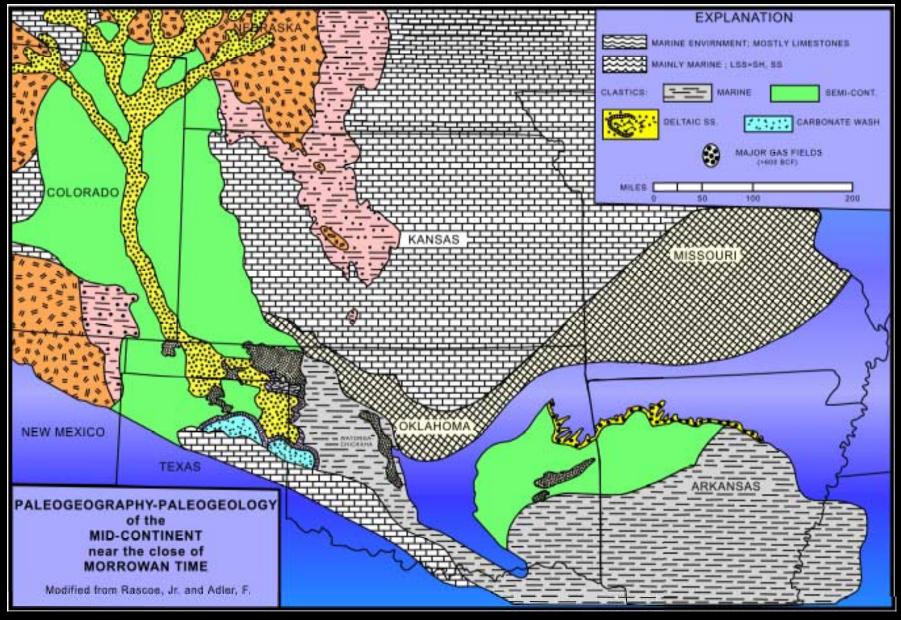
Sequence Stratigraphic Control on Reservoir Quality in Morrow Sandstone Reservoirs, Northwestern Shelf, Anadarko Basin

Zuhair Al-Shaieb Jim Puckette

Research Assistants
Melanie McPhail, Ken Rechlin,
Julie Turrentine, Erin Van Evera
Chris Wiggers

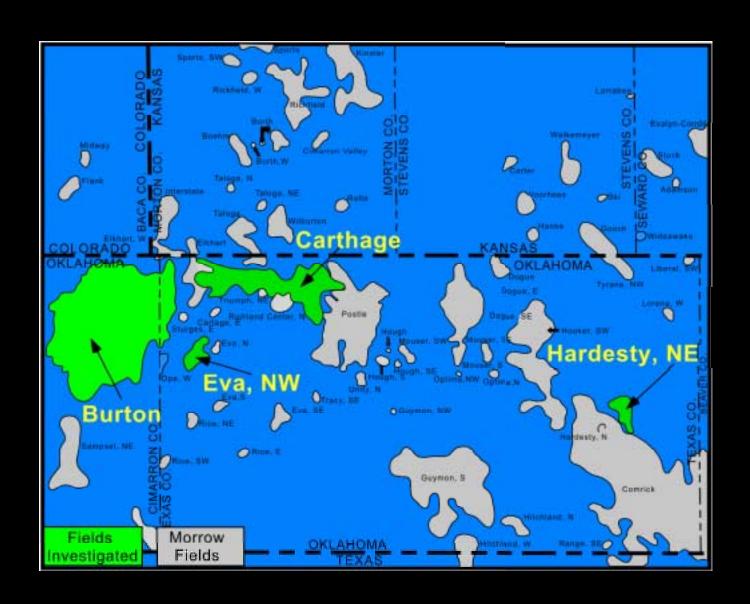
### Objectives

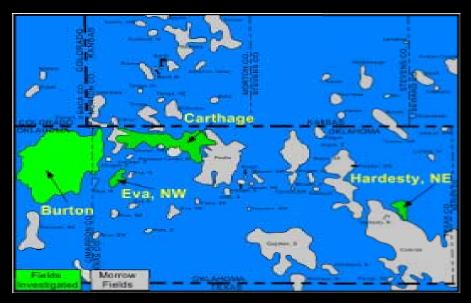
- To define depositional facies, sequence stratigraphic framework and reservoir characterization of the Upper Morrow reservoir.
- Application of the above to exploration and secondary recovery projects.

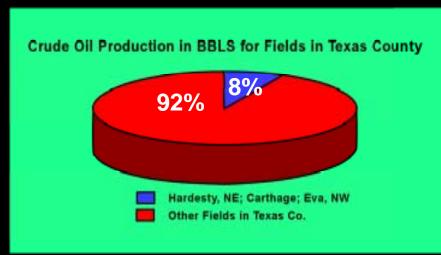


Paleogeology of the Anadarko basin during late Morrowan time. (After Rascoe, and Adler, 1983).

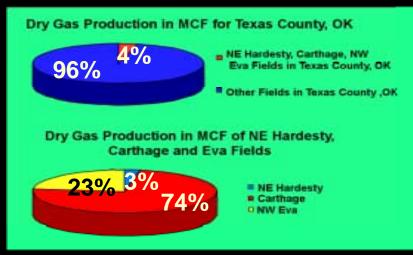
### FIELDS OF STUDY





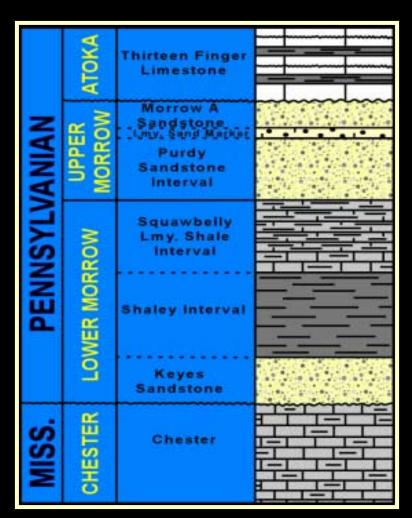


Reservoirs are primarily channel-fill fluvial sandstones within the complex valley fill deposits. Valleys were cut into the underlying shelf muds during sea level lowstands, and filled during transgressive episodes.

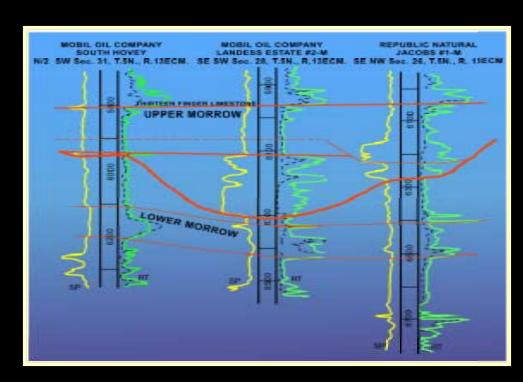


Upper Morrow sandstone reservoirs have produced in excess of 280 million barrels of oil and 3.3 TCF gas from the northwestern shelf of the Anadarko basin and Hugoton embayment in Oklahoma, Texas, and Kansas.

# Stratigraphic and Lithologic column of Morrow in the Oklahoma panhandle.



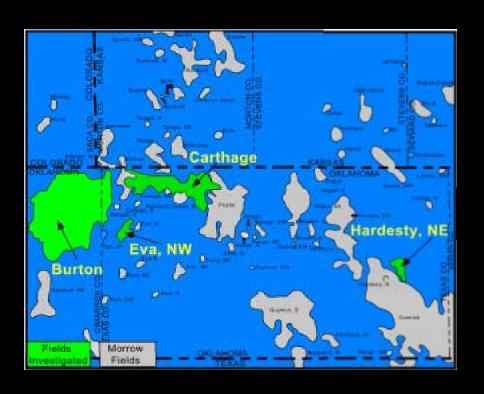
# Model cross-section of typical incised-valley.



Modified from Harrison, 1990, and Luchtel, 1999.

# Case Study 1

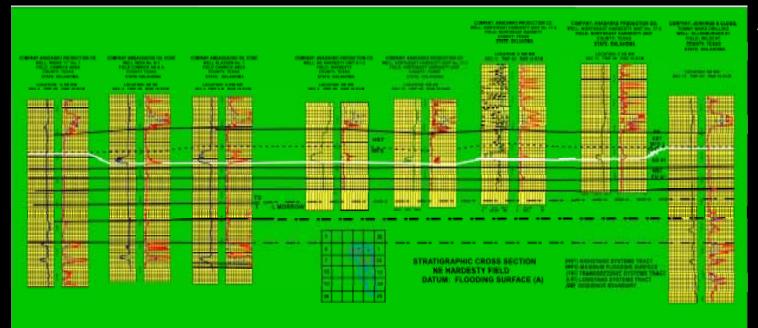
# NE Hardesty Field Texas County, Oklahoma



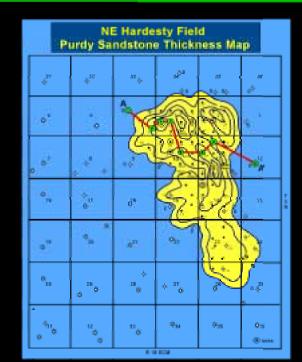


Total Production: 10,162,060 BBLS 1,602,360 MCF



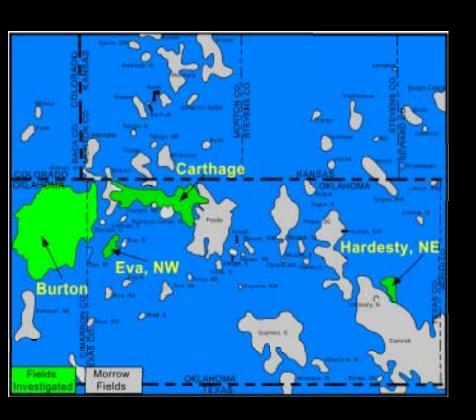


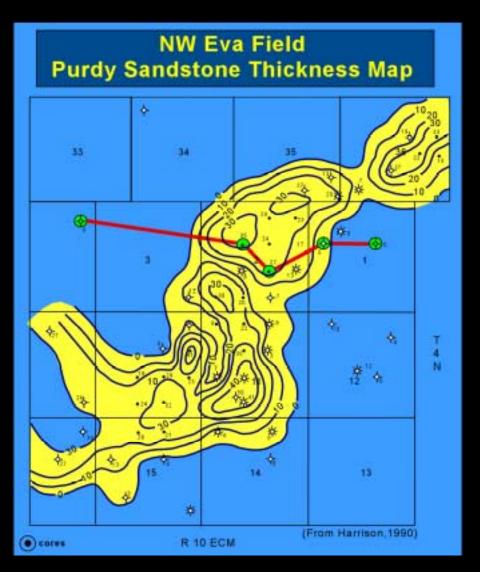
Incised valley in the NE Hardesty Field.



# Case Study II

# NE Eva Field Texas County, Oklahoma



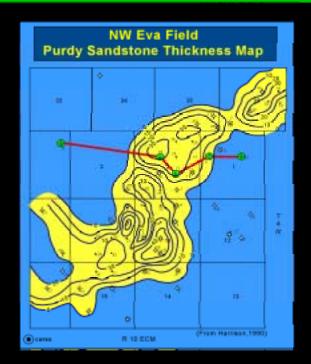


**Total Production: 2,118,433 BBLS 14,063,346 MCF** 



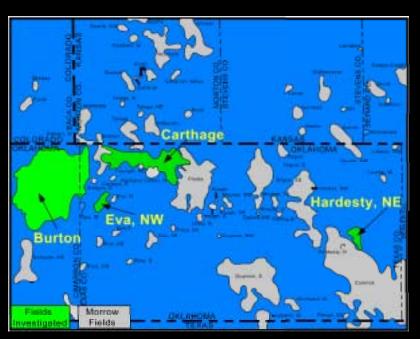
Thickness map of upper Morrow

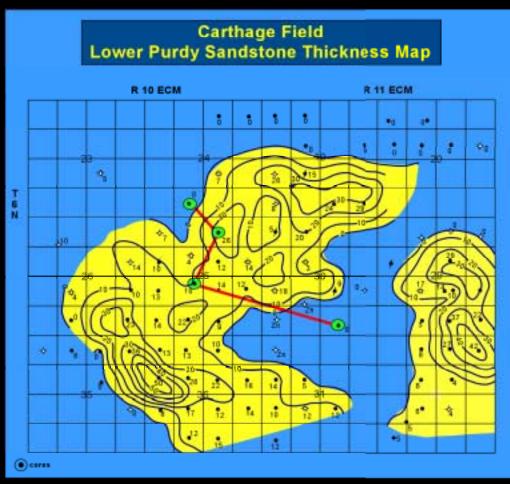
Purdy Sandstone



# Case Study III

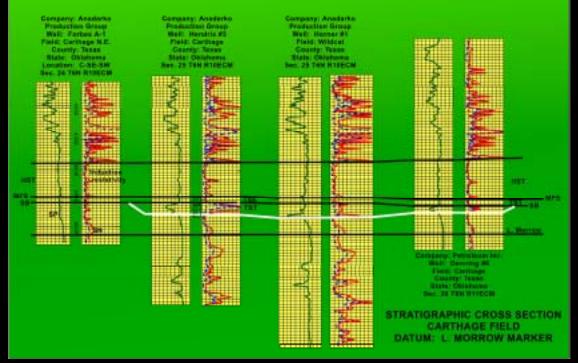
# Carthage Field Texas County, Oklahoma





**Total Production: 1,974,076 BBLS 44,397,505 MCF** 





Thickness map of lower Purdy Sandstone

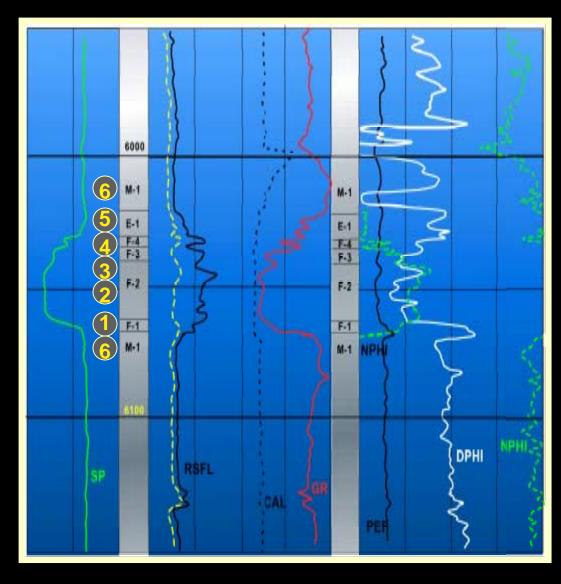


# UPPER MORROWAN FACIES

Lithofacies	Sedimentary Structures and Depositional Facies	Reservoir Characteristics
Fluvial (F)		
F-1	Matrix-supported paraconglomerate high current-energy stream	Generally poor-quality. Low porosity and permeability are due to abundant cement and psuedomatrix.
F-2	Coarse-grained sandstone to conglomerate. This package is characterized by trough and tabular cross-bedding and containing stacked fining-upward sequences.  High energy braided stream of middle to lower channel sequence.	Generally fair to good-quality. Primary and enlarged intergranular perosities are common.
F-3	Ripple to low angle cross- bedded, fine to coarse-grained sandstone with occasional clay clast and carbonaceous material. Meandering-stream of upper channel sequence.	Generally fair to good-quality. Porosity reduction as a result of cementation and/or pore filling authigenic haolinits.
F-4	Fine-grained sandstone occasionally interbedded/interiaminated with silty, shaly and coaly intervals.  Channel abandonwent.	Generally poor to fair- quality. Significant pore space is filled with matrix.
Estuarine (E)		
E-1	Interbedded fine to medium grained sandstone and shale containing abusdant trace lossils. Mid-Estuarine environment Low energy:	Generally poor-quality. Low porosity and permeability are due to abundant coment and psuedomatrix.
E-2	Fine to medium-grained, burrowed sandstone and dark shale that is interbedded with thin coarse-grained sandstones.  Upper-Estuarine environment:	Generally fair-quality. Primery and enlarged intergramular porosities are common.
	Tidally influenced with variable energy and possible fluvial input.	
Marine (M)		
M-1	Thinly laminated black shales and claystone, Calcareous interval contains abundant fossils.  Law-energy environment:  Anaxic, offshare shelf setting.	
W-2	Fine to coarse-grained, calcite-comented and fossiliferous sandstone.  High-energy environment: shallow marice.	Poor-quality reservoir rock due to extensive calcite cement.

Lithofaction	Sedimentary Structures and Depositional Facies	Reservoir Characteristics
Fluvial (F)		
F-1	Matrix-supported paraconglomerate High current-energy stream	Generally poor-quality. Low porosity and permoathilty are due to abundant cement and peuedematrix.
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F-3	Ripple to low angle cross- hedded, fine to coarse-grained exadetone with occasional clay clast and carbonaceous material. Meandering stream of system channel sequence.	Generally fair to good-quality. Percenty reduction as a result of immentation andler sere filling authigenic keelinite.
P4	Fine-grained sandstone occasionally interbedgedlimetamented with sity, shally and coally intervals.  Channel absorbownent.	Conurally poor to fair- quality. Significant pers space is filled with matrix.
Estuarine (E)		
E-1	Interbedded fine to medium grained sandatone and shale containing abundant trace lossils.  Alto-Extractive environment:  Low energy:	Generally poor-quality. Low porosit and permeability are due to abundant cement and pseedomatrix.
E-2	Fine to medium-grained, burrowed sandstone and dark shale that is interbedded with thin coarse-grained sandstones.  Upper-Estuarine environment: Tidnily influenced with variable	Generally fair-quality. Primary and enlarged intergranular poresities are common.
Marine (M)	energy and possible fluvial input.	
maring (M)	Thinly laminated black shales and	
M-1	claystone. Calcareous interval contains abundant fossils. Low-energy environment: Anaxis, affahore shall setting.	
M-2	Fine to coarse-grained, calcite-camented and foothforwas candistens- high-energy environment shadow matrix.	Post-quality seasons rock due to extensive calcite coment.

### Lithofacies

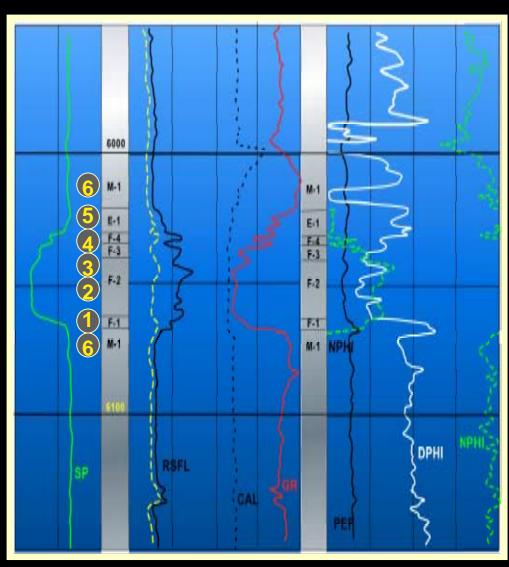


### **Fluvial Facies**

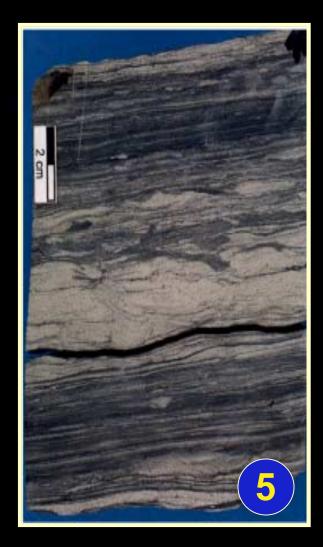




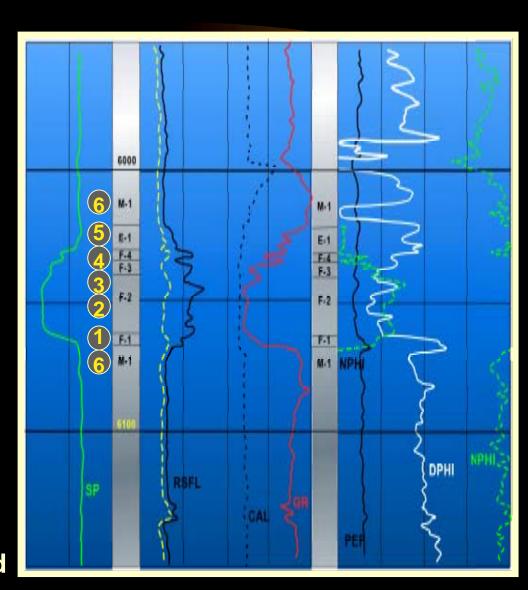




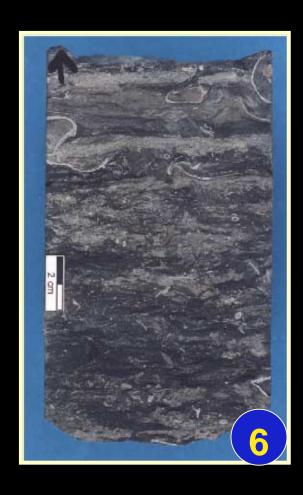
#### **Estuarine Facies**



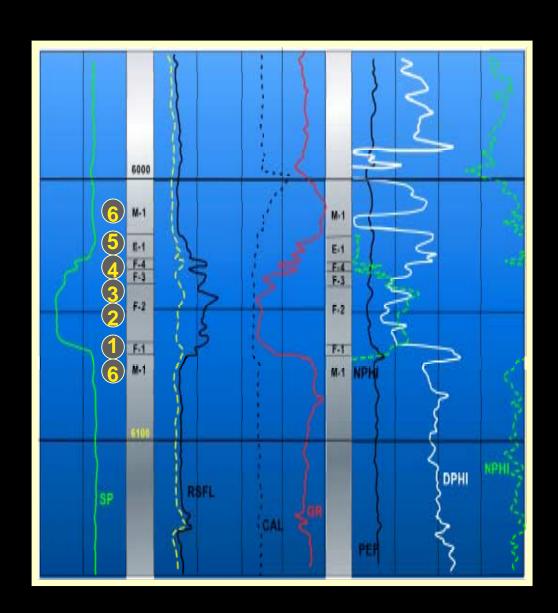
E-1 Interbedded sandstone and shale with trace fossils.



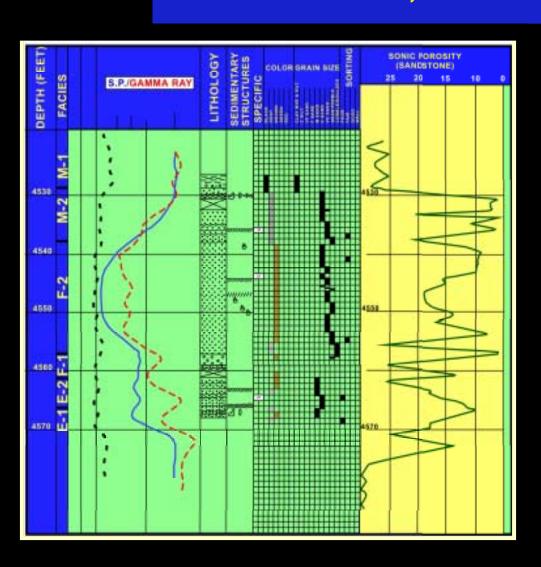
#### **Marine Facies**



M-1 Dark gray shale with abundant marine fossils.



# PETROLEUM INC. HENDRIX #3 CARTHAGE FIELD, TEXAS CO., OKLAHOMA.



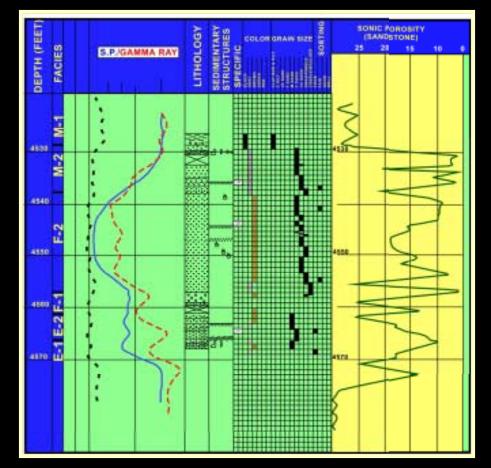




### Hendrix #3











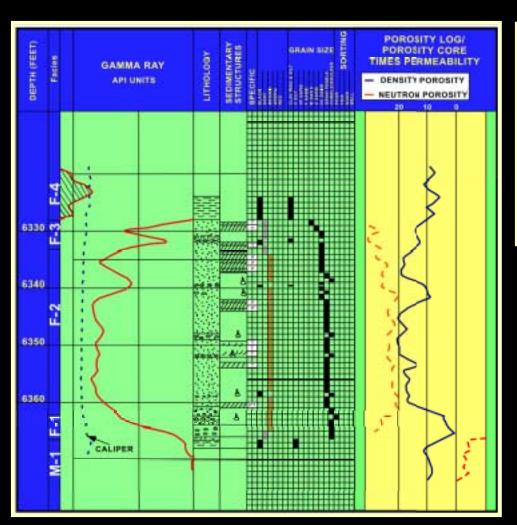


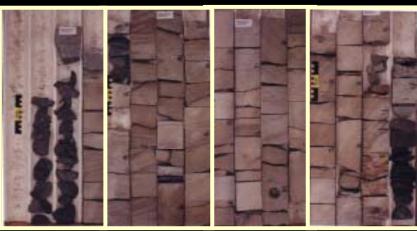


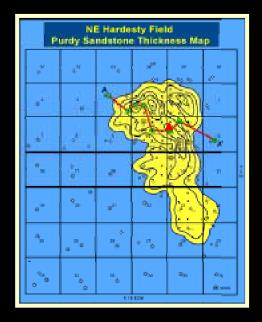


Hendrix #3

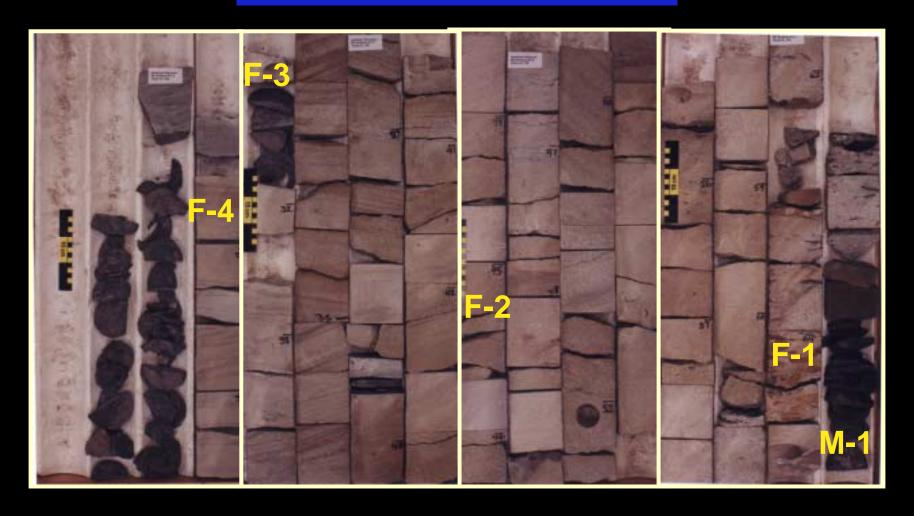
#### Anadarko Petroleum NE Hardesty Unit 11-2, NE Hardesty Field, Texas Co., Oklahoma





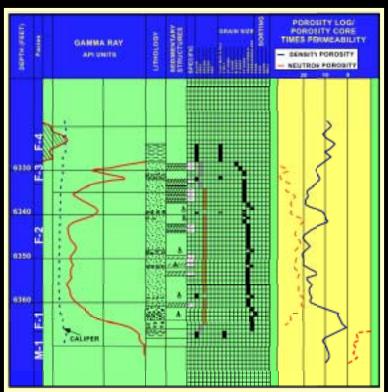


### **NE Hardesty #11-2**



#### NE Hardesty #11-2









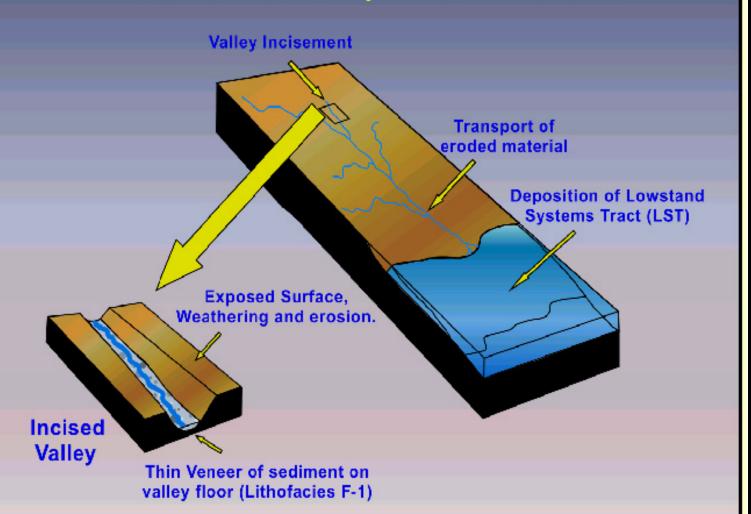


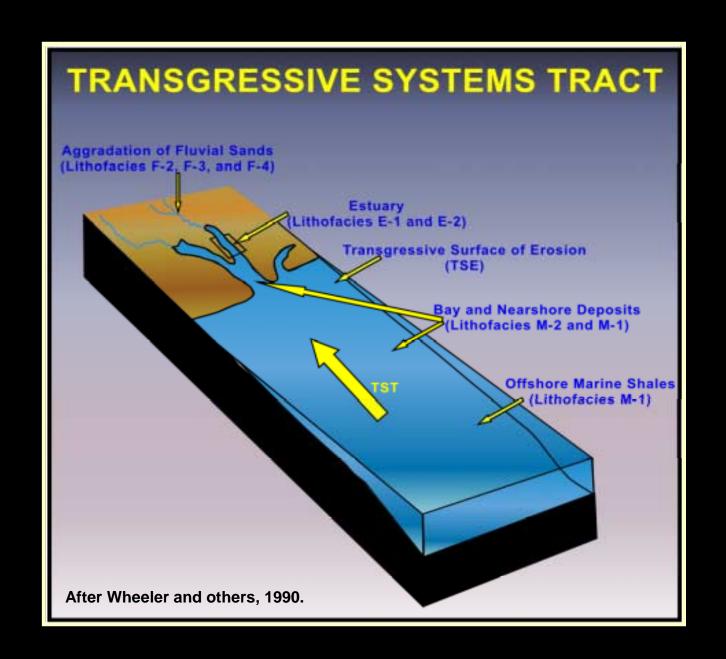




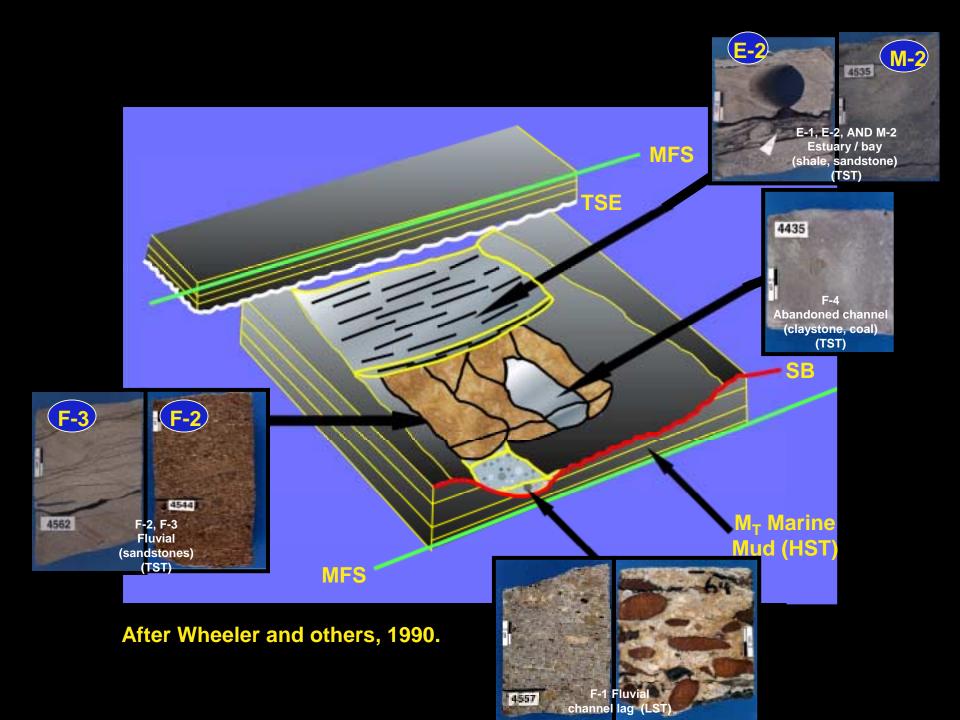
# Evolution of incised valley-fill deposits

# LOWSTAND SYSTEMS TRACT Formation of sequence boundaries





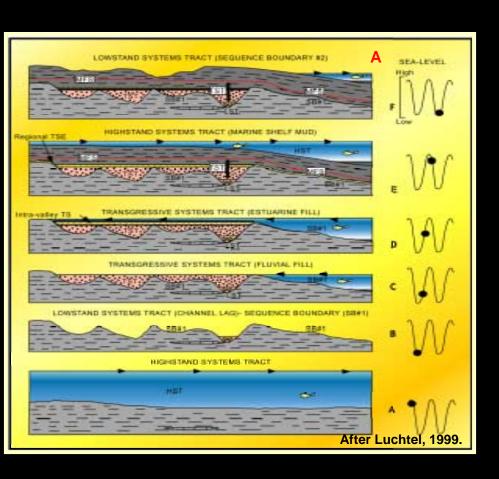
# Valley-fill depositional sequence

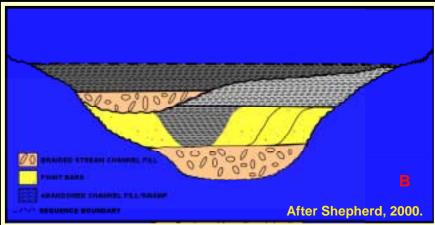


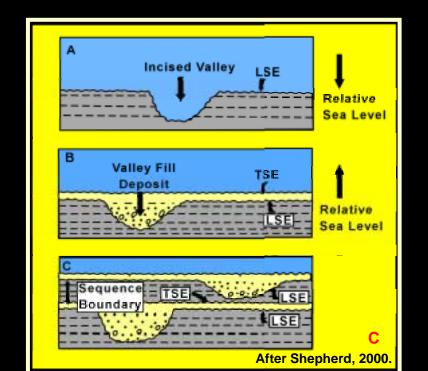
# Sequence Stratigraphic Systems Tracts:

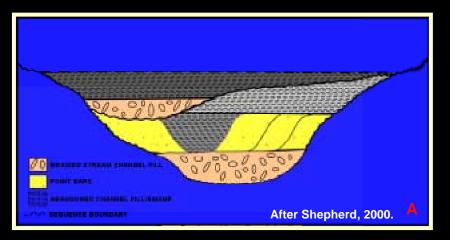
**Succession of Upper Morrowan** 

# **Evolution of Upper Morrowan Successions In Study Area**

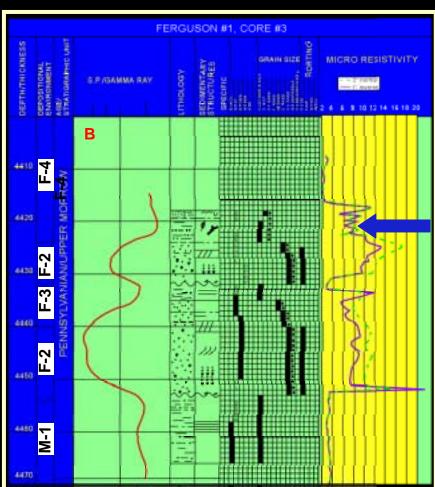










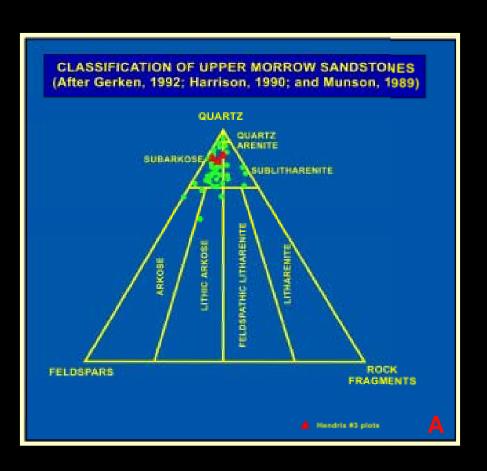


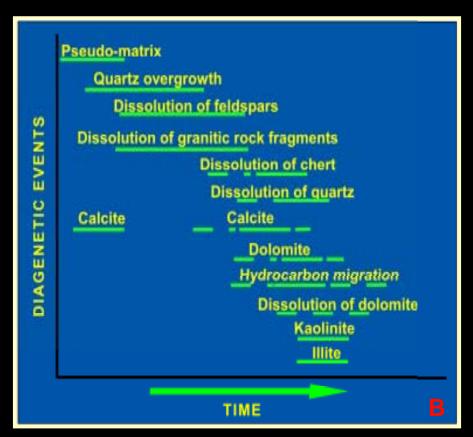
paleosol

Photomicrograph showing caliche in paleosol. Ferguson #1 From Harrison, 1990.

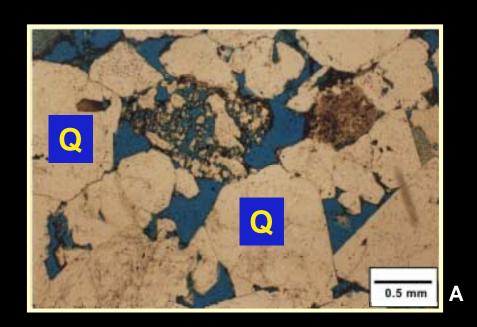
# Reservoir Characterization

#### **Petrology and Diagenesis**

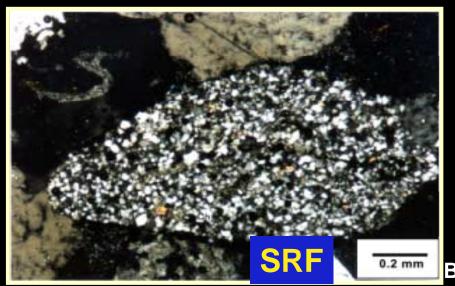


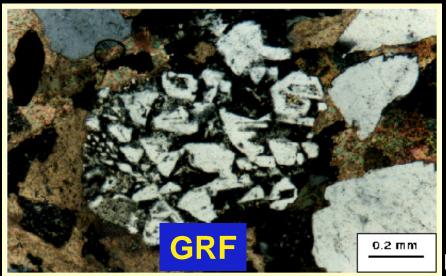


## **Detrital Constituents**









#### **Diagenetic Constituents**



Authigenic Kaolinite (K) derived from dissolution of feldspars that partitions pore space.

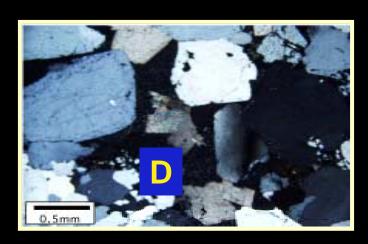


Kaolinite (K)"books" filling center of pores while chlorite coats quartz grains.

 $\mathbf{B}$ 



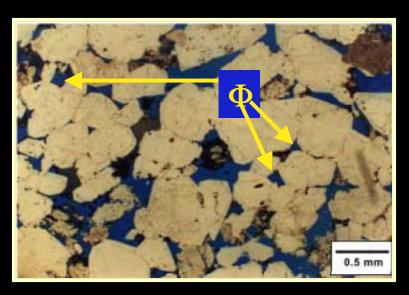
Bioclast filled with intraparticle glauconite (G).

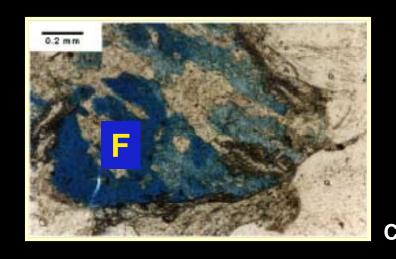


Thermal dolomite (D) with sparry calcite cement.

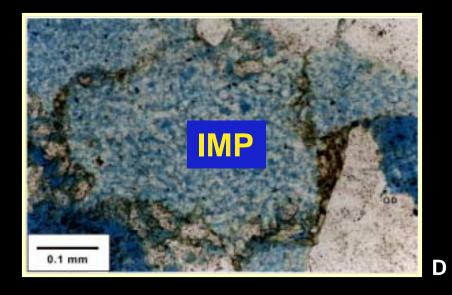
D

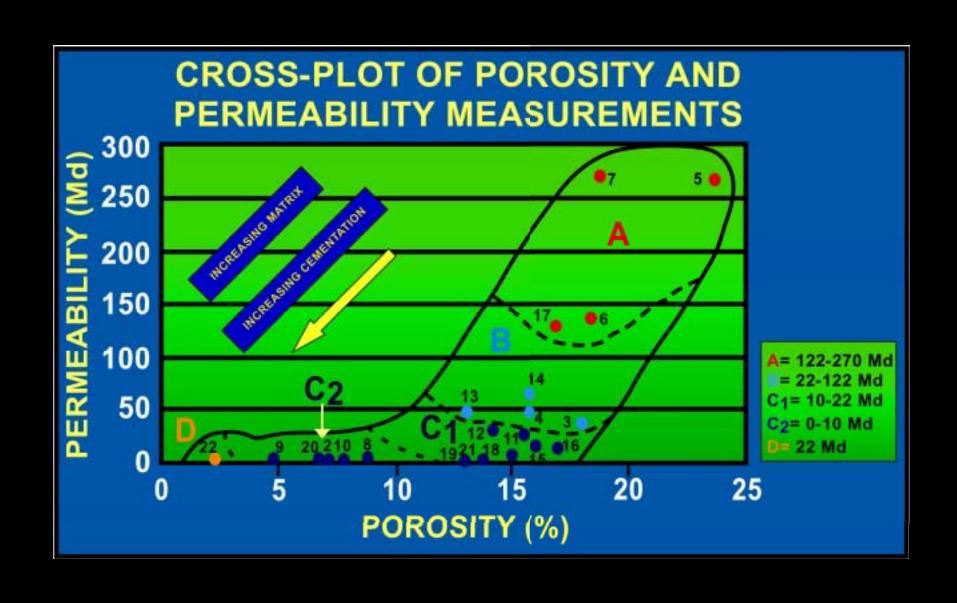
# **Porosity**







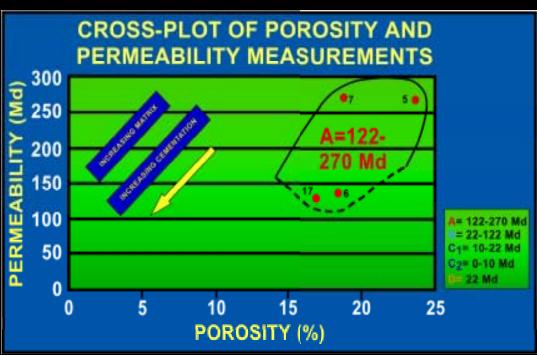




#### Zone A

**Hendrix #3** 





#### Northeast Hardesty #11-2



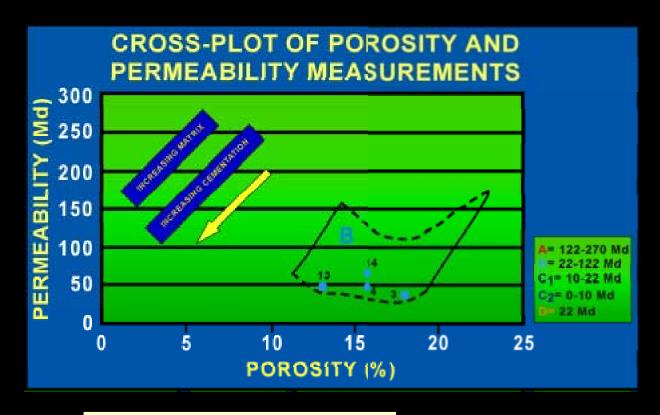


Porosity: 18.76% Permeability: 269.7 md



Porosity: 16.84% Permeability: 127.109 md

#### **Zone B**



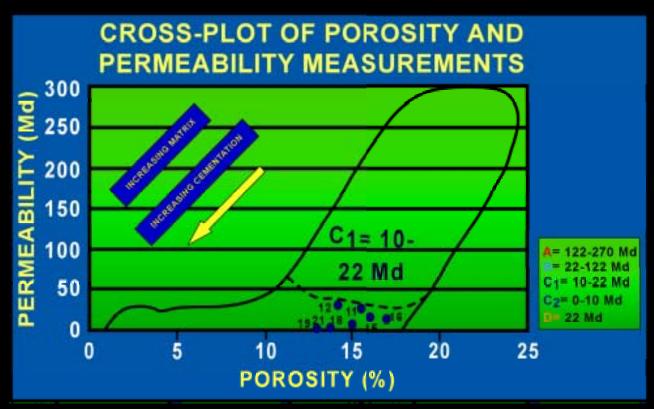
### Northeast Hardesty #11-2





Porosity: 17.93% Permeability: 33.63 md

#### Zone C<sub>1</sub>





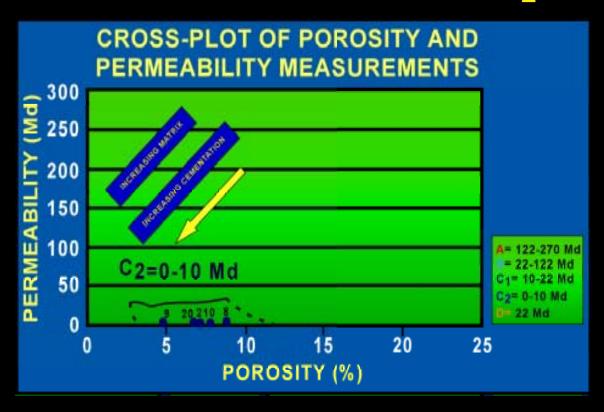
Northeast Hardesty #11-2



Porosity: 12.87% Permeability: 0.016 md

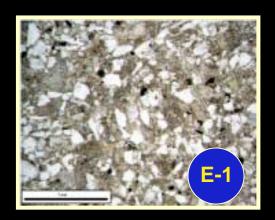


### Zone C<sub>2</sub>



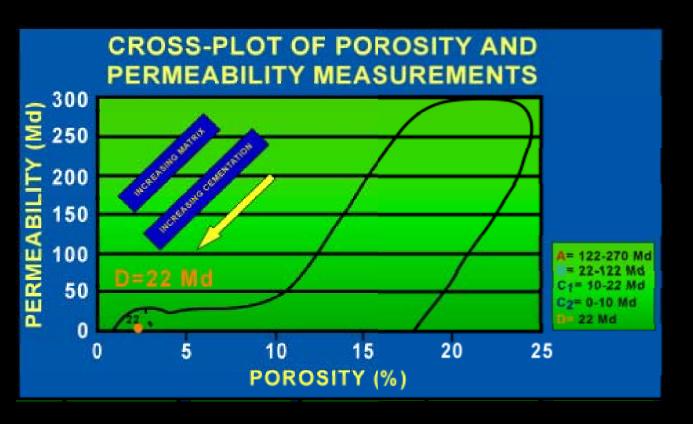
#### **Hendrix #3**

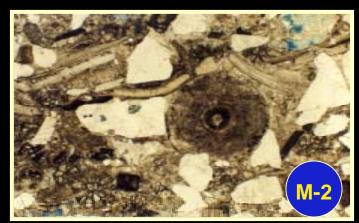




**Porosity: 6.62%** 

#### **Zone D**





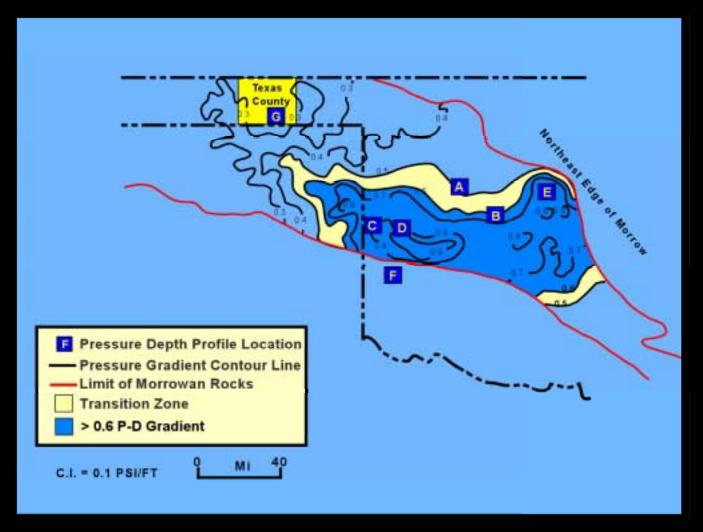
#### Northeast Hardesty #11-2



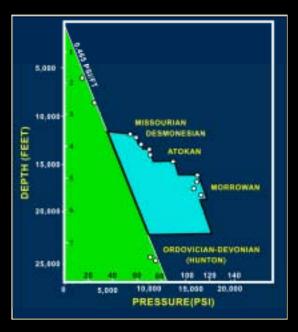
**Hendrix #3** 



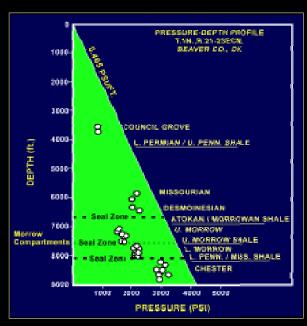
## Pressure Gradient Map of the Morrow Reservoirs in Anadarko Basin and Oklahoma Panhandle



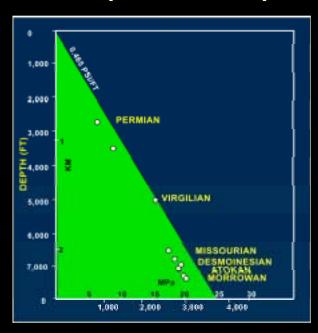
Normal pressure gradient is 0.465 psi/ft. Pressure gradients in underpressured Texas County Morrow reservoirs are approximately 0.3 psi/ft.



(Locations of points on pressure-gradient map)

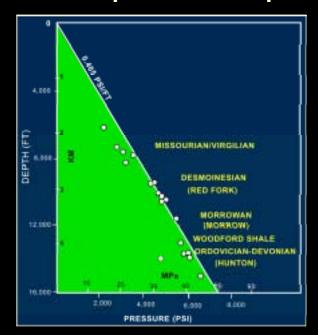


**Pressure Depth Profile at point C** 



**Pressure Depth Profile at point F** 

**Pressure Depth Profile at point G** 



Pressure Depth Profile at point A

#### CONCLUSIONS

- The upper Morrow reservoirs in Texas County, Oklahoma exhibit a variety of facies typical of incised valley systems.
- Lowstand systems tract deposits are limited to clay clast conglomerates (F-1). Transgressive systems tract deposits are represented by fluvial (F-2, F-3, and F-4) lithofacies as well as the estuarine (E-1 and E-2) lithofacies.
- Three major lithofacies were recognized: fluvial, estuarine, and marine. Using textural, sedimentological, structural, and depositional parameters, each major lithofacies was subdivided. Fluvial facies consist of F-1, F-2, F-3 and F-4. Estuarine facies contain E-1 and E-2; marine facies M-1 and M-2.

#### **CONCLUSIONS**

- Petrographic, petrophysical, and core measured porosity/permeability data indicate that F2 and F3 fluvial facies are better quality reservoirs.
- Authigenic kaolinite and clay matrix drastically reduce permeability in various lithofacies. Carbonate cement, and to a lesser extent dolomite, reduce both porosity and permeability.
- In summary, the F2 and F3 lithofacies have better potential of being high-volume oil- and gas-producing reservoirs.