

# **Denver Basin Isolated Sandbodies: Signature of Dynamic Subsidence, Laramide Uplifts and Shoreline Transitions\***

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## **Abstract**

A set of six vertically stacked late Campanian isolated sandbodies, previously interpreted as offshore (shelf) bars or shoreface sandstones was studied in outcrops in the Denver Basin. Based on detailed facies analyses we reinterpret the Hygiene, Terry, Rocky Ridge and Laramie Sandbodies as deltaic and the Richards sandbody as estuarine. The riverine origin of these sandbodies is conformed by petrographic observations that indicate relatively coarse grain size (up to medium sand) and relatively immature composition including lithic clasts and feldspar. Several of the sandbodies, especially Hygiene, Terry and Richards indicate strongly tide-influenced to tide-dominated deltaic and estuarine settings. This interpretation is based on ubiquitous occurrence of tidal depositional features like mud-drapes, bidirectional palaeocurrent indicators, compound cross stratification, cyclic changes in cross-strata thickness (neap-spring cyclicity), etc. Rocky Ridge and Larimer Sandstones indicate a stronger (storm) wave influence on deposition. Architecture and stacking pattern of these sandstones is variable and include progradation with flat to falling as well as rising trajectory. In some sandstones, transgressive ravinement surfaces and lag deposits occur at the tops of the deltaic units. Other sandstones are based by landward-stepping transgressive lag deposits.

The deltaic and estuarine nature of these sandbodies indicates episodic shoreline progradation to the Denver Basin area during late Campanian. A general eastward migration of WIS depocenter was predicted by dynamic subsidence models proposed to accompany the change to flat-slab subduction and initiation of the Laramide Orogeny. The Hygiene, Terry, Rocky Ridge and Larimer Sandstones each reflect eastward migration of shorelines. In contrast, the estuarine Richards Sandstone occurs above a regressive-transgressive turnaround and indicates the beginning of the Almond landward-stepping trend and Lewis Sea transgression. We assign the significant tidal influence also to the initiation of the differential Laramide subsidence that created local irregularities in the WIS basin that have been suggested to be especially significant during relative sea-level lowstands.

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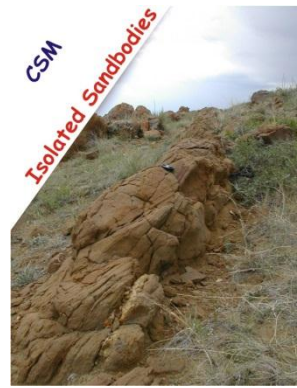
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# Denver Basin Isolated Sandbodies: Signature of dynamic subsidence, Laramide uplifts and shoreline transitions

**Piret Plink-Bjorklund and Louise Kiteley**

**Colorado School of Mines**

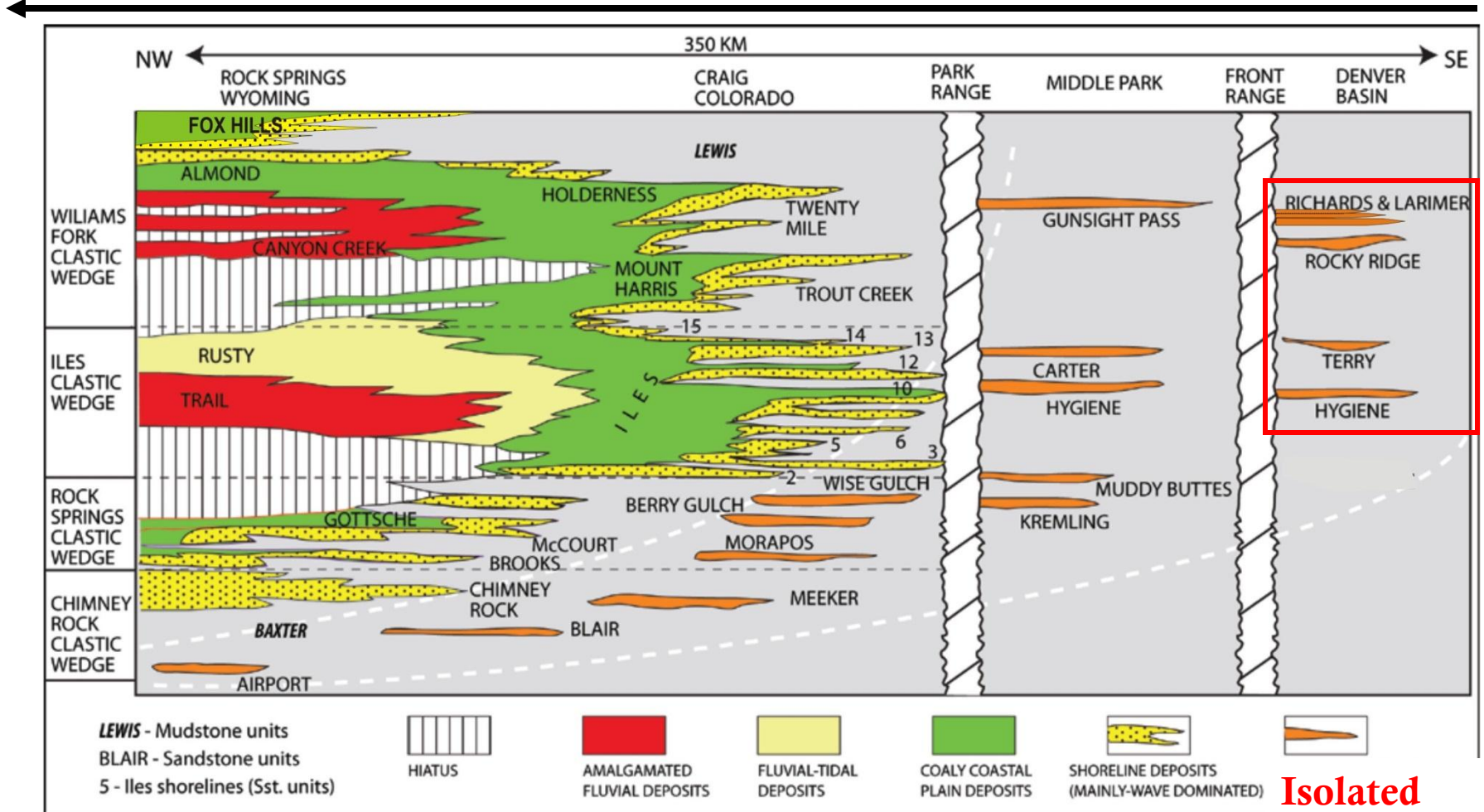
**[pplink@mines.edu](mailto:pplink@mines.edu)**



## Isolated sandbodies:

**enigmatic marine or marginal marine coarse clastic deposits  
encased in offshore or shelf mudstone – offshore bars?**

**500 km**



## Isolated sandbodies

# Problem:

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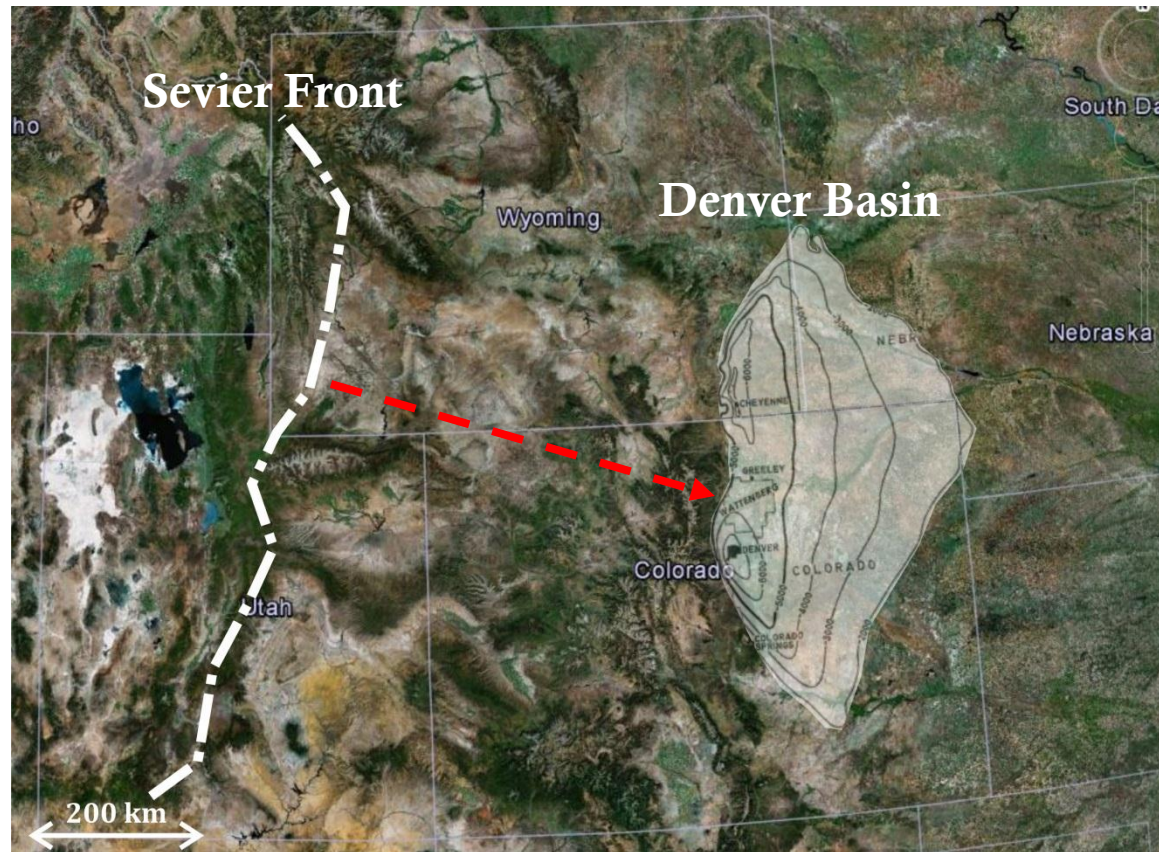
- **Originally interpreted as offshore bars, but most WIS isolated sandbodies have been reinterpreted as:  
FRST, LST or TST shorefaces  
incised valleys  
FRST-LST deltas**
- **Denver Basin isolated sandbodies still considered offshore bars**



# Questions:

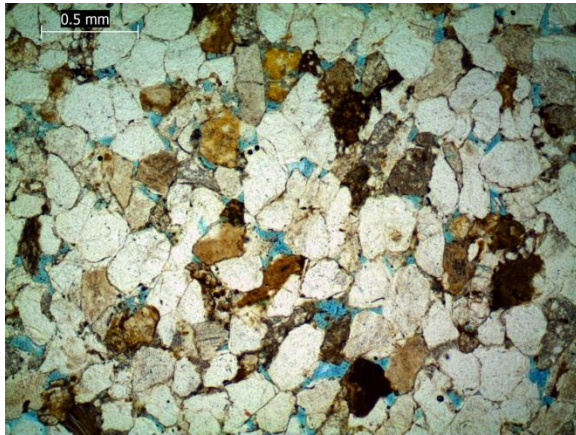
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1. What are the Denver Basin isolated sandbodies?
2. Why are they out in the Denver Basin so far from the Sevier front where the foredeep should be?
3. Why are so many isolated sandbodies strongly tide influenced/ dominated?
4. Is that important?
5. Why are these sandbodies N-S oriented?



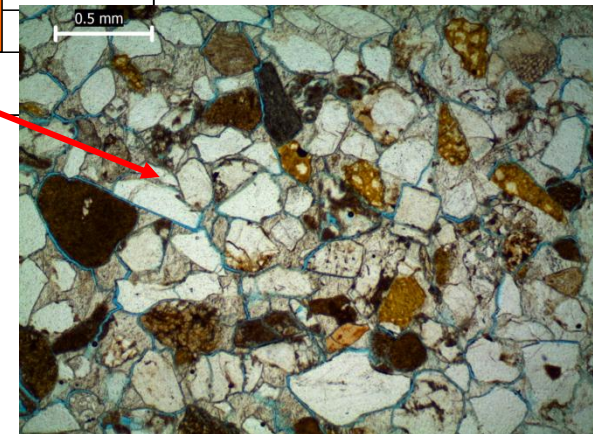
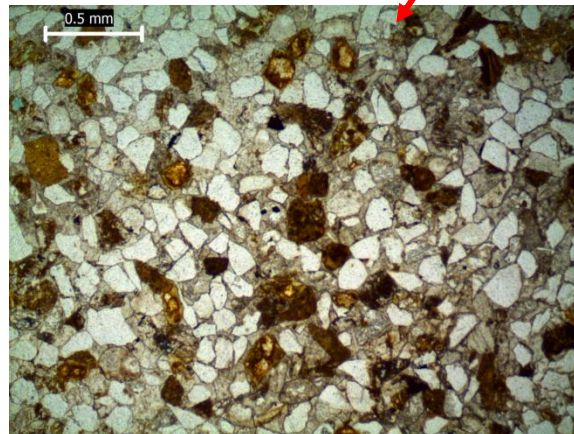
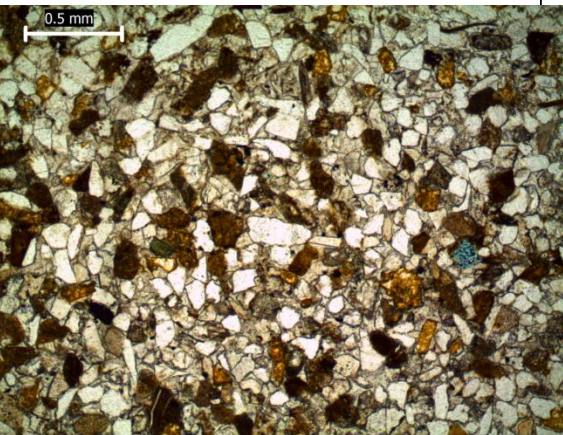
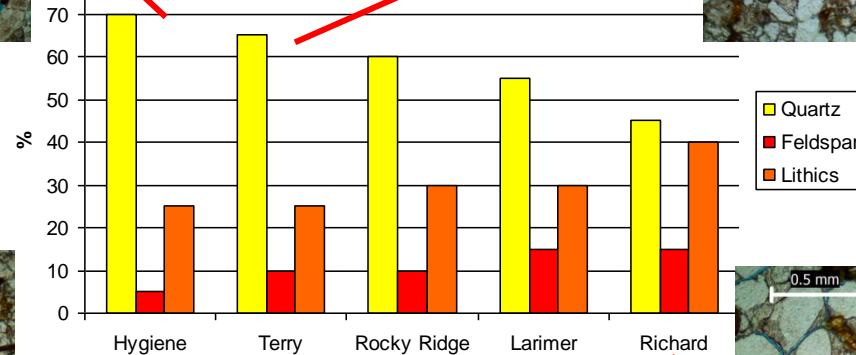
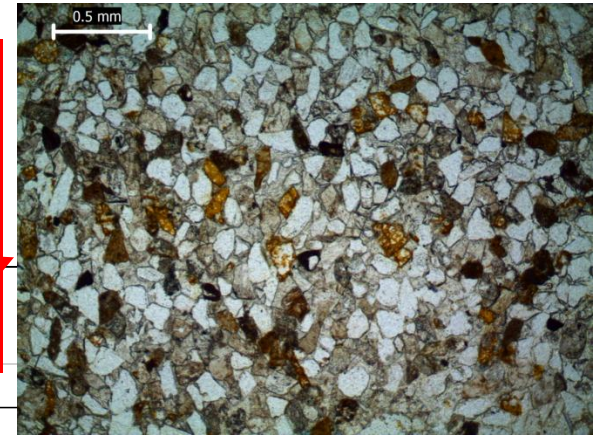


# Denver Basin isolated sandbodies: Composition, textures



**Compositionally &  
texturally immature**

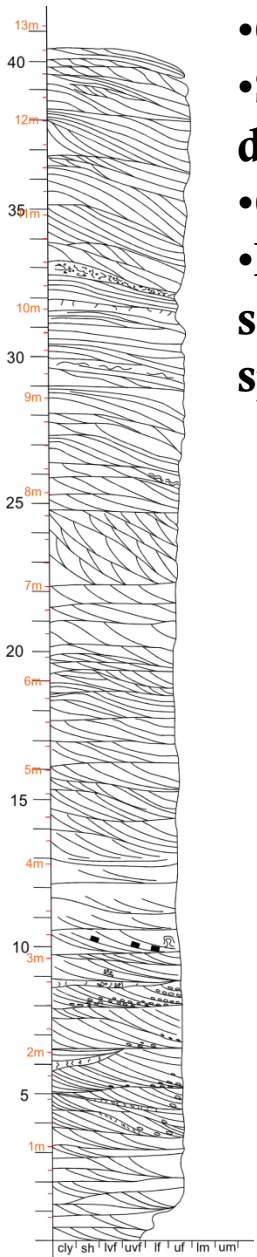
**= Fluvial origin**





# Denver Basin isolated sandbodies: sedimentary structures, geometry

- Clinoform sets
- Steep in proximal position, gentler downcurrent (southward)
- Coarsening-up
- Proximal sandy facies: cross stratified, sigmoidal, compound, mud drapes, neap-spring cyclicity





# Denver Basin isolated sandbodies: sedimentary structures, geometry

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- Clinoforms
- Steep in proximal position, gentler downcurrent (southward)
- Coarsening-up
- Proximal sandy facies: cross stratified, sigmoidal, compound, mud drapes, neap-spring cyclicity
- Distal facies: heterolithic, thinly bedded, flaser, wavy, lenticular bedding, neap-spring cyclicity

**Tidal deposition**

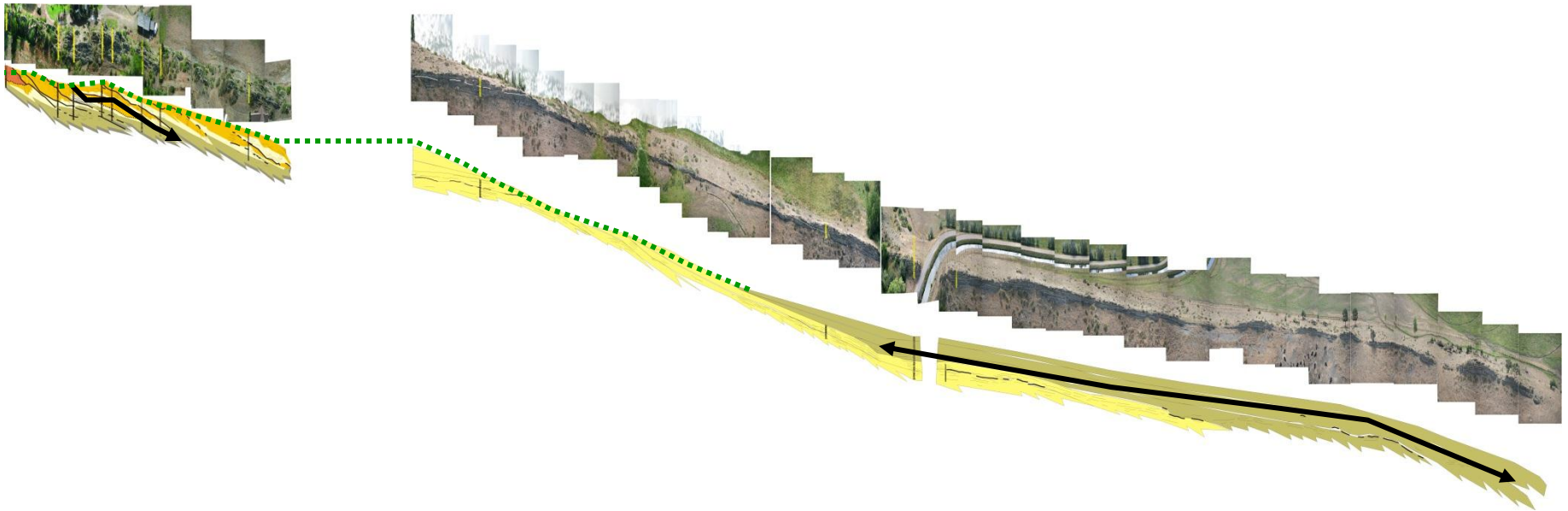


**Fluvial material +  
Tidal deposition +  
Progradational clinoform sets =  
Tide-dominated deltas**

# Denver Basin isolated sandbodies: outcrop architecture - Hygiene

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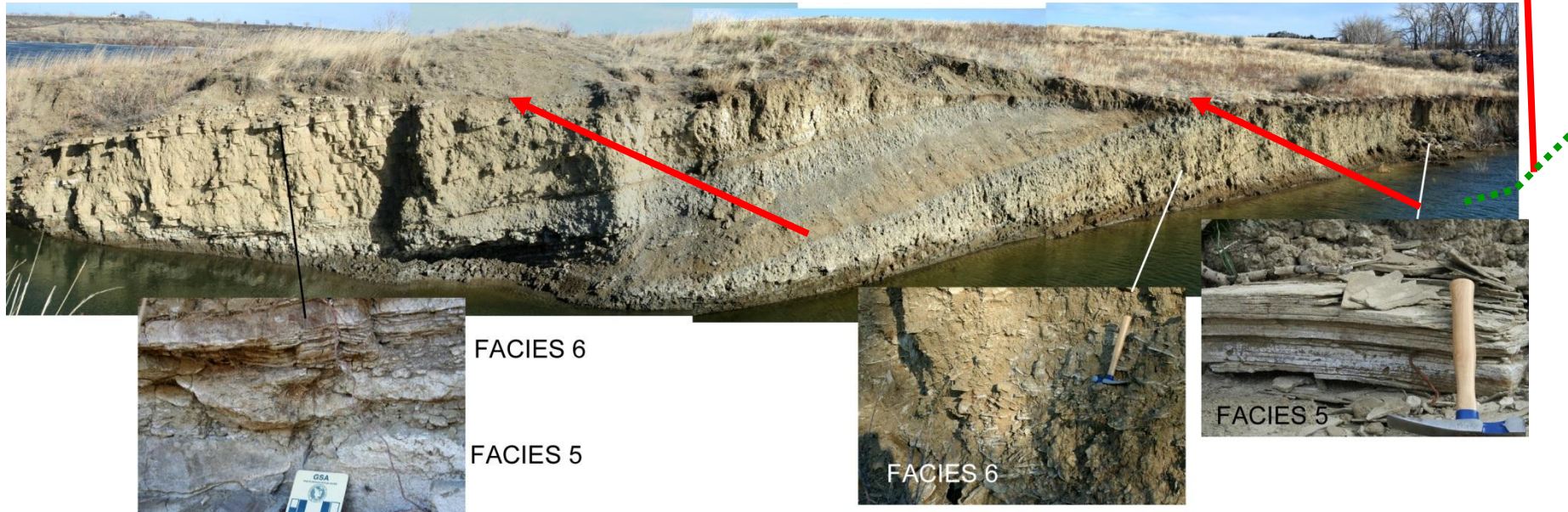
- Single progradational clinoform set in northern part of outcrop belt
- Multiple clinoform sets in southern part, onlap the top of the single clinoform set
- Top eroded by transgressive ravinement (lag, glauconite)
- FRST – LST delta progradation with transgressive reworking





# Denver Basin isolated sandbodies: outcrop architecture - Terry

- Multiple progradational clinoform sets in outcrop belt
- Based by a transgressive lag sandstone with phosphate nodules
- In outcrop: based by ravinement surface, LST delta



FACIES 6

FACIES 5

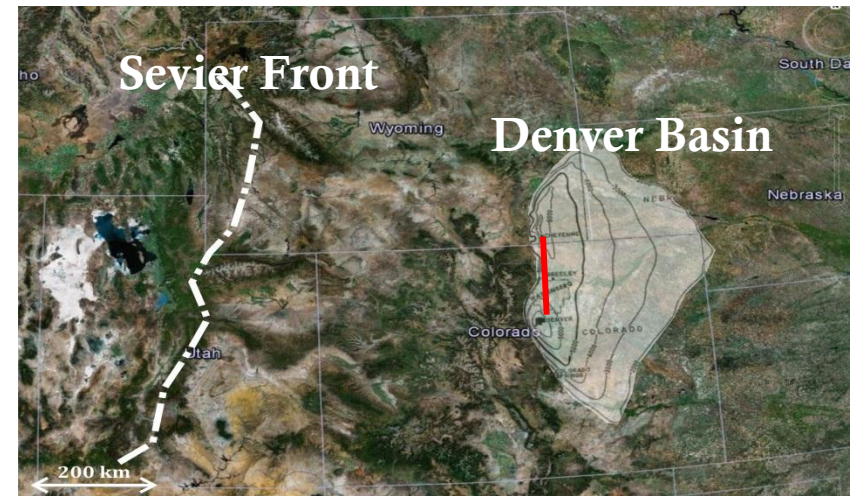
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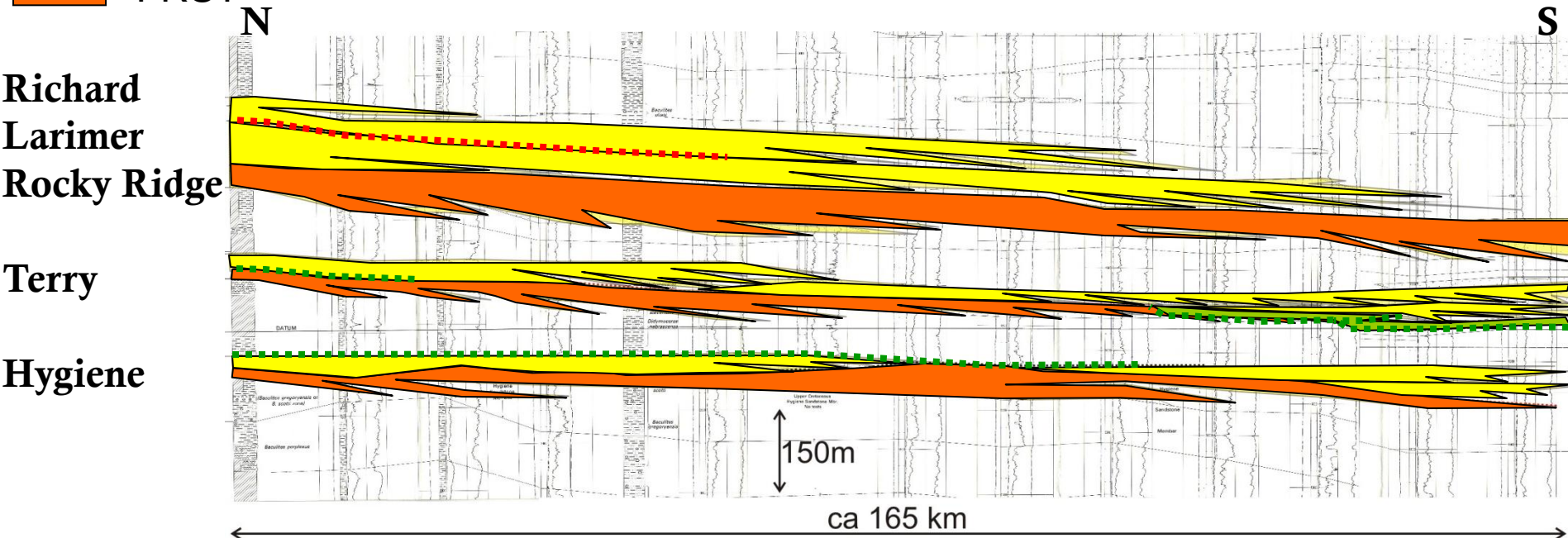


# Denver Basin isolated sandbodies: subsurface architecture

**Internally complex FRST,  
LST deltas;  
Transgressive reworking  
Prograde N-S**

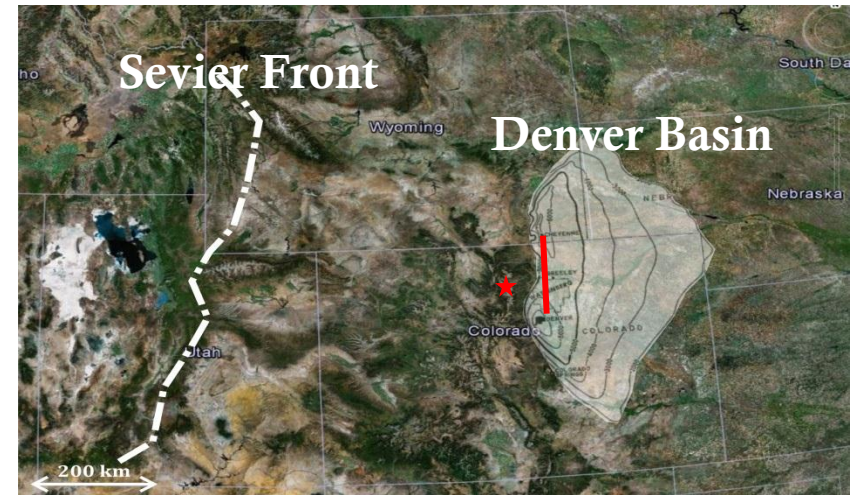


 LST  
 FRST



# Denver Basin isolated sandbodies: architecture towards W

West, across the Front Range:



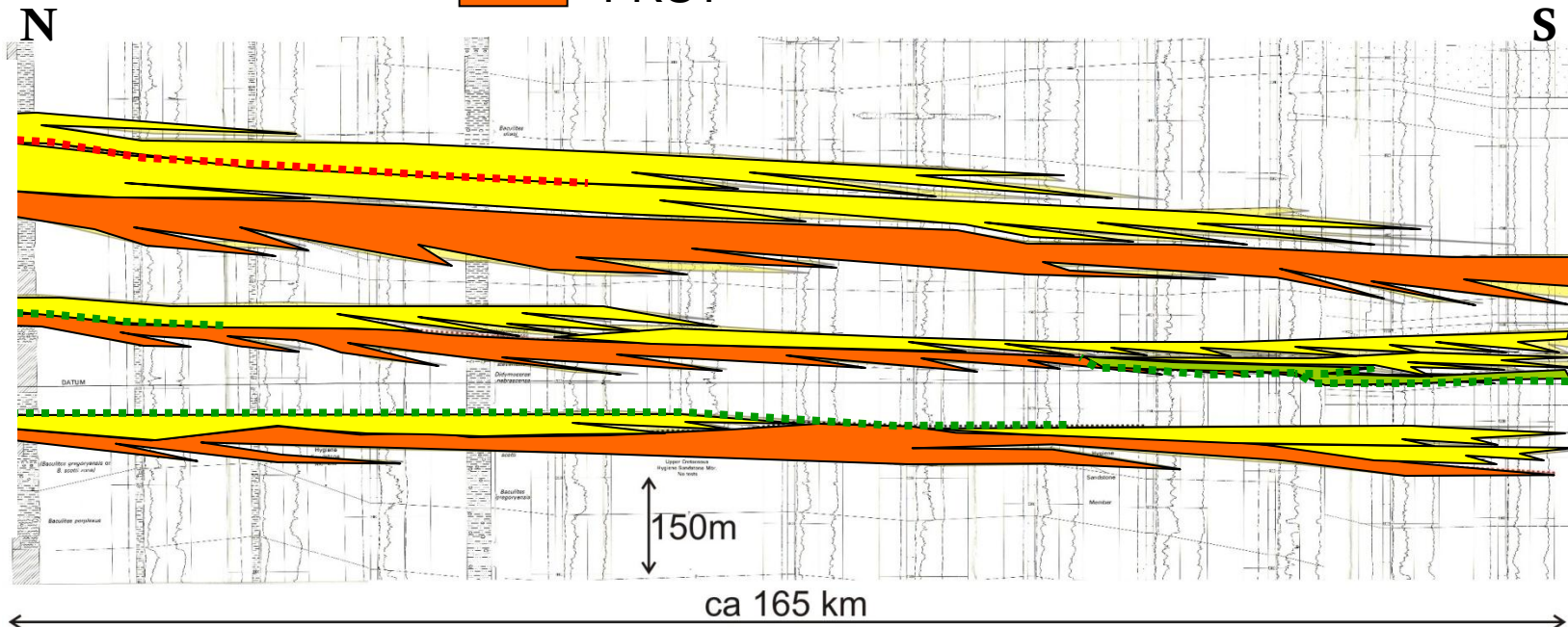
Middle  
Park

LST  
FRST

Gunsight  
Pass

Carter

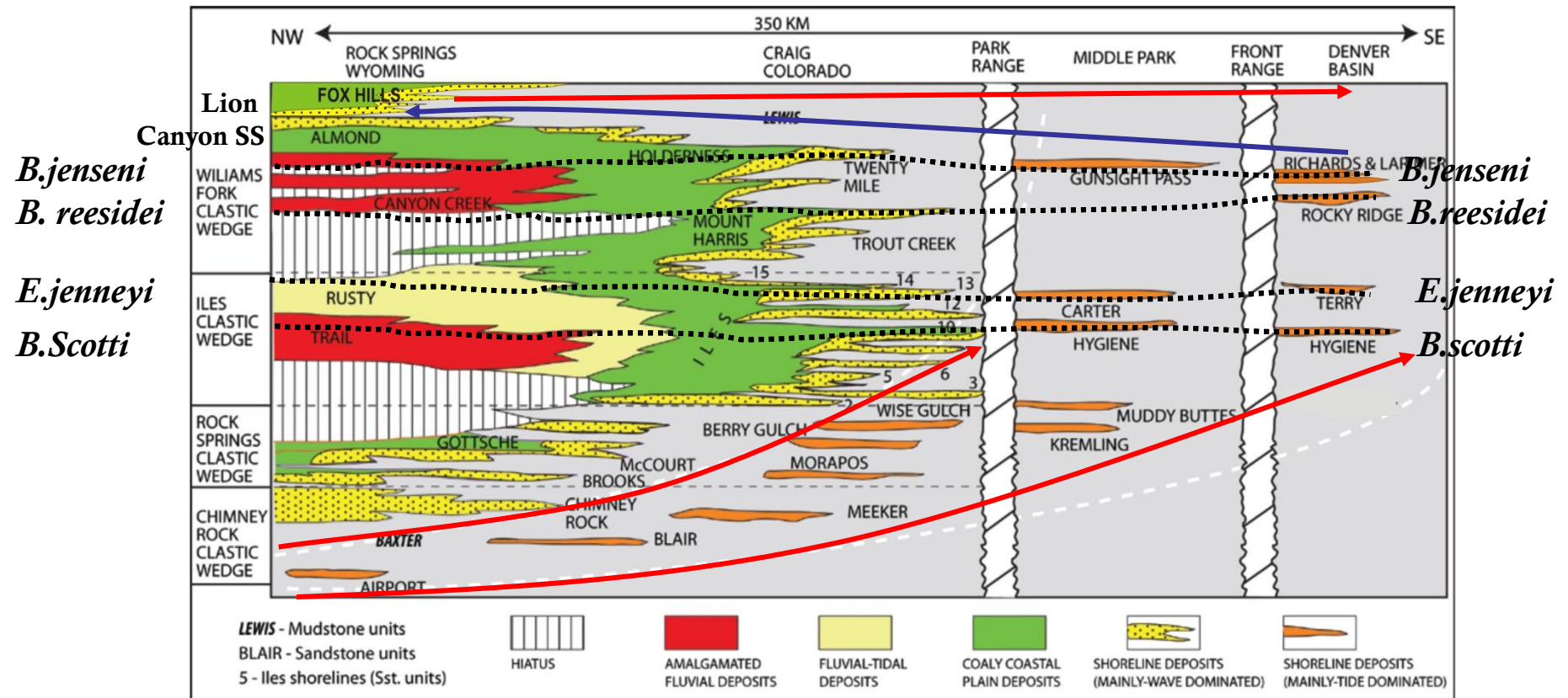
Hygiene





# Why are they as far east as in Denver Basin?

1. Related to LST shoreline transitions of 3<sup>th</sup> order clastic wedges; erosion and bypass further west
2. Eastward migration of the WIS depocenter: lack of accommodation in W
3. Almond backstepping

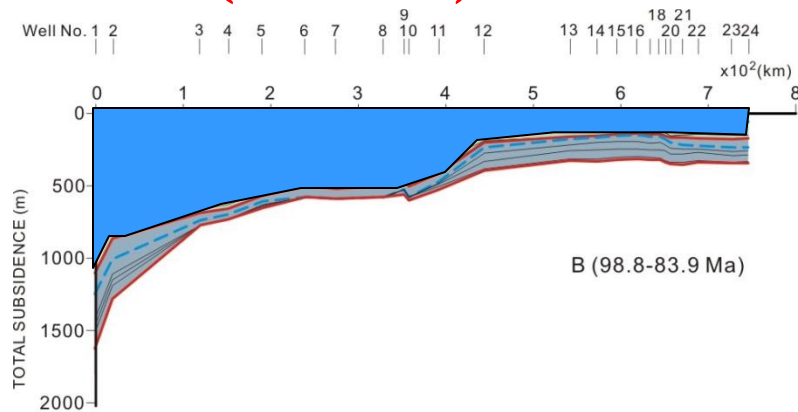




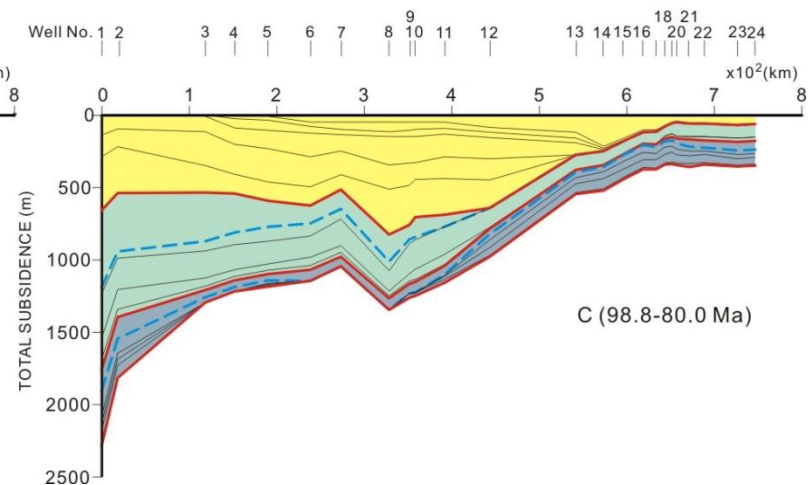
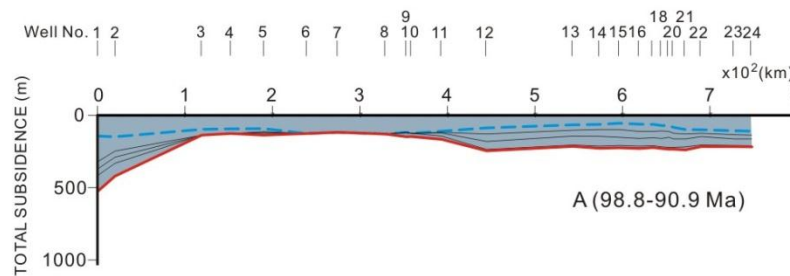
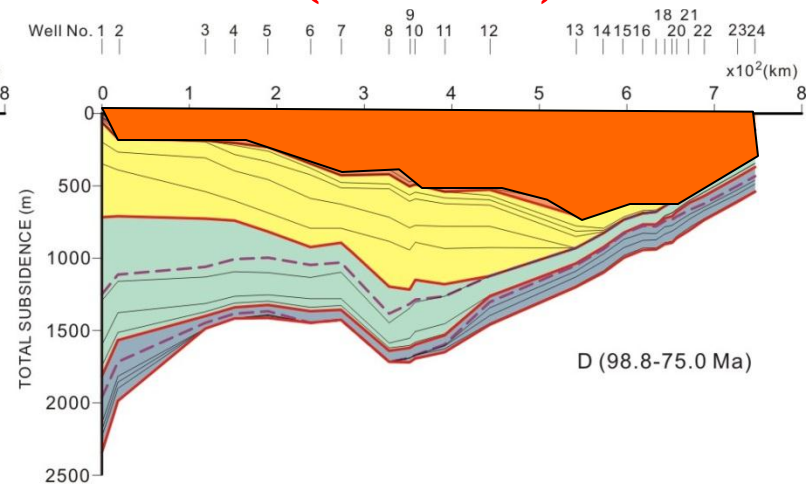
# Why are they as far east as in Denver Basin?

Lack of accommodation in west + depocenter migration towards east

**Foredeep basin  
(90-84 Ma)**

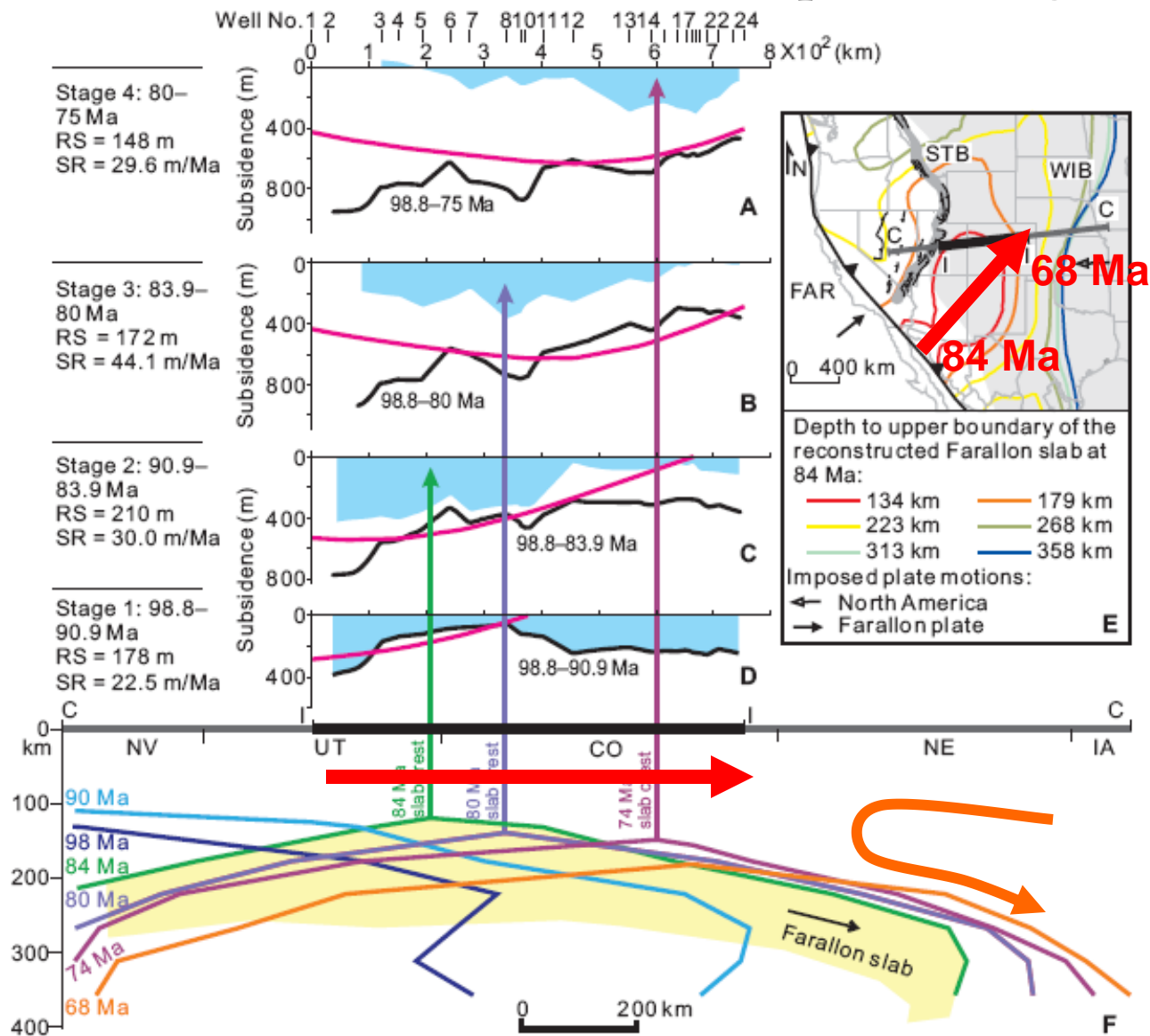


**Eastward deepening basin  
(80-75 Ma)**



# Why are they as far east as in Denver Basin?

Lack of accommodation in west + depocenter migration towards east



Liu et al, 2011

**NE relative motion of the subducted oceanic Shatsky plateau**  
(Liu et al., 2010)

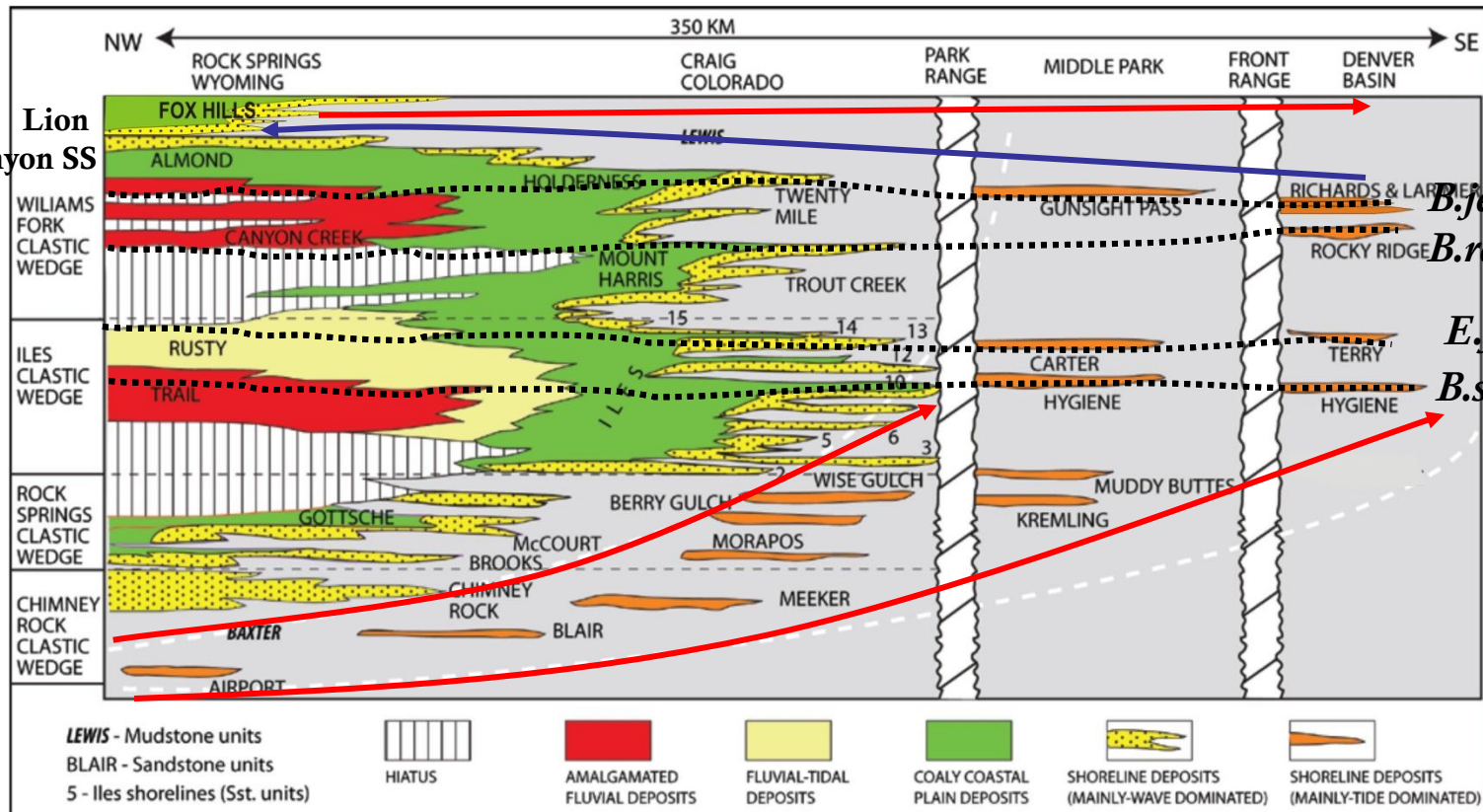
**Eastward migration of subduction slab crest = eastward migration of dynamic subsidence**  
(Liu et al., 2011)

# Why are the isolated sandbodies so tide influenced/dominated:



1. Related to LST in WIS: **Shallow, narrow basin**  
**= wave energy dissipation & amplification of tides**

Lion  
Canyon SS  
*B.jenseni*  
*B.reesidei*  
*E.jenneyi*  
*B.Scotti*

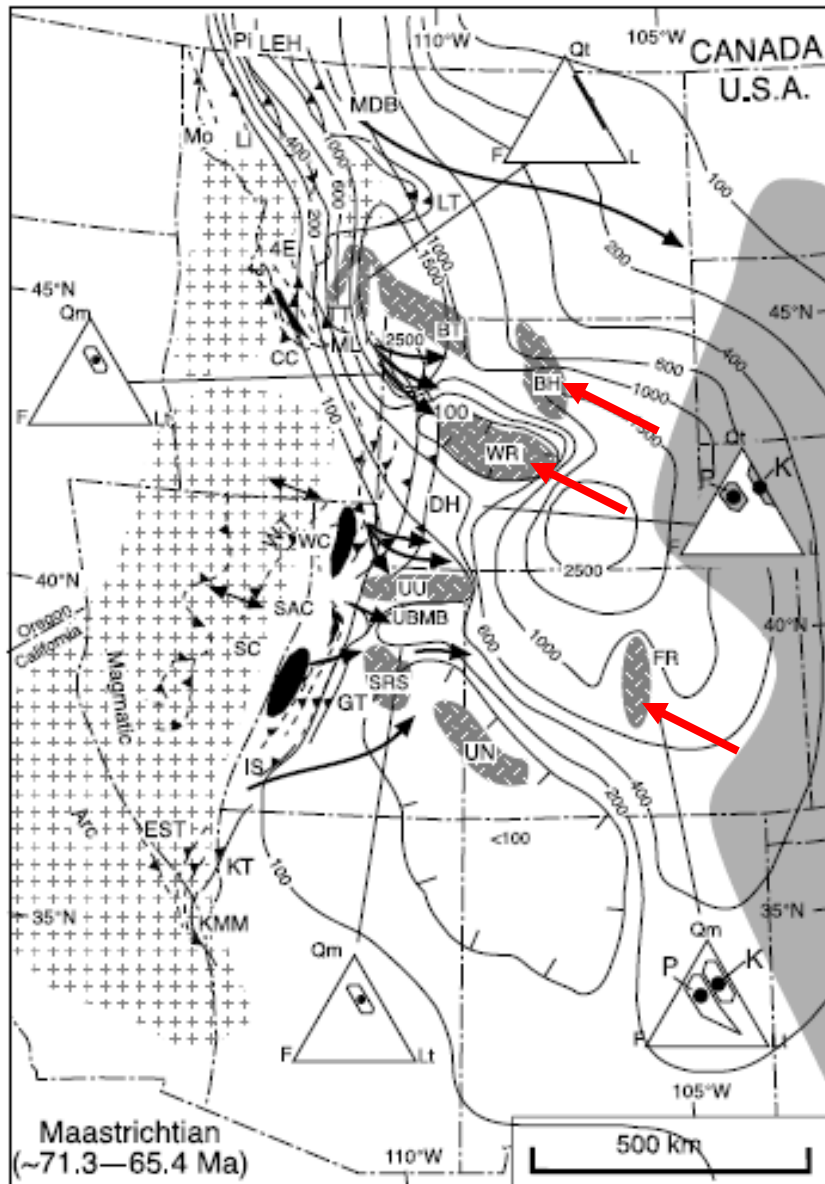


*B.jenseni*  
*B.reesidei*  
*E.jenneyi*  
*B.Scotti*

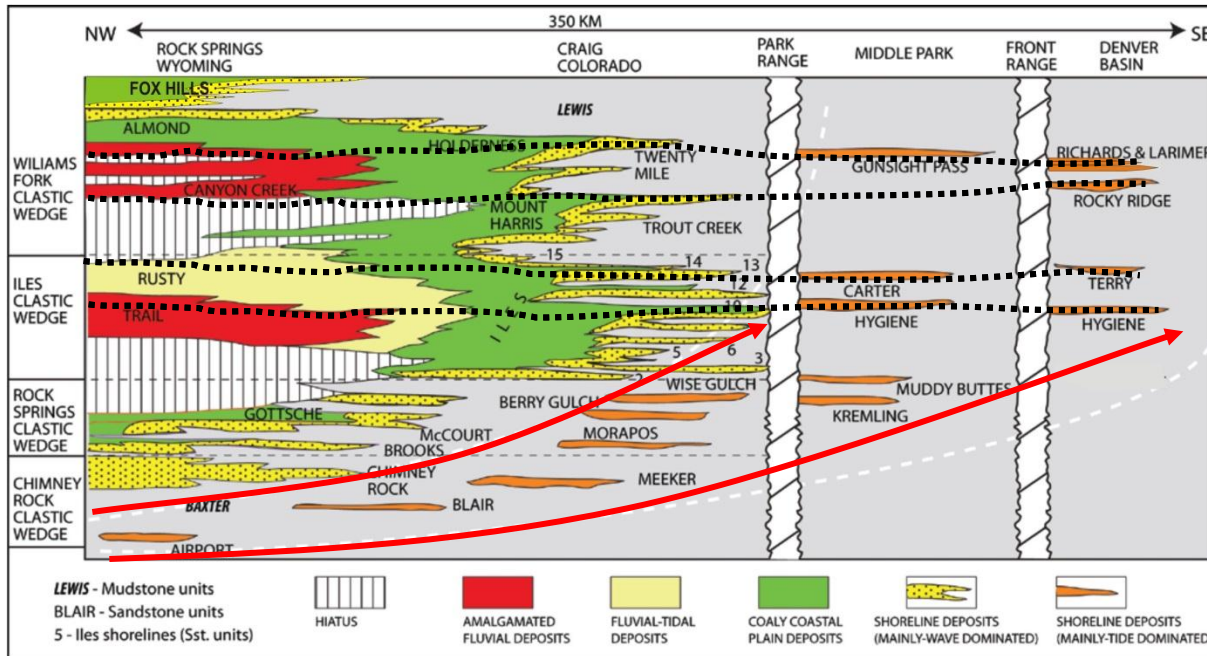


# Why are the isolated sandbodies so tide influenced/dominated:

2. Developing Laramide structures:  
increased irregularity in the WIS  
=further wave energy dissipation & amplification of tides

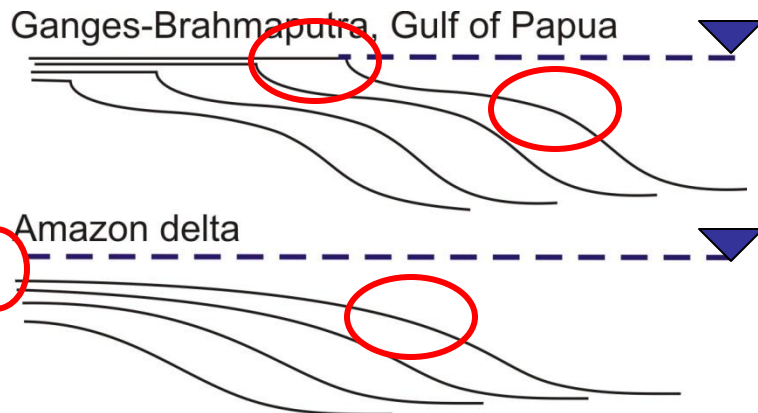


# Are tides important?



Tide-dominated isolated sandbodies **prograde eastward at higher rate** than the corresponding fluvial/wave-dominated shorelines

## Modern tide-dominated deltas



Modern strongly tide-influenced/dominated delta fronts **prograde subaqueously** at higher rates than their corresponding shorelines:

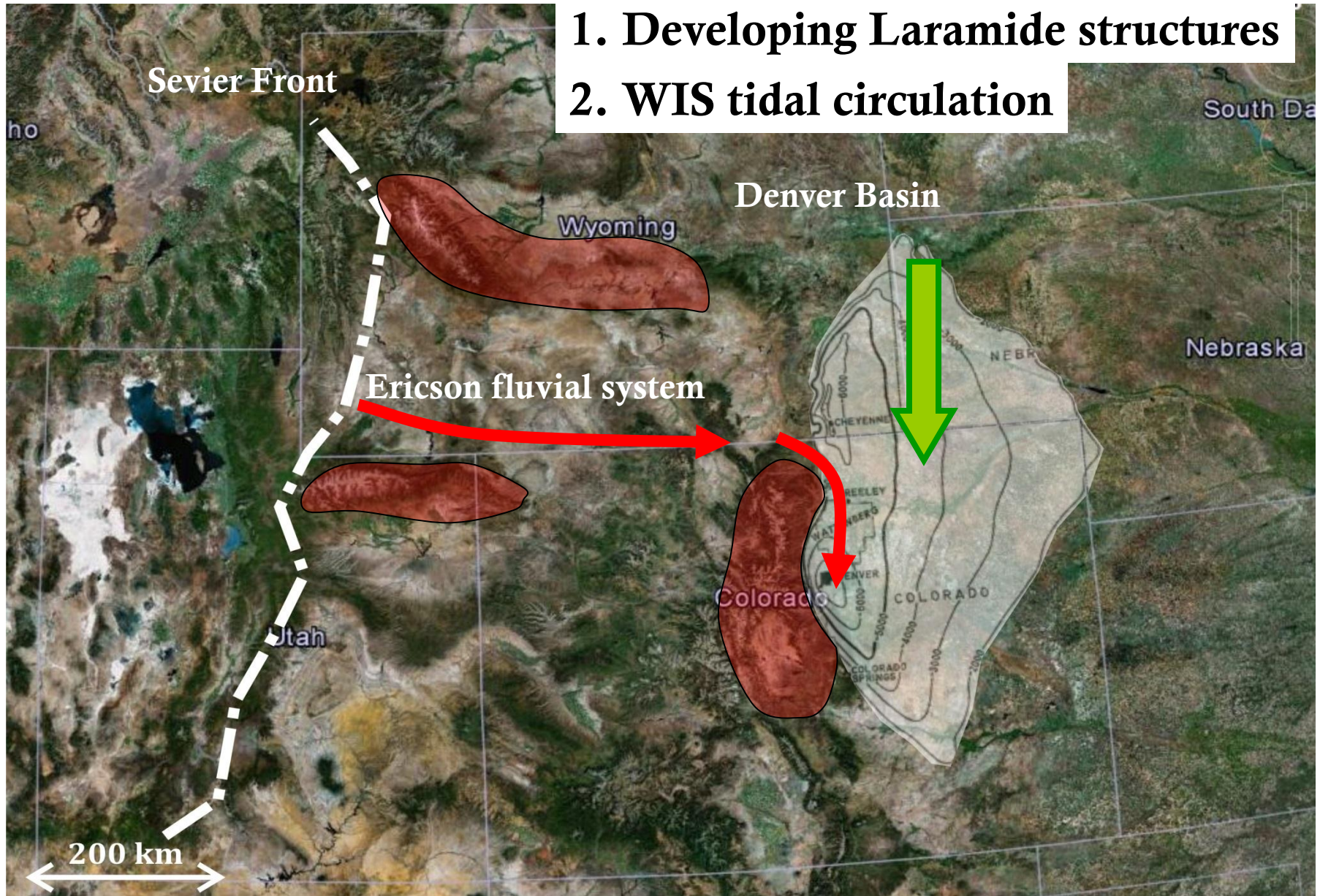
**Higher tidal energy during FRST-LST increases progradation distance of delta fronts, compared to shoreline**

**No topset facies**



# Why are isolated sandbodies north-south oriented?

1. Developing Laramide structures
2. WIS tidal circulation





# Conclusions:

1. Denver Basin isolated sandbodies are **internally complex FRST-LST tide-dominated deltas**
  1. Occur so far east due to
    - **Eastward migration of WIS depocenter** following the migration of **dynamic subsidence** or/and the **relative motion of the Shatsky plateau**
    - **Eastward transits of 3<sup>rd</sup> order LST shorelines**
    - **High delta-front progradation rates of tide-dominated deltas**
  3. Are so strongly tide-influenced due to
    - **Shallow, narrow seaway**
    - **Developing Laramide structures**
  4. Are N-S oriented due to:
    - **Developing Laramide structures**
    - **North to south tidal circulation**

