The 3rd SCEC-ERI Joint Workshop on
“Earthquake Hazards in Urban Area” and
“Toward Constructing Forecast Systems of Earthquakes

Evaluation of seismic events and earthquake faults with weak surface features

Kunihiko Shimazaki

Association for Earthquake Disaster Prevention

Earthquake Research Institute
14:50-15:15, March 16, 2010

How much information can we obtain on an underground source fault by geomorphological, geological, and geophysical surveys on active faults ?

Weak earthquake feature on active faults

Weak feature of active fault

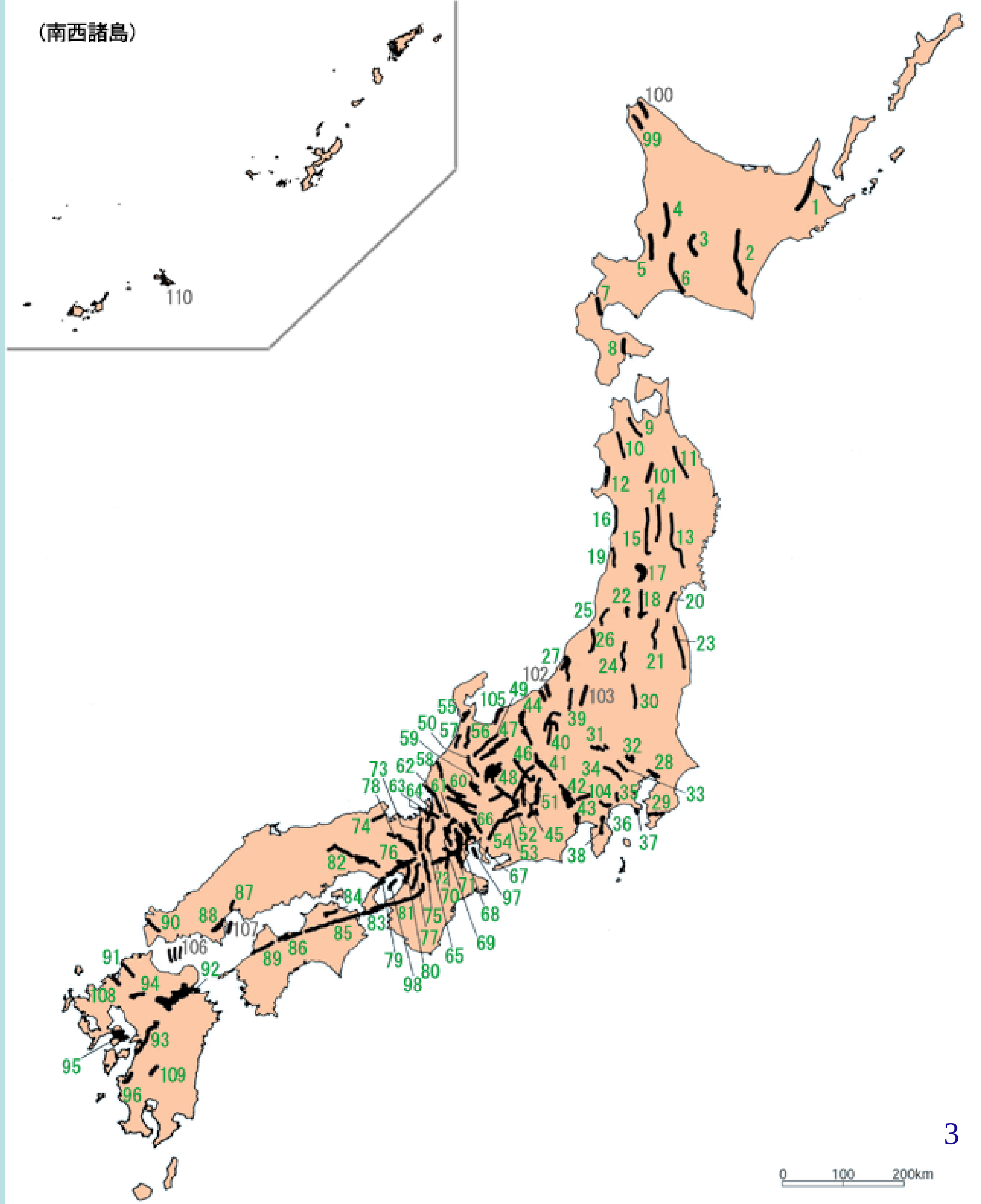
Evolutionary development of active faults

The longer an active fault is, the higher is its activity.

Major active faults in Japan

Length: 20km or longer （M7.0 or above＊）

＊Matsuda (1975)



Headquarters for Earthquake Research Promotion

How much information can we obtain on an underground source fault by geomorphological, geological, and geophysical surveys on active faults ?

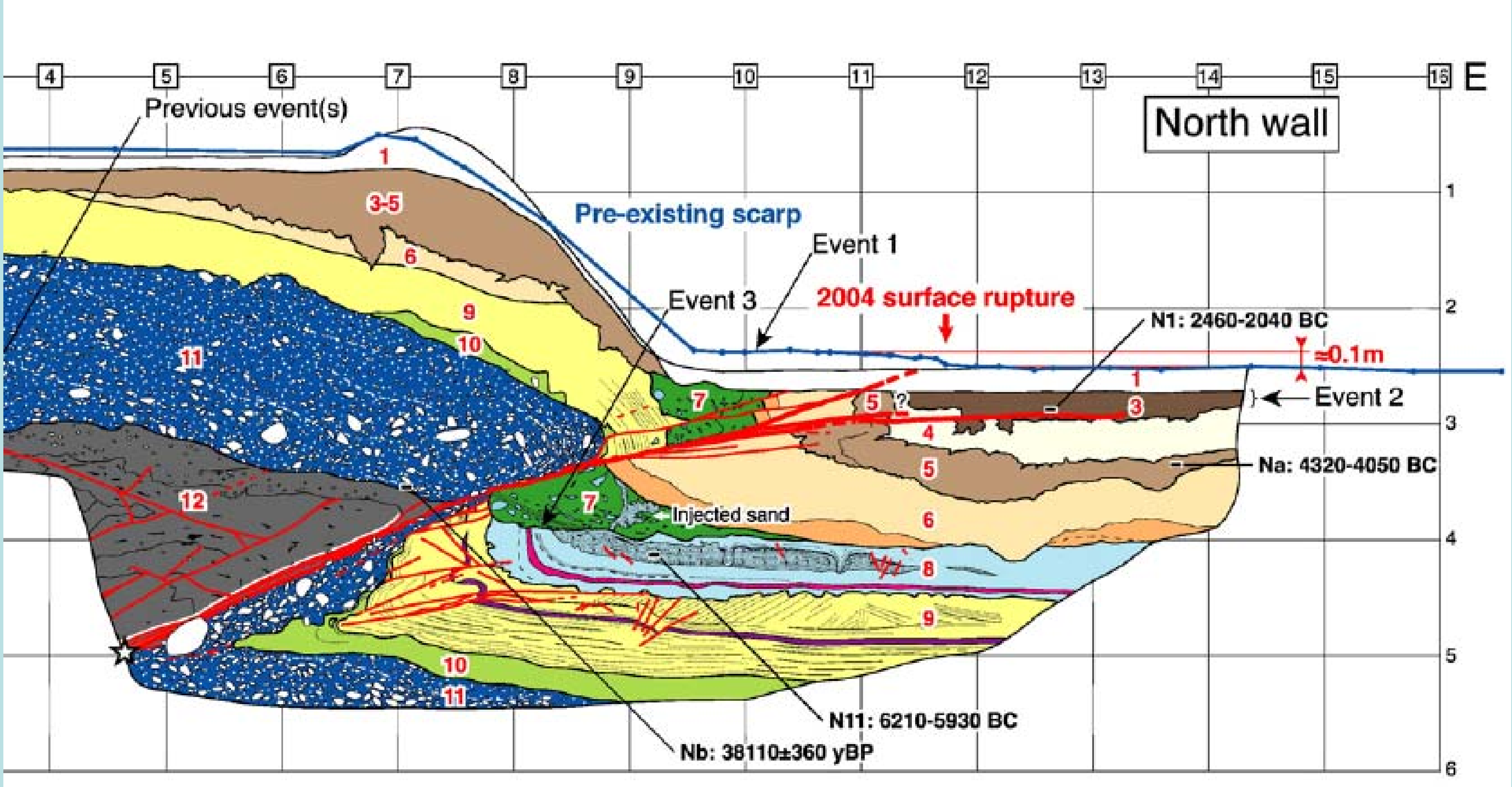
Weak earthquake feature on active faults

Weak feature of active fault

Evolutionary development of active faults

The longer an active fault is, the higher is its activity.

10cm vertical offset due to the M6.8 Chuetsu EQ of 2004 vs. 2m offset found at the trench site



Obirou site, northern Muikamachi fault

Maruyama et al (2007)

Ten earthquakes with magnitude 7.0 or above, which occurred on the major active faults during the past 200 years

Recognizable by trench excavation survey?　NO for three cases

M7.4 Zenkoji earthquake of 1847 M7.4

M71/4　Iga-Ueno earthquake of 1854 No earthquake fault was observed

M7.0-7.1 Hietsu earthquake of 1858

M8 Nobi earthquake of 1891

NO　M7　Shonai earthquake of 1894

M7.2 Rikuu earthquake of 1896

M7.3 Kita-Tango earthquake of 1927

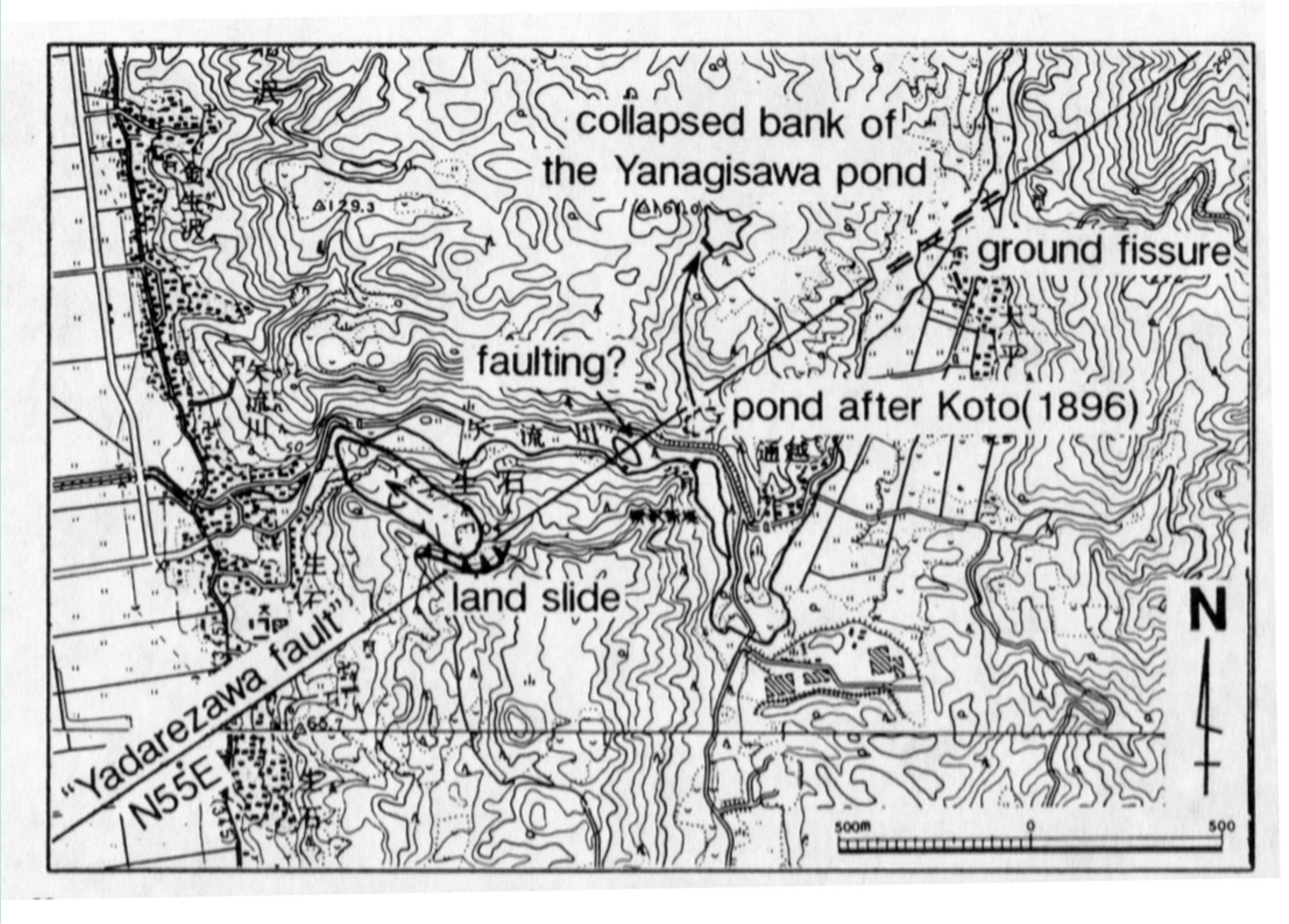
M7.3 Kita-Izu earthquake of 1930年

NO　M7.1 Fukui earthquake of 1948

NO M7.3 Kobe earthquake of 1995 (Kobe segment)

The M7 Shonai EQ of 1894

Yadarezawa fault proposed by Koto (1895) was not found to exist (Suzuki et al., 1989). The azimuth of reported rupture is not consistent with that of the Shonai-Heiya-Toen fault. The reported surface disturbance features are not on a line.

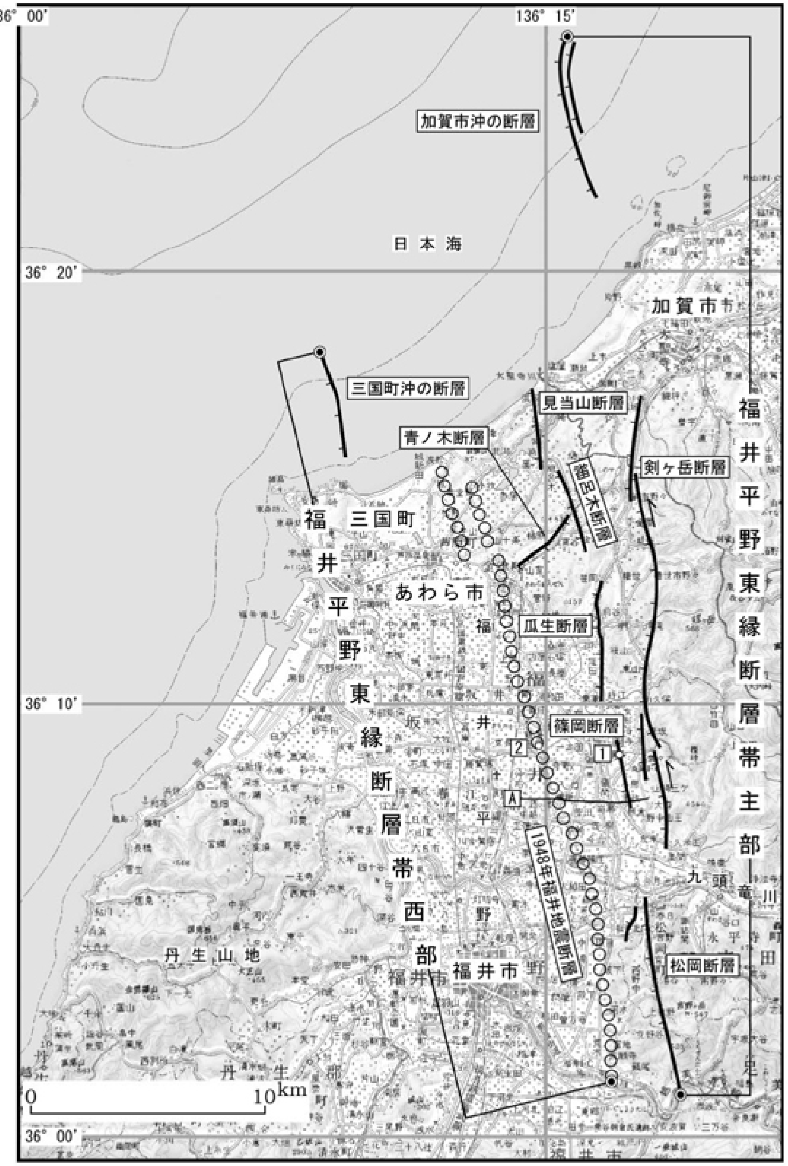


Suzuki et al.(1989)

The M7.1 Fukui EQ of 1948

No clear earthquake fault was recognized on the surface.

The source fault (Sagiya, 1999) is estimated to be 4-5km west of the major fault zone.

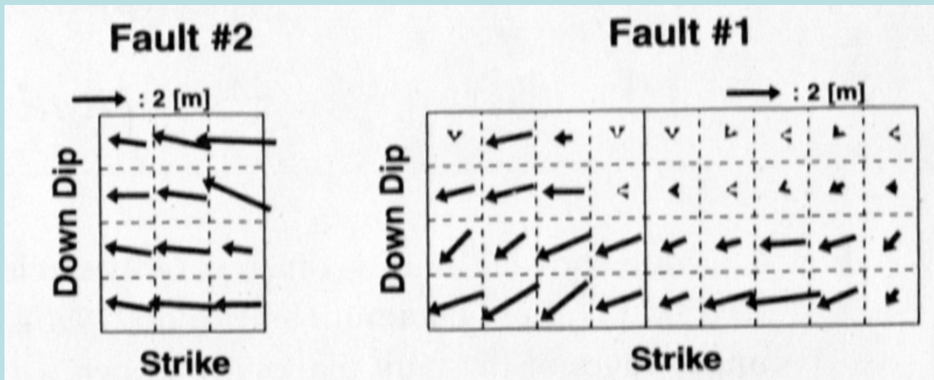


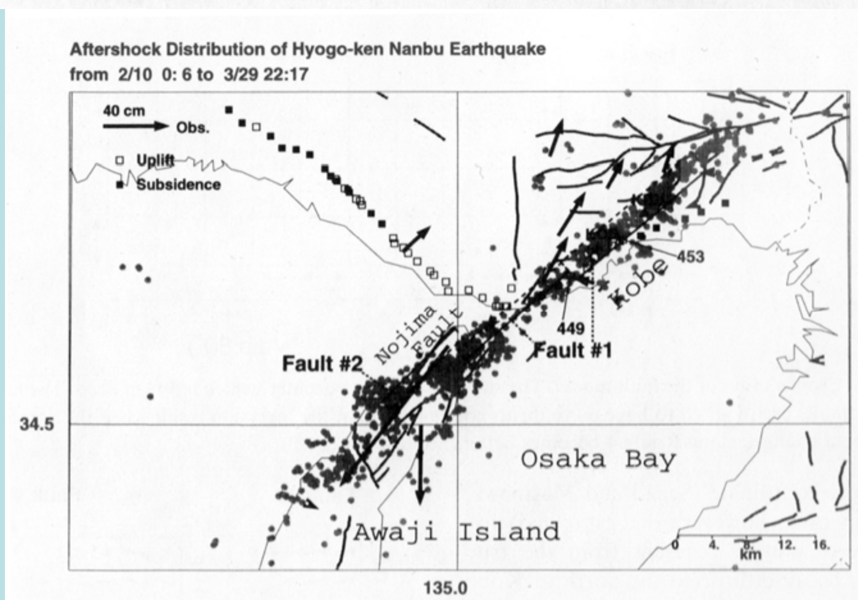
1：丸岡地点　2：田島川地点
A：反射法弾性波探査測線（文献１）
◉：断層帯の両端　○：1948年の地表地震断層
断層の位置は文献１，３，６，７，９及び10に基づく．
基図は国土地理院発行数値地図200000「金沢」「岐阜」を使用．

Earthquake Research Committee（2004)

The M7.3 Kobe earthquake of 1995

No clear earthquake fault is recognized on the Kobe segment, which is consistent with the distribution of co-seismic slip.





Horikawa et al. (1996)

1995 surface rupture on the Nojima fault

Photo taken by Nakata

Ten earthquakes with magnitude 7.0 or above, which occurred on the major active faults during the past 200 years

Recognizable by trench excavation survey?　NO for three cases

M7.4 Zenkoji earthquake of 1847 M7.4

M71/4　Iga-Ueno earthquake of 1854 No earthquake fault was observed

M7.0-7.1 Hietsu earthquake of 1858

M8 Nobi earthquake of 1891

NO　M7　Shonai earthquake of 1894

M7.2 Rikuu earthquake of 1896

M7.3 Kita-Tango earthquake of 1927

M7.3 Kita-Izu earthquake of 1930年

NO　M7.1 Fukui earthquake of 1948

NO M7.3 Kobe earthquake of 1995 (Kobe segment)

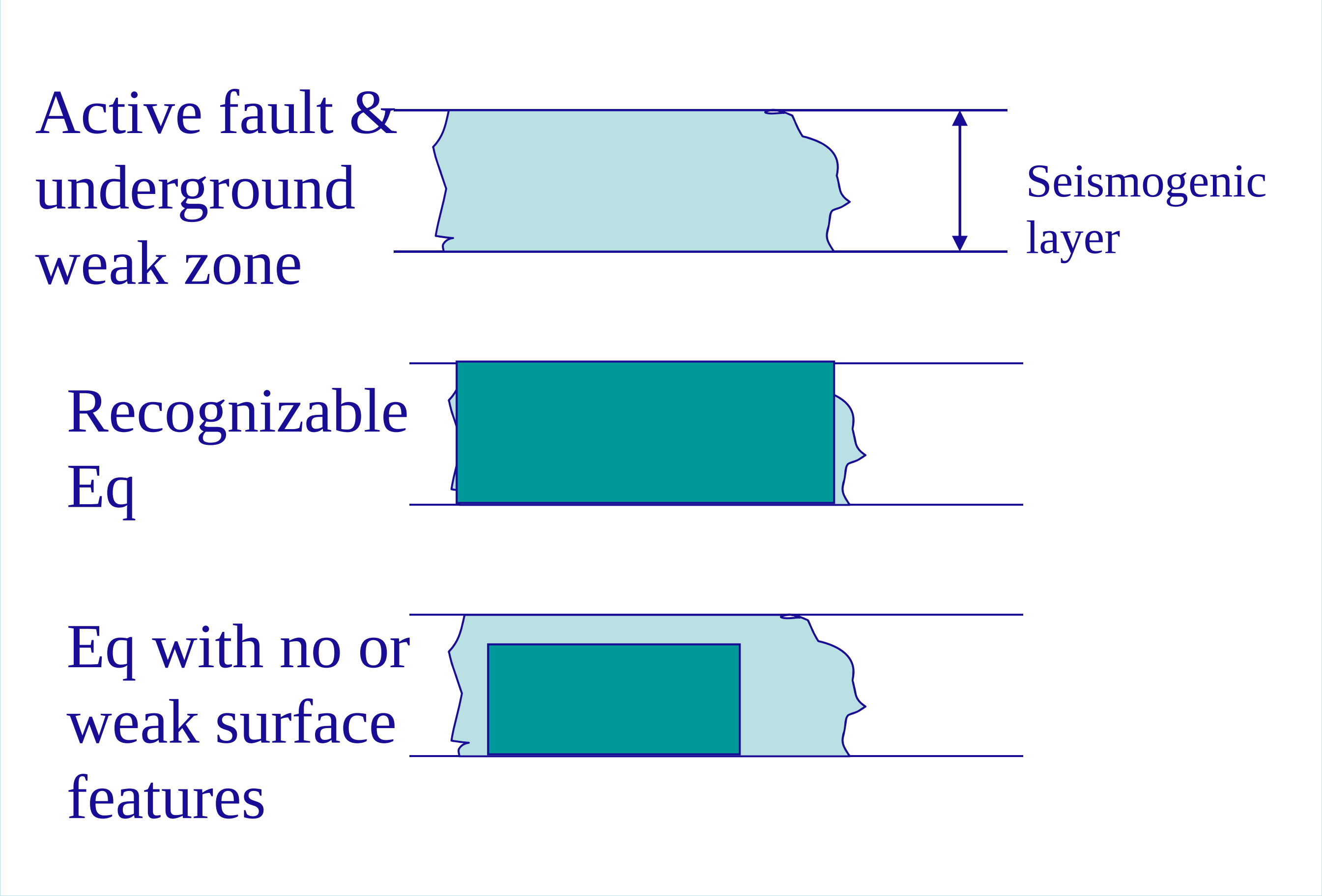
Expected number of earthquakes with magnitude 7 or above in 30 years on the major fault zones

1.5 Past 200 year history

0.9 Long-term forecast

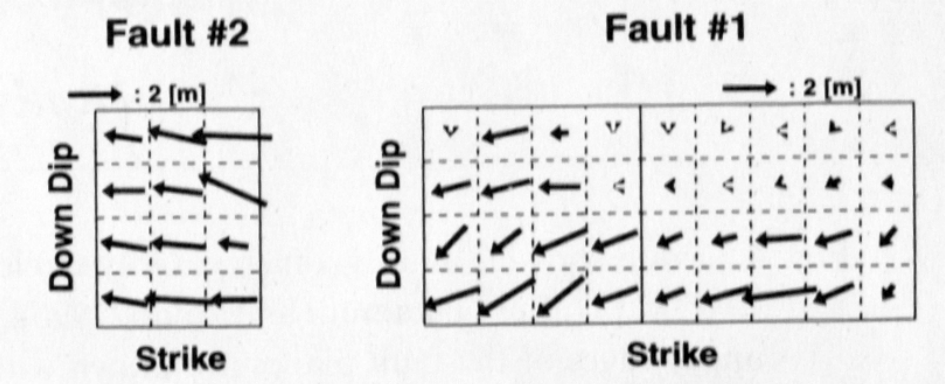
0.4 Earthquake with weak surface feature

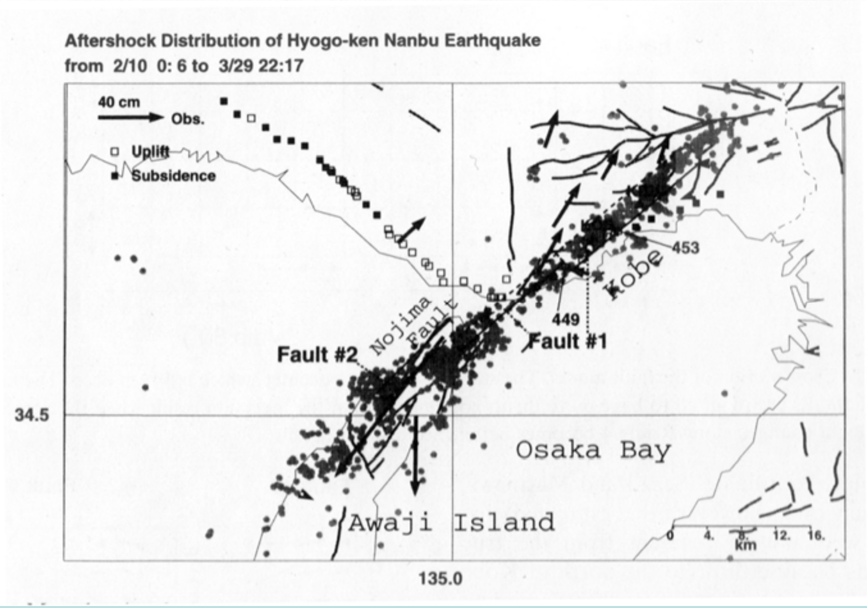
Existence of an earthquake which does not leave recognizable features on the surface



It is necessary to evaluate an event without clear surface feature

No surface feature on a deep asperity



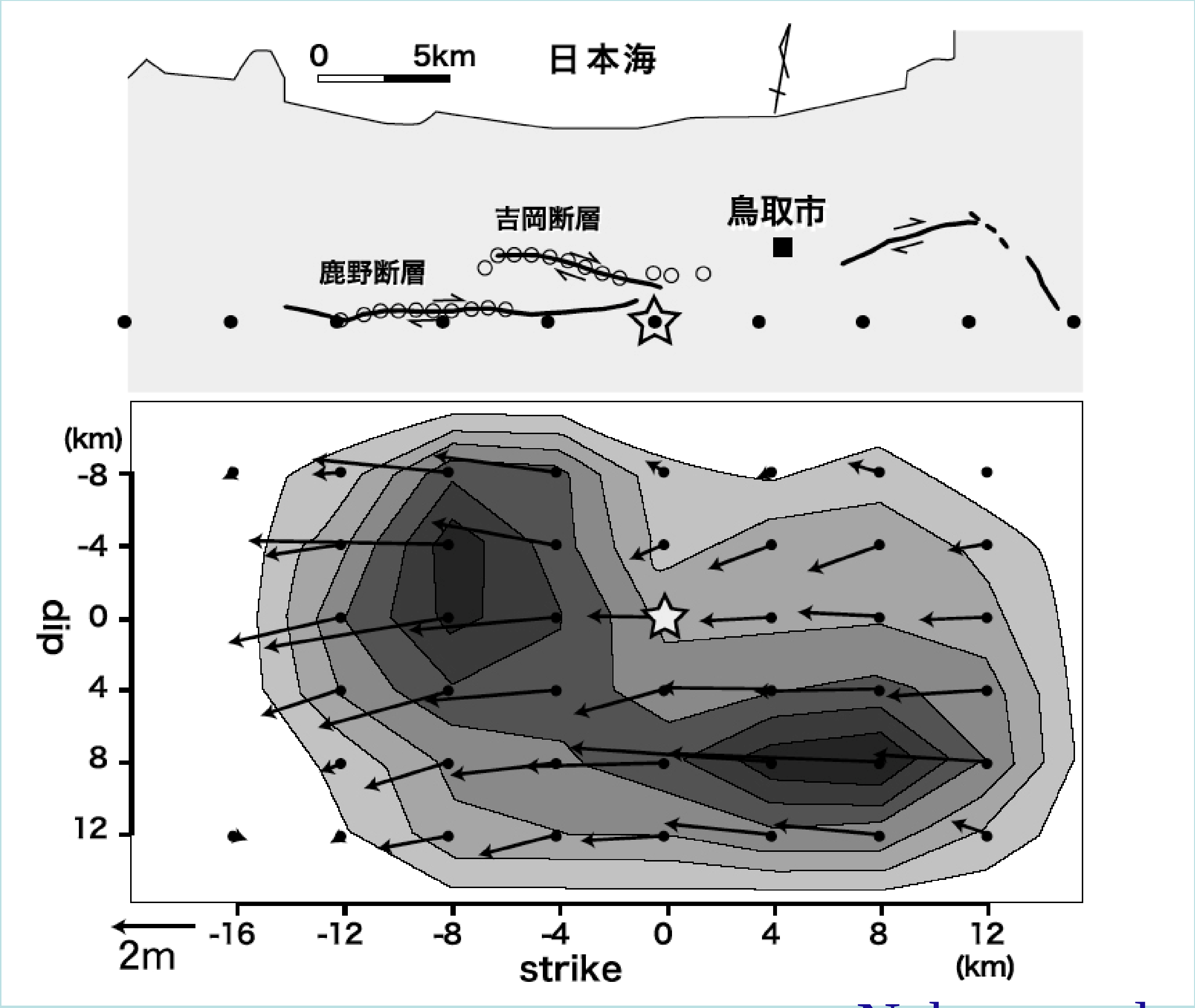


Horikawa et al. (1996)

Another example of **shallow and deep asperities**

The M7.3 Tottori earthquake of 1943

15km long surface rupture vs. 28km long source fault



Nakata et al.

How much information can we obtain on an underground source fault by geomorphological, geological, and geophysical surveys on active faults ?

Weak earthquake feature on active faults

Weak feature of active fault

Evolutionary development of active faults

The longer an active fault is, the higher is its activity.

Empirical relationship

M: magnitude

L: fault length $\log L(km)=0.6M-2.9$

D: co-seismic slip $\log D(m)=0.6M-4.0$

(Matsuda, 1975)

Seismic moment $Mo(Nm)=3.8x10^{16}L^2$

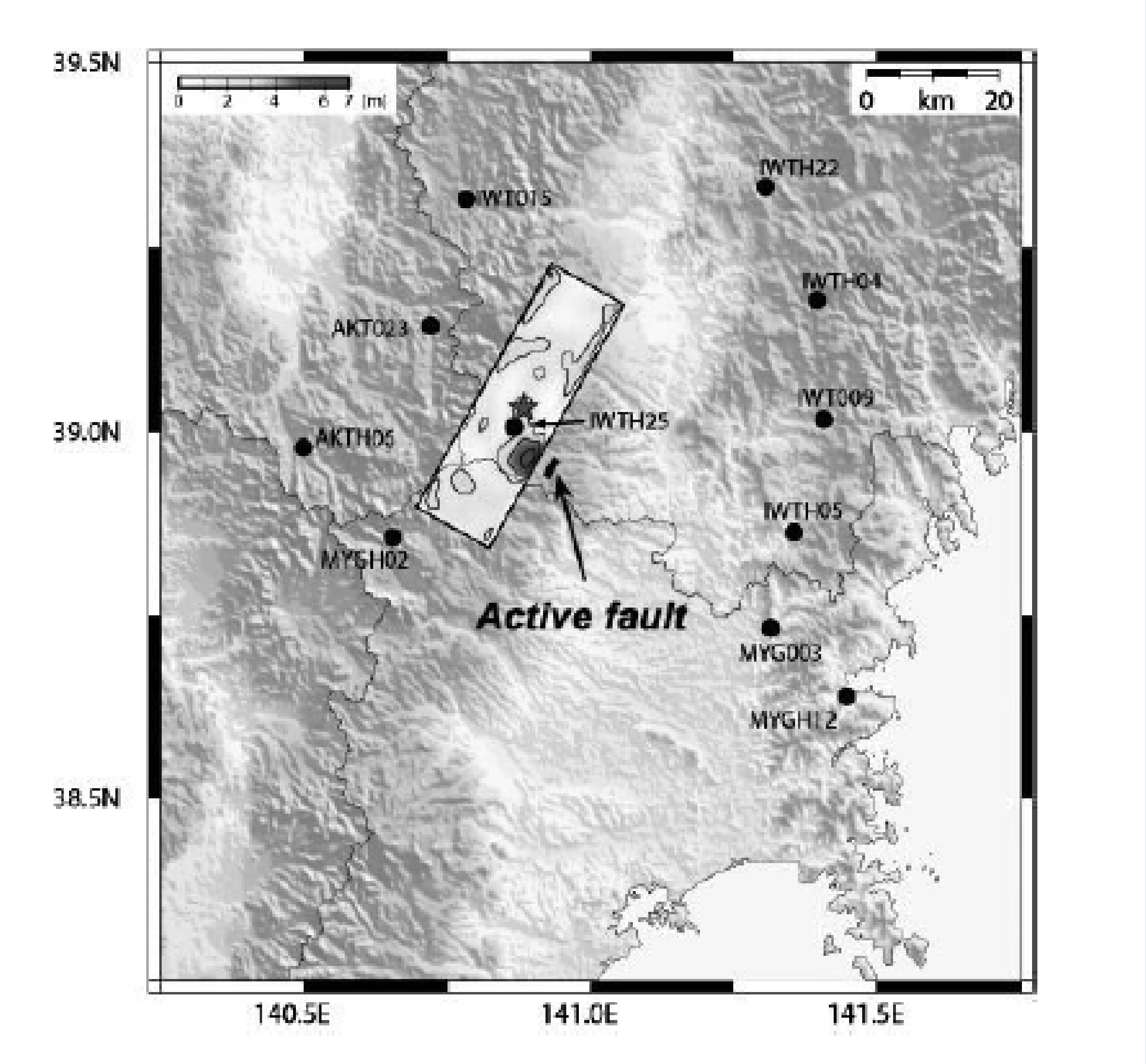
Average repeat time $T(y)\sim 80L/s$

s(mm/y): average slip rate

Recent earthquakes with magnitude 7.0 or larger, which took place on a short active fault

M7.2 Iwate-Miyagi EQ of 2008
M7.0 Fukuoka-Seihouoki EQ of 2005
M7.3 Western Tottori EQ of 2000

The M7.2 Iwate-Miyagi earthquake of 2008

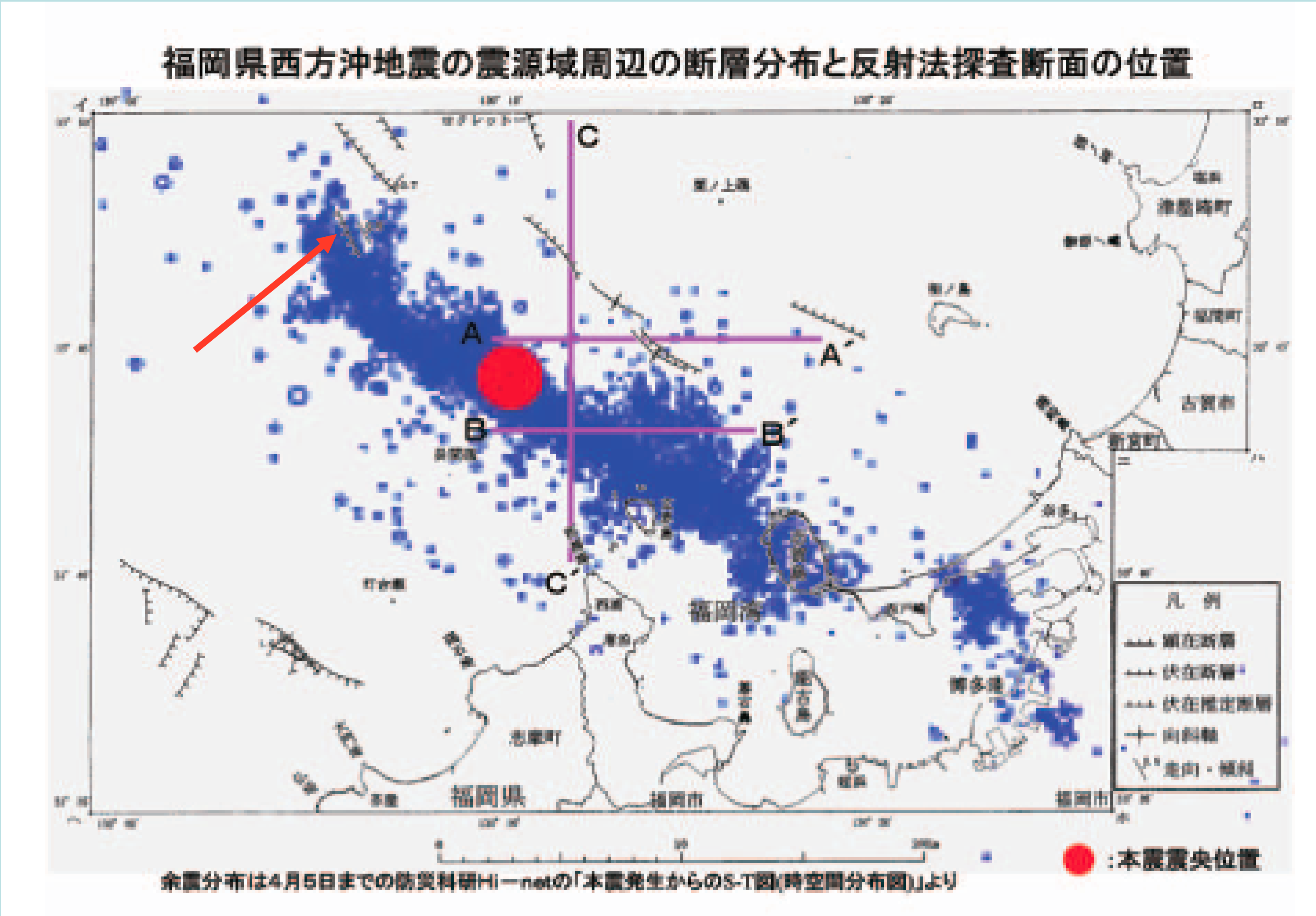


Source fault 40km

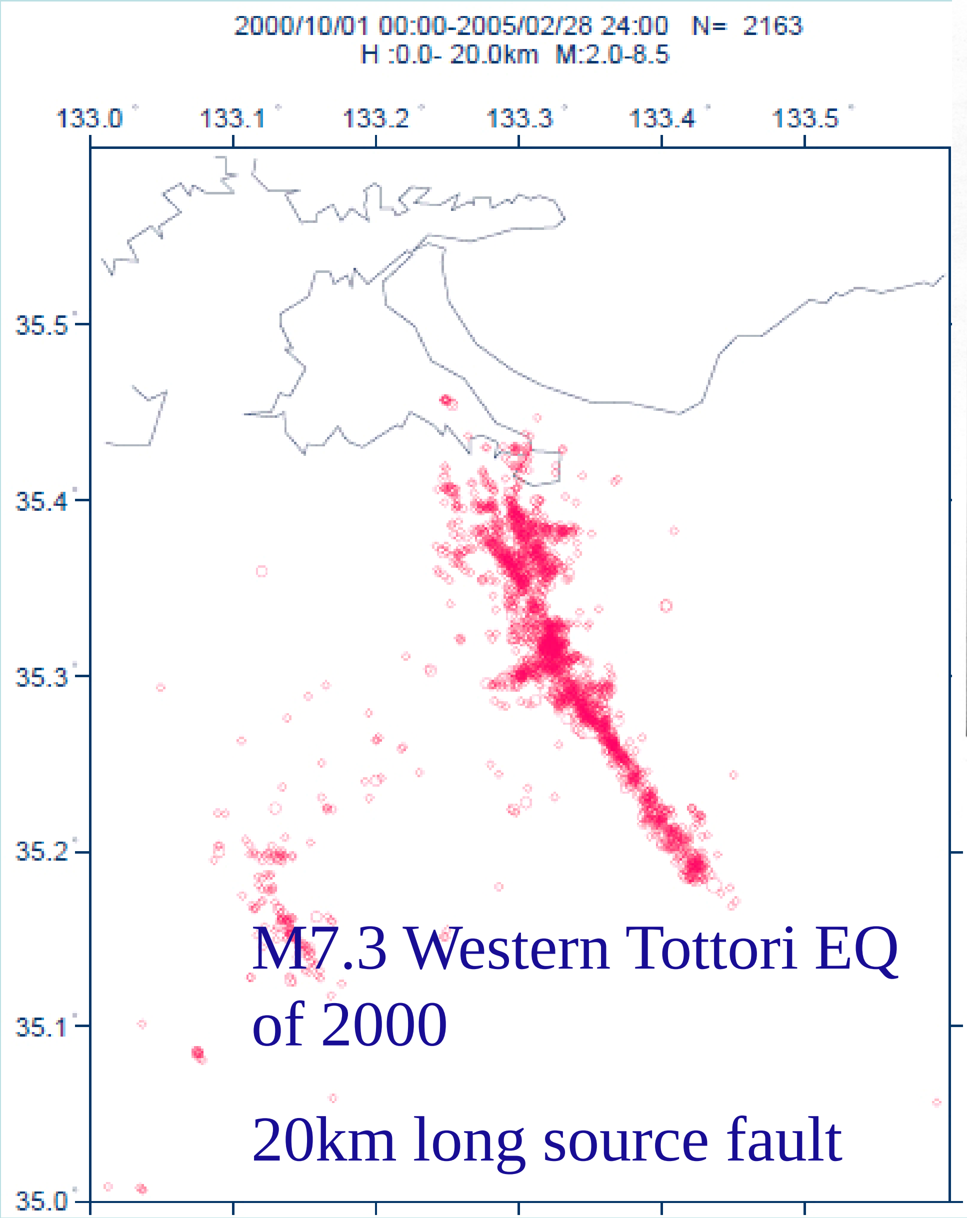
Active fault 3-4km

Suzuki et al. （2008）

The M7.0 Fukuoka-Seiho-Oki EQ of 2005

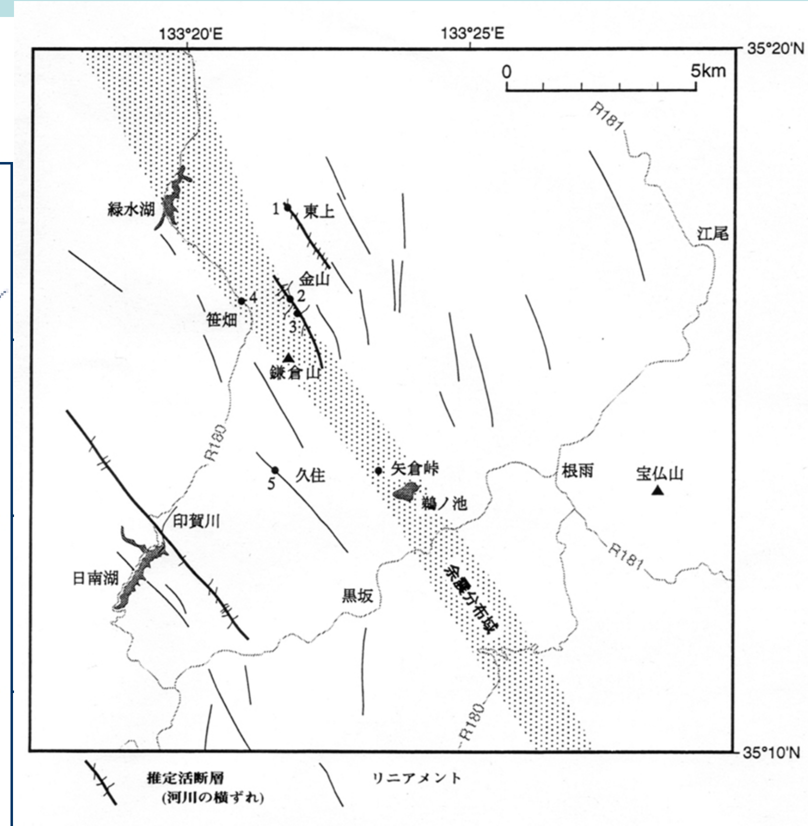


Hydrographic and Oceanographic Dept., Japan Coast Guard （2005）



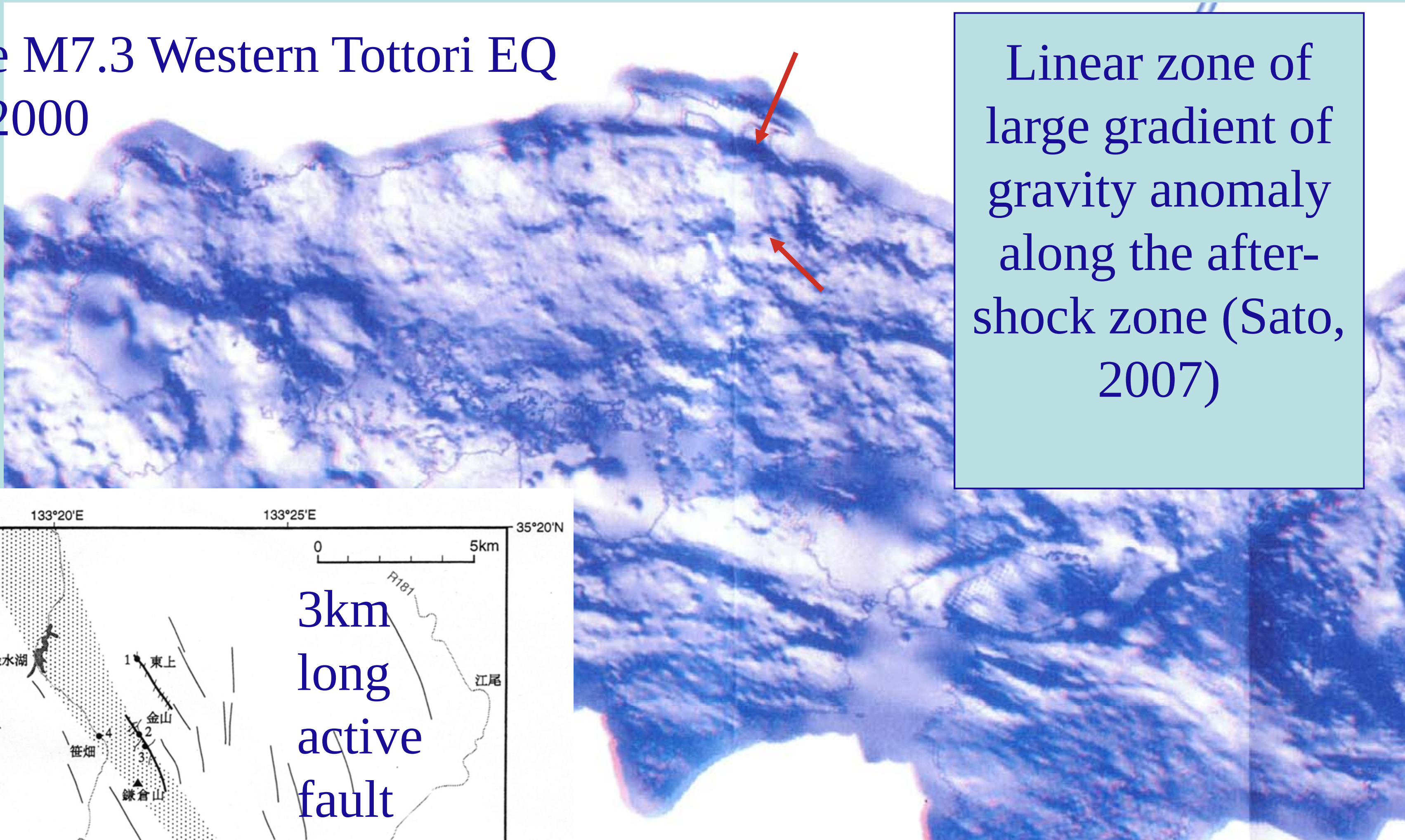
M7.3 Western Tottori EQ of 2000

20km long source fault

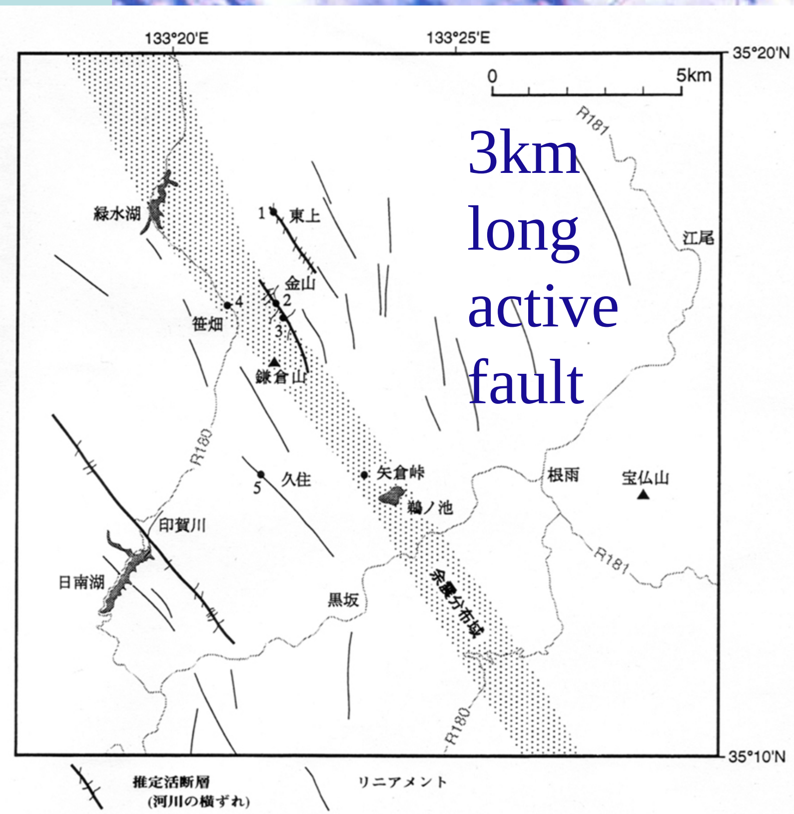


3km long estimated active fault on the aftershock zone （Tsutsumi et al., 2000）

The M7.3 Western Tottori EQ of 2000



Linear zone of large gradient of gravity anomaly along the after-shock zone (Sato, 2007)



3km long active fault

The length of 25km corresponds to M7.2

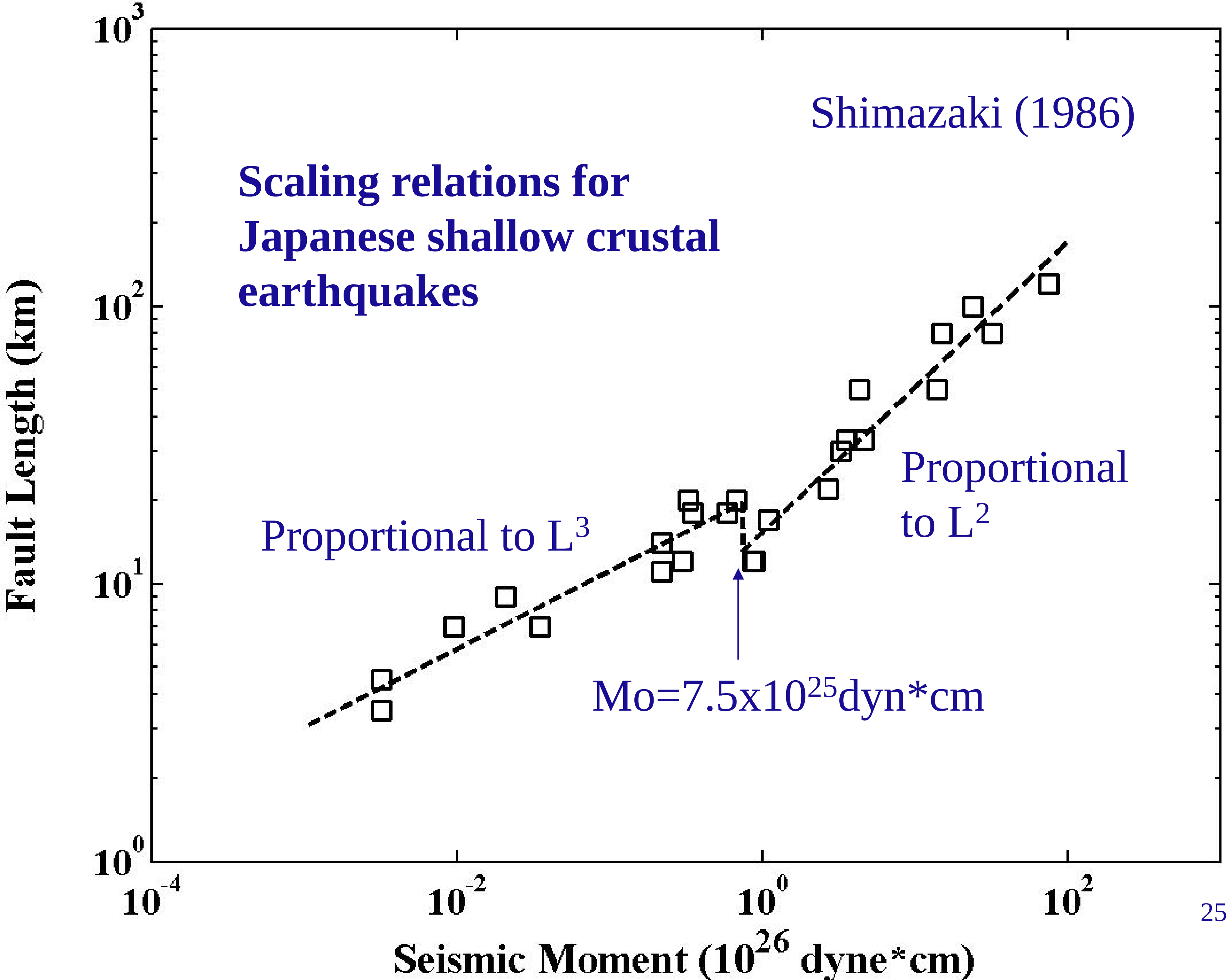
How much information can we obtain on an underground source fault by geomorphological, geological, and geophysical surveys on active faults ?

Weak earthquake feature on active faults

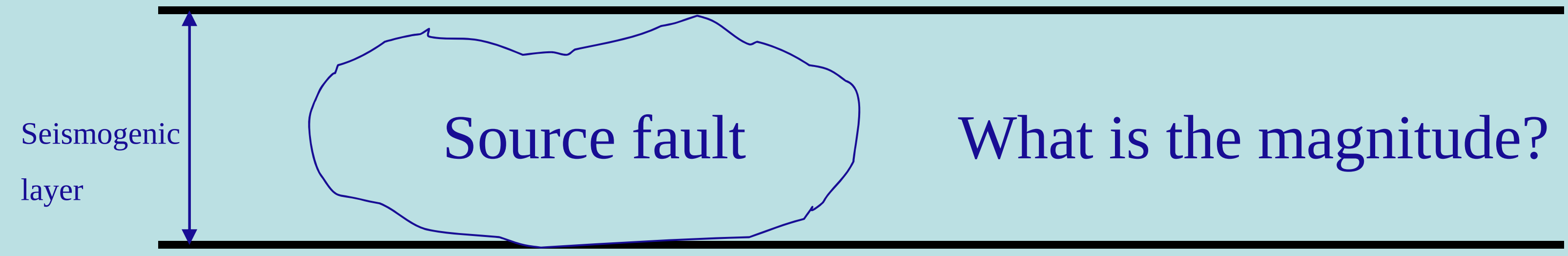
Weak feature of active fault

Evolutionary development of active faults

The longer an active fault is, the higher is its activity.

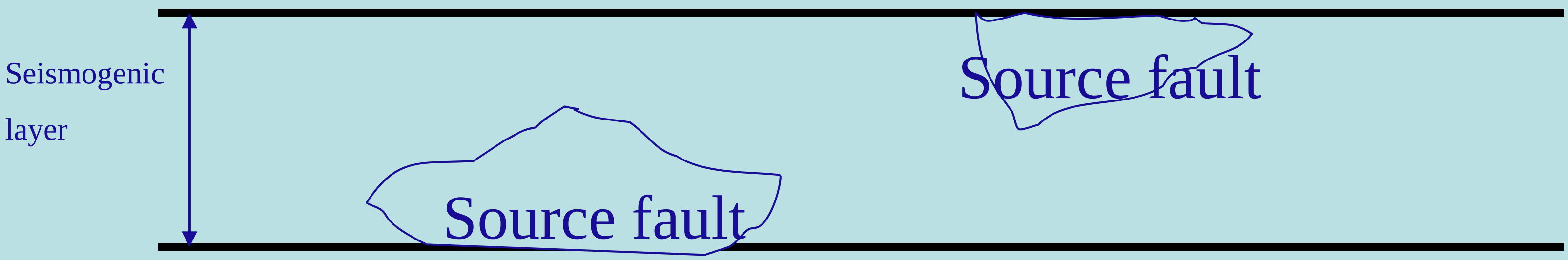

Shimazaki (1986)
Scaling relations for Japanese shallow crustal earthquakes
Proportional to L3
Proportional to L2
Mo=7.5x1025dyn*cm
Fault Length (km)
Seismic Moment (1026 dyne*cm)
10-4
10-2
100
102
100
101
102
103

Short active fault

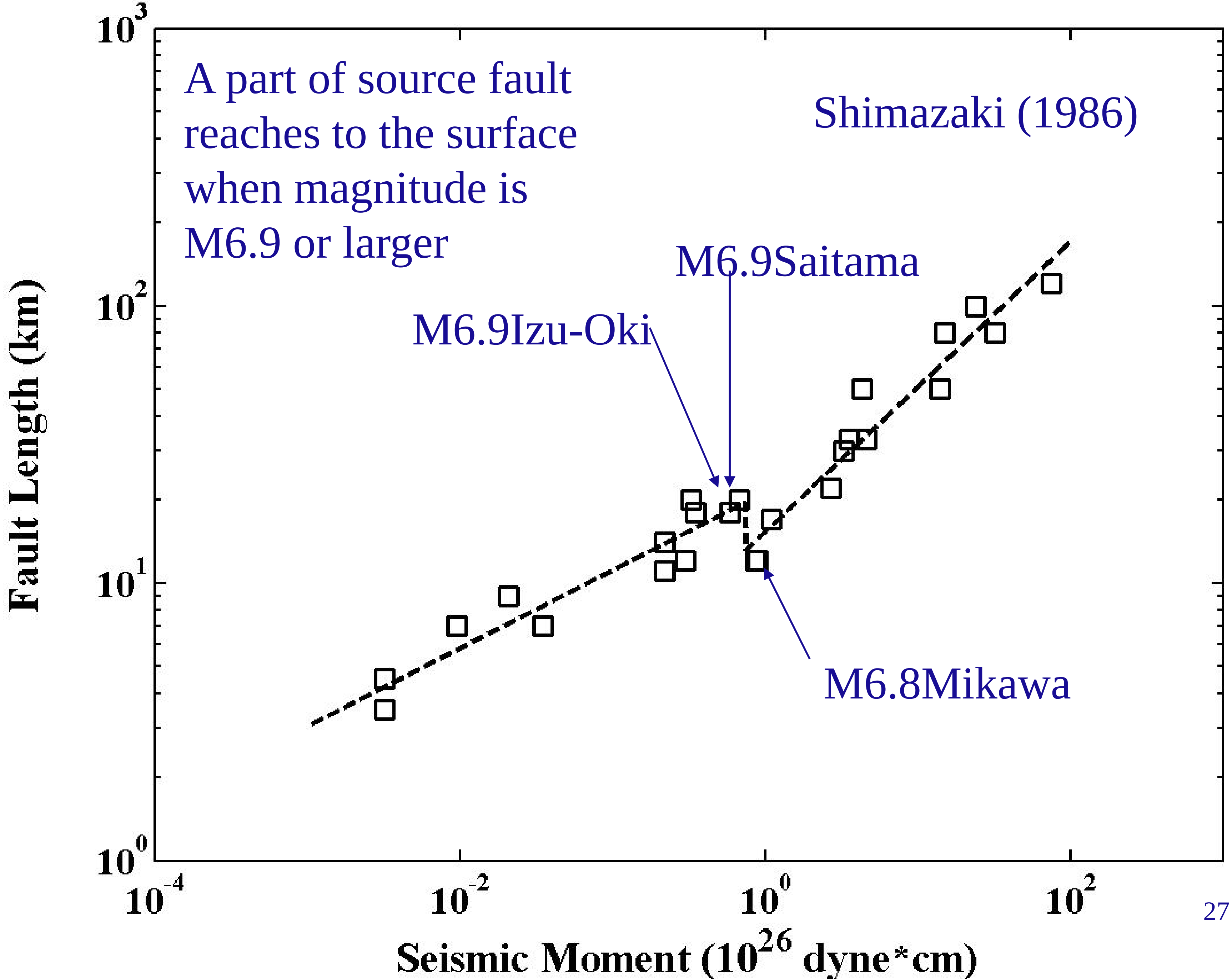


Brittle rupture starts from the bottom of seismogenic layer.

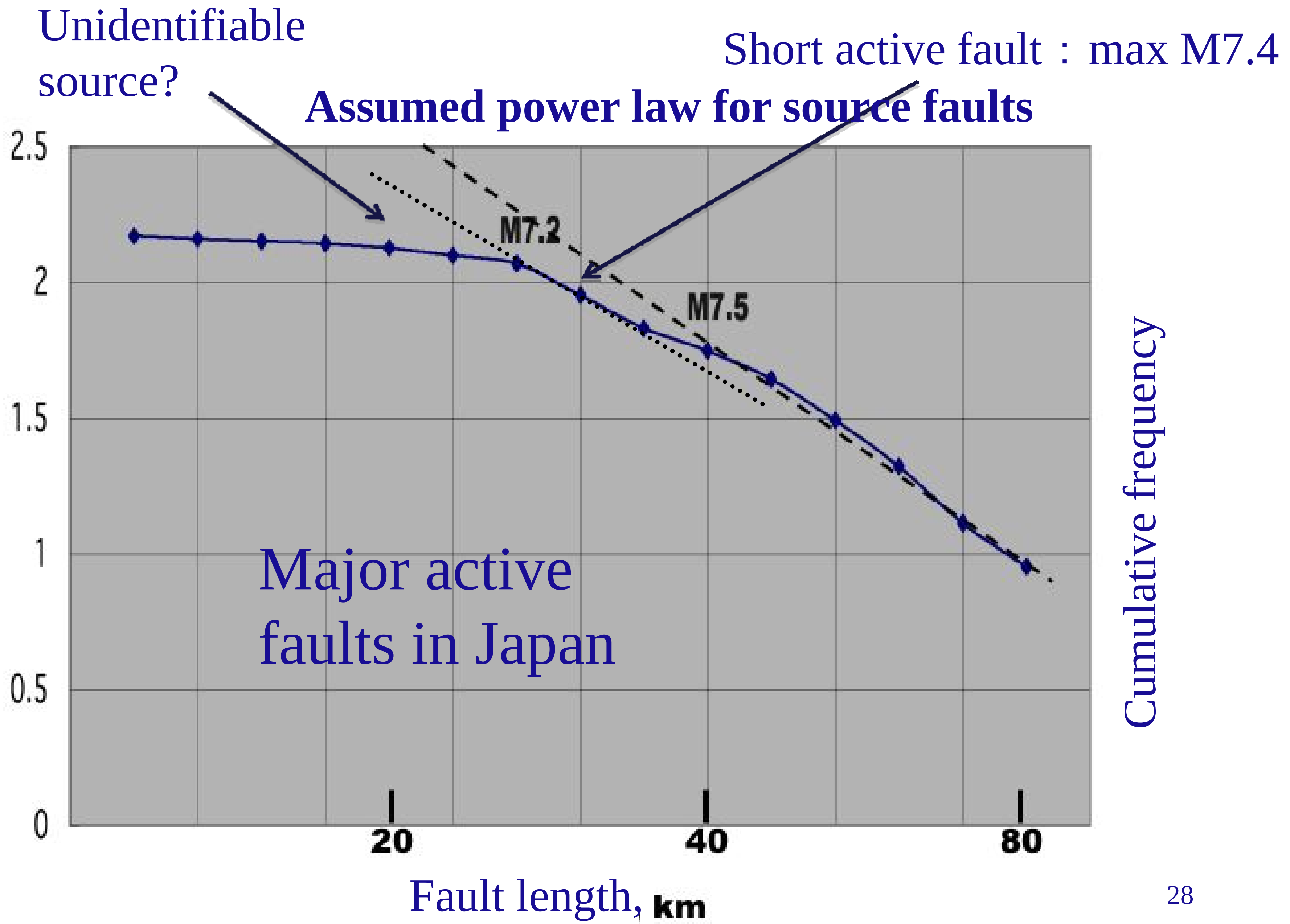
Exception near a volcano



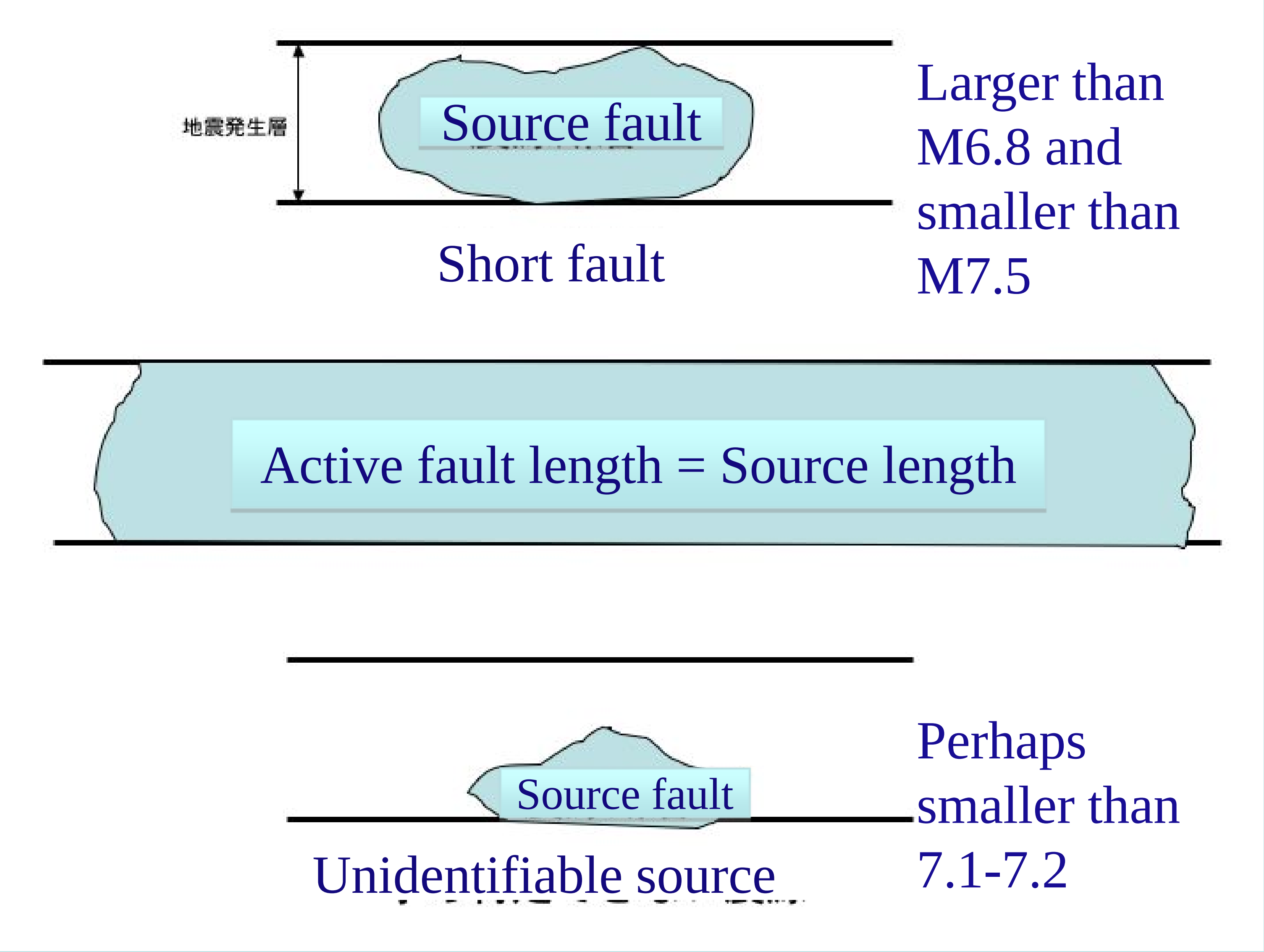
Unidentifiable source

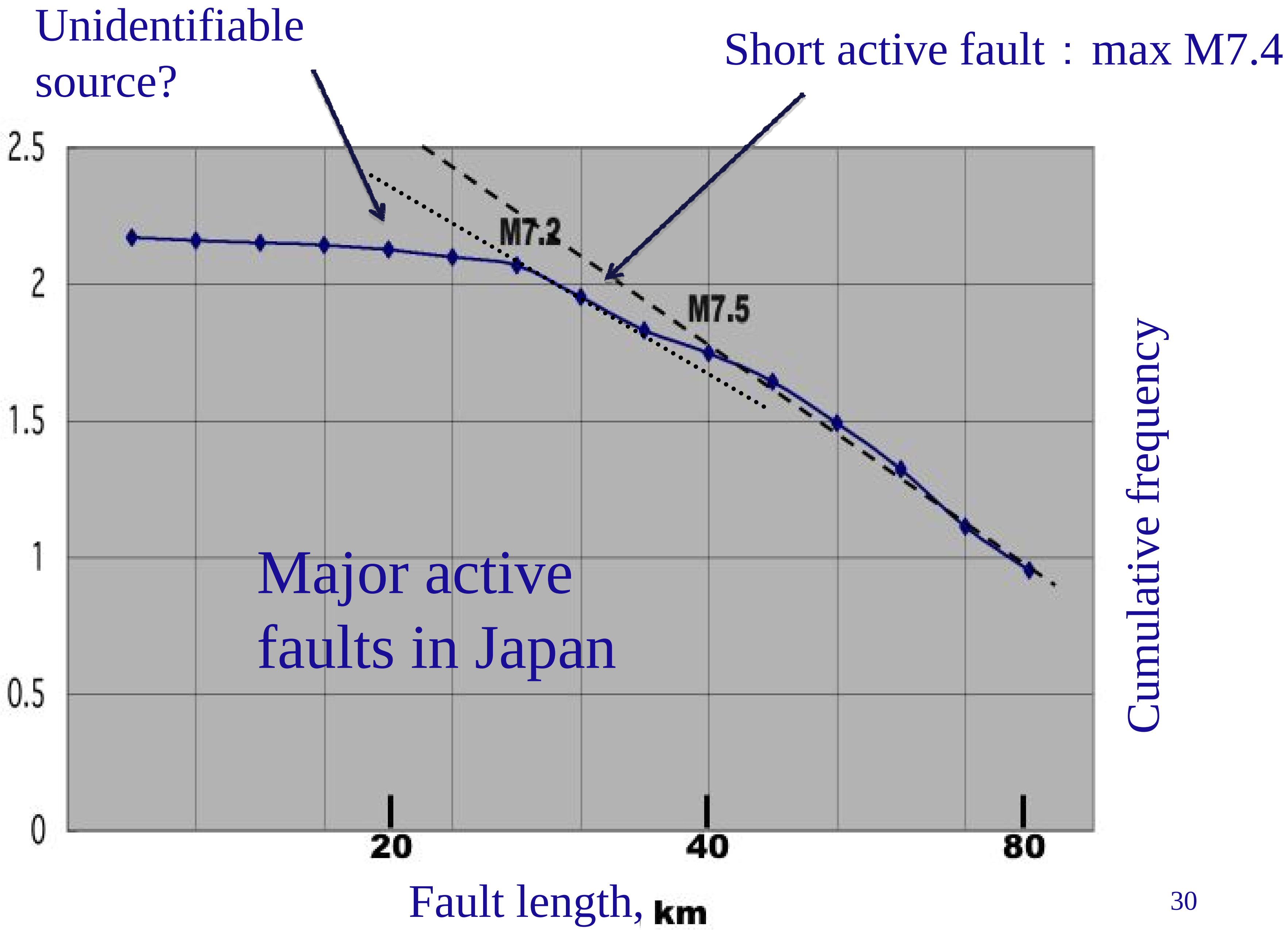


A part of source fault
reaches to the surface
when magnitude is
M6.9 or larger
Shimazaki (1986)
M6.9Saitama
M6.9Izu-Oki
M6.8Mikawa
Fault Length (km)
Seismic Moment (10^{26} dyne*cm)
10^{3}
10^{2}
10^{1}
10^{0}
10^{-4}
10^{-2}
10^{0}
10^{2}

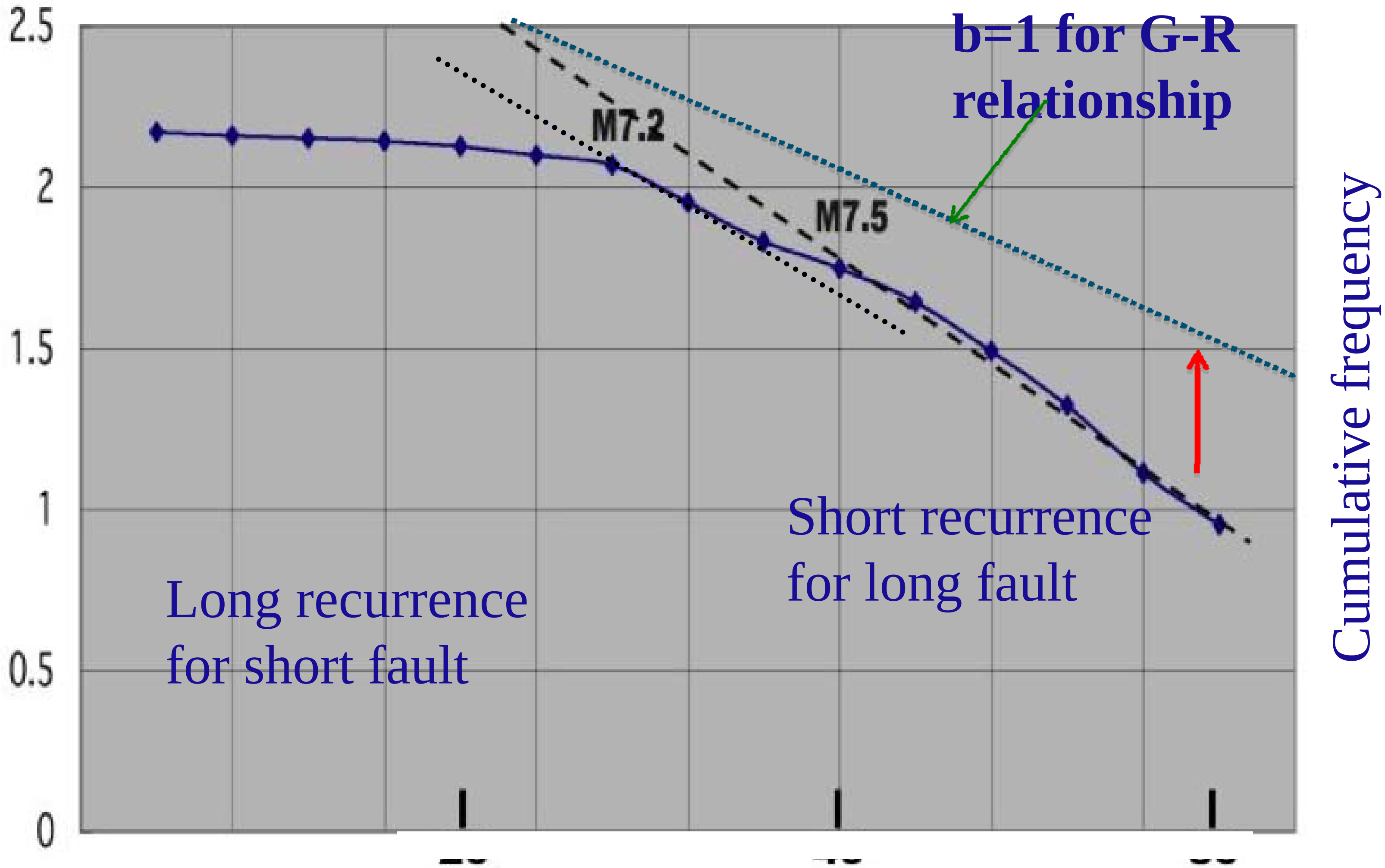

Unidentifiable source?
Short active fault：max M7.4
Assumed power law for source faults
2.5
2
1.5
1
0.5
0
M7.2
M7.5
Major active faults in Japan
20
40
80
Fault length, km
Cumulative frequency

Surface active fault and underground source fault

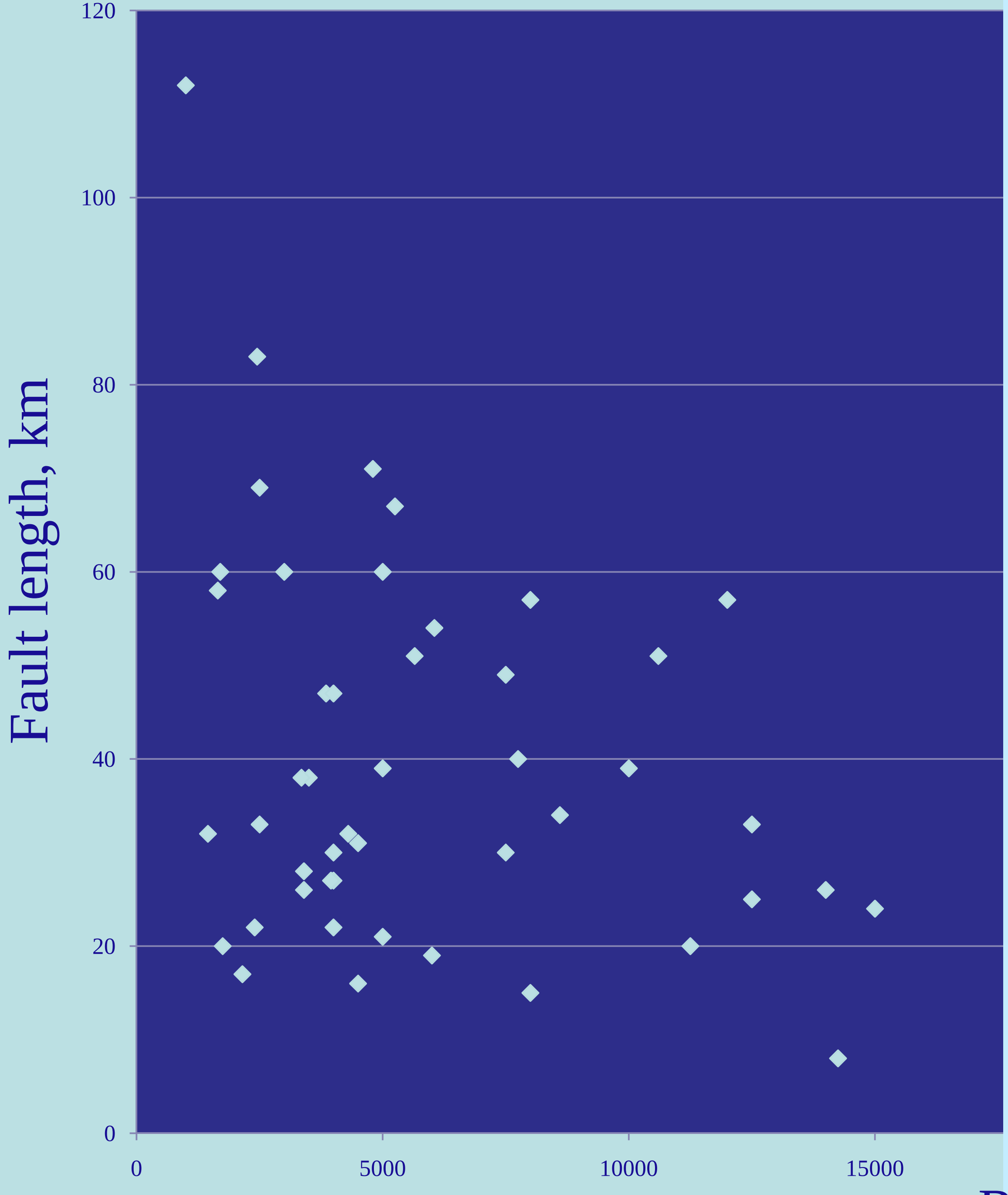



Unidentifiable source?
Short active fault：max M7.4
2.5
2
1.5
1
0.5
0
M7.2
M7.5
Major active faults in Japan
Cumulative frequency
20
40
80
Fault length, km

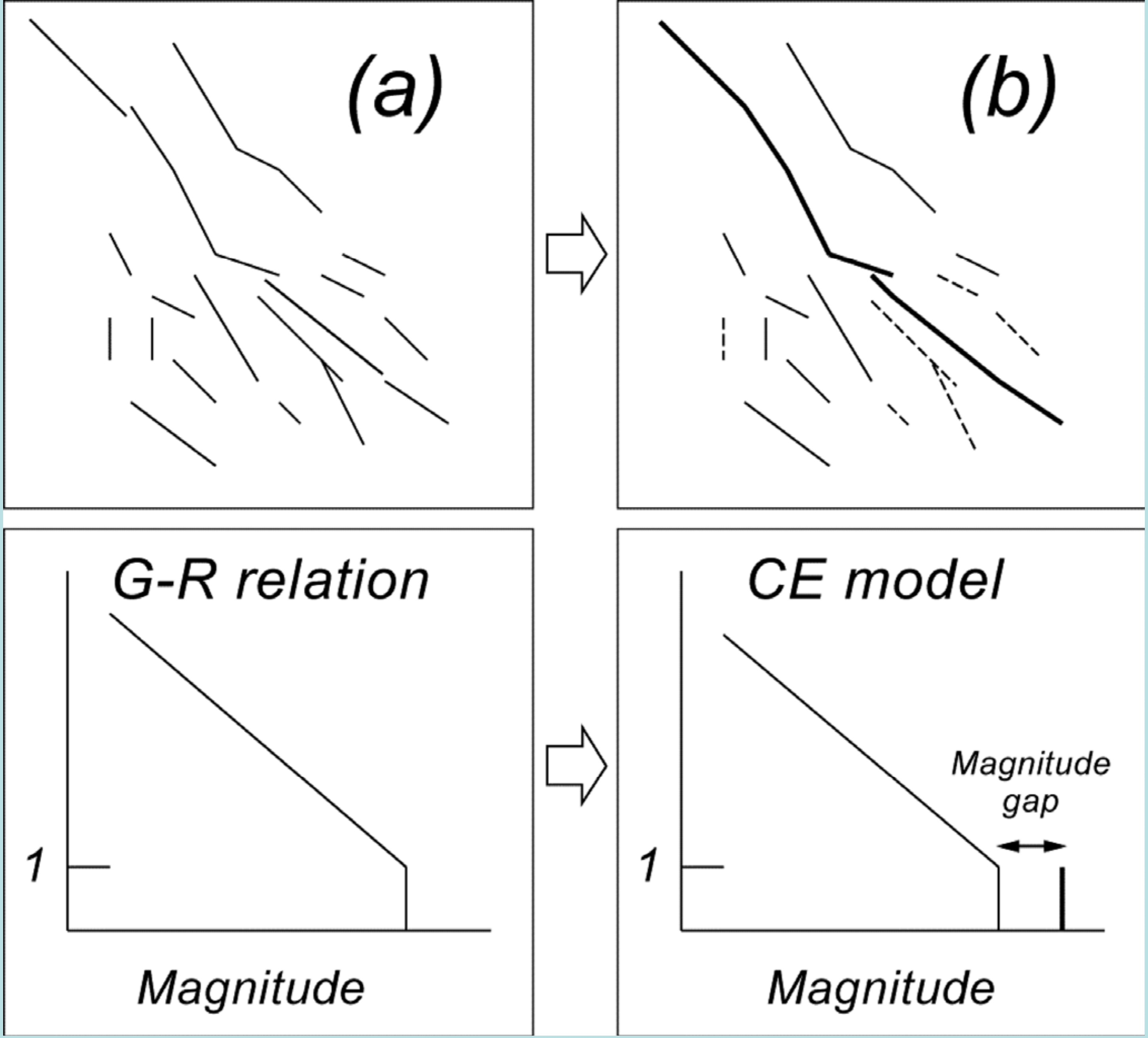
Major active faults in Japan



M= 7.0 7.5 7.5
8.0



The longer an active fault is, the shorter is the recurrence interval.



Ishibe and Shimazaki (2009)

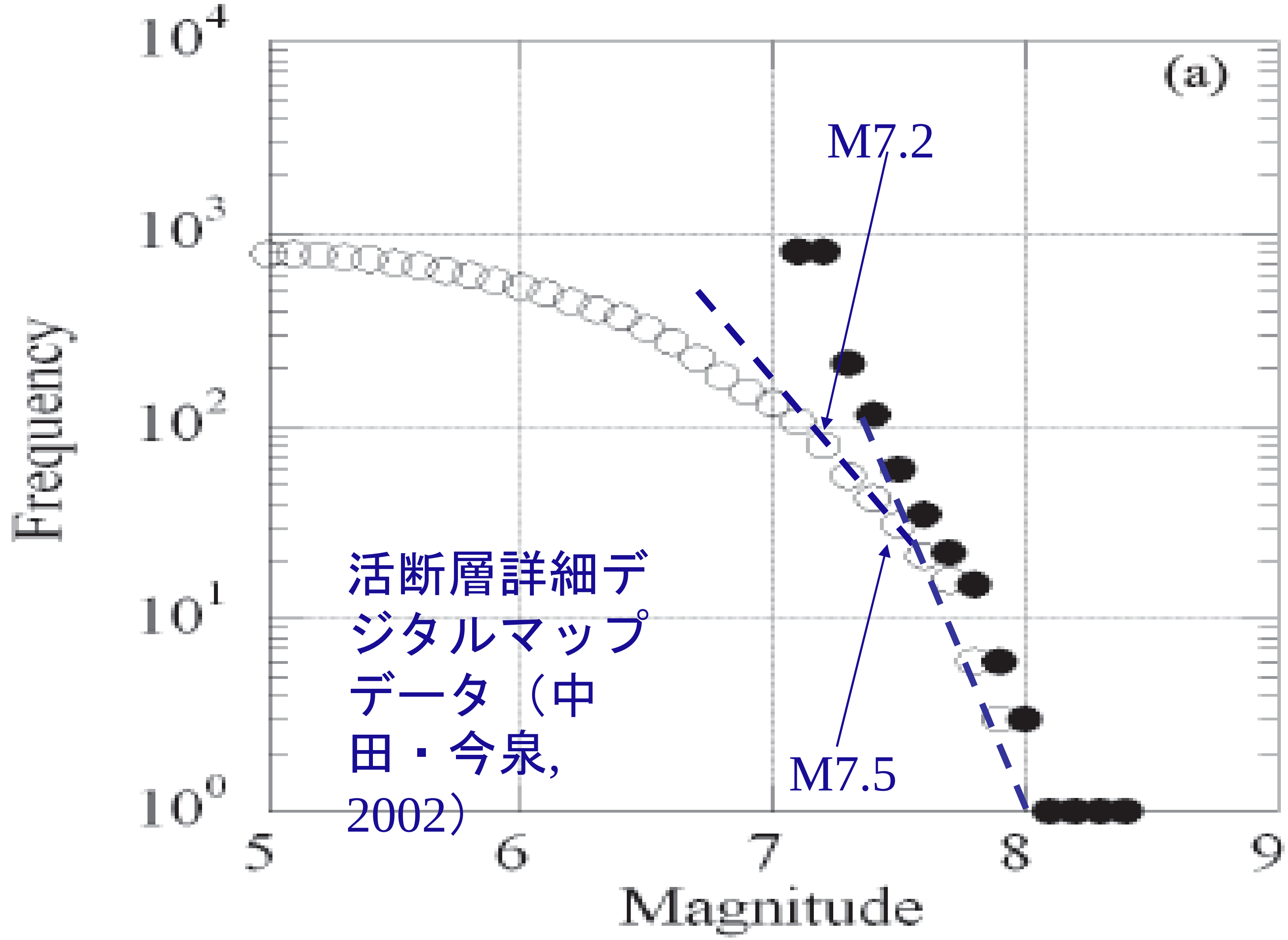
Conclusions

There exist
an earthquake leaving no clear feature on the surface, and
an active fault whose source fault is much longer than surface features.

The longer an active fault is, the higher is its activity.

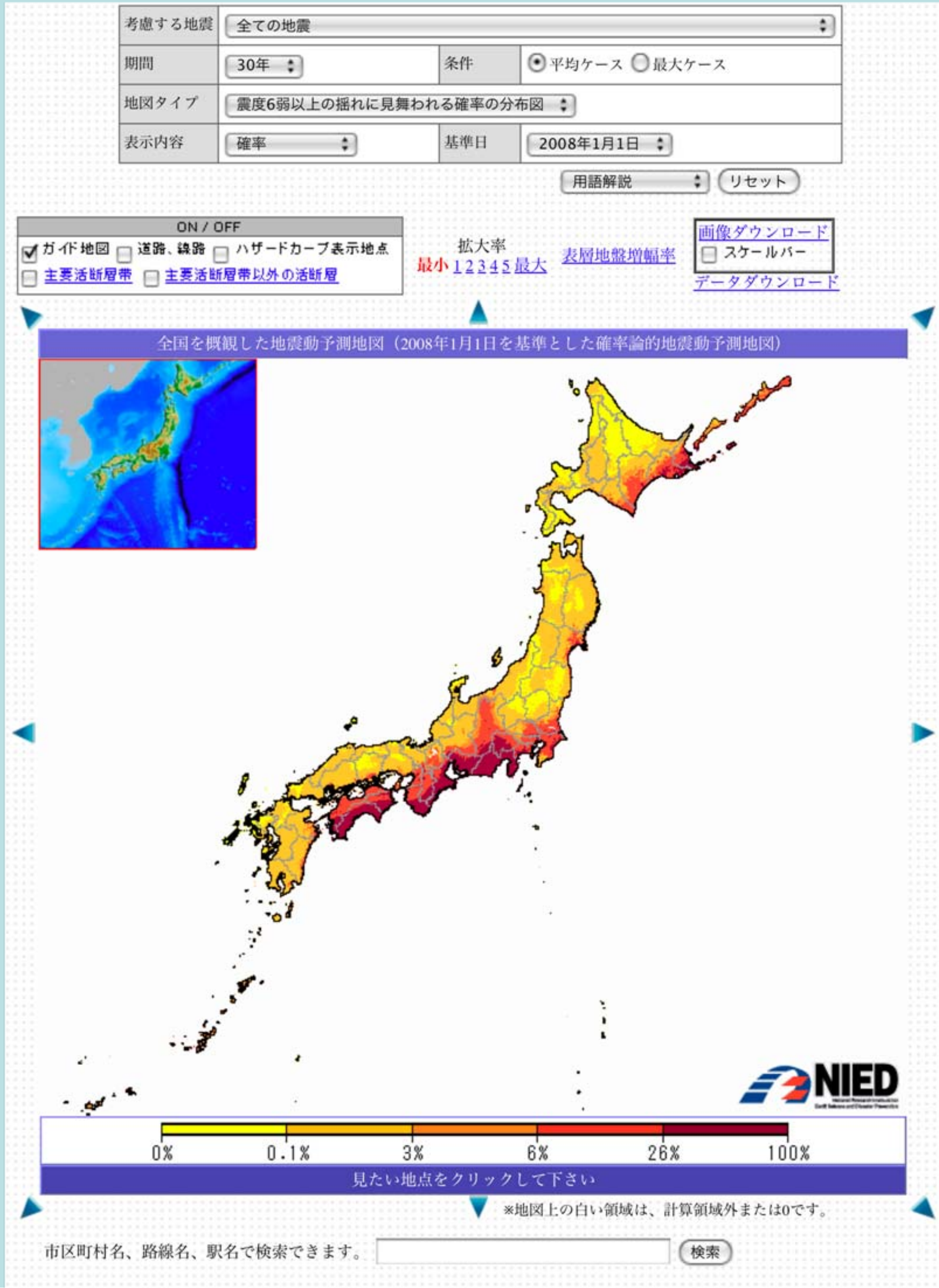
活断層セグメント長の頻度分布

沖野・隈元（2007, 活断層研究）



マグニチュードの範囲

	最小	最大
予め震源が特定しにくい地震	-	7.0-7.1
地表で活動が認めにくい地震	-	?
短い活断層の地震	6.9	7.4程度

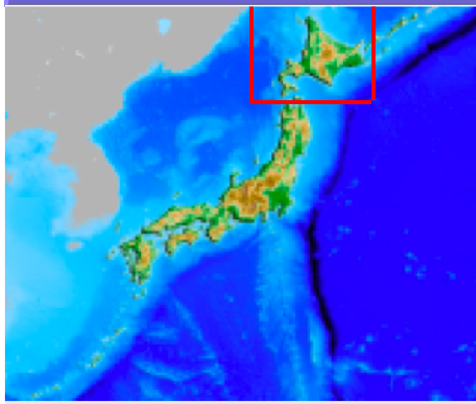

考慮する地震
全ての地震
期間
30年
条件
平均ケース
最大ケース
地図タイプ
震度6弱以上の揺れに見舞われる確率の分布図
表示内容
確率
基準日
2008年1月1日
用語解説
リセット
ON / OFF
ガイド地図
道路、鉄路
ハザードカーブ表示地点
主要活断層帯
主要活断層帯以外の活断層
拡大率
最小 1 2 3 4 5 最大
表層地盤増幅率
画像ダウンロード
スケールバー
データダウンロード
全国を概観した地震動予測地図（2008年1月1日を基準とした確率論的地震動予測地図）
NIED
0%
0.1%
3%
6%
26%
100%
見たい地点をクリックして下さい
※地図上の白い領域は、計算領域外または0です。
市区町村名、路線名、駅名で検索できます。
検索

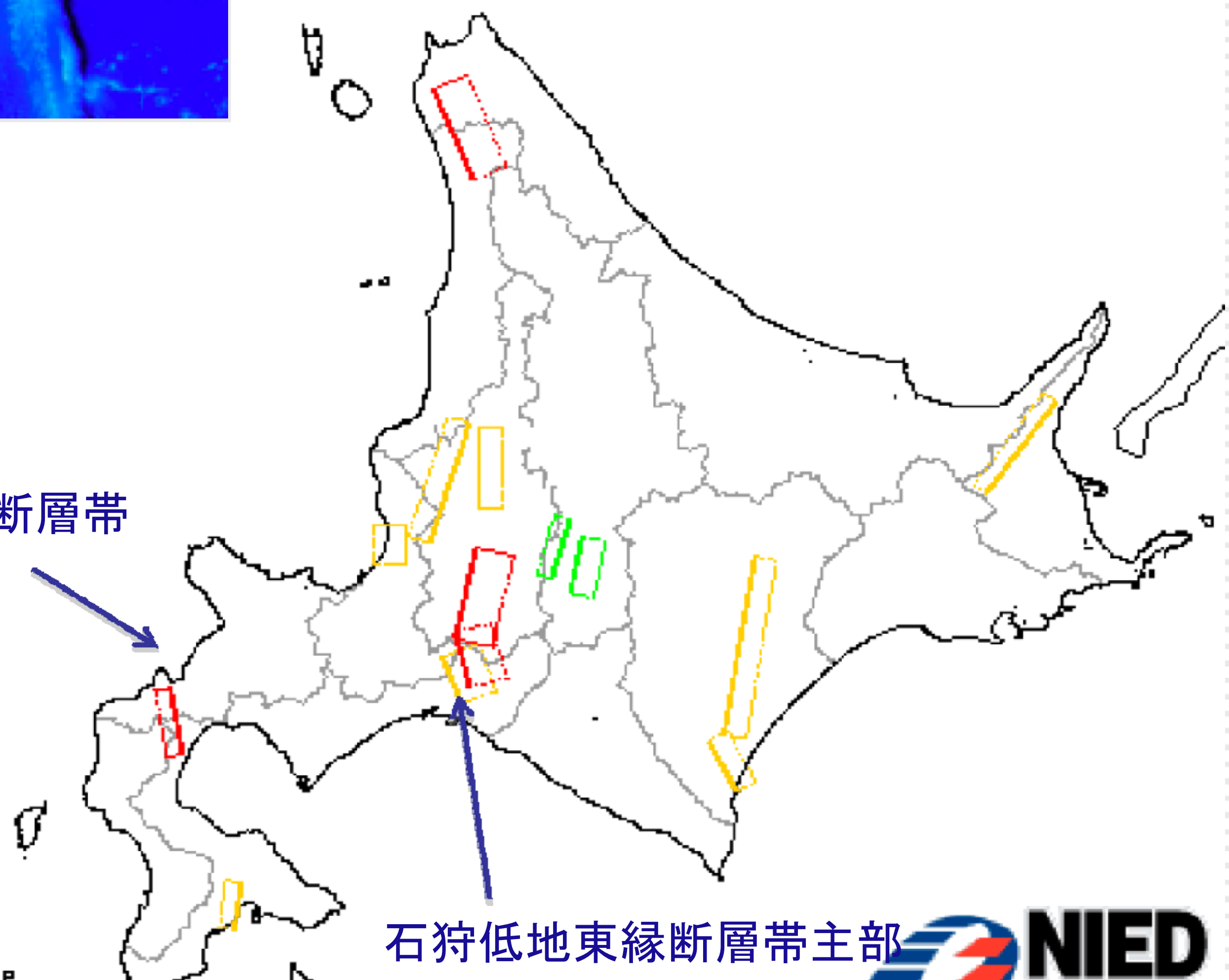
J-SHIS

主要活断層帯

ON / OFF
ｲﾄﾞ 地図
路、線路

拡大率
小 1 **2** 3

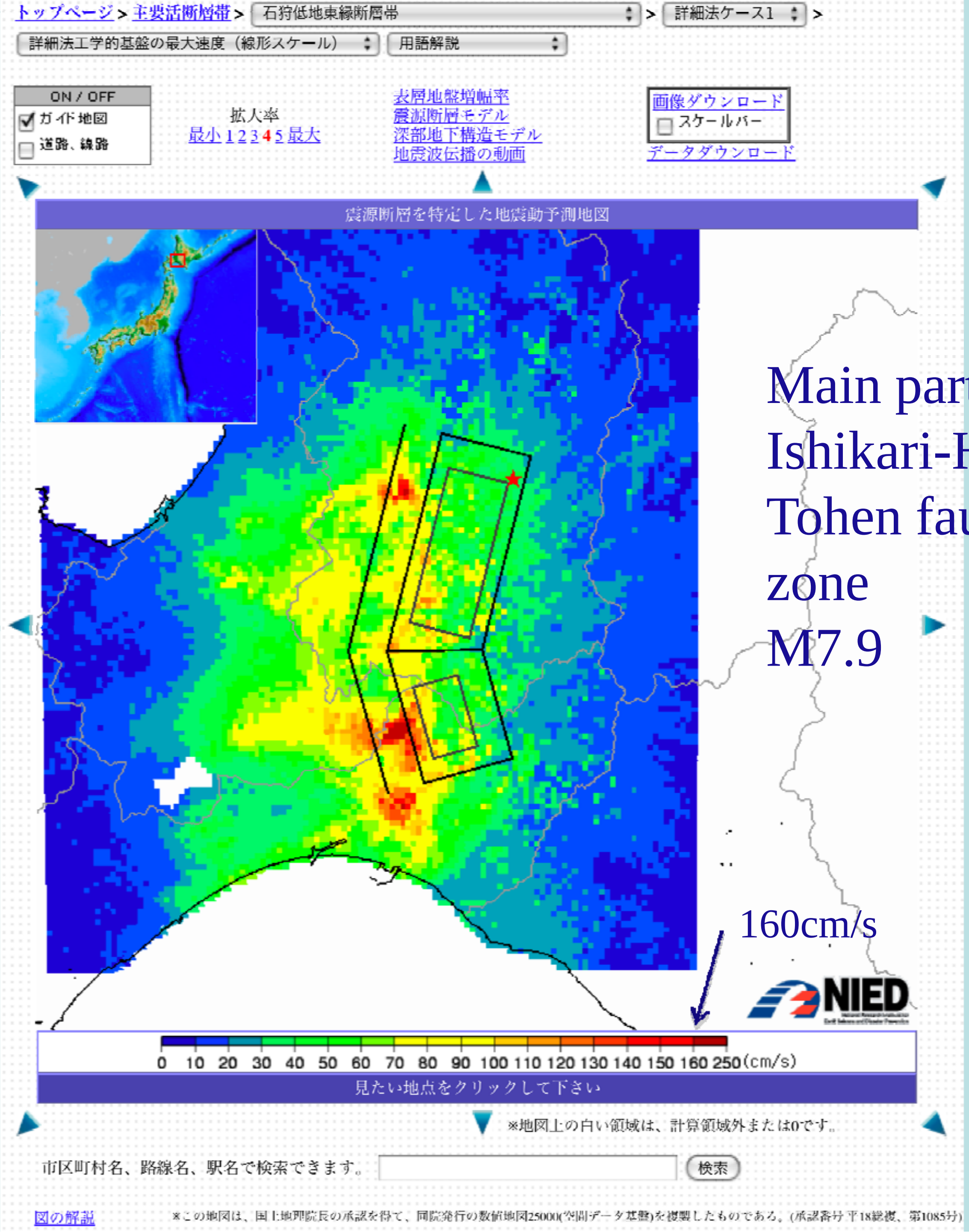




例
期評価結果
年発生確率
大ケース)

- 3%以上
- 0.1%以上 3%未満
- 0.1%以下

NIED



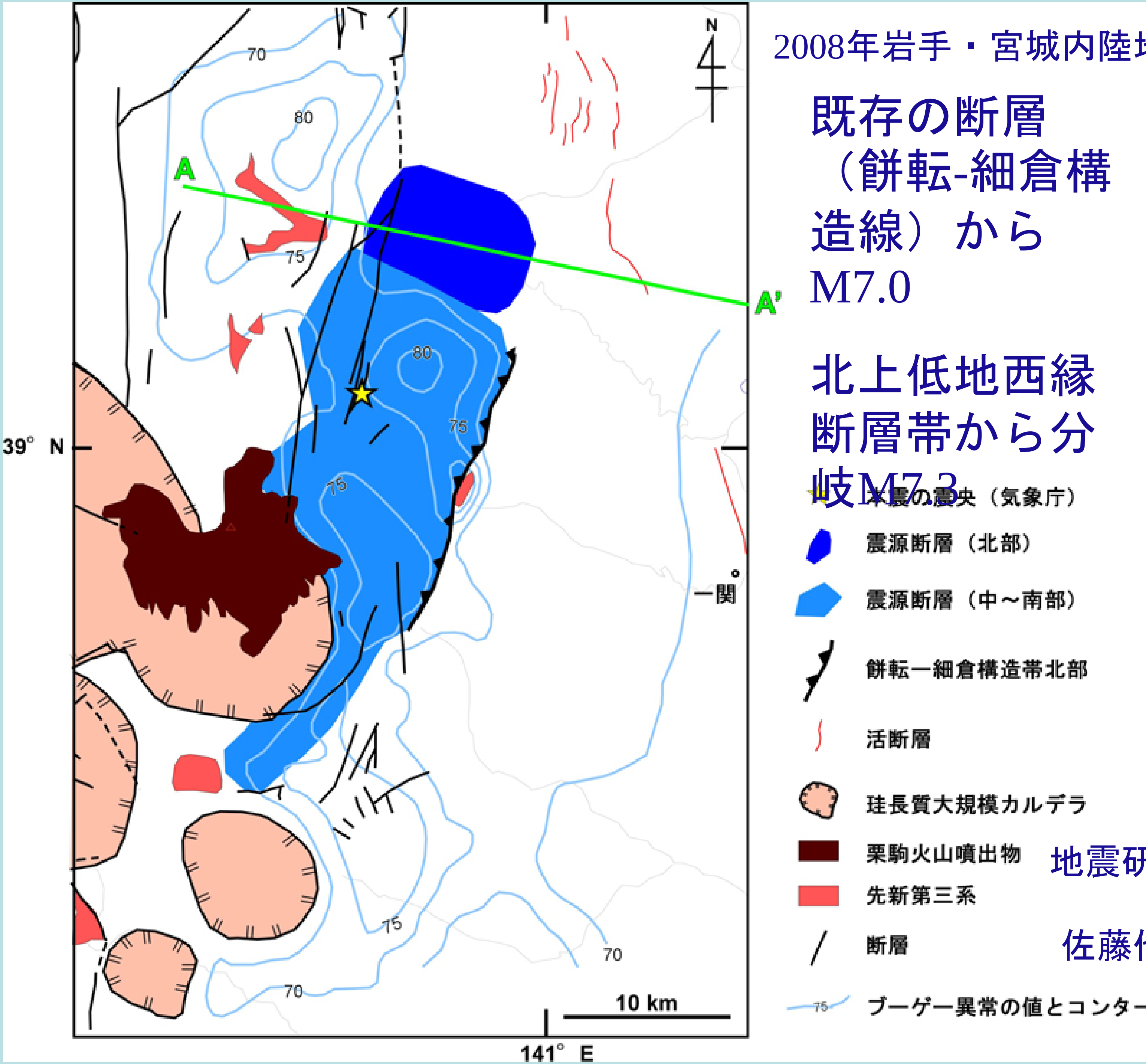
Main part of Ishikari-Heiya-Tohen fault zone M7.9

160cm/s

2008年岩手・宮城内陸地震

既存の断層（餅転-細倉構造線）から M7.0

北上低地西縁断層帯から分岐M7.3



地震研HPより

佐藤他, 2008