

LIQUEFACTION-INDUCED DAMAGE CAUSED BY M 9.0 EAST JAPAN MEGA EARTHQUAKE ON MARCH 11, 2011

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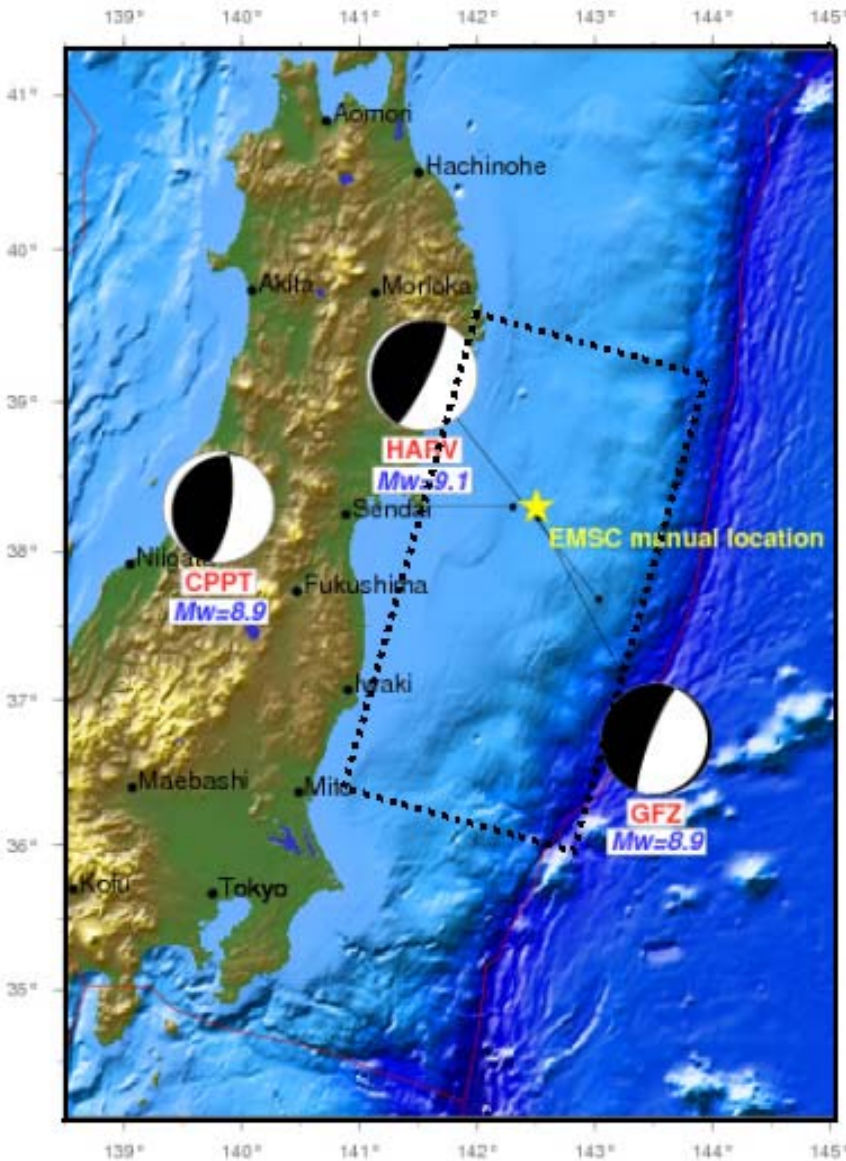
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Investigation Routes

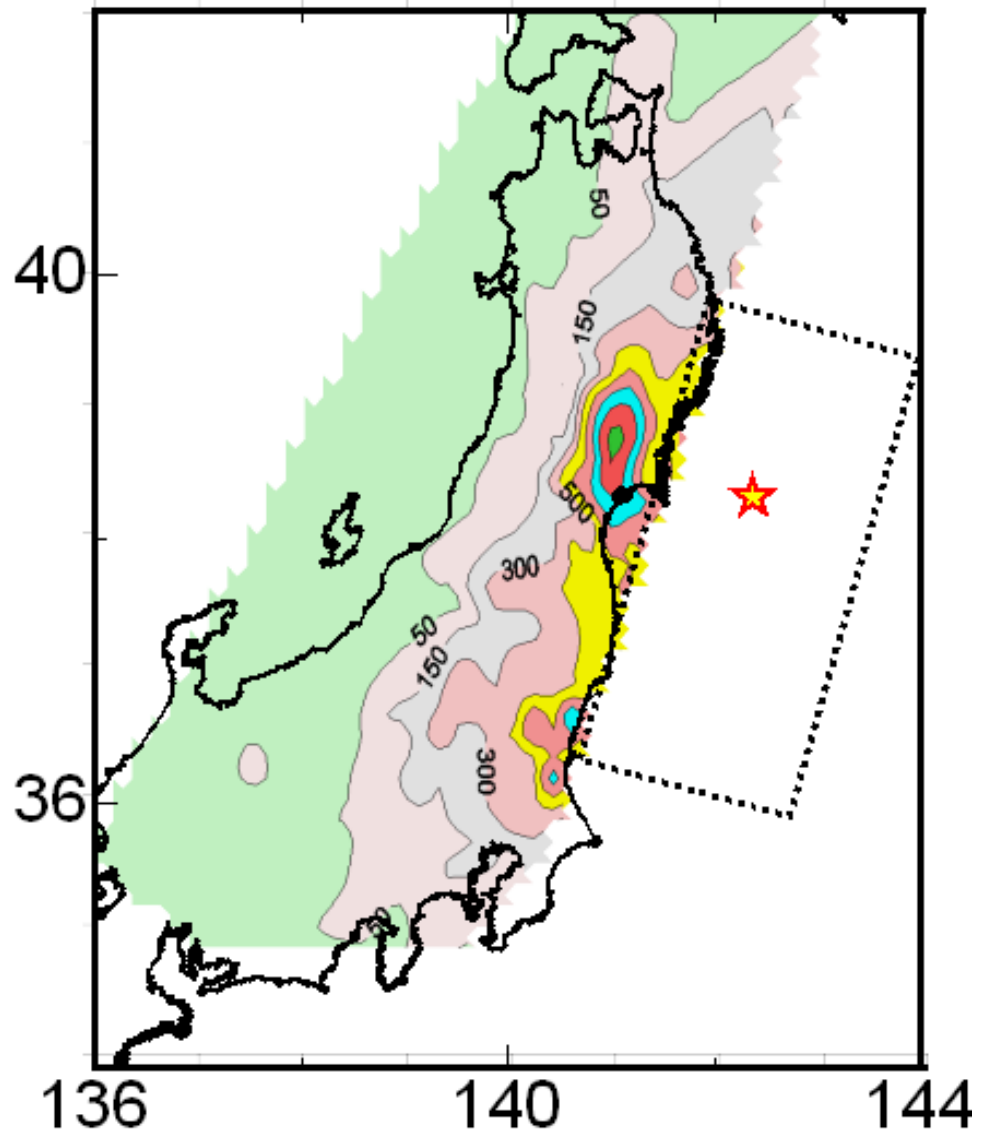


Modified from Google Map

Focal Mechanism and Strong Ground Motions



Focal Mechanism



Maximum ground acceleration

Ground Liquefaction and its effects

Ground liquefaction and lateral spreading occurred wherever soils prone to liquefaction exist. The ground liquefaction caused heavy damage to lifeline facilities and structures particularly in reclaimed areas.

I) Effects of ground liquefaction on ground surface

- a) Ondulation of ground surface
- b) Non-uniform settlement
- c) Lateral spreading

II) Effects of ground liquefaction on lifelines and structures

- a) Uplift of light structures
- b) Settlement of heavy structures
- c) Stretching or compression of linear structures due to lateral spreading (pipes etc.)

Investigated liquefaction locations in Tokyo Bay Area

- 1) Shin-Kiba (extensive liquefaction)
- 2) Shin-Urayasu (extensive liquefaction)
- 3) Maihama (Disneyland) (various extents of liquefaction)
- 4) Daiba (very limited liquefaction)



Shin-Kiba



Shin-Urayasu-1



Shin-Urayasu-2



Shin-Urayasu-3



Shin-Urayasu-4



Shin-Urayasu-5



Shin-Urayasu-6



Maihama (Disneyland-Disneysea)-1



Maihama (Disneyland-Disneysea)-2



Maihama (Disneyland-Disneysea)-3



Maihama (Disneyland-Disneysea)-4



Liquefaction-induced damage in Ibaraki Prefecture

The authors have particularly investigated ground liquefaction and liquefaction-induced damage in the Northern Ibaraki Prefecture between Oarai and Hitachi. However, it is reported that extensive ground liquefaction occurred in Kashima, Hokota, Itako along Tone River in the Southern Ibaraki.

Liquefaction in Northern Ibaraki



Liquefaction-induced failure of sand dune in Tokai-mura



Liquefaction-induced damage in Tokai-mura



Liquefaction-induced damage in Ajigaura



Damaged Nakaminato Thermal Power Plant due to heavy liquefaction

**Tilted
Chimney**



Thermal Power Plant



**Uplifted
conveyor
underpass**



Failed Quay of Hitachi Port



Failed roadway in Hitachi due to lateral spreading



Liquefaction-induced damage in Fukushima Prefecture

Liquefaction and its effects were directly observed by the authors in Koriyama and Iwaki. Besides the observations by the authors, there are reports that ground liquefaction in Sukawa and Shirakawa (H. Tano, Personal Communication)

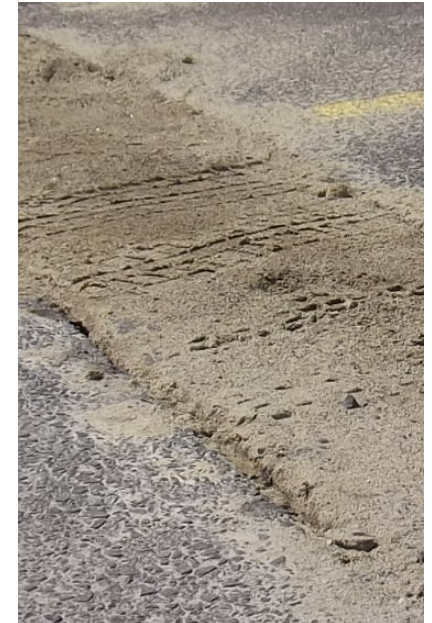


Note the settlement of ground around the buildings

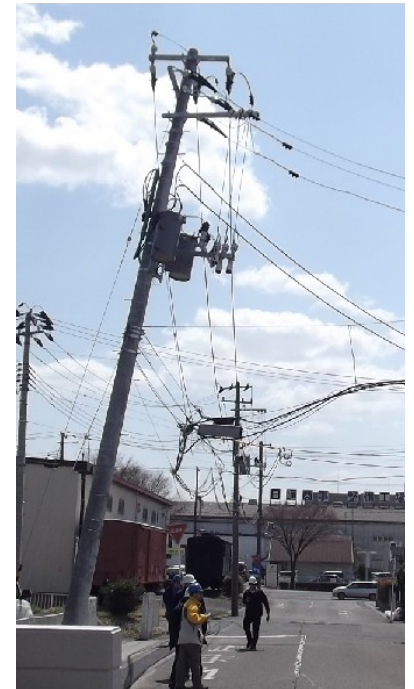
Liquefaction-induced damage in Miyagi Prefecture



**Sand
boils in
Sendai
City**



Effects of ground liquefaction in Sendai City-1



Effects of ground liquefaction in Sendai City-2



Tilted buildings due to pile damage in liquefied ground

Ground liquefaction effects in other places in Miyagi Prefecture

Tomiya



Kesennuma



Natori



Onagawa



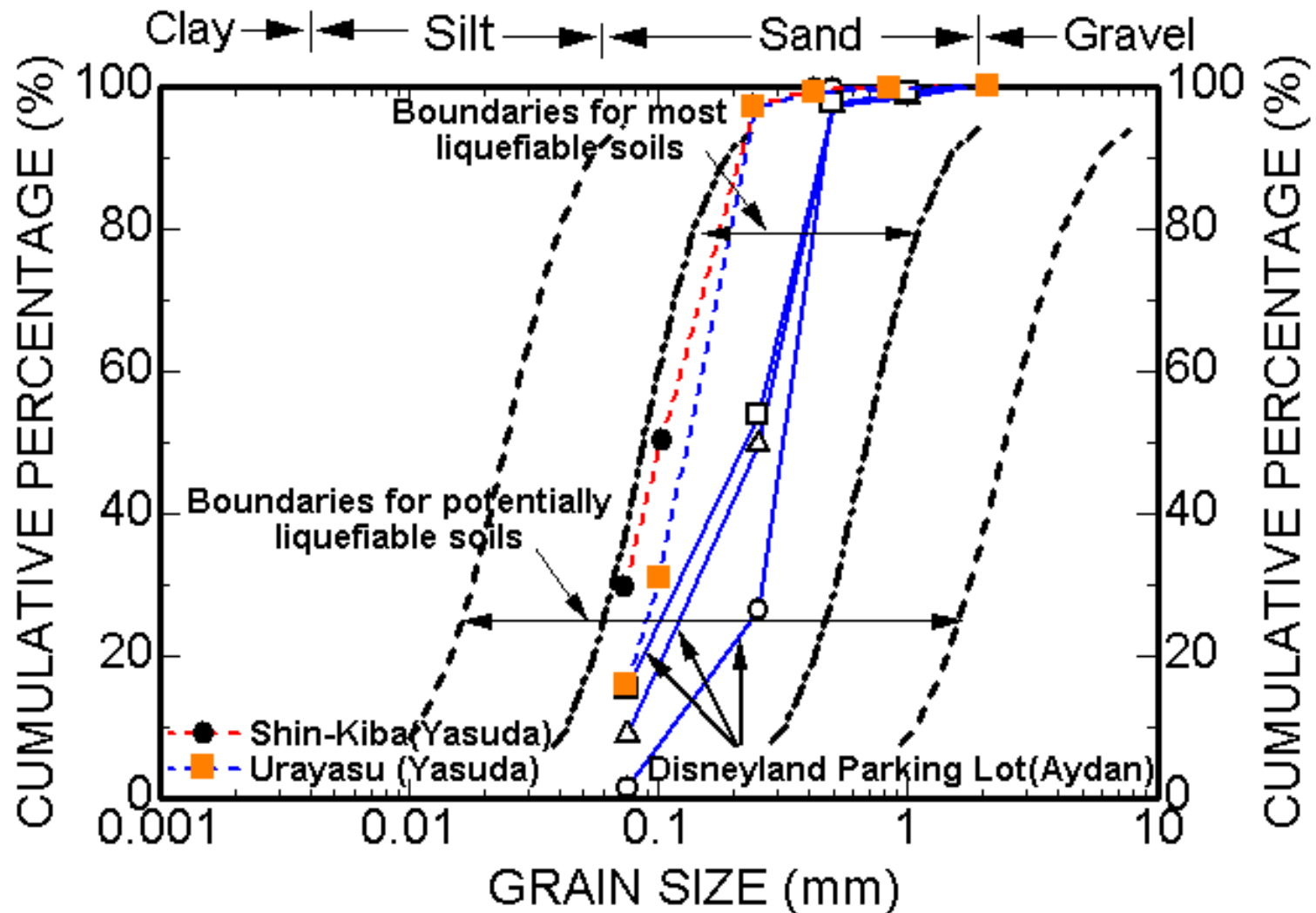
Liquefaction-induced damage in Iwate Prefecture



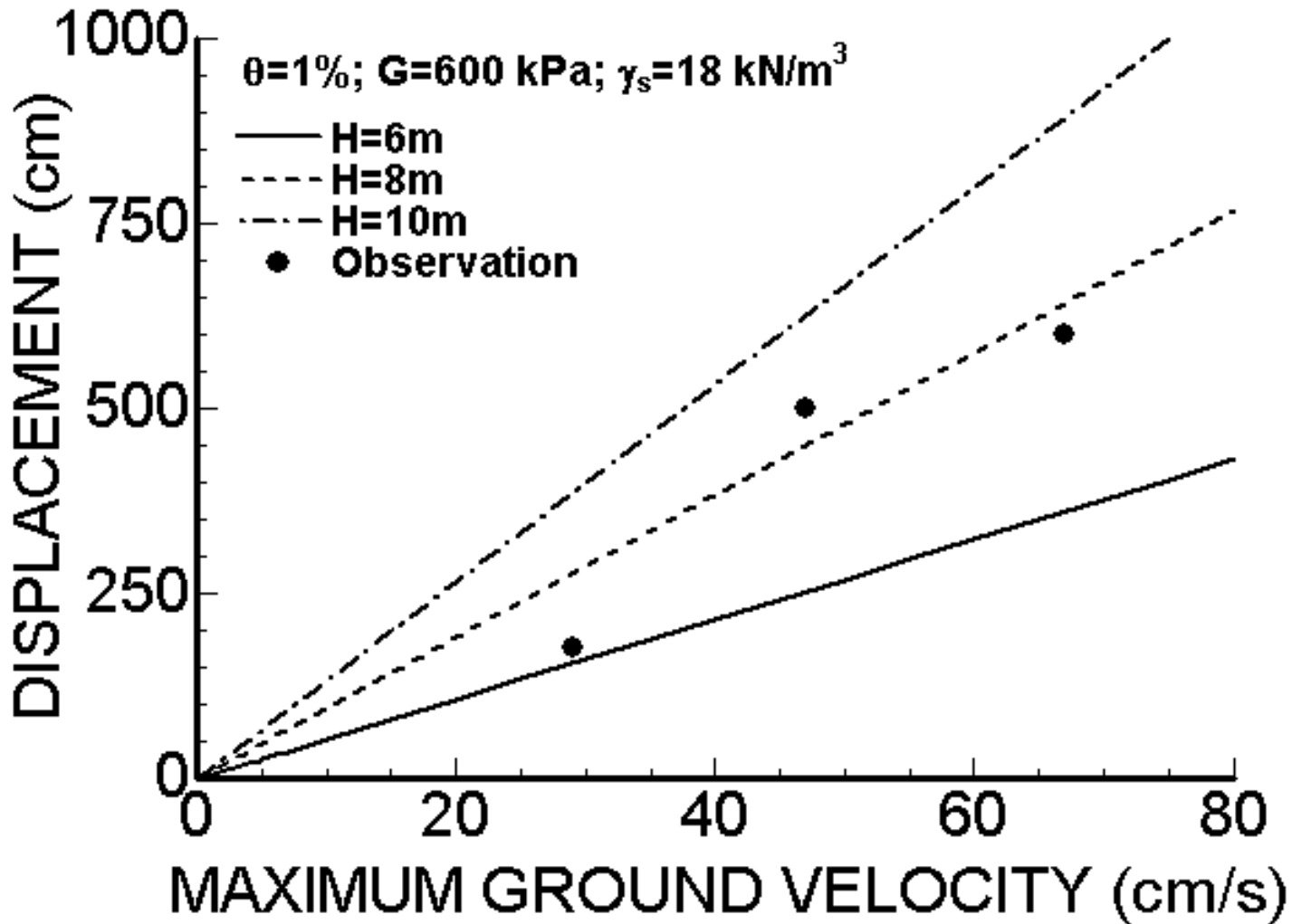
Comparison of observations with empirical relations

- 1) Grain-size distribution approach**
- 2) Empirical V_{\max} -Displacement approach**
- 3) Magnitude-Limit Distance Approach**

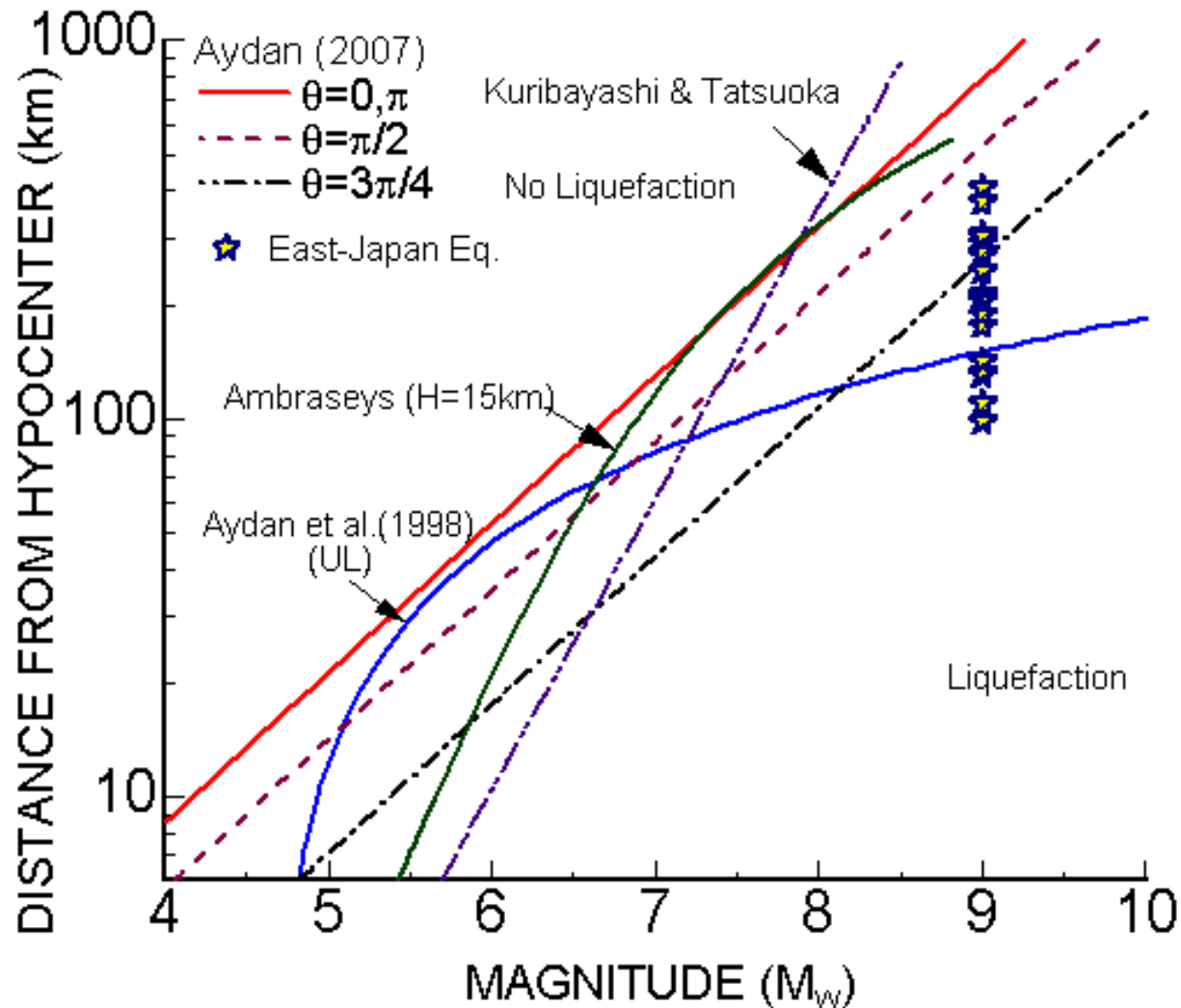
Comparison of grain-size distribution of boiled sand with empirical bounds



Comparison of Aydan's empirical relation between maximum ground velocity and lateral spreading displacement



Comparison of Empirical relation between earthquake magnitude and liquefaction limit distances



Misinterpretations of sand-boils in abandoned lignite mine areas

Some sinkholes occurred in abandoned lignite mine areas due to sloshing of ground water in abandoned mines and subsequent collapse of the roof layers. As sandy material together with fragments of rocks and lignite appears, it is sometimes mis-interpreted as ground liquefaction.



Ejection of sandy material from a sinkhole in Ohira