

Rifts in the Midcontinent: East Continent Rift Basin, Rough Creek Graben and the Rome Trough

**Central and Eastern United States
Seismic Source Characterization Project
Workshop 2**

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*James A. Drahovzal
Kentucky Geological Survey
University of Kentucky*



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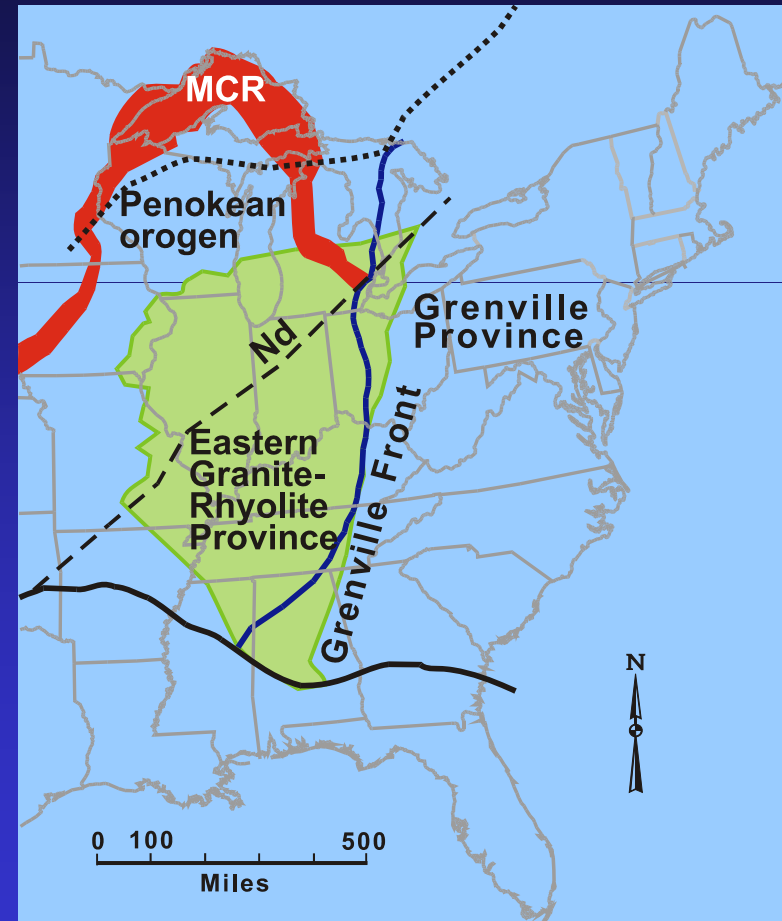


Outline

- **East Continent Rift Basin (ECRB)**
 - Grenville Thrust Belt (GTB)
 - Hoosier Thrust Belt (HTB)
- **Fort Wayne Rift (FWR) and Anna Seismic Zone**
- **Rome Trough (RT)**
 - East Tennessee Seismic Zone (ETSZ)
 - East Continent Gravity High (ECGH)
- **Rough Creek Graben (RCG)**
- **Continuity of the RT and the RCG**

Classical “Basement” Geology

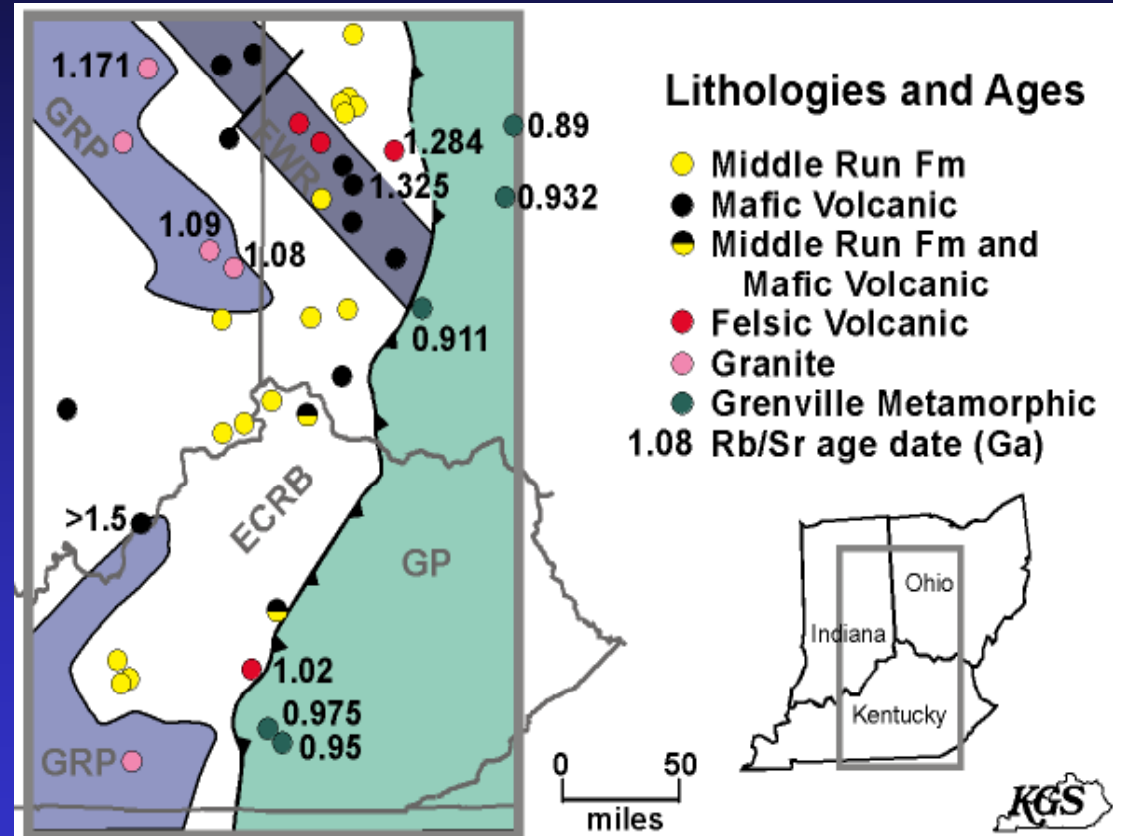
- Crystalline Rock
- Relatively Simple Geology
- Eastern Granite-Rhyolite Province
 - 1.45 - 1.48 Ga
- Grenville Province
 - Emplaced ~ 1.0 Ga



Modified from Denison and others, 1984

Proterozoic Drilling Data in the Eastern Midcontinent Shows a Different Story

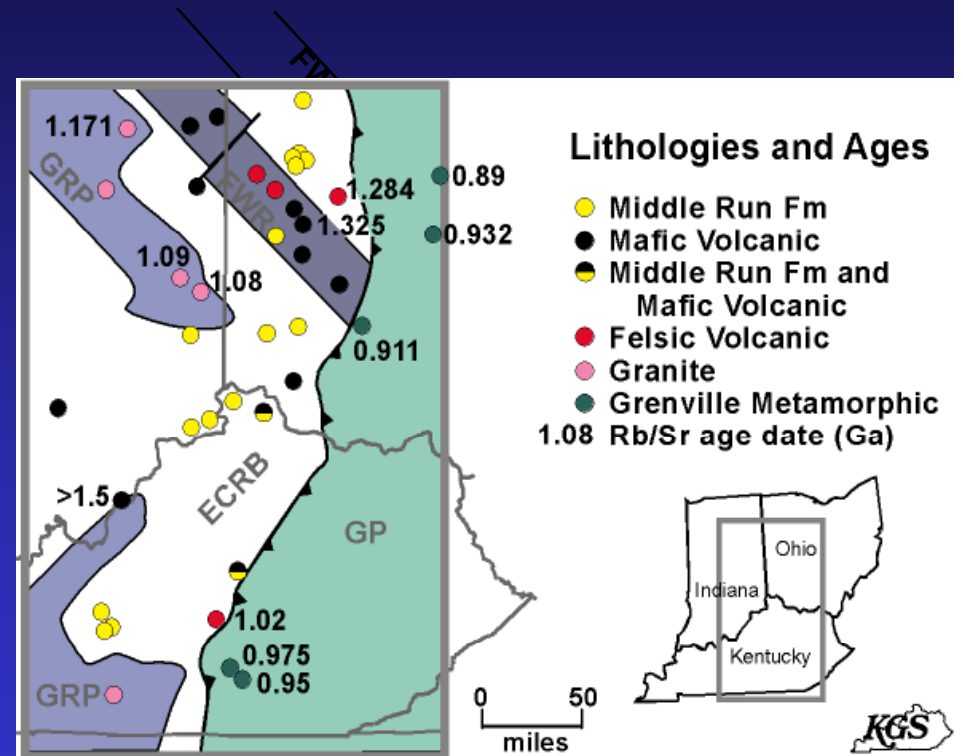
- **East Continent Rift Basin**
 - Largely sedimentary rocks
 - Lithic arenite (Middle Run Fm)
 - Interbedded with mafic volcanic rocks
 - Also felsic intrusions
 - Thick sequence—rift basin
- **Granite-Rhyolite Province to West is distinct and older**
 - Fort Wayne Rift Zone –an early rift center
 - Louisville basalt (also an early rift center?)
 - Younger granite intrusions in this area
- **Grenville Province to East**
 - Thrust over ECRB



Modified from Drahovzal and others, 1991
 Based on Bass, written comm. 1969; Hoppe and others, 1983;
 Denison and others, 1984; Lucius and von Frese, 1988; Collata and
 others, 1990; Drahovzal and others, 1991; Harris, 1991a, 1991b

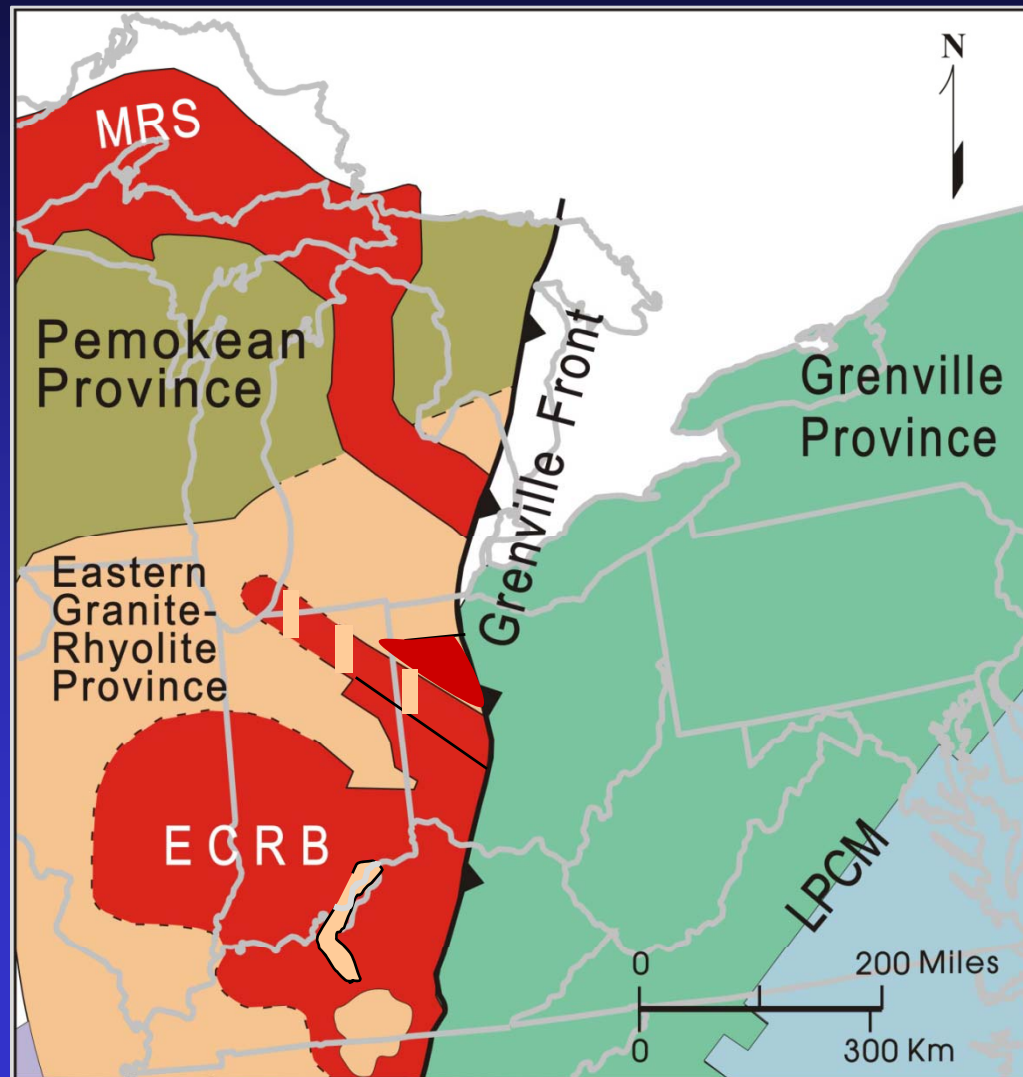
Revised “Basement”/Proterozoic Geology

- Geology more complex
- Eastern Granite-Rhyolite Province
 - Classically 1.45 - 1.48 Ga
 - Includes the Ft. Wayne Rift 1.325 Ga
 - Uplifted basalt at Louisville >1.5 Ga
 - Granite intrusions 1.08-1.171 Ga
- Sedimentary/Volcanic Province (East Continent Rift Basin--ECRB)
 - <1.048 – 0.95 (?) Ga
 - Late Foreland basin fill 0.6? Ga
 - Rift basin overprinted with compressional structures
 - Folds and thrust faults
 - Evidence of later wrench and extensional structures
- Grenville Province
 - Emplaced ~ 1.0 Ga in OH, KY, TN
 - Young metamorphic and thrusting ages (0.89-0.98 Ga)
 - Older petrolith ages in part (1.457 Ga)



Modified from Drahovzal and others, 1991. Based on Bass, written comm. 1969; Hoppe and others, 1983; Denison and others, 1984; Lucius and von Frese, 1988; Collata and others, 1990; Drahovzal and others, 1991; Harris, 1991a, 1991b; Santos and others, 2002

Possible Areal Extent of the ECRB Based Largely on Seismic Reflection Data



Modified from Drahovzal, and others, 1991

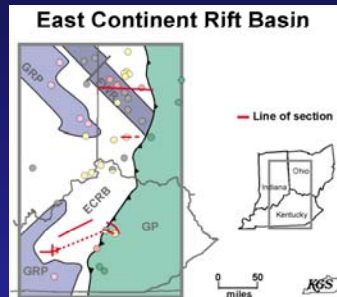


Southwest Ohio Drill and Seismic Data

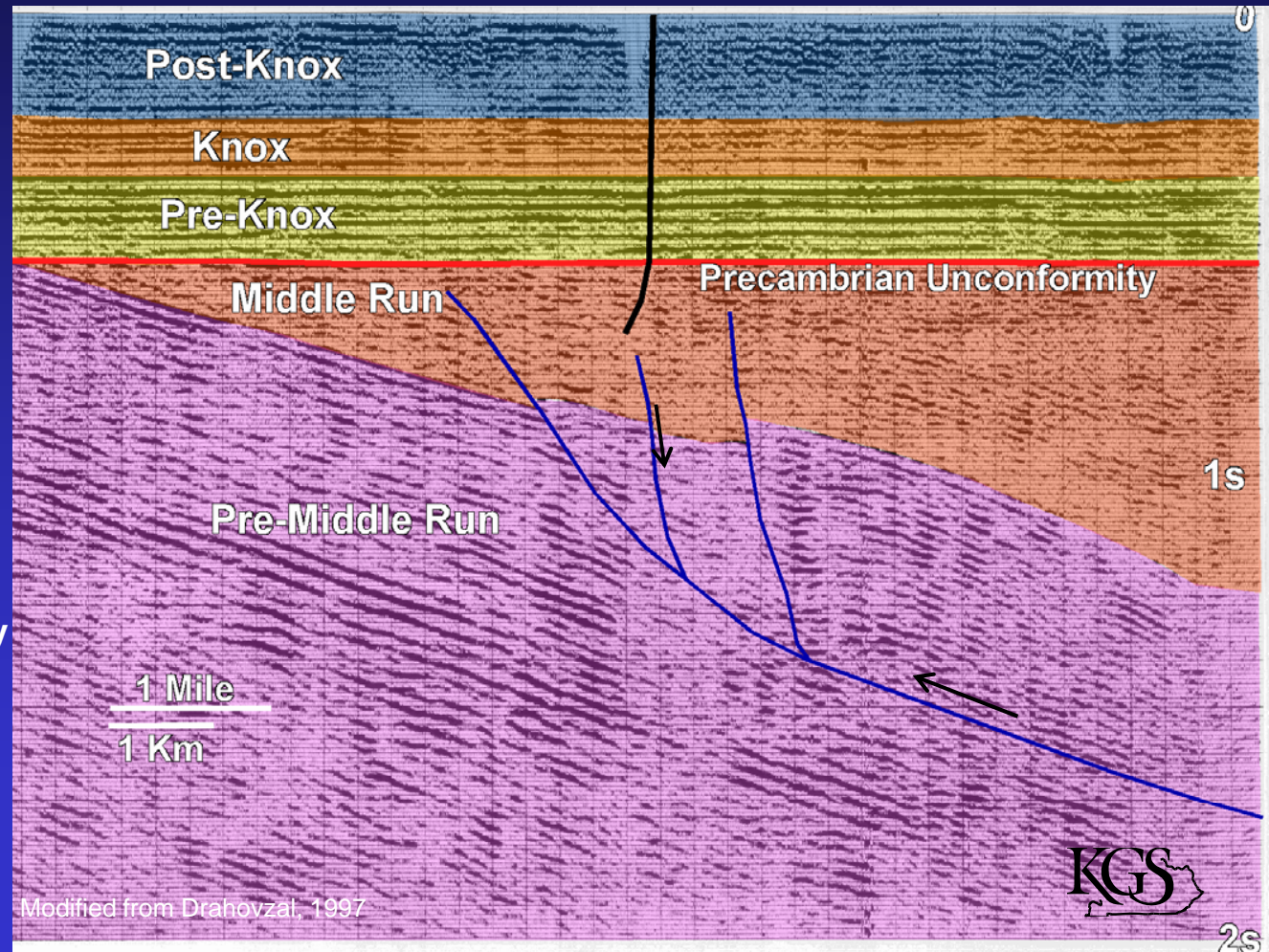
W

● ODGS 2627W

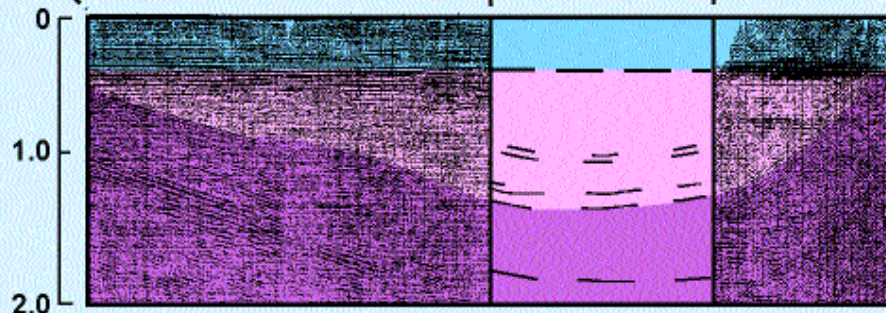
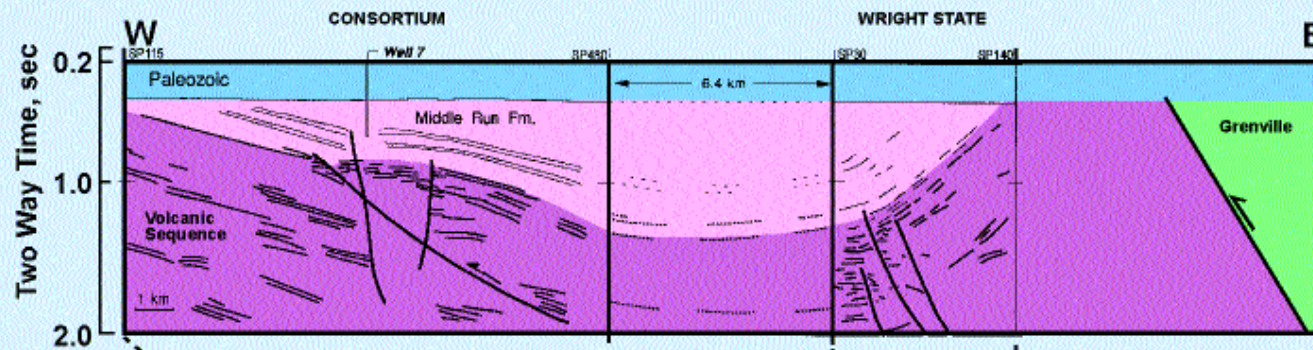
E



- Definition of Middle Run Fm in well
 - Mesoproterozoic
- Seismic data:
 - East dipping
 - angular unconformity
 - ~ 0.5 Ga
 - Pre-Middle Run
- Folding and thrusting
 - Also extensional faulting

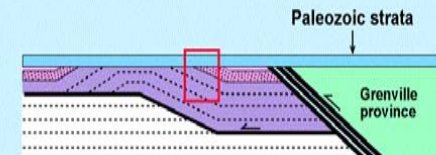


Broader View, Southwest Ohio



Modified from Wolfe and others, 1993

Grenville foreland thrust belt model



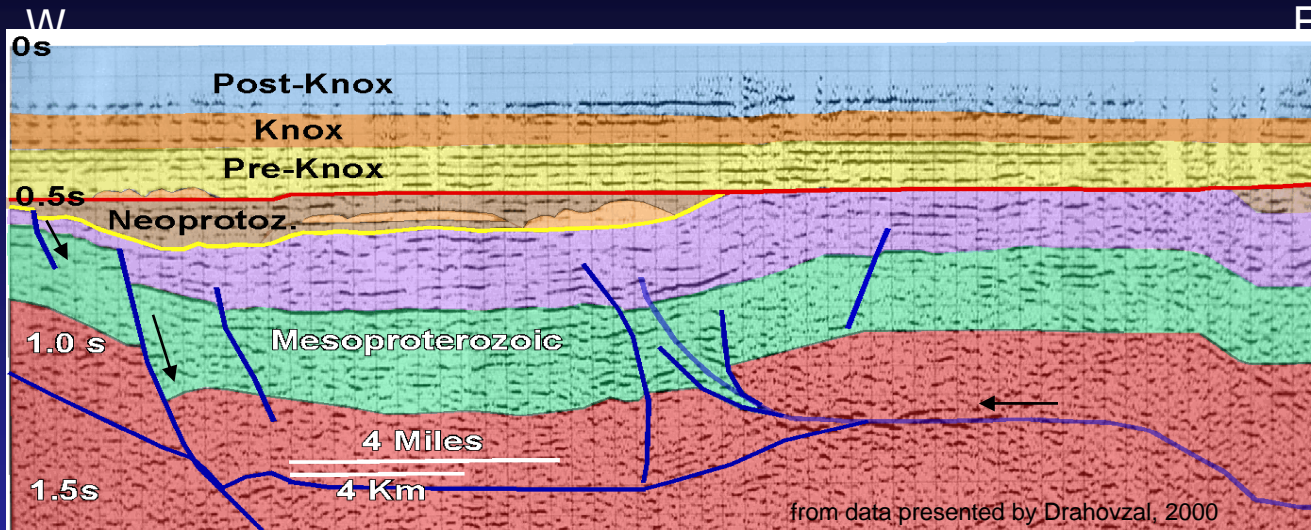
From Hauser, 1993



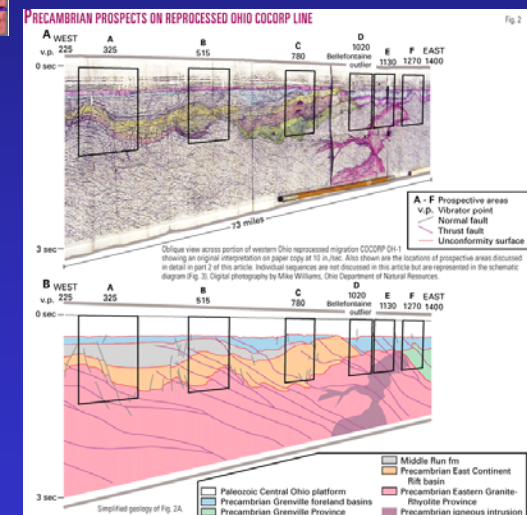
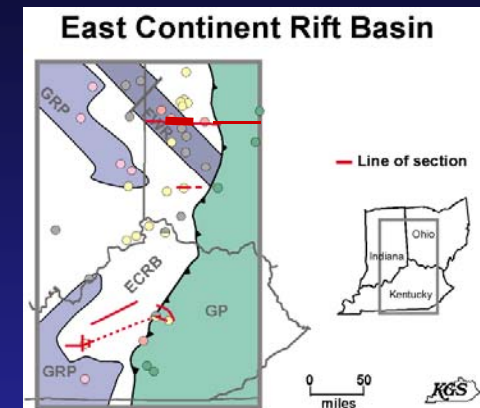
- West-vergent Fold and Thrust Belt



Eastern Ft. Wayne Rift, W. Ohio



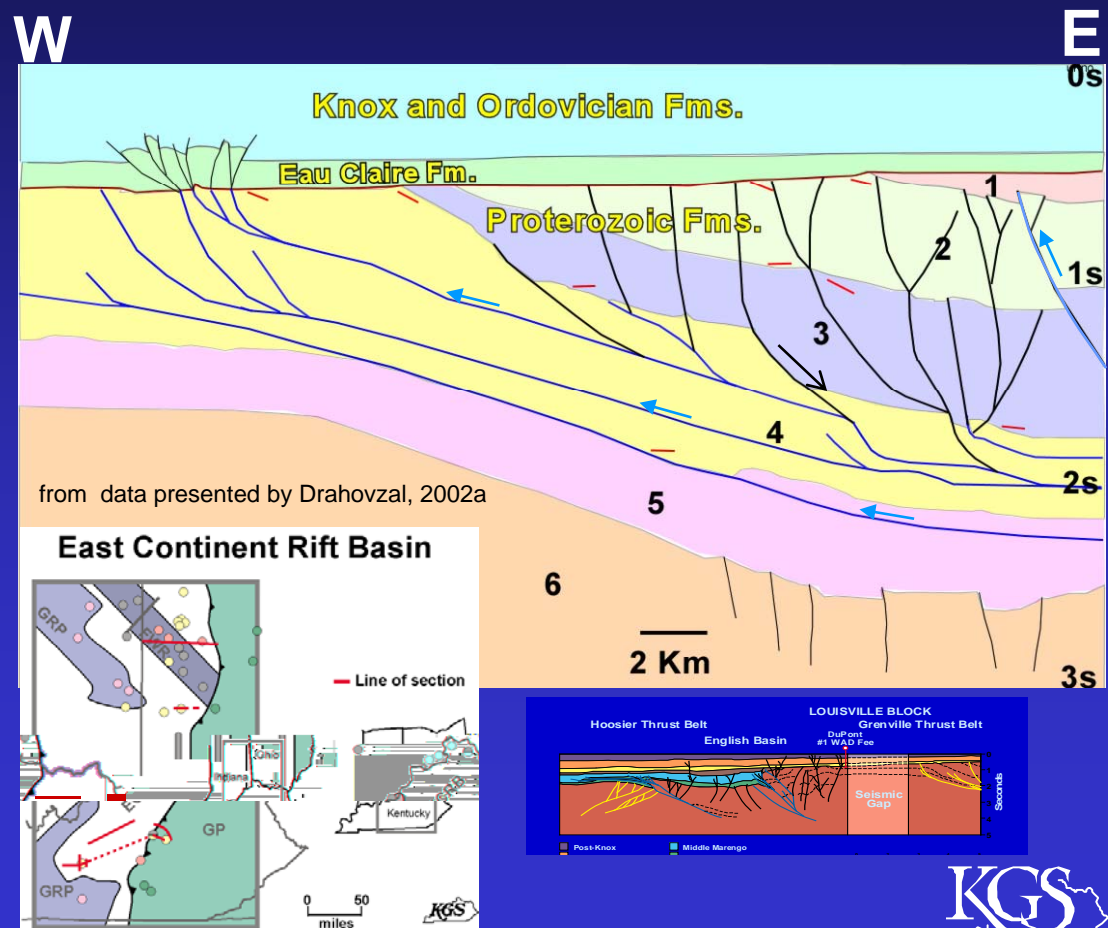
- Layered reflectors below unconformity
 - Lithic arenites, basalts, and rhyolites in nearby wells
- Mesoproterozoic rocks are folded and faulted
 - West-vergent fold and thrust belt (Grenville Thrust Belt)
 - Later extensional faults
- Neoproterozoic (?) undeformed
 - Onlaps onto rocks beneath
 - Cut by extensional faults



from Dean and Baranoski, 2002

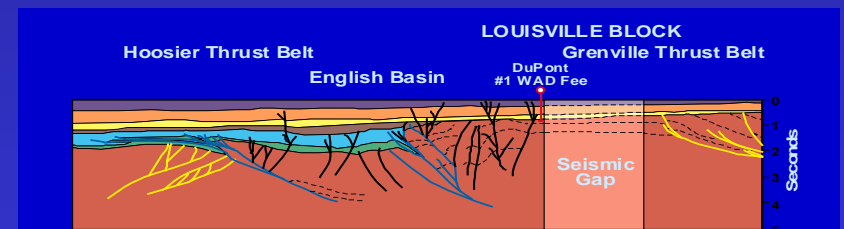
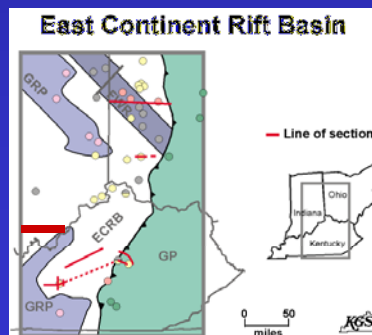
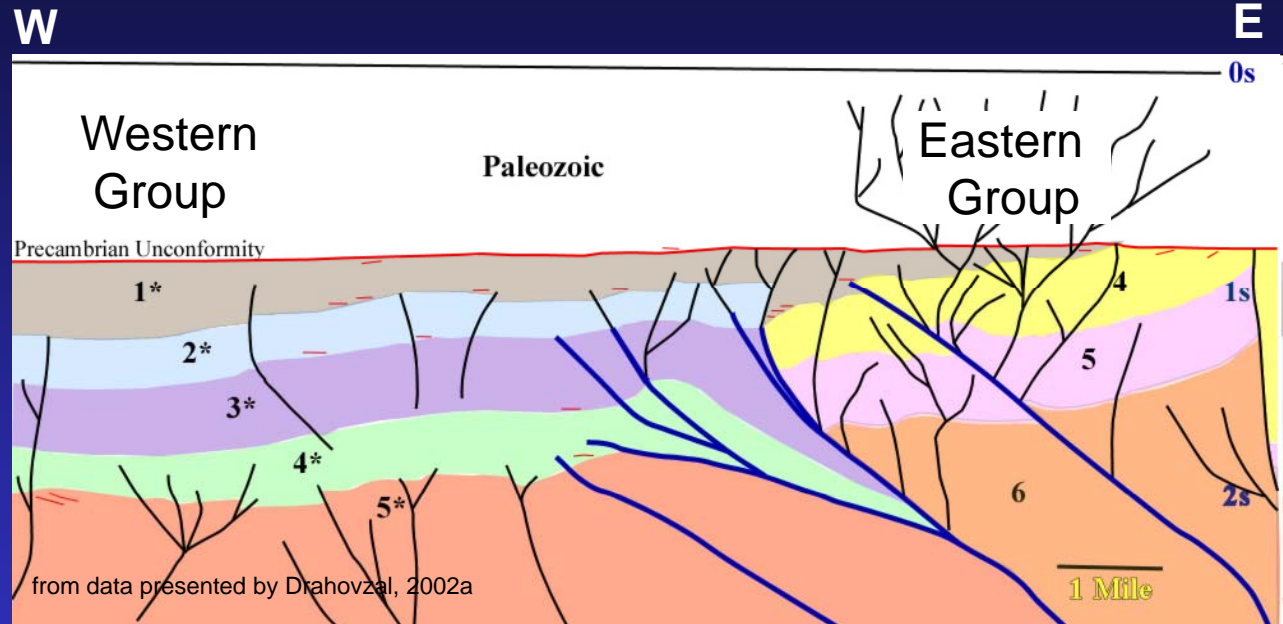
Layered Reflectors in North-Central Kentucky

- Angular unconformity top of Mesoproterozoic
- Thrust-faulted E dipping layered reflectors
 - Six reflector packages labeled 1- 6
 - sequence boundary indicators
 - Truncations, onlap, downlap & toplap
 - 3 and 4 drilled to south—lithic arenite
- Later Proterozoic extensional faulting rooted in the thrust faults
- Some Paleozoic wrench faulting



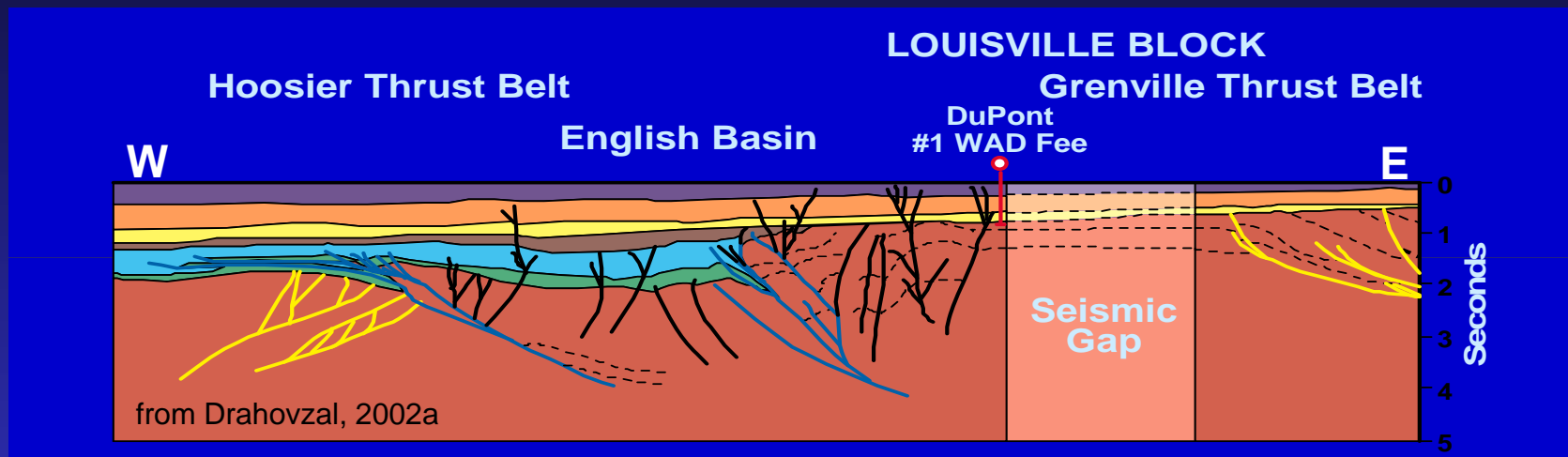
Layered Reflectors in Southwest Indiana

- Angular unconformity top of Mesoproterozoic
- W dipping layered reflectors (Sequences 4-6)
- Sequences in English Basin (Western Group)
 - Five sequence packages labeled 1*- 5*
 - Sequence boundary indicators
 - Not drilled
 - Much of Western Group younger (?) than Eastern Group
 - 1* undeformed
- Late (0.6 Ga) Uplift along reverse faults*
- Extensional faulting
- Some Paleozoic wrench faulting



* Stark, 2002

Cross Section: Northern Kentucky and Southwestern Indiana



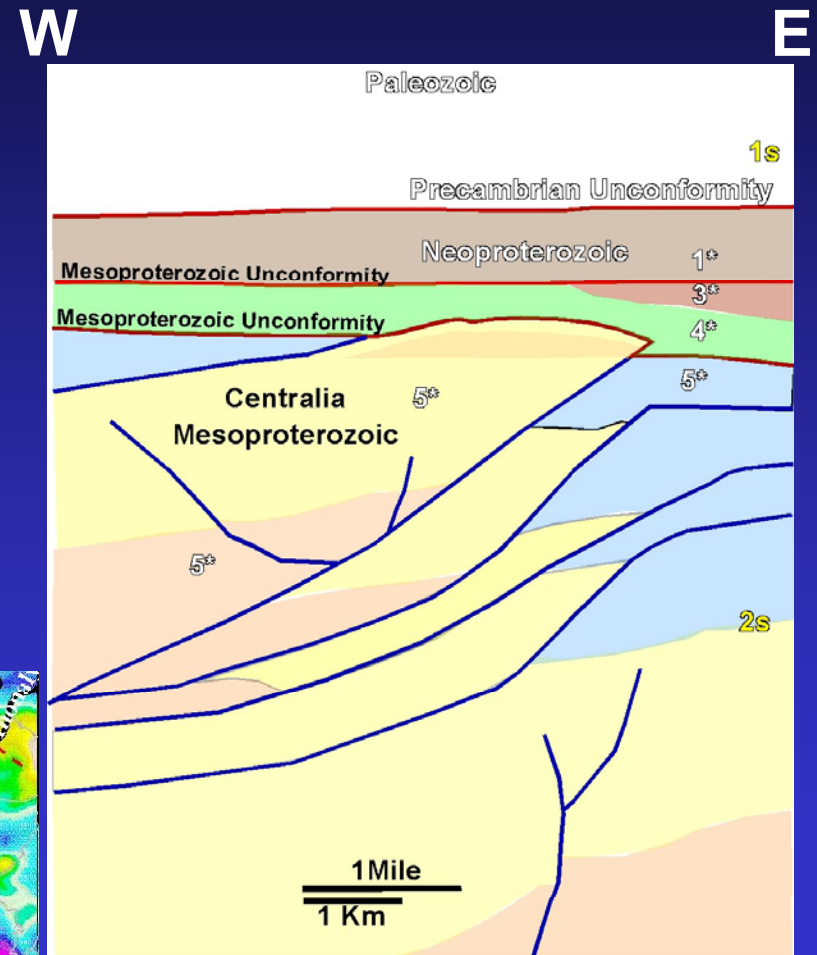
- Louisville Block uplifted 4-8 km 0.6 Ga (based on apatite fission track data, Stark, 2002)
- West vergence to the East
 - Grenville Thrust Belt
 - Faults associated with Louisville Uplift
- East vergence to the West
 - Hoosier Thrust Belt

Thrust Belt in Southern Indiana

- Sequence 5* is deformed by an east-vergent thrust belt
 - Hoosier Thrust Belt
- East-vergent Hoosier Thrust Belt may be age equivalent to the west-vergent Grenville Thrust Belt
- ~12,000 ft to the top of the anticline



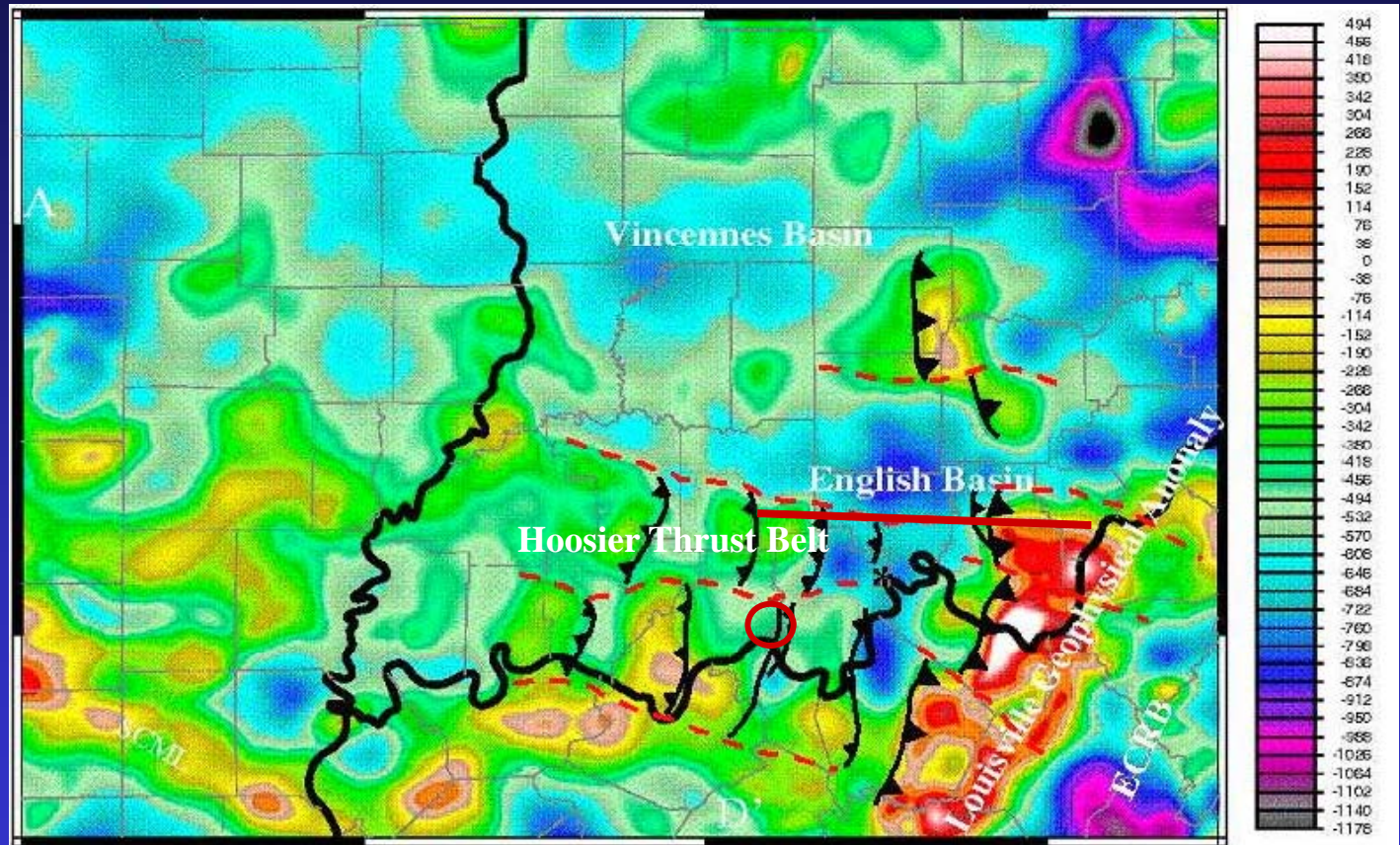
from data presented by Stark and others, 1999



from data presented by Drahovzal, 2002b

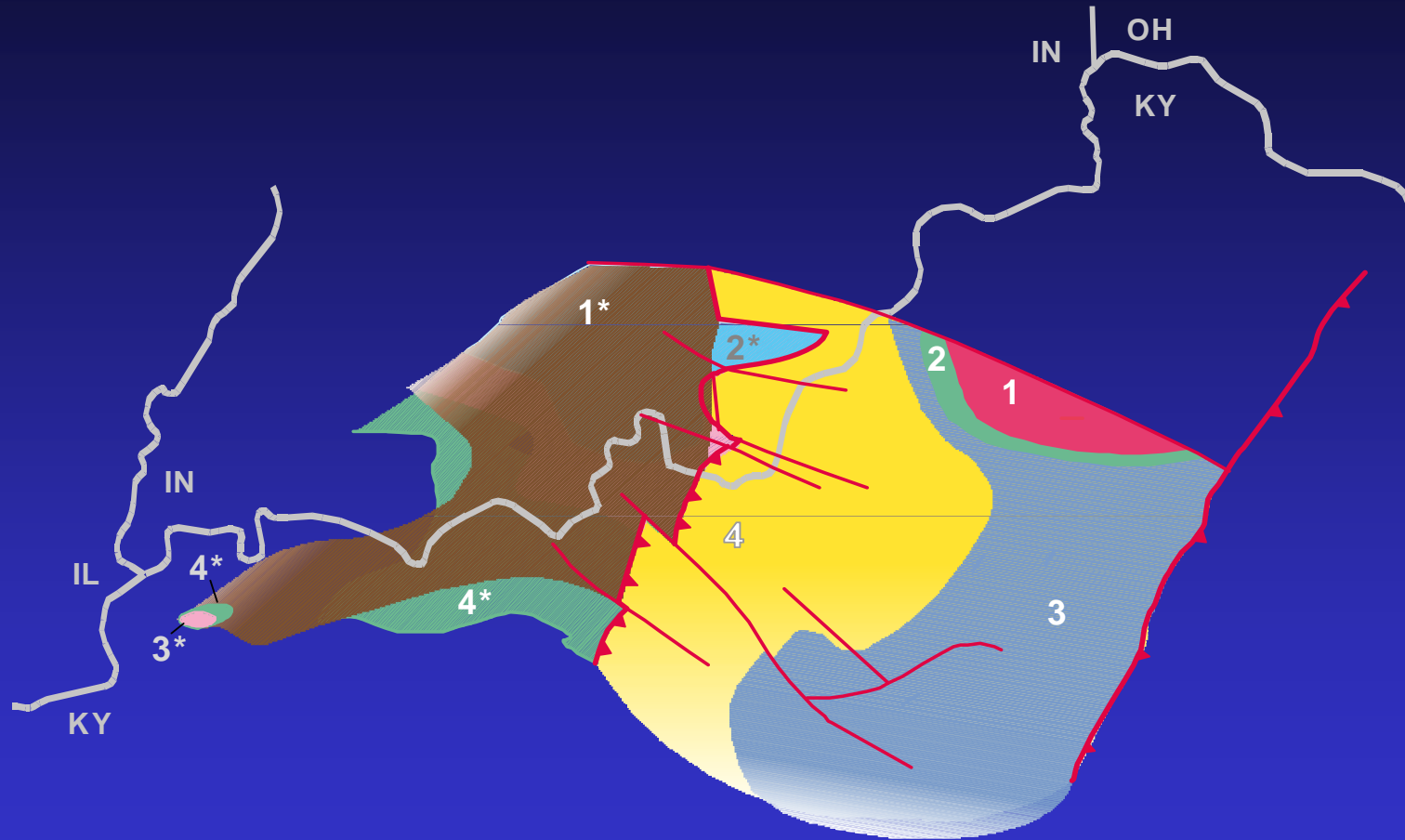
Aeromagnetic Map of the Southeast Midcontinent

- East Continent Rift Basin
- Louisville High and Fault Zone
- English Basin
- Hoosier Thrust Belt

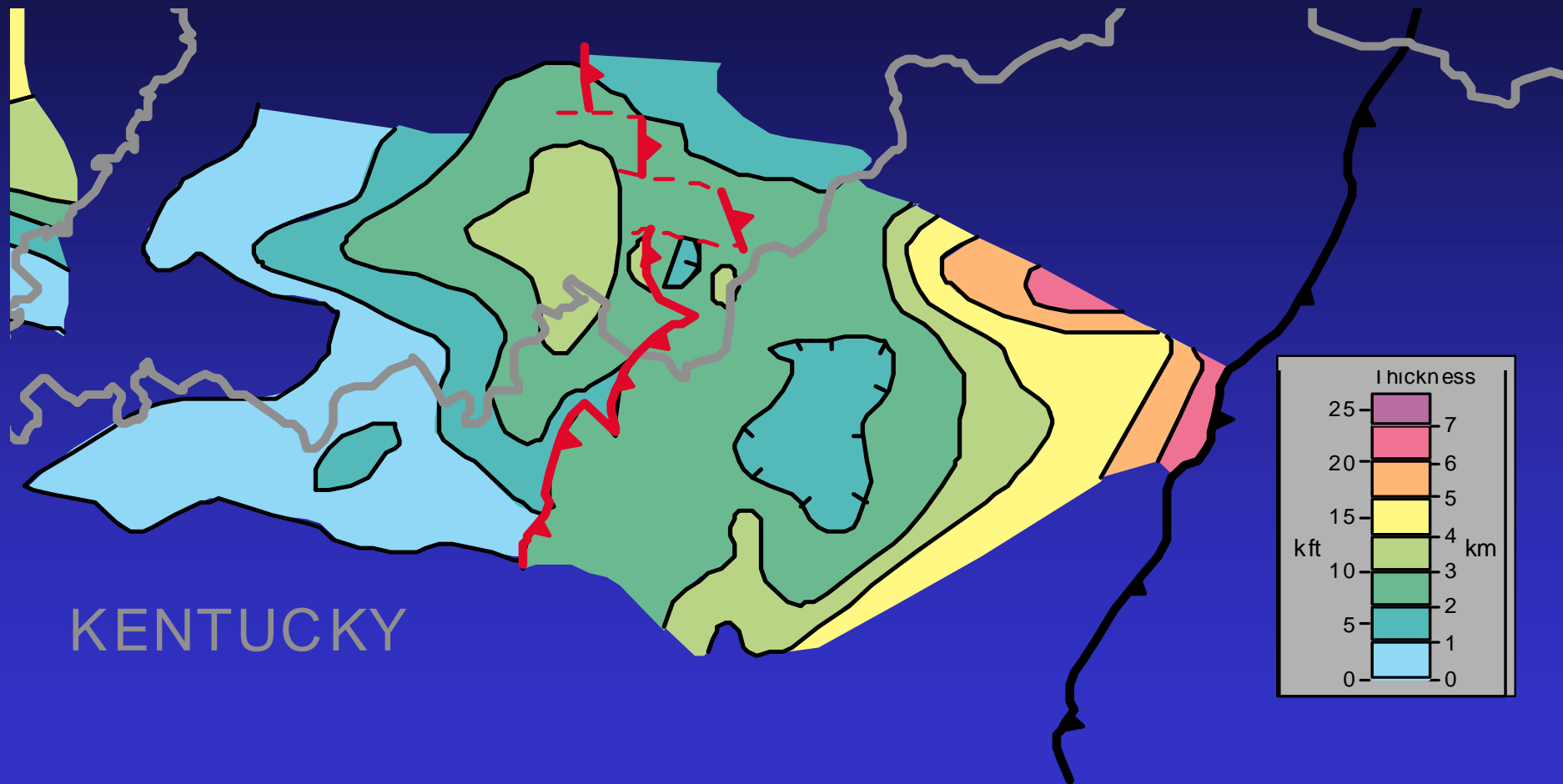


From Stark et al., 1999

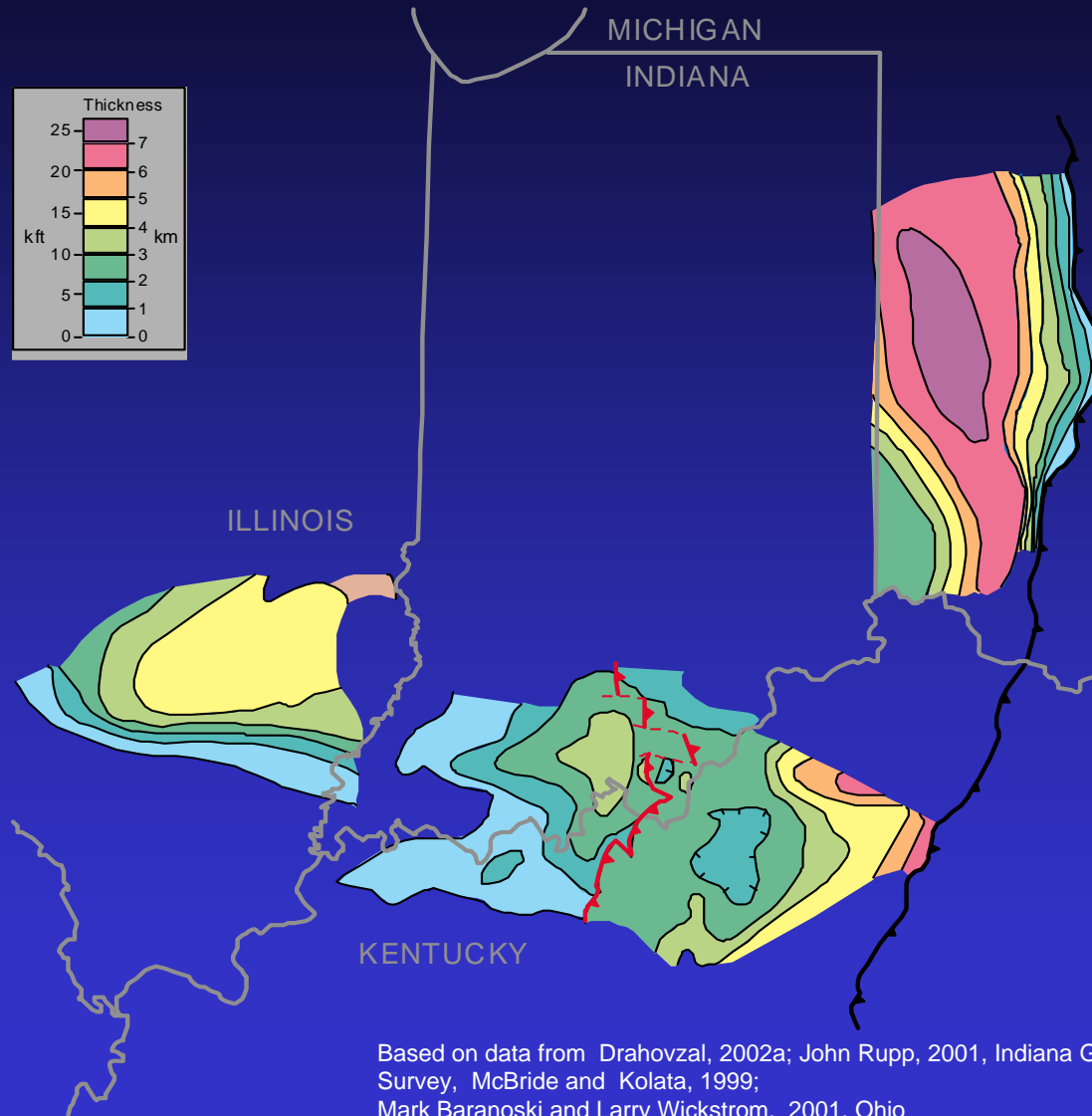
Proterozoic Geologic Map Kentucky and Indiana



Proterozoic Isopach of Map Kentucky and Indiana



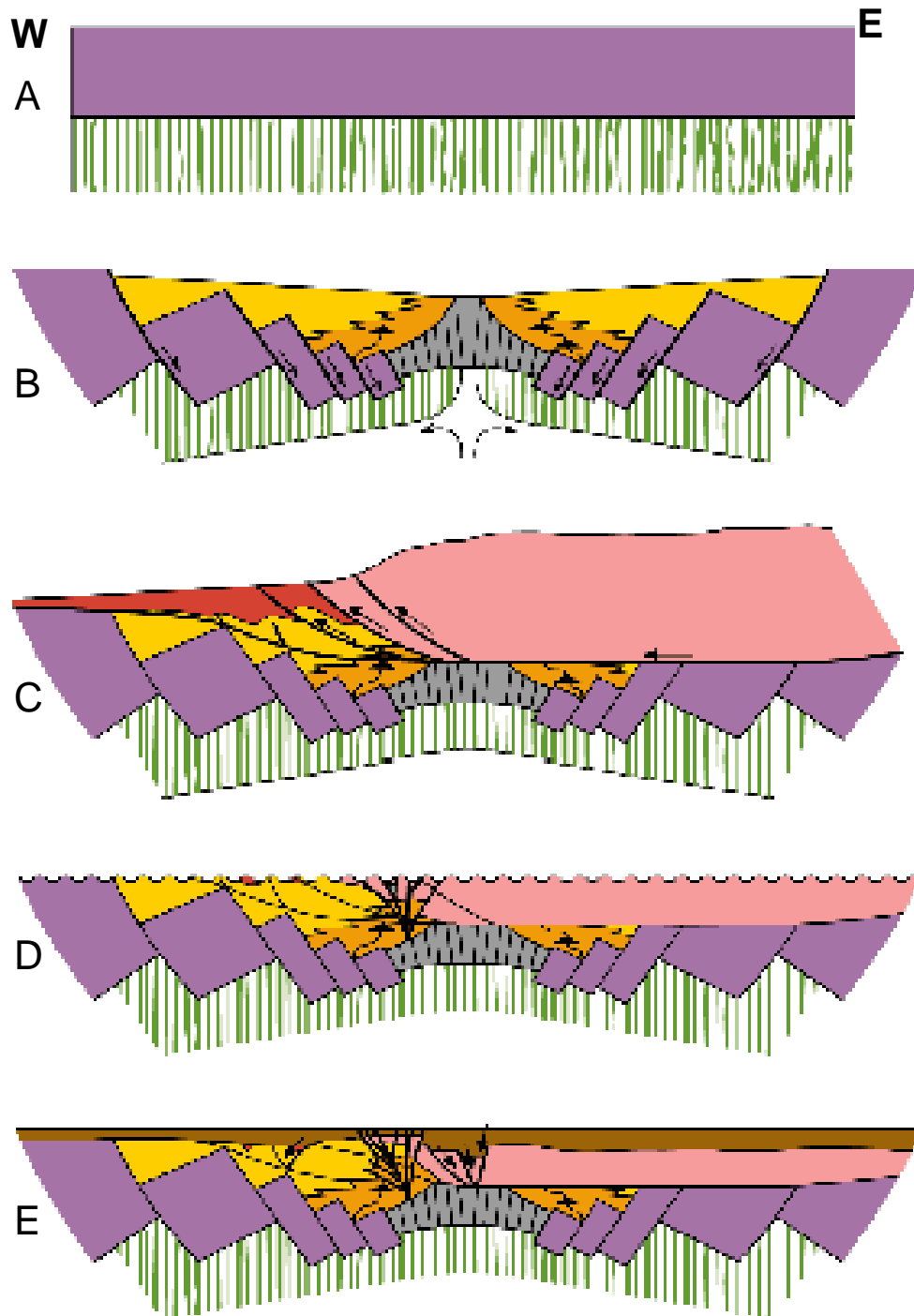
Regional Proterozoic Layered-Reflector Isopach Map



Based on data from Drahozal, 2002a; John Rupp, 2001, Indiana Geological Survey, McBride and Kolata, 1999; Mark Baranoski and Larry Wickstrom, 2001, Ohio Geological Survey

from data presented by Drahozal, 2002a





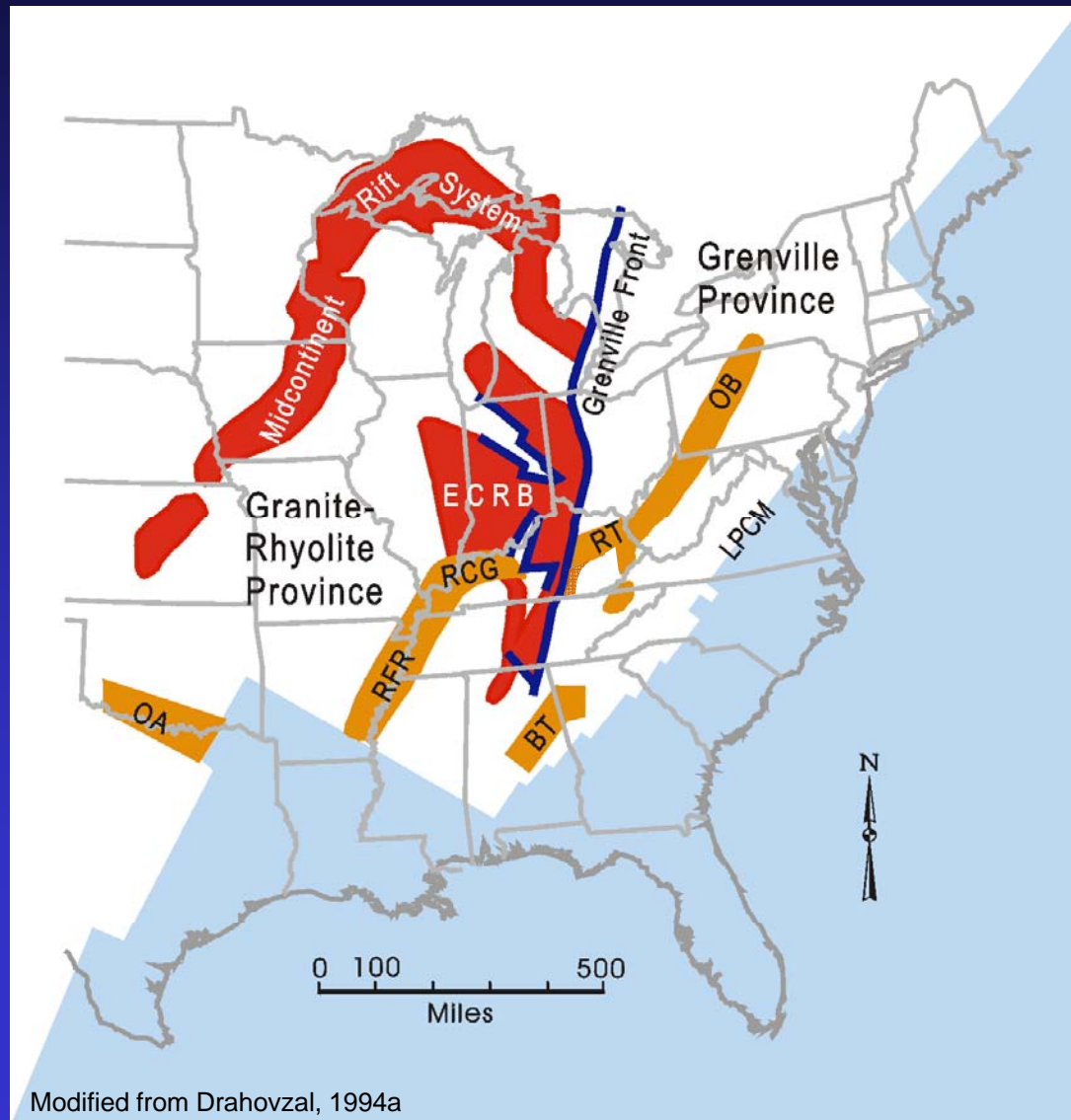
East Continent Rift Basin Development Model

- A. Emplacement of Granite-Rhyolite Province (1.45 – 1.48 Ga)
- B. Extension and emplacement of central mafic plug with attendant basalt flows, felsic intrusions and thick alluvial fan deposits (Middle Run Fm) from eroded fault blocks (0.95 - <1.048)
- C. Emplacement of Grenville allochthon, folding and faulting in Middle Run Fm. (0.89 – 0.975 Ga) and foreland basin development
- D. Deep erosion; extensional and wrench faulting (0.6 – 0.7 Ga); uplift of Louisville Block and deposition of undeformed rocks (not shown)
- E. Cambrian “inversion” to W; extension and subsidence to E (Rome Trough) and far W (Rough Creek Graben; not shown) (~0.5 Ga)

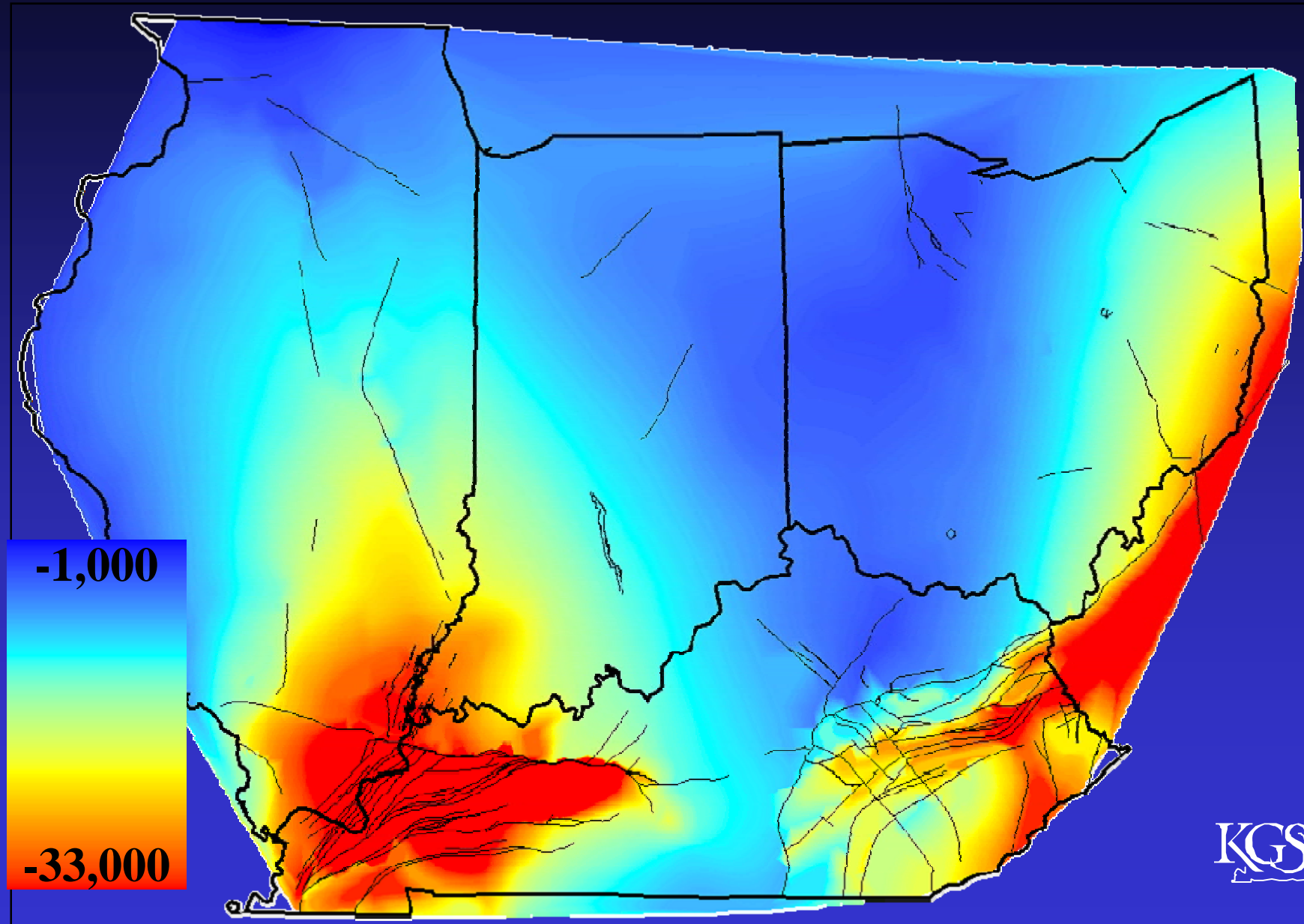
from Drahovzal
and others, 1992



Proterozoic and Cambrian Basins of Eastern US

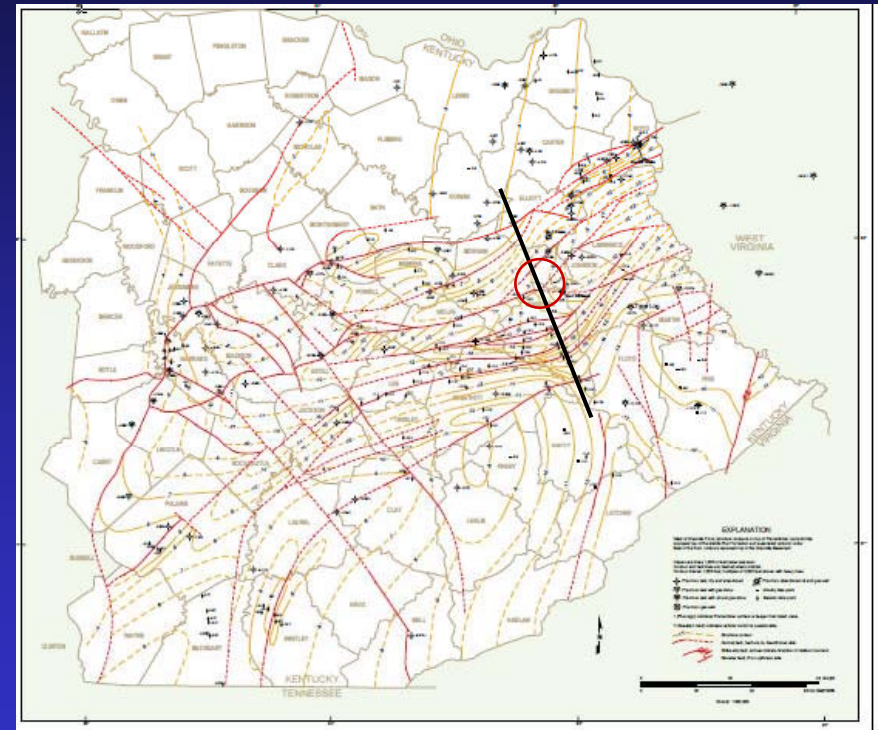


Structure: Top of Proterozoic



Rome Trough: Eastern Kentucky

- **Symmetrical Cambrian rift basin**
- **Three major Fault Zone Boundaries**
 - N: Kentucky River FZ (KRFZ)
 - S: by Rockcastle River FZ (RRFZ)
 - Medial: Irvine-Paint Creek FZ (IPCFZ)
- **Thickening**
 - across the KRFZ is 2.5- 5x
 - across the IPCFZ is 2- 4.5x
 - Across the RRFZ is 0- 2x
- **Structural relief:**
 - ~12,000 ft across the KRFZ to the deepest part of the basin
 - Up to only ~ 7,000 feet across the RRFZ
- **Deepens from -5,000 to -7,000 ft along W edge to -10,000 to -17,000 depth at WV line**



from Drahovzal and Noger, 1995

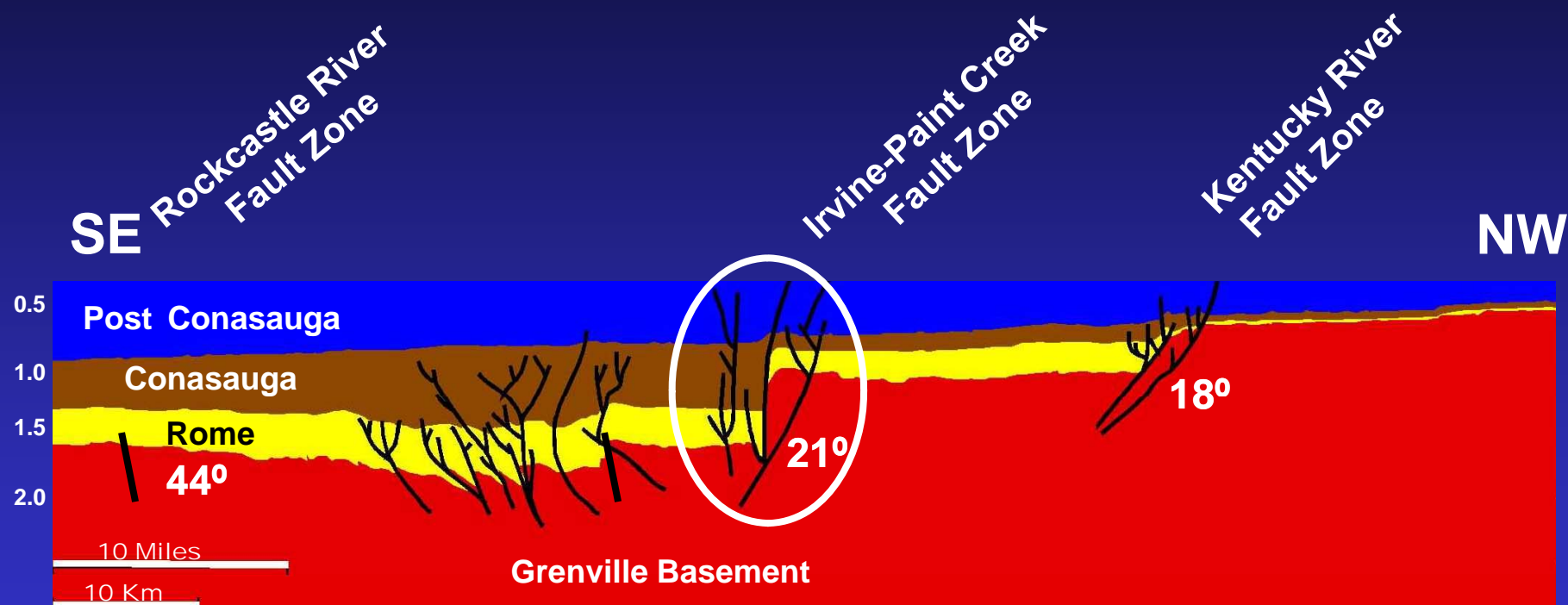
Cross Section of the Rome Trough

- Focus on the eastern part of the Rome Trough
- And on the Irvine-Paint Creek FZ



from data presented by Drahovzal and White, 2002

Cross Section of the Rome Trough

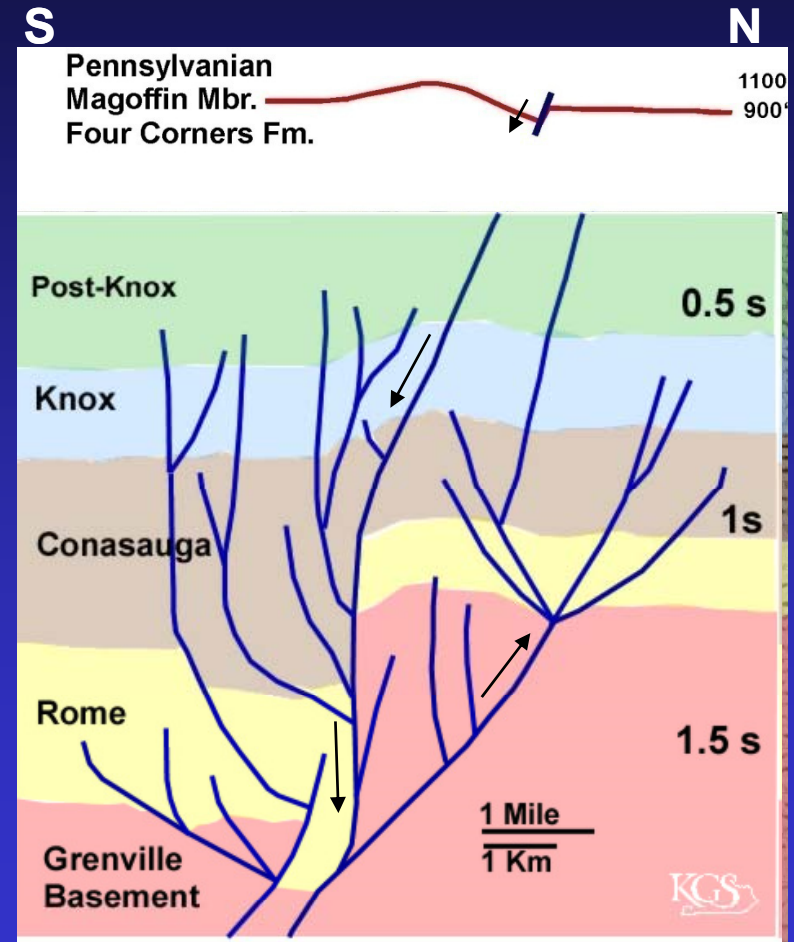


from data presented by Drahovzal and White, 2002

- Note thickening across KRFZ and IPCFZ; but little across RRFZ
- Listric faults in the major fault zones; steeper in near surface
- Note low angles of the faults at depth; suggests influence of a compressional event; also apparent reverse faults in basement
- Focus on Irvine-Paint Creek Fault Zone area

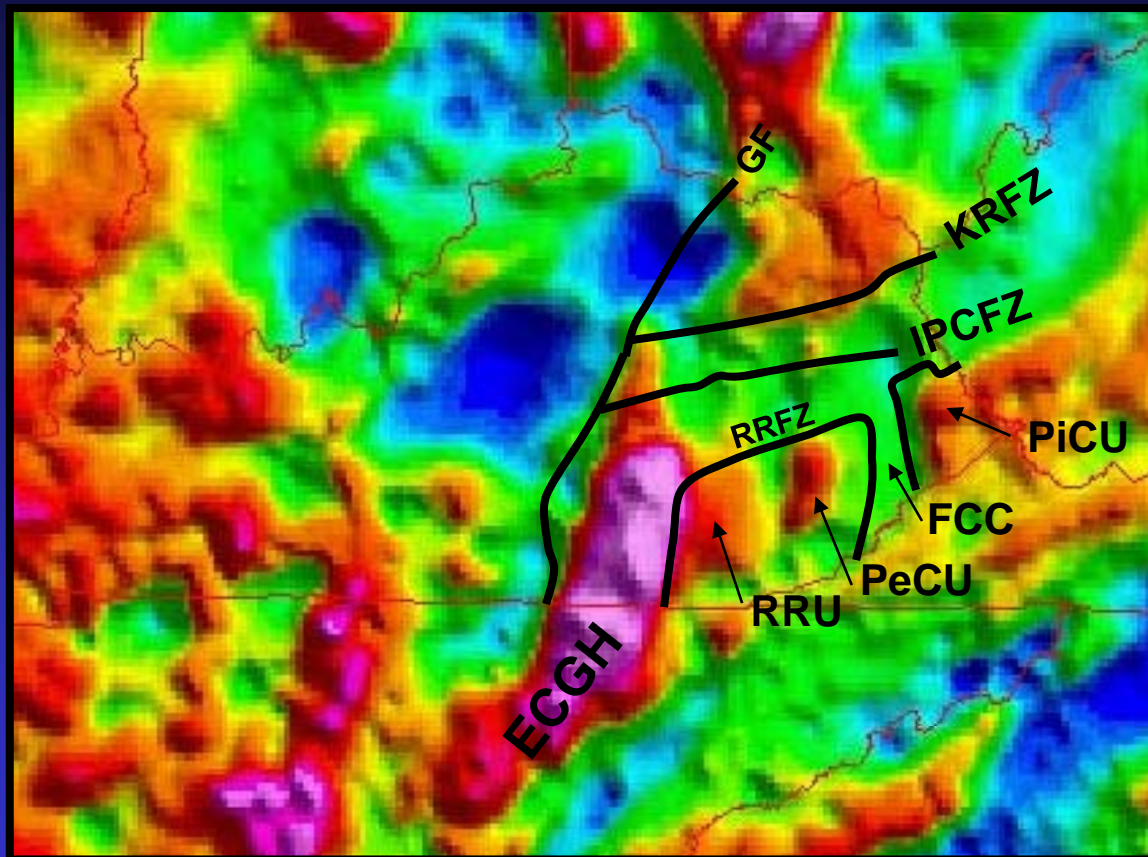
Is there evidence of Mesozoic reactivation in the Rome Trough?

- **Rift Phase: Steep Cambrian extension fault with major Cambrian growth of >2 x**
- **Later, lower-angle reverse faulting folded basement through Pennsylvanian rocks**
 - Note vertically stacked anticlines
 - Likely Alleghanian transpression
- **Down-to-south normal faulting in the Pennsylvanian reactivated the original Cambrian normal fault**
 - Likely due to Triassic-Jurassic regional extension (opening of the Gulf of Mexico?)



from data presented by Drahozal and White, 2002

What is the relationship between East Continent Gravity High (ECGH) and the Rome Trough (RT)?



- ECGH lies within SSW extension of RT
 - Bounded on W by Grenville Front; on E by Rockcastle River Fault Zone
 - ECGH “sinker”?
 - Remainder of RT in gravity lows
- N and S boundaries controlled by gravity highs
 - Rockcastle River FZ – Rockcastle River, Perry Co., and Pike Co. Uplifts
 - Kentucky River FZ— high to N
- Irvine-Point Creek FZ and the Floyd Co. Channel in the Rome Trough

Isostatic anomaly gravity from USGS <http://mrdata.usgs.gov/geophysics/gravity.html>

GF – Grenville Front

KRFZ– Kentucky River Fault Zone

IPCFZ– Irvine-Point Creek Fault Zone

RRFZ—Rockcastle River Fault Zone

RRU—Rockcastle River Uplift

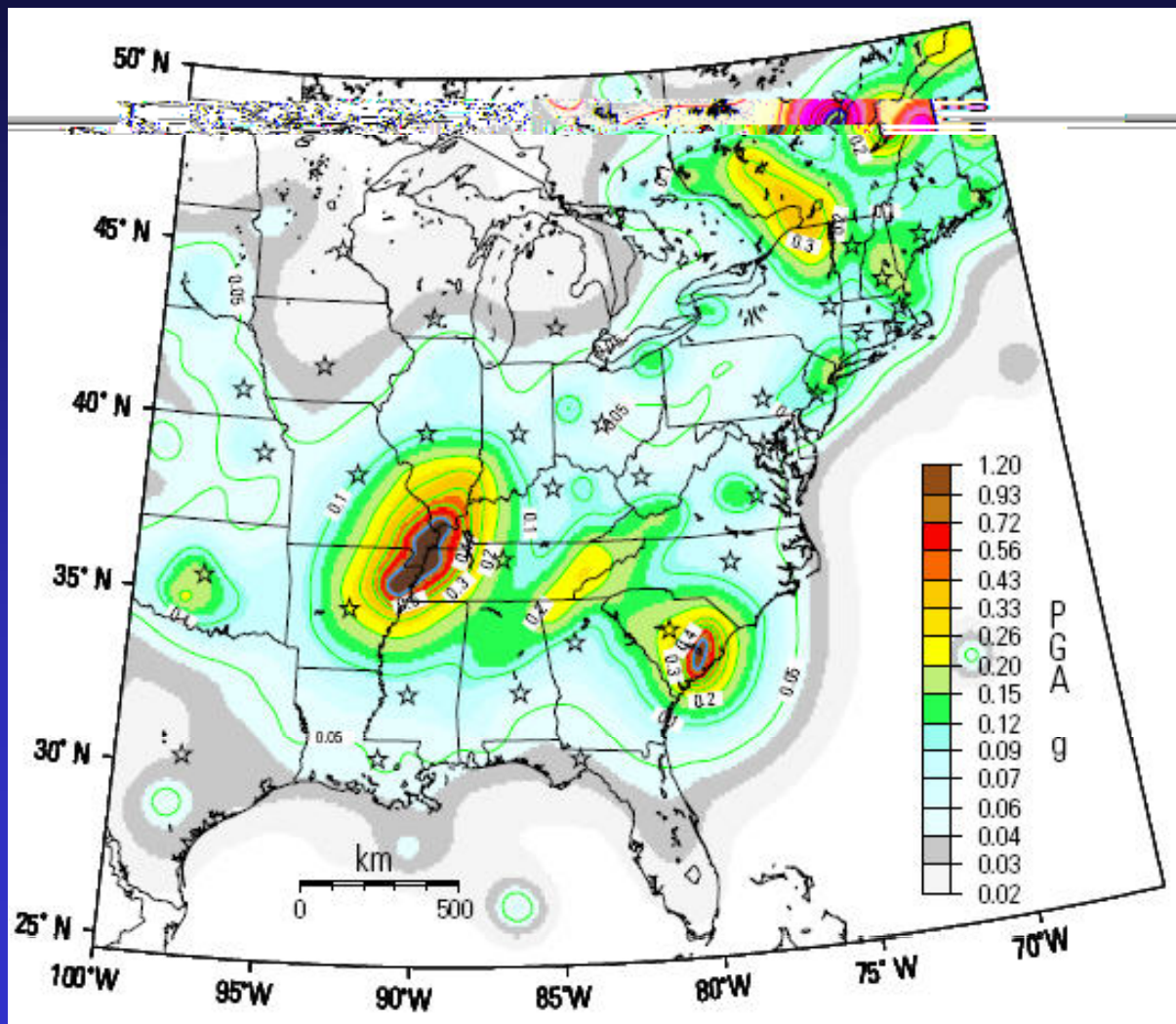
PeCU– Perry County Uplift

FCC—Floyd County Channel

PiCU—Pike County Uplift



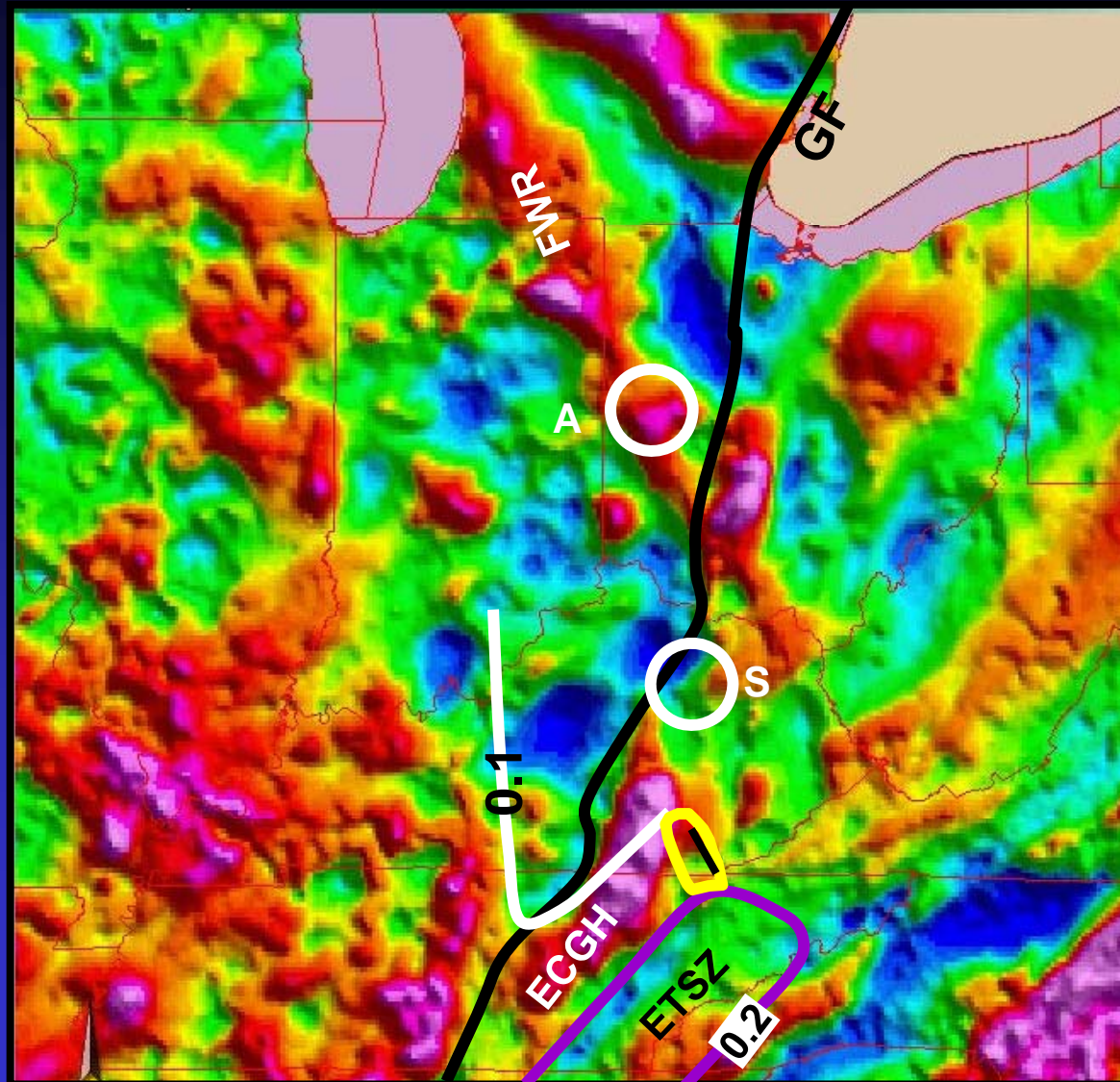
Seismicity: Map of peak ground acceleration (PGA) for 2% probability of exceedance in 50 yrs in std. gravity



USGS 2008



What is the relationship of the East Continent Gravity High (ECGH) and East Tennessee Seismic Zone (ETSZ)?



- East Tennessee Seismic Zone
 - SE and parallel to the ECGH
 - Truncated to NE
 - Spur of earthquake activity in SE KY; truncates at ECGH
 - East edge parallel to the Rocky Face & Dorton Branch FZs (black line)
- The Sharpshurg (S) M 5.2 event lies close to the ECGH
- Anna Seismic Zone (A) is coincident with the Ft. Wayne Rift (FWR)
 - FW R is older (1.2-1.3 Ga) than ECGH, cutting across it*
 - ECGH is ECRB rift center

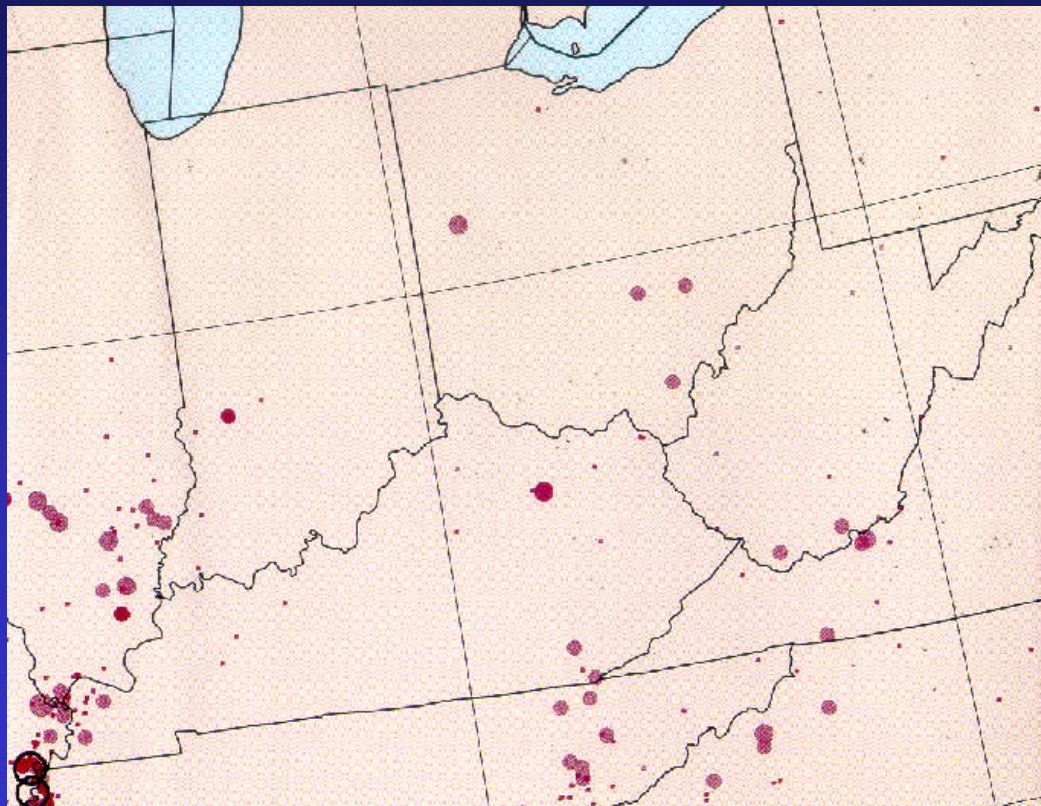
Isostatic anomaly gravity from USGS

<http://mrddata.usgs.gov/geophysics/gravity.html>

*Atekwana, 1996



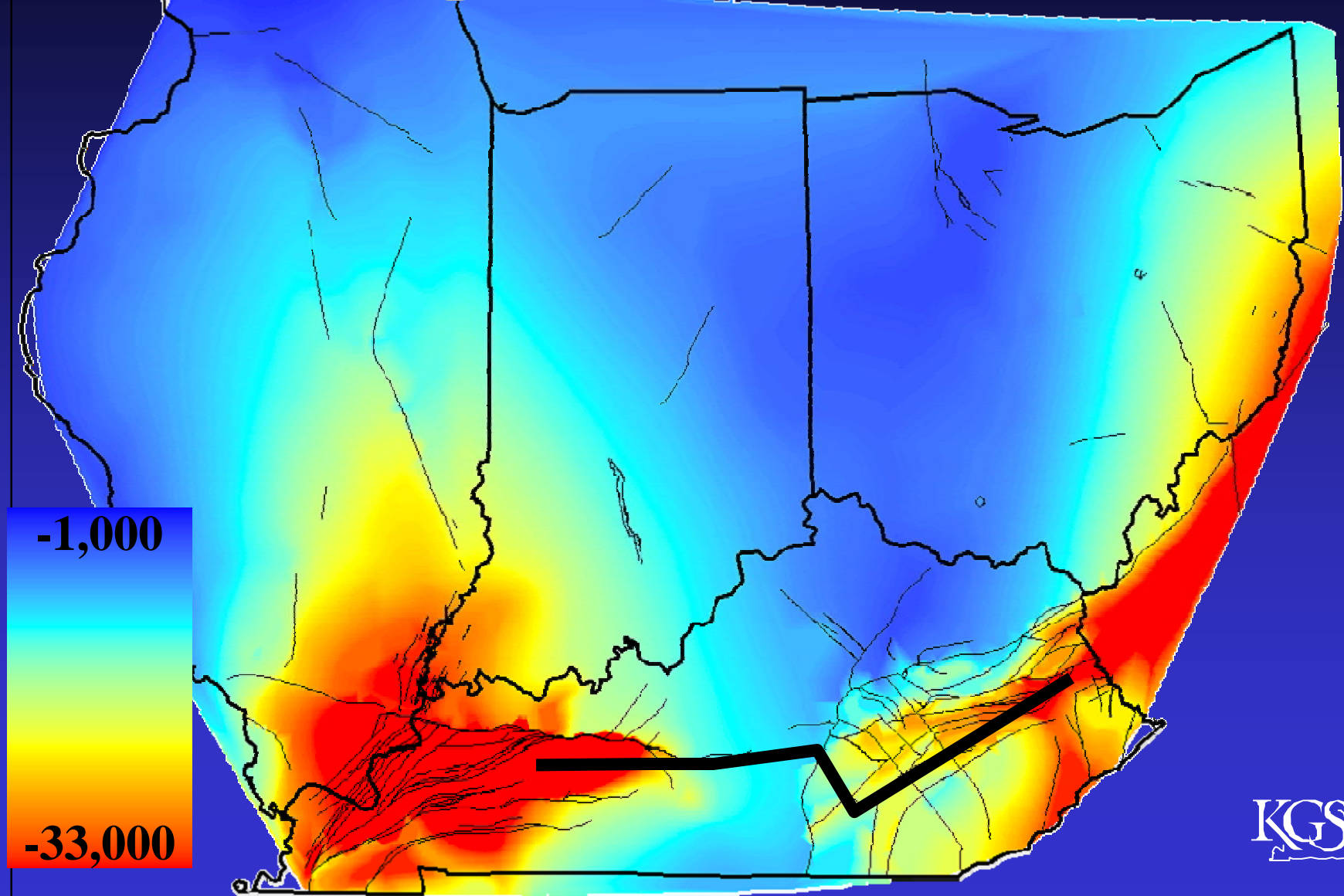
Seismicity in the Eastern Midcontinent



from Geological Society of America, 1988

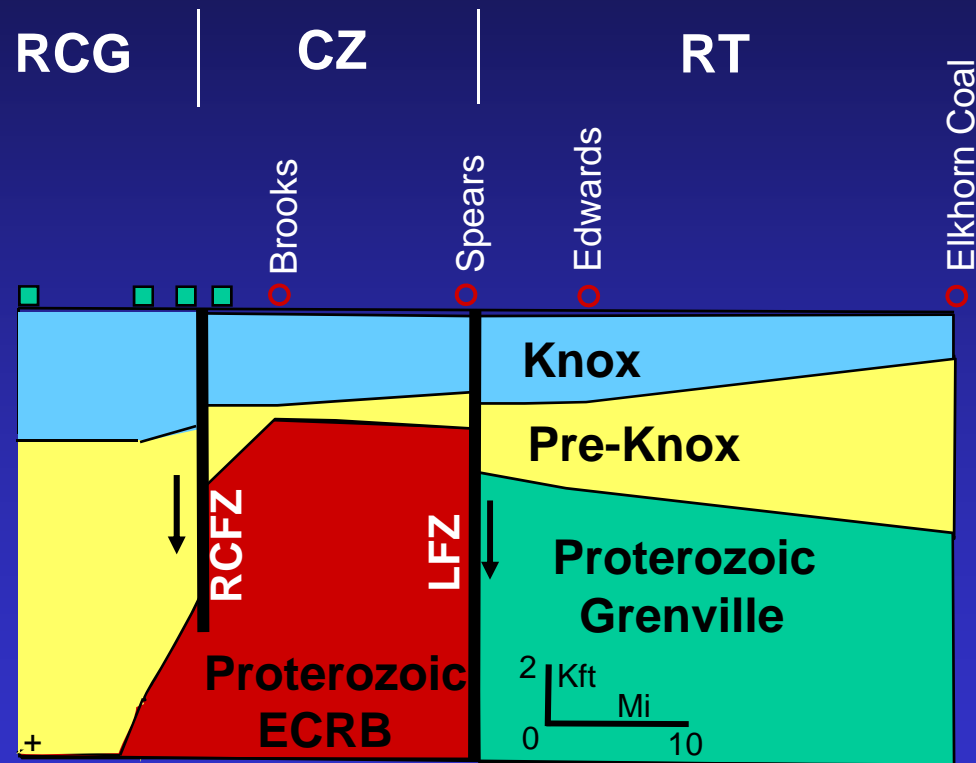
- All M 5 or less earthquakes , except for SW corner
- Aseismic
 - Rough Creek Graben
 - Rome Trough
- East Continent Rift Basin
 - High-level seismicity in southern IL
- Low seismicity on and near ECGH and FWR
 - Anna, Ohio
 - Sharpsburg, KY
 - southeastern KY

Is the Rough Creek Graben and the Rome Trough a continuous feature?



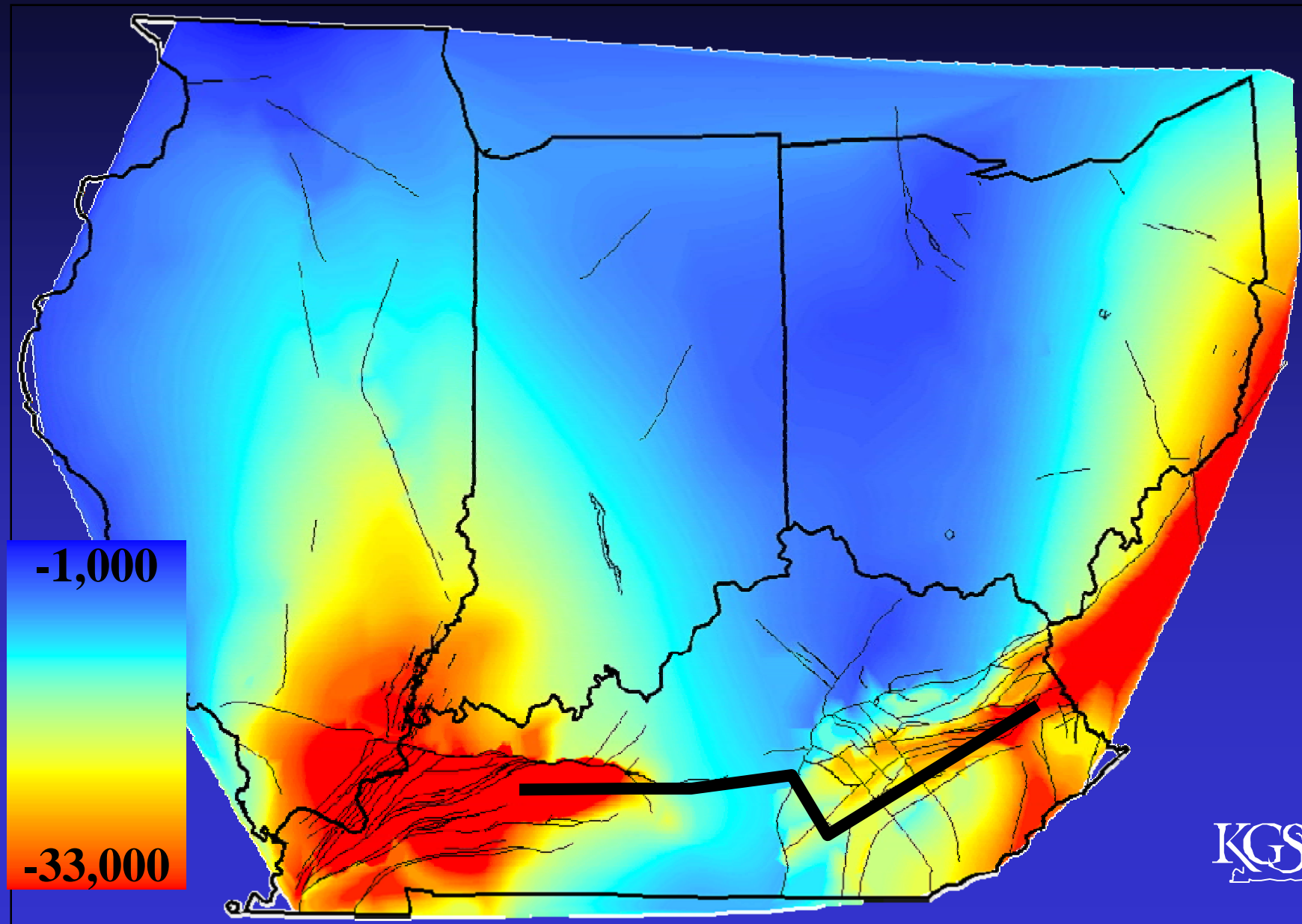
Schematic Cross Section: Rough Creek Graben to Rome Trough, Kentucky

- Cambrian syntectonic deposition (Pre-Knox) in the Rome Trough (RT) & the Rough Creek Graben (RCG)
- Based on available data, cannot demonstrate Cambrian (Pre-Knox) rifting in the central zone (CZ)
 - However, a lack of well and available quality seismic data in south-central Kentucky
- Central zone is coincident with the thickest part of ECRB
 - suggests Cambrian inversion or at least relative stability
 - Conformity of Knox-Pre-Knox boundary suggests non-deposition



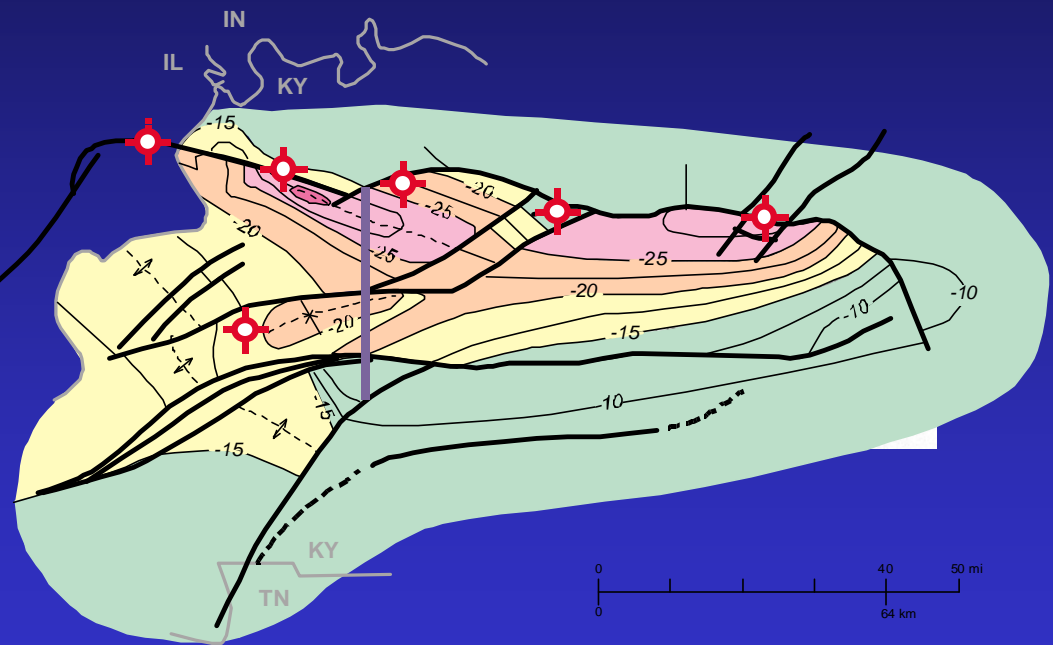
- Proprietary seismic data
- Well data

Structure: Top of Proterozoic



Rough Creek Graben, Western Kentucky

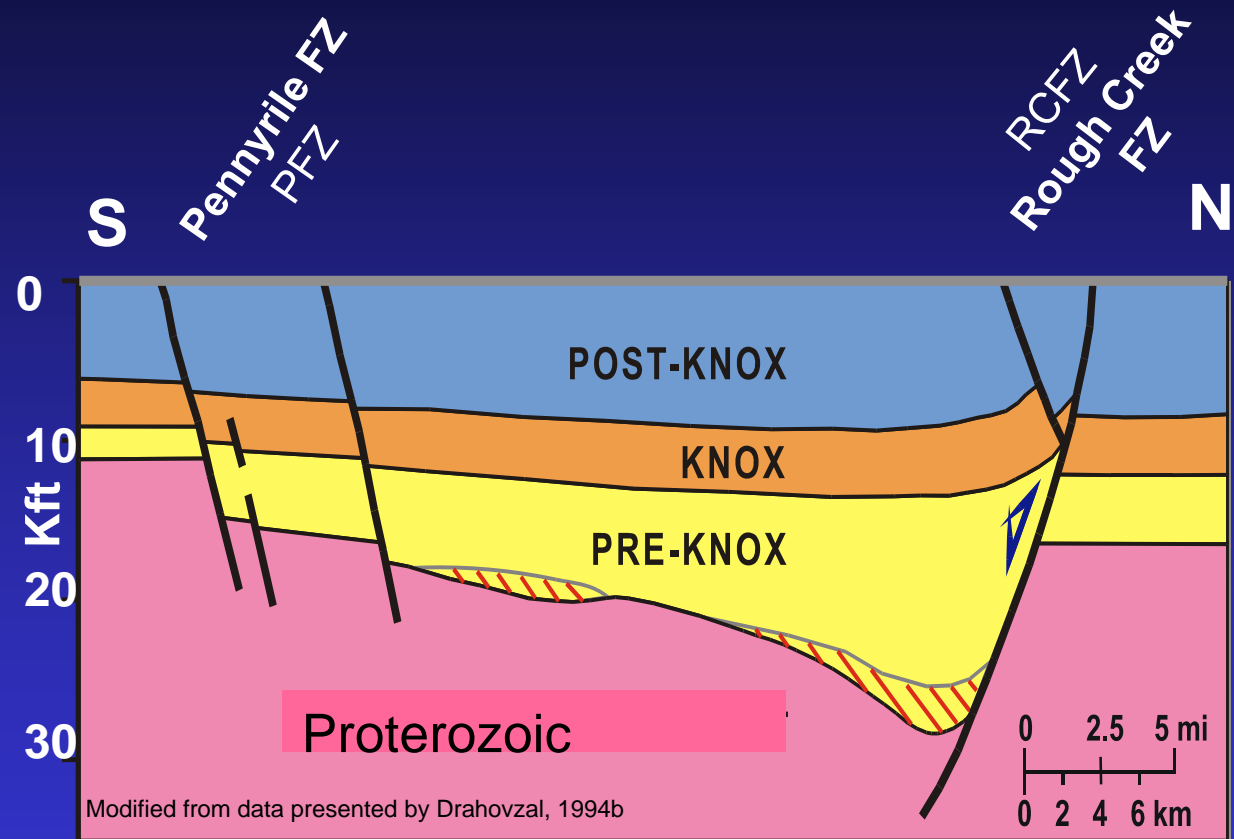
- Cambrian asymmetrical half graben
- Major bounding fault on N side
 - Rough Creek FZ
 - Pennyrite FZ on S edge
- Most deep wells along N edge
 - Known primarily from seismic data
- Changes polarity to SW: more symmetrical Reelfoot Rift (Mississippi Valley Graben)
- Terminates to East on inverted ECRB



Modified from data presented by Drahovzal 1994b

Is there evidence of Mesozoic reactivation of the Rough Creek Graben?

- Deep half-graben > 30,000' depth at deepest part
- Shallows to S and E
- Cambrian thickening on RCFZ up to 8 x
- Up to 15,000' of Pre-Knox Cambrian rocks
- Offset of the Precambrian is up to 17,000'
- Several reactivations
 - Uplift on the S side of RCFZ—transpression during Alleghany Orogeny*
 - subsidence along RCFZ and PFZ—likely regional extension during Triassic-Jurassic**



* Bertagne and Leising, 1991; Kolata and Nelson, 1991

**Strunk, 1984; Bertagne and Leising, 1991; Kolata and Nelson, 1991

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