# Paleodrainage and Sediment Routing for the Mannville Group, Eastern Margins of the Alberta Foreland Basin System*

**Mike Blum[1] and Deserae Jennings[1]**

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## Abstract

The Aptian McMurray Formation, eastern Alberta foreland basin, consists of basal fluvial deposits that become increasingly marine-influenced upwards. This presentation examines the McMurray drainage area and sediment-routing system within the context of the evolving foreland basin. Detrital zircon (DZ) data indicate the McMurray was the axial stream for a drainage sourced in the Appalachian Cordillera of the SE US through eastern Canada, which served as the divide between the Gulf of Mexico-Atlantic and the Boreal Sea. This continental-scale drainage, the Mississippi or Amazon of its time, was routed through the US midcontinent to the Assiniboia paleovalley, and was a contributive system, joined by shield-derived tributaries from the east, but remained separate from Western Cordillera-derived fluvial systems that dominate McMurray-equivalent strata in the foredeep farther west. The position of the McMurray axial drainage is consistent with the broad low-relief backbulge of the Cordilleran foreland basin, with the forebulge represented by the area of thin McMurray deposition to the west. The McMurray paleodrainage is interpreted to represent the last vestiges of continental-scale east-to-west sediment transfer that resulted from development of the Paleozoic Appalachian Cordillera along the eastern margin of North America. Prior to development of the Mesozoic Western Cordillera, this drainage routed sediments to the western North America passive margin, then, with development of eastward-propagating foreland flexural topography, the axial drainage was routed to the northwest Throughout this reconstructed drainage, Lower McMurray fluvial channel-belt sands rest on the sub-Cretaceous unconformity, which cuts sedimentary rocks of Jurassic to Devonian age. These relationships are consistent with what geomorphologists refer to as mixed bedrock-alluvial valleys. In the modern world, mixed bedrock-alluvial valleys (a) dominate the low-relief, erosional continental interiors, (b) require net rock uplift, (c) deepen and widen over long periods of time ($\gg 10^6$ yrs) by lateral migration and channel-belt deposition, punctuated by periods of bedrock valley incision and terrace formation, and (d) are contributory. One possible interpretation would be that plate-scale geodynamic processes drove net rock uplift and bedrock incision throughout the drainage basin, while the superimposed, eastward-propagating flexural signal steered drainage to the north and the Boreal Sea.

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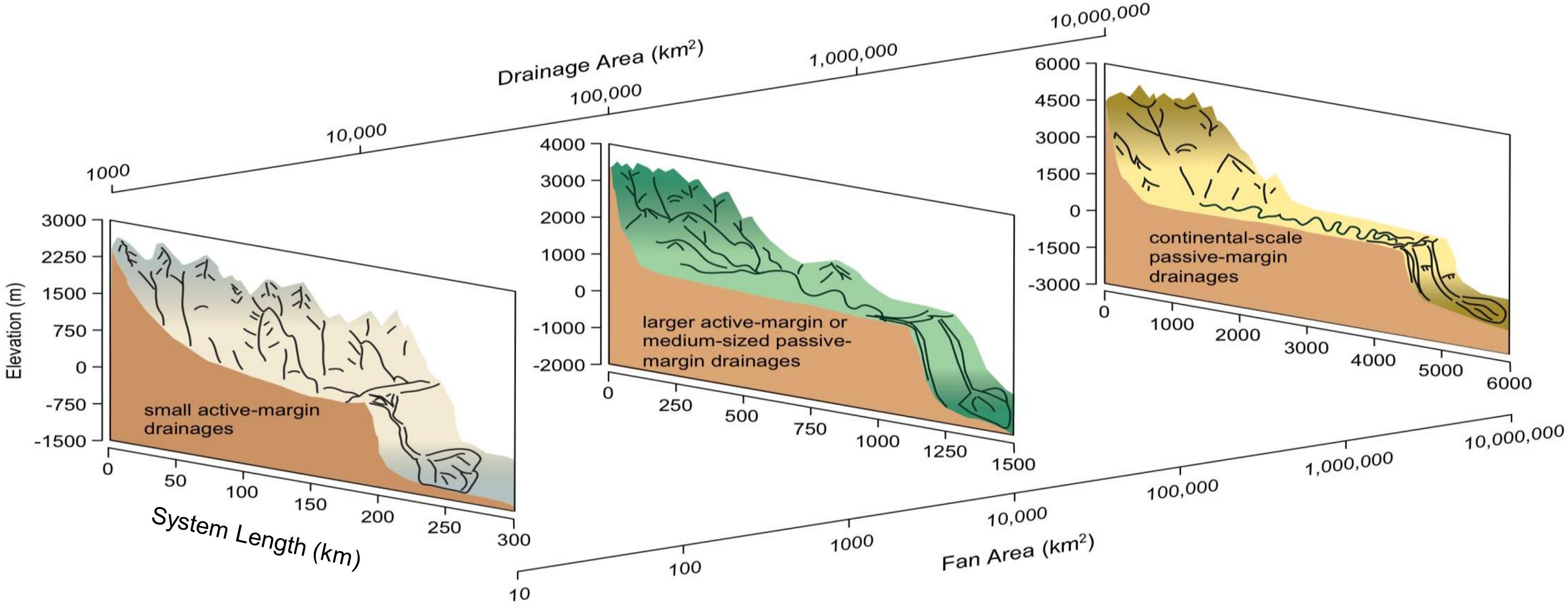
*The University of Kansas*
*Lawrence, Kansas USA*

Special thanks to ExxonMobil Upstream Research and Imperial Oil for supporting this research and releasing DZ data, and to Mark Pecha and the University of Arizona Laerchron Center for conducting U-Pb dating

# General Outline

- *Mannville Group, Western Canada Sedimentary System*
- *McMurray/Mannville Paleodrainage Reconstructions*
    - *A Continental-Scale River from Point-Bar Scales*
    - *A Continental-Scale River from Detrital Zircons*
- *Mannville Geochronology from Detrital Zircons*
- *The McMurray as a Mixed Bedrock-Alluvial Valley System*

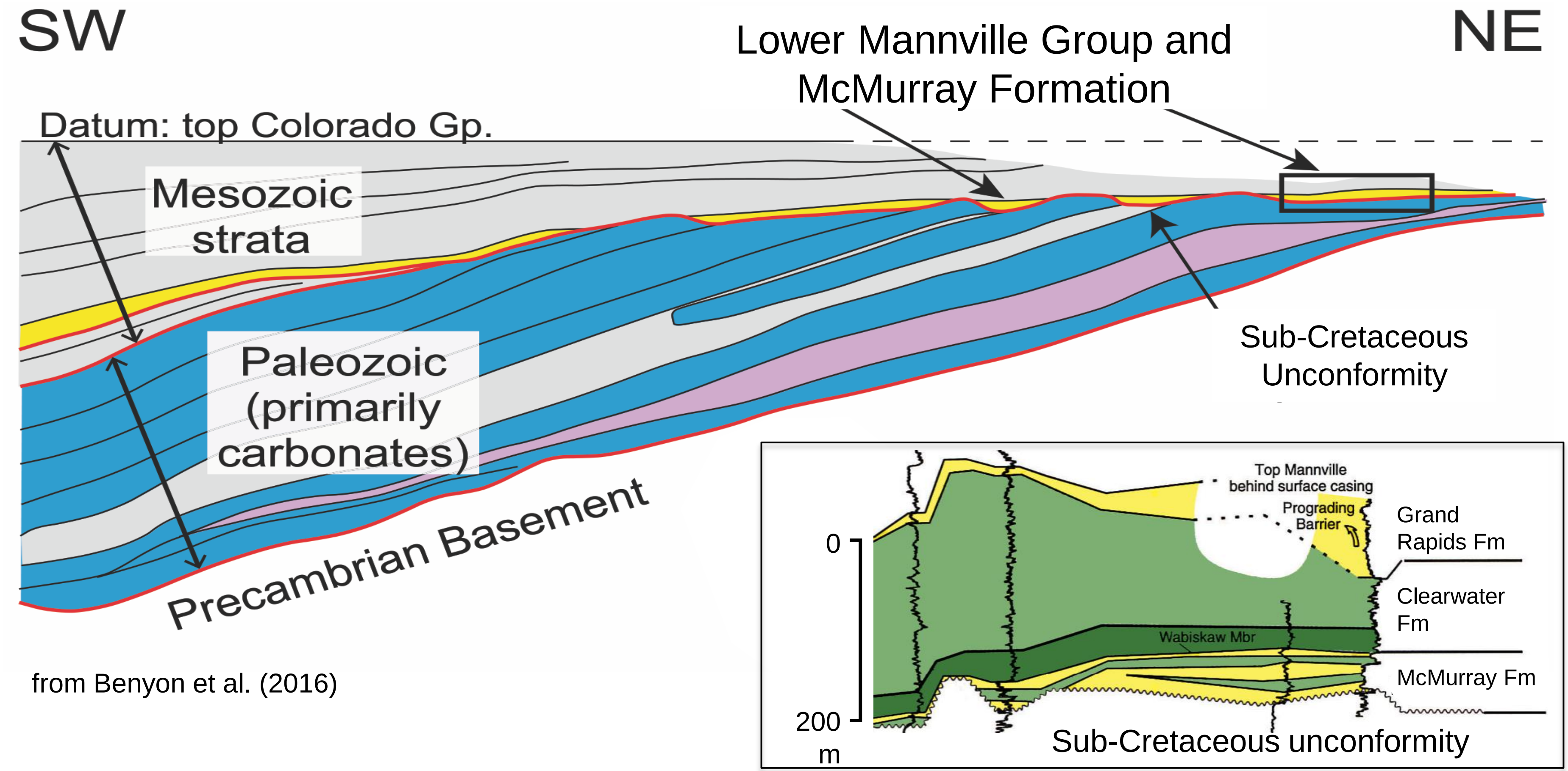
# SOURCE-TO-SINK SCALING RELATIONSHIPS




| | **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 |

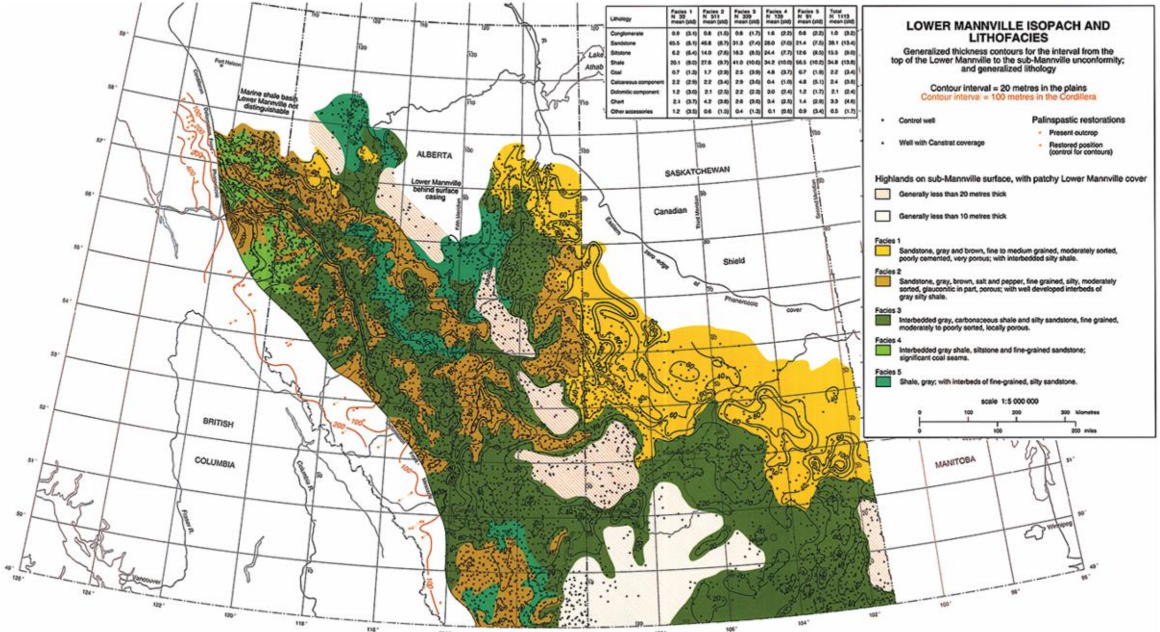
after Somme et al. (2009) and Blum et al. (2013)

# WCSB STRATIGRAPHIC FRAMEWORK




from Benyon et al. (2016)

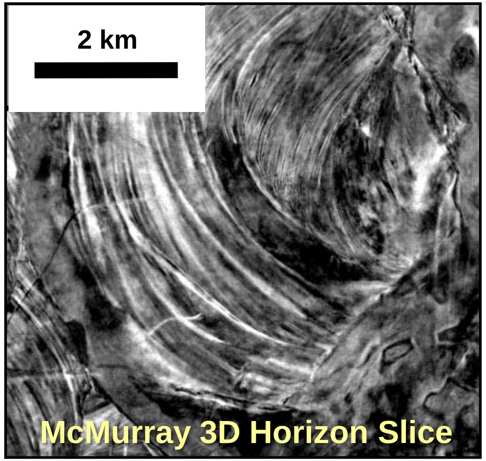
# MCMURRAY DISTRIBUTION AND THICKNESS



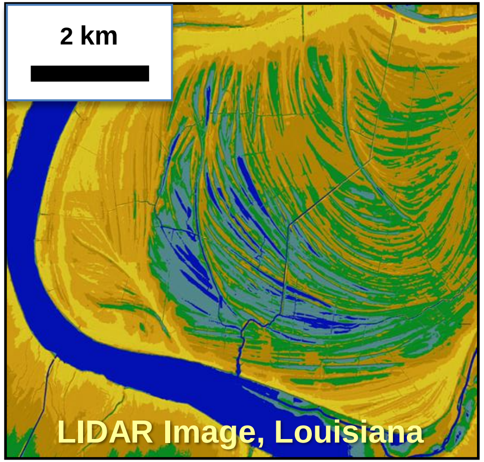

| Lithology | Facies 1 N 33 mean (std) | Facies 2 N 511 mean (std) | Facies 3 N 339 mean (std) | Facies 4 N 139 mean (std) | Facies 5 N 91 mean (std) | Total N 1113 mean (std) |
|---|---|---|---|---|---|---|
| Conglomerate | 0.9 (3.1) | 0.8 (1.5) | 0.8 (1.7) | 1.6 (2.2) | 0.6 (2.2) | 1.0 (3.2) |
| Sandstone | 65.5 (8.1) | 46.8 (8.7) | 31.3 (7.4) | 28.0 (7.0) | 21.4 (7.5) | 38.1 (13.4) |
| Siltstone | 6.2 (6.4) | 14.0 (7.6) | 16.3 (8.5) | 24.4 (7.7) | 12.6 (8.5) | 15.5 (9.0) |
| Shale | 20.1 (8.0) | 27.6 (9.7) | 41.0 (10.6) | 34.2 (10.0) | 56.5 (10.2) | 34.8 (13.8) |
| Coal | 0.7 (1.3) | 1.7 (2.9) | 2.5 (3.9) | 4.8 (3.7) | 0.7 (1.9) | 2.2 (3.4) |
| Calcareous component | 2.2 (2.9) | 2.2 (3.4) | 2.9 (3.6) | 0.4 (1.0) | 4.8 (5.1) | 2.4 (3.6) |
| Dolomitic component | 1.2 (3.0) | 2.1 (2.5) | 2.2 (2.3) | 3.0 (2.4) | 1.2 (1.7) | 2.1 (2.4) |
| Chert | 2.1 (3.7) | 4.2 (3.8) | 2.6 (3.6) | 3.4 (2.5) | 1.4 (2.9) | 3.3 (4.6) |
| Other accessories | 1.2 (3.5) | 0.6 (1.5) | 0.4 (1.3) | 0.1 (0.6) | 0.9 (3.4) | 0.5 (1.7) |

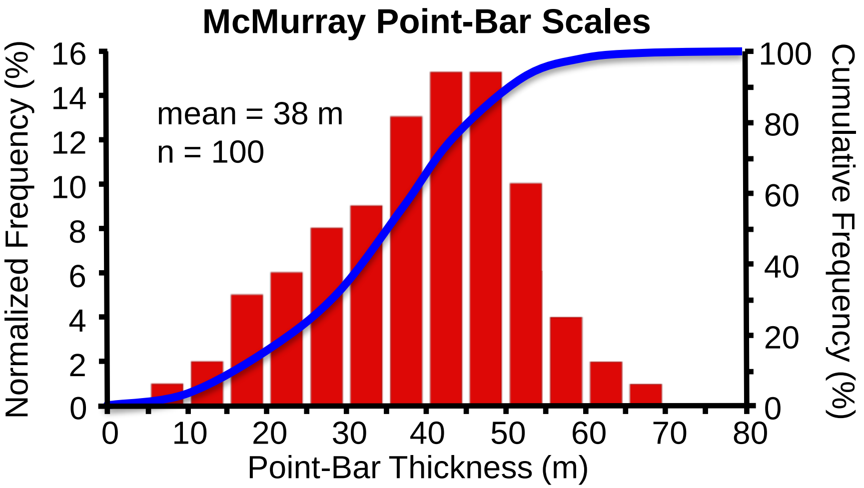
Presenter's notes: Broader context for study. Previous mapping in the Western Canada Atlas shows a primary sand fairway that connects the Lower Mannville (McMurray) in Cold Lake and Athabasca Oil Sands areas, and which is separated from the bulk of Lower Mannville by a zone stratal thicknesses are significantly less

# A CONTINENTAL-SCALE RIVER SYSTEM



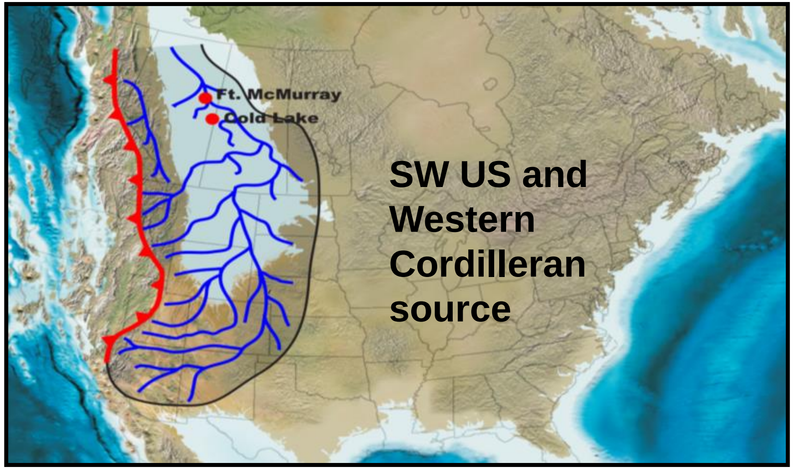

After Moreton and Carter (2015)

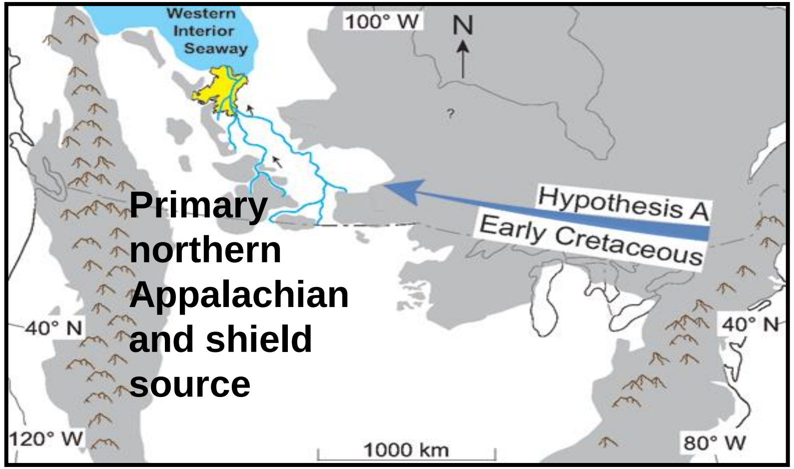



# MCMURRAY PALEODRAINAGE (1970s through 2014)

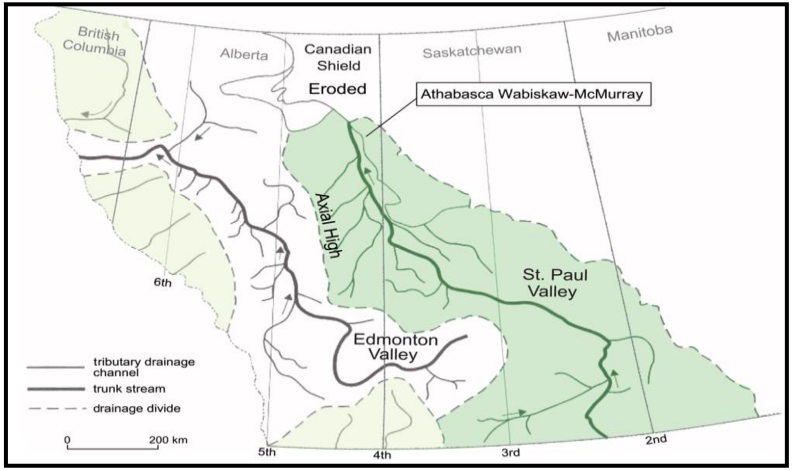
based on Christopher (1980, 1984), McGookey (1976) and Young (1970)

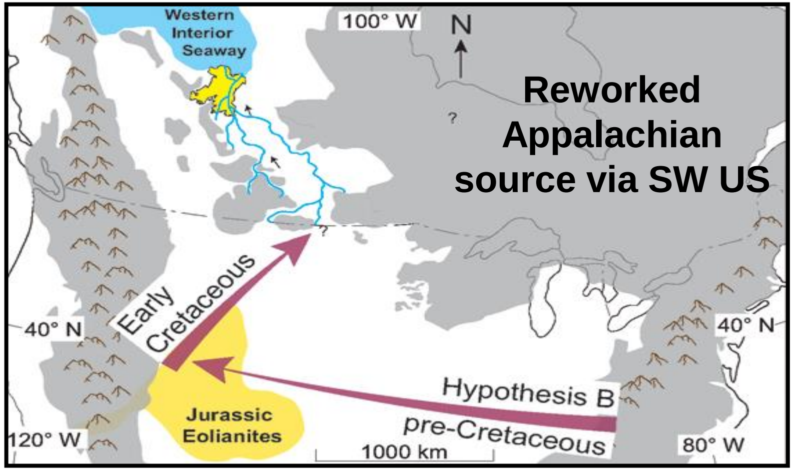


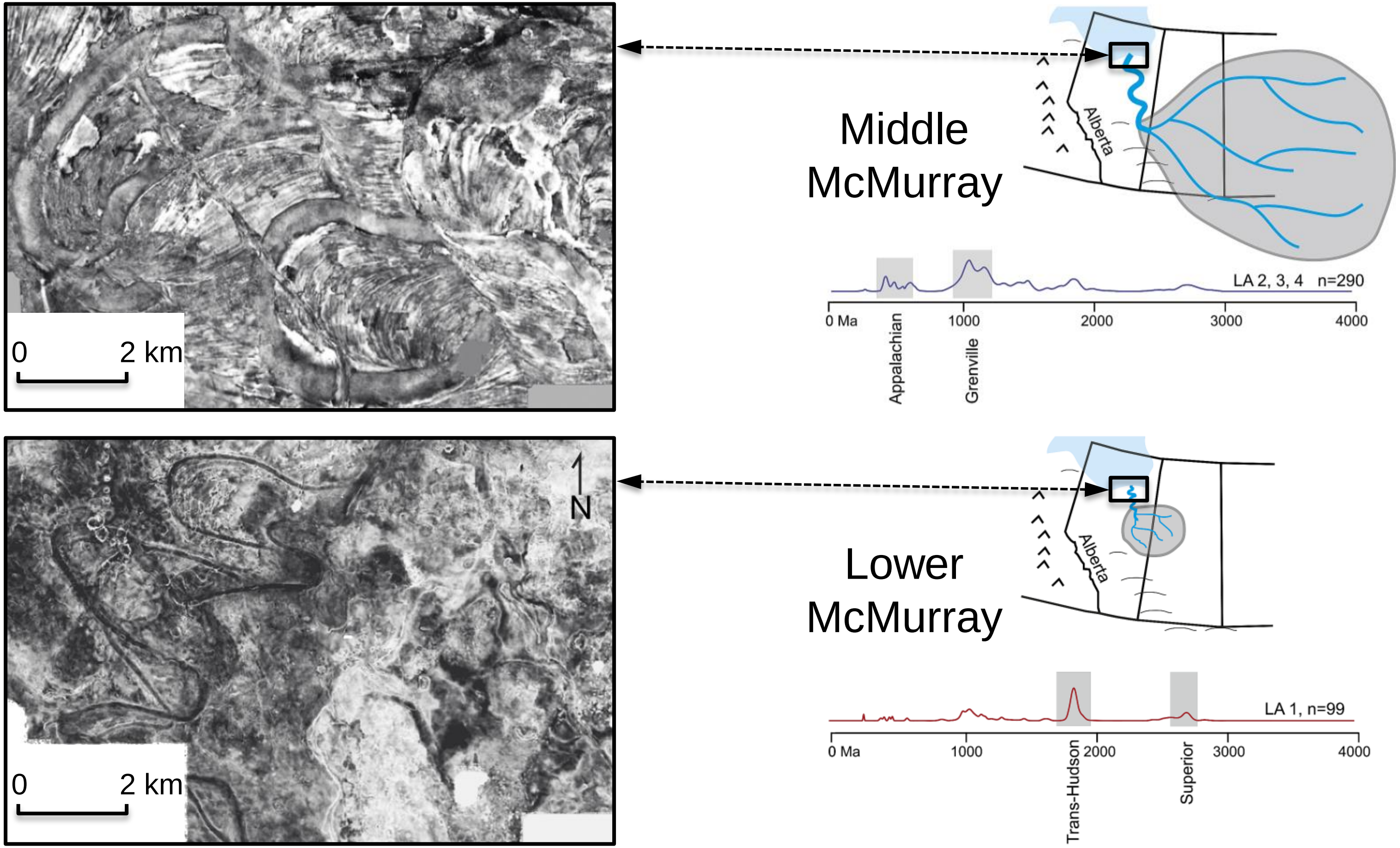

after Benyon et al. (2014)

after Hein et al. (2012)



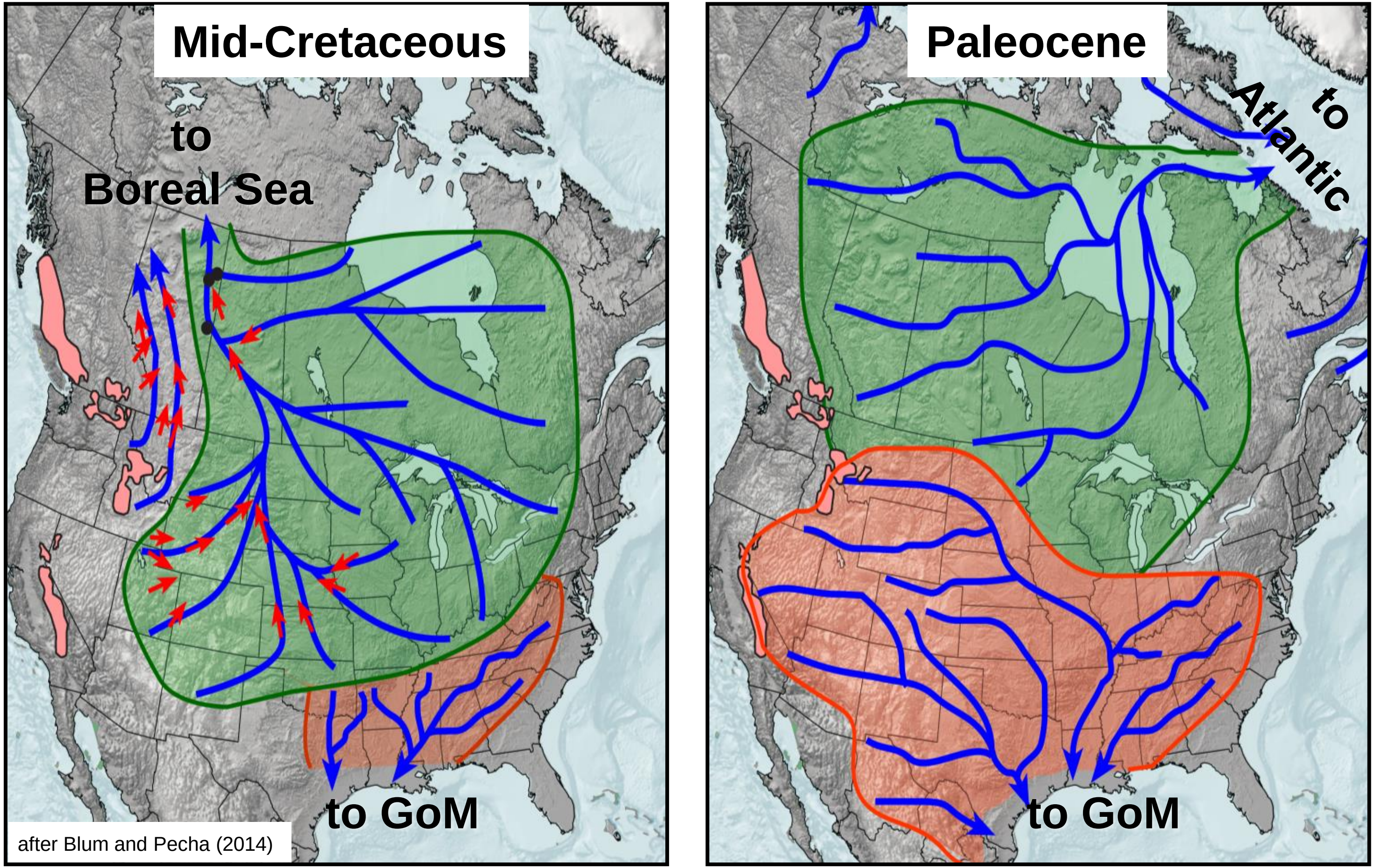



# MCMURRAY PALEODRAINAGE – RECENT WORK



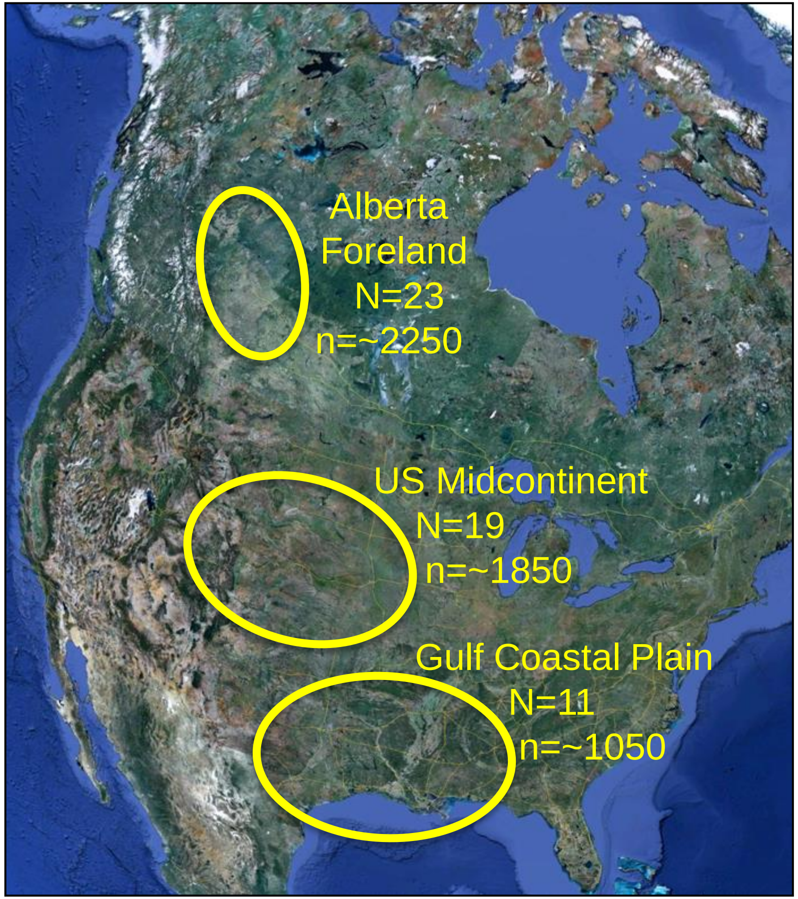

after Benyon et al. (2016)

# CONTINENTAL-SCALE DRAINAGE REORGANIZATION

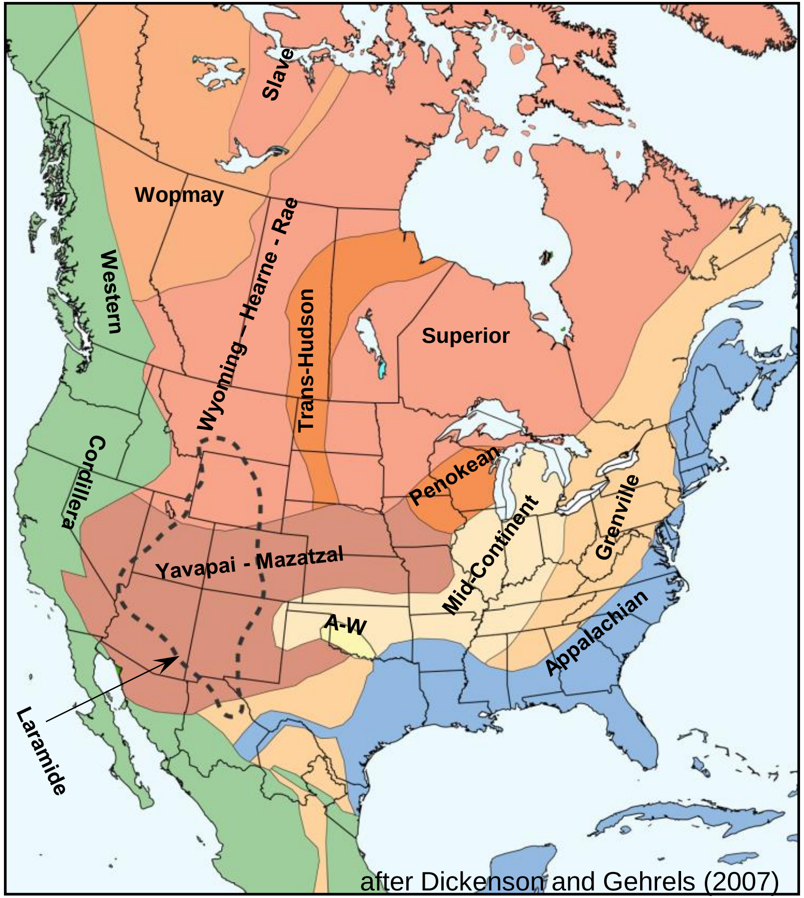


# PALEODRAINAGE RECONSTRUCTION PROJECT

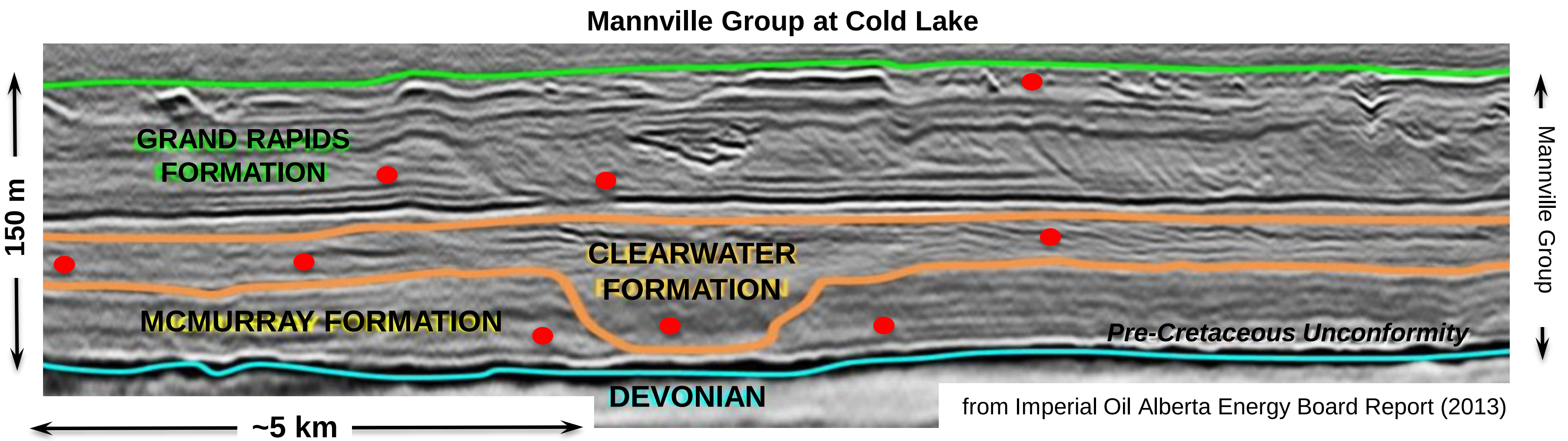
## Study Areas

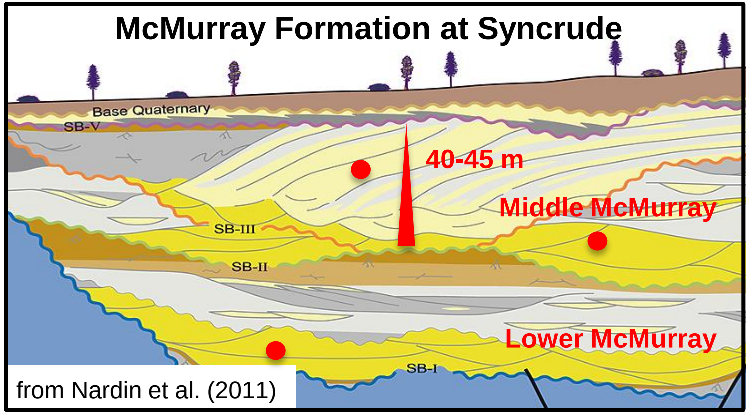


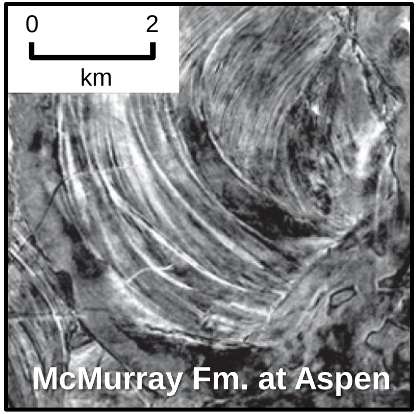

## North American DZ Source Terrains

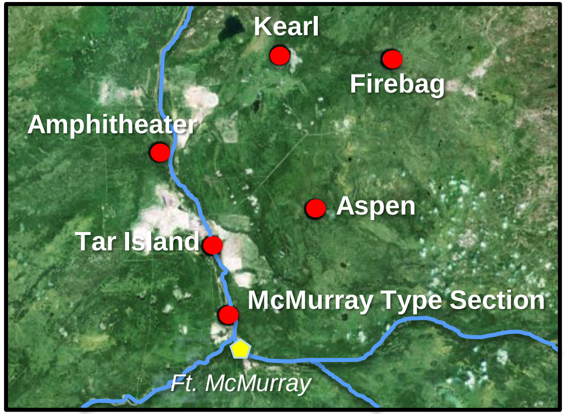


# MANNVILLE DETRITAL ZIRCON SAMPLES

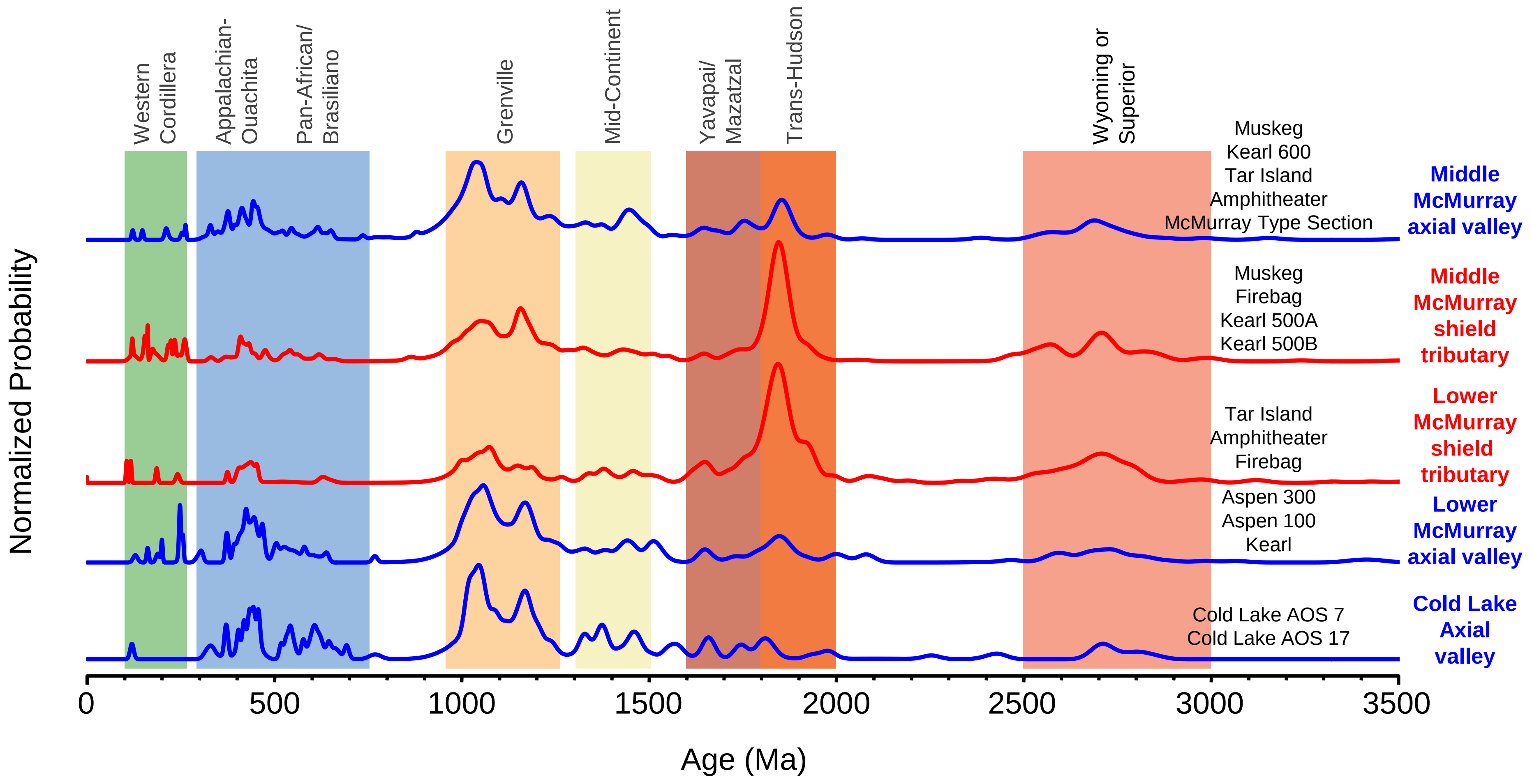


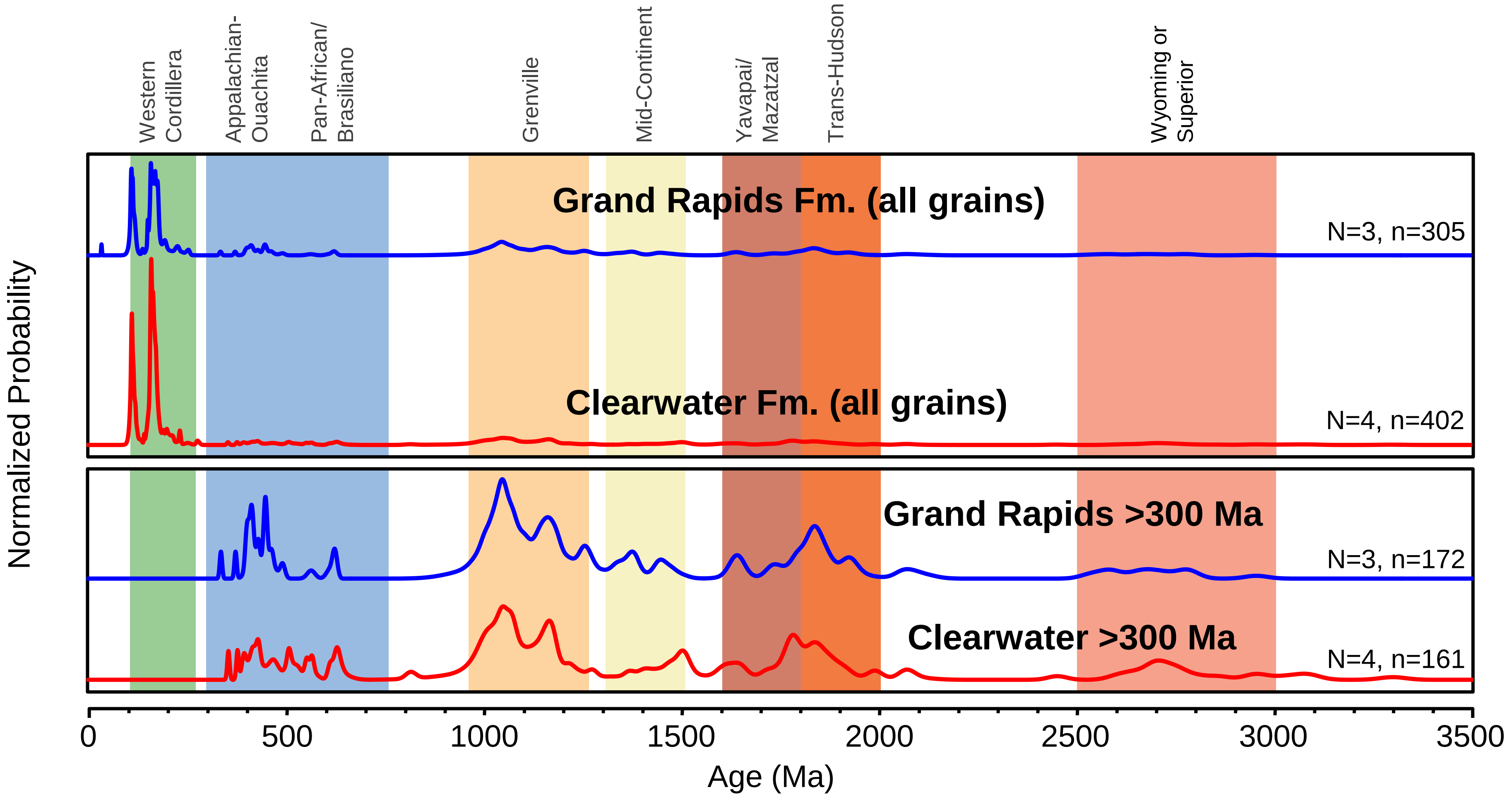



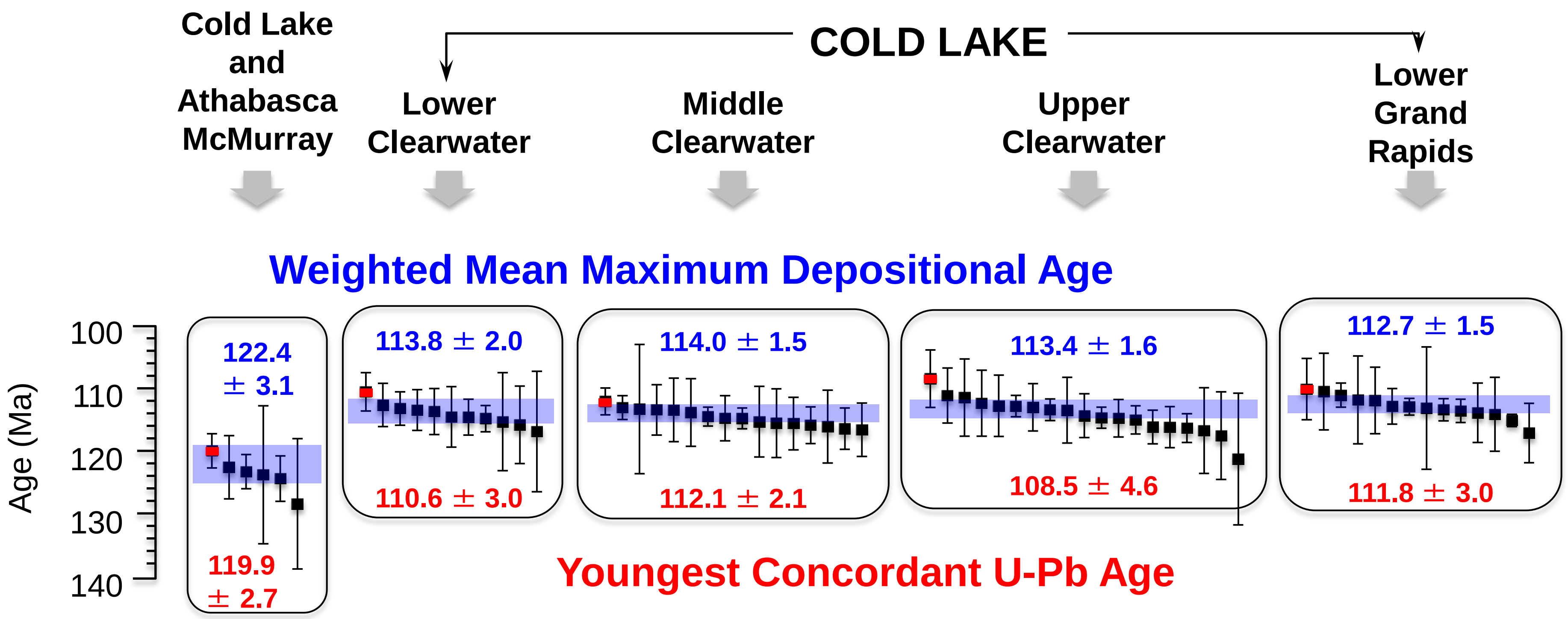
# DZ SIGNATURE – APTIAN MCMURRAY FM.



# DZ SIGNATURE - ALBIAN UPPER MANNVILLE



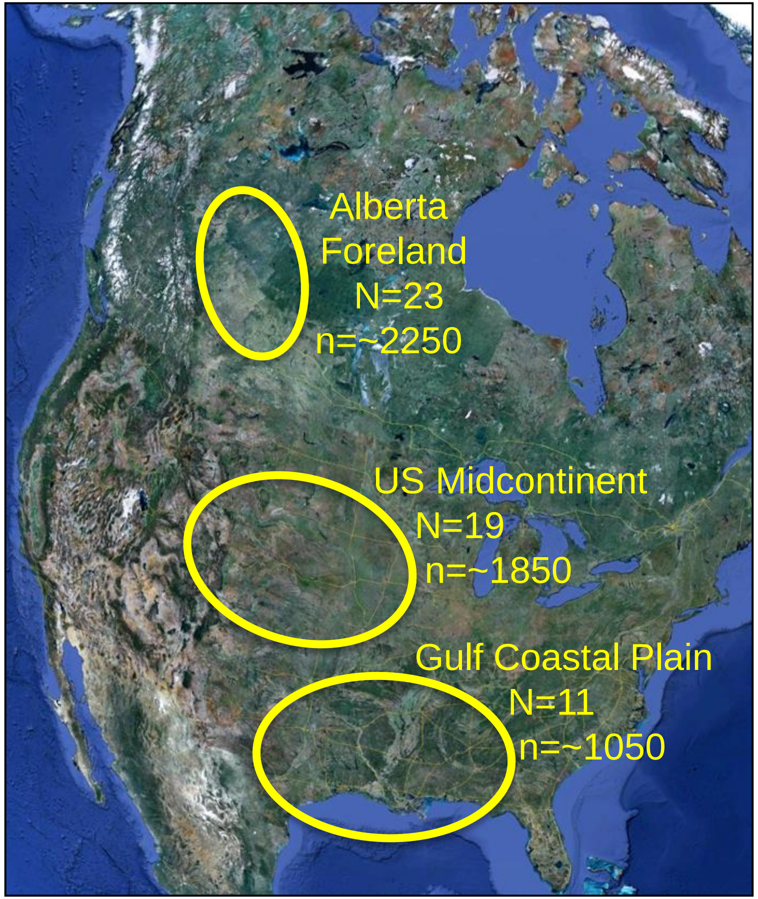
# U-PB DETRITAL-ZIRCON GEOCHRONOLOGY



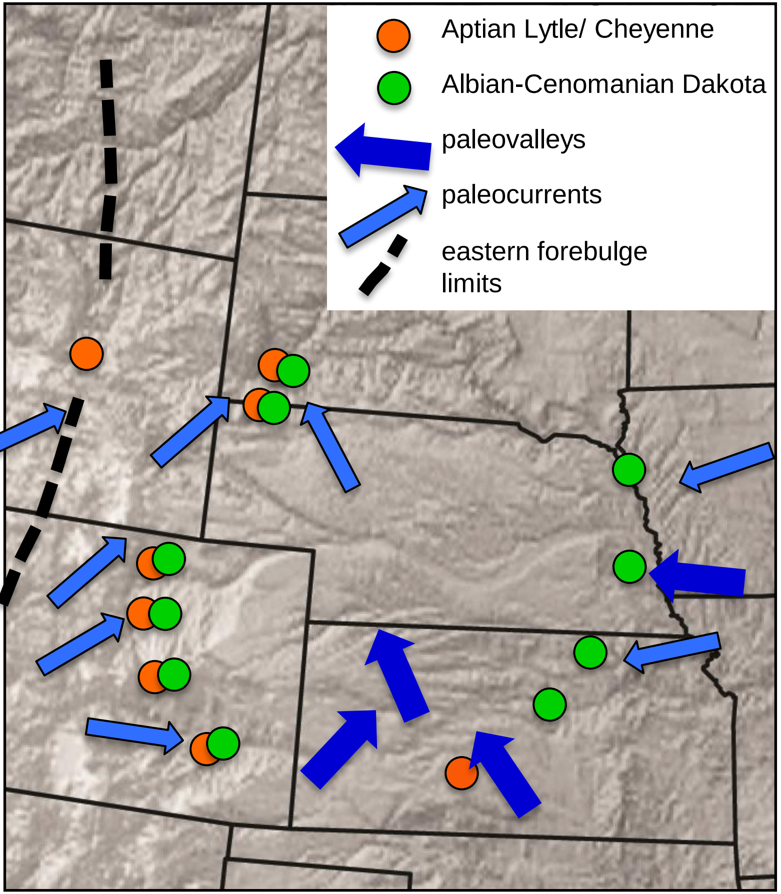

note – A single U-Pb age of 117.6 ± 8.8 Ma was reported from the lower McMurray in Benyon et al. (2016)

# EARLY CRETACEOUS MIDCONTINENT DRAINAGE

Study Areas

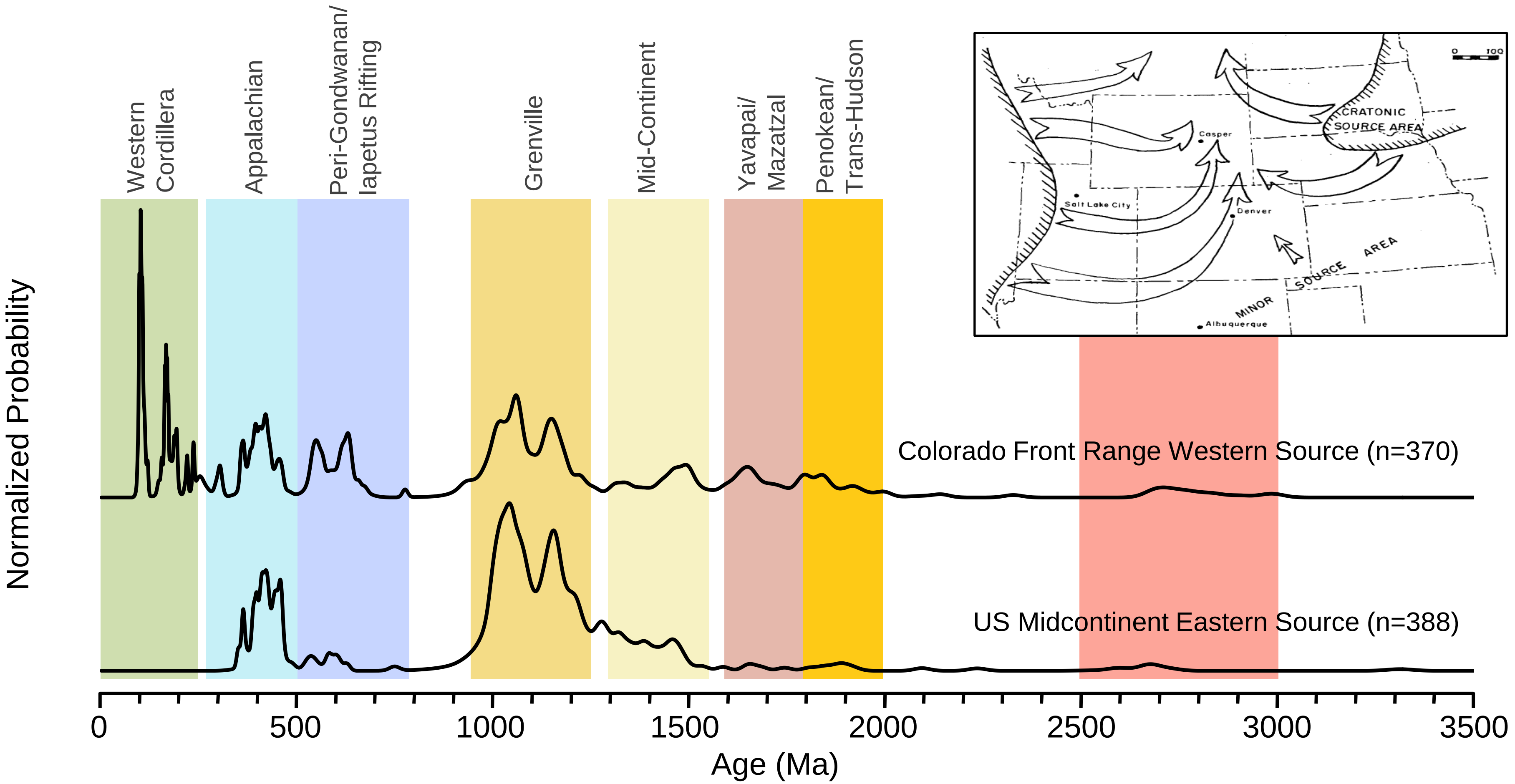



DZ Samples

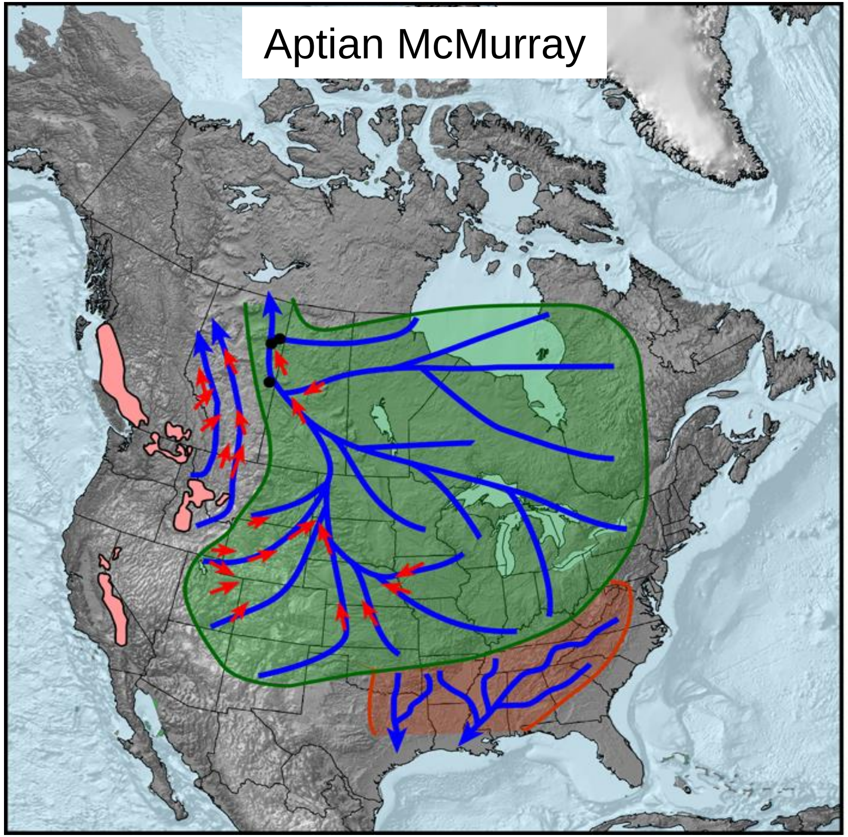



forebulge after Currie (2002), paleocurrents/paleoflow after Leier et al (2012), Willis (1993), Brenner et al. (2003), Joeckel et al. (2005), Merriam (1962)

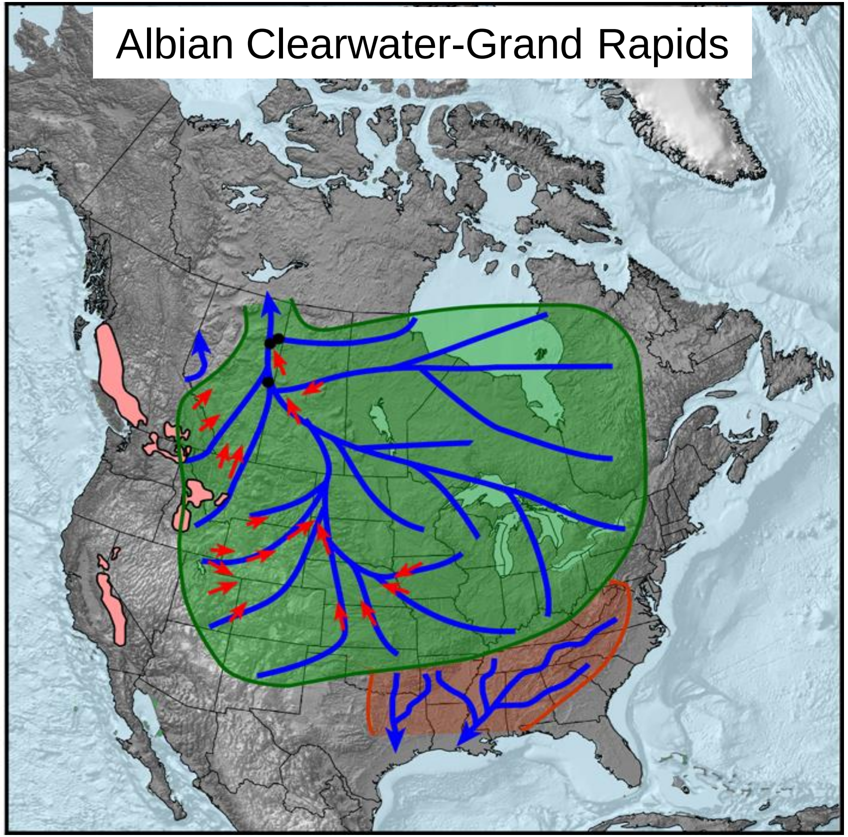
# US MIDCONTINENT DZ SIGNATURES



# PALEODRAINAGE RECONSTRUCTION FROM DZS



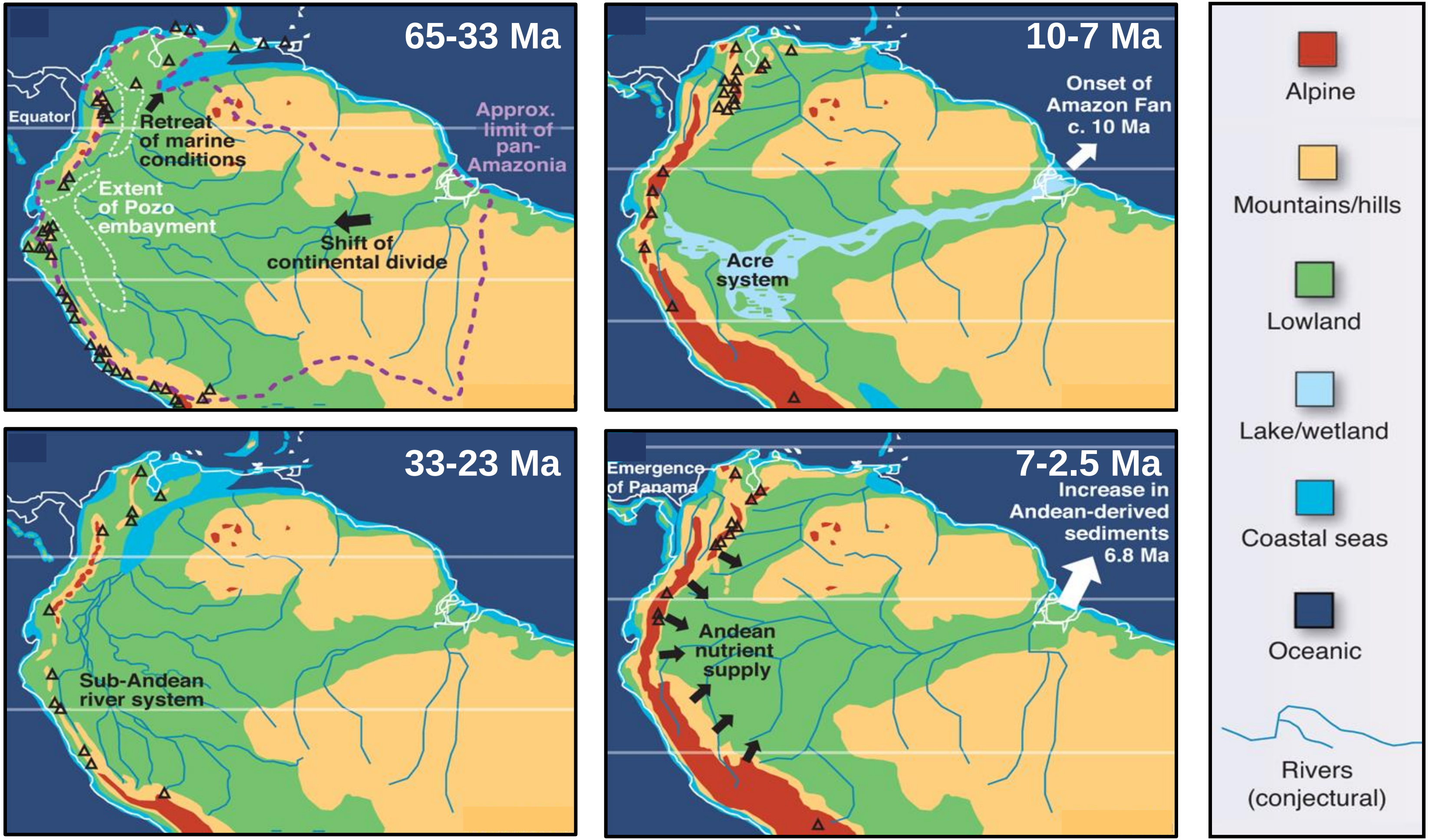

- Primary SE US Appalachian source
- Tributaries from the Canadian Shield, and the SW US




- Primary SE US Appalachian source
- Tributaries from the Canadian Shield and the SW US
- New tributaries from the NW US and SW Canada

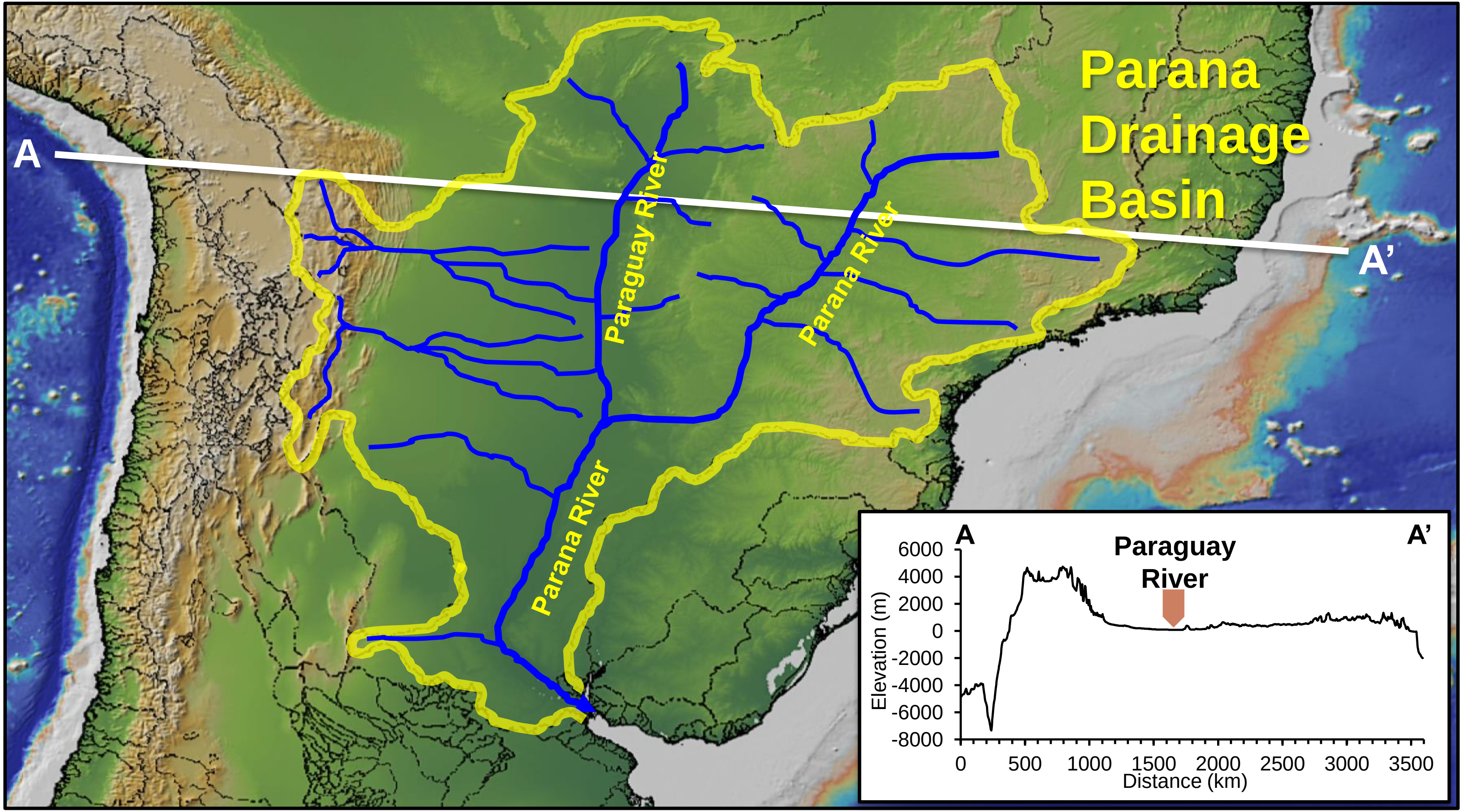
after Blum and Pecha (2014) and unpublished

# FOREL AND STEERING OF DRAINAGE?




after Hoorn et al. (2010)

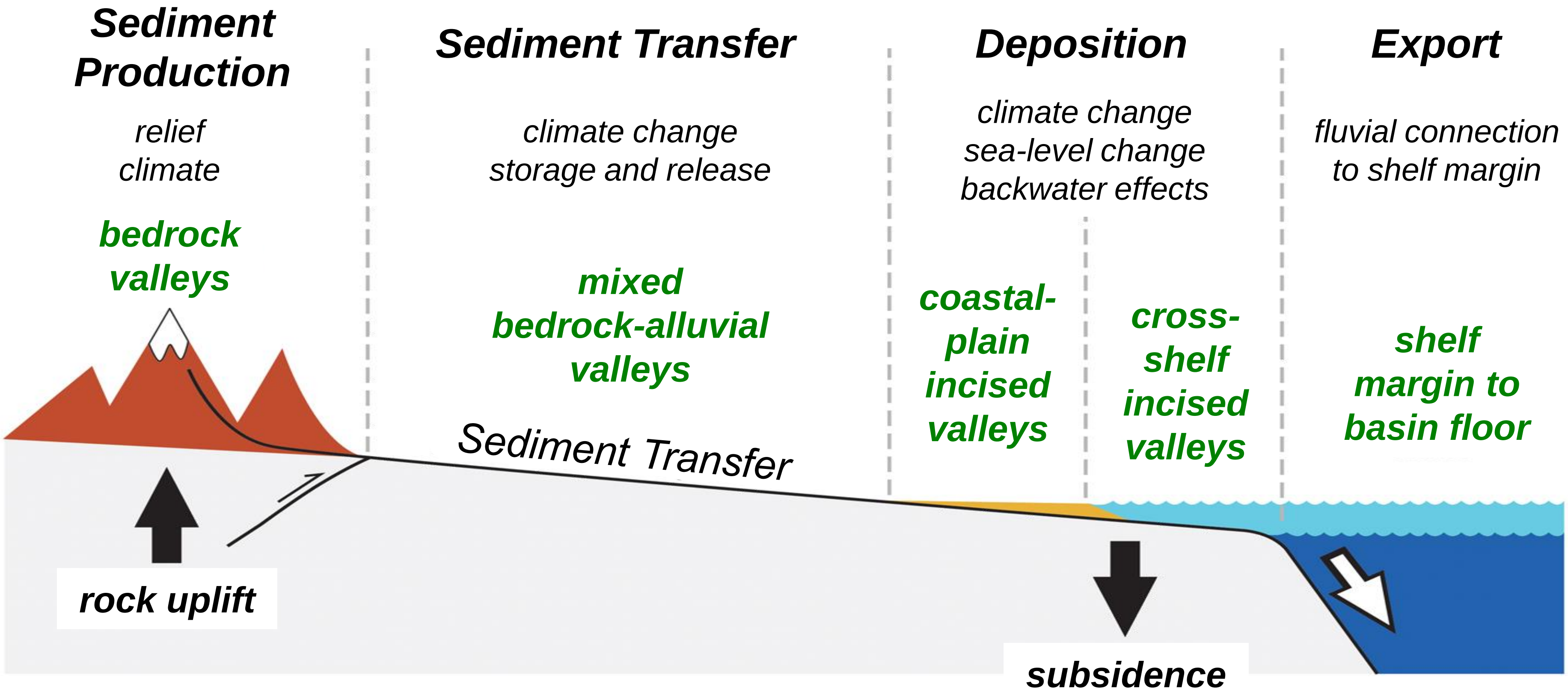
# FORELAND STEERING OF DRAINAGE?



# General Outline

- *Mannville Group, Western Canada Sedimentary System*
- *McMurray/Mannville Paleodrainage Reconstructions*
    - *A Continental-Scale River from Point-Bar Scales*
    - *A Continental-Scale River from Detrital Zircons*
- *Mannville Geochronology from Detrital Zircons*
- *The McMurray as a Mixed Bedrock-Alluvial Valley System*

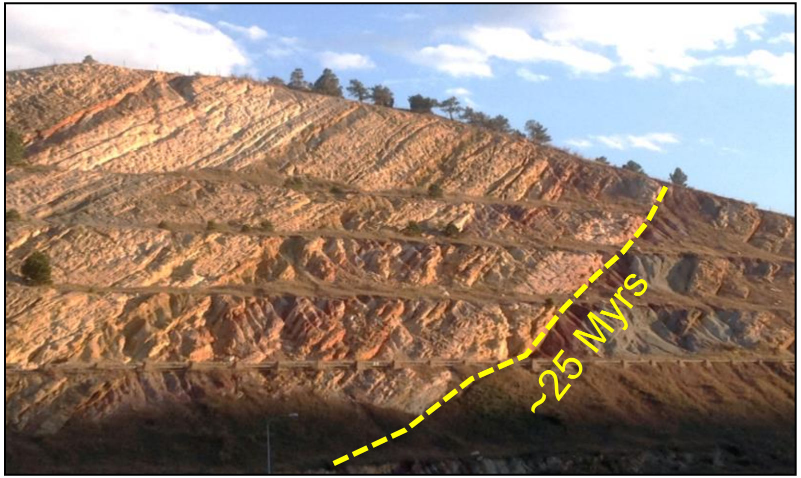
# TYPES OF VALLEYS – A SOURCE-TO-SINK VIEW



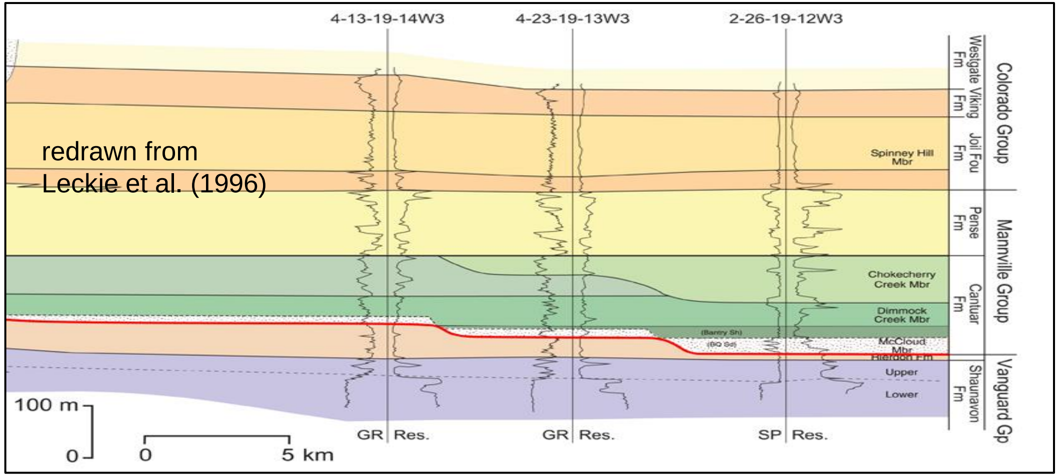

after Blum et al. (2013)

# The McMurray as a Bedrock Valley System

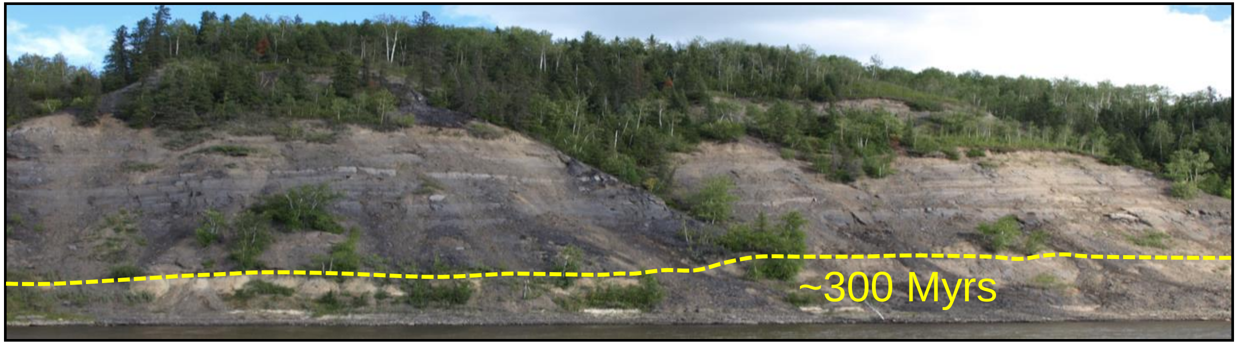
## Sub-Cretaceous Unconformity in Colorado




## Bedrock Valley in SW Saskatchewan

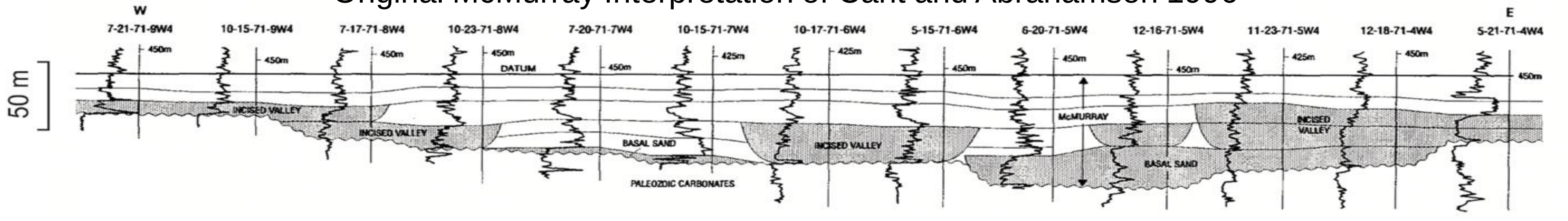



## Sub-Cretaceous Unconformity in Ft. McMurray Area

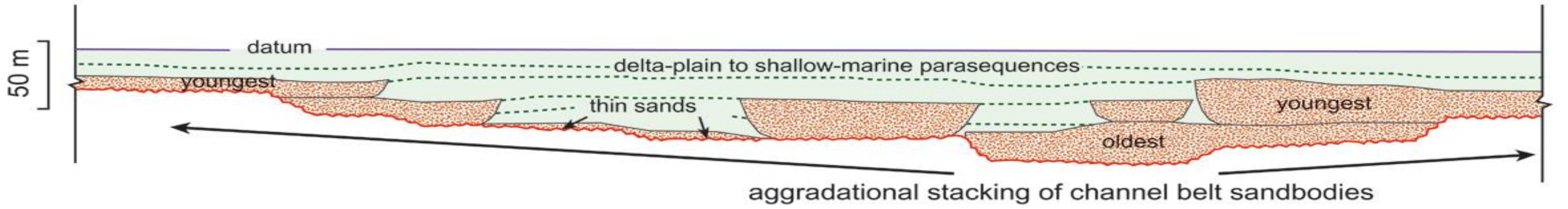



# MCMURRAY DEGRADATIONAL BEDROCK VALLEY

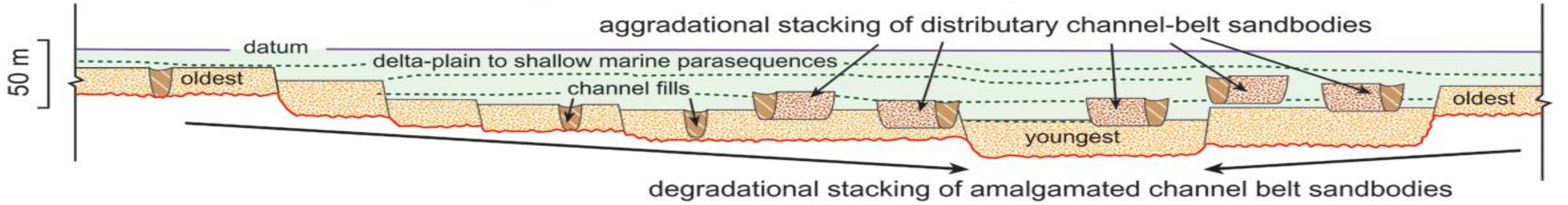
Original McMurray Interpretation of Cant and Abrahamson 1996




Implications – Pre-Existing Valley with Aggradation




Alternative Degradational Bedrock-Valley Model



# SUMMARY

*The Mannville Group records a continental-scale drainage, the Mississippi of its time*

*The McMurray is part of a long-lived bedrock valley system that extends from the Appalachians and shield to the Sevier fold and thrust belt, with major tributaries joining from the shield all the way to the Athabasca Oil Sands Area*

- *During McMurray deposition, there was minimal connection to the Cordilleran magmatic arc*
- *A few U-Pb ages place McMurray deposition in the range of 123-120 Ma*

*The Albian Clearwater and Grand Rapids represent the same system, but by this time, the tributary network had connected with arc-dominated terrain*

- *An abundance of U-Pb ages place Clearwater and Grand Rapids deposition in the range of 113-110 Ma.*

*Mixed bedrock-alluvial valleys require surface and rock uplift, and are inherently degradational. Valleys of this type tectonic drivers that are not readlily explained by a simple foreland-basin models, and likely reflect interactions with dynamic topography.*