

Architecture of Reservoirs Confined by Early Diagenesis in Paleosols from Sequence Boundaries in Permian Eolianites*

By

Richard P. Langford¹, David M. Tatum⁴, Pierre Depret³, Katy Duncan⁶, Krystal Pearson², and Luqman Adams⁵

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¹Geological Sciences, University of Texas at El Paso, El Paso, TX (langford@utep.edu)

²Conoco-Phillips, Houston, TX

³Mid-Continent Business Unit, British Petroleum, Houston, TX

⁴ChevronUSA, New Orleans, LA

⁵Chemistry, Prairie View A & M University., Prairie View, TX

⁶El Paso Corporation E&P, Denver, CO

Abstract

The Permian Cedar Mesa Sandstone of Southeastern Utah is divided into 20 to 40 m thick units by prominent erosion surfaces. These surfaces correlate with color changes from red to white within the unit and mark barriers to fluid flow. The white units were probably reduced in the Paleocene by hydrocarbon-bearing fluids, and some may represent exhumed reservoirs. The erosion surfaces form permeability barriers within the sandstone that segregate reservoir and non-reservoir strata.

Some erosion surfaces represent dune seas that formed after the previous ergs were stabilized and partly eroded. Petrographic analyses show that two of these horizons contain fragmented marine fossils. The erosion surfaces are associated with large ponds, and are extensively vegetated; suggesting a high water table and correlation with transgressions associated with Permian sea level highstands. This correlation of eustasy with the erosion surfaces allows development of a sequence stratigraphic model for this and similar Permian eolianites, which are found on most continents.

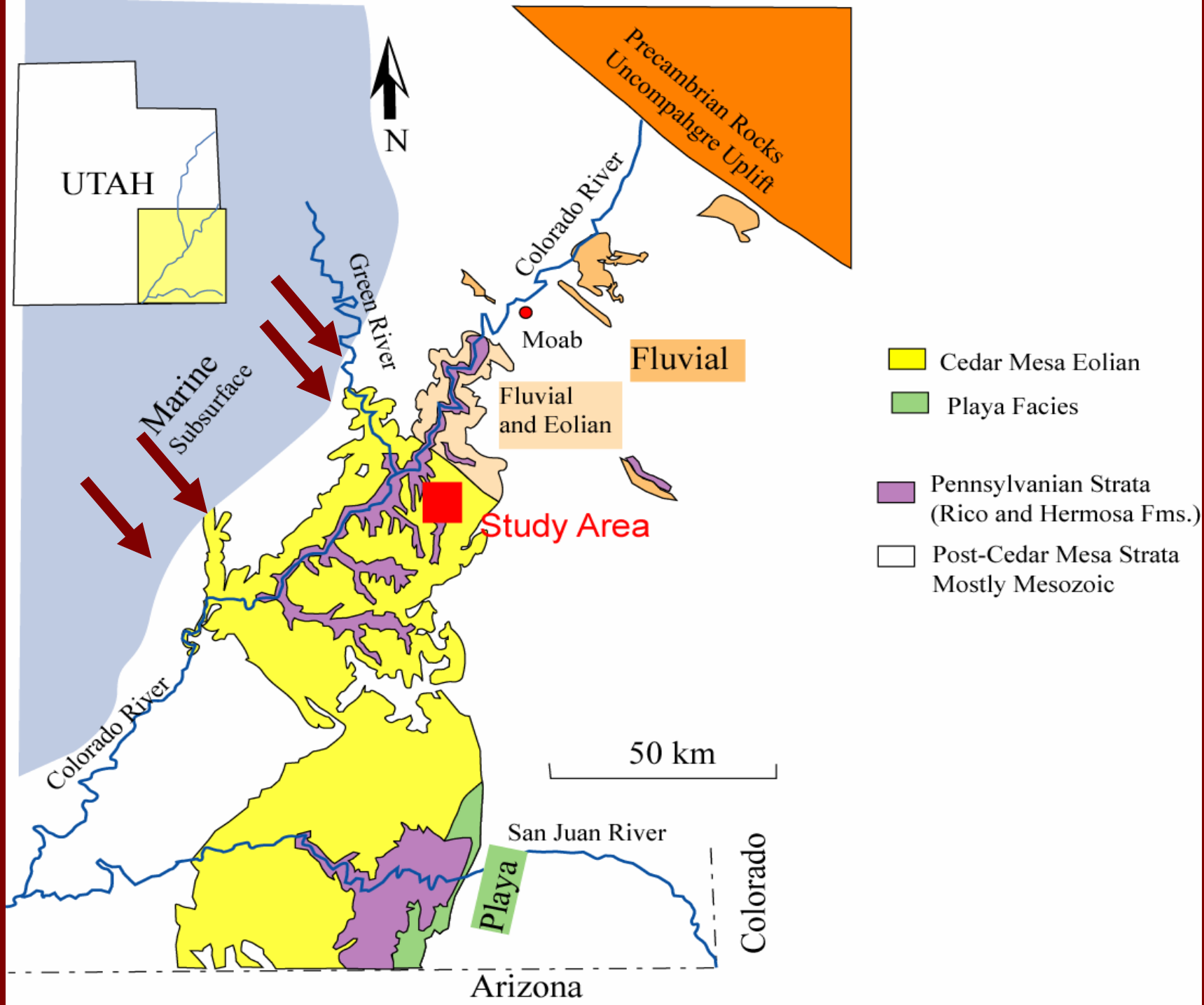
The erosion surfaces mark highstands that flooded the sources of eolian sand. The intervening dune fields mark lowstands. Within the intervals, reservoirs are large transverse mounds, accumulated during erg aggradation. The barriers to flow are complex surfaces with discontinuous shales and diagenesis in soils that precipitated clay and hematite cements. Permeabilities, measured with an air permeameter drop from 10 to 10s of milliDarcys to less than 1 mD (the limits of our equipment across several meters at the boundaries). The basal 1 to 3 m of the overlying eolian sandstones are also cemented with early calcite cement. The origins of this cementation are uncertain, but it contributes to the ability to obstruct fluid migration.

Architecture of Reservoirs Confined by Early Diagenesis in Paleosols at Sequence Boundaries in Permian Eolianites

Rip Langford, Univ Texas El Paso
David Tatum Chevron USA, New Orleans, LA
Pierre-Andre Depret, British Petroleum, Houston
Katy Duncan, Halliburton, Denver, CO
Krystal Pearson, Conoco-Phillips, Houston TX
Luqman Adams, Prairie View A & M

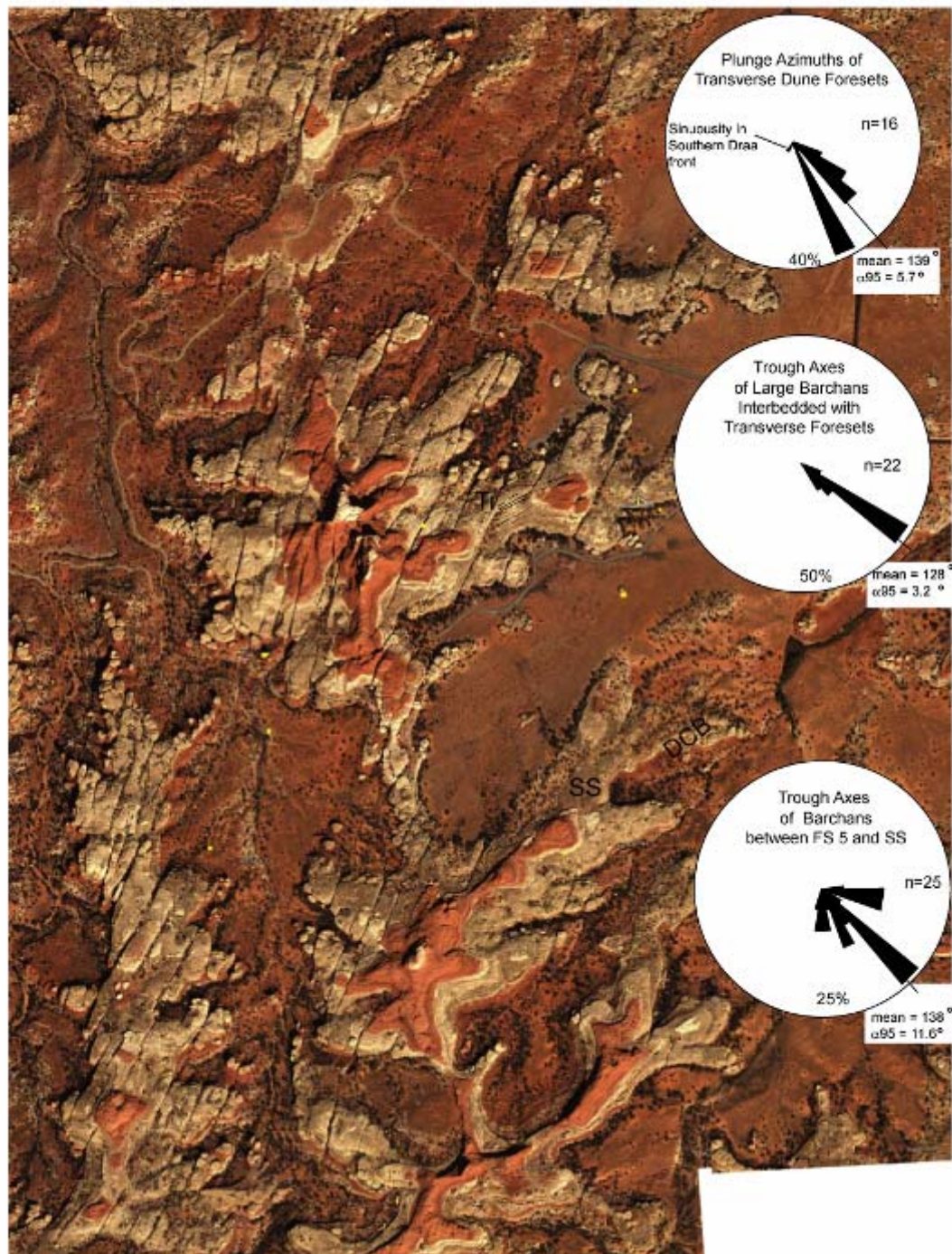
Eolian Sequences

- Kocurek, Halvholmm Carr Craybaugh (1993, 1994)
- Mountney (2006, Cedar Mesa)
- Smith, L. B., Al-Tawil, A., Read, J. F., (2001)
- Atchley, S.C. and Loope, D.B. (1993)



Stratigraphy





What segregates reduced sandstones from oxidized?

- Permeability fabric
- Small scale to large, ending in sequence boundaries.
- Sedimentology combined with petrography and permeability measurements

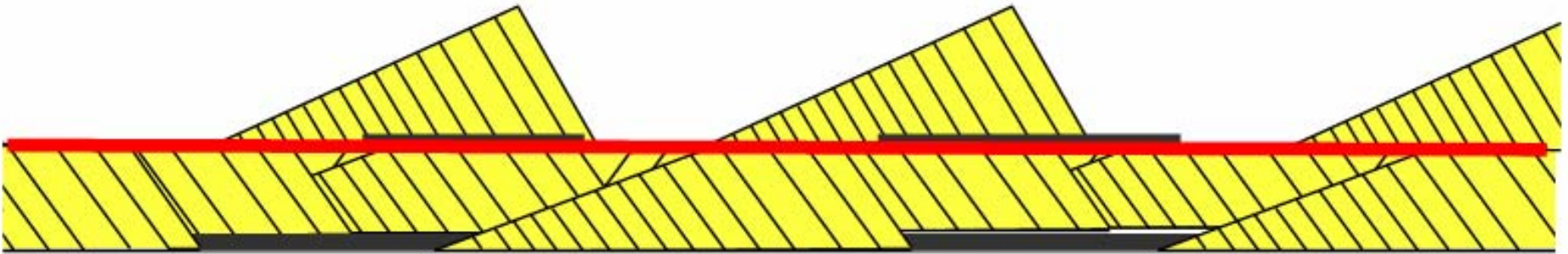
Permeability measured with calibrated air permeameter

- Effective range 0.5 mD to 1 Darcy

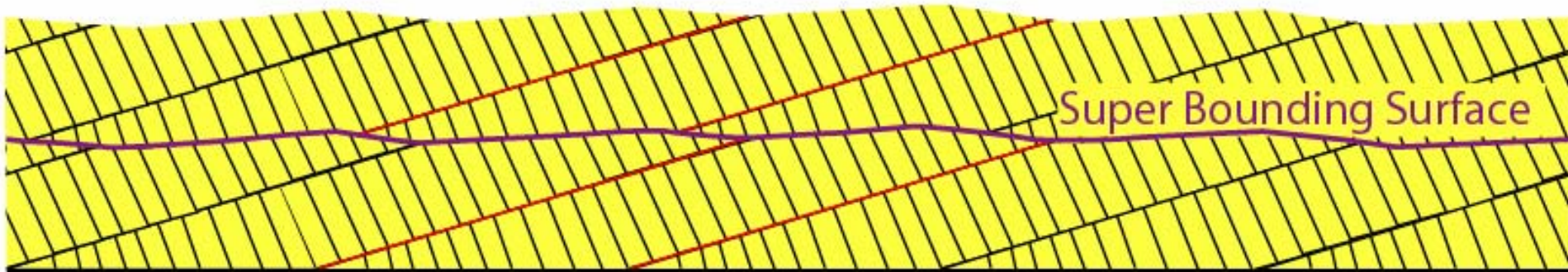
Bypass Surfaces “Flood Surfaces”

5- 400 km² at erg margin

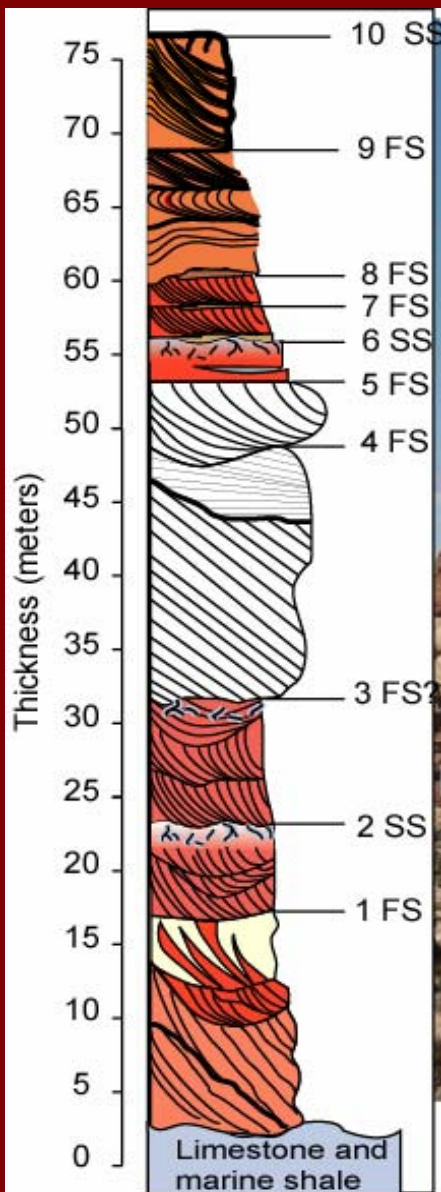
Translation without climb little missing time



Stabilization Surfaces – Super surfaces. Sequence boundaries.

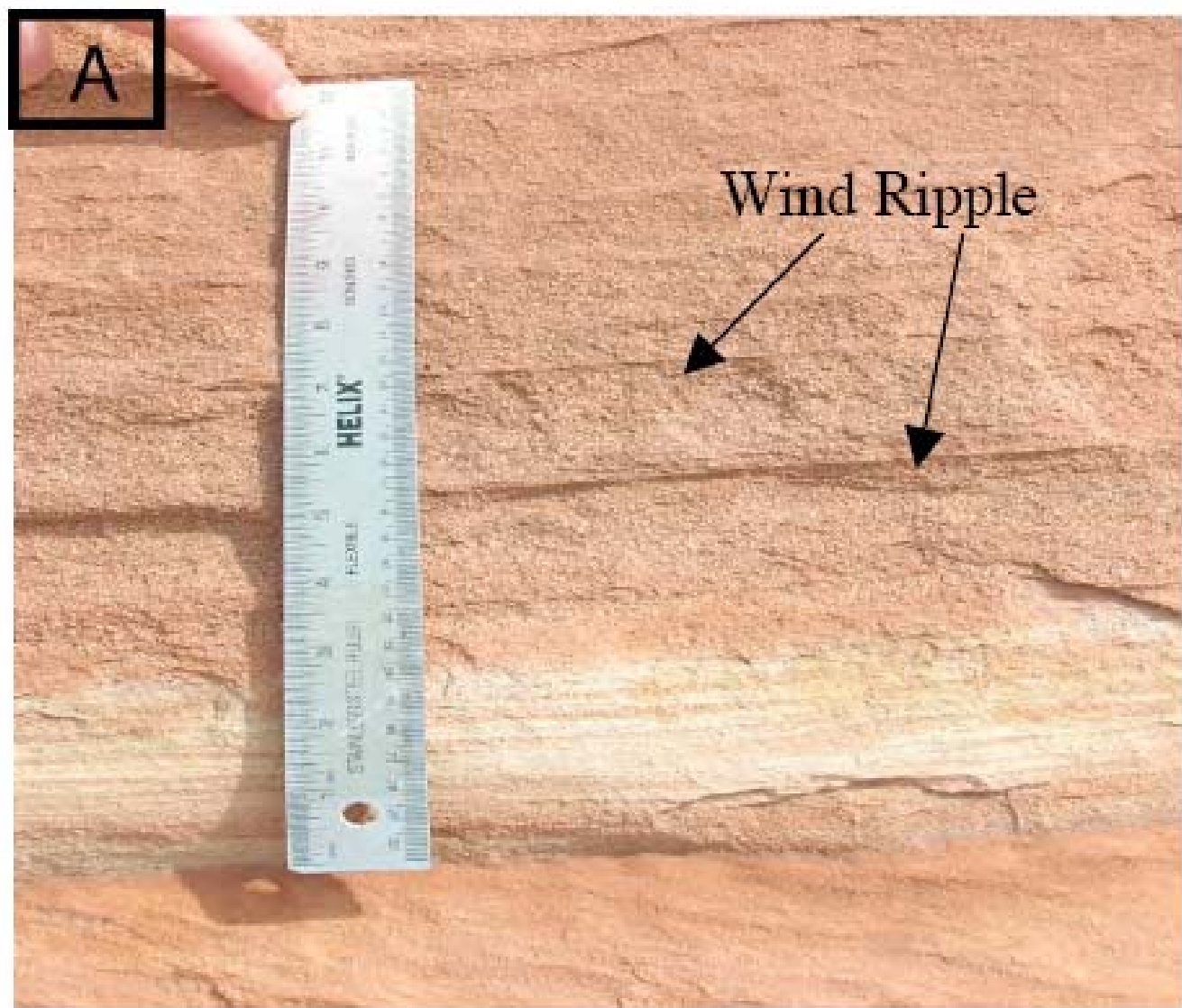


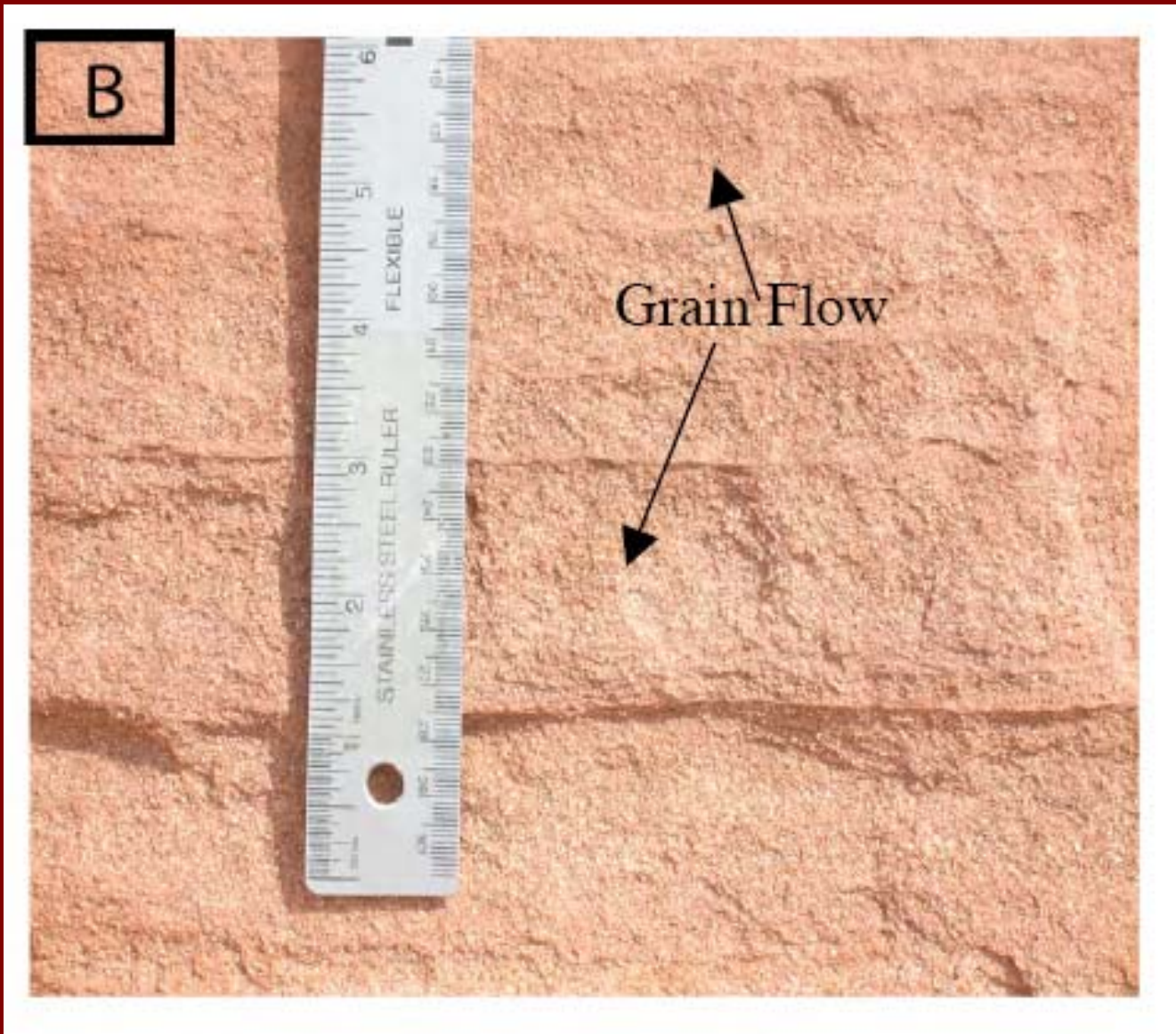
Stratigraphy



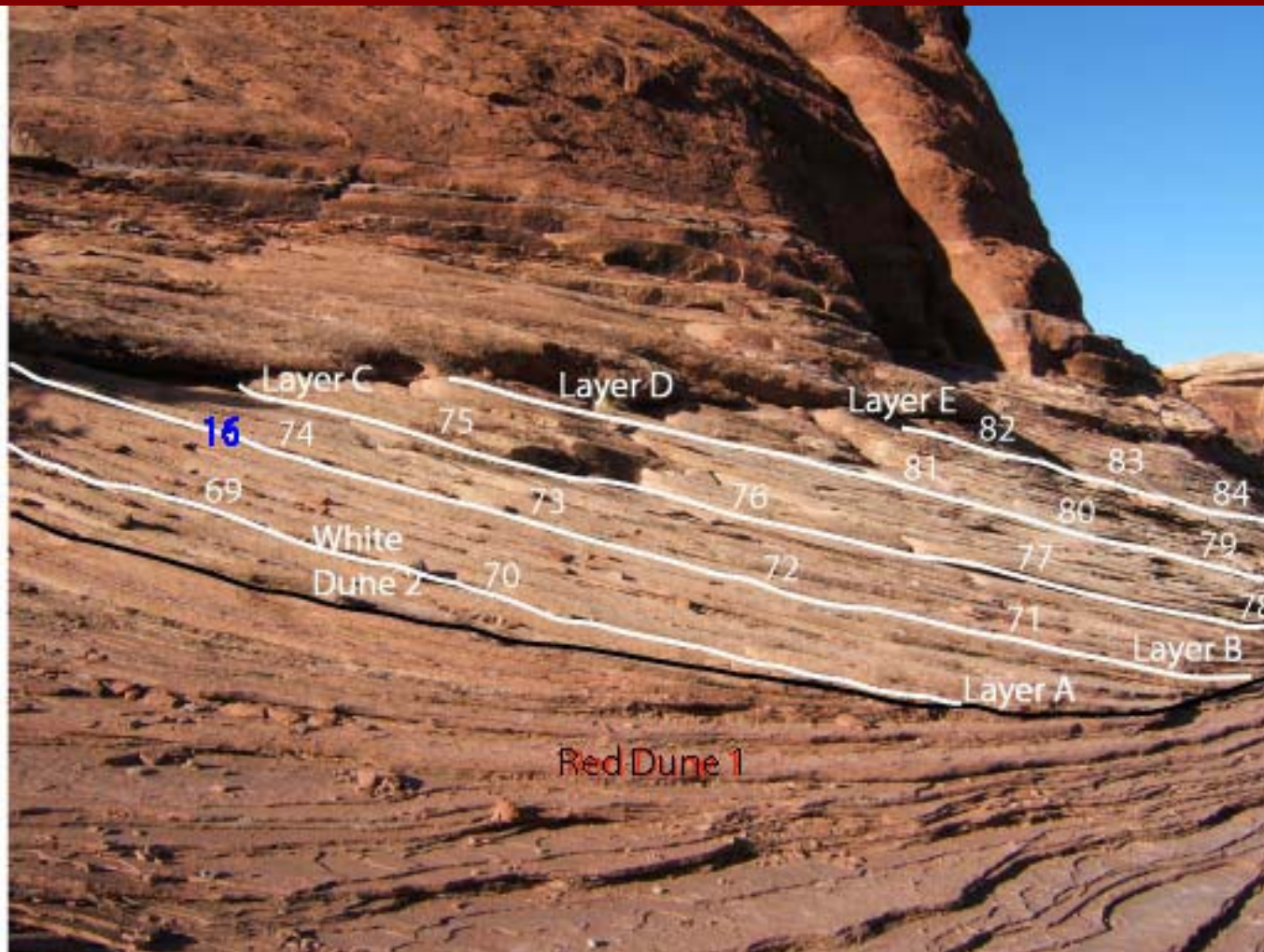
Small Scale Structure

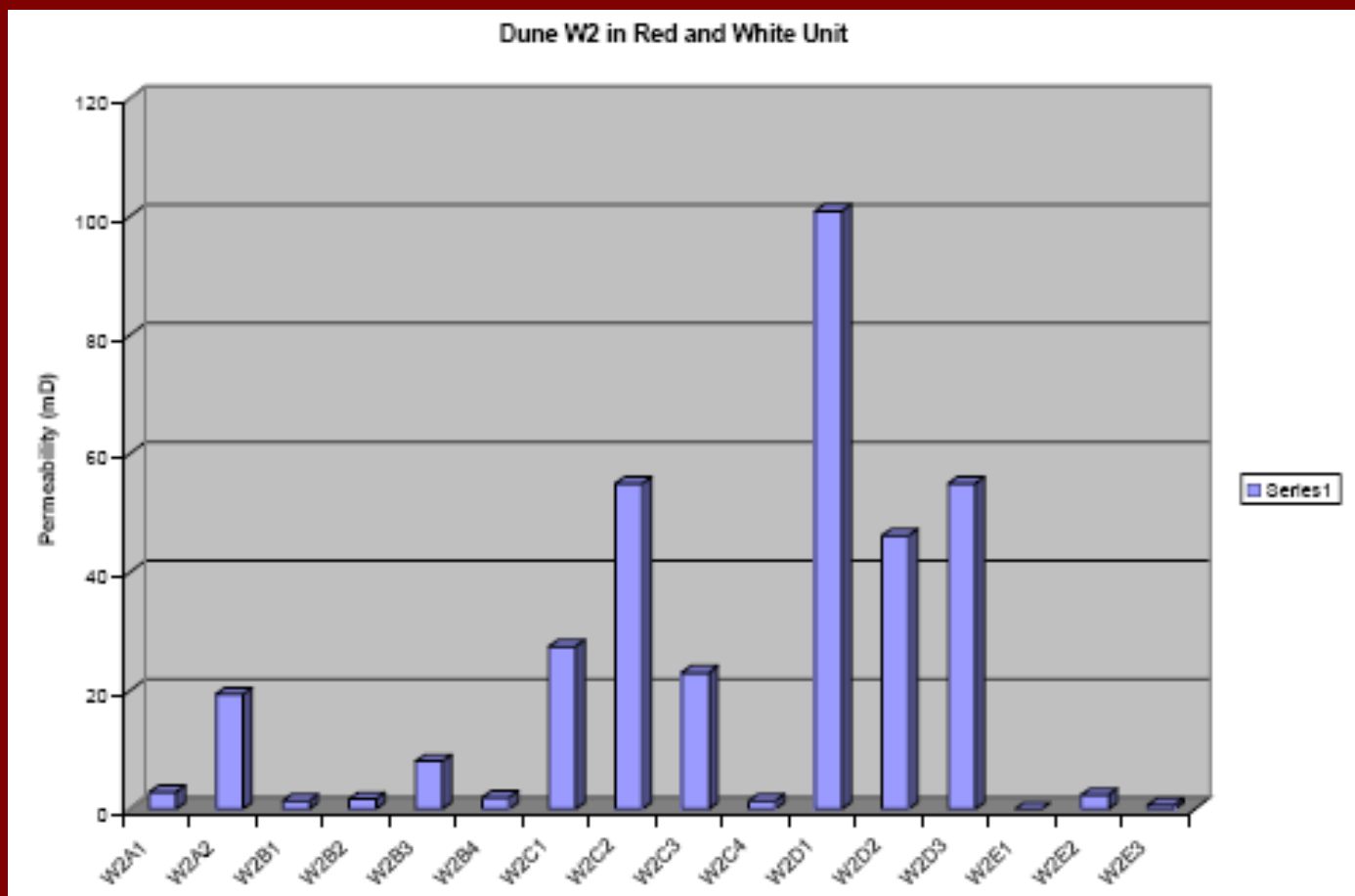
- Inclined wedges and bed-sets of grain flow and wind ripple cross-strata.

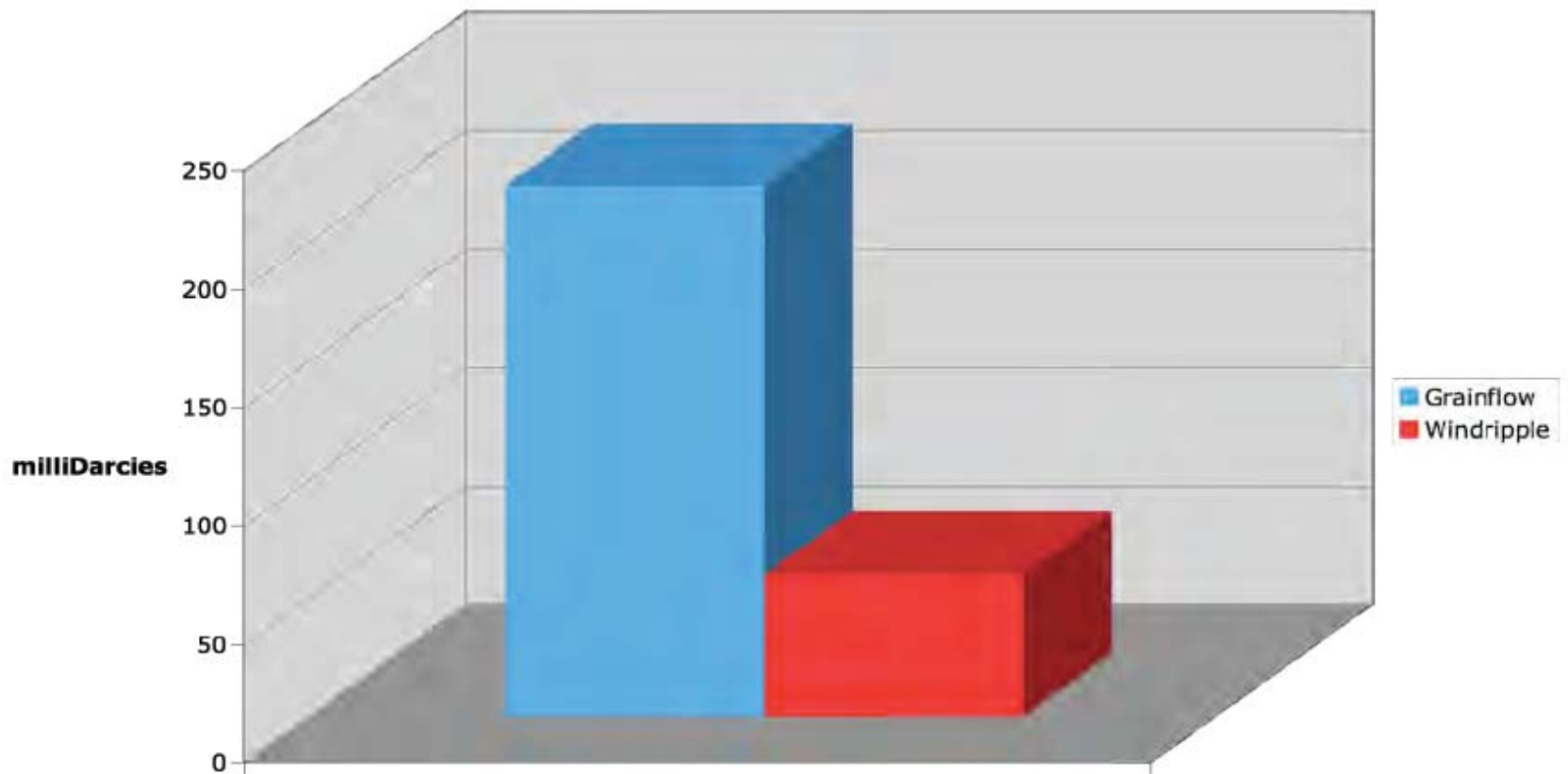






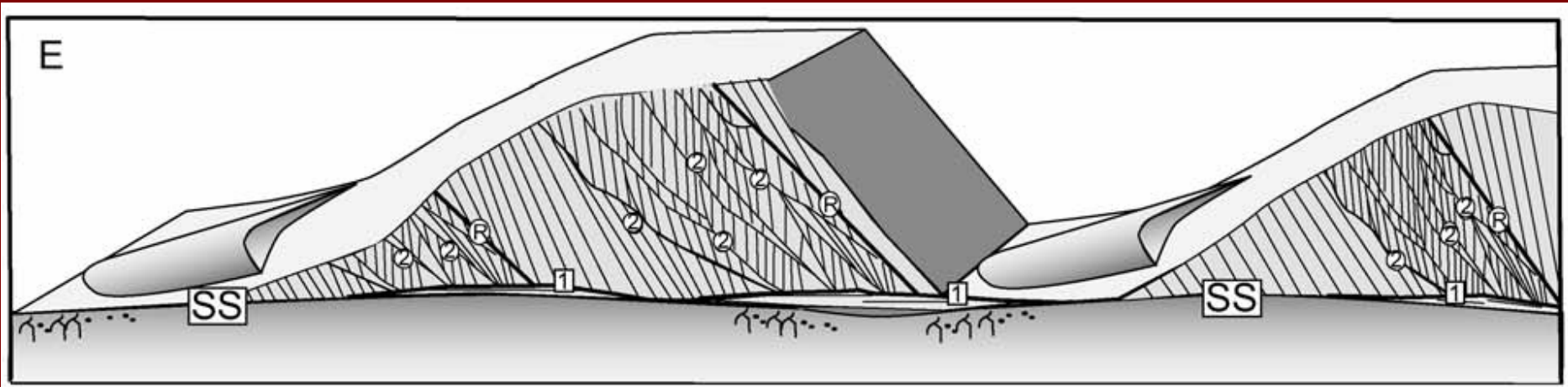






Larger Scale Features

- Megadunes (draas) 500 m in direction of migration several kilometers in depositional strike. 20-25 m thick.
- Interdraa contain pond deposits that are shingled ponds and associated sand sheets are comparatively low permeability

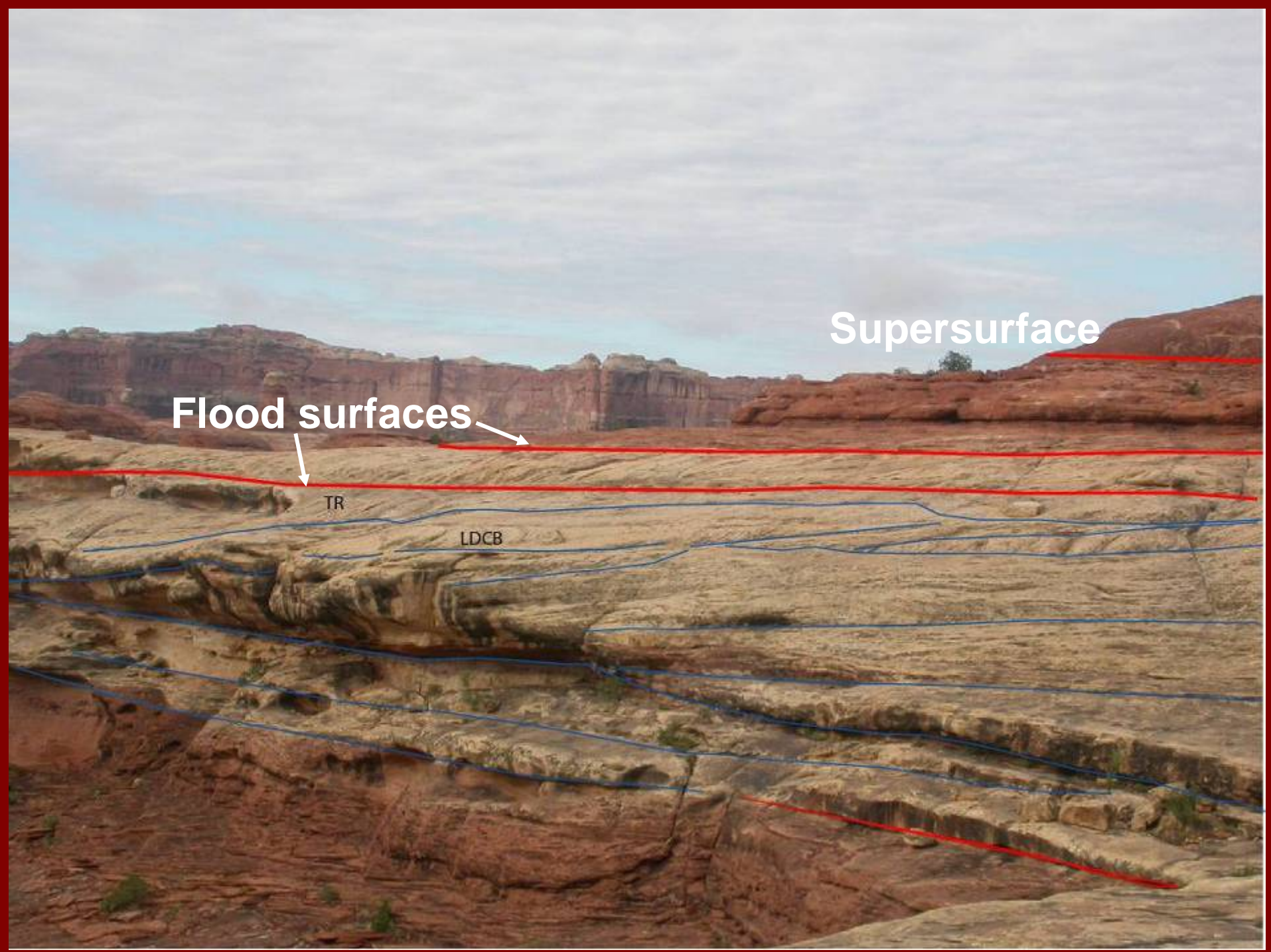


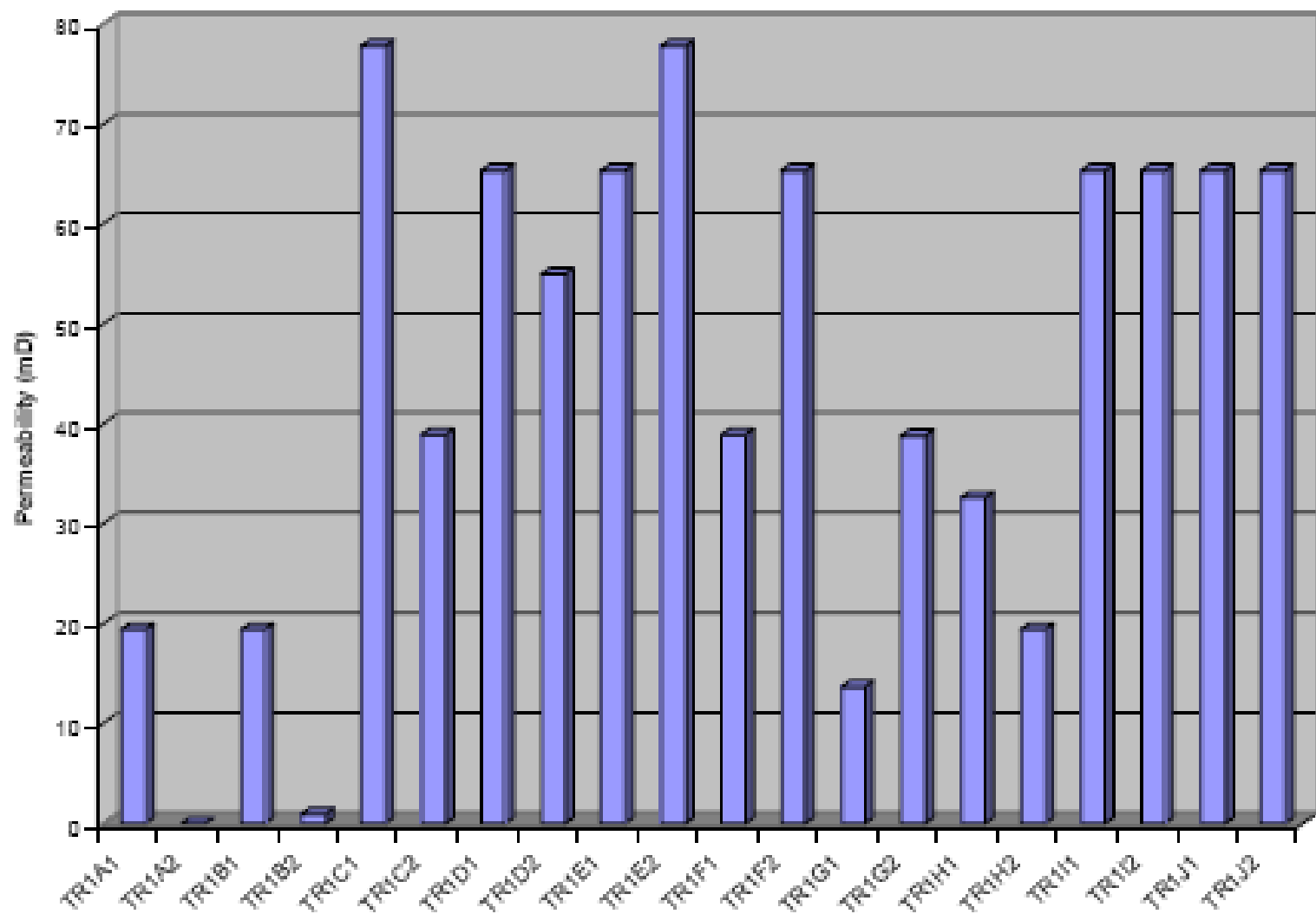
Supersurface

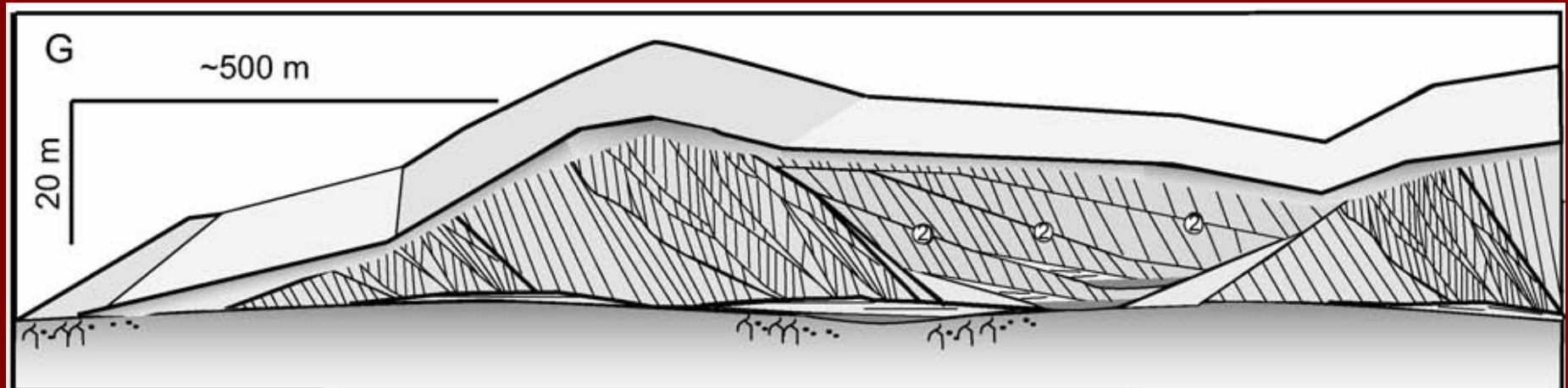
Flood surfaces

TR

LDCB

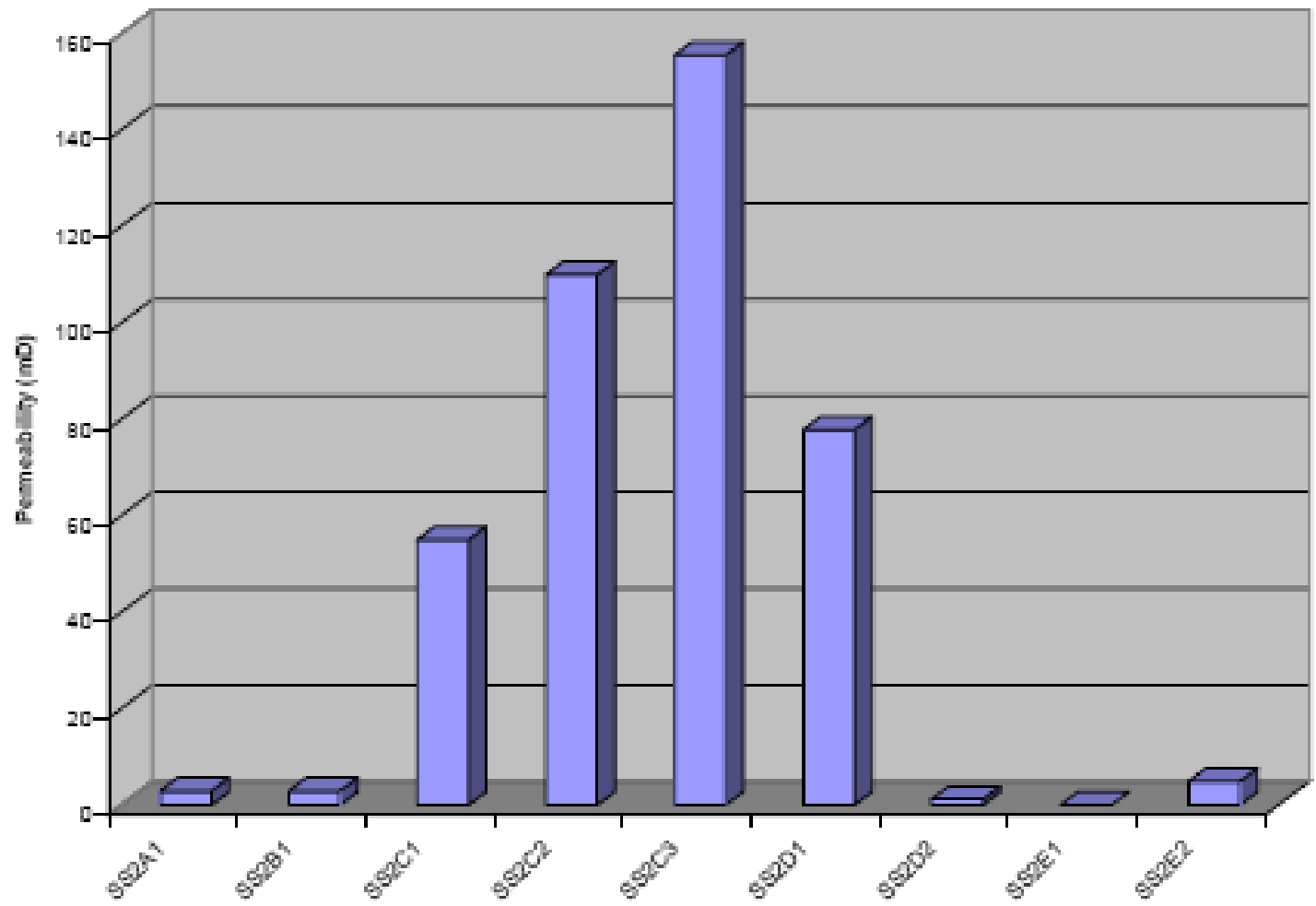












A photograph of a rock outcrop showing distinct geological layers. The upper part of the image shows a light-colored, relatively smooth rock surface. Below this is a darker, more textured layer. A vertical scale bar, marked with yellow and orange segments, is placed against the rock face for scale. The lower part of the image shows a more complex, layered structure with varying shades of brown and tan.

Red
Dolomite
cemented
Sandstone

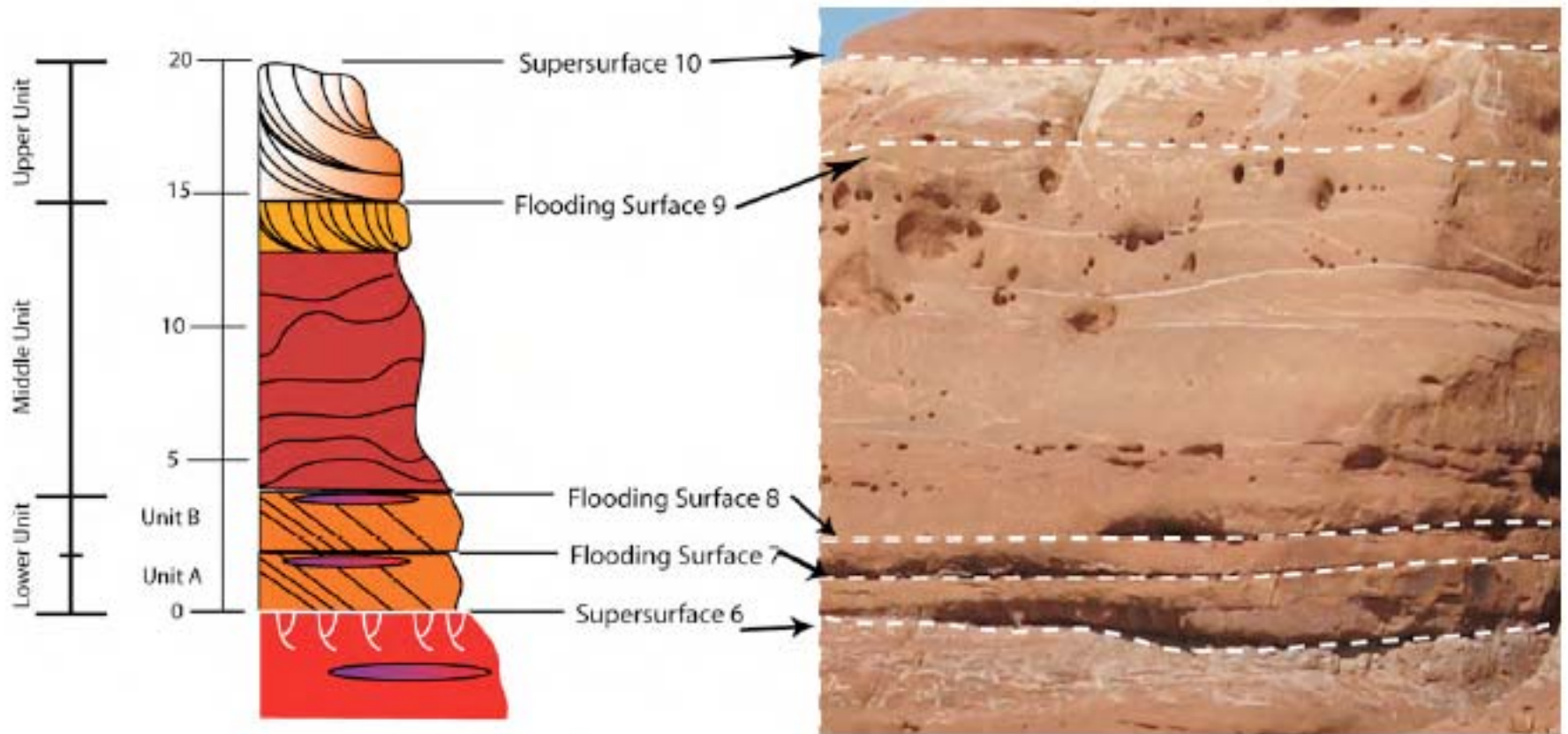
Sandy
Carbonates

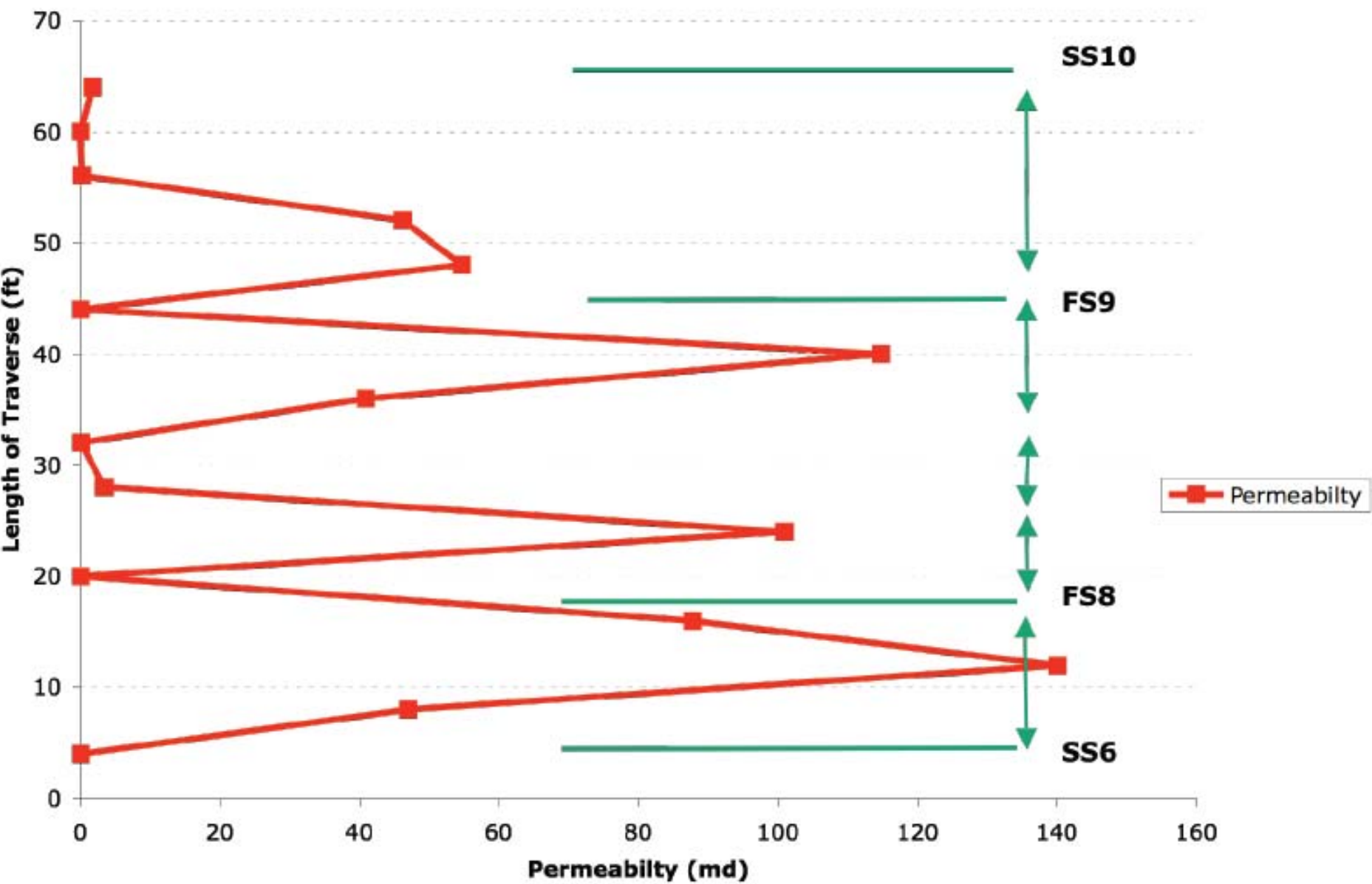
Permeability

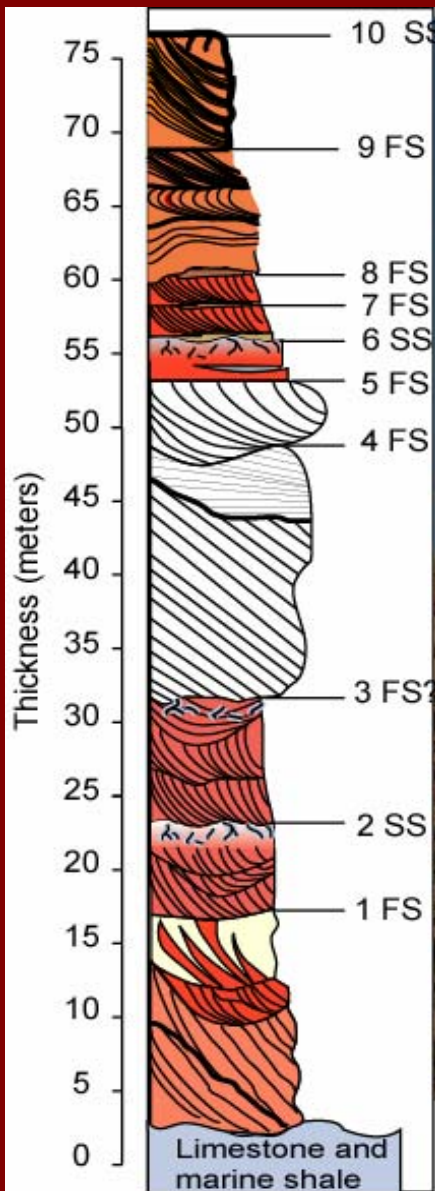
- Too Low to measure

Flood Surfaces

- Localized silt and clay filled ponds
- Different flood surfaces have different degrees of soil formation and associated diagenesis







Larger Scale Structure– Origin of the Super surfaces bounding reservoirs

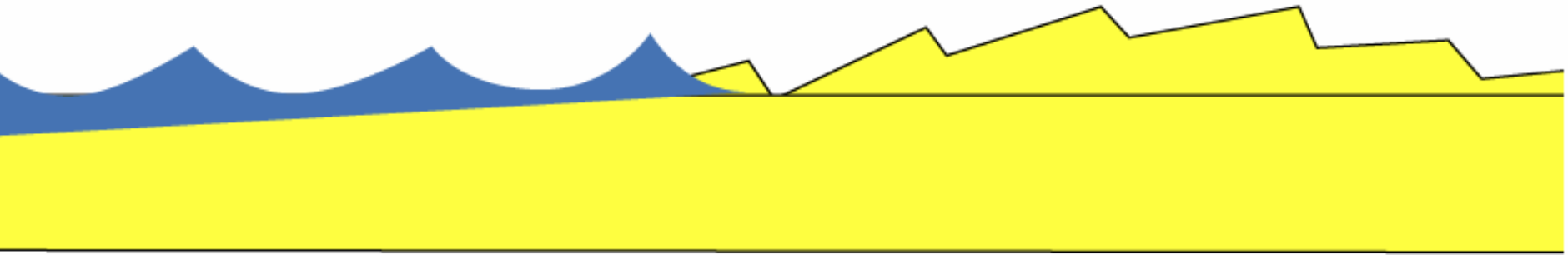


Two basic models – many elaborations

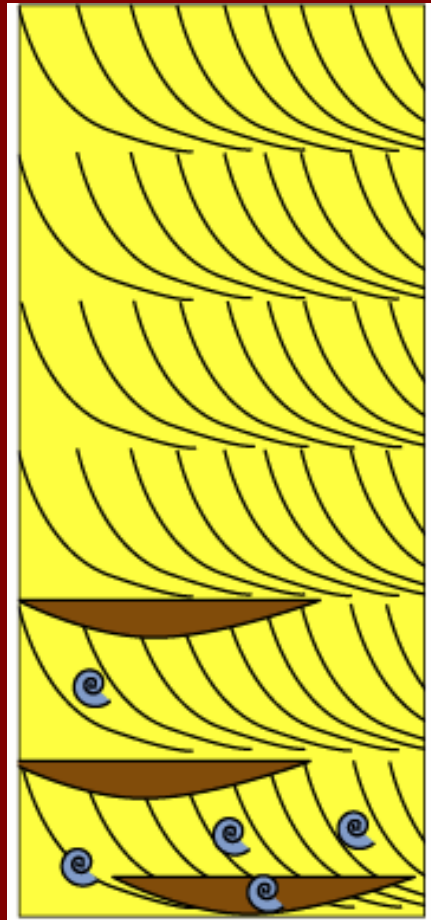
- Falling sea level exposes sand sources, which is deflated into dunes
 - During regression – Carbonate eolianites
 - During lowstand
- Lowstands are erosion surfaces,
 - Sediment accumulates during rising sea level when rising water tables allow preservation

Model 1

Regression uncovers source and
provides sediment for constructing erg

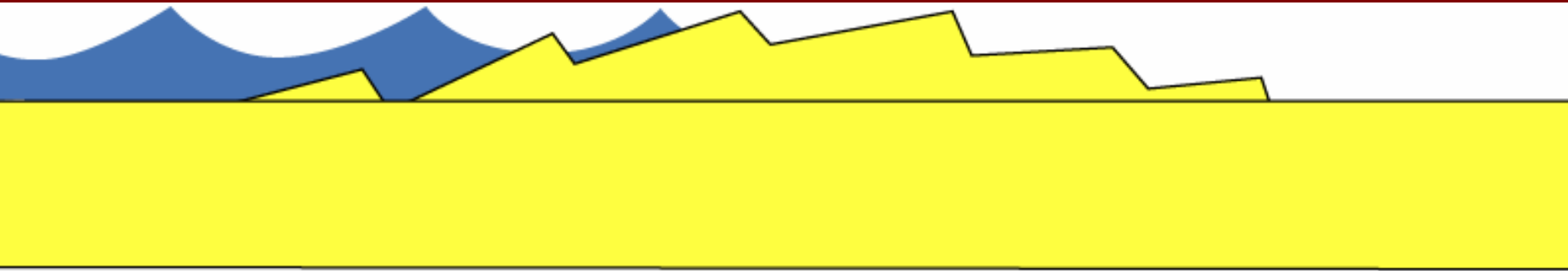


Falling sea level deposition predicts upward crying
and fossil fragments found in basal eolianites

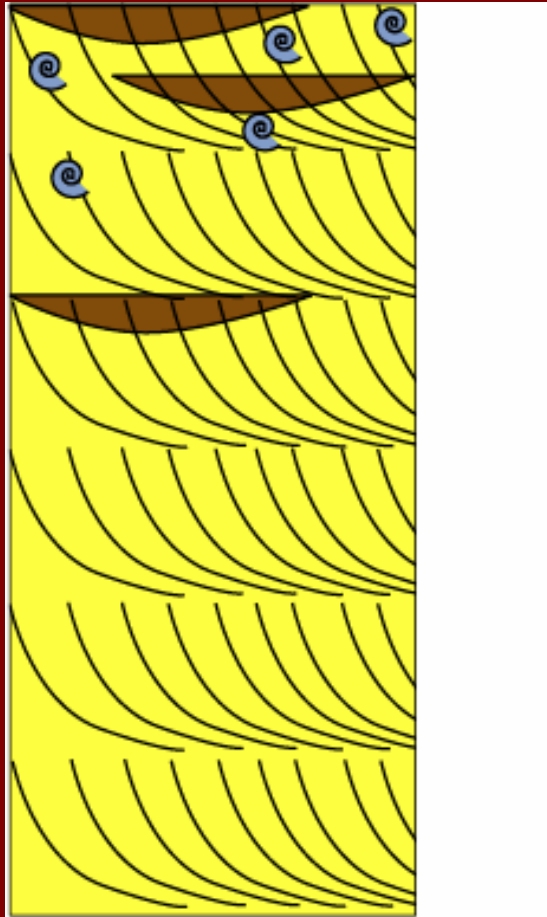


Model 2

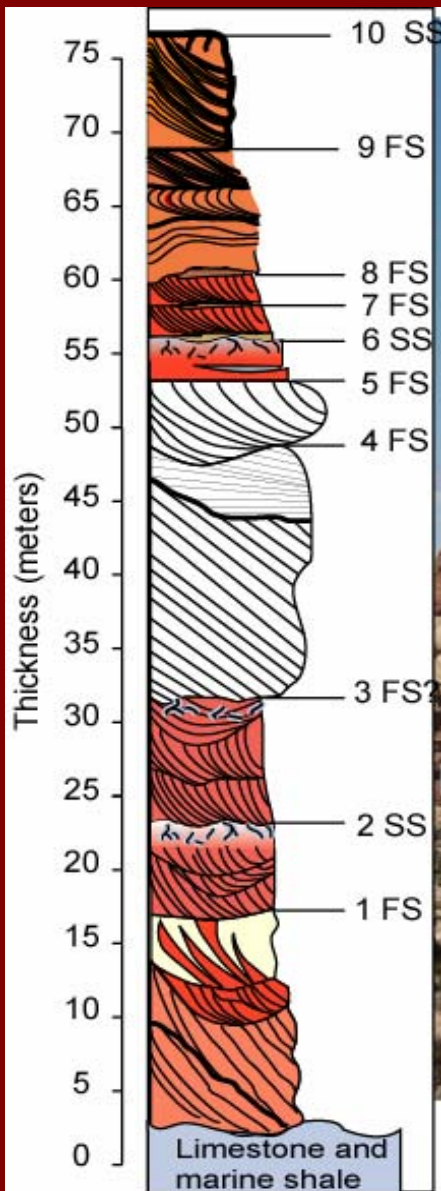
Rising sea level preserves eolianites
changing climate and rising water table



Predicts upward wetting and fossil fragments in upper eolianites



Results



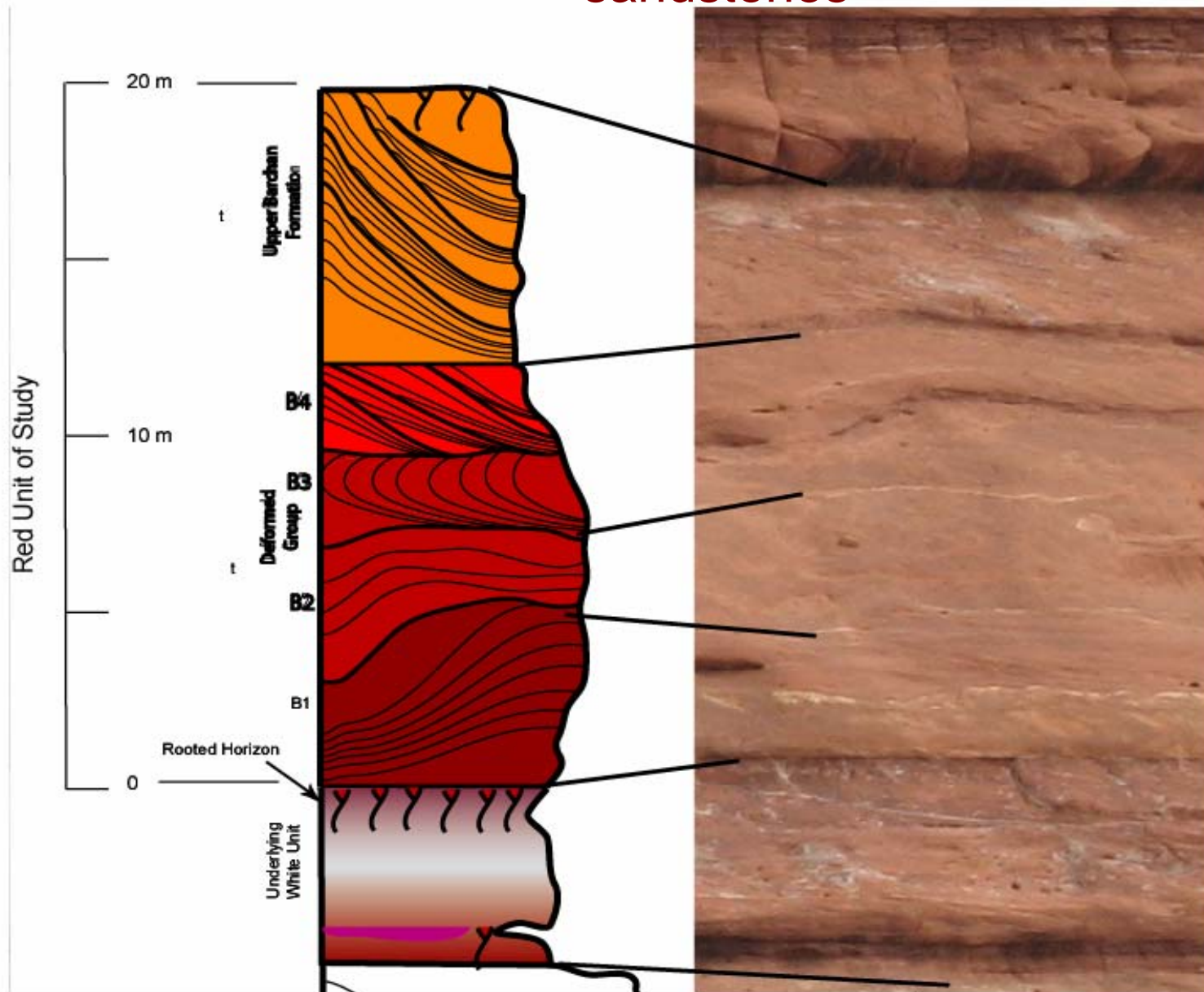
Upward Drying trends within both eolian units

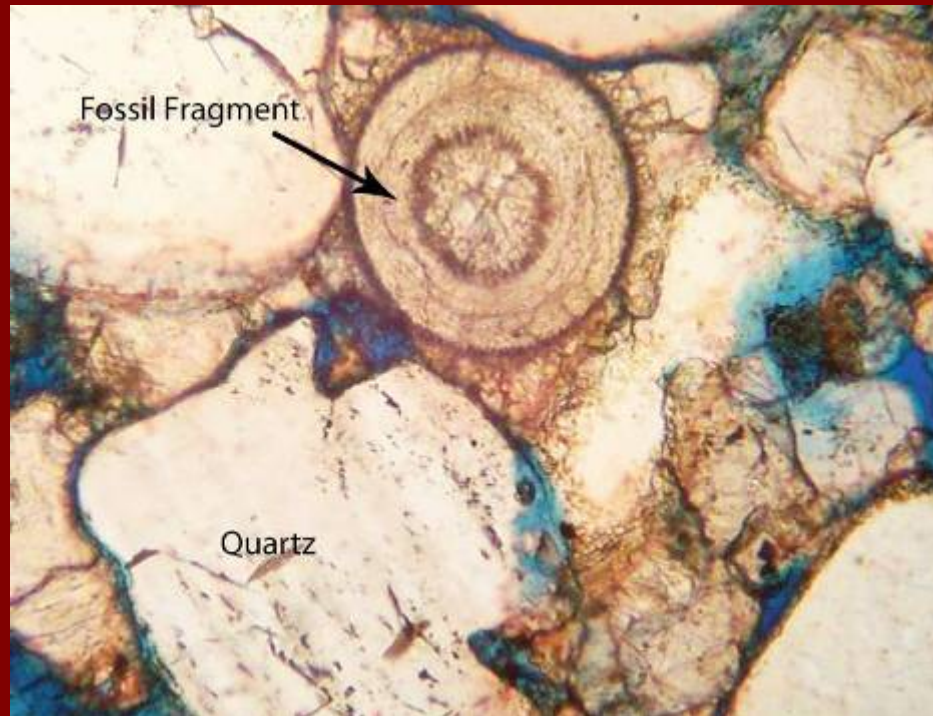
- Geomorphic-topographic effect
- Topographic lows are preserved lower in the section
- Dune field construction created larger topographically higher topography.

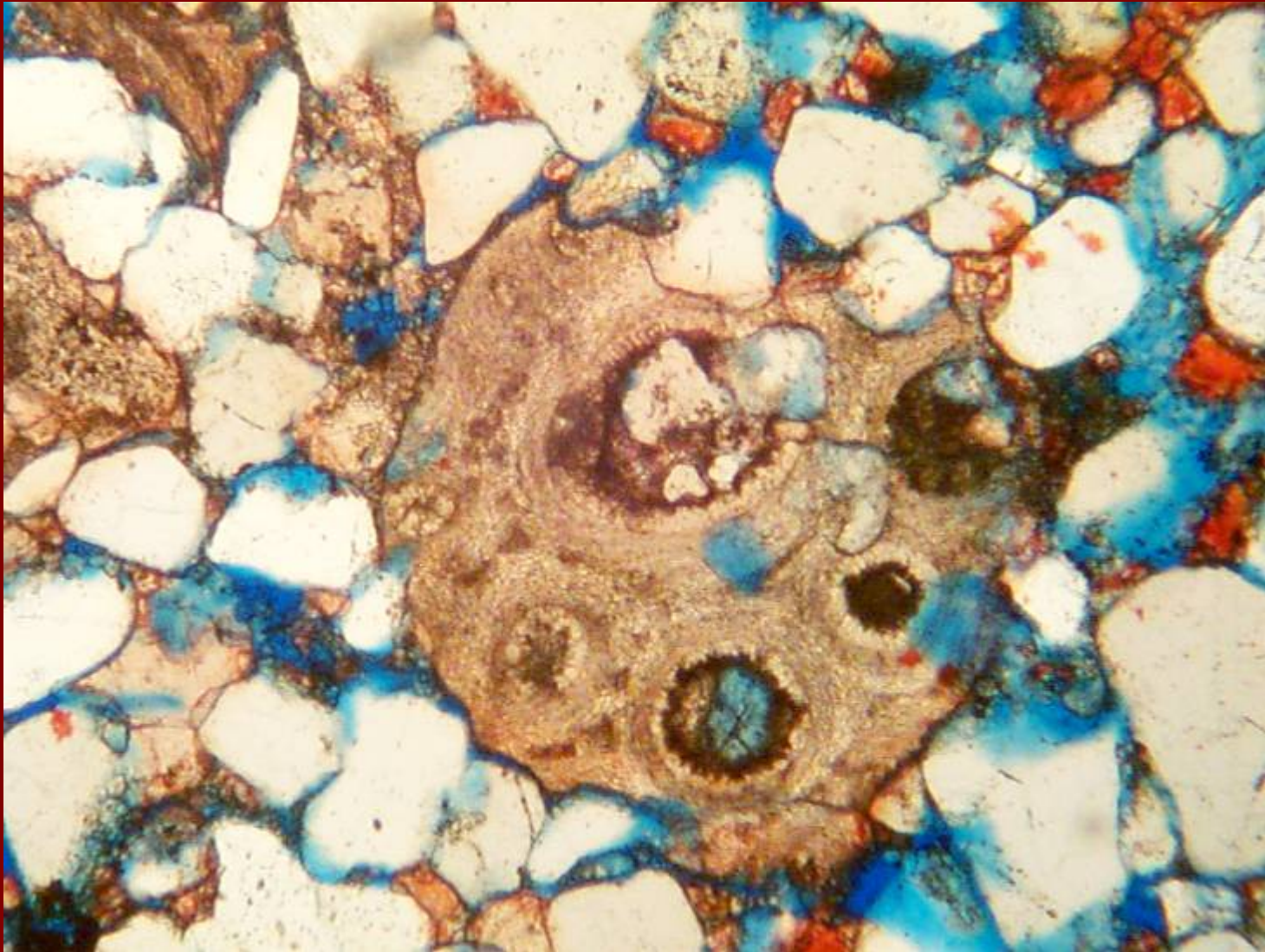


Fossil fragments in uppermost, widely bioturbated sandstones

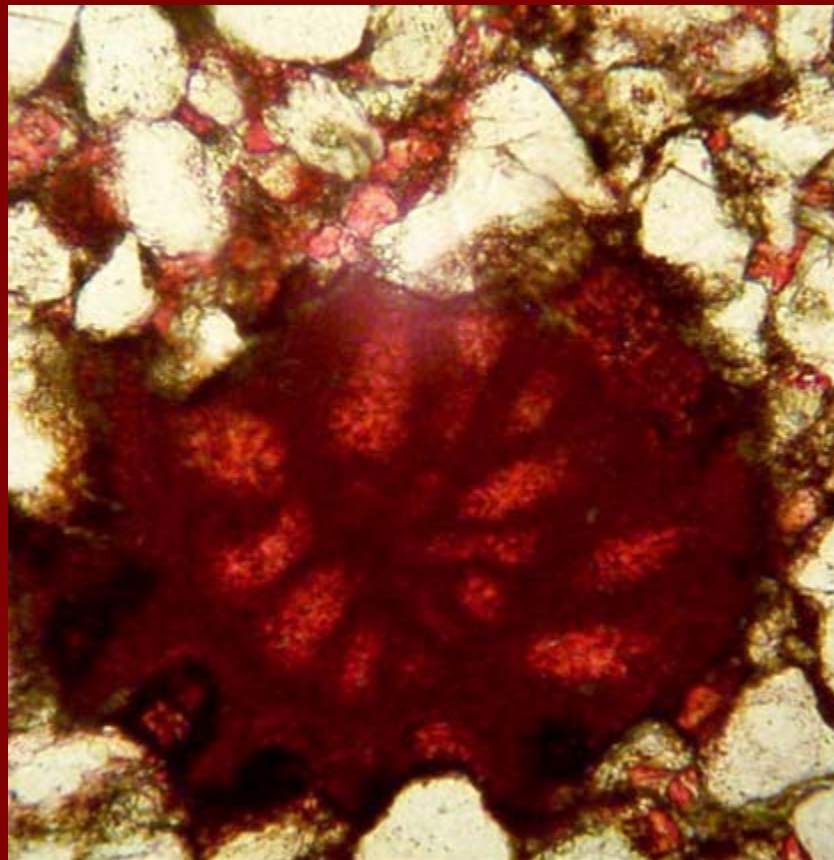
Fossil fragments occur as clasts in rhyzolith bearing sandstones







AAPG San Antonio Wed 10:05

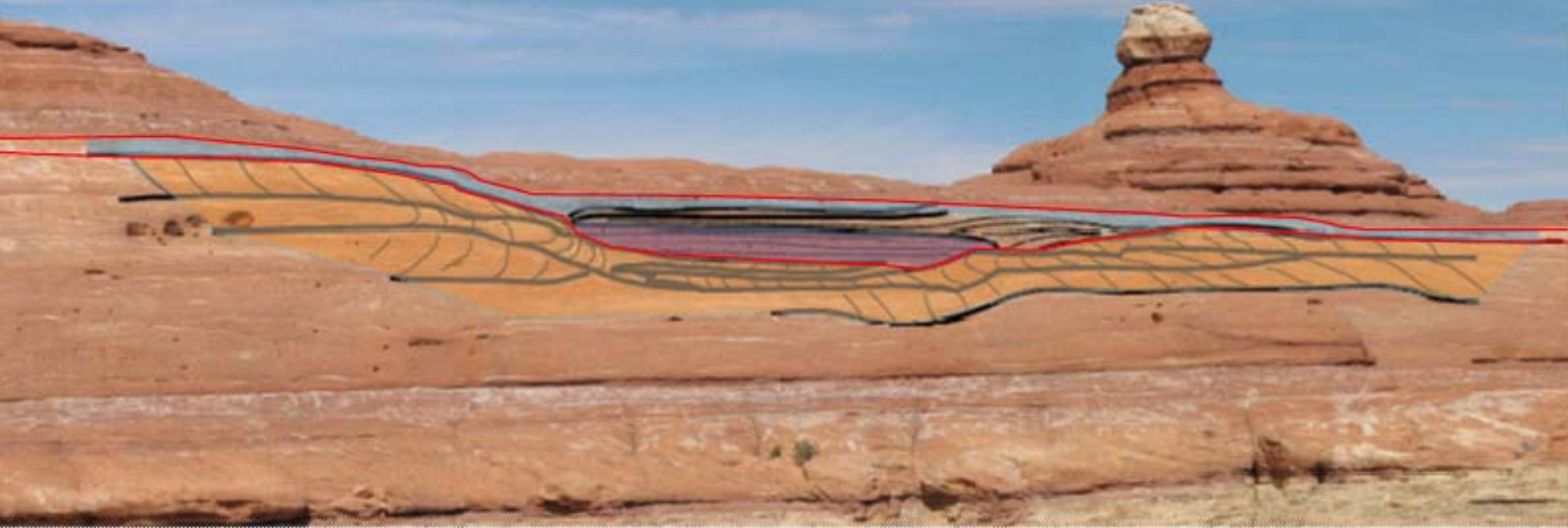


AAPG San Antonio Wed 10:05



Also in pond deposits above and below rooted horizons





Summary

- Fossil Fragments worked into eolian sand in upper part of units just below sequence boundaries
- Occurrence of fossil fragments fits generation of eolianites during lowstand, and subsequent rising sea level
- Stabilization and formation of “super surface” boundaries occurred during late sea level rise and highstand.
- Ponds and wet interdunes lie above bioturbated surfaces and formed after initial stabilization of the dune sea.

Summary 2

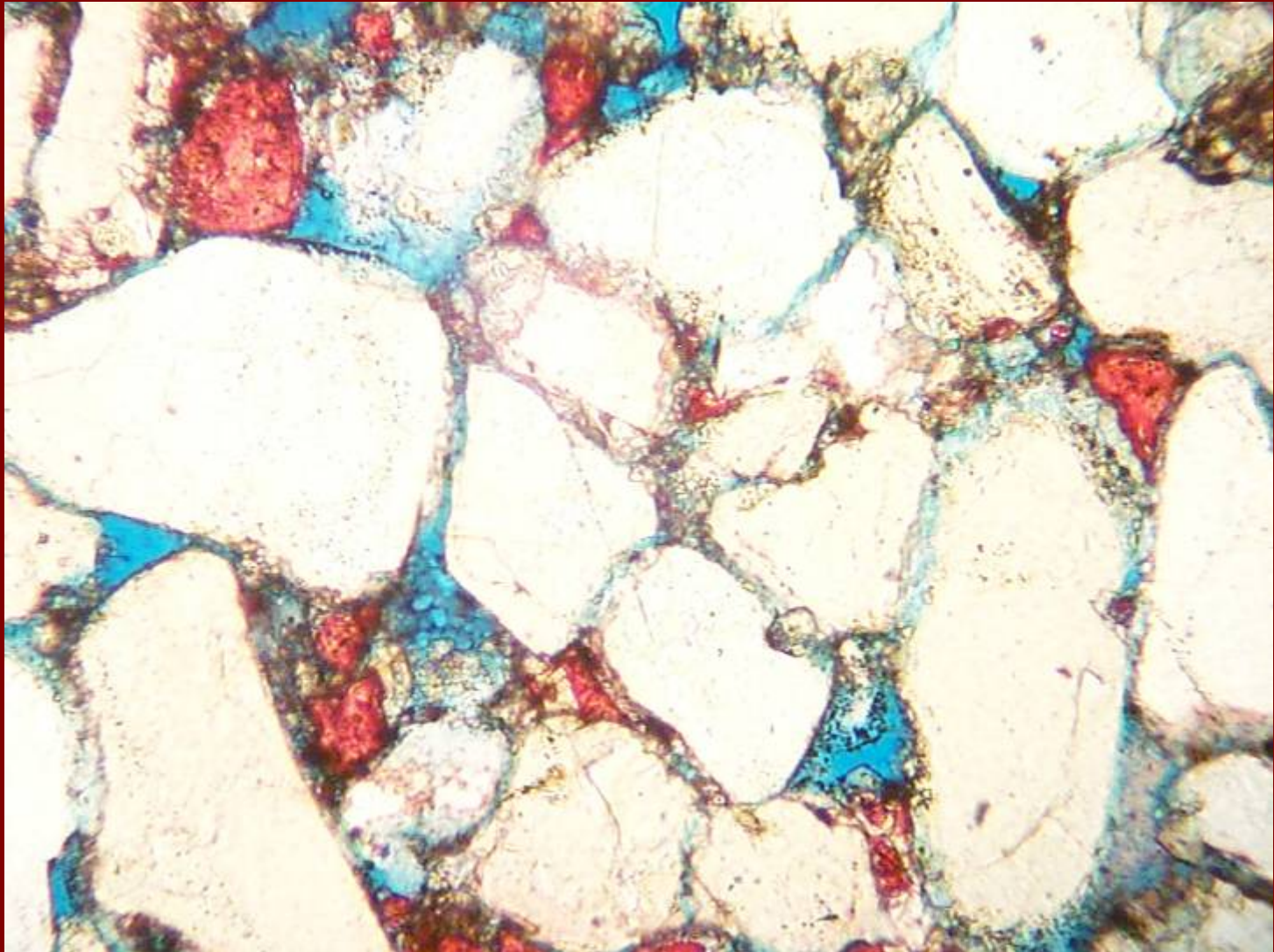
- The association of fossils along the erosion surfaces that preserve up to 8 m of relief indicate that water table was not a controlling factor in the deposition and preservation of the eolianites.
- The sequence boundaries have up to 8 m of relief and are shaped by underlying eolian topography.

Diagenesis

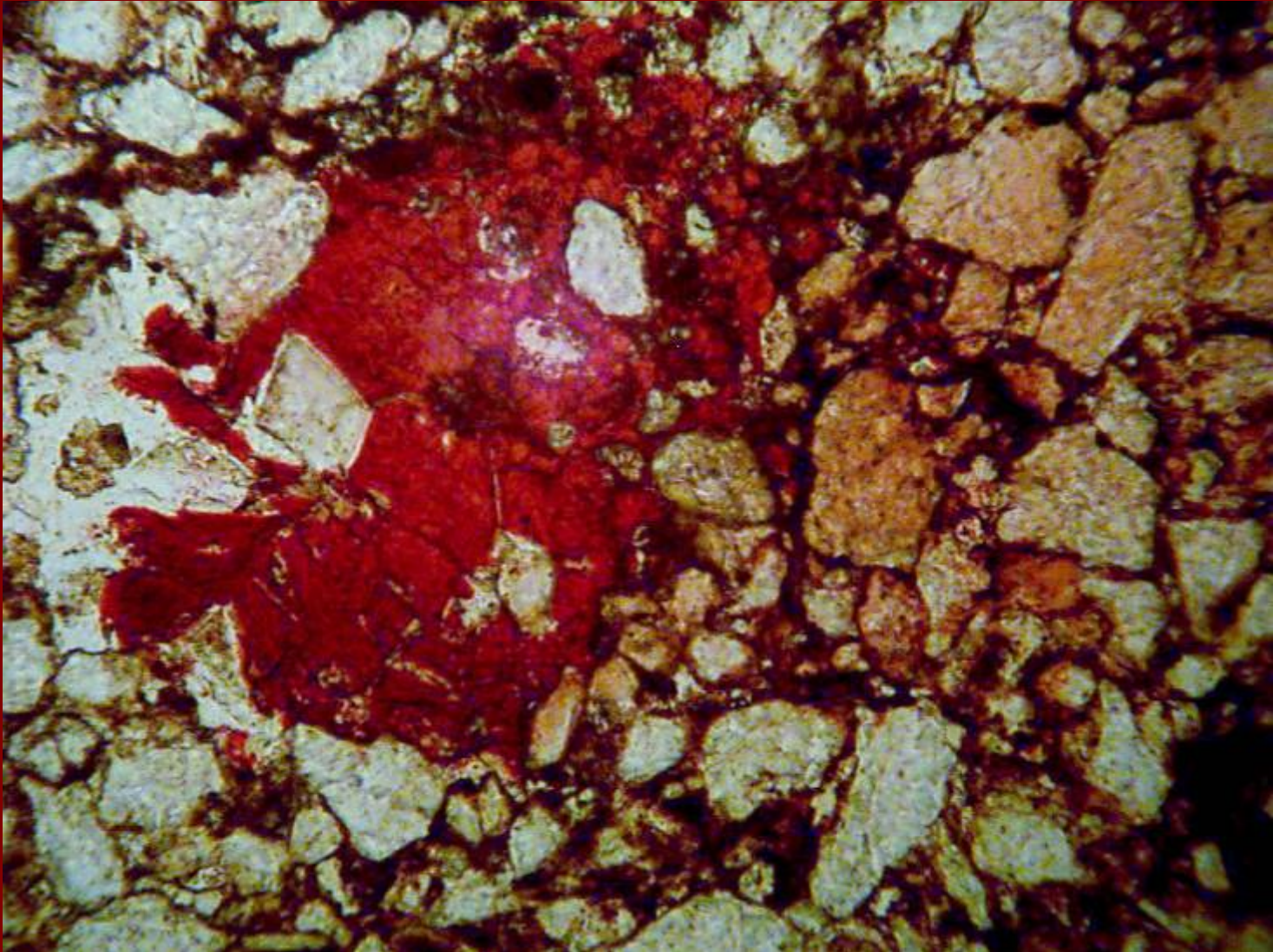
- Supersurfaces show distinct diagenesis

Grain flow

Slide 0.5 mm wide



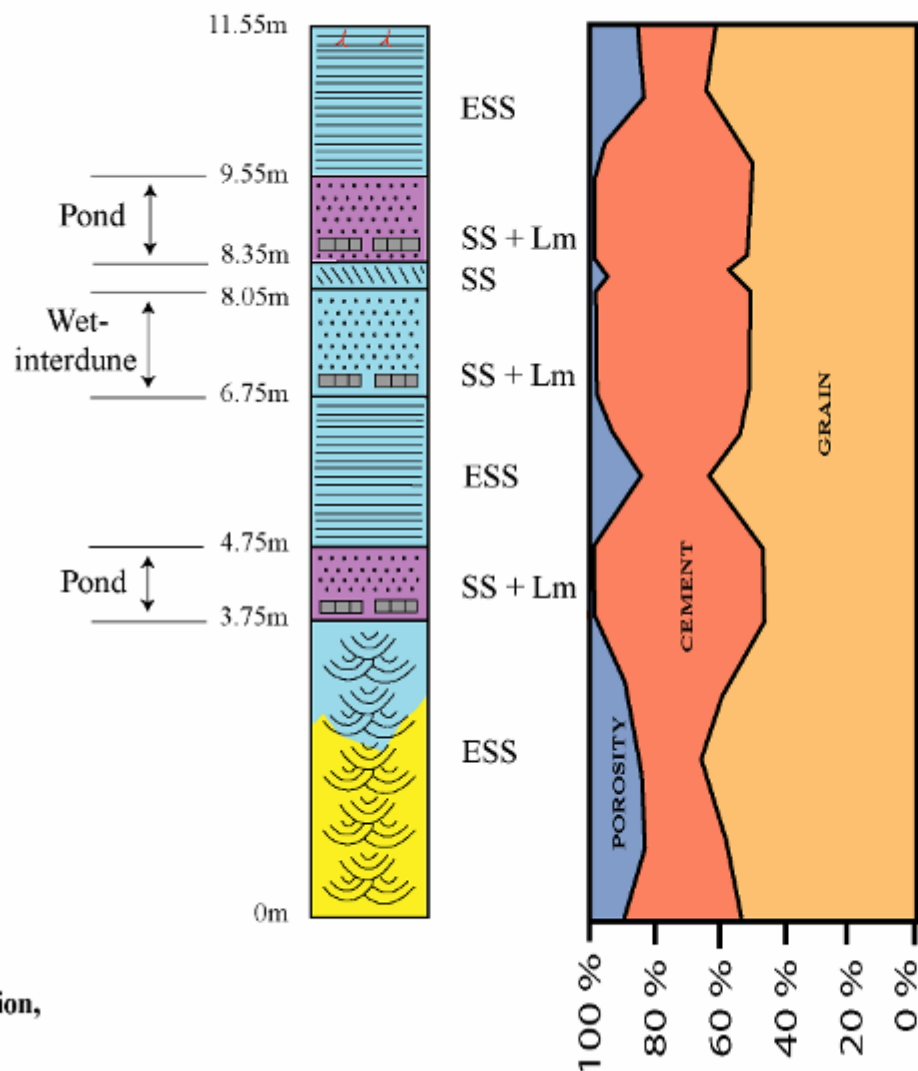
Below Horizon Root Cast—Calcite Clay hematite





to top

stratigraphic section,
facies.



DIAGENETIC FACIES

HIGH DOLOMITE + MODERATE EARLY CALCITE / MODERATE POROSITY

Cement is largely early dolomite and early calcite cement. Total cement ranges from 20 to 30% whereas porosity is lower averaging 15%).

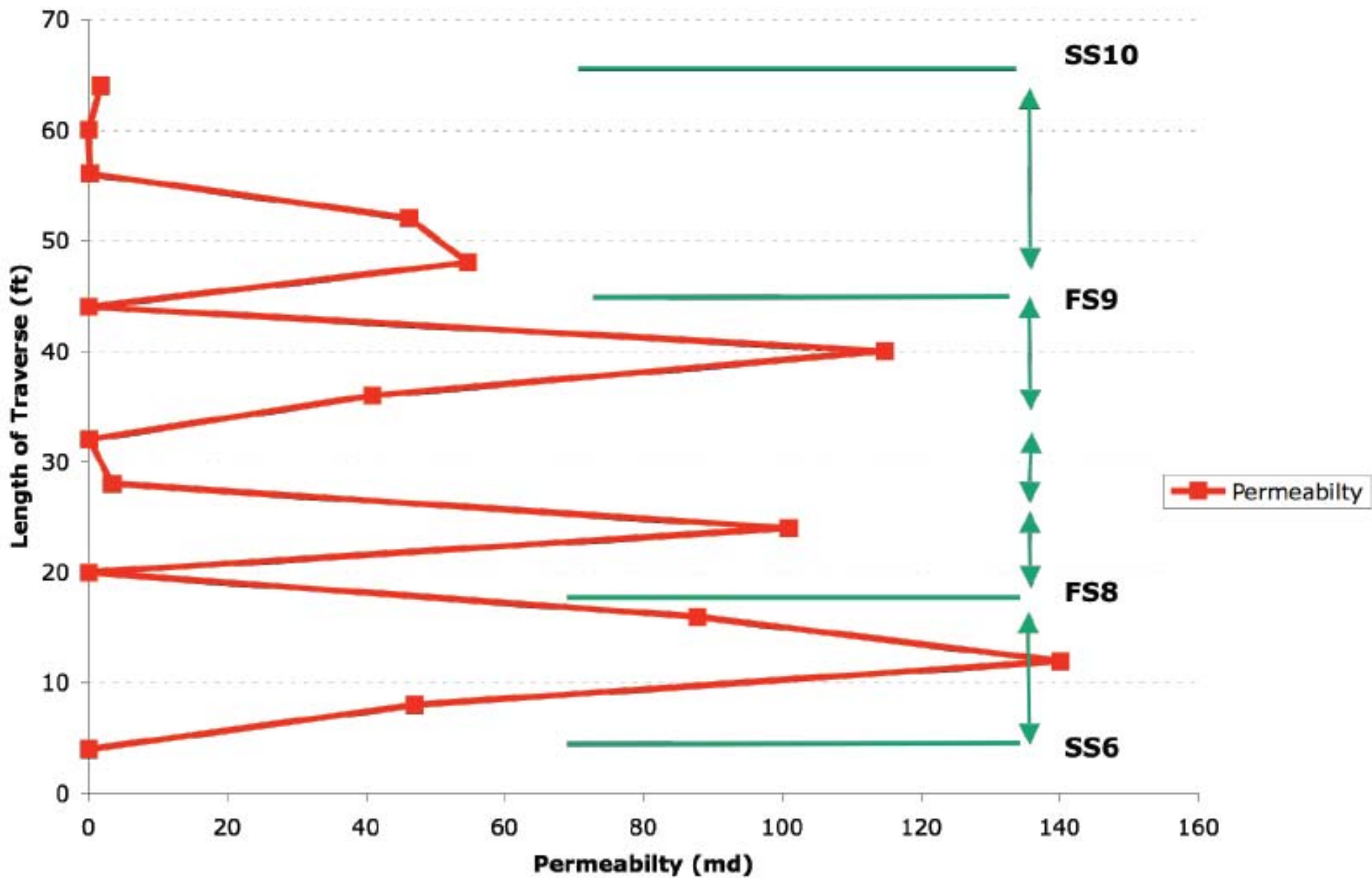
EARLY CALCITE / MODERATE TO HIGH POROSITY

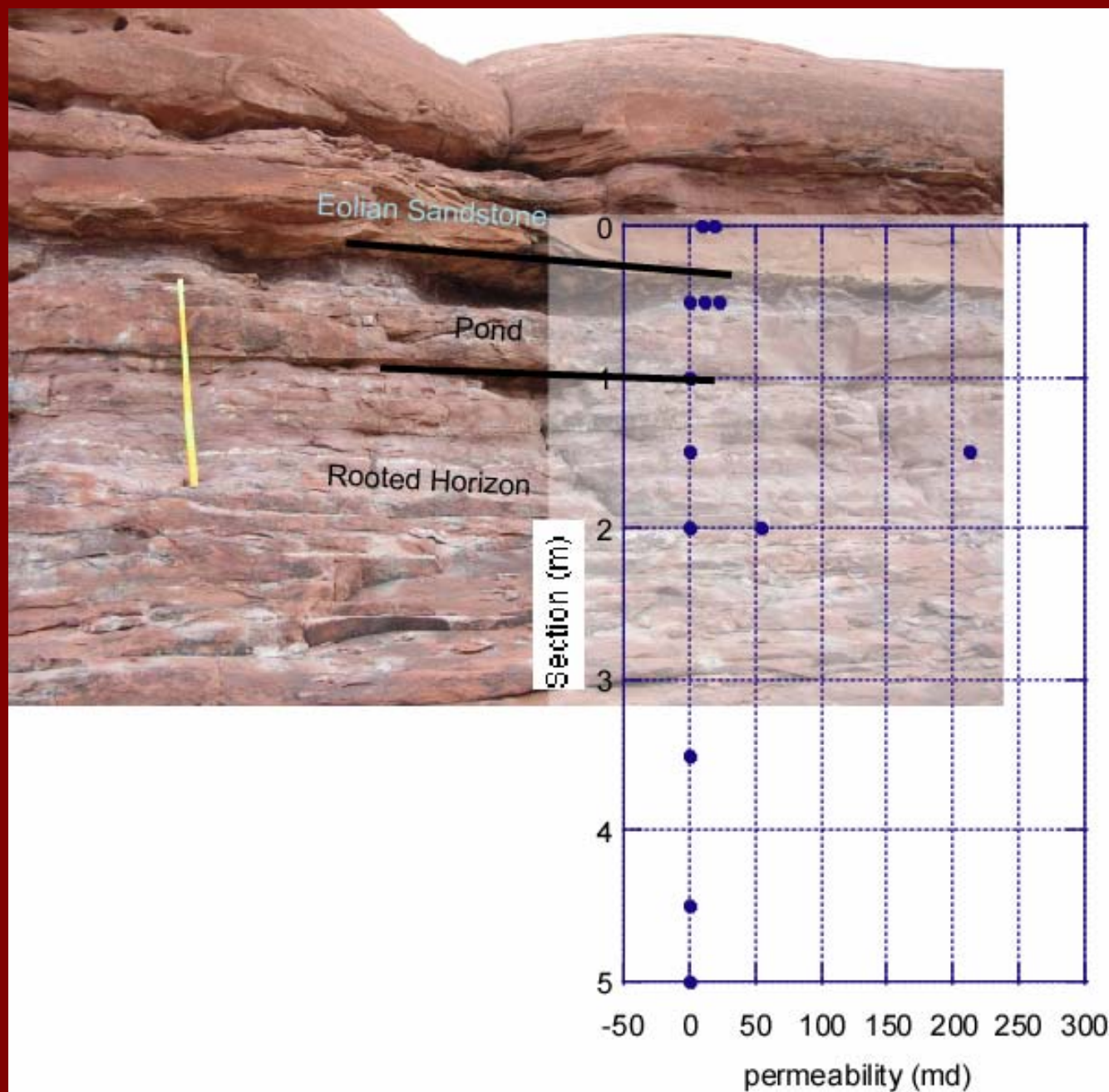
Porosity in those sandstones ranges between 10% and 20%) and cement making up more than 20% of the rock. Cement is early calcite, with some patches of early hematite. This facies has undergone less late-stage dissolution than higher-porosity facies.

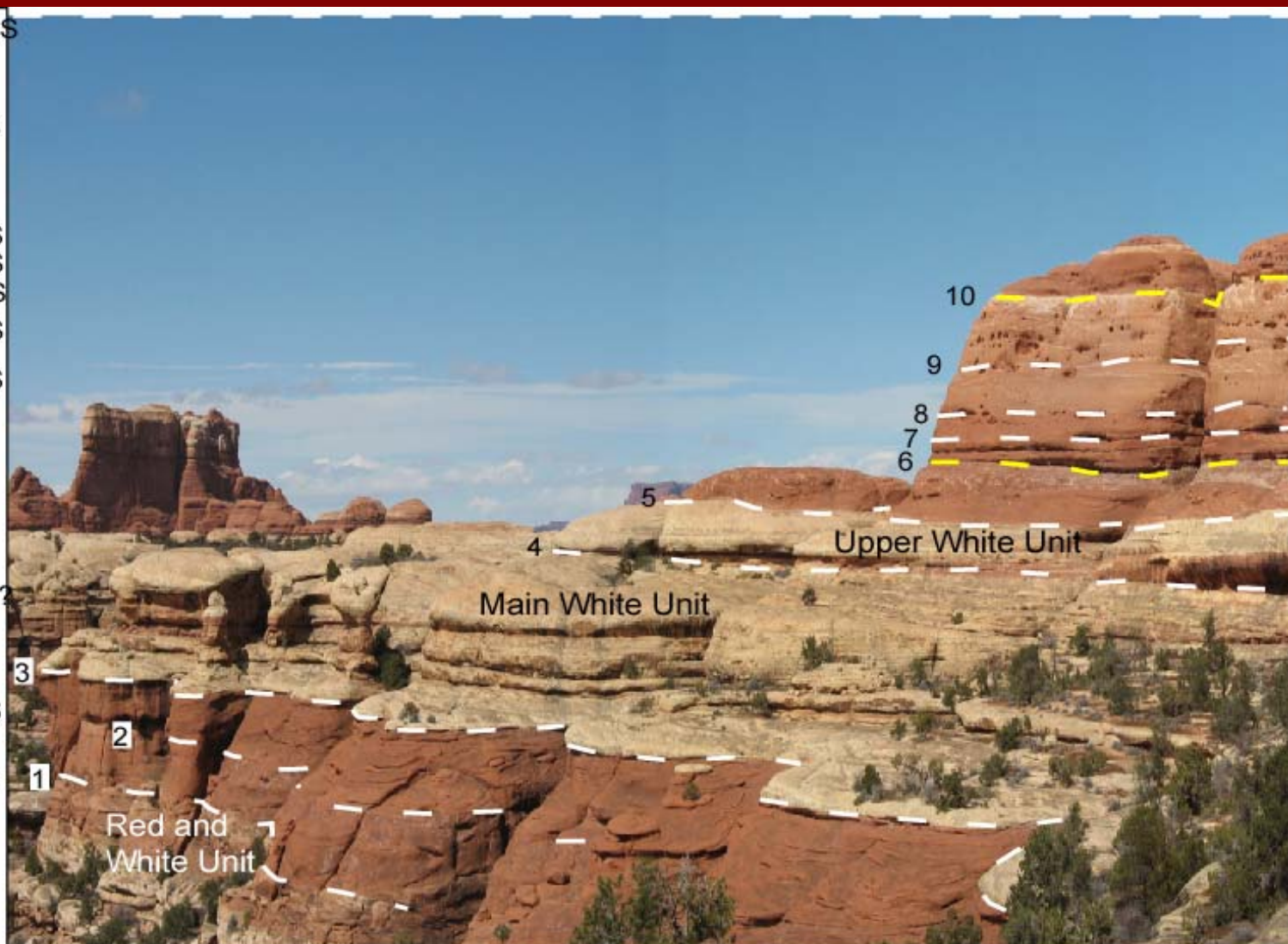
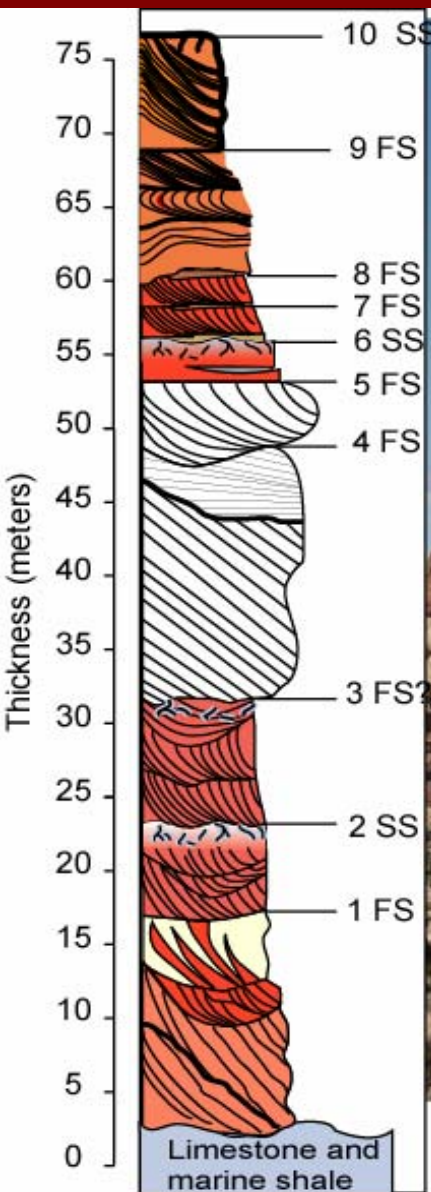
HIGH DOLOMITE + EARLY CALCITE / VERY LOW POROSITY

This facies is restricted to pond deposits close to the marine environment. Early dolomite cement is in majority and associated with some early calcite cement. Some limestone might also be present. cement represents 25 to 30% of point counts. Porosity is almost non-existent.

Permeability of Supersurfaces







Conclusions

- The primary control on diagenesis- reservoir quality is early diagenesis related to sequence stratigraphy
- The erosion surfaces mark highstands, resulting in transgression and flooding of eolian sand sources.
- The barriers are complex surfaces formed by discontinuous shales and early diagenesis in the soils at the erosion surfaces, which precipitated clay and hematite cements

Conclusions 2

- Smaller scale heterogeneities can also subdivide the units, both horizontally and laterally.
- In all cases the heterogeneities are related to early diagenesis associated with sandstone fabric and depositional environment.