

1854 Ansei Nankai Earthquake Tsunami Hit ‘The Water Metropolis of Osaka’. Monument Warns of the Next Nankai Earthquake Tsunami.

Takeshi Nagao¹

§ 1. Introduction

There is a stone memorial about 2.0 m tall, inscribed with many characters, on the north side of the east end of Taisho Bridge in Naniwa Ward, Osaka City(Fig. 1). This memorial is called ‘Daijishin Ryo Kawaguchi Tsunamiki’ (‘The Record of the Great Earthquakes and the Tsunami at the Mouths of the Two Rivers’) (Photo 1). It was constructed, not only to commemorate the victims of the 1854 Ansei Nankai earthquake tsunami, but also to warn the Citizens of Osaka City the next Nankai earthquake tsunami.

Since ancient times Nankai earthquakes have repeatedly occurred. Their hypocentral region is situated off southwest Japan, along the Nankai trough, in the bottom of the Pacific Ocean. Each Nankai earthquake generated a tsunami, which usually caused serious damage to the Osaka region.

In ancient times Osaka flourished as the gateway port to the old Japanese capitals of Kyoto and Nara. Osaka is situated at the east end of the Seto Inland Sea. Ships from China and Korea would arrive at Naniwazu (the old name of Osaka port), and would transfer cargo to the river boats bound for Kyoto via the Yodo River, and Nara via the Yamato River.

During the second half of the 16th century, Toyotomi Hideyoshi built Osaka Castle on the Uemachi plateau, from where he looked down upon the junction of the Yodo and Yamato Rivers.

Hideyoshi dug the Higashiyokobori River as a third outer moat. During the age of Hideyoshi and his son Hideyori, the Nishiyokobori River, the Tenma Horikawa River, and the Awabori River were created.

In the Summer Battle of 1615, Toyotomi was overthrown by Tokugawa. Matsudaira Tadaaki, appointed governor of Osaka by Tokugawa, continued the expansion of Osaka City. The area of Osaka City was extended to the Osaka Bay area. By about 1630, many canals, such as the Dotonbori, Kyomachibori, Edobori, Kaifubori, Nagahori, Itachibori and the Satsumabori Rivers, were dug in this lowland area. The Horie River was the last excavated canal,



Photo 1. The memorial of the Ansei Nankai earthquake tsunami .

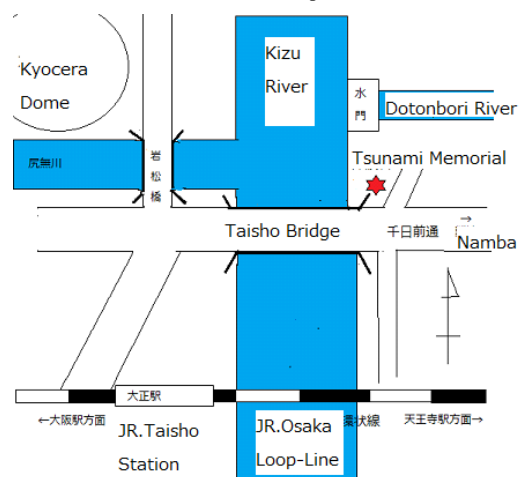


Fig. 1 The location of the memorial.

¹ Email: nagaotakeshi345@hotmail.com.

completed in 1698.

The primary purpose for construction of the canals was to use the excavated soil to raise the ground up to a height safe against natural disasters, such as tidal waves and tsunamis. The secondary purpose of the canals, which ran in all directions in Osaka, was for transport.

Blessed with waterways and the large consumer neighbor of Kyoto, Osaka held a significant role in commerce and distribution in Japan. The two mouths of the Yodo River, Kizugawaguchi and Ajigawaguchi, thrived. A thousand incoming and outgoing ships could usually be found in ports and in Osaka's waterways. During the Edo era the 'Water Metropolis of Osaka' was hit twice by big Nankai earthquakes². The first one hit during the 4th year of Hoei (1707) and another one hit during the first year of Ansei (1854).

During the Hoei earthquake (M8.6) people in Osaka, fearing the severe shaking, fled into boats. After a while a big tsunami rushed in and people boarding the boats were caught by big tsunami waves. Consequently the fatalities were numerous. The mistake of people rushing to boats was repeated after the Ansei Nankai earthquake (M8.4). The people that suffered from the Ansei tsunami regretted that they had not learned the lessons of the Hoei tsunami. In 1855, the year after the Ansei Nankai earthquake tsunami, residents built a monument not only as part of a memorial service to the victims, but also to remind future generations of these fearful tsunamis and to warn them to take precautions against the next Nankai earthquake. This monument stands at the east end of the Taisho Bridge and has been warning of another tsunami for over 150 years.

The following is a translation of the monument's inscription.

'Daijishin Ryo Kawaguchi Tsunamiki'('The Record of the Great Earthquakes and the Tsunami at the Mouths of the Two Rivers').

At midnight on June 14th of the seventh year of Kaei period [the first year of the Ansei period]³, a big earthquake hit Osaka. People were frightened and went out and stood in the streets or by the rivers, fearful after the shock. Many had been anxious and were not able to sleep well. It was said many people were injured in Yamato [Nara Prefecture] and Iga [Ueno City in Mie Prefecture] .

In the same year, on November 4th ⁴ at about 8:00am, in Osaka, a big earthquake suddenly occurred. People were afraid and ran out of their houses into huts and small boats for safety.

The next day (November 5th) a second big earthquake hit at about four o'clock in the afternoon. Houses collapsed and fires broke out. The shaking subsided, but with a sound like thunder, huge mountain-like waves rushed into Osaka Bay and reached the mouths of the Aji River and the Kizu River.

As far inland as the Higashibori River, muddy water rose to 120 cm above normal levels (Fig. 4) . Many large and small ships moored along the two rivers were suddenly carried upstream, and the Ajigawabashi, Kameibashi, Takahashi, Mizuwakebashi, Kuroganebashi, Hiyoshibashi, Shiomibashi, Saiwaibashi, Sumiyoshibashi, and Kanayabashi [bridges] were all destroyed. The floodwaters powered into the streets and people ran about, trying to escape. Some fell from the bridges into the rivers. A large

² [Nagao, T. (2012b)]

³ July 9, 1854 on the Gregorian calendar. This is also the first year of Ansei period; on November 27th of that year the name of the period was changed to Ansei.

⁴ December 23 on the Gregorian calendar.

ship that was trapped in the Daikokubashi [bridge] formed a barricade and many other ships being carried by high waves crashed into it. West of the Daikokubashi, from north to south of Matsugahana, a mountain of ships covered the surface of the rivers; most of the ships were wrecked.

Sheds along the riversides were crushed by the big ships. With crushing sounds and people's cries, there was nothing that could be done to stop the sudden tragedy. In an instant, many people were either drowned or seriously injured. Word spread that the tsunami would reach Senba and Shimanouchi and so people in these areas ran for Uemachi⁵(Fig. 4).

One hundred and forty-eight years ago⁶, on October 4th in the fourth year of Hoei⁷, another large earthquake hit Osaka. Many people fled into boats in the river and consequently died when the tsunami surged.

Many years have passed and there is little talk of the incident. Now again many people have died [here] in the same place. It was a terrible disaster. It was wretched. The future is a concern. Always be careful of a tsunami when a big earthquake occurs and do not try to escape in boats. Houses may collapse and fires may break out. Money and bonds should be kept in earthen storehouses. Be most careful of fires.

Large and small ships on the river should be moored in calmer areas. In winter, ships resting for repair should be pulled up as high as possible.

The tsunami rushes in not only from offshore, but also from the bottom of the shallow near the sea or rivers. A lot of muddy water springs up from the reclaimed land along the shore. This kind of phenomenon happened in Furuichi in Yamato [Nara]. Pond water flooded and many houses were swept away.⁸ People living by the seaside, large rivers and ponds should be careful. Nowadays people are aware of the fact that tsunamis are different from normal high tides. We have written this for the benefit of future generations and to commemorate those who drowned. It is my desire that over the years, people of conscience will add ink [to this inscription] in order to keep it legible.

§ 2. Lessons Learned from the Ansei Nankai Earthquake Tsunami.

Since ancient times, Nankai earthquakes occurred at 90~150 year intervals. Each Nankai earthquake generated a tsunami, which usually caused serious damage to the Osaka region. Intervals between earthquakes are so long that people are not aware of the lessons learned from previous disasters.

When both the Hoei and Ansei earthquakes happened, people were frightened of the violent shaking and fled into boats. People on the boats felt safe and relieved, but shortly afterwards, a tsunami hit Osaka Bay.

Large cargo ships which were carried up the canals by the tsunami crashed into the small boats. Several documents stated that the fatalities ran into the thousands.



Photo 2 Saiwaicho resident Kenzo Masui, whose family has been adding ink to the memorial for five generations.

⁵ The tsunami run-up height did not in fact reach Senba and Shimanouchi. However, frightened residents fled to the Uemachi plateau, where the ground height was around 20m.

⁶ In fact, it was 147 years prior. At the time of the inscription, the method for counting years generally resulted in adding one year compared with modern times.

⁷ October 28, 1707 on the Gregorian calendar.

⁸ The writer of this inscription misunderstood the cause of the disaster in Nara Prefecture, where the floodwater was caused by the shaking of the earthquake, and was not related to tsunami. This happened during the Igaueno earthquake.

The inscription on the memorial warns people not to board boats when earthquakes occur.

Why did people flee into boats when the earthquakes occurred? In the Edo era big fires often broke out in Osaka City. During fires, people used to flee into boats with their possessions. When earthquakes occurred, people were wary of fires. They did not consider tsunamis. The streets of Osaka were narrow, so people thought the wider canals were the safest place. The people in Osaka who suffered from the Ansei Nankai earthquake tsunami regretted that they did not learn the lesson from the Hoei earthquake tsunami. A year after the Ansei Nankai earthquake tsunami, they built a stone monument not only as a memorial for the victims of the earthquake and tsunami, but also as a warning for future generations.

The memorial inscription includes a lot of information about earthquakes and tsunamis. People are warned not to forget the lessons learned from the disaster. The memorial inscription begins with the Igaueno earthquake, which occurred five months before the Ansei Nankai earthquake. It is possible that other earthquakes tend to occur inland before a powerful earthquake occurs at the bottom of the Nankai trough.

The inscription describes ground liquefaction: “Tsunamis rush in not only from offshore but also from the bottom of the shallows near the sea or rivers. The muddy water springs up in reclaimed land.” This phenomenon was caused by the shaking of the earthquake, and was not related to a tsunami.

Since the beginning of the Edo era the area of reclaimed land has grown to 11,600 hectares. Especially since the period of rapid economic growth, land reclamation has accelerated. Even though economic growth has slowed down, reclamation has continued. Recently, at Kansai airport, even at a depth of 20 meters, reclamation has been underway.

When the Hanshin earthquake occurred, liquefaction happened on Rokko Island and Port Island (reclaimed land) where they had taken modern measures against liquefaction.

Hereafter we should develop better safeguards against liquefaction. Over 150 years have passed since the construction of the memorial to the Ansei Nankai earthquake tsunami. Now the landscape along the Kizu River has been transformed and the residents changed. However the memorial has been preserved by the people of Saiwaicho (Photo 2). As the last sentence of the inscription states, “It is my desire that over the years people of conscience would add ink [to this inscription] in order to keep it legible.”

2.1. The Lessons of the Ansei Nankai Earthquake

The people of Osaka who suffered from the Ansei Nankai earthquake tsunami regretted that they had not learned from the experience of the Hoei earthquake tsunami. They built a monument by the Kizu River at the ferry crossing in 5 Chome Saiwaicho⁹. The inscription, which is titled ‘The Record of Big Earthquakes and Tsunamis at the Mouths of Two Rivers’, gives information about other powerful earthquakes and tsunamis for future generations.

We have extracted important lessons from the inscription¹⁰.

(1) “Do not board boats when a powerful earthquake occurs, because a tsunami might hit after the earthquake.”

During the Ansei Nankai earthquake tsunami most of the fatalities were due to people fleeing into boats, afraid of the terrible shaking. The tsunami which ran up the Kizu River and the Aji River swiftly carried large cargo ships up the canals in Osaka.

⁹ The memorial was originally erected at the ferry station. There was no bridge at that time. Taisho Bridge was constructed in 1915.

¹⁰ [Nagao, T. (2012a)] , [Nagao, T. (2012b)]

They crushed small boats and many people drowned.

People who suffered at the time of the Ansei Nankai earthquake tsunami thought that boats in canals were the safest place when a powerful earthquake occurred. They had completely forgotten the lessons of the Hoei earthquake tsunami which had occurred 147 years earlier.

(2) “Be careful of fires.”

The Bugyosho ordered the town’s senior officials to conduct fire patrols to protect the streets, including the back streets. When earthquakes occur, fires tend to break out; the men on fire patrol also needed to protect against looting. At the time, houses were made of wood and paper. If fires broke out, the damage was devastating. When the Ansei Nankai earthquake occurred, protection against fire was thorough; only a few fires occurred and they were put out quickly.

(3) “Money and bonds should be kept in the warehouse”

Warehouses were protection not only against fire but also theft.

(4) “Ships on the river should be moored in calmer areas”.

In winter, ships resting for repair should be pulled up as high as possible. During this tsunami, large ships moored or resting on the mouth of either river were carried up the canals in Osaka City, causing a lot of damage. Therefore, we should take measures to prevent ships from being carried by tsunamis when powerful earthquakes occur.

(5) “A lot of muddy water springs up from the reclaimed land along the shore.”

The inscription says that a lot of muddy water sprang up from the reclaimed land along the shore. This phenomenon, known as liquefaction, occurred at the time of the Ansei Nankai earthquake. The damage, however, was not so extensive because the area of reclaimed land was far from Osaka City and few people lived there. However, the inscription notes and warns against this phenomenon.

2.2. Applying the lessons of the Edo era to modern protection against tsunamis.

We extracted five lessons from ‘The Record of the Great Earthquakes and the Tsunami at the Mouths of the Two Rivers’. However, we did not find the most important lesson, which is that we should run for higher ground when a tsunami hits. In most of Osaka City the ground height was over 3.0 meters above sea level. Therefore the tsunami did not cause serious flooding.

In modern times the Osaka Bay area has been developing, and the lowland area has become densely populated. What is worse, land subsidence, caused by heavy reliance on ground water, continued for several decades. It is most serious in western Osaka City where the maximum recorded subsidence is about 3.0 meters (Fig. 2). Today in Osaka City, the area of ground height below sea level is 21 square kilometers(Fig. 3). If a tsunami ever hits Osaka again, we must run for higher ground.

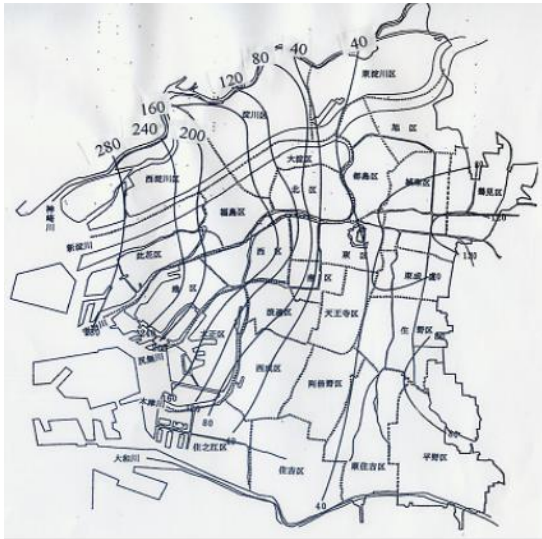


Fig. 2 Cumulative land subsidence in Osaka City. (1935 ~1981) Based on "The General Situation of Subsidence in Osaka", published by the Conference of Synthesis Measures Against Subsidence in Osaka, 1983. Units of cumulative subsidence are in cm.

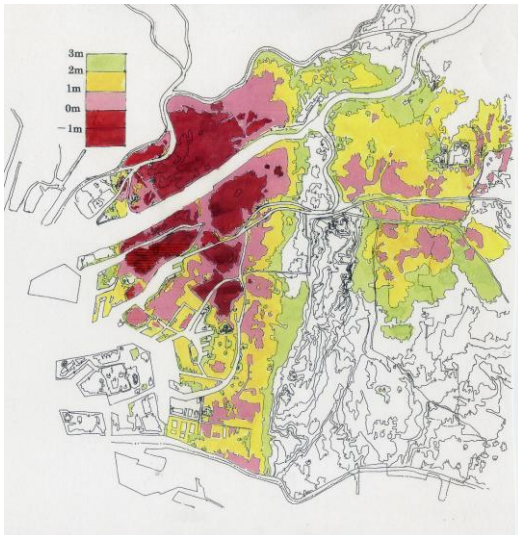


Fig. 3 Height of the land in Osaka city (1990). Based on a map of ground height in Osaka, compiled by the Geographical Survey Institute. I colored four levels of ground height under 3.0 m.

§ 3. Illustration of earthquakes and tsunami in 1854, Osaka.

3.1. Igaeno Earthquake (June 14th in the 7th year of Kaei period [July 9th, 1854])

The inscription begins with the Igaeno earthquake. The epicenter of this earthquake was Igaeno and it was M7.25. In Yamato (Nara) 280 people died and 700~800 houses collapsed¹¹.

In Osaka people did not suffer from this earthquake. According to another document, 'The Record of the Earthquake in the 6th Year of Kaei Period'¹², many people in Osaka were frightened by the shaking and fled into ships on the canals. They thought that the canals were the safest place to be in Osaka City. This time people were lucky not to have met with a tsunami because the epicenter of this earthquake was inland..

3.2. Ansei Tokai Earthquake (December 23rd, 1854)

At about 8:00 am on November 4th in the 7th year of Kaei period (the first year of Ansei period), the Ansei Tokai earthquake

¹¹ [Usami, T.(2003)]

¹² [Kuroha, H. (1979)] , The 6th Year of Kaei Period is an error on the part of the document's writer; it was actually the 7th year.

occurred. The hypocentral region was in the Pacific Ocean off the coast of Shizuoka prefecture and it was M8.4. It was said in Osaka that the shaking was three times as hard as that of the earthquake in June and the shaking lasted a long time. [‘Shokisai Hibizakki’ (‘Shokisai’s diary’)]¹³.

3.3. Ansei Nankai Earthquake (December 24th , 1854)

Thirty two hours after the Ansei Tokai earthquake, at about 4:00 pm, the Ansei Nankai earthquake occurred. The hypocentral region was in the Pacific Ocean off the Kii peninsula and Sikoku island. It was M8.4. In Osaka, 2 people who were registered as residents died and 83 houses collapsed as a result of the Nankai and Tokai earthquakes.

3.4. Ansei Nankai Earthquake Tsunami

After a long period of shaking there was silence for a while. In the evening a big tsunami rushed into Osaka Bay. The height of the tsunami was about 3.0 m, according to ‘Kinrai Nendaiki’ (‘Recent Chronicle’)¹⁴.

The tsunami came in through the two mouths of the Yodo River and ran upstream, and muddy water reached the east end of the canal, the Higashiyokobori River, where the water level was 120cm higher than usual (‘Daijishin Ryo Kawaguchi Tsunami’). (Fig. 4)

I researched how long it would have taken for the tsunami to reach Osaka Bay after the Ansei Nankai earthquake occurred.

After examining 26 documents, I calculated that it took from one hour 22 minutes 30 seconds to one hour 50 minutes. People were frightened by the violent shaking and chose to escape into boats on the canals. They did not think of the tsunami that would hit Osaka after a big earthquake.

3.5. Damage caused by the Ansei Nankai Earthquake Tsunami.

In Osaka the damage caused by the Ansei Nankai earthquake was comparatively small but the damage caused by the subsequent tsunami was great.

3.5.1. Ships

According to ‘Naniwa no Shinji’ (‘The Record of Earthquakes in Naniwa’)¹⁵, the ships anchored at the two mouths of the Yodo River (Kizugawaguchi and Ajigawaguchi) were suddenly carried up into the canals of Osaka by a big tsunami. There were 1,118 of these vessels, 59.2% of which (662) were severely damaged.

By river:

370 ships in the Kizu River (including the Hyakkenbori, Nagahori and Itachibori Rivers)

163 ships in the Dotonbori River

129 ships in the Aji River

662 total.

According to the document ‘Kinrai Nendaiki’, 80% of the severely damaged ships were carried from the mouth of the Kizu River.

"High waves washed over Maedarejima [Island] and Nanbajima [Island] . All of the large and small ships resting on these

¹³ [Kuroha, H. (1979)]

¹⁴ [Kuroha, H. (1979)]

¹⁵ [Kuroha, H. (1979)]

islands were carried up the Dotonbori River. Large ships collided, causing the collapse of four bridges, crushing many small ships and finally stopping at the Daikokubashi [bridge] ." (Fig. 4)

The inscription describes it as follows:

"West of the Daikokubasi [bridge] and from north to south of Matsugahana, a mountain of ships covered the surface of the rivers; most of the ships were damaged".

The tsunami hit in early November on the lunar calendar (Dec.24th on the Gregorian calendar). It was in winter, cargo ships (called Kitamae Bune) used for transport to the northern parts of Japan in warmer months were docked at the Sangenya River for repair. The inscription reads: "In winter, ships resting for repair should be pulled as high as possible."

3.5.2. Bridge

The tsunami carried many large cargo ships up the rivers. These ships collided with and destroyed many bridges.

The inscription says "Ten bridges were destroyed." However, the documents 'Naniwa no Shinj' and 'Osaka Kawaguchi Ohtsunami konzatsuki'¹⁶ indicates that the Kunitsubashi was also destroyed. So, in total eleven bridges were destroyed. (Table 1) (Fig. 4)

Table 1. Destroyed bridges, by river.

River	Destroyed Bridge	
Aji River	Ajikawabashi,	1
Furukawa River	Kunitsubashi	1
Kizu River	Kameibashi	1
Nagahori River	Takahashi	1
Horie Rive	Mizuwakebashi, Kuroganebashi (Tetsuhashi)	2
Dotonbiri River	Hiyoshibashi, Shiomibashi, Saiwaibashi, Sumiyosibasi	4
Nishiyokobori River	Kanayabashi	1
Total		11

¹⁶ The original is in Osaka Prefectural Nakanoshima Library.

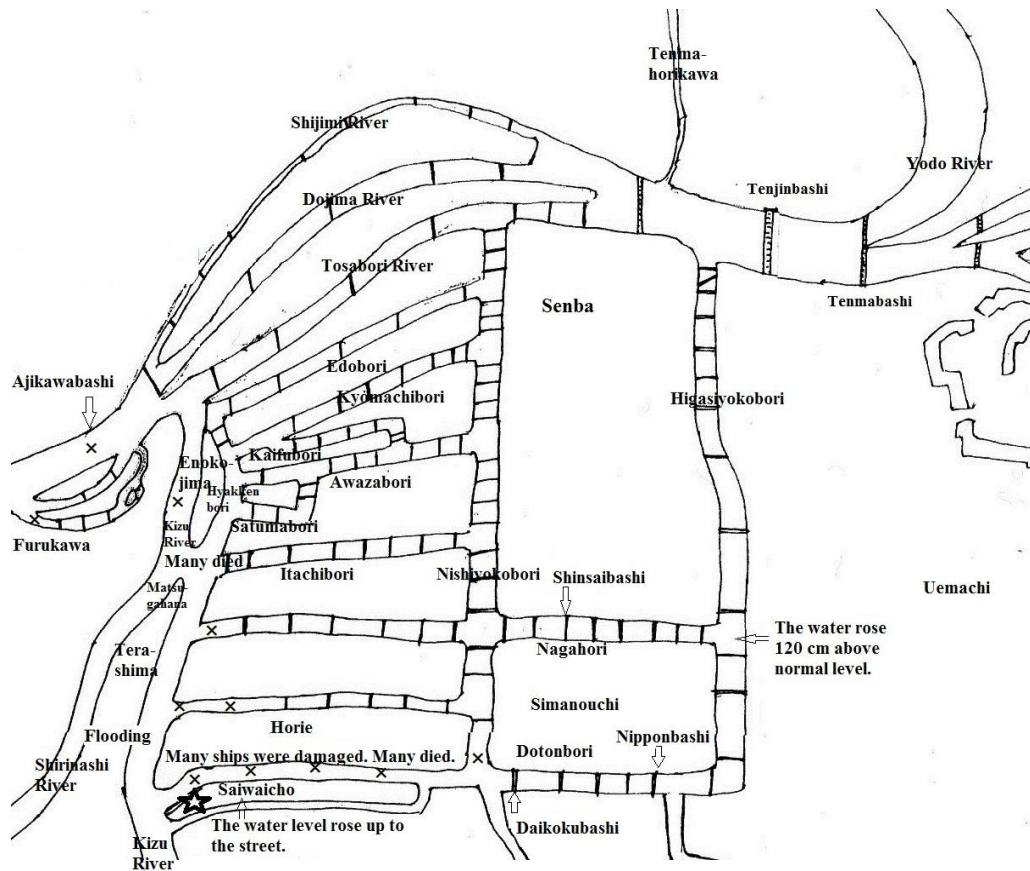


Fig.4 Map of tsunami damage in Osaka City. Based on: Map of Osaka in 14th year of Tempo Period(1843), compiled by Osaka City History compilation Office.

× : The eleven destroyed bridges. ☆ : The location of the memorial.

Saiwaicho is on the southern border of Osaka City.

3.5.3. Houses and Sheds

In Osaka, most of the damage to buildings was caused by large ships that smashed into buildings along the rivers. The inscription reads:

"The sheds by the rivers were crushed by the big ships with crushing sounds and the sounds of people's cries. There was nothing that could be done to stop this sudden tragedy."The Kinrai Nendaiki' said:

"The houses, warehouses, and sheds on the riversides were crushed by the big ships. Ships' bows pierced the walls of the buildings. These ships could not go down the river after the tsunami"

According to 'Ofure and Kudatsu'¹⁷⁾ ('Official Notice and Verbal Notification'), the numbers of damaged houses by the tsunami in Osaka City were as follows.

Collapsed houses:	3
Seriously damaged houses:	76

¹⁷ [Kuroha, H. (1979)]

3.5.4. Fatalities

In Osaka City there were only 2 fatalities (among people registered as inhabitants of Osaka City¹⁸) as a result of the Ansei Tokai earthquake and the Ansei Nankai earthquake. This was relatively few people. The fatalities as a result of the tsunami were great. The numbers of deaths as recorded in various documents are quite different.

['Ofure and Kudatsu'] 273 people (registered as inhabitants of Osaka City)

['Syokisai hibizakki'] 2600 people

['Suzukidaizassyu' ('Suzuki's big miscellany')]¹⁹ 7000 people

Which of these is accurate?

'The Kinrai nendaiki' says:

"Five or ten corpses were pulled out at a time; 200 to 300 corpses were pulled out every day. All had to be investigated and most of them had been living in Saiwaicho or Nanbajima or had been sailors. There was a mountain of funerals and corpses had been burning day and night. After five or six days passed the number of corpses gradually began to diminish to five or ten a day. However, when the large ships were removed, corpses began to be pulled out again. This work took more than ten days to finish."

According to this document the number can be guessed to be over one thousand.

'Matsudai hikae'('Notes for future generations')²⁰ wrote:

" It was most pitiful that people were so afraid of the preceding day's and that day's earthquakes: people in town, young and old, women and men, rich and poor all lost their heads, cried out, and fled into ships. No sooner had they felt relief when the big tsunami rushed in. They fell into the river. Their cries sounded throughout Osaka. It was so pitiful. We could not even look at the sight."

The reason that so many people fled into boats.

According to Saichiro Isedo²¹, the streets in Osaka were very narrow, because the merchants built long eaves out toward the streets. Usually the canals had been safe, sound open spaces. In Osaka many big fires often occurred; people loaded their property into boats and fled.

The inscription reads:

"Always be careful of a tsunami after a big earthquake occurs and do not seek refuge in boats."

¹⁸ In the Edo era Osaka City consisted of three wards(Northern ,Southern and Tenma)

¹⁹ [Kuroha, H. (1979)]

²⁰ [Kuroha, H. (1979)]

²¹ [Isedo, S. (1983)]

3.5.5. Flooded areas.

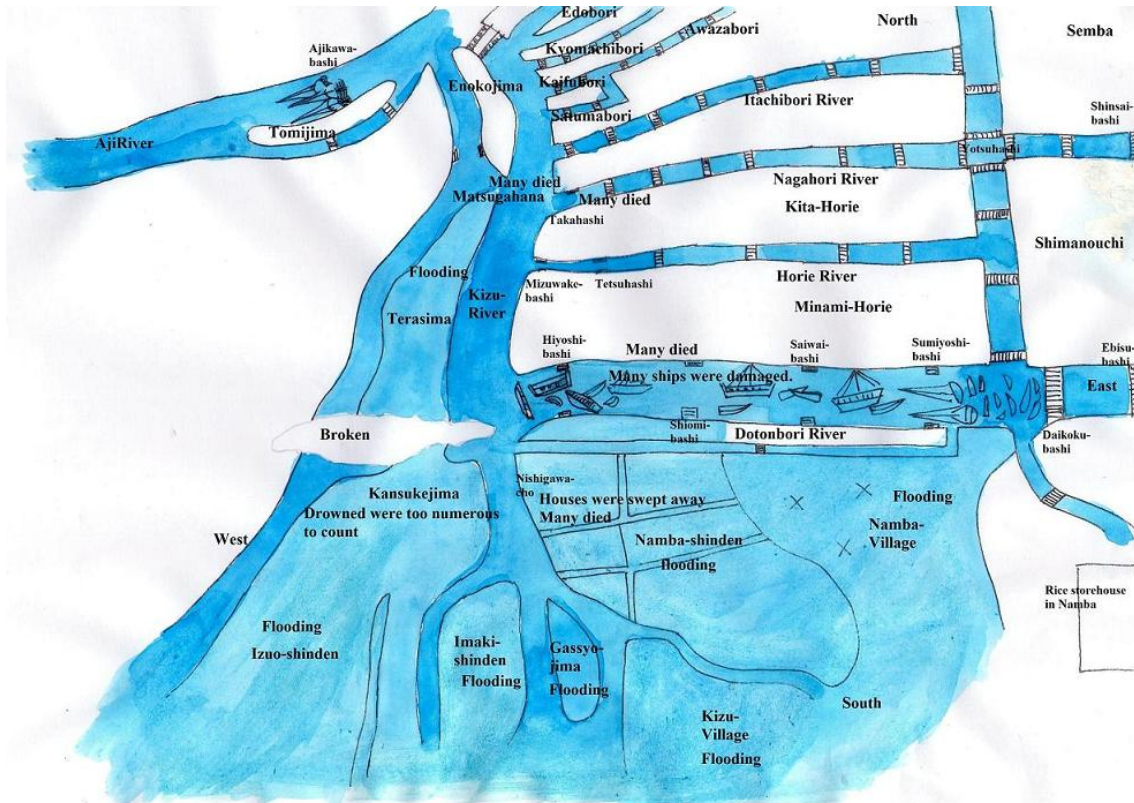


Fig. 5 'Osaka Ohtsunami Zu'('The Map of a Big Tsunami in Osaka'). The original is in Osaka Castle; this is a copy. On the original map, south is at the top, north is at the bottom. I changed this copy, putting north at the top. I translated the Japanese to English.

On this map, there is information about the damage.

Three points—the northern part of the Kizu River near Matsugahana, and along the Nagahori and the Dotonbori Rivers: — are labeled “Many died.”

The areas flooded by the tsunami are labeled “Flooding”.

At Kansukejima, “Drowned were too numerous to count.”

At Nishigawacho, “Houses were swept away, many died”.

The blank space on the left is where the title and description are located on the original; the translation follows here:

‘Osaka Ohtsunami zu’(‘The Map of a Big Tsunami in Osaka’)

At about 9:00am, Nov. 4th, 1854, a big earthquake occurred. In Osaka, many houses were damaged. On the next day (the 5th), earthquakes occurred frequently, in the evening, a tsunami suddenly hit; large ships anchored at the mouths of the Aji and Kizu Rivers were carried upstream, smashing into and destroying bridges.

Many ships were carried from the mouth of the Kizu River to Daikoku-bridge, and from the mouth of the Aji River to Ajikawa-bridge. The ships were too numerous to count. The dead and injured were great number. It is a pity; we could not watch them. Drowned were too numerous to count in Kansukejima. Terashima, Imaki-shinden, Gasshojima, Kizu and Namba were

flooded; it looked like a sea. It's really an unprecedented occurrence. We recorded details on this map.

Based on 'The Map of a Big Tsunami in Osaka' (the original of which is in Osaka Castle), we estimated the flooded area.

(1) The areas flooded, In Osaka City. (Fig.5, 6)

- Saiwaicho (the town along the Dotonbori River).
- The north part of Terashima (the island in the Kizu River)

We estimate the depth of inundation in these areas to have been no more than 30 cm. We do not find any other inundated area on the map. According to the document 'Naniwanoshinji' ('The Record of Earthquakes in Naniwa'), the tsunami did not cause flooding in Osaka City.

The document records a very strange phenomenon: The tsunami waves were so high that they carried big ships up the river swiftly, although the water only reached the surface of roads in the city's lowest places, and at the higher places did not exceed even half the height of the banks. This document says that serious flooding did not occur in Osaka City.

(2) The areas flooded, Outside Osaka City. (Fig.5, 6)

- Kansukejima (island), Izuoshinden (reclaimed land) and Imakishinden (reclaimed land) . . . Now, Taisho ward.
- Gasshojima (island), Kizu village, Namba village . . . Now, Naniwa ward.

These districts are along the Kizu River.

These flooded areas are now the north of Taisho ward and the west of Naniwa ward. In these areas, which were outside of Osaka City, people who climbed onto roofs were safe and those who fled into boats died.

- Tenpozan (now Minato Ward in Osaka City)

Tenpozan belongs to Osaka-sango (Osaka City), but Tenpozan was far from the centre of Osaka City, so for convenience's sake, we place Tenpozan outside of Osaka City.

'The Map of a Big Tsunami in Osaka', does not include Tenpozan, which is outside of the map. However two documents record Tenpozan as an inundated area and include the depth of inundation.

According to 'The letter from Yamamotoya Iemon and Kantaro'²², "At the hut of both Bugyo (East Bugyo, west Bugyo), the tide water rose to 15 cm under the floor". The people who climbed Mt. Tenpozan were safe.

Another document 'Shokisai hibizakki' stated; "At the hut of Doshin (officers of Bugyo), the tide water rose to the floor". (Fig. 6)

- In the area north of the Aji River.

We did not find any documents recording the inundation in the area north of the Aji River.

According to 'The Letter from Osaka'²³, the northern area was not damaged, and Kasugade-shinden was safe.

However, I presume that Tsuneyoshi-shinden situated at the north of the Aji River would have been seriously inundated, because there is a memorial²⁴ inscribed "grave for those drowned in a Kaisho [a word meaning both "tsunami" and "high tide"] in the third year of Ansei". Referring to the history of Osaka, we can't find a flood in the third year of Ansei. So, it is thought that

²² [Musha, K. (1951)]

²³ [Earthquake Research Institute Of The University of Tokyo(1986)]

²⁴ There is a stone memorial at 5 chome, Torishima in Konohana Ward, Osaka City. It situated along the bank of the New Yodo River.

the inscription is wrong, and it was in fact the first year of Ansei.

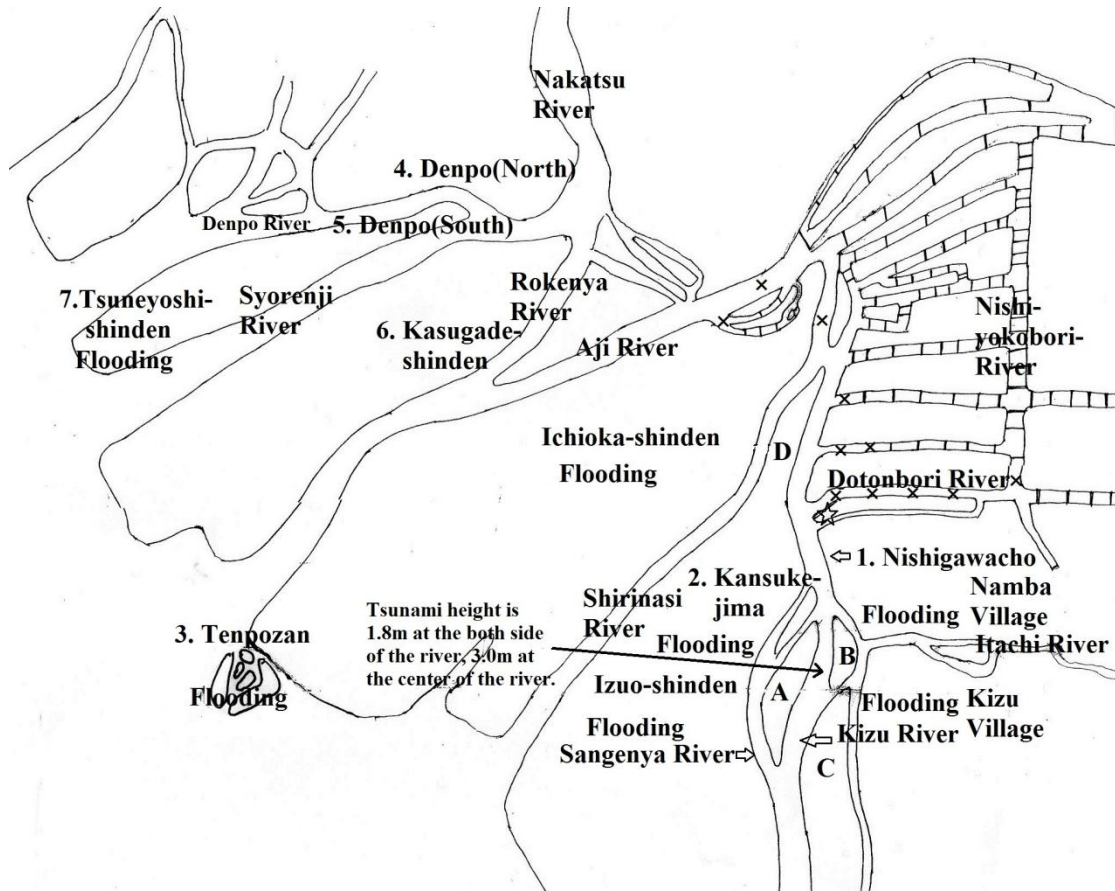


Fig.6 Map of the Osaka Bay area, damaged by tsunami in1854

Based on Map of Osaka in 14th year of Tenpo period (1843), compiled by Osaka City History Compilation Office. Topography of Osaka compiled by Army General Staff Office in 1885, Osaka, Tenpozan, Amagasaki.

I added the Ansei period location of the coastline, and noted damage in Osaka, the name of the river and etc.

1. Nishigawacho "House were swept away, many drowned.
2. Kansukejima "Drowned were too numerous to count".
3. Tenpozan "At the hut of Doshin (officers of Bugyosho) the tide water rose to the floor.
4. Denpo Village (North) "Tsunami just reached the whart".
5. Denpo Village (South) "Tsunami just reached the whart".
6. Kasugade-shinden "Safe from flooding".
7. Tsuneyoshi-shinden According to the memorial in Konohana Ward, We presume flooding in Tsuneyoshi-shinden.

A: Nambajima B: Gasshojima C: Tsumori-shinden D: Terashima

× : Destroyed Bridges

☆ : The location of the memorial: 'The Record of the Great Earthquakes and the Tsunami at the Mouths of the Two

3.5.6. The phenomenon of the liquefaction.

The inscription reads:

“Tsunamis rush in not only from offshore but also from the bottom of the shallows along the shore. A lot of muddy water sprang up from the reclaimed land along the shore.”

This phenomenon is called “liquefaction of the ground.” It is actually caused by the earthquake, and is not related to the tsunami. When a big earthquake occurred in Niigata prefecture in 1964, muddy water sprang up from the reclaimed land and wet land along the Shinano and the Agano Rivers. Modern structures such as the Showa Bridge collapsed, and new concrete apartments were laid flat. One of the safety myths also collapsed in this disaster. Scientists and architects had never been aware of this phenomenon before the Niigata earthquake (1964A.D.). They started to seriously consider countermeasures against liquefaction of the ground. But this phenomenon was already described in old documents.

§ 4. The Construction of the Memorial of the Ansei Nankai Earthquake Tsunami

In July (the lunar calendar), the second year of Ansei, the stone memorial, ‘The Record of the Great Earthquakes and the Tsunami at the Mouths of the Two Rivers’ was erected. It now stands at the east end of Taishobashi [Bridge] . However, it was originally erected at the ferry station, Kizu River, in 5chome, Saiwaicho. At that time there was no bridge.

On the surface of the stone memorial, many characters are carved. On the west (front) side of the memorial, Buddhist scriptures are carved. On the east and south sides, the inscription reads: “The Record of the Great Earthquakes and the Tsunami at the Mouths of the Two Rivers”. On the north side, the names of the people who cooperated in the construction of the memorial are carved. The contributors were townspeople (householder class) and yamori (janitors) in Nagahorimozaemoncho.

In this town the Sumitomo family had their large houses and copper refineries. According to Sumitomo family documents, the Isemaru, a ship owned by the family, was anchored beside the Hiyoshibashi [bridge] on the Dotonbori River. When the big tsunami rushed in it carried the Isemaru up to the Daikoku-bashi [bridge] where the Isemaru covered several small ships.

However, the Isemaru was not damaged and sailors were not injured. So the Sumitomo family celebrated their good fortune and gave presents to its captain and sailors. It is probable that the family donated money for the construction of the stone memorial.

The memorial was initiated by Mori whose family name alone is written on the memorial. The assistants were townspeople in 5chome Saiwaicho. The town leader was Harimaya Chushiro. The landowner was Harimaya Juzou. The donors of the big stone were the townspeople in Nishigawacho. The coordinator of the memorial was Awajiya Kiuemon.

It is assumed that the Sumitomo family would have donated money for the construction of the monument, but up until now no documentary evidence has been found in the Sumitomo family documents. In the 24th year of Meiji (1891 A.D), 36 years after the construction of the memorial, the people donated money to construct the flower stands, the incense holder, and the stone wall which encloses the memorial stone.

Over one hundred fifty years have passed since the memorial was built. Every year during the Bon Festival people living in Saiwaicho hold a memorial for the victims of the Ansei Nankai earthquake tsunami. People in Saiwaicho have been caring for the memorial and have been adding ink to the inscription every year.

§ 5. The Relief and Reconstruction Measures After the Ansei Nankai Earthquake Tsunami in Osaka.

Immediately after the big earthquake hit Osaka, the Bugyosho (The Magistrate's Office) issued notifications to the people in Osaka City. These notifications firstly transmitted to the Town's Elders. Northern Towns Elder Nagase Hichirouemon, ordered area towns' leaders to examine the number of collapsed houses, fatalities and wounded, and to warn people to watch out for fires. Furthermore, ordered townsmen to patrol as far as the tenant houses in back streets in order to prevent fires. Only a few fires occurred, and they were soon put out.

On November 6th another Northern Towns Elder, Egawa Shozaemon, prohibited activities such as drinking parties by evacuees who had fled into ships in the rivers, or into huts, fearing aftershocks. However this prohibition was not appropriate to issue when people were suffering so much from the tsunami disaster. The prohibition was probably issued before the tsunami by the Bugyosho, but the Town Elder in Osaka informed the townspeople of it only after the tsunami hit. On the same day, the Bugyosho ordered leaders in Osaka towns to examine sufferers who were in extremely difficult situations.

On November 7th the Bugyosho issued a prohibition against people picking up and keeping gold, silver, and timber which had been carried away by the tsunami. If anyone did so, he would be investigated and punished as a thief.

That same day, the Bugyosho encouraged people to make donations to those sufferers who had been staying in the open since the earthquake and tsunami disaster.

We have examined a document that records the donations from 3 Chome in Dosyomachi. According to this document, on November 11th, seven people donated 15 bales of rice and thirty-six people donated 109 kan 500mon (copper coins). The donors were not only household class but also tenant class.

On December 17th, the government gave rewards to donors —money equal to 2.9% of their donations. Many people living in other towns in Osaka also probably donated to the sufferers, but so far I have not found any documents to support this.

§ 6. The Cycle of Nankai Earthquakes and the Next Nankai Earthquake.

6.1. The Number of Previous Nankai Earthquakes and the Intervals Between Each Earthquakes.

In Japan, we have ancient documents that record over one thousand years of history, so we know of eight previous Nankai earthquakes. We can say that Nankai earthquakes have a tendency to occur at roughly regular intervals. We have examined the intervals between Nankai earthquakes which we know by historical documents. In the following, (M) means magnitude; values are taken from 'Rika Nenpyo, 24th Year of Heisei.'²⁵

684 A.D. The Hakuho earthquake (M8.25)

203- year interval

887 A.D. TheNinna Nankai earthquake (M8.0~8.5)

212-year interval (The interval between the Ninna and the 1096 Eicho earthquake was 209 years)

1099 A.D. The Kowa Nankai earthquake (M8.0~8.3)²⁶

262- year interval

²⁵ National Astronomical Observatory (2011): Rika Nenpyo (The Chronological Table of Science) Heisei 24,1108pp.

²⁶ Three years before the Kowa earthquake(i.e. in 1099 A.D.), 1096 A.D. Eicho earthquake (M 8.0~8.3) occurred.

- 1361 A.D. The Shohei (Ko'an) Nankai earthquake (M8.25~8.5)
244- year interval
- 1605 A.D. The Keicho earthquake (M7.9) This was a tsunami-only earthquake²⁷.
102- year interval
- 1707 A.D. The Hoei earthquake (M8.6)
147- year interval
- 1854 A.D. The Ansei Nankai earthquake (M8.4)
92- year interval
- 1946 A.D. The Showa Nankai earthquake (M8.0)

The intervals between five earthquakes from the Hakuho to the Keicho ranged from 203 to 262 years.

The intervals between four earthquakes from the Keicho to the Showa Nankai ranged from 92 to 147 years.

The latter group's average interval is roughly half as long as the former group's.

Why have the intervals of the Nankai earthquakes post- Edo era (the Edo era was from 1603A.D.to1867A.D.) been shorter?

The documents of the post-Edo era were many and detailed; furthermore, many have survived, so we know of all Nankai earthquakes which occurred in the post-Edo era.

However, the documents prior of the Edo era were few, and what is worse, most of them were lost for years, so several Nankai earthquakes which occurred before the Edo era would be unknown to us.

Researching Nankai earthquakes before the Edo era, is difficult using only documents. Recently, archeologists and geologists have found traces of liquefaction or tsunami-deposits in soil strata²⁸. This research aids in the discovery of unknown Nankai and Tokai earthquakes.

The Hakuho earthquake (684A.D.) had been classified a Nankai earthquake, however, traces of liquefaction which occurred in the latter half of the 7th C A.D. were found in Shizuoka Prefecture. Therefore, a Tokai earthquake might have occurred in conjunction with the Hakuho earthquake (684A.D.)²⁹,

The Ninna earthquake (887A.D.) had been classified a Nankai earthquake; however, traces of liquefaction from the latter half of the 9th C A.D. were found in Inazawa City, Aichi Prefecture. The Tokai earthquake might have occurred in conjunction with the Ninna earthquake.

The Kowa earthquake (1099 A.D.) was classified a Nankai earthquake, but the documentary evidence is not sufficient

The Shohei (Ko'an) earthquake (1361A.D.) had been classified a Nankai earthquake; however, traces of liquefaction from the early 14th C A.D. were found at Kadomanuma in Aichi Prefecture. The Tokai earthquake might have occurred in conjunction with the Shohei (Ko'an) earthquake.

The Meio earthquake (1498A.D.) had been classified a Tokai earthquake. However, traces of liquefaction from the end of 15 century A.D. were found at Azono in Kochi Prefecture. The Nankai earthquake might have occurred in conjunction with the Meio

²⁷ The damage caused by the tsunami was great, but we could not find any record of damage caused by the earthquake itself.

²⁸ [Sangawa, A. (2007)]

²⁹ [Sangawa, A. (2007)]

earthquake.

We know of eight Nankai earthquakes from historical documents. According to Seismic-Archeological research, the Nankai earthquake might have occurred during the Meio earthquake.

There is a possibility that the Kowa earthquake (1099 A.D.) was not a Nankai earthquake, but an inland earthquake. Because, we did not find any document of tsunami³⁰.

6.2. The Hypocentral Regions of Historical Nankai , Tokai and Tonankai Earthquakes

We show the hypocentral regions of historical Nankai, Tokai and Tonankai earthquakes (Fig. 7). These regions are situated in what is known as the Nankai trough, divided into five segments A to E. Segment E is called the Suruga trough.

- Segments A and B are the hypocentral region of the Nankai earthquake.
- The three segments C, D and E are the hypocentral region of the Tokai earthquakes.
- Segments C and D are the hypocentral region of the Tonankai earthquakes.

- **The Hakuho earthquake (684A.D.)** The confirmed hypocentral region corresponds to segments A and B. Traces of liquefaction the latter half of the 7th century A.D. were found in the Tokai region, so we speculate that segments C, D and E might have ruptured.
- **The Ninna earthquake (887A.D.)** The confirmed hypocentral region corresponds to segments A and B. Traces of liquefaction were found in the Tokai region, so we speculate that segments C, D and E also might have ruptured.
- **The Eicho Tokai earthquake (1096A.D.)** The confirmed hypocentral region corresponds to segments C and D. Segment E might have ruptured.
- **The Kowa earthquake (1099 A.D.)** The hypocentral regions corresponds to segments A and B. However, the evidence is not sufficient.
- **The Shohei (Ko'an) earthquake (1061 A.D.)** The confirmed hypocentral region corresponds to segments A and B. Traces of liquefactions were found in Aichi Prefecture, so we speculate that C, D and E also might have ruptured.
- **The Keicho earthquake (1605 A.D.)** The hypocentral region corresponds to segments A, B, C and D. The damage caused by the tsunami was great, but, we could not find any record of damage caused by the earthquake itself. This earthquake is different from others which occurred in the Nankai trough.
- **The Hiei earthquake (1707 A.D.)** The hypocentral region corresponds to segments A, B, C, D and E. This earthquake was one of the largest in Japanese history.
- **The Ansei Tokai earthquake (1854 A.D.)** The hypocentral region corresponds to segments C, D and E.
- **The Ansei Nankai earthquake (1854 A.D.)** The hypocentral region corresponds to segments A and B. The Nankai earthquake occurred 32 hours after the Tokai earthquake
- **The Showa Tonankai earthquake (1944 A.D.)** The hypocentral region corresponds to segments C and D.
- **The Showa Nankai earthquake (1946 A.D.)** The hypocentral region corresponds to segments A and B.

³⁰ [katsuhiko Ishibashi (2004)]

6.3. Tendencies of Past Nankai Earthquakes.

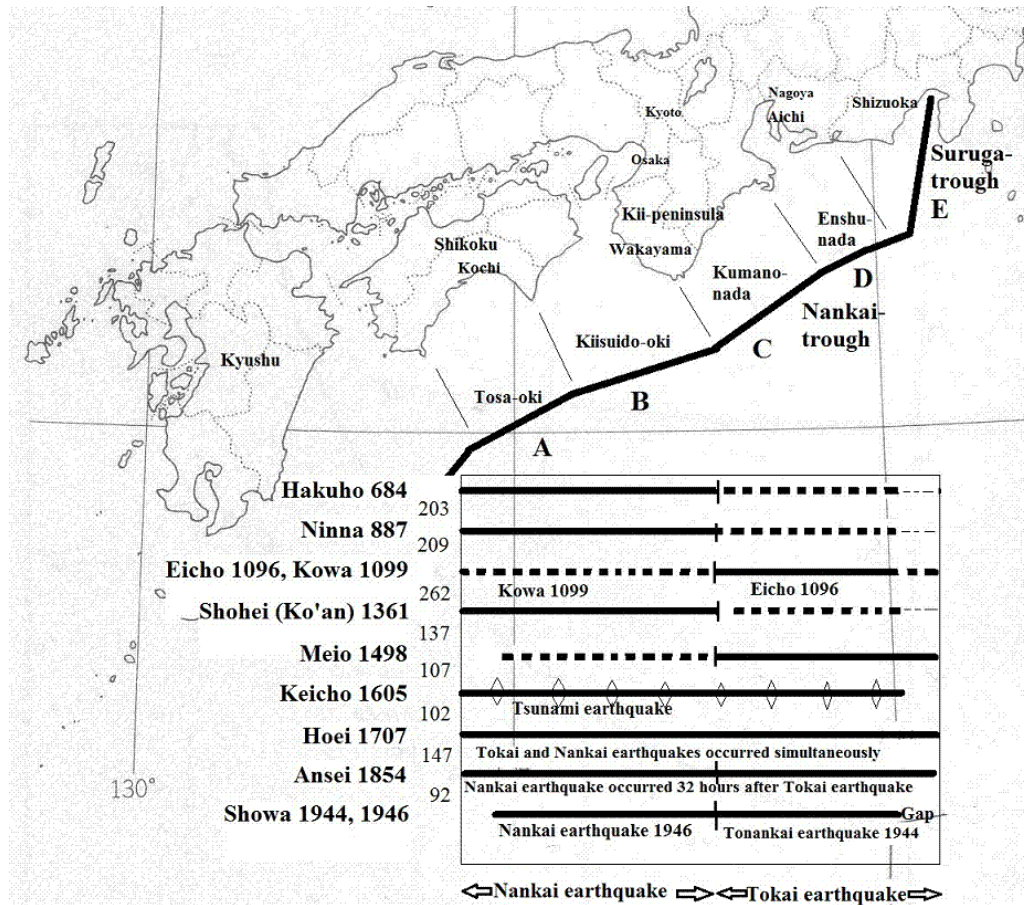


Fig. 7 The Hypocentral Region of Nankai , Tokai and Tonankai Earthquakes.

1)

Thick solid lines represent certain rupture zones, thick broken lines represent probable ones, and thin broken lines represent possible ones.

Reference:

[Ishibashi, K. (1999)]

[Katsuhiko Ishibashi (2004)]

[Sangawa, A. (2007)]

The interval between Nankai earthquakes which have occurred since the Edo era have ranged from 92 to 147 years.

2) Nankai earthquakes have a tendency to occur in conjunction with Tokai (Tonankai) earthquakes.

a. A Tokai (Tonankai) earthquake precedes a Nankai earthquake. [Eicho (Tokai)-Kowa(Nankai)] , [Ansei (Tokai-Nankai)] , [Showa (Tonankai-Nankai)] .

b. Tokai (Tonankai) and Nankai, earthquakes occurred simultaneously.

This is the most powerful type of earthquake. [Hoei earthquake.]

c. Nankai earthquakes occur in conjunction with Tokai (Tonankai) earthquakes; however, it is not clear whether they occur simultaneously or whether one precedes the other.

[Hakuho] , [Ninna] , [Shohei (Ko'an)]

※ The Keicho earthquake was a tsunami-only earthquake, different from other Nankai earthquakes.

3) Strong shaking hit almost the whole western region of Japan.

4) The earthquakes are always accompanied by big tsunamis. Big tsunamis hit along the Pacific coast.

5) Ground subsidence occurred at Kochi Plane. During the 1946 Showa Nankai earthquake, the ground subsided about 1.2 m, and the inundated area extended about 10 km² in Kochi City.

6) Natural hot springs were said to have stopped. [Kanayama (Shirahama) · Yunomine-Wakayama Prefecture, Dogo-Ehime Prefecture] ,.

7) Before and after Tokai and Nankai earthquakes, many inland earthquakes occurred.

6.4. Prediction of the next Nankai earthquake.

We have seen that Nankai earthquakes have repeated at 92-147 year intervals since the Edo era.

Nankai earthquake will certainly occur in the future. When will the next one occur?

The most recent Showa Nankai earthquake occurred in 1946, 66 years ago. If Nankai earthquakes occur at the mean interval of 120 years, the next would occur 54 years from now. However, the Showa Nankai earthquake (M8.0) was smaller than other Nankai earthquakes (over M8.0), and the 1944 Showa Tonankai earthquake (M7.9) was also smaller than other Tokai earthquakes. Furthermore, during the Tonankai earthquake, segment E did not rupture (a seismic gap). One hundred fifty eight years have passed since the most recent Tokai earthquake (Ansei Tokai earthquake). A great deal of stress will be present in the continental plate. Therefore, next Nankai earthquake might occur earlier than average interval.

It is said that the Tokai earthquake might occur at any time. Nankai earthquakes have a tendency to occur in conjunction with Tokai (Tonankai) earthquakes; if a Tokai earthquake occurs, a Nankai earthquake may occur around the same time.

For the reasons stated above, we think that the next Nankai earthquake will occur within 30 years. In the worst case scenario, three earthquakes—a Tokai, a Tonankai and a Nankai would occur simultaneously.

Epilogue

About 30 years ago I passed by the Taisho Bridge and found a big, grey rectangular, stone memorial. The inscription stated that tsunamis had hit Osaka and caused serious damage. At that time I did not know about tsunamis had hit Osaka, despite having grown up in Osaka City. On Dec.26th, 2004, a large tsunami hit the coasts around the Indian Ocean; it was the first time for me to watch a terrible tsunami disaster on television. I remembered the memorial by the Taisho Bridge and went to see it and reread the inscription.

My study of the Ansei Nankai earthquake tsunami began by copying the memorial's inscription, sitting for a while in front of the memorial in the winter sun. The inscription says that when the earthquake hit, many people fled into boats to escape. After a while, the tsunami rushed into Osaka Bay; large ships anchored at the mouths of two rivers were carried up canals in Osaka City, where they destroyed bridges and many smaller boats. Consequently, many people boarding the boats died.

It says "Always be careful of a tsunami when a big earthquake occurs, and don't try to escape into boats."

The people that experienced the Ansei Nankai earthquake tsunami regretted that they had not learned the lessons of the Hoei

earthquake tsunami. They built the monument not only as a memorial but also to teach future generations of this fearful tsunami and to warn them to take precautions against the next Nankai earthquake. People living in Saiwaicho have preserved the memorial and still hold a memorial service during the Bon festival in August every year.

We should learn from past disasters and also presume that new disasters will occur. In modern times, Osaka City has expanded and developed. The lowland has become densely populated and, what is worse, the land has seriously subsided. If a tsunami hits Osaka in the future the damage will be more serious than that of the Edo era. We should anticipate different disasters from the Edo era and take precautionary measures accordingly.

While writing this article, foreign language teachers helped with my English translations from Japanese. Without their kind help, I could not have completed this article. I am deeply grateful to them.

Assistant English translators: Todd Meyers, Chie Mori, Brendan Hurley, Simon Oettle, Erika Luley, Robyn Smith, Emily Long, Reena Redcar, Tony Malloy, Jonathan Brown, Jeremy Larsen.

References

- Earthquake Research Institute Of The University of Tokyo (Editor) (1986): Shinsyu Nihon Jishin shiryō (New Collection of Historical Documents on Earthquakes in Japan), supplementary vol. 5-1, 1438pp. (in Japanese)
- Isedo, S. (1983): Ohtsunami no Hi (The Memorial of the Big Tsunami), Osaka shunju, 36, 105-111. (in Japanese)
- Katsuhiko Ishibashi (2004): Status of historical seismology in Japan, ANNALS OF GEOPHYSICS, VOL. 47,N, 2/3, April/June 2004, 339-368. (in English)
- Kuroha, H. (Editor) (1976): Osaka Hennenshi (The chronicle of Osaka), 22, The Central Library of Osaka City, 428pp. (in Japanese)
- Musha, K. (Editor) (1951): Nihon Jishin Shiryo (Historical Documents on Earthquakes in Japan), The Mainichi News Papers Co., 1119pp. (in Japanese)
- Nagao, T. (2012 a): Daijishin Ryokawaguchi Tsunamiki ni miru Osaka no Tsunami to sono Kyokun (The Lesson learned from Tsunamis in Osaka Referred to the Memorial 'The Record of the Great Earthquakes and the Tsunami at the Mouths of the Two Rivers'), Historical Disaster Studies in Kyoto, 13, Kyoto Society of Historical Disaster, 17-26. (in Japanese with English abstract)
- Nagao, T. (2012 b): Suito Osaka wo Osotta Tsunami (Tsunamis Hit The Water Metropolis of Osaka), Revised edition, Nagao Takeshi, 528pp, English abstract 40pp.
- Nishiyama, A.(2004): Ansei Nankai Jishin (1854) niokeru Osaka deno Shinsai Taio (People's reaction in Osaka to disaster from the 1854 Ansei Nankai earthquake), Historical Earthquakes, 19, Society of Historical Earthquake Studies,116-138. (in Japanese)
- Oda, Y. (1995): Osaka ni okeru Ansei no Jishin Tsunamihito Sinsai no Kiroku, Historia, 148, Osaka Historical Association. 91-95. (in Japanese)
- Sangawa, A. (2007): Jishin no nihonshi, Chuokoron shinsya,268pp. (in Japanese)
- Usami, T. (2003): Nihon Higai Jishin Soran (Materials for Comprehensive of Destructive Earthquakes in Japan), The latest edition, University of Tokyo Press, 605pp. (in Japanese)