

# **Channels, Overbanks and Paleosols: The Relationship Between Climate, Base Level and Lithofacies Heterogeneity Within the Triassic Sonsela Member, PFNP Arizona\***

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## **Abstract**

Sedimentologic, stratigraphic and paleopedologic investigations of the Late Triassic Sonsela Member in the Petrified Forest National Park (PFNP) reveal a cyclic succession of alluvial deposits and bounding paleosols. Sedimentologic data from eight measured sections are used to characterize the spatial distribution of alluvial architectural elements along a continuous 1.2 km Sonsela outcrop. Architectural elements include downstream accretion, lateral accretion, crevasse splay, and overbank deposits that indicate a mixed-load fluvial system. Within the measured sections, paleosol profiles were repetitively described along the bounding discontinuity surfaces that partition the stratigraphic succession into seven fining-upward meter-scale depositional cycles. Lithofacies and paleosols were walked-out to establish distributions and variability within cycles. Cycles systematically stack in response to what was a longer-period variation in accommodation. Cycles at the base of the succession are thick and dominated by extensive downstream-accretion deposits, and associated bounding discontinuities have weak paleosol development. Cycles in the upper portion of the succession are thinner and dominated by more discontinuous lateral accretion, crevasse splay and overbank deposits, and bounding discontinuities have better developed, well-drained paleosols. The uppermost portion of the succession is characterized by very thin cycles with discontinuous channel sandstones, and bounding paleosols that are well developed and poorly drained. Point counts of porosity within channel facies and subsequent transform to permeability (based on grain size and sorting) provides a 2D depiction of the lateral variability in reservoir quality as correlated to architectural element. Flow baffles between cycles coincide with paleosols owing to their low permeability silty clay to clayey-silt texture. The reduction in both reservoir quality and continuity within the study interval was produced by fluvial aggradation during an episode of long-term accommodation deceleration within a period of uniform climatic conditions.

### **Selected References**

Dickinson, W.R. and G.E. Gehrels, 2008, Sediment delivery to the cordilleran foreland basin; insights from U-Pb ages of detrital zircons in Upper Jurassic and Cretaceous strata of the Colorado Plateau: *American Journal of Science*, v. 308/10, p. 1041-1082.

Keogh, K.J., A.W. Martinius, and R. Osland, 2007, The development of fluvial stochastic modeling in the Norwegian oil industry; a historical review, subsurface implementation and future directions: *Sedimentary Geology*, v. 202-1/2, p. 249-268.

Lawton, T.F., 1994, Tectonic setting of Mesozoic sedimentary basins, Rocky Mountain region, United States, *in* M.V. Caputo, J.A. Peterson, and K.J. Franczyk, (eds.) *Mesozoic systems of the Rocky Mountain region, USA*: SEPM, Rocky Mountain Section, p. 1-26.

Lucas, S.G. and A.B. Heckert, 1996, Vertebrate biochronology of the Late Triassic of Arizona: *Proceedings Fossils of Arizona Symposium*, v. 4, p. 63-81.

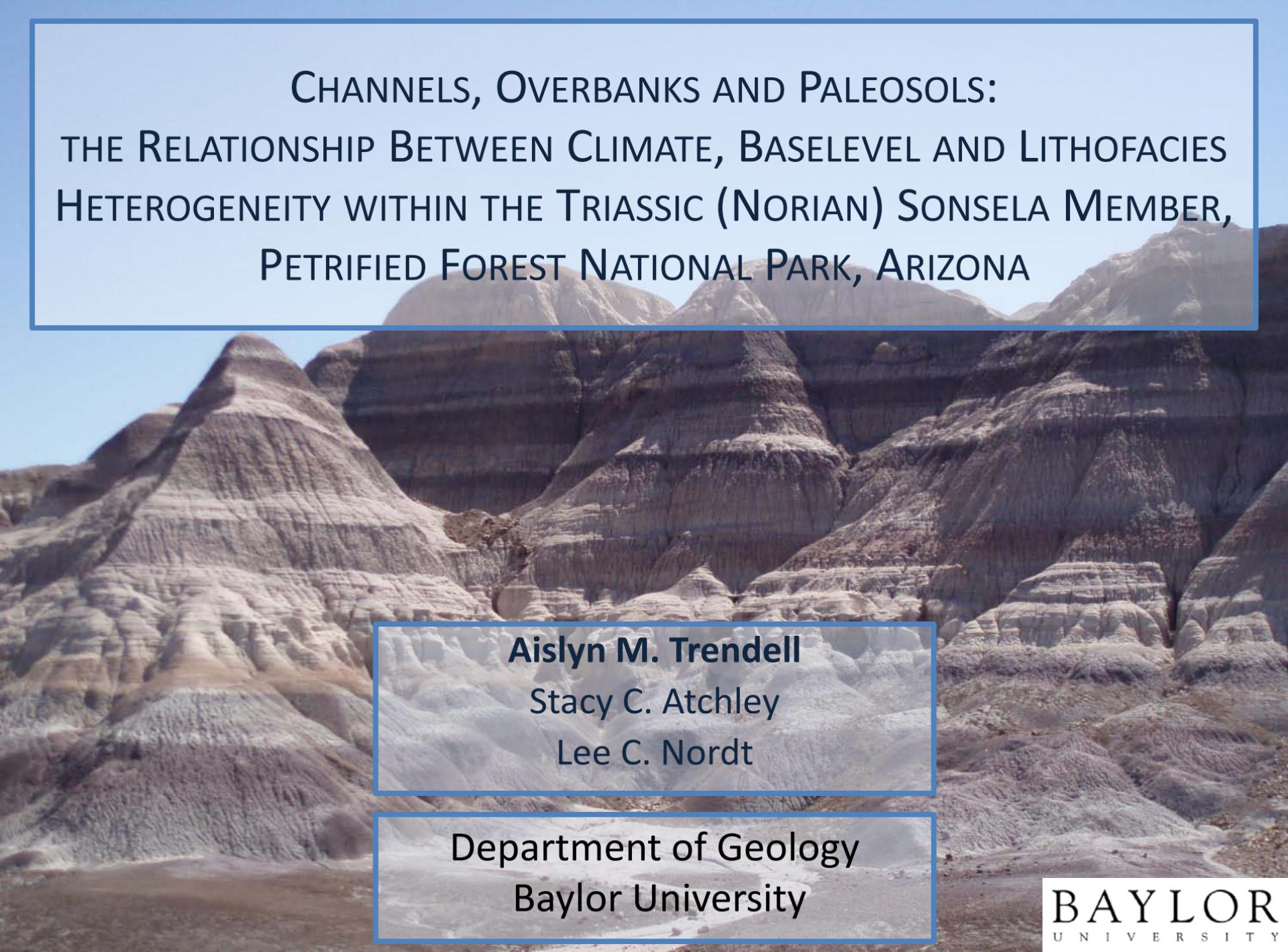
Martz, J.W. and W.G. Parker, 2010, Revised Lithostratigraphy of the Sonsela Member (Chinle Formation, Upper Triassic) in the Southern Part of Petrified Forest National Park, Arizona: *PloS ONE*, v. 5/2, p. e9329. doi:10.1371/journal.pone.0009329

Pape, H., C. Clauser, and J. Iffland, 2000, Variation of permeability with porosity in sandstone diagenesis interpreted with a fractal pore space model: *Pure and Applied Geophysics*, v. 157/4, p. 603-619.

Raucci, J.J., R.C. Blakey, and P.J. Umhoefer, 2006, New geologic mapping of Petrified Forest National Park aids in understanding evolution of land animals in Arizona: *Arizona Geology*, v. 36/2, p. 1-4.

Riggs, N.R., T.M. Lehman, G.E. Gehrels, and W.R. Dickinson, 1996, Detrital zircon link between headwaters and terminus of the Upper Triassic Chinle-Dockum paleoriver system: *Science*, v. 273/5271, p. 97-100.

Wright V.P. and S.B. Marriott, 1993, The sequence stratigraphy of fluvial depositional systems; the role of floodplain sediment storage: *Sedimentary Geology*, v. 86/3-4, p. 203-210.



**CHANNELS, OVERBANKS AND PALEOSOLS:  
THE RELATIONSHIP BETWEEN CLIMATE, BASELEVEL AND LITHOFACIES  
HETEROGENEITY WITHIN THE TRIASSIC (NORIAN) SONSELA MEMBER,  
PETRIFIED FOREST NATIONAL PARK, ARIZONA**

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# OBJECTIVE

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Evaluate the role of climate, tectonics, and base level in the evolution of fluvial style through time and its relationship to initial vs. current reservoir quality.

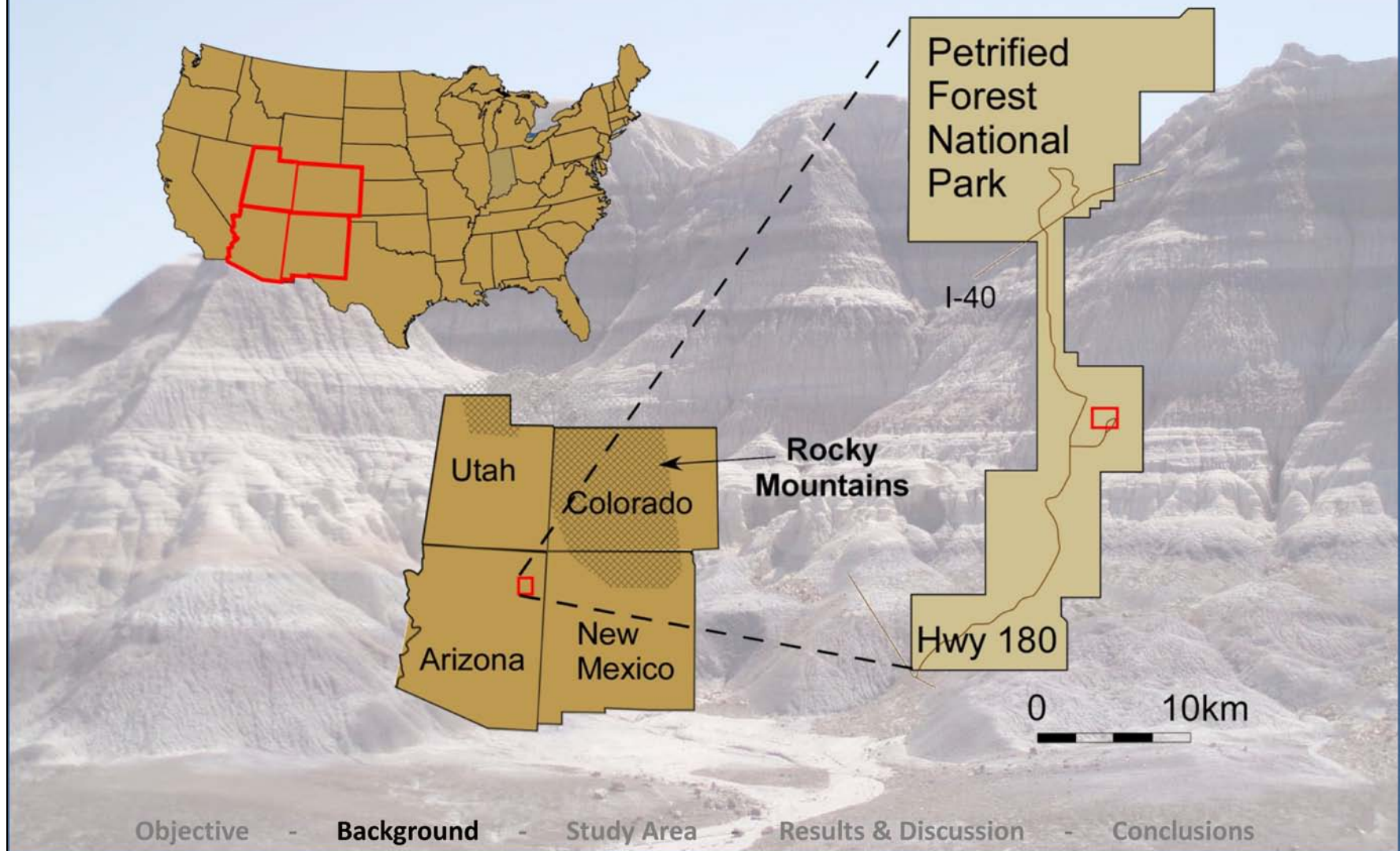
Objective - Background - Study Area - Results & Discussion - Conclusions

Notes by Presenter: Fluvial heterogeneity is challenging to petroleum geologists. Fluvial reservoirs - account for over 20% of the world's remaining energy reserves (Keogh et al., 2007). Prediction is complicated by sensitive responses *climate, sediment supply and dynamic equilibrium*. We have made advancements in understanding extrinsic controls on fluvial style. But, how do these processes interact? How can we use what we know to predict reservoir facies?

# GEOLOGIC BACKGROUND

## PETRIFIED FOREST NATIONAL PARK

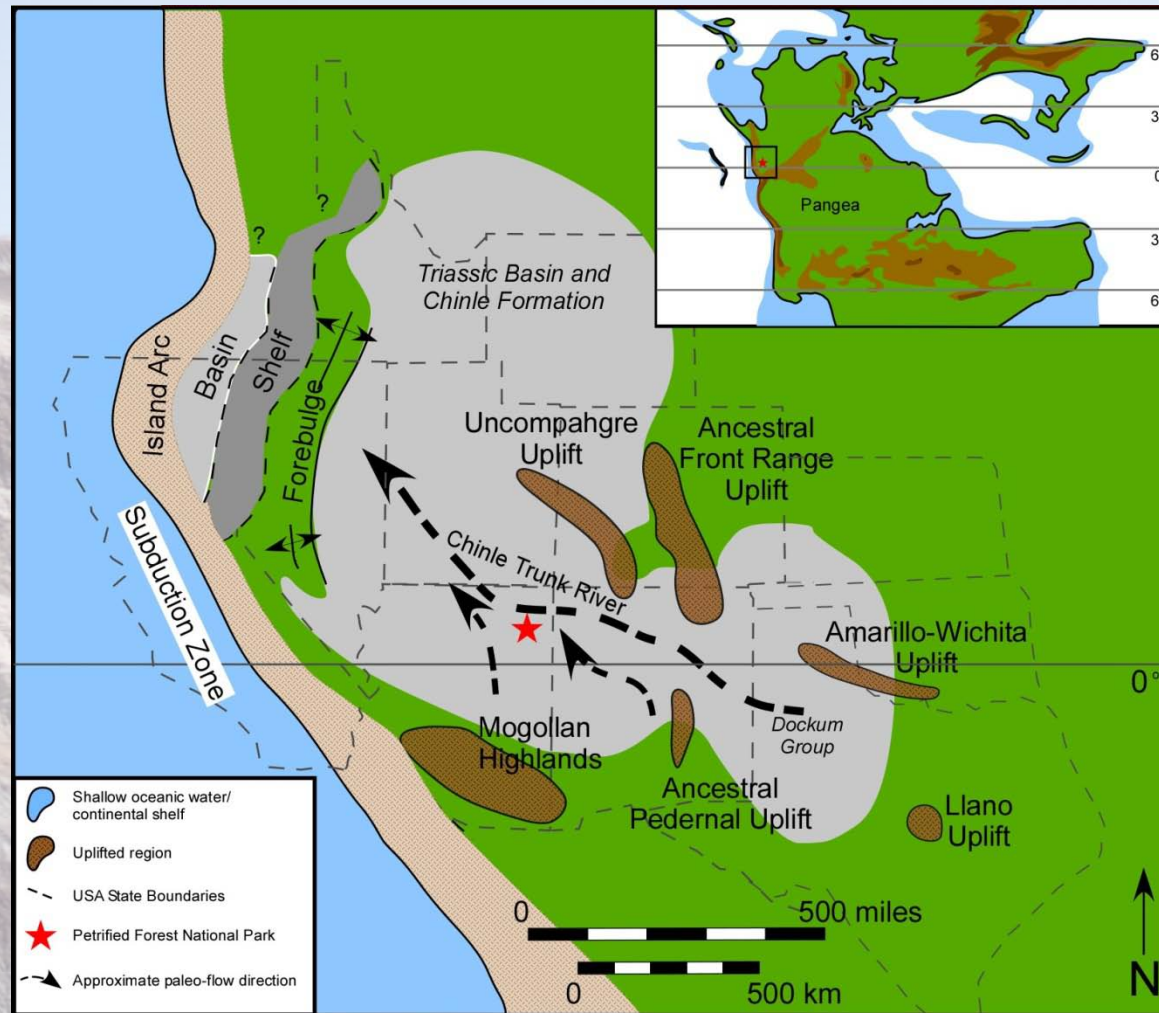
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Notes by Presenter: WHY CHOSEN? Very well exposed, entirely terrestrial succession that was deposited during a time when terrestrial deposits are the primary record for climate. Triassic record must rely primarily on the terrestrial record.

# GEOLOGIC SETTING

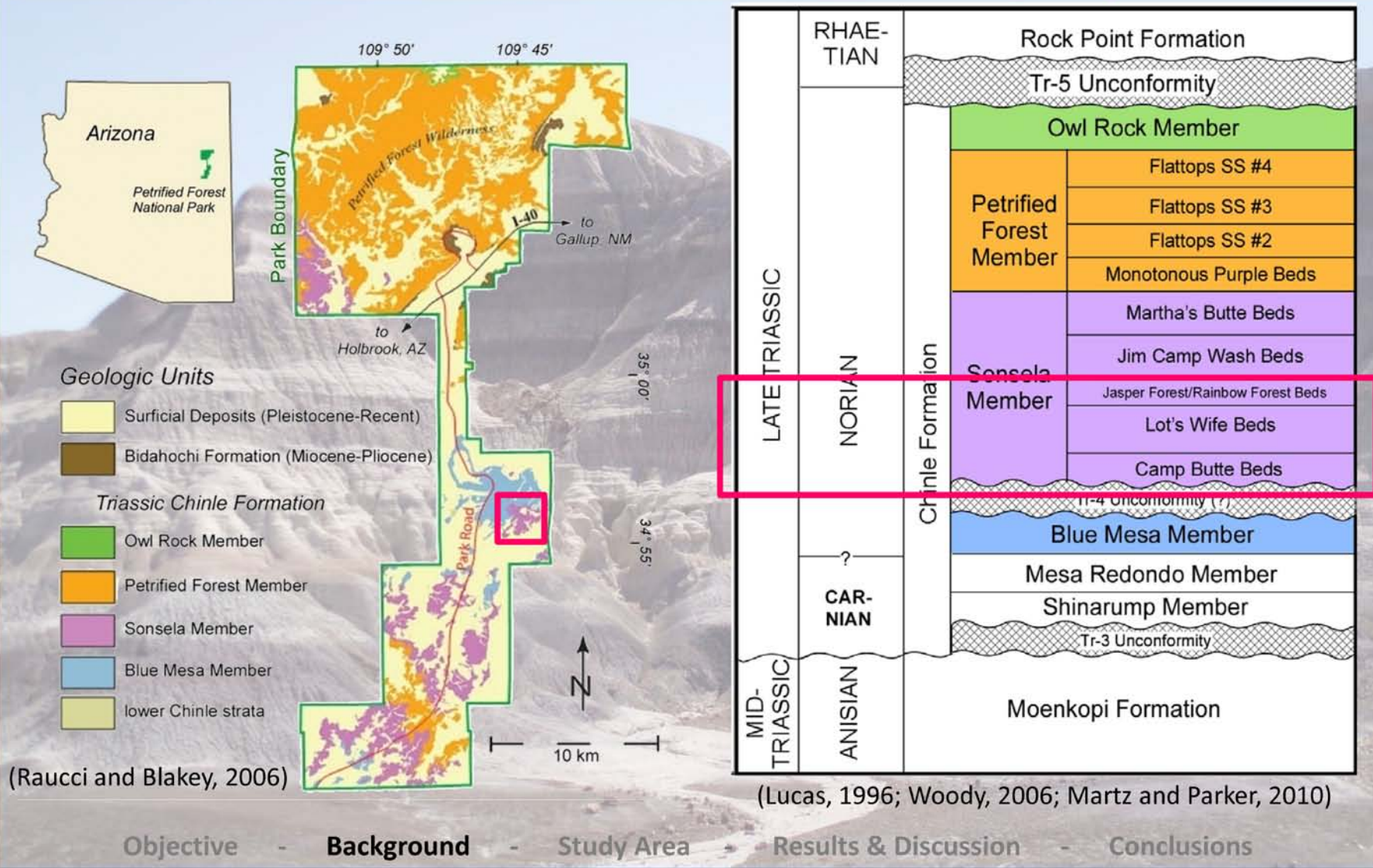
## LATE TRIASSIC PALEOGEOGRAPHY



(Modified from Dickinson and Gehrels, 2008; Riggs et al, 1996; Lawton, 1994; Scotese, 2008)

# GEOLOGIC SETTING STRATIGRAPHY OF THE PARK

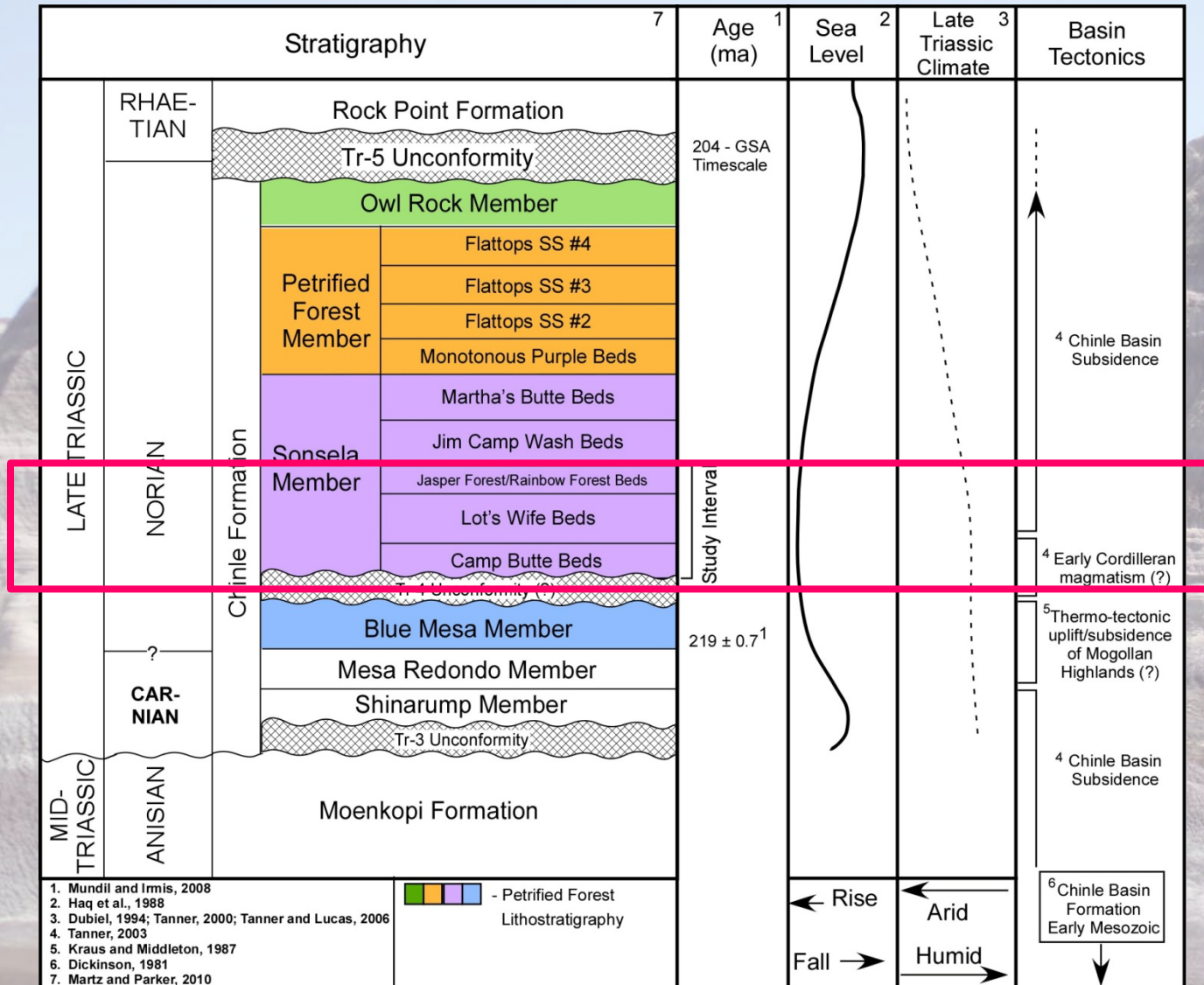
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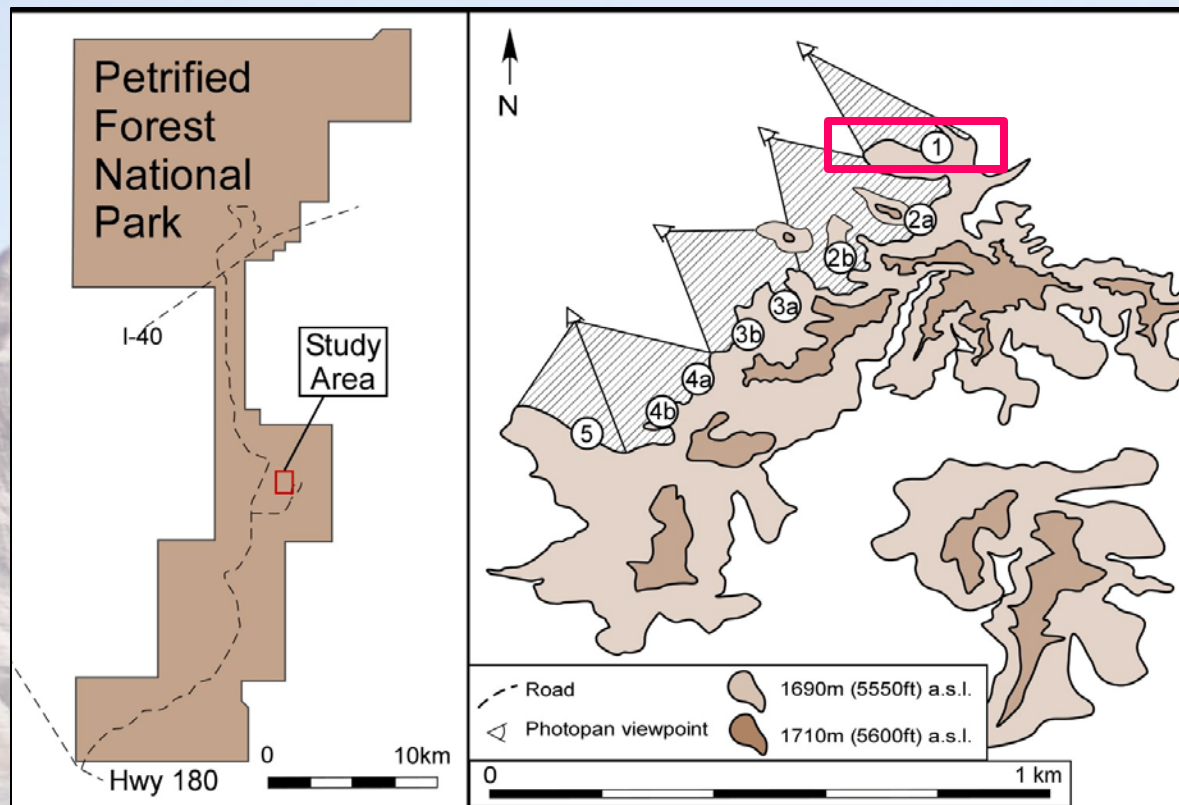
Notes by Presenter: Anomalous succession of bed load dominated fluvial deposits.

# GEOLOGIC SETTING

## REGIONAL CONTEXT



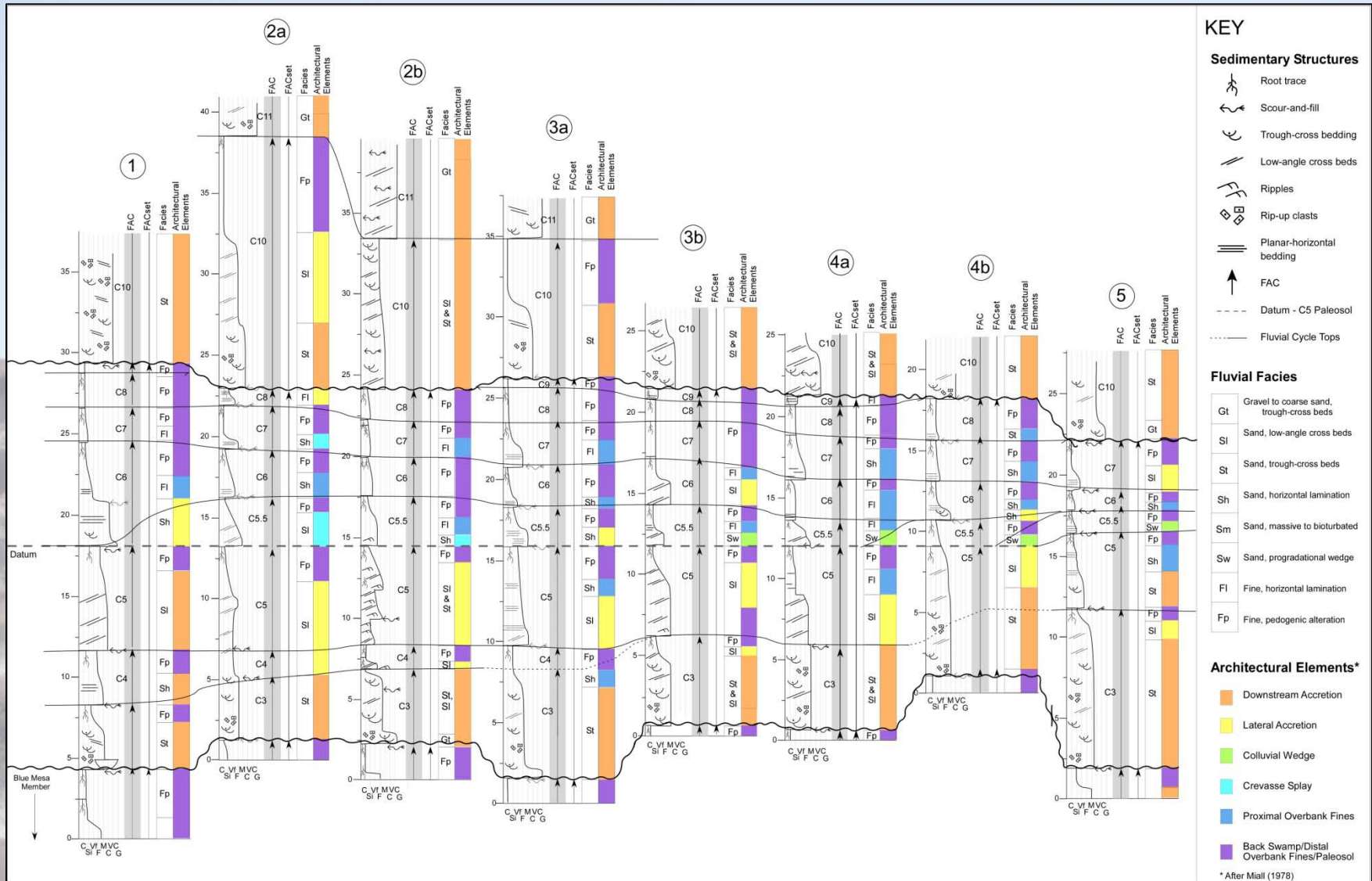
# STUDY AREA



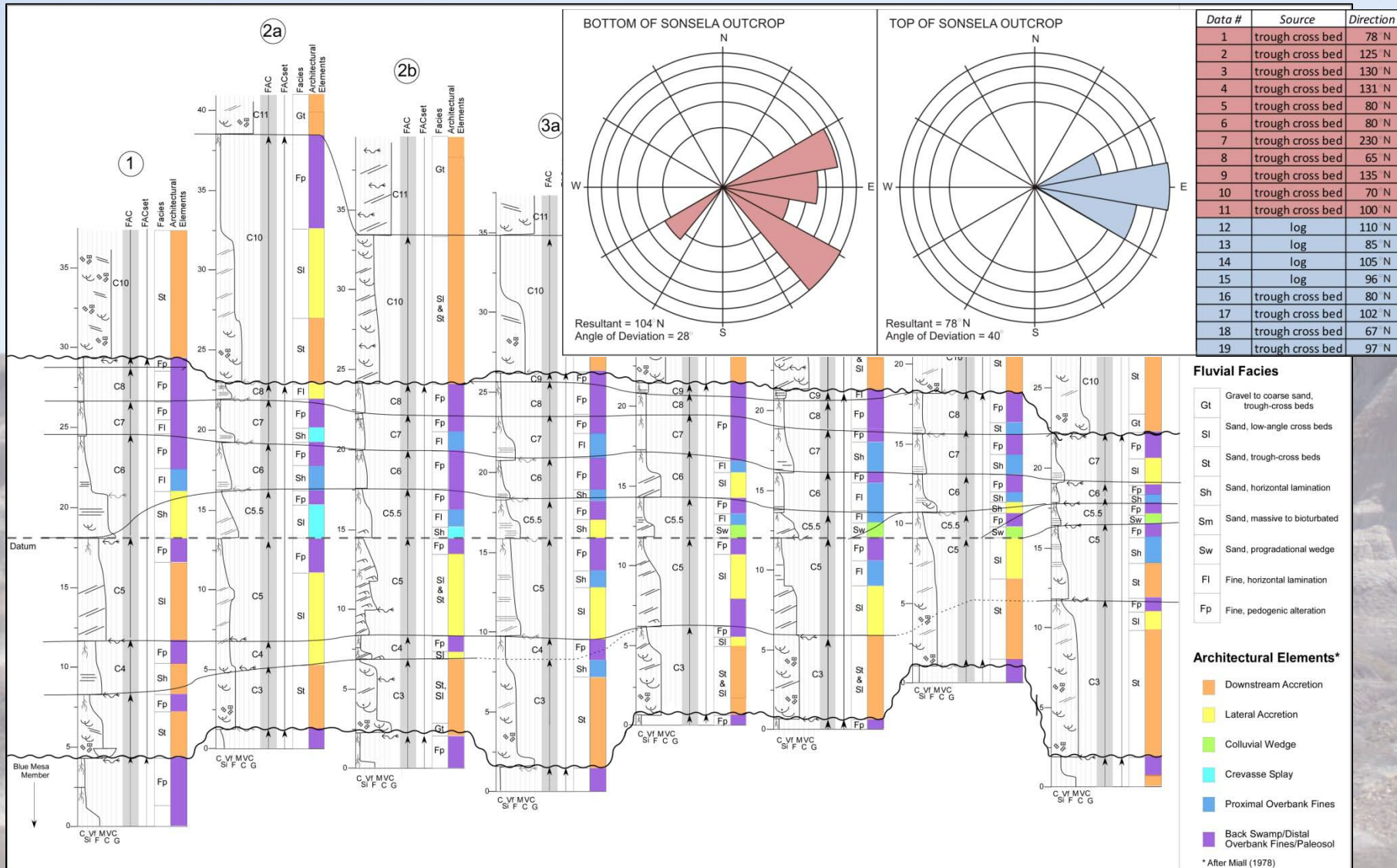
**Area 1** Blue Mesa Lookout



# MEASURED SECTIONS



# MEASURED SECTIONS



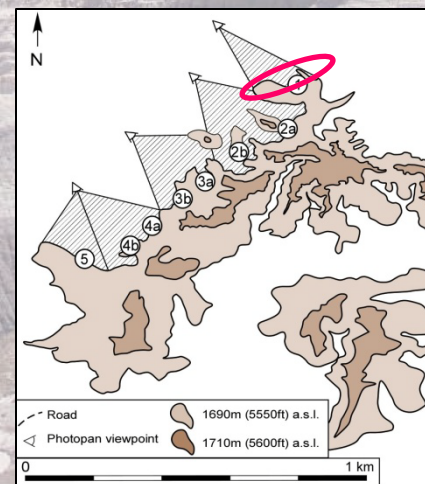
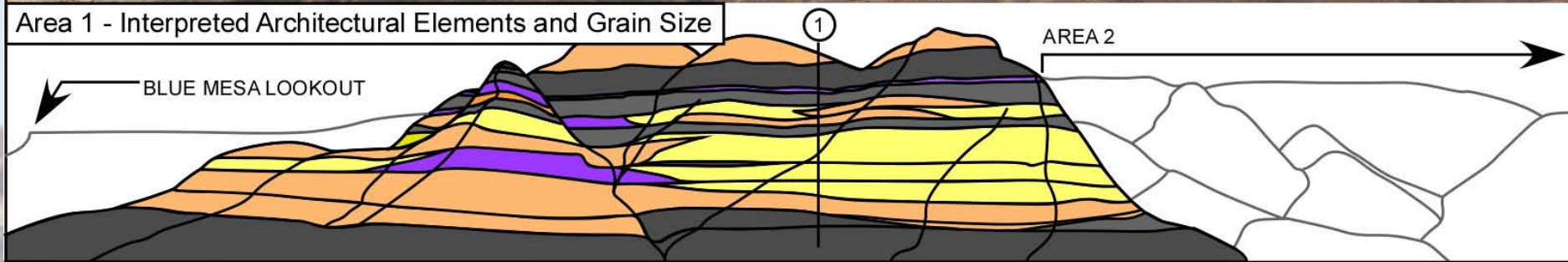
# RESULTS

## ARCHITECTURAL ELEMENT DISTRIBUTION

Area 1 - Photopan Image



Area 1 - Interpreted Architectural Elements and Grain Size



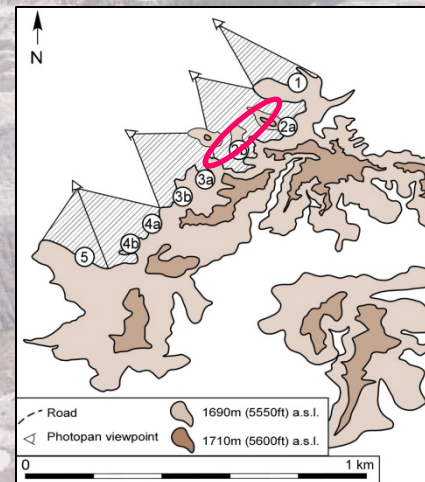
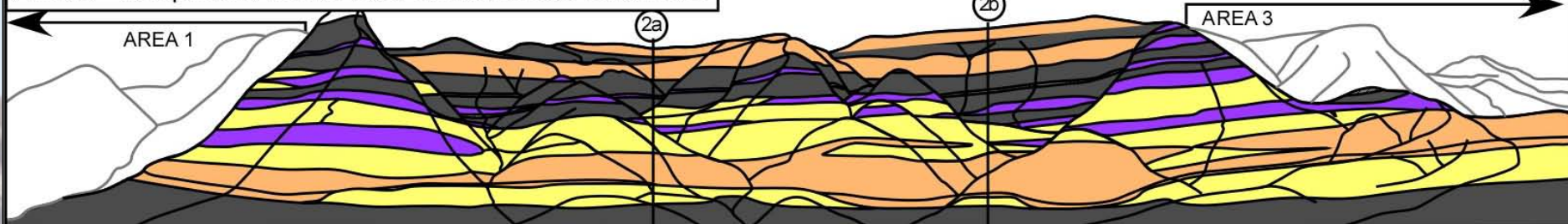
# RESULTS

## ARCHITECTURAL ELEMENT DISTRIBUTION

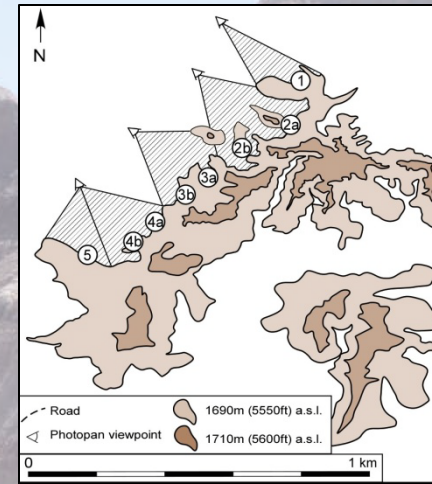
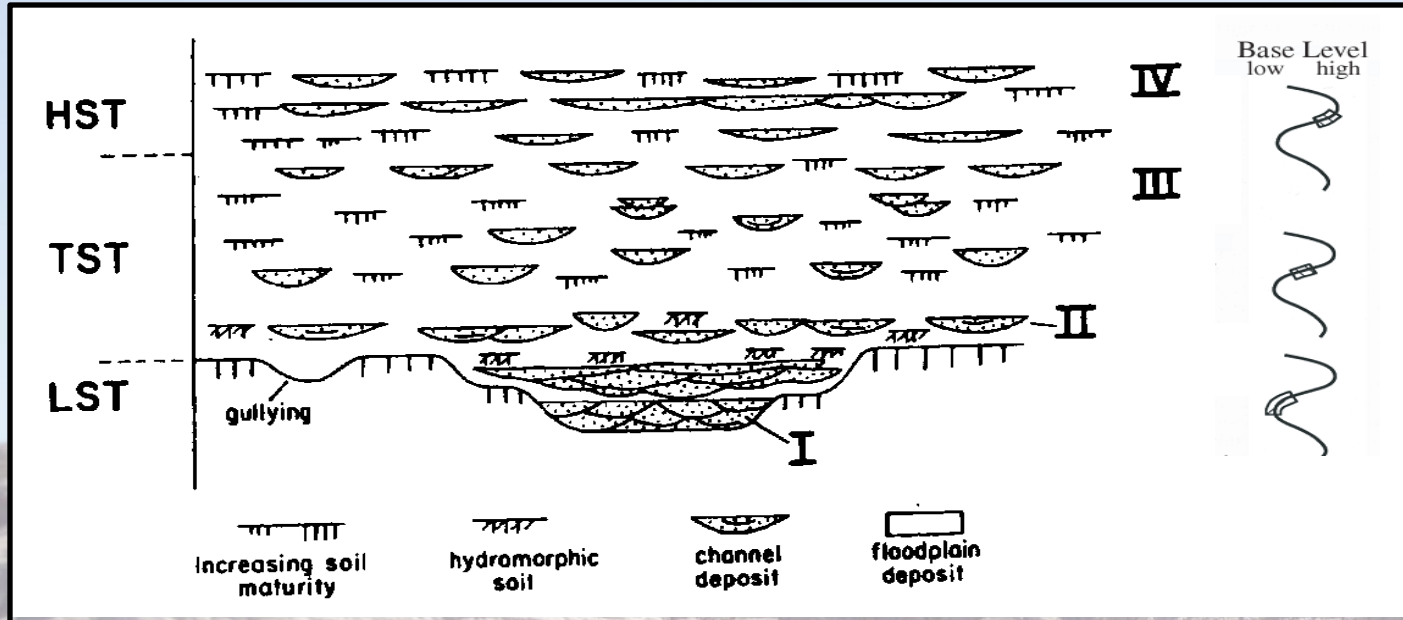
Area 2 - Photopan Image



Area 2 - Interpreted Architectural Elements and Grain Size



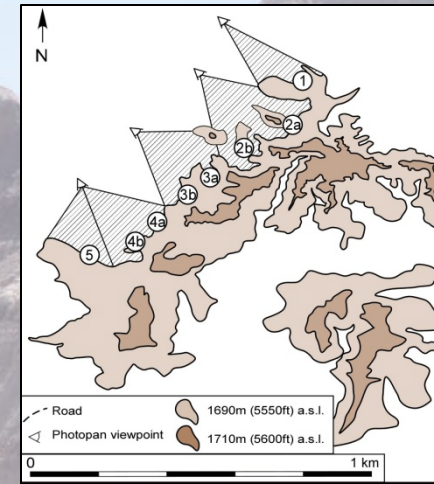
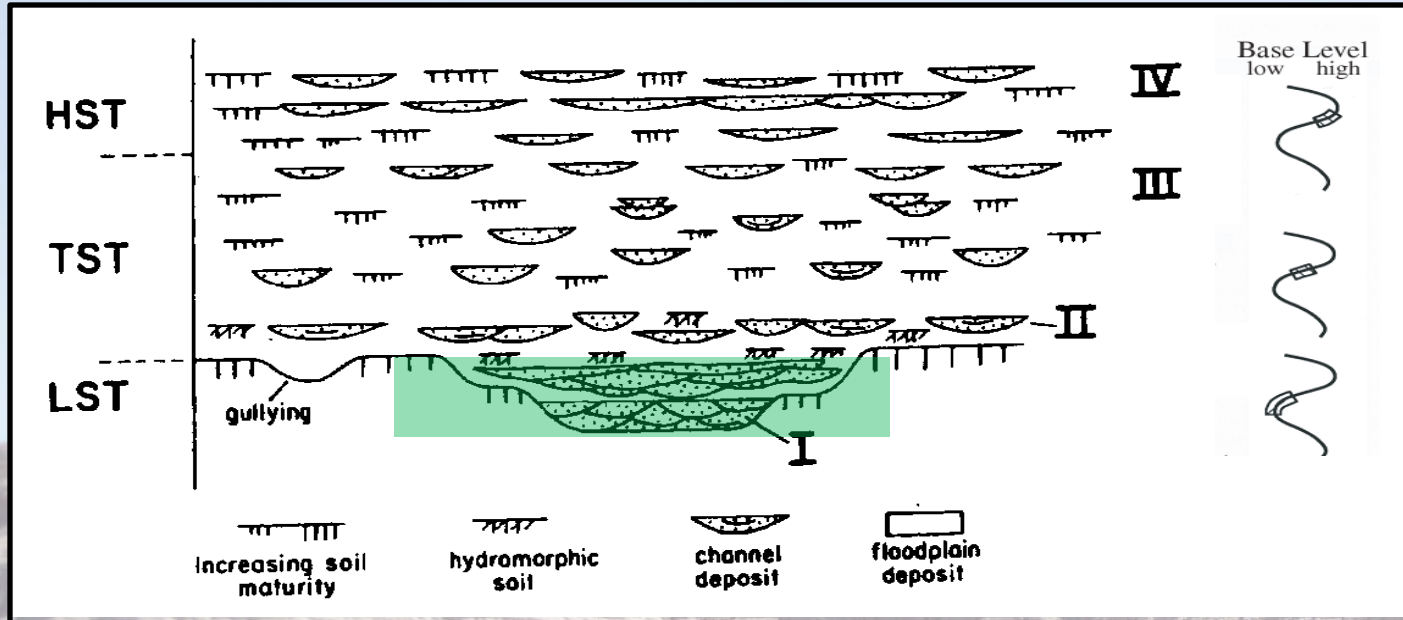
# BASELEVEL AND FLUVIAL STYLE



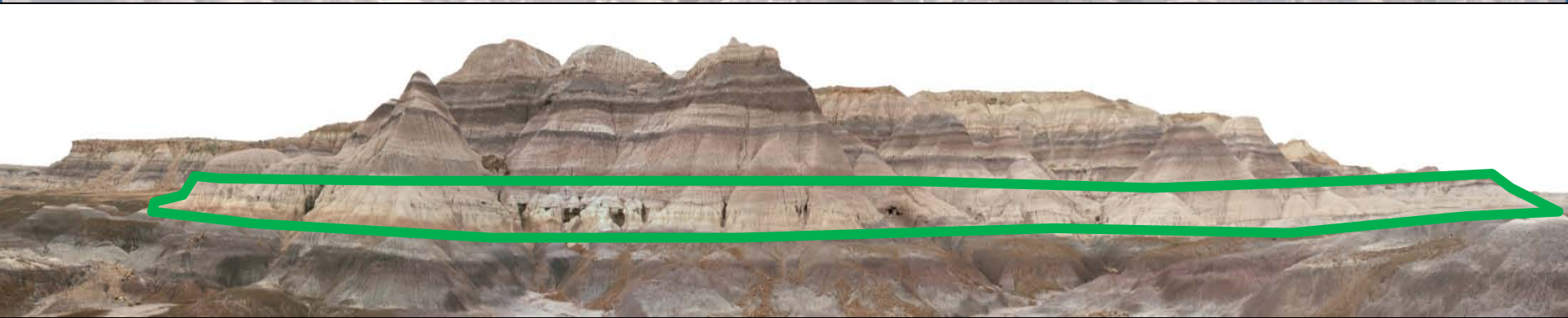
(Wright and Marriott, 1993)



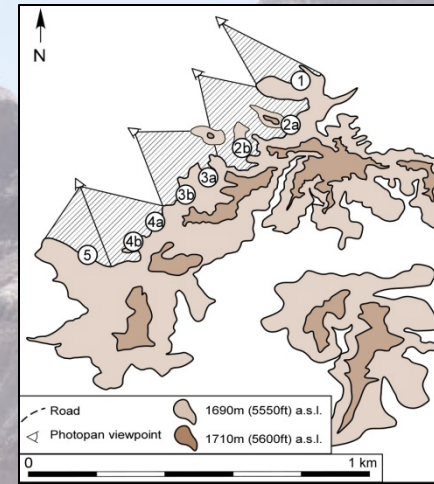
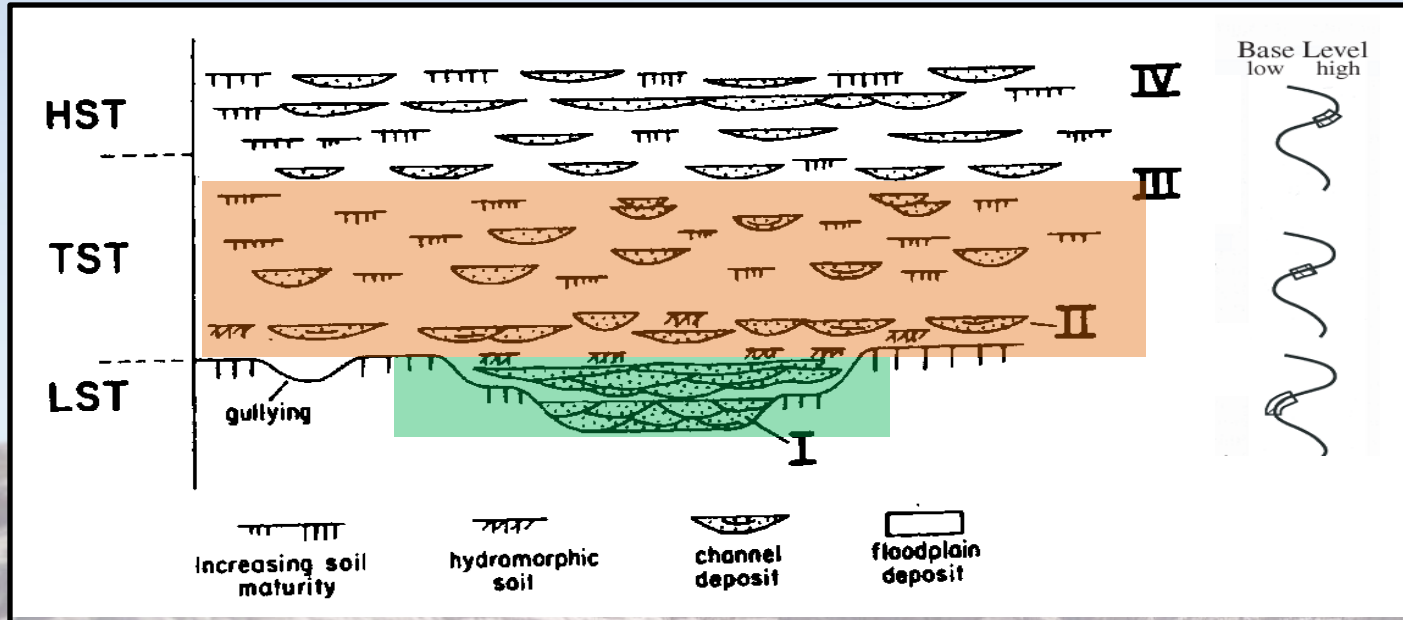
# BASELEVEL AND FLUVIAL STYLE



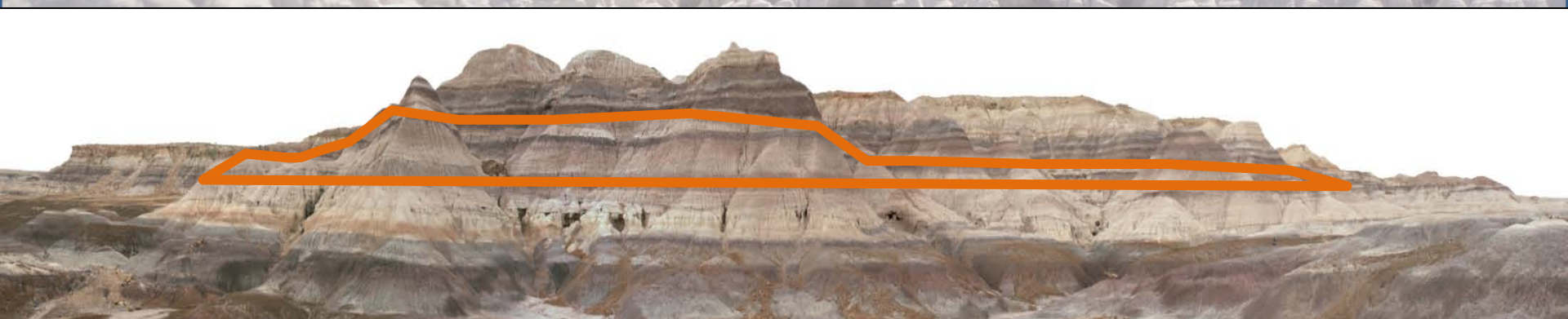
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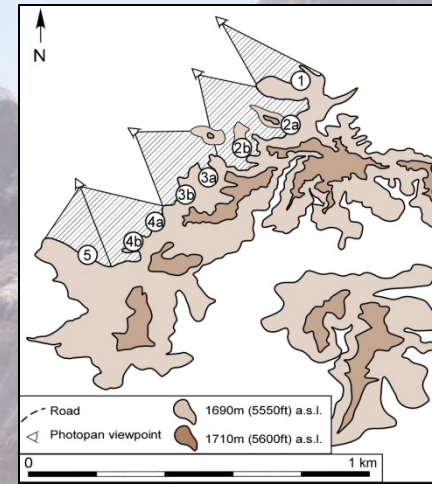
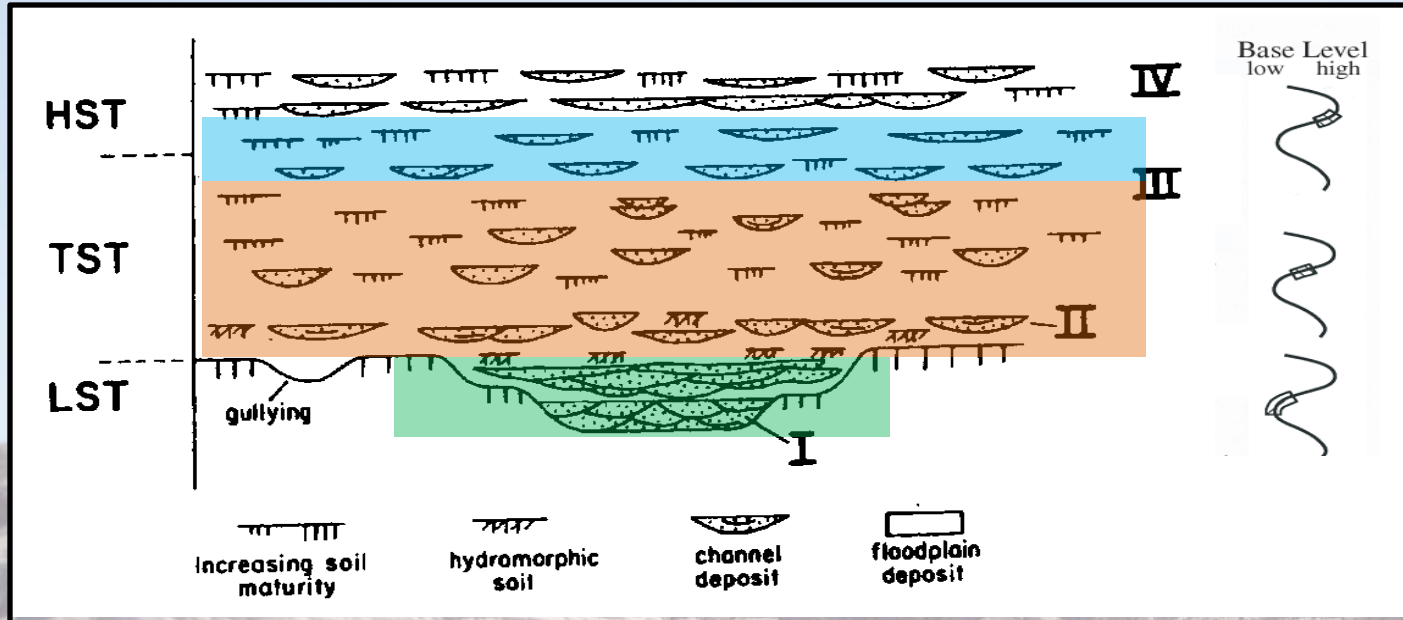
# BASELEVEL AND FLUVIAL STYLE



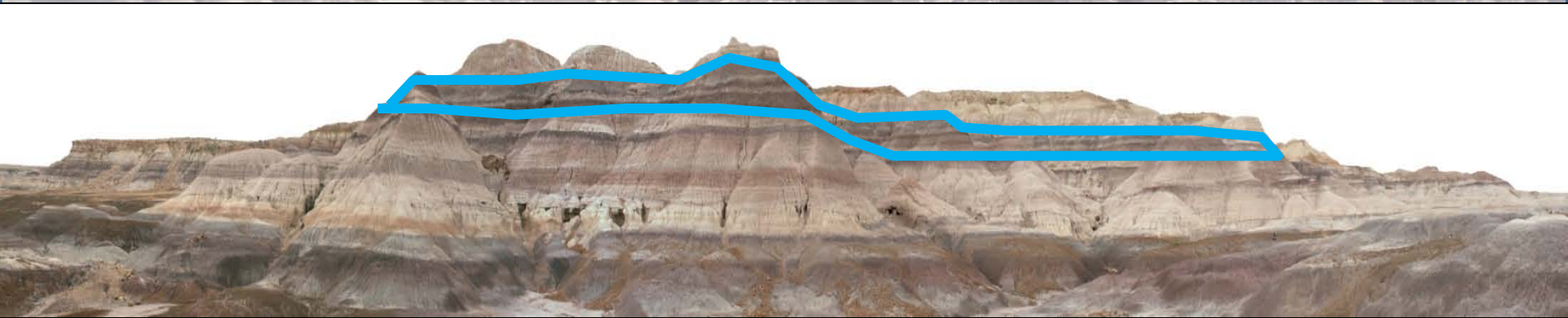
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# BASELEVEL AND FLUVIAL STYLE



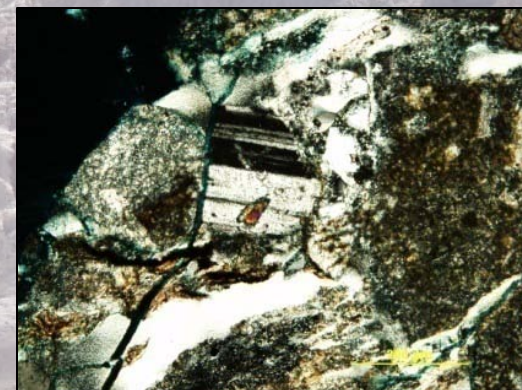
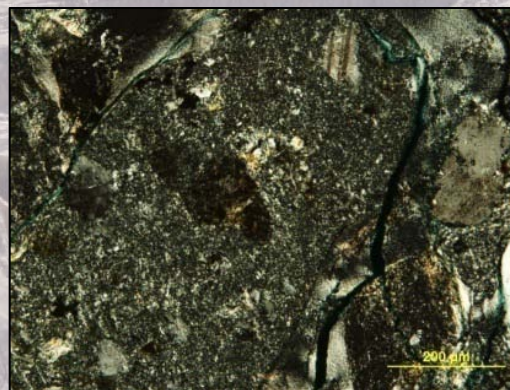
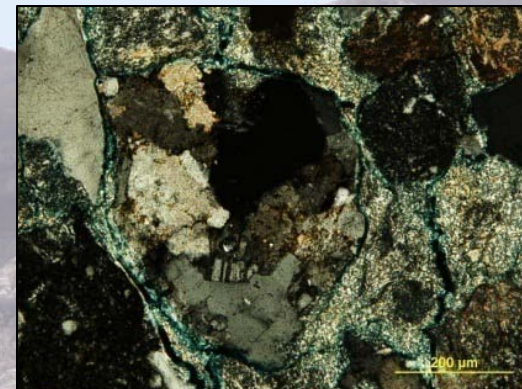
(Wright and Marriott, 1993)



# RESULTS

## SANDSTONE PETROLOGY

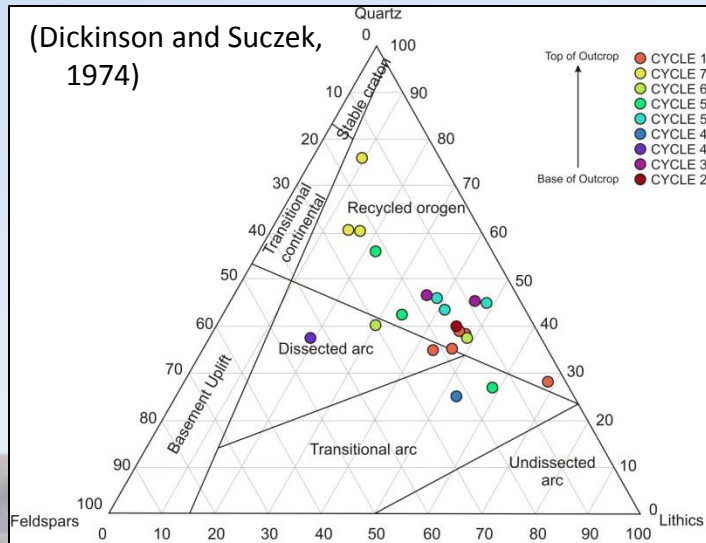
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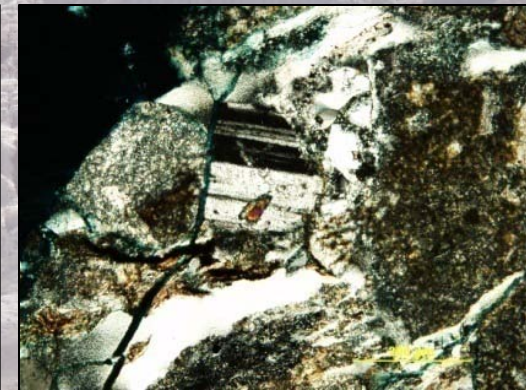
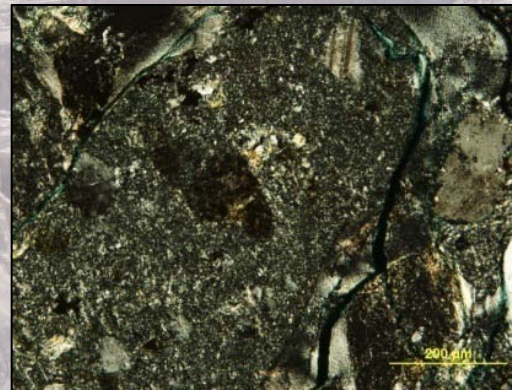
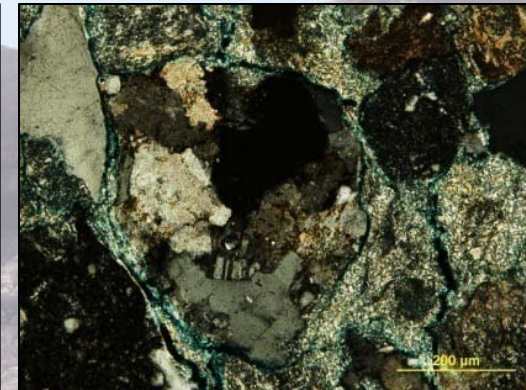
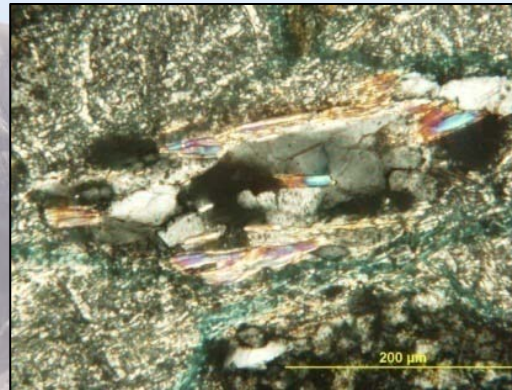
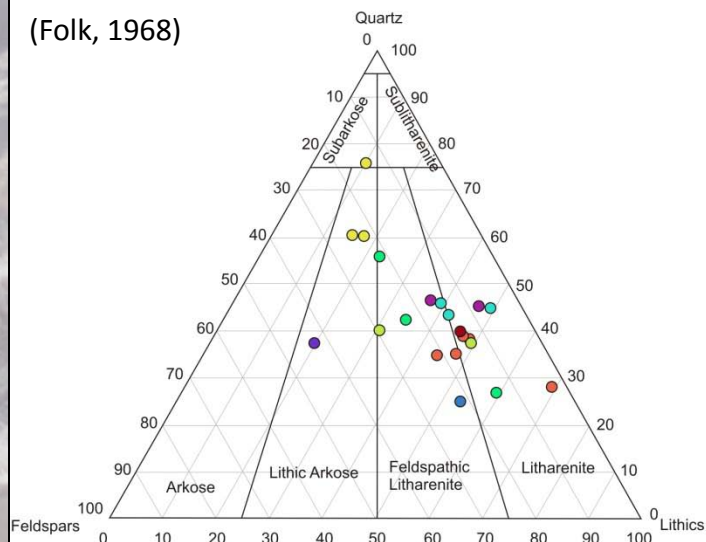
# RESULTS

## SANDSTONE PETROLOGY

(Dickinson and Suczek,  
1974)

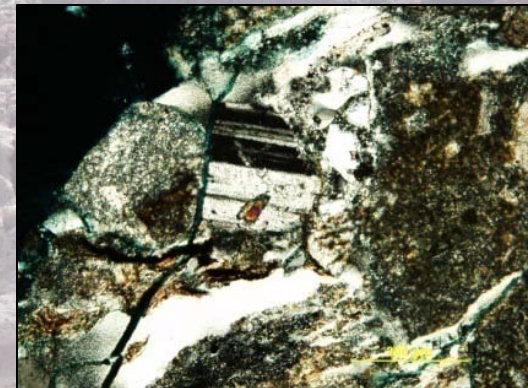
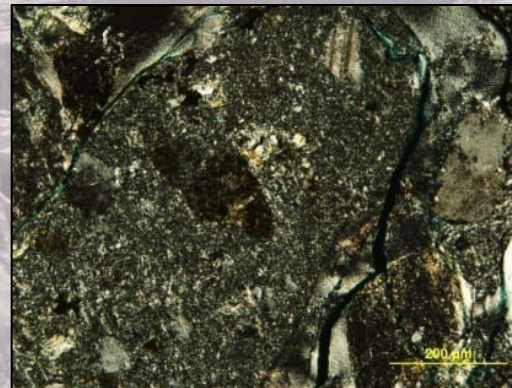
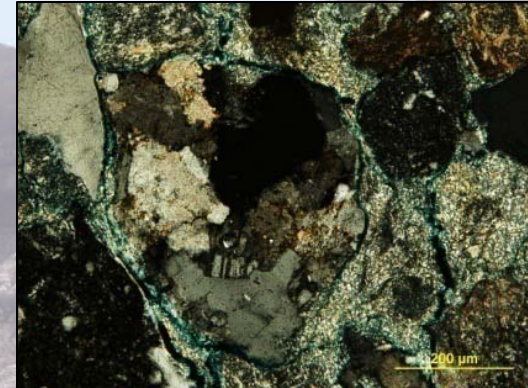
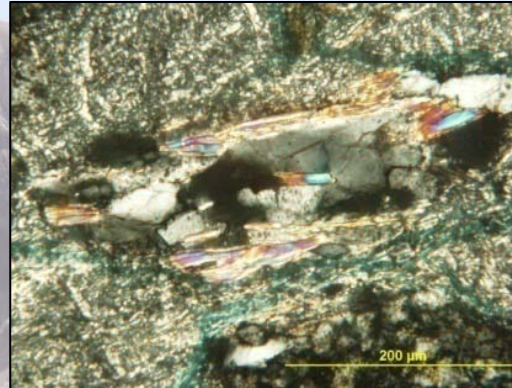
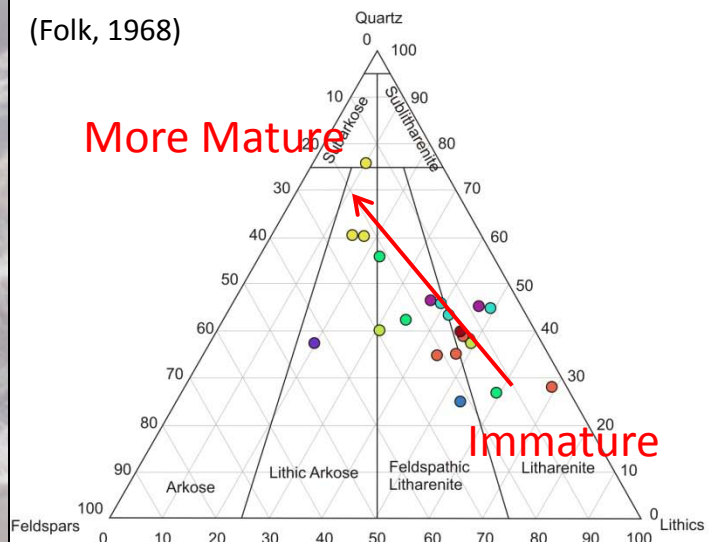
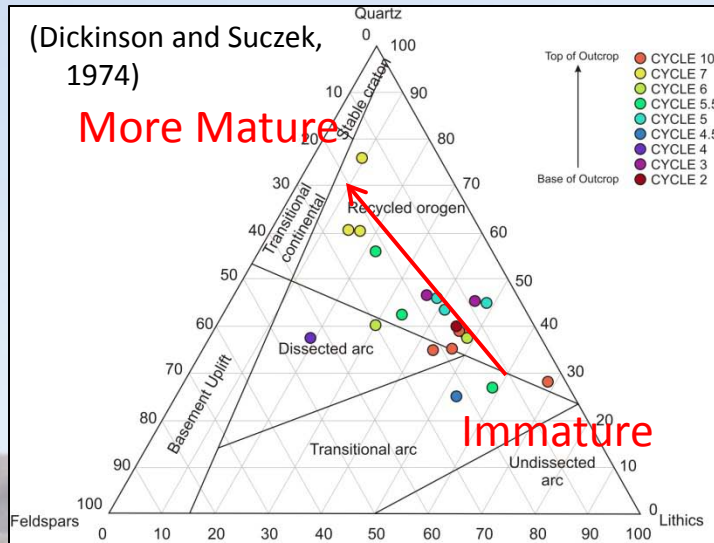


(Folk, 1968)



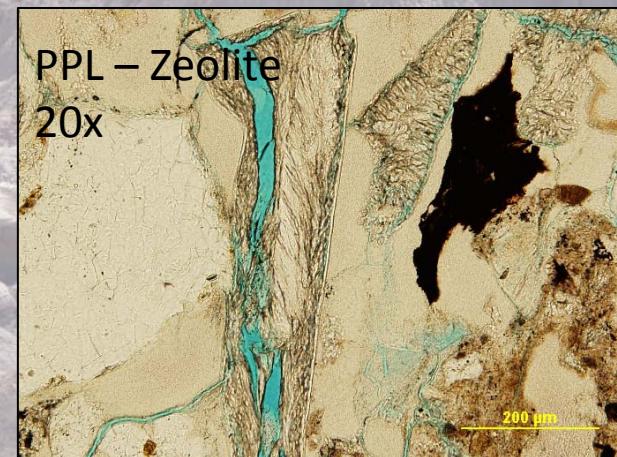
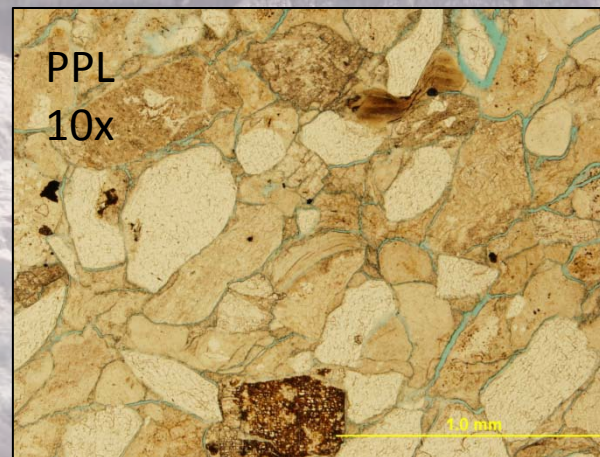
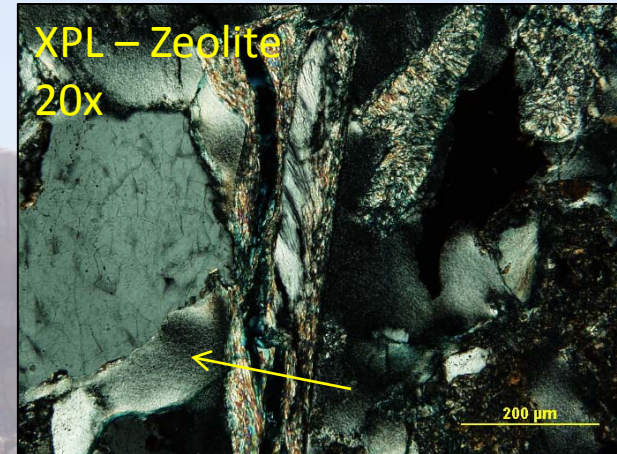
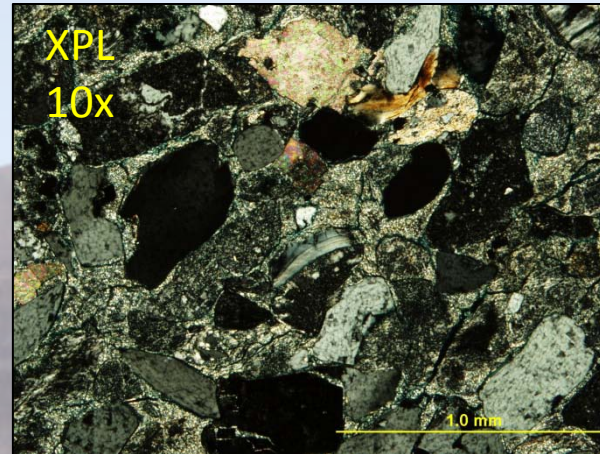
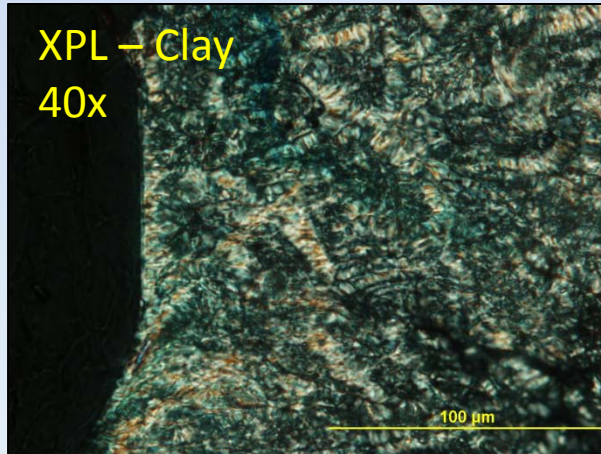
# RESULTS

## SANDSTONE PETROLOGY



## RESULTS

# DIAGENESIS AND POROSITY LOSS

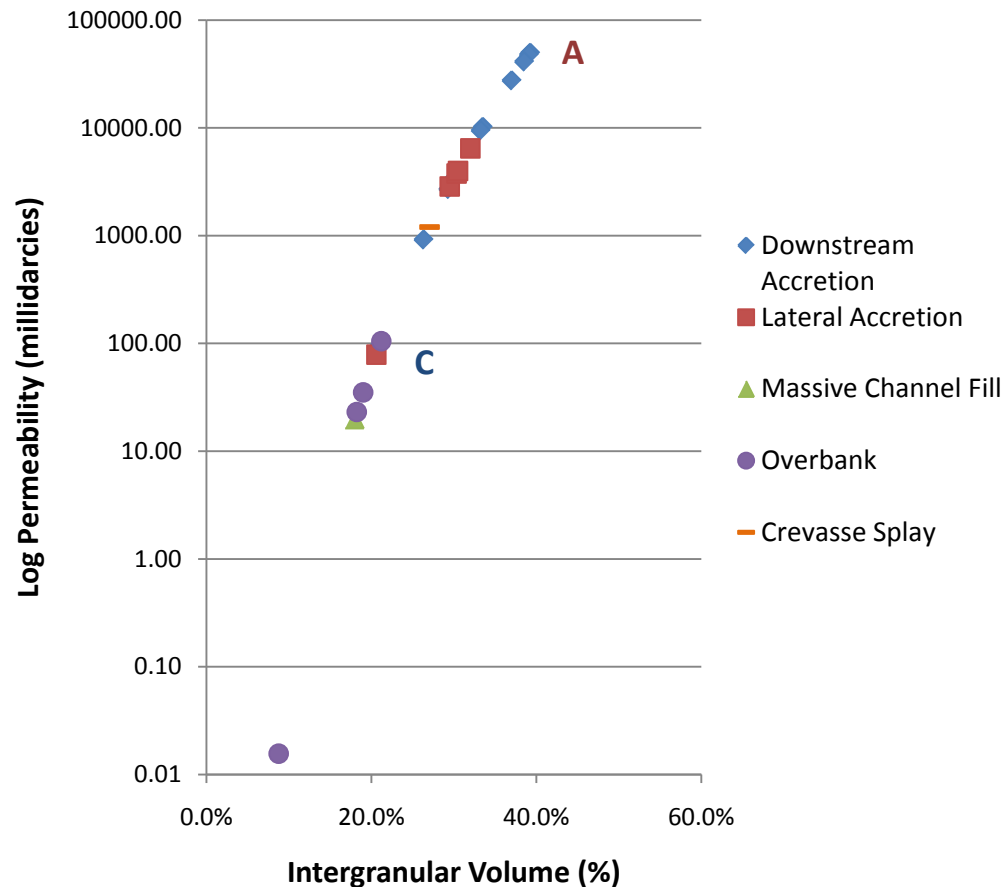


**Ordered nature suggests pore filling matrix is diagenetic.  
Almost complete diagenetic loss of porosity.**

# RESULTS

## POROSITY AND PERMEABILITY

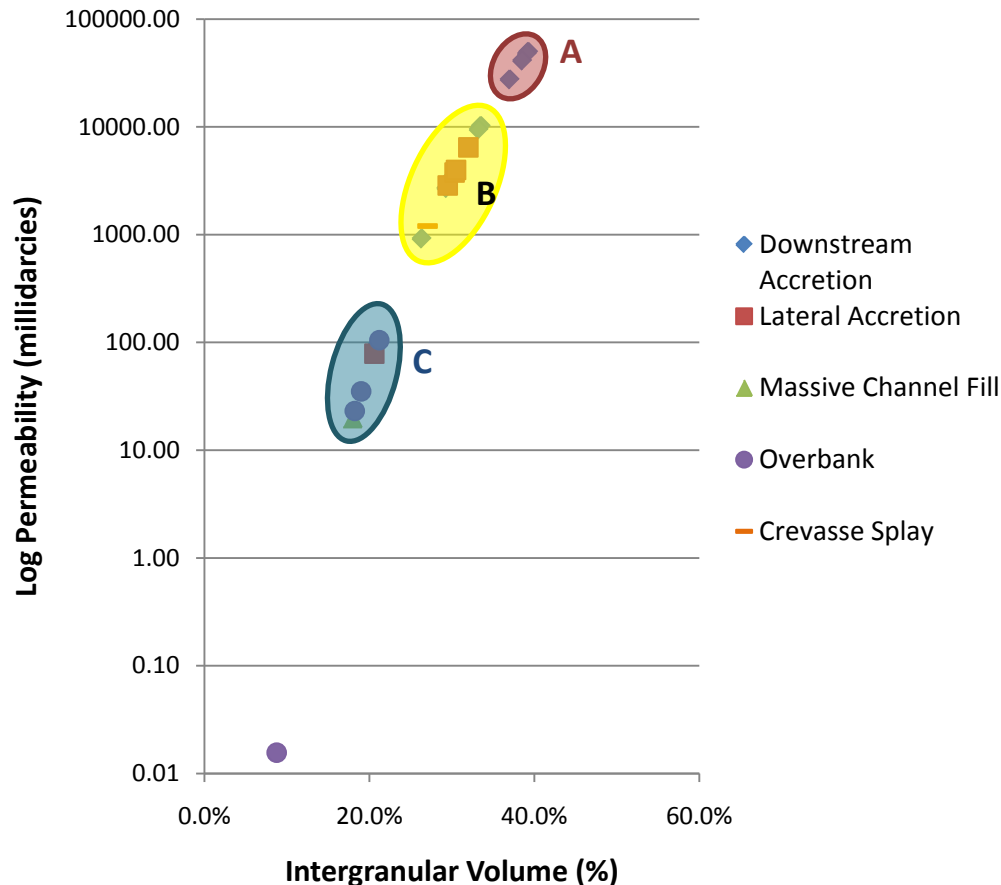
**Intergranular Volume vs. Log Permeability by Architectural Element**



# RESULTS

## POROSITY AND PERMEABILITY

Intergranular Volume vs. Log Permeability by Architectural Element



Transform Function by Pape et al. (2000)

- A. Average  $\phi$  – 39%  
Average K  $\approx$  50000 md  
(Downstream Accretion)
- B. Average  $\phi$  – 30%  
Average K  $\approx$  4500 md  
(Downstream and Lateral Accretion)
- C. Average  $\phi$  – 17%  
Average K  $\approx$  40 md  
(Lateral Accretion and Overbank)

Paleosols – Baffles and Barriers to Fluid Flow

# RESULTS

## RESERVOIR CLASS MAPS

Area 1 - Photopan Image



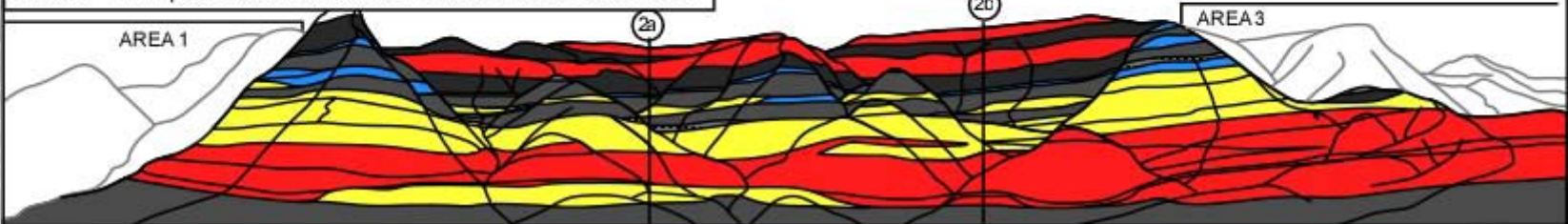
Area 1 - Interpreted Architectural Elements and Grain Size



Area 2 - Photopan Image



Area 2 - Interpreted Architectural Elements and Grain Size



# CONCLUSIONS

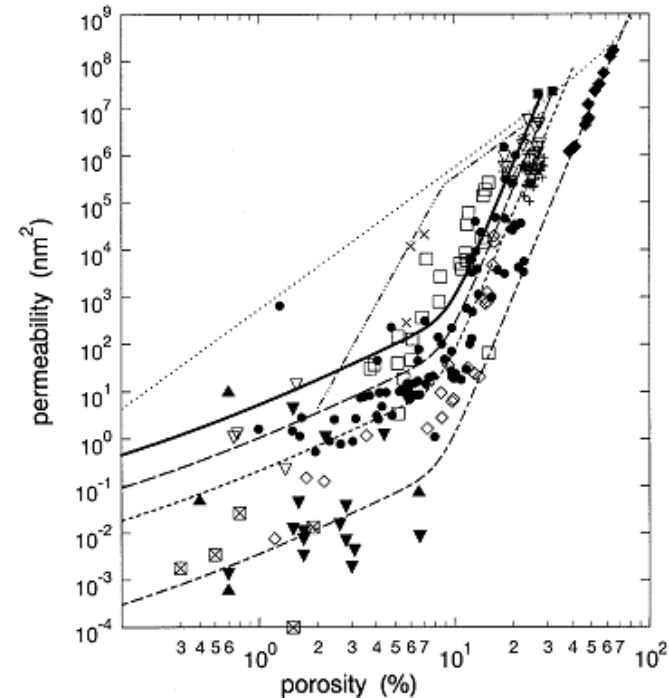
- Paleosol characteristics change little throughout the outcrop – suggesting a period of relatively stable climate conditions.
- Sandstone compositions are mineralogically immature.
- Relationship of sandstone immaturity with change in fluvial style suggests that tectonic pulses or phases are associated with fluvial style change.
- Best initial reservoir class sandstones consists of downstream and lateral accretion and are ***found during the early transgression equivalent stage.***
- Reservoir classes based on initial reservoir quality correlate well to depositional distributions. However, current reservoir quality has been completely destroyed by diagenetic pore-plugging products.
- Cross-cutting relationships of diagenetic features suggests loss of porosity occurred relatively early. **Has implications on reservoir risk when exploring mineralogically immature basins within this climatic regime.**

A landscape photograph capturing a sunset or sunrise. The sky is a mix of deep blues, purples, and oranges, with wispy clouds catching the low light. In the foreground, the dark, jagged silhouettes of mountains or hills frame the bottom and sides of the image. The word "Questions?" is written in a light, sans-serif font in the bottom right corner.

Questions?

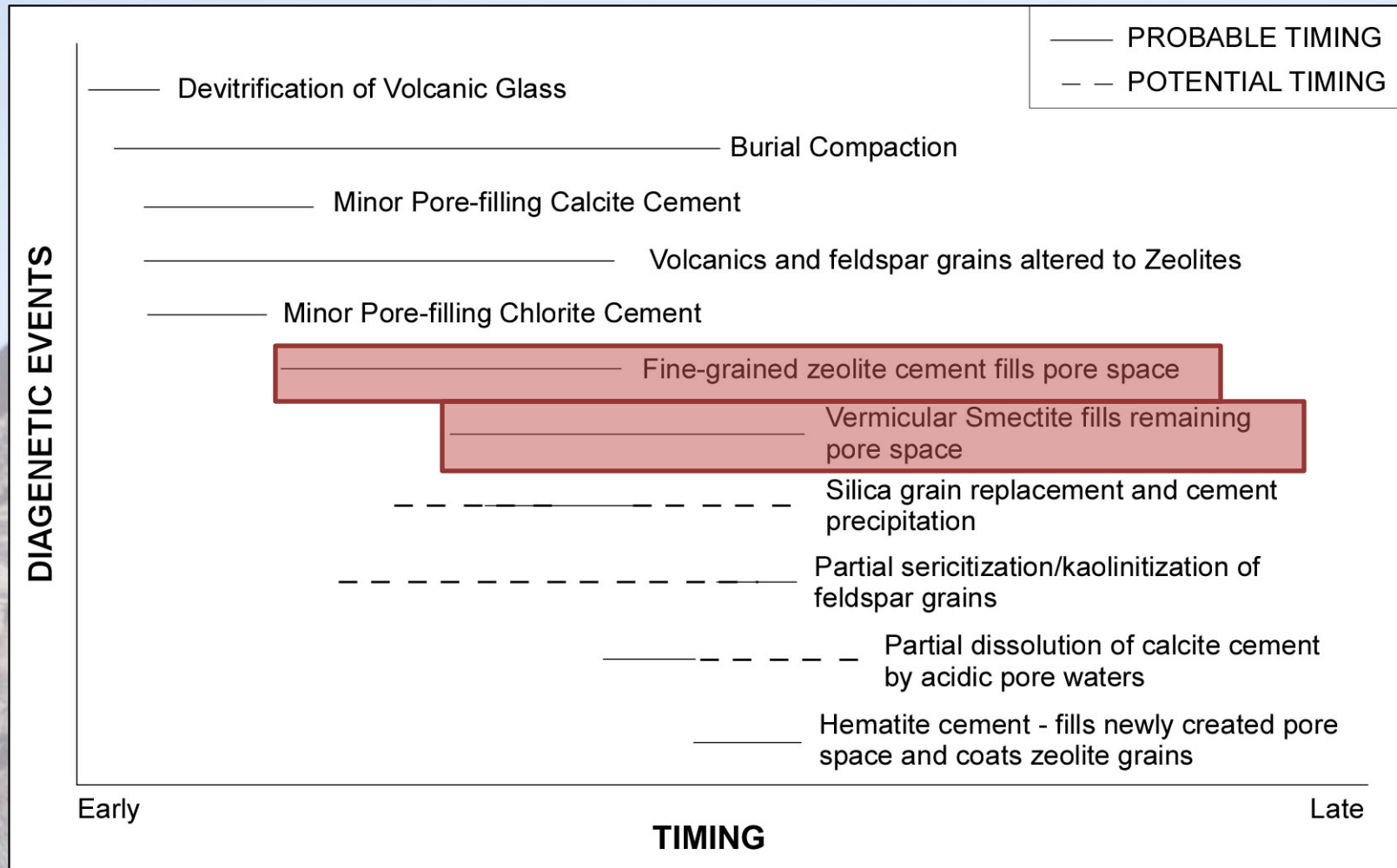
# FRACTAL MODEL TRANSFORM FUNCTION

Pape et al., 2000



- $k = 31\phi + 7.463\phi^2 + 191(10\phi)^{10}$  fractal model for an average type of sandstone
- $k = 155\phi + 37.315\phi^2 + 630(10\phi)^{10}$  fractal model for Rotliegend sandstone northeast Germany
- - -  $k = 6.2\phi + 1.493\phi^2 + 58(10\phi)^{10}$  fractal model for a shaly sandstone
- - -  $k = 0.1\phi + 26\phi^2 + (10\phi)^{10}$  fractal model for a shale
- .....  $k = 303(100\phi)^{3.05}$  for  $\phi > 0.08$  Fontainebleau sandstone (BOURBIE and ZINSZNER, 1985)
- .....  $k = 0.0275(100\phi)^{7.33}$  for  $\phi \leq 0.08$  Fontainebleau sandstone (BOURBIE and ZINSZNER, 1985)
- .....  $k = 0.5 (r_{\text{grain}})^2 \phi^3 / (1 - \phi)^2$  smooth capillary model
- sand (SCHOPPER, 1967)
- ◆ kaolinite (MICHAELS and LIN, 1954)
- × Fontainebleau sandstone
- ▽ Dogger sandstone
- Keuper sandstone
- + Bunter sandstone
- Rotliegend sandstone, northwest Germany
- ◇ Carboniferous sandstone
- ▼ Jurassic shale (SCHLÖMER and KROOSS, 1997)
- ▲ Rotliegend shale (SCHLÖMER and KROOSS, 1997)
- ⊠ Carboniferous shale (SCHLÖMER and KROOSS, 1997)

# PARAGENETIC HISTORY



# BACKGROUND INFORMATION

## FLUVIAL STYLE

### Meandering (Suspended Load)



#### Poor Reservoir

Lateral Accretion and  
Overbank  
Isolated channel bodies

### Braided (Bedload)



#### Good Reservoir

Downstream Accretion  
Multi-story channel  
deposits

