Utilizing Channel-Belt Scaling Parameters to Constrain Discharge and Drainage Basin Character with Application to the Cretaceous to Tertiary Evolution of the Gulf of Mexico*

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Abstract

Fluvial systems possess a range of scaling relationships that reflect drainage-basin controls on water and sediment flux. Quaternary channel-belt thickness (as controlled by bank-full water discharge) has been documented as a reliable first-order proxy for drainage basin size if climatic regimes are independently constrained. In hydrocarbon exploration and production, scaling relationships for fluvial deposits can be utilized to constrain drainage basin size with implications for sequence-stratigraphic interpretations. This study documents the scales of channel belts within Cretaceous to Tertiary fluvial successions from the Gulf of Mexico. Data on single-storey channel-belt scales were compiled from well logs and utilized to constrain contributing catchment areas of Cretaceous, Wilcox, and Oligocene fluvial systems. The data indicate that the Wilcox and Oligocene fluvial systems were significantly larger than the Cretaceous fluvial systems which can be related to drainage basin reorganization. Furthermore the Wilcox fluvial systems were relatively larger than the Oligocene fluvial systems. This could reflect either smaller drainage basins or climatic aridification. These scaling relationships can be validated by regional paleogeographic maps and provide additional insight to the sediment routing systems through time.

References Cited


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Northern Gulf of Mexico Tectonic Framework

- Basement influenced tectonic elements influence stratigraphy throughout the Mesozoic to Cenozoic.
- Interior salt basins (East Texas, North Louisiana, and Mississippi) cradled between Paleozoic-originated uplifts and arches (e.g., Sabine uplift, Monroe arch, La Salle Arch, Wiggins Arch).
- Houston, Rio Grande, and Mississippi Embayments funneled clastic sediment between Paleozoic-originated uplifts/arches (e.g., Llano Uplift, San Marcos Arch, Sabine Arch, Monroe Uplift).
- Cenomanian through Eocene clastic sediment onlap Arches and Uplifts.

Example regional cross section- Eocene time

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Modified from Ewing, 1991

Modified from Jung Echols and Malkin, 1948
Fluvial Input Locations and Shelf Margin Progradation

- Gulf Basin fluvial/deltaic depocenters and shelf progradation documented over past 4+ decades
- Fluvial input and deltaic depocenters linked to locations of shelf progradation

From: Galloway et al., 2000; Galloway, 2005; Galloway 2008

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Gulf Basin Shelf Margin Development

- Genetic sequence development
- Siliciclastic shelf margin progrades by siliciclastic sediment

Example – South Texas Margin Progradation

From Galloway, 1989

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On-shelf depositional system/facies variations from updip to downdip systematically vary from amalgamated fluvial to fluvial-deltaics to shallow marine
Well Log – Fluvial Recognition

- Utilize classic studies that documented log pattern linkages to depositional environment
- Blocky to fining upward excursions on SP/Resistivity/Gamma differentiated from serrated or coarsening upward

From Fisher, 1969
Channel Belt Thickness Variations
Upper Cretaceous Cenomanian to Oligocene

- Channel Belt thickness populations
- 12-15 m – moderate size rivers
- 18-24 m – large size rivers
- 30-42 m – continental size rivers
~15 m thick blocky to fining upward packages

From Ambrose et al., 2009
Channel Belt Interpretation Techniques

- Basin margin to Basin center – subsidence variation
- Basin margin: Amalgamated channel belts
- Basin center: Non-amalgamated channel belts
- ~15 m thick blocky to fining upward channel belts

From Ambrose et al., 2009
Published cross-sections provide cross check on depositional environment and correlations

Blue scale is 20 m

From Tye et al., 1991
Published cross-sections provide cross check on depositional environment and correlations

Blue scale is 20 m

From Tye et al., 1991
Upper Cretaceous channel belt measurements

Fluvial systems – onshore basins – shelf edge location
Lower Wilcox channel belts – significantly thicker

Significant shelf progradation

Mean Channel belt thickness not best indicator of distribution
- Paleo-Rio Grande – 20-30+ m thick channel belts
- Paleo Tennessee – 2 populations, 15m – Appalachians, 24 m Mississippi Embayment?
Quantitative Channel belt comparison:
Upper Cretaceous to Paleocene

- Upper Cretaceous Cenomanian fluvial system channel belt thickness are significantly thinner than Paleogene Wilcox fluvial system channel belts.
- Oligocene fluvial systems active from South Texas to East Louisiana – significant shelf progradation
Quantitative channel belt comparison: Lower Wilcox to Oligocene variations

- Lower Wilcox Paleo-Colorado and Paleo-Houston Brazos channel belts are thickest
- Oligocene Paleo-Mississippi similar to LW Paleo-Mississippi
Calibration: Quaternary Channel Belt Thickness to Drainage Size

- Channel belt thickness as a proxy for drainage basin area

Modified from Blum et al., 2012
For a given drainage basin size, channel belts developed in Arid climates are thinner. Therefore, a thinner channel belt could be smaller catchment or more arid catchment.

Implication for Oligocene – smaller drainages (compared to Lower Wilcox) or more arid climate?
Quantitative Linkage: Channel Belt Thickness and Paleo-Drainage Basin

- Major drainage reorganization from Cenomanian to Paleocene/Eocene
- Paleo-Tennessee independent at least through Eocene – Upper Wilcox time
- Channel Belt Thickness used to draw representative drainage basin

Drainages modified from Galloway et al., 2011

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Quantitative Linkage:
Channel Belt Thickness and Paleo-Drainage Basin

- Oligocene drainages likely larger than previously published paleo-drainages –
  - Paleo-Rio Grande and Paleo-Colorado

- Channel Belt Thickness used to draw representative drainage basin

Drainages modified from Galloway et al., 2011

Modified from Blum et al., 2012

\[
y = 793.93x^{2.1348}
\]
\[
R^2 = 0.6617
\]
Summary and Conclusions

- Fluvial systems possess a range of scaling relationships that reflect drainage-basin controls on water and sediment flux.

- Quaternary channel-belt thickness (as controlled by bank-full water discharge) has been documented as a reliable first-order proxy for drainage basin size.

- This study documents the scales of fluvial system channel belts within Cretaceous to Tertiary fluvial successions from the Gulf of Mexico.
  - This study focused on fully-fluvial deposition rather than parsing fluvial channel belts from shallow marine blocky sand bodies.
  - Caveat: Recognition criteria for faithfully interpreting fluvial channel belts interspersed with shallow-marine/deltaics needs to be investigated.

- The data indicate that the Wilcox and Oligocene fluvial systems were significantly larger than the Cretaceous fluvial systems which can be related to drainage basin reorganization.

- Furthermore the Wilcox fluvial systems were relatively larger than the Oligocene fluvial systems. This could reflect either smaller drainage basins or climatic aridification.
References


