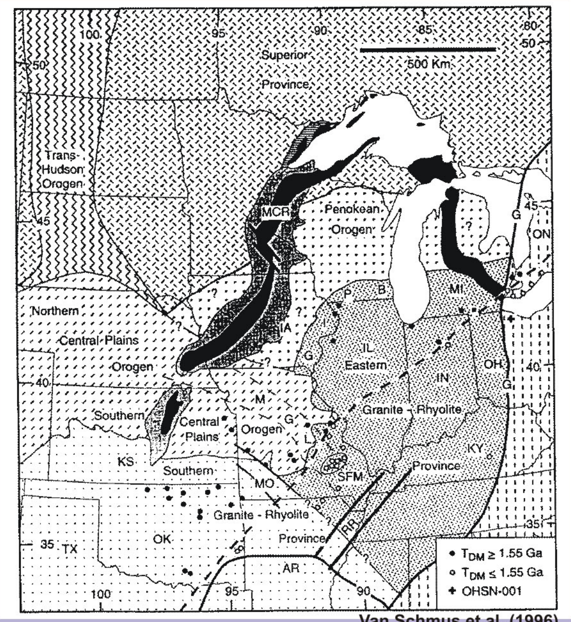
BASEMENT GEOLOGY AND STRUCTURE



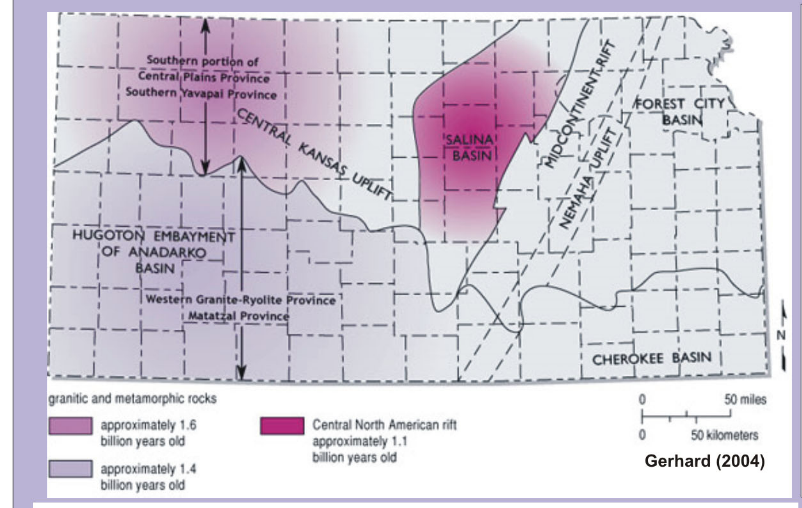
Van Schmus et al. (1996)

Major Precambrian geologic features of the Midcontinent region.

Hypothesis tested in this presentation – Episodic basement deformation serves as a template for segmentation of the shelf and strongly influences the location of carbonate petroleum reservoirs under examination.

Focused deformation is associated with basement weaknesses in the Midcontinent -- episodic, affecting deposition and post-depositional processes often leading to stacked pay zones and indications of deep seated, early structure in younger rocks.

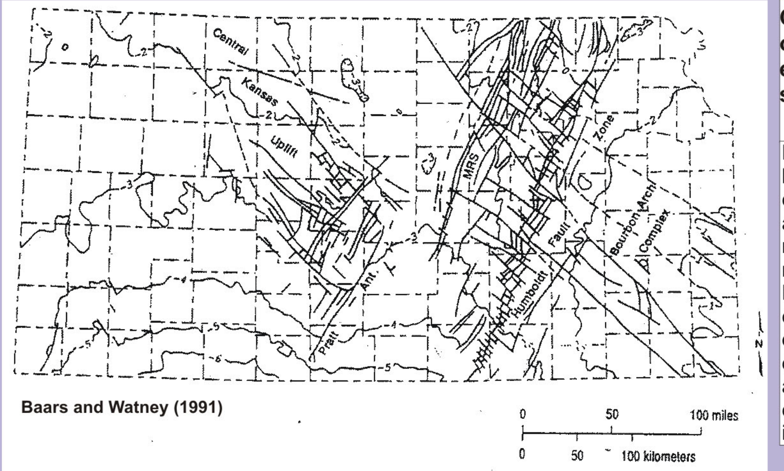
The basement of the upper Midcontinent has been studied extensively using well cuttings, cores, and limited outcrops augmented with the interpretation of potential fields geophysics and, locally, seismic data.



Gerhard (2004)

Generalized map of Precambrian terranes in Kansas, showing ages and lithologies, with major Kansas historical structures identified.

Modified from Newell et al., 1987. Southern portion of Central Plains Province (Van Schmus et al., 1987); Southern Yavapai Province (CD-ROM Working Group, 2002); Western Granite-Rhyolite Province (Van Schmus et al., 1987); Mazatzal Province (CD-ROM Working Group, 2002).

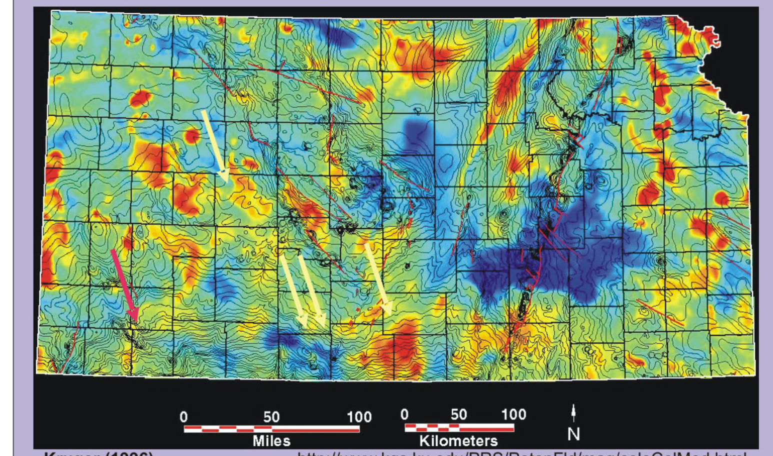


Baars and Watney (1991)

Configuration of the top of Precambrian emphasizing major fault systems.

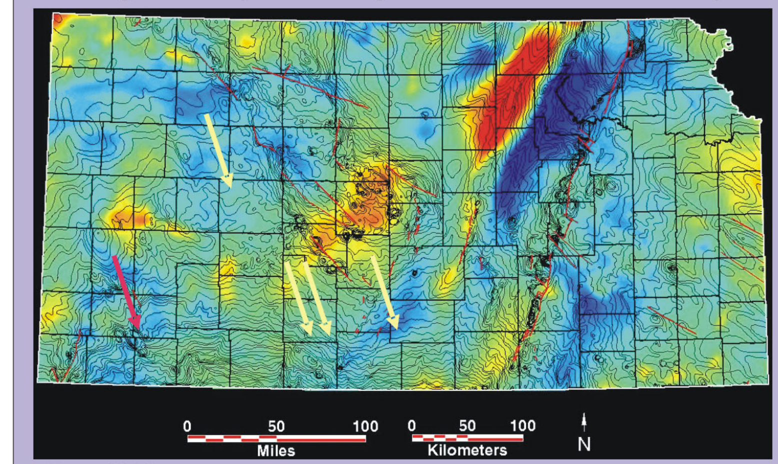
Depending on the interpreter, the Precambrian basement configuration has been depicted with considerable faulting or very limited faults. It is a matter of preference and style of mapping, reflecting limited basement penetrations and near vertical faulting. Similarly, shallower Phanerozoic horizons can be mapped as continuous surfaces or more faulted and discontinuous. The current paradigm has emphasized continuous mapping, but with the advent of 3D seismic, this paradigm of continuity is evolving toward less continuity and instead more segmentation/faulting.

Total Magnetic Field Intensity With Configuration of Precambrian Overlay


Kruger (1996) http://www.kgs.ku.edu/PRS/PotenFld/mag/coleColMed.html

Overlay of the basement configuration on gravity and magnetics maps reveal correlations with compositional and structural variations of the basement (Kruger, 1996). Moreover, the Precambrian terranes mapped using the gravity and magnetic maps provide the means to systematize the basement framework and collectively associate them with Phanerozoic structures.

Bouguer Gravity With Configuration of Precambrian Overlay


Kruger (1996) http://www.kgs.ku.edu/PRS/PotenFld/grav/coleColMed.html

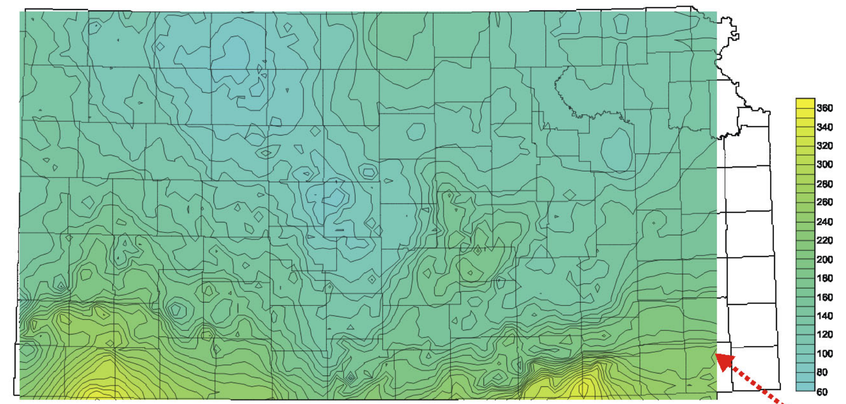
REGIONAL FAULT CONTROL OF SHELF MARGIN

Shelf margins of the Middle Mississippian and Upper Pennsylvanian are distinctively developed in southern Kansas.

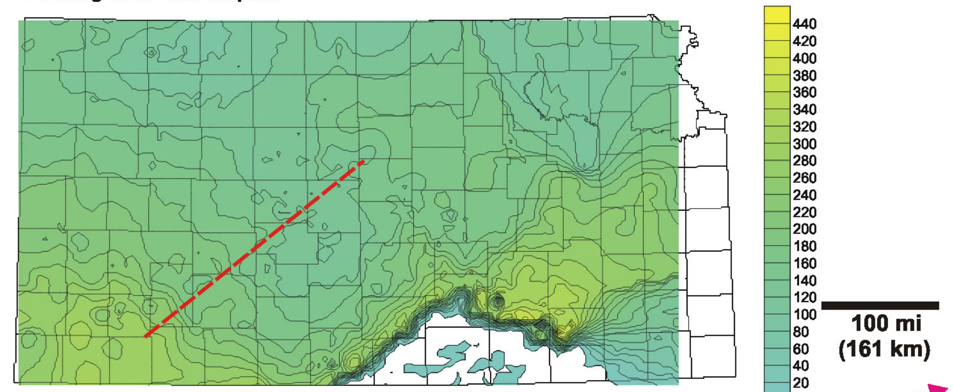
Interval isopachs were previously mapped for a succession of Upper Pennsylvanian 4th order genetic units (mapped from flooding unit to flooding unit, *see maps below*). Composite sequences (3rd order Muncie Creek and Nuyaka Creek) were recognized through examination of the stacking pattern along the shelf margin (*see well log and regional cross section below*).

The 3rd order sequences exhibit a transgressive-regressive behavior whereby initial 4th-order cycles in the composite sequence extend farther landward. Recognized onlap lies beyond study area, but higher sea level at beginning of 3rd order cycle is suggested by abrupt landward migration (10's to 100's of km) of thicker cycles and peritidal lithofacies. This landward shift in lithofacies is paralleled by km-scale backstepping of carbonate shelf margin (*see cross section*).

G-K Isopach (genetic set isopach)

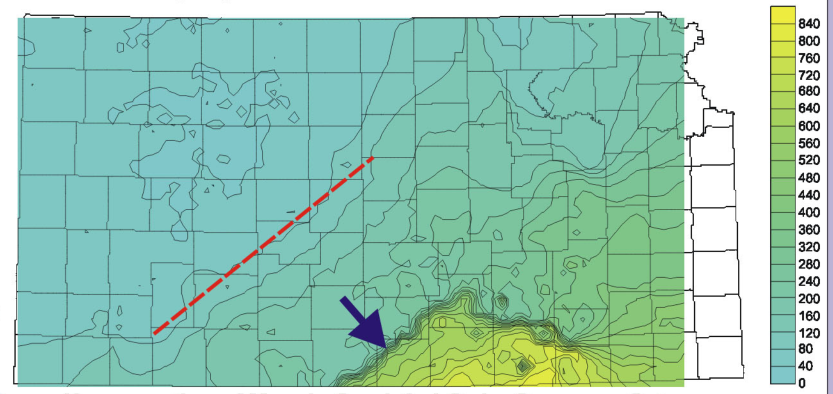

Most of Nuyaka Creek 3rd-Order Sequence Set

Lansing to G-Zone Isopach

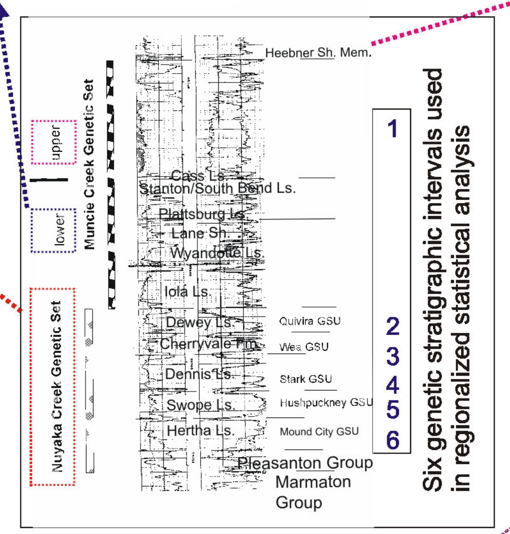


Lower Portion of Muncie Creek 3rd-Order Sequence Set

Heebner-Lansing Isopach


Upper portion of Muncie Creek 3rd-Order Sequence Set

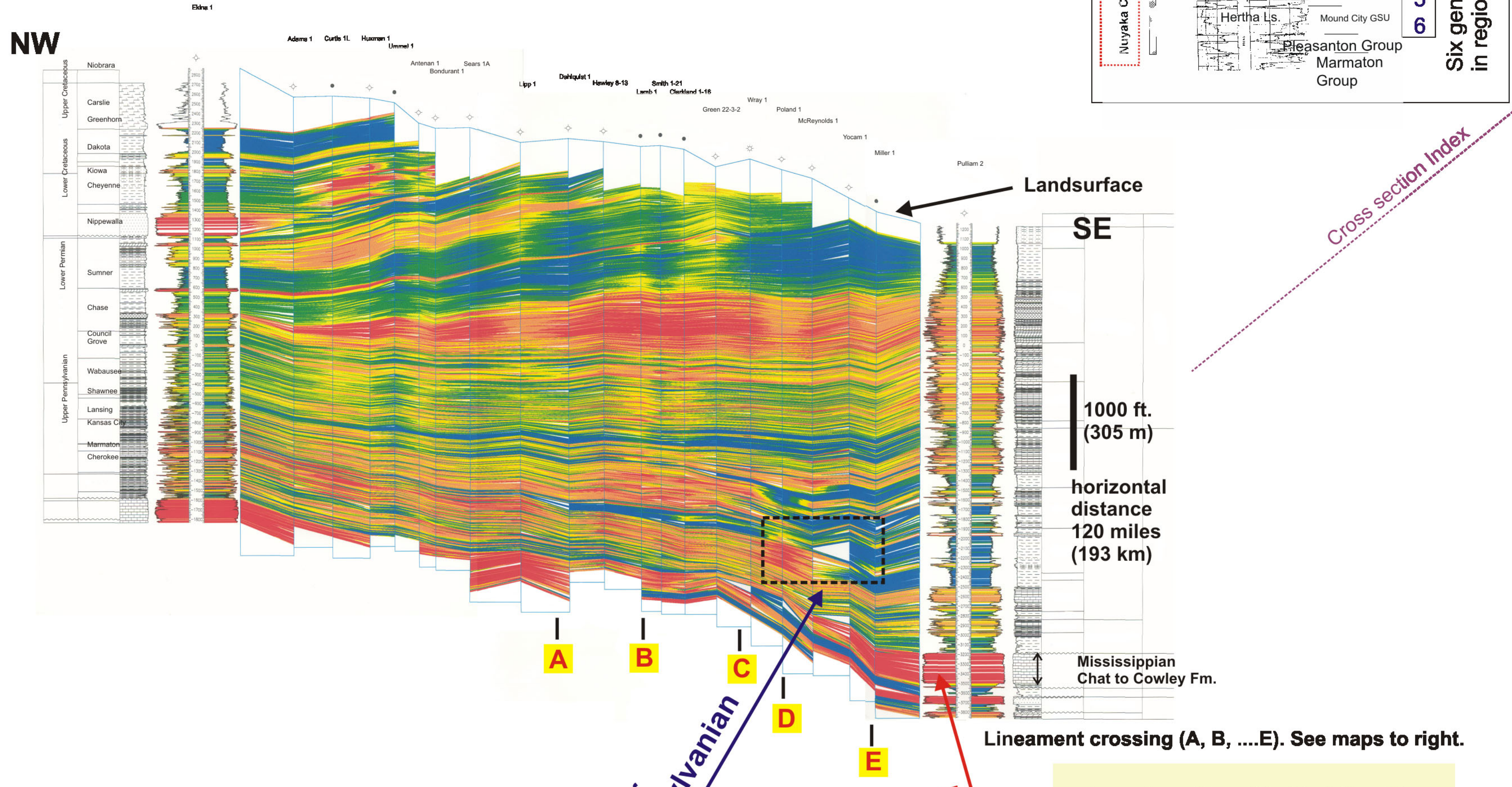
The southern shelf margin is distinctly linear and the shelf interior also contains linear features (*see blue arrow*). Importantly, many lineations are common between maps (*see red dashed lines on maps above*).



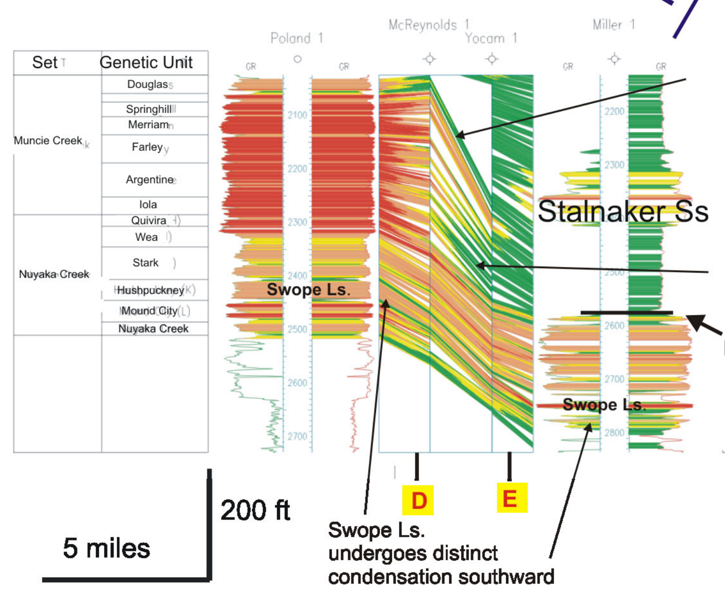
Regional Cross Section Showing Natural Gamma Ray Intensity using Correlator Software (Olea, 1988)

Reds and yellows = carbonate and sandstone   Greens and blues = shales

Persistence of regional lineaments established using regionalized spatal statistics, as described above, intersect the cross section (*labeled as A-E*). The effect of these lineaments appears to persist up through some of the Phanerozoic strata. In particular, lineament "D" is associated with two upper Pennsylvanian carbonate shelf margins and coincides with the underlying updip (shelf edge) limit of the Middle Mississippian Cowley Formation. Lineament "D" is also highlighted in subsequent field studies along the Mississippian shelf margin in the Panel #3. Details of the shelf margins are shown in two smaller cross sections found beneath the regional section.

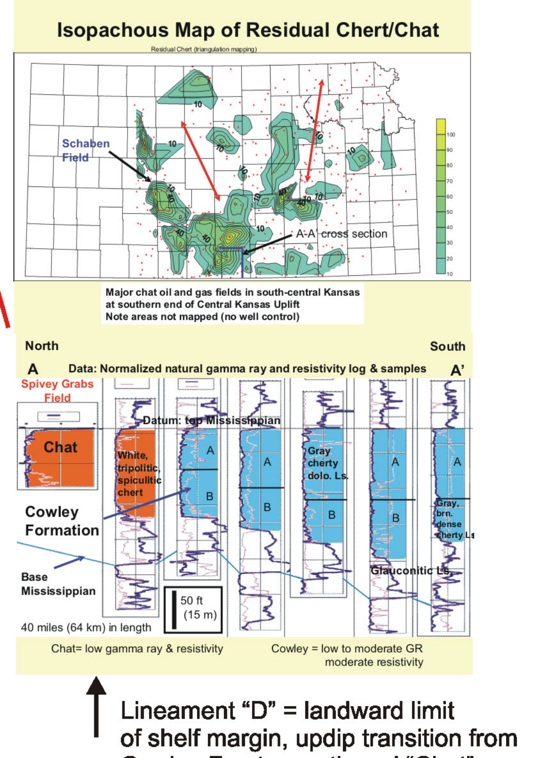


Lineament crossing (A, B, ...E). See maps to right.



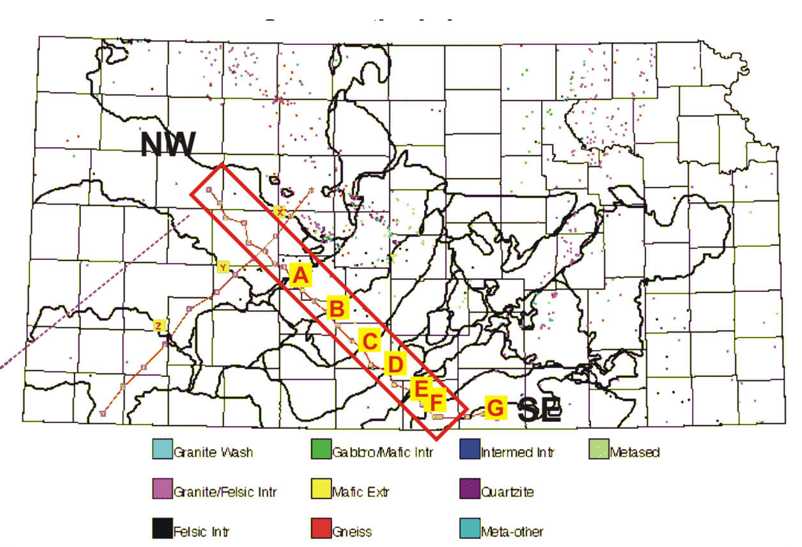
Swope Ls. undergoes distinct condensation southward across "D" lineament

Isopachous Map of Residual Chert/Chat



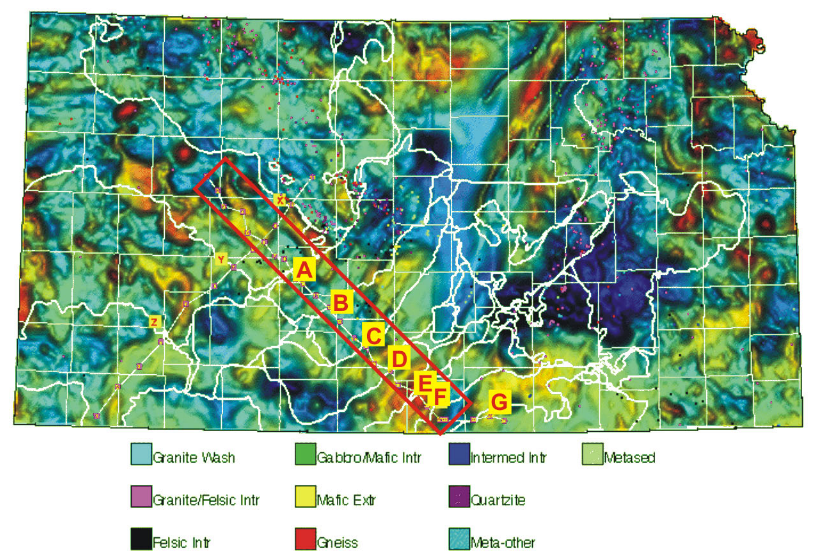
Lineament "D" = landward limit of shelf margin, updip transition from Cowley Fm. to weathered "Chat"

Region boundaries with basement samples

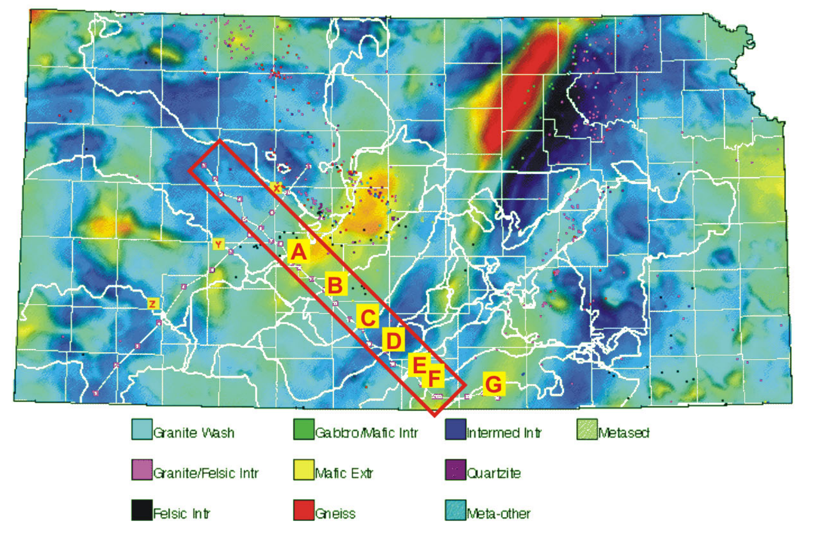


A set of 6 isopach maps of genetic units (*defined in stratigraphic column in above on left*) based on 3700 data points was previously analyzed using regionalized spatial statistics to define areas of relative homogeneity in thicknesses bounded by areas of changes thickeness (Watney, Davis, Harff, and Olea (1997). The result was an organized, distinctive northwest and northeast trending **segmentation of the shelf for the Pennsylvanian interval examined**. The boundaries of the regions was sharply defined, strongly suggesting segmentation vs. continuity in stratal thickness patterns. Maps and cross section also suggest this. Moreover, region boundaries often correspond to magnetic and gravity anomalies (*see overlay maps below*).

Magnetics, Kruger, 1997



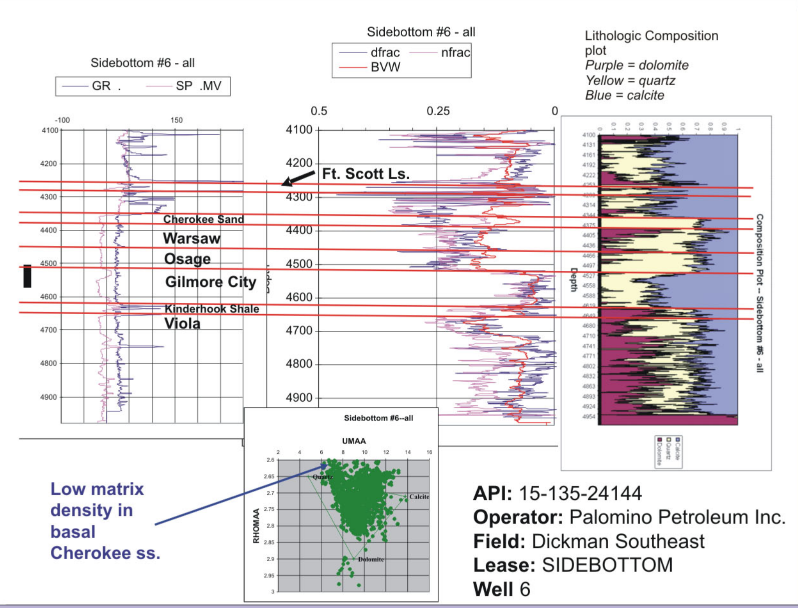
Gravity, Kruger, 1997

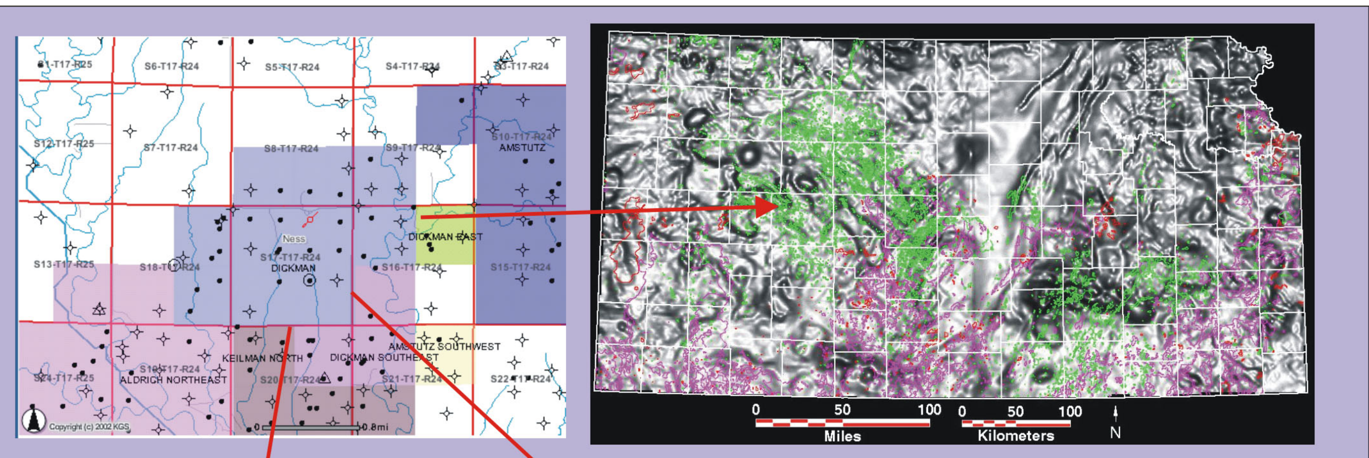


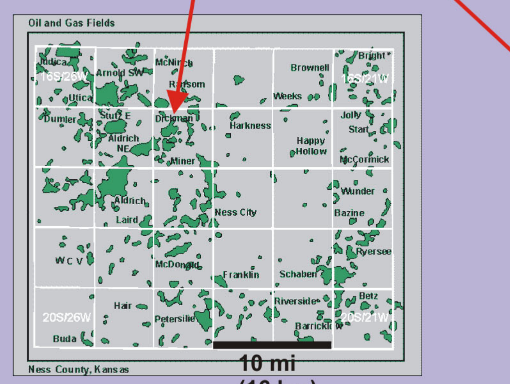
SHELF/RAMP CONTROLS ON LITHOFACIES DISTRIBUTION AND PETROLEUM RESERVOIR DEVELOPMENT

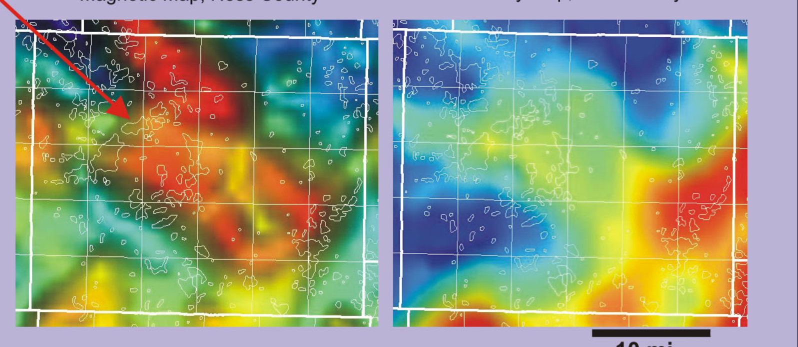
Dickman Field, Ness County Kansas

Example of Recurrent Structural activity affecting Ft. Scott, Cherokee, and Mississippian Pays









Dickman Field is located in Ness County, Kansas, in a mid-shelf setting. Primary producing intervals include the Mississippian-Upper Mississippian Spergen and Warsaw cherty dolomites and an incised valley fill Middle Pennsylvanian sandstone that lies directly and locally above the Mississippian (*see well logs above*). The Middle Mississippian Osage produces in nearby fields in similar reservoir types as those producing here. Some 1.7 million barrels of oil have been produced from the Mississippian cherty dolomite, Cherokee sandstone, and to a lesser extent from an oolitic facies of the Middle Pennsylvanian Ft. Scott Limestone (*see well logs above*).

Dickman Field and this portion of the Mississippian subcrop lies along a northwest-trending basement terrane boundary. Basement lineaments at the county scale trend NW and NE. The structural picture at Dickman is revealed with a 3D seismic survey that covers the extend (~1.5 mi. x 1 mi.) of this relatively small field (*images to right of text*).

Three seismic interpretation processes used:

1) trace picking for horizon mapping,
2) volumetric curvature attribute, and
3) impedence attribute computation.

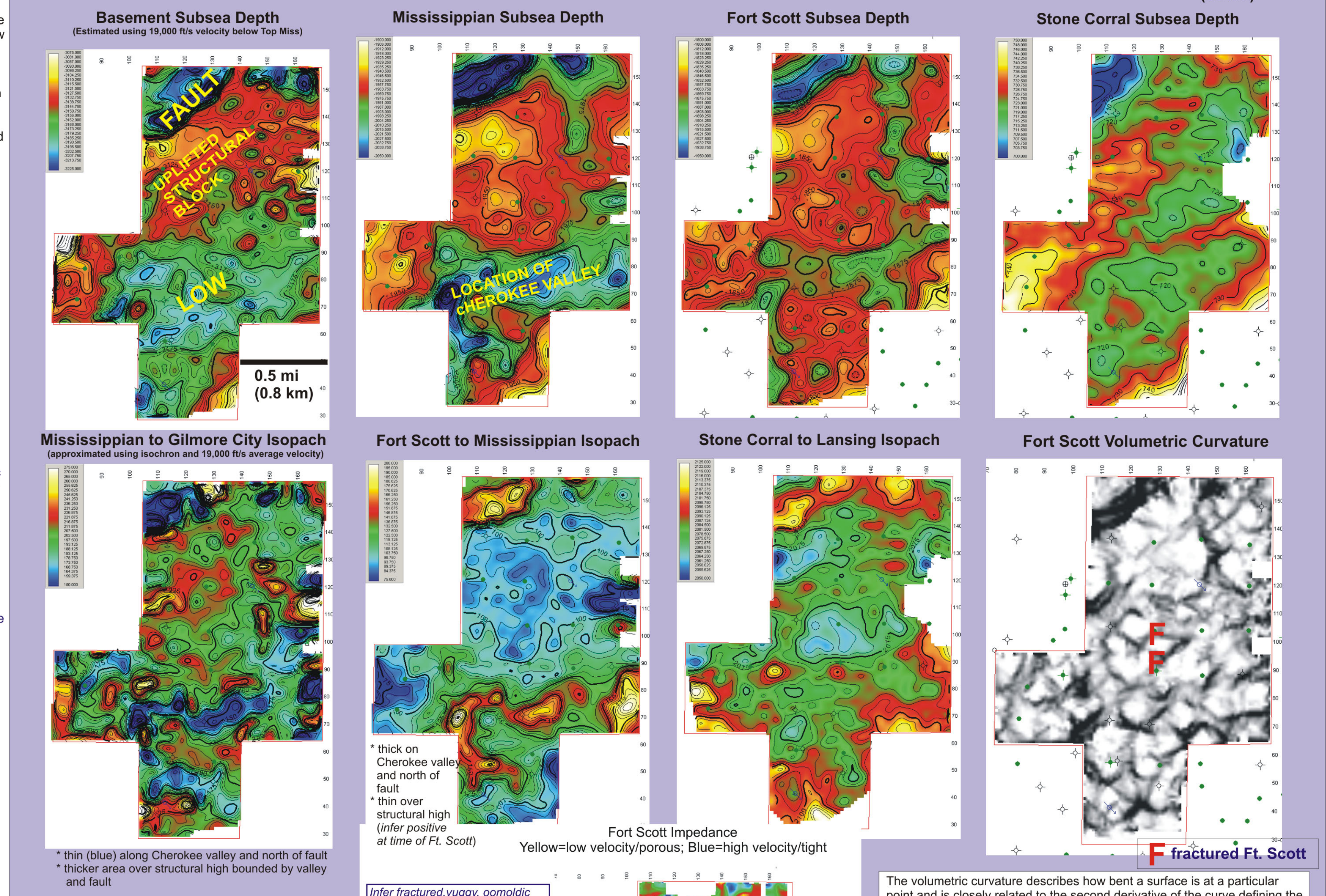
Seismic images: 1) examine evidence for structural segmentation and reactivation of the local shelf and 2) aid in evaluating the potential for infill well locations in the Ft. Scott oolitic facies.

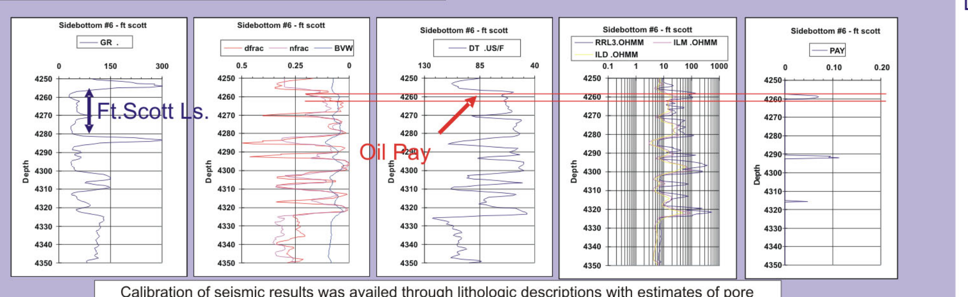
The deepest horizon illustrated in a series of 3D seismic images is the Precambrian surface followed by younger surface including the top of the Mississippian, top of Ft. Scott, and up to the much shallower Lower Permian Stone Corral Formation. Major features include a **north bounding fault** directly located next to a **high upthrown angular block**. This combination persists through every horizon. Interestingly the "incised valley" seen in the top of the Mississippian on the south end is also expressed by a general to **narrow and winding low** both at deeper and younger shallower horizons. The course of the Cherokee valley fill sandstone is antecedent to a persistent structural low!

Three interval isopachs arranged from old to younger show:

1) consistent thickening over the northern fault,
2) thinning over upthrown angular block, and
3) thickening into the southern low occupied by a Cherokee channel sandstone.

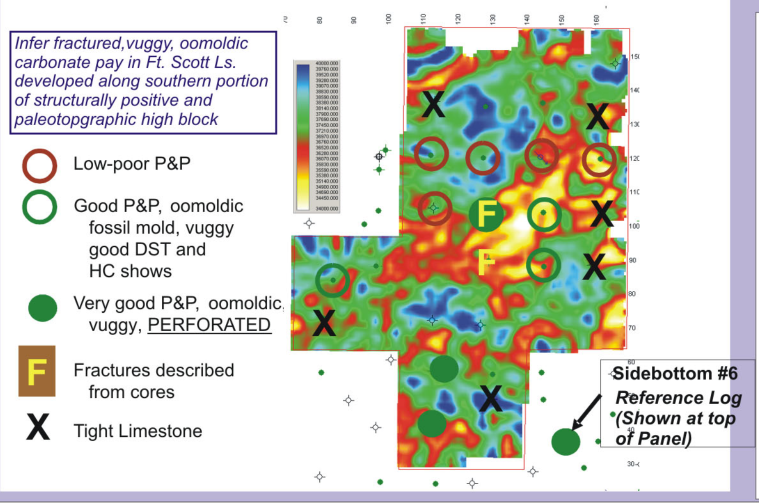
Significantly, in the objective to examine the Ft. Scott potential infill development, the **Ft. Scott to Mississippian isopach shows in excess of 50 ft (15 m) of thinning** over the angular upthrown block suggesting a topographic high during Ft. Scott deposition -conditions favorable for shoal water oolite deposition, that is, if sea level during peritidal periods was sufficiently long to permit sufficient ooid accumulation and that diagenetic or structural enhancement to pores allowed permeable reservoir rock to evolve.





Calibration of seismic results was availed through lithologic descriptions with estimates of pore types and amounts, and drill stem test recoveries to judge relative performance regarding fluid recovery and to make estimates of permeability. Log analyses were limited, but also provided additional independent indications of potential or actual hydrocarbon pay.

Fort Scott Impedance
Yellow=low velocity/porous; Blue=high velocity/tight



F fractured Ft. Scott

The volumetric curvature describes how bent a surface is at a particular point and is closely related to the second derivative of the curve defining the surface. The resultant curvature analysis for the Ft. Scott Limestone horizon shows NW and NE "wrinkles" on that surface that may reflect fractures/joints. A similar joint system is solution-enhanced into the top of the Mississippian surface, but one set of joints is shale filled and compartmentalize that reservoir. In the Ft. Scott Limestone, on the other hand, two cored wells with abundant fractures correspond to locations of these "wrinkles", thus validation that these are likely images of joints.

– *Seismic impedence modeling* done at 4 milliseconds below the top of Ft. Scott resolved a patch of low velocity on the southern flank of the angular uplifted structural block corresponding to areas of higher porosity or lithology change. Sample descriptions and DST tests confirm: 1) higher velocities (blues/greens) generally tight rock, 2) lower velocities (red/yellow) good to excellent porosity in vuggy oomoldic and fossil mold lithofacies.

The key points are: 1) a fault bounded structural block was reactivated during Ft. Scott Limestone deposition focusing the deposition of reservoir facies, 2) subsequent fracturing resulting from continued uplift further enhanced the porosity through mechanical deformation and possible enhanced diagenesis, 3) sea level conditions were appropriate at Ft. Scott time to permit momentary shoal water conditions.