Lithostratigraphy of the 'Burbank' (Red Fork) Sand in Western Osage County, Oklahoma*

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Abstract

A lithostratigraphic study of the 'Burbank' (Red Fork) Sand in western Osage County supports the commonly-accepted interpretation published by the Oklahoma Geological Survey of this unit as being deposited in a fluvial-deltaic sedimentary environment, within an incised valley. In this study well log correlations were used to define five sand units within the Red Fork, arbitrarily identified as 'A', 'B', 'C', 'D', and 'E'. Careful well log correlations suggest that the valley was created by two separate erosional events. The first event created the original incised valley, followed by the deposition of the underlying Bartlesville Sand. After a subsequent sea level fluctuation created a depositional interruption, a second erosional event removed some but not all of the Bartlesville Sand, which is interpreted to compose the 'E' sand in areas where the Bartlesville was not removed. This was followed by deposition of the Red Fork Sand, filling the channel once more. The inferred depositional environment for the Red Fork is believed to have changed from fluvial-deltaic ('E' sand - Bartlesville) to near-shore marine ('A' sand).

References Cited:

Andrews, R.D., 1997, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Red Fork Play: Oklahoma Geological Survey, Special Publication 97-1, Part II, p. 13-79.

Northcutt, R.A., 1997, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Bartlesville Play: Oklahoma Geological Survey, Special Publication 97-6, Part II, p. 13-92.

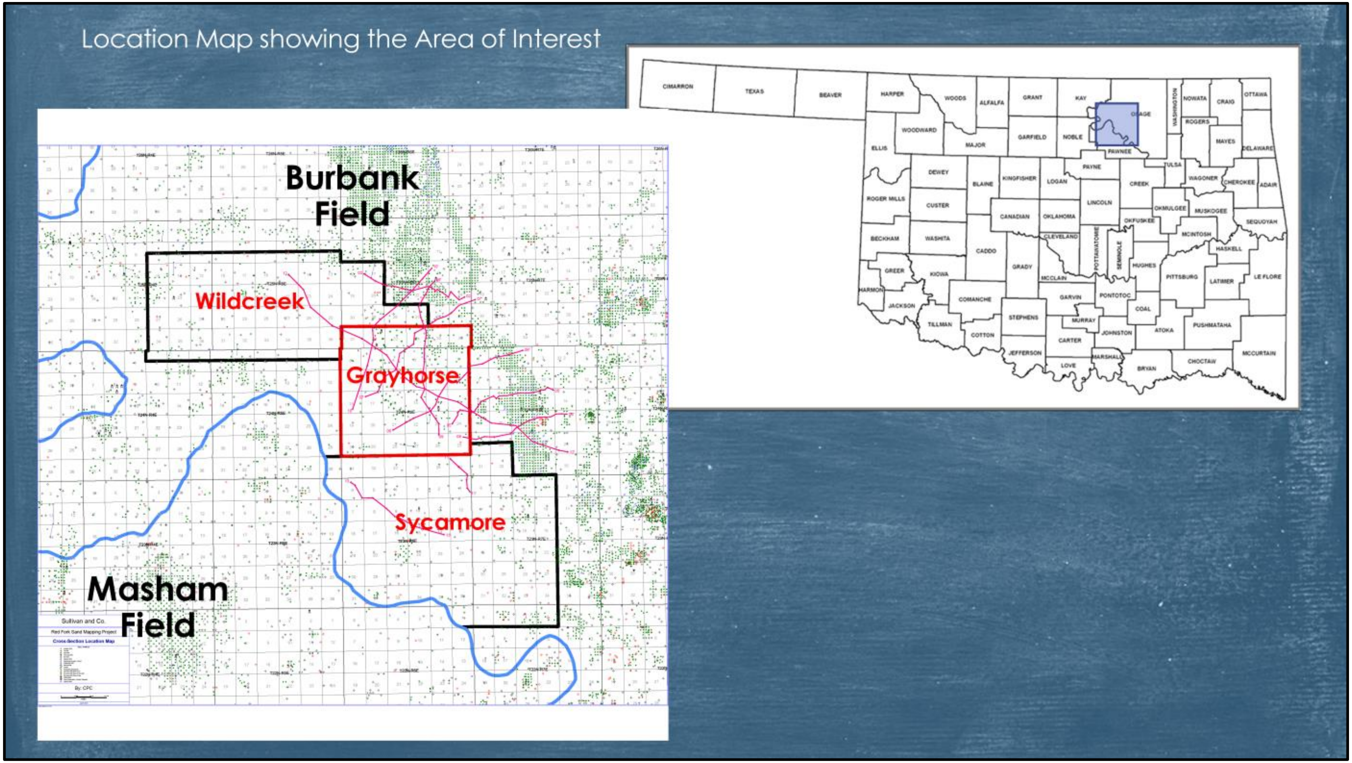
October 5, 2015 Chris P. Cunningham

Lithostratigraphy of the "Burbank" (Red Fork) Sand in Western Osage County, Oklahoma

Presenter's notes: In this talk I will present the results of a stratigraphic study of well logs conducted from 4/1/2011 through 7/31/2012 for Sullivan and Co. The area studied was the Grayhorse area in western Osage County, Oklahoma.

The study results

- supported the prevailing interpretation of the Red Fork sand as being deposited in an incised valley by largely deltaic processes.
- The study found that an interval isopach map of the interval between the top of the Brown lime marker and the Inola lime marker could be used to map the base of the incised channel and predict its path.
- The study found evidence that some of the sand in the lowermost part of the sand section in the channel might actually be Bartlesville.



Presenter's notes: A dewatering project ("Grayhorse") located in western Osage County, Oklahoma and operated by Sullivan and Co. LLC, has been in operation since 2001. Modeled after the success of the Masham field, the project has been successfully extracting oil, gas and gas liquids primarily from the "Burbank" (Red Fork) sand.

As the dewatering project has grown during this time period additional wells have been drilled. A distinctive feature of the dewatering project was that it was not possible to predict in advance the performance of each well without completing it and putting it on production.

It was observed that it was difficult to satisfactorily predict where the best wells would be, and to avoid drilling poorer wells.

A statistical approach, in which the predominance of "good" wells compensated for the relatively few "poor" wells, was being used. However, it was deemed unsatisfactory.

As a result it was decided that it was desirable to see if mapping the Red Fork stratigraphically and inferring depositional environments could reduce the risk of drilling a "poor" well. Accordingly the Red Fork Sand Mapping Project was initiated.

The area of interest is shown in blue on the inset map of Oklahoma, and in detail on the "blow-up" version. It consists of the west-southwest portion of Osage County. Three separate areas within the area of interest were defined by Sullivan: Wildcreek, Grayhorse, and Sycamore. This study encompassed all three of these areas, including surrounding townships. The focus of the study was Grayhorse, consisting of Sections 1 – 30 of Township 24 North – Range 6 East, and Sections 31-36 of T25N-R6E.

Project Scope

The goals of the project were as follows:

- To map the Red Fork (Burbank) sand extent, shape and porosity distribution
- To interpret the depositional environment and flow directions of the streams and/or water currents that deposited the sands.

Study Limitations

- In an effort to minimize bias, the author was shielded from detailed production and other historical information until late in the study.
- To control cost, the project was limited to the study of geophysical logs. This interpretation is based solely on log character and isopach mapping of electric log correlations.
- Physical core examination was rejected due to cost and core availability.
- No biochronological information was used in this study.
- Primary focus was on the Grayhorse area.

Presenter's notes: It was felt that someone not already familiar with the dewatering project, and with the time to focus attention on the tasks, might bring in a different viewpoint and see something new, or confirm something already suspected. To that end the author was contracted and given the task of accomplishing the goals.

Methodology

- Literature search
  - OGS SP97-1. Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Red Fork Play, by Richard D. Andrews and others.
  - OGS SP97-6. Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Bartlesville Play, by Robert A. Northcutt and others.
- Examination of available geologic data
  - Geophysical ("Electric") logs
  - Lithologic ("Mud") logs
  - Core reports

Presenter's notes: Numerous documents, including AAPG, TGS and OGS publications, were reviewed in preparation for the project.

The "Burbank Sand" (Red Fork)

- Pennsylvanian in age
- Age-equivalent to the Red Fork sand
- Desmoinesian series
- Krebs group
- Barrier bar? Or Deltaic/Fluvial?

Presenter's notes: The literature search revealed that:

stratigraphically the "Burbank" sand was Pennsylvanian in age, and belonged to the Desmoinesian series and the Krebs group., and is considered to be age-equivalent to the Red Fork sand.

There was some dispute at Sullivan about the depositional environment of the "Burbank" sand, with some believing it to be deposited as one or more barrier bars in a longshore marine environment, while others insisted it was fluvial, with the sands interpreted as point bars, channel chute bars, etc.

The literature contended that in NE Oklahoma the Red Fork sand had been deposited by fluvial deltaic processes within incised valleys.

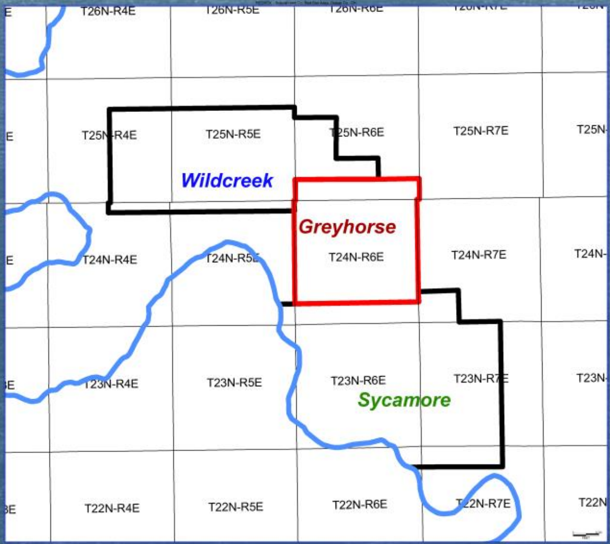
Rock Information

- Rock description:
  - The Red Fork sand size is predominately very fine- to medium-grained. The sand is well sorted.
  - The sand is often interbedded with siltstone; shale laminae are frequently present.
  - Density porosities typically range between 10 and 25%.
  - A 14% porosity cut-off was used to predict productive intervals
- Log character:
  - Wells had either “fining-upwards” or “blocky” log character
  - “Coarsening upwards” log character was not observed

Procedure

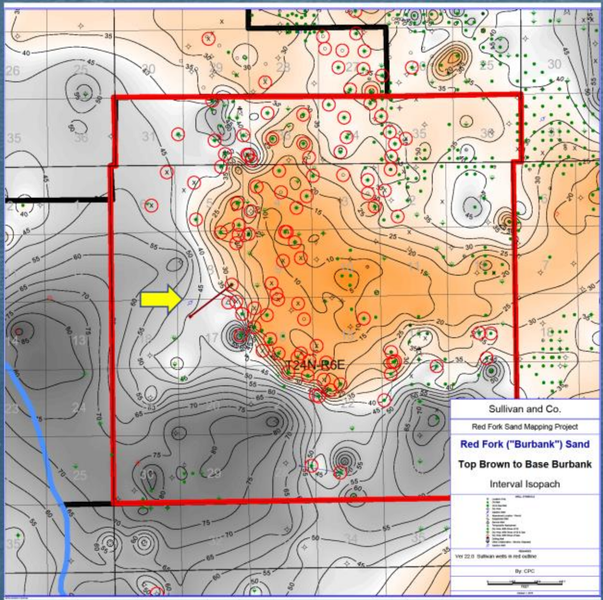
- Correlate all the modern porosity logs in the area of interest
- Correlate older logs as appropriate
- Attempt to break the Red Fork sand into sub-units
- Map the sub-units
- Compare the maps to production, EURs, etc.
- Develop a depositional model to explain the study results

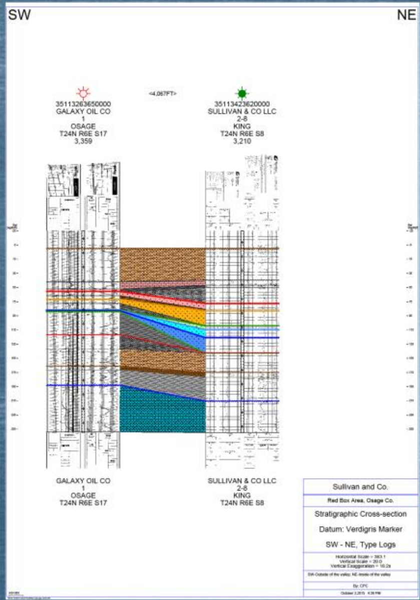
Location Map



Presenter's notes: Sullivan owned concessions from the Osage tribe covering the areas shown here. For convenience the entire concession was organized into three projects: Wildcreek, Greyhorse and Sycamore. This study is focused on the Greyhorse area, which contains nearly all of the Sullivan dewatering wells and infrastructure.

Type Logs



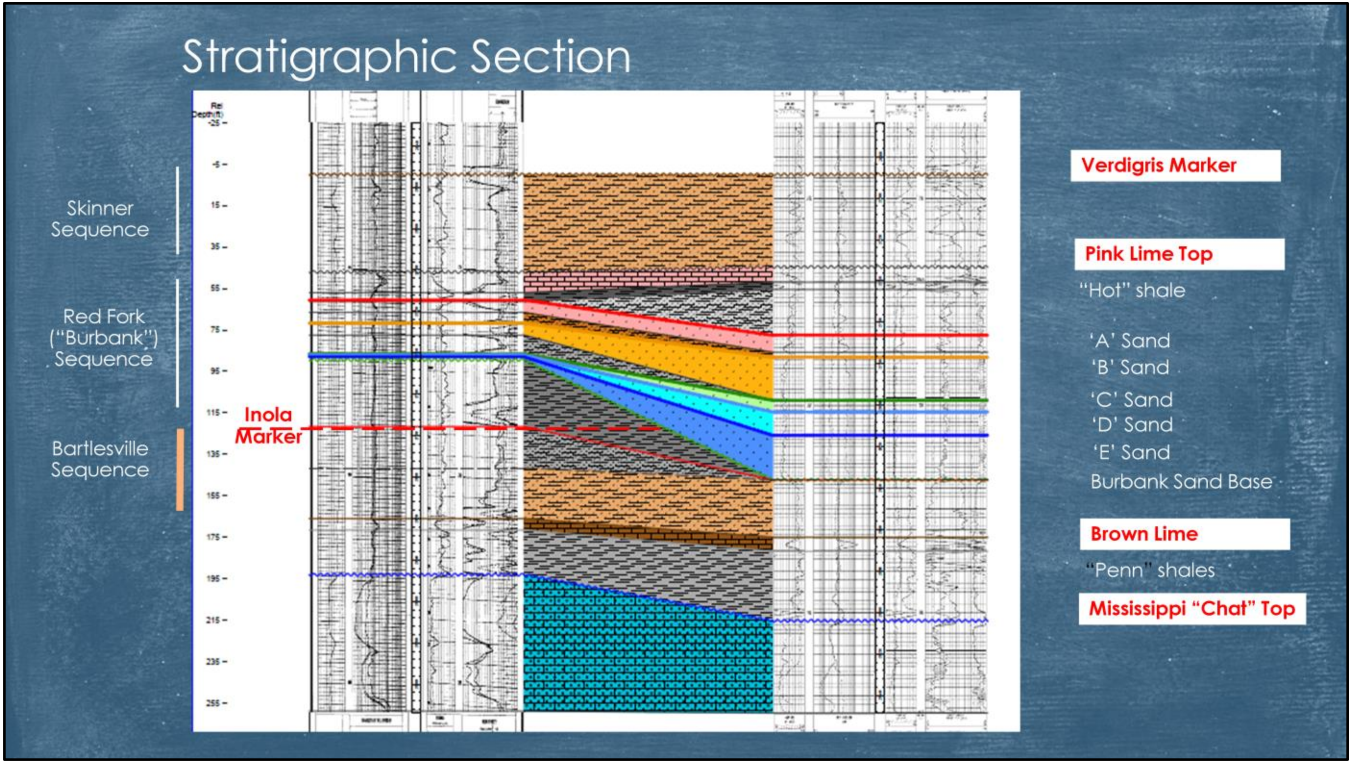


Presenter's notes: The location of the cross-section is shown on the "paleogeographic" map by the yellow arrow. This map will be discussed further later in the presentation.

Type logs for two wells are presented here.

The logs on the right are raster images of the electric and density logs for the Sullivan 2-8 King, a nearby well inside the channel. The logs on the left are raster images of the electric and density logs of the Galaxy Oil Co 1 Osage, T24N R6E S17, a well outside of the channel

The map and logs are used here to show how rapidly the stratigraphy and the sediments change over a short distance (in this case, 4087'.)

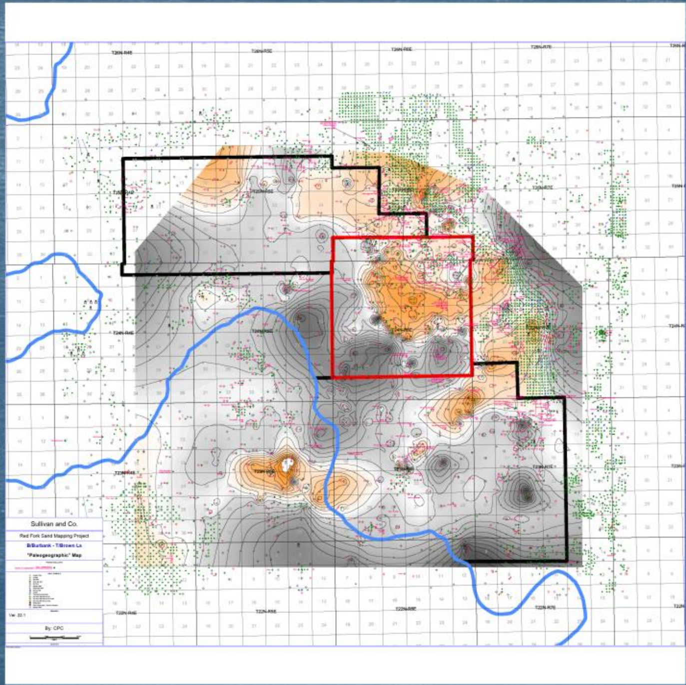


Presenter's notes: Here is the same cross-section, showing the detailed correlations developed in the study. On the left the major sequences are labeled. On the right are the markers and sand definitions. Pay particular attention to the interval from the Inola Marker/Base of Burbank to the top of the Brown Lime. (Bartlesville sequence.) Also note that in the channel the Inola marker is absent.

In this study work began inside of the channel. Inasmuch as the literature defined the Red Fork sequence as being from the Inola lime to the Pink lime, initially the Brown lime was mistaken for the Inola. It wasn't until it was decided to try to map outside of the sand body and work inward That this error was identified and corrected..

Paleogeographic Map

Isopach Map
of the
Inola – Brown interval
("Bartlesville Sequence")

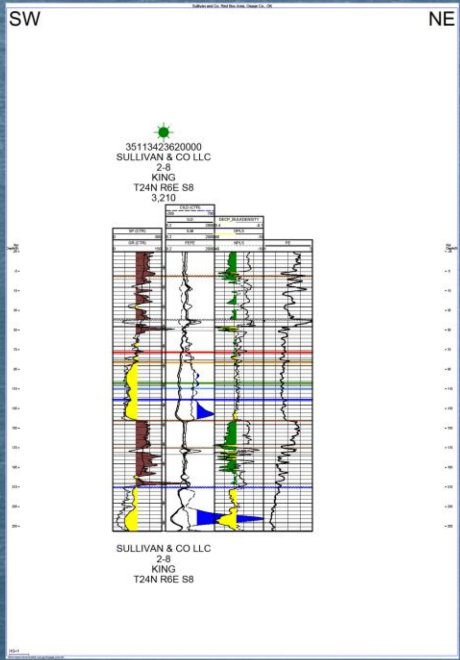


Presenter's notes: A further issue was what markers should be used for isopaching. Previously focus had been on the Mississippi-Pennsylvanian boundary, and the Pink Lime, as these were relatively easy to identify on seismic.. After trying various datums, the author found that, using the Brown lime marker as the datum and isopaching the Inola – Brown interval produced this map. Where the Inola was absent, at the bottom of the channel, the base of the Burbank sand was used.

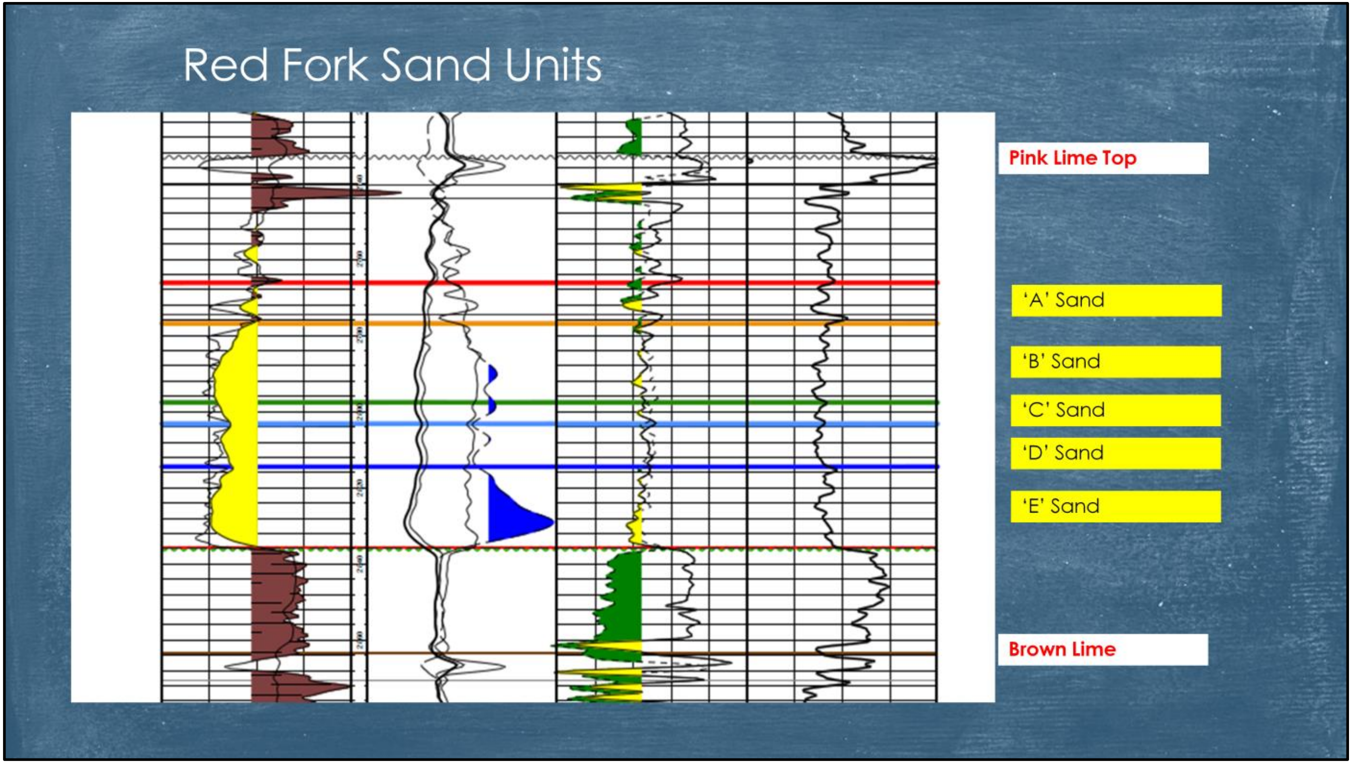
The resulting map above has proven to be very useful in picturing the topography at the beginning of deposition of the Burbank sand.

Please note the orange channel shown in the Grayhorse area, and also the small orange channel just to the SE of Grayhorse south boundary.

Digital Version



Presenter's notes: This log display based on LAS files from the logging companies, in Petra, was developed early in the project to help with correlations within the channel.

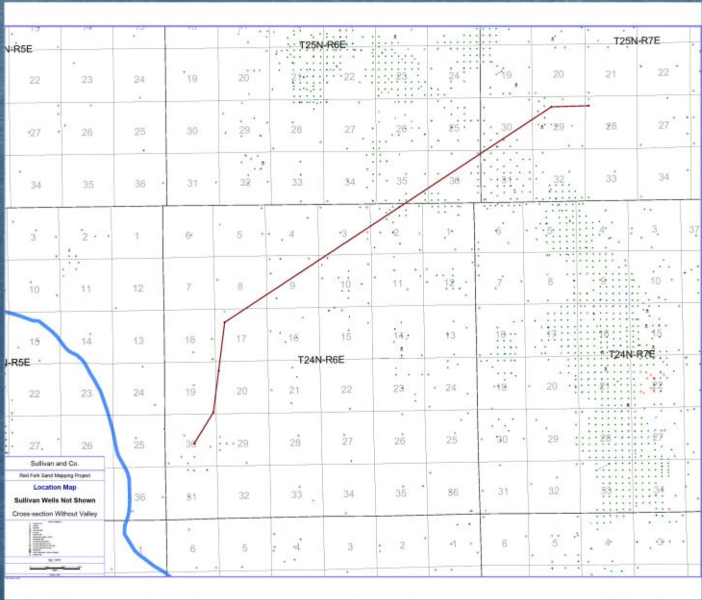


Presenter's notes: Shown is a sample of the log character, and where markers within the sand section were placed.

These markers were very subtle, and I wondered during the project just how 'real' they were. However, at the end of the project Sullivan drilled a well, the Truman, and ran an FMI (image) log. As part of the image log a detailed dip meter log was obtained. I first correlated the log without looking at the FMI, then checked my correlations against the FMI flow direction changes. I was pleased to find that at least for this well I was picking points that matched the dip meter interpretation on the FMI log almost perfectly.

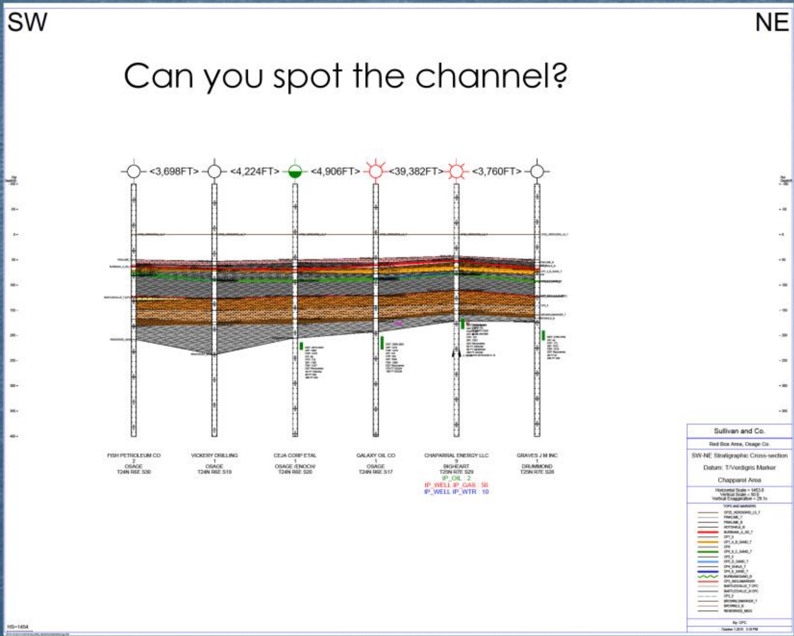
Note the conductivity 'kick' representing the 'E' sand: This is typical of the 'E' sand in the channel.

Location of Cross-section (incised channel not shown)



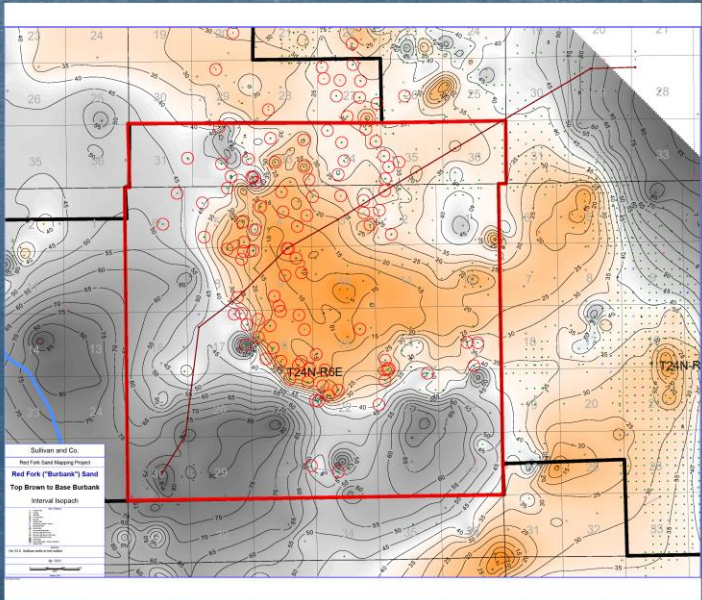
Presenter's notes: While working outside of the channel, I noticed something that I found interesting. Above is a map showing the location of the next cross-section. All of Sullivan's wells have been hidden, and only wells outside of the channel are on the cross-section.

Cross-section Without Incised Channel



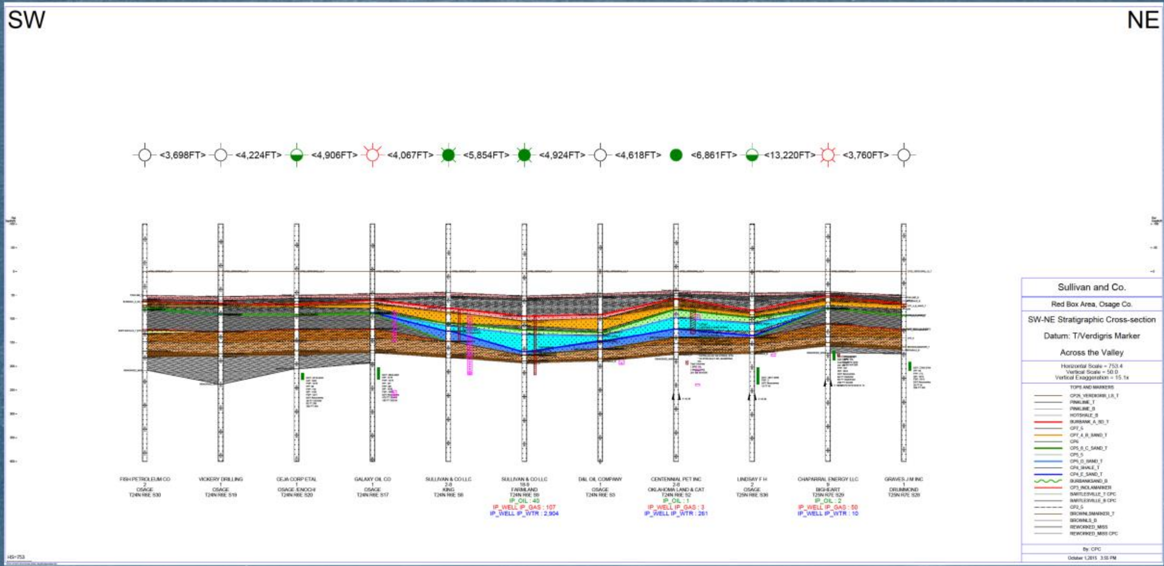
Presenter's notes: I was struck by how unnecessary the channel seemed to be in this area, when correlating logs outside of the channel. It was quite easy to correlate right through it in all directions. I interpret this to strongly support the concept of the incised channel, at least in this area of Osage County.

Location of Cross-section (Incised Channel shown)



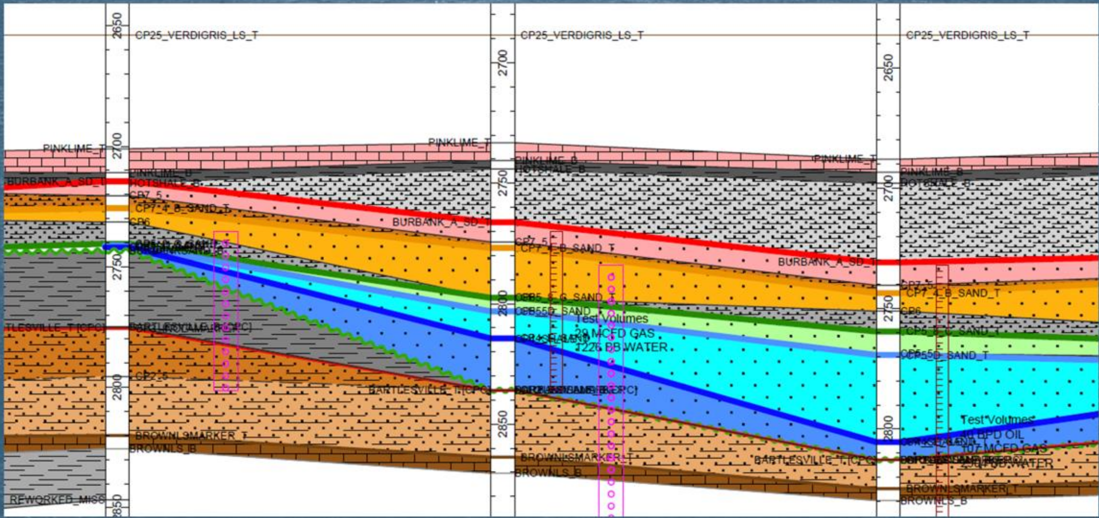
Presenter’s notes: Here is the location of the same cross-section, with ‘channel-wells’ added, superimposed on the ‘paleogeographic’ map showing the channel.

Cross-section With Incised Channel



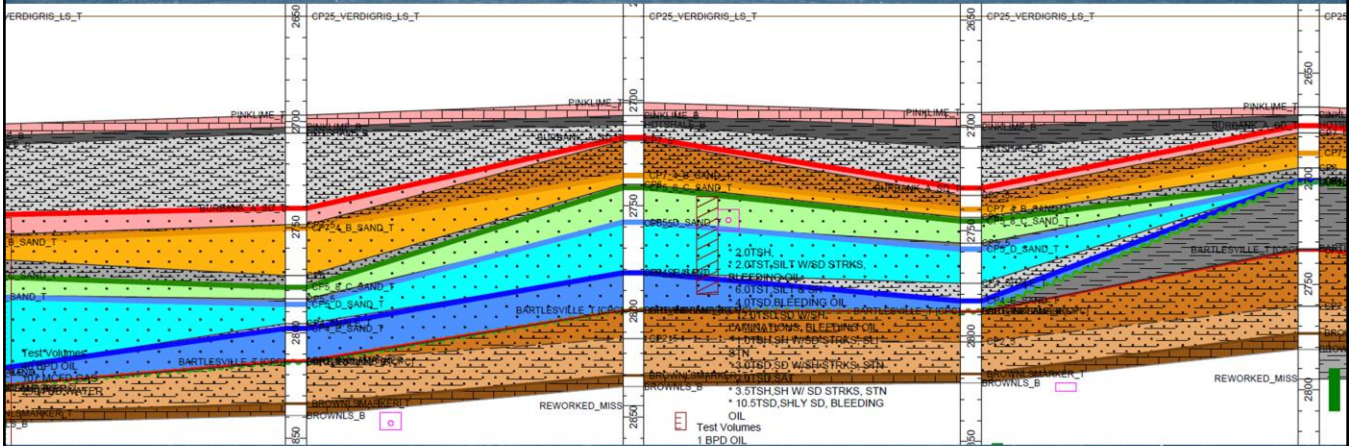
Presenter's notes: Here we can see the channel and the Burbank sands.

Close up of pinchouts against the "incised" valley wall



Presenter's notes: Note how the sands appear to pinchout against the valley wall to the left.

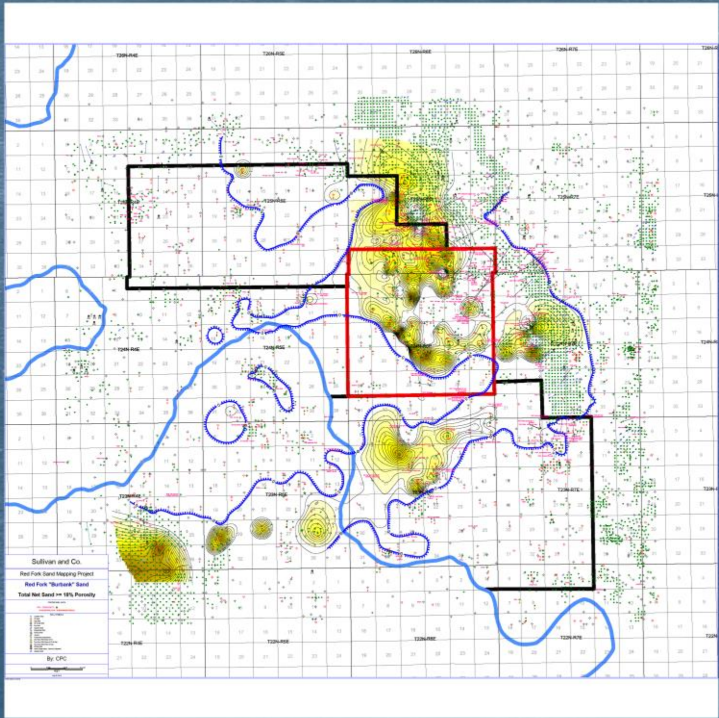
Close up of pinchouts against the "incised" valley wall



Presenter's notes: Here is a similar situation on the right side of the channel.

Red Fork Sand

Total Porosity >= 18%



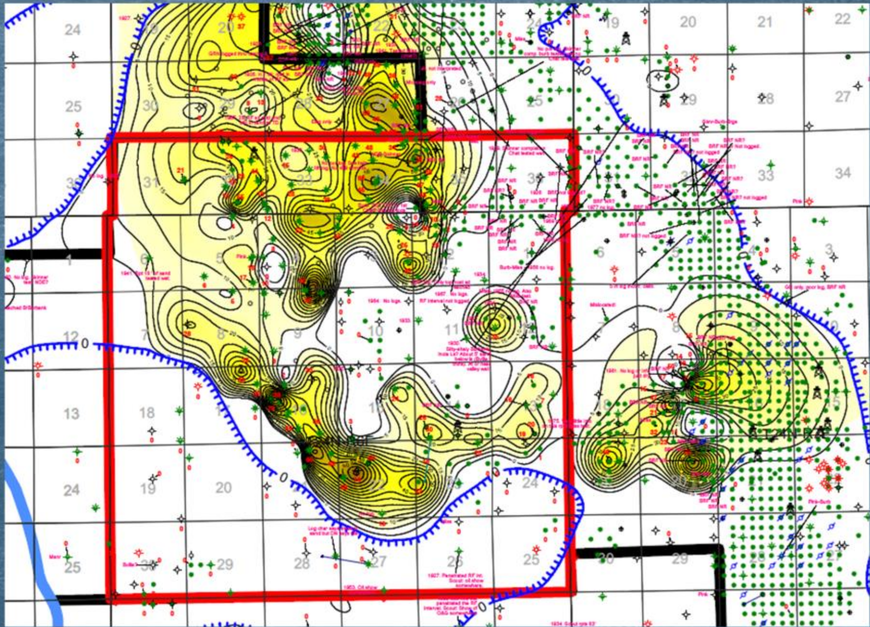
Presenter's notes: As you will recall, a major goal was to map porosity. Sullivan had used a 14% density porosity cut-off for perforating producing sand, and had mapped accordingly. Again trying to do something different, I tried other cutoffs. I found that there seemed to be natural 'break at or near 18%, so all of my maps use density porosity >= 18% as a cutoff.

This shows total feet of porosity >=18% for the entire Burbank sand section, total for sands A-E.

The blue outline is intended to show the boundaries around the main channel and other sand bodies inferred to be present.

Red Fork Sand

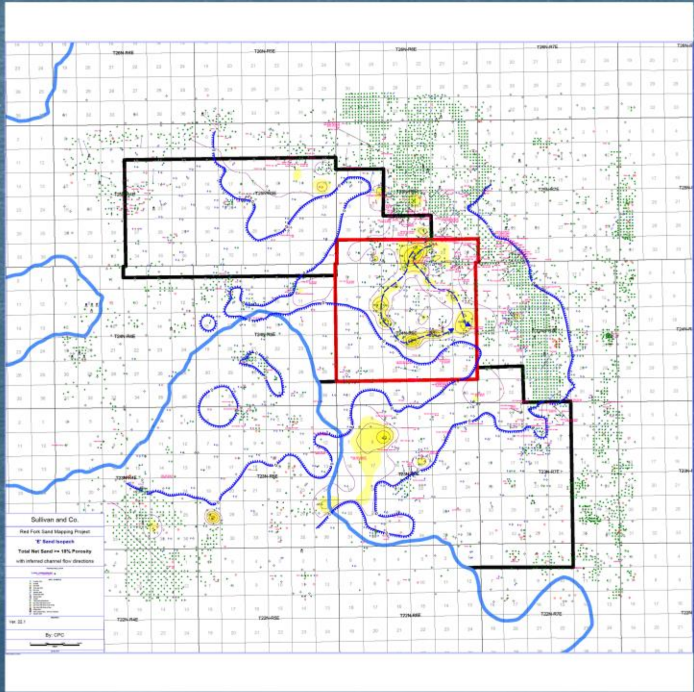
Total Porosity >= 18%



Presenter's notes: This is a close-up of the total porosity map for Greyhorse. Note that the map gives some predictability as to where the best porosity might be found.

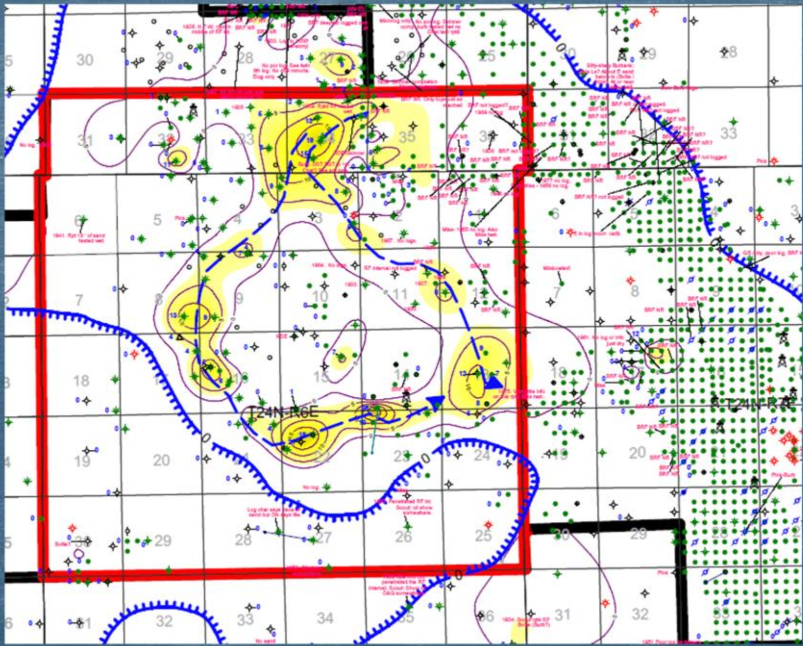
'E' Sand

Porosity >= 18%



'E' Sand

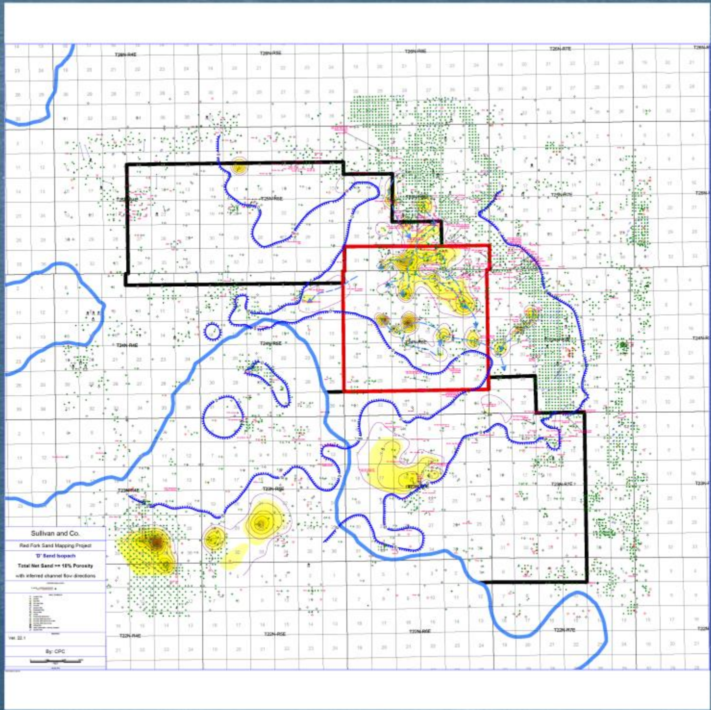
Porosity >= 18%



Presenter's notes: Close up of the flow directions proposed for the E sand.

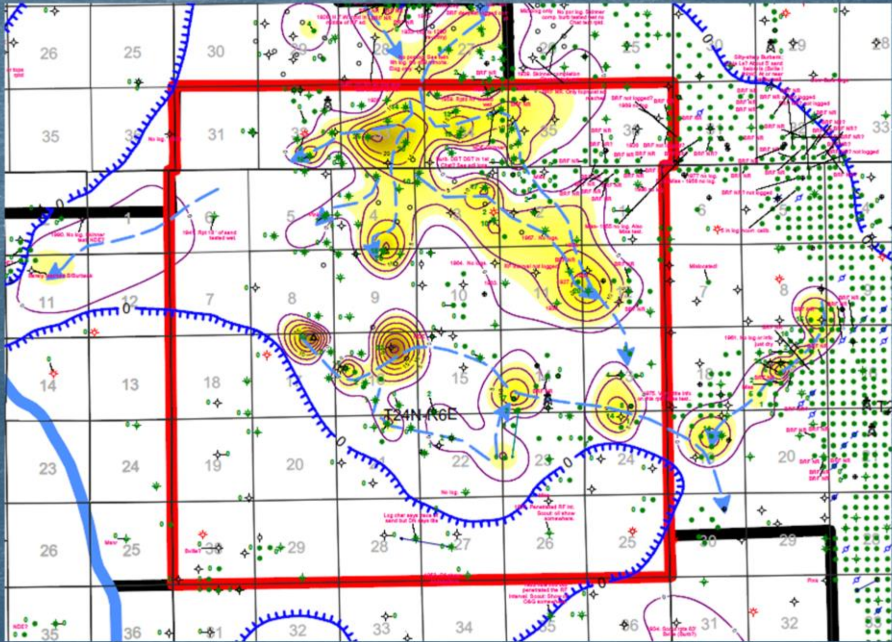
‘D’ Sand

Porosity >= 18%



'D' Sand

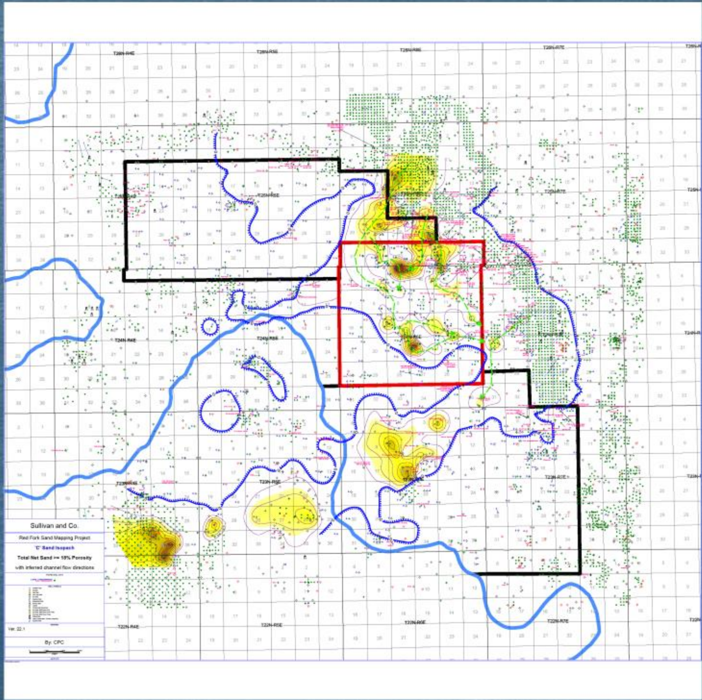
Porosity >= 18%



Presenter's notes: Close up of the flow directions proposed for the D sand.

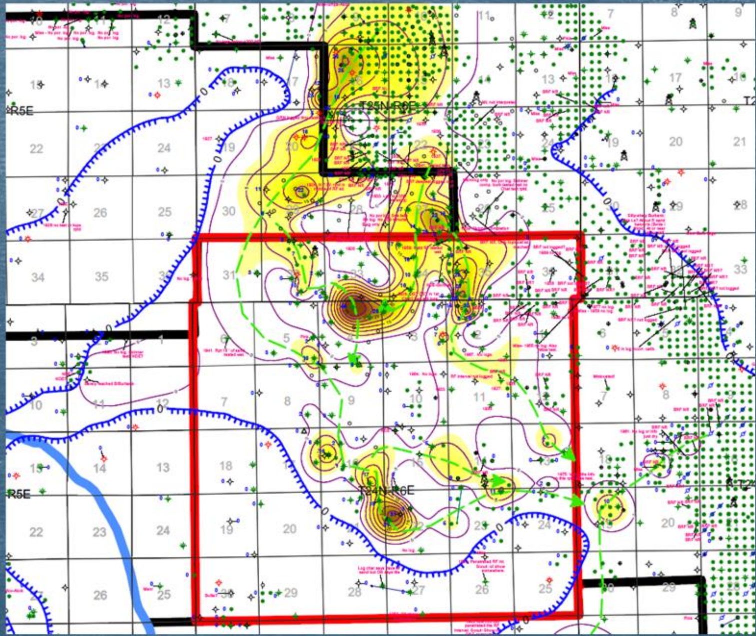
‘C’ Sand

Porosity >= 18%



'C' Sand

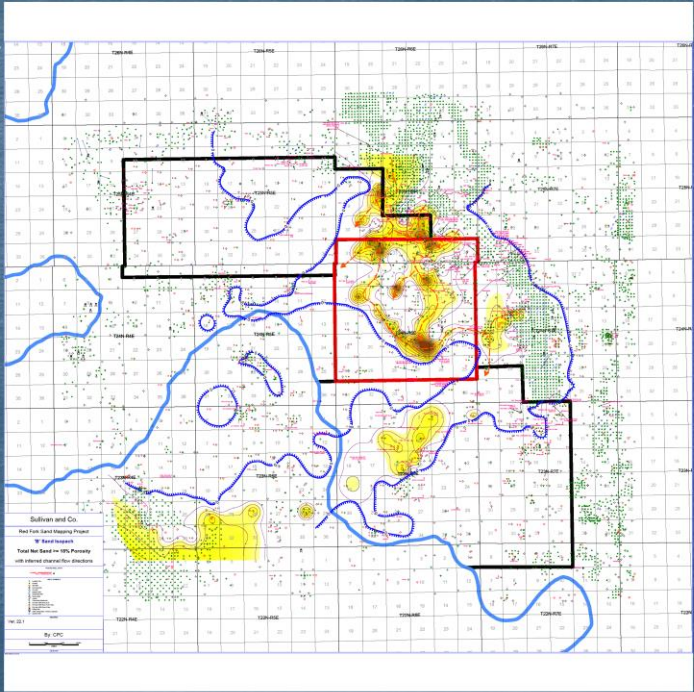
Porosity >= 18%



Presenter's notes: Close up of the flow directions proposed for the C sand.

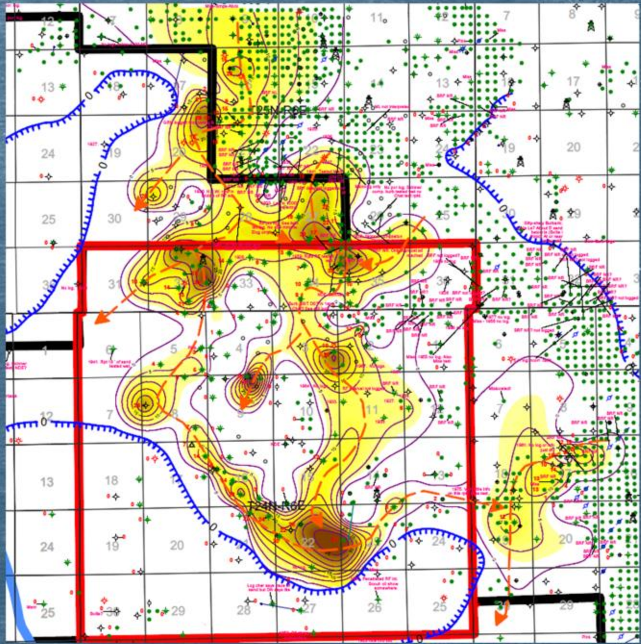
‘B’ Sand

Porosity >= 18%



'B' Sand

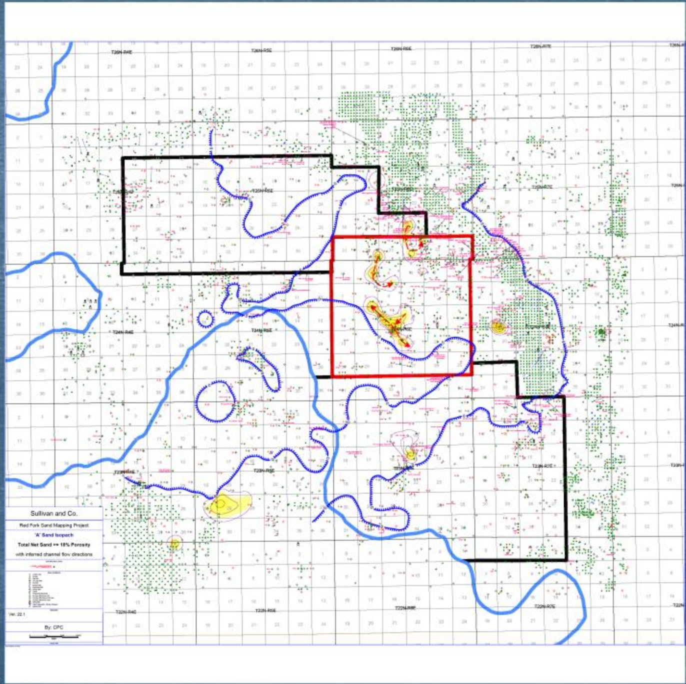
Porosity >= 18%



Presenter's notes: Close up of the flow directions proposed for the B sand.

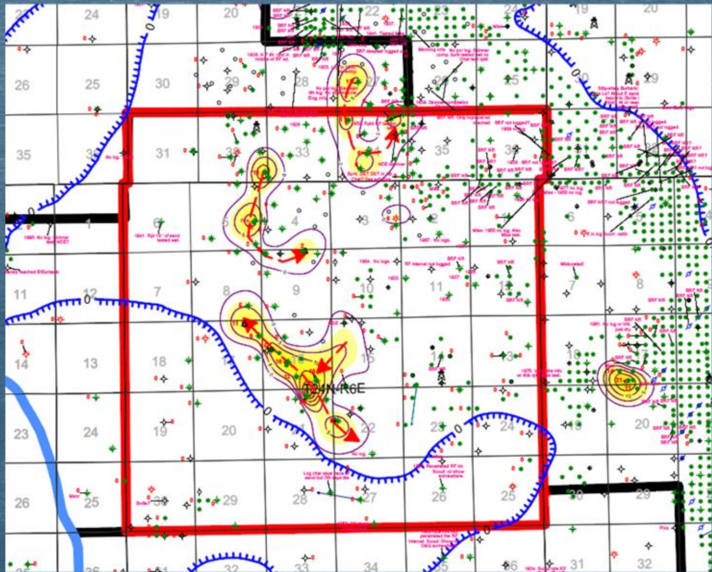
'A' Sand

Porosity >= 18%



'A' Sand

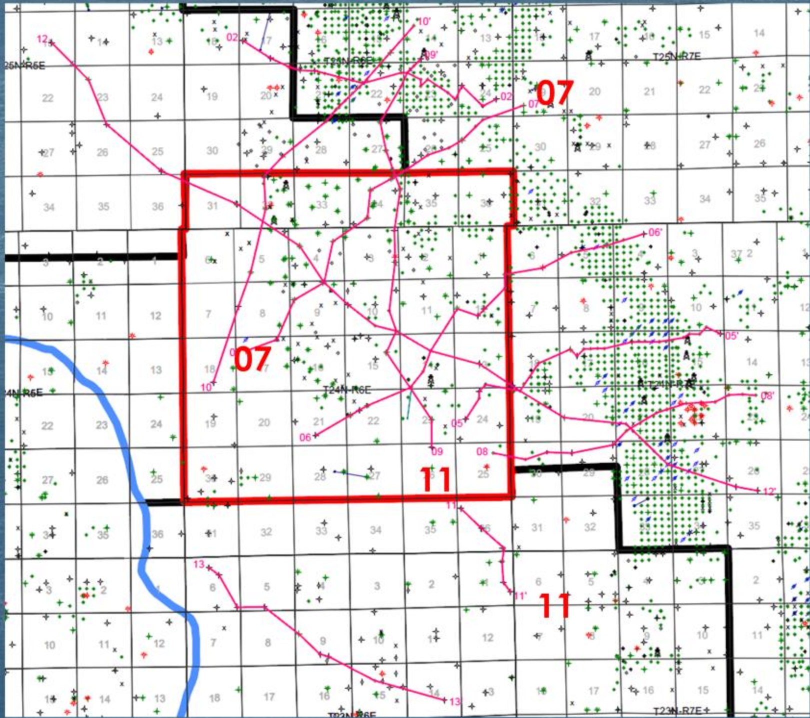
Porosity >= 18%



Presenter's notes: Close up of the flow directions proposed for the A sand.

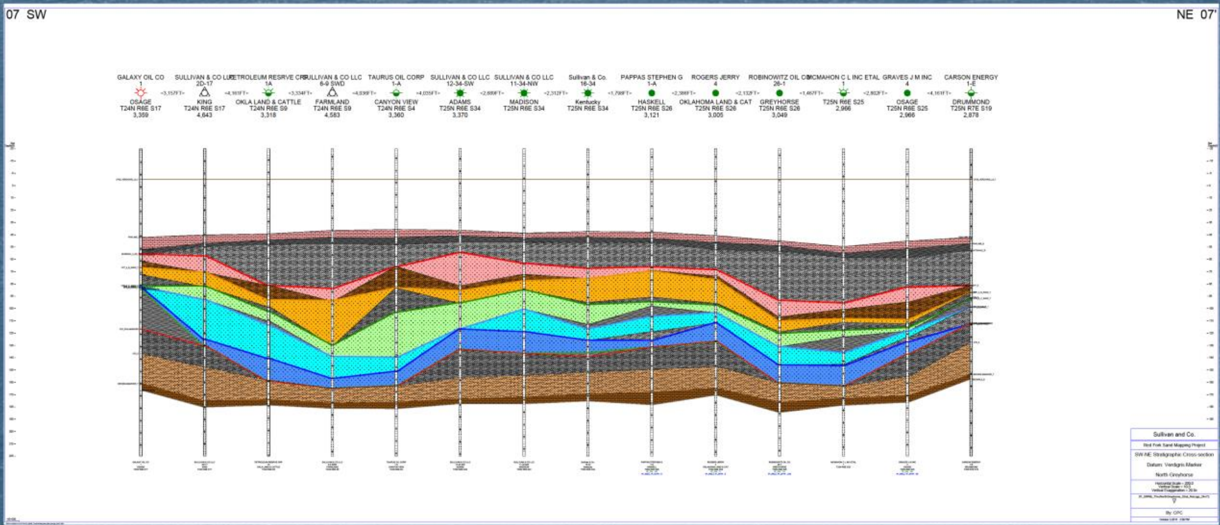
I think that these sand bodies were deposited in a nearshore marine environment, possibly barrier bar, channel mouth bar, with storm reworking.

Cross-section Locations

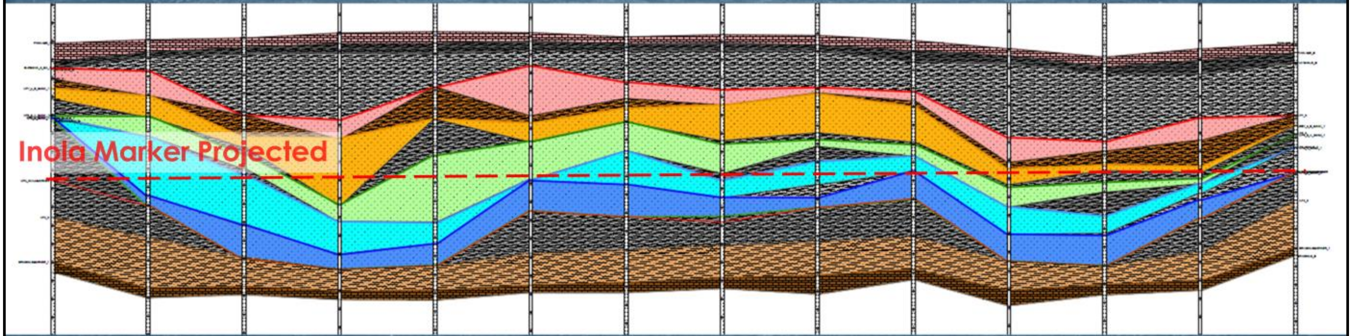


Presenter's notes: I want to talk about my idea that there might be remnants of Bartlesville in the E sand, possibly in some places making up the entire E sand. Note the cross-=section locations, with 07 traversing the heart of the channel; and cross-section 11 traversing a narrower channel just south of Greyhorse.

Cross-section Across Grayhorse

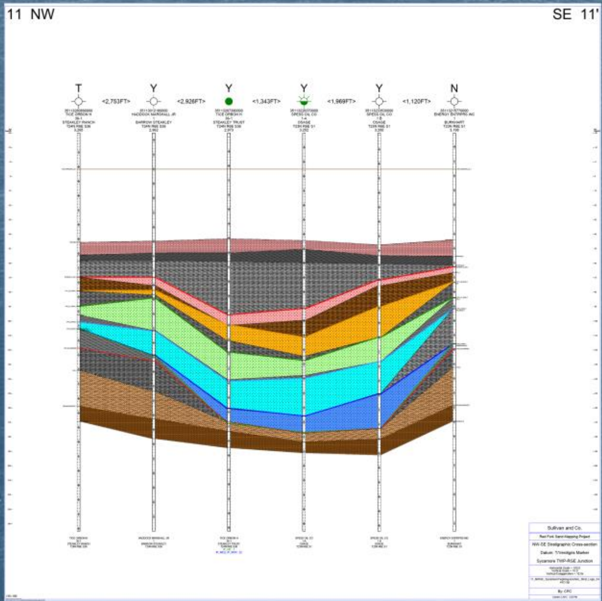


Cross-section Across Grayhorse



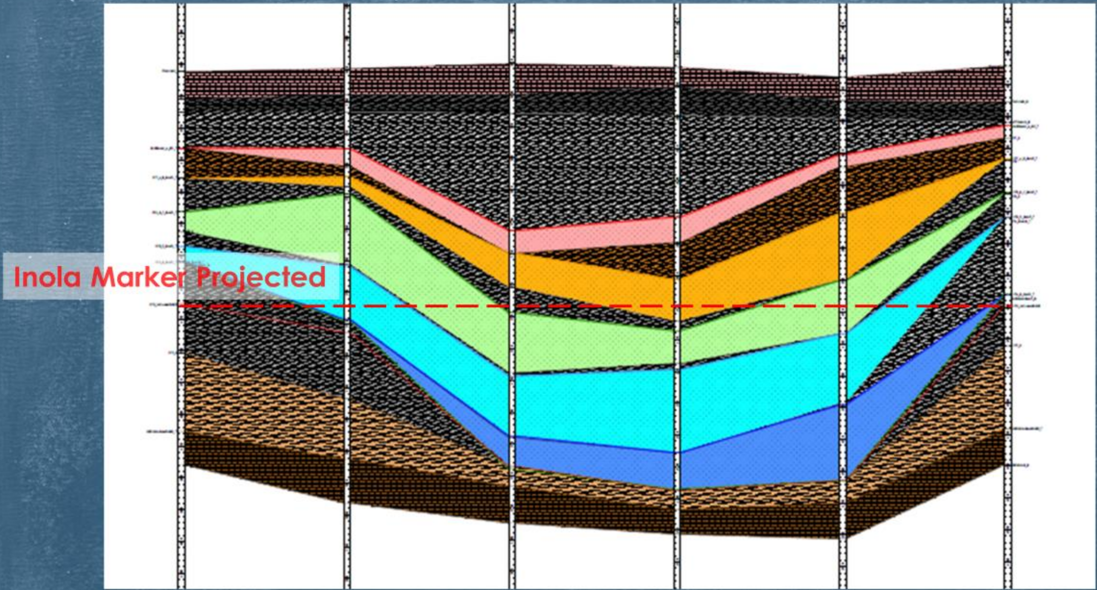
Presenter's notes: I have projected the Inola Marker across the channel on this cross-section, to show how much sediment must have been removed and then replaced. Note how the E sand pinches out on the left and the right very near the Inola projection point.

Cross-section across channel south of Grayhorse



Presenter's notes: Here is the cross-section 11 across the 'south' channel.

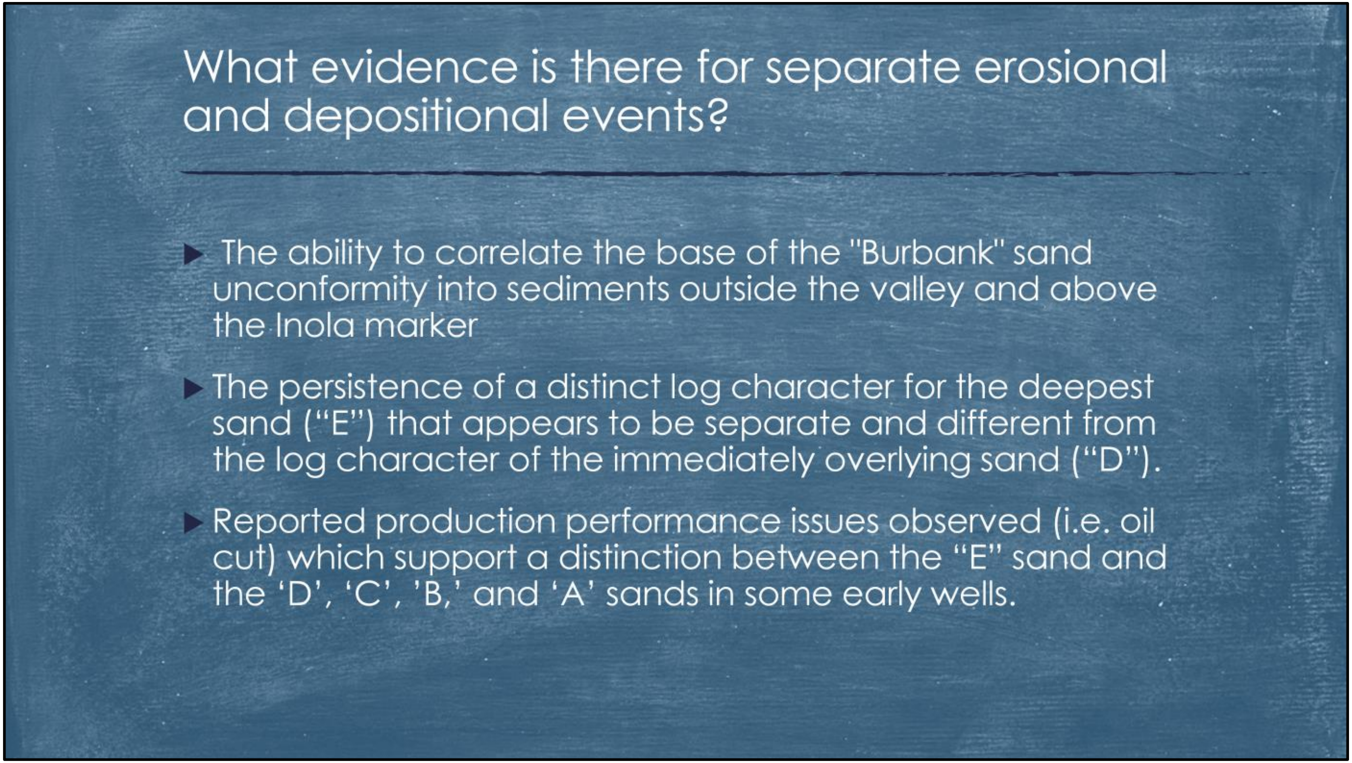
Is the 'E' Sand a Bartlesville Sand Remnant?



Presenter's notes: Again, note how the Inola Marker projected seems to correspond closely to the point where the E sand disappears.

Working with the E sand, I had noticed its distinctive character in many (not all) of the wells. This led me to the idea that, perhaps, the channel had originally been cut by the Bartlesville, the Inola deposited, and then the Inola removed by the Red Fork depositional event.

I looked for evidence one way or the other. What I found was this: [next slide]



Presenter's notes: The "two valley" interpretation is based on:

- The ability to correlate the base of "Burbank" sand unconformity into sediments outside the valley and above the Inola marker; and
- The persistence of a distinct log character for the deepest sand ("E") that appears to be separated and different from the log character of the immediately overlying sand ("D").
- There have been production performance issues observed which support a distinction between the "E" sand in some wells. When Sullivan started this project, they saw a higher oil cut from the E sand. The oil cut, along with the oil composition, was in their experience more characteristic of the Bartlesville oil and Red Fork oil.

An alternative hypothesis is that there was only one valley-forming event which led to deposition of the "Burbank" sand. In this scenario, there is no Bartlesville sand and no Bartlesville valley, only a Red Fork valley and a Red Fork sand.

Based on the study from which this report is derived, and the author's experience with the data available, the "two valley" hypothesis is the one which best explains the geological observations.

Summary and Conclusions

- the "Burbank" (Red Fork) Sand in western Osage County is herein interpreted as being deposited in a fluvial-deltaic sedimentary environment, within an incised valley.
- five sand units within the Red Fork, arbitrarily identified as "A", "B", "C", "D" and "E" have been defined in this study.
- The inferred depositional environment for the Red Fork is believed to have changed over time from fluvial-deltaic ("E" sand / Bartlesville) to nearshore marine ("A" sand).
- Careful well log correlations suggest that the valley was created by two separate erosional – depositional events:
  - The first event created the original incised valley, followed by the deposition of the underlying Bartlesville Sand.
  - a second erosional event removed some but not all of the Bartlesville sand, remnants of which are interpreted as sometimes composing part or all of the "E" sand within the study area.
  - This was followed by deposition of the Red Fork Sand, filling the channel once more, and it is inferred, reworking some of the Bartlesville remnants.

Acknowledgements

- Sullivan and Company, LLC
- Scout Energy

Presenter’s notes: I want to thank Don Unruh, of Sullivan and Co. for his invaluable help, encouragement and trust in me with this project. I also want to thank Warren Thomas, formerly of Sullivan and now Independent, for his suggestions and comments. Both of these gentlemen were very helpful as sounding boards during the project.

Questions & Discussion