The M_{JMA} 7.6 "Noto Peninsula" Japan Earthquake of January 1st 2024

Preliminary Report with Emphasis on Recorded Motions and Soil Effects

GeoEngineers Without Borders (GeoWB), ISSMGE

Evangelia GARINI and **George GAZETAS**

Technical University Crete

National Technical University Athens

8 January 2024

We are grateful to **Dr. Hiroyuki Kimata**

and

the Japanese **K-Net** and **KiK-Net** Administrations

for providing us with all the records* of this disastrous earthquake.

* The processing and analysis of the records were performed by the Authors

CONTENTS

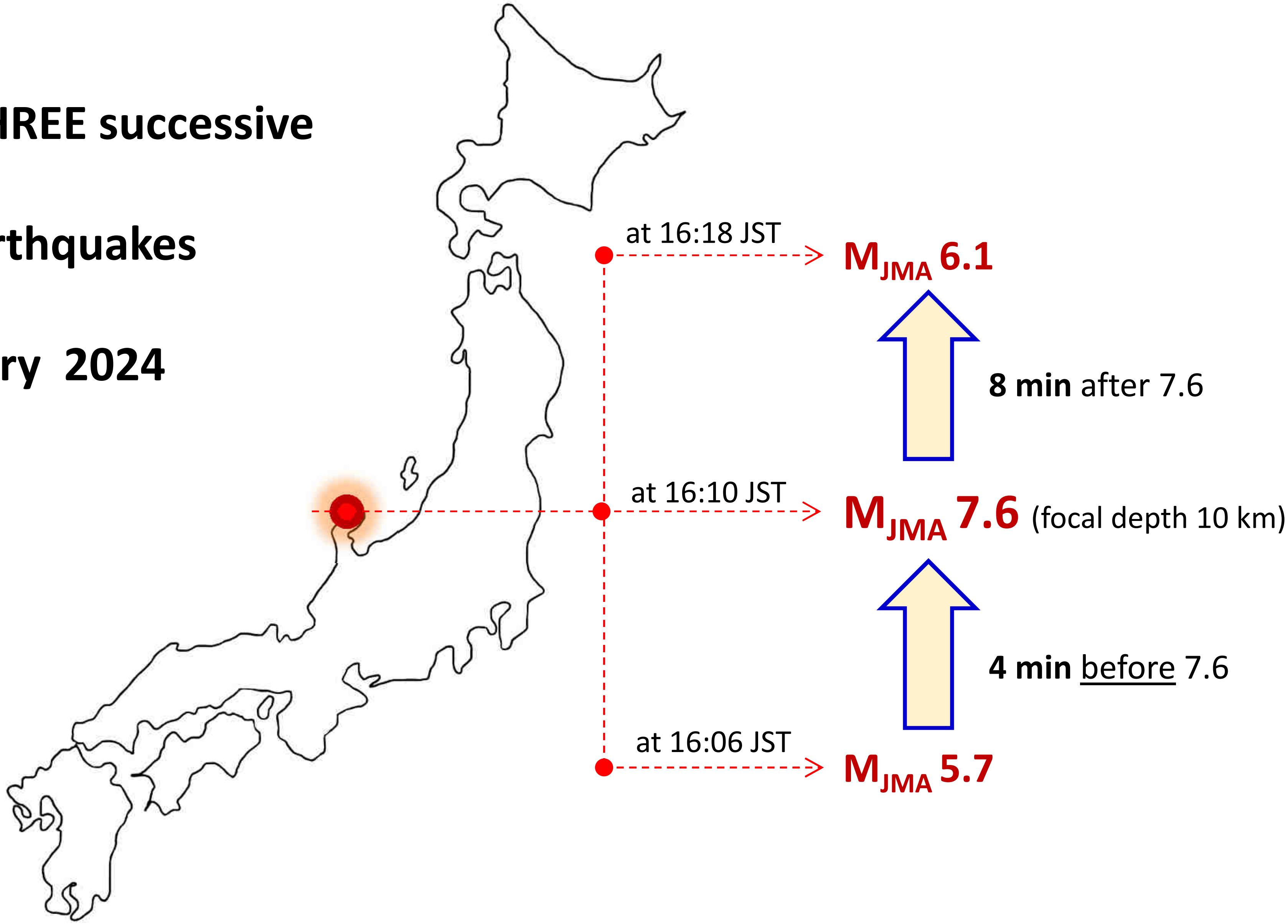
On 1 January 2024, at 4:10 p.m. local time an **M_{JMA}7.6** or **M_w7.5** earthquake occurred near the **Noto Peninsula** (Hanto, in Japanese) **of Ishikawa Prefecture**, on the western coast of the so-called (by the Japanese) East Japan, i.e., the northern part of Honshu island. It was triggered by a **shallow reverse faulting system**.

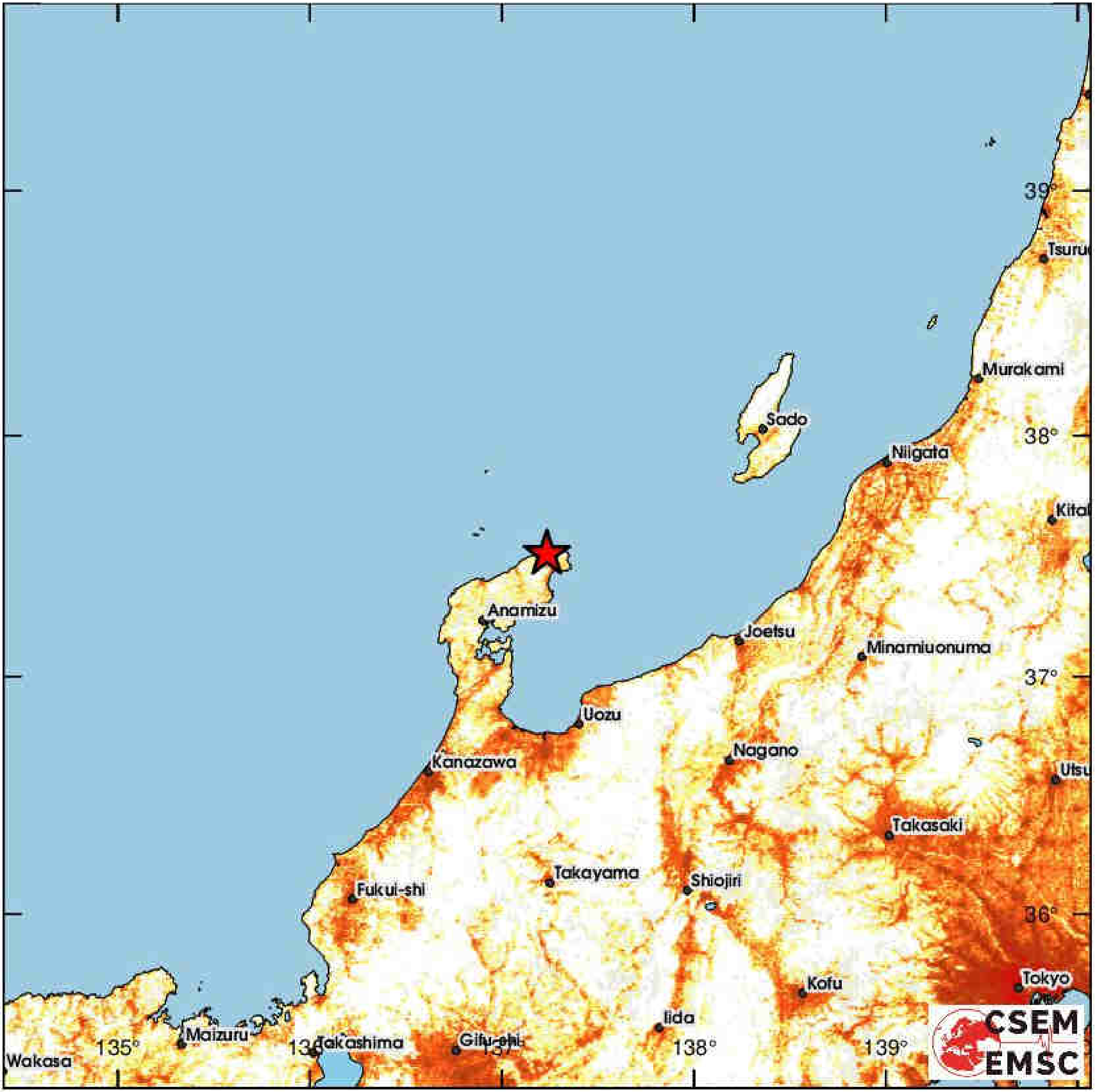
In Japan most earthquakes occur off the eastern coast, *where the Pacific tectonic plate* and the *Philipine plate s*ubduct beneath the *North American* and the *Eurasian plates*. This earthquake occurred on the western coast of Japan in the *Sea of Japan*.

While strong earthquakes are very frequent in Japan, the region surrounding the January 1, 2024, earthquake has lower rates of seismicity compared to the major subduction zone along its eastern coast. Since 1900, almost 30 earthquakes with magnitudes over 6 have occurred (within 250 km distance radius). However, 3 or 4 earthquakes of about M 6.5 - 7.0 occurred in this area between 2000 and 2010. We mention the Noto Hanto earthquake of 25 March 2007 (a day easy for Greeks to remember) of M 6.7, which members of the NTUA team (GG, NG) along with Professor Tokimatsu visited, before meeting the students of his NTUA class for the annual field trip to Kobe. The collapse of roofs that we see in this earthquake (later photos) are easily explained based on our observations of that time (as will be explained below).

NOT one but THREE successive strong earthquakes

1 January 2024





Population Density

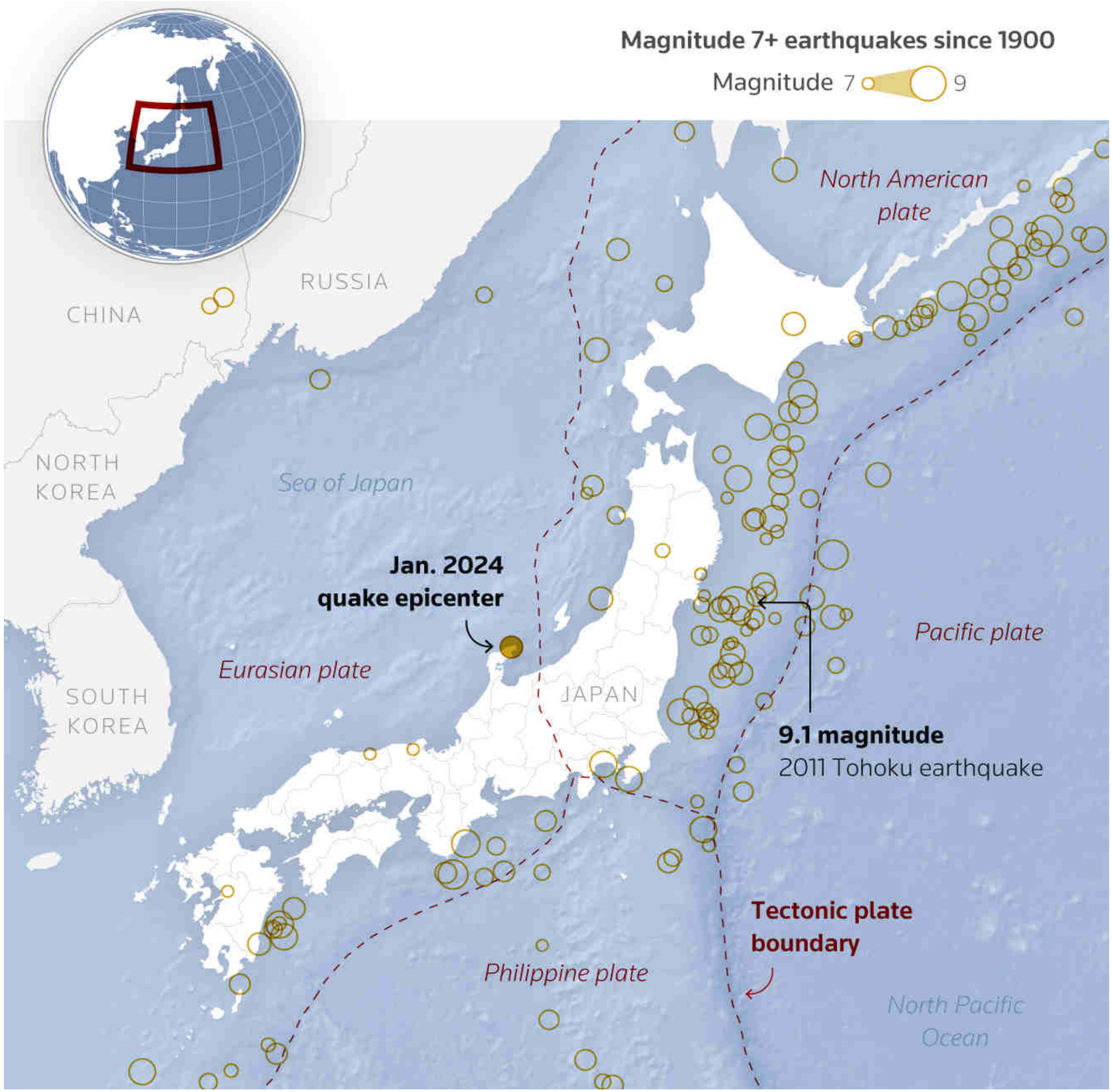
Number of inhabitants per square km

- pop < 5
- 5 < pop < 25
- 25 < pop < 125
- 125 < pop < 600
- 600 < pop < 3000
- 3000 < pop < 15000
- pop > 15000

100 km

★ Earthquake epicentre

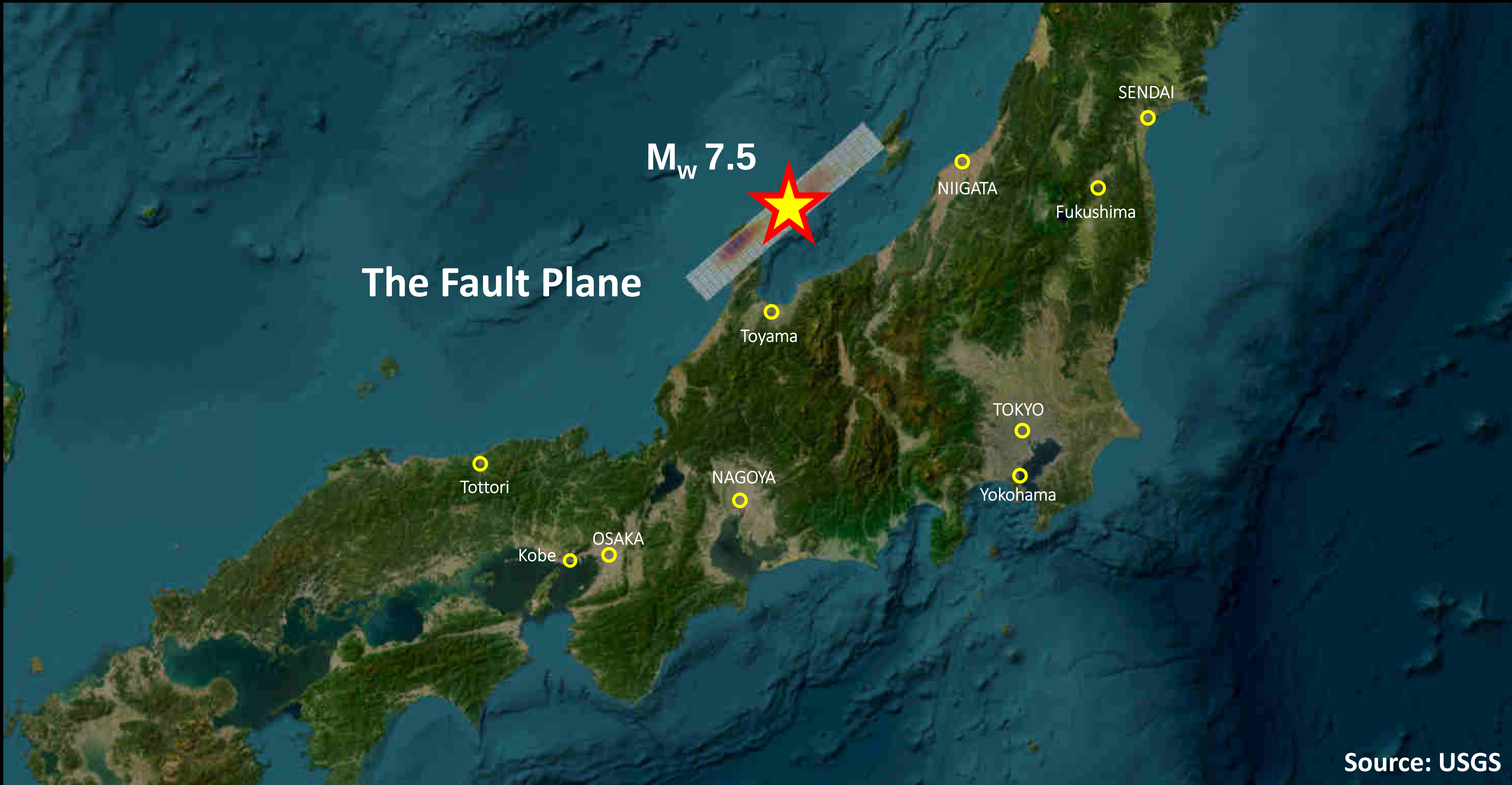
SEISMOLOGICAL ASPECTS

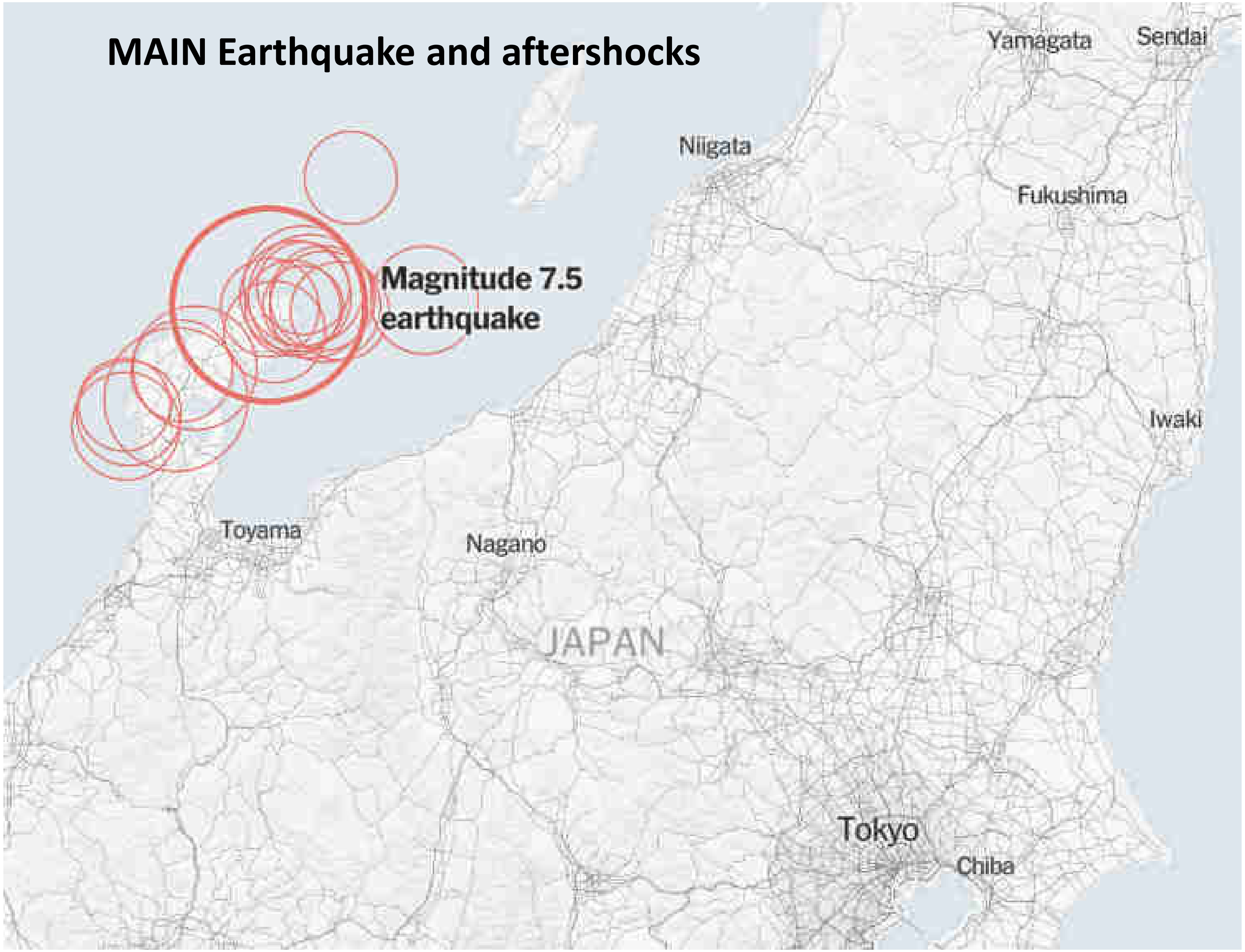


Japan and the Major Tectonic Plates

Sources: United States Geological Survey; Natural Earth

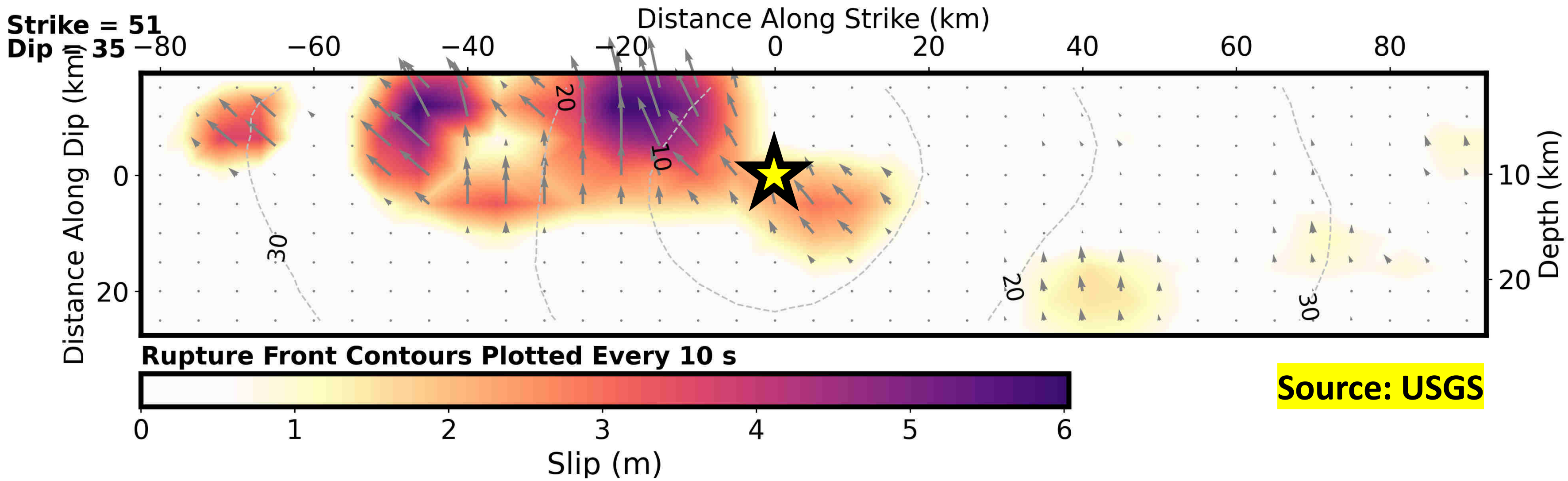
Vijdan Mohammad Kawoosa • Jan. 1, 2024 | REUTERS


M_W 7.5
The Fault Plane
SENDAI
NIIGATA
Fukushima
Toyama
TOKYO
Yokohama
NAGOYA
Tottori
OSAKA
Kobe
Source: USGS



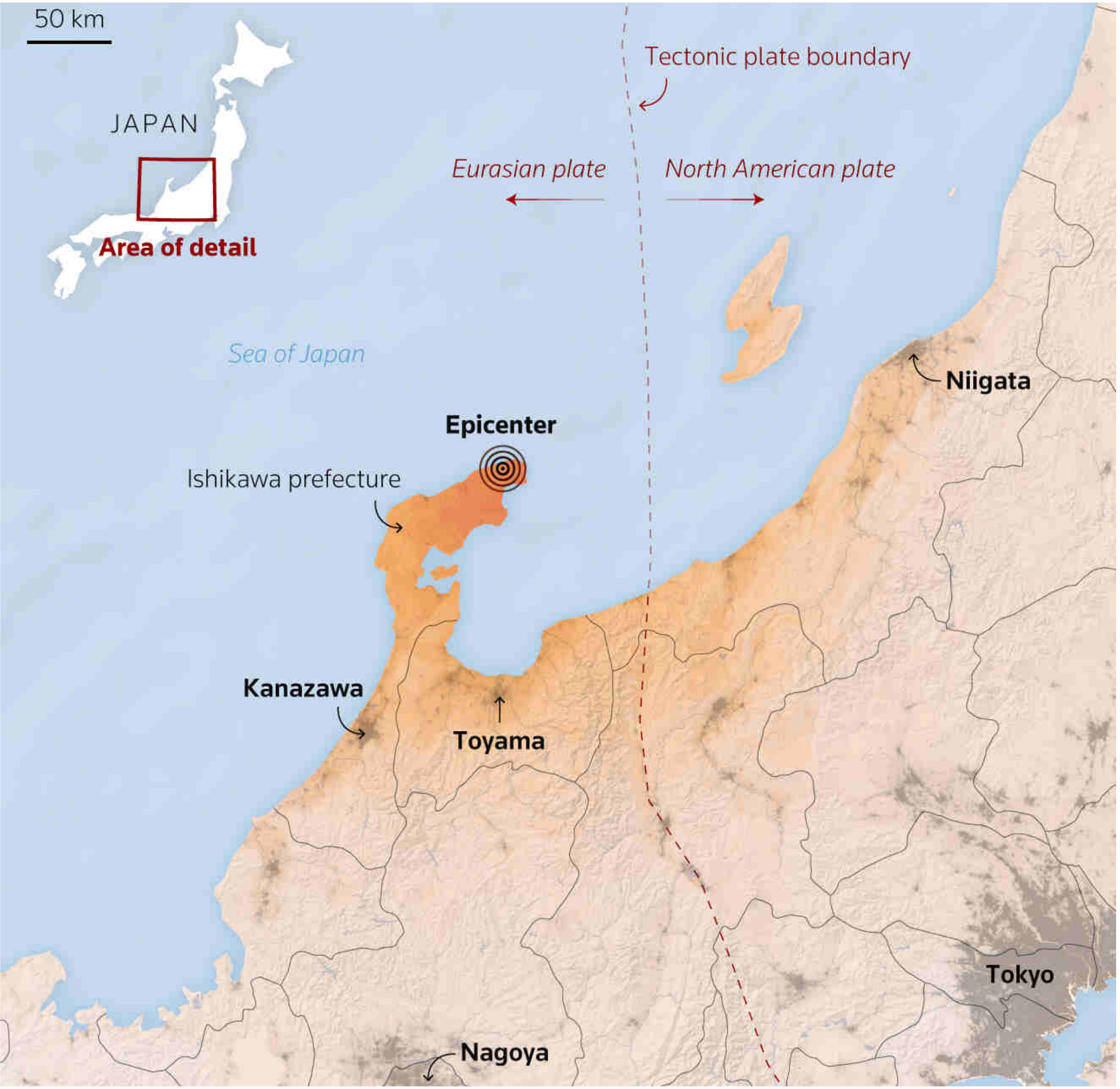
Source:
The New York Times

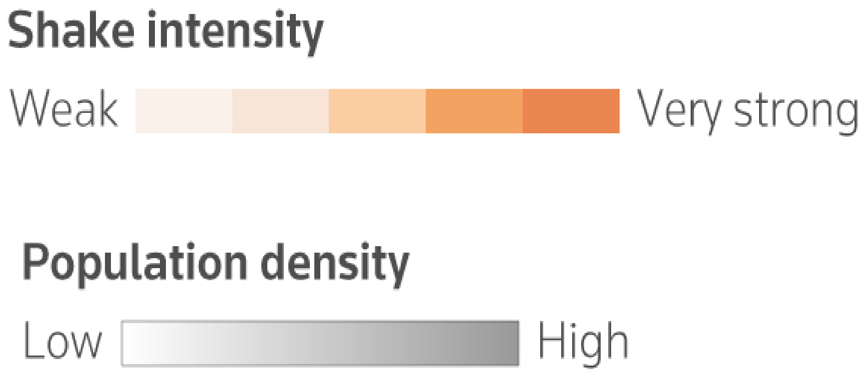
Slip Distribution on the Seismogenic Fault Plane （Computed by USGS）



Cross-section of slip distribution. The strike direction is indicated above each fault plane and the hypocenter location is denoted by a star. Slip amplitude is shown in color and the motion direction of the hanging wall relative to the footwall (rake angle) is indicated with arrows. Contours show the rupture initiation time in seconds.

Notice that according to USGS's finite fault model, the earthquake rupture extended to a length approximately 200 km. The rupture was bi-lateral, starting in the middle and propagating north-east and south-west. The largest fault slip displacement is estimated to be 3.6 m beneath the peninsula (southeast). The second zone of slippage occurred between the peninsula and Sado Island (northeast), producing up to 1.9 m of slip.

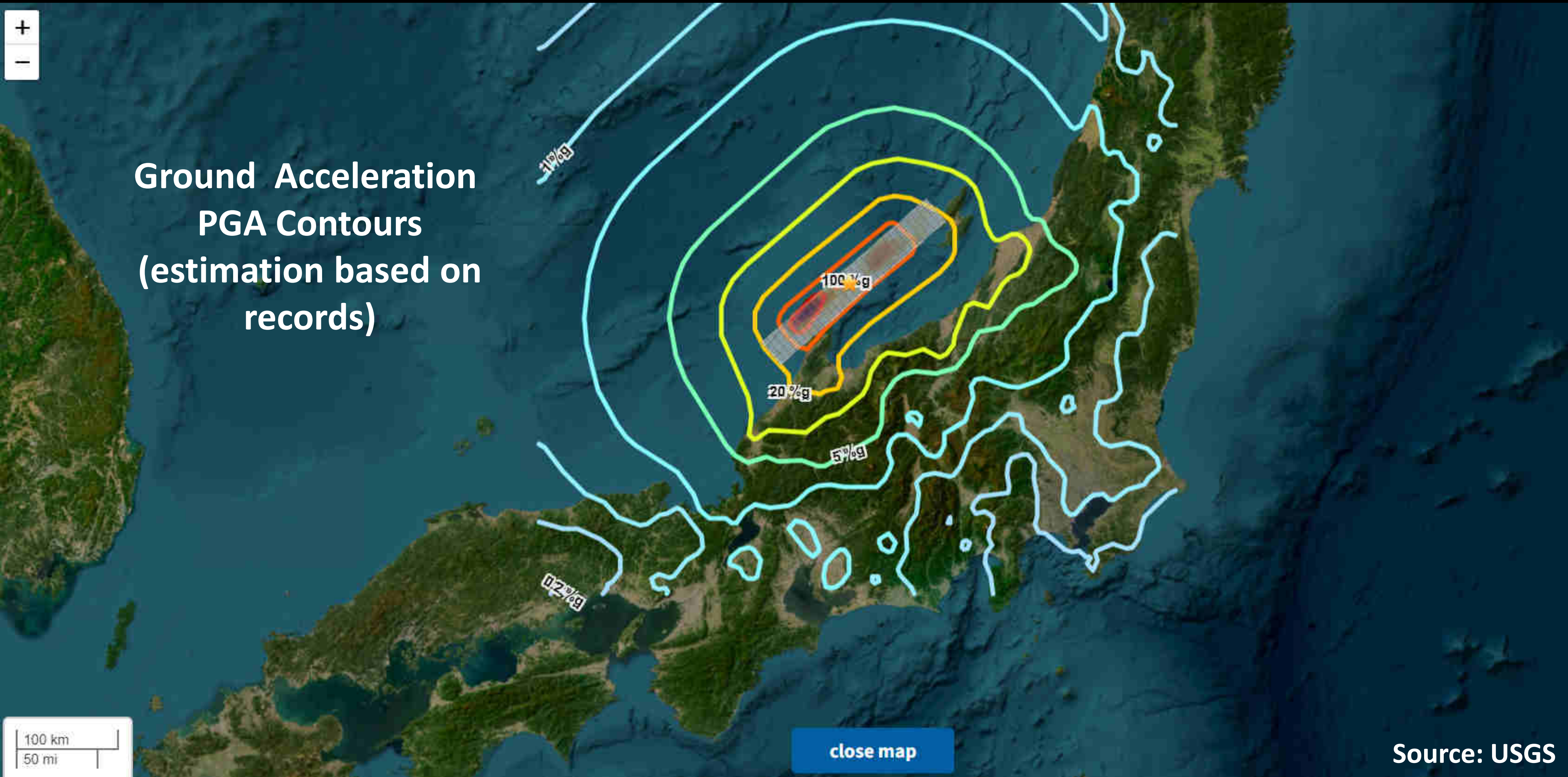




Sources: United States Geological Survey; Shuttle Radar Topography Mission, NASA; project, University of Southampton

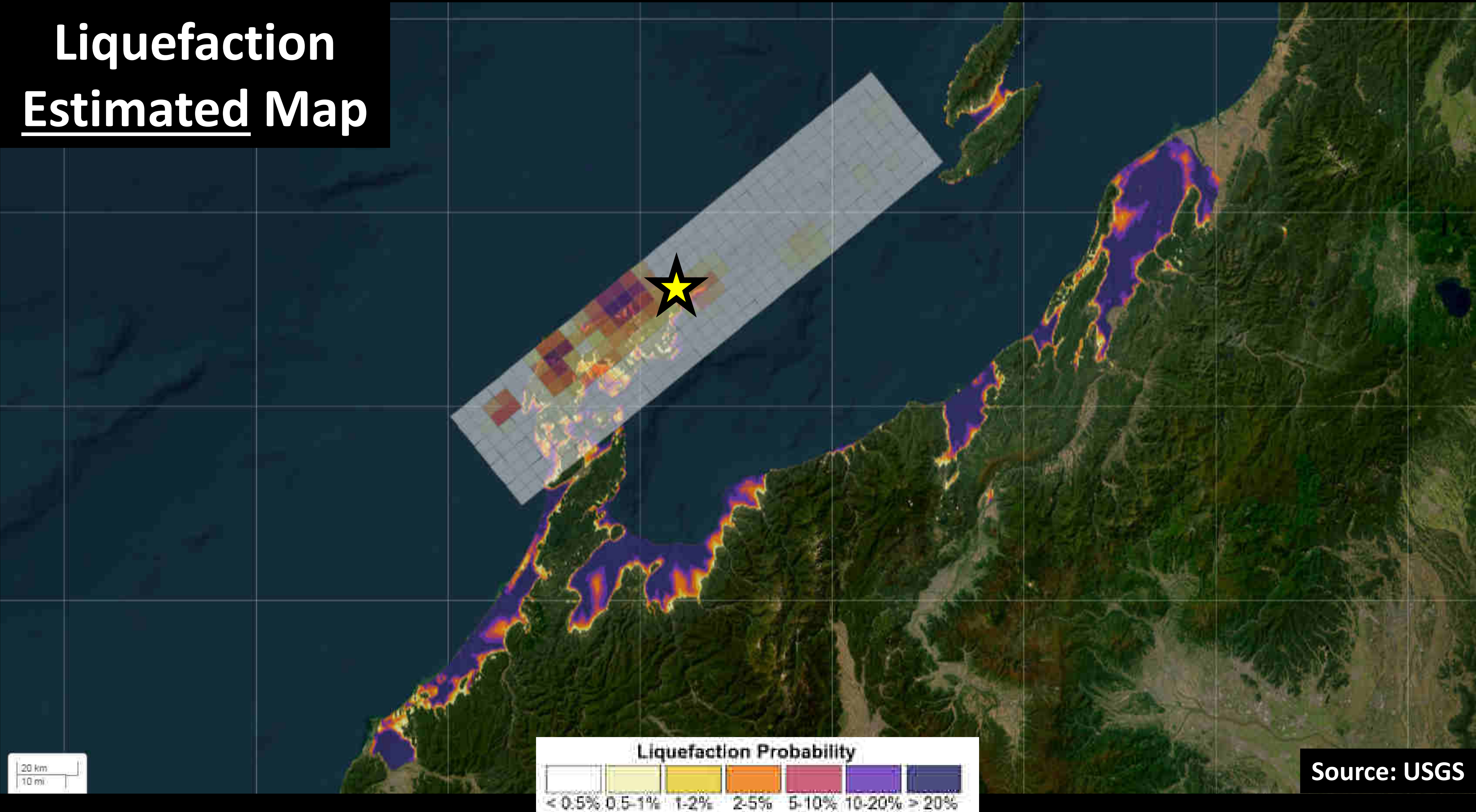
Vijdan Mohammad Kawoosa • Jan. 1, 2024 | REUTERS

Ground Acceleration
PGA Contours
(estimation based on records)



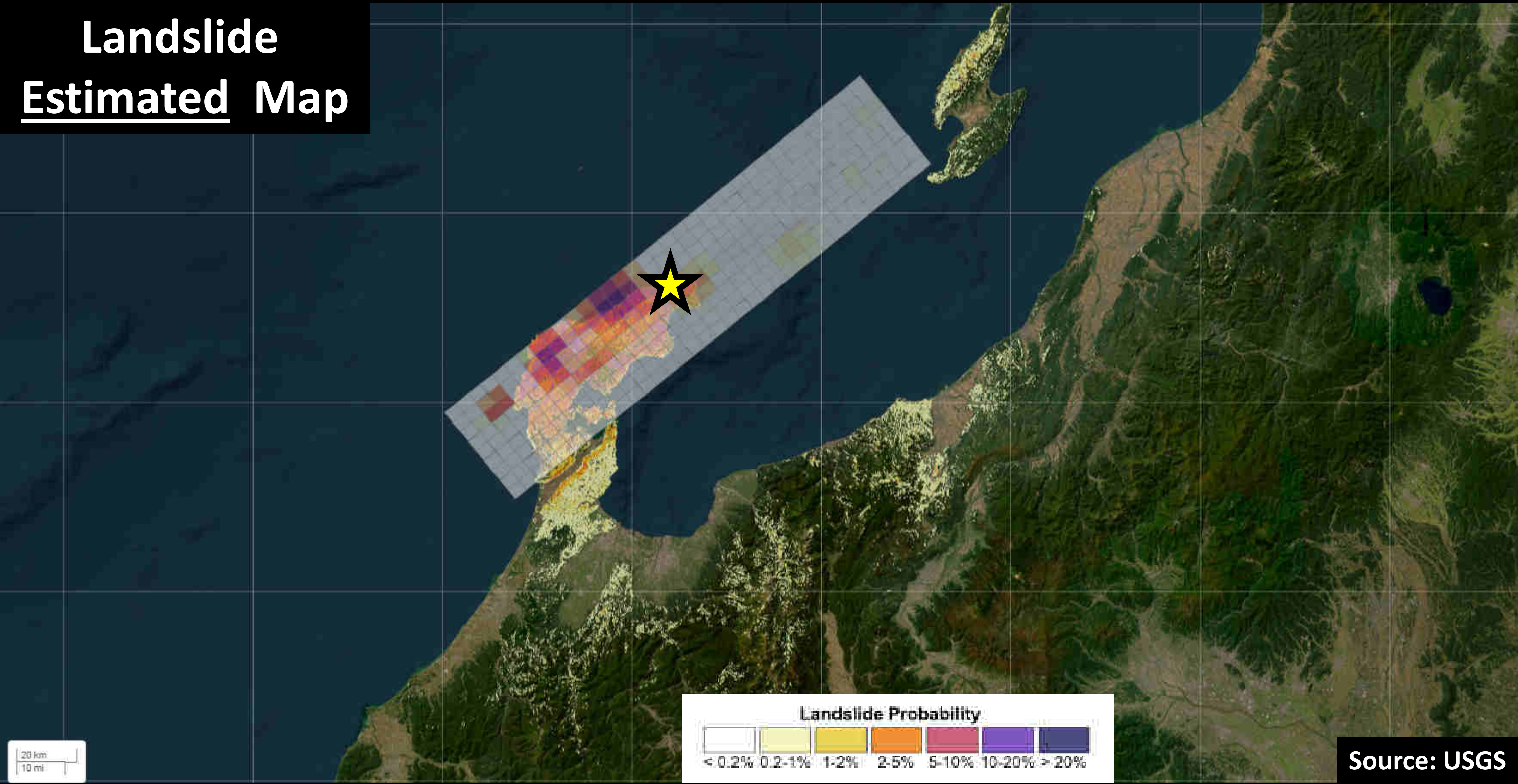
Source: USGS

Liquefaction Estimated Map



Source: USGS

Landslide Estimated Map

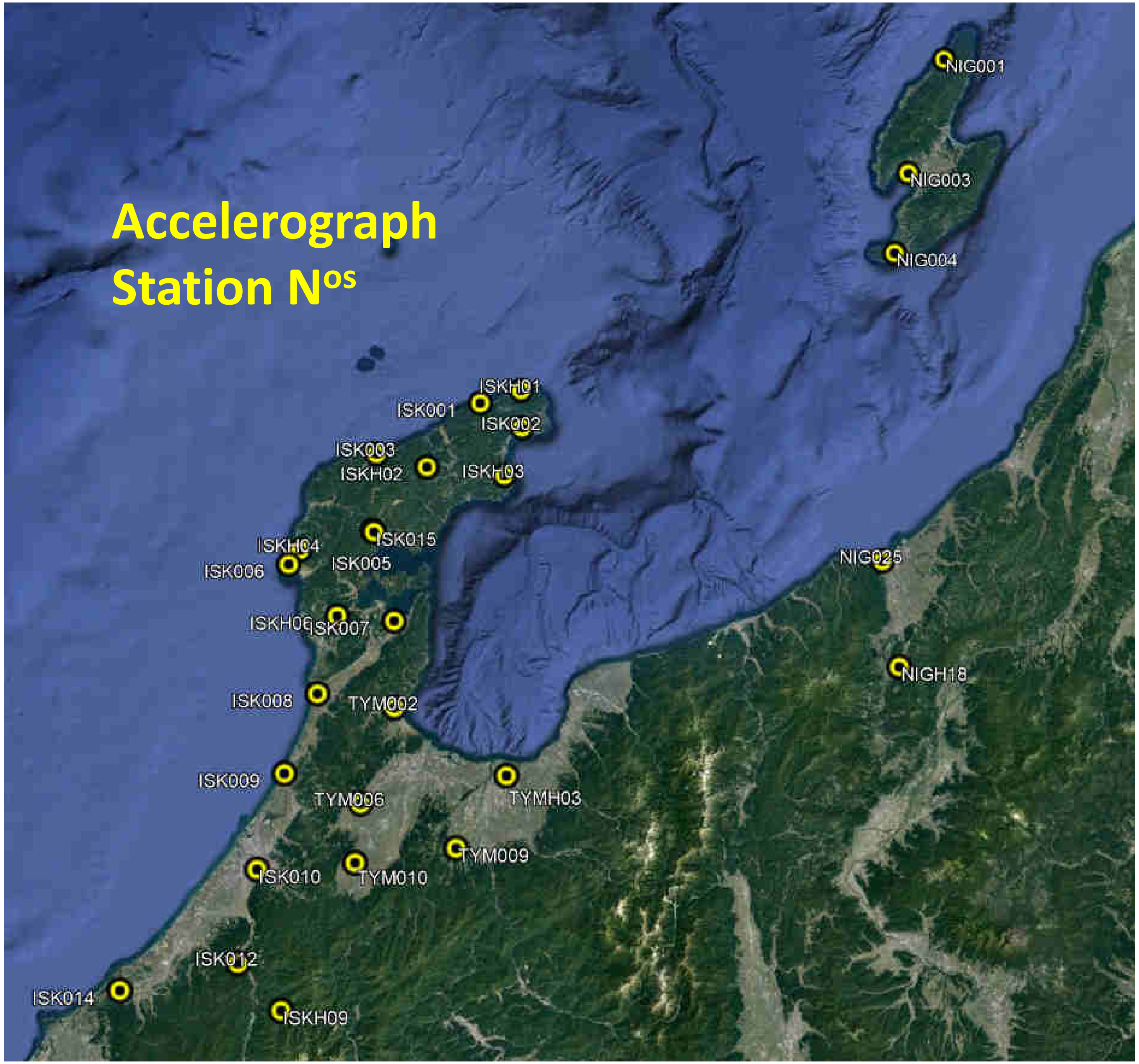


Source: USGS

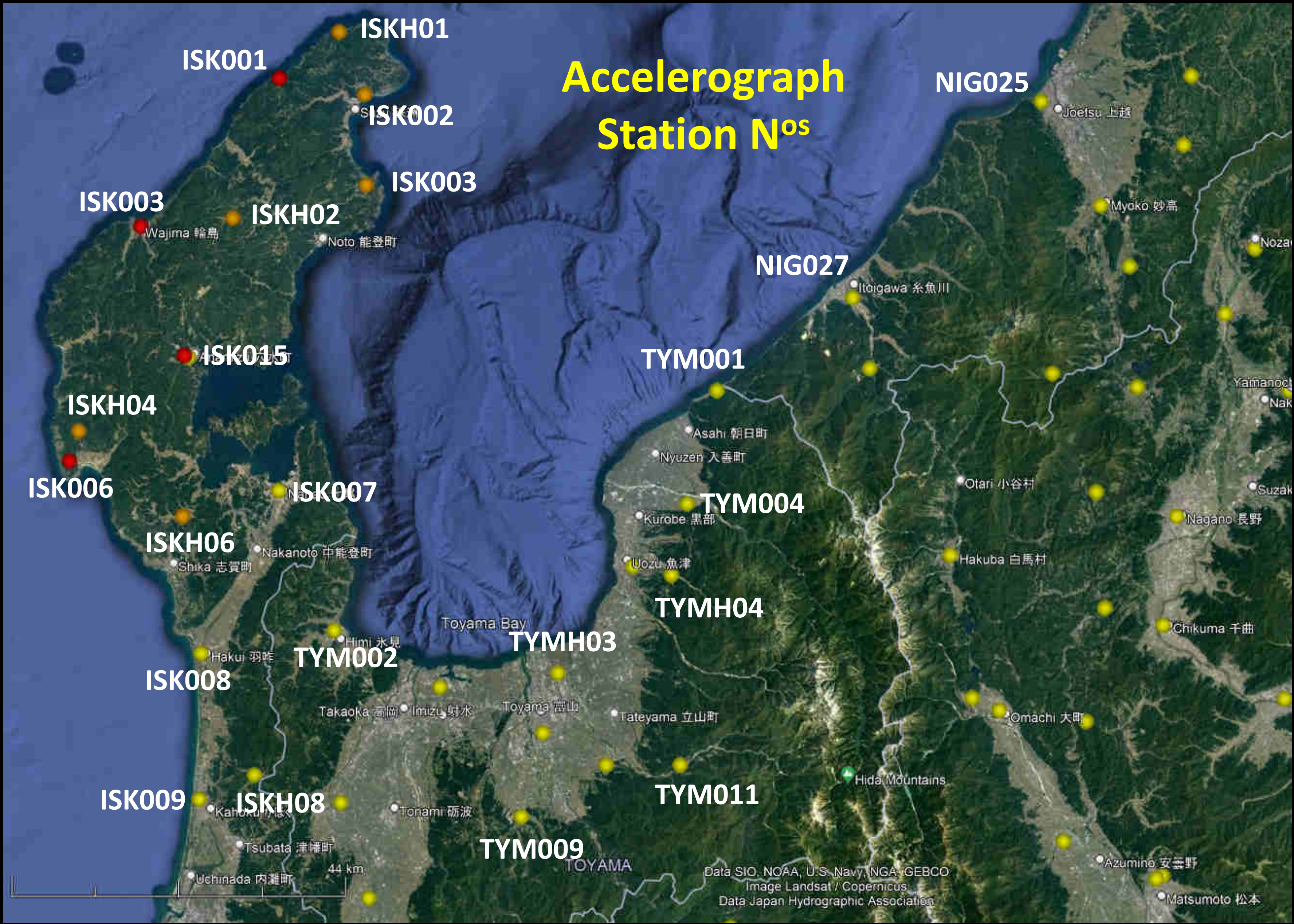
Accelerographs: Analysis, Interpretation, Soil Effects

Recorded

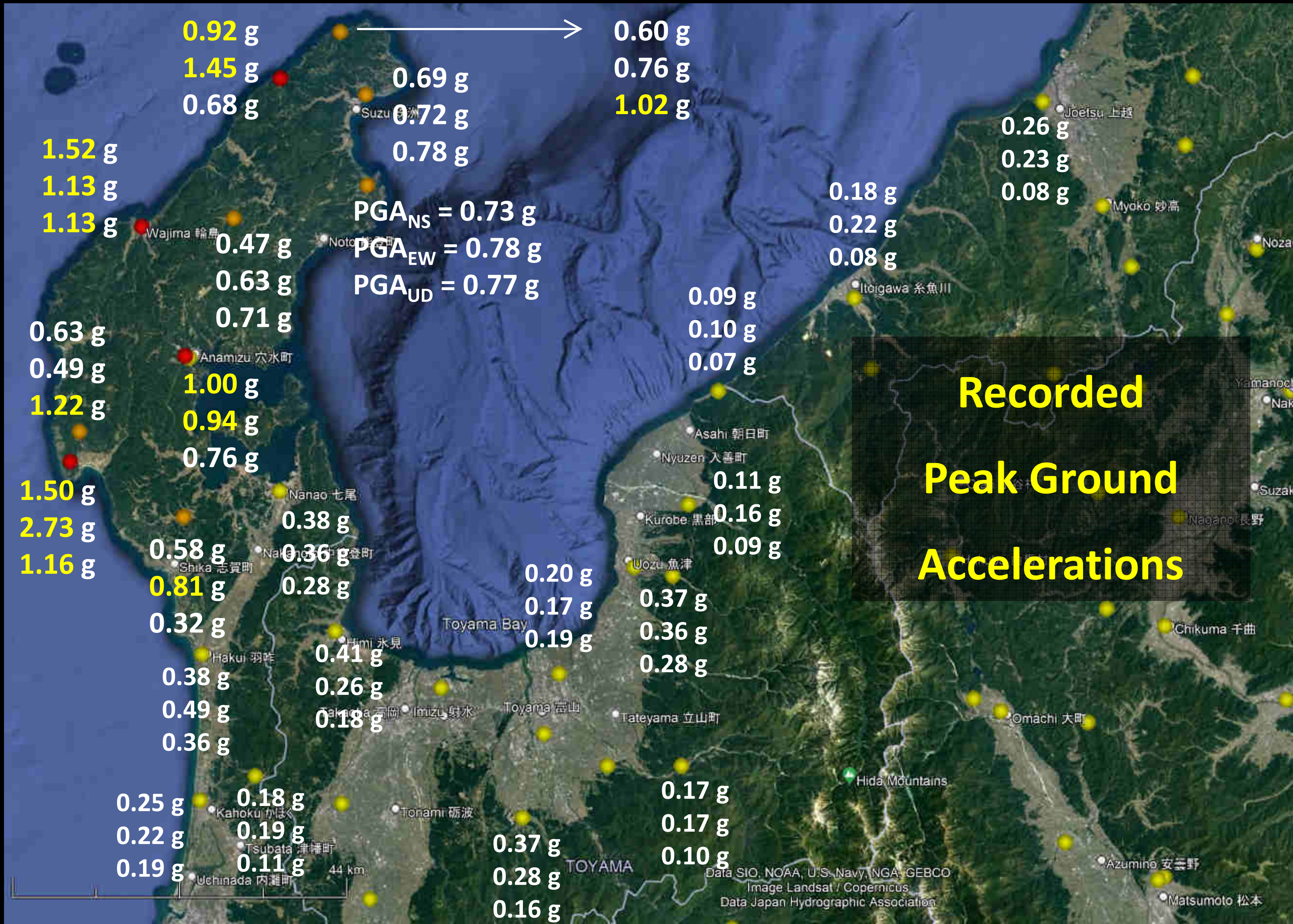
On the K-Net and KiK-Net accelerograph stations



	PGA in g		
STATION	N-S	E-W	U-D
ISK006	1.479	2.678	1.142
ISK003	1.496	1.12	1.11
ISK001	0.904	1.429	0.674
ISK005	1.023	1.146	1.044
ISKH04	0.618	0.484	1.202
ISKH01	0.595	0.748	1.006
ISK015	0.979	0.926	0.747
ISKH03	0.714	0.772	0.759
ISK002	0.686	0.707	0.775
ISKH06	0.573	0.797	0.32
ISKH02	0.47	0.617	0.69
NIG004	0.533	0.475	0.213
ISK008	0.374	0.483	0.354
ISK007	0.374	0.359	0.283
TYM002	0.404	0.26	0.181
NIGH18	0.336	0.379	0.123
TYM009	0.377	0.281	0.156
TYM006	0.304	0.304	0.069
NIG001	0.189	0.305	0.09
NIG003	0.284	0.247	0.175
TYMH03	0.201	0.165	0.192
ISK009	0.251	0.219	0.195
NIG025	0.263	0.231	0.082
TYM010	0.143	0.256	0.076
ISK014	0.178	0.253	0.111
ISK012	0.156	0.236	0.061
ISKH09	0.203	0.162	0.108
ISK010	0.215	0.163	0.101



Accelerograph
Station N^os
ISKH01
ISK001
ISK002
ISK003
ISK003
ISKH02
Wajima 輪島
Noto 能登町
ISK015
ISKH04
ISK006
ISK007
ISKH06
Nakanoto 中能登町
Shika 志賀町
Hakui 羽咋
ISK008
TYM002
Himi 氷見
Toyama Bay
TYMH03
TYMH04
Uozu 魚津
Kurobe 黒部
TYM004
Nyuzen 入善町
Asahi 朝日町
TYM001
NIG027
Itoigawa 糸魚川
NIG025
Joetsu 上越
Myoko 妙高
Otari 小谷村
Hakuba 白馬村
Nagano 長野
Chikuma 千曲
Omachi 大町
Azumino 安曇野
Matsumoto 松本
Takaoka 高岡
Imizu 射水
Toyama 富山
Tateyama 立山町
TYM011
Hida Mountains
TYM009
TOYAMA
Tonami 砺波
ISK009
ISKH08
Tsubata 津幡町
Uchinada 内灘町
44 km
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Data Japan Hydrographic Association


Recorded Peak Ground Accelerations
0.92 g
1.45 g
0.68 g
0.69 g
0.72 g
0.78 g
0.60 g
0.76 g
1.02 g
1.52 g
1.13 g
1.13 g
PGA_{NS} = 0.73 g
PGA_{EW} = 0.78 g
PGA_{UD} = 0.77 g
0.47 g
0.63 g
0.71 g
0.26 g
0.23 g
0.08 g
0.18 g
0.22 g
0.08 g
0.09 g
0.10 g
0.07 g
0.63 g
0.49 g
1.22 g
1.00 g
0.94 g
0.76 g
1.50 g
2.73 g
1.16 g
0.38 g
0.36 g
0.28 g
0.58 g
0.81 g
0.32 g
0.11 g
0.16 g
0.09 g
0.20 g
0.17 g
0.19 g
0.37 g
0.36 g
0.28 g
0.41 g
0.26 g
0.18 g
0.38 g
0.49 g
0.36 g
0.25 g
0.22 g
0.19 g
0.18 g
0.19 g
0.11 g
0.37 g
0.28 g
0.16 g
0.17 g
0.17 g
0.10 g
Suzu
Wajima 輪島
Noto
Anamizu 穴水町
Nanao 七尾
Shika 志賀町
Hakui 羽咋
Himi 氷見
Toyama Bay
Toyama 富山
Imizu 射水
Takaoka 高岡
Tonami 砺波
Kahoku かほく
Tsubata 津幡町
Uchinada 内灘町
TOYAMA
Uozu 魚津
Kurobe 黒部
Nyuzen 入善町
Asahi 朝日町
Tateyama 立山町
Itoigawa 糸魚川
Joetsu 上越
Myoko 妙高
Nagano 長野
Chikuma 千曲
Omachi 大町
Azumino 安曇野
Matsumoto 松本
Hida Mountains
44 km
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Data Japan Hydrographic Association

Records at 9 stations:

$A(t)$, $V(t)$, $S_a(T)$

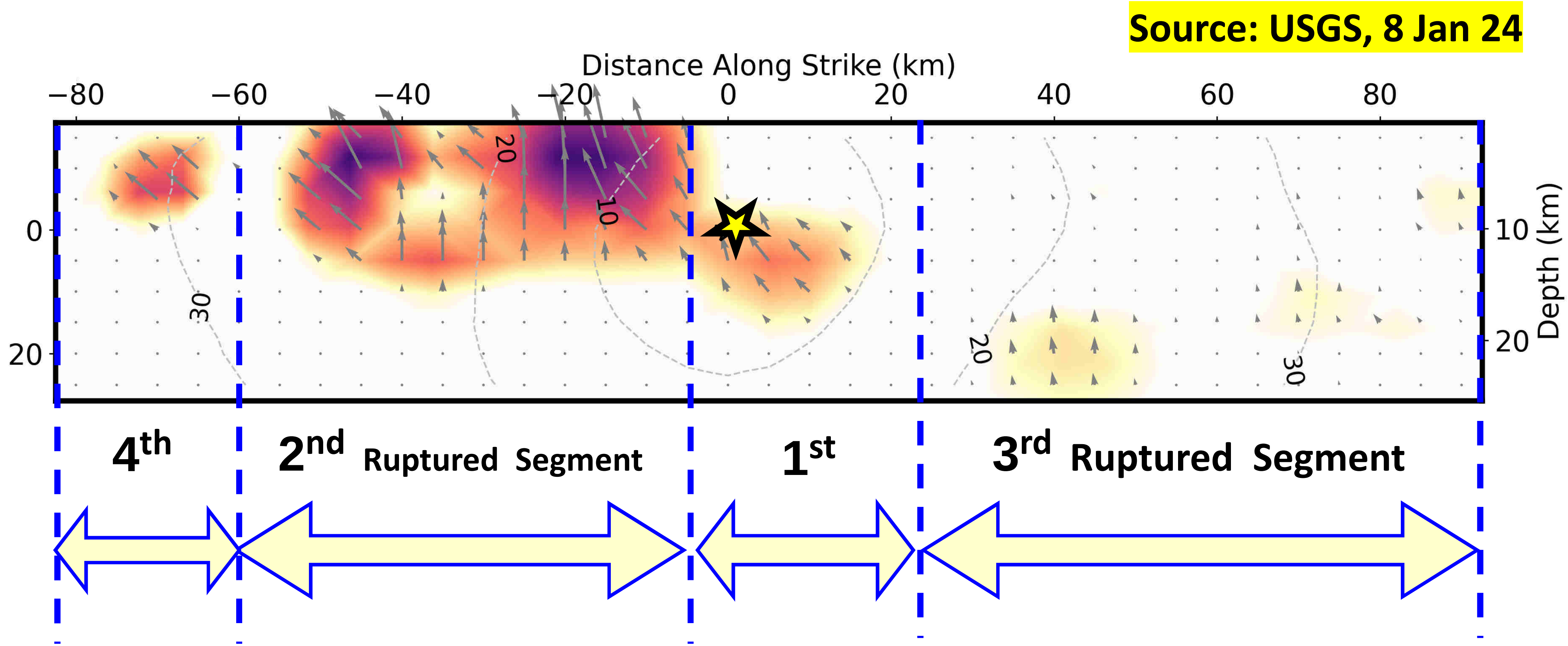
with the Soil Profiles.

We start with the two stations (1 and 2) at the epicenter,

then the station (3) in front of the south-western rupture, and so on (up to 9).

In two of the stations, ground motions in the BEDROCK (at great depths)

were recorded and are compared with ground-surface motions



the shallower SW Part with the greatest slippage

the deeper NE Part with much smaller slippage and a little delayed

REMARKS on RECORDED GROUND MOTIONS and SOIL EFFECTS

The **recorded ground motions are extraordinary** from several viewpoints, some quite as expected from “on”-the-fault motions of an M 7.5 event, but others very surprising. Here are some examples:,

(a) In the towns which were essentially just above the ruptured fault the peak accelerations were consistently **greater than 1g**. This is no surprise. Recall for instance the earlier earthquake in Turkey (6 Feb 23) and the motions recorded “on” the fault. And many other cases.

(b) The duration and appearance of the records, with or without the presence of “packets” of acceleration, are quite **consistent with**, and in fact would have revealed, **the fault rupture process** as shown in **USGS’s latest Slip Distribution on the Fault Plane**. For example, as you will see in subsequent slides, the acceleration time-histories of ***the two***

records that are ≈ at or very-very close to the epicenter (**ISKH 01** and **ISK 001**) display three such packets:

(i) the **first**, originating from the **weak but very close rupture around the epicenter** (peaks of about 0.45 g and 0.35 g, respectively)**;**

(ii) the **second**, arriving in about 10 s later but originating from **the strongest part of the rupture**, 5 - 50 km SW from the epicenter (largest peaks of 0.76 g and 0.86g)**;** and

(iii) the **third** packet, arriving in about 35 s later originating from **the deepest less-strong and farther way** (50 km) part (3rd segment) of the NE rupture and the **very shallow and farthest away** (70 km) part (4th segment) of the SW rupture. Hence, quite naturally, the total duration quite long, at least 60 seconds (including the trailing "coda").

Of course, this analysis is a simplification of reality, and the demarcation of packets is not so clear, as the waves emitted during rupture are continuously arriving at each station.

By contrast, in the motion **ISK 003** recorded on the devastated town of **Wajima** (population ≈ 26.000), **30-35 km SW of the epicenter, the arrivals of various wave "packets" are almost indistinguishable**. Located at the middle of the strongest rupture, it is affected mainly by the waves emitted from the latter's 40 km long rupture. The much later arriving waves from the 70 km away NE less-strong part and the 50 km away SW part of the rupture, have been much attenuated and make a small effect on the intensity of the motion, although its coda waves contribute to the long duration of the record.

(c) In general, the motions are rich in extremely-high-frequency components. **Dominant periods of 0.1 s to 0.2 s are quite a surprise.** The current observation-based belief in earthquake engineering: the larger the magnitude, the larger the dominant period of the motions. *Here we have a complete reversal: a huge magnitude M 7.6 event leads to extremely low dominant periods, that are believed to be appropriate for earthquakes with M ≈ ≤ 5.5 !* We have attempted a sweeping filtering-out of frequency components exceeding 10 Hz (see analysis of record No. 3, ISK 003) — but to little avail.

Can we ask if, perhaps, some isolated huge spikes of acceleration, of no substantial practical consequence incidentally, are a spurious artefact of the recording system ?? (Specialists: advice !).

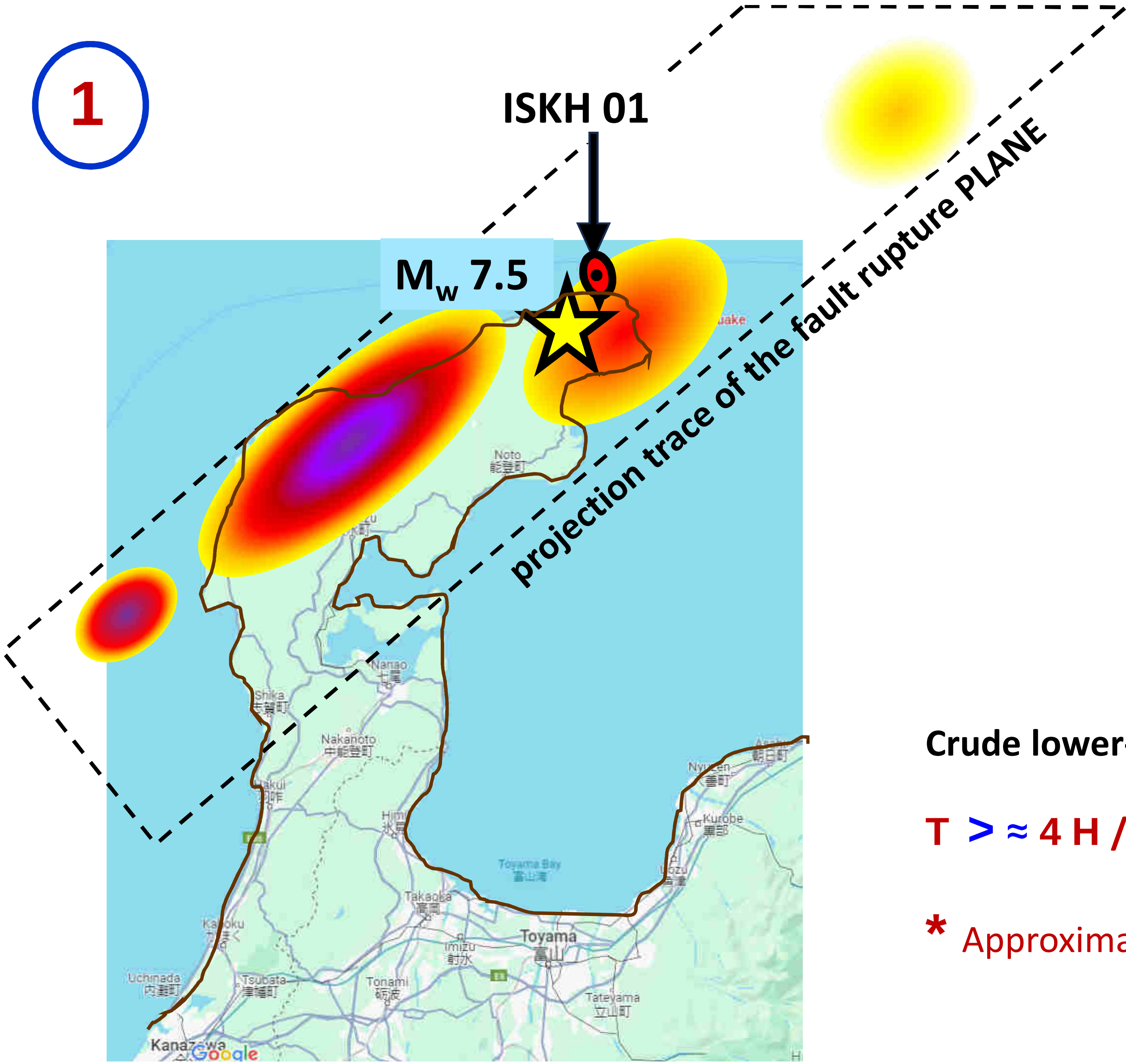
(d) Regarding the **role of soil** in modifying the intensity and frequency content of the incoming seismic waves, and hence affecting the ground-surface motions, we draw several conclusions:

- The fundamental natural elastic periods of the soil deposits, roughly estimated by the authors from the **V_S profiles reported by K-Net/KiK-Net,** are **only in a few cases consistent** with the dominant periods of the ground-surface motions.
- In the two sites where the motions were recorded in both the ground surface *and* in the bedrock (at huge depths, 152 and 188 meters), **soil amplification is quite clear, and substantial (**spectral amplification ratios, $\mathscr{A}$, of about 3 to 5. This is an unambiguous observational fact. However, the natural soil frequencies computed using

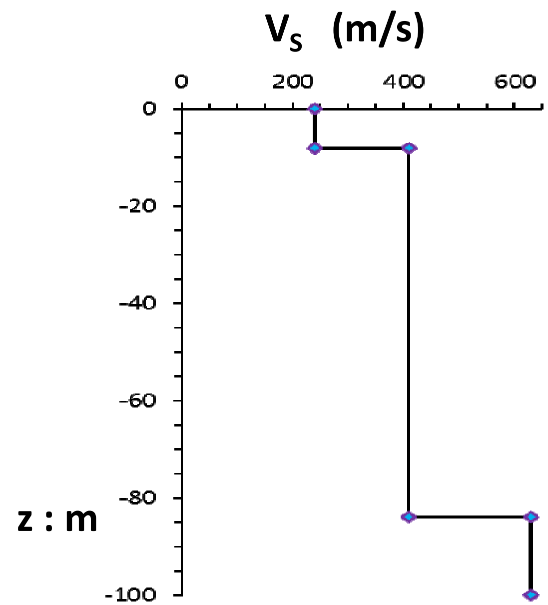
the shear-wave velocity profiles reported in the sites of K-Net and KiK-Net, are not consistent with the periods of the peak Amplification functions.

Further investigation is needed to explain if this inconsistency stems from inaccuracies in V_s profiles; or because the soil amplification in some of the more-rocky stations was overshadowed by seismological phenomena; or if due to 2D and 3D wave propagation effects in the numerous narrow valleys of Noto Hanto !

1



STATION: SUZU (ISKH 01)

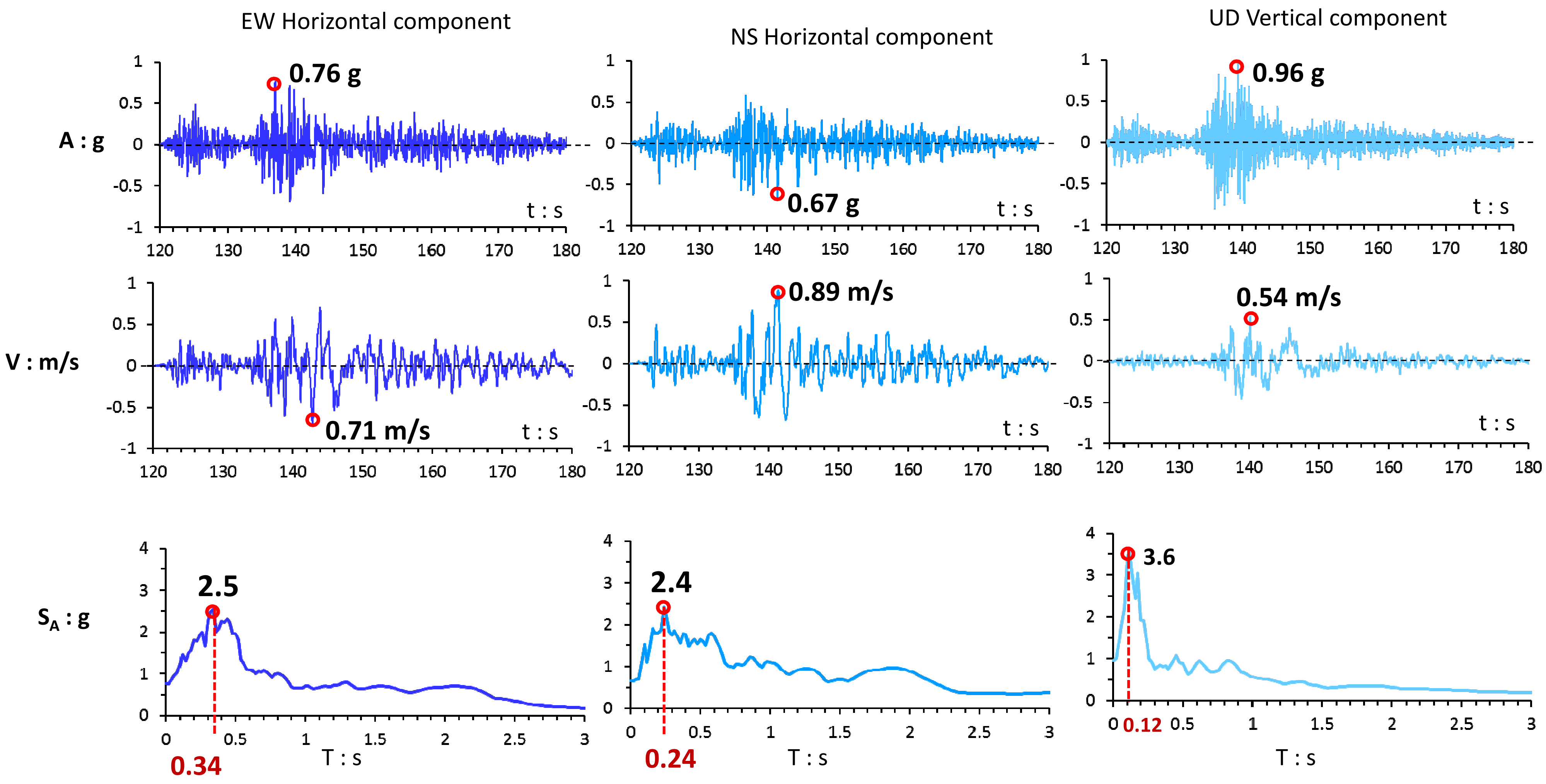


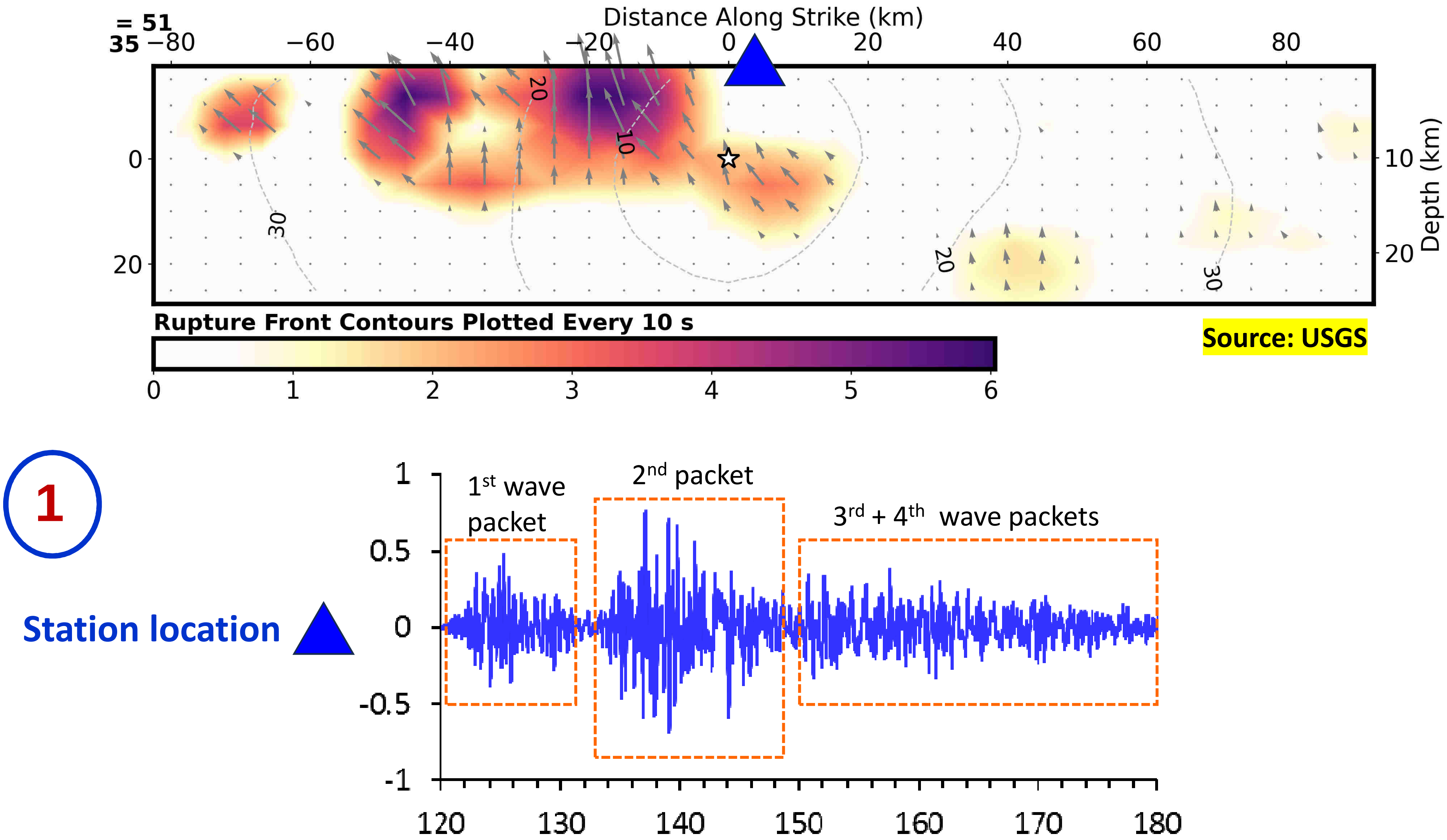
Crude lower-bound estimates of natural soil periods:

$$T > \approx 4\,H / V_S \approx 4 \times 80 / 350^{*} \approx 0.9\ \text{s}$$

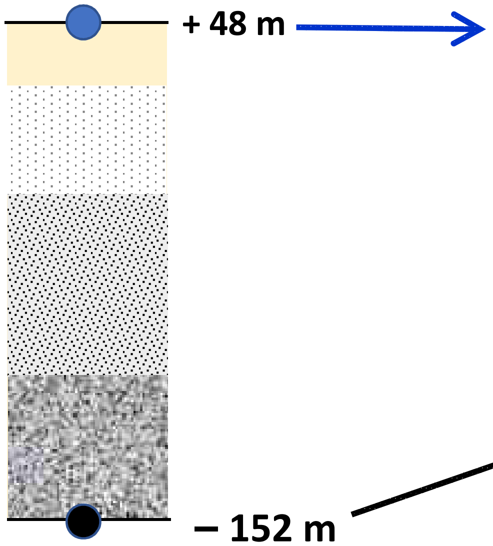
* Approximate weighted average velocity

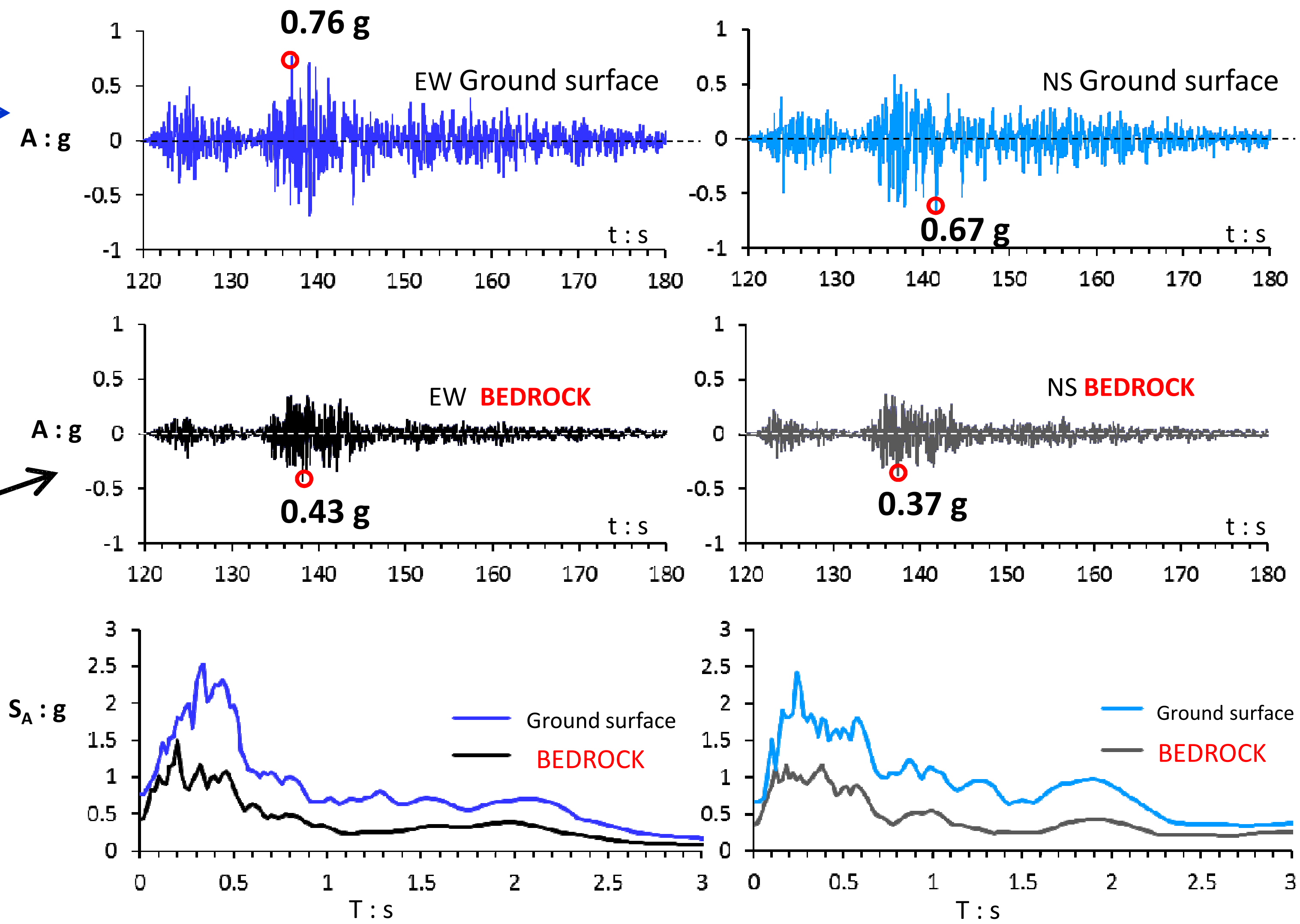
1 STATION: SUZU (ISKH 01) Motion on the ground surface




= 51
35
Distance Along Strike (km)
−80 −60 −40 −20 0 20 40 60 80
Depth (km)
Rupture Front Contours Plotted Every 10 s
0 1 2 3 4 5 6
Source: USGS
1
Station location
1st wave packet
2nd packet
3rd + 4th wave packets
1 0.5 0 -0.5 -1
120 130 140 150 160 170 180

1 STATION: SUZU (ISKH01) Ground surface vs Bedrock Motions



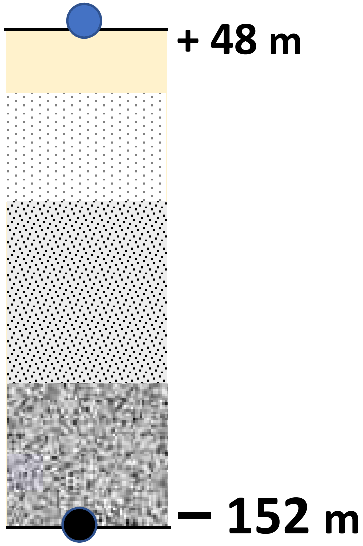


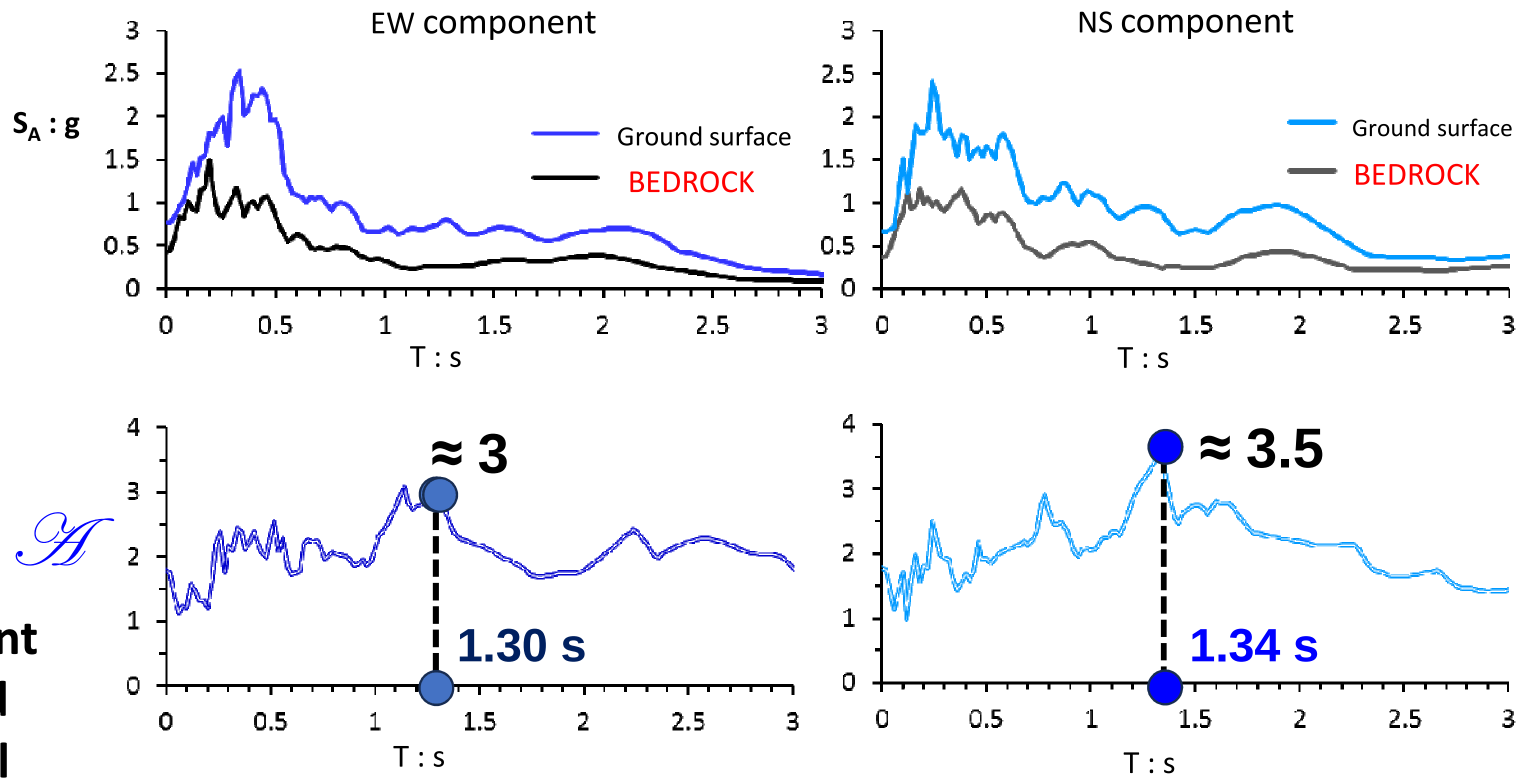
Strong soil amplification. But, for the correlation with the estimated elastic natural periods, see the Amplification (Transfer) functions in the next page.

1

STATION: **SUZU** (ISKH01)

Ground surface vs Bedrock Motions

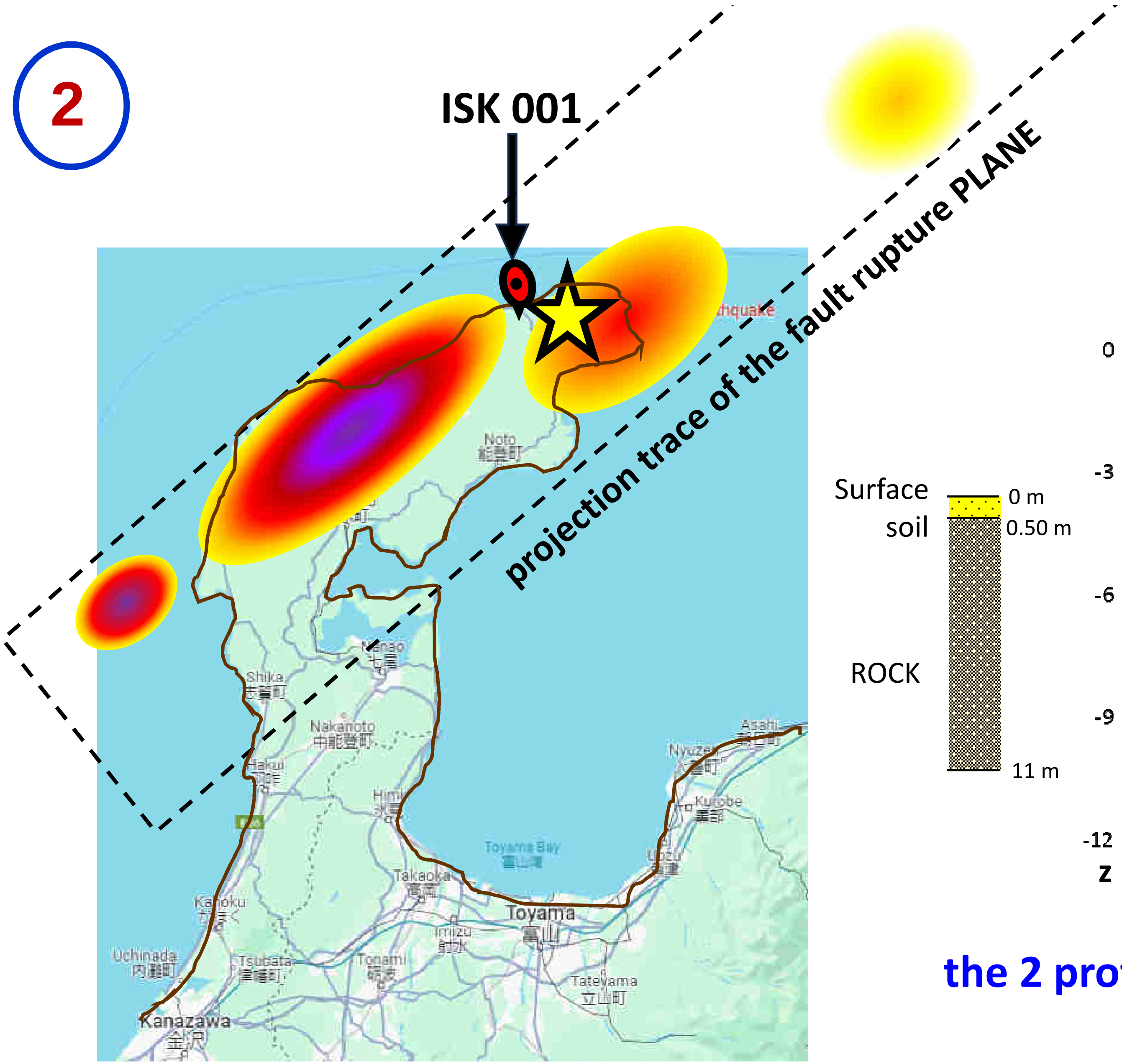




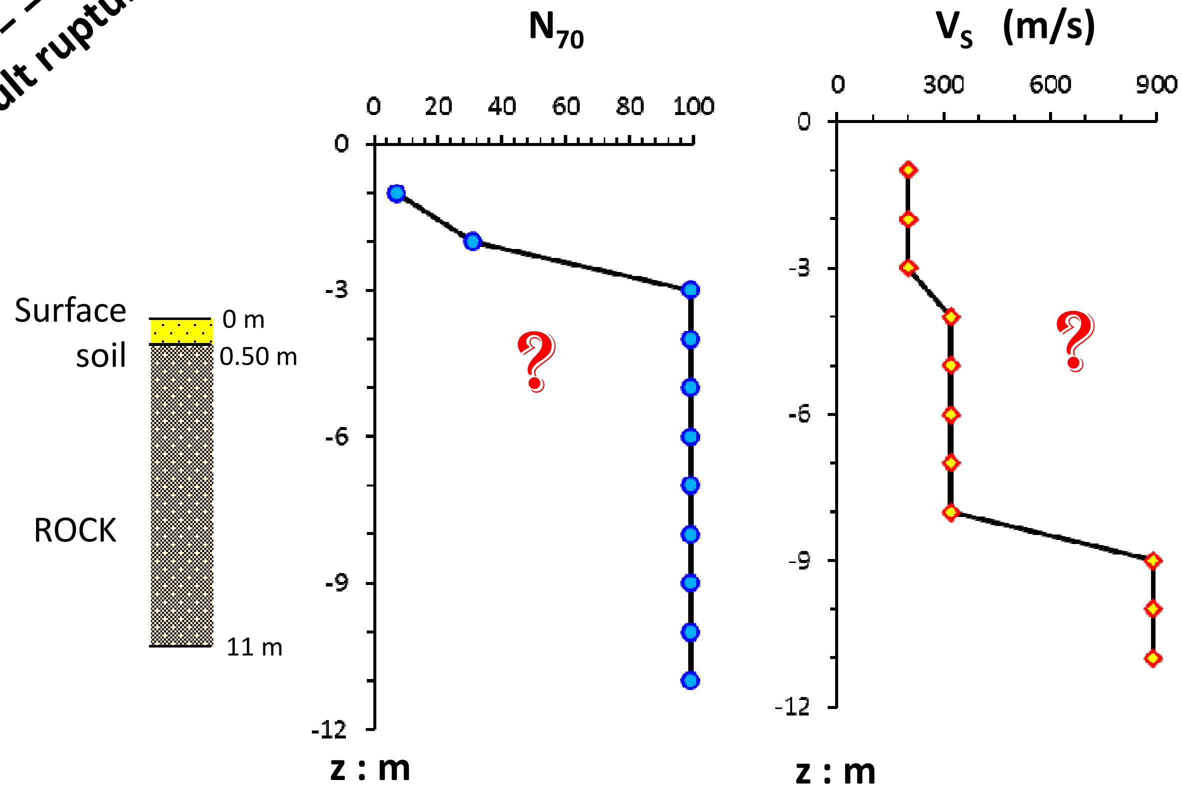
Soil amplification maximum at T ≈1.3 s. Roughly consistent with computed lower-bound estimate of fundamental soil period.

Amplification Ratios $\mathscr{A} = \mathscr{A}(T) = S_{a,\ surface} / S_{a,\ BEDROCK}$

2



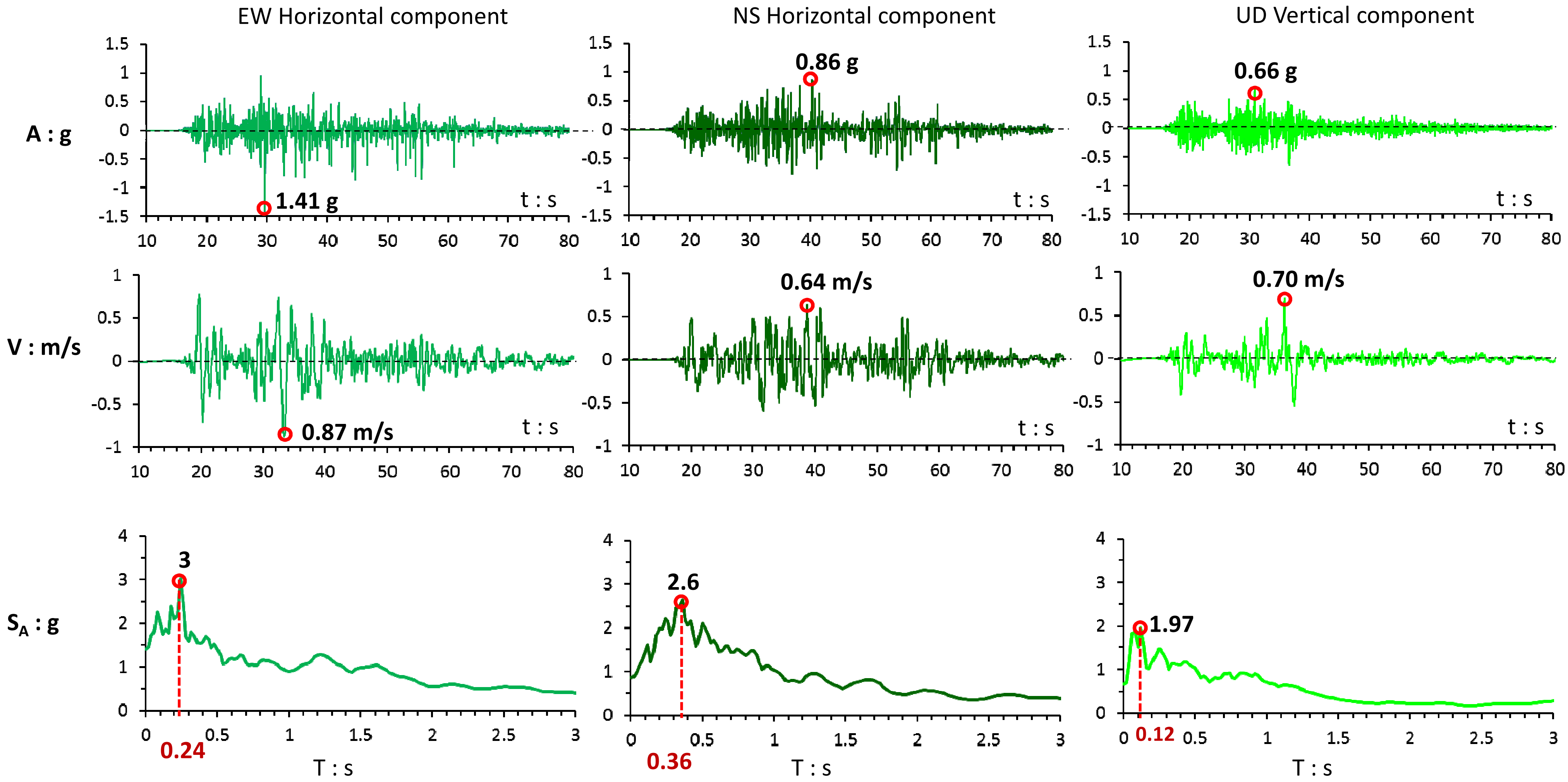
STATION: OHYA (ISK001)

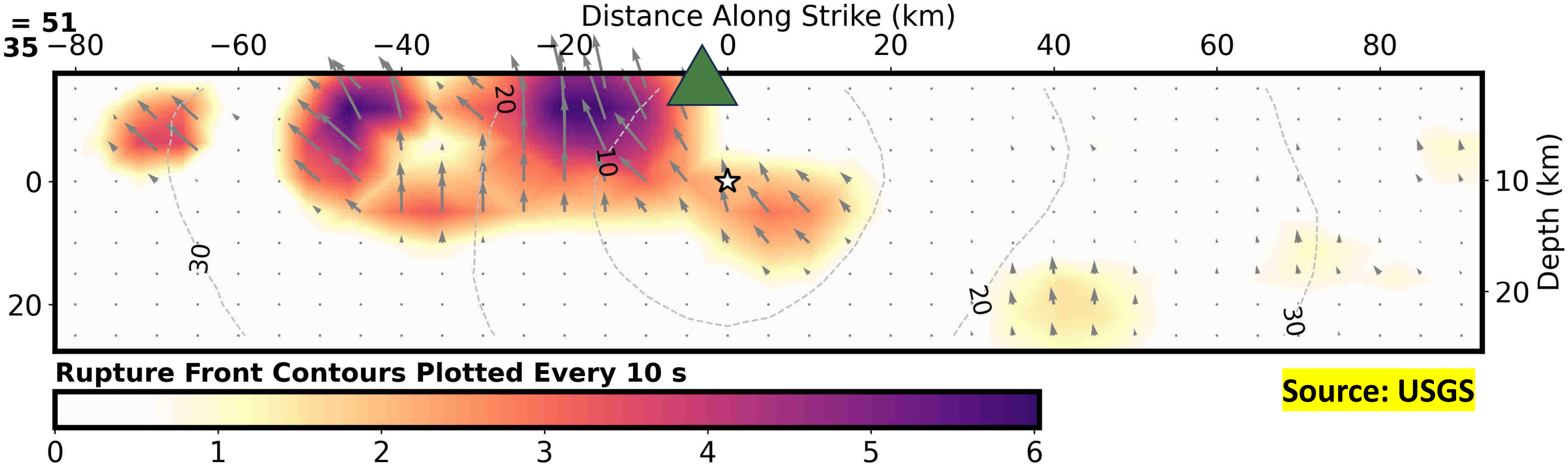


the 2 profiles, N_{70} and V_s , are incompatible

2

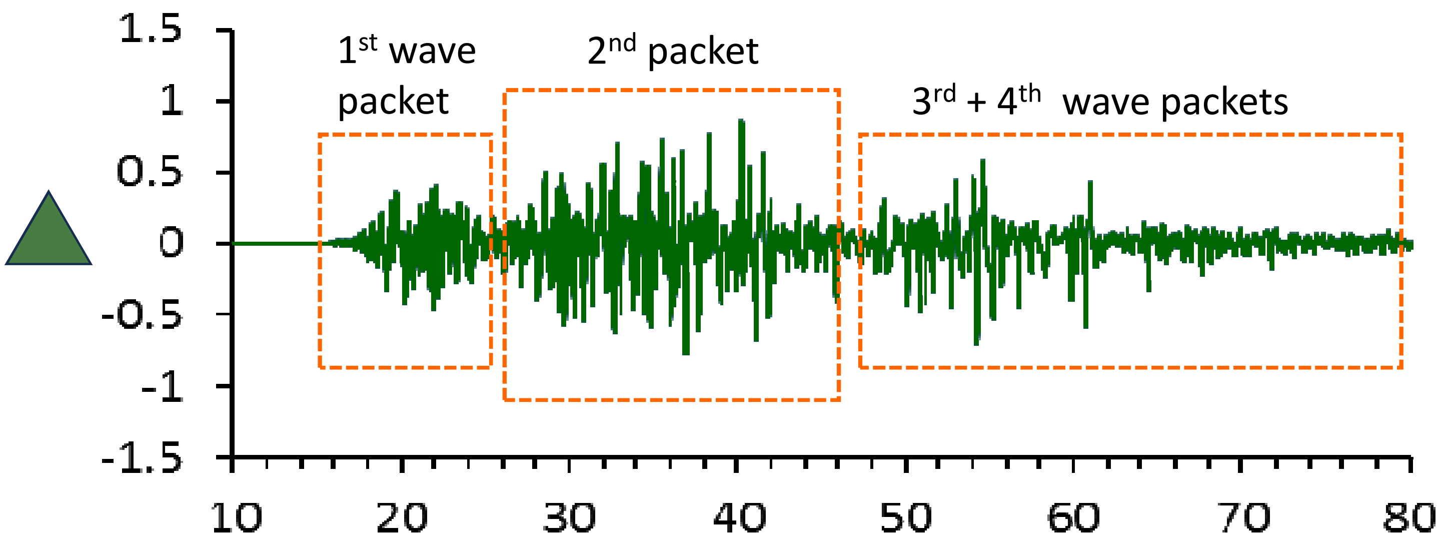
STATION: OHYA (ISK 001) essentially on Rock



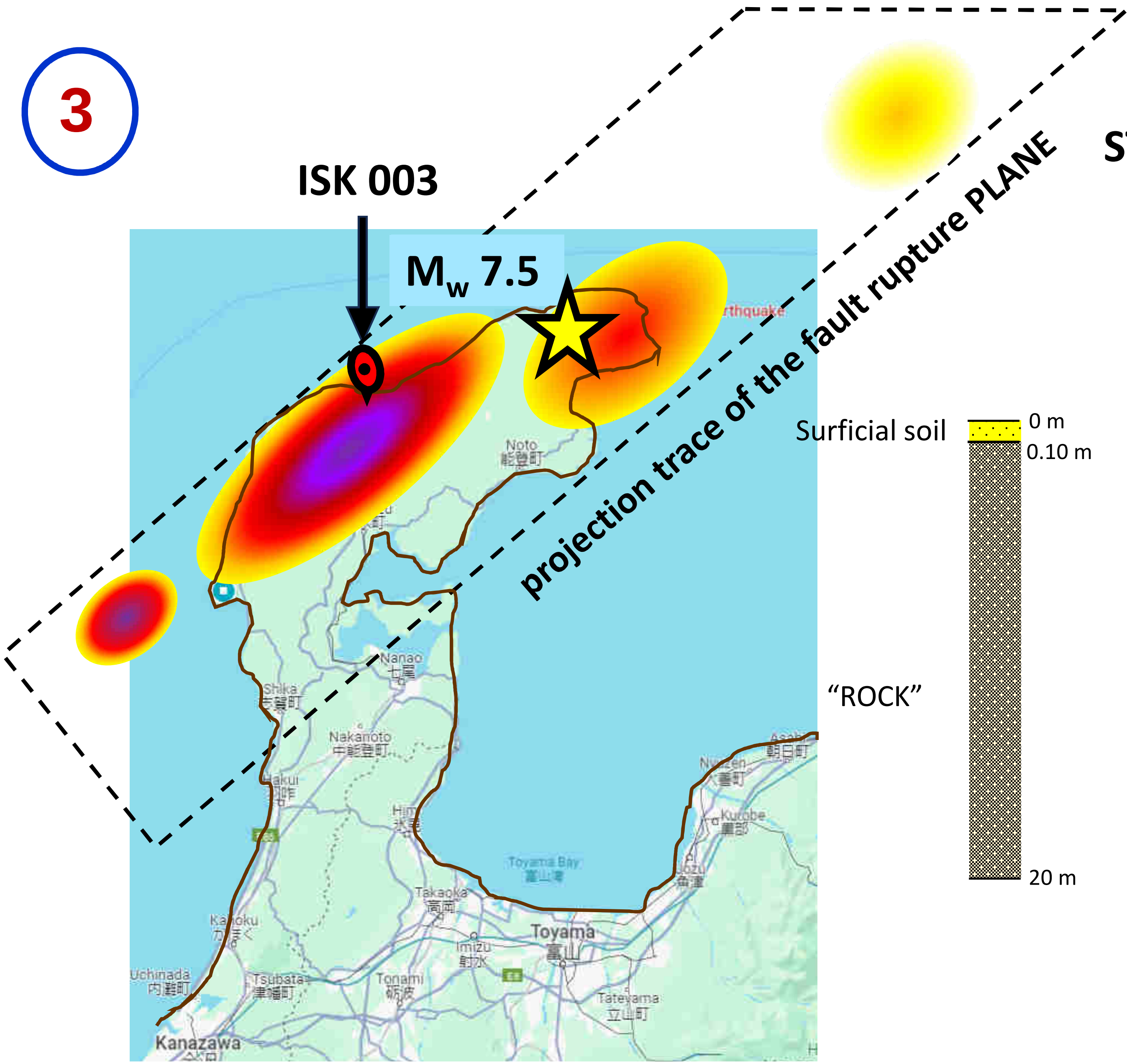


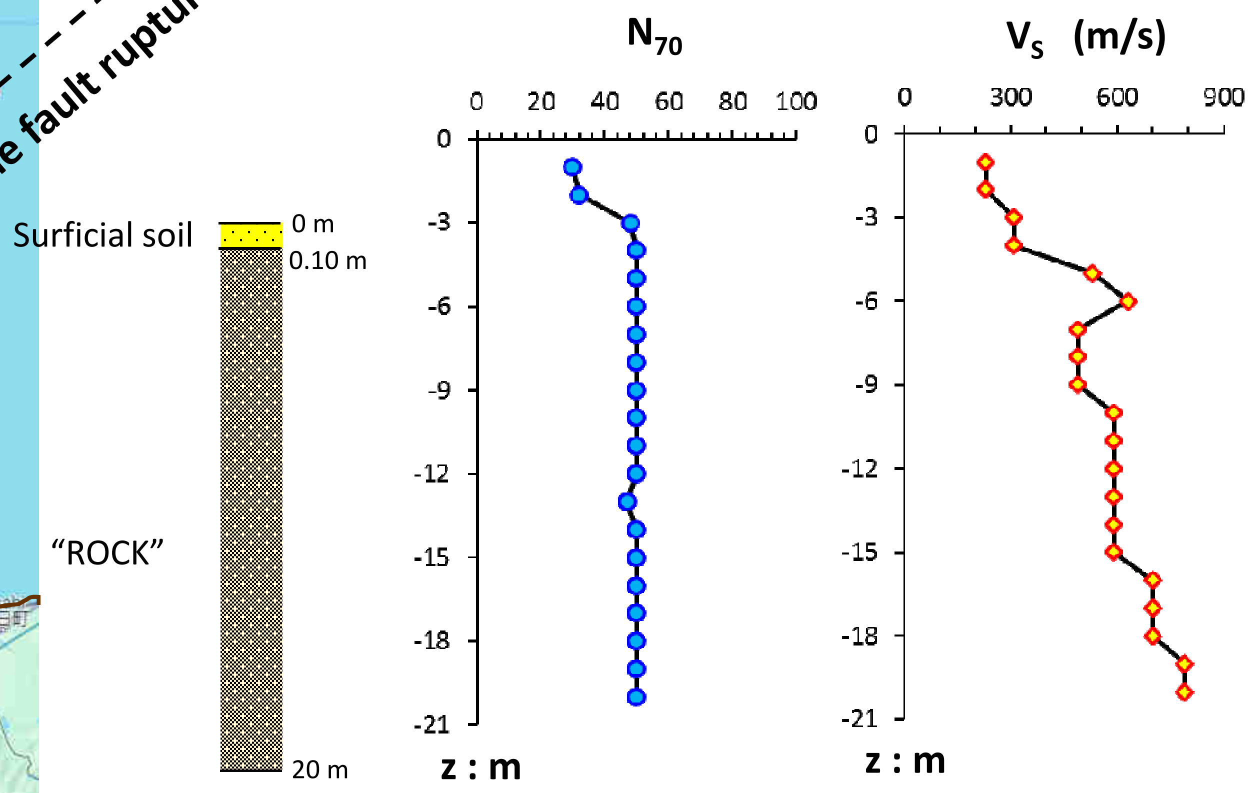
2

Station location



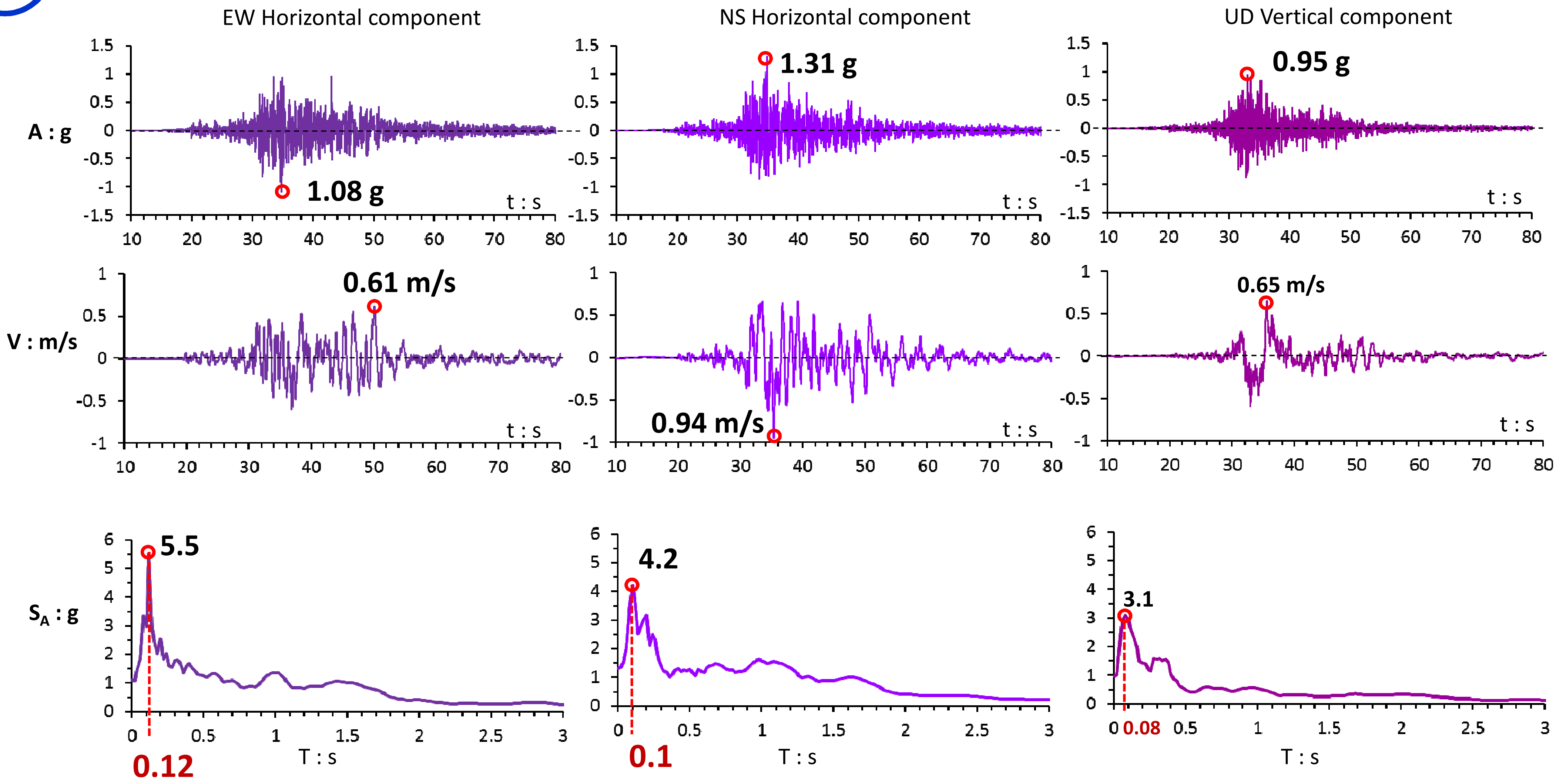
STATION: WAJIMA (ISK 003)





3

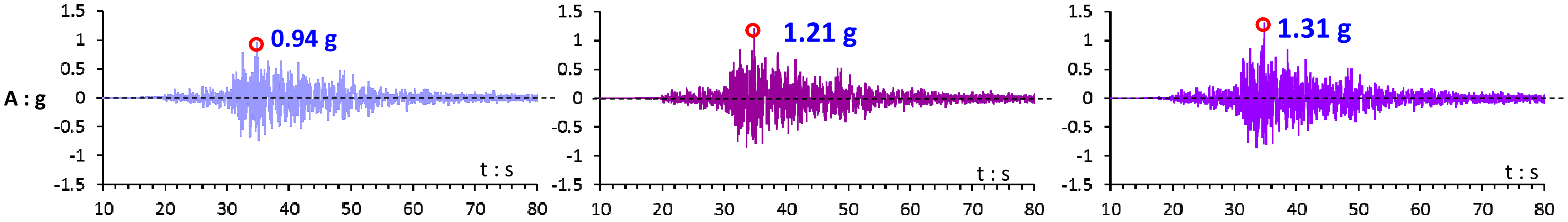
STATION: WAJIMA (ISK 003)

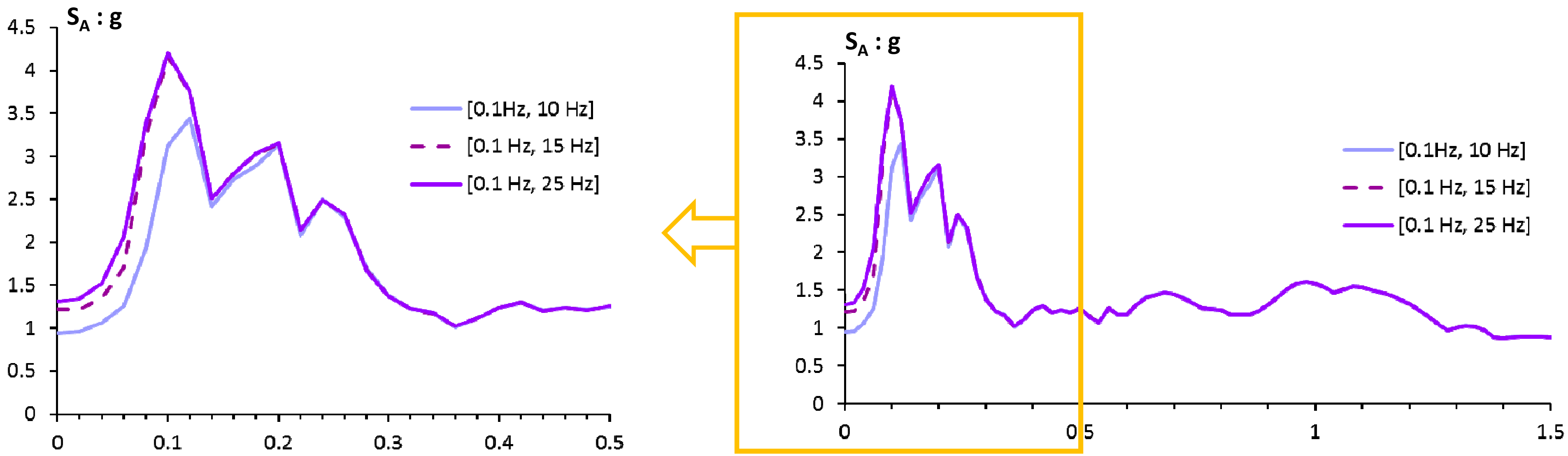


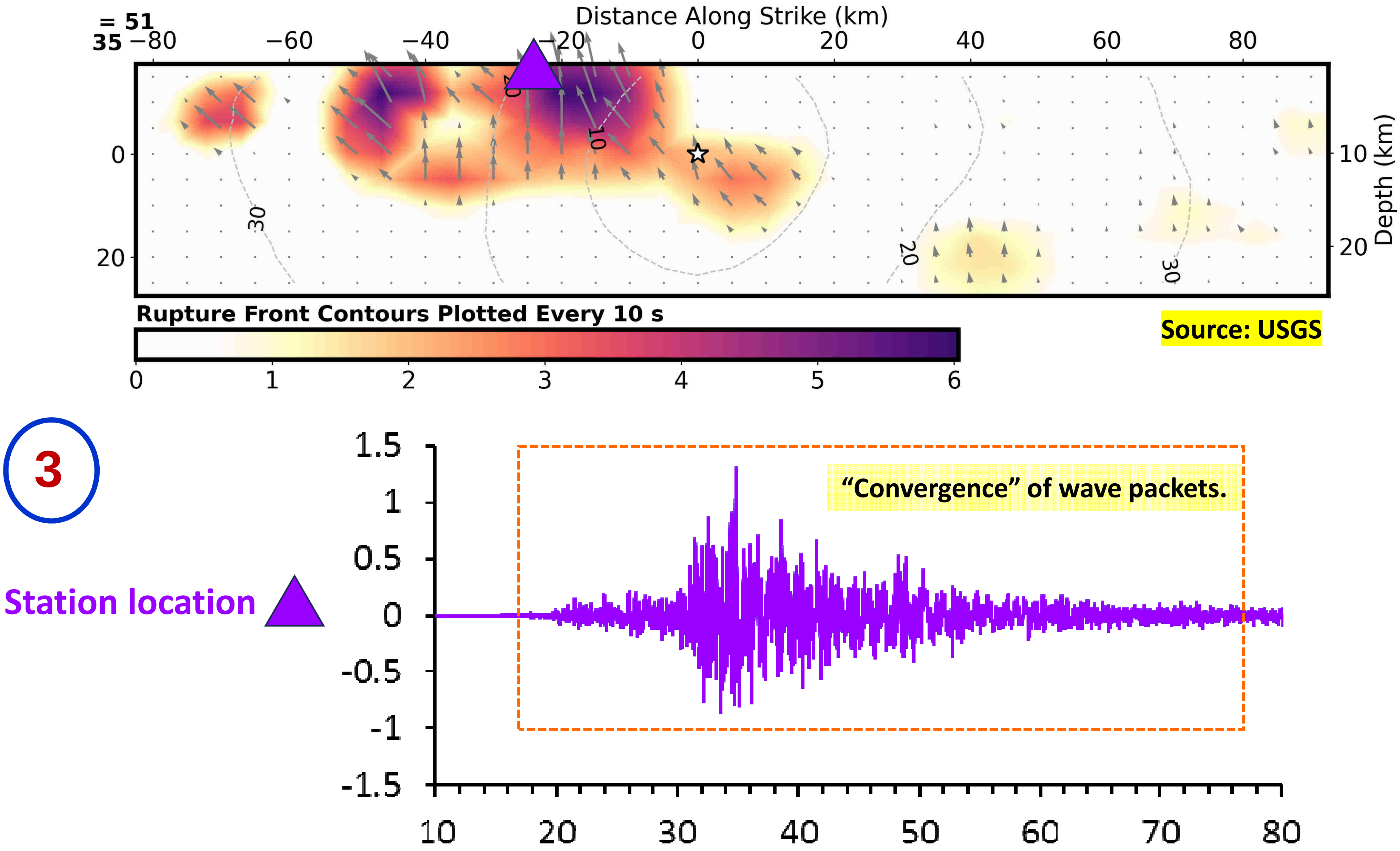
Effect of Filtering on the WAJIMA (ISK 003)- NS Component

3

Butterworth Bandpass	Butterworth Bandpass	Butterworth Bandpass
[0.1 Hz, 10 Hz]	[0.1 Hz, 15 Hz]	[0.1 Hz, 25 Hz]

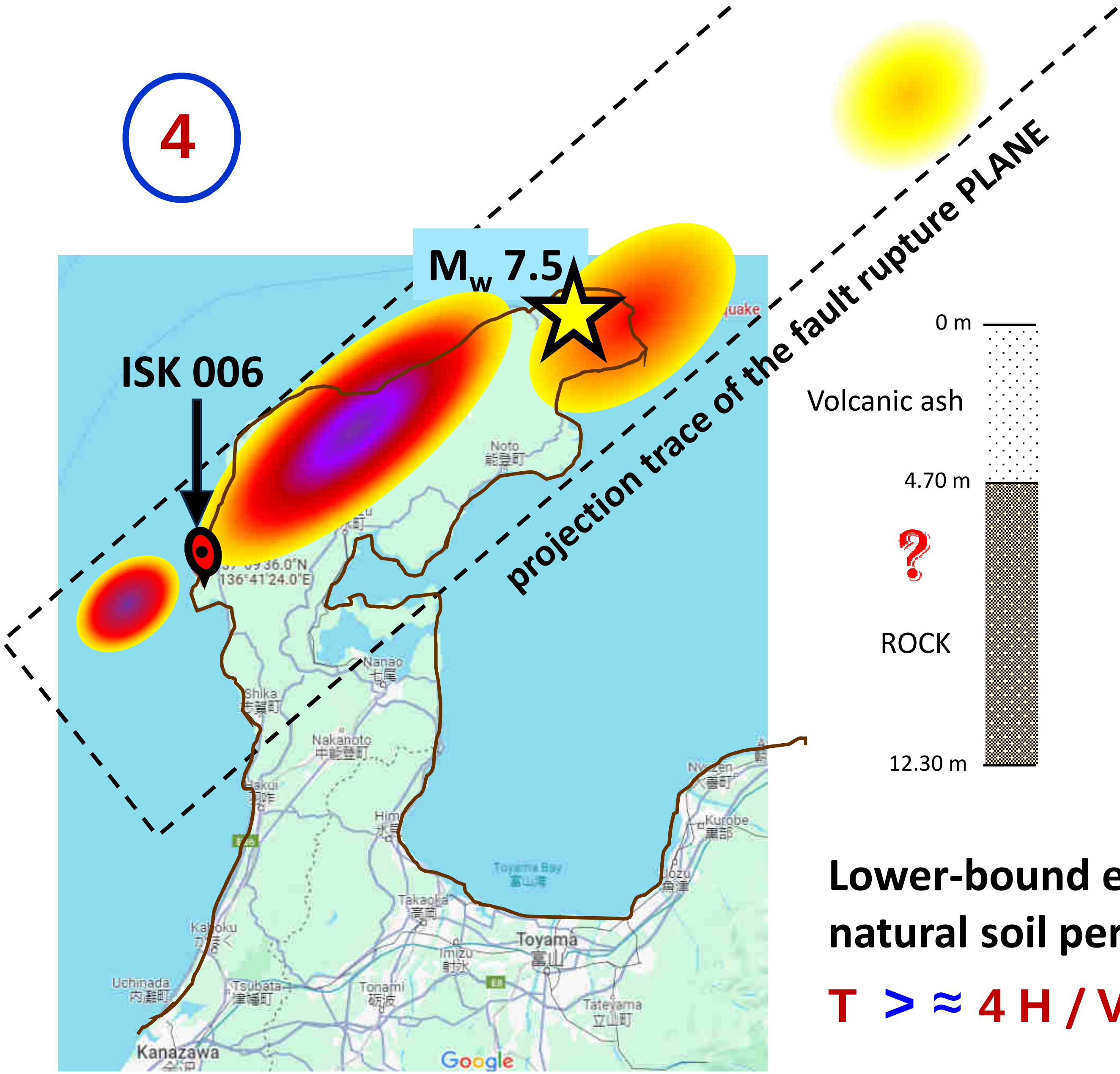




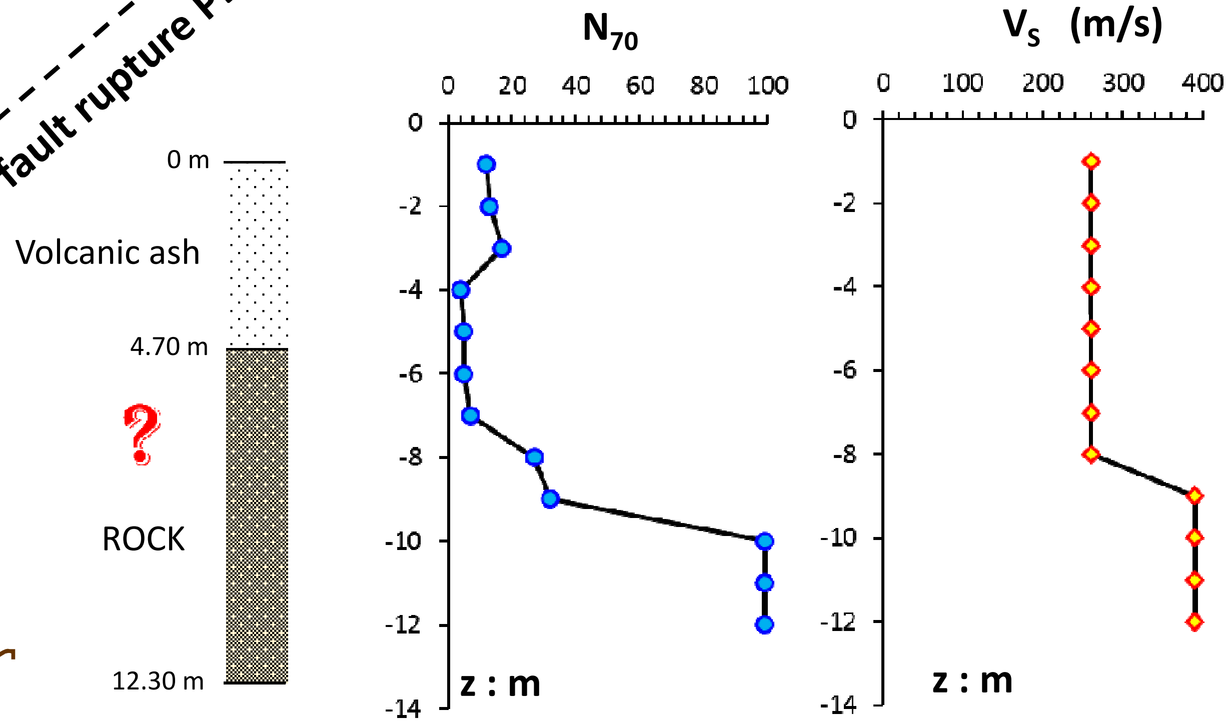


= 51
35
Distance Along Strike (km)
−80
−60
−40
−20
0
20
40
60
80
0
20
10
20
Depth (km)
10
20
30
30
Rupture Front Contours Plotted Every 10 s
0
1
2
3
4
5
6
Source: USGS
3
Station location
1.5
1
0.5
0
-0.5
-1
-1.5
10
20
30
40
50
60
70
80
“Convergence” of wave packets.

4



STATION: TOGI (ISK 006)



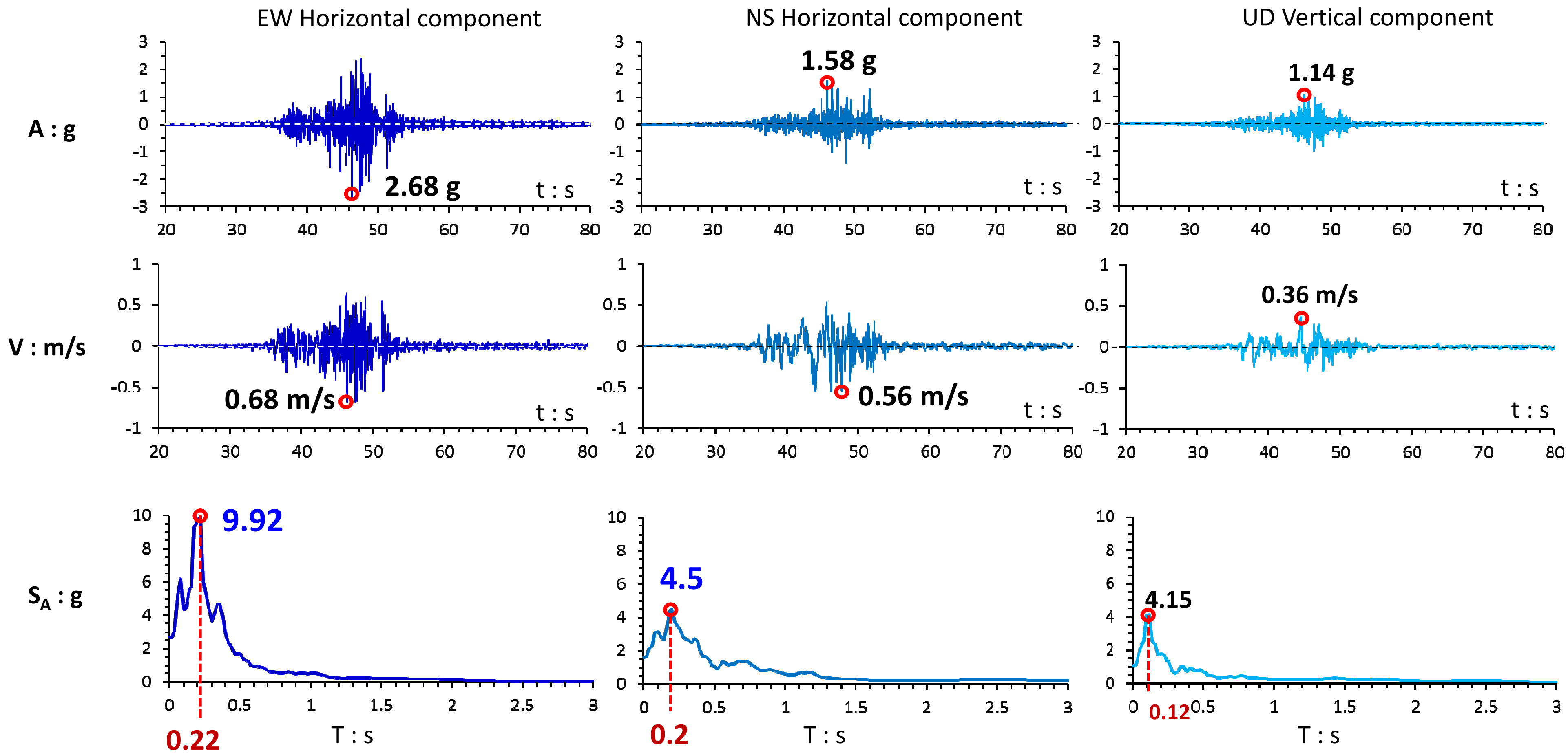
Lower-bound estimate of the elastic natural soil period:

$$T \; > \approx 4\,H / V_S \approx 4 \times 8 / 260 \approx 0.12 \text{ s}$$

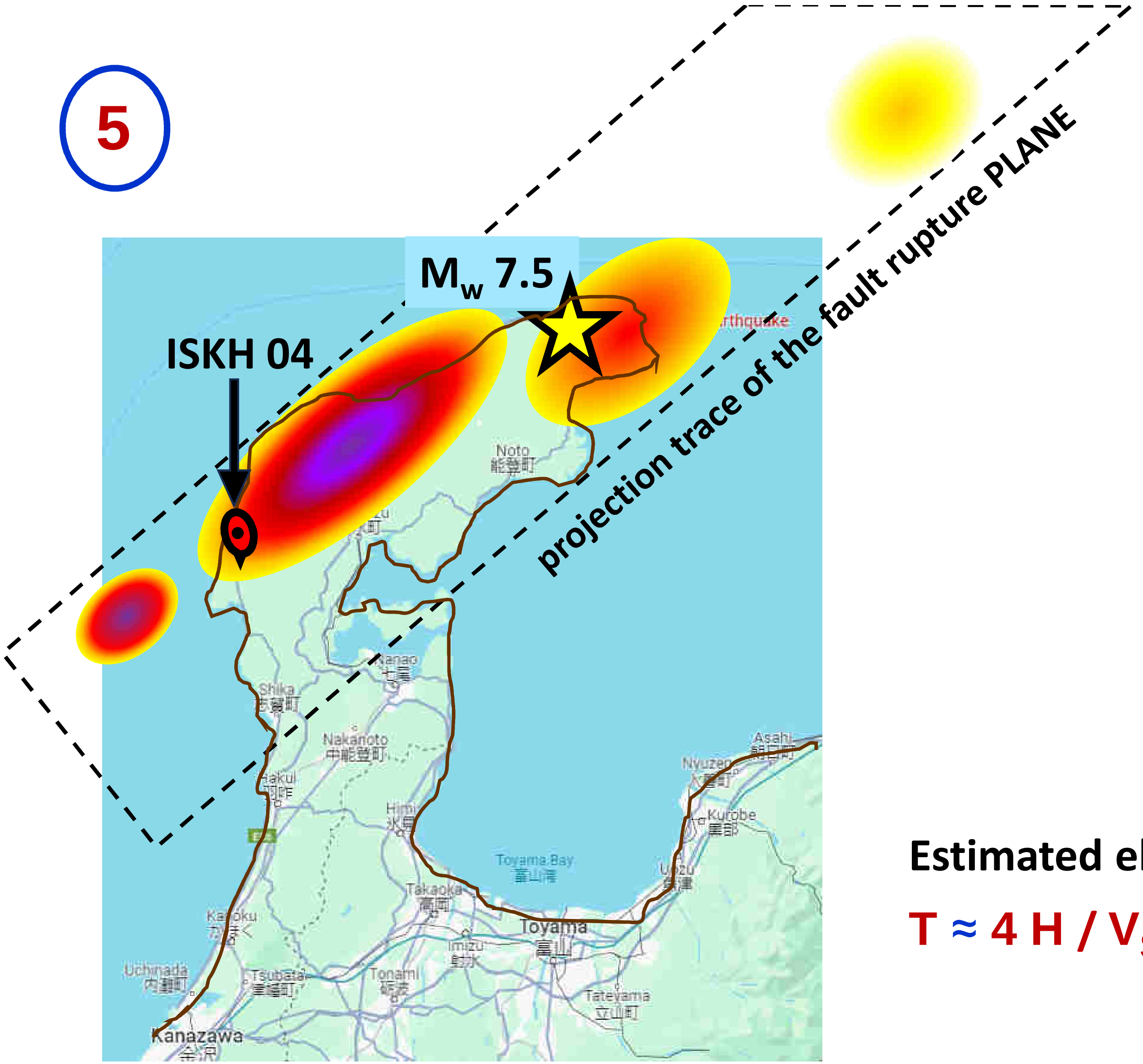
4

TOGI (ISK 006)

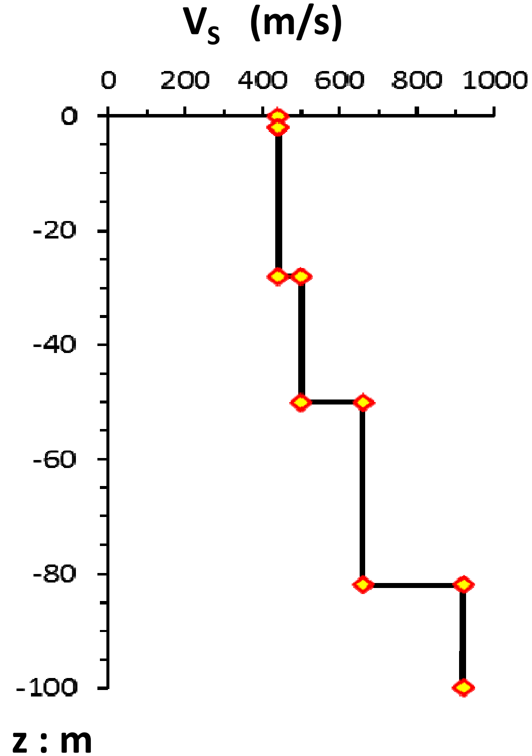
A strangely-huge PGA record, with *relatively* minute PGV !!



5



STATION TOGI : (ISKH 04)

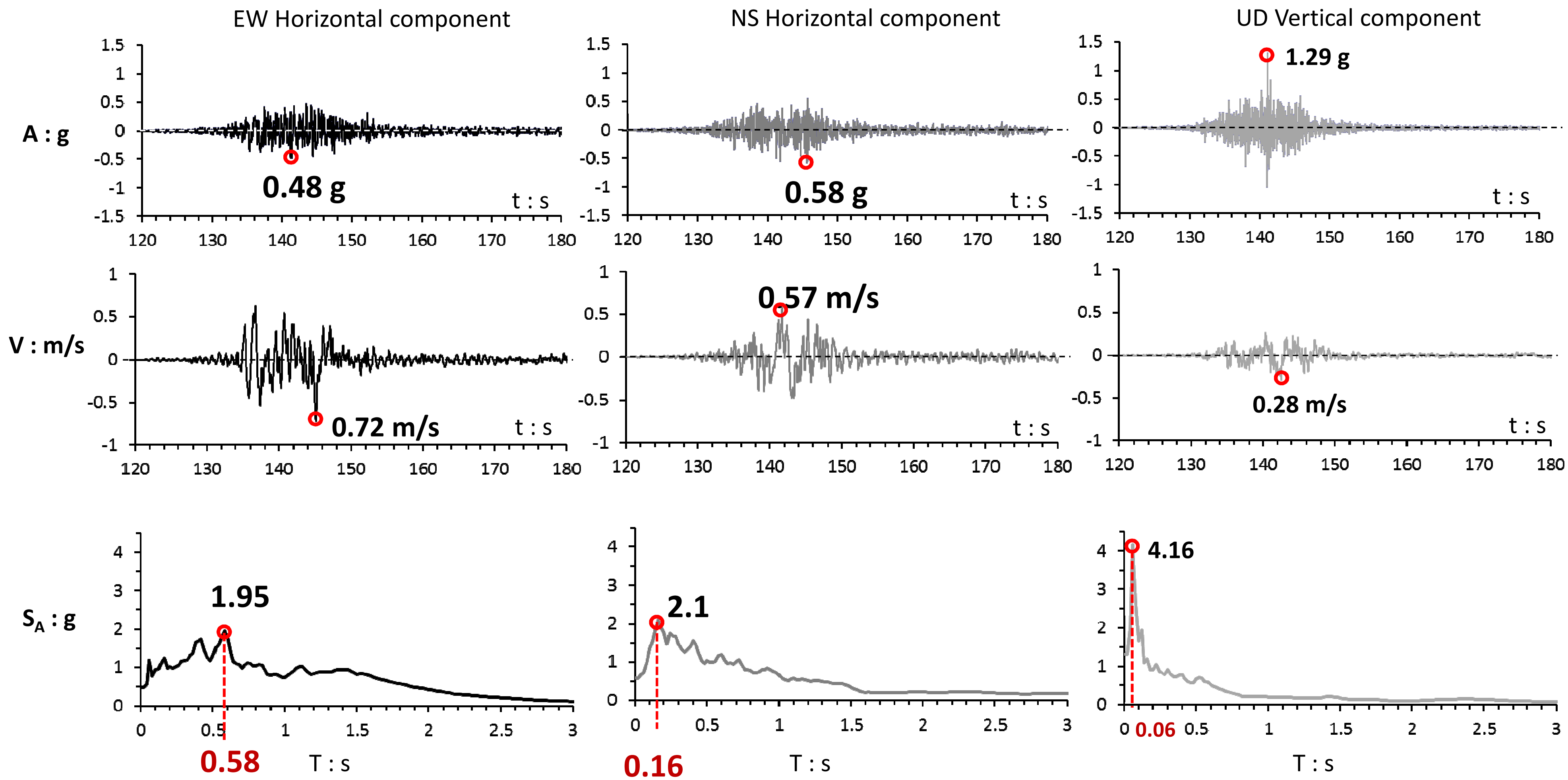


Estimated elastic natural soil period:

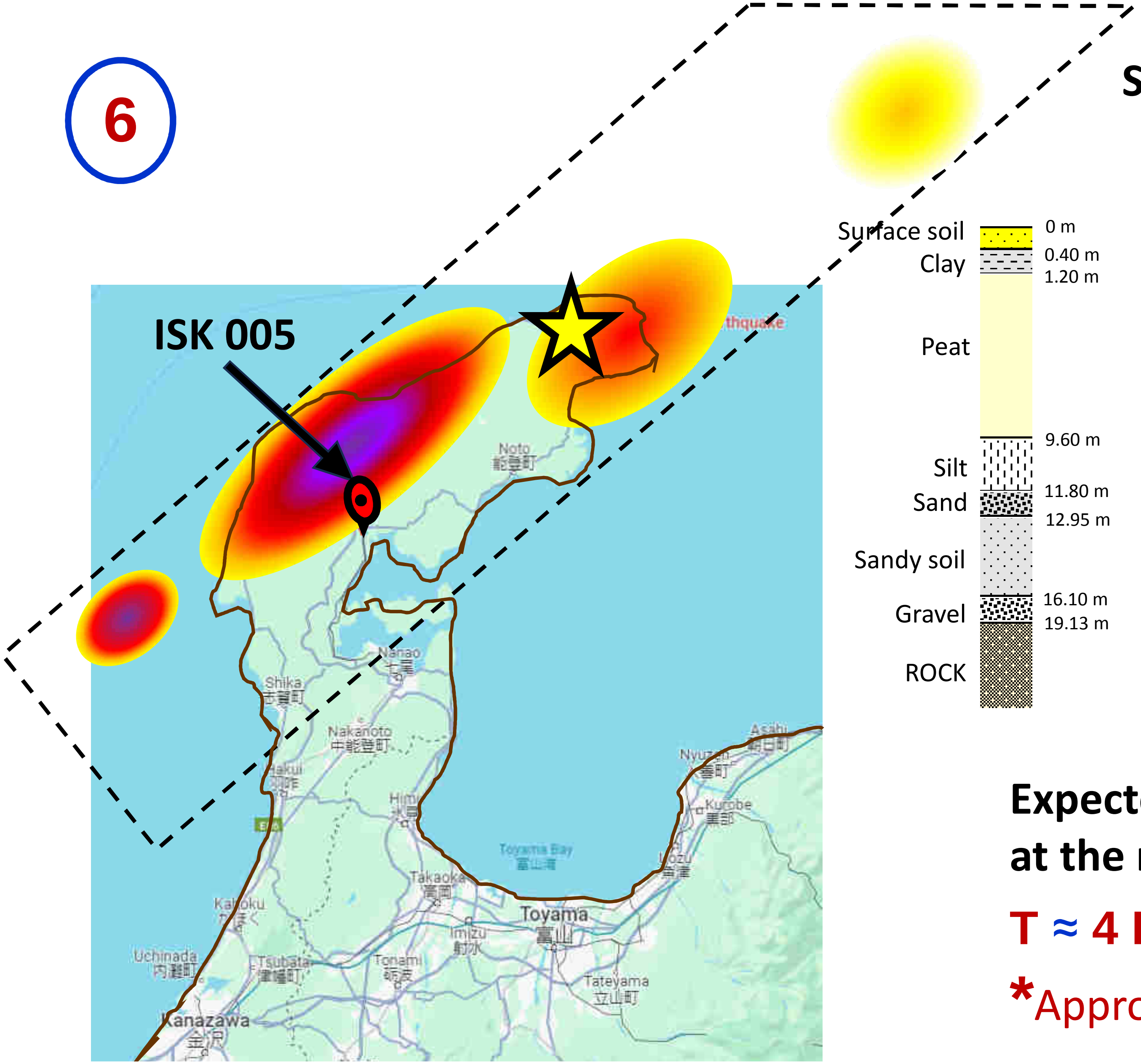
$$T \approx 4\,H / V_S \approx 4 \times 80 / 500 \approx 0.64\ \text{s}$$

5

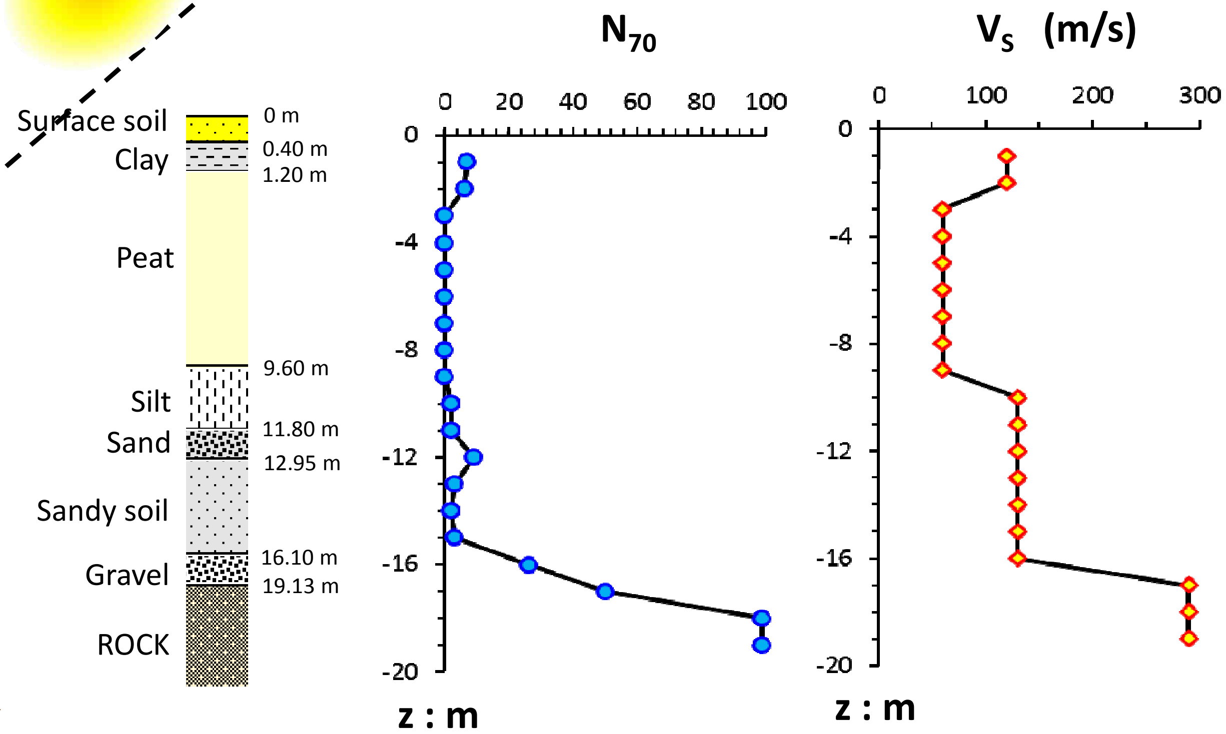
STATION TOGI : (ISKH 04)



6



STATION: ANAMIZU (ISK 005)



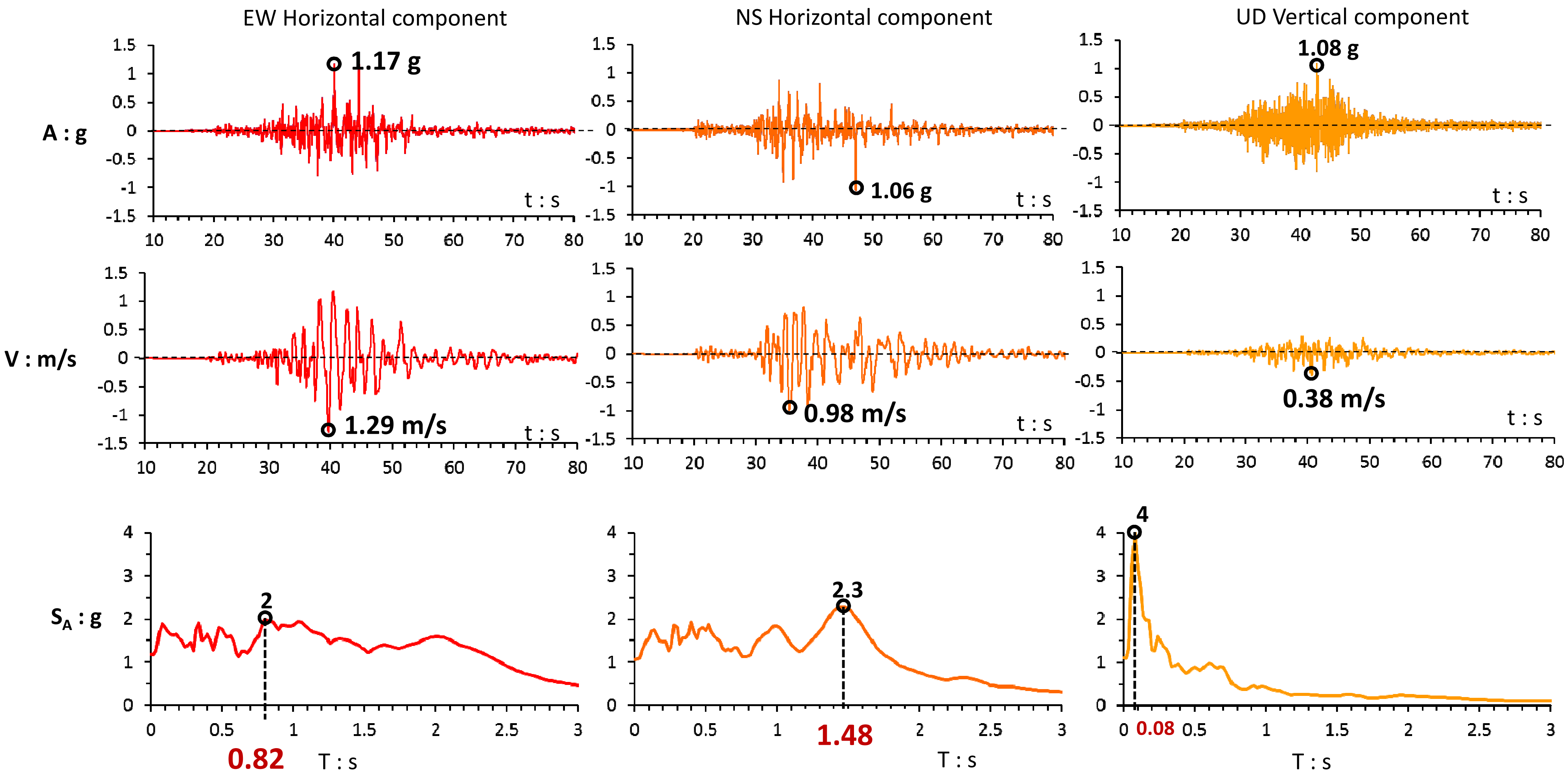
Expected Soil Amplification at the natural soil period:

$T \approx 4\,H / V_S \approx 4 \times 16 / 70^* \approx 0.9$ s

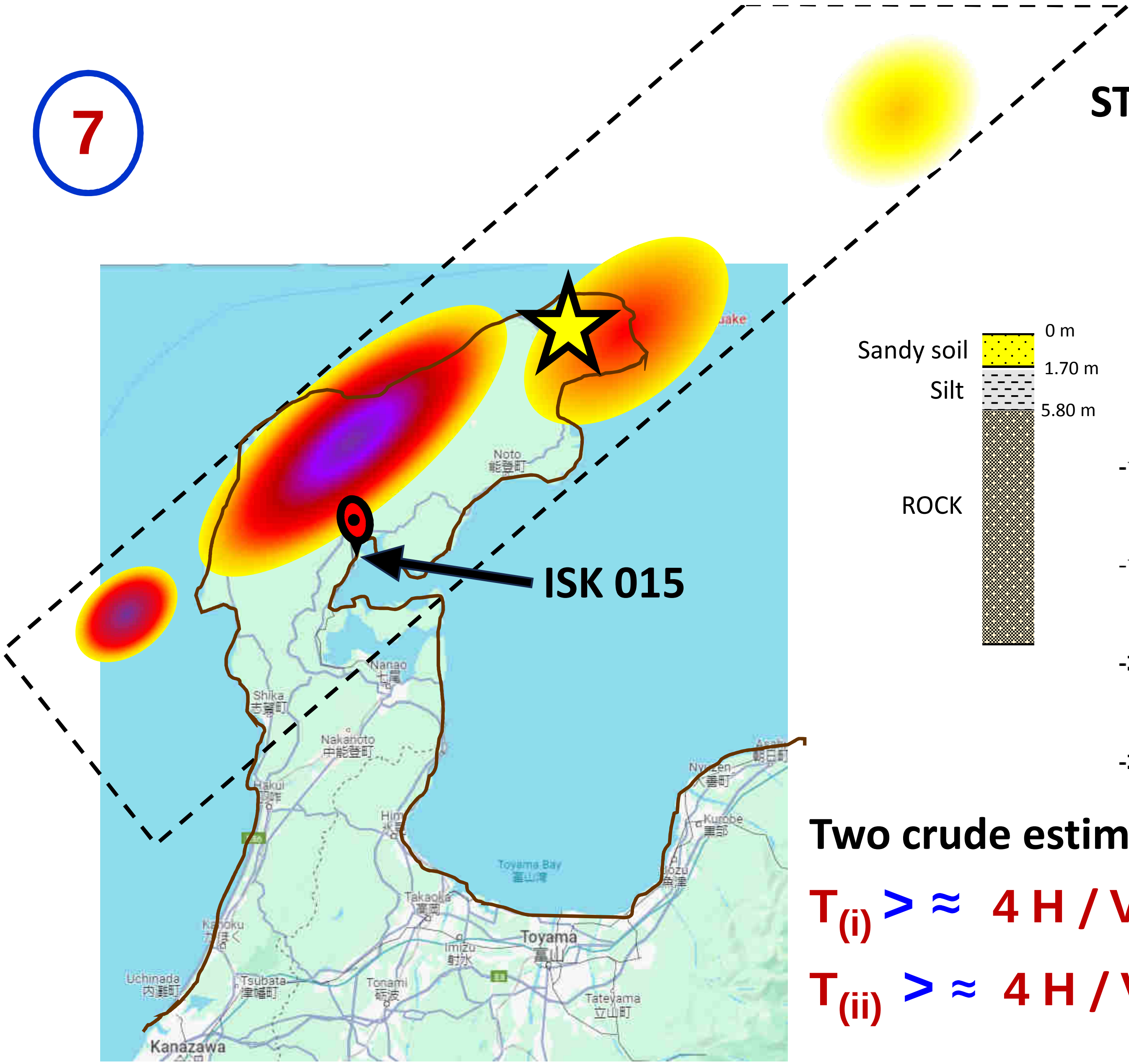
*Approximate weighted average velocity

6

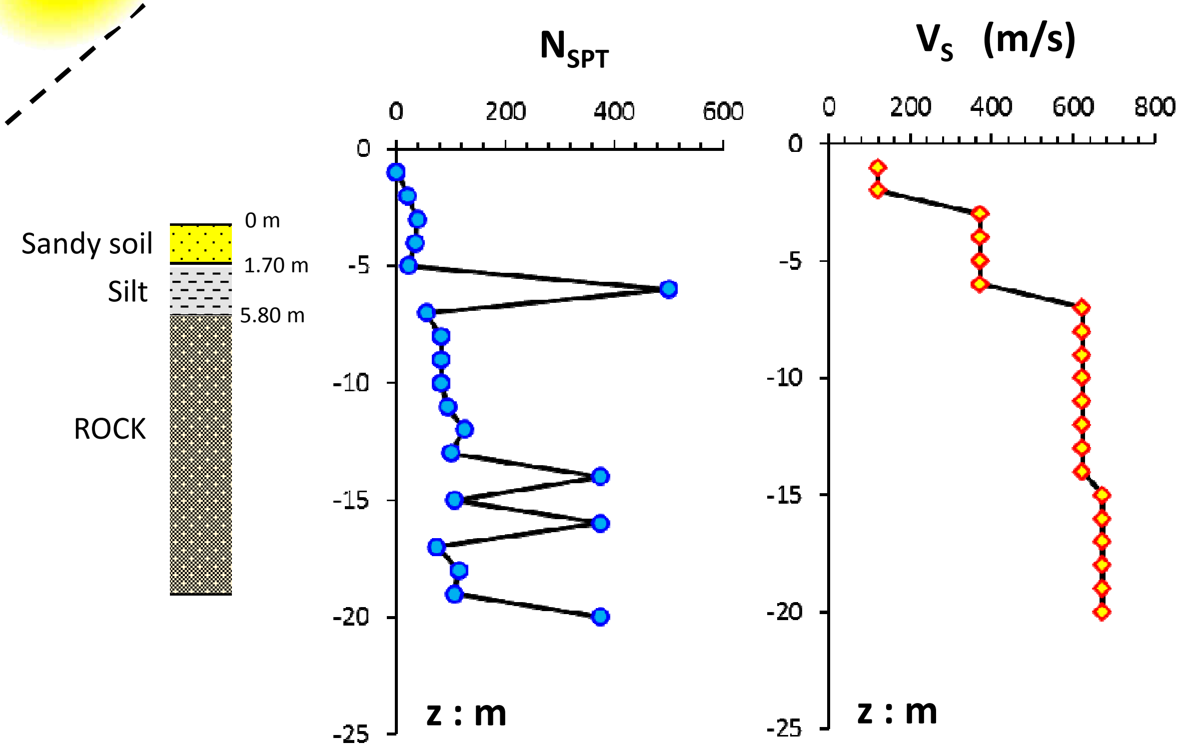
STATION: ANAMIZU (ISK 005) Dominant periods indicate partial resonance of incident waves with natural soil !!



7



STATION: OHMACHI (ISK 015)



Two crude estimates of elastic natural soil period:

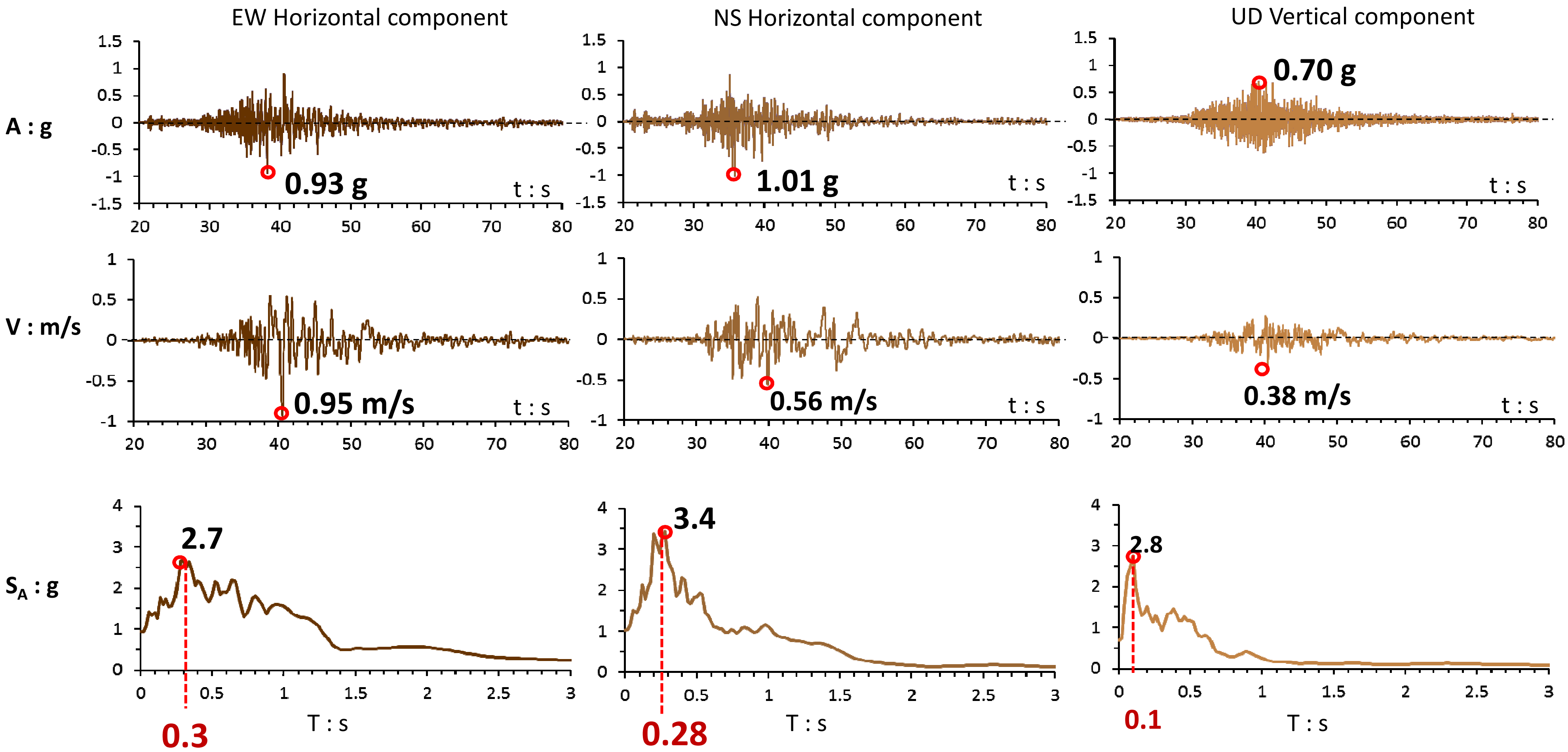
$T_{(i)} > \approx 4\,H / V_S \approx 4 \times 7 / 300 \approx 0.1$ s

$T_{(ii)} > \approx 4\,H / V_S \approx 4 \times 20 / 420 \approx 0.2$ s

7

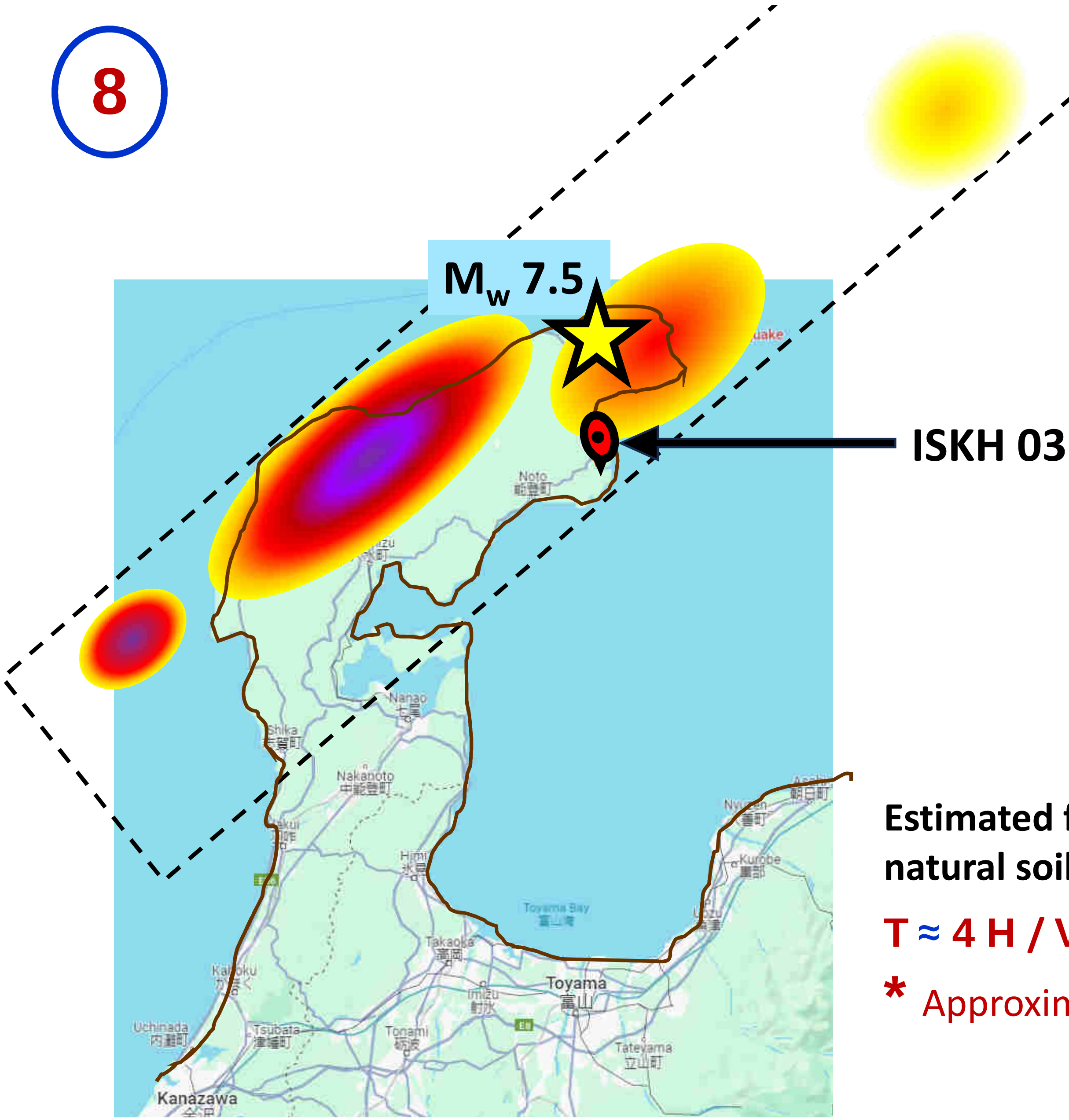
STATION: OHMACHI (ISK 015)

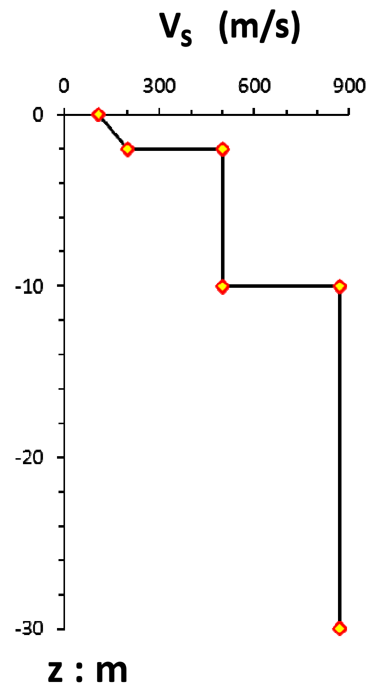
In view of soil nonlinearity, the dominant periods are consistent with the crude estimates of soil period



8

STATION: ICHIURA (ISKH 03)





Estimated fundamental natural soil period:

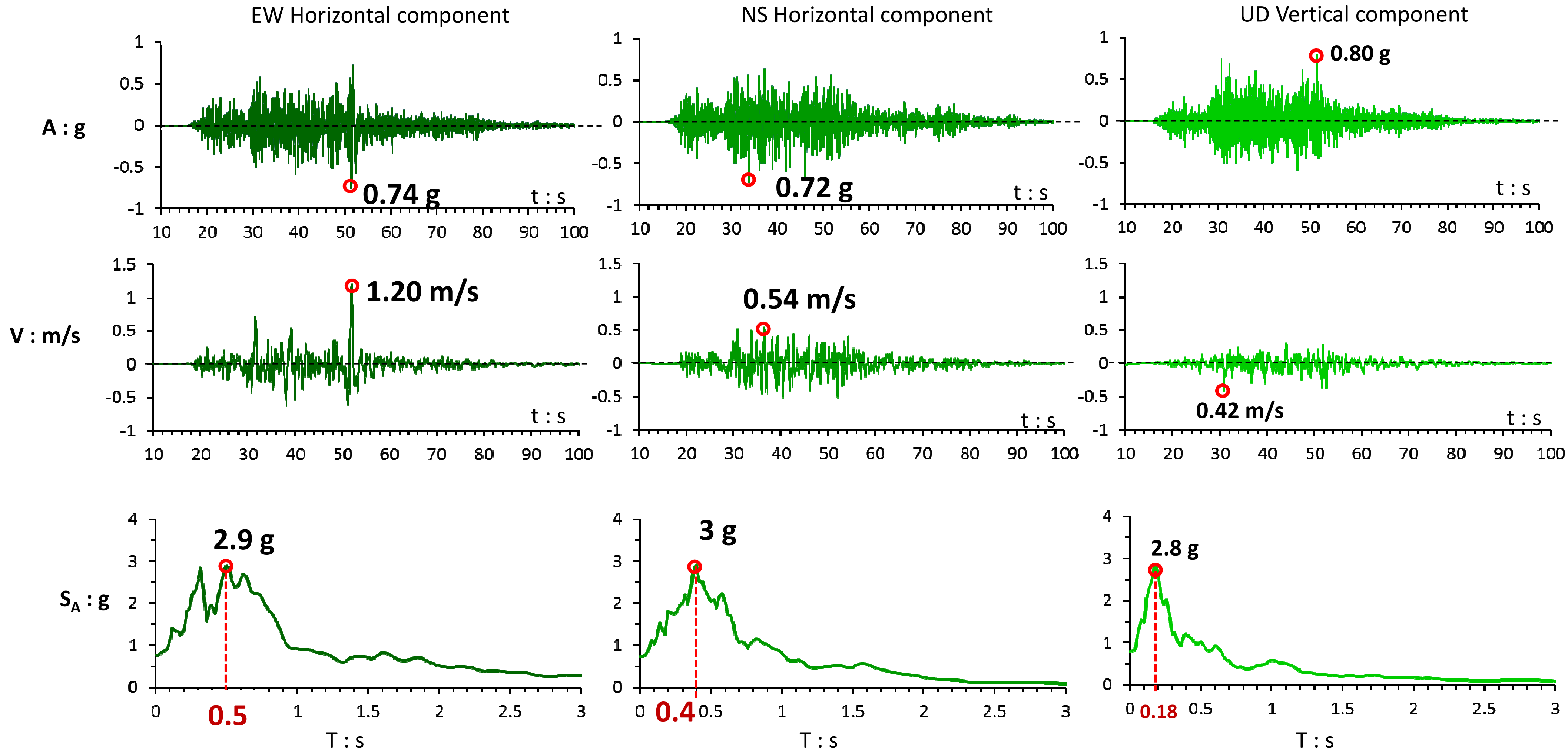
$T \approx 4\,H / V_S \approx 4 \times 10/\,410\,^{*} \approx \mathbf{0.1}$ s

* Approximate weight ed average velocity

8

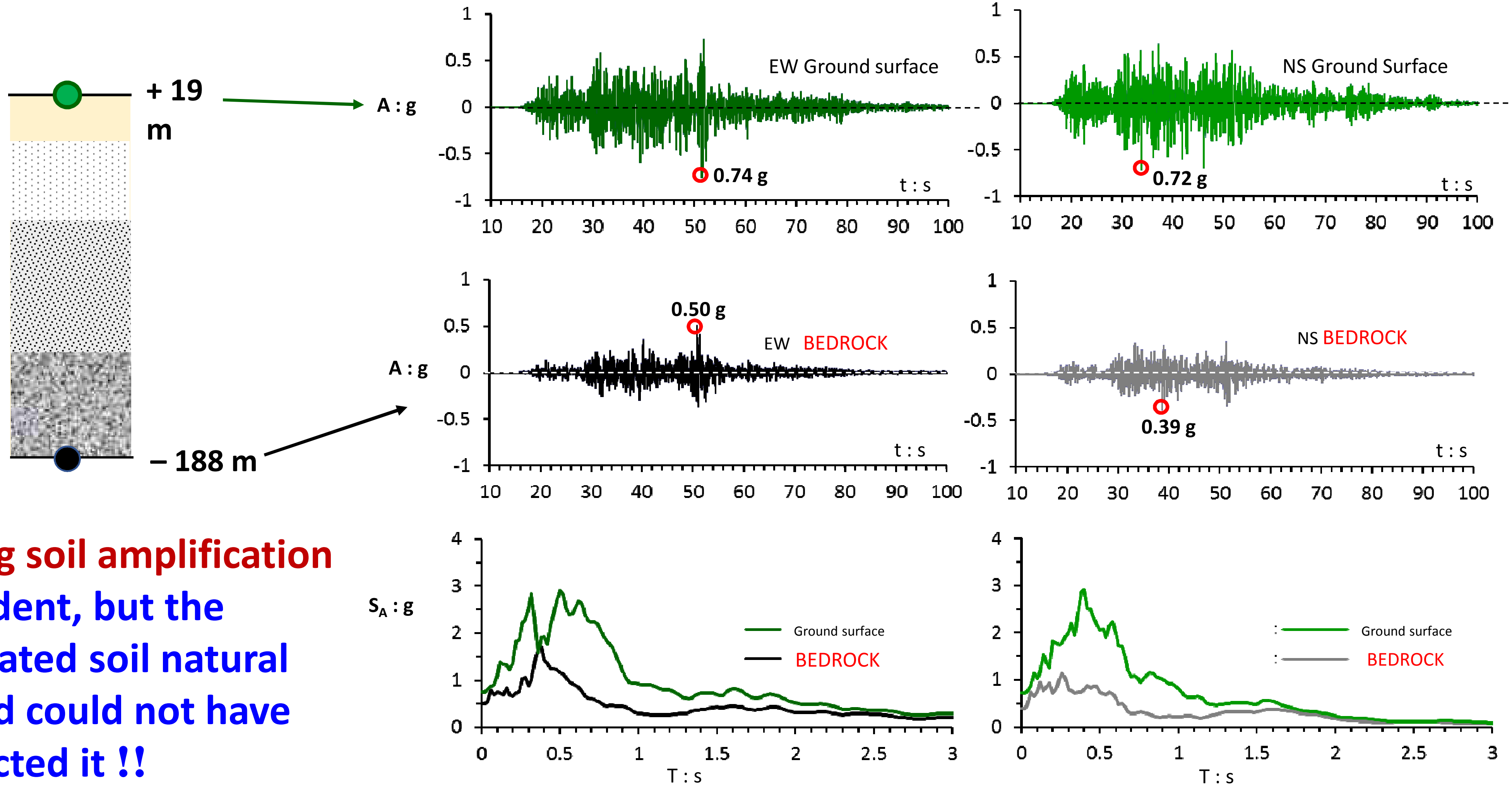
STATION: ICHIURA (ISKH 03)

No apparent relation of dominant with natural periods. Yet, see next slides....



8 STATION: ICHIURA (ISKH 03)

Ground surface vs Bedrock Motions

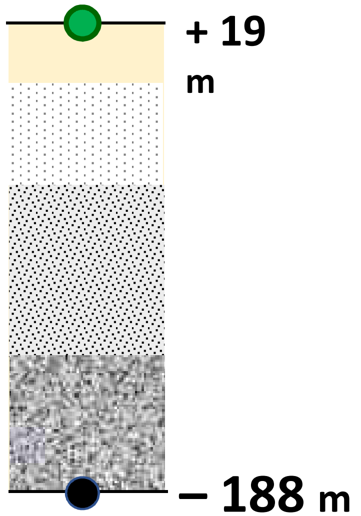


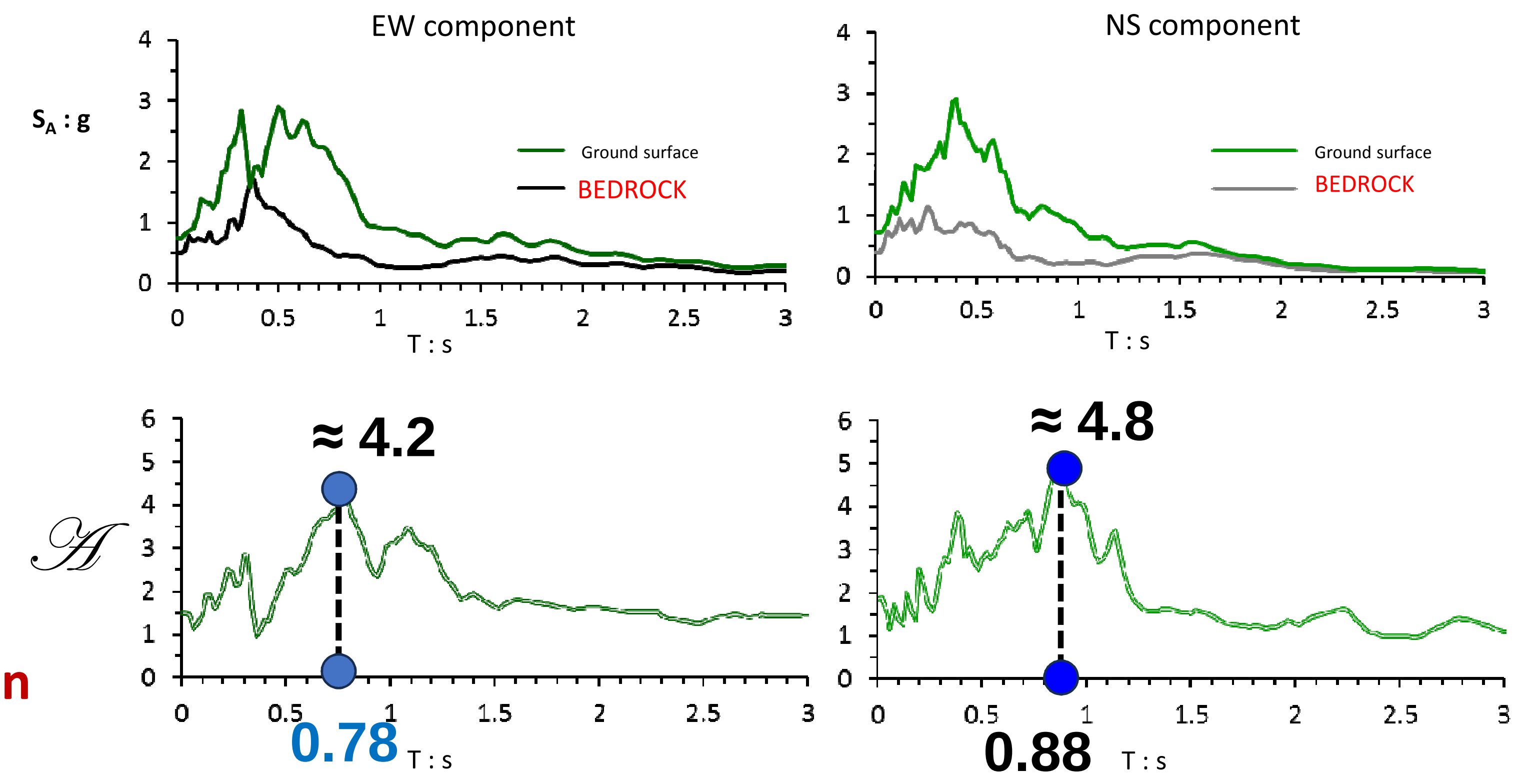
Strong soil amplification is evident, but the estimated soil natural period could not have predicted it !!

8

STATION: ICHIURA (ISKH 03)

Ground surface vs Bedrock Motions



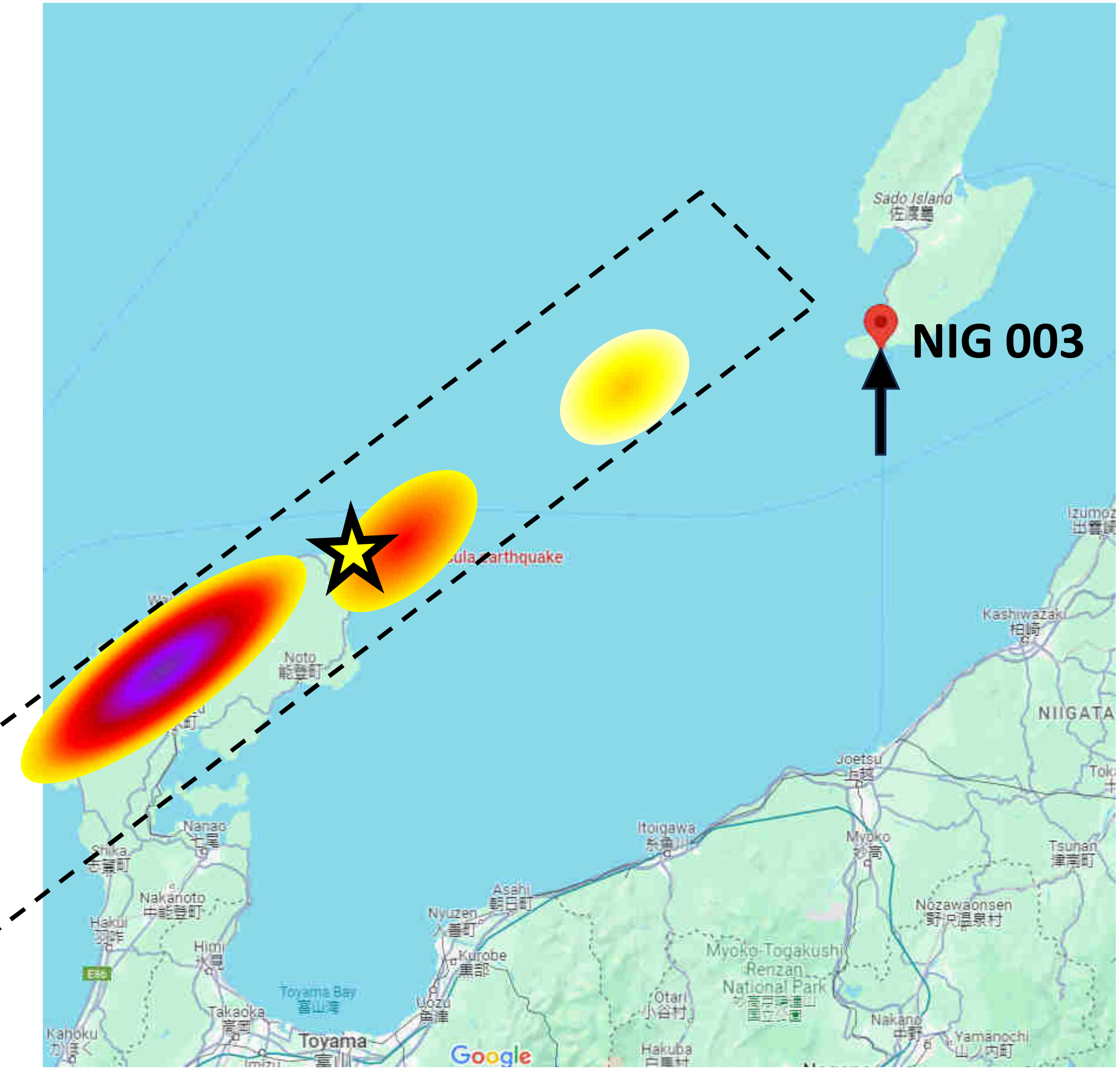


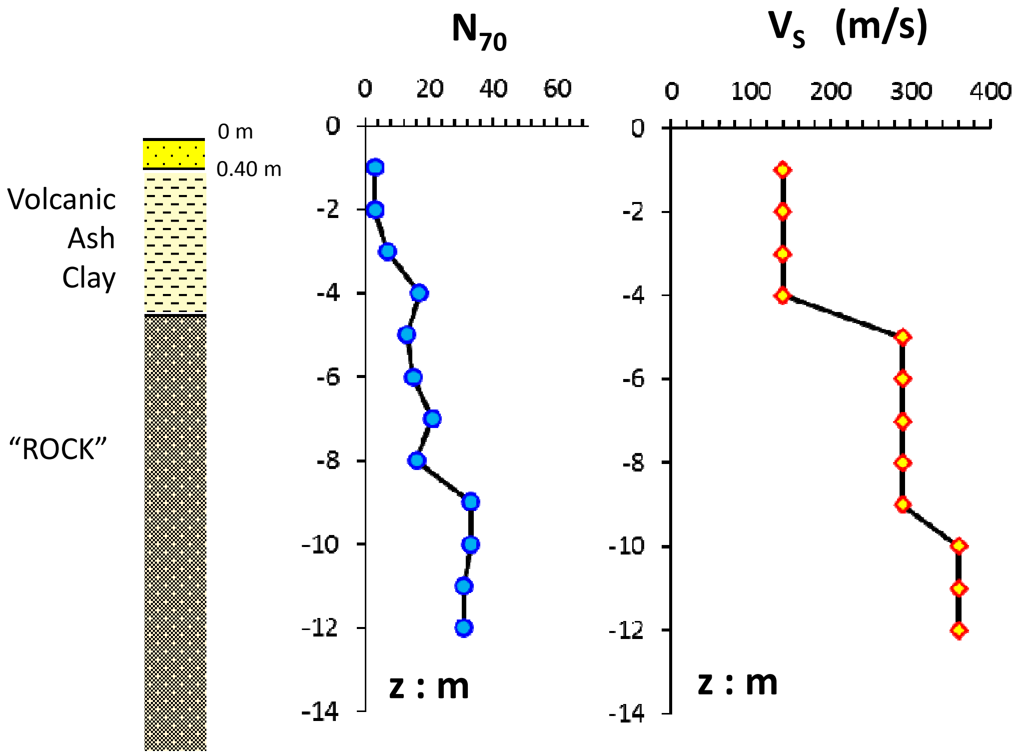
Strong soil amplification

But the soil natural period could not have predicted it !!

Amplification Ratios $\mathscr{A} = \mathscr{A}(\tau) = S_{a,\ surface} \,/\, S_{a,\ BEDROCK}$

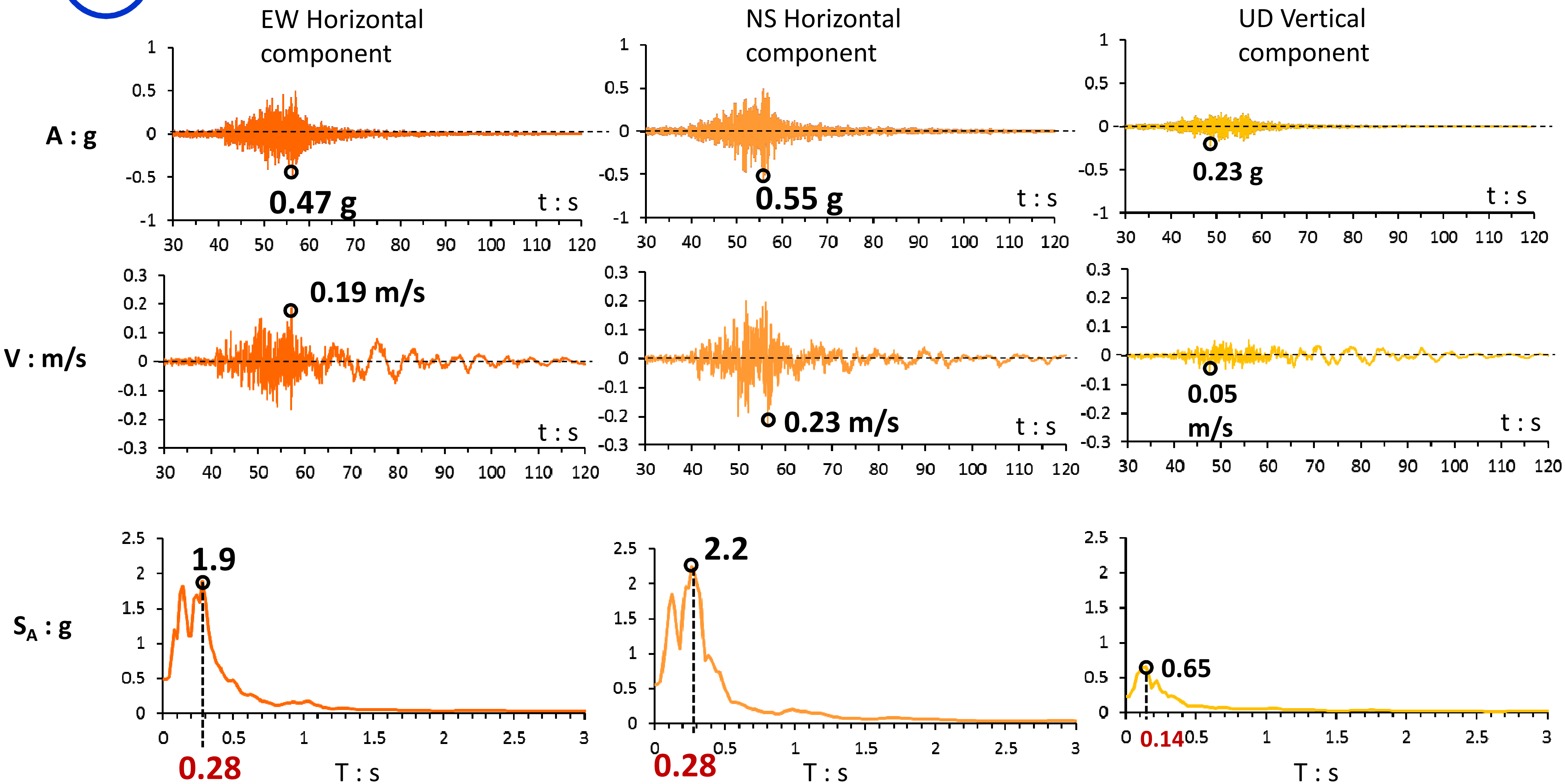
9 STATION: OGI (NIG 004)



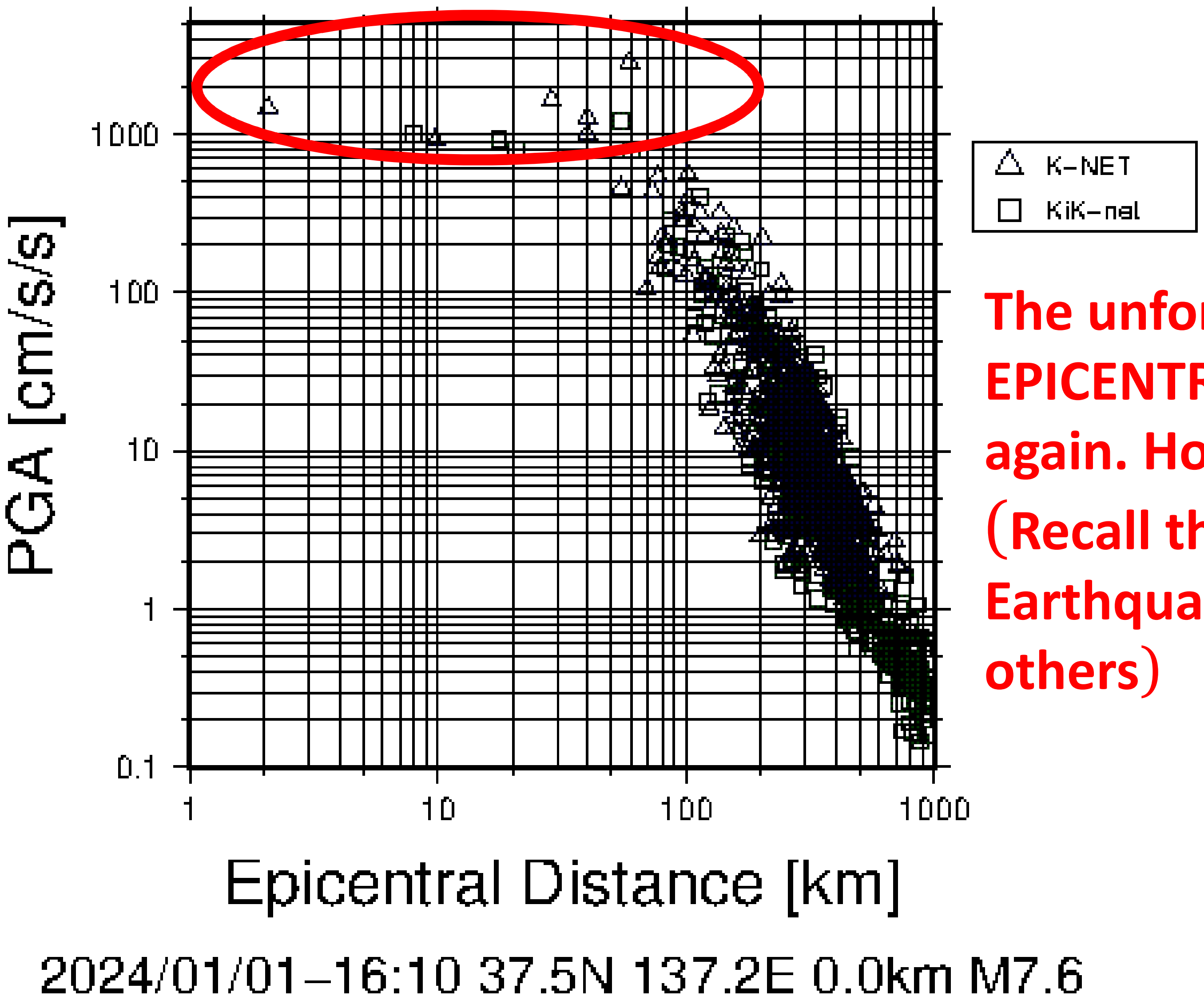


9

STATION: OGI (NIG004)



From K-NET NIED



The unfortunate use of EPICENTRAL Distance, again. How misleading !

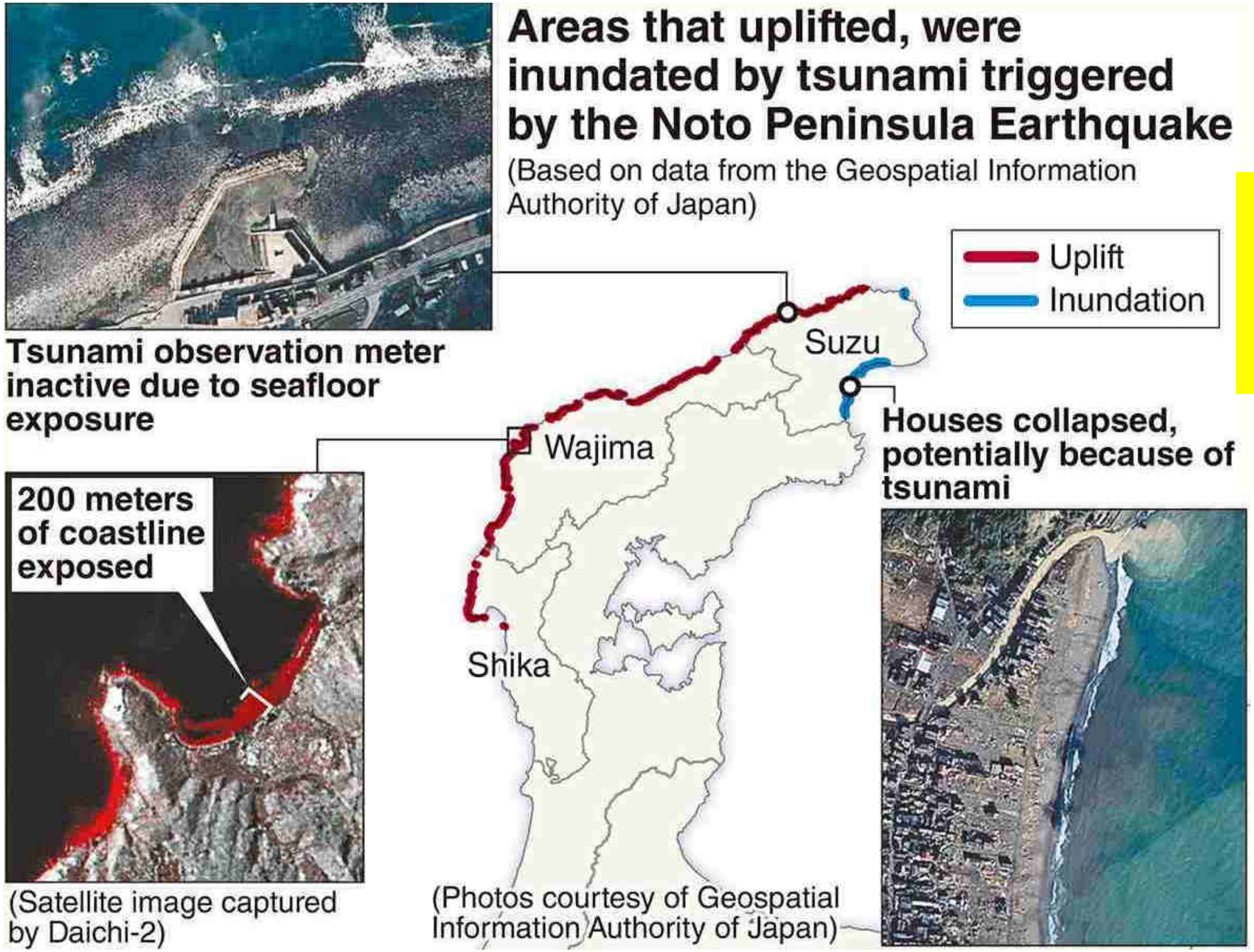
(Recall the Turkey Earthquake … and many others)

EARTHQUAKE CONSEQUENCES

- At least **300 deaths** is the current estimate. All the victims were in Ishikawa prefecture, most of them **in Suzu** and **Wajima** cities.
- **Major damage to roads and houses** in the whole Noto peninsula**.**
- More than **36,000 households lost power** in Ishikawa and Toyama prefectures. [https://www.hindustantimes.com/world-news/dozens-earthquakes-hit-japan-tsunami-warning-photos-101704116052162.html.]
- In **Wajima**, the quake **flattened** at least **50 homes** in the city, trapping dozens of people under the rubble, according to NHK [https://www.ettoday.net/news/20240102/2655265.htm]
- In **Suzu, 90% of houses were heavily damaged/destroyed**. [https://www.reuters.com/world/japan/least-six-dead-after-huge-earthquake-rocks-japan-new-years-day-2024-01-01/]
- In **Nanao**, there were many **landslides, cracked roads, and collapsed houses..** [https://www.nbcnews.com/news/asia/japan-issues-tsunami-warning-strong-earthquakes-sea-japan-rcna131783/]
- **Liquefaction** occurred in **Niigata** 40 km from the NE part of the faultsewer pipes ruptured, and many homes were left without water [https://www.sankei.com/article/20240101-VIXLI6IAHVKOFAHSCHEENE6INQ/];
- A **fire** occurred in the Wajima city. Due to damaged roads, firefighters were unable to extinguish the flames. An estimated of **200 buildings were burnt** in the fire. [https://www.jiji.com/jc/article?k=2024010200075&g=flash.]
- The highest **tsunami recorded was almost 1.5 meters at Wajima Port .** [https://en.wikipedia.org/wiki/2024_Sea_of_Japan_earthquake.]

Tsunami

Noto Peninsula Earthquake Exposes 200 Meters of New Coastline



Source: https://japannews.yomiuri.co.jp/society/noto-peninsula-earthquake/20240107-160559/

Photo: MAINICHI PHOTOGRAPHY

Photo: Kyodo/via REUTERS

Cars and houses are washed away by the tsunami on the coast in Noto

Suzu

Photo: **AFP-JIJI**

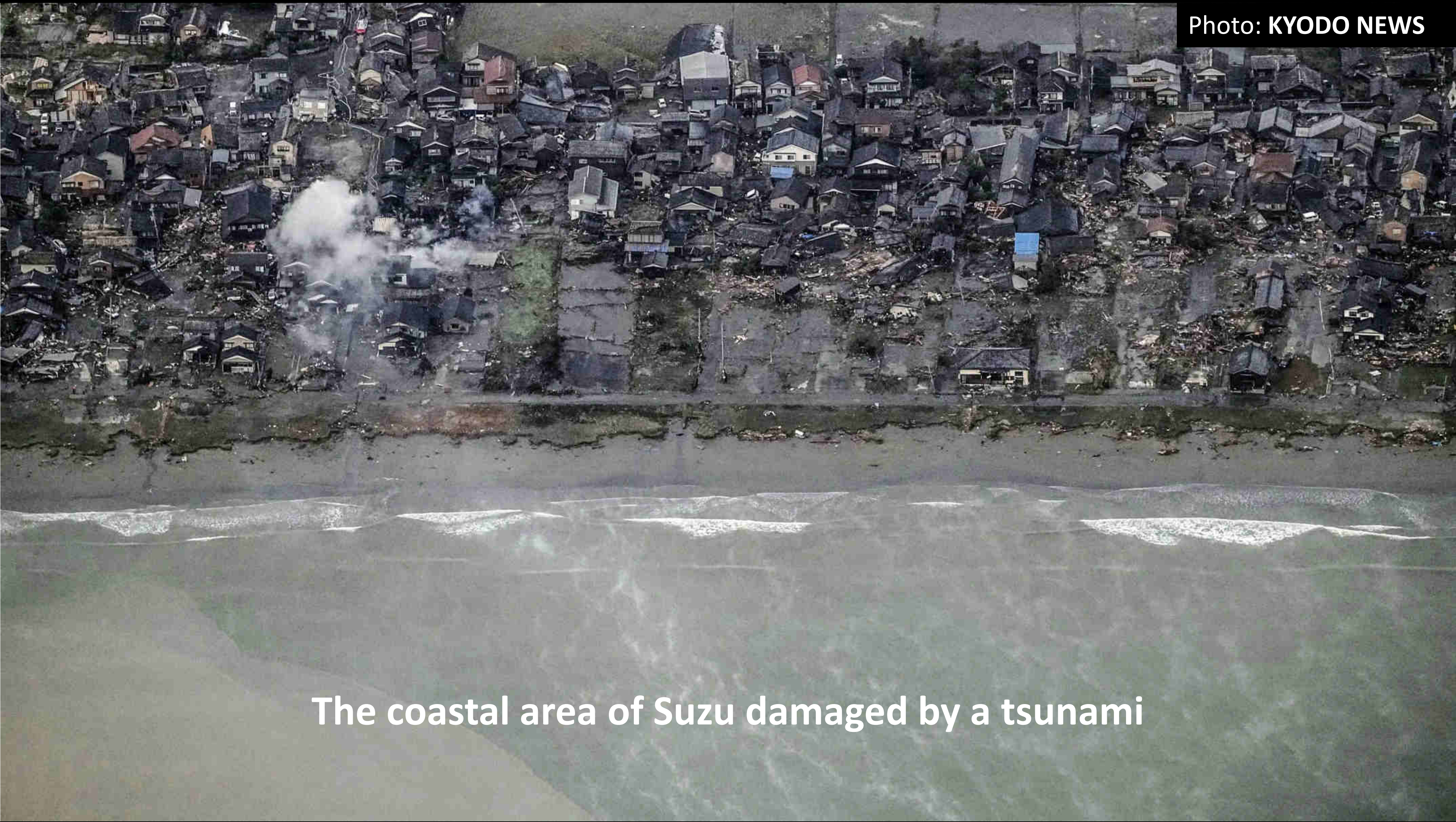


Photo: **KYODO NEWS**

The coastal area of Suzu damaged by a tsunami

Photo: **KYODO NEWS**

Damaged by the tsunami neighborhoods along the shore in Suzu

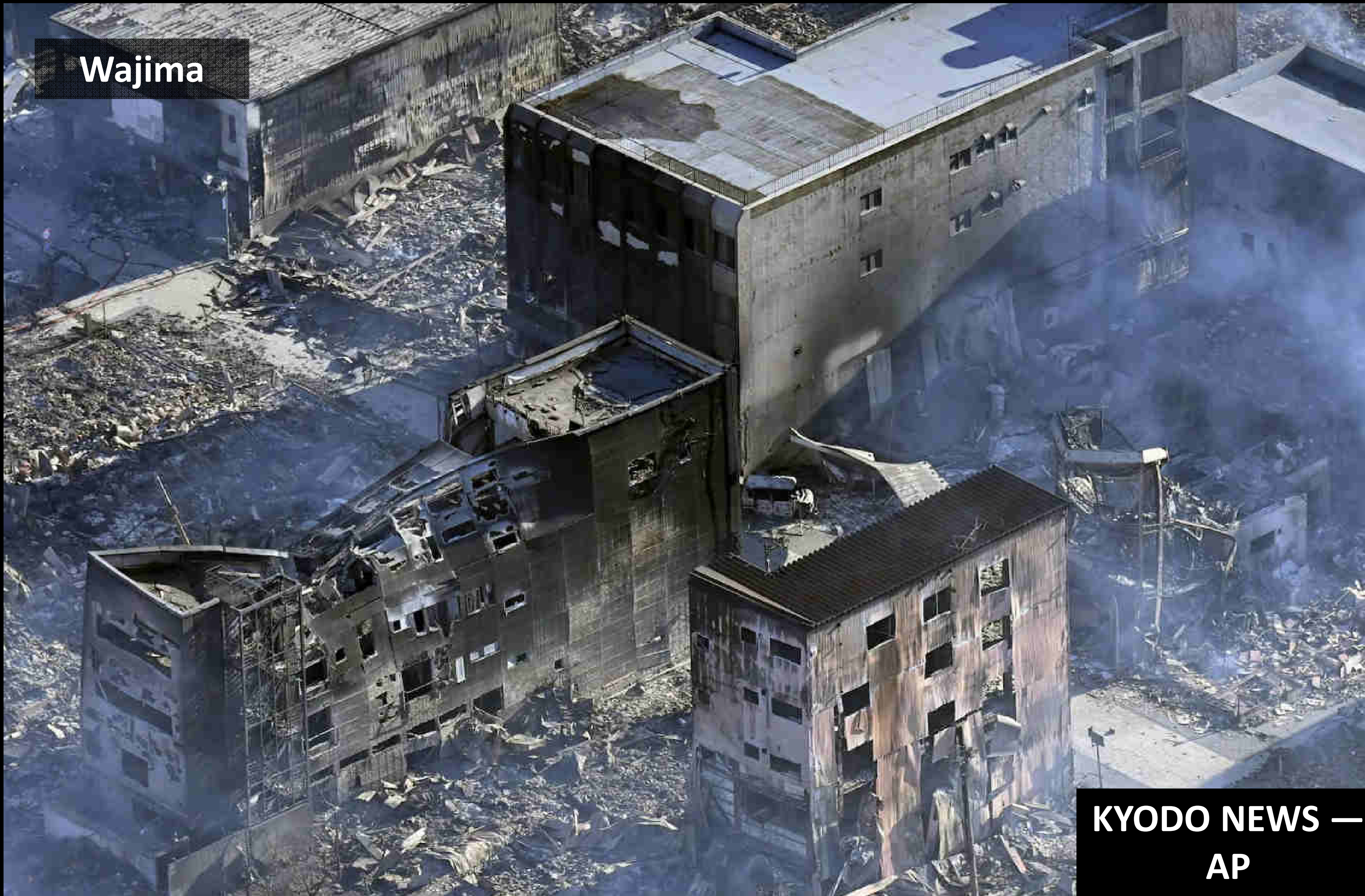

Suzu
Photo: AFP

Structural Damage

(aerial photos)

Wajima — AFP

This aerial photo shows the consequence of a large fire in Wajima. Photo: Fred Mery, AFP



KYODO NEWS — AP

Damage of a Bridge in Suzu


Cracked bridge
Photo: KYODO NEWS via AP

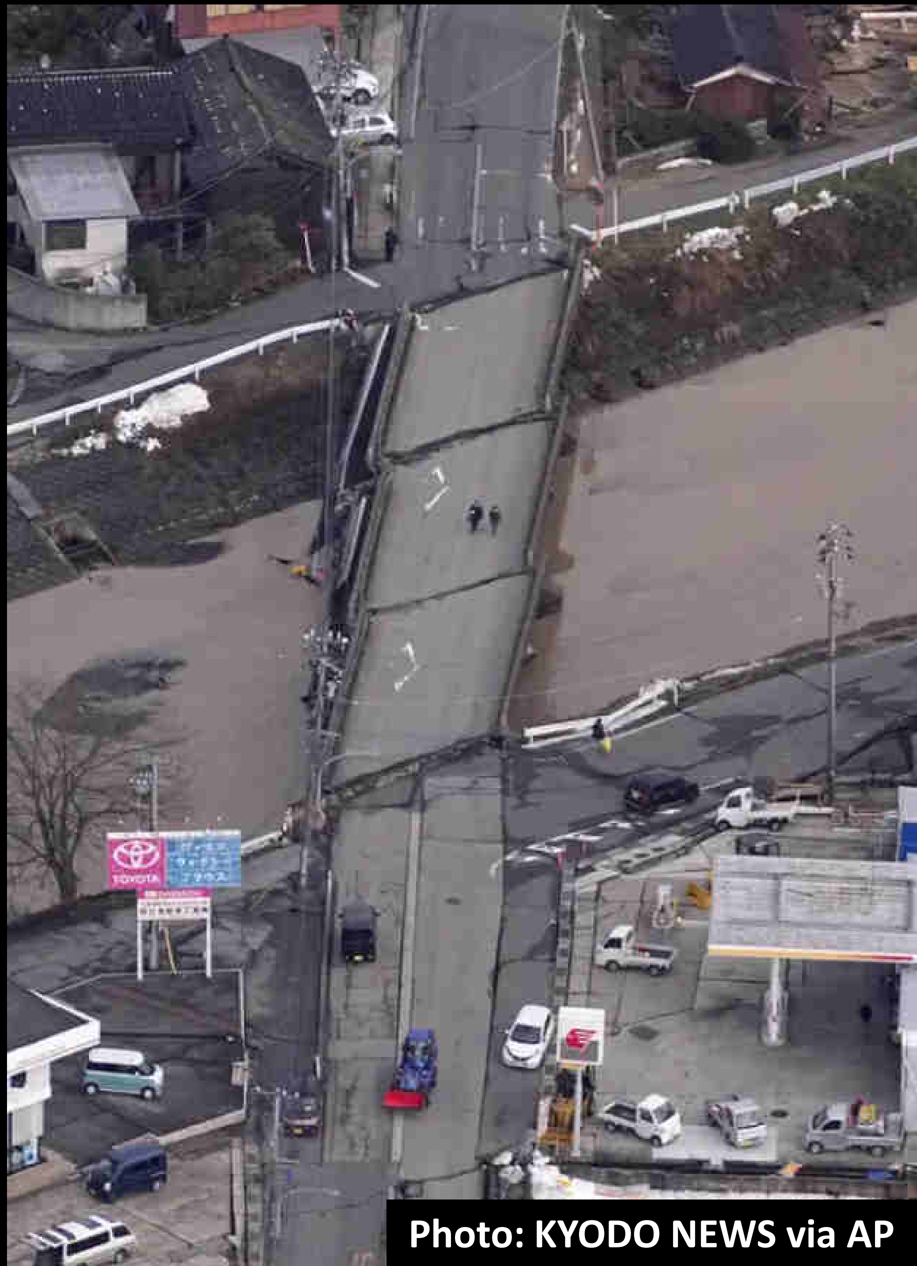


Photo: KYODO NEWS via AP

Collapse

of traditional wooden houses

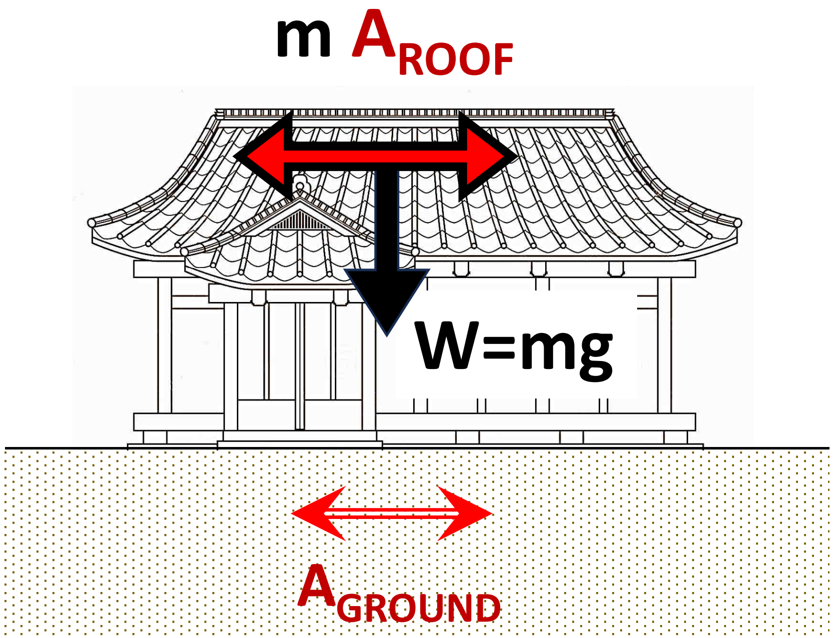
Source: **The Independent**

Anamizu (Photo: AP)


Collapsed wooden house in Wajima
Picture: Kazuhiro NOGI/AFP
Heavy roof tiles

Many structural failures (especially in 1 or 2 storey houses).

They were apparently largely (if not only) due to oscillation of the HEAVY ROOFS



Each of the beautiful roof tiles weighs about 4 kg !! (estimate) *

- Natural Period (estimate) at **0.4 – 0.6 s**. Hence roughly $A_{ROOF} \geq 2\ A_{GROUND}$
- Therefore, **mA** is **unbearingly large (even) for the resilient wooden frames !!**

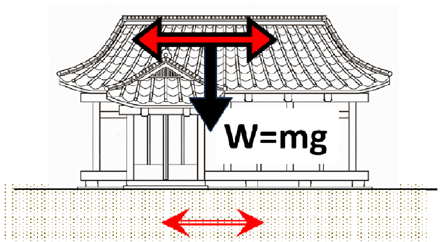
* The justification for the use of such heavy tiles: to protect against the typhoons/hurricanes which may occur up to **10 times/year** !!, not just **1 time/30 years** as earthquakes do !!!

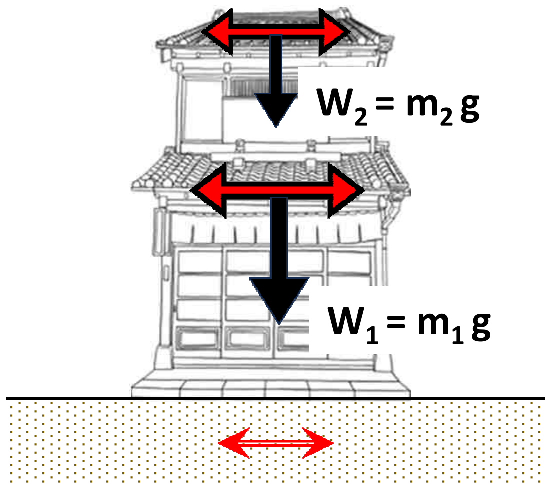
We observed three MODES of FAILURE of the destroyed houses:

I. The most frequent: failure of the ground-floor supporting wooden frame from the large Shear Force from the roof.

II. Also frequent: the heavy roof was detached and thrown away, in front of the house, wherever the anchoring of the roof onto the frame was weak.

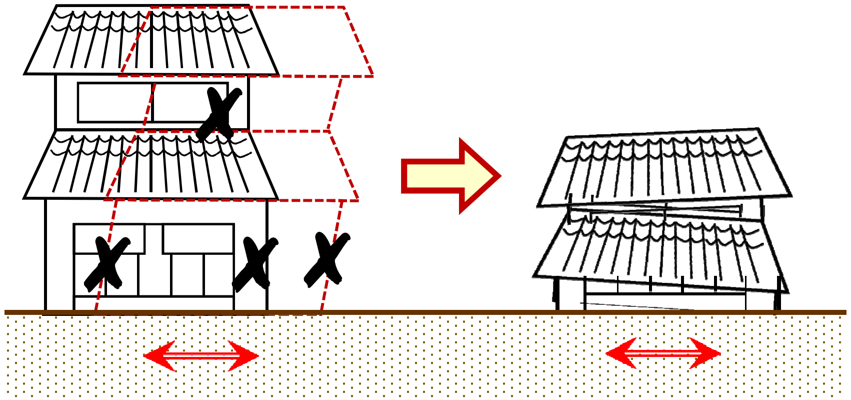
III. Less frequent: Well-anchored roof of 2-strory houses and the developed huge inertia force produce large overturning moment that caused tilting and toppling of the buildings.



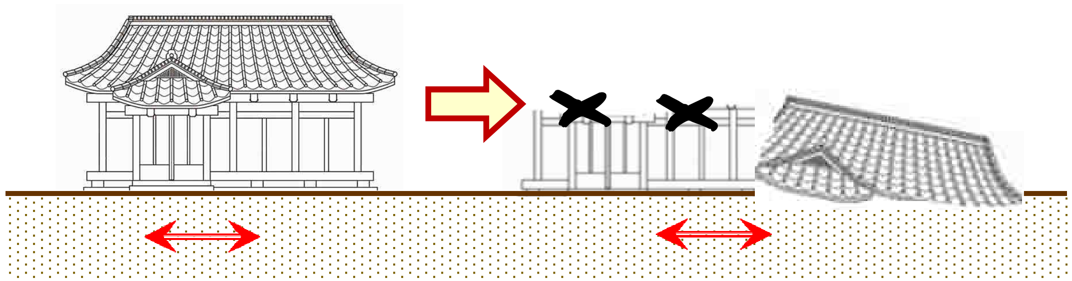


THREE MODES OF FAILURE

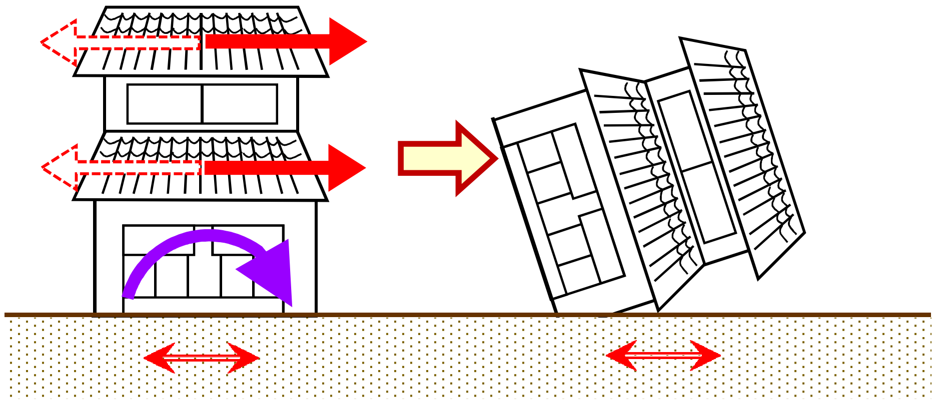
MODE I



MODE II



MODE III



FAILURE MODE I.

Screenshot from an AFPTV video taken on January 2, 2024, in Wajima. — AFP

A vehicle trapped underneath a collapsed building in Shikamachi

Credit: Kyodo News via AP

WAJIMA.

Photo: Buddhika Weerasinghe/Getty Images

Damaged houses in Noto town
Photo: Hiro Komae via AP


2-story wooden house in Nanao
(Photo: Getty Images)
FAILURE MODE III.

Collapsed building in Nanao Photo: Kyodo News


Suzu
FAILURE MODES III and I
Photo: KYODO

Structural damage of modern buildings

(Few cases have been seen until now.

Here is one that has been shown in the Media)

An aerial view shows a collapsed overturned building in Wajima, Ishikawa prefecture.
Credit: Kyodo via REUTERS

Image Source: https://www.yomiuri.co.jp/pluralphoto/20240101-OYT1I50140/

Seismic response of rigid blocks:

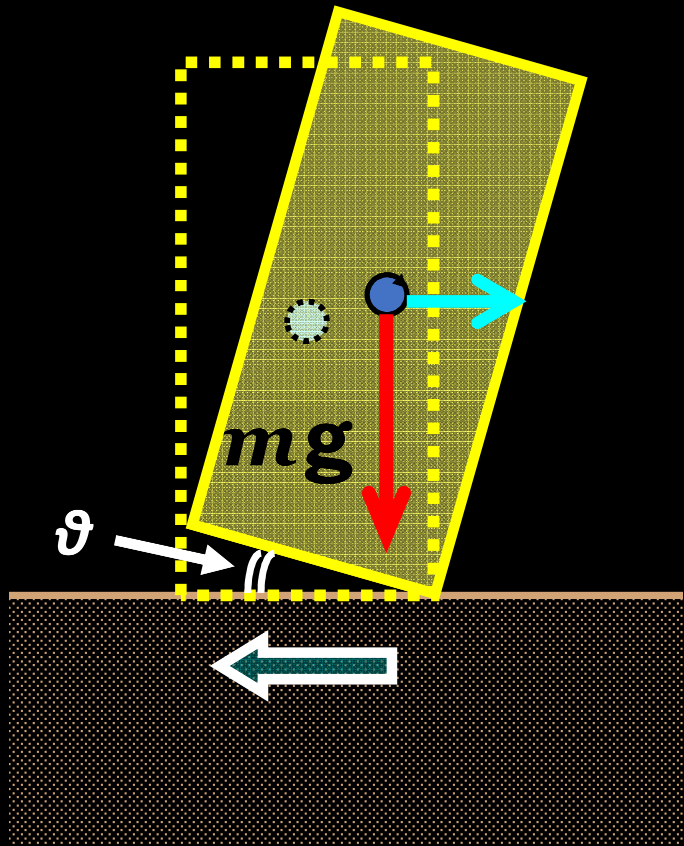
tombstones and traditional gates in shrines

(It would be interesting to find out **safely standing** slender tombstones and relate their performance with recorded nearby **motions**)

Source: https://asia.nikkei.com/Economy/Natural-disasters/In-Pictures-Japan-earthquake-shatters-New-Year-s-Day-calm

A damaged shrine in Ujima Source: REUTERS/Kim Kyung-Hoon

rigid block rocking oscillation



The collapsed Torii gate at Ono-Hiyoshi Shrine in Kanazawa

Photo: KYODO

The collapsed Torii gate at Ono-Hiyoshi Shrine in Kanazawa

Photo: KYODO

Endless Geotechnical Failures !

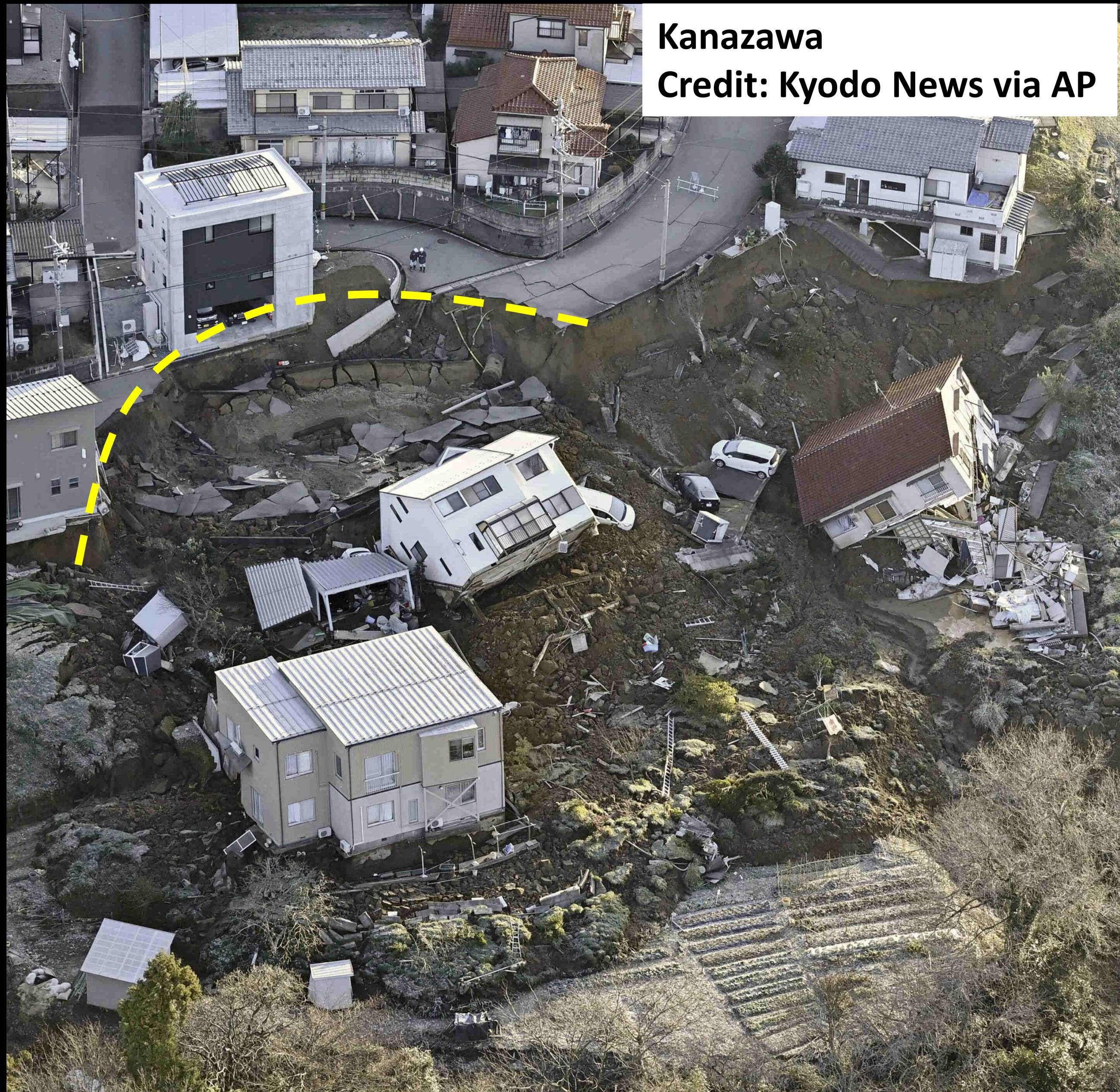
local slope failures, embankment subsidence, retaining failures, landslides, sinkholes, liquefaction, and so on…

Photo: X/ @JustusUwakwe

collapsed houses, cars, roads in Kanazawa
Source: Kvodo/via REUTERS

The same failure of the previous photo, from a different viewpoint.

Notice the circular slope failure mechanism




in Hakui
Photo: Xinhua/Zhang Xiaoyu


50
Close to Noto
Exact causes : indistinguishable from the photo alone.

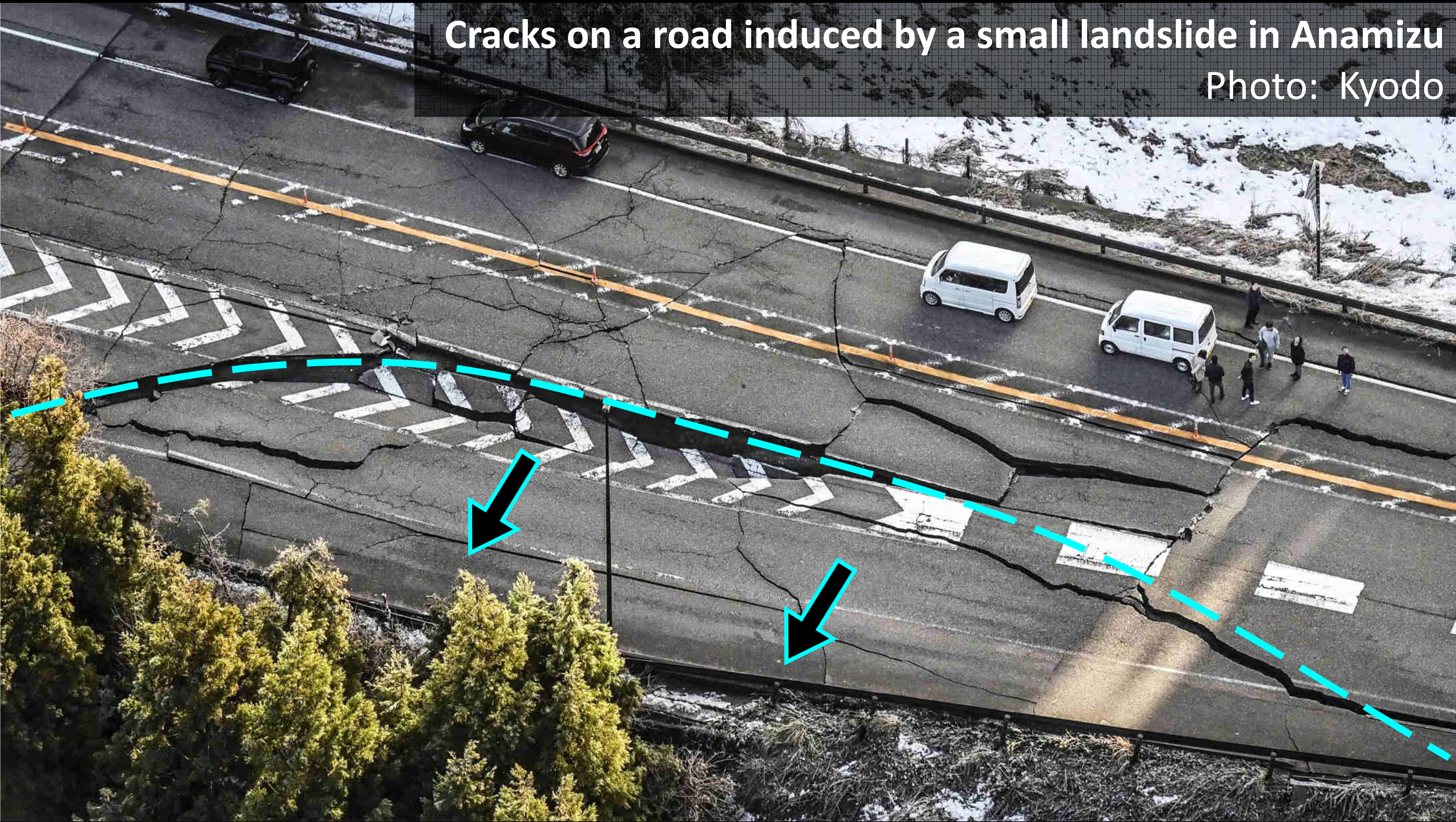
Landslide in Wajima Photo: FRED MERY (AFP)

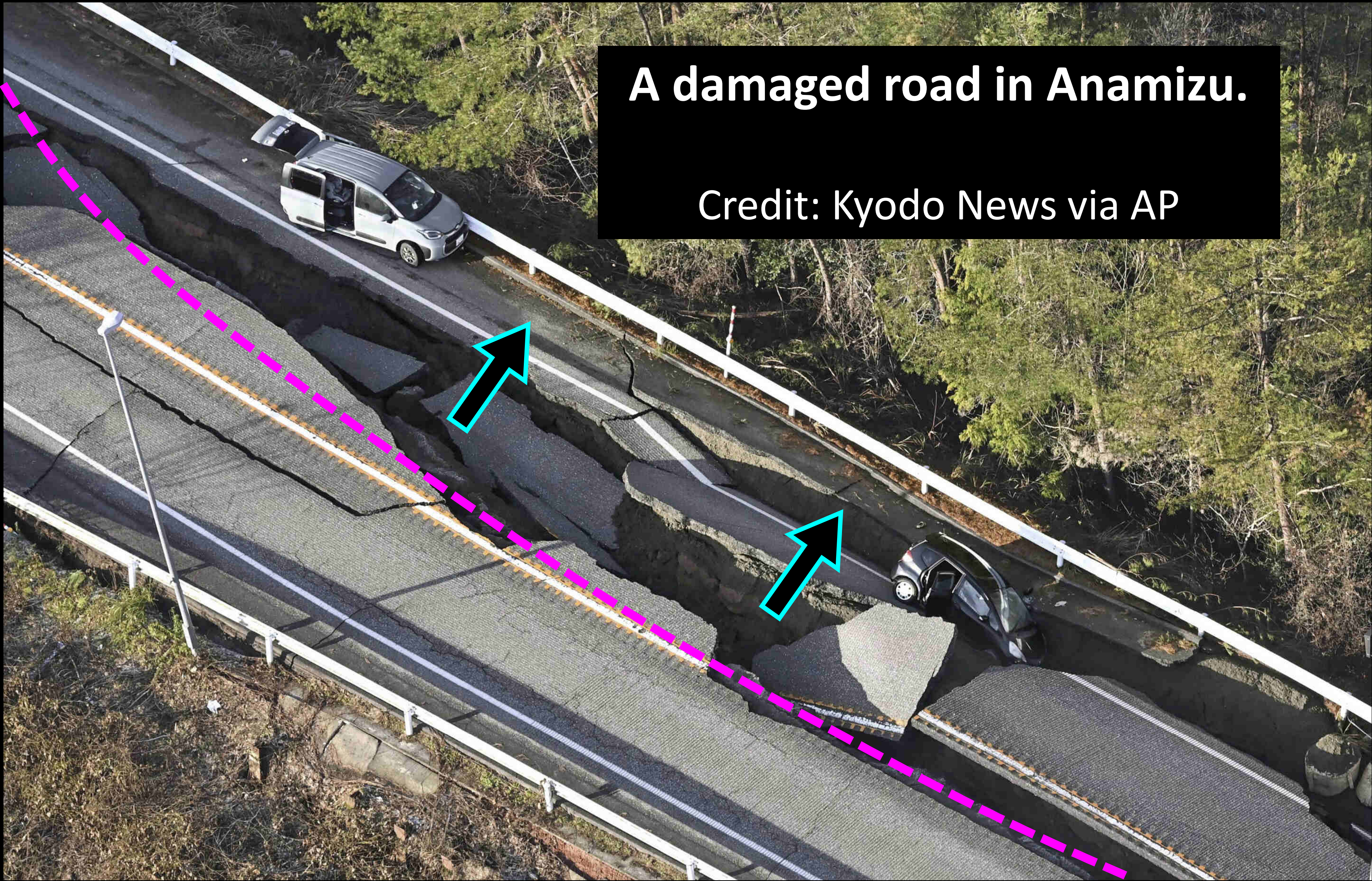
near Anamizu Town

Photo: AP Photo/Hiro Komae

Road near Anamizu Town.

Photo: Hiro Komae/AP


Cracks on a road induced by a small landslide in Anamizu
Photo: Kyodo


A damaged road in Anamizu.
Credit: Kyodo News via AP

Shika town (Photo by Fuminori Ogane / Yomiuri / The Yomiuri Shimbun via AFP)

Shika Town


YONHAP NEWS


Photo: Masamichi Kirihara

Source:
https://www.jiji.com/jc/article?k=2024010200068&g=soc&p=20240102at07S&rel=pv

Mega cracks. Road in Anamizu.

REMINISCENT of LATERAL SPREADING-INDUCED FAILURE

(Photo by Yoshinori Saito)

Photo: The Japan Times


In Wajima
Photo: KYODO


A view of a collapsed road
and houses in Wajima
Source: KYODO/VIA REUTERS

Cracks on a road in Kanazawa
Source: IMAGO / Kyodo News

Rockfalls in Wajima

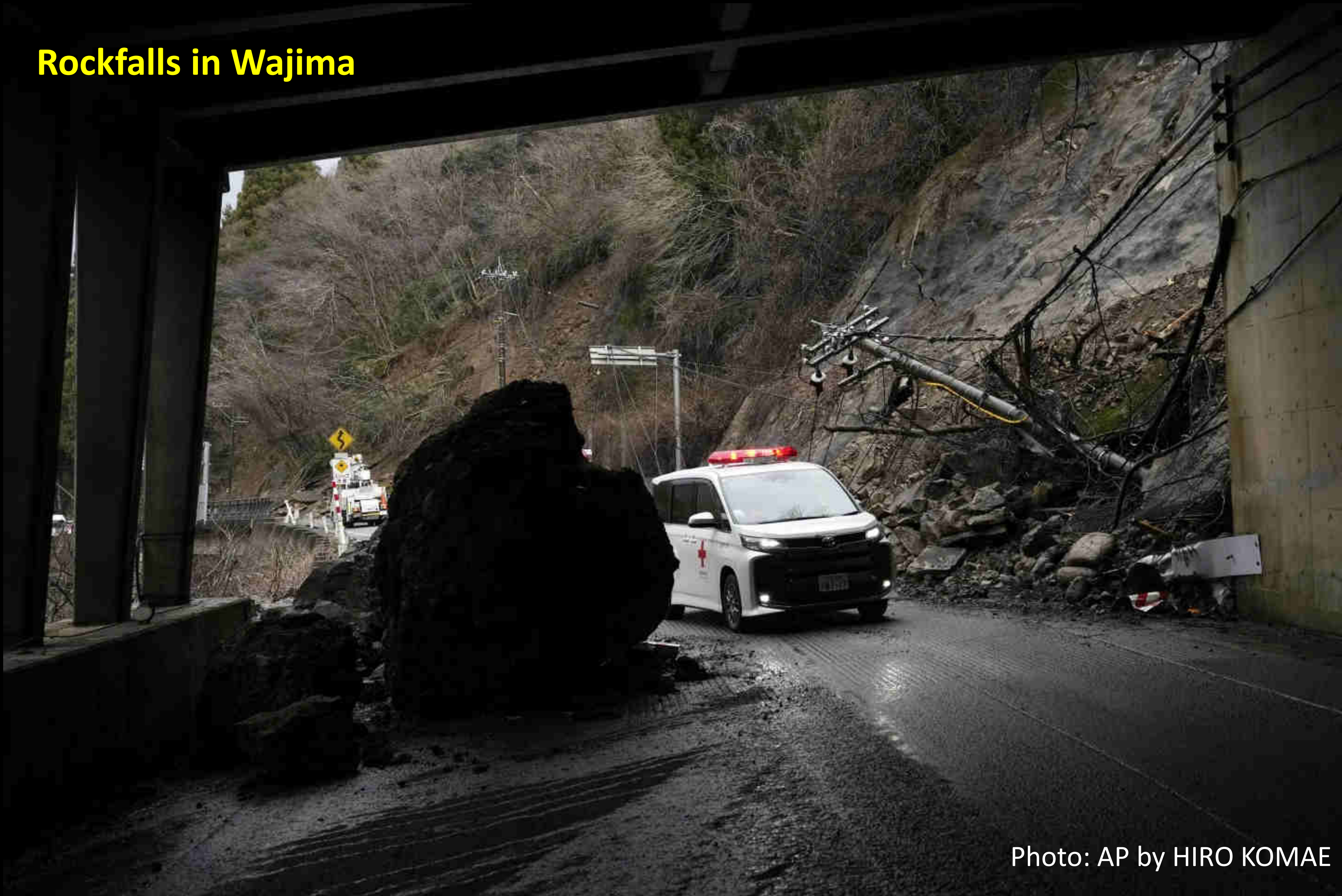


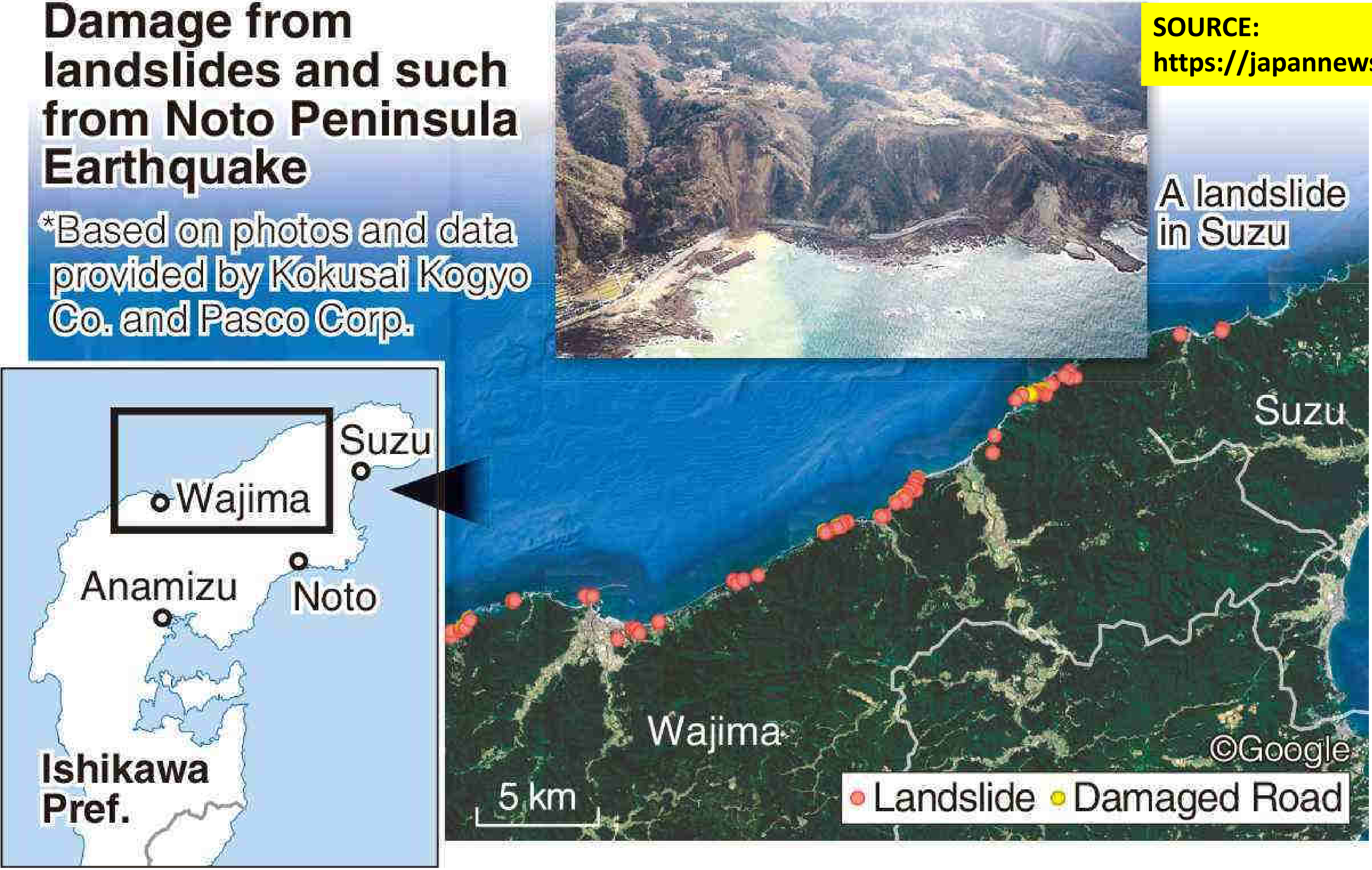
Photo: AP by HIRO KOMAE

Major LANDSLIDES

(over 100)

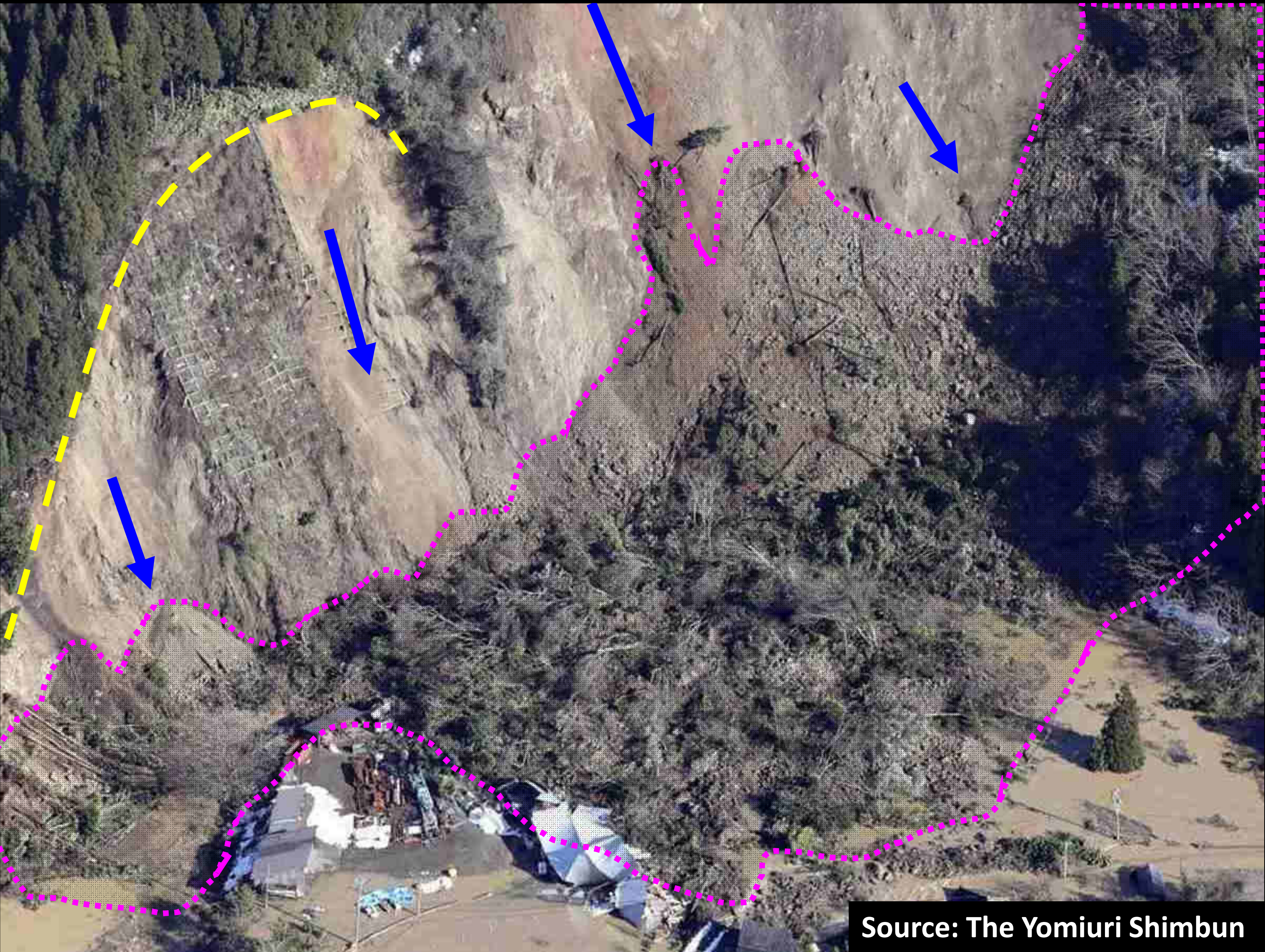
Damage from landslides and such from Noto Peninsula Earthquake

*Based on photos and data provided by Kokusai Kogyo Co. and Pasco Corp.



SOURCE: https://japannews.yomiuri.co.jp


WAJIMA
Source: https://eos.org/landslide-blog



Extensive landslide in Wajima

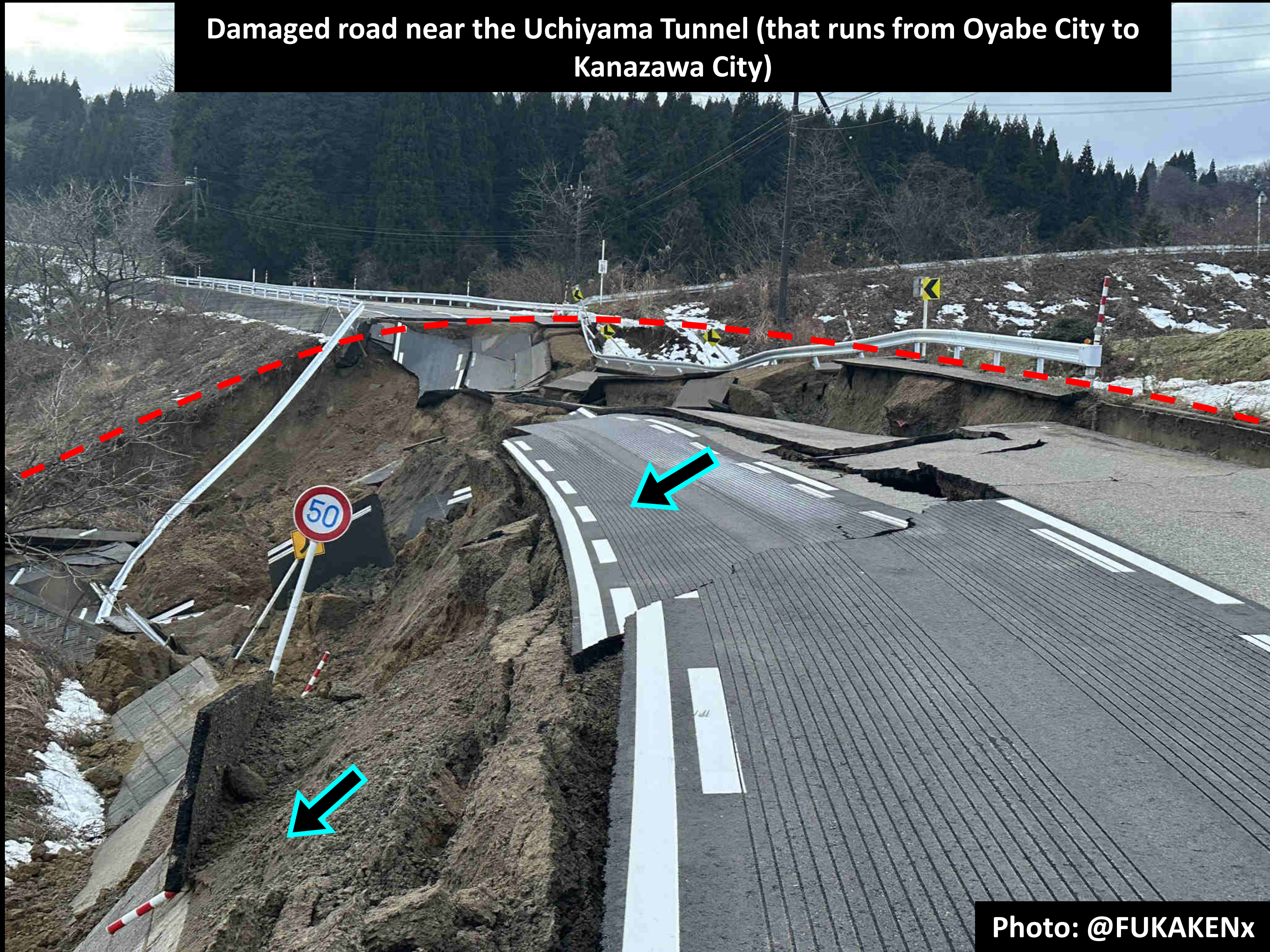

National Route 249
cut by a landslide
near Minamishimi
MAINICHI
PHOTOGRAPHY
Photo: MAINICHI PHOTOGRAPHY

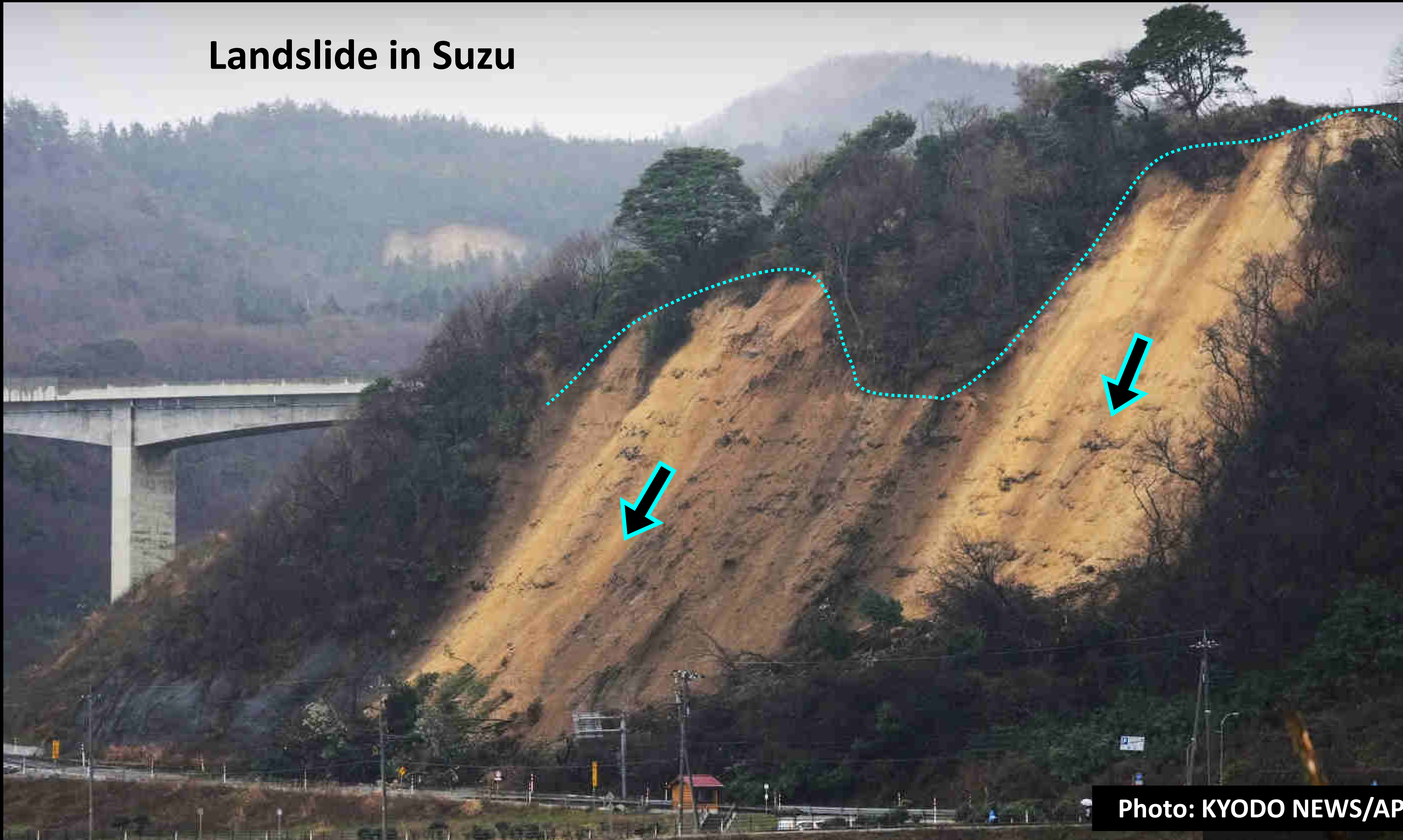
Photo: MAINICHI PHOTOGRAPHY

SOURCE: **https://youtu.be/6yq_H1Fyghs?si=U7OtC79MhzfivZ0l**

Location Map

Damaged road near the Uchiyama Tunnel (that runs from Oyabe City to Kanazawa City)




Landslide in Suzu
Photo: KYODO NEWS/AP

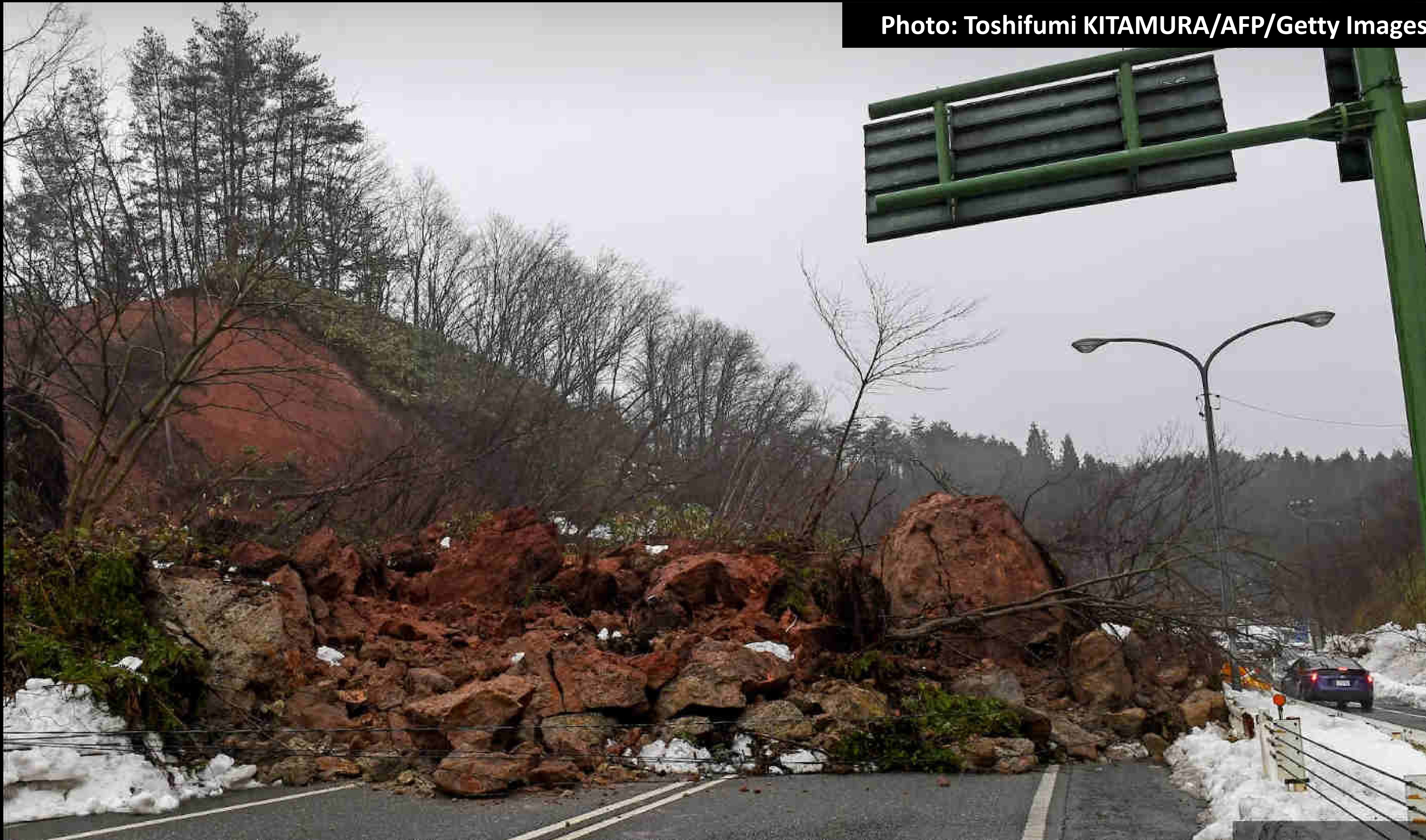


Photo: Toshifumi KITAMURA/AFP/Getty Images

(More Obvious) Soil Liquefaction Cases

Traces of soil liquefaction ejecta occurred in Niigata City

Source: The Sankei Shimbun


Screenshot from Spectee video via Reuters

Snapshot from a video of a soil liquefaction

Source: Daily Mail


soil ejecta
in grey
colour
Source: Maxar Technologies

Source: BBC News

An Update will follow (along with more robust Conclusions), after the Japanese Engineers make and publicize their interpretation of more observed failures.

8 January 2024

E.G., G.G.

(T.U.C, N.T.U.A)

For Reference:

Garini E., Gazetas G. (2024) "The M_{JMA}7.6 Noto Peninsula Earthquake of January 1st 2024, Japan: Preliminary Report with Emphasis on Recorded Motions and Soil Effects", DOI: 10.13140/RG.2.2.12972.85129