A New Look at the Williams Fork Formation: Tight-Gas Sands in the American Rocky Mountains*

Bryan P. McDowell[1] and Piret Plink-Björklund[2]

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Abstract

The Williams Fork Formation in western Colorado is a significant tight-gas producer, containing up to 423 Tcf of original-gas-in-place (Law, 2002). Production comes from isolated-to-amalgamated fluvial sandstones encased in floodplain muds and sourced by laterally- and vertically-adjacent coals. This interval, known as the Mesaverde Group, records the eastward progradation of siliciclastic material from the Sevier Orogeny into the Western Interior Seaway during the latest Cretaceous. The Mesaverde Group, and the Piceance Basin in general, has been the subject of tight-gas sand research for decades through collaboration between industry, government, and academia, reaching its peak in the 1980s and 1990s. Past field research has focused primarily on the western basin margin where outcrop is well-exposed at near-horizontal dips as opposed to the eastern margin where vertical-to-overturned strata and weathering have limited research to a handful of studies in recent years. Regional unconformities make matters worse by juxtaposing unique fluvial deposits (i.e., three separate formations) that span the rise of the American Rocky Mountains. Increased drilling and downspacing occurred during the natural gas boom of the early 2000s; however, the subsequent crash in natural gas prices has left little interest in this region, except for current operators and academics. This has left a surplus of new data in the public realm with little attention, including production volumes, completion reports, and subsurface well logs. Heightened well control now aids detailed subsurface correlation, allowing a real comparison to outcrop studies and their applicability for field development and future exploration. This study aims to integrate recent outcrop work along the eastern margin of the basin with current subsurface well control, production characteristics, and past research for a coherent understanding of stratigraphic variability and how it relates to basin productivity and the petroleum system. In addition, an attempt to clarify and constrain the nature and extent of regional unconformities is made to resolve the disconnect commonly seen between geologists working in outcrop versus operators working in the subsurface. Simple reservoir engineering techniques are also proposed as a novel method to help characterize effective formation permeability during late-time boundary-dominated flow.

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B.P. McDowell, P. Plink-Björklund
Colorado School of Mines

16 September 2015

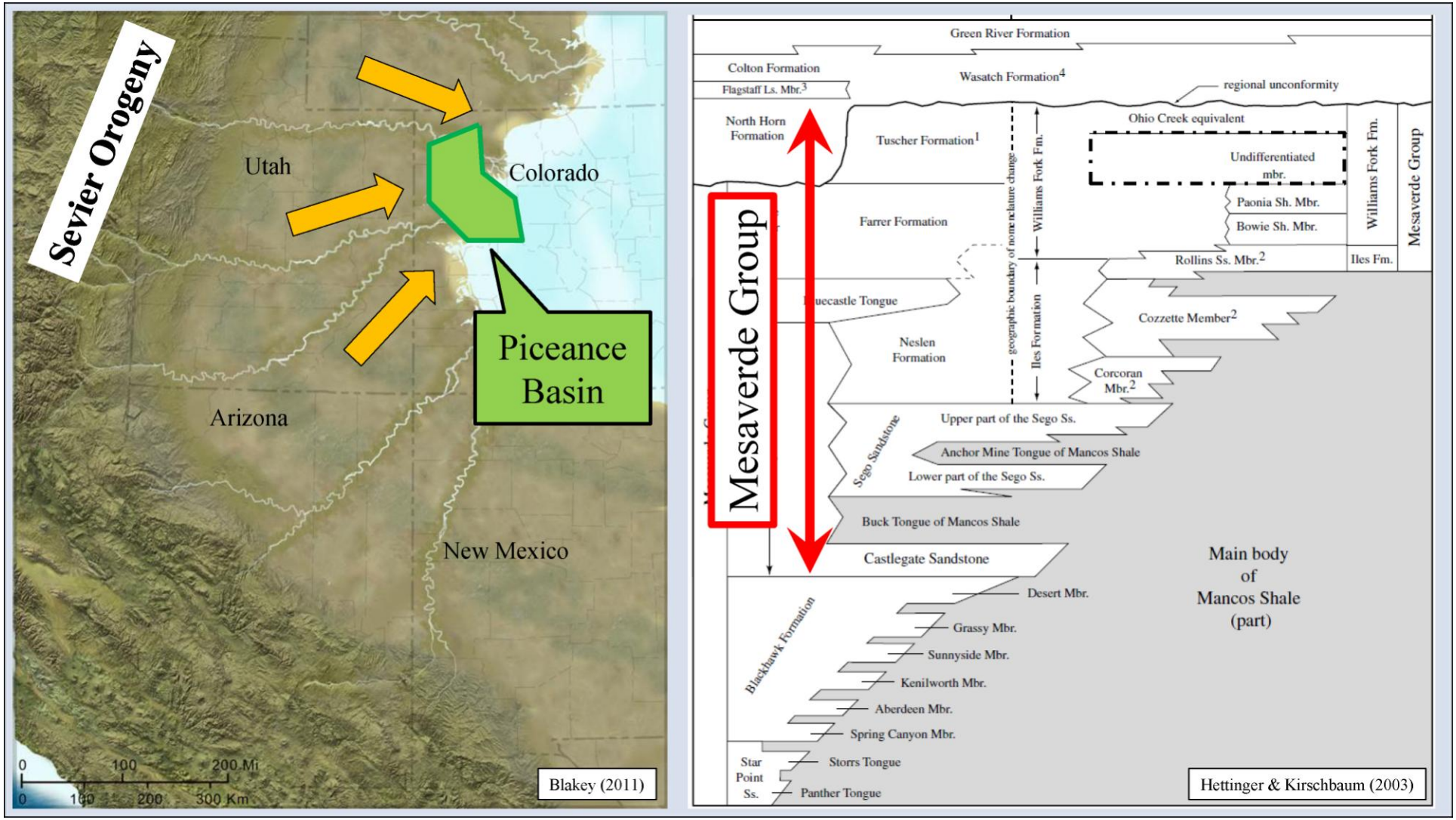
Outline

- Introduction
  - Geologic Setting
  - Petroleum System
- Research
  - Questions
  - Methods
  - Results
- Conclusions
- References

Introduction

- Williams Fork Fm. is Late Cretaceous stratigraphic unit composed primarily of coals, mudstones, and isolated-to-amalgamated sandstones
  - Campanian – Maastrichtian

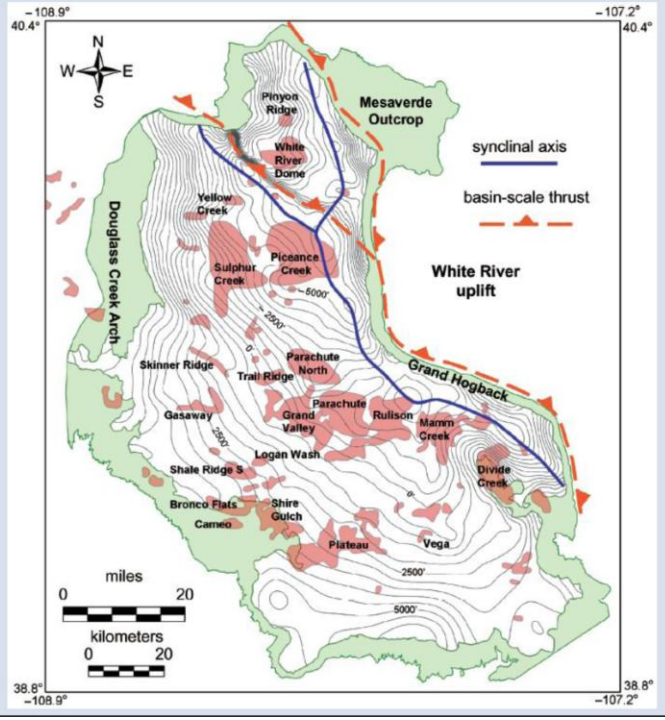
- Focus of integrated studies between government, academia, and industry
  - Multiwell Experiment (DOE, Sandia National Labs, CER Corp.)
  - Williams Fork Consortium (CU Boulder)
  - Piceance Basin Consortium (CU Boulder)
  - RPSEA & Colorado School of Mines



Presenter's notes: The Williams Fork Formation is a Late Cretaceous stratigraphic unit, deposited during the Campanian to Maatrichtian. These rocks were formed as a clastic wedge prograded from the Sevier Orogeny in the west towards the Western Interior Basin in the east.

Petroleum System

- Prolific natural gas producer
  - Up to 423 Tcf original gas-in-place (Law, 2002)
  - > 9,000 producing wells (WFF, Jan. '15)
    - Peak production at 2.0 Bcf/d in (Jan. '12)
    - Currently ~ 1.5 Bcf/d
  - Contains 5 of Top-100 gas fields in the U.S.
- Reservoir types:
  - Fluvial sandstones
  - Coalbed methane
  - Marine sandstones



Hood & Yurewicz (2005)

Presenter's notes:

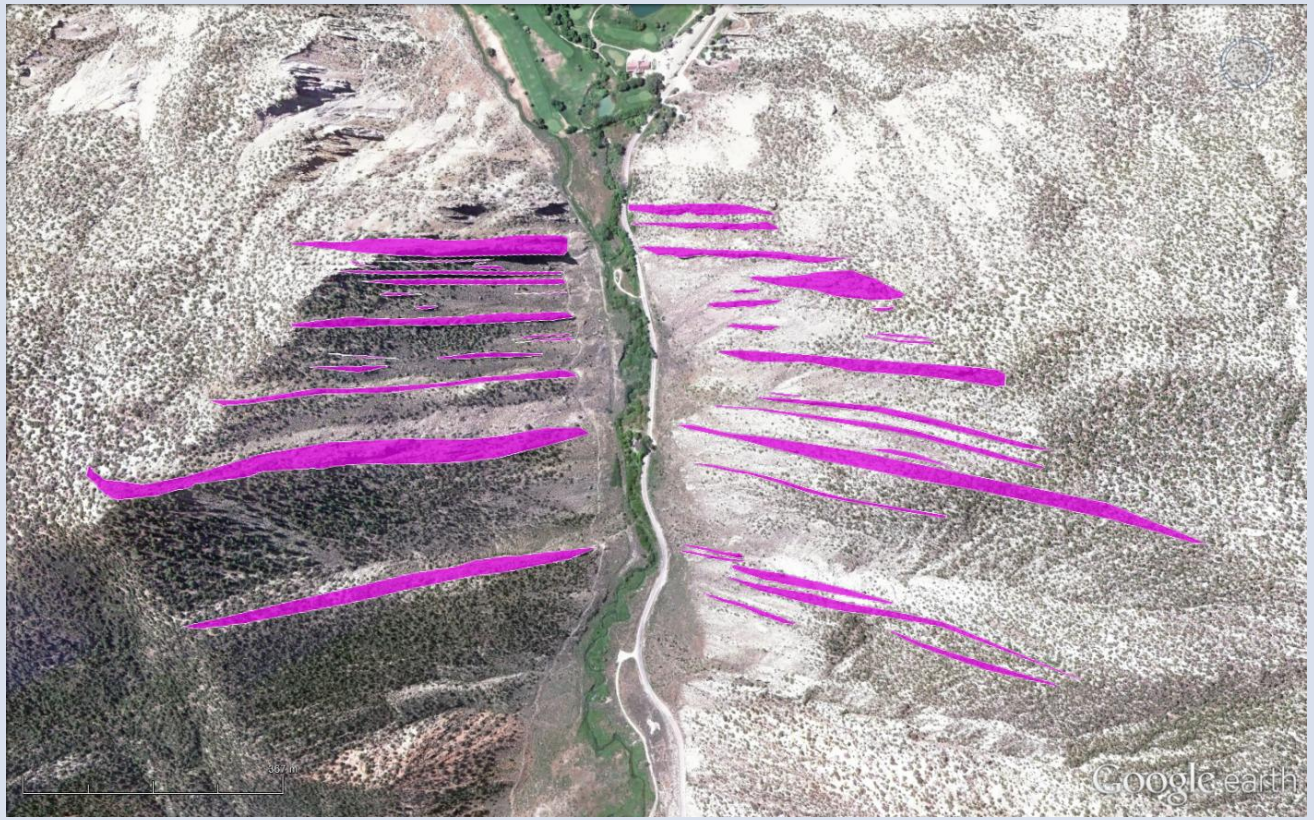
- ***6.5 Tcf*** *cumulative gas production (1 Jan. 2015)*
- Contains 5 of Top-100 gas fields in the U.S.
  - Mamm Creek (#16)
  - Rulison (#27)
  - Grand Valley (#28)
  - Parachute (#32)
  - Parachute North (#50)
- Another 3 Top-100 fields produce from Mesaverde Group reservoirs, but sourced by underlying Mancos/Niobrara shale
  - Love Ranch (#81)
  - Vega North (#88)
  - Piceance Creek (#99)

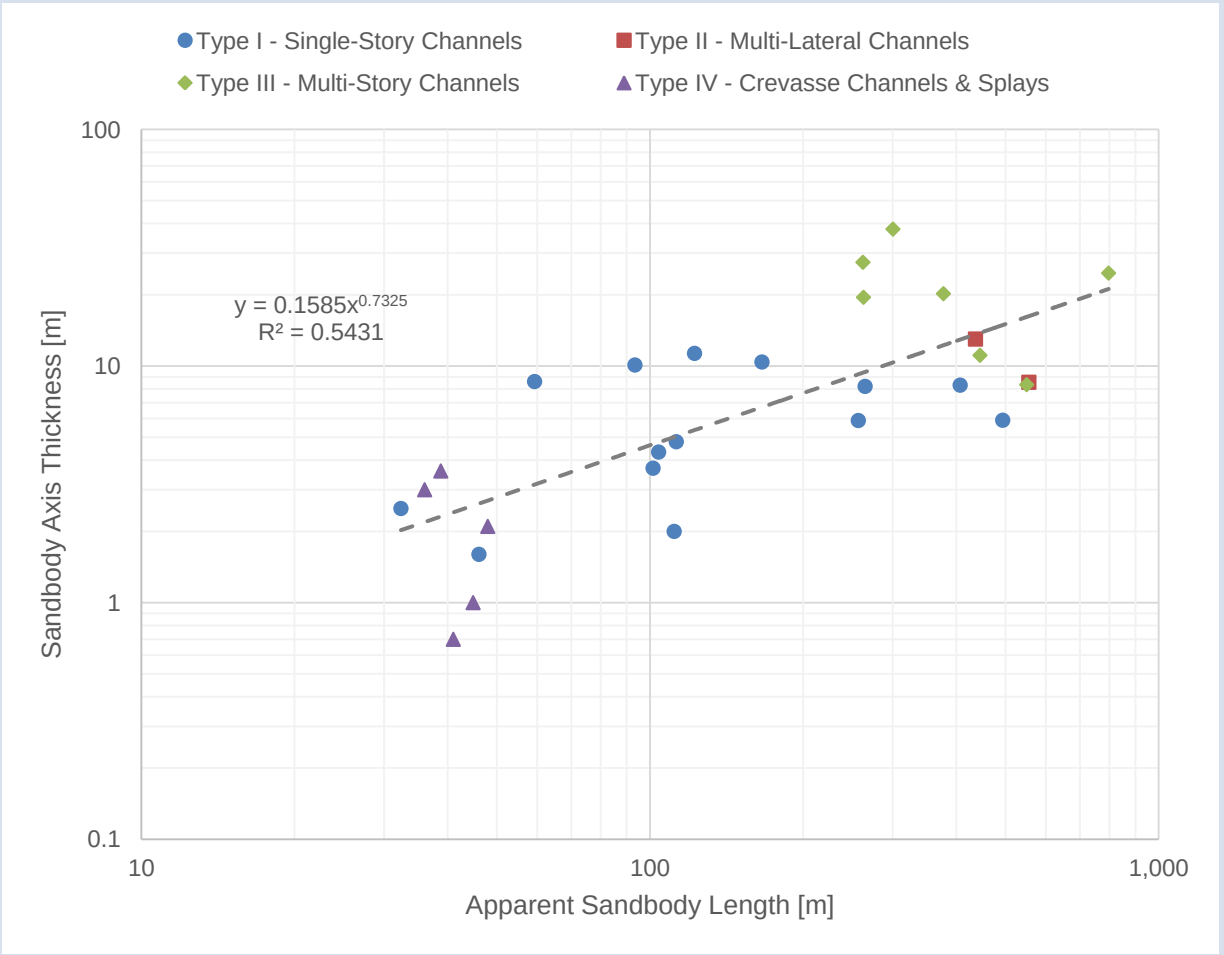
Original Research Questions

- > 25 theses/dissertations completed on Mesaverde Group within the basin
  - Mostly focused on western margin
  - Analog for nearby natural gas fields
  - Not representative for other fields

- Original Research Questions:
  - What are the reservoir geometries found in the Upper Williams Fork Fm?
  - How do these geometries change across the basin?

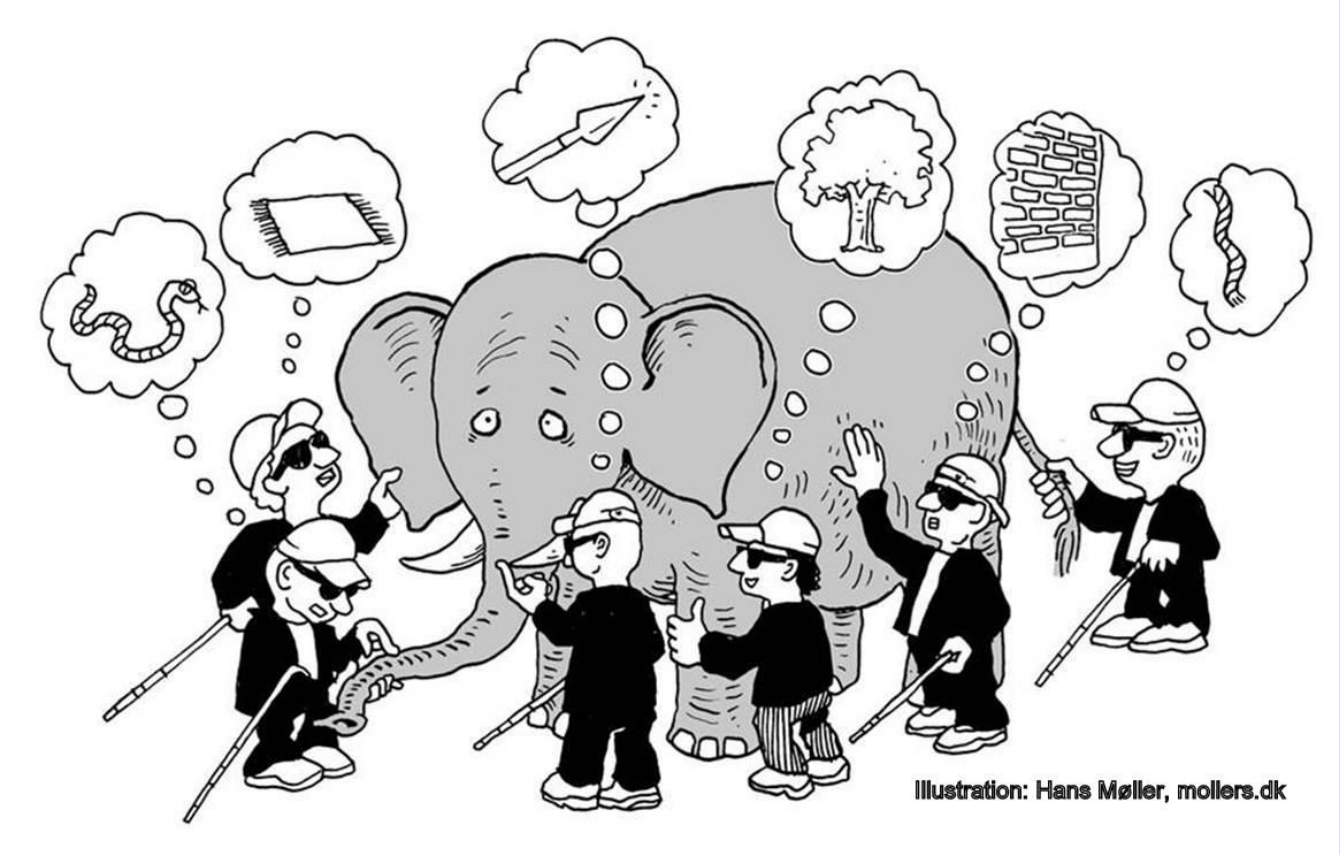
Early Work


Google earth

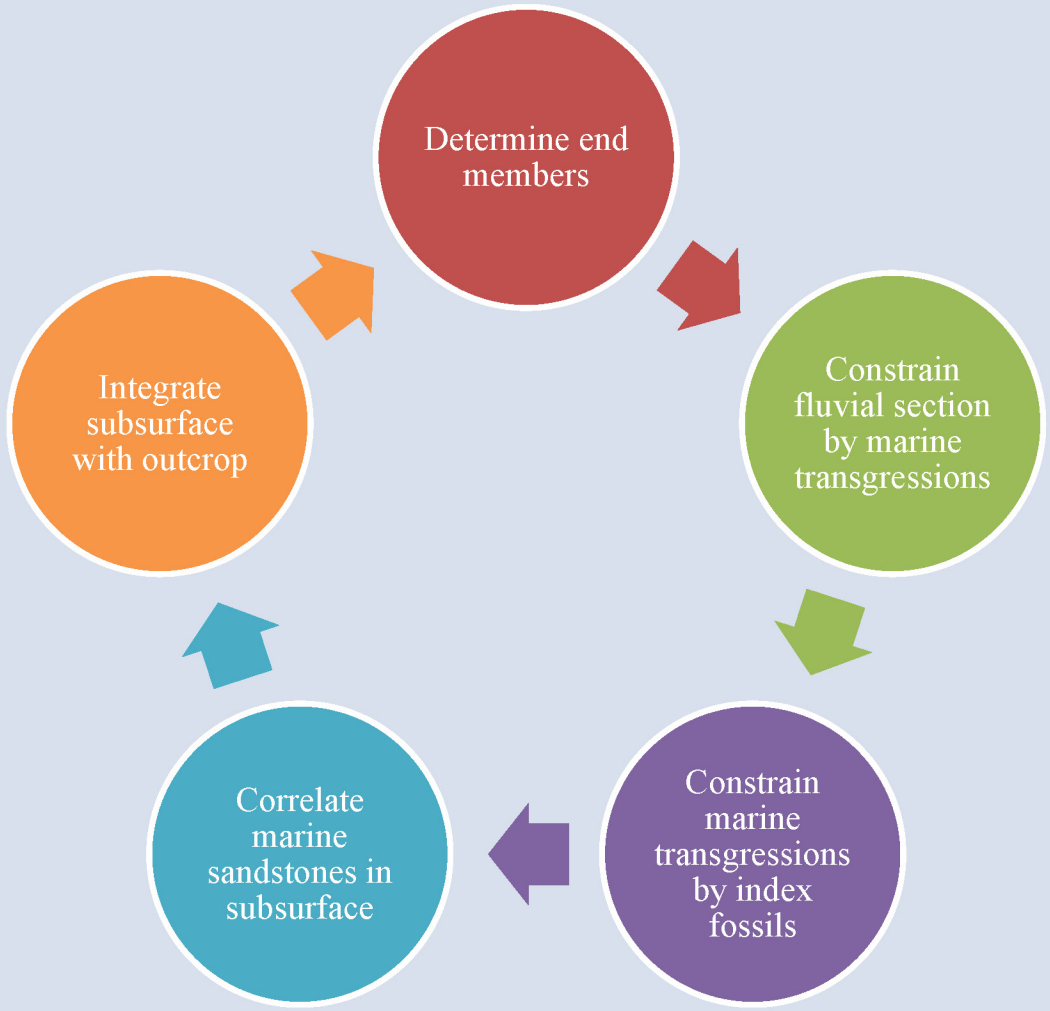

Type I - Single-Story Channels
Type II - Multi-Lateral Channels
Type III - Multi-Story Channels
Type IV - Crevasse Channels & Splays
y = 0.1585x^0.7325
R² = 0.5431
Sandbody Axis Thickness [m]
100
10
1
0.1
10
100
1,000
Apparent Sandbody Length [m]

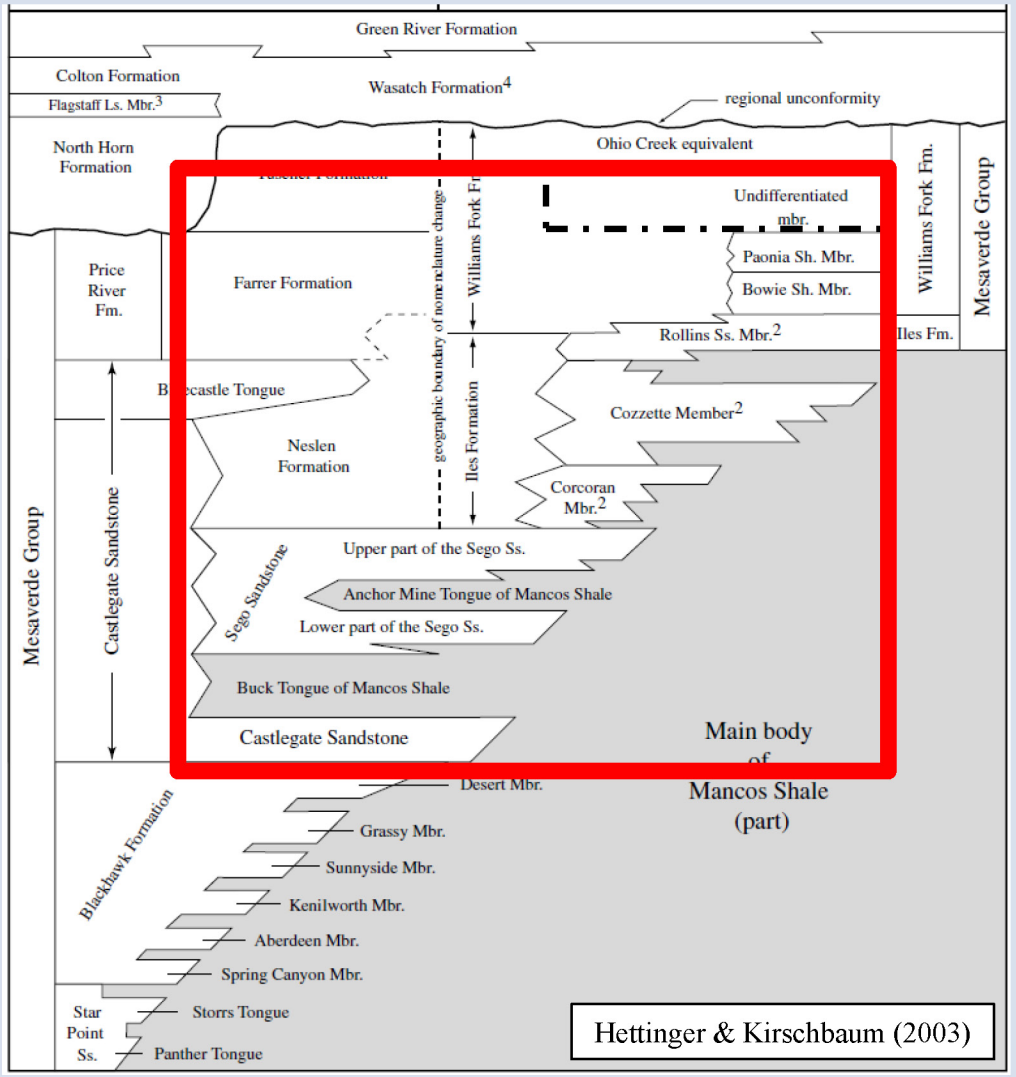
New Research Questions

- Early problems…
  - Complicated stratigraphy
  - Regional unconformities
  - Inconsistent nomenclature
- Why?
  - Recent studies have concentrated on:
    - Discrete stratigraphic intervals
    - Limited field areas
    - Limited focus
- ***New research questions:***
  - What is the Upper Williams Fork?
  - Can we integrate subsurface and outcrop for a more complete picture?



Methodology





Marine Sandstones

10 — *Lion Canyon*

9 — *Upper*

8 — *Middle*

7 — *Rollins*

6 — *Cozzette*

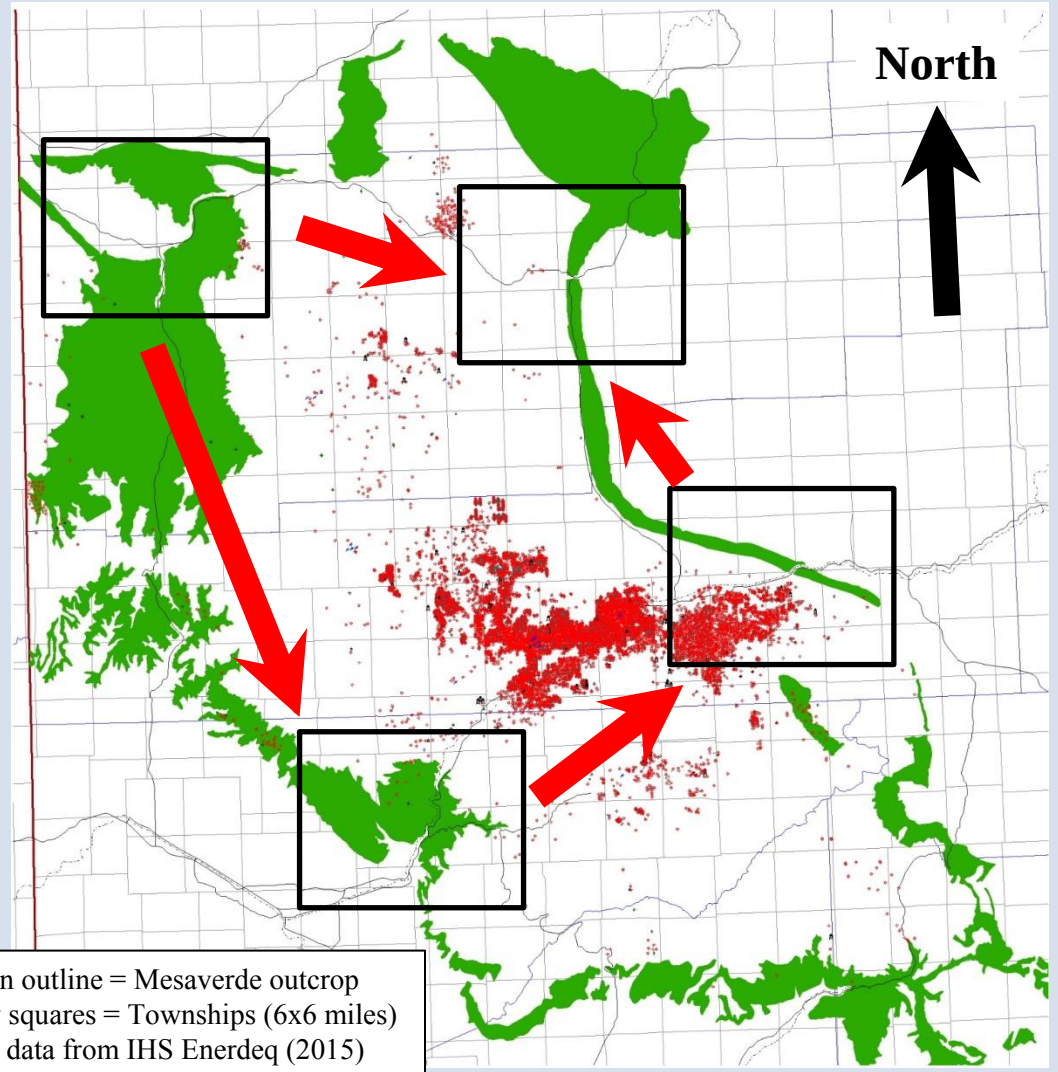
5 — *Corcoran*

4 — *Sego*

3 — *Loyd*

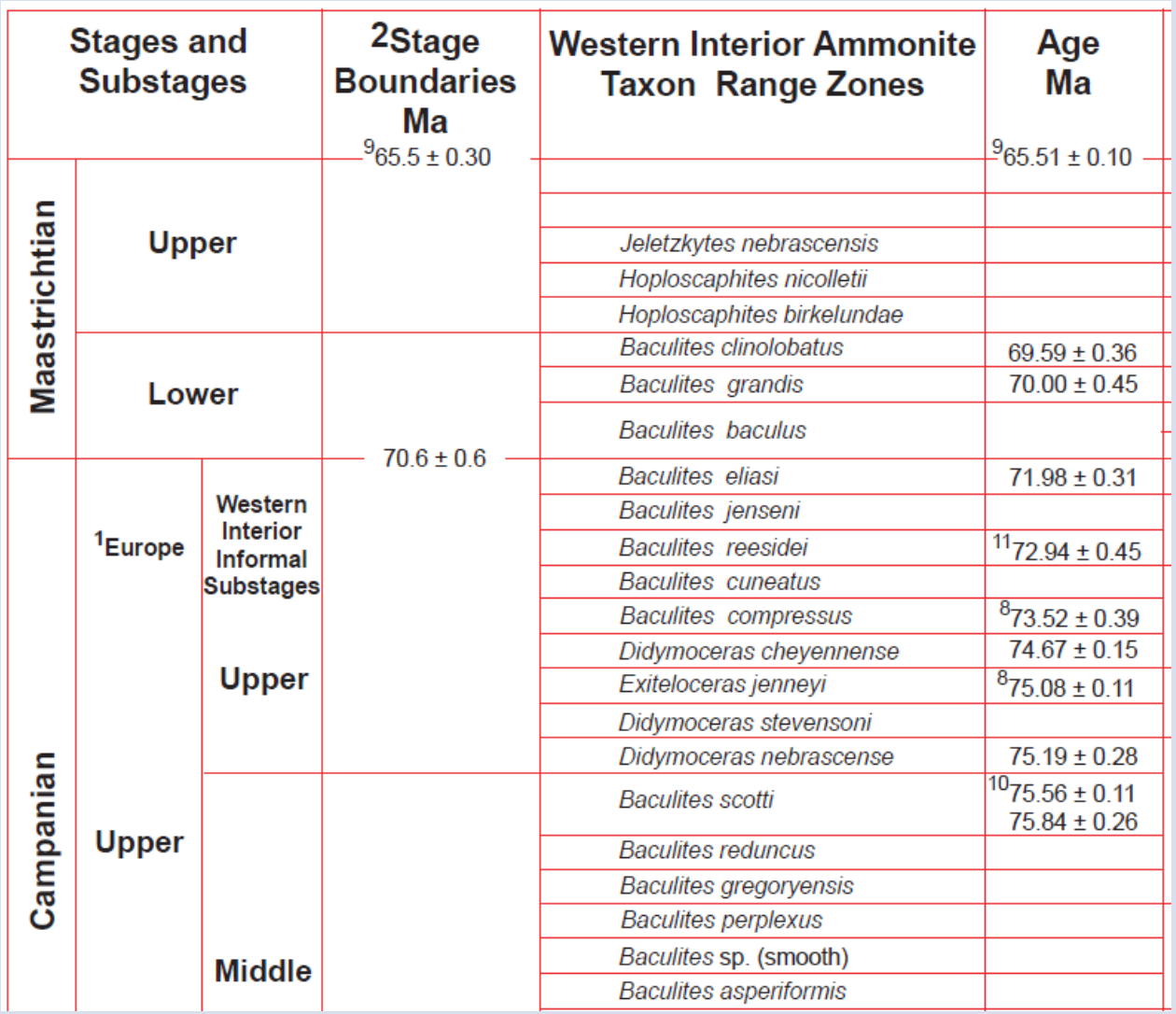
2 — *Castlegate*

1 — *Morapos*



- Green outline = Mesaverde outcrop
- Grey squares = Townships (6x6 miles)
- Well data from IHS Enerdeq (2015)

Ammonite Zones



Stages and Substages			[2]Stage Boundaries Ma	Western Interior Ammonite Taxon Range Zones	Age Ma
			[9]65.5 ± 0.30		[9]65.51 ± 0.10
Maastrichtian	Upper				
				Jeletzkytes nebrascensis	
				Hoploscaphites nicolletii	
				Hoploscaphites birkelundae	
	Lower			*Baculites clinolobatus*	69.59 ± 0.36
				Baculites grandis	70.00 ± 0.45
				Baculites baculus	
			70.6 ± 0.6		
Campanian	[1]Europe	Western Interior Informal Substages		*Baculites eliasi*	71.98 ± 0.31
				Baculites jenseni	
				Baculites reesidei	[11]72.94 ± 0.45
				Baculites cuneatus	
				Baculites compressus	[8]73.52 ± 0.39
		Upper		*Didymoceras cheyennense*	74.67 ± 0.15
				Exiteloceras jenneyi	[8]75.08 ± 0.11
				Didymoceras stevensoni	
				Didymoceras nebrascense	75.19 ± 0.28
	Upper			*Baculites scotti*	[10]75.56 ± 0.11 75.84 ± 0.26
				Baculites reduncus	
				Baculites gregoryensis	
				Baculites perplexus	
		Middle		*Baculites* sp. (smooth)	
				Baculites asperiformis	

Cobban et al. (2006)

Ammonite Zone	Stratigraphic Unit
Didymoceras cheyennense	Upper Sandstone
Exiteloceras jenneyi	Rollins-Cozzette Tongue
Didymoceras stevensoni	Cozzette Sandstone
Didymoceras nebrascense	Cozzette-Corcoran Tongue
Baculites scotti	Sego Sandstone, Anchor Mine Tongue
Baculites reduncus	N/A
Baculites gregoryensis	Lower Sego Sandstone
Baculites perplexus	Buck Tongue, Loyd Sandstone
Baculites sp. (smooth)	N/A
Baculites asperiformis	N/A
Baculites maclearni	Morapos Sandstone

Complied from Gill & Hail (1975), Madden (1983)

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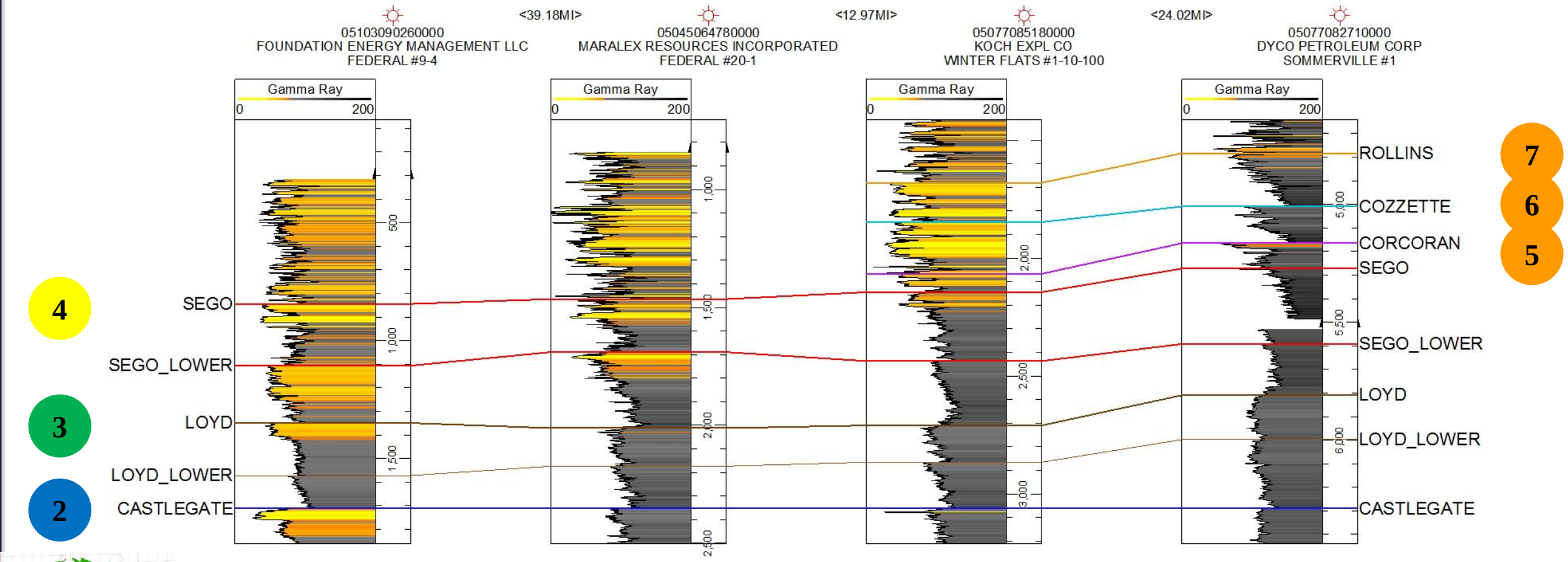
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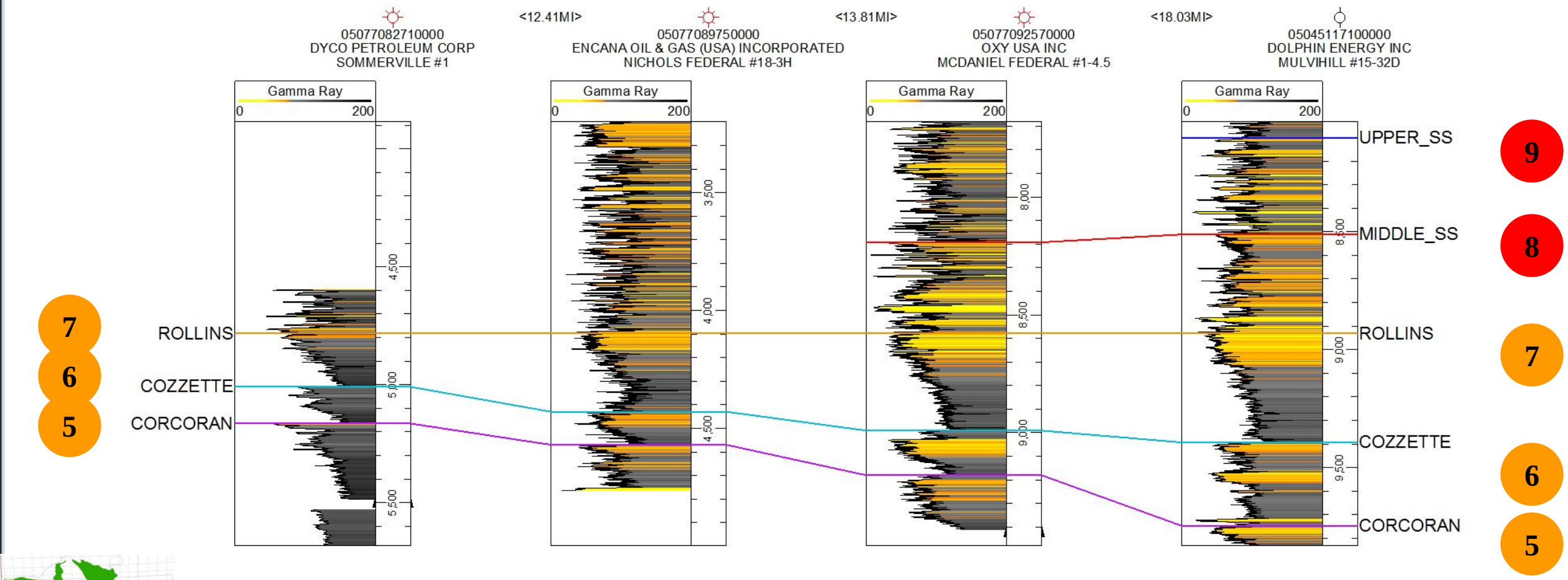
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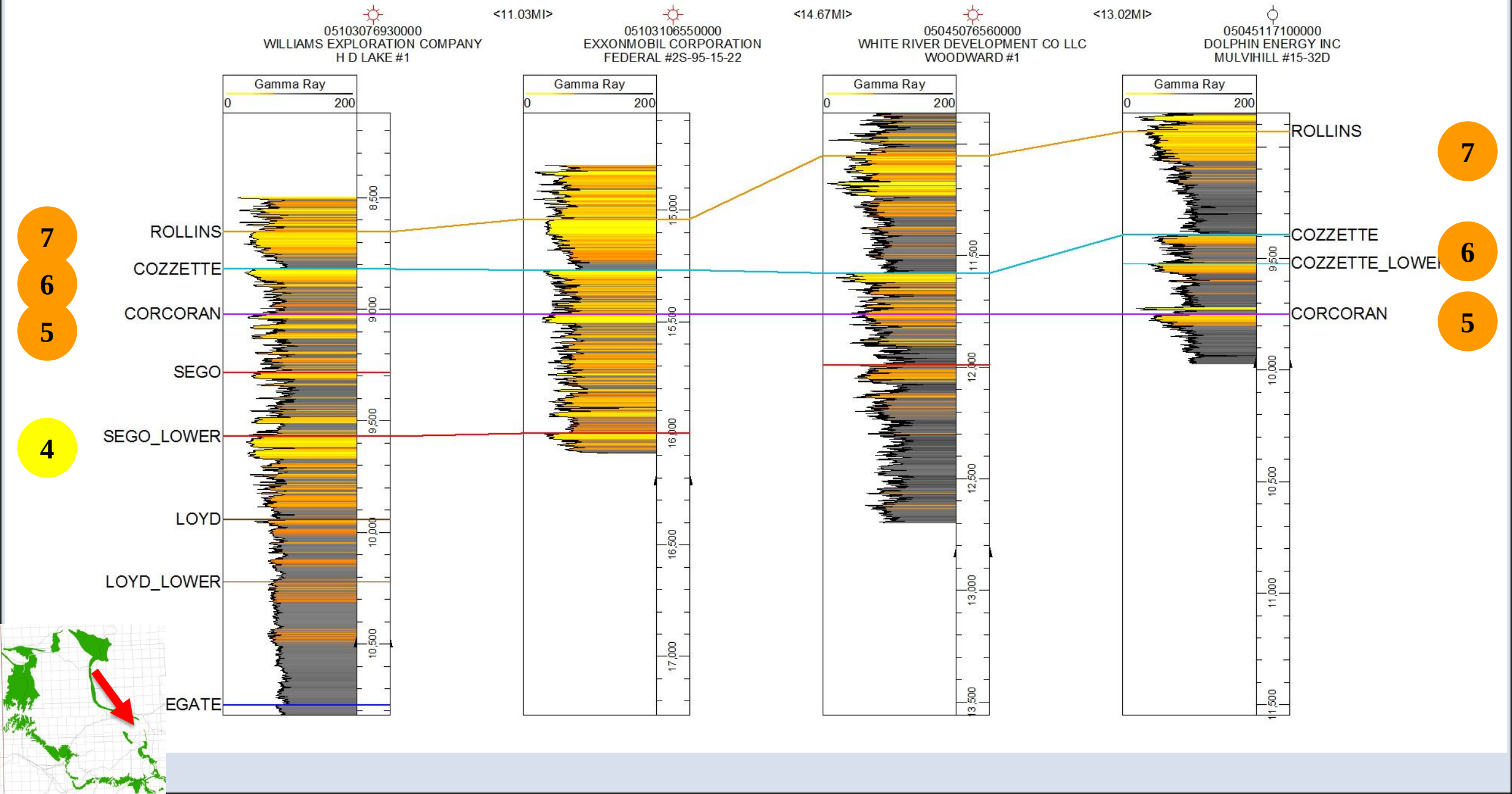
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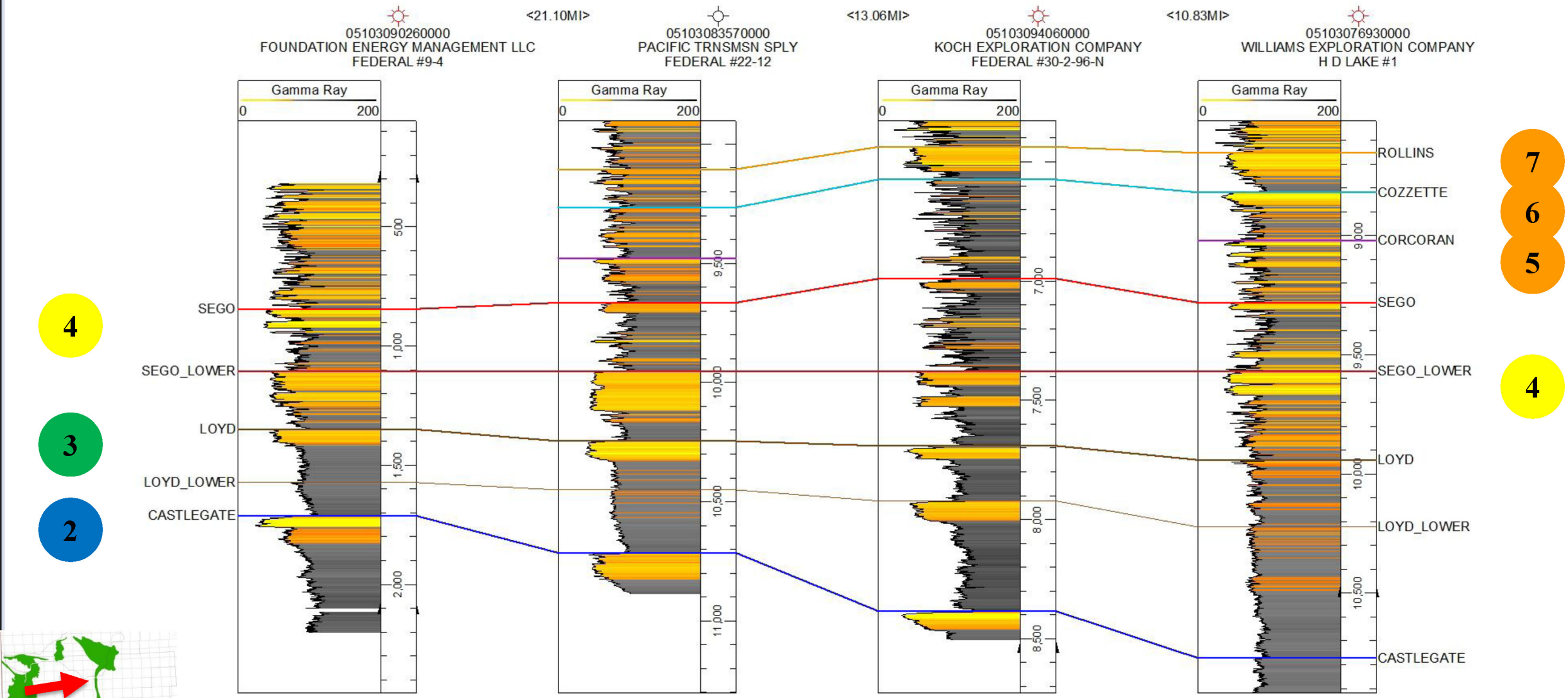
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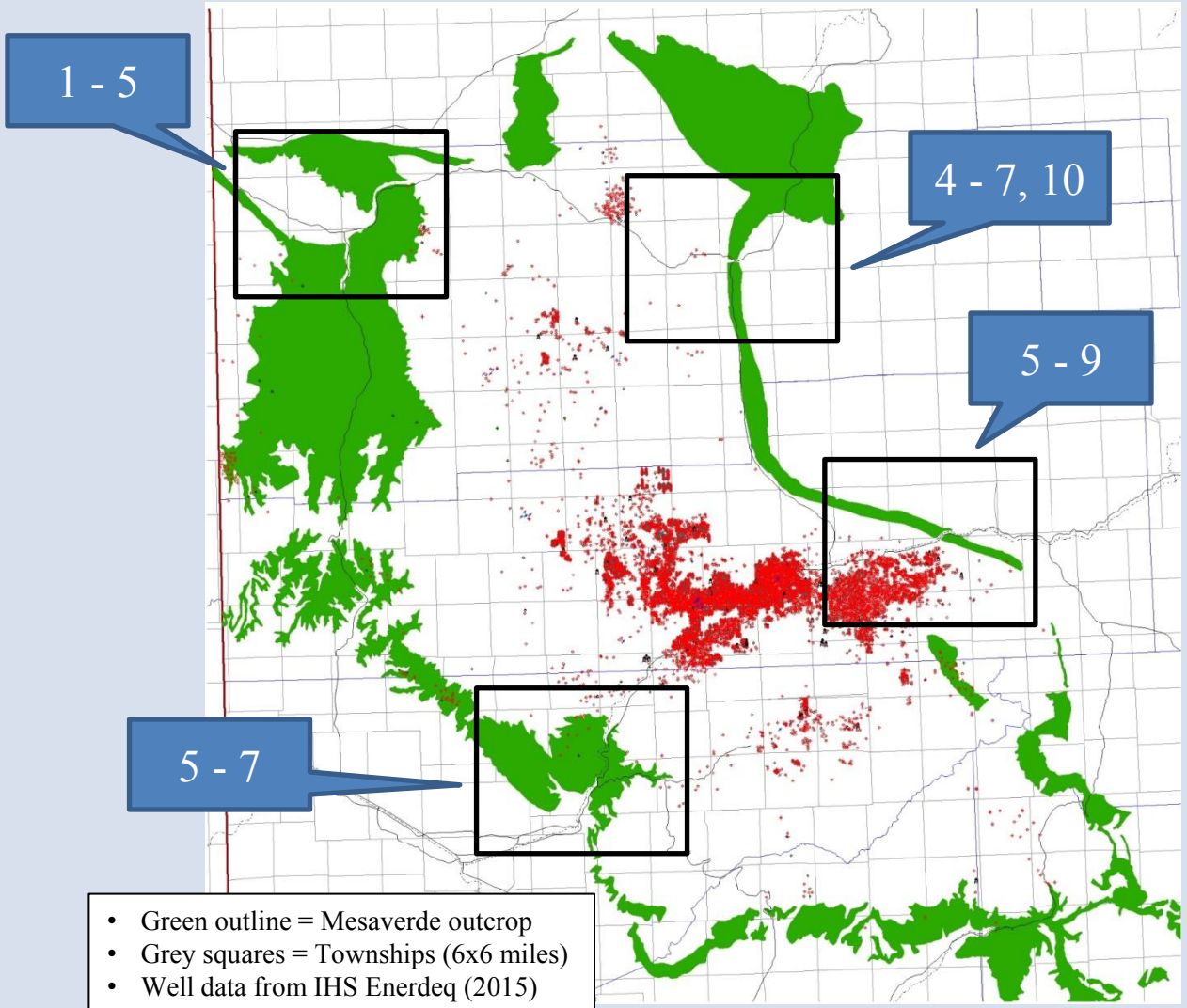

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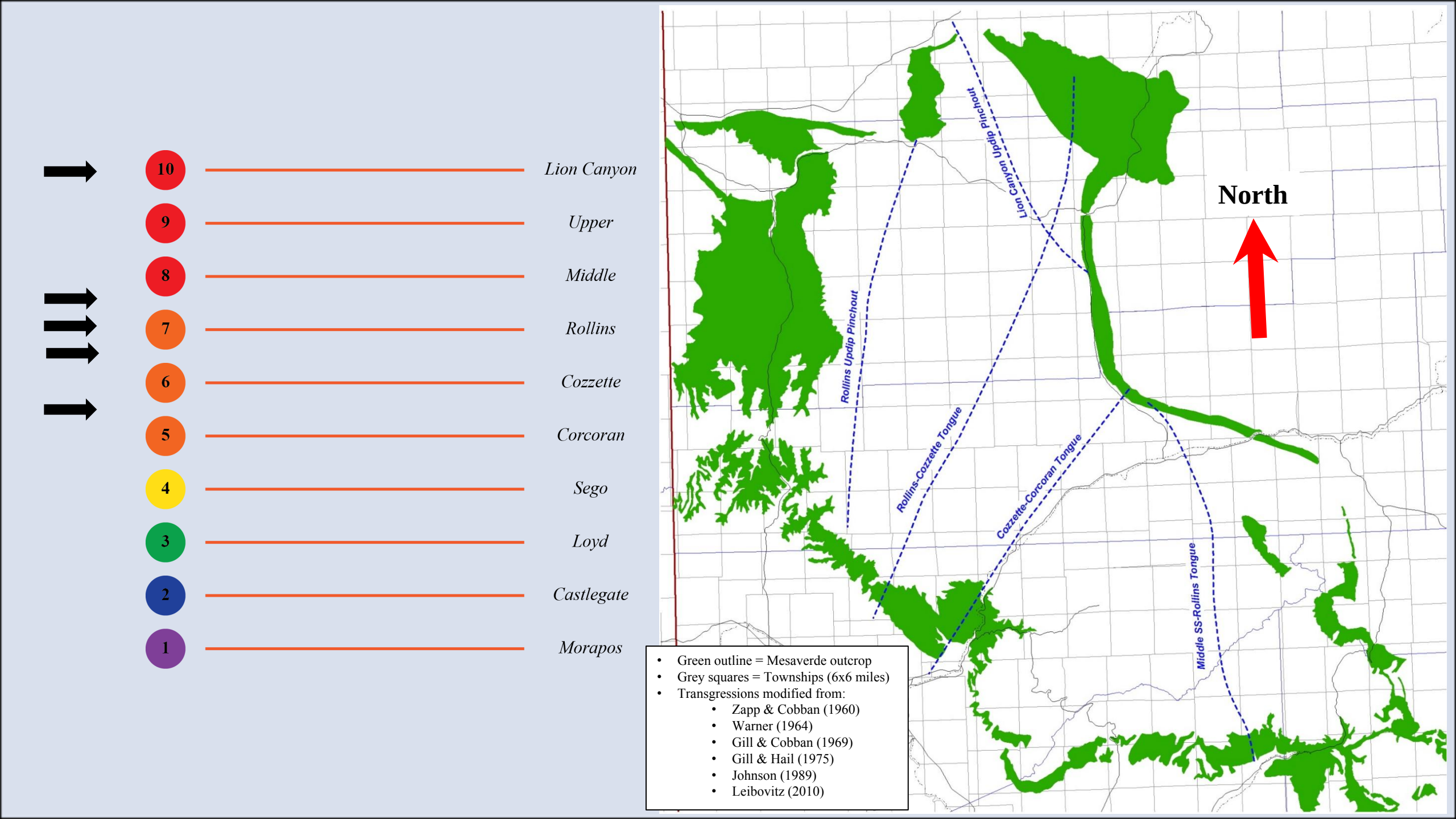
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  • Warner (1964)
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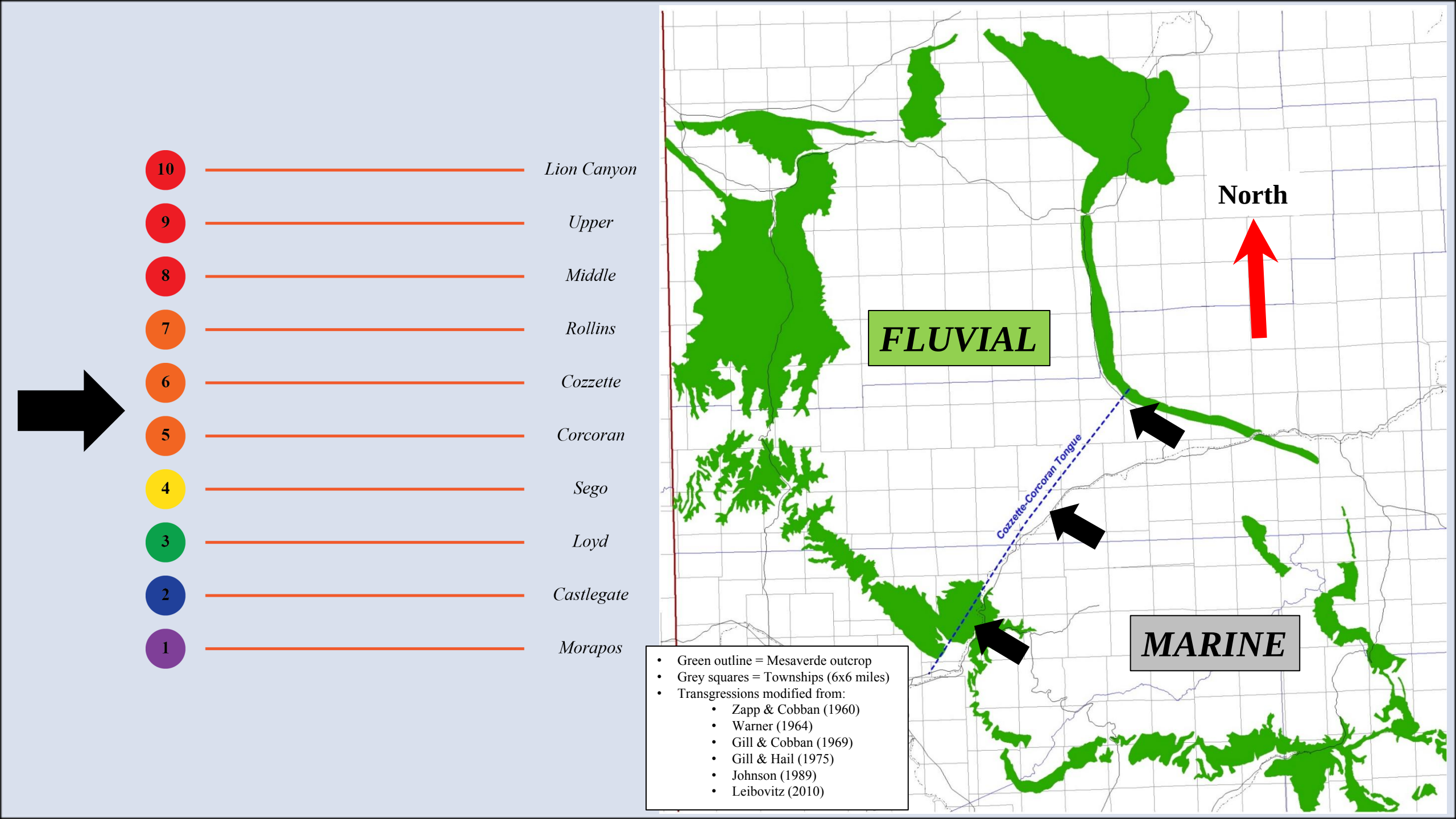
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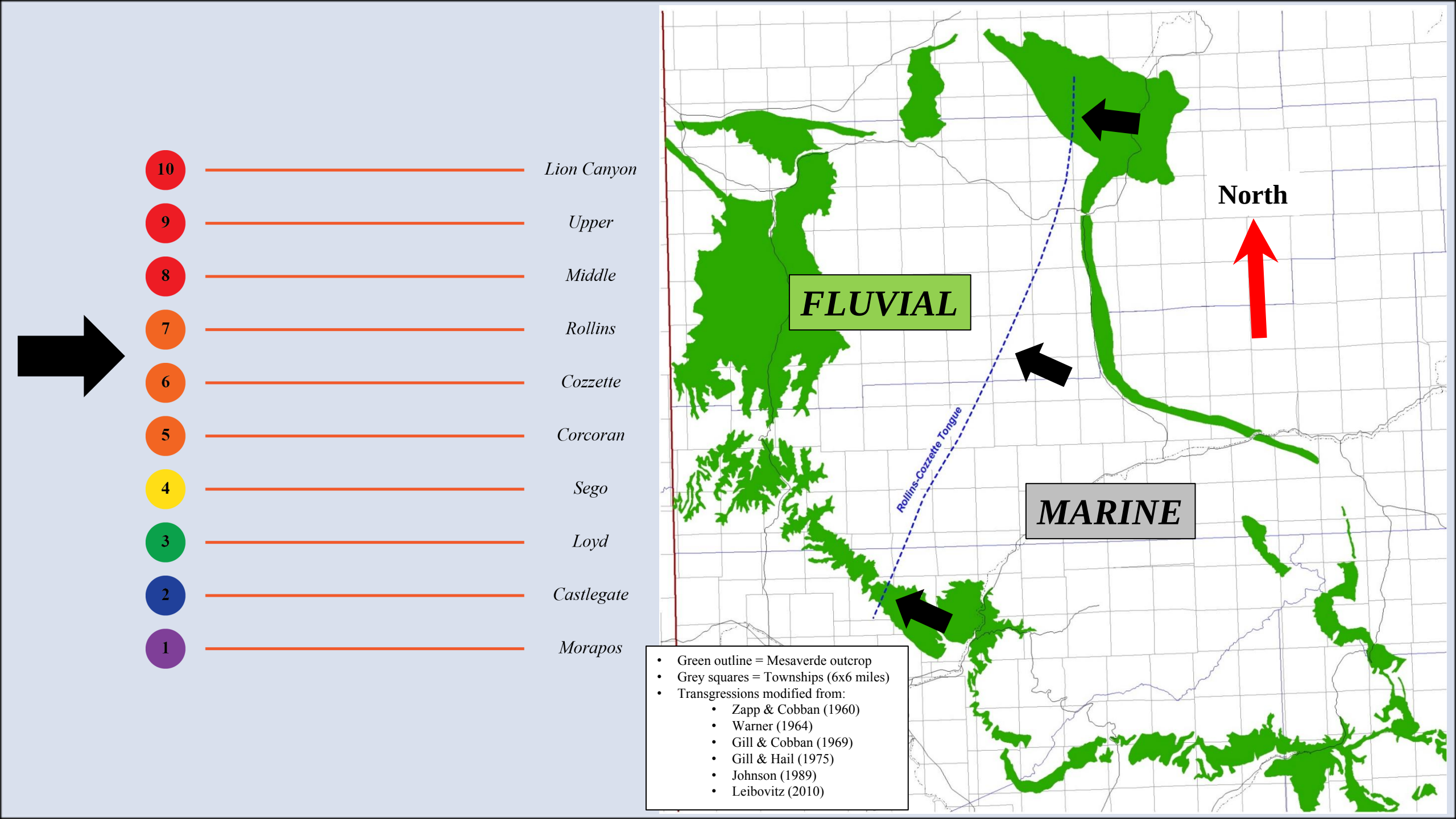
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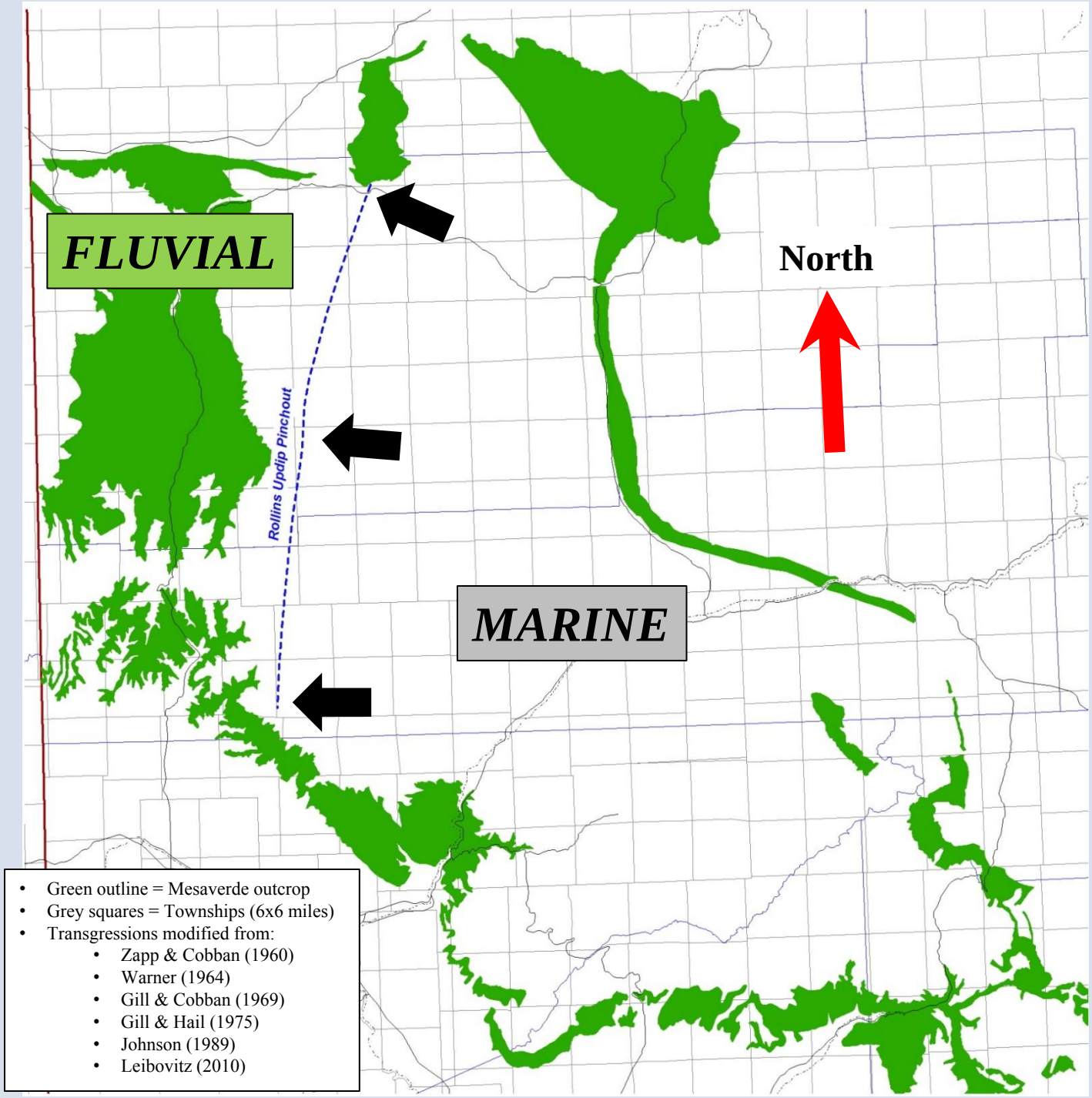
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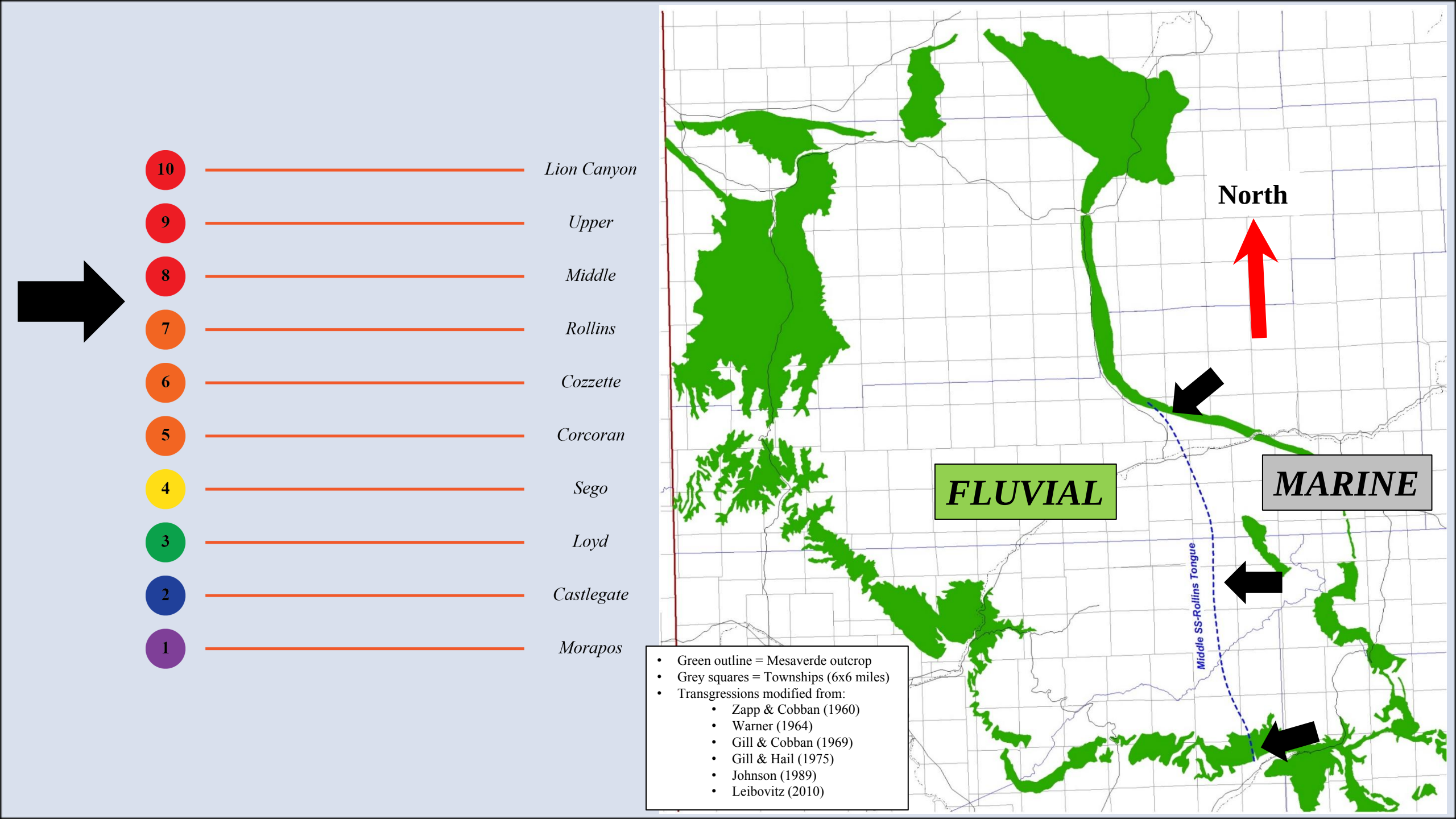
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• Johnson (1989)
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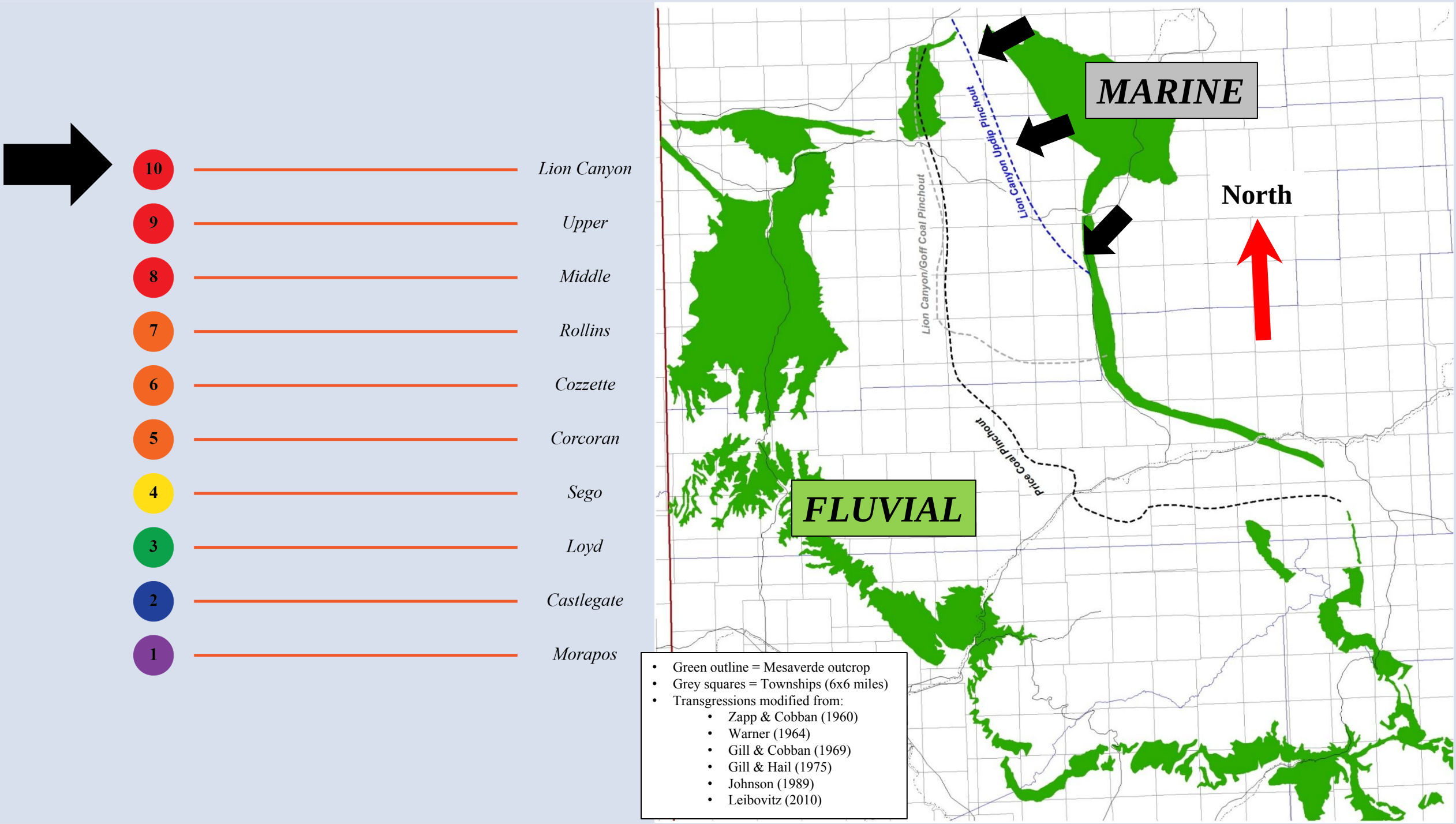
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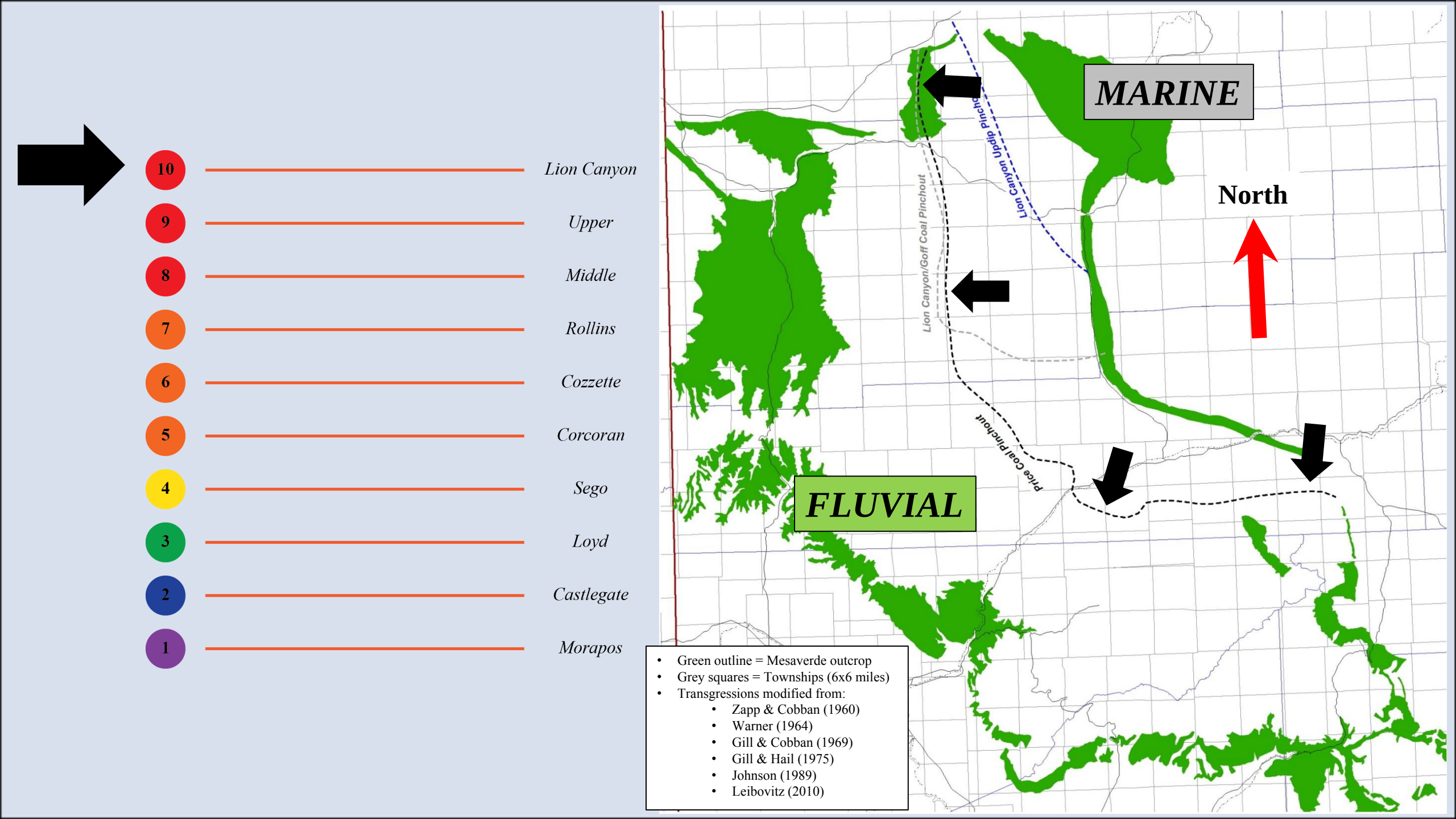
Lion Canyon
9
Upper
8
Middle
7
Rollins
6
Cozzette
5
Corcoran
4
Sego
3
Loyd
2
Castlegate
1
Morapos
MARINE
North
Lion Canyon Updip Pinchout
Lion Canyon/Goff Coal Pinchout
Price Coal Pinchout
FLUVIAL
Green outline = Mesaverde outcrop
Grey squares = Townships (6x6 miles)
Transgressions modified from:
Zapp & Cobban (1960)
Warner (1964)
Gill & Cobban (1969)
Gill & Hail (1975)
Johnson (1989)
Leibovitz (2010)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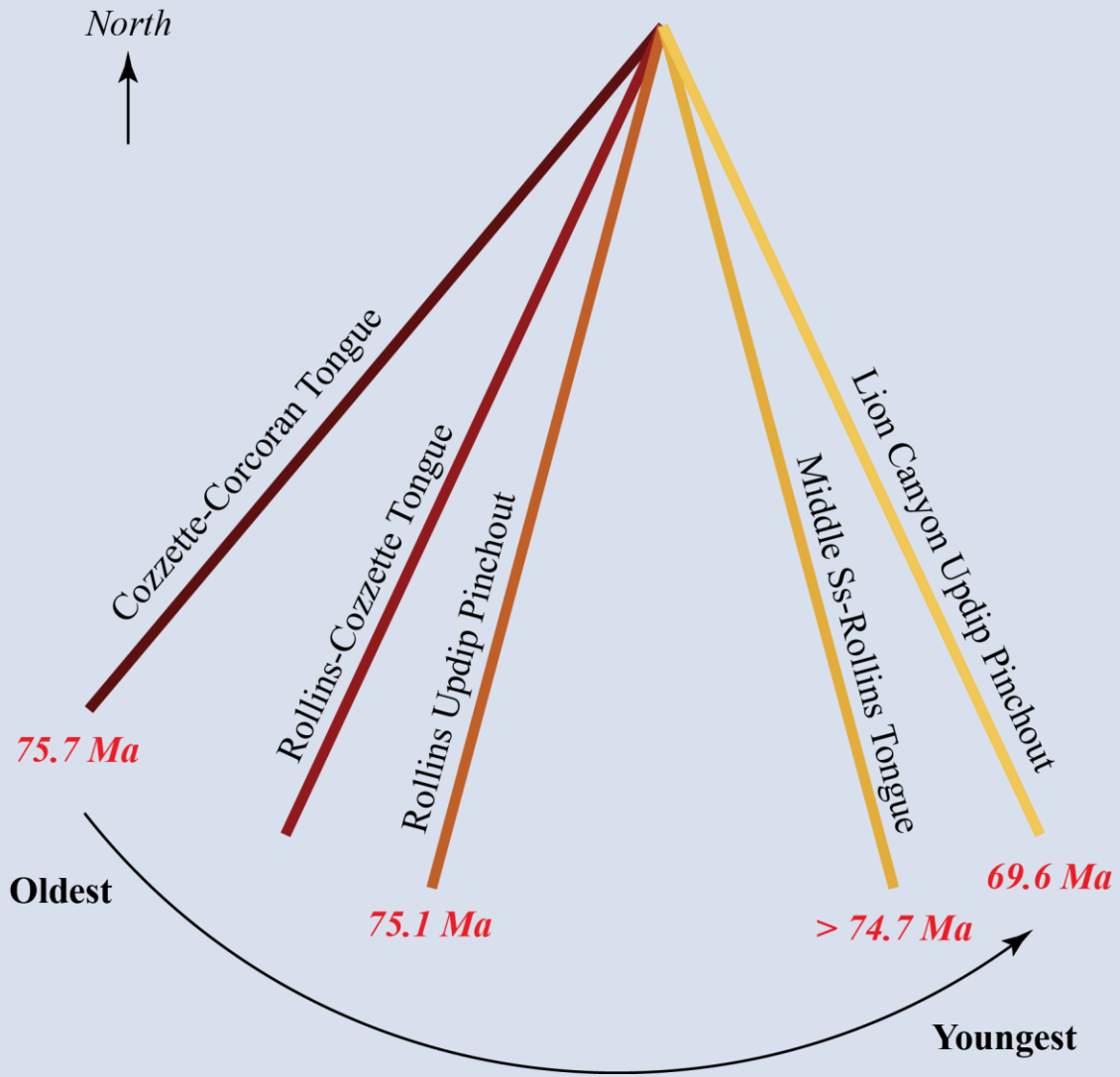
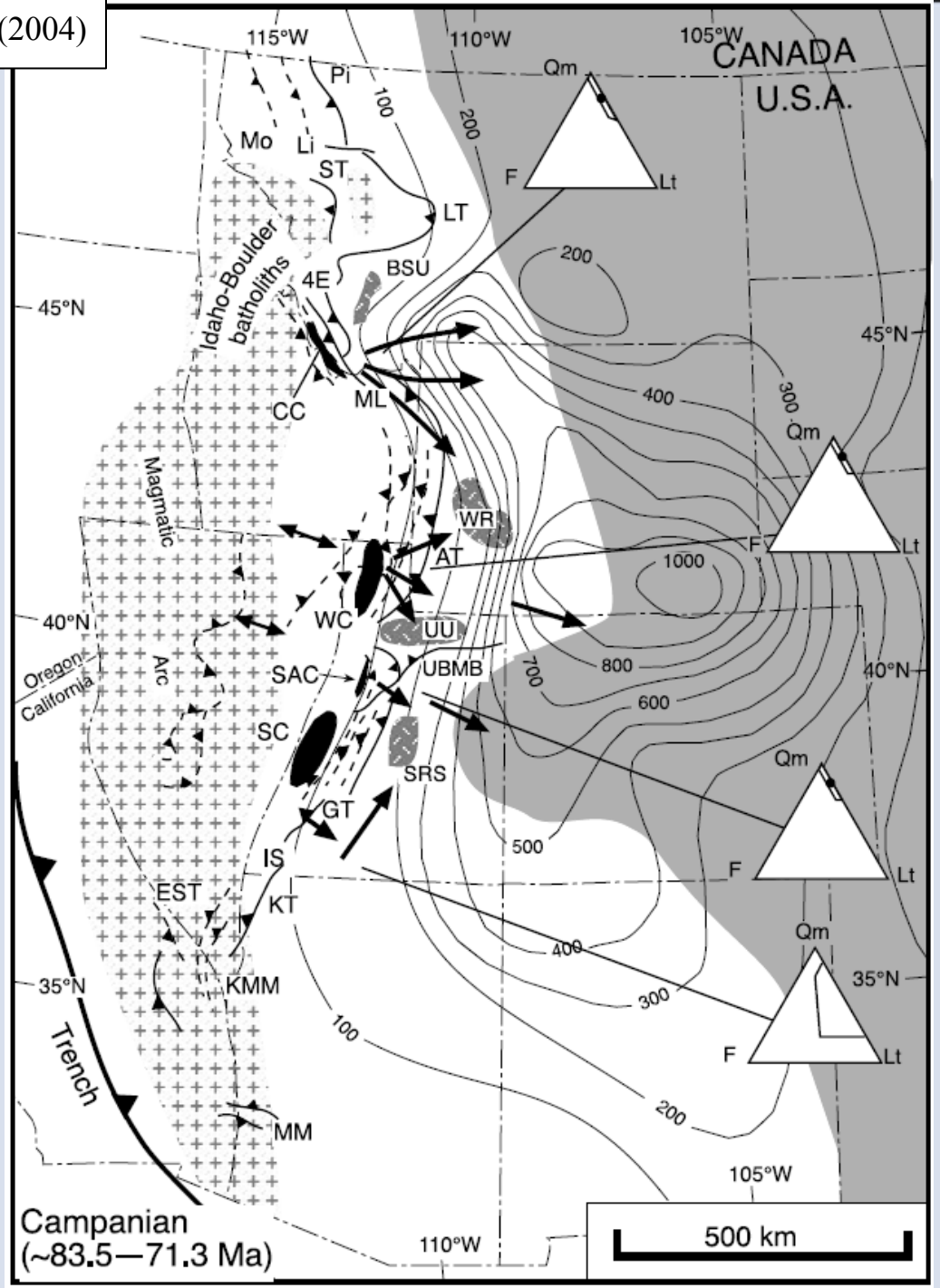
Johnson (1989)
Leibovitz (2010)

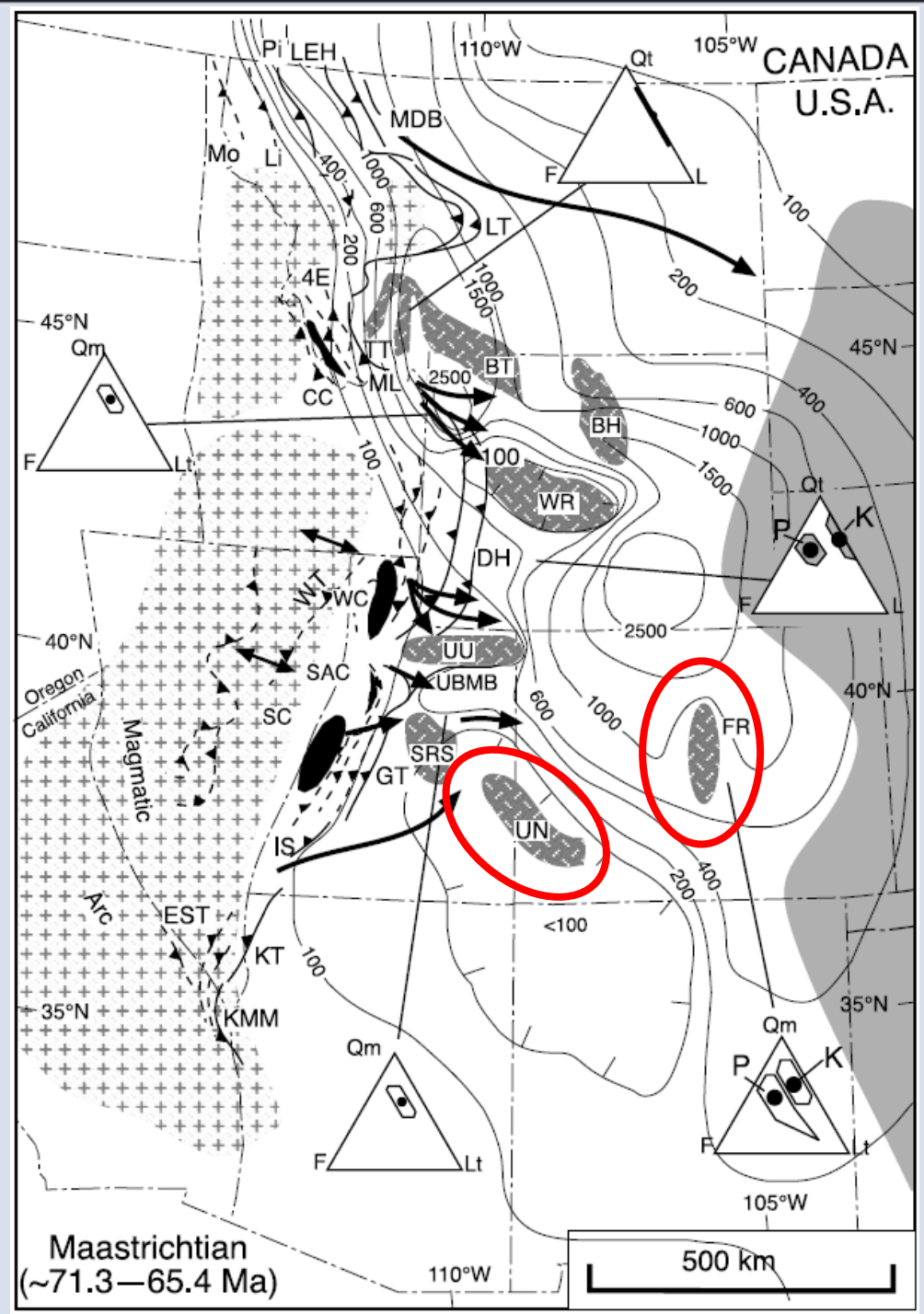
Depositional Strike

- Approx. 60° rotation over 1 Ma
  - (Sandstone intervals 5 – 8)
- Additional 10° over subsequent 1 Ma
  - (Sandstone intervals 8 – 10)



DeCelles (2004)





Conclusions

- We can use regional marine transgressions to constrain complex fluvial systems
  - Start at regional-scale in marine system
  - Follow depositional systems up-dip

- Mesaverde Group appears to be syntectonic (at least partially)
  - Rotation of marine strandlines
  - Changes in mineralogy

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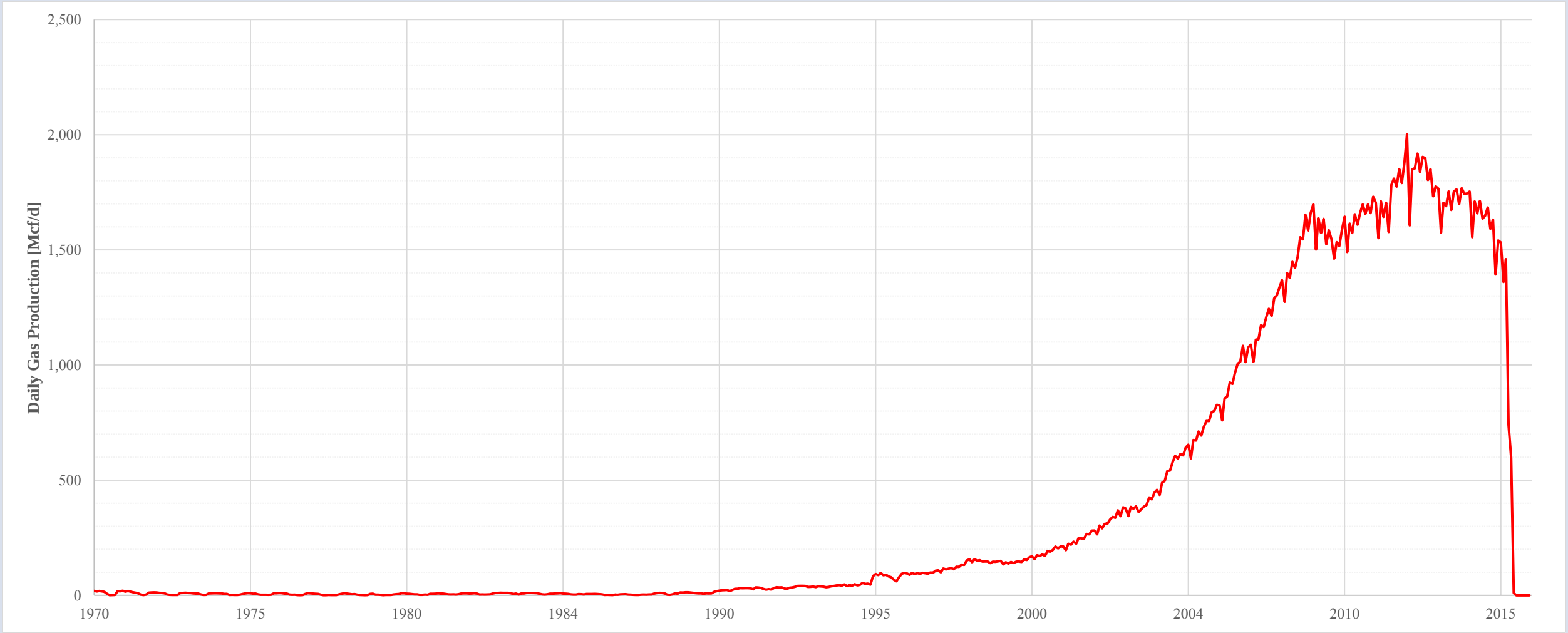
Questions?

EXTRA SLIDES

Gas Production



** Data from IHS Enerdeq (2015)*

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Nomenclature Problems

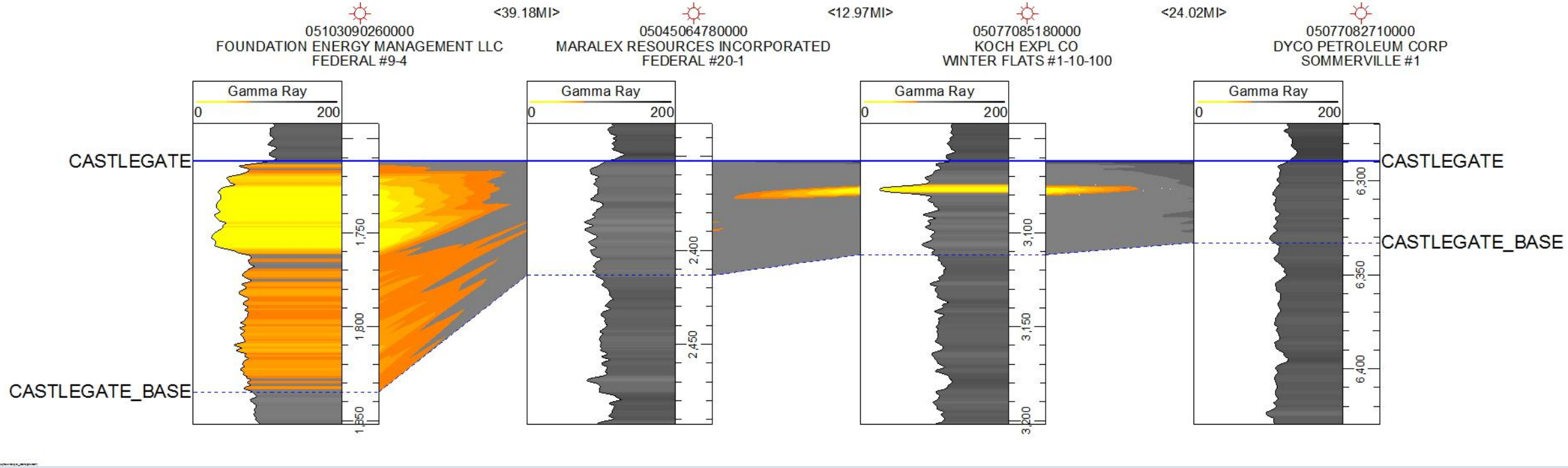
Anderson (2005)	
Ohio Creek Conglomerate	
Williams Fork Fm	Upper Unit
	Coal Unit
	Lower Unit
Sego Sandstone	Upper Sego
	Anchor Mine Tongue
	Lower Sego
Buck Tongue	
Castlegate Sandstone	
Mancos Shale	

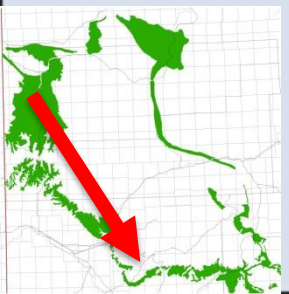
Shaak (2010)	
Ohio Creek Conglomerate	
Williams Fork Fm.	Upper
	Middle
	Lower
lles Fm.	Rollins Ss
	Cozzette Ss
	Corcoran Ss
Sego Sandstone	Upper Sego
	Anchor Mine Tongue
	Lower Sego
Buck Tongue	
Castlegate Sandstone	
Mancos Shale	

Shaak (2010)	
Ohio Creek Conglomerate	
Williams Fork Fm.	Upper
	Middle
	Paonia Shale
	Bowie Shale
lles Fm.	Rollins Ss
	Cozzette Ss
	Corcoran Ss
Sego Sandstone	Upper Sego
	Anchor Mine Tongue
	Lower Sego
Buck Tongue	
Castlegate Sandstone	
Mancos Shale	

Moyer (2011)	
Ohio Creek Conglomerate	
Williams Fork Fm.	Upper (Lion Canyon Ss)
	Middle
	Lower
Iles Fm.	Trout Creek Ss
	Cozzette Ss
Mancos Shale	

(1) Castlegate Sandstone





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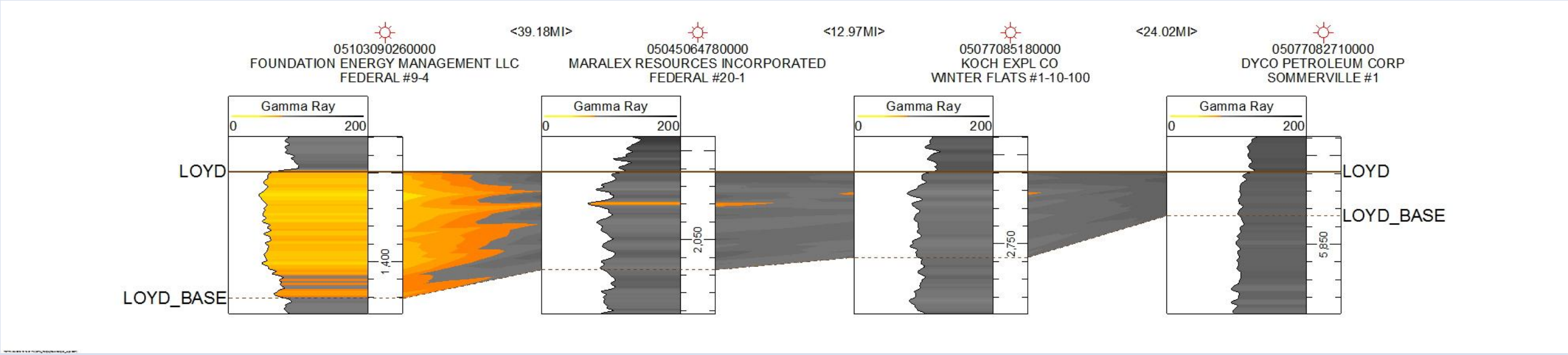
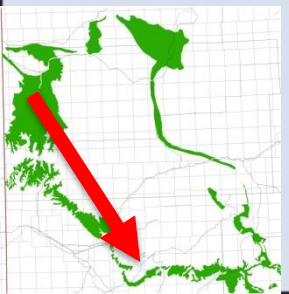
(2) Loyd Sandstone





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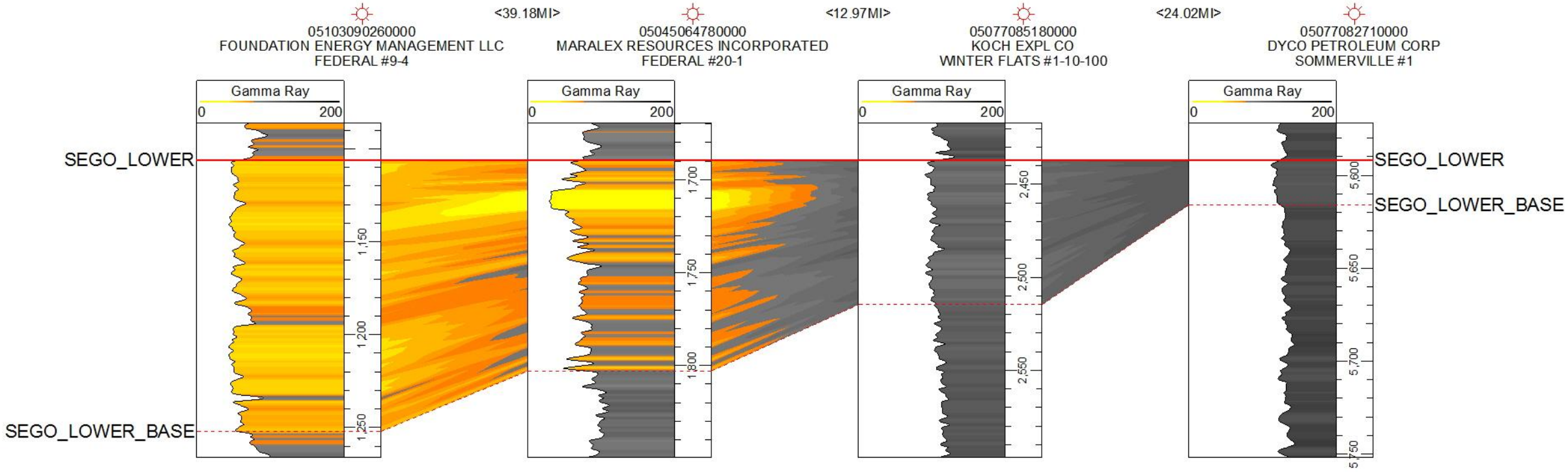
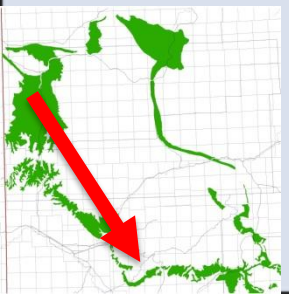
(3) Lower Sego Sandstone





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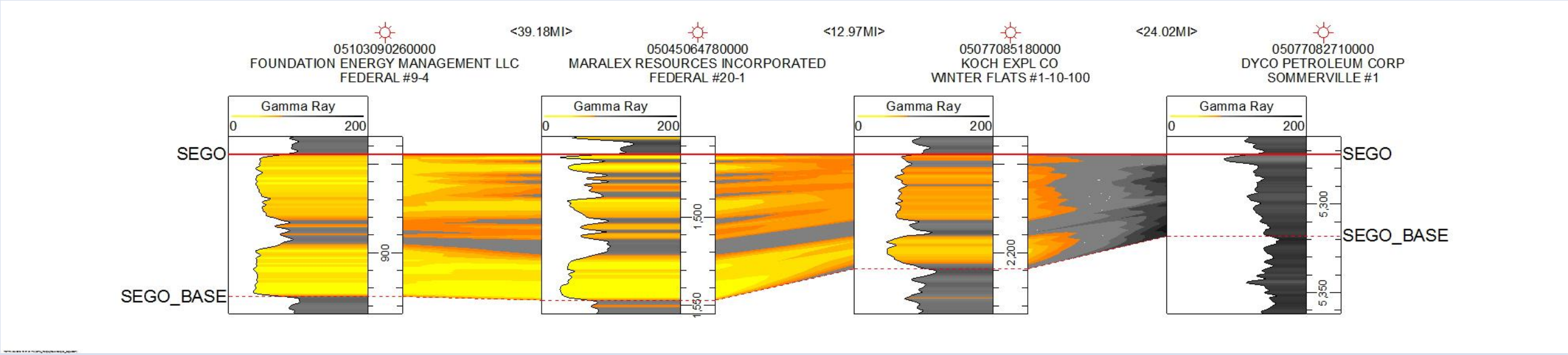

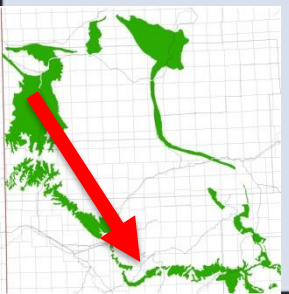

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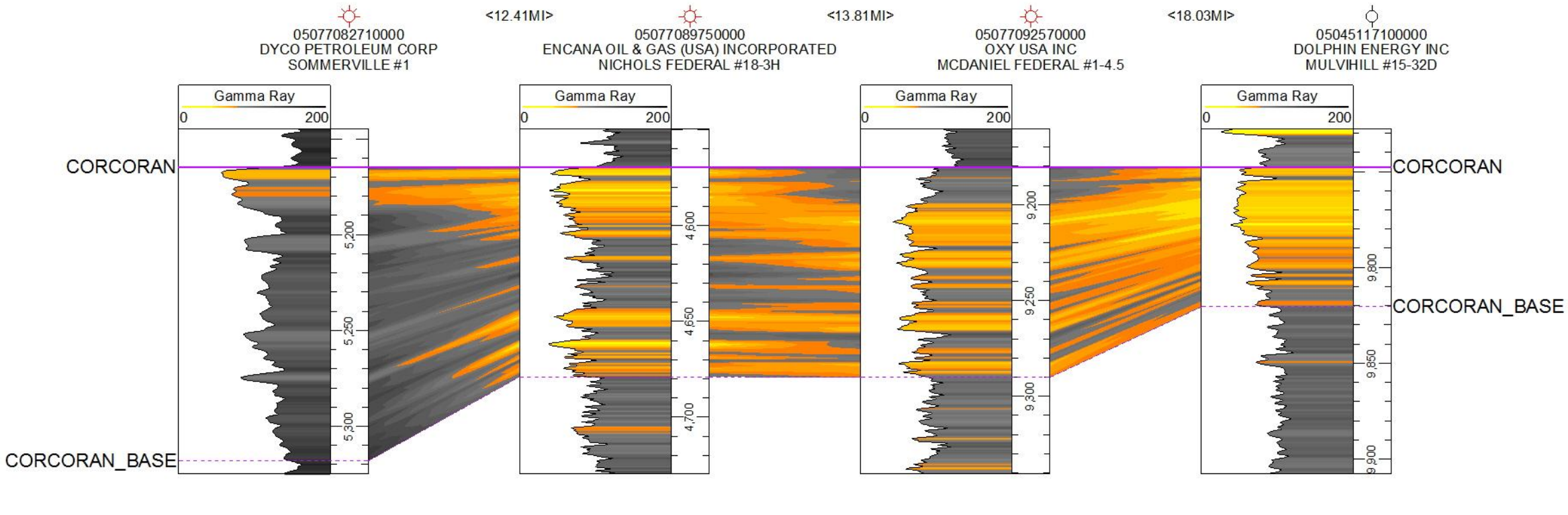
(5) Corcoran Sandstone



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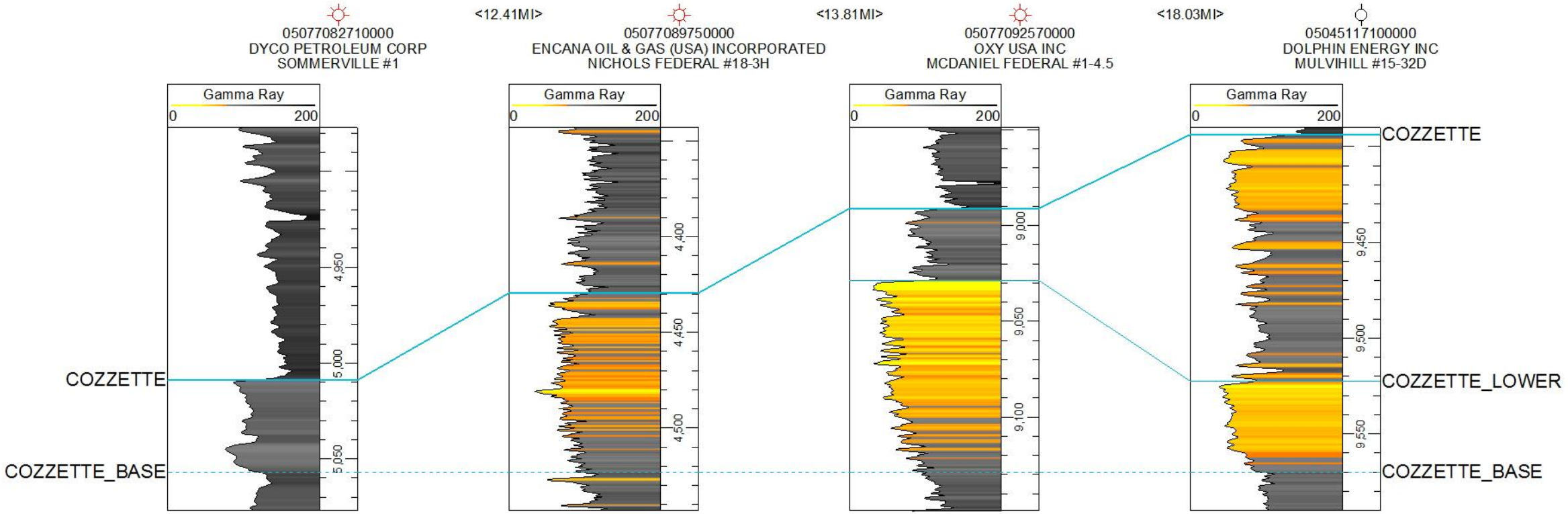
(6) Cozzette Sandstone



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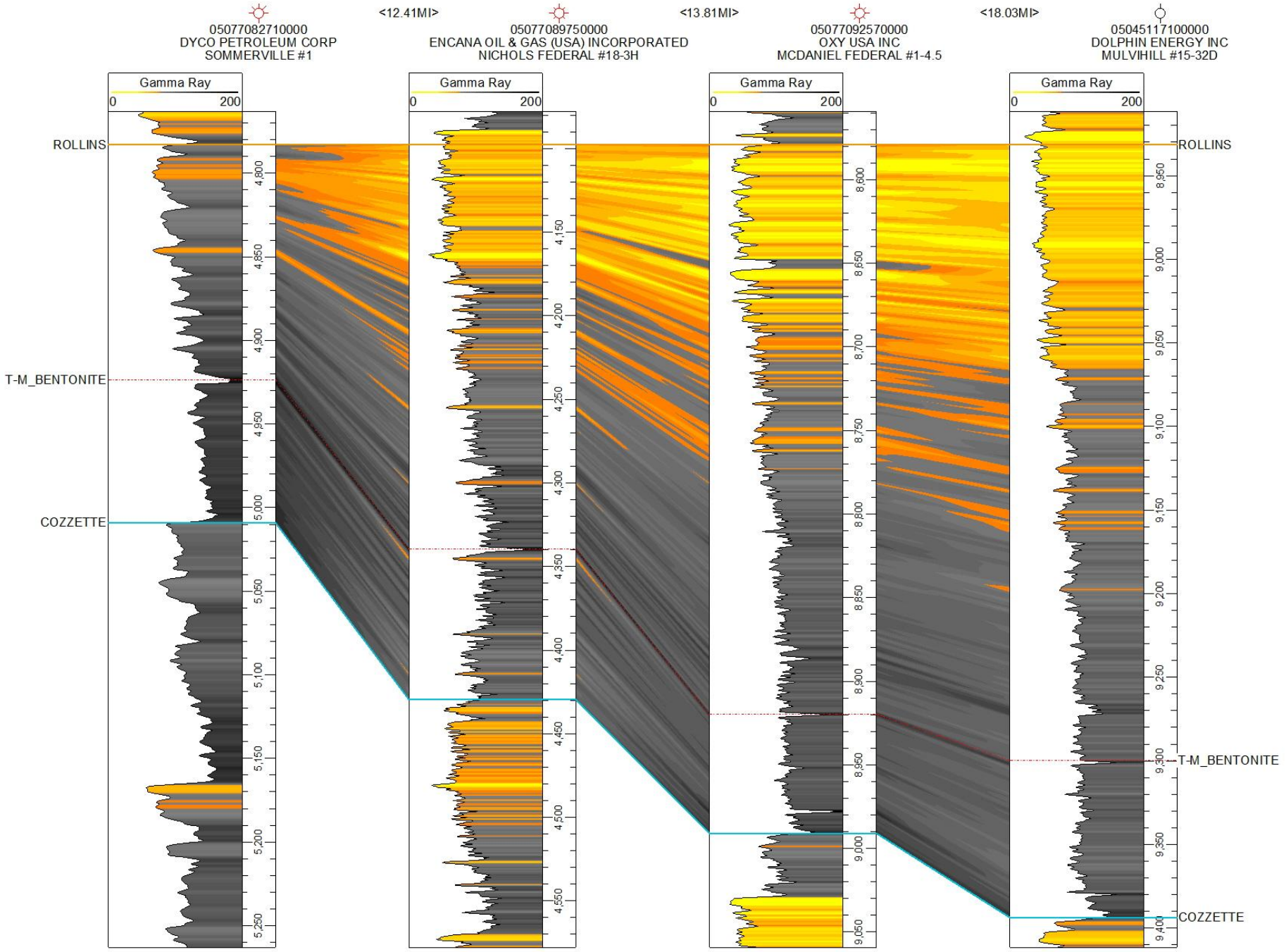
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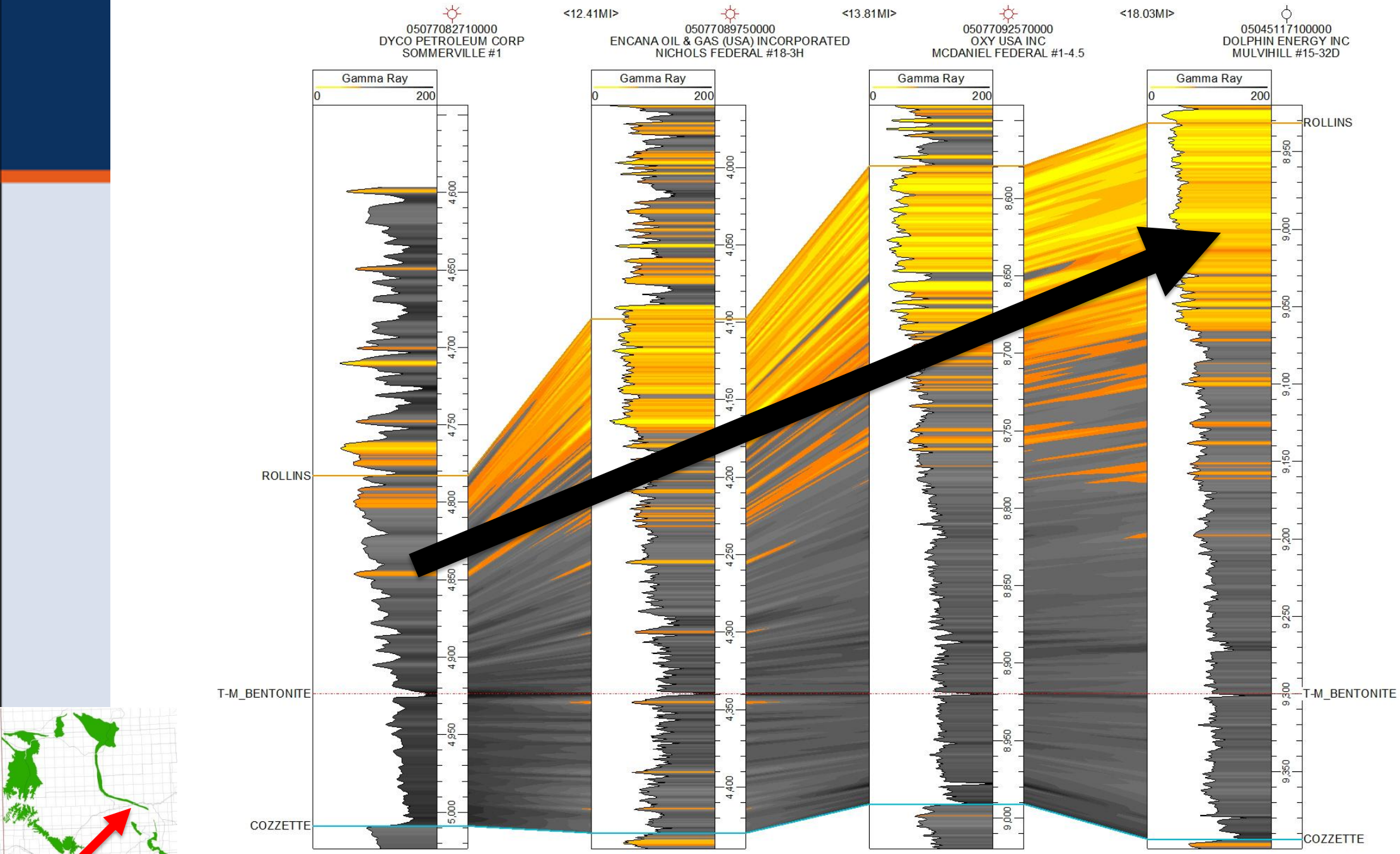
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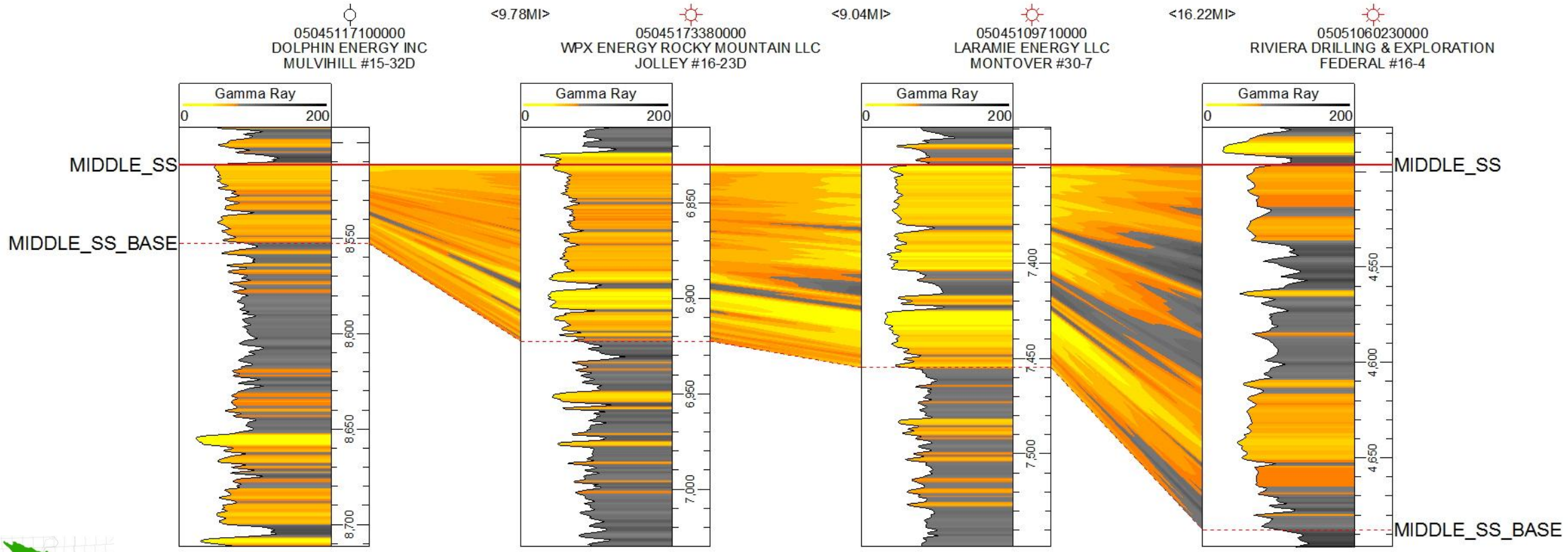
COZZETTE

(8) Middle Sandstone



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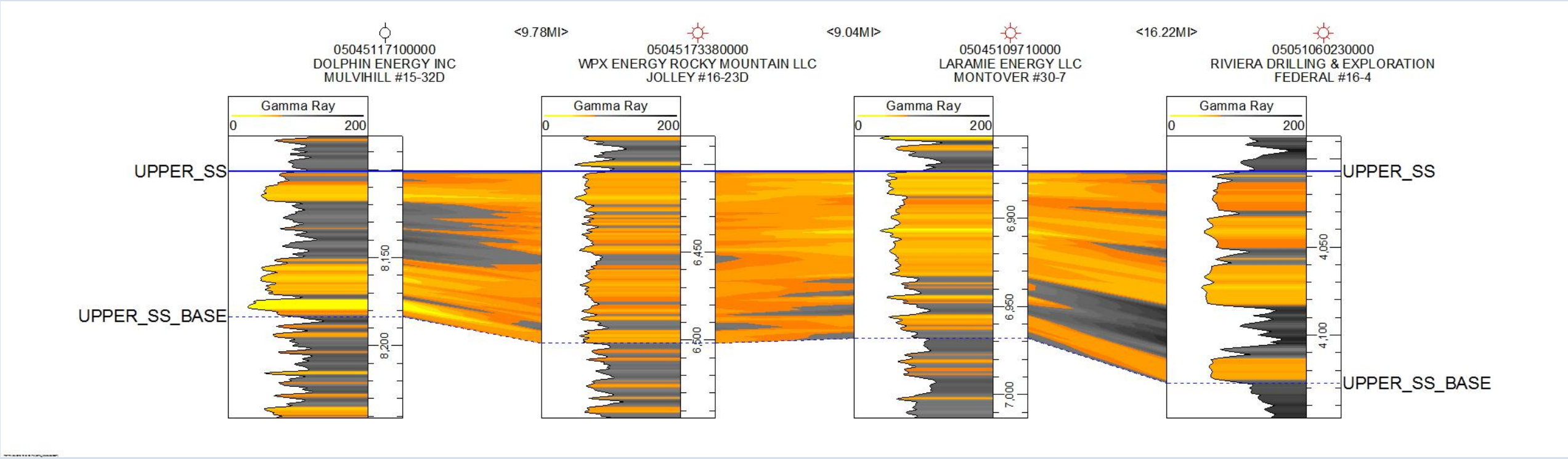
(9) Upper Sandstone



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