Emplacement and Post-Depositional Alteration of Sedimentary Event Layers: Lessons from the Eel River Margin*

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Abstract

The sedimentary record of active continental margins is created by a complex set of physical and biological processes that occur over a broad range of time and space scales within both the terrestrial and marine realms. Despite (or perhaps because of) this complexity there is much to be gained from a careful reading of margin stratigraphy because it is here that the fidelity of the coupled land-ocean record is likely to be greatest. On northern California's Eel River margin, intense rainfall events result in the episodic discharge of relatively large fine-grained sediment loads (>10's of billion kg/d) into a receiving basin characterized by intense wave events. Variation in the phasing of the discharge and wave events results in the formation of several types of sedimentary event layers, including tempestites, hyperpycnites and deposits of wave-supported gravity flows. Several interrelated factors lead to significant variability in the post-depositional fate of these deposits. First, layer thickness has a first-order impact on the preservation of event deposits, with thin (< 1 cm) tempestites of the mid to outer shelf having little chance of preservation. Second, a decrease in bioturbation intensity with increasing water depths means that hyperpycnites, which are deposited on the upper slope, have a higher preservation potential than deposits formed by wave supported gravity flows. Third, the sequential timing and frequency of events imparts a stochastic nature to margin stratigraphy, such that high magnitude events may not necessarily have the highest preservation potential. Examples, mainly from the Eel margin, will be provided that illustrate these diverse concepts.

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Emplacement & Post-Depositional Alteration of Sedimentary Event Layers: Lessons from the Eel River Margin

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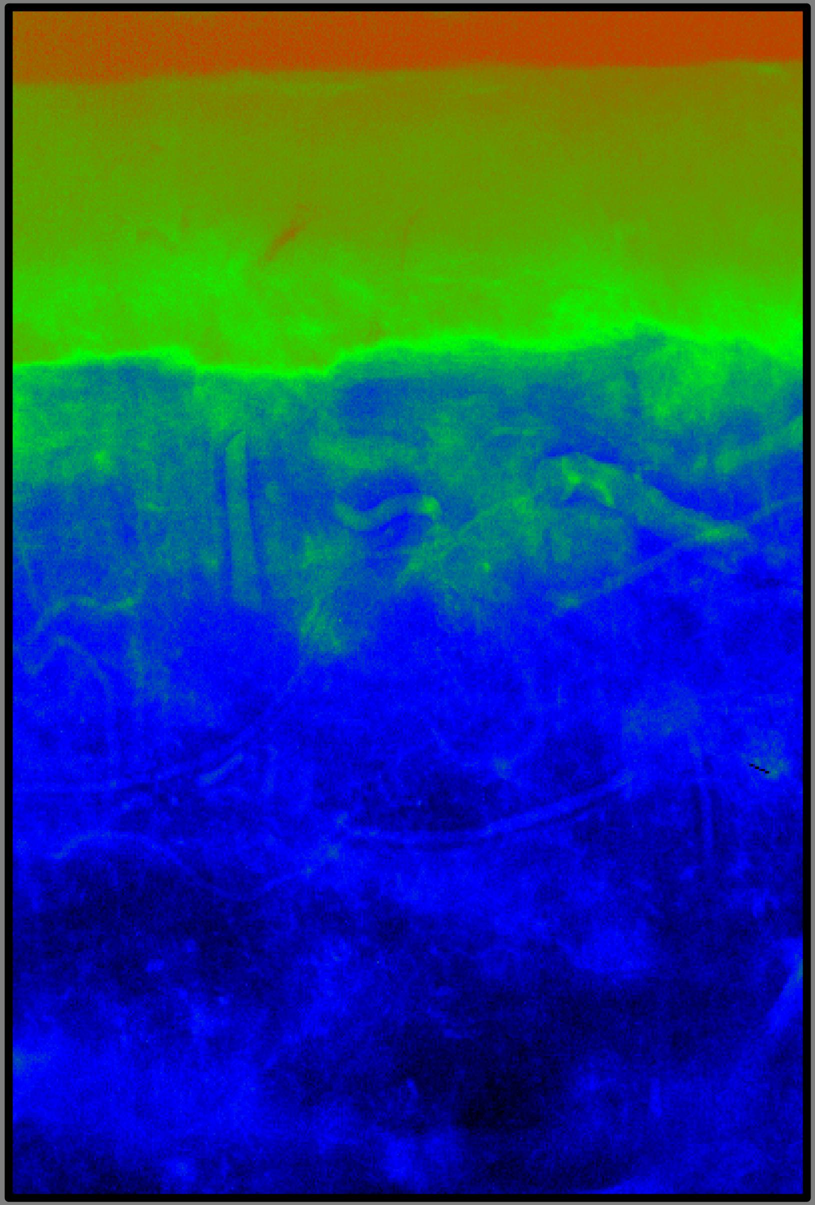
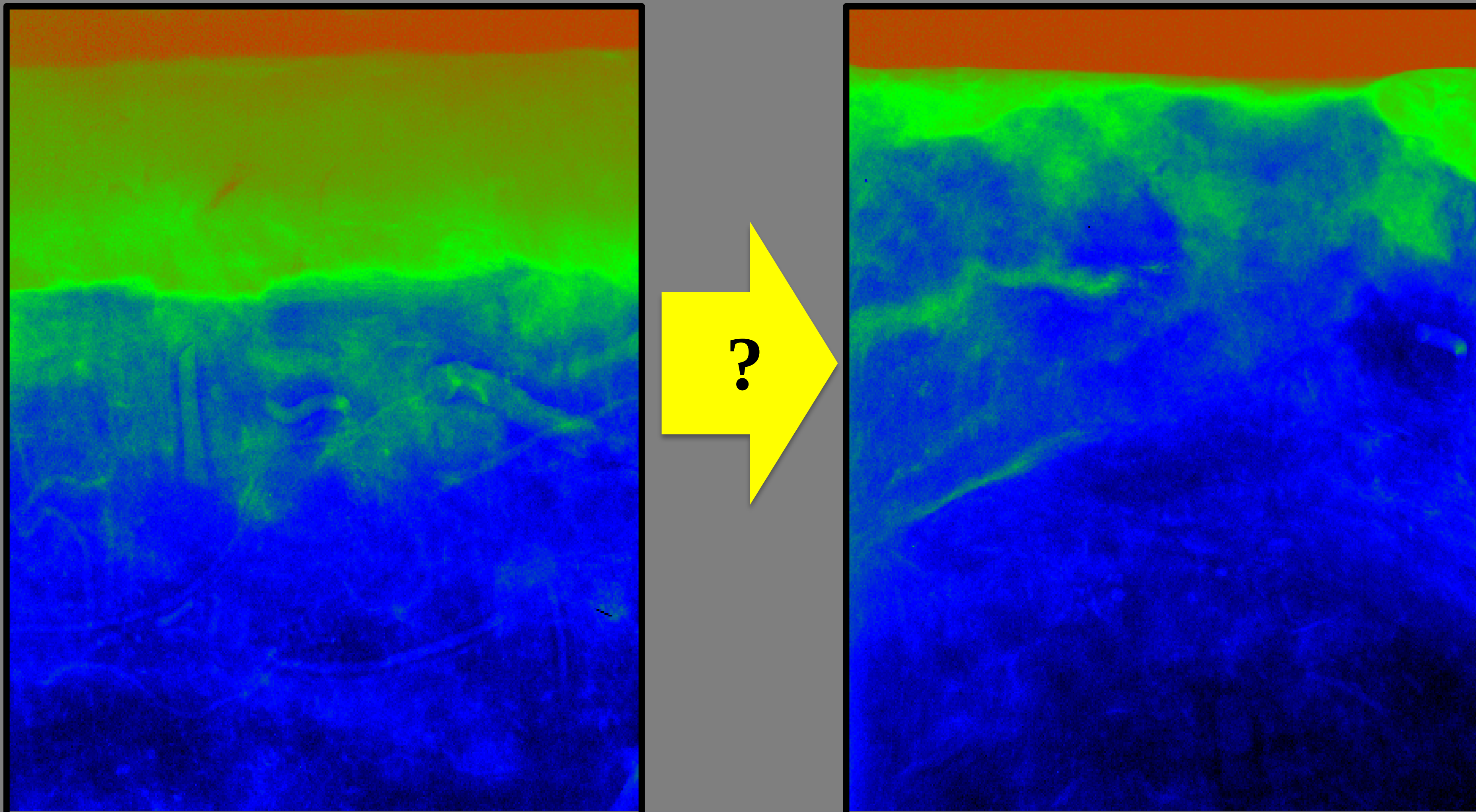


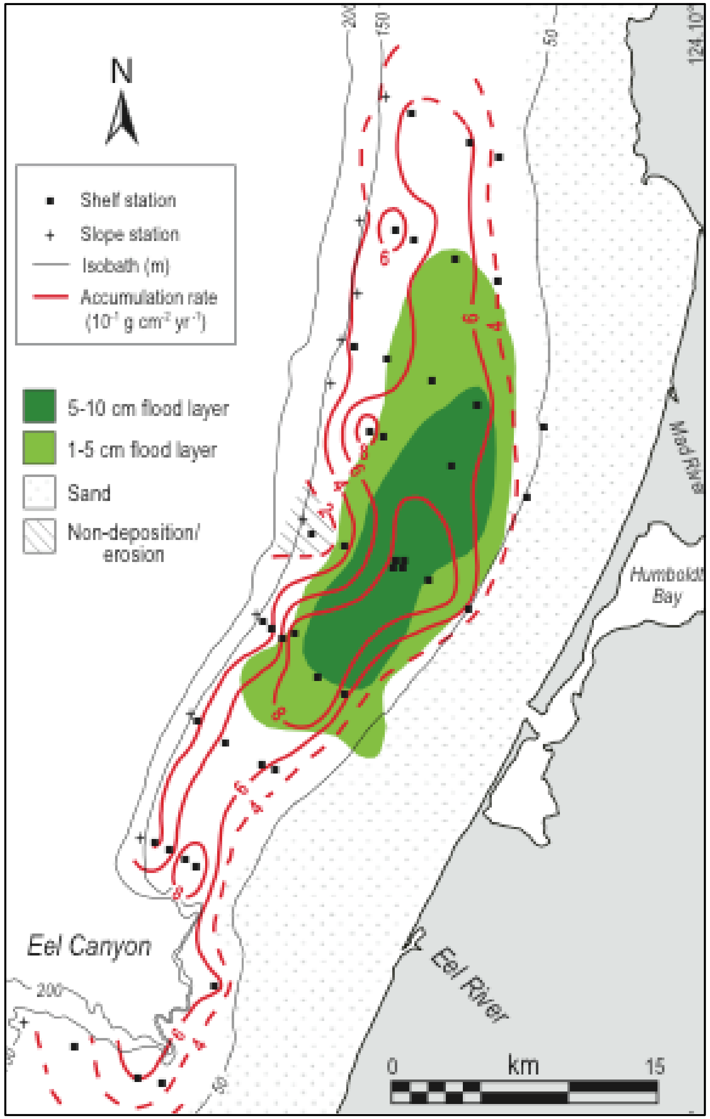


- Eel River margin
- Governing variables
- Questions & (partial) answers

STRATAFORM - Eel River Margin (N California)

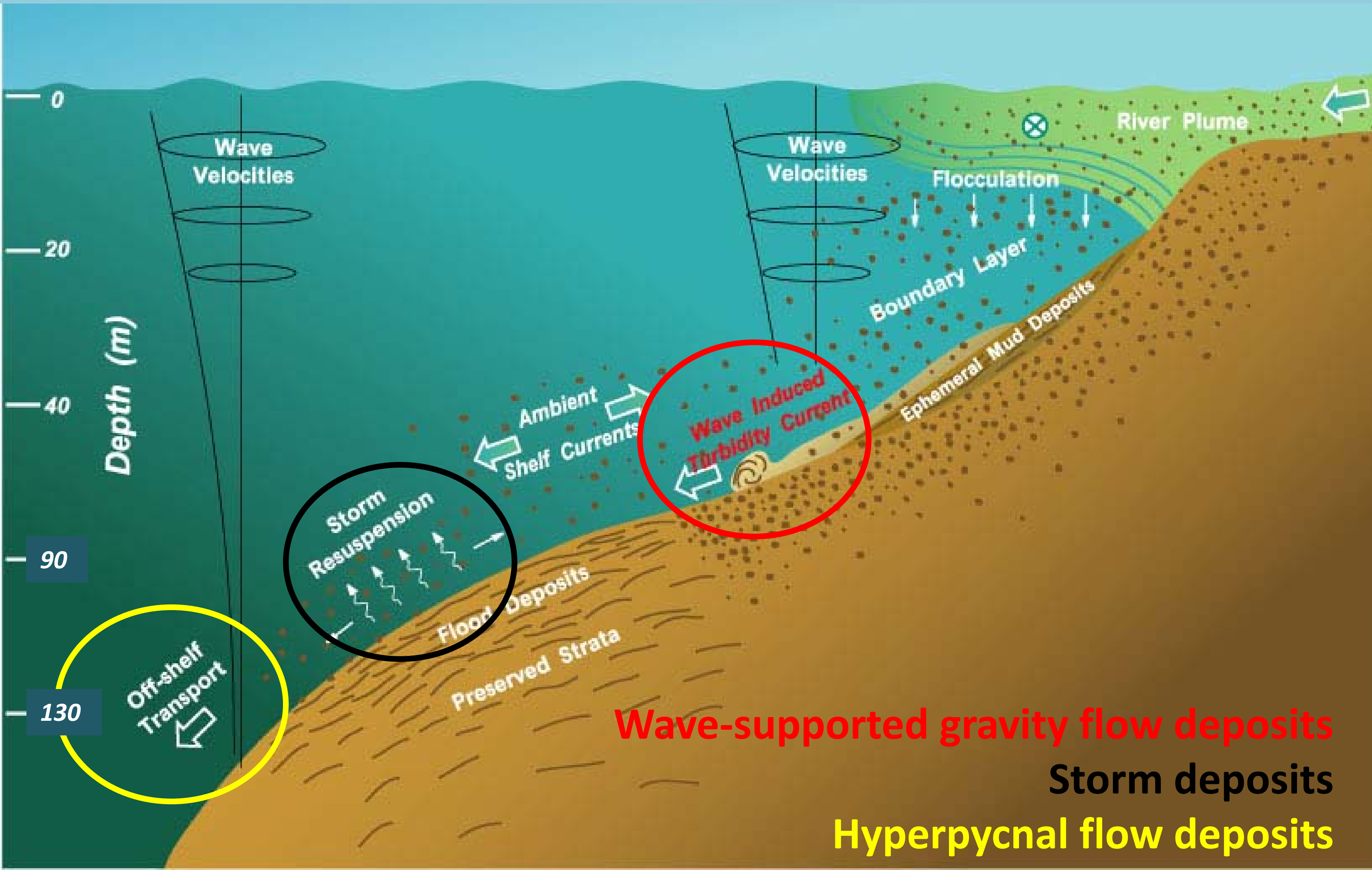
- ER basin: <10^4 km^2
- Sediment load: 1.5-2 x 10^9 kg/y
- Therefore, high yield & concentration
- Floods (>40x base flow) in 1955, 1964, 1974, 1986, 1995 & 1997 (2006)
- Highly energetic wave climate
- Seasonal upwelling (org-C flux)

An excellent natural laboratory to study signal formation, alteration & preservation



Sommerfield et al (2007)

Sediment Transport Events on the Eel Margin

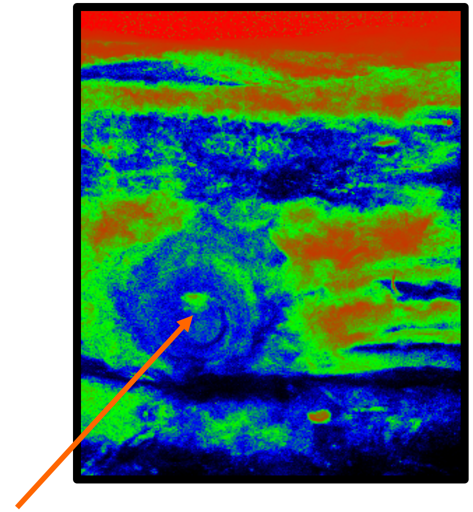


Wave-supported gravity flow deposits

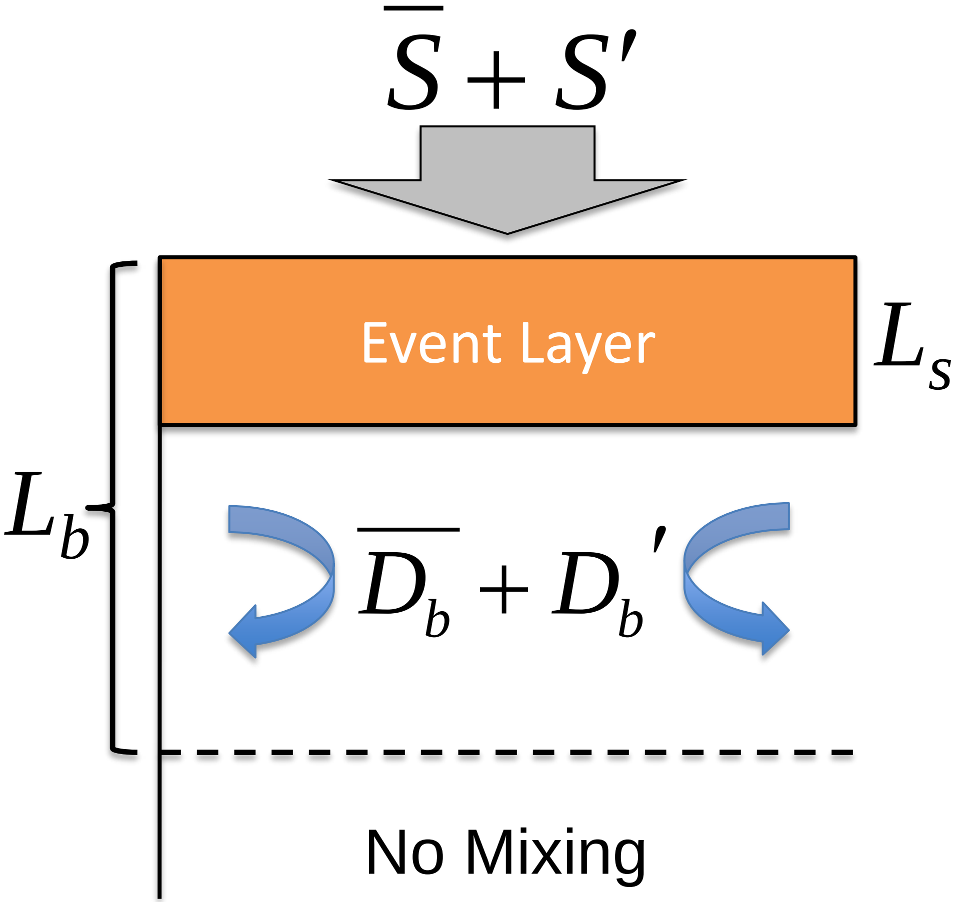
Storm deposits

Hyperpycnal flow deposits

What determines signal alteration & preservation?



Echinoid destroying flood bed



Transit time (T_t)
vs.
Destruction time (T_d)

from Nittrouer & Sternberg (1981); Wheatcroft (1990); Wheatcroft & Drake (2003)

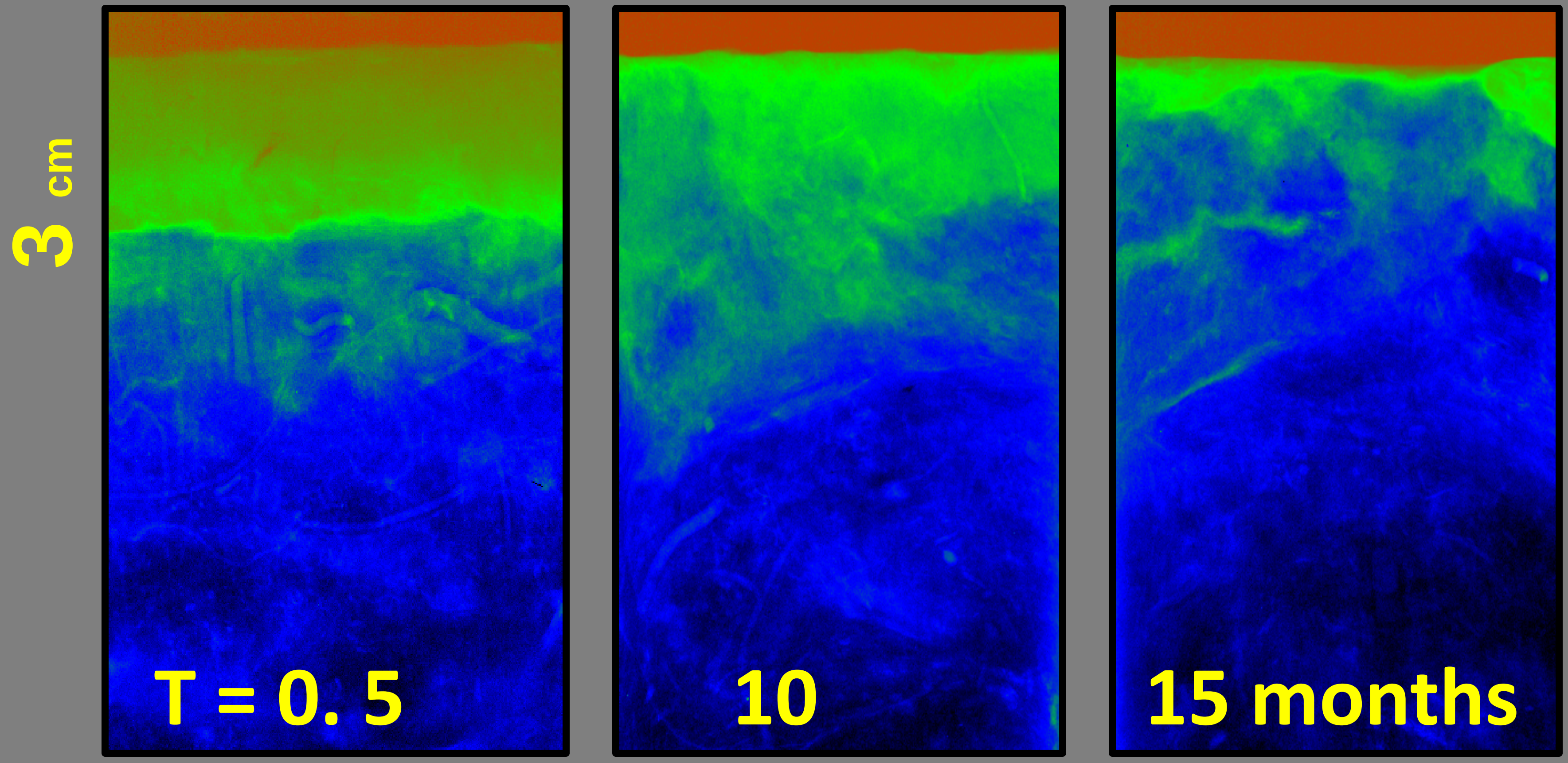
- How does event layer thickness (L_s) affect alteration & preservation?

- Does destruction time (T_d) vary as a function of 'signal type'?

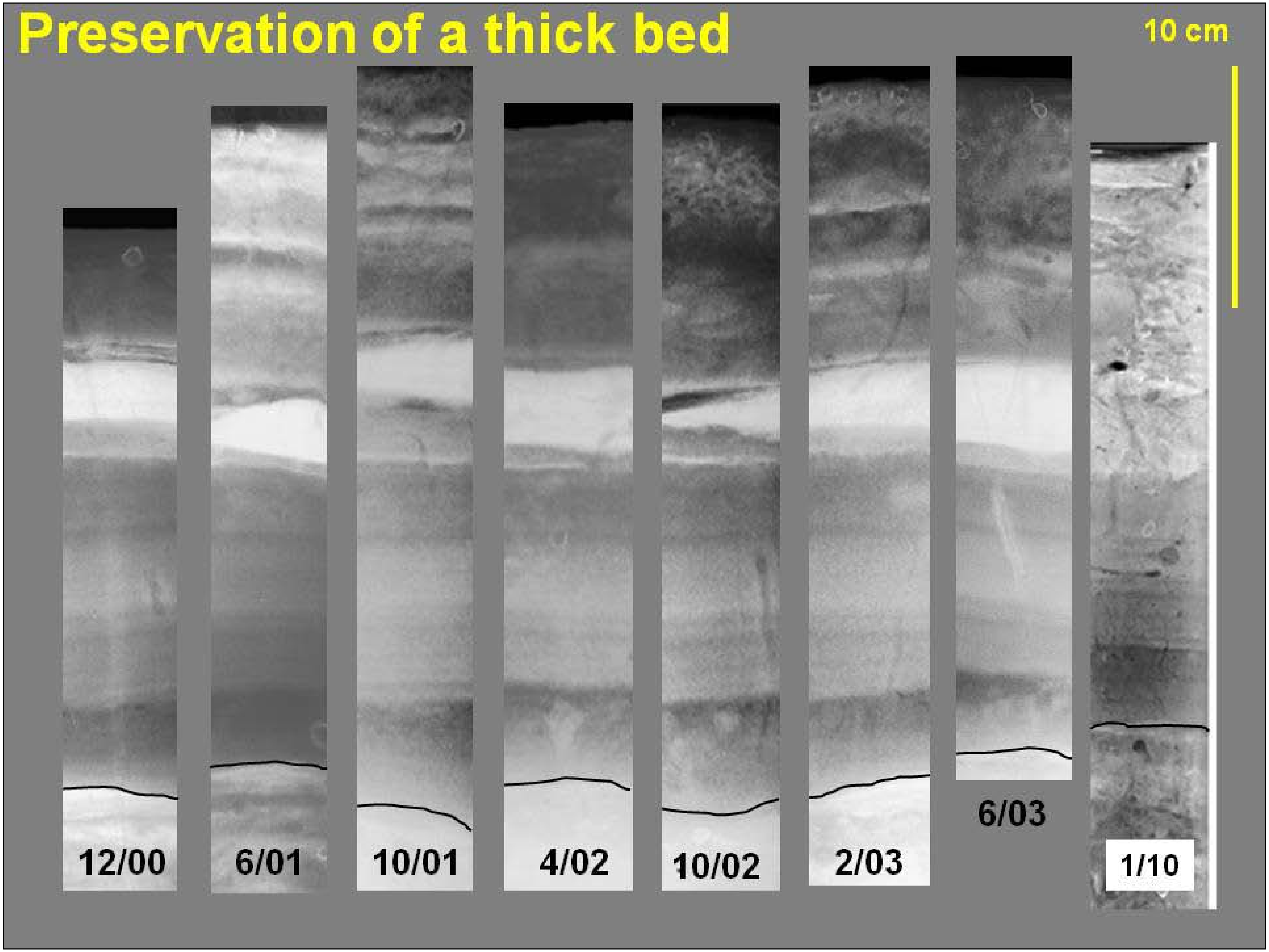
- Is bioturbation intensity decreased by emplacement of event beds?

- Can we predict *a priori* the preservation of event layers?

Transit Time
$= (L_b - L_s)/S$

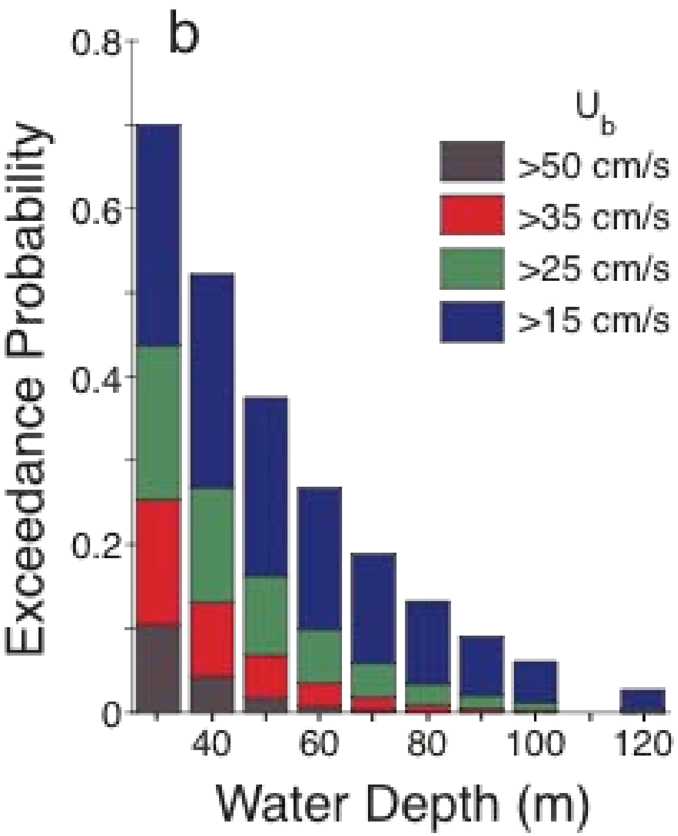


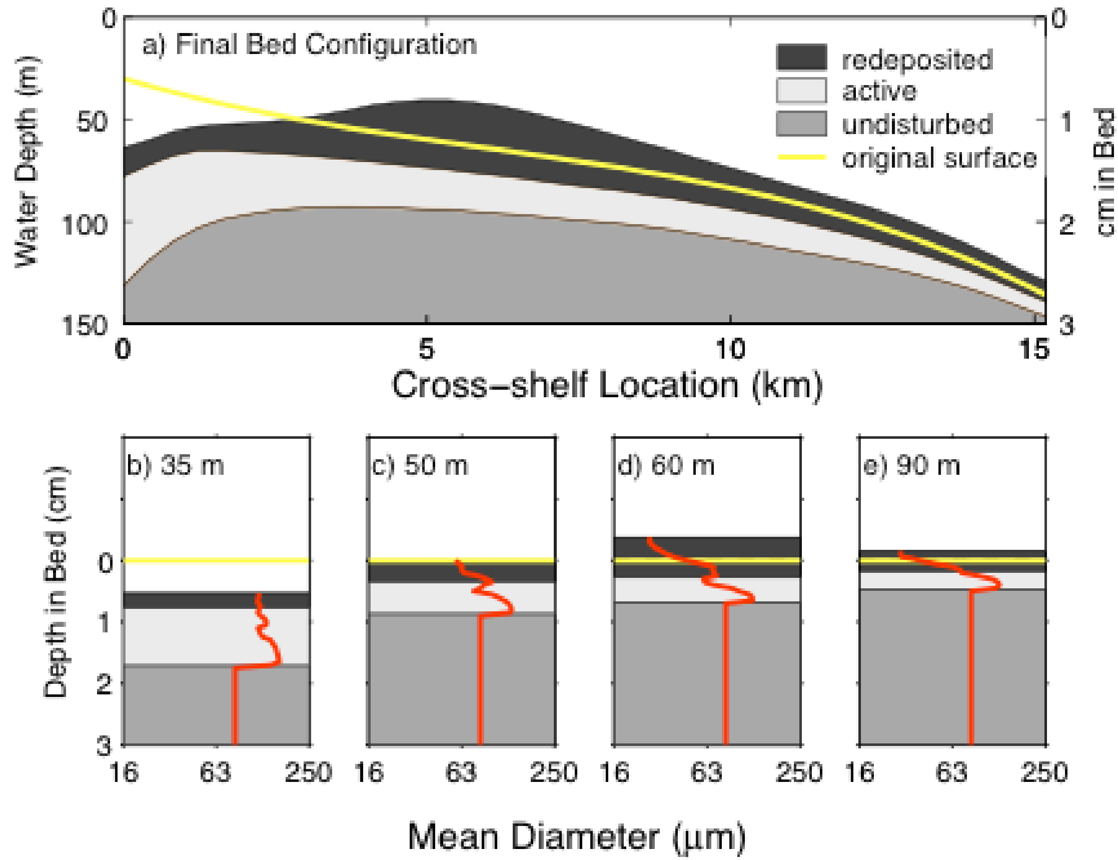
Thin beds are destroyed



Notes by Presenter: Event layer thickness is important because it shows up in the numerator of transit time – in the limit if Ls > Lb, then some fraction of the signal is preserved no matter what the mixing intensity is.

Because storm deposits are <u>always</u> thin they have an extremely low preservation potential

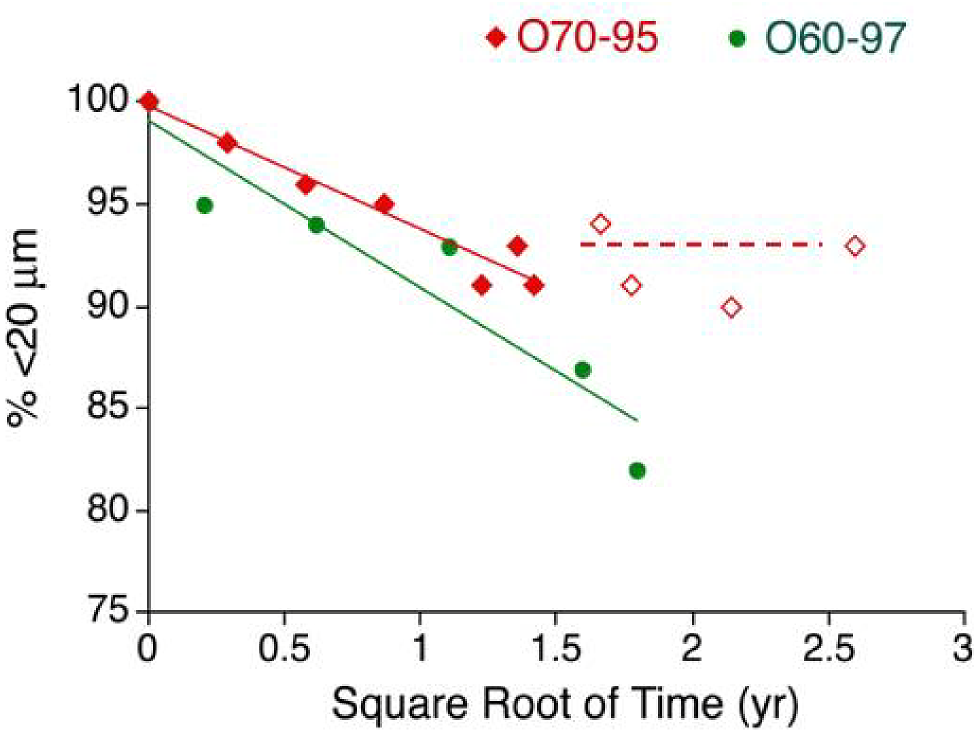


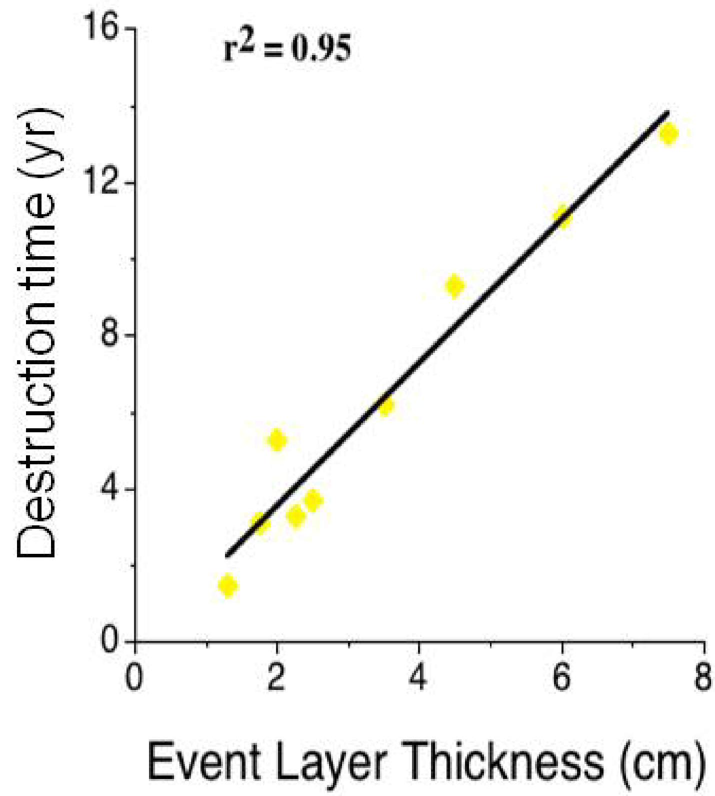


Wiberg (2000); Harris & Wiberg (2001; 2002)

Destruction time of a textural signal

- Grain size of new flood layers all <20 μm
- Repeat vertical profiles yields a time series of sediment texture
- When bed has <20% of the <20 μm fraction it is taken to be destroyed



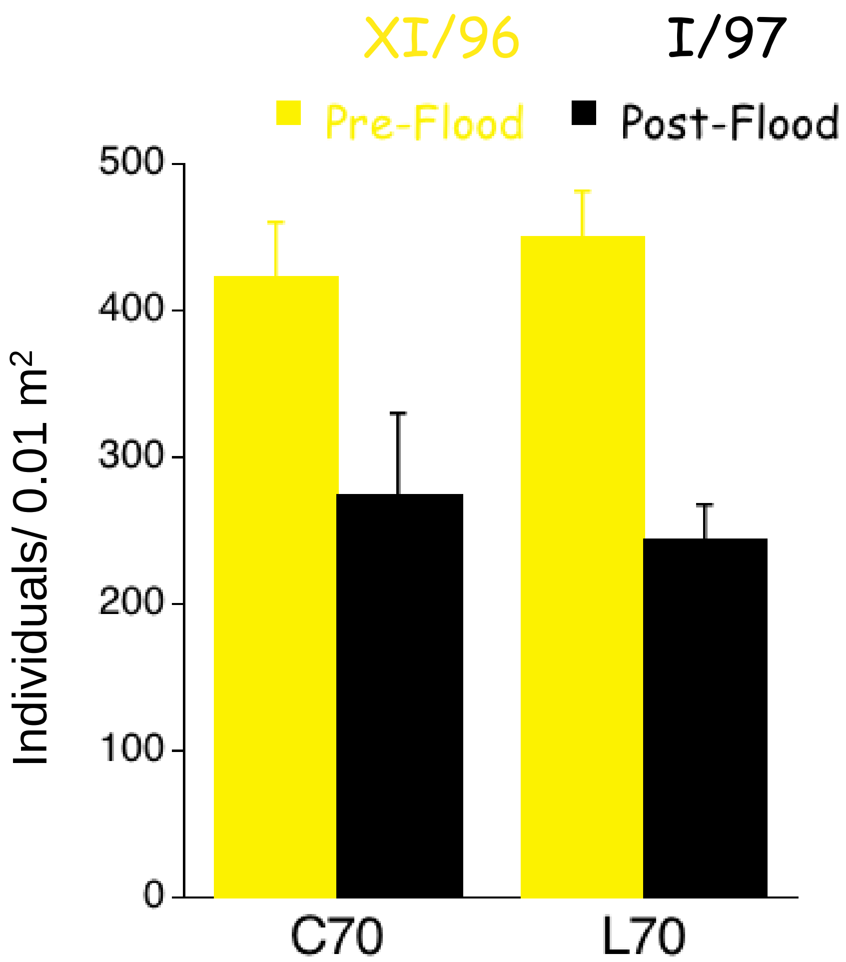


Wheatcroft & Drake (2003)

Notes by Presenter: Storm deposits, even those formed by the ‘perfect storm’, are always thin - < cm.

Click to View Notes by Presenter

Macrofaunal response to the 1997 flood



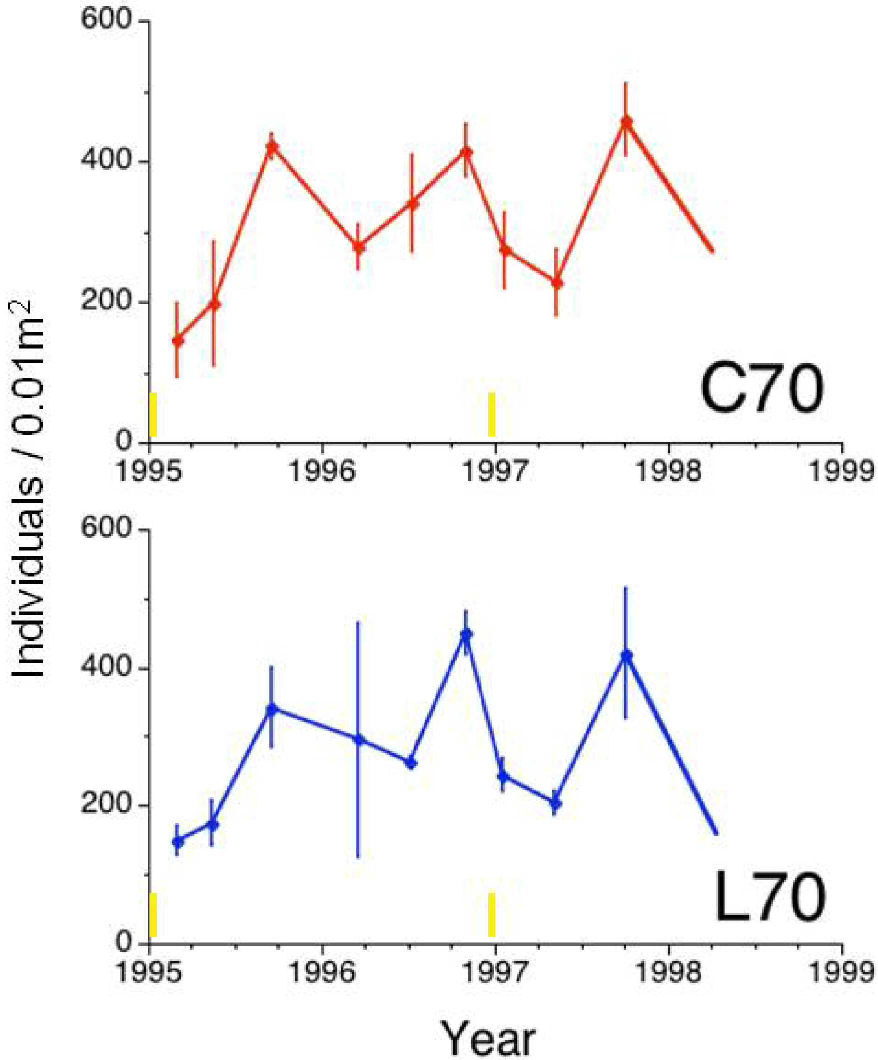
- Clear mortality at both stations
  - C70: 3 cm
  - L70: 6 cm
- True for most taxa & functional groups
- Significant disturbance?

Wheatcroft (2006)

Notes by Presenter (for previous slide):

Now, I mentioned that destruction time depends on the signal of interest – here is an example involving grain size. On the Eel river shelf, flood deposits start out with a grain size that is almost all < 20 micrometers. Through repeat sampling, Dave Drake was able to quantify grain size in the same bed, as it was bioturbated. Shown here are results from 2 beds – one created in Jan 95 at a 70 m site, the other created in Jan 97 at a 60 m site. In both cases the decrease in the concentration of the <20 um falls off as a linear function of the square root of time. Note that the near constant grain size of the Jan 95 bed after 1.5 years is due to the fact that it was buried by the 1997 deposit. To estimate destruction time we extrapolated the line to a <20 um concentration of 20% (which piston core data showed was the background grain size). This results in the plot shown at right, where once again destruction time scales directly with signal thickness.

Longer time series…

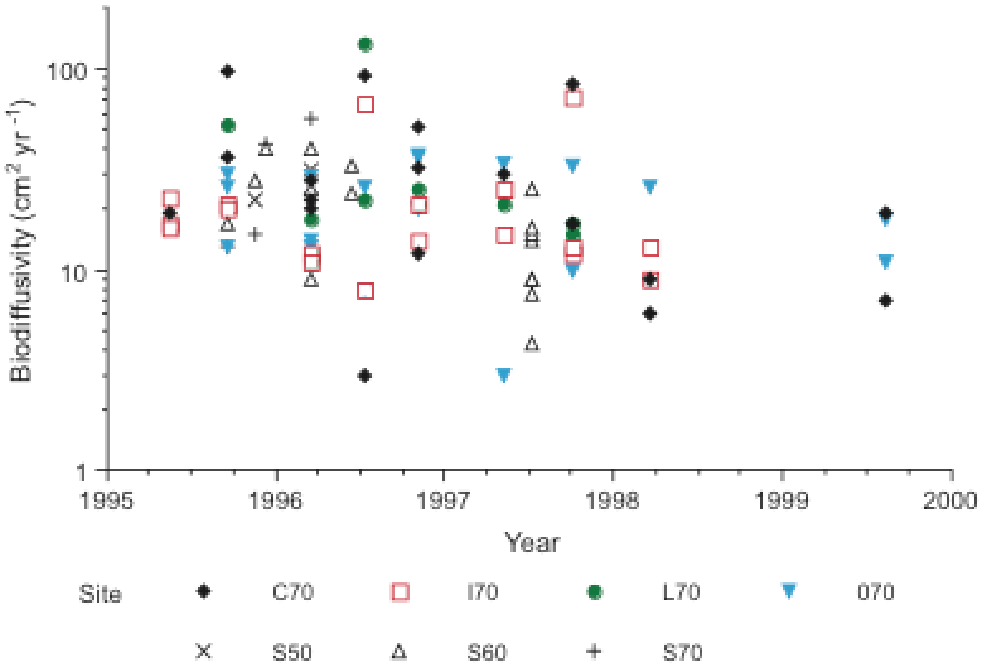


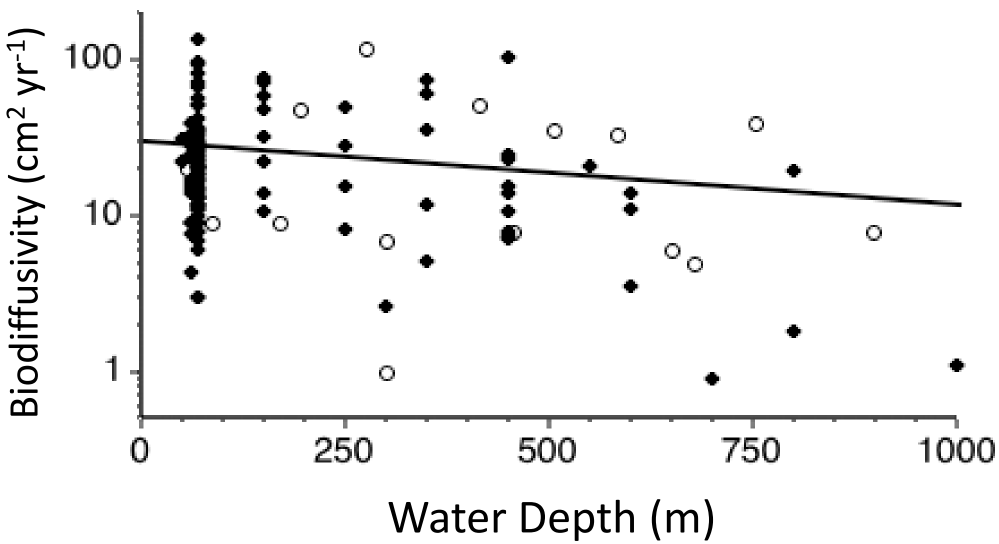
- Just seasonality!
  - Spring: recruitment
  - Summer: growth
  - Fall: maximal numbers
  - Winter: mortality
- Insensitive to floods

Wheatcroft (2006)

Notes by Presenter: Intuitively we would expect there to be a negative feedback between deposition and biological mixing intensity, as these flood beds are potential disturbance agents.

Bioturbation

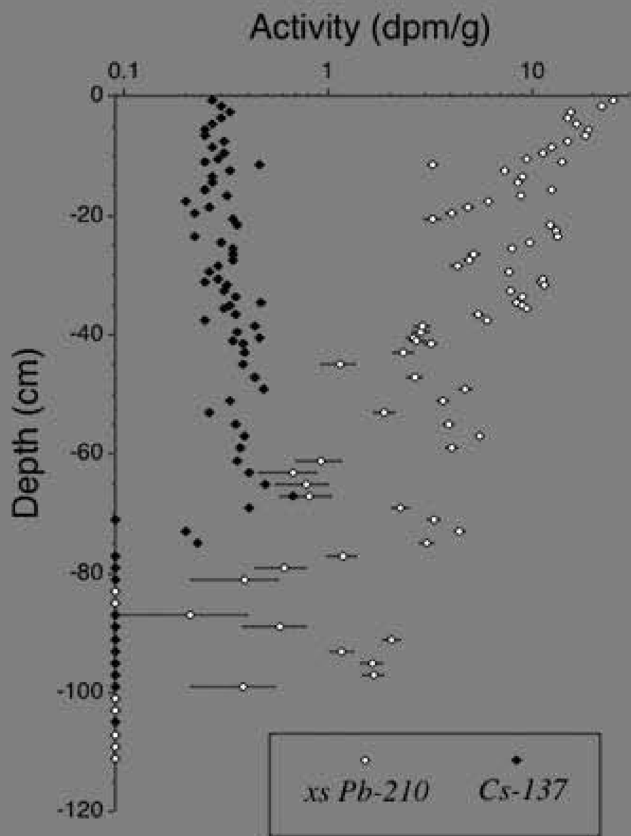




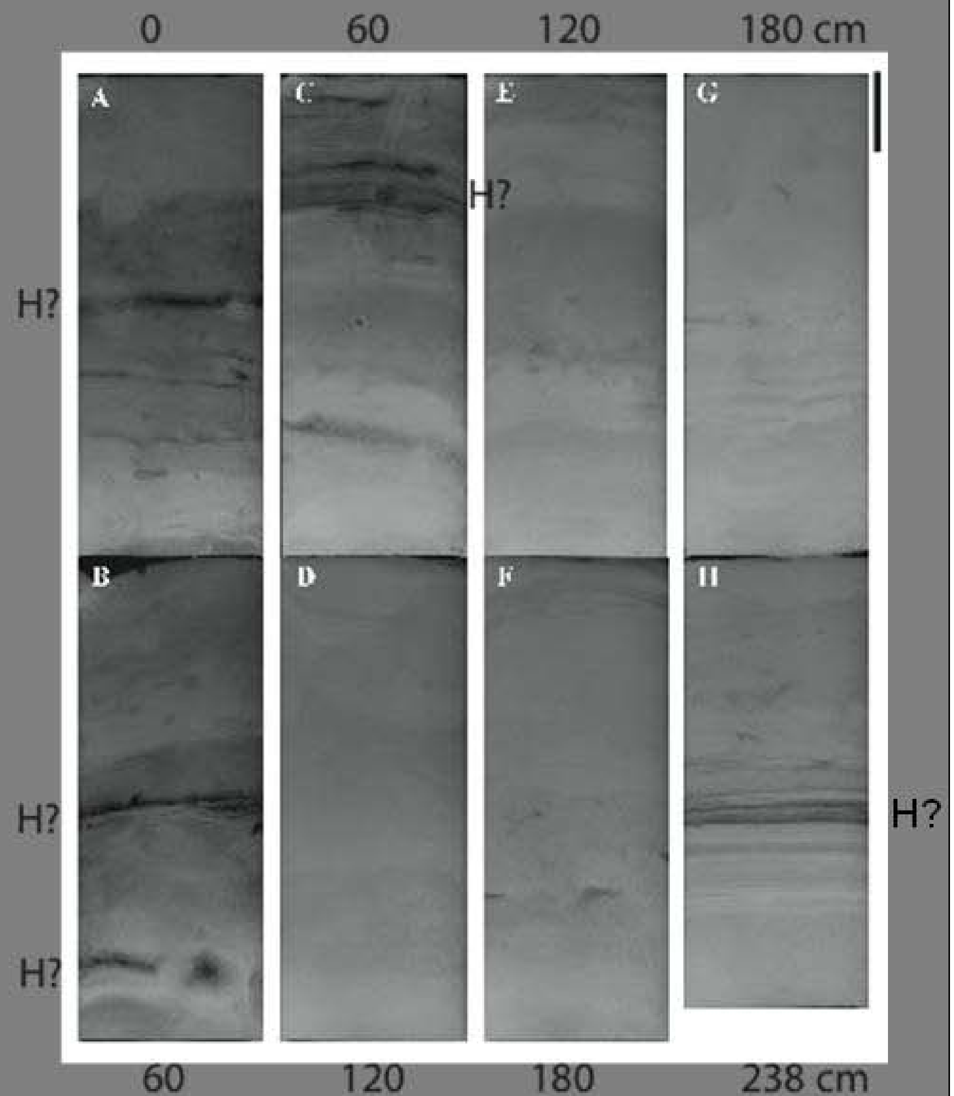
- No evidence for a suppression of mixing intensity post flood
- Mixing intensities are generally high on the Eel margin
- Hint of a decrease with water depth

Wheatcroft et al. (2007)

Preservation of slope hyperpycnites?



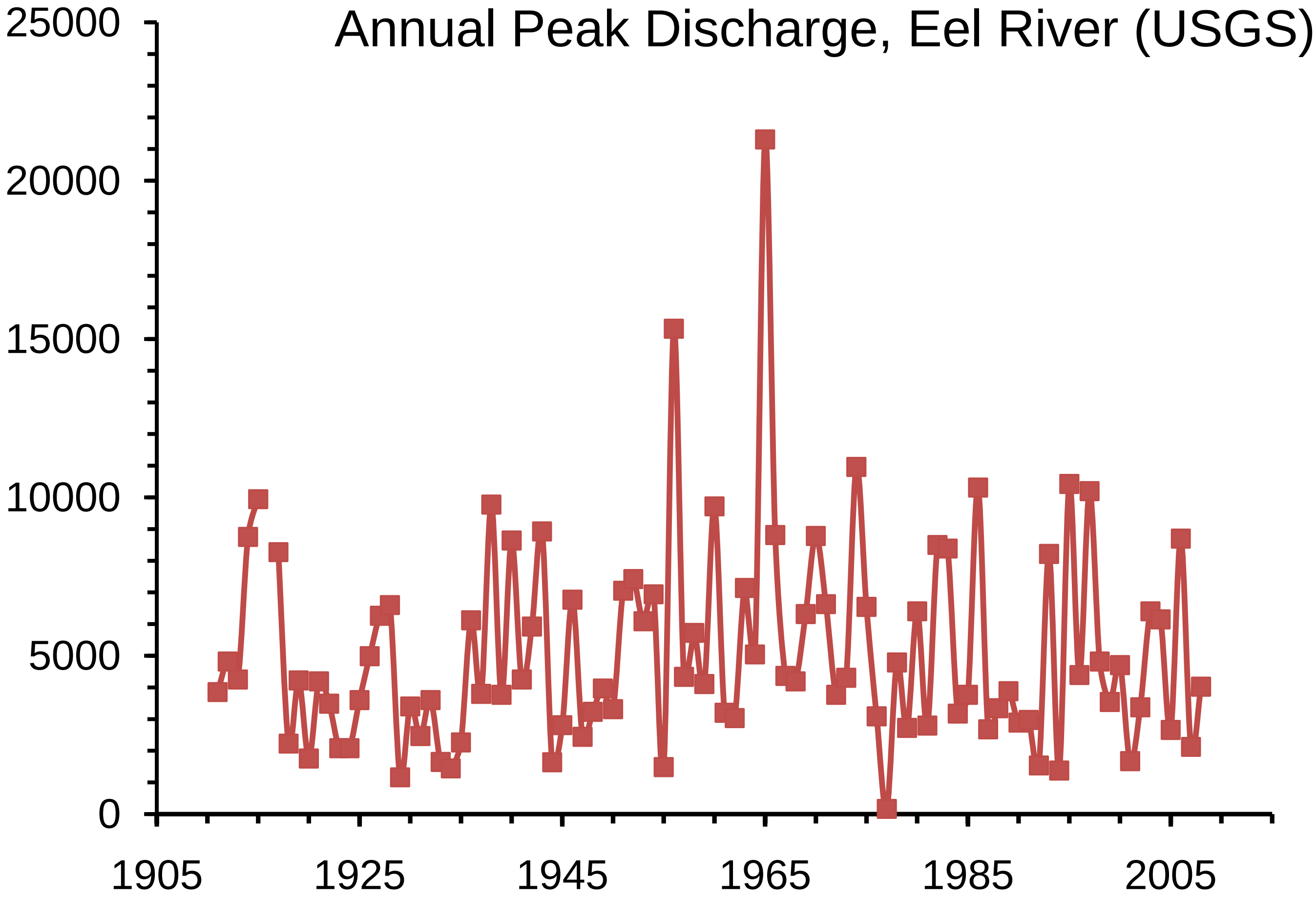
M. Tekverk, COAS REU student 2009



Decreases in D_b, L_b & resilency may favor preservation...

Notes by Presenter: Lots of variation!!

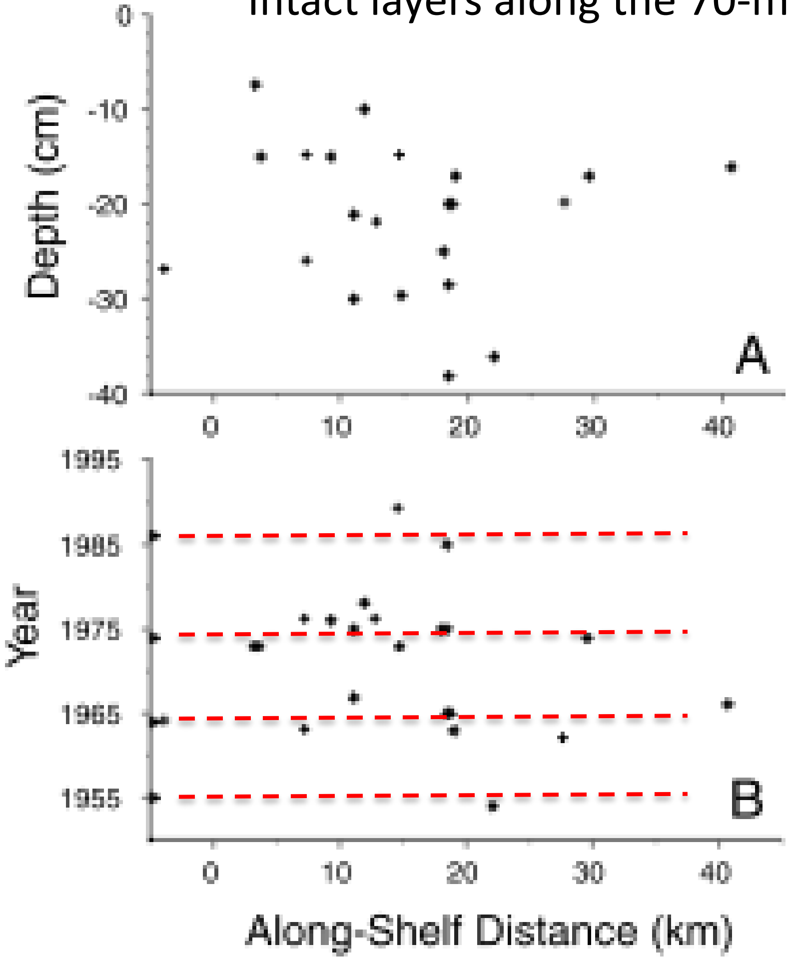
How predictable is the preservation of flood deposits?



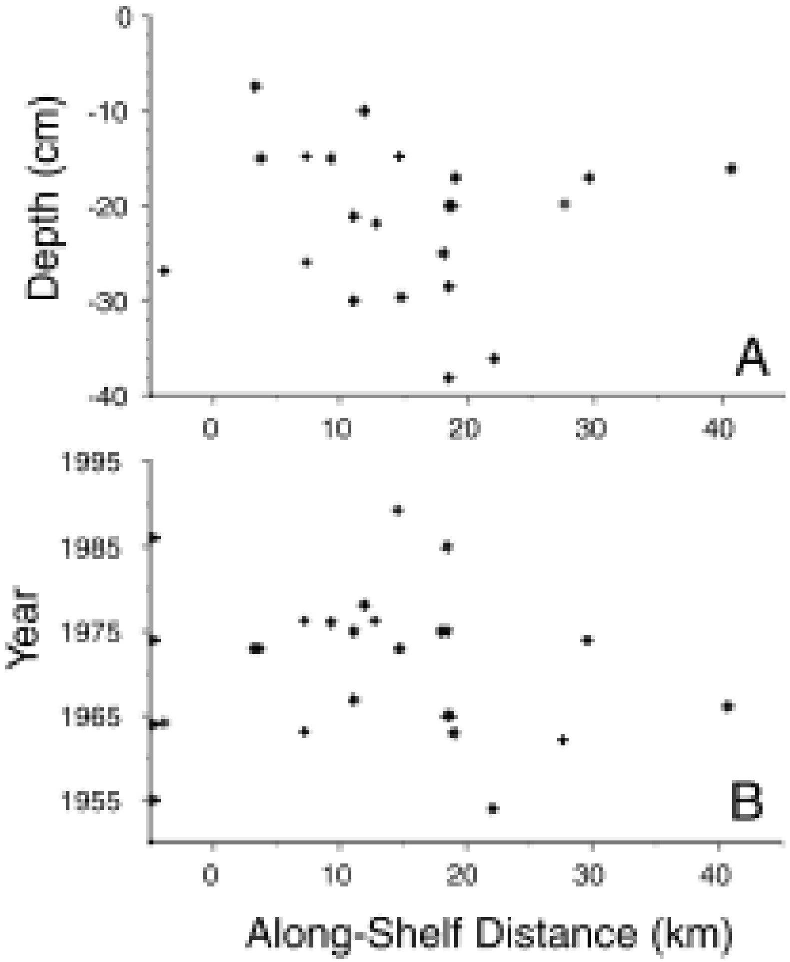
1964
1955
1986
1997
1974
1995

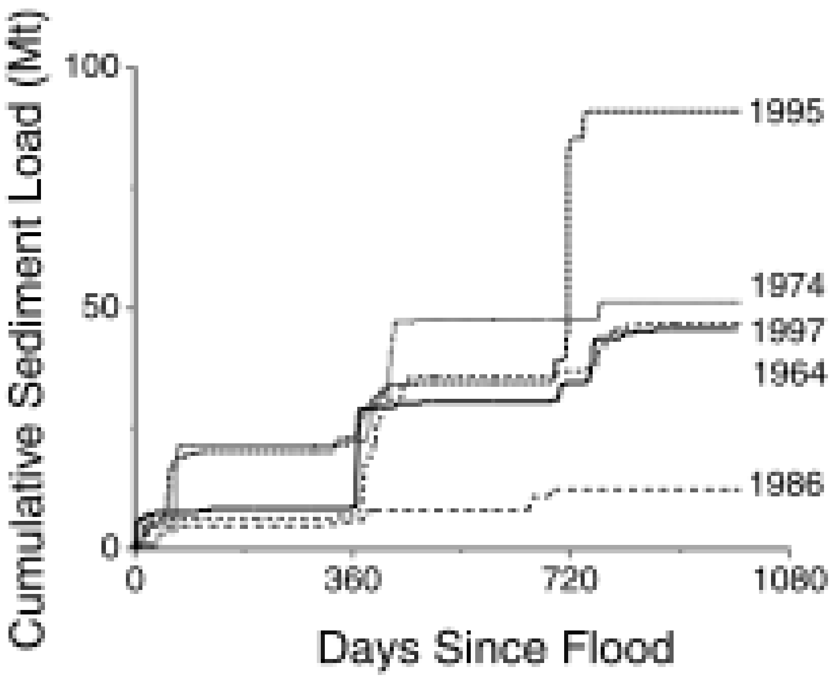
Timing is everything!

Intact layers along the 70-m isobath



Timing is everything!





- The 1995 flood deposit was preserved by the 1997 event, which has been completely destroyed.
- Clustering is important!

Wheatcroft & Drake (2003)

Shelf macrobenthos on the US West Coast

			Shelf		
Phylum	**WA**	**OR**	**Eel**	**RU**	**LA**
Annelida	**48**	**55**	**86**	**62**	**66**
Mollusca	**27**	**38**	**8**	**17**	**10**
Arthro.	**18**	**3**	**6**	**2**	**13**
Echino.	**7**	**4**	**0.4**	**18**	**12**

Sources: WA - Lie, 1970; OR - Richardson et al., 1977; Eel- Wheatcroft, 2006; RU - C.A.Zimmer, unpubl; LA - Wheatcroft & Martin, 1996

An entire group of important bioturbators
-echinoderms-
is missing from the Eel shelf. Why?

Click to View Notes by Presenter

Heart urchins (*Brisaster latifrons*) & amphiurid brittle stars absent on the Eel shelf

Russian River shelf (90 m), Cacchione & Drake (1981)

Differences in…?

- ~~Grain size~~
- ~~Organic carbon~~
- ~~Temperature~~
- ~~Salinity~~
- ~~Biogeographic boundary~~
- ~~Sedimentation rate~~

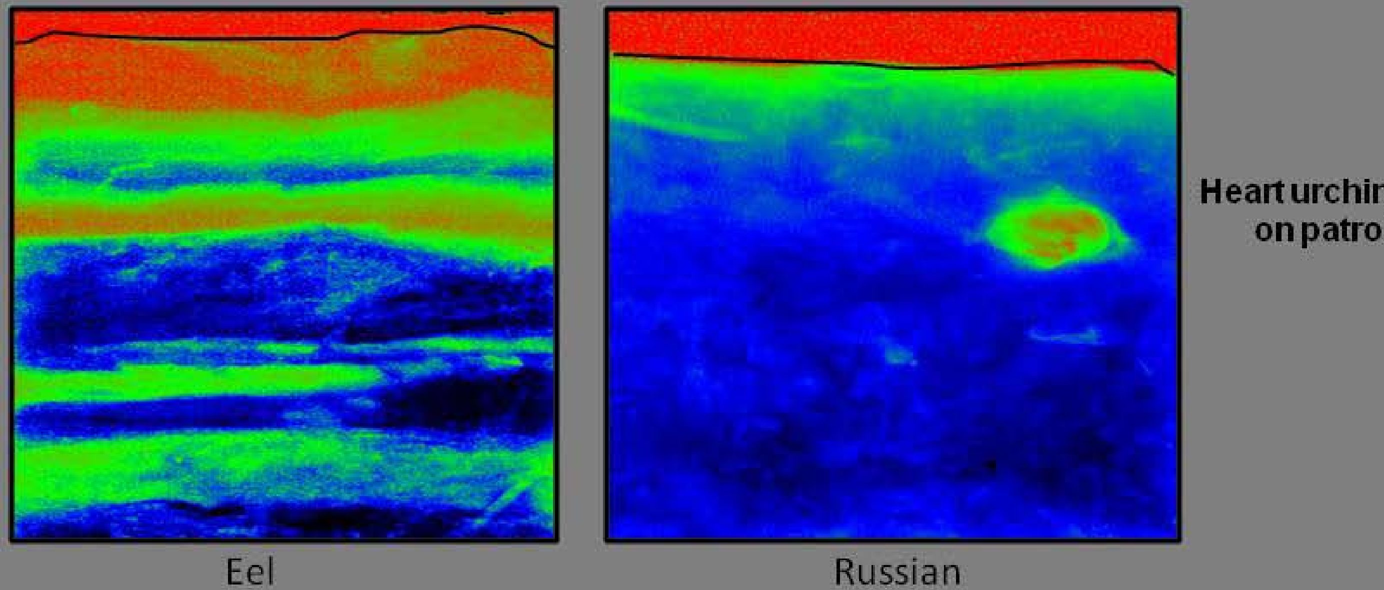
- **Wave climate?**
- **Trawl data from the late 1950's report echinoderms**

Physical – biological feedback on multi-decadal timescales

Notes by Presenter (for previous slide):

I want to close with a story that I think some of you have heard before, but I think that given its relevance to the topic at hand, it bares repeating. The title of my story is “the great echinoderm mystery”. Shown here is a comparison of macrofauna phyla found at mid-shelf depths at five locations along the U.S. west coast – now these samples were collected in different ways at different times, but they represent multiple samples in each case – so I think the result is robust. The main thing I would like to point out is the missing echinoderms – specifically heart urchins of the genus brisaster and amphiurid ophiuroids. In particular I would like to compare the Russian vs. Eel and ask the question of why?

Summary



- Signal thickness & type are critical
- No evidence for biological-physical feedbacks on event time scales, but possibly on decadal scales
- 'Chance' makes prediction (and inversion) difficult for parts of the preservation problem

Notes by Presenter: On the Russian shelf, every box core that is taken has at least one, sometimes two brisaster and many adult ophiuroids – in contrast, on the eel shelf in 100's of box cores the total number of brisaster can be counted on one hand. Yet it turns out that if you look at many of possible causes, for example grain size, org-carbon content, sediment accumulation rate and others that there really is no difference between these two shelves.