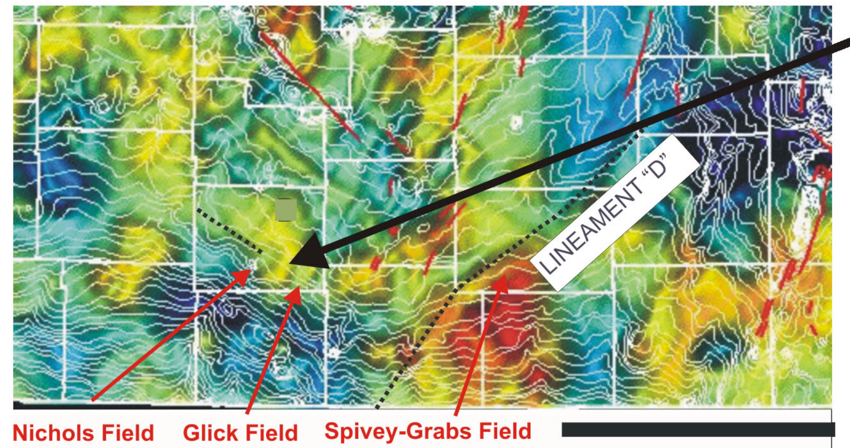
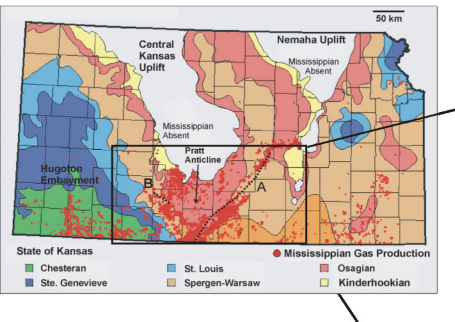
Three Mississippian Field Examples - Southern Shelf Margin

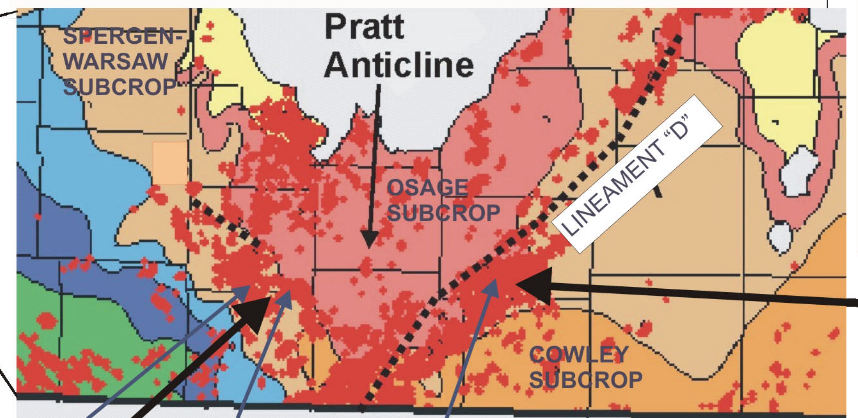
Total Magnetic Field Intensity

Shelf margin “Chat” reservoir petroleum play developed along the updip Cowley Formation in south-central Kansas. The three fields reside along prominent basement lineaments including lineament “D”, described and illustrated in the previous panel. In addition to northeasterly lineaments, orthogonal northwest trending lineaments are prominent on the regional magnetic map in this area of investigation. A comparison of this map with the basal Pennsylvanian subcrop shows a close correspondence between basement lineaments and the location of subcrops.



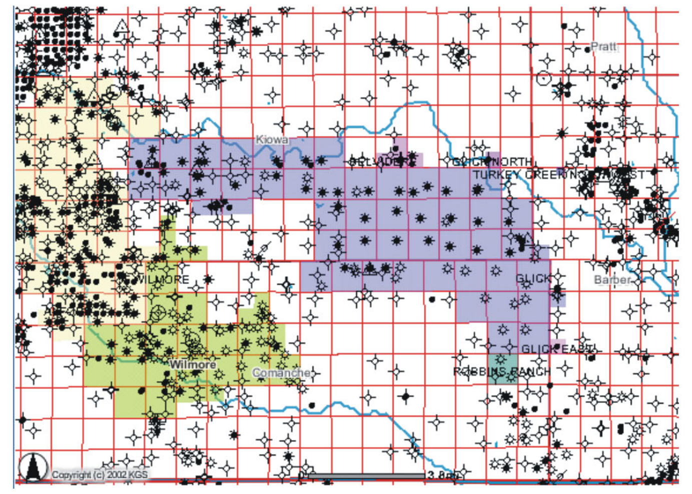
Basal Pennsylvanian Subcrop

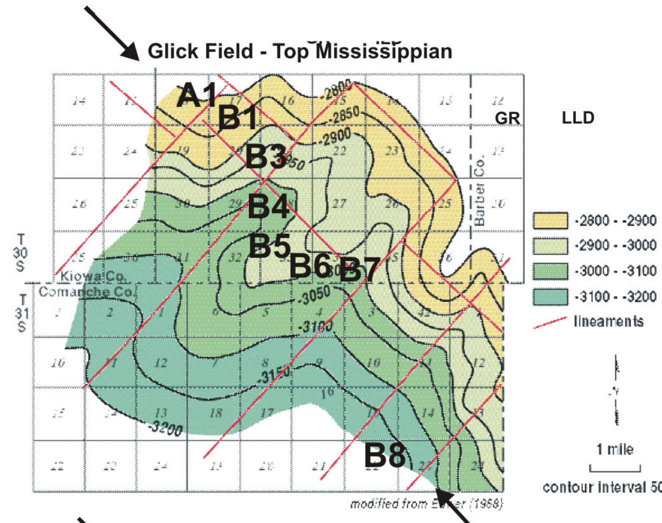


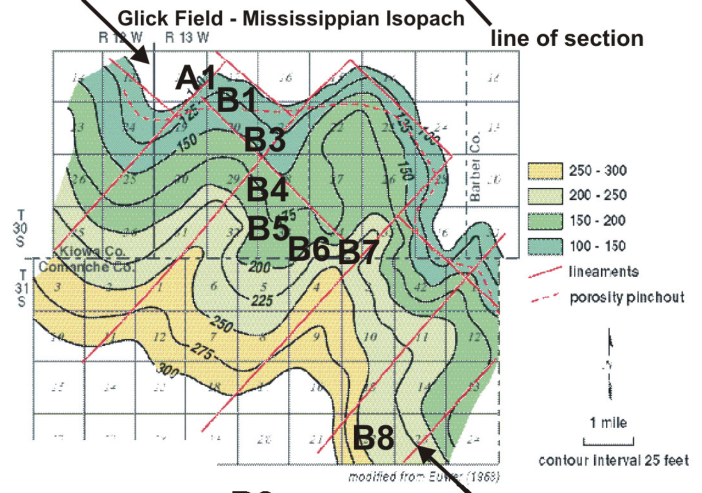


Structure and isopach maps of Spivey Grabs Field can be re-examined as a response to the deformation of a set of structural blocks leading to differential preservation and diagenesis of the “Chat” reservoir (Watney et al., 2000).

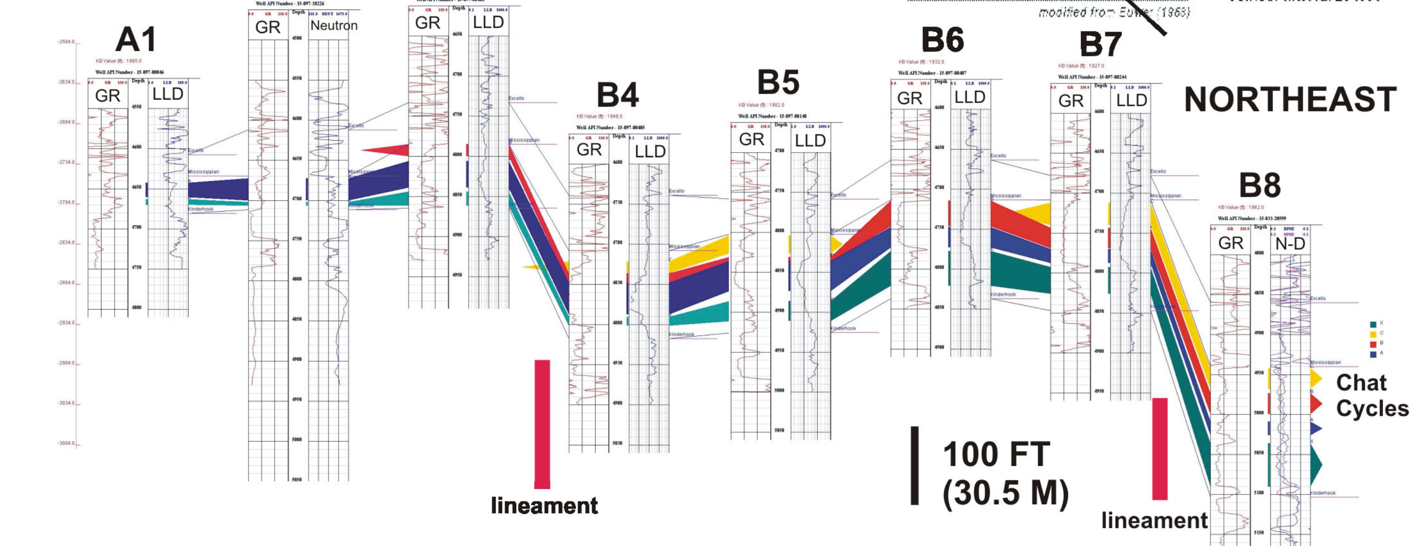
Glick Field



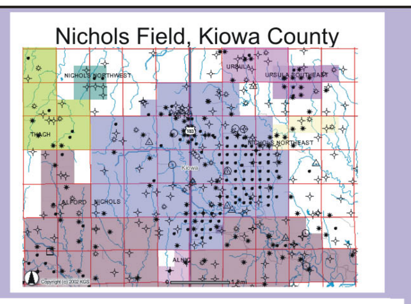


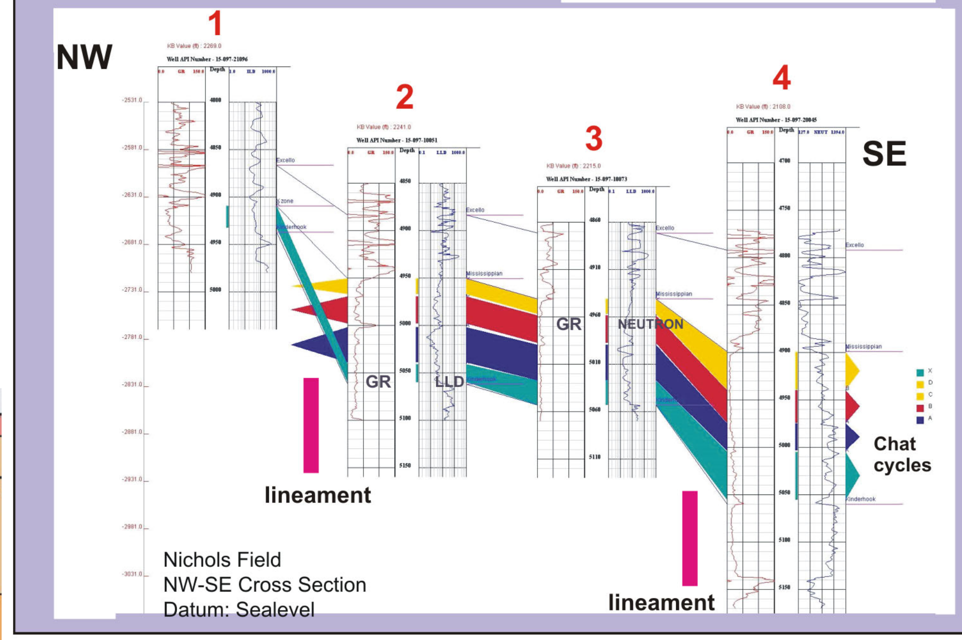


Glick Field is a prolific reservoir having produced in excess of 447 BCF of natural gas and over 683,000 barrels of oil. The field has been ascribed to a buildup of sponge spicules along the shelf margin and along the updip fringe of the Cowley Formation. The field is located along the subcrop of the Osage strata containing the sponge spicules. As in other locations, the “Chat” that is formed is an intensely weathered chert, in this area consisting of clean layered chert beds that accumulated to in excess of 150 ft (46 m) (see culmination of chert buildup in well B6 in accompanying cross section).

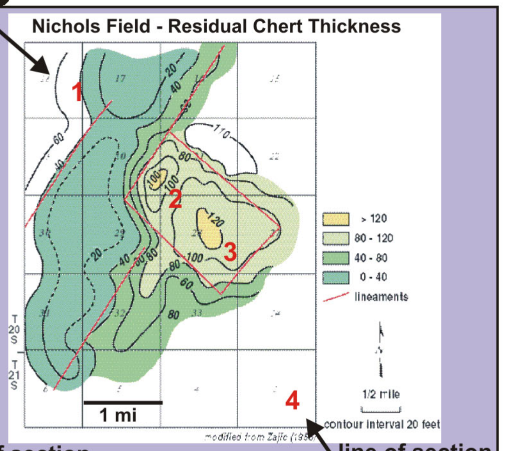


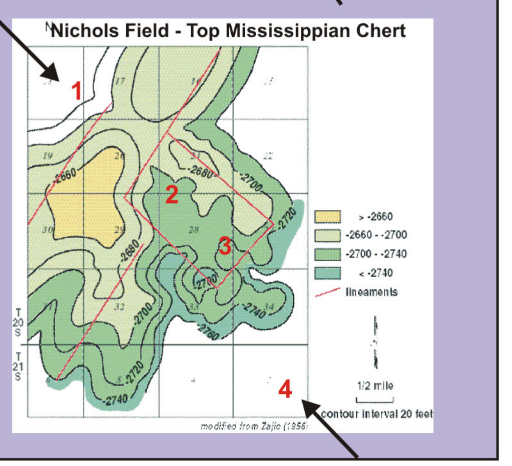
Nichols and Glick Fields, in proximity to each other, can be similarly re-interpreted as a response to shelf segmentation and structural block deformation. The accompanying cross sections in Nichols and Glick Fields show differential preservation of the “Chat” layers at the subcrop across “lineaments” drawn on maps and identified in the cross sections.

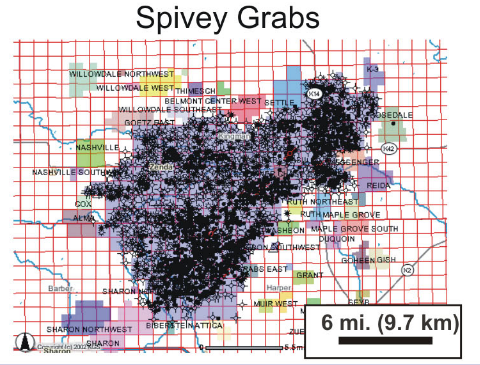


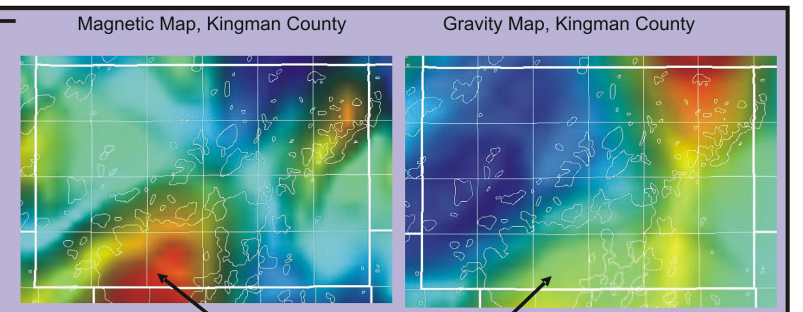


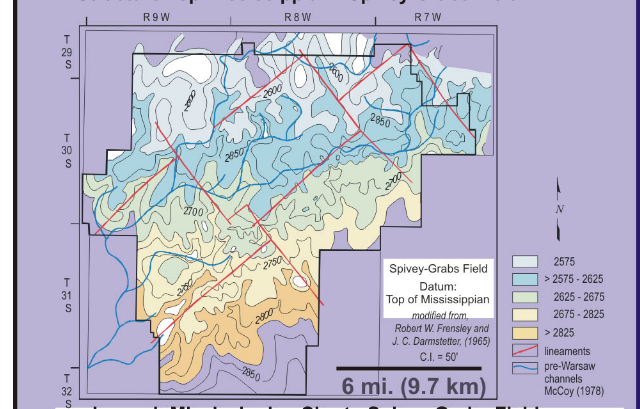
Nichols Field
NW-SE Cross Section
Datum: Sealevel

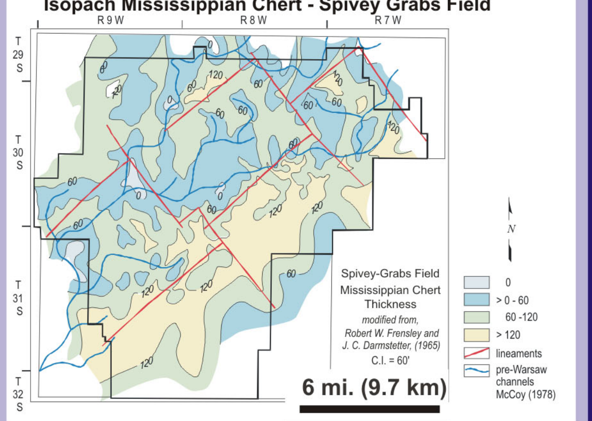


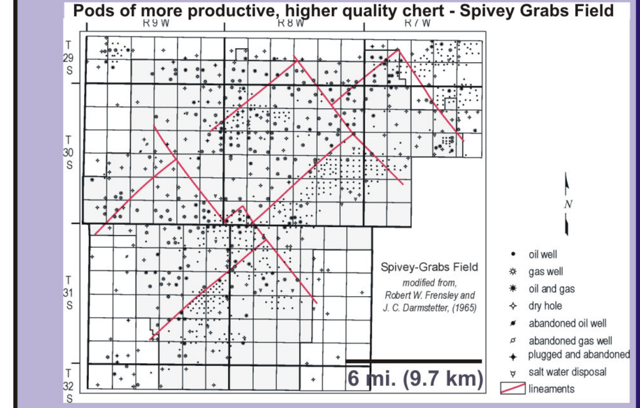






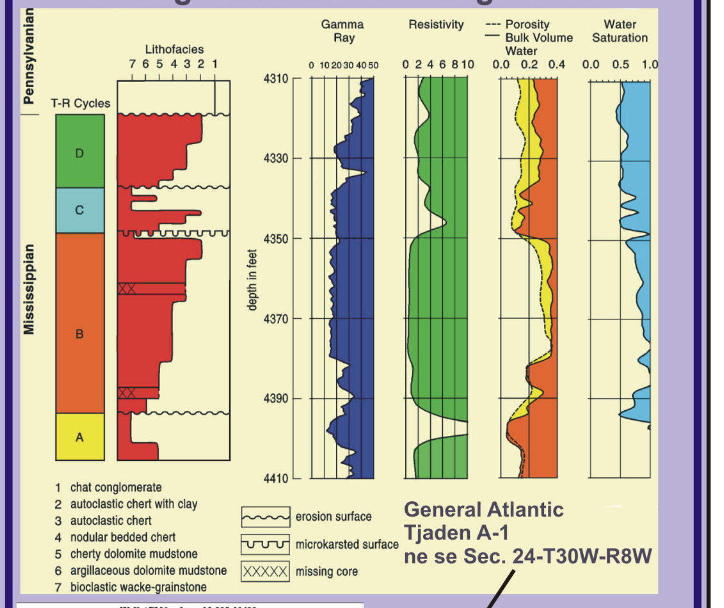




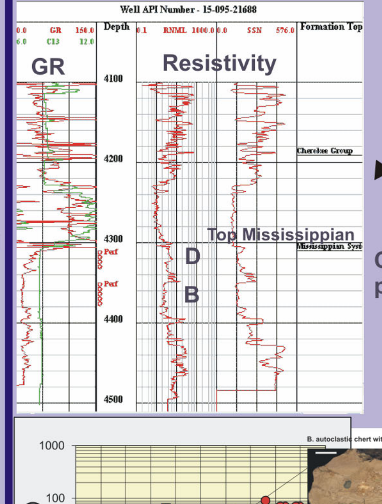


NW-SE lineaments
* structure, paleogeomorphology, diagenesis, reservoir chat

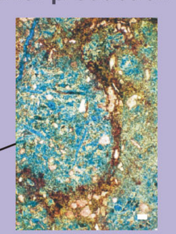
“Chat” depositional cycles seen throughout the shelf margin area

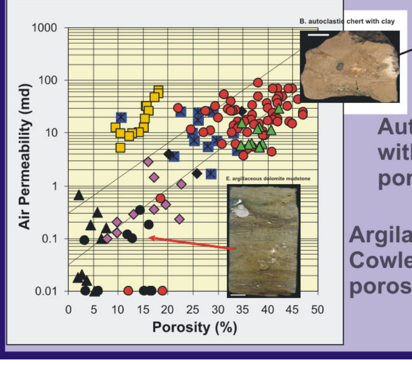


General Atlantic Tjaden A-1
ne se Sec. 24-T30W-R8W



Chat cycles D and B are perforated for production



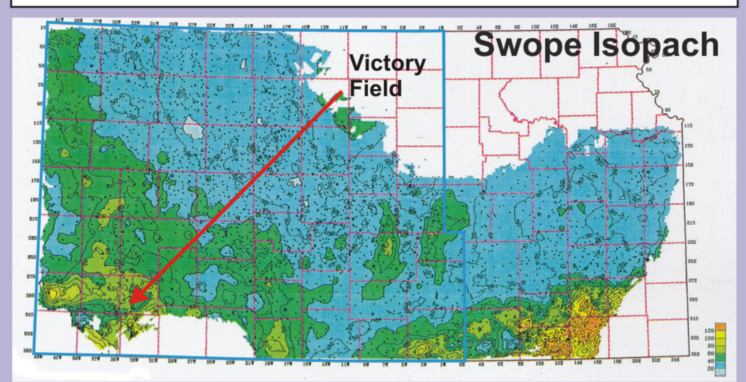


Autoclastic Chert with clay - high porosity and permeability

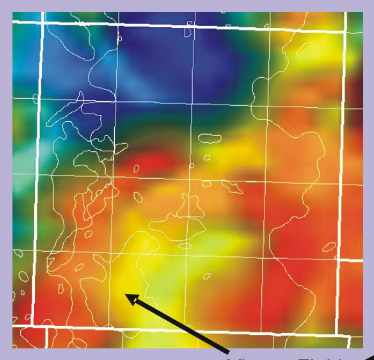
Argillaceous unweathered Cowley Formation - low porosity and permeability

Pennsylvanian Field Example - Lower Shelf

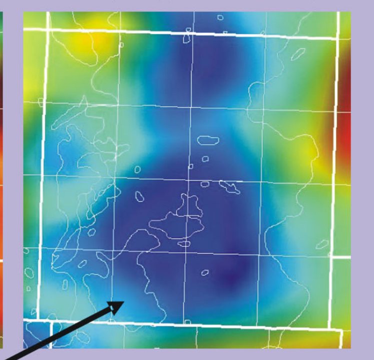
Information is shown below that it is another example of structural reactivation following an apparent basement template that has persisted through at least 10’s of millions of years including affecting the accumulation of oolitic grainstones, the primary reservoir rock in this field.



Magnetic Map, Haskell County

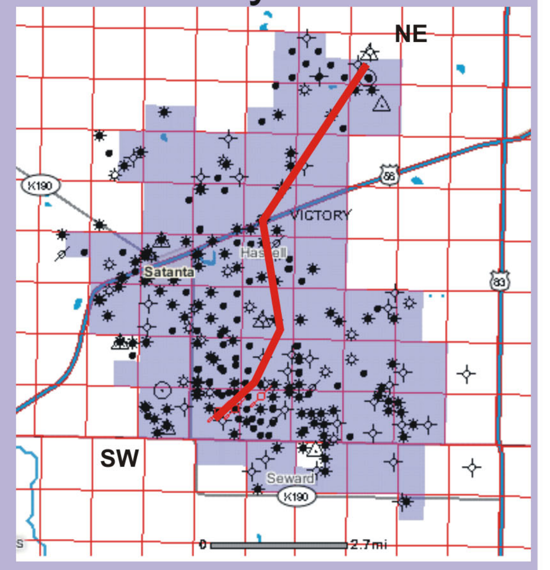


Gravity Map, Haskell County



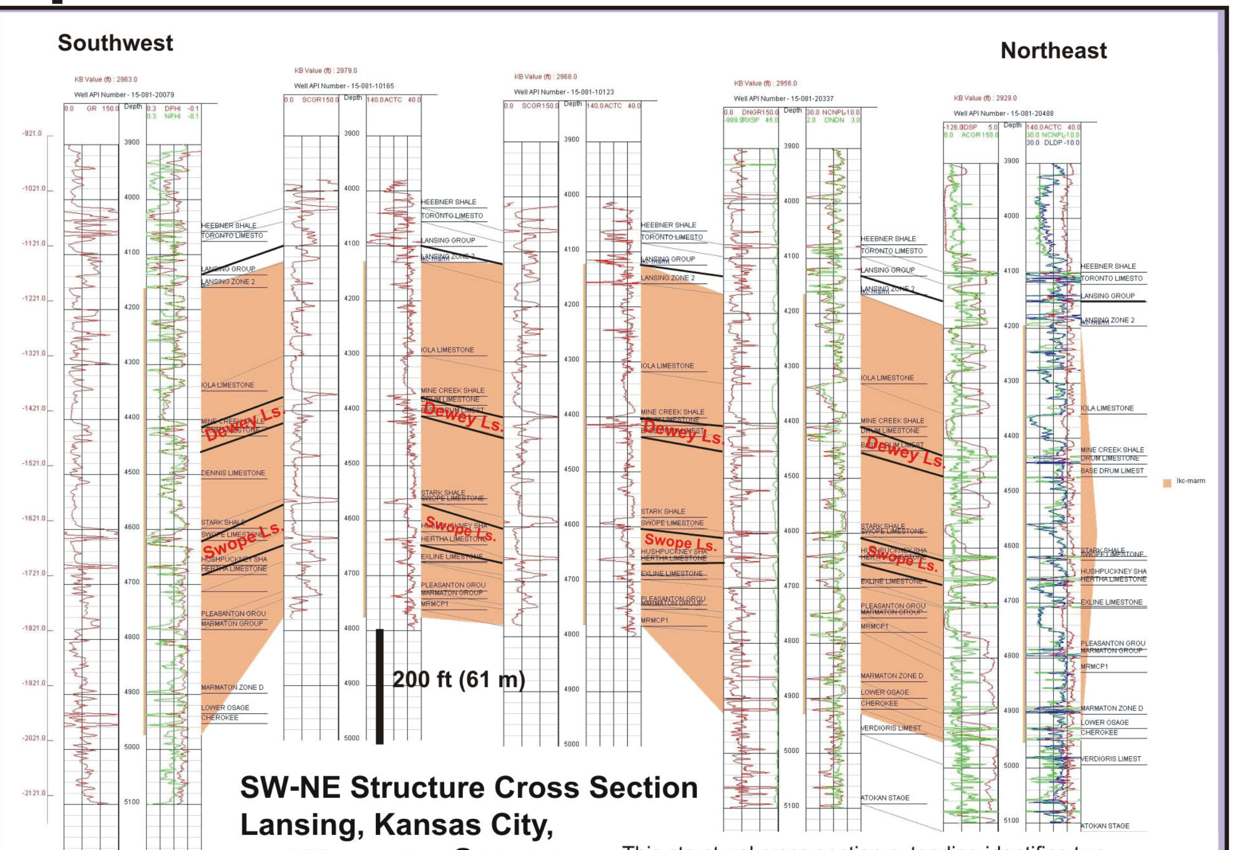
Victory Field

Victory Field



5 miles (8 km)

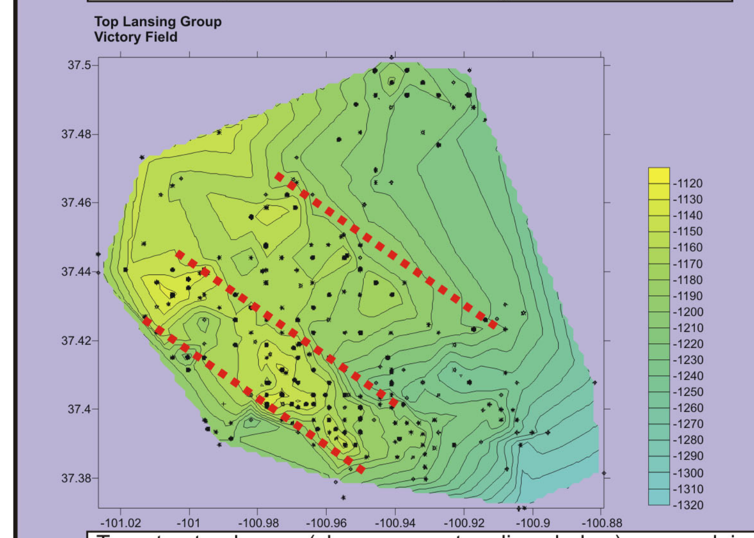
Victory Field is a large oil and gas field having produced over 54 BCF gas and 12.5 MBO. A considerable amount of oil may still be behind pipe, making fields like this lucrative to further exploit.

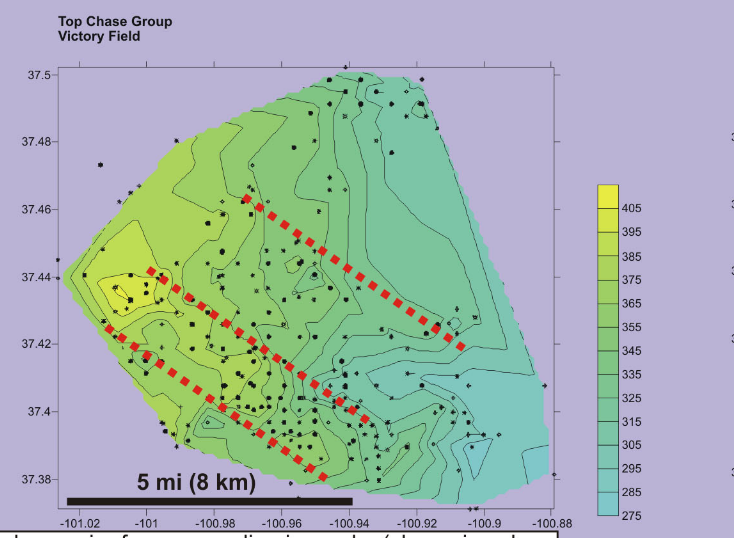


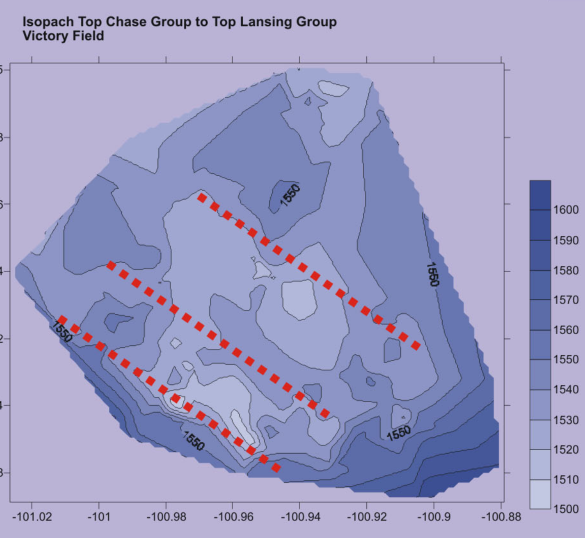
SW-NE Structure Cross Section
Lansing, Kansas City, and Marmaton Groups

This structural cross section extending identifies two reservoirs that are mapped lower in this panel, the Dewey Limestone and the Swope Limestone. Both carbonate reservoirs are oolitic grainstones but distinguished by contrasting geometries as a result of different responses to variations in structural deformation and sea level.

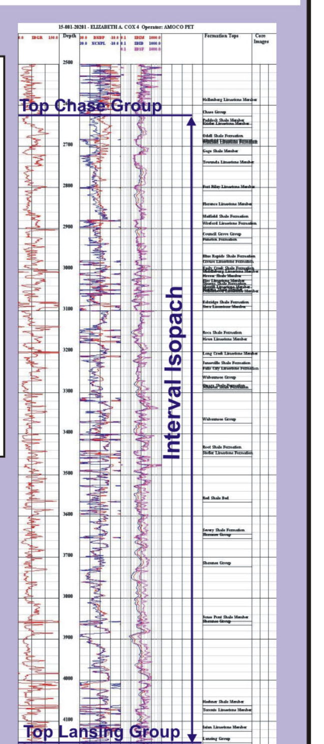
Structure maps of the tops of the Lansing and Chase Groups



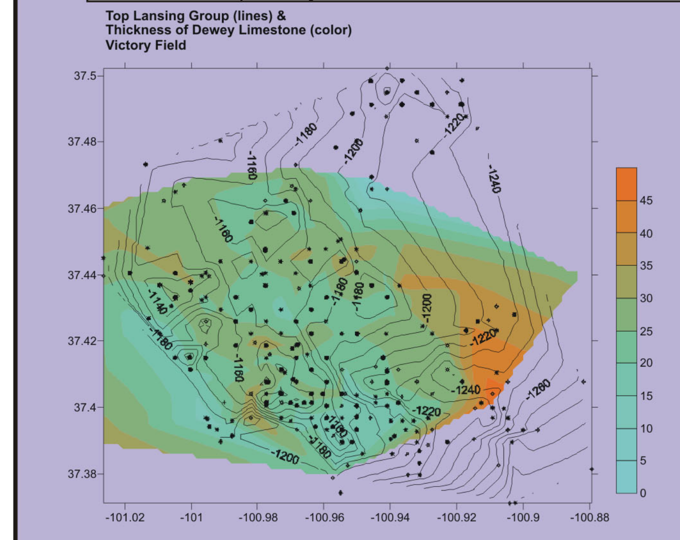


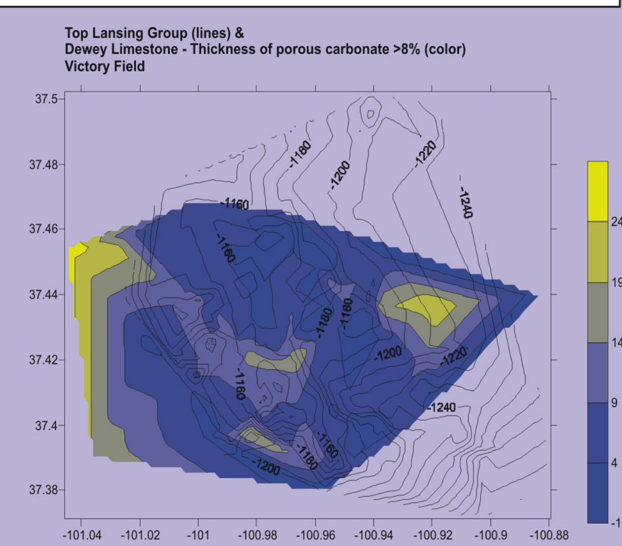


Structural configuration compared to isopach of the interval between these horizons, showing persistent thinning corresponding to structurally high locations at both horizons. This strongly suggests structural reactivation along same sites of a basement feature during this time interval **spanning nearly 30 Ma.**



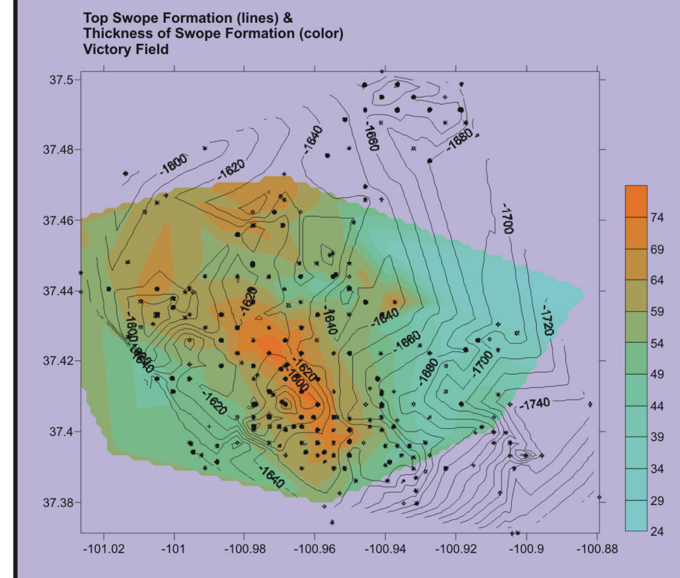
Two structural maps (shown as contour lines below) are overlain by a pair of corresponding isopachs (shown in color fill): 1) thickness of 4th-order scale Dewey and Swope Limestone formations and 2) thickness of porous carbonate in excess of 8% porosity within each of these units.

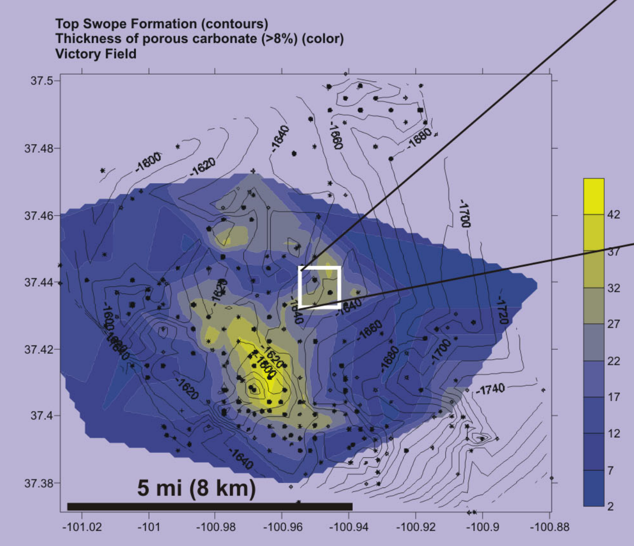


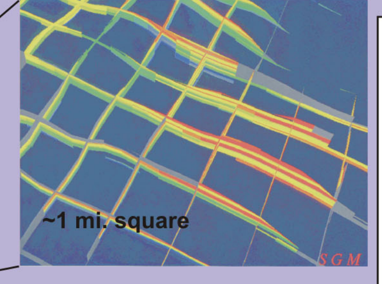


Interpretation: Both sets of isopach data correlate with current structure, but contrast between each other. The Swope Limestone resides near the base of a 3rd-order sequence set (Watney et al., 1995) when shelf margin stacking indicates sea level conditions were relatively high. The isopachs of the Swope Limestone show notable thickening at the crest of the anticline. The inferred positive bottom topography led to a locus for high-energy shoal conditions and the buildup of oolitic grainstone. Smaller-scale cycles suggested from core may help to explain in excess of 40 ft (12 m) of porous grainstone accumulation in the Swope Limestone.

In contrast, the Dewey Limestone resides at the top of the same 3rd-order sequence set and shelf margin stacking suggests relatively lower sea level conditions. This probably accounts for the thinning of the interval over the crest of the structure with a broader distribution of porous carbonate.

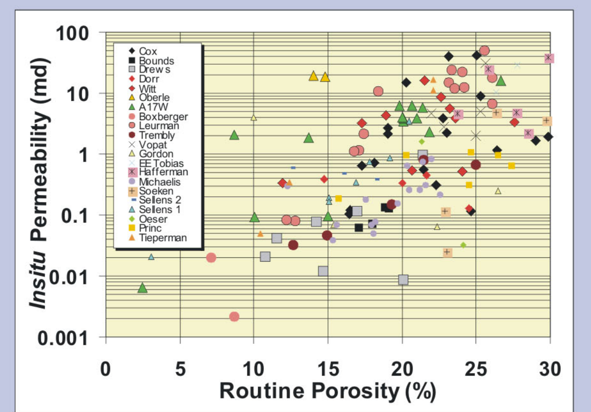






Stratamodel 3D display of porous carbonate with red representing higher porosity and yellow indicating lower values. Oolite is layered in this area and the oolite geobody extends down the flank of the structure.

Crushing or dissolution enhanced oomoldic pores required to create permeable, economic reservoir rock. Example shows oomoldic and fractured oomoldic limestone from the Swope Limestone in Victory Field. This zone produces in this well, the Amoco Cox #A-4.



While effective porosity is highly dependent on the presence of oolitic grainstone, the impact of diagenesis and structure to make oomoldic pores permeable through crushing or vug development can not be overemphasized. The porosity-permeability crossplot shows three orders of magnitude change in permeability at a given porosity. Factors leading to enhanced dissolution and crushing are still poorly understood. Pay cutoffs for Pennsylvanian highly oomoldic rocks has been empirically been defined as:

Phi = 17%
Sw = 0.55
Vsh = 0.3
BVW = 0.97

with Archie water saturation parameters:

cementation exponent, m = 3.5 (reflecting complex pore throats)
saturation exponent, n = 2

Summary and Conclusions

Mississippian and Pennsylvanian shelf margin to inner shelf carbonate settings were affected by subtle, but important block faulting and contemporaneous and recurrent tectonism of 1-10’s of km on the northern Midcontinent U.S.A.
Structural activity during active foreland basin development has demonstrably impacted reservoir development in shelf areas by creating localized lineaments and faults. The recurring nature of these structures often leads to stacked pays through time. Reservoir types examined range from accumulation of sponge spicule-rich Cowley and Osage Middle Mississippian (in Nichols, Glick, and Spivey Grabs Fields), to oolitic reservoirs in Middle and Upper Pennsylvanian (in Dickman and Victory Fields).

Areas of large to small scale structural reactivation through time are predictable.
Large, prominent, named structures have often been shown to have antecedent components, but application to extensive shelf segmentation and sedimentation has not been clearly stated or systematically assessed except in a few instances -- Ettensohn et al., 2004 in Ordovician Trenton carbonates along growth faults; measuring “structural gradient” in plains folding (Merriam, 1993); Paleozoic structures of Gerhard (1977,1982, 1987, 2004); Cretaceous seaway structures contemporaneous with deposition (Weimer, 1984; 1986); Lower Carboniferous ramp and links to basement reactivation, Canada (Brandley et al., 1996). As observed in this study, the shelf segmentation extends to smaller systems including play and field scale.

Faulting is closely linked to reactivation of basement lineaments.
Basement geology and geophysics suggest a template of lineaments that apparently represent structural weaknesses. These weaknesses are apparently more easily strained by nearby and deep-seated tectonic stresses that were active during plate convergence and mountain building in the Pennsylvanian and Mississippian in the Midcontinent U.S.A. Interpretations of potential fields data can provide possible templates for structures that were active at any given time.

Block faulting influenced locations of shelf edges and caused segmentation of the ramp/shelf profile.
Shelf edges are linear and those of the Mississippian and Pennsylvanian closely coincide with one another in south-central Kansas suggesting a common control. Basement lineaments also coincide with the shelf margins and thus are deemed an important control. Block faulting and segmentation of the inner shelf is more difficult to demonstrate due to more subtle deformation and episodic response. Yet, technologies such as 3D seismic can be used to reaffirm recurrent structural growth including that contemporaneous with deposition. Collectively the segmentation ranges in scale from km to 10’s of km affecting play characterization and reservoir prediction.

Distinct, localized differences in lithofacies, thicknesses, and strata architecture occur across faulted segments.
Strata and lithofacies changes across faults and lineaments can be pronounced and significant at the reservoir scale and important to understand in the development of predictive geologic models. Preferentially preserved, locus areas for thick accumulations of sponge spiculite and oolite reservoir deposits are demonstrated in this investigation. High resolution sequence stratigraphy coupled with 3D seismic can verify high resolution paleogeography.

Sea level, climate, depositional setting, and regional tectonics interacted with local paleotopography affected by contemporaneous structural movements to establish site specific conditions favorable for reservoir development.
Reactivated structures were an important control on depositional patterns, paleotopography, weathering intensity, and movement of fluids.

The recognition of reactivated structural areas and segmentation of the shelf as important elements for reservoir character are improving geomodels and prediction of reservoir quality for development of remaining oil and gas in Mississippian and Pennsylvanian reservoirs in this mature Midcontinent setting.