The McMurray Conundrum: Conflicting Interpretations of Environment of Deposition and Paleogeography*

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Abstract

Scaling relationships in modern fluvial systems provide useful guidance for interpretation of the stratigraphic record of the McMurray Formation, within the eastern margins of the Alberta foreland basin. Important scaling relationships include width:thickness of channel-belt sand bodies that form under normal flow conditions (~70–300:1), and the width:thickness of associated abandoned channel fills (~10–30:1). In addition, predictable transformations occur as a river system goes from normal flow through its backwater reach and begins to feel the effects of sea level. Rates of lateral migration and resultant channel-belt width decrease significantly, the channel aggrades, and avulsion is common: channel-belt width-to- thickness ratios within the backwater reach are therefore significantly less (20–50:1), and sand bodies are encased in muddy flood-basin or delta-plain strata. The backwater reach for large systems can be hundreds of kilometers upstream from a coeval shoreline. Detrital zircon signatures show the McMurray represents a true continental-scale fluvial system, the Mississippi or Amazon of its time, with a source terrain that stretched from the Appalachian Cordillera in the SE US to the Western Cordillera: thicknesses of McMurray point-bar sand bodies commonly exceed 30-35 m, which is consistent with a continental-scale system. The well-imaged McMurray in Athabasca displays channel-fill width:thickness ratios consistent with those from modern rivers, and sand body width:thickness ratios >100:1, typical of amalgamated channel belts within that part of a river system that is characterized by normal flow through the uppermost limits of the backwater reach. With channel depths that exceed 30 m, backwater lengths would have been in the range of 4-600 km, and, by this reasoning, contemporaneous shorelines would have been very far to the north. It would be rare to see significant tidal influences on sedimentation this far upstream in any large, inherently low gradient river, and it would be perhaps unprecedented to see brackish conditions extend upstream more than 100 km or so from a large river's mouth. There is, as a result, something of a conundrum with the interpretation of McMurray environments of deposition and paleogeography, because sedimentological and ichnofacies characteristics in these deposits have historically been, and still are in many cases, interpreted to record brackish and/or tidal influences, and a tidally-influenced fluvial system.

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THE MCMURRAY CONUNDRUM

CONFLICTING INTERPRETATIONS OF ENVIRONMENT OF DEPOSITION AND PALEOGEOGRAPHY

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M. Blum thanks former colleagues at Imperial Oil and ExxonMobil Upstream Research for sharing ideas, and releasing data pertinent to this presentation

General Outline

- Overview of Fluvial Scaling Relationships and Inherent Downstream Transformations

- Application to the McMurray System, Alberta Foreland Basin:

  - The McMurray as a continental-scale river from detrital zircons and point-bar scales

  - The McMurray conundrum

  - The McMurray is a fully fluvial, highly migratory river with possible tidal influence (maybe?), but well upstream from any plausible brackish water influence associated with marine environments

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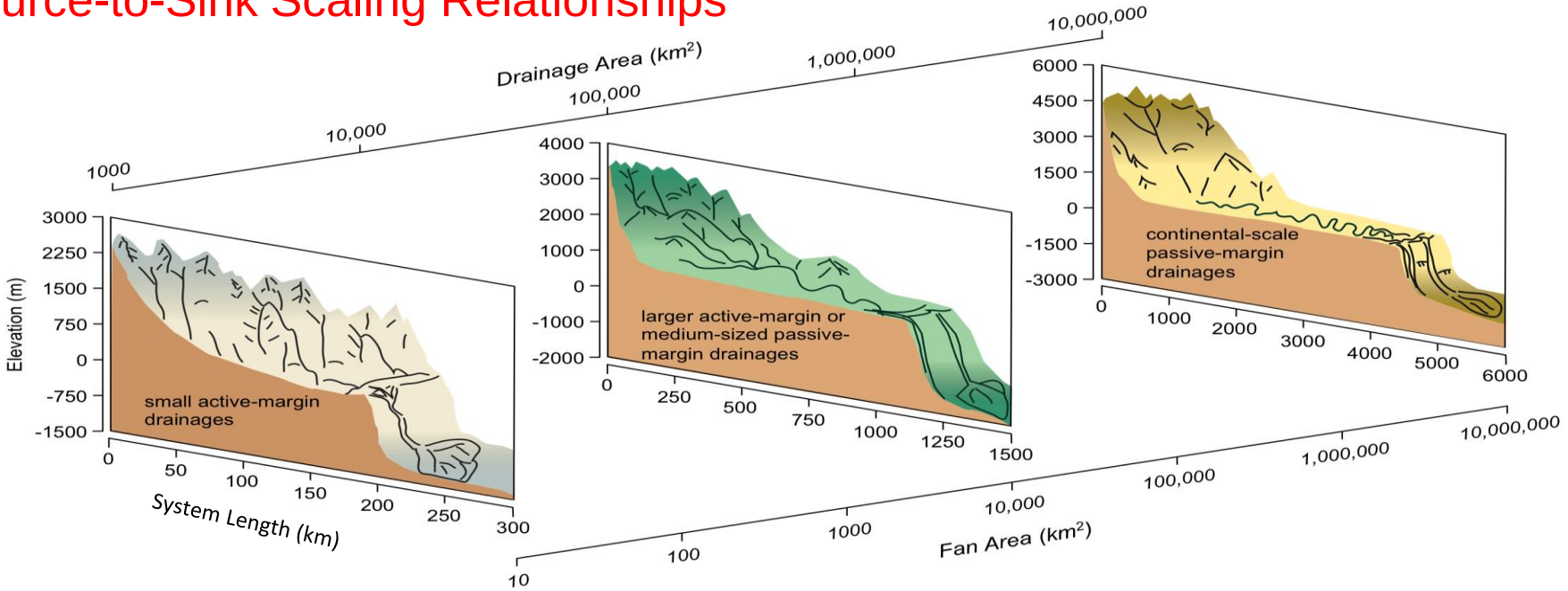
Source-to-Sink Scaling Relationships



	Drainage basin area (km²)	Fluvial system length (km)	Fluvial sand body thickness (m)	Backwater Length (km)	Fan Length (km)	Fan Width (km)	Fan Area (km²)
Small	10,000	75-100	5-7	10-30	<25	25-50	<1000
Moderate	100,000	750-1000	10-15	50-100	100-200	100-200+	100,000
Large	1,000,000+	2000-4000	25+	300-500+	500-1000	500-1000+	10,000,000

after Somme et al. (2009) and Blum et al. (2013)

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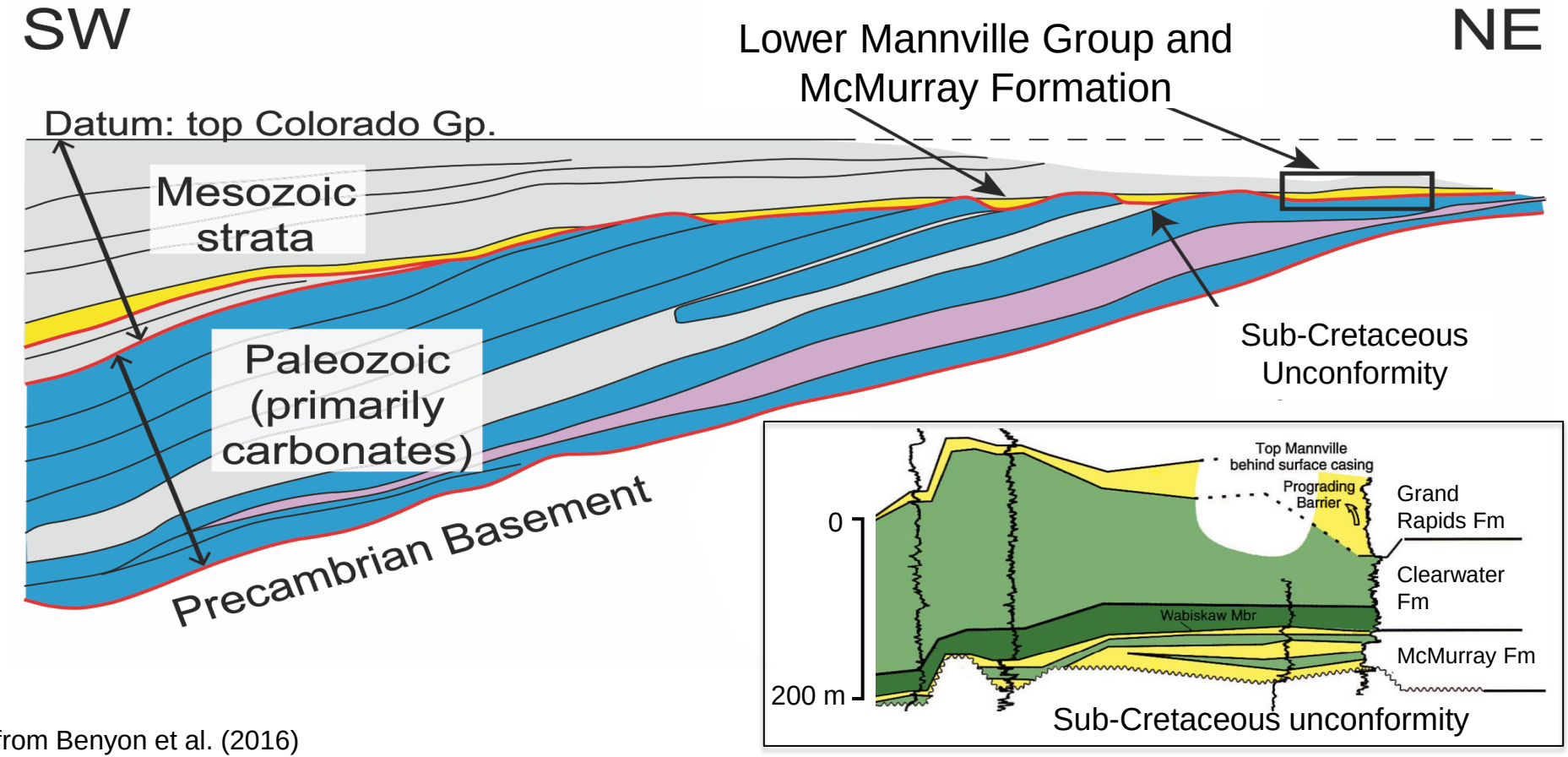
Western Canada Sedimentary Basin Stratigraphic Framework



from Benyon et al. (2016)

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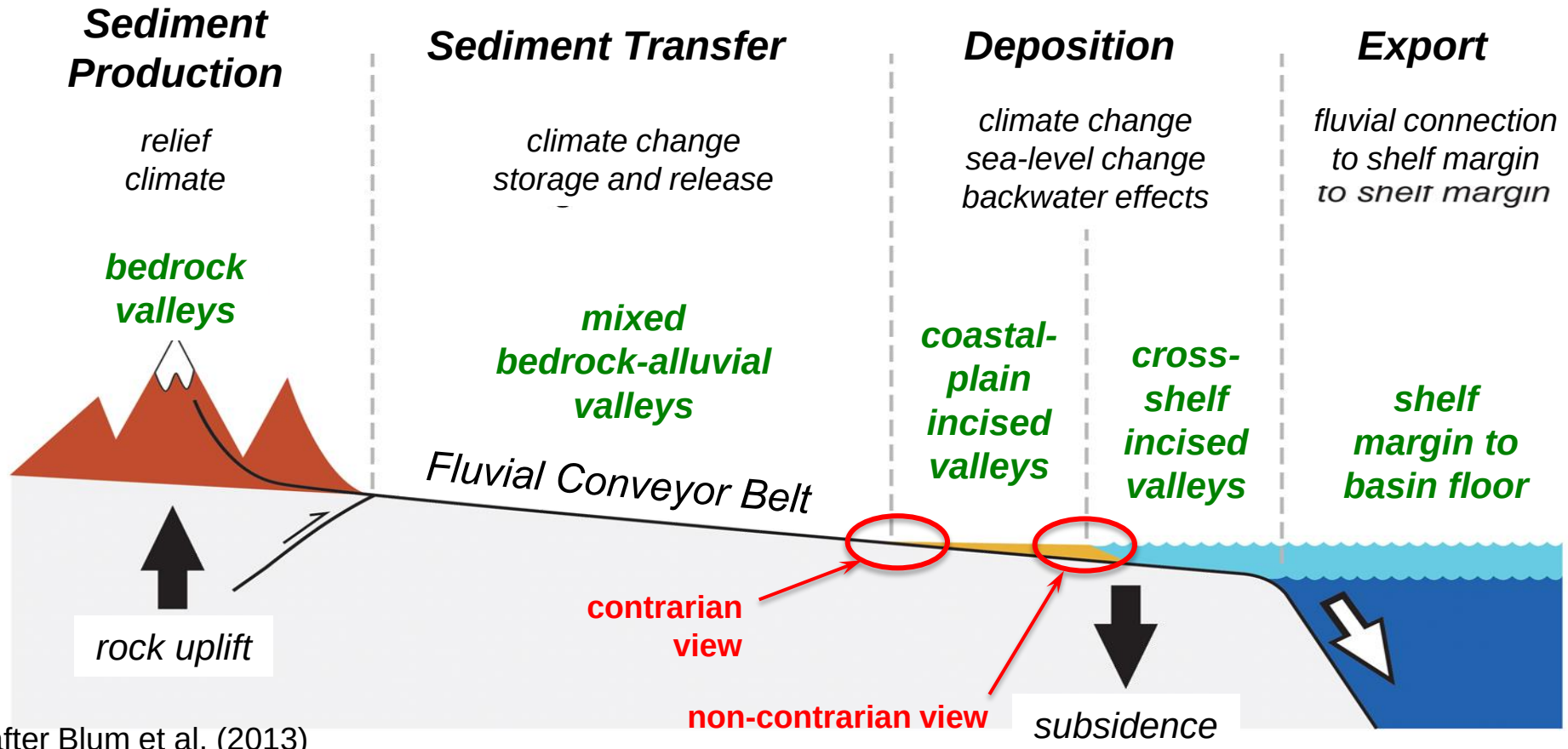
Types of Valleys – A Source-to-Sink View



after Blum et al. (2013)

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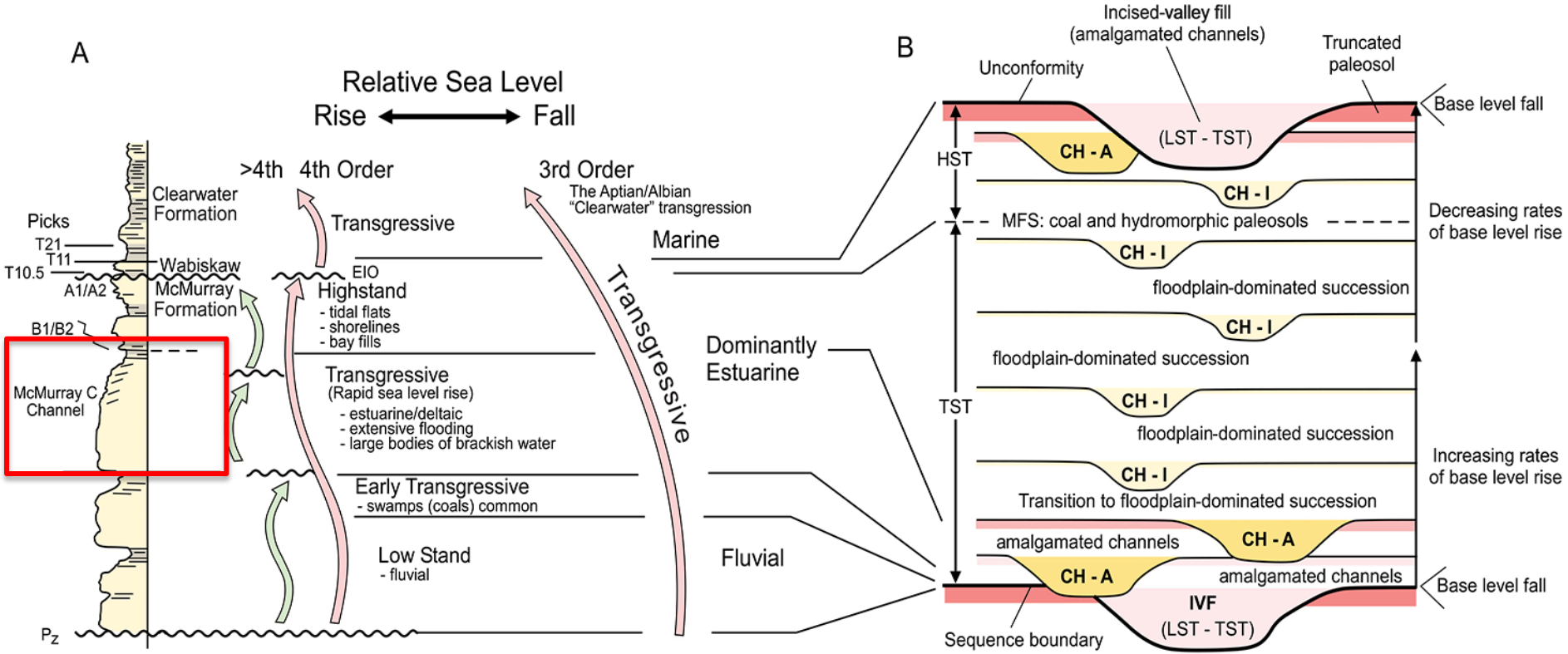
Widely Published Model for McMurray Environments of Deposition



from Hein et al. (2013)

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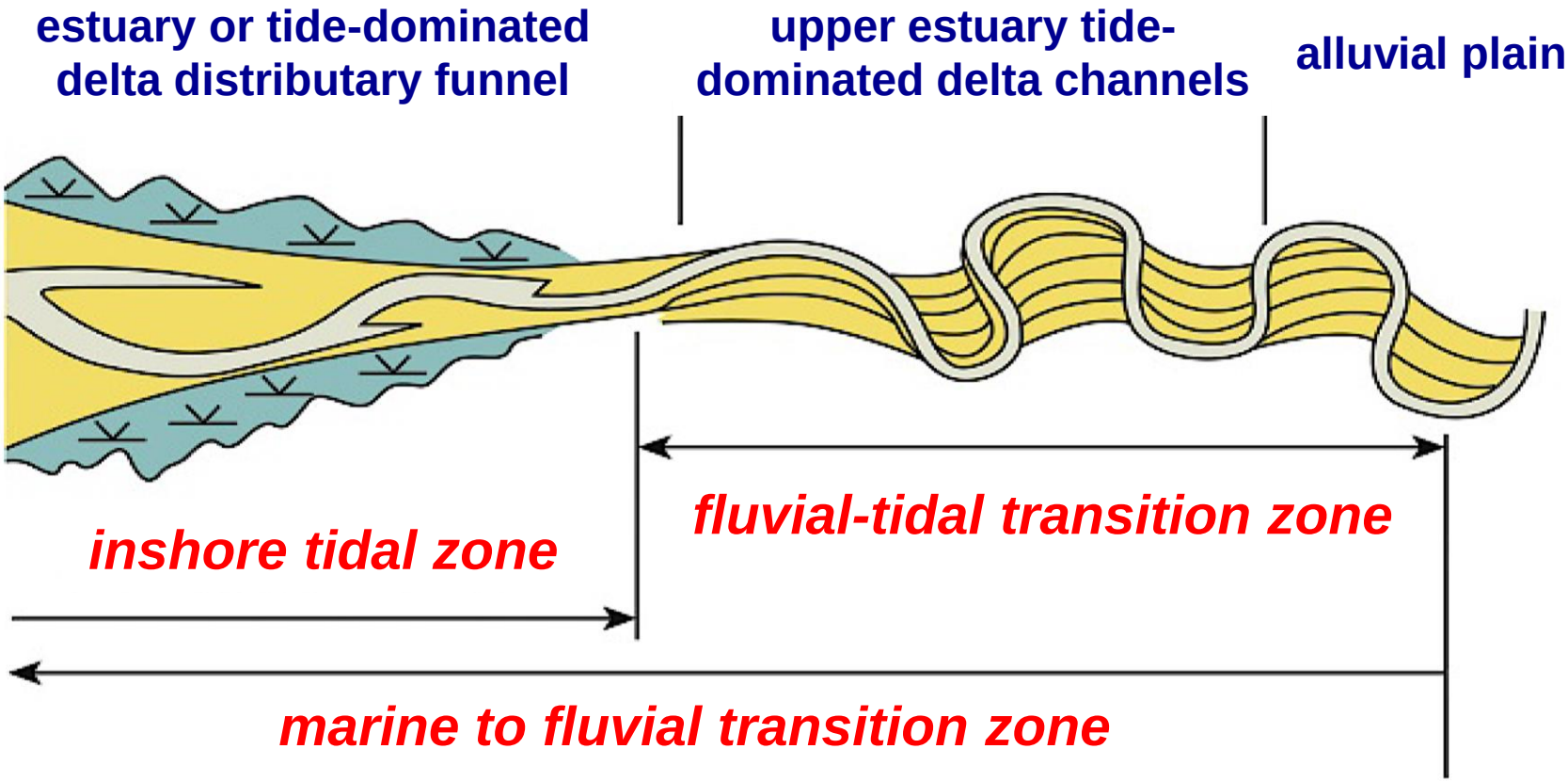
A Common McMurray Interpretation – Estuarine Point Bars



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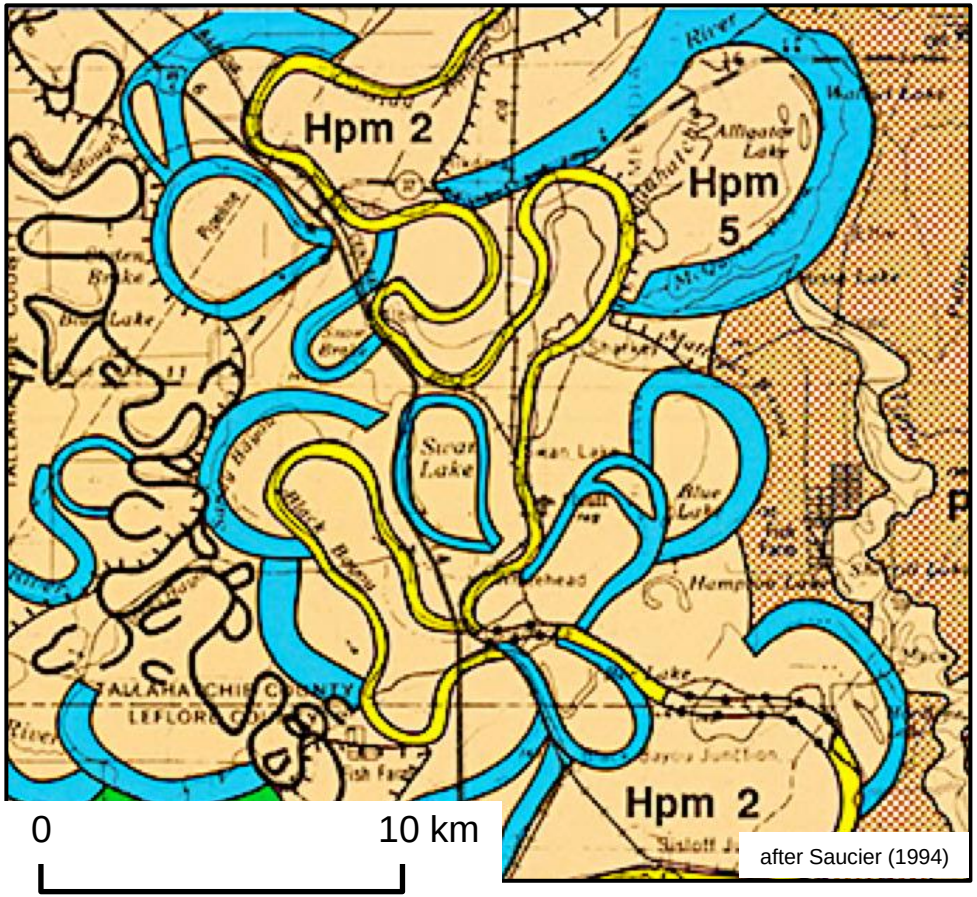
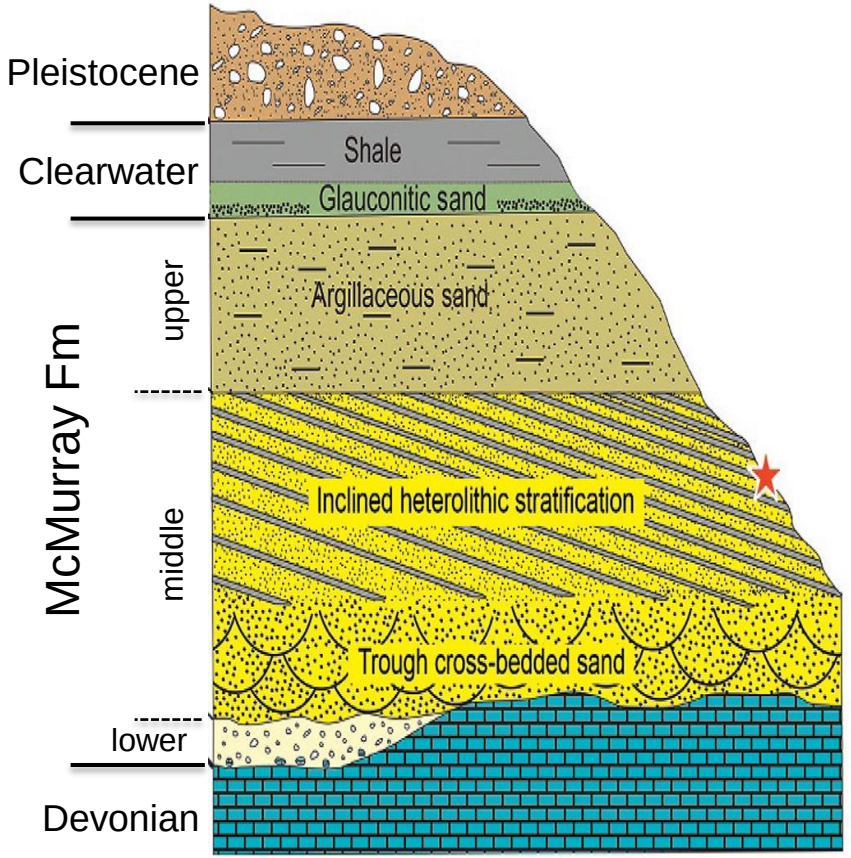
A “Contrarian View” – Amalgamated Fluvial Channel Belts



after Saucier (1994)



modified from Dalrymple (2015), originally from Mossup and Floch (1983)

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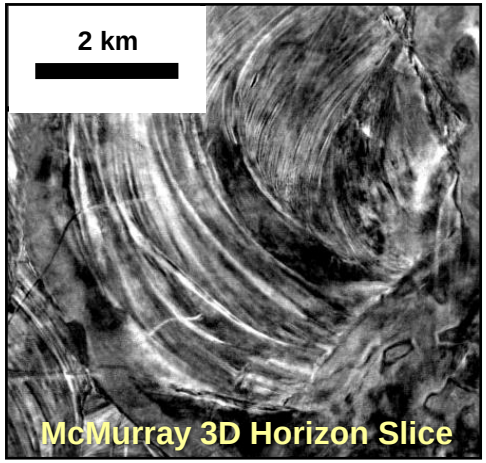
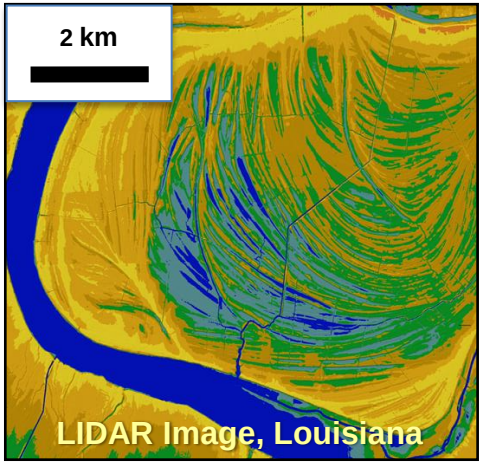
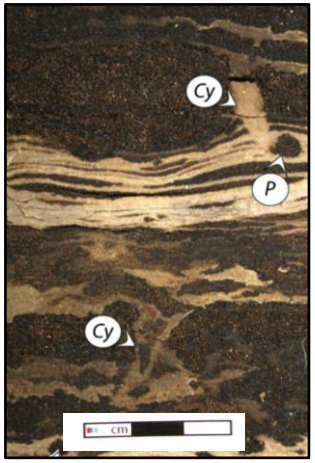
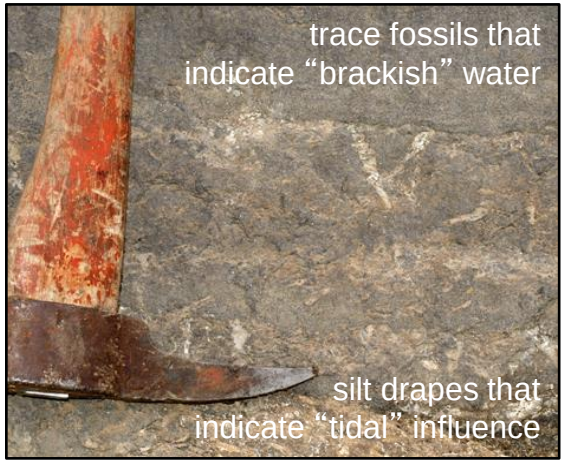
McMurray Channel-Belt Deposits – Conflicting Empirical Realities









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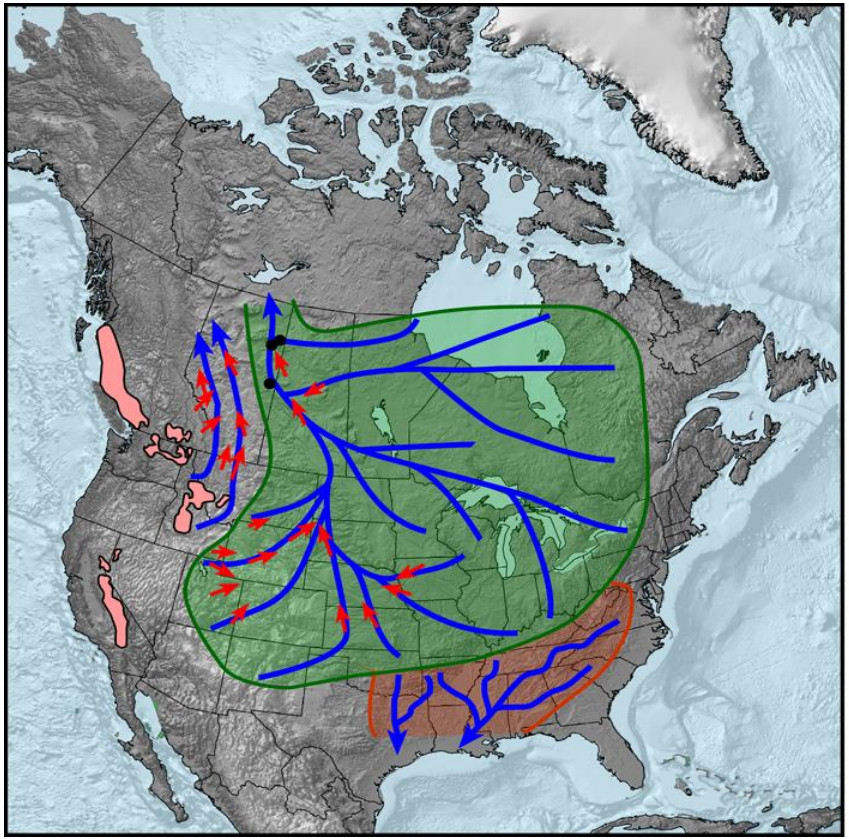
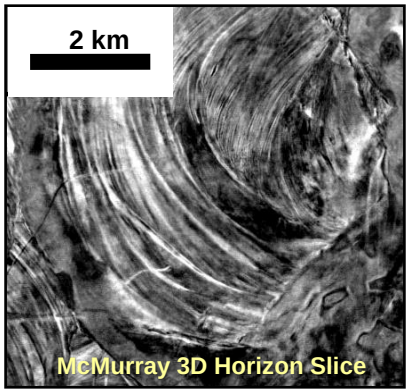
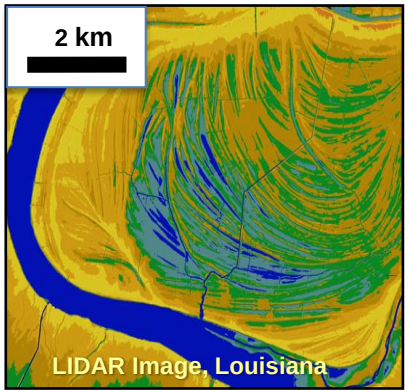
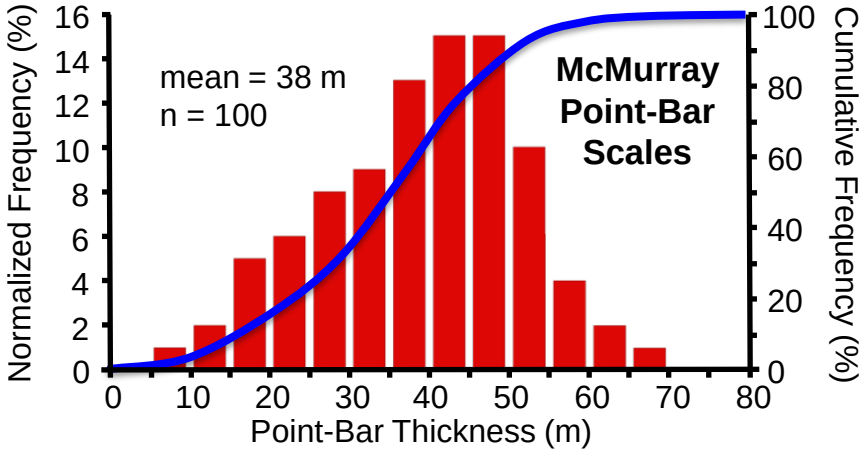
The McMurray as a Giant Continental-Scale Fluvial System









after Blum and Pecha (2014) and unpublished

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The McMurray as a Giant Continental-Scale Fluvial System

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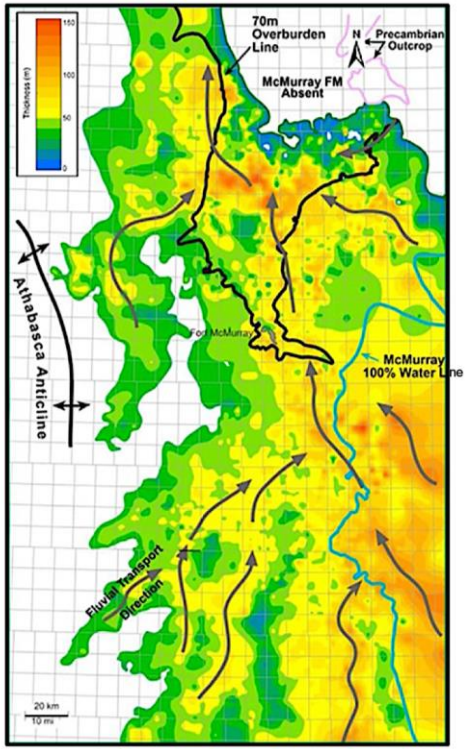
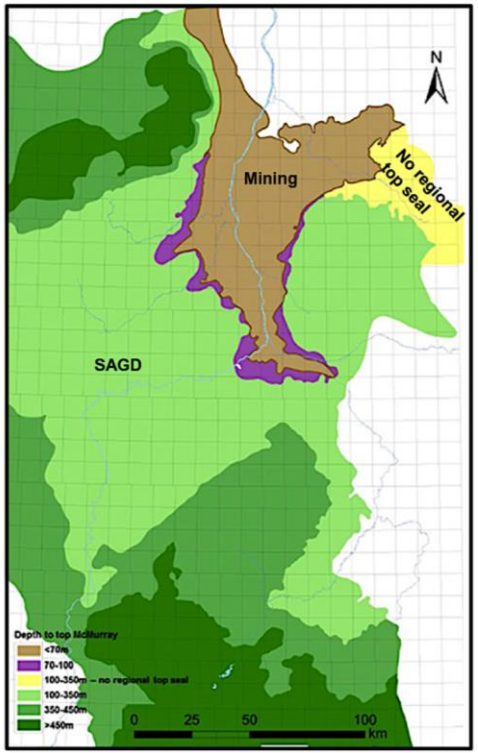
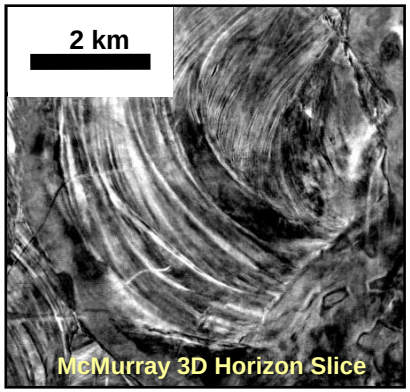
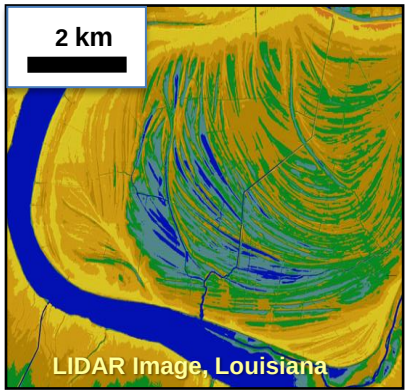
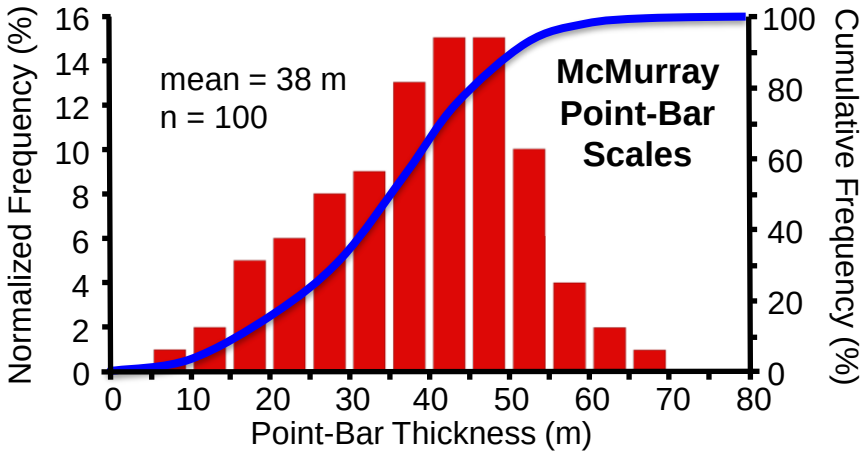


RECOVERY TECHNOLOGY









after Moreton and Carter (2015) and Blum unpublished

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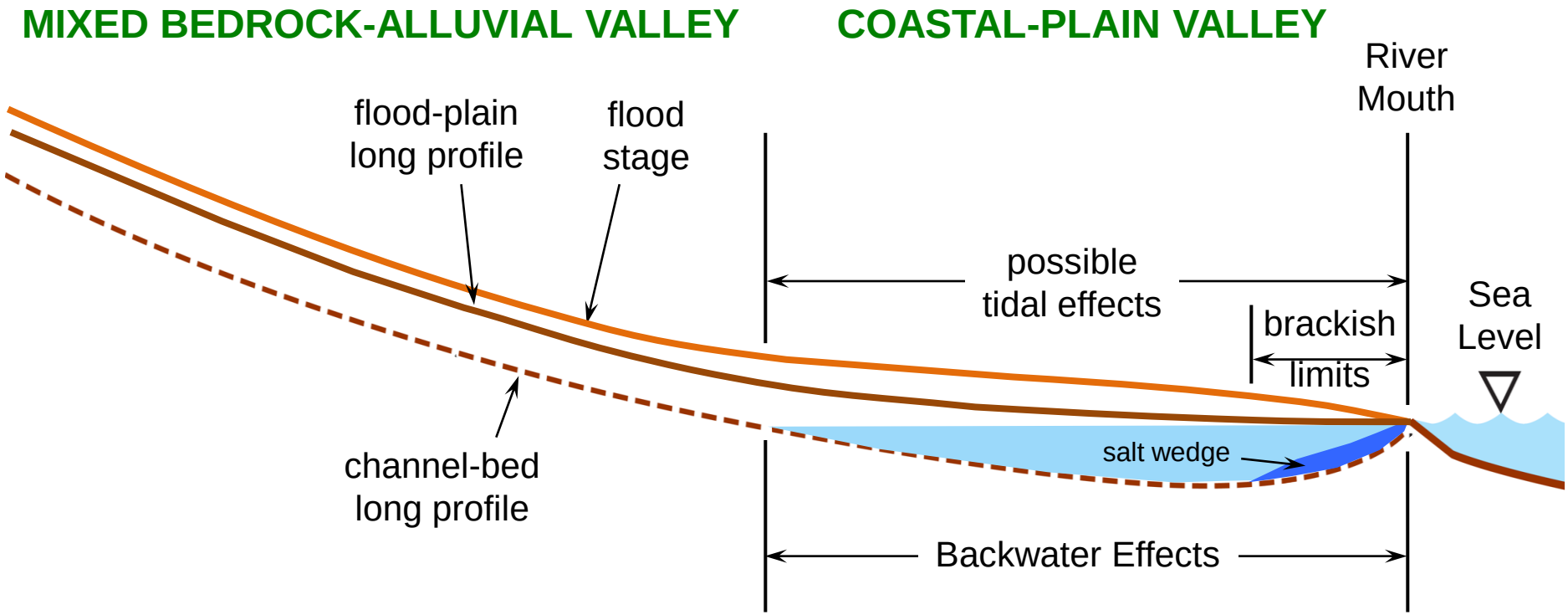
Normal Flow to Backwater Transition – Where Rivers Begin to Feel Sea Level



modified from Li et al. (2006)

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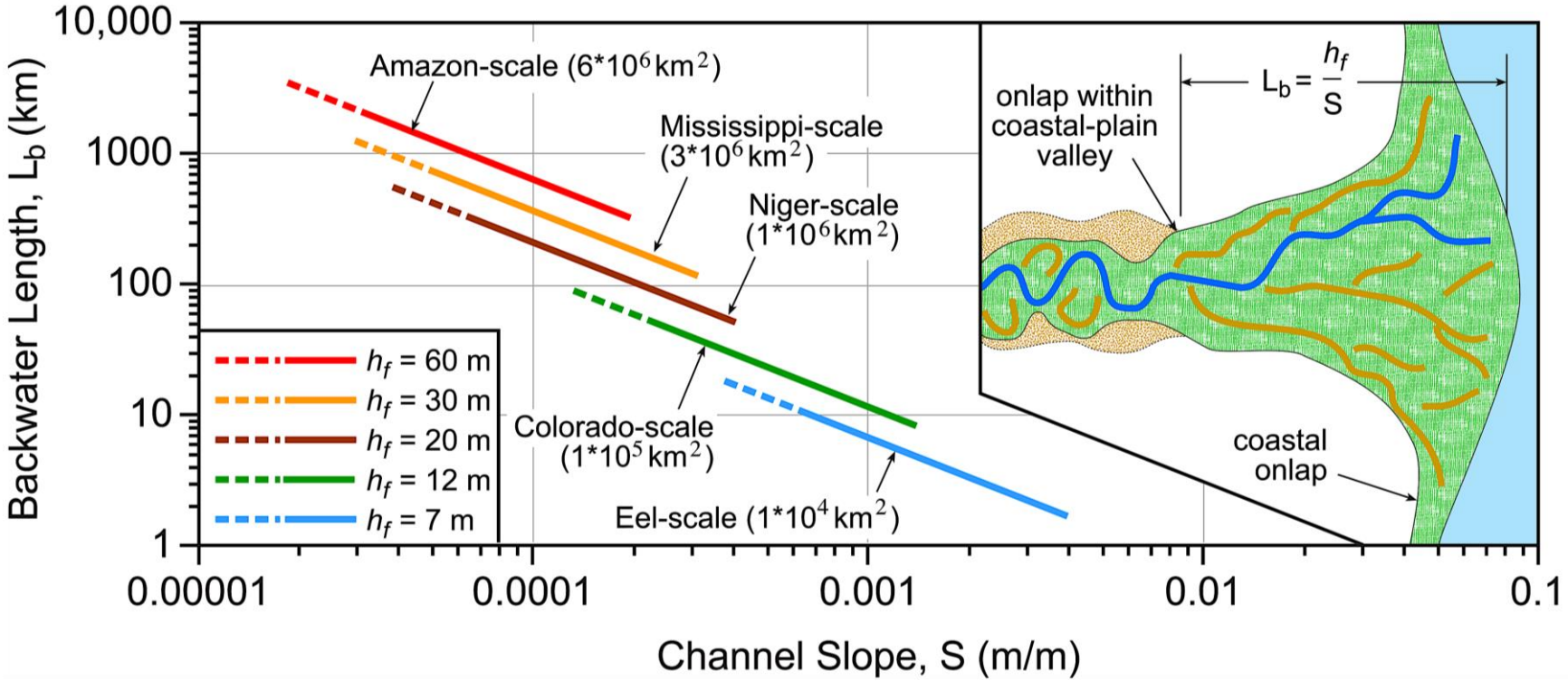
Backwater Length Scaling Relationships



after Blum et al. (2013)

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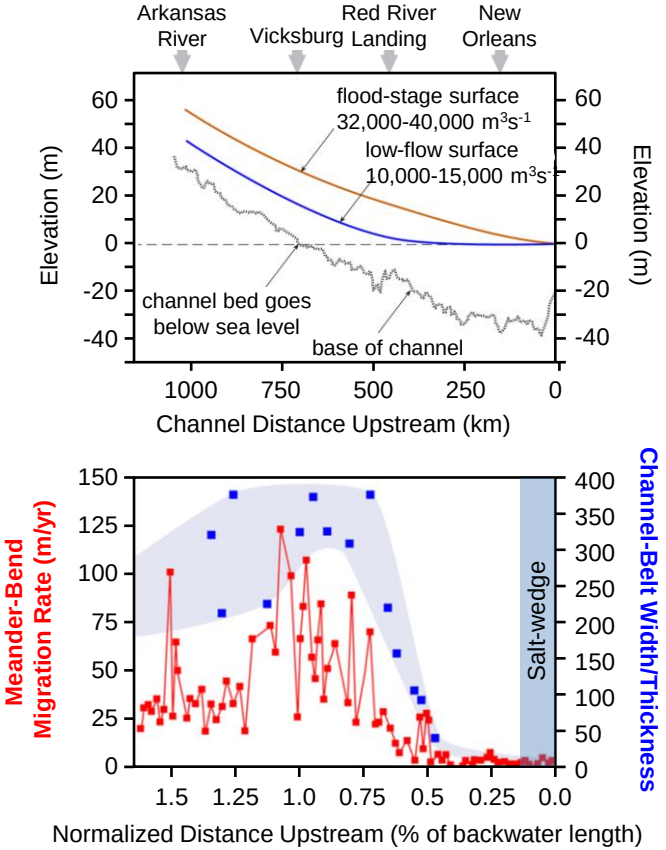
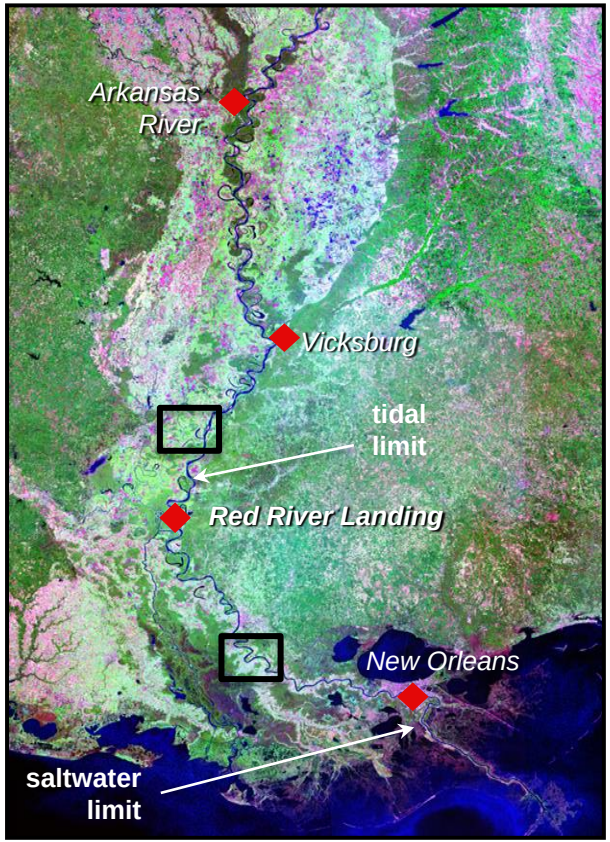
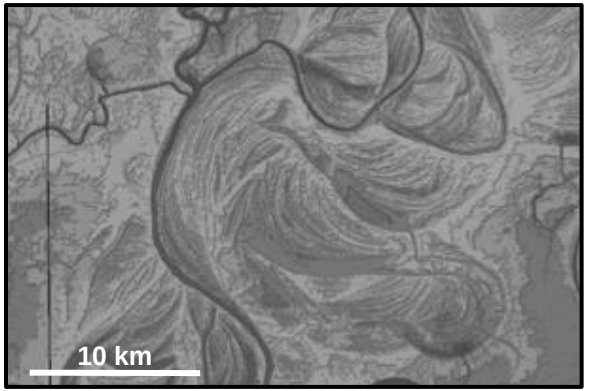
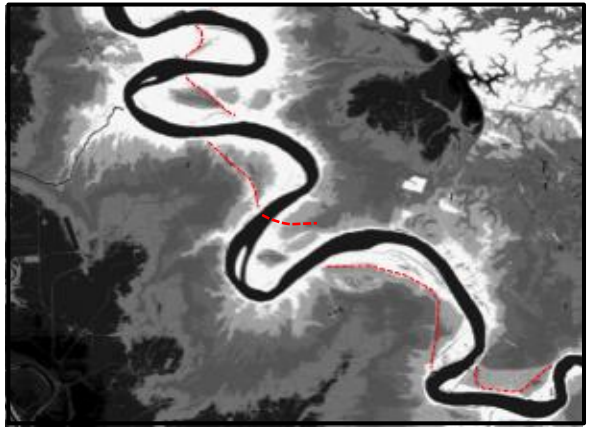
Backwater Effects on Channel-Belt Morphology and Scales









after Hudson and Kesel (2000), Nittrouer et al. (2011), Blum et al. (2013)

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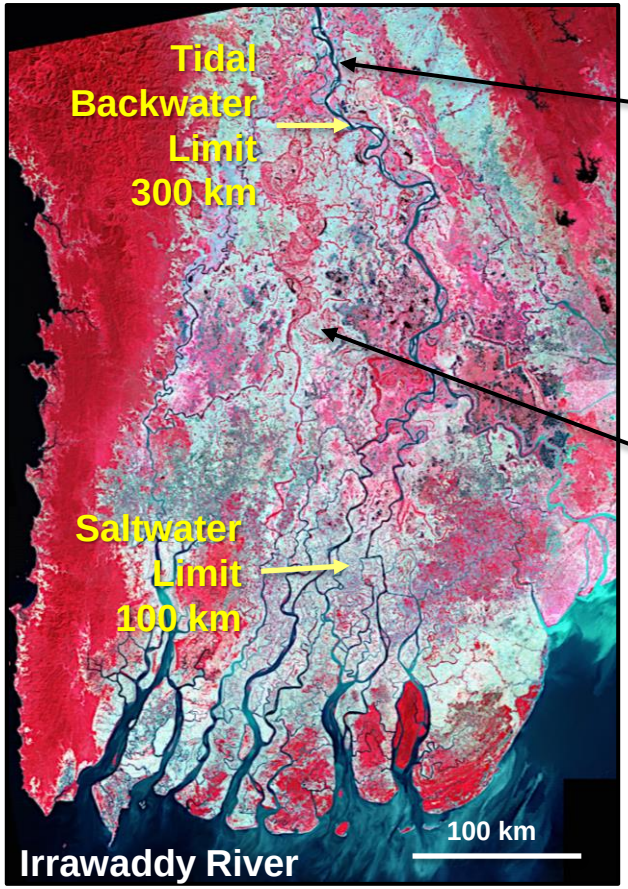
Downstream Transformations in a Macrotidal System



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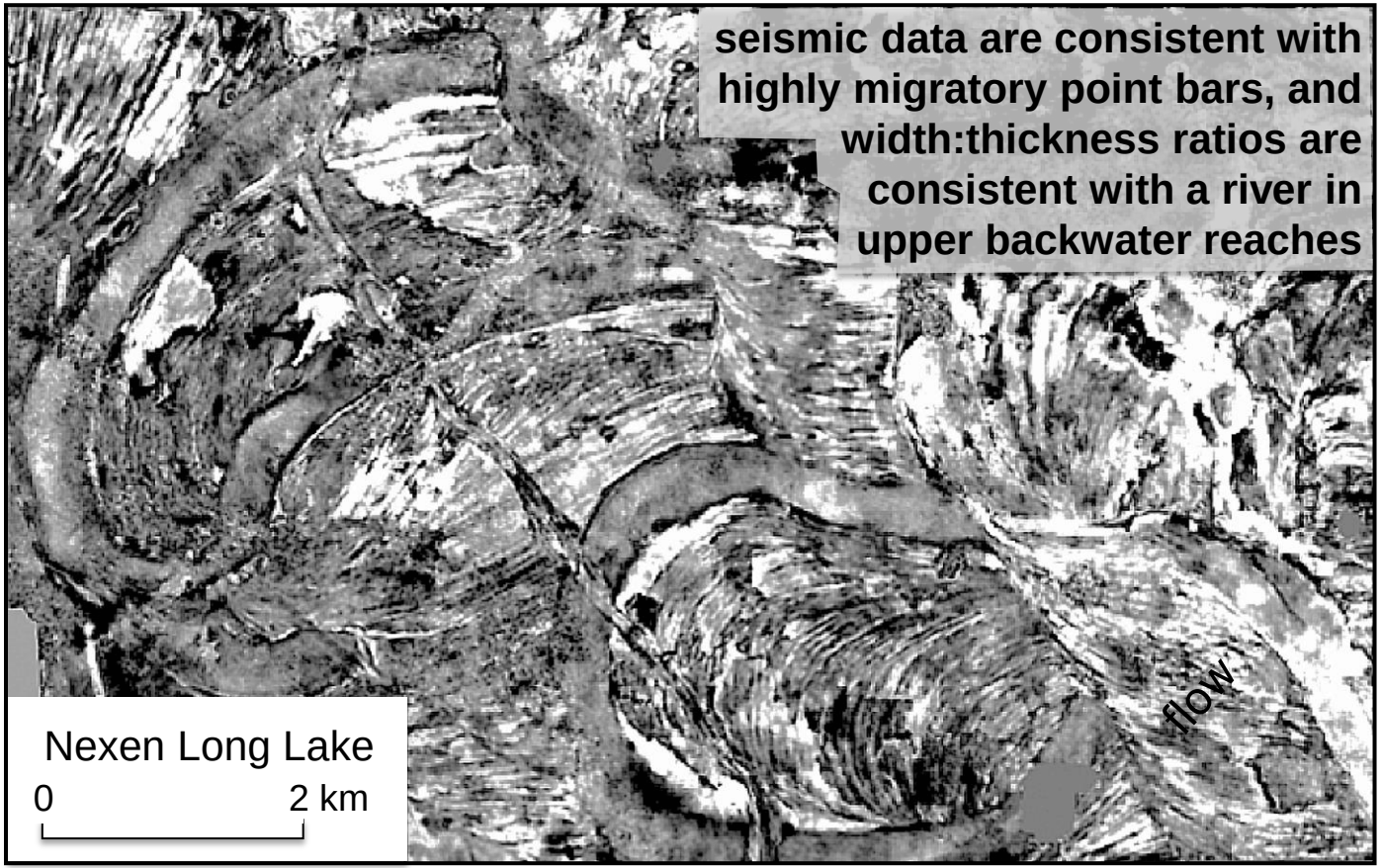
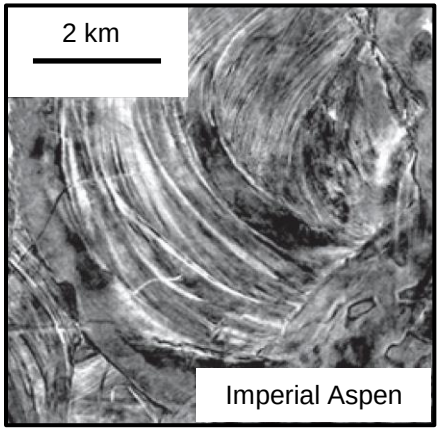
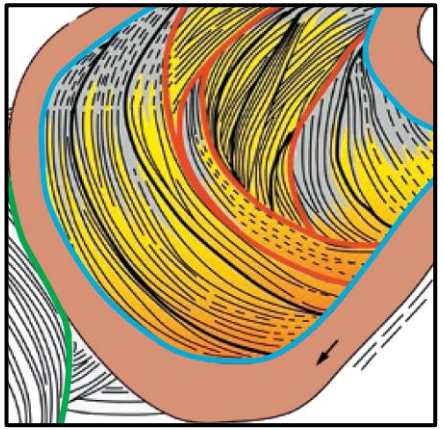
Seismic Data - Large Multi-Storey Amalgamated Point Bars



after Hubbard et al. (2012)





from Moreton and Carter (2015)

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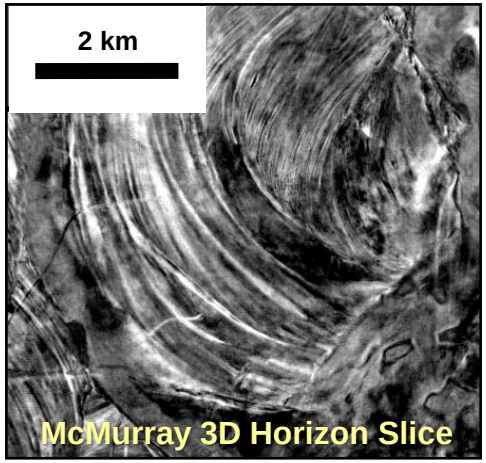
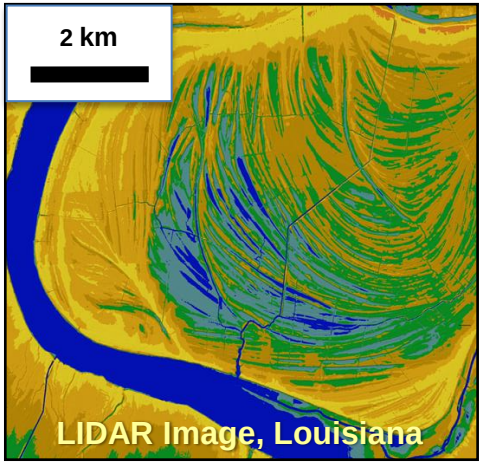
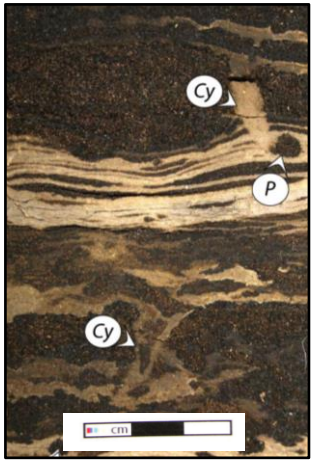
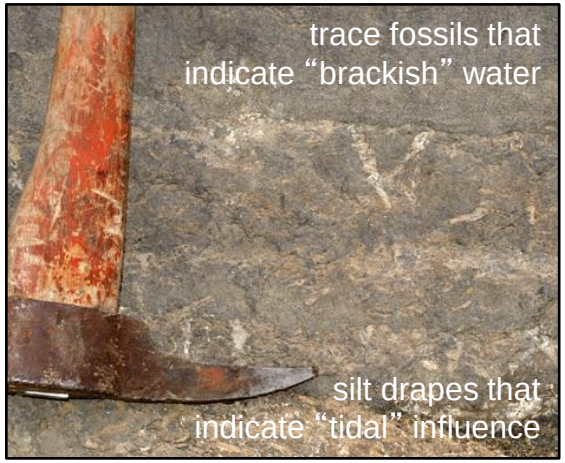
McMurray Channel-Belt Deposits – Conflicting Empirical Realities









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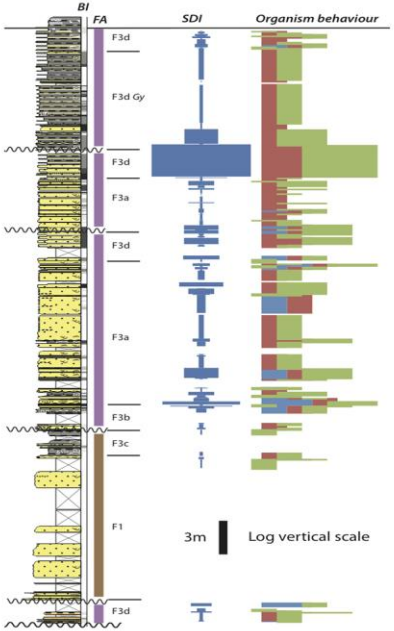
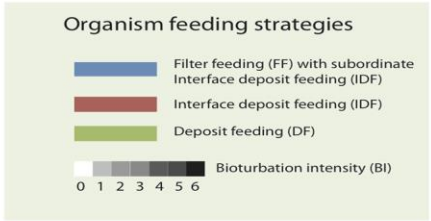
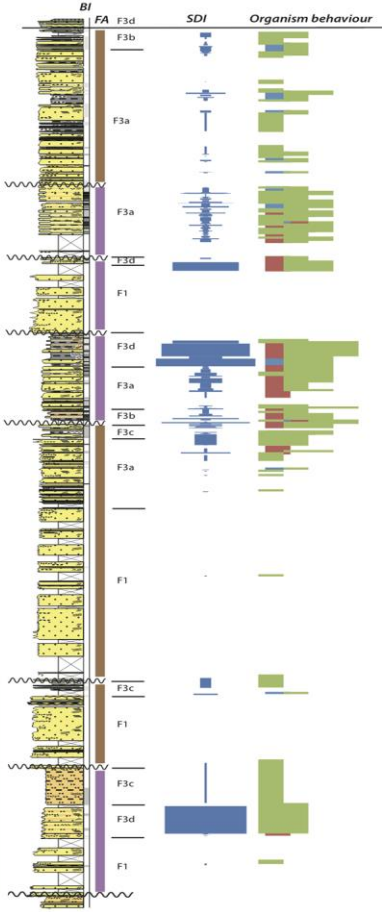
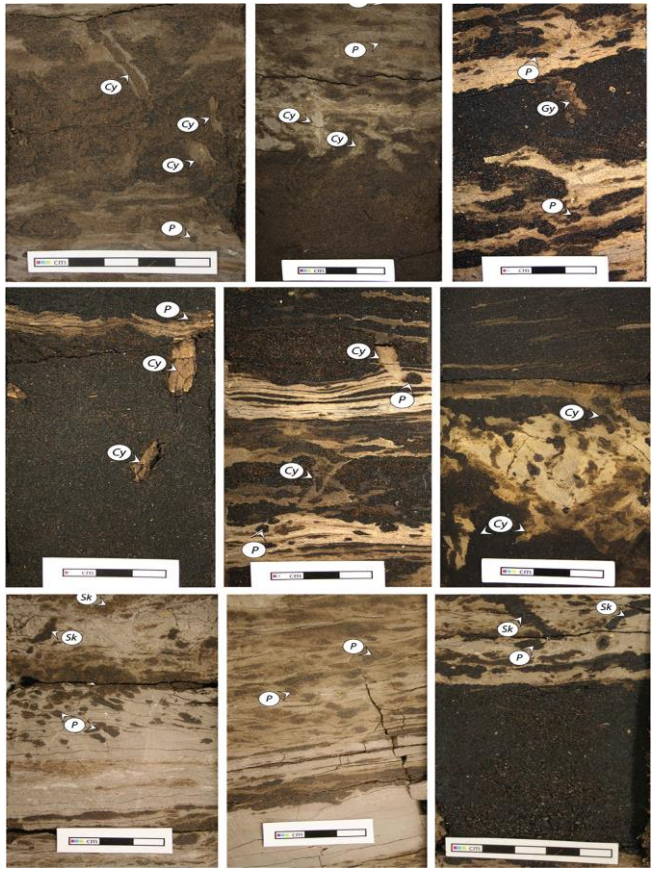
The Conundrum with Ubiquitous Trace Fossils…..







brackish trace fossils continuous through point-bar successions



Shchepetkina et al. (2016)

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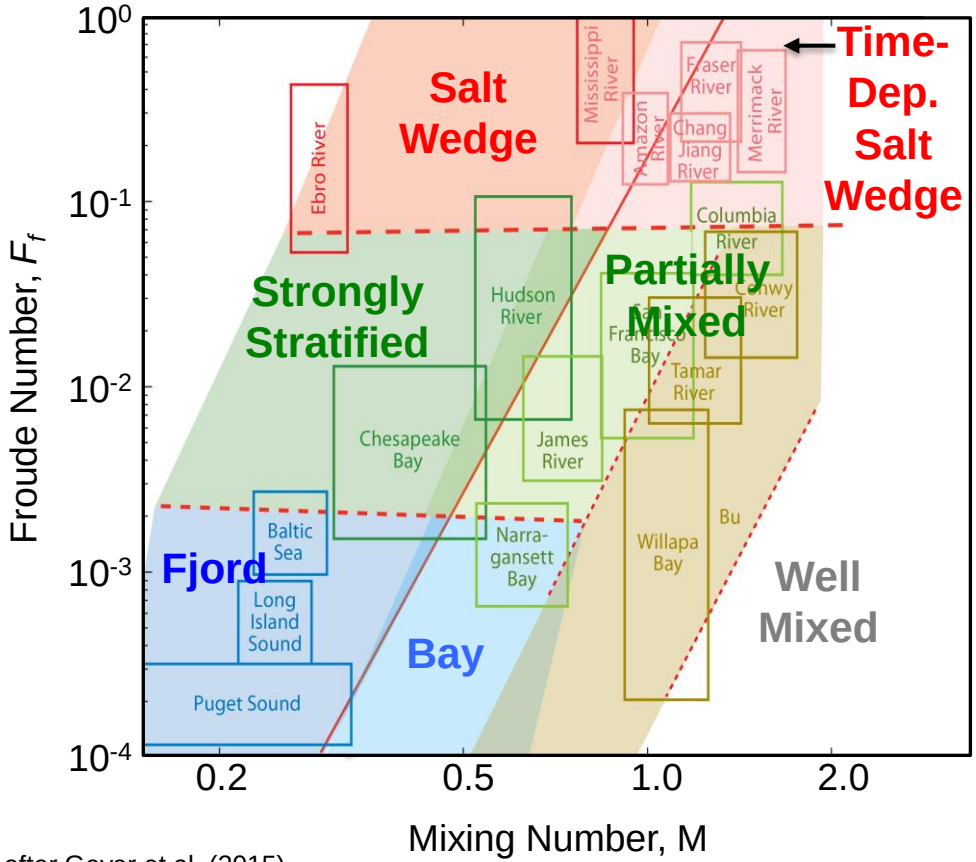
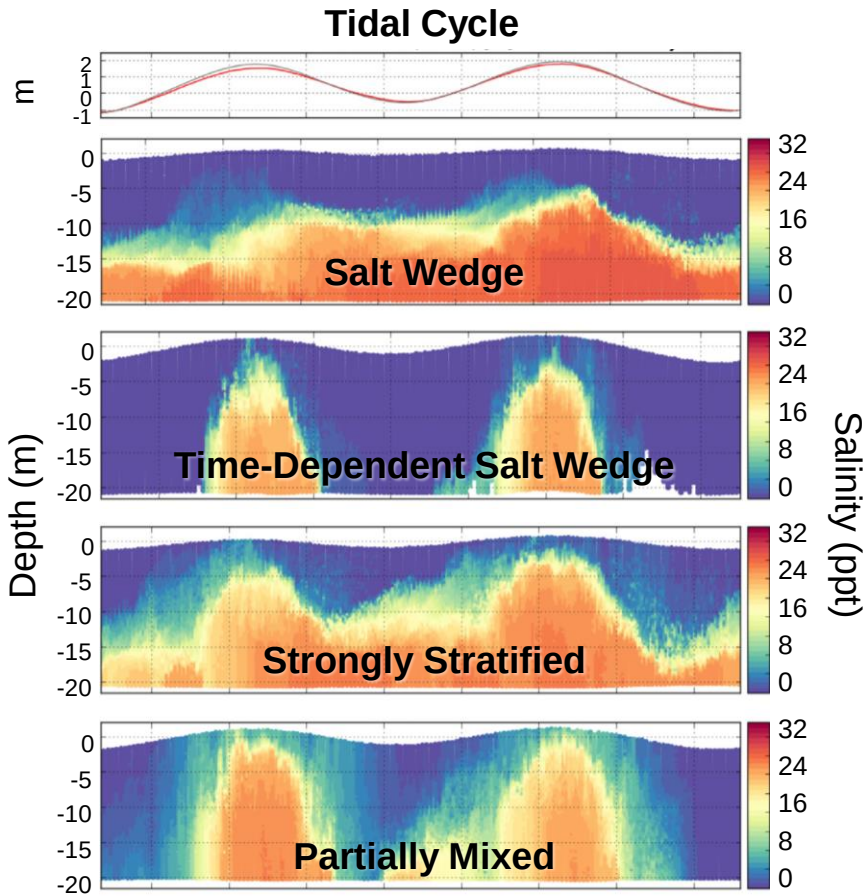
Estuarine Salt-Water Penetration Concepts



after Geyer et al. (2015)



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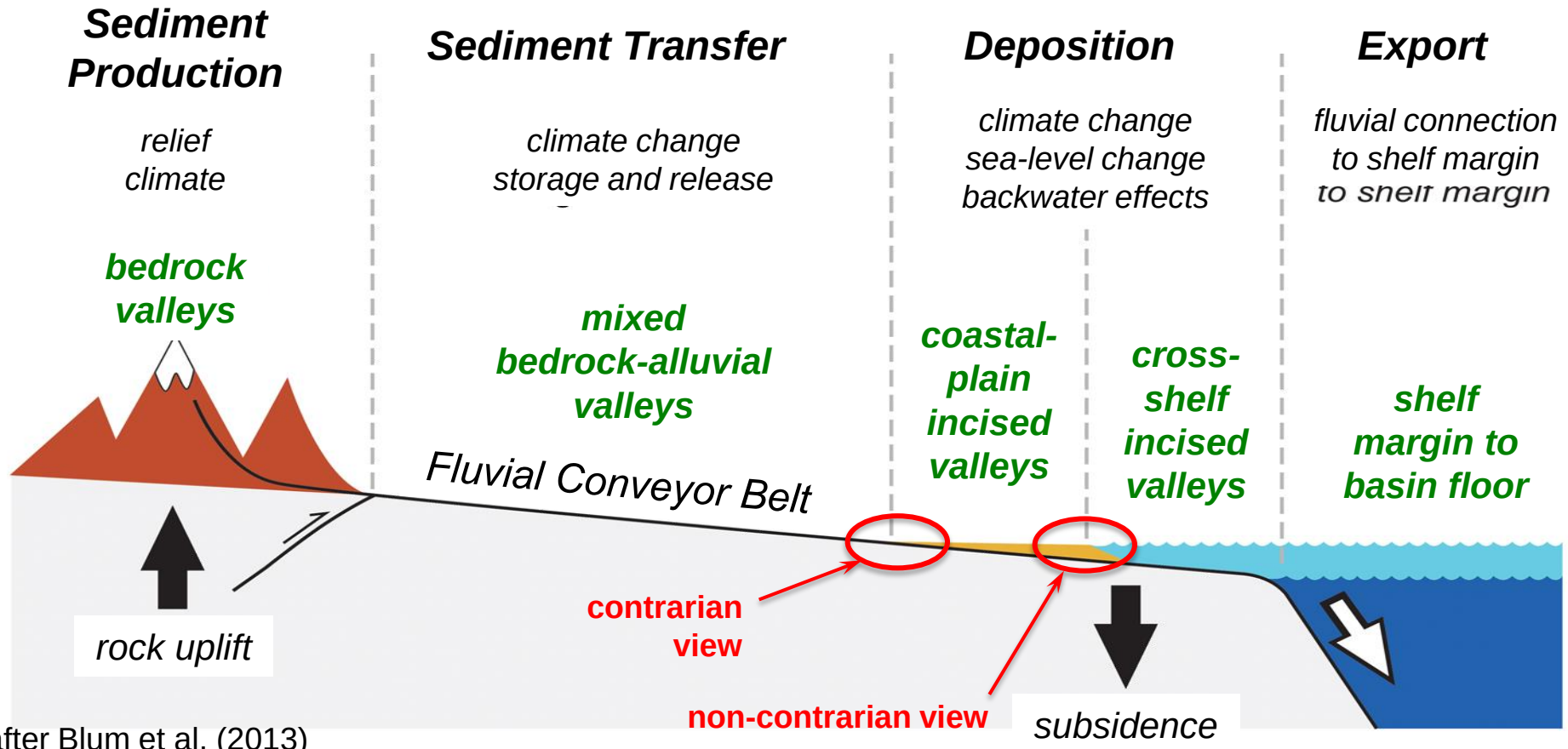
Types of Valleys – A Source-to-Sink View



after Blum et al. (2013)

Summary

- **The McMurray is a giant river from detrital zircons and point-bar scales**

- **The McMurray conundrum:**
  - **large laterally-amalgamated point bars extend upstream to downstream through the Assiniboia paleovalley for over >400 km**
  - **trace fossils that indicate brackish conditions are ubiquitous, even up to the top of the point bars**

- **The McMurray is a fully fluvial, highly migratory river with possible tidal influence ?**

- **The scale, distribution, and physical characteristics of the deposits are incompatible with brackish water influence associated with marine environments…….perhaps an outside-the-box explanation?**