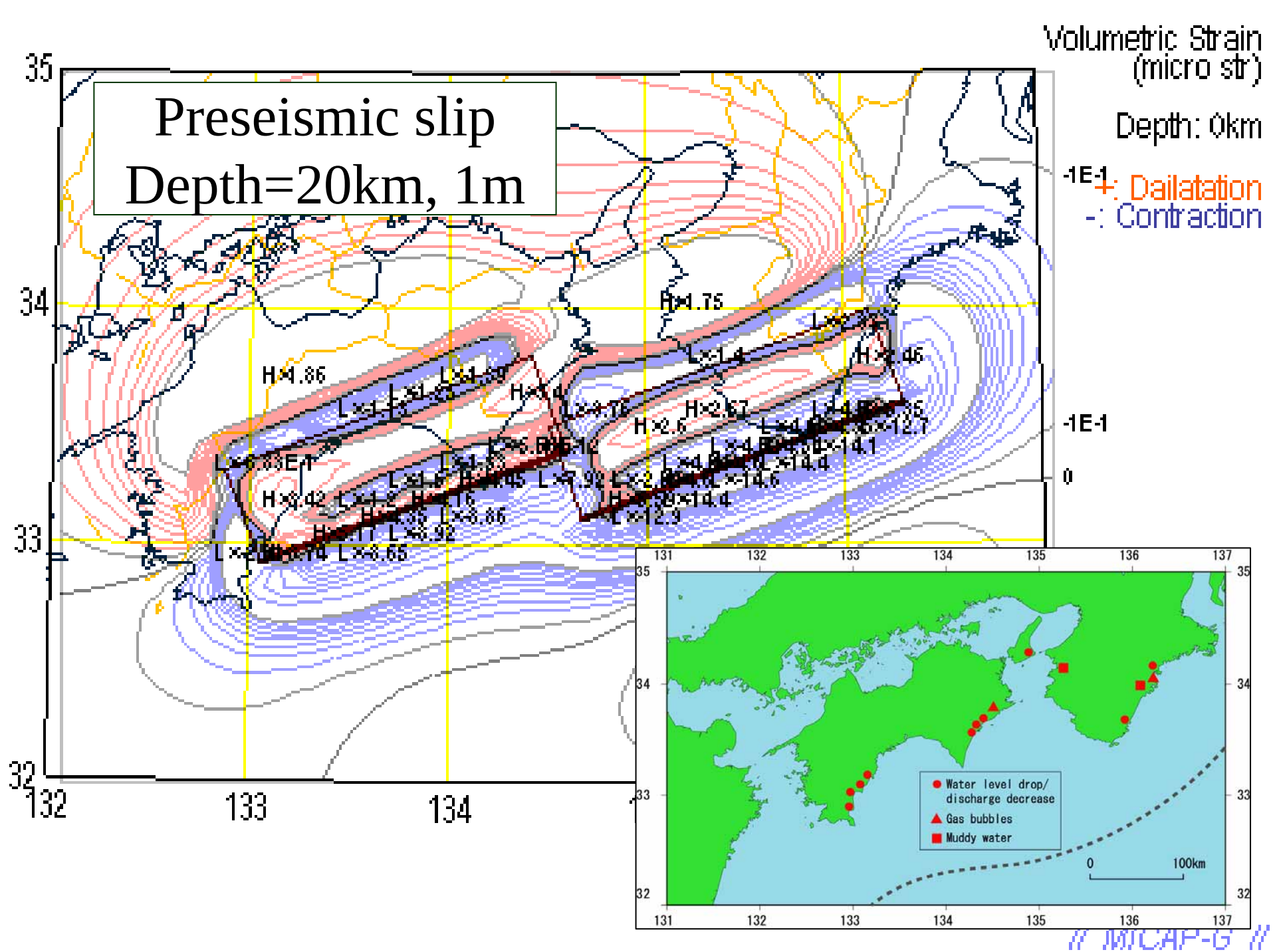
Water level changes at shallow wells can be noticed by eyes, when Dilatation > 2 x 10^{-6}



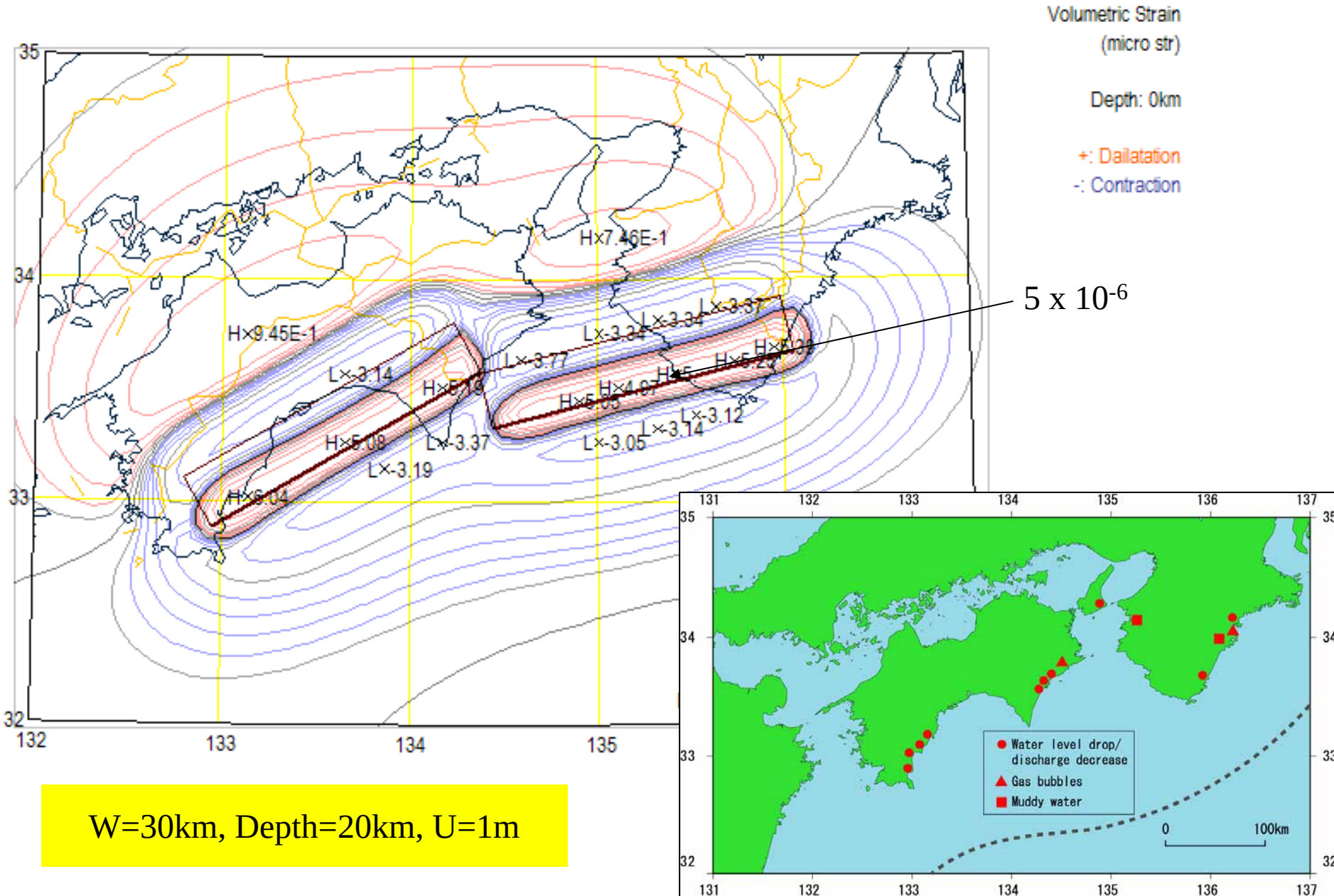


	2L	W	U	θ
A:	130km	70km	4m	20 °
B:	150km	70km	3m	20 °

Modified from Ando(1981)


Preseismic slip
Depth=20km, 1m
Volumetric Strain
(micro str)
Depth: 0km
+: Dailatation
-: Contraction
-1E-1
-1E-1
0
35
34
33
32
132
133
134
131
135
136
137
Water level drop/
discharge decrease
Gas bubbles
Muddy water
0
100km

Preseismic Volumetric Change



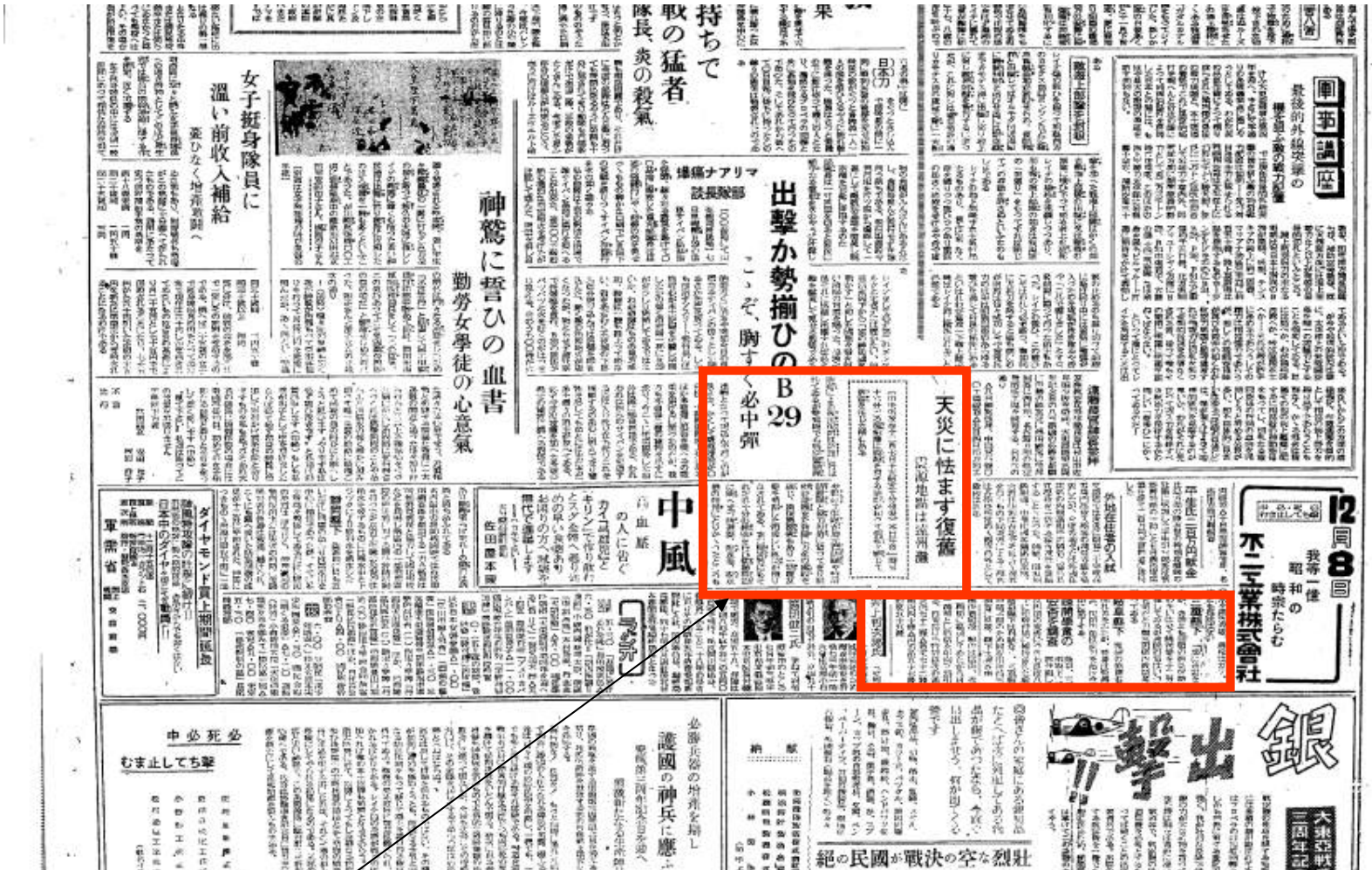
W=30km, Depth=20km, U=1m

Groundwater level changes with 1944 Tonankai Earthquake

- No data has been systematically collected.

Tonaankai earthquake

Data of the earthquake not taken properly due to severe censorship



Only slight damage caused by the earthquake!

中日本新聞, 8 Dec 1944

Noticed by world though concealed inside Japan

DISASTROUS QUAKE IN CENTRAL JAPAN

Round-the-World Seismograph Stations Stress 'Violence'— Earth Rocks for 6 Hours

A violent earthquake, described by observers as "catastrophic," struck in the vicinity of Japan yesterday, third anniversary of Pearl Harbor, The Associated Press reported.

[Tokyo radio reported early Friday that Central Japan had been shaken by an earthquake Thursday, causing "a landslide on a minor scale and the crumbling of cottages * * * over a limited area." The broadcast reported by the Federal Communications Commission, added that the central meteorological observatory had just announced that the "seismic center was somewhere in the Sea of Ensyu.]

Seismograph stations around the world recorded a prolonged earthquake of terrific intensity.

The shocks were reported by scientists in Britain, Switzerland, Germany, India and the United States.

Each observatory said the trem-

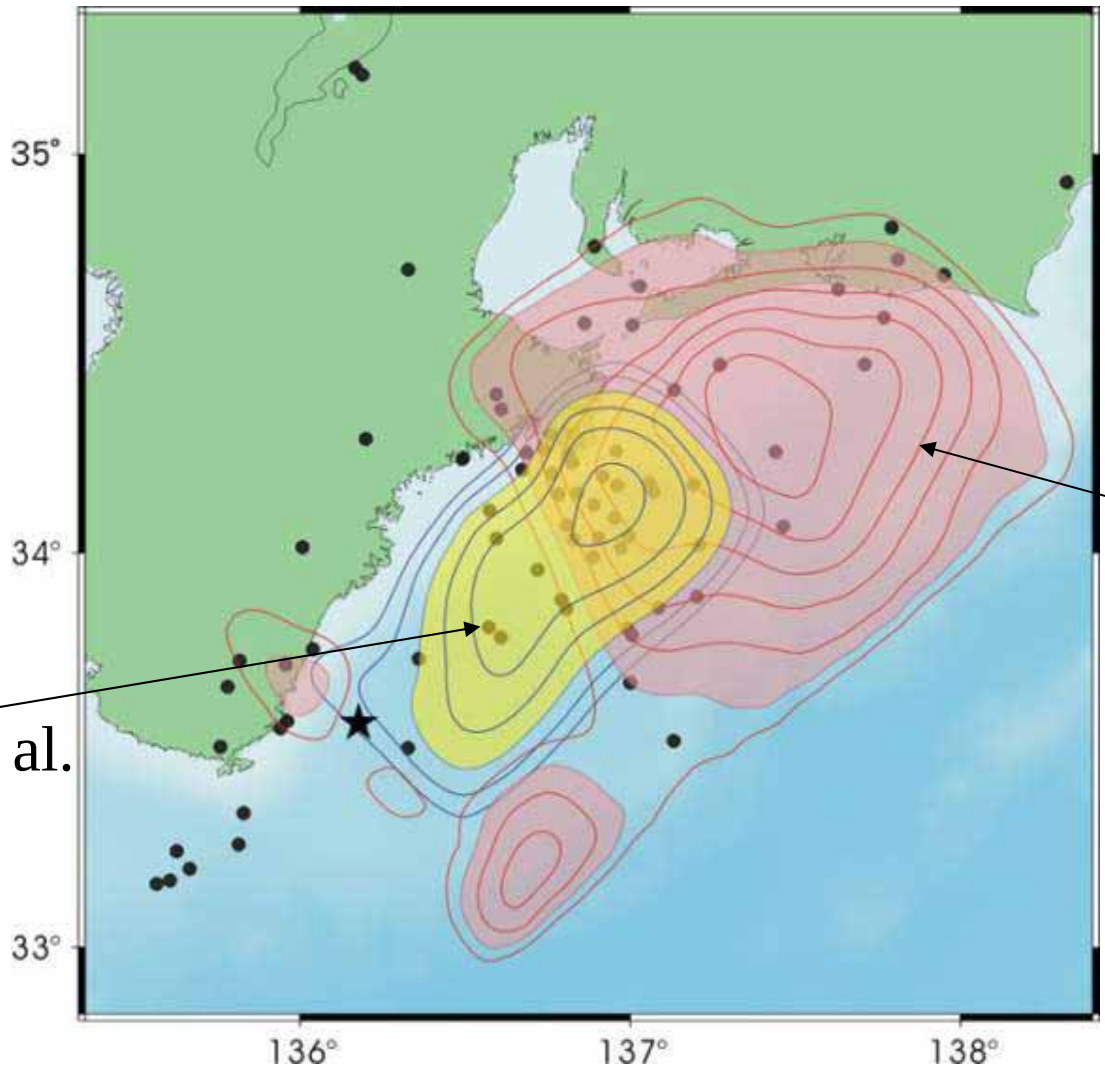
Terrifying Water Wall Seen

Father Lynch thinks the tidal wave must have been a terrifying water wall, possibly sixty to seventy feet high, when it hit Japan's coast. Tidal waves increase in size in proportion to a quake's distance from shore.

Thursday's quake was five times farther from Japan than the earthquake of twenty-one years ago. The tidal fury that rushed into Tokyo Bay, Sagami Bay, Ise Bay and Suruga Bay must have carried shipping far inland, crushing all in its path, he said.

New York Times, December 8, 1944, (the next day)

Fault model of 1944 Tonankai earthquake still controversial



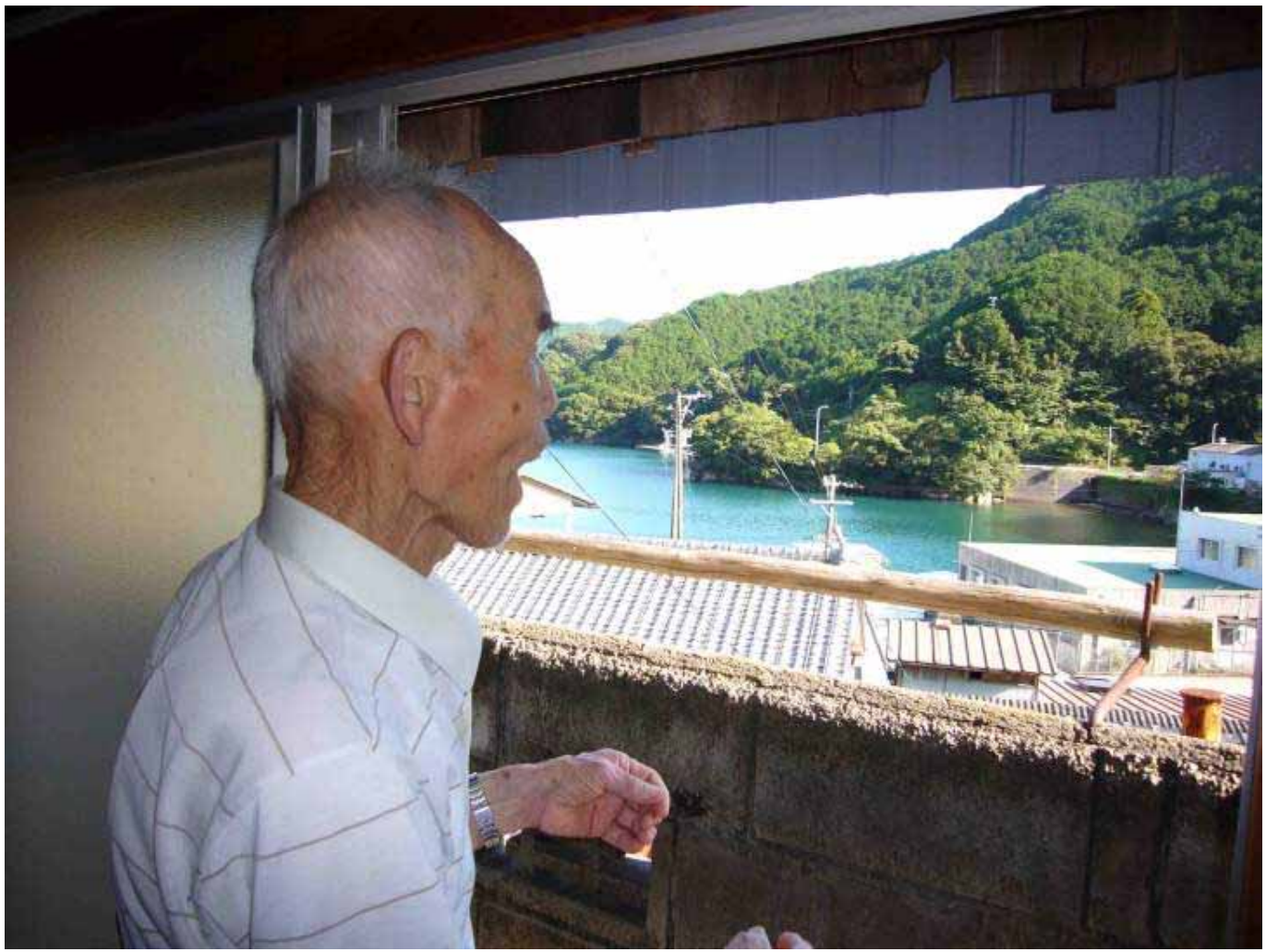
Yamanaka (2006)

Kikuchi et al. (2003)

Interviews with local people, more than 60 years after the earthquake

Interviews

Bubbles generated in the seawater was witnessed before the tsunami struck at Haeda. Gases in the soil squeezed into the seawater due to the surface loading by the tsunami?



Tsunami height

No well water level change and no retreat of sea water in Owase

1000m

Kojiroy et al. (2007)

A man having a prior knowledge of tsunami, the well water level lowering before the tsunami, and the retreat of sea water preceding the tsunami wave, checked for both the wells and seawater levels immediately after the shaking, but could not find either of the phenomena. Thus, he decided to stay. Unfortunately, the tsunami inundated the area and he was killed.

Photo taken by a U.S. combat plane
3 days after the earthquake

Conclusions

Postseismic volumetric changes > 1 x 10-6 is the lower limit for observable groundwater level changes in the case of 1946.

The preseismic changes were possibly caused by slow slips on the fault at depths around 20 km in 1946.

On the contrary, prior to the 1944 event no significant precursory and coseismic ground water change at the eastern part of Kii peninsula was not found, which could be another variety of precursory deformations, associated with subduction events.