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# Fault model of the 1703 Genoku Kanto Earthquake (*M* 8.2) along the Sagami Trough deduced from renewed coseismic crustal deformation

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Abstract

Analyzing height distributions of paleo-shorelines identified by marine terraces, bio-constructions and historical records, we estimated the vertical crustal movement during the 1703 Genroku Kanto earthquake (M 8.2). The Miura Peninsula and the Oiso coastal area were 1-2 m uplifted as well as during the 1923 Taisho Kanto earthquake (M 7.9). In the Boso Peninsula, it was different movement to the 1923 earthquake. The peninsula was steeply tilted, accompanied with uplift of over 6 m in the southernmost area and with subsidence of at least 1 m in the central area. Based on the renewed crustal movement, we also re-estimated the tsunami height of the 1703 earthquake. It is inferred that larger tsunami was inundated along the eastern coast of the Boso Peninsula, compared with the 1923 tsunami.

Using these data, we proposed the fault model of the 1703 earthquake which is composed of a combined fault system of fault A, B and C. The fault A is an inter-plate fault ruptured at same area as the 1923 earthquake. The uplift of the Miura Peninsula and the Oiso coastal area can be explained by about 6.7 m slip of the fault A. The fault B is a low angle dip thrust located off the southeast of the Boso Peninsula. The steep tilting deformation in the Boso Peninsula has been derived from about 12 m slip of the fault B. The fault C generated the large tsunami along the eastern coast of the Boso Peninsula.

## 1. Introduction

Two historical great earthquakes, the 1703 Genroku Kanto Earthquake (*M* 8.2) and the 1923 Taisho Kanto Earthquake (*M* 7.9) occurred along the convergent plate boundary of the Sagami Trough where the Philippine Sea Plate subducts beneath the North American Plate (Figure 1). These earthquakes accompanied with crustal movement and tsunami in South Kanto district.

According to the re-leveling of benchmarks conducted by Land Survey Department [1926], it was inferred that the Boso Peninsula, the Miura Peninsula and the Oiso coastal area were uplifted up to 2 m during the 1923 earthquake (Figure 2 [Miyabe, 1931]). In early studies, most of the fault models for the 1923 earthquake have been estimated along the northern edge of the Phippine Sea Plate, based on such geodetic data. Ando [1974] inferred the model as reverse and right lateral faulting on a low angle plane extending along the trough. Improved model was developed by Matsu'ura and Iwasaki [1983], using new method of inversion analysis. Wald and Somerville [1995] discussed a heterogeneous slip distribution model, combining with teleseismic data. Recently, Nyst *et al*. [2003] reevaluated the fault model considering with newly added geodetic data.

No geodetic and teleseismic data about the 1703 earthquake, but historical records and tectonic geomorphology suggest much useful information to estimate a fault model. According to the historical documents, the source regions of the 1923 and 1703 earthquakes seem to overlap in the

Sagami Bay due to similar seismic intensity and tsunami generation around the bay area [Hatori, 1976 and Usami *et al*. 1977]. Larger rupture extent southeastward during the 1703 earthquake is suggested from remarkable differences of crustal movement and tsunami around the Boso Peninsula, which were revealed from historical records and coastal topography. Matsuda *et al*. [1974] measured the height of 1703 shoreline which indicates the accumulation of vertical crustal movement after the earthquake, and suggested the pattern of 1703 coseismic movement (Figure 3). Based on this result, Matsuda *et al*. [1978] estimated the 1703 fault model which consists of three thrusts including same rupture area of Ando's 1923 model. Aida [1993] also proposed the fault model composed of two fault planes, referring with Kasahara [1973] and basing on tsunami inversion.

Recently, Sasou [2003] introduced some historical maps which described coastal regression and transgression caused by land level change along the Boso Peninsula. His report indicates that the position of the 1703 shoreline identified by Matsuda *et al*. [1974] partly disagrees with the descriptions of historical documents and maps. Matsuda *et al*.'s data was insufficient of chronological evidence and geomorphological interpretation for paleo-shoreline. This uncertainty affects the fault models of the previous studies.

In this study, we re-evaluated the crustal movement and tsunami during the 1703 earthquake from the height of re-identified 1703 paleo-shoreline by combining geomorphological and historical records. Analyzing this result, we propose the new fault model of the 1703 earthquake.

## 2. Crustal movement

### 2-1. Method

In order to know the crustal movement of past earthquake before starting instrumental observation, it has to be inferred from historical records and geological and geomorphological traces. Leveling the paleo-shoreline is one of the best ways to estimate the vertical displacement accompanied with subduction-zone earthquake. The identification of paleo-shoreline is generally based on erosional marks such as marine terrace and in-situ bio-constructions, which were formed around mean sea-level. Historical records also are useful for deciding exact position of paleo-shoreline. Analyzing the height distributions of paleo-shoreline indicators identified by such kinds of records, we discuss the crustal movement during the 1703 earthquake.

### 2-2. Southern part of the Boso Peninsula

Several levels of distinct Holocene marine terraces incised into the Neogene bedrock are well-developed along the southern coast of the Boso Peninsula. The lower two levels of this series have been emerged during the 1703 and 1923 earthquakes (Figure 4).

Emergence of wave-cut-bench during the 1923 earthquake has been reported by Yamasaki [1926]. This emerged bench named the 1923 terrace is intermittently distributed by width of 50-100 m. The height distribution of the paleo-shoreline is 1.0-2.0 m above mean sea-level, which is correlated with amount of uplift revealed from geodetic data (Figure 5).

The position of the paleo-shoreline emerged during the 1703 earthquake can be identified from comparing with historical maps (figure 6). The pre-earthquake shoreline has been drawn on 200-500 m inland from present shoreline in that maps around the southernmost part of the Boso Peninsula. Historical documents also described abrupt marine regression during the 1703 earthquake. Emerged area is now observed as marine terrace named the 1703 terrace, which is wider than the 1923 terrace. Wide surface of the terrace means larger uplift than the 1923 earthquake. Even in the area without historical maps, the paleo-shoreline can be easily recognized, because the 1703 terrace continues geomorphologically from the identified area.

Height distribution of the 1703 shoreline is reached to 7.3 m in the tip of the peninsula and is sharply decreasing northward (Figure 5). When amount of the 1923 uplift is subtracted from the height of the 1703 shoreline, we have minimum amount of the 1703 uplift (e.g. 5.3 m in Mera). Because interseismic slow subsidence rate was estimated from recent tide gauge data of the Mera station as 2.5 mm/year [Ozawa et al., 1996], total amount of subsidence is accumulated to 0.8 m after the 1703 earthquake. Therefore the amount of the 1703 uplift can be inferred to be maximum 6.1 m in Mera.

## 2-3. Central part of the Boso Peninsula

Along the central part of the Boso Peninsula, the 1703 terrace cannot be identified, although the 1923 terrace is partly developed. Emergence age of the terrace which is distributed one step higher than the 1923 terrace was dated to be older age than AD 1703 [Shishikura, 1999; Shishikura et al., 2001]. It implies that this area was not uplifted during the 1703 earthquake.

In Hota, western coast of the Boso Peninsula, there is a pair of historical maps described the shoreline change between before and after the 1703 earthquake (Figure 7 [Usami et al. 1977; Sasou, 2003]). It shows clearly that the shoreline regressed landward after the earthquake. This shoreline regression can be explained by coseismic subsidence. Historical documents also have mentioned that the land dropped beneath the sea during the 1703 earthquake.

Evidences of subsidence induced by the 1703 earthquake are also in Kominato and Kamogawa, eastern part of the Boso Peninsula. Submerged terrace is distributed about 1.0 m below mean-sea-level in this area (Figure 8). Local residents mentioned that the drowned wells and pillar holes can be found on the surface of this terrace. In the historical map drawn at AD 1700, the terrace has been represented clearly as emerged land [Sasou, 2003].

No tidal station in Kominato, but recent tide gauge data of the nearest station, Katsuura, shows gradual subsidence as 2.3 mm/year [Ozawa et al., 1996]. If referring this trend, it is estimated that the total amount of subsidence after the 1703 earthquake was about 0.7 m. As the amount of

1923 uplift in this area was also 0.7 m, it was canceled out. Therefore the amount of subsidence during the 1703 earthquake is estimated to be at least 1.0 m.

### 2-4. Miura Peninsula

Marine terraces are also distributed in this area, but not noticeable than the Boso Peninsula. For this reason, we mainly argue about crustal movement in this area by using biological records.

Two levels of emerged sessile assemblages of *Pomatoleios Kraussii* (which can live only in mid-littoral zone) were identified in growth position along the rocky coast of the Miura Peninsula. Each of two assemblages are zoning vertically in 30-50 cm width on sea cliff (Figure 9). The upper limit level of them indicates the most plausible reference position to determine the timing and amount of coseismic uplift, because the assemblage has been grown upward by responding the gradual sea-level rise caused by interseismic subsidence.

The lower assemblage must be emerged during the 1923 earthquake, because the height difference from the present assemblage is nearly equal to the amount of coseismic sea-level fall (1.4 m) recorded in tide gauge data in the Aburatsubo station.

To reveal the emergence age of the higher assemblage, we collected three samples for radio-carbon dating. Derived conventional age (790-650 yr BP) was calibrated into calendar years using Dataset 3 of CALIB ver. 4.3

[Stuiver and Braziunas, 1993; Stuiver et al., 1998]. Marine reservoir effect was evaluated from radio-carbon ages of the lower assemblage, which give average $\Delta R = 77 \pm 21$ (detailed calibration process will be discussed in another manuscript). In this case, the calibrated age of the higher assemblage can be estimated to be AD 1583-1795 (1$\sigma$). This result appears to be in good agreement age with the 1703 earthquake, because any other destructive earthquake accompanied with episodic uplift has not occurred around the Miura Peninsula in past four century.

Height difference between two emerged assemblages was measured with 0.5-1.0 m, which indicates amount of minimum uplift during the 1703 earthquake (Figure 10). Tide gauge data of the Aburatsubo station suggests that 3.0 mm/year of interseismic slow subsidence have continuously occurred during at least recent 40 years [Ozawa et al., 1996]. If same rate of such movement has continued since the 1703 earthquake, total amount of subsidence during 220 years (until just before the 1923 earthquake) is estimated to be about 0.7 m. It is therefore inferred that the amount of 1703 uplift reached to 1.2-1.7 m, which is almost same as the 1923 earthquake.

## 2-5. Oiso coastal area

No information about the paleo-shoreline indicators related to the 1703 and 1923 earthquakes was able to be found along the Oiso Coast. Geodetic data shows that this area was uplifted up to 2 m during the 1923 earthquake. In spite of this movement, marine terrace was not created due to local geomorphological and geological conditions. However, three or four steps of Holocene marine terraces can be identified in this area. Emergence of these terraces may have been induced by inland active fault, the Kozu-Matsuda Fault Zone, rather than subduction-zone earthquakes. Vertical fault displacement is inferred to be 3.0-6.5 m from trench survey conducted by Kanagawa Prefecture [2003]. In order to create a marine terrace, it probably needs over 3 m uplift in this area. The fact that the 1703 terrace is not distributed in this area suggests that it was not so much uplifted during the 1703 earthquake. Historical documents have not made mention of visible land-level change either. On the other hand, historical records of shaking damage indicate that seismic intensity in this area was similar to the 1923 earthquake [Usami, 2003]. These data imply that the 1703 crustal movement in this area was equal or a little smaller uplift in comparison with the 1923 earthquake.

## 2-6. 1703 coseismic crustal movement

Compiling above results, coseismic crustal movement during the 1703 earthquake is summarized as Figure 11. Around the northernmost part of the Sagami Trough, almost same movement as the 1923 earthquake, which was uplift of 1-2 m, occurred in the Miura Peninsula and the Oiso coastal area. In the Boso Peninsula, contrastively, there are remarkable differences between two earthquakes. During the 1923 event, whole of the peninsula was uplifted (maximum 2 m in Mera) and tilted toward northeast, whereas the 1703 event resulted in northward tilting accompanied with the uplift of over 6 m in the southernmost area and subsidence of at least 1 m in the central area. Our result is quite different with Matsuda *et al*. [1974] especially in the Boso Peninsula, by comparison between figure 3 and figure 11.

## 3. Tsunami height

Tsunami height of the 1703 earthquake has been inferred by Hatori [1976], who identified inundation limits based on historical records such as documents and monuments. The method of his estimation was that the vertical crustal movement of 1703 was added to relative height between the altitude of 1703 terrace and inundation limit position. He used Matsuda et al.'s data, which we revised in the former chapter, for the parameter of 1703 movement. We re-evaluate the Hotori's result using renewed crustal movement data and re-leveling the inundation limit identified by him.

As a result of our evaluation, the tsunami heights are basically same as Hatori [1976] but differ 1-2 m in the southern part of the Boso Peninsula (Table 1). The largest 1703 tsunami was recorded in Mera and Wada. Inundation height in Mera has been estimated to be about 5-6 m, judged from extensive damage [Hatori, 1976]. When adding the 1703 uplift (6.1 m), we get maximum of 11-12 m tsunami. In Wada, the southeastern part of the Boso Peninsula, an evidence of inundation limit still remains on the front steps of Itokuin temple where a monument indicates the attainment position of 1703 tsunami. Relative height between that and the 1703 shoreline was measured at 8.3 m. Adding the 1703 uplift of 2.6 m, the tsunami height can be estimated at 10.9 m.

Comparison between these result and 1923 tsunami data are shown in Figure 12. The most of the area along the eastern coast of the Boso Peninsula, the 1703 tsunami heights are estimated to be three to four times larger than the 1923 tsunami. Contrastively, in the Miura Peninsula and the Oiso coastal area, 1703 tsunami height was similar to the 1923 event, although it was partially twice large.

The 1703 tsunami in distant areas was also recorded in historical documents [Tsuji, 1981]. The record of the most distant place was 1 m tsunami in Kochi of 600 km southwest from the hypocenter.

## 4. Fault model of the 1703 earthquake

On the basis of renewed vertical crustal movement, we synthesized the two dimensional displacement field by using the method of Mansinha and Smylie (1971) to obtain the best fit of the fault parameters as strike angle, dip angle, rake angle, length (L), width (W) and net slip (U). As the result of inversion analysis, we proposed the 1703 fault model which consists of three rectangular fault planes named fault A, B and C (Fig. 13, Table 2).

The fault A has basically same parameters to the model of 1923 earthqauke. Around the Miura Peninsula and the Oiso coastal area, crustal movement, tsunami height and seismic intensity during the 1703 earthquake were similar to the 1923 earthquake. This suggests that both events were caused by same source in this area. Based on this interpretation, we set the fault A as the 1923 model of Ando (1974).

The fault B mainly generates the crustal deformation in the Boso Peninsula. The peninsula was steeply deformed accompanied with large uplift in the southern part and subsidence in the central part during the 1703 earthquake. This short wavelength deformation which extremely differs to the 1923 event cannot be reproduced, even if it extends the fault A to southeast along the Sagami Trough. It implies that another thrust simultaneously ruptured near the peninsula. Consequently, we set the fault B striking ENE-WSW along the Kamogawa submarine cliff off the southeastern part of the Boso Peninsula. The fault B is characterized by low angle dip of 20° and large net slip of 12 m in order to create the subsidence in the central part of the peninsula.

The fault C is set for explaining the large tsunami height along the eastern coast of the Boso Peninsula and distant coasts as well as the Matsuda et al.'s model. The fault trace is not fitted along the Sagami Trough, but it locates on parallel position where the straight submarine valley can be identified as probably tectonic topography.

## 5. Discussions

### 5-1. Different points to the Matsuda et al.'s model

The geometry of our fault model is basically similar arrangement to the model of Matsuda et al. [1978], but some parameters are greatly different.

Matsuda et al.'s fault A is shorter length than ours, because they considered that the Oiso costal area was hardly uplifted. The most important difference point is the parameters of the fault B which are affected by the crustal movement of the Boso Peninsula. Since Matsuda et al. did not take account of subsidence in the central part, their fault B was high angle dip and relative small net slip. In our model, the renewed crustal movement characterized by steep northward tilting of the Boso Peninsula is constrained to be that the fault B is low angle dip and large net slip.

### 5-2. Tsunami simulation

Aida [1991] maintained that the 1703 tsunami can be explained by only two faults as the fault A and B. Aida model is similar to our model, but differ about the higher dip angle of the fault B and lacking the fault C. In order to judge the validity of the fault C, we compute the maximum tsunami heights generated from two conditions of fault model which ruptured all faults of A+B+C or only two faults of A+B. The simulated tsunami heights are compared with the inferred tsunami along the eastern coast of the Boso Peninsula (Figure 14).

In the case of fault A+B+C, the trends are approximately similar to the inferred tsunami, although it is comprehensively 1-2 m smaller. The position of maximum peak which is located in Mera is in agreement, and the shape of height distribution at distances from 40 to 160 km seems to correspond to the inferred tsunami. Around Wada, however, it differs no less than 4m.

On the other hand, the case of fault A+B is obviously too small to explain the inferred tsunami between Onjuku and Choshi (distances from 75 to 170 km). Therefore this case is inappropriate for the fault model of the 1703 earthquake.

## 5-3. Relation to the plate motion

The 1703 earthquake is generally known as inter-plate earthquake. The fault planes of our model, however, are not necessary in agreement with the trace of the Sagami Trough defined as a surface expression of plate boundary. To discuss the relation to plate motion, first, we compare the geometry of fault planes with the upper surface of the slab of Philippine Sea Plate (PHS) proposed by Ishida [1992] (Figure 15). The setting of the fault A approximately agrees with the plate boundary. Although the configuration of the PHS slab around the southern part of the Boso Peninsula (depth from 0 to 20 km) is indefinite due to lack of seismic data, the fault B and C seem to be in discord with the upper surface of the PHS slab.

Next, we compare Holocene mean slip rate of the faults with the velocity of plate motion revealed by recent geodetic data. Analyzing the emergent ages and geometry of marine terraces along the Boso Peninsula, Shishikura [2003] suggested that the relative small uplift event as the 1923 earthquake generated from the fault A has occurred every an average of 400 years, and the 1703-type great event which involved the fault A and B (no evidence about the fault C) has occurred at interval of over 2000 years. If average net slip of every event is 6.7 m and 12 m respectively, mean slip rate of each fault can be estimated to be 17 mm/year (fault A) and < 6 mm/year (fault B).

This result is smaller than recent plate motion rate around the Sagami Trough. Sagiya [1998] inferred that the back slip is accumulated with rate of 20-30 mm/year, based on GPS data. Since the geodetic rate includes various errors, it can be judged that the slip rate of the fault A is in permissible range. Therefore it is likely that the stress around the northern part of the Sagami Trough is almost dropped by the fault A as the subduction fault. Contrastively, if the fault B also has been ruptured as an inter-plate fault, there is impermissible large gap between the Holocene slip rate and recent plate motion.

Lallemant et al. [1996] proposed the shear partitioning system around the convergent plate boundary between the PHS and the North American Plate. They defined the Boso transform fault on the same position of the fault C. It has been inferred that this transform fault strikes across the Boso and Miura Peninsula. However, no evidence of Quaternary faulting can be detected in on-shore faults in the Boso Peninsula [Chiba Prefecture, 2001]. This suggests that recent active portion of the Boso transform fault does not extend to such area. It may bend to southwest and be traced along the Kamogawa submarine cliff where the fault B is laid. In this case, probably the fault B and C have been ruptured as a result of shear partitioning.

If this interpretation is correct, it can be expected that another type of earthquake occurs at the plate interface along the Sagami Trough southeastward from the fault A. Aida [1981] pointed out a possibility that the 1605 Keicho earthquake (M 7.9) occurred in such area. However, there is no reliable evidence, and recently it is inferred that seismic source was along the Nankai Trough. Because the exact trace of plate boundary and the configuration of shallow part of the PHS slab are indistinct along the Sagami Trough, it should be further studied in detail to obtain a definite conclusion about the shear partitioning.

## 6. Conclusion

We have re-evaluated the vertical crustal deformation during the 1703 earthquake, analyzing the height distributions of paleo-shorelines and referring with historical records. Our results are greatly different to Matsuda et al. [1974].

Marine terraces developed in the southern part of the Boso Peninsula are distinguished into two different sizes indicating the large uplift of 1703 event and the small uplift of 1923 event. It has been inferred that maximum amount of the 1703 uplift reached to over 6 m, three times larger than the 1923 uplift. Contrastively the central part of the Boso Peninsula is considered to have subsided at least 1 m from historical records and altitude of submerged terrace. Therefore the Boso peninsula was steeply tilted to north. In the Miura Peninsula, height distributions of two emerged bio-constructions suggest that both of the 1703 and 1923 earthquakes were accompanied with 1.0-1.5 m uplift. Although the bio-constructions and marine terraces related to two earthquakes are not distributed along the Oiso coastal area, probably almost same uplift (2 m or less) as the 1923 event has occurred during the 1703 event.

Based on this result, we also have re-estimated the tsunami height of the 1703 earthquake. As a result, there are no large differences from Hatori [1976]. The 1703 tsunami is characterized by larger inundation height along the eastern coast of the Boso Peninsula, compared with the 1923 tsunami.

Using renewed data, we have proposed the fault model of the 1703 earthquake which is composed of three faults named fault A, B and C. The fault A is an inter-plate fault ruptured at same area as the 1923 earthquake, which well explains the crustal movement of the Miura Peninsula and the Oiso coastal area. The steep tilting deformation in the Boso Peninsula is well interpreted by reverse faulting of the fault b characterized by low angle dip and large net slip. The fault C generated the large tsunami along the eastern coast of the Boso Peninsula. The fault B and C are intra-plate faults in the upper plate of the subduction zone, probably ruptured as the result of sear partitioning due to oblique subduction, although it has not yet been coherently explained. Nevertheless, our new fault model will contribute to prediction of future disasters by strong shaking and tsunami in South Kanto district which is one of the largest urban concentrations in the world.

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Caption

Figure 1. Index maps of (a) central Japan and (b) the southern Kanto region. KMF: Kozu-Matsuda Fault Zone, NAM: North American Plate, PAC: Pacific Plate, PHS: Philippine Sea Plate. Thin solid line in inland of (b) is major active fault based on Research Group for Active Fault in Japan [1991]. Star in (b) is hypocenter of historical earthquake after Usami [2003]. Submarine contour interval is 100 m.

Figure 2. Vertical crustal movement during the 1923 Taisho Kanto earthquake, deduced from geodetic data after Miyabe [1931]. Contour interval is in meter.

Figure 3. Vertical crustal movement during the 1703 Genroku Kanto earthquake and its fault model after Mastuda et al. [1974, 1978]. Heavy contour line is observed vertical displacement in meter. Light dotted contour line is simulated vertical displacement in meter. White arrow is slip direction of fault.

Figure 4. Two levels of marine terraces in Kenbutsu, southern part of the Boso Peninsula.

Figure 5. Height distributions of geomorphological paleo-shoreline

indicators and leveling data of the 1923 earthquake along the southern part of the Boso Peninsula.

Figure 6. History of shoreline change around the coast of Nemoto, southernmost part of the Boso Peninsula, based on comparison of three maps in different ages.

Figure 7. A pair of historical maps drawn around the coast of Hota, central part of the Boso Peninsula.

Figure 8. Schematic geomorphological profile in the coast of Kominato, central part of the Boso Peninsula.

Figure 9. Two levels of emerged sessile assemblages in Jogashima, southern part of the Miura Peninsula.

Figure 10. Height distributions of biological paleo-shoreline indicators and leveling data of the 1923 earthquake along the southern coast of the Miura Peninsula.

Figure 11. Vertical crustal movement during the 1703 Genroku Kanto earthquake. Contour interval is in meter.

Figure 12. Tsunami heights during the 1923 Taisho Kanto earthquake

(based on Hatori, 1976) and during the 1703 Genroku Kanto Earthquake.

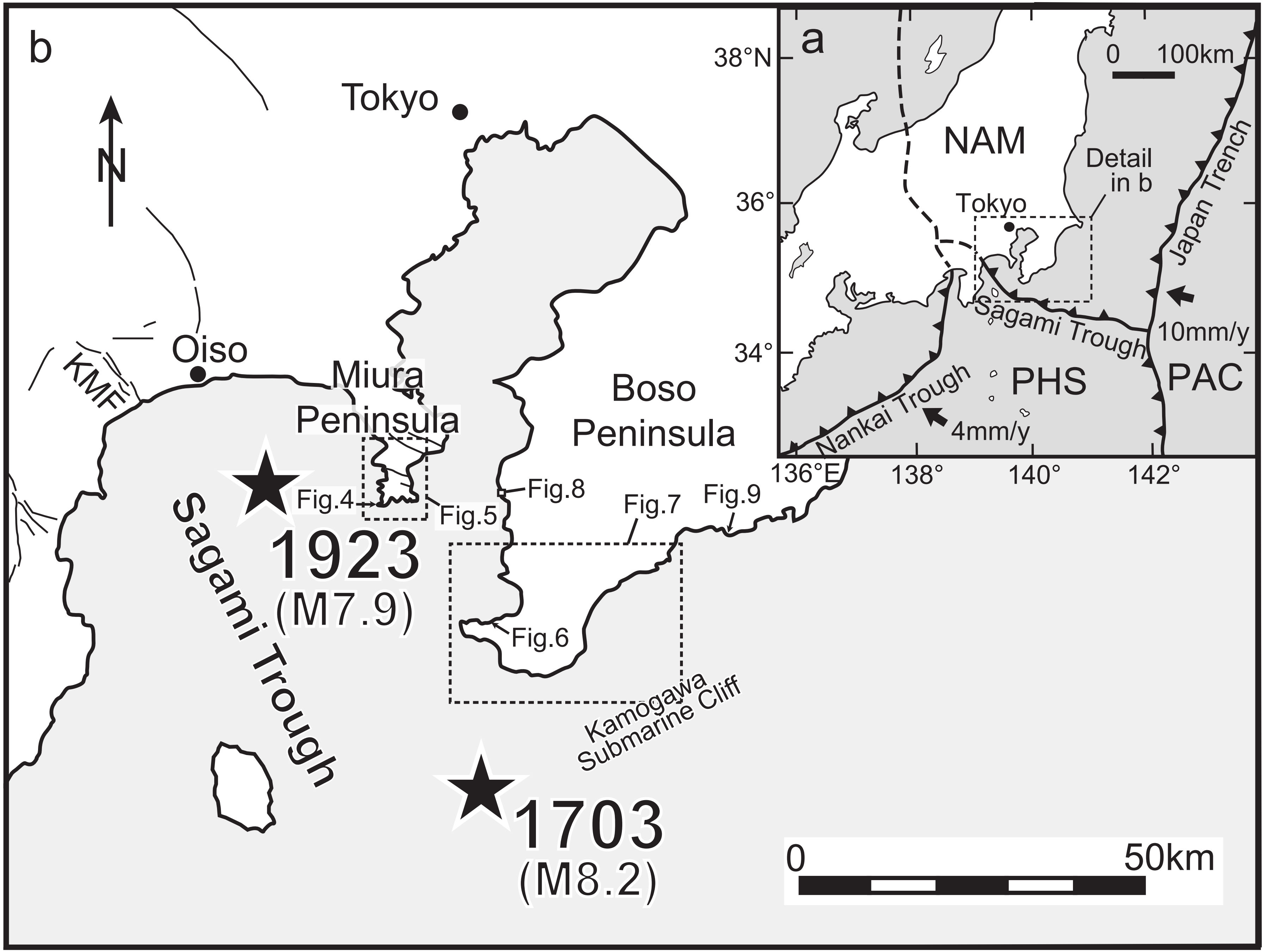
Figure 13. Fault model of the 1703 Genroku Kanto earthquake. Contours are theoretical vertical displacements in meters.

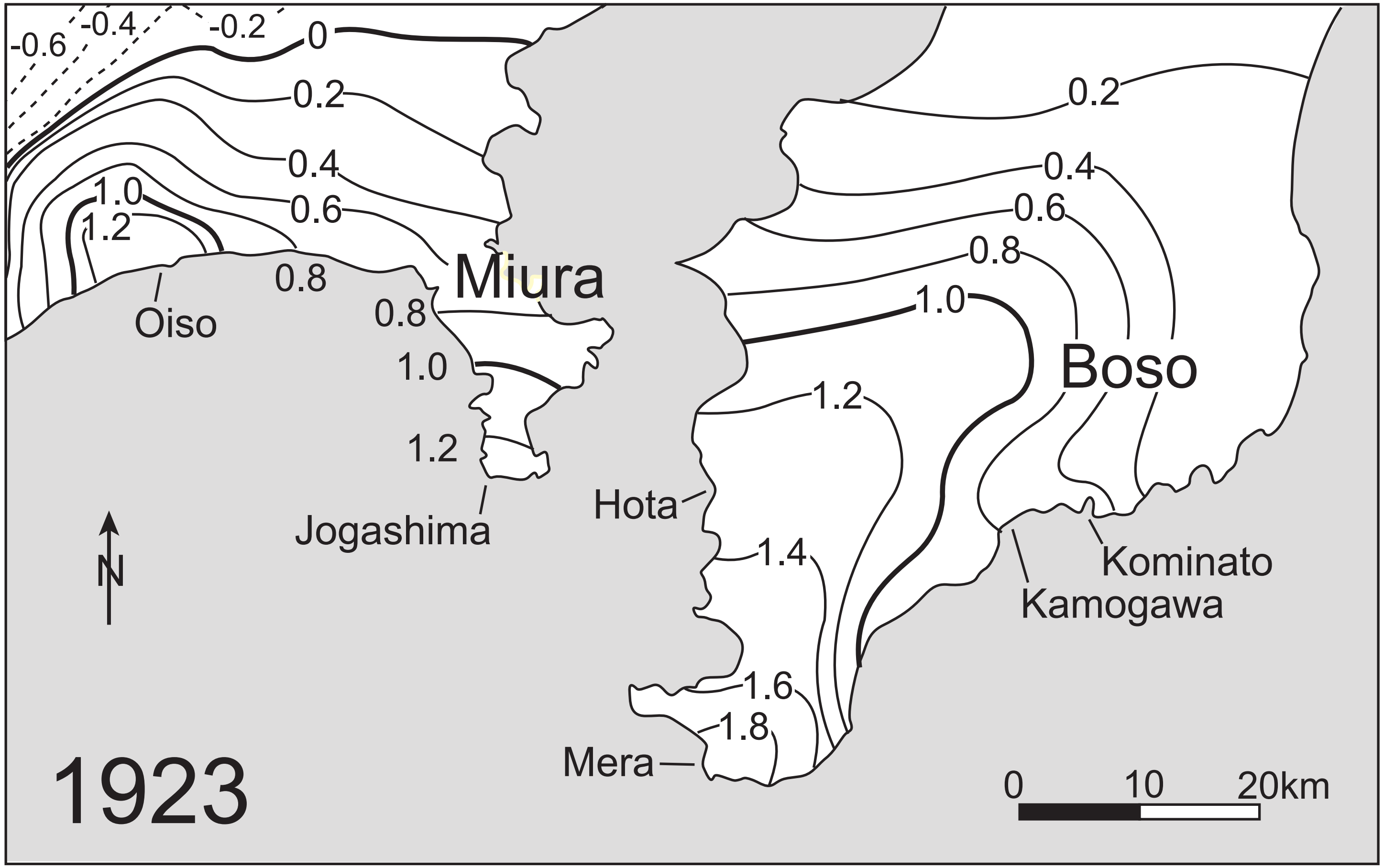
Figure 14. Comparison between inferred 1703 tsunami and two conditions of simulated tsunami along the eastern coast of the Boso Peninsula.

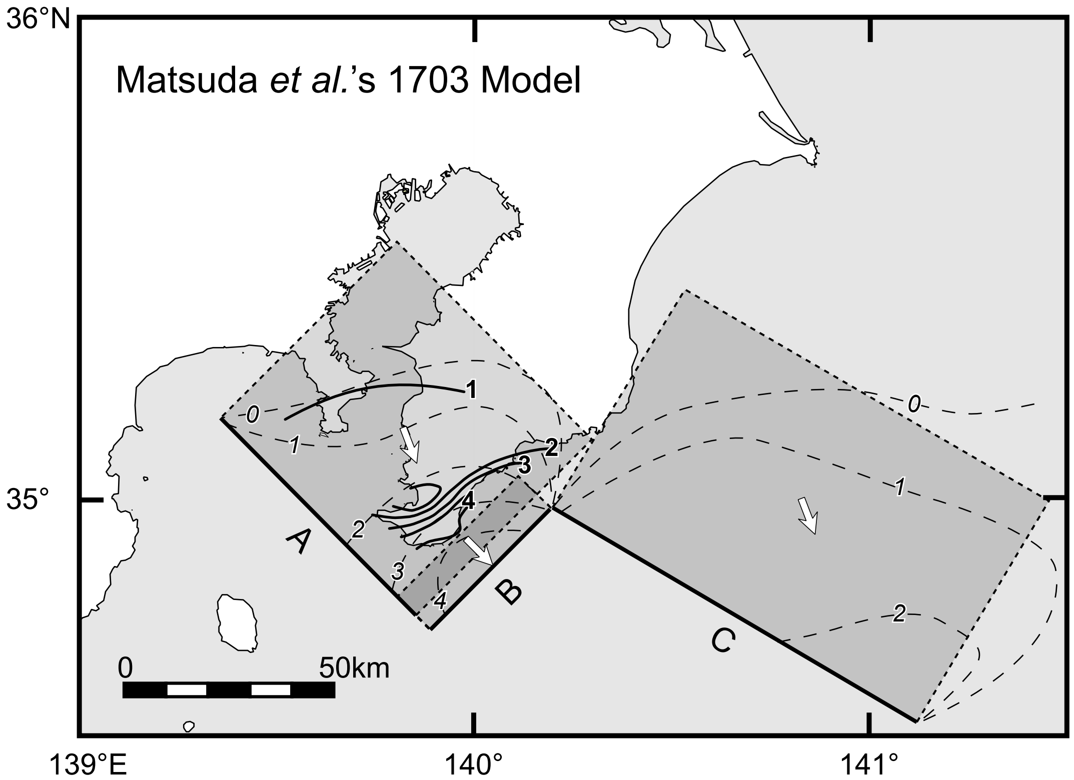
Figure 15. Depth contour map of the upper plate boundary of the Philippine Sea Plate proposed by Ishida [1991].

Table 1. Inferred and simulated tsunami heights for the 1703 Genroku Kanto earthquake.

Table 2. Parameters of the fault models for the 1703 Genroku Kanto earthquake.


b
Tokyo
N
Oiso
KMF
Miura
Peninsula
Boso
Peninsula
Fig.4
Fig.5
Fig.8
Fig.7
Fig.9
Fig.6
1923
(M7.9)
Sagami Trough
Kamogawa
Submarine Cliff
1703
(M8.2)
0
50km
a
38°N
36°
34°
136°E
138°
140°
142°
0
100km
NAM
Detail
in b
Tokyo
Japan Trench
Sagami Trough
10mm/y
PHS
PAC
Nankai Trough
4mm/y

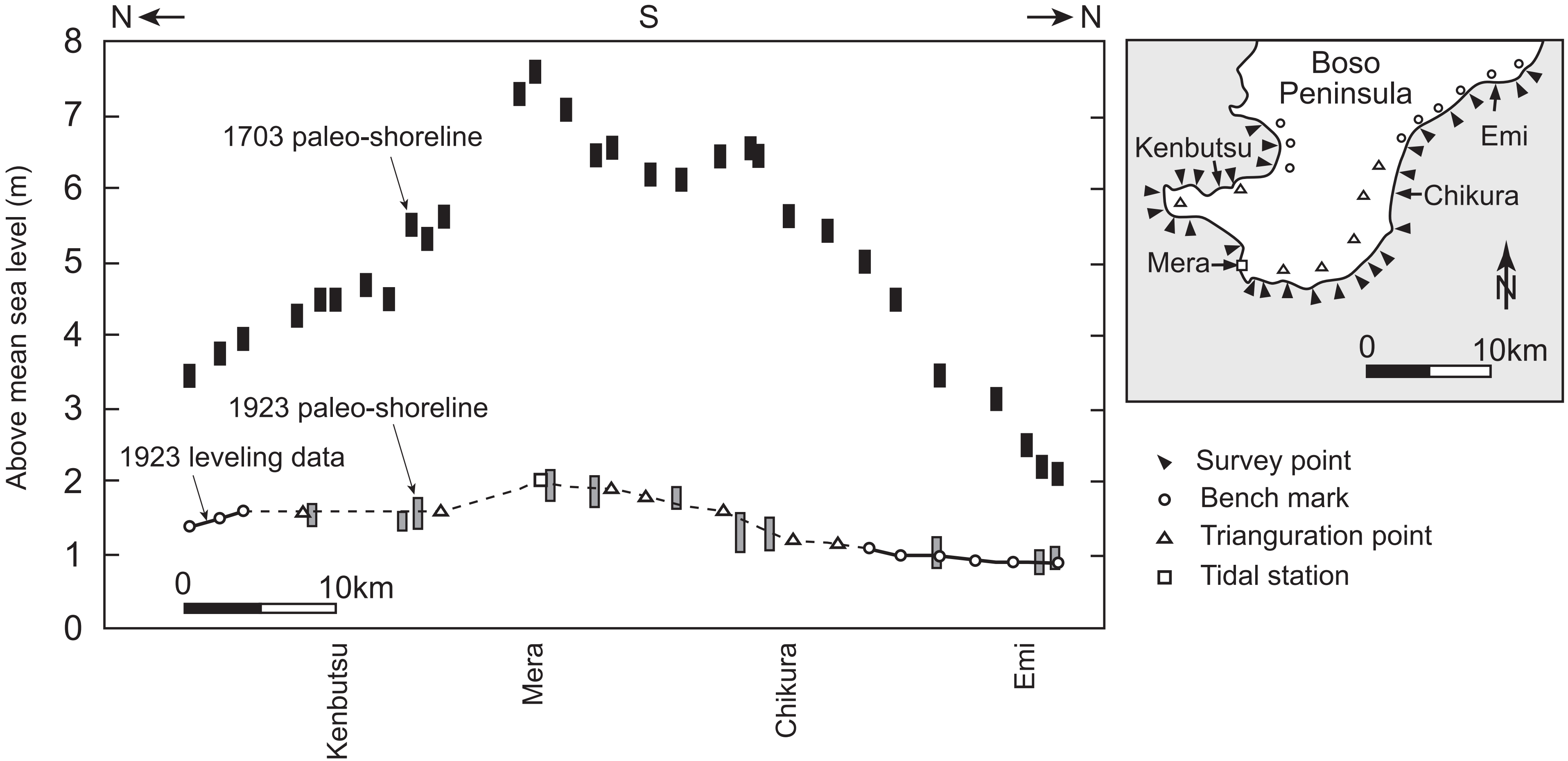

-0.6
-0.4
-0.2
0
0.2
0.4
0.6
1.0
1.2
0.8
Oiso
Miura
0.8
1.0
1.2
Jogashima
N
1923
0.2
0.4
0.6
0.8
1.0
Boso
1.2
Hota
1.4
1.6
1.8
Mera
Kominato
Kamogawa
0
10
20km



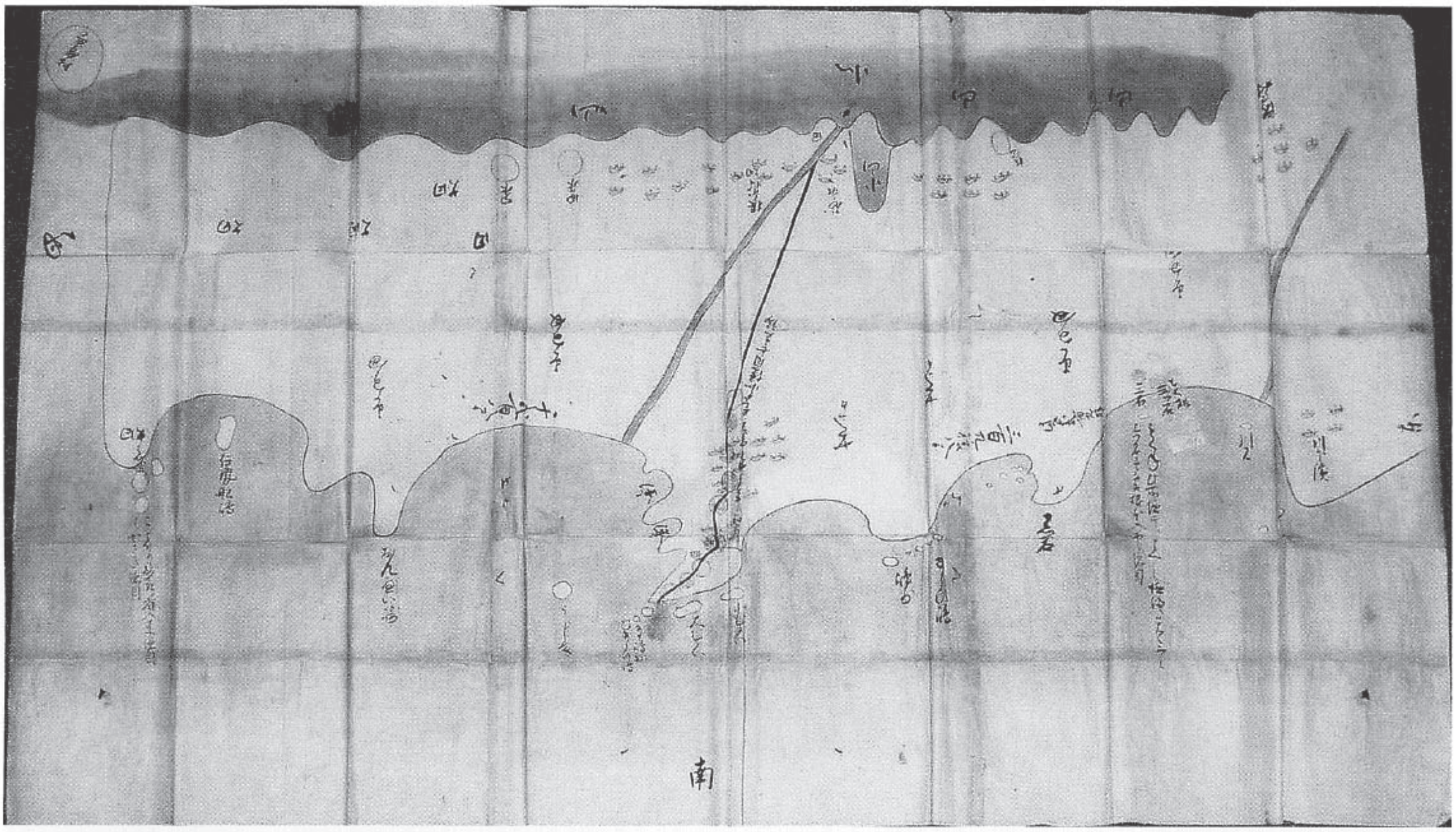
Matsuda et al.'s 1703 Model
36°N
35°
139°E
140°
141°
0
50km
A
B
C
0
1
2
3
4

1703 Terrace
4.5m asl.

1923 Terrace
1.5m asl.



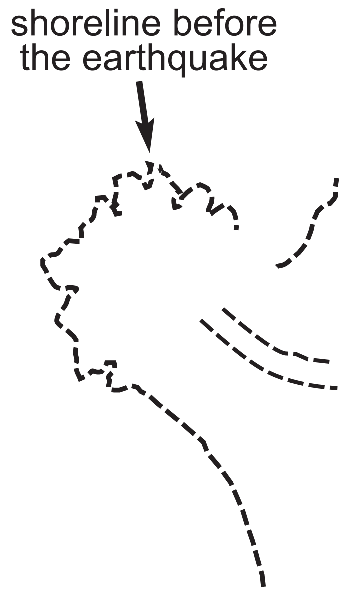
N
S
N
Above mean sea level (m)
0
1
2
3
4
5
6
7
8
1703 paleo-shoreline
1923 paleo-shoreline
1923 leveling data
0
10km
Kenbutsu
Mera
Chikura
Emi
Boso
Peninsula
Kenbutsu
Emi
Chikura
Mera
N
0
10km
Survey point
Bench mark
Trianguration point
Tidal station



Historical map painted in AD1673（modified from Sasou, 2003)

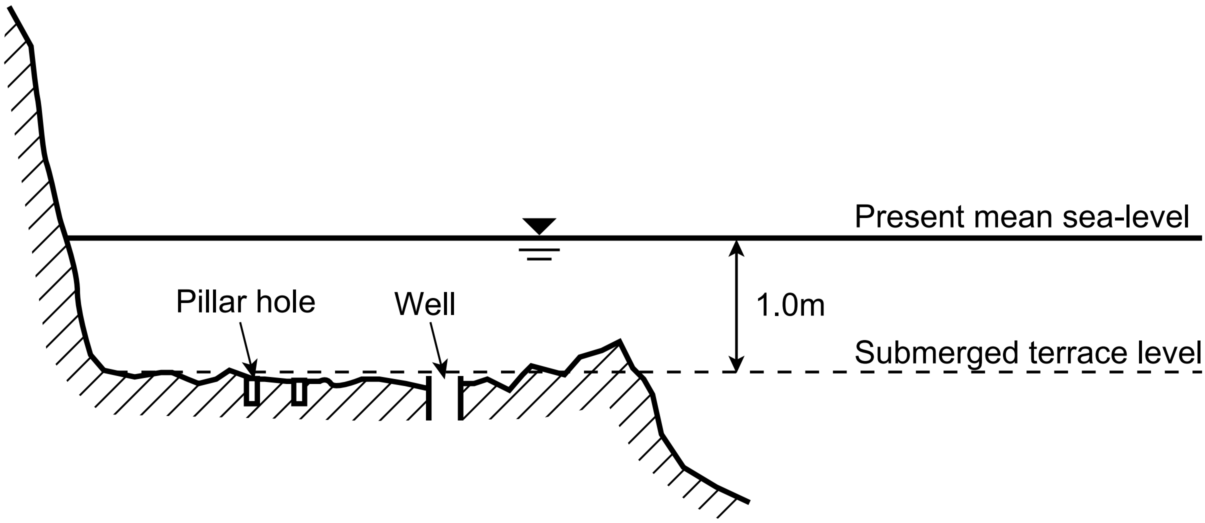
Topographic map surveyed in AD1884

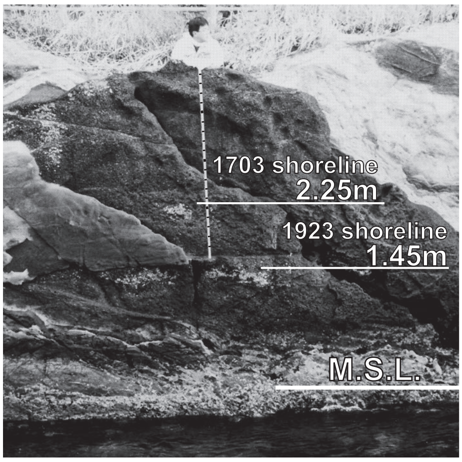

Recent topographic map



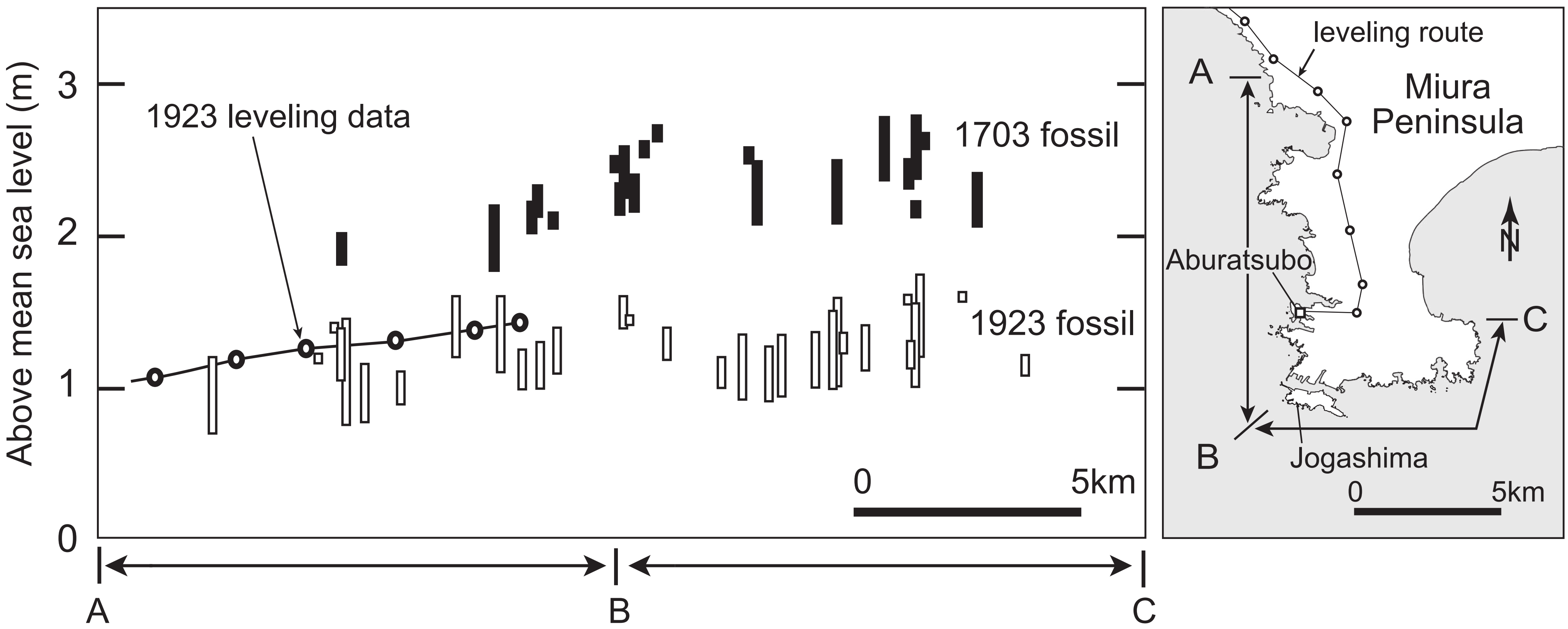

before the 1703 earthquake

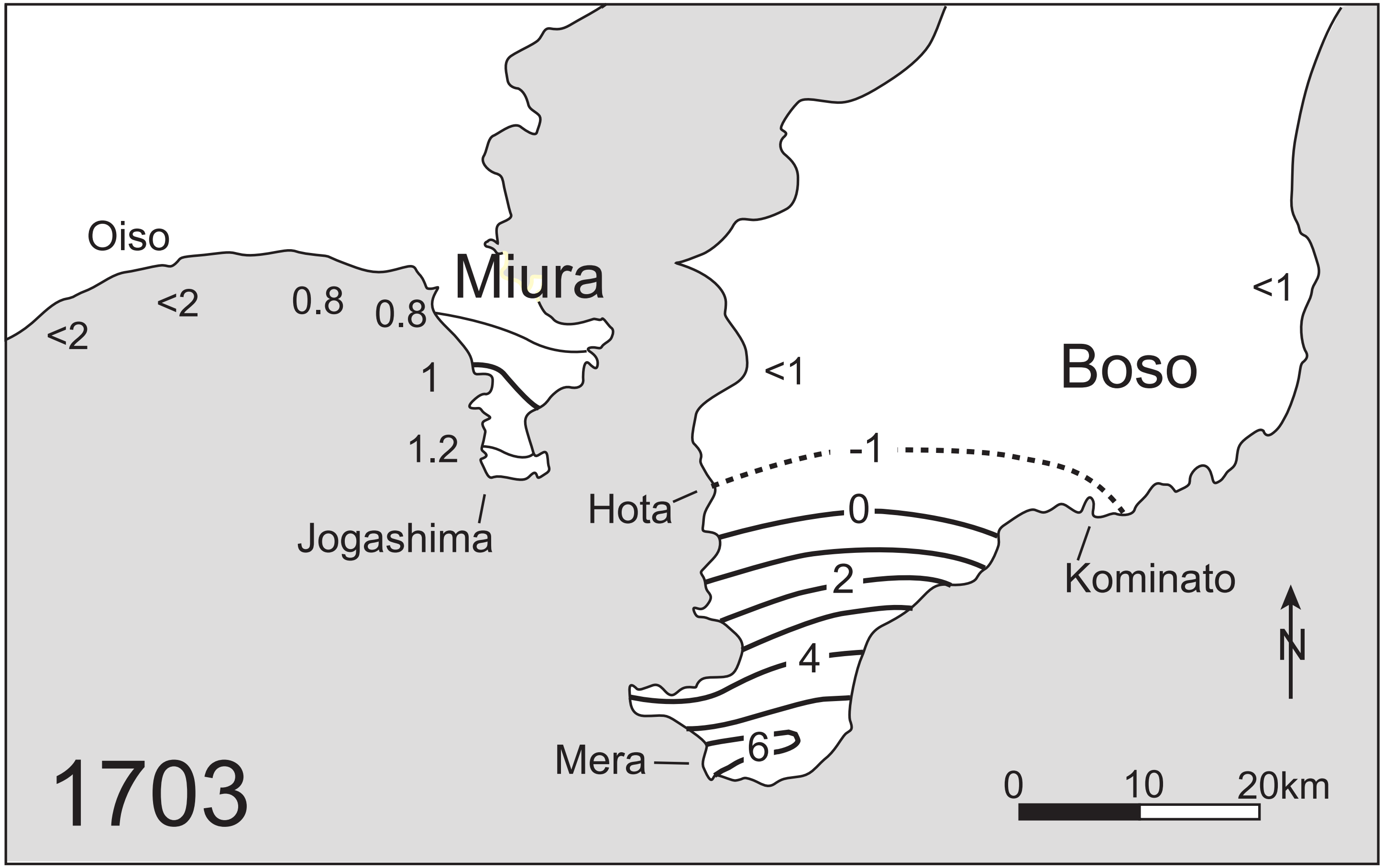
after the 1703 earthquake

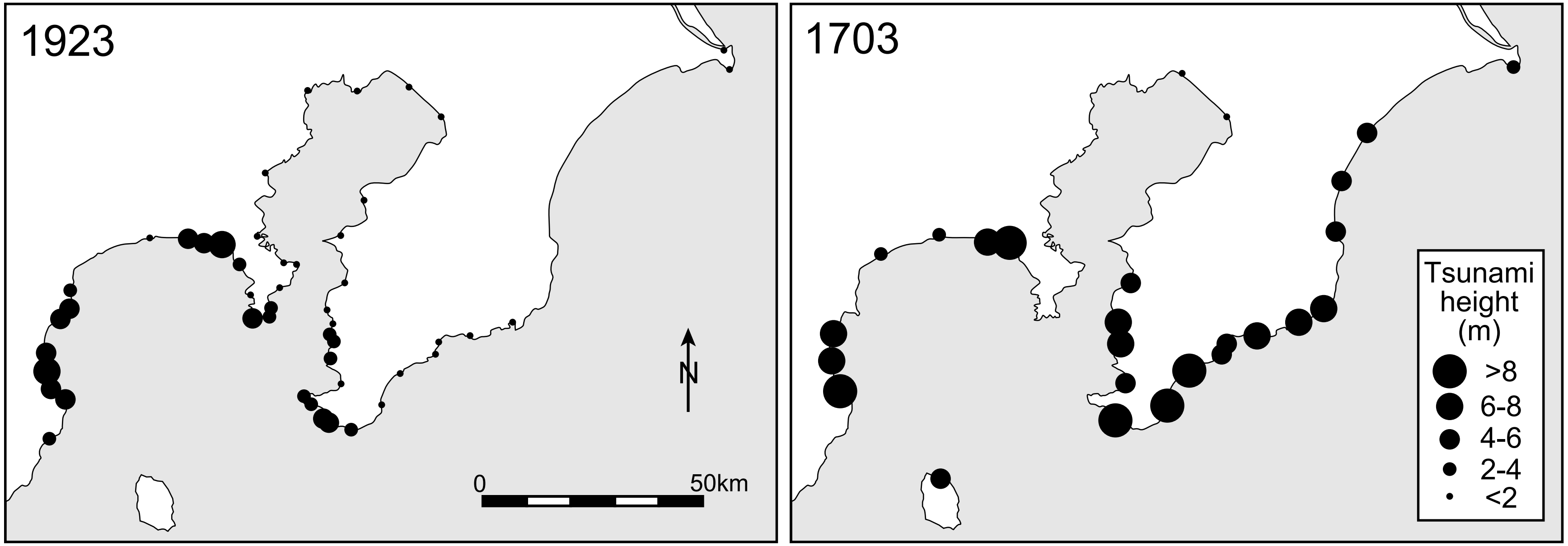

Present mean sea-level
1.0m
Pillar hole
Well
Submerged terrace level

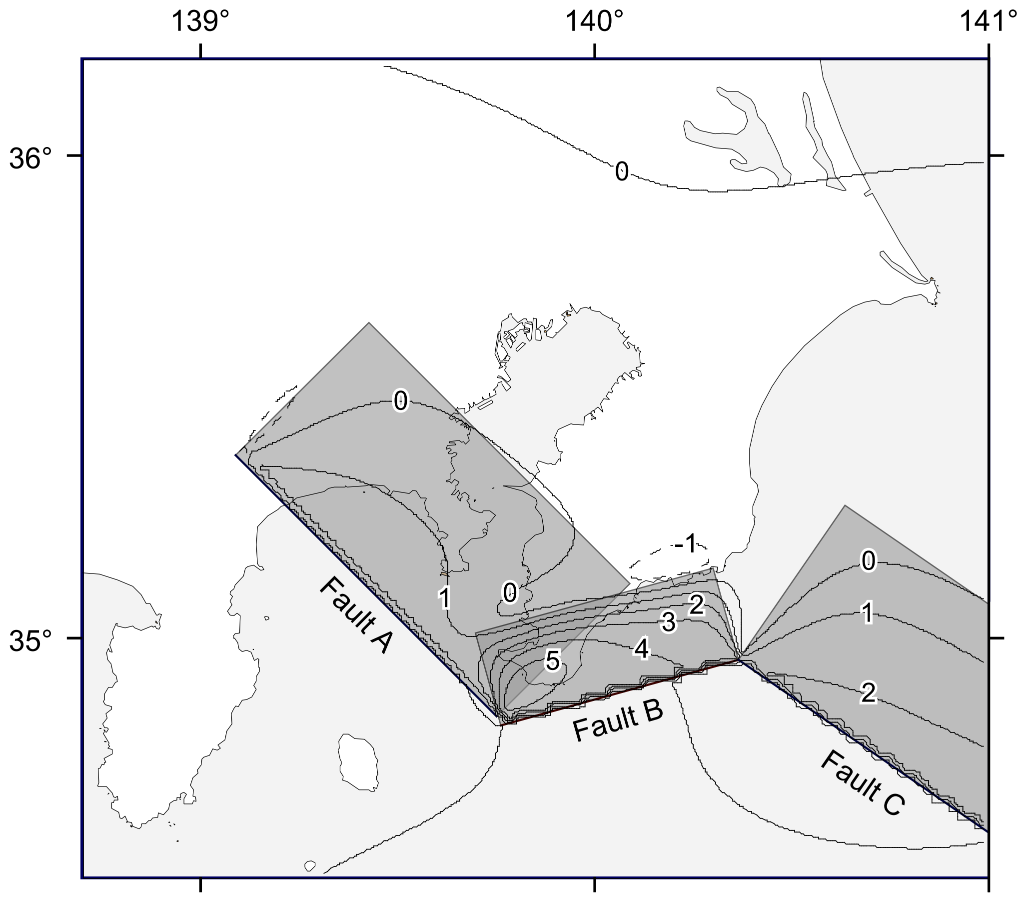


1703 shoreline
2.25m
1923 shoreline
1.45m
M.S.L.

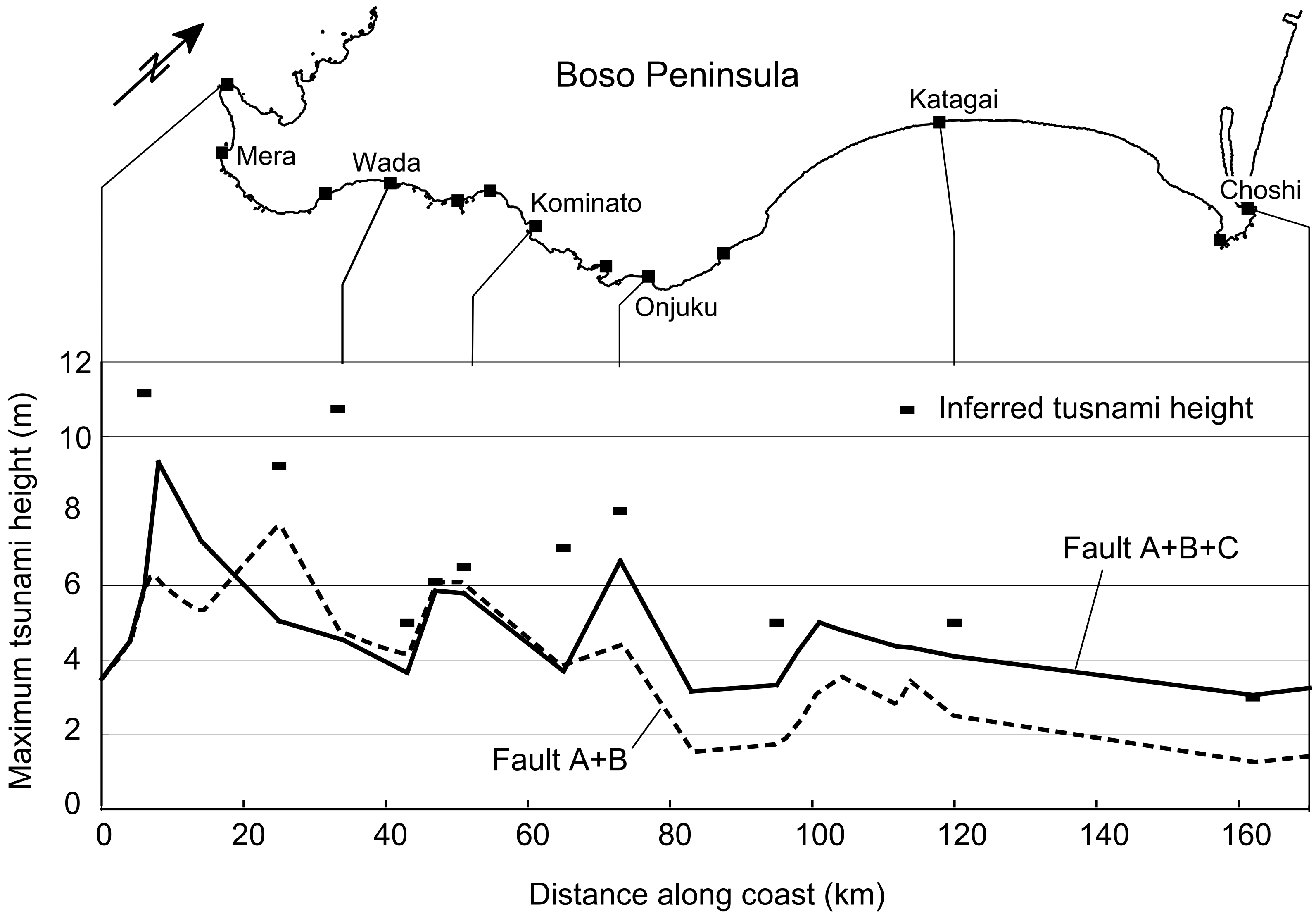

Above mean sea level (m)
0
1
2
3
1923 leveling data
1703 fossil
1923 fossil
0
5km
A
B
C
leveling route
Miura
Peninsula
A
Aburatsubo
N
C
B
Jogashima
0
5km


Oiso
<2
<2
0.8
0.8
Miura
1
1.2
Jogashima
<1
Boso
<1
-1
Hota
0
2
4
6
Mera
Kominato
N
0
10
20km
1703

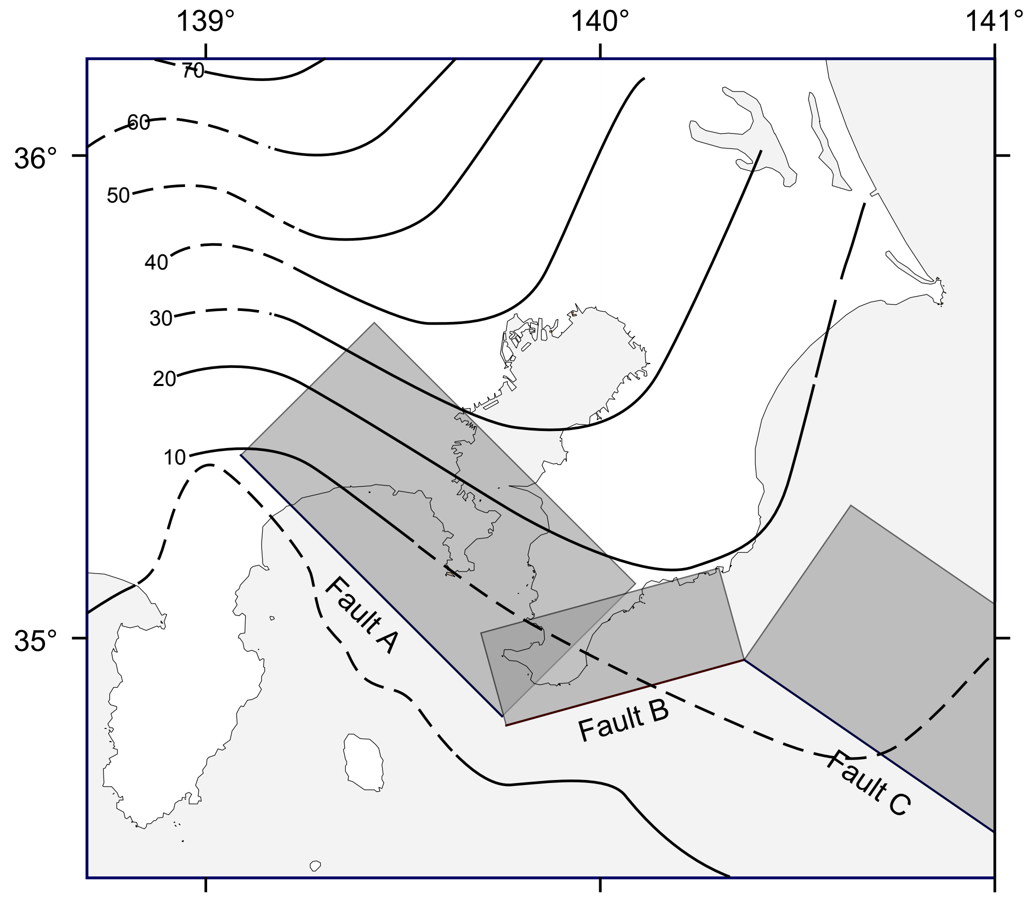

1923
0
50km
N
1703
Tsunami height (m)
>8
6-8
4-6
2-4
<2



139°
140°
141°
36°
35°
0
0
1
0
-1
0
1
2
2
3
4
5
Fault A
Fault B
Fault C



Boso Peninsula
Mera
Wada
Kominato
Onjuku
Katagai
Choshi
Inferred tusnami height
Fault A+B+C
Fault A+B
Maximum tsunami height (m)
Distance along coast (km)
0
2
4
6
8
10
12
0
20
40
60
80
100
120
140
160



139°
140°
141°
36°
35°
70
60
50
40
30
20
10
Fault A
Fault B
Fault C

| | 1923 Tsunami height (m) | 1703 Tsunami heighjt (m) | | | |
|---|---|---|---|---|---|
| | | Inferred tsunami | | Simulated tsunami | |
| | | Hatori (1976) | This study | Fault A+B | Fault A+B+C |
| Urayasu | 0.3 | 2 | 2 | 0.57 | 0.57 |
| Funabashi | 0.5 | 2 | 2 | 0.86 | 0.81 |
| Minato | 2 | 5.3 | 5 | 2.47 | 2.47 |
| Hota | 2 | 6.5 | 6.5 | 3.37 | 3.37 |
| Iwai | 3 | 7.3 | 7 | 4.99 | 4.99 |
| Tateyama | 1.8 | 5.6 | 6 | 4.47 | 4.47 |
| Mera | 6 | 10 | 11-12 | 5.94 | 5.94 |
| Chikura | 2 | 8.8 | 9.2 | 7.66 | 5.05 |
| Wada | 2 | 10.5 | 10.9 | 4.68 | 4.54 |
| Niemonjima | 2 | 7 | 5 | 4.18 | 3.66 |
| Kamogawa | 1.5 | 6.1 | 6.1 | 6.17 | 5.86 |
| Kominato | 1.8 | 6.5 | 6.5 | 6.09 | 5.79 |
| Katsuura | 1.2 | 7.4 | 7 | 3.84 | 3.7 |
| Onjuku | - | 8 | 8 | 4.4 | 6.66 |
| Torami | - | 5 | 5 | 1.71 | 3.33 |
| Ichinomiya | - | - | - | 2.27 | 4.24 |
| Hitotsumatsu | - | - | - | 3.2 | 5.01 |
| Koji | - | - | - | 3.58 | 4.81 |
| Ushigome | - | - | - | 2.84 | 4.36 |
| Shitengi | - | - | - | 3.52 | 4.33 |
| Katagai | - | 5 | 5 | 2.5 | 4.1 |
| Togawa | 1.5 | 3 | 3 | 1.29 | 3.06 |
| Choshi | 0.3 | - | - | 1.44 | 3.25 |

| | | strike (°) | dip (°) | rake (°) | L (km) | W (km) | U (cm) |
|---|---|---|---|---|---|---|---|
| | Fault A | 315 | 30 | 153 | 85 | 50 | 670 |
| This study | Fault B | 255 | 20 | 90 | 57 | 23 | 1200 |
| | Fault C | 300 | 30 | 135 | 100 | 50 | 710 |
| | Fault A | 315 | 30 | 153 | 65 | 70 | 670 |
| Matsuda et al. (1978) | Fault B | 225 | 70 | 90 | 40 | 30 | 600 |
| | Fault C | 300 | 30 | 135 | 100 | 70 | 710 |

Table 2