Late Pennsylvanian and Early Permian Sedimentation on the Central Basin Platform and Implications to the Wolfberry Deposition in the Western Midland Basin*

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Abstract

In the Late Pennsylvanian and Permian, deposition of the Wolfberry interval in the Midland Basin was controlled by sediment supply from the adjacent shelves and platform. Depositional systems on the eastern Central Basin Platform supplied sediment to the western Midland Basin, however those sediments varied greatly through time depending on rate of subsidence, eustatic sea level fluctuations, and climate. The Permian Basin was dominated by a humid to subhumid climate from the Middle Pennsylvanian to the Early Wolfcampian causing siliciclastic systems to be dominated by shales transported to the basin by rivers. Limestone was the dominant carbonate during that time. The climate in the region became increasingly arid in the Permian resulting in Middle to Upper Permian carbonates dominated by dolomite and evaporites, and siliciclastics dominated by feldspathic sand and silt transported by wind. The Middle Pennsylvanian to Early Permian was a time when large continental glaciers in the southern hemisphere repeatedly grew and melted causing repeated large amplitude rises and falls of sea level (50-100 m fluctuations every 110,000 years) similar to the Pleistocene. As a result, the Strawn to Lower Wolfcamp interval contains more than 90 depositional cycles with highly variable depositional facies and common subaerial exposure surfaces. The Southwest Andrews area of the eastern Central Basin Platform was studied with core, logs, and seismic data to interpret the depositional history of Strawn through Wolfcamp strata, and that information was used to infer depositional processes for the Wolfberry in the adjacent Midland Basin. Strawn and Canyon strata at the Southwest Andrews Area are dominated by

limestones with relatively thick cycles that were capped by subaerial exposure surfaces. Although most cycles included periods of deposition and subaerial exposure, most of the time represented by each cycle was spend underwater with carbonate deposition. The Strawn and Canyon are associated with a vertically building platform margin with modest amounts of micritic and grain-rich carbonate expected to be transported off the platform and deposited as channels, aprons and fans on the adjacent slope and basin floor.

The Cisco to Lower Wolfcamp at Southwest Andrews is dominated by thin cycles with interbedded carbonates and shales. Sinkholes filled with shale are present in Upper Canyon and Cisco carbonates. Shale-filled fluvial valleys occur in the siliciclastic-rich lowest Wolfcamp. The Cisco and lowest Wolfcamp cycles are thin and experienced intense subaerial exposure indicating that most of the time represented by each cycle was spent subaerially exposed. As a result of being dominated by low sea level, substantial amounts of siliciclastics from the interior of the Central Basin Platform were transported across the platform margin and deposited in the western Midland Basin. Hence, Late Cisco and Earliest Wolfcamp are expected to be times when large amounts of shale accumulated in the western Midland Basin during many different eustatic cycles. A general transgression and deepening of environments followed the "maximum regression" or period of lowest relative sea level which occurred near the Cisco-Wolfcamp boundary. The "Wolfcamp Reef" is an interval of widespread shallow-marine limestone deposited during part of that transgression. Limestone detritus and mud were probably transported off the platform and into the basin during deposition of the "Wolfcamp Reef". A major drowning and backstepping of the platform margin followed "Wolfcamp Reef" deposition, and the Southwest Andrews Area was covered by deep-water shales as the Abo/Wichita platform margin grew to the west. The western Midland Basin was likely starved during much of Abo/Wichita time.

Middle to Upper Permian strata were affected by a more arid climate and less continental glaciation. As a result, eustatic sea-level fluctuations generally had relatively low amplitudes (maybe 2-10 m) with more long-lived periods of high and low sea level. The Middle to Upper Permian is characterized by thick intervals of prograding carbonate platforms, and thick intervals of sandstones and siltstones in the basin. The prograding carbonate shelves and platform are dominated by dolomite and evaporites that were probably deposited during times of high relative sea level. Sands and silts were probably deposited in the basin during long periods of generally low sea level when sand and silt were blown across the exposed shelves and platforms, and then deposited in the basin as onlapping packages. Thin sandstones and siltstones were deposited repeatedly on the shelves and platform generally during transgressions following lowstands of sea level.

References Cited

Saller, A.H., J.A.D. Dickson, and F. Matsuda, 1999, Evolution and distribution of porosity associated with subaerial exposure in upper Paleozoic platform limestones, west Texas: AAPG Bulletin, v. 83, p. 1835-1854.

Saller, A.H., J.T. Noah, A.P. Ruzuar, and R. Schneider, 2004, Linked lowstand delta to basin-floor fan deposition, offshore Indonesia: an analog for deep-water reservoir systems: AAPG Bulletin, v. 88, p. 21-46.

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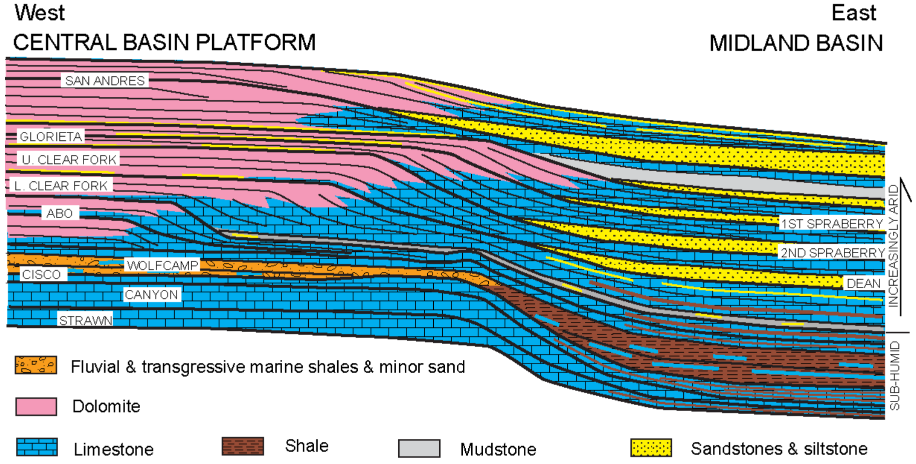
Central Basin Platform Deposition & Implications to Wolfberry Deposition in the Western Midland Basin

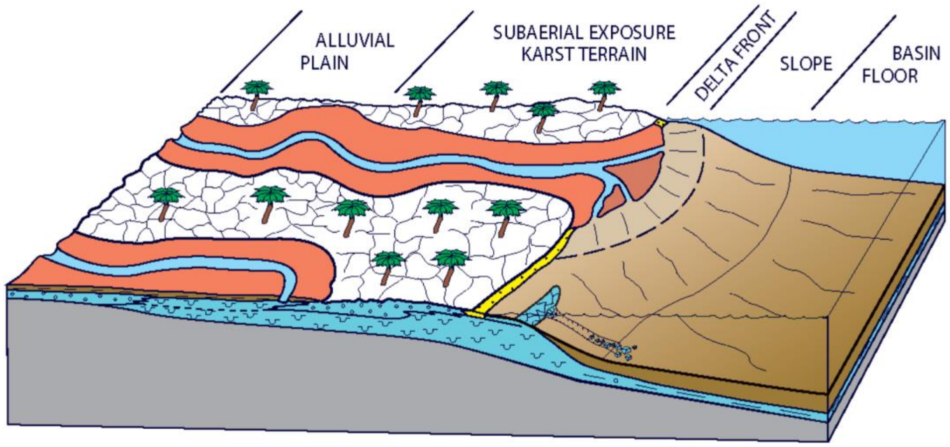
- **The Southwest Andrews Area (SWA) on the eastern edge of the Central Basin Platform provides insight into sediments being deposited to the Wolfberry interval in the western Midland Basin**
- **During middle Pennsylvanian to early Permian time, large continental glaciers in the southern hemisphere repeatedly grew & melted causing repeated large amplitude rises & falls of sea level (50-100 m fluctuations every 110,000 years) similar to the Pleistocene**



- **Strawn to lower Wolfcamp strata in the SWA contain more than 90 depositional cycles with highly variable depositional facies & common subaerial exposure surfaces with deposition in a humid to subhumid climate**
- **Limestones were deposited on the platform during times of high sea level**

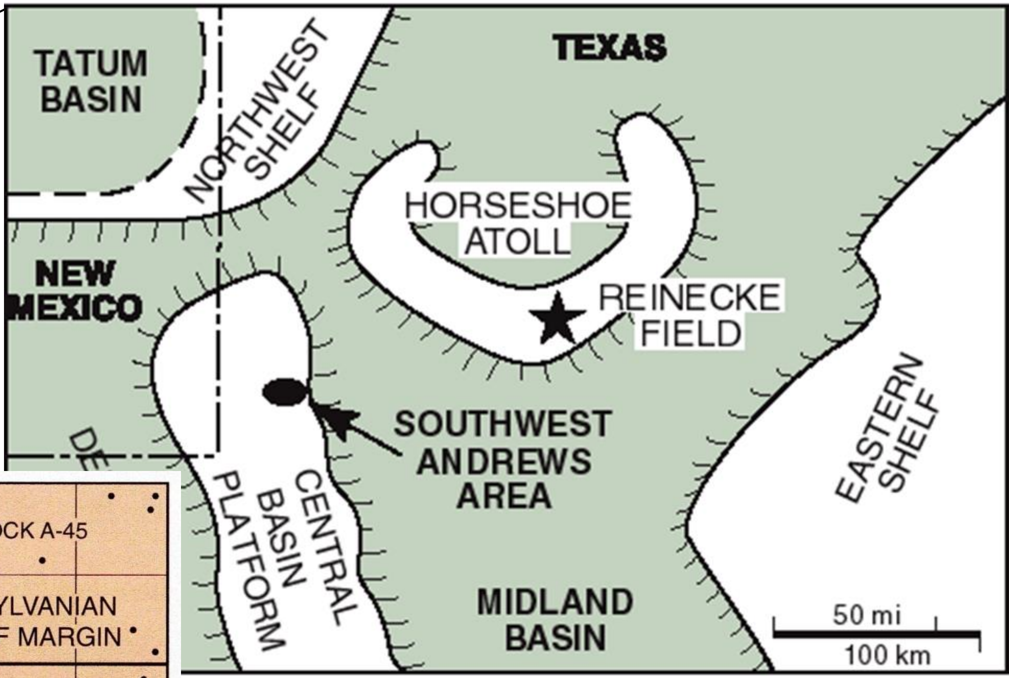
Central Basin Platform Deposition & Implications to Wolfberry Deposition in the Western Midland Basin

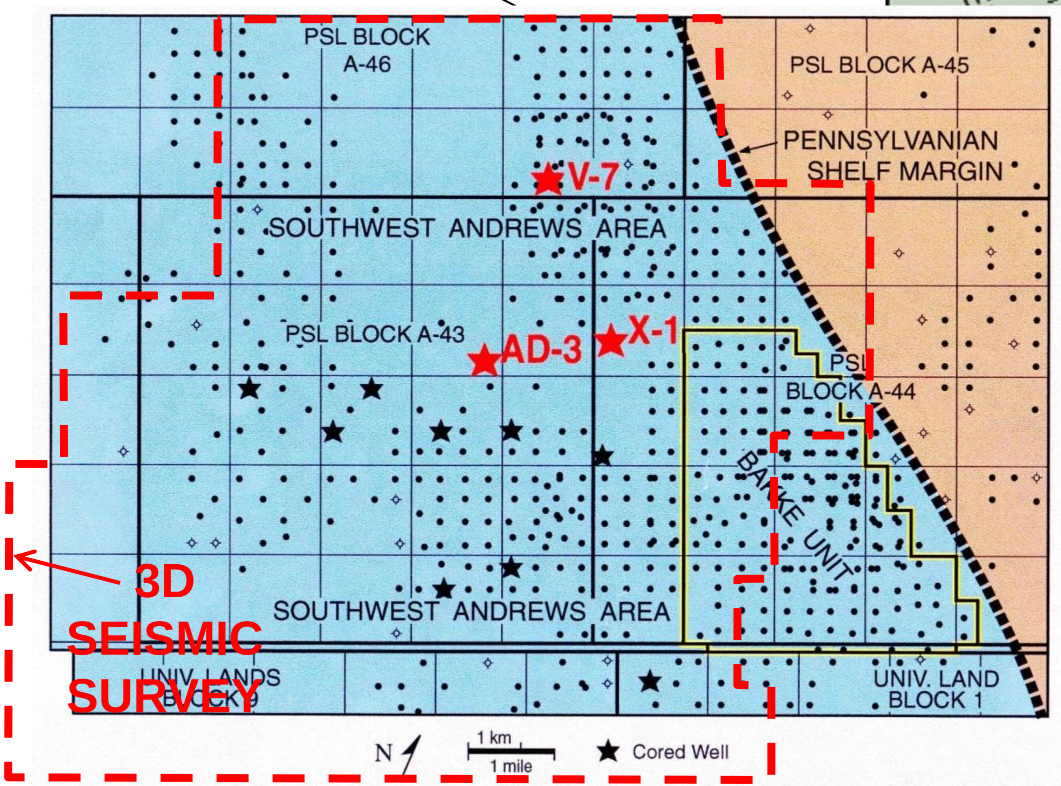
- During periods of low sea level, the platform was exposed & rivers transported siliciclastic mud to the slope & basin
- Upper Strawn & Canyon are dominated by thick limestone cycles capped by subaerial exposure surfaces
  - Some micrite & carbonate grains expected to be transported off the platform & deposited as channels & aprons on the adjacent slope



- Cisco & early Wolfcamp on the platform are dominated by thin cycles of carbonate & shale with prolonged exposure
  - Siliciclastics from of the Central Basin Platform were transported across the platform margin and deposited in the western Midland Basin
- The Permian Basin climate became increasingly arid in the Permian resulting in the middle to upper Permian platform dominated by dolomite and evaporites, & siliciclastics in the basin dominated by feldspathic sand & silt transported by the wind

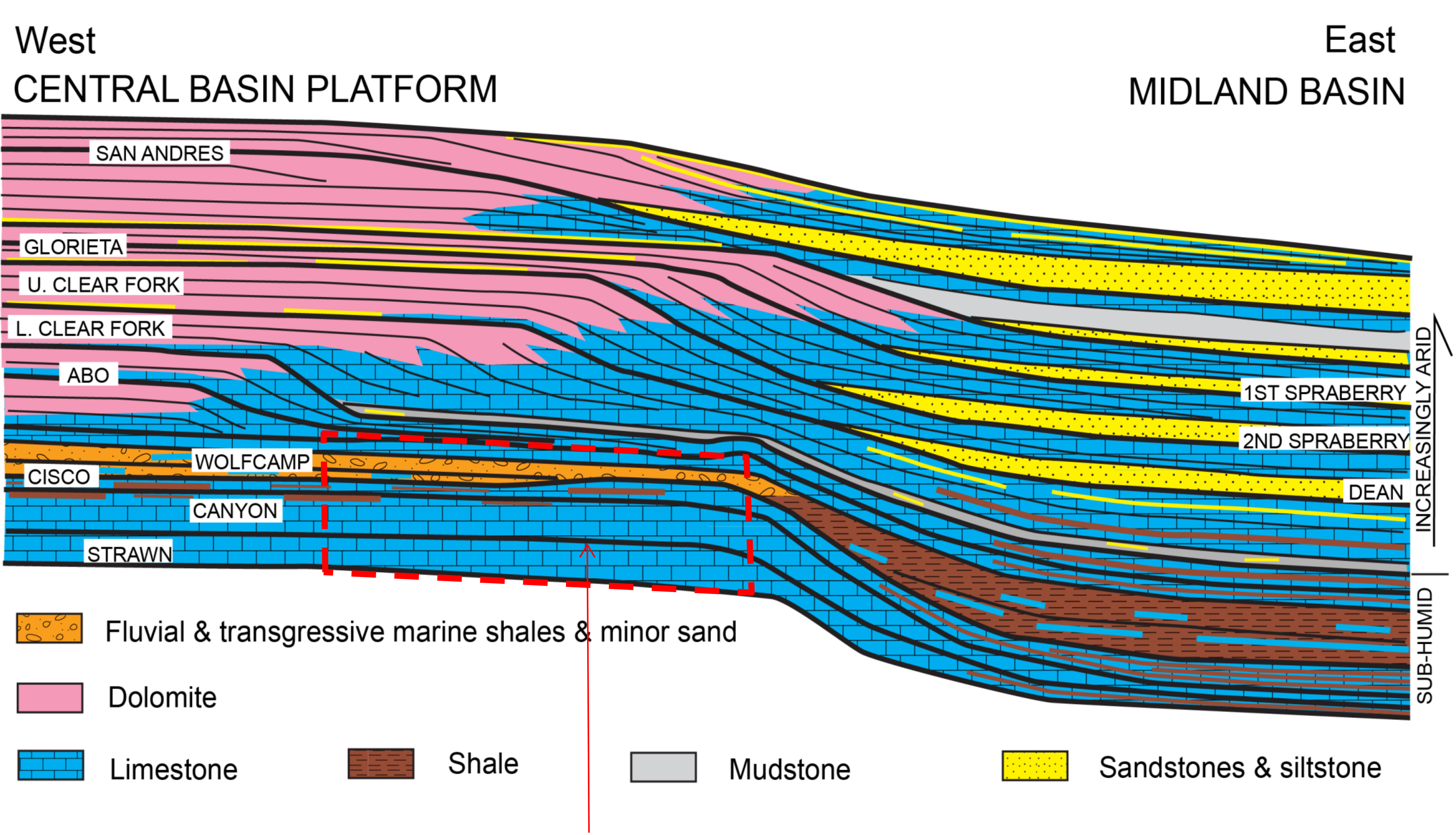
Location Maps for Southwest Andrews Area





From: Saller, A.H., J.A.D. Dickson, and F. Matsuda, 1999, Evolution and distribution of porosity associated with subaerial exposure in upper Paleozoic platform limestones, west Texas: *AAPG Bulletin*, v. 83, p. 1835-1854

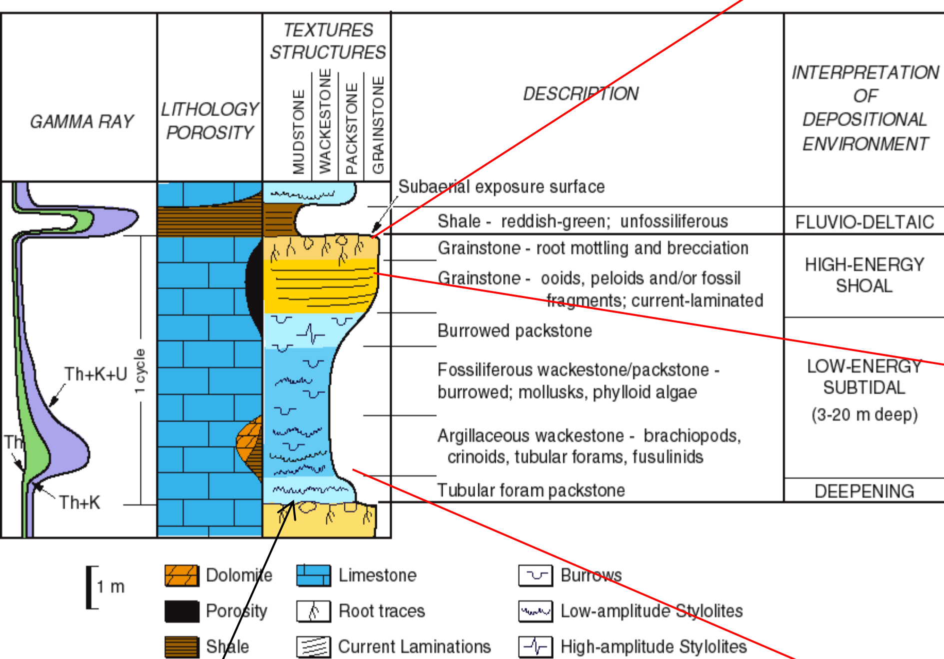
Schematic Stratigraphy: Central Basin Platform to Midland Basin



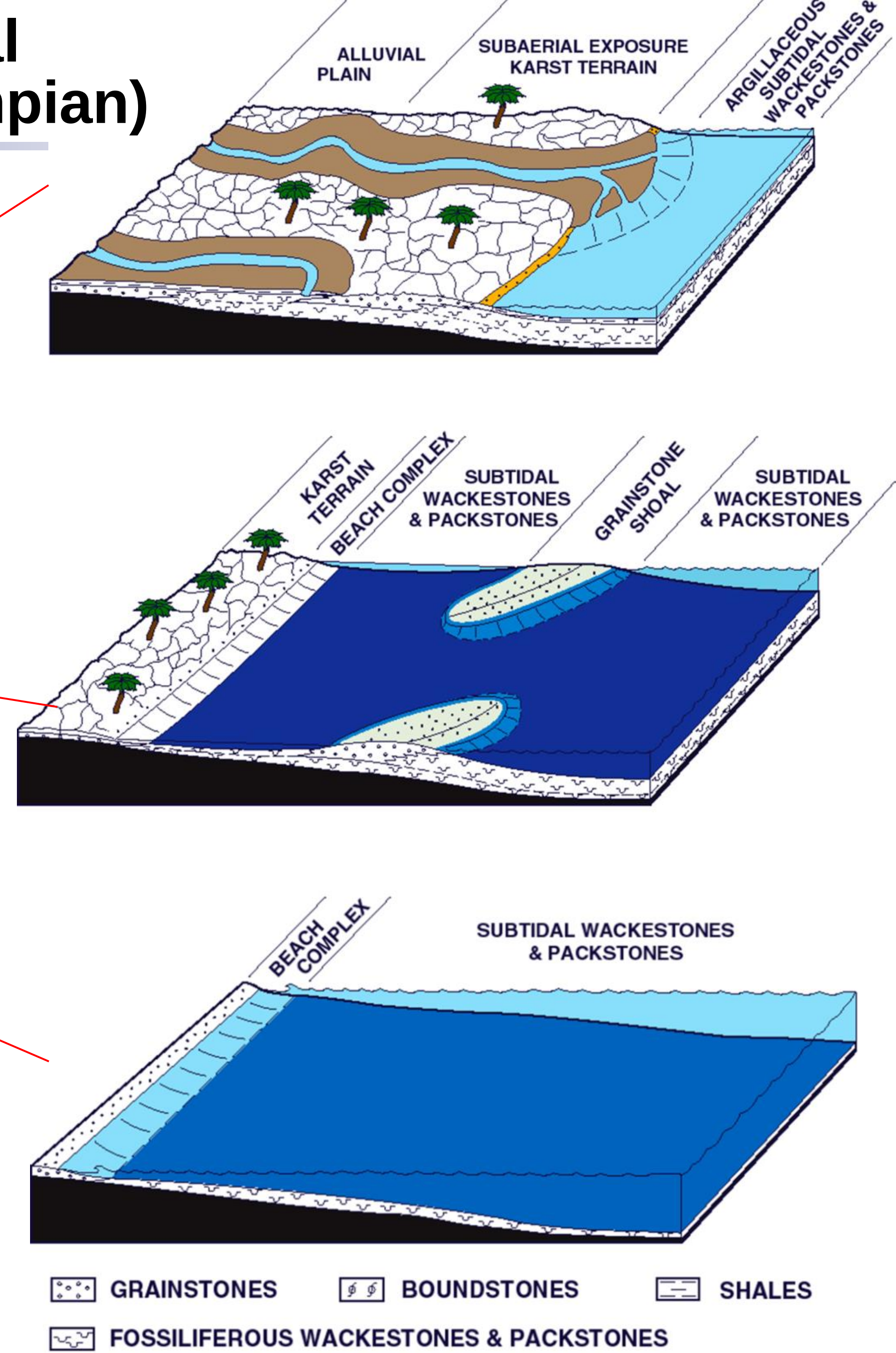
Southwest Andrews Reservoir

SWA Contains ~90 Depositional Cycles (Strawn-Lower Wolfcampian)

TYPICAL SOUTHWEST ANDREWS CYCLE



Exposure Surface (Cycle Base)



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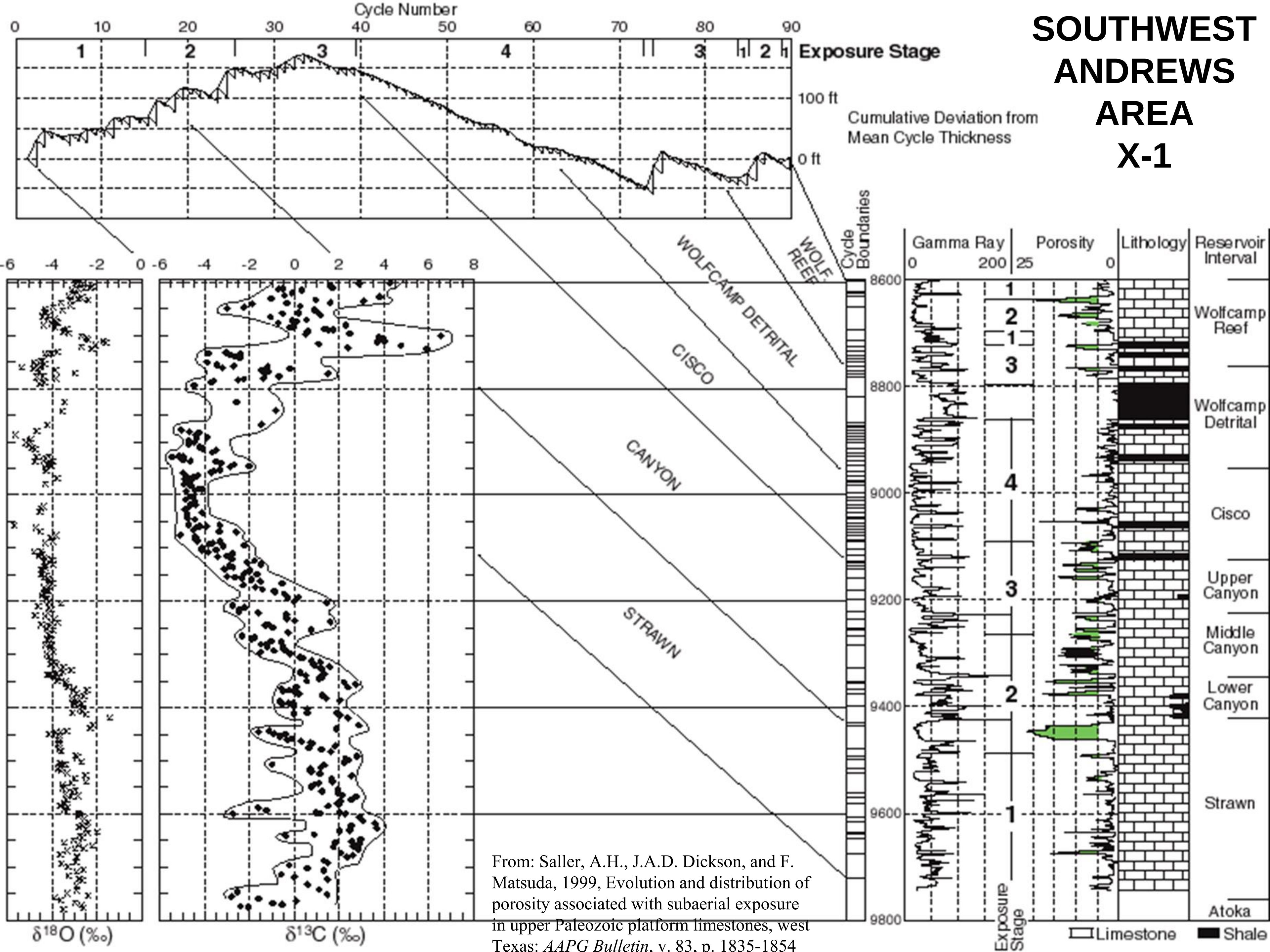
SOUTHWEST ANDREWS AREA X-1



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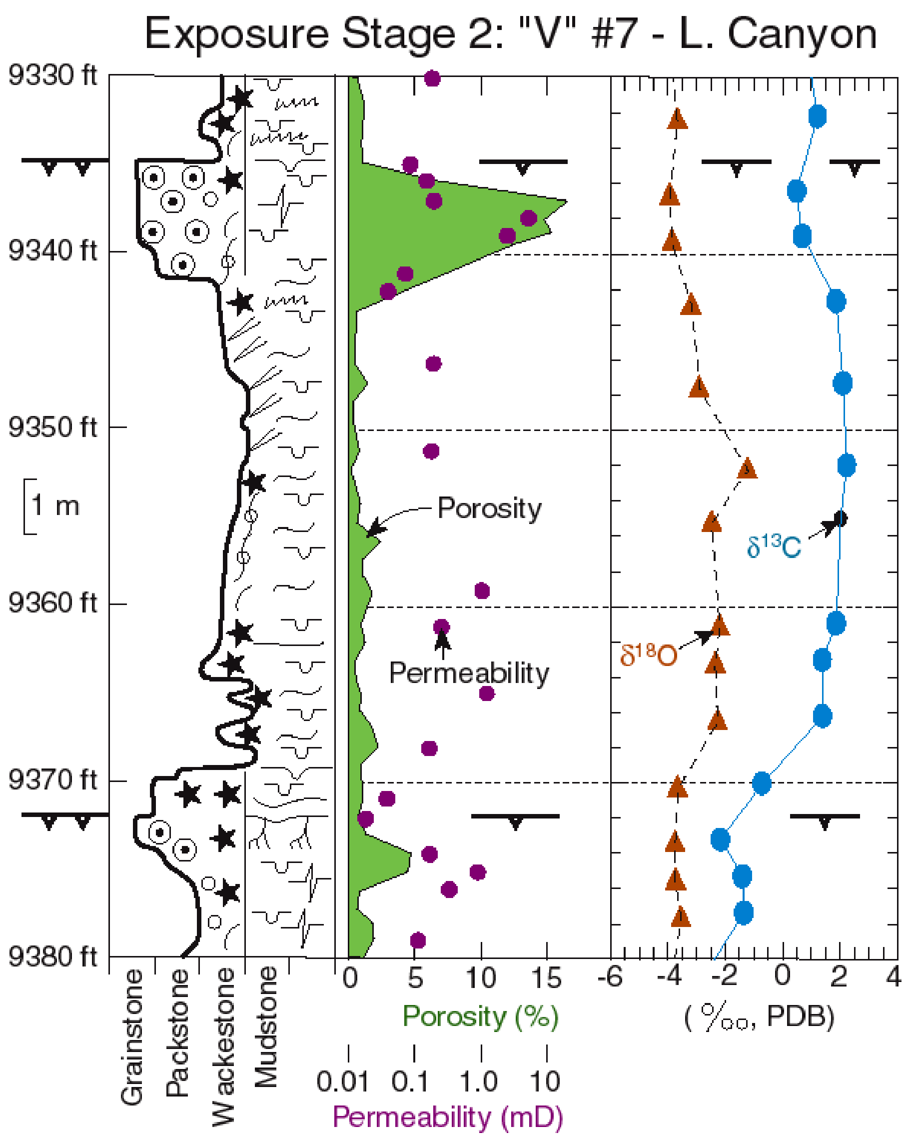
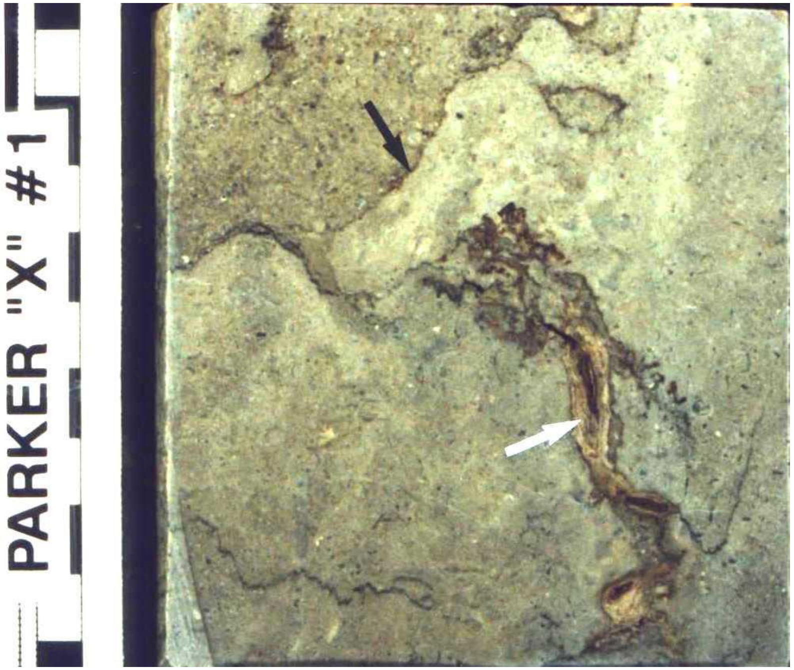
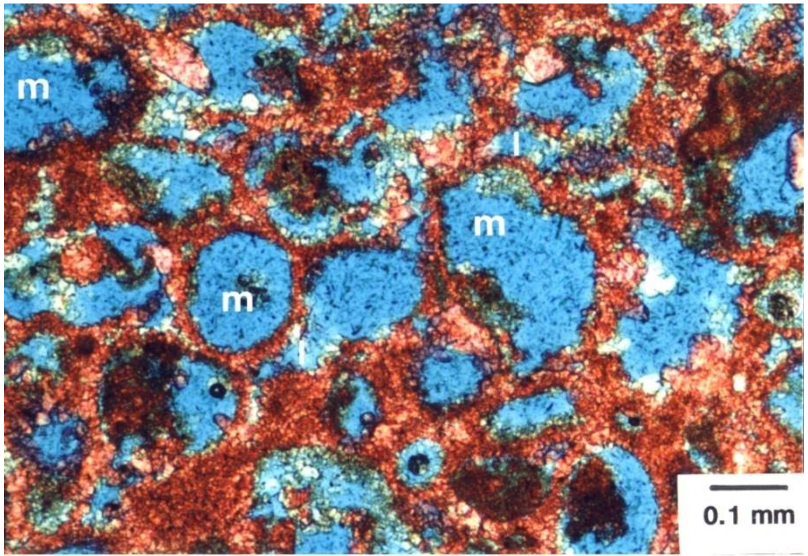
Upper Strawn & Canyon are dominated by relatively thick cycles capped by subaerial exposure surfaces







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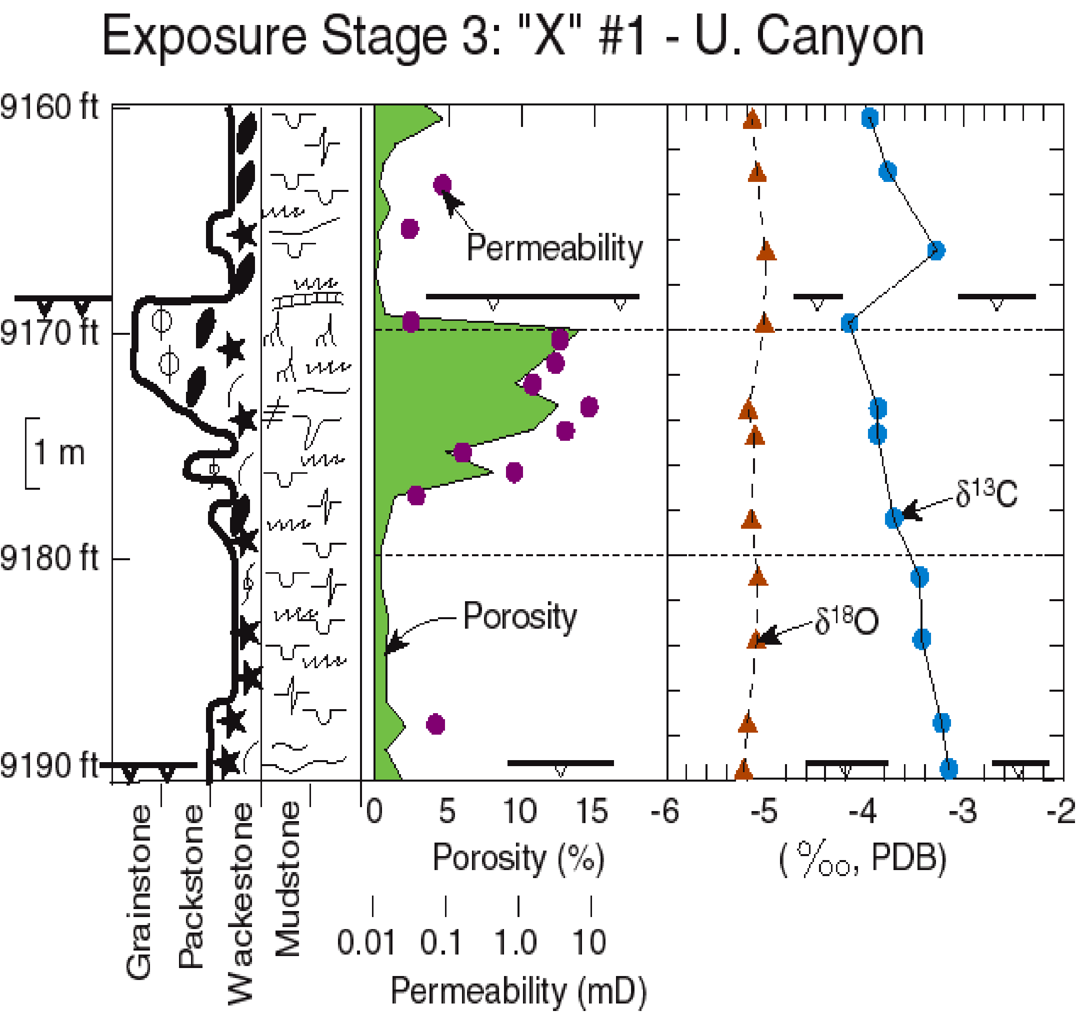
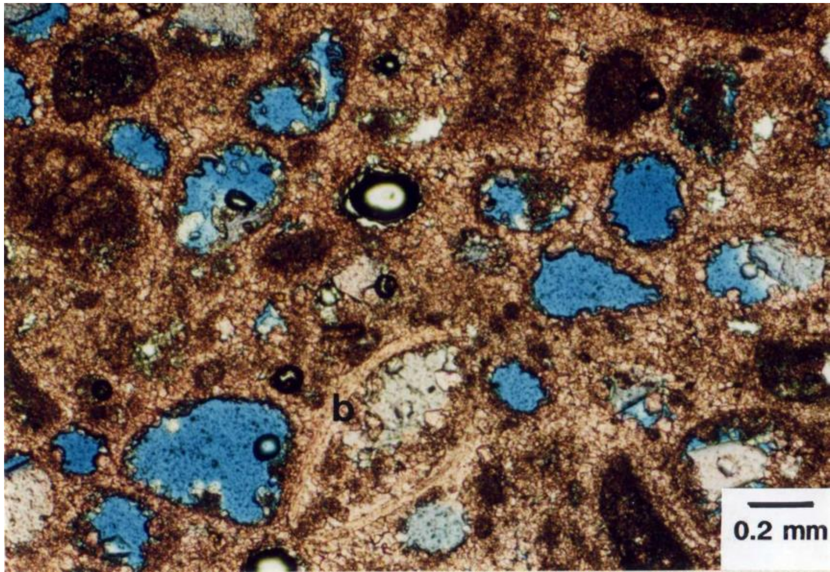
UPPER CANYON: MODERATE SUBAERIAL EXPOSURE





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Upper Canyon: Seismic Time Slice; Moderate Subaerial Exposure; Scattered Sinkholes

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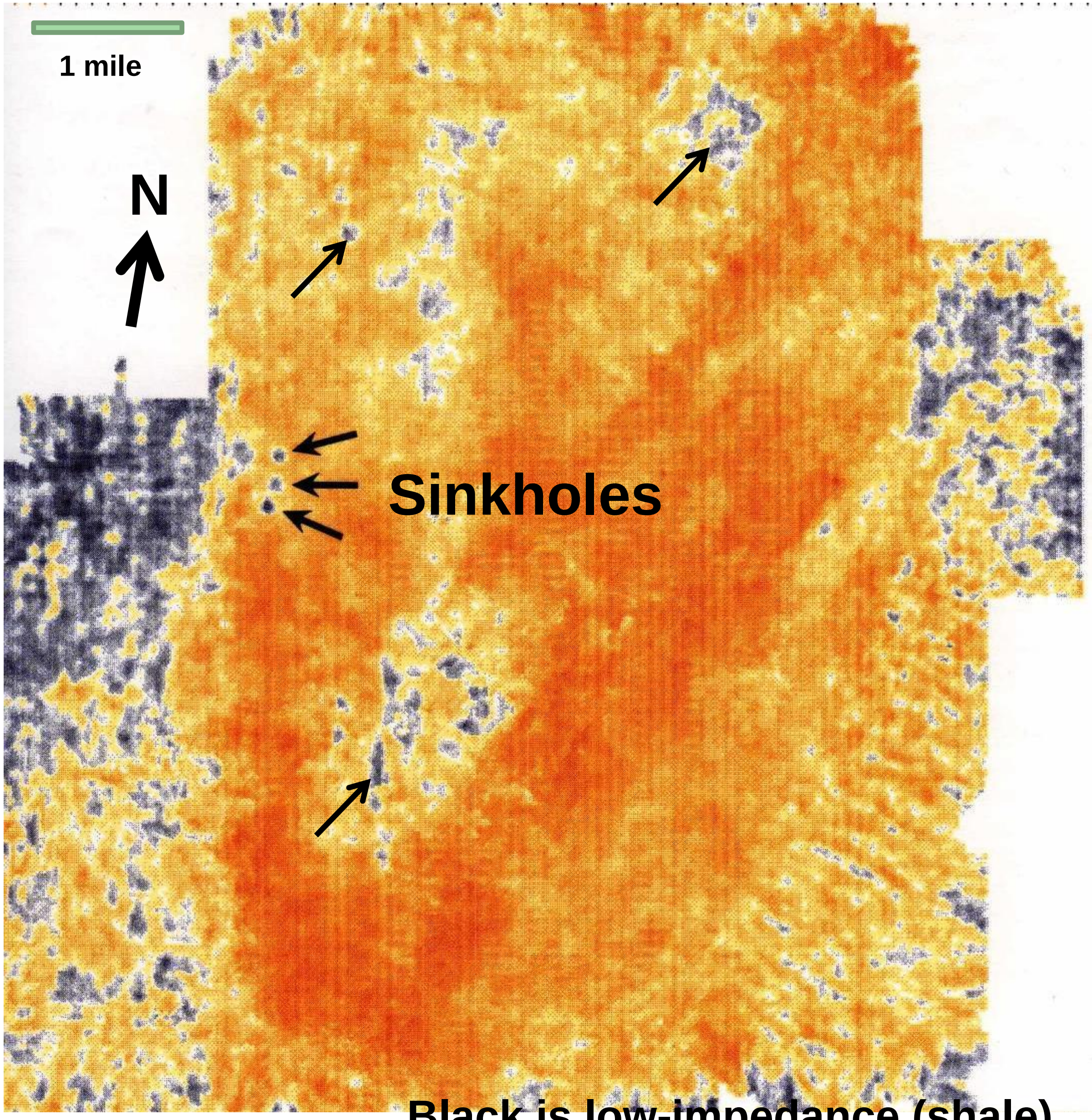
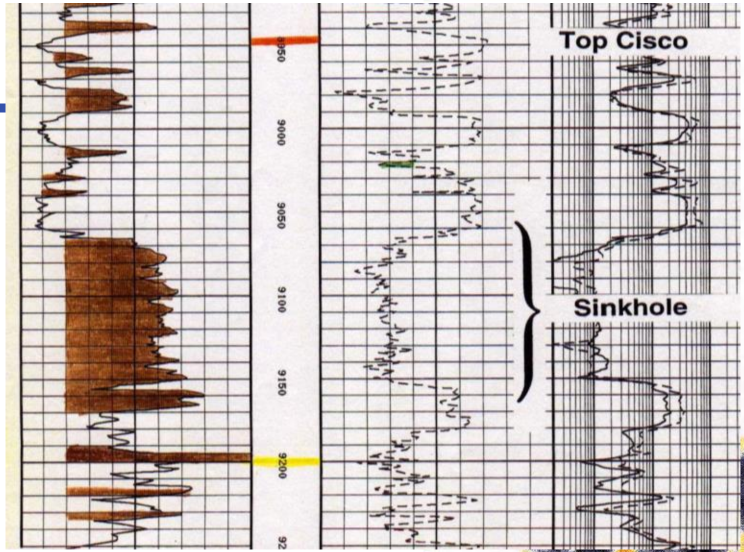
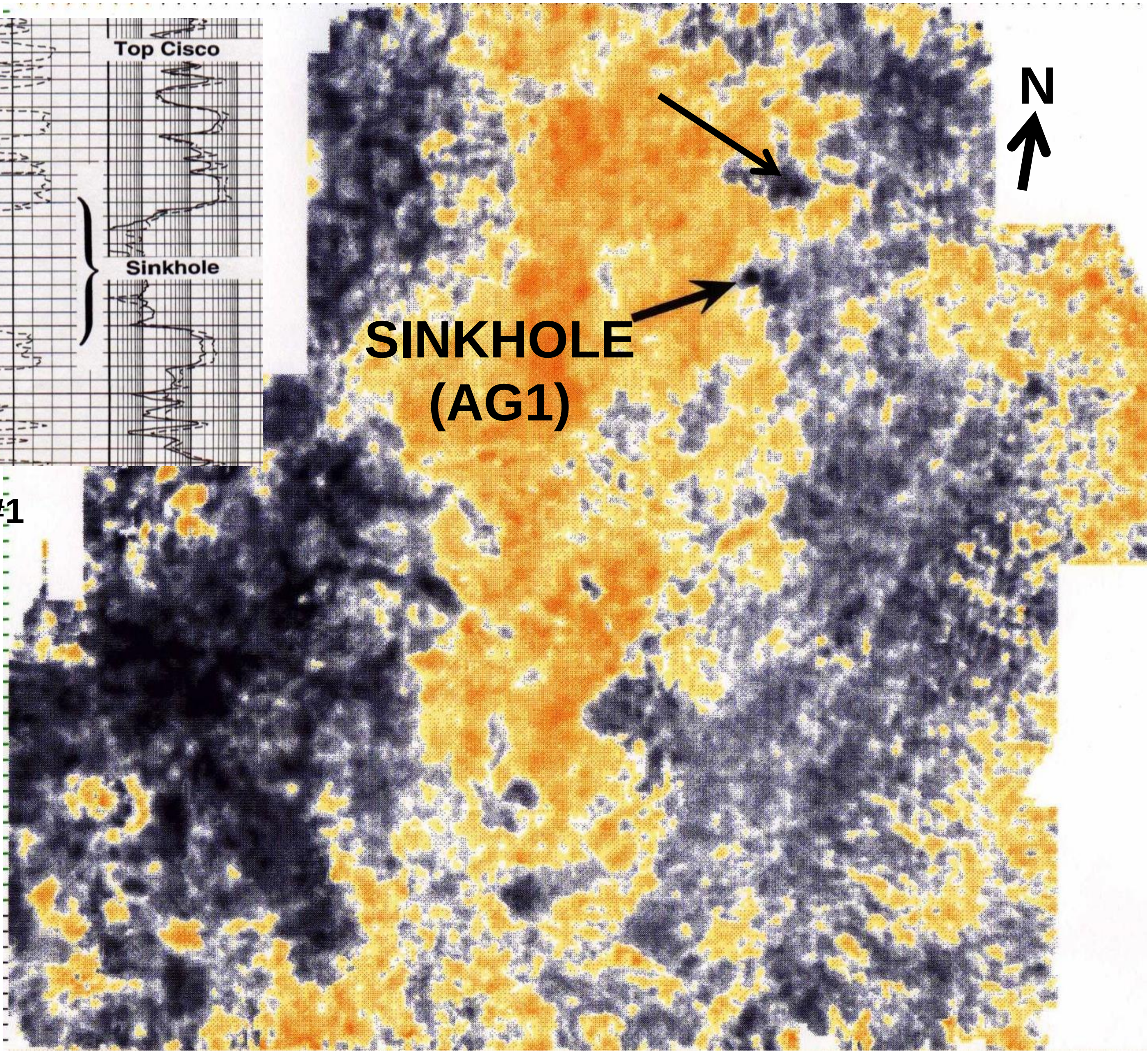
Modern Sinkholes; Eastern Yucatan





PARKER "AG" #1

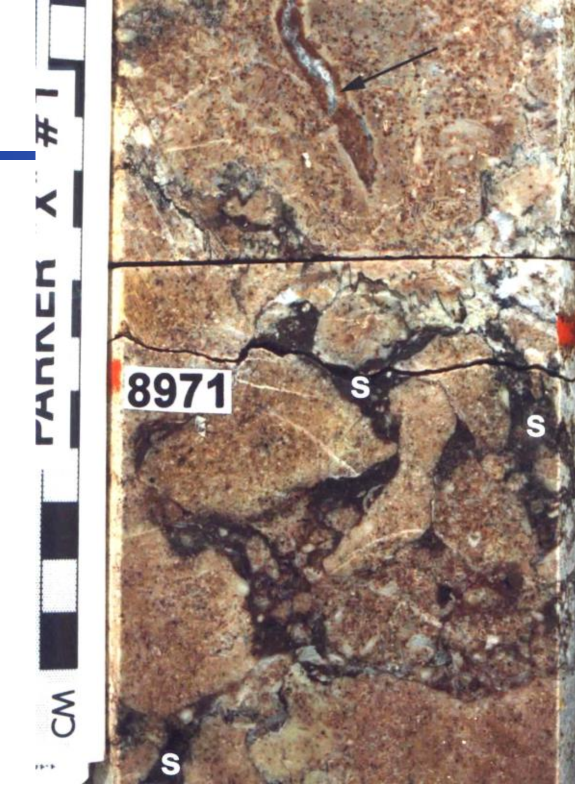
1 mile



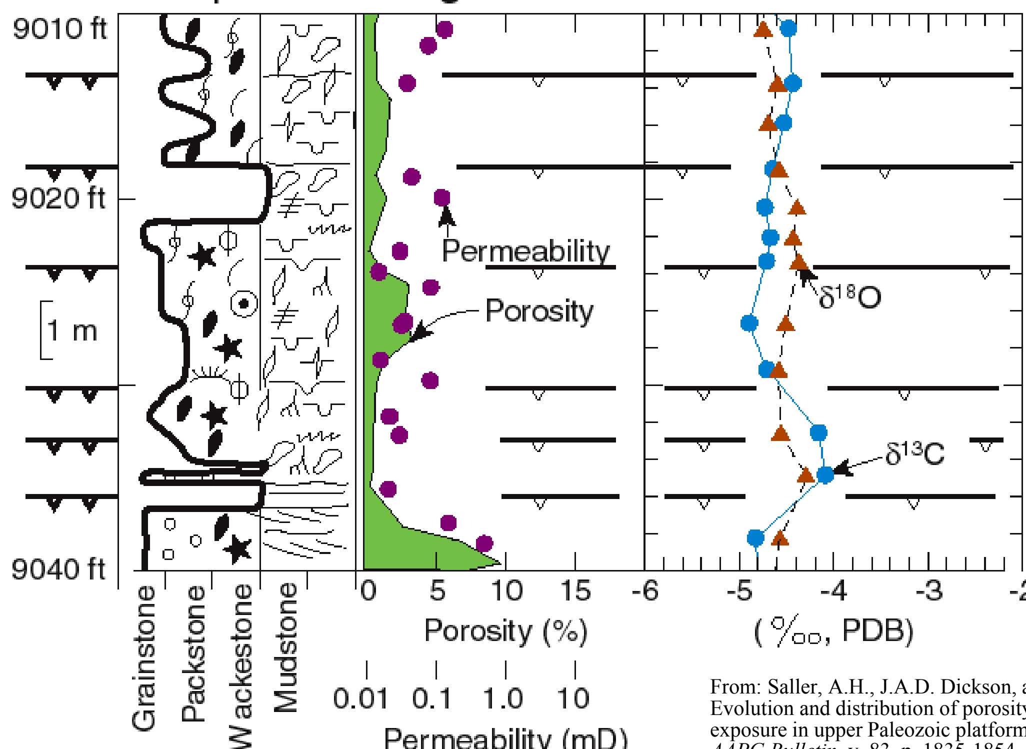
TIME SLICE
LOWER
CISCO

Black is low-impedance (shale)

Cisco-early Wolfcamp: Thin cycles, limest & shales: intense exposure



Exposure Stage 4: "X" #1 - Cisco



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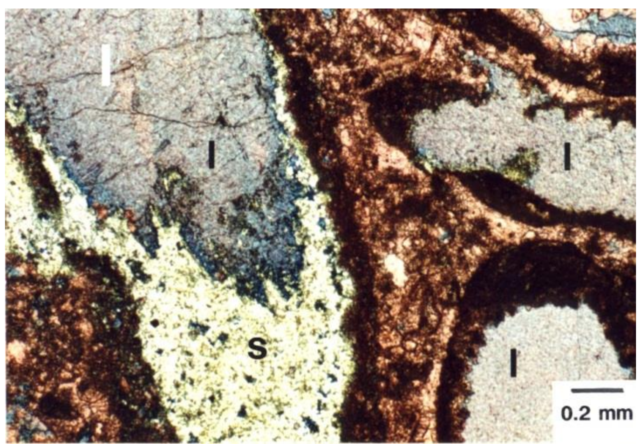

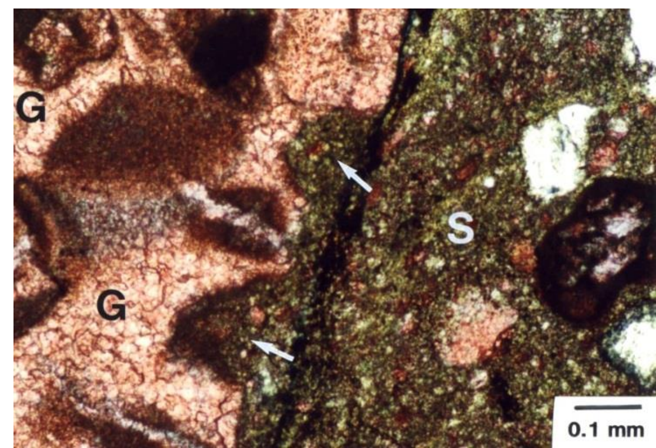

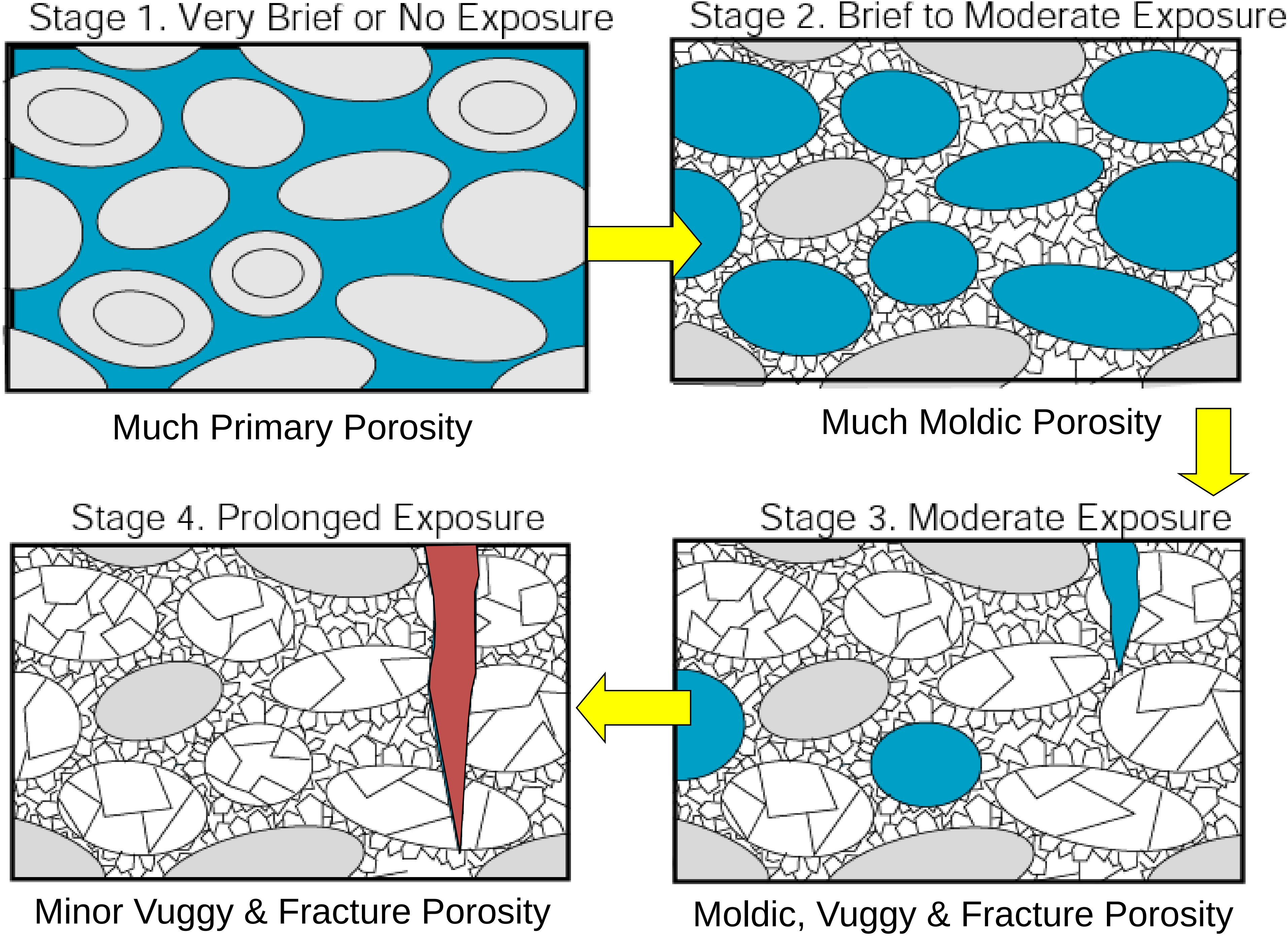

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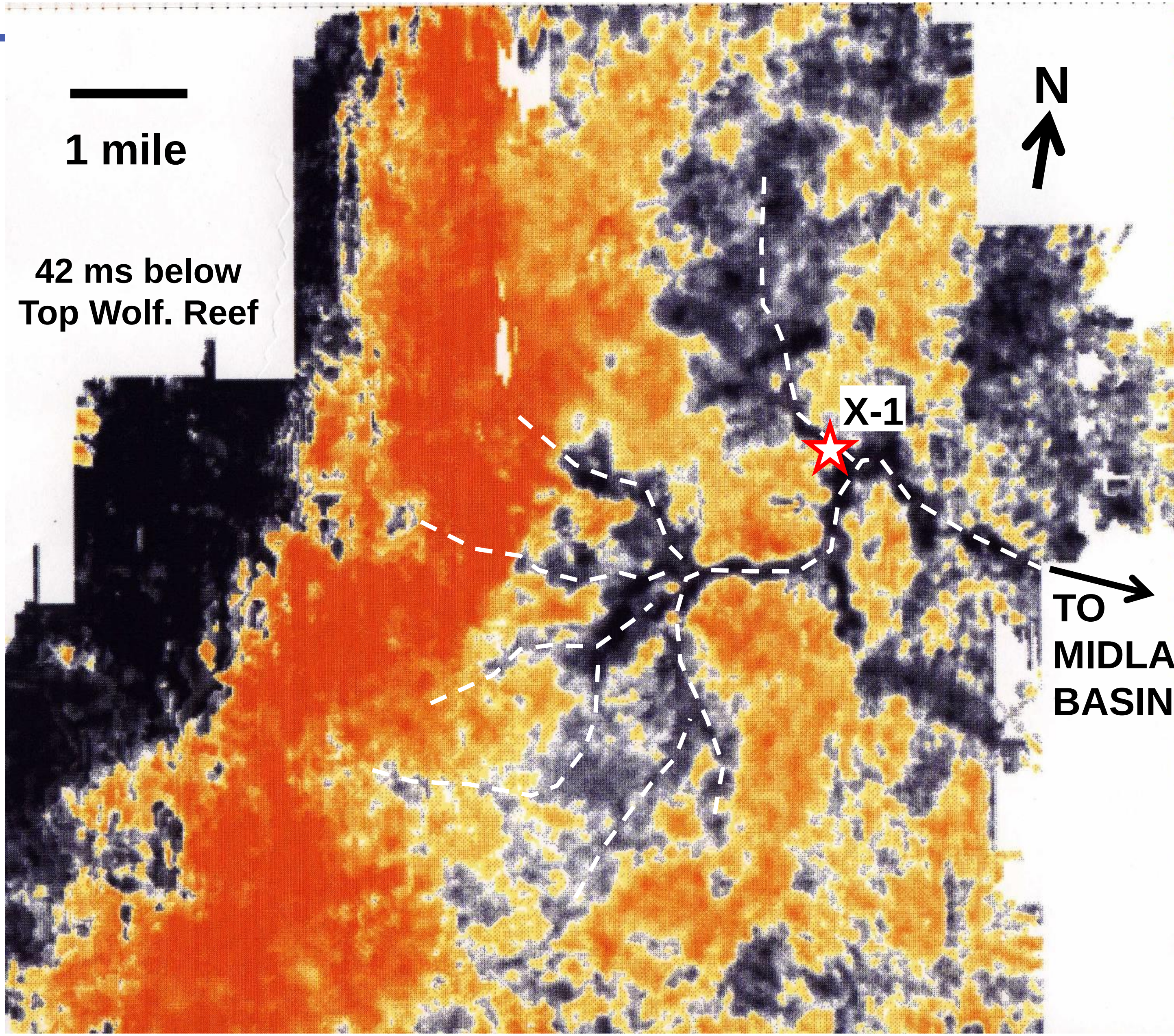
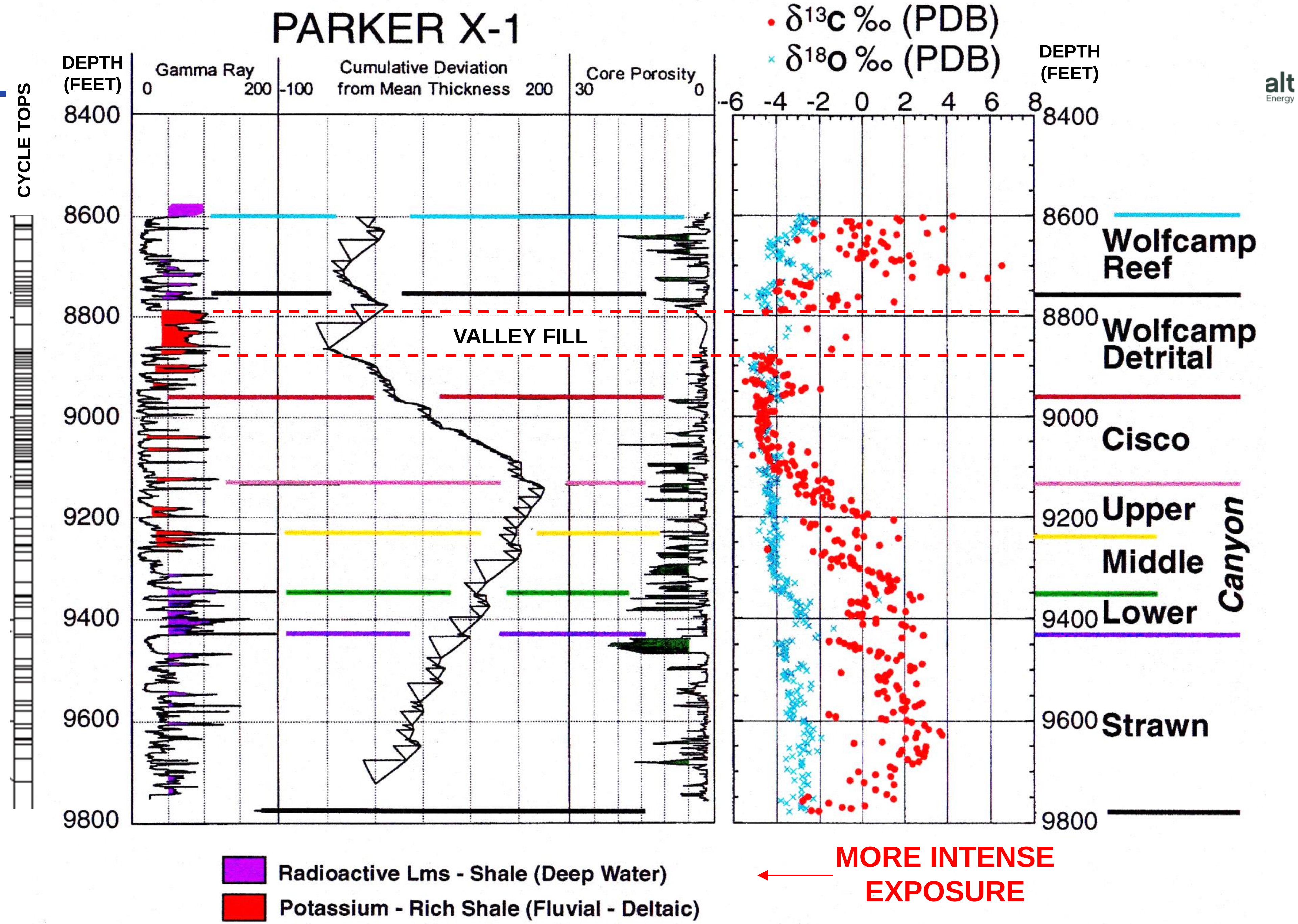
TIME-SLICE: WOLFCAMP DETRITAL



Black is low-impedance (shale)



PARKER X-1
CYCLE TOPS
DEPTH (FEET)
Gamma Ray
0 200
Cumulative Deviation from Mean Thickness
-100 200
Core Porosity
30 0
• δ13c ‰ (PDB)
× δ18o ‰ (PDB)
-6 -4 -2 0 2 4 6 8
DEPTH (FEET)
8400
8600
8800
9000
9200
9400
9600
9800
VALLEY FILL
Wolfcamp Reef
Wolfcamp Detrital
Cisco
Upper
Middle
Lower
Canyon
Strawn
Radioactive Lms - Shale (Deep Water)
Potassium - Rich Shale (Fluvial - Deltaic)
MORE INTENSE EXPOSURE

Strawn & Canyon in SWA were Dominated by Highstand Carbonate Cycles & probably Carbonate on the Slope

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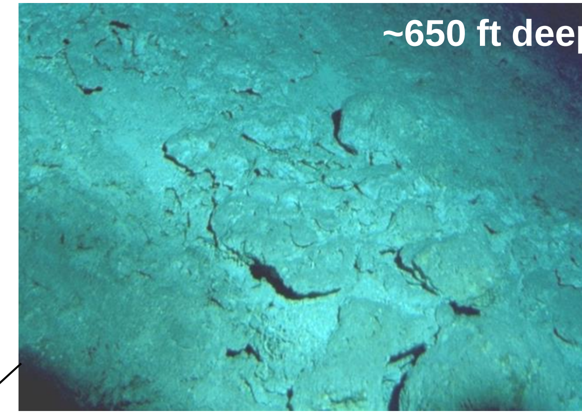

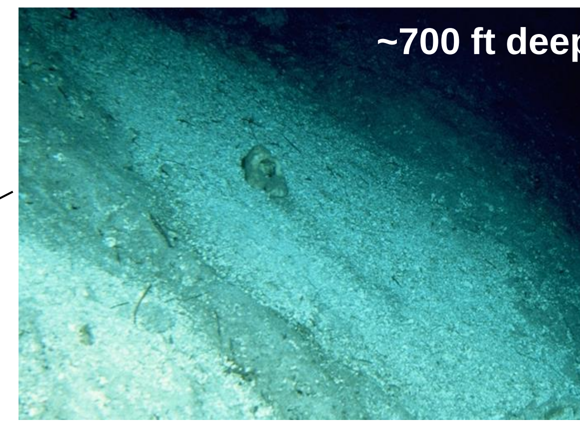

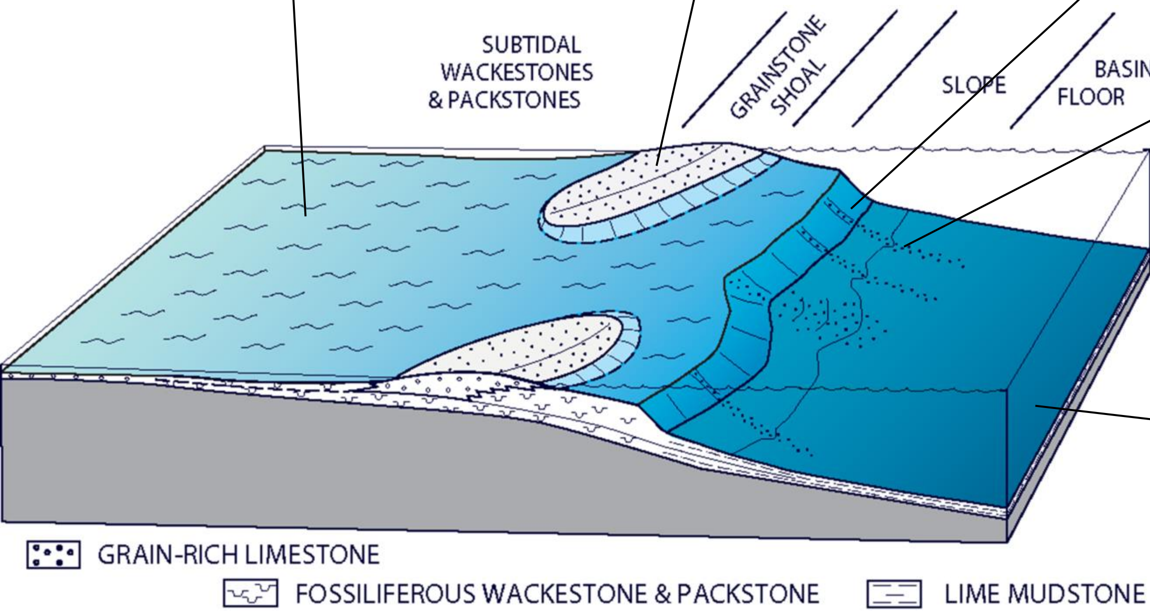

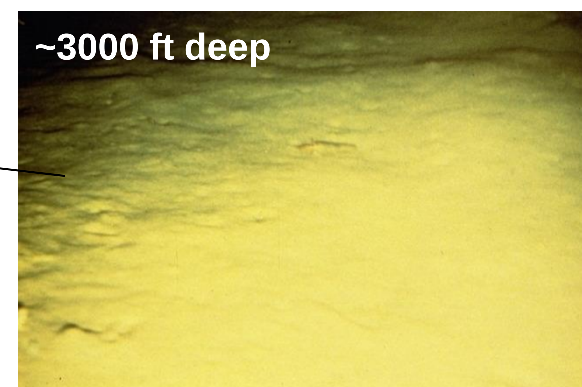

Late Cisco & Early Wolfcamp are dominated by Exposure causing many Shales in the adjacent Slope & Basin

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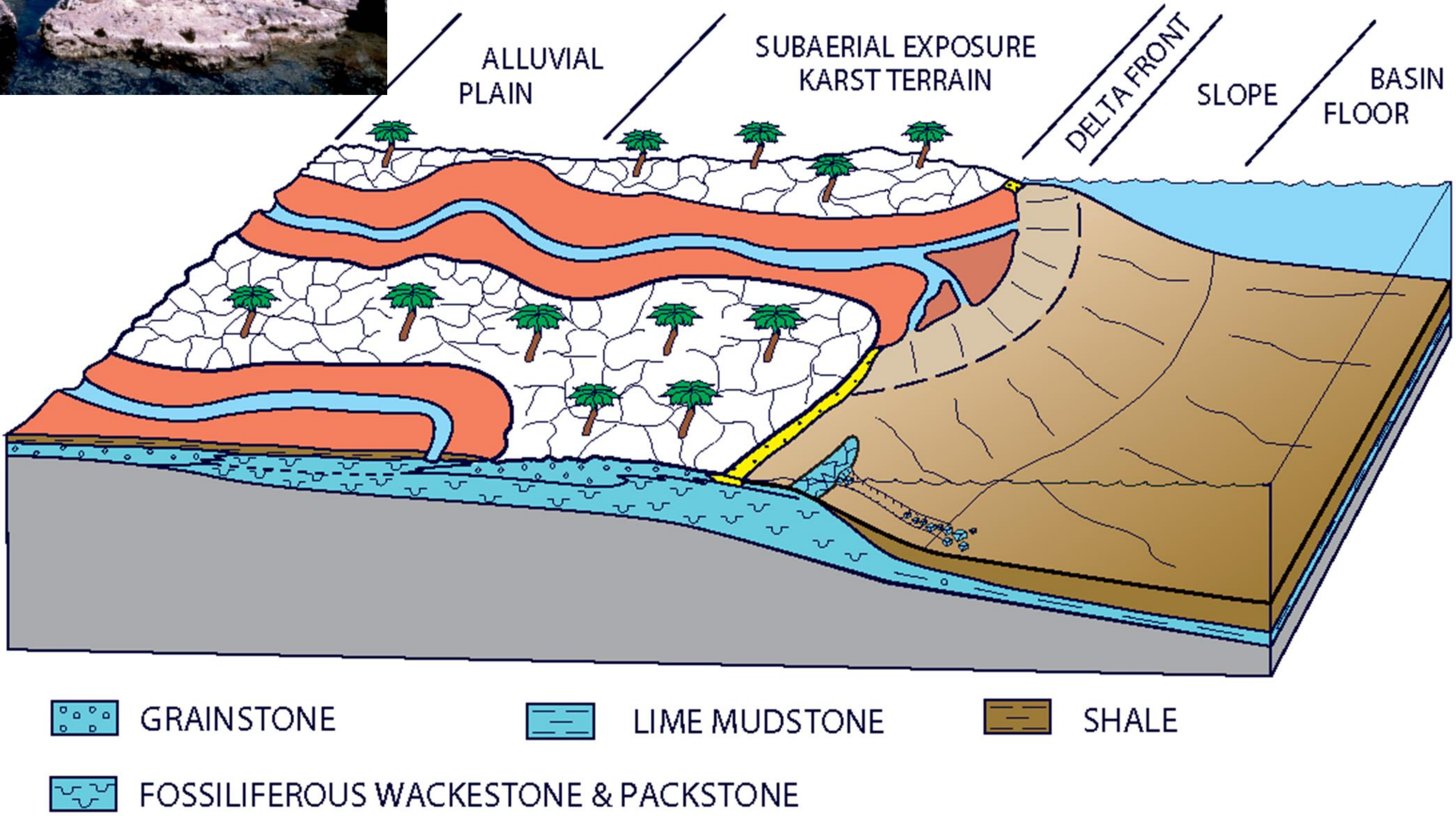
LOW SEA LEVEL: CARBONATE PLATFORM IS EXPOSED; RIVERS CARRY SILICICLASTICS (MAINLY SHALE) TO SLOPE & BASIN



Slope Deposition Alternates between Lowstand Siliciclastics & Highstand Carbonates Flowing Down Channels

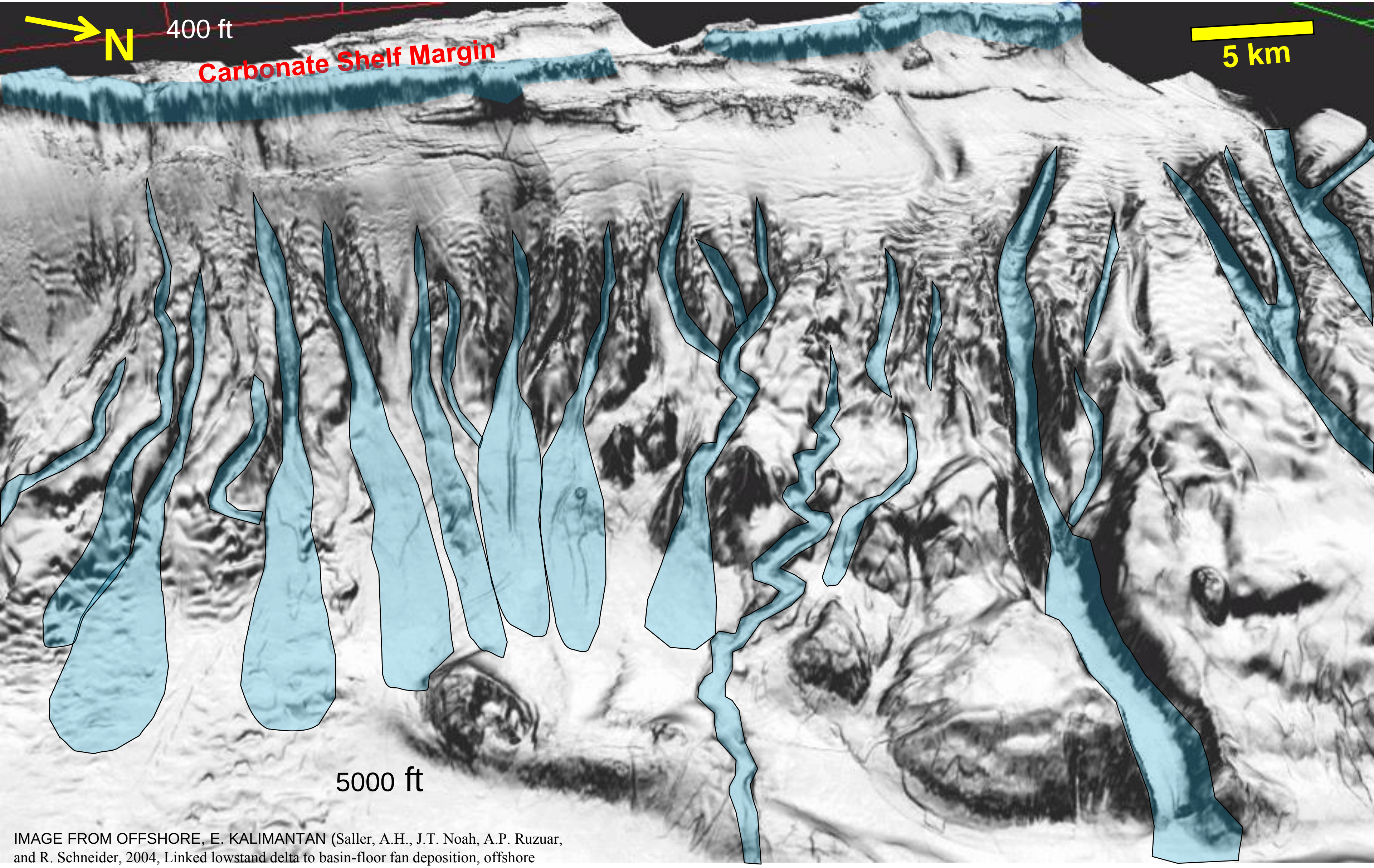


IMAGE FROM OFFSHORE, E. KALIMANTAN (Saller, A.H., J.T. Noah, A.P. Ruzuar, and R. Schneider, 2004, Linked lowstand delta to basin-floor fan deposition, offshore Indonesia: an analog for deep-water reservoir systems: AAPG Bulletin, v. 88, p. 21-46.
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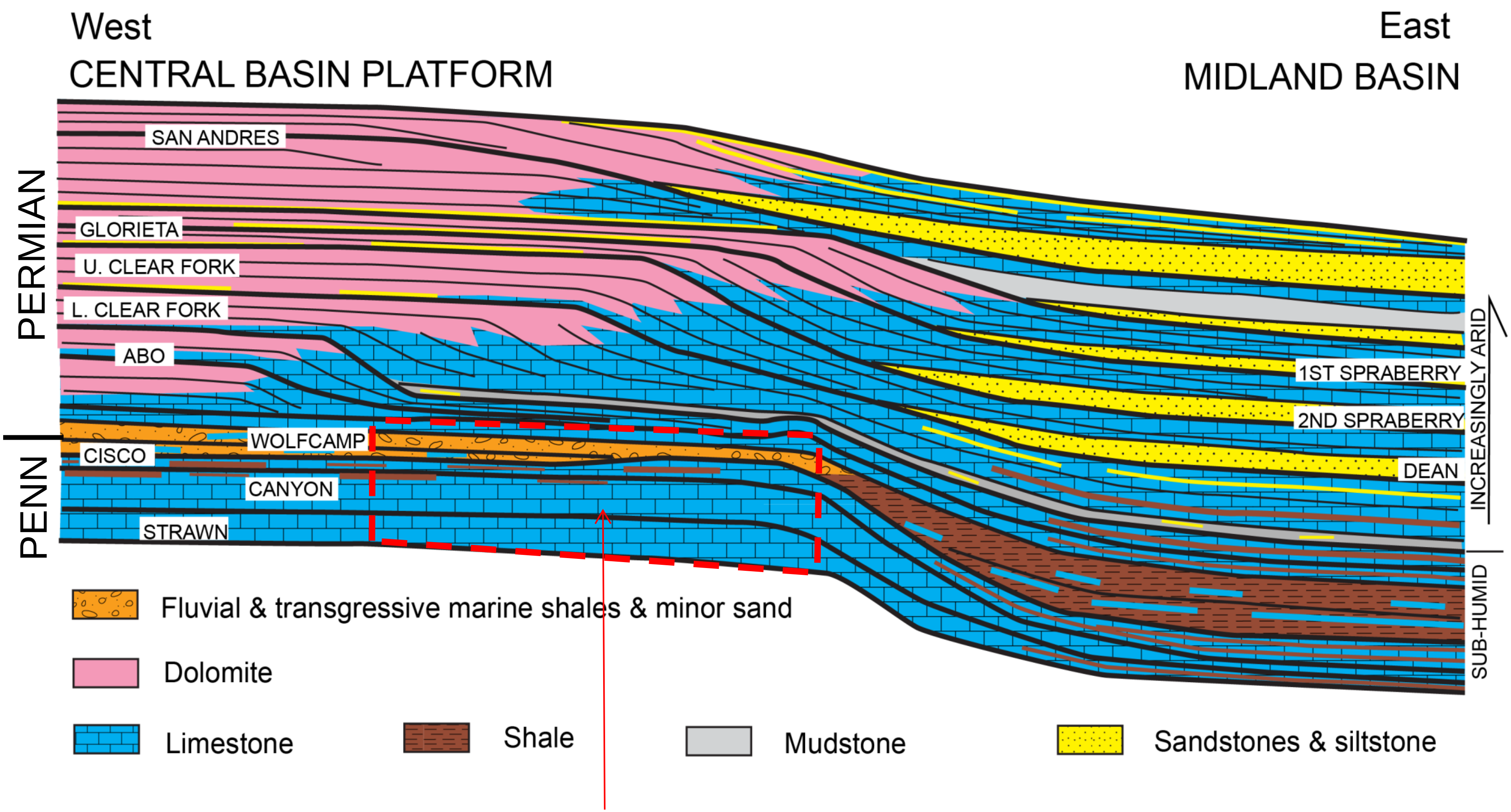
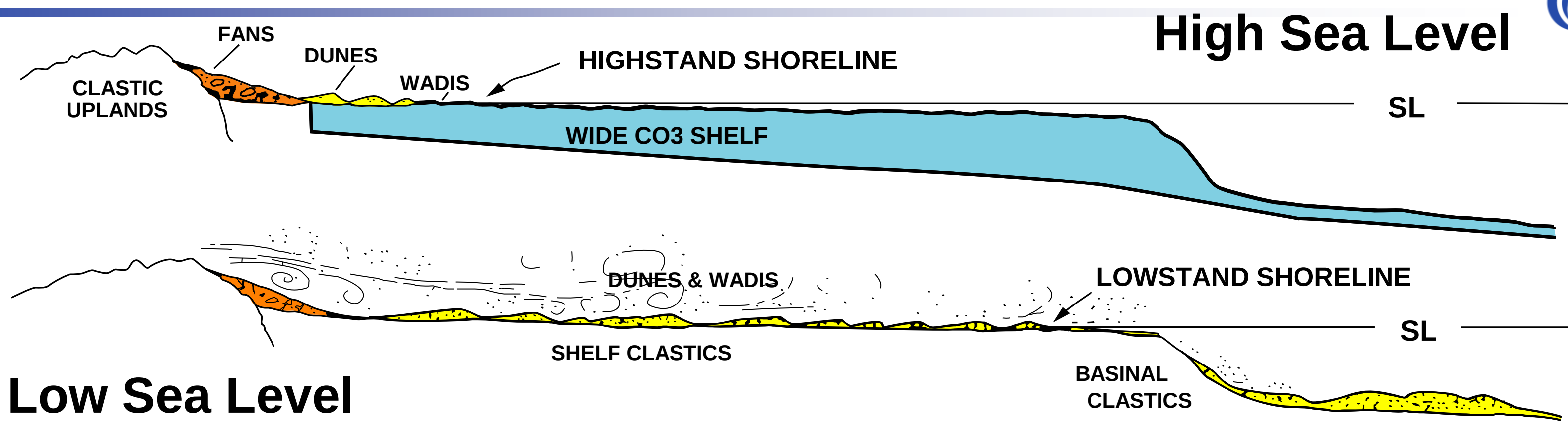
Permian: Change from Limestones & Shale Deposited Humid Climate to Dolomites & Sand Associated with Increased Aridity

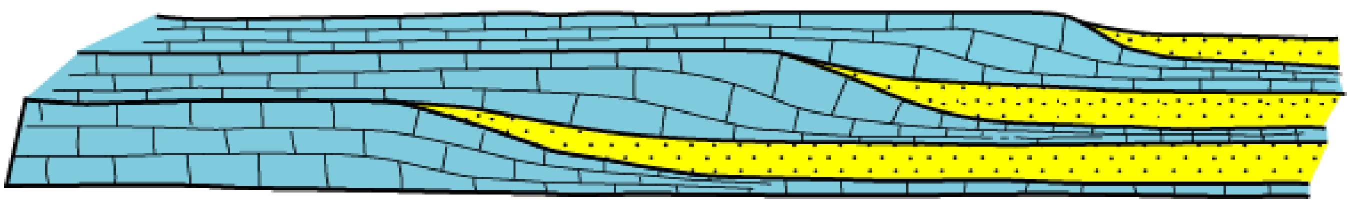


Southwest Andrews Reservoir

Mid & Late Permian Arid Climate Deposition



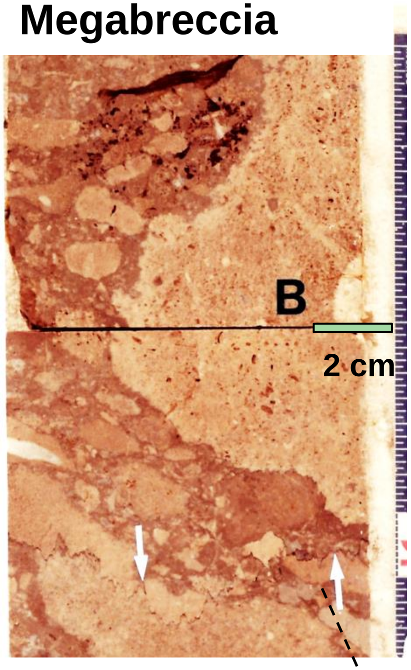
(from Tom Elliott, Unocal/Chevron



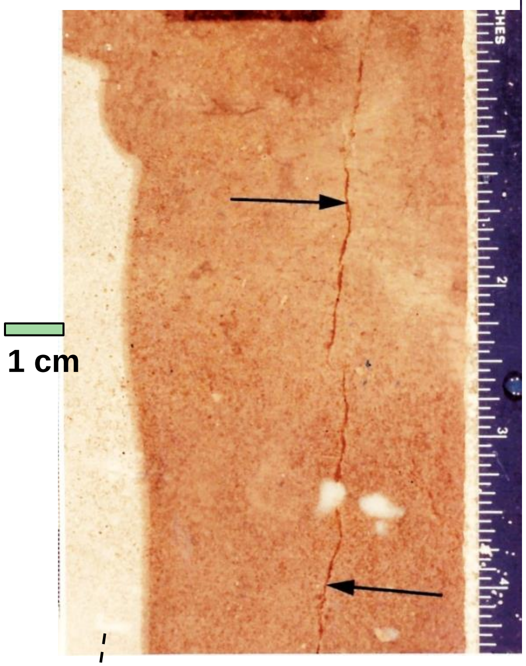
- Carbonates (mainly dolomites) & evaporites are deposited during high sea level
- During low sea level, siliciclastic transport is dominated by eolian processes with sand & silt being blown across the shelf & into the basin.
- Siliciclastic deposits in the basin are dominated by very fine sand in channels & silt (wind-blown dust) away from channels

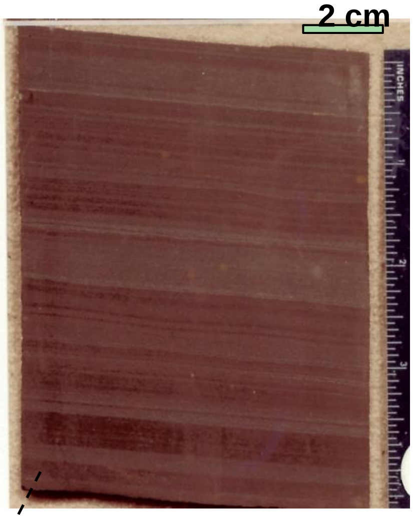
Middle Permian Slope & Basin Strata

Dolomitized Megabreccia

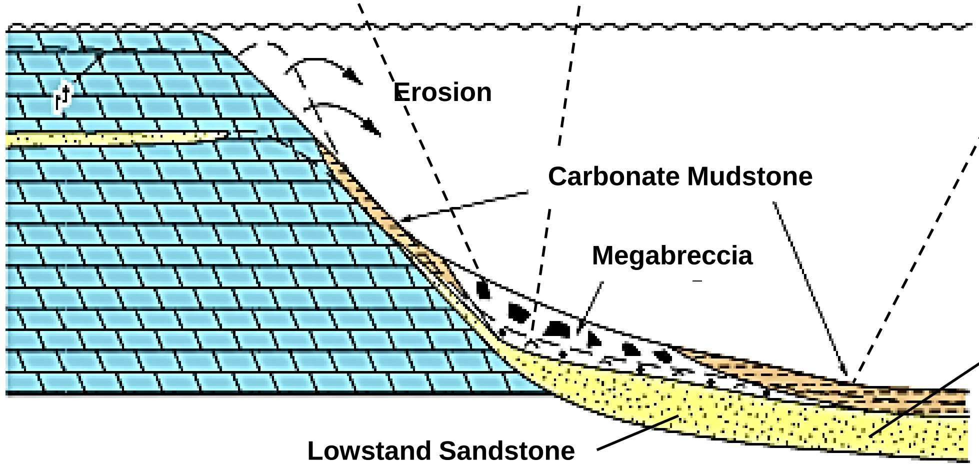


Dolomitized Packstone





Dolomitic mudstone

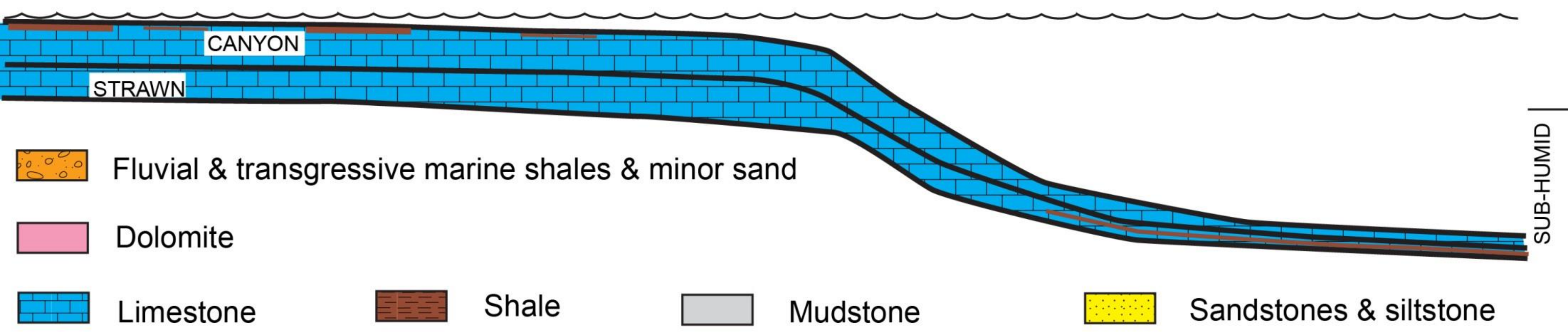


DEPOSITIONAL SUMMARY

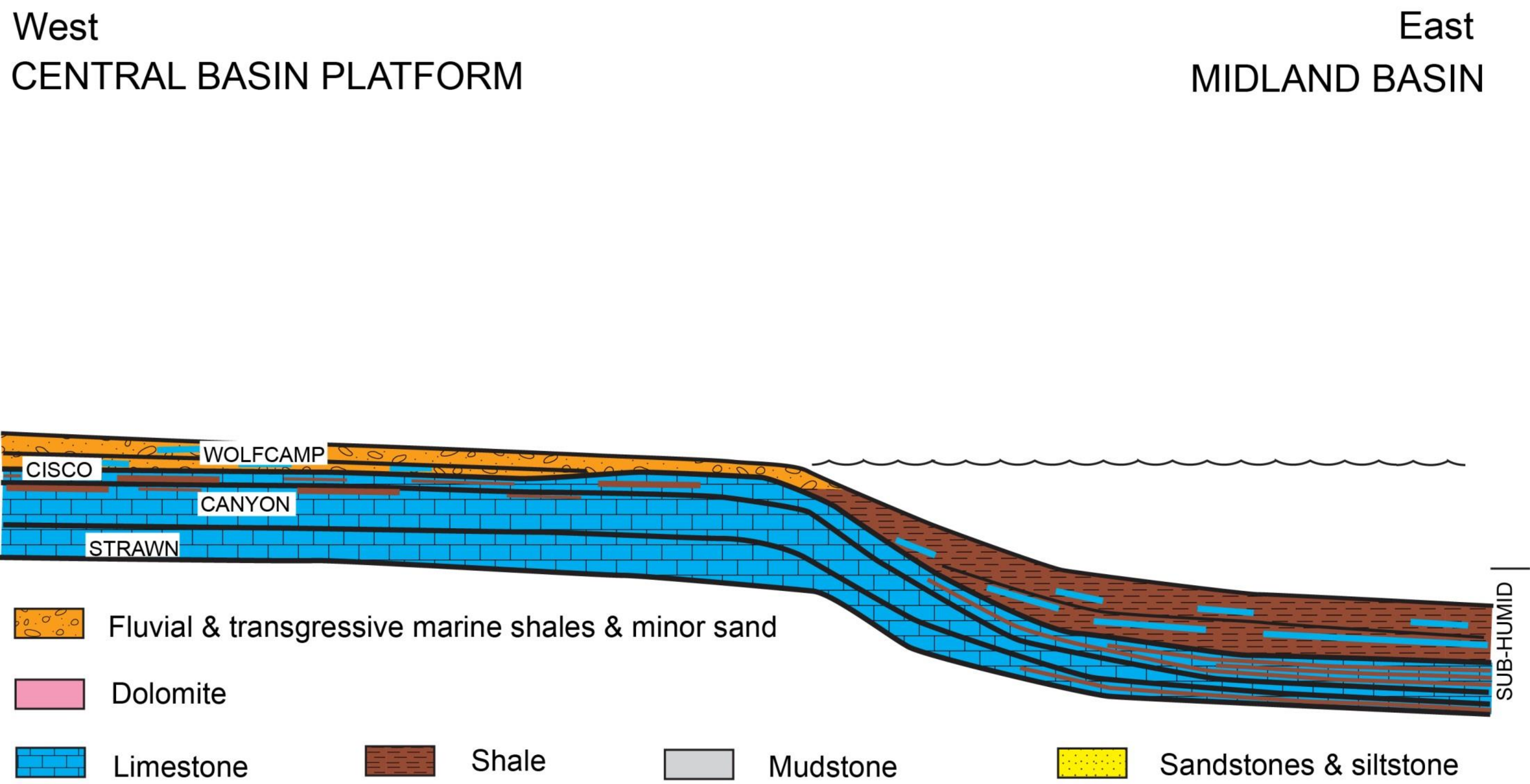
West
CENTRAL BASIN PLATFORM

East
MIDLAND BASIN

Canyon: Deposition of Generally High Sea Level; Cyclic Shallow Water Limestones on the Platform with Some Lime Muds, Sands, & Breccias Deposited in the Basin

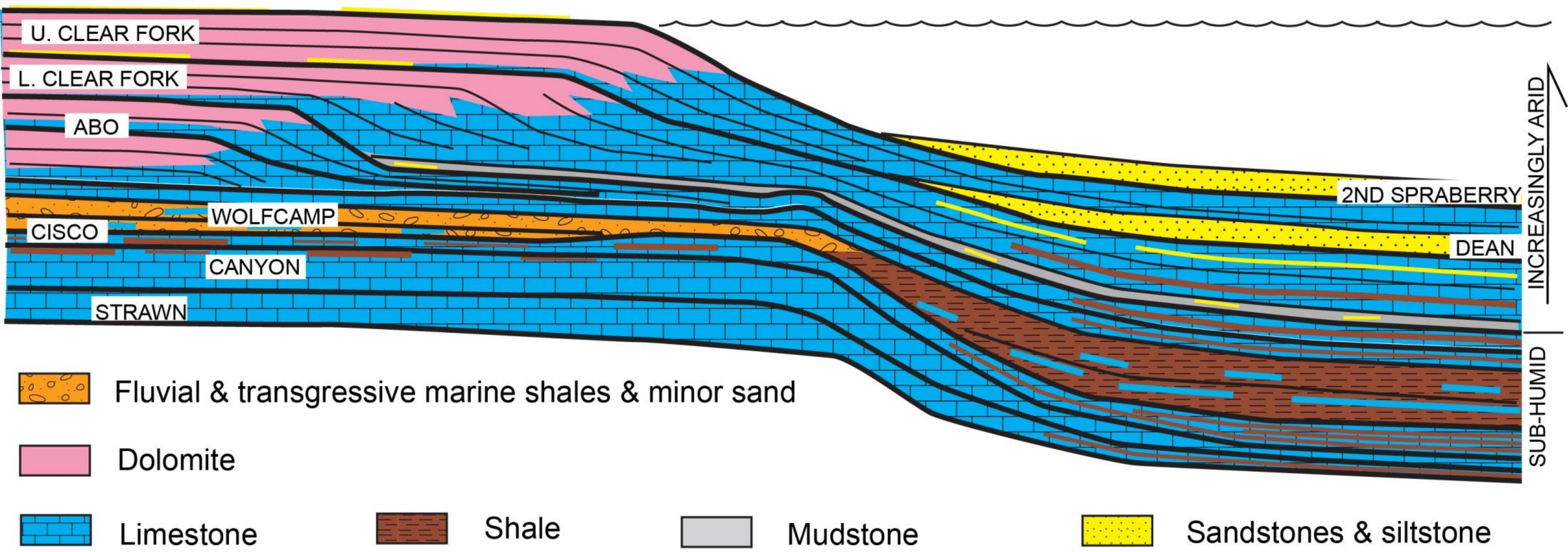


DEPOSITIONAL SUMMARY



Earliest Wolfcamp: Dominated by Low Sea Level. Thin Carbonates & Shales Deposited on the Platform. Siliciclastics (mainly shales) Carried to the Basin.

DEPOSITIONAL SUMMARY



Leonardian: Arid. Dolomites Deposited on the Platform during High Sea Level. Sands & Silts Deposited in the Basin during Low Sea Level.

Thanks to

- WTGS, Cobalt International Energy
- Many wonderful people who I have worked with, esp
  - Tom Elliott, Tony Dickson, Greg Hinterlong, Al Crawford, Skip Walden, Steve Robertson, Tim Anderson, Brian Ball, Greg Fitzgerald, Sherman Smith, Stacie Boyd, Stan Frost, **George Moore**