Paleotsunami Workshop 3 July 2013

Sediment erosion, resuspension, transportation and redeposition by tsunami: Evidences from the 2011 Tohoku-oki tsunami

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Earthquake/Tsunami and Sea Floor

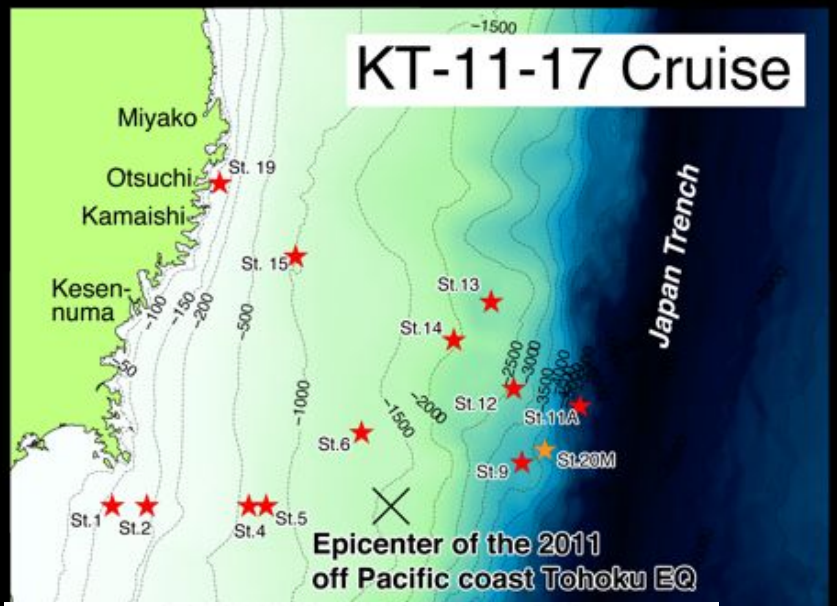
- Strong ground motion by earthquake and large flow speed and friction velocity by tsunami waves might resuspend and further transport unconsolidated marine surface sediments.
- Response of surface sediments for earthquake ground motion and tsunami waves differs place by place, controlled by degree of ground motion, angle of slope, grain size and composition of covered sediments, sediment thickness, major and minor bathymetric relieves, tsunami moving direction and speed, and so on.
- We have only little knowledge or real evidence (ground truth data) on the influence of tsunami to sea floor environments and marine sediments.

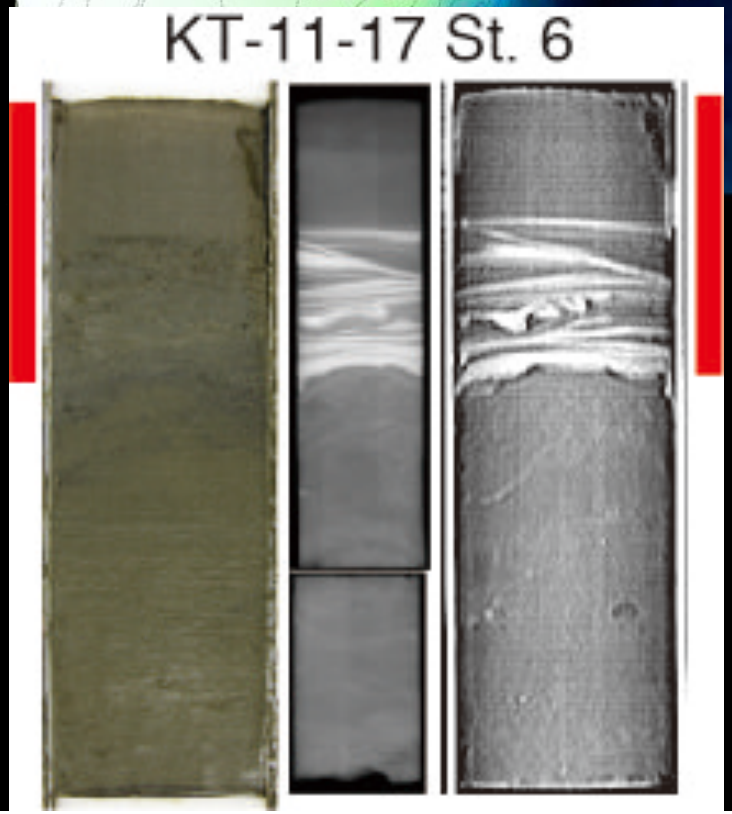
Evidences of Tsunami-related Marine Sediment Movements

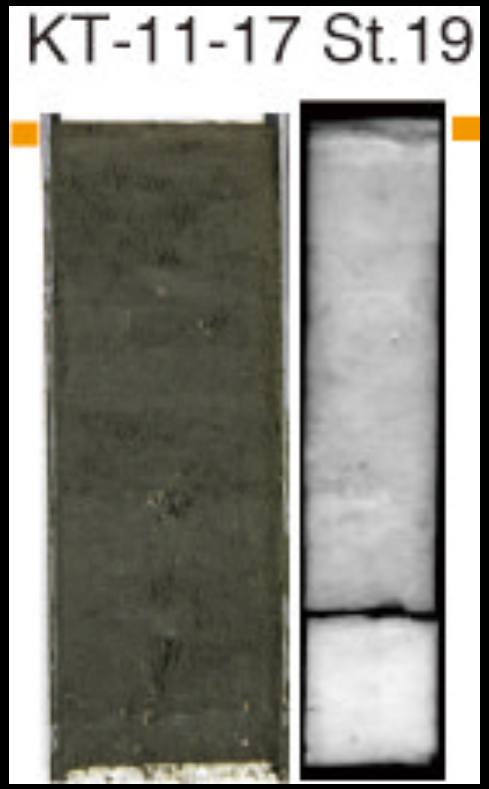
- Sea bottom bathymetry changes (erosion and redeposition) by tsunami in the shallow bay (ex. Kesen-numa Bay)
- "Tsunami boulders" (ex. Ishigaki Island)
- Upper bathyal microfossils in on-shore tsunami deposits (ex. 1993 Hokkaido-nansei-oki EQ)
- Deep/shallow-marine event deposits? Useful for paleoseismology/paleotsunami history?

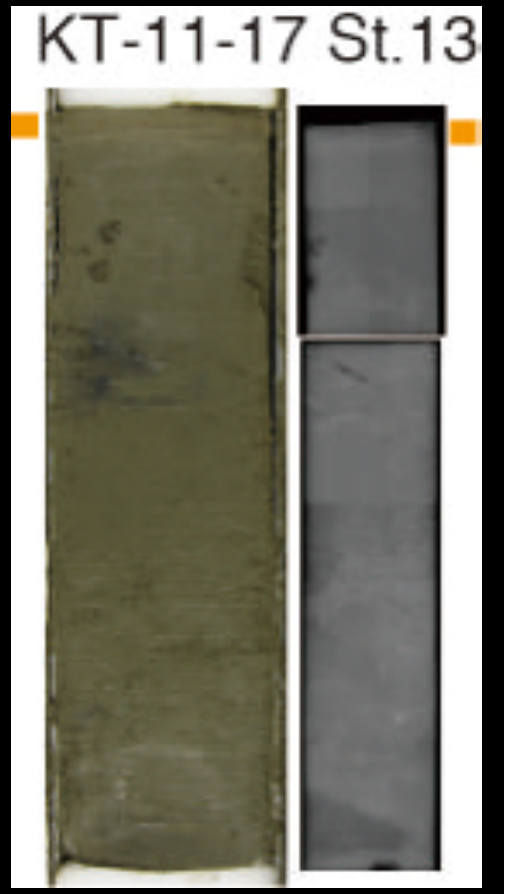
The 2011 Event Deposits from Coast to Trench

- We conducted several survey cruises to find the 2011 event deposits from coastal (shoreface) areas to the Japan Trench floor
- The event deposits were widely recognized from shallow- to deep-water
- The observed event deposits are variable reflecting the source materials and transportation processes









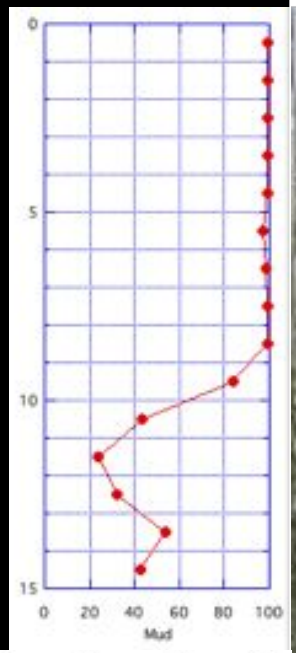
Type B:
Homogeneous (structure less) mud at top
Sharp basal contact, but no turbidite sand

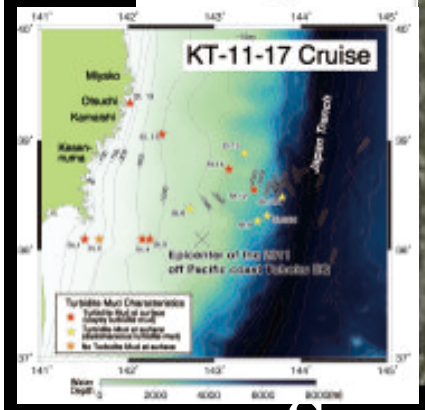
Shelf-slope Event Deposits:

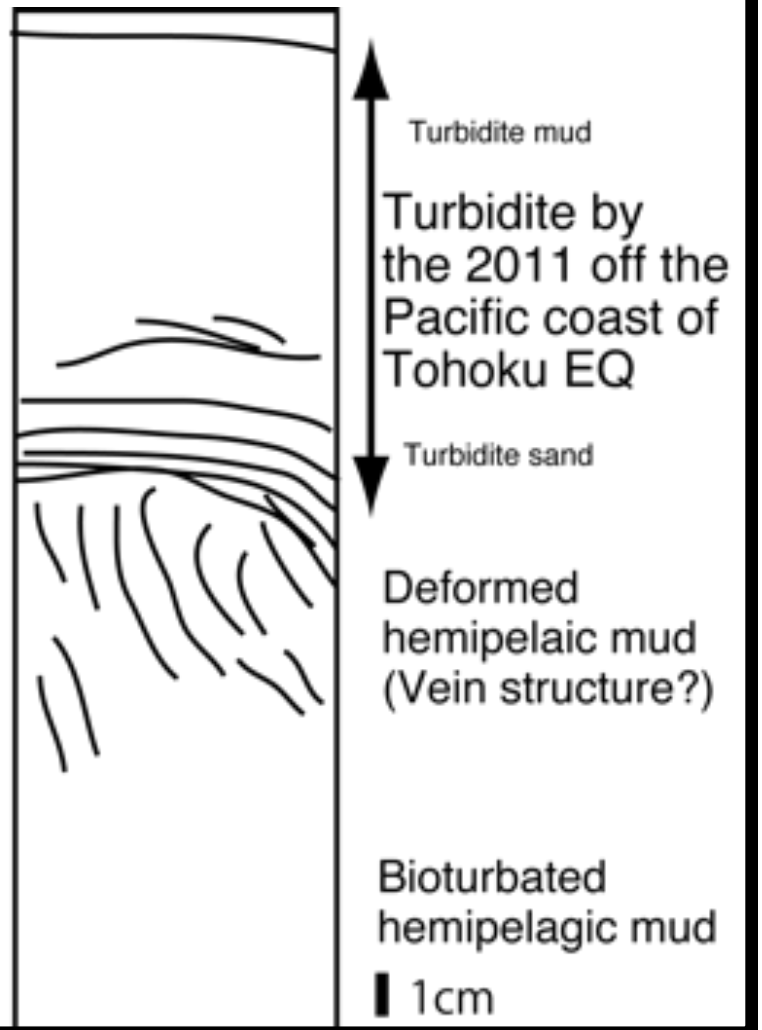
Two Types of Event Deposits

Type A:
Upward fining graded structure,
Sharp basal contact with turbidite sand

KT11-17 St.1 off Sendai (122m)





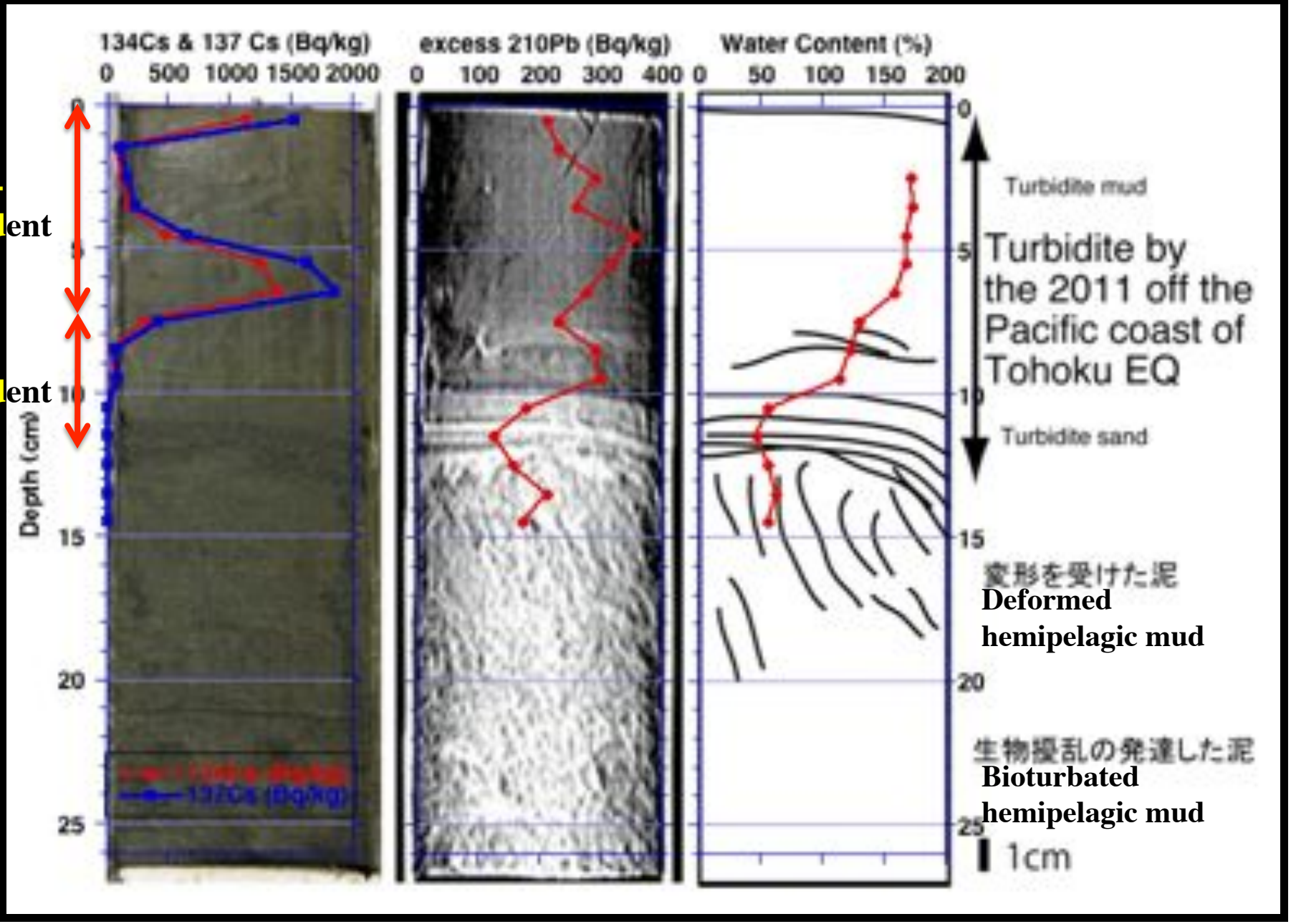


Second-storied turbidite

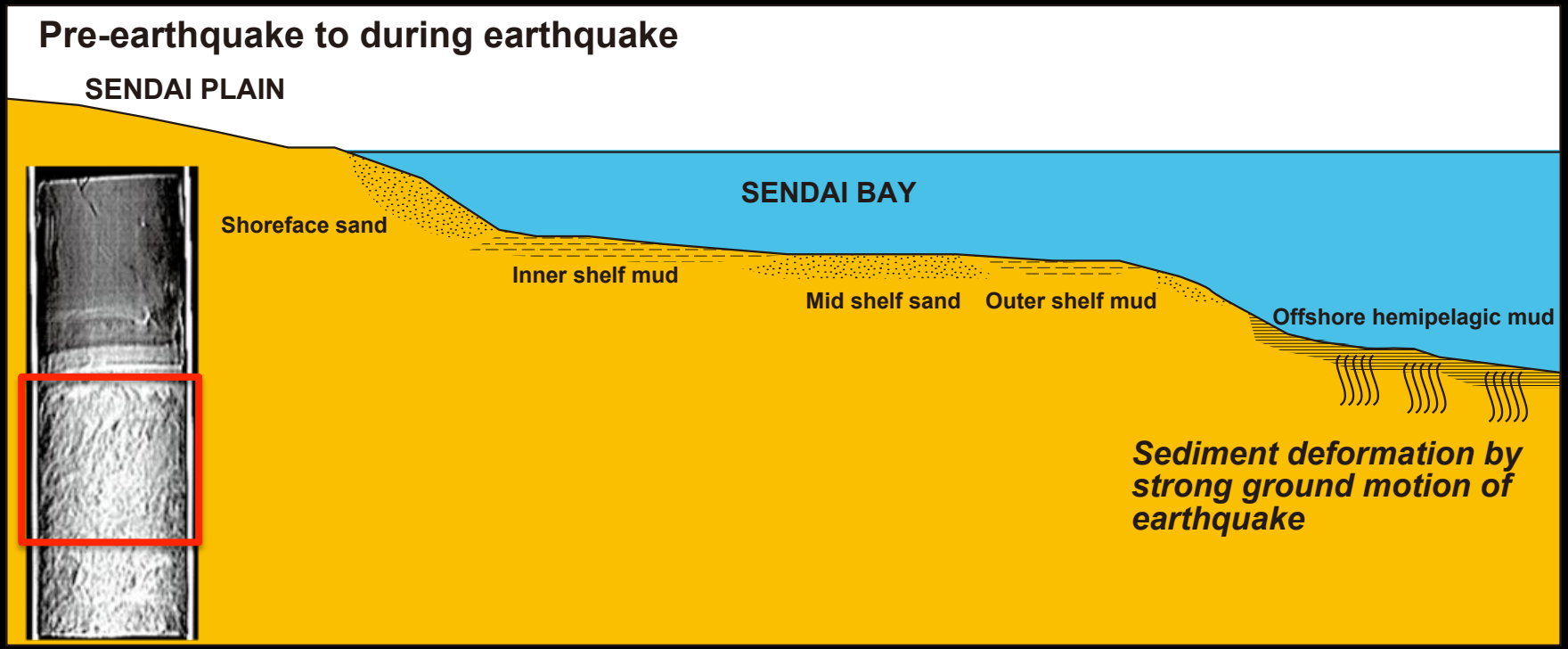
A typical Type A event deposit

	TM	HM
C/N ratio :	10.5-10.8,	10.1-10.4
δ13Corg :	-22.4,	-22.0

Radiological Measurement Result

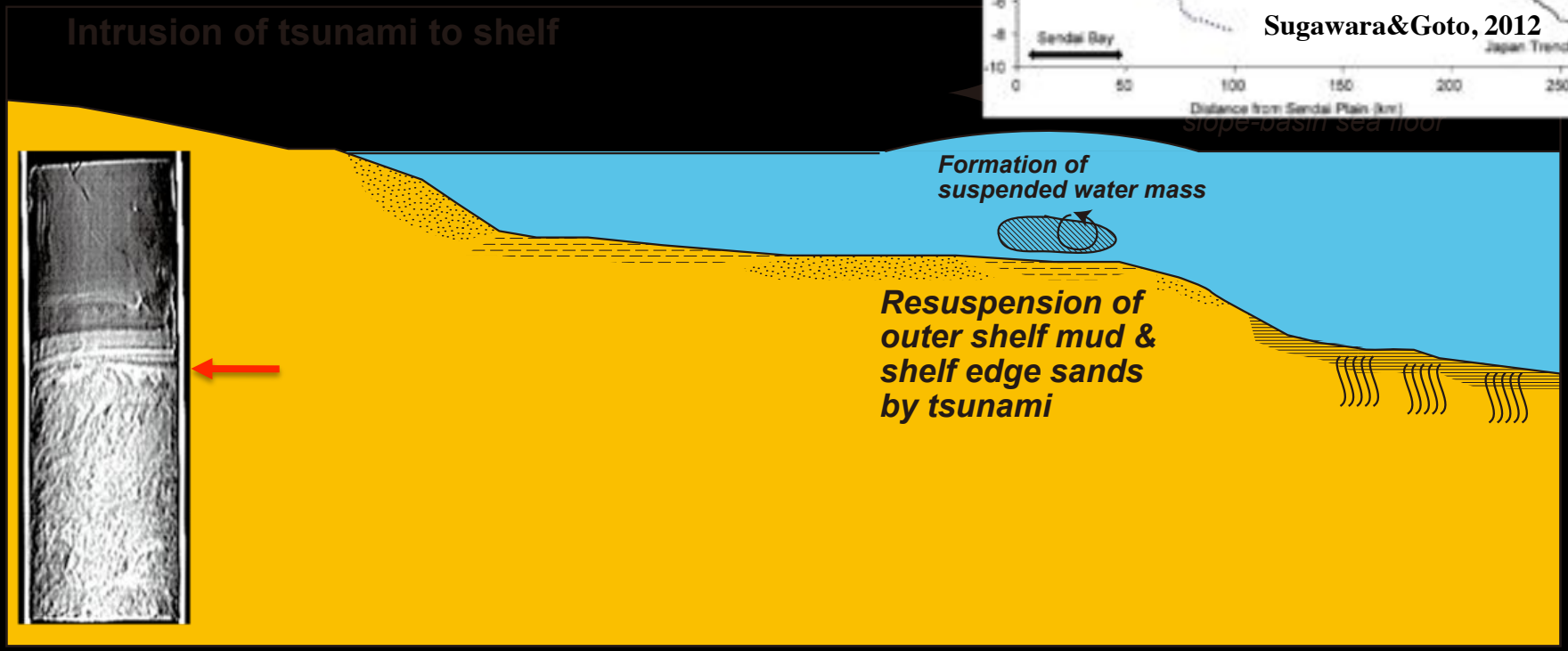


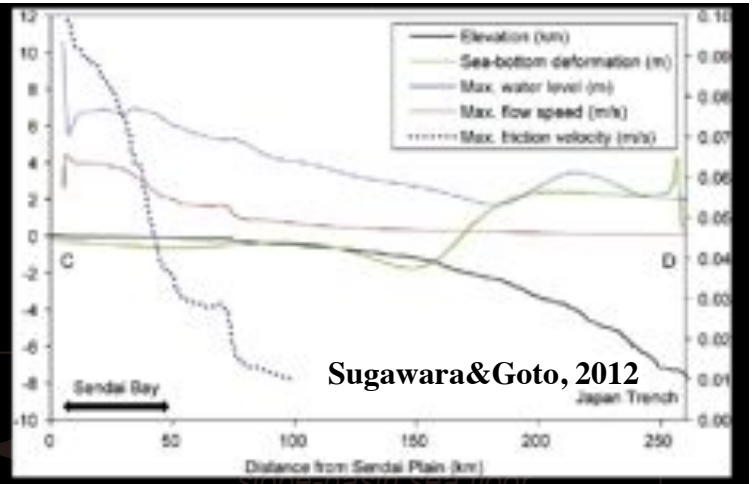
Occurrence of Earthquake



* Surface sediment breakout/deformation (and resuspension of surface loose mud) by strong ground shaking by earthquake

Intrusion of Tsunami to Shelf

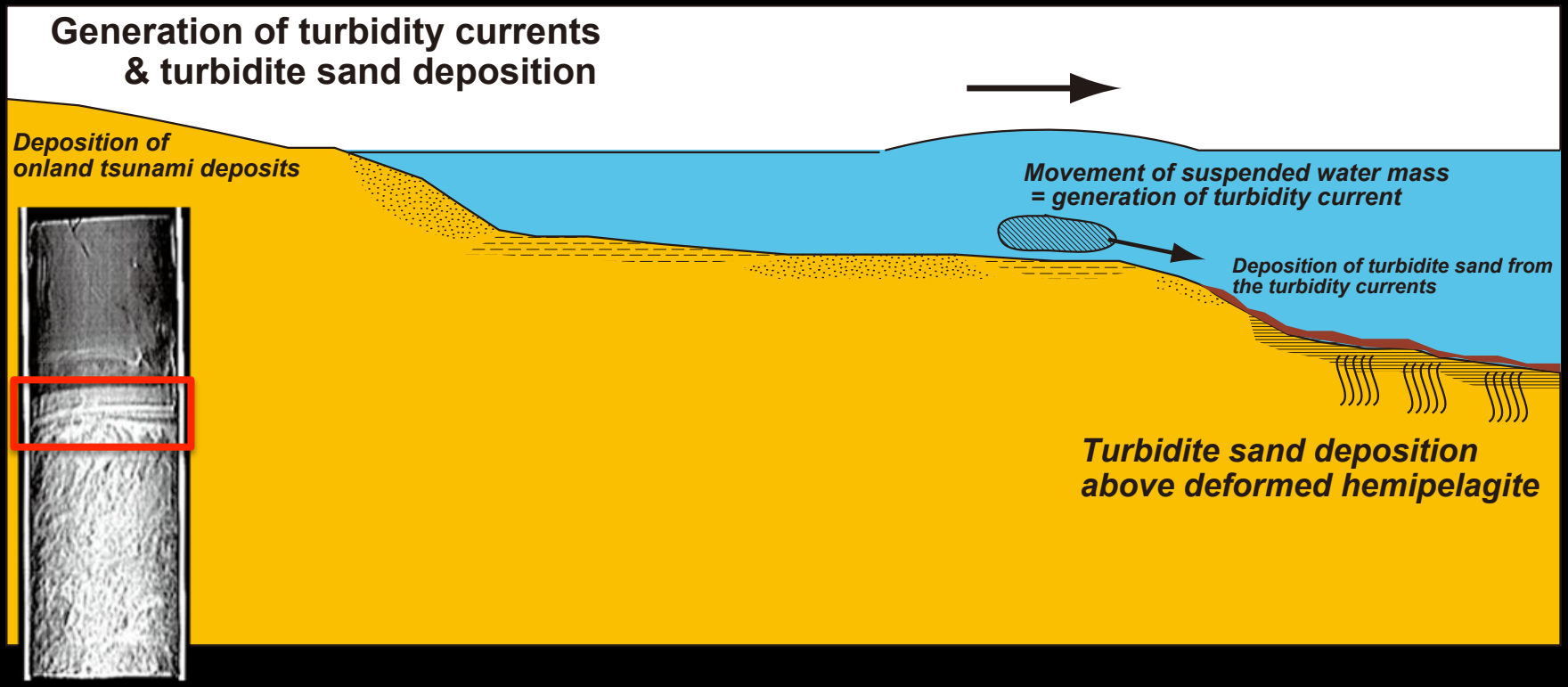




* Large friction velocity of tsunami at shelf edge

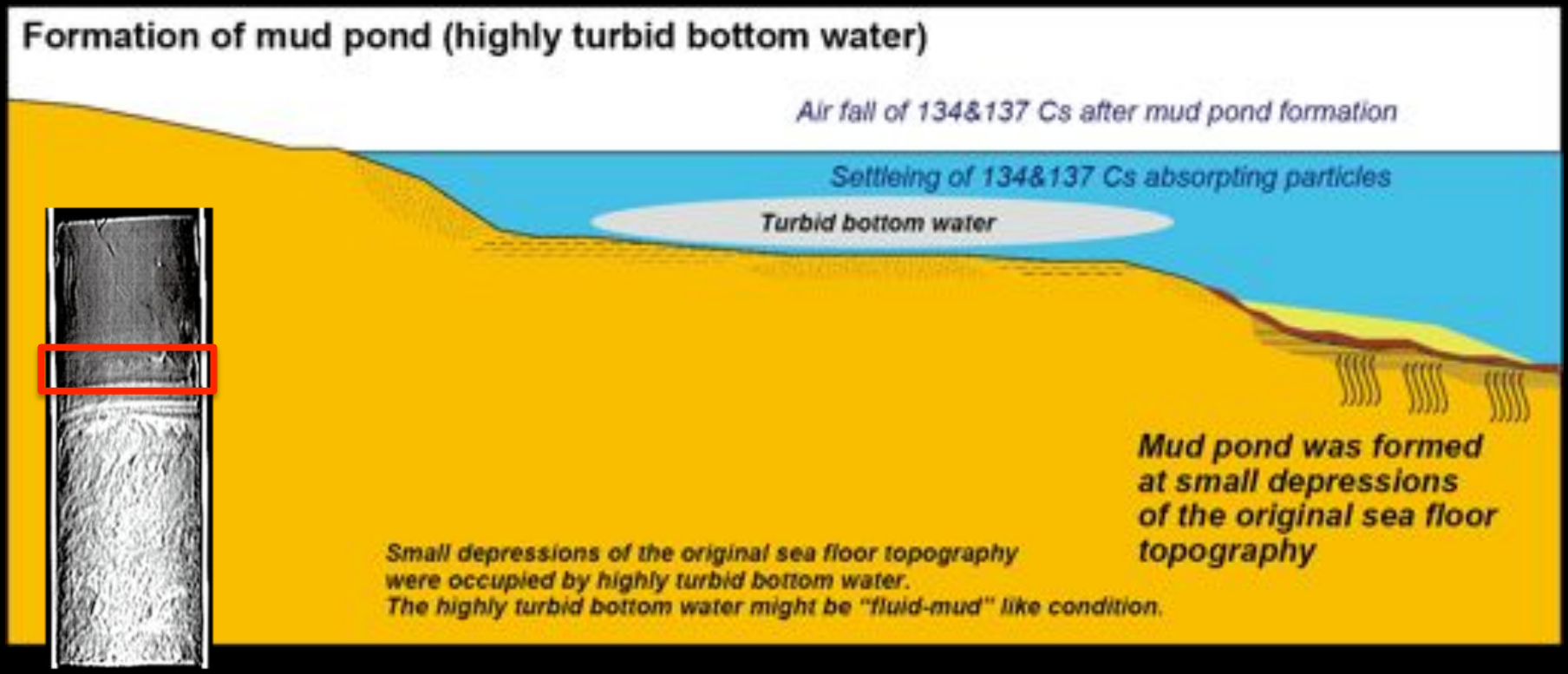
* Sea bottom erosion, sediment resuspension, and formation of turbid shelf water

Generation of Turbidity Current



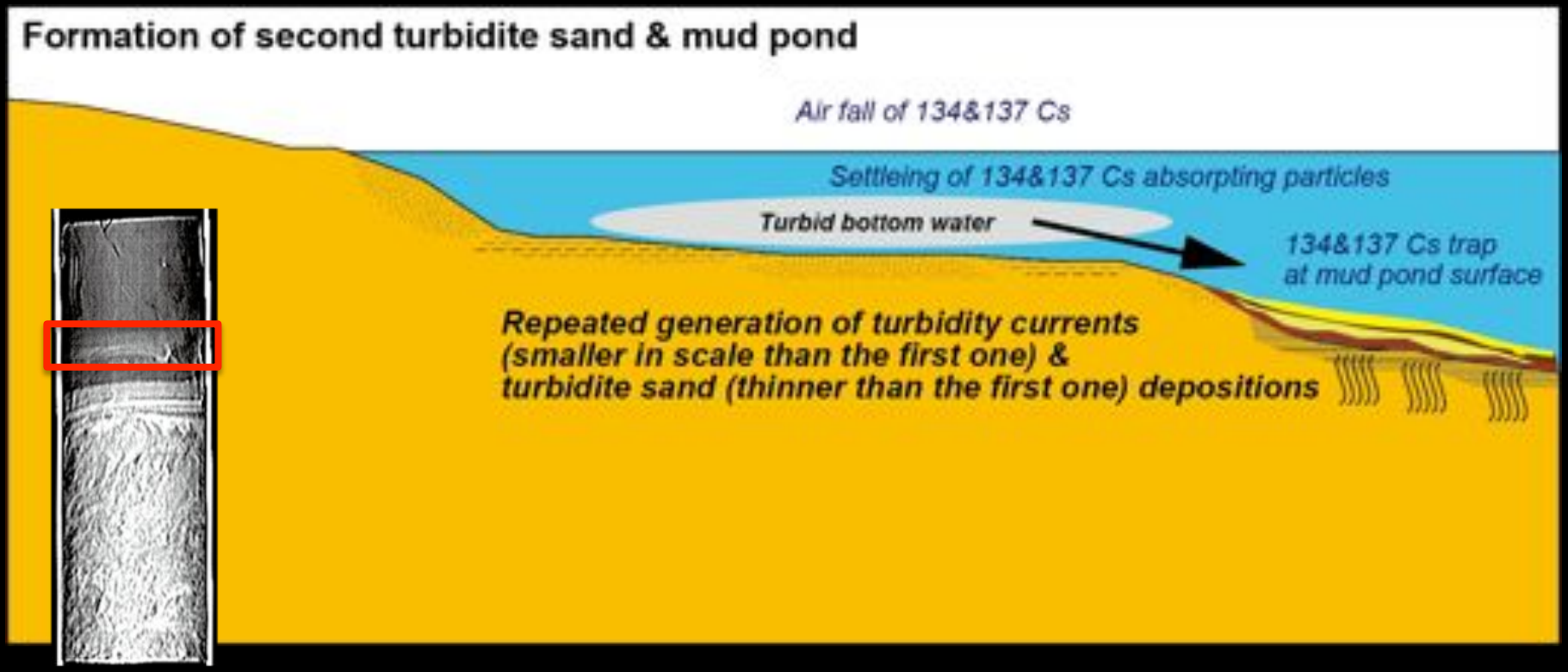
* Sea bottom erosion by turbidity current, and lower turbidite sand deposition

Mud Pond Formation & Maintaining Turbid Shelf Water



* Lower turbidite mud deposition from mud pond
* Release of 134- & 137-Cs from Fukushima No.1 NPP
* Absorption of 134- & 137-Cs to suspended particles

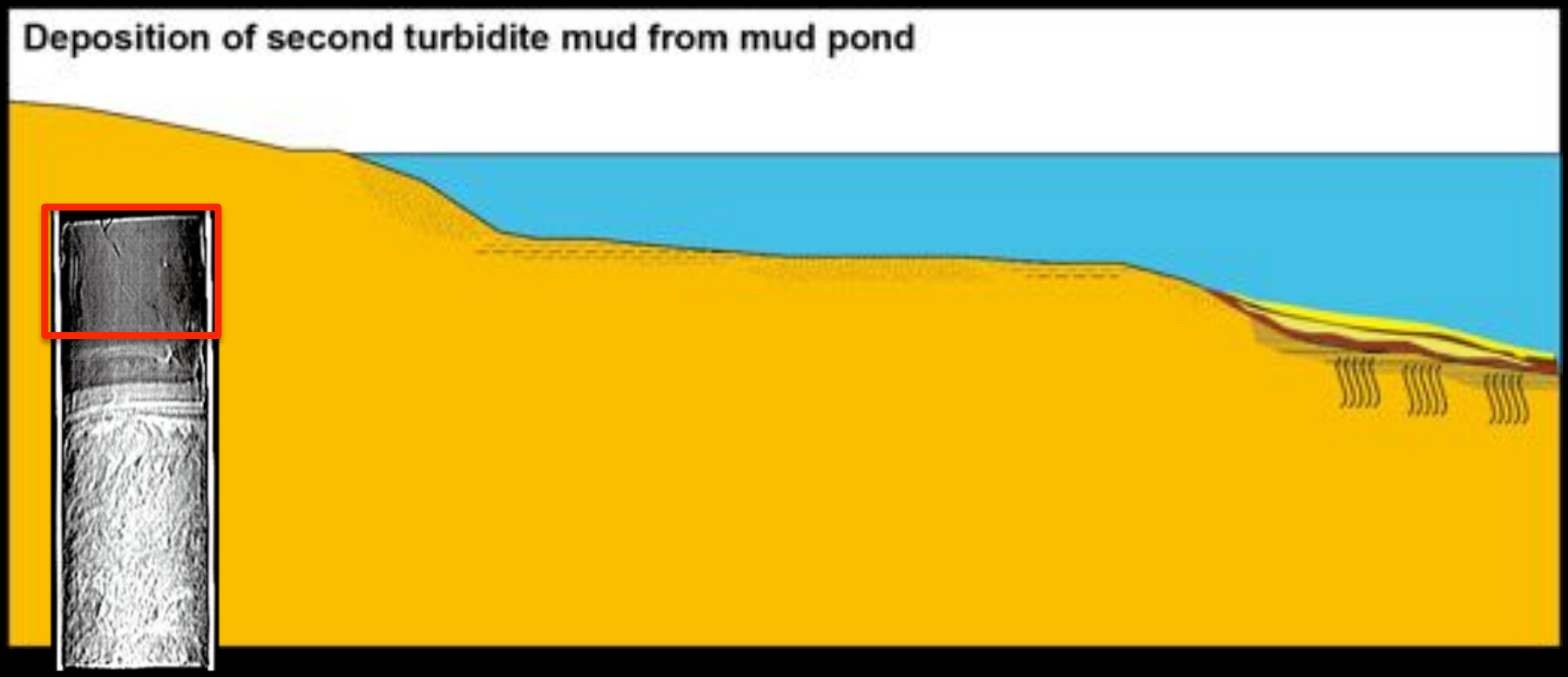
Regeneration of Turbidity Current



* Increasing of bottom water density by settling of suspended particles and/or sediment resuspension by ASs

* Deposition of upper turbidite containing 134& 137 Cs

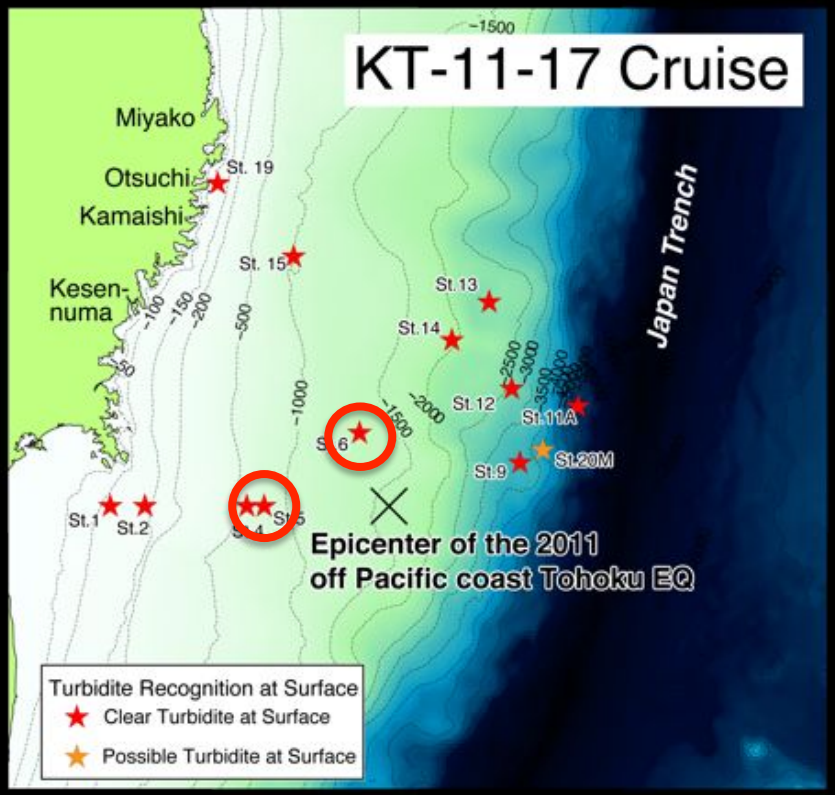
Deposition of Upper Turbidite Mud

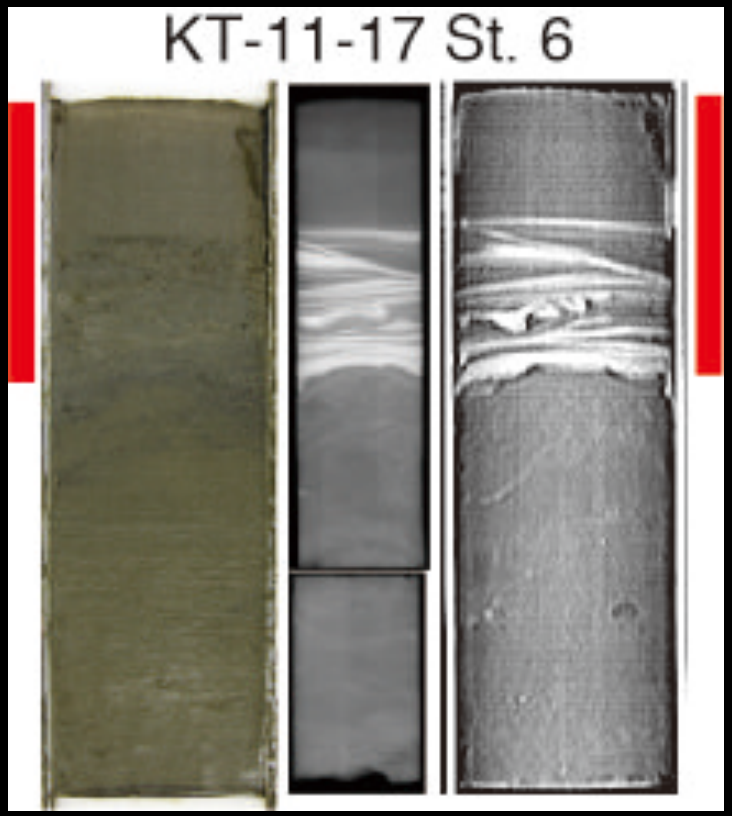


*** Upper turbidite mud deposition from mud pond**

Settling of 134&137-Cs containing particles to sea floor

Only on Sendai Shelf?

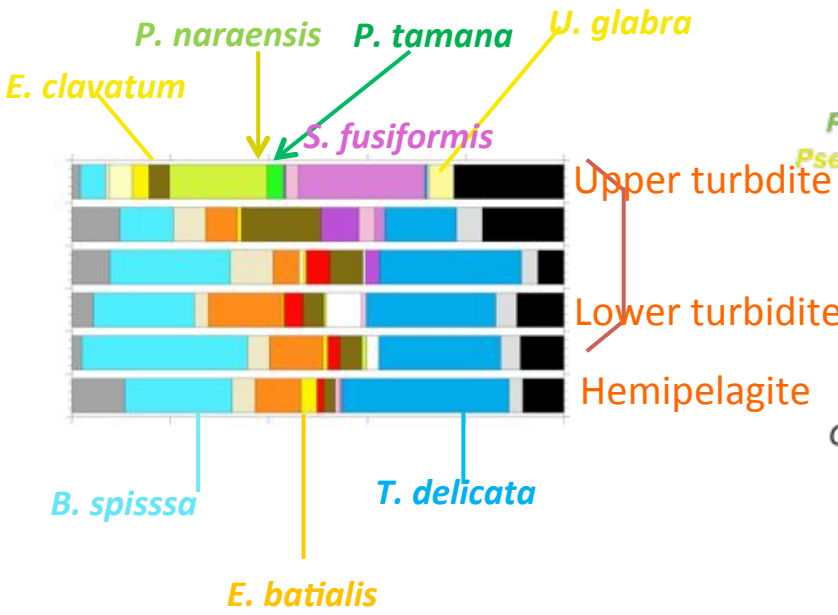


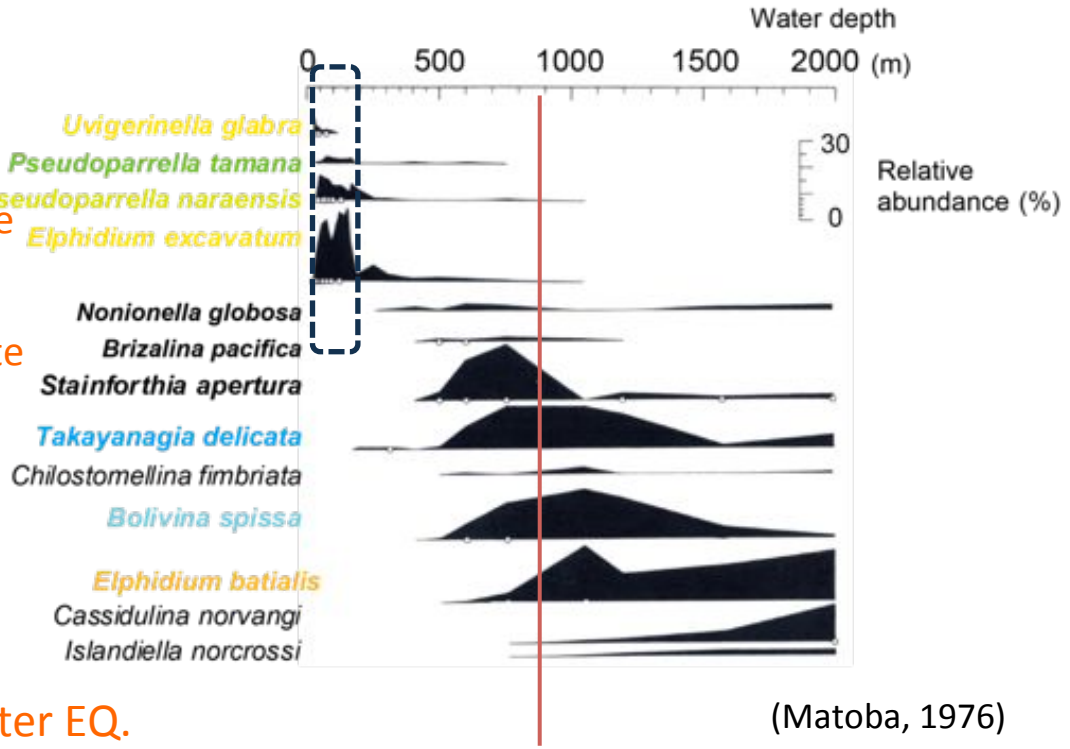


The other Type A event deposits at Sts. 5 and 6

Origin of St. 5 turbidite

S. fusiformis - Continental shelf and upper slope (Gooday and Alve, 2001)





(Matoba, 1976)

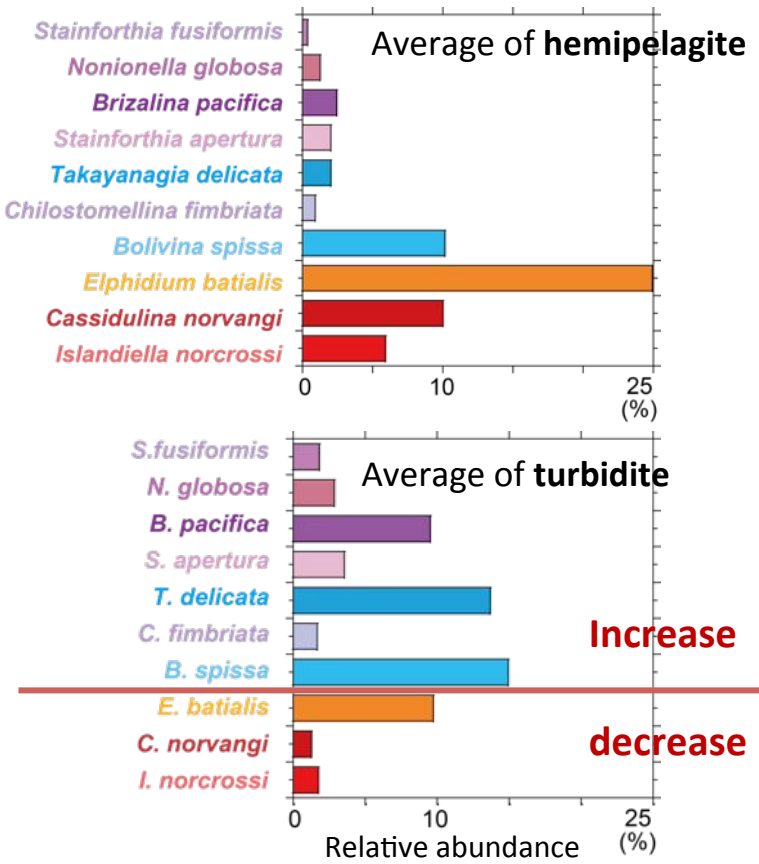
Lower turbidite might be formed just after EQ.
Upper turbidite might be deposited from the different flow.

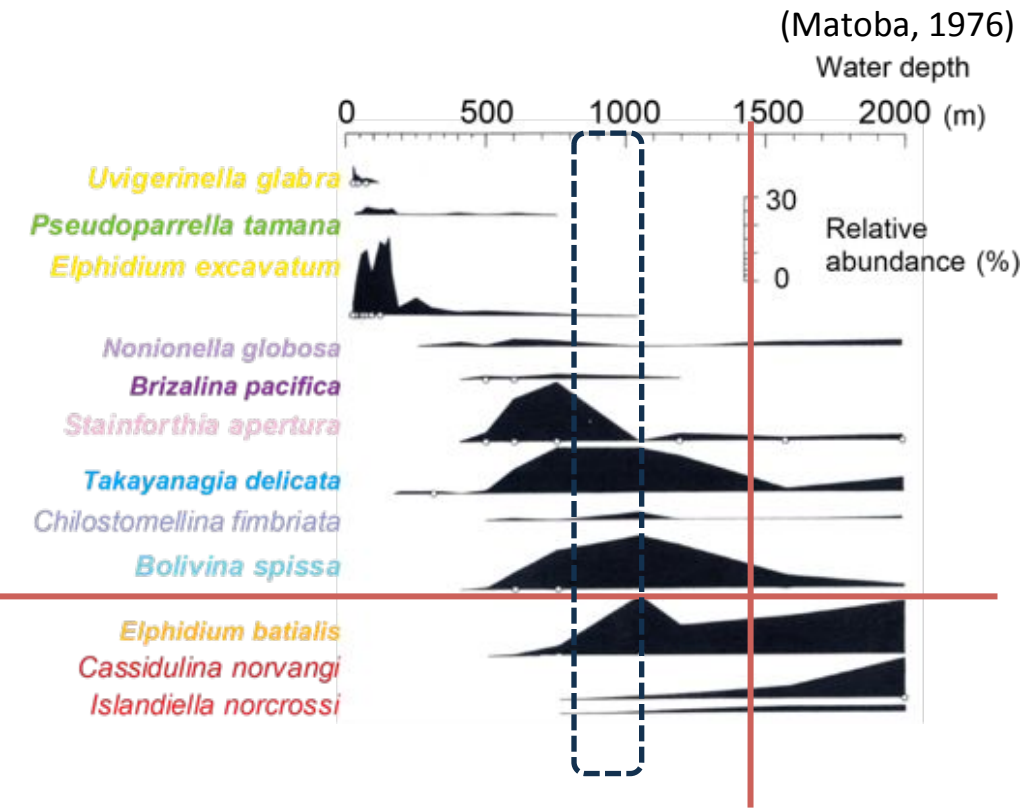
St. 5 (893 m)

- The basal sand is transported from relatively close area.
- On the other hand, partial origin of uppermost clay layer is resuspension in outer shelf

Multi-spatio-temporal generation of turbidity currents!

Origin of St. 6 turbidite





St. 6 (1446m)

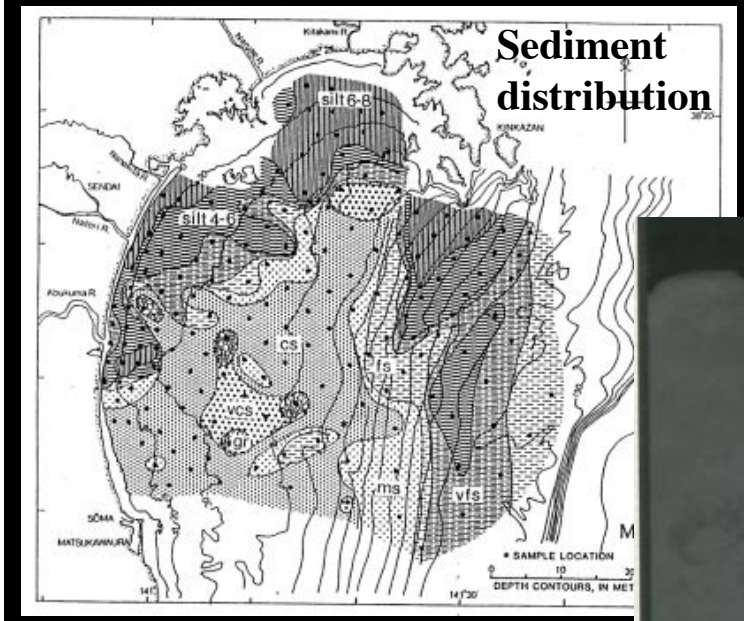
- Increase in species inhabiting relatively shallower water depth.

- The sediment was transported from several-hundred meters shallower water depth (around 900-1000 m ?) than the site.

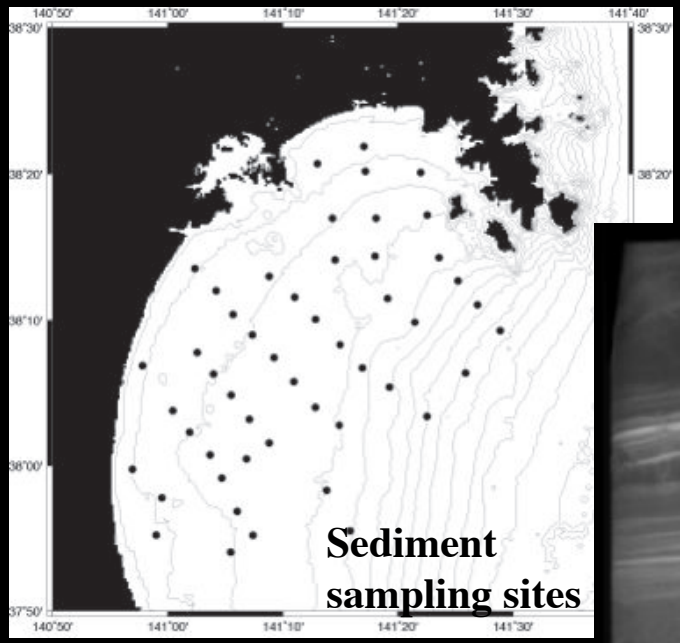
Maybe the similar to lower turbidite at St.5?

Did we find the tsunami influence on the inner-mid Sendai shelf?

Comparison of 1985 and 2012 Sediment Characteristics



Pre

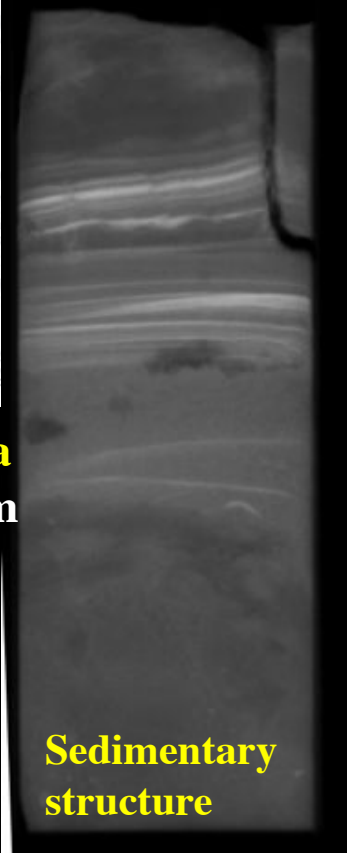


Post

Pre-earthquake/tsunami data
by Saito (1989) etc.

1985 Survey Results
* Surface sediment grain size
* Sedimentary structures
* Sediment geochemistry

Post-earthquake/tunami data
* Selected sites (50 sites) from Saito's survey sites
* Survey at Aug-Sept., 2012
* Analyses (grain size, compositions, geochemistry, structures, etc.) on-going



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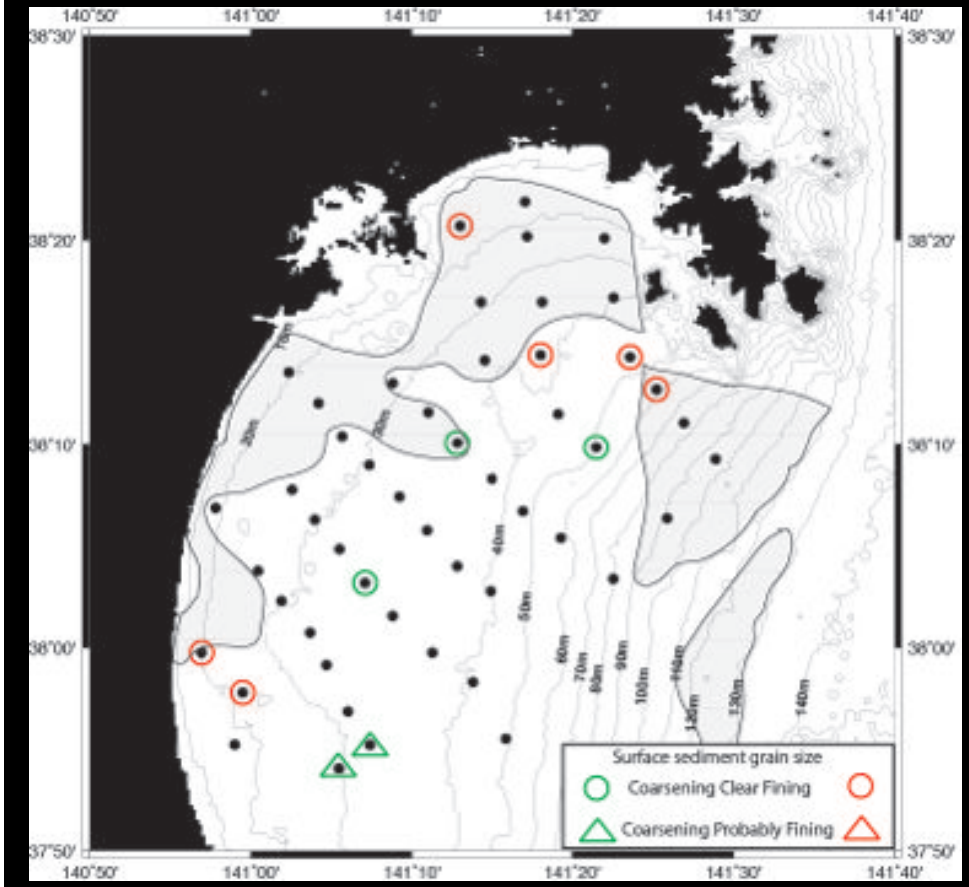
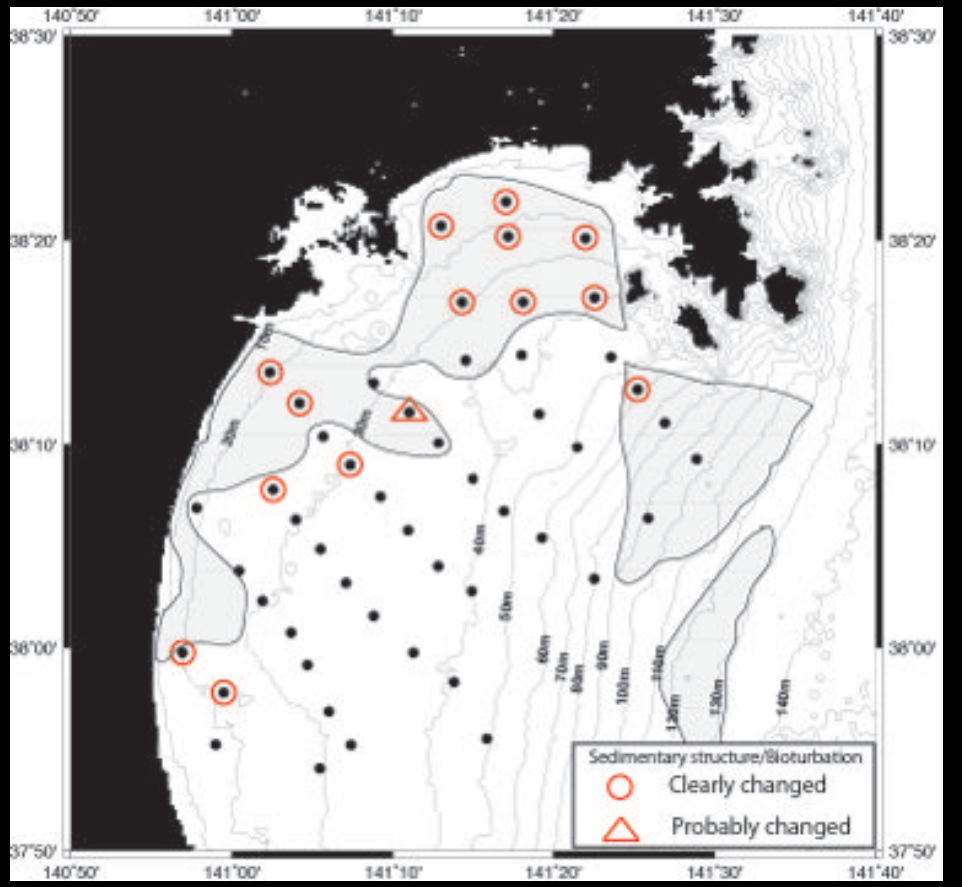


Sediment Grain Size Change



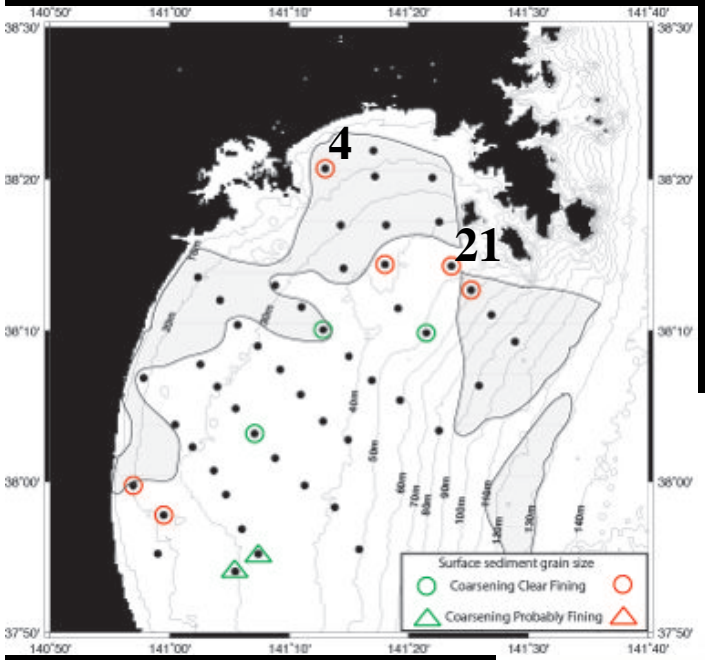
Sedimentary Structures/Bioturbation Change

*** Hatched areas show shelf mud distribution from the 1985 survey by Saito (1989)**

Homogeneous/laminated Mud Deposition

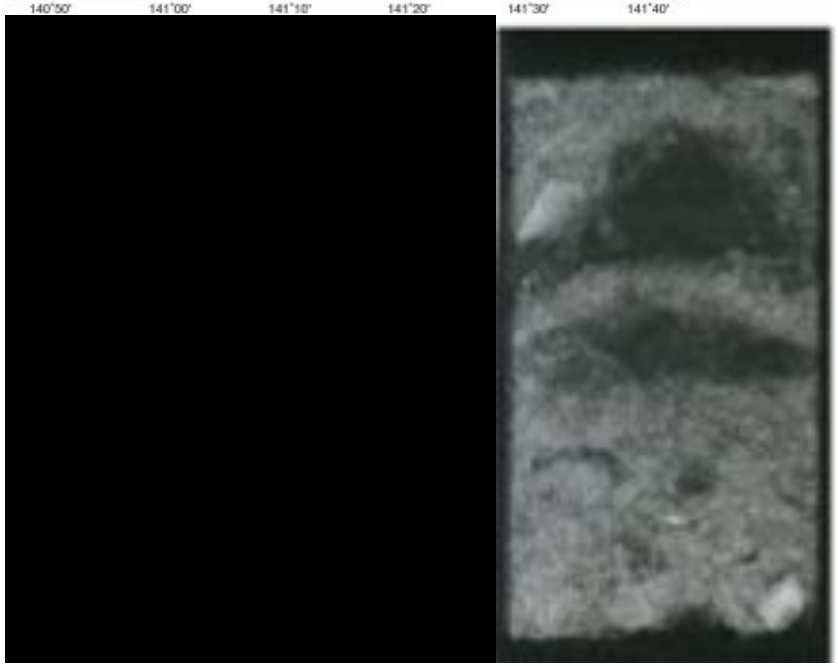
Comparison of lithology and sedimentary structures

* Surface mud has no or little bioturbation



St. 21

1985

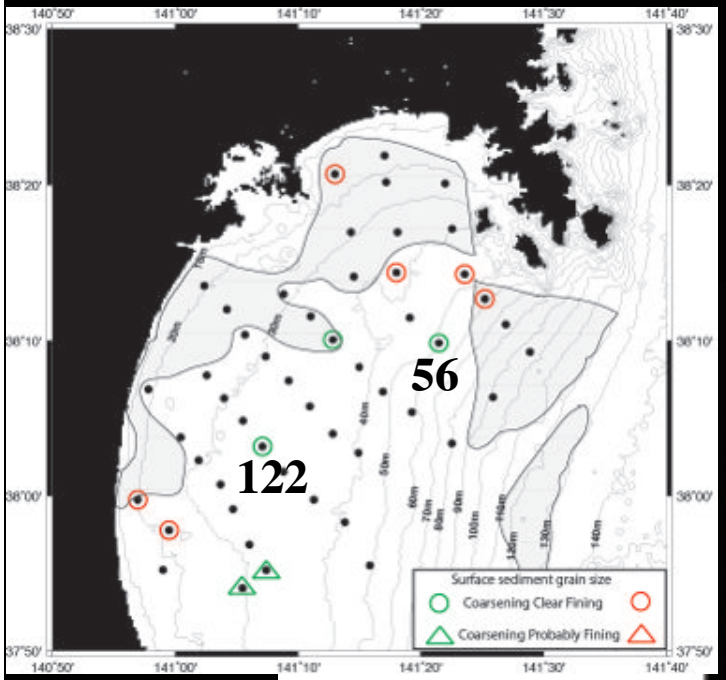


2012

St. 4 1985

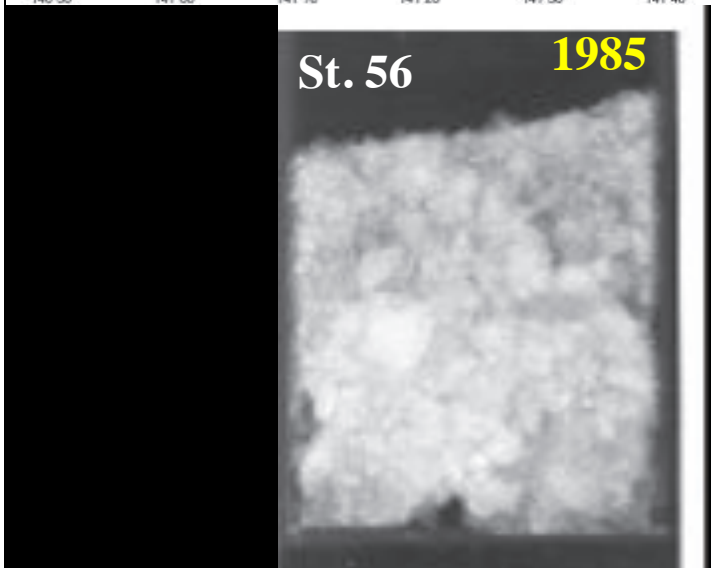
2012

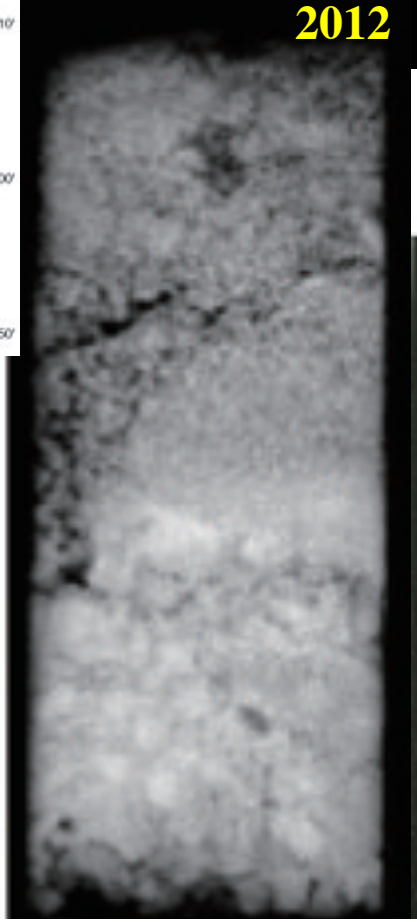
Clean&Well-sorted Fine sand Deposition

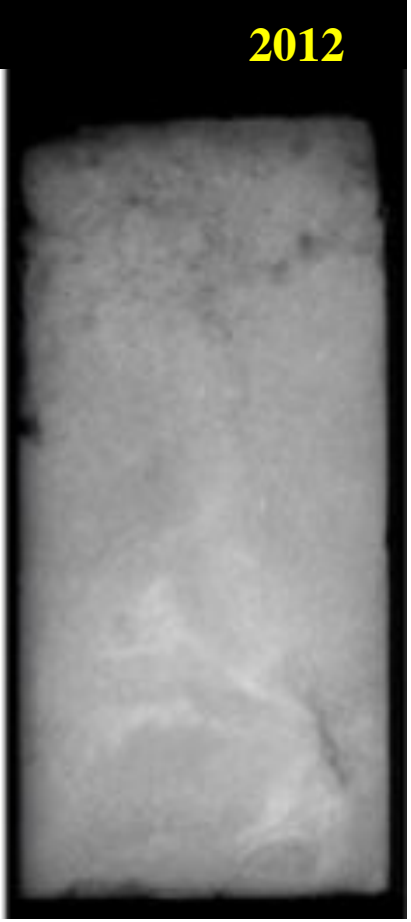


Comparison of lithology and sedimentary structures

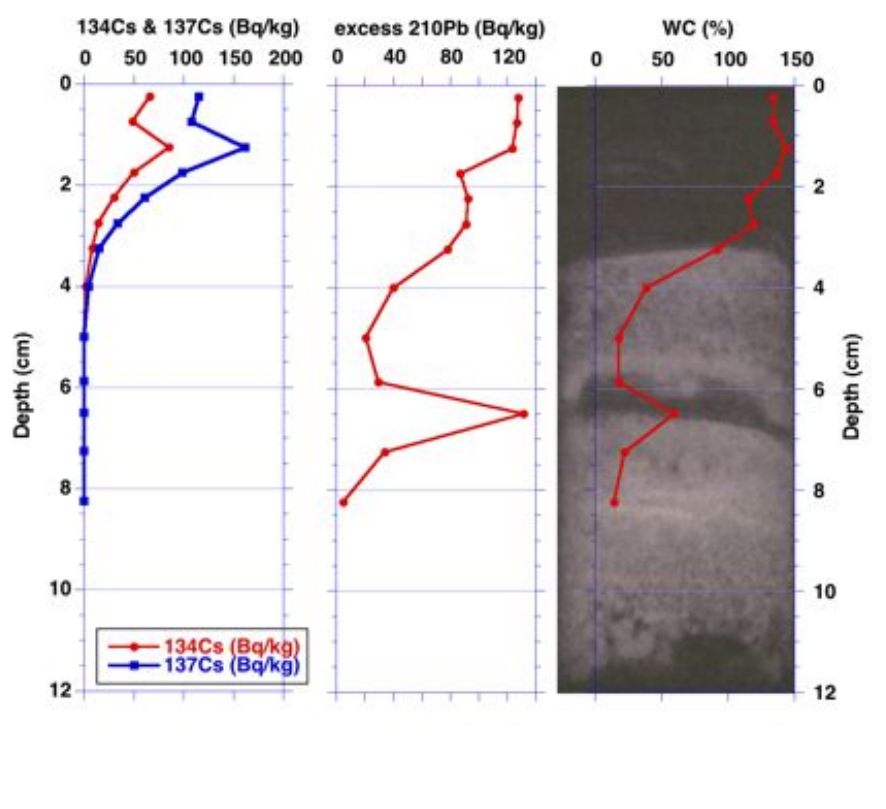
* Clean & well-sorted fine-medium sand covered poorly sorted gravelly coarse sand

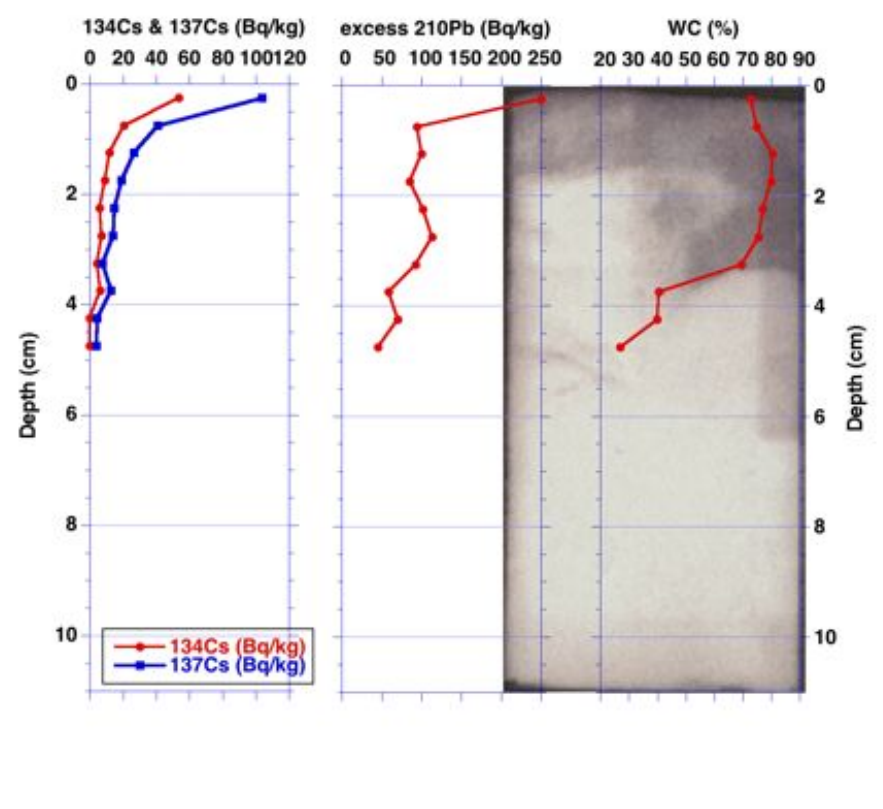






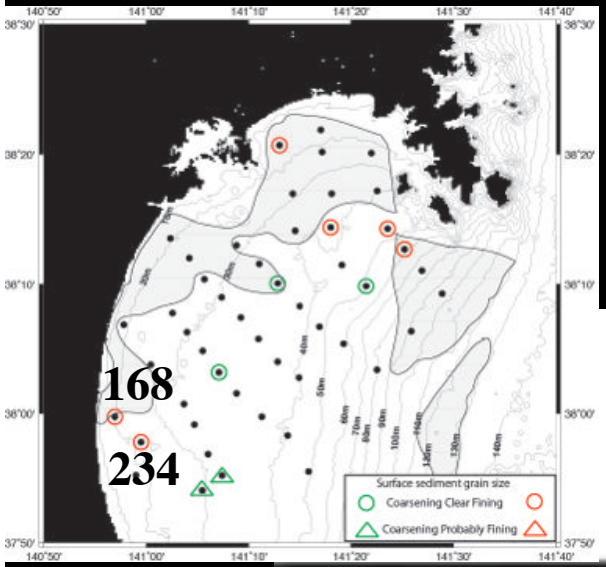
134-&137-Cs profile of Sendai Shelf Event Deposits





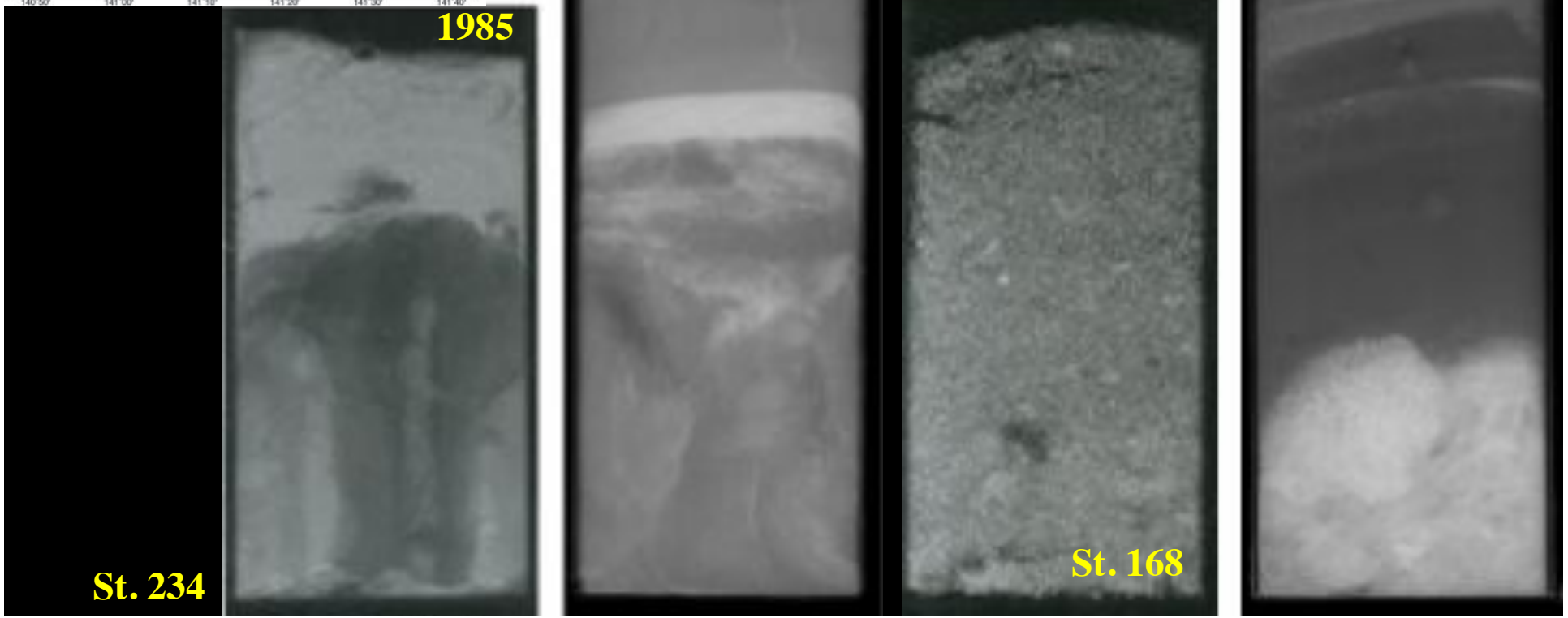
* Homogeneous/laminated mud contains 134- & 137-Cs
* Homogeneous/laminated mud deposited after FNPP No.1
* Highly suspended shelf water maintained at least a few days, maybe a few weeks or a few tens days

Tsunami vs (Post-tsunami) Storm?



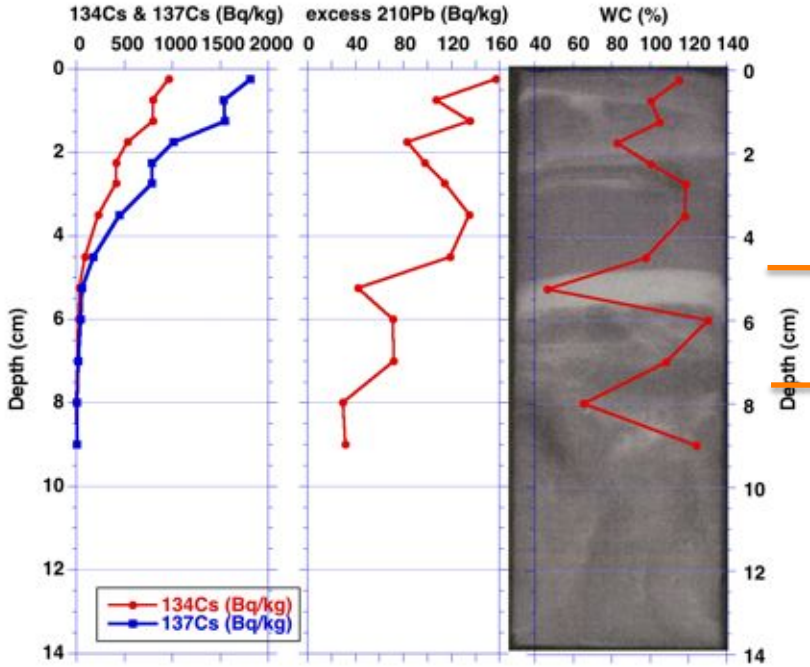
* Clear sediment change, but really tsunami-related?
* We should consider storm/flood events after the 2011 EQ/tsunami

Up-ward coarsening,
Sharp top boundary,
Internal erosional surfaces
= Hyperpycnite?



Sendai Inner Shelf

St.234 (23 m)

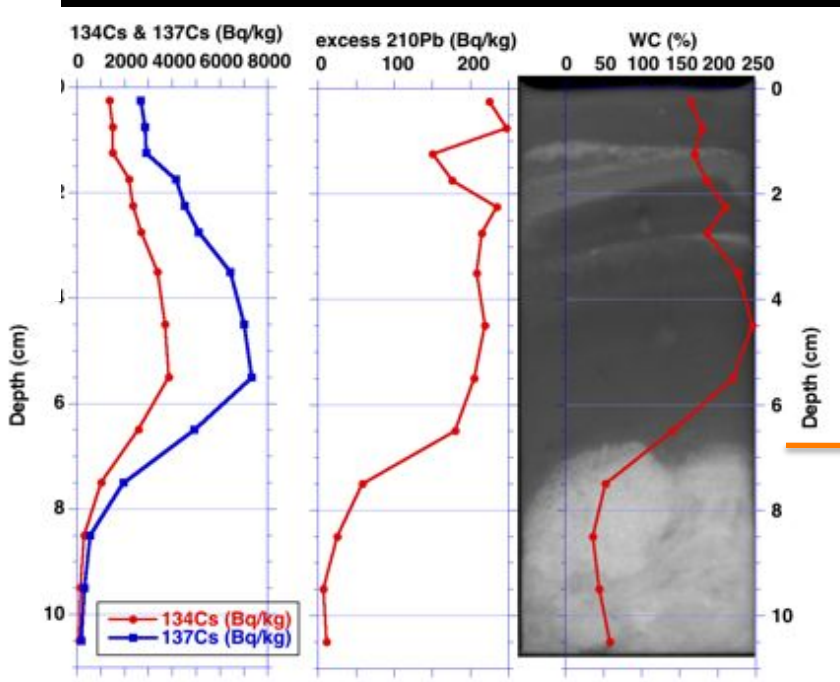


Post-tsunami Flood

Tsunami rewoking?

Pre-tsunami&earthquake

St.168 (26 m)



Post-Tsunami Flood

Tsunami Re-working?

Preliminary Summary

- The 2011 earthquake/tsunami-related event deposits were widely recognized from coast to trench, and had wide variation in sedimentary structures, sediment composition and thickness.
- Multiple generation of turbidity currents was estimated. Tsunami might be a triggering mechanism.
- Surface sediments on inner-mid shelf of Sendai Bay might be resuspended and/or transported by the 2011 tsunami.
- Large speed and friction velocity of tsunami might contribute shelf mud resuspension.
- Resuspension of shelf mud might form the turbid shelf water, and homogeneous/laminated mud on shelf.
- Resuspension of shelf mud might generate turbidity currents, and form turbidites further offshore.
- Transportation of shelf sand might form massive clean sand layer on mid shelf terrace.