



On the well-water and sea-level changes witnessed before the past Nankai Earthquakes

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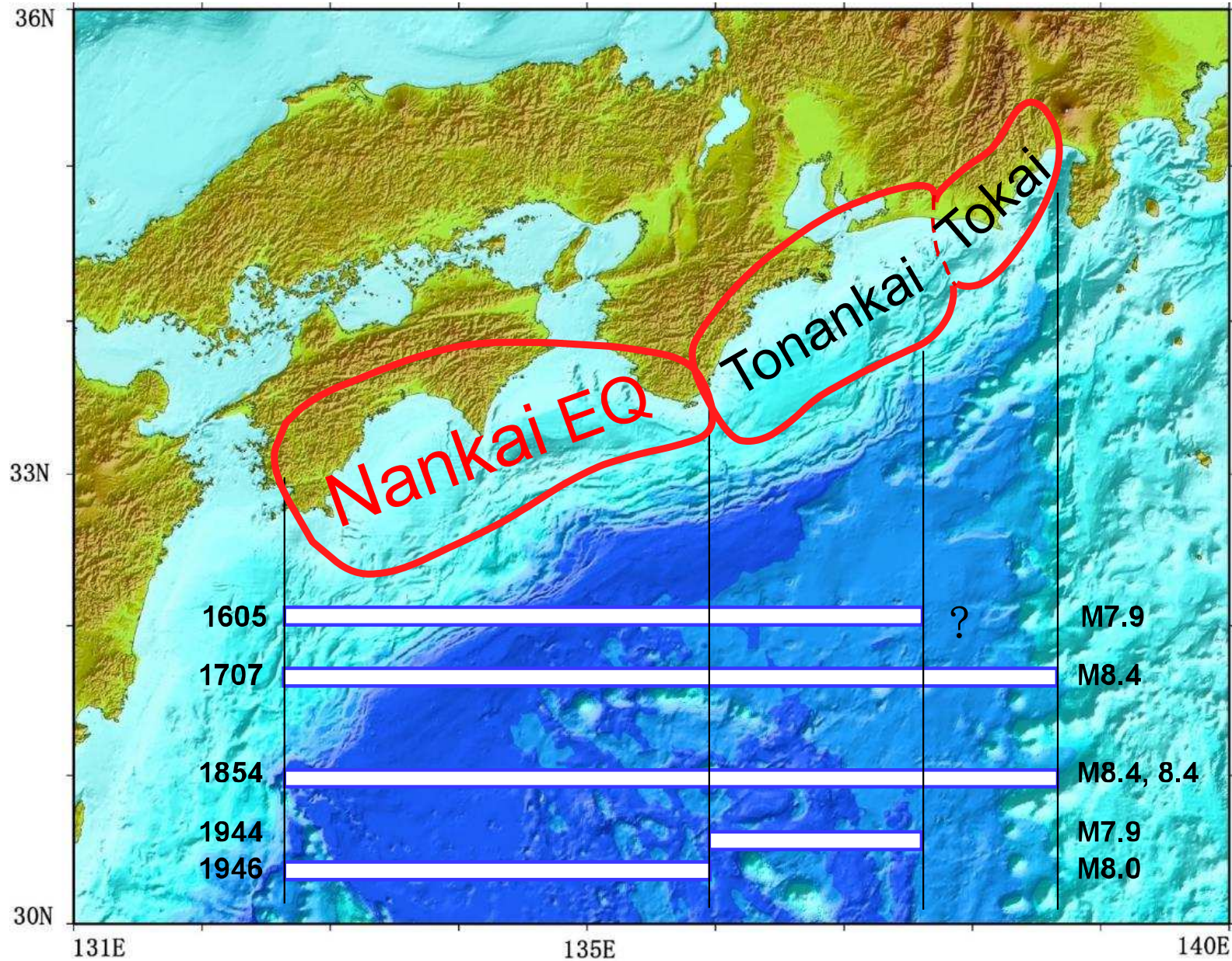
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Acknowledgement: We appreciate Mr. Fujio Nakamura in Tosa City, Kochi Prefecture who supported the investigation of testimony and everyone who gave valuable testimony.

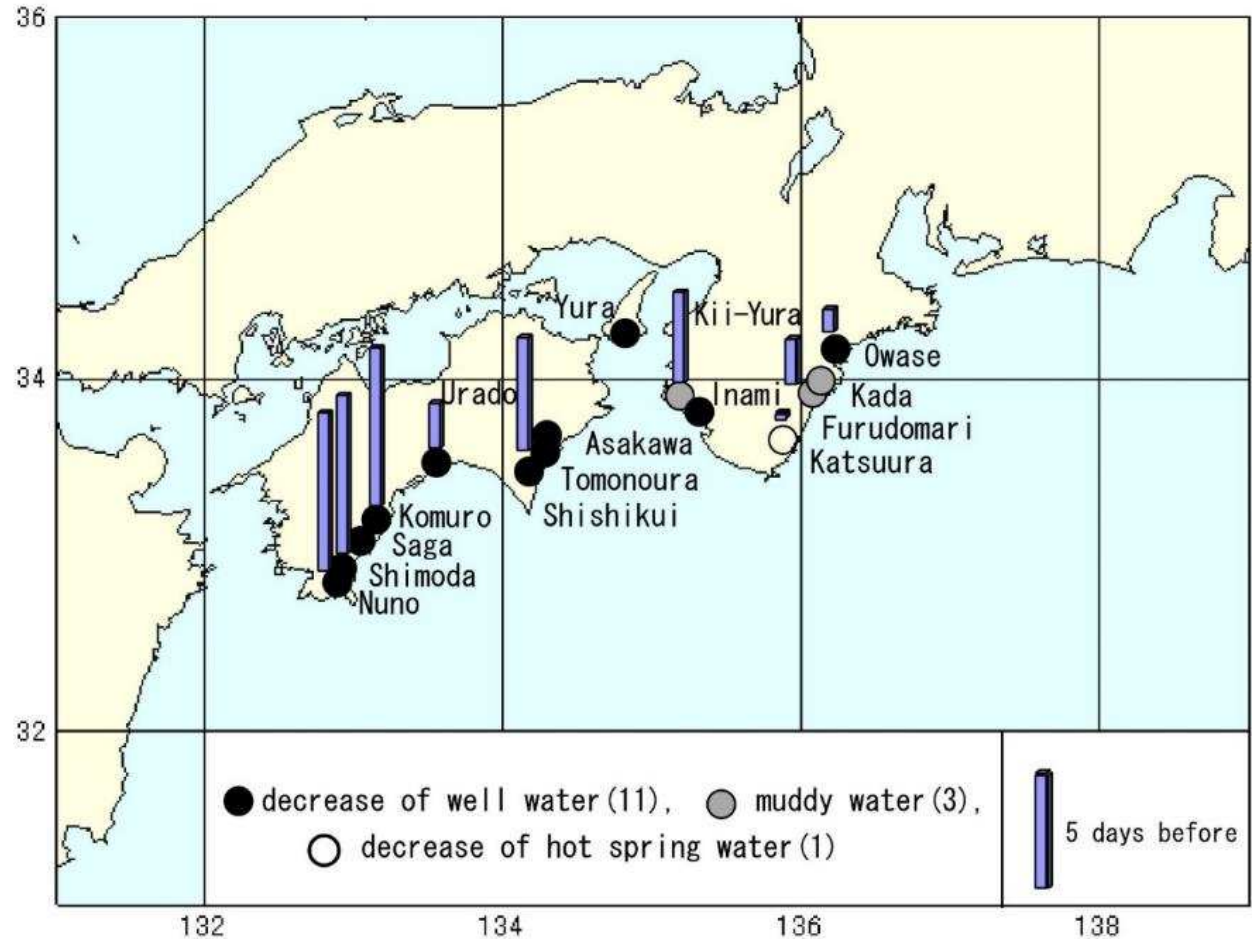
The Nankai Earthquake



Precursor phenomenon of the 1946 Showa Nankai Earthquake (M8.0)



“Hydrographic bulletin”
Hydrographic Department
(Now: Japan Coast Guard)



Well or hot spring water change: 15
decrease: 11, increase: 0

Outline for the next Nankai Earthquake Prediction

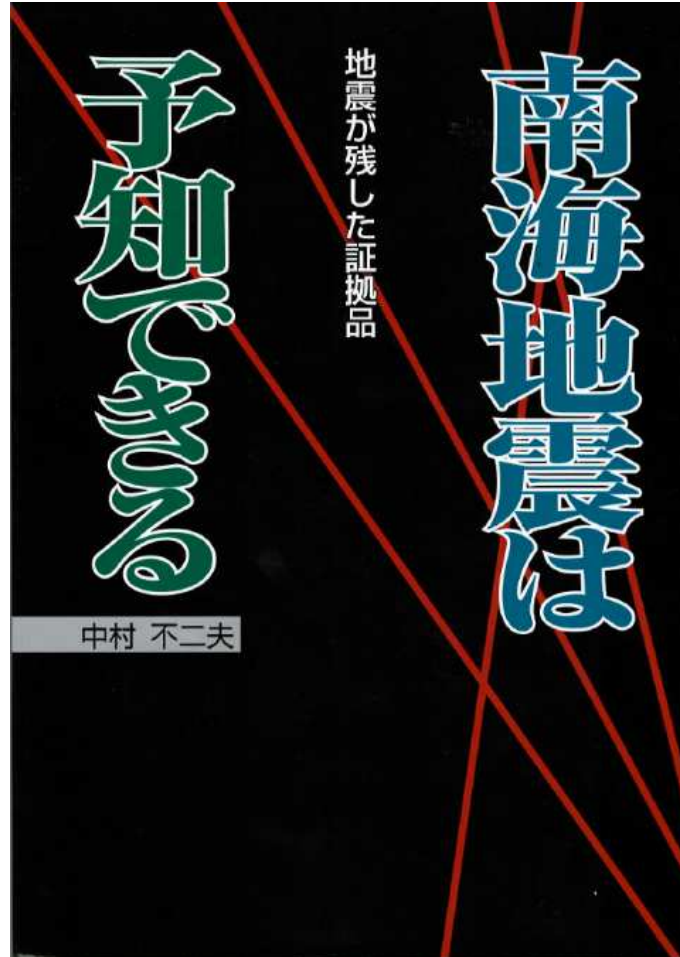


- Step 1: Survey testimony of precursor phenomenon
 - Confirmation of reliability
 - By interview with witness
 - Specificity of testimony
 - Testimony that seems to be related to crustal movements
- Step 2: Quantitative evaluation of phenomena
 - The magnitude and time of the phenomenon
- Step 3: Estimation of source model
- Step 4: Understand fluctuation range at steady state
- Step 5: Confirmation of repeatability
 - 1854 (Ansei) Nankai Earthquake

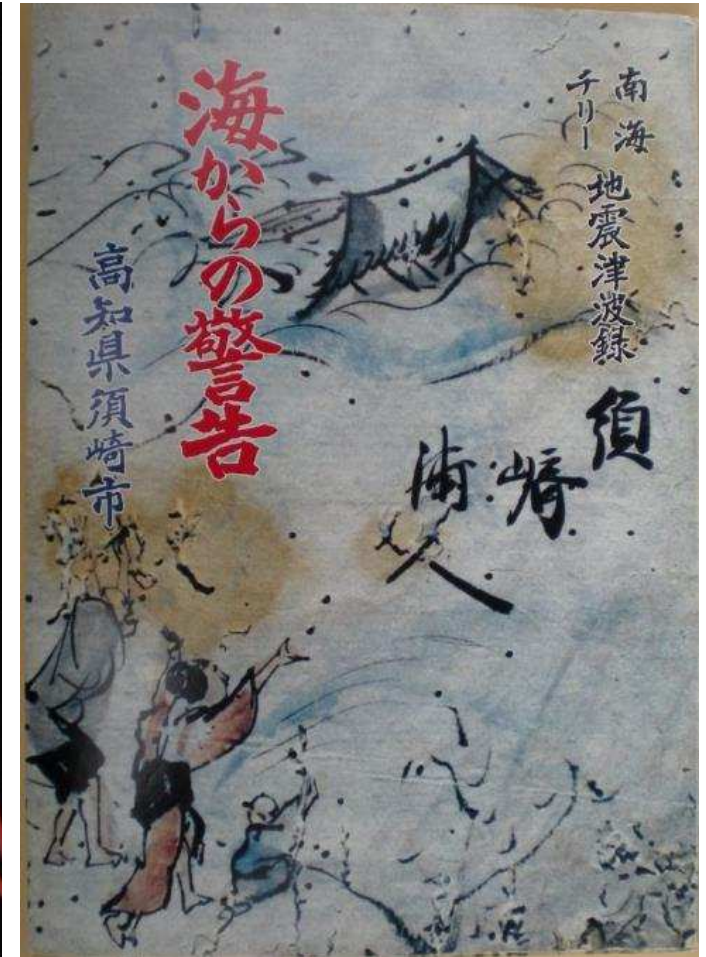
Precursor phenomenon of the 1946 Nankai Earthquake



“Hydrographic bulletin”
Hydrographic Department
(Now: Japan Coast Guard)



“The Nankai Earthquake
is predictable”
Fujio NAKAMURA



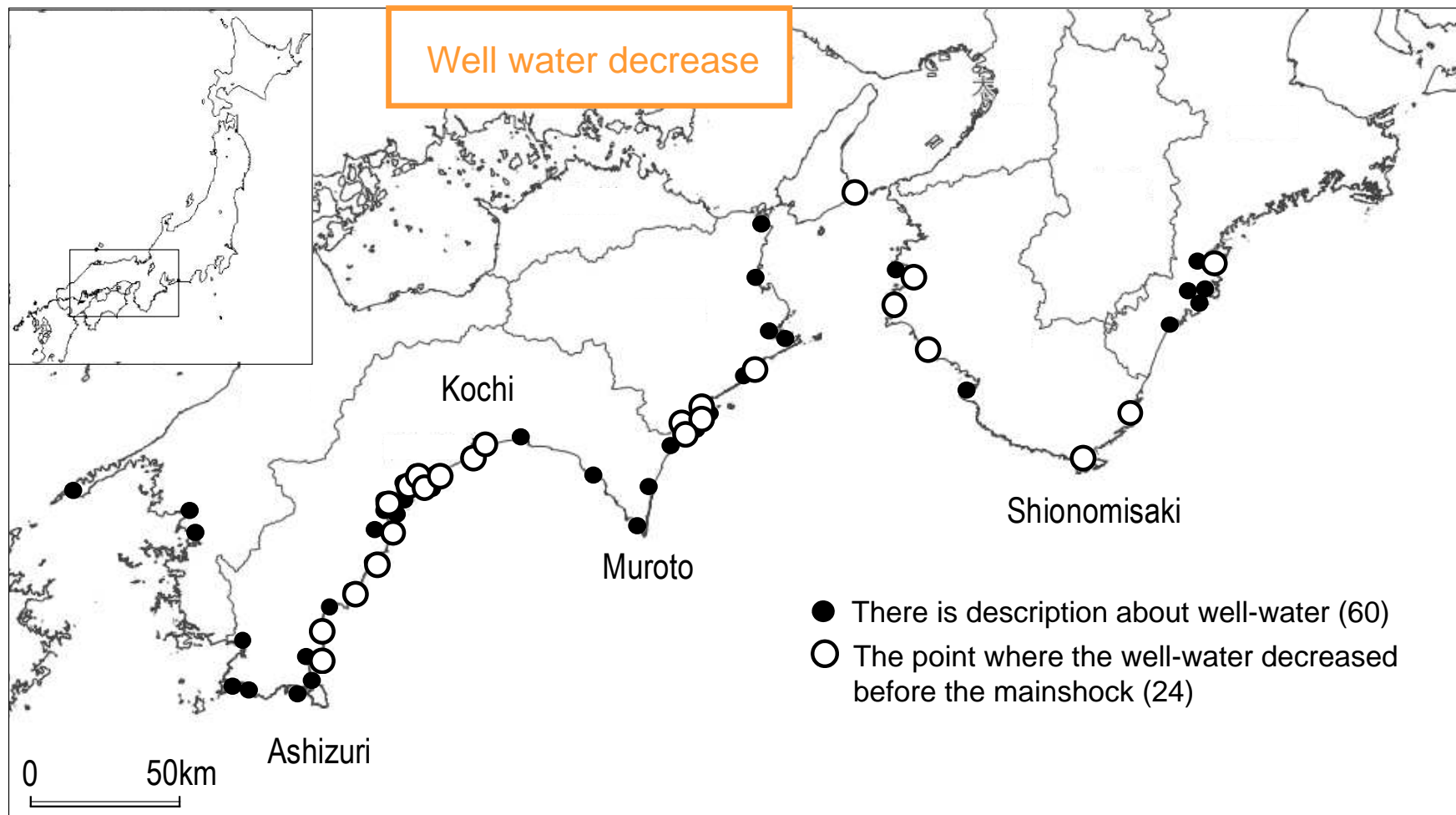
“Warning from the sea”
Susaki city, Kochi Pref.

Precursor phenomenon of the 1946 Nankai Earthquake



- Well-water level change
 - Dry up, decrease
 - Discharges of hot spring stopped or decreased
- Muddy of well-water
- Sea-level change
- Muddy of sea-water
- Rumbling of the earth
- Luminescence phenomenon

Well-water level changes before the 1946 Nankai EQ



Well-water decrease (dry up): 24 wells

W1: Tosa City, Kochi



Name: Mr. Shigeyoshi Matsuoka

Interview date: Feb 4, 2010

He was a member of the fire brigade in the Nii district. About 4 pm on the day before the earthquake, they inspected fire protection water in the storage pool.

The water in the pool was gone.

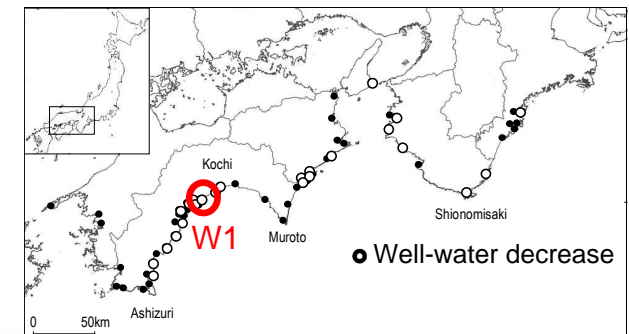
He hurried back to his house and saw his well at home. The well water was also gone.

The depth of the well at home is 3 meters.

He was able to draw water on the morning of the 20th.

After the earthquake, he heard from others that "other well water was also dry before the earthquake."

From his testimonials, it can be seen that there was a 3 meter decrease in nine hours between 7 am and 4 pm on the 20 th



W2: Tosa City, Kochi



Name: Mr. Mareo Kadota
Interview date: Apr 7, 2007
Age at the 1946 Nankai EQ: 20

His father went mackerel fishing around 4 pm, and went home around 2 am of the next day.

His father said, "I could not catch a mackerel today, the sea water is dirty, my hands are sticky, I have to wash my hands quickly from the smell".

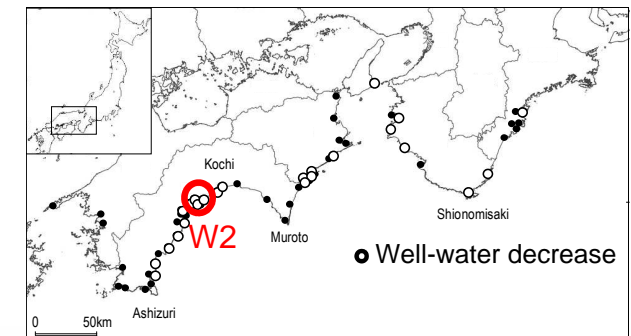
His father went to the well to wash his hands, but the well was dry up.

His father said "This is strange, sea water is abnormal, the wells is dried up.

An earthquake will occur at such times. My father also said so. "

Then, his father put on clothes at the bedside and had a nap."

[Nakamura, 2009; "The Nankai Earthquake is predictable"]



W3: Kaiyo Town, Tokushima



Name: Mr. Tatsuji Minami

Interview date: Dec 9, 2002

He is the owner of the Japanese-style hotel.

At that time, well-water was pumped up at his house.

Until the day before the earthquake, the water was pumped up without any problems.

From the evening of the day before the earthquake, it became difficult to draw water, and it was not able to pump up around 8 pm.

Around around 4 hours before the earthquake, he went to a shared well with his older brother.

A shared well is located about 60 m from his hotel and water is scooped up with a tub with rope.

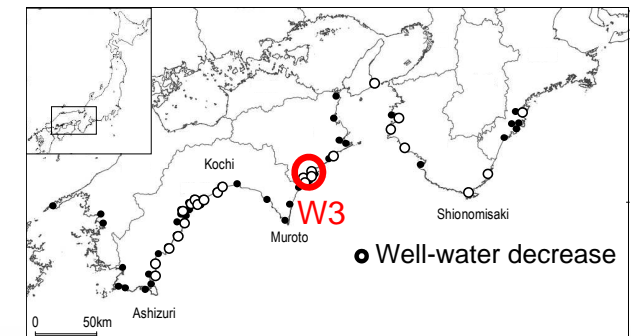
Since the well-water was decreased, they scooped up water by adding 2 m of rope.

Unfortunately, the scooped water was cloudy with mud.

In this area, some of the well-water has decreased or dried up before the earthquake.

His testimony shows that there was a decrease in the well-water level of 2 m in the 8 hours between the 12 pm oand 0 am.

It is important that the wells of the surrounding well are also dry.



W4: Hidaka Town, Wakayama



Name: Mrs. Akiyo Tanabe
Interview date: Dec 15, 2012
Age at the 1946 Nankai EQ: 4

It is a message from her grandmother.

The witness was 4 years old at the time of the earthquake. This old well was used as domestic water for neighboring residents.

In this well, the water level gradually decreased from about several weeks before the earthquake.

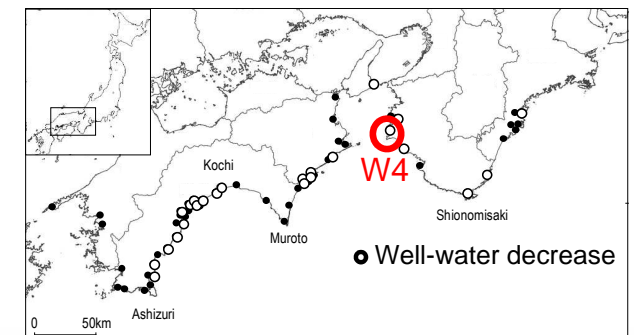
The length of the string that draws water from the well is insufficient, and her grandmother has added a string several times.

The well-water level recovered after the earthquake.

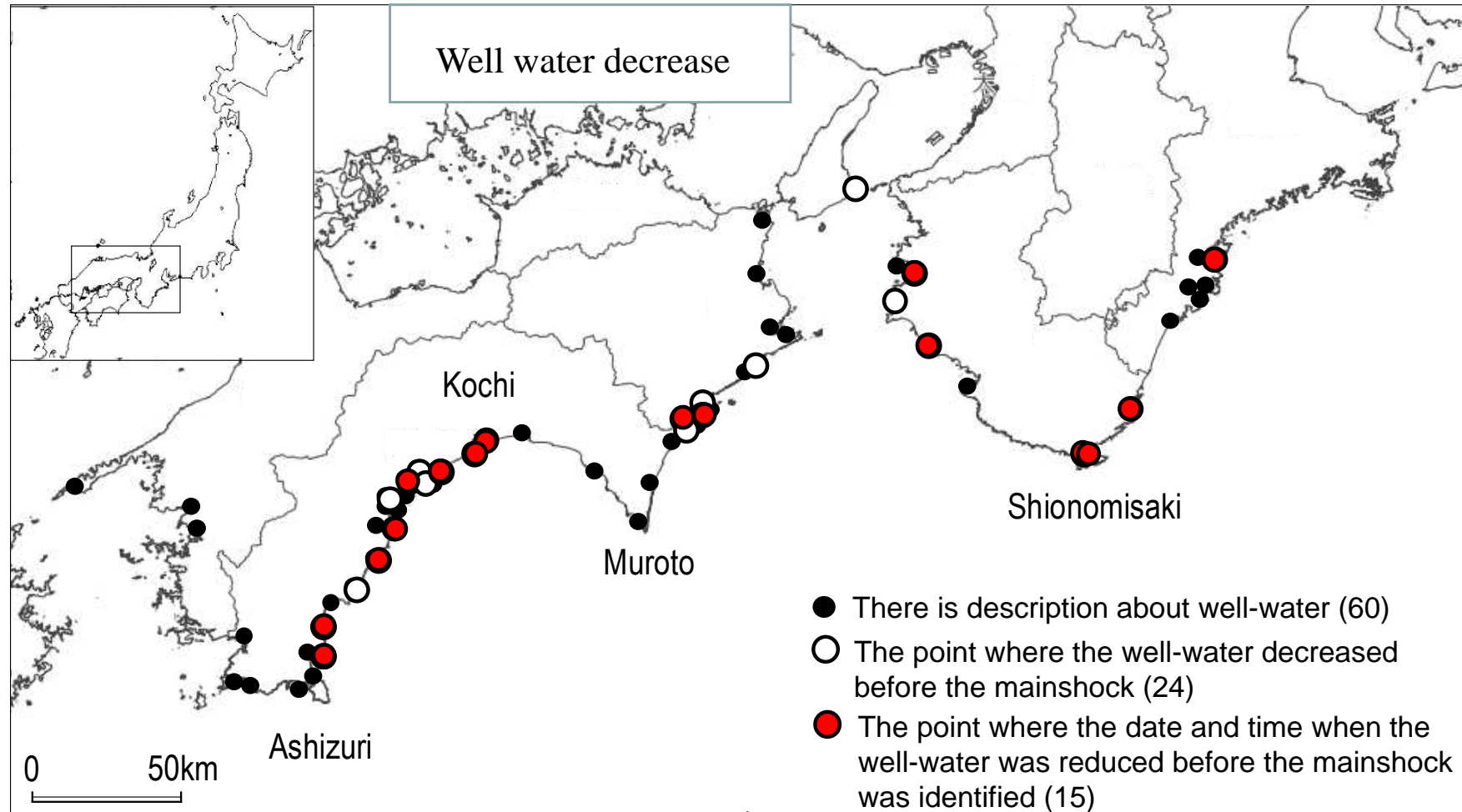
As usual, when the sunny weather continued, the water level of this well did not decrease easily.



String and
bucket to
draw water



Well-water level changes before the 1946 Nankai EQ



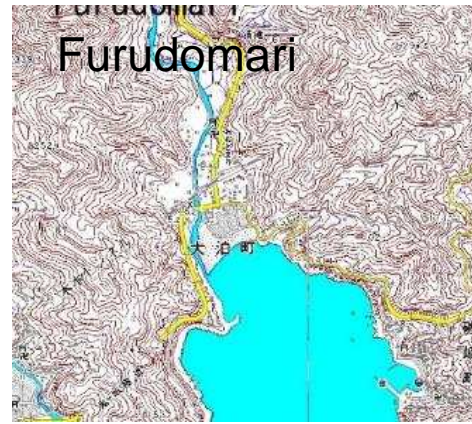
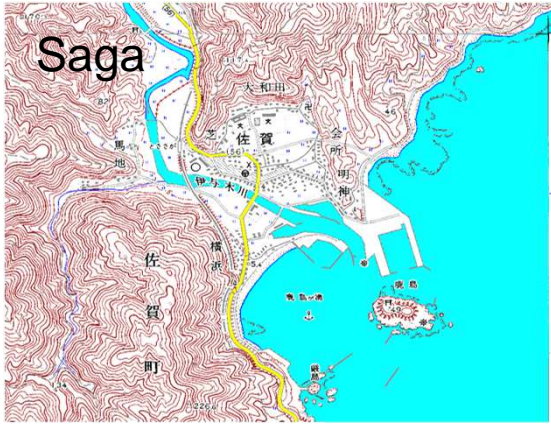
The time was identified: 15 wells

Water level decrease starts from 1 week to several hours ago

Water decreased: 1~3 m or more

Why did the well-water dry up?

Topographic features where well-water had decreased

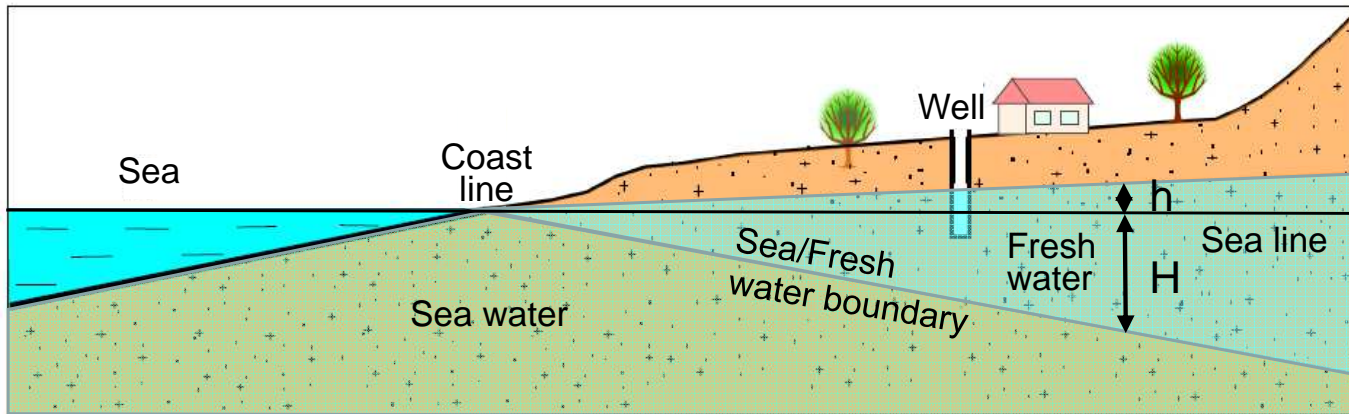


Common appearance:
Small delta surrounded
by mountains



Freshwater supply: poor

Hydrogeological structure in delta near the coastline

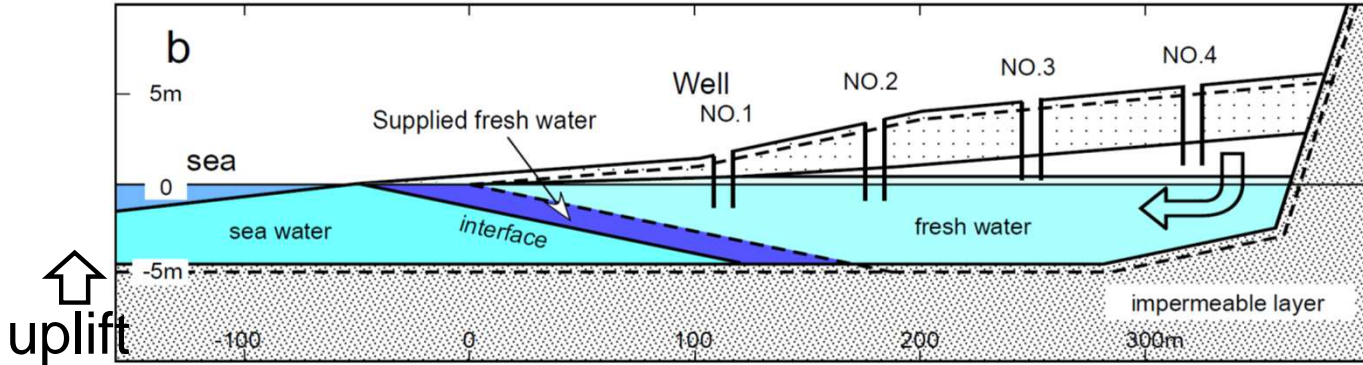


- > Seawater permeates under the delta
- > Freshwater is floating above seawater

h/H : about 40

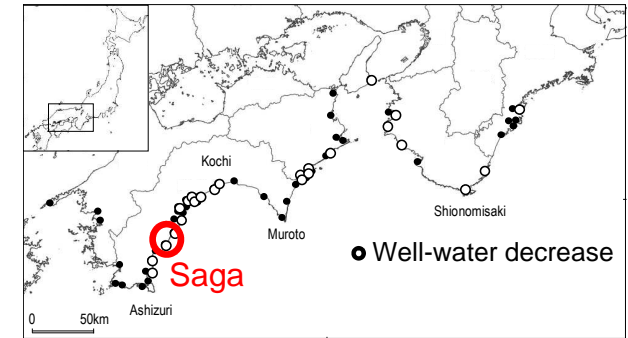
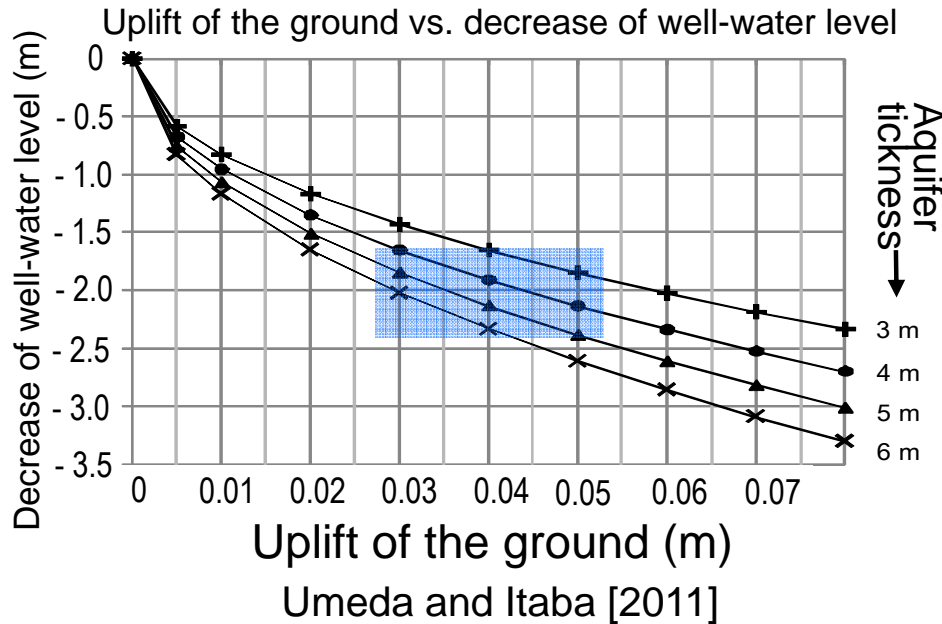
Why did the well-water dry up?

Hydrogeological structure in delta near the coastline



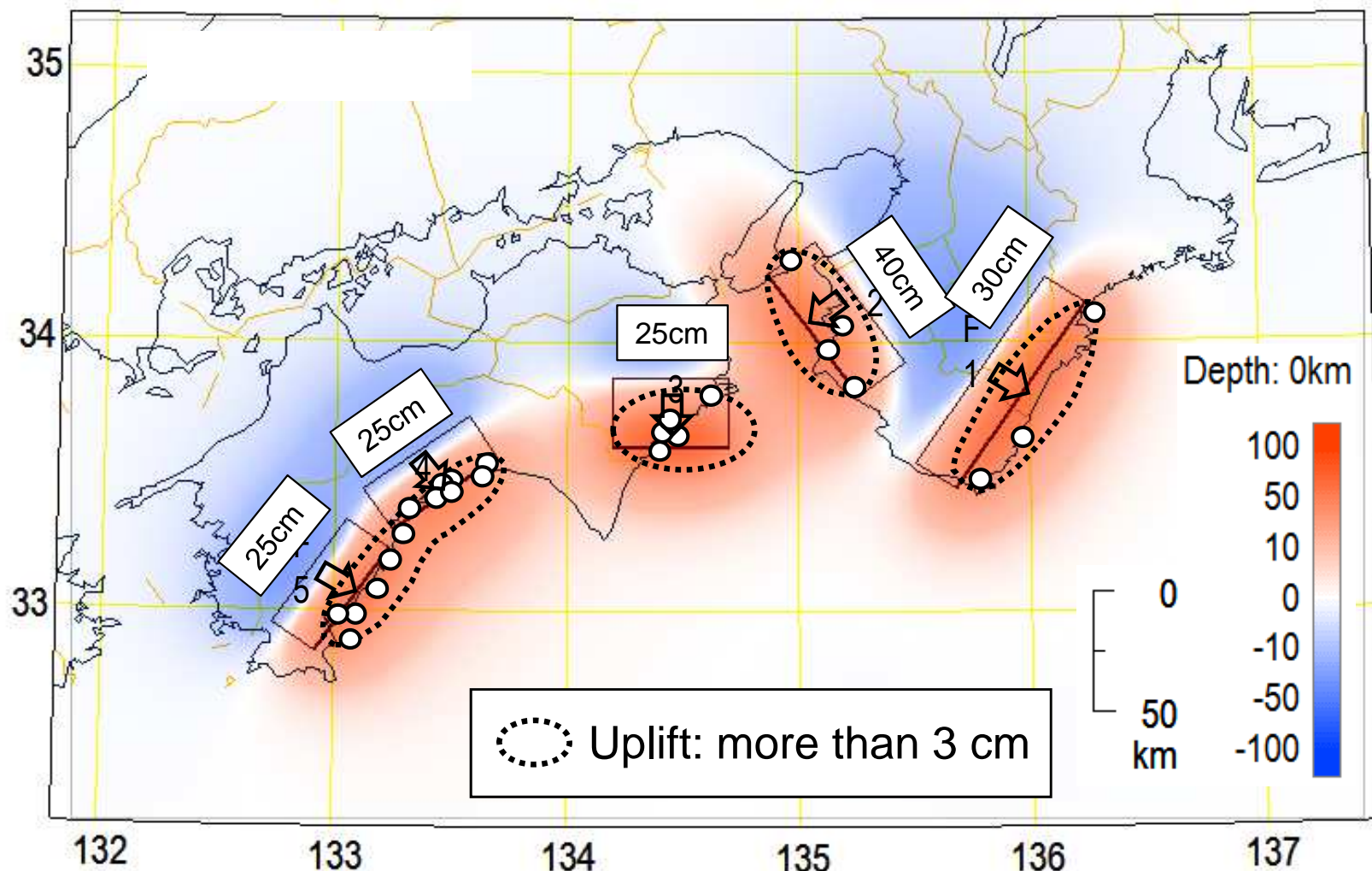
Umeda et al. [2010]

- If the supply of freshwater is small..
- No.4: dry up
- No.3: decrease
- No.2: little decrease
- No.1: not change



Well-water level decrease 2 m
= equivalent to 3 - 5 cm uplift

How to uplift 3 cm?



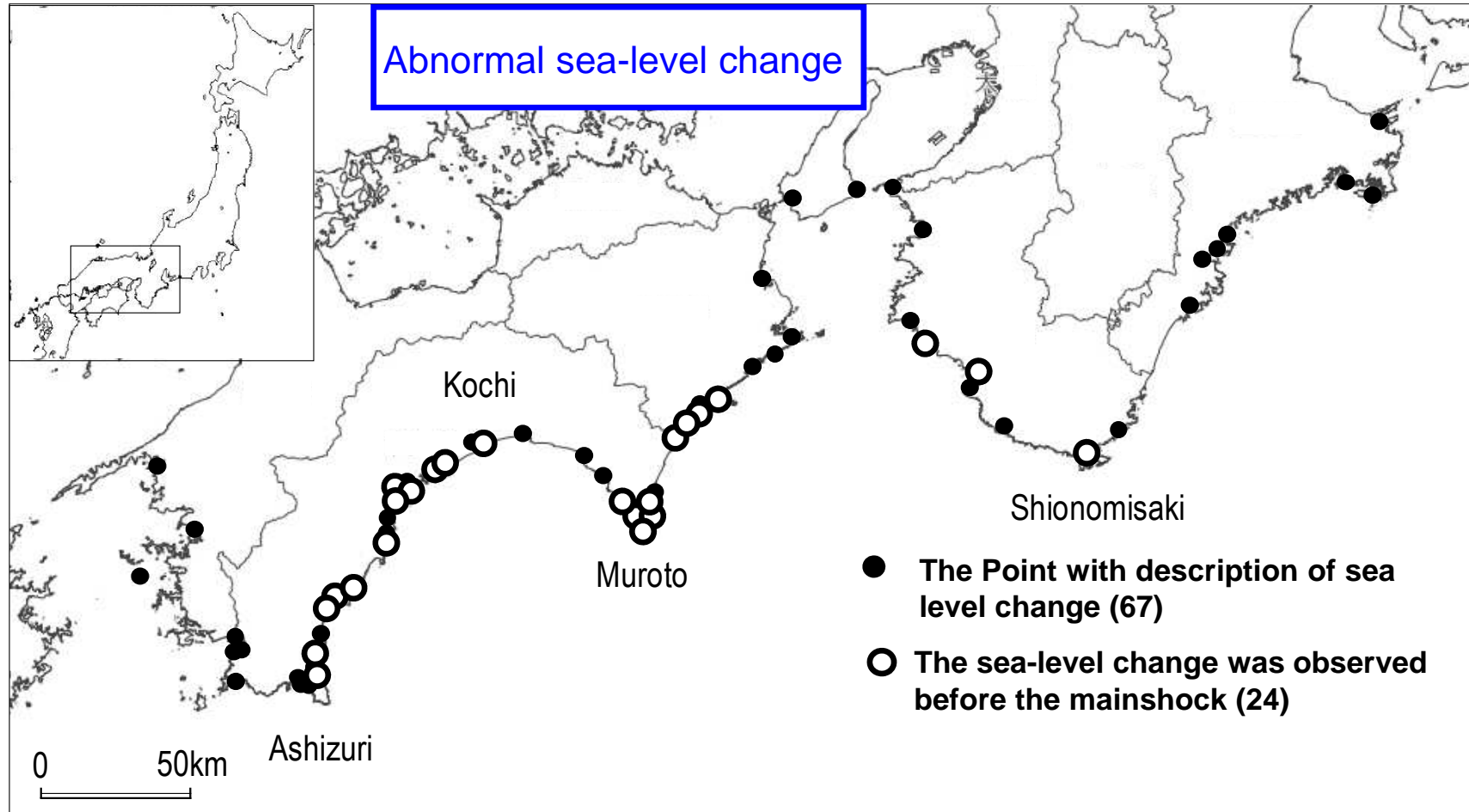
Preslip 25~40cm >> uplift can be explained.

Well-water decreases



- Well-water level decreased significantly before the 1946 Nankai Earthquake: 24 wells
- Decreased time was identified: 15 wells
- Well exists in Delta with less freshwater supply
- Water decreased: 1~3 m or more
- Water level decrease starts from 1 week to several hours ago
- A large water-level decrease can be explained by a slight uplift of the ground (3~5 cm).
 - A slow slip (preslip) occurred at deep side of focal region ?

Abnormal sea-level changes



Abnormal sea-level change: 24 points

S1: Tosa City, Kochi



Name: Mr. Susumu Yokogawa

Interview date: Feb 5, 2010

Age at the 1946 Nankai EQ: 22

He was a fisherman.

At around a half day before the earthquake, their boat departed from the harbor.

The ship was 7 - 8 tons and 12 fishermen were on board.

There was no abnormality in the sea-level at the departure.

They could not catch any fish.

Ten other ships were on the fishing.

They also could not catch fish.

They returned to the wharf around about 4 hours before the earthquake.

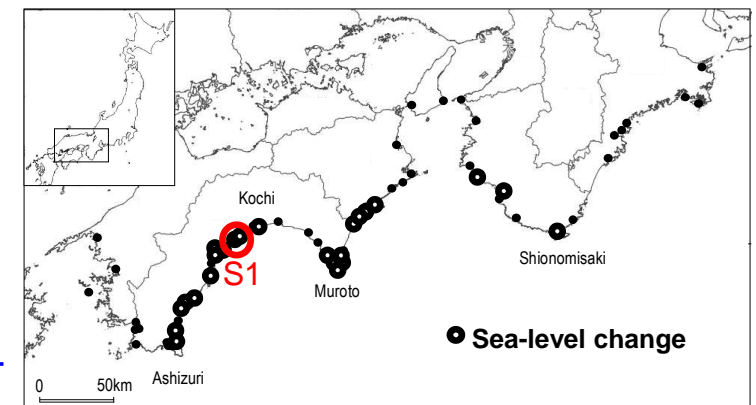
Because the seawater level was low, the bottom of the ship hit the ocean floor.

Normal water depth is 3 to 4 m, but at that time it was only 1.5 m.

Other ships also could not return to the wharf and they anchored off the coast.

Everyone was surprised, as the sea level was severely low.

His testimony suggests that the sea level had lowered 1.5 m - 2.5 m about four hours before the earthquake.



S2: Susaki City, Kochi



Name: Mr. Tsugio Morimitsu

Interview date: Oct 7, 2010

Age at the 1946 Nankai EQ: 24

On the evening of the day before the earthquake, 10 people boarded five fishing boats and left Otani wharf.

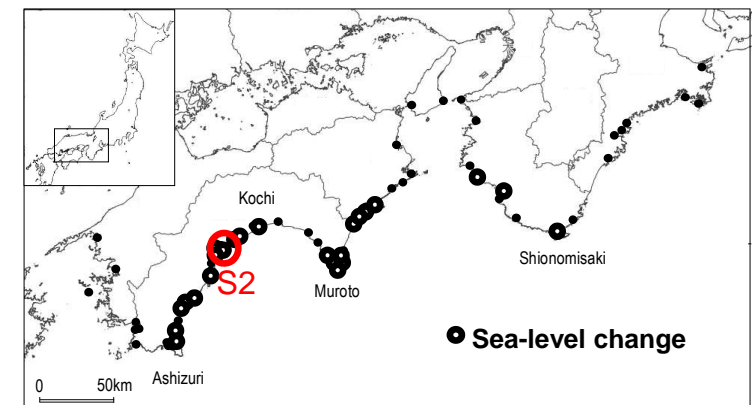
Between the rocks leading to the open sea, we could pass through without any problems.

However, 2 hours before the earthquake on the way back, the tide level was so low that he could hardly pass through. They finally entered the inland sea by riding the crest of a wave, and returned to the Otani wharf about 1 hour before the earthquake.

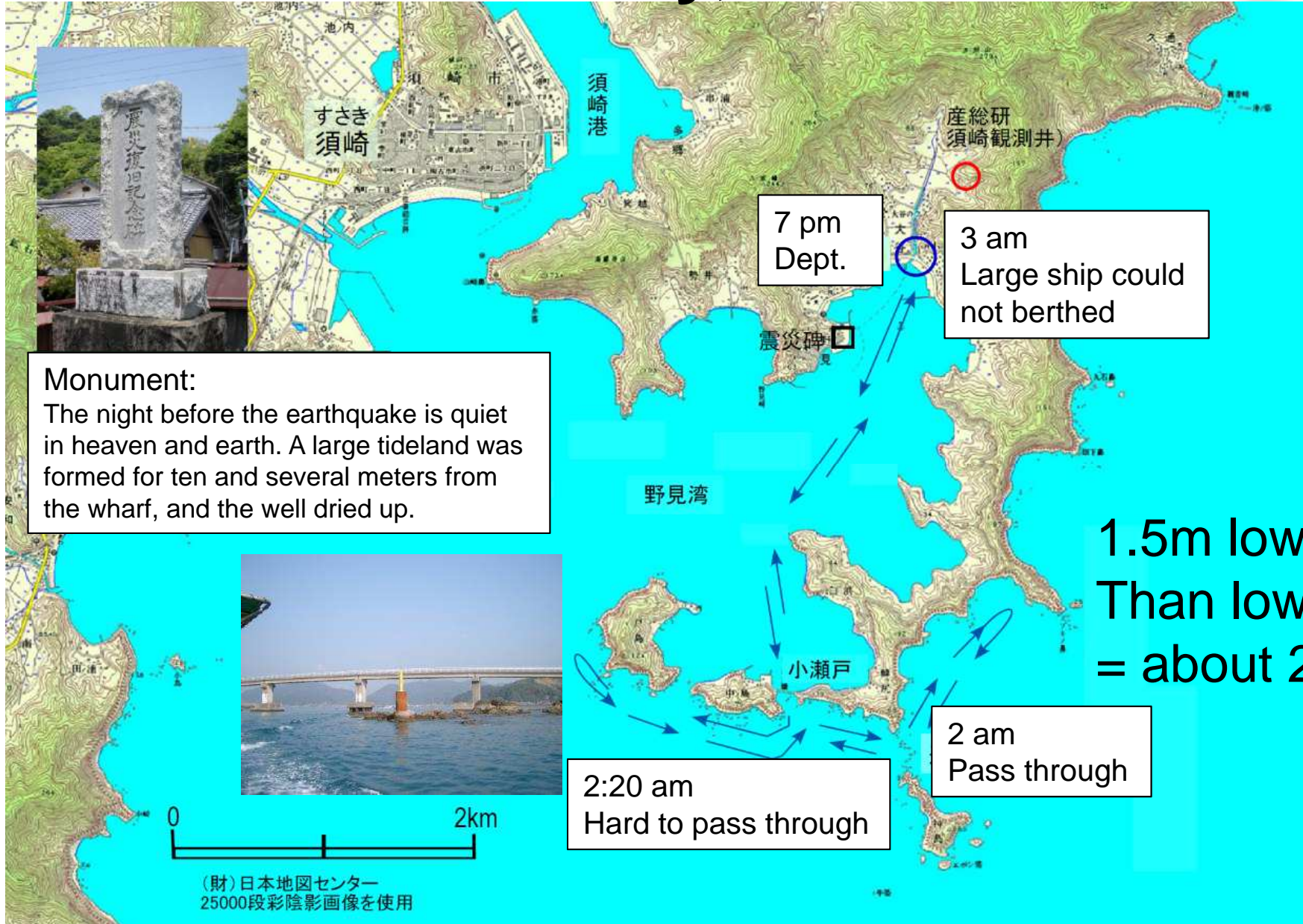
However, as the tide level was low, a large ship could not be berthed to the wharf and they burned for a while at the shipyard and warmed up.

After a while, the tide level rose, a large ship could be berthed to the wharf, and they extended the fish net to the netting platform.

One of the fishermen came home and was besieged by the earthquake at home.



S2: Susaki City, Kochi



1946 Nankai Earthquake: 4:19 am, Dec 21 (M8.0)

S3: Kuroshio Town, Kochi



Name: Mrs. Kunie Nomura.

Interview date: Jan 24, 2010

Age at the 1946 Nankai EQ: 17

Her family made salt from sea water.
She was scooping up the seawater with a tub.

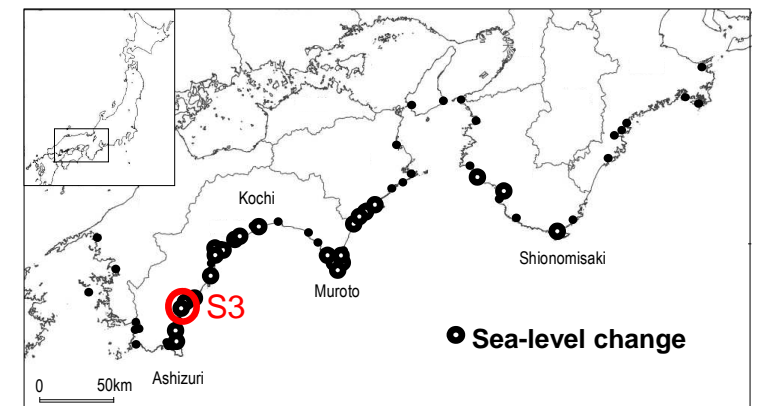
It was around 3 pm the day (13 hours) before the earthquake.

When she tried to scoop up the sea water, the water suddenly retreated to offshore.
After a while, seawater came back.

Retreat and return of seawater were repeated over and over.

She was not remember repeating time intervals.
But she said that it was longer than ordinary wave.

It is a testimony that the sea level change occurred.



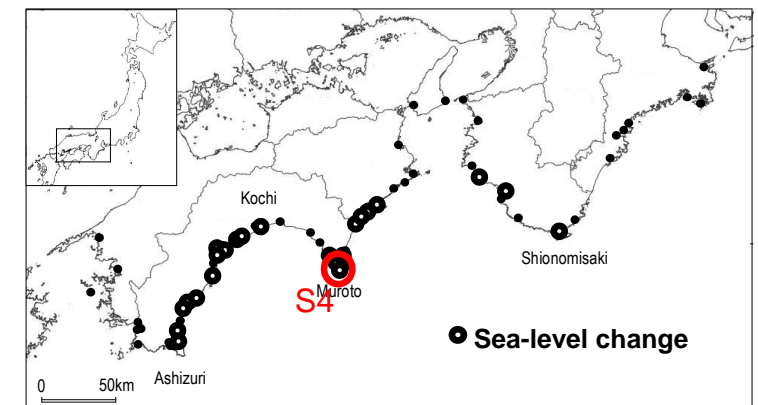
S4: Muroto City, Kochi



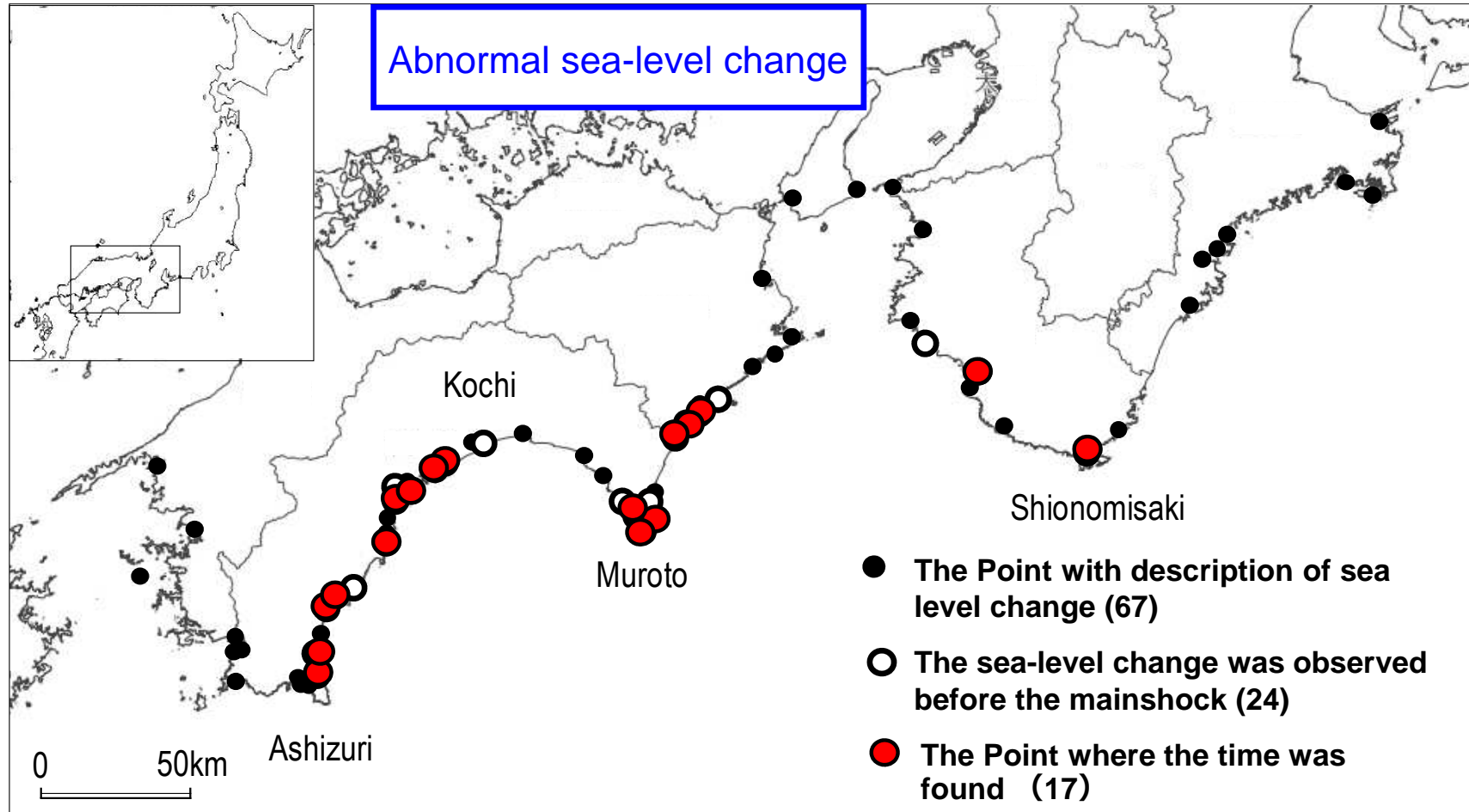
Name: Mr. Kakuichi Tokunaga
Interview date: Jan 10 to 11, 2010
Age at the 1946 Nankai EQ: 19

About 3 pm of the day (13 hours) before the earthquake, I was putting water in a tank of a boat
The boat carrier of raw fish, about 20 tons.
My older brother drew water from the well, and I carried it.
When the ship arrived at the wharf, the tide level was low and the transfer board (3.6 m in length, 0.3 m in width, and 3 cm in thickness) was tilted much more than usual.
I think that the boat was down about 0.3 m more than usual.
For that reason, I stepped on my feet about the fourth time, hit the edge of the ship and fell to the sea.
So I remember well that the tide level had decreased.
Because I bruised the right leg strongly, I could not carry water and returned to my parents home in Kagoryo district.

When I walked up from the sea, the transfer board was returning to the normal angle, and **the drift of the tide was repeated at the cycle of about 30 minutes.**
I think that the tide level never got higher than usual.



Abnormal sea-level changes



The time was identified: 17 points

Sea-level change starts several hours before the Earthquake.

Abnormal sea-level changes



- Abnormal sea-level changes: 24 points
- Change time was identified: 17 points
- It changed from several hours to half a day before the earthquake
- There are conflicting testimony in almost the same place
 - Sea-level decreased or returned (increased) repeatedly ?
- Oscillatory change testimony
 - Possibility of small scale tsunami
 - Slow slip (preslip) occurred near the trench axis ?

Discussion

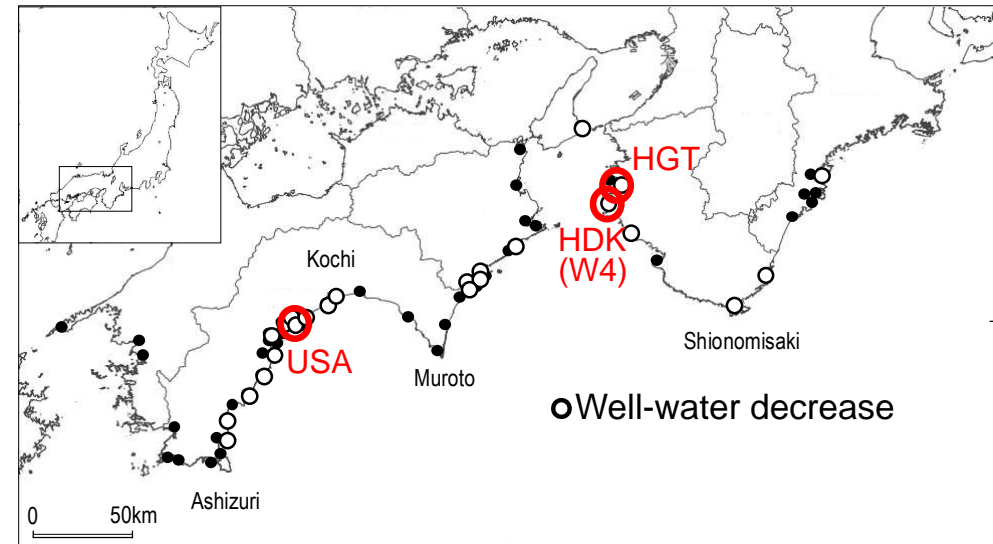


- Is not it a coincidence that the witnessed precursor phenomenon ?
 - e.g. Sunny weather last long time
 - > Well-water level decreased greatly
- Is that will it reappear at the next Nankai Earthquake ?
 - How was the past Nankai earthquake?
 - The 1854 Ansei Nankai Earthquake (M8.4)

Understanding of steady fluctuation range



- Water level observation in 3 wells whose water level decreased before the 1946 Nankai Earthquake.
- We have been observing for 5 to 7 years.



USA
Nov, 2011 ~

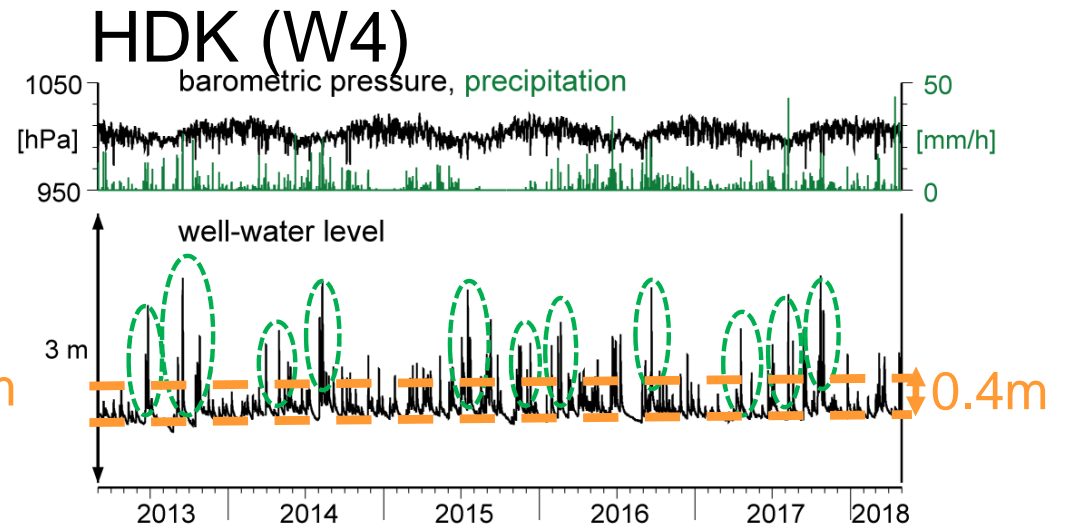
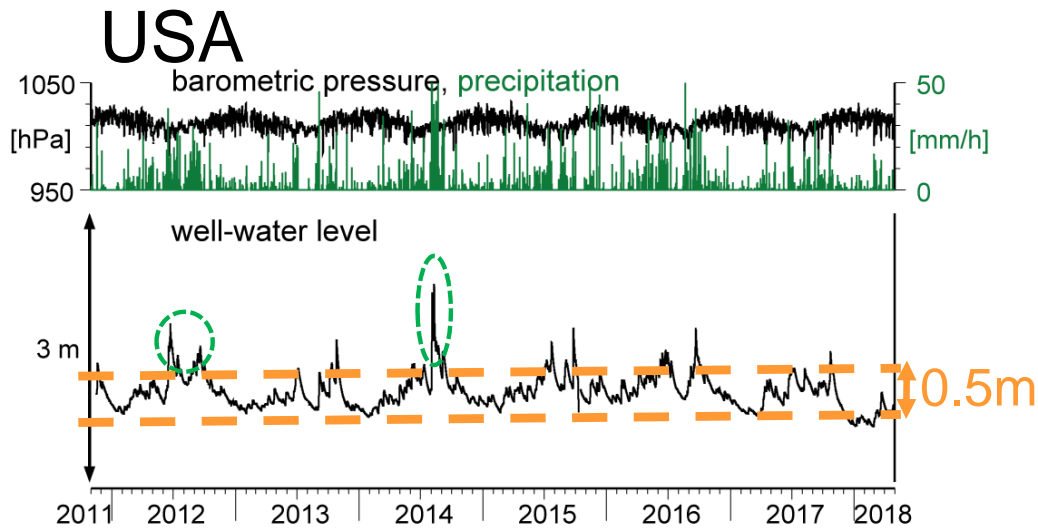
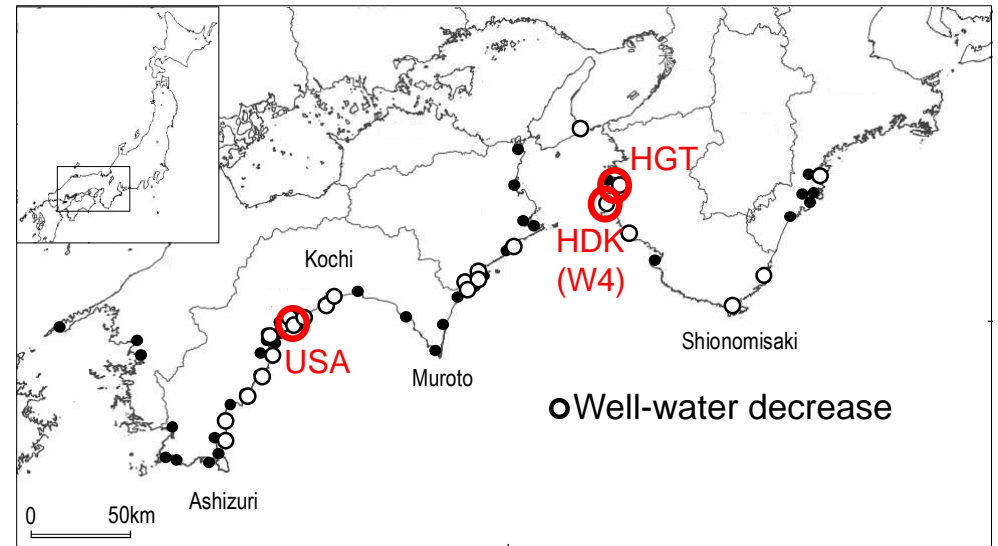
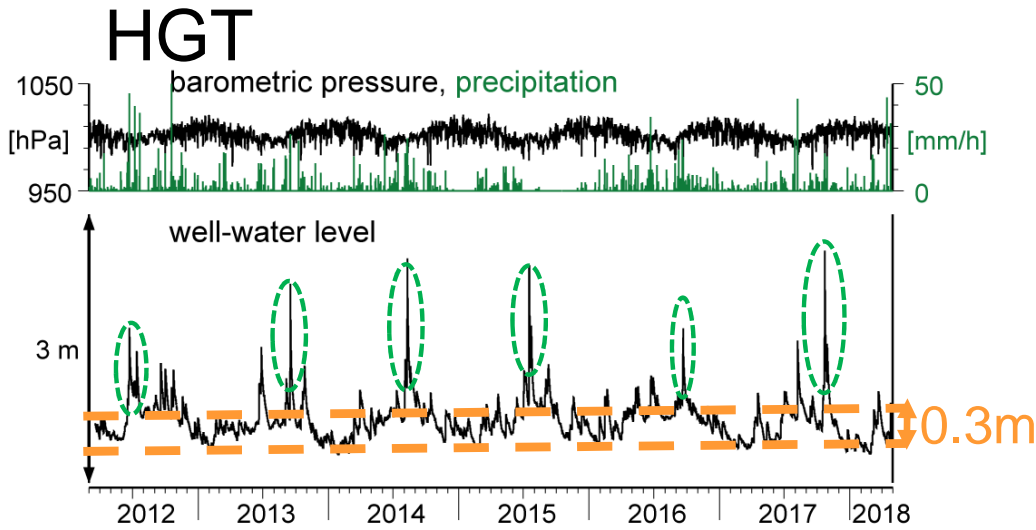


HDK (W4: Hidaka)
Mar, 2013 ~



HGT
Mar, 2012 ~

Fluctuation range: Well-water level change



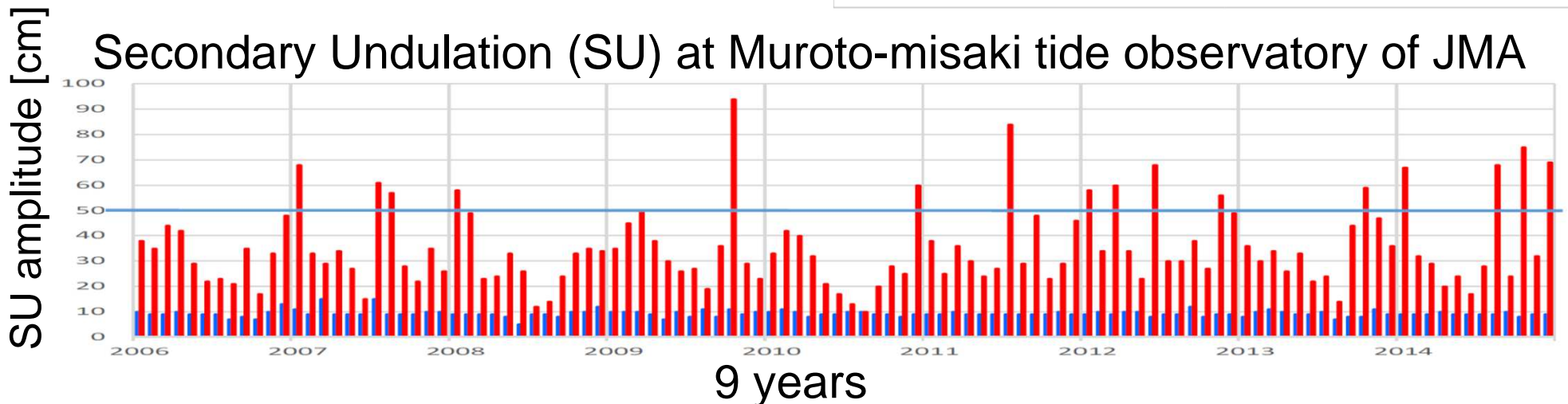
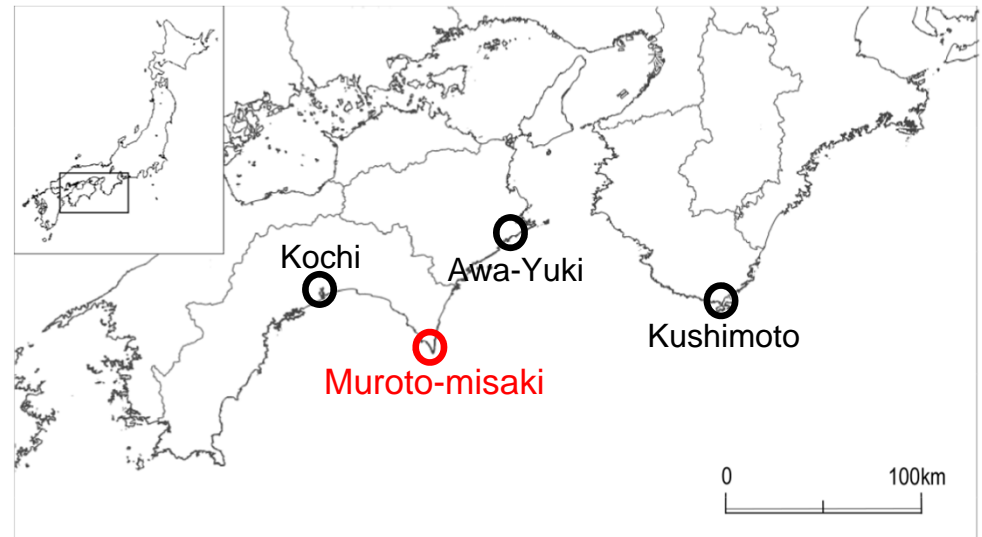
Large increase is due to precipitation

Variation: less than 0.5m > Large decrease was not observed

Fluctuation range: Sea-level change



- We checked the tide record for more than 10 years at 4 observatories of the Japan Meteorological Agency (JMA).
- Decrease in sea-level exceeding 0.5m was not observed.



Exceeding 0.5m: 17

Due to low air pressure: 16

Due to the hard wind: 1

Due to non-weather conditions: 0

1946 Nankai: mild sunny day
Hard to think that weather induced SU

Summary:

steady fluctuation range



- We investigated steady-state fluctuation range of well-water decrease and sea-level change with recent observation data.
- Well-water:
 - In the last 5 to 7 years, no abnormal water level decrease was observed.
- Sea-level
 - In the last 10 years, no abnormal sea-level change was observed.

Discussion



- Is not it a coincidence that the witnessed precursor phenomenon ?
 - e.g. Sunny weather last long time
 - > Well-water level decreased greatly
- Is that will it reappear at the next Nankai Earthquake ?
 - How was the past Nankai earthquake ?
 - The 1854 Ansei Nankai Earthquake (M8.4)

Legend of the 1854 Ansei Nankai earthquake

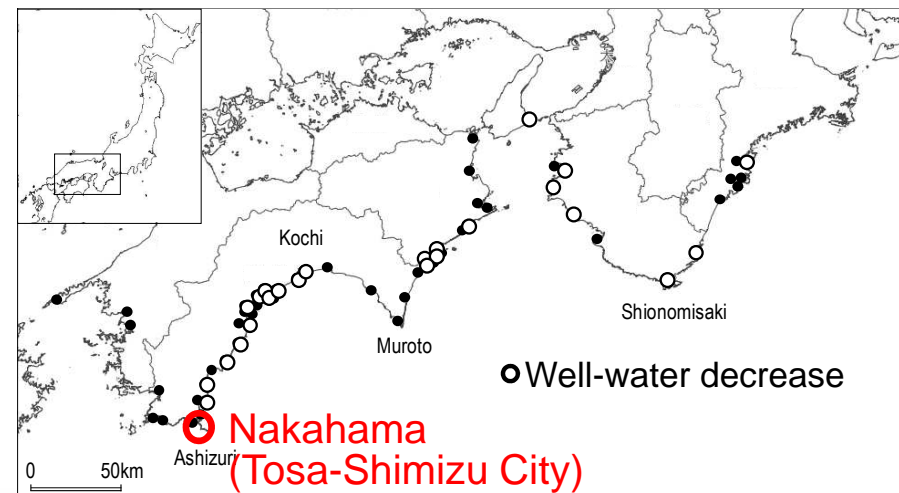


- 150 years ago, Mr. Ike reported the decrease of the well water before the 1854 Ansei Nankai Earthquake.



Mr. Michinosuke Ike “Konjaku-taihenki”

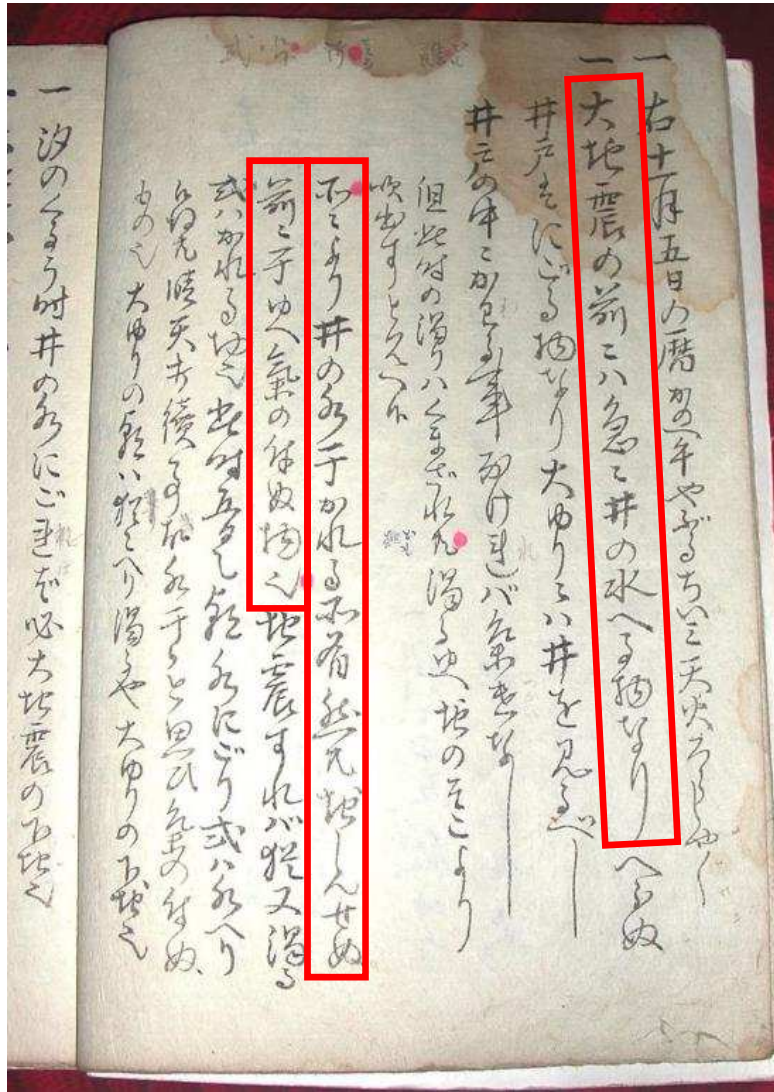
- He found that the well water decrease at Nakahama where was the south west of Japan.



Legend of the 1854 Ansei Nankai earthquake



- Before the 1854 Earthquake, well-water suddenly decrease.
- The well-water dried up on some wells.
- However, peoples do not notice it, because it is occurred prior to the earthquake.



大地震の前には急に井の水へるものなり．．．．
所により井の水平しかれ有り、然れども地しんせぬ
前に干ゆえ氣の付かぬ物也．．．．

Legend of the 1854 Ansei Nankai earthquake



Sketch of the monument design



The monument in
Tosa-shimizu City, Kochi

Evacuation by legend



Witness: Mrs. Mineko Takemura

Interview date: Feb 4, 2010

Age at the 1946 Nankai EQ: 17

Her father was a fisherman.

About 2 hour before the earthquake, he went to beach for inspection of his ship.

The returning father said “ It’s strange ! Sea water is gone”

Her mother was trying to draw well water.

Mother said in a loud voice “It’s strange ! There was no well water !”

Her father said “An earthquake will occur, a tsunami will come”

We carried foods and clothes many times to high places.

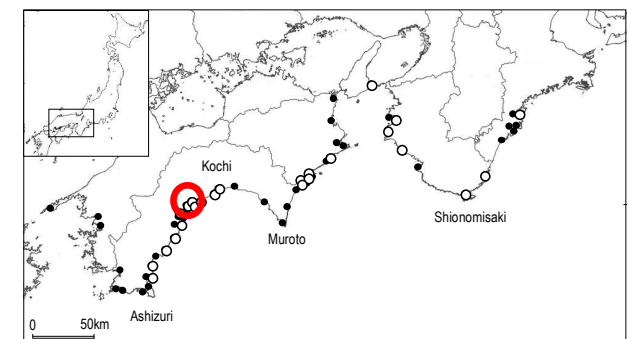
At that time, the earthquake occurred.

It is a legend from her grandfather that an earthquake will come when there is a large change in well-water or sea water.

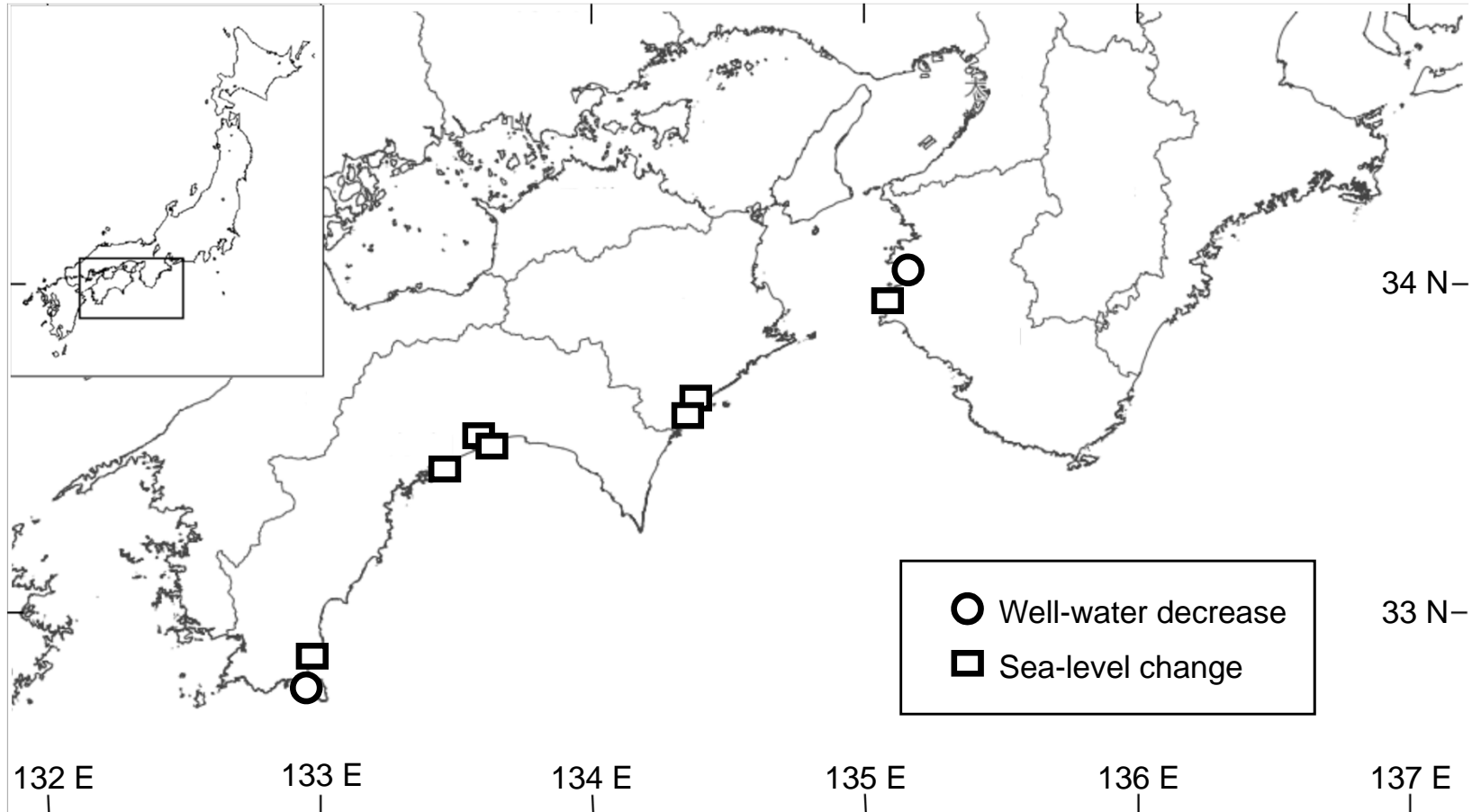
This legend saved us.

It has been known that well-water decreases and sea-level changes abnormally before the earthquake for long time.

So they were ready for evacuation.



Well-water decrease and sea-level change just before the 1854 Ansei Nankai earthquake



Well-water decrease: 2 wells

Abnormal sea-level change: 7 points

Summary



- Well-water decrease: 24 wells
 - A large water-level decrease can be explained by little uplift of the ground (3~5 cm).
 - A slow slip (preslip) occurred at deep side of focal region ?
- Sea-level change: 24 places
 - Oscillatory change testimony
 - Slow slip (preslip) occurred near the trench axis ?
- The witnessed phenomenon greatly exceeds the steady fluctuation range
- A similar phenomenon was also observed before the 1854 Ansei Nankai Earthquake.