Scaling Relationships in Fluvial Depostional Systems*

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Search and Discovery Article #30245 (2012)**
Posted August 20, 2012

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012

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Abstract

Fluvial systems possess a range of scaling relationships that reflect drainage-basin controls on water and sediment flux. In hydrocarbon exploration and production, scaling relationships for fluvial deposits can be utilized to constrain environmental and sequence-stratigraphic interpretations, as well as predict the lateral extent of fundamental reservoir flow units. This study documents the scales of channel fills, point and channel bars, channel belts, and coastal-plain incised valleys from well-constrained Quaternary fluvial systems.

Data on channel-fill and point-bar to channel-belt scales were compiled from published thicknesses for sinuous single-channel systems, with spatial dimensions measured from GoogleEarth. Fluvial systems included in this database span 3 orders of magnitude in drainage area, from continental-scale systems to small tributaries, and span tropical to sub-polar climatic regimes. Channel-fill and channel-belt scales were measured upstream from backwater effects, so as to minimize inclusion of distributive, highly avulsive systems. Scales of incised valleys were derived from well-constrained published examples that are known to have formed during the last 100 kyr glacio-eustatic cycle.

All scaling relationships are represented by statistically-significant power laws, with absolute dimensions that scale to drainage area, but distinct clustering occurs between channel fills, point bars and channel belts, and incised valleys. Mean width-to-thickness ratios for channel fills are ~10:1, whereas point bars commonly range from 70-250:1. Coastal-plain incised valleys from the last glacio-

eustatic cycle range from 25-150 m in thickness, and a few kilometers to more than 80 km in width, with width-to-thickness ratios of ~600-800.

Scales of Quaternary examples compare well with previous compilations of channel-belt scales interpreted in the ancient record, and with theory. However, the smallest Quaternary incised valleys in our database reside in the uppermost part of the domain of published compilations of ancient incised valleys, with ancient examples overlapping significantly with both interpreted channel fills and channel belts. When interpreted within the context of this database from modern systems, we suggest many ancient examples may have been overinterpreted, which in turn suggests a persistent lack of objective criteria for differentiating channel fills, channel belts, and incised valleys.

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Scaling Relationships in Fluvial Depositional Systems

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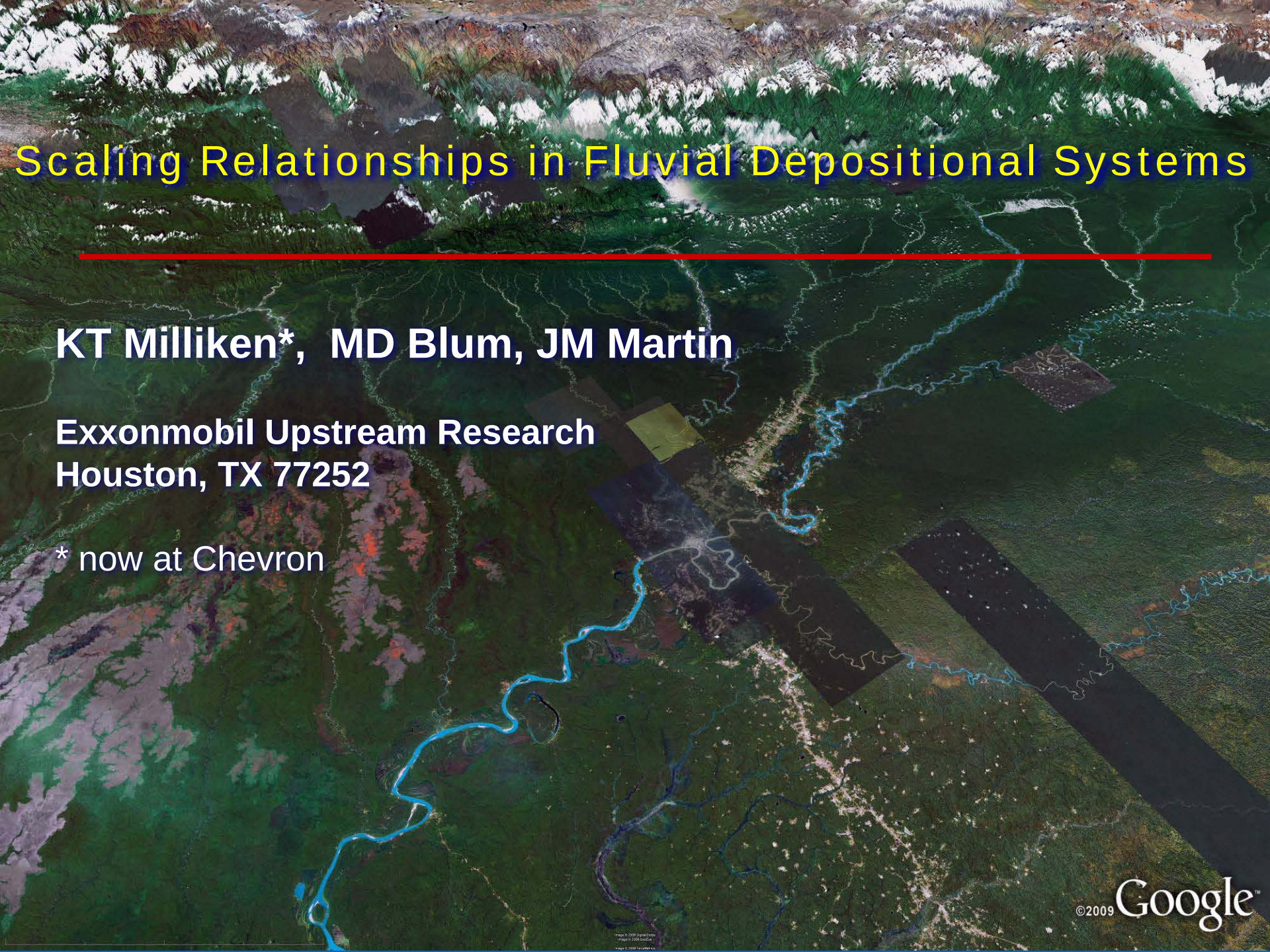

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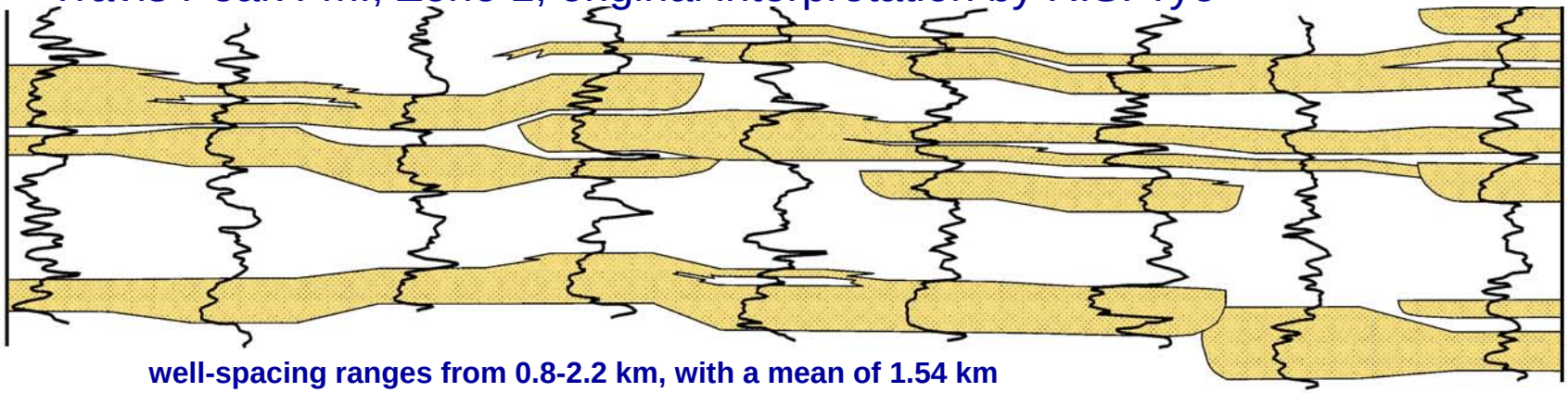
Channel-Belt Sand Bodies – Significance of Scaling Relationships

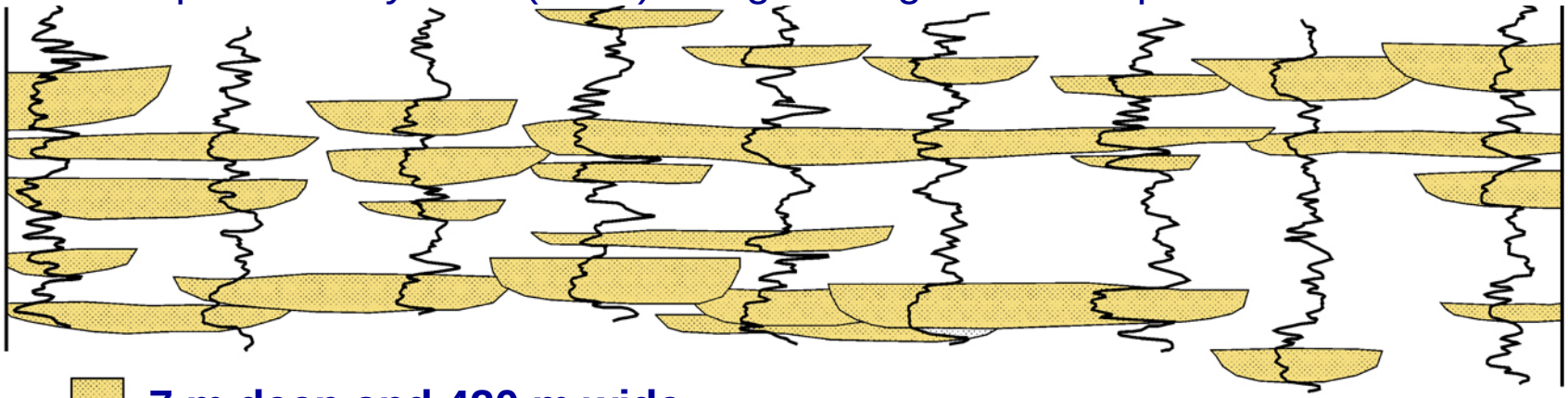
Travis Peak Fm., Zone 1, original interpretation by R.S. Tye



well-spacing ranges from 0.8-2.2 km, with a mean of 1.54 km

50 m

reinterpretation by Miall (2006) using scaling relationships



7 m deep and 420 m wide

7 m deep and 1750 m wide

50 km

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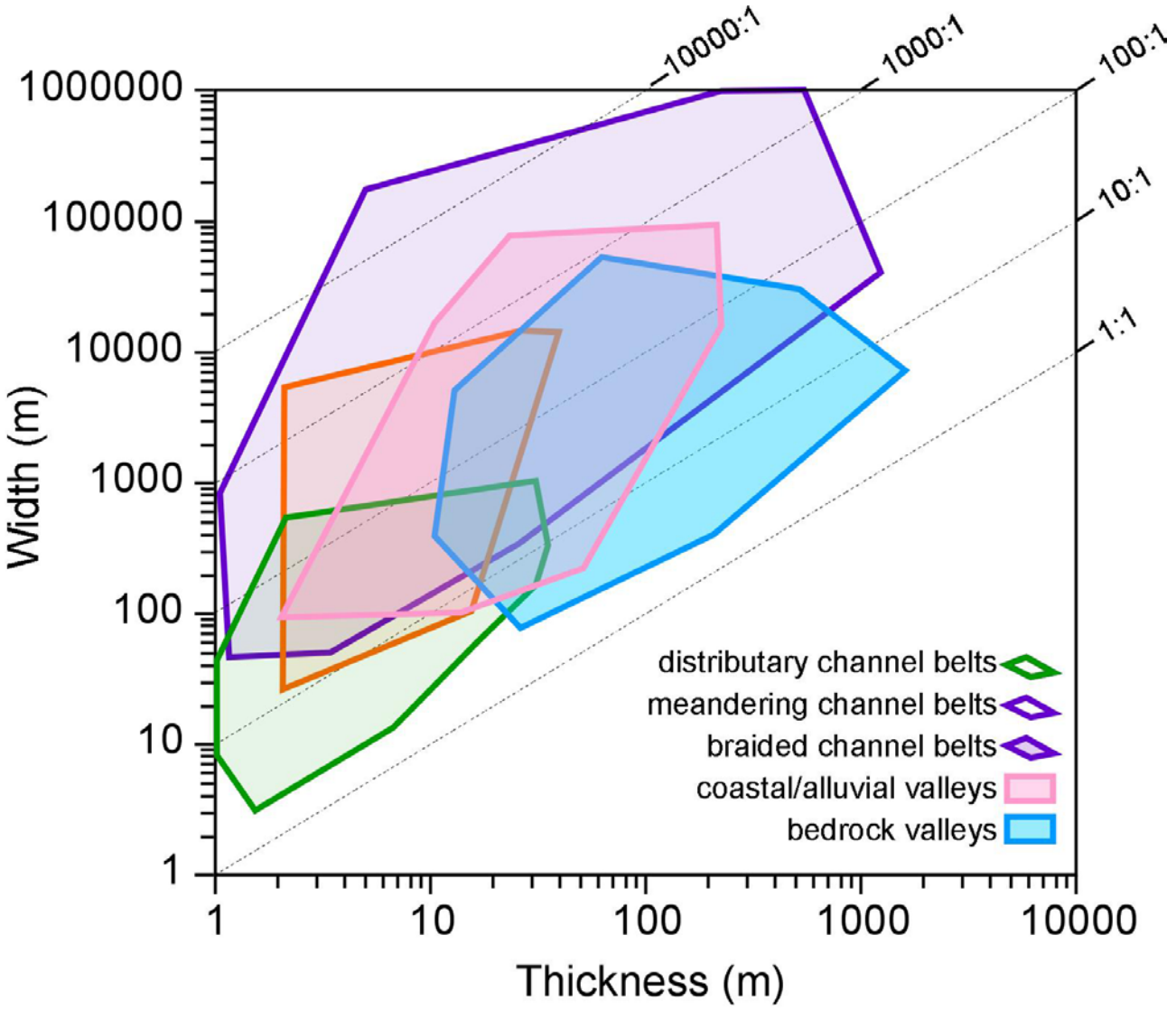
Motivations – Recent Compilation by Gibling (2006)



Compilation of scales in published literature

Scale domains are very different from modern systems, much larger range

Raises issue of how original data were interpreted, and criteria that were used

Need to cross-check with modern systems, where dimensions are an observation, not interpretation

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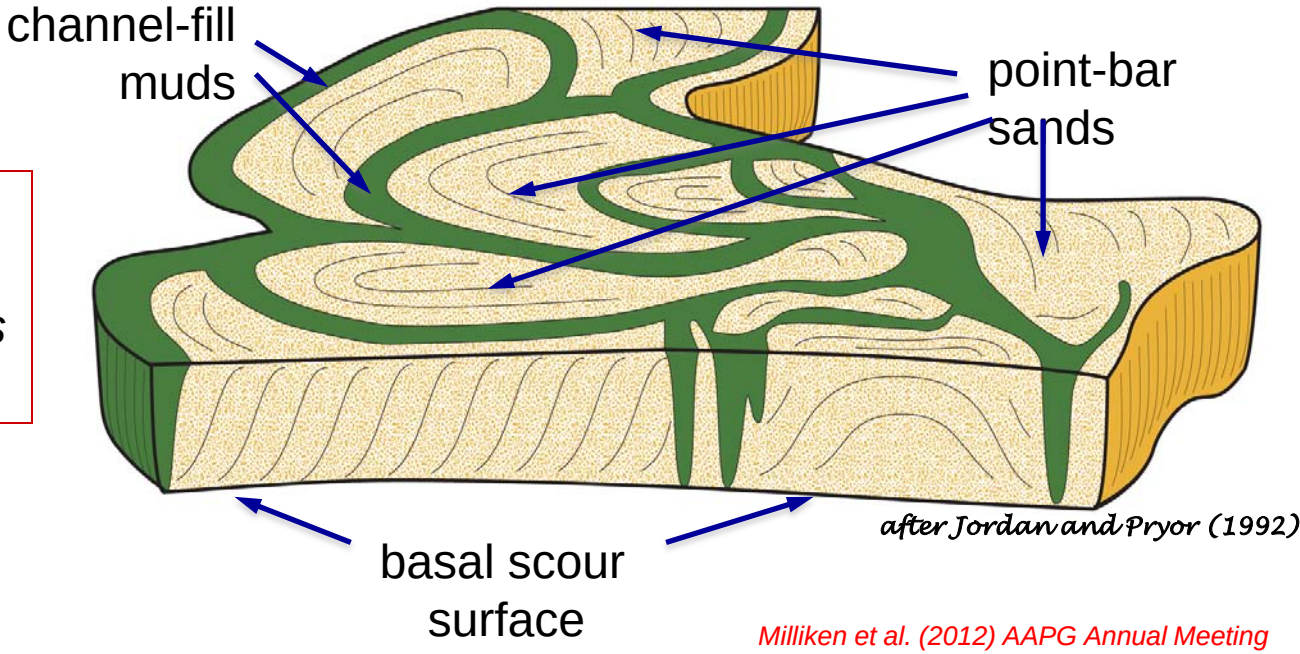
Goals – Quantify Scales of 1st Order Fluvial Elements

- Construct a database of modern channel-belt and channel-fill scales
  - Google Earth Approach: Scour literature and global landsat / DEM
  - mature point bars, recently cutoff or close to cutoff
  - point bars with thickness measurement, i.e. core through deposit, measure width, thickness, asymetry
- Construct dataset of Late Quaternary incised-valley scales
  - coastal-plain valleys with robust geochronological control

channel fills and channel-belt margins are fundamental barriers to flow



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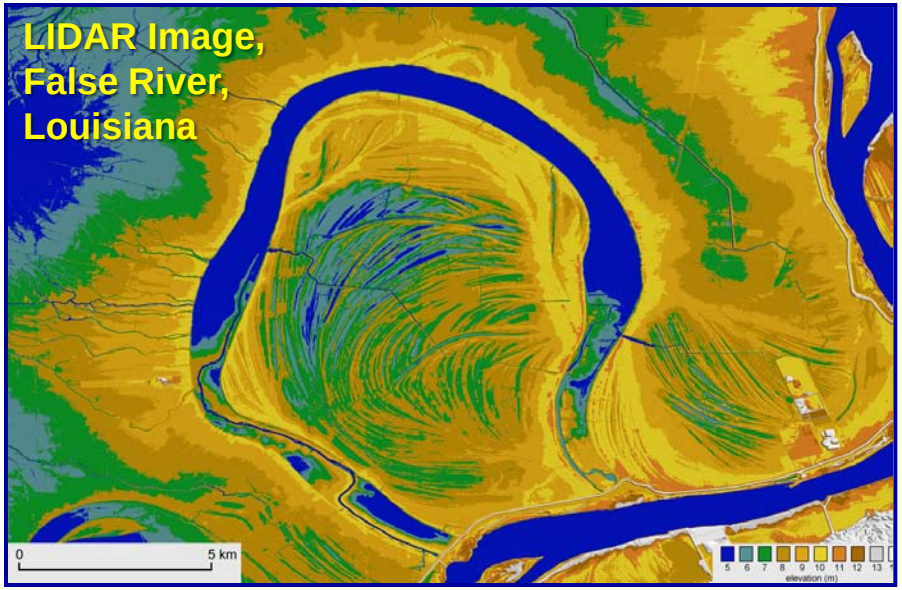
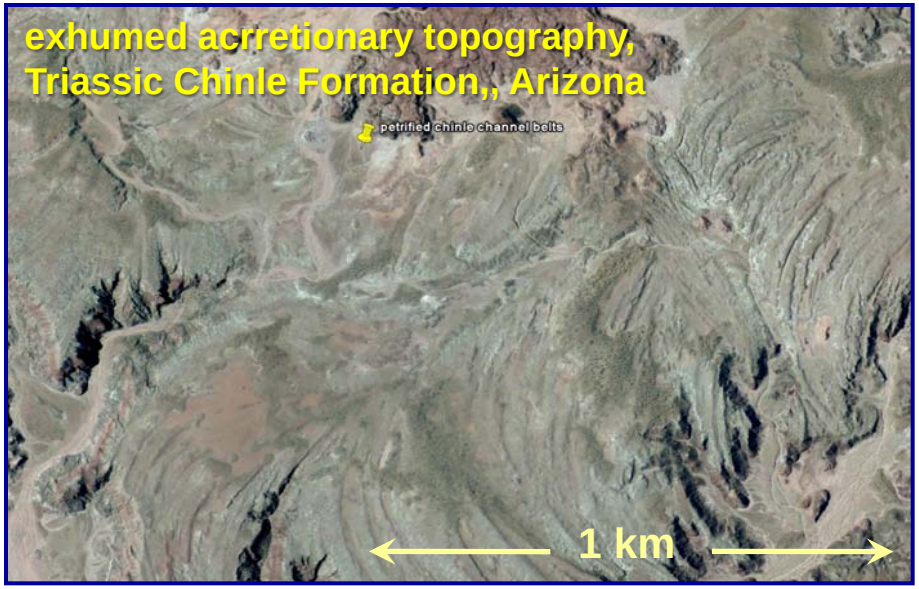
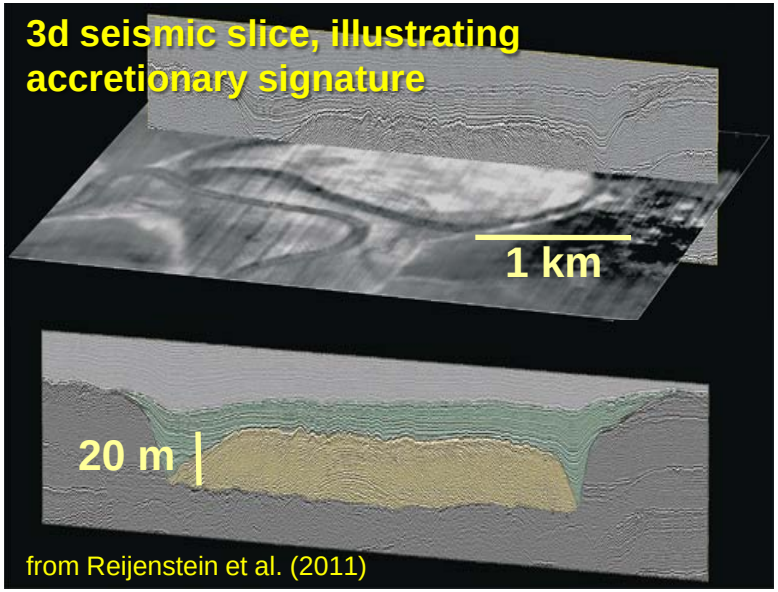
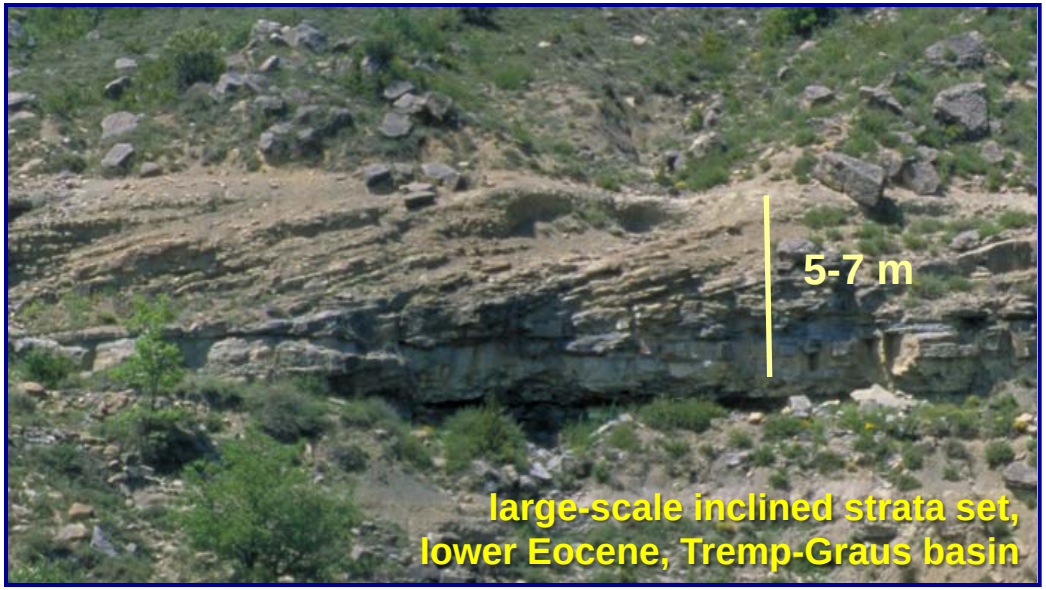
Bar Accretion and Large-Scale Inclined-Strata Sets









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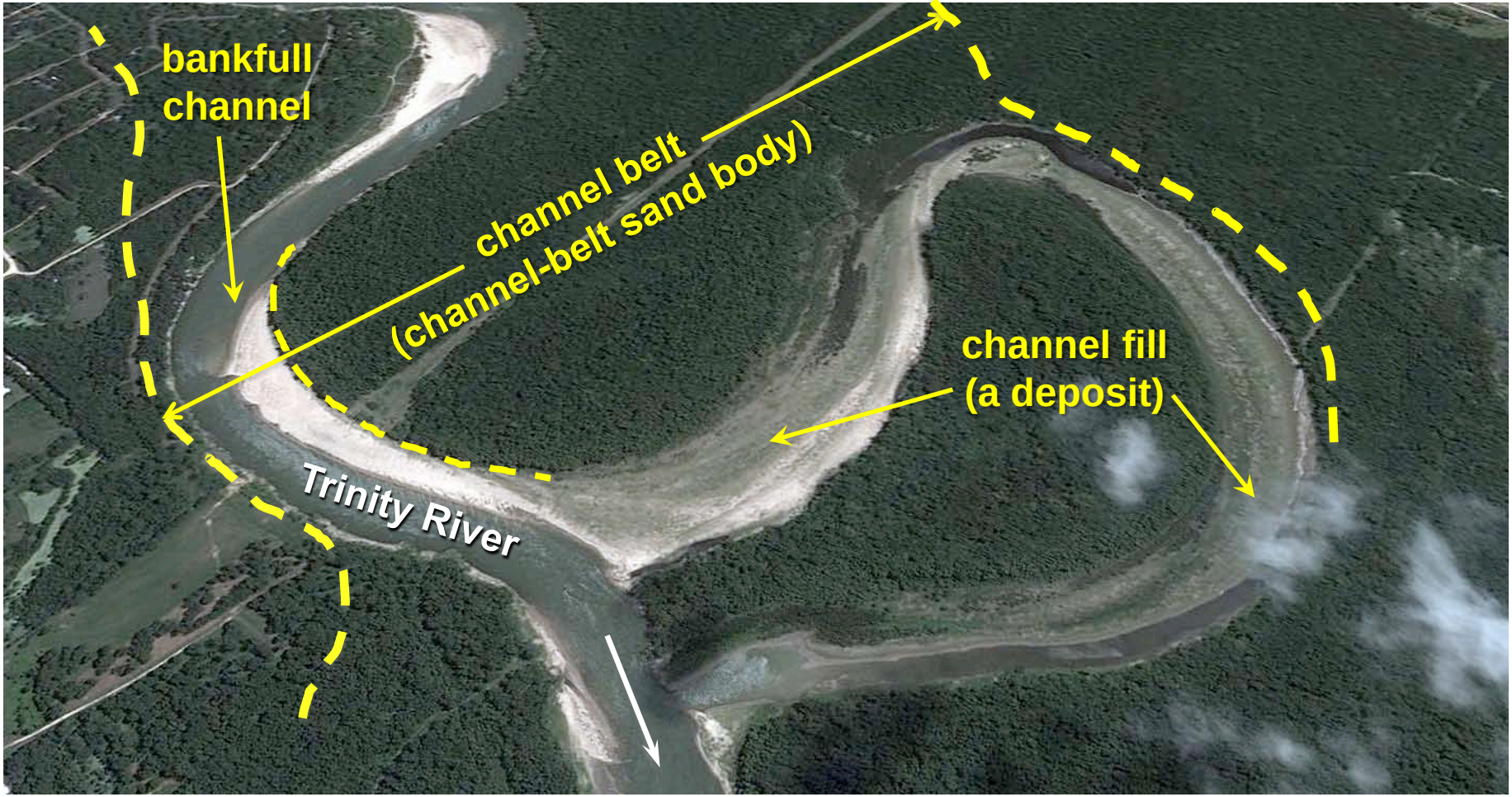
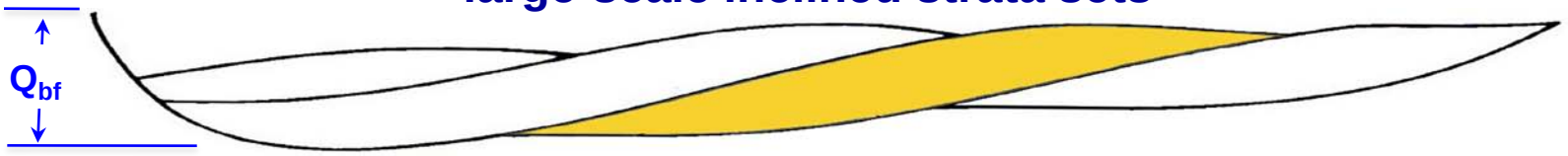
Definitions – Channels, Channel Fills, and Channel Belts



large-scale inclined strata sets



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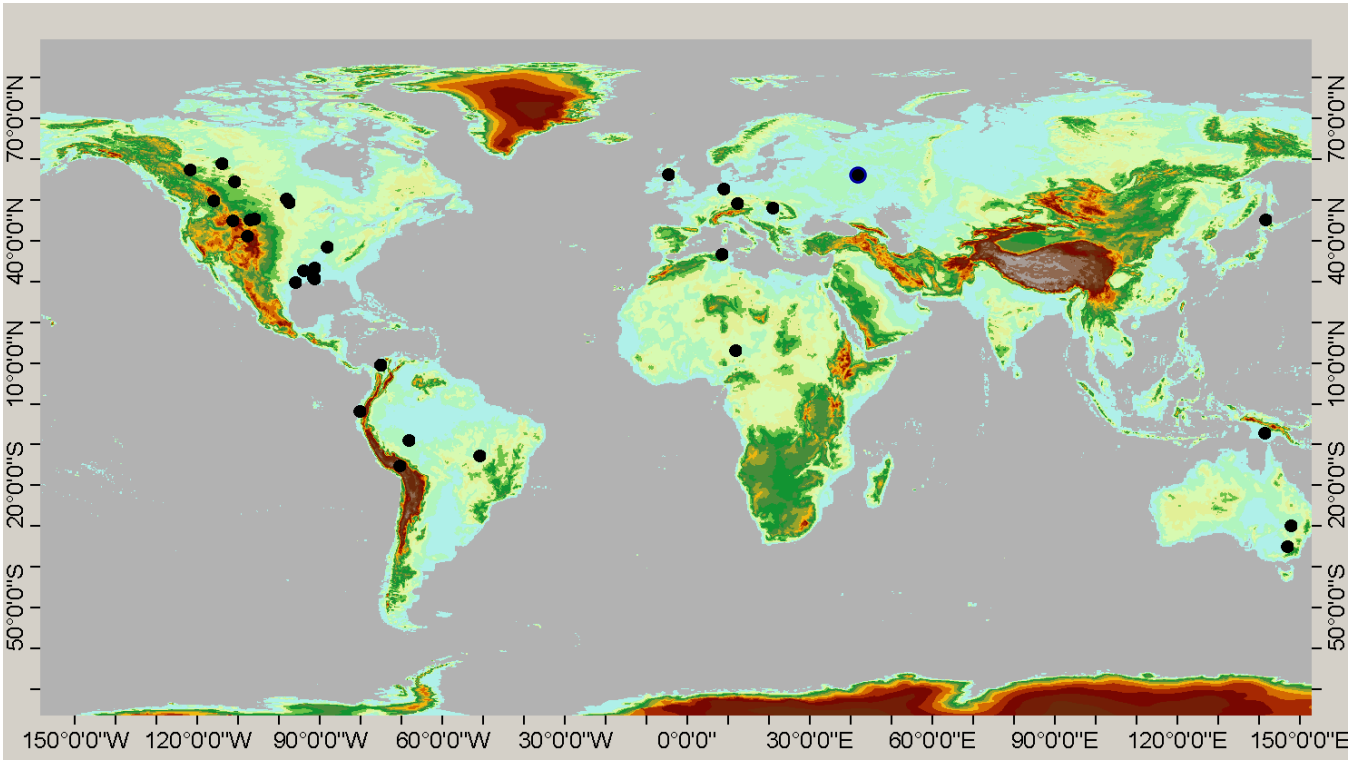
Dataset

- Channel-belt and channel-fill scales from 38 modern rivers
  - periglacial to tropical
  - drainage areas = 250 to 3,000,000 km^2
  - 124 measured meanders
- Incised-valley Scales from 10 Late Quaternary Systems
  - drainage areas = 50,000 to 3,000,000 km^2



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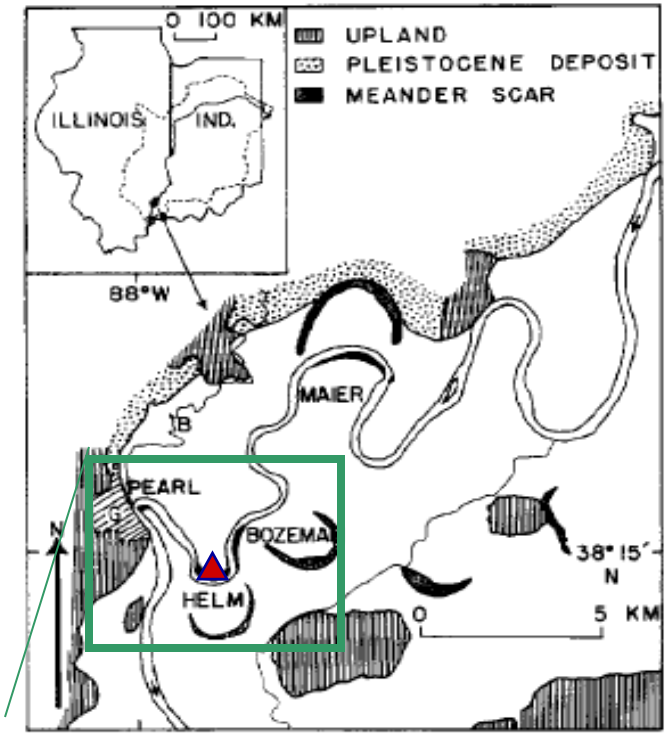
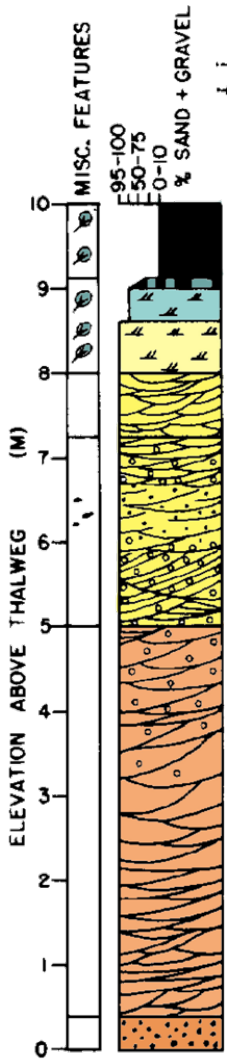
Methodology: Wabash River Example



Jackson (1976)



GRAPHIC COLUMN

- Thickness: 9 m
- Point bar areal extent: 0.8 km^2
- Abandoned Channel Width: 190 m
- Translation Length: 1450 m
- Non-translation length: 650 m
- Drainage Basin: 75,700 km^2

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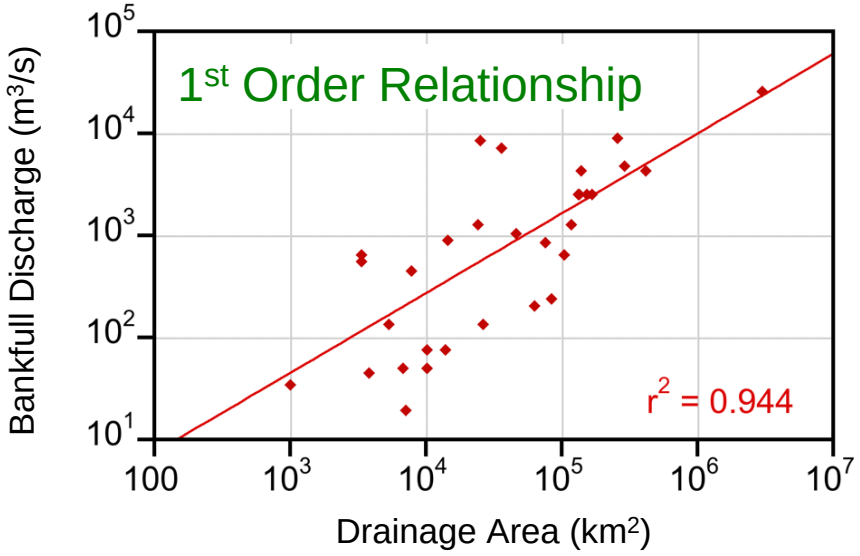
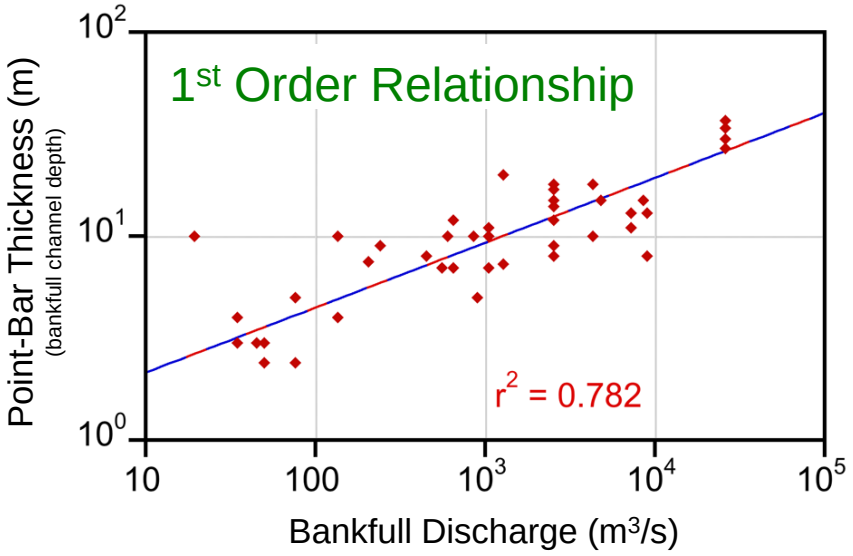
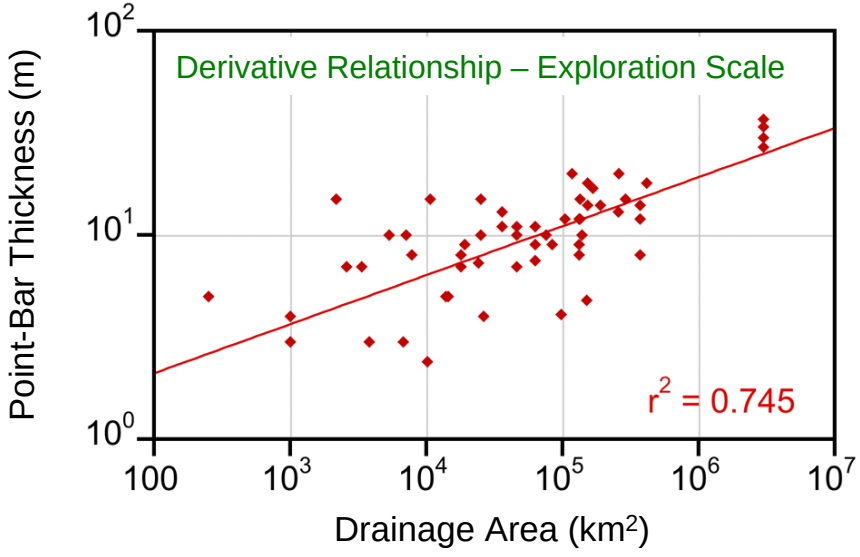
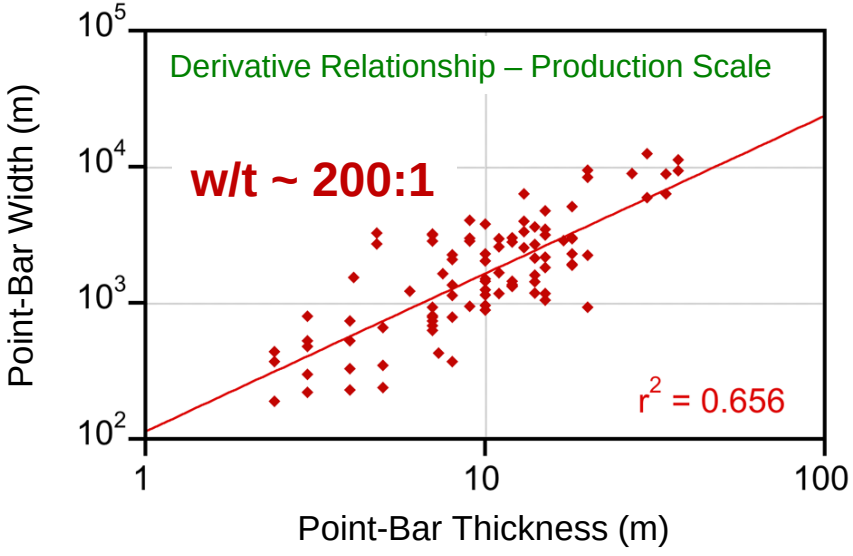
Scaling of Channel Belts









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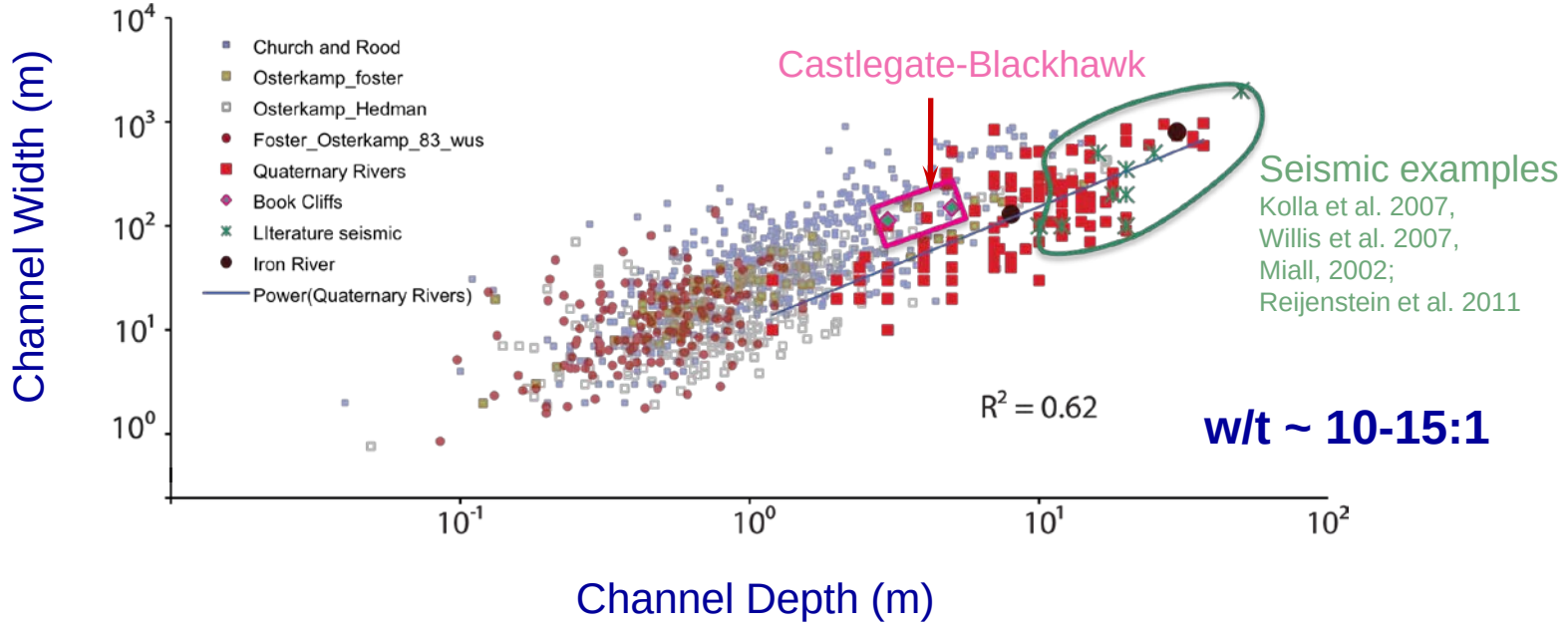
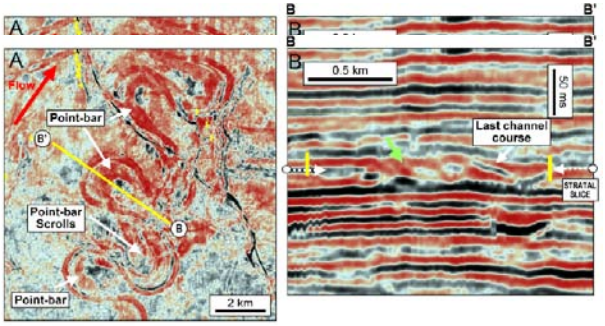
Heterolithic Abandoned Channel Fills



Examples from other studies

Blackhawk Fm

Donselaar and Overeem, 2008



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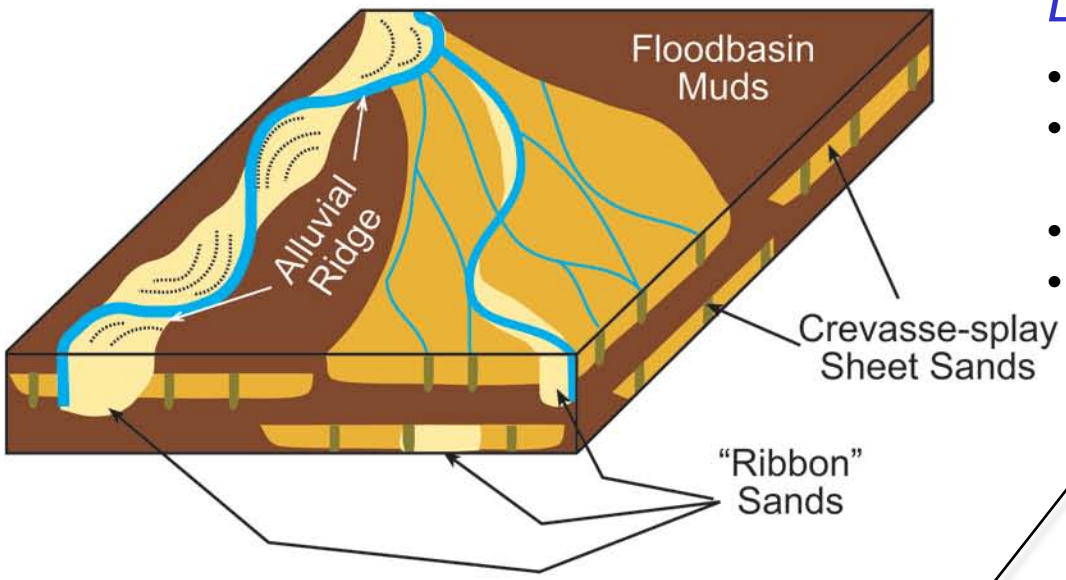
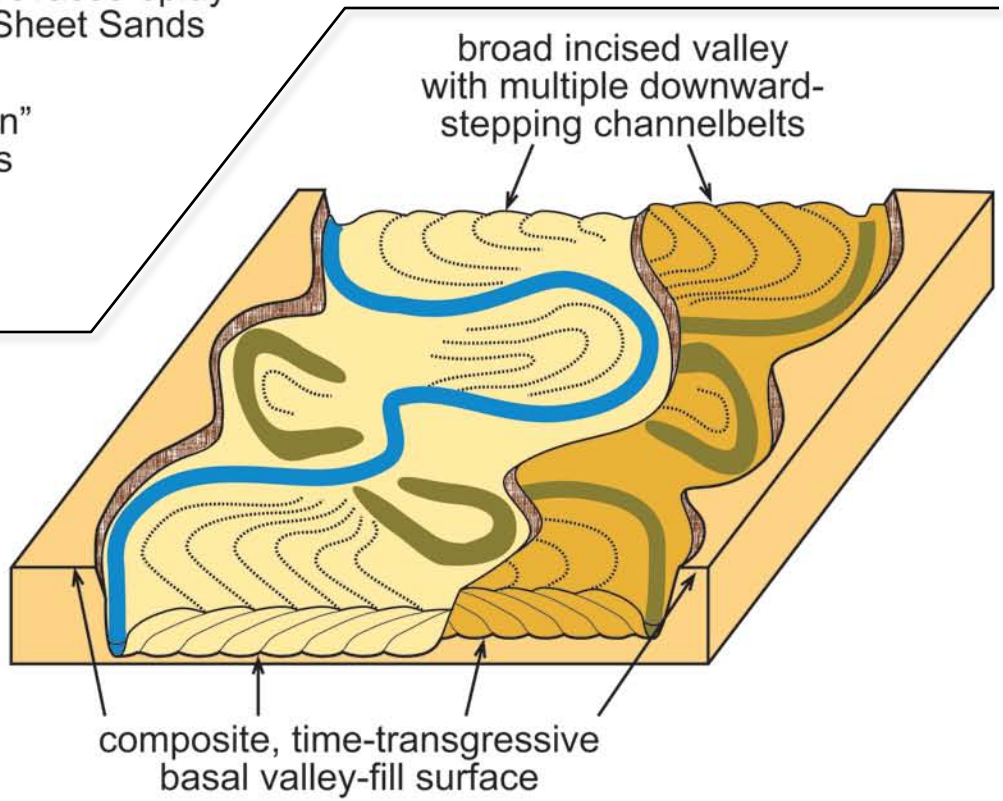
Fundamental Contrasts in Channel-Belt Scales: Why??



Low-Net End Member

- Highly heterolithic
- Ribbon sands and thin sheet sands encased in muds
- Dominated by avulsion processes
- Highly aggradational stacking



High-Net End Member

- Amalgamated sand bodies
- Channel fills and channel-belt margins are dominant barriers to flow
- Dominated by channel-belt migration
- Fluvial processes confined to discrete valley
- Degradational or low aggradational stacking

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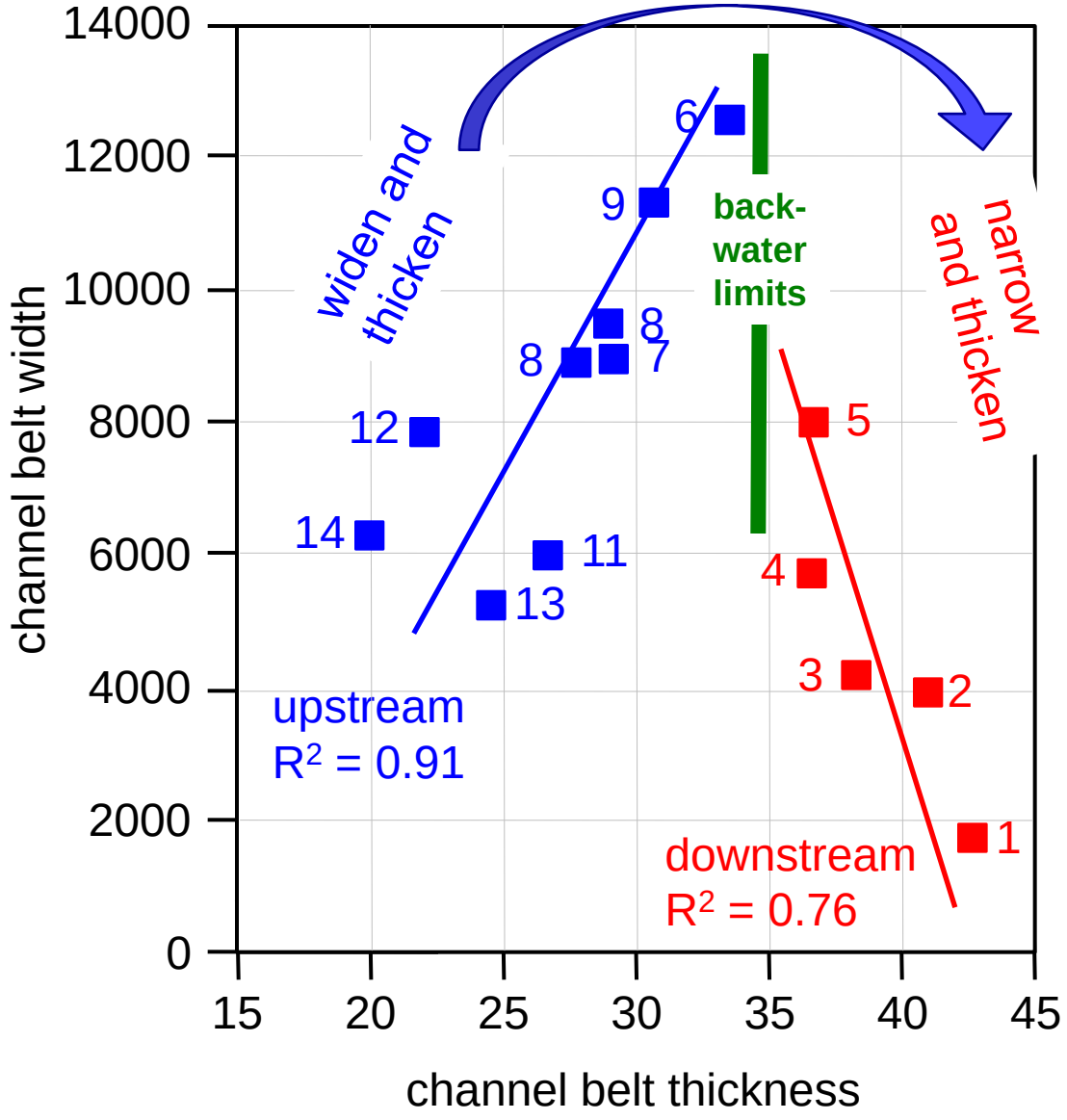
Fundamental Contrasts in Channel-Belt Scales: Backwater Effects



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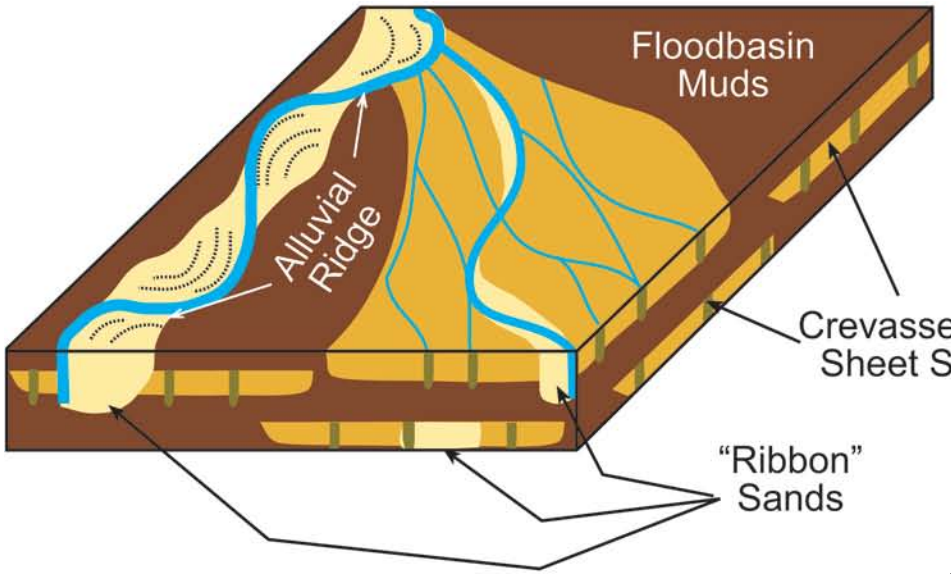
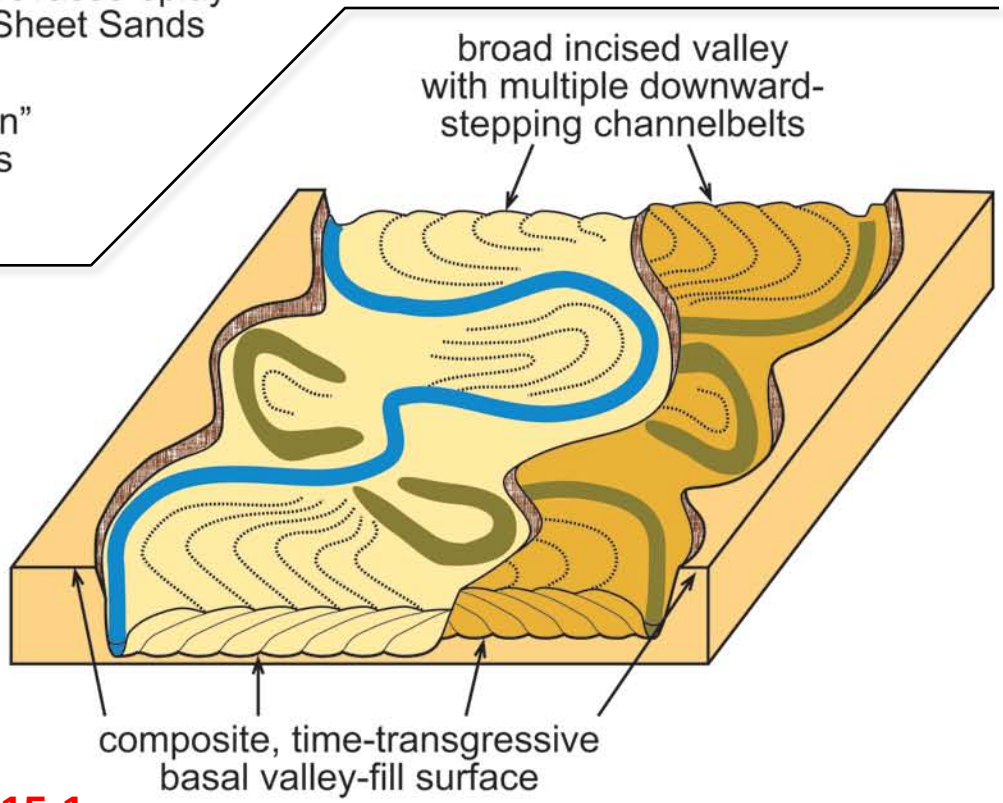
Fundamental Contrasts in Channel-Belt Scales: Why??



Low-Net End Member

- Highly heterolithic
- Dominated by avulsion processes within backwater length
- Highly aggradational stacking
- **Distributary channel belts w/t = 20-50:1**



High-Net End Member

- Amalgamated sand bodies
- Channel fills and channel-belt margins are dominant barriers to flow
- Dominated by channel-belt migration
- Fluvial processes confined to discrete valley
- Degradational or low aggradational stacking
- **Channel belts w/t = 200:1, channel fills 15:1**

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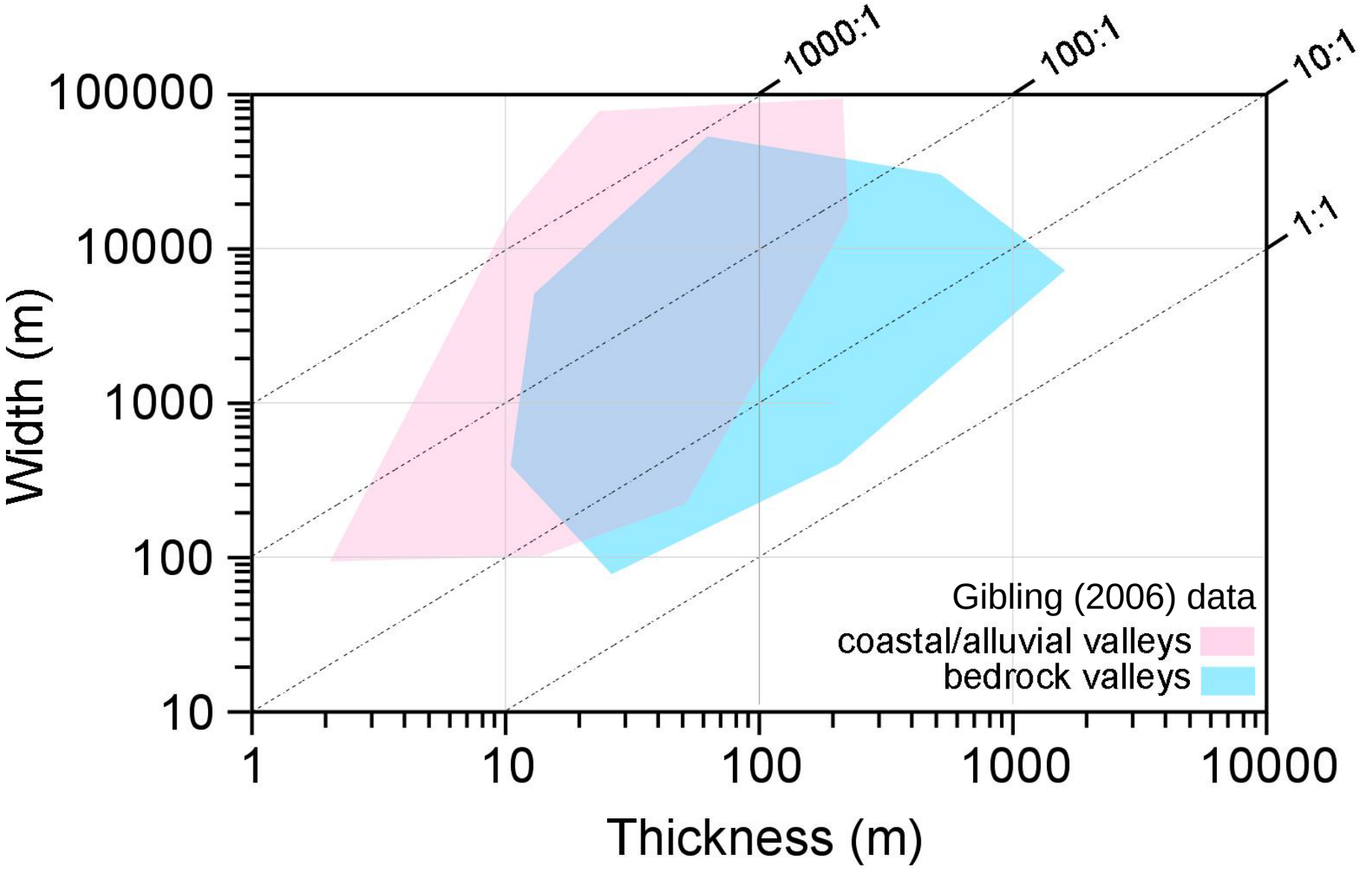
Scales of Incised Valleys – Published Ancient



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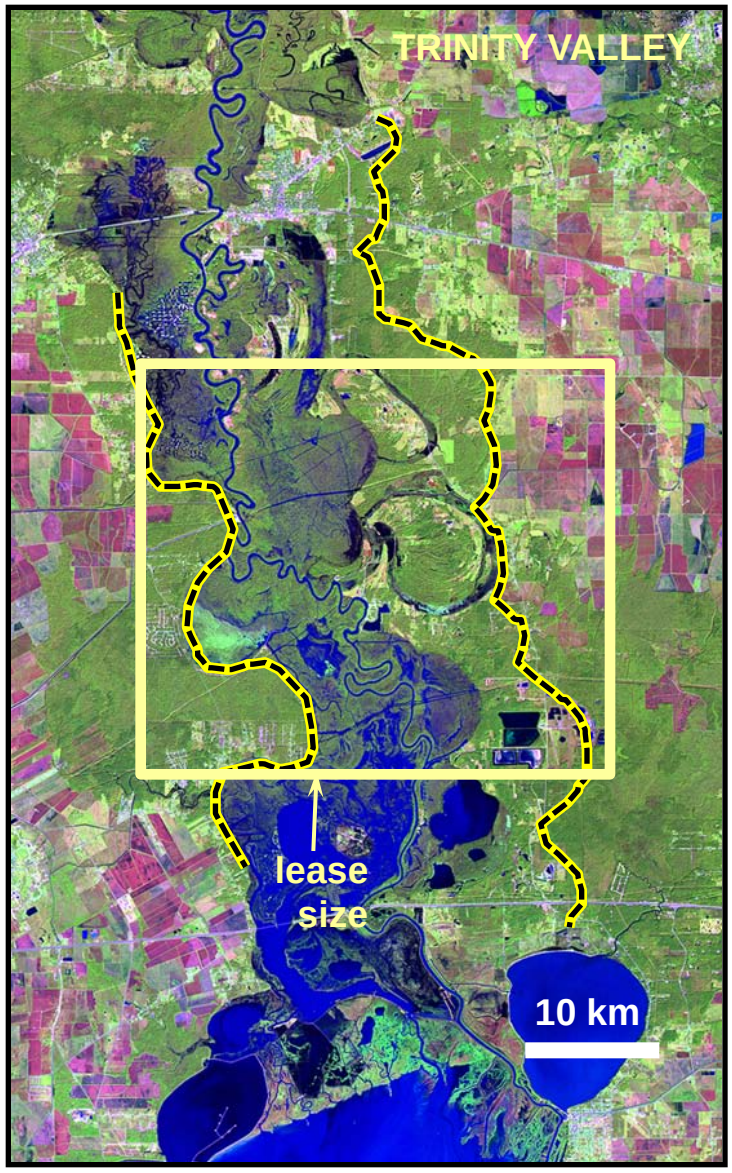
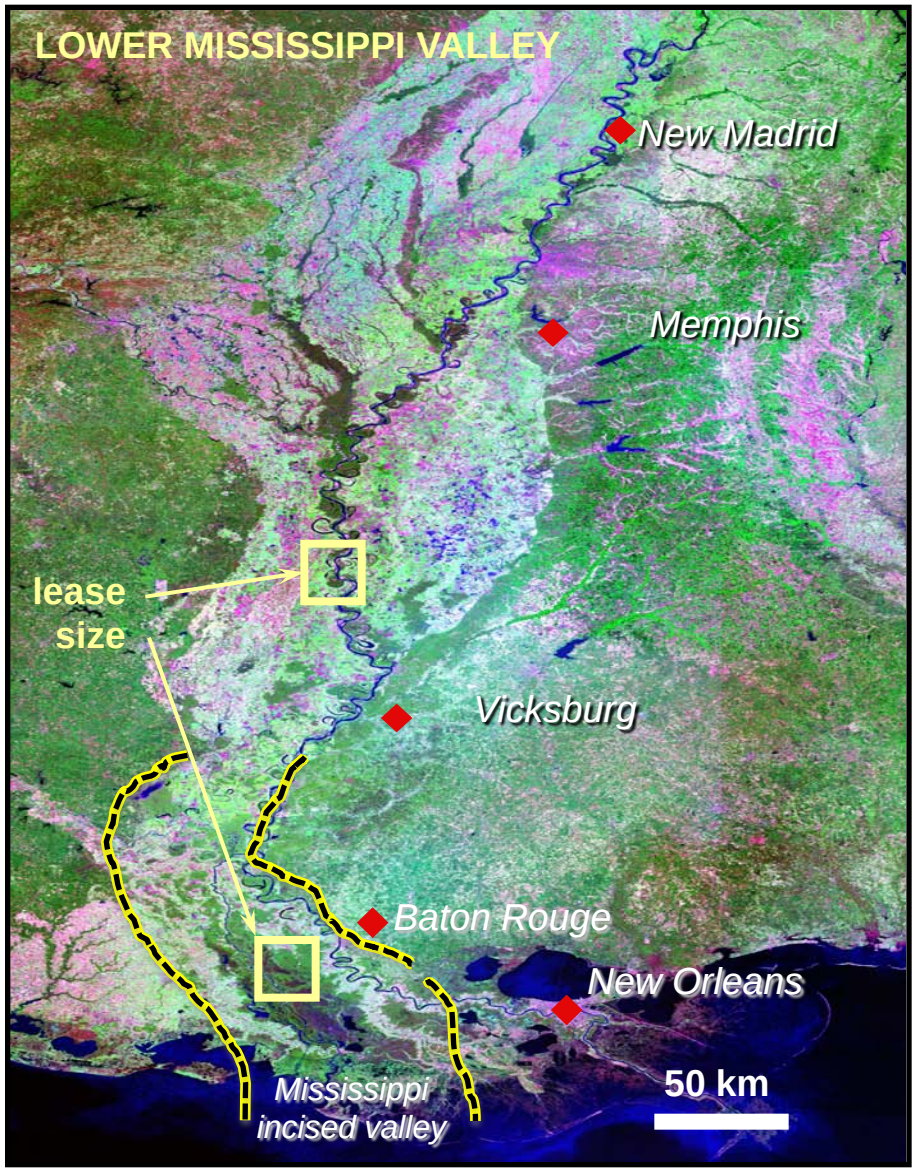
Significance of Incised-Valley Scales to Interpretation





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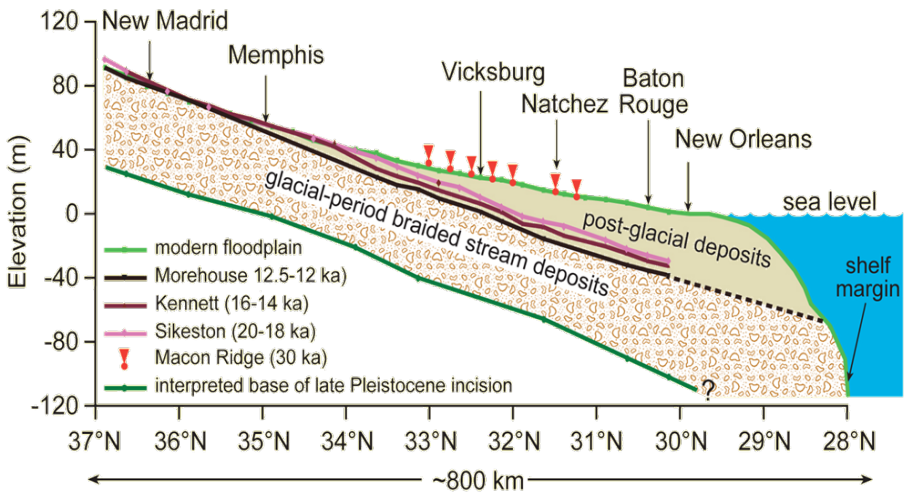
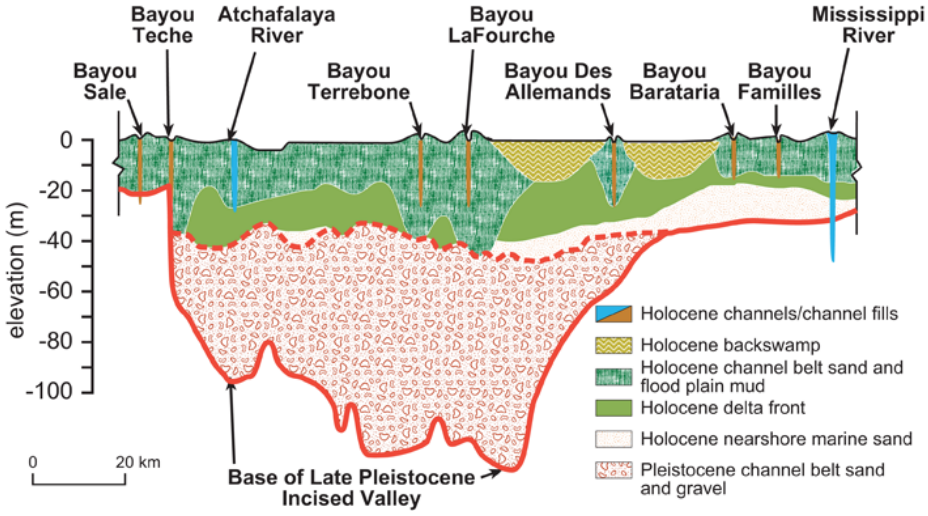
Coastal-Plain Incised Valleys - Lower Mississippi River





based on Blum et al. (2000), Rittenour et al. (2005, 2007), and Blum et al. (2008)

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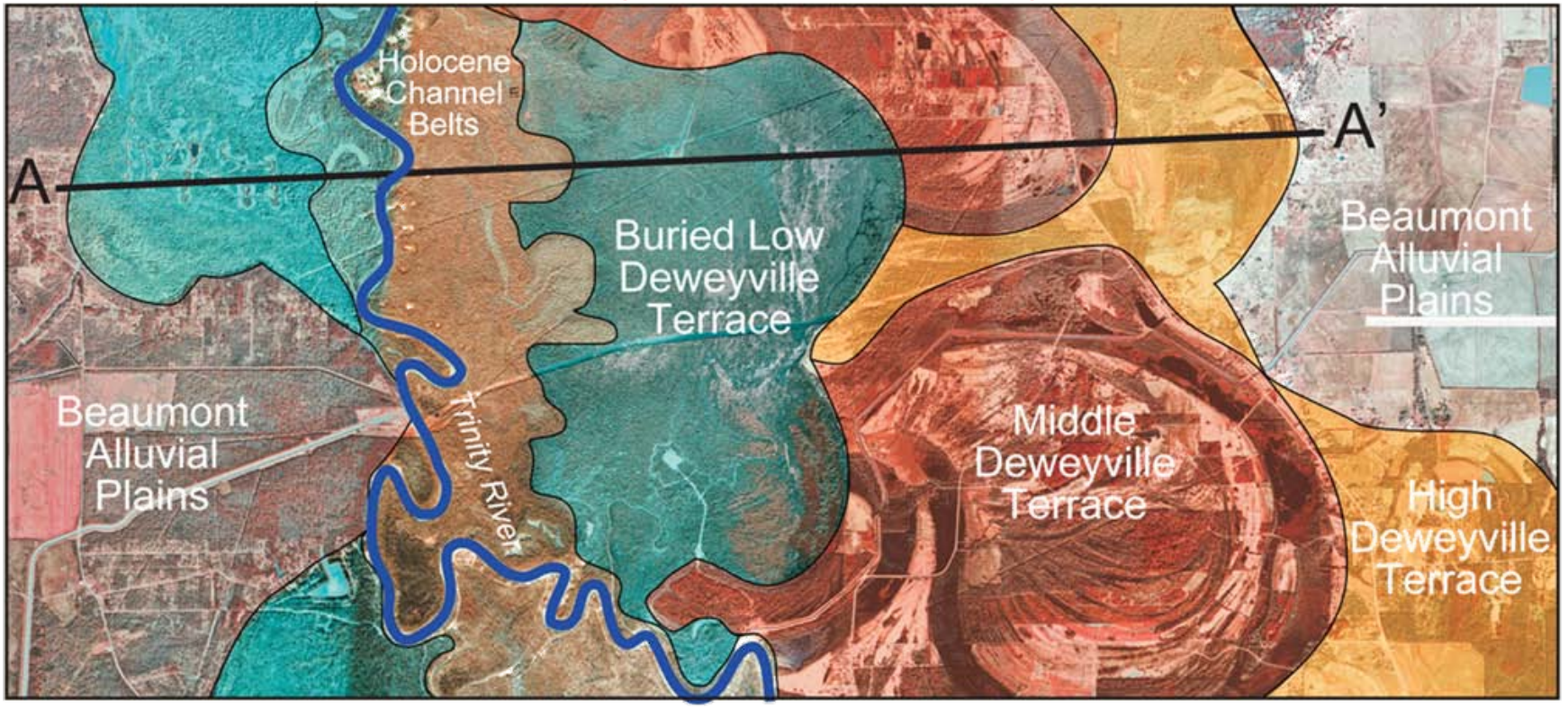
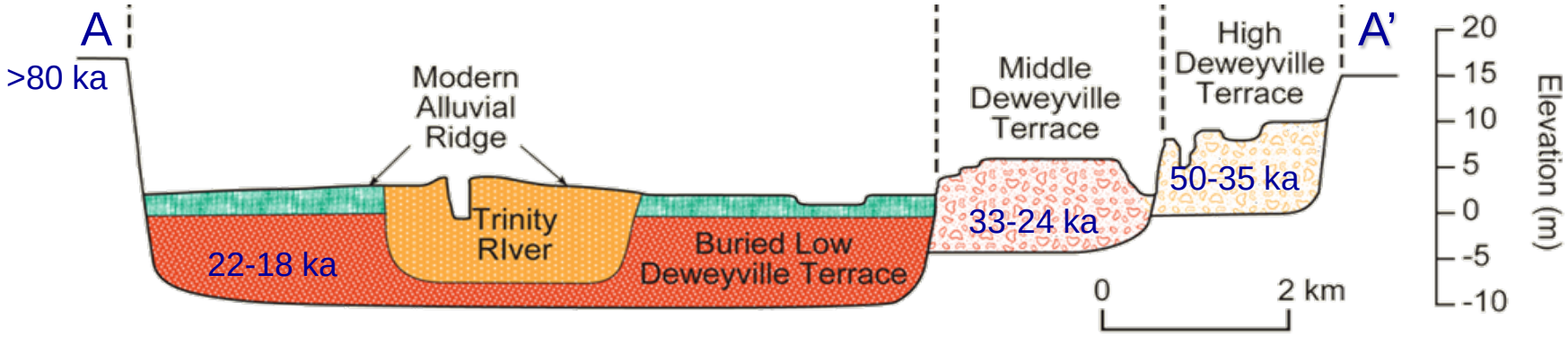
Coastal-Plain Incised Valleys - Lower Trinity River, Texas





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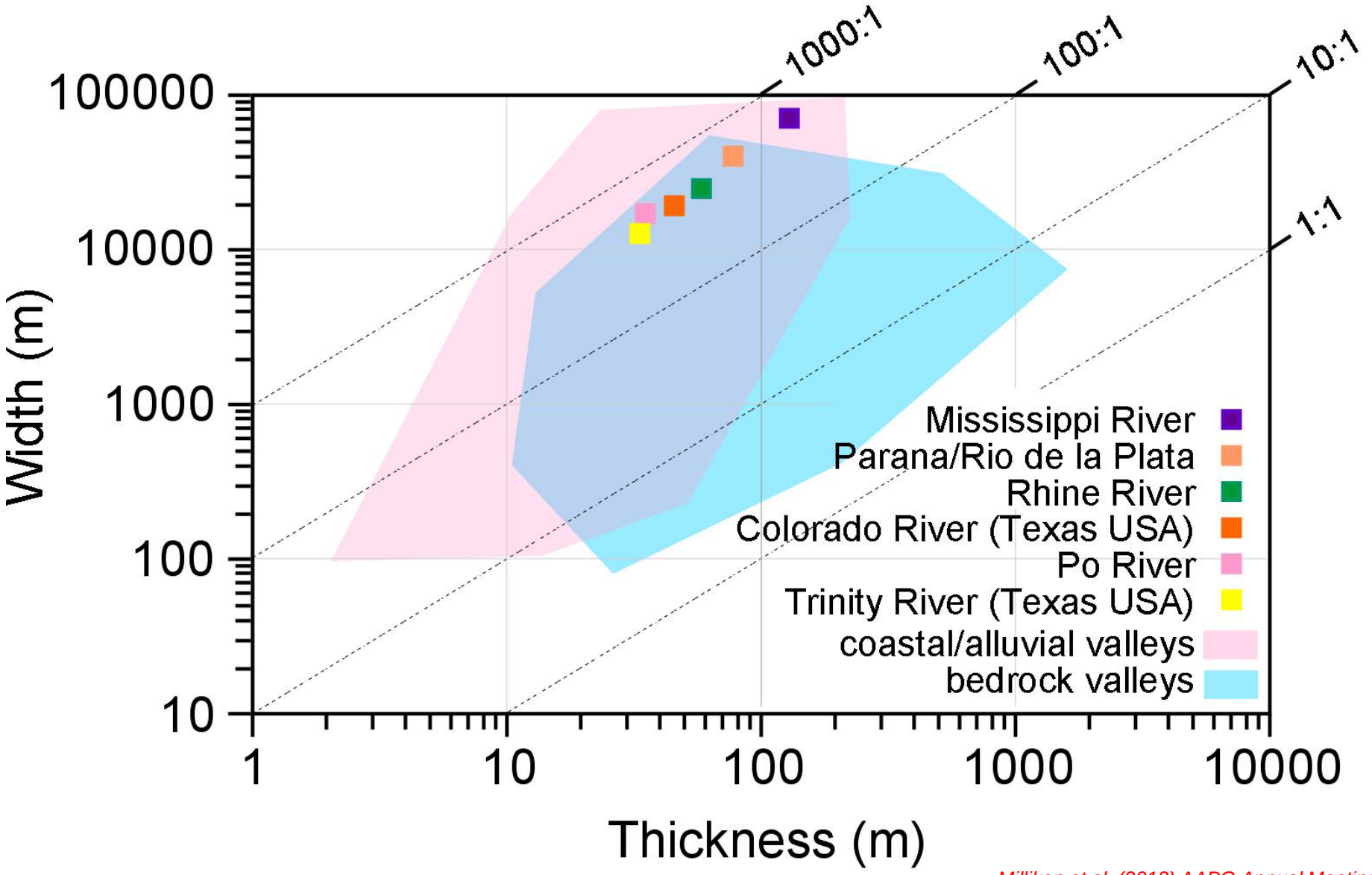
Scales of Incised Valleys – Published Ancient vs. Late Quaternary



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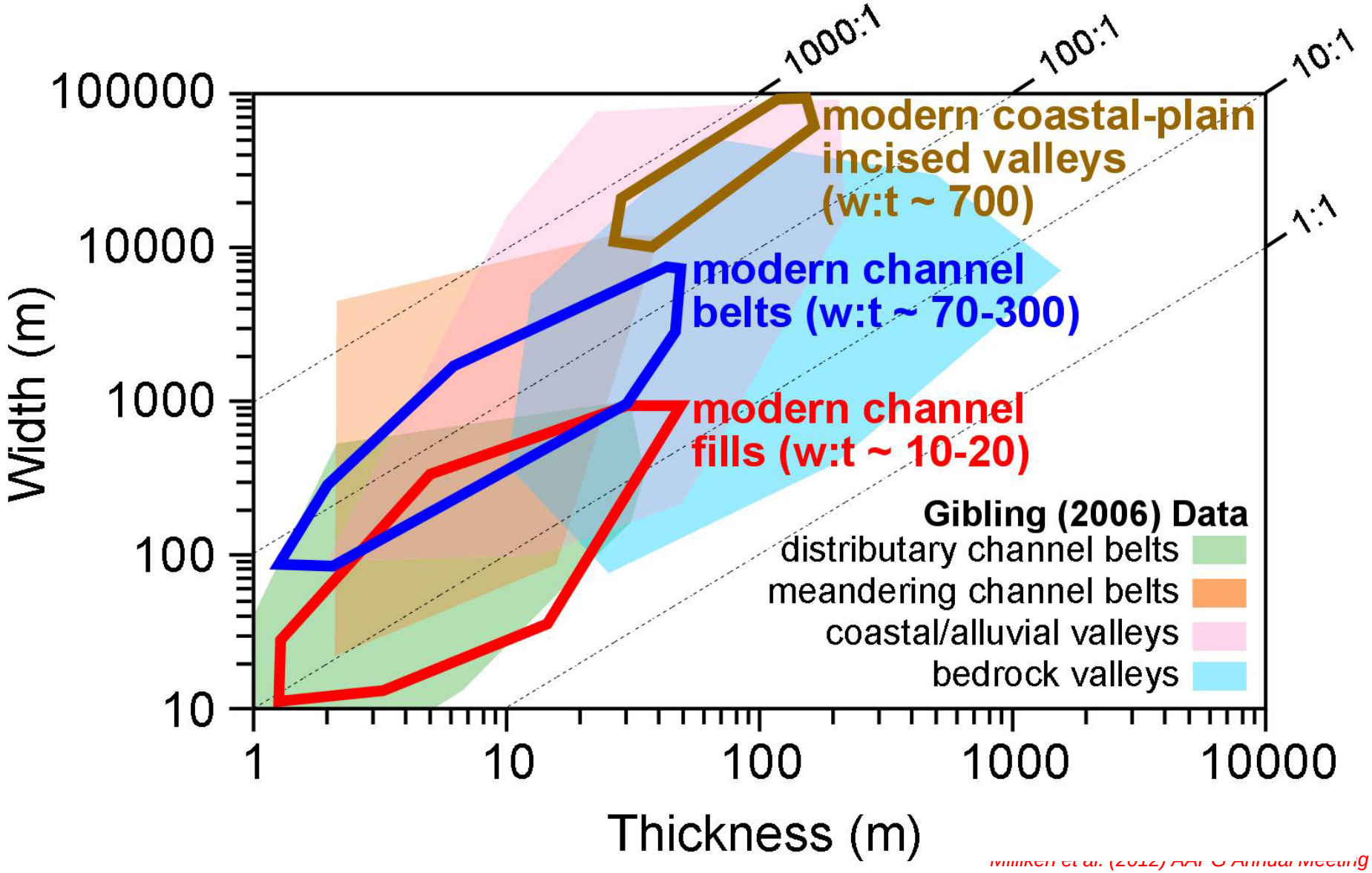
Scales of Incised Valleys, Channel Belts, and Channel FIlls



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Summary

Fluvial stratigraphic elements exhibit scaling relations that are consistent across a range of river system scales

- **Channel-belt sand bodies range from ~100-300:1, with a mean of ~200**
- **Distributary channel-belts range from ~20-50:1**
- **Abandoned channel-fills range from 10-30:1**
- **Each element occupies the same thickness domain, because of scaling to bankfull discharge, but differ in width domains due to lateral migration**

- **Coastal-plain incised valleys range from 500-800:1**

Scaling relations defined from modern systems commonly differ from scales interpreted in the stratigraphic record

- **Scaling relationships from modern systems are *observations*, not interpretations, and tied to process-based understanding of system parameters (discharge, sediment flux)**
- **Can be used as an additional set of recognition criteria to guide, cross-check, or calibrate interpretations in outcrop or subsurface data**