

Liquefaction case histories at strong motion recording sites

MIKE GREENFIELD, PE, PHD

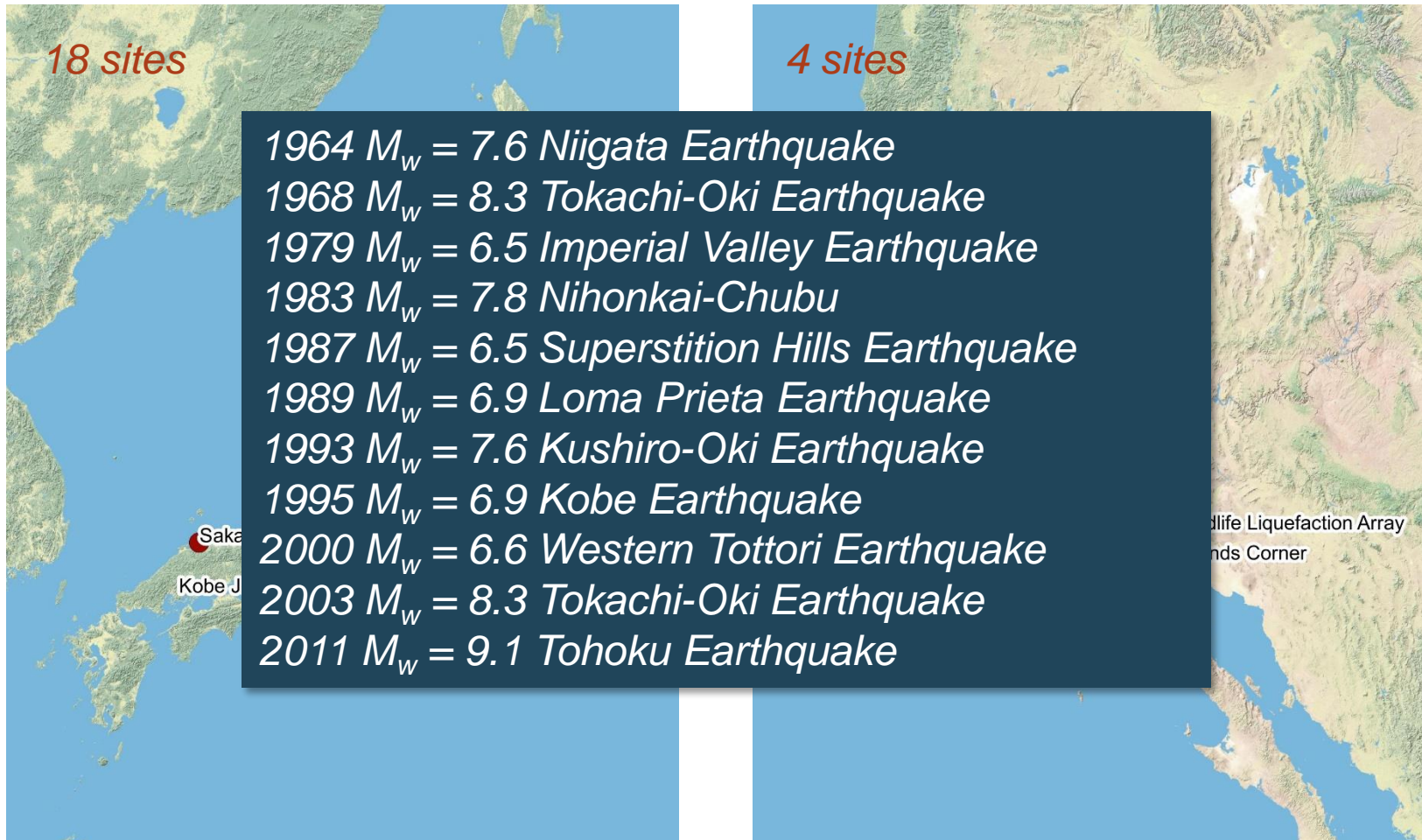
Liquefaction case histories at strong motion recording stations

Liquefaction case histories

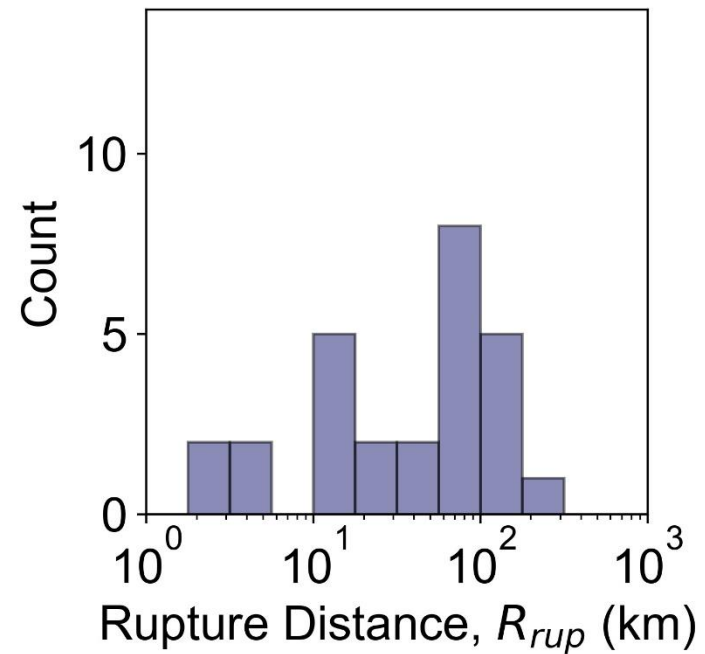
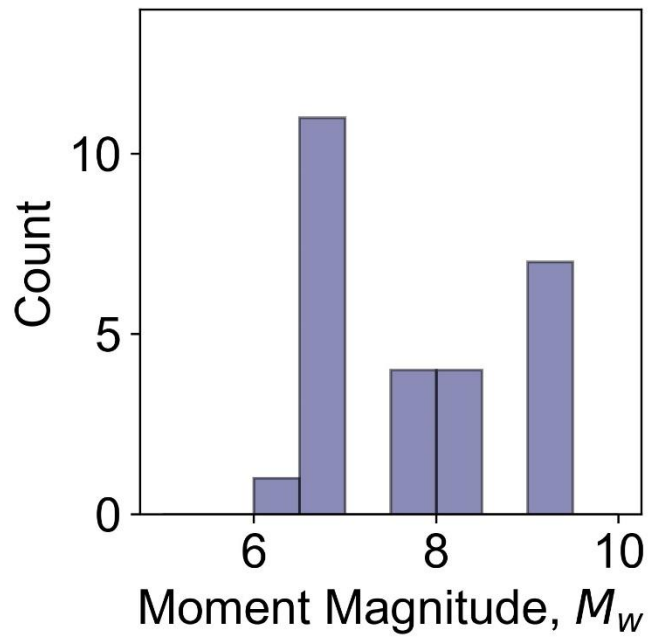
- Past research has focused on binary observation of surficial manifestation of liquefaction
 - Seed and Idriss (1971) compiled 35 case histories
 - Cetin et al. (2004) compile 108 case histories
 - Cetin et al. (2018) 113 case histories
 - Kayen et al. (2013) compiled 287 case histories
 - NGL Project may include hundreds more
- However, there have been limited observations of the impact of liquefaction on ground motions
 - Boulanger and Idriss (2010) database includes 5
 - Gingery et al. (2014) identified 19 ground motions that were affected by liquefaction

Liquefaction case histories at strong motion recording stations

Case histories in the NGL database



Liquefaction case histories at strong motion recording stations



Liquefaction case histories at strong motion recording stations

Recorded motions that have been affected by liquefaction have great value

- Directly measure intensity of shaking at the ground surface
- Isolate ground motions before and after liquefaction is triggered
- Observe the effects of liquefaction on ground motions

- Identify liquefaction without requiring surficial manifestation
 - Identify liquefaction where reconnaissance is not possible
 - Clarify questionable case histories

- Databases already incorporate this approach
 - Treasure Island and Kushiro Port case histories

Liquefaction case histories at strong motion recording stations

Example 1 – Kawagishi-cho Apartment Buildings

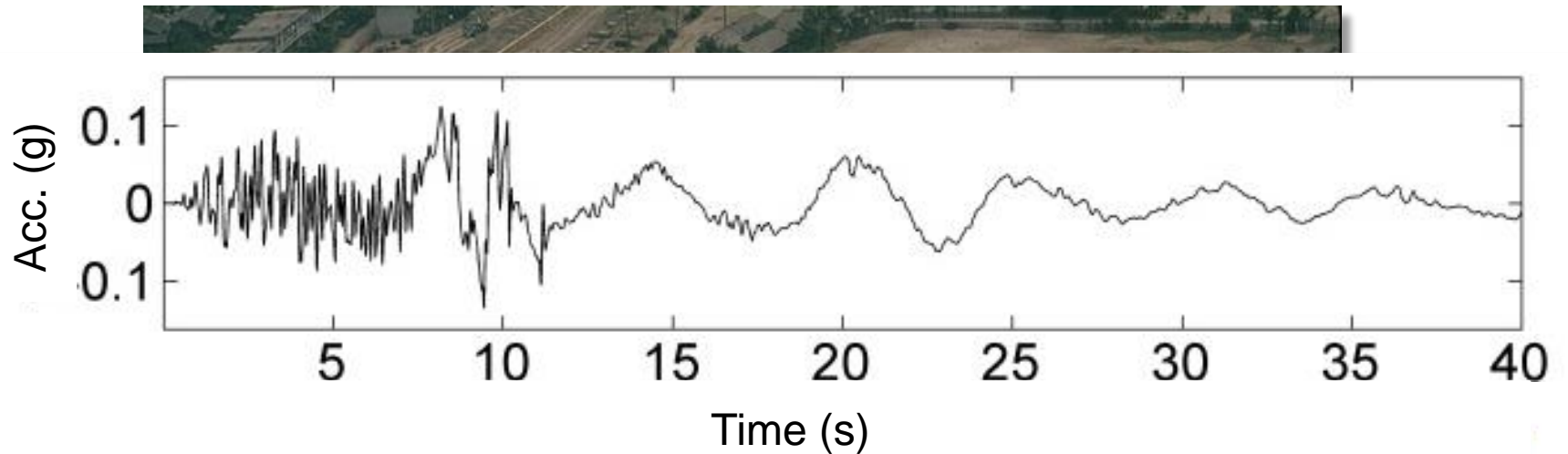
1964 $M_w = 7.6$ Niigata earthquake



Liquefaction case histories at strong motion recording stations

Example 1 – Kawagishi-cho Apartment Buildings

1964 $M_w = 7.6$ Niigata earthquake



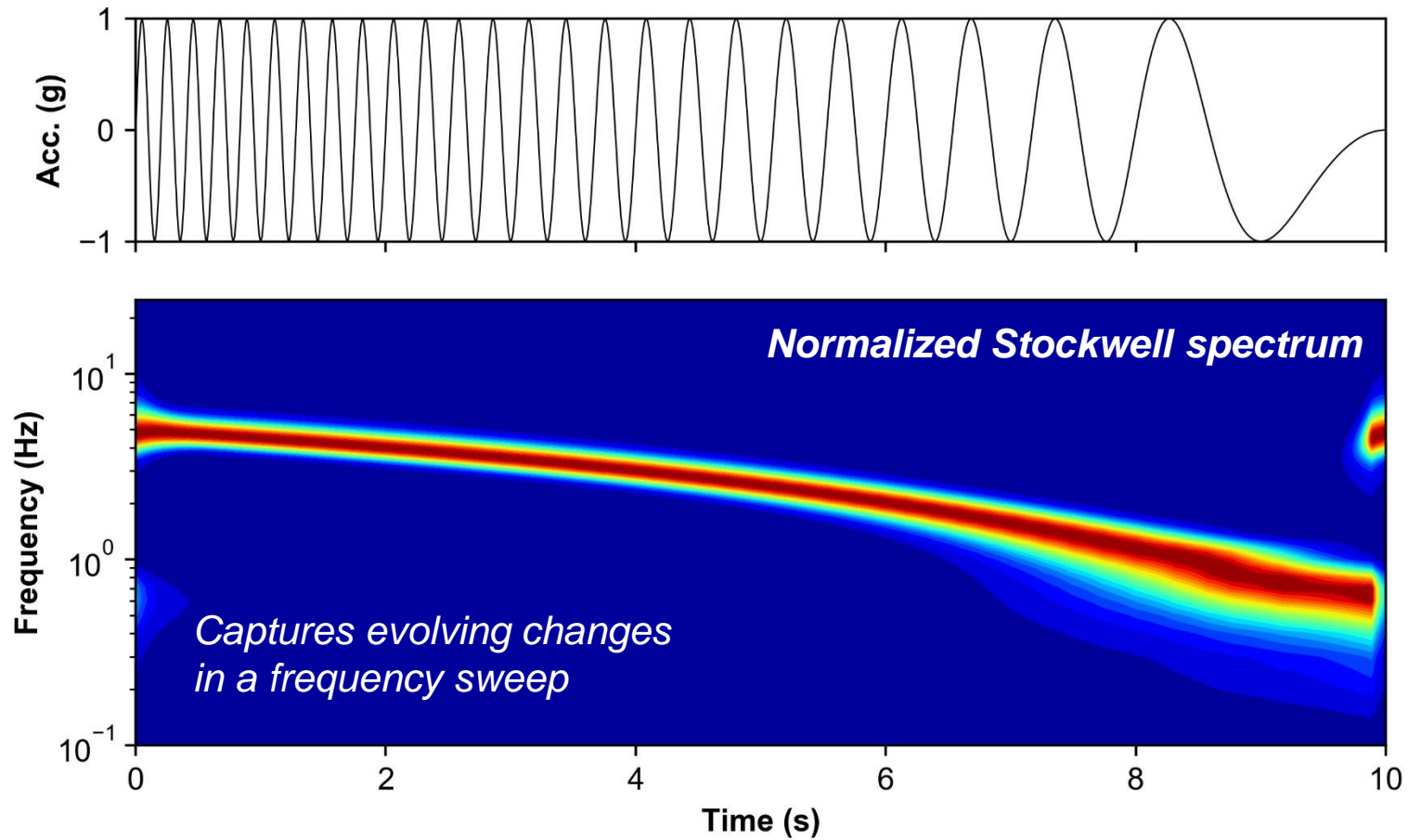
Ground motion shift

- *High-frequency at the early part of the record*
- *Low-frequency after about 10 seconds*



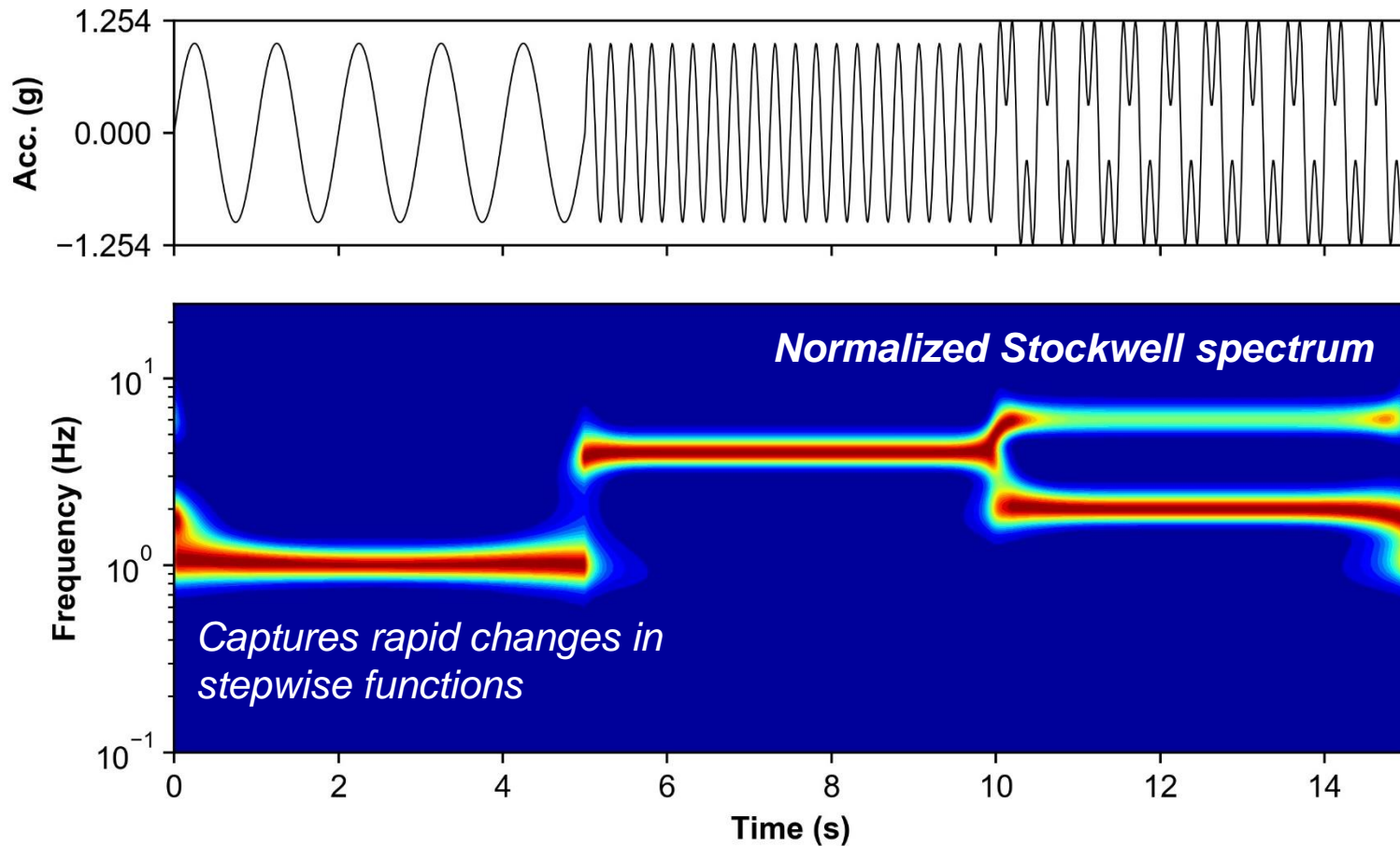
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Time-frequency analysis of ground motions



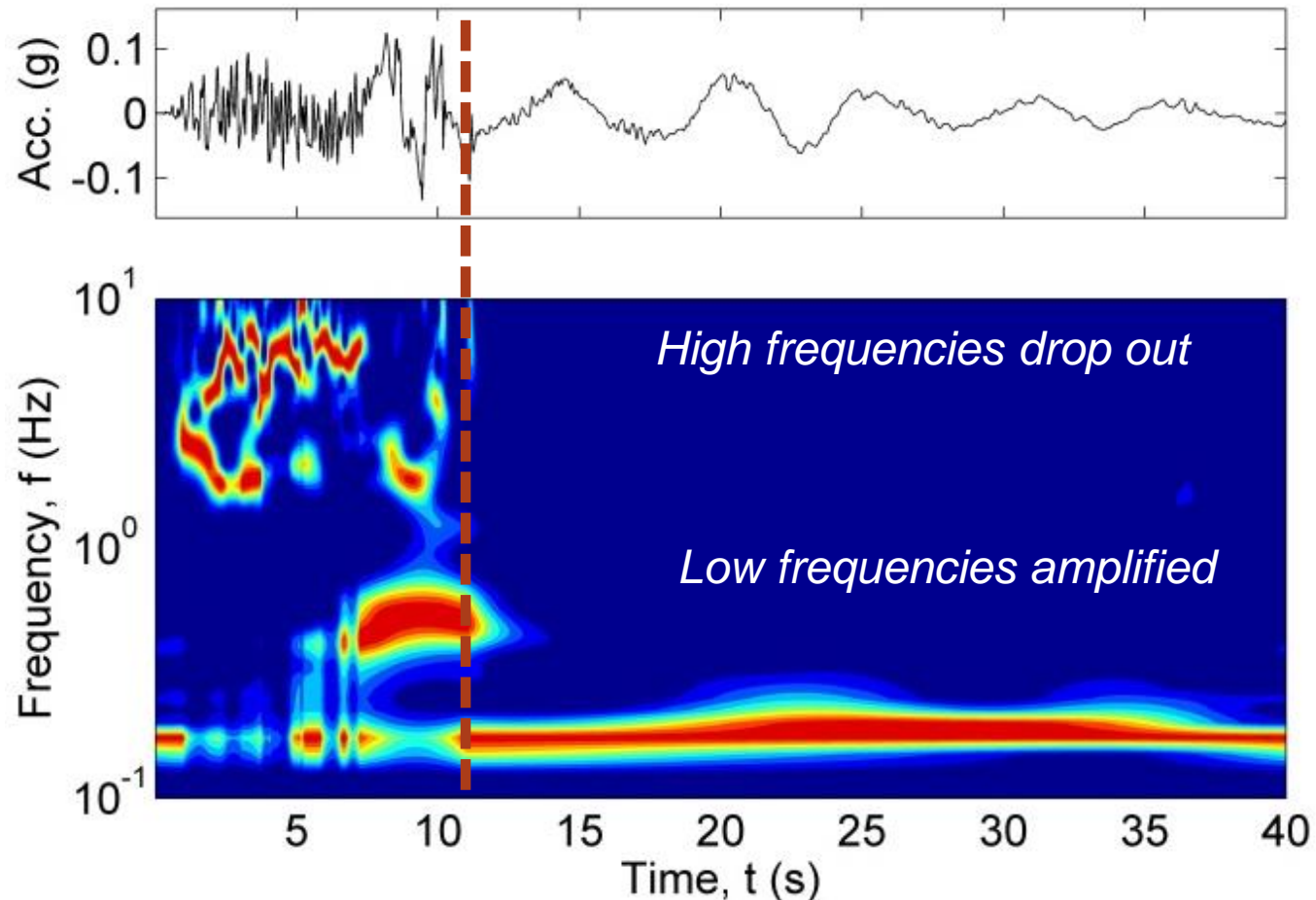
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Time-frequency analysis of ground motions



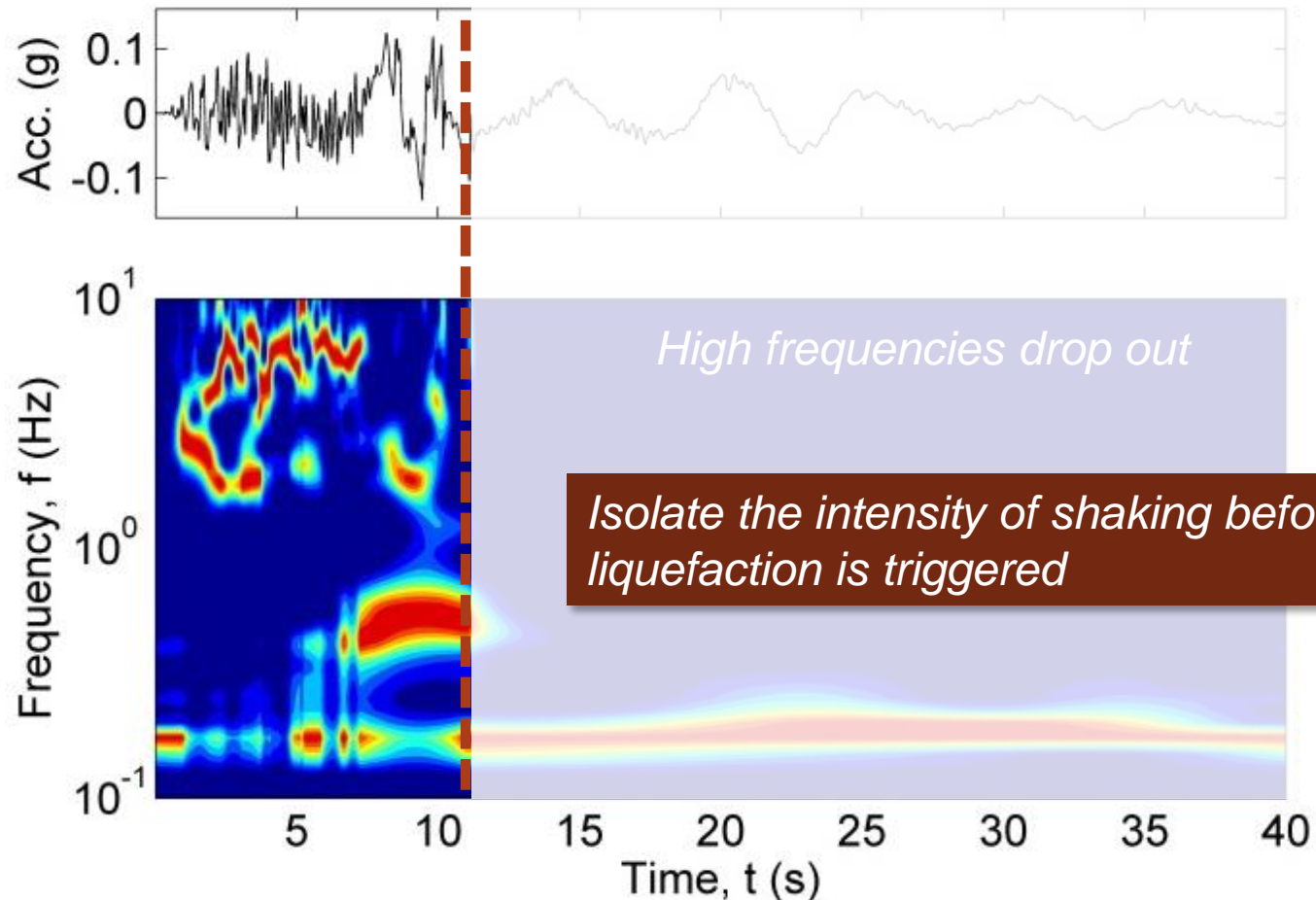
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Example 1 – Kawagishi-cho Apartment Buildings



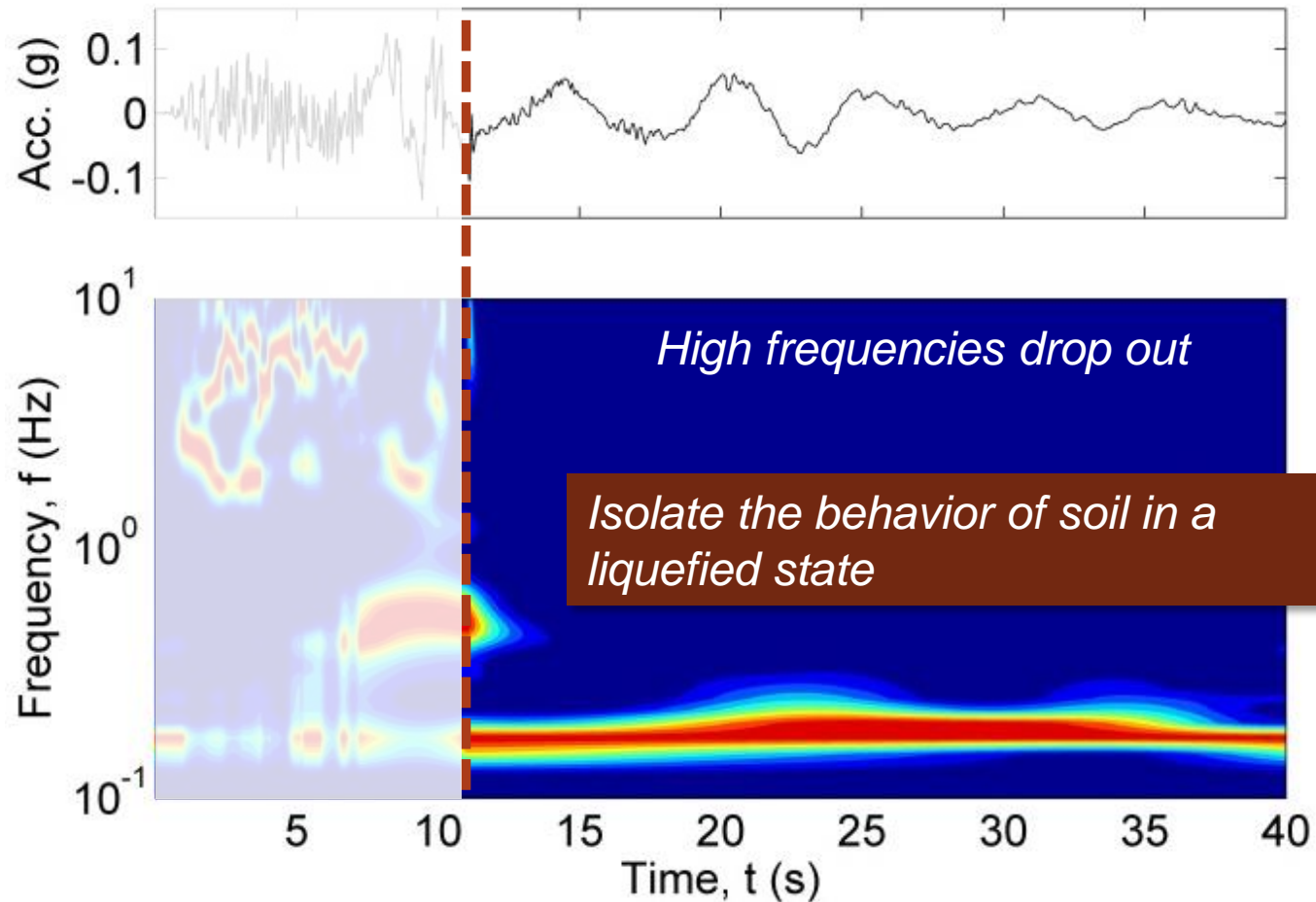
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Example 1 – Kawagishi-cho Apartment Buildings



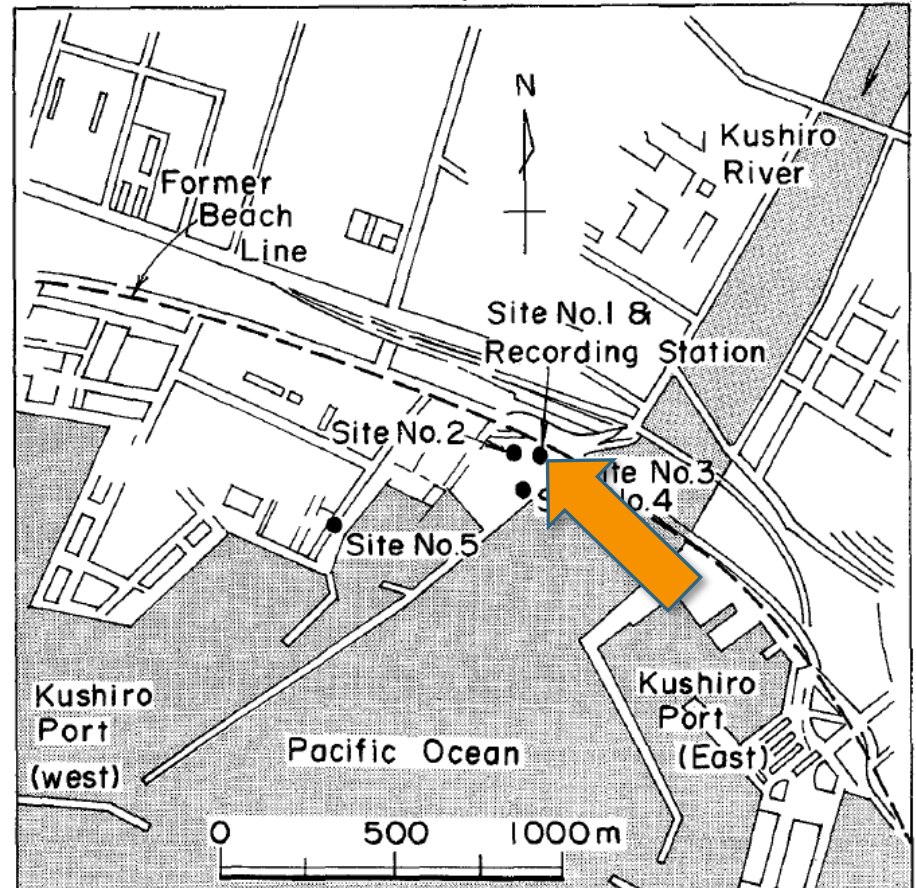
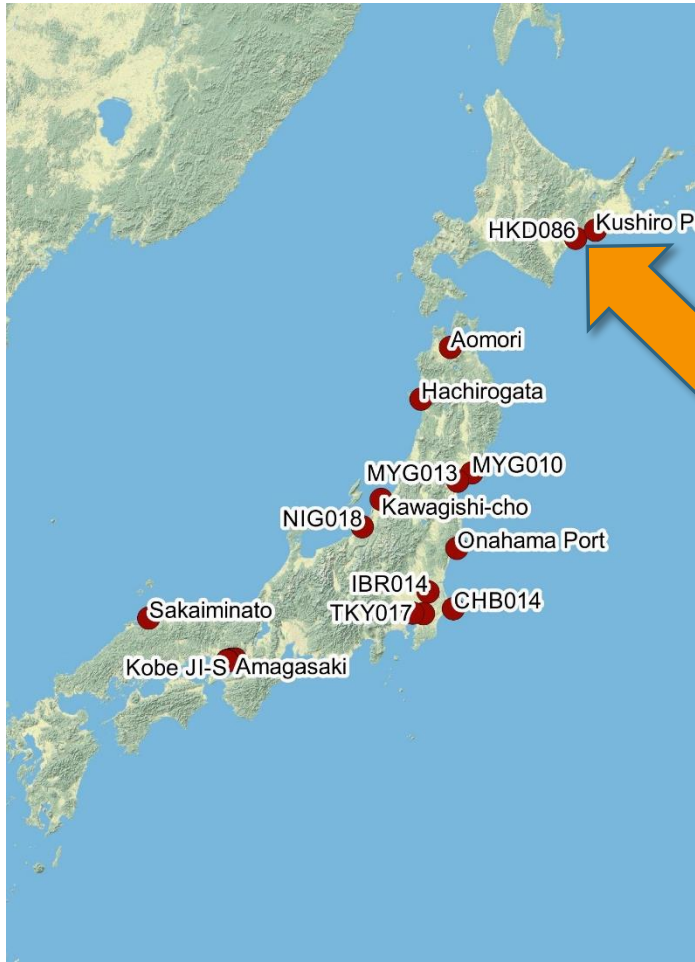
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Example 1 – Kawagishi-cho Apartment Buildings



Liquefaction case histories at strong motion recording stations

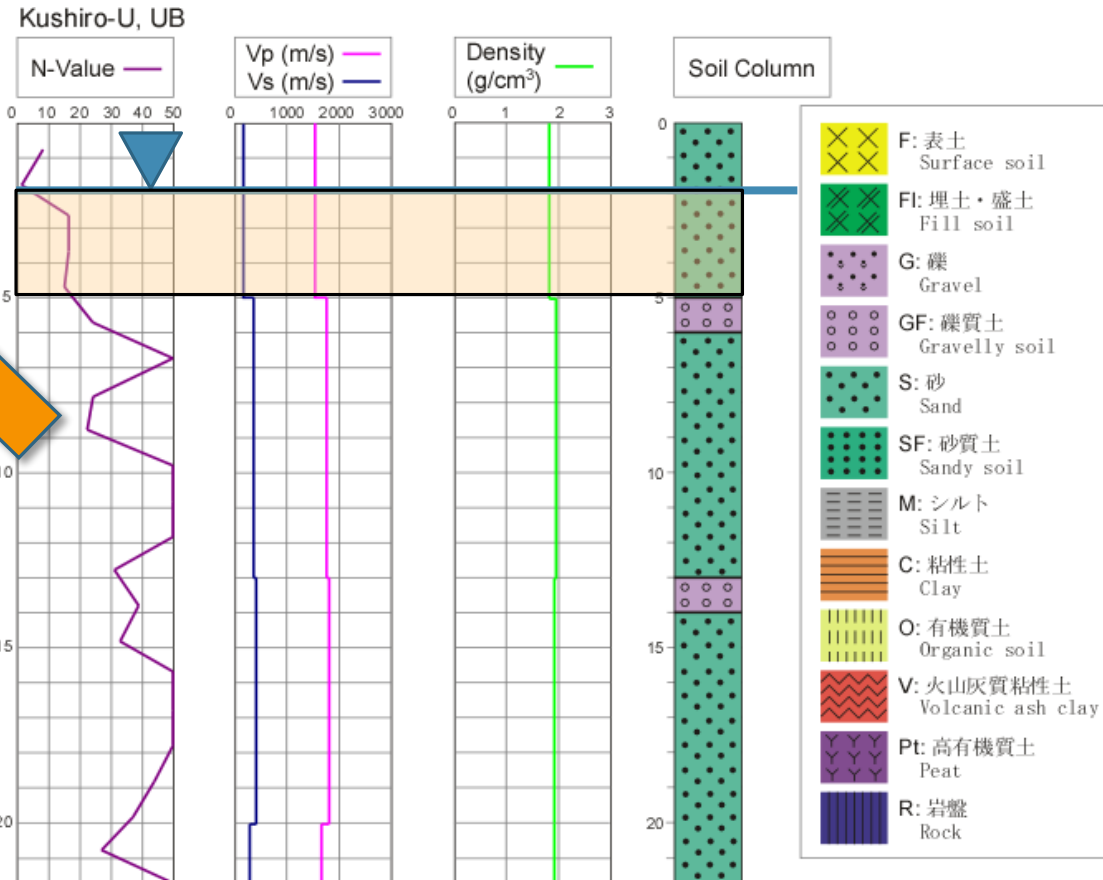
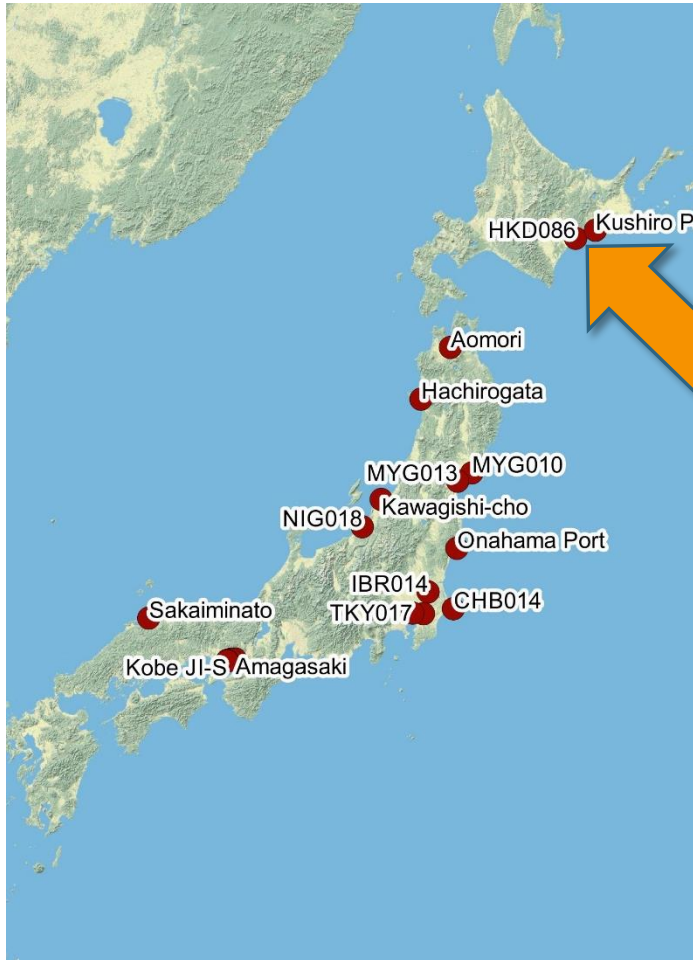
Example 2 - Kushiro Port



The recording station at Kushiro Port is on native sand just outside of filled area

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Example 2 - Kushiro Port

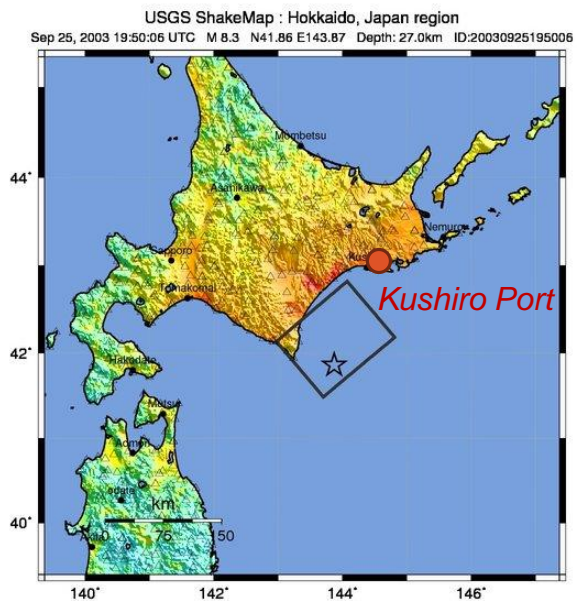
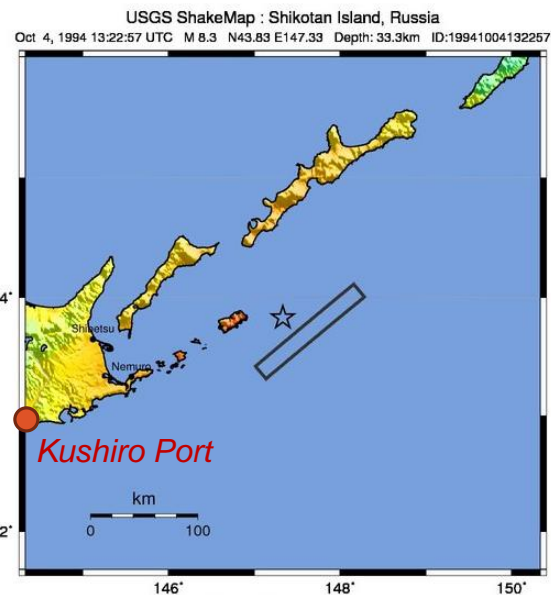
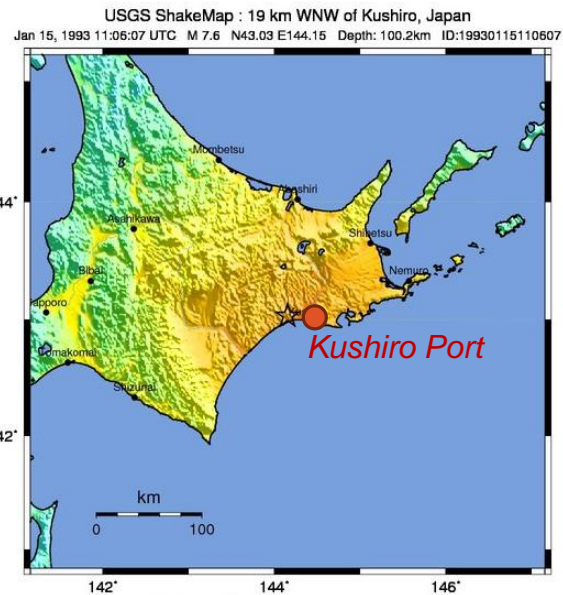


Downhole accelerograph at 77 m deep

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Example 2 - Kushiro Port

Three very strong earthquakes



1993 Kushiro-oki
 $M_w = 7.6$
PGA = 0.353 g

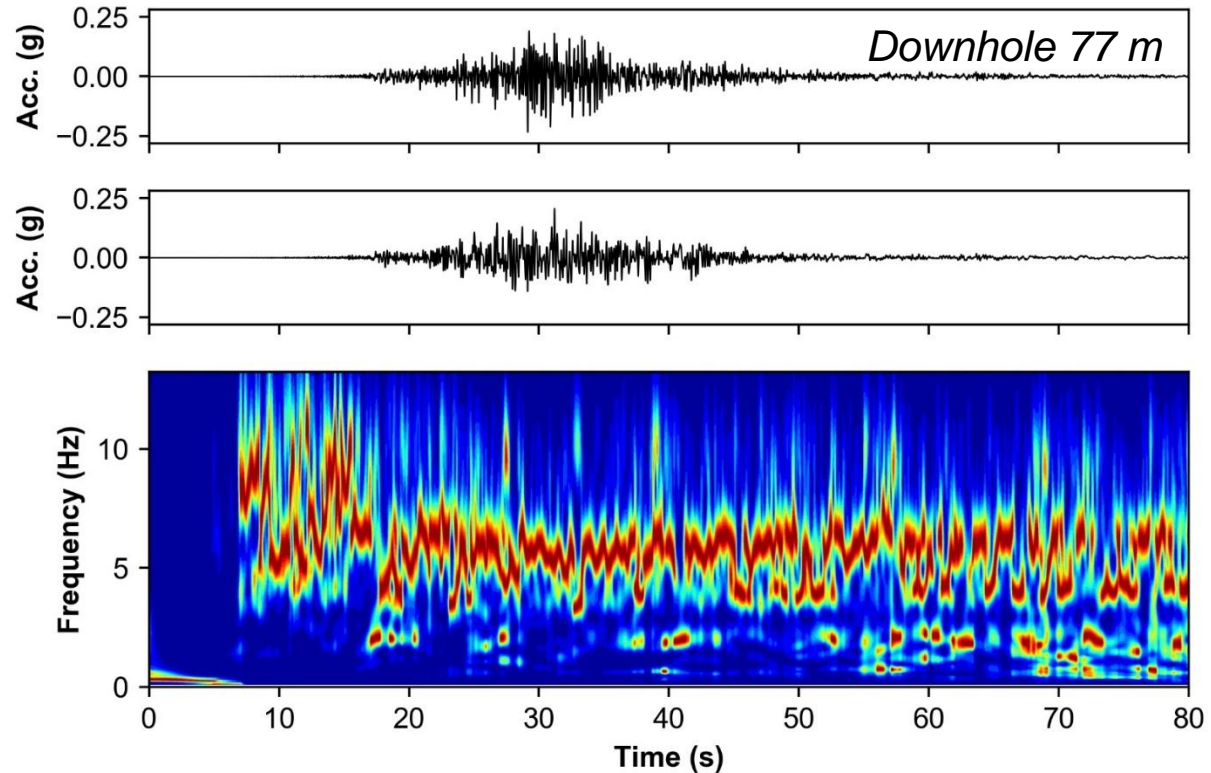
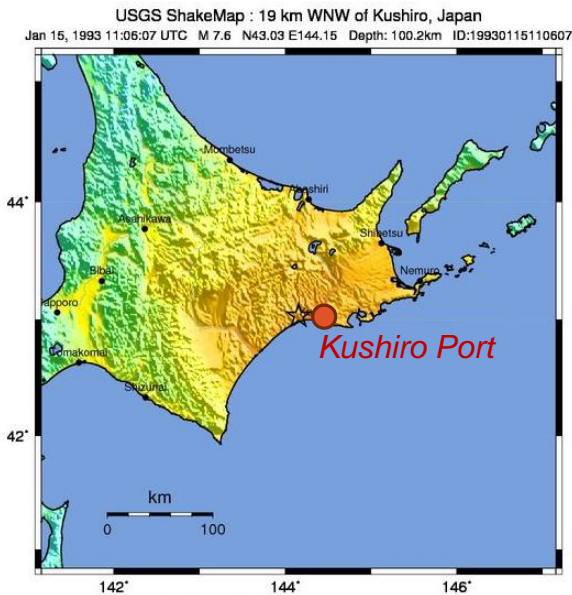
1994 Hokkaido Toho-oki
 $M_w = 8.3$
PGA = 0.225 g

2003 Tokachi-oki
 $M_w = 8.3$
PGA = 0.413 g

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Example 2 - Kushiro Port

1993 $M_w = 7.6$ Kushiro-Oki Earthquake. Downhole record

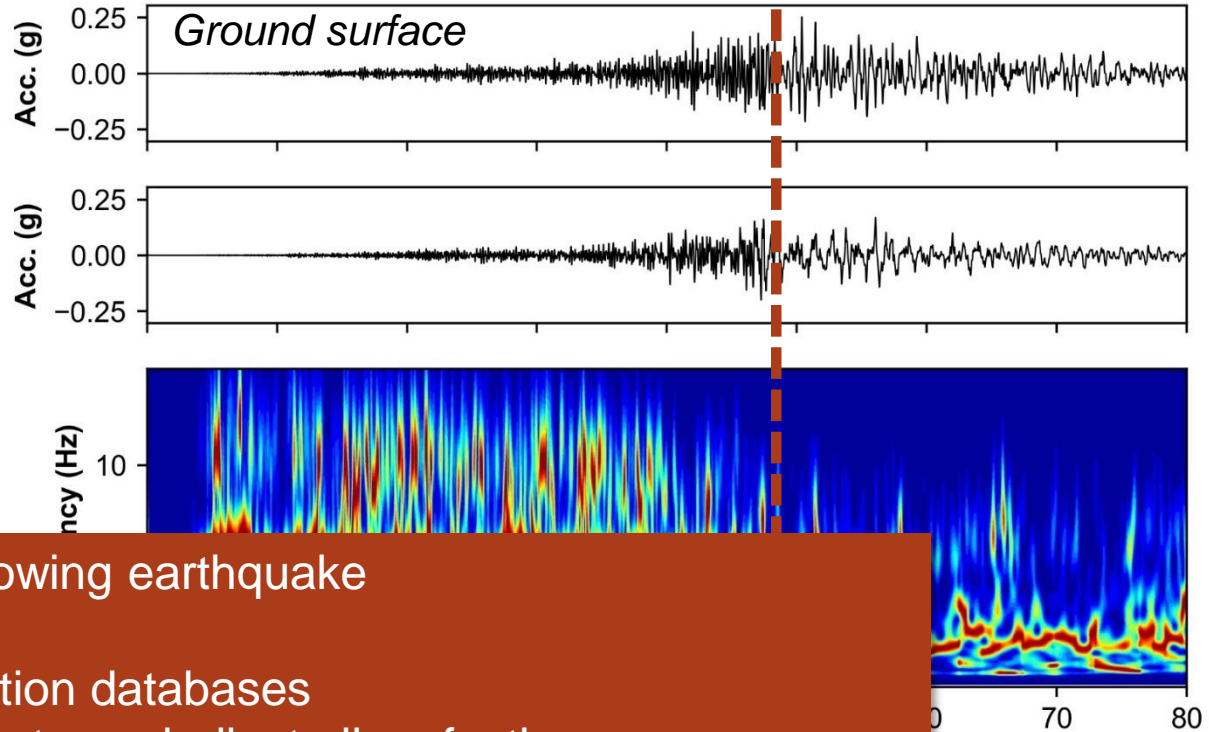


Modal frequency is consistently around 6 Hz

Liquefaction case histories at strong motion recording stations

Example 2 - Kushiro Port

1994 $M_w = 8.3$ Hokkaido Toho-Oki Earthquake



USGS ShakeMap : Shikotan Island, Russia
Oct 4, 1994 13:22:57 UTC M 8.3 N43.83 E147.33 Depth: 33.3km ID:19941004132257

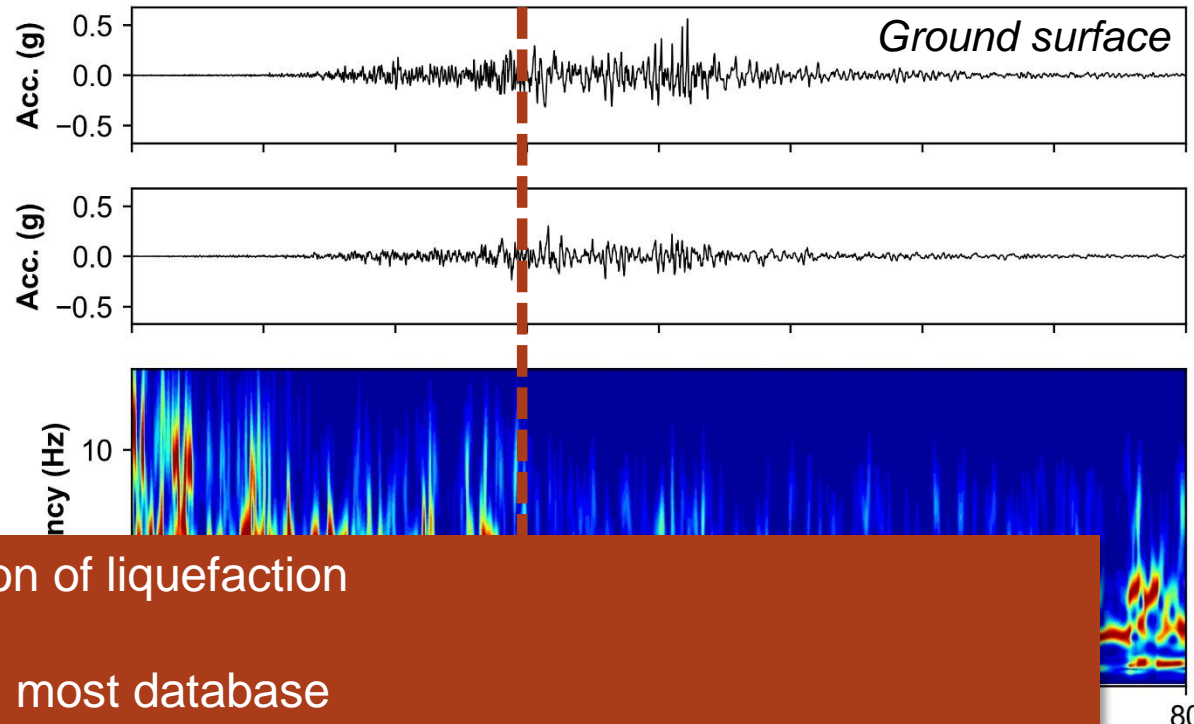
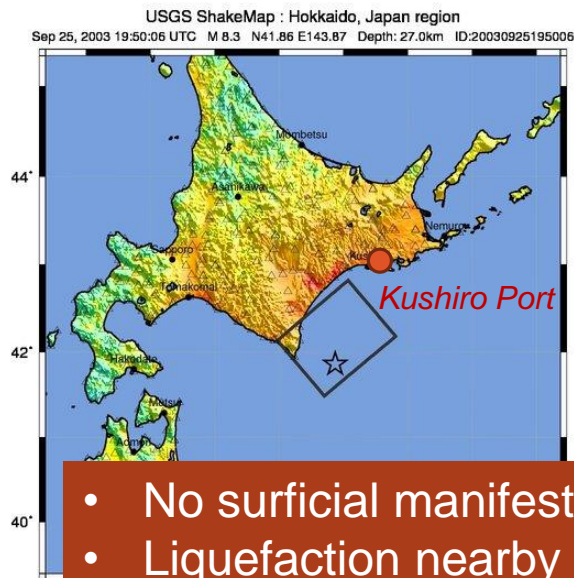


- No reconnaissance following earthquake
- Liquefaction nearby
- Not included in liquefaction databases
- Shift in frequency content may indicate liquefaction

Liquefaction case histories at strong motion recording stations

Example 2 - Kushiro Port

2003 $M_w = 8.3$ Tokachi-Oki Earthquake



- No surficial manifestation of liquefaction
- Liquefaction nearby
- Not in most liquefaction most database
- Shift in frequency content may indicate liquefaction

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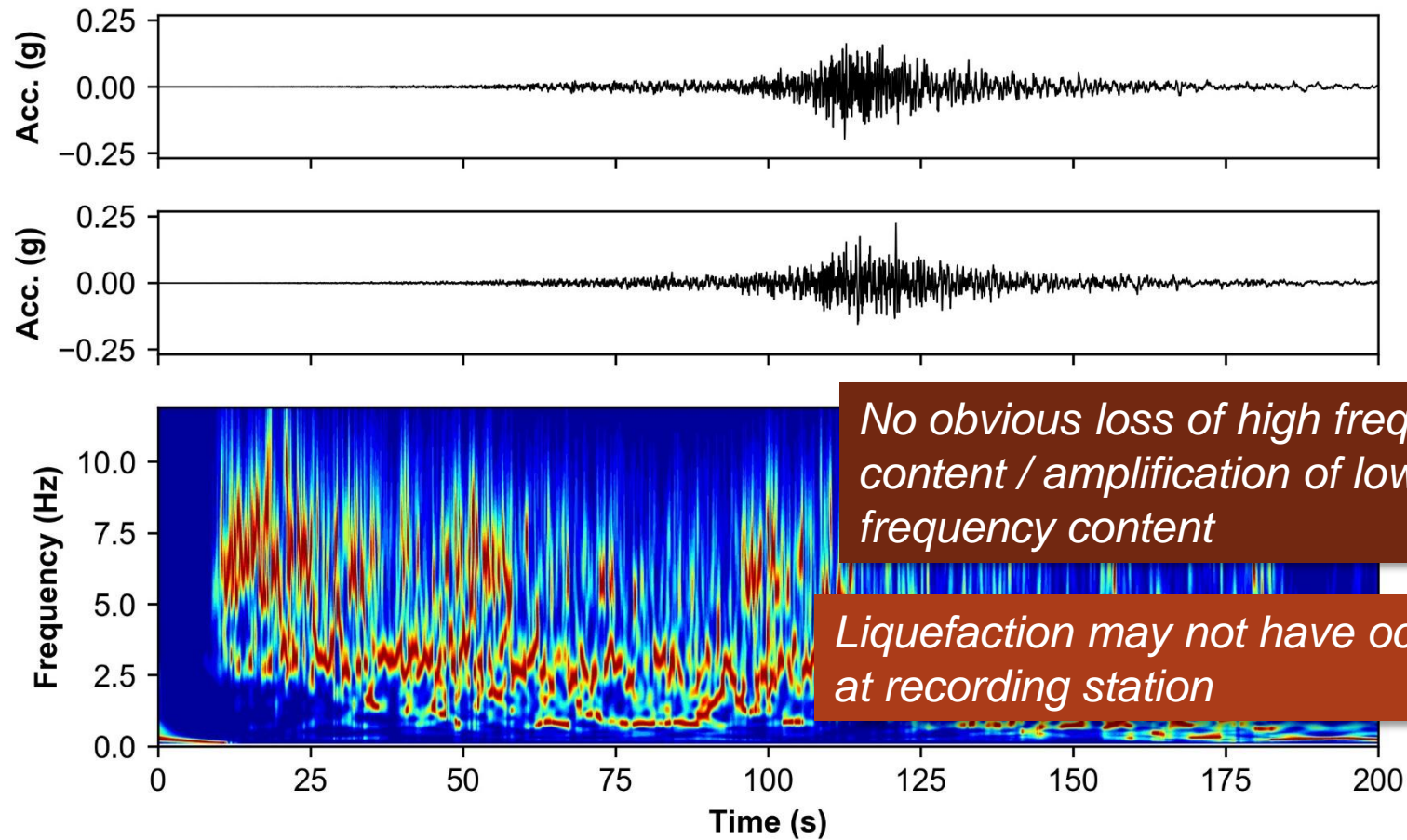
Example 3 - IBRH20

2011 $M_w = 9.1$ Tohoku earthquake



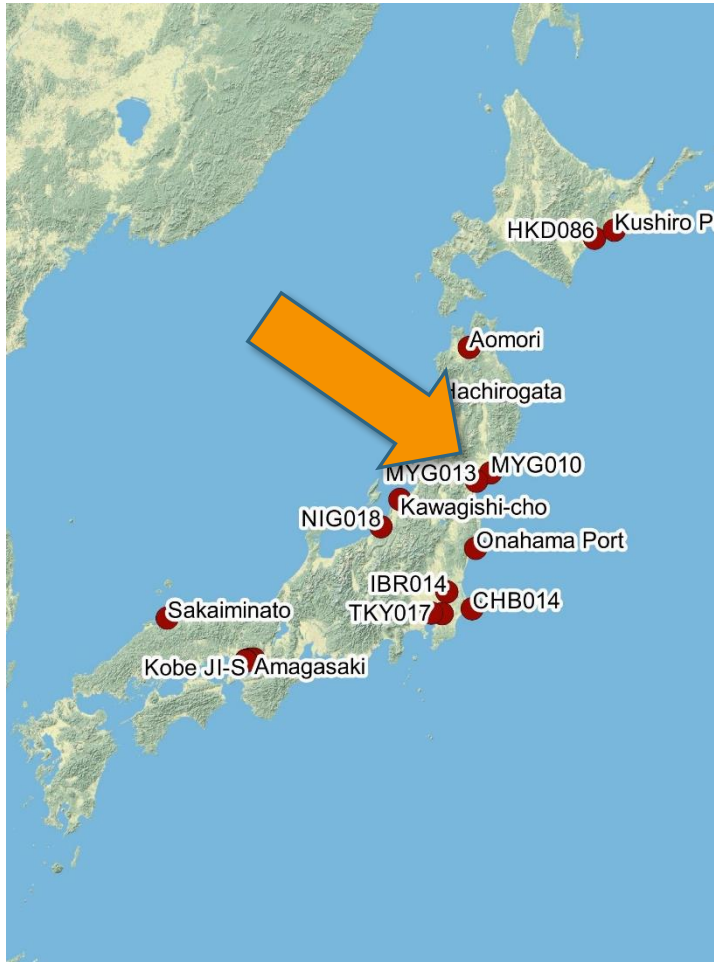
Liquefaction case histories at strong motion recording stations

Example 3 - IBRH20



Liquefaction case histories at strong motion recording stations

Example 4 - MYG013

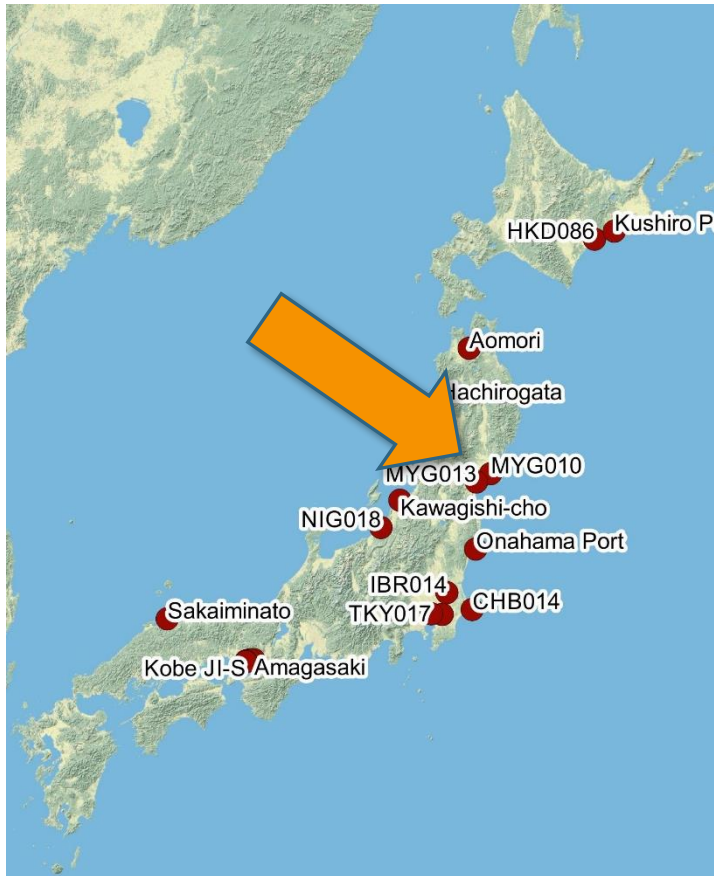


The MYG013 recording station is at a fire station in Sendai

Liquefaction case histories at strong motion recording stations

Example 4 - MYG013

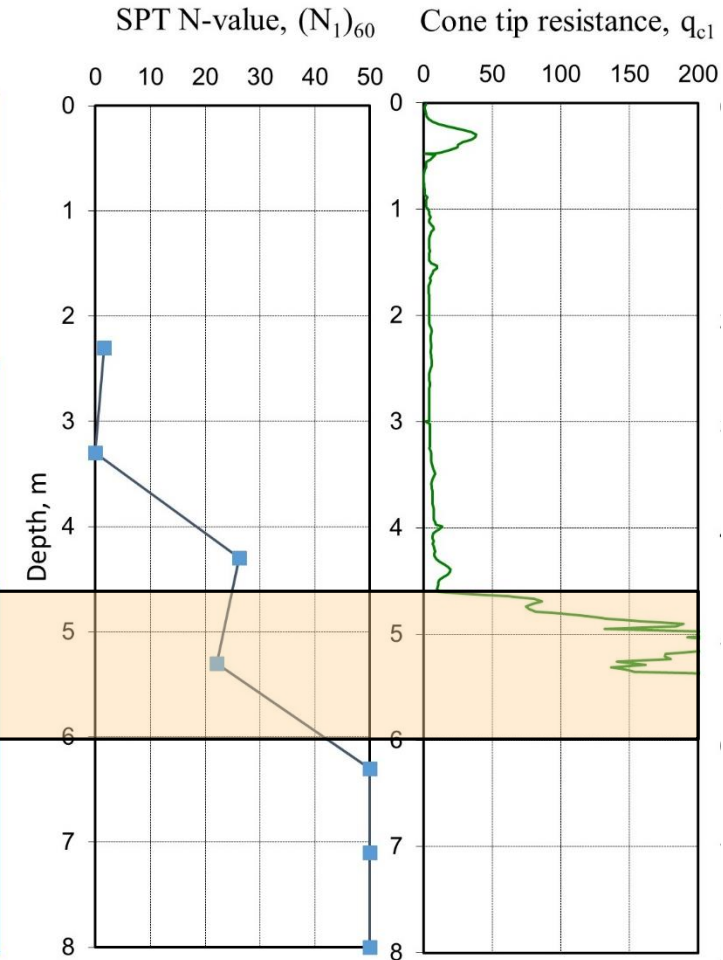
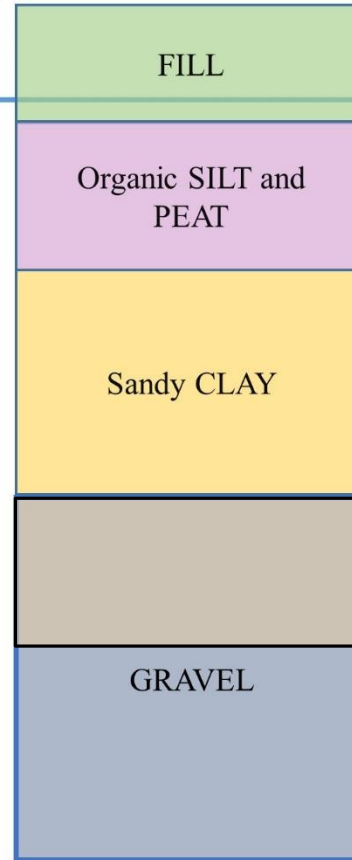
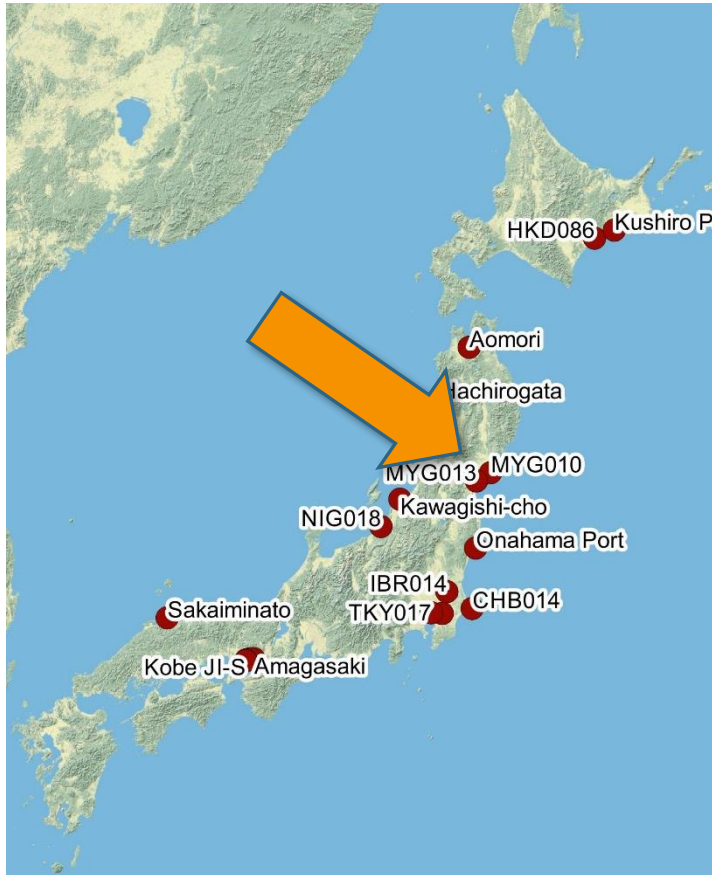
2011 $M_w = 9.1$ Tohoku earthquake



Liquefaction case histories at strong motion recording stations

Example 4 - MYG013

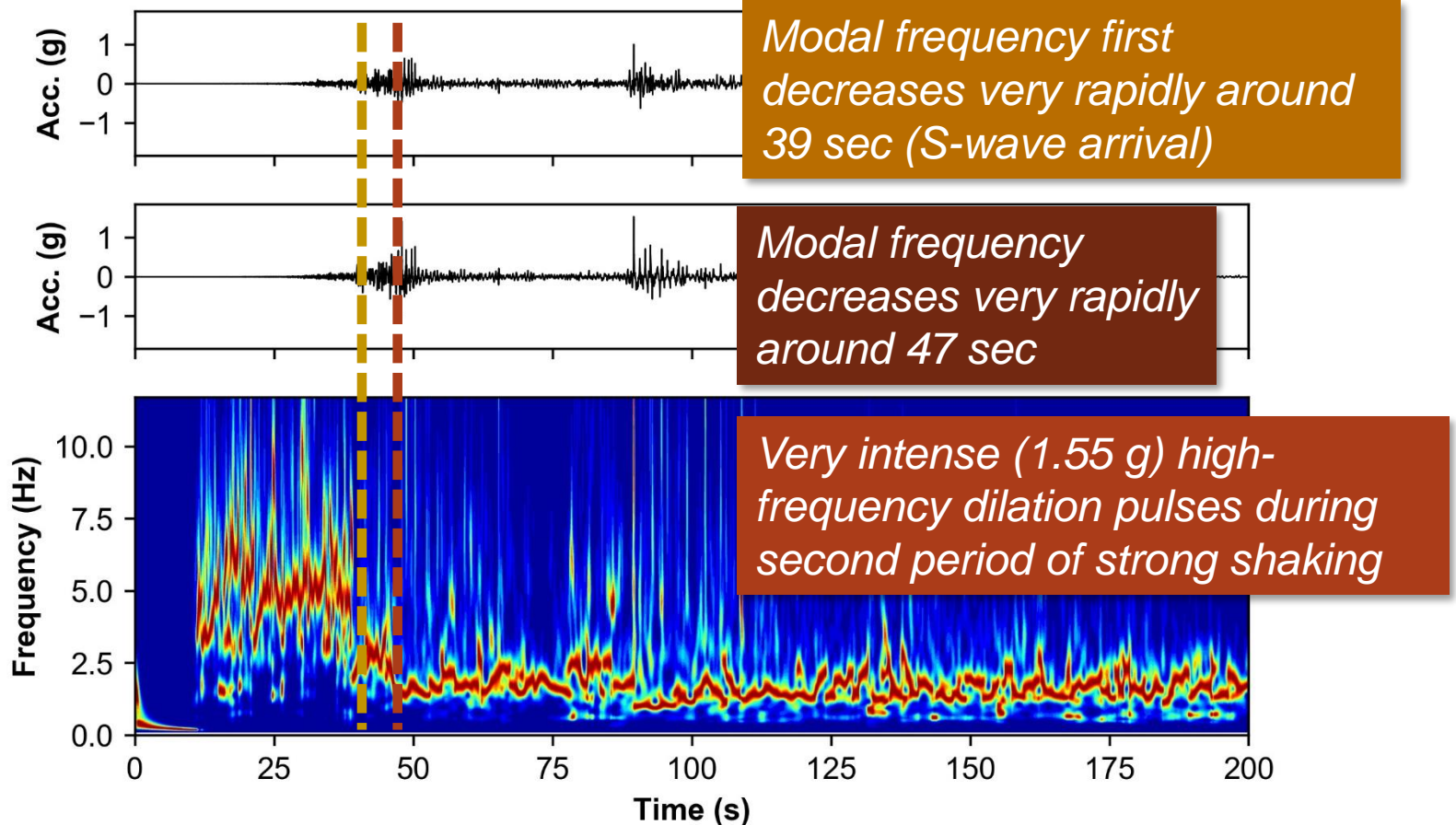
2011 $M_w = 9.1$ Tohoku earthquake



Liquefaction case histories at strong motion recording stations

Example 4 - MYG013

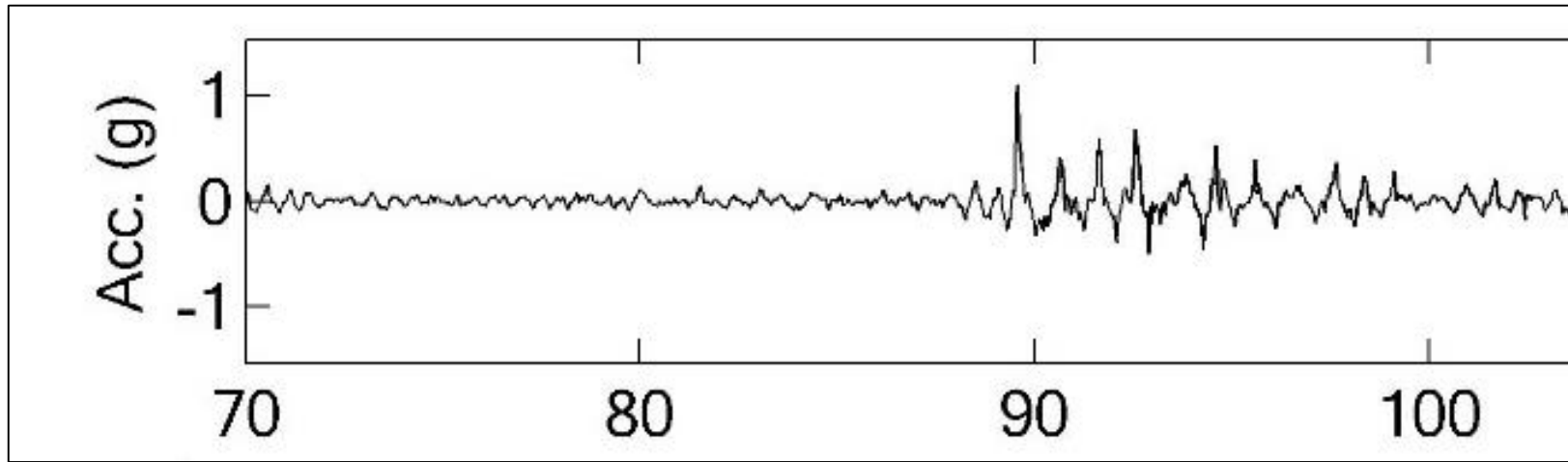
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Example 4 - MYG013

2011 $M_w = 9.1$ Tohoku earthquake

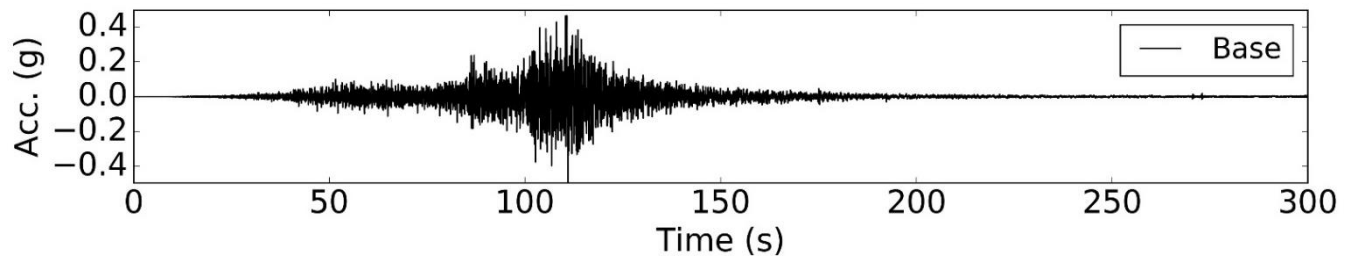
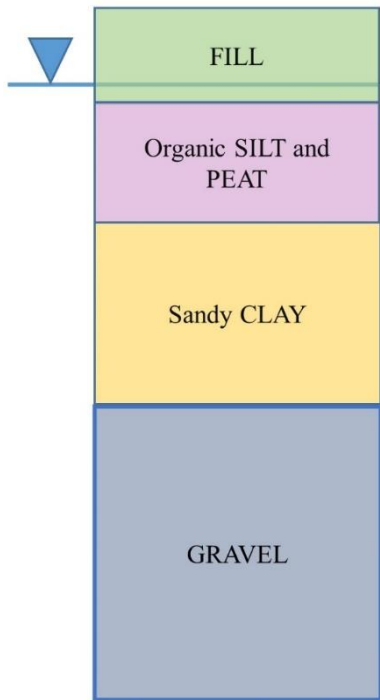


Why the very strong pulses?

Liquefaction case histories at strong motion recording stations

Example 4 - MYG013

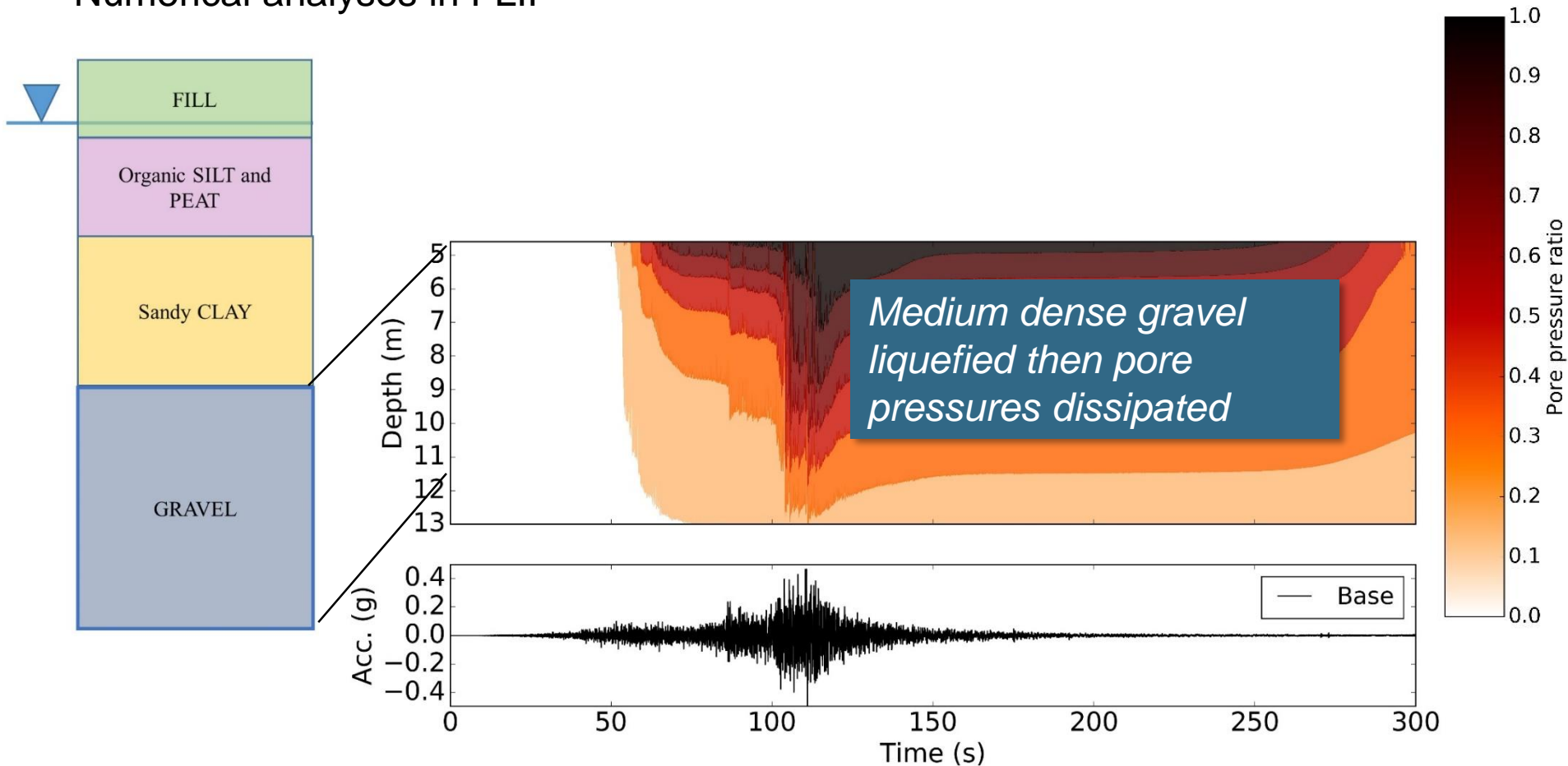
Numerical analyses in FLIP



Liquefaction case histories at strong motion recording stations

Example 4 - MYG013

Numerical analyses in FLIP

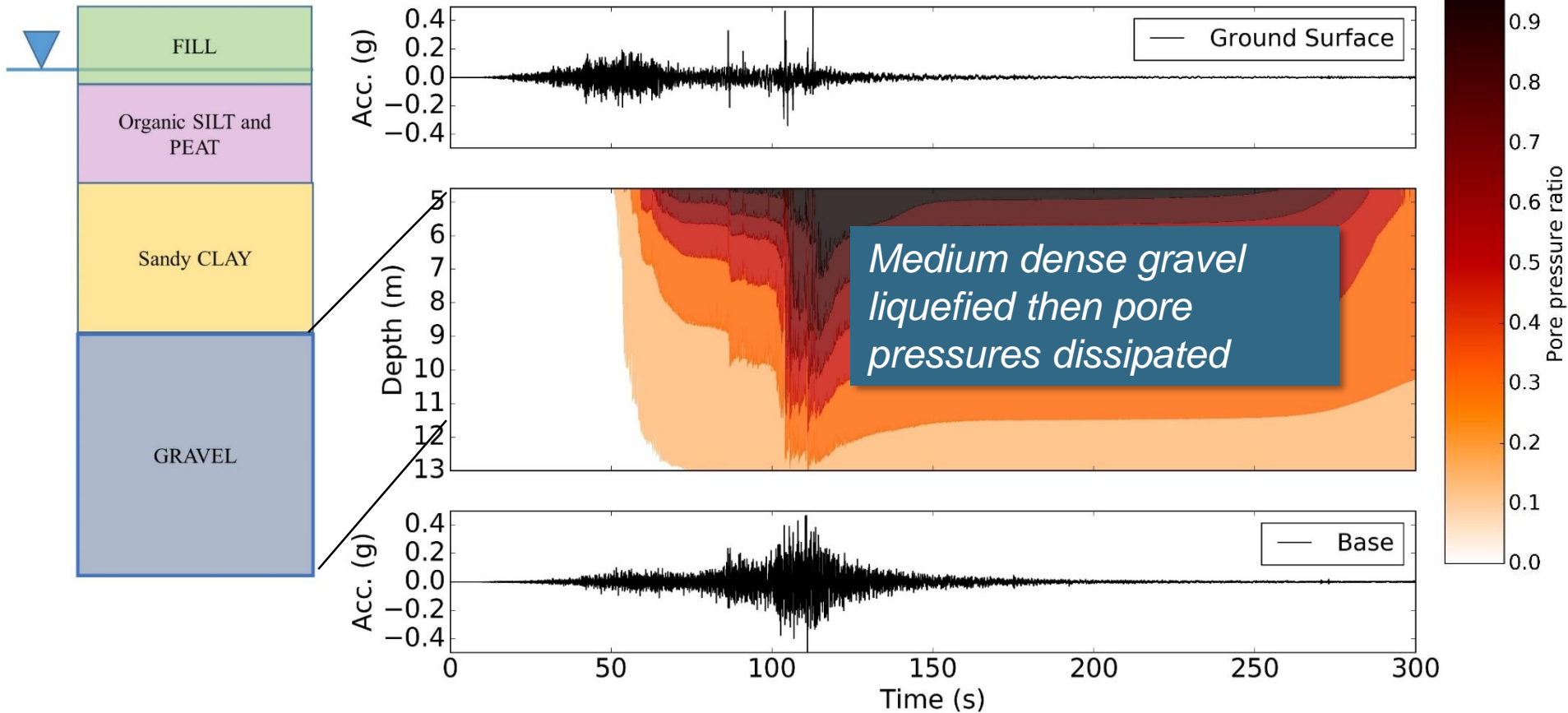


Liquefaction case histories at strong motion recording stations

Example 4 - MYG013

Numerical analyses in FLIP

Strong dilation pulses at the ground surface



Summary

Recorded ground motions affected by liquefiable soils have unique value

- Isolate the soil behavior before and after liquefaction is triggered
 - Kawagishi-cho
- Identify liquefaction without requiring surficial manifestation
 - Kushiro Port
- Clarify questionable case histories
 - IBRH20
- Understand behavior of liquefiable soil
 - MYG013

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More case histories to investigate

At least 12 more well-known

