Depositional Environments and West–East Stratigraphic Correlations of the Upper Pennsylvanian Honaker Trail Formation, the Paradox Basin, Southeast Utah*

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Search and Discovery Article #50510 (2011)
Posted November 7, 2011

*Adapted from oral presentation at the West Texas Geological Society Fall Symposium, Midland, Texas, September 28-30, 2011. Please refer to the authors' companion article presented as a poster at the above-noted WTGS symposium; the title is "Lithofacies, Depositional Environments, and a Stratigraphic Correlation of Upper Pennsylvanian-aged Paradox and Honaker Trail Formations: A Closer Look at the Rocks from Hand Specimens and Thin Sections," Search and Discovery Article #30199 (2011).

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Abstract

The canyons of the San Juan River provide impressive outcrops exposing the Upper Pennsylvanian strata of the Paradox and Honaker Trail Formations, and the Lower Permian Group. These outcrops reveal the Upper Paleozoic geology of the Paradox Basin; the same units are productive in the subsurface. They are the analog to the prolific Greater Aneth Oil Field.

Four vertical sections along the canyon of the San Juan River were measured, sampled, and described. The data collected was used to build detailed stratigraphic columns. Eight depositional environments were identified and they include: fluvial, eolian, beach, lagoon, tidal flat, high energy shoal, proximal open shelf, distal open shelf.

The Upper Pennsylvanian Paradox and the Lower Honaker Trail Formations (Desmoinesian through early Missourian) are dominated by transitional – marginal marine and open marine carbonates with intermittent tidal flat sandstones and siltstones. The Upper Ismay Member is dominated by marine sediments that become shallower from west to east. The Lower Honaker Trail Formation is deeper marine on the west and shallow to transitional environments eastward. As the cycles transitioned into the Middle Missourian – Virgilian, siliciclastic content increased. The Upper Honaker Trail Formation and the Lower Permian all appear to be predominantly non-marine sands. These upper cycles are composed of flood plain, fluvial, and eolian sandstones.

The various lithofacies observed in outcrop sections were bundled into depositional cycles that represent intervals of sea level rise and fall and exhibit a deepening to shallowing succession of facies. These cycles represent a mixed system of carbonates and sandstones that were

deposited on the shelf of the Paradox Basin (Grammer et al., 1996). The best reservoir units appear to be shallow marine grain-dominated carbonates and fluvial and eolian sands.

The Pennsylvanian strata on the Eastern Shelf of the Permian Basin are very similar to those located on the shelf of the Paradox Basin. The results from this study can be directly applied to the deposits on the Eastern Shelf and in North Central Texas.

Selected Bibliography

Baars, D.L., and G.M. Stevenson, 1981, Tectonic evolution of the Paradox Basin, Utah and Colorado, *in* D.L. Wiegand, (ed.) Geology of the Paradox Basin: Rocky Mountain Association of Geologists, Field Conference: p. 23-31.

Baars, D.L., 1973, Geology of the Canyons of the San Juan River: Four Corners Geological Society, Durango, Colorado, 94 p.

Condon, S.M., 1997, Geology of the Pennsylvanian and Permian Cutler Group and Permian Kaibab limestone in the Paradox Basin, southeastern Utah and southwestern Colorado: United States Geological Survey Bulletin, 2000-P, 46 p.

Goldhammer, R.K., O.J. Oswald, and P.A. Dunn, 1991, The hierarchy of stratigraphic forcing: an example from Middle Pennsylvanian shelf carbonates of the Paradox Basin, *in* E.K. Franseen, W.L. Watney, and C.G.St.C. Kendall, (eds.) Sedimentary modeling: Computer simulations and methods for improved parameter delineation: Kansas Geological Survey Bulletin 233, p.361-413.

Grammer, G.M., G.P. Eberli, F.S.P. Van Buchem, G.M. Stevenson, and P. Homewood, 1996, Application of high resolution sequence stratigraphy to evaluate lateral variability in outcrop and subsurface –Desert Creek and Ismay intervals, Paradox Basin, *in* M.W. Longman, and M.D. Sonnenfield, (eds.) Paleozoic systems of the Rocky Mountain region: Society of Sedimentary Geology, Rocky Mountain Section, p. 235-266.

Helms, C.D., Jr., and E.L. Stoudt, 2011, Lithofacies, depositional environments, and a stratigraphic correlation of Upper Pennsylvanian-aged Paradox and Honaker Trail formations: A closer look at the rocks from hand specimens and thin sections: Web accessed 2 November 2011, AAPG Search and Discovery Article #30199 (2011).

Hite, R.J., D.E. Anders, and T.G. Ging, 1984, Organic-rich source rocks of Pennsylvanian age in the Paradox Basin of Utah and Colorado, *in* J. Woodward, F.F. Meissner, and J.L. Clayton, (eds.) Hydrocarbon source rocks of the greater Rocky Mountain Region: Rocky Mountain Association of Geologists, Guidebook, p. 255-274.

Nuccio, V.F., and S.M. Condon, 1996, Burial and thermal history of the Paradox Basin, Utah and Colorado, and petroleum potential of the Middle Pennsylvanian Paradox Formation: United States Geological Survey Bulletin 2000-O, 41 p.

Stevenson, G.M., and L.L. Wray, 2009, History of Petroleum Exploration of Paleozoic Targets in the Paradox Basin, *in* W.S. Houston, L.L. Wray and P.G. Moreland, (eds.) The Paradox basin revisited –new developments in petroleum systems and basin analysis: The Rocky Mountain Association of Geologists Special Publication 2009 (CD-ROM), p.1-23.

Stevenson, G.M., 2006, Personal PowerPoint slide of Devonian through Pennsylvanian Stratigraphic column.

Stevenson, G.M., 2000, Geology of Goosenecks State Park, San Juan County, Utah, in D.A. Sprinkel, T.C. Chidsey, Jr., and P.B. Anderson, (eds.) Geology of Utah's Parks and Monuments: Utah Geological Survey Publication 28, p. 433-447.

Stevenson, G.M., and D.L. Baars, 1986, The Paradox -A pull-apart basin of Pennsylvanian age, *in* J.A. Peterson, (ed.) Paleotectonics and Sedimentation in the Rocky Mountain Region, U.S.: American Association of Petroleum Geologists, Memoir 41, p. 513-539.

Stevenson, G.M., D.L. and Baars, 1988, Overview -Carbonate reservoirs of the Paradox Basin: Rocky Mountain Association of Geologists, 1988 Carbonate Symposium, p.149-162.

Wengerd, S.A., and M.L. Matheny, 1958, Pennsylvanian system of Four Corners Region: American Association of Petroleum Geologists Bulletin, v. 42/9, p. 2048-2106.

Williams, M.R., 2009, Stratigraphy of Upper Pennsylvanian cyclic carbonate and siliciclastic rocks, western Paradox Basin, Utah, Colorado, *in* W.S. Houston, L.L. Wray and P.G. Moreland, (eds.) The Paradox basin revisited –new developments in petroleum systems and basin analysis: The Rocky Mountain Association of Geologists Special Publication 2009 (CD-ROM), p. 383.

Website

Google Earth, 2011, Web accessed 1 November 2011, http://earth.google.com.

GREAT WESTERN DRILLING CO.

2011 WTGS Fall Symposium

September 28, 2011

Depositional Environments and West – East Correlations of the Upper Pennsylvanian Honaker Trail Formation of the Paradox Basin, Southeast Utah

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ACKNOWLEDGEMENTS

- CrownQuest Operating, LLC
- UTPB Professors
  - Dr. Emily L. Stoudt
  - Dr. Emilio Mutis-Duplat
  - Dr. Robert C. Trentham
  - Dr. Shawn Watson
- Great Western Drilling Company
- Gene Stevenson – Bluff, Utah

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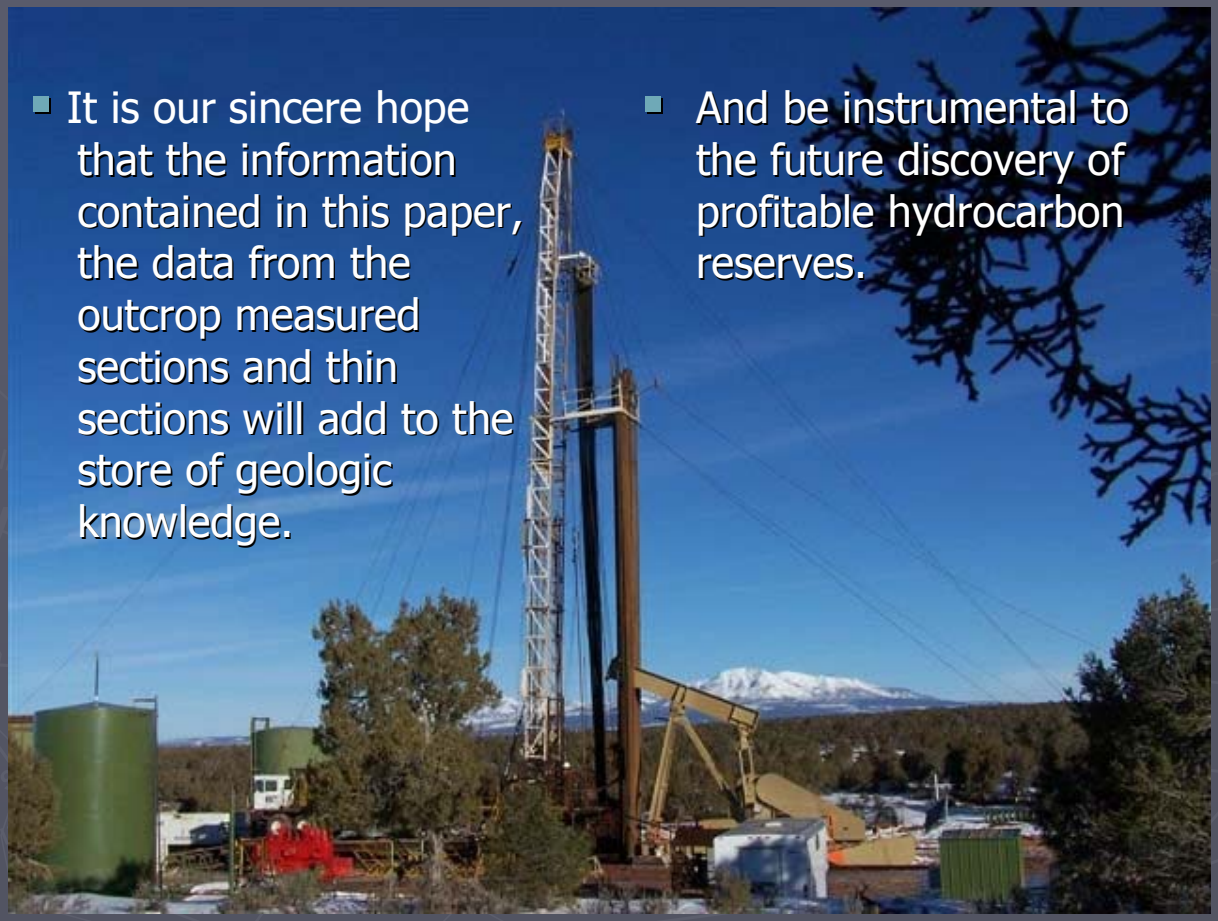
INTRODUCTION

This talk concentrates on the sandstone units of the Honaker Trail Formation that crop out along the canyons of the San Juan River in southeastern Utah. The canyons of the San Juan River provide impressive outcrops exposing the Upper Pennsylvanian strata of the Paradox and Honaker Trail formations. These outcrops reveal the Upper Paleozoic geology of the Paradox Basin; the same units are productive in the subsurface. They are the analog to the prolific Greater Aneth Oil Field.

Purpose of Study

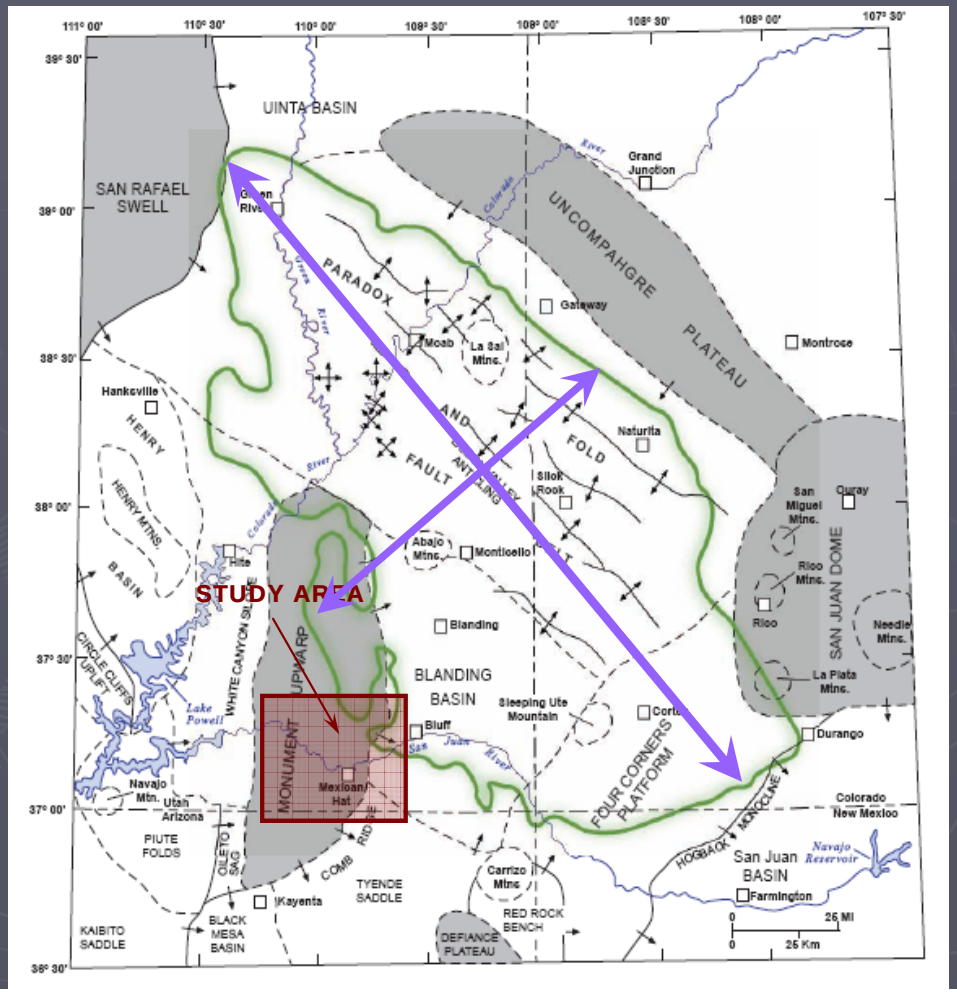


- It is our sincere hope that the information contained in this paper, the data from the outcrop measured sections and thin sections will add to the store of geologic knowledge.
- And be instrumental to the future discovery of profitable hydrocarbon reserves.

Outcrop exposed along canyon of the San Juan River – Abandoned Meander

The four outcrop sections that were measured and described for this study are exposed along the canyon of the San Juan River. This is a picture of my camp at the Abandoned Meander section.

Regional map showing the extent of the Paradox Basin and the major structural features of the central Colorado Plateau. Location of the study area is shown in the red square (Stevenson and Wray, 2009, modified from Nuccio and Condon, 1996).

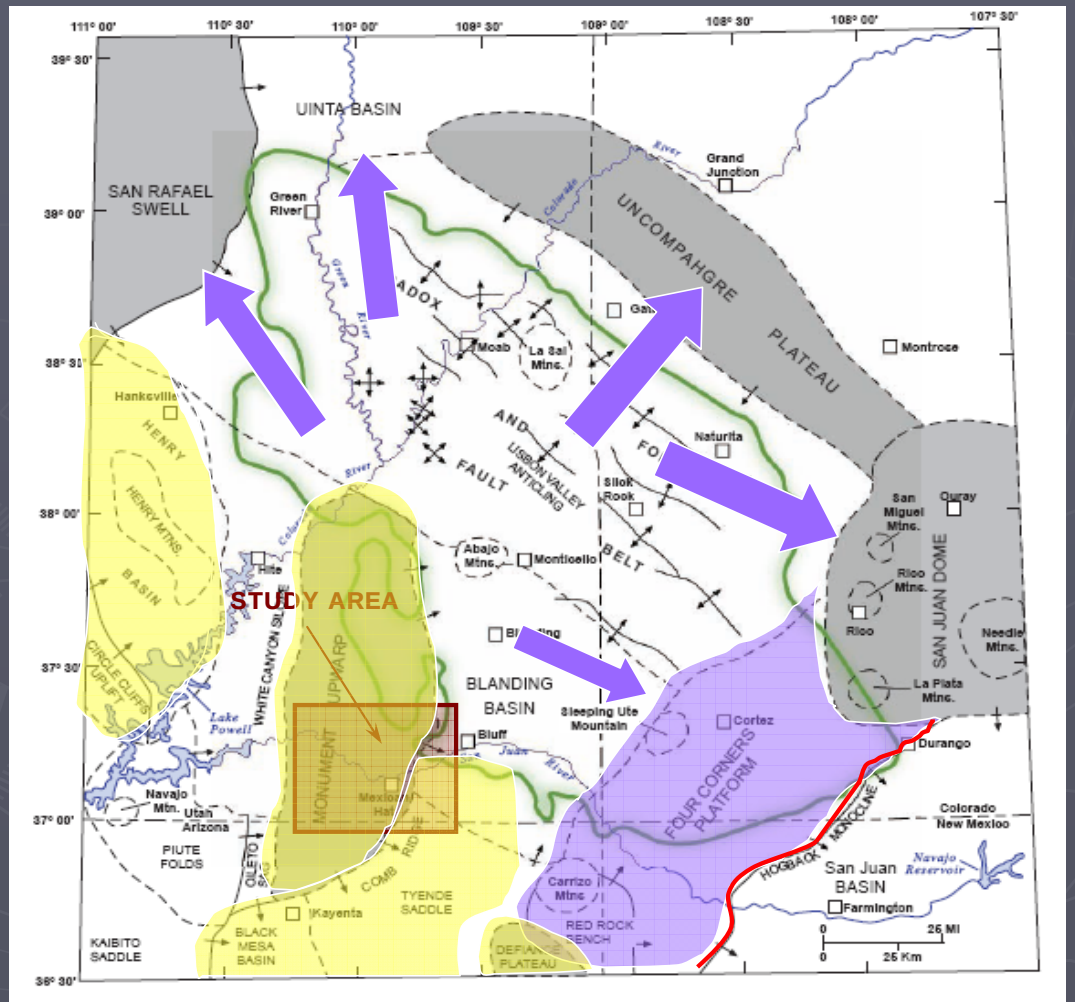


Regional map that shows the extent of the Paradox Basin and the major structural features of the central Colorado Plateau. Location of the study area is shown in the red square. The Paradox Basin is a very complex intracratonic evaporite basin (Stevenson and Baars, 1986; 1988). The basin is defined by the maximum extent of salt deposited during the Middle Pennsylvanian in the Paradox Formation (Baars and Stevenson, 1981; Hite et al., 1984; Nuccio and Condon, 1996). It is an asymmetrical, elongate basin that trends northwest-southeast and extends from the northwestern part of New Mexico into east-central Utah. The maximum northwestsoutheast length is about 190 miles. It covers an area of approximately 10,425 mi^2 in southwestern Colorado and southeastern Utah (Stevenson and Baars, 1986, 1988) and the northeast-southwest width is about 95 miles (Nuccio and Condon, 1996).

Location map showing the four primary measured outcrop sections, Honaker Trail, Raplee Anticline, Abandoned Meander, and River Mile 9.1 with the general sites (yellow stars) along the San Juan River. The vertical measured sections are approximately located at the arrows shown on the map (modified from Google Earth, 2011).

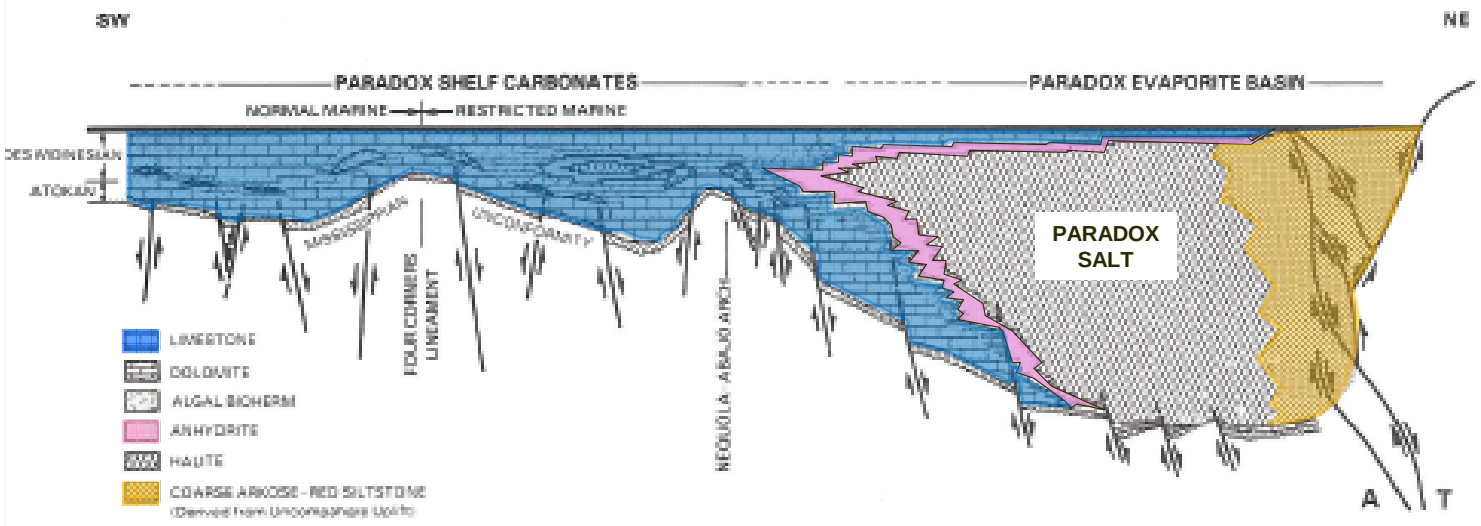
The four outcrop sections that were measured and described for this study are exposed along the canyon of the San Juan River in southeastern Utah. The Honaker Trail, Raplee Anticline, the Abandoned Meander, and River Mile 9.1 exposures are located on the southwestern boundary of the Paradox Basin. These exposures trend west to east across the Pennsylvanian shelf perpendicular to depositional strike. These locations were chosen for accessibility. The first section measured was the Honaker Trail. This section is the "TYPE" section for all the exposures. Second was the Raplee Anticline. The last two sections were chosen because, as of May 2008, these sections have never been measured and they were easily accessible from the San Juan River.

Regional map showing the extent of the Paradox Basin and the major structural features of the central Colorado Plateau. Location of the study area is shown in the red square (Stevenson and Wray, 2009, modified from Nuccio and Condon, 1996).



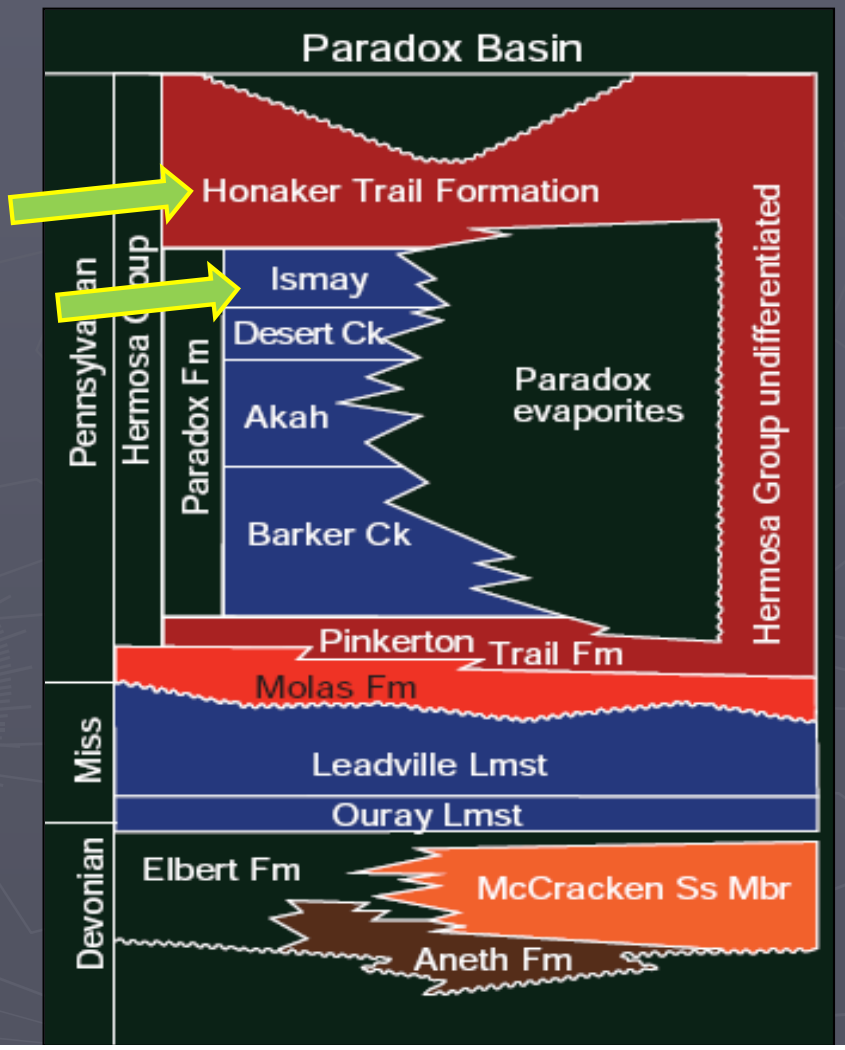
The Paradox Basin is surrounded by m ajor uplifts of the Colorado Plateau. It is bound to the northwest by the San Raf ael Swell and the Uinta Basin. On the north and to the northeast the basin is bound by the Uncompahgre Uplift. The eastern edge is bounded by the San Juan Dom e and the Four Corner's Platform Th e Hogback Monocline on the easter n edge separates the Paradox Basin from the San Juan Basin (Nuccio and Condon, 1996). The south, southwest, and we st are bound by the Defiance Uplift, Black Mesa Basin, Monument Uplift, and the Henry Basin (Wengerd and Matheny, 1958; Nuccio and Condon, 1996).

Generalized southwest-northeast cross section across the Paradox Basin illustrating the gross facies relations between the Middle Pennsylvanian shelf carbonates, basinally restricted evaporites, and coarse clastics proximal to the Uncompaghre Uplift (Grammer and others, 1996. Modified from Stevenson and Baars, 1988).



According to Stevenson and Baars (1986) th e basin is heavily faulted, making it more com plex structurally and stratigraphically than previously realized. This is a SW-NE cross-section illustrating gross facies relations between the Middle Pennsylvanian shelf carbonates, basinally restricted evaporites, and coarse clastics proximal to the Uncompahgre Uplift.

Devonian through Pennsylvanian stratigraphic column illustrating the relationship of the Paradox Formation evaporites and their facies equivalents in the basin (Stevenson and Wray, 2009; from Stevenson, 2006).



The Honaker Trail Formation is Missourian – Virgilian in age. It is the uppermost formation of the Hermosa Group. This talk concentrates on the Upper Ismay and Honaker Trail Formation.

Geologic Stratigraphy

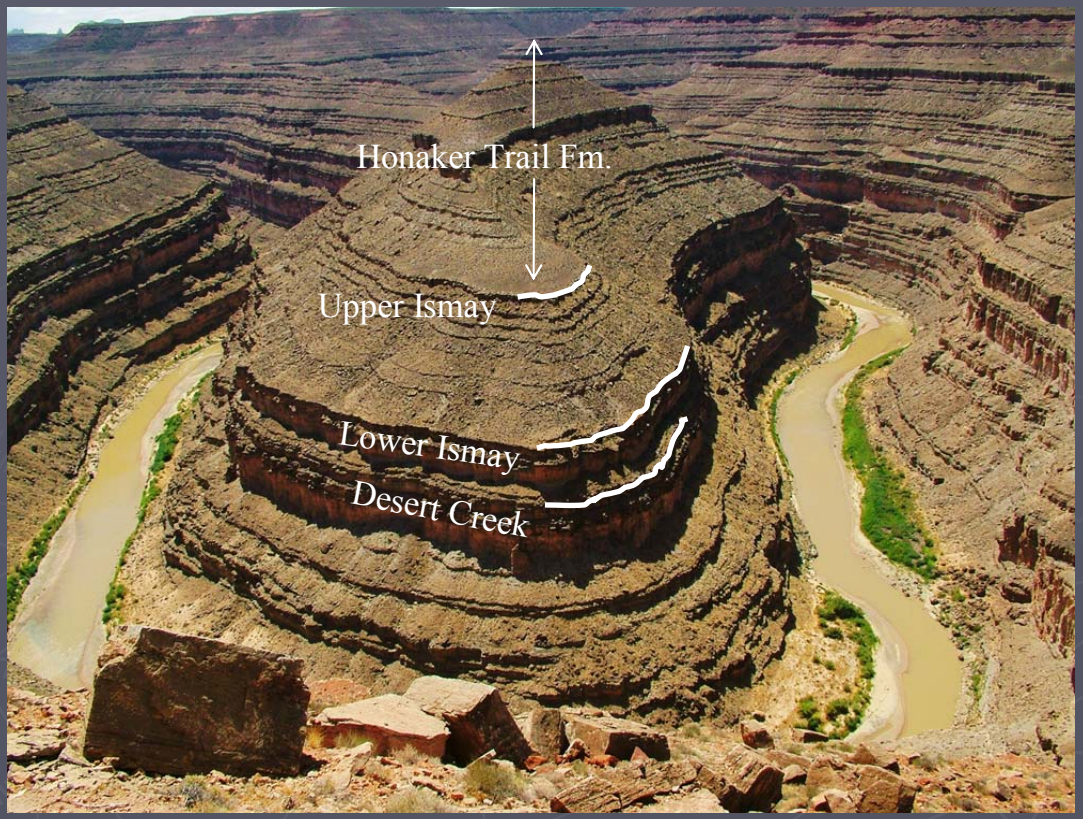
The Desert Creek and Ismay are the most prolific reservoirs in the Paradox Basin. What is shown here is an algal mound in the Lower Ismay on the San Juan River.

Geologic Stratigraphy

The Horn Point Limestone is an excellent marker bed

The Lower and Upper Ismay are separated by a marker bed, the Horn Point Limestone (Grammer et al., 1996). The stratigraphic columns built for this talk are flattened on this marker bed. This picture was taken from the Honaker Trail near the Gooseneck State Park.

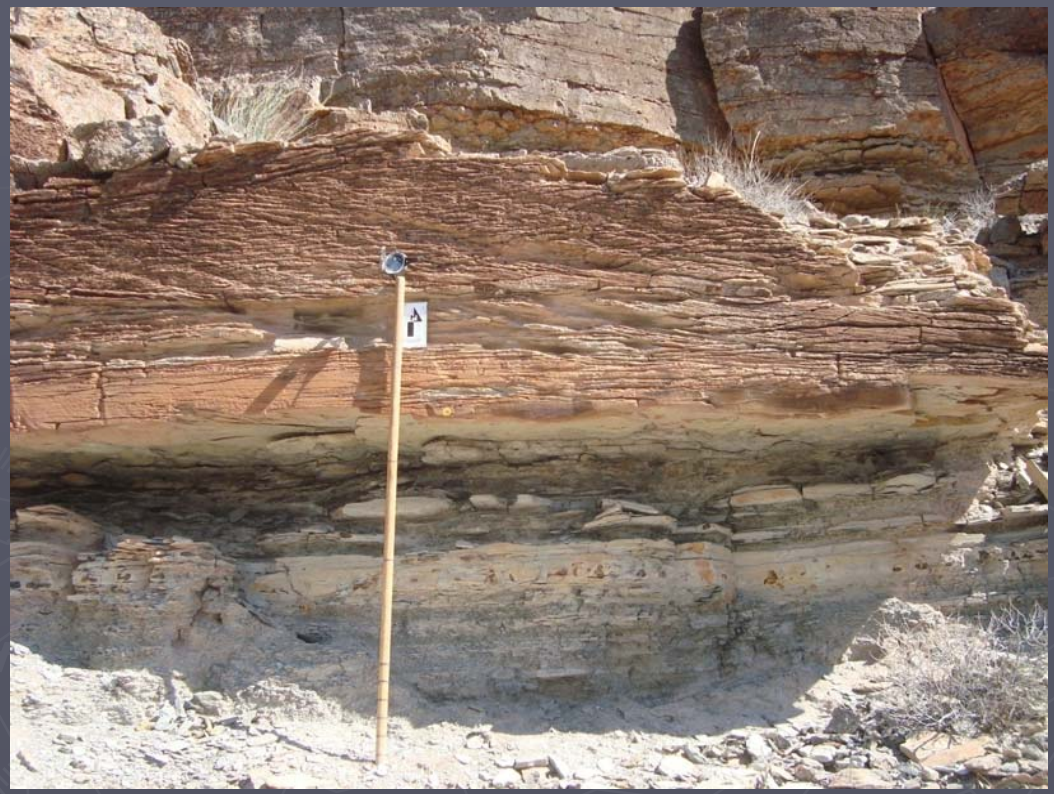
Geologic Stratigraphy



Photograph at the Gooseneck Overlook of the San Juan River showing the Desert Creek, Lower and Upper Ismay, and Lower Honaker Trail sections.

The Honaker Trail Formation is composed of cherty, silty carbonates, and calcareous shales, siltstones, and sandstones with no interbedded evaporites. As Pennsylvanian time ended, the Hermosa sea withdrew from the Paradox Basin, resulting in an unconformity between the Carboniferous and overlying Permian strata (Grammer et al., 1996). It is unlikely that there is a single limestone that extends throughout the basin that could be used as a datum for the top of the Honaker Trail. Limestones have been observed to thin and/or grade into sandstone and shale facies in most exposures (Condon, 1997).

METHODS



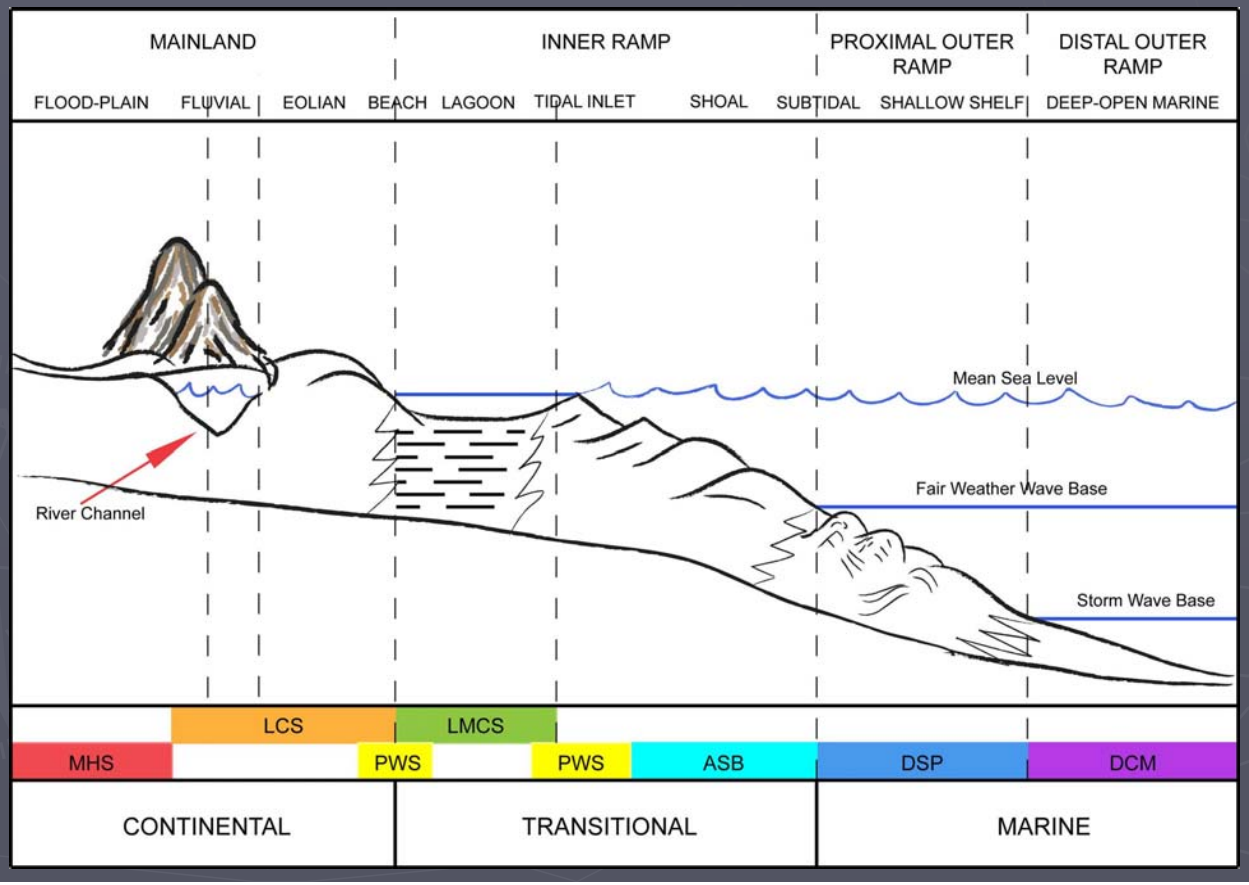
During the summer of 2008 the four outcrop locations along the San Juan river were measured using a Jacob's staff and a Brunton compass. Field descriptions were recorded as measurements were taken. Described intervals ranged from 1 to 5 feet or where significant changes of lithologies in the vertical sections were observed. Samples were also collected at 1 to 5 feet intervals or at significant changes in the vertical lithologies.

Sedimentary Facies

- The 21 lithofacies were identified and described and combined into seven sedimentary facies.
- The sedimentary facies are listed from continental to most distal marine: (From Williams, 2009)
  - MHS (Mottled Heterolithic Sandstone and Shale)
  - LCS (Large-Scale Cross-Bedded Sandstone)
  - PWS (Planar- to Wavy-Bedded Sandstone)
  - LMCS (Laminated Muddy Carbonate-Siliciclastic Sandstone)
  - ASB (Amalgamated Carbonate-Quartz Sandy Beds)
  - DSP (Diverse Skeletal Wackestone to Packstone)
  - DCM (Displacive Cherty Mudstone to Wackestone)

Depositional Environments

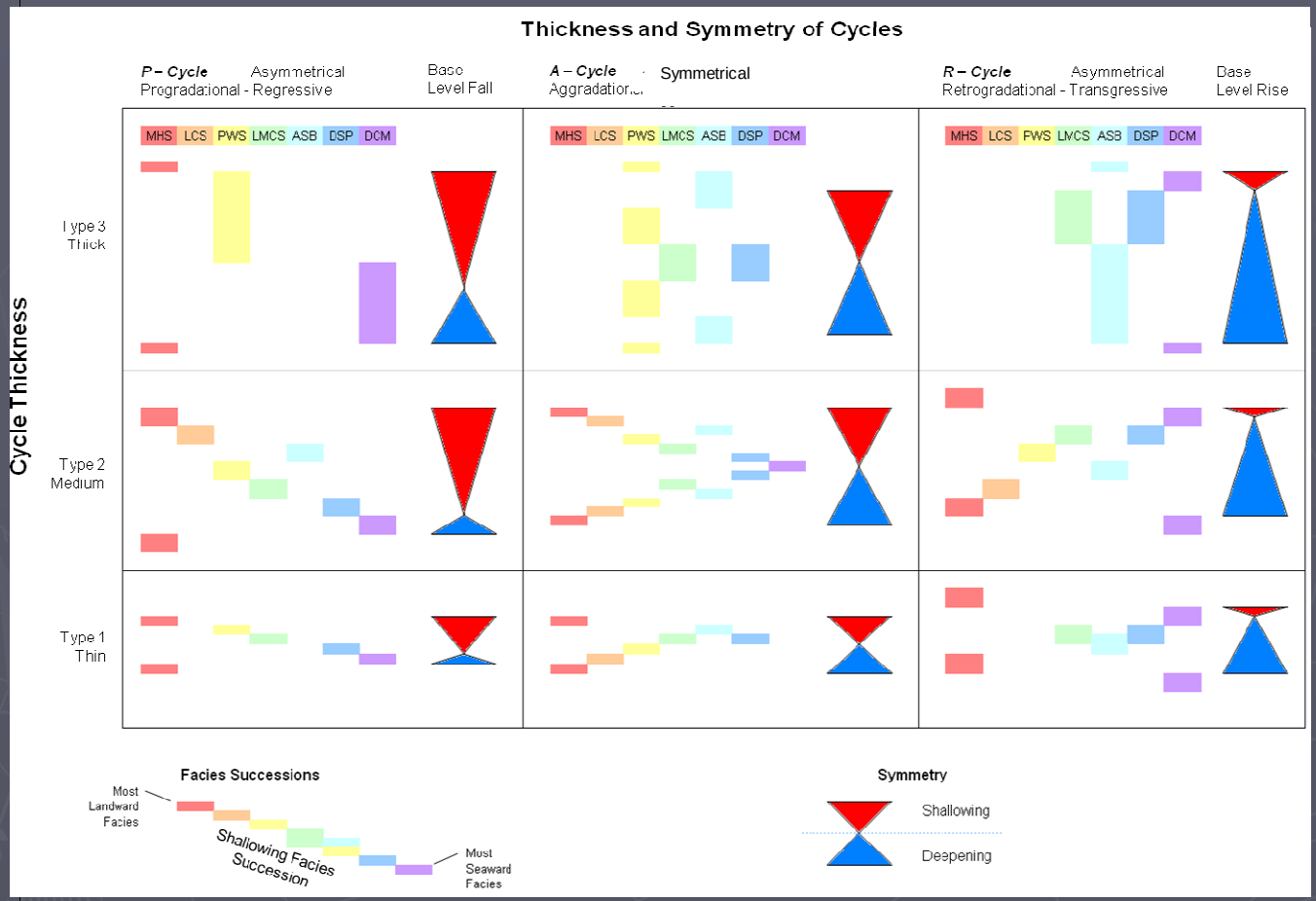
Diagram illustrating primary depositional environments and facies types.



Depositional Environments

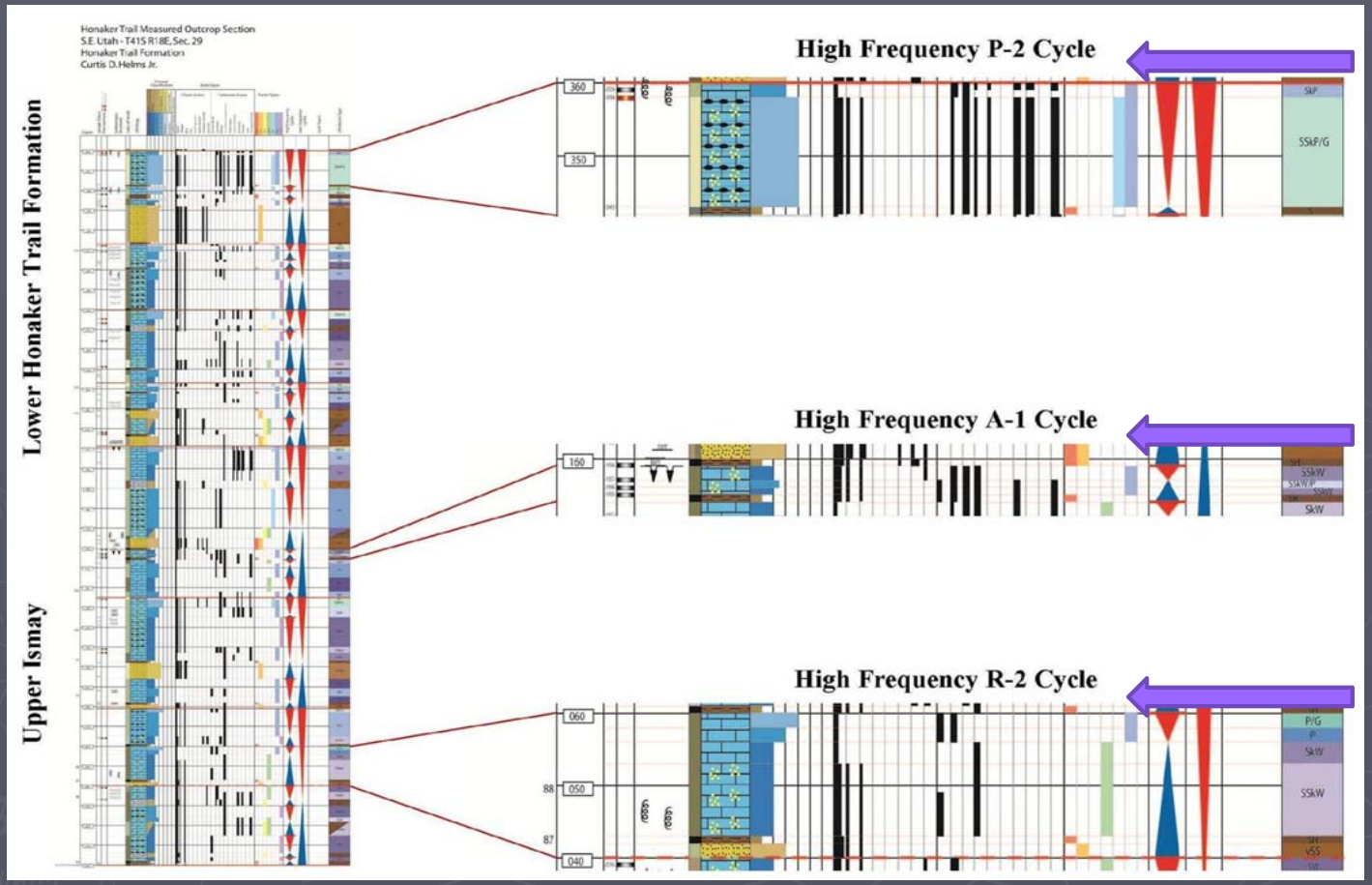
- The depositional environment of the sedimentary facies was interpreted from outcrop descriptions, examination of hand specimens and, where applicable, thin sections.
- We have identified the following depositional environments in our measured sections:
  - Fluvial (MHS)
  - Eolian (LCS)
  - Beach (PWS)
  - Lagoon (LMCS)
  - Tidal flat (LMCS)
  - High energy marine shoal (ASB)
  - Shallow marine (DSP)
  - Deep open marine (DCM)

Diagram showing cycle thickness and symmetry. Modified from Williams, 2009.



The scheme used for classifying th e cycles in the Upper Is may, Honaker Trail, and Lowerm ost Permian deposits was adapted from Williams (2009). The three fundamental cy cle types are 1.) *P cycles*, asymmetrical progradational – re gressive cycles that exhibit sea-level fall. 2) *A cycles*, symmetrical aggradational cycles represent shallow-water sedimentation that kept pace with accomodation; accommodation space is filled about as rapidly as it is created, and facies tracts shift neither seaward or landward. 3) *R cycles*, asymmetrical retrogradational – tran sgressive cycles are pu rely subtidal and occur where accommodation sp ace is created more rapidly than it is filled; sea level is rising. Within the three cycle groups th ere are thin (0' – 10'), m edium (10' – 36'), and thick (36' – 70') cycles. Examples of the fundamental cycles found in the measured sections are illustrated here.

Diagram illustrating high frequency cycle types

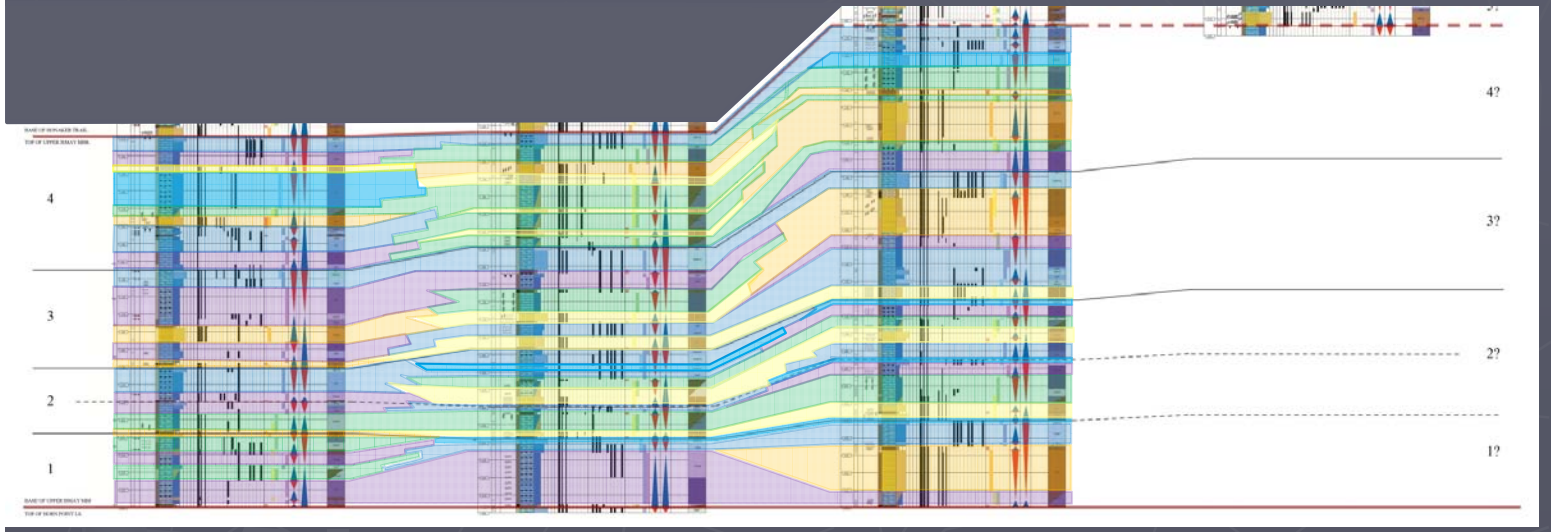


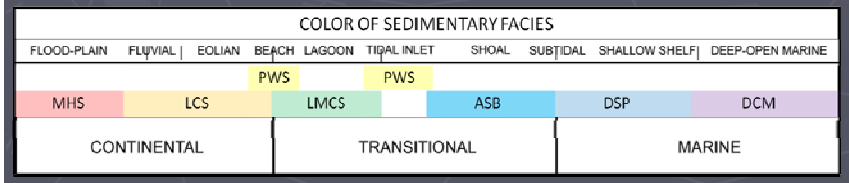
R-Cycle: Sea level rising, A-Cycle:Accommodation space keeping up with sedimentation rate. P-Cycle the sea level falling.

Correlation of Measured Sections

East-west cross-section constructed from the four measured outcrop sections. The cross-section is an oblique section; it is not parallel to strike or dip. The top of the Horn Point Limestone is present in the Honaker Trail, Raplee Anticline, and Abandoned Meander measured outcrop sections. At the River Mile 9.1 location, the Horn Point Limestone is below river level (Baars, 1973). Thus there is no obvious correlation point between this measured section and the other three.

Correlation of Measured Sections
Upper Ismay Interval (cycle sets 1-4)





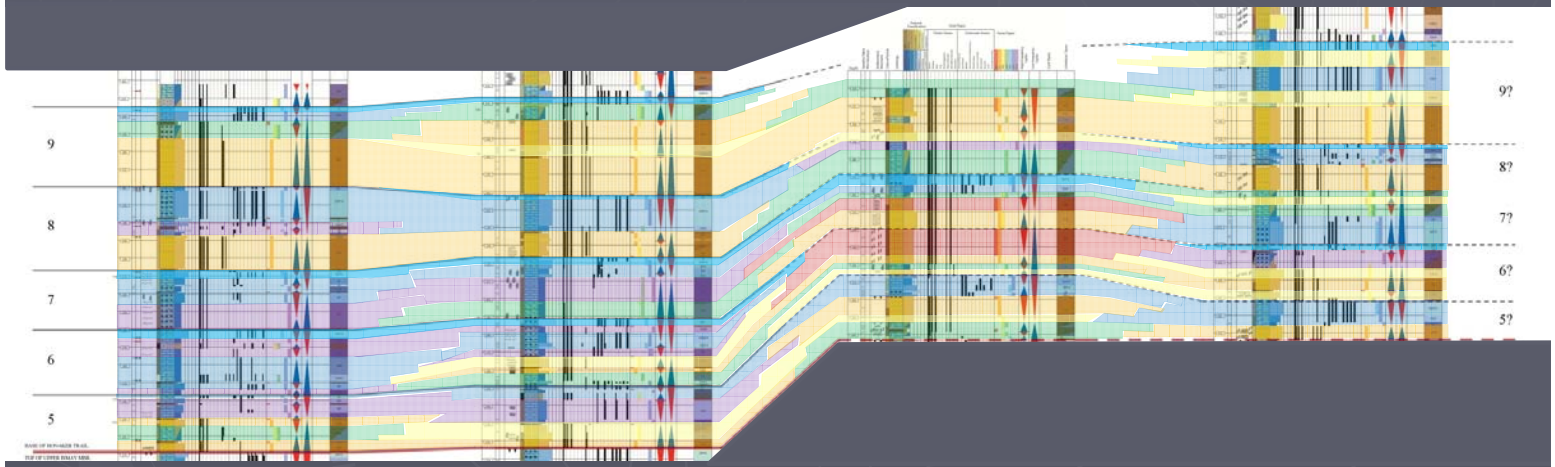
The Upper Ismay is present in three of the four measured outcrop sections and it is represented by cycle sets one through four. Terrigenous sediment increases from west to east. In the Honaker Trail measured section a distal outer ramp (DCM) sedimentary facies dominates cycle sets 1 to 4. Moving eastward to the Raplee Anticline and then to the Abandoned Meander, depositional environments appear to shallow upward and terrigenous sediment increases.

Correlation of Measured Sections
Upper Ismay Interval (cycle sets 1-4)

COLOR OF SEDIMENTARY FACIES										
FLOOD-PLAIN	FLUVIAL	EOLIAN	BEACH	LAGOON	TIDAL INLET		SHOAL	SUBTIDAL	SHALLOW SHELF	DEEP-OPEN MARINE
			PWS		PWS					
MHS	LCS		LMCS			ASB		DSP		DCM
CONTINENTAL			TRANSITIONAL				MARINE			

Cycles tend to be capped by ooid or skeletal grainstones indicative of a transitional inner ramp (ASB) sedimentary facies. The top of cycle four is present in all four measured sections and represents a regional exposure surface that marks the top of the Upper Ismay and the base of the Honaker Trail Formation.

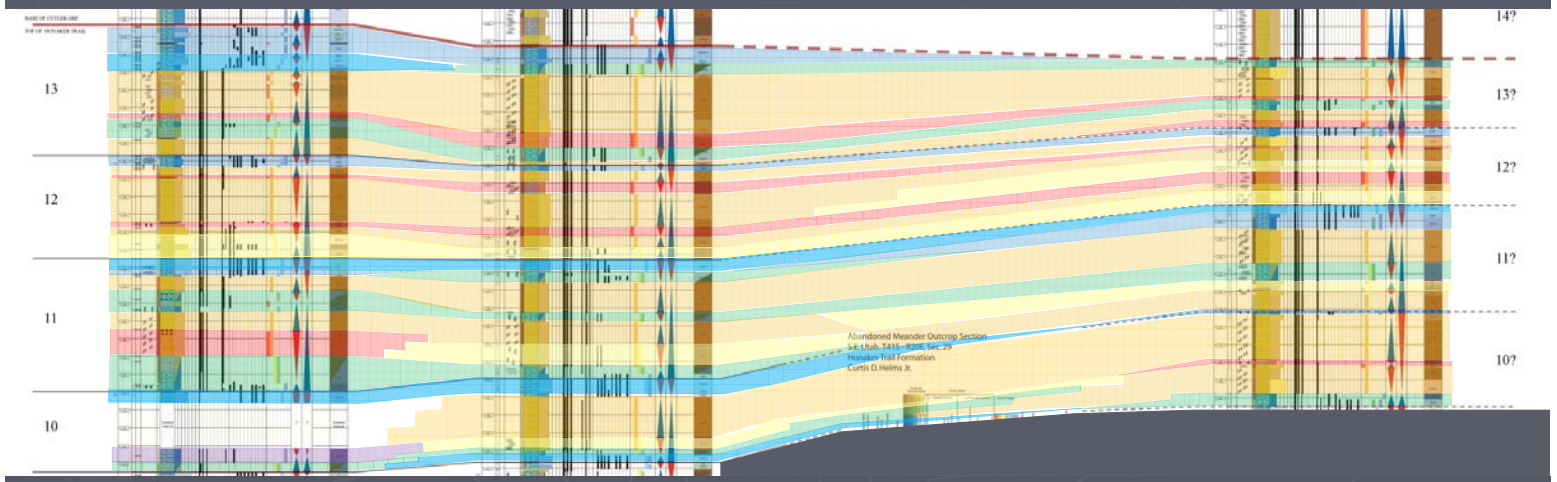
Correlation of Measured Sections Lower Honaker Trail Fm. (cycle sets 5-9)



COLOR OF SEDIMENTARY FACIES										
FLOOD-PLAIN	FLUVIAL	EOLIAN	BEACH	LAGOON	TIDAL INLET		SHOAL	SUBTIDAL	SHALLOW SHELF	DEEP-OPEN MARINE
			PWS		PWS					
MHS	LCS		LMCS			ASB		DSP		DCM
CONTINENTAL			TRANSITIONAL					MARINE		

The Lower Honaker Trail Formation is present in all four measured outcrop sections and is represented by cycle sets five to nine. Cycle sets five through eight of the Honaker Trail measured outcrop section are dominated by distal and proximal outer ramp (DCM and DSP) sedimentary facies.

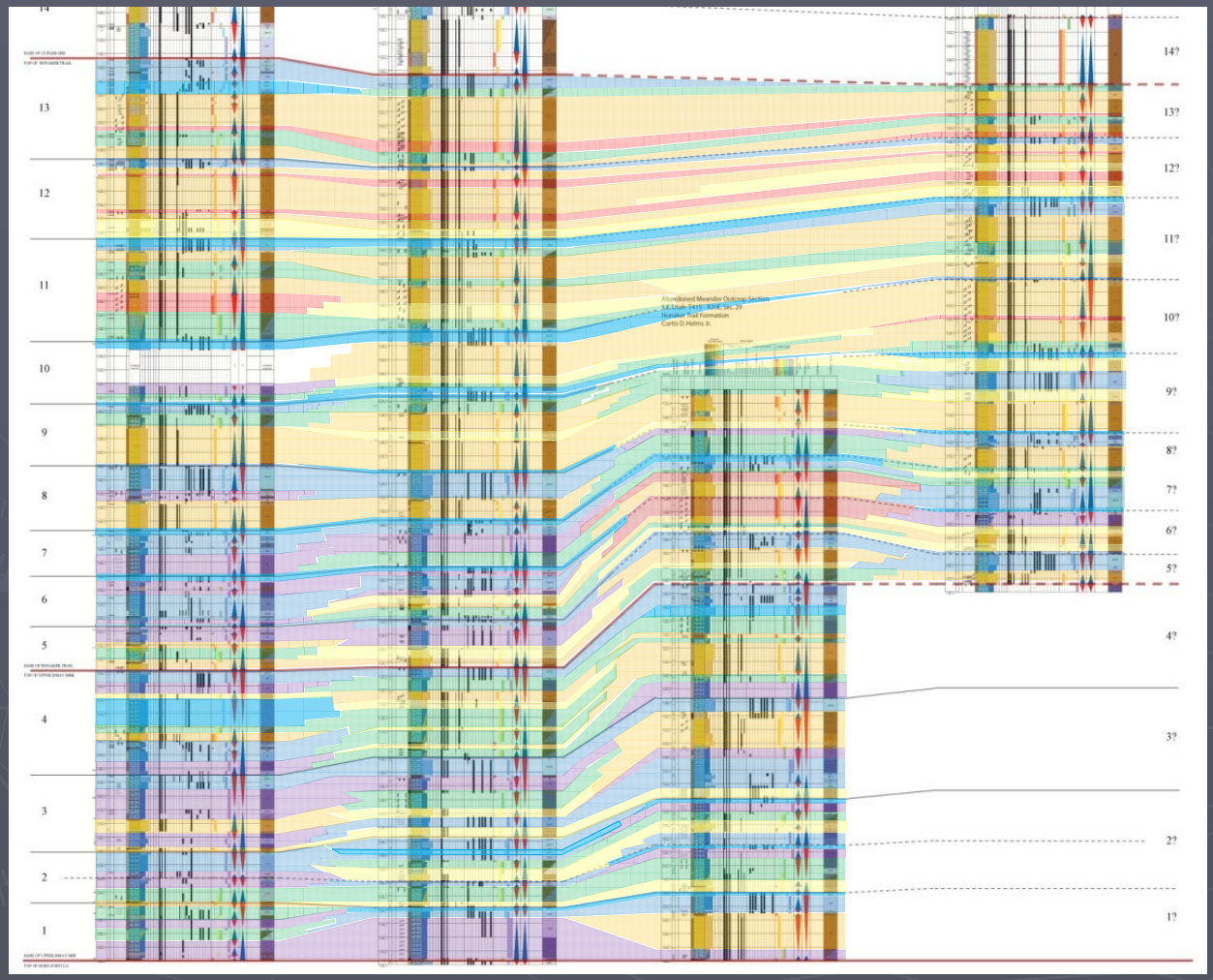
Correlation of Measured Sections
Upper Honaker Trail Fm. (cycle sets 10-13)



COLOR OF SEDIMENTARY FACIES									
FLOOD-PLAIN	FLUVIAL	EOLIAN	BEACH	LAGOON	TIDAL INLET	SHOAL	SUBTIDAL	SHALLOW SHELF	DEEP-OPEN MARINE
			PWS		PWS				
MHS	LCS		LMCS			ASB	DSP		DCM
CONTINENTAL			TRANSITIONAL				MARINE		

The Upper Honaker Trail Formation is only present in three of the four measured outcrop sections. It is missing in the Abandoned Meander measured section. The Upper Honaker Trail Formation is represented by cycle sets ten through thirteen. In all three measured outcrop sections cycle sets ten through thirteen appear to be dominated by very fine grained sandstones that have been sub-aerially exposed. The continental sandstones of LCS and MHS sedimentary facies seem to dominate the Upper Honaker Trail Formation. It is very clear when viewing the correlation of the cross-section from west to east that each section appears to become more siliciclastic as the Upper Honaker Trail Formation is encountered.

CONCLUSION



All of this data was combined into a west to east oblique cross-section which demonstrates that: 1) the Upper Ismay member is dominated by marine sediments and it becomes shallower from west to east; 2) the Lower Honaker Trail Formation is deeper marine on the west and shallow to transitional environments eastward; 3) All the Upper Honaker Trail Formation appears to be primarily non-marine sands. The Pennsylvanian strata on the Eastern Shelf of the Permian Basin are very similar to those located on the shelf of the Paradox Basin. The results from this study can be directly applied to the deposits on the Eastern Shelf and in North Central Texas. A final conclusion concerns the distribution of reservoir-quality facies. Sandstones and carbonates of the LCS, PWS, and ASB sedimentary facies appear to have the best porosity as expressed in thin section from the Honaker Trail measured outcrop section. They would probably make the best exploration targets.