

PS Natural Fractures in the New Albany Shale, Illinois Basin, and Their Importance for Shale-Gas Production*

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Abstract

Success in the New Albany Shale gas play in southern Indiana and western Kentucky, where gas is mostly thermogenic, is partly dependent on understanding how the natural fracture system impacts hydraulic fracture treatments. We consider both the potential for natural fractures to provide permeability enhancement and their potential effects on hydraulic fracture treatment efficiency. We present observations from outcrops in the Illinois Basin in Kentucky and across the Cincinnati Arch into the Appalachian Basin and from cores from Indiana (10 cores) and Kentucky (2 cores) in the Illinois Basin. The structural grain of the two areas - southern Indiana and western Kentucky - is fundamentally different. Southern Indiana is dominated by the Wabash Valley normal fault system, which is currently active and trends approximately N-S. Western Kentucky is dominated by the E-W trending Rough Creek Graben. The major and minor faults and opening-mode fractures in part reflect this difference. The present-day in situ stress must be determined on a site-specific basis. The World Stress Map database suggests a swing in the maximum horizontal stress direction from ENE in southern Indiana to E-W in western Kentucky. The large difference in underlying local structure might have a significant perturbation effect on the far-field stress orientation.

Steep, sealed, or partly sealed fractures, some of which are sheared, are present in several of the cores. They contain both carbonate and quartz cements. These sets are likely to be important either for enhancing permeability or as influences over hydraulic fracture propagation. Compacted, fibrous, quartz-dolomite-bitumen veins are present in the basal Blocher Member in some outcrops. The veins are up to 14 cm wide and mostly < 1 m in height, and commonly contain bitumen in vuggy openings. For completions in the usually-targeted Clegg Creek Member it is unlikely that these large veins will affect production, but they could affect completions in

the Selmier Member, where hydraulic fractures could propagate down into the Blocher. Smaller compacted fractures confined to pyrite-rich layers are present in both outcrop and cores throughout the New Albany Shale. They may be related to the large fractures in the Blocher Member, but they are apparently more widespread, and could act as mechanical discontinuities causing hydraulic fractures to deviate.

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Indiana Geological Survey
Kentucky Geological Survey

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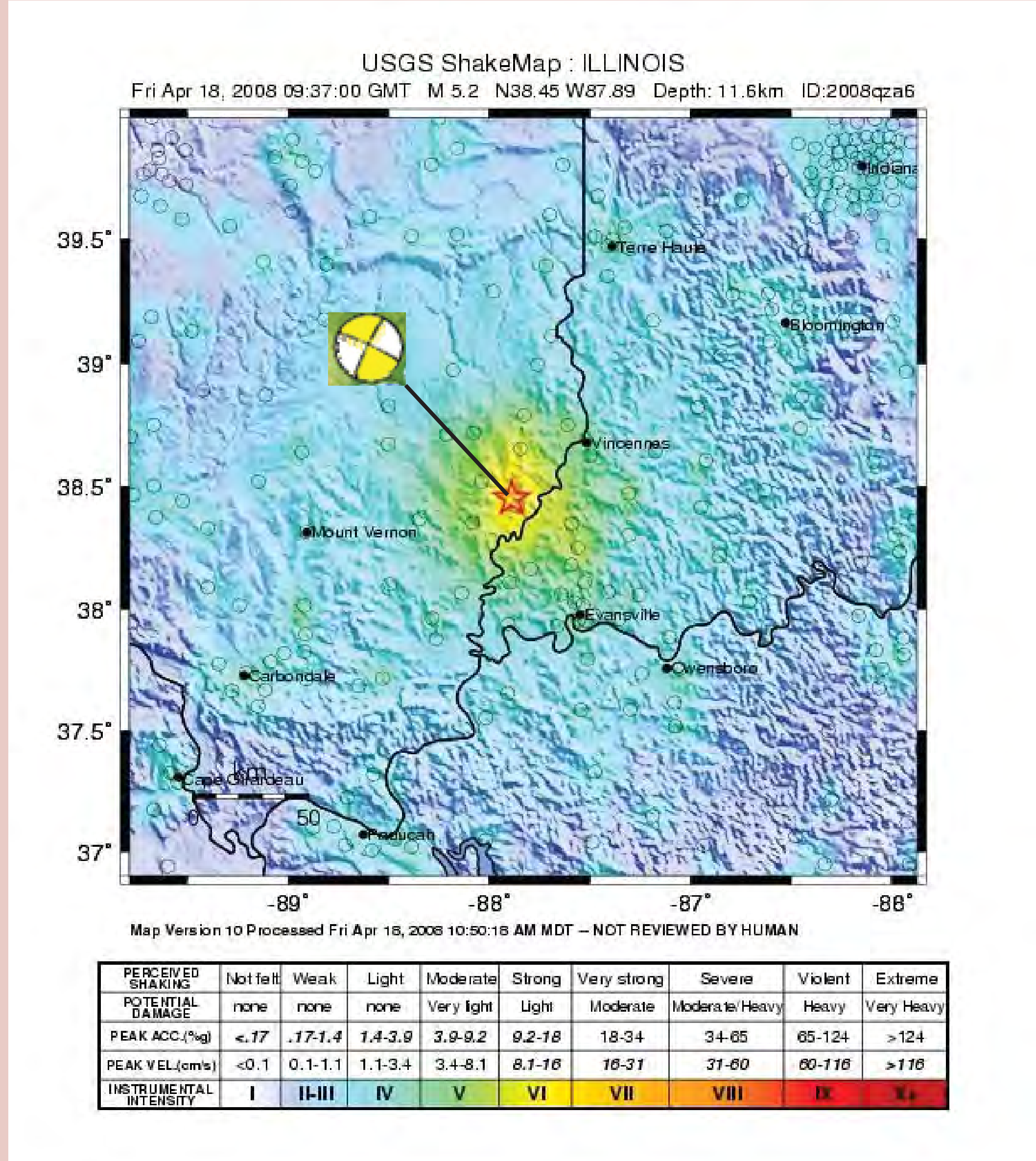
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Abstract

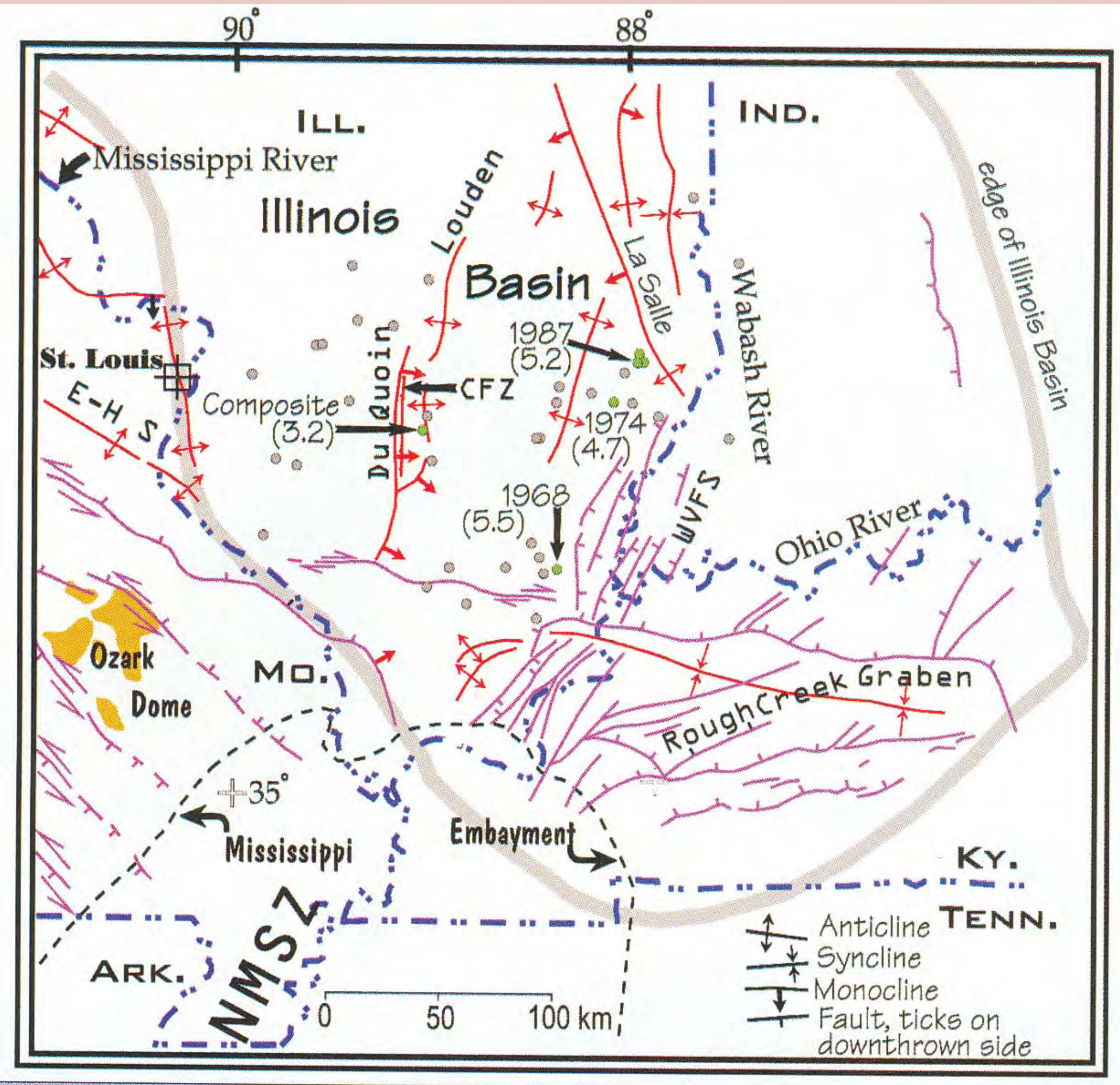
Success in the New Albany Shale gas play in southern Indiana and western Kentucky, where gas is mostly thermogenic, is partly dependent on understanding how the natural fracture system impacts hydraulic fracture treatments. We consider both the potential for natural fractures to provide permeability enhancement and their effect on hydraulic fracture treatment efficiency. We present observations from outcrops in the Illinois Basin in Kentucky and across the Cincinnati Arch into the Appalachian Basin and from cores from Indiana (10 cores) and Kentucky (2 cores) in the Illinois Basin. The structural grain of the two areas – southern Indiana and western Kentucky – is fundamentally different. Southern Indiana is dominated by the Wabash Valley normal fault system, which is currently active and trends approximately N-S. Western Kentucky is dominated by the E-W trending Rough Creek Graben. The major and minor faults and opening-mode fractures in part reflect this difference. The present-day in situ stress must be determined on a site-specific basis. The World Stress Map database suggests a swing in the maximum horizontal stress direction from ENE in southern Indiana to E-W in western Kentucky. The large difference in underlying local structure may have a significant perturbation effect on the far-field stress orientation.

Steep, sealed, or partly sealed fractures, some of which are sheared, are present in several of the cores. They contain both carbonate and quartz cements. These sets are likely to be important either for enhancing permeability or as influences over hydraulic fracture propagation. Compacted, fibrous, quartz-dolomite-bitumen veins are present in the basal Blocher Member in some outcrops. The veins are up to 14 cm wide and mostly < 1 m in height, and commonly contain bitumen in vuggy openings. For completions in the usually-targeted Clegg Creek Member it is unlikely that these large veins will affect production, but they could affect completions in the Selmer Member, where hydraulic fractures could propagate down into the Blocher. Smaller compacted fractures confined to pyrite-rich layers are present in both outcrop and cores throughout the New Albany Shale. They may be related to the large fractures in the Blocher Member, but they are apparently more widespread, and could act as mechanical discontinuities causing hydraulic fractures to deviate.

Tectonic Setting



USGS Shake Map; the April 18, 2008 event is shown by the star.



Structure map of Southern Illinois Basin (McBride and Nelson, 1999)
WVFS = Wabash Valley Fault System;
NMSZ = New Madrid Seismic Zone;
CFZ = Centralia Fault Zone.
Earthquake epicenters shown for body-wave magnitude >3.0 (1960-1995)



Project Goal

Characterize natural fractures in the New Albany Shale and assess their importance for natural gas production. Our focus is on the thermogenic part of the play in southern Indiana and western Kentucky.

Key Questions

- Do sealed natural fractures reactivate during hydraulic fracture treatments?
- Are other fractures open, providing permeability enhancement?
- Can we identify parts of the New Albany Shale that have the most favorable fracture characteristics for economic gas production?

Approach

- Characterize fractures in 12 cores from southern Indiana, 2 cores from western Kentucky and 4 outcrop locations. Synthesize published fracture data.
- Determine how fractures in the NAS seal, and whether part of the fracture population is open and would enhance permeability.
- Measure the subcritical crack index (SCI) of core samples to provide input for geomechanical models of fracture spatial distribution.
- Qualitatively assess the strength of natural fracture planes.
- Consider the relative orientation of S_{Hmax} and natural fractures, and determine if this geometry is favorable for reactivation.

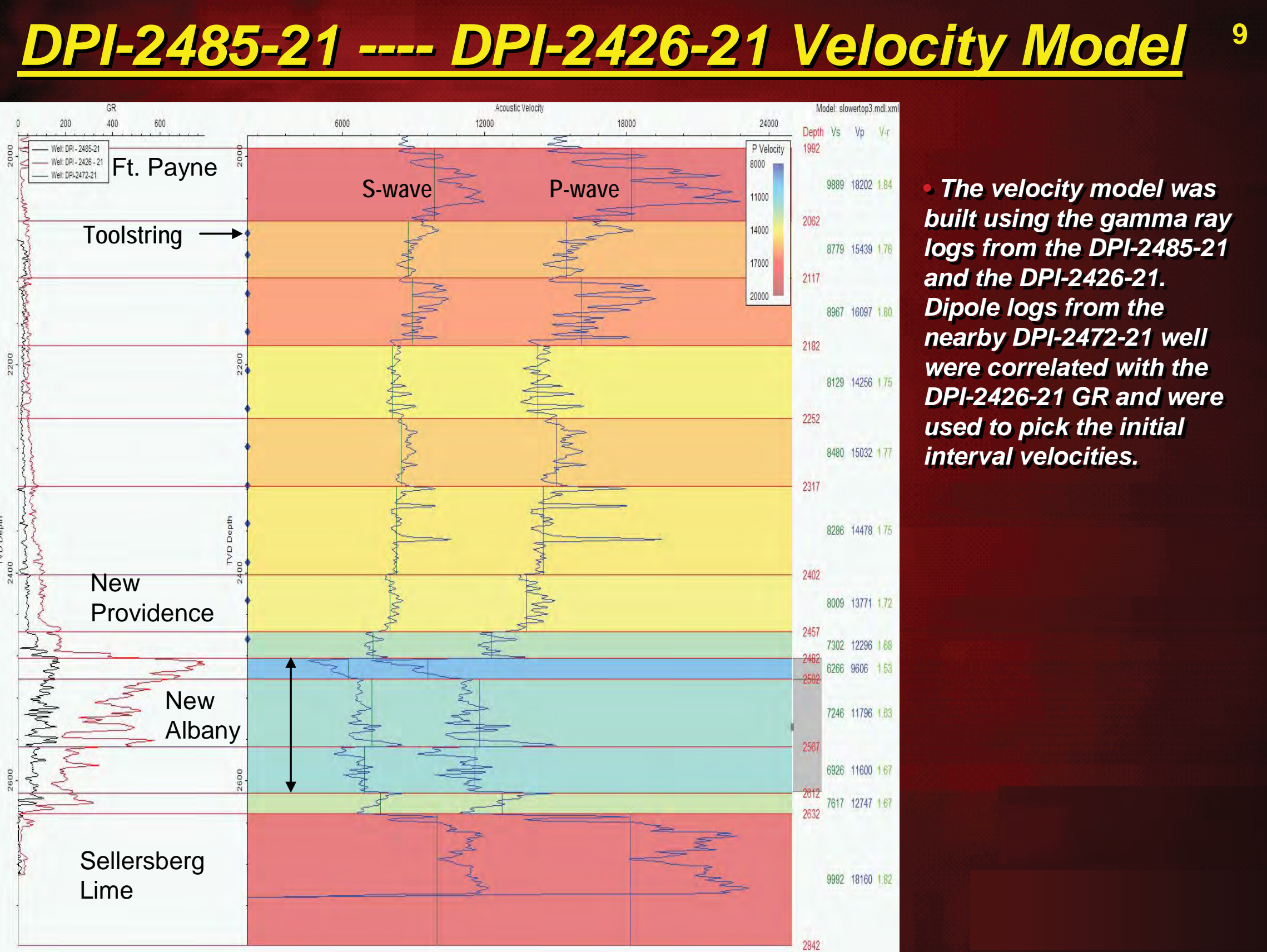
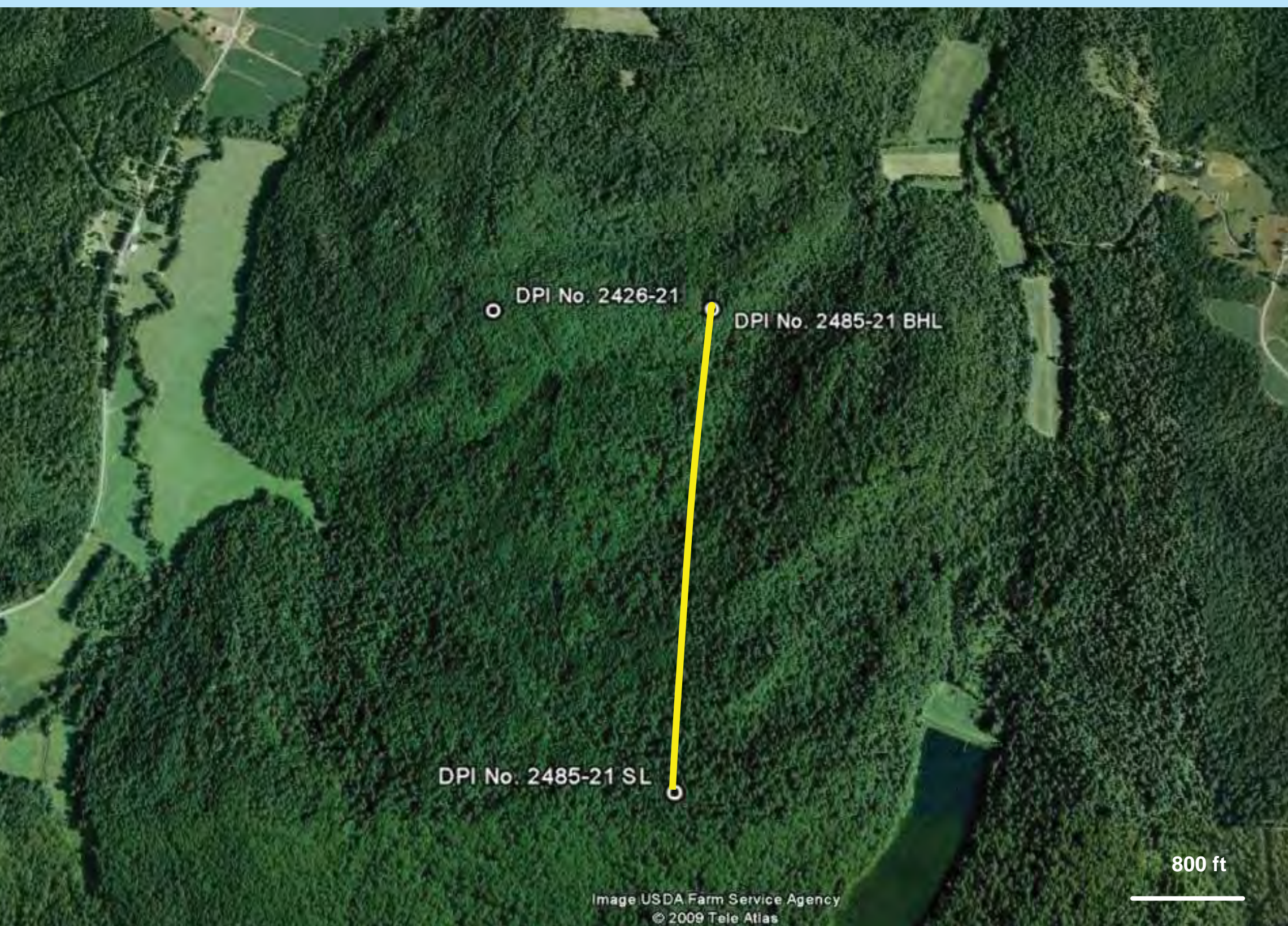
Well Experiment

DPI-2485-21, Christian Co., W Kentucky

Pilot hole logs and core

Horizontal producing well drilled

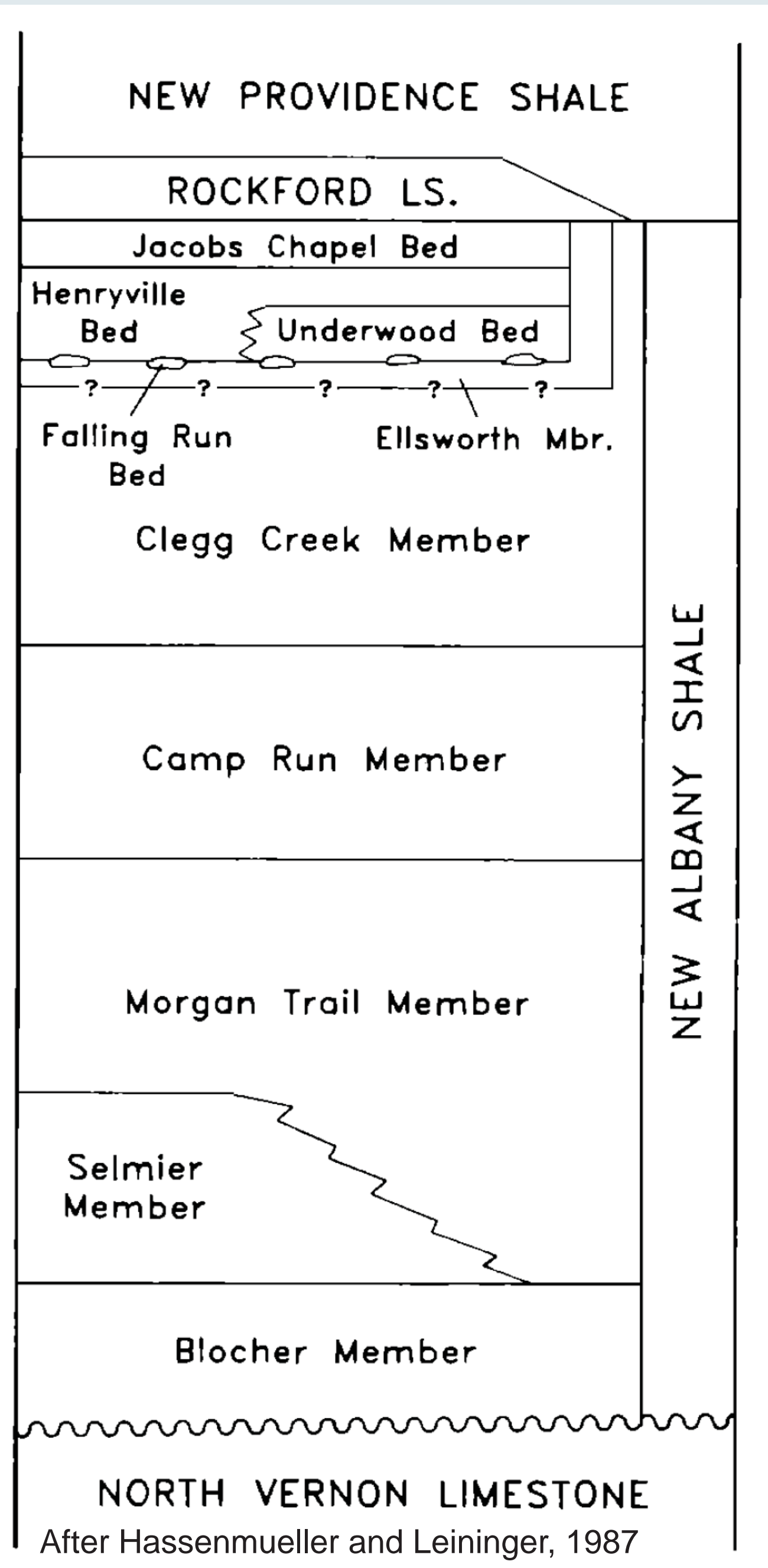
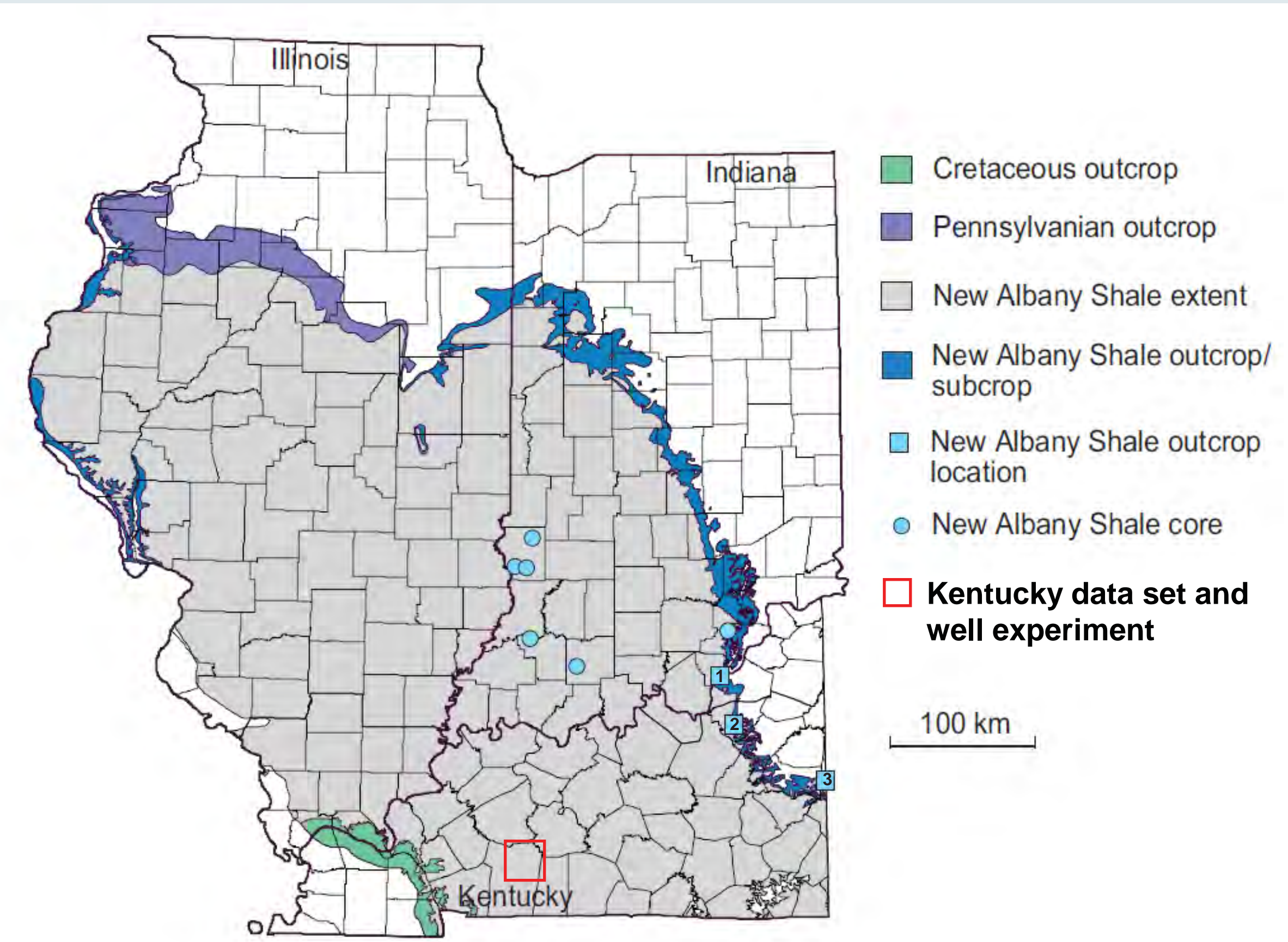
Microseismic monitoring of hydraulic fracture treatment



Images courtesy of Doug Walser, Pinnacle

Fracture Characterization: New Albany Shale

Core and Outcrop Observation

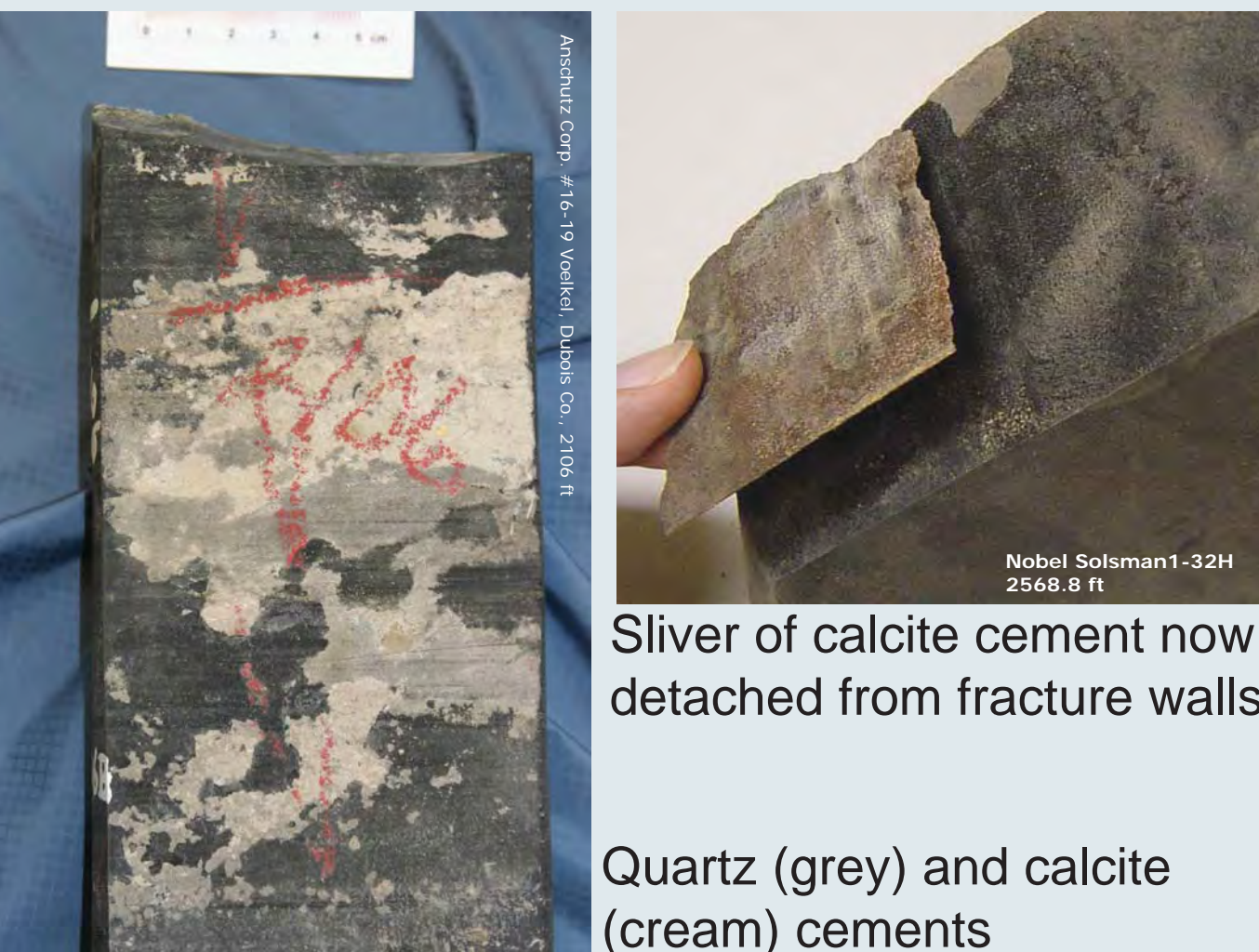


Steeply dipping, calcite sealed fractures are common in cores. Trends vary across the region and may not match surface joint orientations. There may be multiple sets.



Calcite-sealed fracture in core: Diversified Operating McAtee S26-IV, 2,788 ft

Fracture sealing



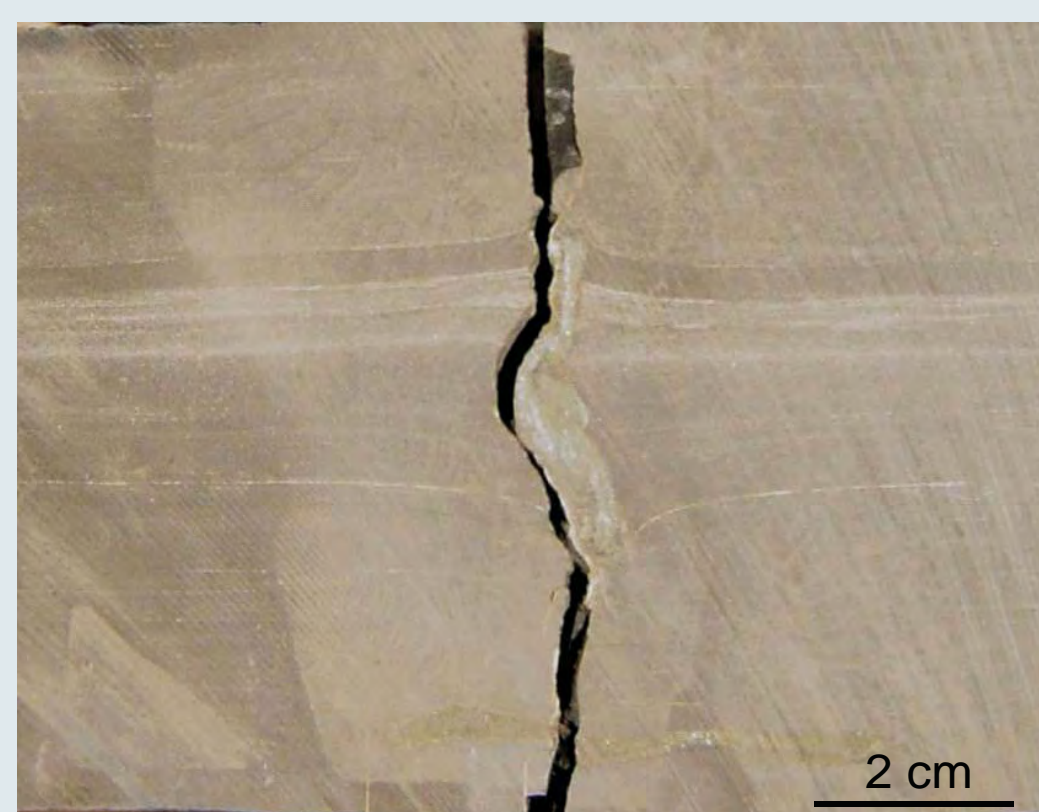
Sliver of calcite cement now detached from fracture walls

Quartz (grey) and calcite (cream) cements

Most fractures are sealed with calcite only, which is weakly bonded to fracture walls, but some have quartz and pyrite. Quartz is likely to be more strongly bonded to fracture walls as it nucleates on quartz grains in the shale.

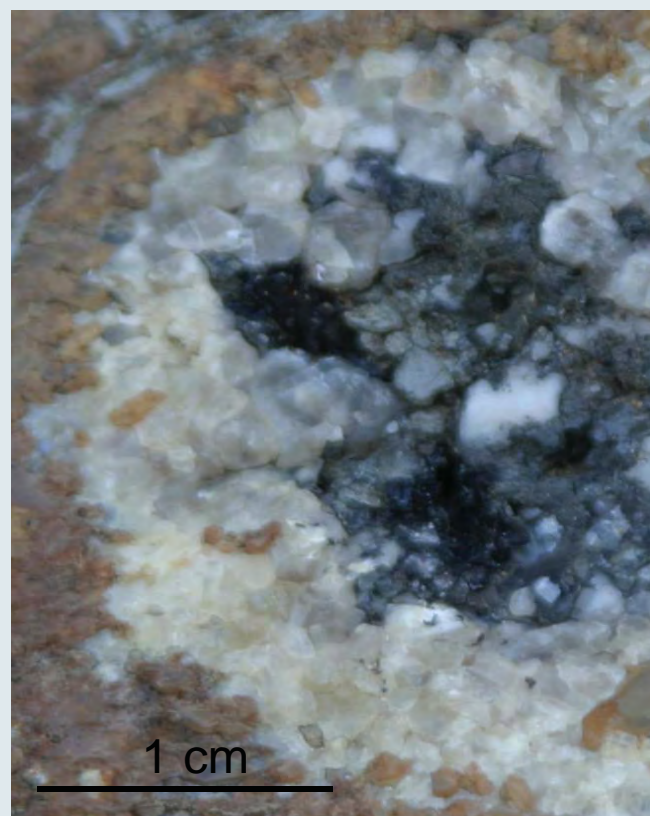
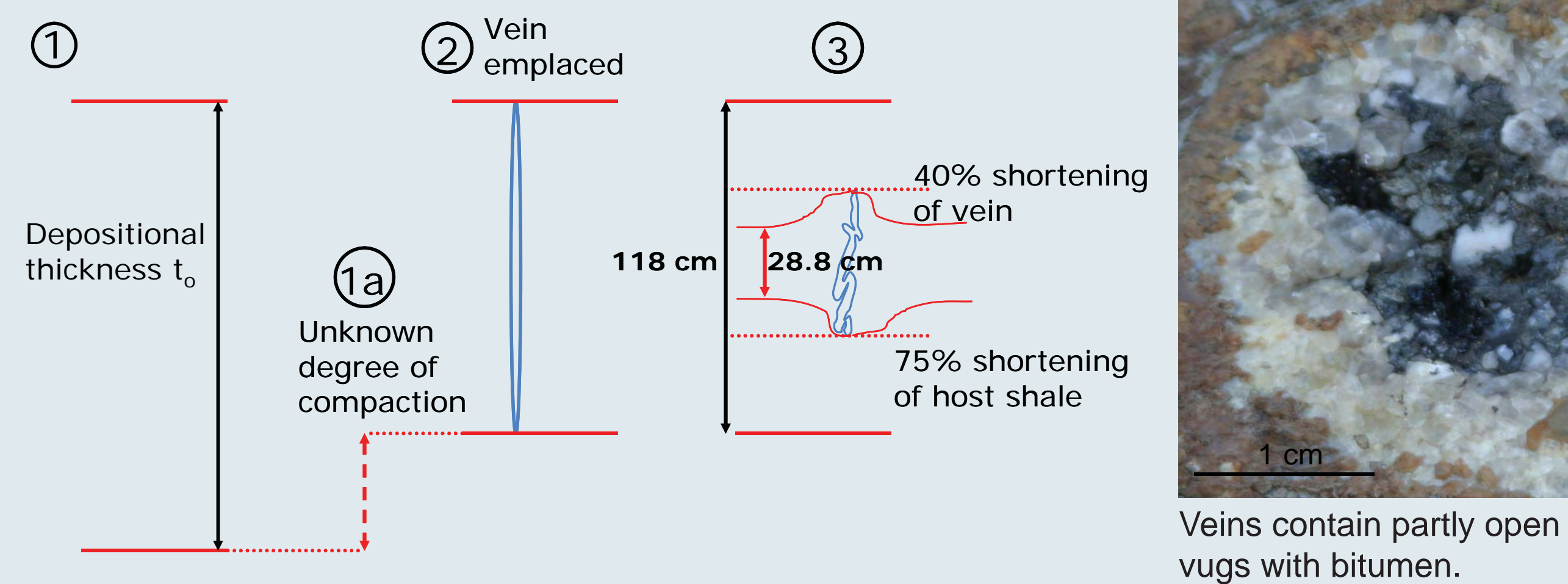


Compacted vein in the Blocher Mbr. in an outcrop of New Albany Shale in western Kentucky (box 2 at left).



Example of compacted fracture in core: Diversified Operating McAtee S26-IV, 2,804 ft

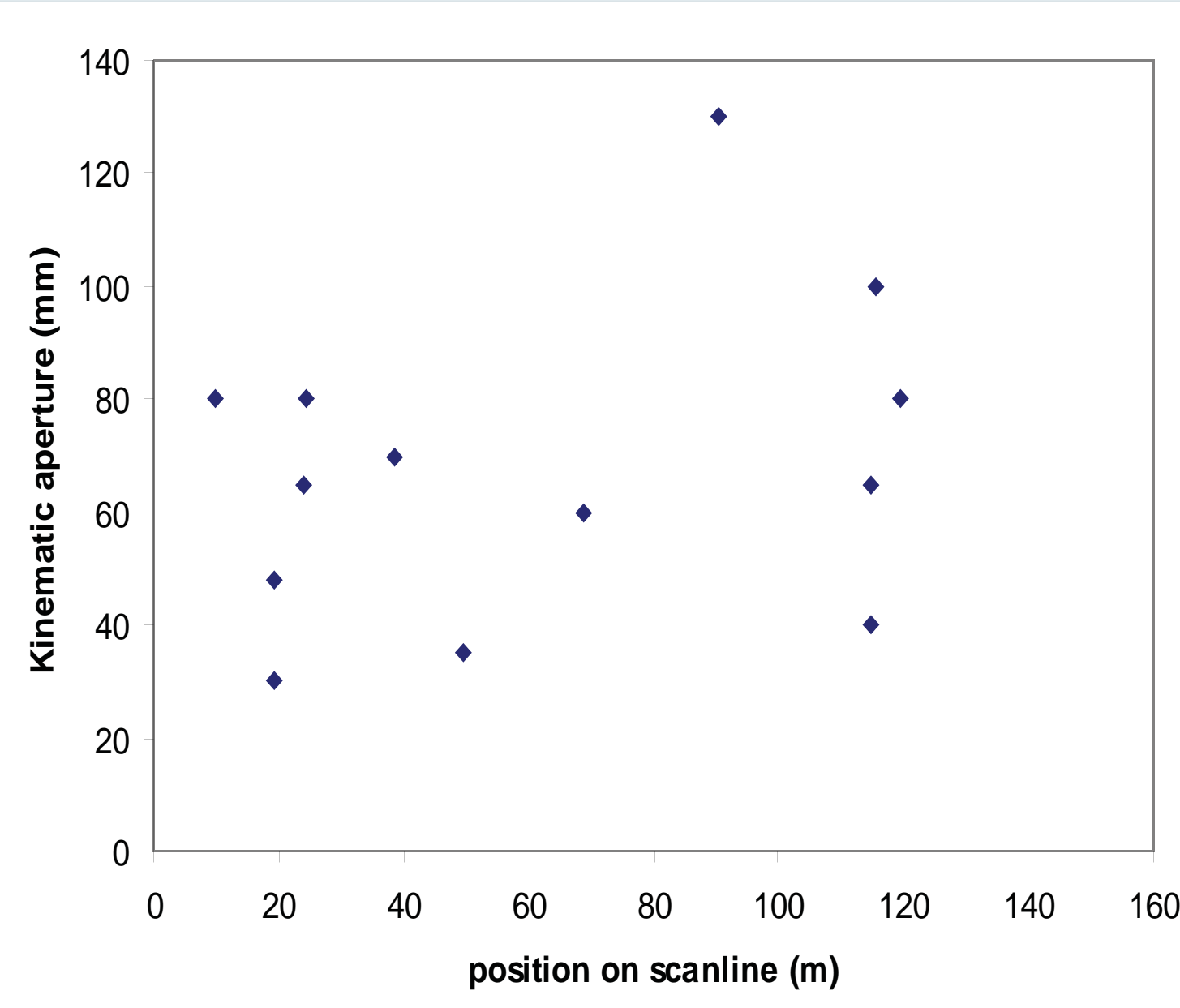
Dolomite veins in the Blocher Member have been compacted, suggesting they are early. The host shale is more compacted than the vein. These relationships may be used to deduce the compaction history of the shale.



Veins contain partly open vugs with bitumen.



Length of outcrop is approx 150 m

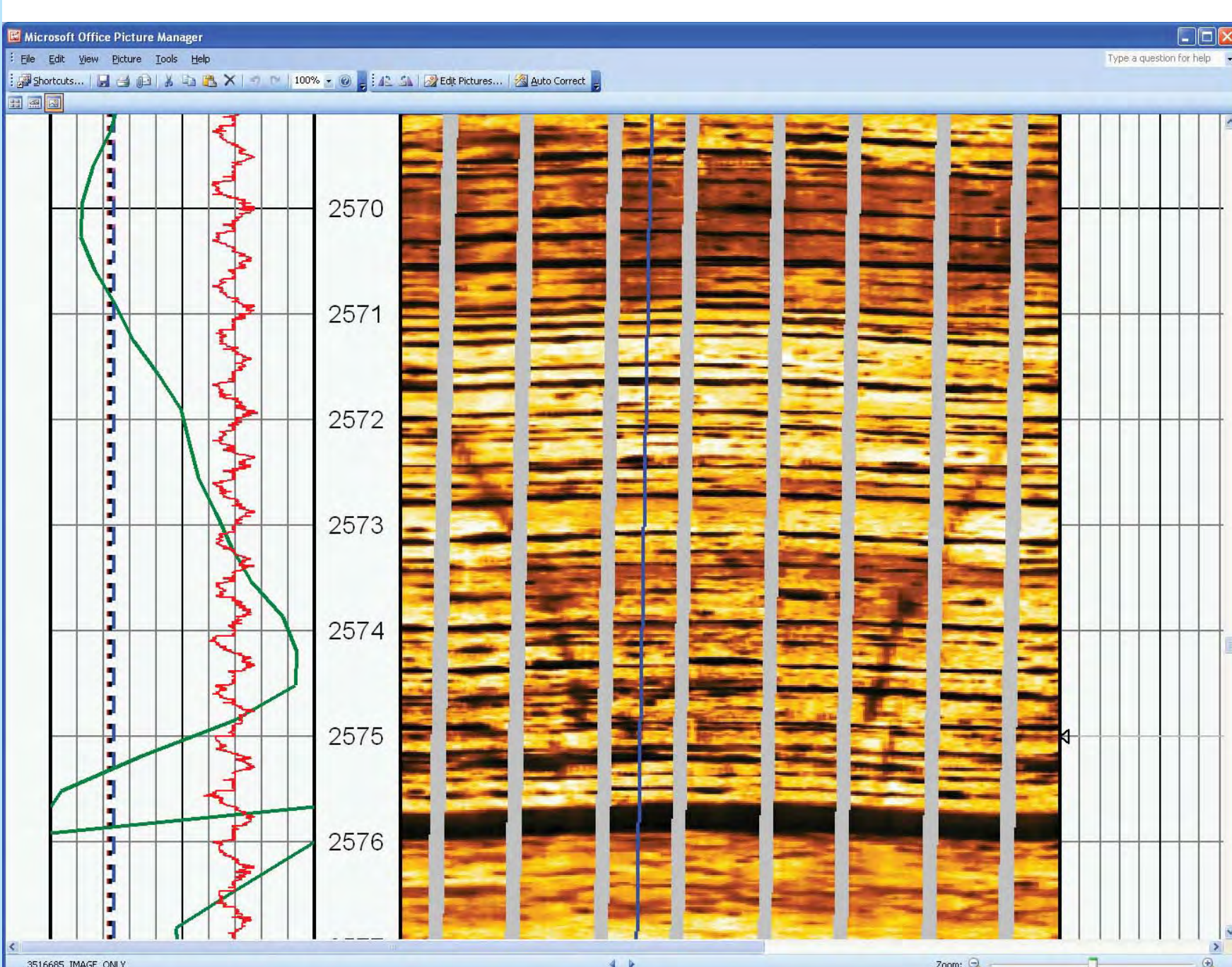


Locations and apertures of fractures crossing a scanline were measured in the outcrop above (box 3, map at top left of panel). Fractures are clustered, but there are insufficient data to know if they are more clustered than if they were randomly distributed.

Well Experiment

DPI-2485-21, Christian Co., W Kentucky

Pilot hole image log and core



En echelon fractures with carbonate cement at 2574-2575 ft

Image log with open fracture in the subsurface

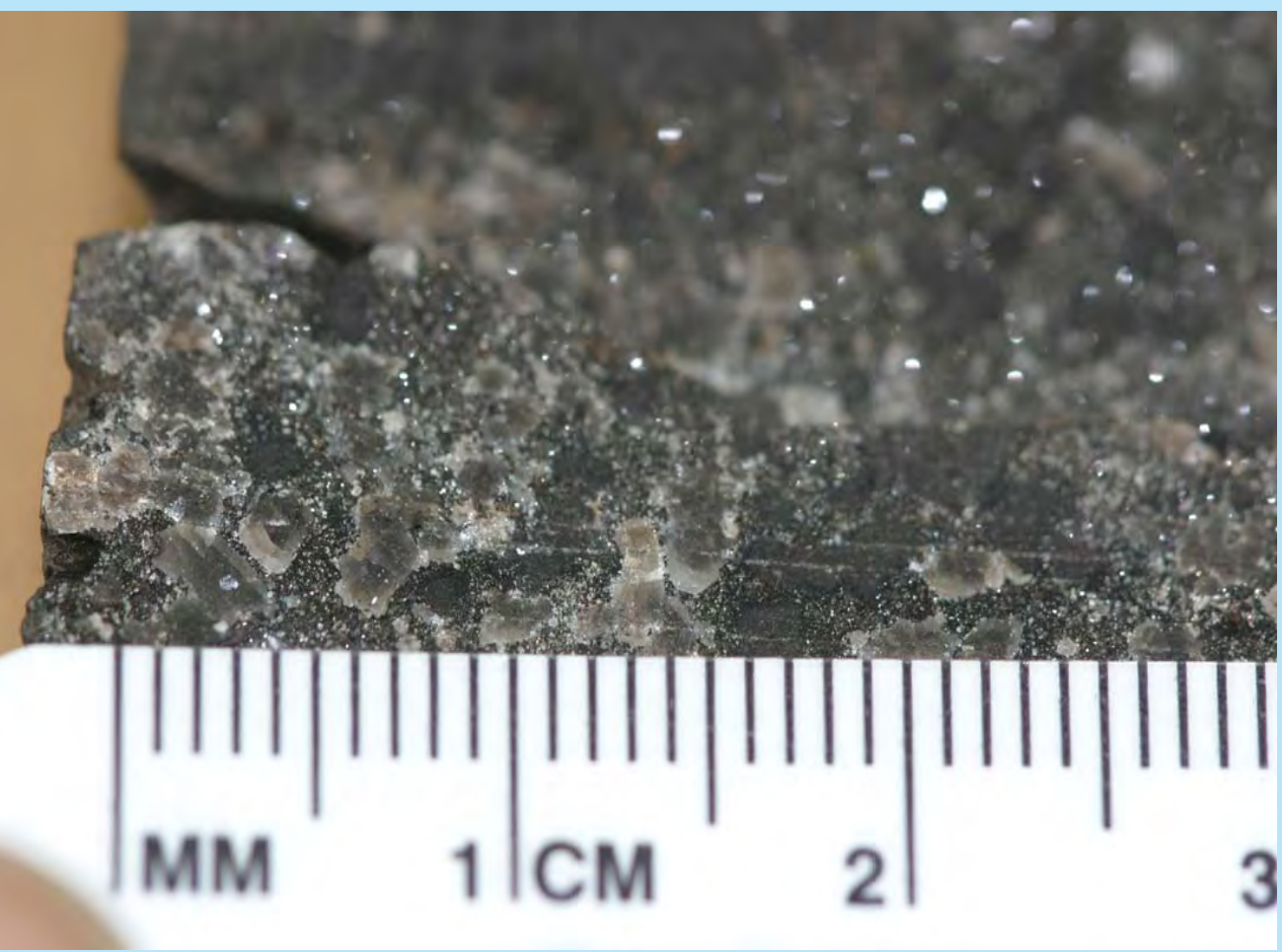
Note offset at 2575 ft on image log.



Natural fracture at depth of 2,575 ft, partly sealed with calcite. Both fracture surfaces have a cement lining. The weakness is within the fracture rather than at the cement-wall interface



Natural fracture, 2,527 ft.



The fracture surface is decorated with euohedral calcite cement crystals and provides evidence that fractures were open in the subsurface.

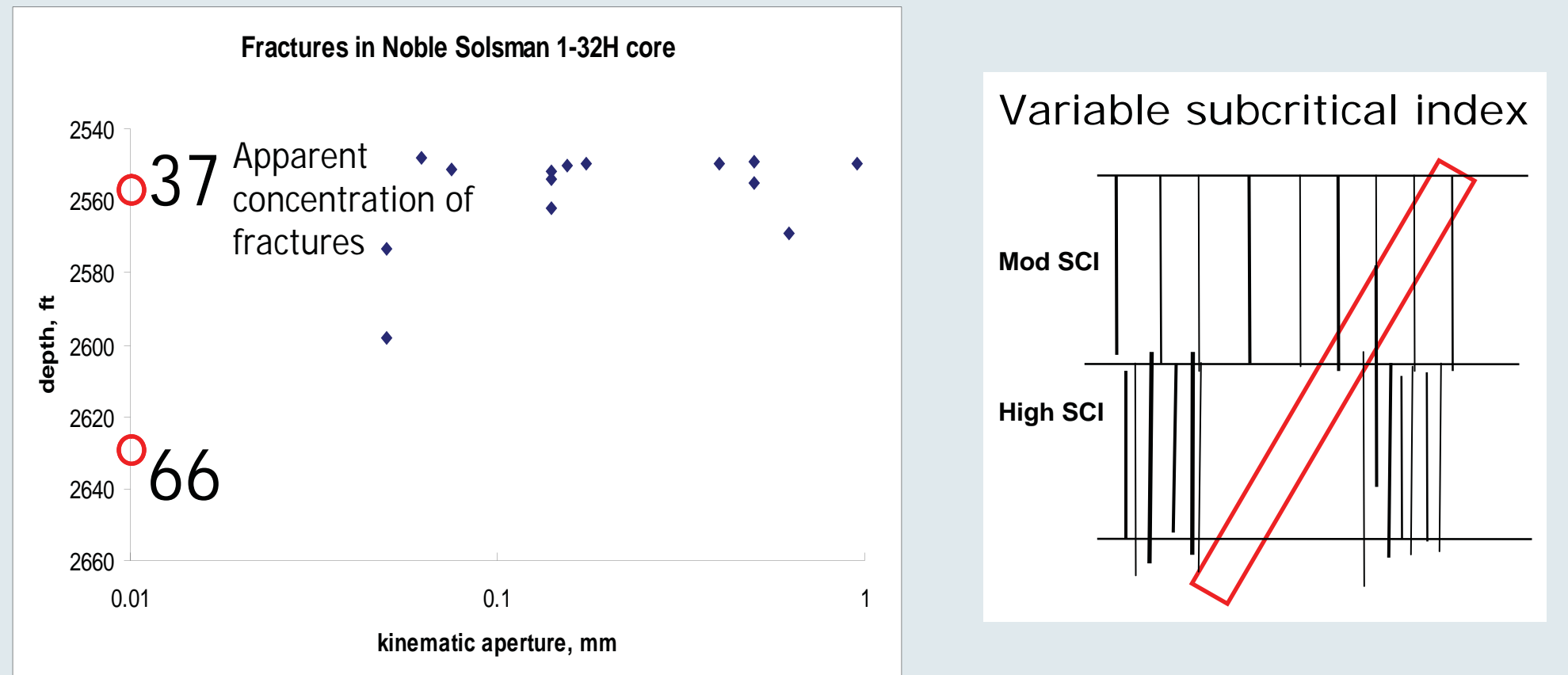
Subcritical Index Measurements

Cores from Indiana

Core	SCI				KIC	
	1	2	3	Avg		Avg
2528' Depth	Osburn Trust 1-11H					
3A	42	46		44		
4B	64	82	76	74	1.8	
8B	88	159	62	103	1.5	
5B	59	93	76	76	1.6	
				74		1.6
2630.6' Depth	Solsman 1-32H					
3B						
4	58	66	75	66	1.4	
1A	70	73	92	78	1.3	
2A	71	76	88	78		
1B	40			40	1.7	
				66		1.5
2557' Depth	Solsman 1-32H					
4A						
10A					0.9	
8A					0.8	
10B	27			27	0.9	
9B	34			34	0.9	
6B	57	41		49	0.9	
5B					1.0	
				37		0.9

Three core samples from Sullivan Co., SW Indiana were tested for subcritical index (SCI).

The highest SCIs were measured in samples from two horizons where the apparent fracture intensity is lower. The Osburn Trust core contained only 4 fractures in 90 ft of core, with mean SCI of 74. In the Solsman core all the fractures observed were in the top 30 ft, with SCI mean of 37. The lower horizon had no fractures and a mean SCI of 66.



Higher SCI generally results in a more clustered fracture pattern. In a highly clustered pattern the chances of sampling fractures decreases, so the lower horizon in the Solsman well (2,630 ft) and the horizon from the Osburn Trust well may be fractured, but clustering means the fractures were not sampled.

Orbit J Ray Clark #1

Sample No.	SCI Value
NAOJ_1B	64.36
	80.34
NAOJ_2A	67.22
	64.86
NAOJ_2B	69.80
NAOJ_3A	46.28
	77.30
NAOJ_3B	47.26
	47.69
NAOJ_6A	70.20
NAOJ_7A	50.07
	47.13
NAOJ_7B	43.49
NAOJ_8A	52.34
NAOJ_8B	67.70
NAOJ_9A	77.80
	68.82
NAOJ_9B	54.06
	58.61



Sample used for subcritical index (specimens taken from unfractured part of the core).

Sub-millimeter layers of quartz silt are present. We will investigate the possibility of compositional control of subcritical index through petrographic and geochemical analysis (XRD and handheld XRF) of the specimens used for the test.

More information on the SCI test:

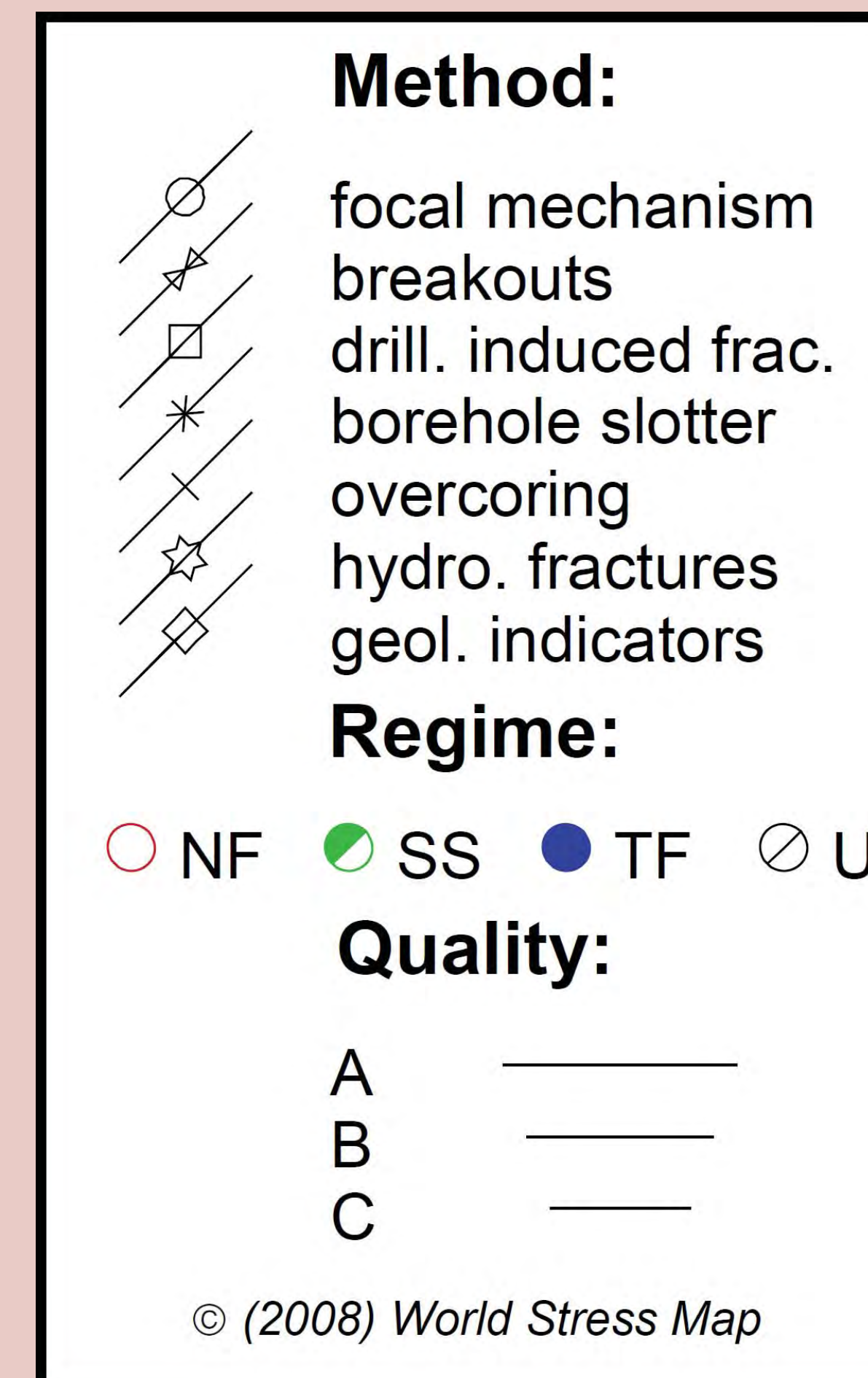
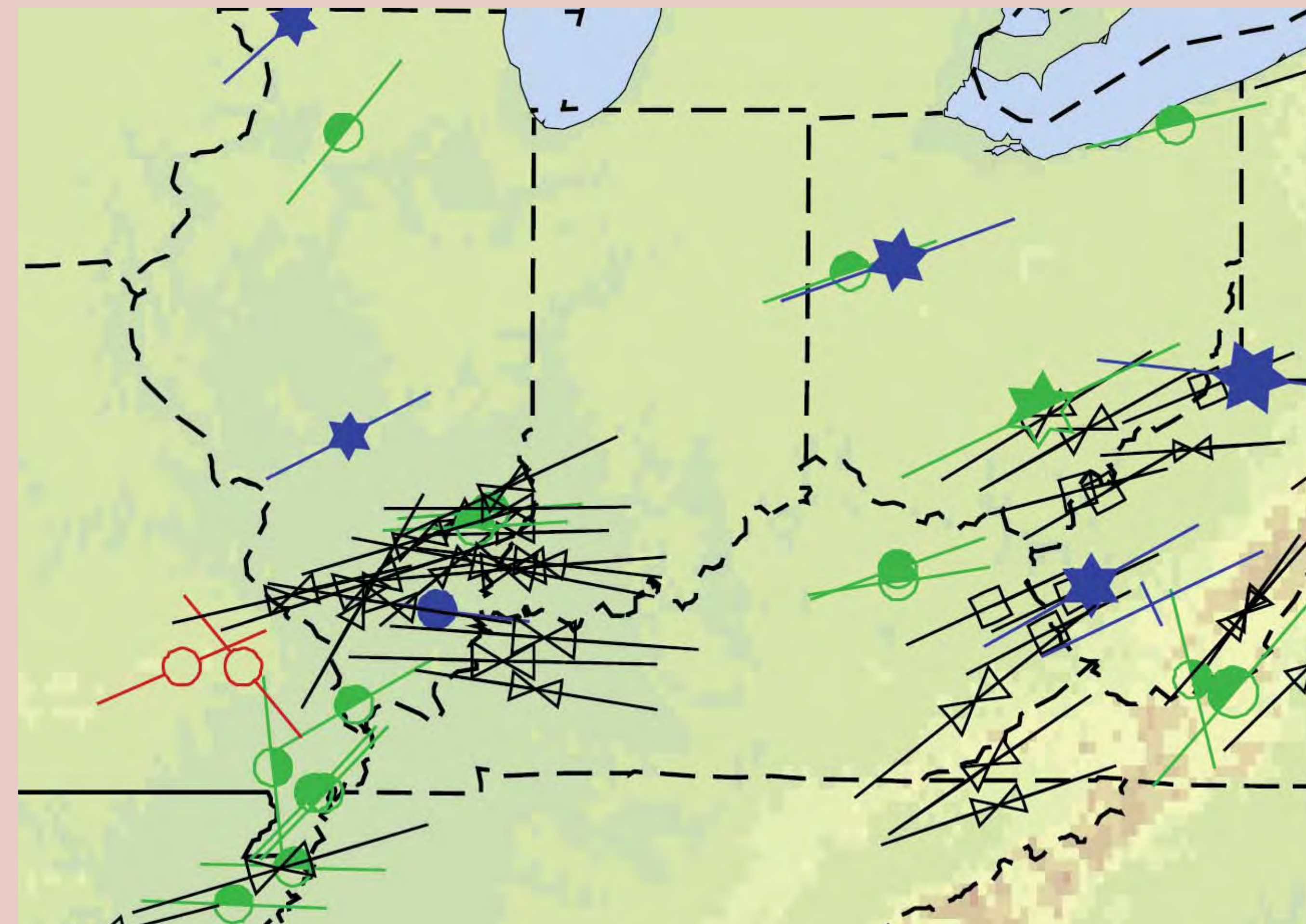
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Impact on Hydraulic Fracturing: New Albany Shale

Natural Fracture Input Data for Hydraulic Fracture Modeling

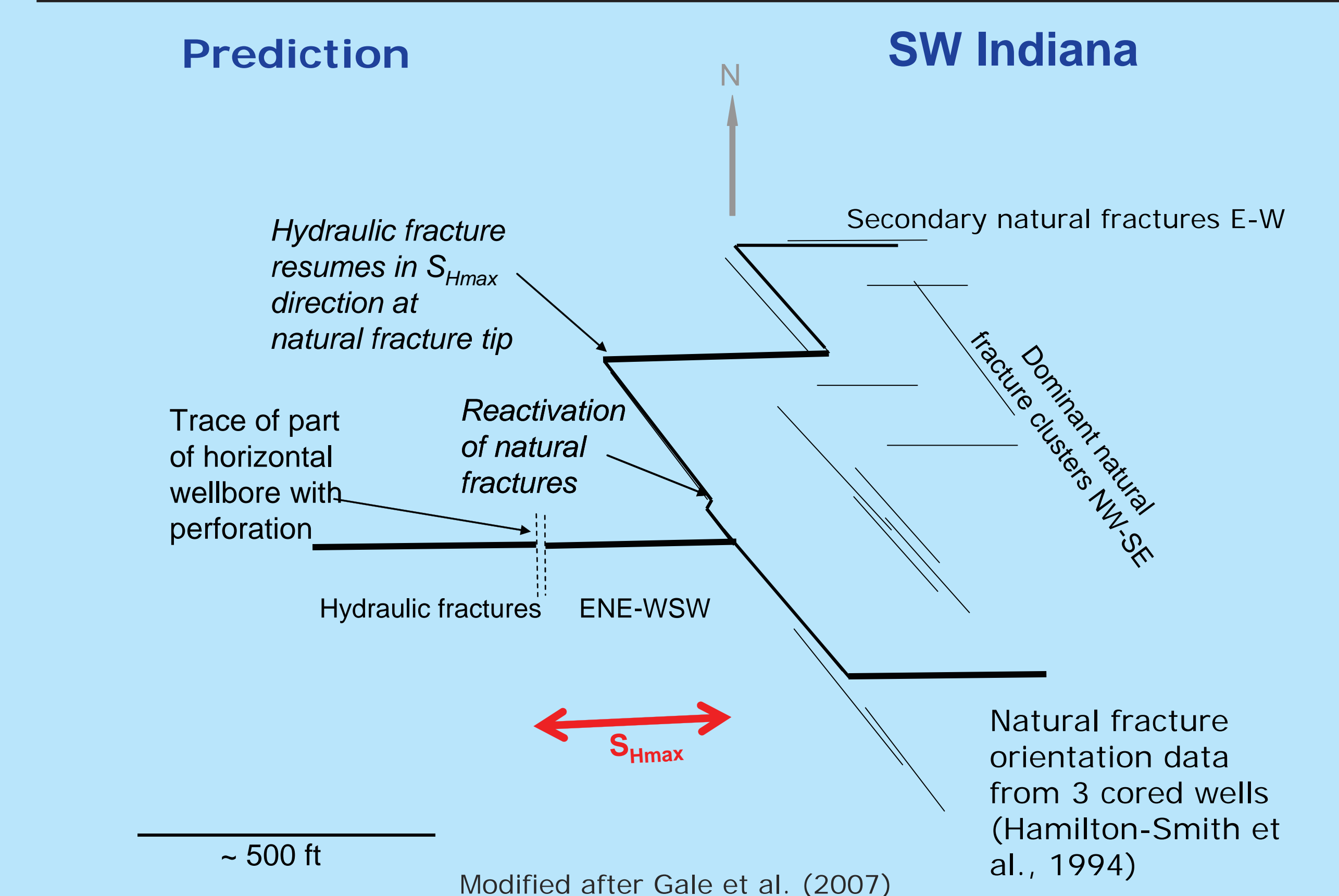
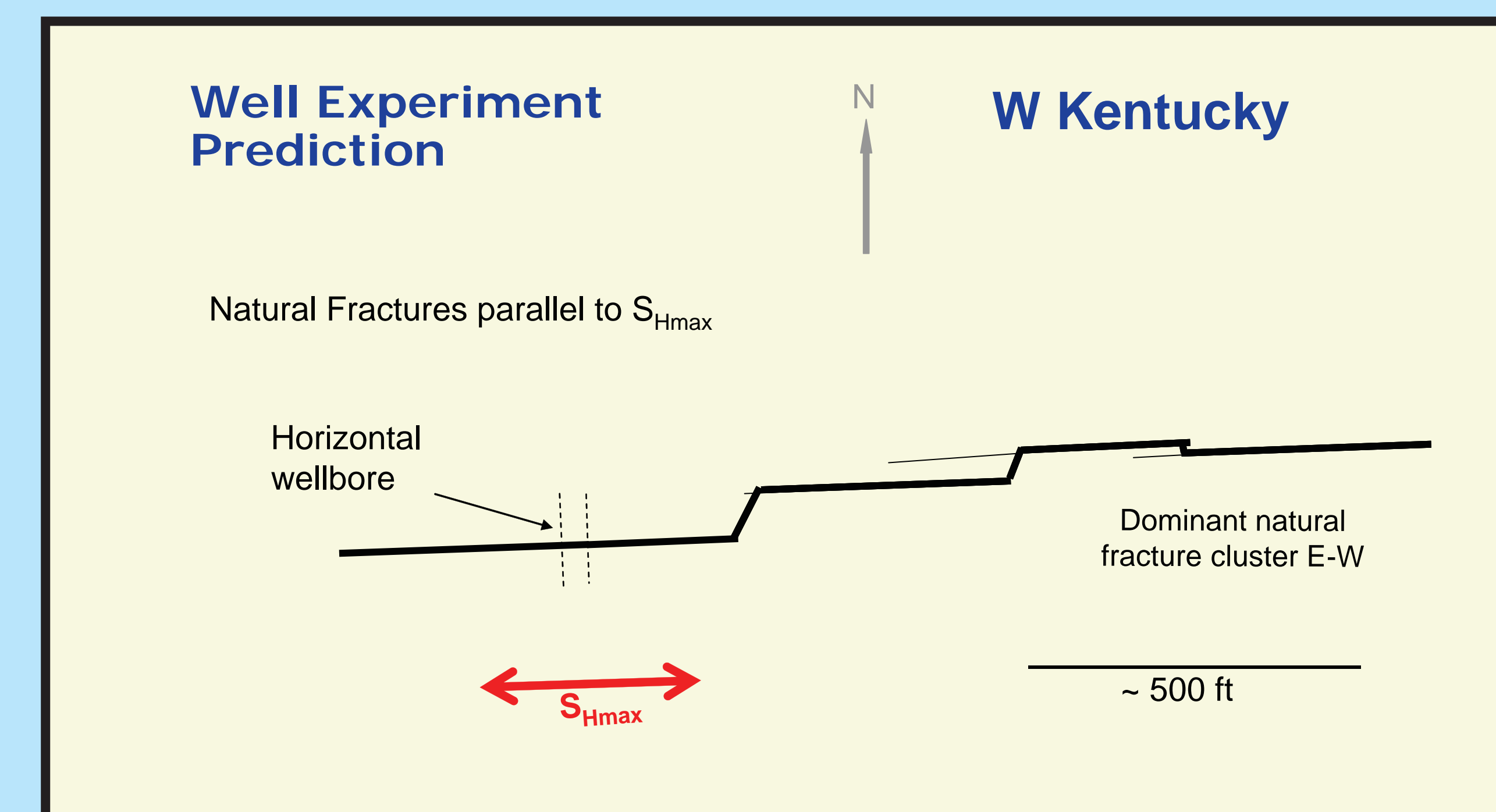
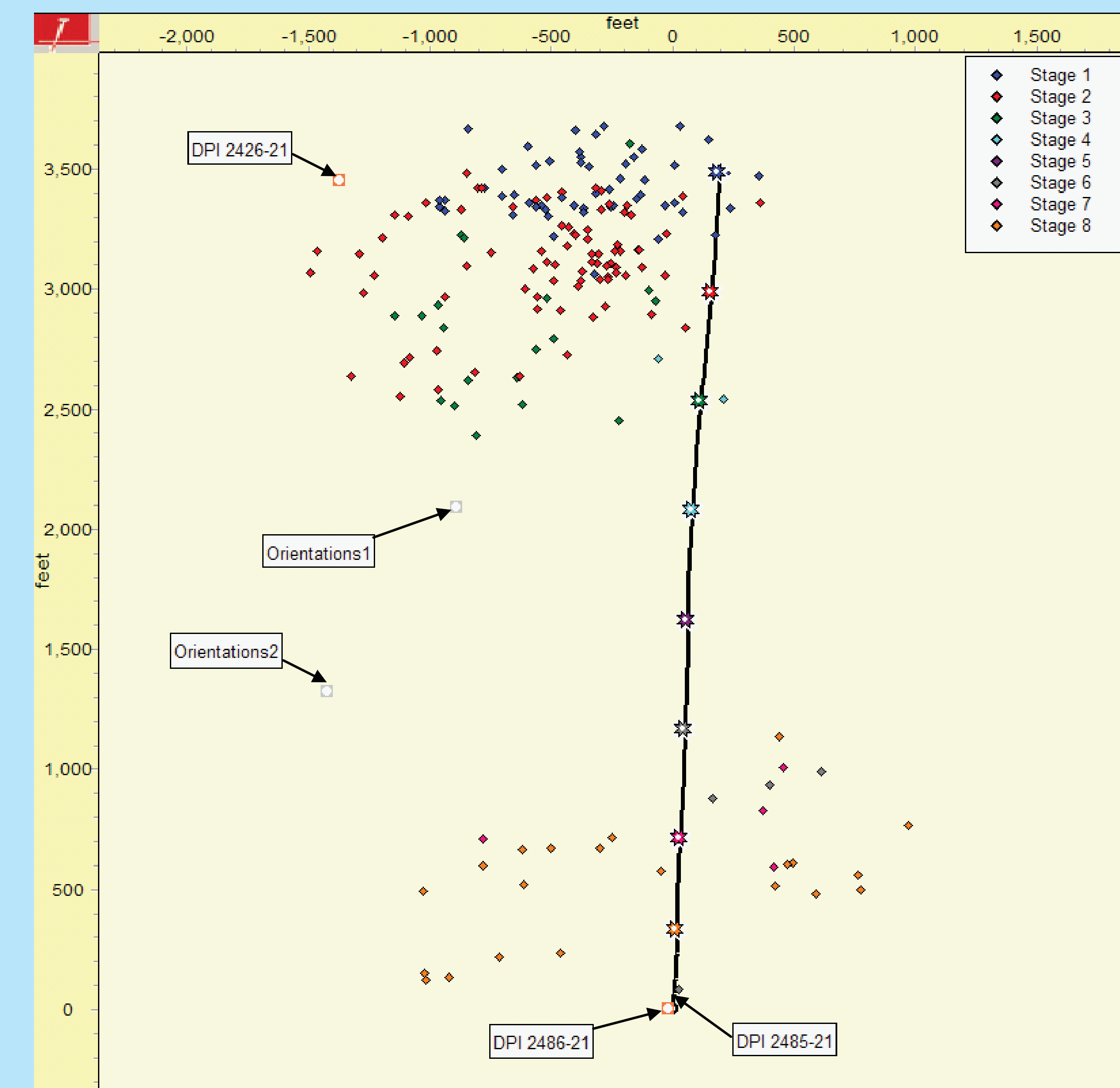
Daugherty Petroleum Inc. 2485-21 Christian County

- Present day orientation of SHmax : E - W



- Orientation of opening-mode fractures E-W, steep dips to N & south
- Orientation of faults; surface faults trend E-W, dip 60° to N or S
Fault on image log at 2,484 ft MD, trend E-W, dip 88° S
- Kinematic aperture is on the order of 0.05 to 2 mm
- Hydraulic aperture is likely 0 to 2 mm
- Strength of fracture planes:
Weak; core and specimens with natural fractures break along fracture
Will use data from Barnett tests (fractures half as strong as host shale)
- Height of opening mode fractures:
1 m for fractures < 1 mm wide; 10 m for fractures > 1 mm wide
- Spacing of opening mode fractures:
Will be modeled using subcritical index and mechanical layer thickness
Will use 1 to 10 m as base cases

Well Experiment Microseismic Monitoring



Conclusions

- Opening-mode fractures and faults are present in New Albany Shale core and outcrop.
- There is commonly more than one opening-mode fracture set.
- Fracture sets are interpreted to have different origins on the basis of aspect ratio, mineral fill, orientation and degree of shortening during sediment compaction.
- Most fractures in core have calcite mineral fill that is weakly attached to the fracture walls. These fractures are undeformed, straight-sided, have high aspect ratios (height to width), and are commonly arranged in en echelon arrays.
- Fractures in the lowest part of the section in the Blocher Member are partly open and have low height to width aspect ratios and irregular fracture walls. They are sealed with dolomite and have residual bitumen and large open vugs.
- The most common sealing cement is calcite, but some samples are sealed by both calcite and quartz. We speculate that quartz cements result in stronger fracture planes because of bonding between wall rock and cement as quartz overgrows broken quartz wall rock grains.
- Subcritical indices are variable, and in general are lower than for other shales we have measured. We will examine the test specimens petrographically to investigate the effect of millimeter-scale compositional differences on subcritical index.
- The structural grain of the two areas – southern Indiana and western Kentucky – is fundamentally different. Southern Indiana is dominated by the Wabash Valley normal fault system, which is currently active and trends approximately NNE-SSW. Western Kentucky is dominated by the E-W trending Rough Creek Graben.
- The present-day in situ stress must be determined on a site-specific basis. Large differences in underlying local structure might perturb the stress orientation.

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