Oil Classification and Exploration Opportunity in the Hugoton Embayment, Western Kansas, and Las Animas Arch, Eastern Colorado*

By

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with acknowledgements to Ray Sorenson[1], Harry Dembicki[1], Warren Winters[1], Ahmed Chaouche[1], Kevin Stacy[1], and Dan Jarvie[2]

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Abstract

Hydrocarbons in the Hugoton Embayment have been considered the result of long distance migration from the deep Anadarko basin. Based on biomarker interpretation from 52 oils and incorporation of data from over 500 source rock samples, this study presents an oil family classification which improves our understanding of hydrocarbon migration pathways into the Hugoton Embayment. We investigated gas chromatography data from over 600 oil samples from published and proprietary databases to compare to our conclusions, and, although each individual study provided valuable clues about oil classification, we found that the gas chromatography/mass spectrometry data provided a clearer understanding of the oil types in the Hugoton Embayment.

Four oil families identified are from Pennsylvanian and Mississippian reservoirs. Direct oil-source rock correlation identifies the Devonian Woodford shale as one of the primary hydrocarbon source rocks. Woodford-sourced oil (Family A) exists in reservoirs throughout the Upper Mississippian and Pennsylvanian section. Family B is primarily found in Morrowan-aged reservoirs and is suspected to be derived from the Pennsylvanian Morrow Formation. Family C is confined to reservoirs in the Middle and Upper Pennsylvanian section. Family D is directly correlated to Ordovician Viola Shale, but is relatively rare in the study area.

Our studies suggest that hydrocarbon migration into the Hugoton Embayment was from multiple sources and was focused along various, but somewhat predictable, lateral and vertical paths. Results from our study improve our understanding about the present-day distribution of oil and gas fields and set up new exploration ideas in this mature hydrocarbon province.

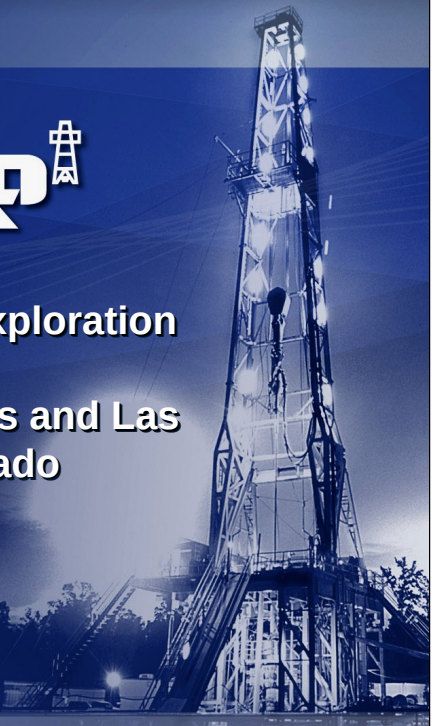
Anadarko
Petroleum Corporation

The Oil Classification and Exploration Opportunity in the Hugoton Embayment, Western Kansas and Las Animas Arch, Eastern Colorado

Presented by Troy Beserra

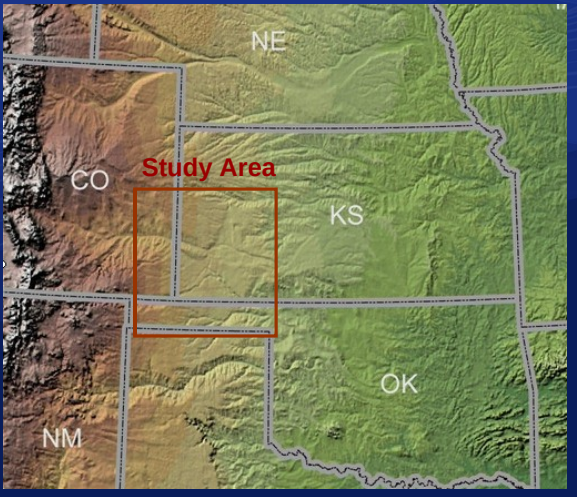
Acknowledgements: R. Sorenson, H. Dembicki, W. Winters, A. Chaouche, K. Stacy, D. Jarvie

Kansas Geological Society - Tech Talk
Friday, February 3, 2006



Outline

- Introduction
- Oil Classification and Methodology
- Hydrocarbon Migration Pathways
- Exploration Opportunities



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Outline: This map illustrates the location of the study area – Western Kansas, Eastern Colorado and the Panhandle of Oklahoma. It also outlines the topics of the presentation.

Purpose

QUESTIONS

- Traps without hydrocarbons?
- Is the eastern Colorado petroleum system related to the Hugoton system?
- Are there overlooked exploration ideas?

APPROACH

- Petroleum System Characterization – H-C generation, migration, and trap timing, oil sources and families, depositional models

DATA

- Gas Chromatography data (1980-2001) - Inconclusive
- Gas Chromatography/Mass Spectrometry (2002-2003)

RESULT

- Better understanding of hydrocarbon distribution in Hugoton Embayment and Las Animas Arch
- Large scale exploration ideas

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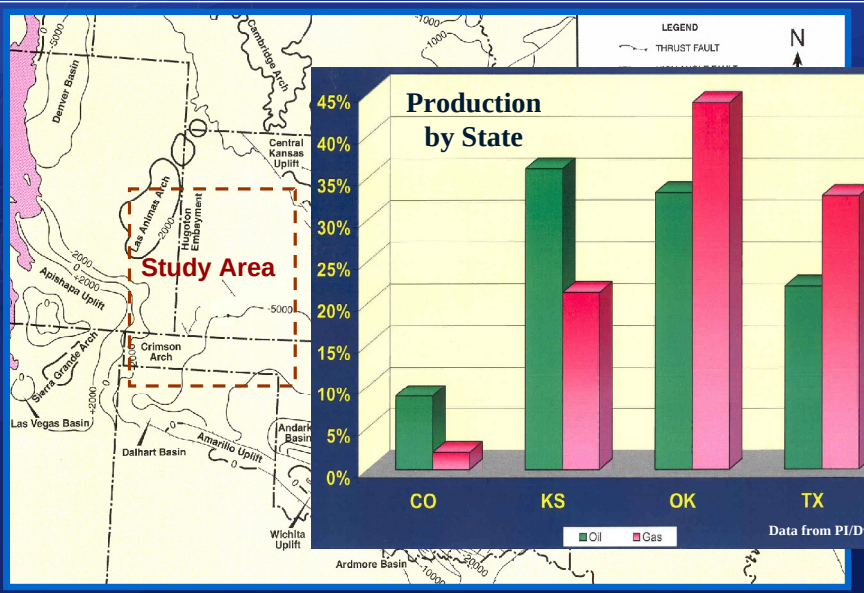
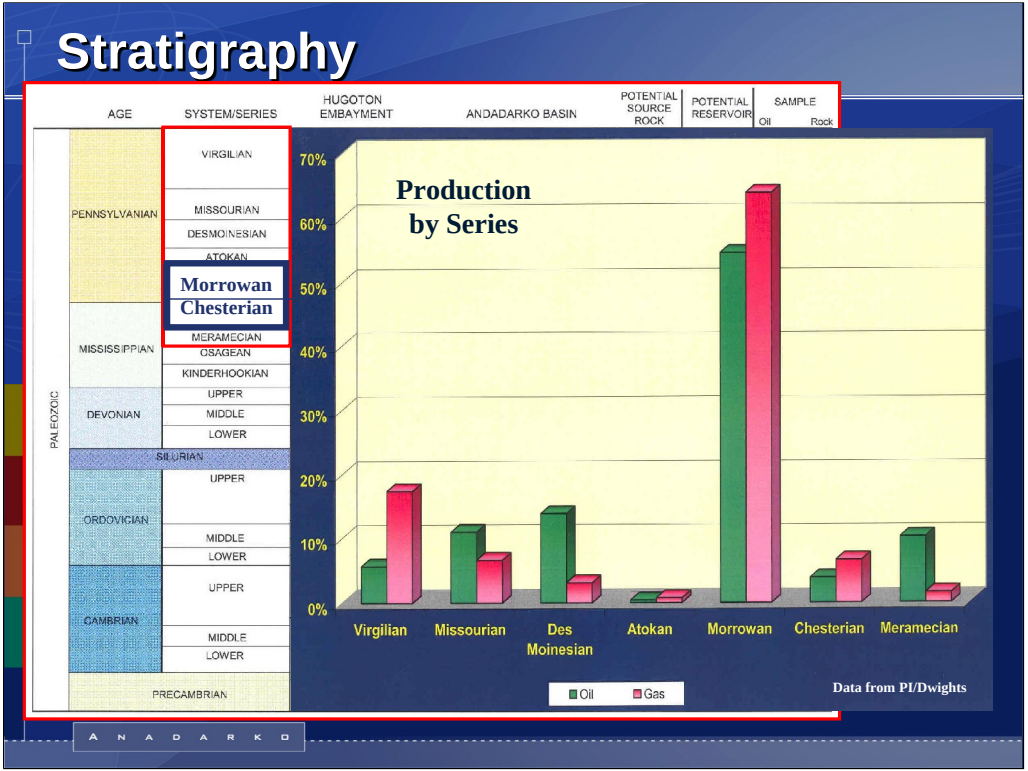
Purpose of the Study

Regional Setting



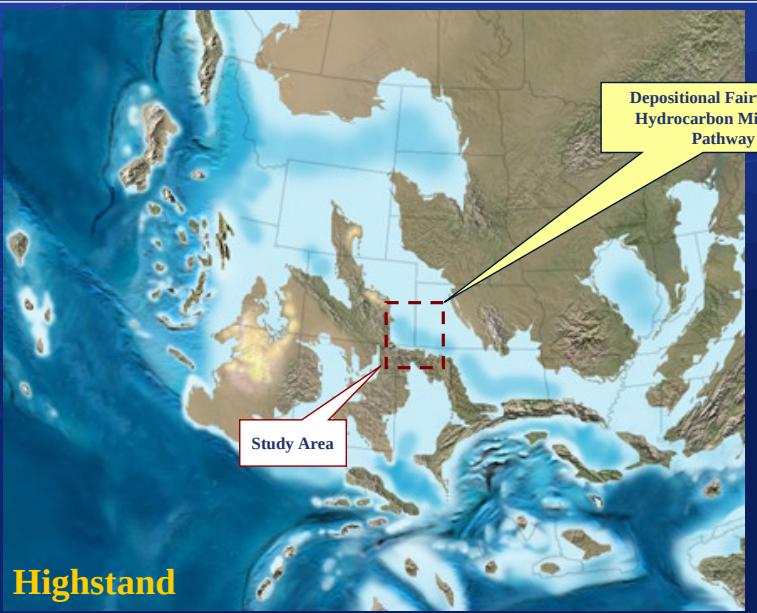
(Basement Structure map modified from Rascoe and Adler, 1983)

Regional Setting – Oil and gas production by state (Mississippian and Pennsylvanian only). This bar chart demonstrates that oil production is dominant in the north part of the study area in Colorado and Kansas and that gas production outpaces oil in the south part of the area in Oklahoma and Texas. Shallow Permian gas production from Hugoton and related fields is derived from a separate petroleum system (Sorenson, 2005) and is excluded from this chart.



Stratigraphy and Production by Series – oil and gas production is dominated by the Morrowan series although significant quantities and opportunities exist in Mississippian and Upper Pennsylvanian reservoirs. Shallow Permian gas production from Hugoton and related fields is derived from a separate petroleum system (Sorenson, 2005) and is excluded from this chart.

Late Morrowan Paleogeography



Modified from http://jan.ucc.nau.edu/%7Ercb7/RCB.html – Dr. Ron Blakey, Northern Arizona University

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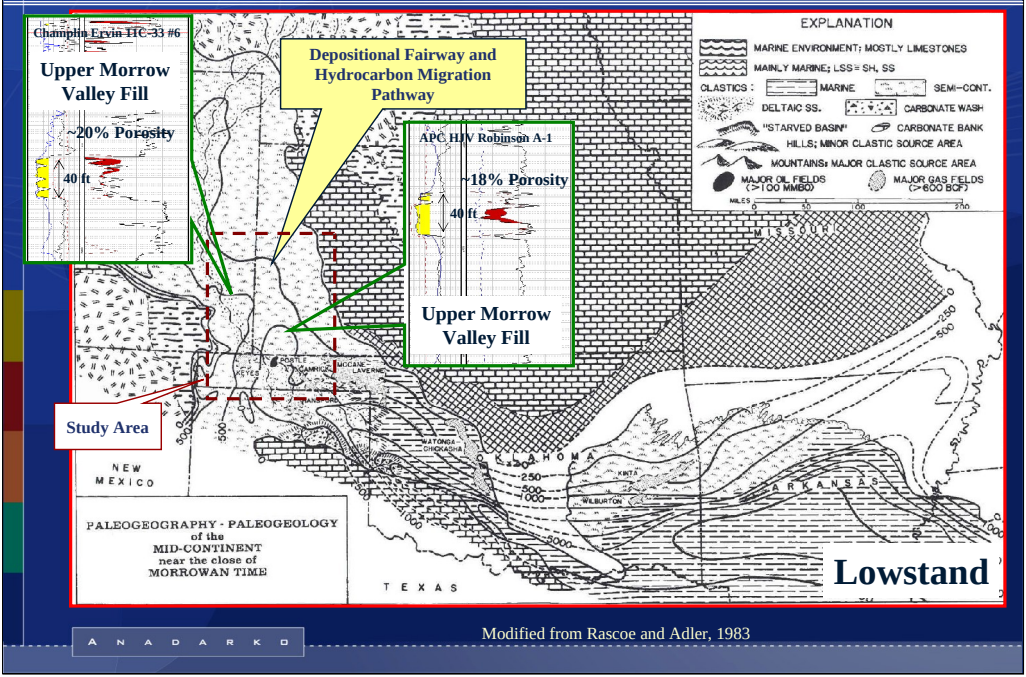
Late Morrowan Paleogeography - outlines the study area relative to the paleogeography of the Upper Morrow

Upper Morrow Paleogeography

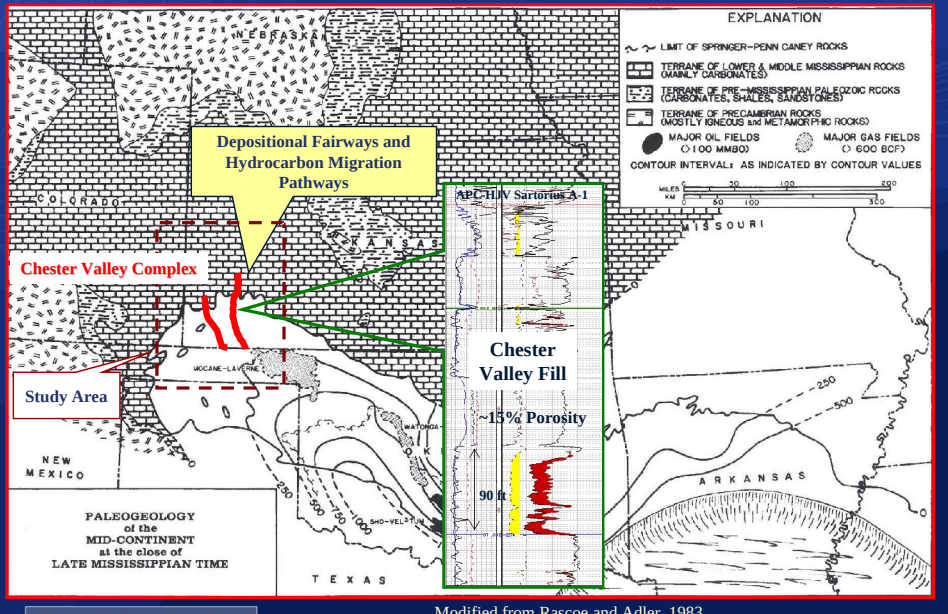


Modified from Rascoe and Adler, 1983

Upper Morrow Paleogeography – Map highlights depositional fairway during lowstand and typical log signature of the Upper Morrow. The depositional fairway is coincident with the hydrocarbon migration pathway.

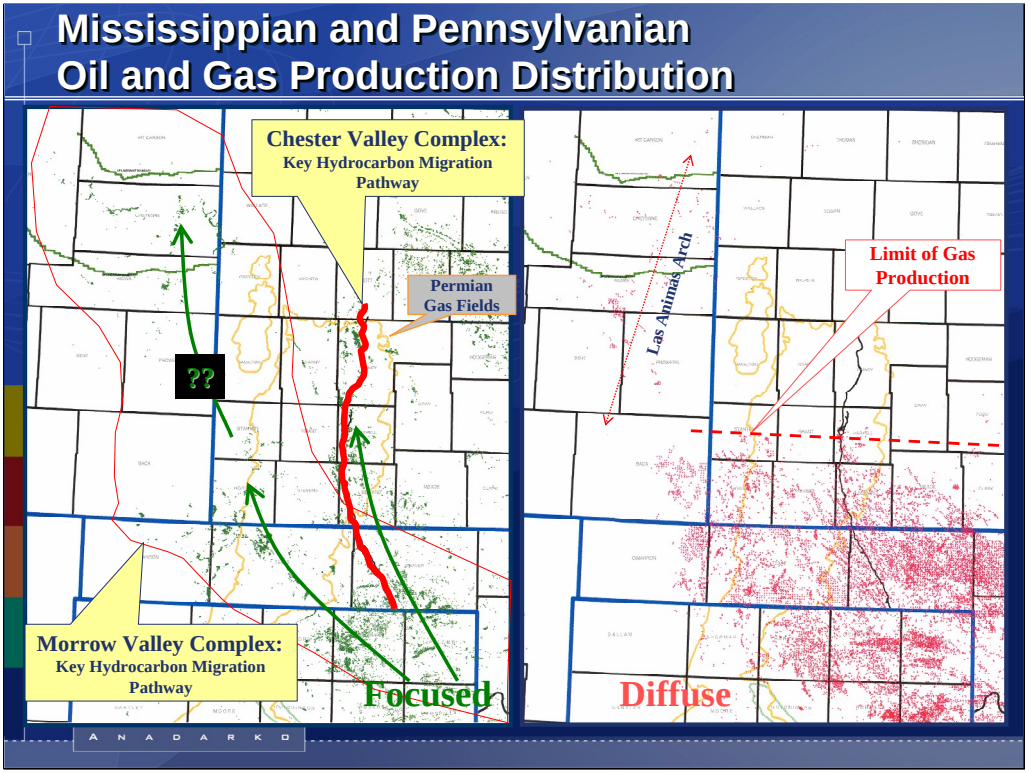
Latest Mississippian Paleogeography – highlights study area and general location of deep Chester valley complexes.

Latest Mississippian Paleogeography



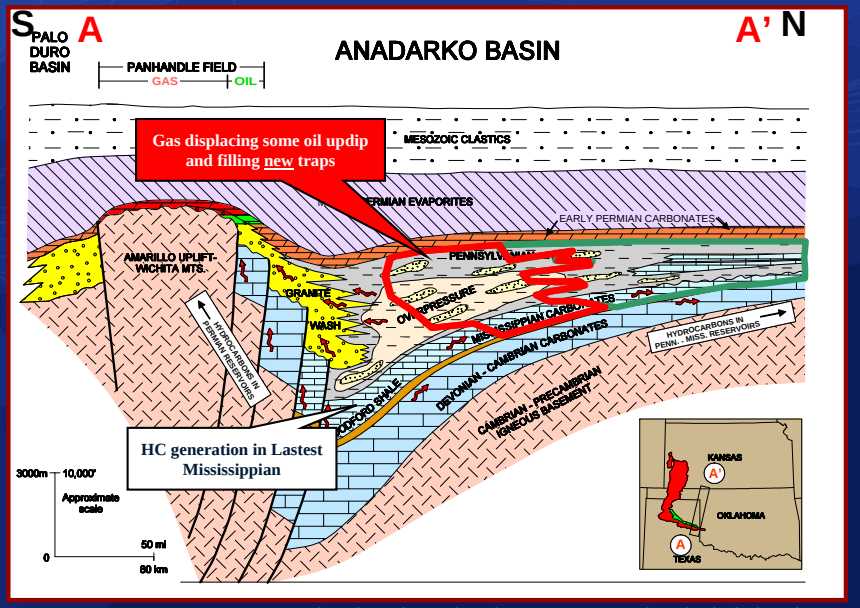
Modified from Rascoe and Adler, 1983

Latest Mississippian Paleogeography – Illustrates paleogeography during Chesterian deposition. Deep Chester valley complexes acted as a sediment transport mecahanism from north to south and as a hydrocarbon migration pathway for oil and gas from south to north.



Mississippian and Pennsylvanian Oil and Gas Production Distribution – Side-by-side maps represent the same area. The map on the left shows only oil production and the one on the right only gas production. The oil reservoir distribution is focused and extends to the far north end of the study area, whereas the gas production trend is more diffuse andthere is a northern limit to gas production about halfway up the second tier of counties in Kansas. Maps highlight the differences in reservoirdistribution and migration characteristics between gas and oil.

Anadarko Basin Cross Section



Cross Section after Johnson (1989), Dutton & Garnett (1989), Pippin (1970)

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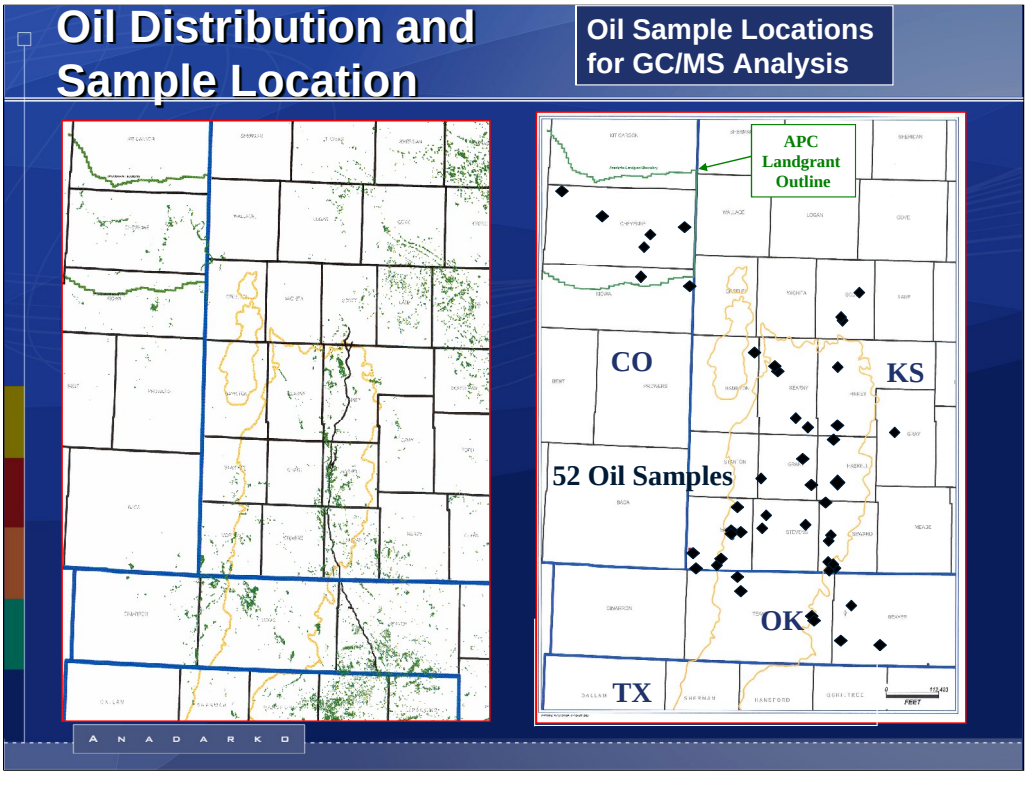
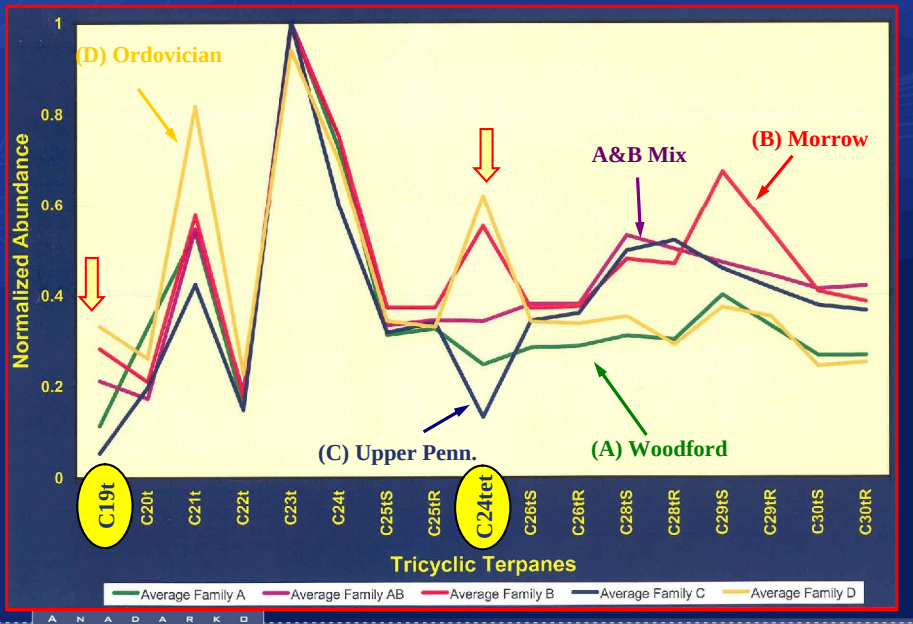
Anadarko Basin Cross Section – Generalized cross section from south to north – illustrated structural and stratigraphic setting of the basin. In addition, it gives a general illustration of gas vs. oil distribution and shows that gas migration occurred later and has not progressed as far to the north as the oil.



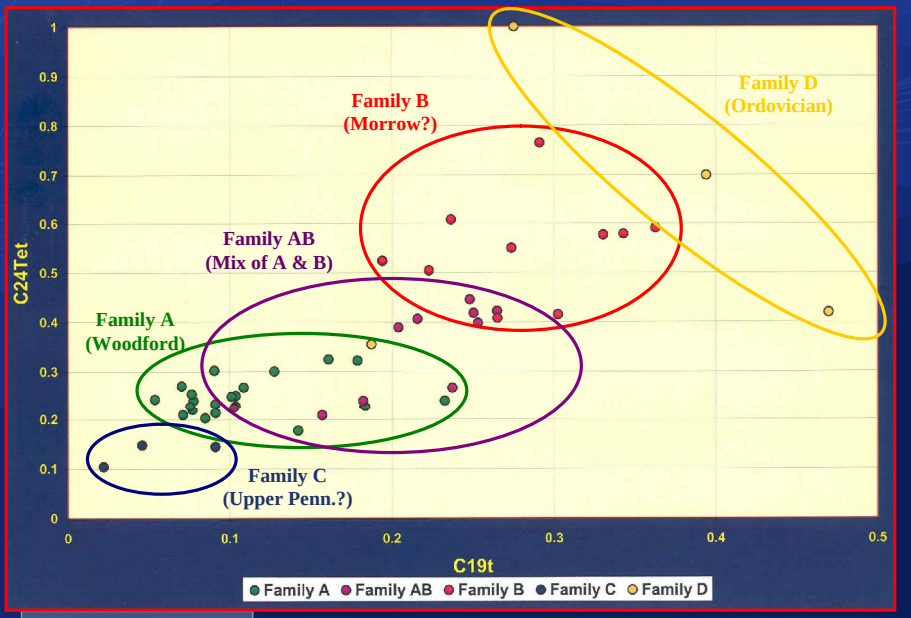
Oil Distribution and Sample Location – The map on the left shows only oil classified wells in the Hugoton Embayment and map on left shows location of oil samples taken (52 total).

Normalized Hopanes



Normalized Hopanes – Line chart illustrating the normalized hopane distribution of the different classes of oils found in the Hugoton Embayment. The x-axis lists the tricyclic terpanes and the y-axis shows their normalized abundance. For simplicity, these curves represent the average of each family identified. From this chart, 4 distinct families of oil as well as one that is consistently mixed can be identified.

C19 tricyclic vs. C24 tetracyclic



C19 tricyclic vs. tetracyclic – Scatter plot of C19 tricyclic vs. C24 tetracyclic helps again point out the 4 distinct families and 1 mixed family of oils.

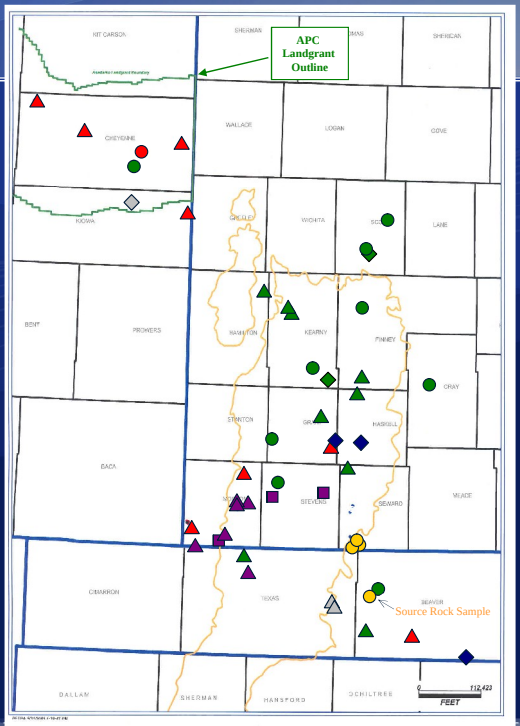
Oil Classification Sample Distribution

Oil Sample Locations for GC/MS Analysis

LEGEND

- Family A (Woodford Source)
- Family AB (A & B Mix)
- Family B (U. Morrow Source?)
- Family C (U. Penn Source?)
- Family D (Viola Source)
- Unknown

- Oil from Upper Penn. Reservoir
- Oil from Upper Morrow Reservoir
- Oil from Lower Morrow Reservoir
- Oil from Mississippian Reservoir



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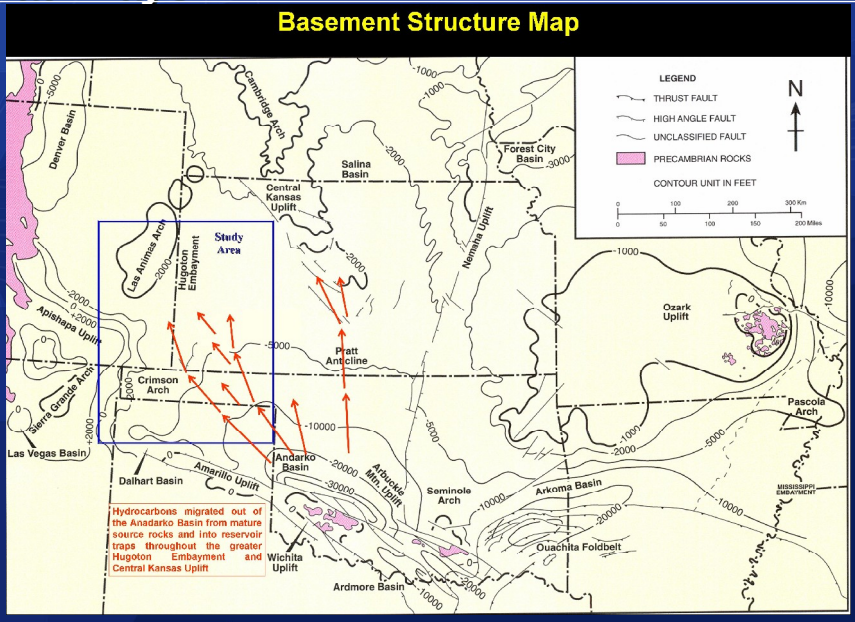
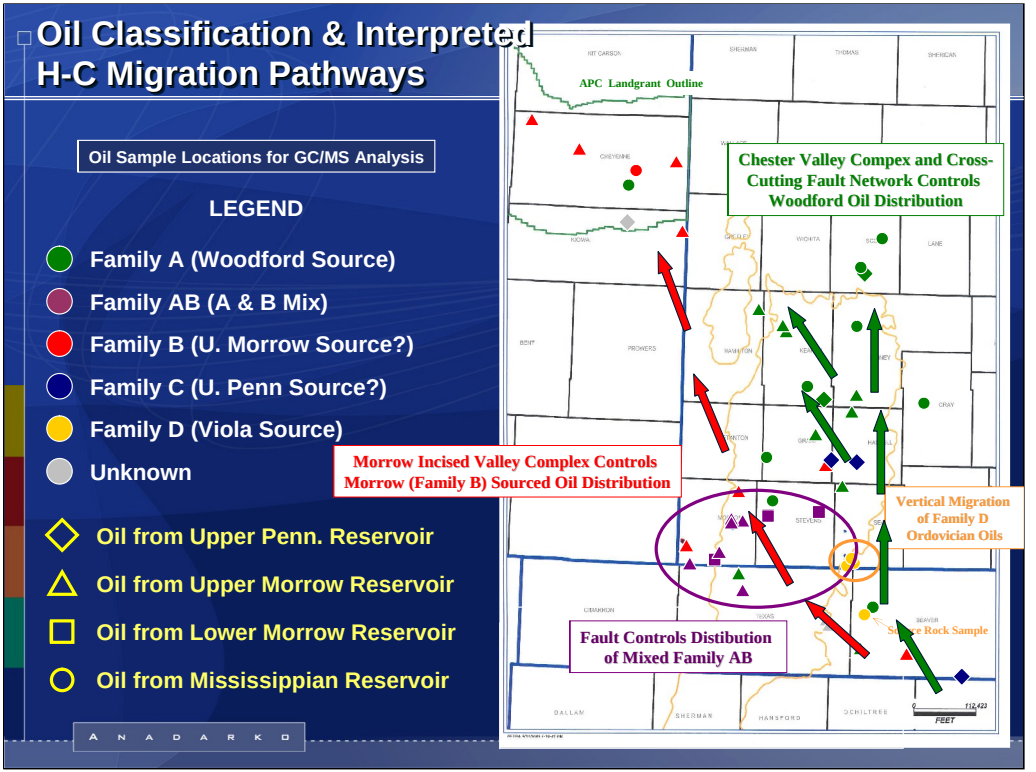
Oil Classification Sample Distribution: Map differentiates oil production by oil family and reservoir age.

Generalized Hydrocarbon Migration Pathways



Generalized Hydrocarbon Migration Pathways



Oil Classification & Interpreted H-C Migration Pathways – Two generalized and dominant hydrocarbon pathways –one focused into southwestern KS and up the KS-CO state line via the Upper Morrow valley complex deposition system and the other focused up the Chesterian valley complex.

Conclusions

- Four distinct families
- Mixing
- Migration pathways identified
- Strong evidence of long distance migration
- Applicable to other basins – including MATURE basins
- Low Cost – High Value

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Conclusions

• four distinct families

• vertical mixing

• migration pathways controlled by major valley complexes and faulting

• Strong evidence for long distance migration since Woodford and potentially Morrow sourced oils are recognized in eastern Colorado – 100's of miles away from mature sources

• Applicable to other basins – including mature basins

• GC/MS is relatively cheap compared to the knowledge you gain about oil source, migration pathways, etc.

Exploration Recommendations

- Recognize Chester and Morrow Valley Systems as primary H-C migration routes and reservoir traps
- Keep in mind the relationship between vertical and lateral migration routes
- Strong correlation between eastern Colorado oils and Hugoton oils suggests exploration potential in relatively underexplored area between the two

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