Sedimentary Structure Distribution and Modification on the Continental Shelf: Relative Roles of River Input, Sediment Transport and Oceanographic Setting*

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Abstract

Studies of sedimentary structures in modern shallow marine environments influenced by rivers have been conducted in active and passive margin settings from numerous areas worldwide (e.g., shelves adjacent to the Amazon, Mississippi, Eel, Waipaoa Rivers). Despite the large differences in scale between such systems, the offshore progression of sedimentary structures has many similarities. Factors indicated in the control on fine-scale sedimentary structures and their post-depositional modification include episodicity of river inputs, sediment transport mode, water depth and wave base, biological activity and the sediment accumulation rate. Many previous studies have suggested sediment accumulation rate as a dominant control on the preservation of primary physical structures on the continental shelf. However, results from recent studies suggest that, within the normal range of accumulation rates observed in shelf environments, other factors such as water depth, flood input history, and proximity to sediment source are the dominant controls on the occurrence and preservation of physically emplaced sedimentary structures. The timing and history of river flood and storm events is one factor in determining the distribution of event layers on the shelf, and their ultimate preservation. For example, concomitant river flooding and storm conditions favor the generation of wave- and current-supported gravity flows capable of broadcasting flood sediments across the shelf. Out of phase flooding would favor rapid deposition in nearshore and shallow shelf environments. The resultant flood layers have a higher preservation potential if they are buried quickly by deposition during subsequent large floods. Surface gravity waves cause physical reworking of the seabed in water depths shallower than wave base, obliterating original structures and winnowing the seabed of fines, but creating layers and laminations which may be similar (albeit coarser) than originally emplaced flood layers. In deeper waters, reworking of primary sedimentary structures arises from biological activity in the near-surface seabed, and the preservation of physically emplaced structures depends on the relative importance of biological mixing depth and intensity, and the sediment burial rate and history. These studies indicate that factors other than long-term accumulation rates primarily influence the formation and preservation of fine scale sedimentary structures on the continental shelf.

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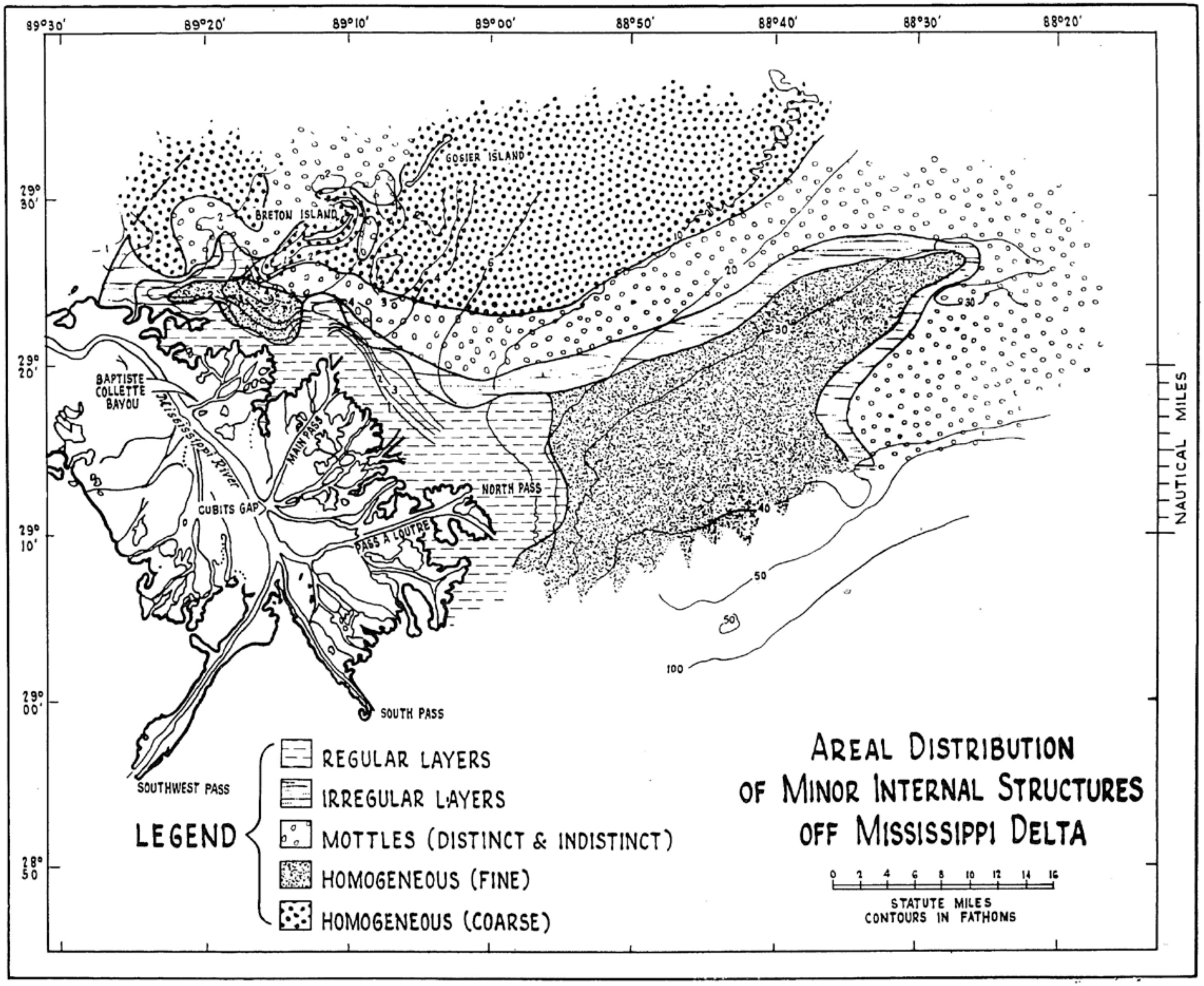
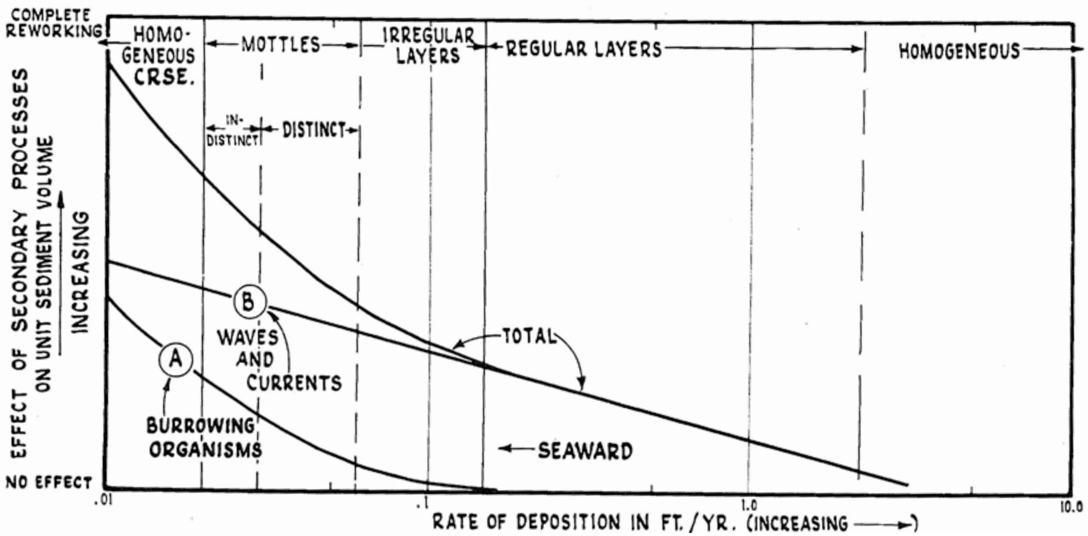
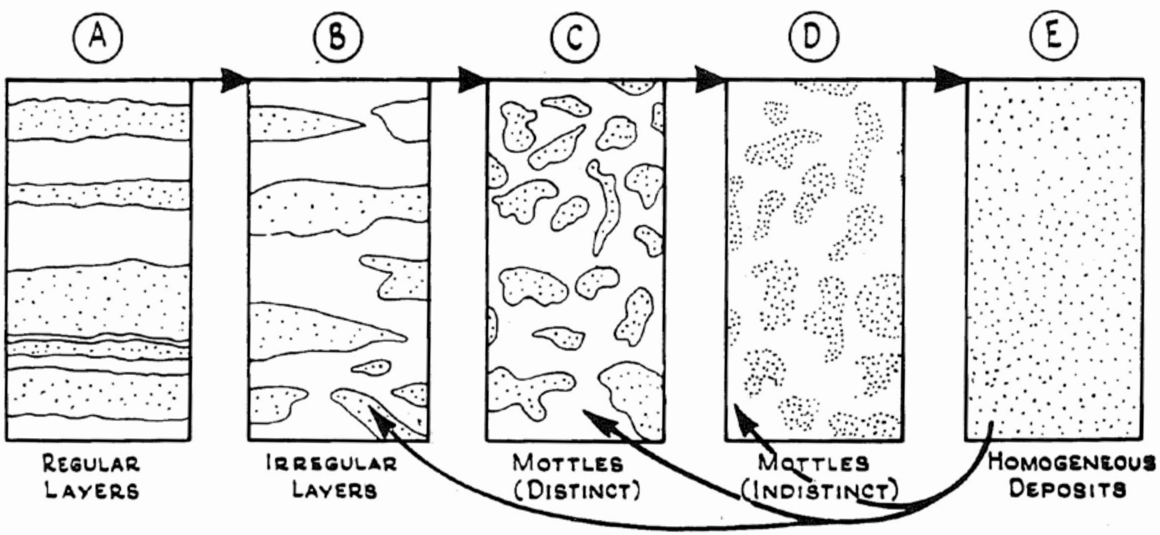


Moore and Scruton, 1957

Sediment Accumulation Rate as the Master Variable?



Moore and Scruton, 1957



Examples from Other Passive Margins

Amazon Delta (Kuehl et al. 1986)

Niger Delta (Allen, 1965)

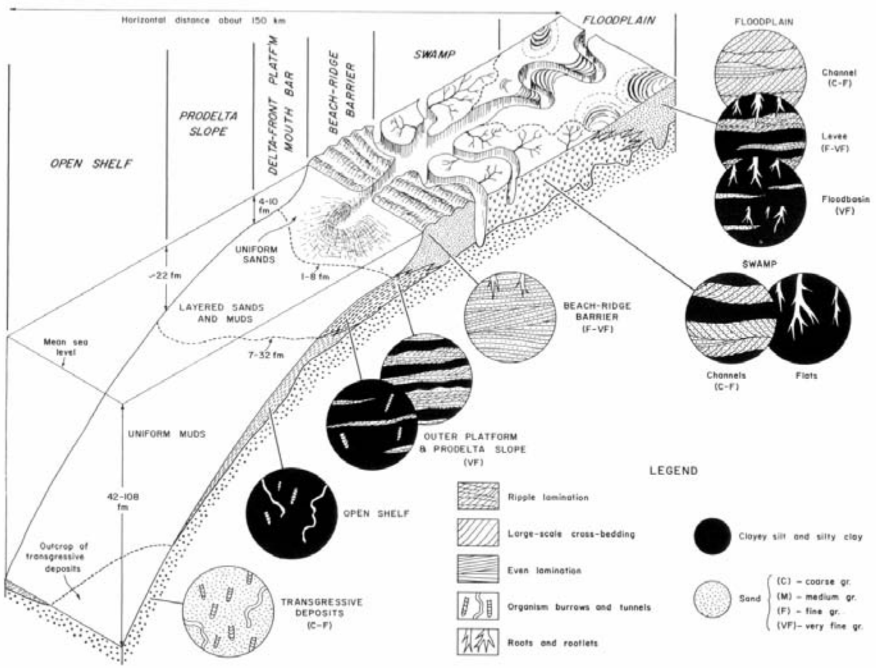
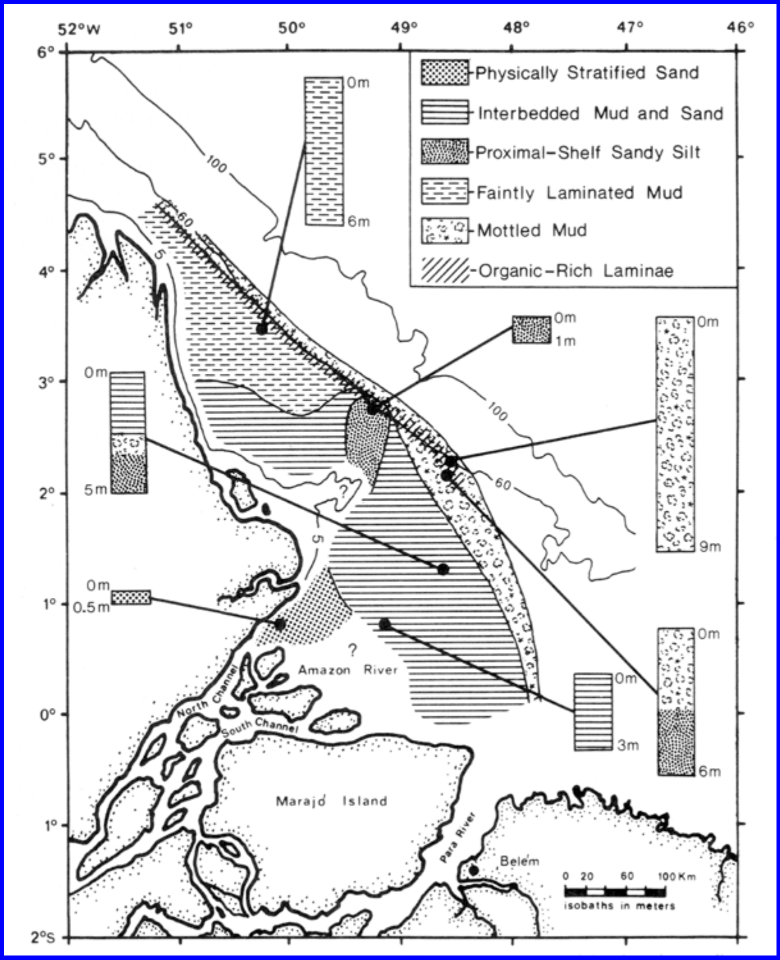
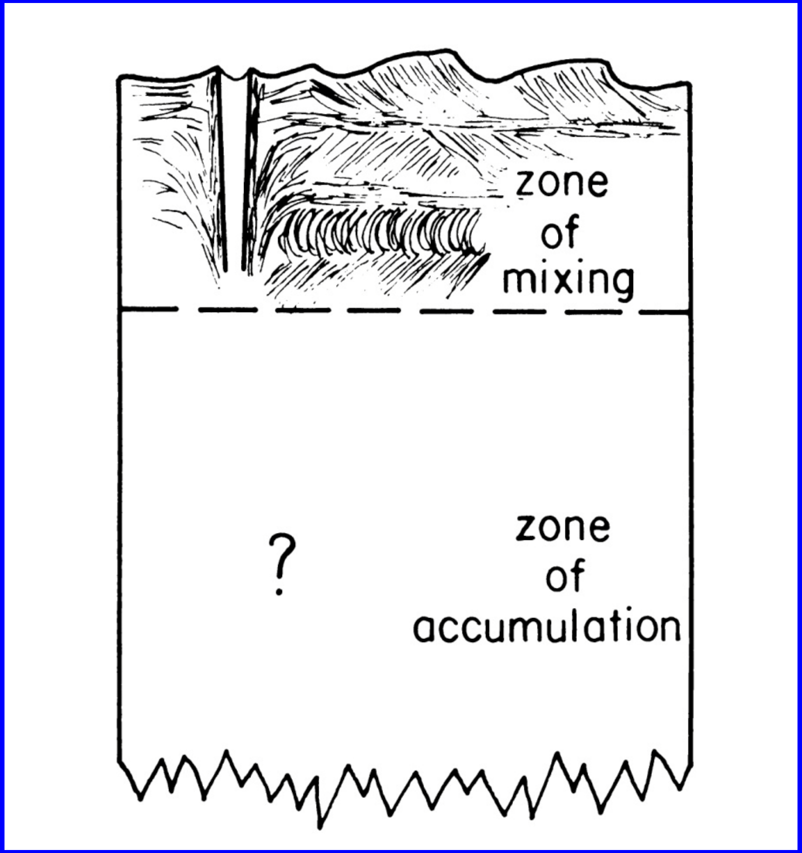


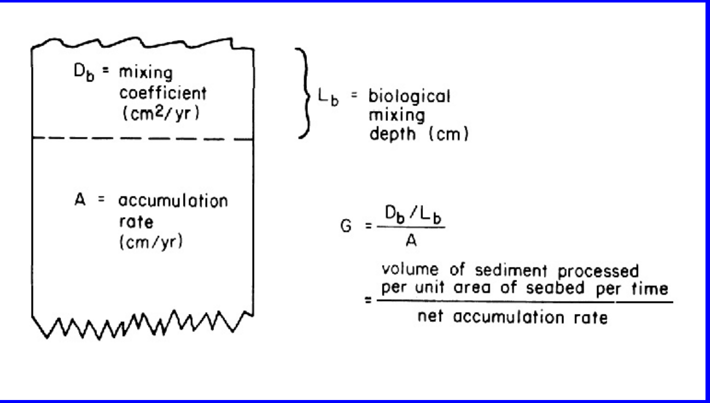
FIG. 4.—Schematic illustration of the properties and relationships of principal sedimentary facies of the modern Niger delta.



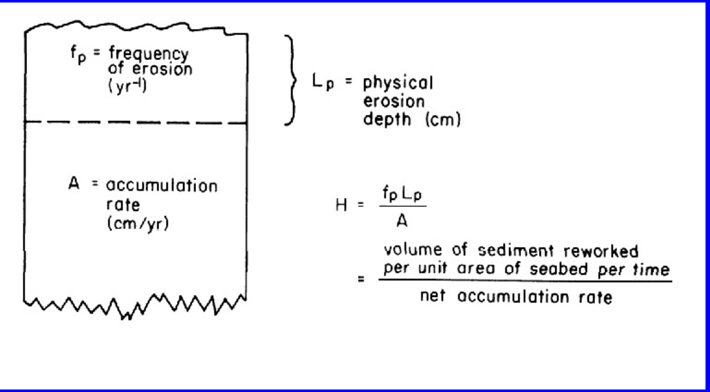
Introducing the Relative Roles of Mixing and Accumulation Rate



Biological Mixing



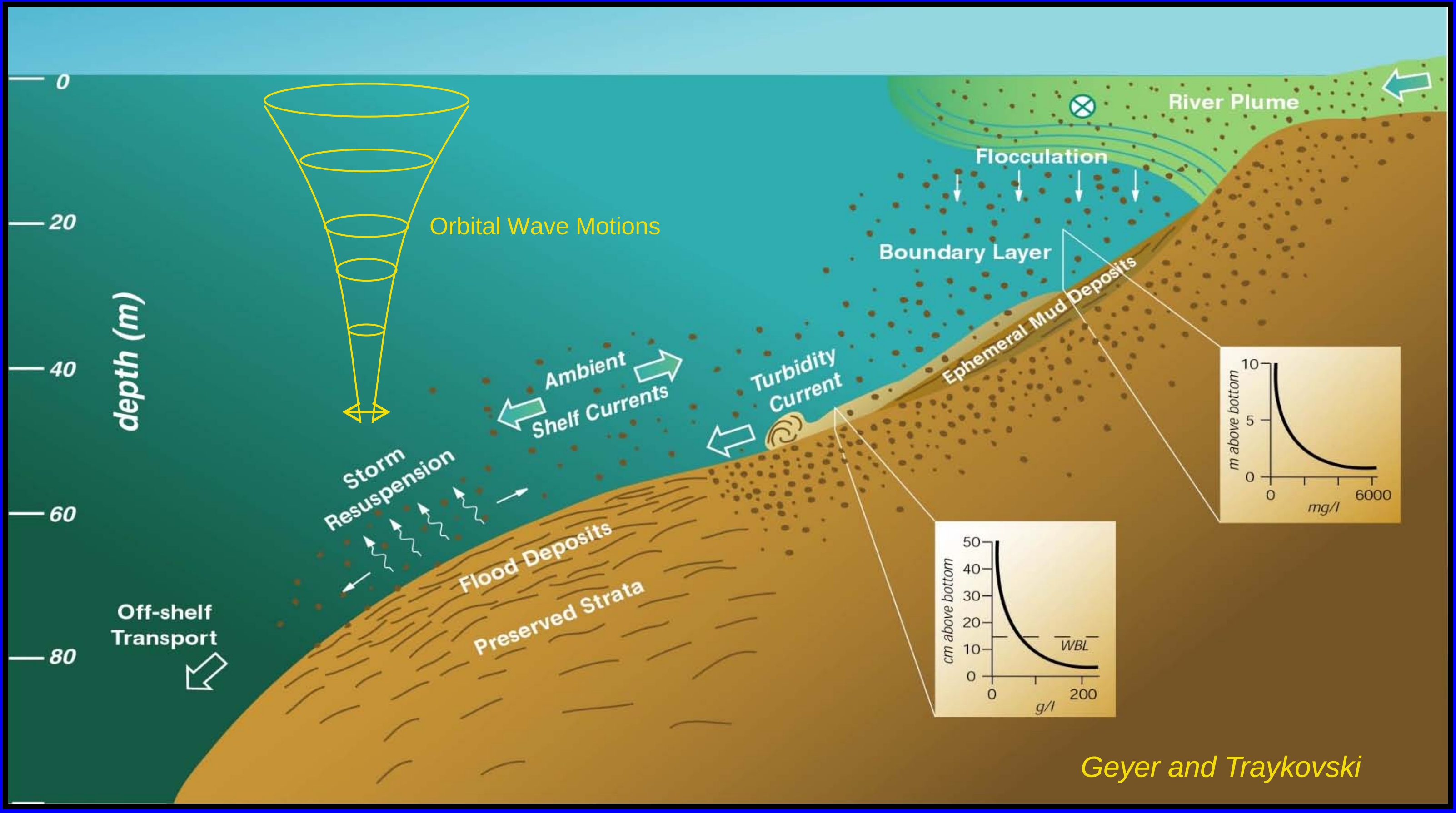
Physical Mixing



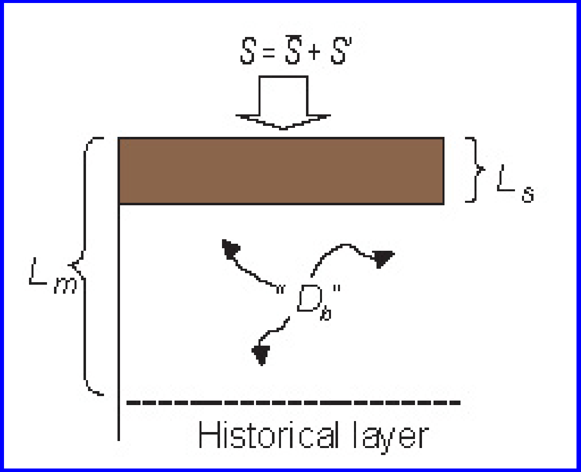
Nittrouer and Sternberg, 1981

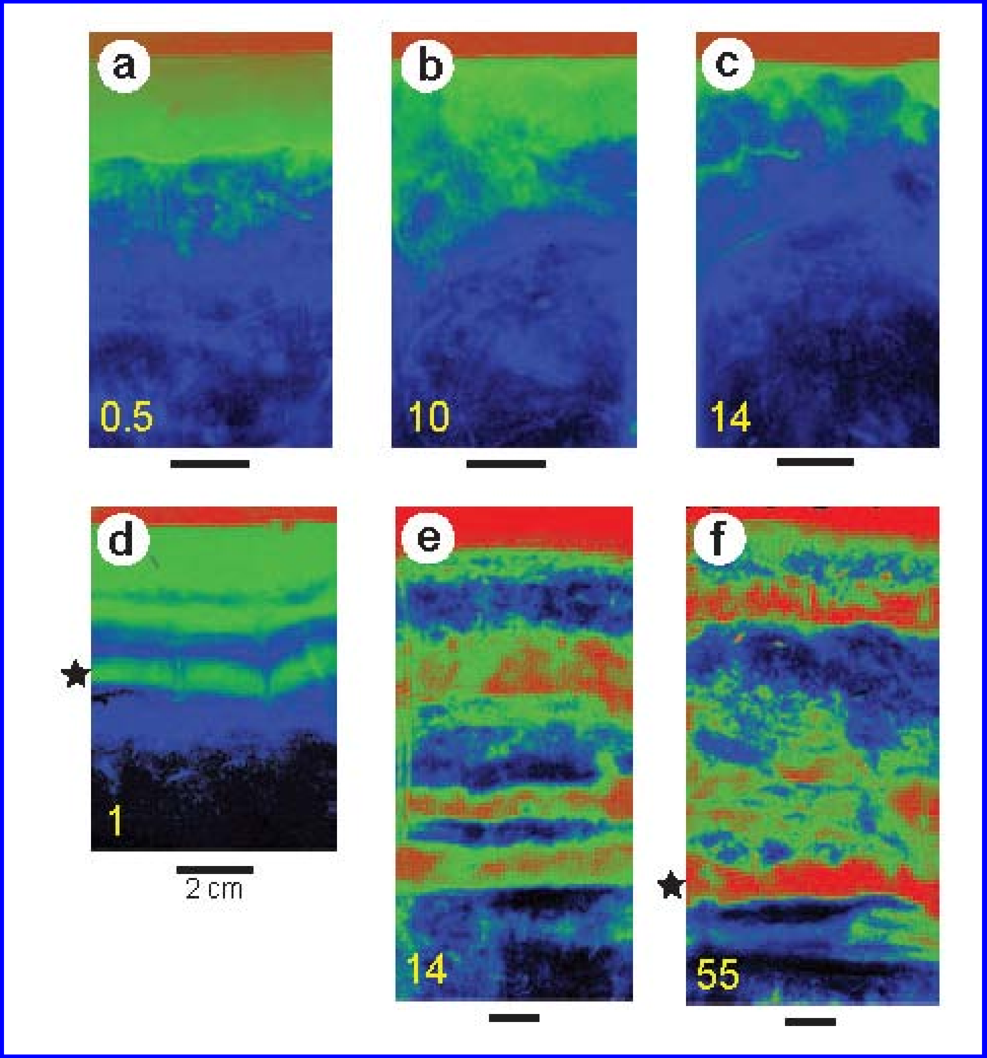
Assessing Importance of Sediment Transport Mechanisms

- sediment gravity flows
- dilute suspension



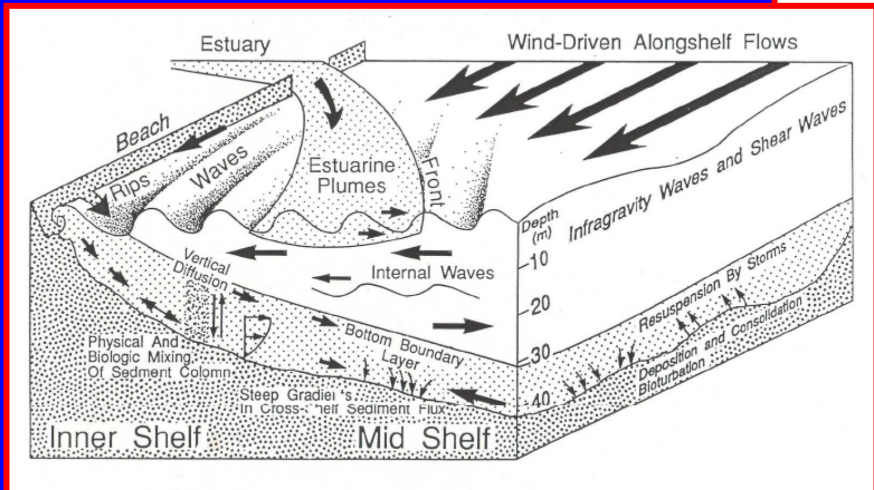
Episodic Burial as the Master Variable?

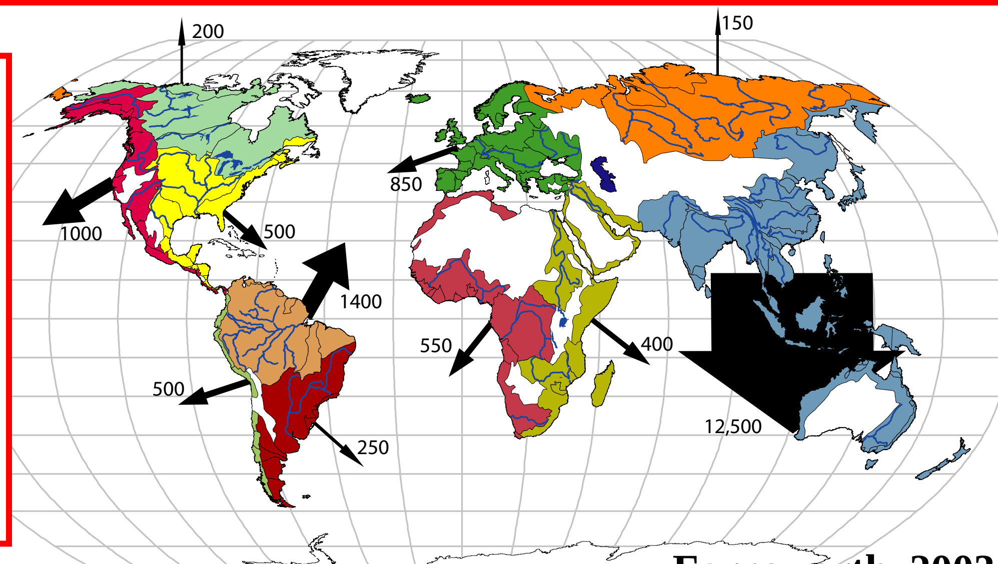




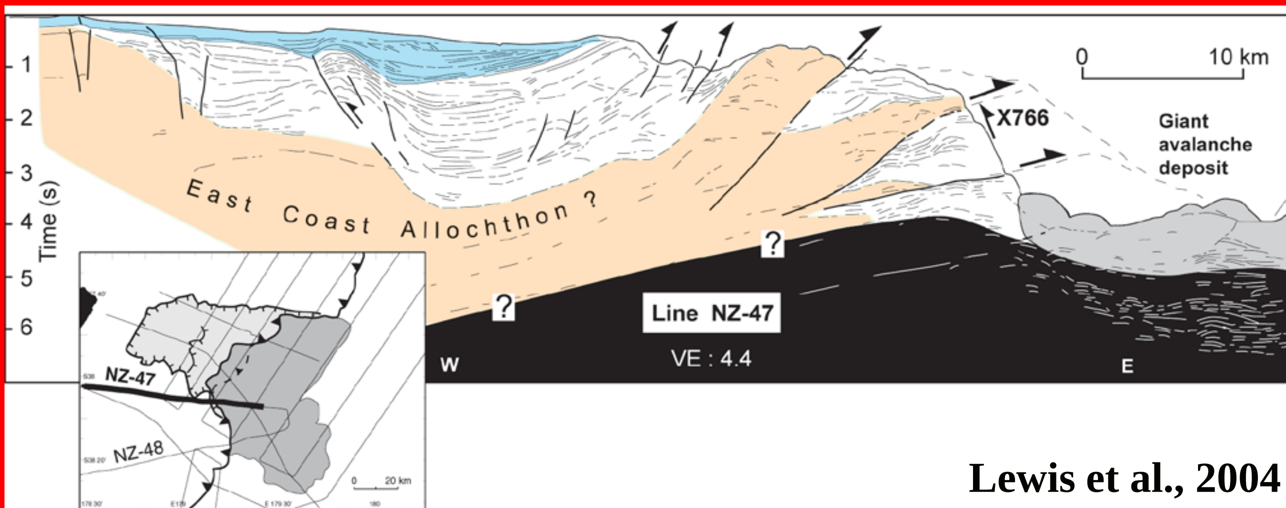
Wheatcroft et al., 2007

High Episodic Inputs Dominate Active Margins





Farnsworth, 2003

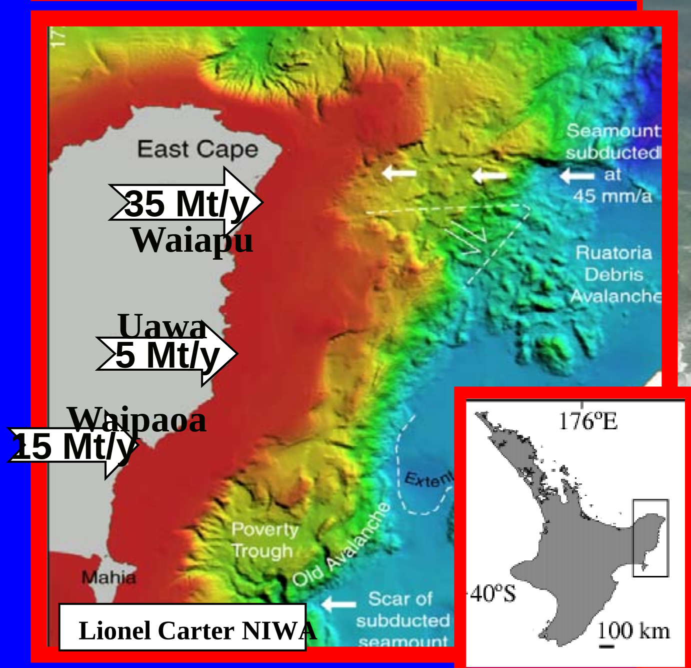


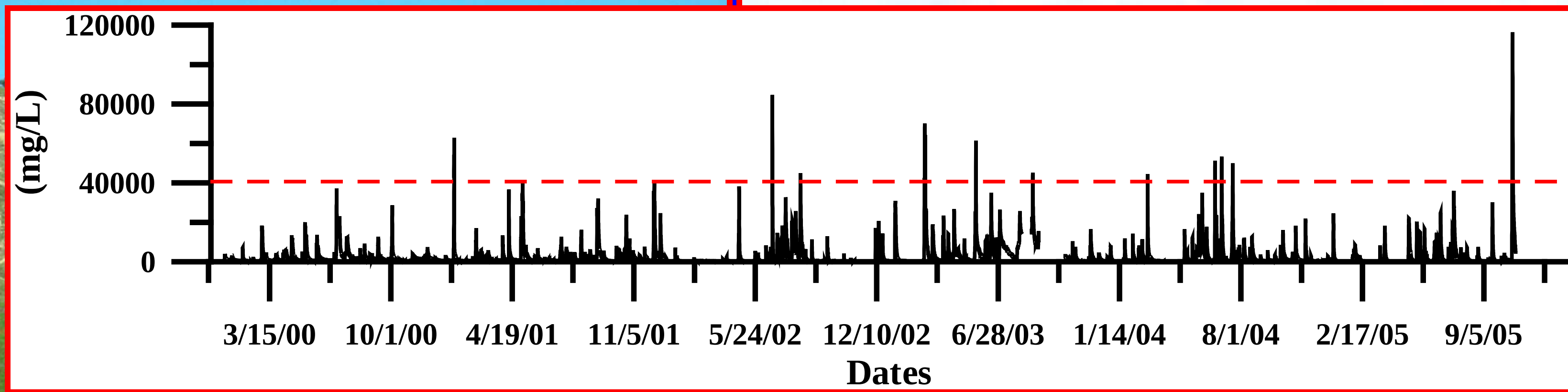
Lewis et al., 2004

- high yields
- various transport pathways
- tectonic control

Insights from New Zealand East Coast: Waipaoa and Waiapu Rivers

Photo courtesy: Jesse McNinch





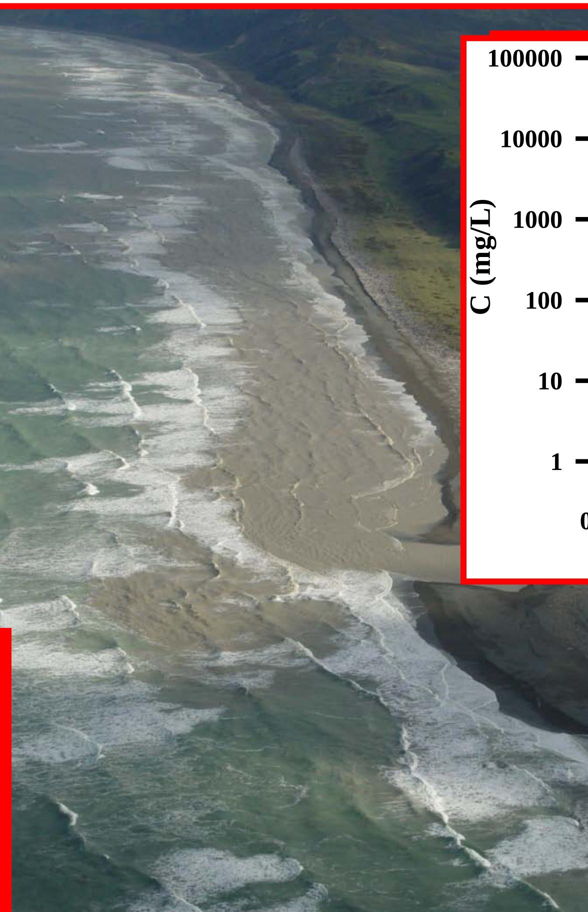
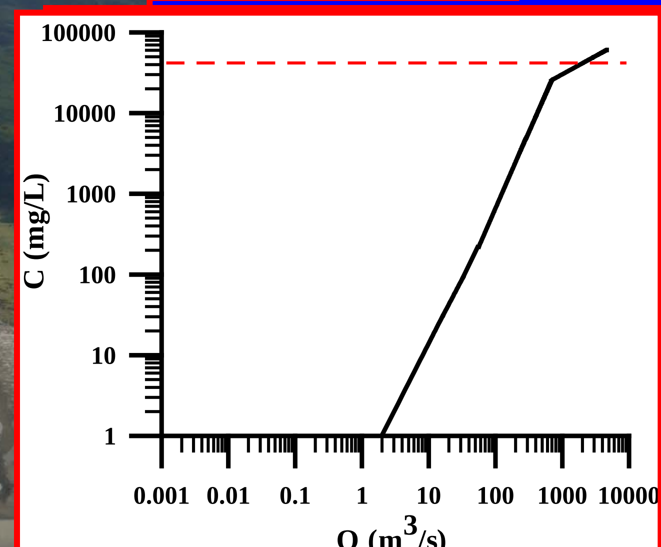
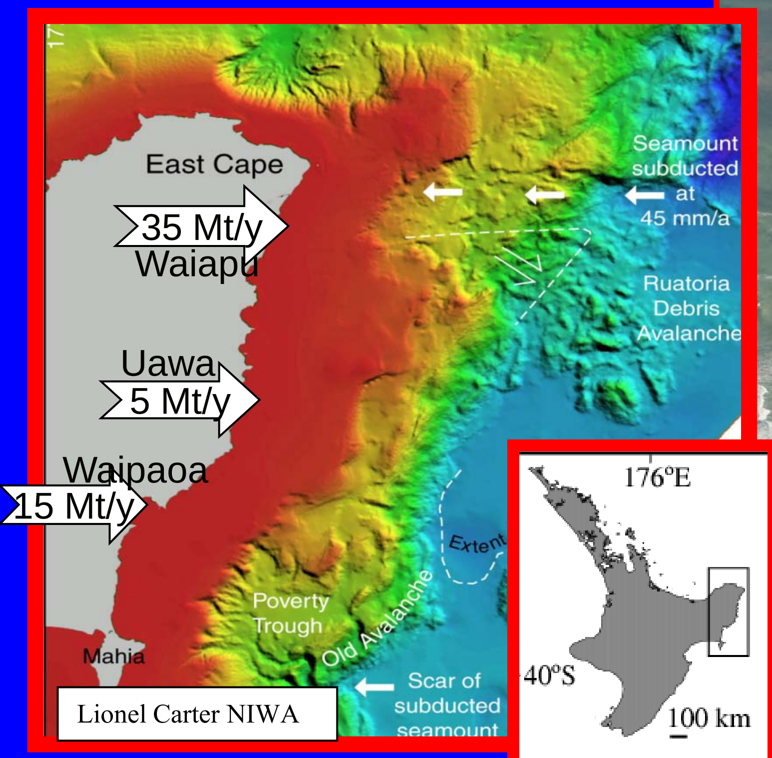


Photo courtesy: Jesse McNinch



Hicks et al. (2004)



Lionel Carter NIWA

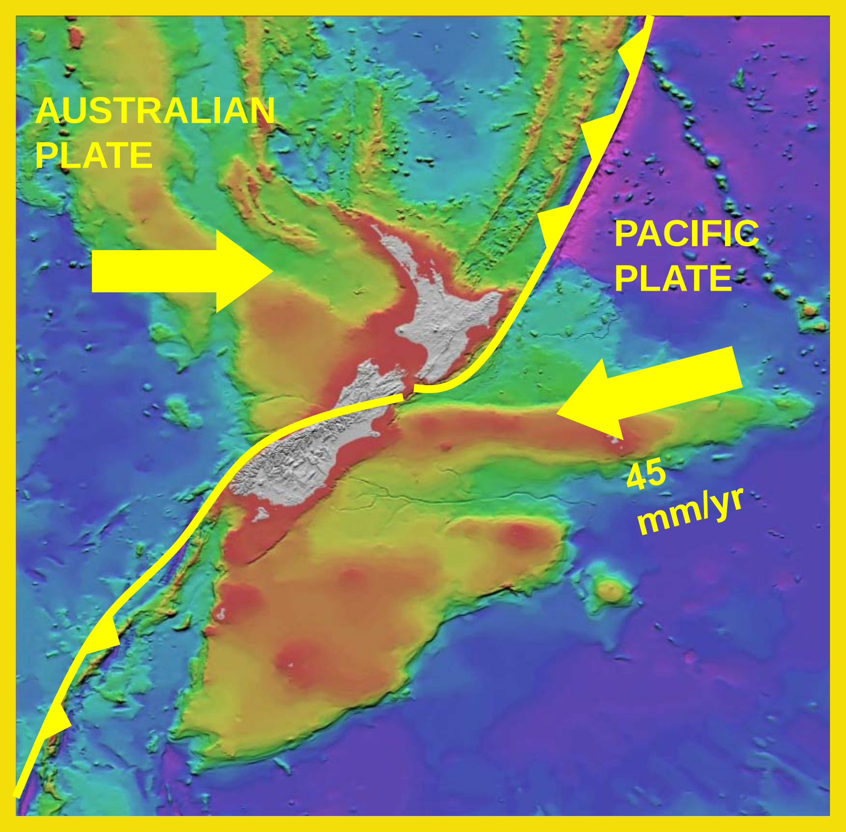
Glorious Mud

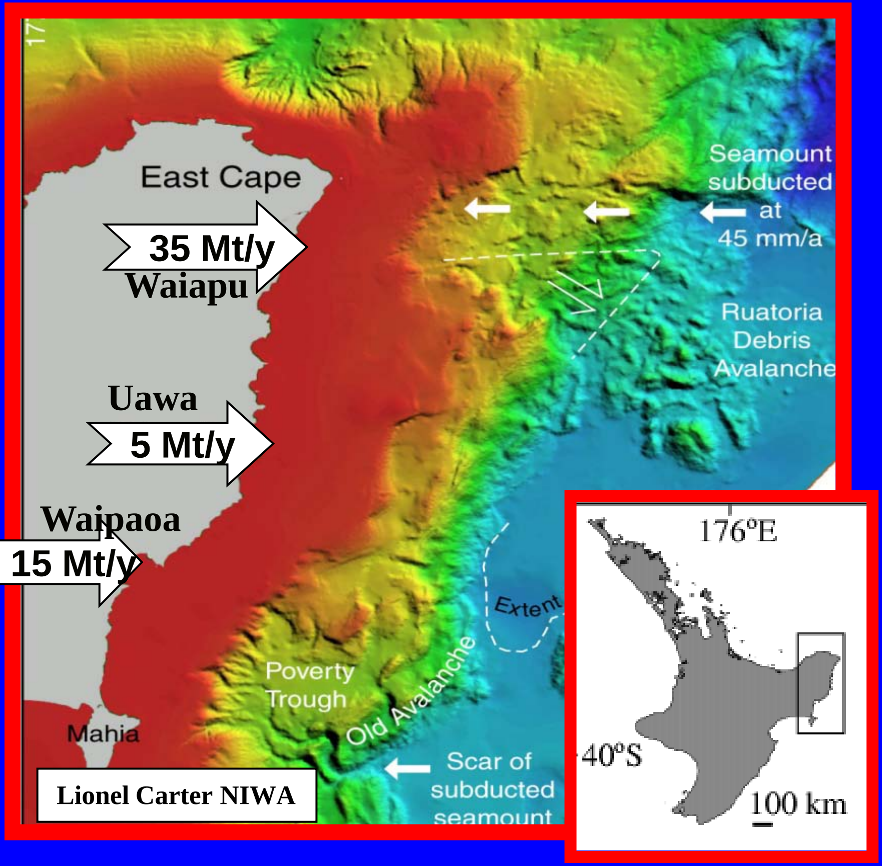
Click to View Notes by Presenter

Study Area

Active Tectonics

High Sediment Yield

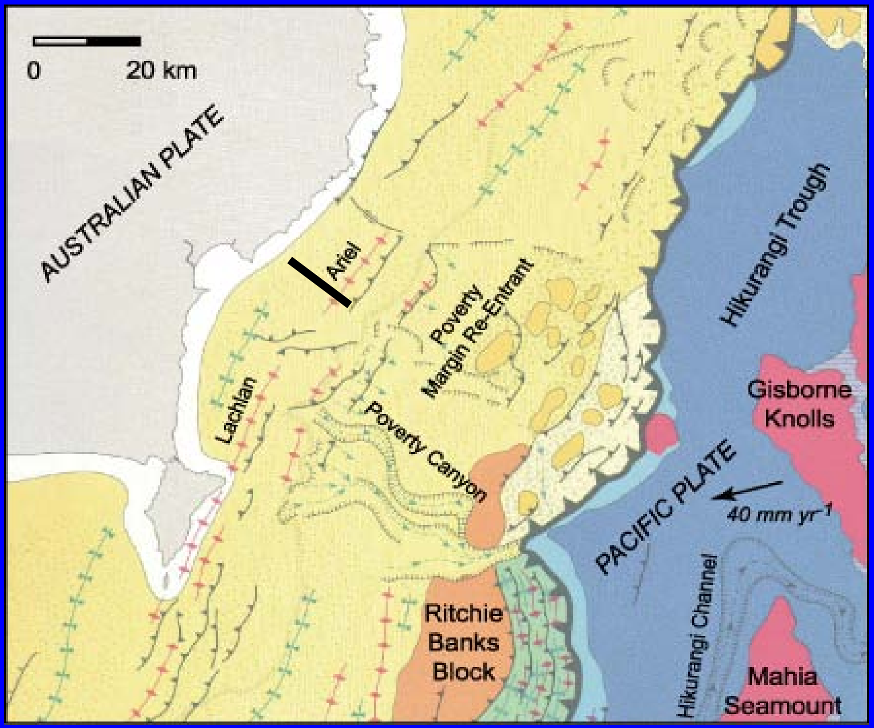




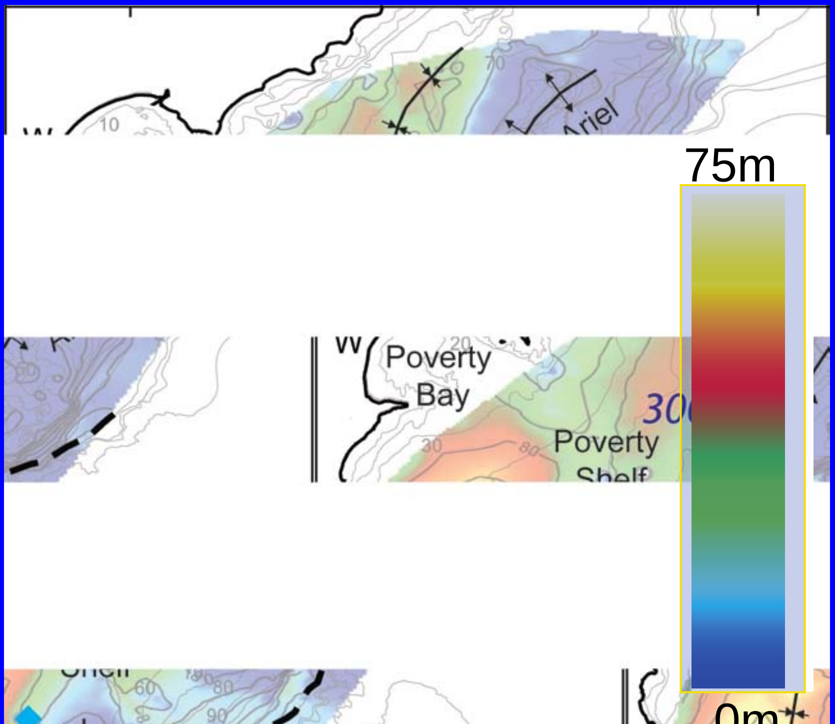
Notes by Presenter (for previous slide):

The catchment of the Waipaoa River originates in the axial ranges of eastern North Island and sediments are emptied into Poverty Bay vial the coastal plains of Gisborne. Waipaoa can be classified as a small mountainous river. These rivers often have large sediment yields and are incredibly important components in delivering sediment to the ocean. Milliman and Meade (1983) estimated that 70% of the sediment reaching the ocean is derived from rivers draining southern Asia and islands in the Pacific and Indian Ocean of which most of these rivers are classified as small mountainous rivers.

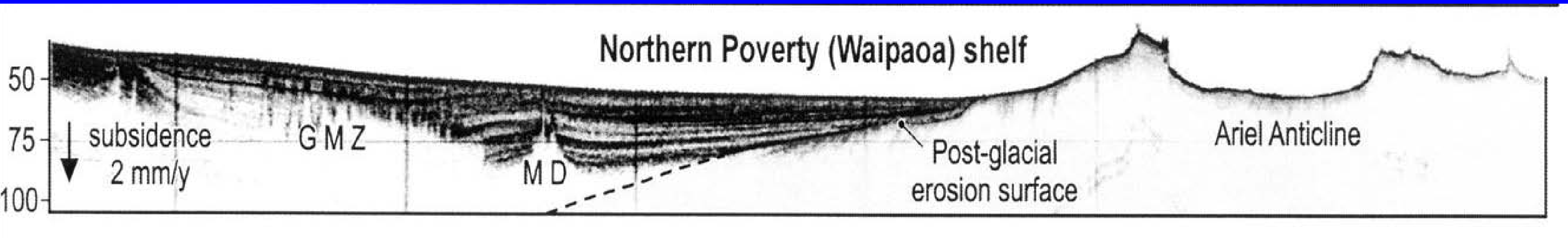
Waipaoa Shelf Setting



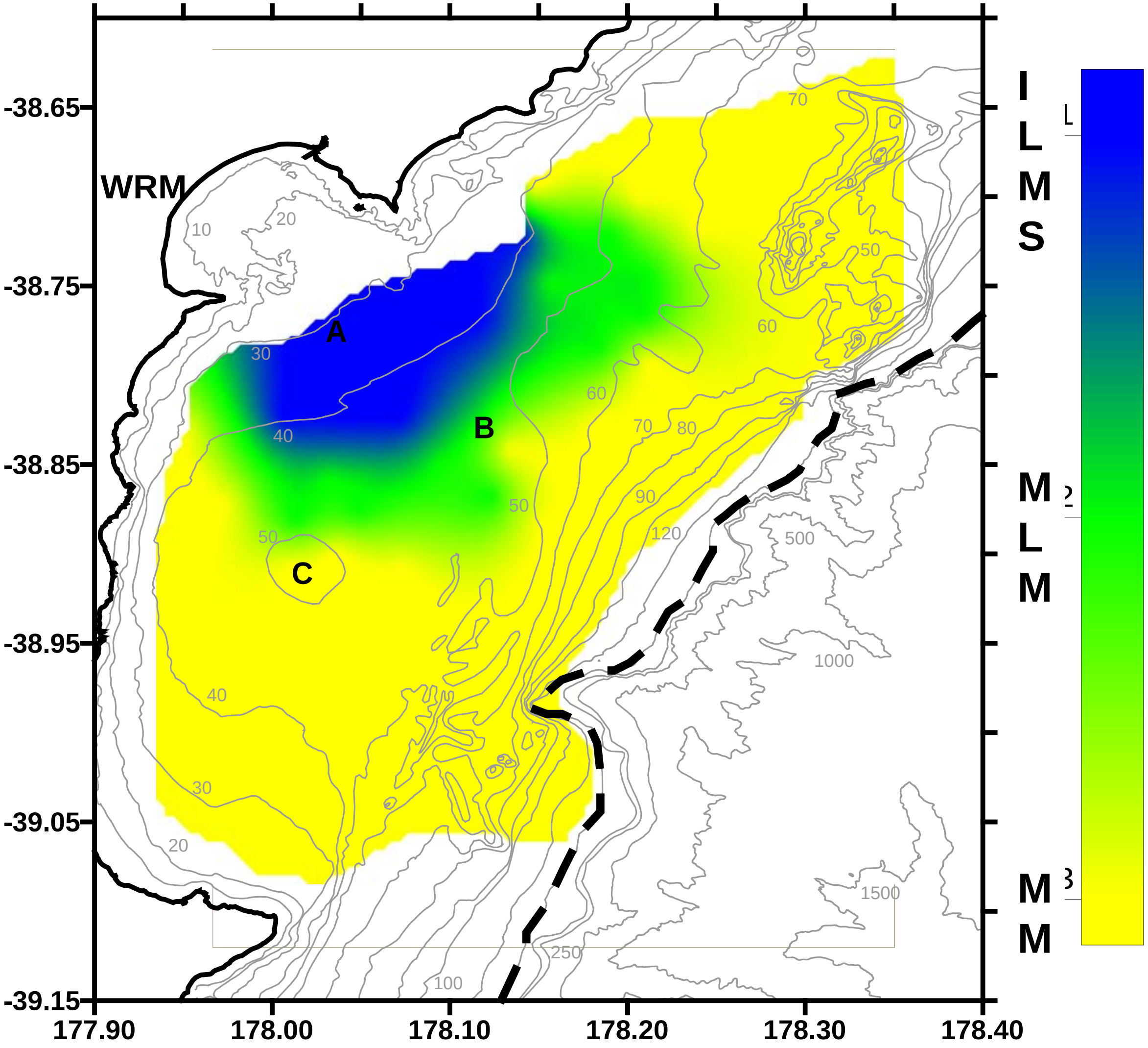
Foster and Carter, 1997

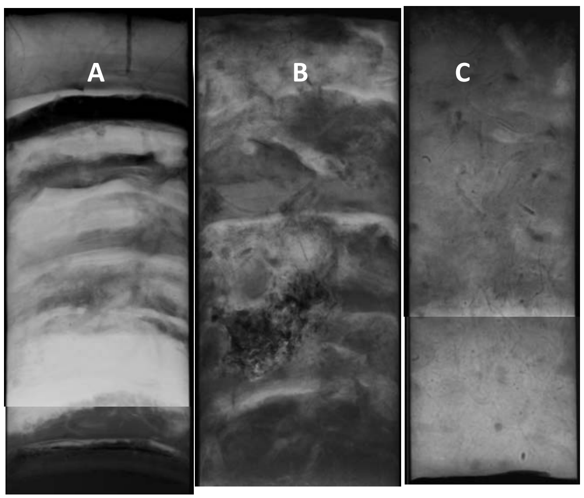


from Gerber et al. 2010

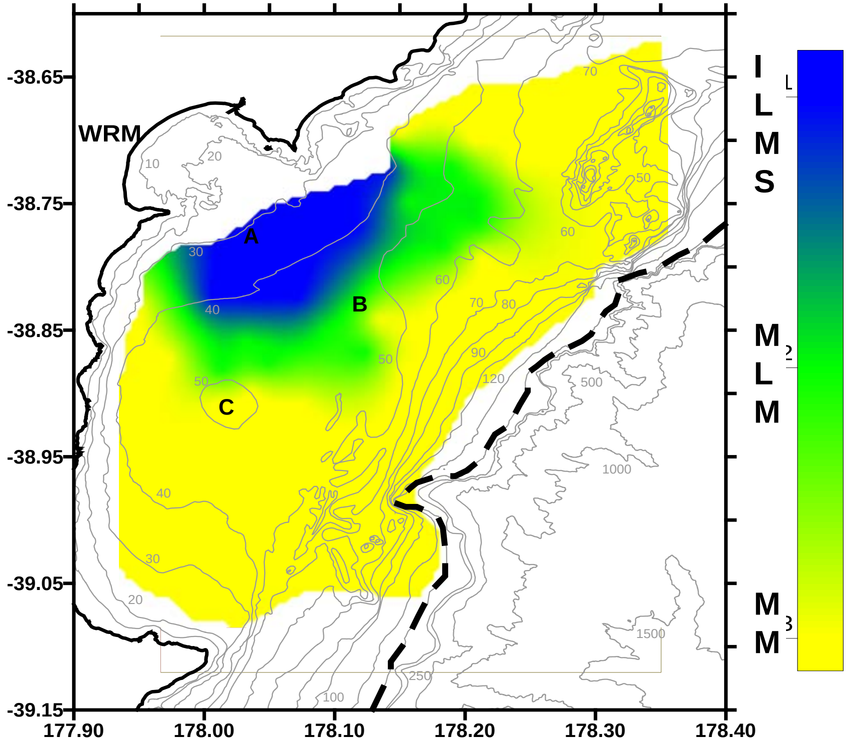


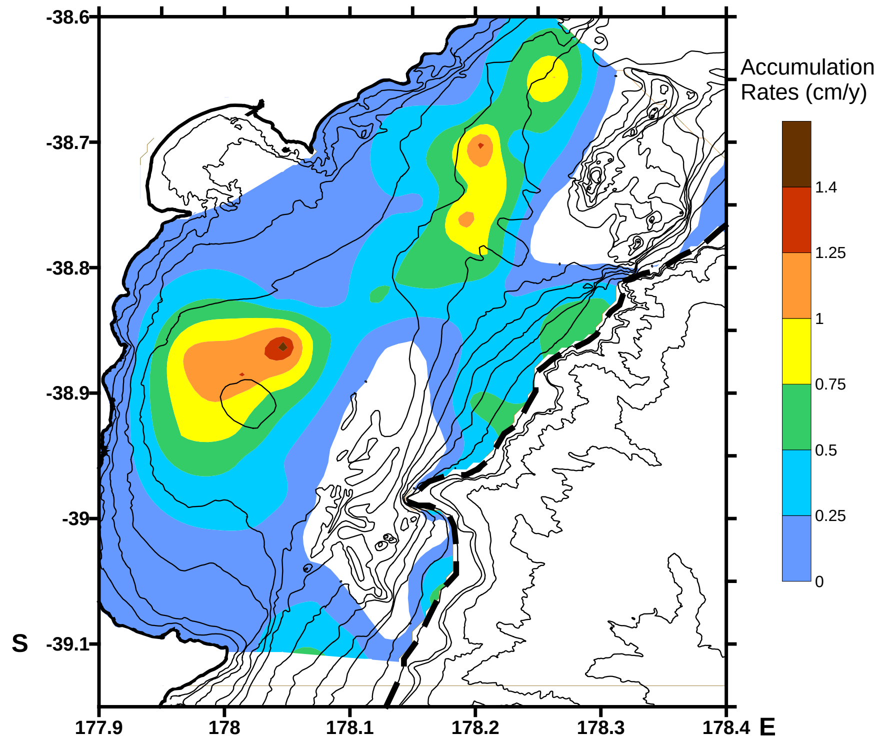
Distribution of Sedimentary Structures on Waipaoa Shelf





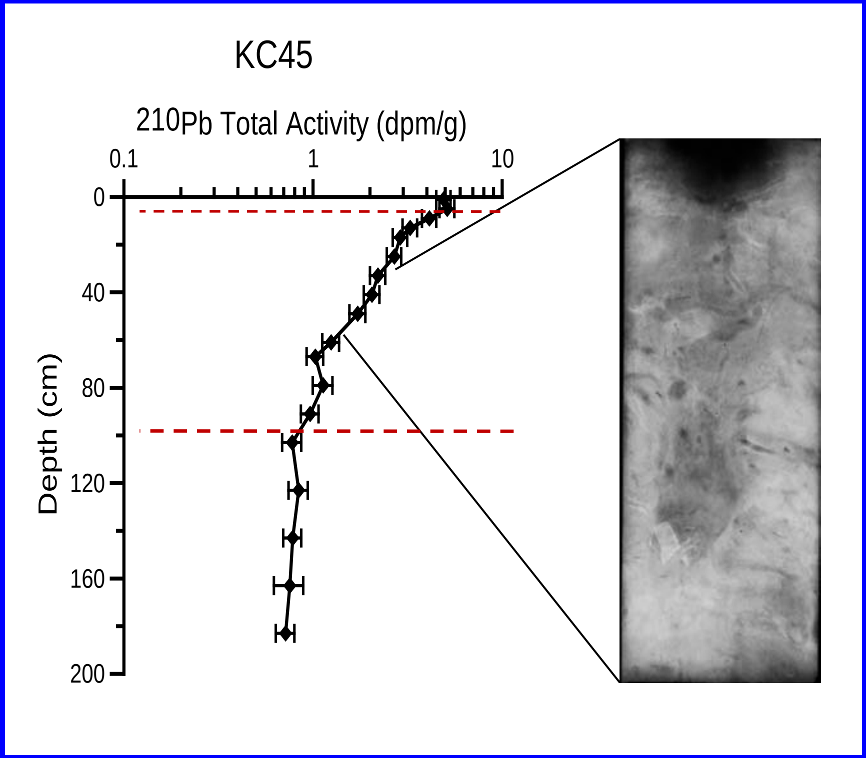
High Accumulation Rate ≠ Preserved Structure!



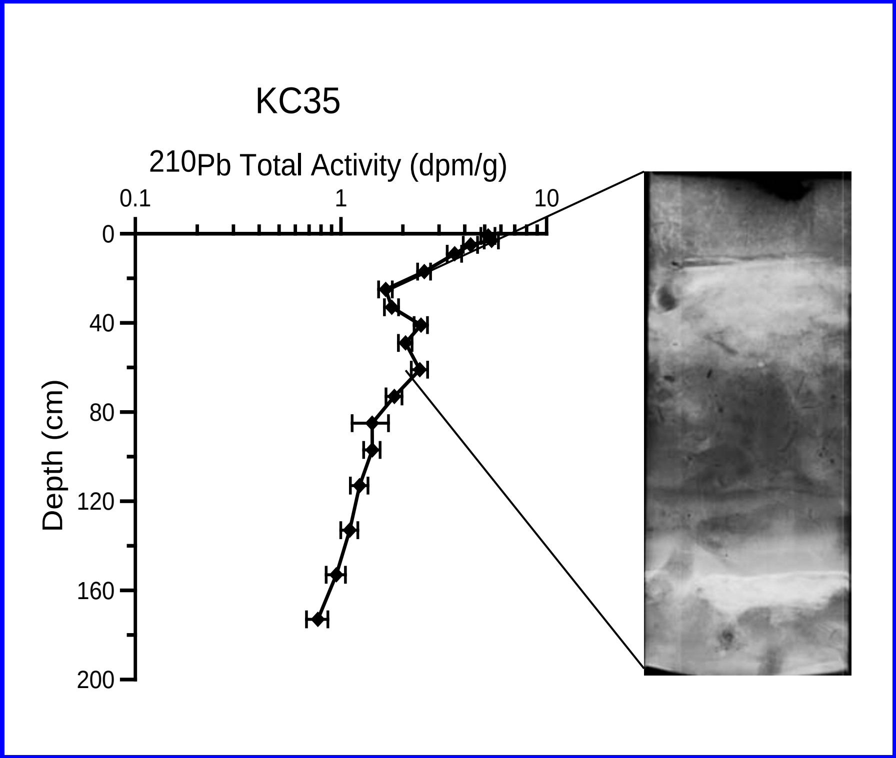


Preservation of Episodic Inputs

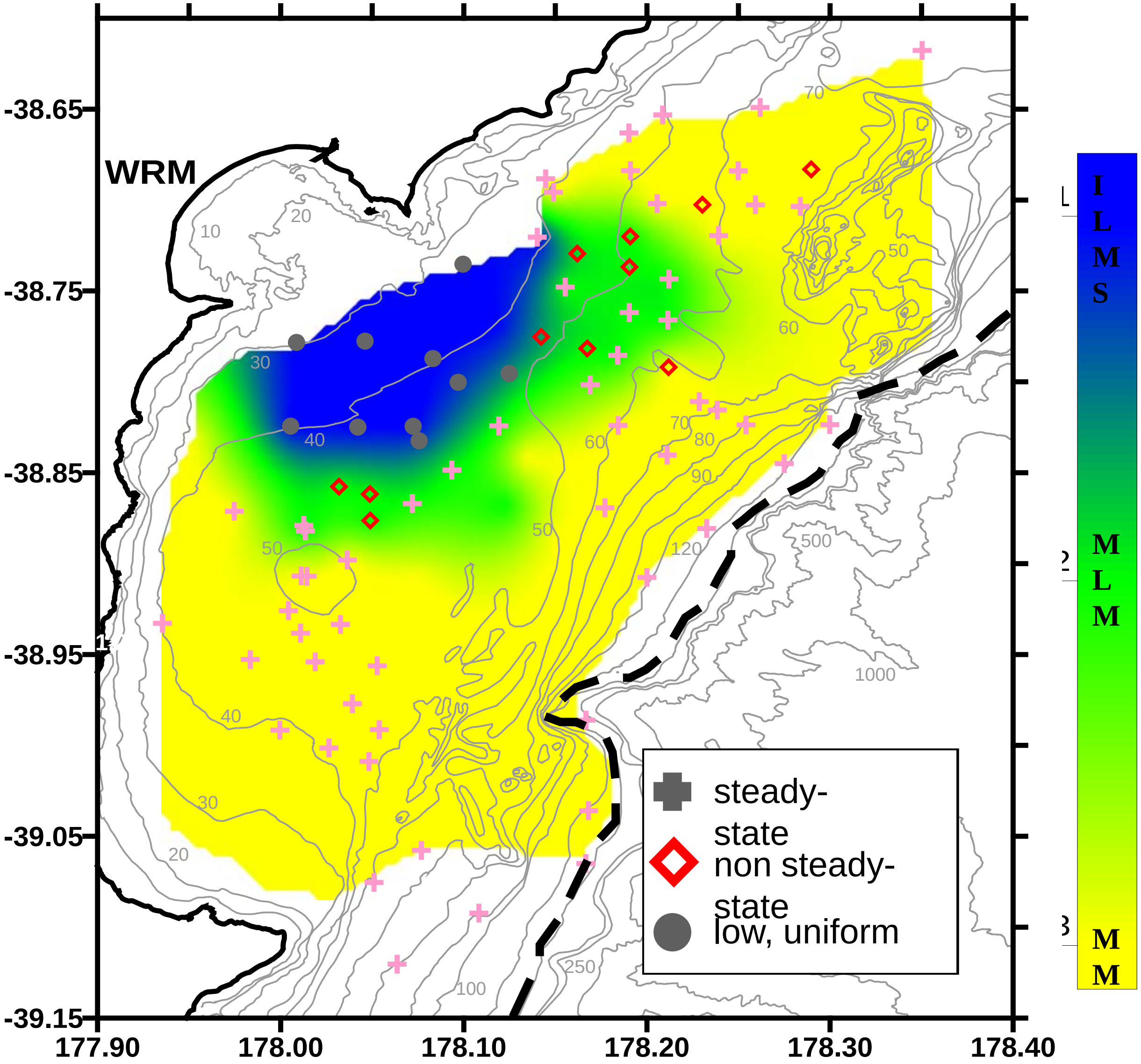
Steady State



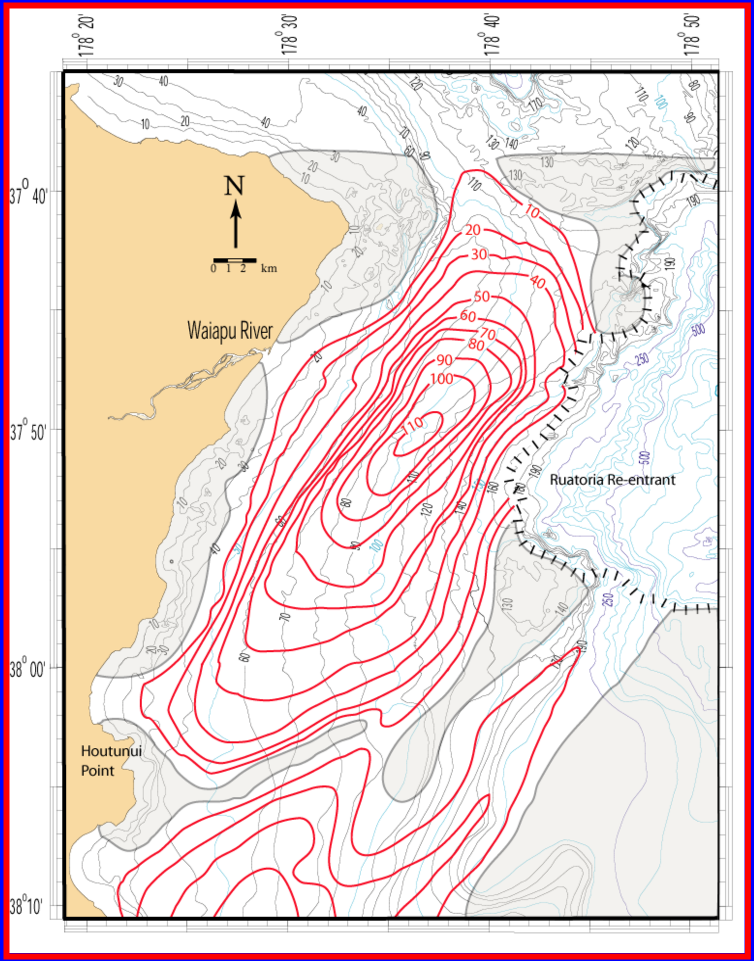
Non-Steady State

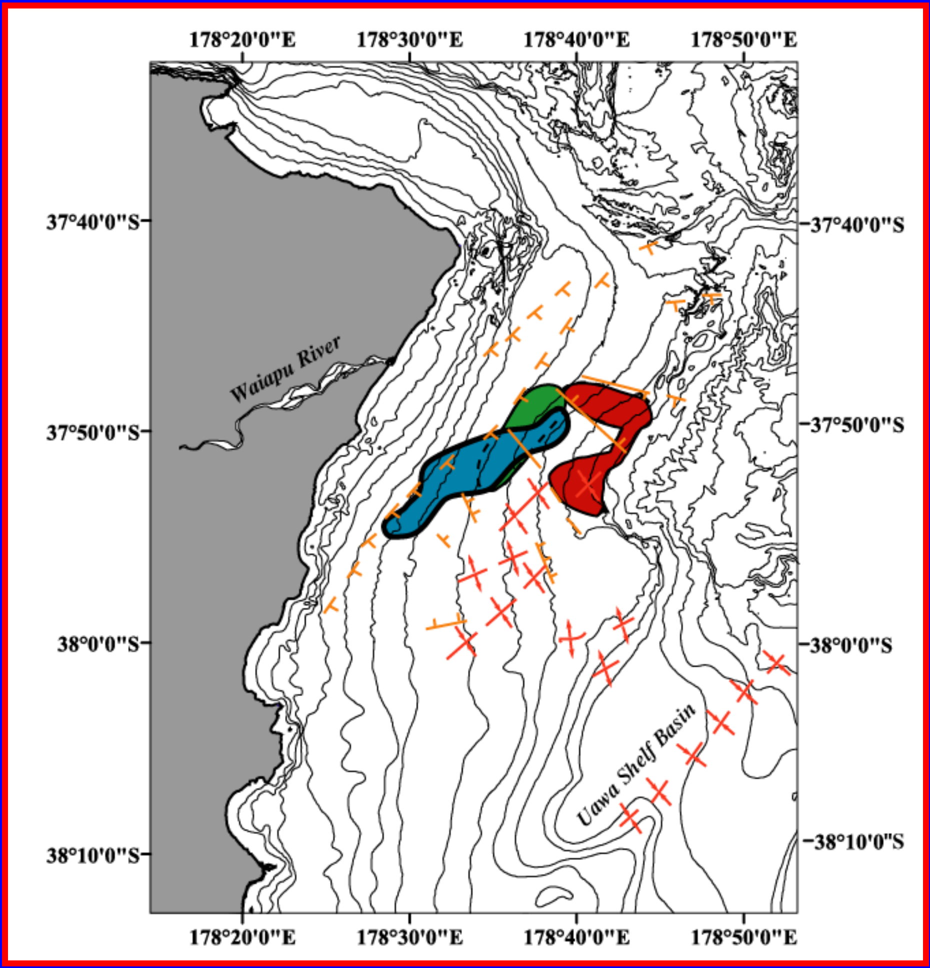


Episodic Inputs (Sediment Gravity Flows?) Preserved

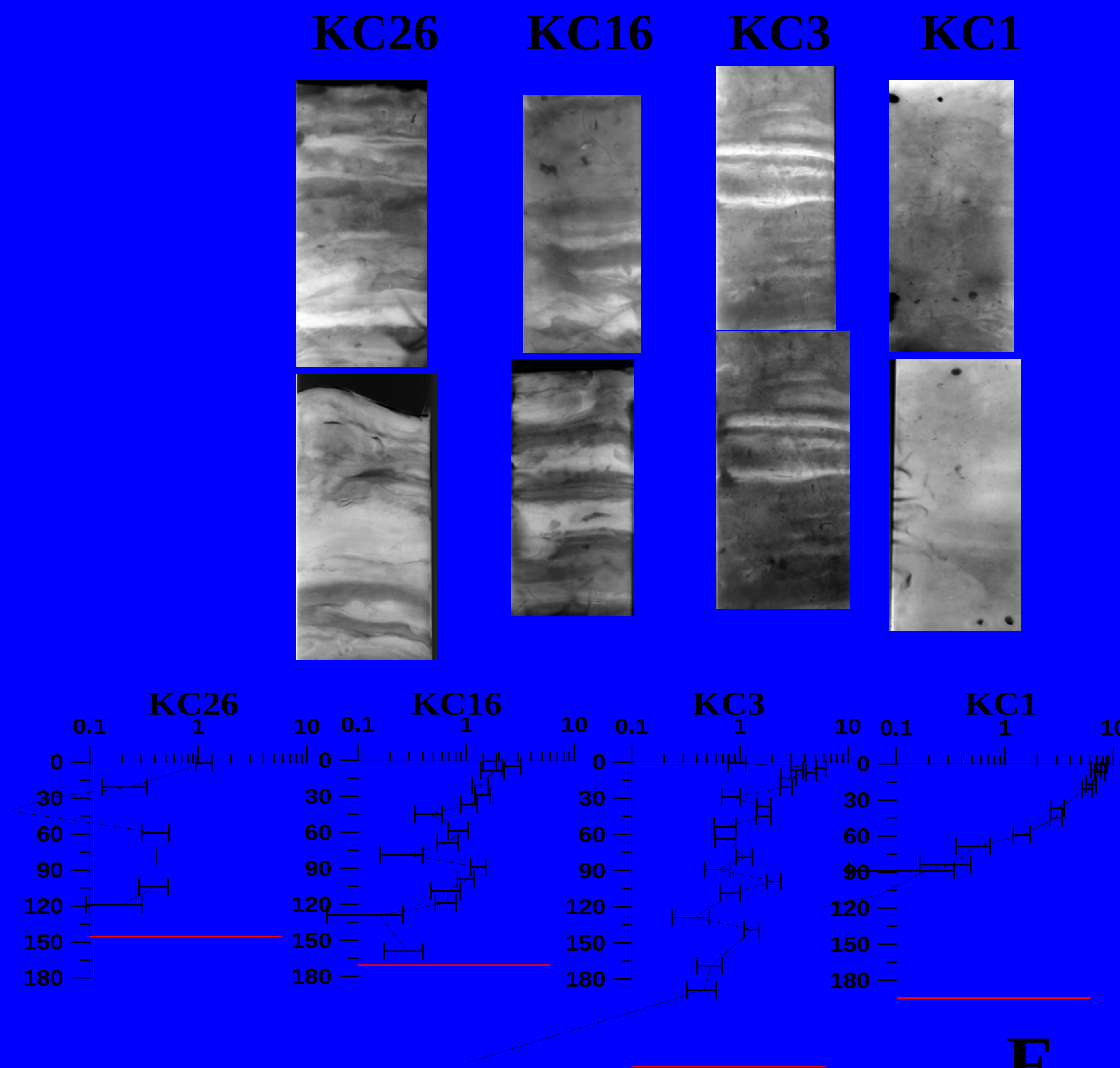


Waiapu Shelf Setting





After Lewis et al., 2004



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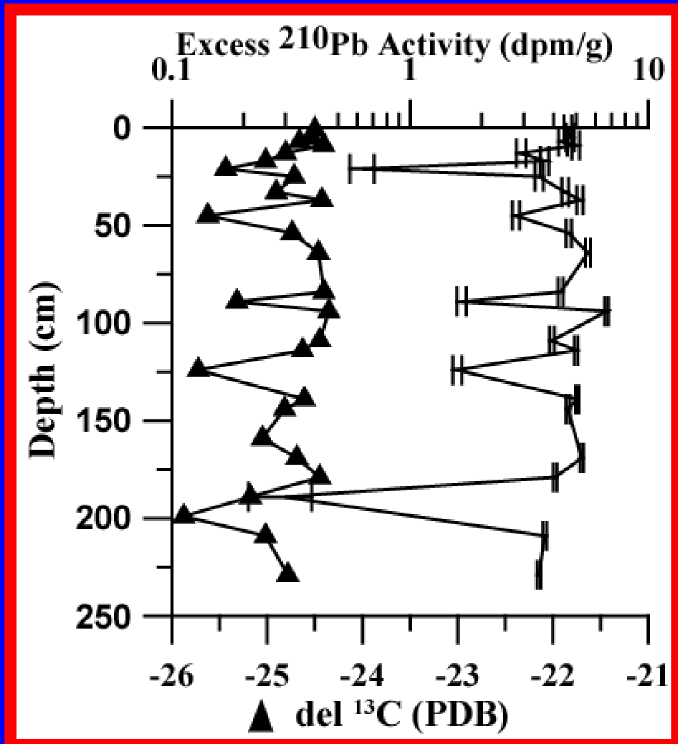
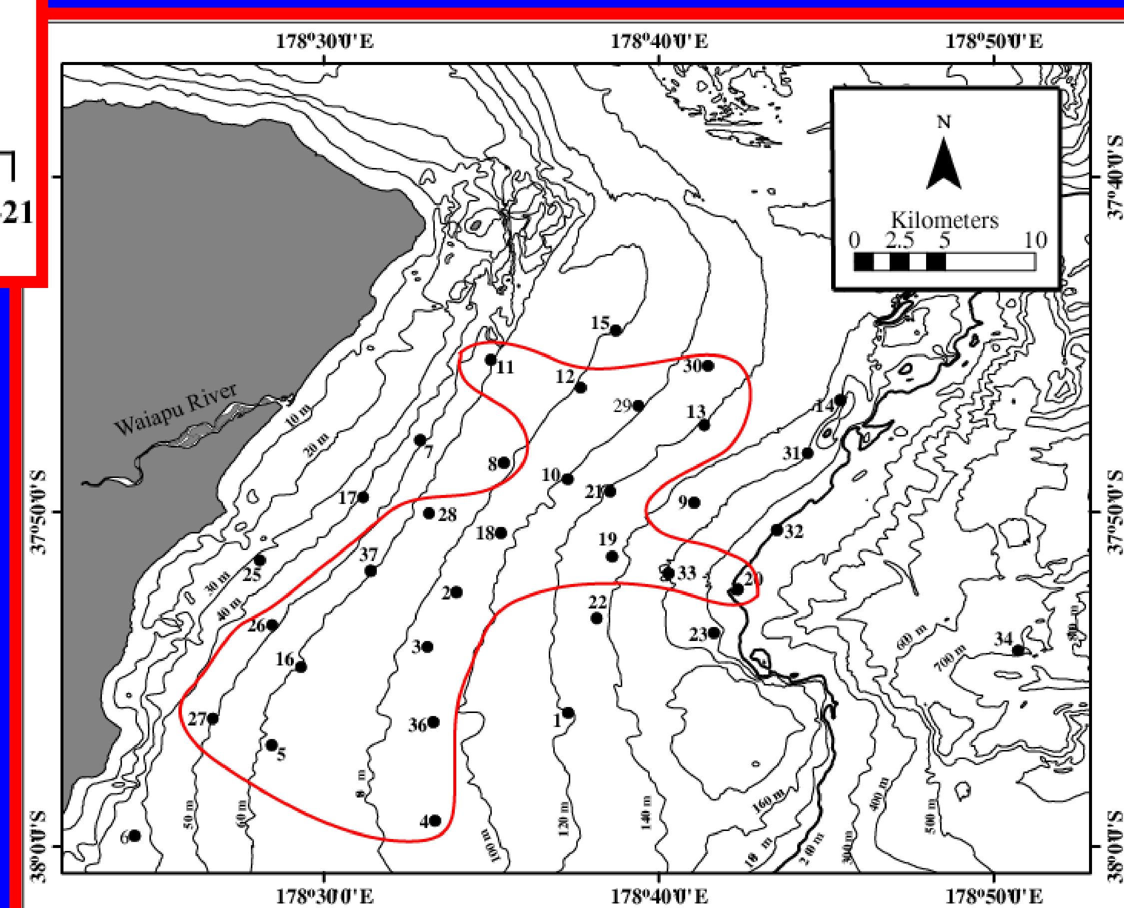
Evidence of Multiple Sediment Transport Mechanisms: Wave/ Current Supported Gravity Flows

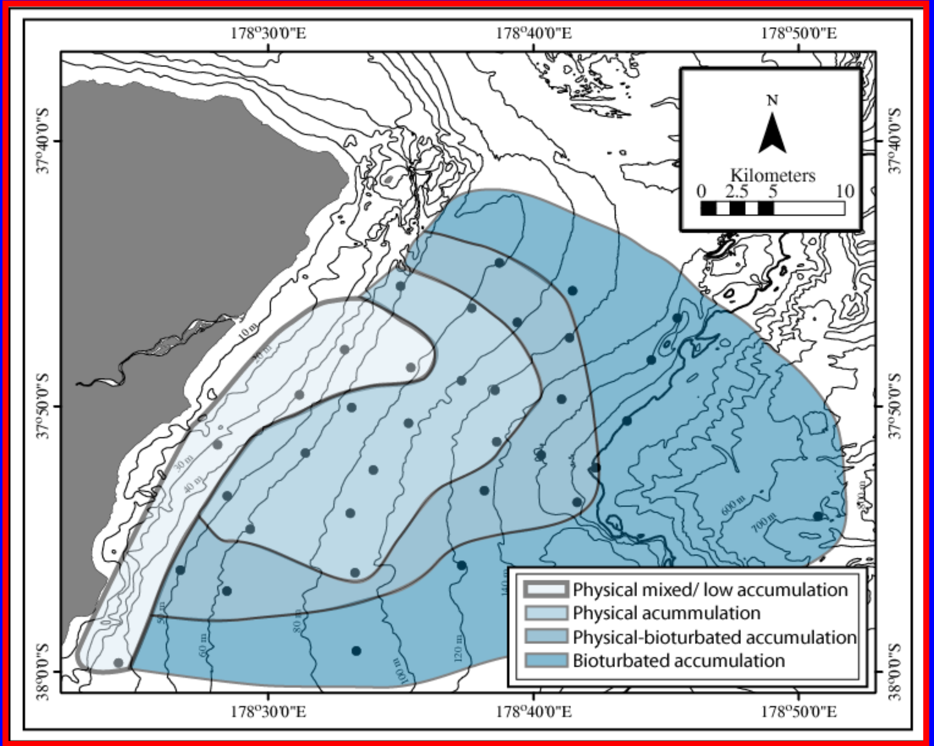


Non-steady state excess ^{210}Pb activity profiles

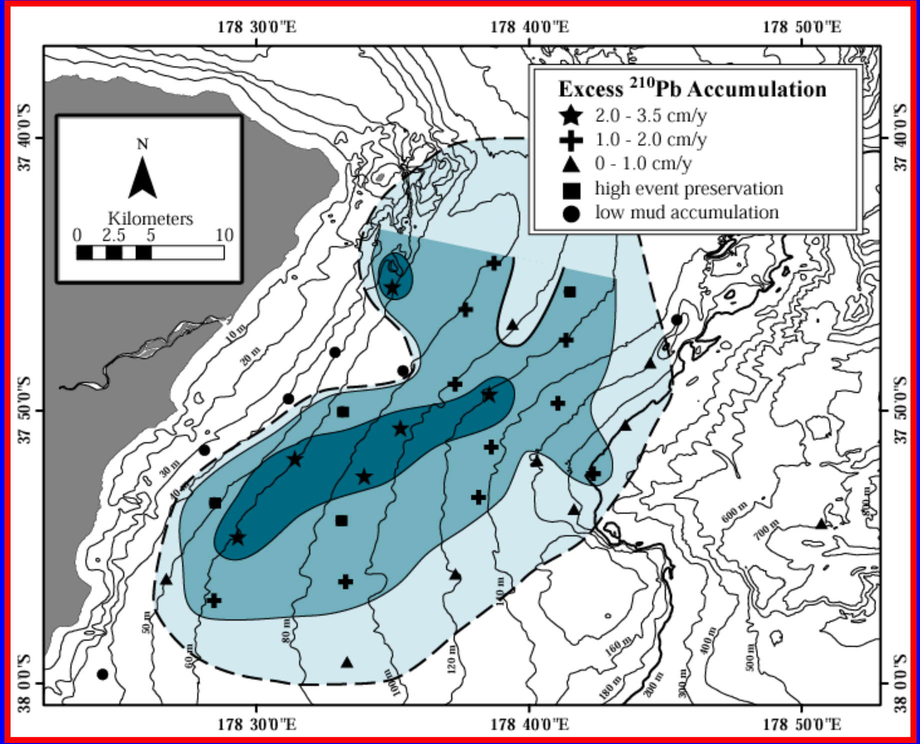


Physical Structures Well Correlated to Accumulation Rate and Episodic Input

Structure Distribution

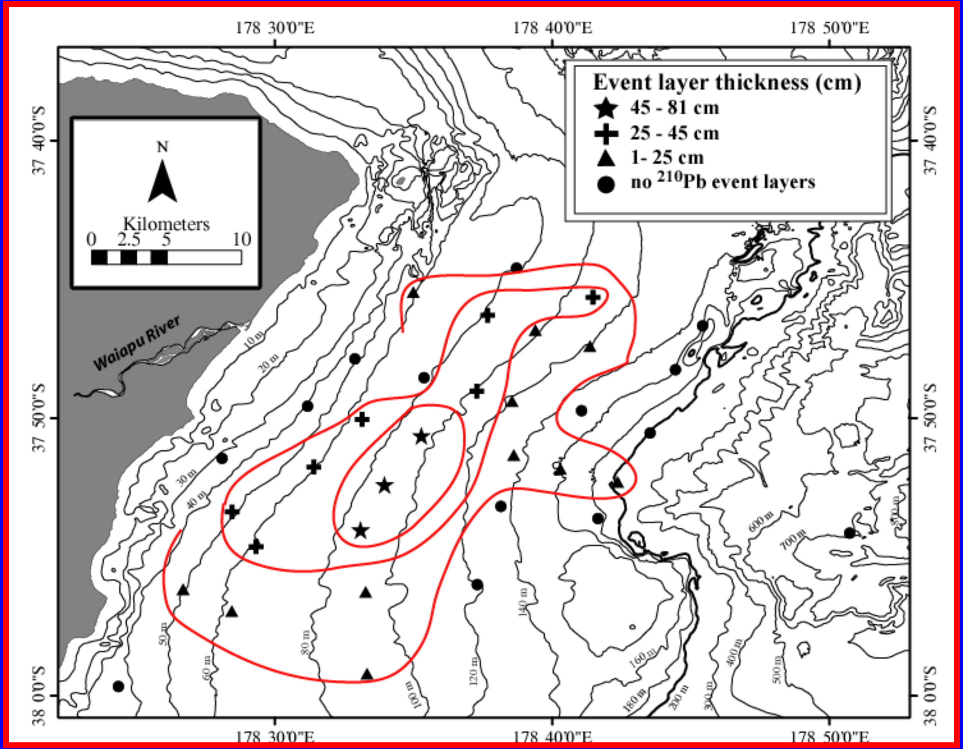


Pb-210 Accumulation Rates

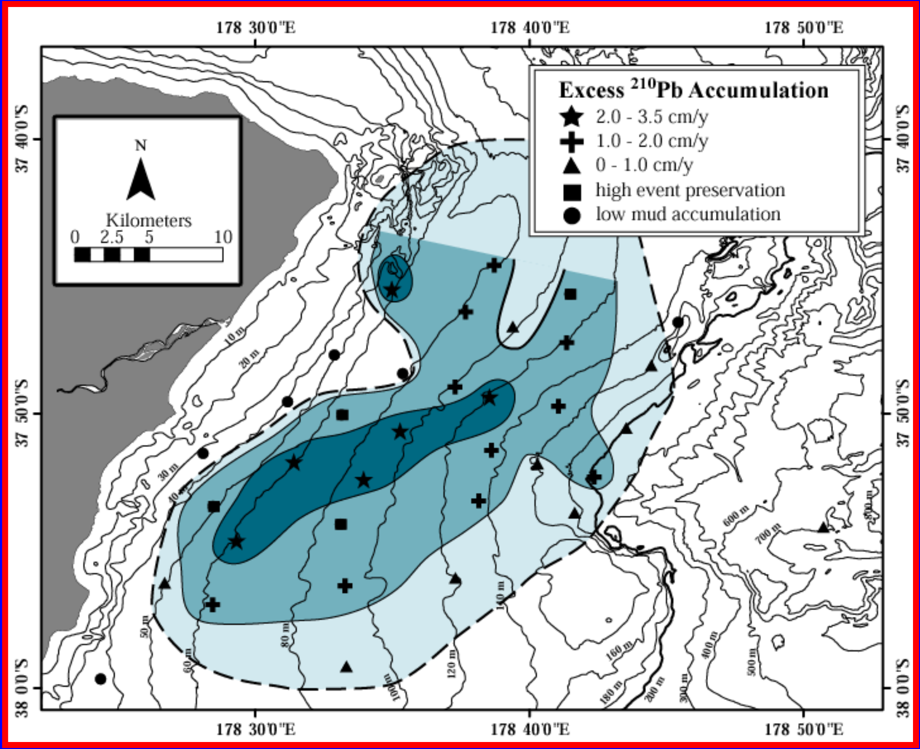


Underlying Tectonics: Wave and Current Driven Gravity Flow Direct Sediment Towards Shelf Basin

Event Layer Thickness



Pb-210 Accumulation Rate



Conclusions

- **Episodic rapid sediment inputs key to signal preservation**
- **Sediment gravity flows sensitive to subtle bathymetric gradients in slope**
- **Tectonic setting (i.e., accommodation) is dominant steering mechanism for sediment gravity flows**
- **Accumulation rate alone not sufficient to predict primary structure preservation**