Identification of Petroleum Productive Low Temperature Hydrothermal Dolomite Reservoirs: Difficulties and Challenges Identifying and Finding*

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Abstract

Low-temperature hydrothermal dolomites that are characterized as Mississippi Valley type (MVT) deposits are well known in the base metals industry but are not as well recognized in the petroleum sector. The historical perception of these types of reservoirs is porous dolomites in structural sags in association with wrench fault systems. Well known examples are the Albion-Scipio and Stoney Point fields in southern Michigan Basin, Michigan, USA. These extremely narrow but very elongated features have produced over 200 MMBOE at less than 6000 feet from these fields. Within these reservoirs, low-temperature hydrothermal fluids replace limestone with dolomite causing reduction in rock volume, increase in porosity; zones are typically 3 to over 50 meters thick, overpressured, brecciated with associated secondary chert, barite, and minor base metals. Similar reservoirs occur in central New York, Southwestern Ontario, south-central Kentucky and north-central Tennessee. The Livengood and Runamuck fields in northeastern Kansas, Midcontinent, USA, are also associated with wrench faults, and their reservoirs are secondary dolomites caused by low-temperature hydrothermal fluids. However, they produce from structural highs. The Arikaree Field in the southern Denver Basin, Rocky Mountains, USA, produces from a low-temperature hydrothermal dolomite reservoir from three different structural closures associated with a wrench fault system of Mississippian to Pennsylvanian in age. The difficulty in finding these types of reservoirs, except for the wrench faulting and closure, is that seismic generally is not definitive. Many of the fields are related to flower structures and structural depressions, representing collapse and brecciation caused by wrenching and replacement of limestone to dolomite. These fields are highly prolific. This article discusses the seismic and the subsurface geology of some of these fields and the caveats and pitfalls associated with finding and developing them.

Selected References

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Presented by:

Dr. Steven A. Tedesco

Running Foxes Petroleum Inc.

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What Are Mississippi Valley Type Deposits(MVT)

- Well known in the minerals industry: Galena District Illinois, Tri-State District, Kansas and Missouri; Viburnum Trend, Missouri; Gainsborough, Tennessee to name a few;
- Low temperature hydrothermal origin;
- Thermally formed dolomites;
- Sphalerite and galena;
- Over pressuring;
- Organic residue to significant petroleum present;
- $CO_{2;}$
- Silica and barite;
- Also known as dolomite chimneys, breccias, collapse structures;

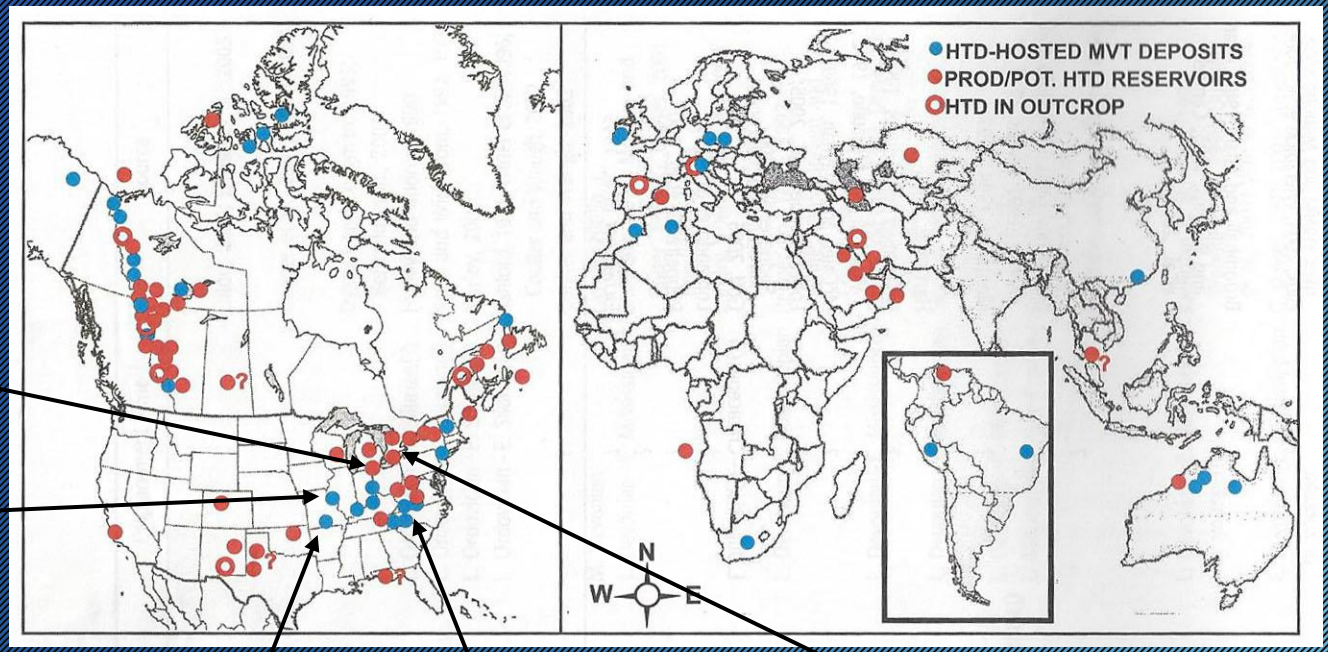
Where are MVT Deposits Found

- Most in North America
- Difficult to find
- Mining – close to surface generally
- Petroleum – up until the 1980s found by accident
- Present exploration uses unconventional thinking
- Paleozoic rocks

Why They Are Significant

- Reserves can exceed 1 MMBOE per 20 acres with one to over 100 feet in reservoir;
- Found within or on the edges of intercratonic and foreland basins;
- Not assessed in an reserve estimate in any basin;
- Field size tends to be large;
- Reservoirs generally erratic;
- Difficult to identify and predict with seismic.

Location of both petroleum and metalliferous MVT deposits



Albion- Scipio Oil and Gas

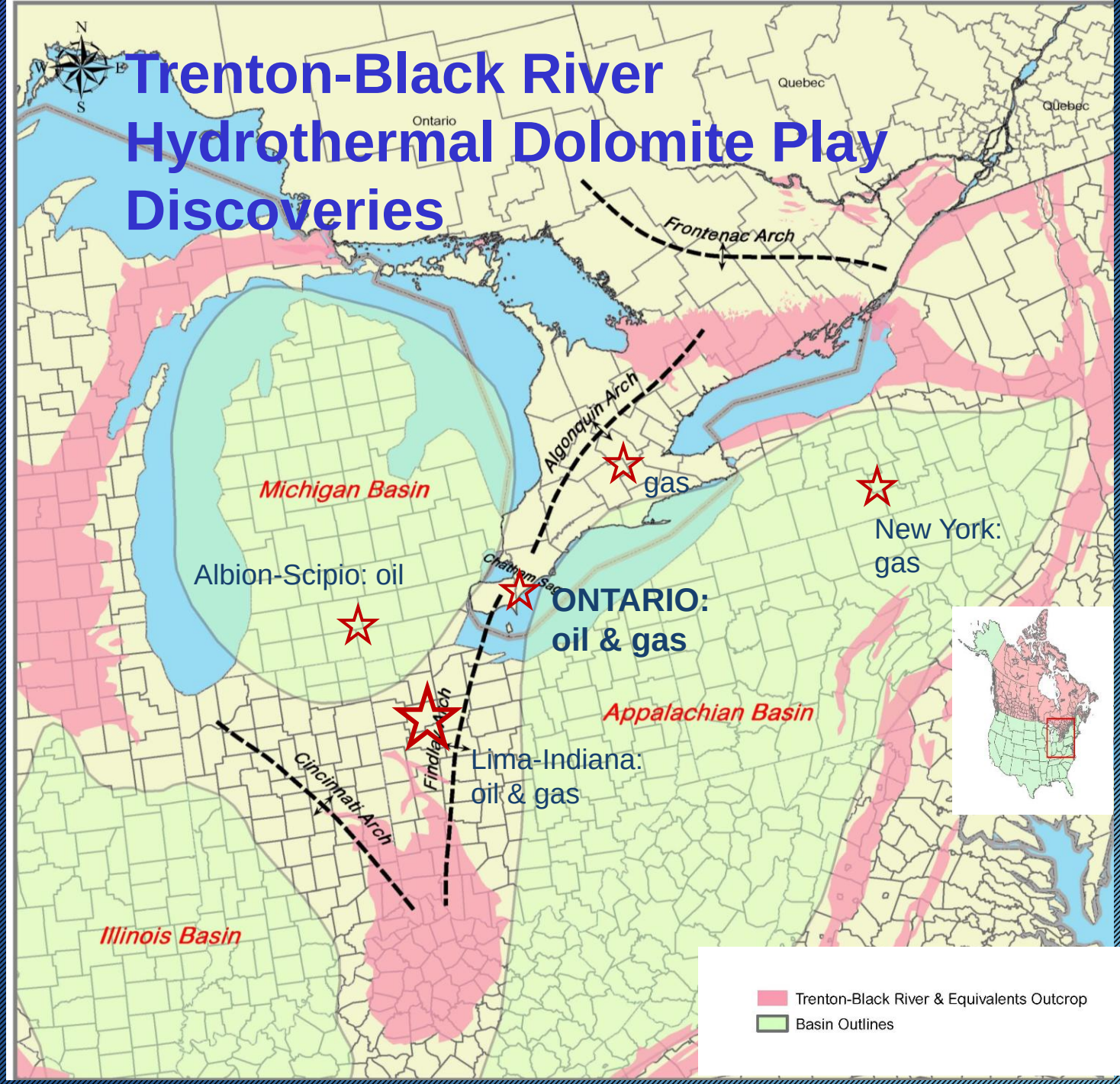
Galena Zinc

Viburnum Lead-Zinc

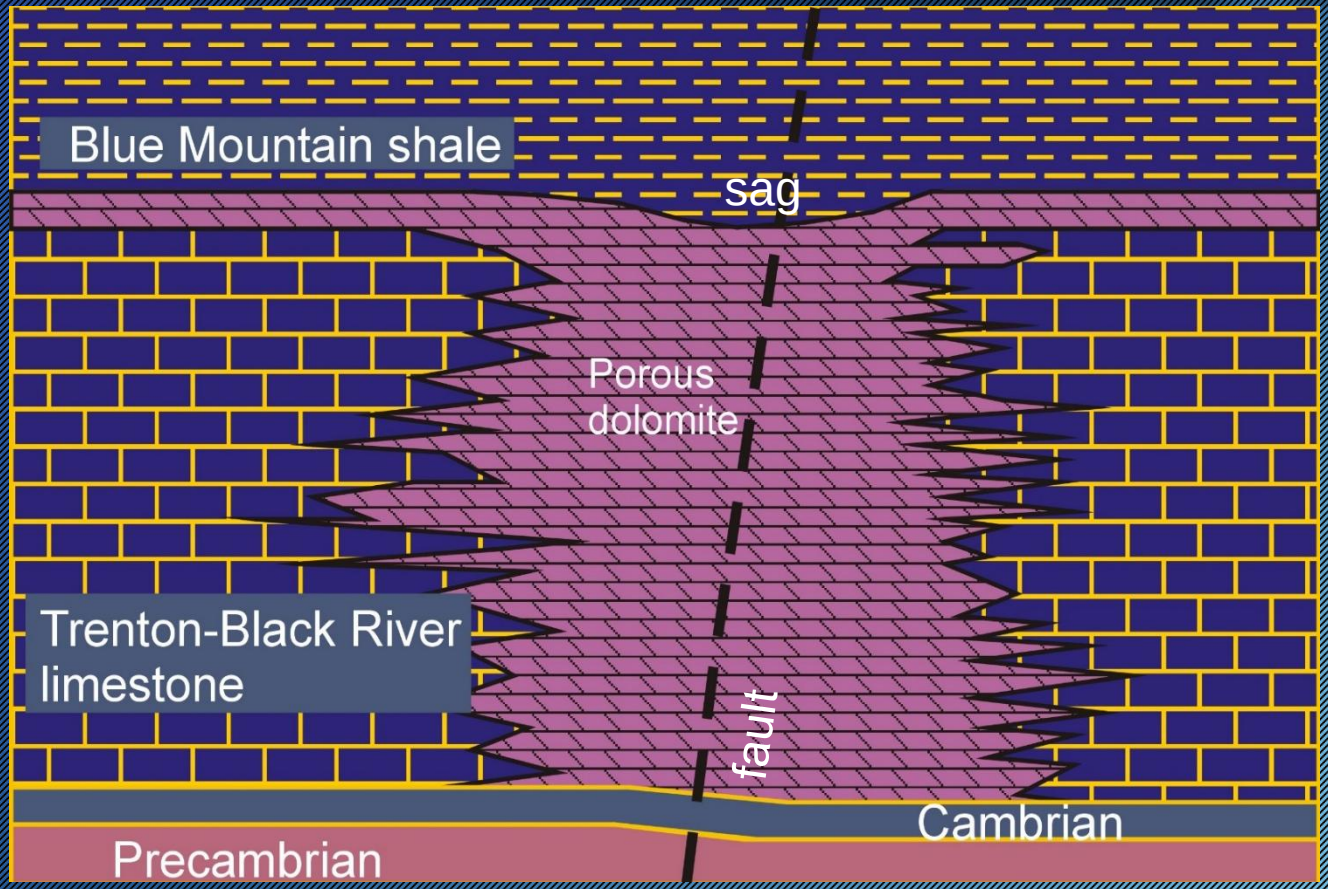
Gainsborough Zinc

Ontario Fields Oil

Trenton-Black River Hydrothermal Dolomite Play Discoveries

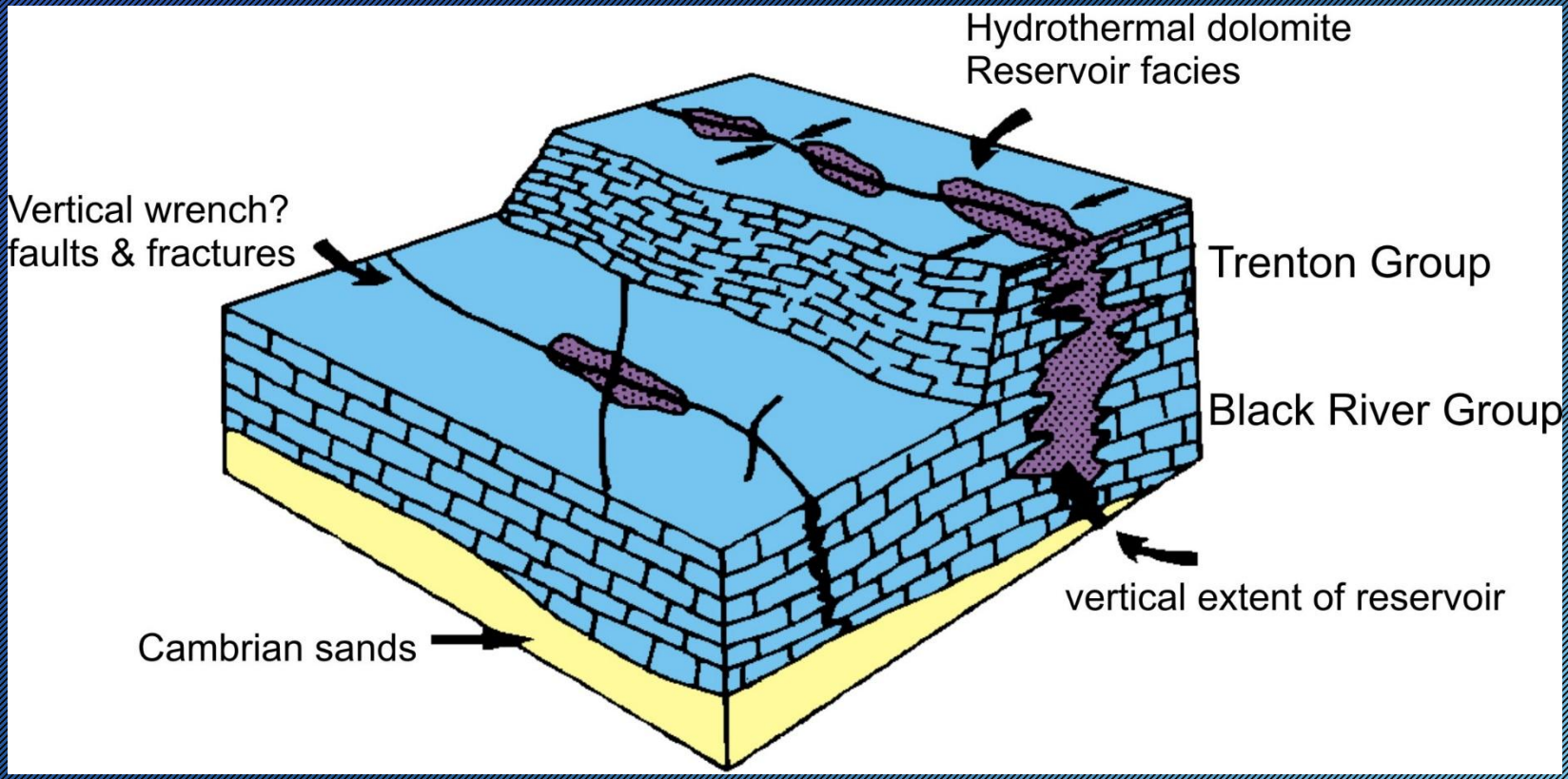


Traditional model of a MVT deposit



Carter et al, 1996

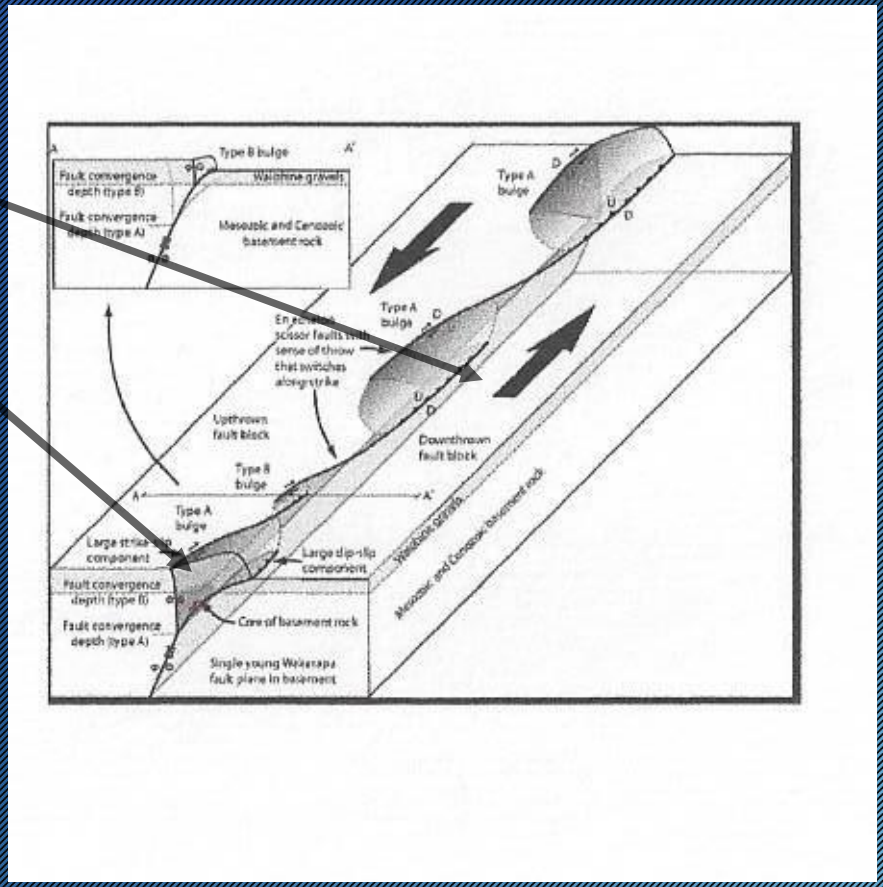
Reservoir Model 3D View



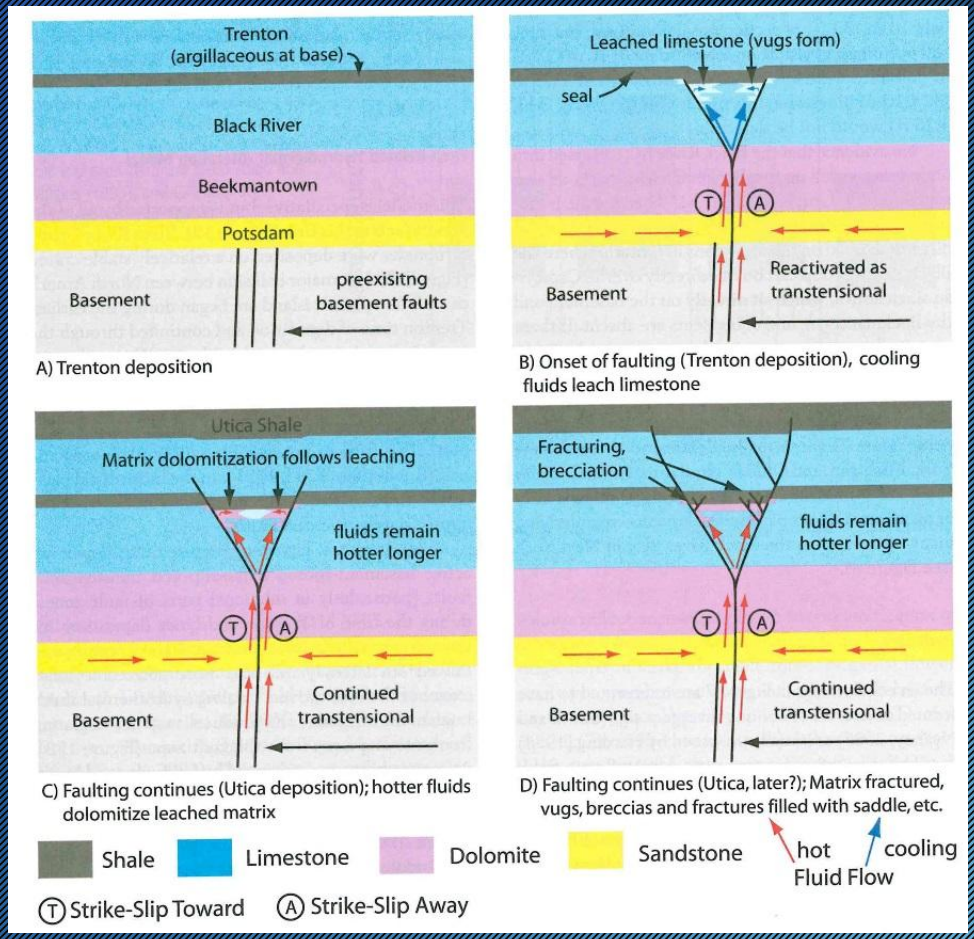
Strike Slip Model

Areas where traps can form both in the up and down block position.

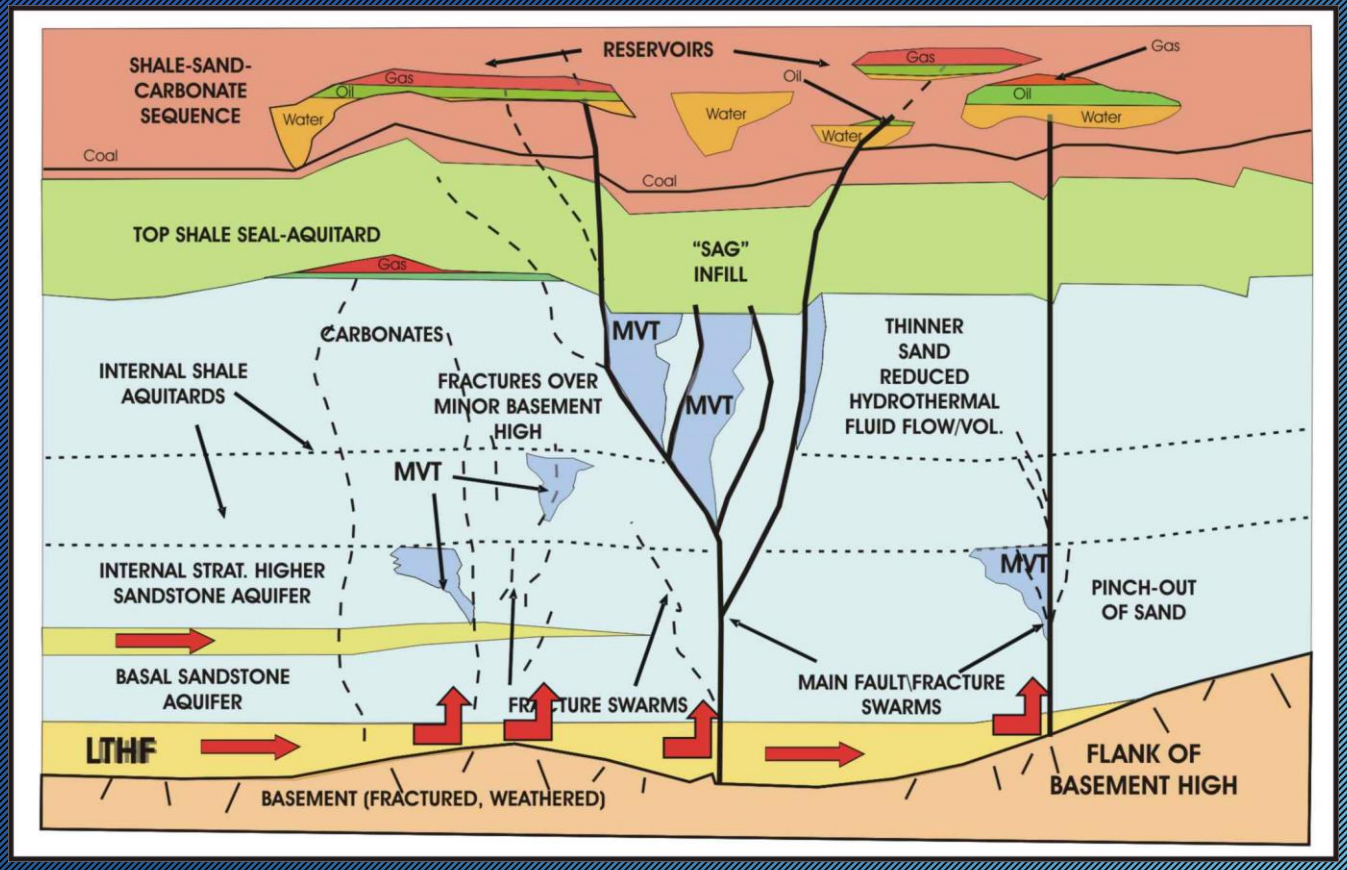
More recently have structural highs on a wrench fault system have been identified as productive



How Are They Formed

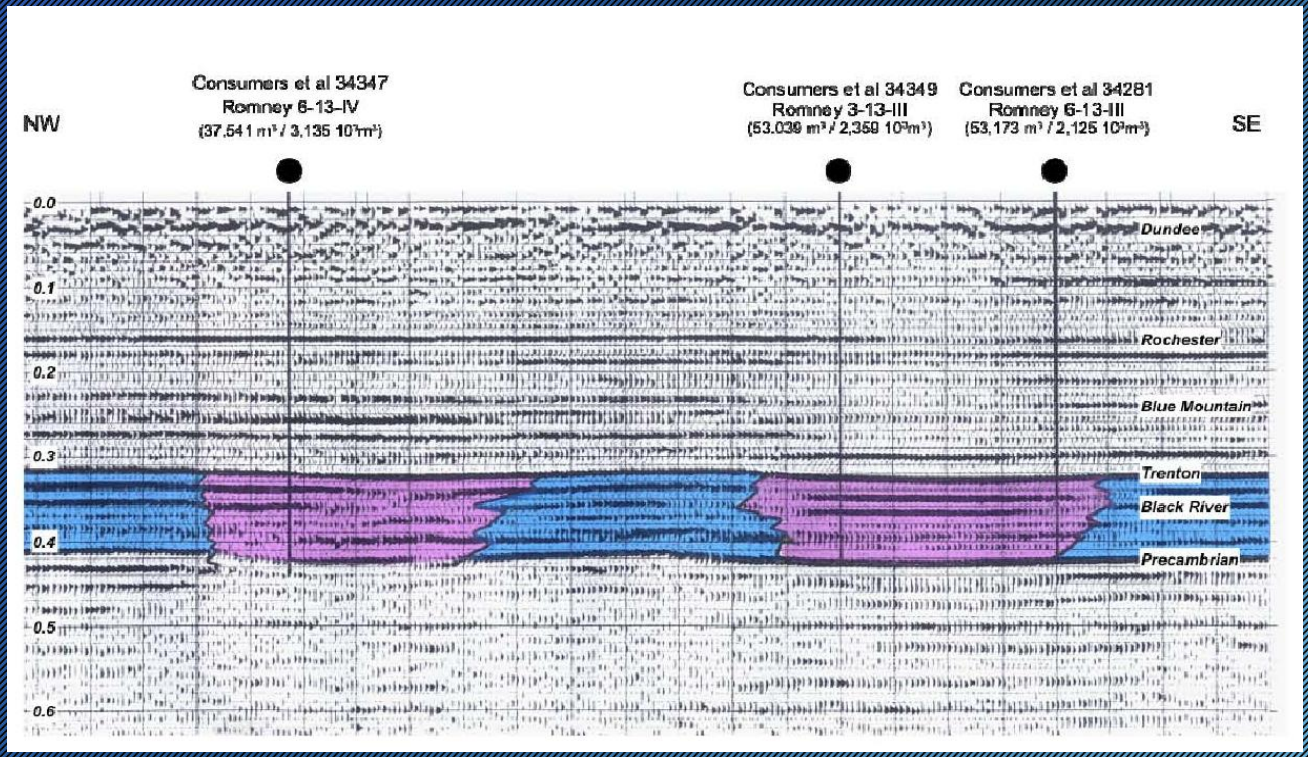


Migration of Low Temperature Hydrothermal Fluids

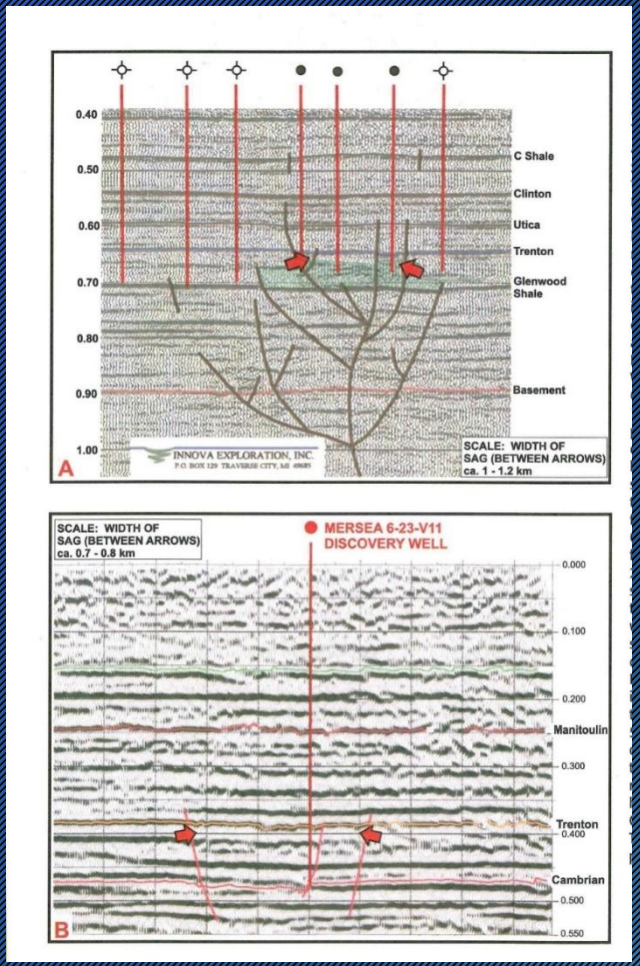


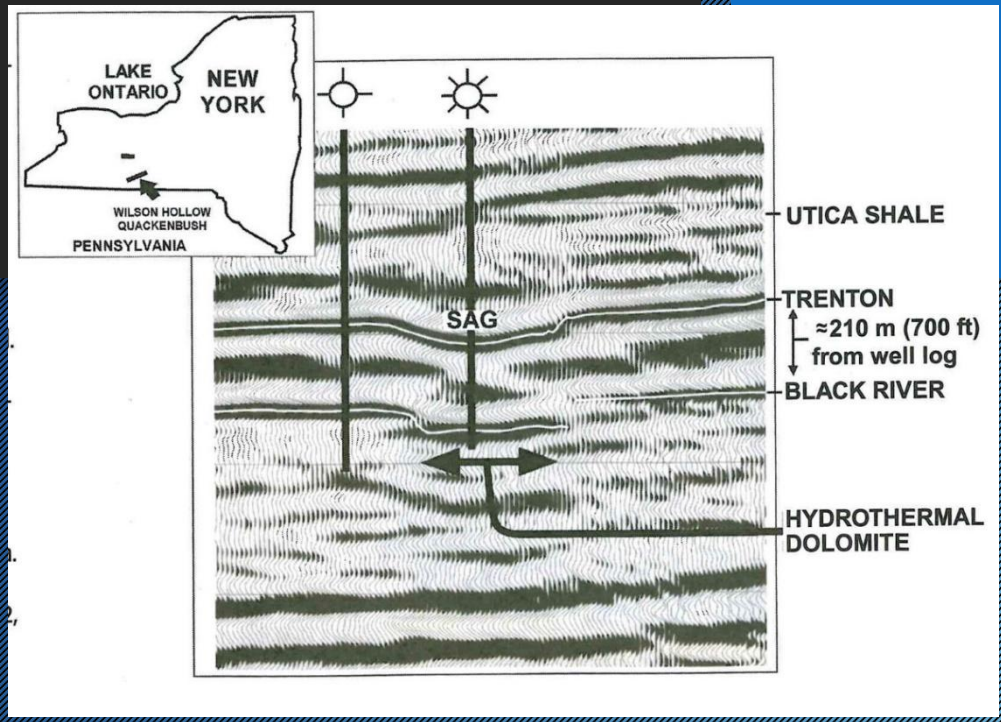
From Davies and Smith (2006) modified for the Cherokee Basin

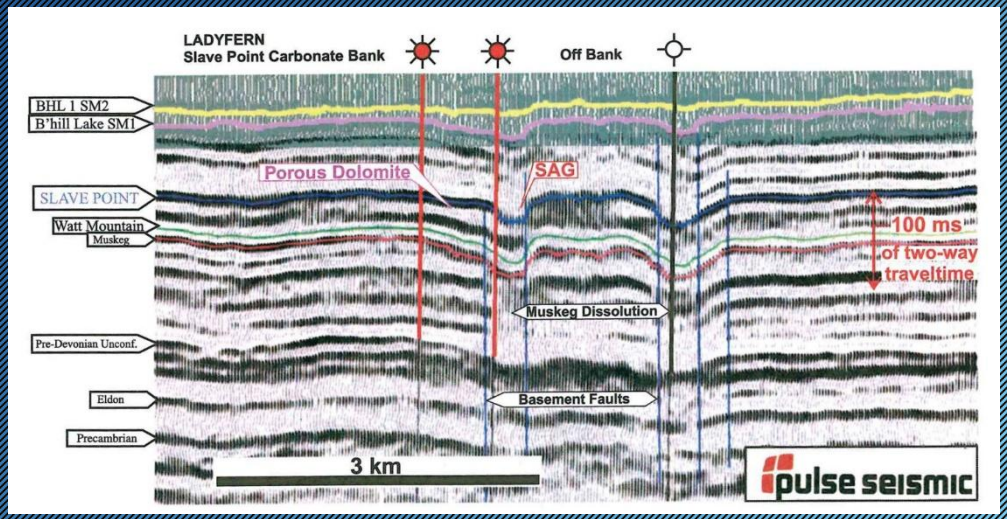
Renwick Field in Ontario, Michigan Basin



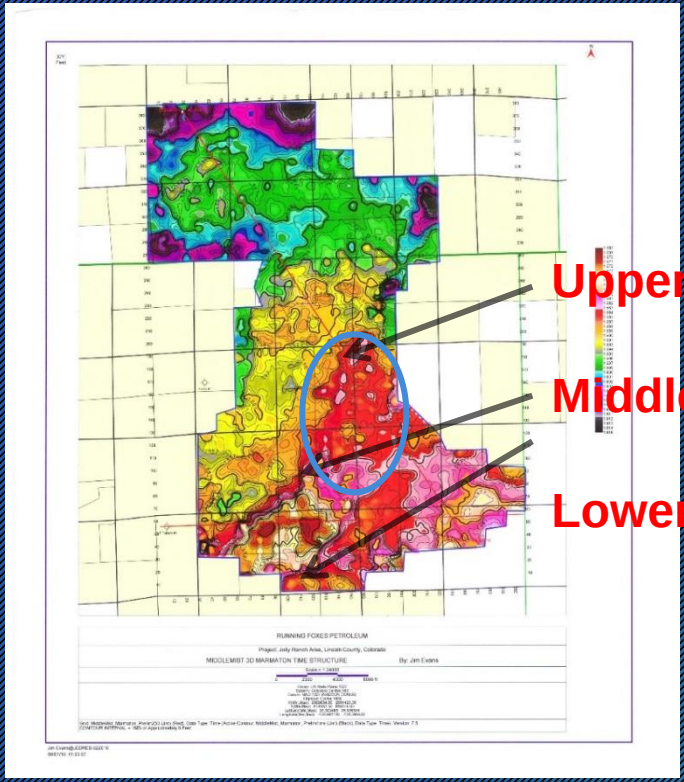
Examples

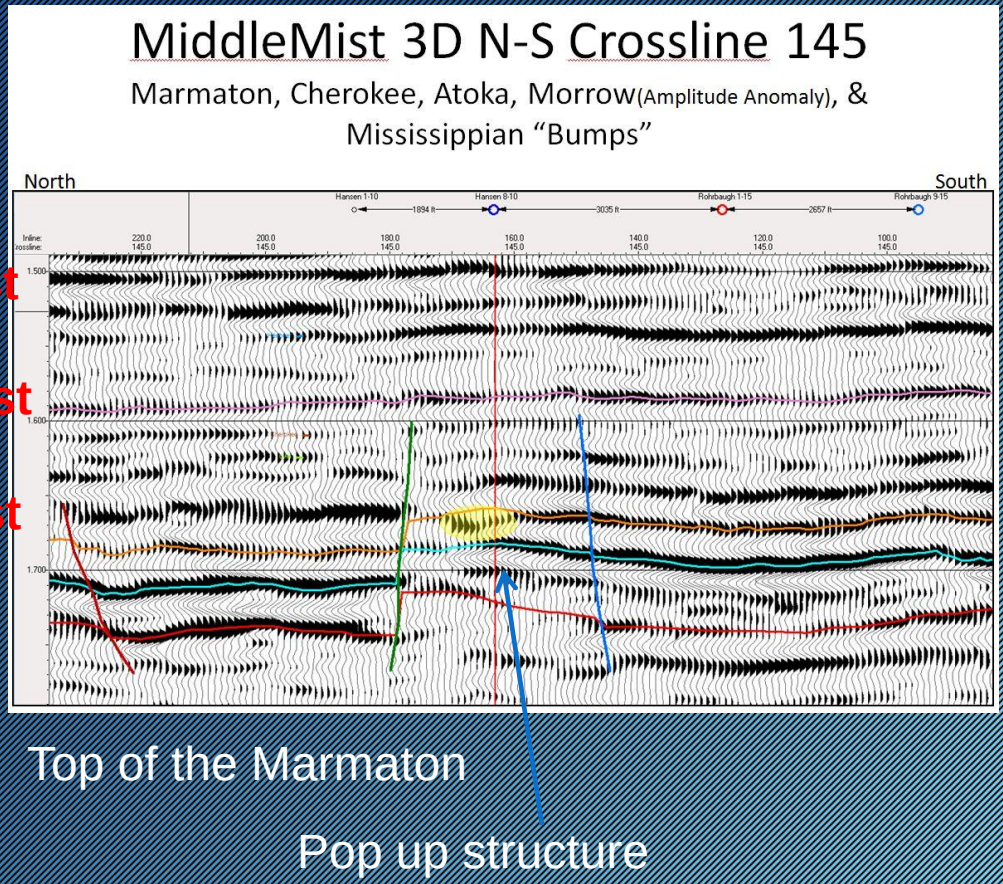

0.40
0.50
0.60
0.70
0.80
0.90
1.00
C Shale
Clinton
Utica
Trenton
Glenwood Shale
Basement
INNOVA EXPLORATION, INC.
SCALE: WIDTH OF SAG (BETWEEN ARROWS) ca. 1 - 1.2 km
A
SCALE: WIDTH OF SAG (BETWEEN ARROWS) ca. 0.7 - 0.8 km
MERSEA 6-23-V11 DISCOVERY WELL
0.000
0.100
0.200
Manitoulin
0.300
Trenton
0.400
Cambrian
0.500
0.550
B


LAKE ONTARIO
NEW YORK
WILSON HOLLOW
QUACKENBUSH
PENNSYLVANIA
UTICA SHALE
TRENTON
≈210 m (700 ft) from well log
BLACK RIVER
SAG
HYDROTHERMAL DOLOMITE


LADYFERN
Slave Point Carbonate Bank
Off Bank
BHL 1 SM2
B'hill Lake SM1
Porous Dolomite
SAG
SLAVE POINT
Watt Mountain
Muskeg
100 ms of two-way traveltime
Muskeg Dissolution
Pre-Devonian Unconf.
Eldon
Basement Faults
Precambrian
3 km
pulse seismic

Pre-drilling 3d seismic survey

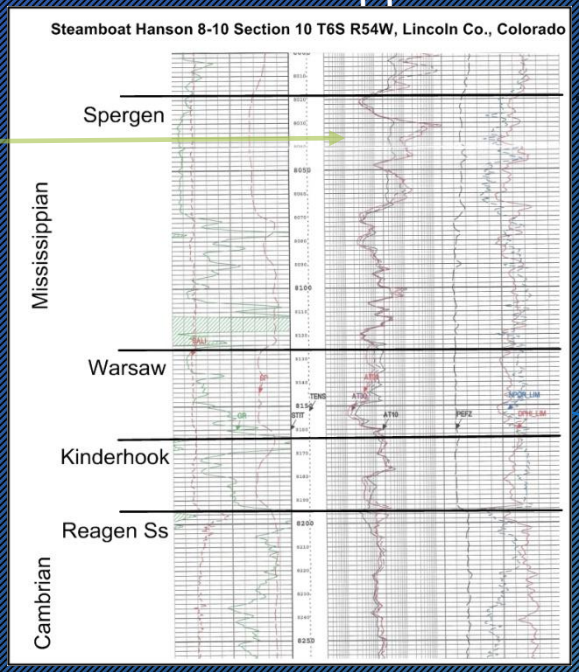




Hanson 8-10

Completed in the Mississippian Spergen;
Upper Horst;
400+ BOPD;
Reservoir is low temperature hydrothermal dolomites;
High pour point oil;
Atokan oil;
No water.

Upper Horst Well



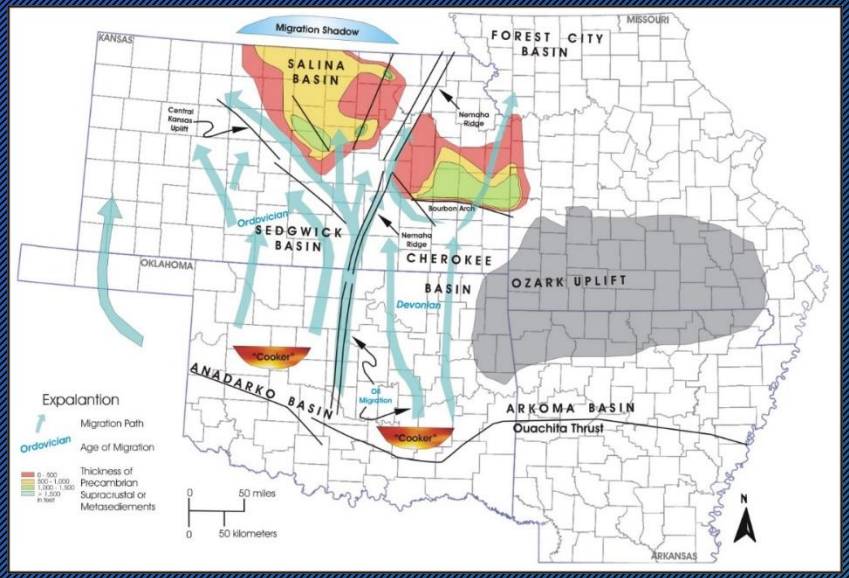
Pay

Discovery Well

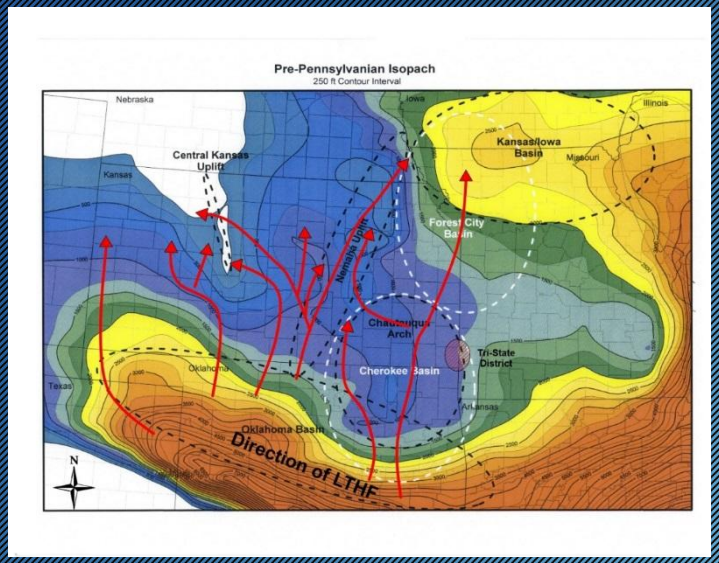
Middle Horst
oil and water zone
Erratic pay;
No predictability.

Lower Horst
Well: Whistler 16-21
33 meters
lower then
upper
block

Migration of Low Temperature Hydrothermal Fluids



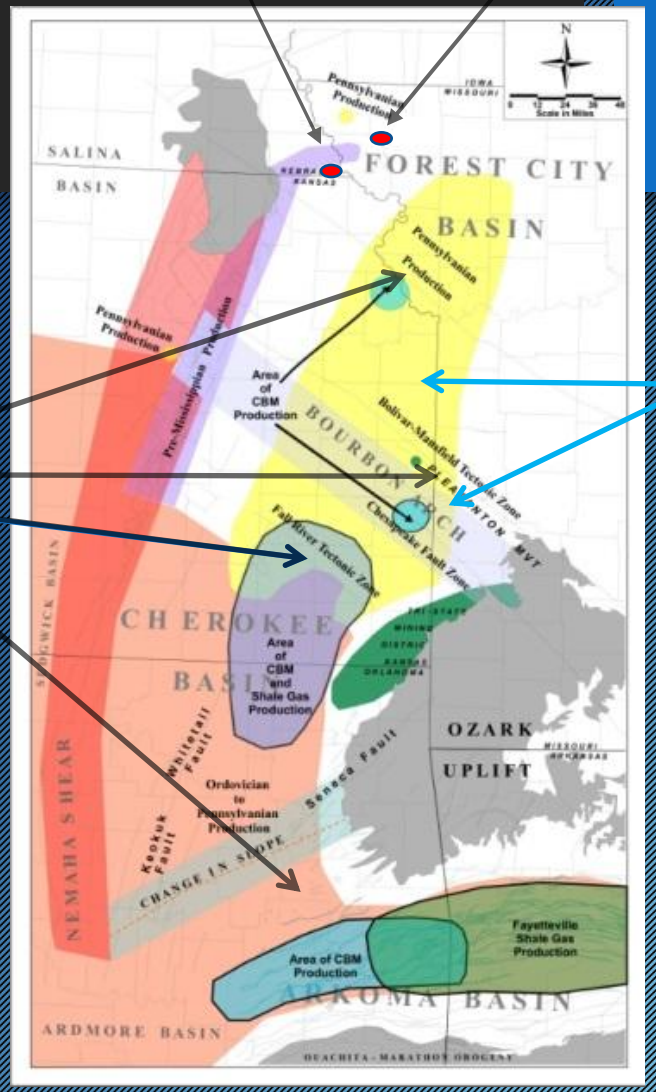
Gerhard, 2004



Adler et al., 1971 and Tedesco, 2014

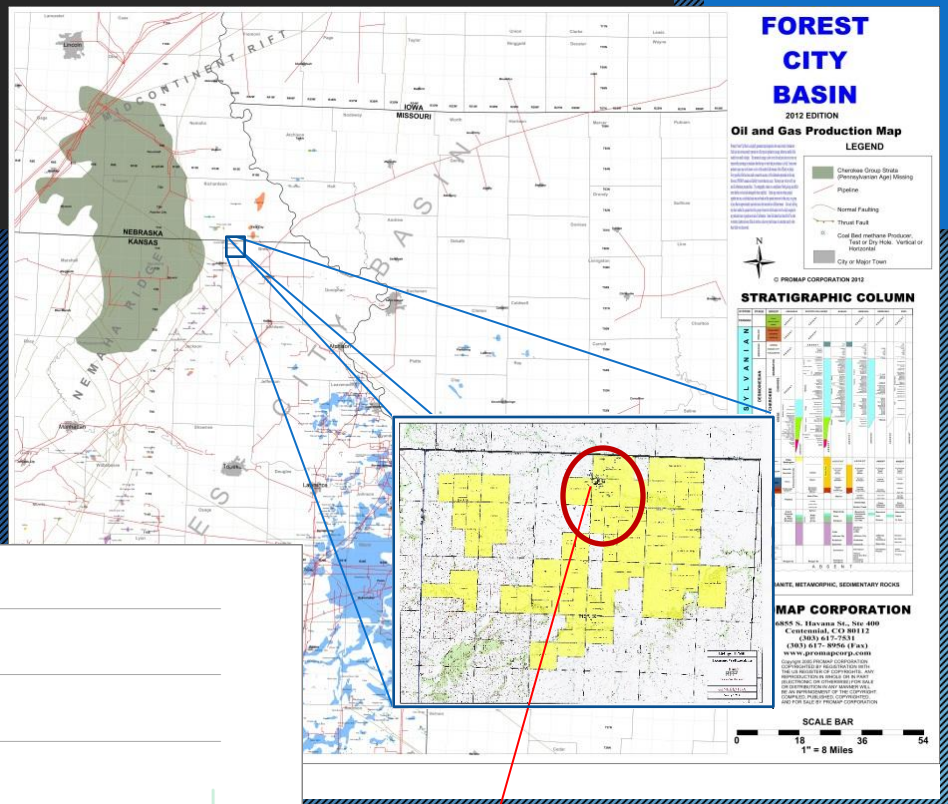
- Expulsion of basin brines during orogenic events;
- Migration upwards or termination at end of plumbing;
- Critical element is a thick shale cap;
- Host rock is typically a dense nonporous limestone;
- Open fault/fracture system;

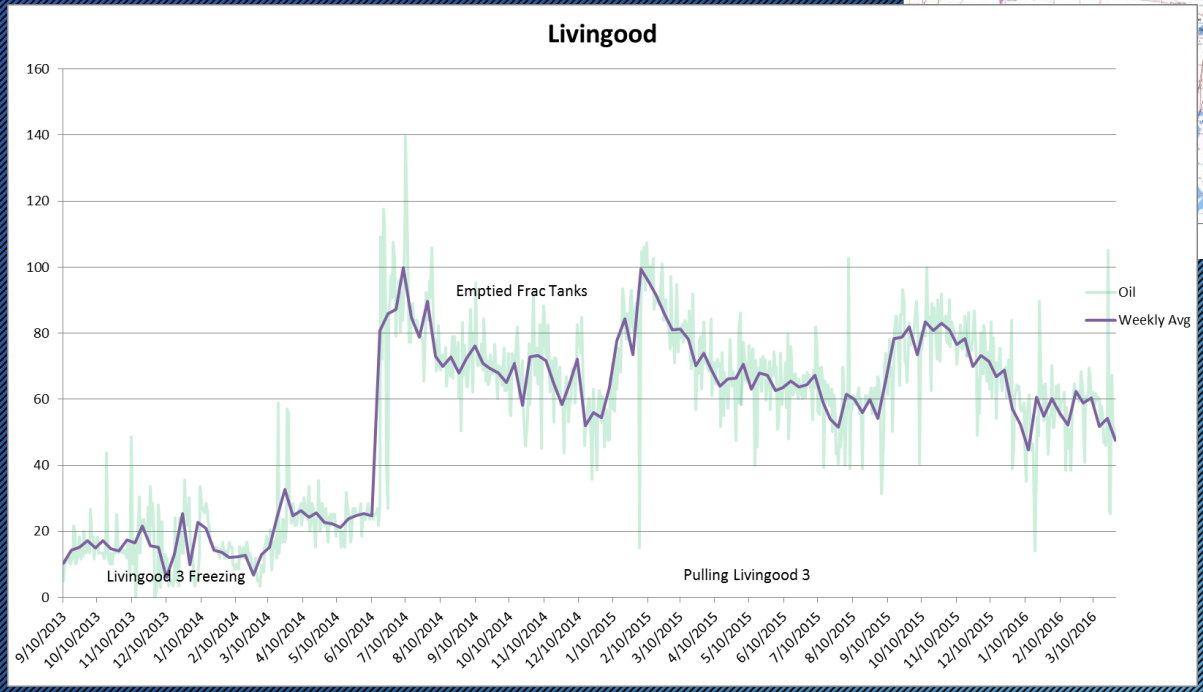
Petroleum and Base Metal Deposits in the Western Interior Basin



Tedesco, 2014

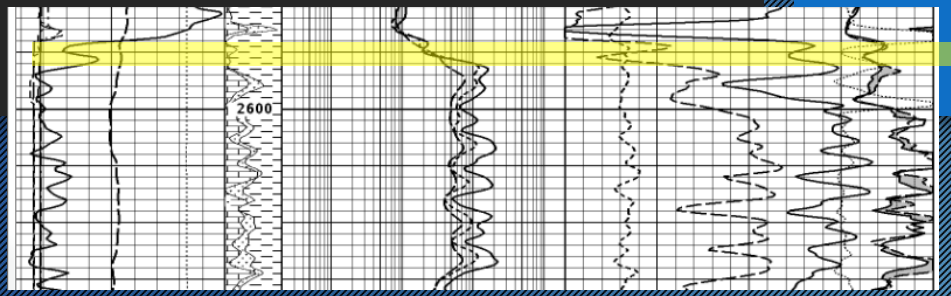
Livengood Field





Livengood Pay Zones

Hunton-Pay commonly found at top, but not limited to. Trap defined by structural closure. Porosity is variable, but does not constrain any given trap.

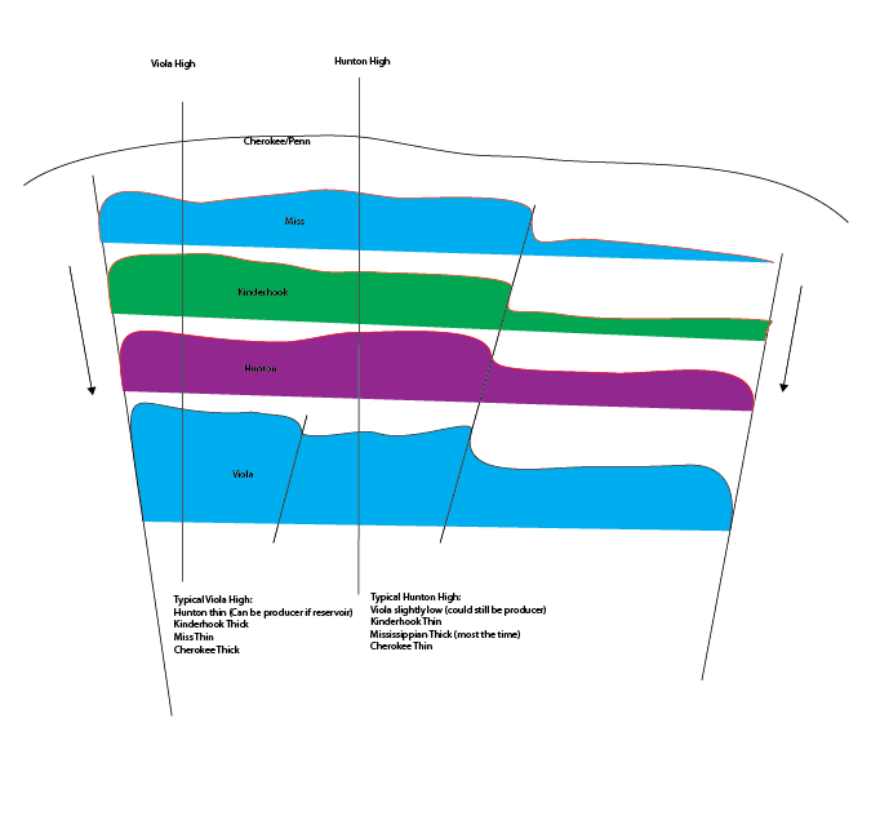


Viola-Pay limited to the upper formation. Trap defined by structural closure, and reservoir. Effective porosity ranges from 3-12% at top of formation. The pay is secondary dolomites.

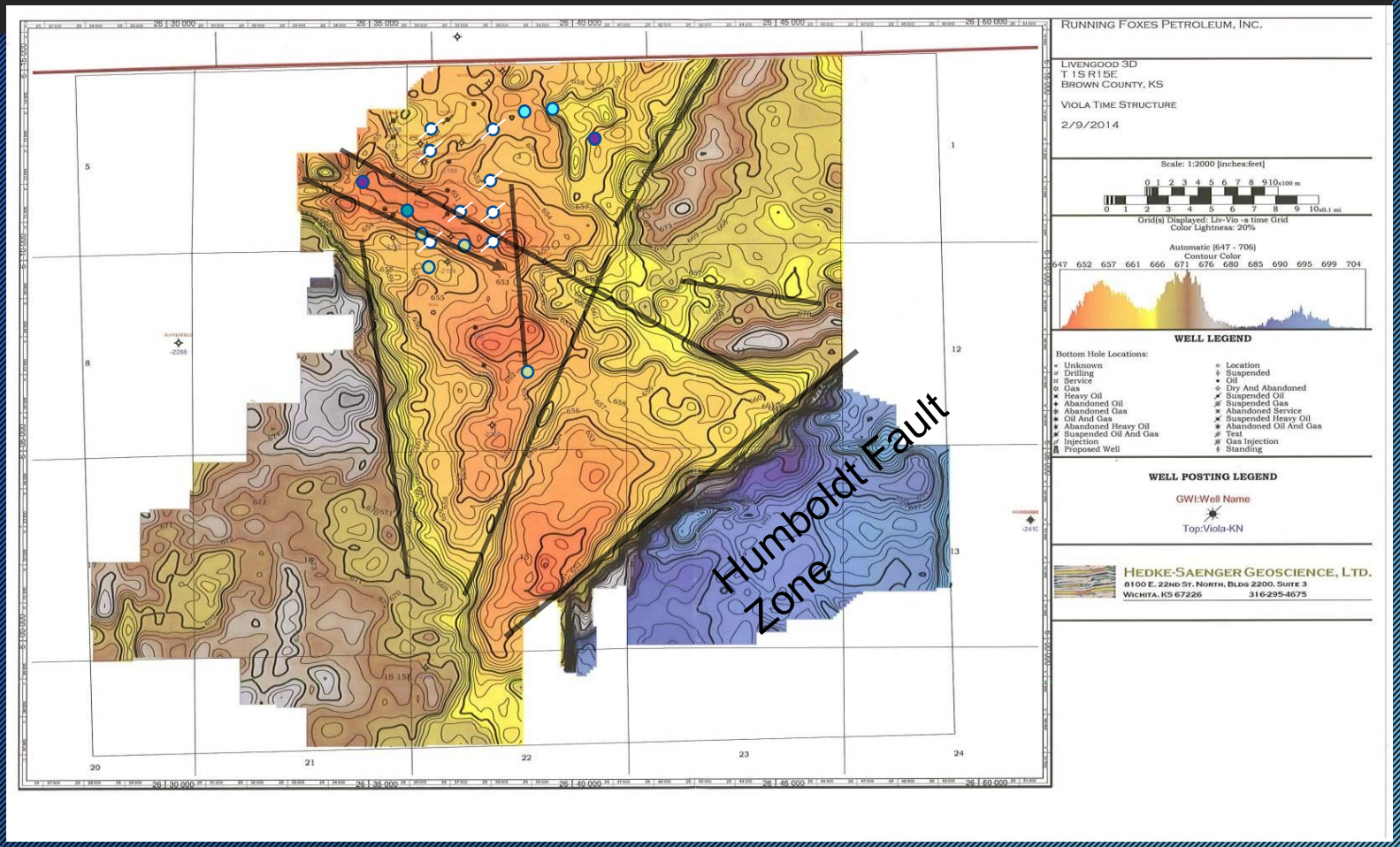
The field has made nearly 200K BO reported, and averages a yield of 30k BO/well on top of the structure. Current results from RFP wells indicates a significant amount of pay left behind.

Lower Paleozoic Isopachs

- Cartoon showing the alternating isopach horizons on top of the structure in the Livengood Field.
- Alternating thins indicate a paleo-high prior to deposition of formations throughout the Paleozoic that may be result of faulting or deposition.
- Fault activity was ongoing from Cambrian to Pennsylvanian time



Livengood Field – Viola – 3D Survey



Exploration Methods

- Identification of secondary dolomite, silica, sphalerite and galena in adjacent host rocks;
- Aeromagnetics – identifying basement faults related to wrench faulting;
- 3D seismic;
- Surface geochemistry in detecting micro-seeps;
- Many discoveries a fluke.

Summary

- Any structural low or high along a wrench fault system;
- Associated with failed rift or wrench fault systems perpendicular to basin dip;
- Boundaries of intercratonic or foreland basins;
- Not in basins where host rocks are porous;
- Not in Post-Paleozoic basins or sediments;
- Caused by migrating low temperature hydrothermal fluids caused by tectonic compression;
- Poorly recognized by the industry.
- .

THE END

Thank you for coming