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

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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

Modified from Sangawa (1992)
1944 and 1946 Events (Tonankai and Nankai)

Tide gage records at San Diego

1944

1946

(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

Recorded at San Diego, Filtered

1854 Tokaido + Nankaido

East

West

1944 Tonankai

East

West

1946 Nankai

amp, cm

time, hours

(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.
Groundwater level changes with 1946 Nankai Earthquake

• Extensive coseismic well water changes in water level, salinity and muddiness
• Extensive preseismic well water level changes
Well water levels at Dogo Spa after 1946 Earthquake

From Kawabe (1982)
Before earthquake

Fresh water

After earthquake

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

Preseismic fault

Coseismic fault
Fault Depth 0 km

Dilatation

Contraction
Fault Depth
20 km
Fault Depth
30 km

Dilatation

Contraction
Coseismic Volumetric Change

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

Modified from Ando (1981)

2L W U □
A: 130 km 70 km 4 m 20 □
B: 150 km 70 km 3 m 20 □
Modified from Ando (1981)
Preseismic slip
Depth=20km, 1m
Preseismic Volumetric Change

W=30km, Depth=20km, U=1m
Groundwater level changes with 1944 Tonankai Earthquake

- No data has been systematically collected.
Data of the earthquake not taken properly due to severe censorship

Only slight damage caused by the earthquake!
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 Eusyu.”]

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

Kikuchi et al. (2003)

Yamanaka (2006)
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?
No well water level change and no retreat of sea water in Owase

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 $> 1 \times 10^{-6}$ 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.