

Damage of the Tsunami of the East Japan  
Earthquake of March 11<sup>th</sup>, 2011  
along the coasts of the Kanto and Tohoku  
Districts

Yoshinobu TSUJI

# Gigantic Earthquakes in the 19<sup>th</sup> and the 20<sup>th</sup> centuries

**1837**    **Valdivia, Chile**    **Mt = 9.3**

**1841**    **Kamchatka**    **9.0**

**1868**    **Arica, Chile**    **9.0**

**1877**    **Iquique, Chile**    **9.0**

69 years

**1946**    **Aleutians**    **9.3**

**1952**    **Kamchatka**    **9.0**

**1957**    **Aleutians**    **9.0**

**1960**    **Chile**    **9.4**

**1964**    **Alaska**    **9.1**

40 years

**2004**    **Sumatra, Indonesia**    **9.0**

**2011**    **East Japan**    **9.0**

# 釜石市街地に滝のような津波が侵入する映像

## Video film taken by a citizen of Kamaishi city shows....

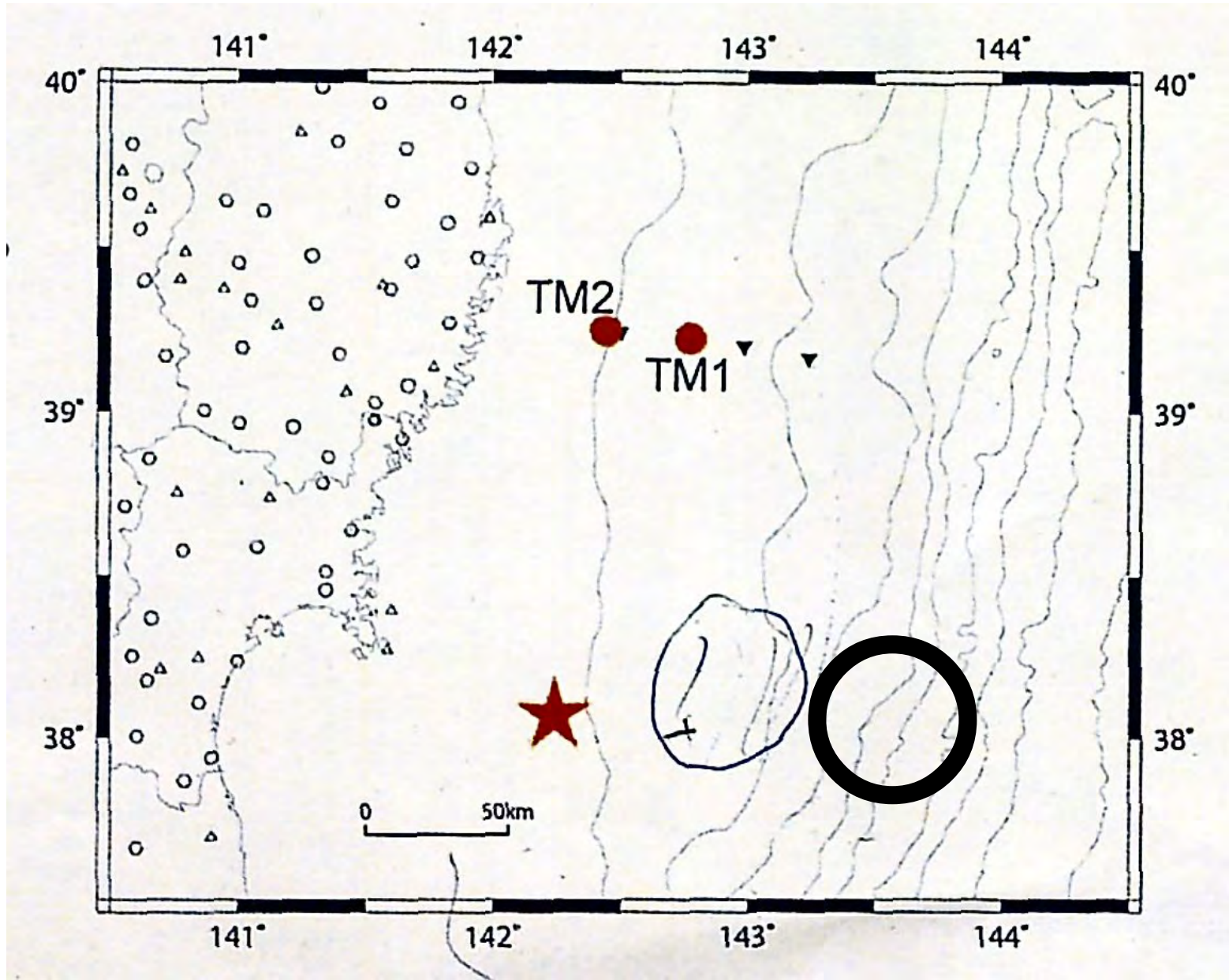
津波警報を聞いて、直ちに高所に避難し終えた人が、高所から撮影した映像

After hearing tsunami warning announcement, a man took video film from a sheltering higher place

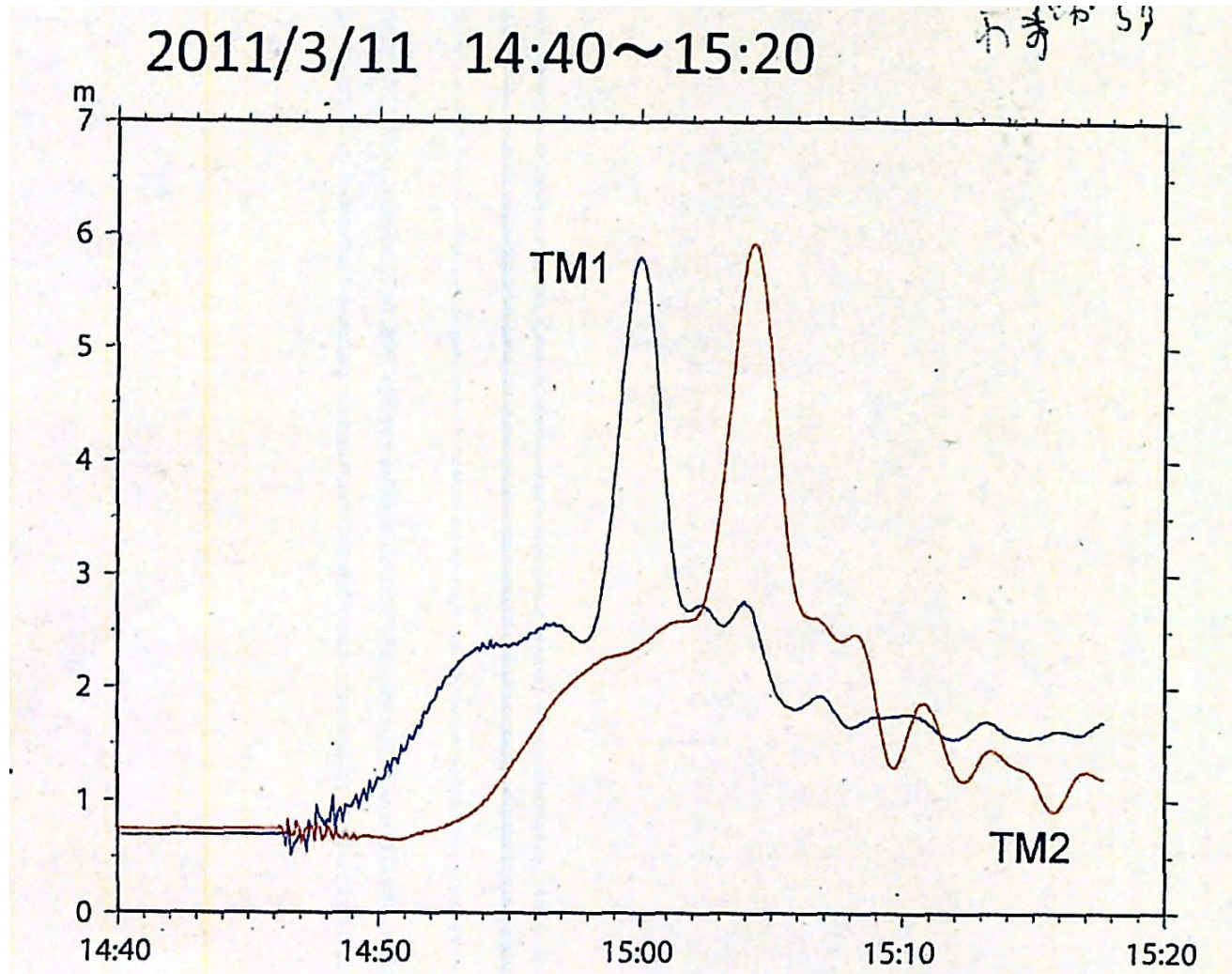
→ 「滝」がやってきたのは、地震後25分以上時間が経過しているように見える。

About 25 minutes after the shaking, suddenly a water made a wall or a water fall rushed into the residential area of Kamaishi City

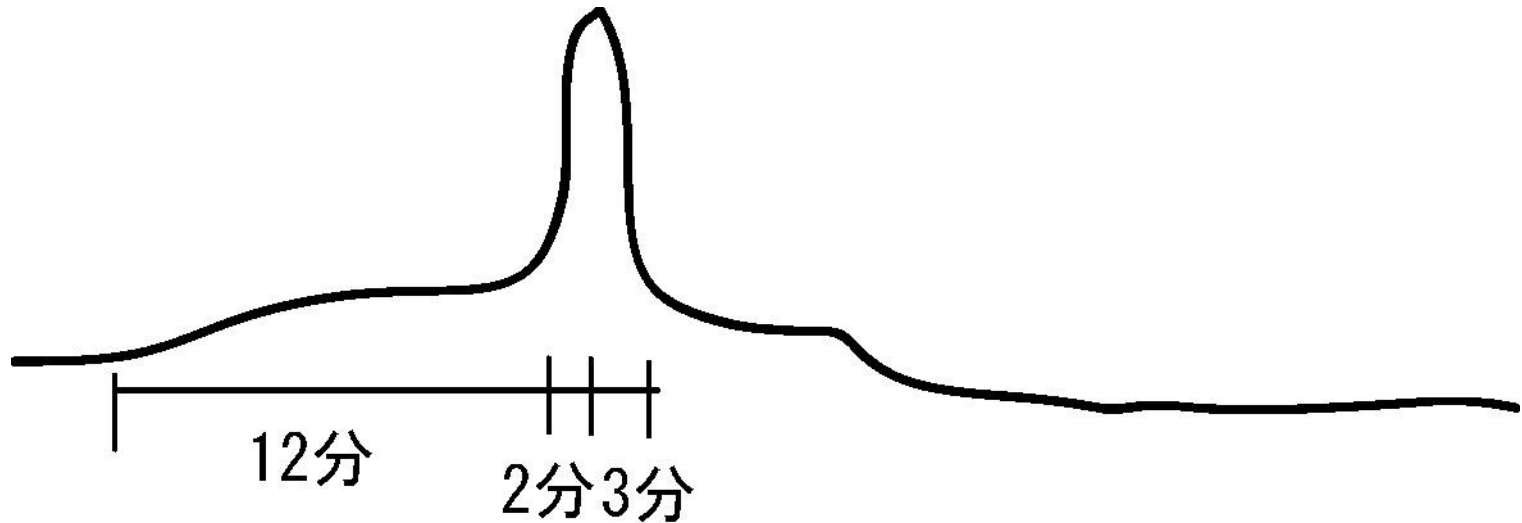
# Locations of the ocean bottom tide gauges



# Records of sea surface level changes recorded by submarine gauges



# The Peak is finished within 5 minutes とがったピークはたった5分で終わる

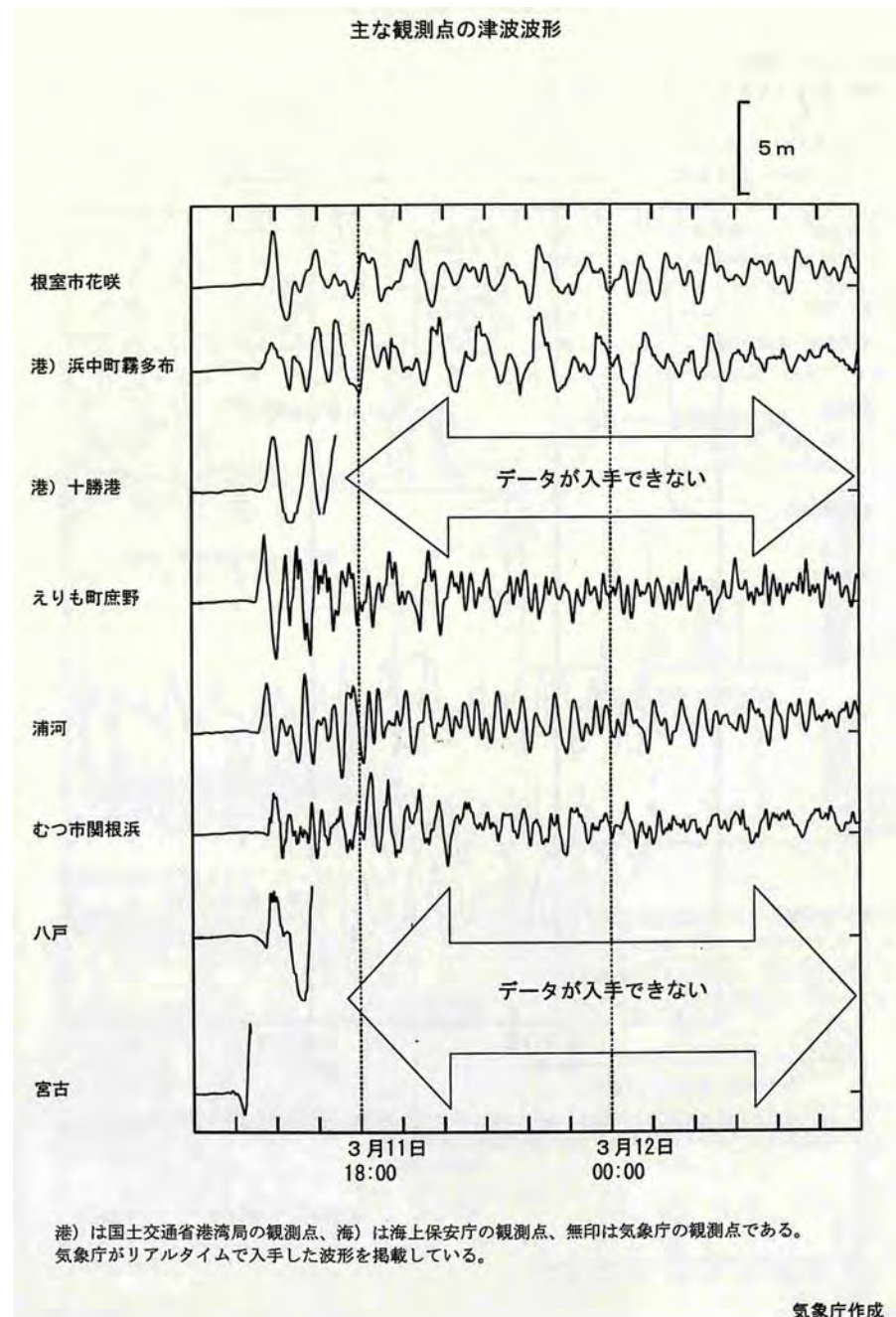


水深1000mだと、波速=6km/分、直径30km以内の現象。

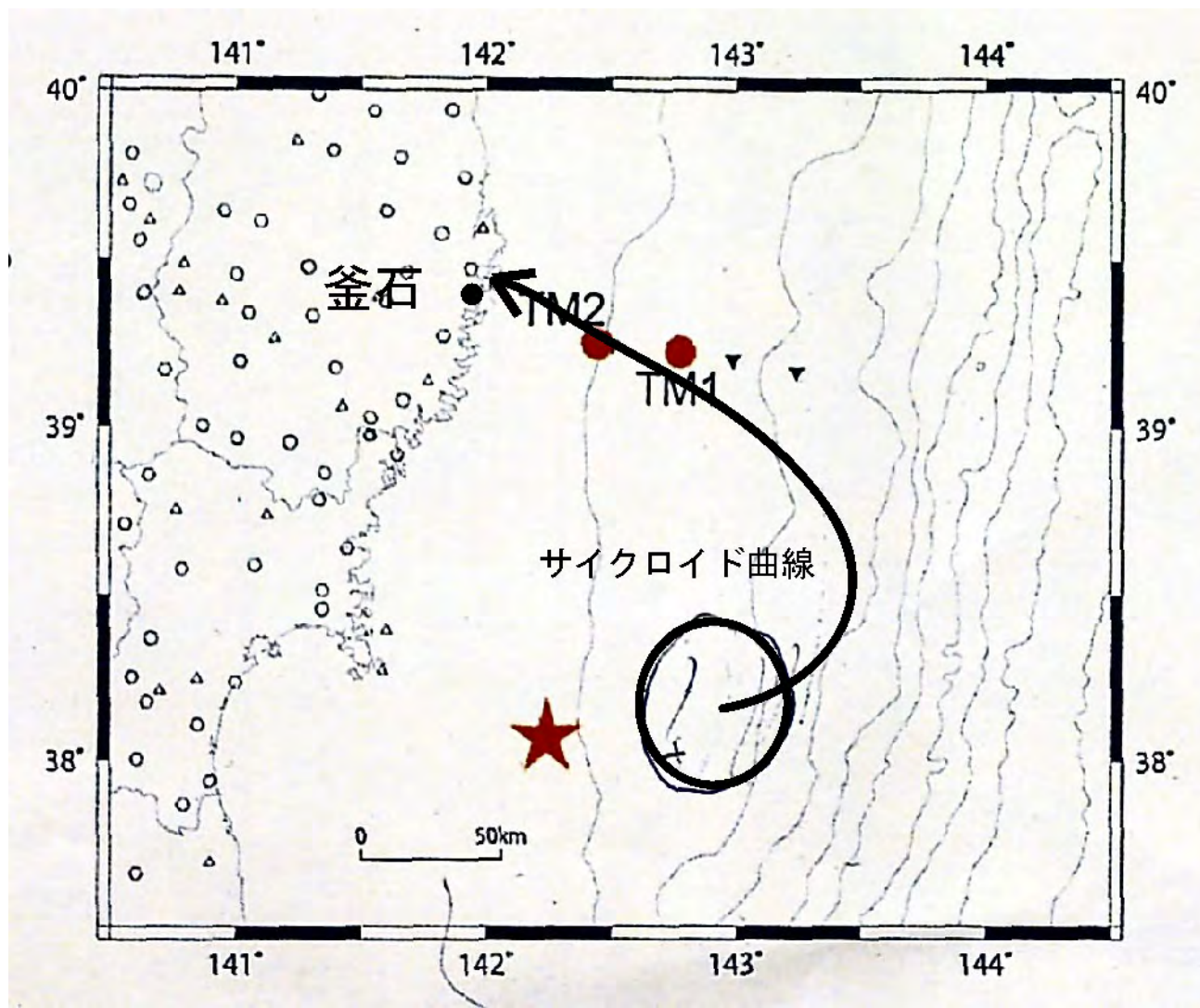
水深3000mでも 直径50km以内に原因がある。そこだけで海底が周囲より3~4m多く隆起した場所がある。



# Tide Gauge Records

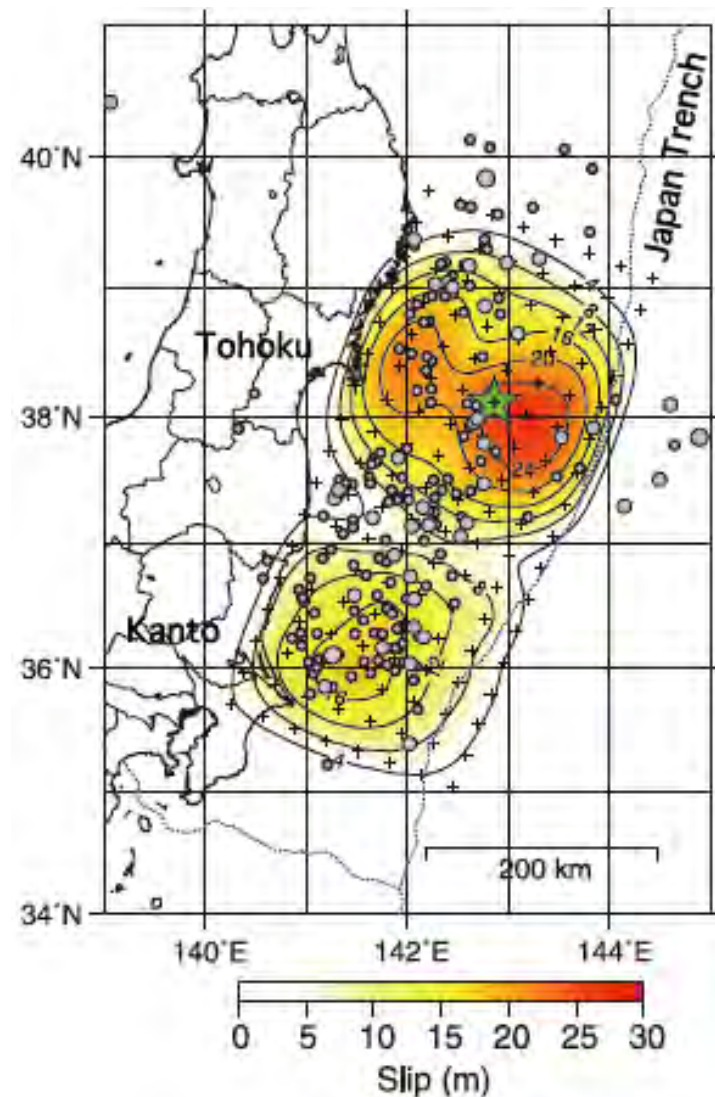


釜石の「滝」の津波は、  
このピークによるものであろう。



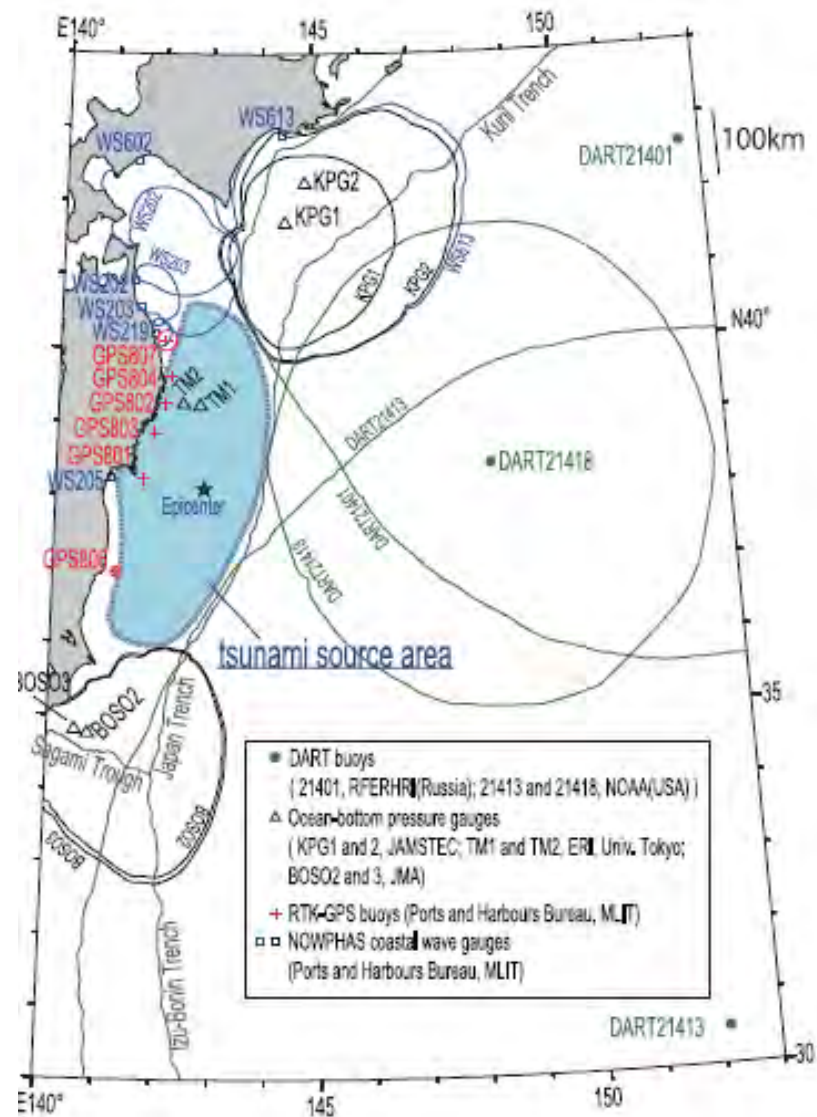


# Distributions of After Shocks and Crustal Motion



Slip distribution on the fault. The large green star represents the epicenter of the mainshock ( $M_w = 9.0$ ), and gray circles represent aftershocks ( $M \geq 5.0$ ) within 24 h of the mainshock. Crosses represent grid points on the fault plane for calculating synthetic waveforms. Contour interval in slip distribution is 4 m.

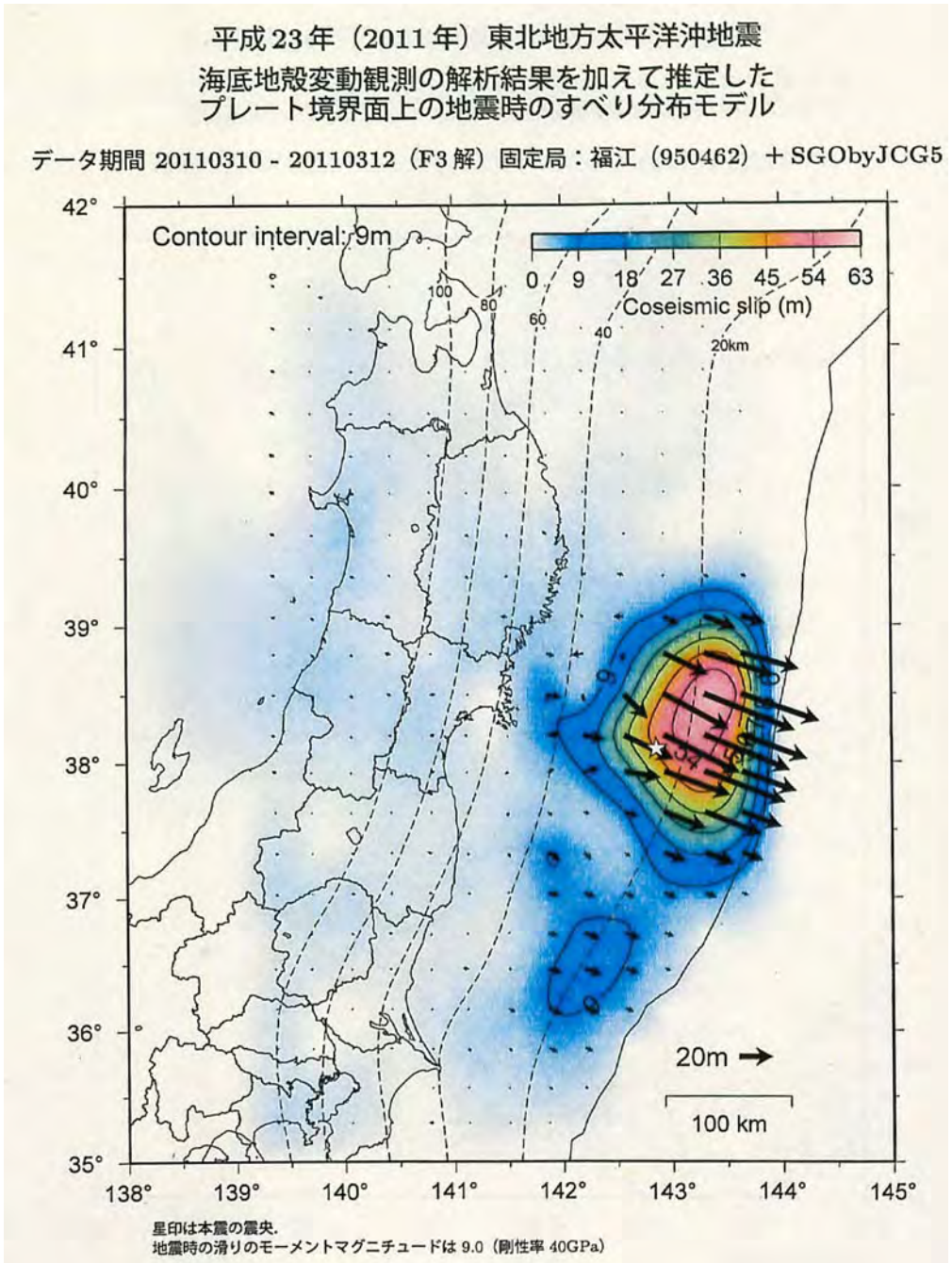
# Source Area of the Tsunami estimated by tidal records



Tsunami source area of the 2011 off the Pacific coast of Tohoku Earthquake determined by the back-propagation of tsunami arrivals from offshore observation stations.

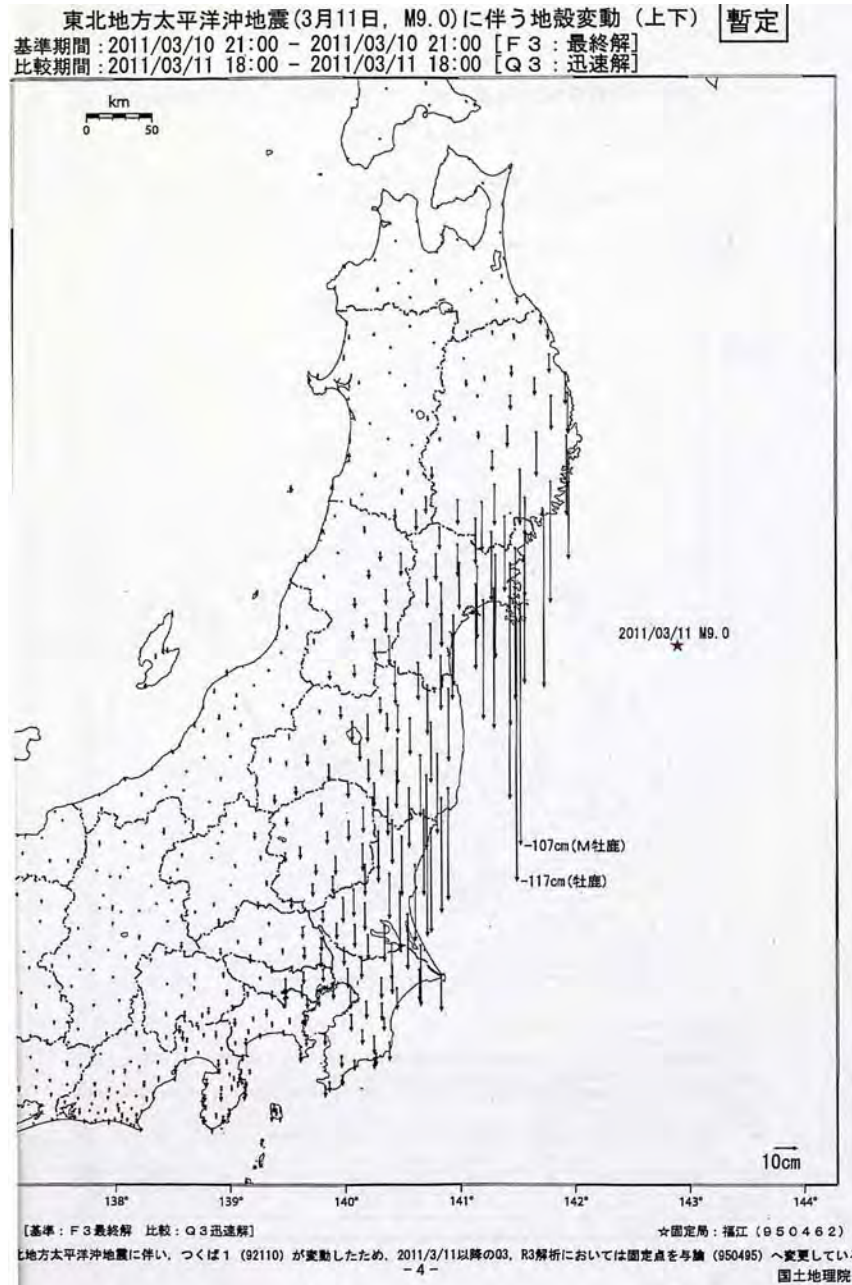
Hayashi et al., Tsunami source area of the 2011 off the Pacific coast of Tohoku Earthquake determined from tsunami arrival times at offshore observation stations, *Earth Planets Space*, **63**, 809–813, 2011

# Horizontal Motion of the Crust

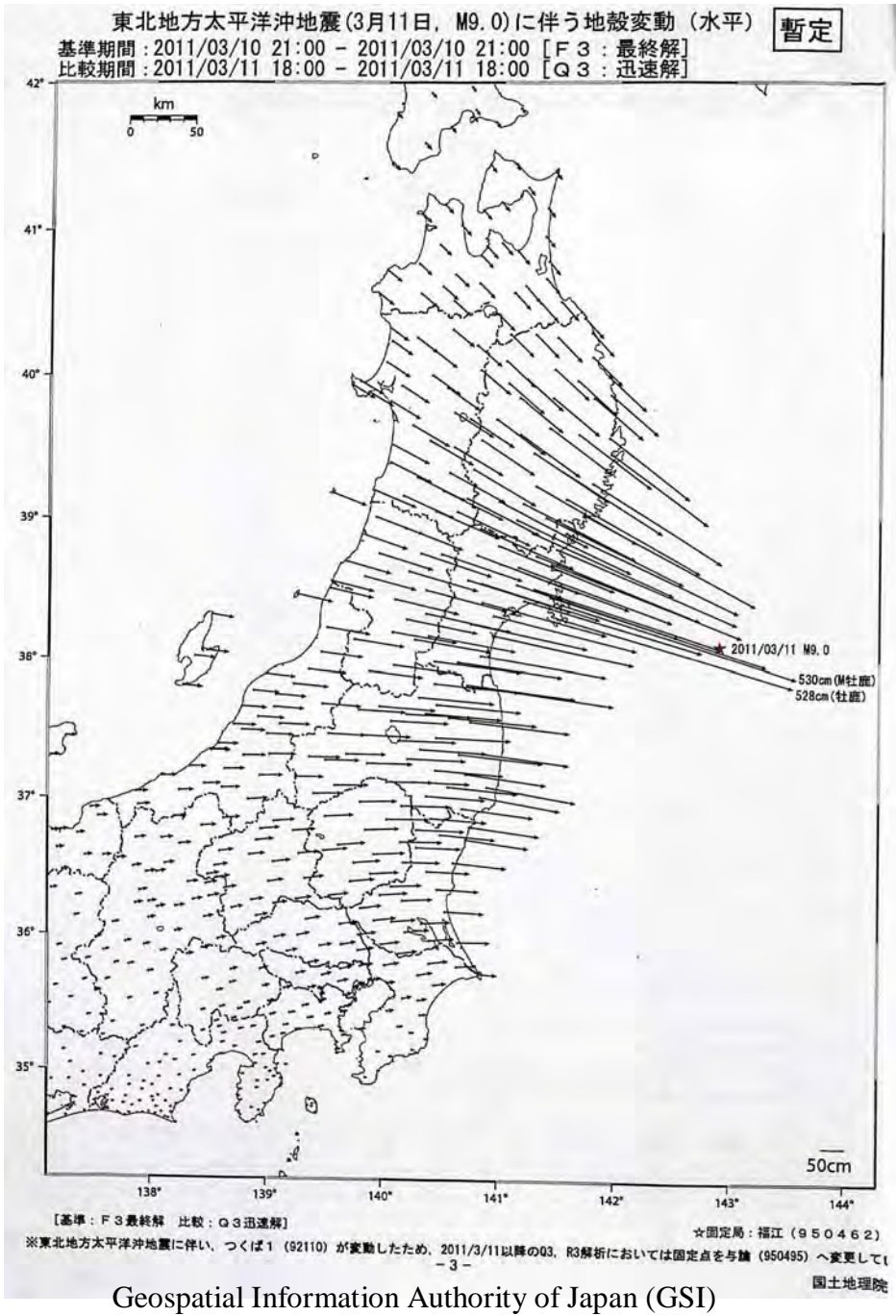




# Vertical Crust Motion



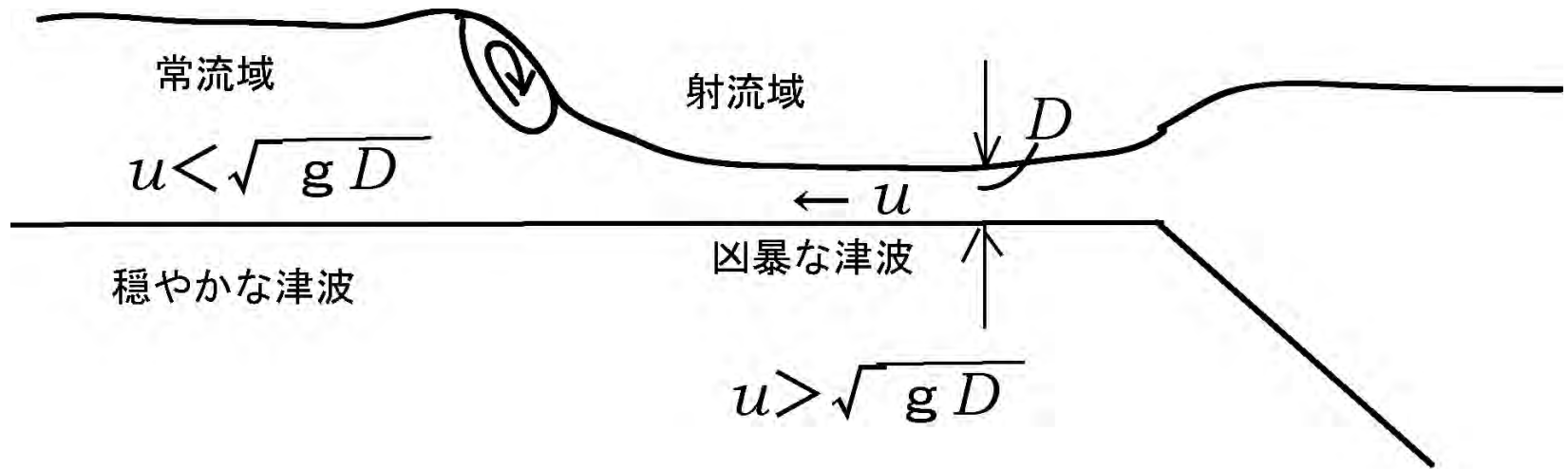
# Horizontal Crust Motion





# 常流の津波と射流の津波

## Tsunami of super and sub-critical flows

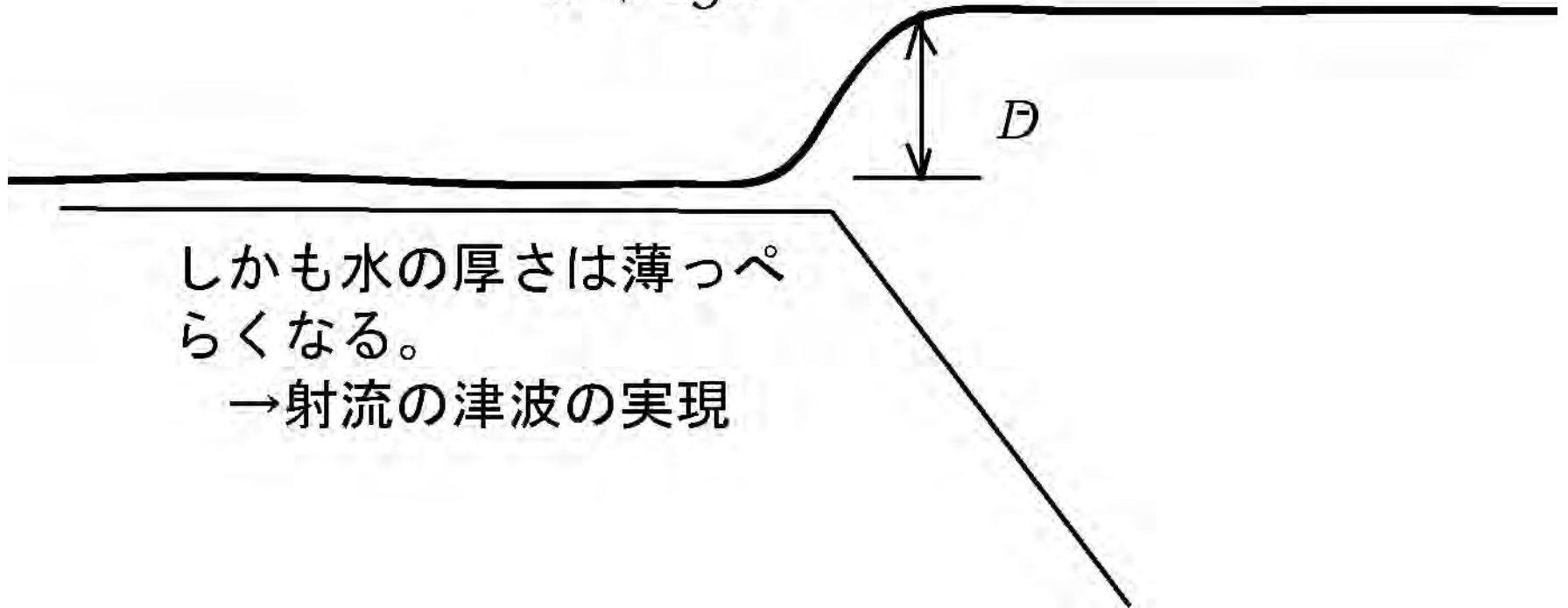


# 射流の津波の形成

## Formation of super critical flow

自由落下の速度を獲得する

$$u = \sqrt{2gD}$$



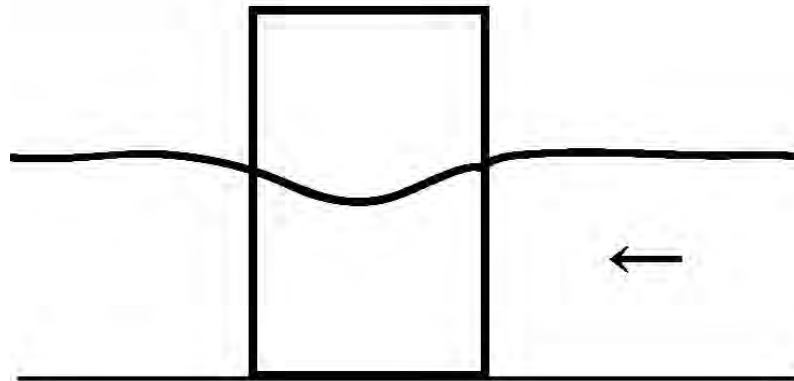
しかも水の厚さは薄っぺらくなる。

→射流の津波の実現

# 常流・射流の見分け方

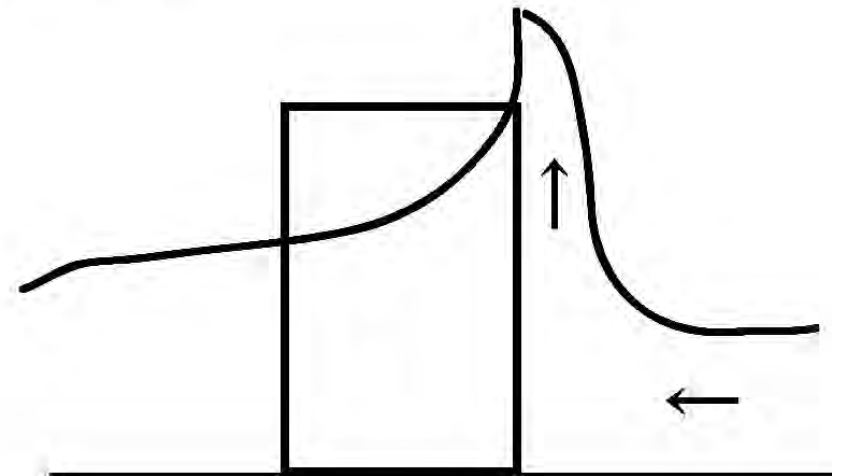
## How do you distinguish super and sub-critical flow?

常流がビルにぶつかったとき



Sub-critical flow

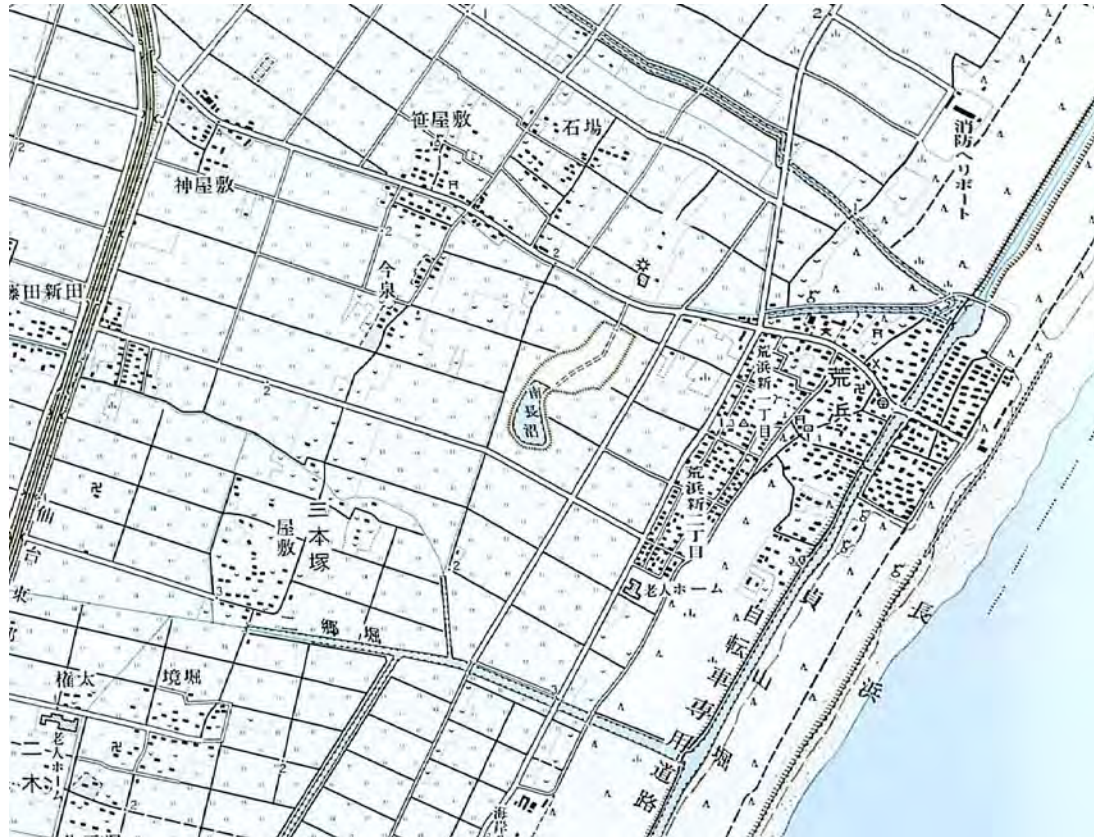
射流がビルにぶつかったとき



Super critical

## 2. 仙台市若林区荒浜で起きたこと

What happened at Arahama village, Sendai ?



集落は1~2mの低地。避難すべき高地が全くない。前面の堤防は6m。

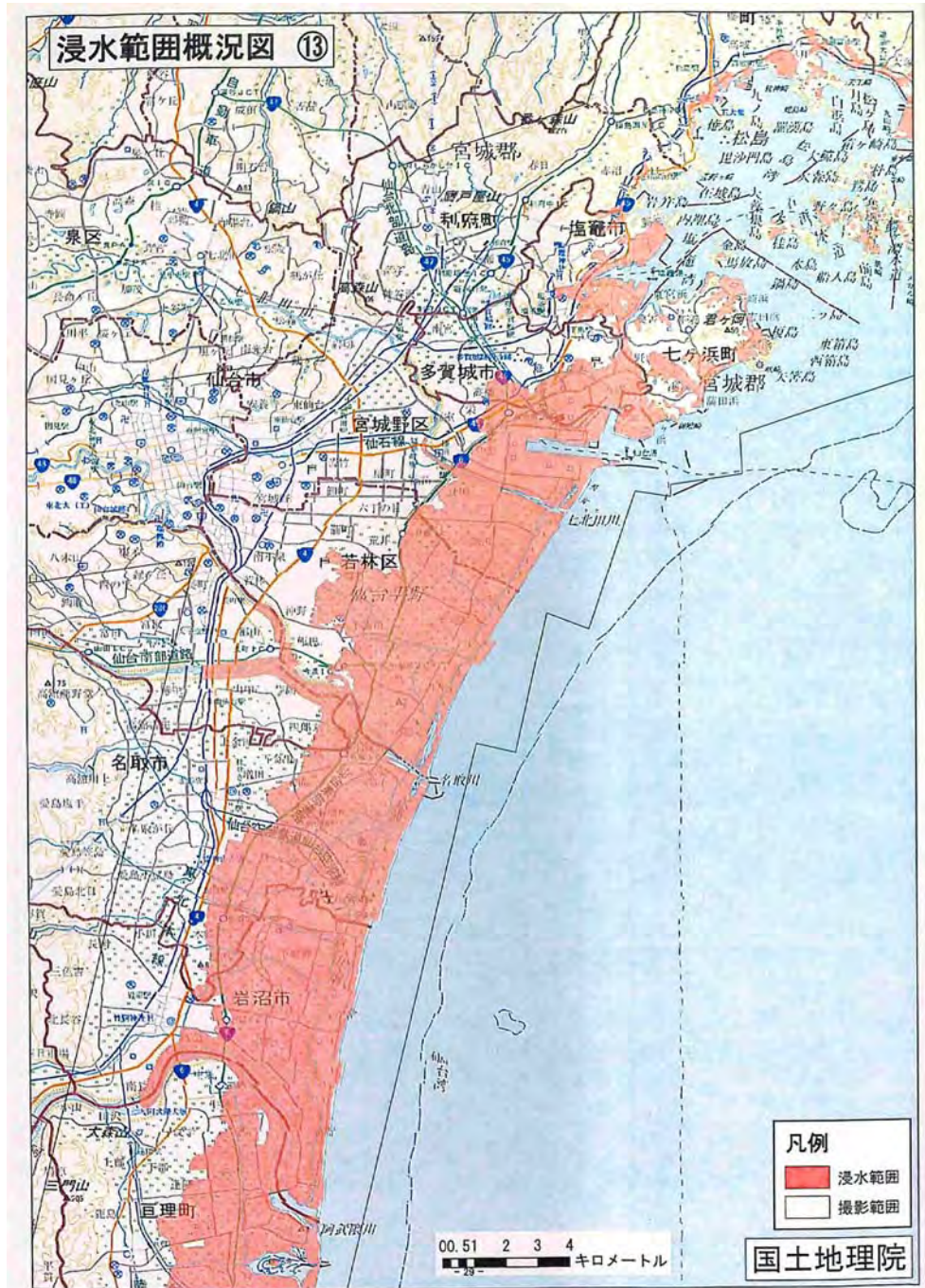


# Inundated Area in Ishinomaki Region





# Inundated Area in Sendai City Zone





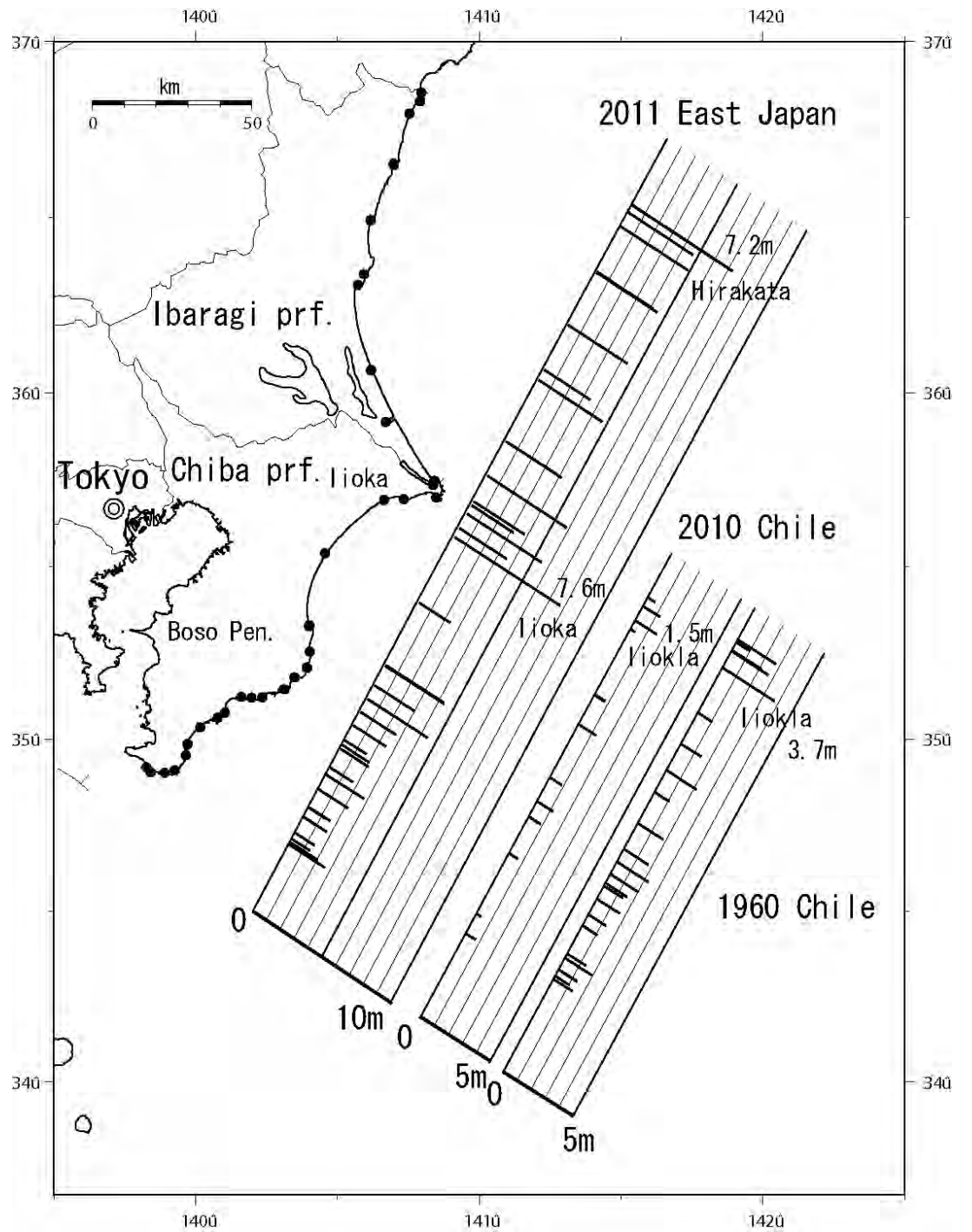
# South of Sendai Air Port





# Inundation Area in Fukushima Prefecture



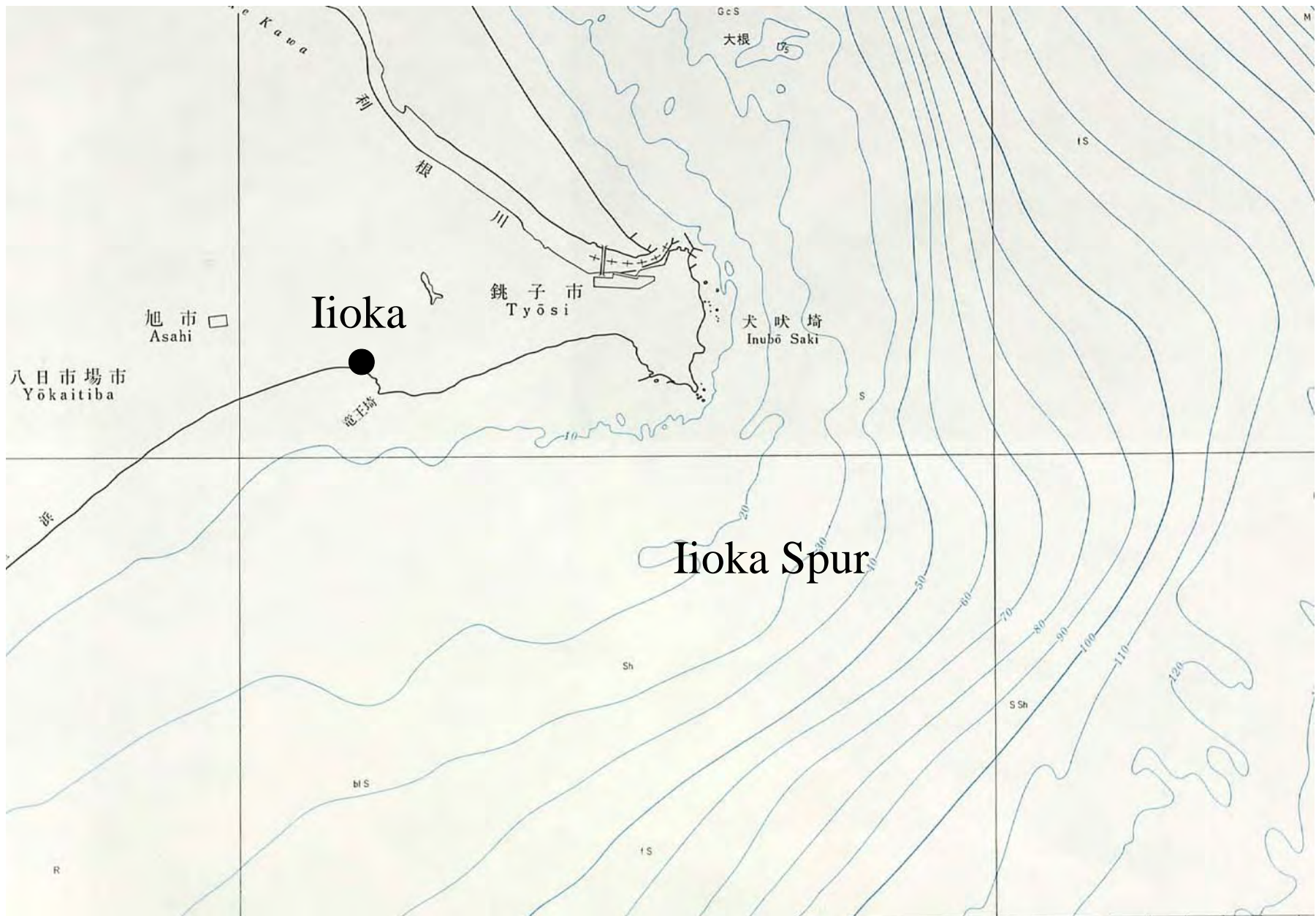


# Chiba Prefecture

## **Damage of Iioka Town**

- 13 people were killed, 3 missings  
at Iioka Town
- → Tsunami Heights 7.6meters











**Sea water passed over the top of the sand  
dune  
Height:7.6m**



# Fishery factory at Iioka









# Tsunami Damage in Iioka Town 1

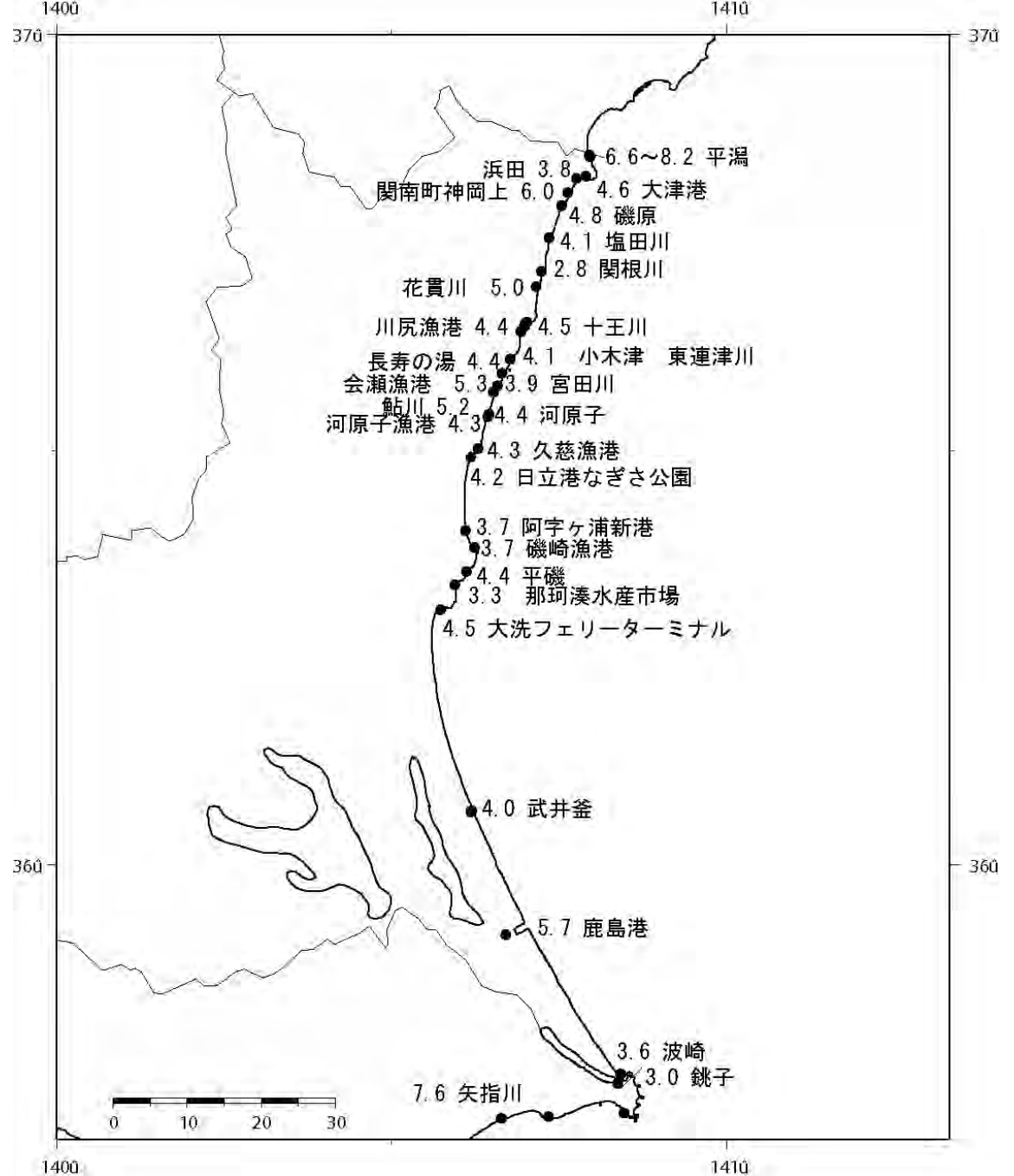








# Distribution of Tsunami Heights on the coast of Ibaraki Prefecture





# Ootsuko Port, Kita Ibaraki city

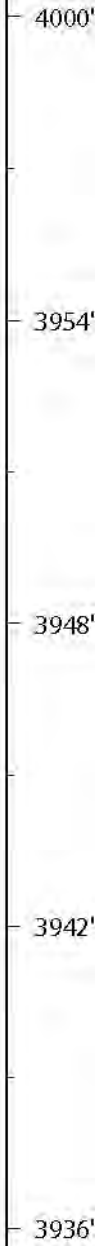
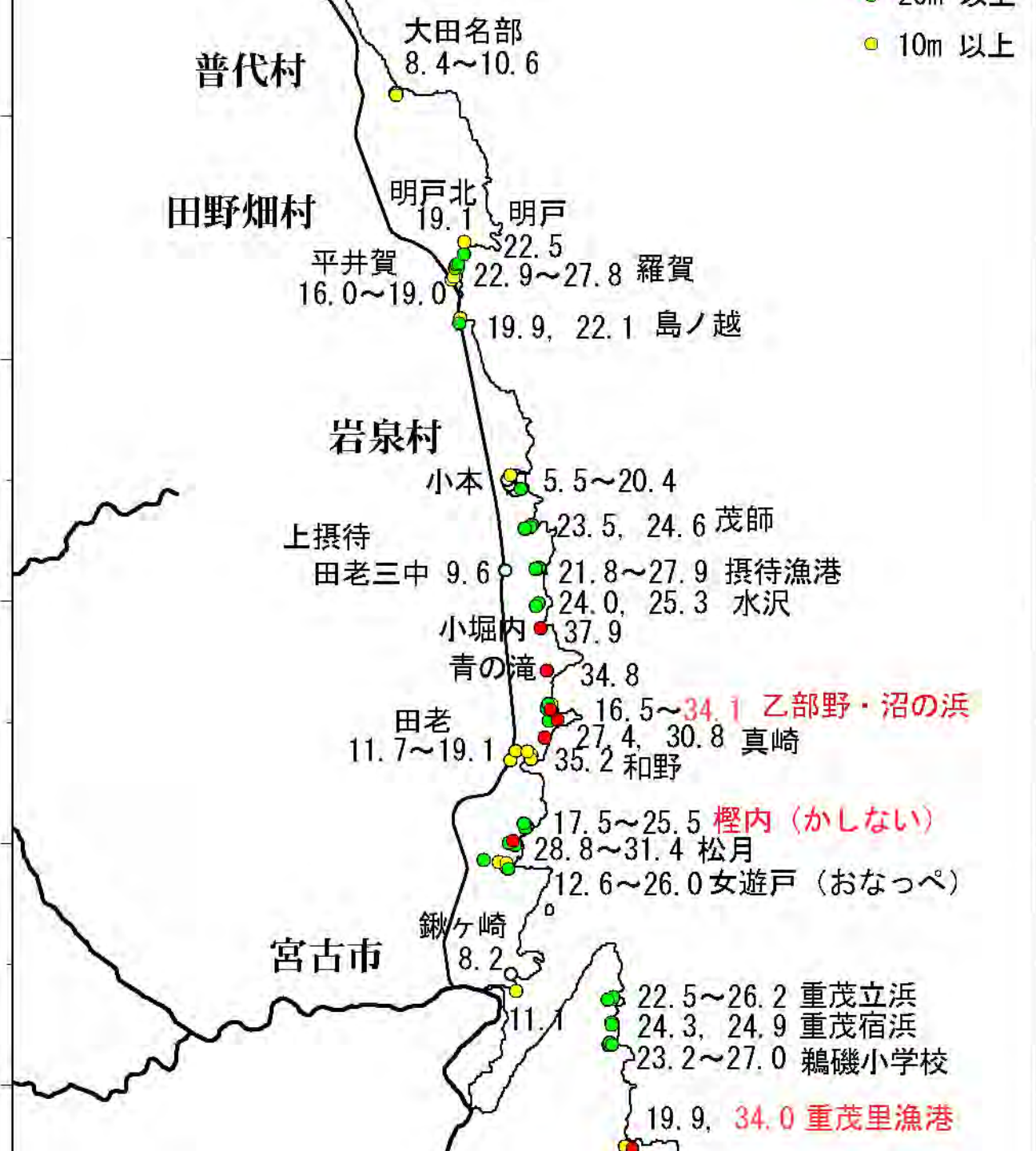
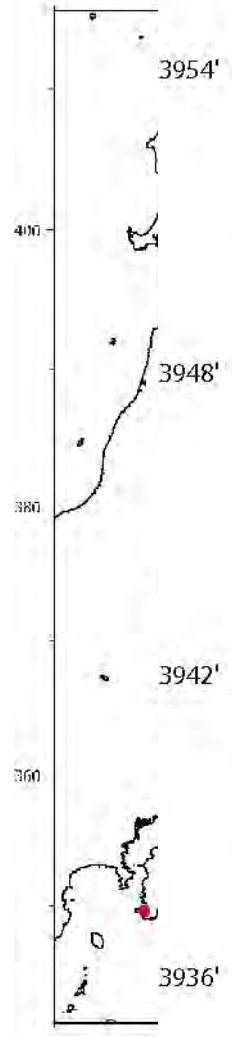




# Tsu on

● 20m 以上  
● 10m 以上

Ari



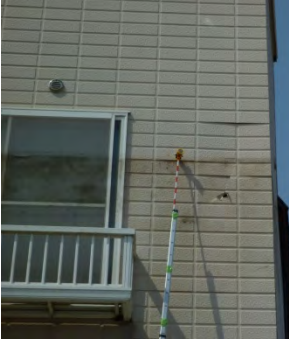


Kuwagasaki,  
Central Part of  
Miyako City





# Iw56. Kuwagasaki Area in Miyako City



\* 七滝湯の隣の家のWater Mark.



# At the entrance of Miyako City Hall





# Standing on the 3rd floor of the City Hall of Miyako





# Tsunami Came!





# Iw7-9. Onappe Coast

## 宮古市崎山・女遊戸(おなっぺ)海岸、南側斜面1-3



\* 測定起点は女遊漁港岸壁面(測定時1.33 m. トータルステーションは堤防面に設置(MSL 7.859 m(測定時潮位補正済み). 雑草流跡・堆積物に基づく.



# 宮古市女遊戸海岸





# 宮古市女遊戸(おなっぺ)栽培漁業センター Damage of fishery cultivation center at Onappe





# Matsutsuki Coast, Miyako city

## No sea wall





# Iw53. 31.4 meter point on the north slope of Matsutsuki valley

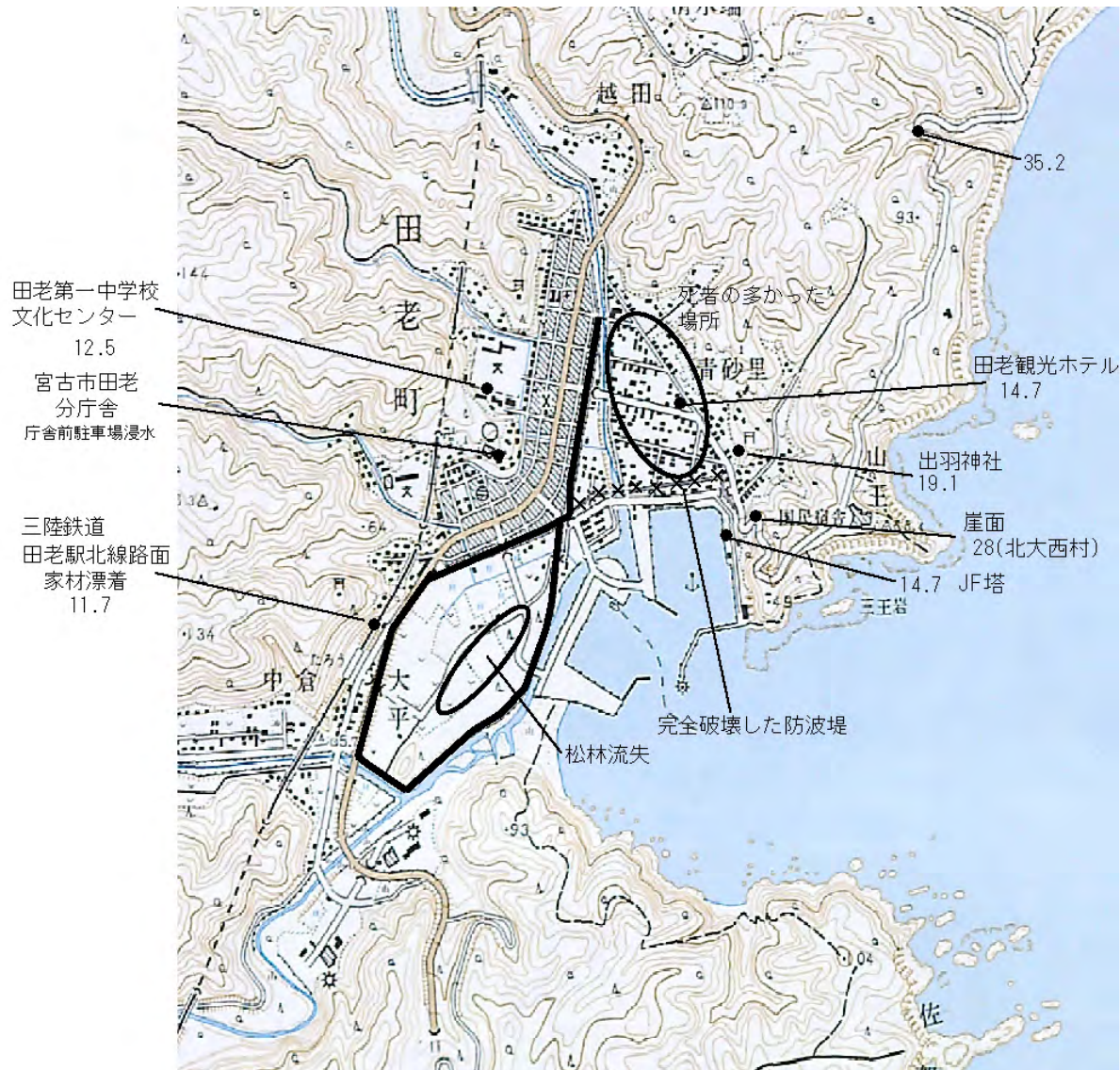


\* 北側の崖. 植生痕跡・堆積物に基づく. 測定時間は8時3分24秒. 汀線測定起点は39度42分03.0秒, 141度58分18.3秒.



# Taro Town, in Miyako City

## 宮古市 田老町



# View from the Taro Town hall





# 田老町外側防波堤の破壊消滅

New sea wall was destroyed. Notice the bottom of the concrete block





# 破壊消滅した10m防波堤

Disappeared sea wall except the part of the  
crossing road gate





**破損が起きていない田老旧防波堤  
家は全壊したが多くの人の命は守った  
Old sea wall was slightly damaged and saved people who lived in the  
residential area.**





# 田老漁港 1 Taro Fishery Port

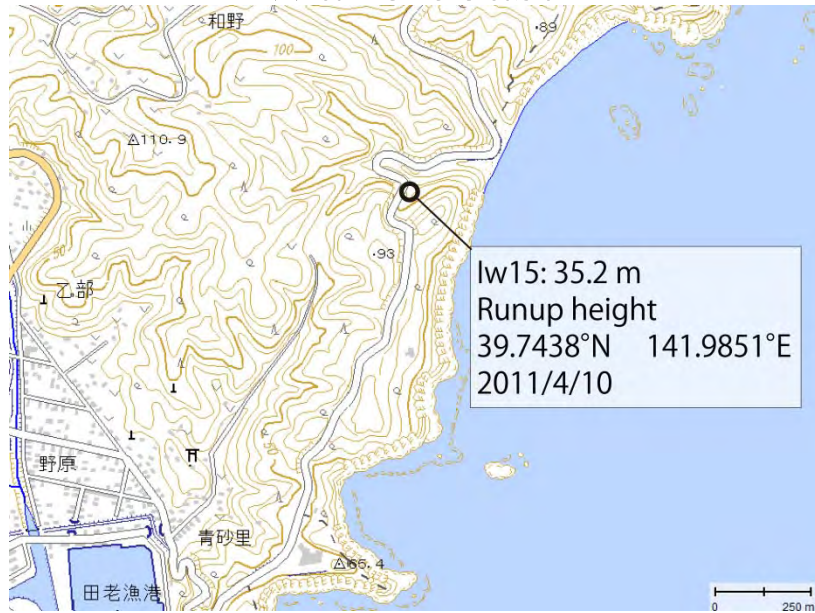


# 田老漁港魚市場 Taro port Fishery Market





# Iw 15. 宮古市田老町和野 Wano coast



\* 斜面上の1点. 汀線上の起点は  
39度44分39.7秒、141度59分  
16.2秒. 漂着物の堆積に基づく.  
幸い無人の海岸。





**田老町青野滝漁港 34.8m**  
**Aonotaki fishery Port**





# 田老・青野滝漁港遡上高測定点



# Koborinai fishery port

## 小堀内漁港地図



37.9m



# 小堀内漁港浸水点測量 Measurement in the KOBORINAI Port





# 小堀内の測量作業 Measurement Work at Koborinai Port





# 小堀内漁港・津波による倒木 Damage of Trees at Koborinai





# 小堀内漁港





# 小堀内海水到達点



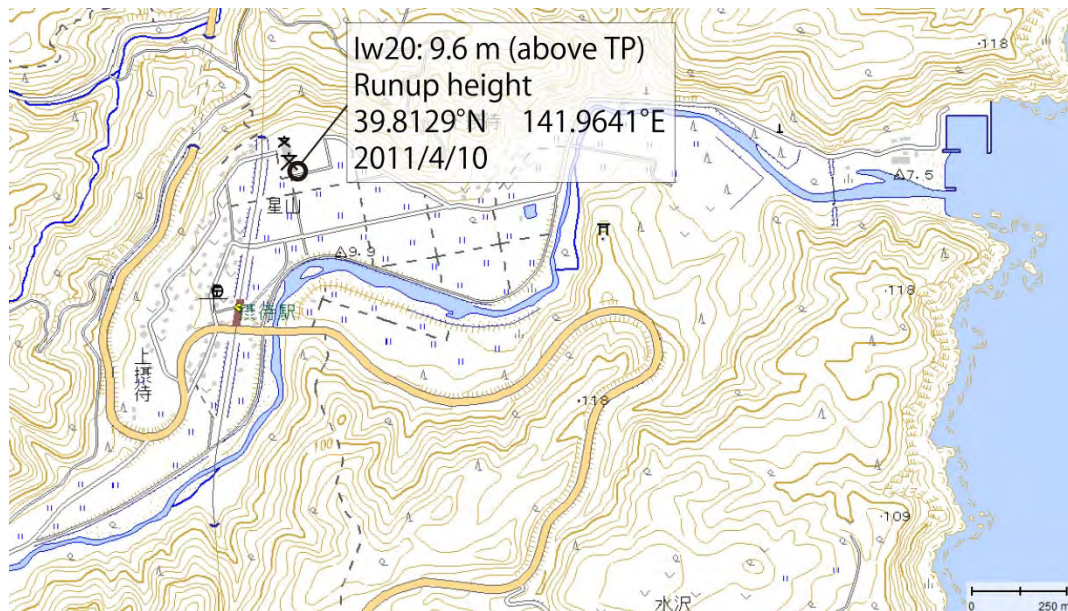


# Three Firepersons were killed 消防士3人、標高30m地点で殉死





## Iw20. Sea water reached at 3 km from the coast at Settai Village



\* 田老第三中学のグラウンドに薄く浸水. グラウンド面を遡上高とする. 接待水準点15.9 mを起点として測定. MSL 0 mはTP 0 mの13.3 cm上方にある. 今回の地震によりこの付近の地盤は約30 cm沈下したことを考慮して正味の津波高さを算出.





田老町摂待  
明治三陸海嘯死者供養塔  
Stone monuments for the victims of the 1896 Meiji  
Sanriku Tsunami at Settai





# 宮古市田老町・摂待の光景

## Damage of rice field at Settai





# 摂待・津波で破壊した道路橋 Destroyed Bridge at Settai





# Shimanokoshi

## 島ノ越 三陸鉄道駅高架部流失





**The railway station of Shimanokoshi was  
destroyed**

**流失した三陸鉄道島ノ越駅**





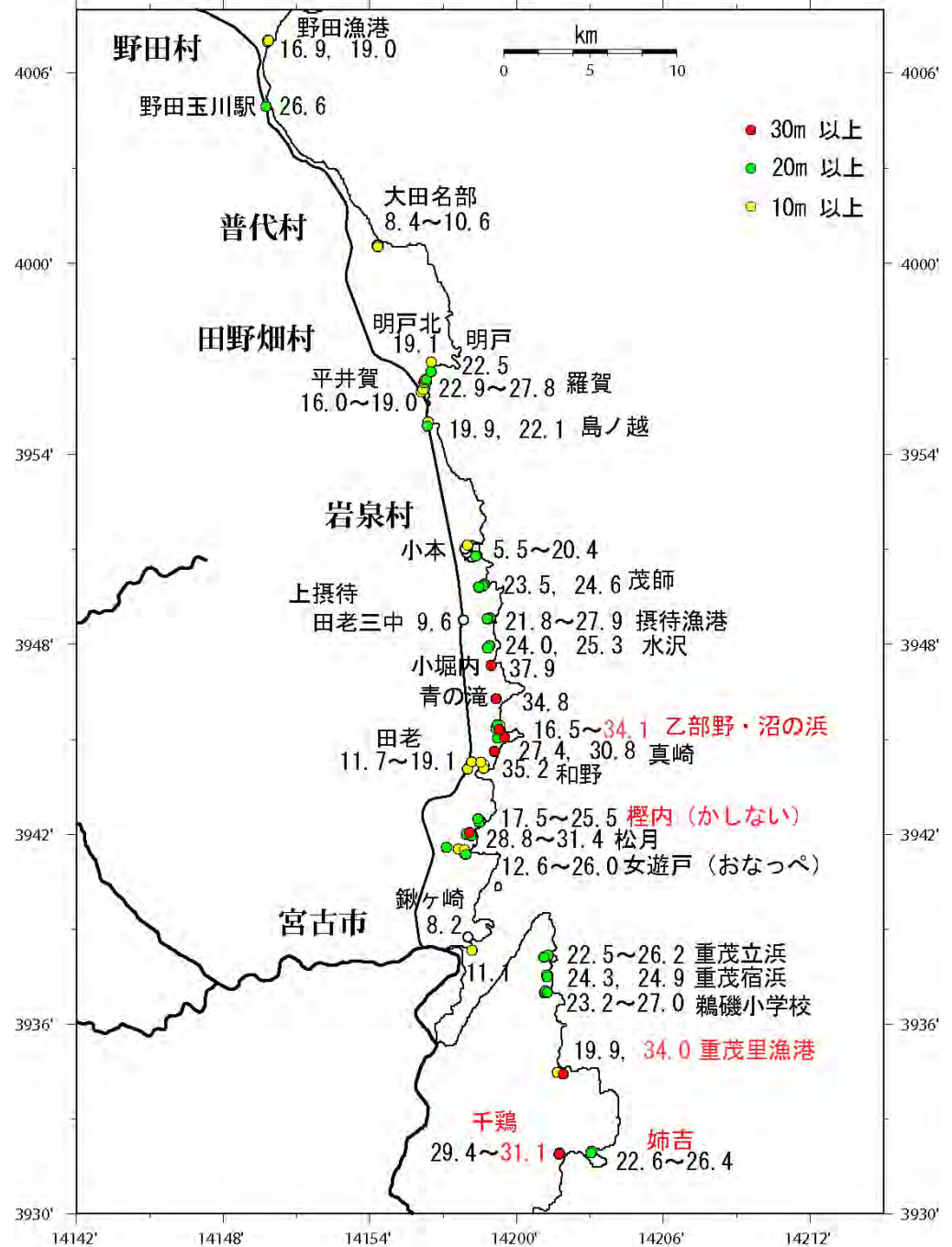
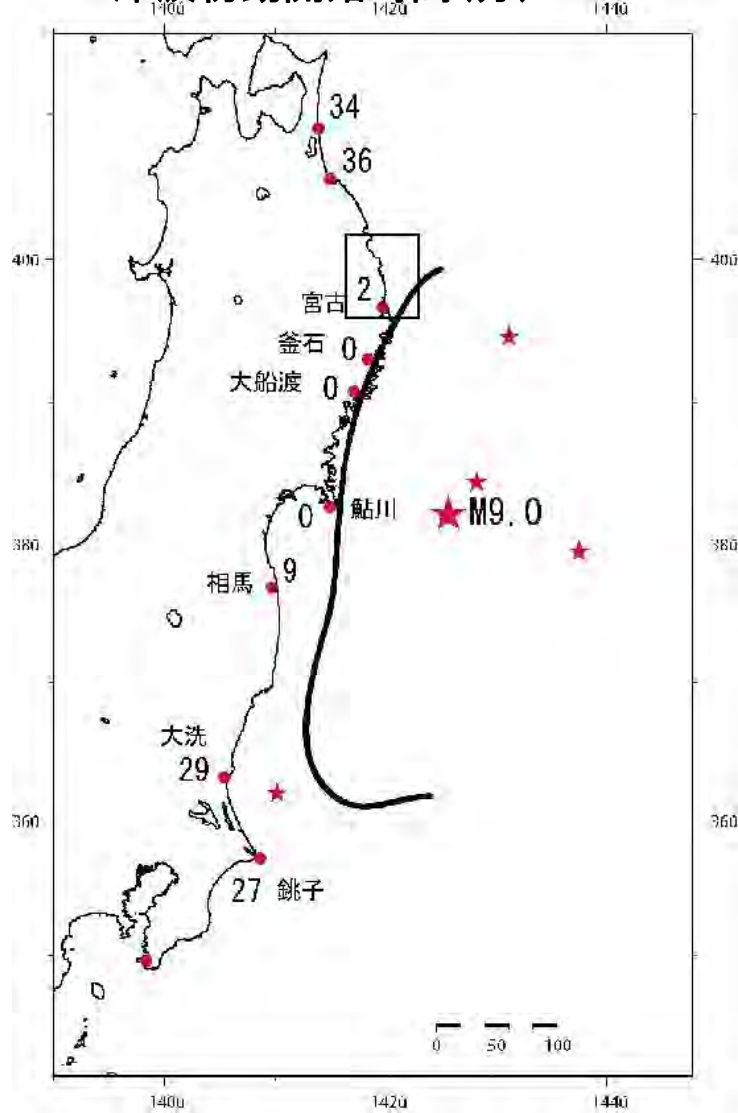
2軒以外すべて壊滅した島ノ越

Only two houses remained at Shimanokoshi, Tanohata village



# 三陸北部の津波 浸水・遡上高さ

津波初動開始時間(分)





明治29年(1896),  
昭和8年(1833),  
および  
平成21年(2011)三陸  
津波の比較  
Comparison of  
Three Sanriku  
Tsunamis

