Extracting the Deep Marine Record of Earthquakes from the Japan Trench

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Objectives

- Document what is known about the 2011 Tohoku event deposit to characterize earthquake event deposits
- This will allow to go back in time and better define recurrence intervals, which segments of the trench have ruptured vs those that haven't
- What can we learn from the lithology that will help characterize the history of earthquakes in Japan and in other settings?
- Generally turbidites are energetic and erosive
- We are trying to document the processes by which homogenites are deposited and their link to the 2011 Tohoku earthquake event.
    - -homogenites are thick, lithologically homogeneous deposits that lack bioturbation and are acoustically transparent.(McHugh et al.,2020)

Methods

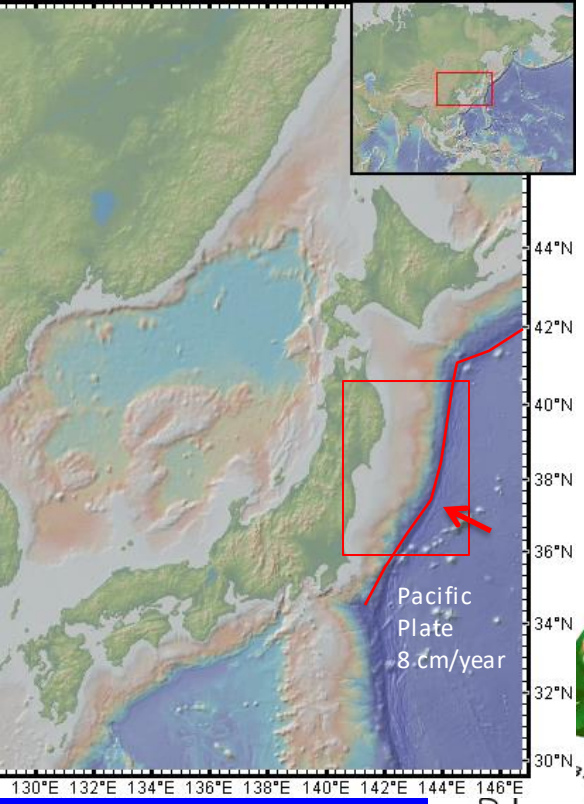
- Previously collected Parasound subbottom profiles and bathymetry
- The 2016 R/V Sonne 251 collected 10 m long sediment cores
  - Core GeoB21818, 21815,21810, 21817, 21812,
  - 21821,21809,21823 and 21804.
  - Descriptions and photos
  - Grain size variability and magnetic susceptibility
  - Interpreted the results within the framework of previous ages obtained from short-lived radioisotopes (McHugh et al., 2016)

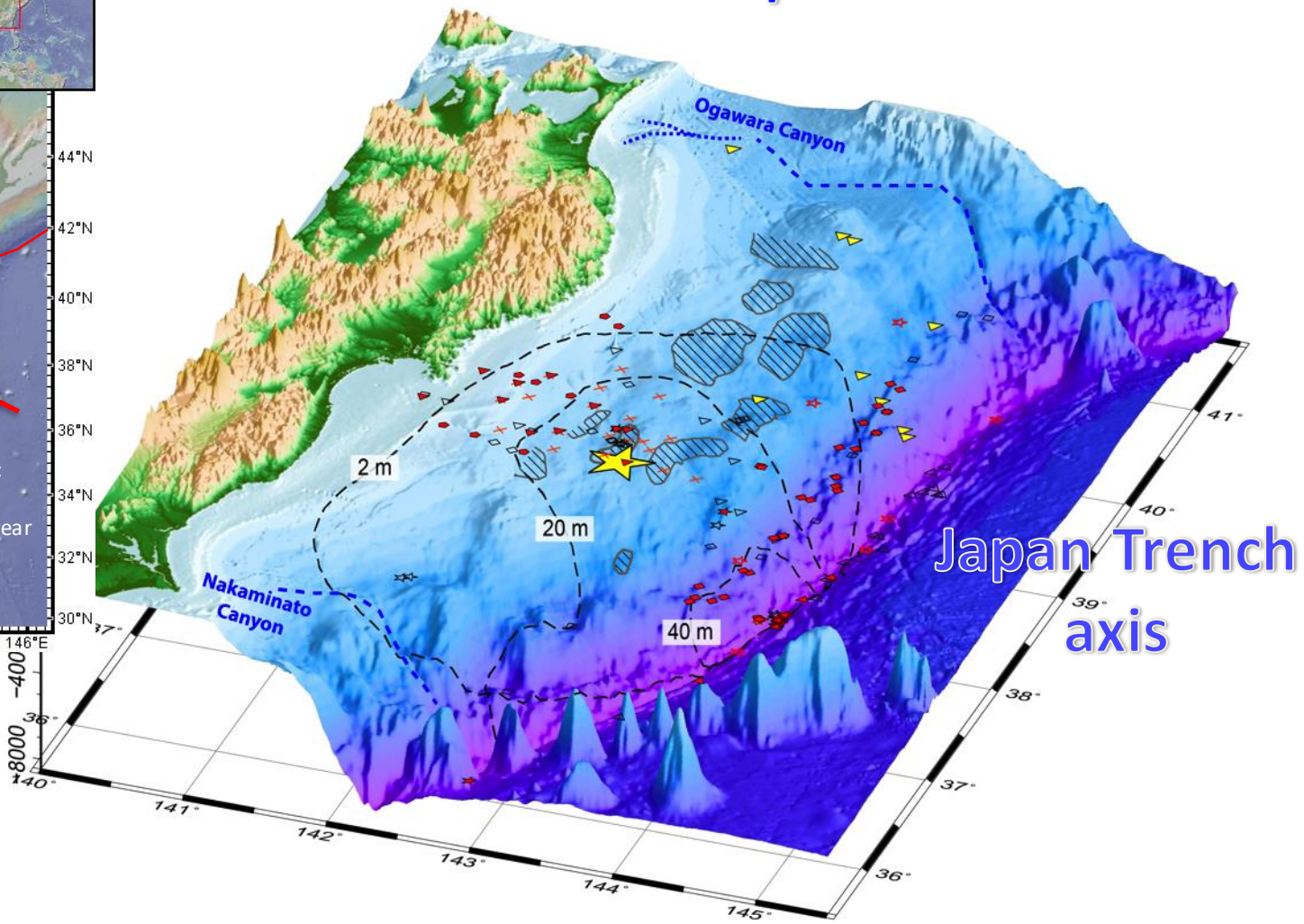
Background

- Tectonics, plates and rates:

  -The Pacific plate subducts beneath the Okhotsk plate at 8.2 cm/year.
- The catastrophic Tohoku earthquake and tsunami M 9.0 event occurred on March 11, 2011.
- The rupture slip increased up-dip and reached the Japan Trench.
- It caused for the overlying plate to move 50 m horizontally and about 7 m vertically in a few seconds.
- - The megathrust rupture triggered large-scale slumping on the outer trench slope near the area of maximum slip.

The 2011 Tohoku earthquake and tsunami





Study area,
Star marks the epicenter
Contours show zones of equal deformation
Trench depths 4,000-8,000 m
Symbols show existing cores

Legend

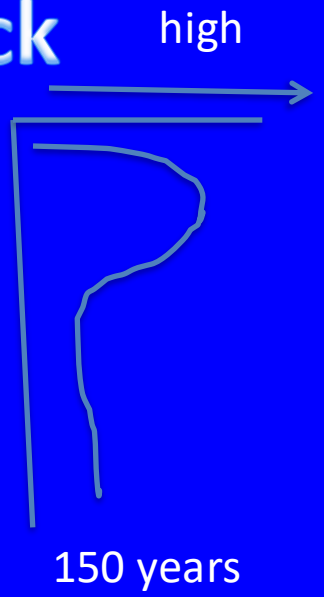
- ☆ JMA's Epicenter of The 2011 Tohoku-oki EQ
- Coseismic slip due to the 2011 EQ compiled in Chester et al. (2013) and Wang & Bilek (2014)
- Isolated basin identified by Arai et al. (2014)
- Submarine canyon
- × OBSs & OBPs

Cores previously obtained

- ▽ IODP/ODP/DSDP
- ☆☆☆ *R/V Sonne*: SO219A & SO251A
- ▽▽▽ *R/V Tansei-Maru*: KT-11-17 & KT-12-9
- ○○○ *R/V Mirai*: MR12-E01 & MR12-E02
- ◇◇◇ *R/V Natsushima*: NT12-02 & NT13-19
- □□□ *R/V Yokosuka*: YK11-E06 & YK14-E
- △△△ *R/V Shinsei-Maru*: KS-14-16, KS-15-3, KS-15-16
- ○○ *R/V Kairei*: KR13-08

Courtesy of A. Kioka, M. Strasser

Short-lived radioisotopes to track earthquake event deposits



- With normal slow deposition offshore Japan, xs^{210}Pb is preserved only in the upper few centimeters of sediment
- The xs^{210}Pb we measured in event deposits had a high concentration and therefore the event deposited was related to the 2011 Tohkou earthquake
- It decays in 150 years because of its short half-live (22.3 years)
- Fukushima Dai-ichi Nuclear power plants accident:

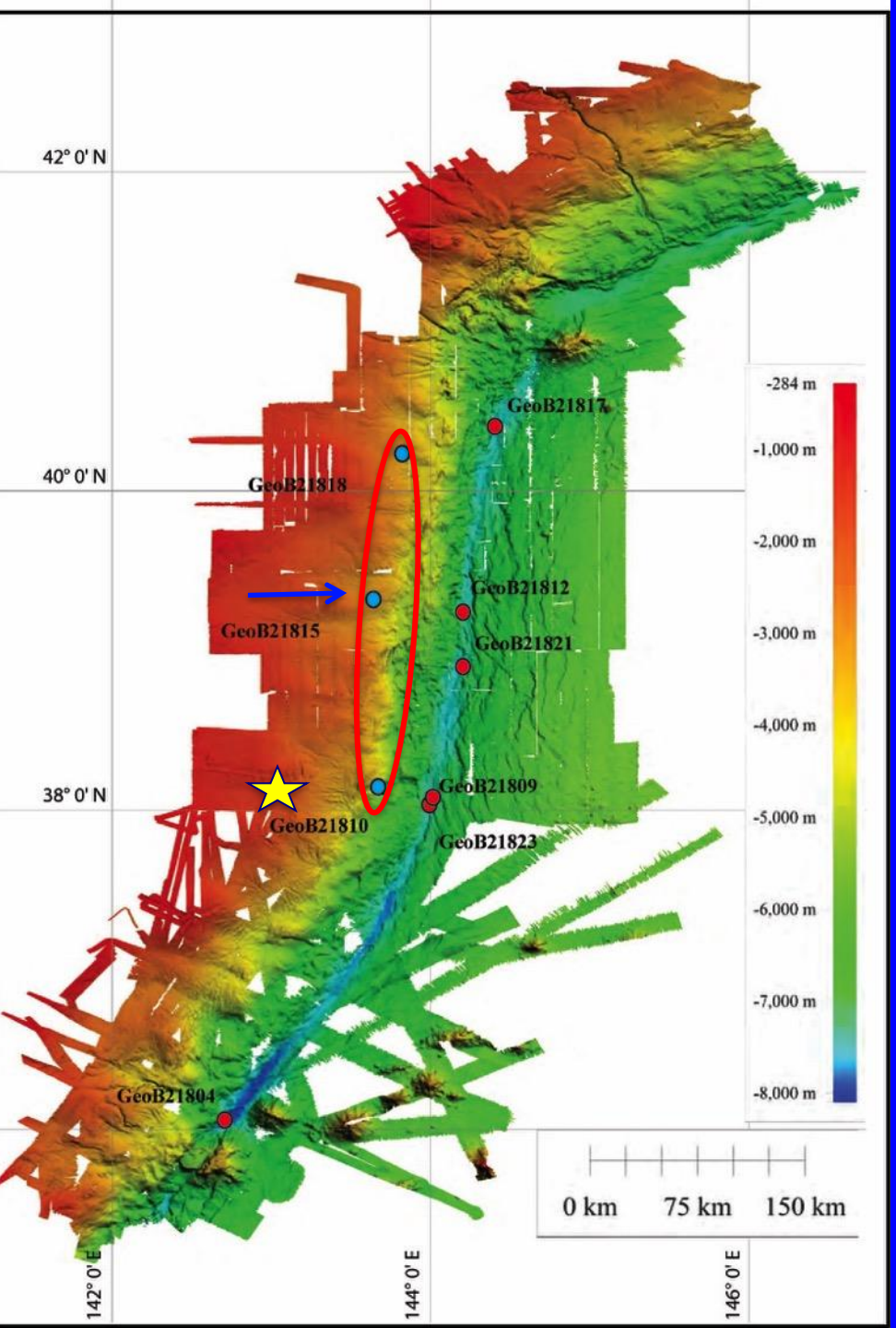
^{137}Cs and ^{134}Cs (half-life 2 years) entered ocean and sediments (e.g., Buesseler et al., 2011; Aoya et al., 2012; Kusakabe et al.2013)

^{137}Cs was also put out into the atmosphere by nuclear testing that peaked in mid-1960's

When the sediments preserve a peak concentration of ^{137}Cs, only it is interpreted as having been deposited in 1960's

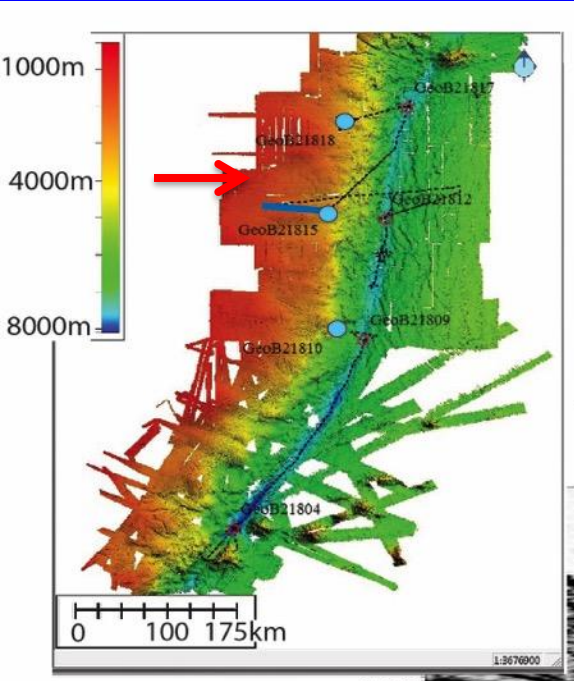
If ^{137}Cs and ^{134}Cs are together they reflect Fukushima disaster

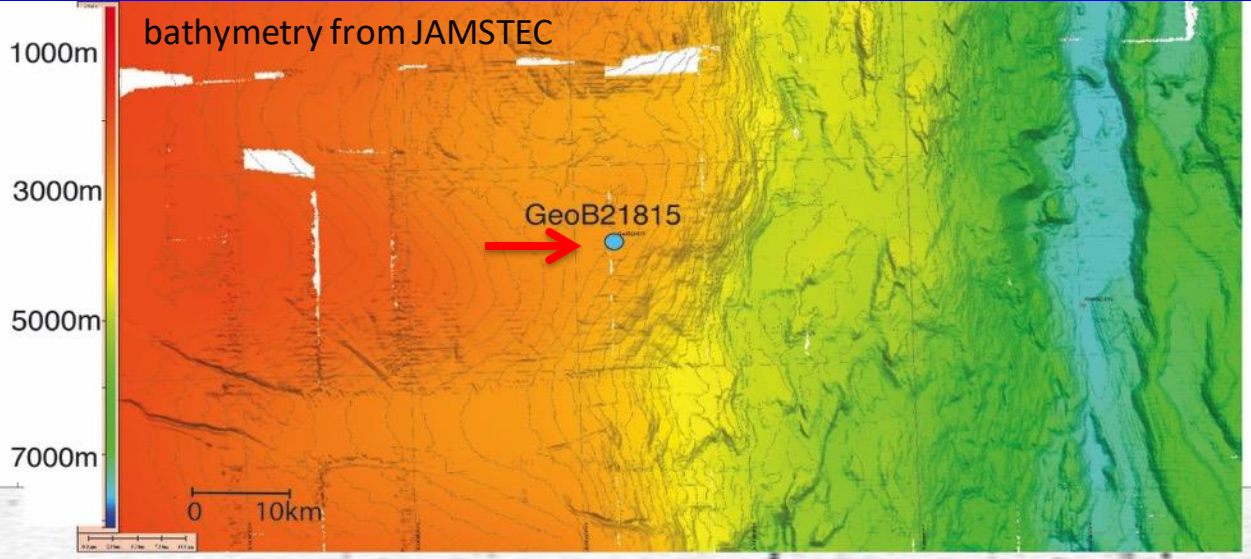
^{134}CS has a half life of 2 years so only traces are found today



Signature of 2011 event deposit in steep parts of slope (3000-4000m)

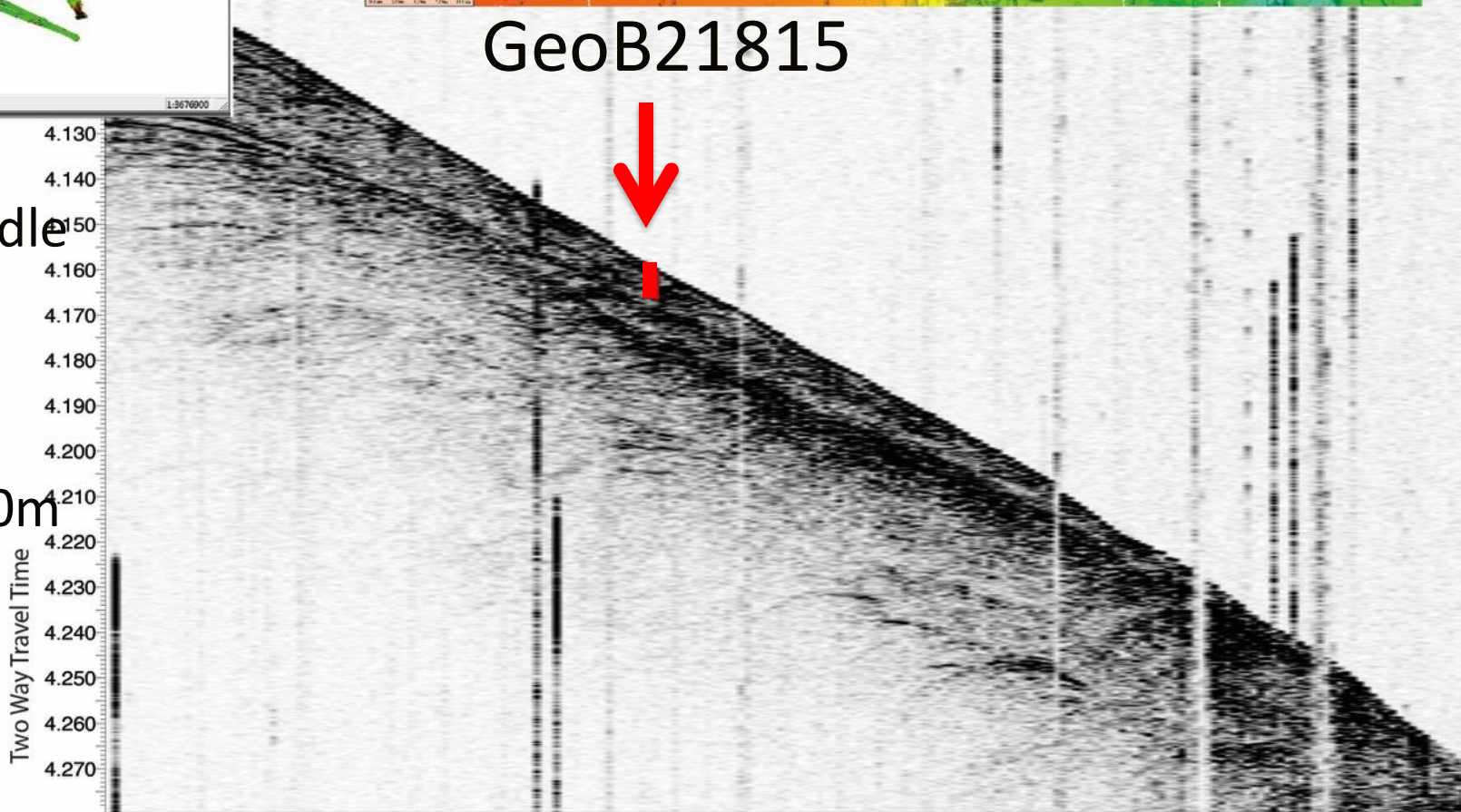
- We identified areas where the 2011 event was deposited because the sediments either contained short-lived radioisotopes or not
- Steep areas of the slope didn't preserve the 2011 event deposit
- Acoustic images coupled to core data indicate more indurated, presumably older strata, exposed at surface





GeoB21815

-steep middle slope
-gradient average 6°
-3000-4000m

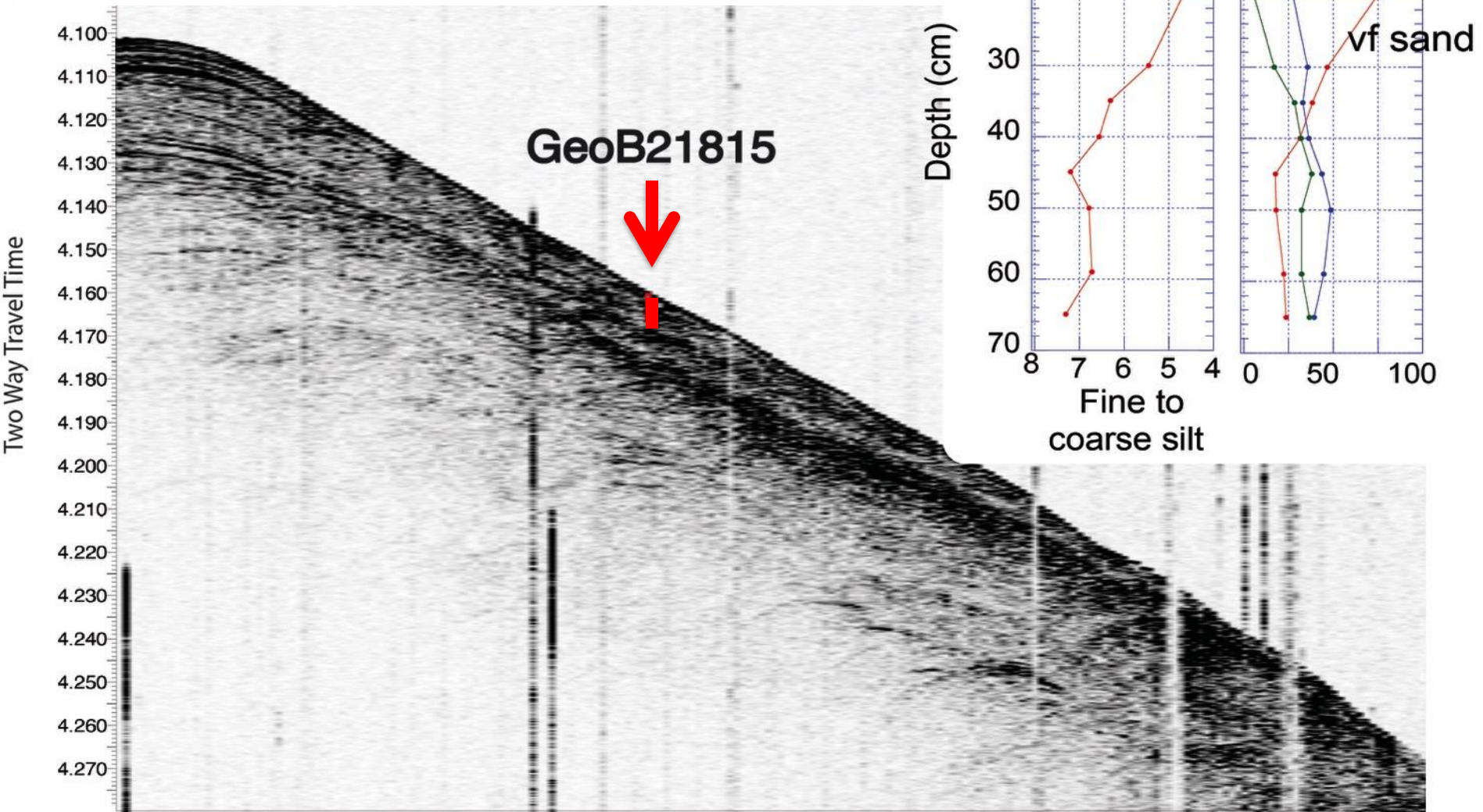


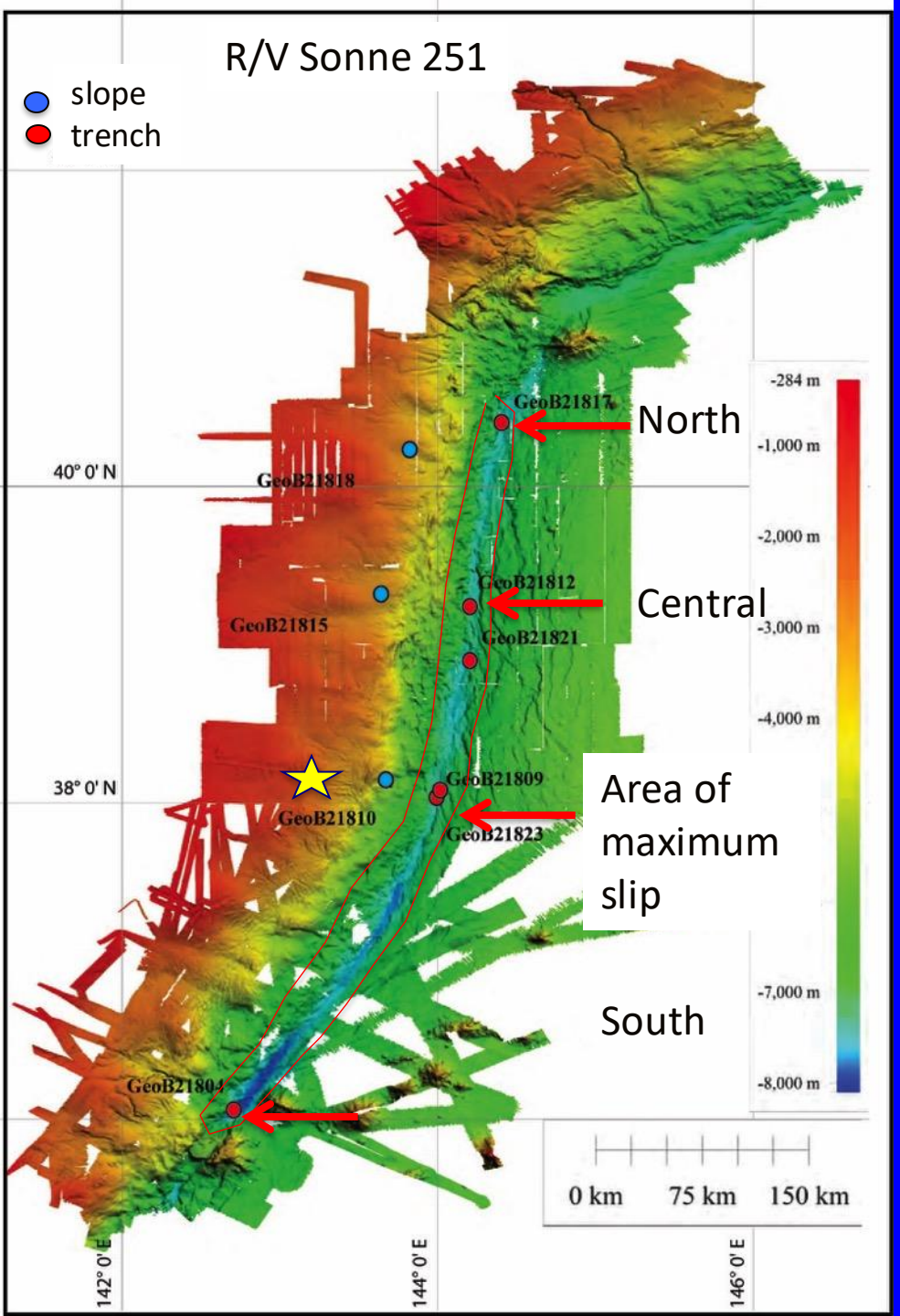
-**Short-lived radioisotopes absent**

- Lithology **sandy silt**

-Grain Size dominated by vf sand and coarse to medium silt

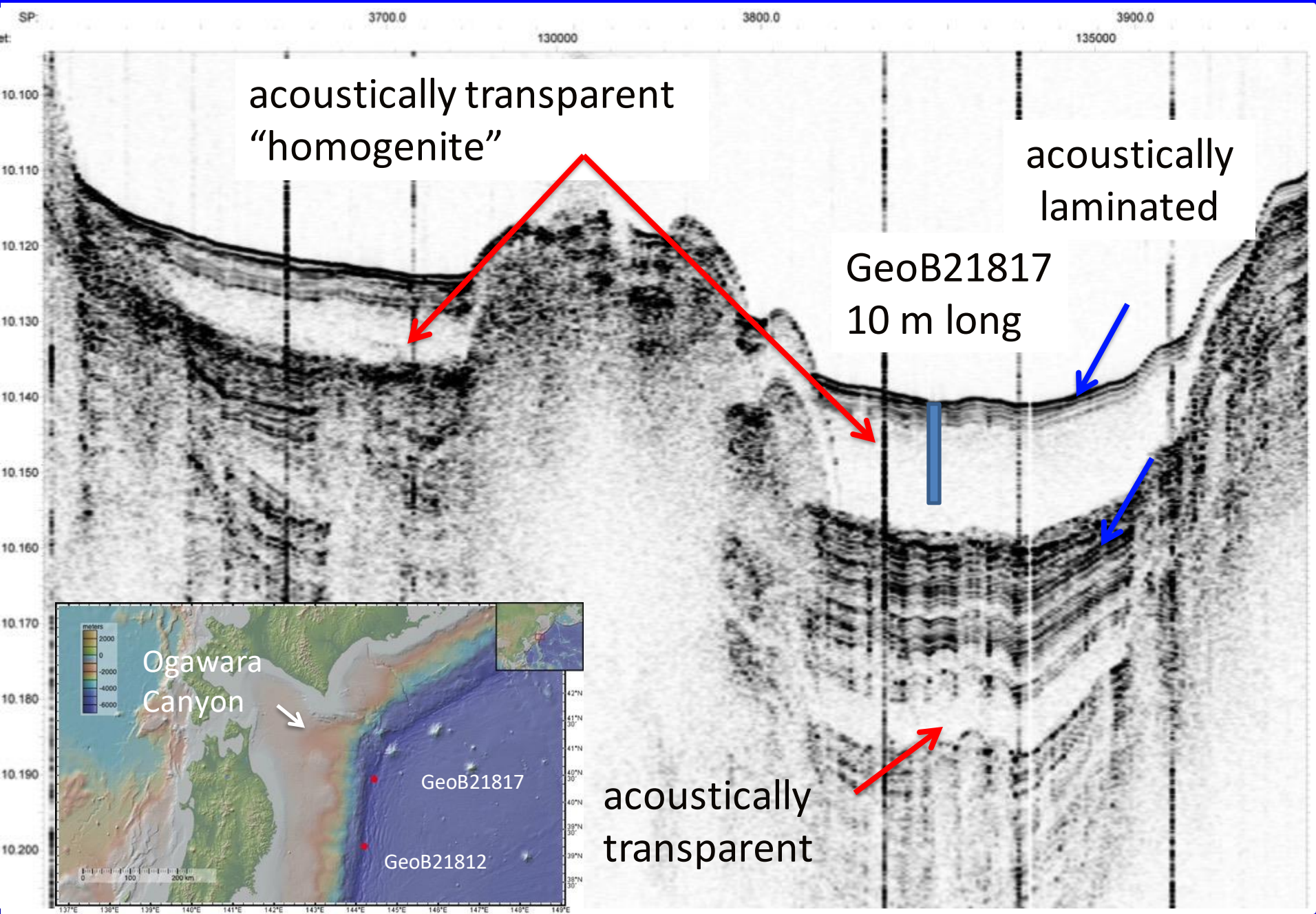
-no evidence of fining upwards into clay





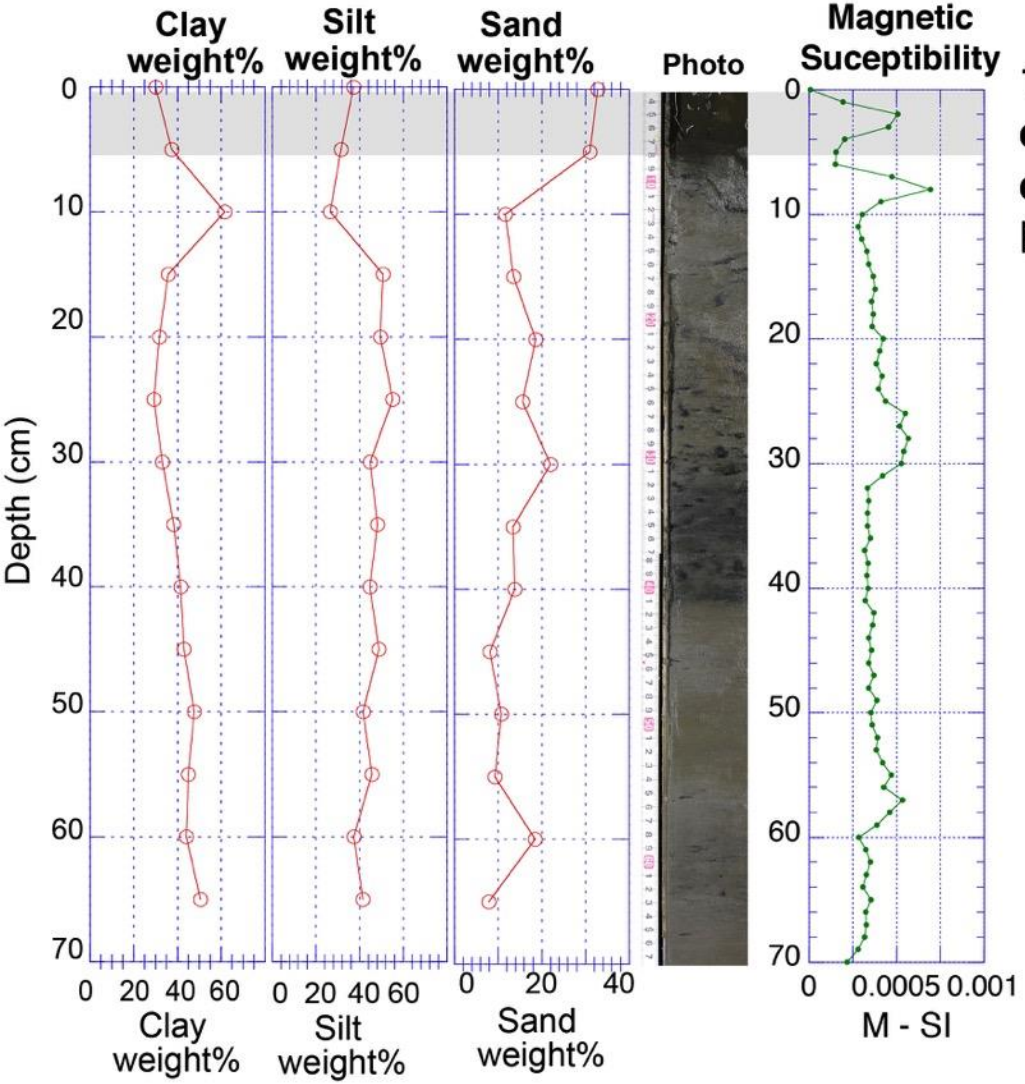
- Signature of 2011 event deposit in the Japan Trench
- Water depths 7000-8000 m
- The trench deepens from north to south
- Studied regions of the trench
- Lihtology: homogenites and turbidites

Northern Japan Trench

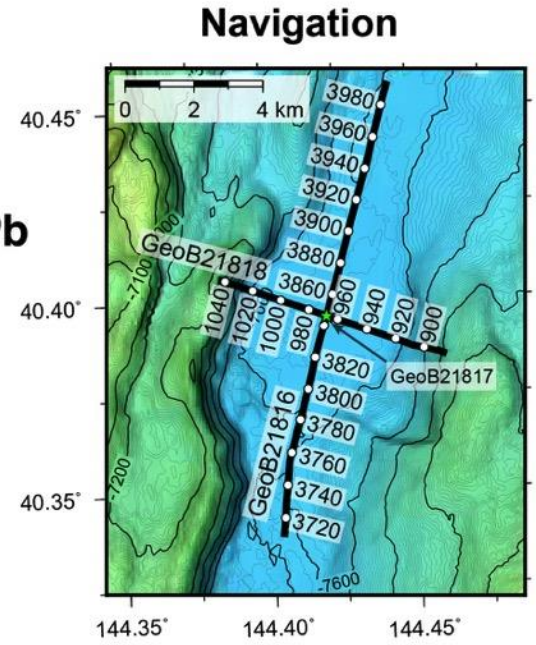


Northern Japan Trench: 1994 Sanriku earthquake homogeneous sandy clayey silt

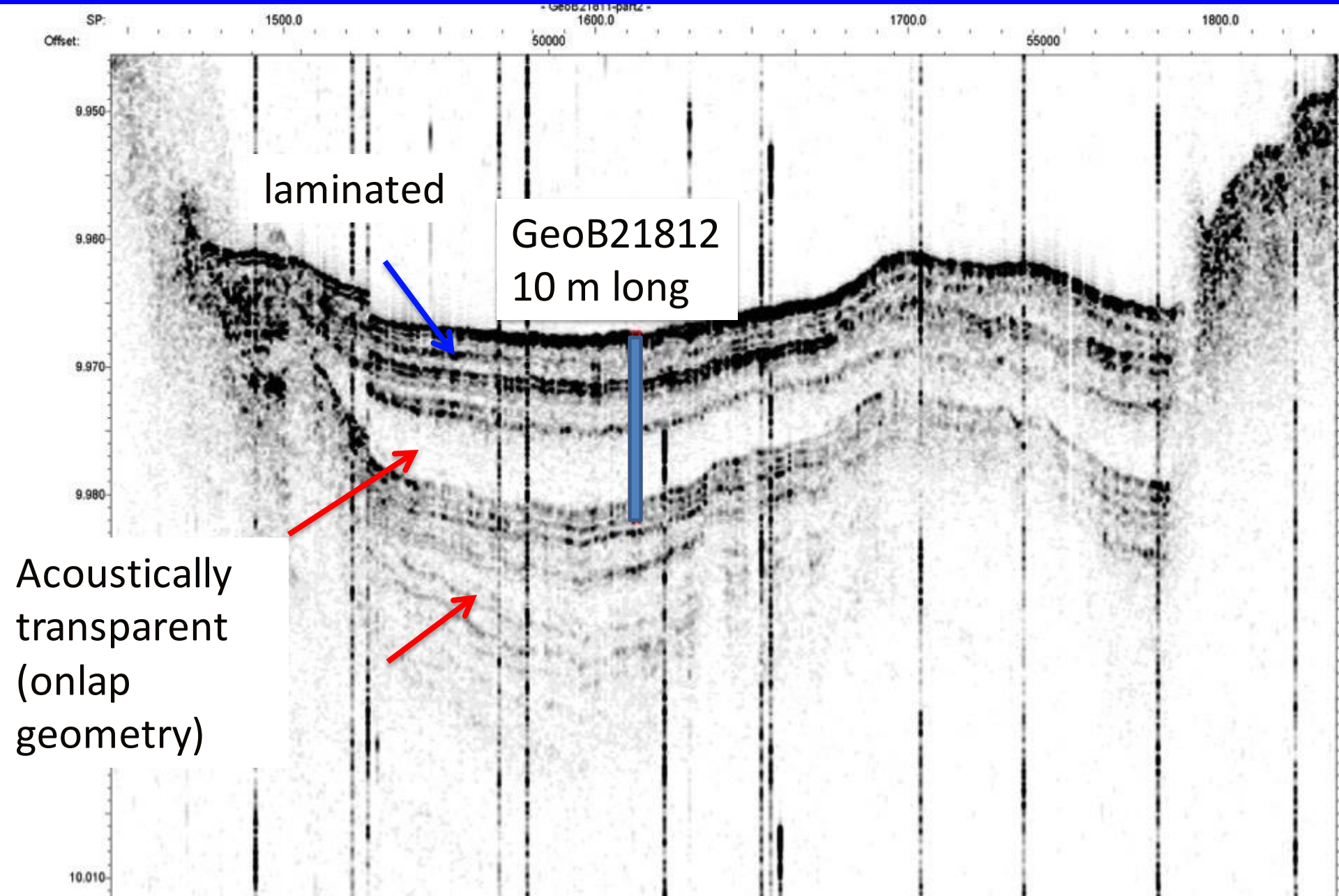
Core GeoB21817-1 Water depth = 7607 m Latitude 40 23.735'N Longitude 144° 25.256'E



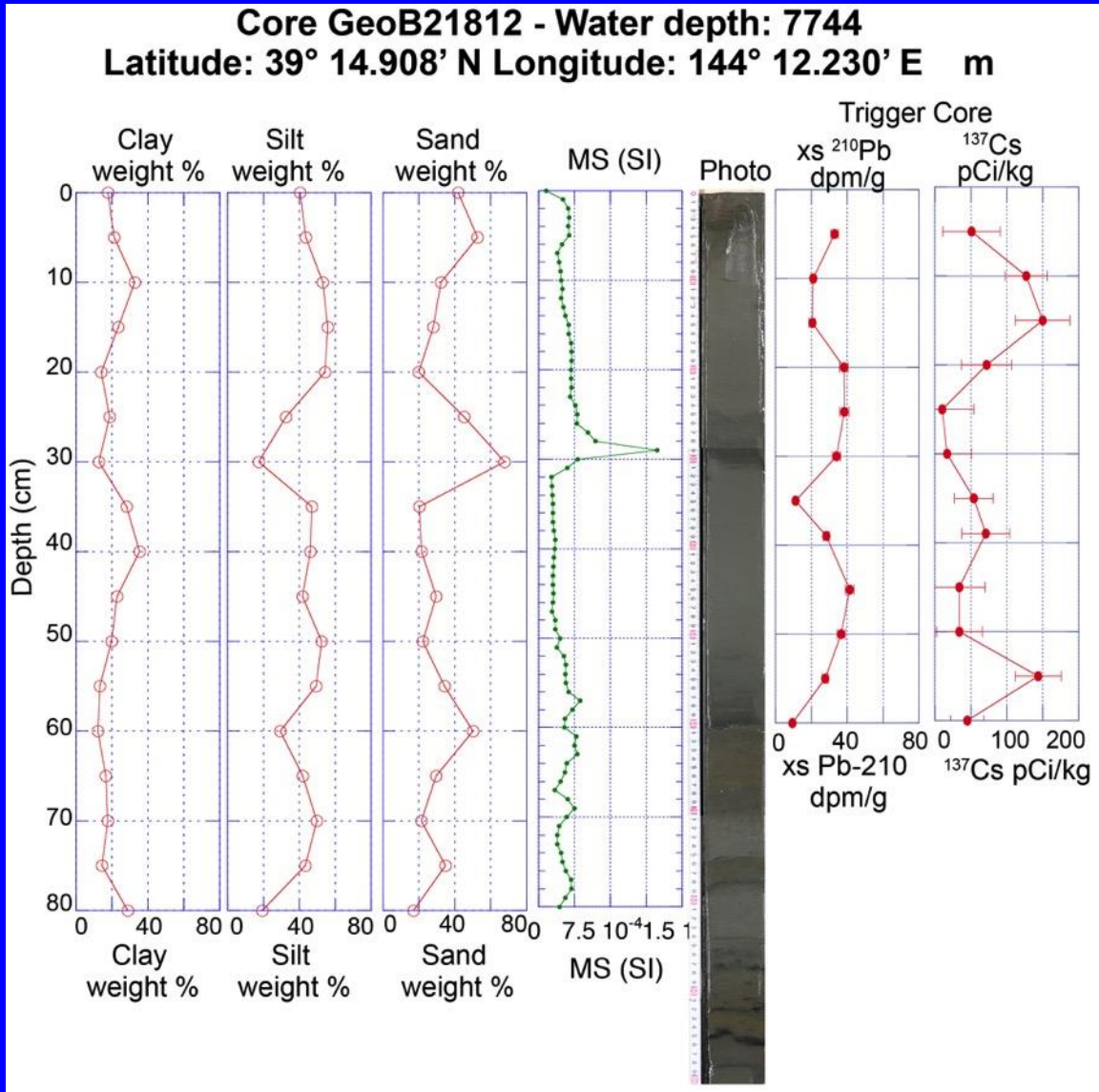
1994 Sanriku earthquake event deposit based on xs^{210}Pb

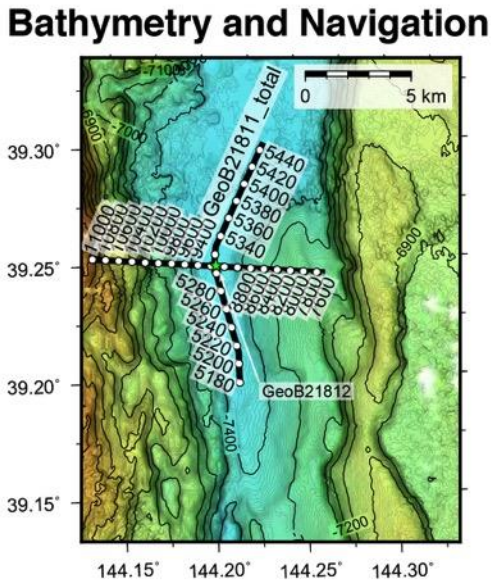


Central Japan Trench

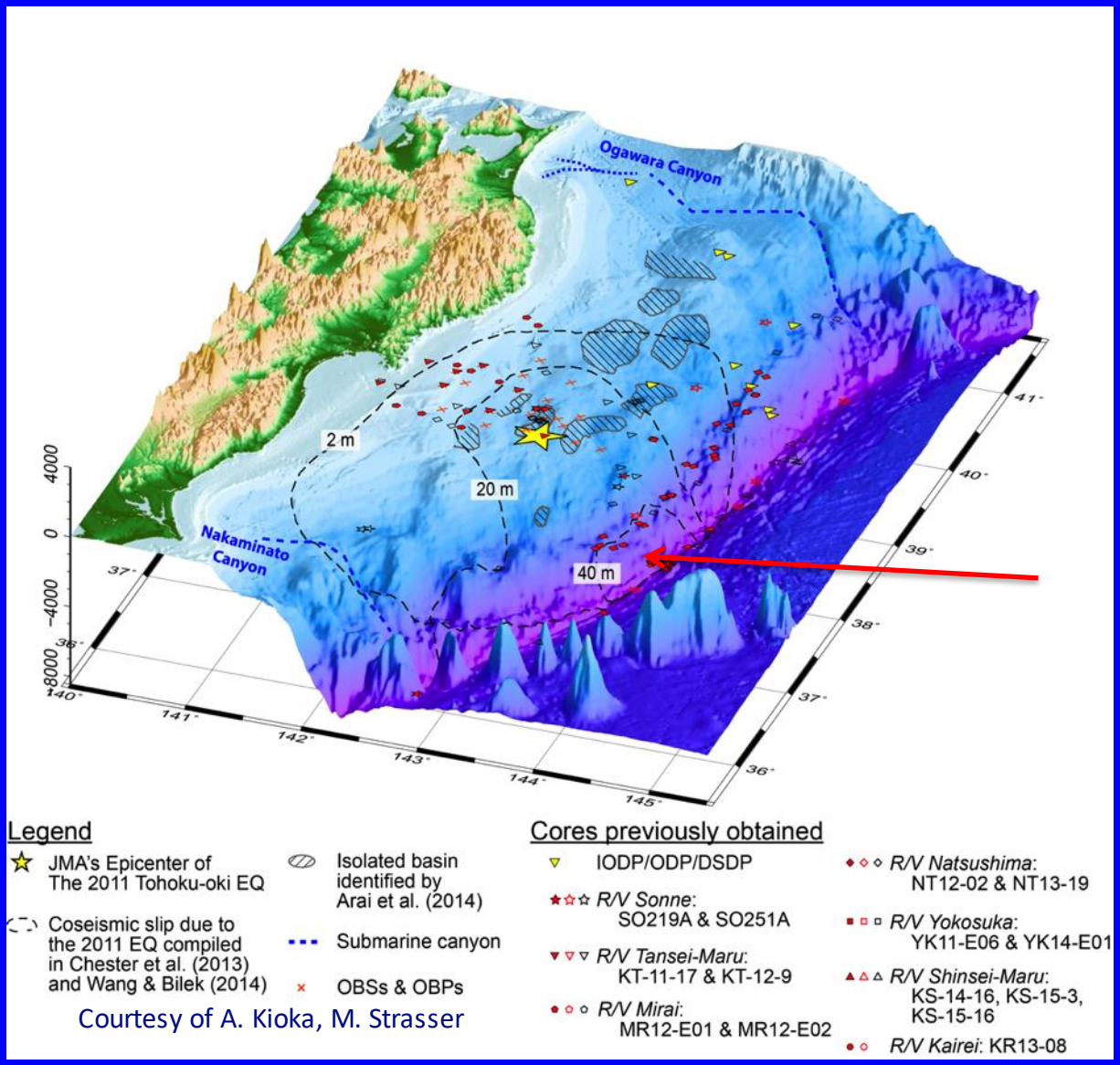


Central Japan Trench: 2011 Tohoku earthquake event not present – Sandy turbidites common



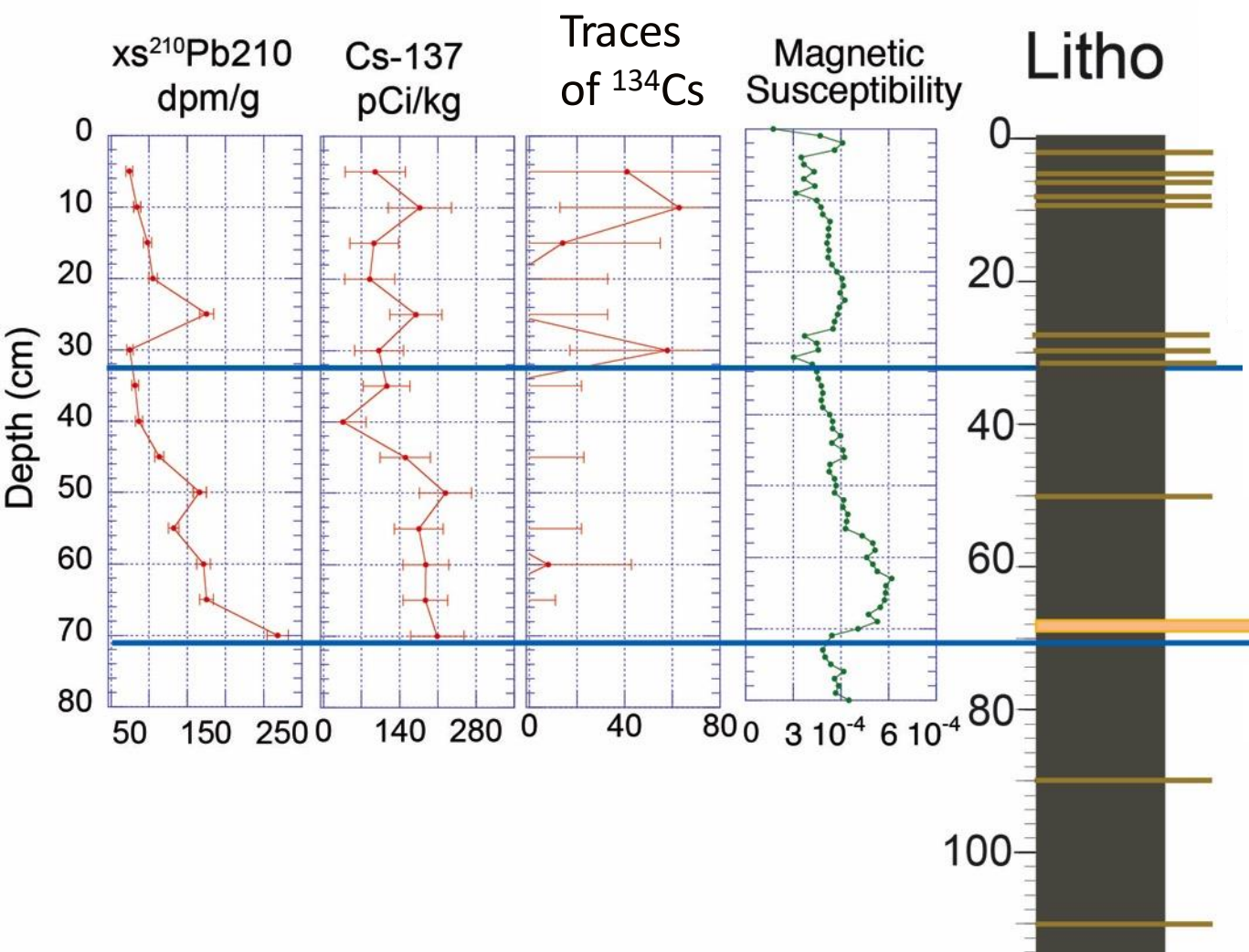


Downslope of area of maximum slip deformation of 2011 Tohoku earthquake



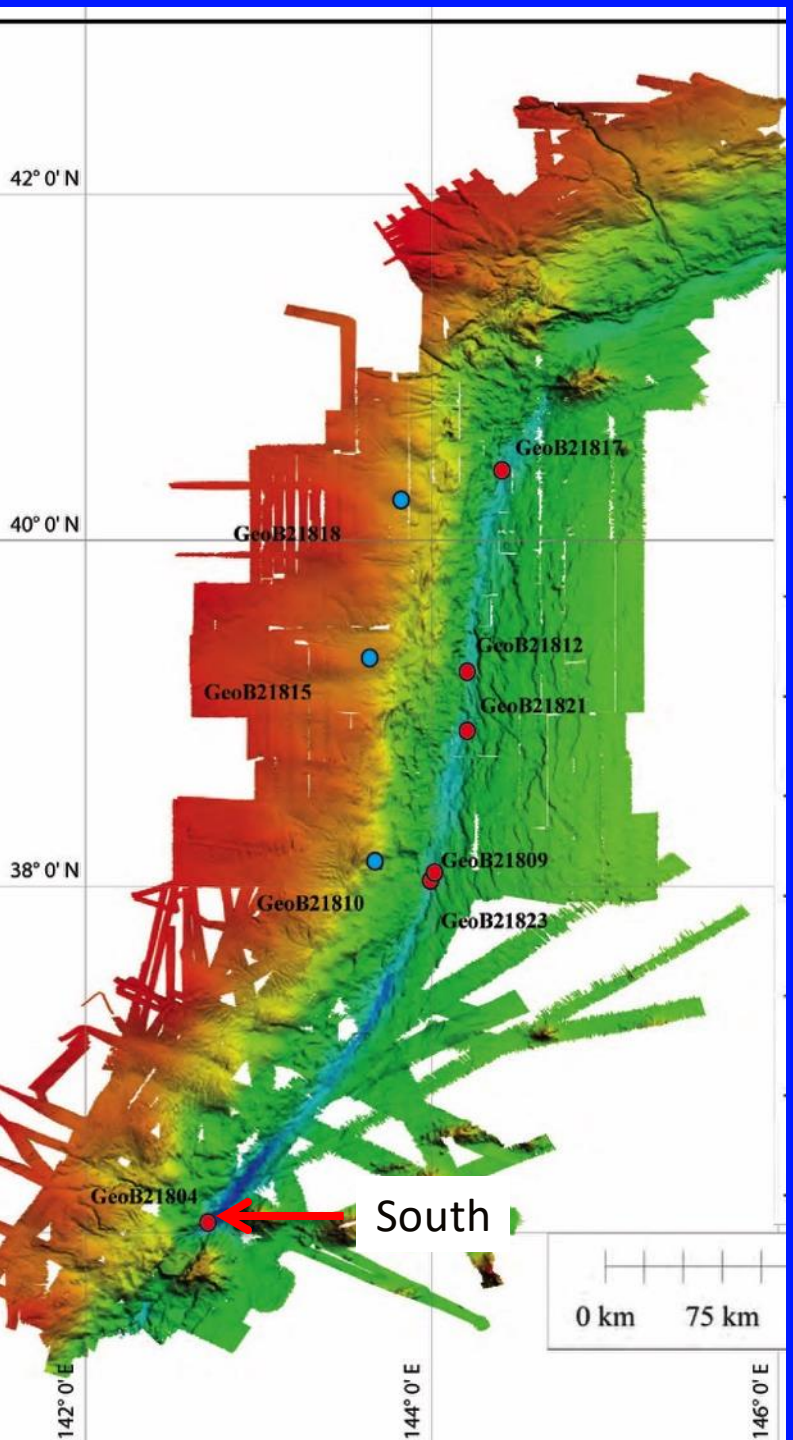
Courtesy of A. Kioka, M. Strasser

2011 Tohoku event deposit
Lithology: homogenous diatomaceous mud, sandy turbidites



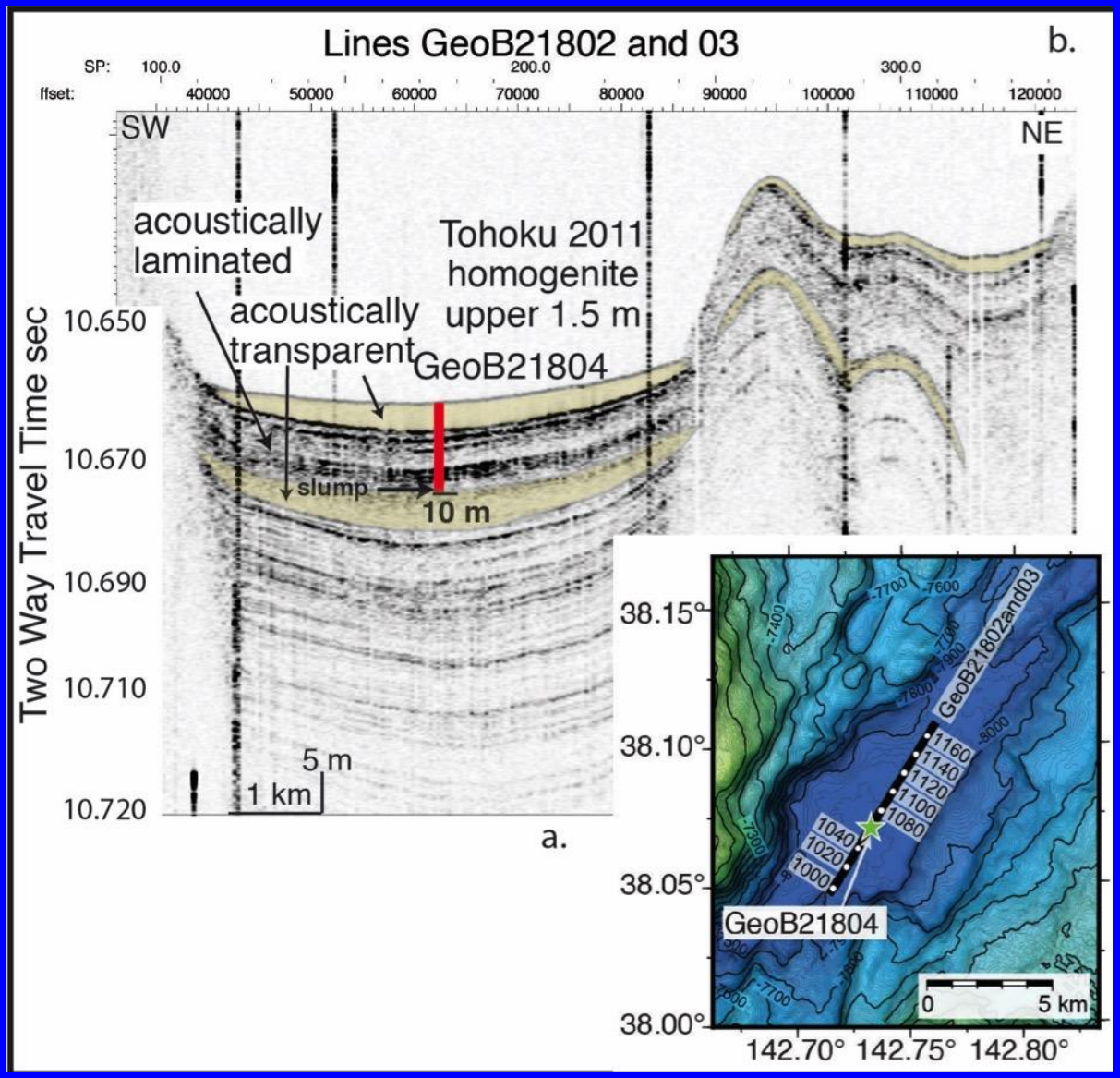
GeoB21823

2011 main event deposit and Fukushima



Southern Japan Trench

Southern Japan Trench: 2011 event deposit 1.5 m thick
Lithology: homogeneous diatomaceous mud

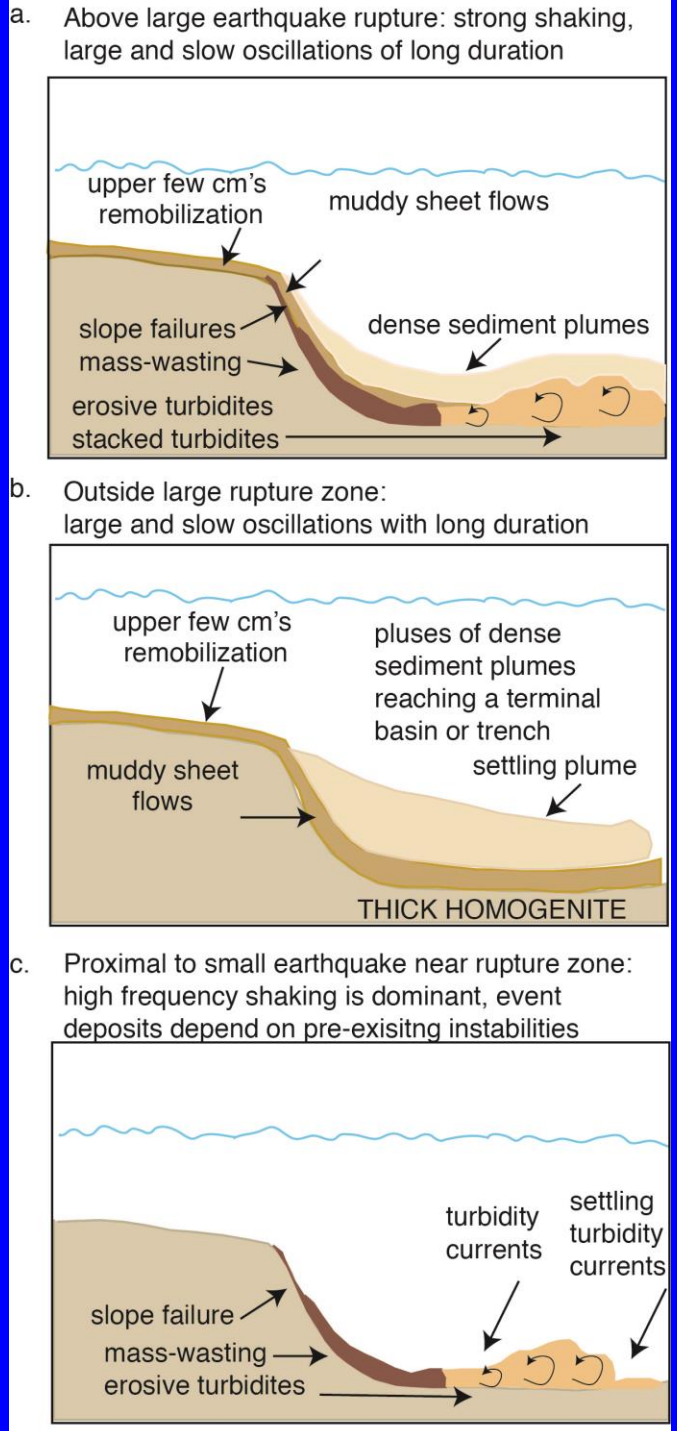


Conclusions

- 2011 Tohoku earthquake event deposit
  - absent from steep areas of the slope
  - present downslope of the area of maximum slip and in the southern segment of the Japan Trench terminal basin
  - It is absent from the northern and central segments of the Trench distal from the area of maximum slip
- Grain size variability:
  - slope lithology contains 25-50% sand
  - trench lithology is finer grained and composed of silt (40-60%), sand (20%), clay (20%)
- Grain size differences between homogenites and turbidites:
  - Homogenites are composed silt and clay
  - Turbidites are composed of sand and silt normally graded

Proposed Processes

- Near the rupture high shaking, high frequency, short duration: mass-wasting, turbidites, homogenites
- Distal from the rupture,: large and slow oscillations with long duration of the M 8.0 or 9.0 earthquakes cause differences in the entrainment process by which the sediment is suspended and homogenized
- Small earthquakes M <8.0 produce turbidites only
- International Ocean Discovery Expedition 386 will take place in 2021-2022 continue to test this hypothesis



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