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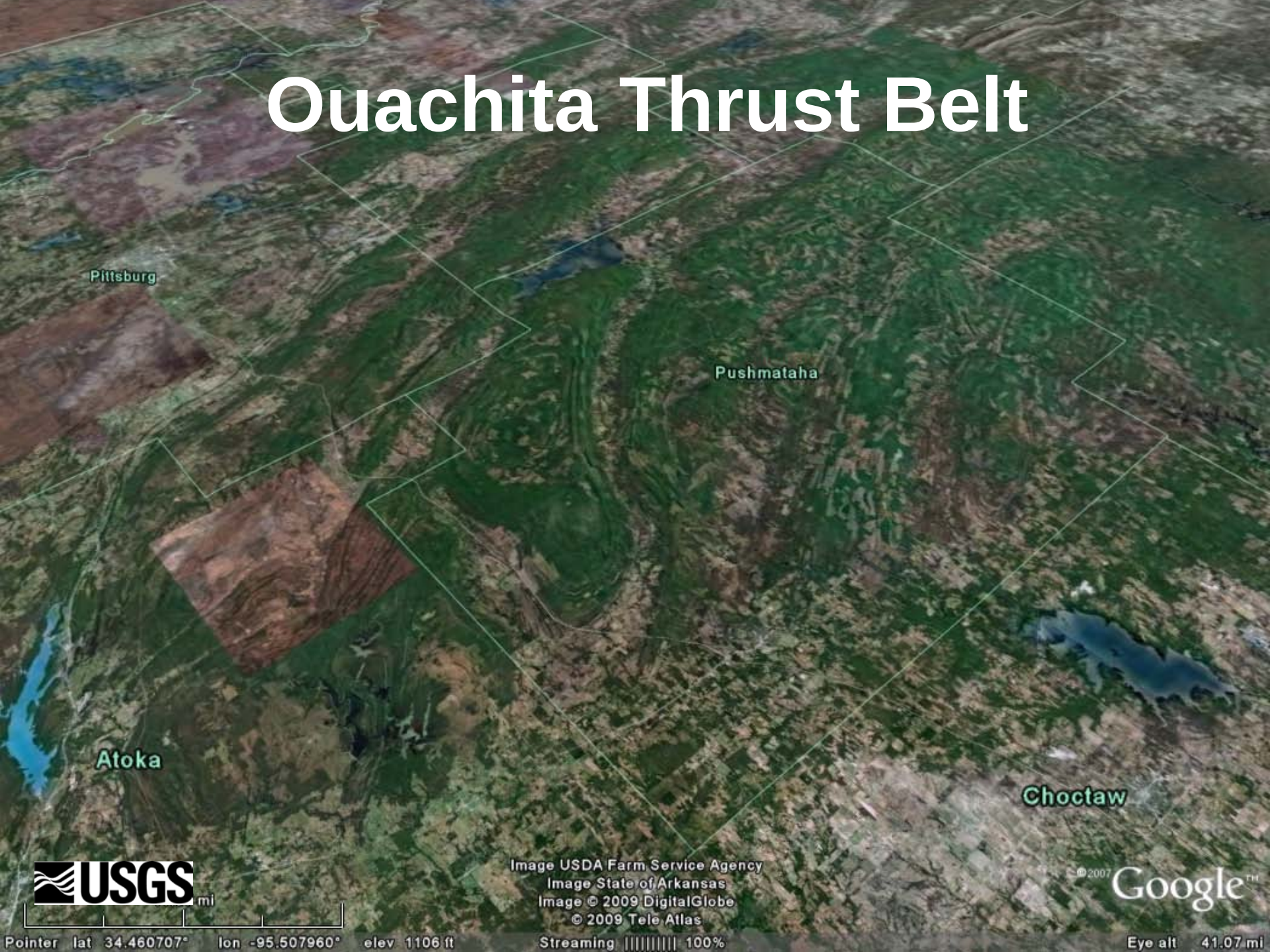
Review of Geology for a USGS Resource Assessment of Ouachita Thrust Belt, Post-Ouachita Successor Basins, and Reelfoot Rift

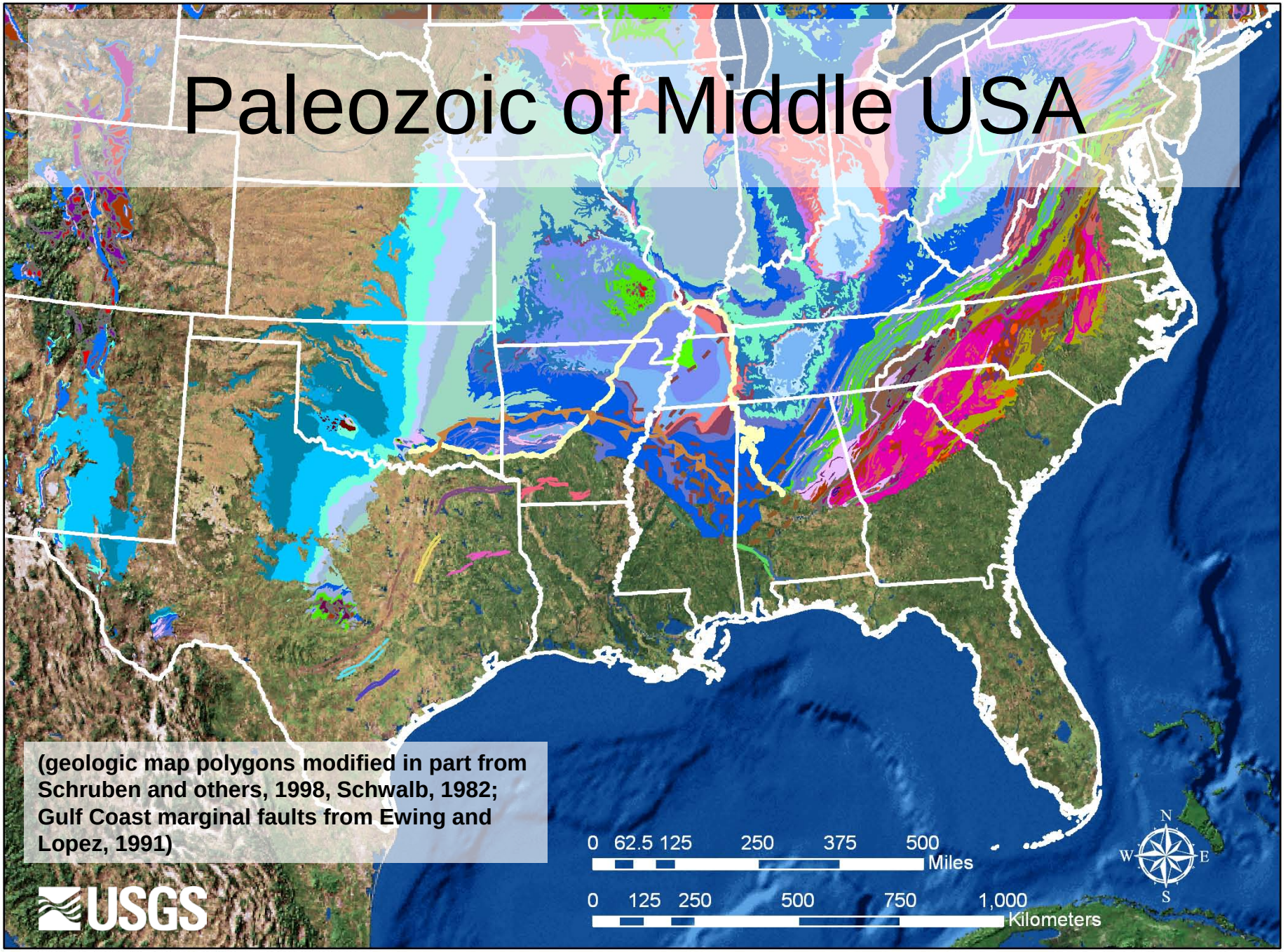
Potato Hills, Latimer & Pushmataha Cos., OK

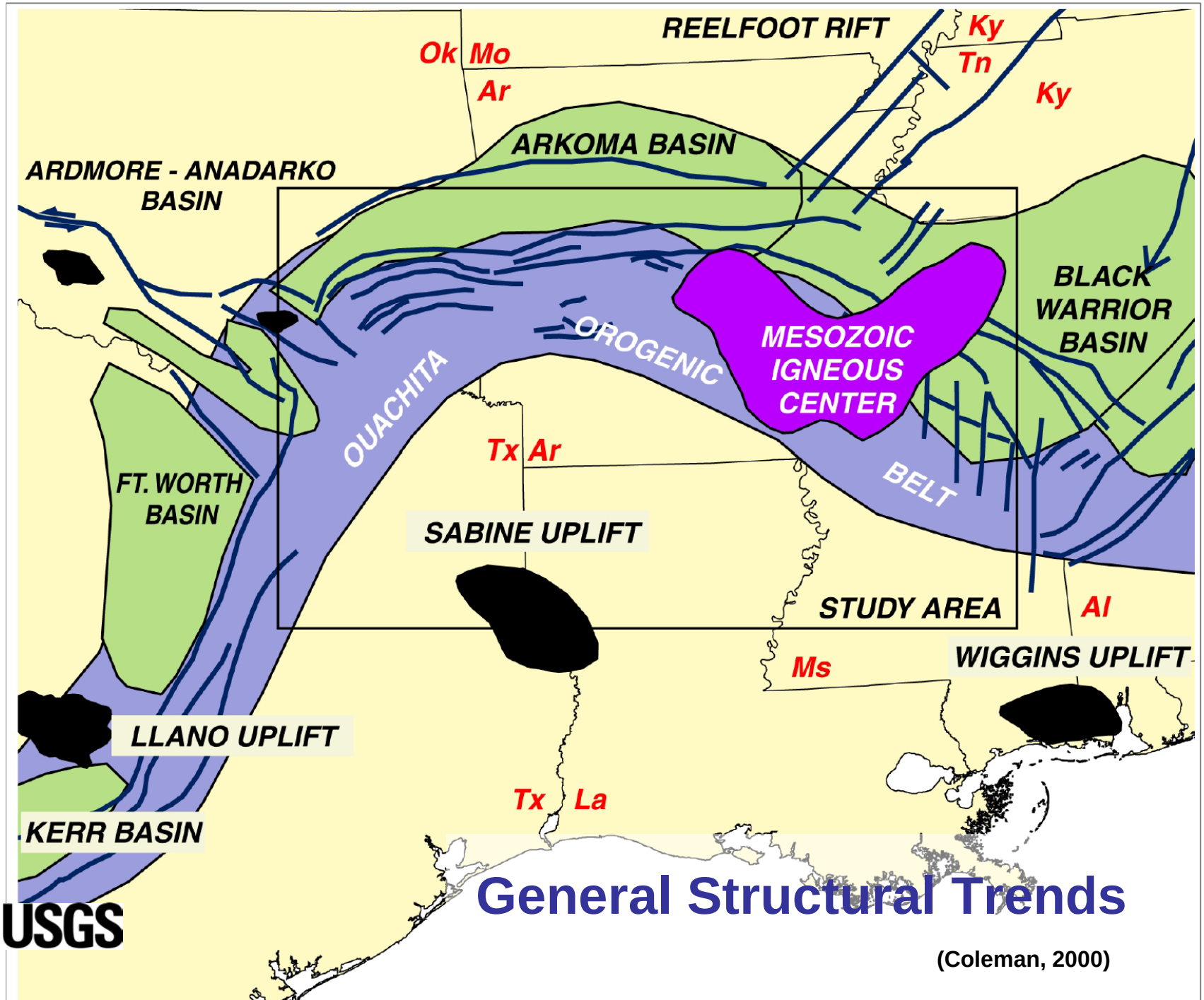
U.S. Department of the Interior
U.S. Geological Survey

James L. Coleman
Eastern Energy Resources Team
USGS, Reston VA 20192


Ouachita Thrust Belt
Pittsburg
Pushmataha
Atoka
Choctaw
Image USDA Farm Service Agency
Image State of Arkansas
Image © 2009 DigitalGlobe
© 2009 Tele Atlas
USGS
mi
Pointer lat 34.460707° lon -95.507960° elev 1106 ft
Streaming 100%
Eye alt 41.07 mi
©2007 Google

Paleozoic of Middle USA

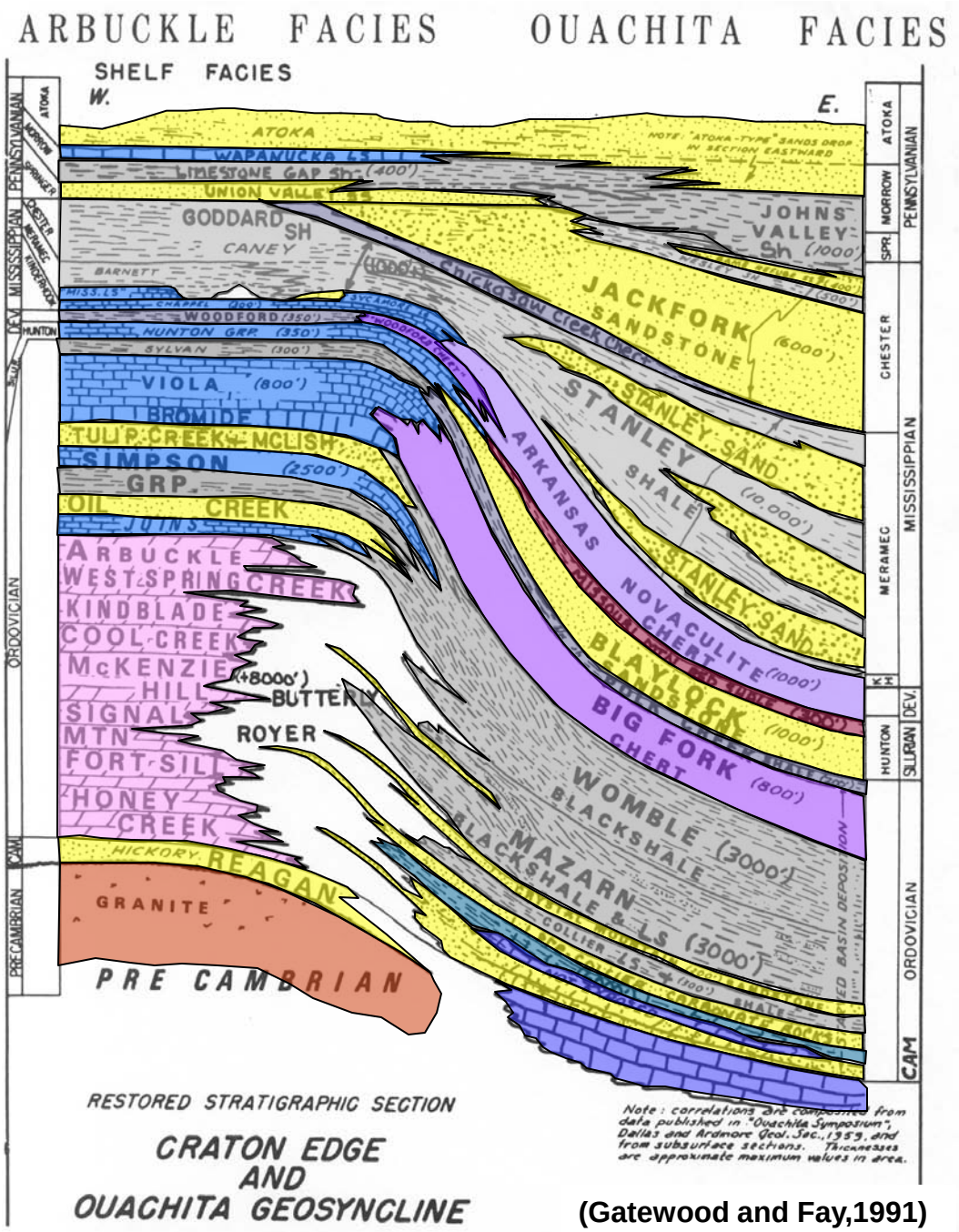




General Structural Trends

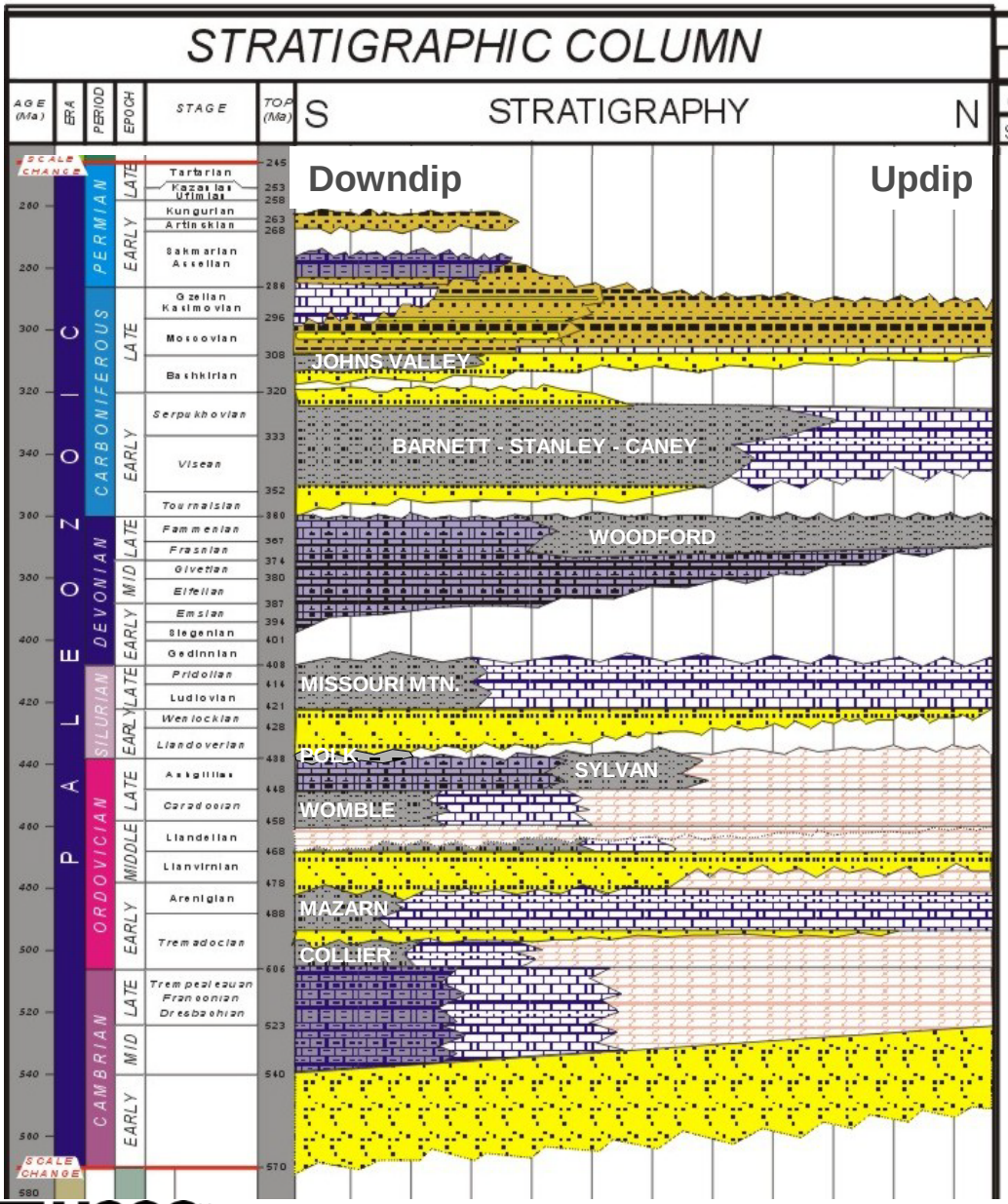
(Coleman, 2000)

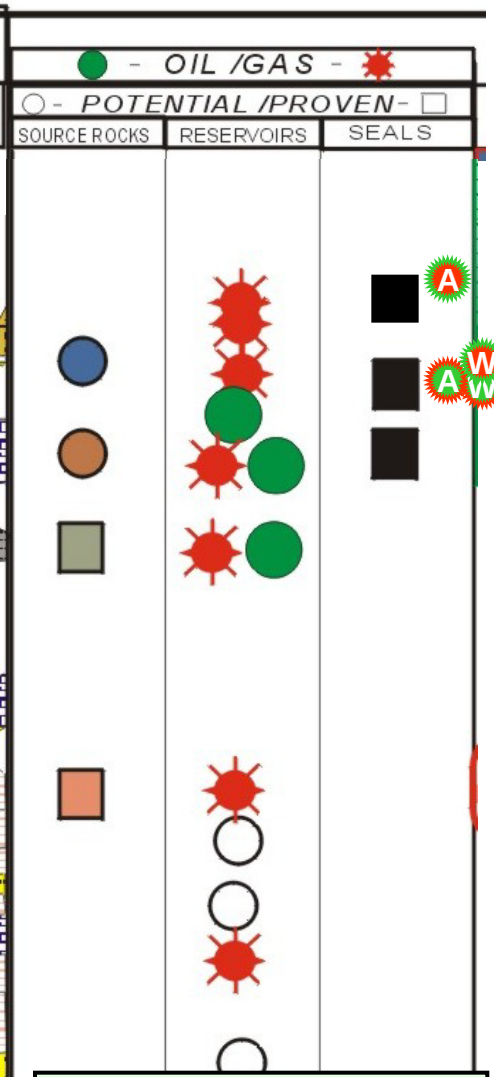
Schematic Shelf – to – Basin Facies Transition: Arbuckle Shelf – Ouachita Basin



(Gatewood and Fay,1991)

Paleozoic Stratigraphy – Arkoma - Ouachita Basin





Oil Gas

A A - Penn. (Atoka)

W W - Dev. (Woodford)

V V - Ord. (Viola)

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(modified from Coleman, et al., 2001)

Source Interval Summary

AGE	FORMATIONS	MIN. TOC (%)	MAX. TOC* (%)	AVE. TOC* (%)
Pennsylvanian	Hartshorne, Atoka, Johns Valley, Jackfork	0.22	3.0	0.96
Mississippian	Fayetteville, Caney, Stanley	0.17	5.4	2.56
Devonian	Woodford, U. Ark. Novaculite	2.0	12.5	8.5
Silurian	Missouri Mtn.	<1.0	1.4	
Ordovician	Sylvan/Viola, Womble, Polk Creek	0.29	6.1	3.2
Cambrian	Collier			

*** excluding coal sample analysis**

USGS

(modified from Curiale, 1989, Weber, 1990, Johnson and Cardott, 1992)

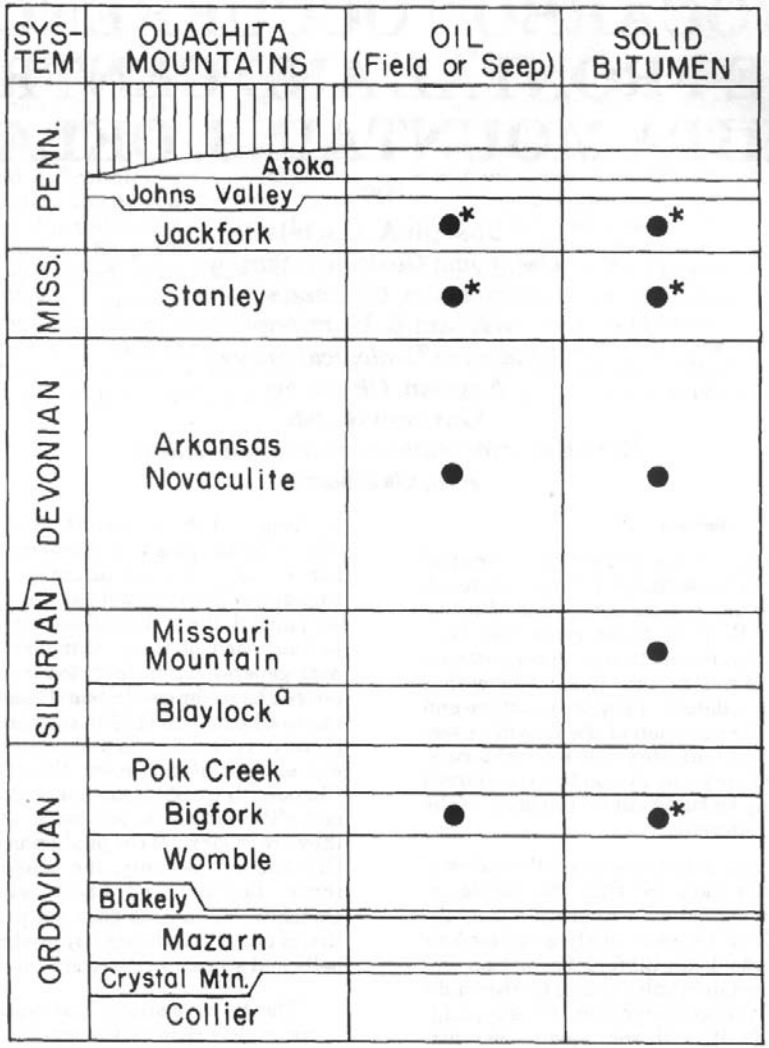
Source Interval Summary

Age	Formations	Kerogen Type	Product
Pennsylvanian	Hartshorne, Atoka, Johns Valley, Jackfork	III	Gas
Mississippian	Fayetteville, Caney, Stanley	III	Gas
Devonian	Woodford, U. Ark. Novaculite	II, III	Oil, Gas
Silurian	Missouri Mtn.	II (?)	Oil
Ordovician	Sylvan/Viola, Womble, Polk Creek	II	Oil
Cambrian	Collier	II (?)	Oil

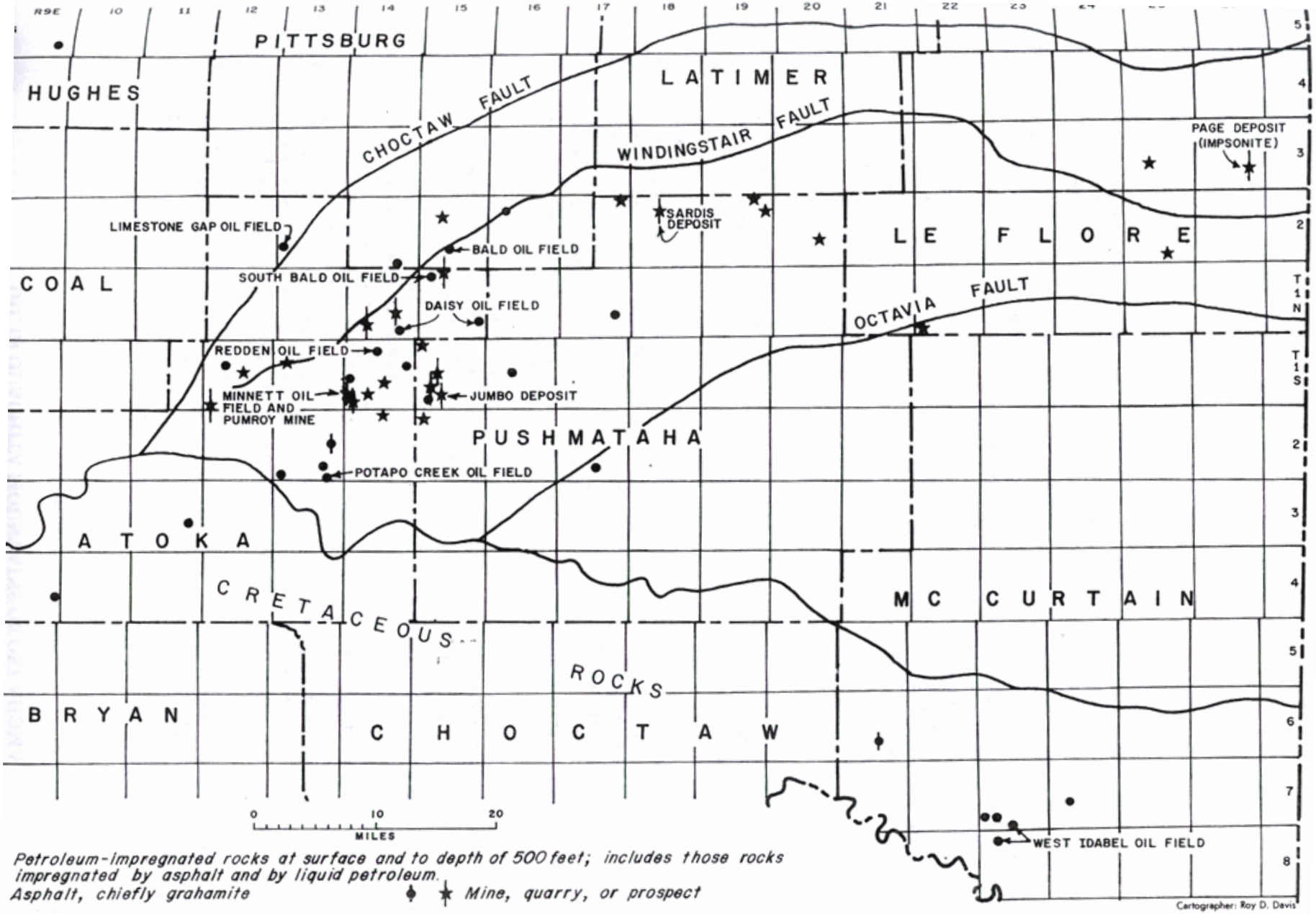
(modified from Curiale, 1989; Weber, 1990; Johnson and Cardott, 1992; Comer, 1992)

USGS

Stratigraphic Column, showing formations with oil and solid bitumen shows or production



(Curiale and others, 1984)



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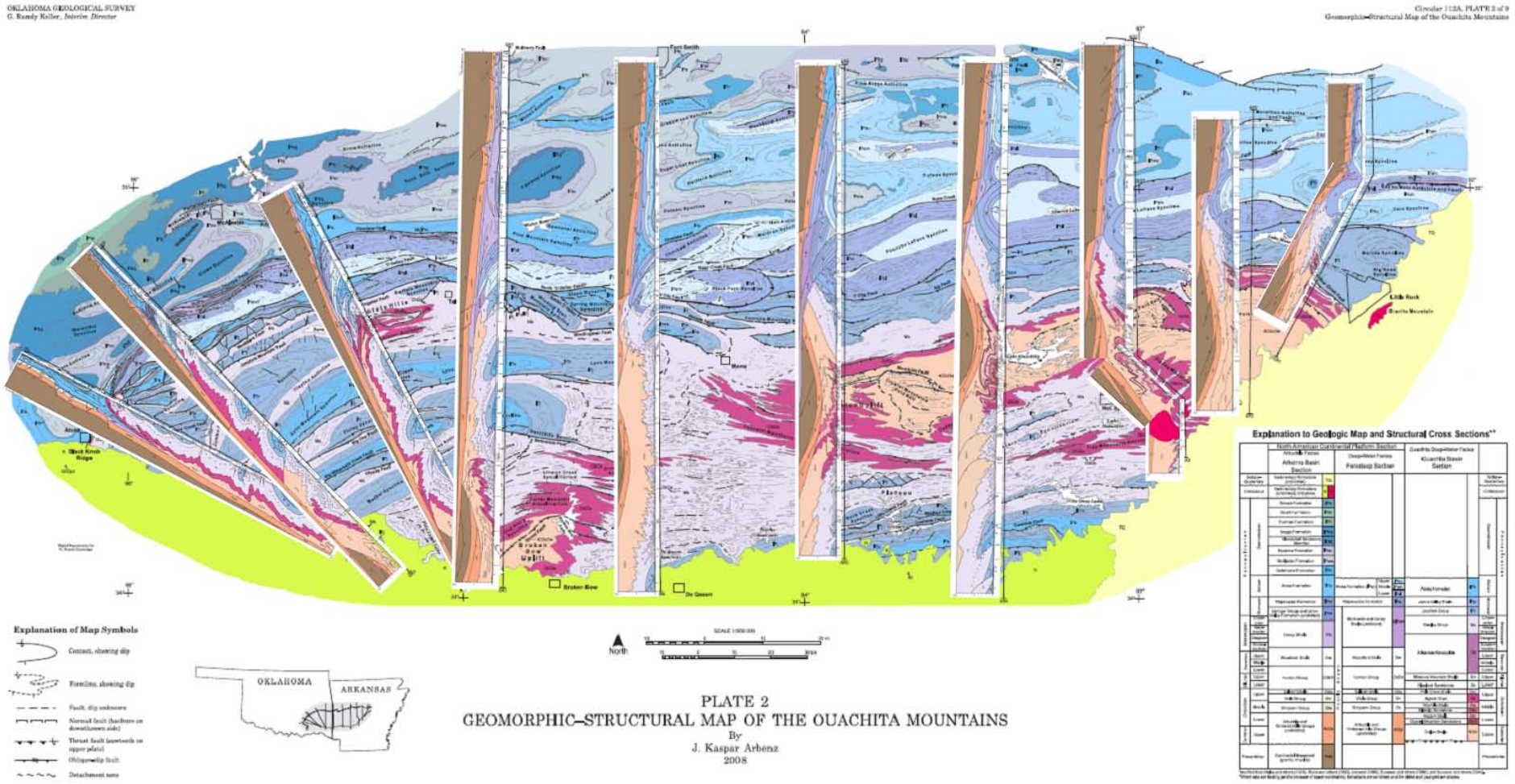
OIL FIELDS AND ASPHALTITE MINES IN OUACHITA MOUNTAINS, OKLAHOMA

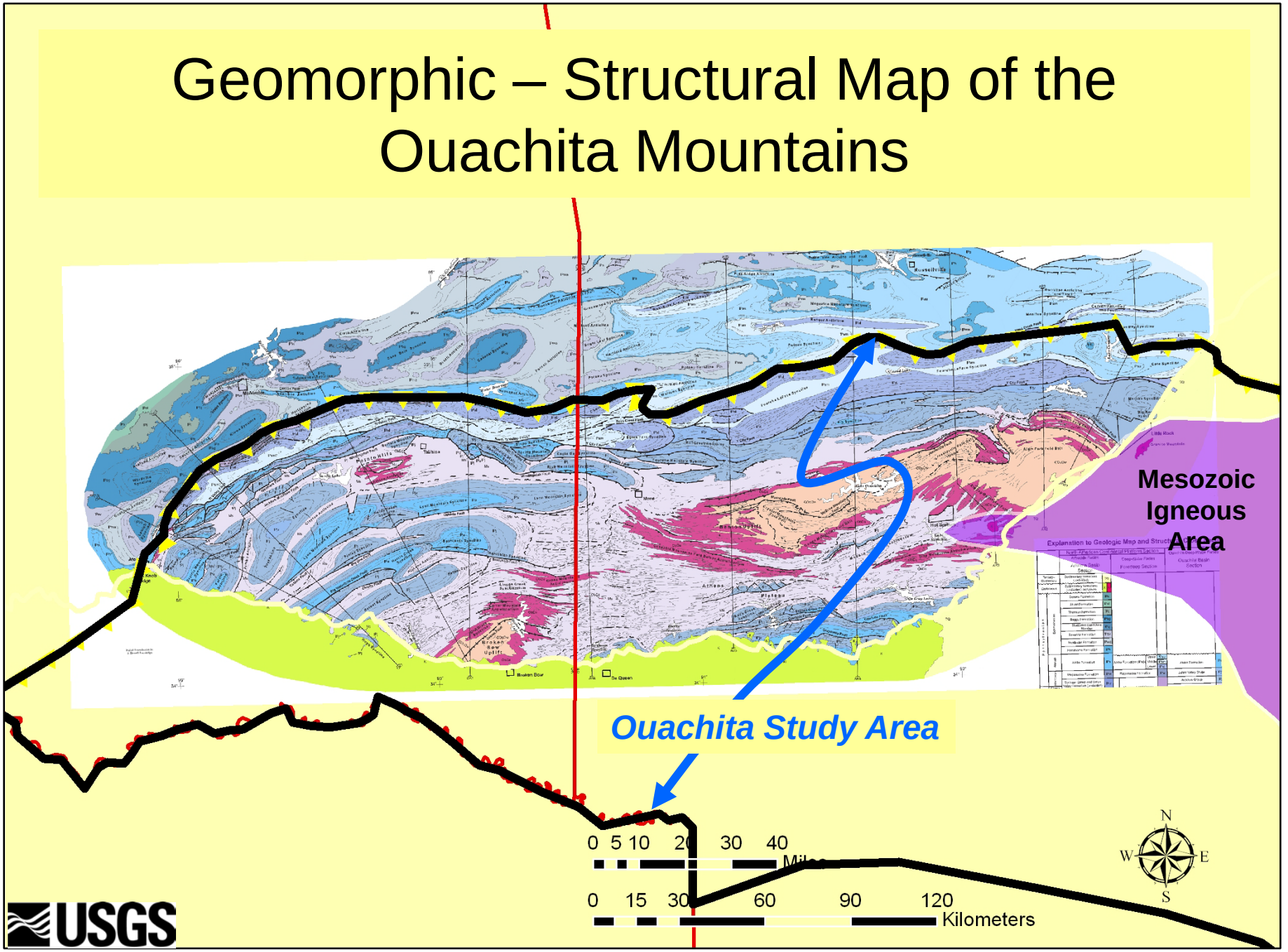
(Fay, 1976)

Geomorphic – Structural Map of the Ouachita Mountains



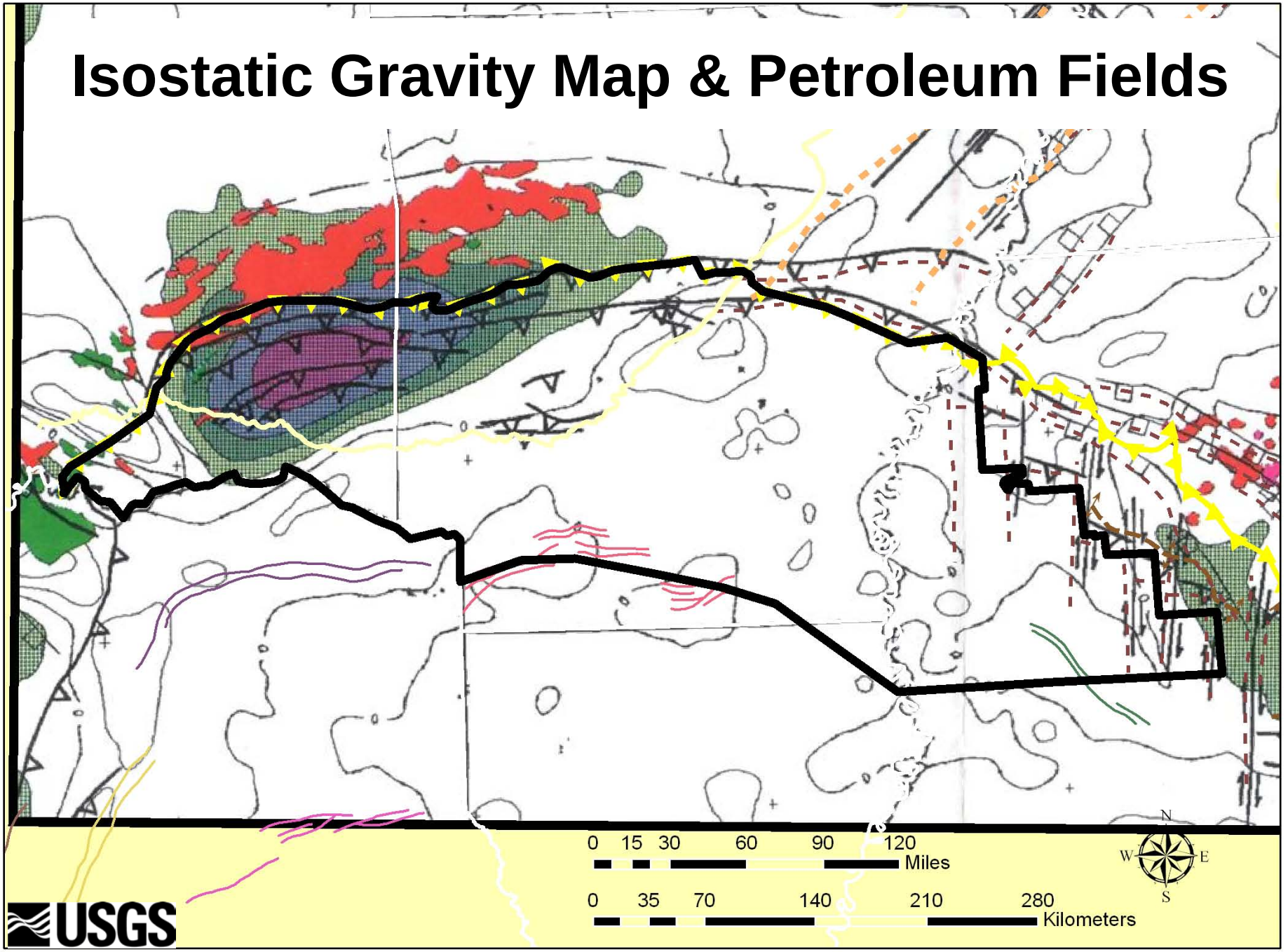
(modified from Arbenz, 2008)

Geomorphic – Structural Map of the Ouachita Mountains



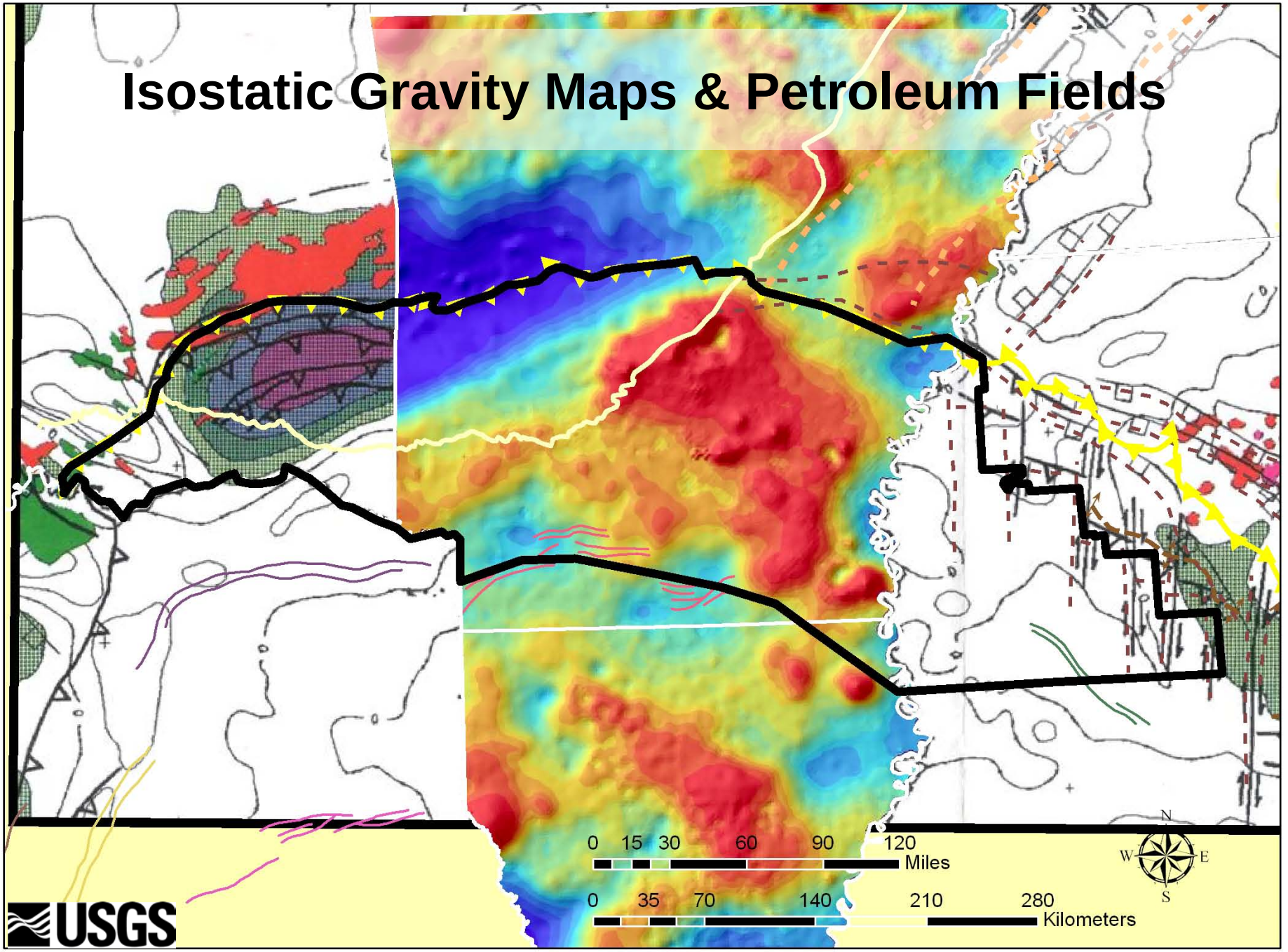
(modified from Arbenz, 2009 and Coleman, 1991)

Isostatic Gravity Map & Petroleum Fields

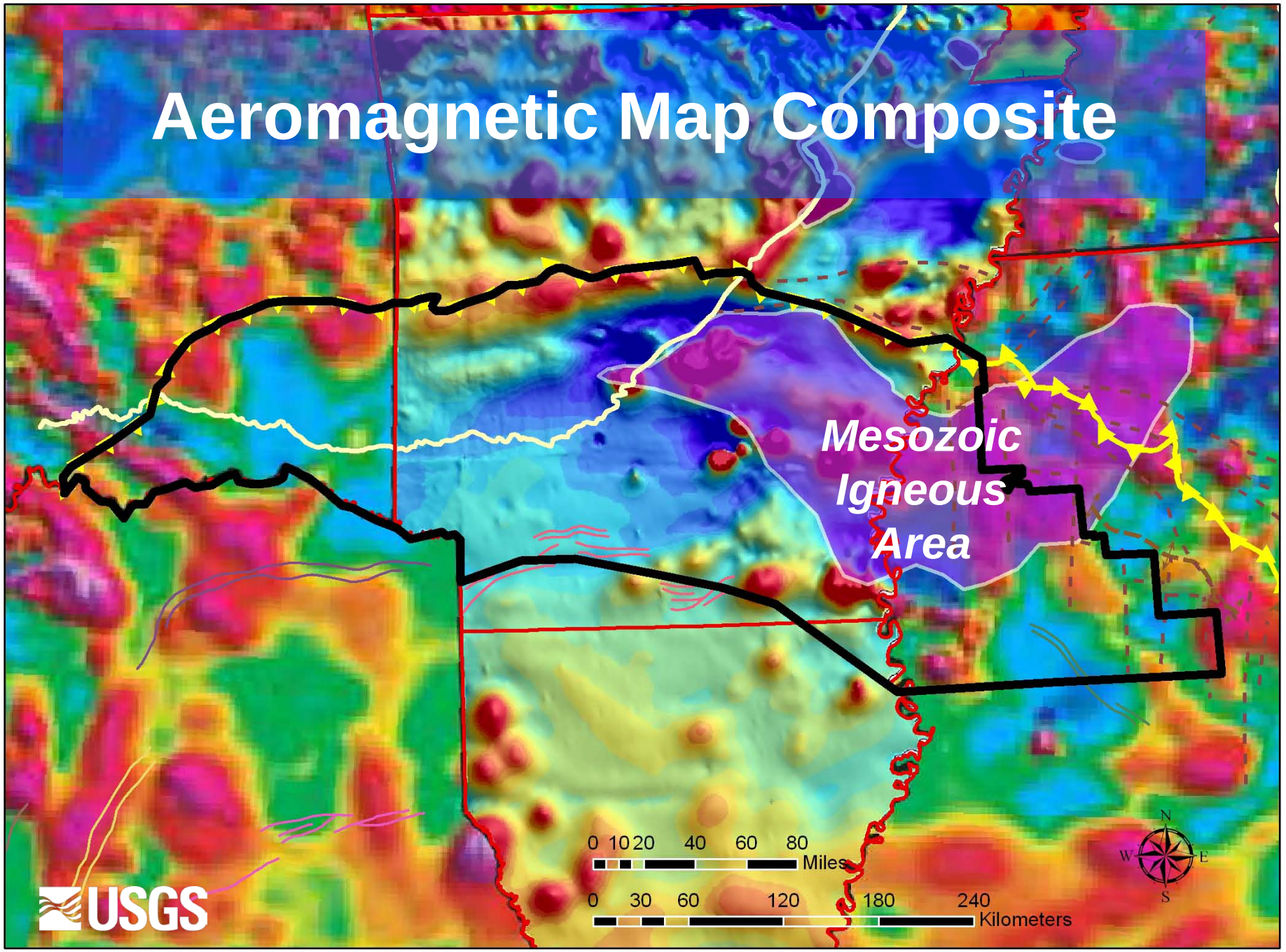


(modified from Coleman, 2008)

Isostatic Gravity Maps & Petroleum Fields

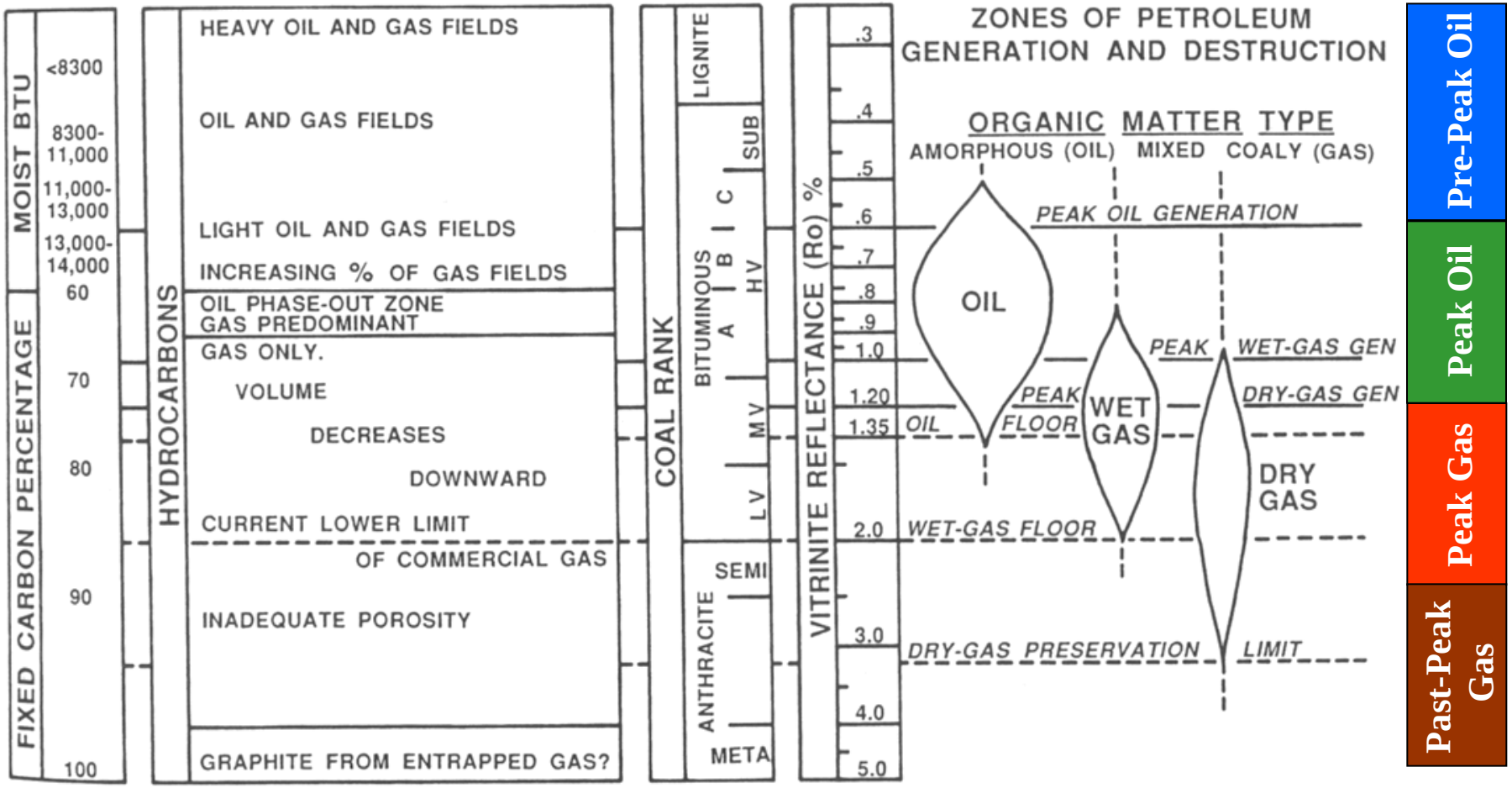


(modified from Coleman, 2008, and Bankey and Daniels, 2008)



(aeromagnetic maps from Bankey and Daniels, 2008; igneous area from Hildenbrand, 1985, and Coleman, 1991)

Thermal Stress Levels



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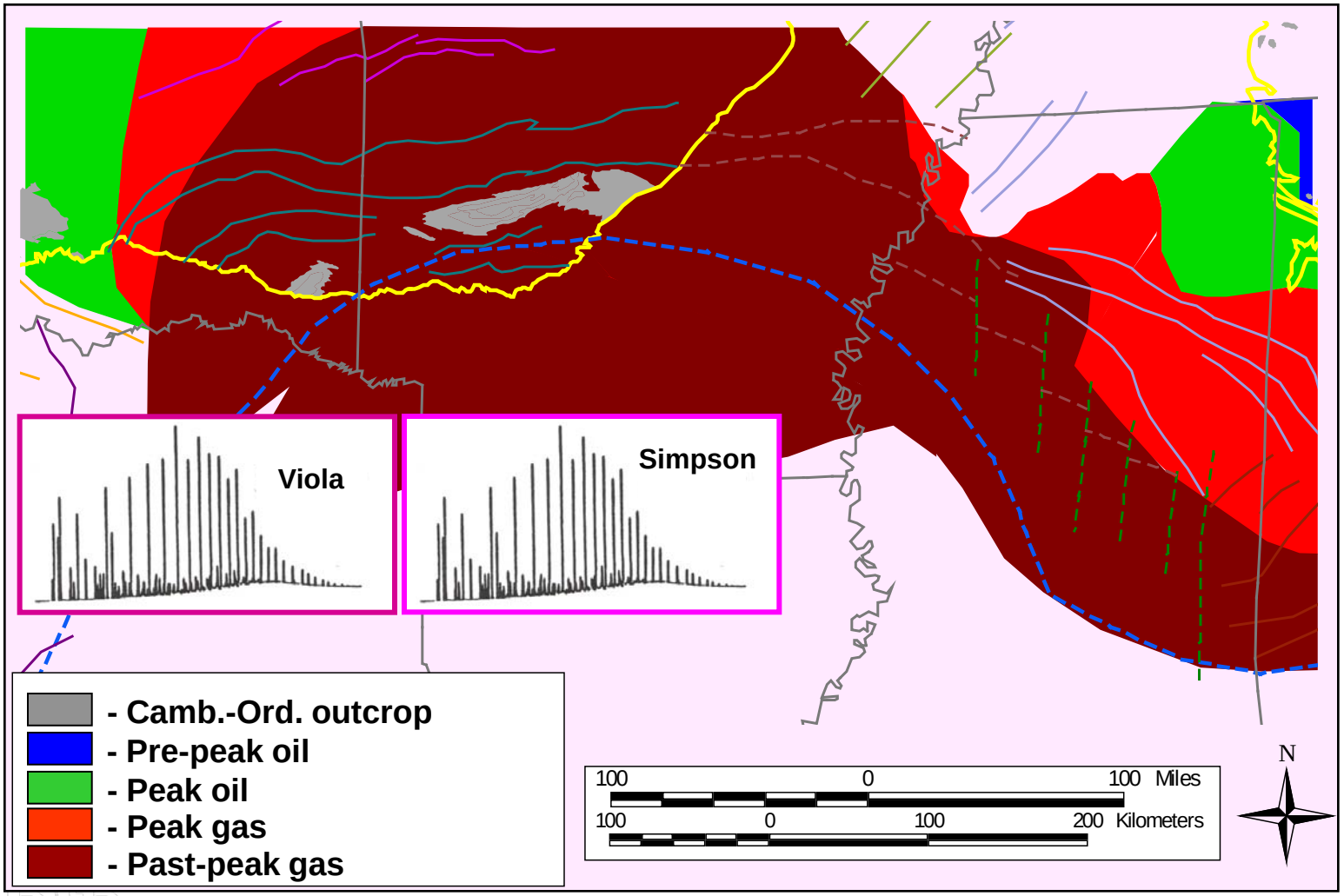
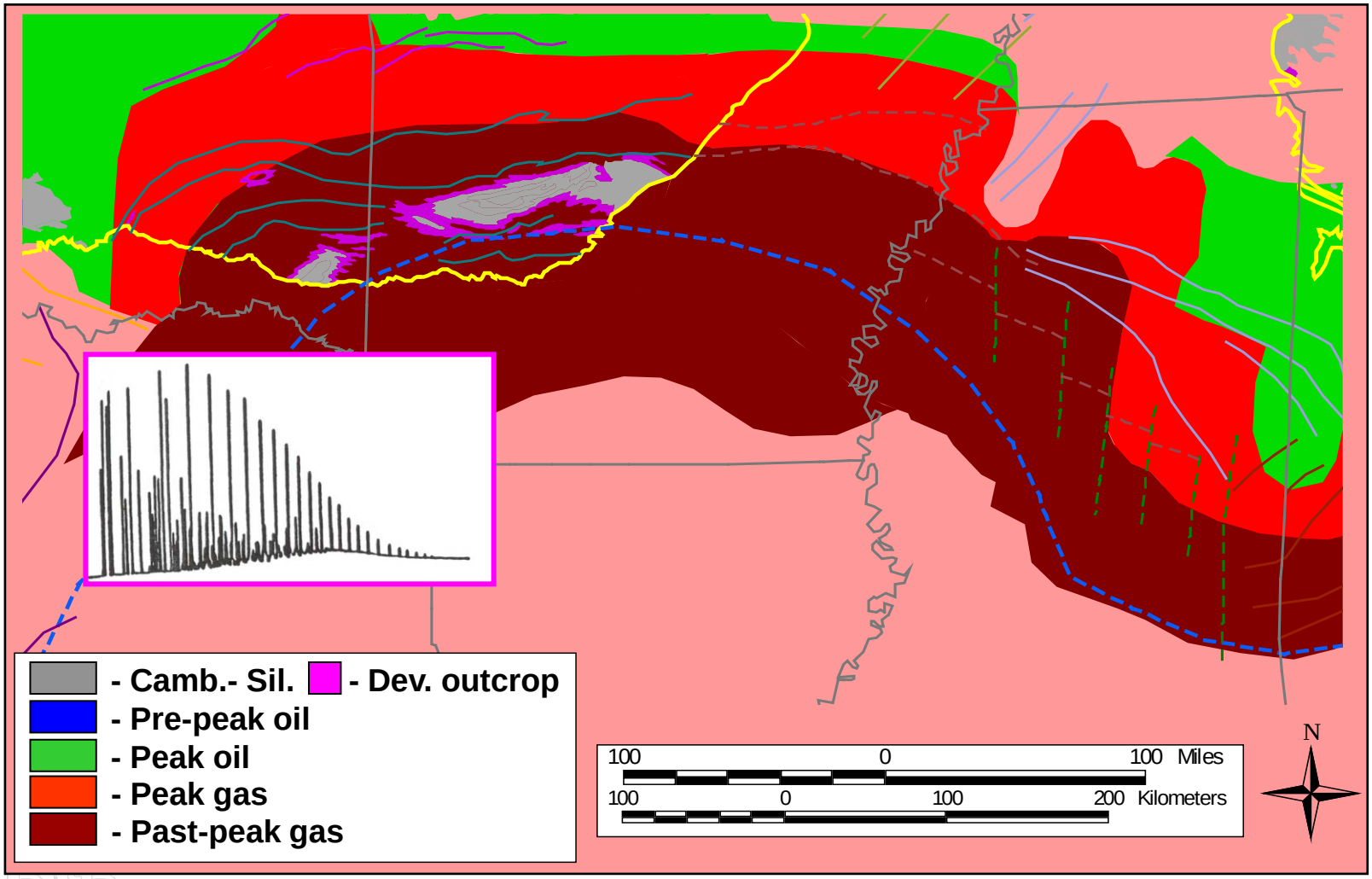
(adapted from Houseknecht and others, 1992)

Thermal Stress Levels – Upper Ordovician



(Coleman, 2008)

Thermal Stress Levels – Upper Devonian (incl. some Lower Mississippian)



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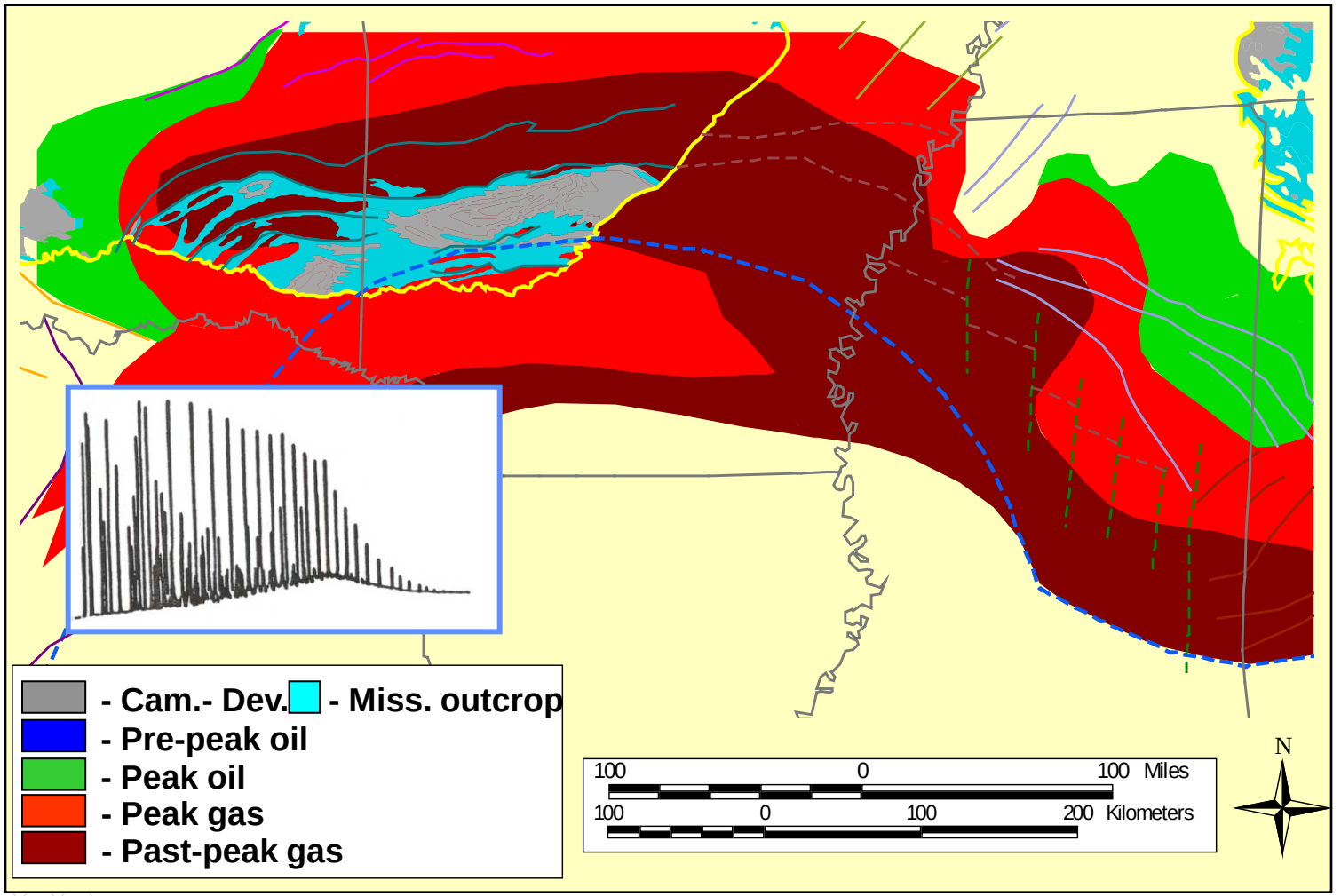
(Coleman, 2008)

Thermal Stress Levels – Upper Mississippian



(Coleman, 2008)

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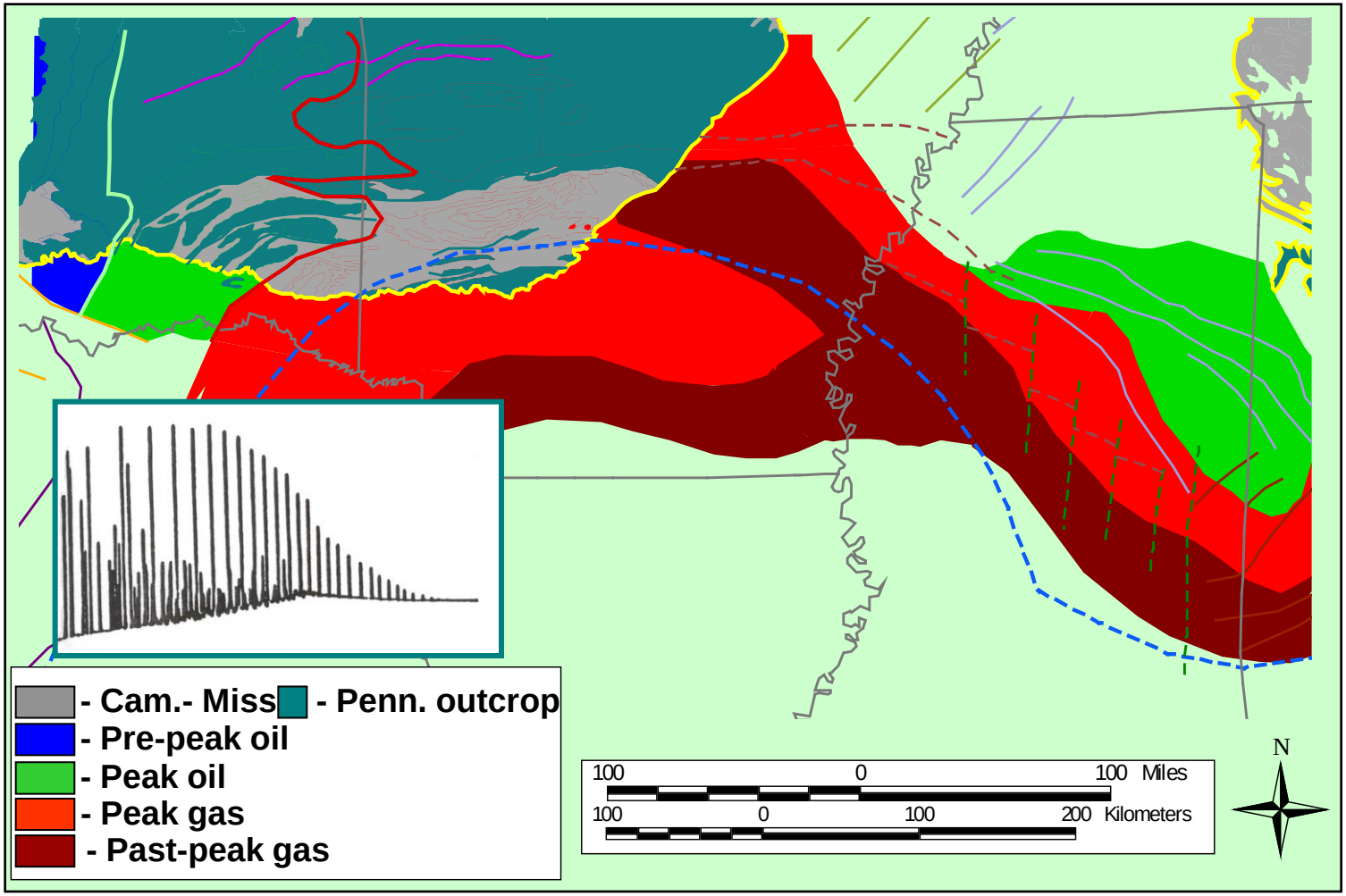
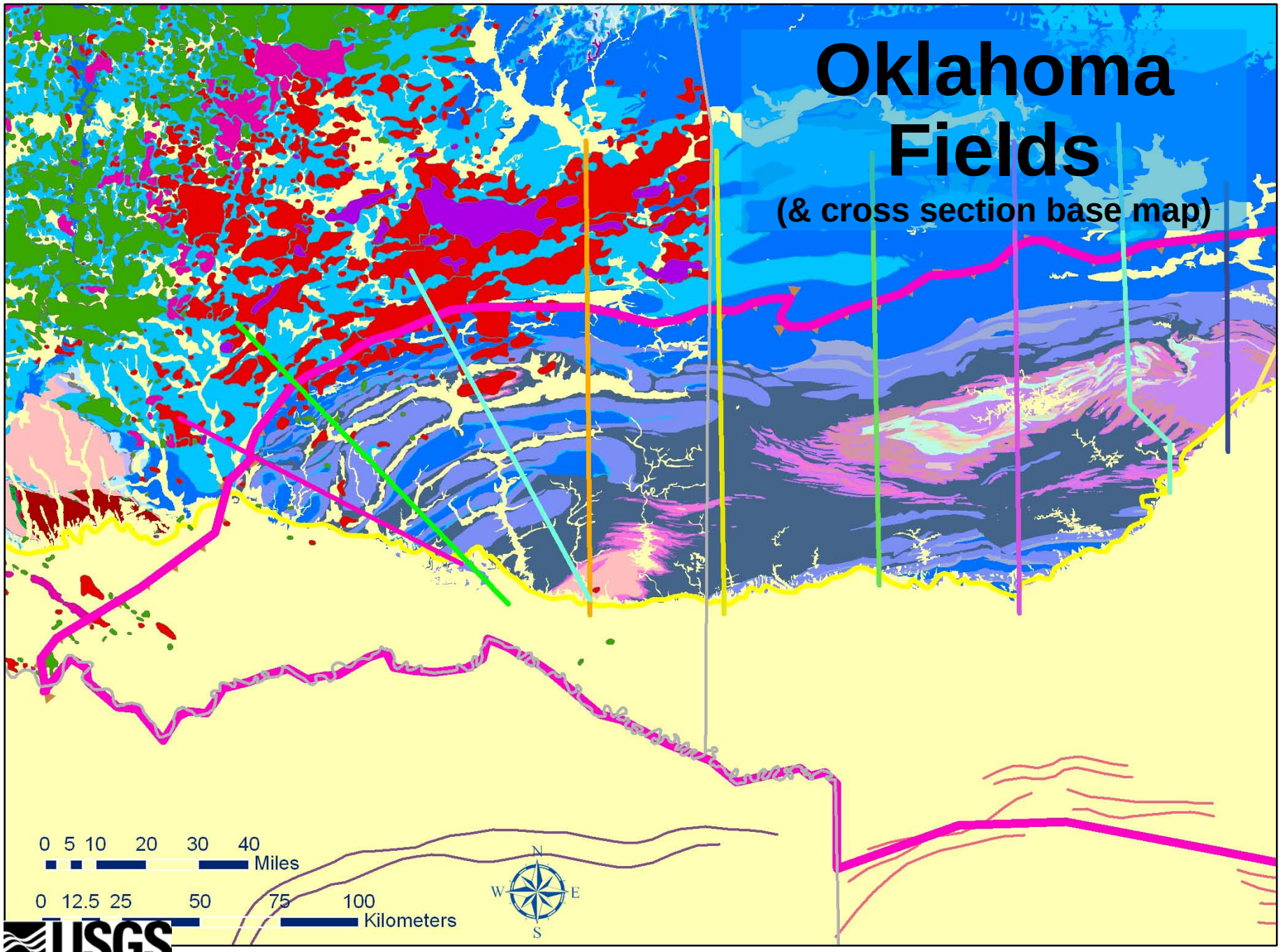
Thermal Stress Levels – Middle Pennsylvanian



(Coleman, 2008)

USGS



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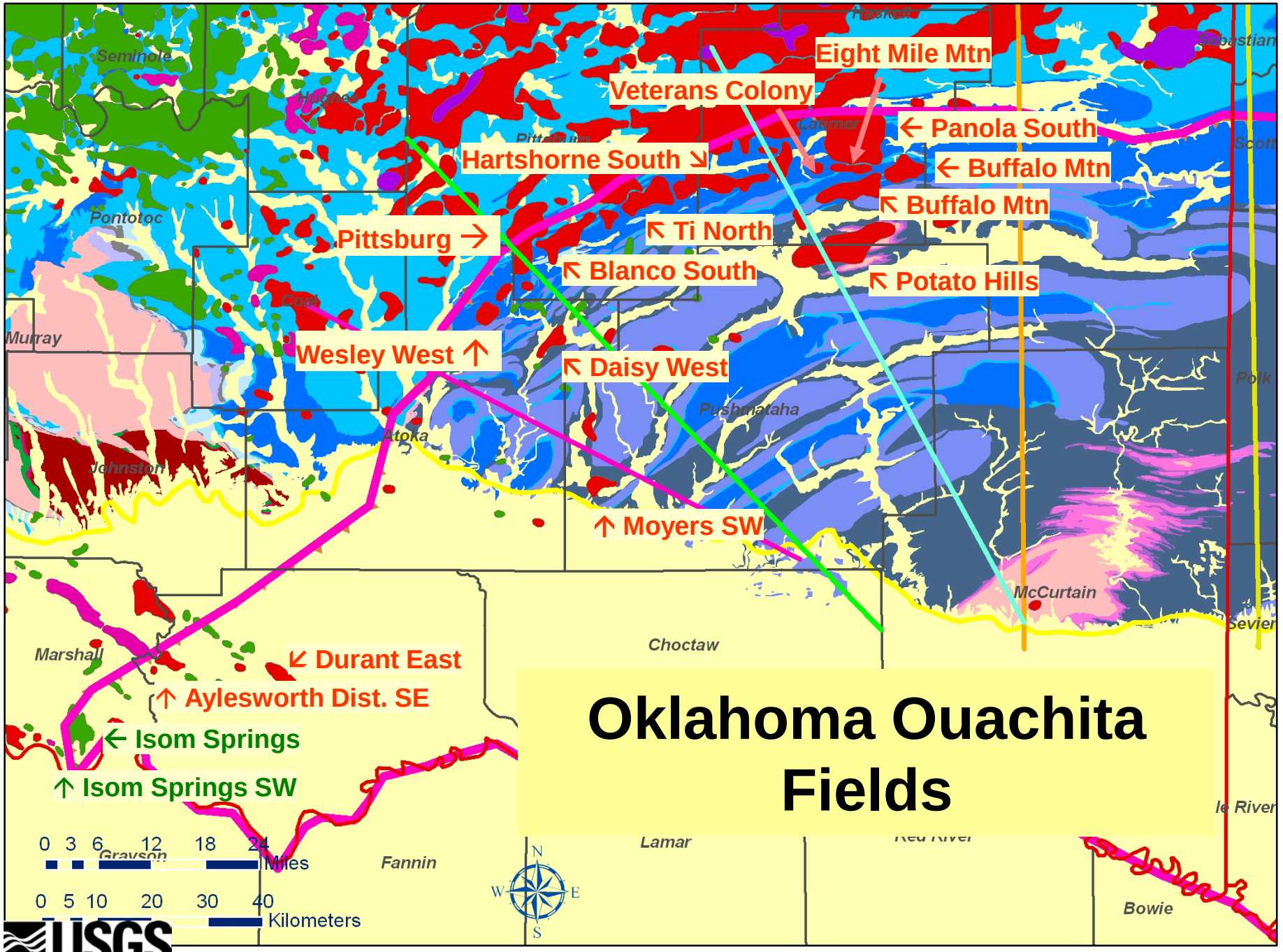
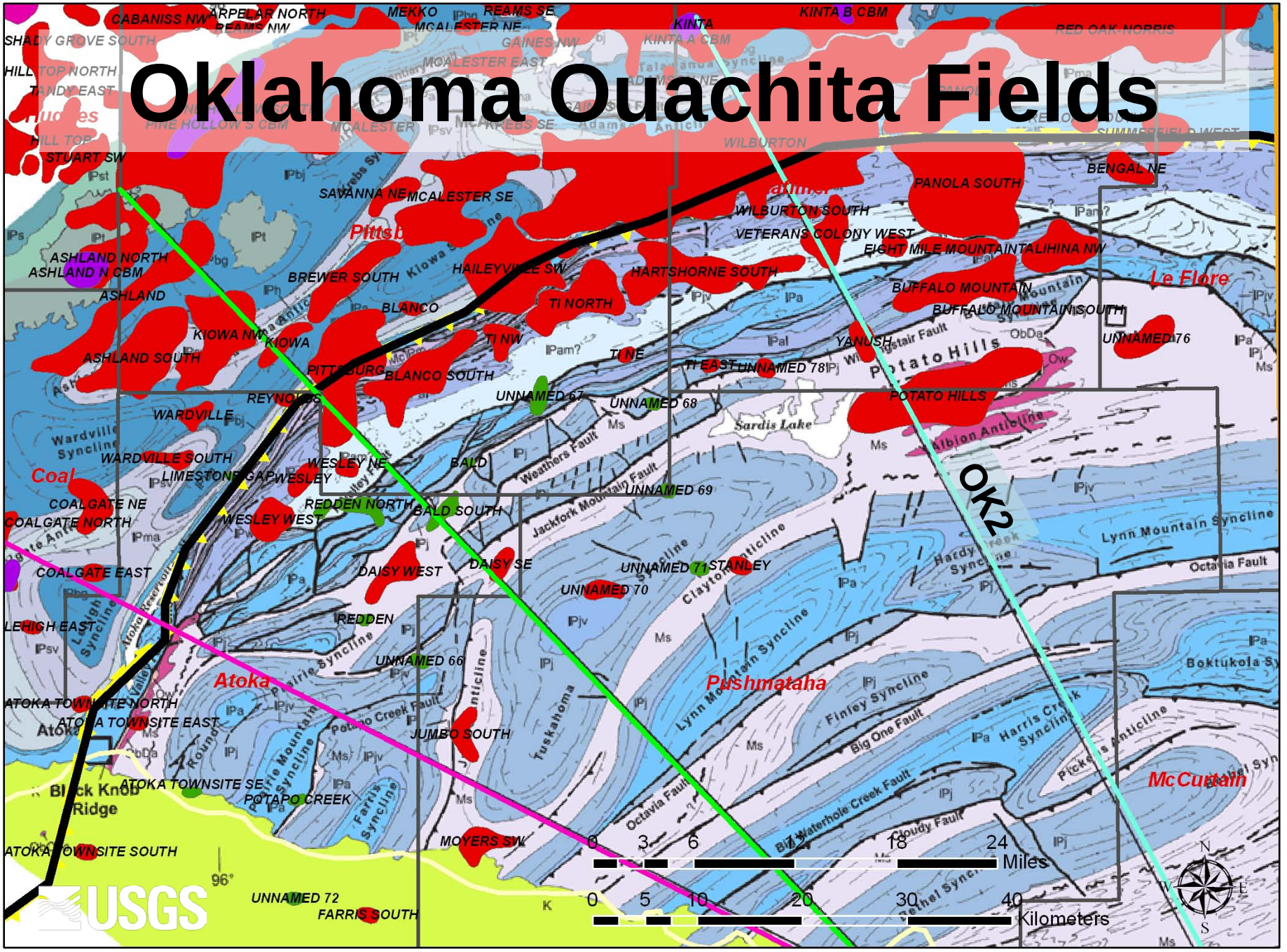
(lines of cross sections from Arbenz, 2009; map from Schruben and others, 1998; OK fields from OGS web site)



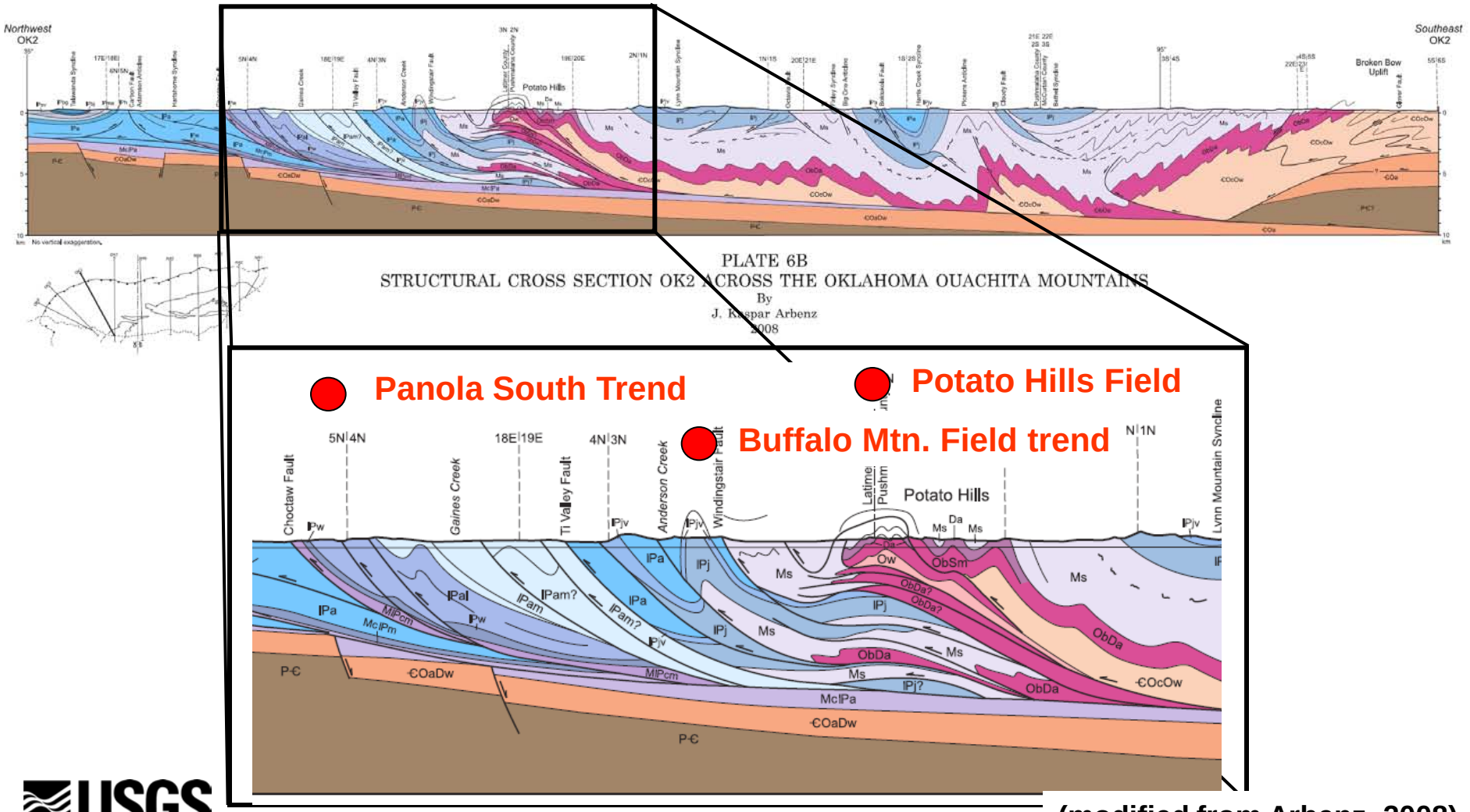
(lines of cross sections from Arbenz, 2009; map from Schruben and others, 1998; OK fields from OGS web site)

Oklahoma Ouachita Fields



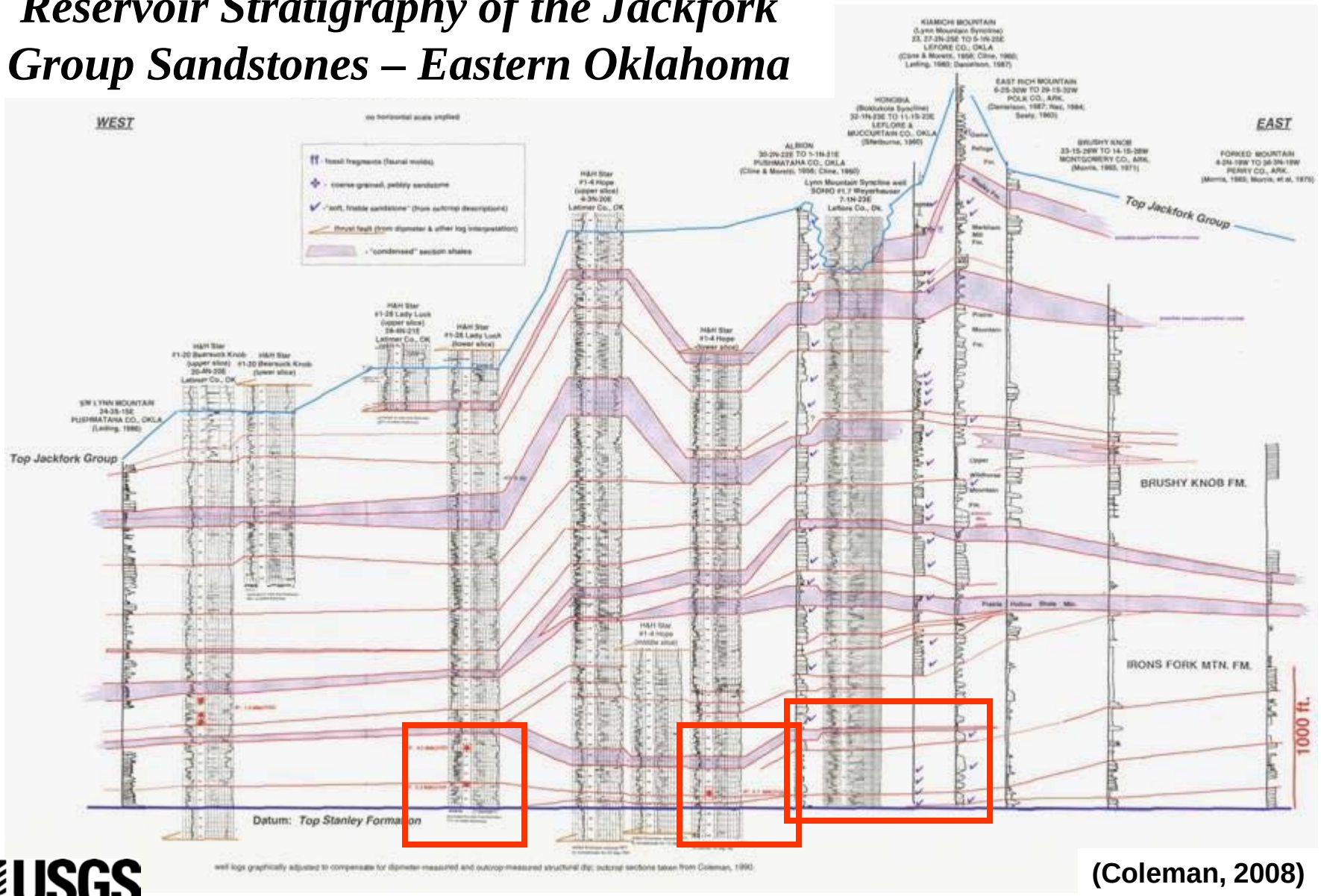
(map from Arbenz, 2008; OK fields from OGS web site)

Structural Cross Section OK2



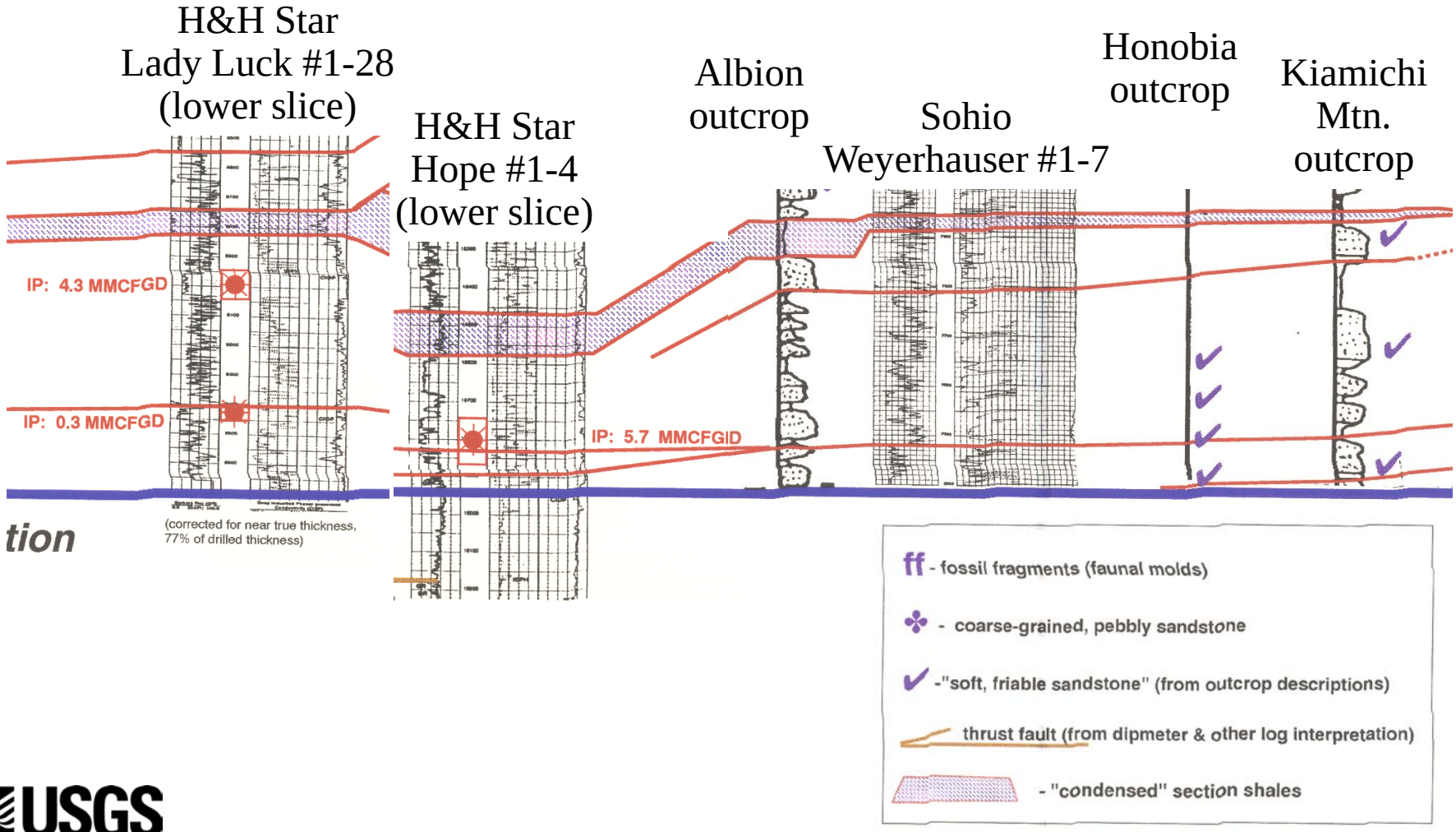
(modified from Arbenz, 2008)

Reservoir Stratigraphy of the Jackfork Group Sandstones – Eastern Oklahoma



(Coleman, 2008)

Lower Jackfork Gas Reservoirs

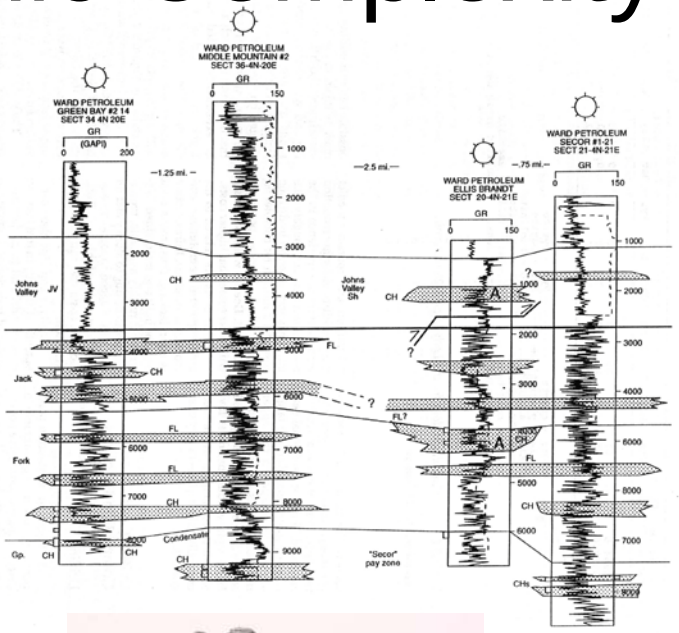


USGS

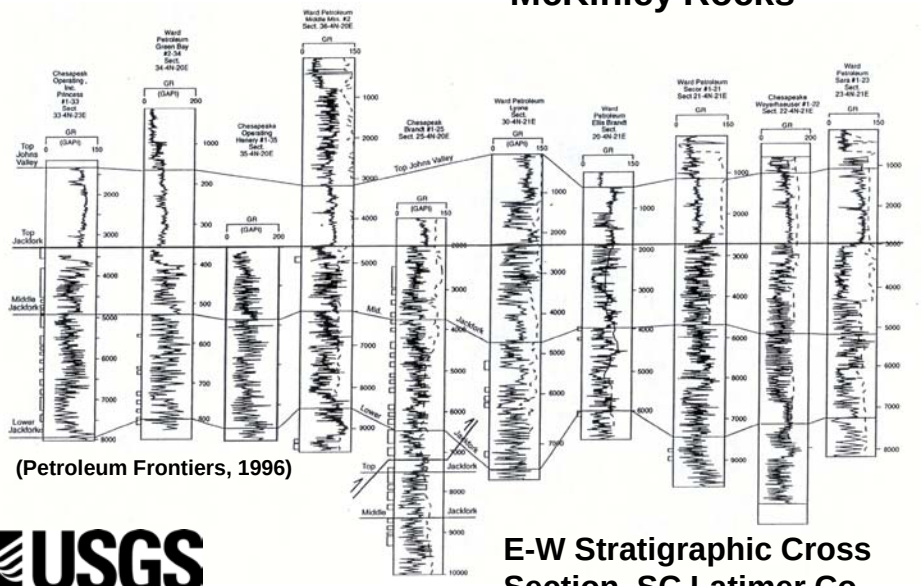
(Coleman, 2008)

Jackfork Stratigraphic Complexity

McKinley Rocks

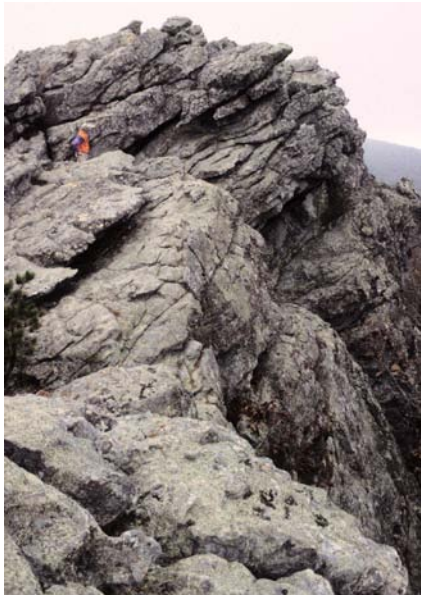


(Petroleum Frontiers, 1996)



(Petroleum Frontiers, 1996)

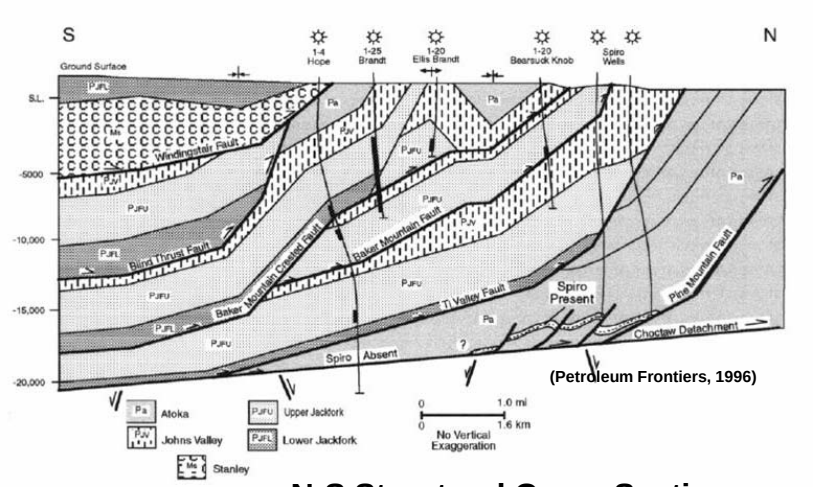
E-W Stratigraphic Cross Section, SC Latimer Co.



McKinley Rocks

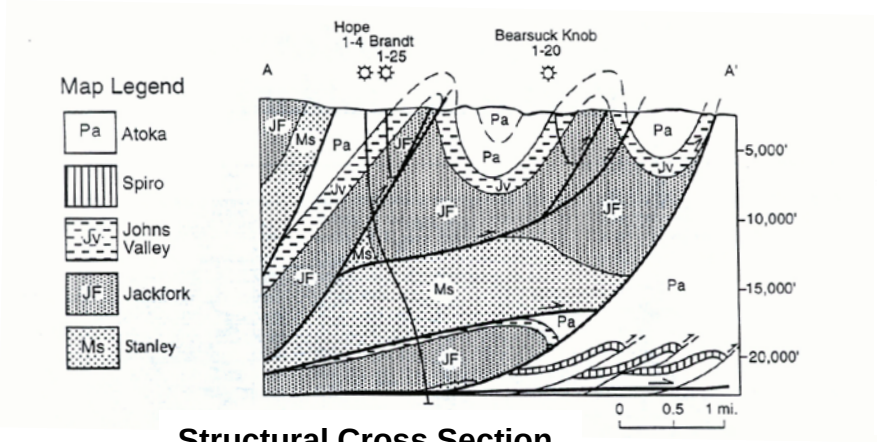
USGS

Jackfork Structural Complexity



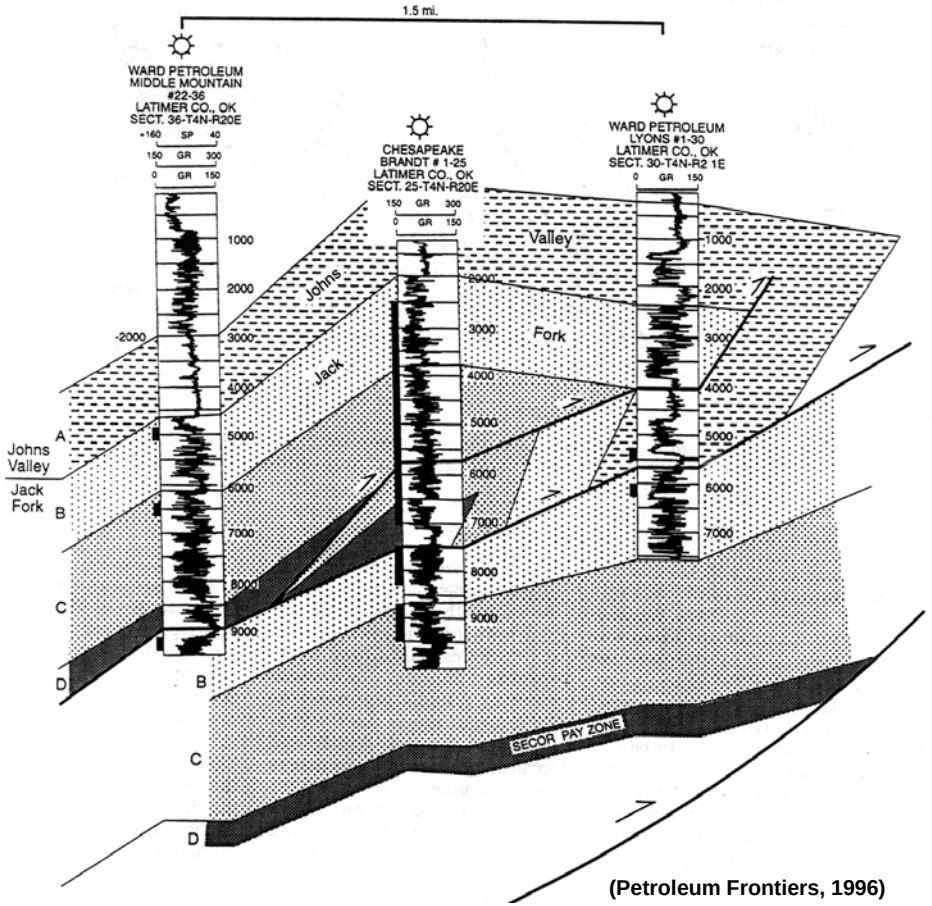
(Petroleum Frontiers, 1996)

N-S Structural Cross Section, So. Latimer Co., OK



Structural Cross Section, Latimer Co., OK

(Petroleum Frontiers, 1996)



(Petroleum Frontiers, 1996)

Structural Cross Section, Latimer Co., OK

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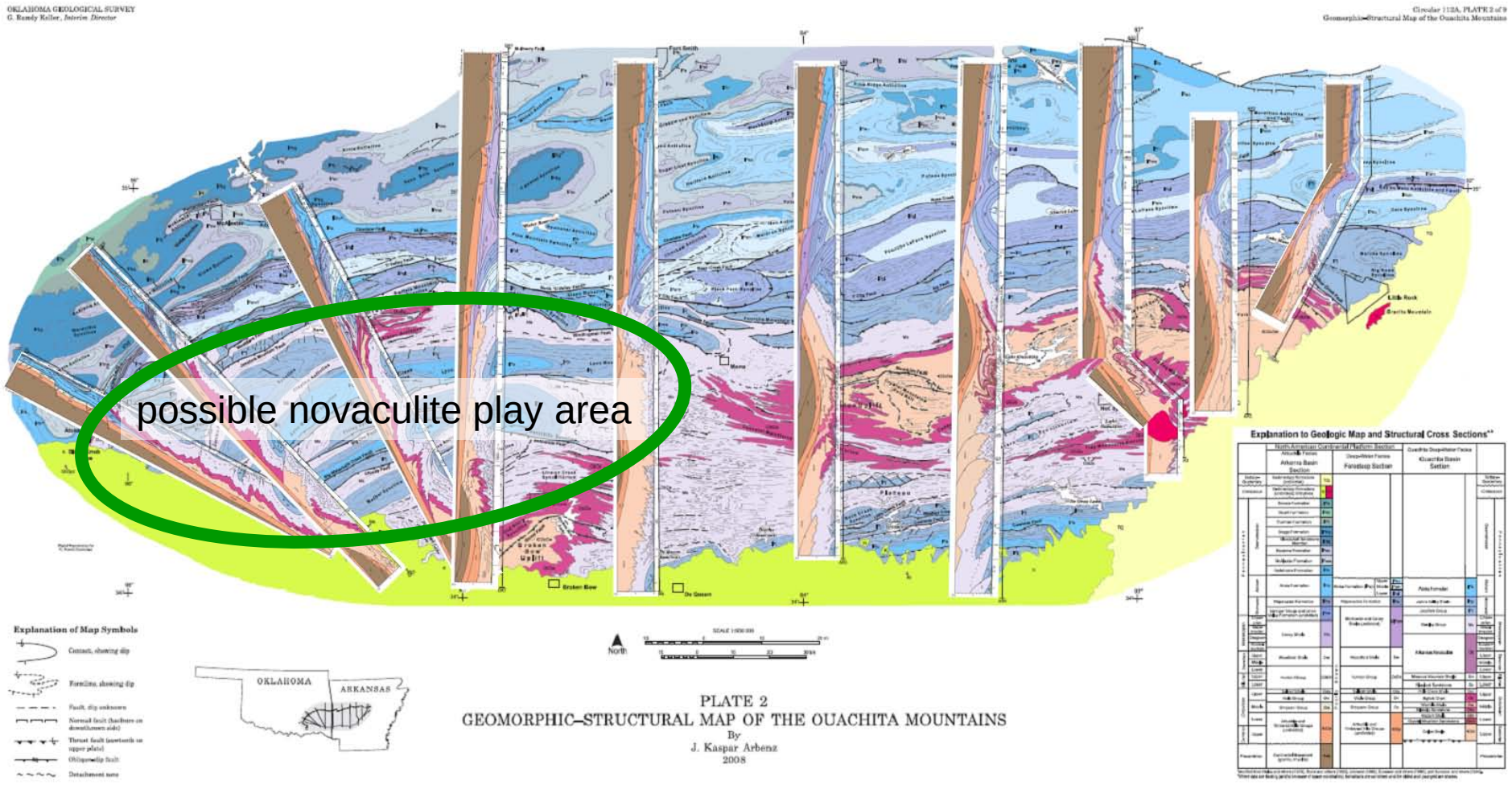
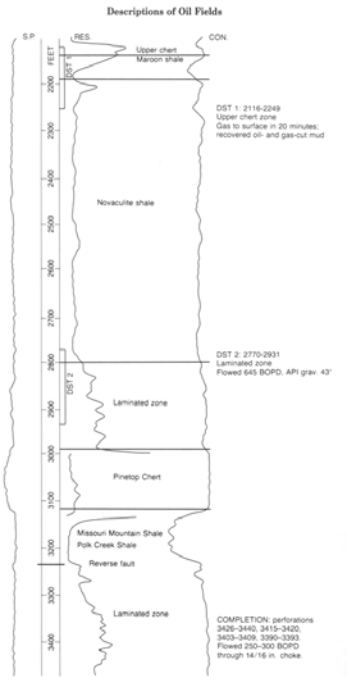
Geomorphic – Structural Map of the Ouachita Mountains



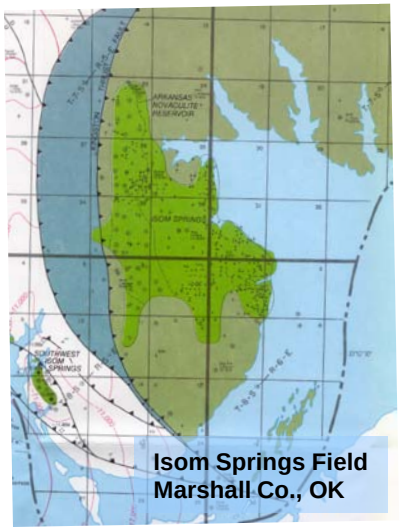
(modified from Arbenz, 2008)

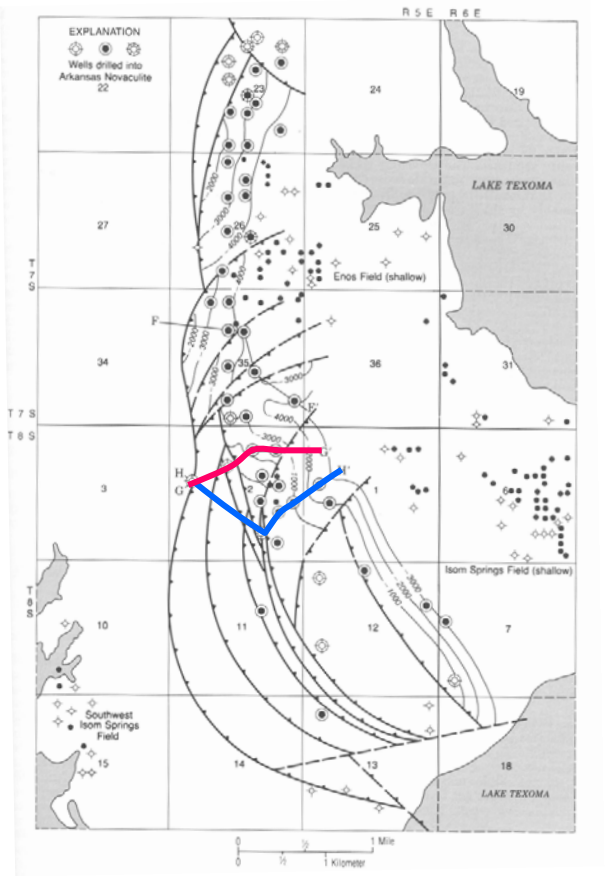
USGS

Isom Springs Field

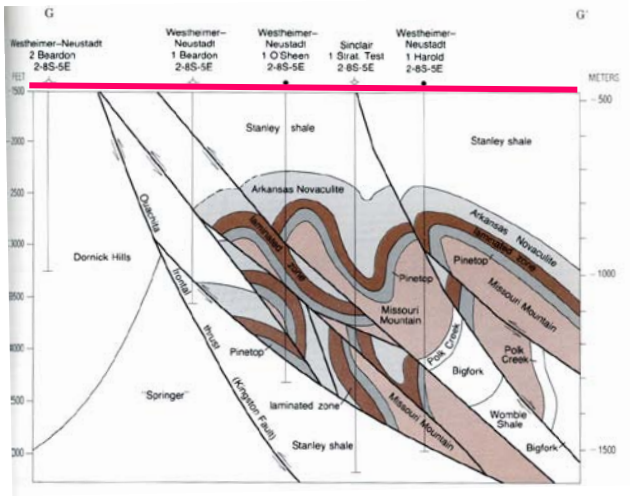


Westheimer-Neustadt #1 Wallace
Isom Springs Field
Marshall Co., OK

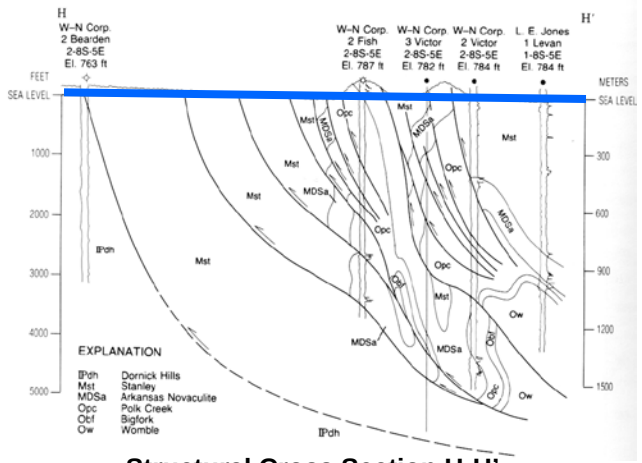




Structure contour map,
Top Arkansas Novaculite,
Isom Springs Field
Marshall Co., OK



Structural Cross Section G-G',
Isom Springs – Enos Fields
Marshall Co., OK



Structural Cross Section H-H',
Isom Springs Field,
Marshall Co., OK

USGS

(illustrations modified from Huffman and others, 1987)

West Texas Analogs

- Caballos novaculite as analog for Arkansas novaculite
- Marathon Thrust Belt as analog for Ouachita Thrust Belt

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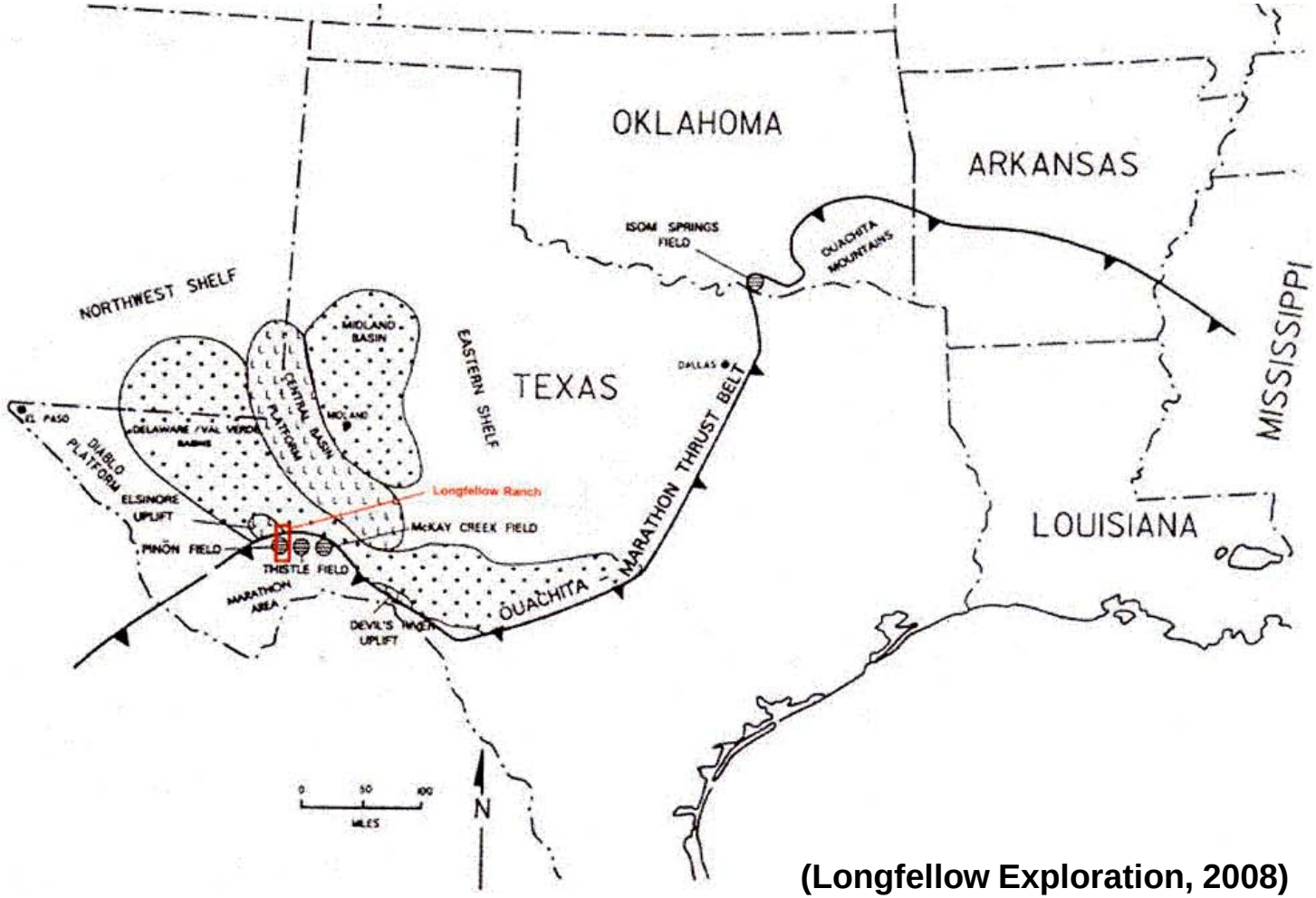
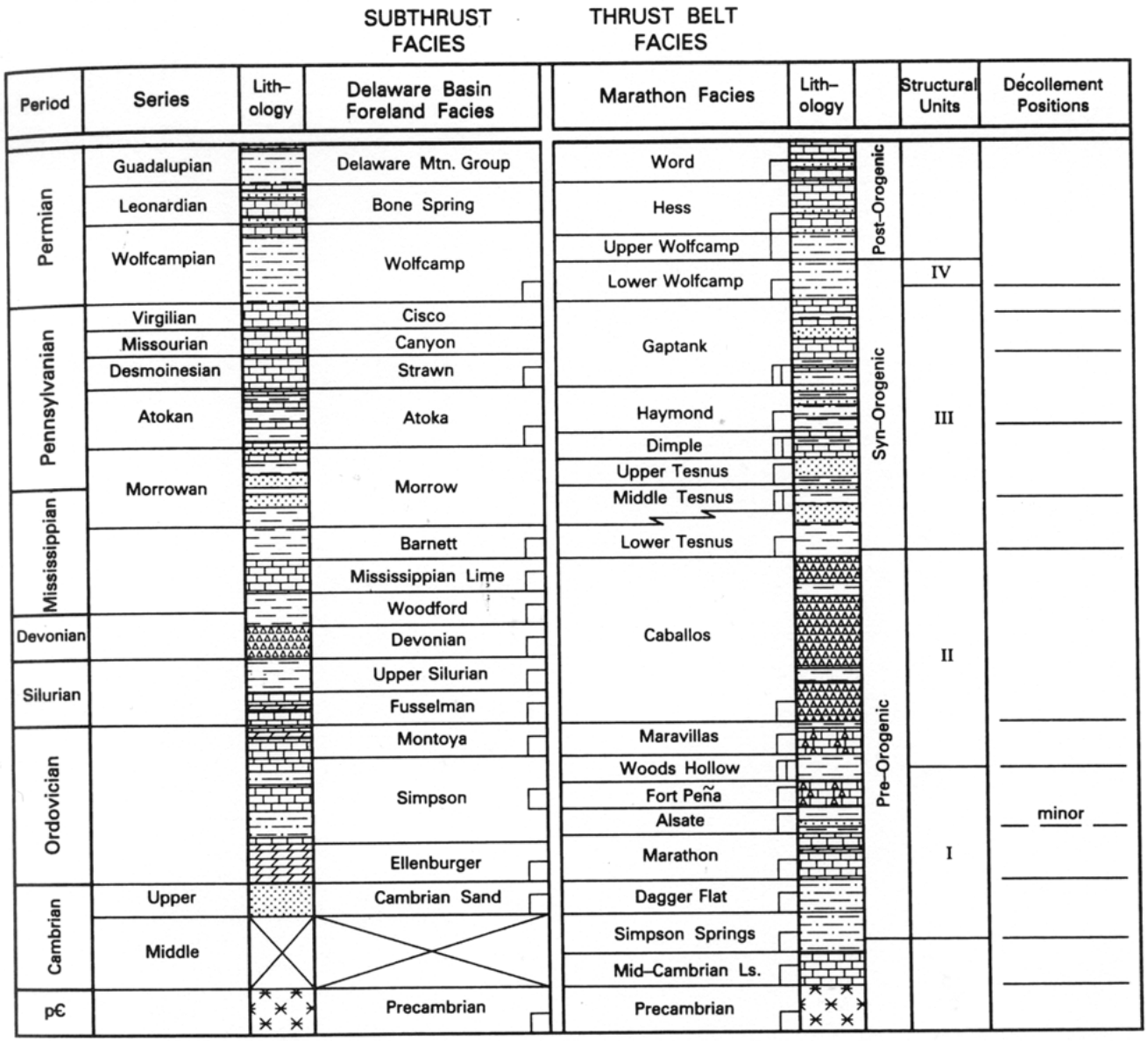
Marathon Thrust Belt



(Longfellow Exploration, 2008)

USGS

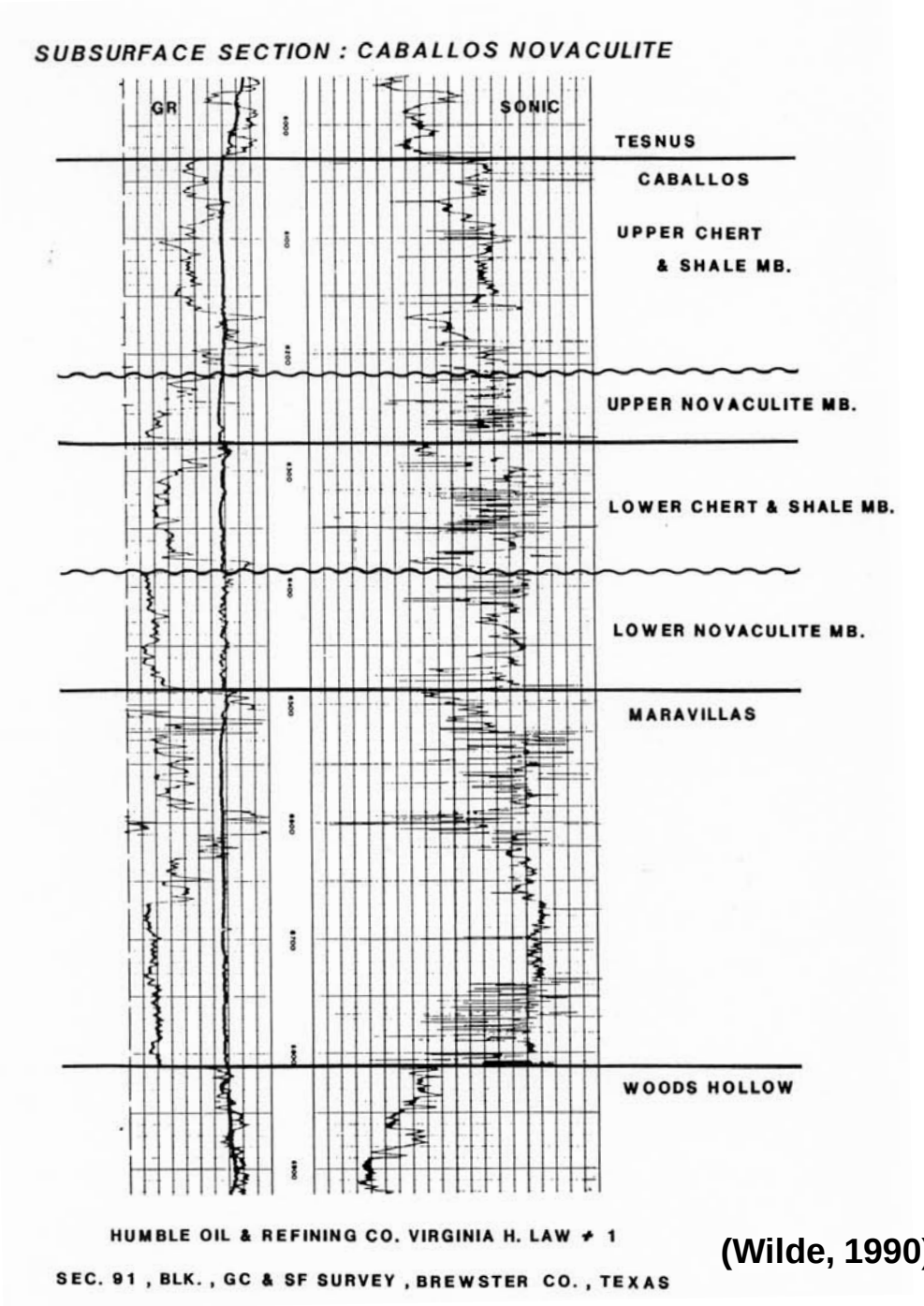
West Texas Stratigraphic Column



(Reed and Strickler, 1990)

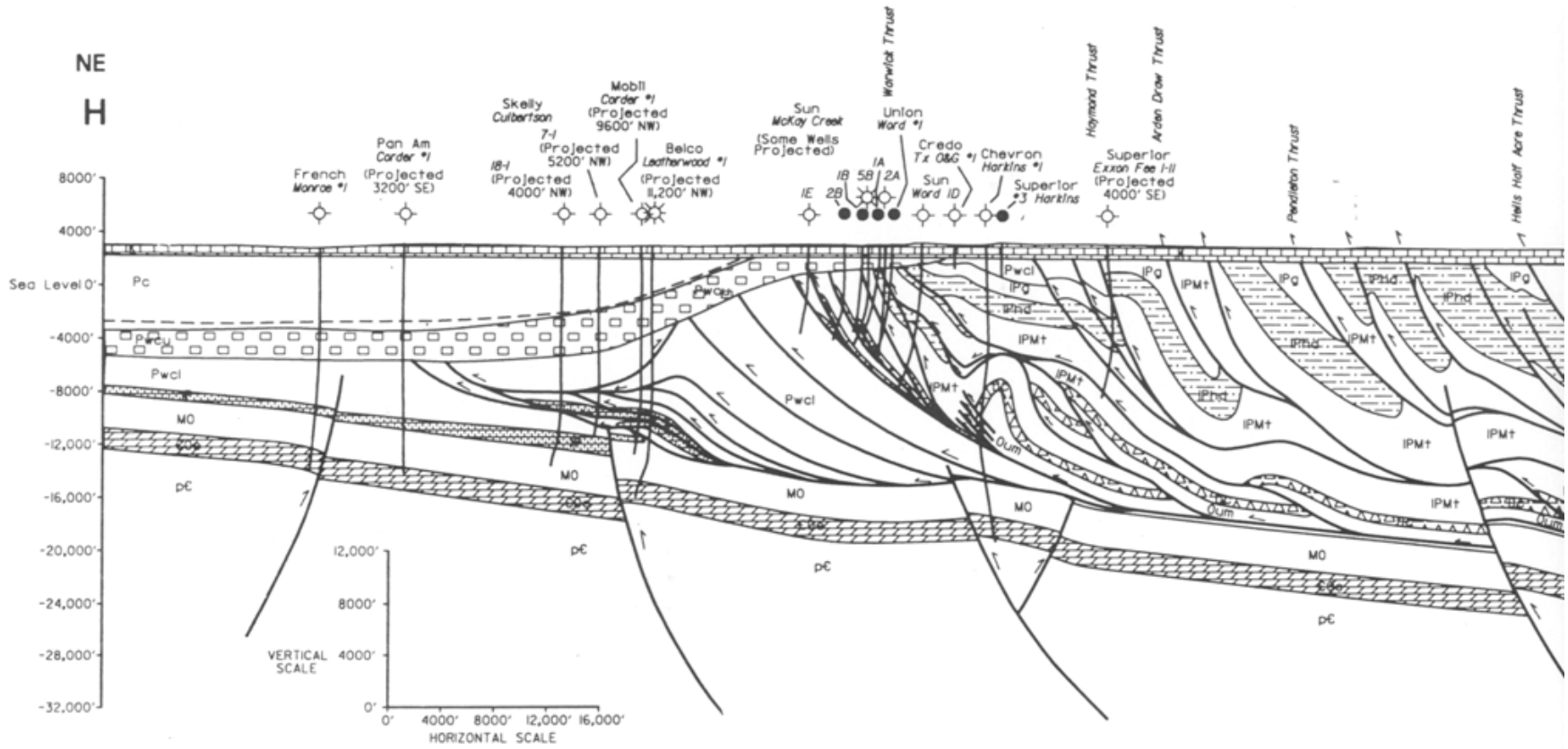
USGS

Subsurface Section, Caballos Novaculite Brewster Co., TX



(Wilde, 1990)

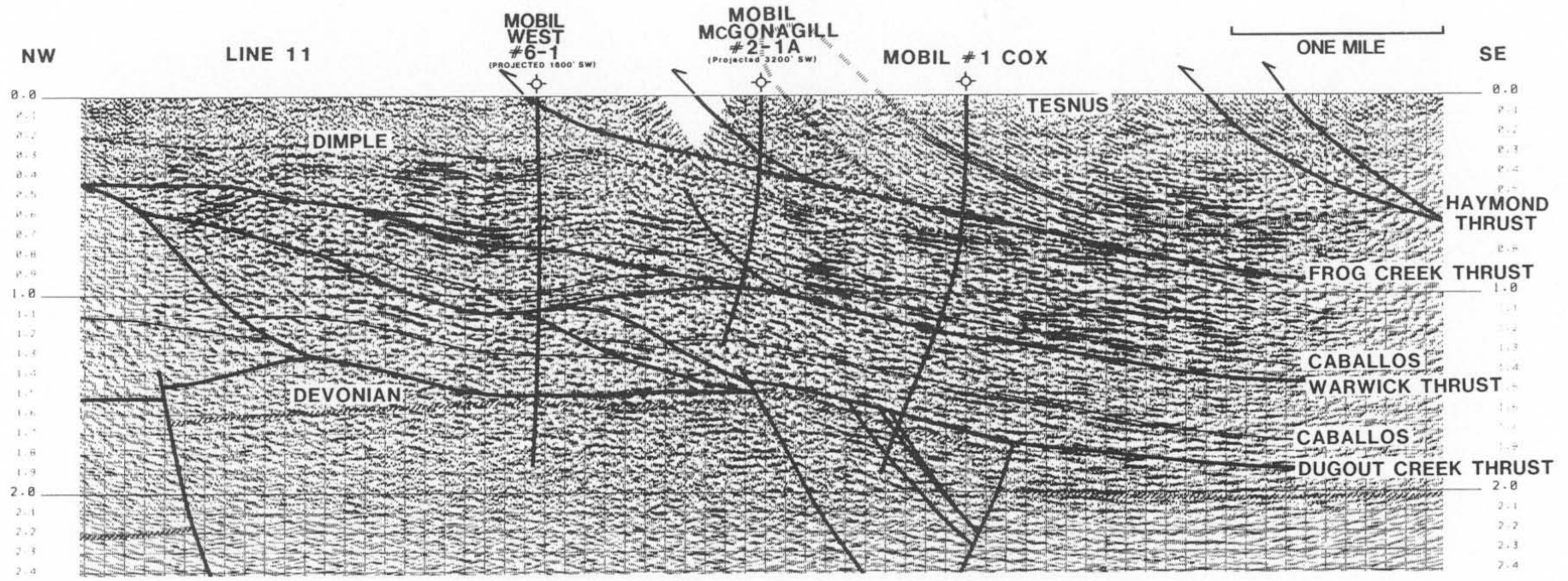
Structural Cross Section
McKay Creek Field



(Reed and Strickler, 1990)

USGS

Seismic Line



(Reed and Strickler, 1990)

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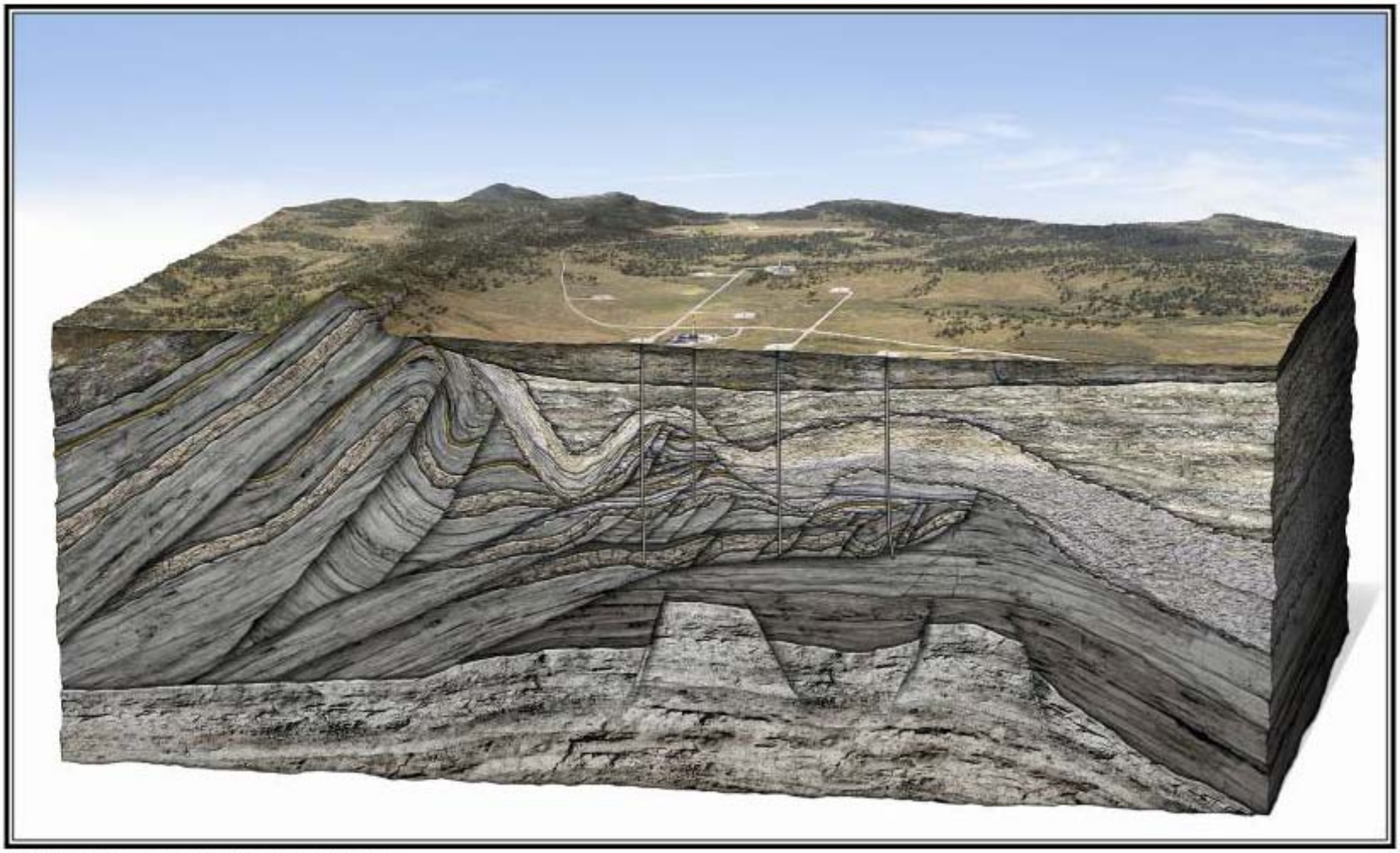
Stratigraphy and Cross Section of the West Texas Overthrust

Period	WTO
Permian	Upper Wolfcamp
	Lower Wolfcamp
Pennsylvanian	Gaptank
	Haymond
	Dimple
	Upper Tesnus
Mississippian	Middle Tesnus
	Lower Tesnus
	Upper Caballos (High CO_2)
Devonian/Silurian	Lower Caballos (Novaculite-Chert)
	Fusselman
Ordovician	Montoya
	Ellenburger

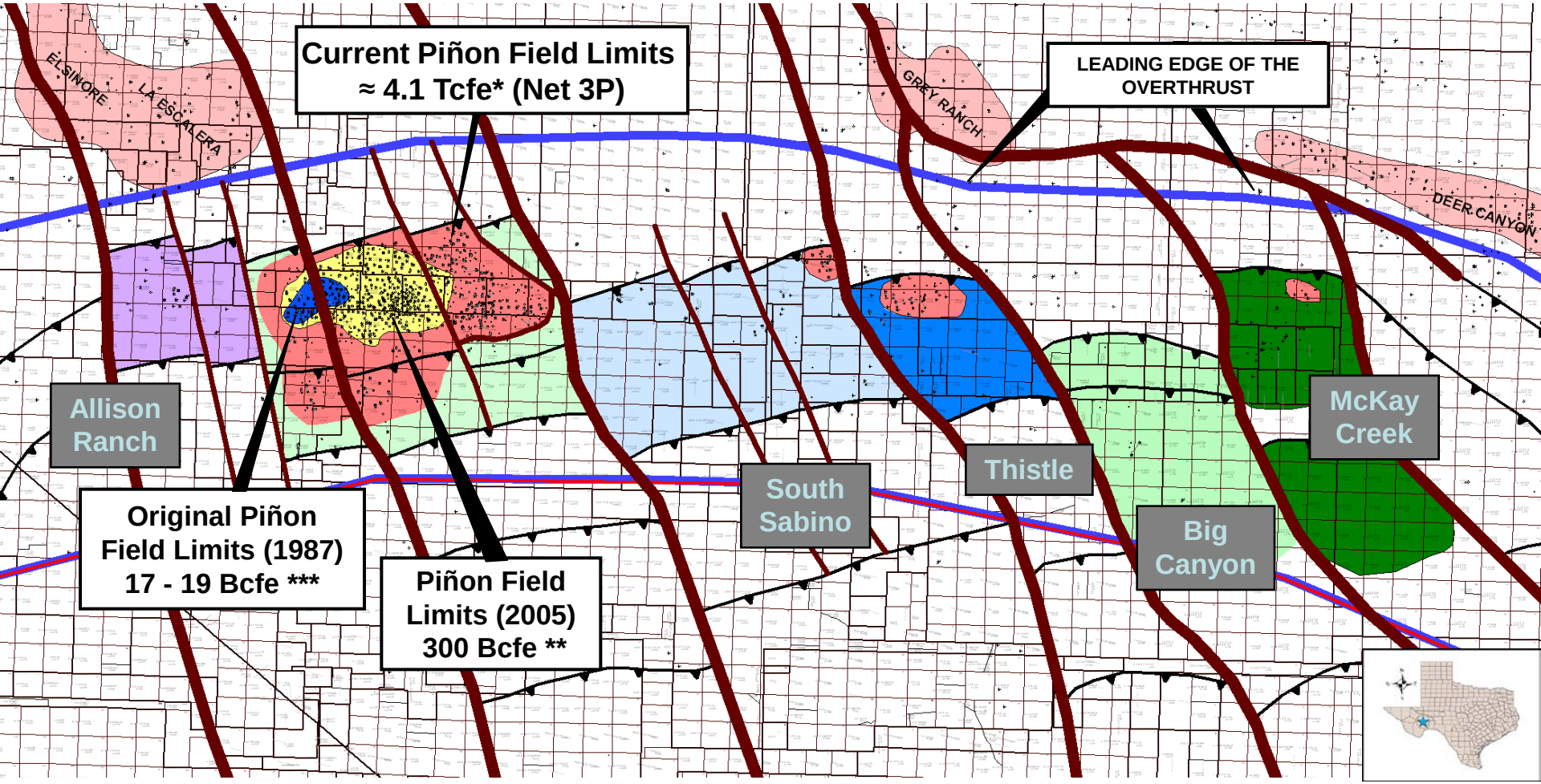


NOTE: Diagram is not to scale, and is for illustration purposes only.

(SandRidge Energy, 2008)

USGS

Pinon – McKay Creek Fields



(SandRidge Energy, 2008)

* Based on 2,594 locations

** YE 2005 D&M Reserve Report

*** Reed,T.A.and Strickler,D.L. 1990, Structural Geology and Petroleum Exploration of the Marathon Thrust Belt, West Texas: WTGS/PBS-SEPM Field, Seminar Handbook, p.51.

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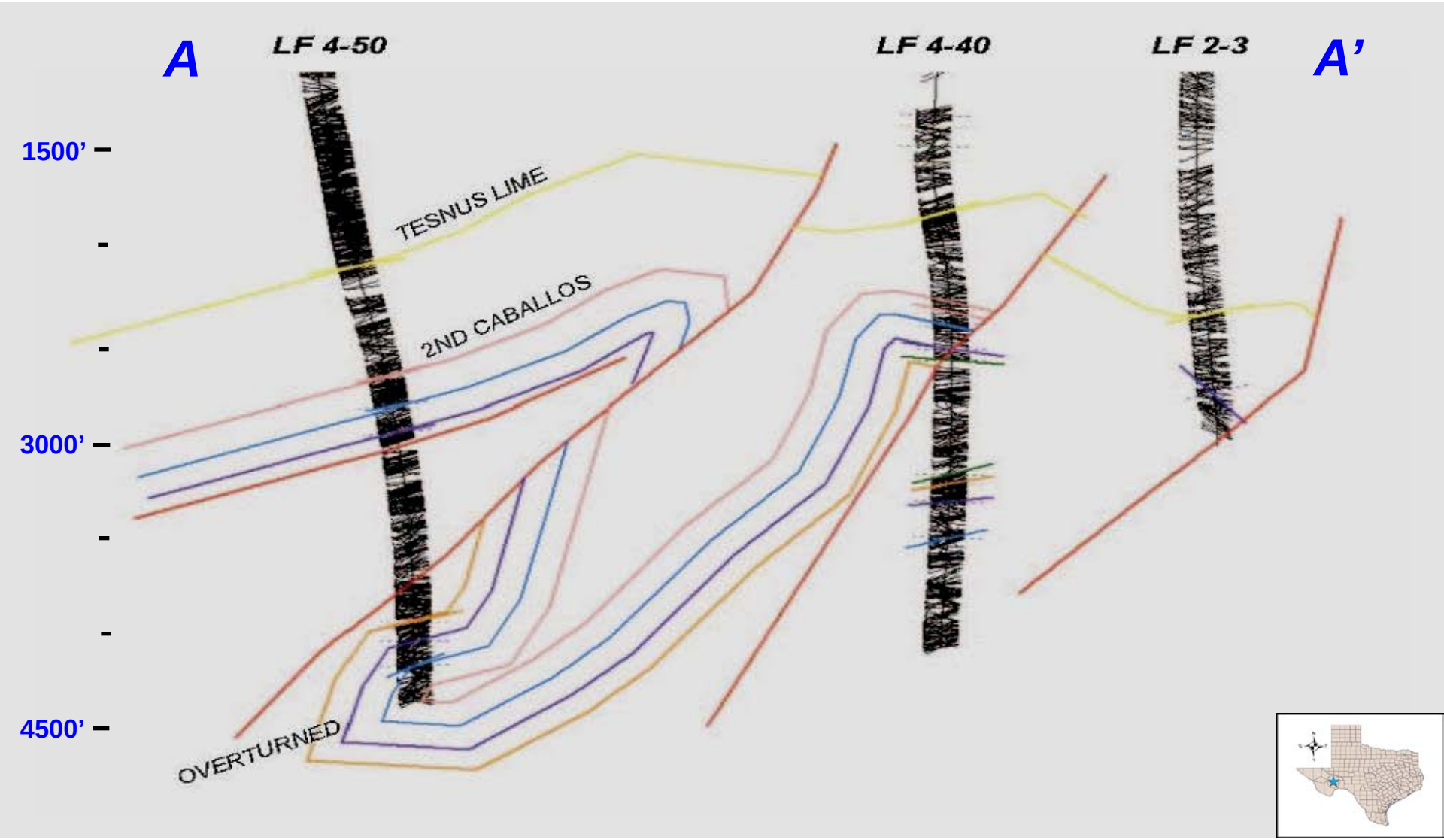
PIÑON – 2ND CABALLOS GEOLOGICAL COMPLEXITY



(SandRidge Energy, 2008)

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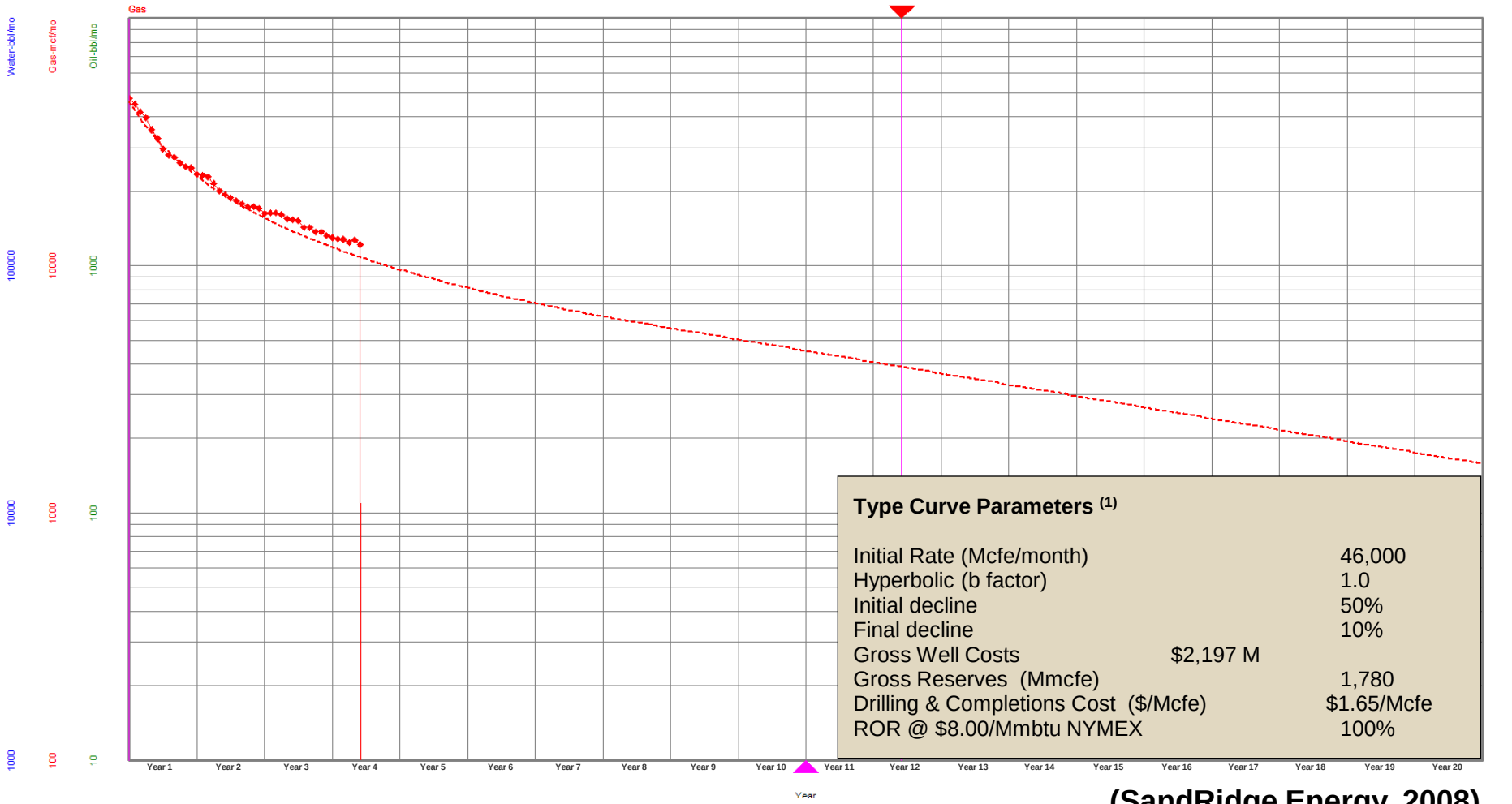
PIÑON SWEET TYPE CURVE



Type Curve Parameters (1)

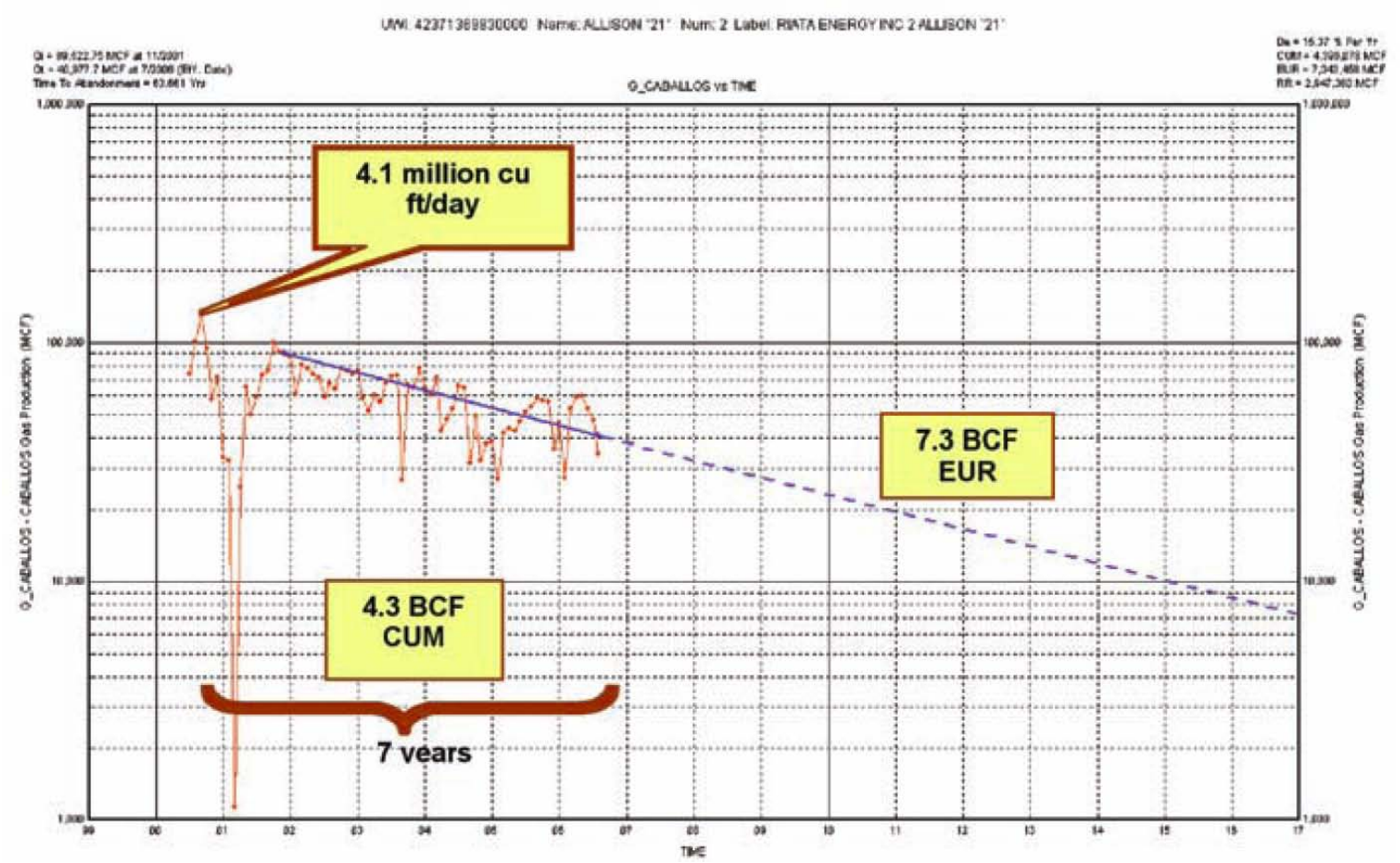
Initial Rate (Mcfe/month)		46,000
Hyperbolic (b factor)		1.0
Initial decline		50%
Final decline		10%
Gross Well Costs	$2,197 M	
Gross Reserves (Mmcfe)		1,780
Drilling & Completions Cost ($/Mcfe)		$1.65/Mcfe
ROR @ $8.00/Mmbtu NYMEX		100%

(1) PUD Weighted Average 12/31/2007

(SandRidge Energy, 2008)

USGS

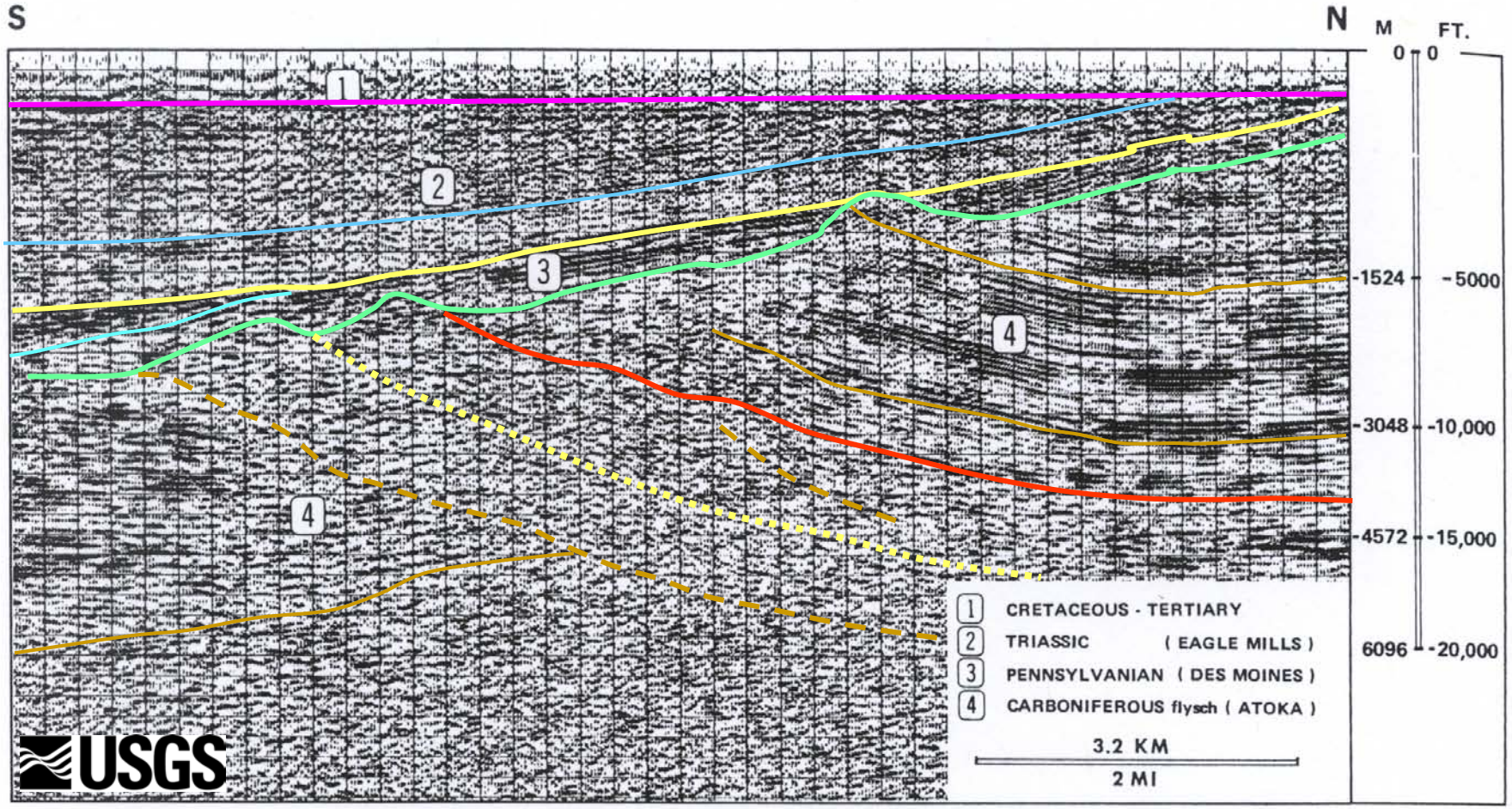
Typical Caballos Novaculite Well



(Boyce, 2008)

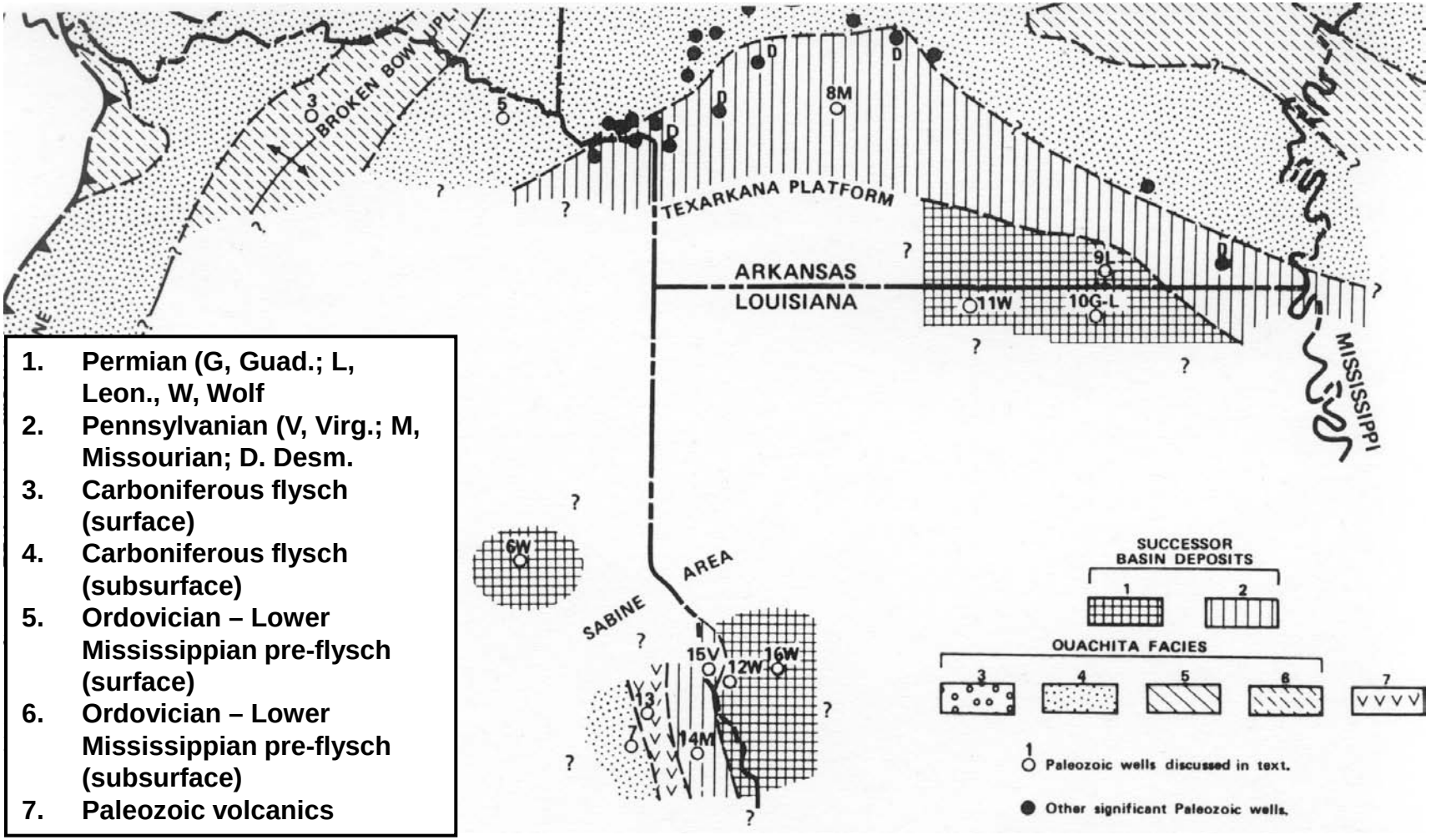
USGS

Post-Ouachita Paleozoic Succession



(modified from Nicholas and Waddell, 1989)

Post-Ouachita Paleozoic "Successor Basins"

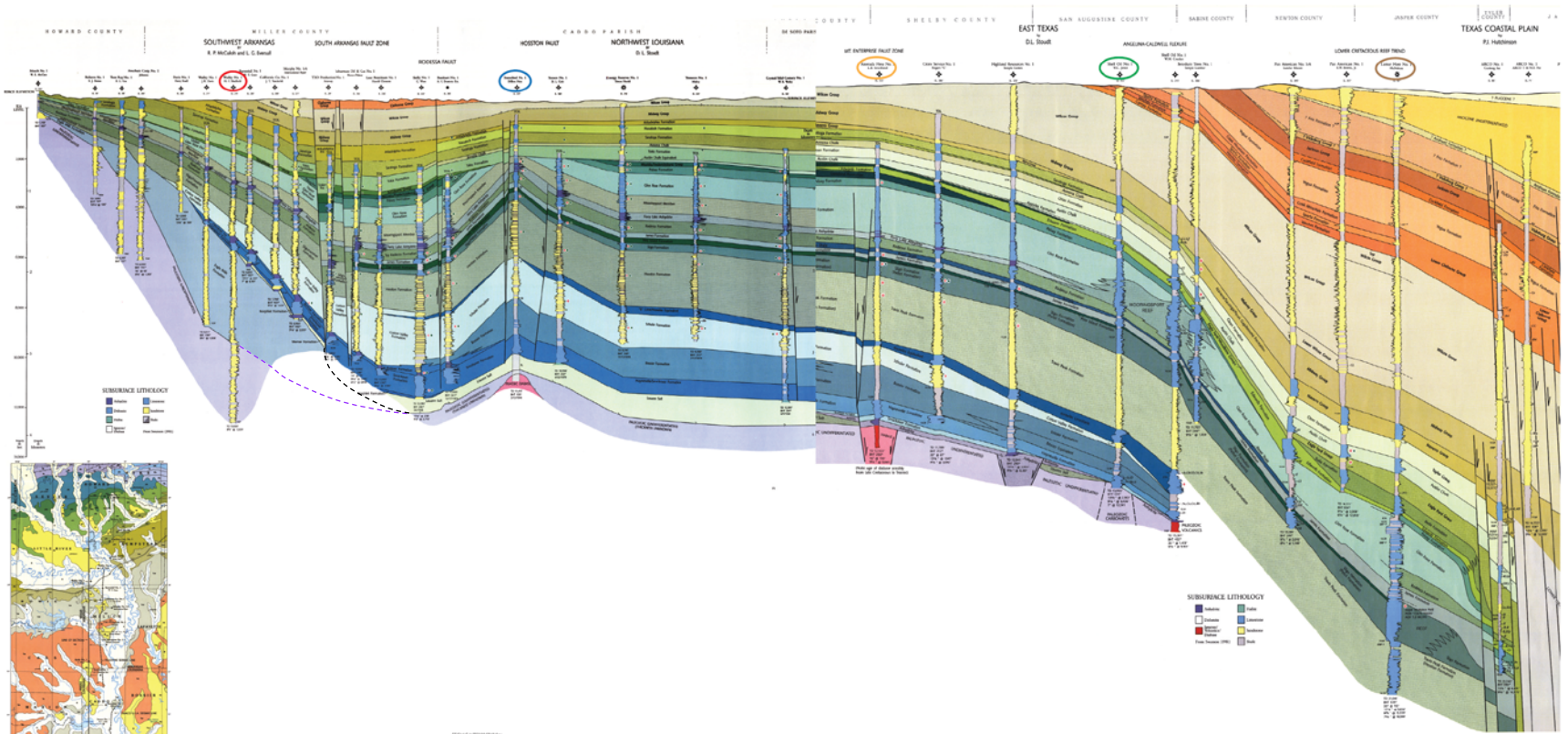


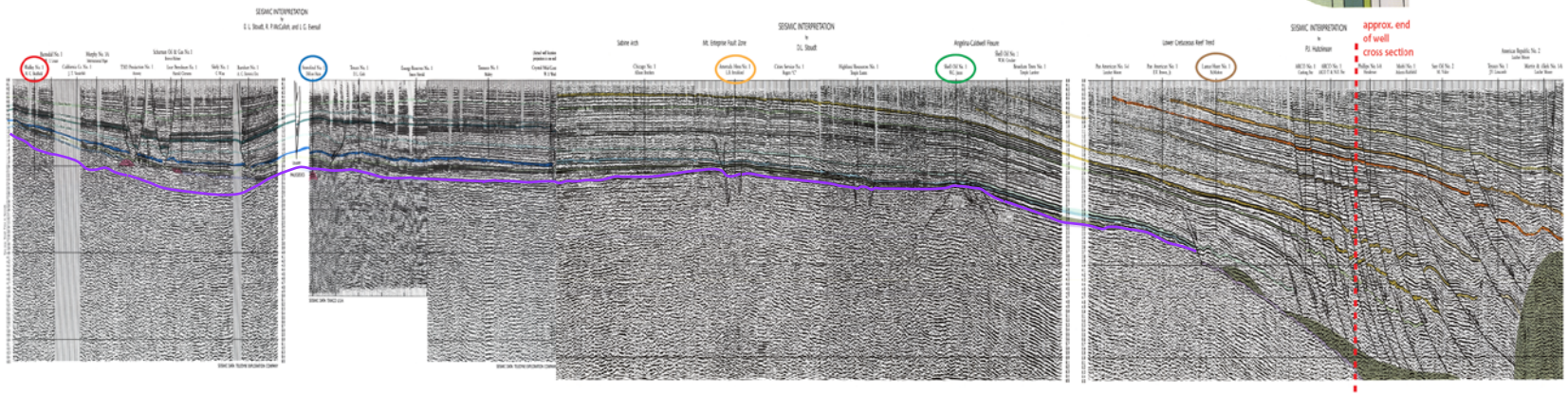
1. Permian (G, Guad.; L, Leon., W, Wolf
2. Pennsylvanian (V, Virg.; M, Missourian; D. Desm.
3. Carboniferous flysch (surface)
4. Carboniferous flysch (subsurface)
5. Ordovician – Lower Mississippian pre-flysch (surface)
6. Ordovician – Lower Mississippian pre-flysch (subsurface)
7. Paleozoic volcanics

USGS

(Nicholas and Waddell, 1989)

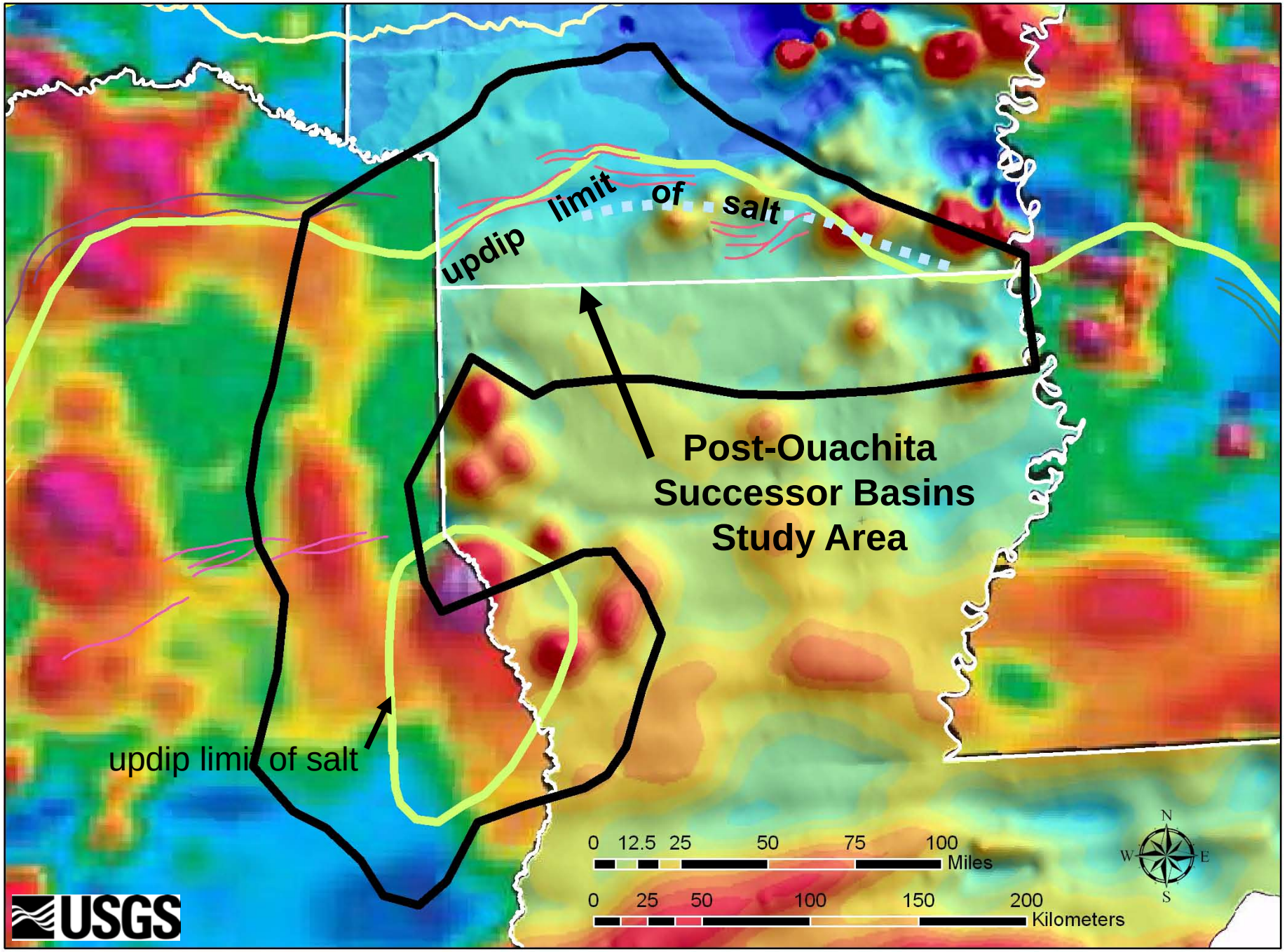
Geologic Cross Section - East Texas & NW Lousiana Gulf Coastal Plain



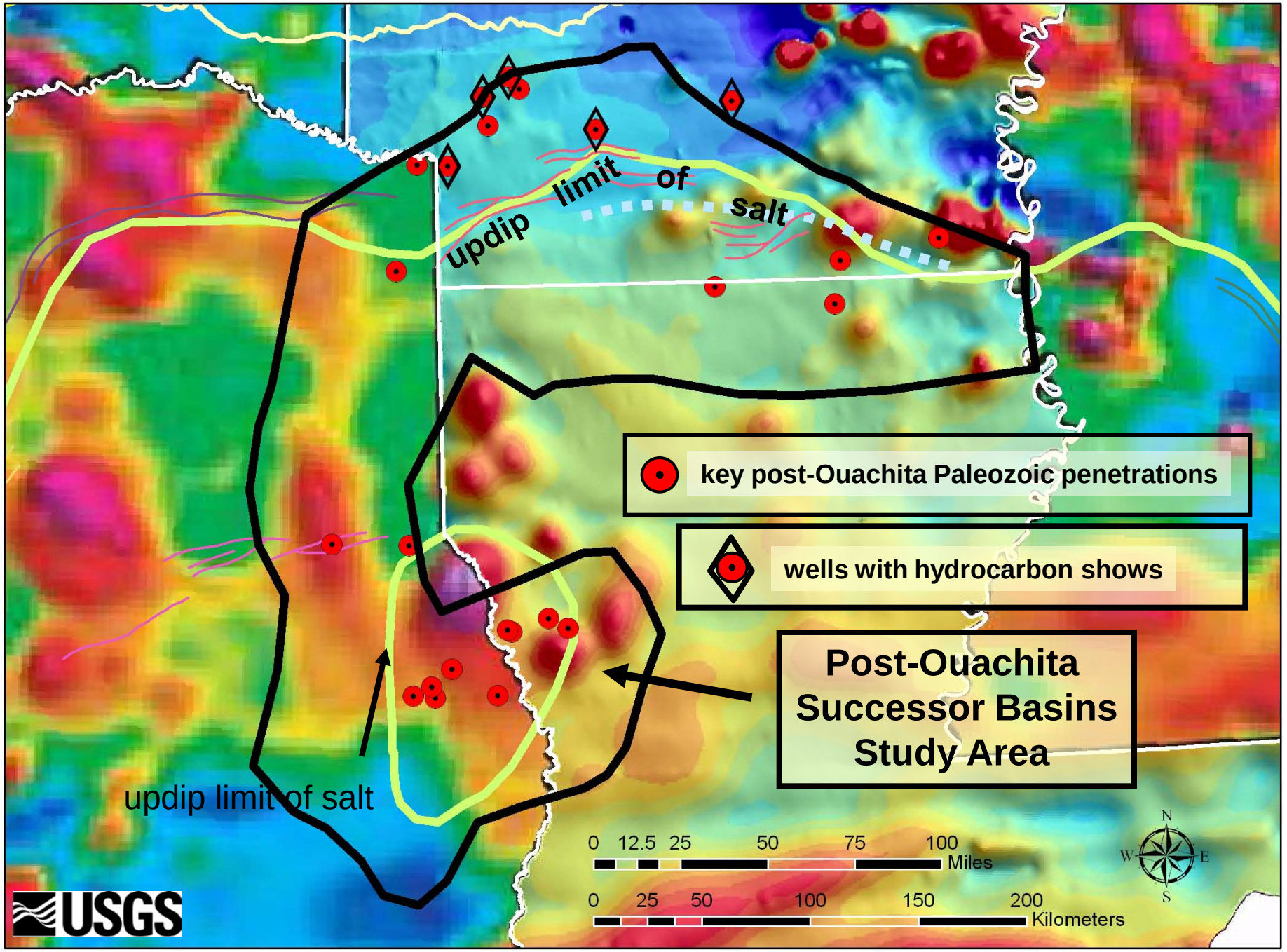


USGS

(modified from Stoudt and others, 1990)

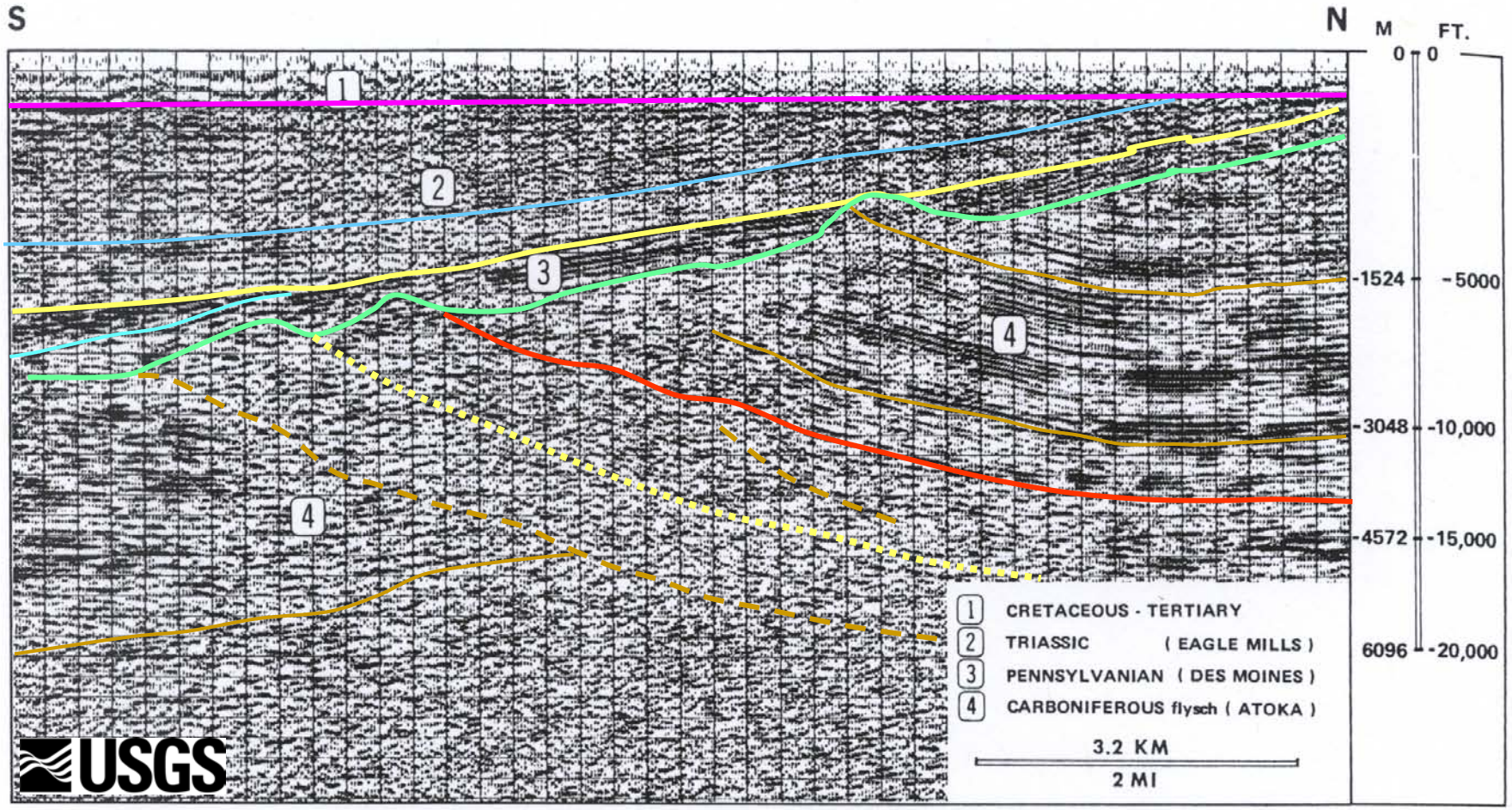


(aeromagnetic maps from Bankey and Daniels, 2008, and Bankey and others, 2002; Gulf Coast marginal faults from Ewing and Lopez, 1991)



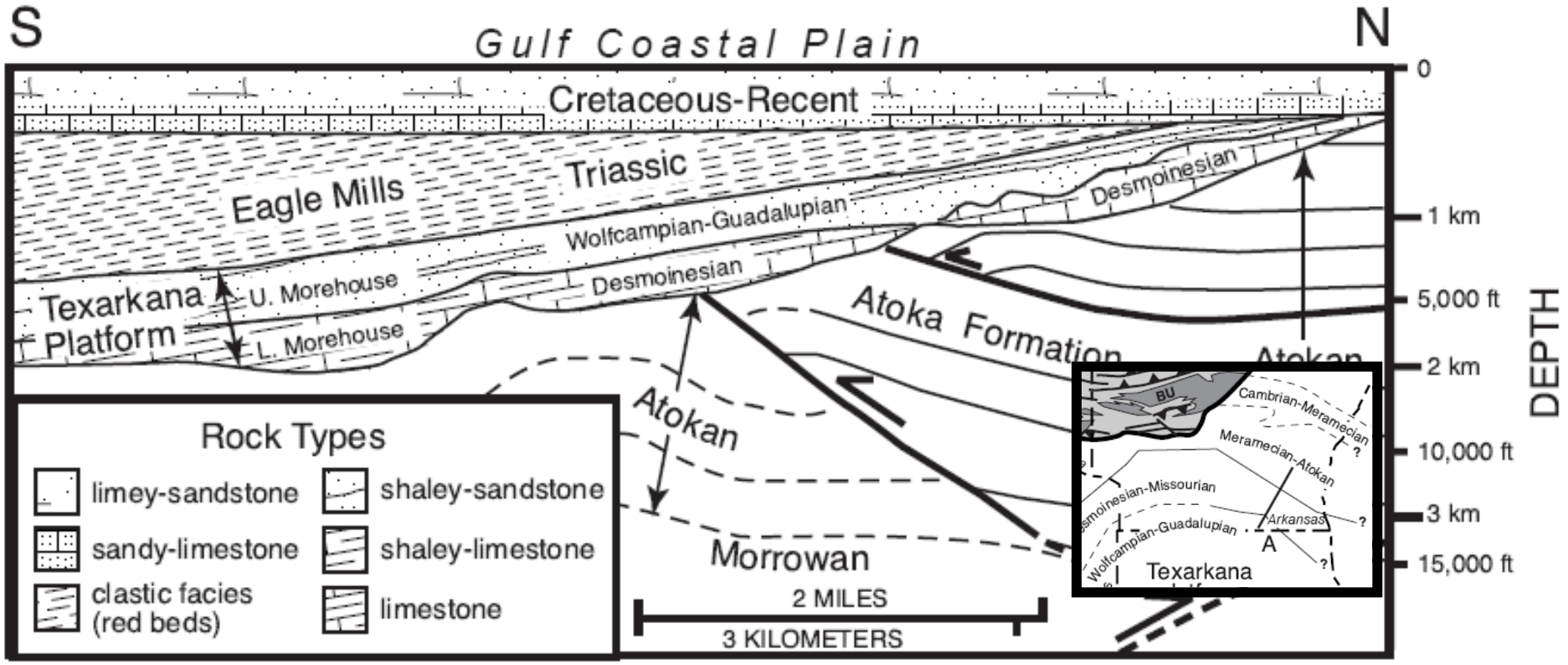
(aeromagnetic maps from Bankey and Daniels, 2008, and Bankey and others, 2002; Gulf Coast marginal faults from Ewing and Lopez, 1991)

Ouachita & Post-Ouachita Seismic Facies



(modified from Nicholas and Waddell, 1989)

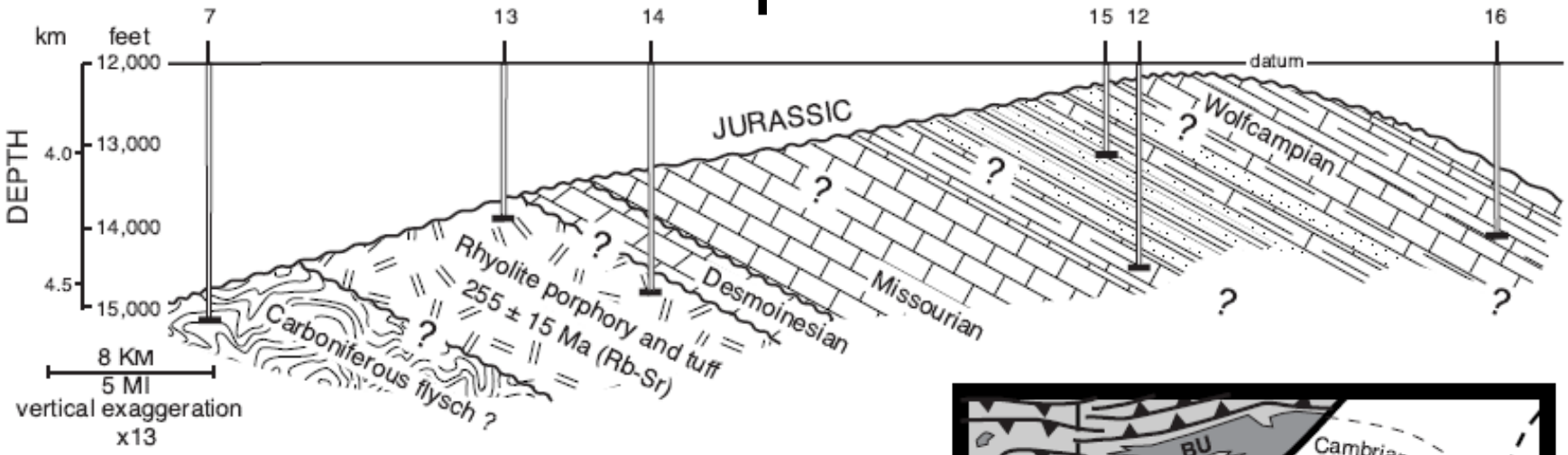
Cross Section of Upper Paleozoic – Mesozoic – Cenozoic, SW Arkansas



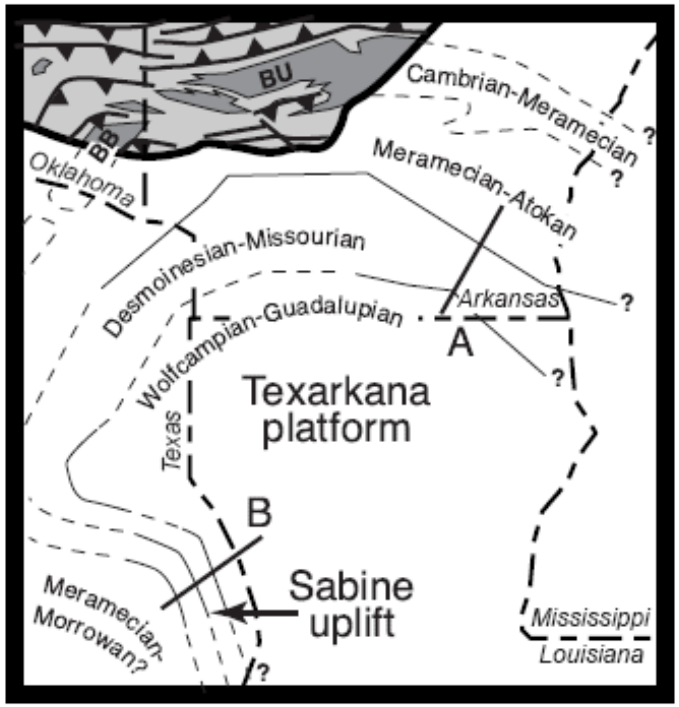
(modified from Fay and others, 1986; Johnson and others, 1988; and Nichols and Waddell, 1989, in Jusczuk, 2002)

USGS

Paleozoic – Jurassic of Sabine Uplift



(modified from Nicholas and Waddell, 1989, in Jusczuk, 2002)



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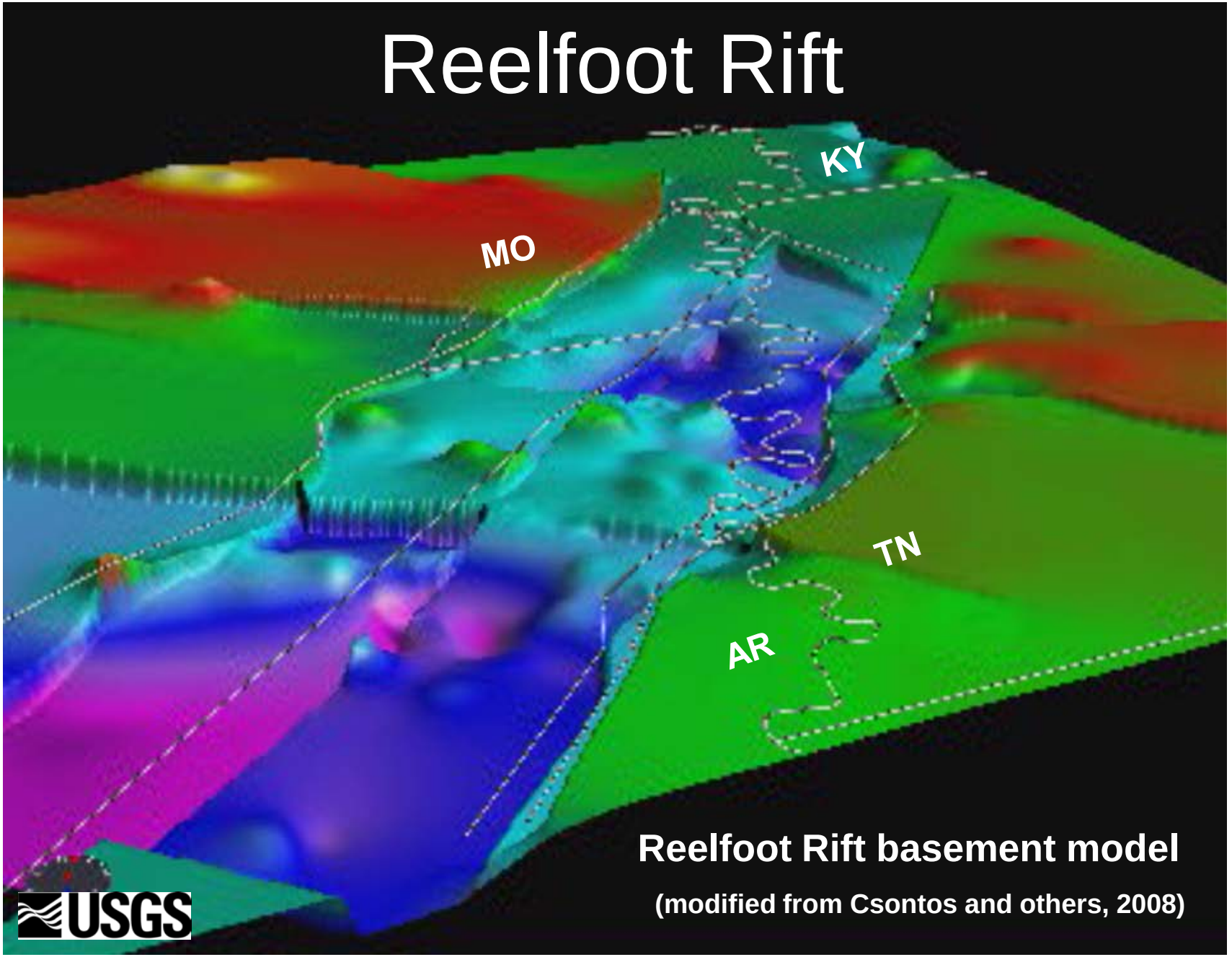
Reelfoot Rift



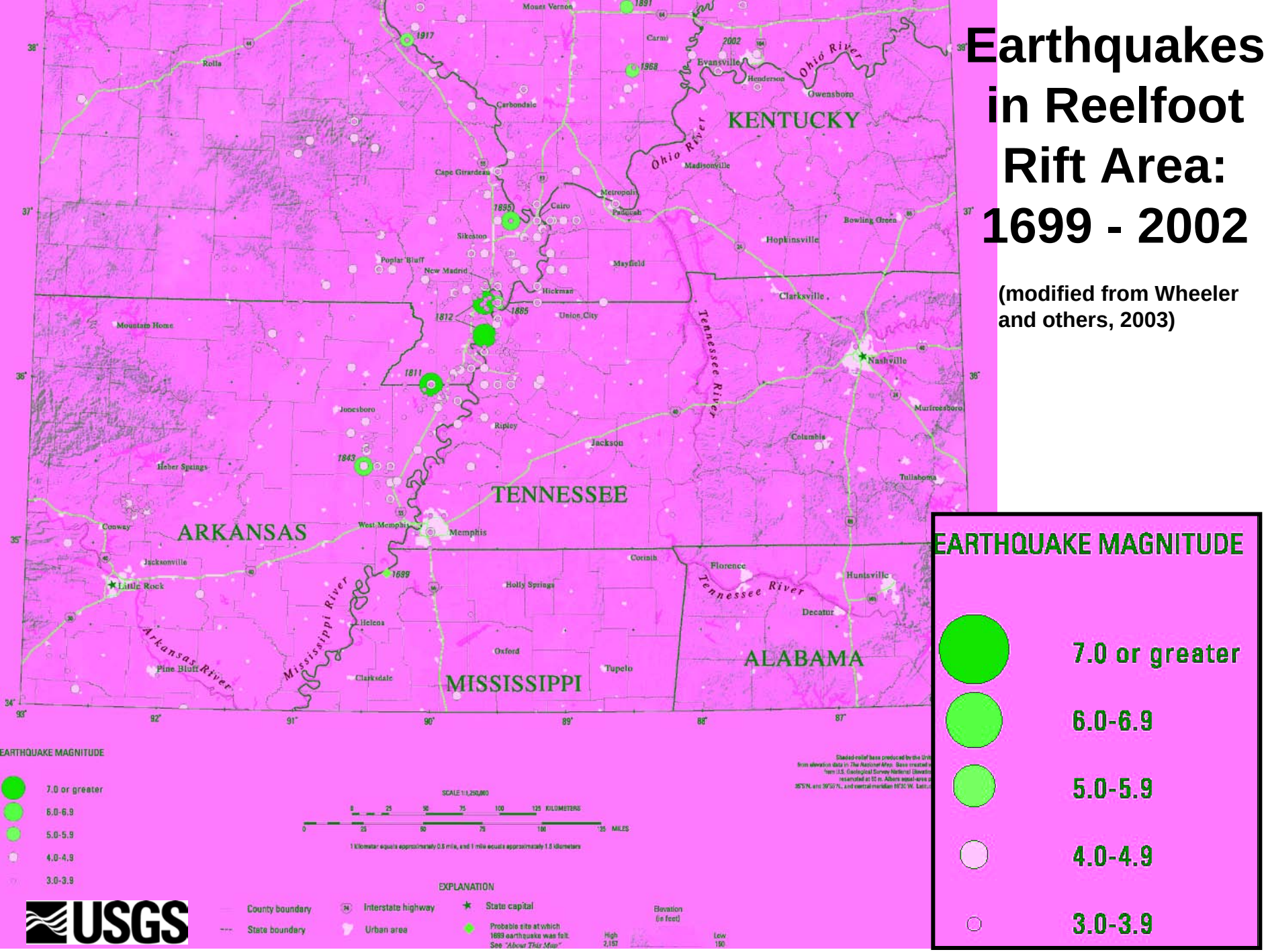
Reelfoot Rift basement model

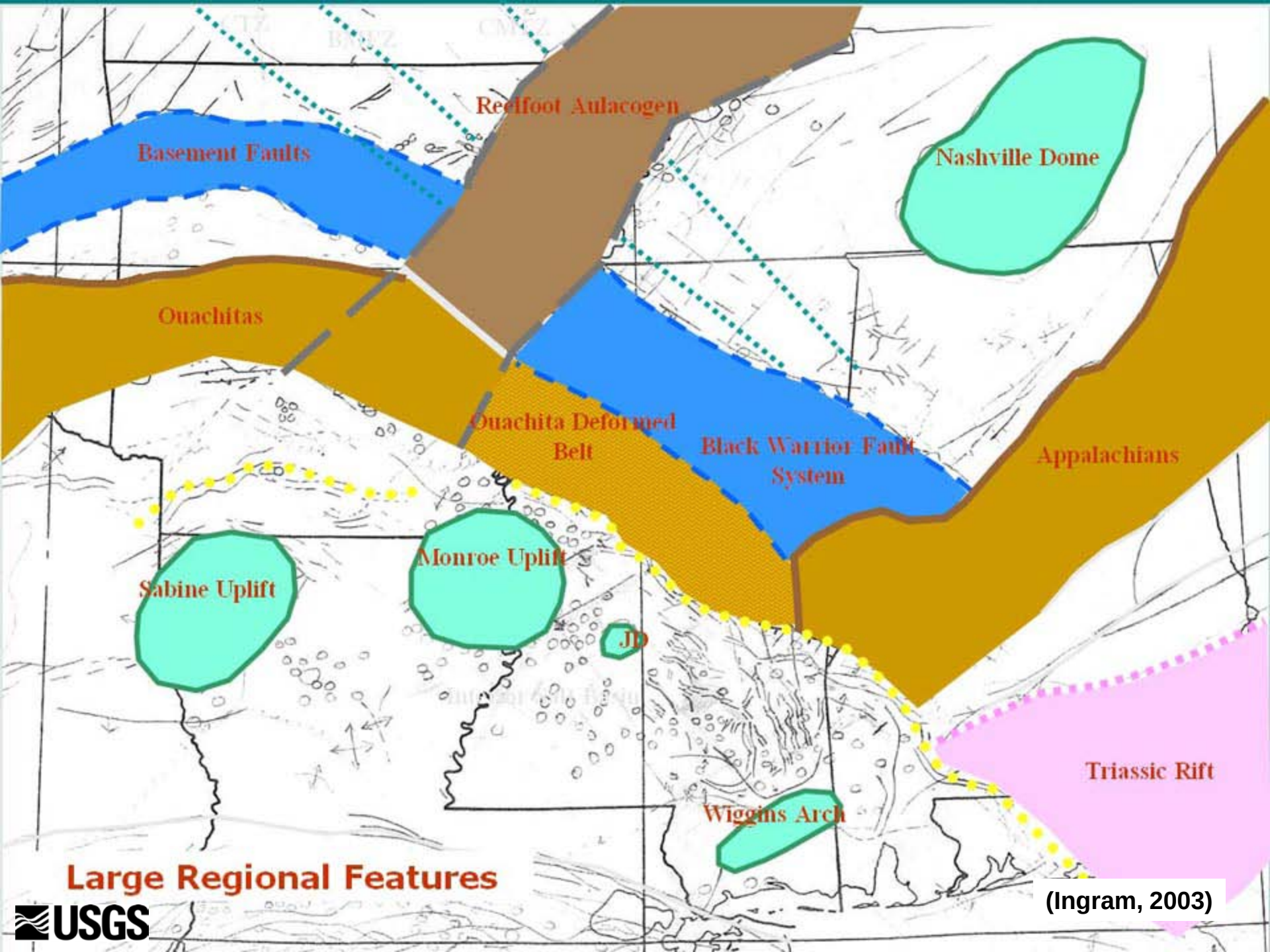
(modified from Csontos and others, 2008)

USGS

Earthquakes in Reelfoot Rift Area: 1699 - 2002

(modified from Wheeler and others, 2003)





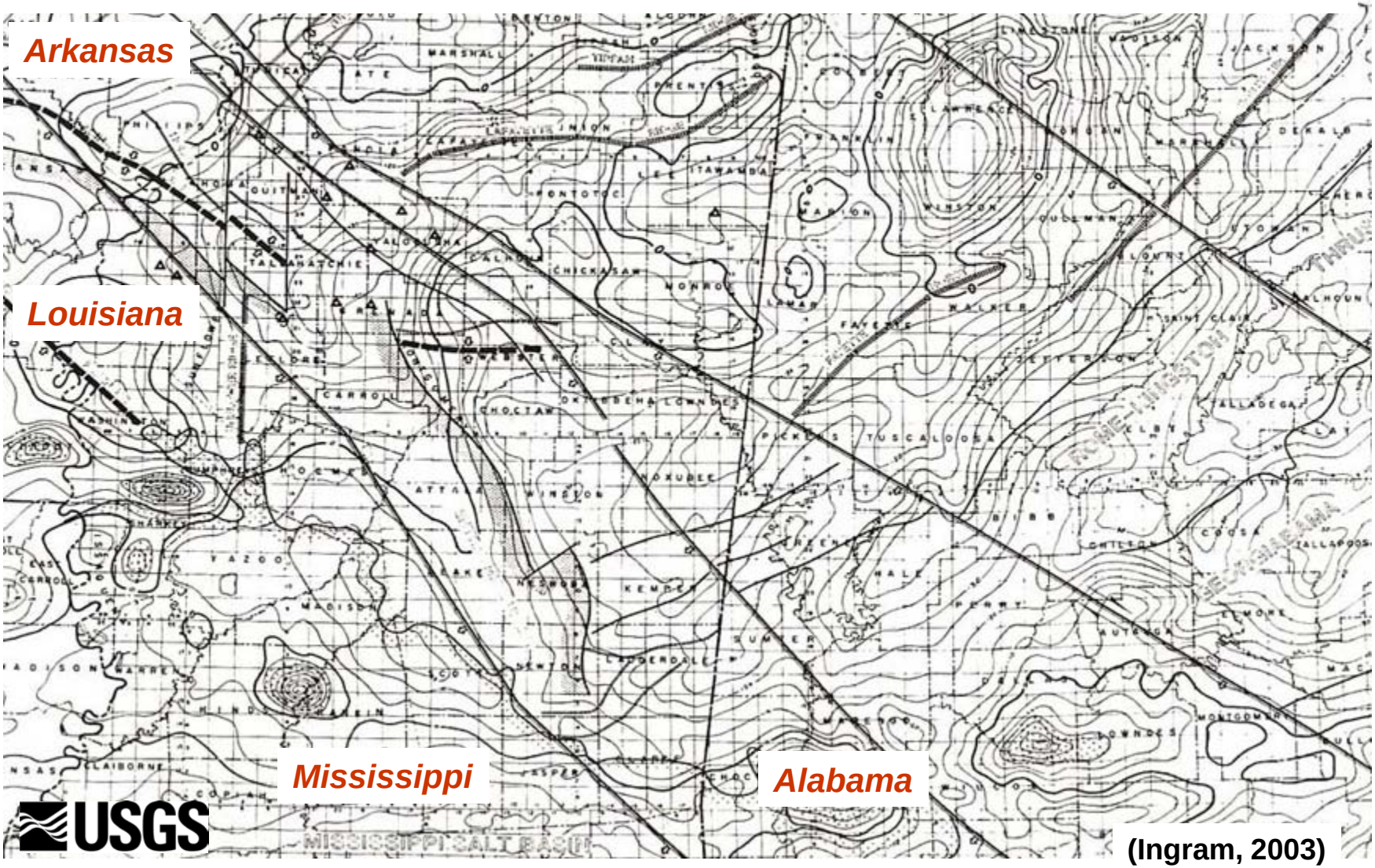
Large Regional Features

USGS

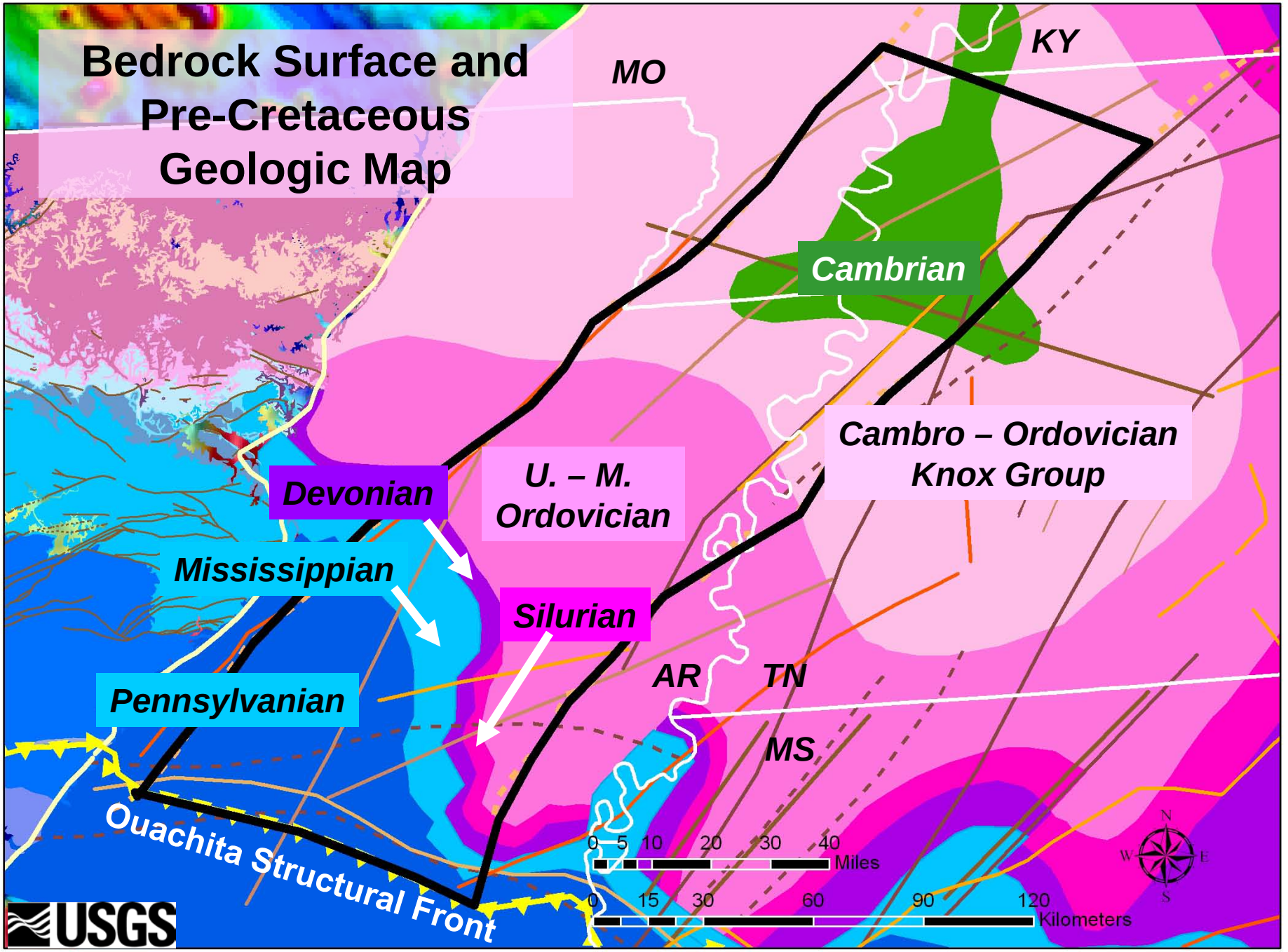
(Ingram, 2003)

Interpreted Regional Fault Trends

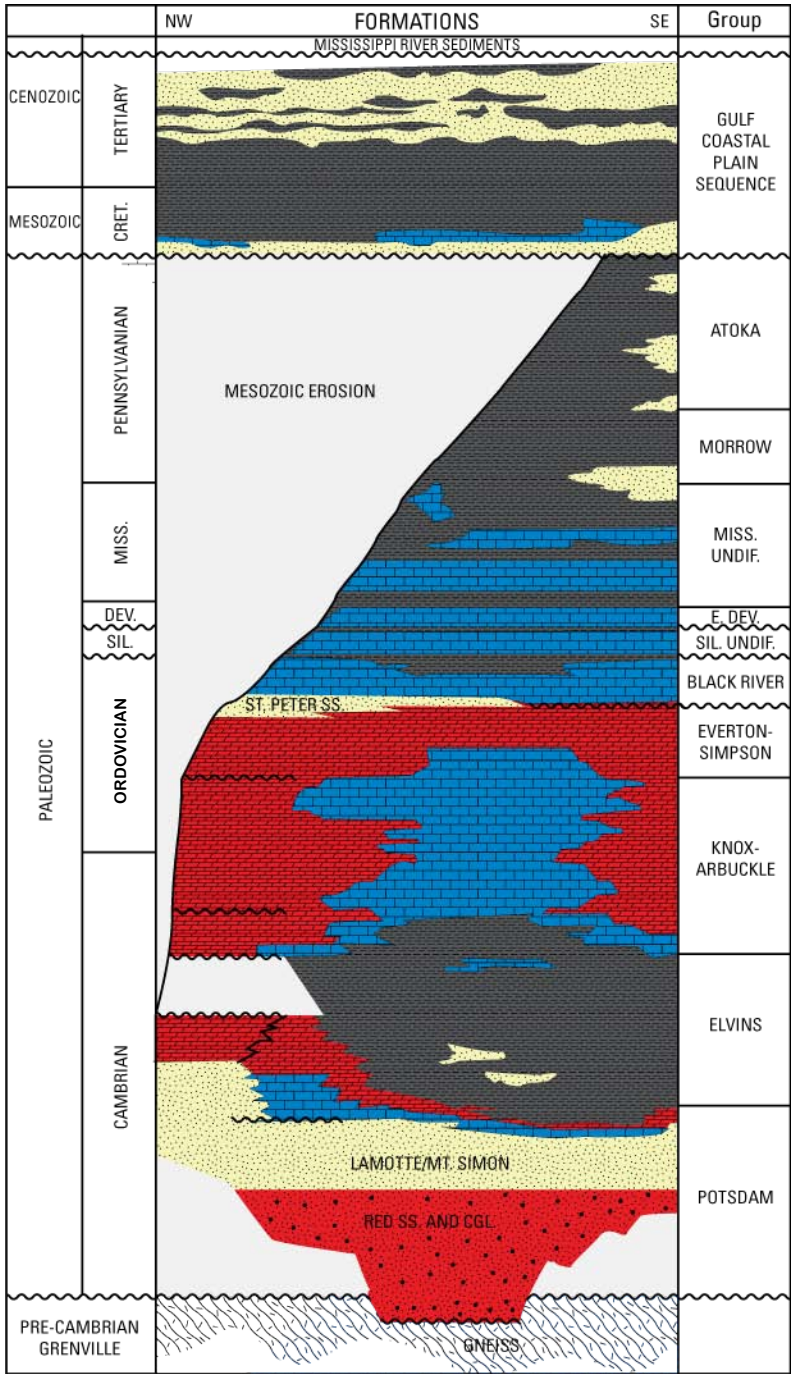
(Oxley, 1991)



(Ingram, 2003)



(modified in part from Schruben and others, 1998 and Schwalb, 1982)



Reelfoot Rift Stratigraphic Column

potential source interval

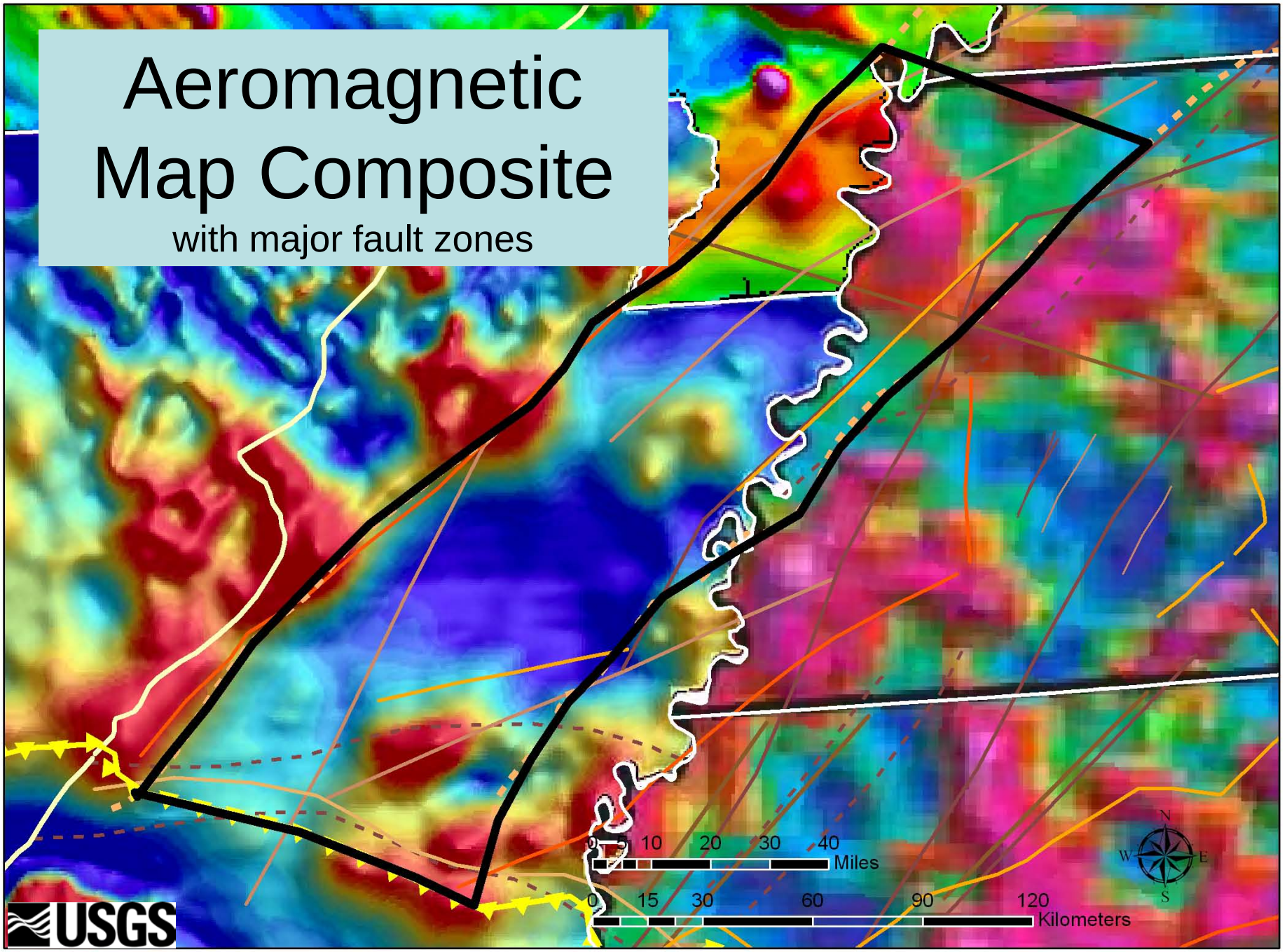
known source interval

known source interval

potential source interval

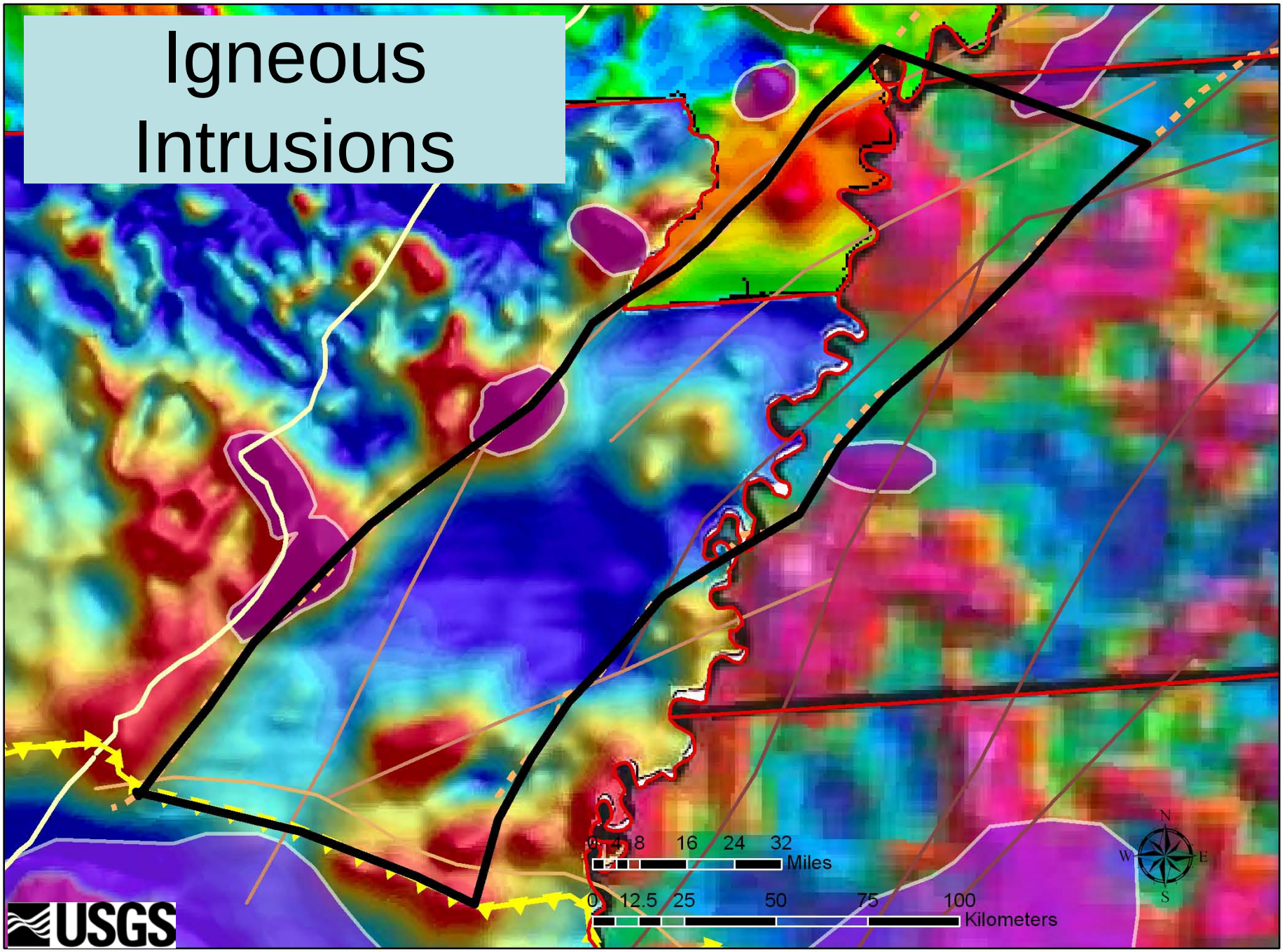
USGS

(section courtesy G. Van Swearingen, 2009)



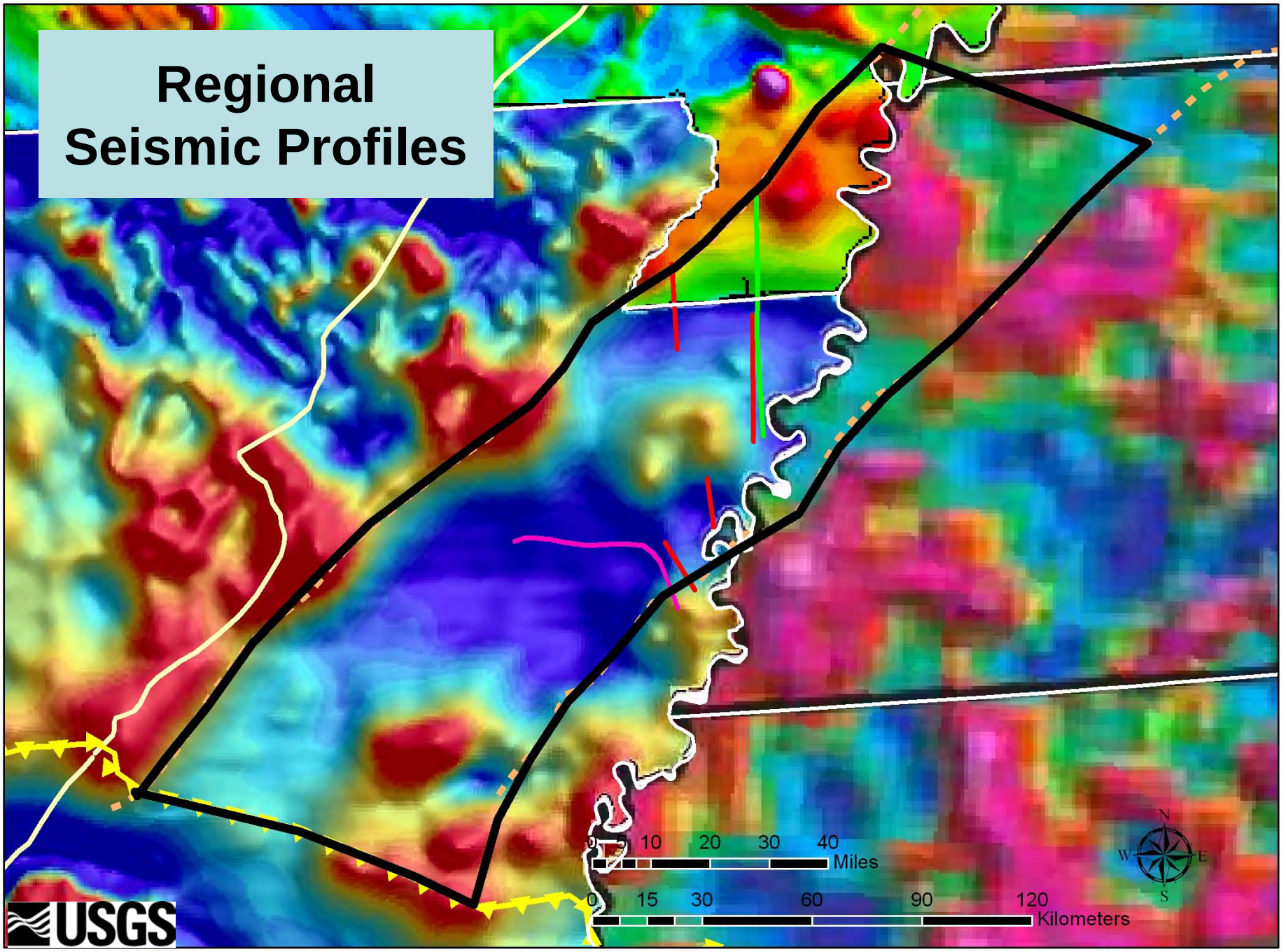
(aeromagnetic maps from Bankey and Daniels, 2008, Kucks and Hill, 2006, and Bankey and others, 2002)

Igneous Intrusions



(aeromagnetic maps from Bankey and Daniels, 2008, Kucks and Hill, 2006, and Bankey and others, 2002; igneous areas from Coleman, 1991 & Hildenbrand, 1985)

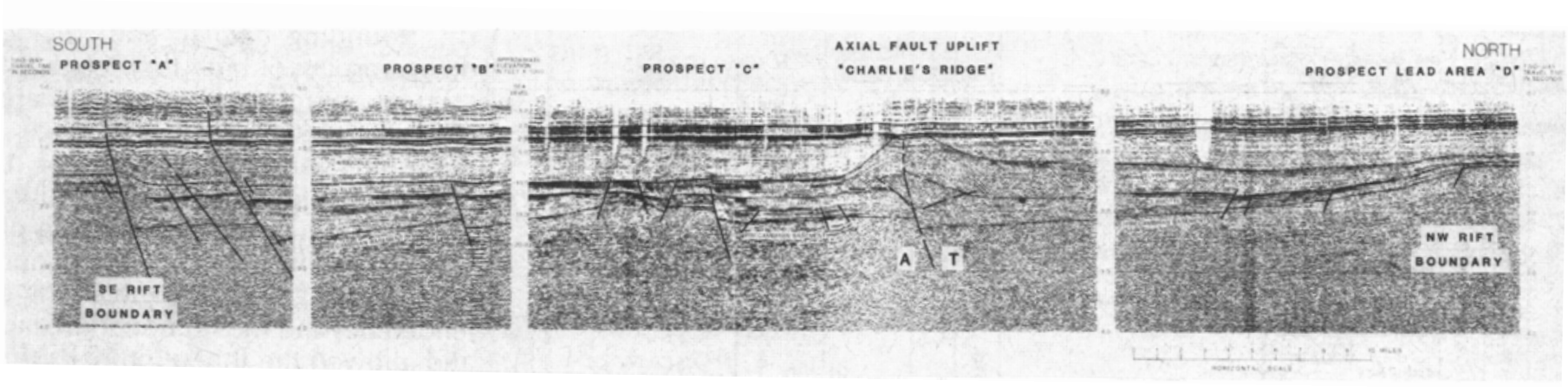
Regional Seismic Profiles



(aeromagnetic maps from Bankey and Daniels, 2008, Kucks and Hill, 2006, and Bankey and others, 2002)

Reelfoot Regional Seismic Line

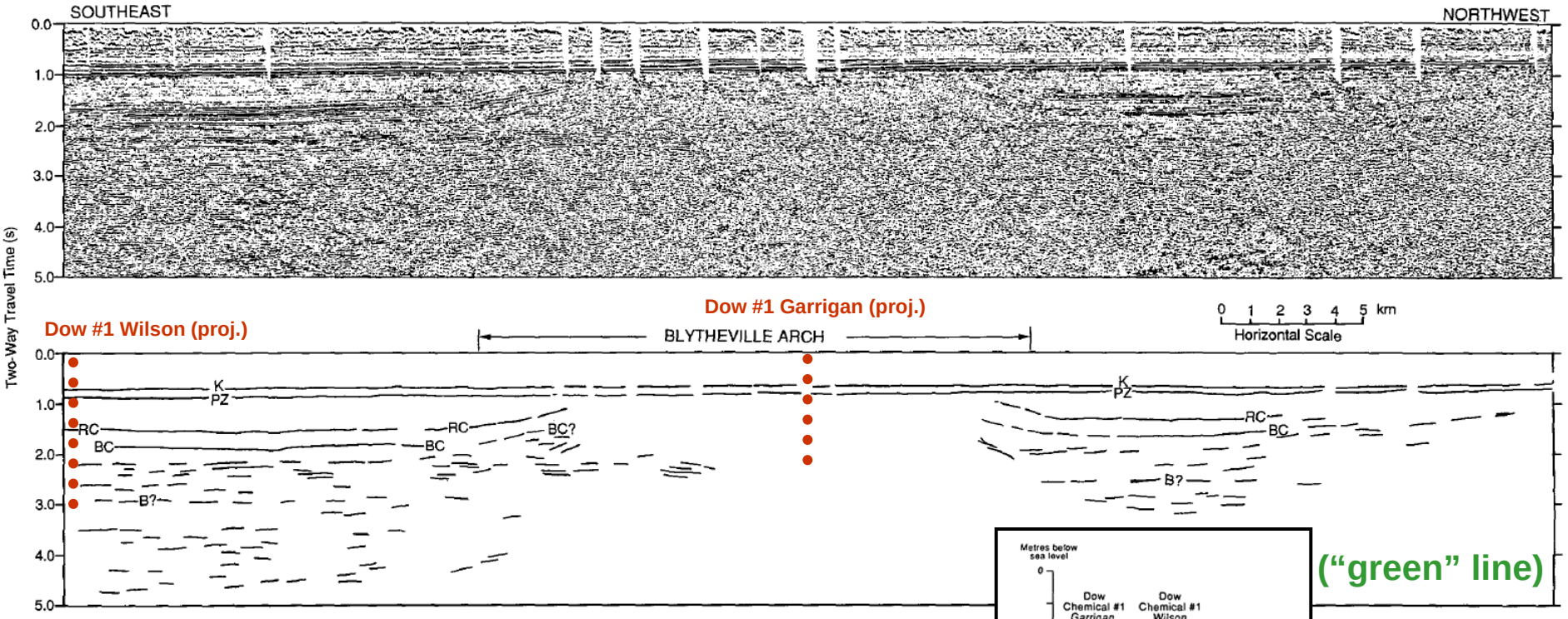
(“red” line)

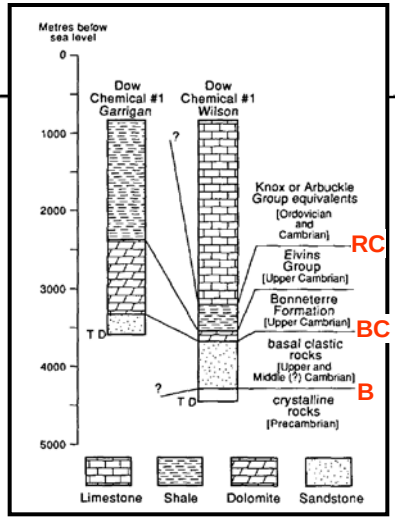


(Howe and Thompson, 1984)

USGS

Reelfoot Rift Deep Seismic





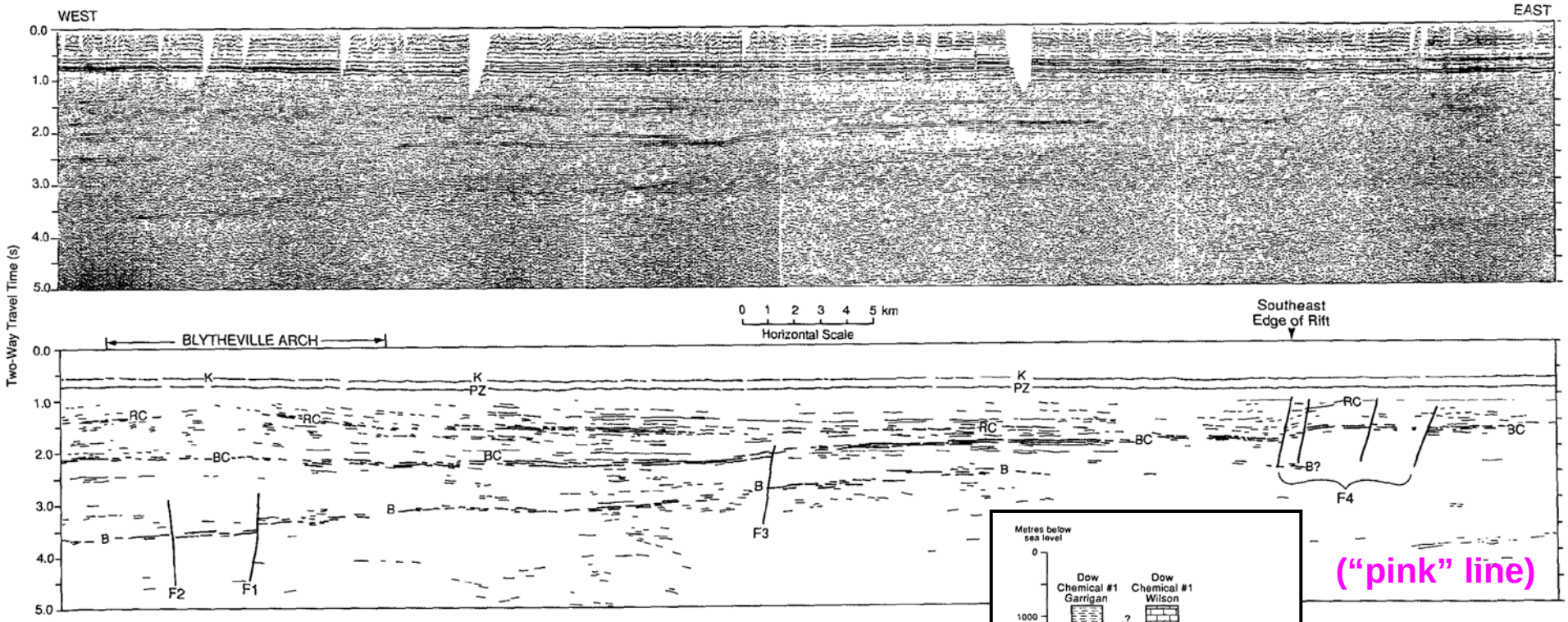
(“green” line)

K = K-T boundary
Pz = UK – Pz contact
RC = top of red clay unit (“maybe top of Elvins Group”)
BC = top of basal clastic rock unit (“lithic arenites and graywackes”)
B = Pz – crystalline rock contact

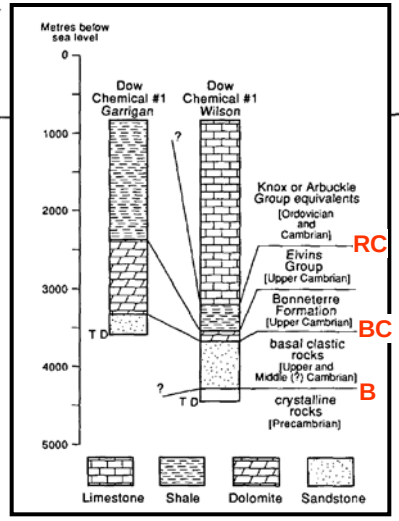
USGS

(modified from McKowen and others, 1990)

Reelfoot Rift “Deep” Seismic



(“pink” line)

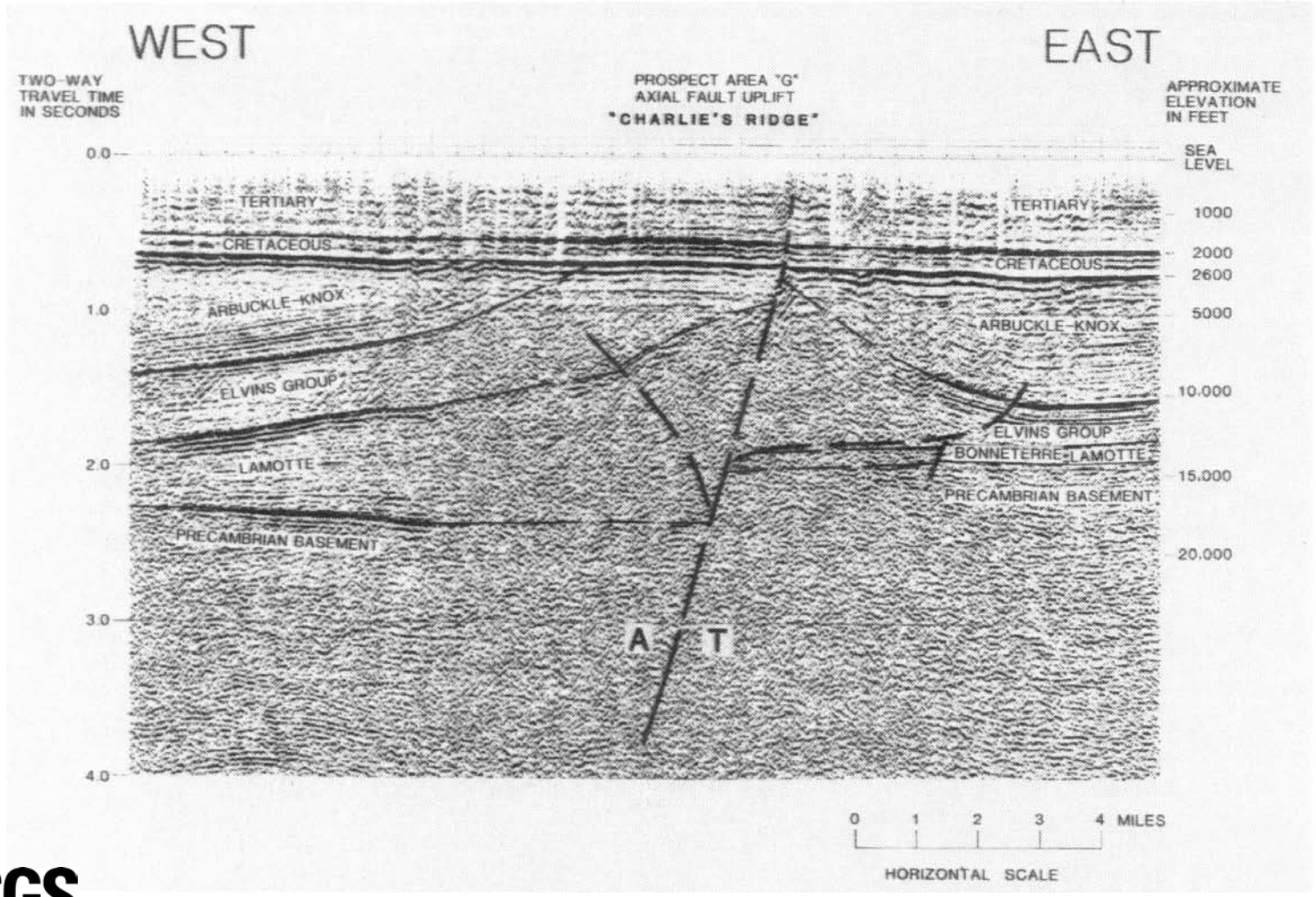


K = K-T boundary
Pz = UK – Pz contact
RC = top of red clay unit (“maybe top of Elvins Group”)
BC = top of basal clastic rock unit (“lithic arenites and graywackes”)
B = Pz – crystalline rock contact

USGS

(from McKowen and others, 1990)

Reelfoot Rift Prospect “G”



USGS

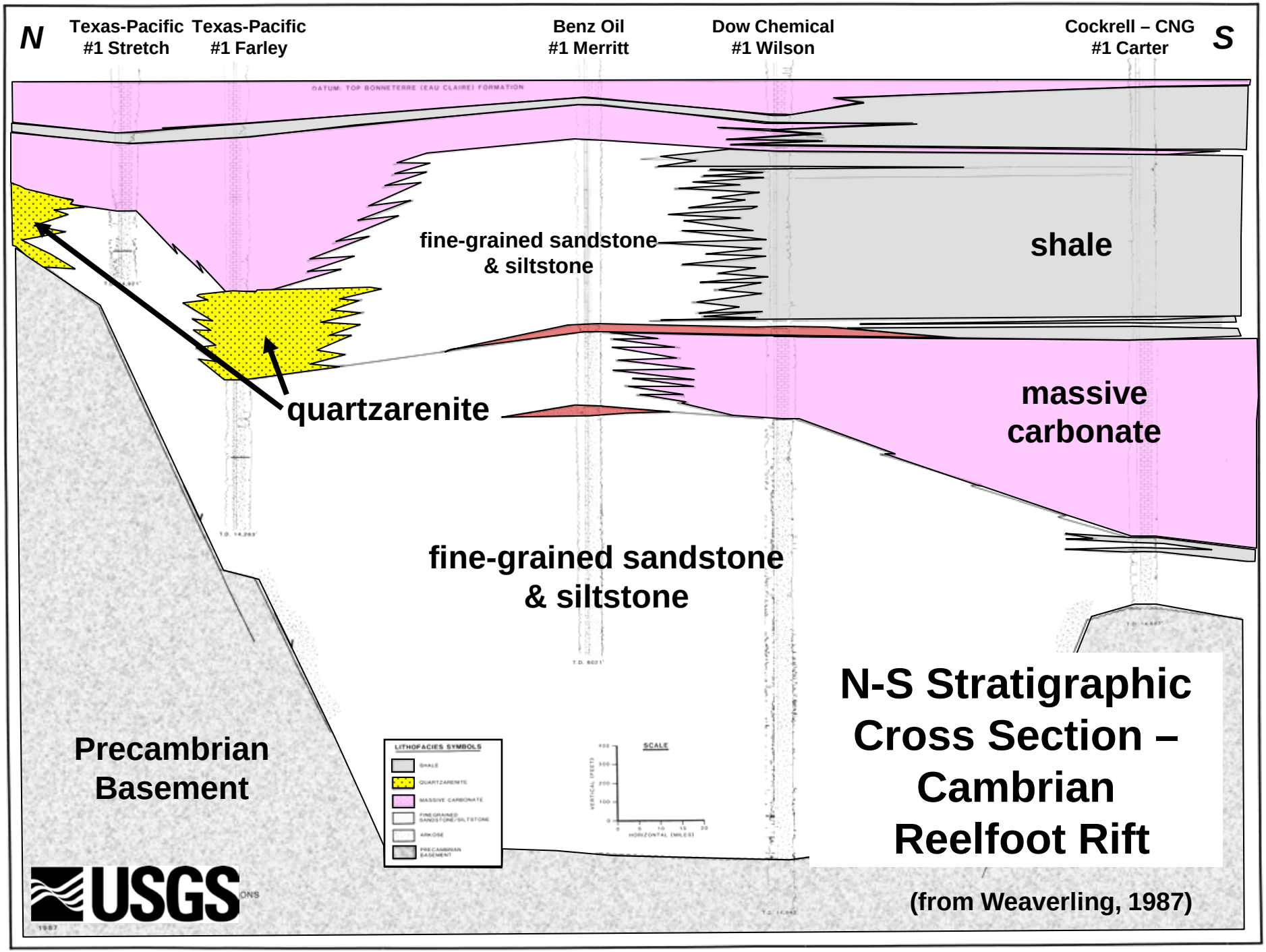
(Howe and Thompson, 1984)

Reelfoot Rift – Key Wells

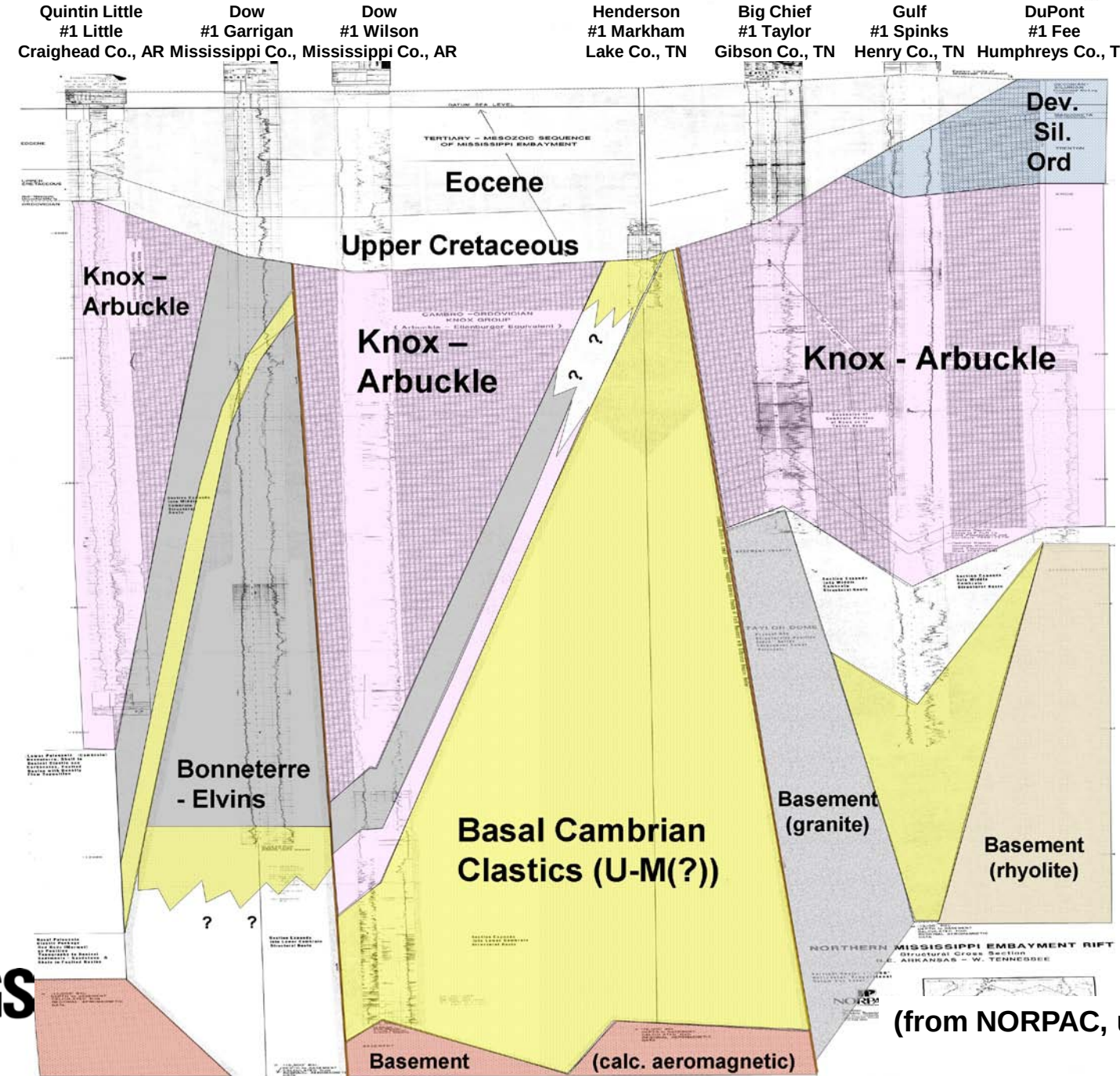
Year	Operator	Lease	Number	County	State	TD (ft)	Shows	Results	Key Observations
1939	Benedum-Trees	Mack	1	Mississippi	Arkansas	4,535	asphalt - Upper Knox	P&A	flowed SW ARO 2400 BWPD from Knox; no logs run
1940	Tennark	Martin	1	Craighead	Arkansas	5,092	O&G (inc. asphalt) - upper PZ	P&A	TD'd in Knox, logs run
1940	Pure Oil	McGregor	1	Tipton	Tennessee	2,753	no shows reported	P&A	TD'd in nepheline syenite; drilled on Covington Pluton gravity high
1941	Strake	Russell	1	Pemiscot	Missouri	4,740	water w/H2S odor	P&A	drilled on gravity high; logs rn to 2152 ft; v. lean Pz srx analyses
1941	Killam	Pattinson	1	Pemiscot	Missouri	3,345	O&G in Elvins Fm.	P&A	drilled on gravity high; P&A when surface casing collapsed; lean to v. lean Pz srx analyses
1945	U.S. Bur. Mines	Oliver	1	New Madrid	Missouri	3,728	no shows reported		drilled on west margin of rift; Elvins flowed water ARO 24,000 BOPD; logs runs; TD'd in Bonneterre
1965	Quintin	Little	1	Craighead	Arkansas	8,682	no shows reported	P&A	not drilled on seismic data
1966	Quintin	Griffith	1	Green	Arkansas	5,866	no shows reported	P&A	logs run; no info available
1966	Benz	Merritt	1	Lake	Tennessee	6,021	no shows reported	P&A	TD'd in pre-Lamotte sandstones; several zones of igneous rocks encountered
1971	Cockrell	Carter	1	St. Francis	Arkansas	14,743	no shows reported	P&A	TD'd in Pre-Cambrian granite; ~350 ft granite wash near TD; recorded Miss., Dev., Sil., Ord., & Camb. Seds
1972	Cockrell	Bunch	1	Lee	Arkansas	14,855	no shows reported	P&A	TD'd in Pre-Cambrian granite; recorded Miss., Dev., Sil., Ord., & Camb. Seds
1978	Reserve Oil	Hazen	1	Prairie	Arkansas	16,491	no shows reported	D&A	
1979	Houston O&M	Singer	1	Cross	Arkansas	11,158	no shows recorded or reported	D&A	TD'd in Lower Knox Elvins Fm.; not drilled on seismic data; v. lean srx analyses
1981	Dow	Wilson	1	Mississippi	Arkansas	14,869	slight incr. in gas while drilling; no oil or asphalt shows reported while drilling; 3300 ft of solid hydrocarbon residue reported from Cambro-Ordovician section in post-drill analysis	P&A	TD'd in Pre-Cambrian granite; drilled on seismic & gravity structure; thin igneous dikes encountered in C-Ord section; later determined that well drilled in saddle between 2 seismic highs
1981	Dow	Garrigan	1	Mississippi	Arkansas	12,014	gas shows, but no oil or asphalt shows reported while drilling; several completion attempts failed	P&A	Multiple drilling problems; TD'd in (Cambrian clastics); drilled 1000's of ft of Elvins shales, sandstones, and siltstones; srx values > 0.5% with some intervals ave. = 1.8% TOC; thin turbiditic ss's recv'd in cores
1982	Sunmark	Nichols Trust	1	Woodruff	Arkansas	13,800	no shows reported	D&A	TD'd in Arbuckle
1985	Harrison Interests (took over Dow interests)	Berry	1	Mississippi	Arkansas	3,150	single show of asphalt; no other shows reported from SWC's	P&A	
1985	Harrison Interests (took over Dow interests)	Portis-Potter	1	Poincett	Arkansas	8,015	gas & asphalt shows reported @ top Pz while drilling w/mud - diminished considerable after switching to mist	P&A	TD'd in Cambrian Undiff.
1987	Amoco	Haynes	1	Mississippi	Arkansas	12,416	no shows recorded or reported	D&A	TD'd in Lamotte Fm.
1987	Amoco	Spence Trust	1	Dunlin	Missouri	10,089	no oil or asphalt shows recorded or reported; gas shows recorded throughout drilling; no hydrocarbons found during post-drilling fluid inclusion study	D&A	TD'd in Lamotte Fm., flowed **fresh water** ARO 28,900 BWPD from Bonneterre algal reef
1988	Griffin & Griffin	Essex Farms	1	Arkansas	Arkansas	11,032	no shows reported	D&A	TD'd in Stanley Fm.

USGS

(from various public and private sources)


N
Texas-Pacific #1 Stretch
Texas-Pacific #1 Farley
Benz Oil #1 Merritt
Dow Chemical #1 Wilson
Cockrell – CNG #1 Carter
S
DATUM: TOP BONNETERRE (EAU CLAIRE) FORMATION
fine-grained sandstone & siltstone
shale
quartzarenite
massive carbonate
fine-grained sandstone & siltstone
Precambrian Basement
LITHOFACIES SYMBOLS
SHALE
QUARTZARENITE
MASSIVE CARBONATE
FINE-GRAINED SANDSTONE/SILTSTONE
ARKOSE
PRECAMBRIAN BASEMENT
SCALE
VERTICAL (FEET)
HORIZONTAL (MILES)
USGS
N-S Stratigraphic Cross Section – Cambrian Reelfoot Rift
(from Weaverling, 1987)

Well Log Cross Section – Reelfoot Rift



USGS

(from NORPAC, undated)