Feedbacks between surface processes and subduction zone dynamics

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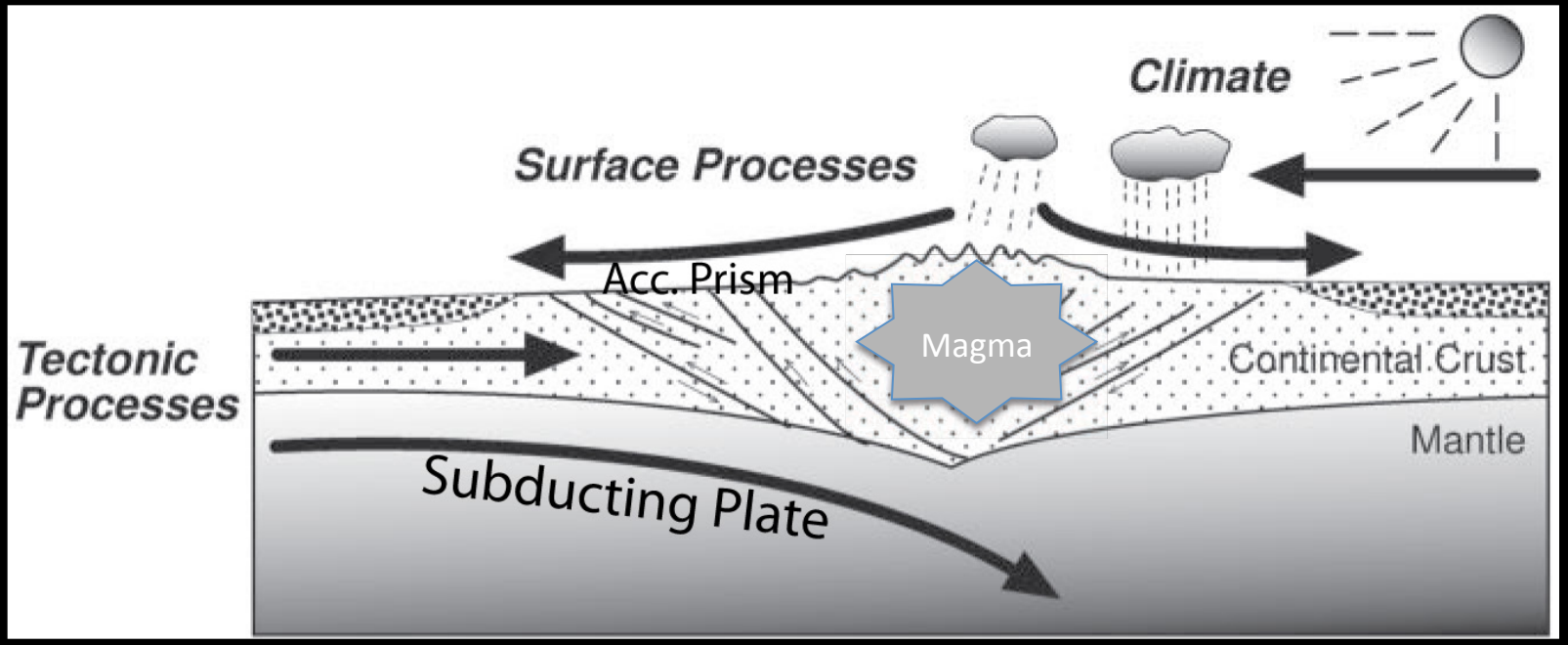
University of Florida



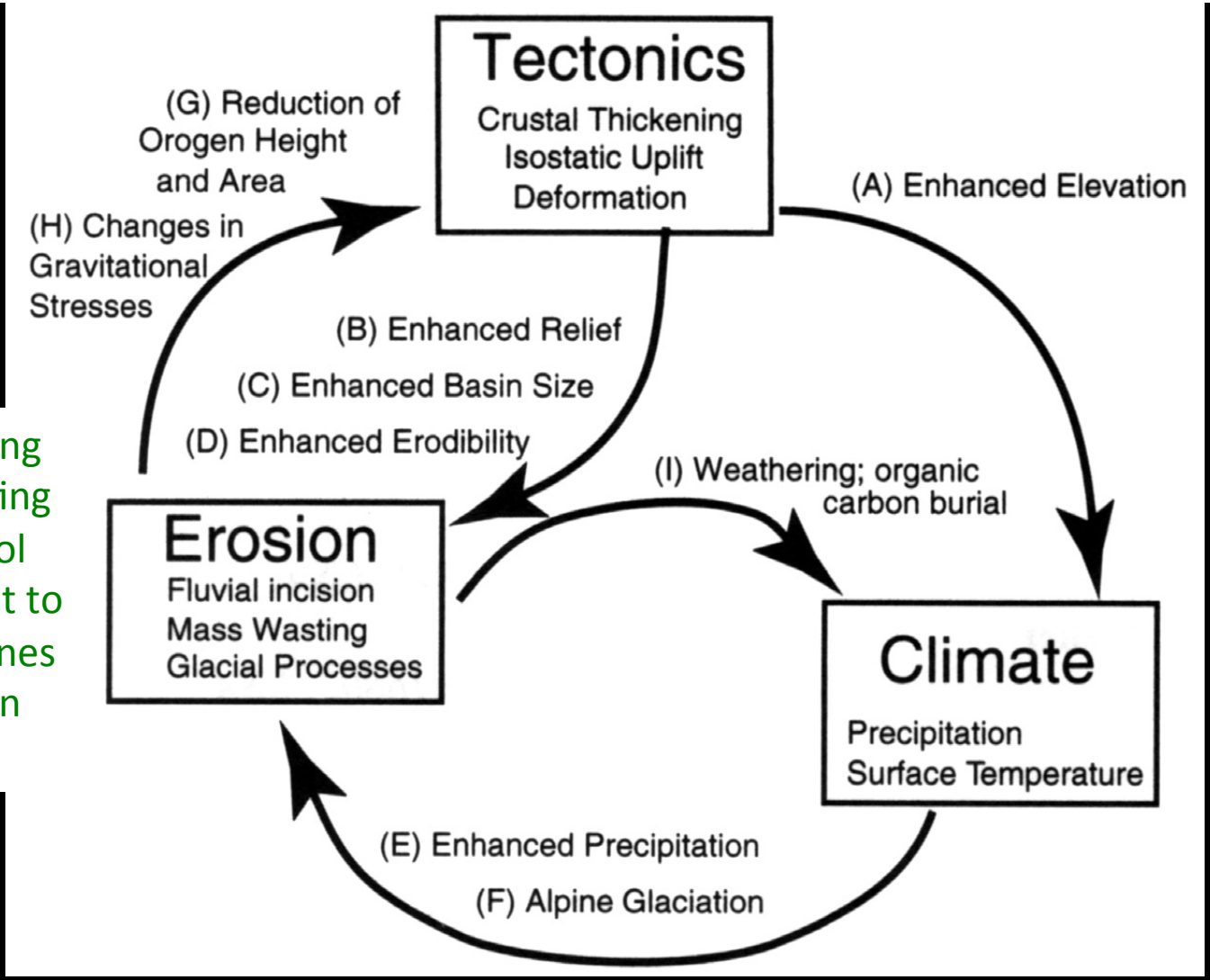
After Roe et al. (2007)

- Slingerland et al. (2009) -How would convergent margin dynamics be different if there were no sediments?
- 4-D: How do temporally and spatially evolving surficial processes influence subduction zone processes?

Feedbacks between surface processes and subduction zone dynamics

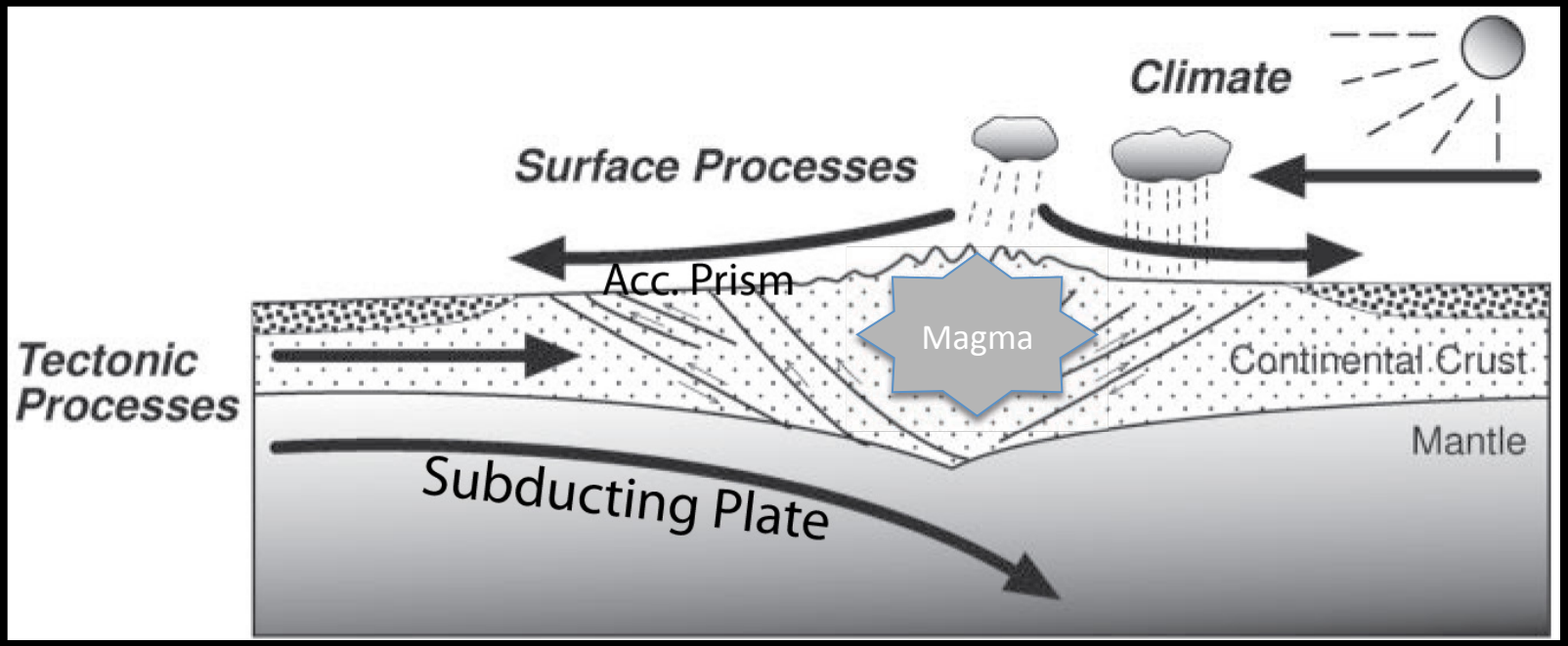
- Sediment subduction and melt production rates
- Sediment subduction and earthquake cycle
- Variable sediment composition input and orogen rheology and deformation behavior

How do evolving sediment routing systems control sediment input to subduction zones and subduction dynamics?



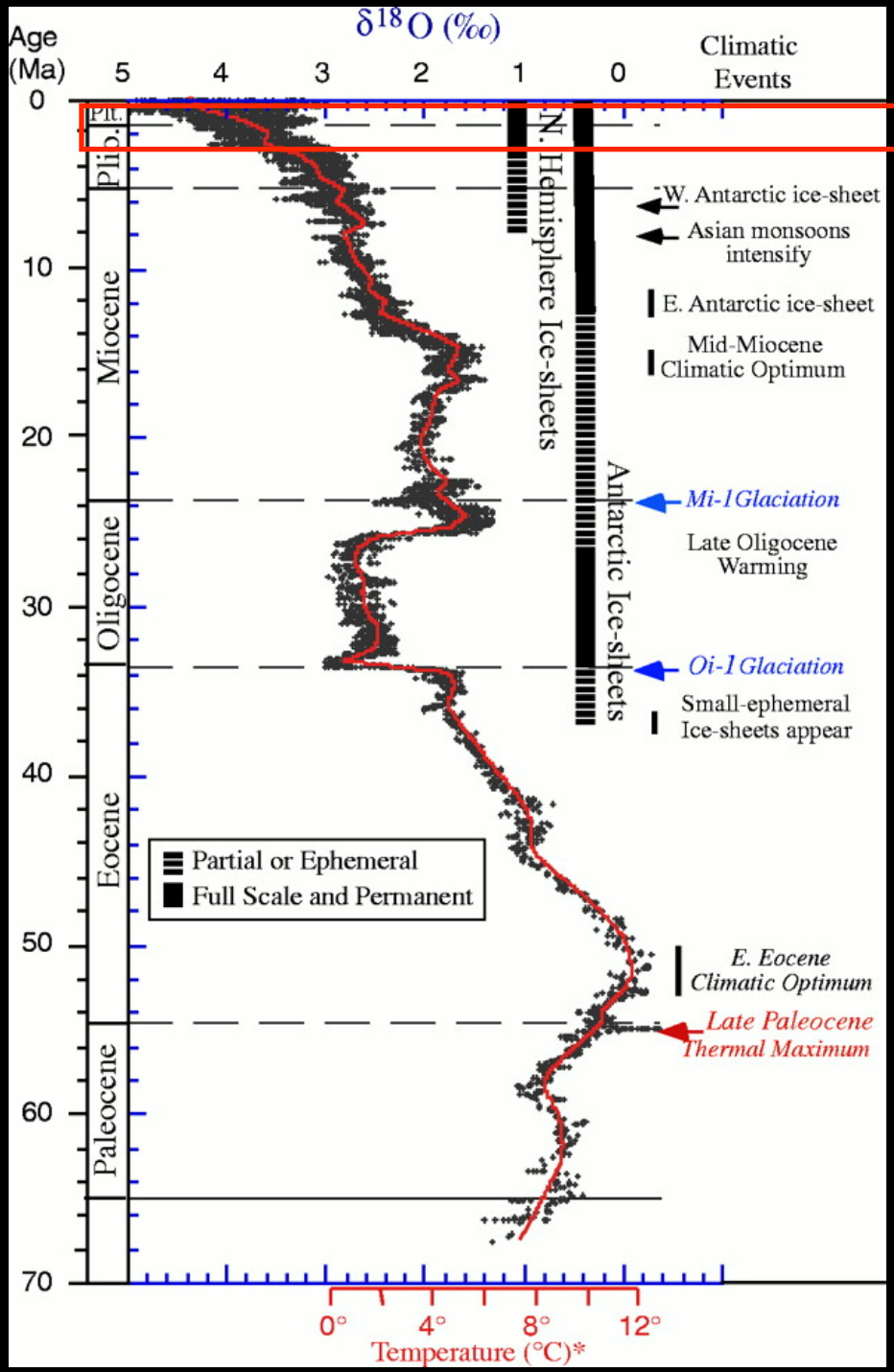
After Willett et al., (2007)

Why Surface Process Studies are Necessary Component of SCD



After Roe et al. (2007)

- Climate forcing can produce first-order changes in surface processes and tectonic responses
- Sedimentary strata are the key link between surfaces processes and subduction dynamics
- Subduction zones sediments are an ideal recorder of subduction processes because of extensive accommodation space created by the down-going slab
- Strata in the accretionary prism and forearc basin record the temporal evolution of the interactions between the arc and the subduction zone

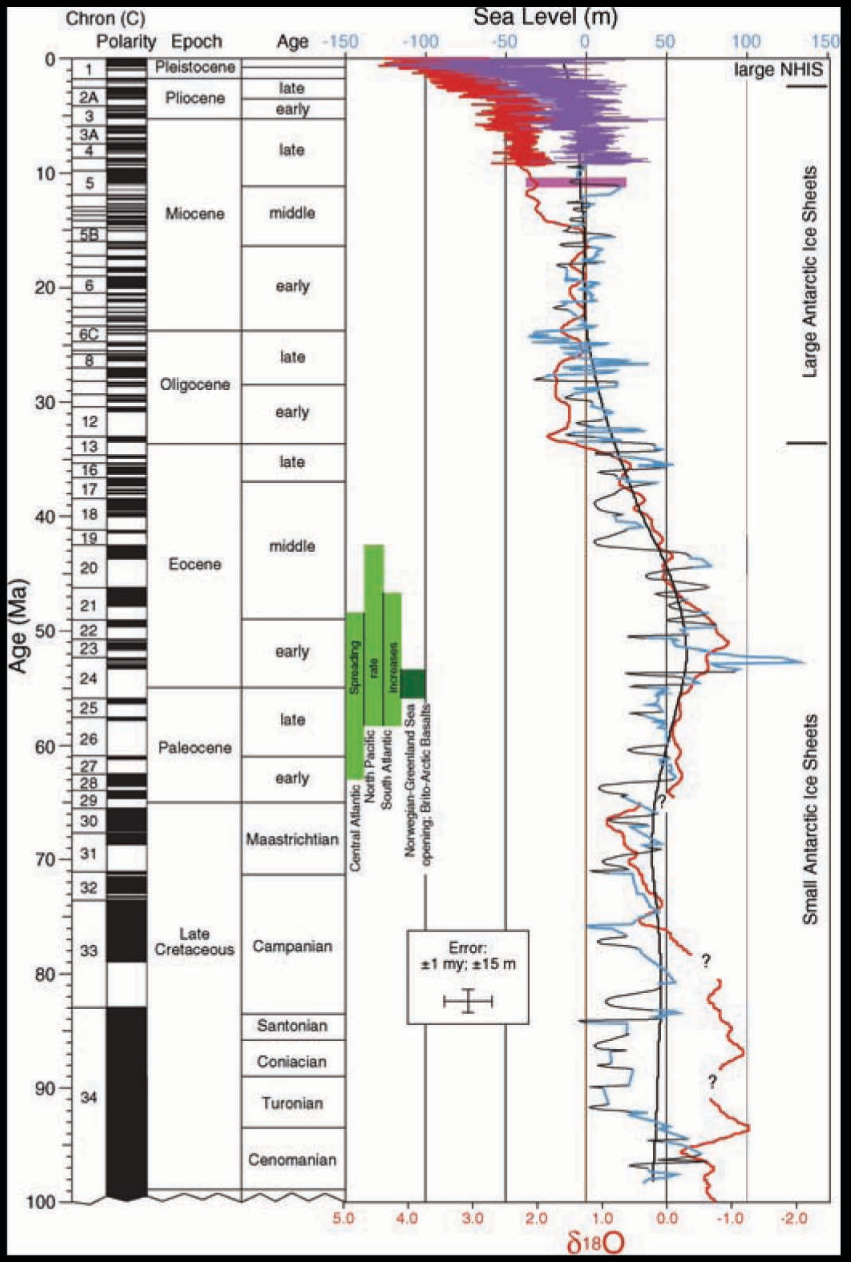


Feedbacks and Perturbations- Hothouse to Icehouse Climate

- How do landscapes and biota respond to stepwise climate shifts
- Stepwise climate shifts should lead to changes in erosion rates in arcs/orogens
- How have the surface processes that transfer sediment from arcs to forearc basins, acc. prism, and down-going slab responded to such climatic transitions?

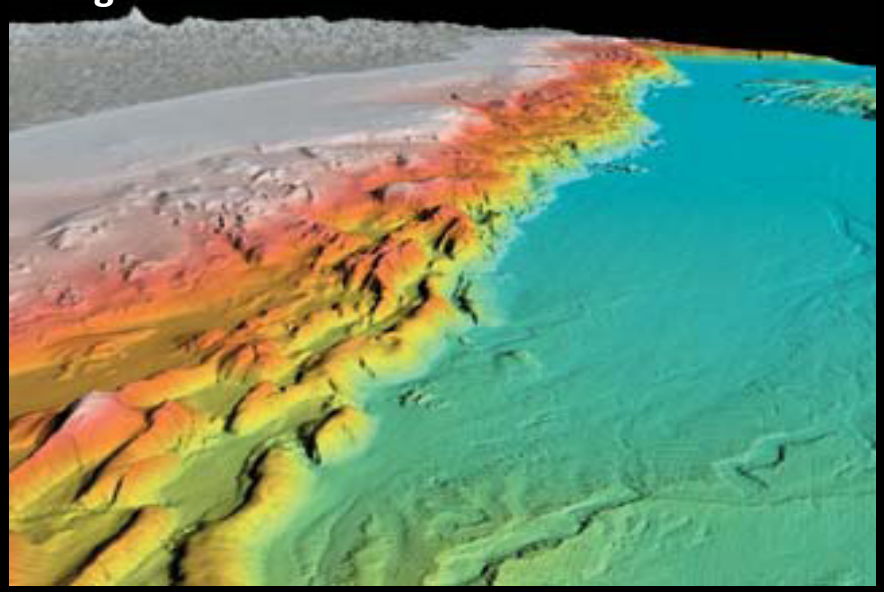
Zachos et al., 2001, Science

Marine Response to Hothouse-to-Icehouse Climate Transition



Miller et al., 2005, Science

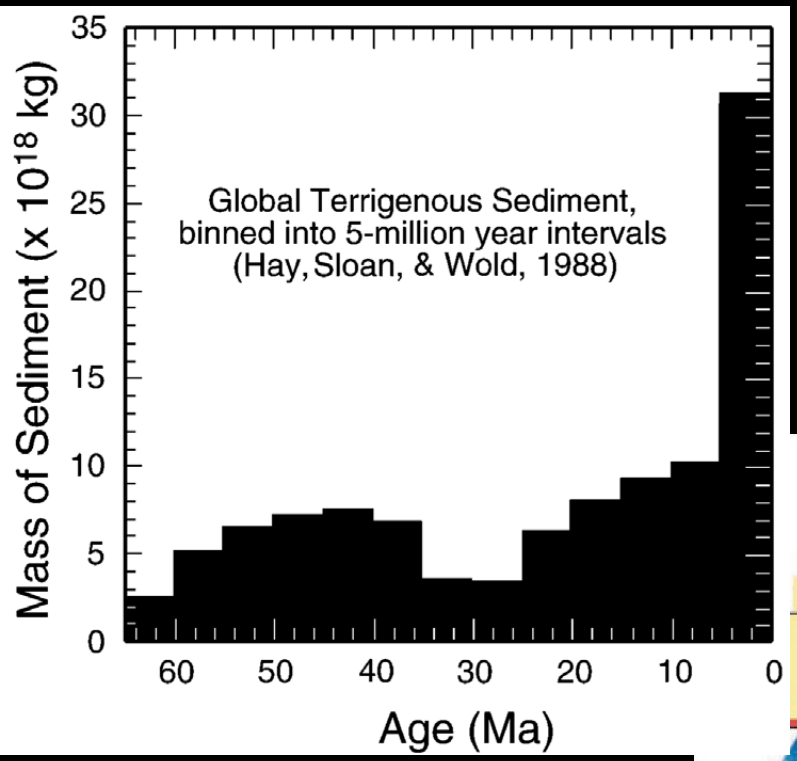
Oregon

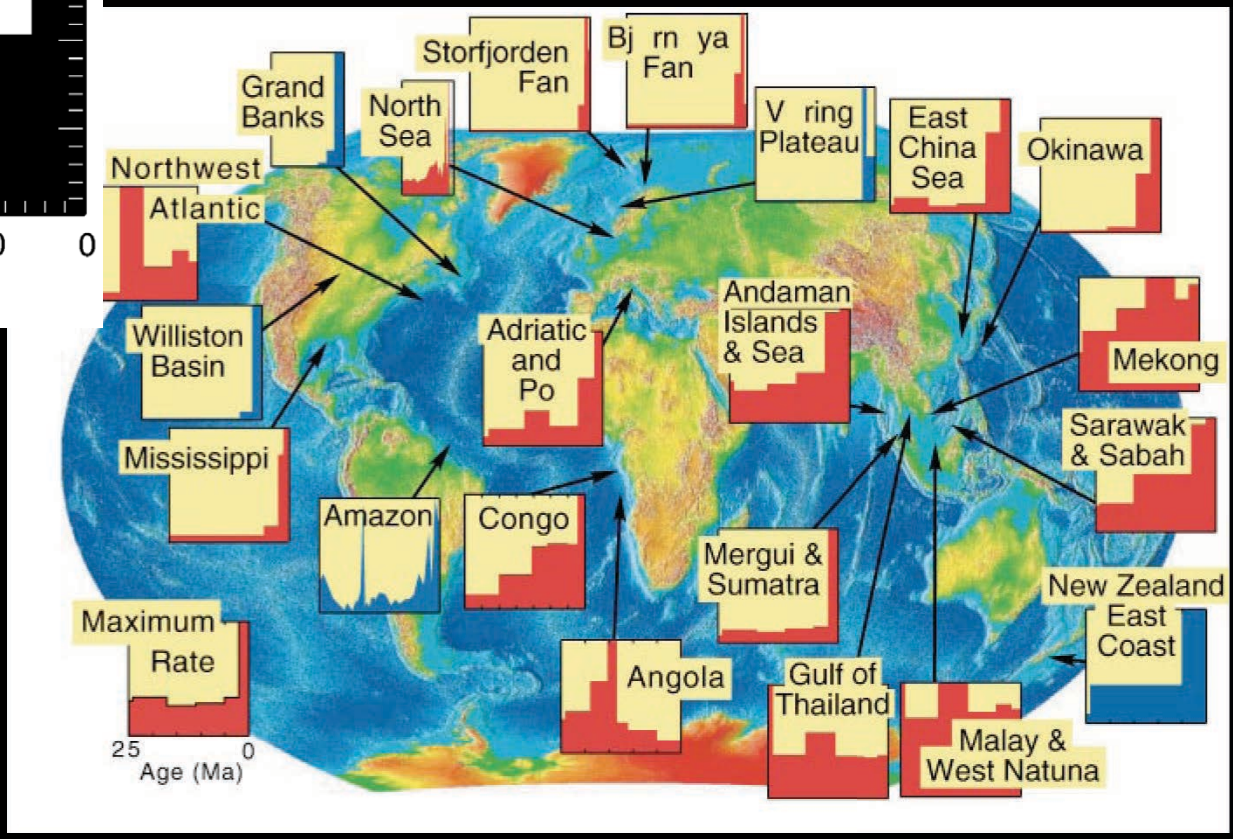


(Praston & Haxby, 2005)

- What aspects of sediment routing to downgoing slab are driven by allogenic vs autogenic processes?
- Is there a difference in subduction dynamics during icehouse versus greenhouse worlds due to changes in sediment routing?

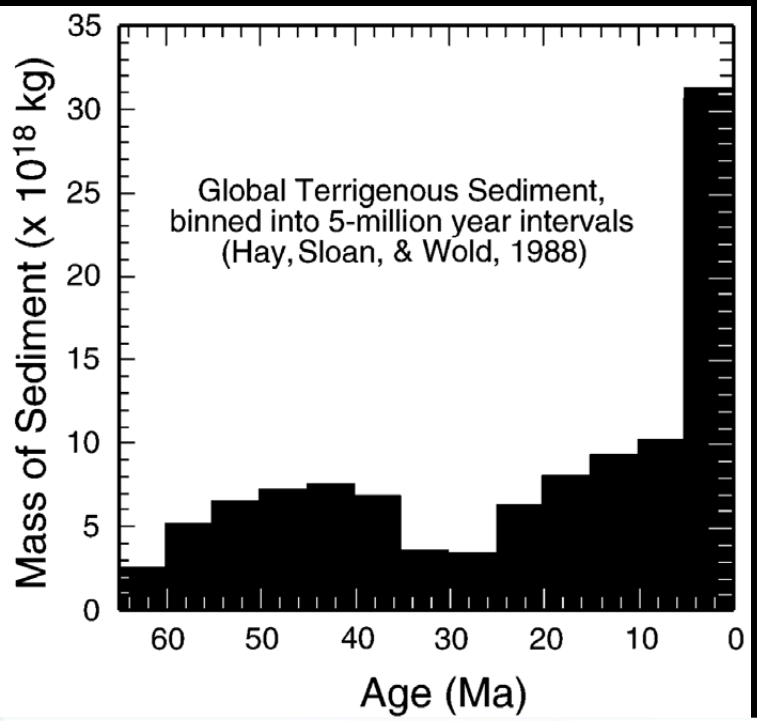
Is there a Global Sedimentary Record of Climate-Enhanced Erosion

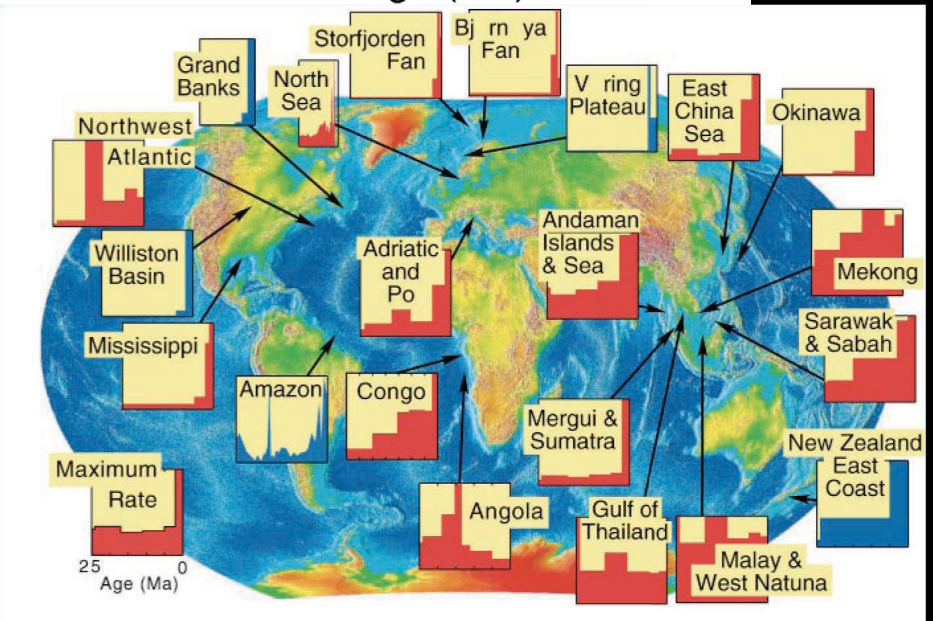




(Zhang et al., 2001; Molnar, 2004)

Sediment Burial and the Carbon Cycle-Climate and Subduction Dynamics



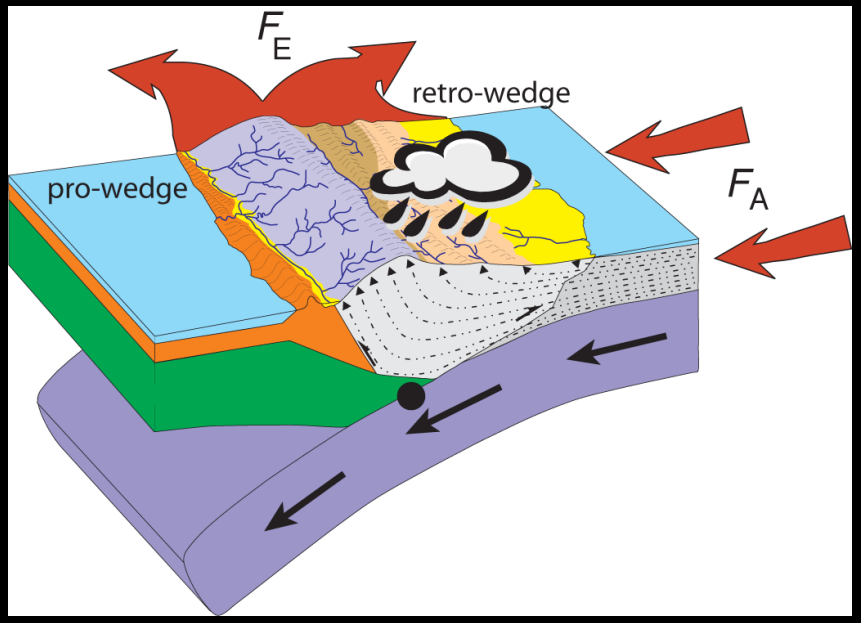


- How much organic carbon is recycled within acc. prisms versus subducted, if ancient POC constitutes significant fraction of carbon delivered from high-sediment yield convergent margins

  (e.g., Leithold and Blair, 2001; Blair et al., 2003; Leithold et al., 2005; Blair et al., 2010)

(Zhang et al., 2001; Molnar, 2004)

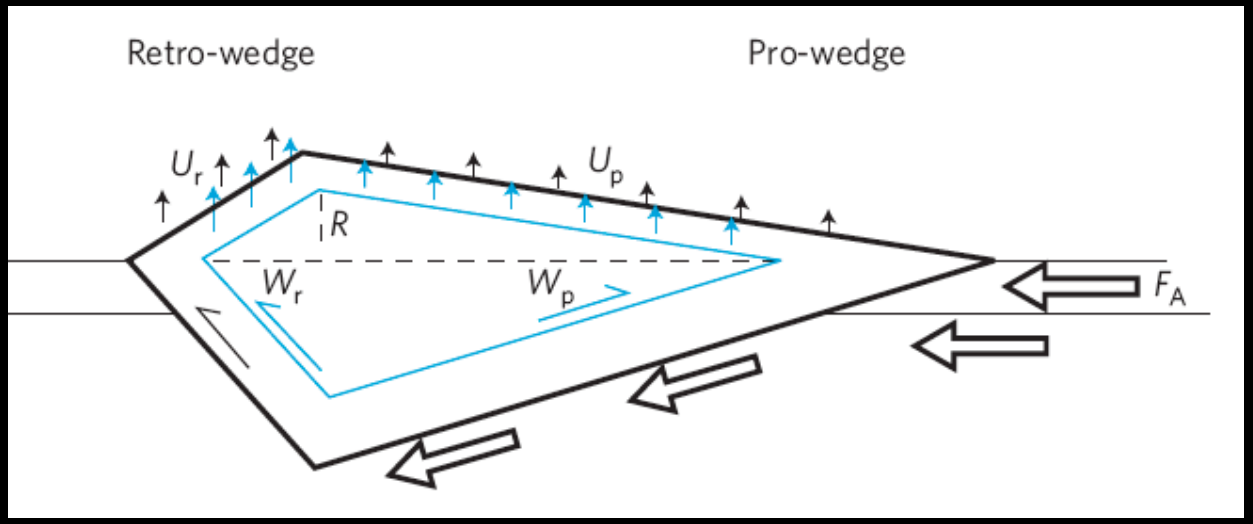
Climate Feedbacks and Perturbations-Geodynamic Response of the Orogen/Arc



Modified from Stolar et al. (2007)

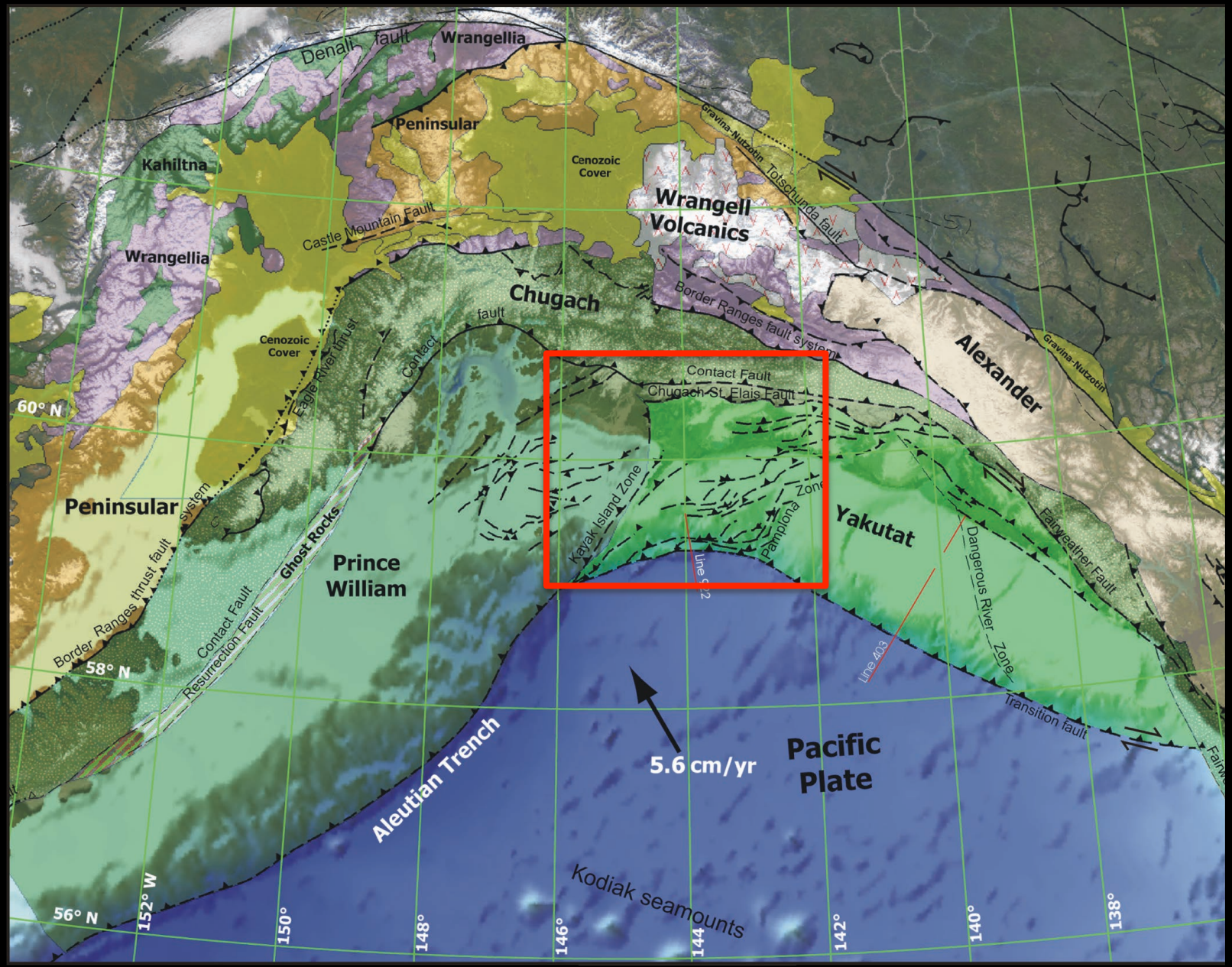
Models allow for predictable geodynamic response to climatically increased Erosion Flux ($F_E > F_A$) (Whipple, 2009):

- a retreat of the deformation front & a concentration of strain within the interior (out-of-sequence thrusting in acc. prism)
- a decrease in relief
- an increase in rock exhumation rate
- a temporary increase in sediment flux to the surrounding basins

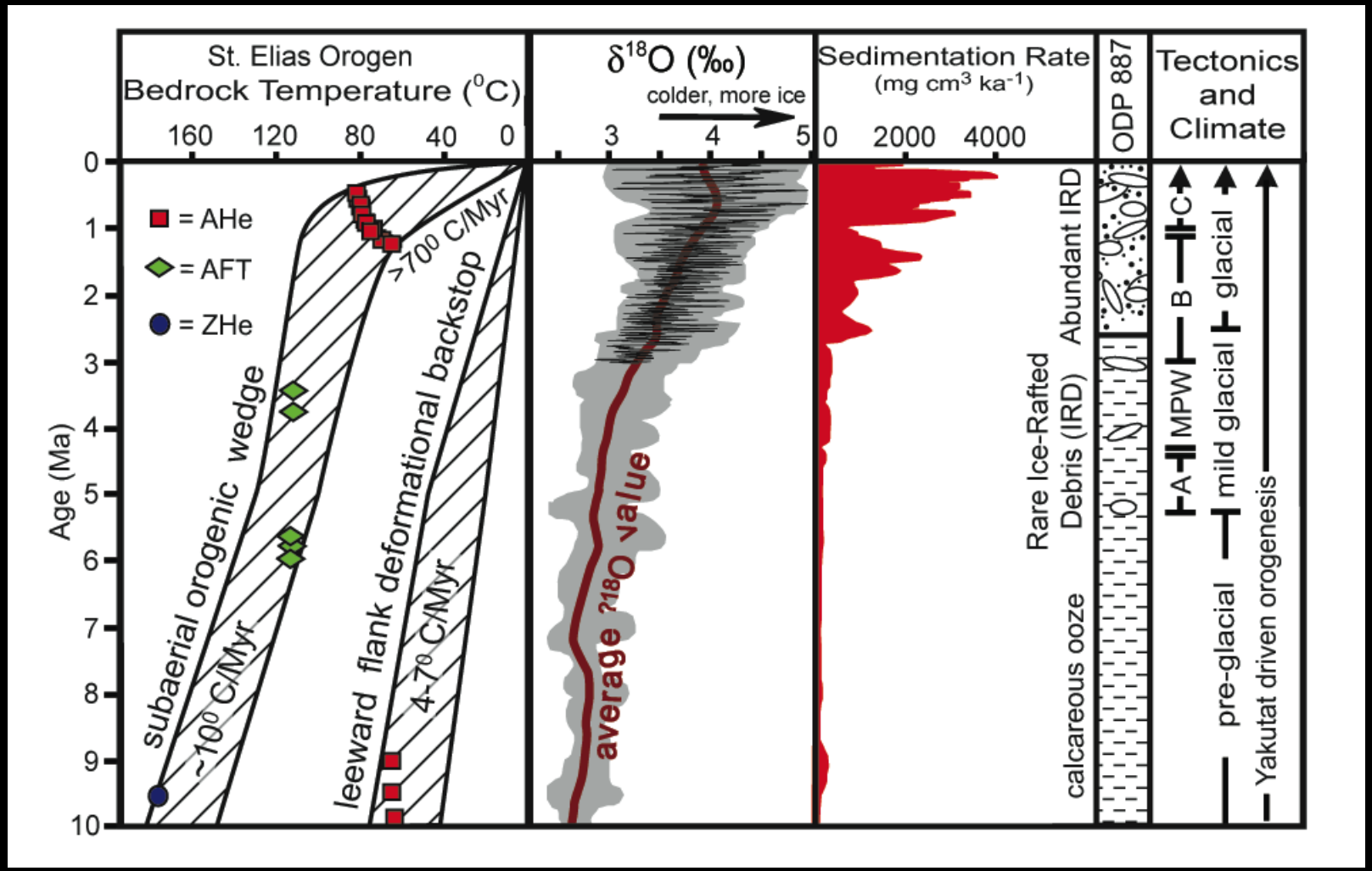


After Whipple (2009), *Nat. Geosci.*

Evidence of Feedbacks in Convergent Orogens

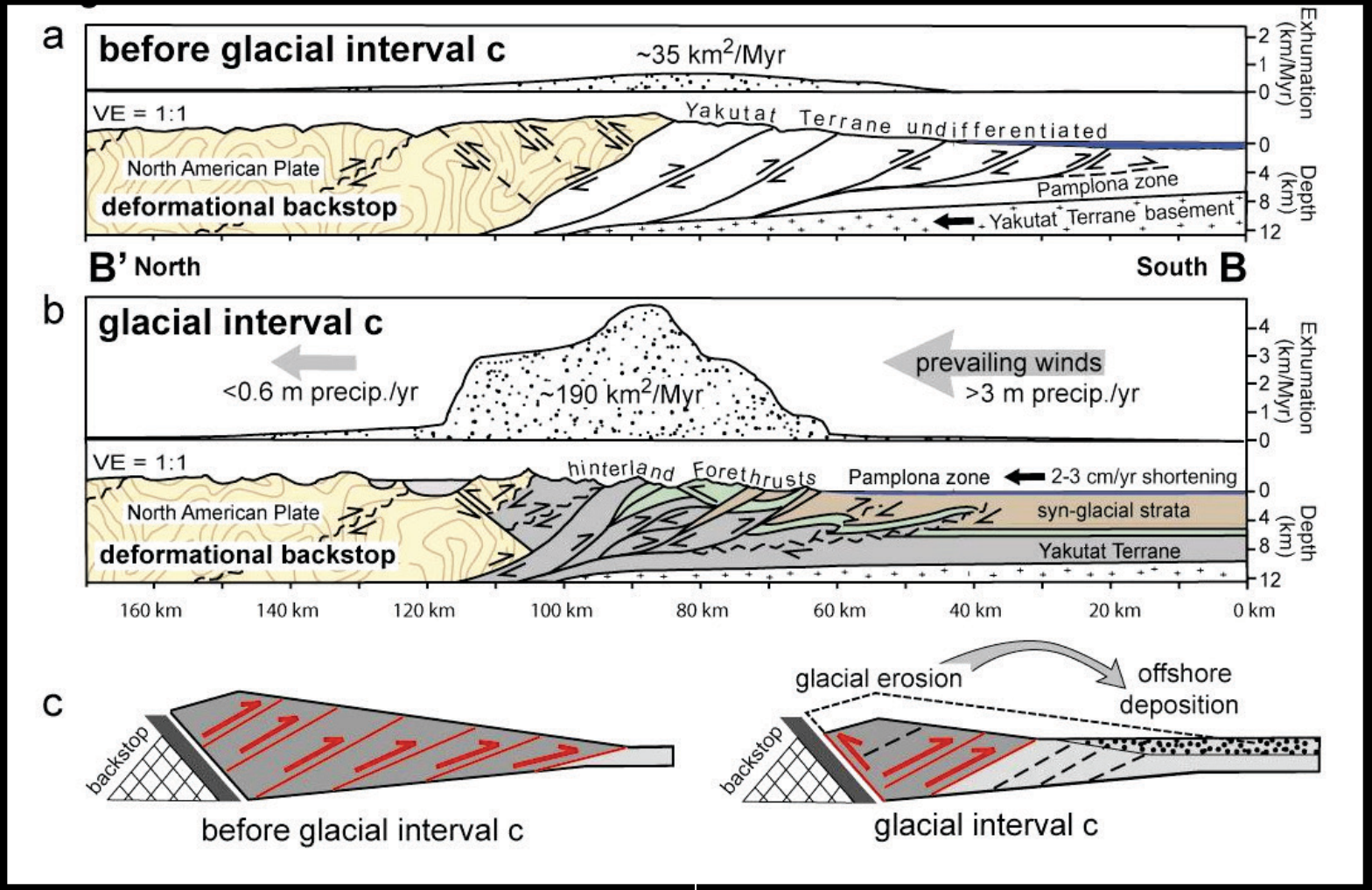


Climate-Erosion and Exhumation Linkage-Southern Alaska



Berger et al., *Nature Geosciences*, 2008

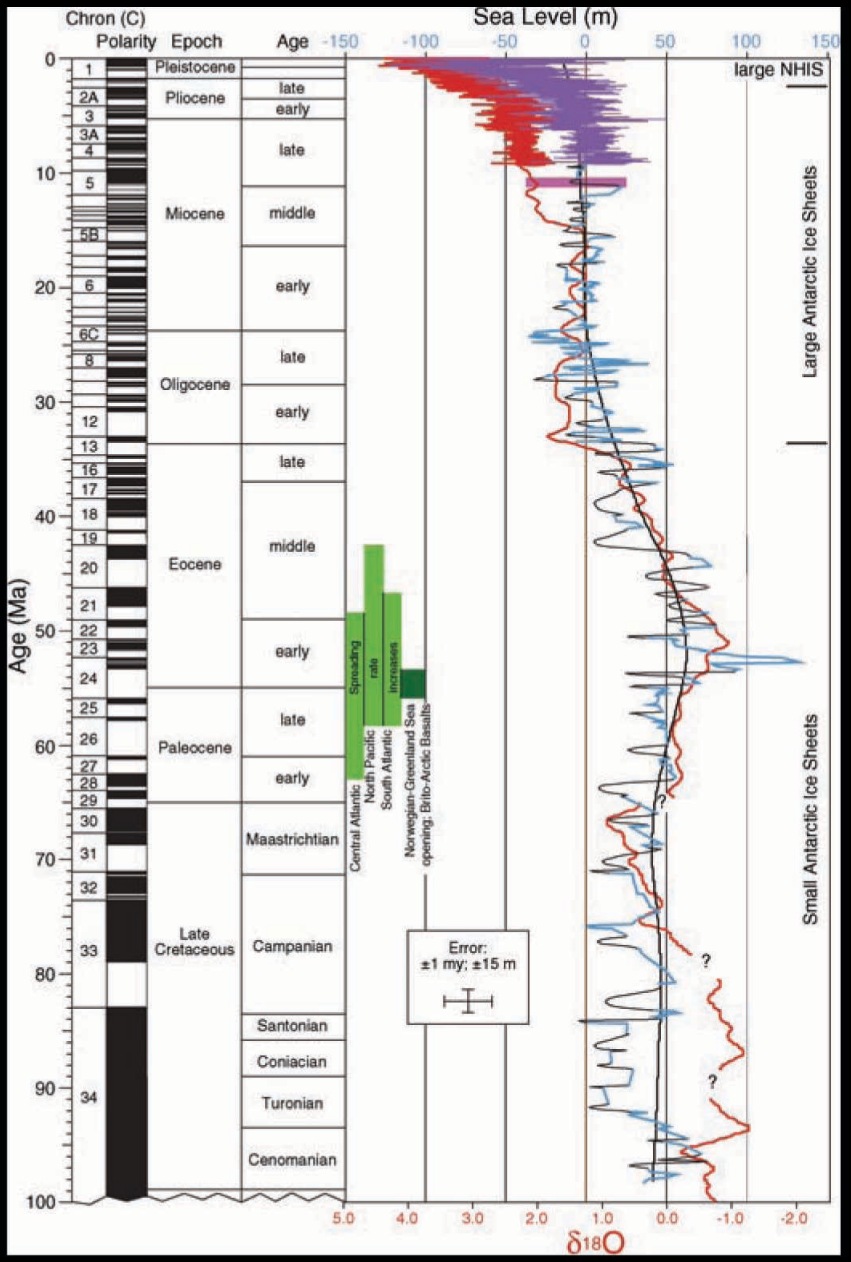
Climate-Tectonic Feedback and the Orogenic Wedge



- Deformation focused beneath glacial ELA front
- Out-of-sequence thrusting in acc. prism
- Increased sediment flux to downgoing plate

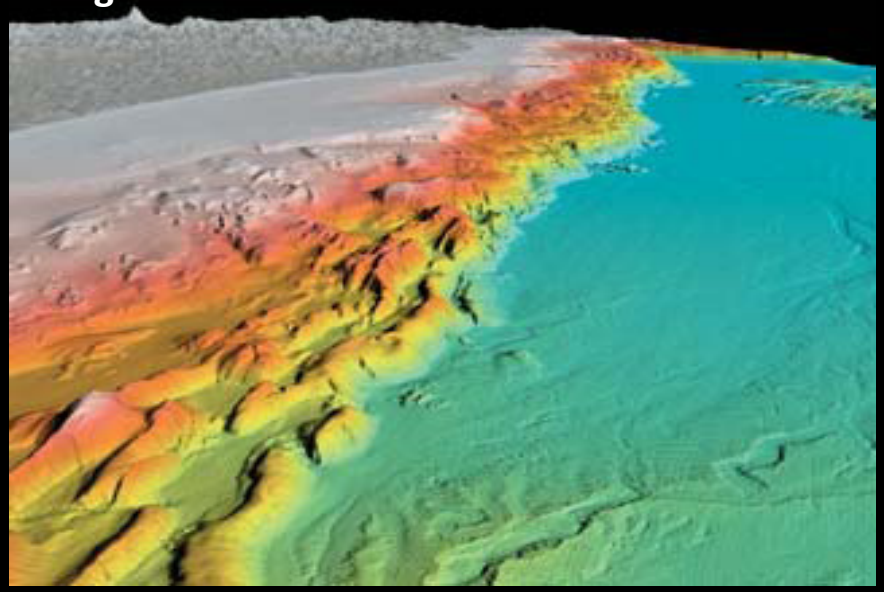
Berger et al., *Nature Geosciences*, 2008

Marine response to hothouse-to-icehouse transition



Miller et al., 2005, Science

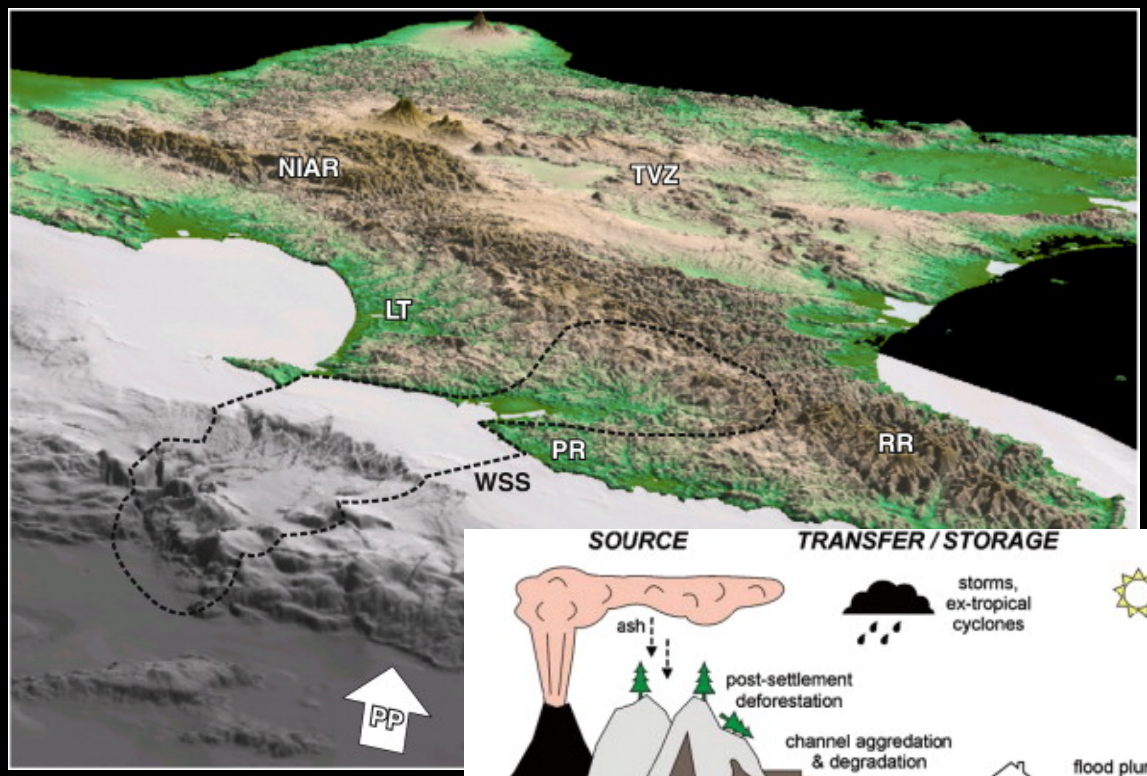
Oregon



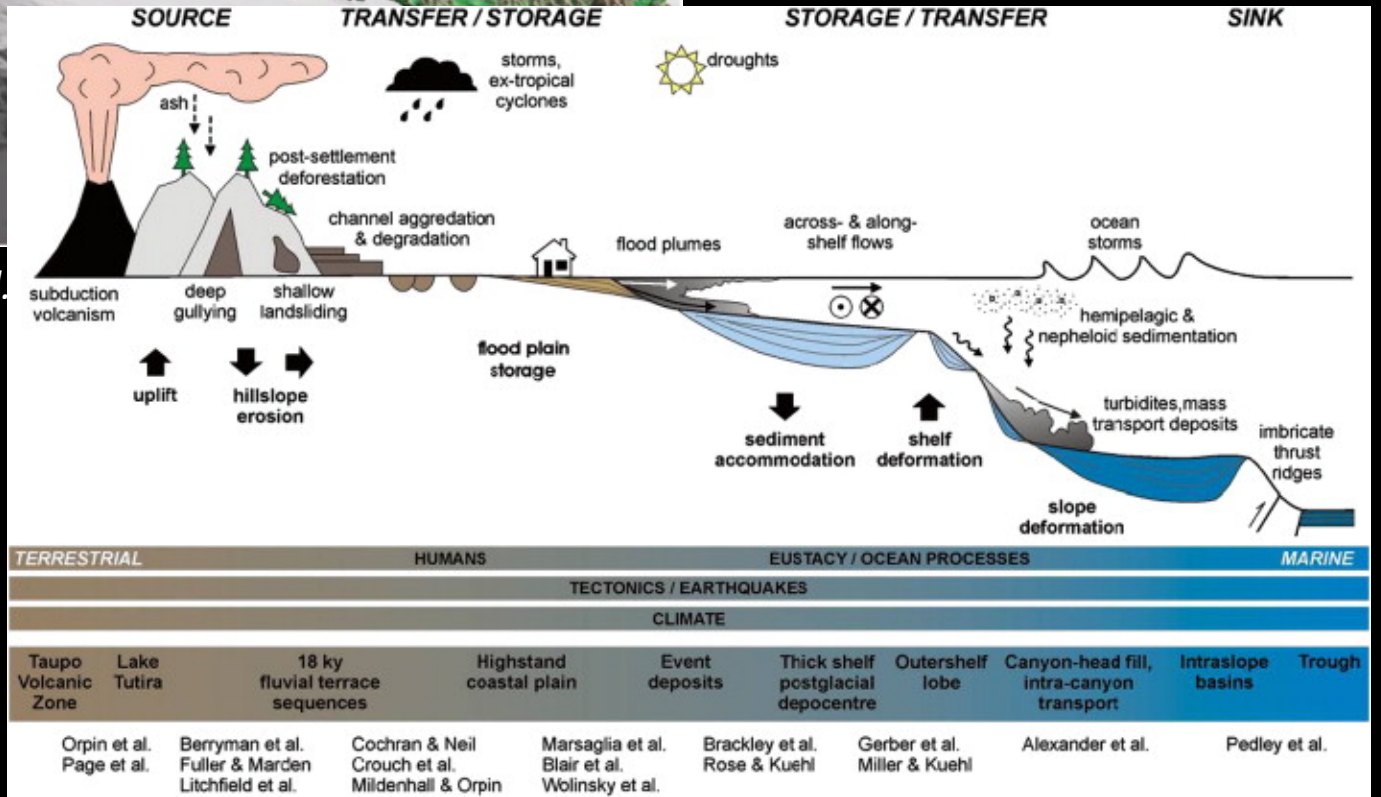
(Praston & Haxby, 2005)

- What aspects of sediment routing to downgoing slab is driven by allogenic vs autogenic processes?

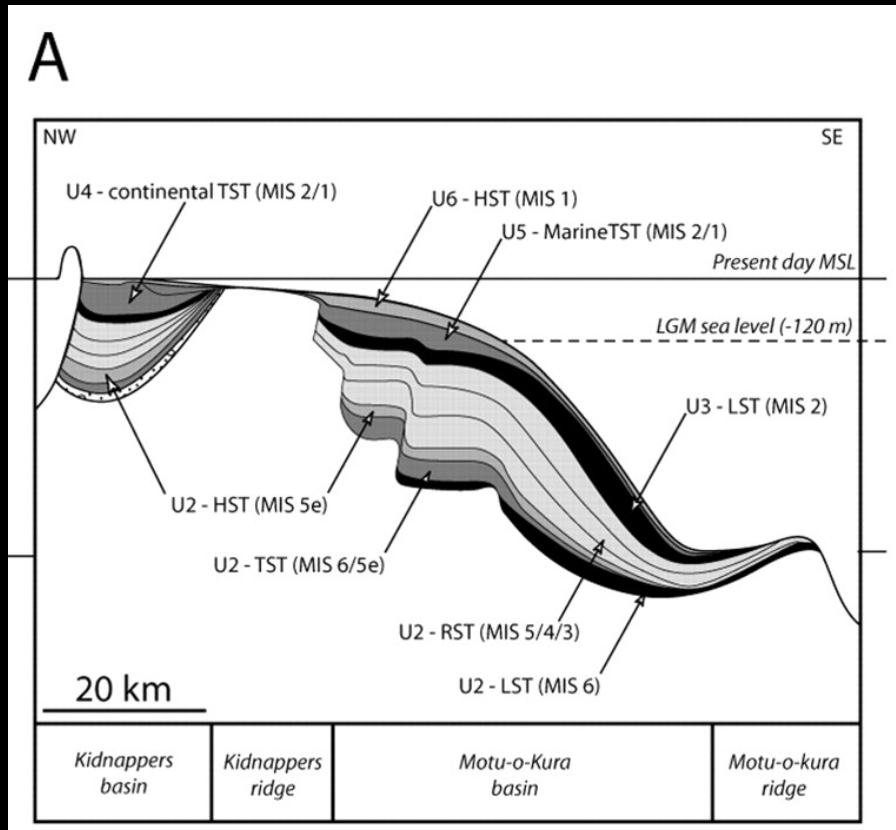
Sediment Routing on Convergent Margins-Waipaoa S2S

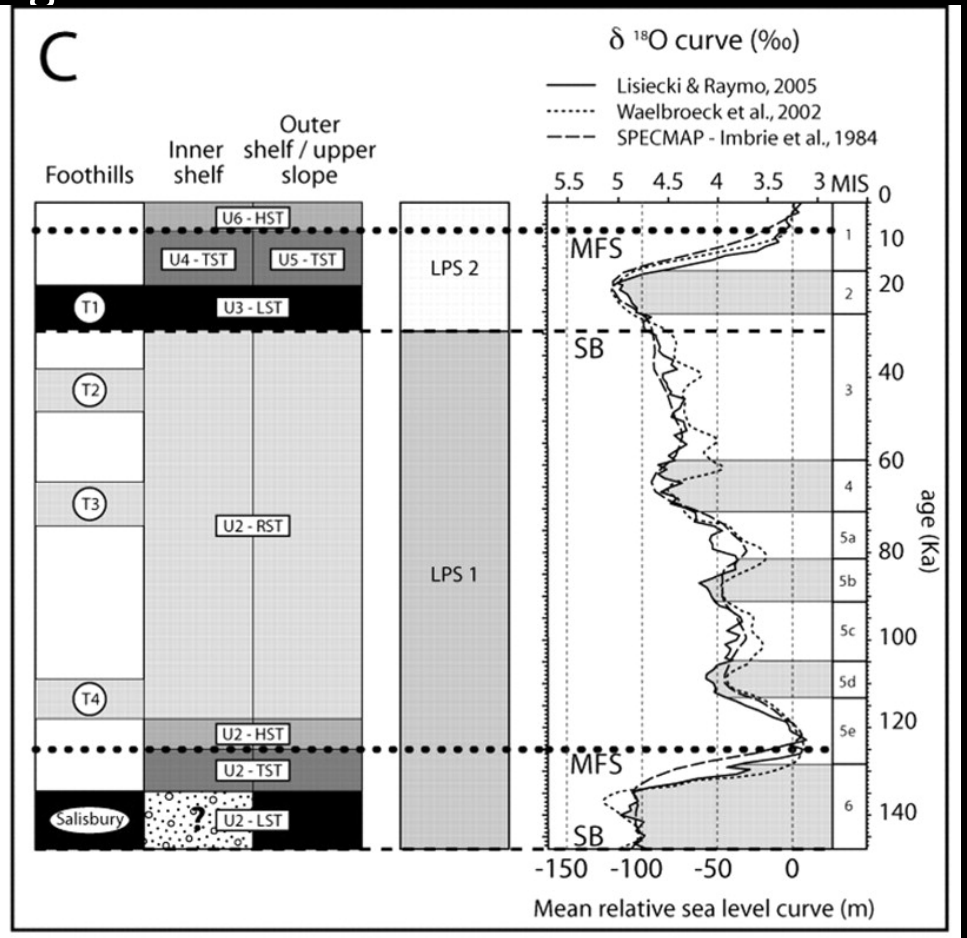


Carter et al. (2010), *Mar. Geol.*



Sedimentary Record of Eustatic Forcing of Sediment Routing on Convergent Margins

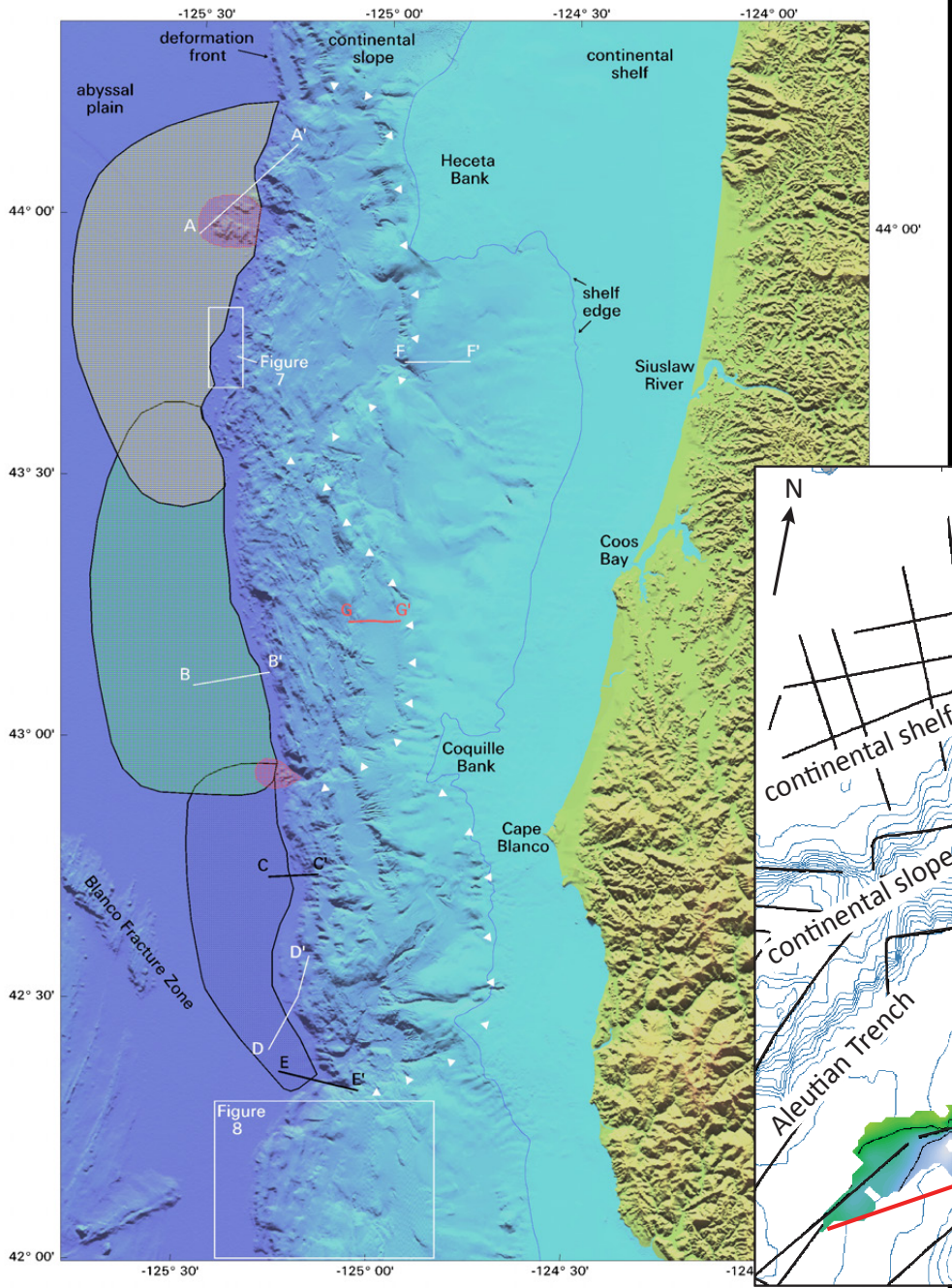




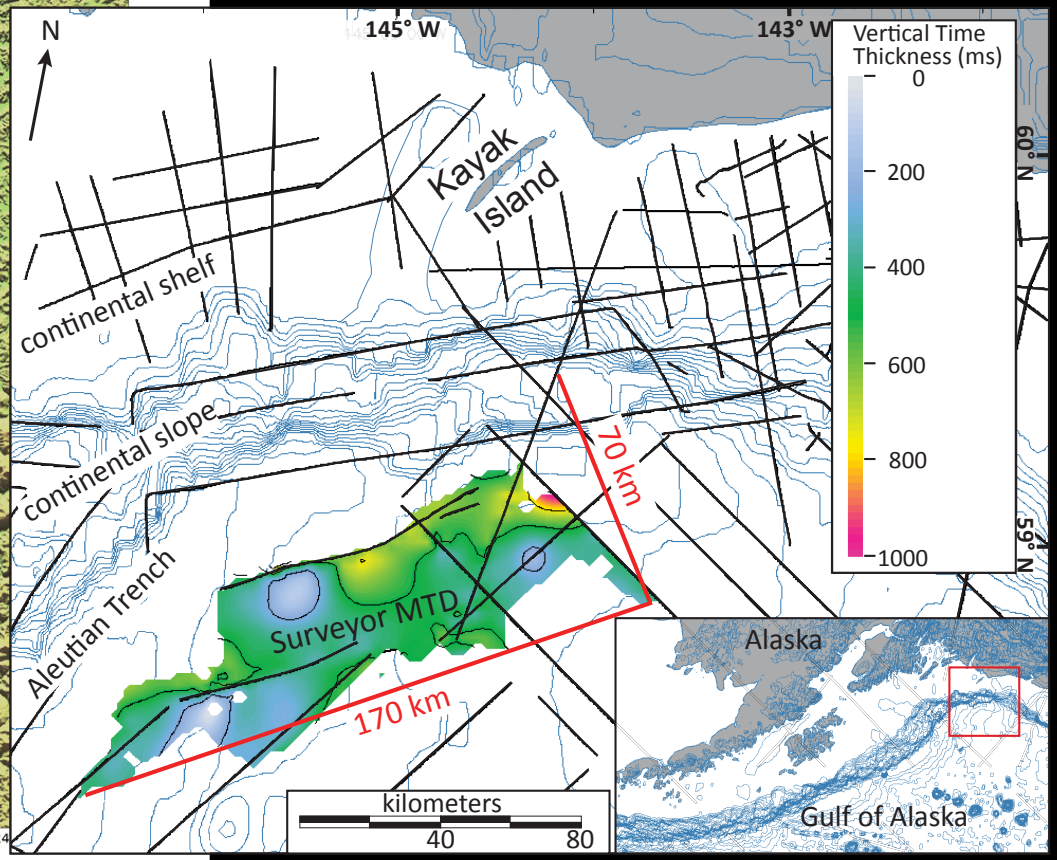
- Cascadia/Eel River –Burger et al. (2002)
- Adriatic-Ridente et al. (2009)
- New Zealand-Carter and Manighetti (2006); Paquet et al. (2009)

Large Mass Transport Deposits on Oregon and Alaska margin estimated to form on Pleistocene time scales-

- Allogenic or autogenic forcing?
- What is impact on sediment flux to down-going slab?

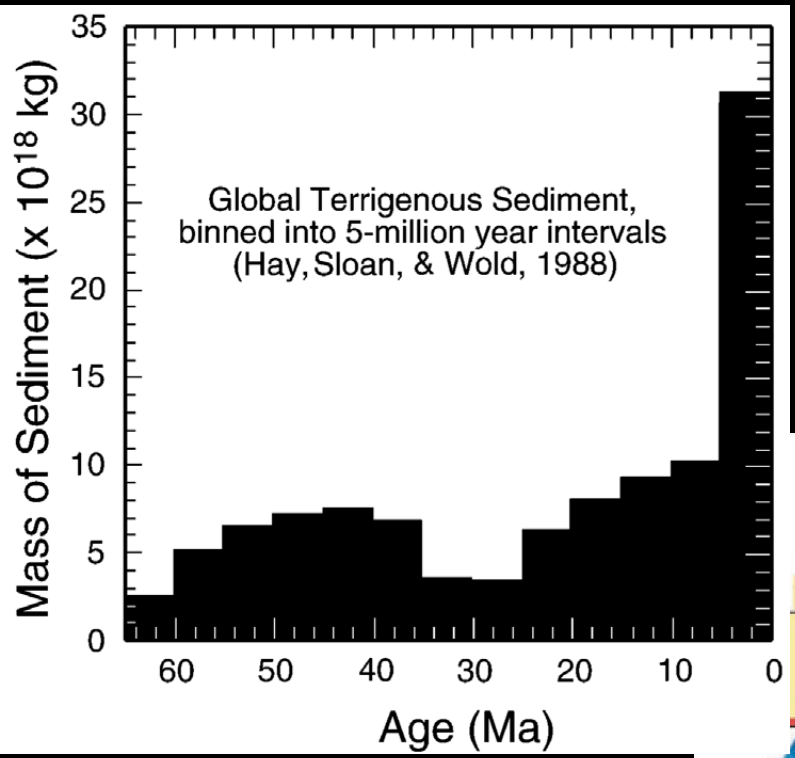


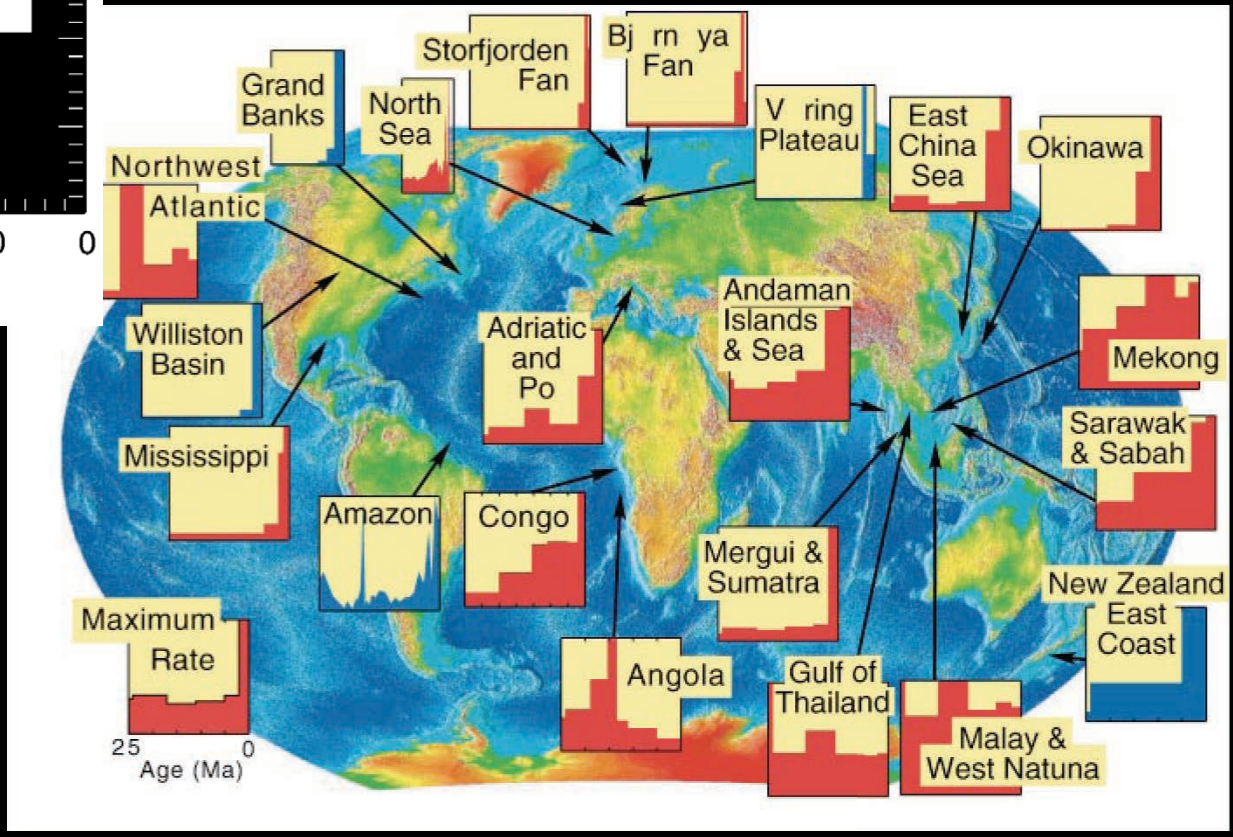
Goldfinger et al. (2000)



Reece et al., AGU, 2010

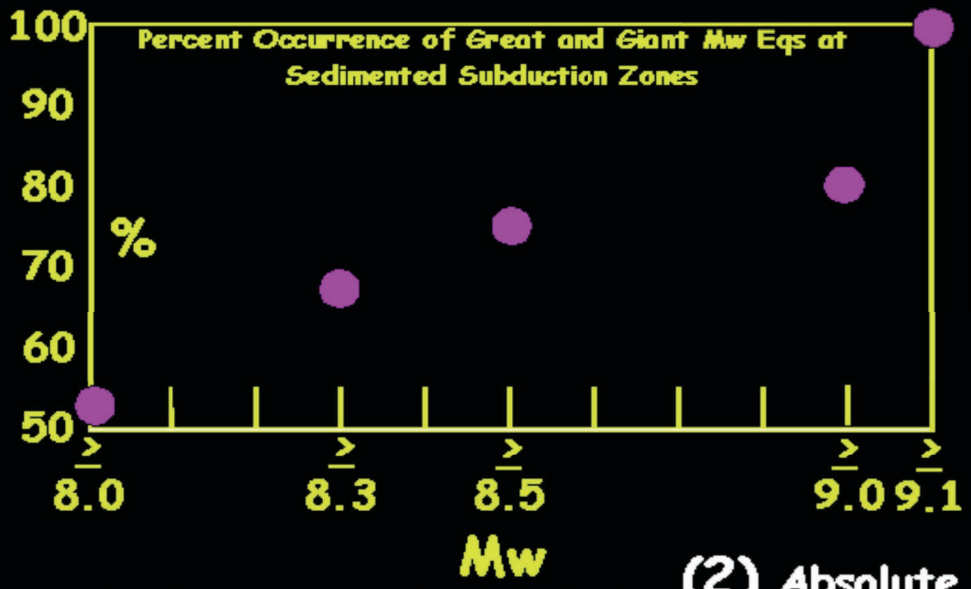
Potential Feedbacks on Subduction Zone From Temporally Evolving Sediment Fluxes

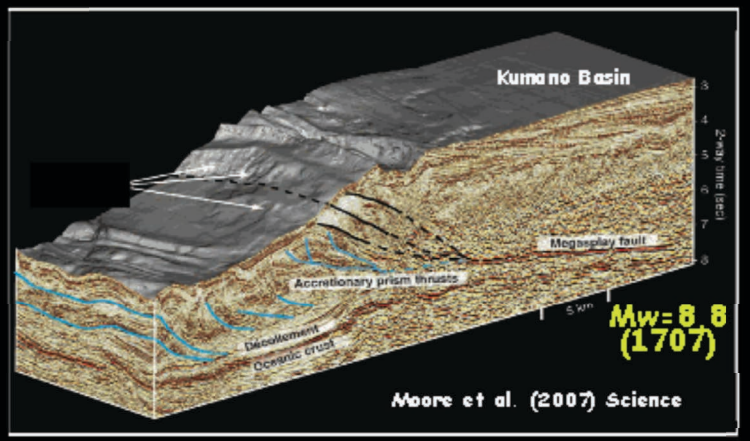


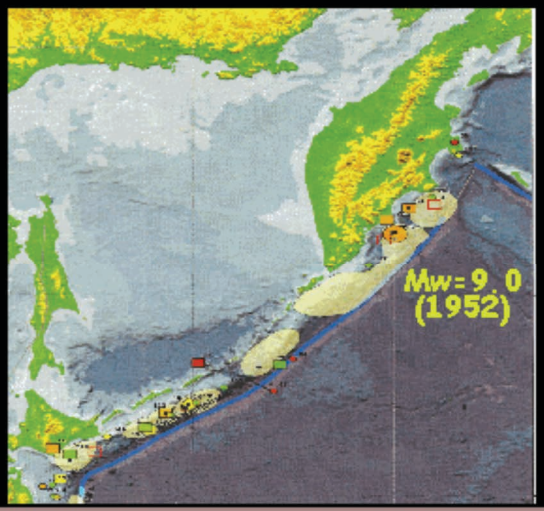


(Zhang et al., 2001; Molnar, 2004)

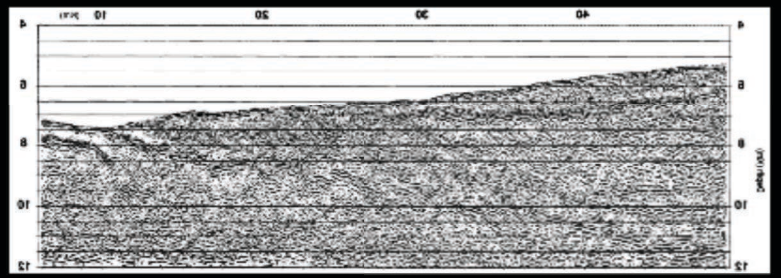
(1) Occurrence of Great and Giant EQs Where Thick Sections of Sediment Are Subducted Is Statistically Significant





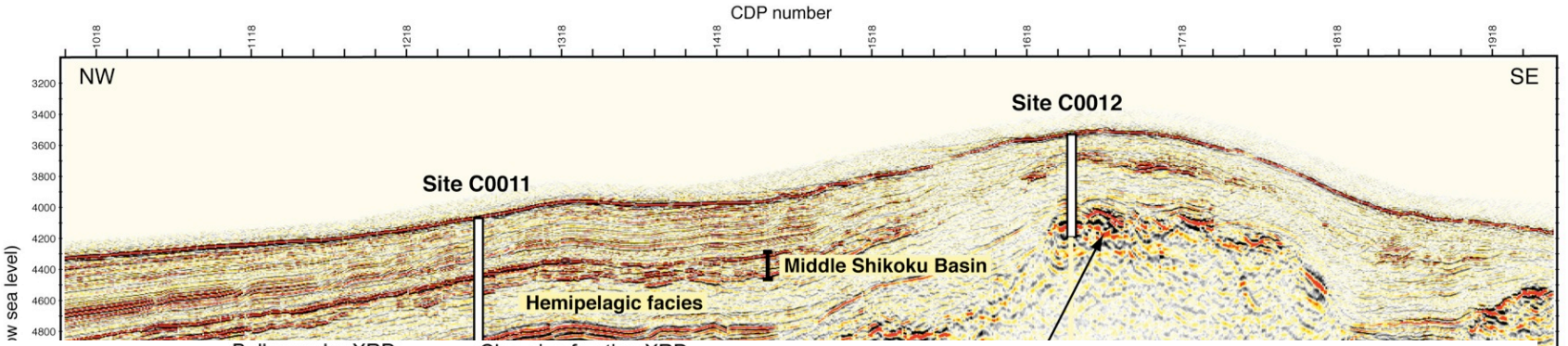


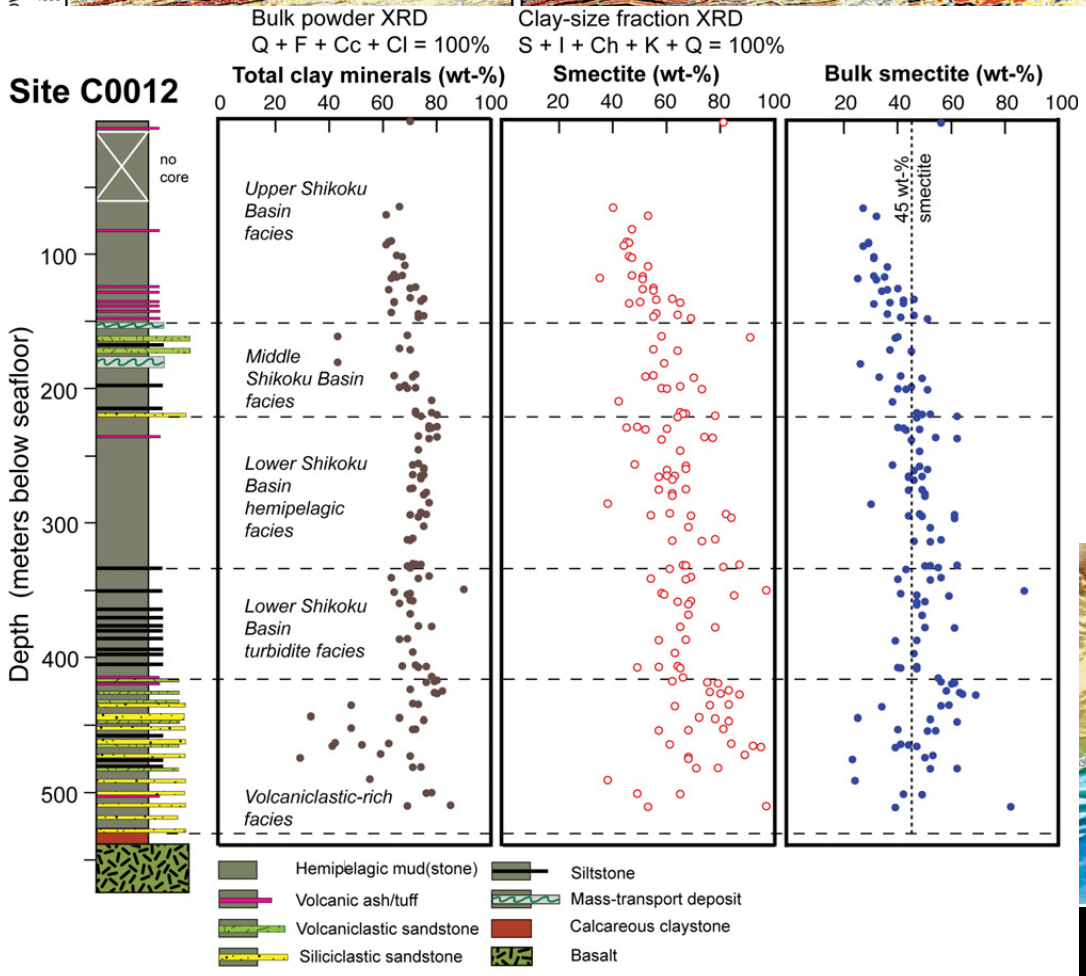
(2) Absolute Thickness of Subducted Sediment May Not Be as Important as Thickness Relative Roughness of Subducted Relief



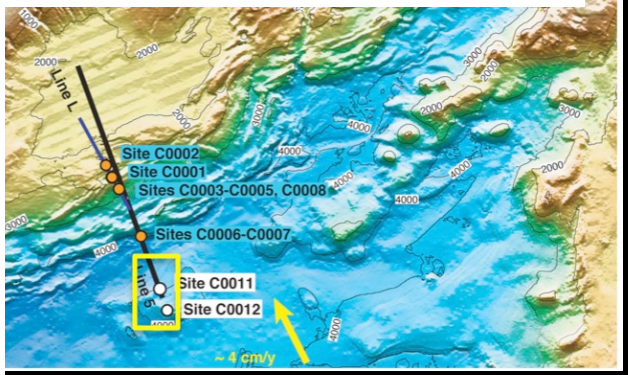
Scholl et al., AGU, 2010

NanTroSEIZE-Subduction Inputs IODP Exp. 322





Temporally and spatially evolving *sediment composition* impacts fluid flow, rheology, melting-*crustal thickening & deformation patterns and sediment transfer*



Expedition 322 Scientists (2009)

Take Away Points

- Models and observations indicate that there are myriad of potential, TESTABLE feedbacks between Cenozoic climate change and subduction dynamics, from ice/eustatic loading and base-level changes over G-I cycles to 10^7-y cycles in sediment delivery to subduction zones

- We can test feedbacks in geodynamic, geomorphic, and volcanic models (numerical, analytical, physical) with well-constrained stratigraphic records from acc prisms, forearc basins, and incoming plate at a range of time scales

- Detecting feedbacks requires knowledge of temporally evolving sedimentary system behavior of subduction zones, and we need to expand observations beyond modern high-stand, interglacial conditions (Possible target-Quaternary Glacial-Interglacial cycles)