

COALBED METHANE AND SHALE GAS IN THE CHEROKEE BASIN: EMERGING FROM EXPLORATION TO EXPLOITATION

By

Steven A. Tedesco
Admiral Bay Resources Inc.
Centennial, Colorado

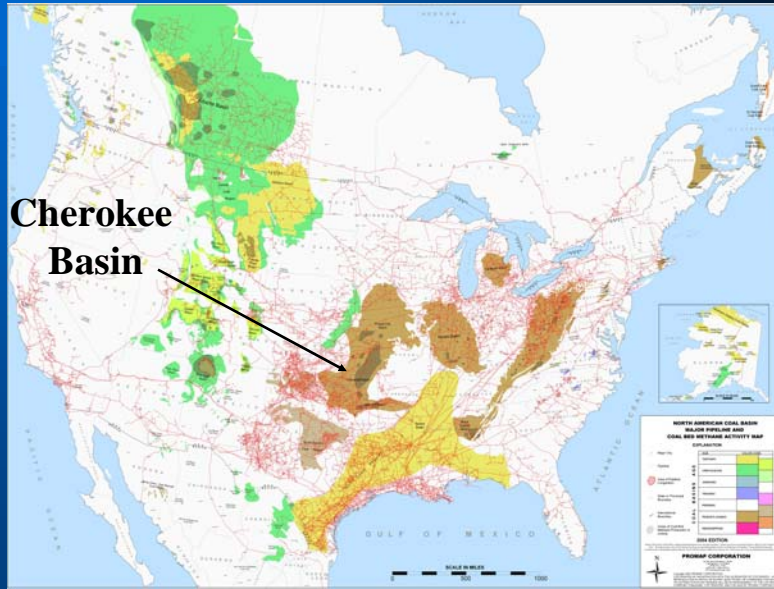
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Rocky Mountain of Association of Geologists 2007 Coalbed Methane
Symposium

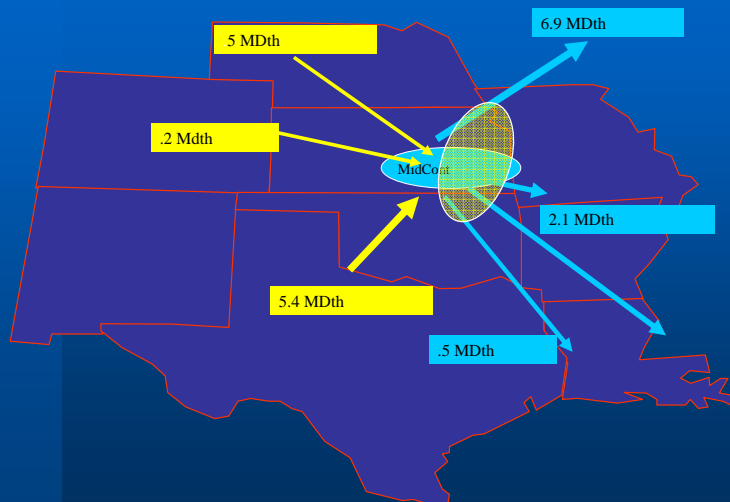
INTRODUCTION

- Regional Setting
- History
- Geology
- Coals and Shales
- Gas Content
- Permeability
- Desorption Isotherm
- Initial Water Saturation And Dewatering Rates
- Production
- Reserves

COAL BASINS OF THE US



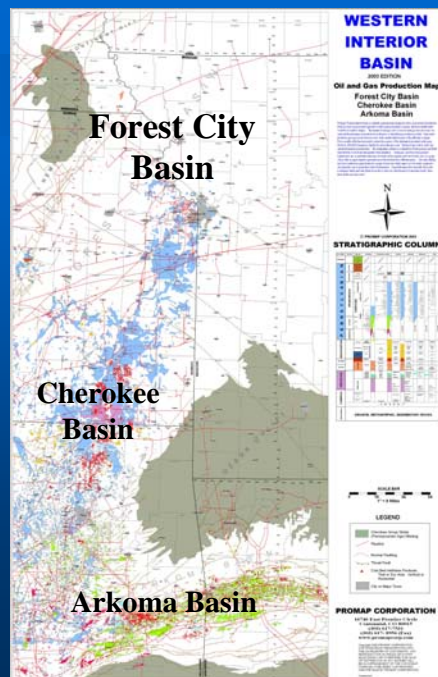
2005 MID CONTINENT GAS BALANCE



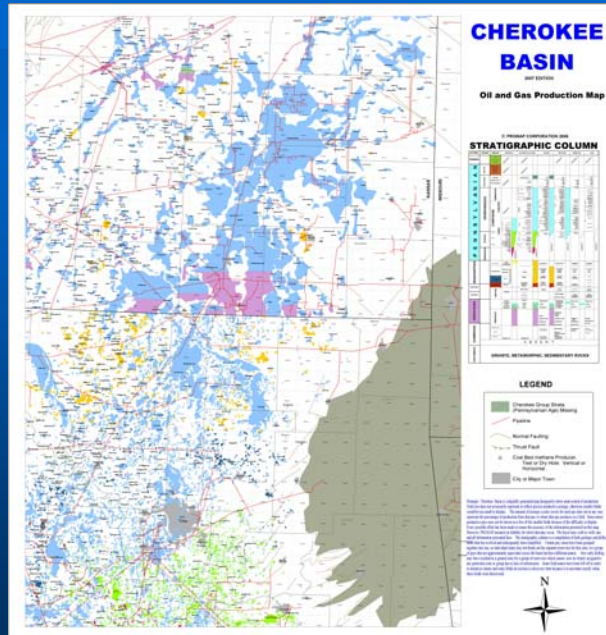
Cherokee Basin

- In its market area
- Recent deal – Constellation Energy bought Energy Quest for \$115M, 7.4 MMCFGPD, 550 wells (ave 13 MCFGPD) for \$2.37 proven MCF in the ground.
- Low environmental costs
- Fee acreage

WESTERN INTERIOR BASIN



CHEROKEE BASIN

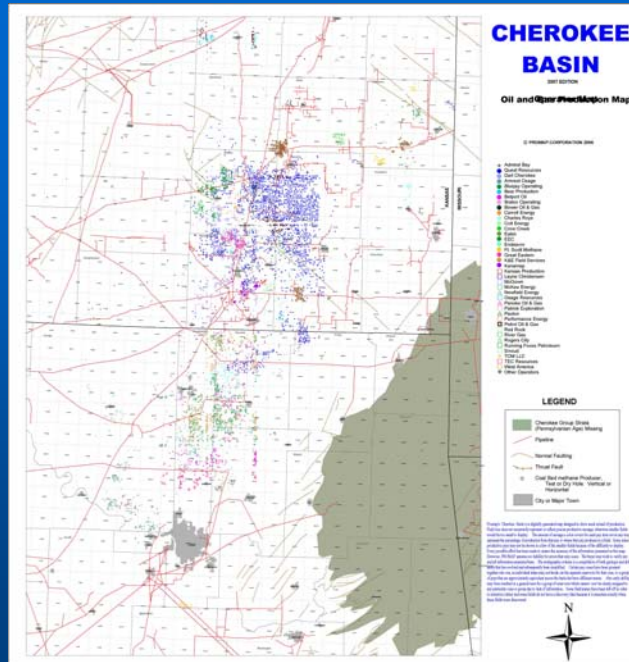


HISTORICAL PERSPECTIVE - MINING

- Mining has been active since the late 1800s, reached its peak during the first half of the last century.
- Underground mines restricted to areas adjacent to outcrop or along the major rivers. This type of mining limited to last half of first century.
- Present mines are surface.
- Coal quality tends to be high in sulfur, nature of ash requires prep for market. Thin nature of the coals limits strip ratio.
- Historically no coal severances.

HISTORICAL PERSPECTIVE - GAS

- Coal bed methane and shale gas first targeted as a resource in the 1920s and 1930s.
- Second round of exploitation in the late 1980s to 1992 as the result of the tax credit.
- Third round of exploitation in the year 2000 to present initiated by Devon Energy.
- Recent data has focused exploitation in certain areas
- Mine explosions documented in Kansas and Missouri.
- Areas where air drilling has occurred gas shows a common occurrence when drilling through black shales and coals.



CBM and
Shale
Gas
Activity

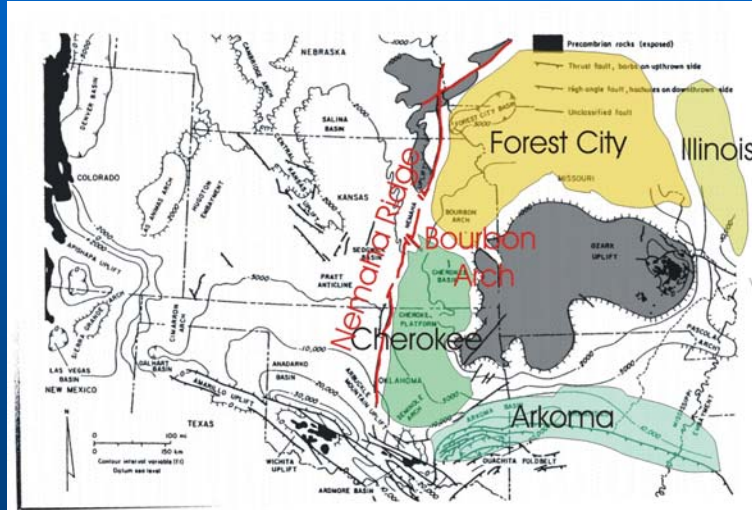
Technical Issues that Impact on Coal Bed Methane Production

- Geology

GEOLOGY

- Basin edges ill defined
- Sediments representing a tidal type delta.
- Partial classic cyclothem.
- Limited amount of accommodation.
- Numerous periods of erosion.
- Cherokee Group equivalent to Spoon Formation in Illinois.
- Overlying Marmaton Group equivalent to Carbondale Formation in Illinois Basin – middle delta plain.

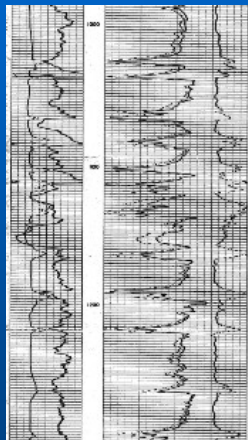
Structural Features in relation of the Cherokee Basin



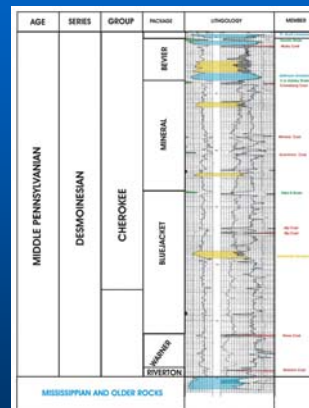
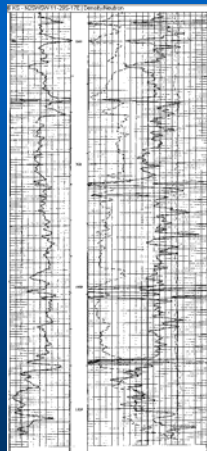
LOG TYPES

New Log

Type Section

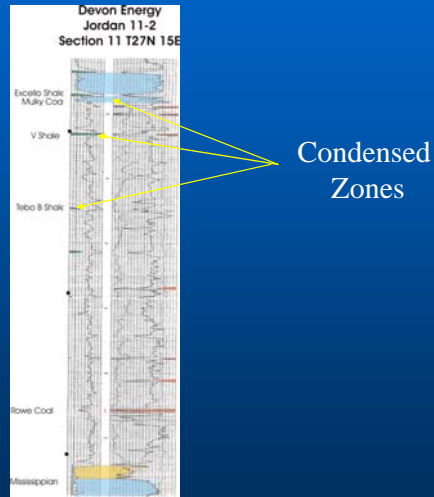


Old Log

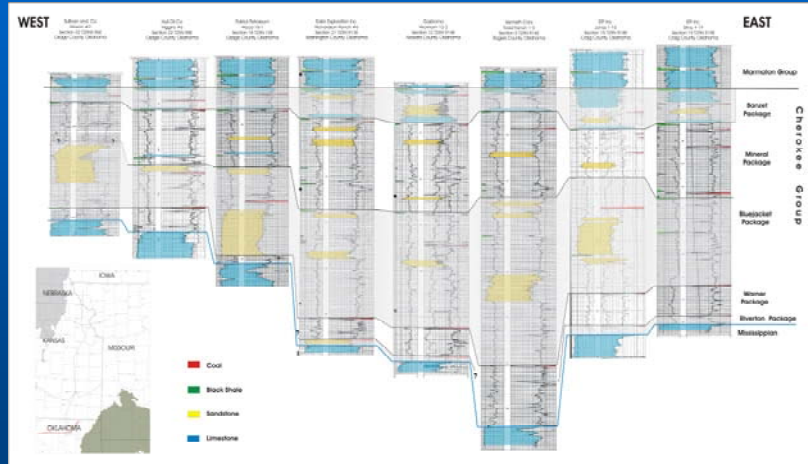


TYPICAL LOG – CHEROKEE

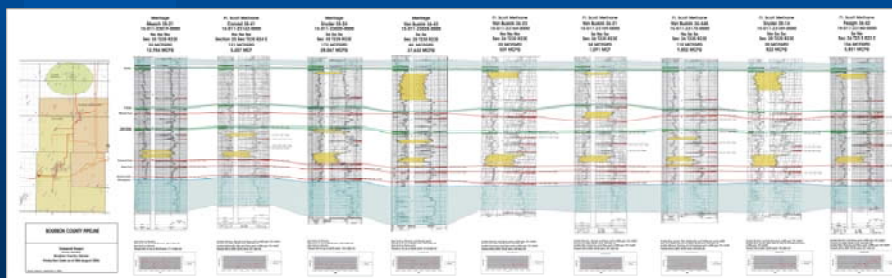
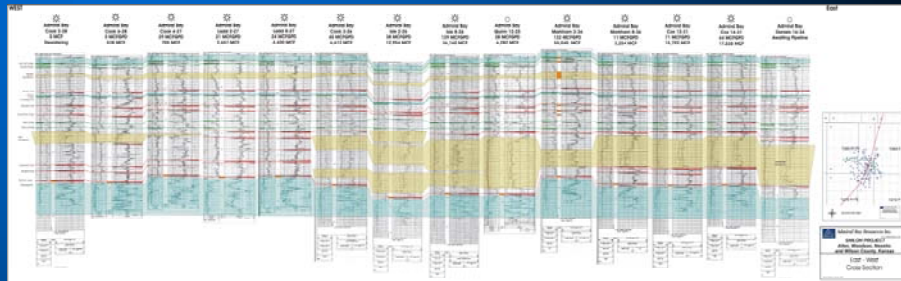
- Coals found in the Cherokee Group
- Depths of 400 to 2,600 feet
- High sulfur coals
- High Volatile A Bituminous coal
- Coals contain thin ash lamination – 5 to 50%
- High inerts



Cherokee Basin Cross-Section



Geology



Technical Issues that Impact on Coal Bed Methane Production

- Geology
- Coals and Shales

MAIN COALS

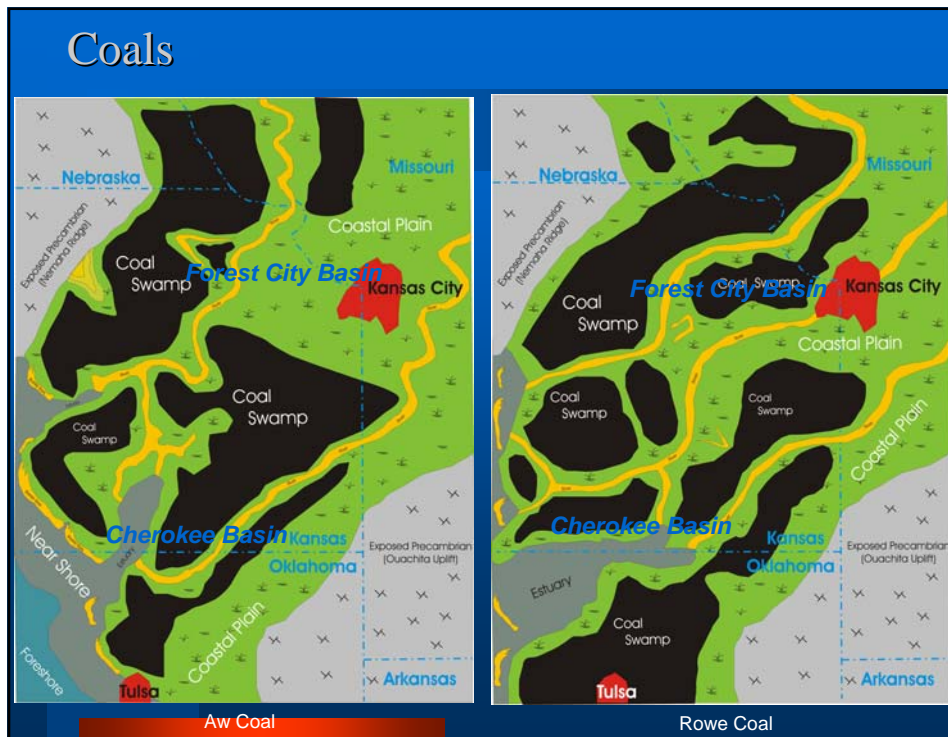
- Mulky
- Bevier
- Croweberg
- Mineral
- Scammon
- Weir-Pittsburg
- Drywood
- Rowe
- Aw
- Riverton

GENERAL CHARACTERISTICS OF CHEROKEE BASIN COALS

- Thickness: 1 to 10 feet, usually less than two feet
- Rank: High Volatile A
- Moisture: 3% to 10%
- Ash: 5% to 50%
- BTU: 11,000 to 15,500 DAF
- Poor to moderate cleating, excellent cleating rare
- Thermogenic and Biogenic gas
- Net coal thickness: 2 to 50 feet
- Well laminated, coal and shale within a seam, discontinuous beds.

GENERAL MACERAL CHARACTERISTICS OF CHEROKEE BASIN COALS

- Vitrinite: 45% to over 85%
- 2% to 10% Exinite
- Inertinite: 1% to 50%
- Vitrinite banding limited.
- Shale partings or coal splits common.
- Swamp development – discontinuous to extensive, rapid changes, constant tidal influx, potential forest fires common, fluvial interruption, stability for 100,000 to 200,000 years.



CHEROKEE BASIN - SHALES

Organic Rich Shales

- TOC 1% to 20%, generally around 4% to 5%
- Contributing at least 50% of gas to all CBM wells
- Main Beds:
 - Little Osage (Summit) Shale
 - Excello (Mulky) Shale
 - Oakley or V Shale
 - Tebo Shale
 - Tebo B Shale
 - Bbj Shale
 - Unnamed Shale above the Rowe Coal
 - Unnamed Shale above the Aw Coal

Technical Issues that Impact on Coal Bed Methane Production

- Geology
- Coals and Shales
- Gas Content

GAS CONTENT - COALS

- Gas Content varies from 1 to over 300 scf per ton - desorption. Generally averages around 180 scf
- Gas contents vary dramatically within a well and within an individual seams.
- Gas Contents varies from 100 to over 375 scf per ton for adsorption – overly optimistic.
- Gas Quality – 90% to 98% methane, some are less than 2% CO₂,
- Presence of C₂ to C₄.
- BTU range of 800 to 1050.

SOURCE OF GAS IN CHEROKEE GROUP – CHEROKEE BASIN OR PLATFORM

- USGS – indicates at least in Cherokee Basin, Cherokee Group shales and coals generating gas. 6 TCF of gas
- Petroleum in Middle Pennsylvanian, Mississippian and Ordovician reservoirs result of long distance migration from the Anadarko Basin.
- Gas in the Kansas City-Lansing (Mid to Late Pennsylvanian is biogenic).
- Gas across basin across western half of basin is thermogenic.
- Gas in Northeast – Southwest trend from 100 to 2300 feet has a significant biogenic gas.
- Gas in eastern half of basin associated with conventional reservoirs.
- No gas associated with conventional Pennsylvanian Age reservoirs in Northwest part of Cherokee Basin.

GAS CONTENT – BLACK SHALES

- Gas Content varies from 1 to over 60 scf per ton.
- Gas contents maybe be uniform over a large area.
- Gas Quality – 90% to 98% methane, some are less than 2% CO₂,
- Some areas > 6% N₂.
- Presence of C₂ to C₄.
- BTU range of 800 to 950.

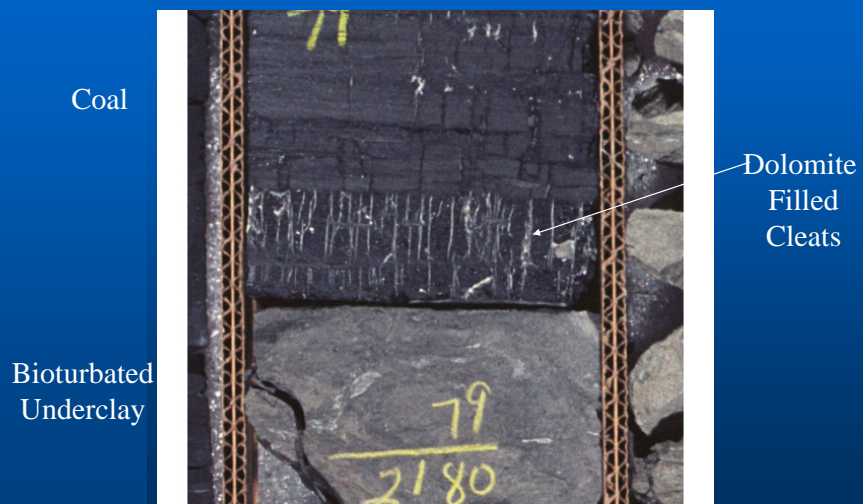
Technical Issues that Impact on Coal Bed Methane Production

- Geology
- Coals and Shales
- Gas Content
- Permeability

PERMEABILITY

- Measured permeability via falloff tests indicate anywhere from .01 to over 200 md.
- Highly variable in a well and in the same seam laterally throughout a project area.
- Calcite filling common in some area.
- Secondary thermal dolomite reported
- Generally seeing an average range of 10 to 20 md in productive areas.

COAL SEAM CLEAT FILLING



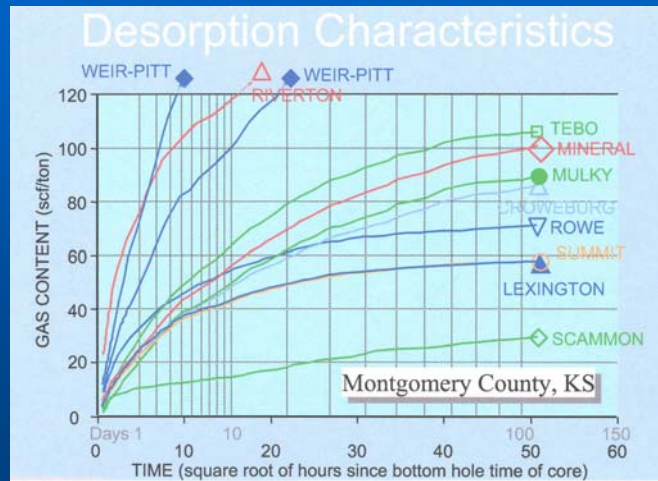
Technical Issues that Impact on Coal Bed Methane Production

- Geology
- Coals and Shales
- Gas Content
- Permeability
- Desorption Isotherm

DESORPTION CURVE

- Coals in Southeastern Kansas and Northeastern Oklahoma are near saturation – gas production within a short period of time.
- Desorption curve reflects gas saturation and permeability.

DESORPTION CURVE



Technical Issues that Impact on Coal Bed Methane Production

- Geology
- Coals and Shales
- Gas Content
- Permeability
- Desorption Isotherm
- Initial Water Saturation And Dewatering Rates

DEWATERING AND DISPOSAL

- Initial water rates from a individual coal varies from 1 to over 500 barrels a day.
- Multiple seam completion varies from a mist to over 1,000 barrels a day.
- Peak dewatering achieved in on average is 18 months.
- Water is salty to slightly salty through out most of the play.

Technical Issues that Impact on Coal Bed Methane Production

- Geology
- Coals and Shales
- Gas Content
- Permeability
- Desorption Isotherm
- Initial Water Saturation And Dewatering Rates
- Production

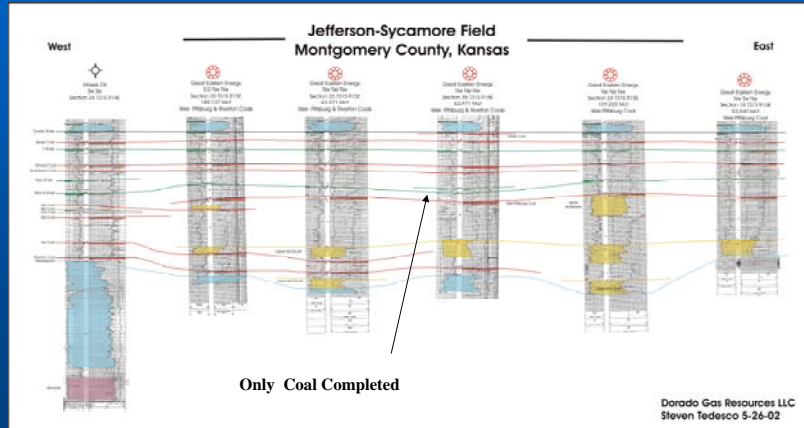
GAS PRODUCTION AND RESERVES FOR THE CHEROKEE BASIN

- Initial gas rates anywhere from 0 to over 100 Mcf per day from a single seam.
- Multiple seam completions there is generally no gas initially. Reservoirs are interfering.
- Reserves .05 to .3 BCF per 2 to 3 feet of coal from 80 to 160 acres.
- Percentage contribution of shale gas unknown.
- Peak rates on average 45 MCFGPD reached on average in 18 months.
- Almost all wells vertical, horizontal wells have proven unsuccessful to date.

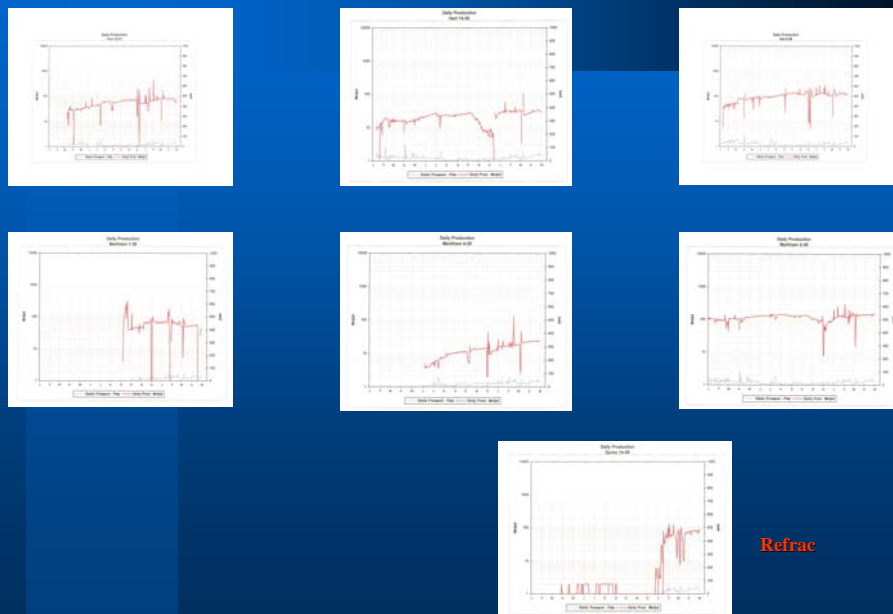
GAS PRODUCTION AND RESERVES FOR THE CHEROKEE BASIN

- Most wells single zone completion
- Multiple seam completions there is generally no gas initially.
- Average reserve, based on analysis of all wells, is presently 143 MMCFG.
- Spacing not determined.
- Percentage contribution of shale gas unknown.
- Peak rates on average are 45 MCFGPD (5,000+ wells) reached on average in 18 months. Wells post 2004 indicate peak rates exceeding 85 MCFGPD – slick water fracs

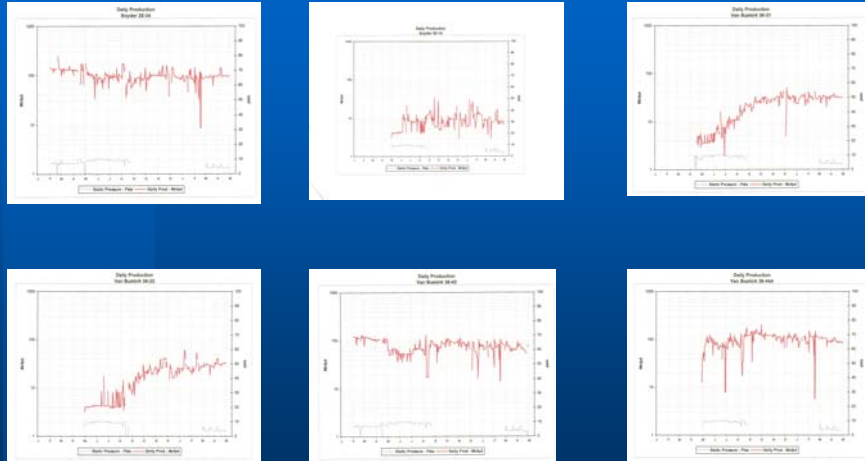
Jefferson-Sycamore Field



Production - Central Cherokee Basin



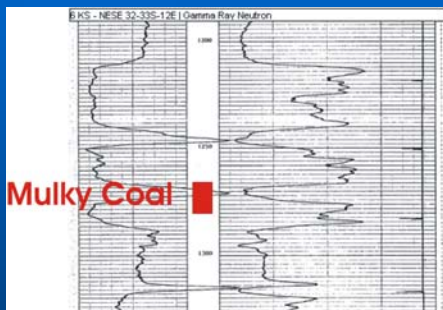
Production - Northern Cherokee Basin



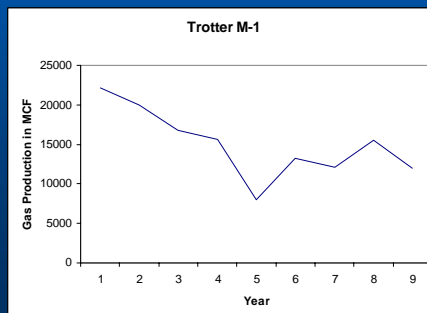
GAS PRODUCTION AND RESERVES FOR THE CHEROKEE BASIN - PROBLEM

- Rock properties calculation indicates a max of 98 MMCFG in place for 160 acres for single coal seam.
- Production exceeds projected reserves.
- Initially spacing on 160 acres, most companies down spacing to 80 acres, Admiral Bay down spacing to 40 acres.
- Percentage contribution of shale gas unknown.
- Peak rates on average 45 MCFGPD reached on average in 18 months.

Gamma Ray-Neutron log from the Trotter M-1 indicating the zone completed. Well produces from Excello Shale not the Mulky.



Well has produced 137 MMCFG as of 2005



CONCLUSIONS

- Economic or producible gas in coals presently limited to eastern half of basin – depth limit
- Play seems to be a large up-dip strat trap?
- At least one period of degassing.
- Biogenic gas (based on isotope data) present on the east side of the basin.
- Coals on northwest side of basin under saturated with thermogenic gas only.
- Shales across basin at saturation or are oversaturated.
- Specific coals and shales producing most of the gas
- Mapping of coal geology will lead to finding conventional reservoirs

CONCLUSIONS

- Focus on areas with good permeability.
- Focus on areas with gas content > than 150 Scf per ton for coals, 25 to 60 Scf per ton for shales.
- Focus on areas where coals density less than 1.8.
- Eastern half of the Cherokee Basin are working for coals and areas in the northwest part of the basin are not working for coals.
- Shale play related to organic content.

CONCLUSIONS

- Basin is unique in that the entire section contributing gas from coals and shales.
- Thermal history complex.
- Still unclear actual area being drained by individual coal seams.
- Wells are typically producing from a single two foot coal seam fraced with slick water.
- Reserves are exceeding calculated in place by a factor of two or more

