Overview of Selected Shale Plays in New Mexico*

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Search and Discovery Article #10627 (2014)**
Posted August 18, 2014

*Adapted from presentation at RMAG luncheon meeting, Denver, Colorado, August 6, 2014.

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Abstract

New Mexico, with its multiple productive and frontier basins of different ages, has multiple opportunities for shale plays in strata ranging in age from Early Paleozoic to Late Cretaceous. For this article, emphasis is placed on the emerging Mancos Shale play in the San Juan Basin. Also discussed are productive and potentially productive shale plays in the Permian Basin, the Raton Basin, and a frontier play in the Pedregosa Basin of southwestern New Mexico.

In the San Juan Basin the Mancos Shale (Upper Cretaceous) has been productive from three plays: 1) the basal Niobrara ("Gallup") offshore marine sandstone bar play in the southwest; 2) the naturally fractured Mancos shales along the southeastern and northwestern flanks of the basin; and 3) "offshore" shales with thinly interbedded sands that occur northeast of the offshore bars. The first two plays are conventional and are mature. The third play is unconventional and consists of marine shales and thinly interbedded sandstones deposited farther offshore (northeast) of the marine bar sandstones. These shales have been produced mostly subeconomically by vertical wells in sparsely drilled reservoirs. The shallower Mancos along the south flank of the basin is within the oil window, and the deeper Mancos in the northern part of the basin is within the thermogenic gas window. With the advent of horizontal drilling and multi-stage hydraulic fracturing this play now has the potential to be economically developed on a large scale. Recent exploratory drilling has been positive.

Several plays are present in the Permian Basin in southeastern New Mexico. The Bone Spring Formation (Permian) has seen extensive development within the Avalon Shale, but horizontal drilling has mostly switched to the Second and Third Bone Spring sandstones as the Avalon has proved gas prone in its western extent. The Bone Spring sandstones have been mostly responsible for the rise in New Mexico oil production from 70 million bbls to 100 million bbls over the last three years. Other possible plays include the Barnett Shale (Upper Mississippian) and the Woodford Shale (Upper Devonian).

The Niobrara Shale of the Raton Basin of north-central New Mexico is an emerging gas play. The Niobrara has been productive from five vertical exploratory wells. The Niobrara is within the thermogenic gas window within the deeper axial part of the Raton Basin and is thermally mature along the shallow eastern flank of the basin, resulting in the possibility of both gas and oil plays.

Southwestern New Mexico has seen multiple stages of tectonic deformation from the Pennsylvanian through the Late Tertiary. The marine Percha Shale (Upper Devonian) is dominated by gas-prone kerogens and is affected structurally and thermal by all tectonic stages. The Percha is within the thermogenic gas window throughout southwestern New Mexico and is metamorphosed where proximal to large intrusive bodies.

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Overview of Selected Shale Plays in New Mexico

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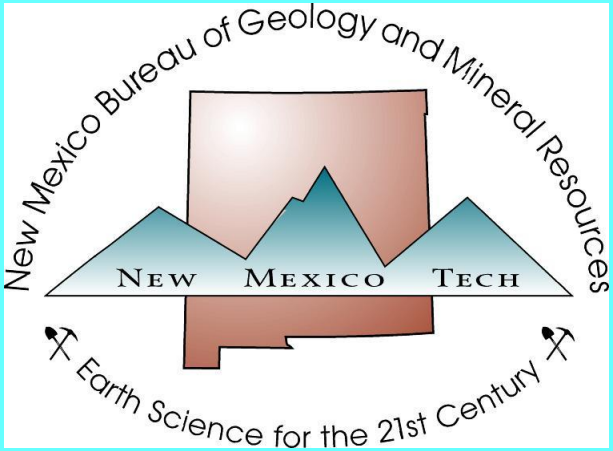
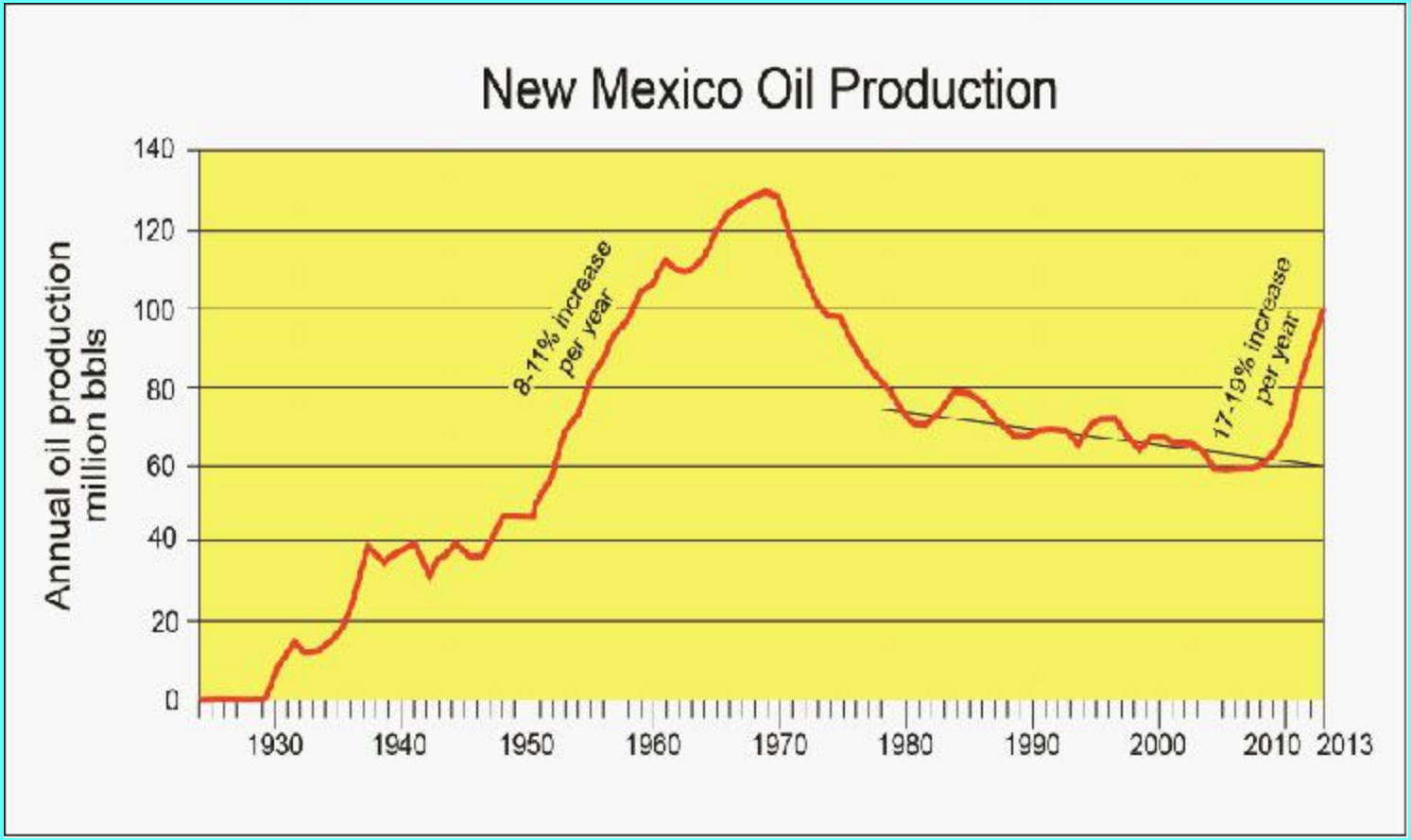


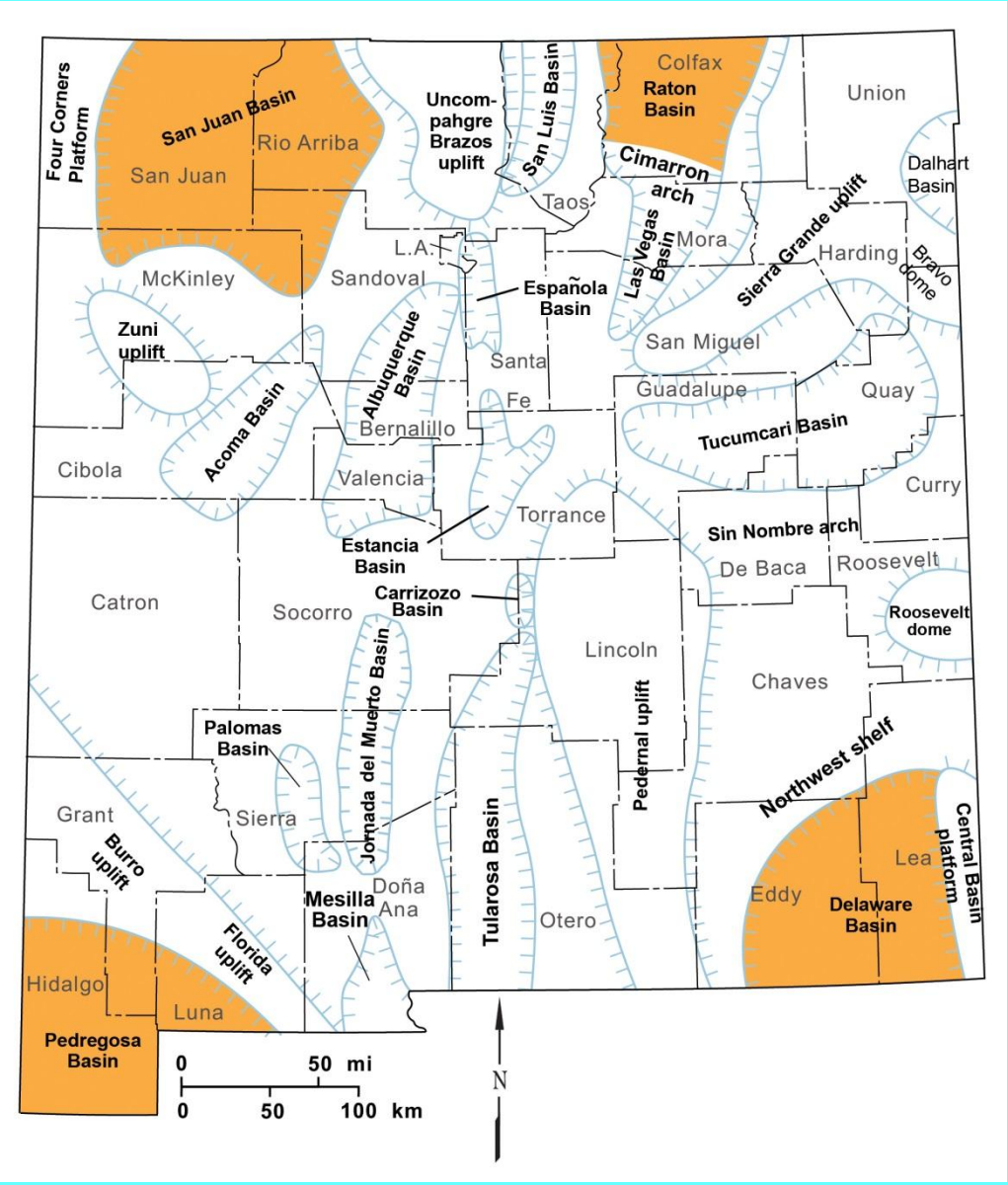
RMAG Luncheon Meeting, August 6, 2014

Unconventional oil production made possible by horizontal drilling and multi-stage hydraulic fracturing has revived New Mexico oil production

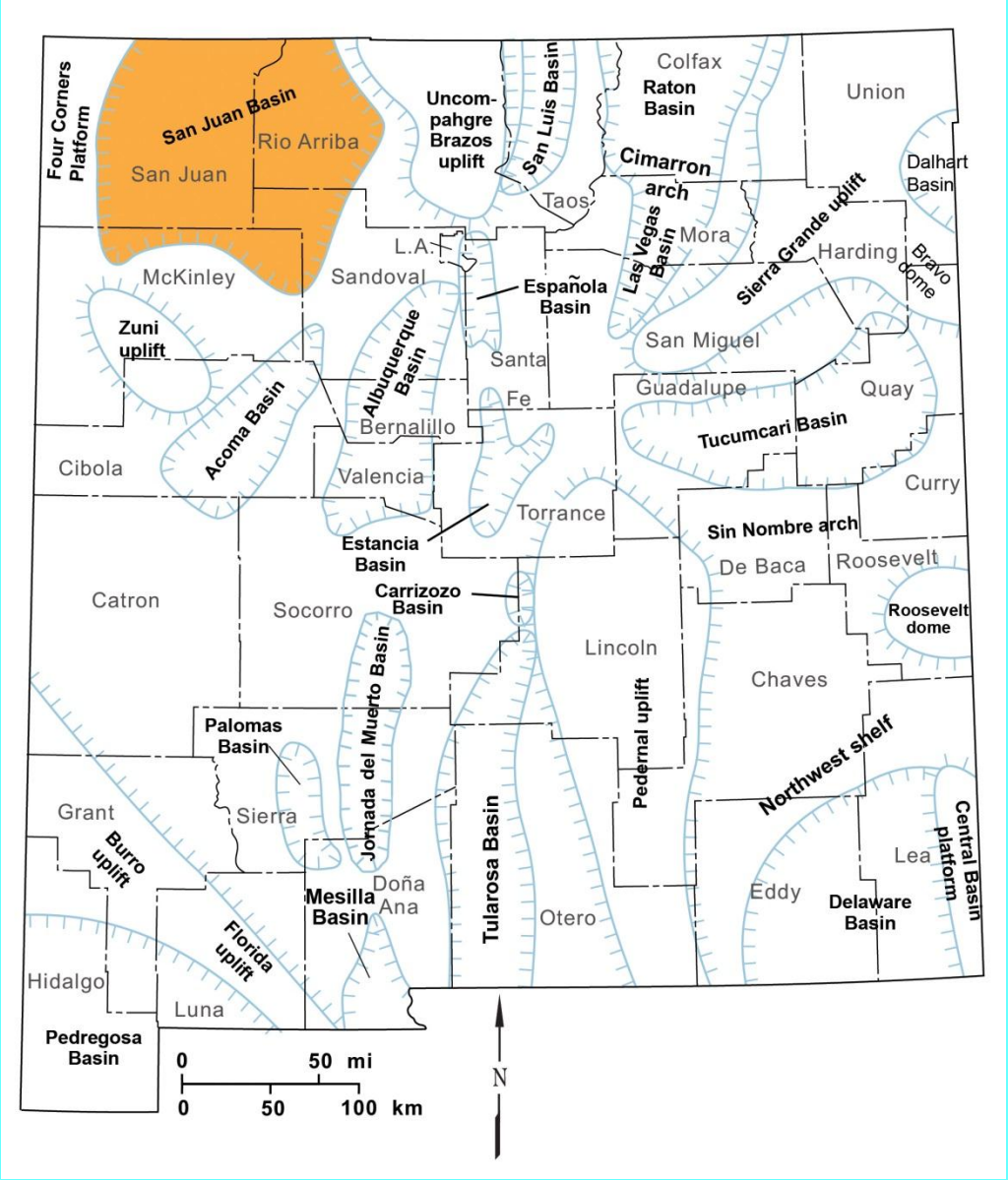


We'll look at the four corners of NM, producing basins in NW, NE, SE:
1) San Juan
2) Raton
3) Permian

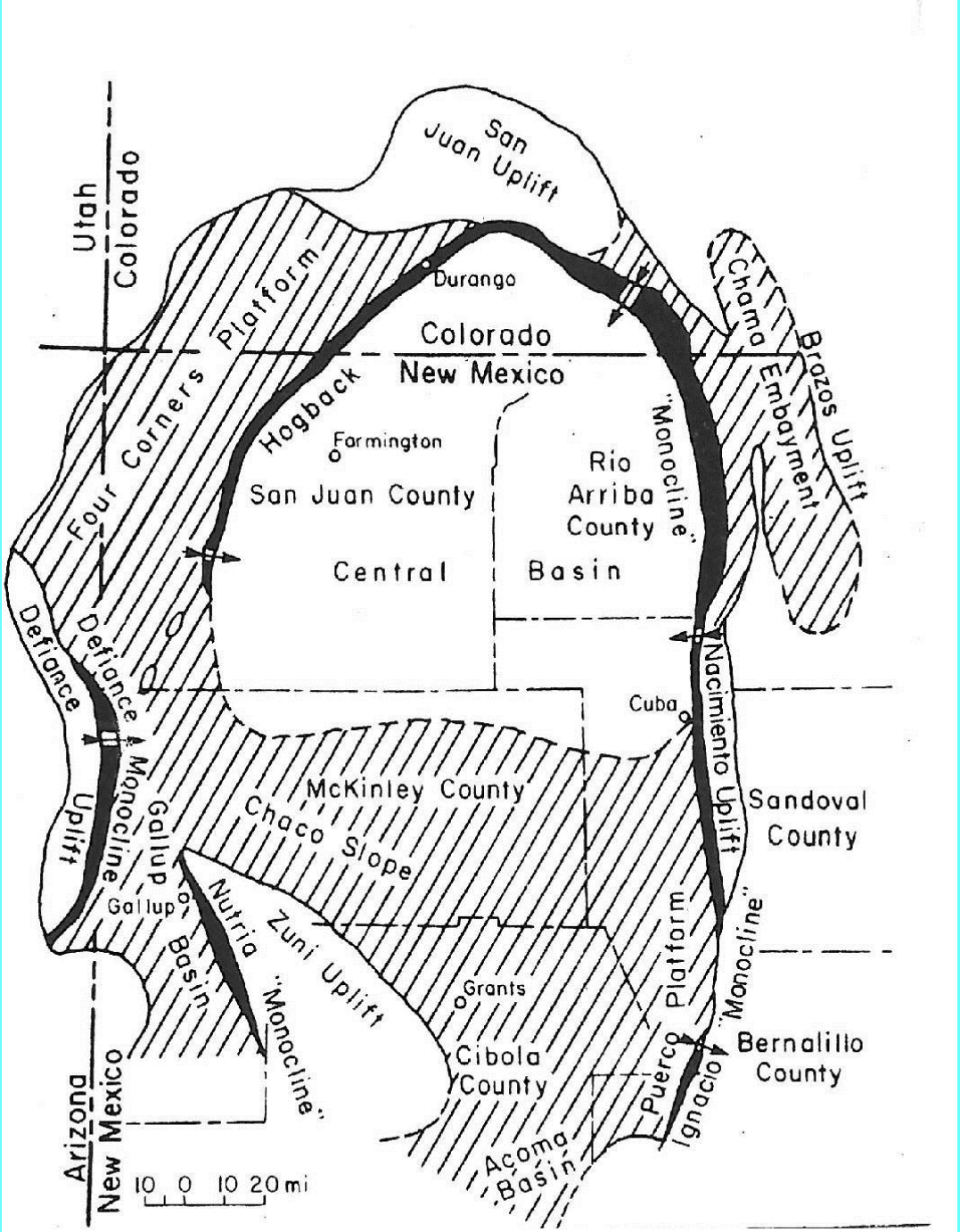
And a frontier basin In the southwest:
4) Pedregosa



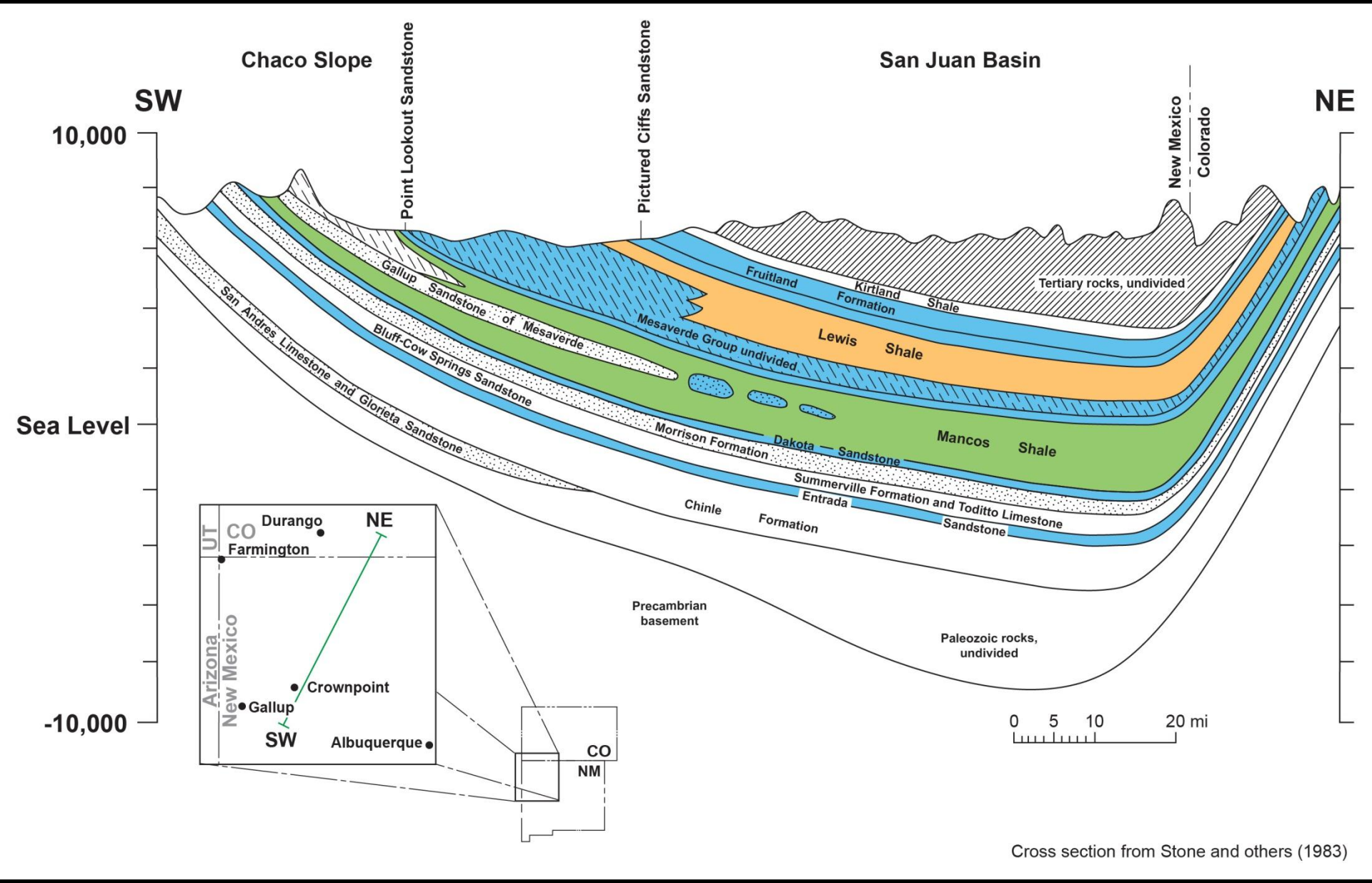
San Juan Basin



San Juan Basin geology

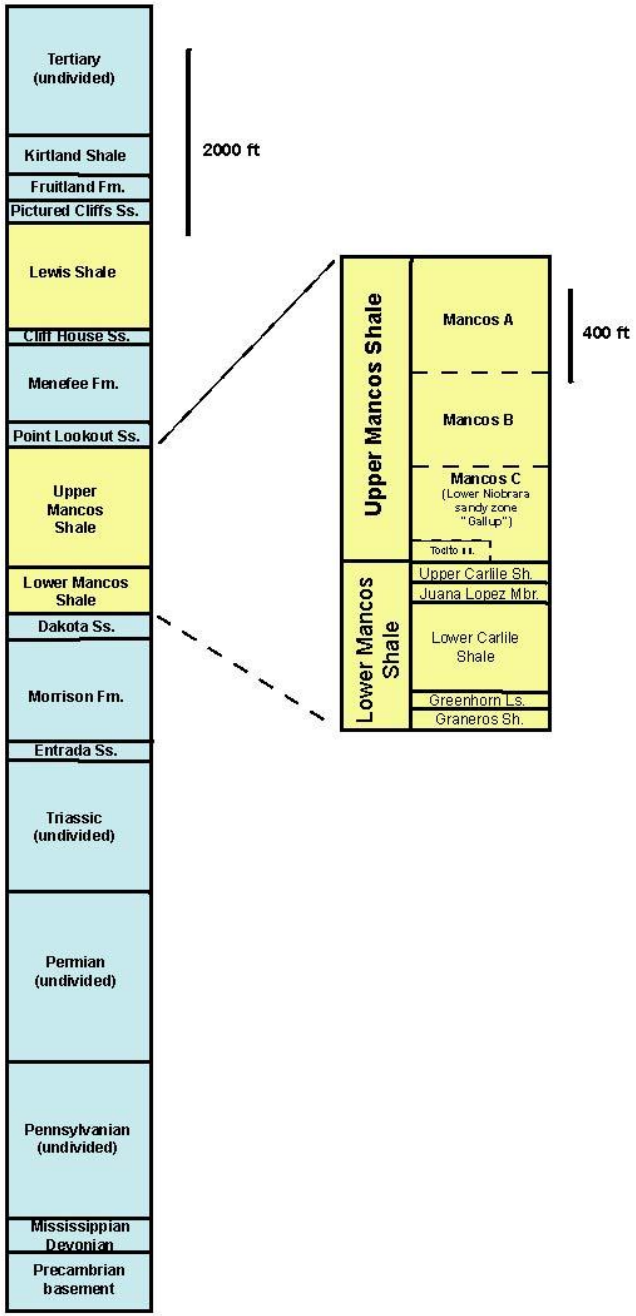


From Stone and others (1983)

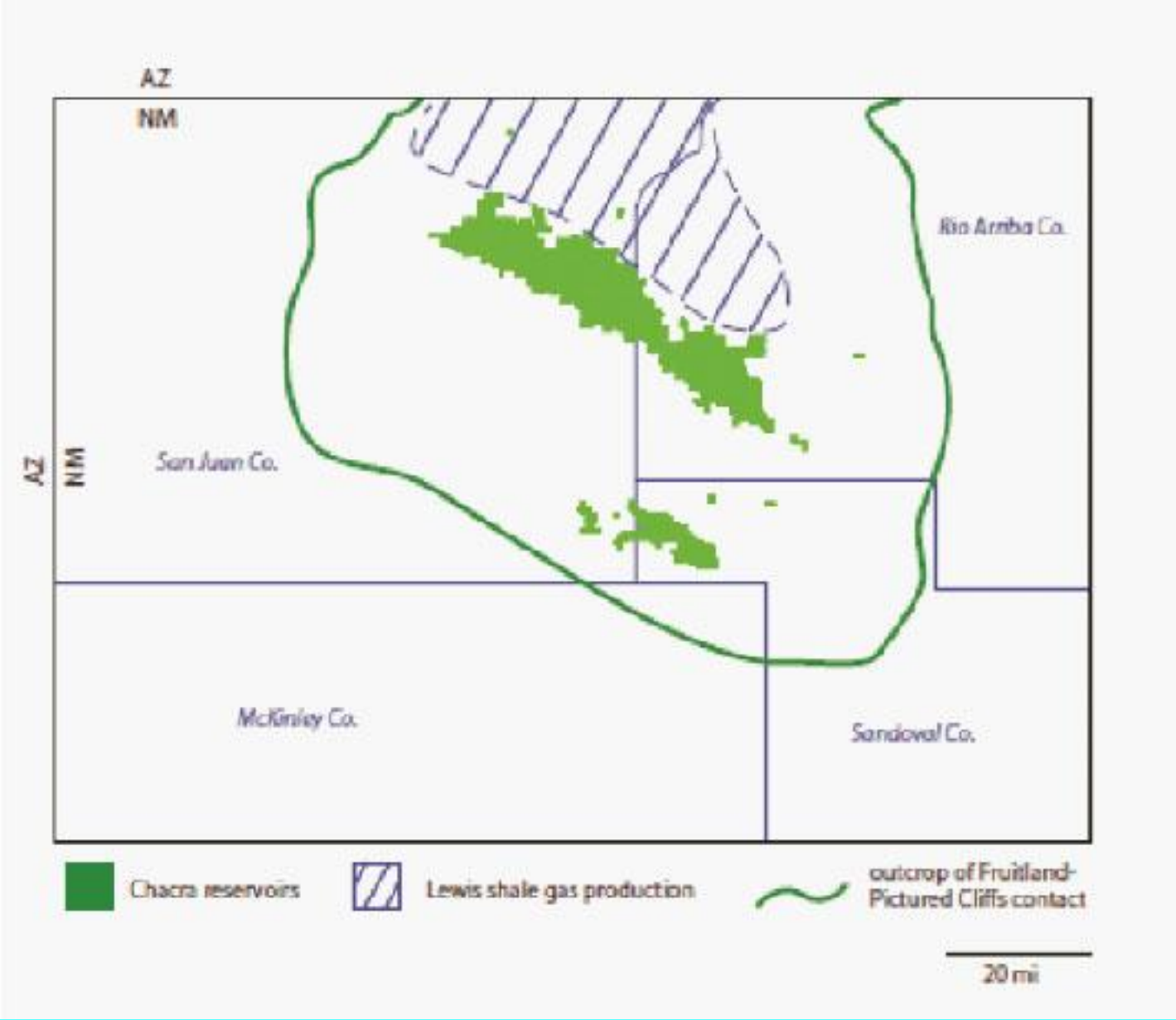


Cross section from Stone and others (1983)

San Juan Basin Stratigraphic Column
T25N R8W

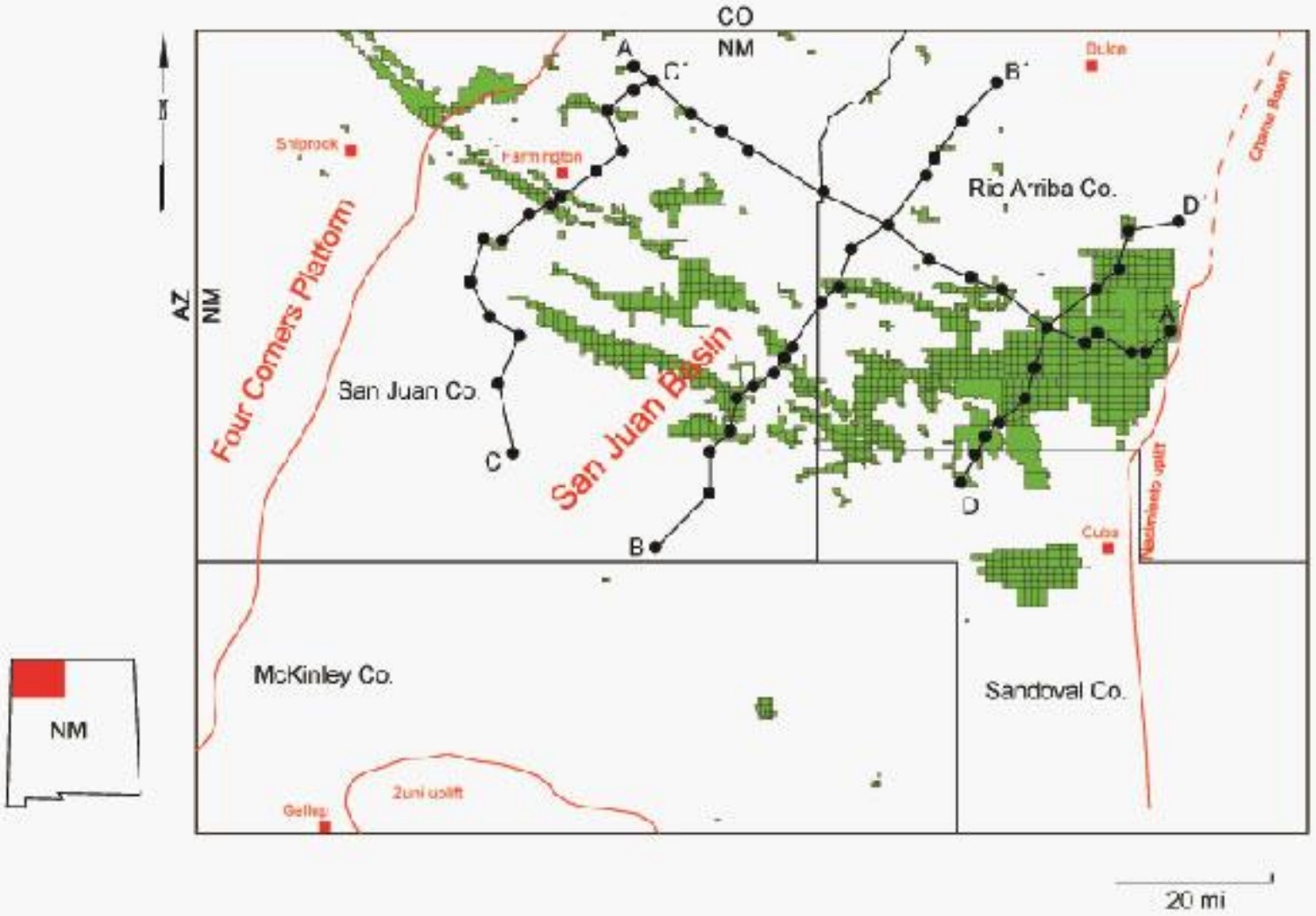


Gas from Lewis Shale

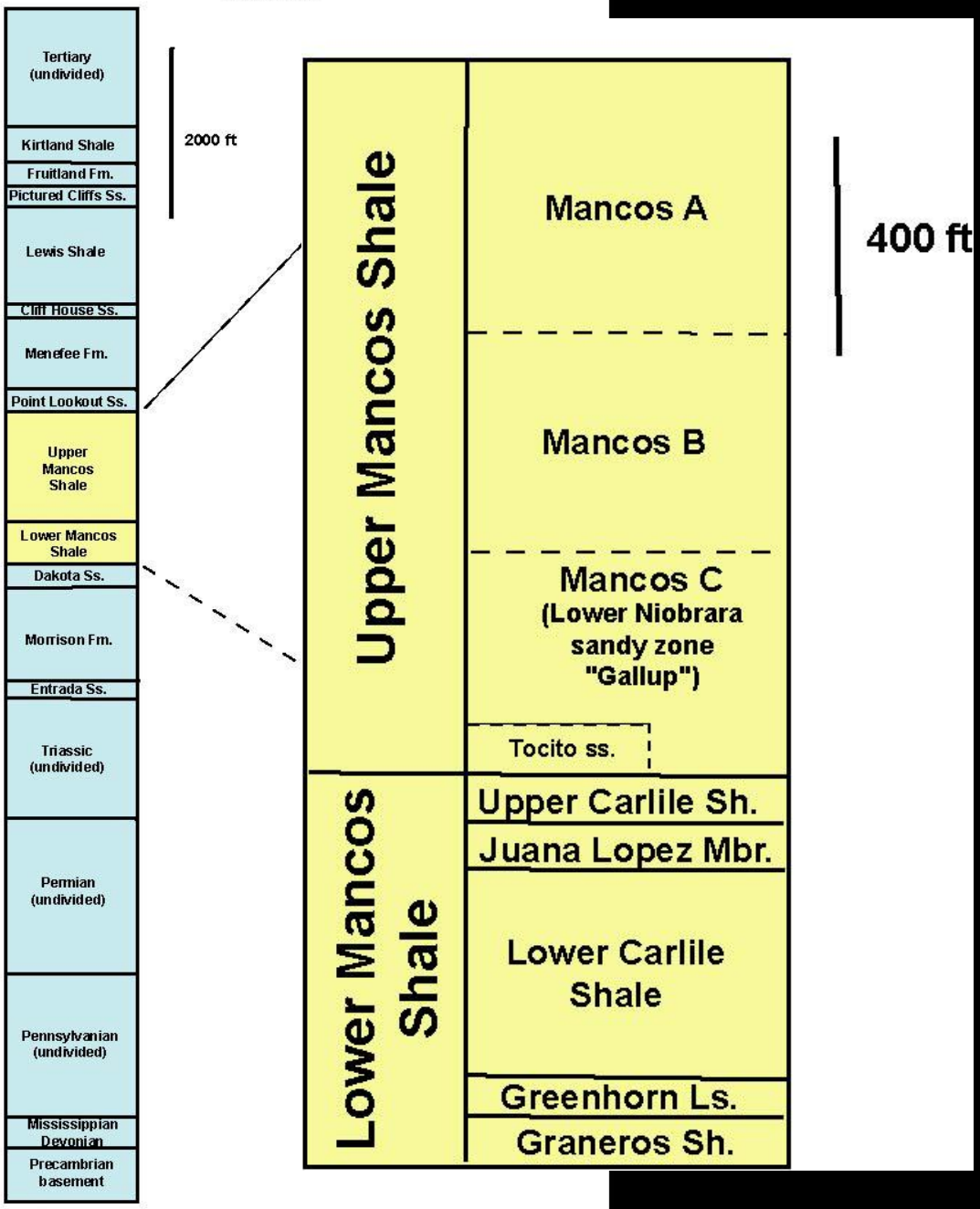


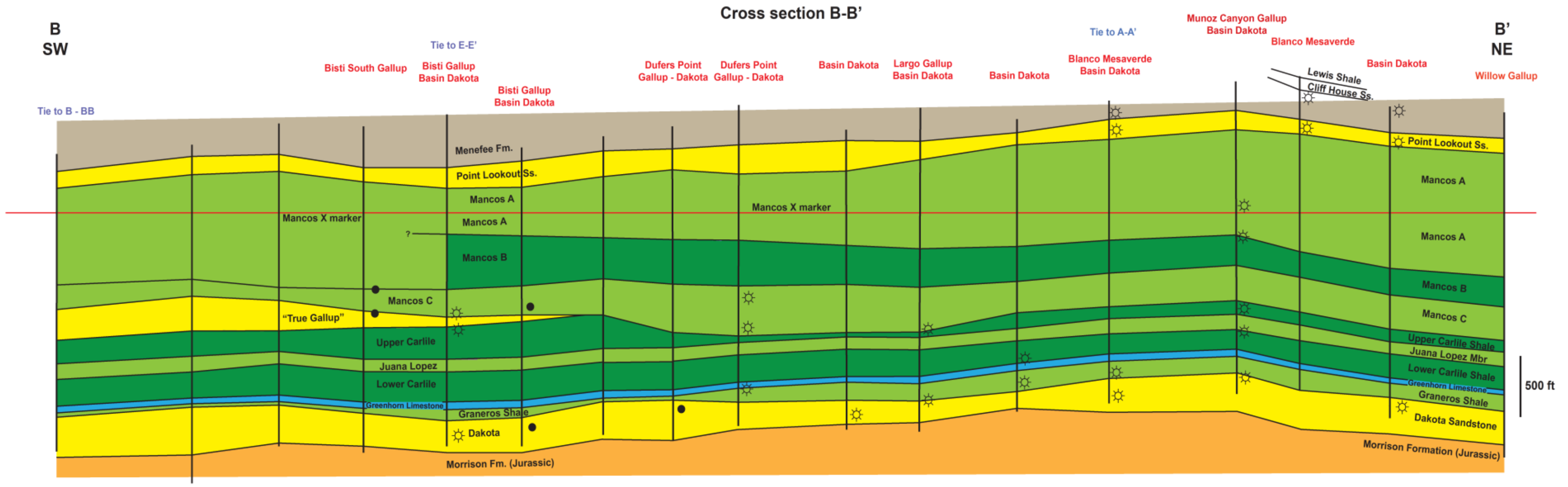
From Broadhead (in press)

Mancos and “Gallup” reservoirs

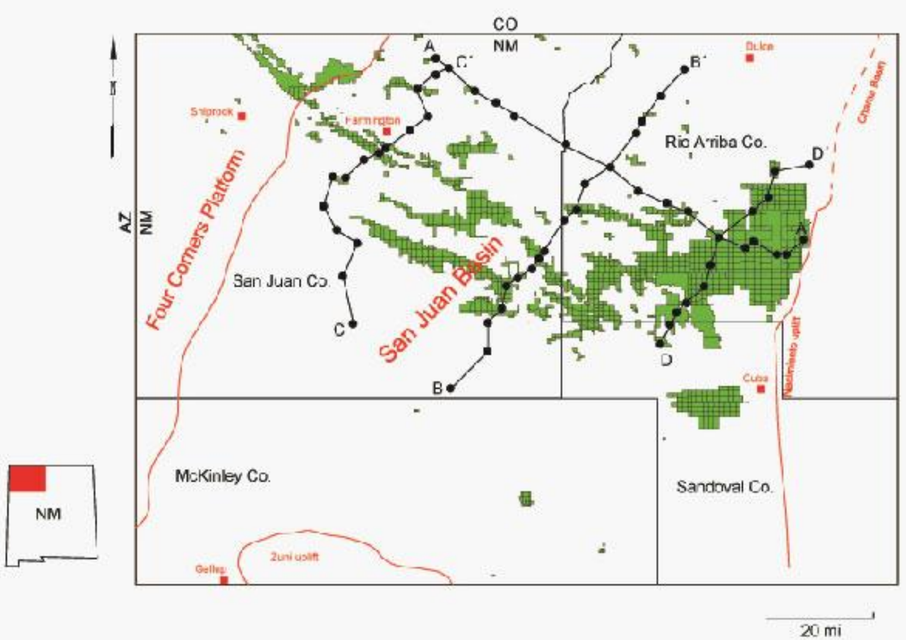


San Juan Basin Stratigraphic Column
T25N R8W





Cross section B-B'
B
SW
B'
NE
Tie to B - BB
Bisti South Gallup
Tie to E-E'
Bisti Gallup
Basin Dakota
Bisti Gallup
Basin Dakota
Dufers Point
Gallup - Dakota
Dufers Point
Gallup - Dakota
Basin Dakota
Largo Gallup
Basin Dakota
Basin Dakota
Tie to A-A'
Blanco Mesaverde
Basin Dakota
Munoz Canyon Gallup
Basin Dakota
Blanco Mesaverde
Basin Dakota
Willow Gallup
Lewis Shale
Cliff House Ss.
Menefee Fm.
Point Lookout Ss.
Mancos A
Mancos X marker
Mancos B
Mancos C
"True Gallup"
Upper Carlile
Juana Lopez
Lower Carlile
Greenhorn Limestone
Graneros Shale
Dakota
Morrison Fm. (Jurassic)
Upper Carlile Shale
Juana Lopez Mbr
Lower Carlile Shale
Dakota Sandstone
Morrison Formation (Jurassic)
500 ft

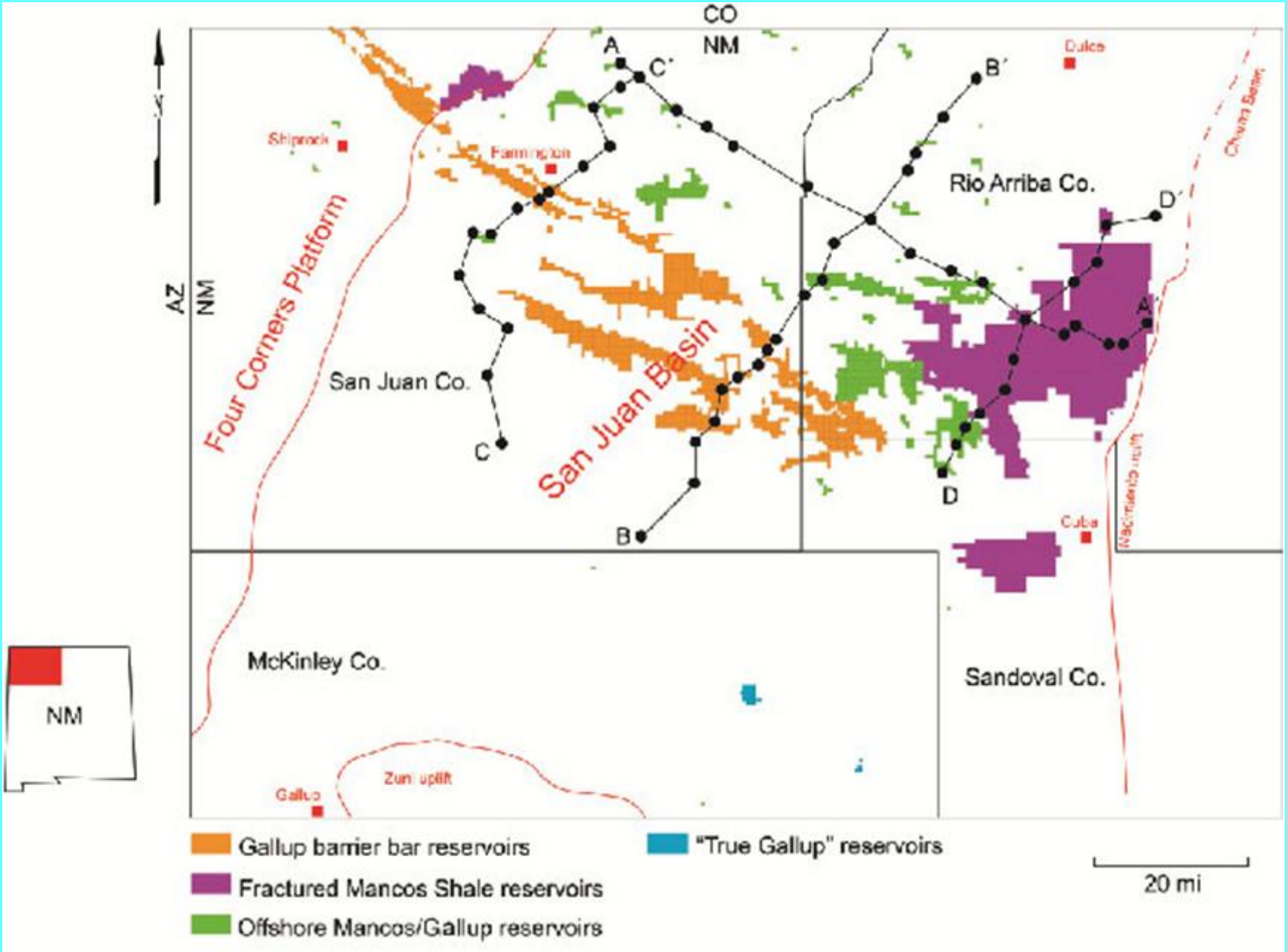


CO
NM
AZ
NM
Shiprock
Farmington
Four Corners Platform
San Juan Co.
San Juan Basin
Rio Arriba Co.
McKinley Co.
Sandoval Co.
Cuba
Gallup
Zuni uplift
A
A'
B
B'
C
C'
D
D'
NM
20 mi

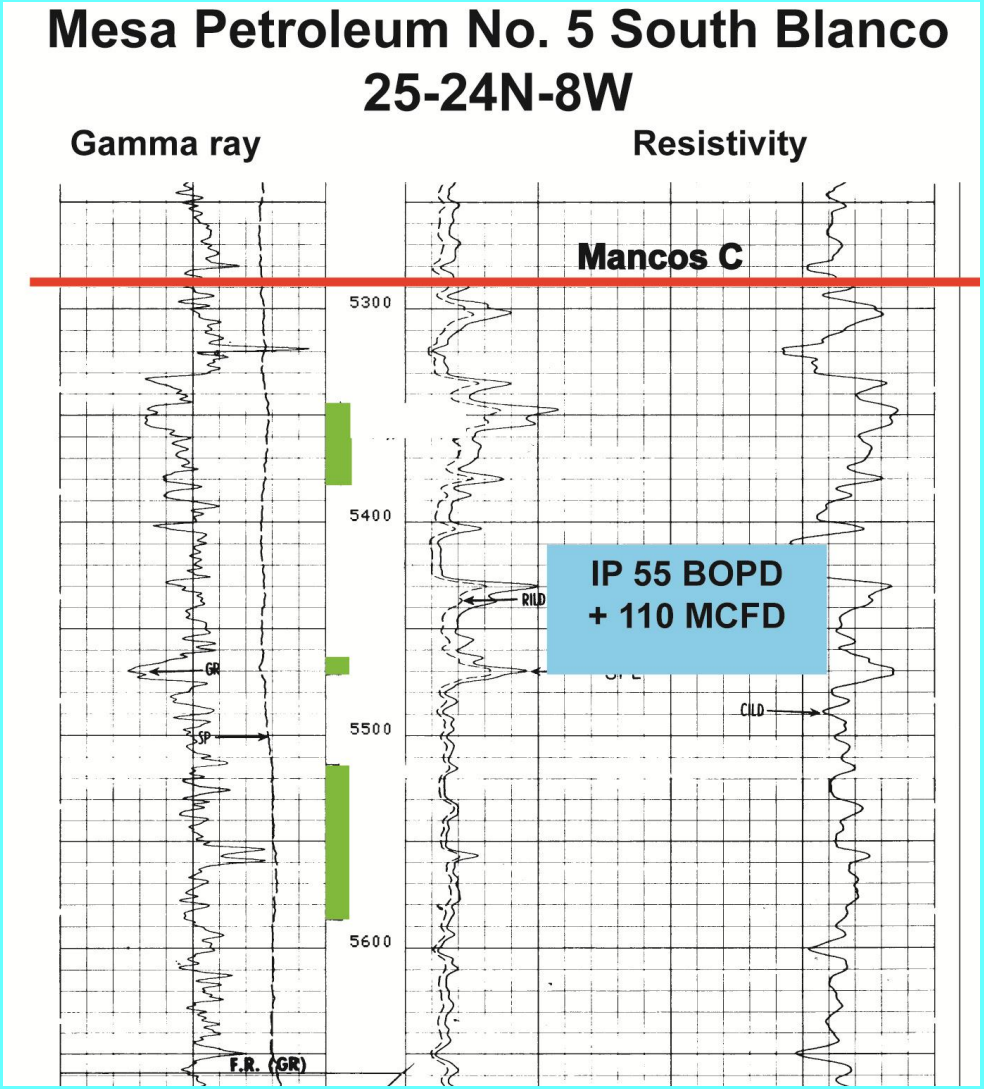
Three Mancos and “Gallup” plays

- **Older play – “Gallup” marine bar/barrier island sandstone reservoirs along shoreline trend**
- **Older play – naturally fractured, oil-filled Mancos shales along eastern and western flanks of basin**
- **New play – “offshore” shales with thin sands with economic potential rendered by horizontal drilling & multi-stage hydraulic fracturing**

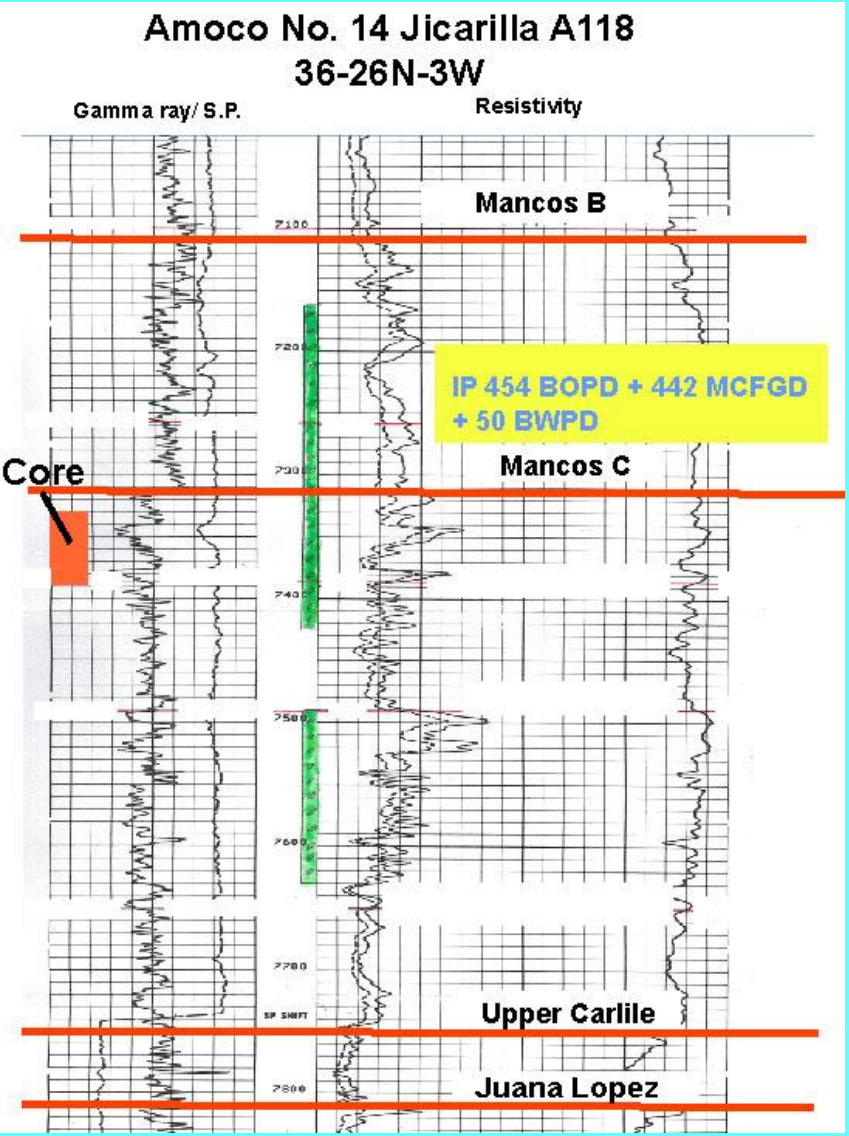
Mancos and "Gallup" reservoirs by play type



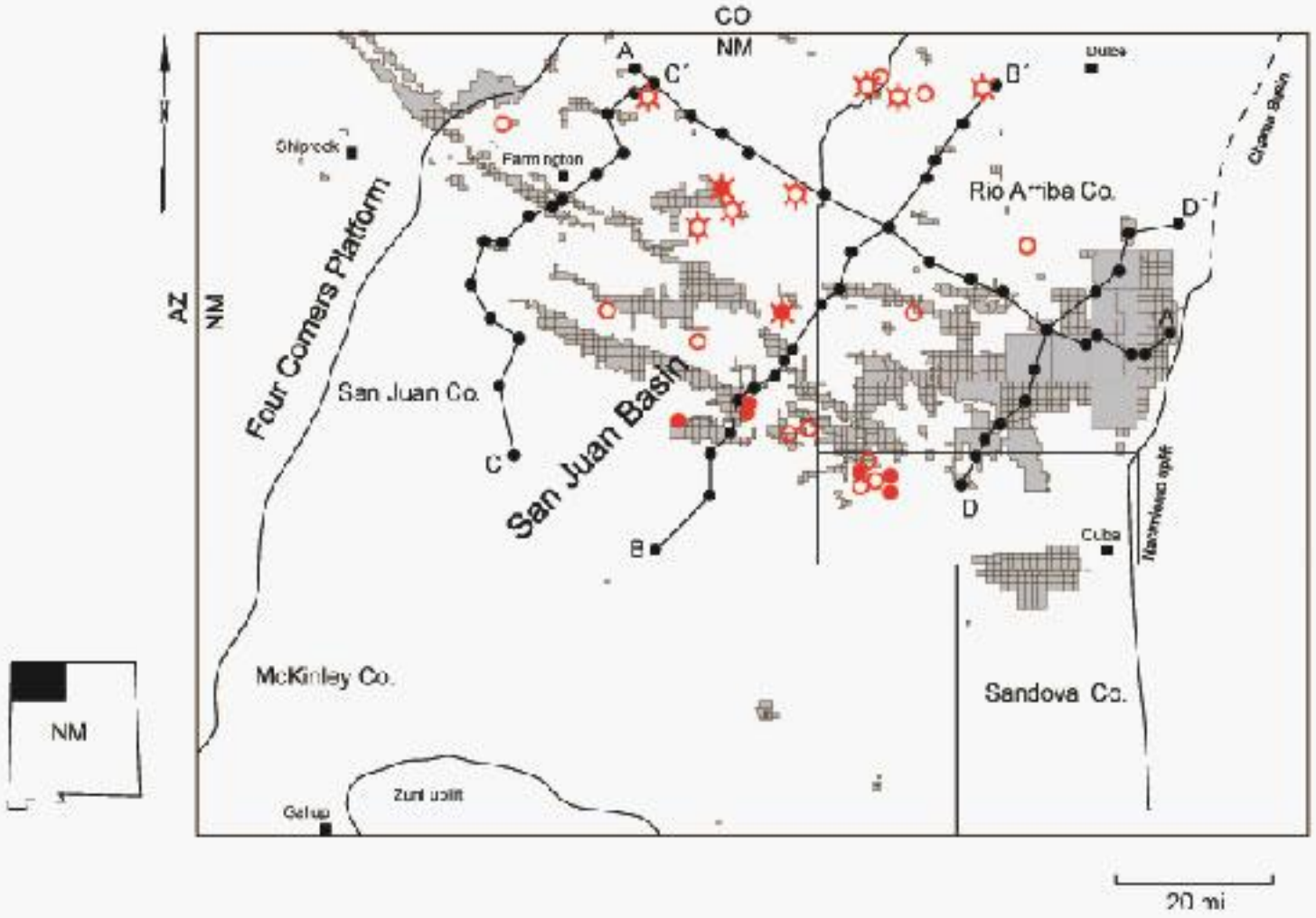
Older “traditional” marine bar reservoir
Lybrook pool



New “offshore” horizontal targets

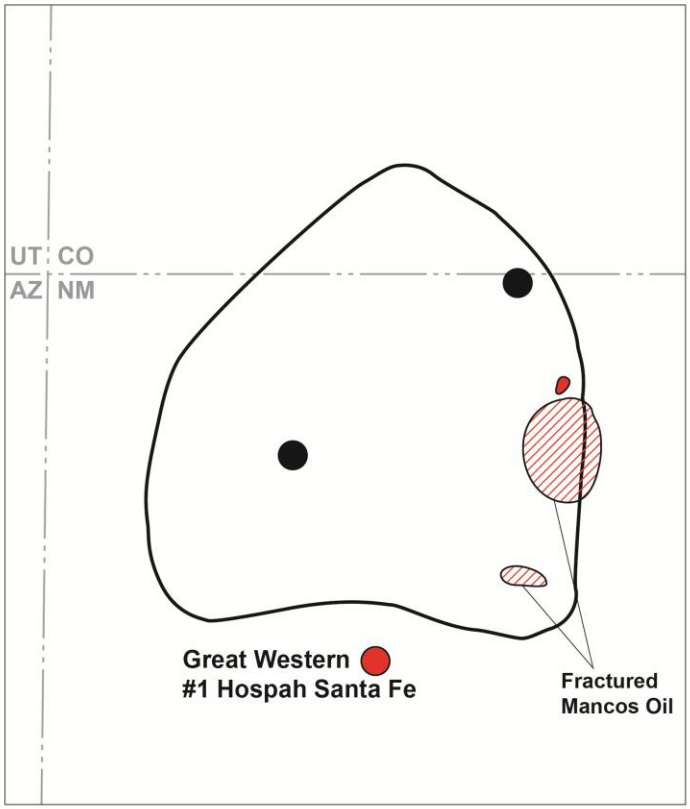


Recent Mancos Shale exploratory wells

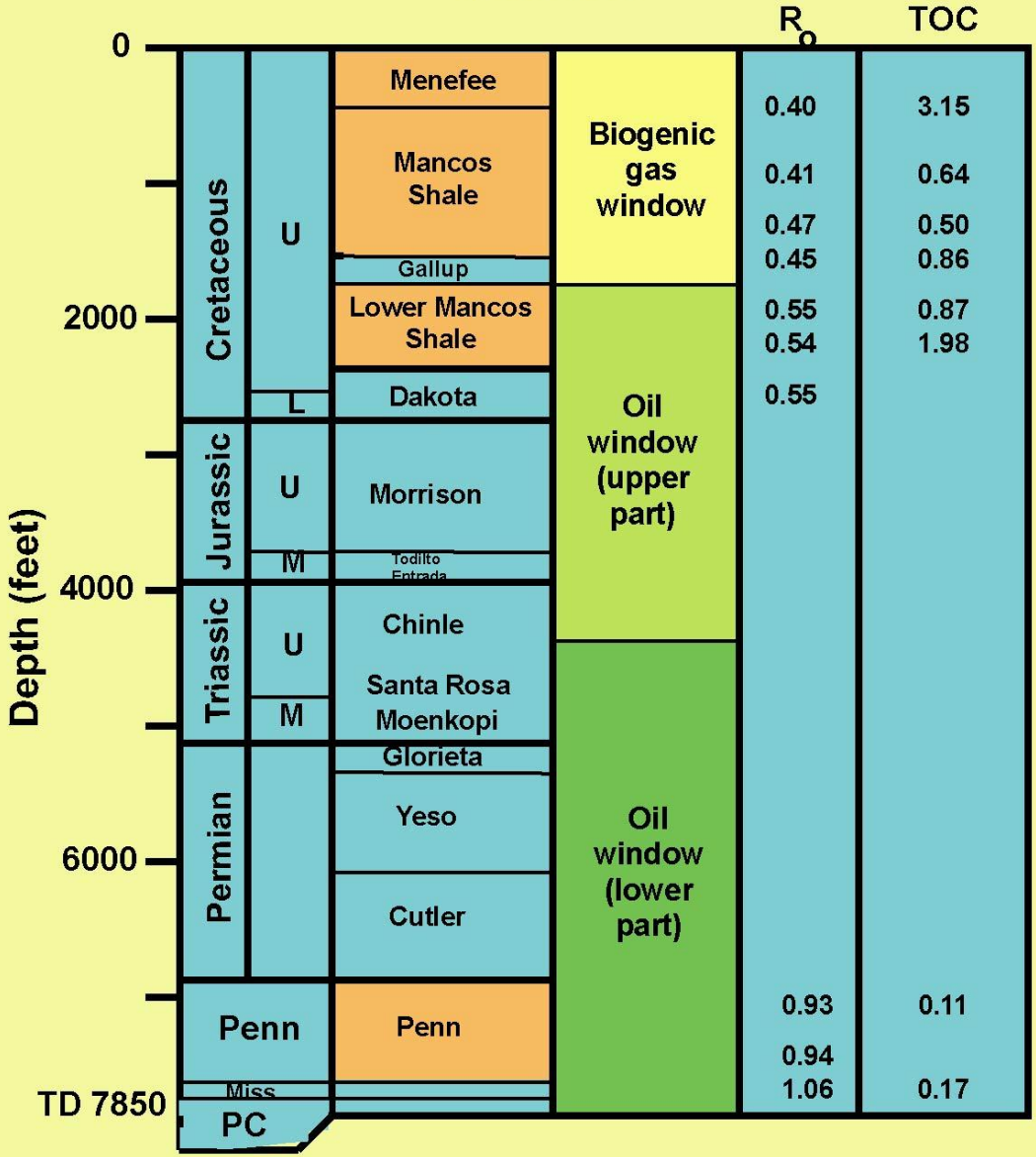


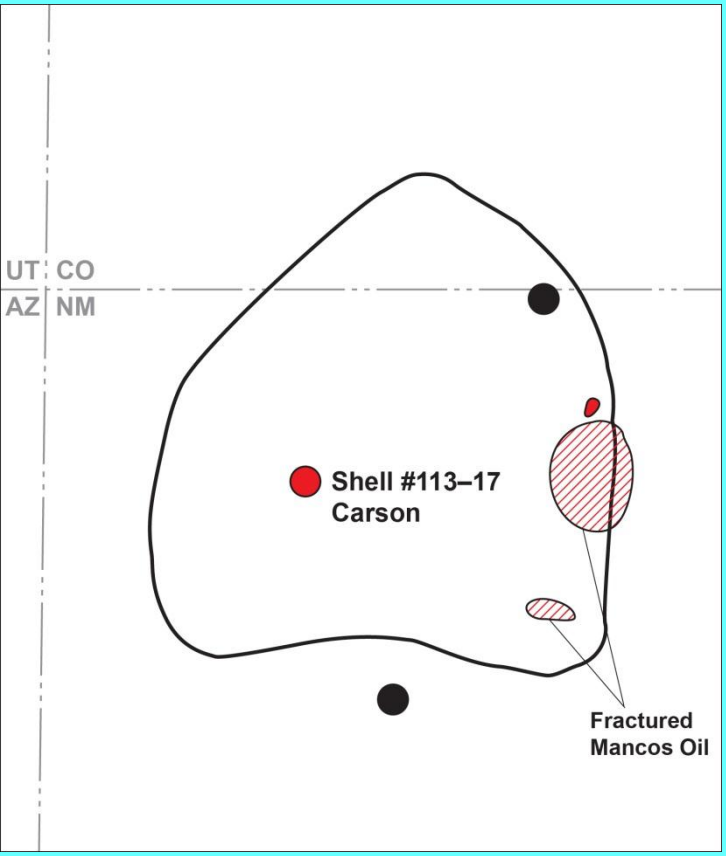
Hydrocarbon source rocks

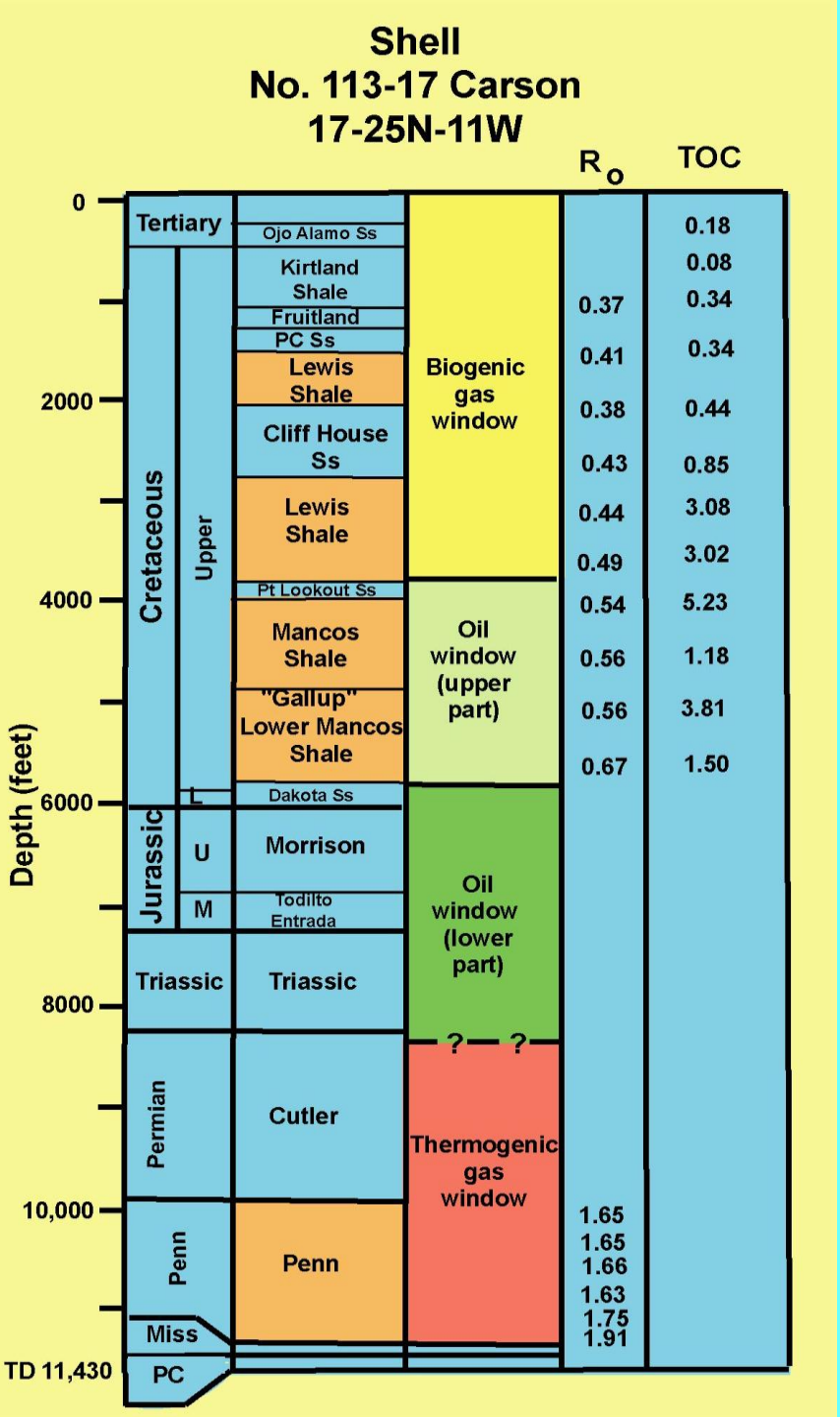
- Mancos shales are organic-rich hydrocarbon source rocks
- Oil window in shallow, southern part of basin
- Thermogenic gas window in deeper northern part of basin
- Maturation influenced by depth and proximity to Tertiary San Juan volcanic field of southern Colorado

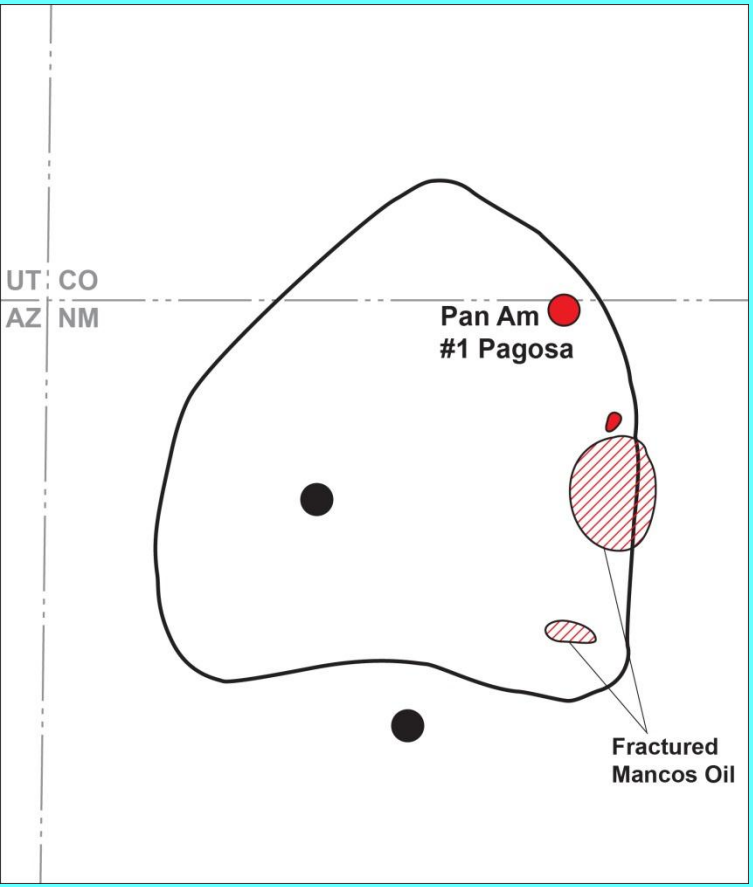


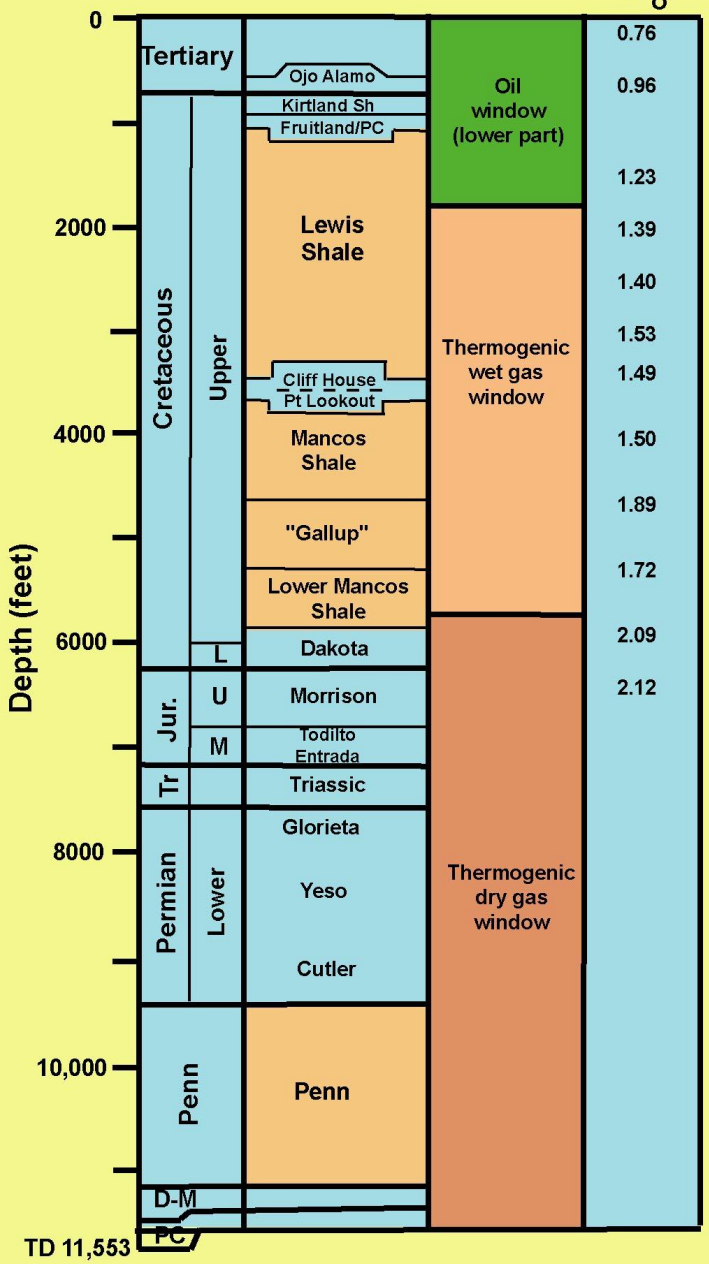
Great Western
No. 1 Hospah Santa Fe
1-17N-9W



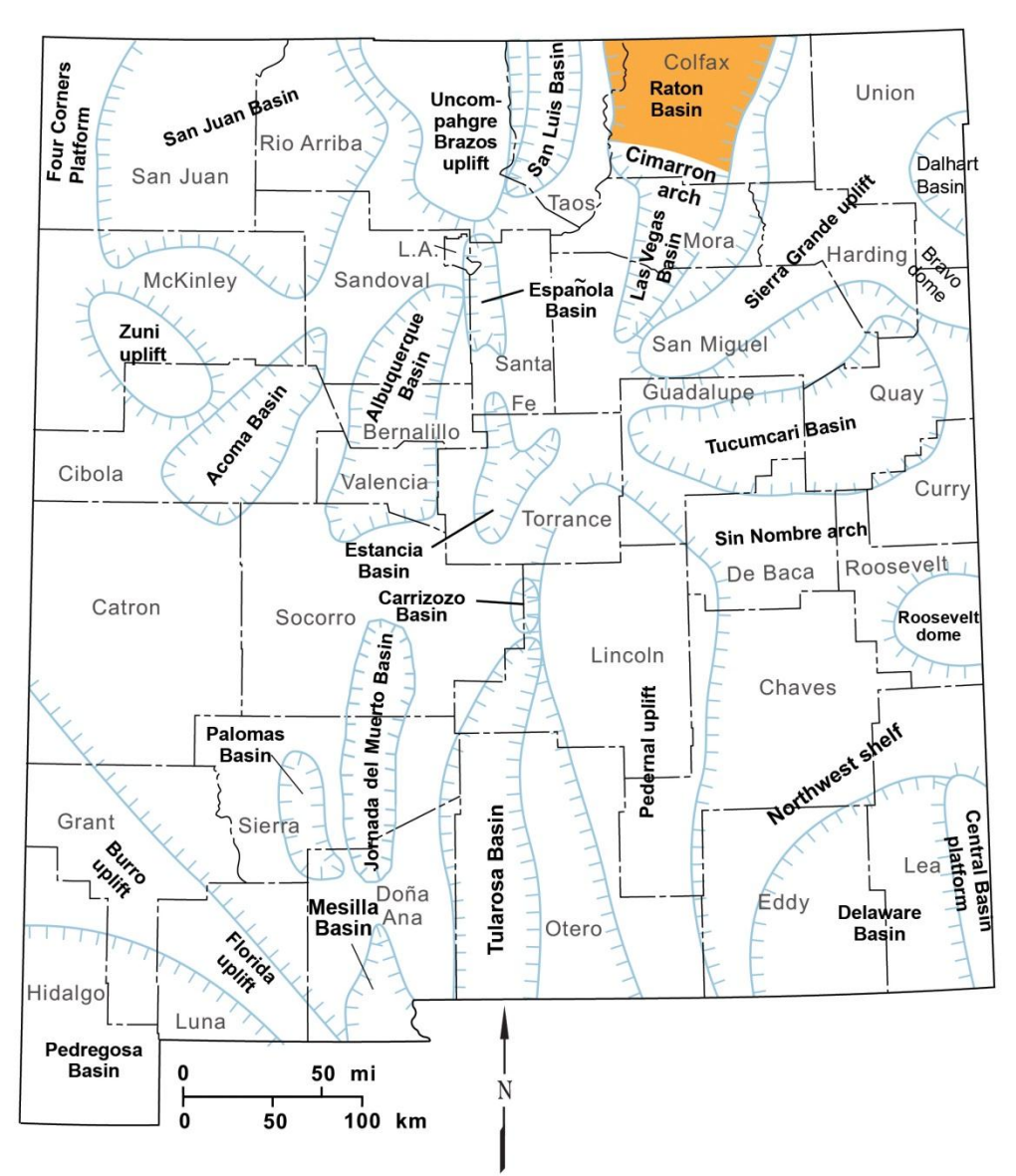

UT CO
AZ NM
Shell #113–17
Carson
Fractured
Mancos Oil

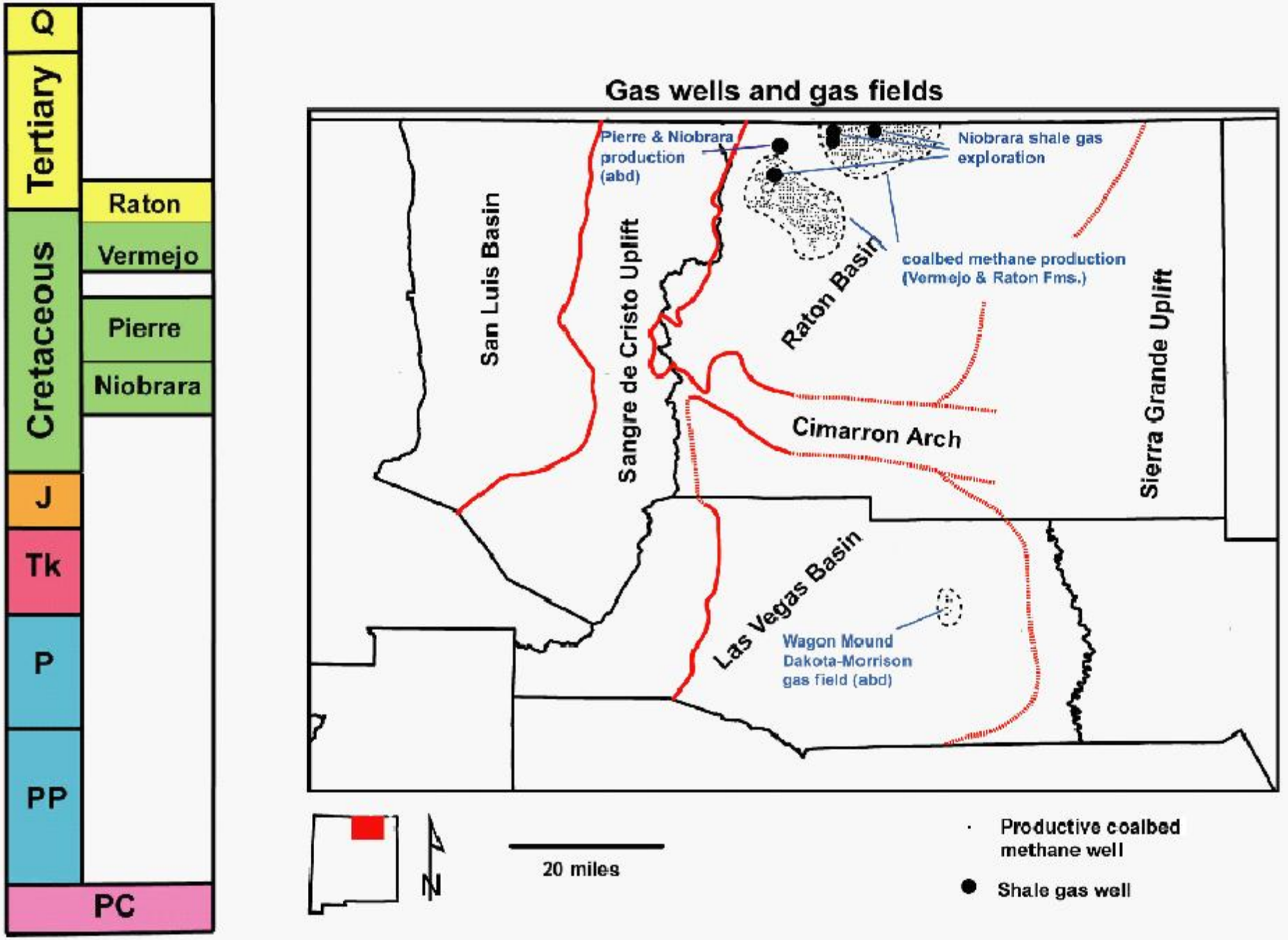

Shell
No. 113-17 Carson
17-25N-11W
Ro
TOC
Depth (feet)
0
2000
4000
6000
8000
10,000
TD 11,430
Tertiary
Ojo Alamo Ss
Kirtland Shale
Fruitland
PC Ss
Lewis Shale
Cliff House Ss
Lewis Shale
Pt Lookout Ss
Mancos Shale
"Gallup"
Lower Mancos Shale
Dakota Ss
Cretaceous
Upper
L
Jurassic
U
Morrison
M
Todilto
Entrada
Triassic
Triassic
Permian
Cutler
Penn
Penn
Miss
PC
Biogenic gas window
Oil window (upper part)
Oil window (lower part)
? ?
Thermogenic gas window
0.37
0.41
0.38
0.43
0.44
0.49
0.54
0.56
0.56
0.67
1.65
1.65
1.66
1.63
1.75
1.91
0.18
0.08
0.34
0.34
0.44
0.85
3.08
3.02
5.23
1.18
3.81
1.50

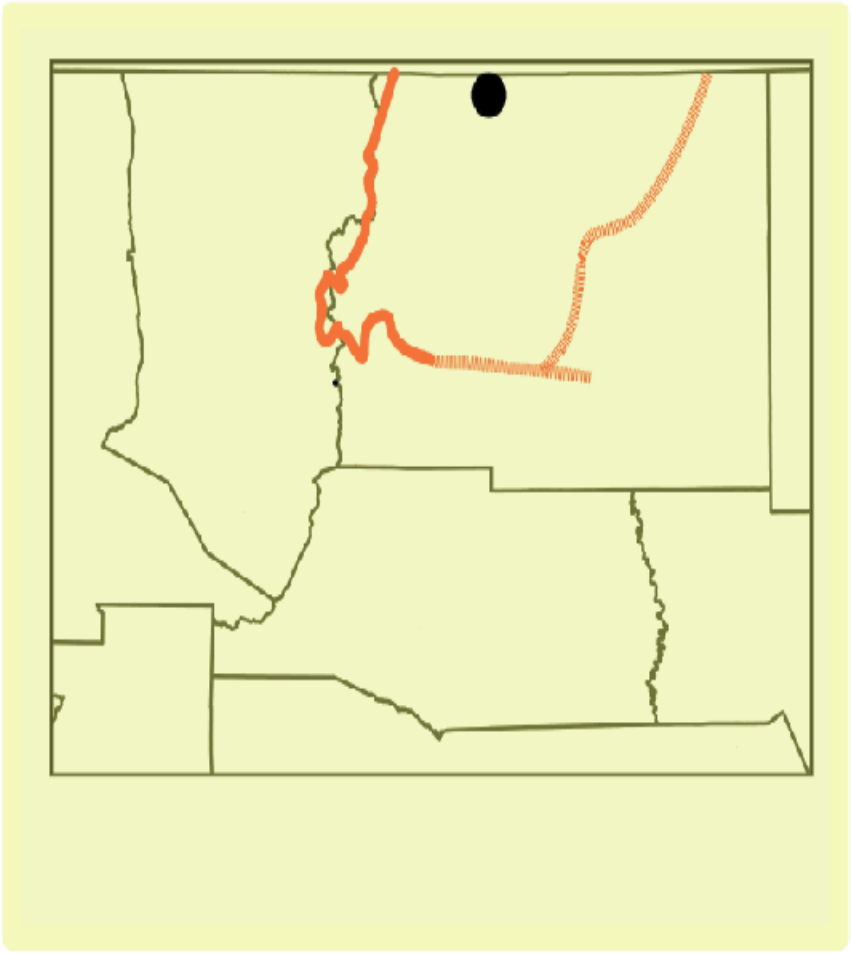

UT CO
AZ NM
Pan Am
#1 Pagosa
Fractured
Mancos Oil


Pan American
No. 1 Pagosa Jicarilla
23-32N-3W
R_o
Depth (feet)
0
2000
4000
6000
8000
10,000
TD 11,553
Tertiary
Ojo Alamo
Kirtland Sh
Fruitland/PC
Lewis Shale
Cliff House
Pt Lookout
Mancos Shale
"Gallup"
Lower Mancos Shale
Dakota
Morrison
Todilto
Entrada
Triassic
Glorieta
Yeso
Cutler
Penn
D-M
PC
Cretaceous
Upper
L
Jur.
U
M
Tr
Permian
Lower
Penn
Oil window (lower part)
Thermogenic wet gas window
Thermogenic dry gas window
0.76
0.96
1.23
1.39
1.40
1.53
1.49
1.50
1.89
1.72
2.09
2.12

Raton Basin


Four Corners Platform
San Juan Basin
San Juan
Rio Arriba
Uncom-pahgre Brazos uplift
San Luis Basin
Colfax
Raton Basin
Union
Cimarron arch
Dalhart Basin
Taos
Las Vegas Basin
Mora
Sierra Grande uplift
Harding
Bravo dome
L.A.
McKinley
Sandoval
Española Basin
Zuni uplift
Albuquerque Basin
Santa Fe
San Miguel
Guadalupe
Quay
Tucumcari Basin
Acoma Basin
Bernalillo
Cibola
Valencia
Torrance
Curry
Sin Nombre arch
Estancia Basin
De Baca
Roosevelt
Carrizozo Basin
Catron
Socorro
Roosevelt dome
Lincoln
Chaves
Jornada del Muerto Basin
Palomas Basin
Pedernal uplift
Northwest shelf
Grant
Sierra
Burro uplift
Tularosa Basin
Central Basin platform
Lea
Doña Ana
Mesilla Basin
Eddy
Delaware Basin
Florida uplift
Otero
Hidalgo
Luna
Pedregosa Basin
0 50 mi
0 50 100 km
N

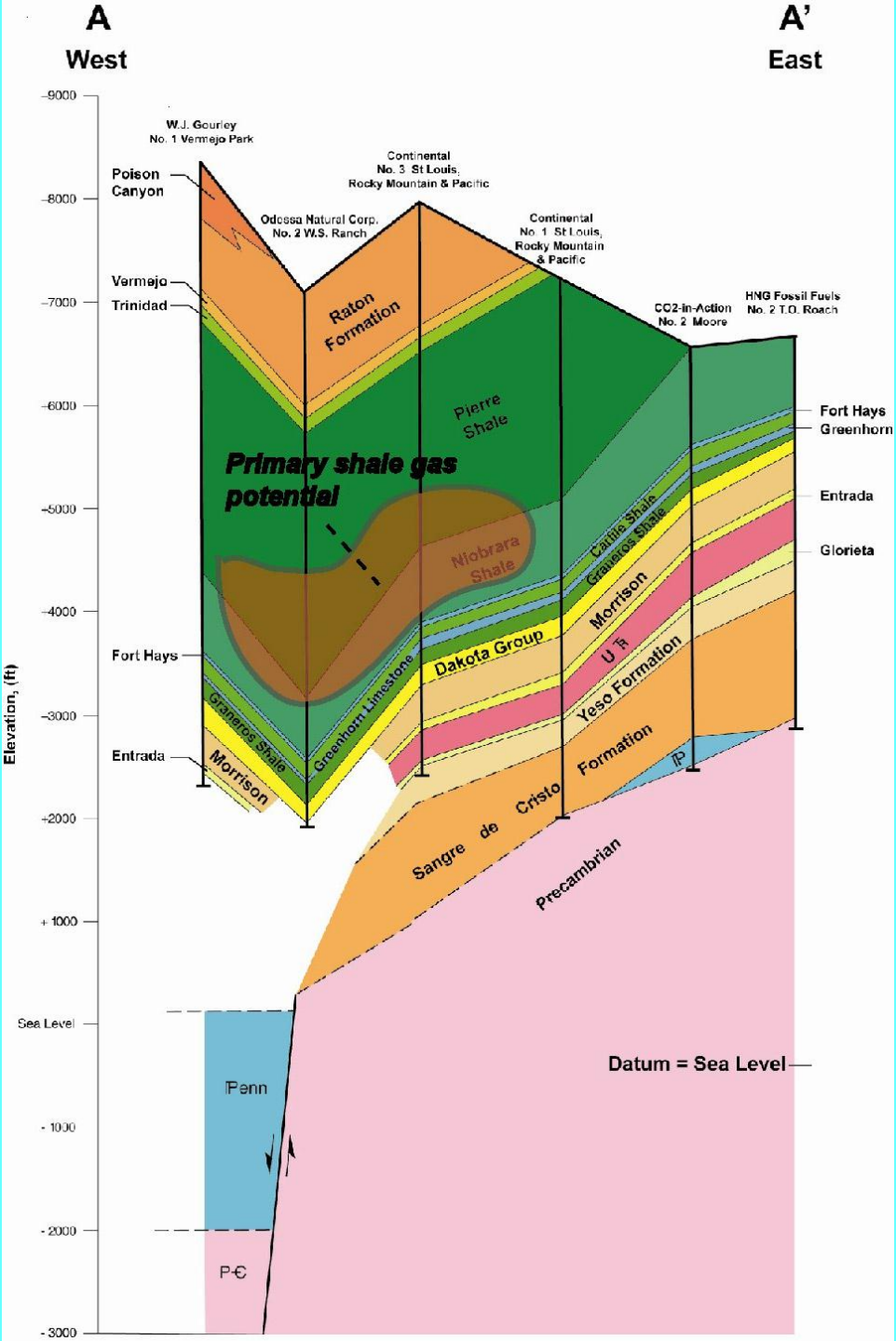

Q
Tertiary
Cretaceous
Raton
Vermejo
Pierre
Niobrara
J
Tk
P
PP
PC
Gas wells and gas fields
Pierre & Niobrara production (abd)
Niobrara shale gas exploration
coalbed methane production (Vermejo & Raton Fms.)
San Luis Basin
Sangre de Cristo Uplift
Raton Basin
Cimarron Arch
Sierra Grande Uplift
Las Vegas Basin
Wagon Mound Dakota-Morrison gas field (abd)
N
20 miles
Productive coalbed methane well
Shale gas well

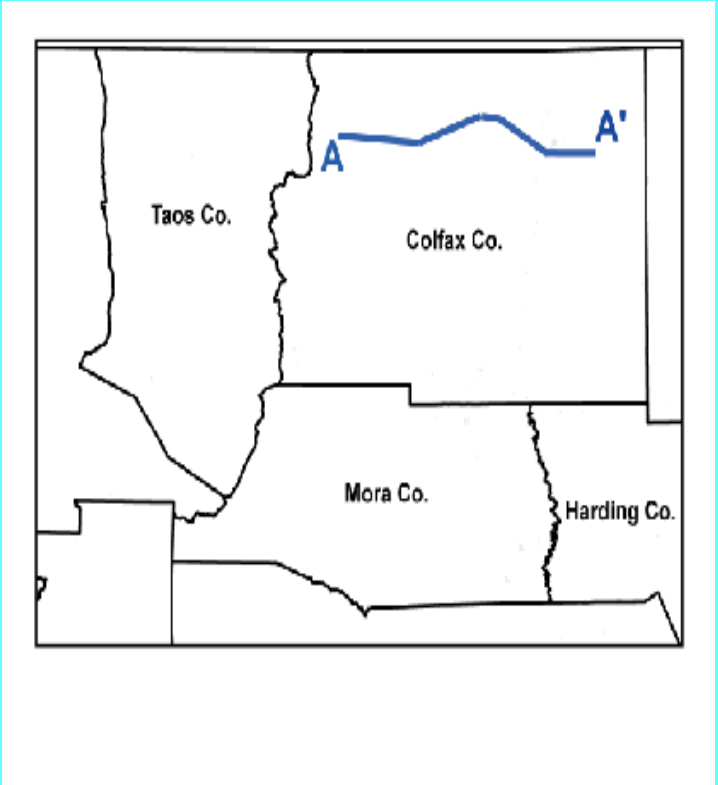


El Paso Natural Gas
No. 7 WDW VPR A
Sec. 1 T31N R19E

Depth (feet)					R_o	TOC	AOM Conversion
0	Tertiary	Paleocene	Poison Canyon Fm.	oil window (lower part)			
1000			Raton Fm.				
2000			Vermejo Fm.	wet gas + dry gas window			
			Trinidad Ss.				
3000	Cretaceous	Upper	Pierre Shale		1.55	0.93	83%
4000							
5000				dry gas window			
			Niobrara Shale		2.30	1.36	92%
6000		Lower	Carlile Sh.	Ft Hays Ls	2.39	1.10	94%
			Graneros Sh.	Greenhorn Ls.	2.42	1.14	92%
			Dakota Ss.				
	Jur.	U	Morrison Fm.				
		M		Entrada Ss.			
	Tr.	U	Chinle Gp.				
			Santa Rosa Ss.	Glorieta Ss.			
TD 7467	Perm	L					

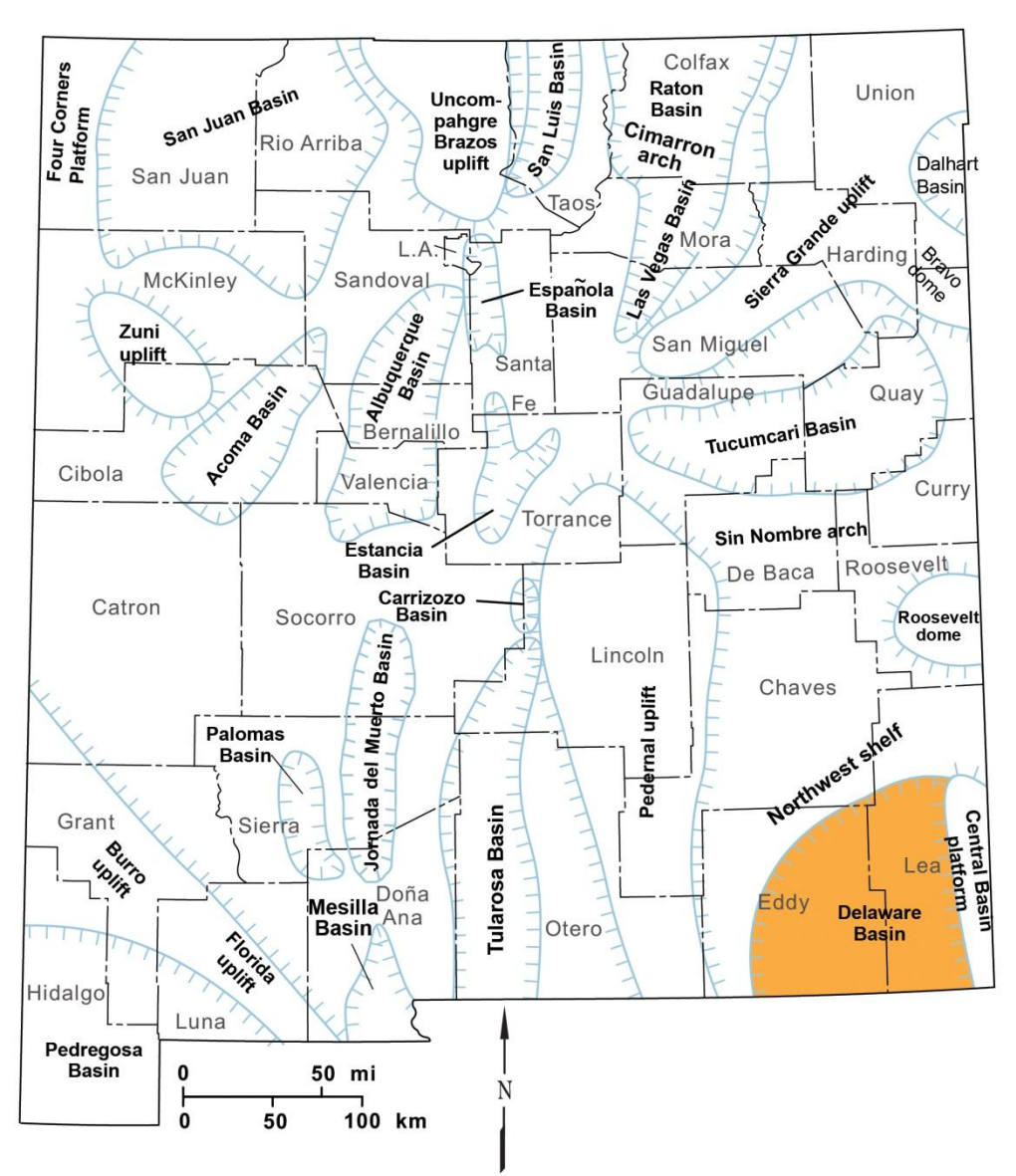
From Broadhead (2008)



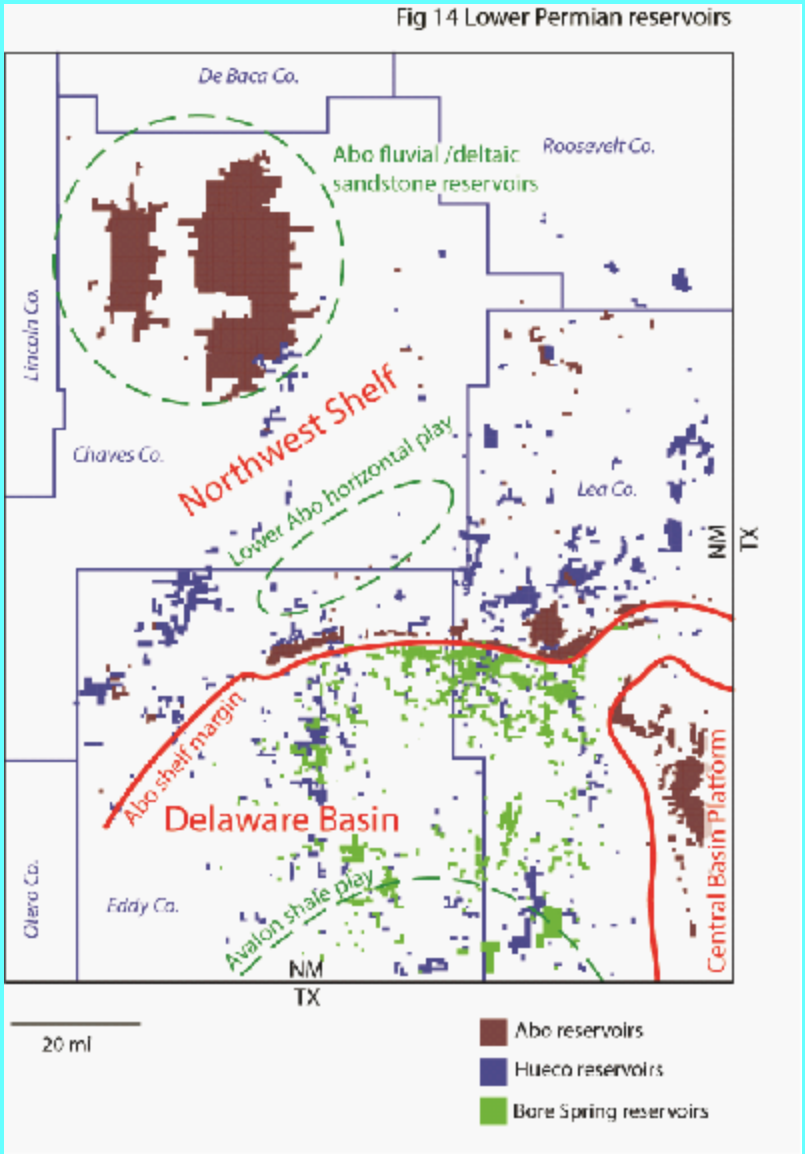


Modified from Broadhead (2010)

Permian Basin



Bone Spring Formation (Lower Permian)



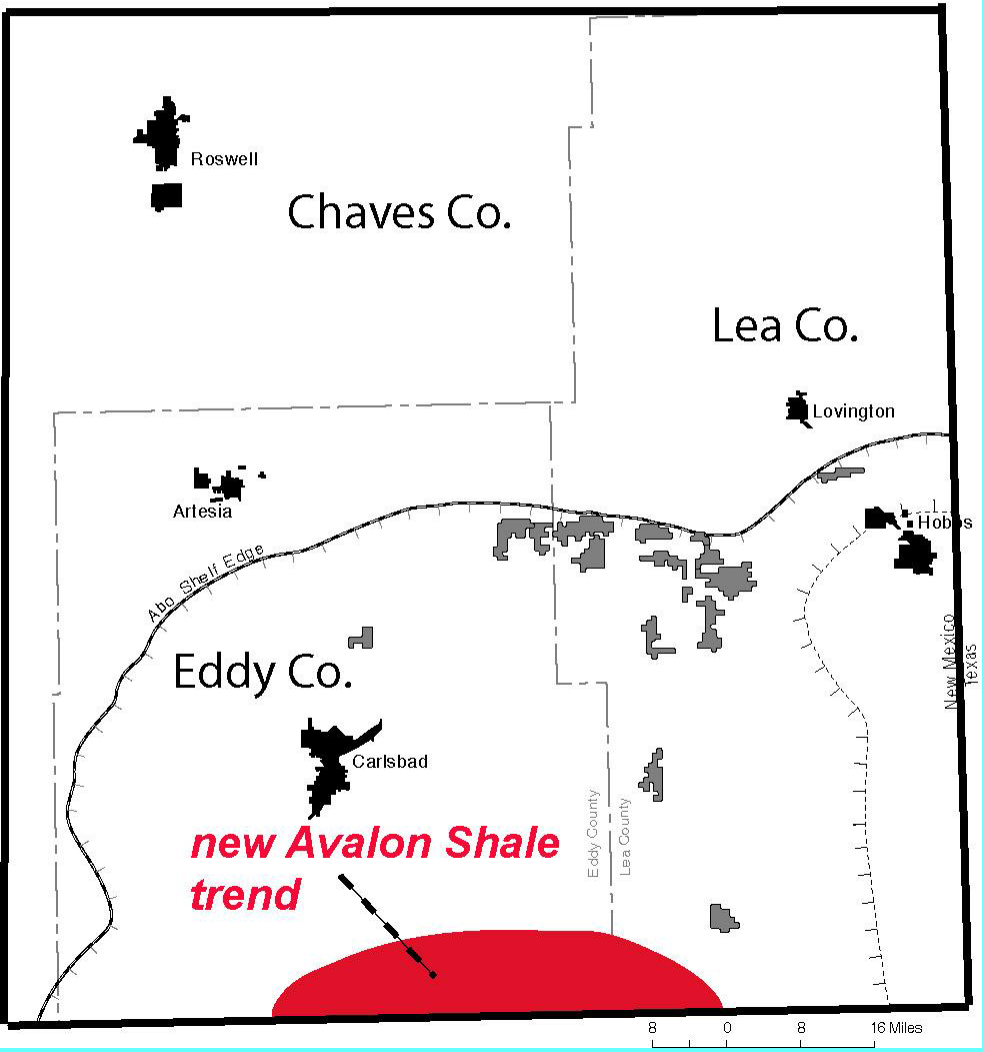
From Broadhead (in press)

Delaware Basin

Age		Strat	
Triassic		Chinle	
		Santa Rosa	
Permian	Ochoan	Dewey Lake	
		Rustler	
		Salado	
	Guadalupian	Delaware Mountain Group	Bell Canyon
			Cherry Canyon
			Brushy Canyon
	Leonardian	Bone Spring	
	Wolfcampian		
		"Wolfcamp"	
Pennsylvanian	Virgilian	Cisco	
	Missourian	Canyon	
	Des Moinesian	Strawn	
	Atokan	Atoka	
	Morrowan	Morrow	
Miss.	Upper	Barnett Shale	
	Lower	lower Miss lime	
Dev.	Upper	Woodford	
	Middle		
	Lower	Thirtyone	
Sil.	Upper	Wristen	
	Middle		
	Lower	Fusselman	
Ord.	Upper	Montoya	
	Middle	Simpson	
	Lower	Ellenburger	
Cambrian		Bliss	
Precambrian			

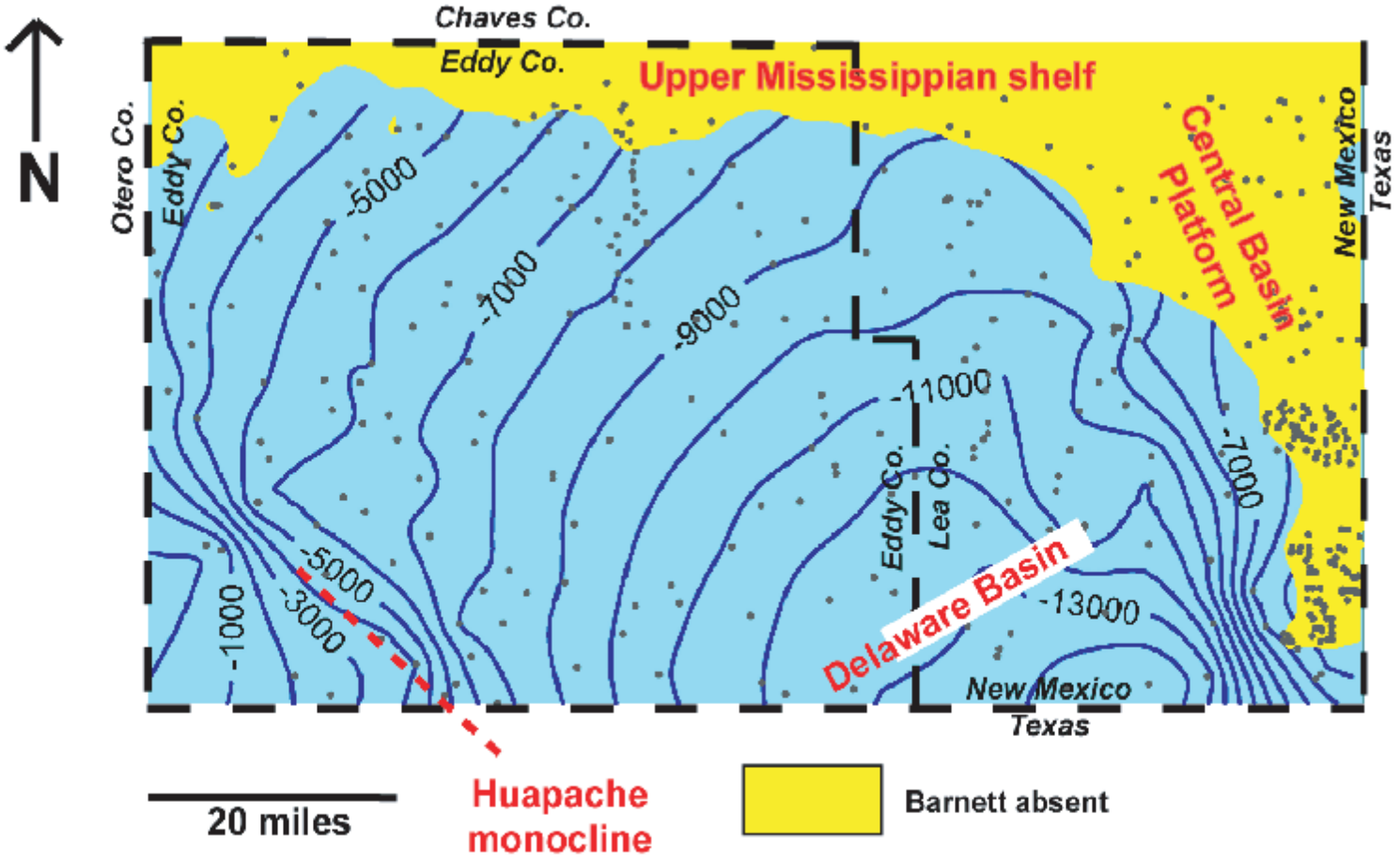
Bone Spring Formation (Lower Permian)

Bone Spring oil reservoirs



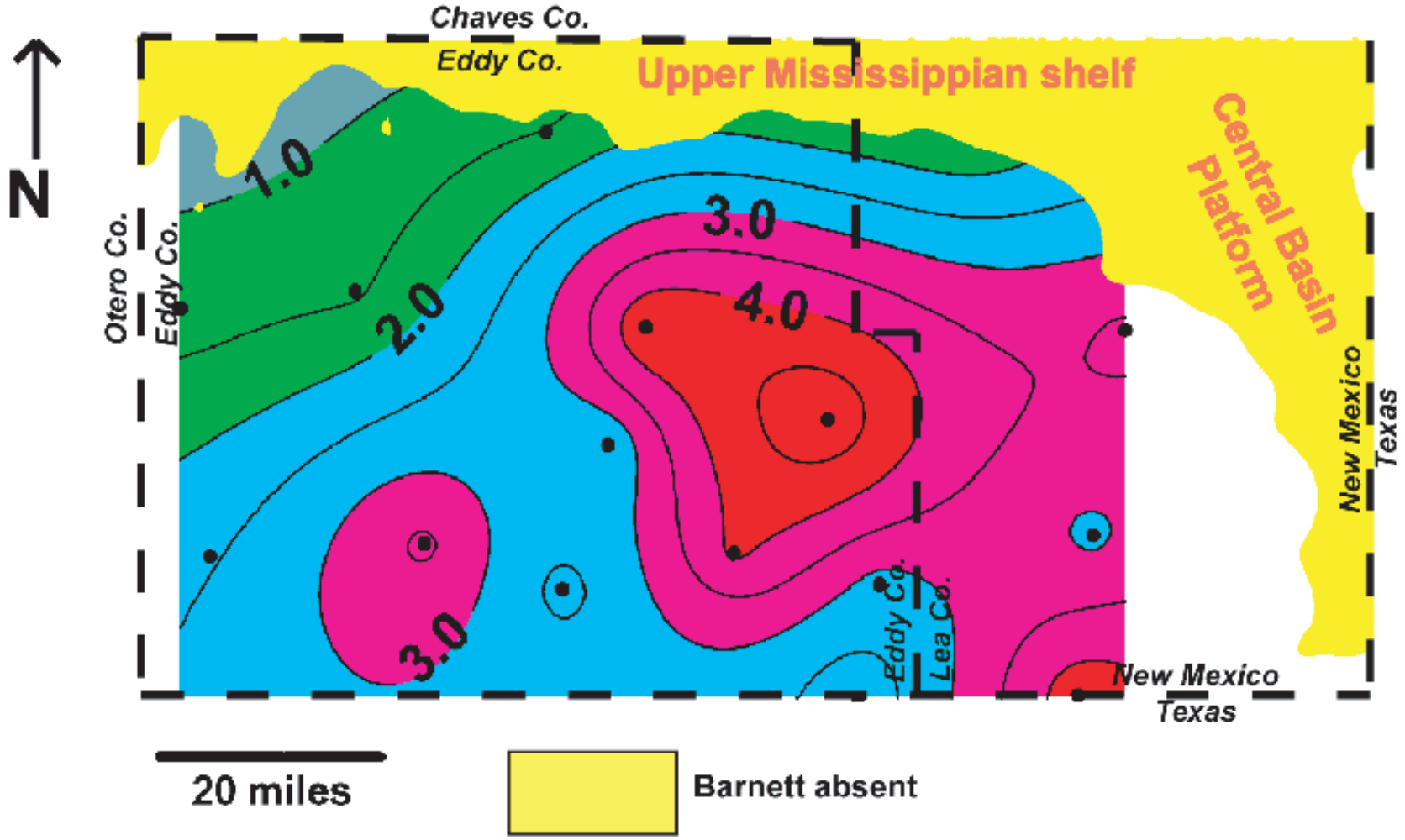
Geologic age		Delaware Basin strata		Northwest Shelf strata
Permian	Leonardian	Bone Spring Formation	1st carbonate	Glorieta Ss.
			1st sand	
			2nd carbonate	Yeso Formation
			2nd sand	
			3rd carbonate	
			3rd sand	
			lower carbonate	Abo Formation
	Wolfcampian	"Wolfcamp" (Hueco Fm.)		"Wolfcamp" (Hueco Fm.)

Barnett Shale (Upper Mississippian)

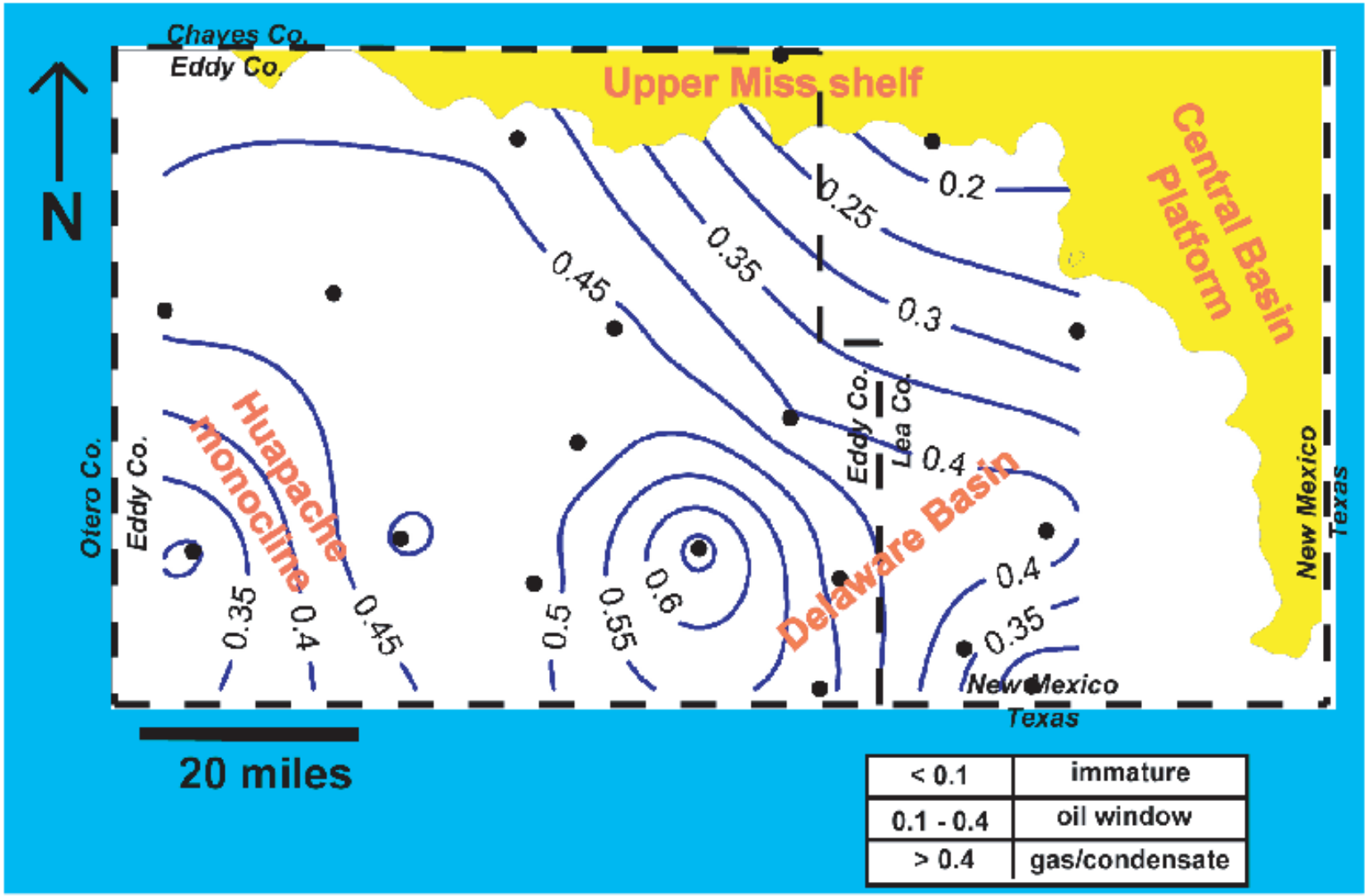


From Broadhead (2007)

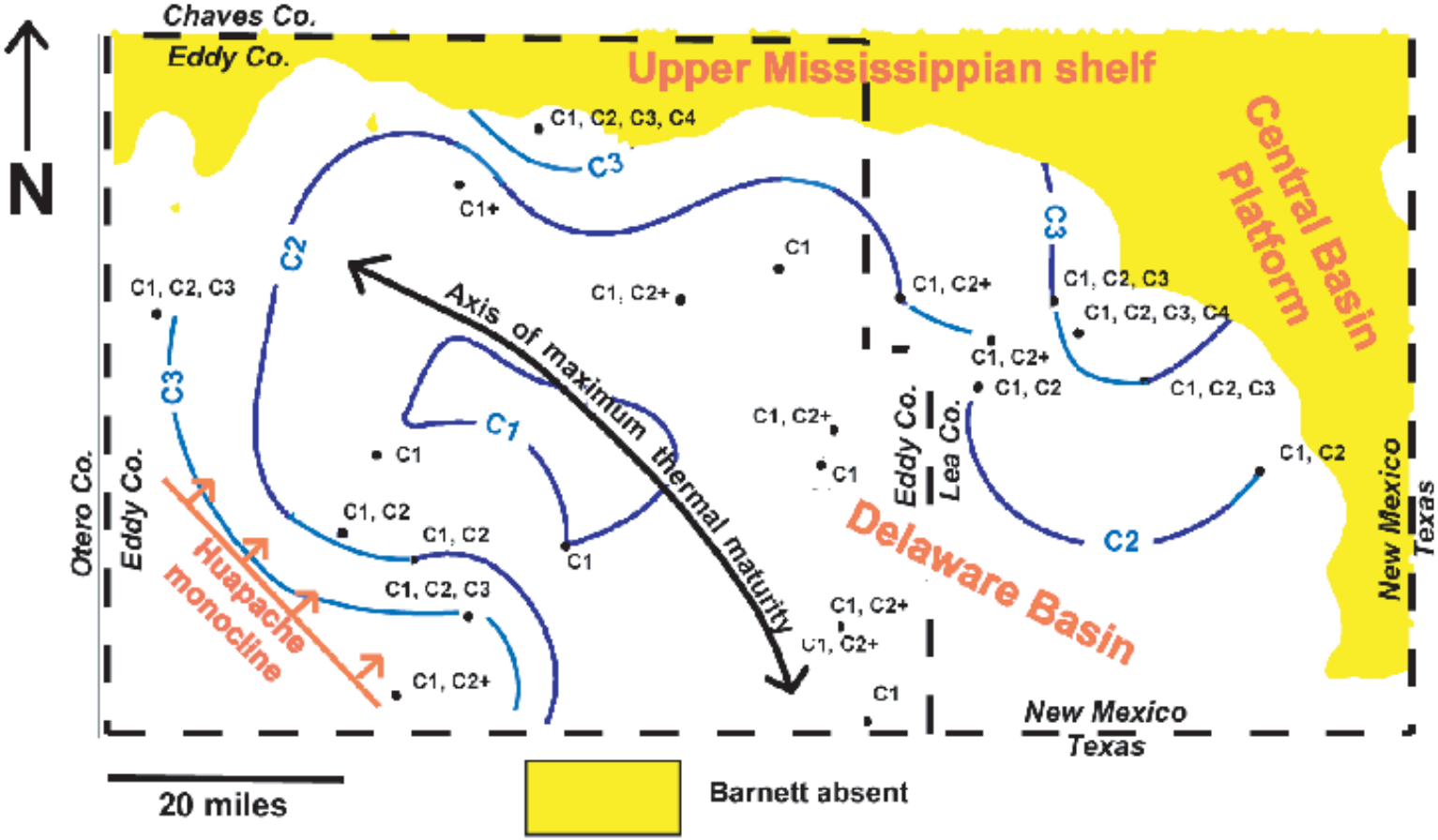
Barnett TOC



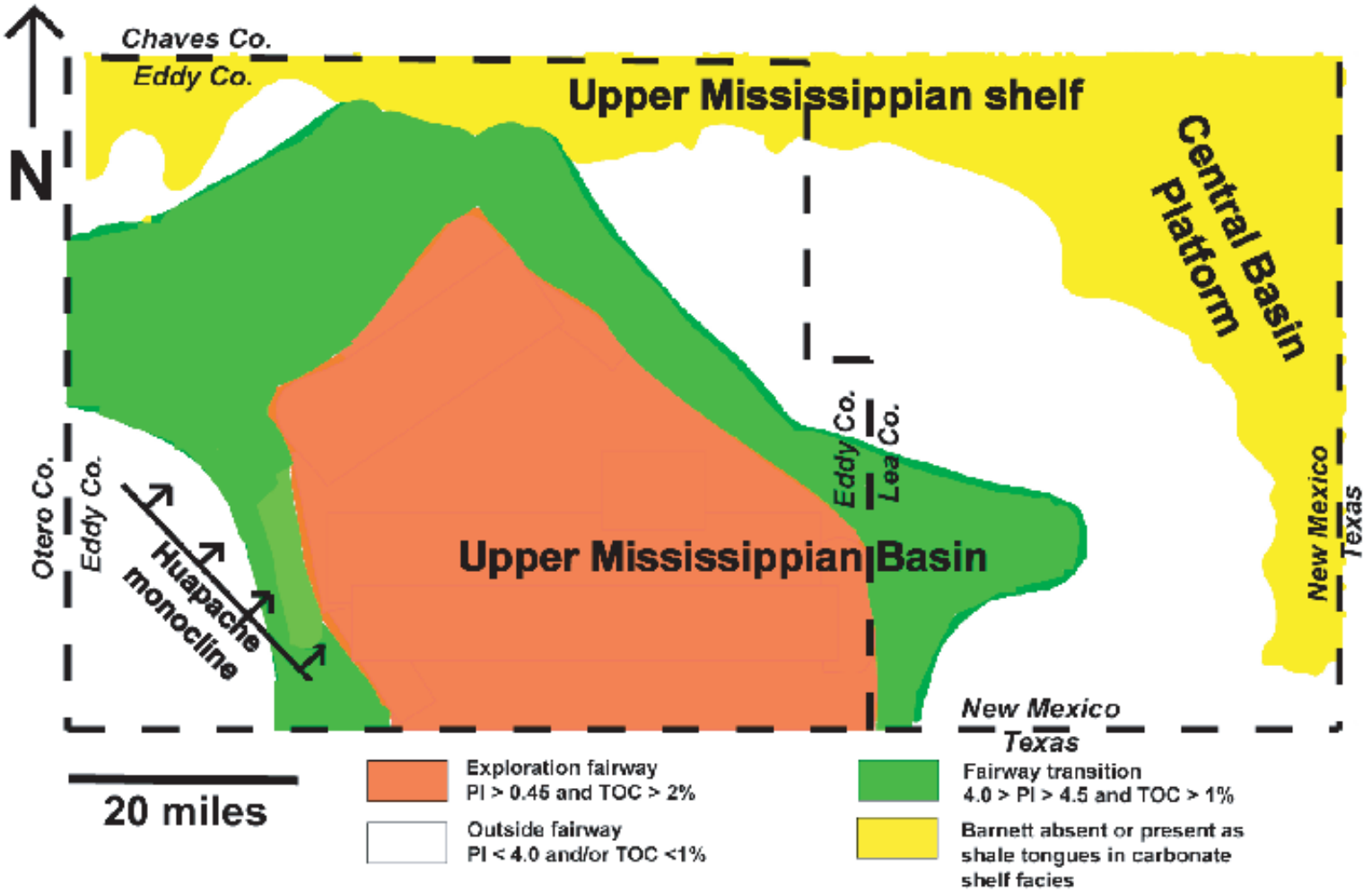
From Broadhead (2007)



After Broadhead and Gillard (2007)

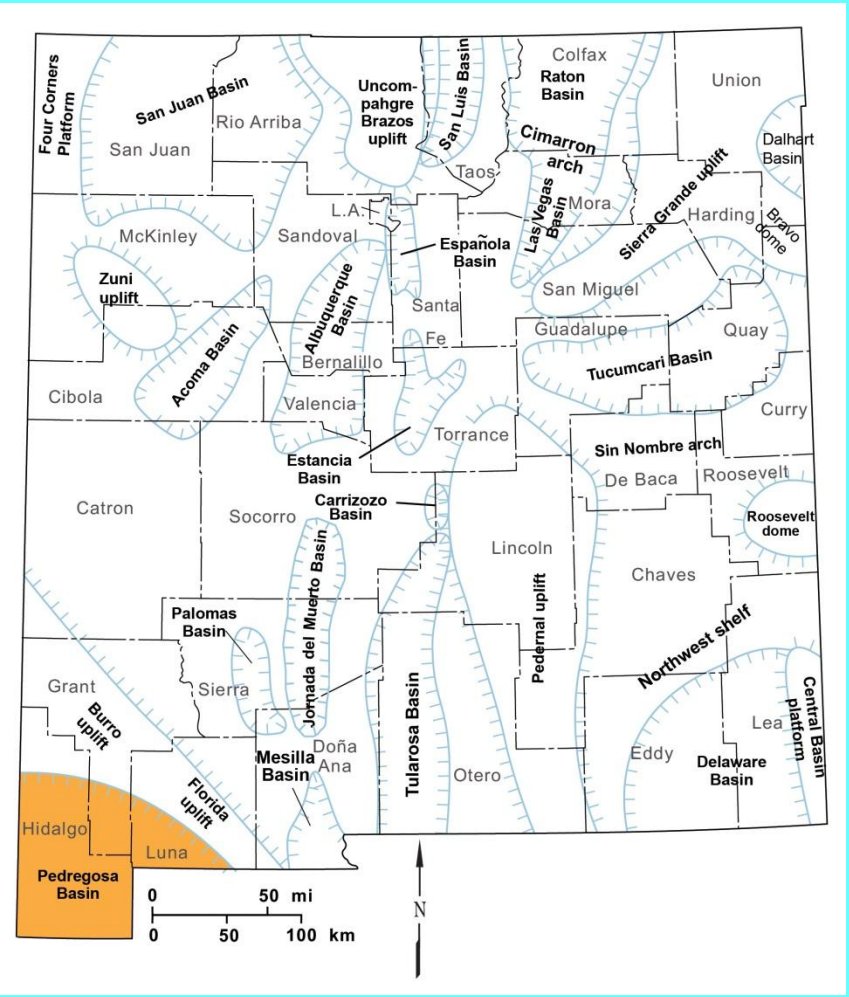


From Broadhead (2007)



From Broadhead (2007)

Pedregosa Basin

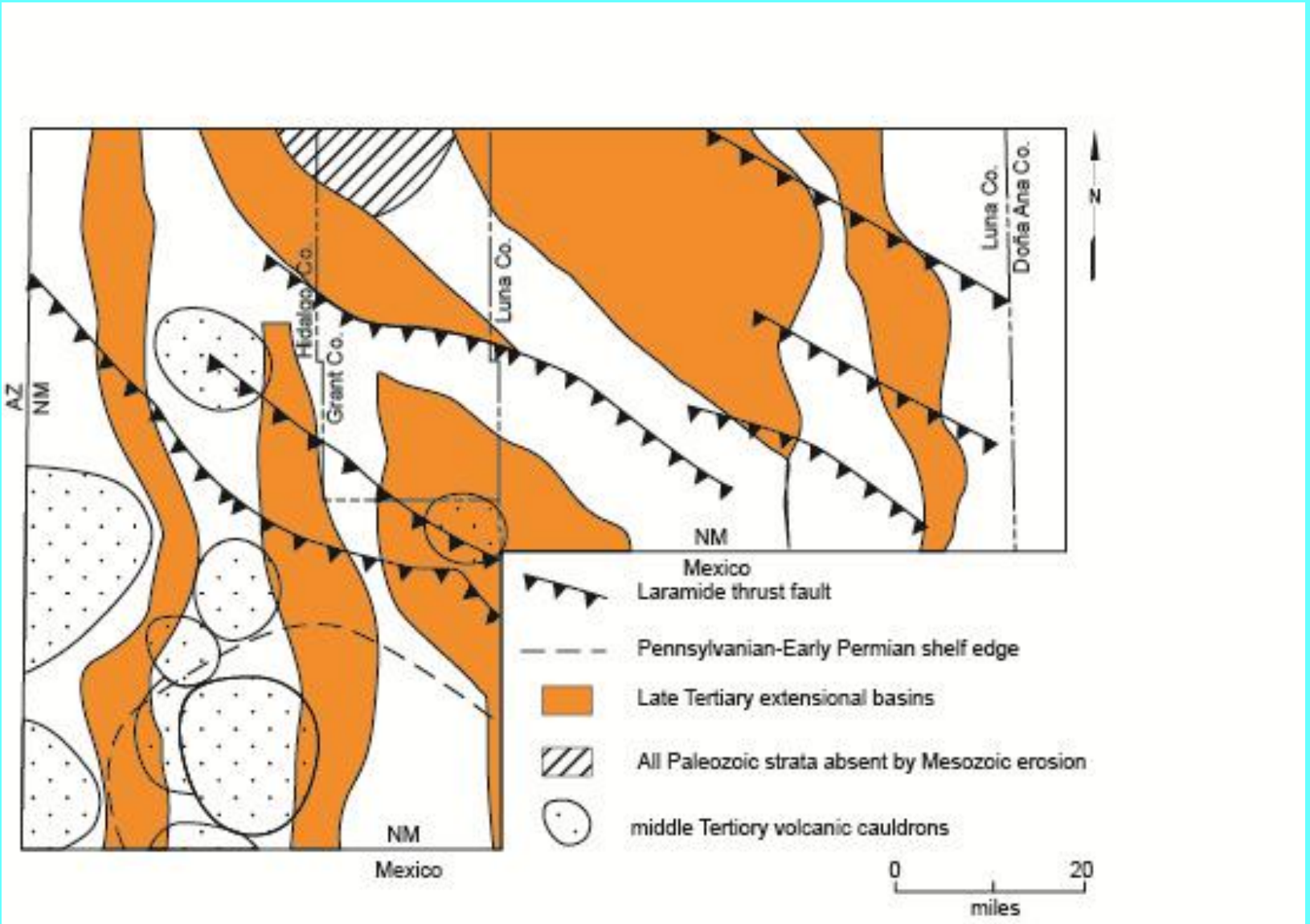


Tertiary		clastics, volcanics
Cretaceous	Lower	Mojado
		U-Bar
		Hell-to-Finish
Permian		Concha
		Scherrer
		Epitaph
		Colina
		Earp
Penn.		Horquilla
Miss.		Paradise
		Escabrosa
Dev.		Percha Shale
Ord.		Montoya
		El Paso
Cambrian		Bliss
PC		

500 - 6,000 ft deep

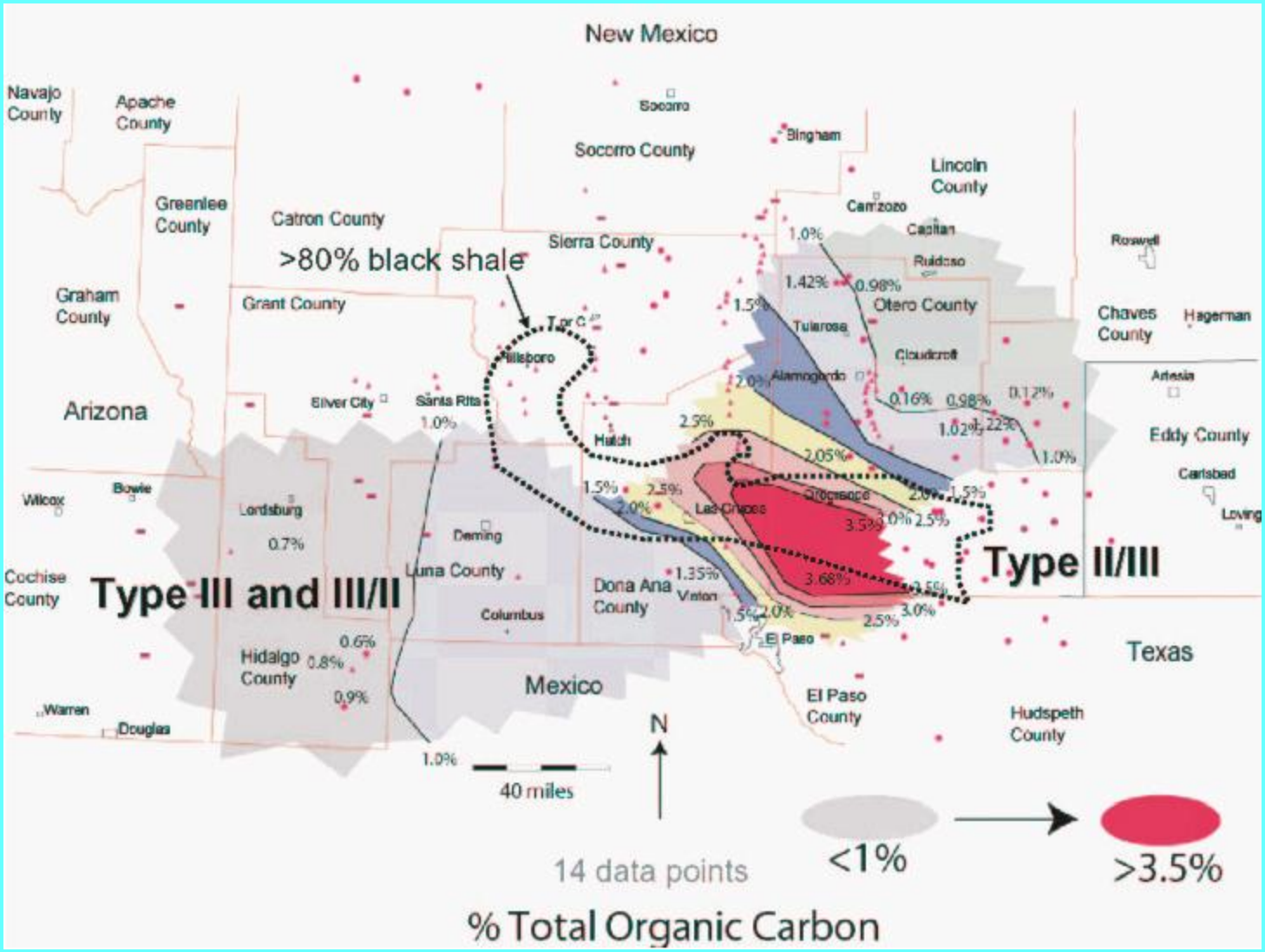
800 - 12,500 ft deep

Southwestern New Mexico – Multiple tectonic episodes
Exploration is not for the faint of heart!



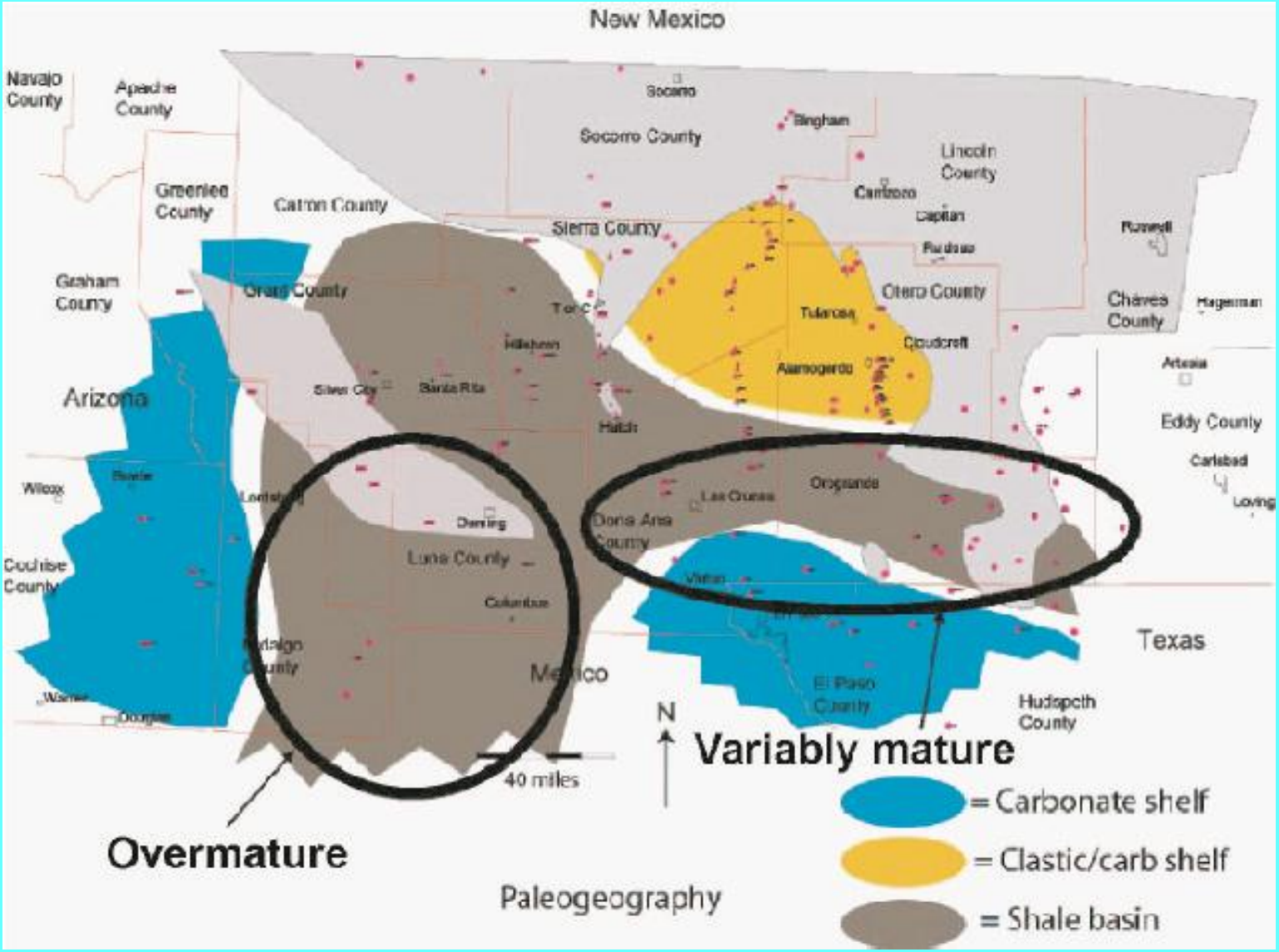
From Broadhead (in press)

Percha Shale Organic Richness



From Raatz (2005)

Percha Shale Thermal Maturity



From Raatz (2005)

Summary

- The San Juan Basin has produced low-volume gas from vertical wells in the Upper Cretaceous Lewis and Mancos Shales.
- Current efforts in the San Juan are aimed at pursuing oil from the Mancos Shale on the southern flank of the basin and gas in the northern part. Long-lateral horizontal wells with multi-stage artificial fracturing are essential.
- The Raton Basin has produced modest volumes of gas from the Upper Cretaceous from vertical wells in the Pierre and Niobrara Shales. These are in the thermogenic gas window in the deeper parts of the basin and in the oil window on the shallow basin flanks. Artificially fractured horizontal wells are a must.

Summary (cont'd)

- The Permian Basin has multiple targets for unconventional oil and unconventional gas. At the current forefront are the fine-grained clastics in the Bone Spring Formation. Other shales are intriguing, including the Mississippian Barnett Shale where thermal maturation trends are depth independent.
- There are also possibilities in non-productive frontier basins, including the Pedregosa Basin of southwestern New Mexico. The Devonian Percha Shale is in the gas window.

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