

# **Utilizing Aeromagnetism and Micromagnetism to Define Petroleum Reservoirs in the Denver, Forest City, and Cherokee Basins\***

**Steven Tedesco<sup>1</sup>**

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## **Abstract**

The use of aeromagnetism in petroleum exploration to define basement structural features has been well established. The use of micromagnetism to find petroleum reservoirs has been more controversial. The presence of magnetic minerals in the near surface has been related to seeping hydrocarbons depositing magnetic minerals under a variety of soil conditions. The literature has several case histories that show strong correlation between micromagnetic anomalies and existing oil fields. Discussed here will be aeromagnetic surveys and their micromagnetic derivative analysis over three areas in the Midcontinent, USA. One survey was flown over Lincoln County, Colorado, Denver Basin, where production is from 1.2 to 3 kilometers in depth; a second survey was flown over Anderson and Linn counties, Kansas, Forest City Basin, where production is from 45 to 760 meters in depth; and the survey was flown over an area in part of Brown County, Kansas, Forest City Basin, where production is from 800 to 1050 meters in depth. Primarily in Bourbon County, Kansas, Cherokee Basin, production is from historically shallow oil and gas zones in the Cherokee Group, Mississippian “Chat,” and CBM.

The aeromagnetic surveys defined basement features and in many cases imply fault systems that coincide strongly with existing oil fields both post- and pre-survey. The results of the aeromagnetic surveys and the derivative micromagnetic analysis is discussed along with problems, caveats, and ideas for going forward with this type of work.

## Selected References

- Baars, D.L., and W.L. Watney, 1991, Paleotectonic control of reservoir facies; *in* E.K. Franseen, W.L. Watney, C.G.St. C. Kendall, and W. Ross, editors, *Sedimentary Modeling: Computer Simulations and Methods for Improved Parameter Definition*: Kansas Geological Survey Bulletin 233, p. 253-262.
- Gerhard, L.C., 2004, A New Look at an Old Petroleum Province, Kansas Geological Survey, Bulletin, 250, part 2, 27p. Website accessed March 15, 2017, <http://www.kgs.ku.edu/Current/2004/Gerhard/>.
- Kruger, J.M., 1996, 1997, On-line gravity and magnetic maps of Kansas: Kansas Geological Survey, Open-file Report, no. 96-51, updated 1997. Website accessed March 15, 2017, <http://www.kgs.ku.edu/PRS/PotenFld/potential.html>.
- Kruger, J.M., W.L. Watney, and R.A. Olea, 1999, Use of gravity and magnetics for low-cost exploration and development in mature areas such as Kansas, *in* D.F. Merriam, editor, *Geoscience for the 21st century*, transactions of the 1999 American Association of Petroleum Geologists, Midcontinent Section Meeting: Kansas Geological Survey, Open-file Report No. 99-28, p. 51.
- Sims, P.K., R.W. Saltus, and E.D. Anderson, 2005, Preliminary Precambrian Basement Structure Map of the Continental United States – An Interpretation of Geologic and Aeromagnetic Data: Open-File Report 2005-1029, 31p. Website accessed March 15, 2017, <https://pubs.usgs.gov/of/2005/1029/pdf/OFR-1029.pdf>.
- Watney, W.L., E.K. Franseen, A.P. Byrnes, and S.E. Nissen, 2006, Evaluating Structural Controls and Their Role in Forecasting Properties of Phanerozoic Rocks in the Northern Midcontinent, U.S.A. – Ancient Examples and Modern Analogs: KGS Open-File Report 2006-19, 91p. Website accessed March 15, 2017, [http://www.kgs.ku.edu/PRS/publication/2006/2006-19/2006\\_19.pdf](http://www.kgs.ku.edu/PRS/publication/2006/2006-19/2006_19.pdf).

## Website

<http://www.promapcorp.com/PRODUCTION-MAPS.html>. Website accessed March 15, 2017.

# *Utilizing aeromagnetics and micromagnetics to define petroleum reservoirs in the Denver, Forest City and Cherokee basins*

Presented by:

Dr. Steven A. Tedesco

Running Foxes Petroleum Inc.



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The use of aeromagnetism in petroleum exploration to define basement structural features has been well established. The use of micromagnetism to find petroleum reservoirs has been more controversial. The presence of magnetic minerals in the near surface has been related to seeping hydrocarbons depositing magnetic minerals under a variety of soil conditions. The literature has several case histories that show strong correlation between micromagnetic anomalies and existing oil fields. Discussed here will be aeromagnetic surveys and their micromagnetic derivative analysis over three areas in the Midcontinent, USA. One survey was flown over Lincoln County, Colorado, Denver Basin, where production is from 1.2 to 3 kilometers in depth; a second survey was flown over Anderson and Linn counties, Kansas, Forest City Basin, where production is from 45 to 760 meters in depth; and the survey was flown over an area in part of Brown County, Kansas, Forest City Basin, where production is from 800 to 1050 meters in depth. Primarily in Bourbon County, Kansas, Cherokee Basin, production is from historically shallow oil and gas zones in the Cherokee Group, Mississippian "Chat," and CBM.

The aeromagnetic surveys defined basement features and in many cases imply fault systems that coincide strongly with existing oil fields both post- and pre-survey. The results of the aeromagnetic surveys and the derivative micromagnetic analysis is discussed along with problems, caveats, and ideas for going forward with this type of work.

# Purpose of Using Aeromagnetics

- To define general fault trends, horsts and grabens;
- Faults are the conduits for petroleum migration;
- Faults may be water-bearing – production from certain reservoirs need to avoid them;
- Provide target areas for seismic and surface geochemistry;
- Part of the regional geologic picture.

# What's Needed Other Than Aeromagnetics

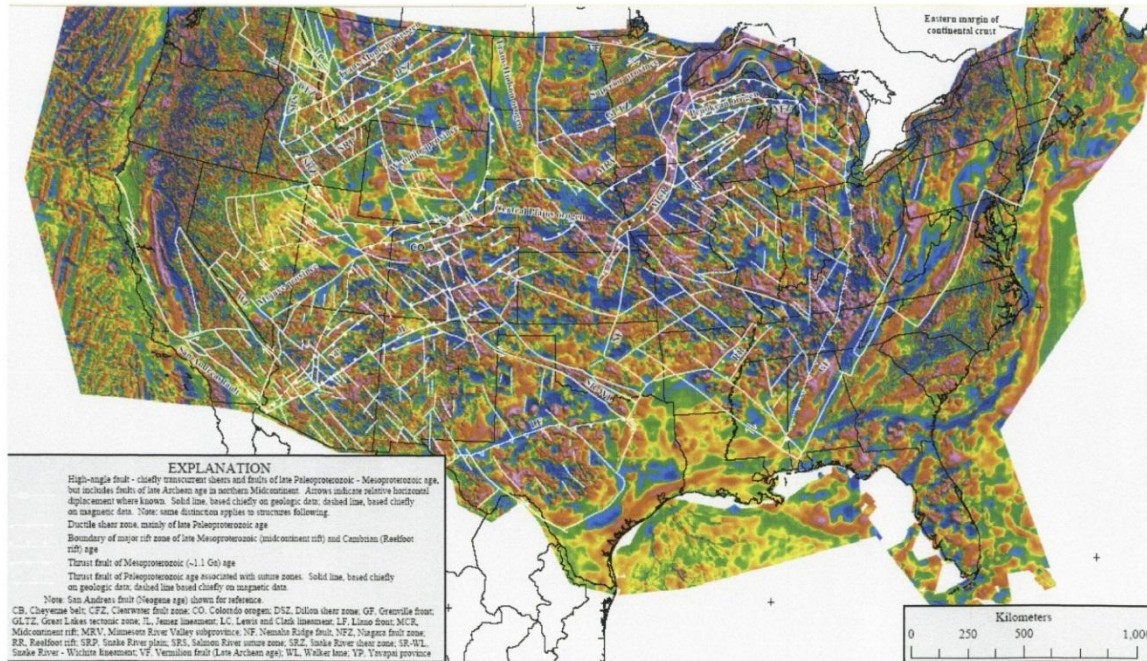
- Source Rock;
- Timing of Generation;
- Reservoir;
- Basement or aeromagnetic faults act as conduits for petroleum migrating into the traps.

# Types of Aeromagnetics

- Regional – widely spaced line data available from the USGS
- Proprietary surveys with tighter grid – still regional
- Detail grid with very tight spacing  $\frac{1}{4}$  mile or less

# Regional Aeromagnetics Map of the US

## Preliminary Precambrian Basement Structure Map of Continental U.S. -- An interpretation of Geologic and Aeromagnetic Data

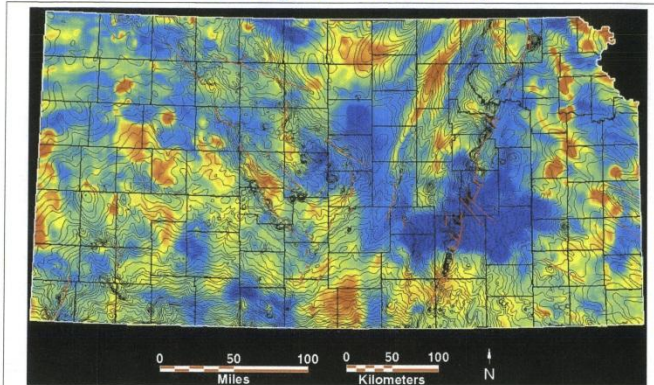


Sims, Saltus, and Anderson (2005)



# Regional Kansas Aeromagnetics

Total Magnetic Field Intensity

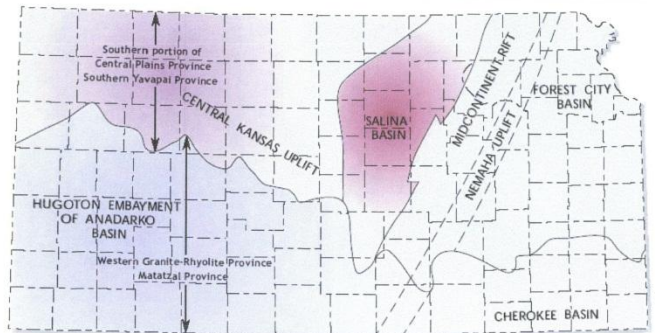


Kruger (1997)

Contours = Precambrian surface isochores

Red = high mag.  
Blue = low mag.

## Basement Structures and Terranes



granitic and metamorphic rocks

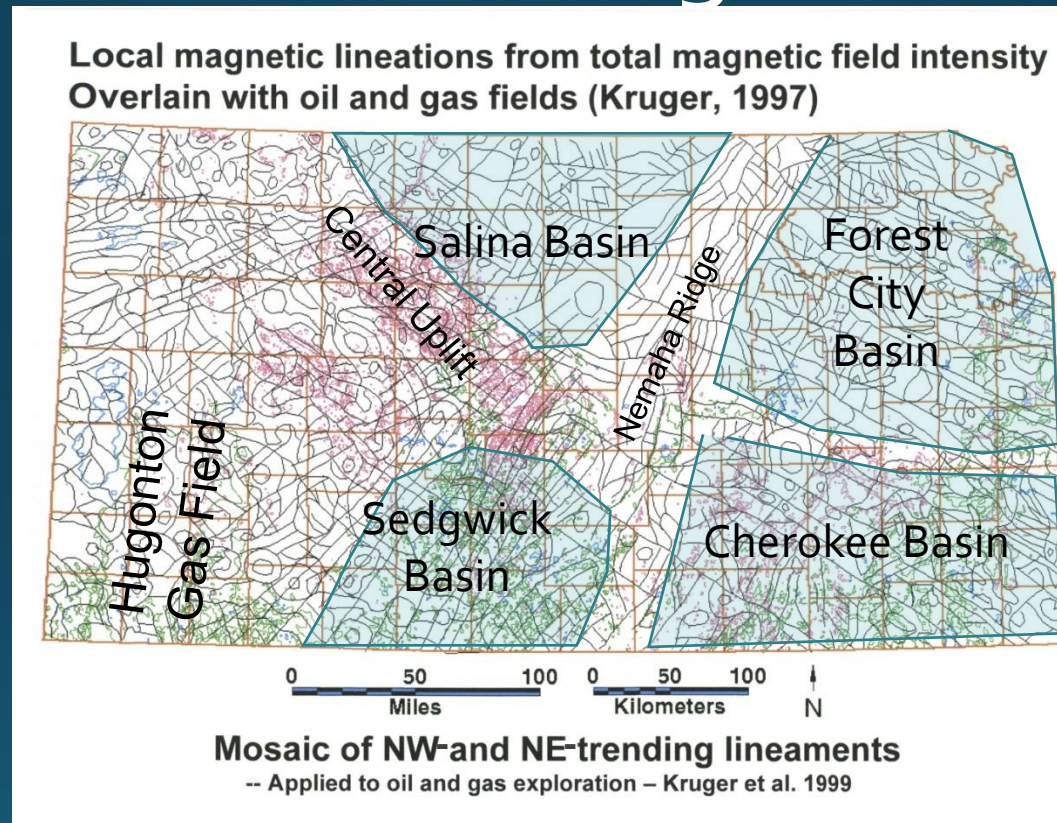
approximately 1.6 billion years old  
approximately 1.4 billion years old

Central North American rift  
approximately 1.1 billion years old

Gerhard (2004)

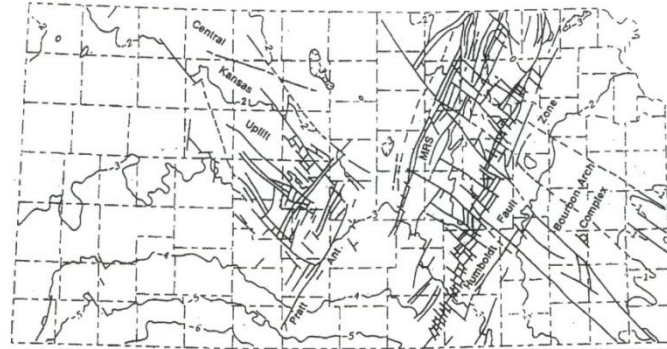
From the KGS website: [www.kgs.ku.edu](http://www.kgs.ku.edu)

# Lineaments derived from Landsat and aeromagnetics

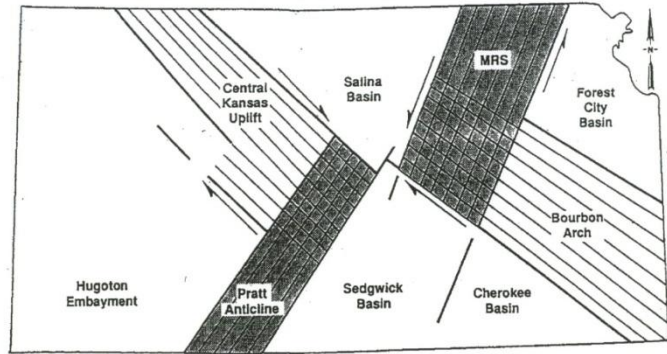


From the KGS website: [www.kgs.ku.edu](http://www.kgs.ku.edu)

# Fault Systems of Kansas



Configuration of the Precambrian Surface  
*(well based)*

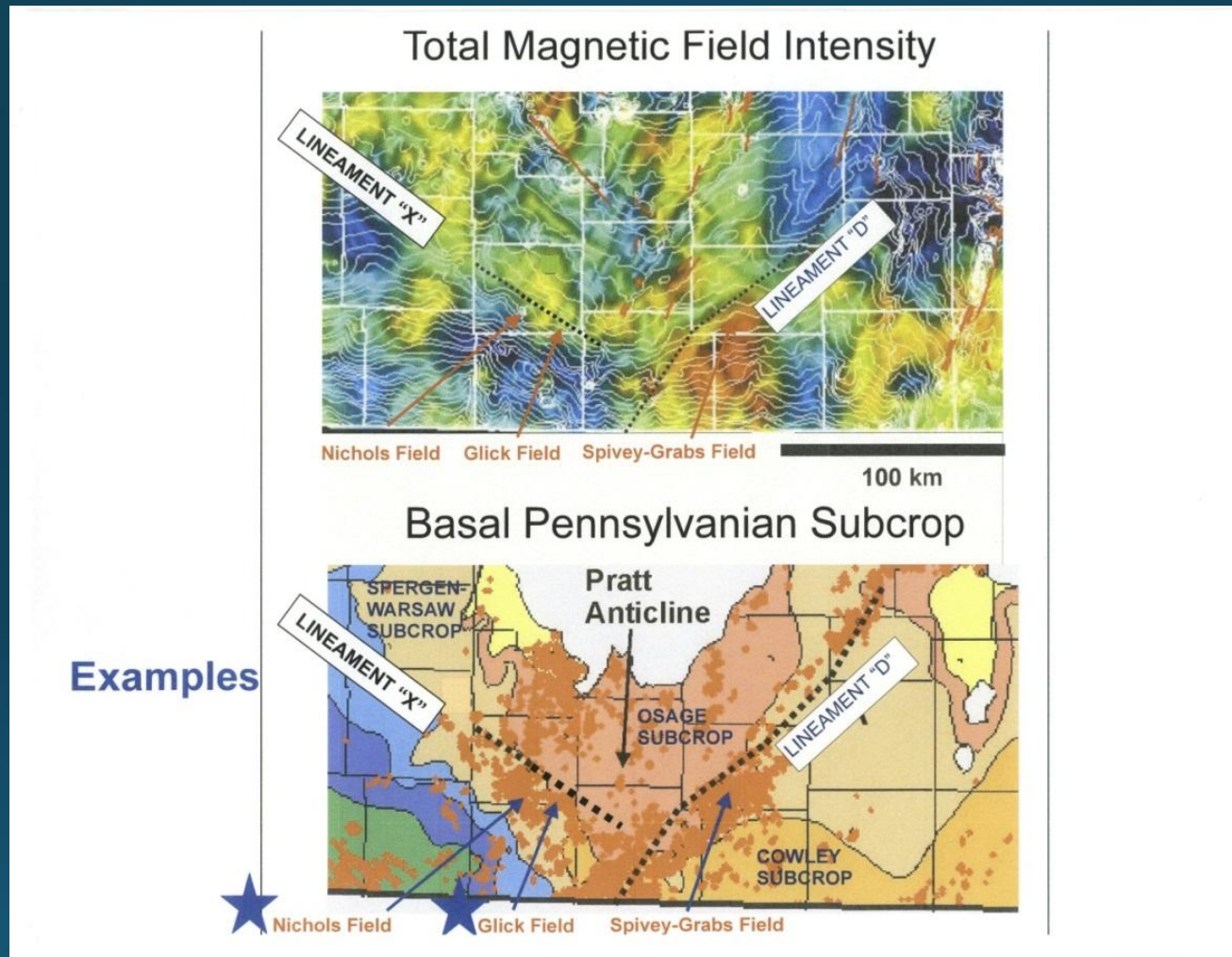


Precambrian structural domains and strain behavior – wrench faulting?

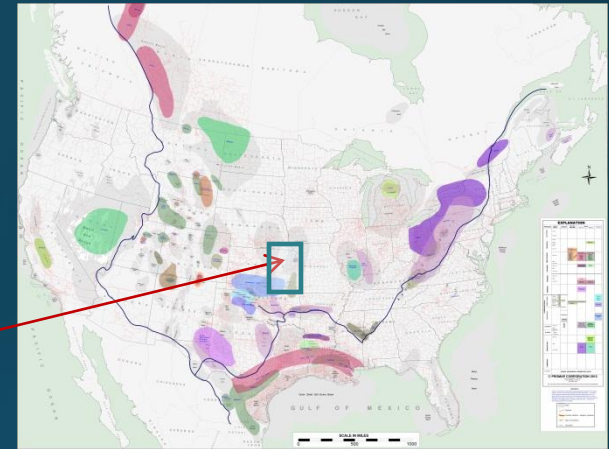
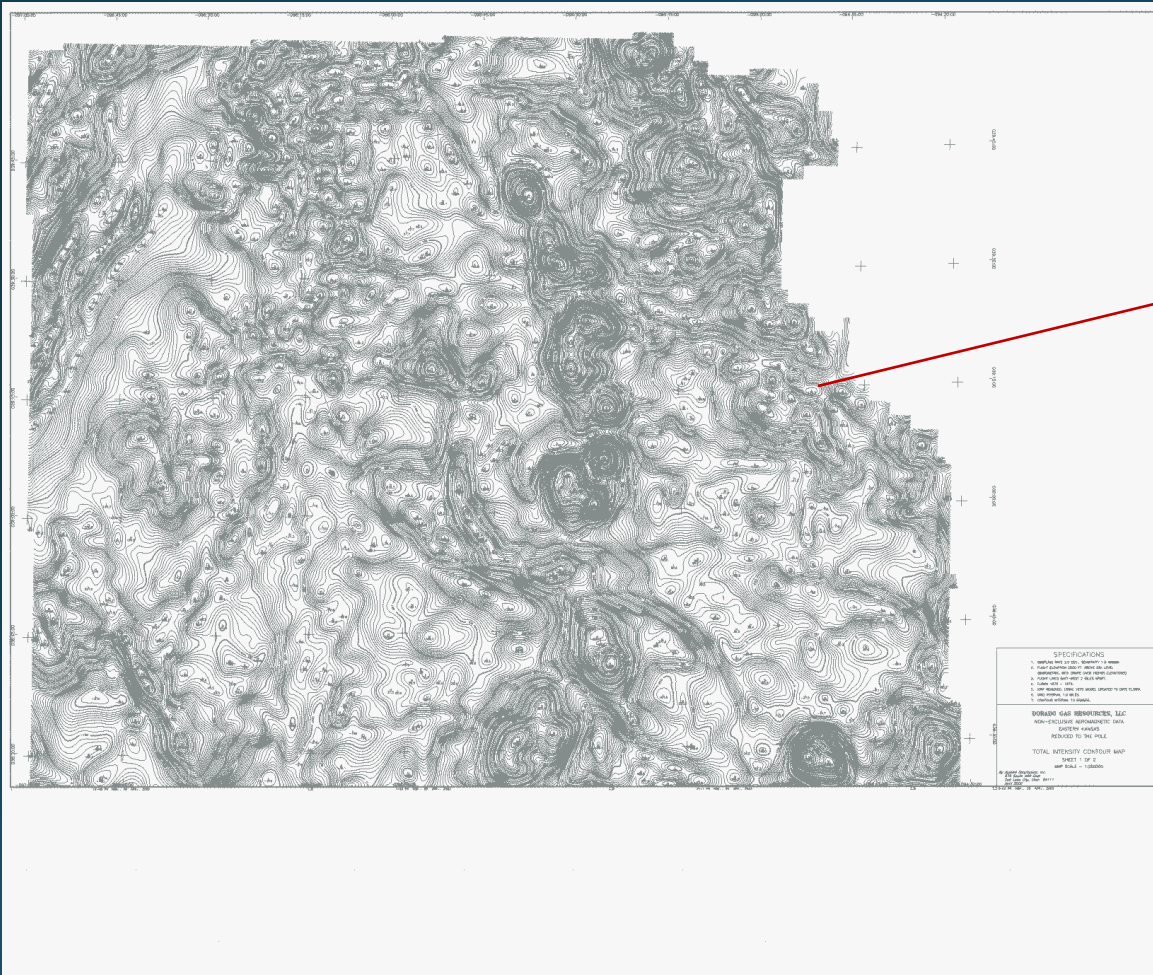
Baars and Watney (1991)

From the KGS website: [www.kgs.ku.edu](http://www.kgs.ku.edu)

# Use of Regional Data



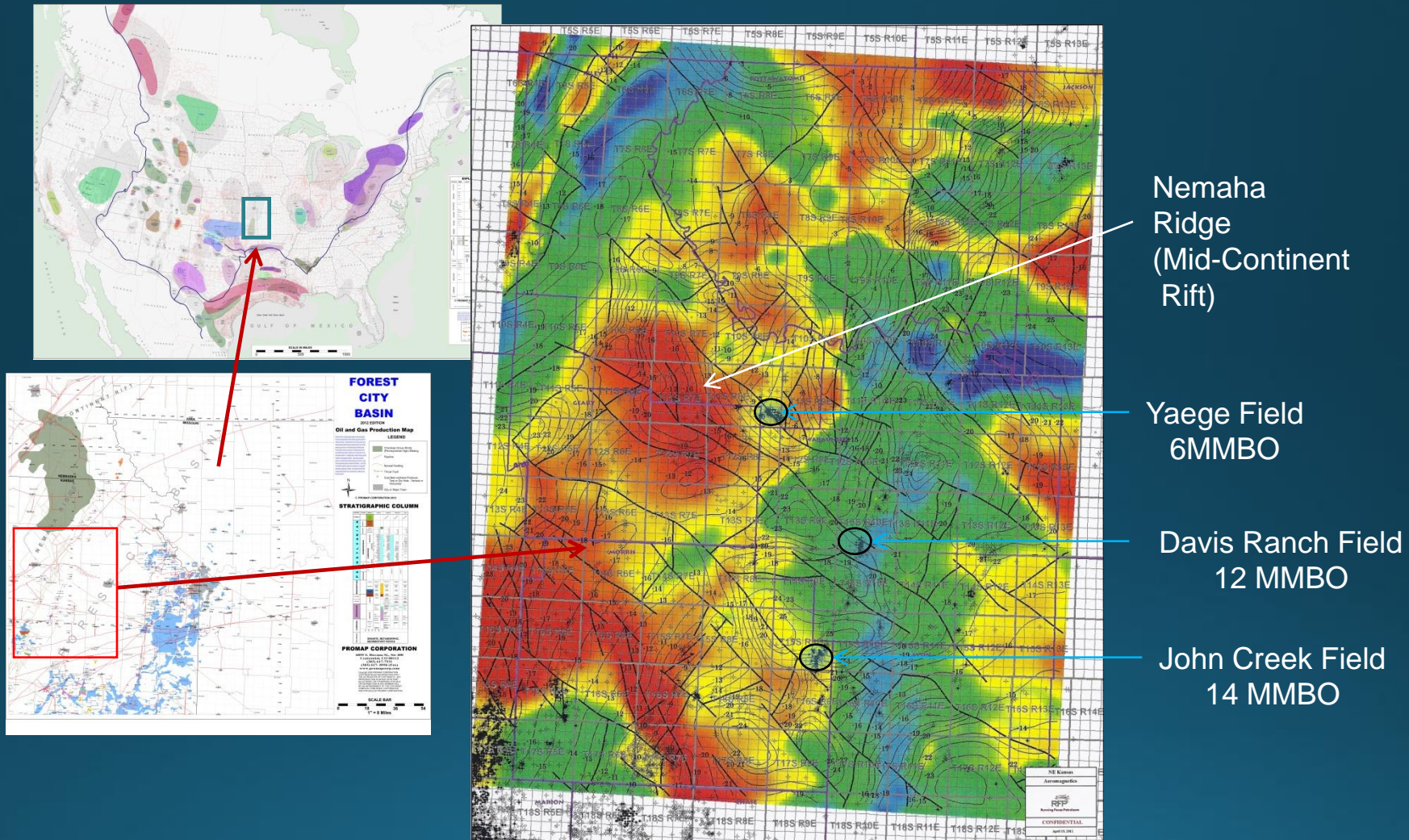
# Eastern Kansas Total Magnetic Field – Using Regional Data USGS



Unconventional Shale,  
CBM and Other Plays in  
the US

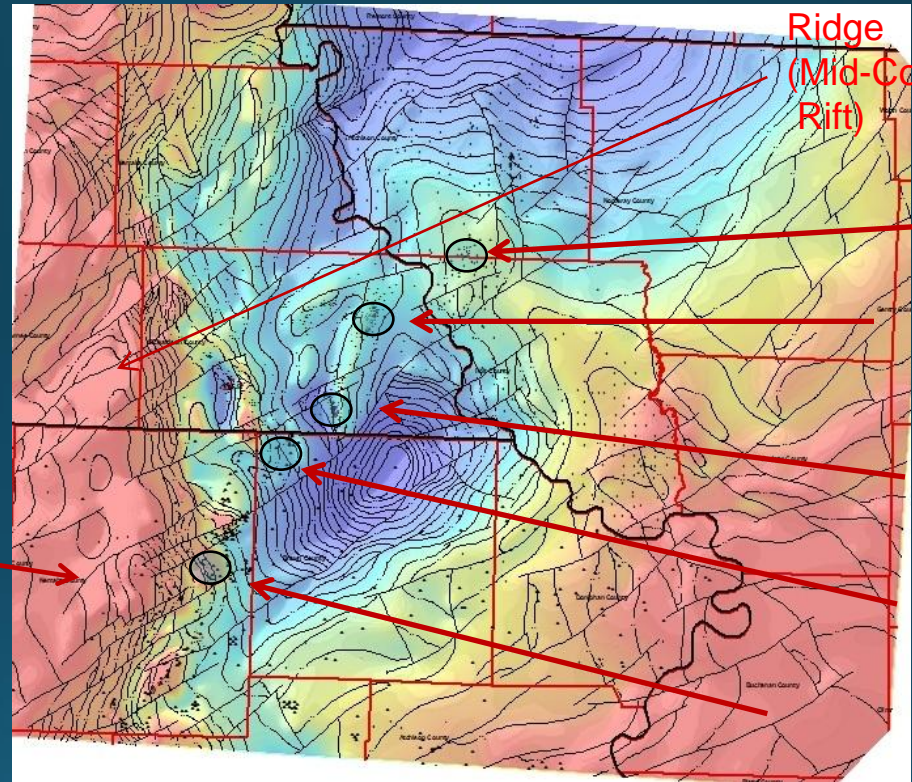
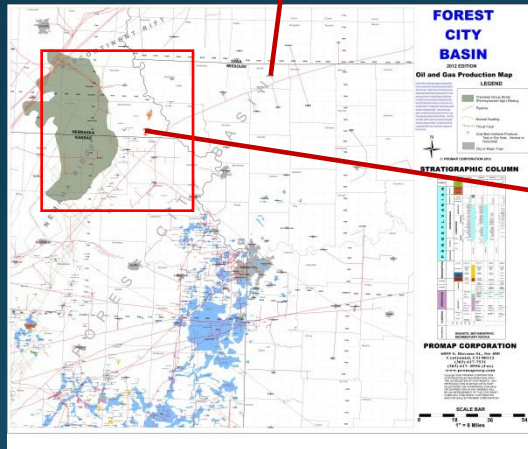
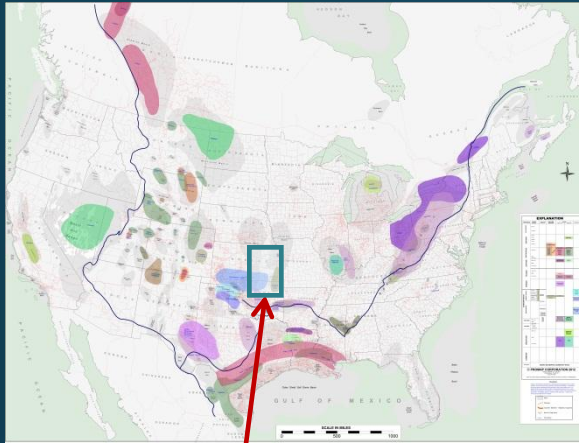
([www.promapcorp.com](http://www.promapcorp.com))

# Southern Forest City Basin – Nemaha Ridge



Source of data: USGS; Fault Interpretation by Earthfield Technologies of Houston, Texas

# Northern Forest City Basin – Nemaha Ridge



Nemaha  
Ridge  
(Mid-Continent  
Rift)

Runamuck  
Field  
200+ MBO

Falls City  
Field  
3+ MMBO

Barada Field  
3+ MMBO

Livengood  
Field  
300 MBO

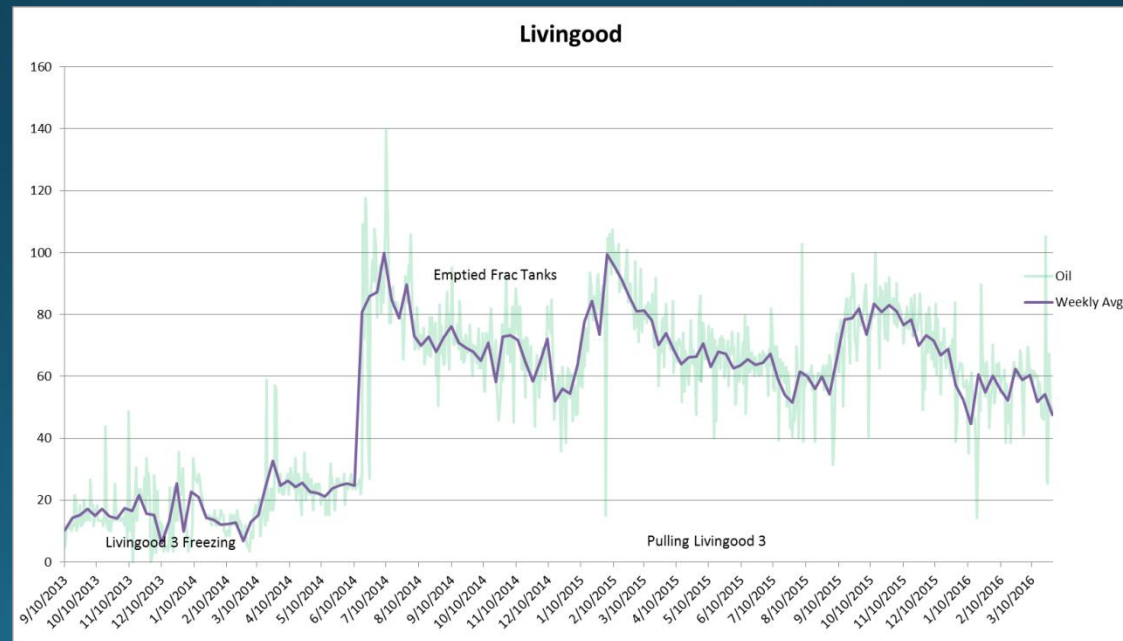
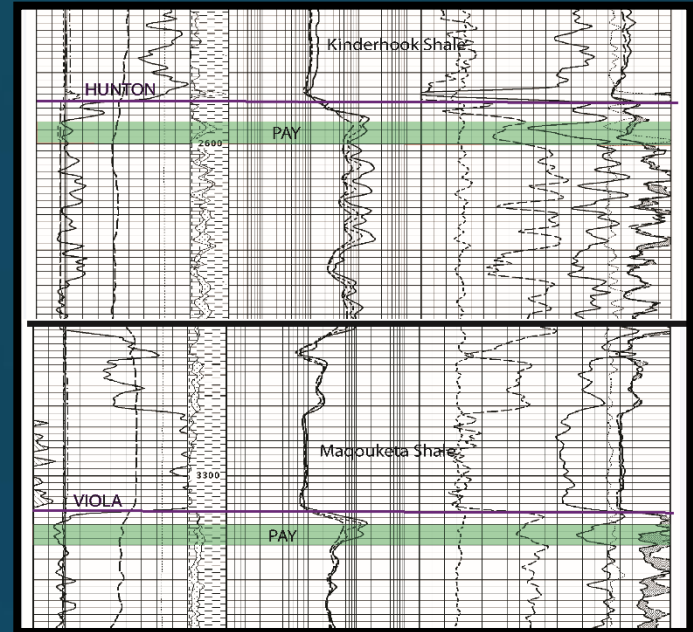
McClain Field  
3+ MMBO

Source of data USGS; Fault Interpretation by Earthfield Technologies of Houston, Texas

# Livengood Field

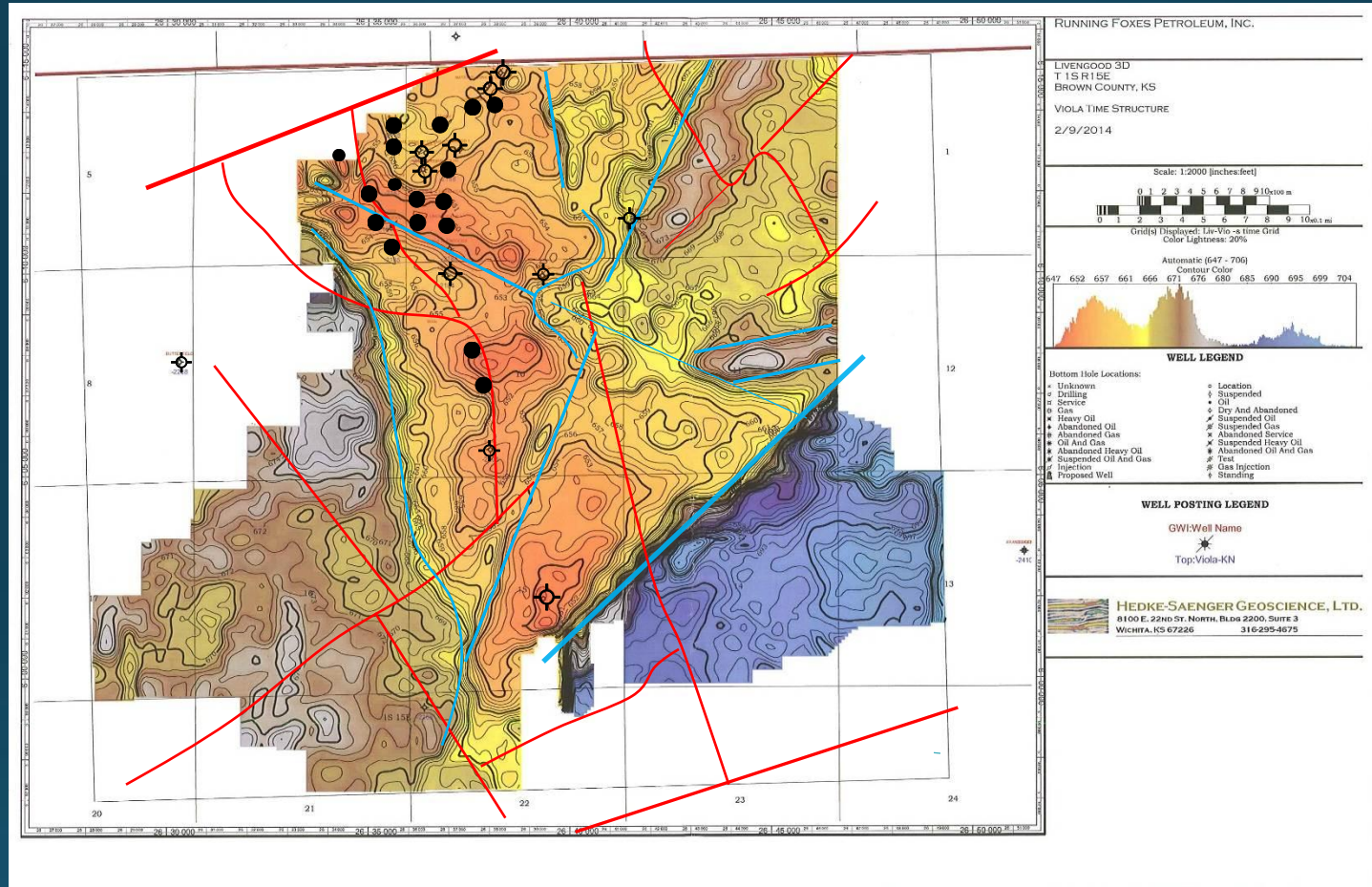
Discovered in 1944

Viola and Hunton Production

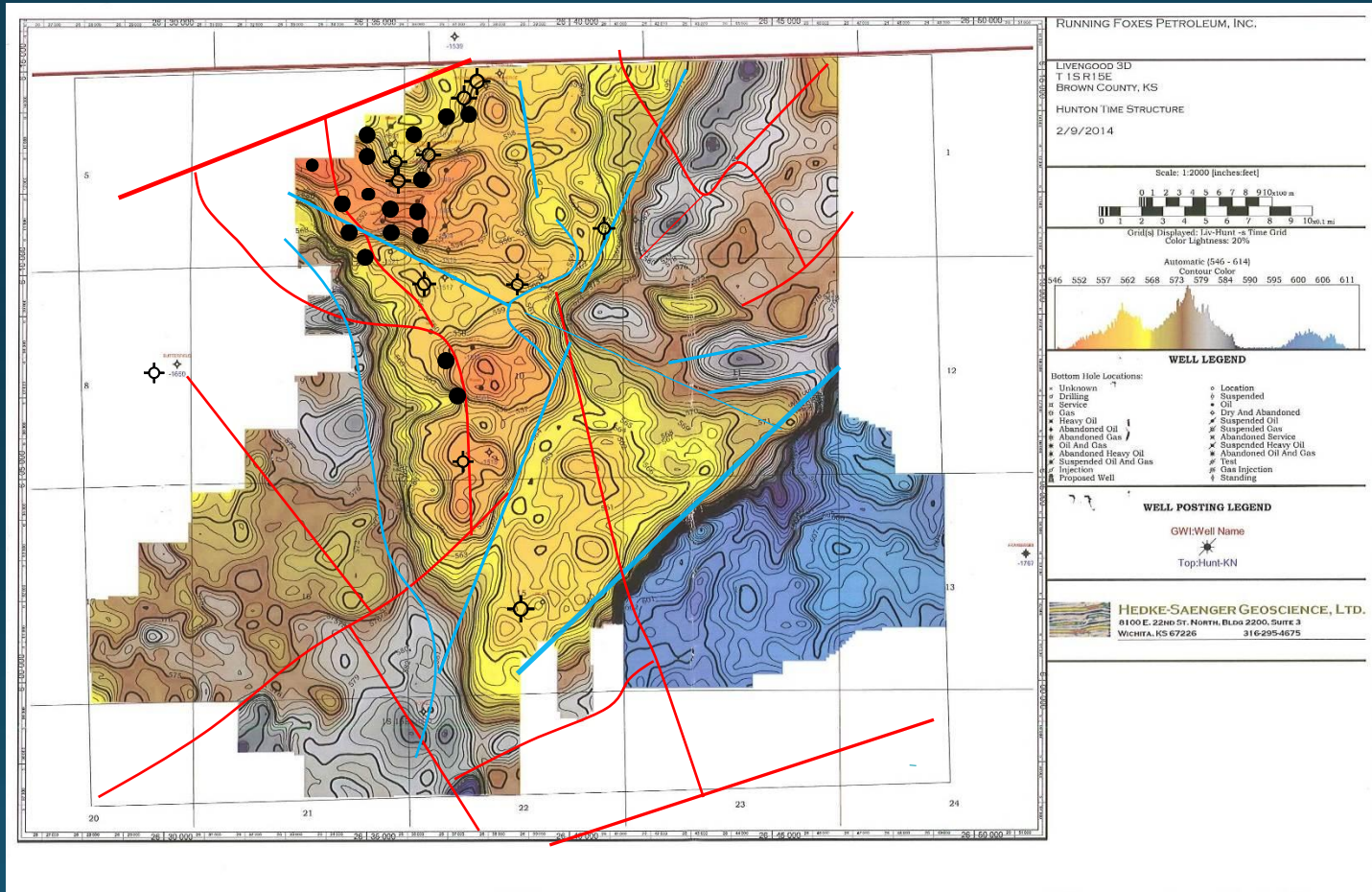




# Livengood Area Viola Time Structure and Basement Faults (5Km)



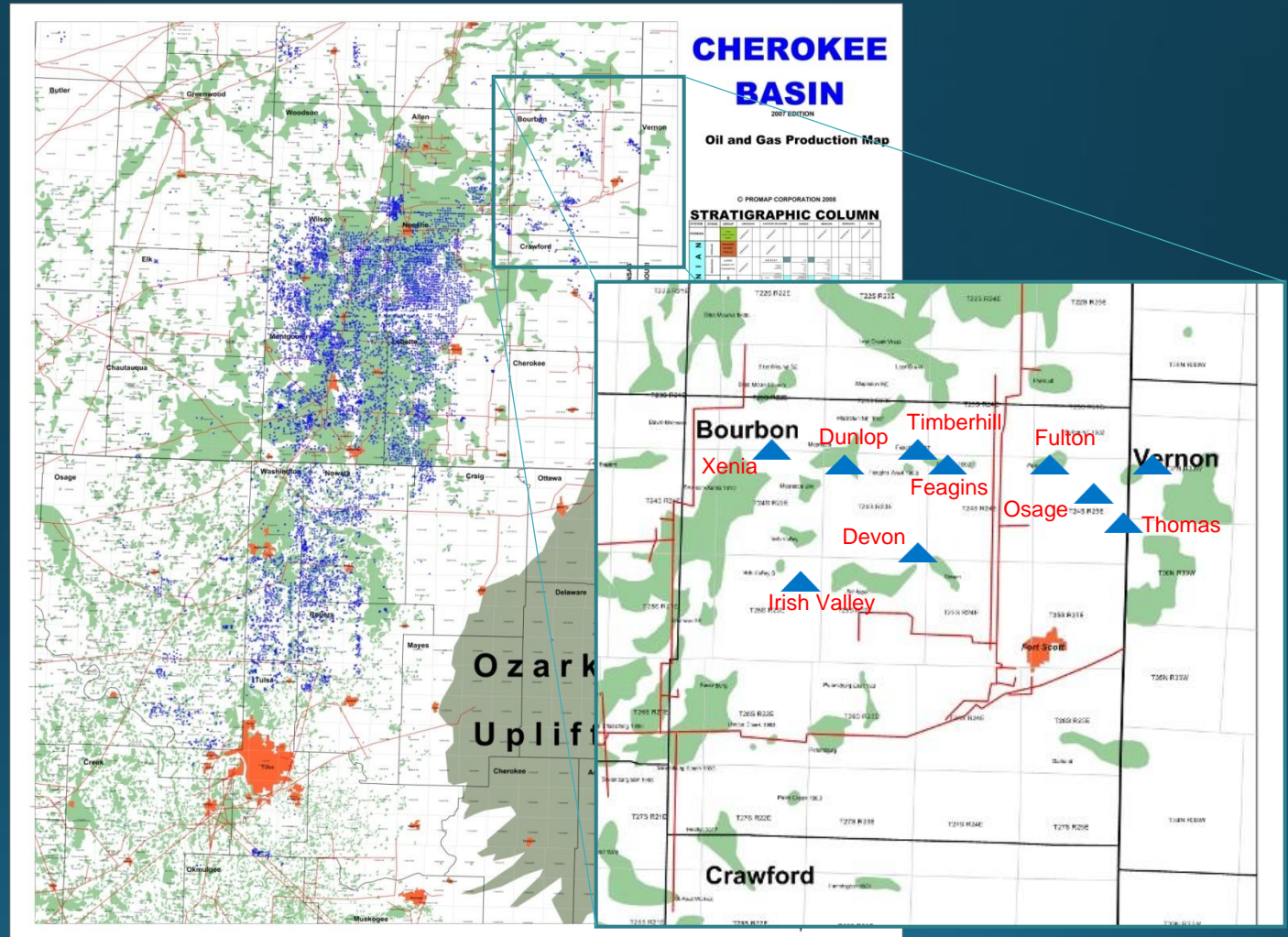
# Livengood Area Hunton Preliminary Time Structure and Basement Faults (5 Km)



# Cherokee Basin

Bourbon Arch Project

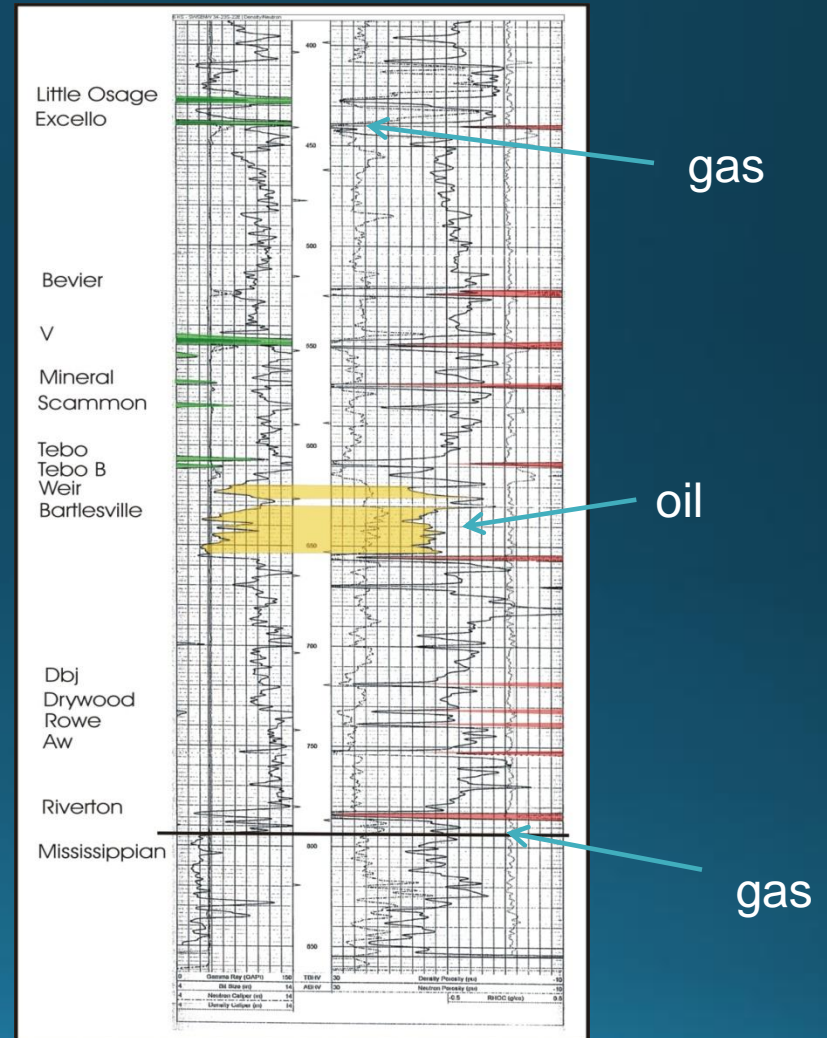
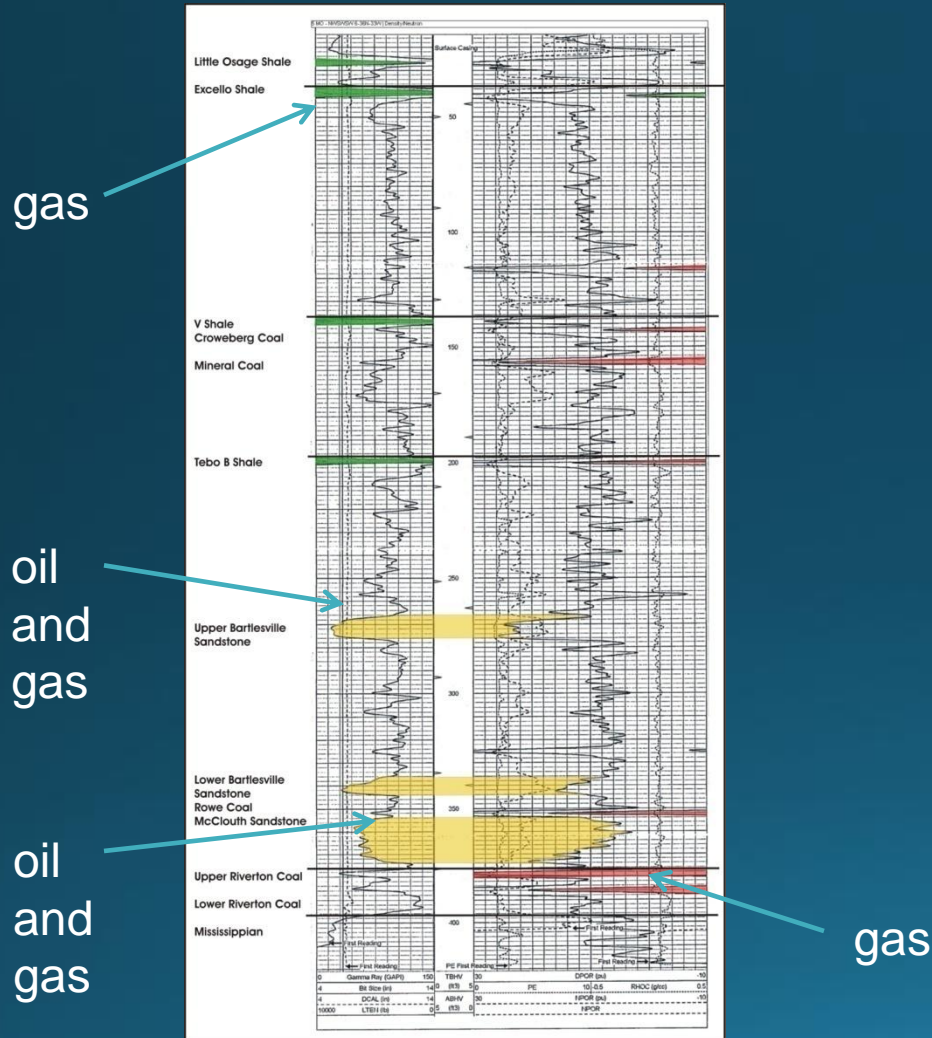
RFPI has discovered several new fields and reactivated old ones.



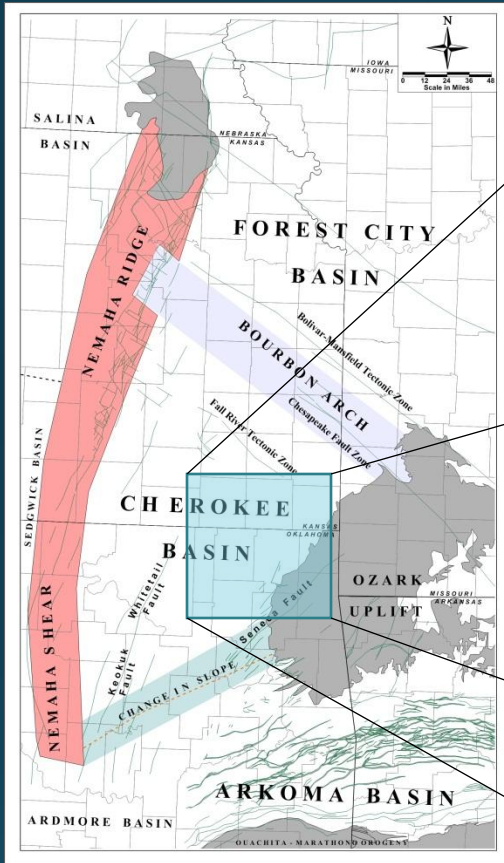
# Cherokee Basin

- Historically shallow oil and gas zones in the Cherokee Group, Mississippian “Chat” and CBM;
- Average producing well is ½ to 5 BOPD; 40 to 200 MCFGPD;
- Oil fields have a 50+ year life;
- Gas fields has 5 to 10 year life;
- Most of the oil fields require waterflooding;
- Multiple oil zones: Mississippian “Chat”, Bartlesville, Weir, Cattlemen, Squirrel, Chelsea and Warner sandstones;
- Multiple gas zones: Cherokee sandstones; Rowe, Riverton and Weir-Pittsburg coals; and Excello shale;
- Source rock Chattanooga Shale; migrated hydrocarbons from the Anadarko and Ardmore basins;
- 3D seismic not useful;
- Surface geochemistry is useful;
- Reserves at depths of 50 to 900 meters;
- Mainly vertical play;
- Well costs (all in) \$30K to \$115K depending upon depth;
- Best oil producing zones lie in proximity to basement faults as defined by aeromagnetics.

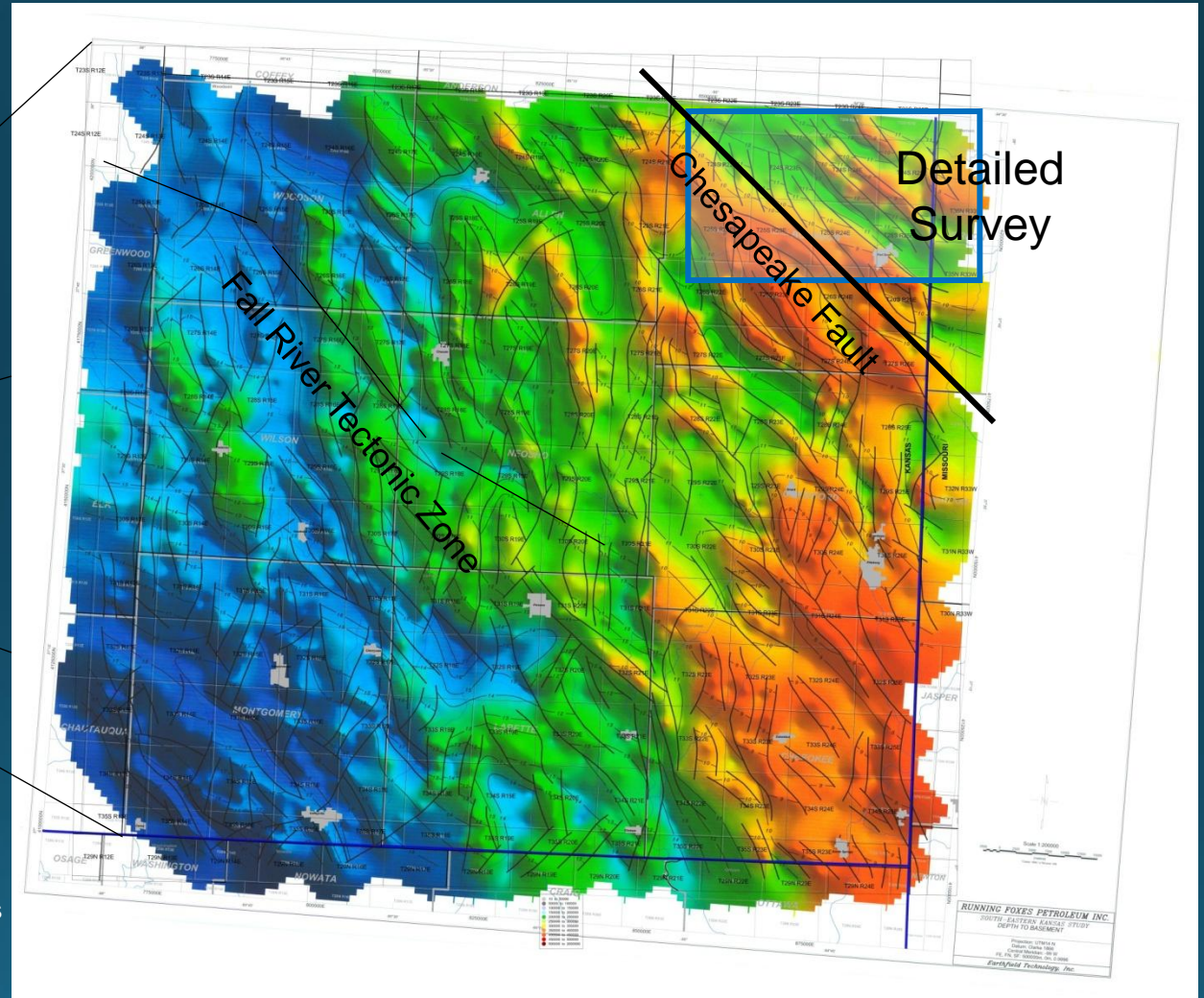
# Typical Log Section



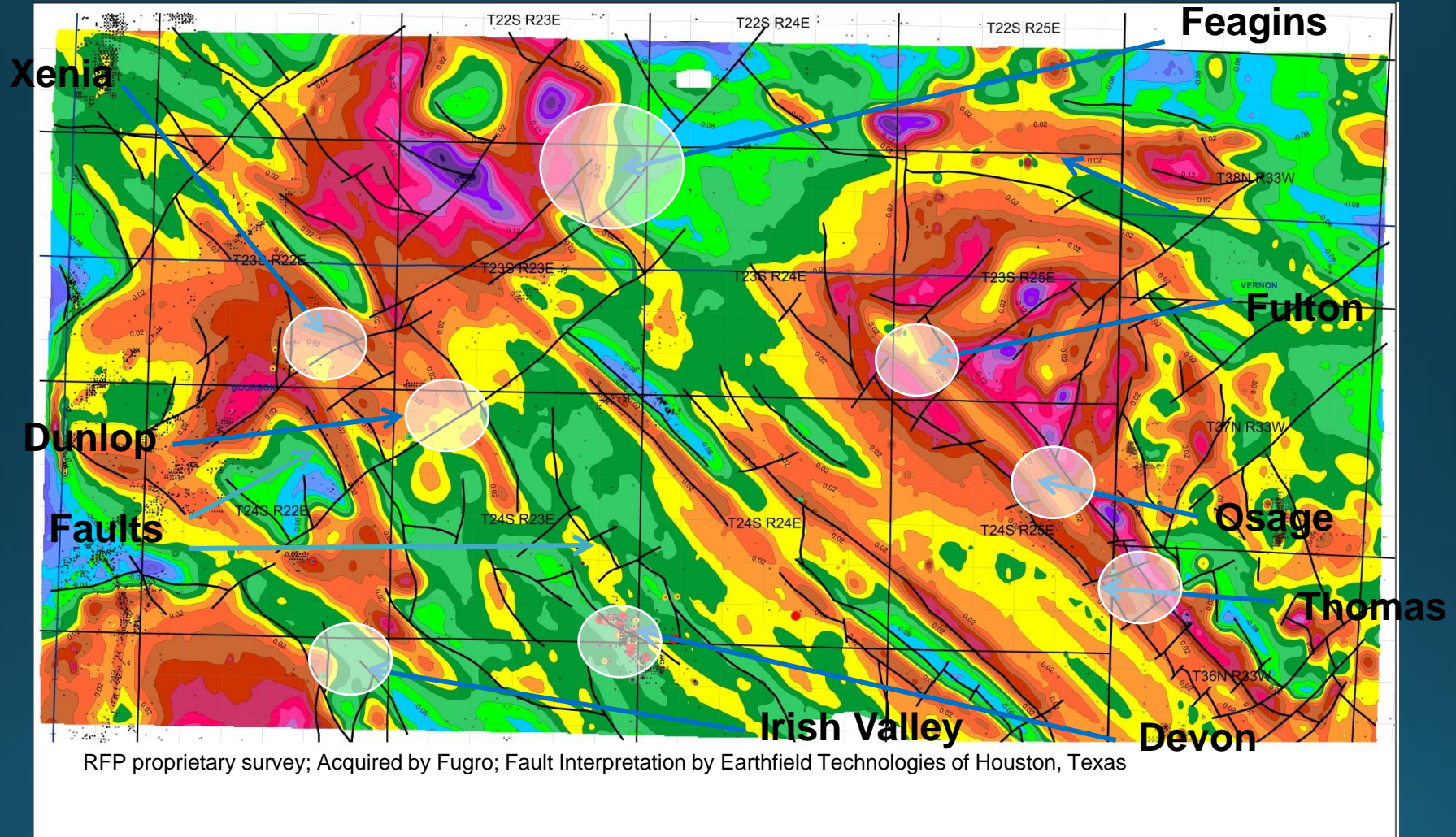
# Northeastern Cherokee Basin – Proprietary Survey



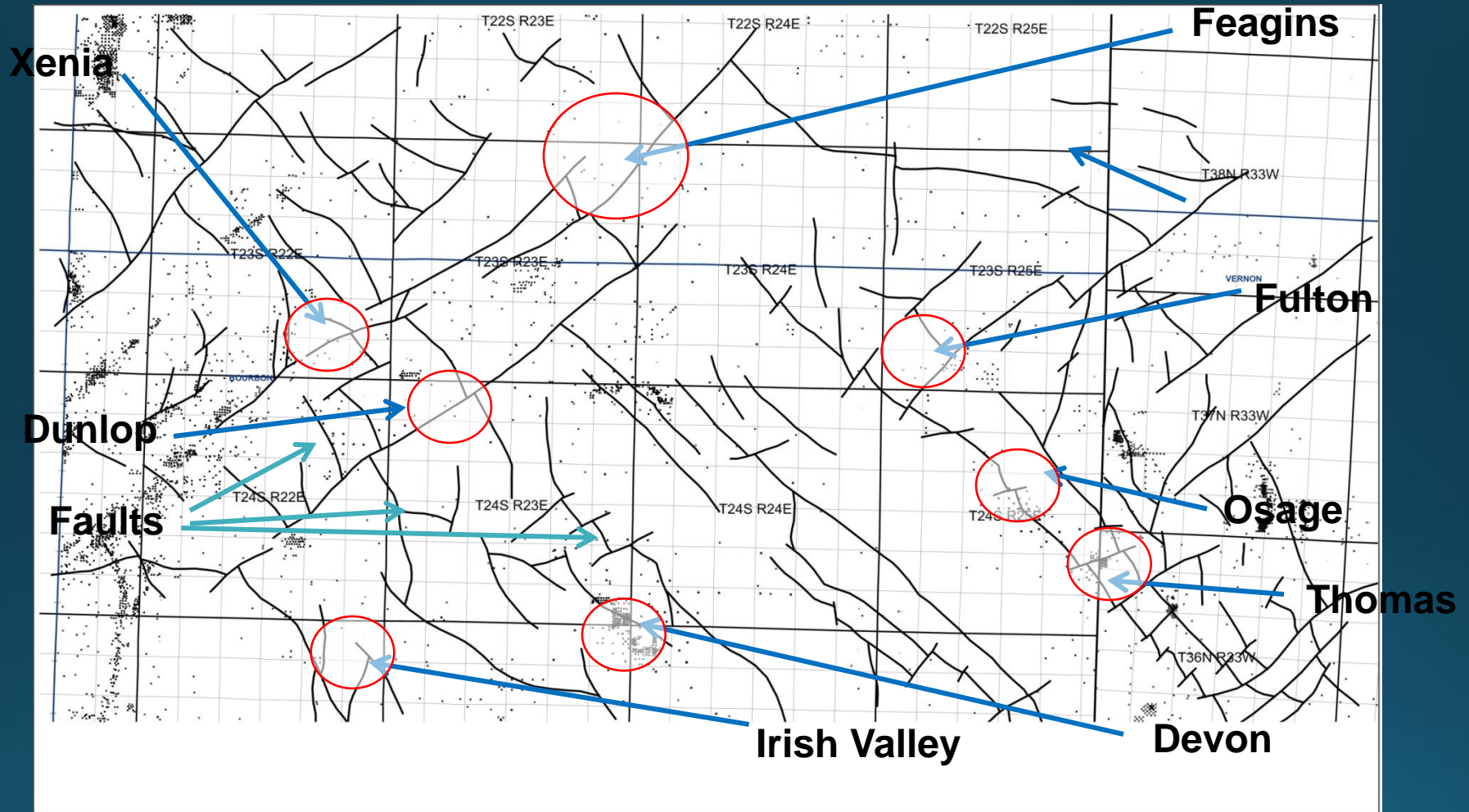
Source of data Applied Geophysics Salt Lake, UT; Fault Interpretation by Earthfield Technologies of Houston, Texas



# Proprietary Aeromagnetics



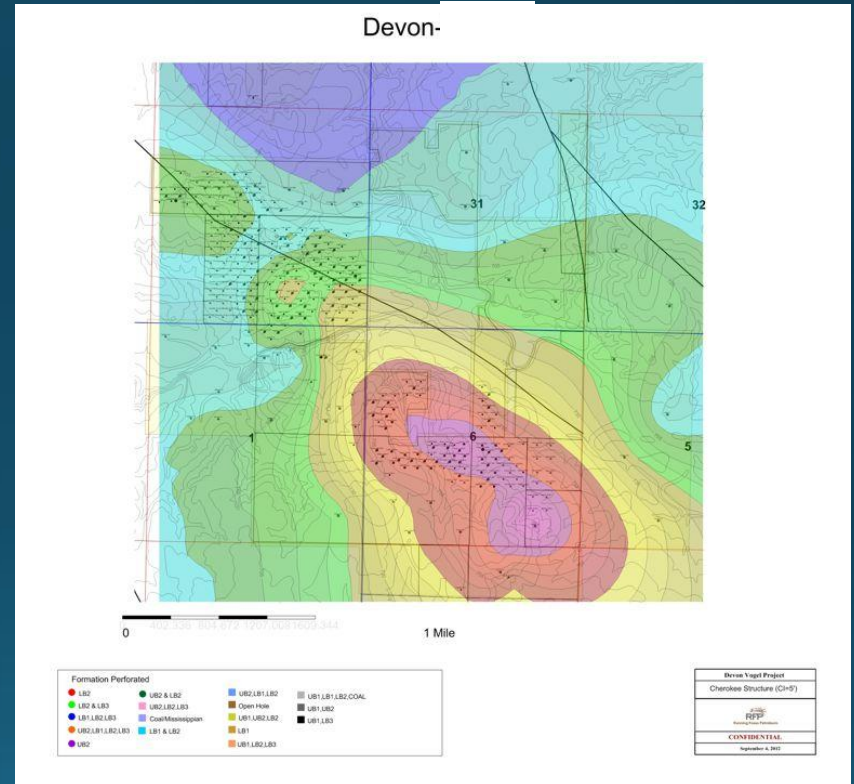
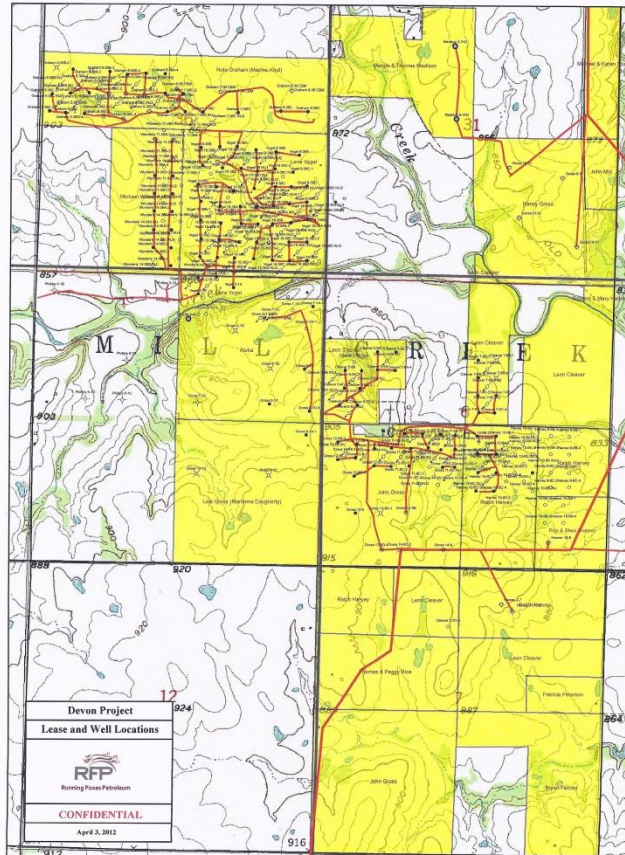
# Detail Survey Northeastern Cherokee Basin



RFP proprietary survey; Acquired by Fugro; Fault Interpretation by Earthfield Technologies of Houston, Texas

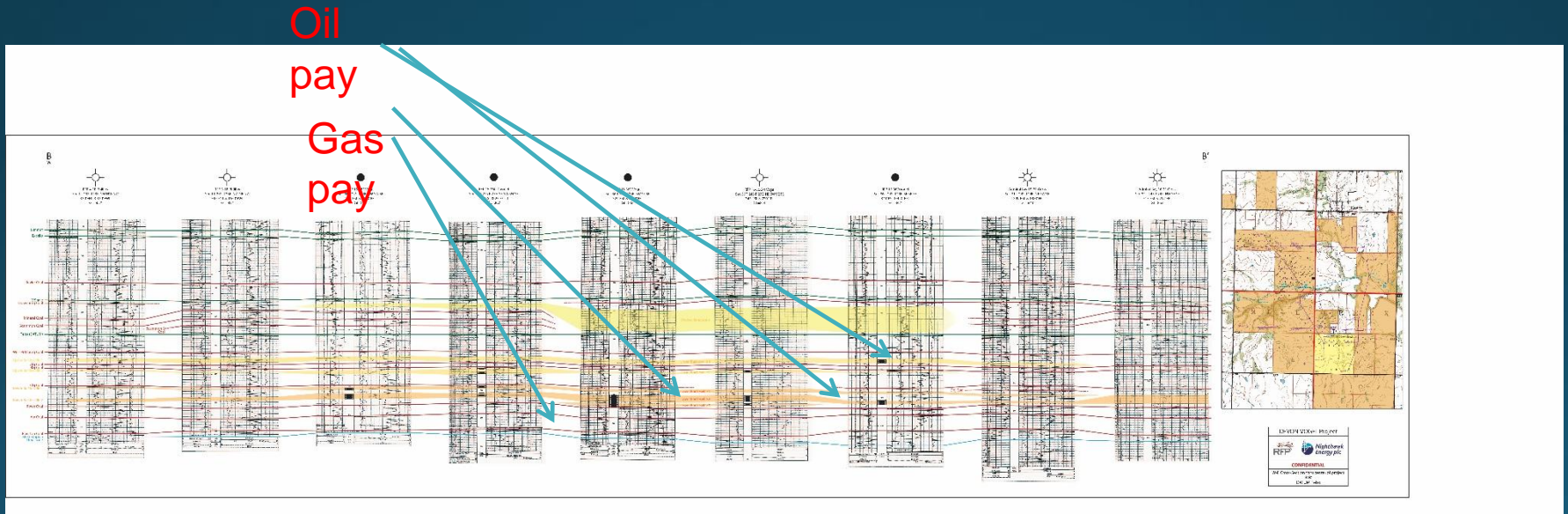
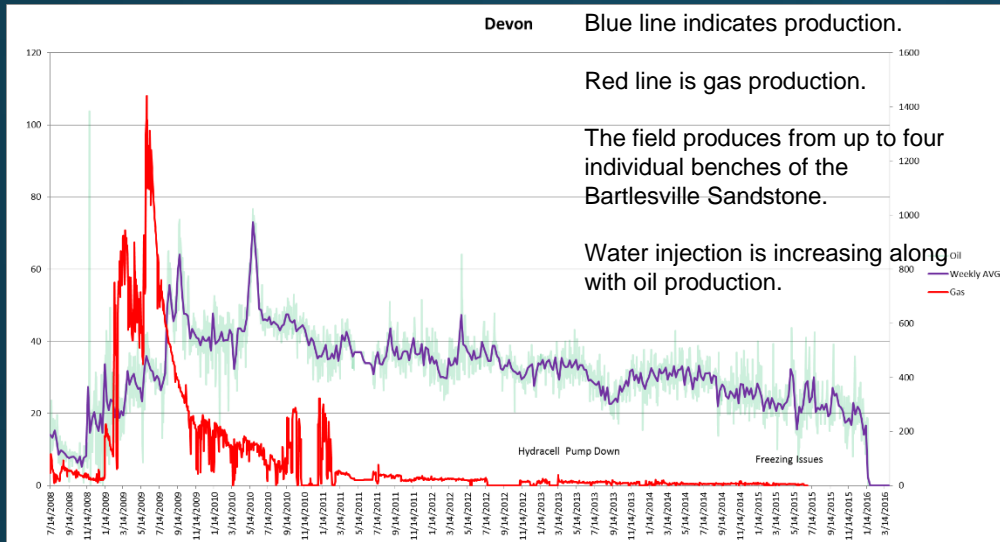


# Devon Field

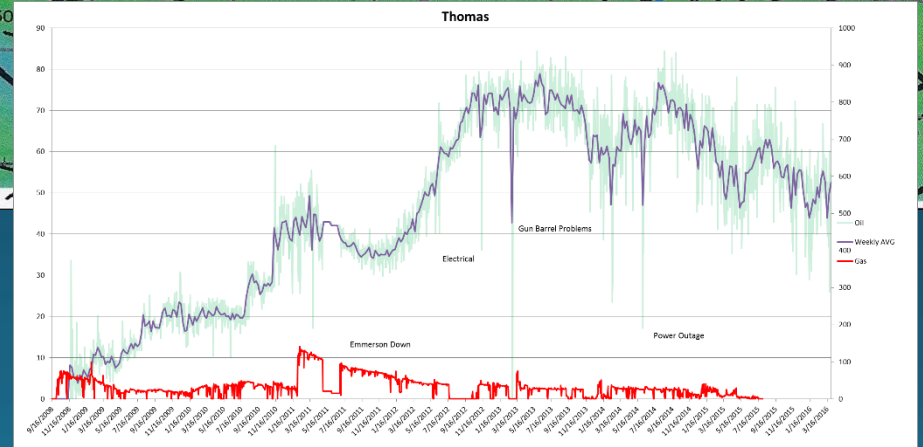
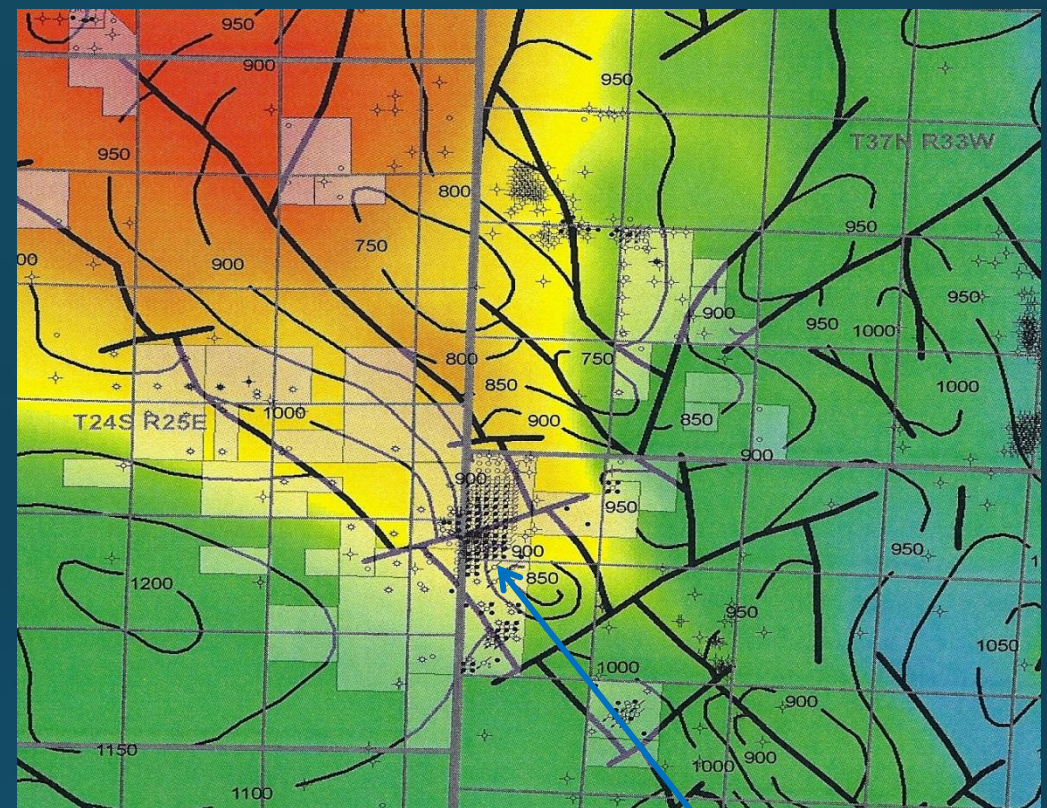
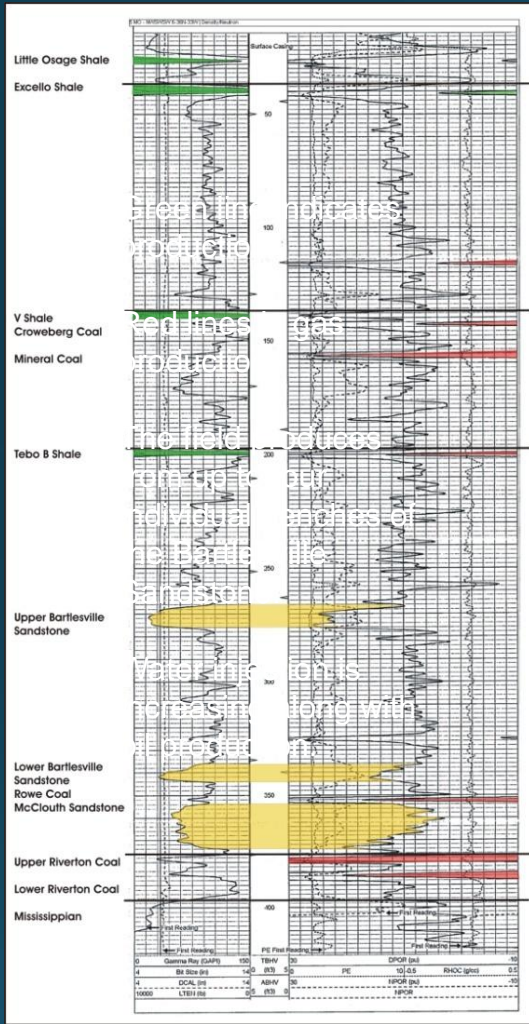


Structure on top of the Cherokee

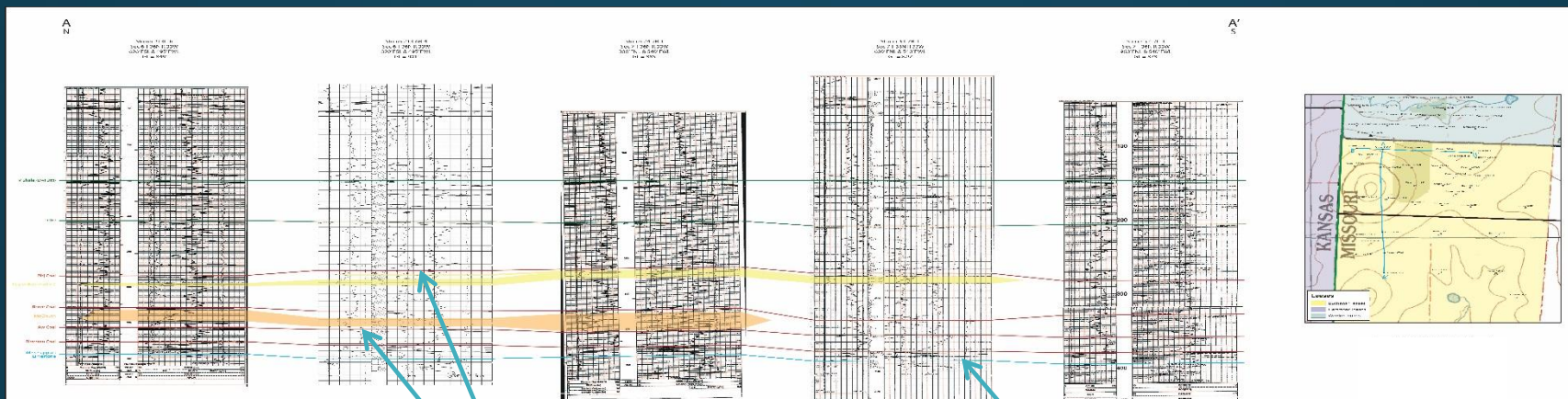
# Devon Field



# Thomas Field

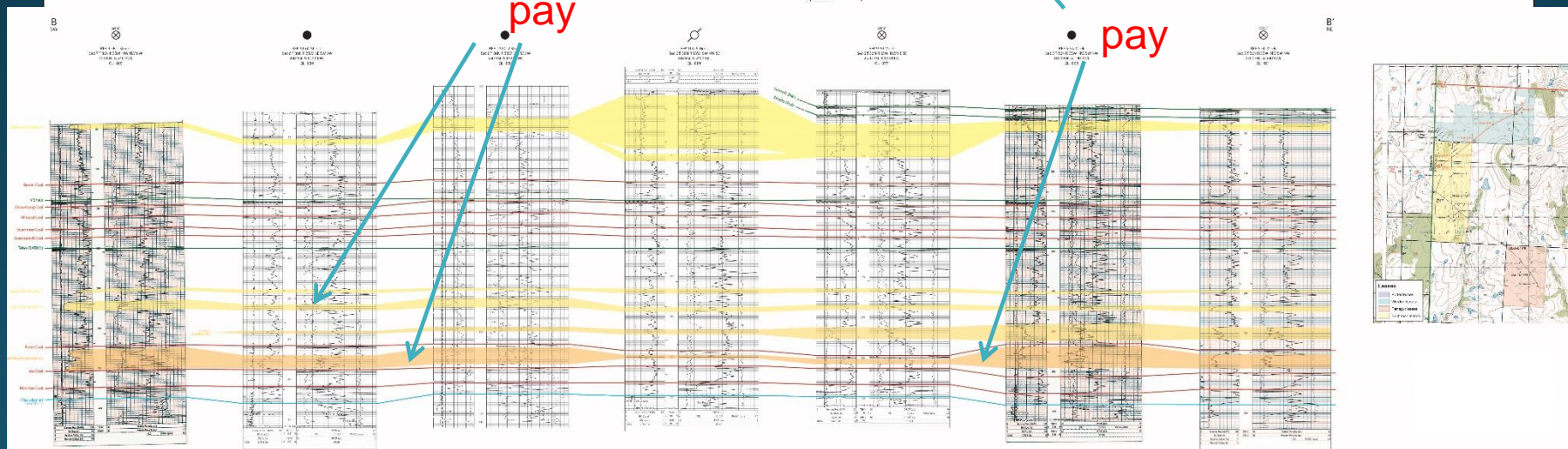


# Thomas Field



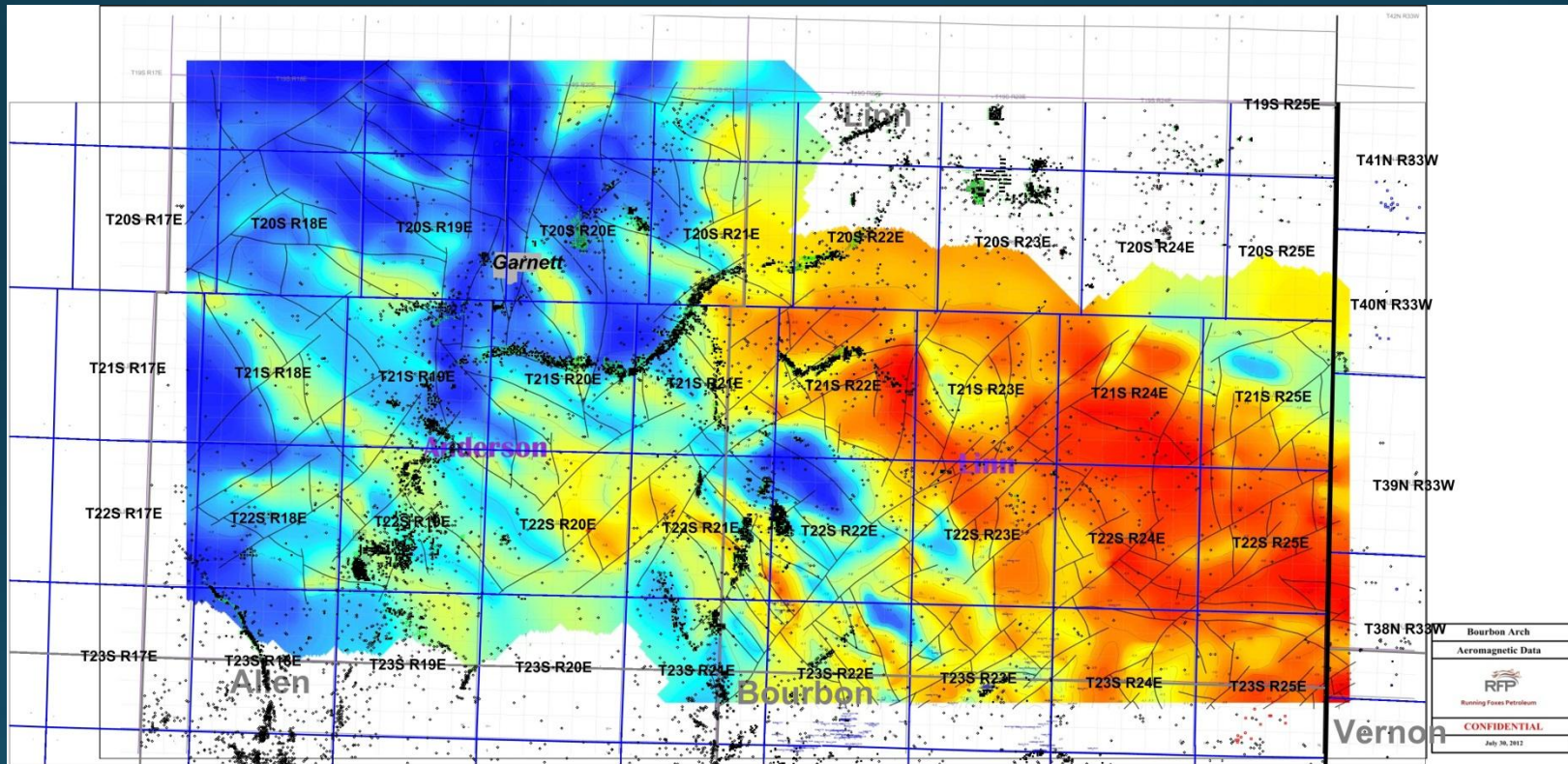
Oil pay

Gas pay



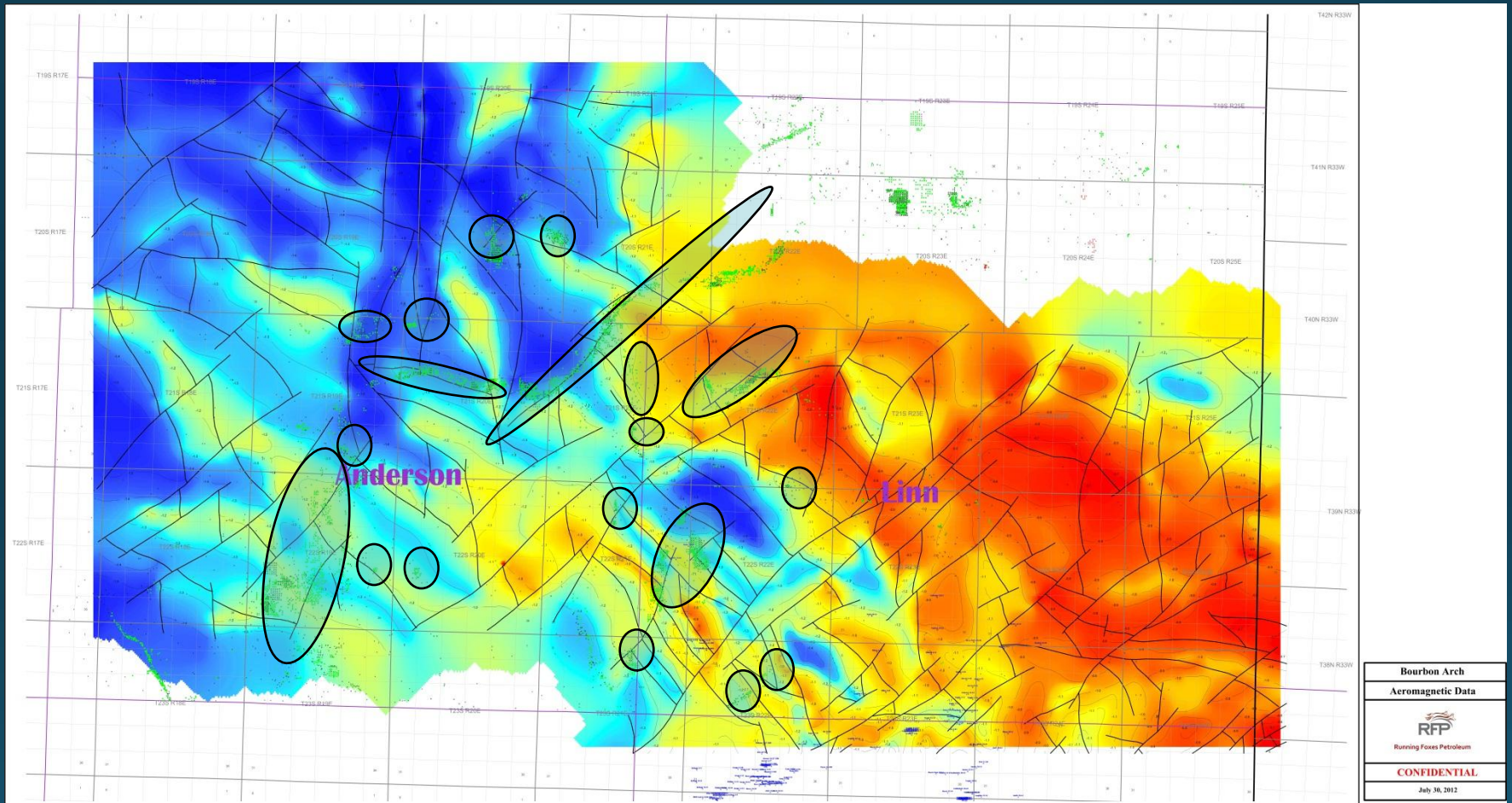


# Bourbon Arch - Southern Forest City Basin



FP Proprietary Survey; Acquired by Fugro; Fault Interpretation by Earthfield Technologies of Houston, Texas

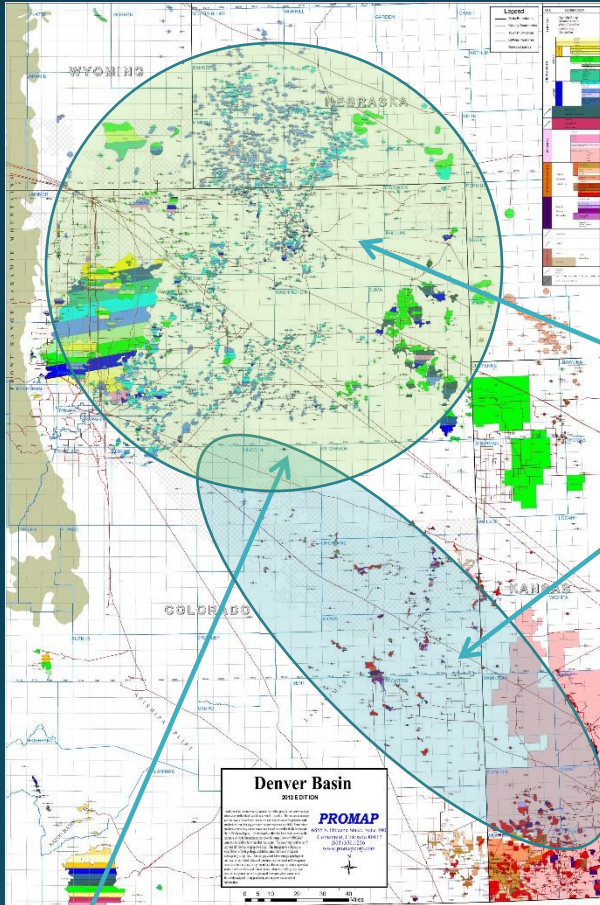
# Bourbon Arch - Southern Forest City Basin



FP Proprietary Survey; Acquired by Fugro; Fault Interpretation by Earthfield Technologies of Houston, Texas

# Integrated approach

## Example: Denver basin



Arikaree Creek Field

Denver Basin – Colorado, Mid-Continent USA  
Foreland Basin

Reservoir Types:

Cretaceous: D and J channel sands

Paleozoic:

Depths - 1,606 – 3,500 meters;

Mississippian carbonates – 3 to 20 meters thick;

Morrow sandstone channels – 2 to 20 meters thick;  
Cherokee A and C shoals or secondary dolomite  
features

0.5 to 3 meters thick;

Marmaton B carbonate shoal – 1 to 3 meters thick.

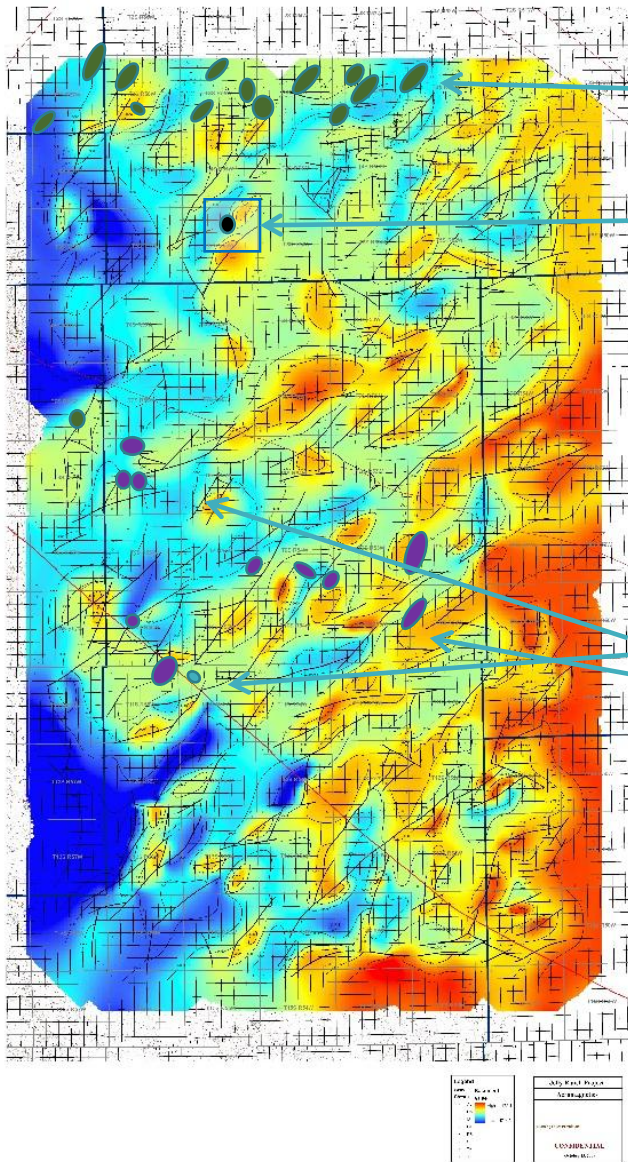


# Aeromagnetics in northern Lincoln County

Cretaceous Oil Fields

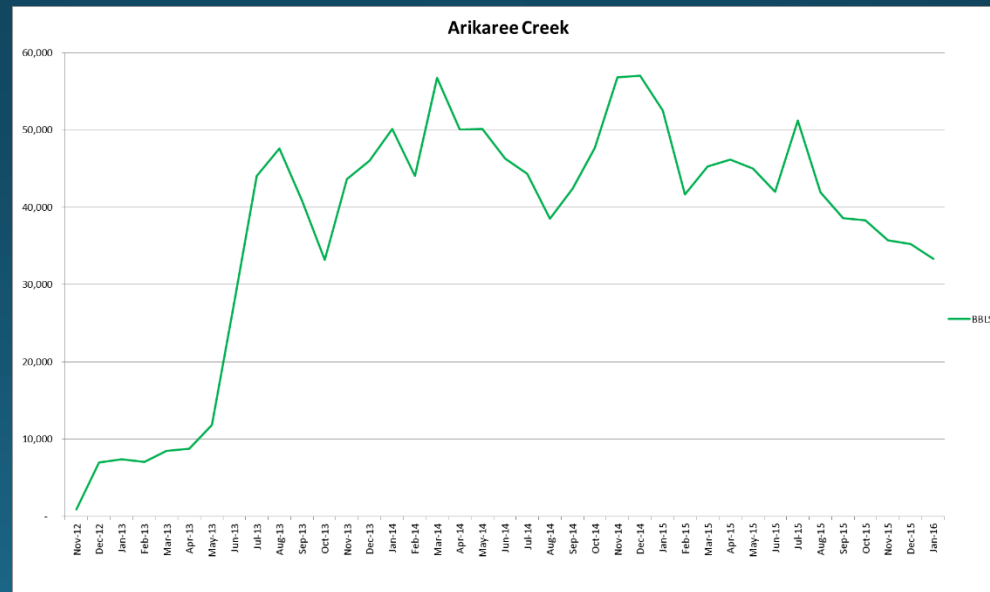
Arikaree Creek

Pennsylvanian – Mississippian Oil Fields



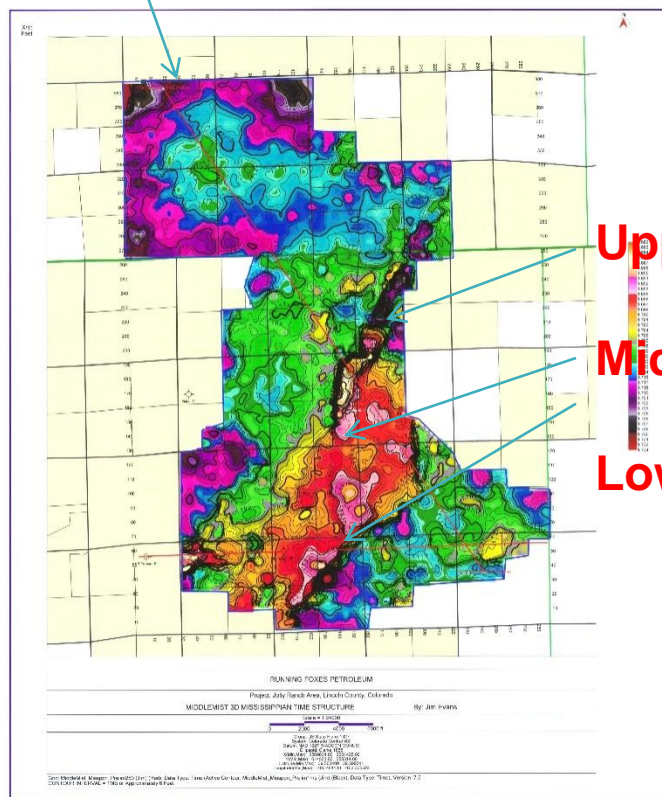
# Arikaree Creek Oil Field

- Discovered in 2012;
- Project developed by Running Foxes, partner bought out part of Company interest prior to drilling;
- Field found using:
  - Projection of productive reservoirs deeper into Denver Basin toward source of generated hydrocarbons;
  - Detail surface geochemistry;
  - 3D seismic survey;
  - Identification of structure with associated wrench faulting.



# Pre-drilling 3D seismic survey

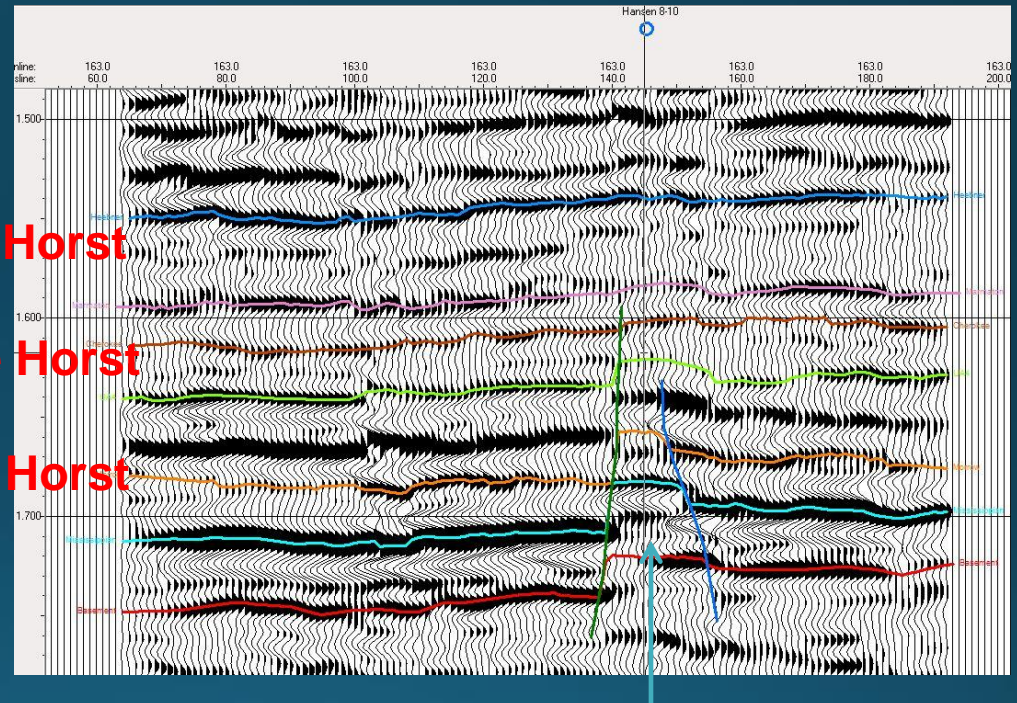
## 3D Outline



Upper Horst

Middle Horst

Lower Horst



## Mississippian Structure Pop up structure

Data Processed by Excel Geophysical  
Interpreted by JED Resources

# Discovery Well

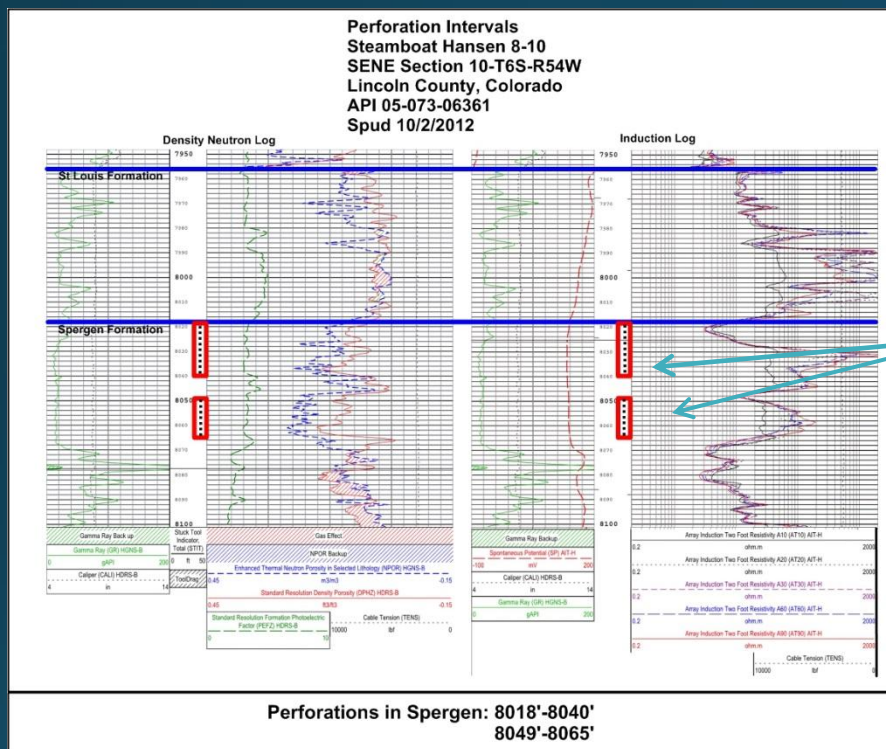
Hanson 8-10

Completed in the Mississippian  
Spergen

400+ BOPD

Reservoir is low-temperature  
dolomite

No water



Middle Horst, oil and water zone

# Conclusion

- Aeromagnetics provide a way to high grade a large area for exploration;
- Allows the ability to more focused 3D surveys, surface geochemical surveys and drilling programs;
- What it does not do is provide specific drill sites;
- Still need to define source, timing of generation, reservoir and seal rock.

# Thank you for coming



Running Foxes Petroleum Inc.