Appalachian Storage Hub (ASH) Project

Semi-Annual Meeting
March 14, 2017
WVU Erickson Alumni Center

STRATEGY 2: STRATIGRAPHIC CORRELATION

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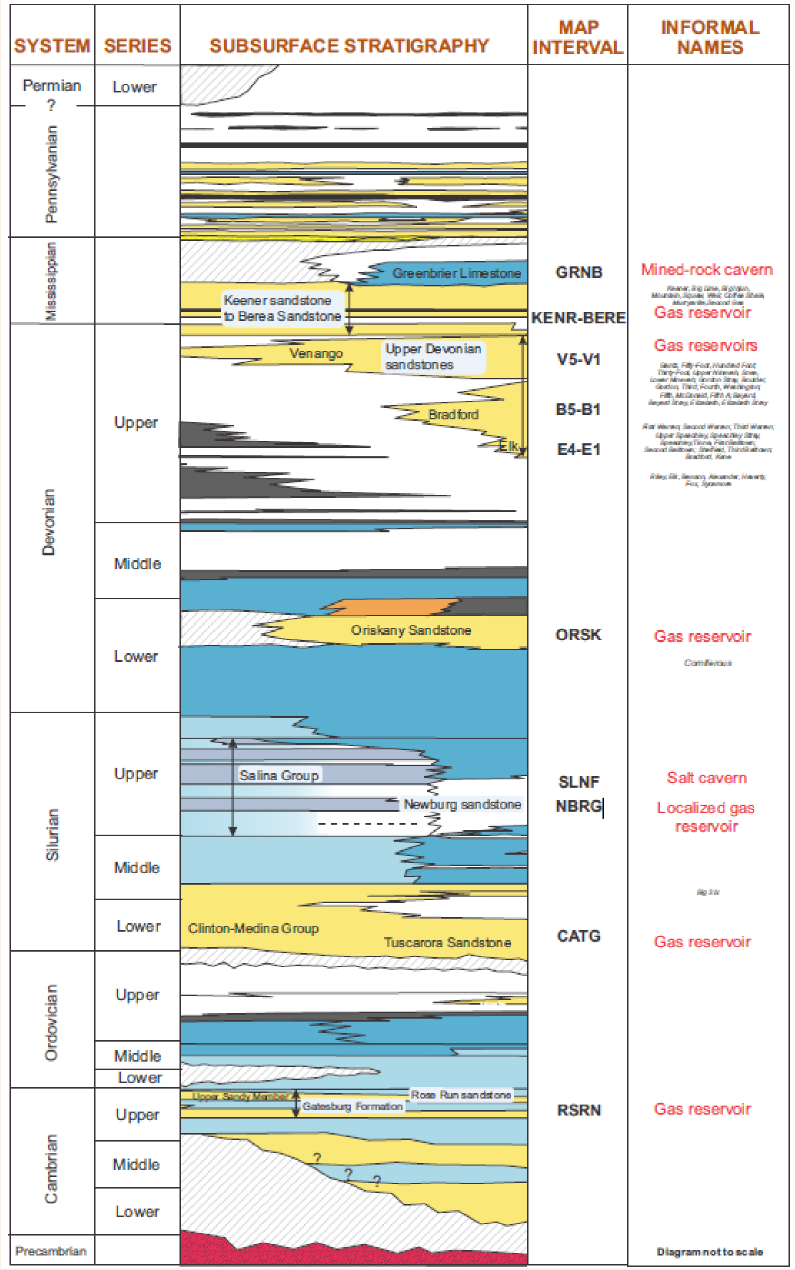
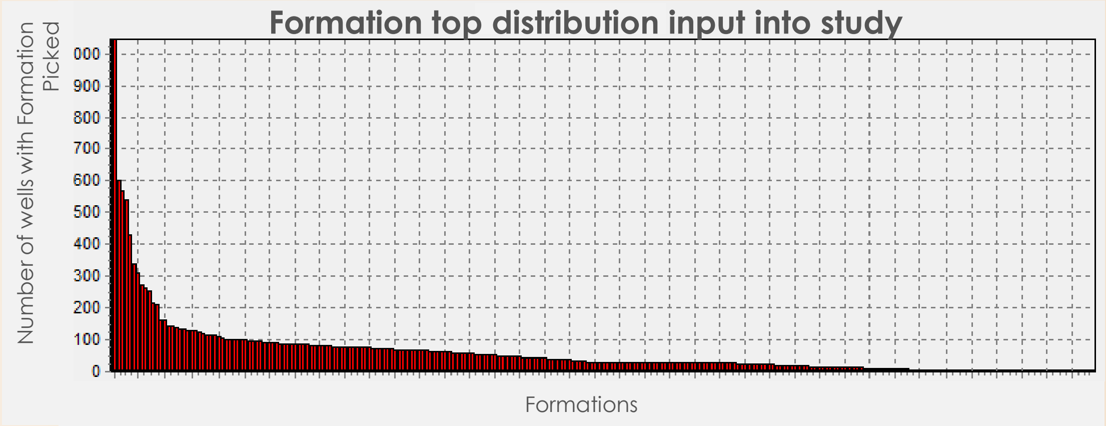
- Gary Daft - WVGES
- Eric Lewis - WVGES
- Kristin Carter – PAGS

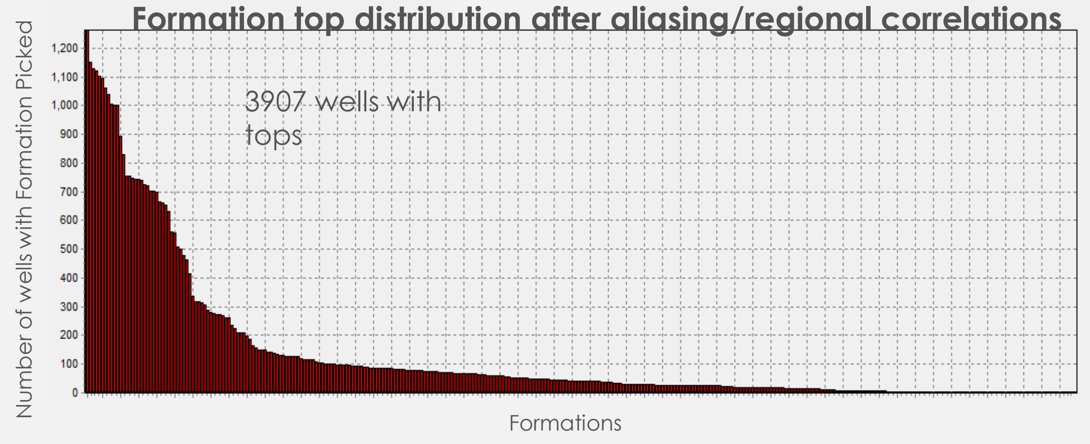
ASH PROJECT

Strategy 2 – Stratigraphic Correlation of Key Units



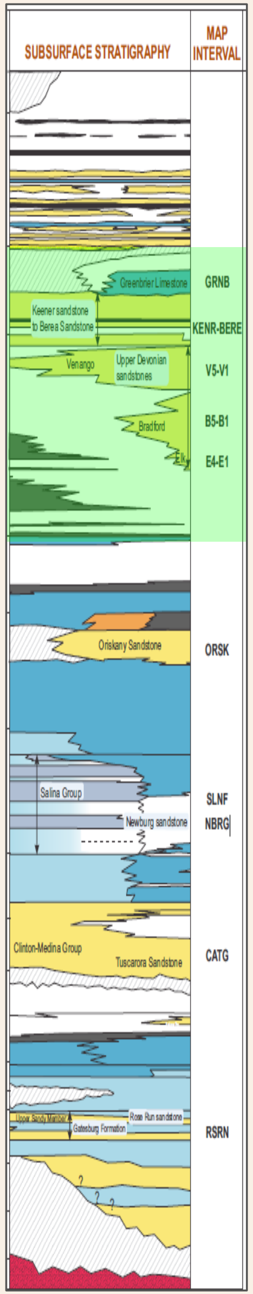


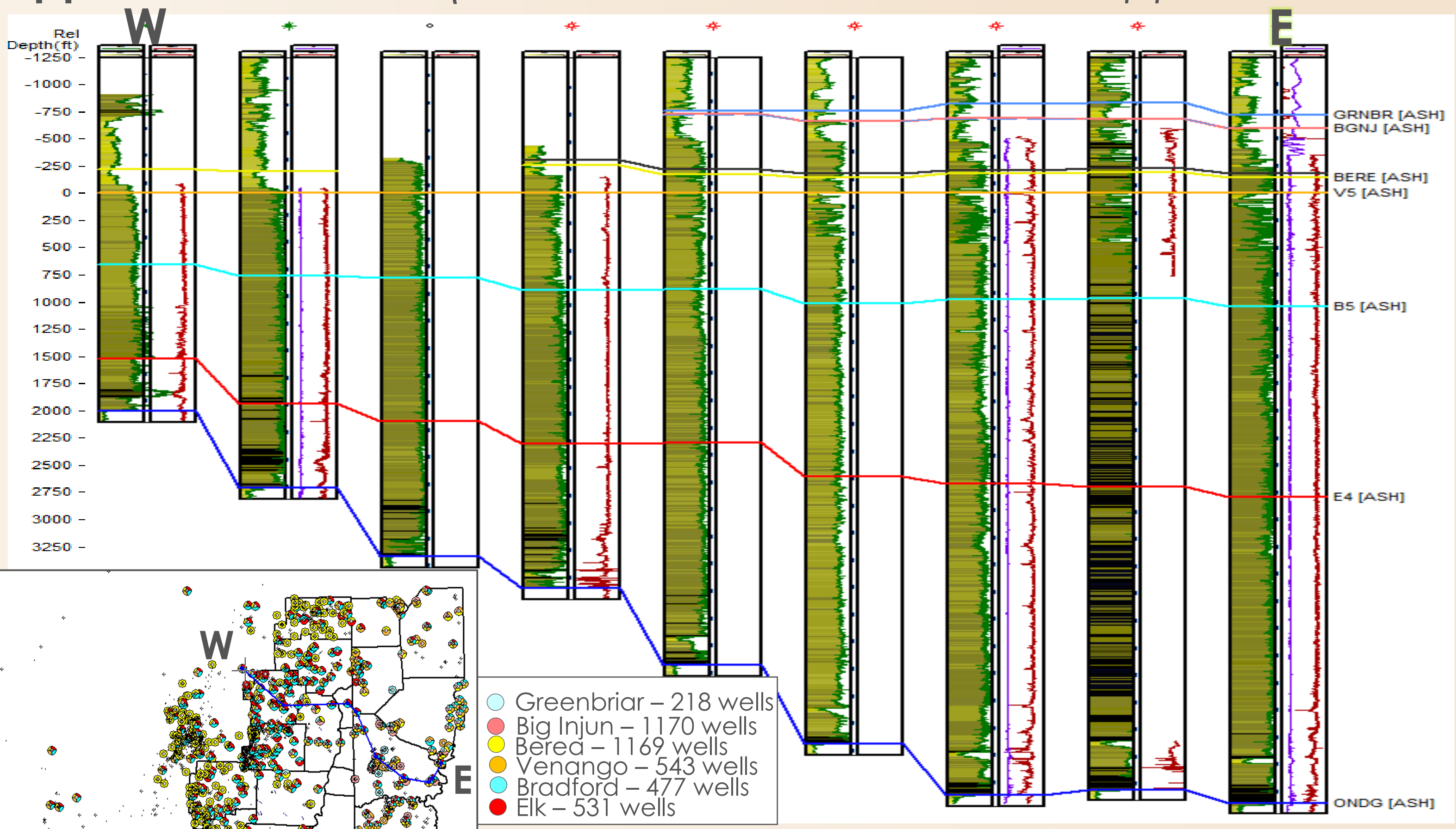
- **Challenge** – over 200 individual named formations. Need to alias formations and correct for state-line 'faults' / jumped correlations to provide a consistent set of maps for the nine intervals of interest within the AOI.
  - Identify formations of value and their lateral equivalents.
  - Extend correlations into areas where well logs are present but tops are missing.

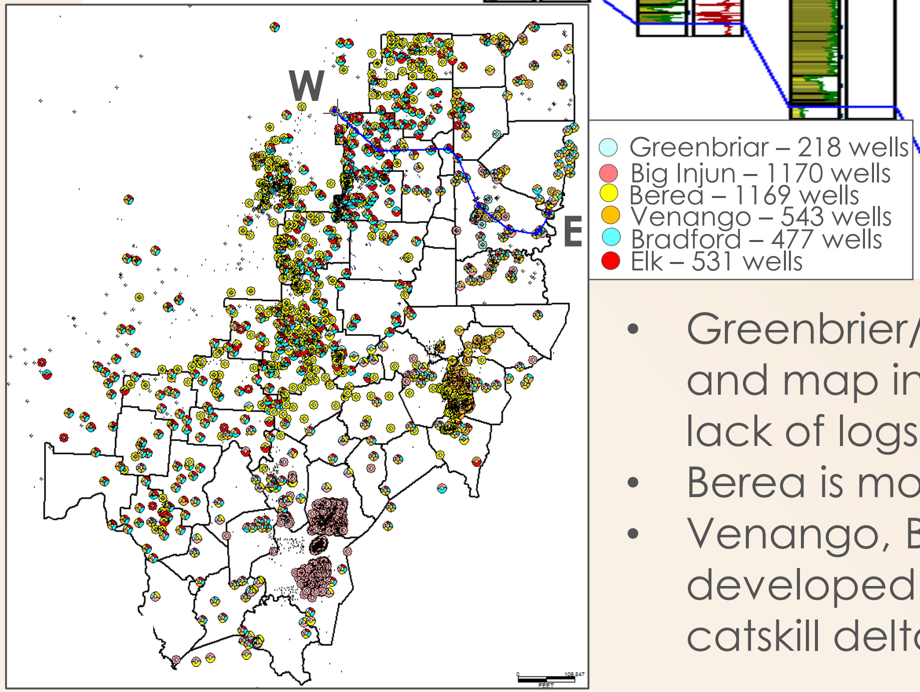


Strategy 2 – stratigraphic correlation

Mississippian – Devonian : *(Greenbrier, Keener to Berea, Upper Devonian Sands)*



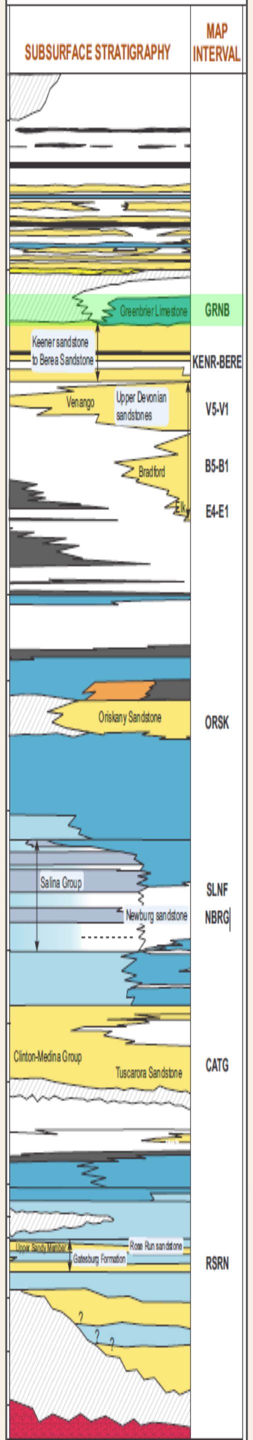




- Greenbrier/Big Injun is difficult to correlate and map in OH due to unconformities and lack of logs over interval
- Berea is more well developed into OH
- Venango, Bradford, and Elk are more well developed in PA & WV due to proximity to catskill delta

Strategy 2 – stratigraphic correlation

Mississippian – Devonian : *Greenbrier*



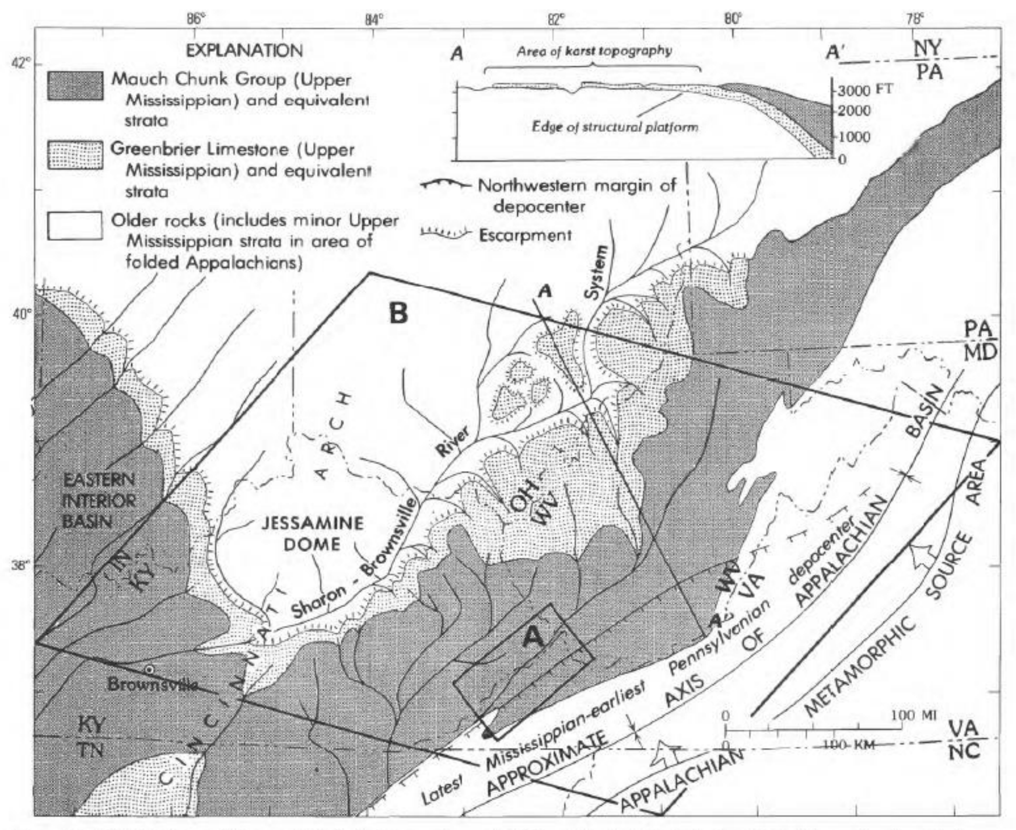


Figure 1. Distribution of Upper Mississippian rocks and inferred Late Mississippian–Early Pennsylvanian drainage system, Kentucky, Ohio, West Virginia, and parts of adjacent States. Locations of areas A and B depicted in figure 7 also shown.

From Rice & Schwietering, 1988

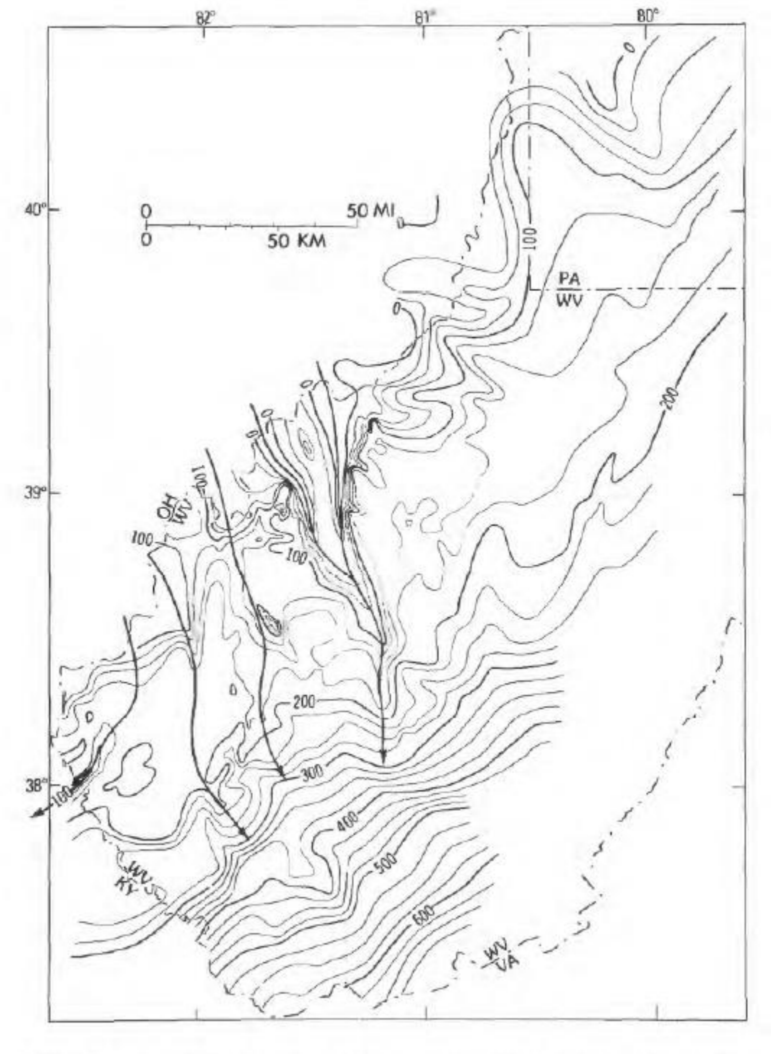


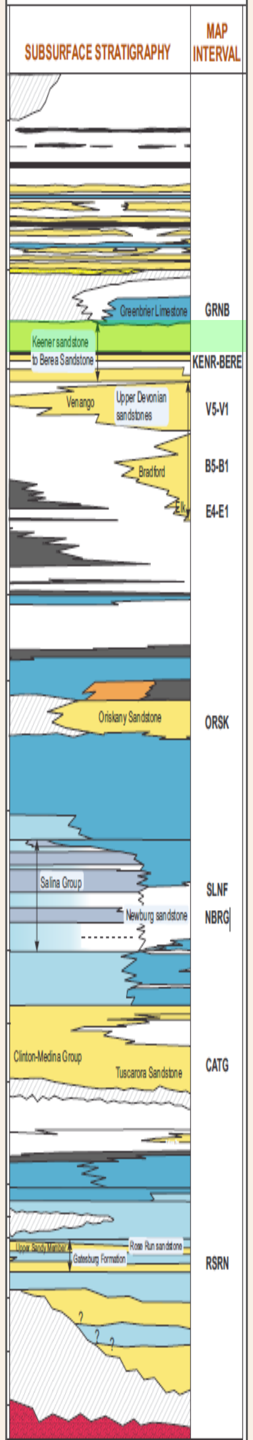
Figure 5. Isopach map of Mississippian Greenbrier Limestone in West Virginia showing traces and directions of flow of inferred paleochannels (indicated by arrows). Contour interval 25 ft. Modified from Flowers (1956, pl. 2).

From Rice & Schwietering, 1988

Greenbrier subcrop sub parallel to Ohio River.
Some erosional remnants complicate contour mapping of interval.

Strategy 2 – stratigraphic correlation

Mississippian – Devonian : *Big Injun*



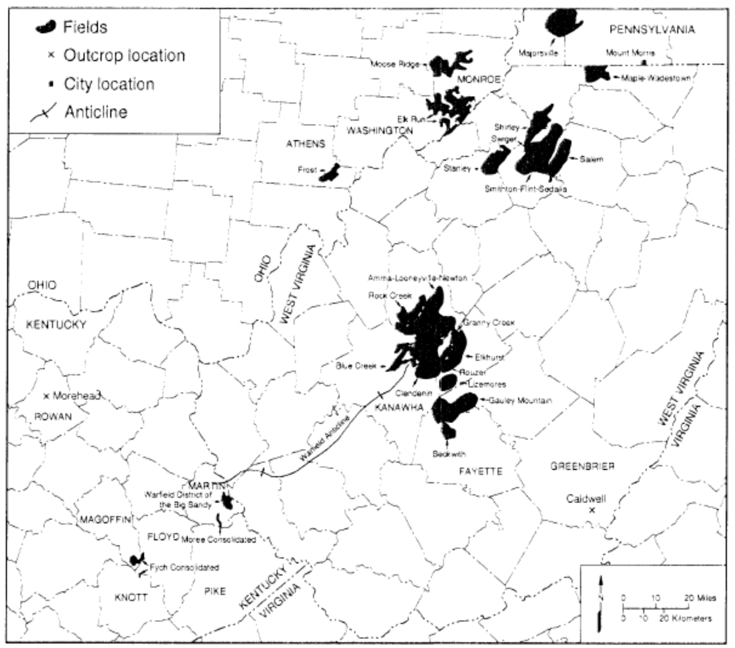


Figure Mbi-2. Location map for fields, anticlines, and outcrop localities mentioned in text and Table Mbi-1.
From Roen et al., 1996

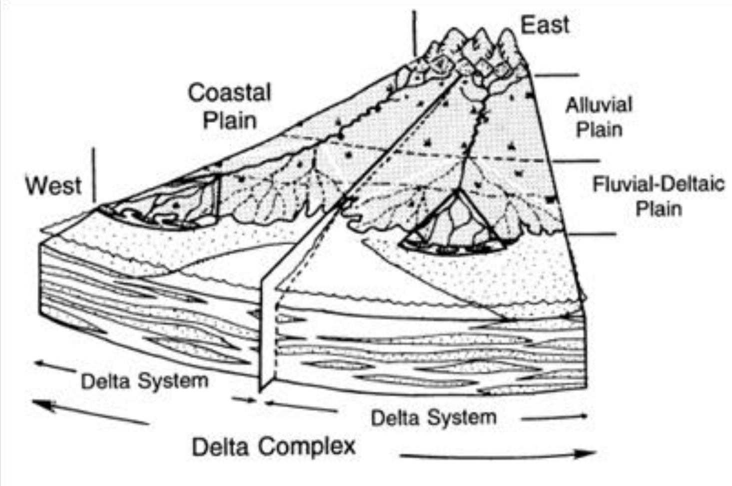
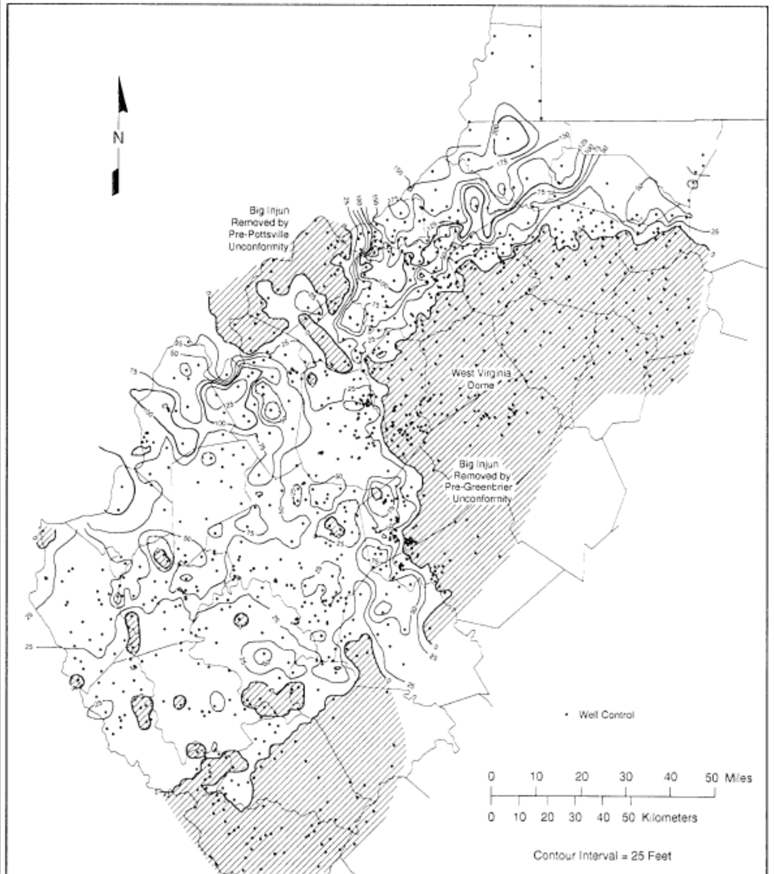


Figure Dvs-12a.
From Roen et al., 1996



From Roen et al., 1996

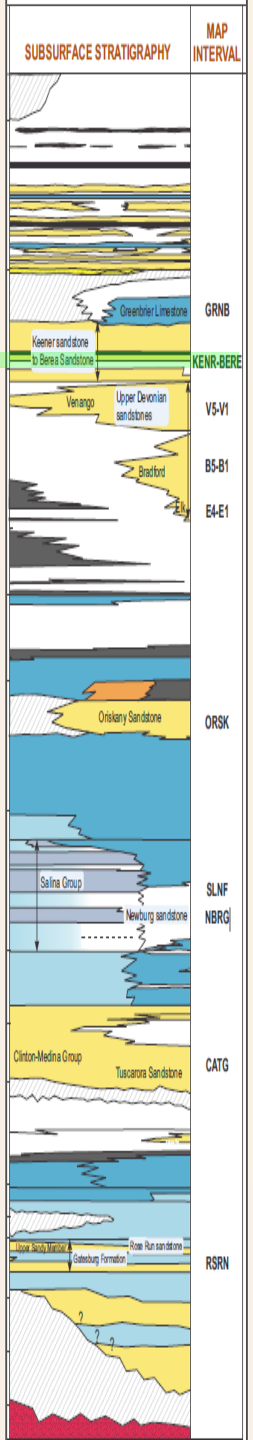
Most productive Lower Miss sandstone in basin.

Discovered in 1886.

Fluvial channel to distributary/delta front environment of deposition.

Strategy 2 – stratigraphic correlation

Mississippian – Devonian : *Berea*



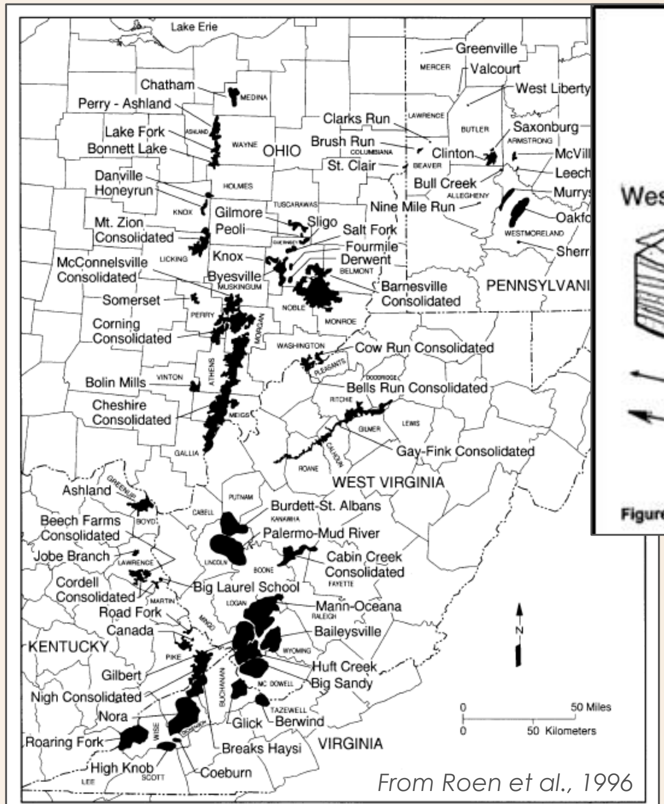


Figure MDe-3. Location of the Lower Mississippian-Upper Devonian Berea and equivalent sandstones productive gas pools and fields mentioned in text or listed in Table MDe-1. Other productive areas illustrated in Figure MDe-1 are not shown.

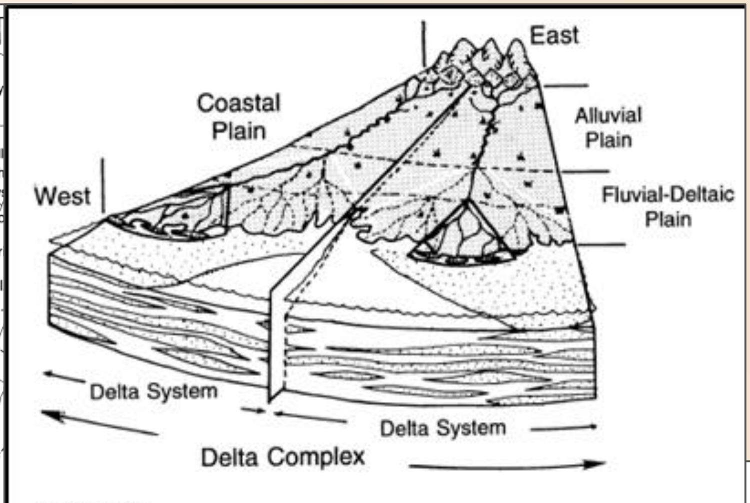


Figure Dvs-12a.

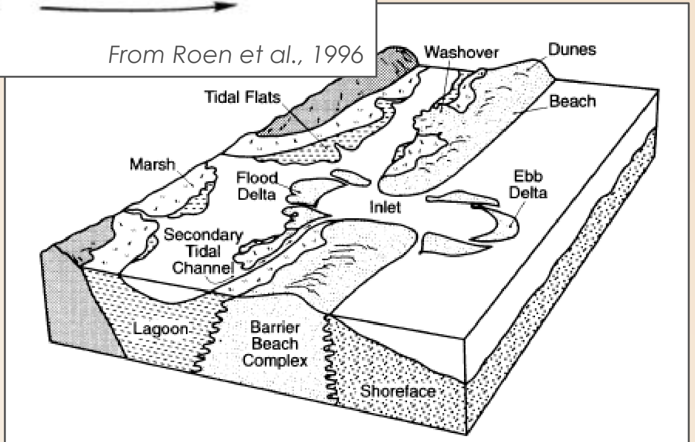


Figure MDe-10. Subdivision of a typical modern barrier island system and its environments. Modified from Reinson (1984).

From Roen et al., 1996

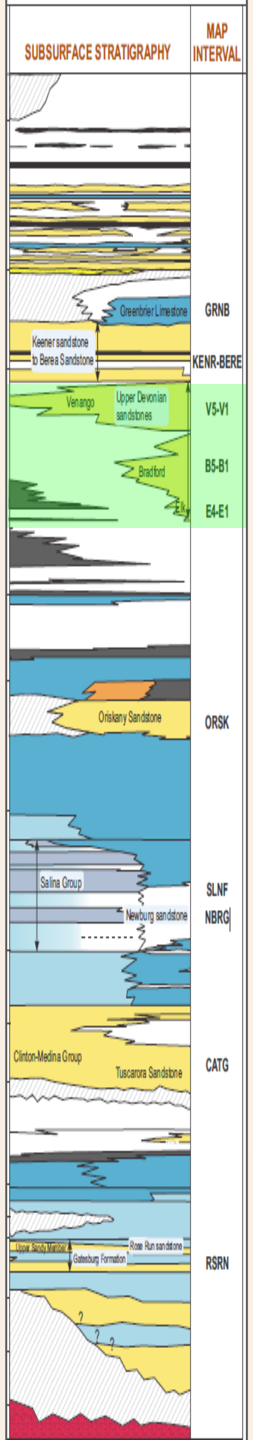
First discovered in 1860.

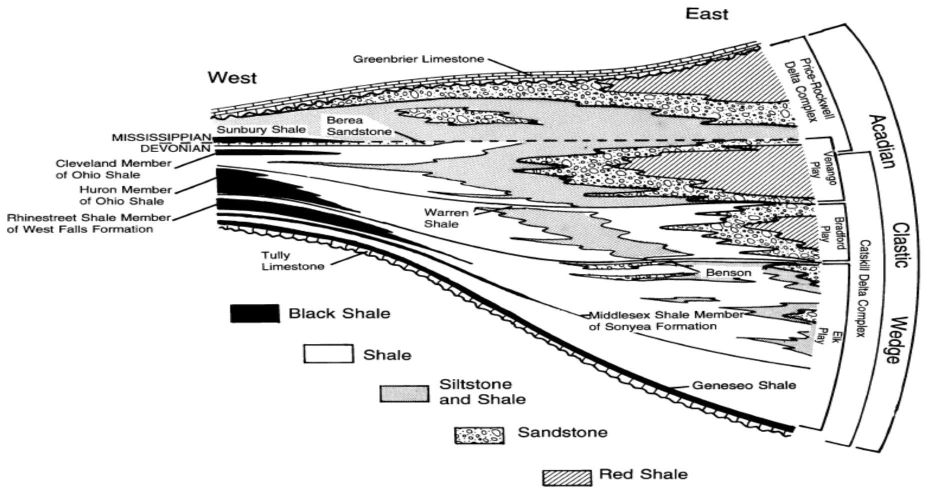
Diverse depositional environments from fluvial-deltaic to shallow marine and barrier beach settings.

Some stacked reservoir potential

Strategy 2 – stratigraphic correlation

Mississippian – Devonian : *Venango, Bradford, Elk sands*





From Roen et al., 1996

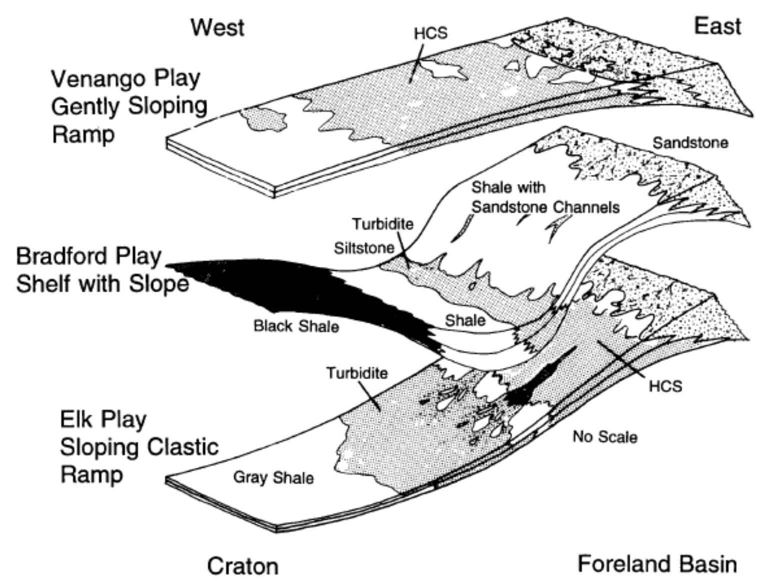


Figure Dbs-23. Schematic diagram contrasting the strike-trending Bradford play siltstones in the productive area of northern West Virginia with more lobate and sheet-like marine siltstone deposits of the underlying Elk and overlying Venango plays. The changing geometry of the units is related to progressive shallowing of sea-floor slopes combined with syndepositional tectonism along the eastern margin of the Rome Trough during Bradford play time. From Boswell (1988b). HCS indicates hummocky cross-stratified, shelf-storm deposits. *From Roen et al., 1996*

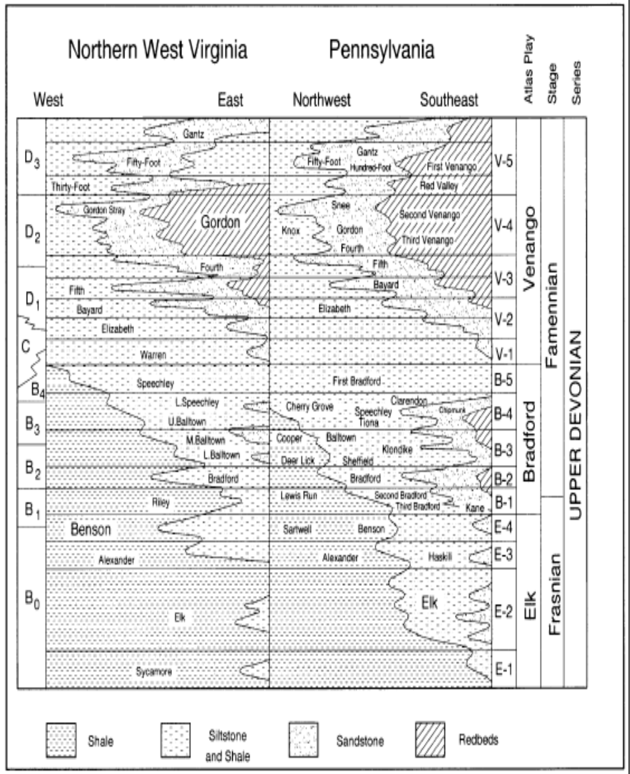


Figure Dvs-6. The sequence and approximate correlation of major drillers' sands in the subsurface of western Pennsylvania and northern West Virginia. Pennsylvania correlations taken largely after Fettke (1938b), Dickey and others (1943), Wolfe (1963), and Harper and Laughrey (1987). West Virginia correlations after Cardwell (1982a), Filer (1985), and Boswell and others (1987). Atlas designations are shown in the column on the right. The terminology of Kelley and Wagner (1970) is given on the left. *From Roen et al., 1996*

First discovered in 1859.

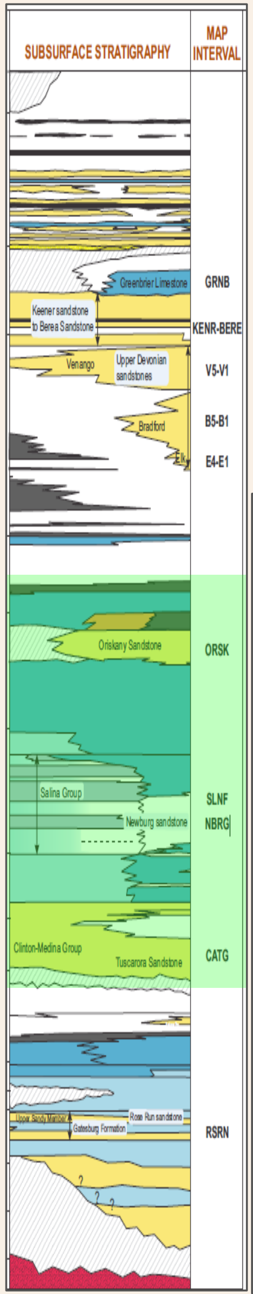
Fluvial-deltaic environment of deposition in Catskill delta complex.

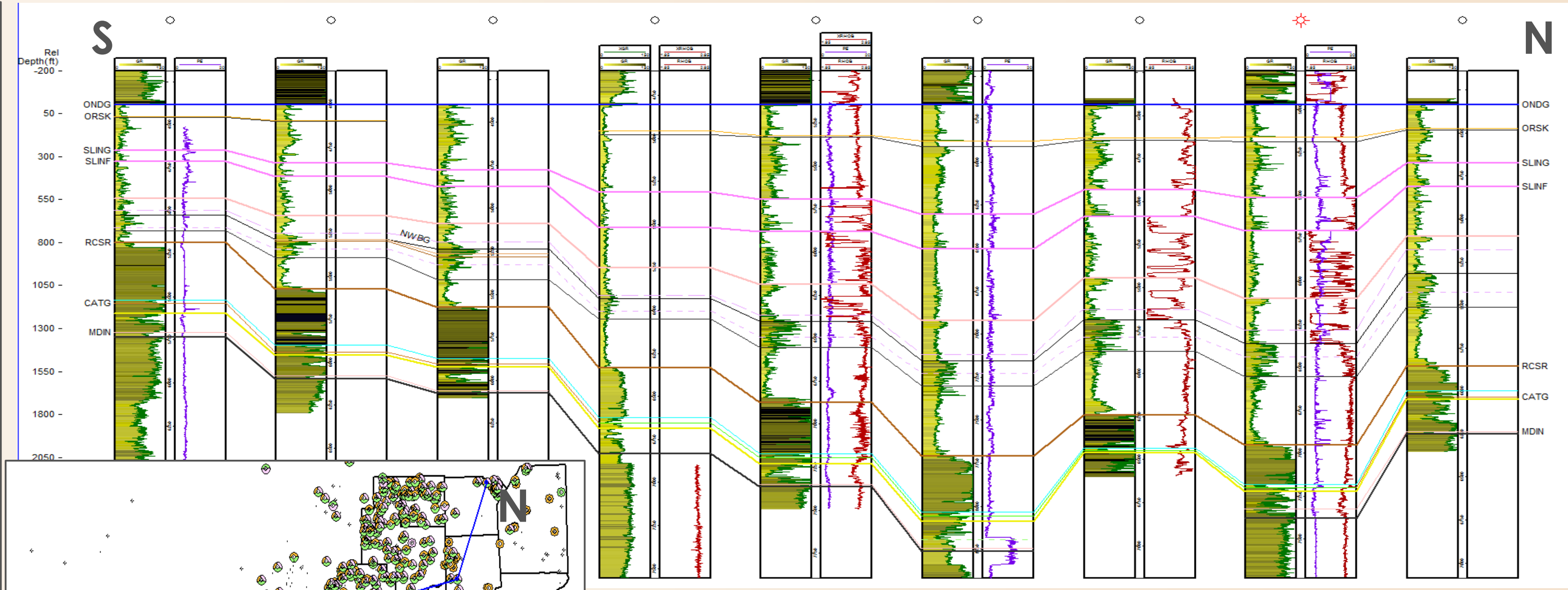
Sediments shed from the Acadian Orogeny.

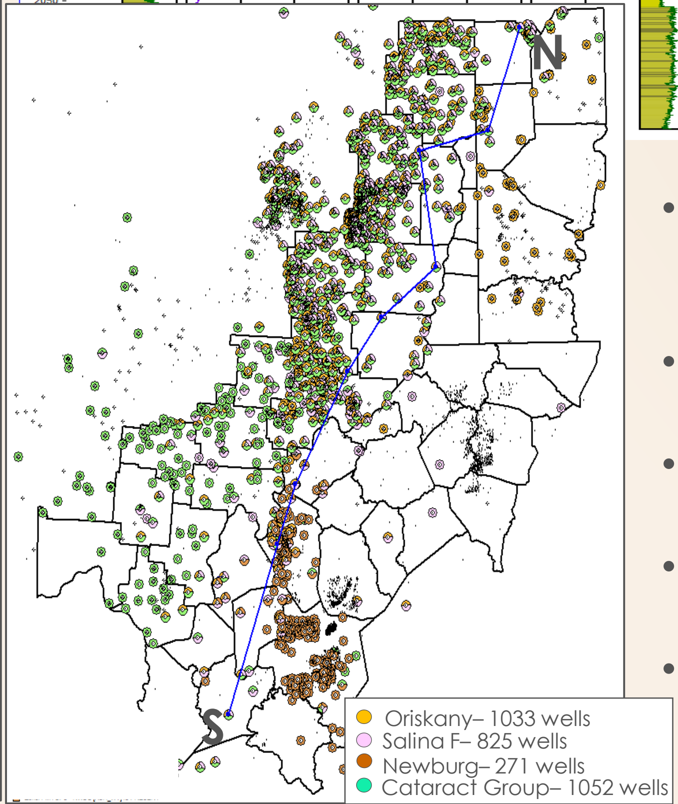
Multiple stacked sandstone reservoirs.

Strategy 2 – stratigraphic correlation

Devonian - Silurian: *(Oriskany, Salina, Newburg, Cataract Group)*



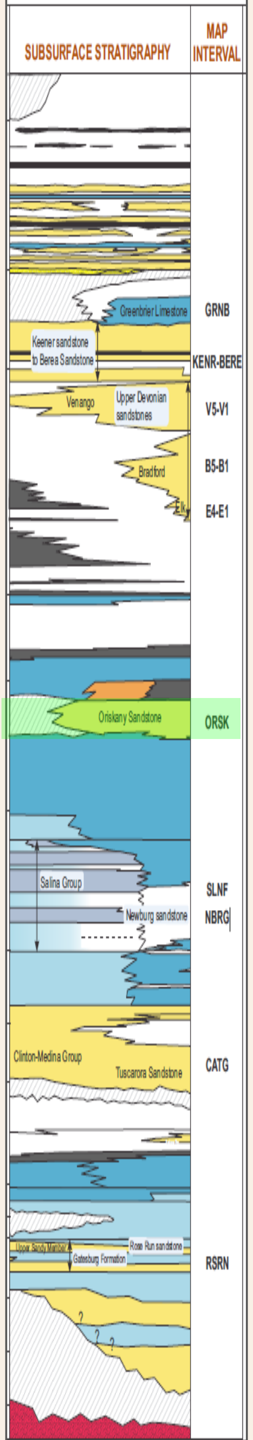




- Oriskany is bound by unconformities on both top and base, so presence is spotty where thin.
- Salina salt basin is centered along West Virginia panhandle.
- Salina F4 salt bound on top by Salina G anhydrite (~100’ thick).
- Newburg developed in southwestern WV.
- Cataract Group (Clinton/Medina) is present throughout area.

Strategy 2 – stratigraphic correlation

Devonian - Silurian: *Oriskany*



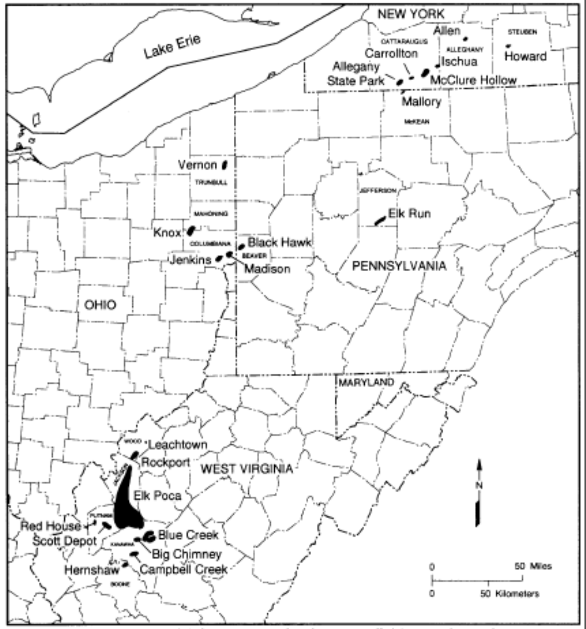
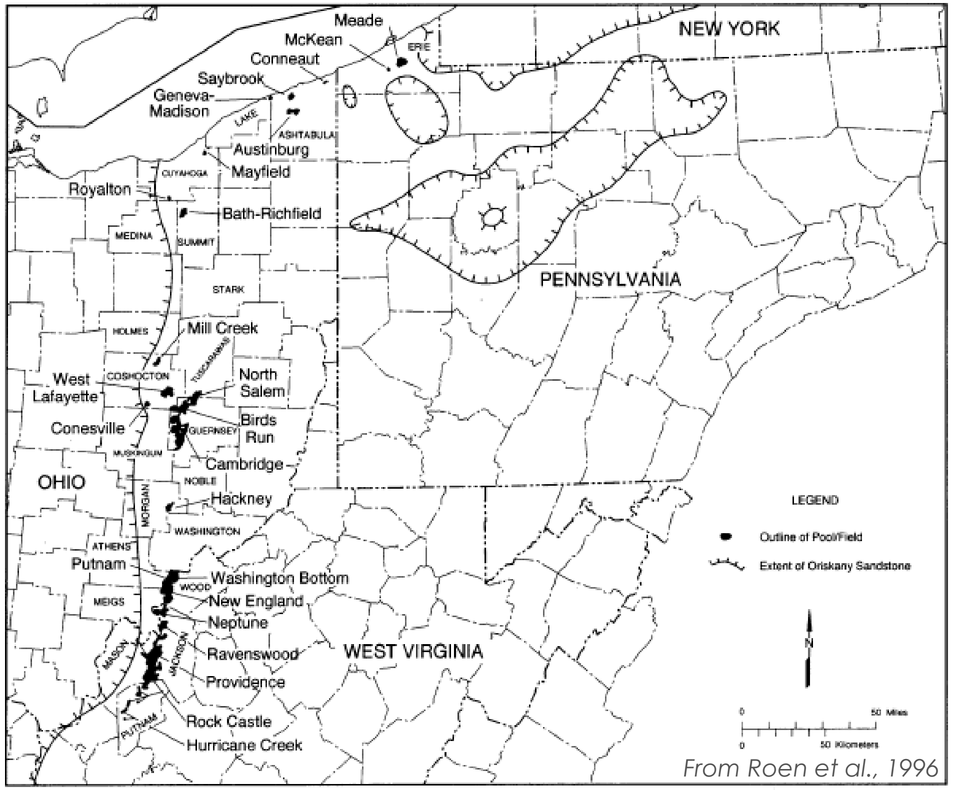


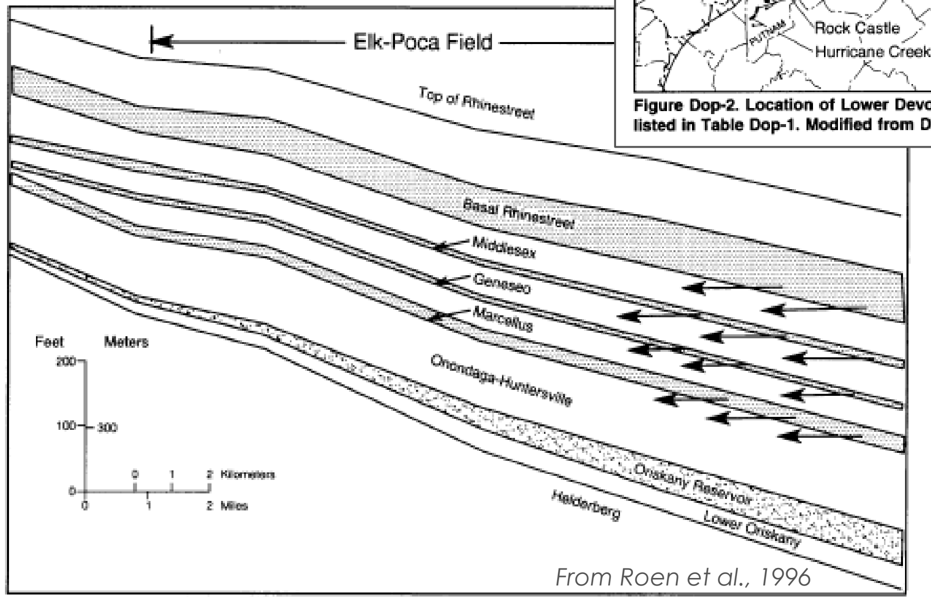
Figure Doc-2. Location of Oriskany combination traps fields mentioned in the text or in Table Doc-1.

From Roen et al., 1996



From Roen et al., 1996

Figure Dop-2. Location of Lower Devonian Oriskany Sandstone updip permeability pinchout fields discussed in text or listed in Table Dop-1. Modified from Diecchio and others (1984).



From Roen et al., 1996

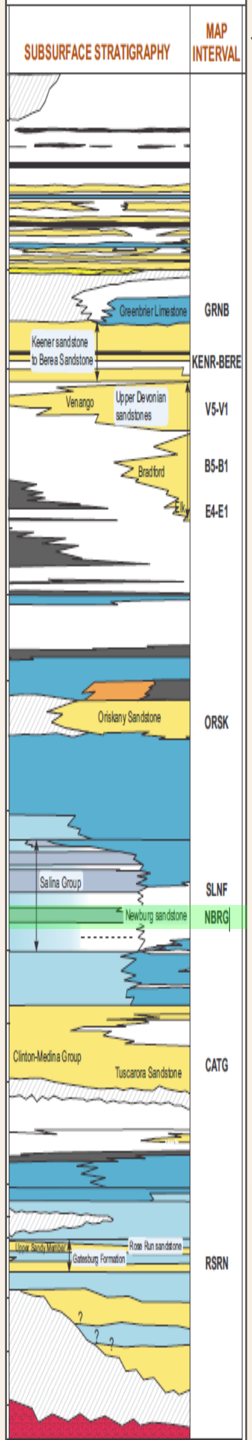
First discovered in 1887.

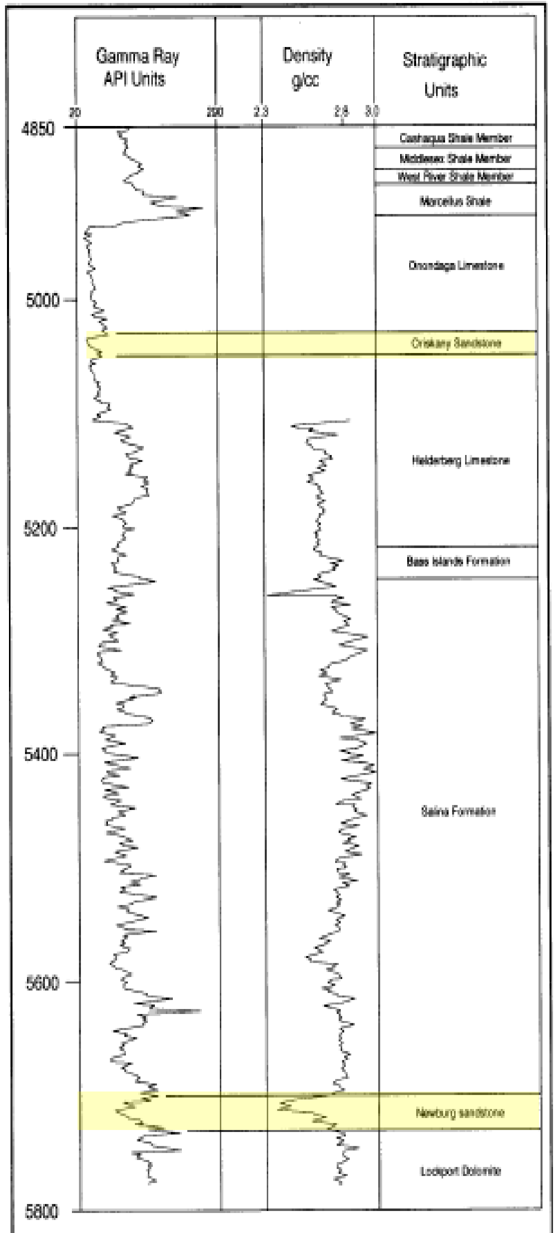
High-energy marine, nearshore environment of deposition.

Single clean sandstone reservoir.

Strategy 2 – stratigraphic correlation

Devonian - Silurian: *Newburg*





From Roen et al., 1996

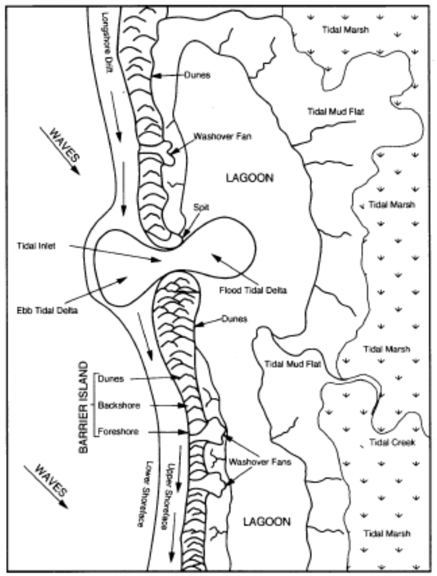


Figure Sns-7. Model for the depositional environments of the Newburg sandstone. Key elements are the barrier island setting, where wind and waves can create a well-rounded, well-sorted, supermature sandstone with frosted, windblown sand grains, and the ebb tidal delta that extends westward of the maximum extent of the barrier island sands.

From Roen et al., 1996

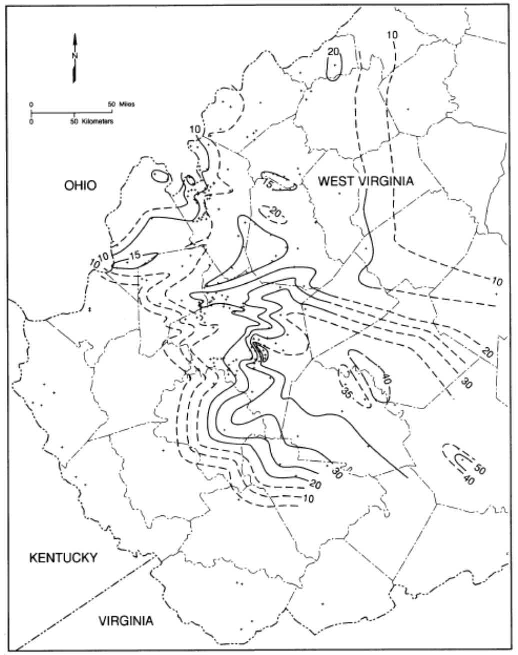


Figure Sns-6. Regional isopach map of the Newburg sandstone, based on data from gamma-ray logs. Thickness values are for the entire Newburg interval, not just the upper, clean sandstone in which porosity and good reservoir qualities are developed.

From Roen et al., 1996

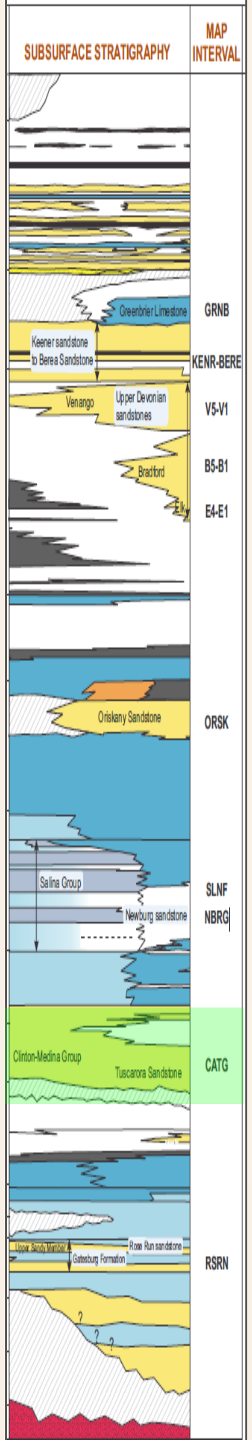
First discovered in 1939, play kicked off in 1964.

Supra-to-intertidal environment with storm influence.

Single clean sandstone reservoir.

Strategy 2 – stratigraphic correlation

Devonian - Silurian: *Cataract Group*



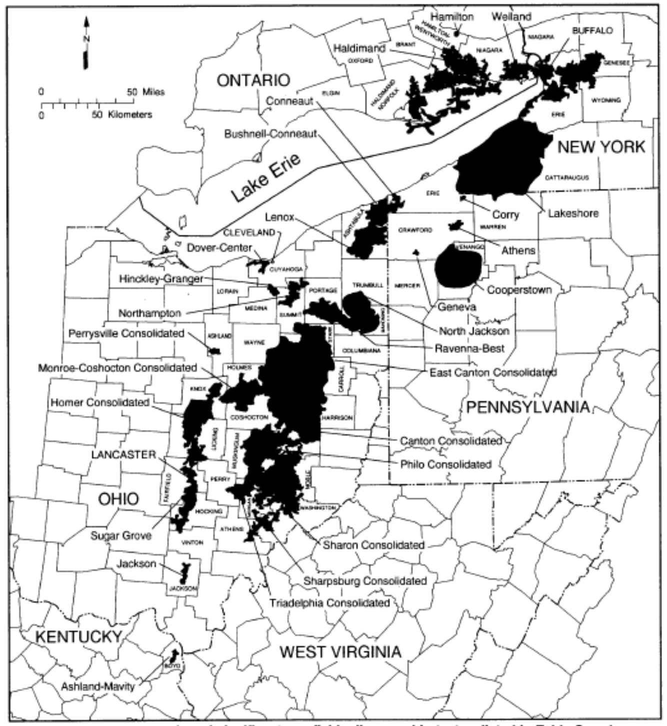


Figure Scm-2. Location of significant gas fields discussed in text or listed in Table Scm-1.

From Roen et al., 1996

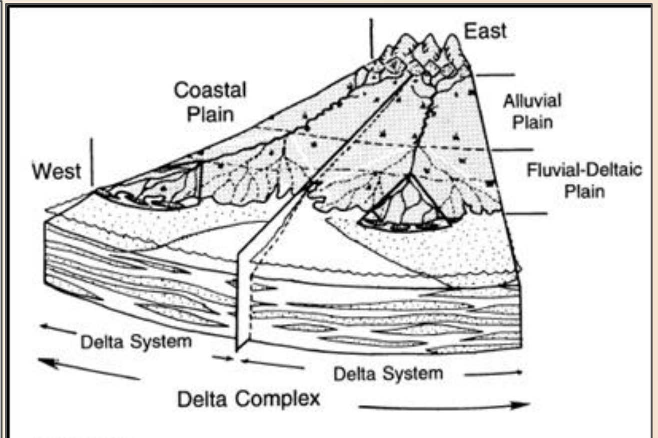


Figure Dvs-12a.

From Roen et al., 1996

First discovered accidentally in 1920s.

Upper 'Clinton' sands are shallow marine – deltaic.

Lower 'Medina' sands are transgressive marine sands.

Generally low porosity. Production enhanced by fractures.

Multiple stacked laterally continuous sandstone reservoirs

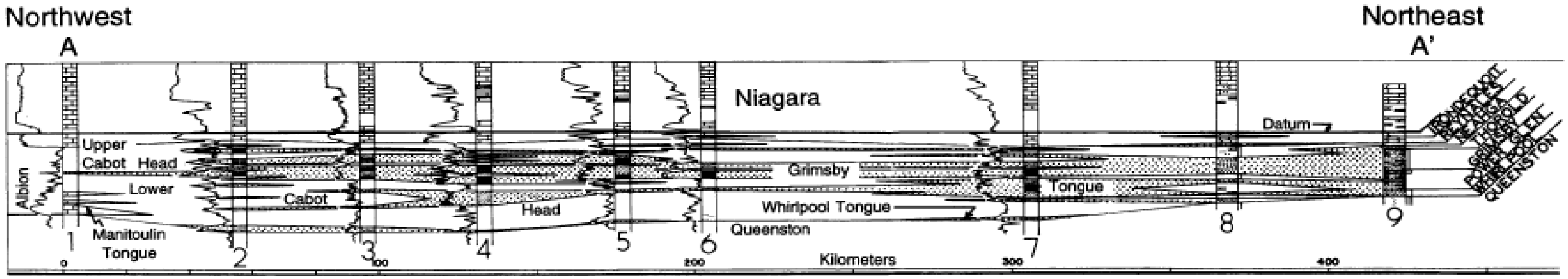
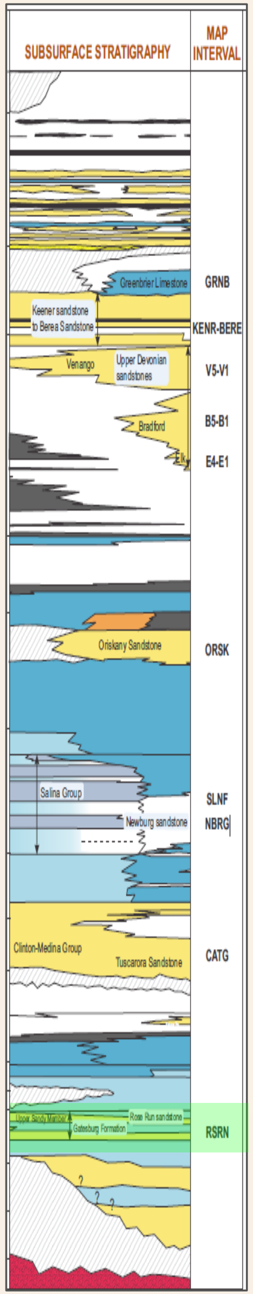
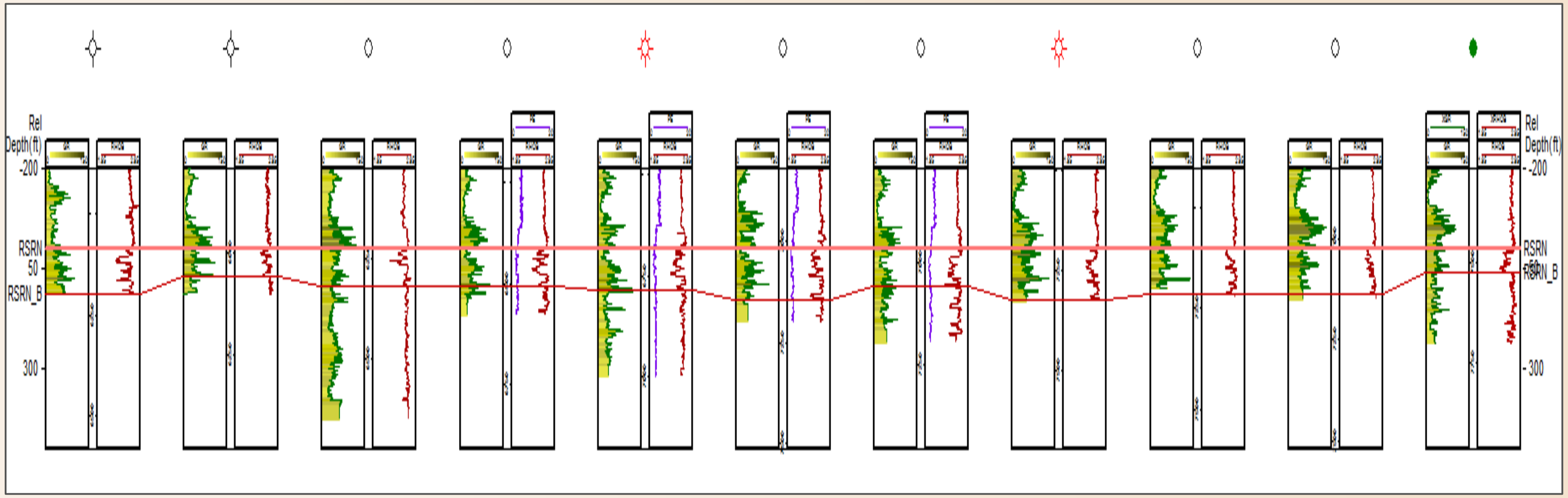


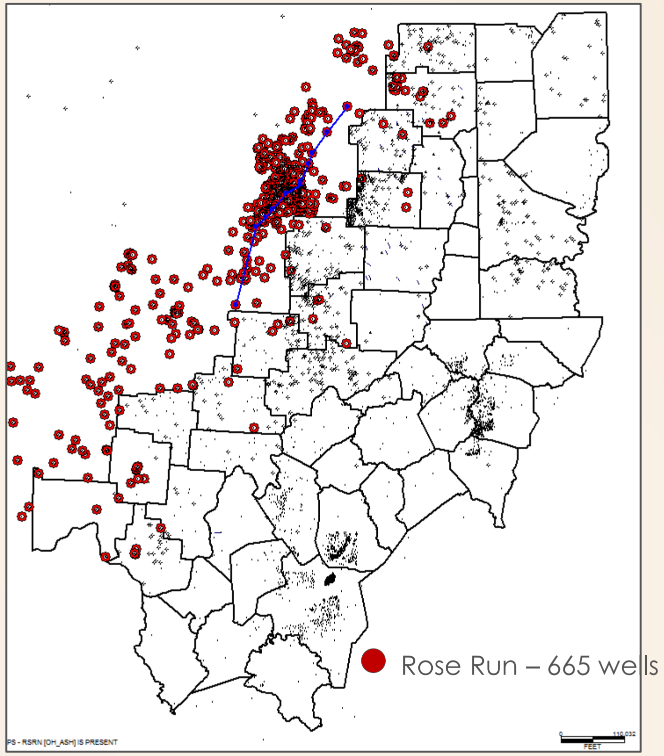
Figure Scm-4. Regional stratigraphic strike cross section A-A' of the Cataract/Medina Group interval. Modified from Knight (1969). Nomenclature is that of Knight (1969).

From Roen et al., 1996

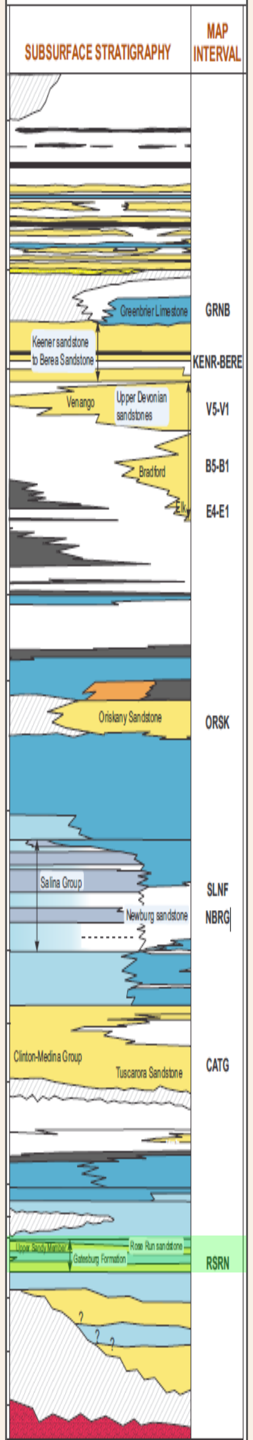
Strategy 2 – stratigraphic correlation
Ordovician – Rose Run







- Rose Run is part of the Knox unconformity play.
- Has complex mineralogy (feldspar) causing GR to read high.
- Best discriminator for reservoir is porosity log.
- Rose Run / Gatesburg is prohibitively deep and poorly defined in WV/PA.



Strategy 2 – stratigraphic correlation

Ordovician - Cambrian: *Rose Run*

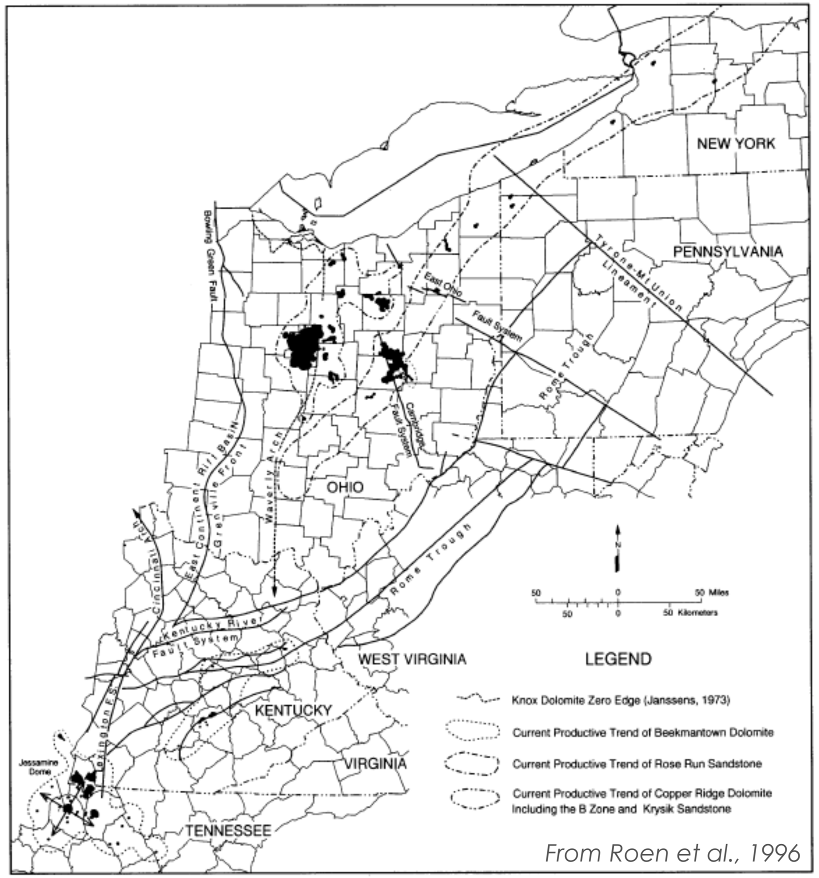


Figure COk-3. Map showing outlines of productive gas trends and major structural features.

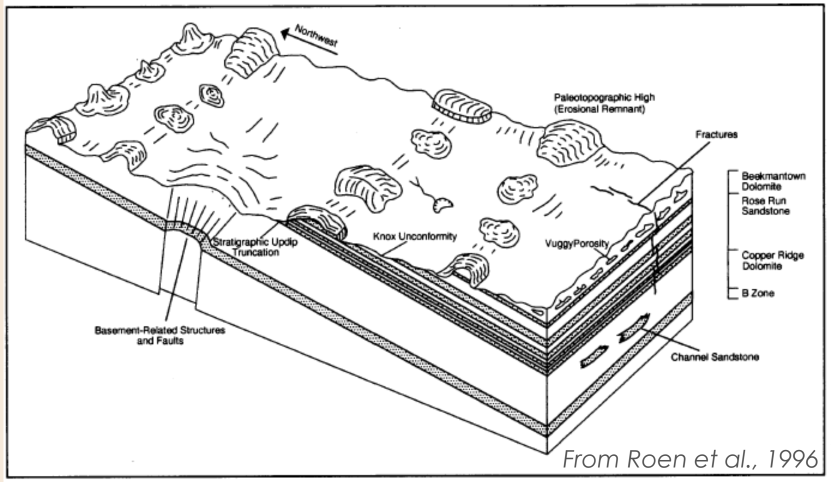


Figure COk-12. Block diagram illustrating trapping mechanisms for the Knox unconformity play.

First discovered in 1961.

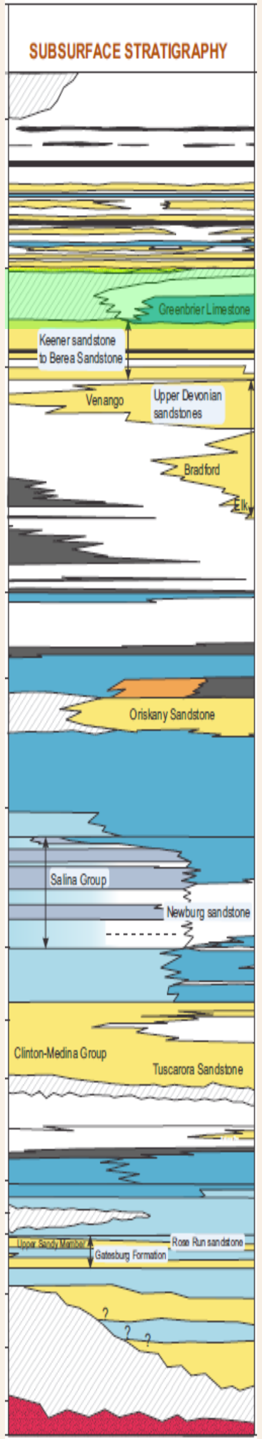
Interpreted to represent lowstand sands that were reworked during sealevel transgression.

Single Laterally continuous sandstone reservoir.

STRATEGY 3: MAPPING

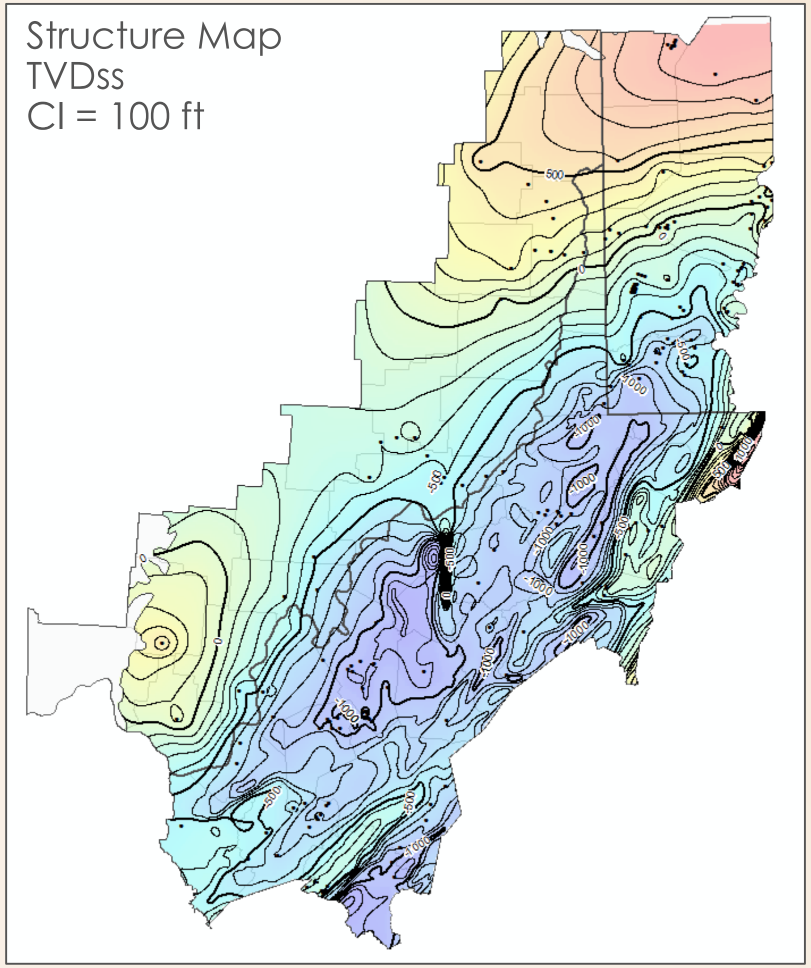
Kyle Metz – Energy Resources Group, Ohio Department of Natural Resources – Division of Geological Survey

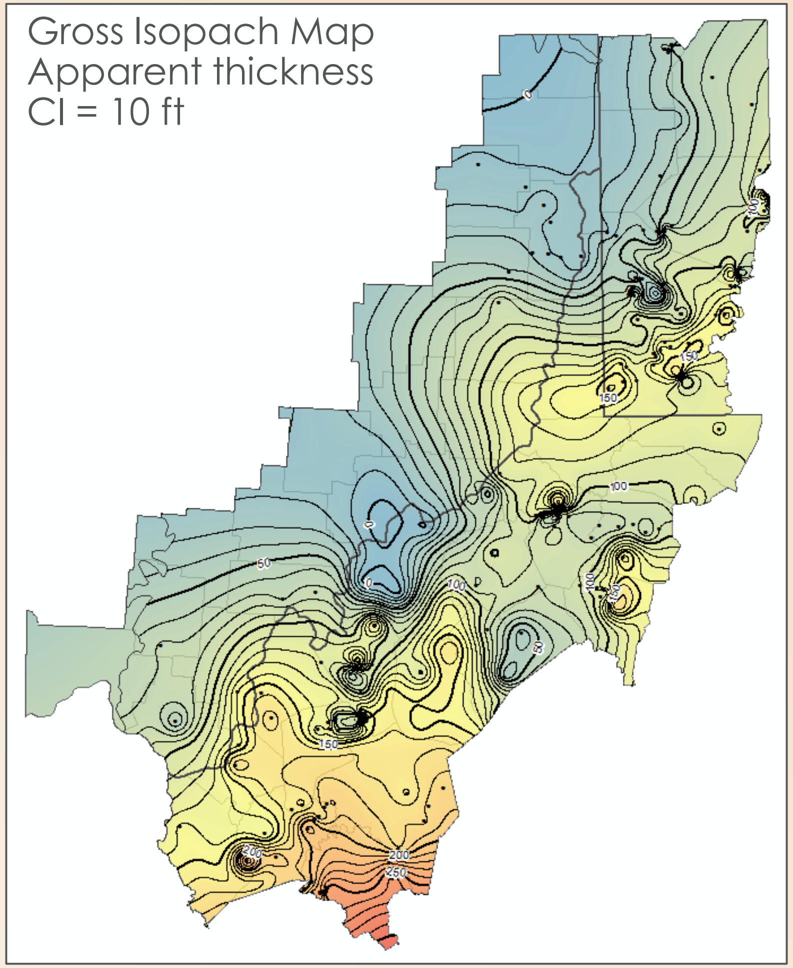
- Michael Solis - ODNR
- Mohammad Fakhari - ODNR
- Gary Daft- WVGES
- Kristin Carter – PAGS



Strategy 3 – Mapping of Key Intervals

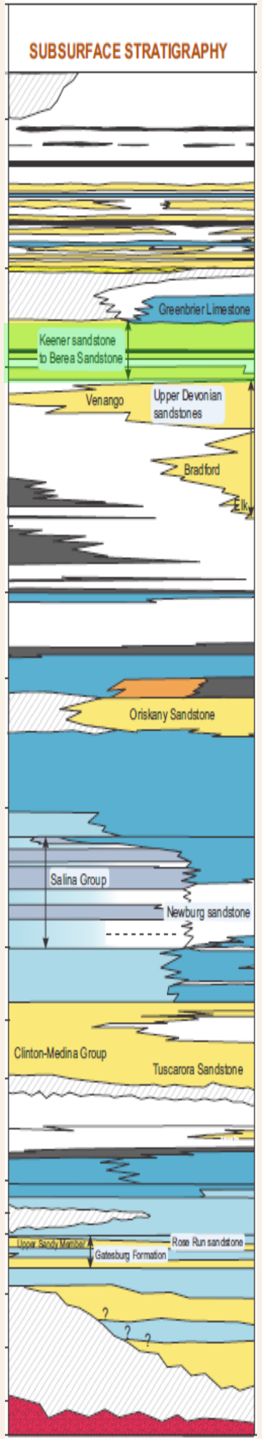
Greenbrier





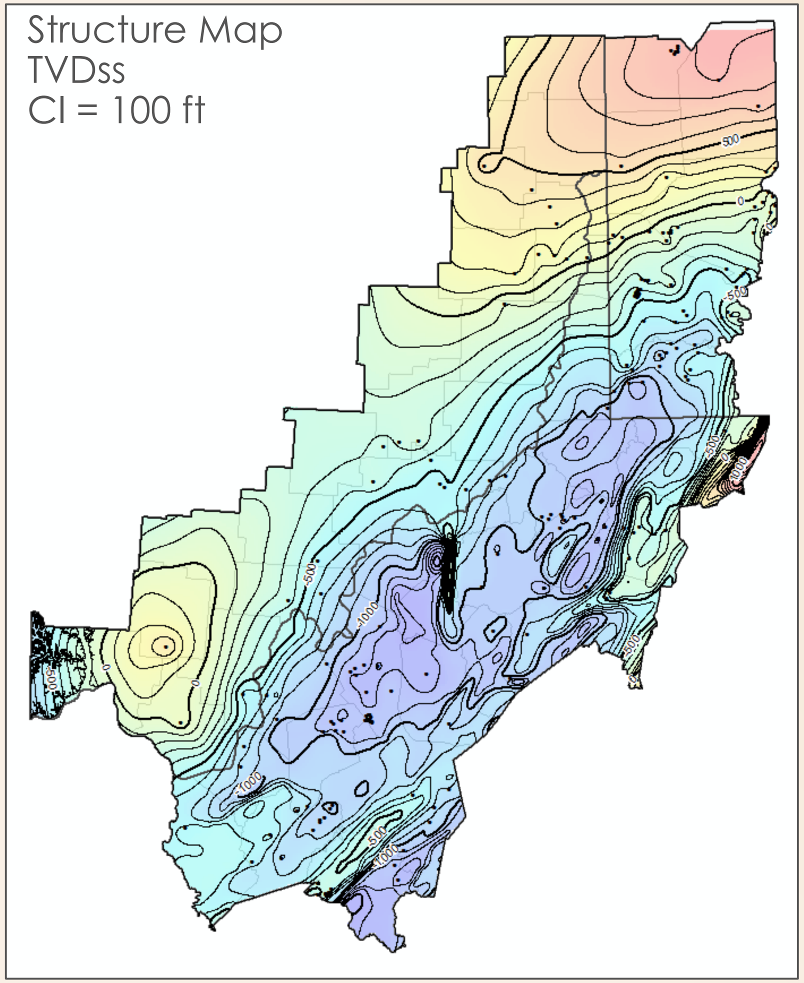
- Structure map from WV combined with well control to generate high-resolution map that honors preexisting structure maps and newest well tops.

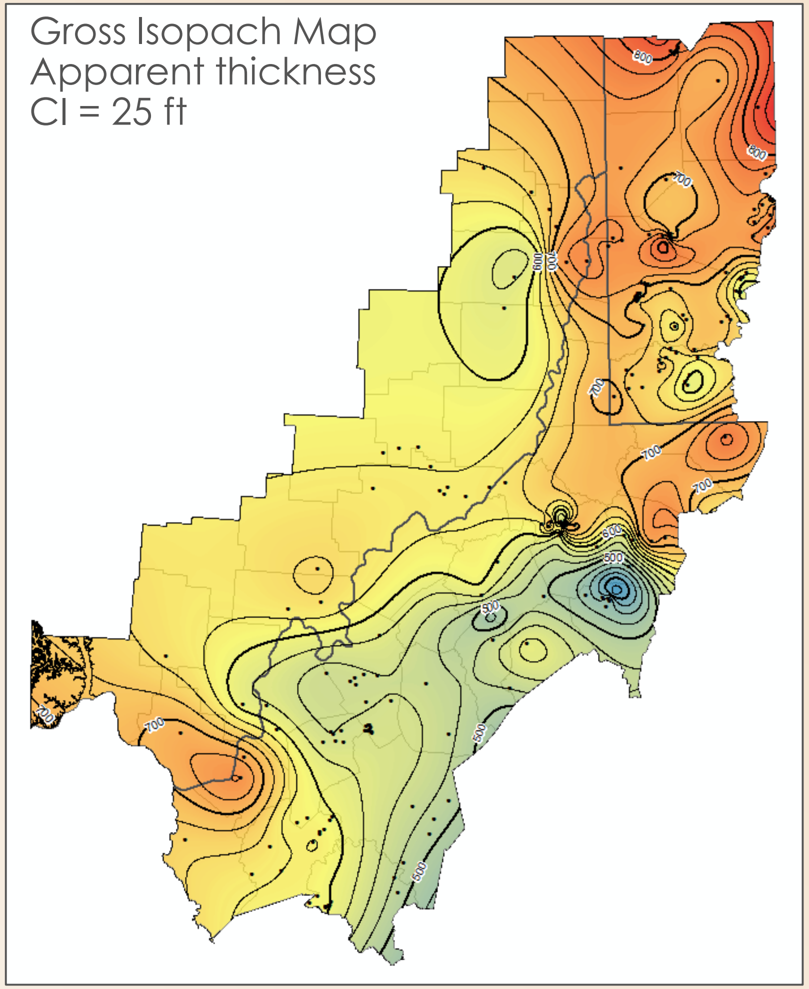
- Data in Ohio is questionable due to drilling/logging practices and Greenbrier subcrop location.



Strategy 3 – Mapping of Key Intervals

Keener to Berea



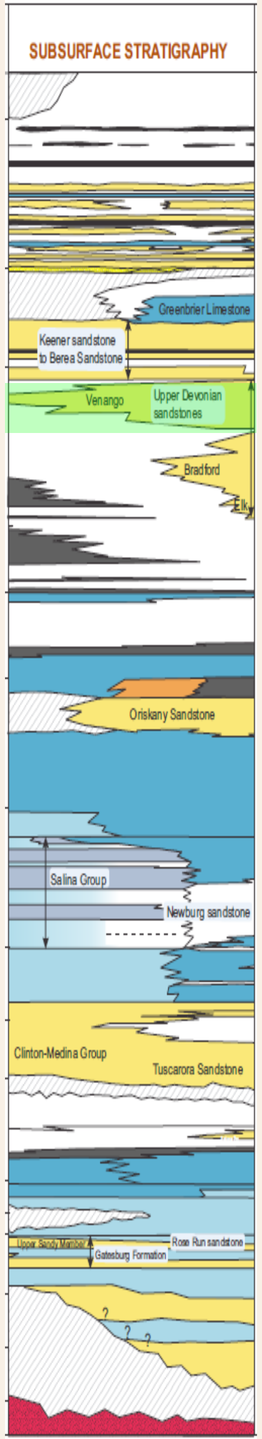


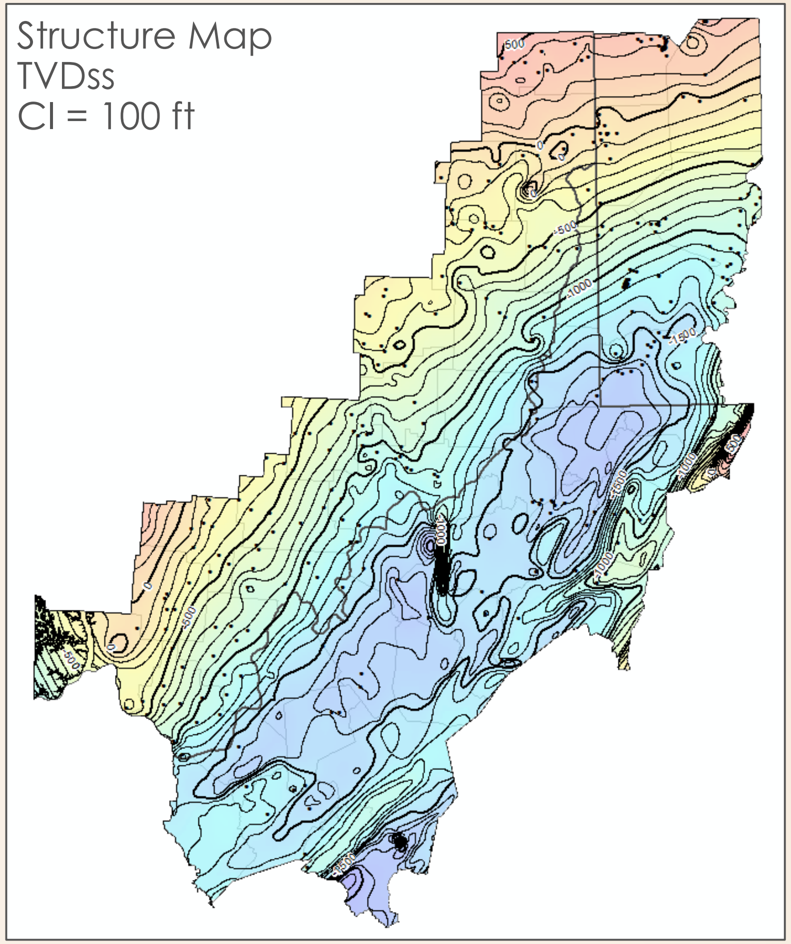
- Used Greenbrier structure map and isopached down to Keener-Berea top, then recontoured with well control.
- Assumes concordant folding with Greebrier Limestone.

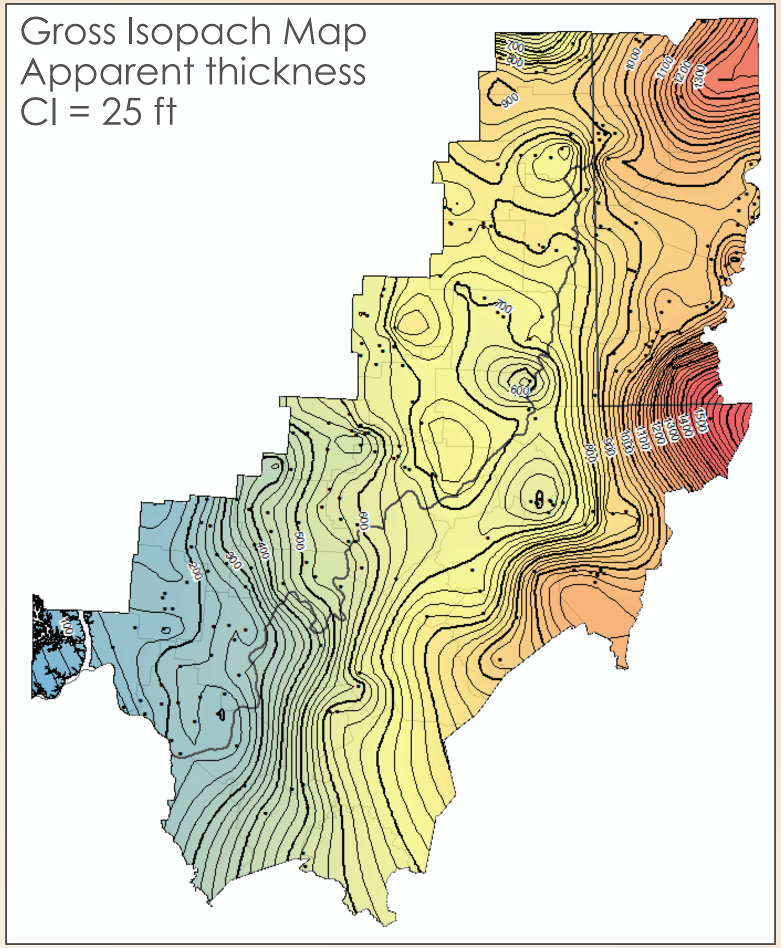
- Keener/Big Injun data is questionable in Ohio due to drilling/logging practices.
- Gross isopach, NOT net sand

Strategy 3 – Mapping of Key Intervals

Venango





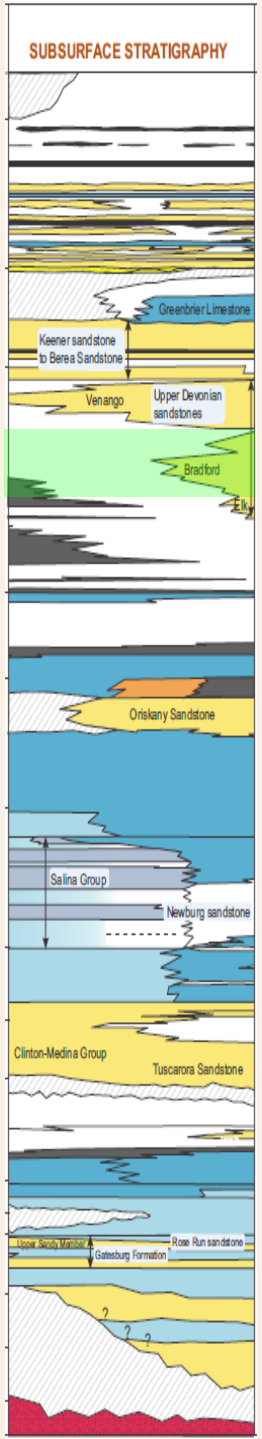


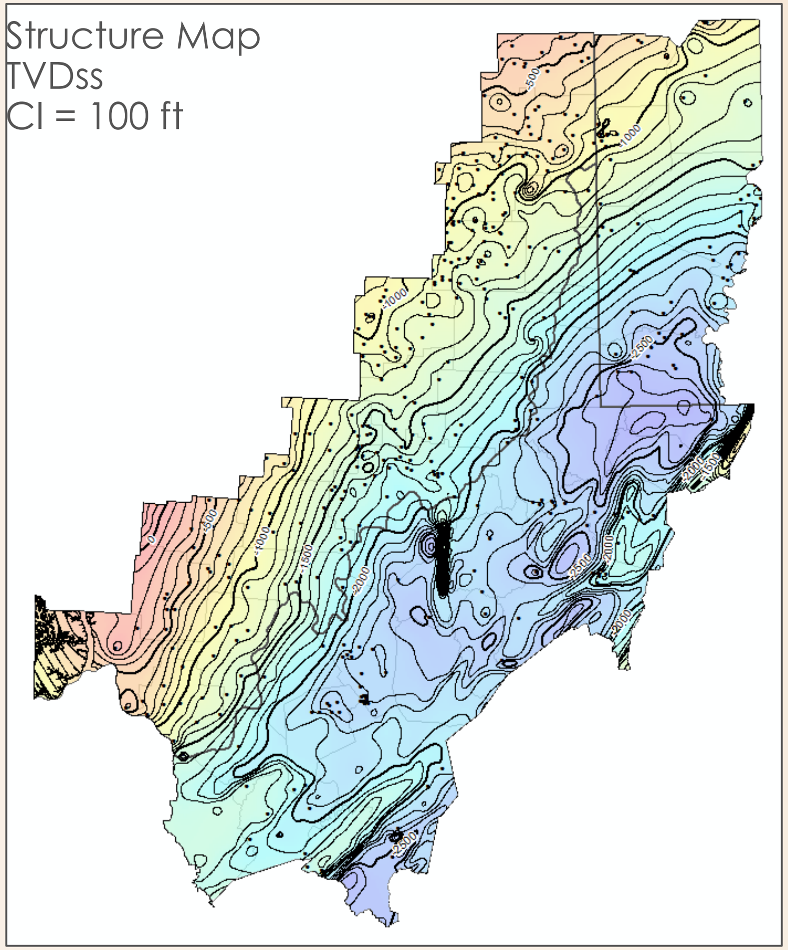
- Used Greenbrier structure map and isopached down to Venango top, then recontoured with well control.
- Assumes concordant folding with Greebrier Limestone.

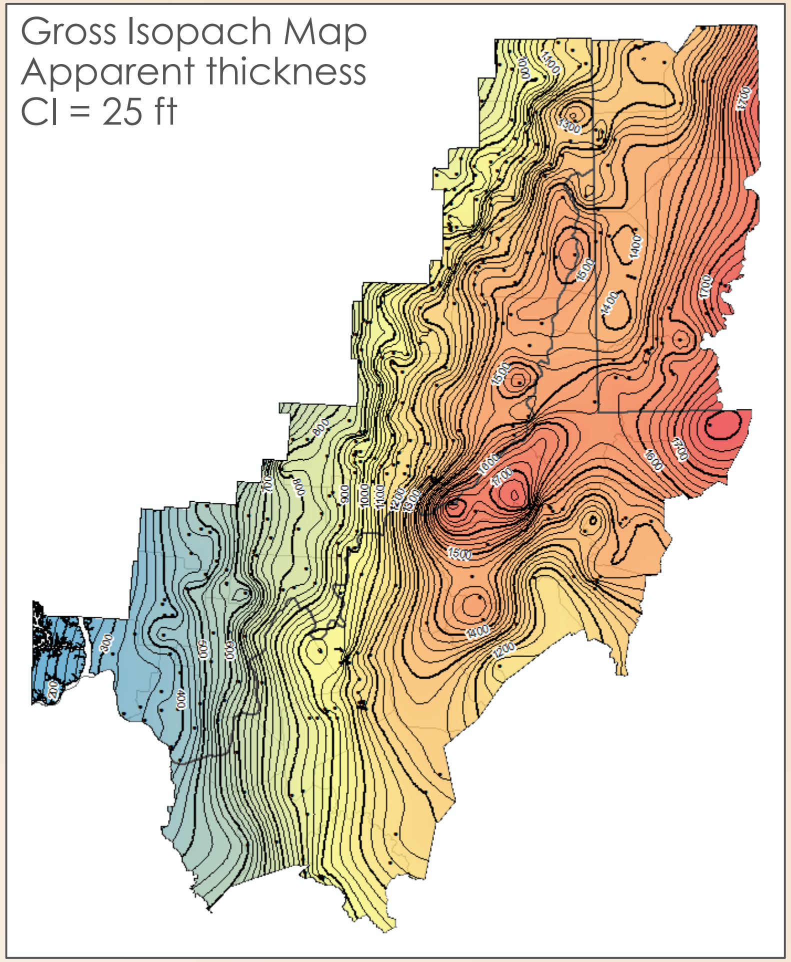
- Gross isopach, NOT net sand

Strategy 3 – Mapping of Key Intervals

Bradford

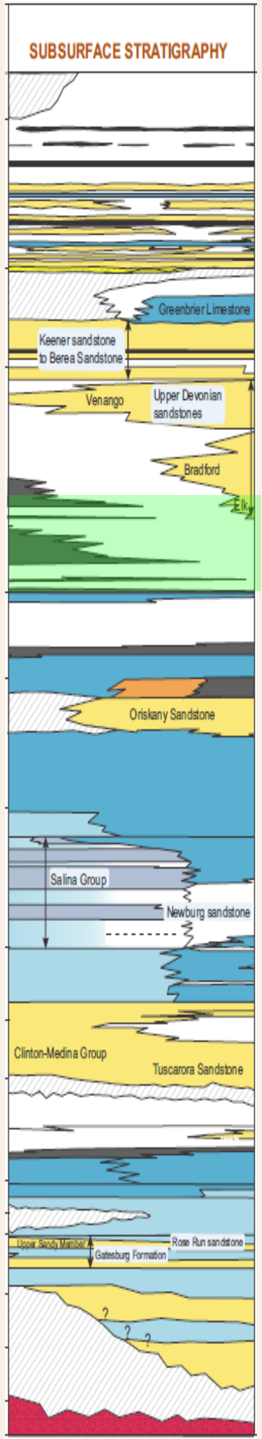






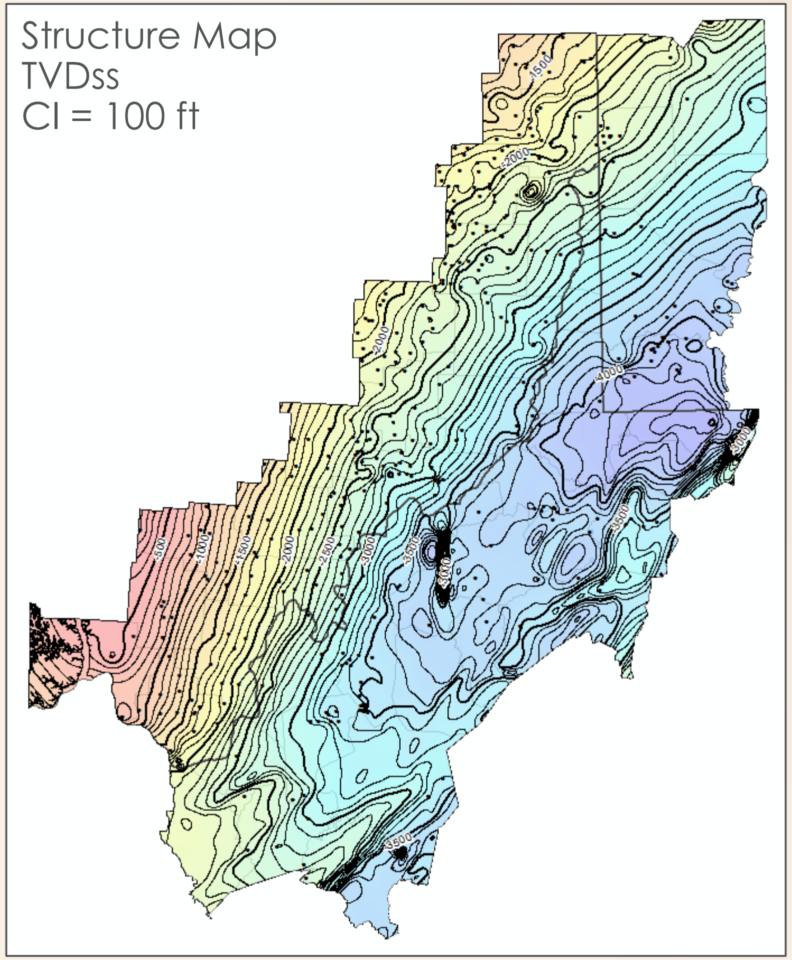
- Used Greenbrier structure map and isopached down to Bradford top, then recontoured with well control.
- Assumes concordant folding with Greebrier Limestone.

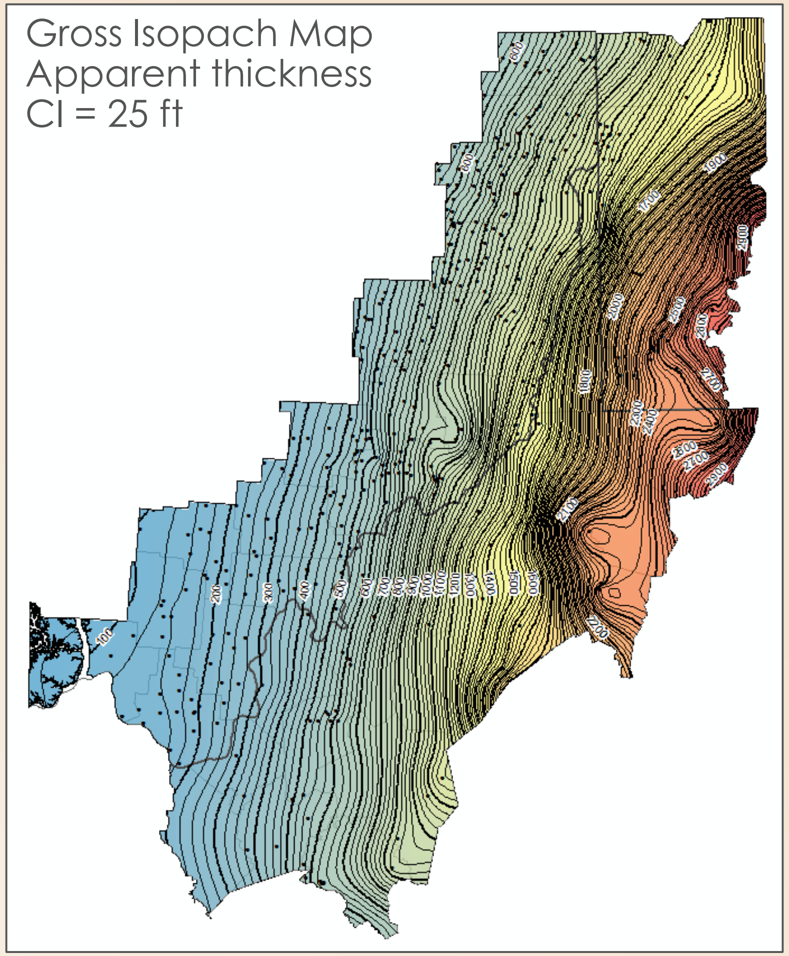
- Gross isopach, NOT net sand



Strategy 3 – Mapping of Key Intervals

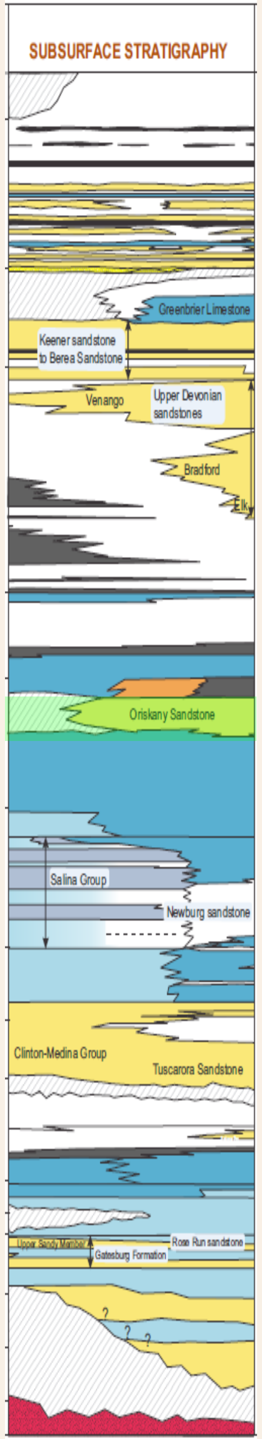
Elk





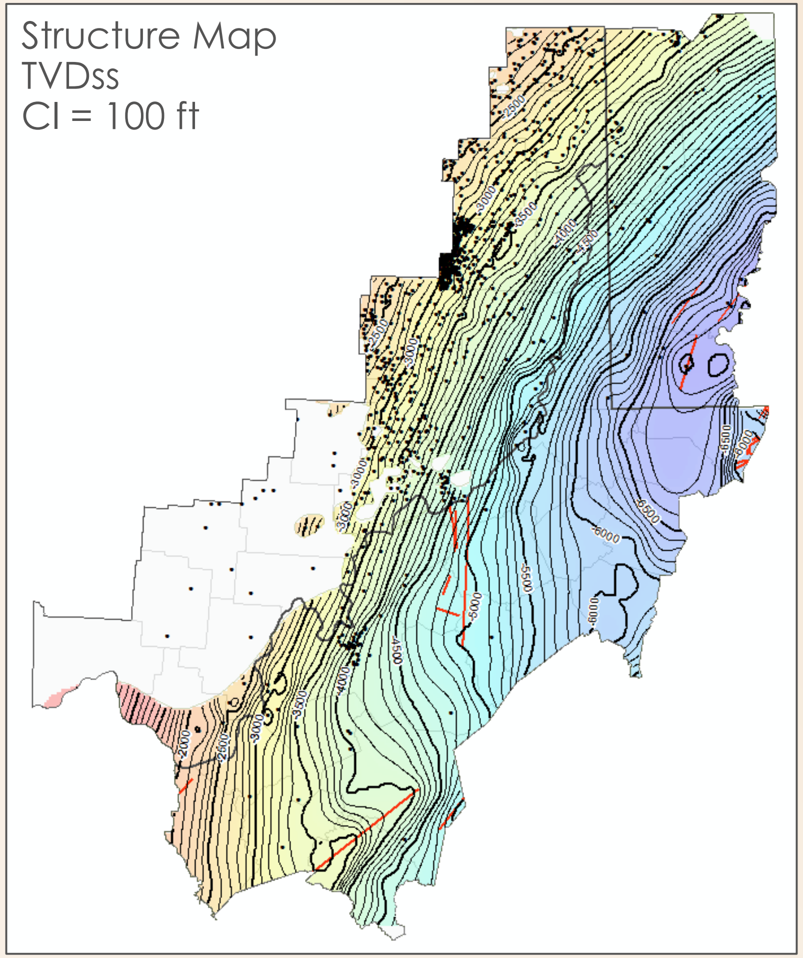
- Used Greenbrier structure map and isopached down to Elk top, then recontoured with well control.
- Assumes concordant folding with Greebrier Limestone.

- Gross isopach, NOT net sand

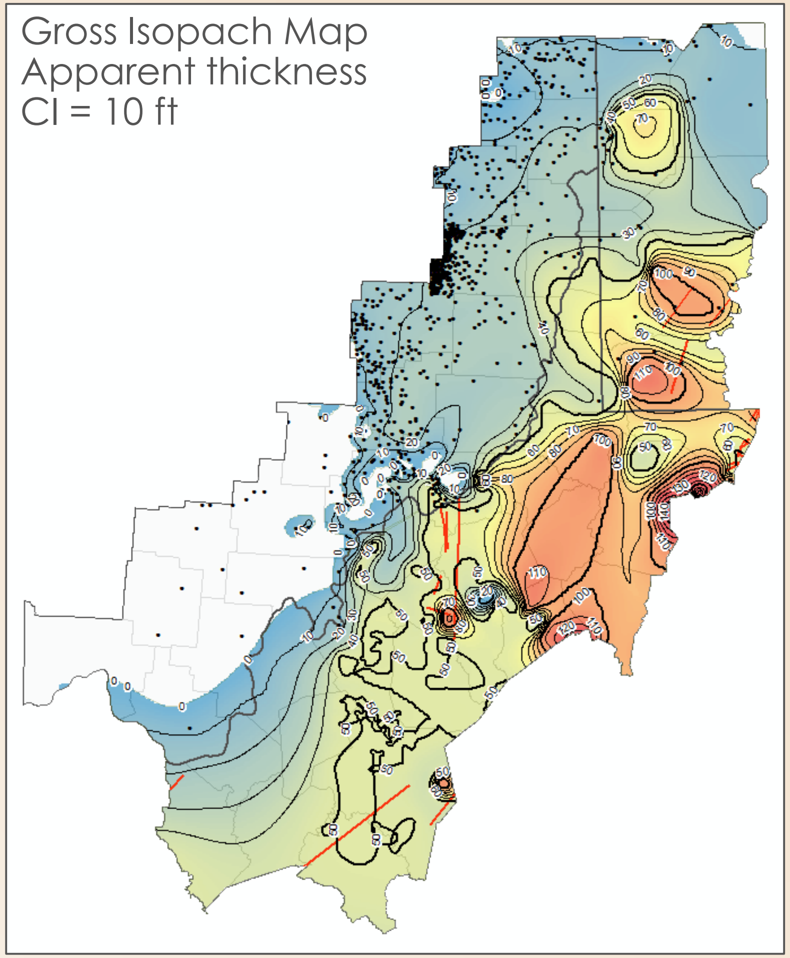


Strategy 3 – Mapping of Key Intervals

Oriskany



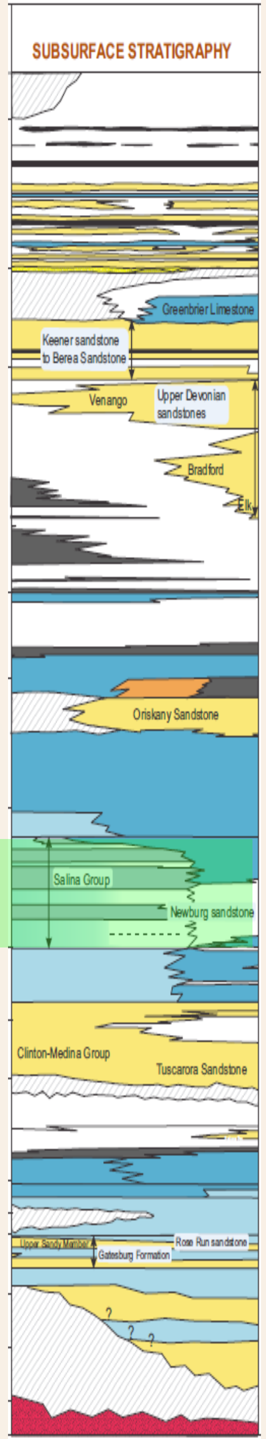
Structure Map
TVDss
CI = 100 ft



Gross Isopach Map
Apparent thickness
CI = 10 ft

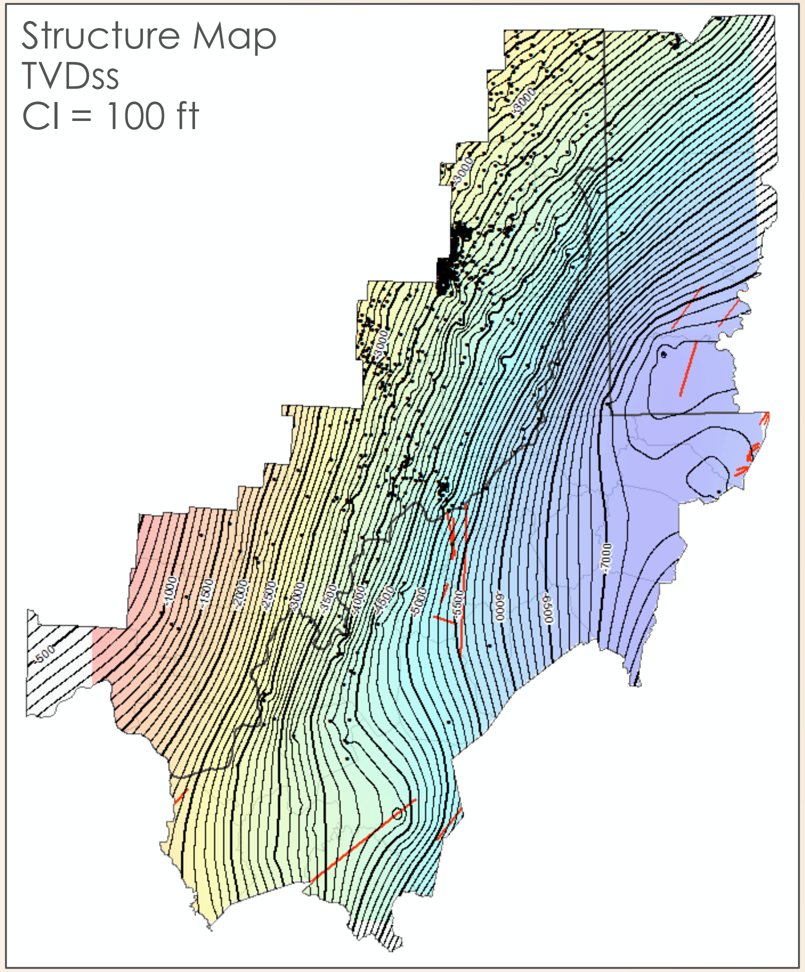
- Combined contours from RPSEA subsurface brine injection project with latest well tops.

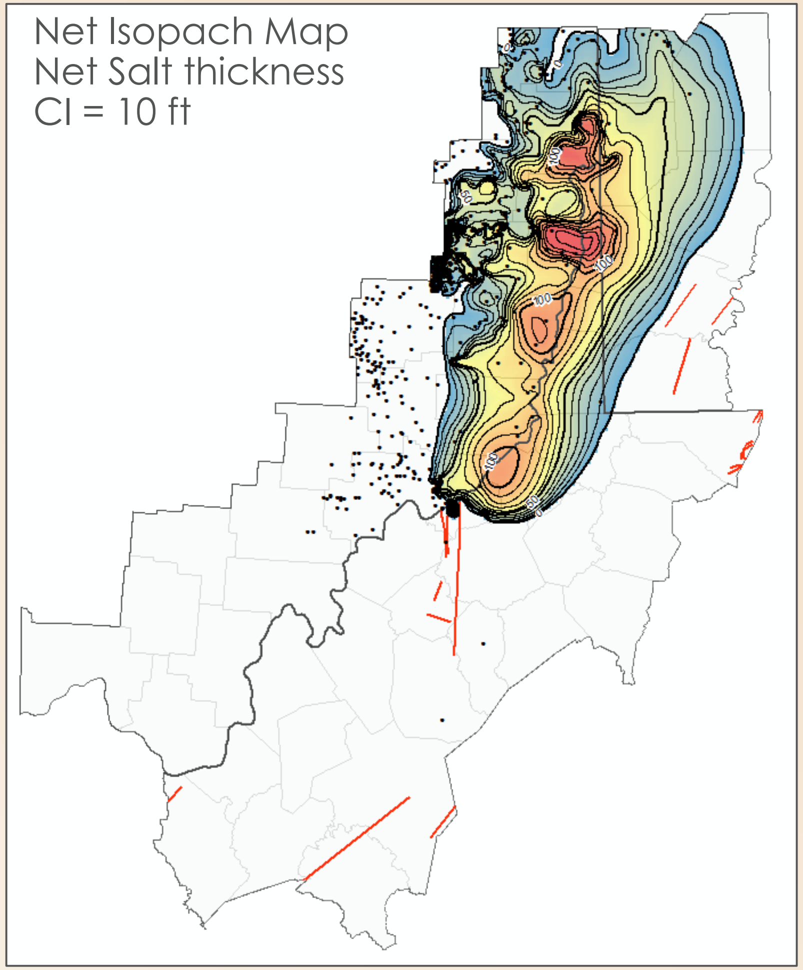
- Combined contours from RPSEA subsurface brine injection project with latest well tops.



Strategy 3 – Mapping of Key Intervals

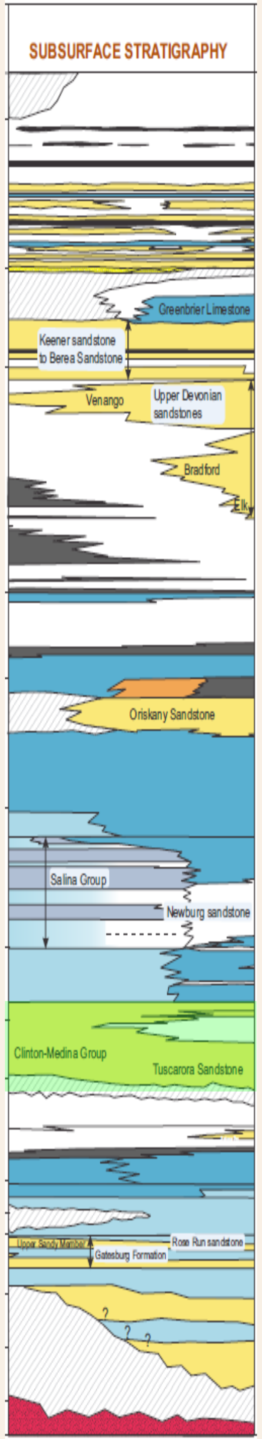
Salina 'F4' Salt





- Salina 'F' salt and stratigraphic equivalent top.

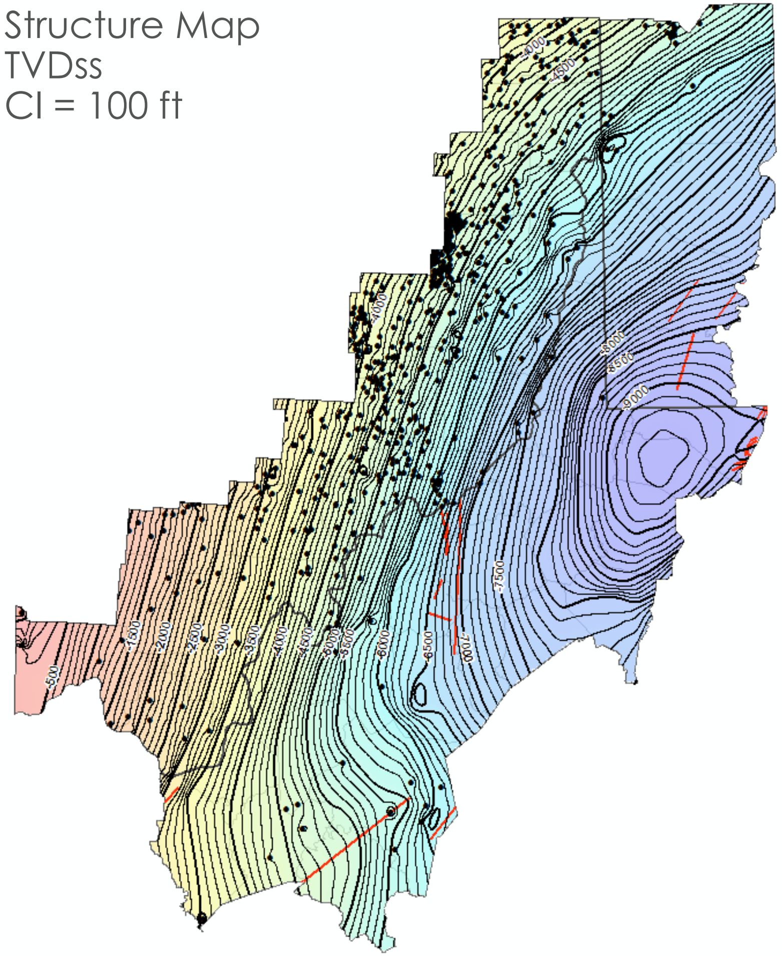
- Net Salina 'F4' salt basin is centered along WV panhandle/Ohio River.
- F4 salt thickness exceeds 100 feet in basin center.
- F3 salt ~20 feet below could add an extra 25 – 50 feet of salt.



Strategy 3 – Mapping of Key Intervals

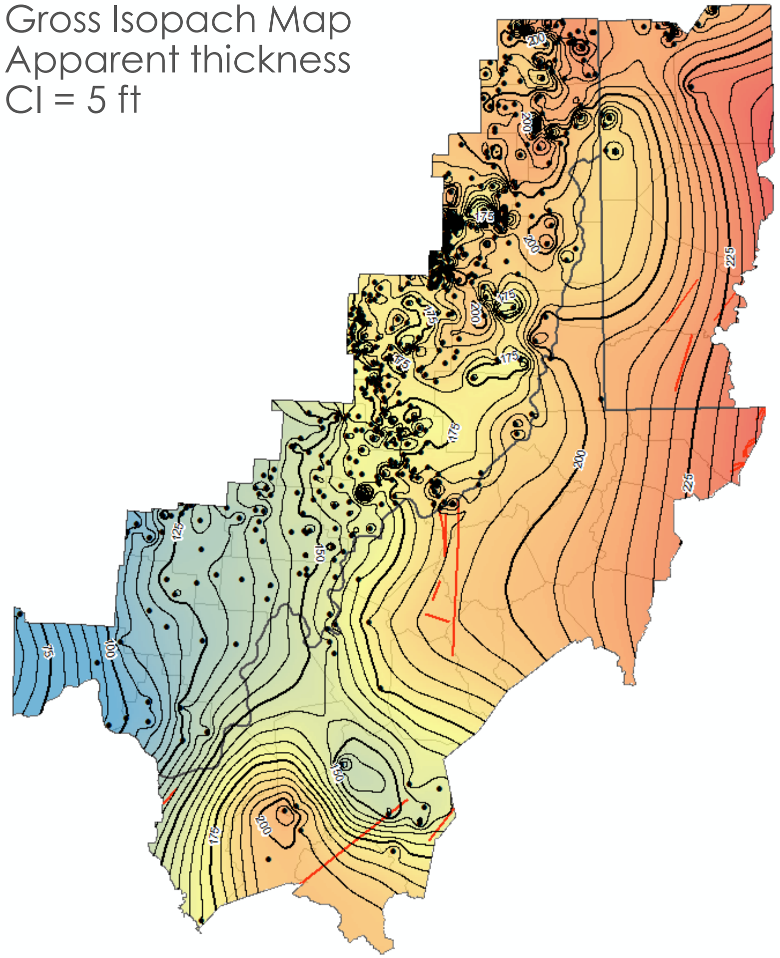
Cataract Group

Structure Map
TVDss
CI = 100 ft

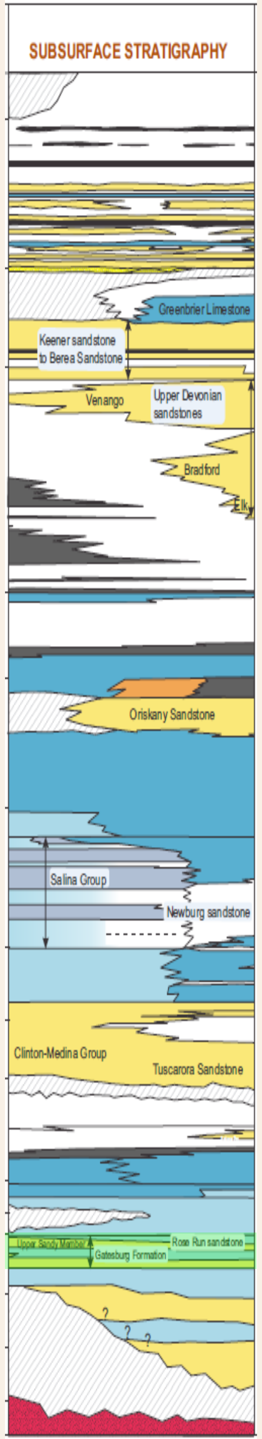


- Combined contours from RPSEA subsurface brine injection project with latest well tops.

Gross Isopach Map
Apparent thickness
CI = 5 ft

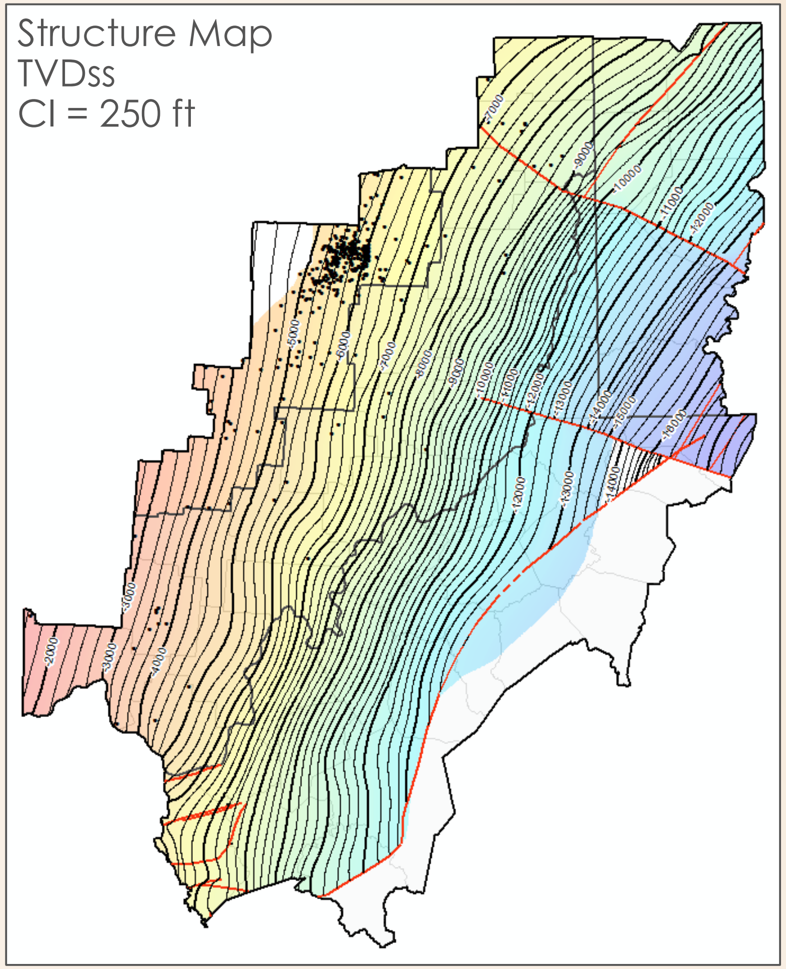


- Combined contours from RPSEA subsurface brine injection project with latest well tops.

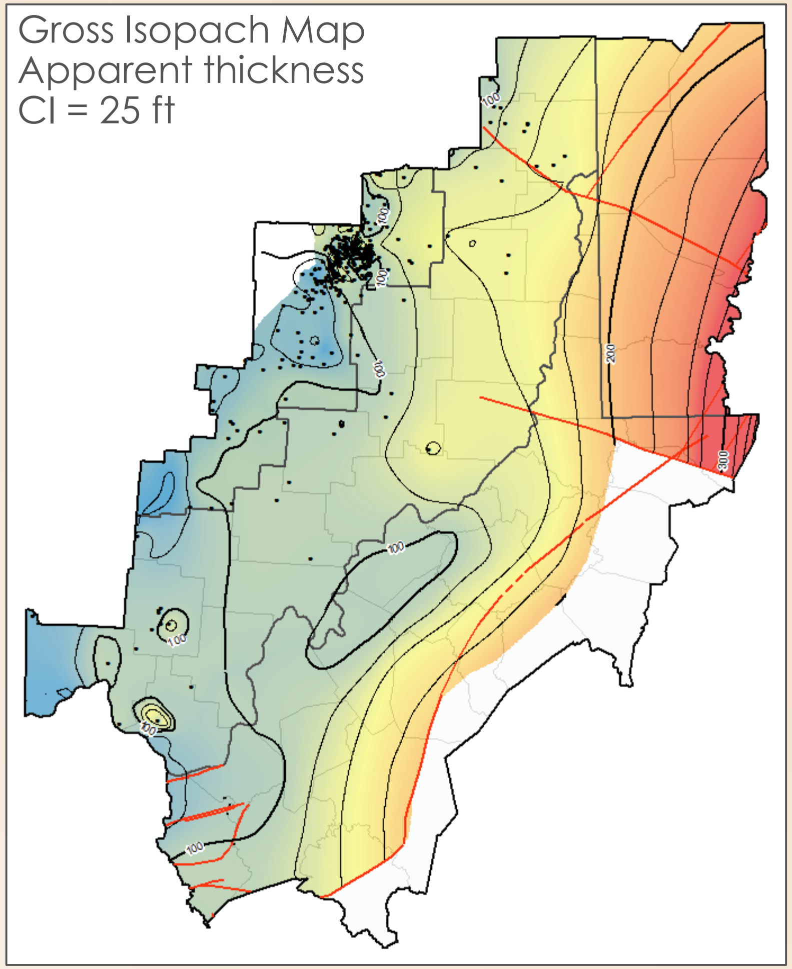


Strategy 3 – Mapping of Key Intervals

Rose Run



- Combined contours from RPSEA subsurface brine injection project with latest well tops.
- Little-to-no well control in deeper part of basin.



- Combined contours from RPSEA subsurface brine injection project with latest well tops.
- Little-to-no well control in deeper part of basin.

References and Acknowledgements

Rice, C.L. and Schwietering, J.F., 1988, Fluvial Deposition in the Central Appalachian During the Early Pennsylvanian, U.S. Geological Survey Bulletin: Evolution of sedimentary basins – Appalachian Basin, QE75.B9 no. 1829A-D, pp. B1-B10.

Roen, John B., Walker, Brian J., and others, 1996, The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey, Publication V-25.

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