What Difference Does a Eustatic Curve Make?*

Ashley D. Harris[1], Jacob Covault[4], Martin Perlmutter[2], Zoltan Sylvester[3], Tao Sun[3], Didier Granjeon[5]

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[1]Chevron Energy Technology Company, Houston, Texas 77002, USA (ashleyharris@chevron.com)
[2]Chevron Energy Technology Company, Houston, Texas 77002, USA Retired
[3]Chevron Energy Technology Company, Houston, Texas 77002, USA
[4]Bureau of Economic Geology, University of Texas at Austin, Austin, TX 78713
[5]IFP Energies nouvelles, 1 à 4 avenue de Bois, Préau, 92852 Rueil-Malmaison, France

Abstract

Eustasy is thought to be a critical control on the distribution of sediment in basin margins and is used in conceptual stratigraphic models to predict the location of sand-rich deposits and explain basin development. We used a nonlinear, diffusion-based numerical forward stratigraphic model in a synthetic basin to test the impact of the widely cited eustatic curves of Haq et al. (1987) and Kominz et al. (2008) on sand distribution. These eustatic curves are distinctly different on the million-year scale in amplitude and frequency. The eustatic record of Haq et al. (1987) has higher amplitude, low frequency fluctuations compared to the Kominz et al. (2008) record. We hypothesize these dissimilarities should result in different loci of sand deposition. The question is: How different? Overall, the Haq model was marginally more effective than the Kominz model at delivering sand to deep water, particularly on the slope and distal part of the basin directly in front of the sediment point source. The large, low frequency short-term eustatic falls of the Haq model resulted in broad deep-water sediment and sand accumulation events. The low amplitude, high frequency short-term eustatic falls of the Kominz model resulted in more punctuated deposition of sediment, with a larger volume of sand distributed across the outer shelf and upper slope. This experimental framework quantitatively demonstrates the impact of two well-known eustatic curves on large-scale deposition and allows for investigation of the processes that lead to the development of the stratigraphic record.

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What Difference Does A Eustatic Curve Make?

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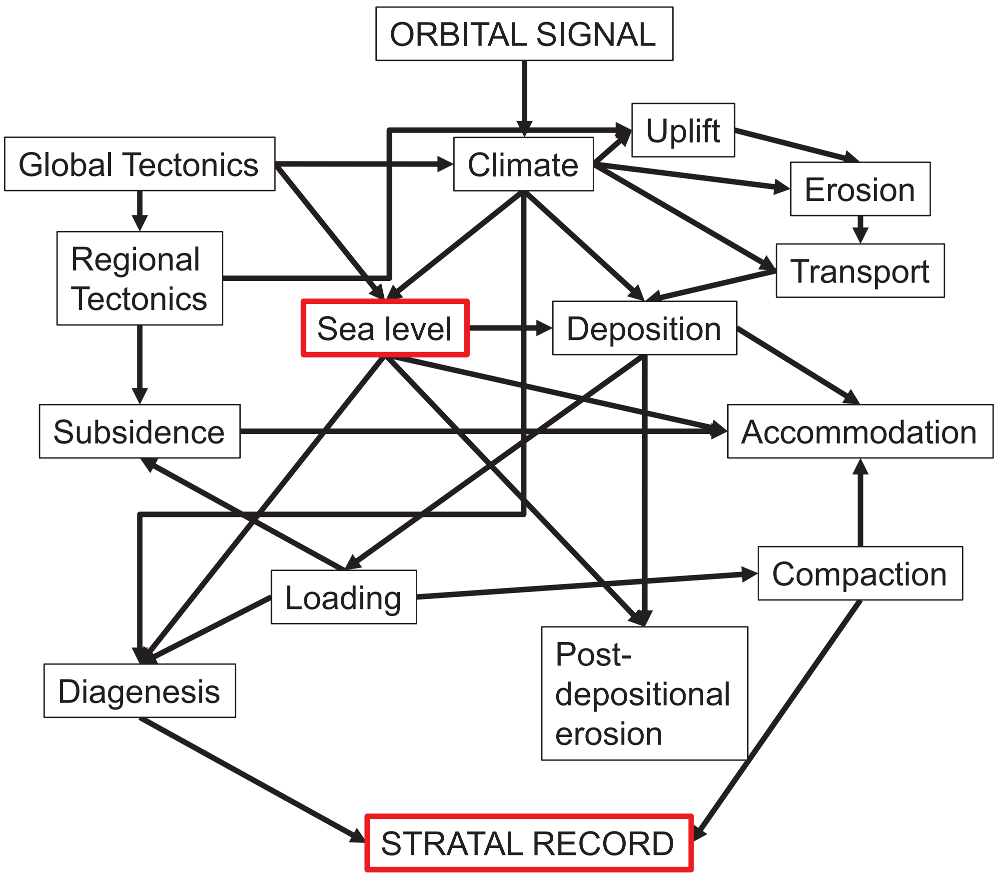
[*]Retired

AAPG 2016 Annual Convention & Exhibition
Controls on Source-to-Sink Systems

Motivation

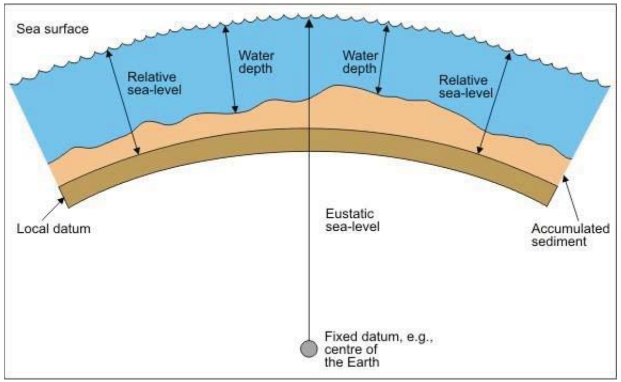


Modified after Smith (1994): *in* Orbital Forcing and Cyclic Sequences

- The stratigraphic record is the result of complex upstream and downstream forcing dynamics:
  - One forcing (*e.g.*, climate) can responsible for different responses across the entire sediment routing system
  - Variables are not independent
  - Positive and negative feedbacks
  - Nonlinear processes
- Use careful geologic observations, numerical, and physical experiments to systematically investigate controls on the stratal record
- Impact of sea level likely increases with proximity to coast within S2S system (Posamentier and Allen, 1999; Sun et al., 2014; Armitage et al., 2016)

Sea Level:
a very abbreviated and incomplete history

- Newberry (1874) thought sea level was the principal control on stratal architecture
- Suess (1885) coined the term "eustasy"
- Chamberlin (1909) proposed a tectono-eustatic control on transgressions and regression on continental margins
- Wanless and Shepherd (1936) proposed glacio-eustatic cause for Paleozoic cyclothems
- Sloss et al. (1949) and Sloss (1963) introduced "sequences"
- AAPG Memoir 26 (1977) - Eustatic control on stacking patterns
- Posamentier and Allen (1999) - Relative Sea Level = Eustasy + Tectonism



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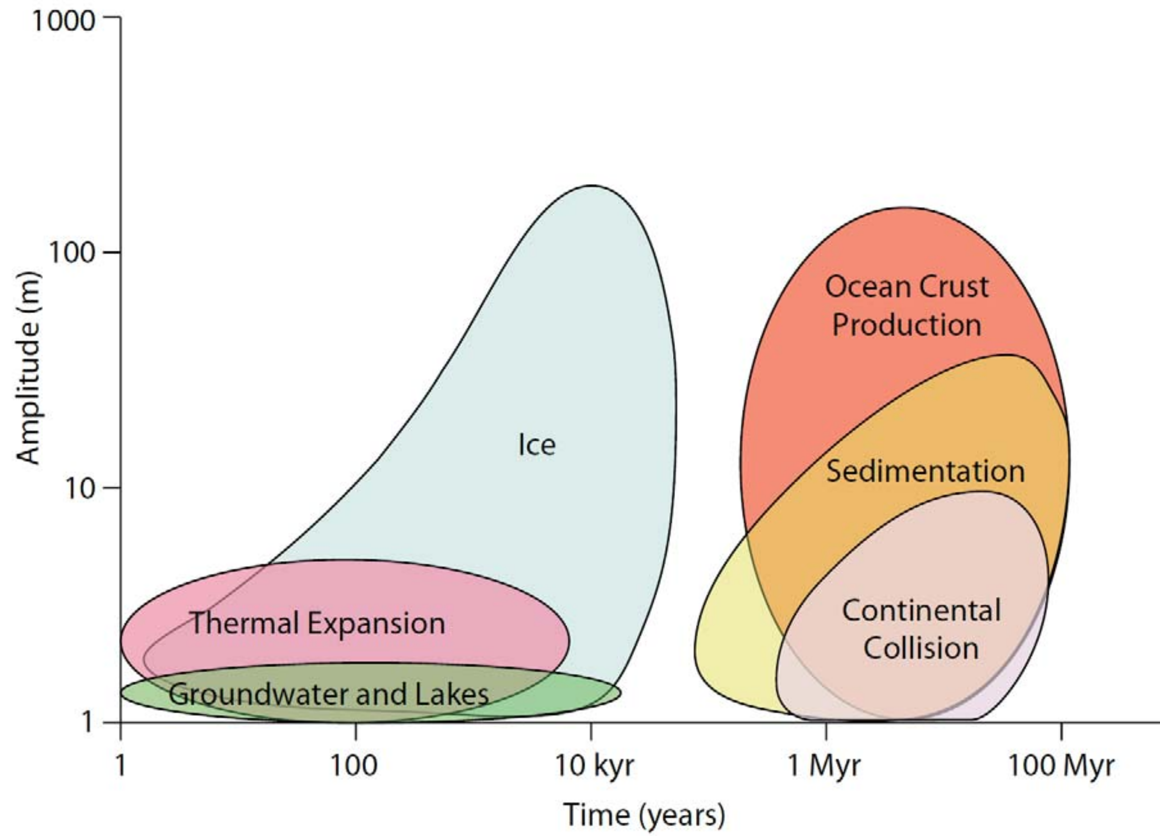
Sea Level

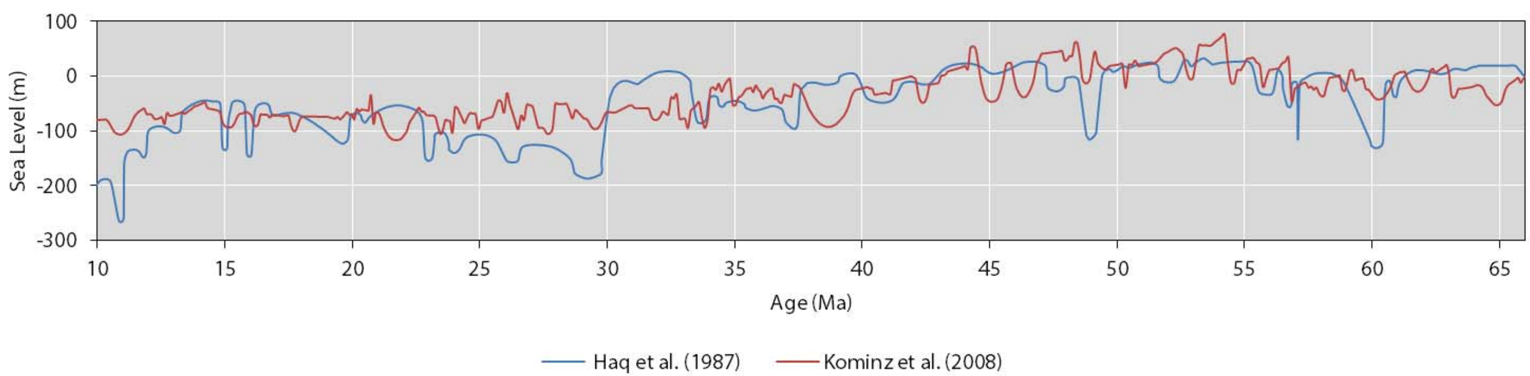
- Mechanisms for sea-level change
  - Ridge Volume
  - Sedimentation
  - Thermal Expansion
  - Lakes
  - Ice Sheets
    - Even during greenhouse times?!
  - Geodynamics
    - Mantle convection processes



Miller et al. (2011): Oceanography

Background

- Haq et al. (1987)
  - Seismic stratigraphy
  - Controversial (Christie-Blick et al., 1991; Miall, 1992)
  - High amplitude, low frequency
- Kominz et al. (2008)
  - NJ margin based (ODP legs 150, 174AX)
  - Backstripped
  - Lower amplitude (2.5 times less than Haq curve), higher frequency



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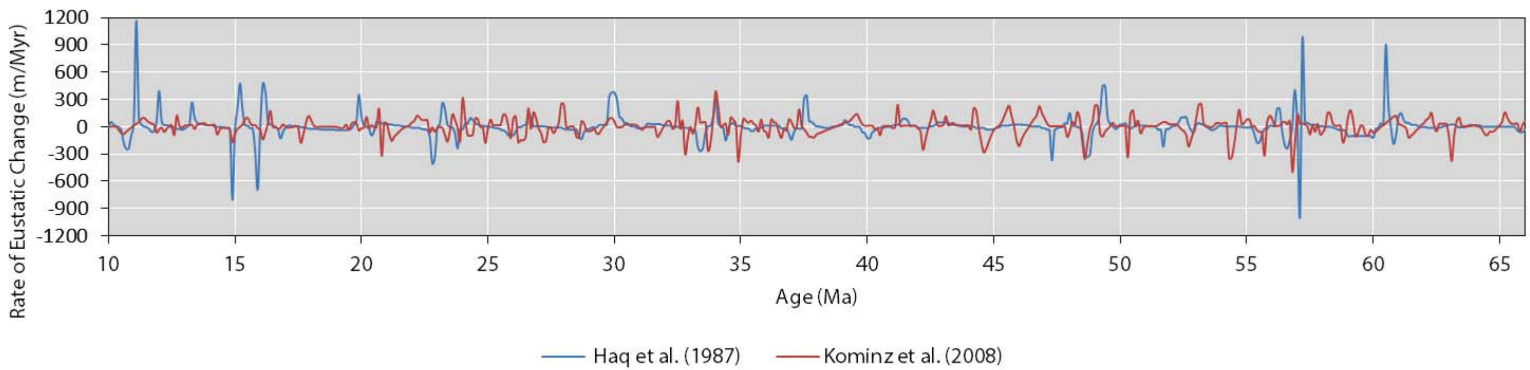
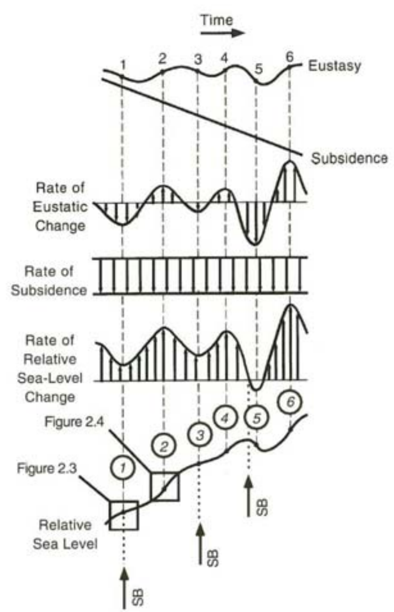


Objective

- What impact do the eustatic curves of Haq et al. (1987) and Kominz et al. (2008) have on:
  - Sand volume delivered to deep water?
  - Position of depocenters in the basin?
  - System response?



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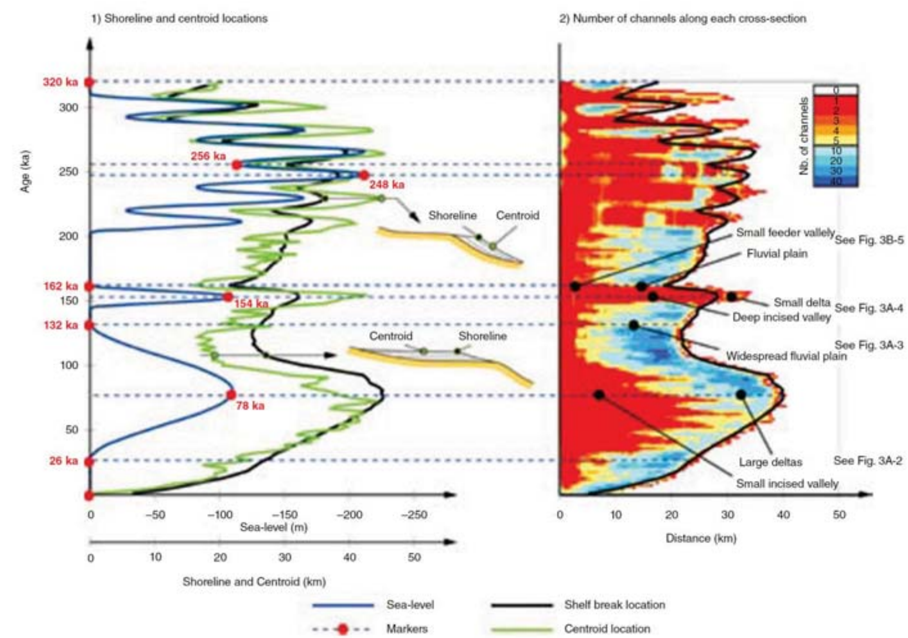

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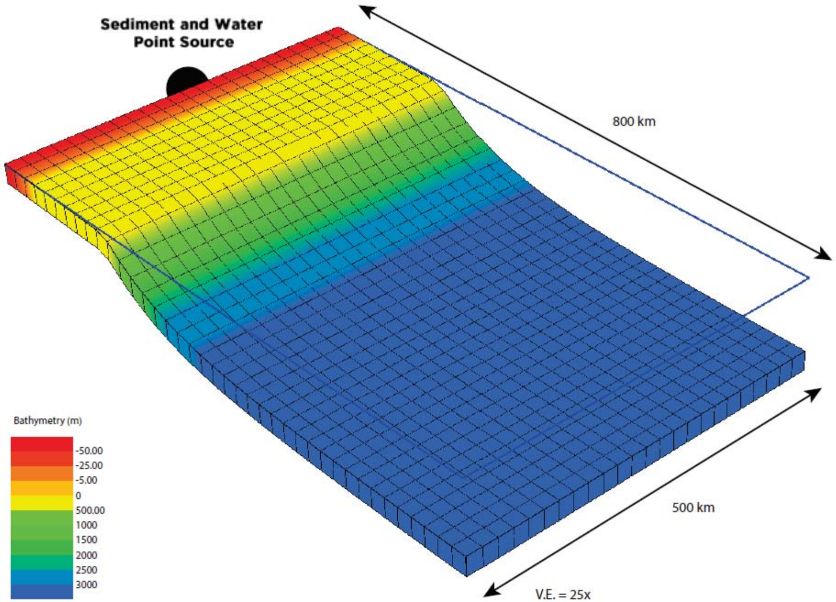
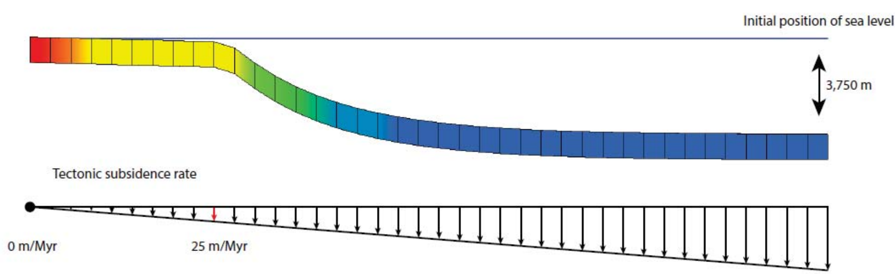
Model Setup



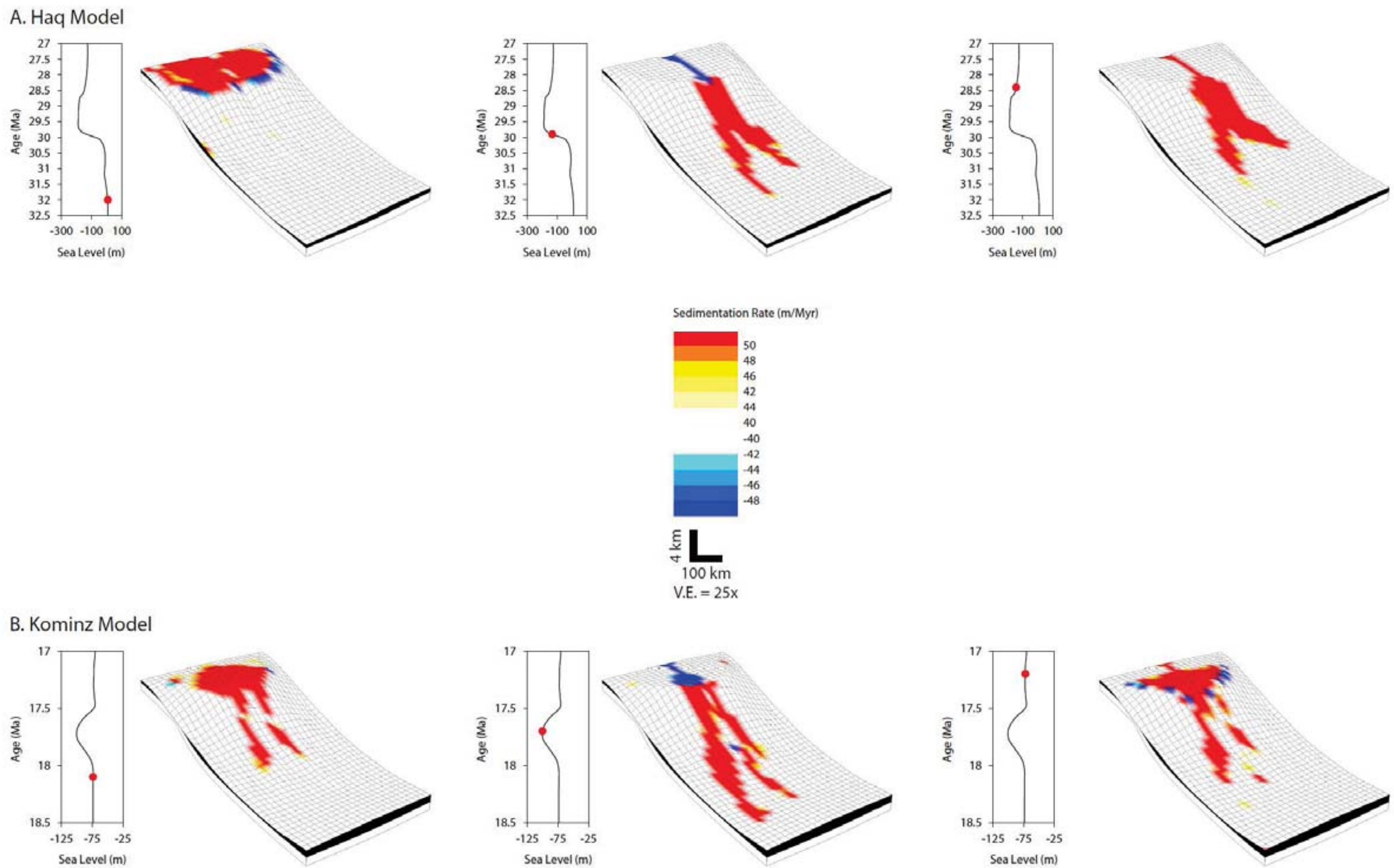


- Dionisos (IFP, Granjeon, 1997)
- Nonlinear Diffusion:

$$Q_s = -(K_s + K_w Q_w^n S^{m-1})\vec{\nabla}h$$

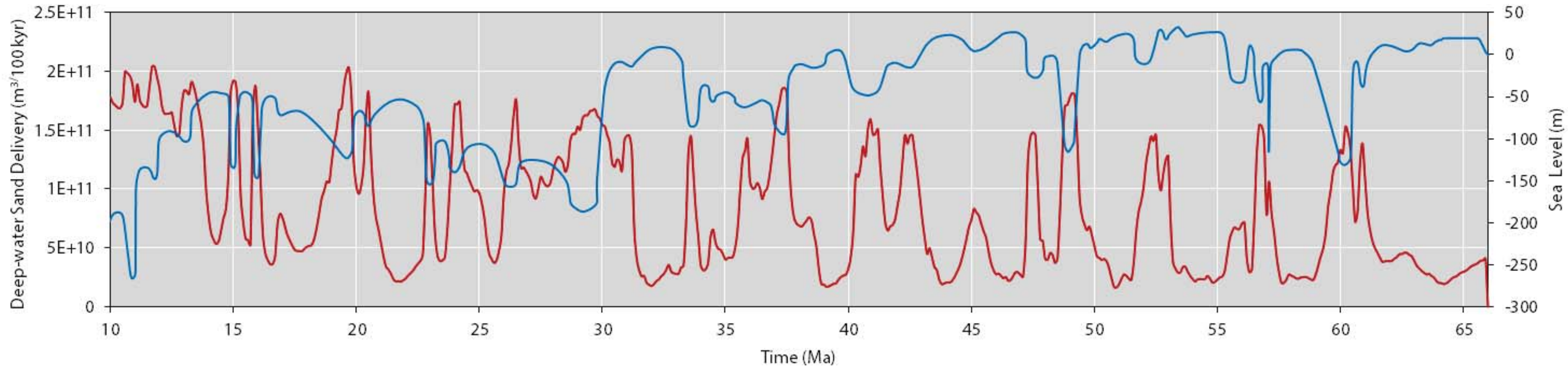
- Will not model individual geologic features
- Large-scale autogenic processes:
  - Avulsion
  - Autoretreat
  - Channel incision
  - Slope failure
- 65-10 Ma
- Constant Water and Sed. Discharge
  - Q_w = 10,000 m^3/sec
  - Q_s = .32 m^3/sec
- Subsidence, compaction, and flexure

Deposition During Sea Level Change

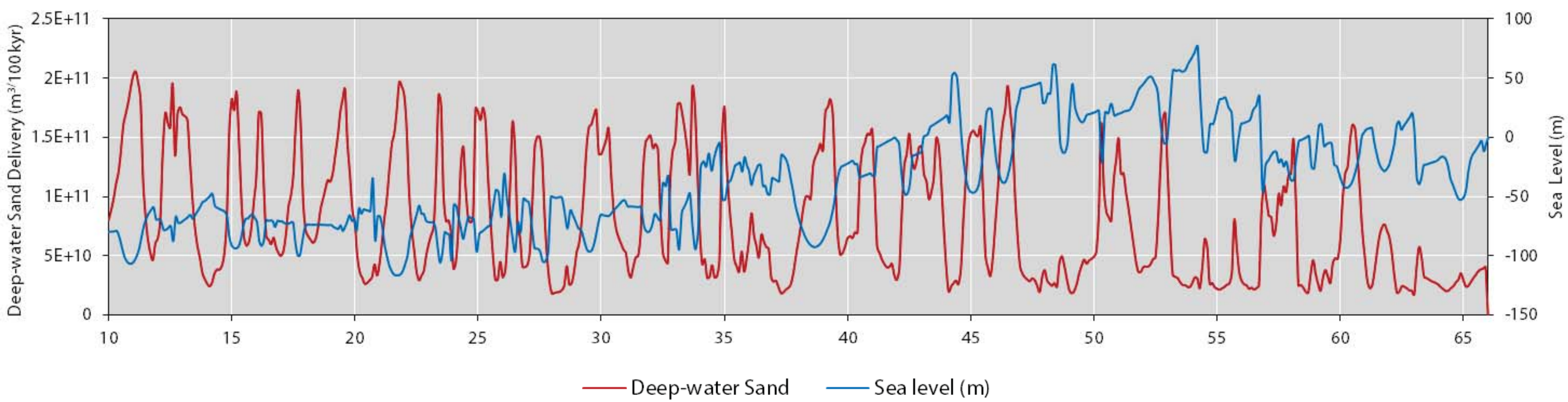


Model Results

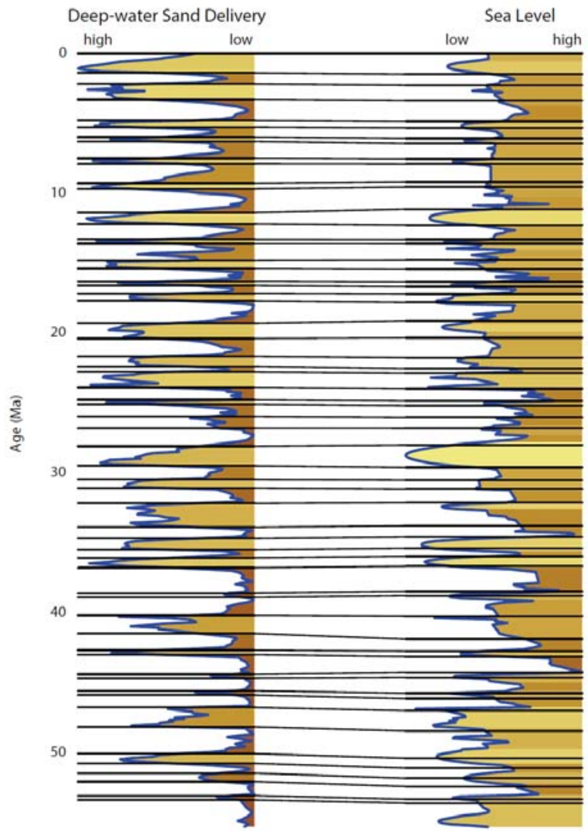
Haq Model



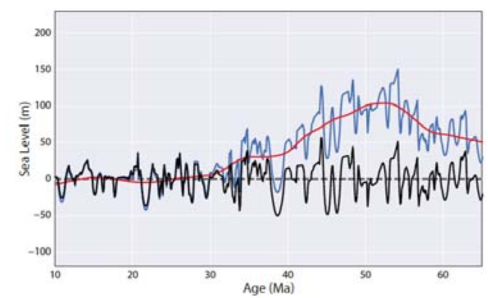
Kominz Model



Model Results
Kominz Model

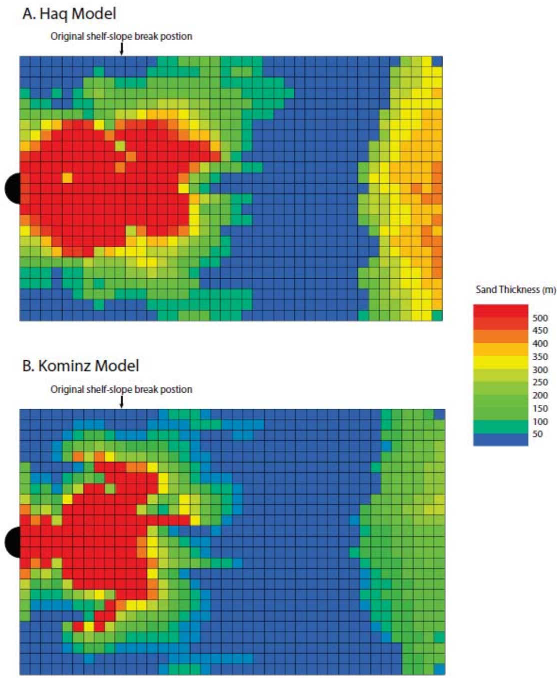


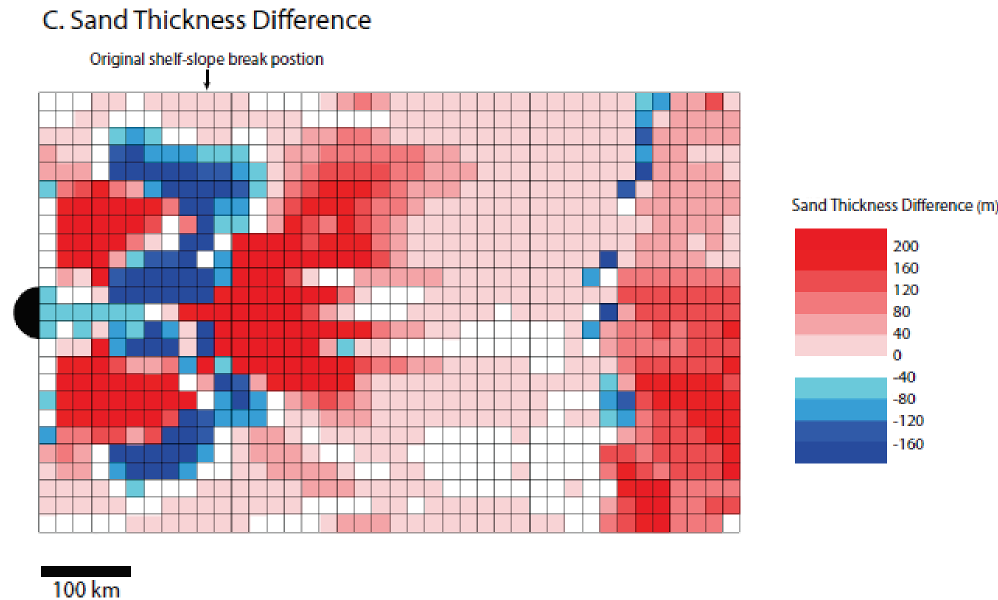
smoothing with LOWESS (locally weighted scatterplot smoothing), window size ~10



- Peaks in deep-water sand delivery correlate well with eustatic minima

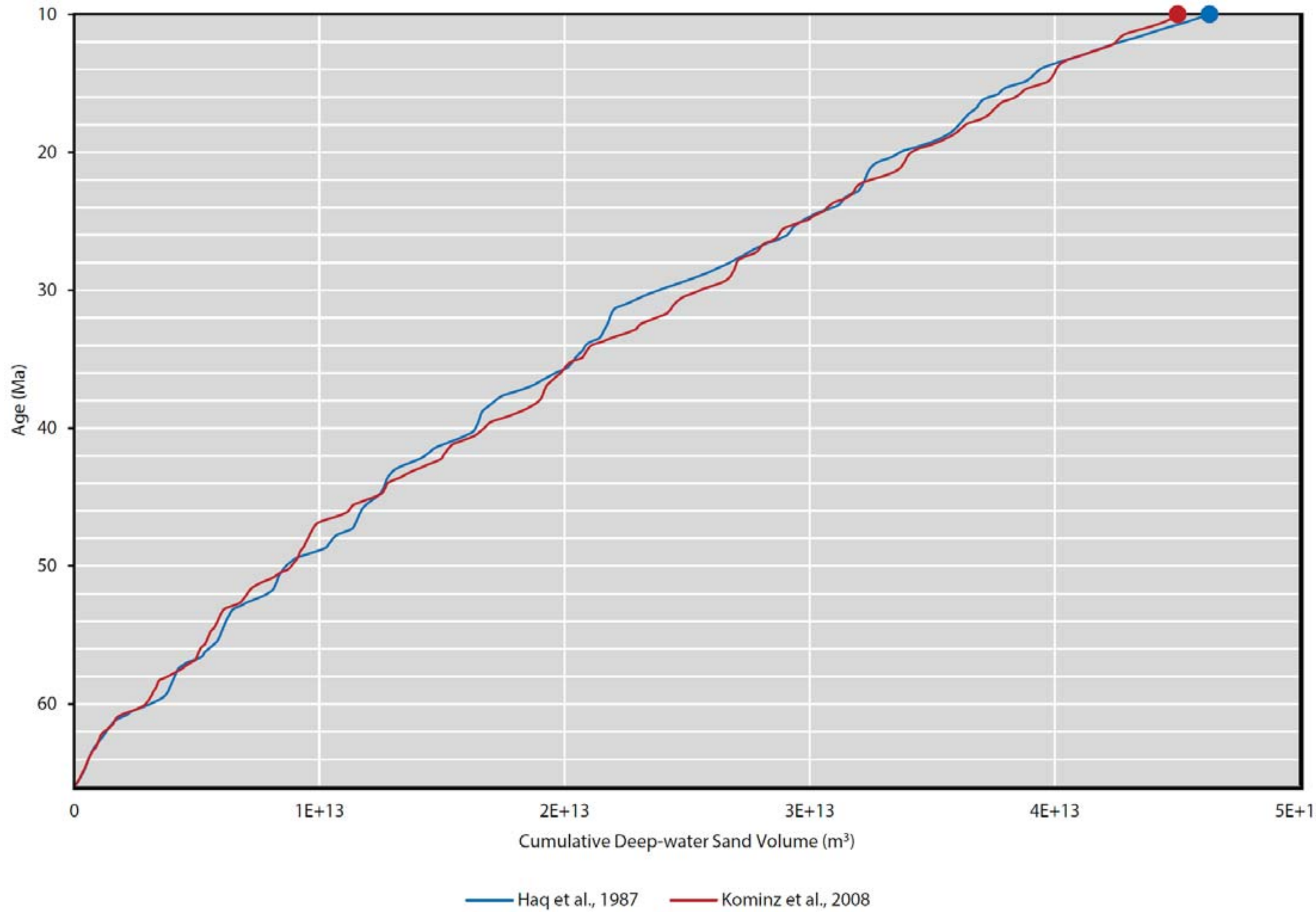
Model Results





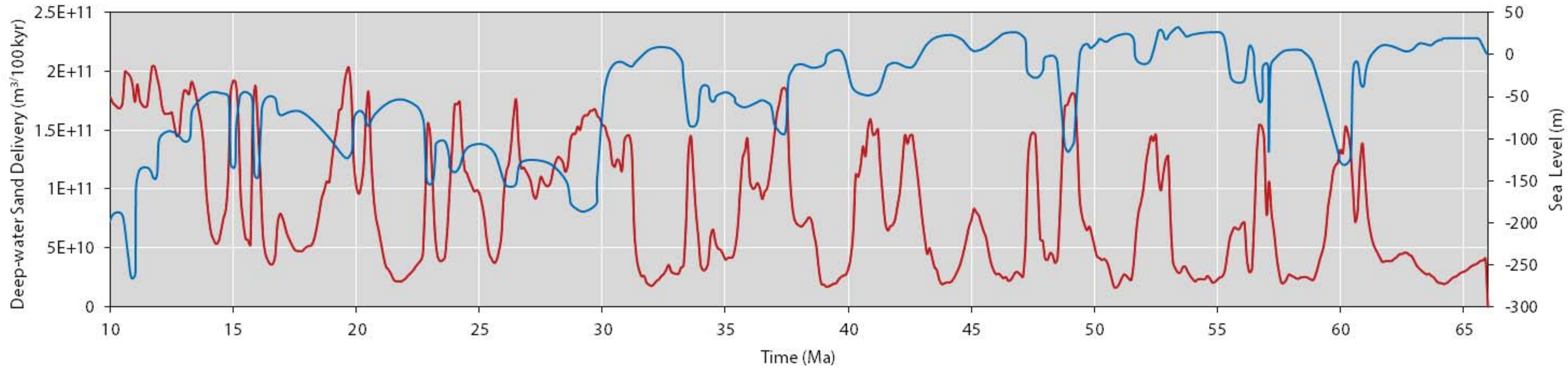
- Sand thickness difference map = Haq model - Kominz model
- Red indicates Haq model sand thickness is greater than Kominz model
- Kominz model deposited a thicker accumulation of sand on the outer shelf-upper slope; Haq model deposited more in deeper sections of the basin

Deep-water Sand Accumulation

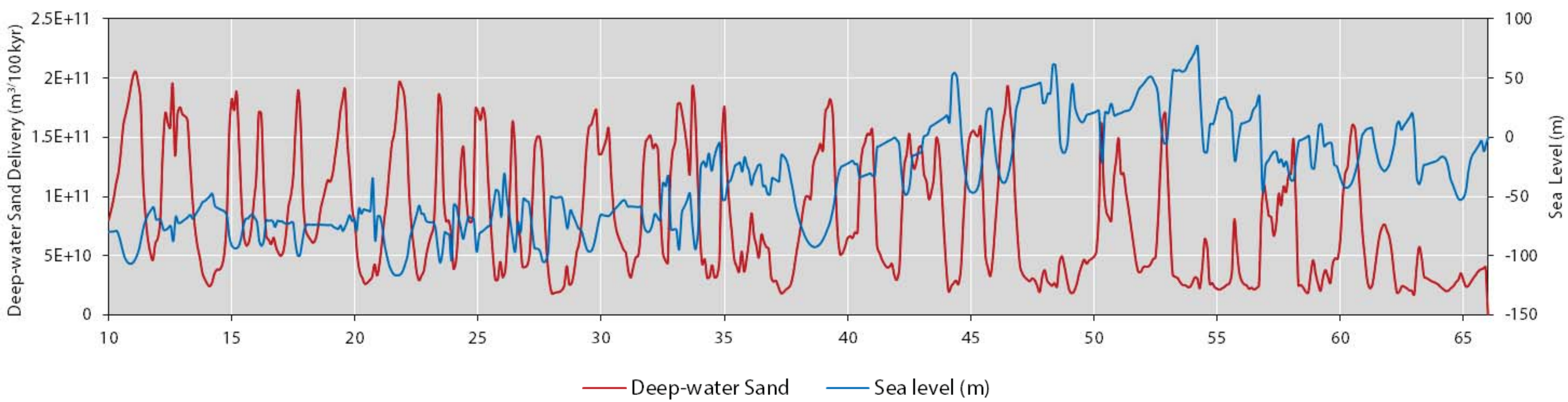


Model Results

Haq Model

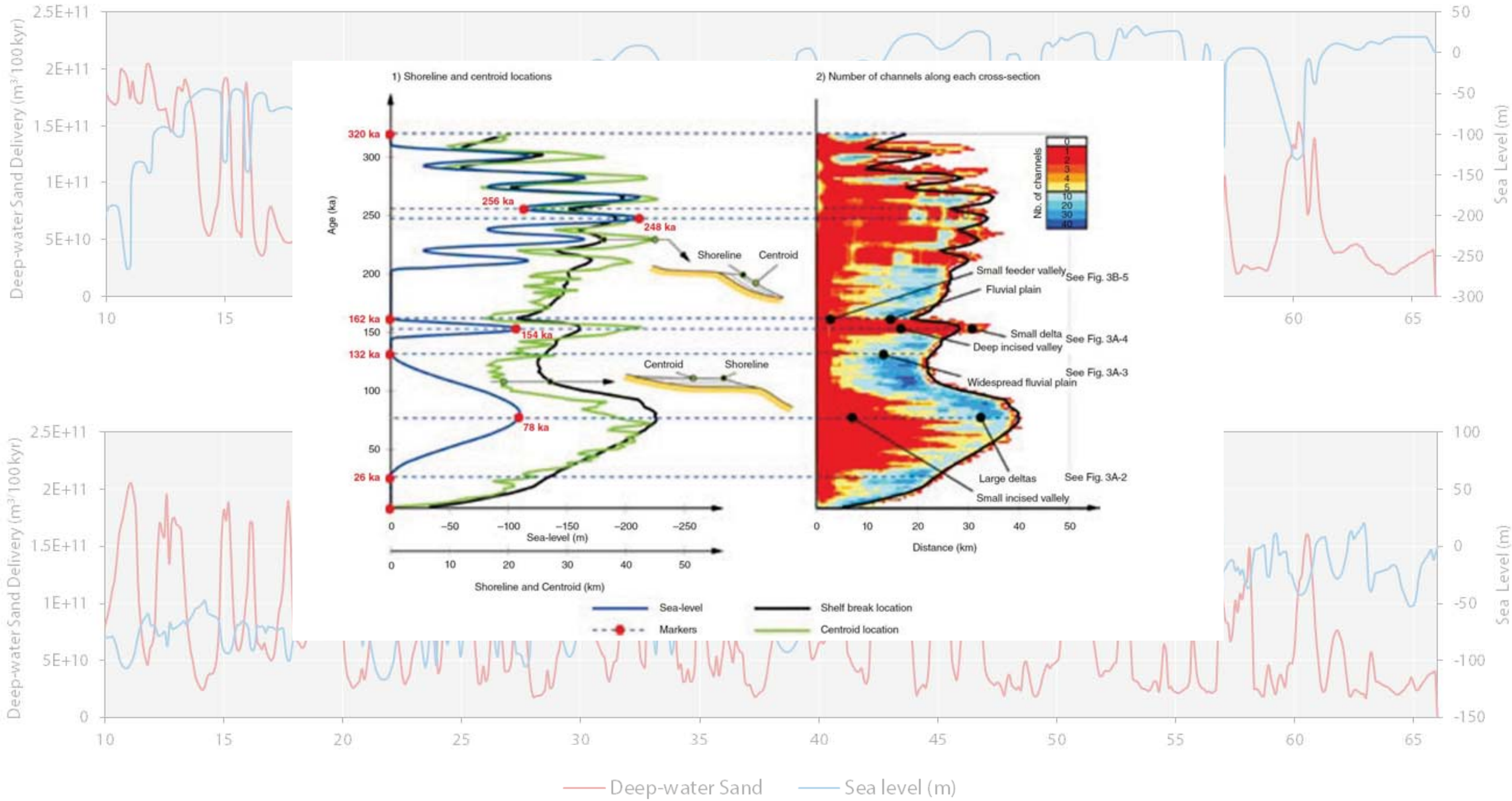


Kominz Model

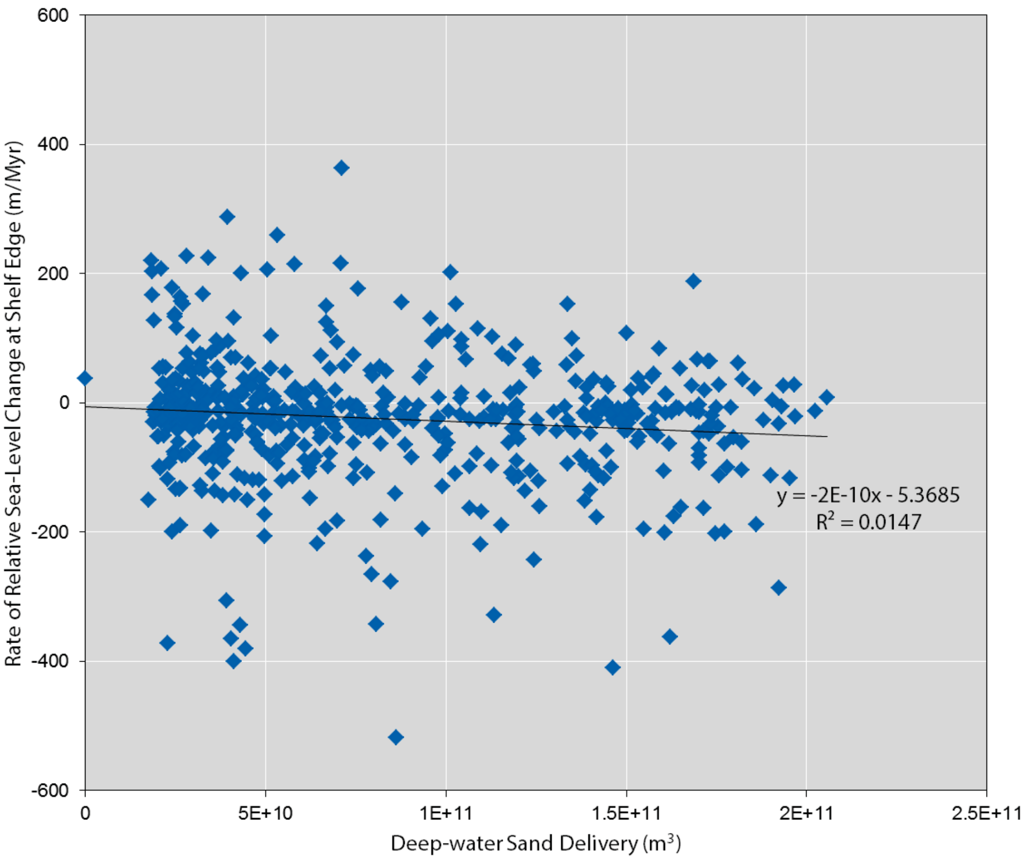


Model Results

Haq Model



Model Results

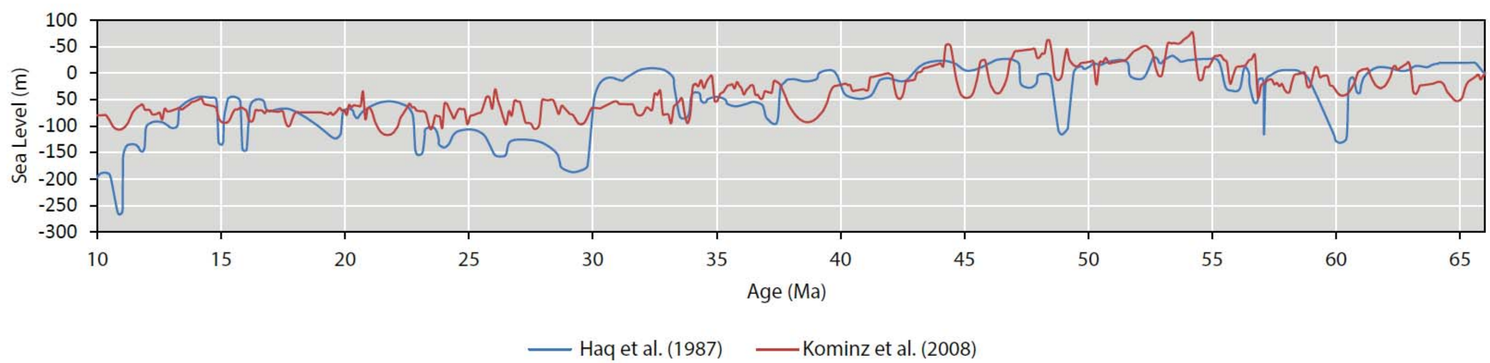


- Poor correlation between rate of relative sea-level change and magnitude of deep-water sand delivery
- Calculated rates did not account for flexure and compaction
- RSL is a 1-D measurement
- Self-regulated equilibrium regression (Burgess et al., 2008)
  - Large and small perturbations to a deltaic system will likely lead to similar responses after a delta has established a position at the shelf edge

Conclusions

What Difference Does A Eustatic Curve Make?

- The Haq model was slightly more effective than the Kominz model at delivering sand to deep water
- The Haq model focused sand in proximal positions on the shelf and in the more distal parts of the basin
- The Kominz model distributed a thick accumulation of sand on the outer shelf and upper slope
- Each peak in deep-water sand delivery rate corresponds to a fall in sea-level
- The magnitude of peaks in delivery rate correlates poorly with rate of relative sea-level change



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