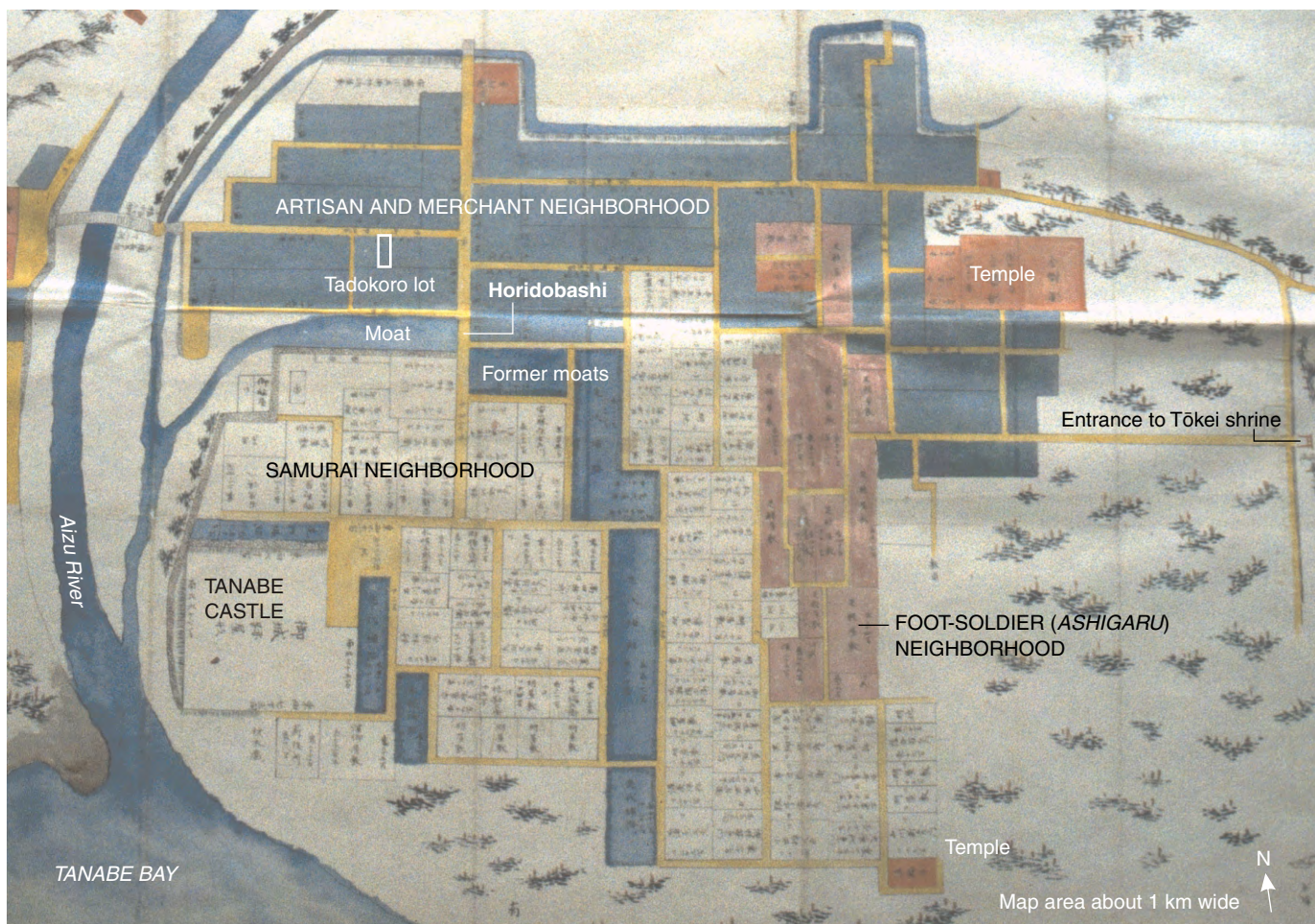


Tanabe 田辺



The castle town of Tanabe zoned large central lots for samurai and outlying neighborhoods for artisans, merchants, and foot soldiers. The town's mayor, of the merchant family Tadokoro, resided 150 meters a limit of the 1700 tsunami: the landward end of a castle moat at Horidobashi.

Volumes of "Tanabe-machi daichō" form a set of official records for the years between 1585 and 1866. The Tadokoro family kept a parallel set of private records, "Mandaiki," between 1471 and 1839. An account of the 1700 tsunami appears in both sets. Ōta Yūji, a Tanabe librarian, watched over "Daichō" in 1999 (right).



THE PICTURE MAP shows Tanabe-machi in the Hōei era (1704-1710). The map is a copy dated 1884, provided courtesy of Tanabe Municipal Library.

"TANABE-MACHI DAICHŌ," temporarily at this library when the photo at right was taken, is ordinarily held at Tōkei shrine (location on picture map above and on index map opposite). Tanabe-shi Kyōiku I'inkai (1987-1991) edited a printed version.

"MANDAIKI" can be translated as "Diary of ten thousand generations." Many of its extant volumes, including the one that covers A.D. 1700, were written in the same hand, according to librarian Ōta. In 1999 he told us that these volumes are probably copies prepared under the direction of Tanabe's seventh Tadokoro mayor (born 1758, died 1818). A printed version of "Mandaiki" runs 10,200 pages (Andō and Wakayama-ken Tanabe-shi Kyōiku I'inkai, 1991-1994).

Main points

Unusual seas off Tanabe entered a government storehouse in Shinjō, ascended a castle moat as far as Horidobashi, and flooded farmland in Atonoura, Mikonohama, and Mera (p. 86).

This inundation probably began after the 1700 tsunami's midnight arrival in Kuwagasaki (p. 43).

The tsunami probably crested 2-4 m above tide level as it crossed shores near Tanabe (p. 88-90). The flooded areas fell during subsequent earthquakes by perhaps 1 m more than they rose in between (p. 91).

Tanabe—town and district

Tanabe's mayor served also as the district mayor (*ōjōya*) of nearby villages. In this dual capacity, a mayor with the family name Tadokoro supervised the writing of "Tanabemachi daichō" in January 1700 from his family's home in the merchant district north of Tanabe castle. There, he likely received news of the flooding in Shinjō through that village's headman, Denbe'e. Perhaps he also saw the water reach Horidobashi, 150 m from his home.

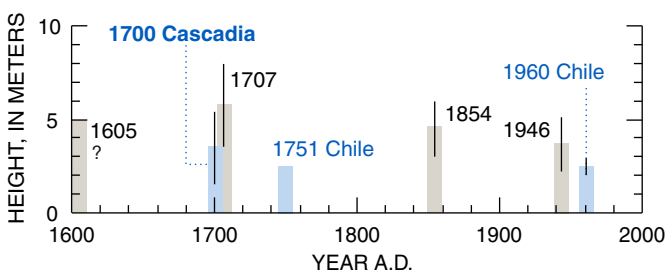
Tanabe in 1700 had 2,600 residents, probably excluding its samurai and their families. Counted among the town's commoners in 1725 were 257 fishermen, 38 fishmongers, 33 house builders, 25 innkeepers, 14 liquor merchants, 13 doctors, 3 makers of floor mats, 2 roofers, 1 stonemason, 1 shipwright, 1 umbrella maker, and 1 merchant of palanquins (*kago*).

Shinjō in 1700 probably contained 185 houses and 240 outbuildings—structures lost to a tsunami of nearby origin in 1707 (p. 89).

Other tsunamis

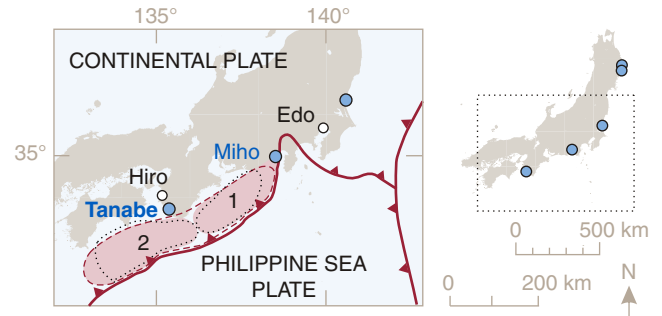
As at Miho, the worst tsunamis in Tanabe originate along a plate-boundary fault off the Pacific coast of southwest Japan (p. 65, 77). An earthquake rupture 500 km long in 1707 produced a tsunami 3.5 m high in Tanabe and perhaps 8 m high in Shinjō. The fault broke again, piecemeal, in 1854 and again in the 1940s. The second of the 1854 earthquakes triggered the tsunami that led to the rice-sheaf fire in Hiro village, 40 km from Tanabe (p. 47). In Tanabe and vicinity, the 1960 tsunami from Chile crested about 3 m above ambient tide.

NOTABLE TSUNAMIS AT TANABE AND SHINJŌ SINCE 1600



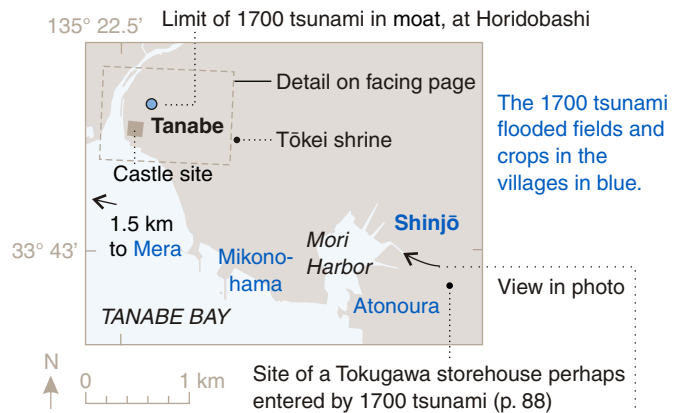
- Tsunami generated nearby—Height for 1605 unknown
- Tsunami from distant source
- | Range of estimates or measurements

PLATE-TECTONIC SETTING



- Upper edge of plate-boundary fault (p. 8, 65, 77)
- Rupture area of great earthquake on plate-boundary fault
- 1707—Areas 1 and 2 combined
- 1854—32 hours apart, area 1 first
- 1944 (1) and 1946 (2)—M 8.1, 8.1; smaller than 1854
- Known site of 1700 Cascadia tsunami

TANABE AND VICINITY



1960 CHILE TSUNAMI IN SHINJŌ



EARTHQUAKES AND TSUNAMIS Ando (1975) and Ishibashi (1981) estimated rupture areas of the 1707, 1854, 1944, and 1946 earthquakes. The Tanabe map is traced from Kokudo Chiriin (Geographical Survey Institute), Kii Shirahama and Kii Tanabe 1:25,000, 1990 and 1996. Shinjō Kōminkan, a community center, provided the above photo (location, p. 89). The tsunami heights are from Watanabe (1998, p. 71, 80, 96, and 136), Japan Meteorological Agency (1961, p. 192), Yoshinobu (1961), and our interpretation of a "Mandaiki" account of slight flooding in Shinjō during the 1751 tsunami (footnote, p. 54).

TOWN AND DISTRICT Takeuchi (1985b, p. 658) lists commoners' occupations and gives Tanabe's population as 2,516 in Kanbun 7 (1667) and 2,720 in Kyōhō 10 (1725). The totals exclude children under nine. Kishi Akinori, a local historian, told us in 1999 about the Tadokoro mayors and the Shinjō headman.

Account in “Tanabe-machi daichō” 『田辺町大帳』の記述

SEAS ROSE STRANGELY near Tanabe around dawn of the 8th day (columns 1-2). The water entered a Tokugawa storehouse in Shinjō village and other buildings, too. In addition, the water damaged crops and fields in the Atonoura

area of Shinjō. Within Tanabe itself, not far from the writer, the water ascended a castle moat as far as Horidobashi (3-4).

This account comes from the water-stained volume pictured at right.

COLUMN 1

5	4	3	2	COLUMN 1
 <p>made as far as</p> <p>shio tide</p> <p>iru entered.</p>	 <p>chi fields</p> <p>mugisaku wheat crops</p> <p>habō lost</p> <p>kore aru there were,</p> <p>yoshi they said.</p> <p>kokomoto Close to me,</p> <p>Horidobashi Horidobashi</p>	 <p>shio tide</p> <p>iri entered,</p> <p>mōsu yoshi it was reported.</p> <p>sonohoka In addition,</p> <p>Shinjō Shinjō,</p> <p>Atonoura Atonoura</p> <p>nado and so on</p> <p>den- rice</p>	 <p>tsuyoku strongly</p> <p>agari rose,</p> <p>Shinjō Shinjō</p> <p>go-kōgi- o-kura government storehouse</p> <p>nado and so on</p> <p>e to</p>	 <p>[new entry]</p> <p>dō Same</p> <p>yōka eighth day</p> <p>no of</p> <p>yo'ake dawn</p> <p>jibun about</p> <p>yori since, uraura coasts</p> <p>e into abiki unusual seas</p>

3, *shio*—Composite symbol for “water” and “morning” (p. 40).

3, *Shinjō Atonoura*—An account from “Mandaiki,” from the year 1707, treats Atonoura as part of Shinjō village (Tokyo Daigaku Jishin Kenkyūsho, 1981, p. 326). Its passage on the 1700 tsunami mentions damage to fields not only in Atonoura but also in Hama (that is, Miconohama) and Mera. See page 85 for an index map and page 84 for notes on “Mandaiki.”

possibilities include tide, storm, wind, and changes in atmospheric pressure, in addition to tsunami (p. 40; Hibiya and Kajjura, 1982; Yanuma and Tsuji, 1998).

2, *go-kōgi*—*go*, honorific; *kōgi*, public affairs (Berry, 1982, p. 158; Hall, 1991, p. 19). Refers here to the branch of the Tokugawa clan that ruled Wakayama-han, of which Tanabe was a part.

2, *e*—Pronounced *e*, written *he*, signifies “to.”

← NOTES. Column 1, *dō*—Same year and month as in preceding entry.

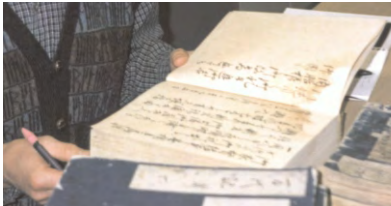
1, *uraura*—Repeat symbol 𠄎 makes *ura* plural. The unusual seas occurred along more than one part of the coast near Tanabe.

1, *e*—Written *e*, means “into.”

1, *abiki*—The term refers to unusual seas without necessarily implying their cause. From usage that varies with region, and perhaps also with time,



VOLUME OPENED TO TSUNAMI ENTRY



2 Column 1

dō
same [era]

jūni
twelve

tsuchinoto
younger
brother
of earth
u
rabbit

made
to,

shirusu
recorded

kore
this.

元禄八乙亥年
同十二已卯追記也

Genroku
Genroku

hachi
eight

kinoto
younger brother
of wood

i
boar

nen
year

yorī
from,

Genroku 8 began in 1696; Genroku 12 ended in 1700 (p. 42).

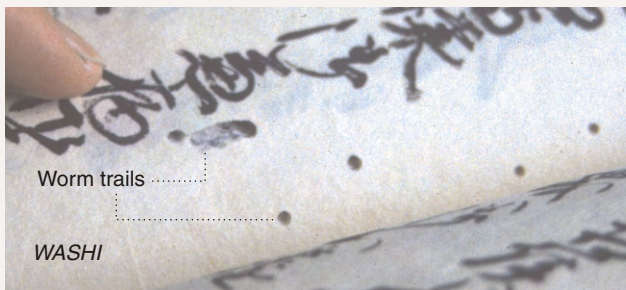
Water damage

一岡八百之夜明時ら浦くはあのみ
強き新名 御公儀御座ると
潮入り新名 御公儀御座ると
地考化破七のくはあのみ
しるす 潮入

Durable history

ACCOUNTS OF THE 1700 TSUNAMI were brushed onto *washi*. Strengthened by fibers of bark, *washi* has served as writing paper, screens, windows, lantern covers, and even clothing. Its use in Japan predates the 1700 tsunami by more than 1,000 years.

The tsunami accounts have survived water and bookworms. Water erased an edge of the account in “Tanabe-machi daichō” (above). Worms known as *shimi* (紙魚 paper fish) explored most of the source documents, including Morioka-han “Zassho” (below). Additional bookworms leaf through sturdy pages at right.



Bookworm passages perforate the volume of Morioka-han “Zassho” for the year Genroku 12 (above; entire volume, p. 42). Such trails also cross the map folds on page 32 and riddle the book cover on page 66. At upper right, earthquake historians devour durable documents in Tanabe.



TANABE LIBRARIAN Ōta Yūji identified as *kōyawashi* the paper used by the Tadokoro mayor who copied “Mandaiki” in the late 1700’s or early 1800’s. This paper takes its name from manufacture in Kōya, 60 km north of Tanabe.

IN MORIOKA, librarian Konishi Hiroaki surmised that the *washi* in “Morioka-han zassho” was imported from the south, for want of suitable fiber in northern Honshu.

ON WASHI’S MANUFACTURE and use, see All Japan Handmade Washi Association (1991). Boudonnat and Kushizaki (2003, p. 187) discuss the paper’s antiquity. Chamberlain (1905, p. 360), introducing Westerners to “Things Japanese,” reported that *washi* “lends itself admirably to the native brush, but not to our pointed pens, which stick and splutter in its porous fibre.” Paper manufacturing in North America’s English colonies probably began in 1700, in Philadelphia (Trager, 1992, p. 271).

Tsunami size near a storehouse 御蔵付近の津波の高さ

The 1700 tsunami probably reached heights of several meters in Shinjō.

CROSSING THE SHORE on its way to the government storehouse in Shinjō, the 1700 tsunami crested at least 2 m above tide (estimate **A**). A height of 4 m is reasonable if the storehouse stood on low ground at least half a kilometer inland, and if the tsunami height descended inland as it did in 1960 (**B**; heights in 1960 mapped on facing page).

The tsunami rose more than 5 m if the storehouse stood on high ground identified in Shinjō oral tradition (**C**). That tradition places a bygone government storehouse at the site in the photo below (map, opposite). However, this site was not necessarily the one flooded in 1700: Shinjō had more than one government storehouse in 1707, when a tsunami destroyed two of them (box, facing page).

STOREHOUSE SITE IN SHINJŌ



Road overtopped by 1946 tsunami but not by 1960 tsunami

STOREHOUSE FLOODING IN 1700

Shinjō
Shinjō
go-kōgi-o-kura
government storehouse
nado e
and so on to
shio iri
tide entered

“Tanabe-machi daichō”
(p. 86, columns 2-3)

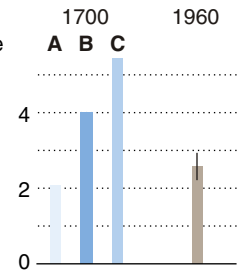
AT THE STOREHOUSE SITE in the photo above, the family of Matsuzaki Tomiji built a house early in the 20th century. Mr. Matsuzaki, born in 1926, told us in 1999 that he saw the 1960 tsunami stop short of this house and also the street fronting it. Mr. Matsuzaki also recalled being told that this street was crossed by the tsunami from the region’s great 1946 earthquake (p. 85).

ESTIMATE **C** is from Tsuji and others (1998).

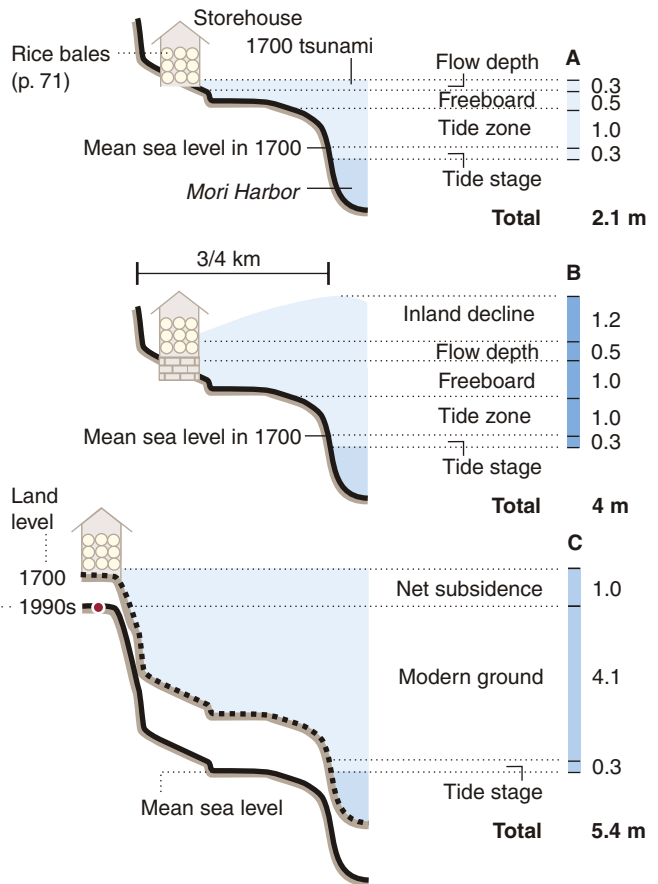
HEIGHT DATUMS. Tide tables of the Maritime Safety Agency (1998) list the highest astronomical tide at Tanabe as 1.04 m above mean sea level. TP is a datum near mean sea level.

SUMMARY OF TSUNAMI HEIGHTS

At edge of Mori Harbor, in meters above ambient tide. Inferred for 1700 (diagrams below), measured for 1960 (map opposite).



INFERRED HEIGHTS, 1700



ASSUMPTIONS

Flow depth 0.3 m for storehouse with minimal foundation (**A**), 0.5 m for foundation typical of traditional storehouses in former samurai neighborhoods of Tanabe (**B**; storehouse photo, p. 108).

Freeboard To keep government rice above waves during storm surges, storehouse was sited 0.5 m (**A**) or 1.0 m (**B**) above highest astronomical tides.

Tide zone Highest astronomical tides were 1.0 m above mean sea level, the modern value for Tanabe listed in tide tables. Relevant to **A** and **B** only.

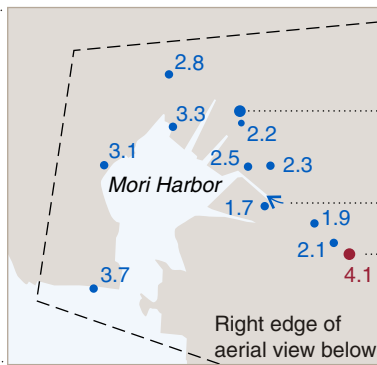
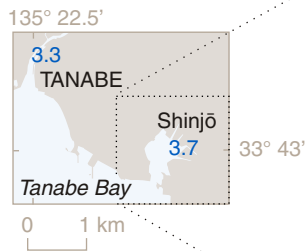
Tide stage When storehouse flooded at or before dawn, tide stood 0.3 m below 1700 mean sea level (p. 83). Used in all estimates.

Inland decline Tsunami crest descended inland in 1700 as much as it did in 1960 (map on facing page). **B** only.

Net subsidence 1.0 m since 1700 (p. 91). **C** only.

Modern ground The storehouse site now stands 4.1 m above TP (photo at left; map and airphoto on facing page). **C** only.

MEASURED HEIGHTS, 1960



• 3.7 Maximum height of 1960 tsunami, in meters above TP. Subtract 0.8 m to obtain height above ambient tide (p. 83).

Site of flooding, lower photo below

View in photo, page 85

Storehouse site on facing page, 4.1 m above TP

Site of tsunami photo, page 85



Modern Shinjō sprawls across lowlands beside Mori Harbor, in an aerial view from the 1990s. Storehouse site overlooks a field that the 1960 tsunami partly flooded.



Hoof-deep water of the 1960 tsunami covers a street 250 meters from the harbor.

1960 TSUNAMI HEIGHTS. The heights plotted above, at left, are from a regional report by the Japan Meteorological Agency (1961, p. 192); at right, from a local survey of Shinjō headed by a schoolteacher, Yoshinobu Eiji. Mr. Yoshinobu sought comparisons with the 1946 tsunami, whose heights he had previously surveyed with a hand level. After the 1960 tsunami, Tanabe’s mayor provided him with the services of Fujino Fumitada, a licensed surveyor, and Otani Yasuzō, an assistant to Mr. Fujino. Mr. Yoshinobu pointed them to the points he had measured in 1946, as well as to levels reached by the Chilean tsunami. The men surveyed for three days. Their findings appear on pages 20 and 23 of Yoshinobu’s report (which also describes the building of a breakwater at the entrance to Mori Harbor in 1965). Okamoto Yoshihiko of Tanabe’s city office provided us with a copy of the report and with the airphoto above. The lower photo comes from a collection at Shinjō Kōminkan (a community center), courtesy of Kashiwagi Tamio.

1960 TSUNAMI DAMAGE. Except for the south shore of Miyako Bay (p. 51), no recorded site of the 1700 tsunami in Japan suffered more damage from the 1960 tsunami than did the area around Mori Harbor. The area’s losses, compiled by Wakayama Prefecture and reported by the Japan Meteorological Agency (1961, p. 193), totaled 1.66 million yen (U.S. \$2,700 in 1960, or \$16,900 adjusted for inflation to 2003; <http://www.bls.gov/cpi/>).

Confounding clue from 1707

BOTH TADOKORO ACCOUNTS of the 1700 tsunami mention the flooding of one *o-kura*, or government storehouse, in Shinjō. Oral tradition in Shinjō places a government storehouse on high ground in a neighborhood called *o-kura yashiki* (government-storehouse district; photo on facing page). But the storehouse flooded in 1700 and that remembered by tradition are not necessarily the same, as shown by an account of the 1707 tsunami in Shinjō.

The great Hōei era earthquake and tsunami of October 28, 1707 devastated Shinjō. Losses there, reported in Tadokoro documents, included 185 houses, 196 sheds, 40 cattle shelters, and five private storehouses (*kura*). The losses also included two *o-kura*—two government storehouses. Which, if either, did the 1700 tsunami enter? Which corresponds to the storehouse in Shinjō’s oral tradition?

ADDITIONAL LOSSES IN 1707 The great Hōei-era earthquake and tsunami of October 28, 1707 devastated Tanabe as well. In that castle town, 24 persons died, 138 houses and 75 storehouses collapsed, 154 houses and 6 storehouses were washed away, and 119 houses suffered severe damage (*taiha*). Among the houses destroyed was that of the Tadokoro mayor (location, p. 84, 90). Left standing, but entered by the water, was the family’s adjacent storehouse that likely held “Tanabemachi daichō” (p. 86) and “Mandaiki.” Salt water soaked the Tadokoro records; these dried the following week.

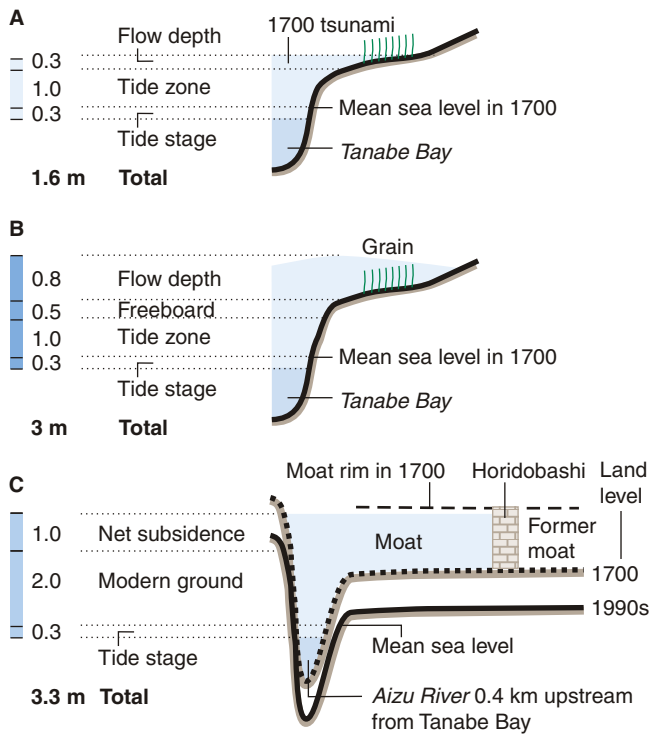
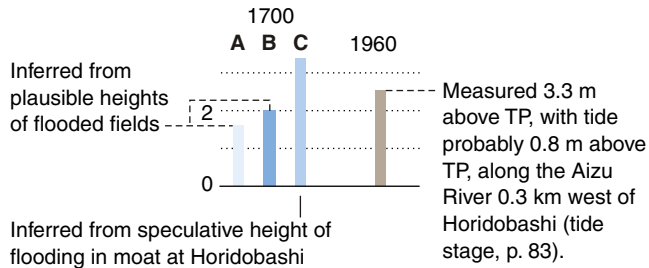
SOURCE DOCUMENTS “Shinshu Nihon jishin shiryō” (p. 62) cites Tadokoro documents as the authority on the 1707 damage in Shinjō, while quoting “Mandaiki” on the losses in Tanabe (Tokyo Daigaku Jishin Kenkyūsho, 1981, p. 117, 135).

Tsunami size near Tanabe Bay 田辺湾付近の津波の高さ

Of modest height, the 1700 tsunami flooded bayside fields but not the mayor's house.

SIMPLE ASSUMPTIONS about reported damage to fields and crops yield bayshore heights up to 3 m for the 1700 tsunami near Tanabe (A and B). In Tanabe proper, near the home of the Tadokoro mayor, the water ascended a castle moat without reportedly overtopping its rim. Perhaps, as assumed in C, the tsunami approached the moat rim in the area of the motorcycle at lower right.

TSUNAMI HEIGHT, IN METERS ABOVE AMBIENT TIDE



ASSUMPTIONS

- Flow depth** At least 0.3 m to damage grain (A); higher at shore (B).
- Freeboard** Kept fields above waves during most storm surges (B).
- Tide zone** Highest astronomical tides 1.0 m above mean sea level, as listed for Tanabe in modern tide tables (A and B; datum, p. 88).
- Tide stage** When fields and moat flooded, tide stood 0.3 m below 1700 mean sea level (p. 83). Used in all estimates.
- Net subsidence** 1.0 m since 1700 (facing page). Used in C only.
- Modern ground** Tsunami approached level of moat rim, now an intersection about 2 m above TP (C; photo, right).

Estimate C from Tsuji and others (1998). TP, a datum near mean sea level.

FLOODING DESCRIBED IN TADOKORO DOCUMENTS

FIELDS IN VILLAGES*

denchi
rice paddies

mugisaku
wheat crops

habō
lost

MOAT IN TANABE

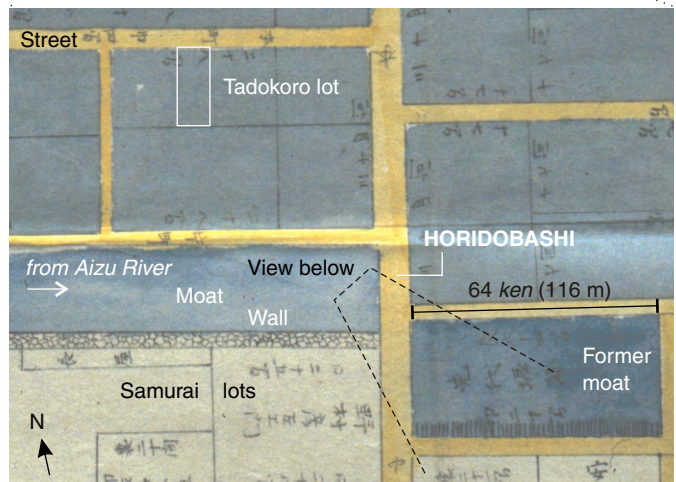
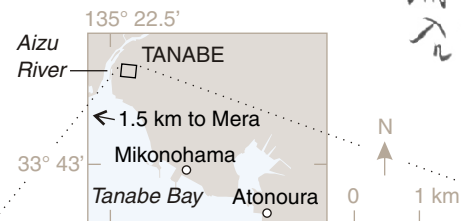
kokomoto
Close to me,

Horidobashi
Horidobashi

made
as far as

shio iru
morning tide entered.

* Mera, Mikonohama, and Atonoura (p. 86, footnote on column 3)



On the picture map from 1704-1711 (p. 84), the former moat is labeled *sendai hori ato* (moat in preceding generation). The neighborhood in the photo is known today as Horidobashi. Officials of the General Affairs Section, City of Tanabe, showed us the location of the Tadokoro lot.

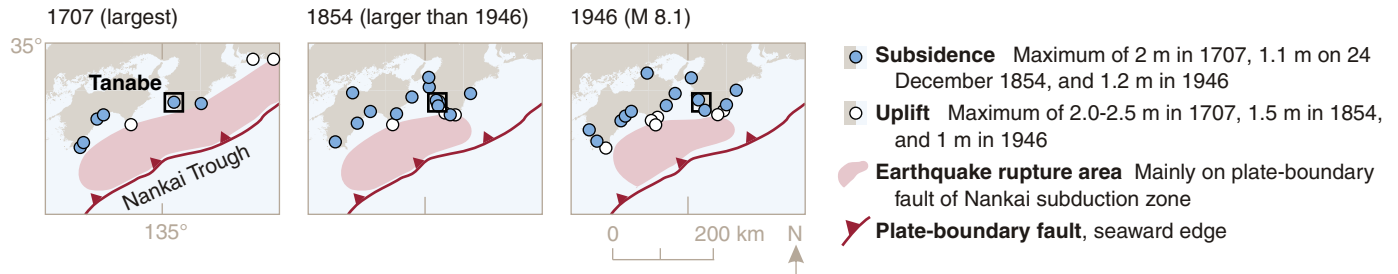
Sawtooth cycles 地震サイクル

Tanabe sinks during great earthquakes and probably rises between them.

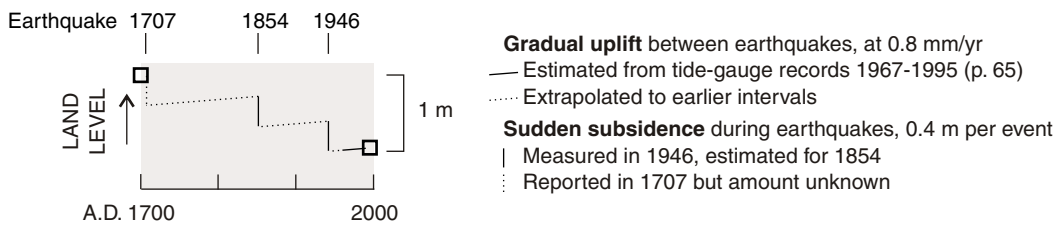
GREAT SUBDUCTION EARTHQUAKES lower land at Tanabe. The subsidence probably punctuates cycles that plot like sawteeth (below). The cycles result from stick-slip subduction (p. 10), as do the land-level changes at Chile,

Alaska, and Cascadia (p. 11, 14-25). The cycles' net effect at Tanabe adds 1 m of inferred tsunami height in estimate C (opposite). At Tanabe since 1700, subsidence during earthquakes probably exceeded the area's gradual uplift.

COASTAL LAND-LEVEL CHANGE DURING EARTHQUAKES ALONG THE NANKAI TROUGH



INFERRED CYCLES OF LAND-LEVEL CHANGE AT TANABE



SUBSIDENCE ESTIMATES for the earthquakes in 1707, 1854, and 1946 are from Usami (1996, p. 303). Tanabe subsided about 0.4 m during the 1946 earthquake according to a comparison of geodetic benchmarks leveled before and after the event (Thatcher, 1984, p. 3090).

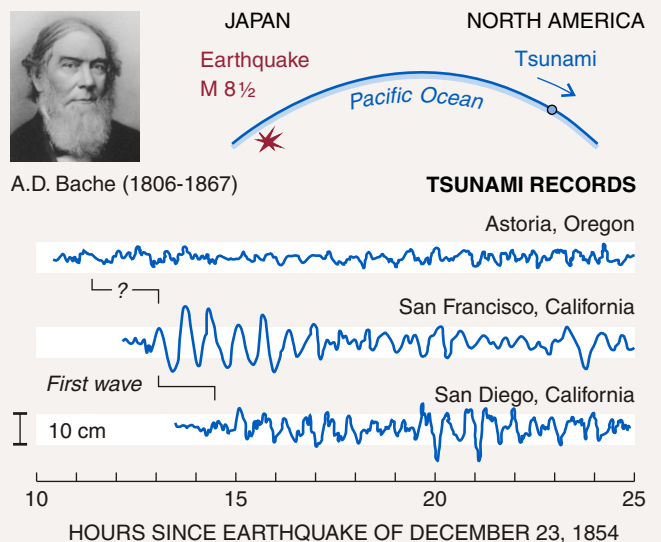
THE UPLIFT RATE of 0.8 mm/yr is the average estimated by Ozawa and others (1997, p. 13) from tide-gauge records at Shirahama, 5 km southwest of Tanabe (graph, p. 65). Ando (1975) and Savage and Thatcher (1992) report additional evidence for historical land-level change at the Nankai Trough.

Firsts

INSTRUMENTAL RECORDS of confirmed tsunamis begin with a pair of Japanese wave trains that registered on tide gauges in Oregon and California on December 23 and 25, 1854.

The December 23 tsunami, originating off Miho (p. 77), in turn yielded pioneering estimates of Pacific Ocean depths. Its wave train was noticed on a San Diego marigram by the gauges' installer, William P. Trowbridge. Suspecting a submarine earthquake, Trowbridge notified Alexander Dallas Bache, head of the U.S. Coast Survey. Months later, Bache learned that an earthquake and tsunami had struck southwest Japan about 9 a.m. local time on December 23, 1854. Bache combined this news with the marigrams and with wave physics to estimate the average ocean depth between Shimoda (location, p. 77) and San Francisco. His estimate, 4.1-4.6 km, scarcely differs from today's, 4.7 km.

The second wave train originated on December 24, Japan time, off Tanabe (map, above). Its effects in Hiro village, 35 km northwest of Tanabe, inspired the story that brought "tsunami" into the English language (p. 47).



THE GAUGED WAVES, as presented by Bache (1856), are plotted relative to ambient tide (like the simulated waves on p. 37). Theberge (2003) tells of the gauges and Bache's estimates; Lander and others (1993, p. 40), early tsunami recordings. The photo accompanies a eulogy at <http://www.history.noaa.gov/giants/bache.html>. Astoria plotted on map, p. 125.

IN JAPAN

- 1603 Edo becomes shogun's capital
- 1612 Earliest known writing of 津波 (p. 41)
- 1644 Earliest volume of Morioka-han "Zassho" (p. 44)

Marking each year's growing season, the annual rings of western red cedar in Washington State strengthen the link between the January 1700 tsunami in Japan and a great earthquake at Cascadia. In this earthquake victim's root, a complete ring from 1699 forms the smooth outer edge at right. The tree lived through August or September of 1699 but died before May 1700, when the next growing season began (p. 96-97).



Tree PX-782, South Fork Palix River, Willapa Bay