

# Illinois Basin Basement and Structure

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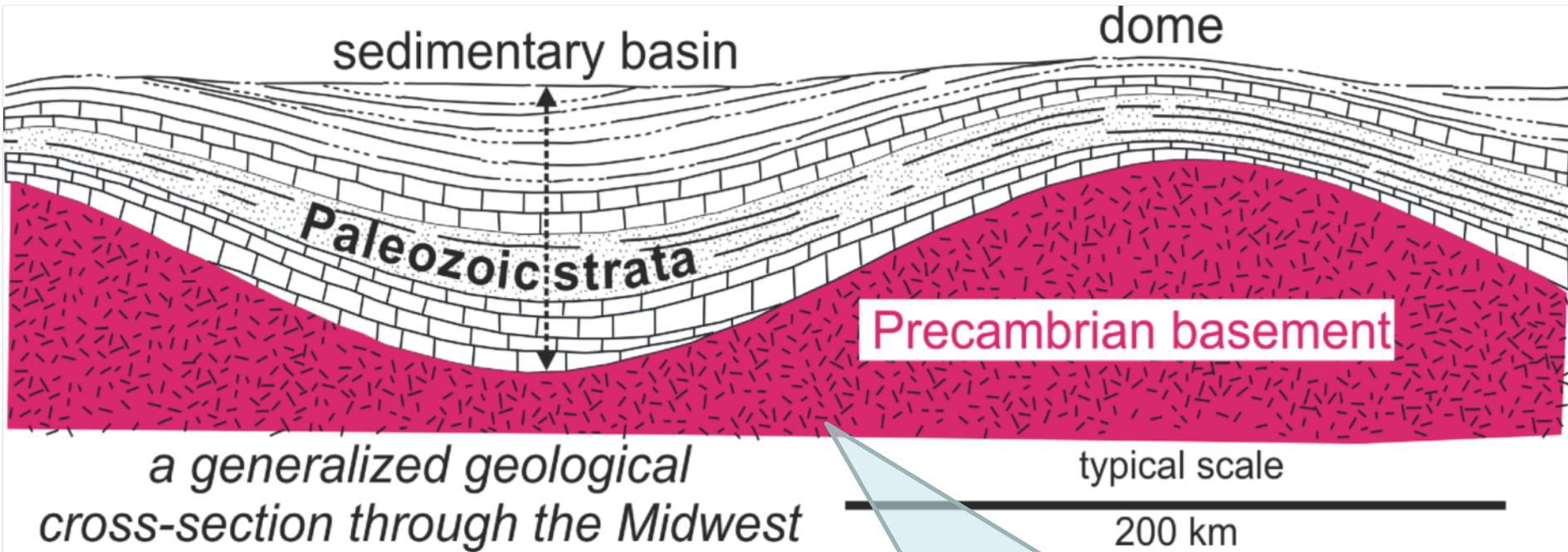
October 8, 2013



# Objectives

- ▶ What is the expected degree of **crustal heterogeneity** for the Illinois Basin Precambrian basement?
- ▶ What are the **dominant structural styles** in the Illinois Basin, especially at the basement-Paleozoic contact?
- ▶ Contrast the **relative stability** of east-central Illinois versus southern Illinois.
- ▶ Style of faulting expected in east-central Illinois, relation to **state of stress**, and **expected degree of continuity** between basement and lower Paleozoic strata.

# Traditional view of Earth's "crystalline" crust below Illinois Basin

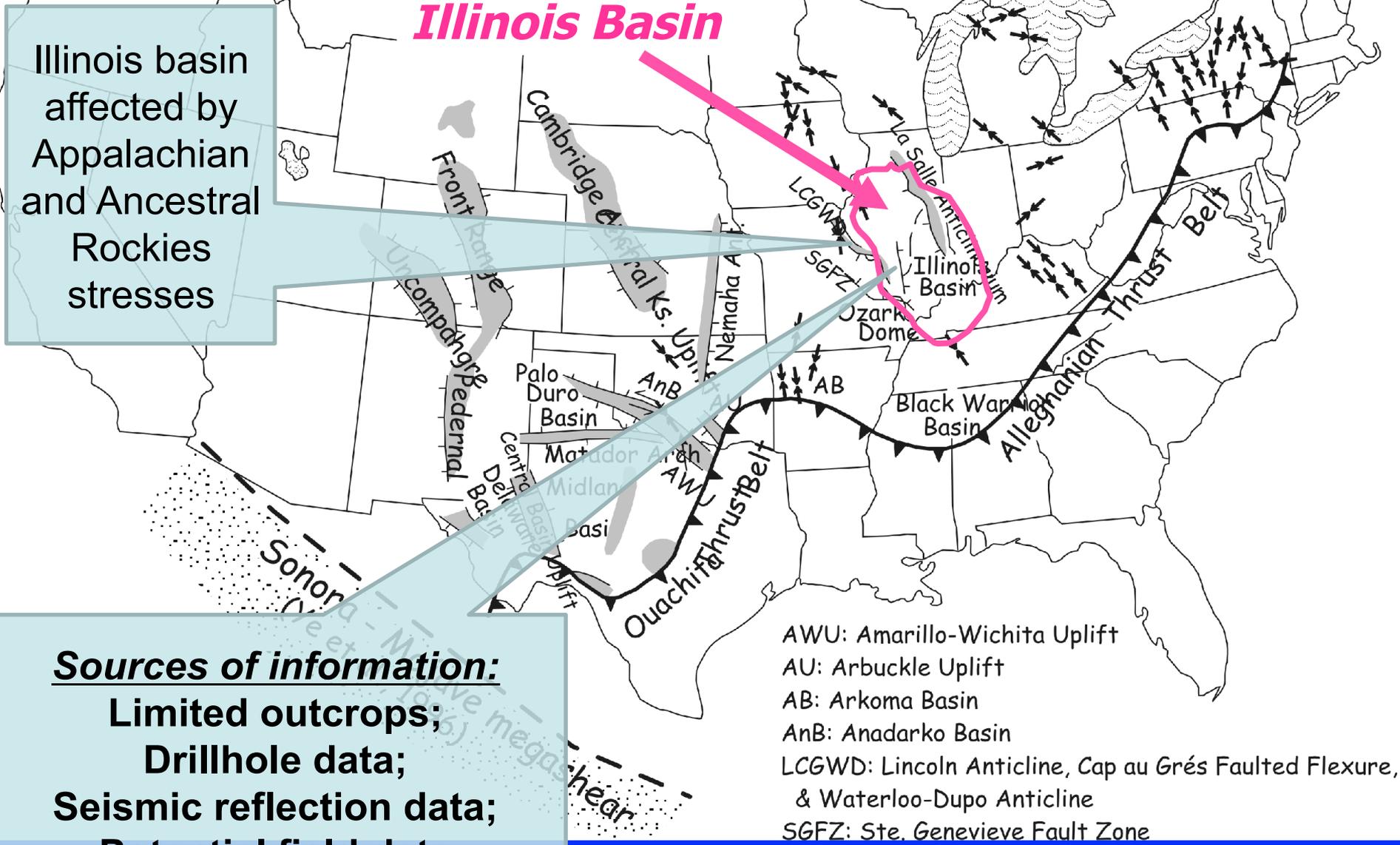


Obj. 1: **crustal heterogeneity** for the Illinois Basin Precambrian basement

# Structural Setting of Illinois Basin

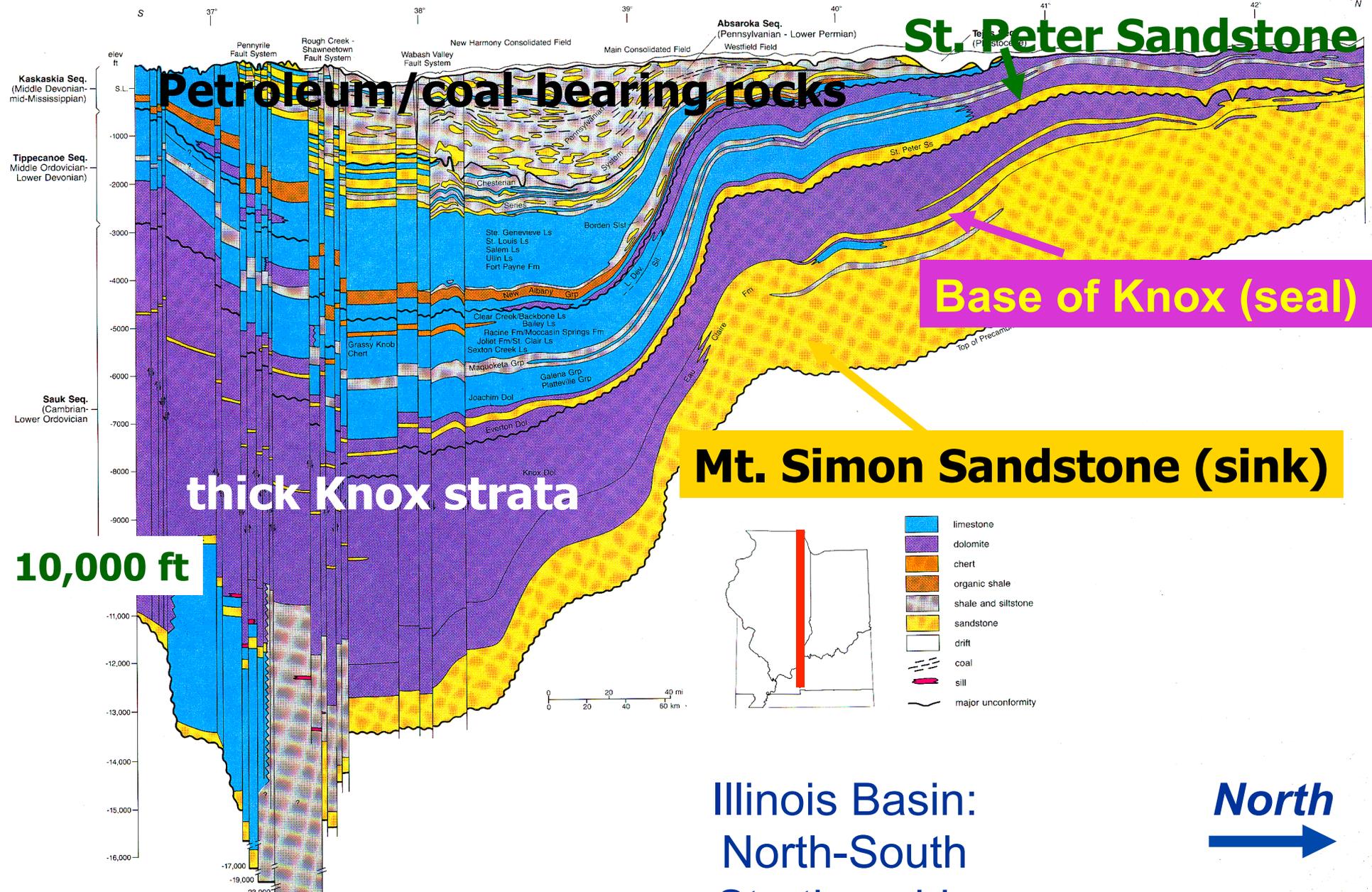
## Illinois Basin

Illinois basin affected by Appalachian and Ancestral Rockies stresses



**Sources of information:**  
Limited outcrops;  
Drillhole data;  
Seismic reflection data;  
Potential field data

AWU: Amarillo-Wichita Uplift  
AU: Arbuckle Uplift  
AB: Arkoma Basin  
AnB: Anadarko Basin  
LCGWD: Lincoln Anticline, Cap au Grés Faulted Flexure, & Waterloo-Dupo Anticline  
SGFZ: Ste. Genevieve Fault Zone

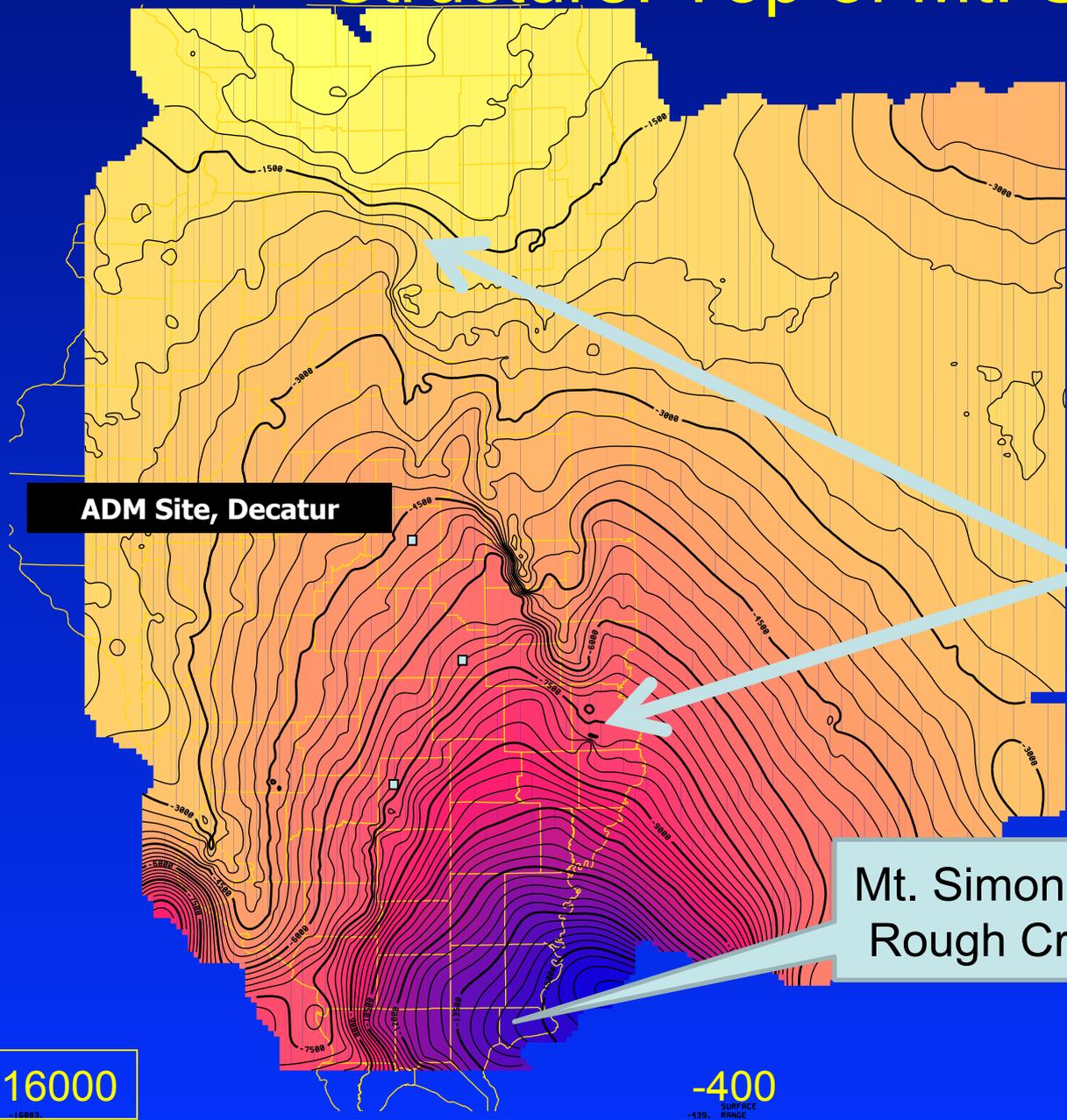


increasing *heterogeneity* to south

Illinois Basin:  
North-South  
Stratigraphic  
Cross-Section

Kolata (1991)

# Structure: Top of Mt. Simon



Mt. Simon ranges from -400 to a projected -16,000 feet below sea level

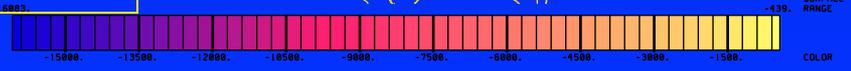
**ADM Site, Decatur**

*La Salle anticlinal belt*

Mt. Simon plunges steeply into the Rough Creek graben/Reelfoot rift

**-16000**

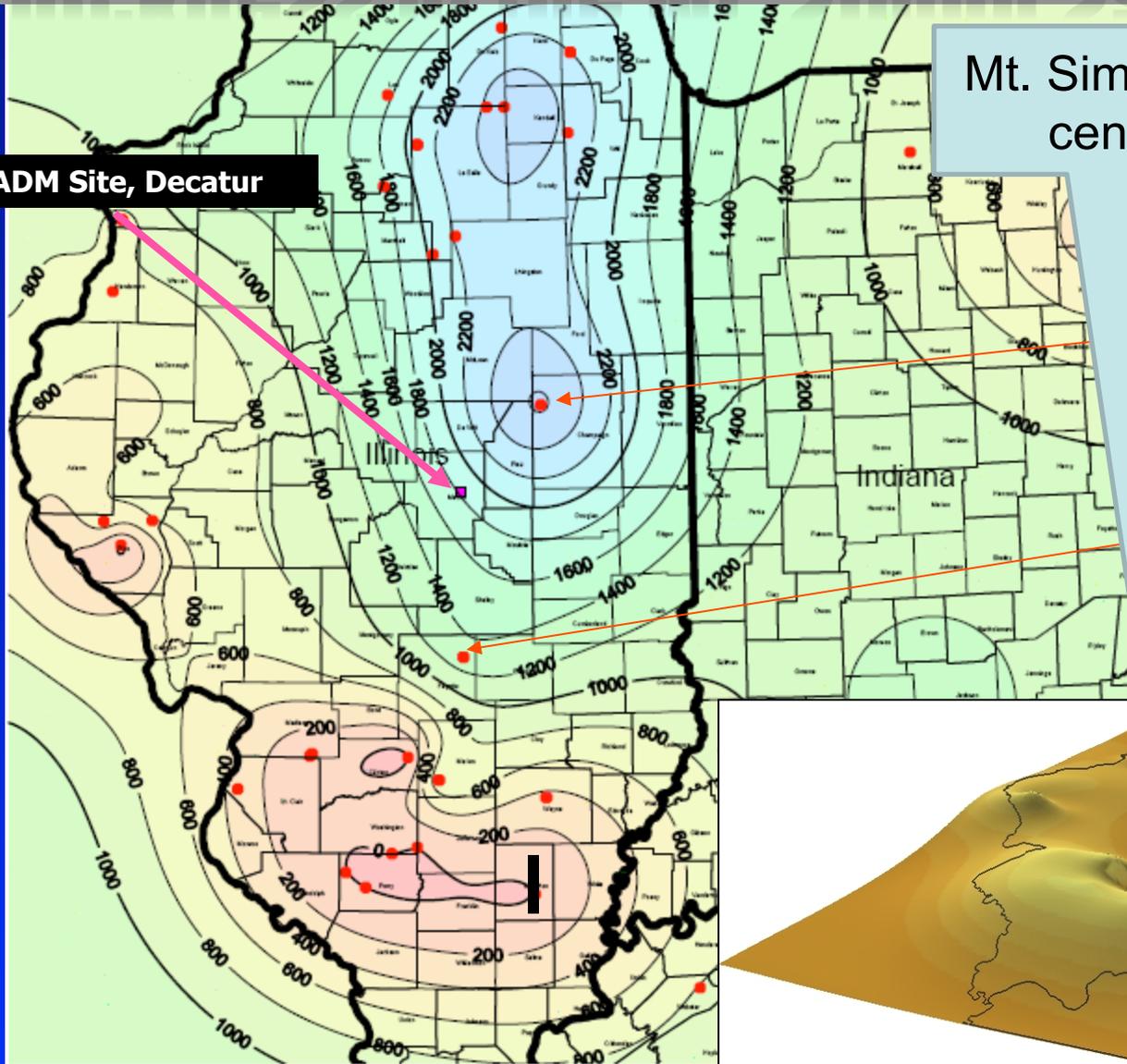
**-400**



CI: 300 ft

# Thickness of the Mt. Simon Sandstone

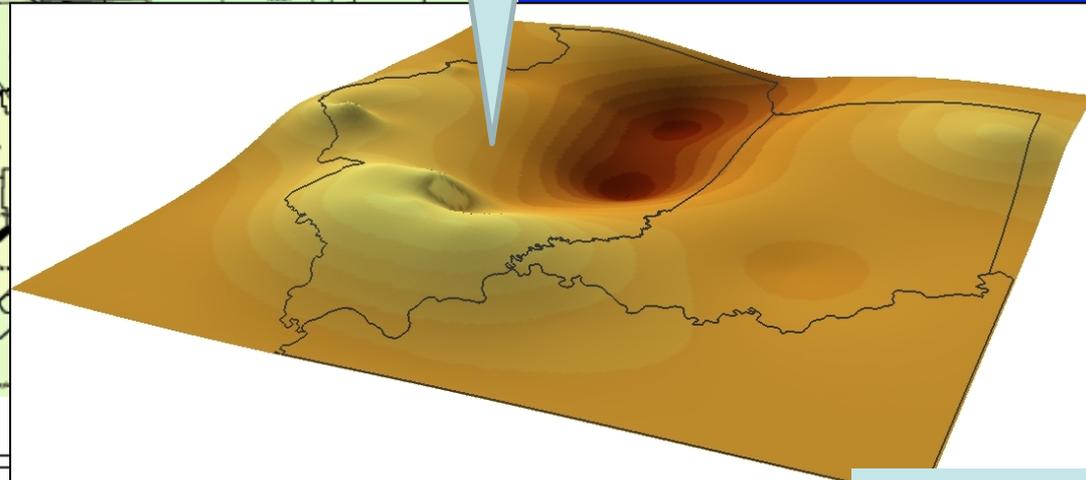
ADM Site, Decatur

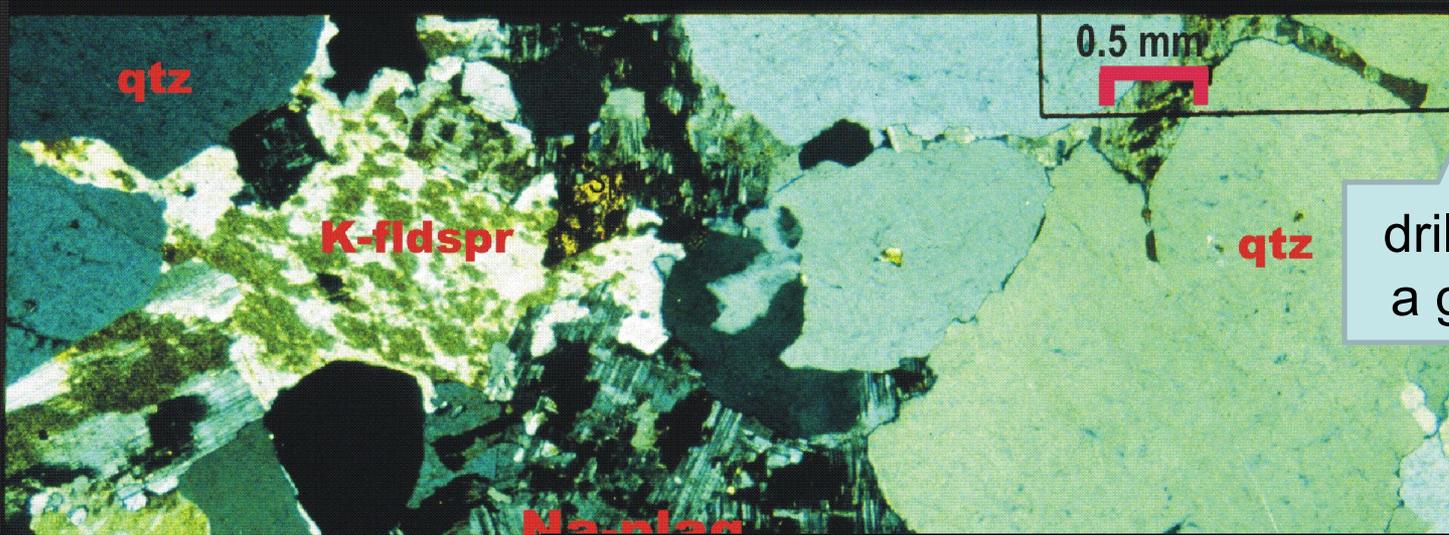


Mt. Simon thickness (depocenter) centered over E-central IL

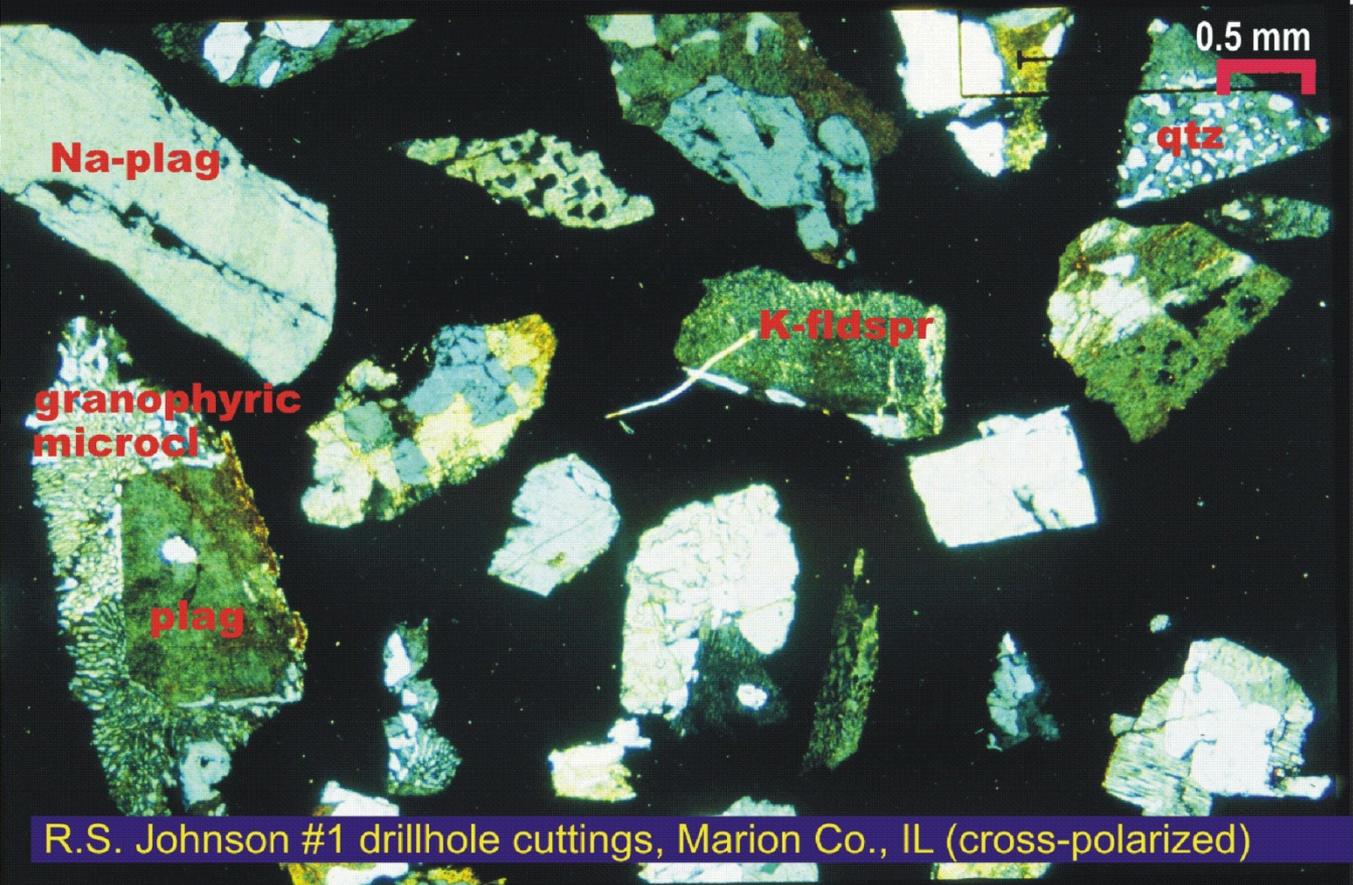
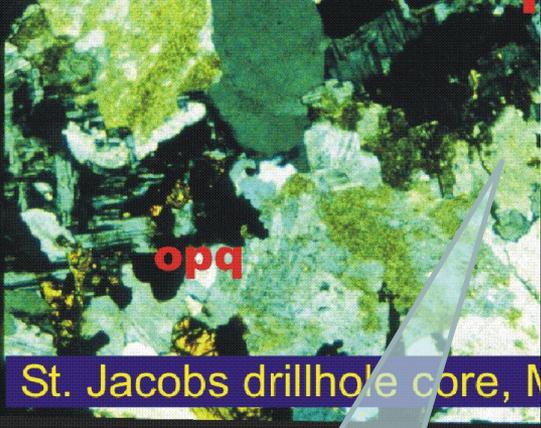
Hinton #7 penetrated 2600 feet of Mt. Simon

Wells with Precambrian granite



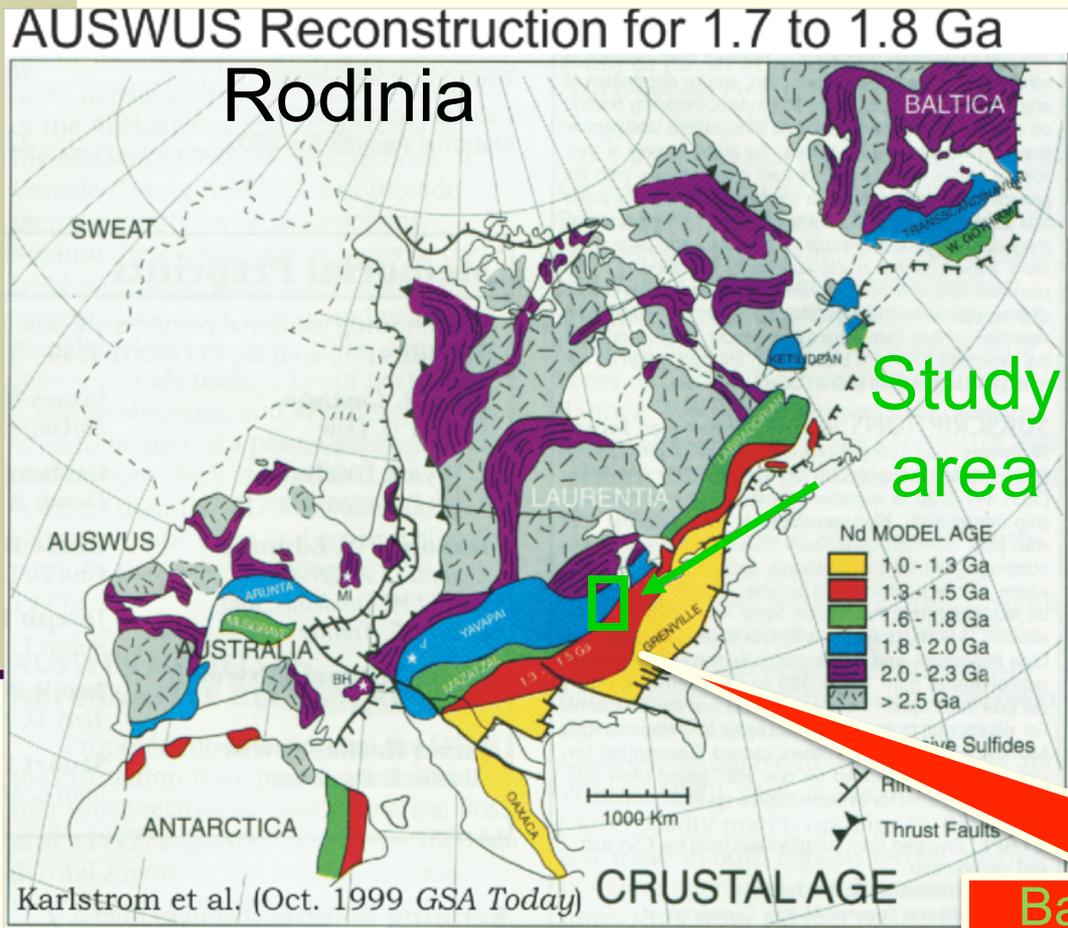


drilling tests indicate a granitic basement



Drillhole data → granitic "basement"

# Deep Basement Geology



Principal basement province:

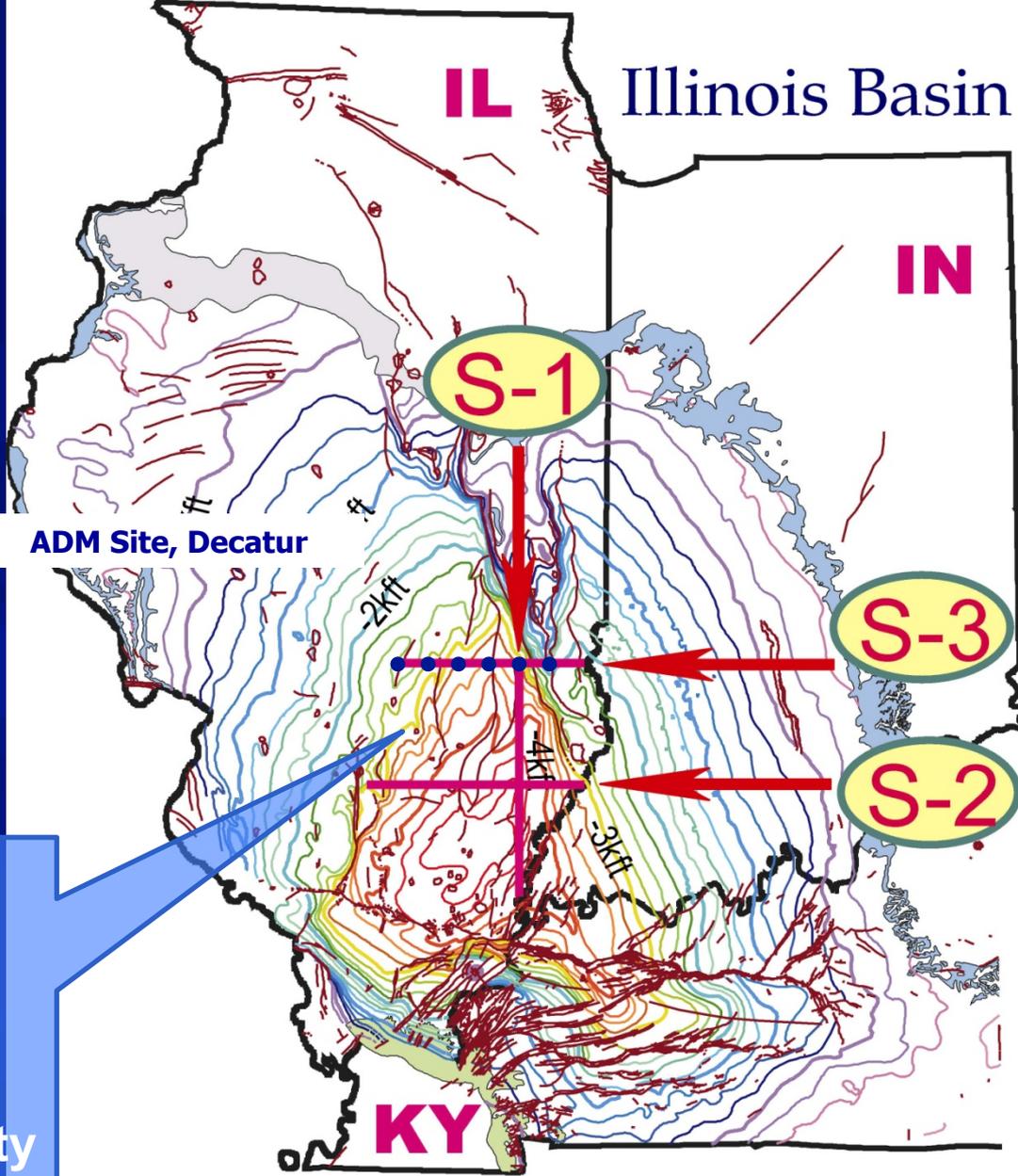
Granite-rhyolite province (EGRP) (1.4-1.5 Ga).

Possible origins for the granite-rhyolite province:

(1) rifting?

(2) subduction?

Basement beneath Illinois basin part of a vast granitic igneous terrane



**IL** Illinois Basin

**IN**

**S-1**

**S-3**

**S-2**

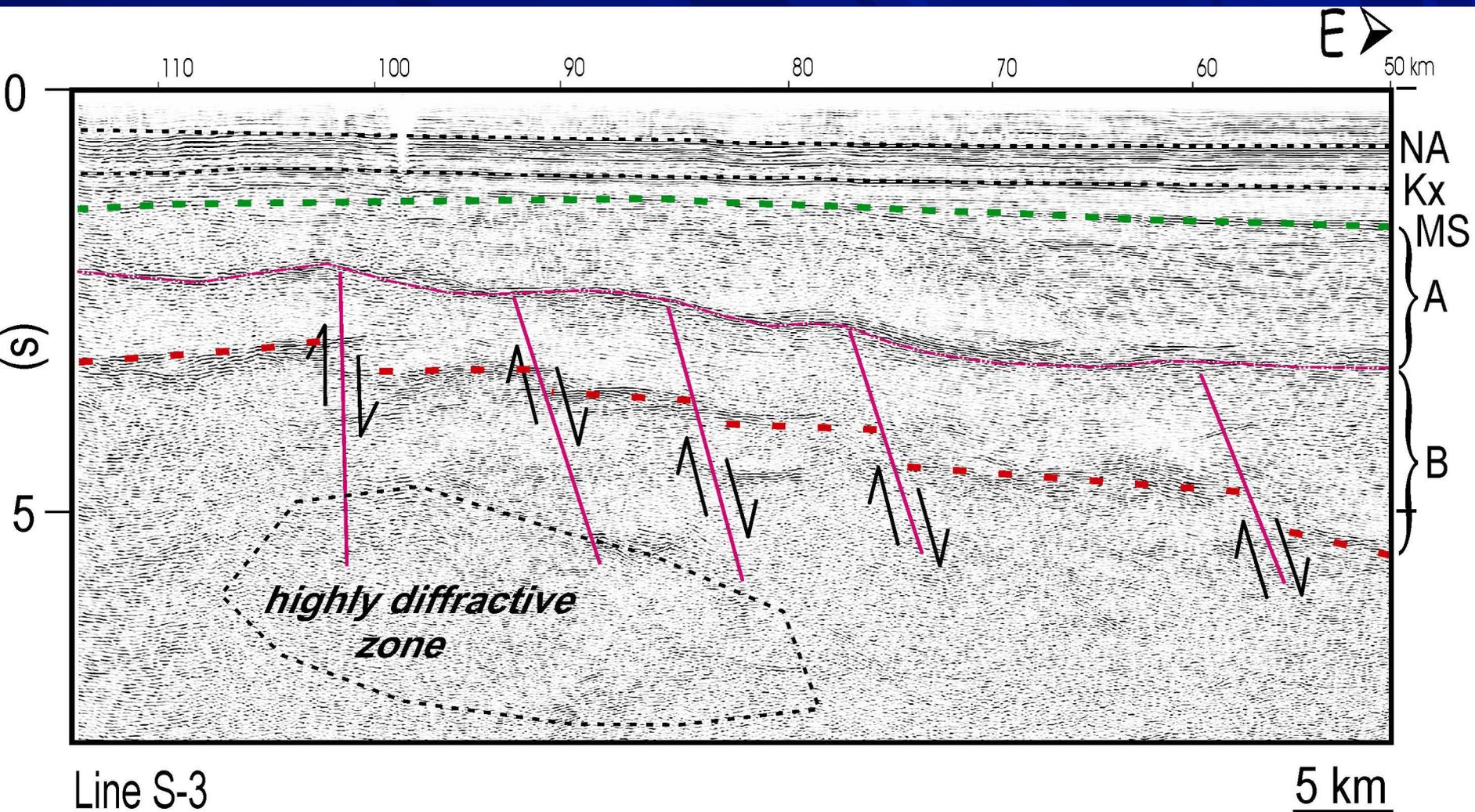
ADM Site, Decatur

**KY**

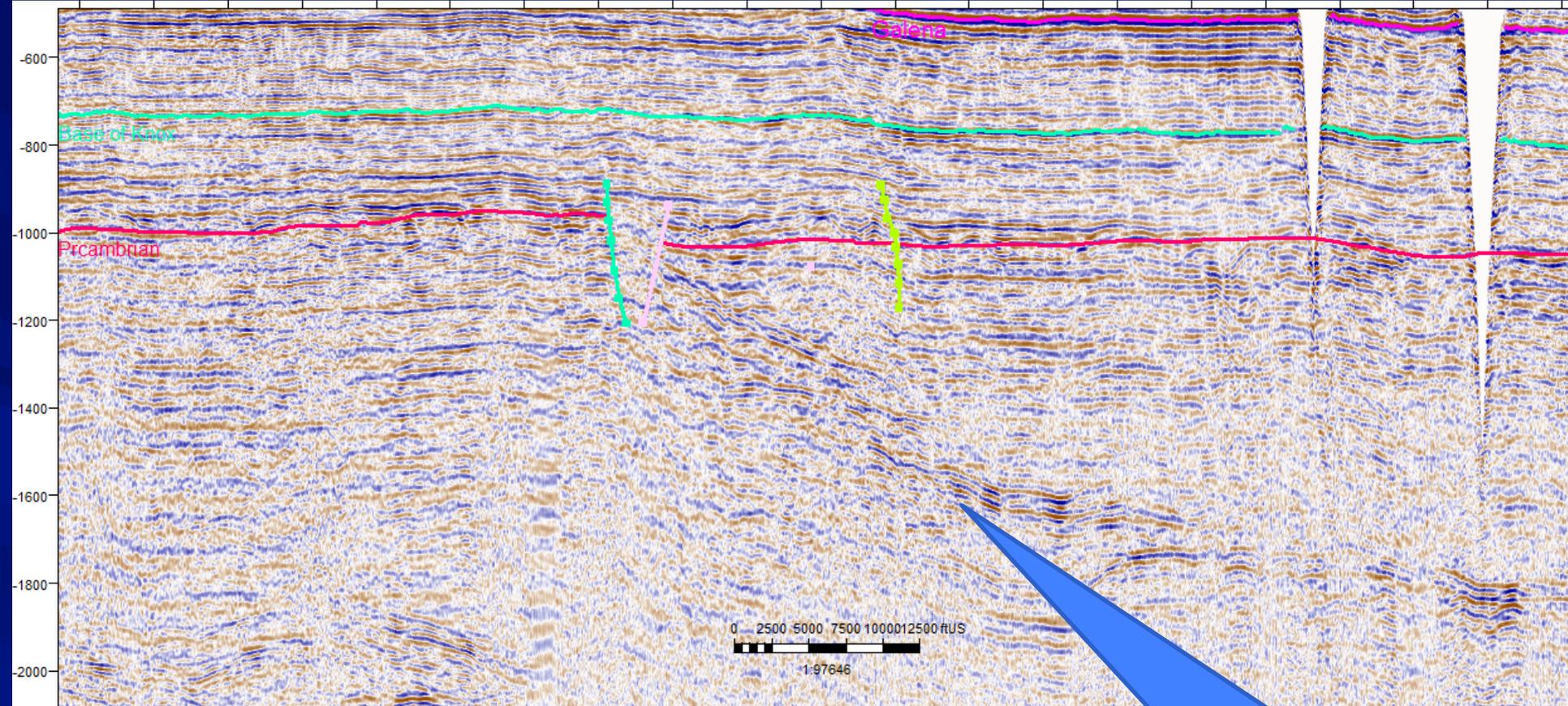
Seismic reflection data → significant heterogeneity

1 kft = 1000 feet  
contour interval = 250 feet

STRUCTURAL AXES AND  
STRUCTURAL CONTOURS  
BASE OF UP. DEVONIAN  
NEW ALBANY SHALE



**“nested” Proterozoic seismic sequences beneath the Paleozoic Illinois Basin**



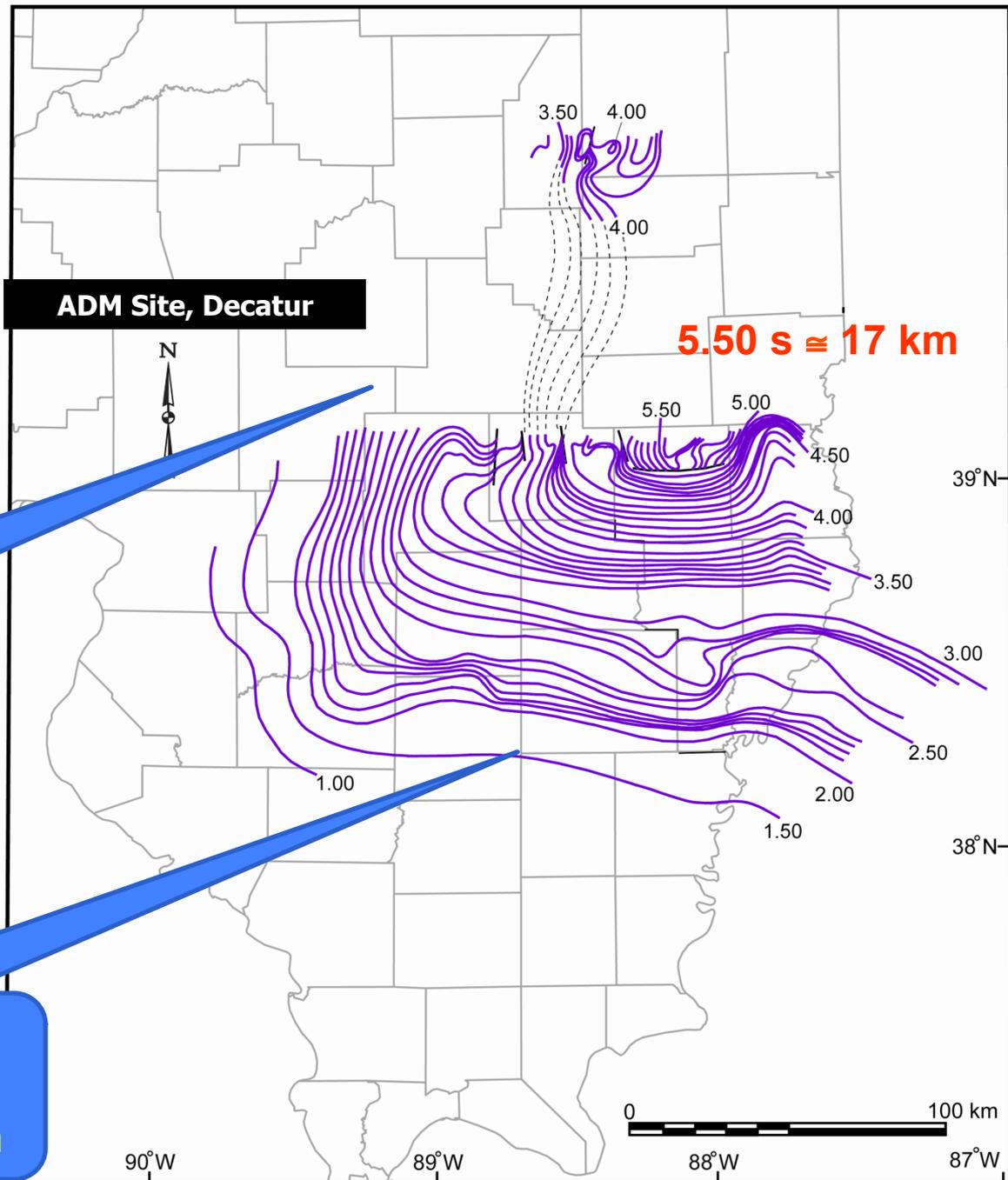
**Much less heterogeneity to the north, in east-central Illinois**

What happens further north in the basin?

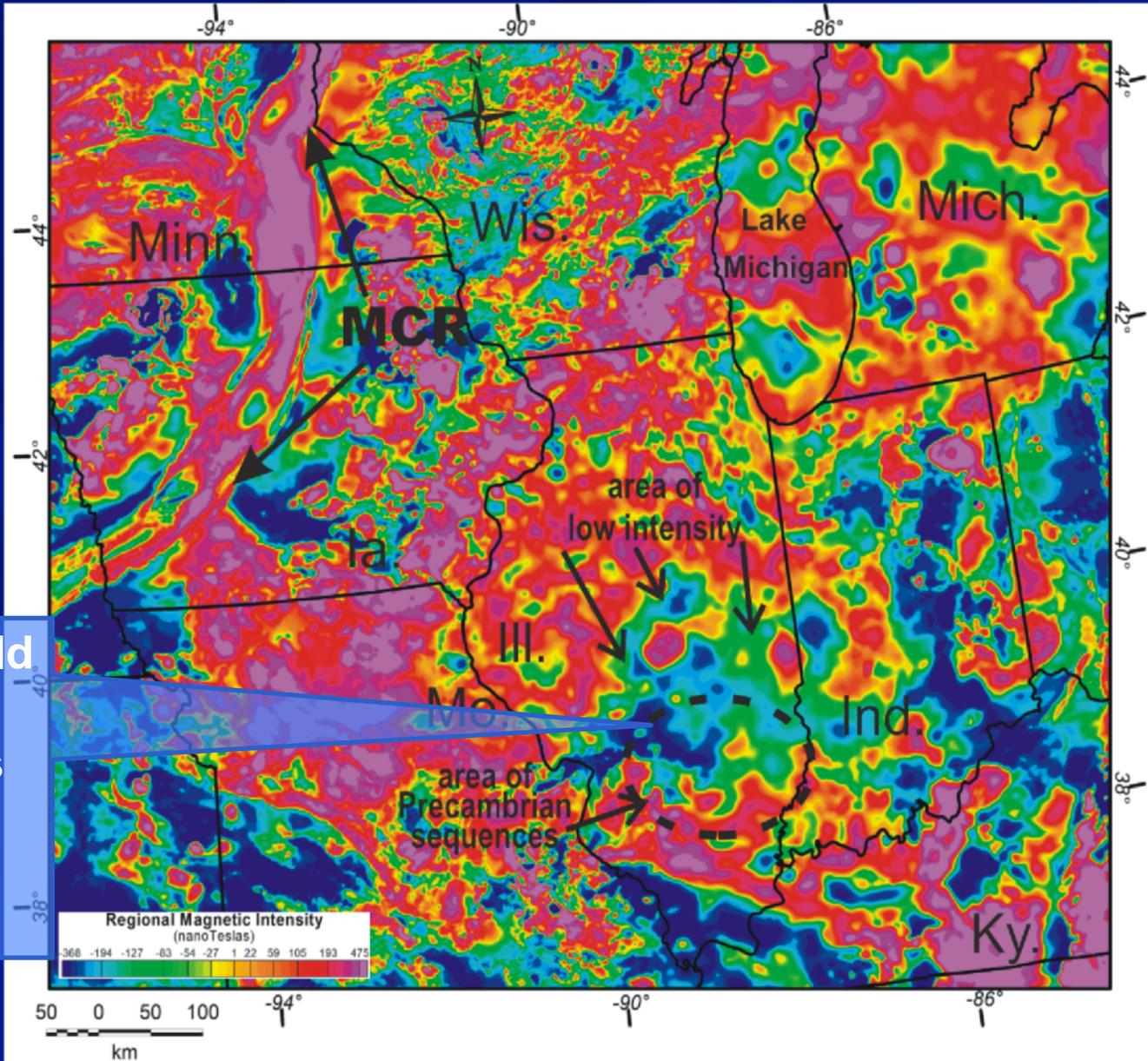
**Iso-travel time structure map for entire Proterozoic sequence beneath the Illinois Basin based on available seismic reflection data.**

**The Proterozoic sequences appear to be dying out to the NW.**

**Increased heterogeneity nearer southern part of basin**

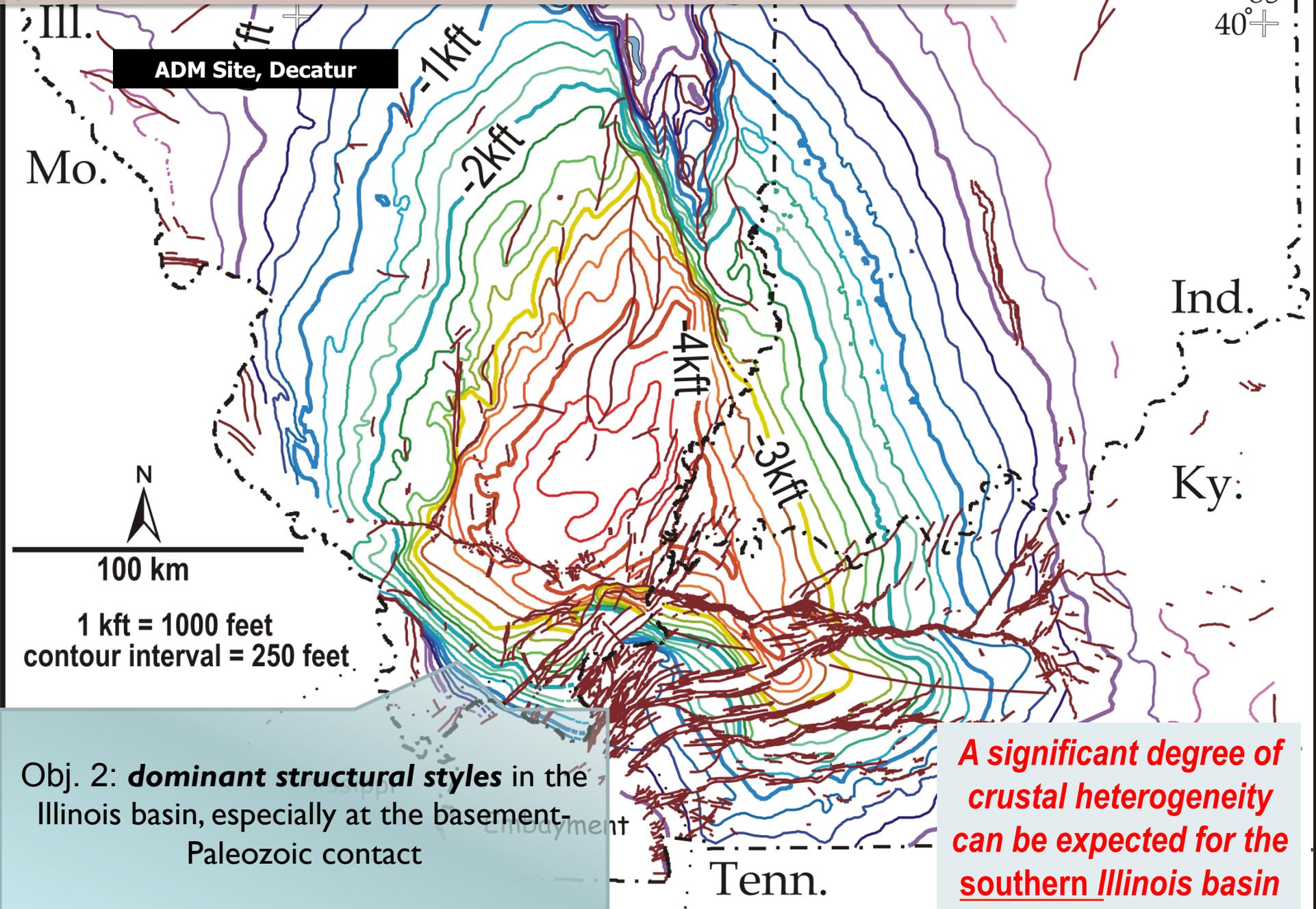


# Regional magnetic intensity: central Midwest

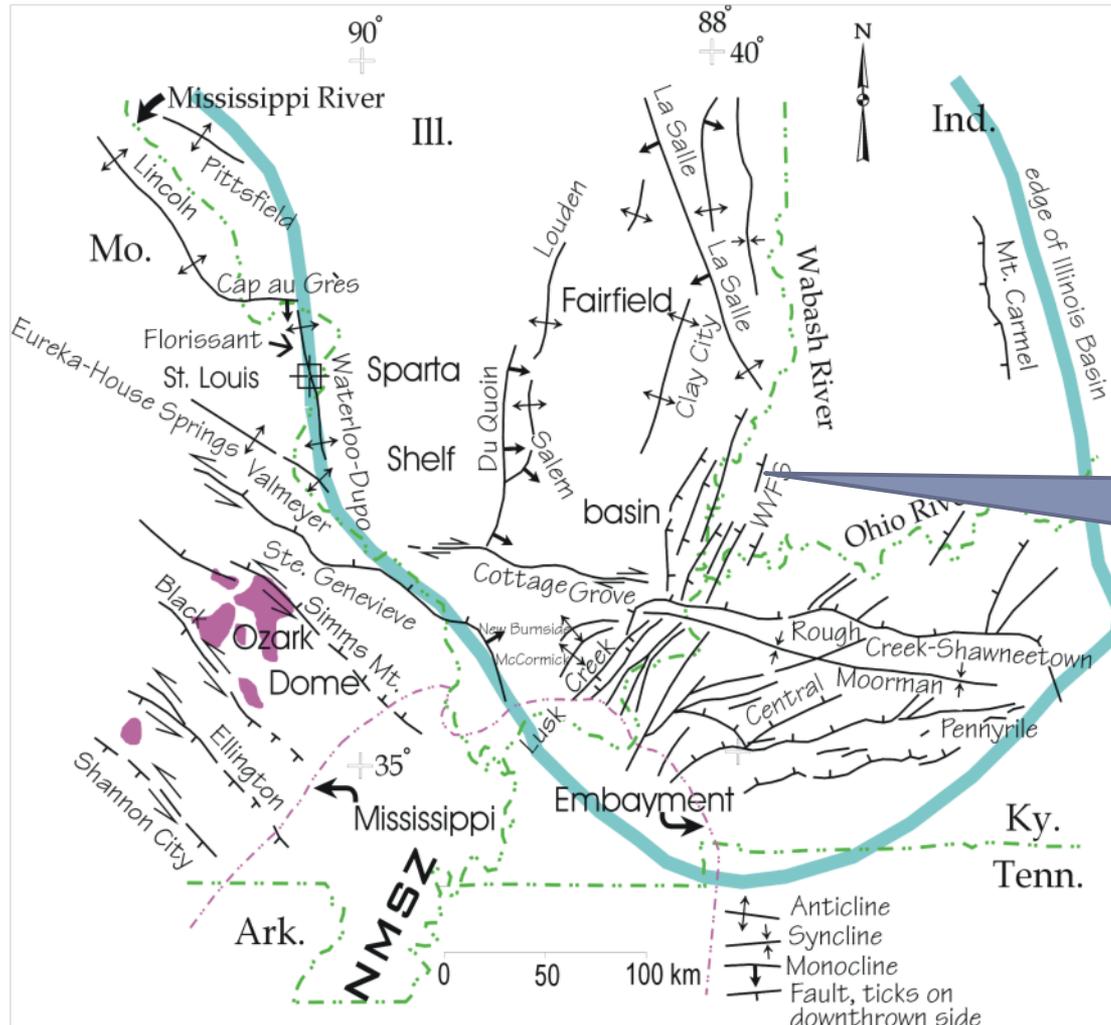


Potential field data → anomalous basement further south?

# Devonian structural contours and fault and fold axes of Illinois basin

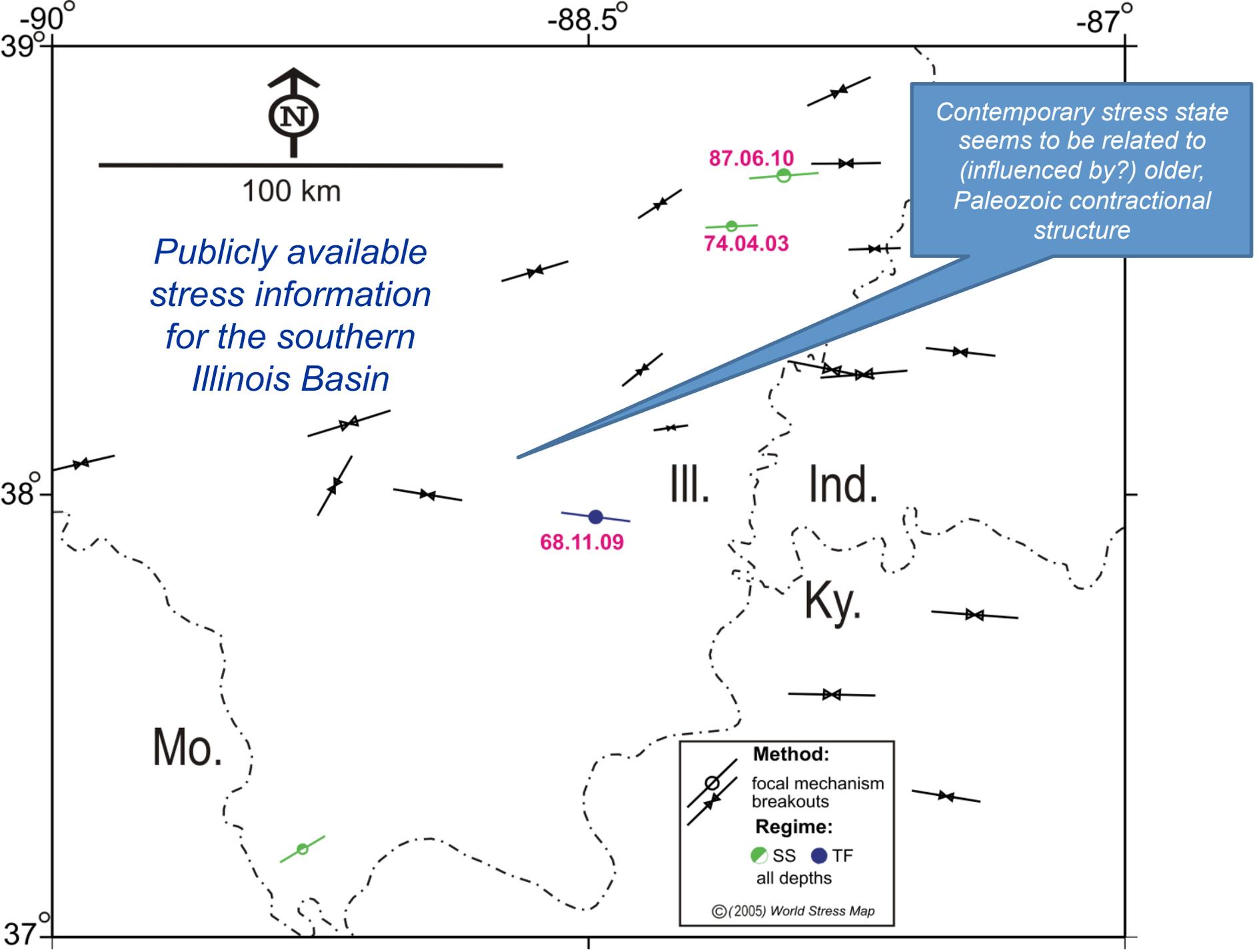


# What is the relation between Paleozoic basement structure and the deep basement?

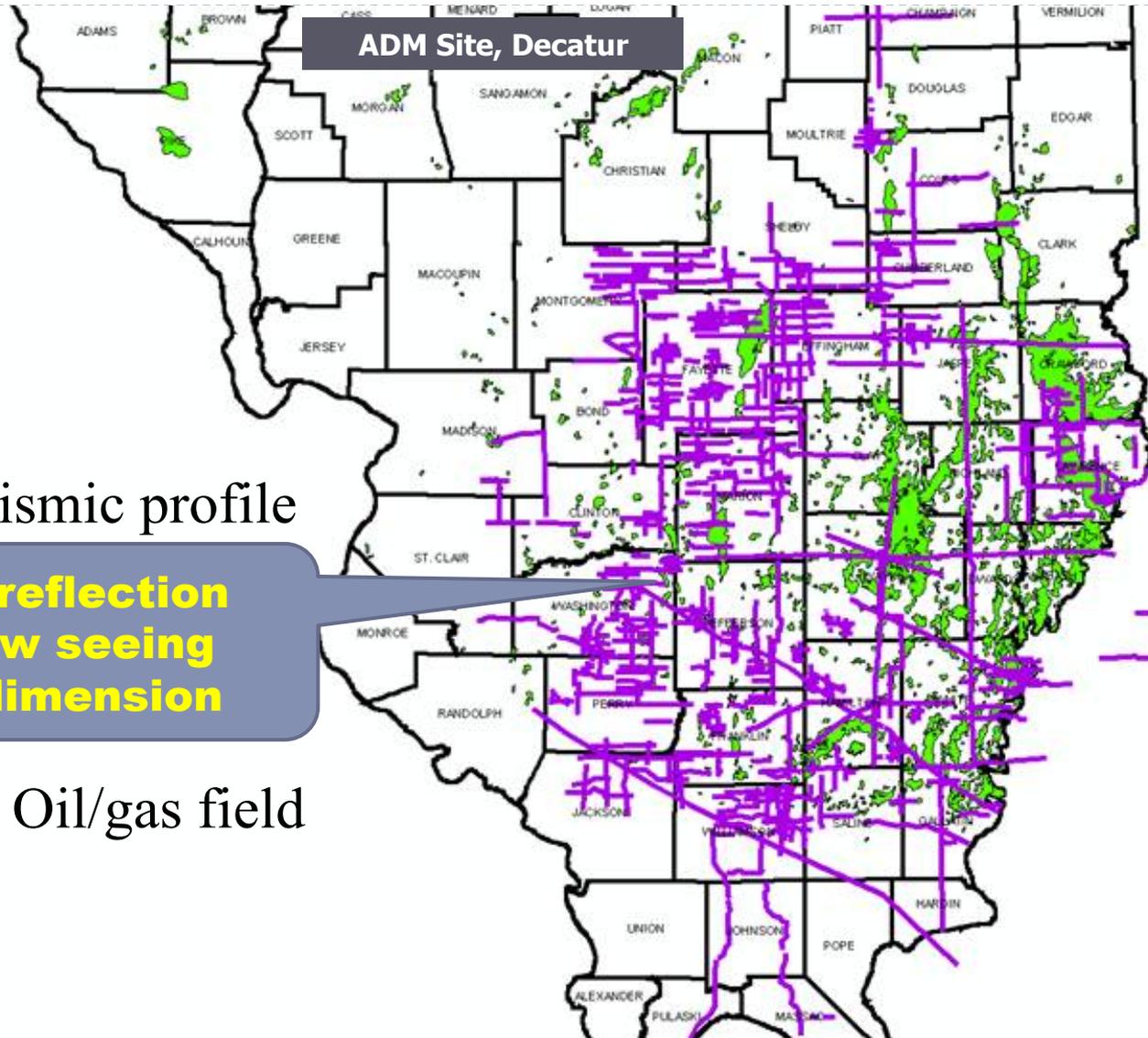


*What is relation between structures defined by vintage drillhole data and lower Paleozoic strata and Precambrian "basement"?*





# Excerpt of seismic reflection data base from the Illinois State Geological Survey (courtesy, Dr. Hannes E. Leetaru)



ADM Site, Decatur

Seismic profile

Seismic reflection data allow seeing into 3<sup>rd</sup> dimension

Oil/gas field

# **Assessment of Major Structures in the Southern Illinois Basin**

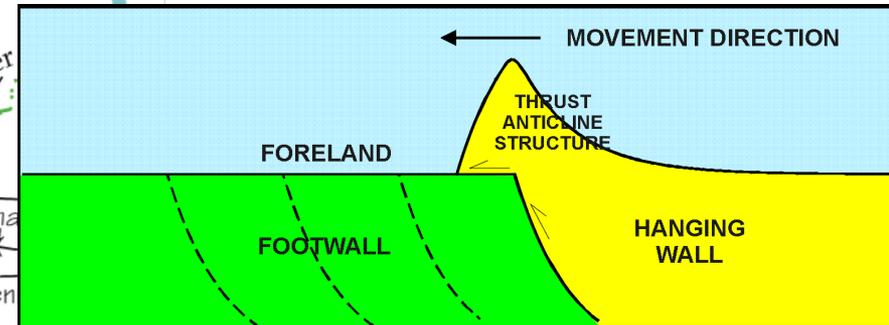
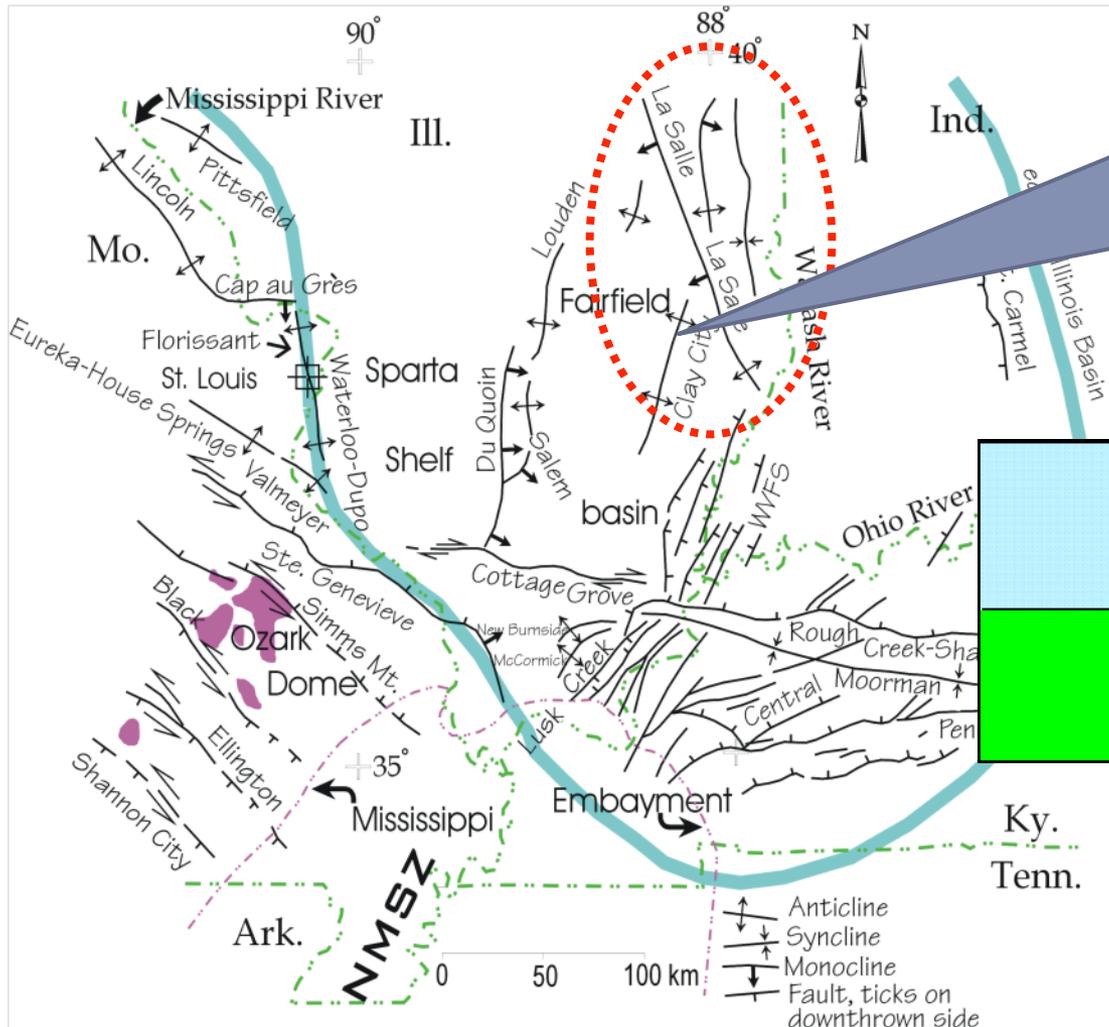
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- ▶ La Salle deformation belt
- ▶ Fairfield sub-basin (a locally deep portion of the Illinois basin)
- ▶ Du Quoin monocline complex

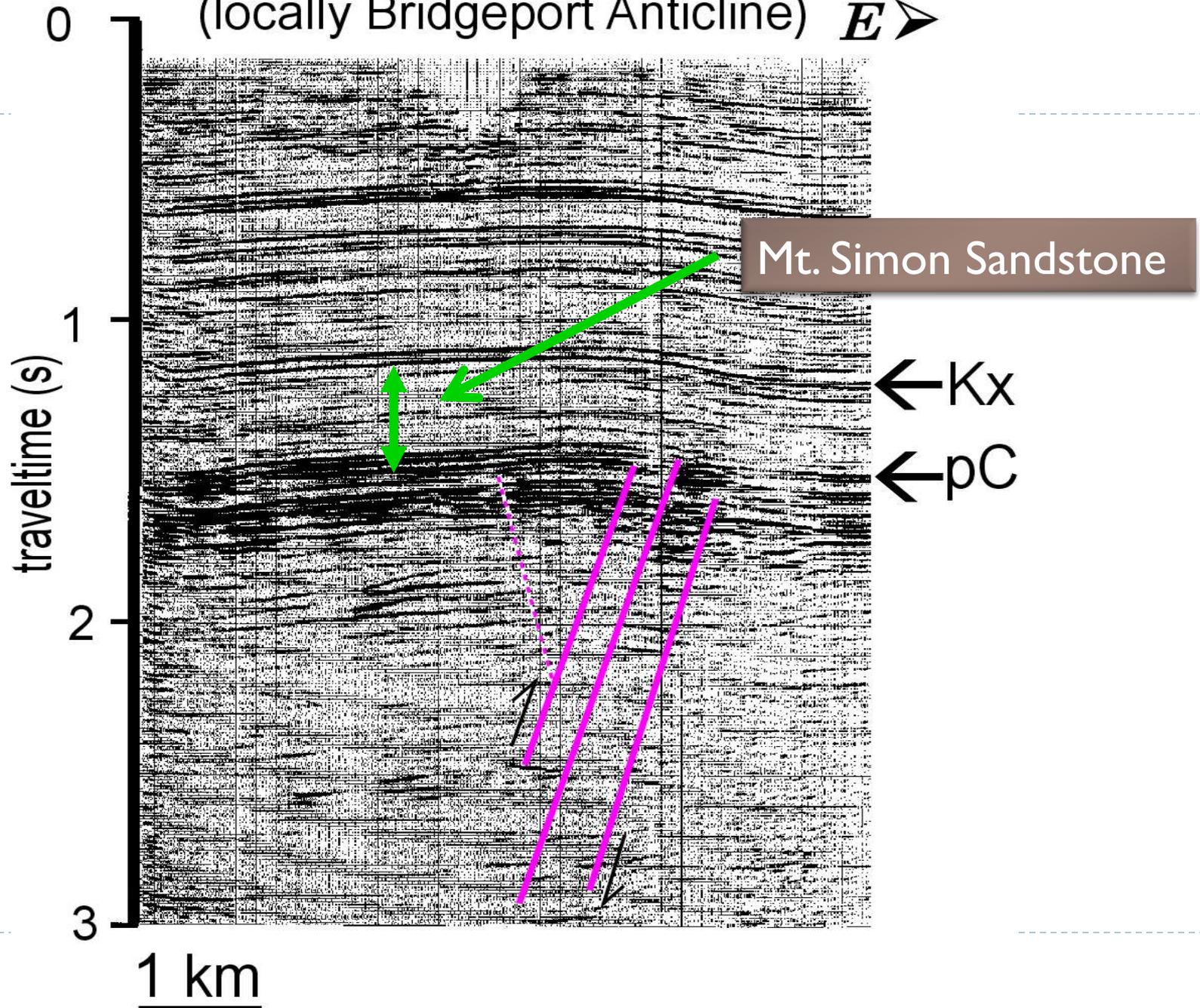


# La Salle deformation belt and vicinity

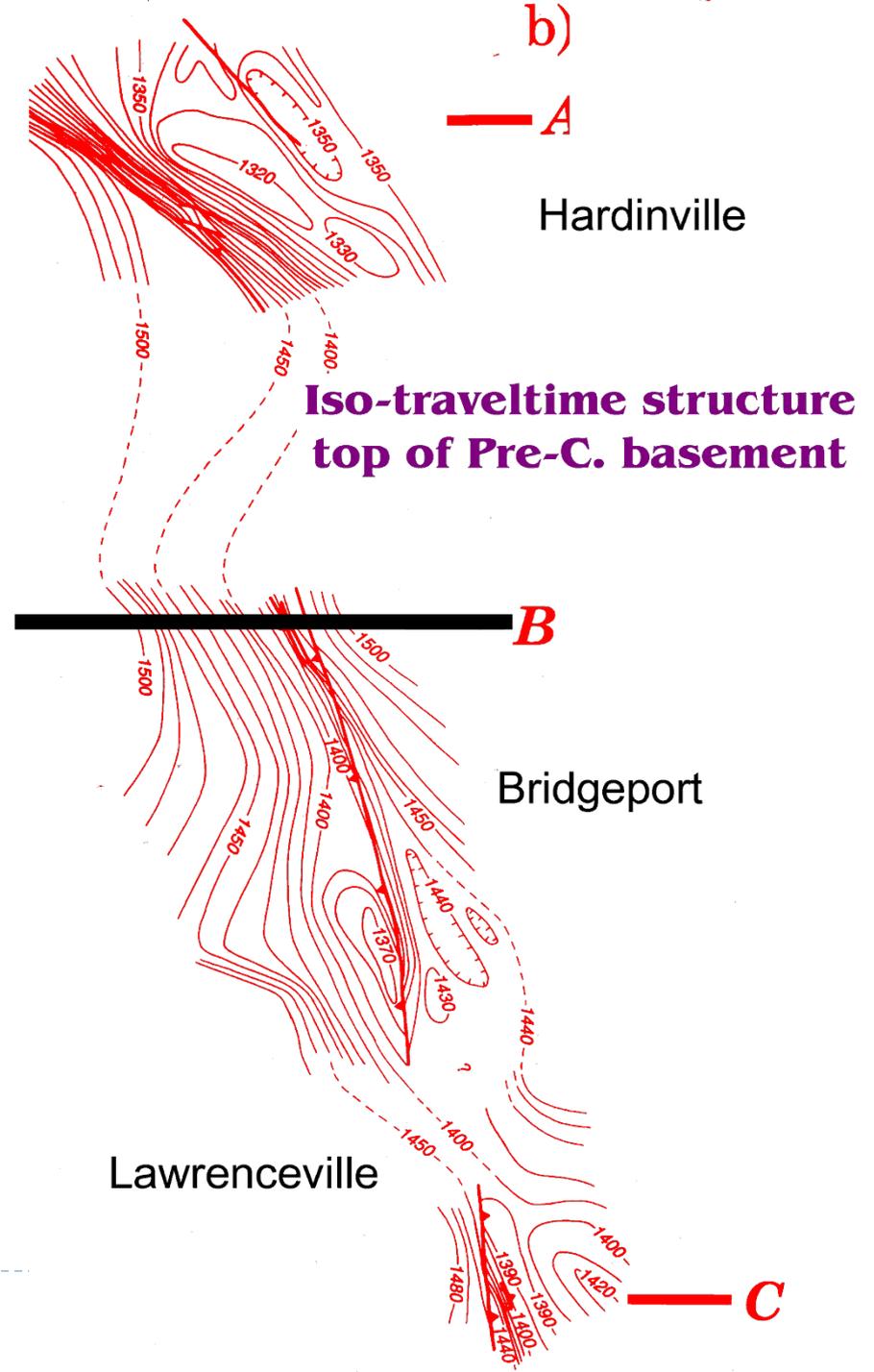
Southern Illinois basin is structurally complex at deeper (Cambrian) levels – Laramide-style fold and fault zones.



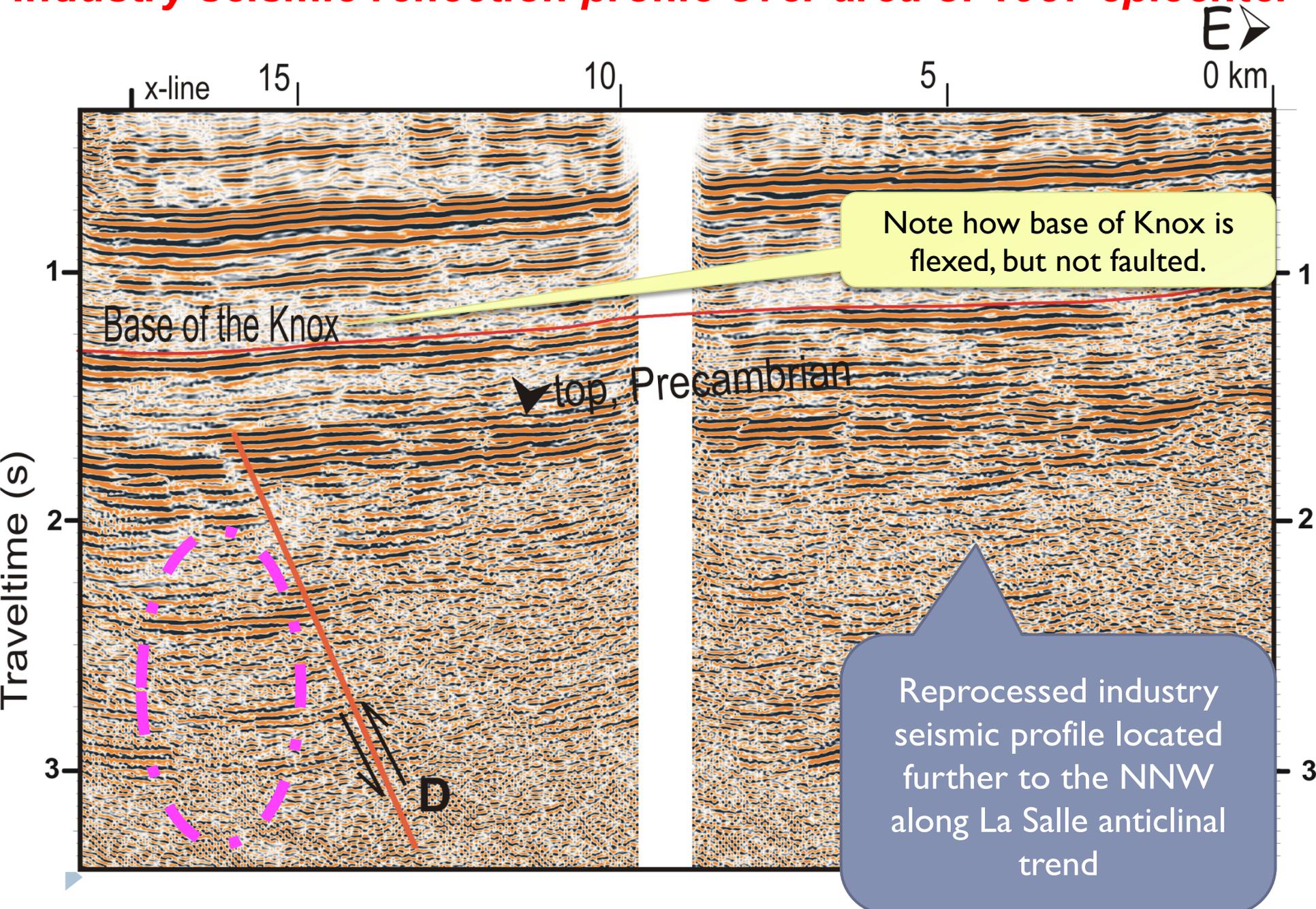
# La Salle anticline (locally Bridgeport Anticline) $E \blacktriangleright$



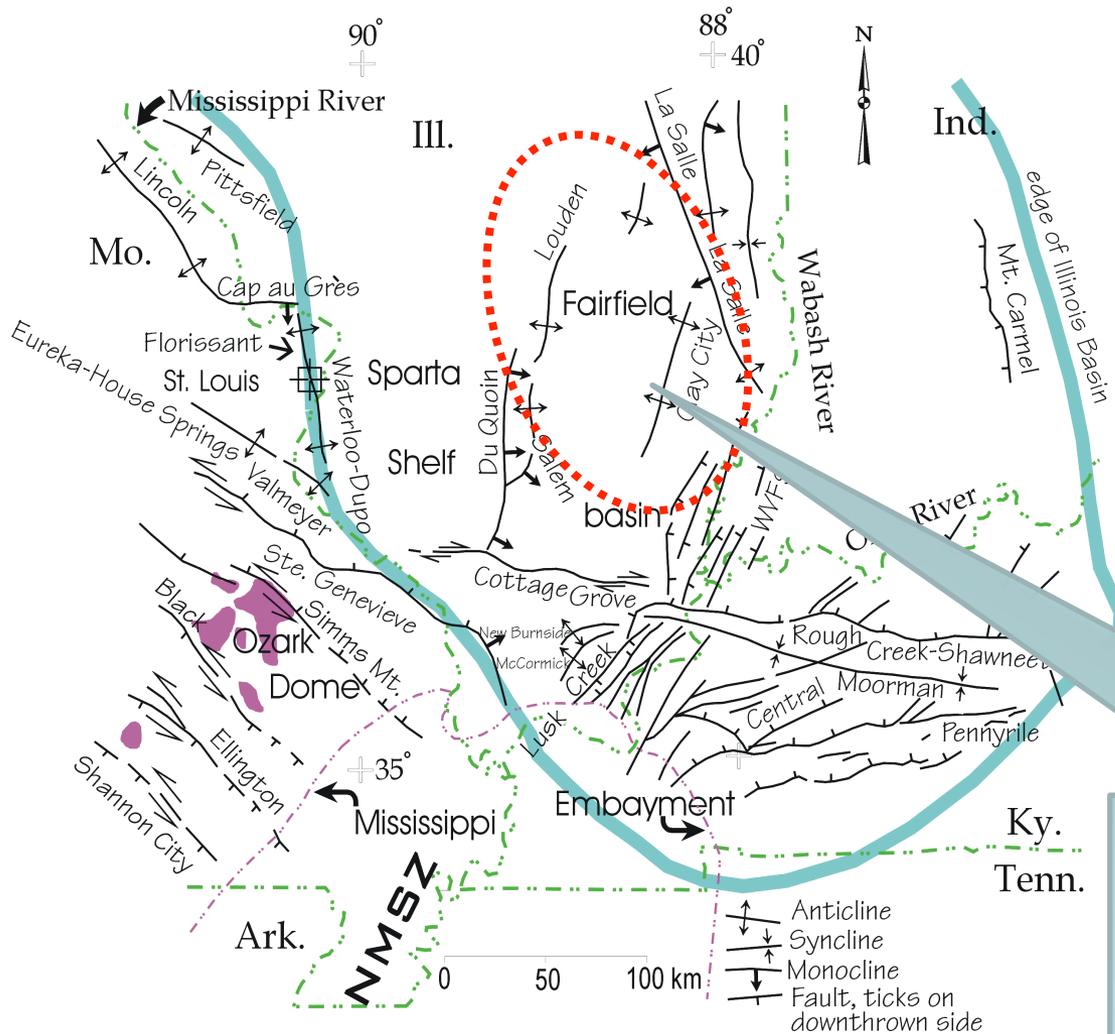
*Reversal of vergence along strike may imply a strike-slip component*



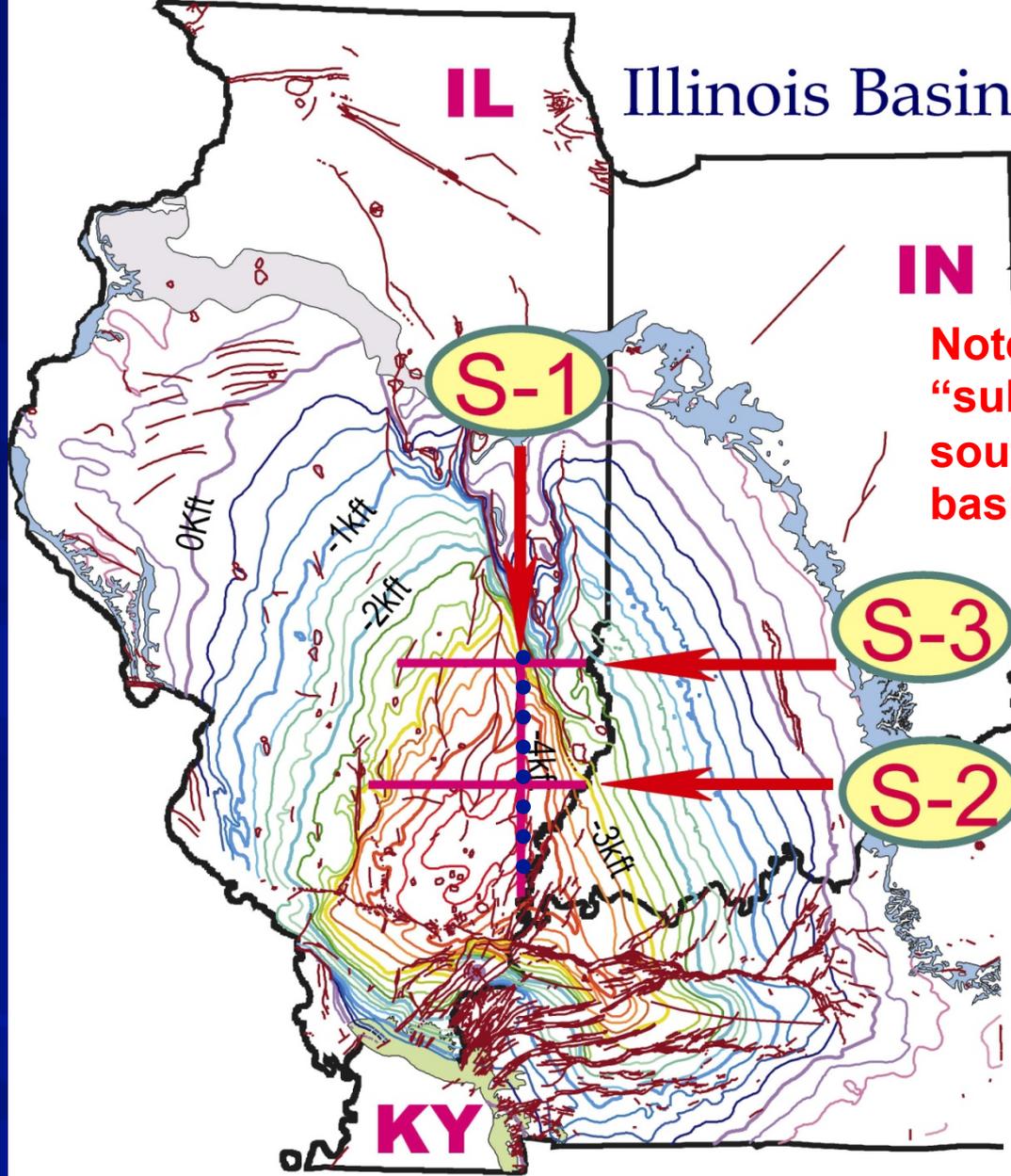
# Industry seismic reflection profile over area of 1987 epicenter



# Fairfield Sub-basin



▶ Obj. 3: Contrast the **relative stability** of east-central Illinois versus southernmost Illinois.



**IL** Illinois Basin

**IN**

**S-1**

**S-3**

**S-2**

**KY**

Note: two areas of "subsidence" for southern Illinois basin

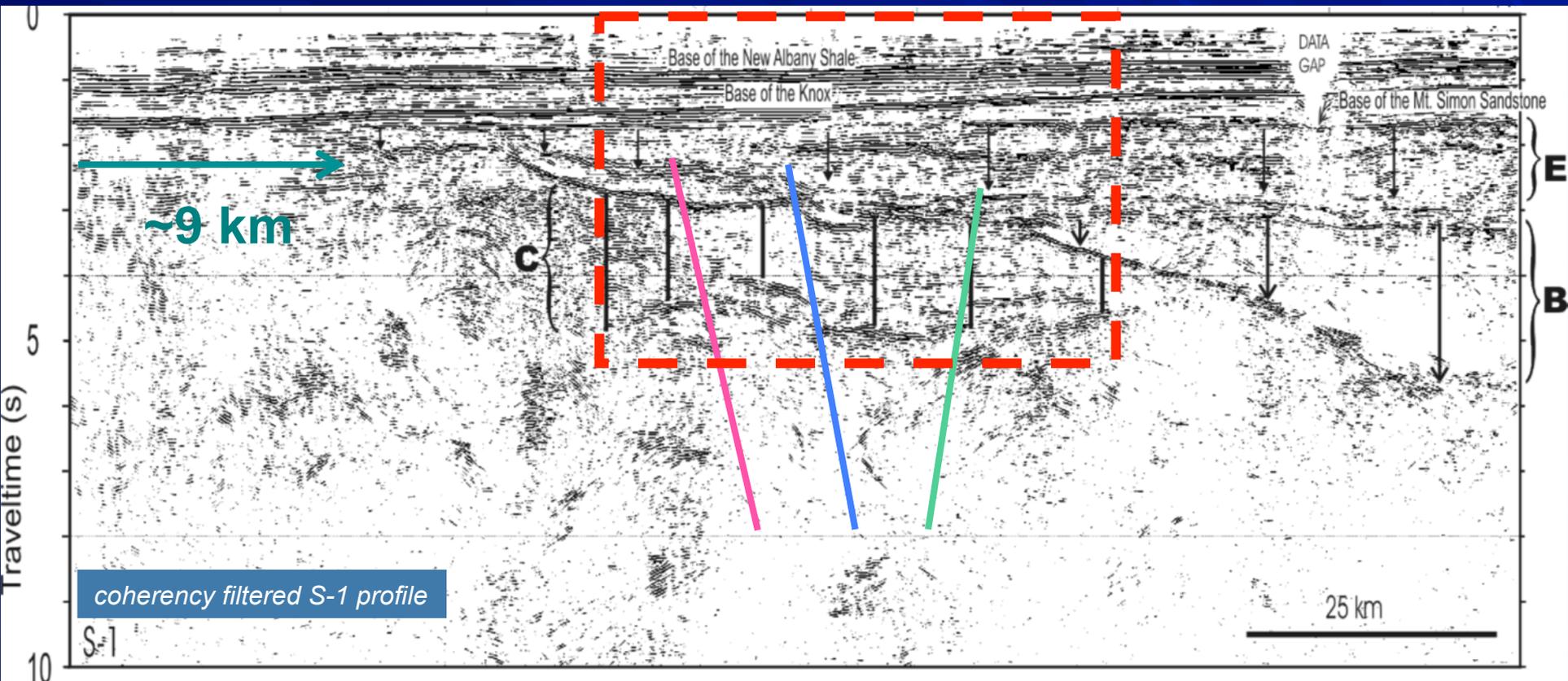
Look at a close-up of the north-south regional deep seismic profile.

1 kft = 1000 feet  
contour interval = 250 feet

**STRUCTURAL AXES AND  
STRUCTURAL CONTOURS  
BASE OF UP. DEVONIAN  
NEW ALBANY SHALE**

# Reprocessed deep record

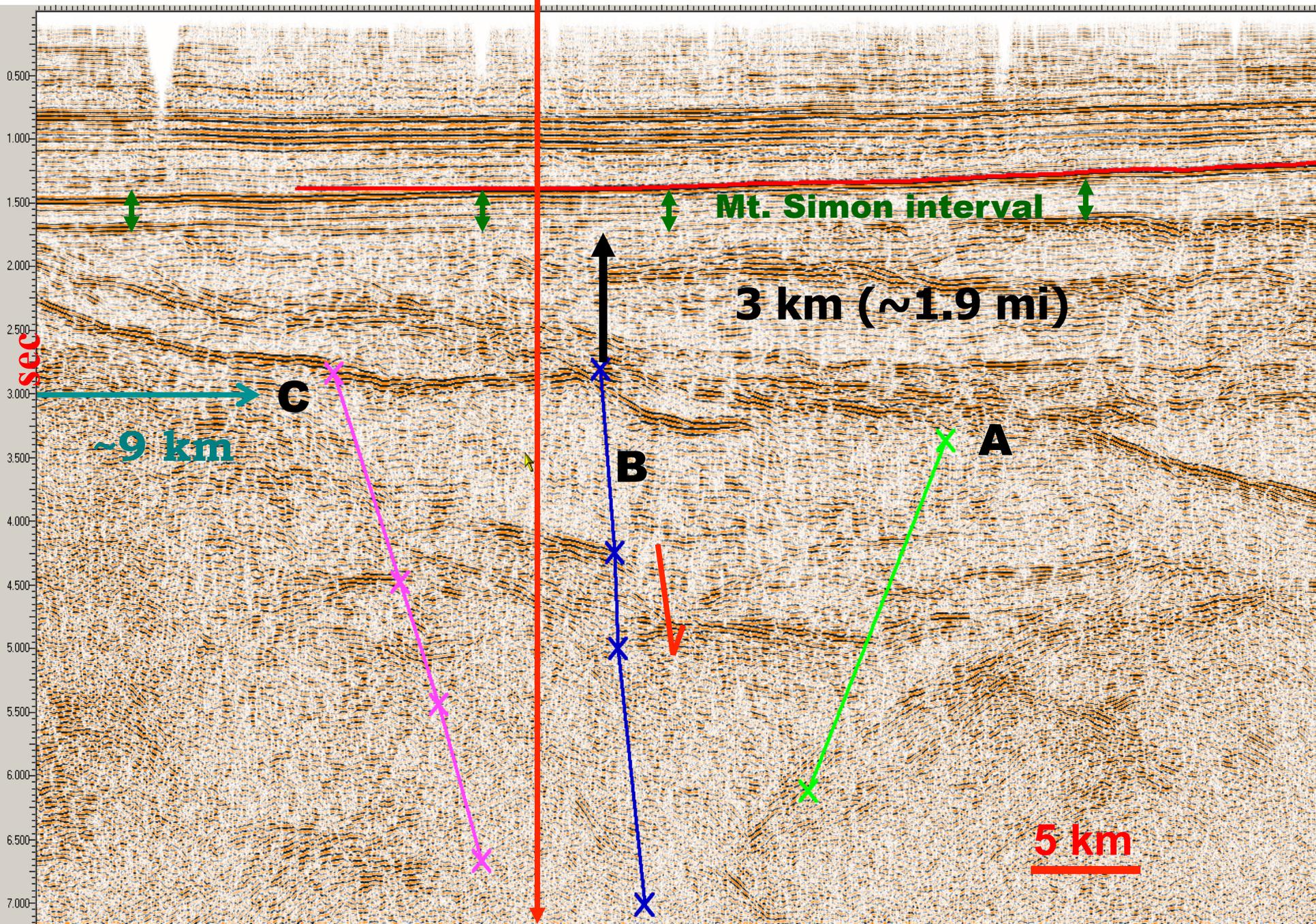
zone of rifting in  
Precambrian "basement"



**South-to-north deep seismic reflection profile  
through Fairfield sub-basin  
(locally, a deep part of the Illinois basin).**

S-1

North



Mt. Simon interval

3 km (~1.9 mi)

C

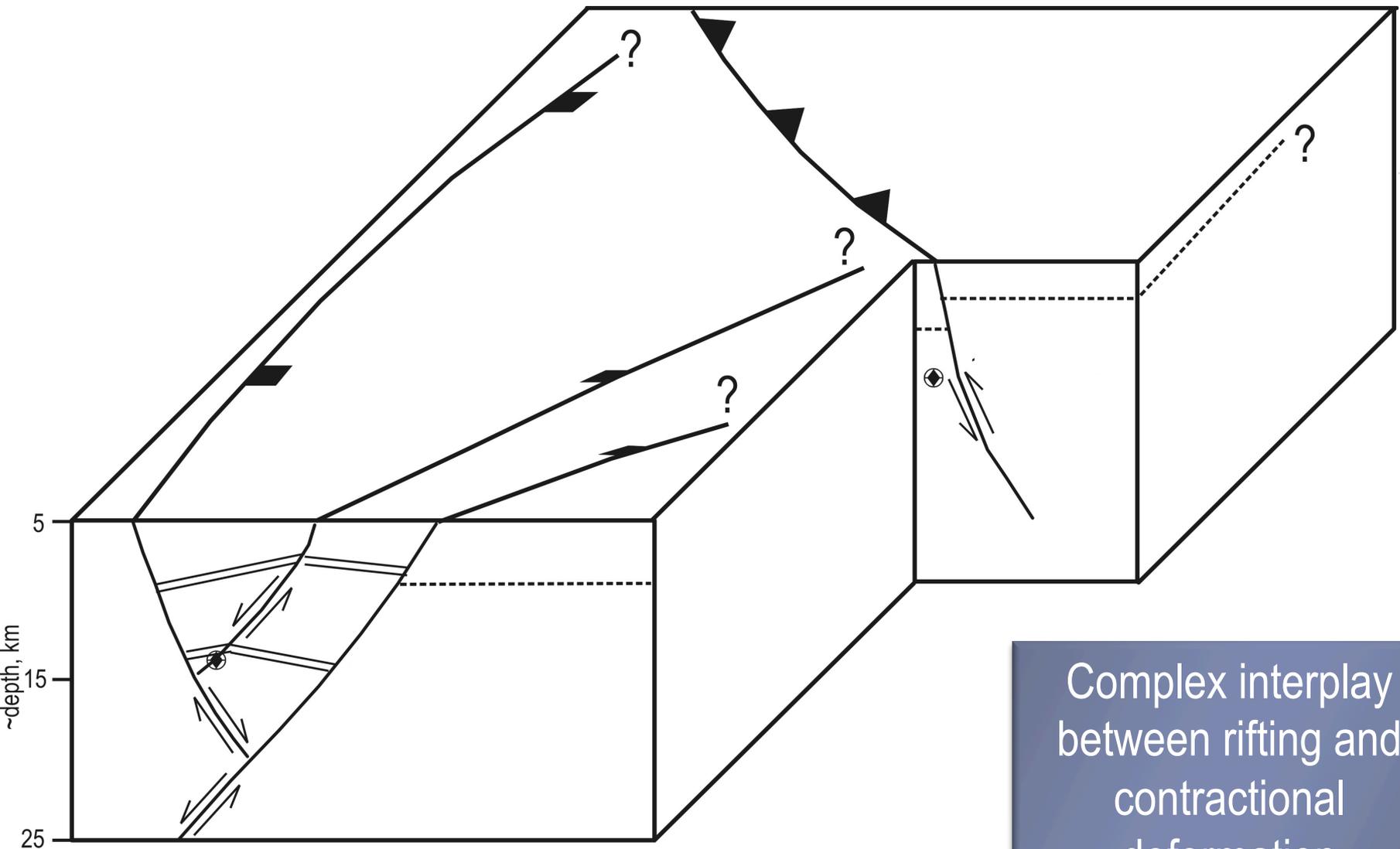
B

A

~9 km

5 km

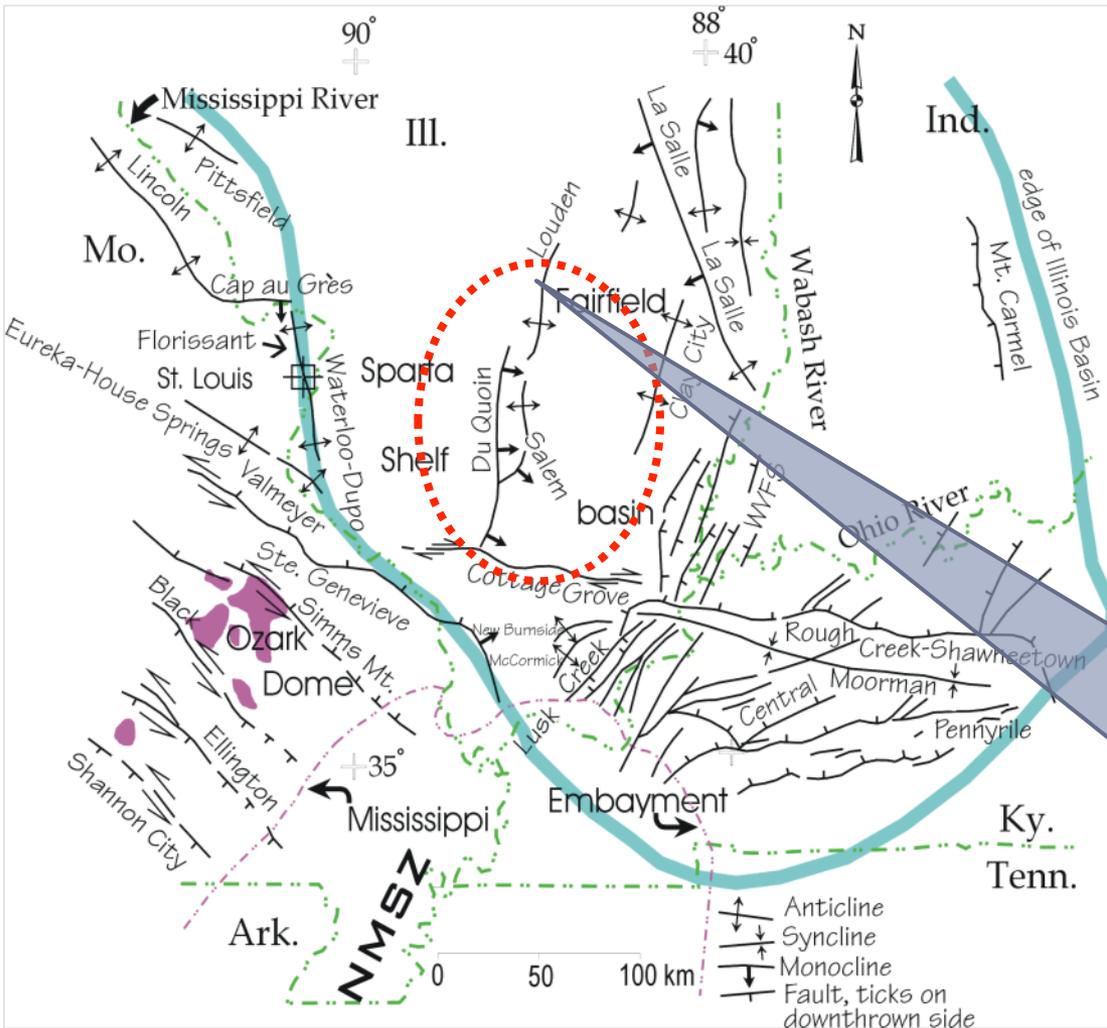
sec



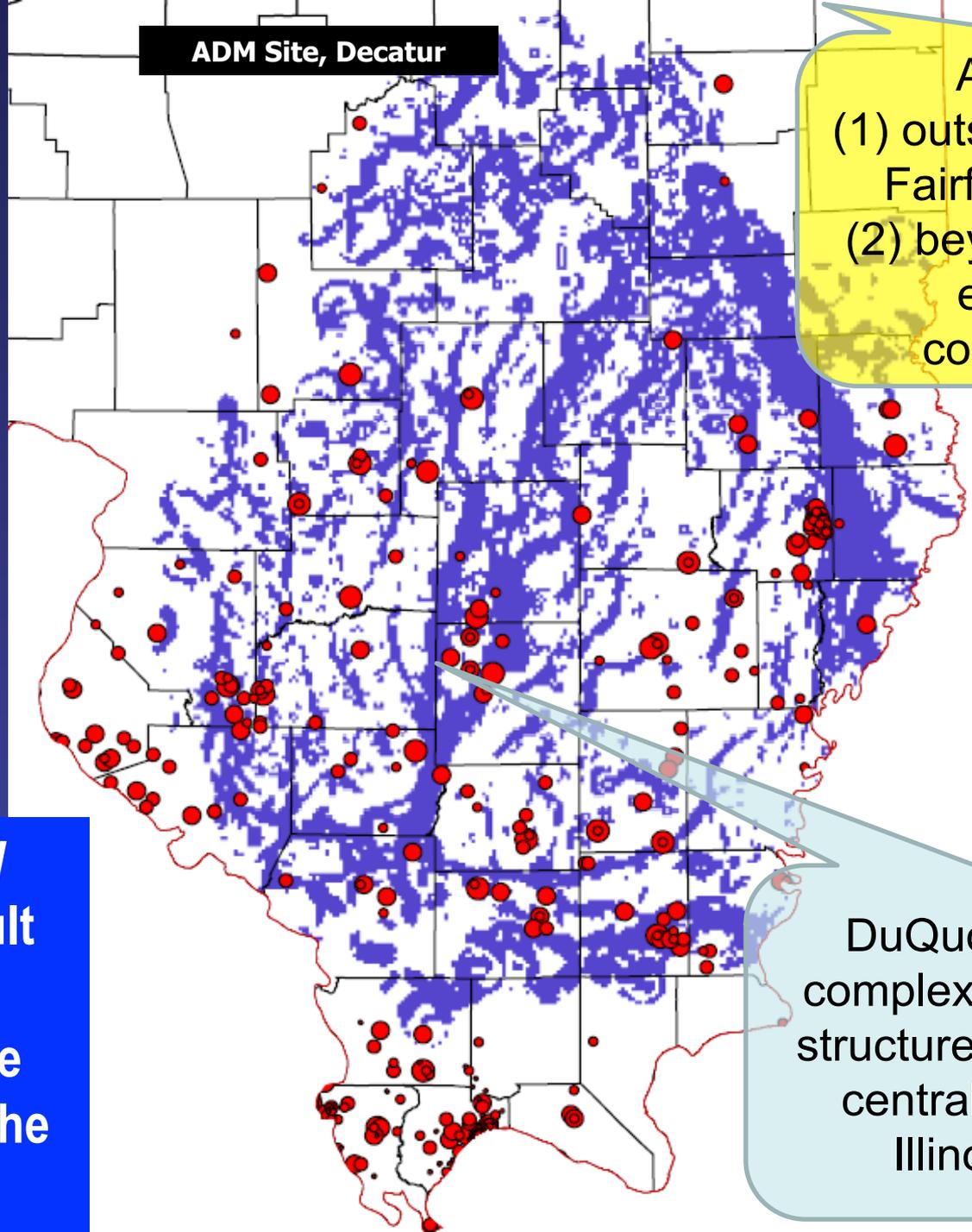
Complex interplay  
between rifting and  
contractional  
deformation

Simple structural model for portion of  
southern Illinois Basin (Fairfield sub-basin);  
contrast this with lack of such known  
structures in east-central Illinois Basin

# Du Quoin monocline complex



DuQuoin-Louden complex: dominating structure of the south-central part of the Illinois Basin and locally western edge of the Fairfield sub-basin



ADM Site, Decatur

ADM site is  
(1) outside the complex  
Fairfield basin and  
(2) beyond the area of  
earthquake  
concentrations

NE&NW  
slope/fault  
trends  
dominate  
much of the  
basin

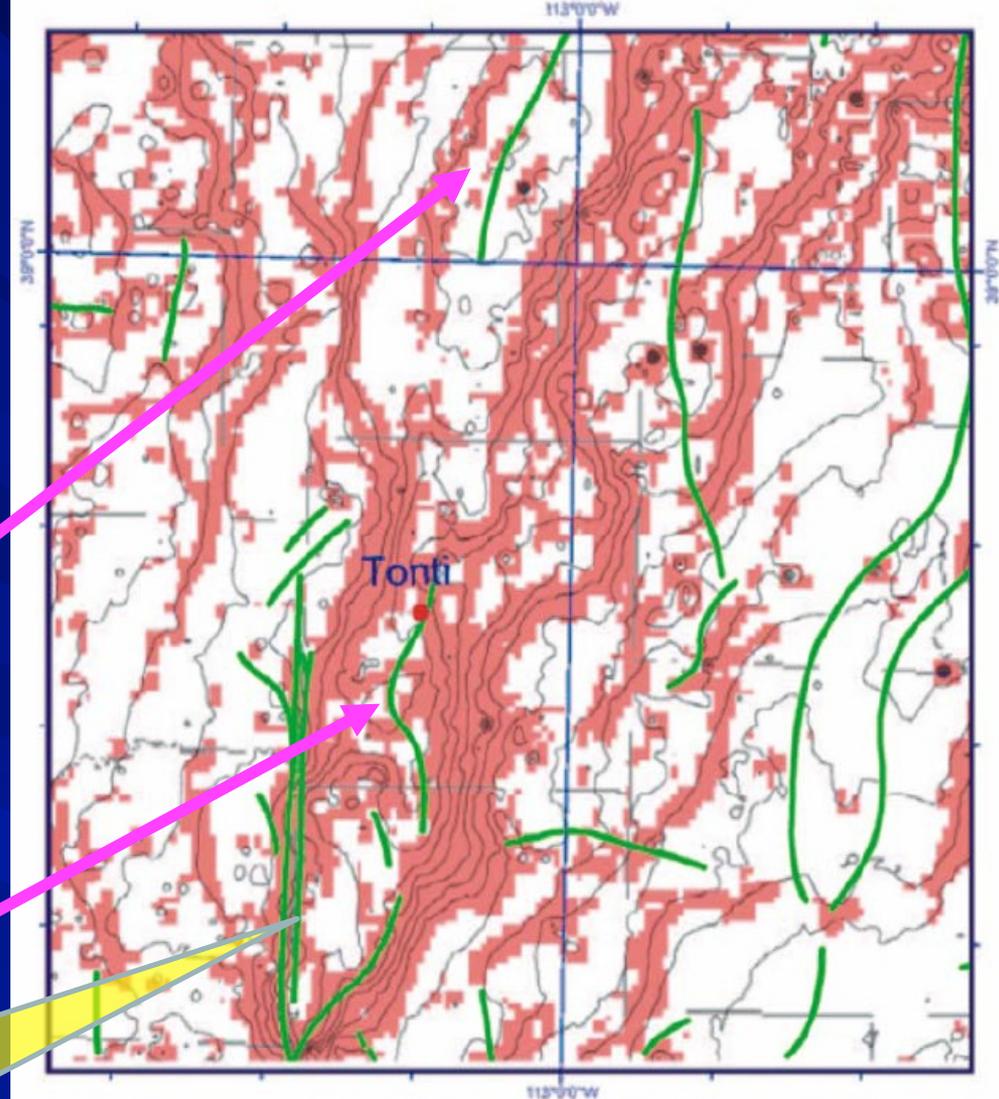
DuQuoin-Louden  
complex: dominating  
structure of the south-  
central part of the  
Illinois Basin

Structural setting of  
Du Quoin  
monocline/  
Centralia fault zone

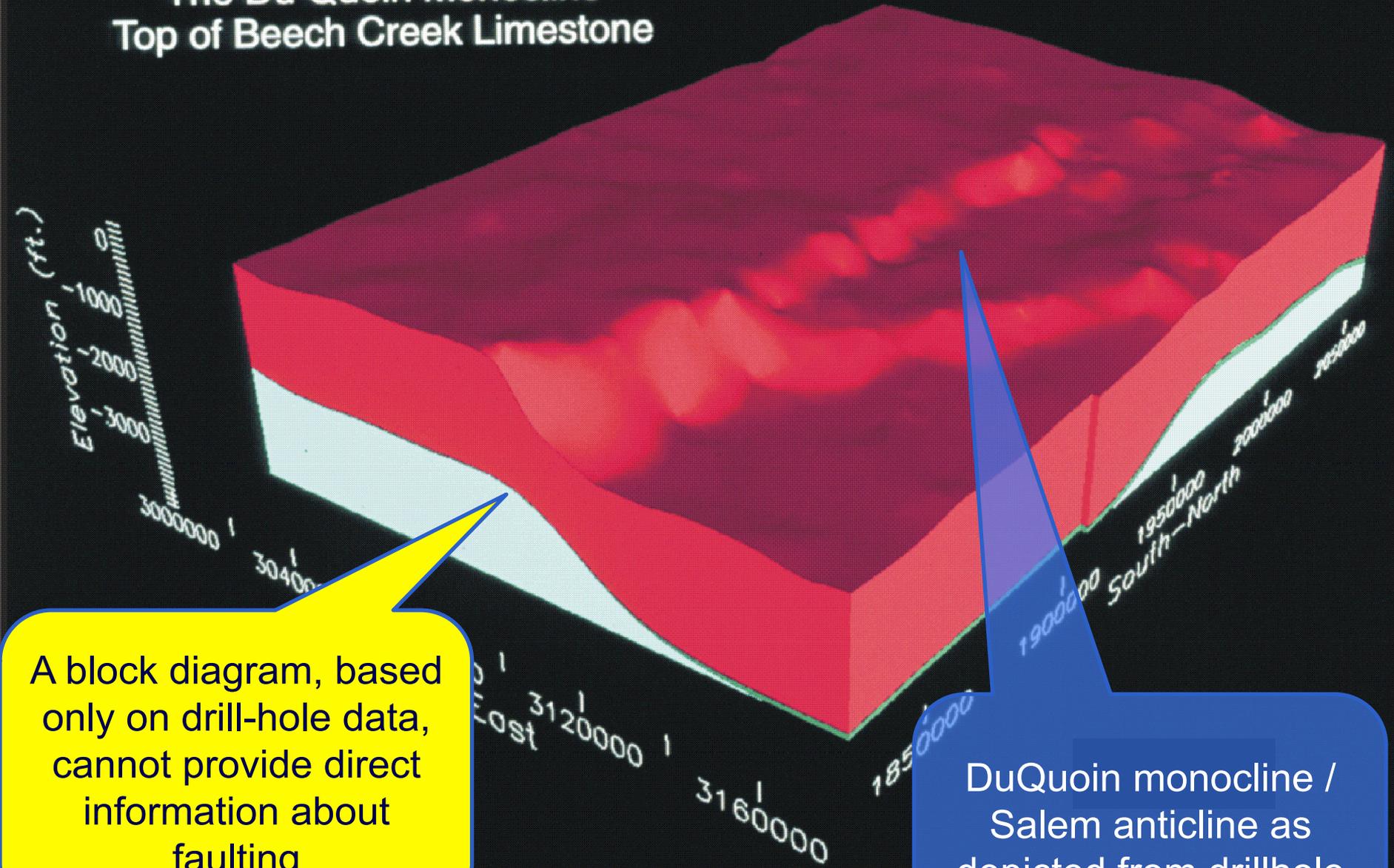
***Louden field***

***Salem field***

A flexural bifurcation  
follows two segments  
of the Du Quoin  
monocline and the  
Salem anticline



# The Du Quoin Monocline Top of Beech Creek Limestone

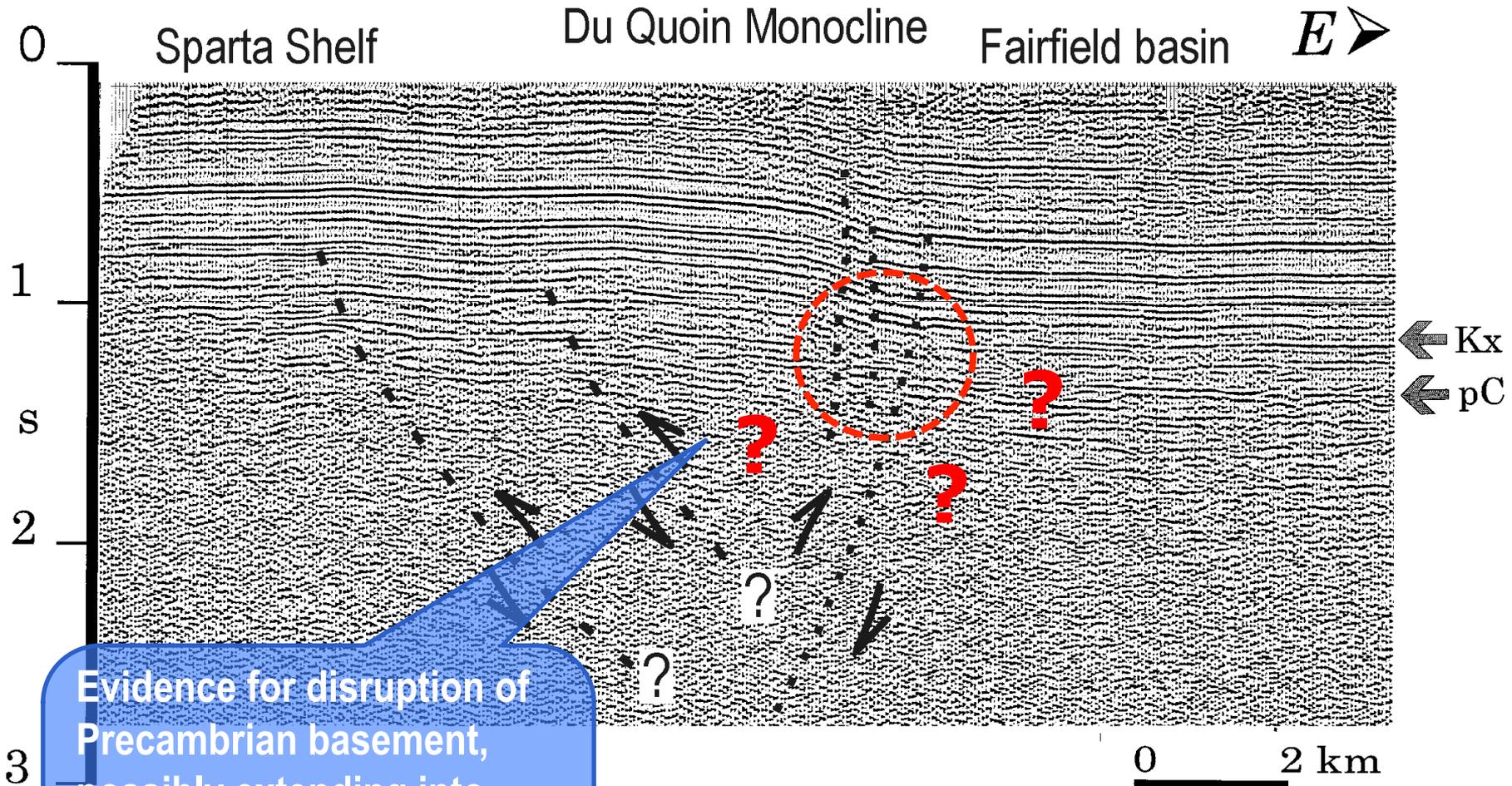


A block diagram, based only on drill-hole data, cannot provide direct information about faulting

DuQuoin monocline / Salem anticline as depicted from drillhole data visualization

from Prof. Steve Marshak (UIUC)

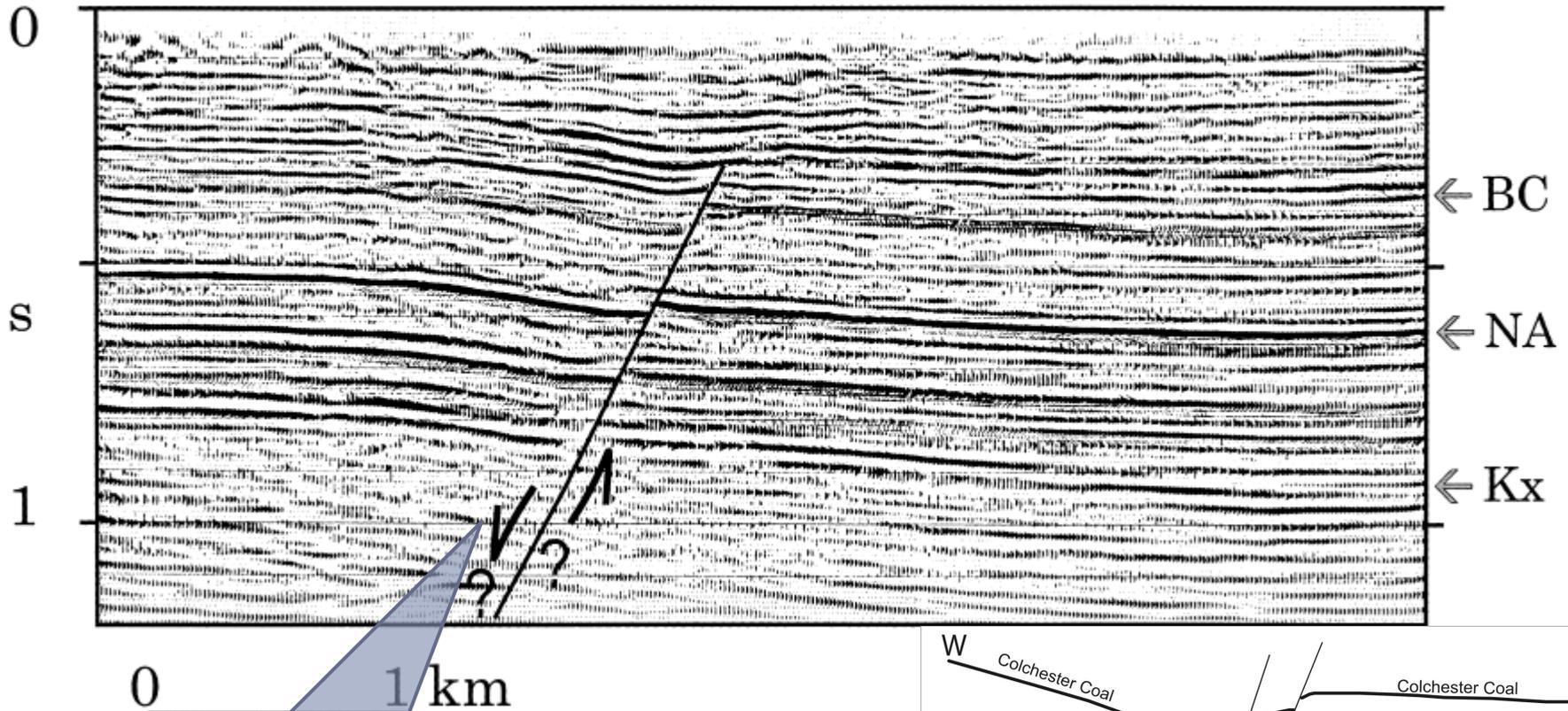
# Vintage seismic record over Du Quoin Monocline



Evidence for disruption of Precambrian basement, possibly extending into basement; however, evidence of post-Paleozoic deformation is lacking.

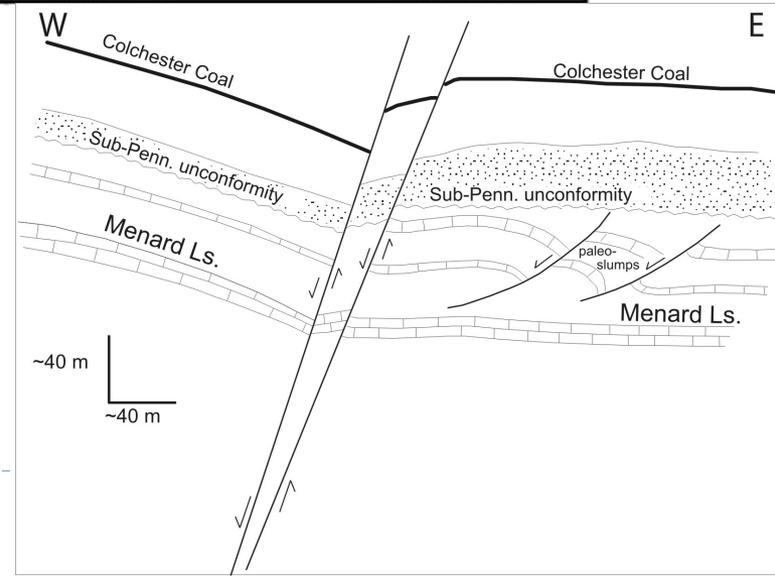
# East flank of Du Quoin Monocline/Centralia Fault Zone

E ➤

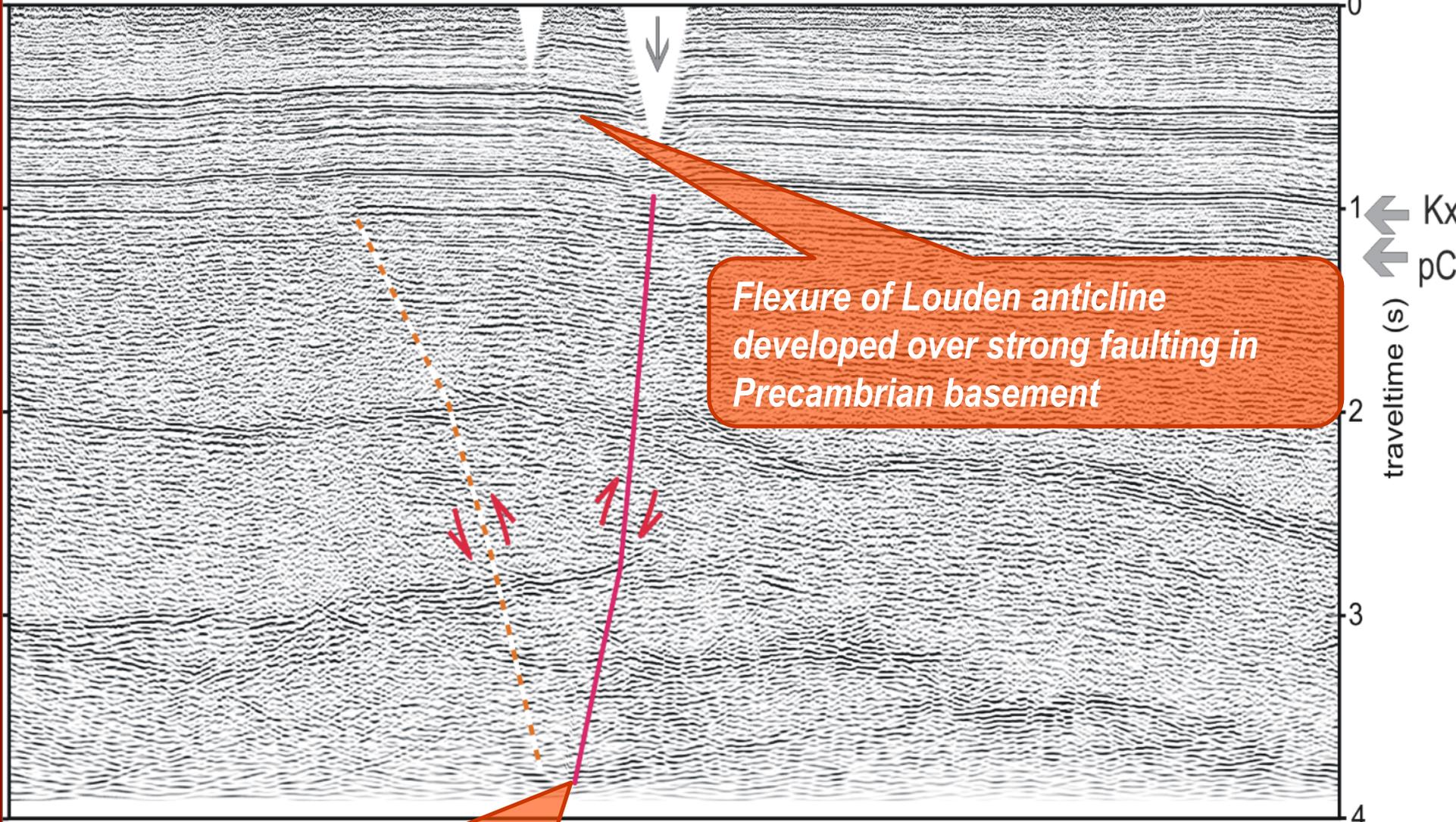


*High-resolution migrated seismic profile provides some evidence for reactivation along the older reverse fault.*

**Interpretive cross-section based on borehole data across the Centralia Fault Zone**



# Louden Anticline



*Flexure of Loudon anticline developed over strong faulting in Precambrian basement*

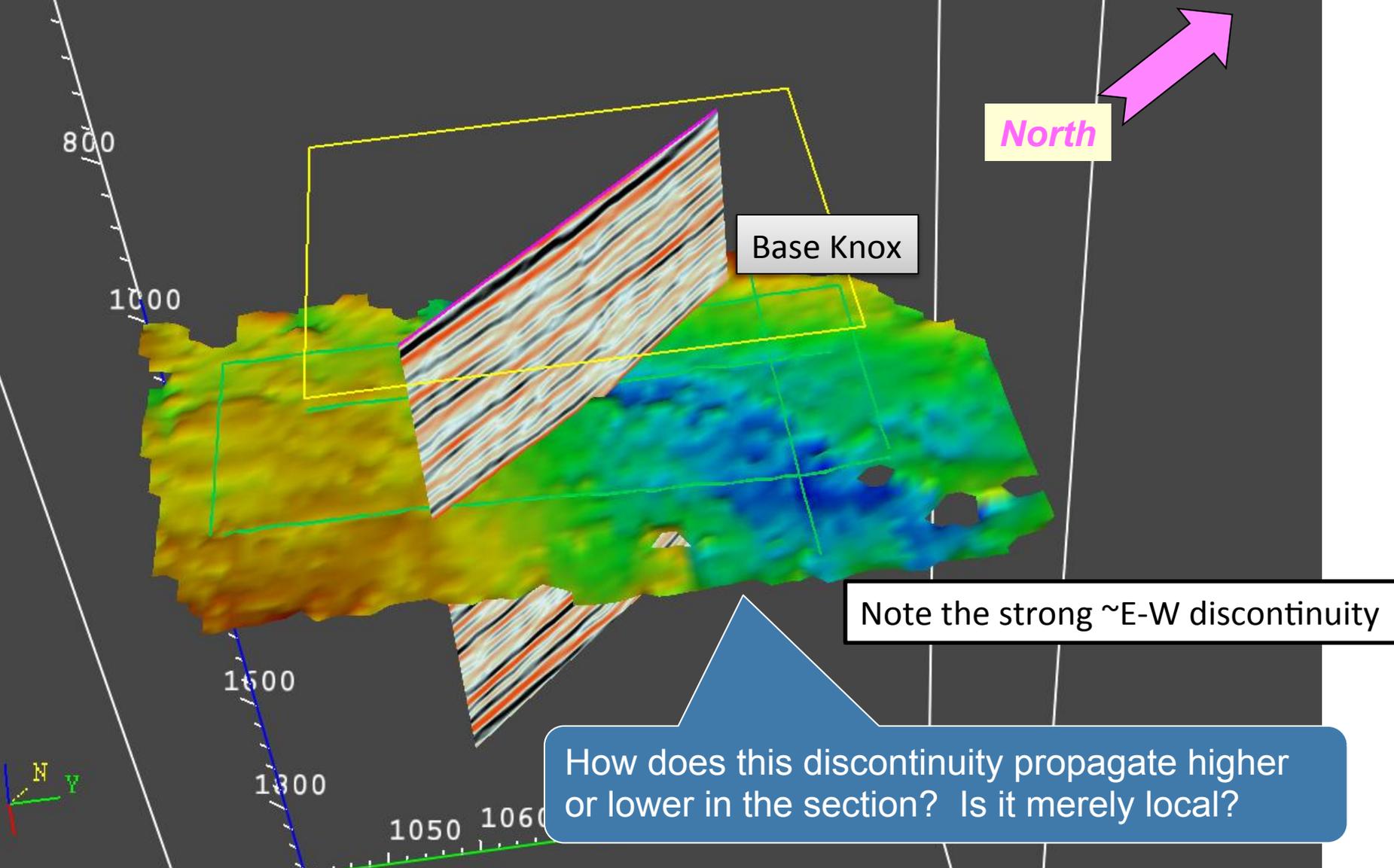
*Evidence for involvement (reactivation?) of Precambrian structure*



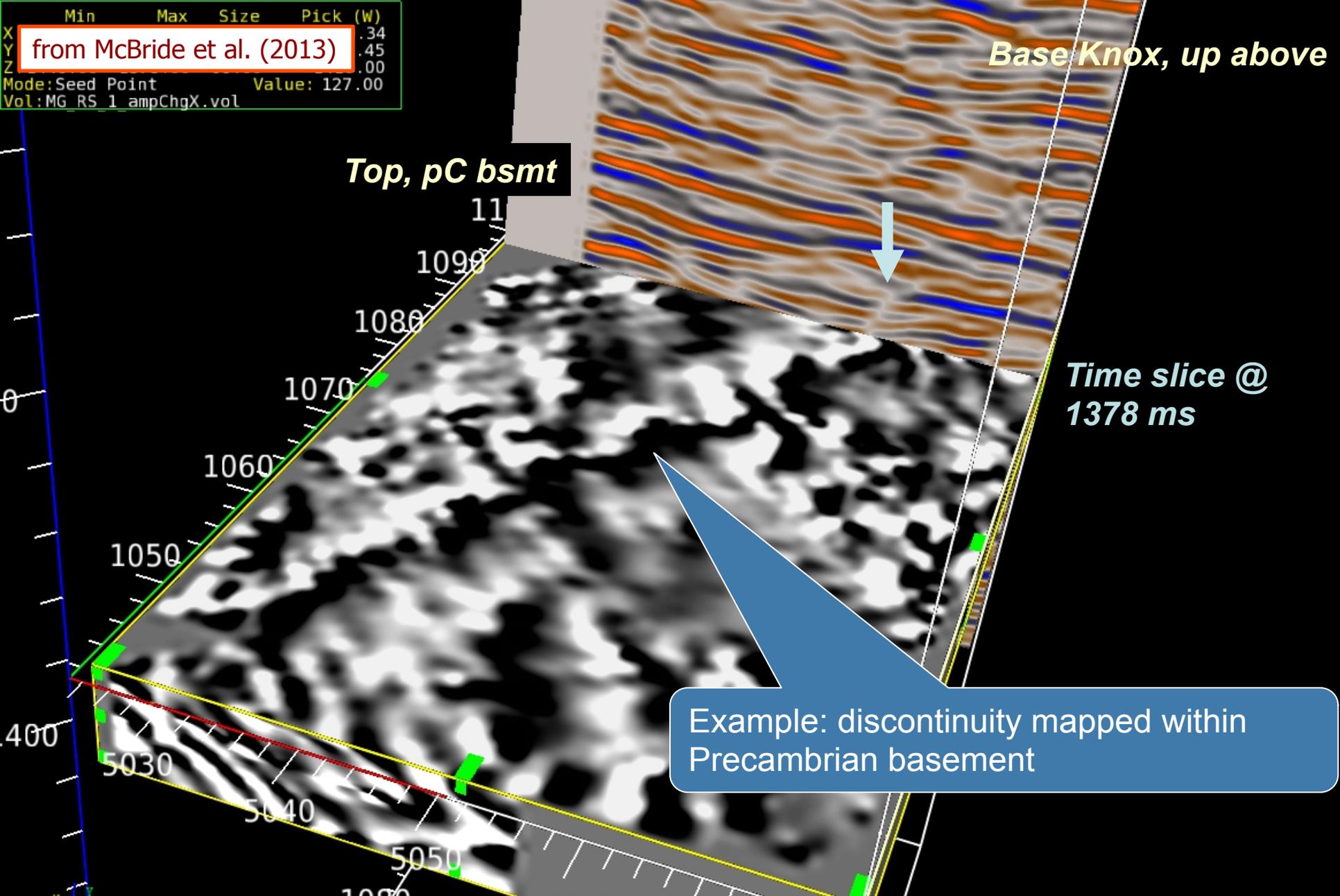
from McBride et al. (2013)

## Stewardson Oil Field

60 Structural contour map on base of Knox → “V”-shaped embayment



Min Max Size Pick (W)  
from McBride et al. (2013) .34  
.45  
.00  
Mode:Seed Point Value: 127.00  
Vol:MG\_RS\_1\_ampChgX.vol



*Base Knox, up above*

**Top, pC bsmt**

*Time slice @ 1378 ms*

Example: discontinuity mapped within Precambrian basement

**Intra-basement fault?-related complexity shown by X-directed amplitude change time slice and vertical view**

→ lack of vertical continuity for small faults.

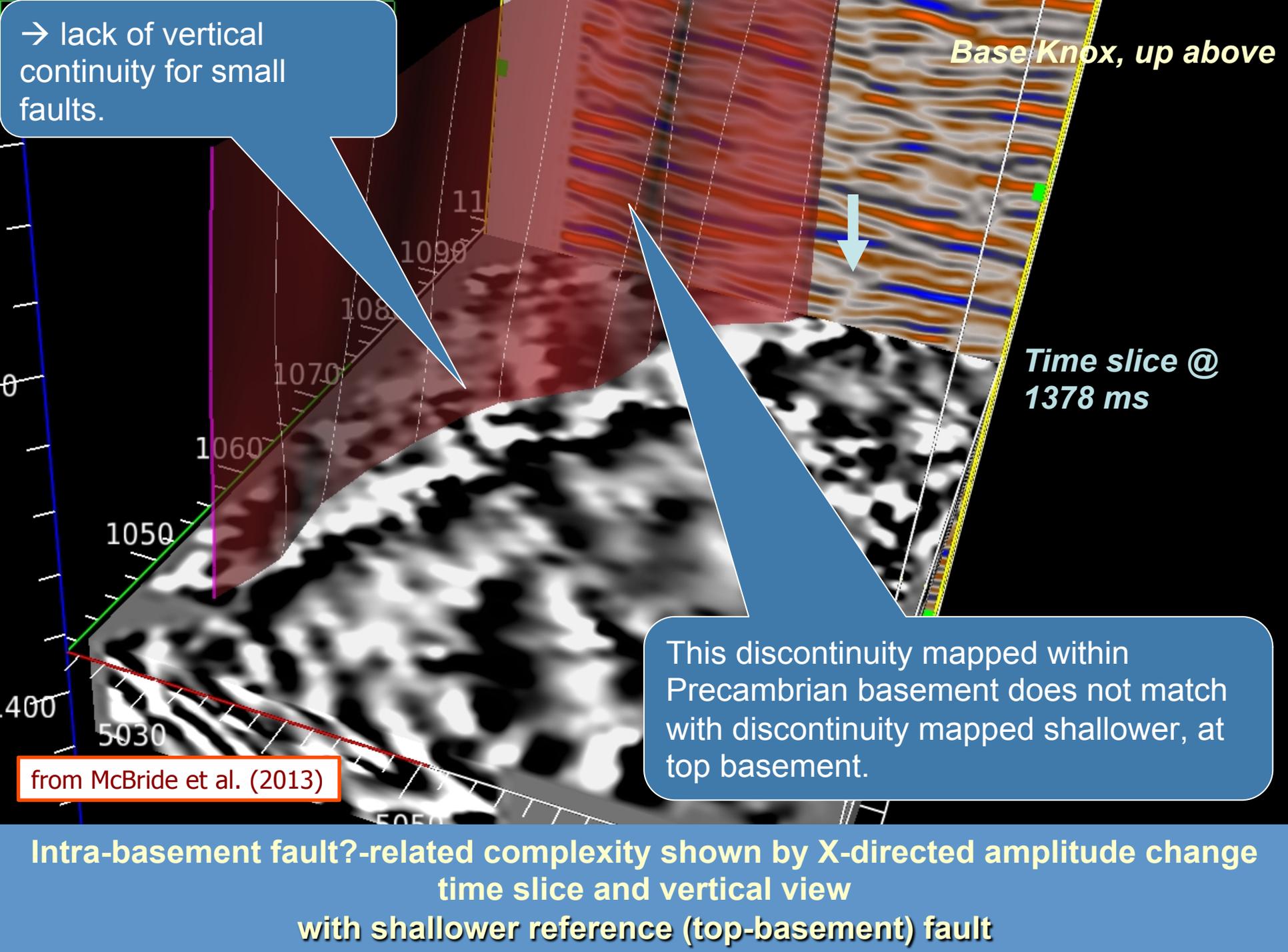
*Base Knox, up above*

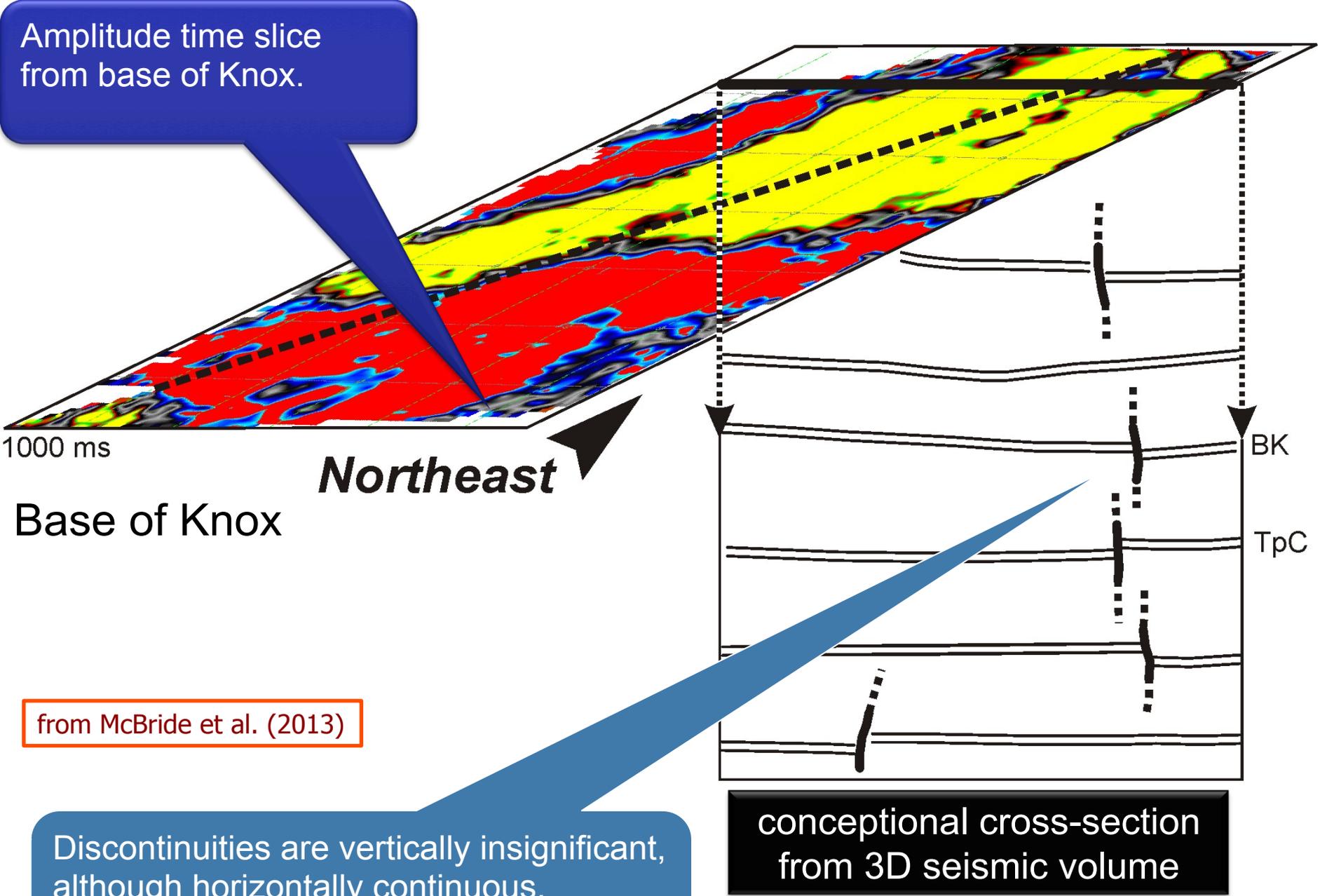
*Time slice @ 1378 ms*

This discontinuity mapped within Precambrian basement does not match with discontinuity mapped shallower, at top basement.

from McBride et al. (2013)

**Intra-basement fault?-related complexity shown by X-directed amplitude change time slice and vertical view with shallower reference (top-basement) fault**





from McBride et al. (2013)

Discontinuities are vertically insignificant, although horizontally continuous. Discontinuities, thus, do not necessarily affect strata above and below.

**Degree of Precambrian basement heterogeneity appears to decrease further north in the Illinois Basin.**

**Dominant structural style in the Illinois Basin at the basement-Paleozoic contact is contractional with a strike-slip component.**

**The structural geology of east-central Illinois appears to be simpler than that of southernmost Illinois, suggesting more stability in the target area.**

**Faulting further north, in east-central Illinois, shows little or no vertical continuity between basement and lower Paleozoic strata.**



**Conclusions**

# Acknowledgments

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- ▶ This research was supported by the U.S. Department of Energy, Office of Fossil Energy, through their Regional Carbon Sequestration Partnership Program under contract DE-FC26-05NT42588 and the Illinois Office of Coal Development with the participation of Illinois State, Indiana, and Kentucky Geological Surveys. Data processing and visualization were made possible by software grants from the Landmark (Halliburton) University Grant Program and from Seismic Micro-Technology.

**Schlumberger**

**HALLIBURTON**

