# Case Studies: Fault Identification Using Borehole Image Log for Mississippian Limestone Horizontal Well Completion Design*

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## Abstract

Our case studies show that an effective well completion design is the key to Mississippian Limestone horizontal well oil production. In another words, understanding the natural fracture system, especially fault attributes, and choosing the right places for stimulation are very important to maximize oil and minimize water production.

Many features on the borehole wall are observed and can be quantified with a borehole image log, including fault and natural fracture systems, besides other geological features. All these features demonstrate different aspects of reservoir properties. We routinely review and understand these image log features, along with other information, before we complete a well. A perfect zone for cluster perforation and hydraulic fracture treatment has three key attributes – good porosity, a multi-strike natural fracture system, and a distance from a large fault – and all can be identified with the borehole image log. The first two are the foundation for maximizing the production rate. The third element is vital for reducing water cut in the Mississippian limestone reservoir. The major point of this presentation is that a large fault could connect the oil reservoir to aquifers above or below, which may increase the water cut significantly.

Four case studies will be discussed. Case #1: A few faults were observed on the borehole image log, but none of them seems to be large. IP results were good (345 bopd and 2000 bwpd). Case #2: A large fault was identified with the image log in the heel interval, although it did show up well on seismic data. Mud loss occurred there and the well was drilled dry for 3 days. We knew that we had to stay far away from the large fault and finally decided 250 ft should be far enough. Unfortunately, IP results (5 bopd and 1000 bwpd) convinced we were still not far away enough. Case #3: Seismic shows a large fault beyond the toe of the well. A test was designed on the small section of the toe to see how the

large fault would associate with the water cut. Again, an IP of 45 bopd and 4500 bwpd proved a large fault is very bad for oil production. Case #4: No fault, small or large, can be seen on the borehole image log in the entire well. The water cut was lower (IP = 250 bopd, 5 mmcfpd gas and 2500 bwpd).

# Case Studies: Fault Identification Using Borehole Image log for Mississippian Limestone Horizontal Well Completion Design

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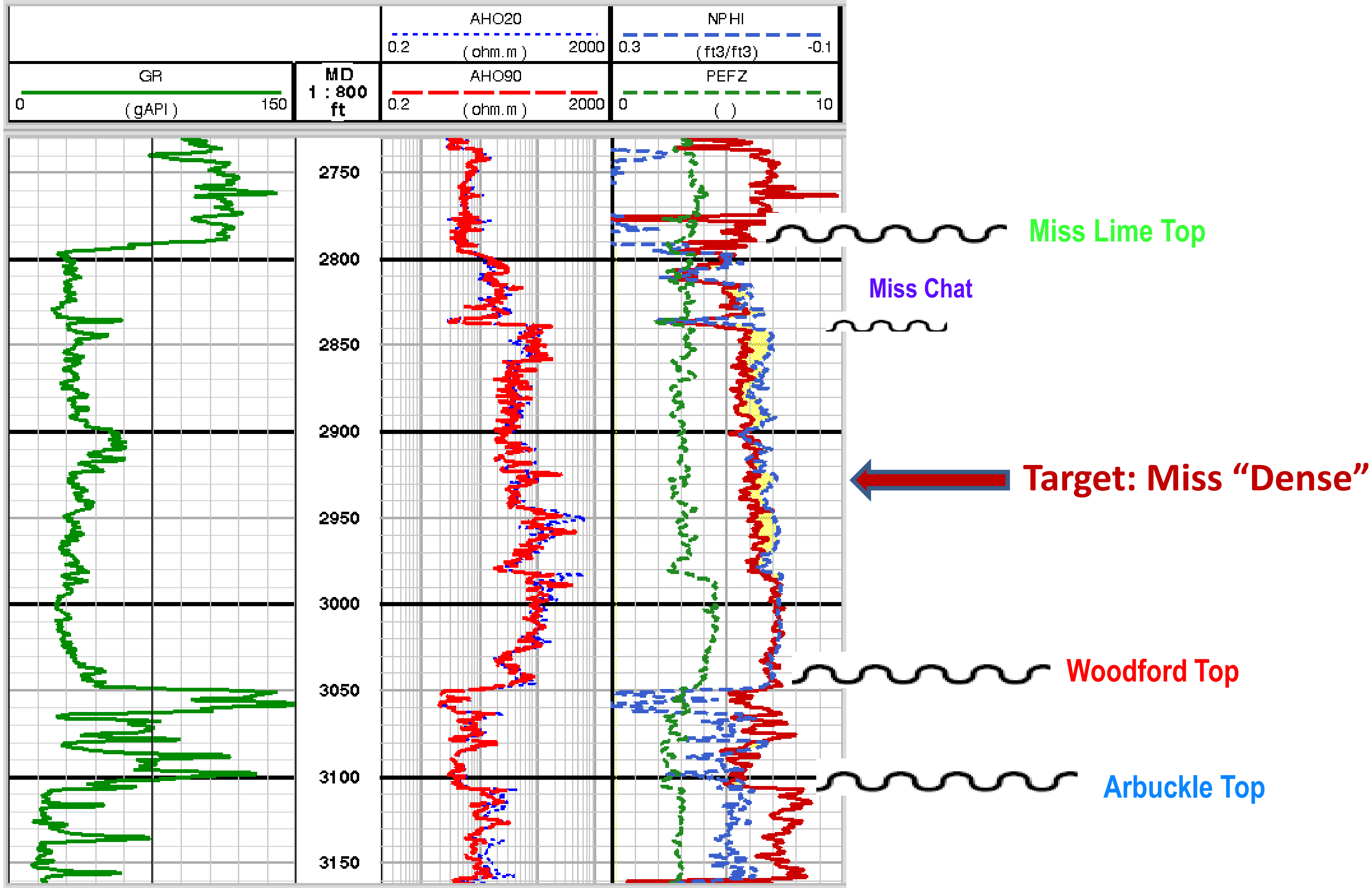
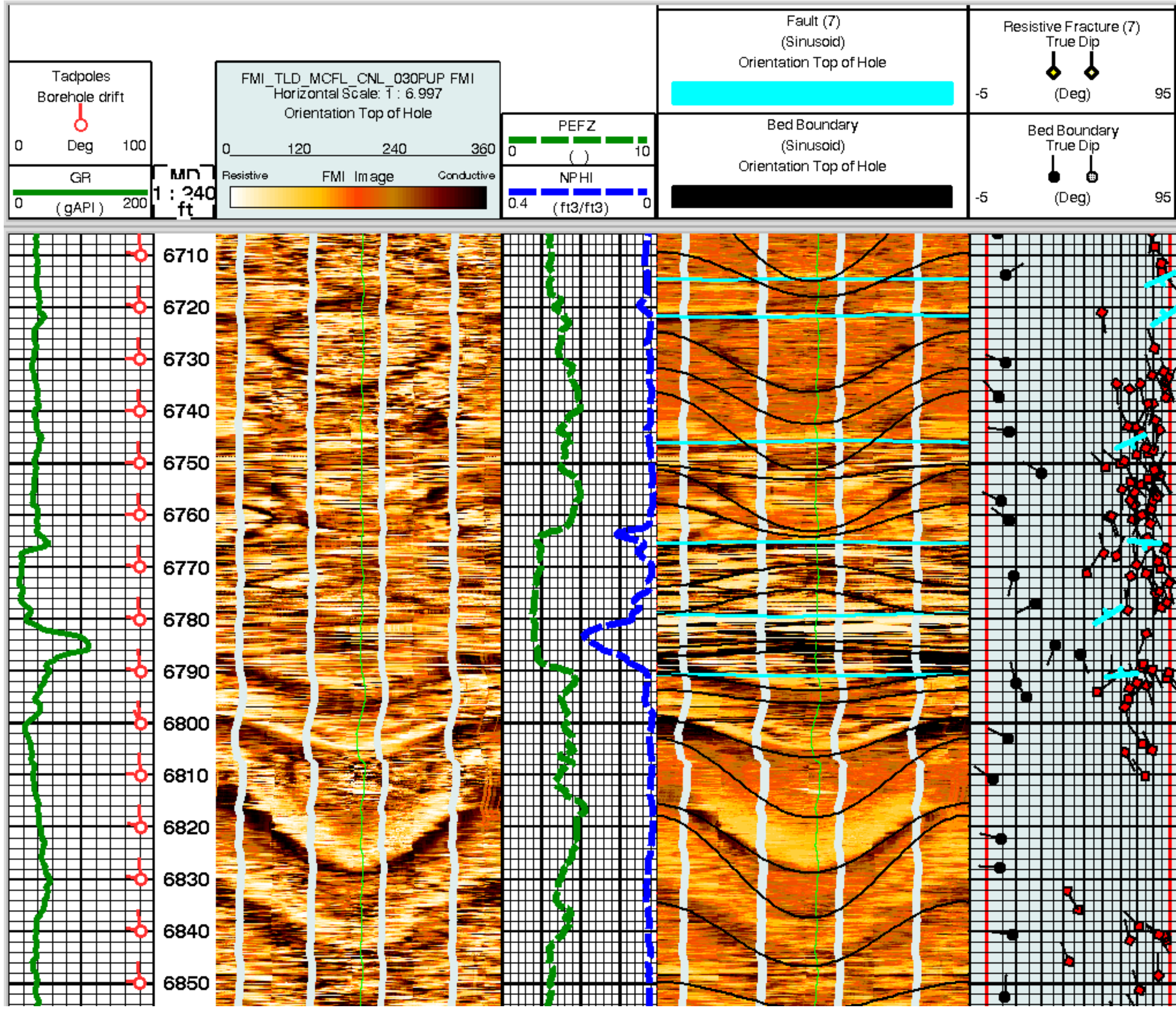
# Agenda

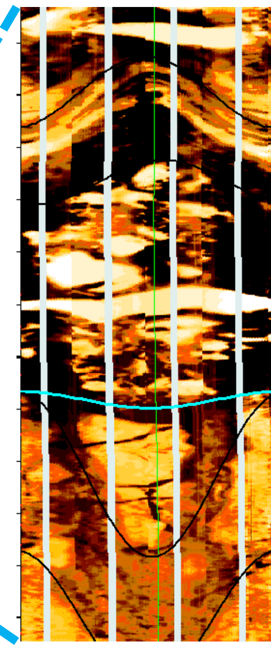
- Large Fault – Culprit for High water-cut?
- What a Fault looks like on Borehole Image Logs
- Case #1: No Large Fault, Lower water-cut, Tahara
- Case #2: Large Fault at Heel, Very High water-cut, Abunda
- Case #3: Large Fault near Toe, High water cut, Shaw
- Case #4: No Fault, Low water cut, NW Strohm
- Conclusion

# Type Logs of the Mississippian Limestone, Osage Co, OK



# A Typical Fault on Borehole Images



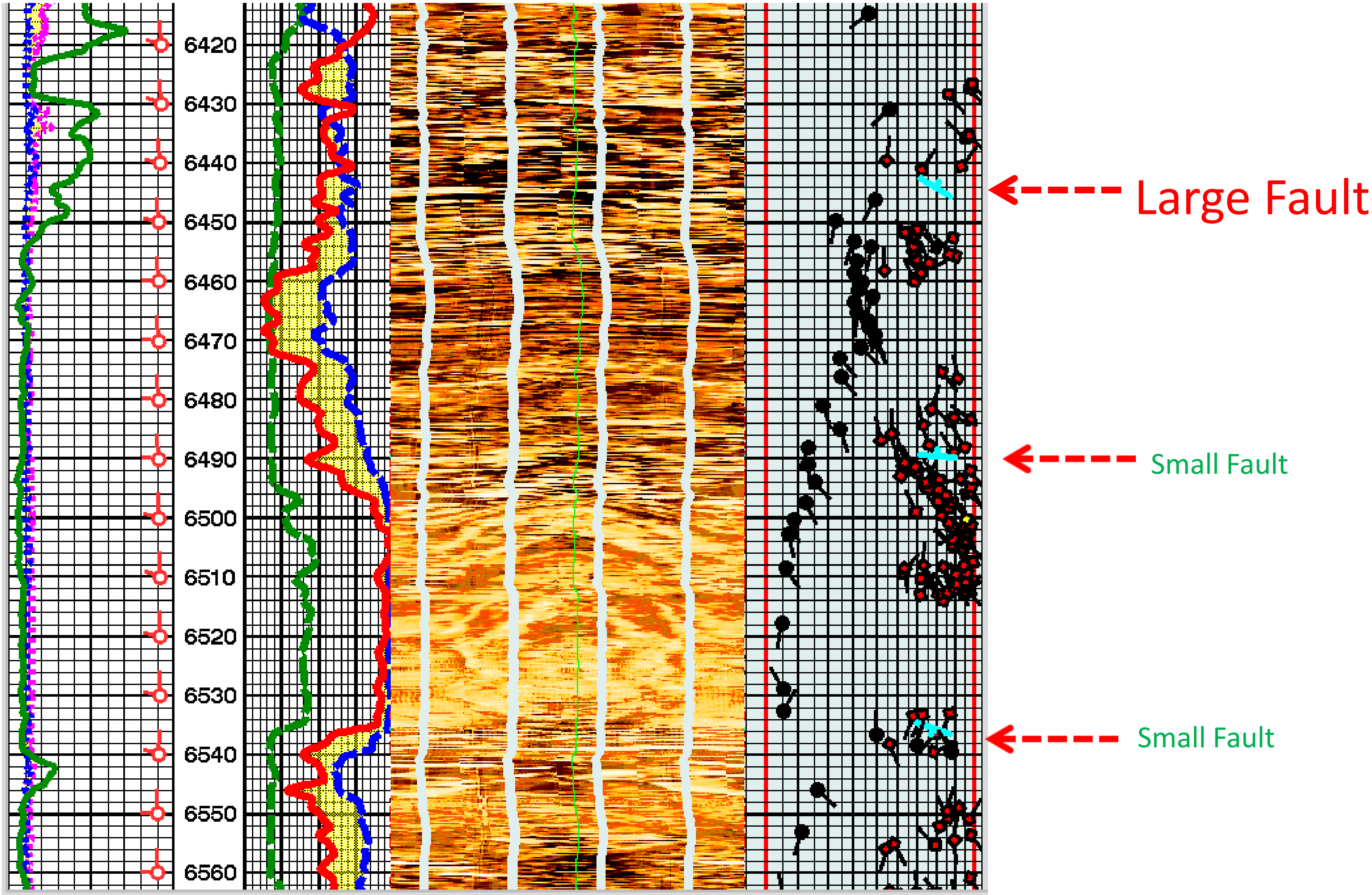
NEW TECHNOLOGIES IN THE MID-CONTINENT

REDFORK ENERGY

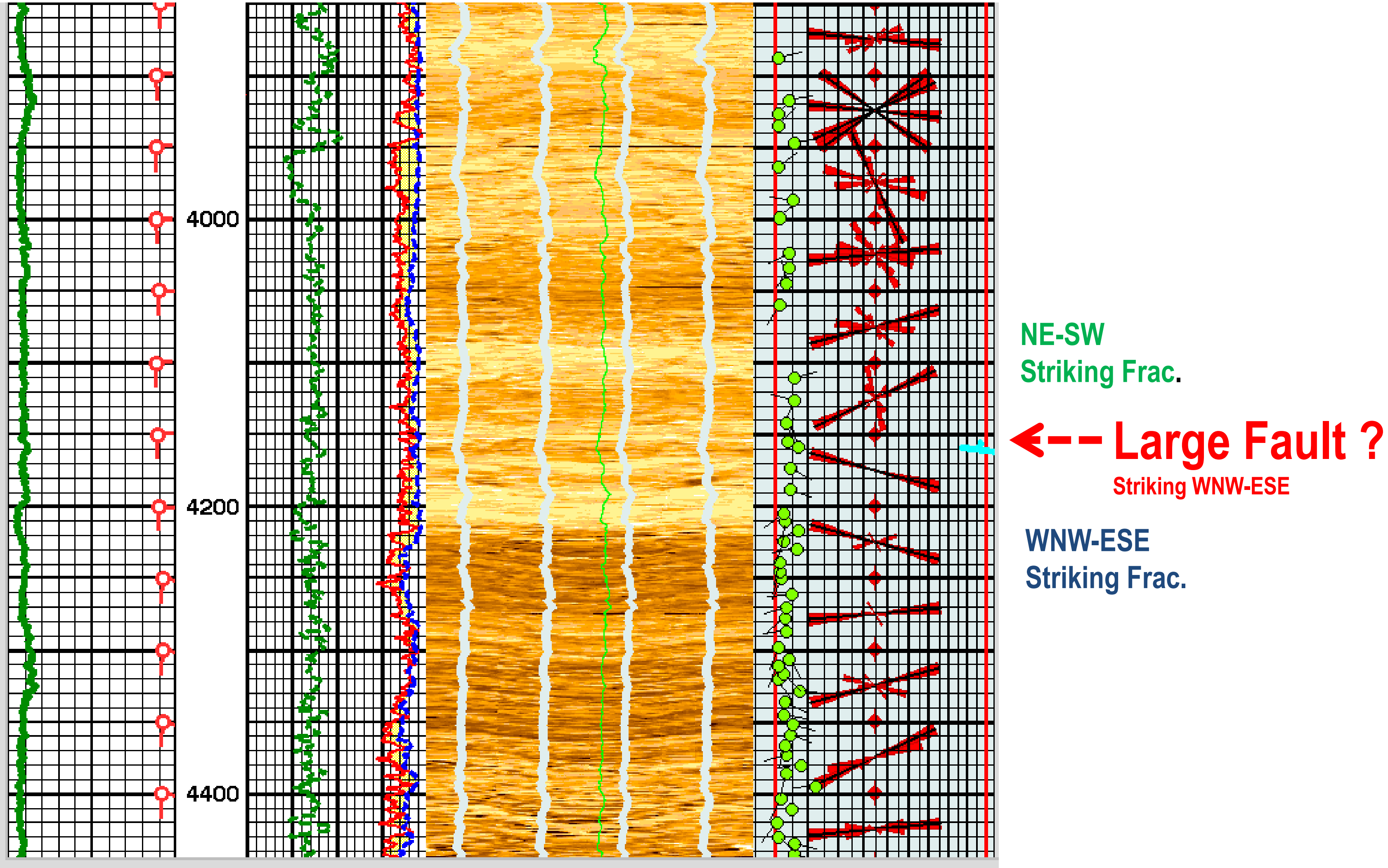
Spyglass Energy Group, L.L.C.

Schlumberger

# Bedding Dip Pattern: A Large Fault of at least 80' Throw?



# Rotation of Natural Fracture Strikes: Caused by a Large Fault ?

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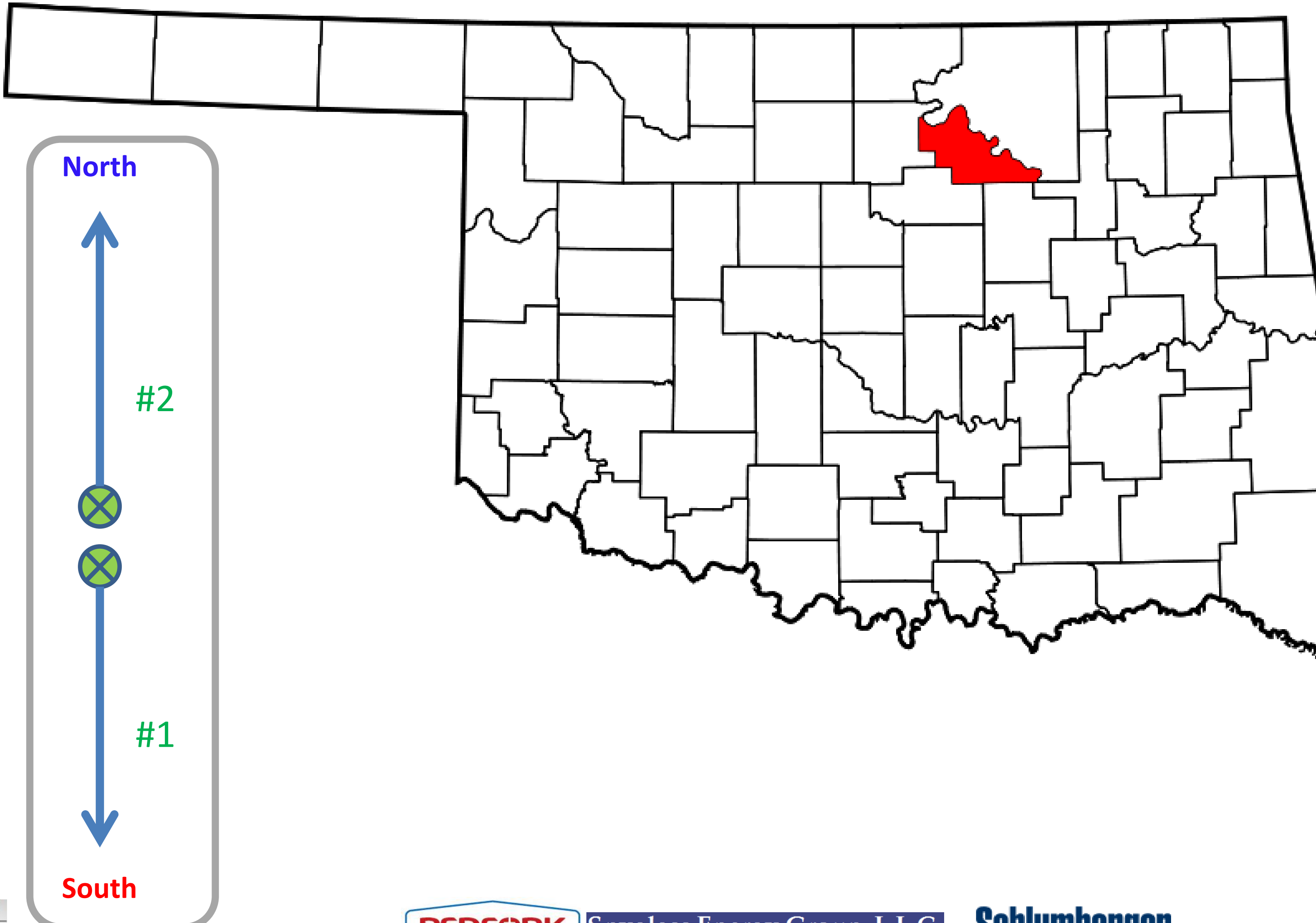
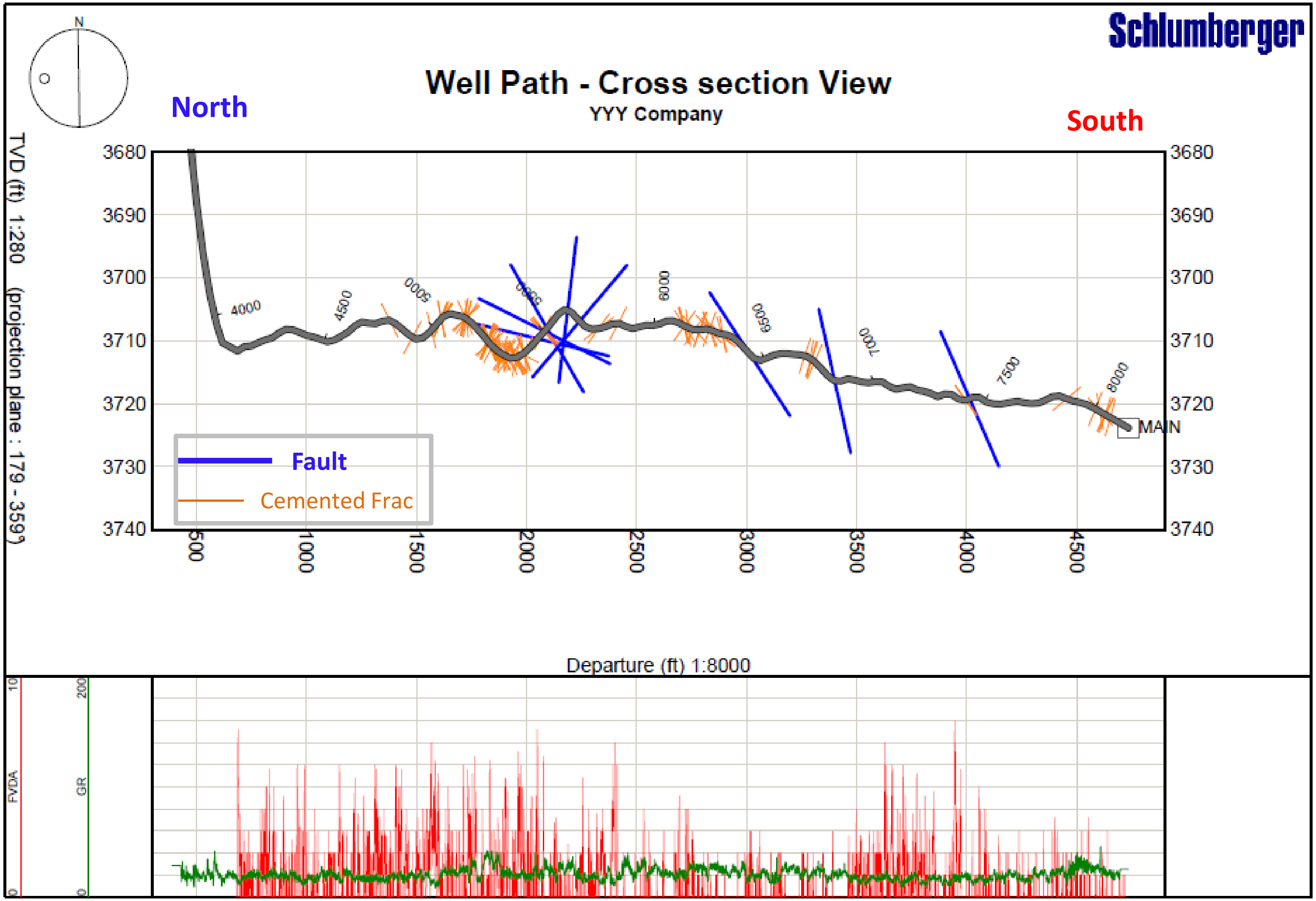
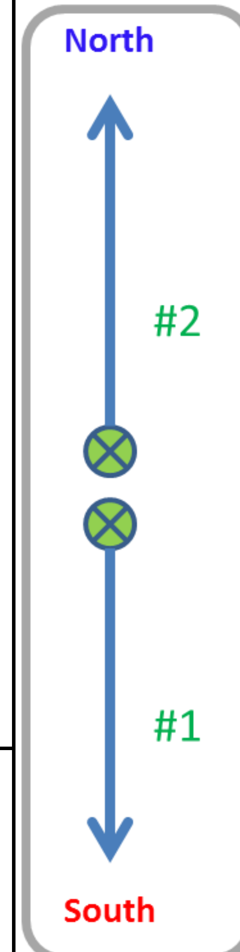
# Locations of the first 2 cases, Pawnee Co.

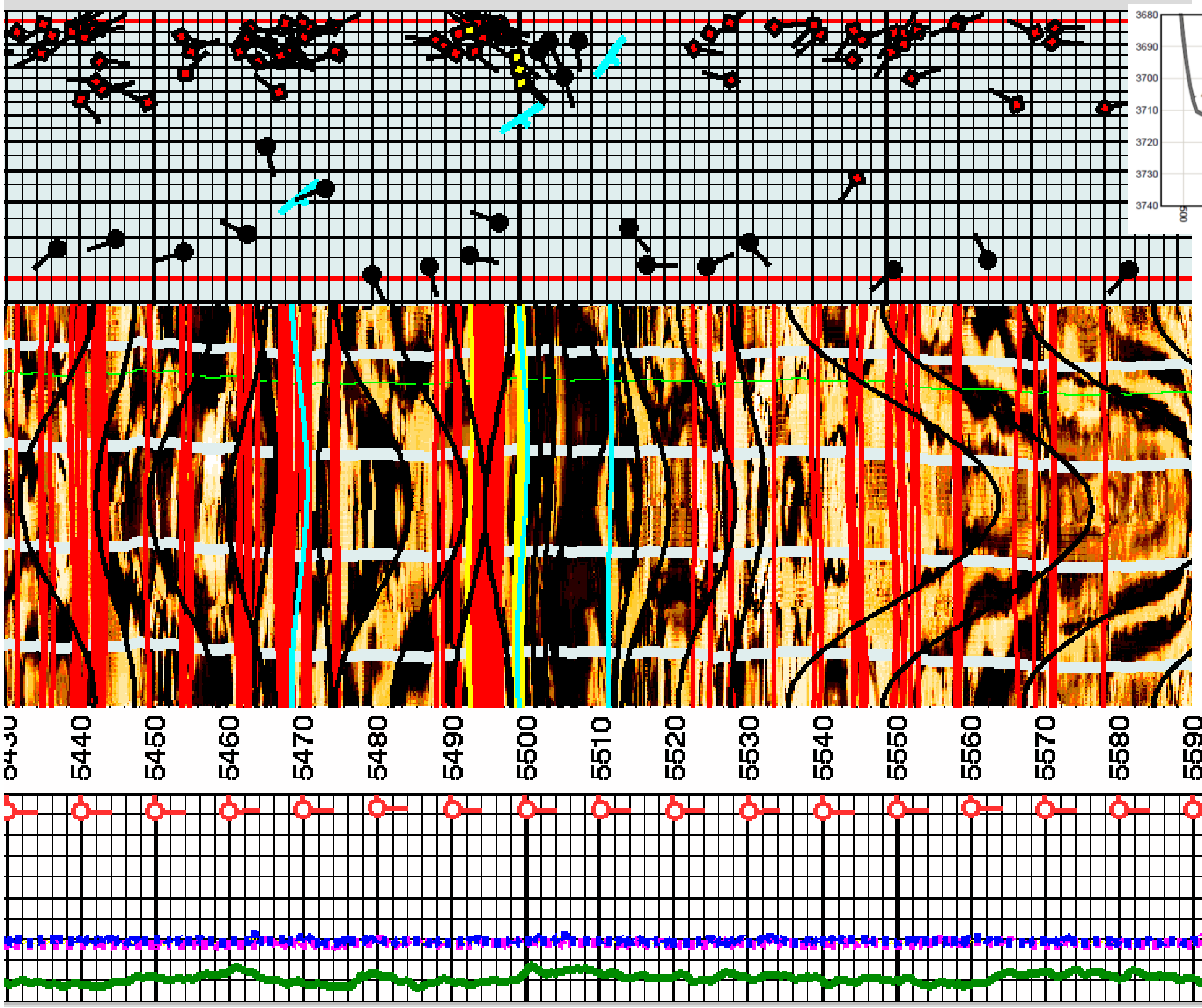


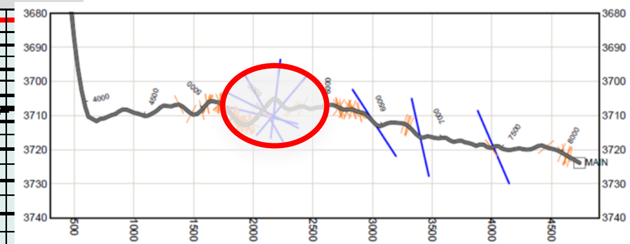
# Case #1: A few Small faults, No Large Fault

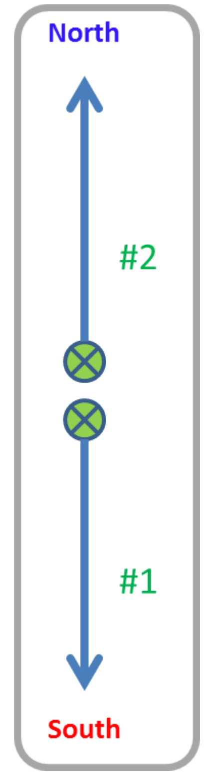


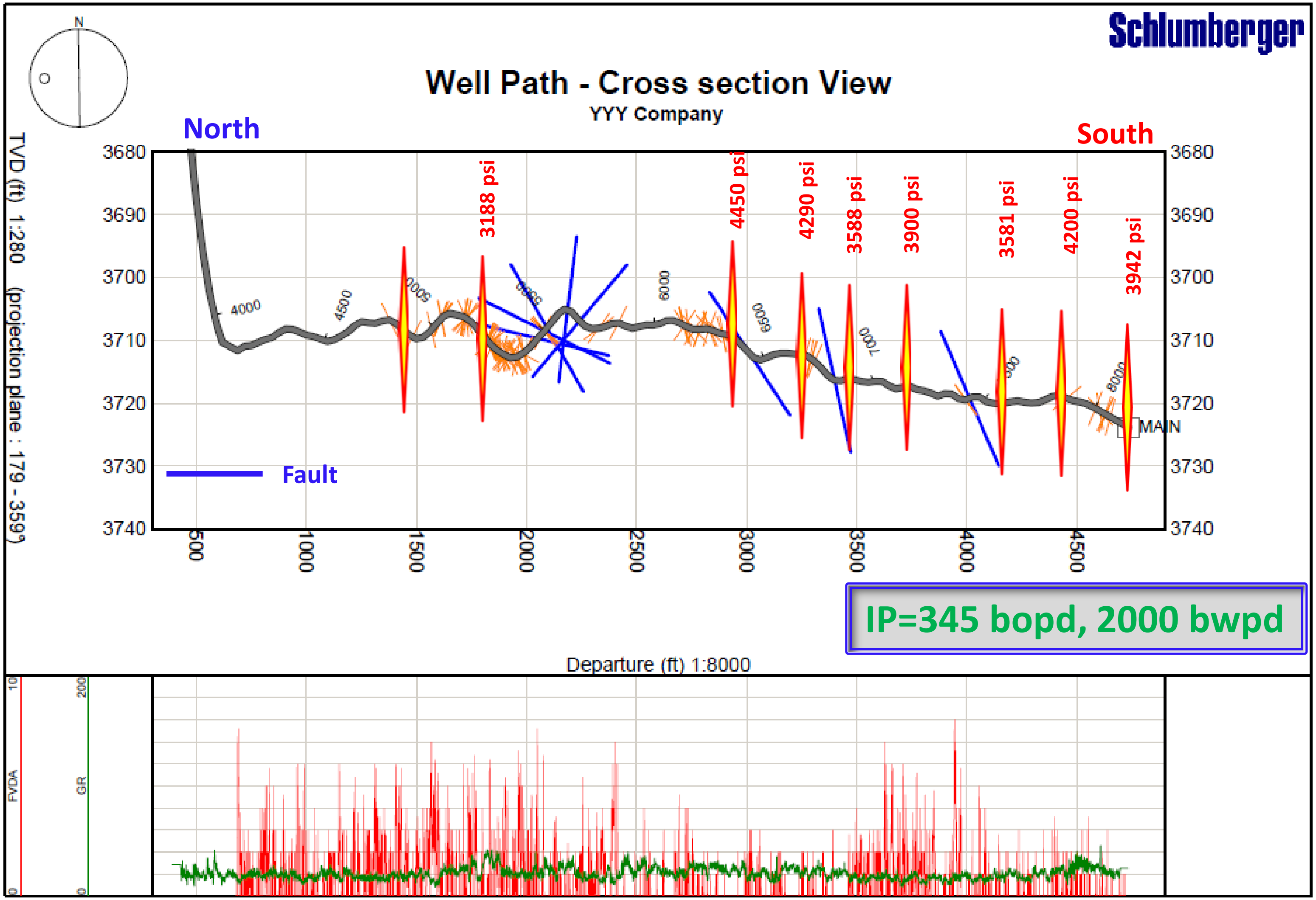
# Case #1: Image Logs of the Small faults

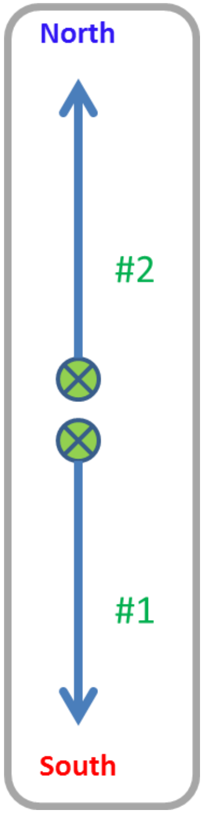


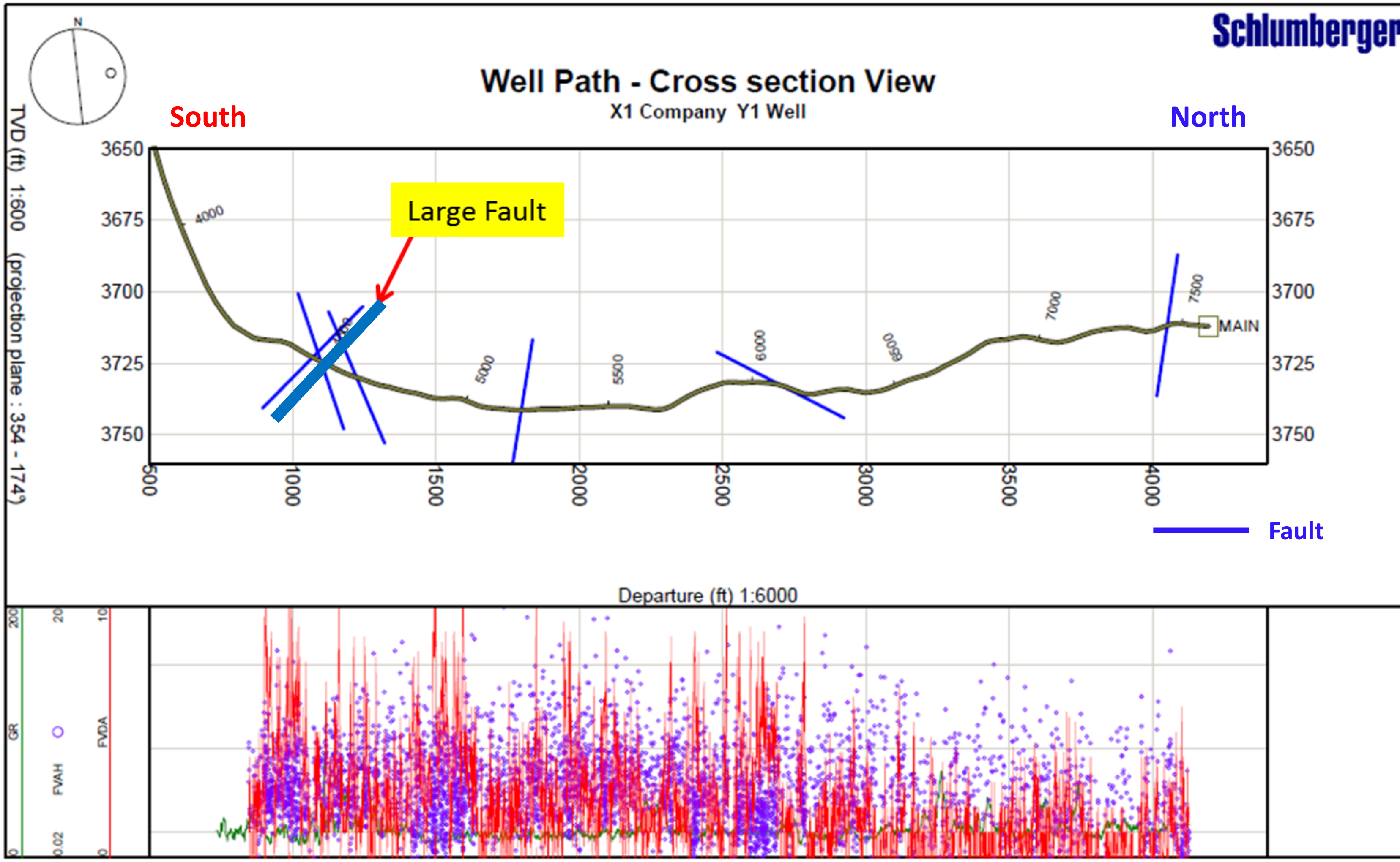



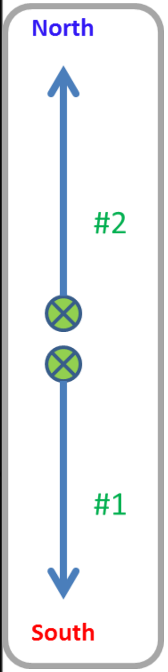
# Case #1: Hydraulic Fracture Stages



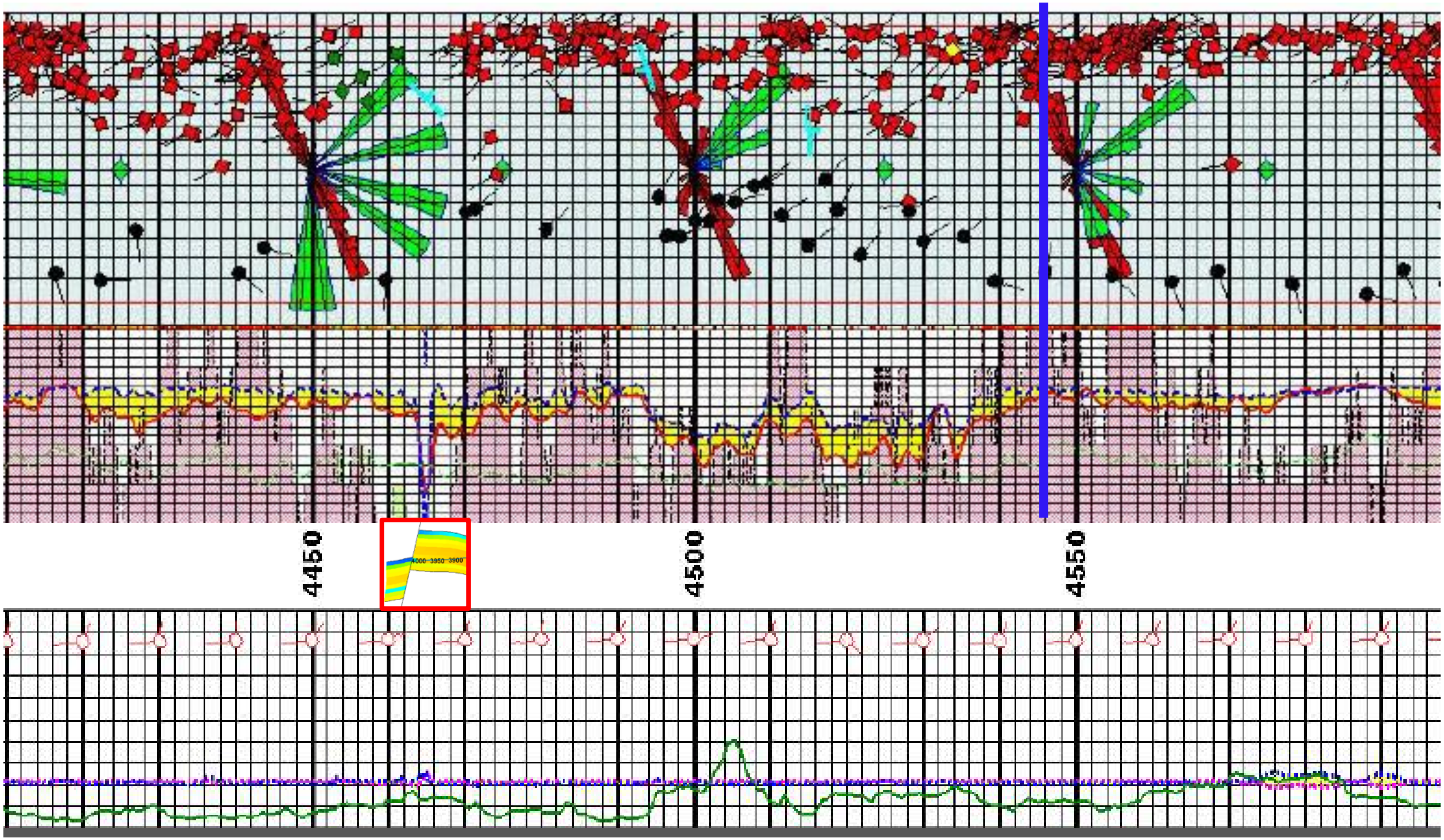



# Case #2: Borehole Image Shows a Large Fault

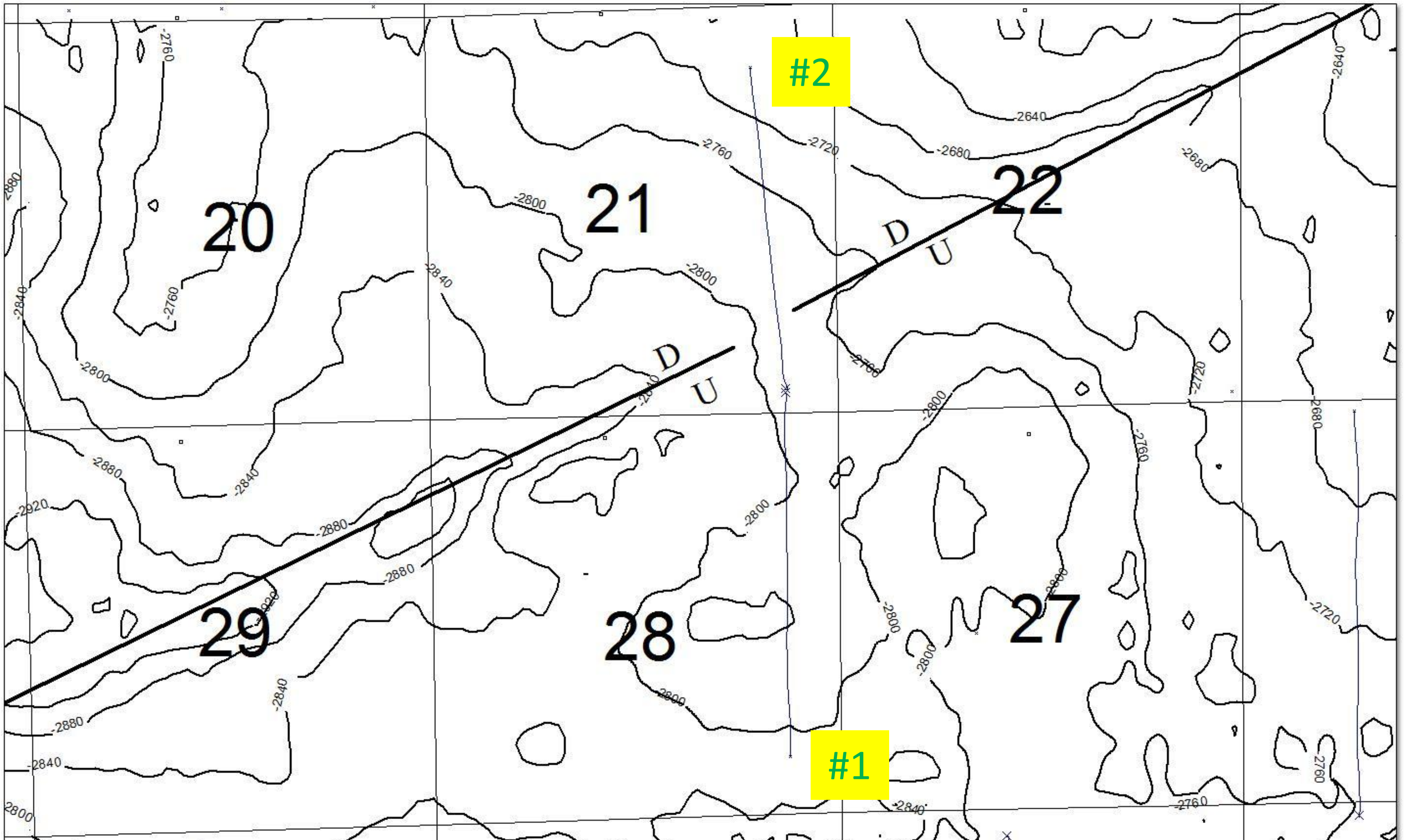


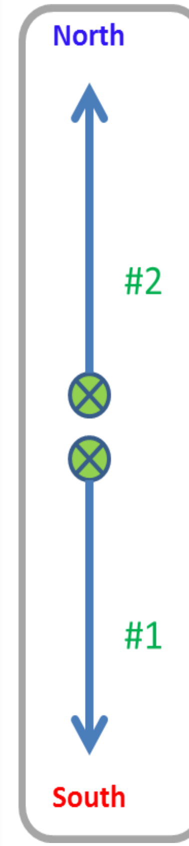



# Case #2: Image Log and Interpretation results – 90' throw?



# Case #2: 3 D Seismic Map - Well drilled thru Gap of the Faults?

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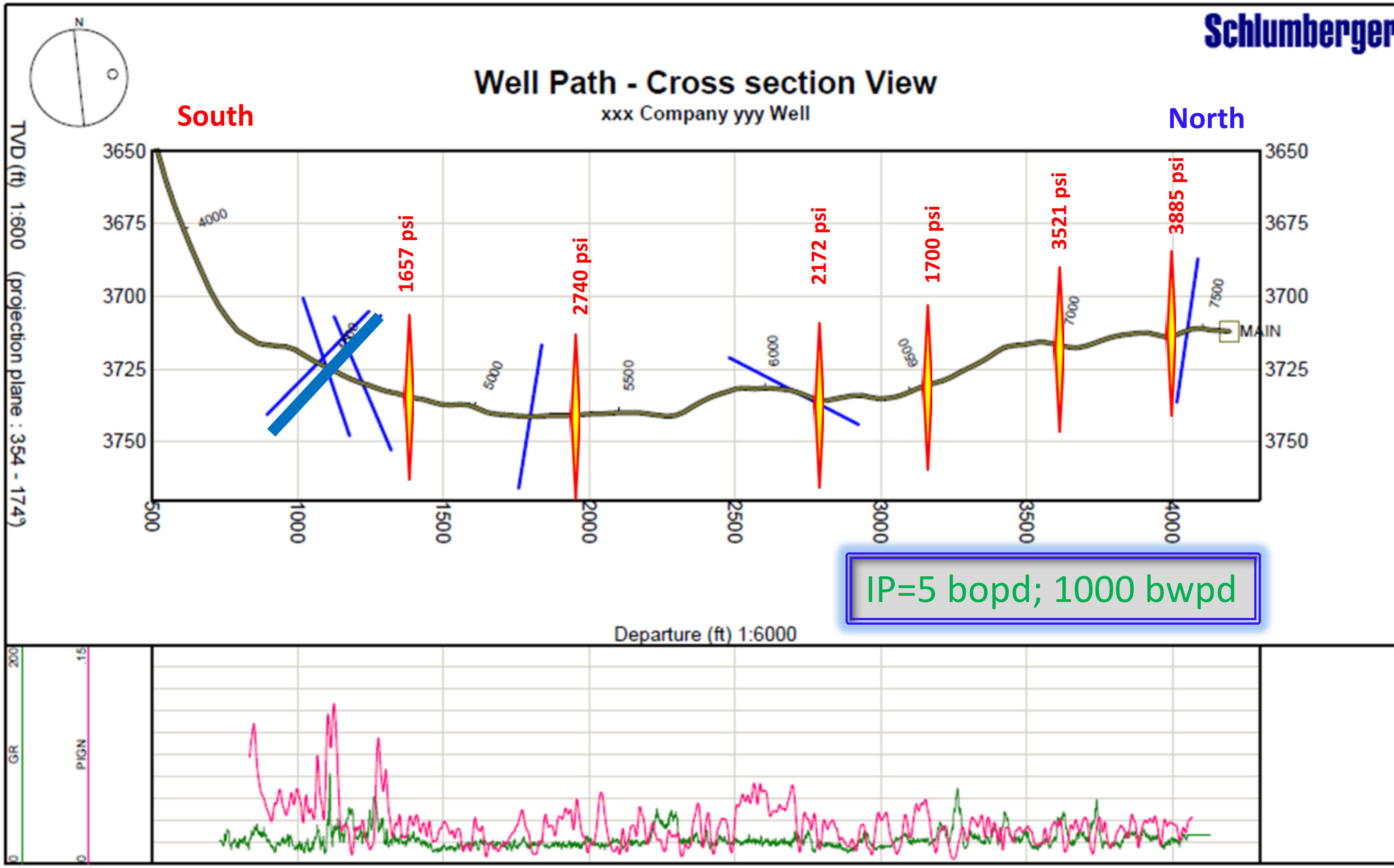
# Case #2: Stage #6, 250' from the Large Fault

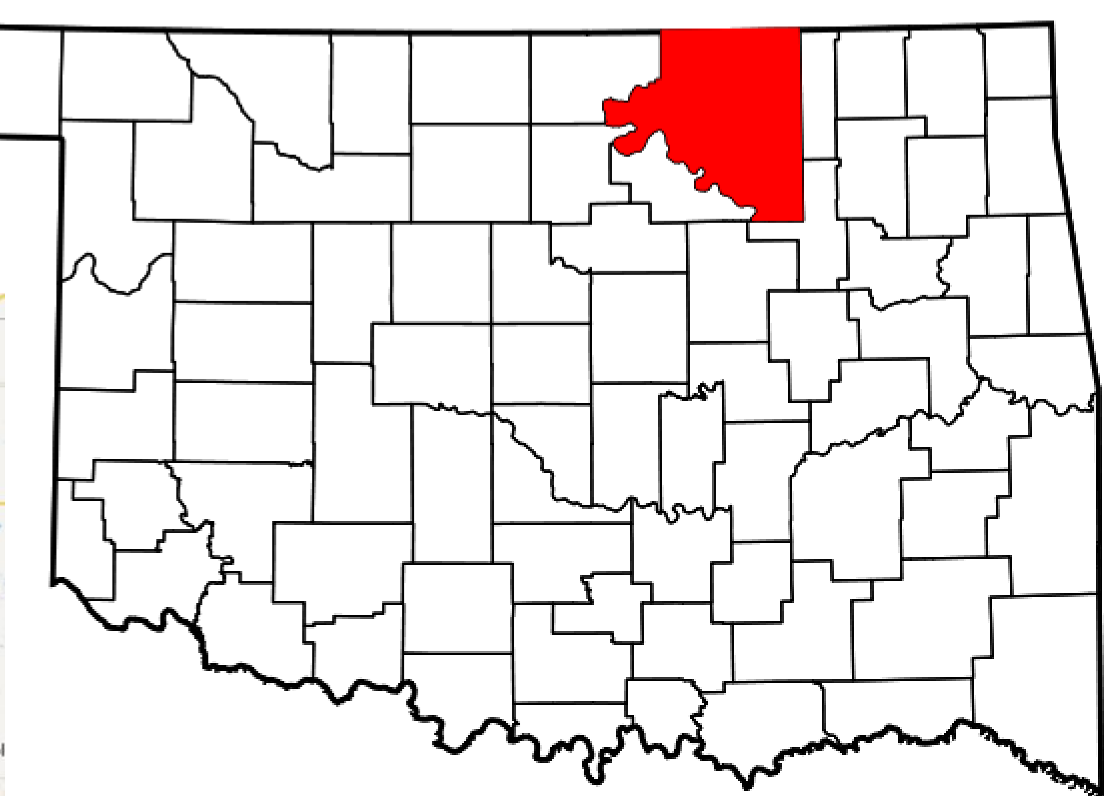


# Case #2: What We've Learnt

- A large fault identified with borehole image log
- Well drilled between 2 faults on 3D Seismic ?
- Lost circulation in the large fault zone, well drilled dry for more than 3 days
- CBL shows poor cement quality 200' on each side of the fault
- porosity is over 10 pu across the large fault while average porosity elsewhere is 3 pu or less
- GR is higher there too.  It may be caused by radioactive (Uranium) deposit
- Well IP 5 bopd and 1000 bwpd in Summer (July), 2012
- Stage #6 is 250' away from the large Fault – Not Enough

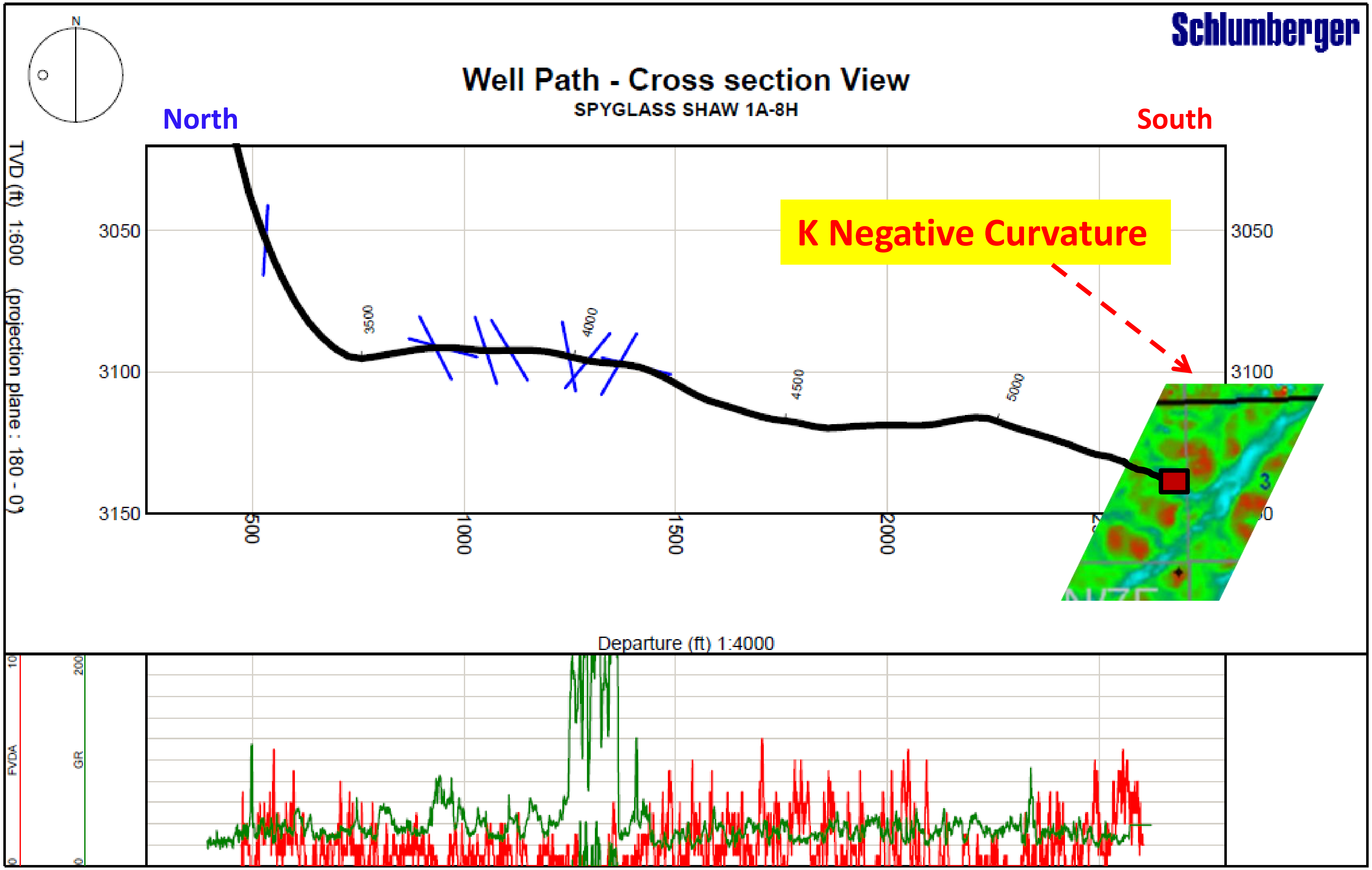
# Locations of the Case #3 and #4, Osage Co.


Osage County Map



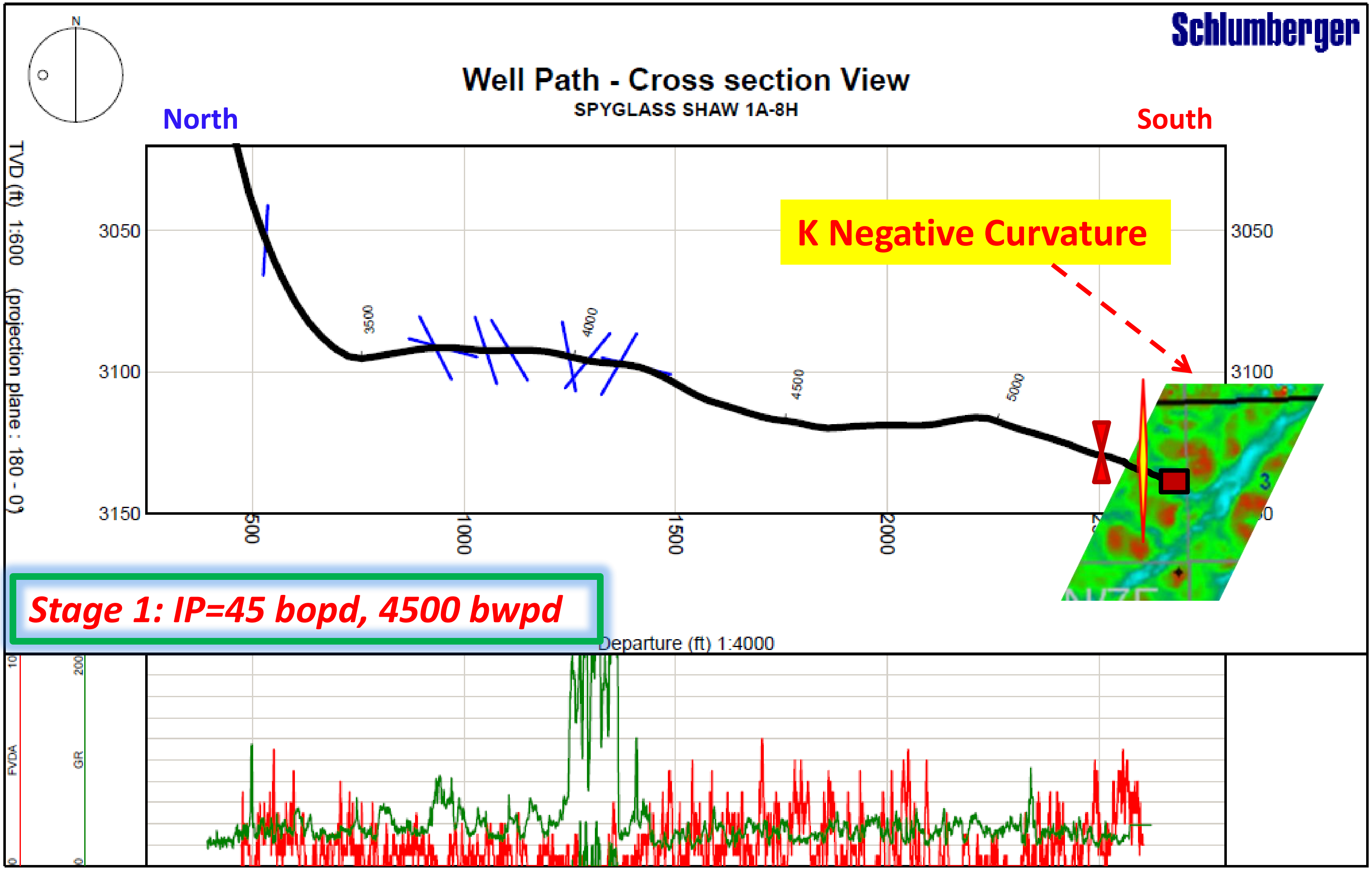
County Map of Oklahoma

# Case #3: A Large Fault from Seismic at Toe of this Lateral; A few Minor or Small Faults at Heel from Image Log




Spyglass Energy Group, L.L.C.

# Case #3: Test #1 (Stage #1) – Zone of a Large Fault

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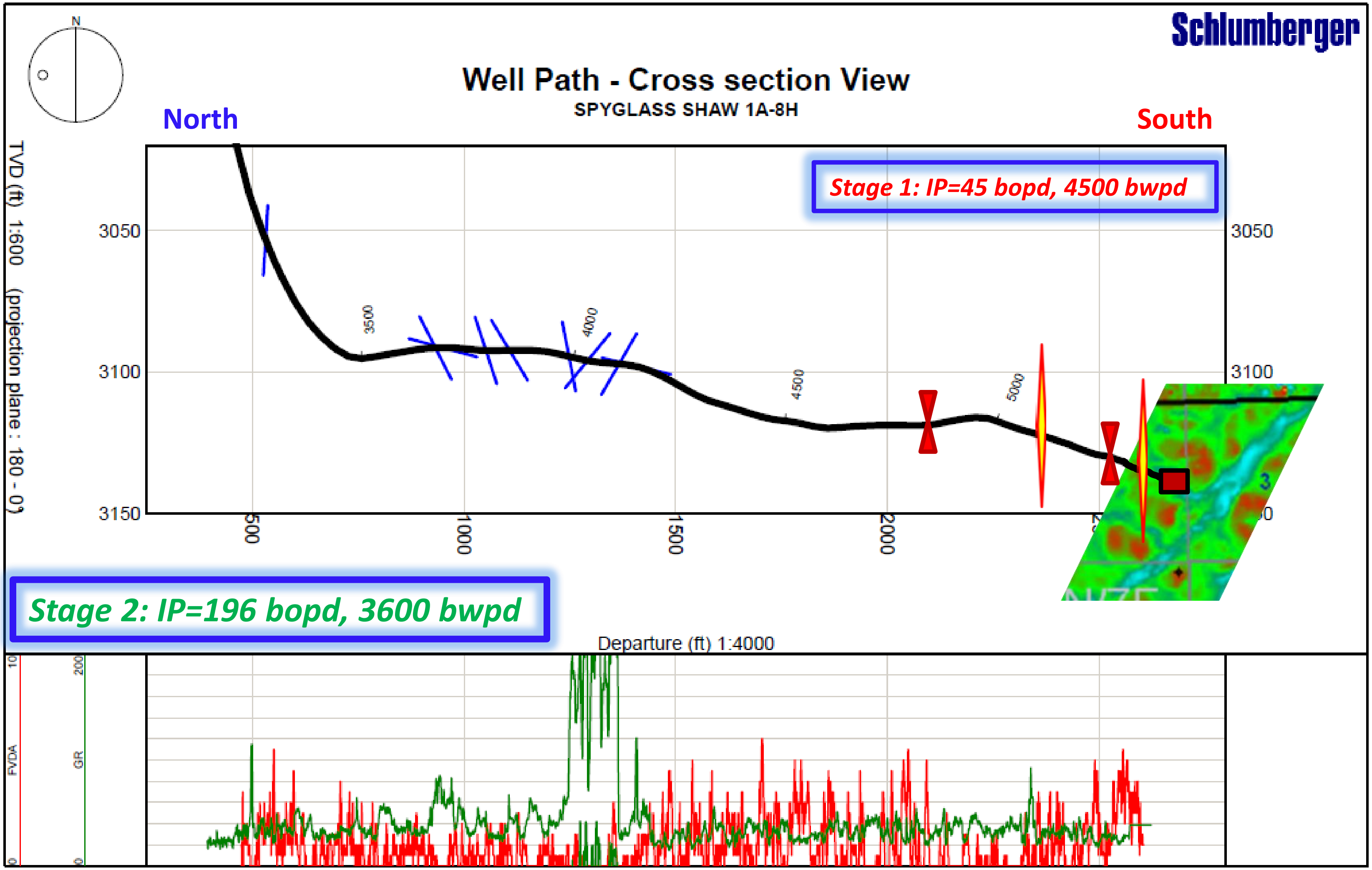
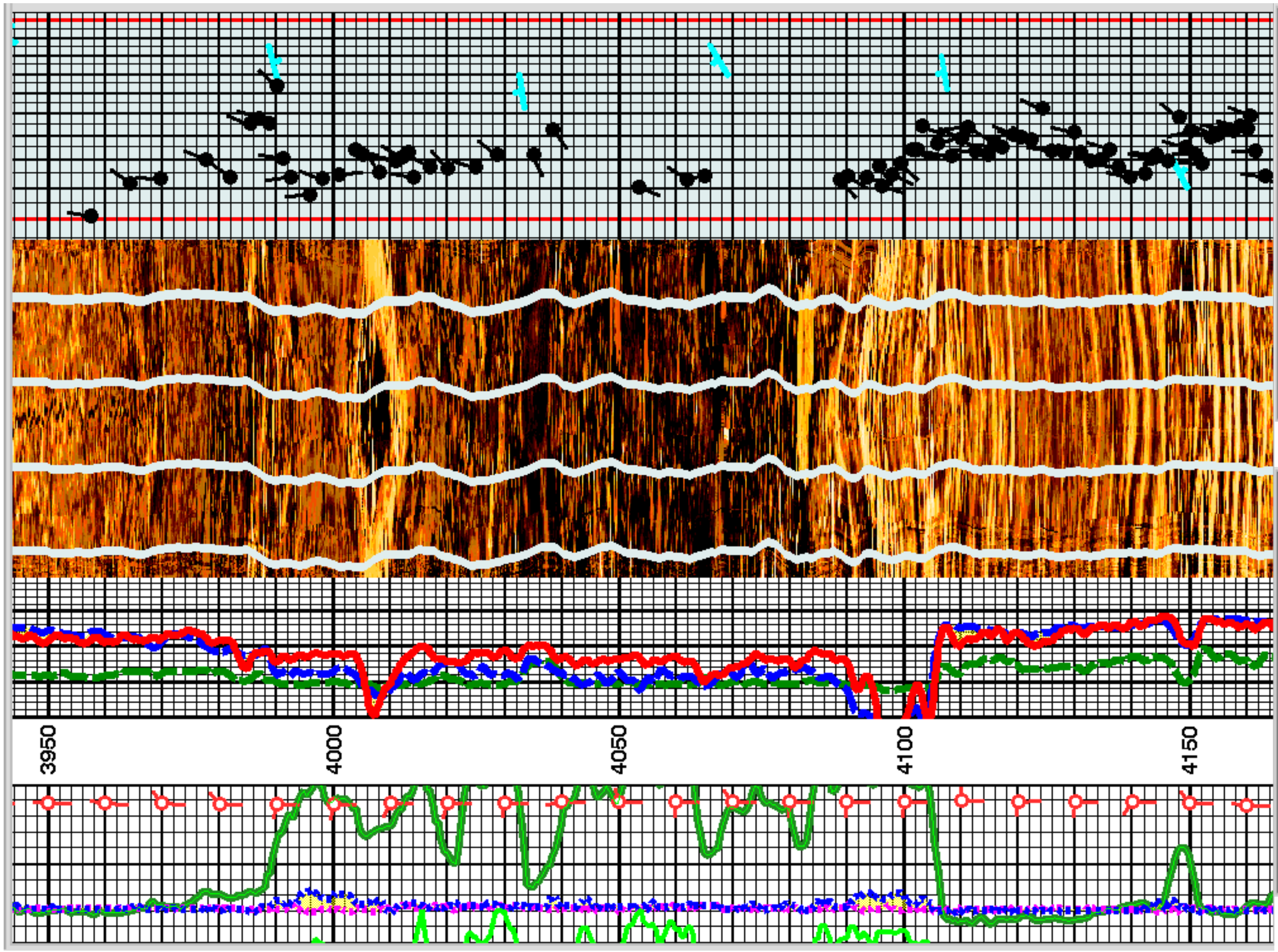
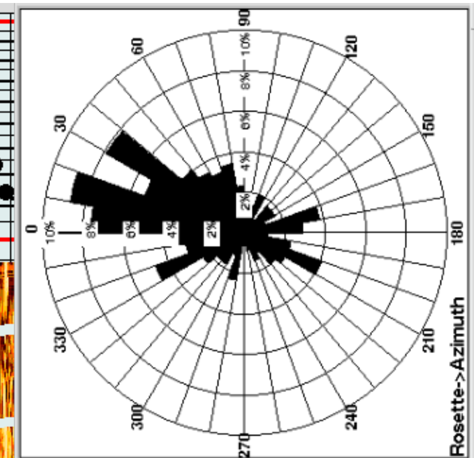
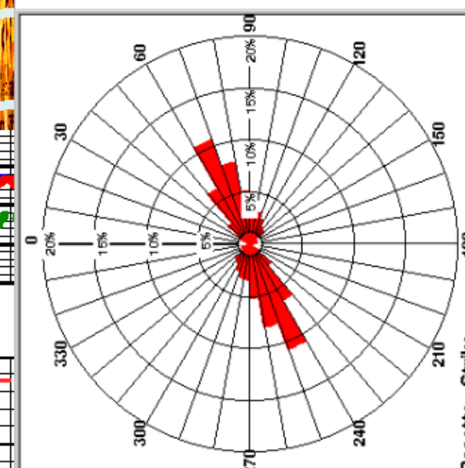
# Case #3: Test #2 (Stage #2) – No Fault



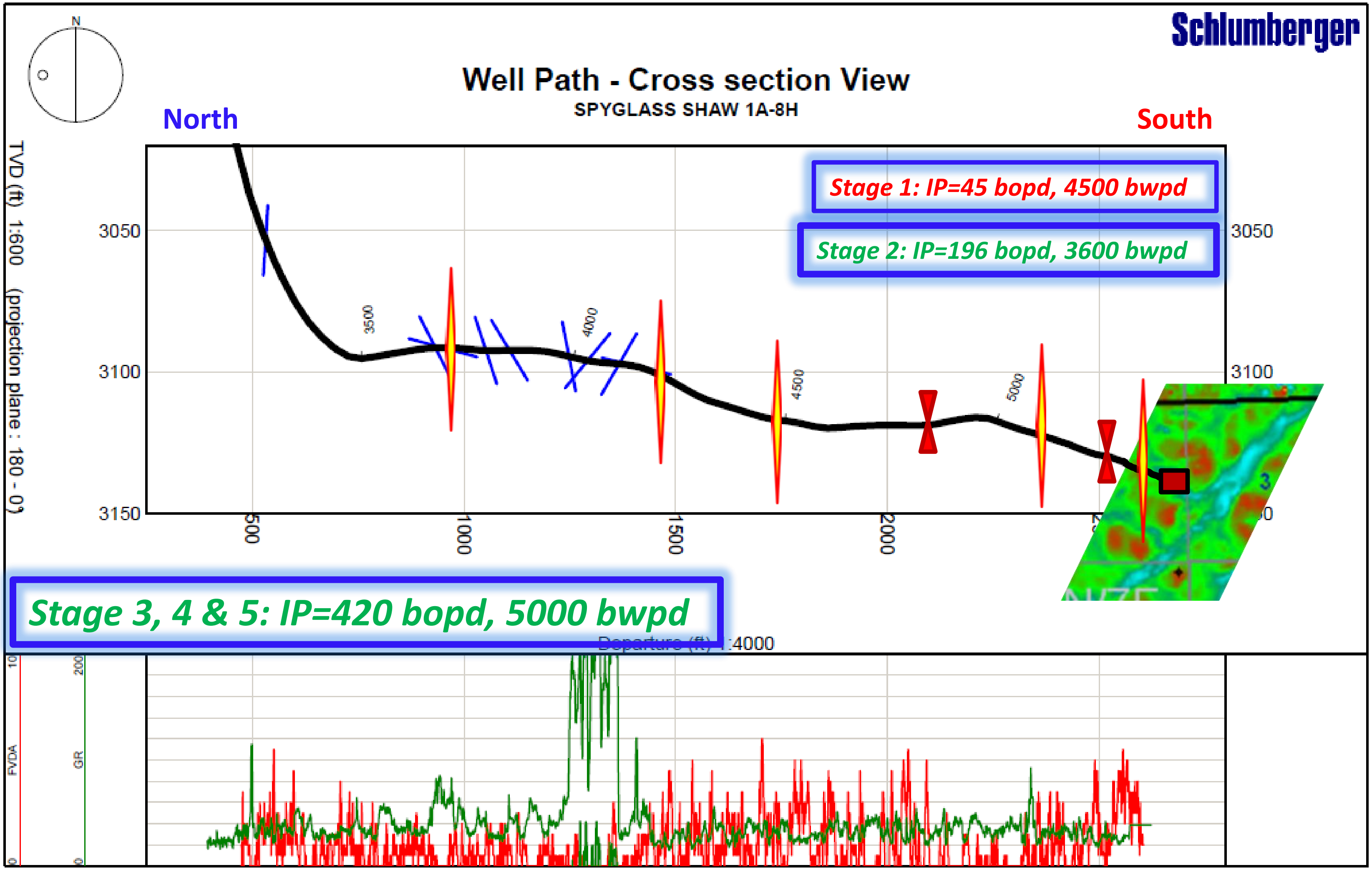
# Case #3: Interval for Test #3 - Faults from Image Log



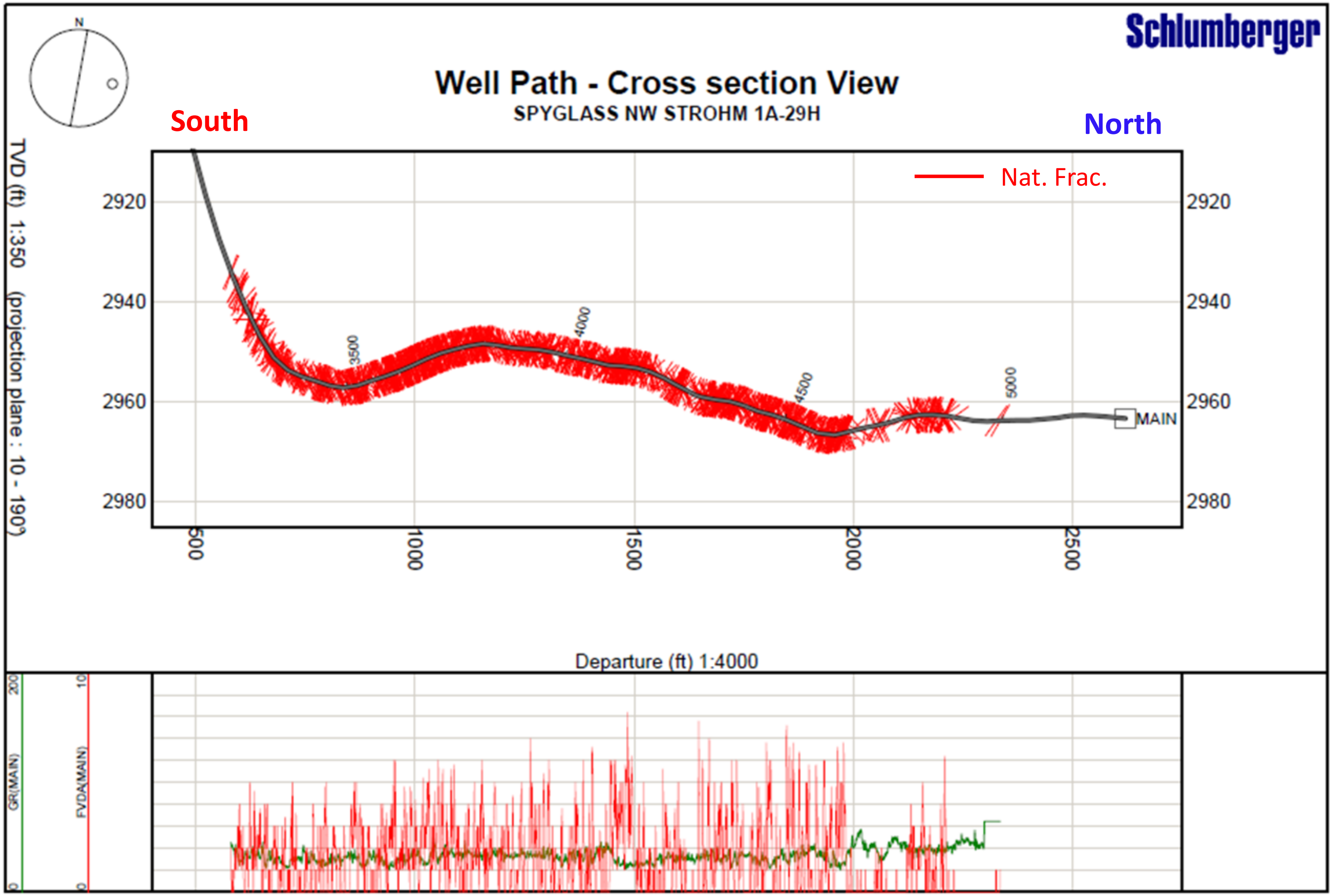



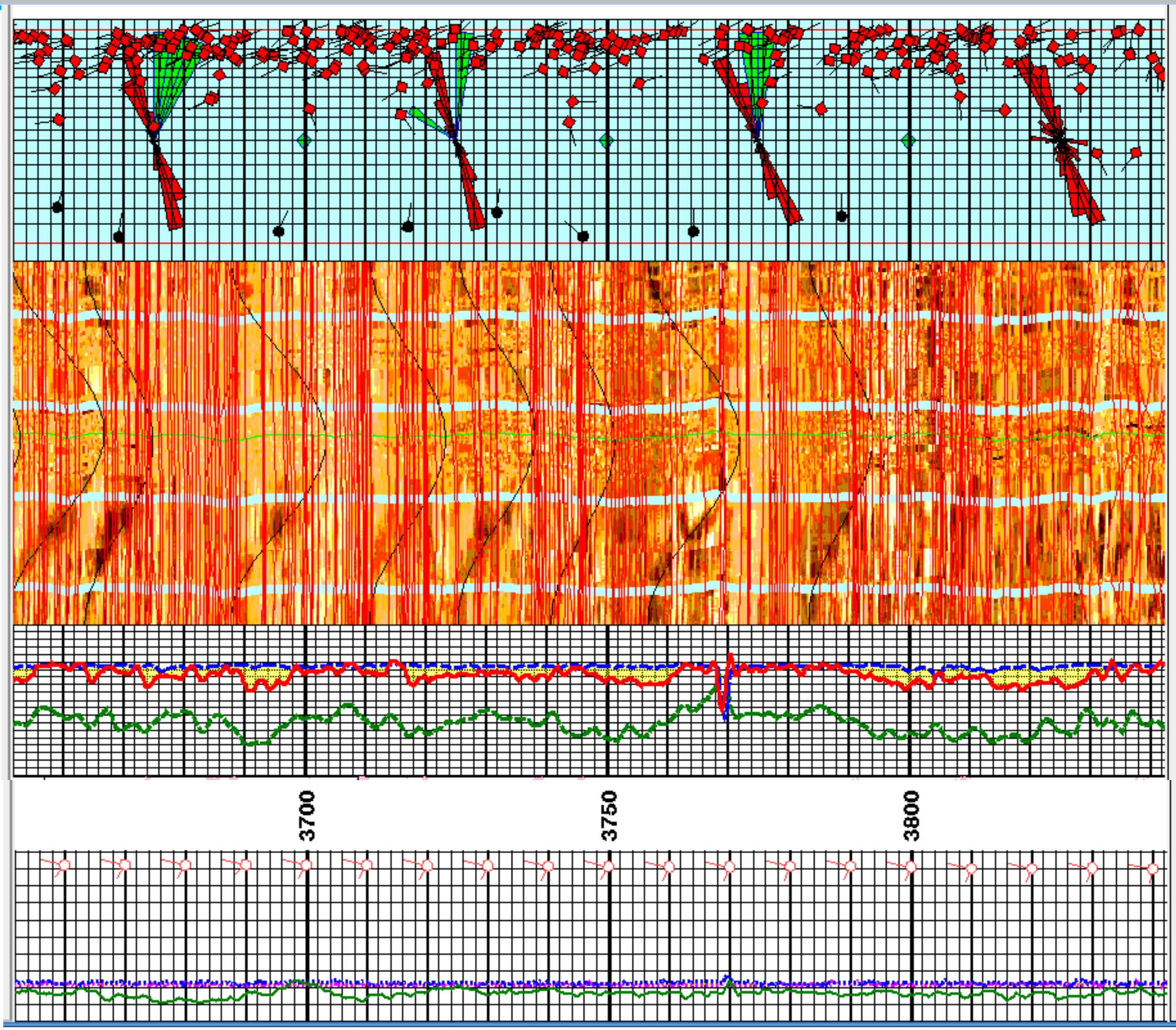
# Case #3: Rest of the Borehole – Test #3 (Stage #3, #4 & #5); a Few Small & Medium Faults

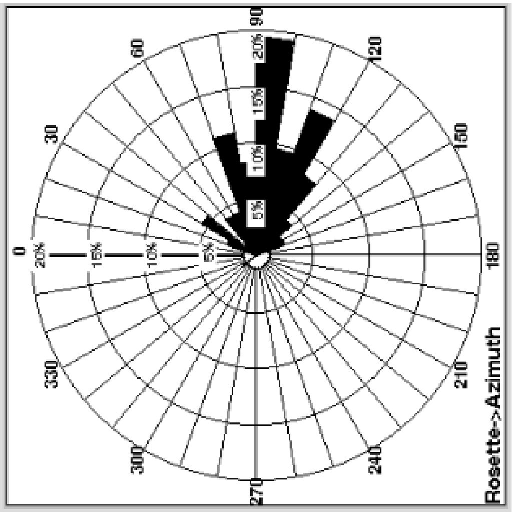


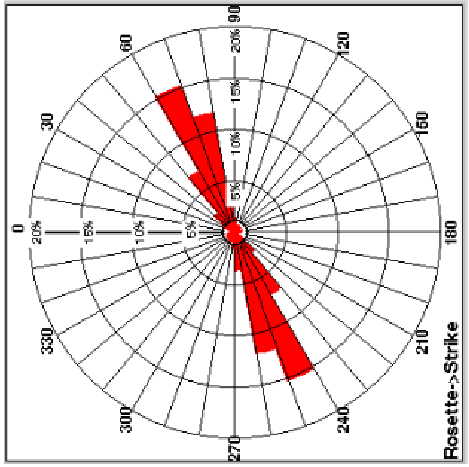
# Case #4: No Fault Observed on Image Log



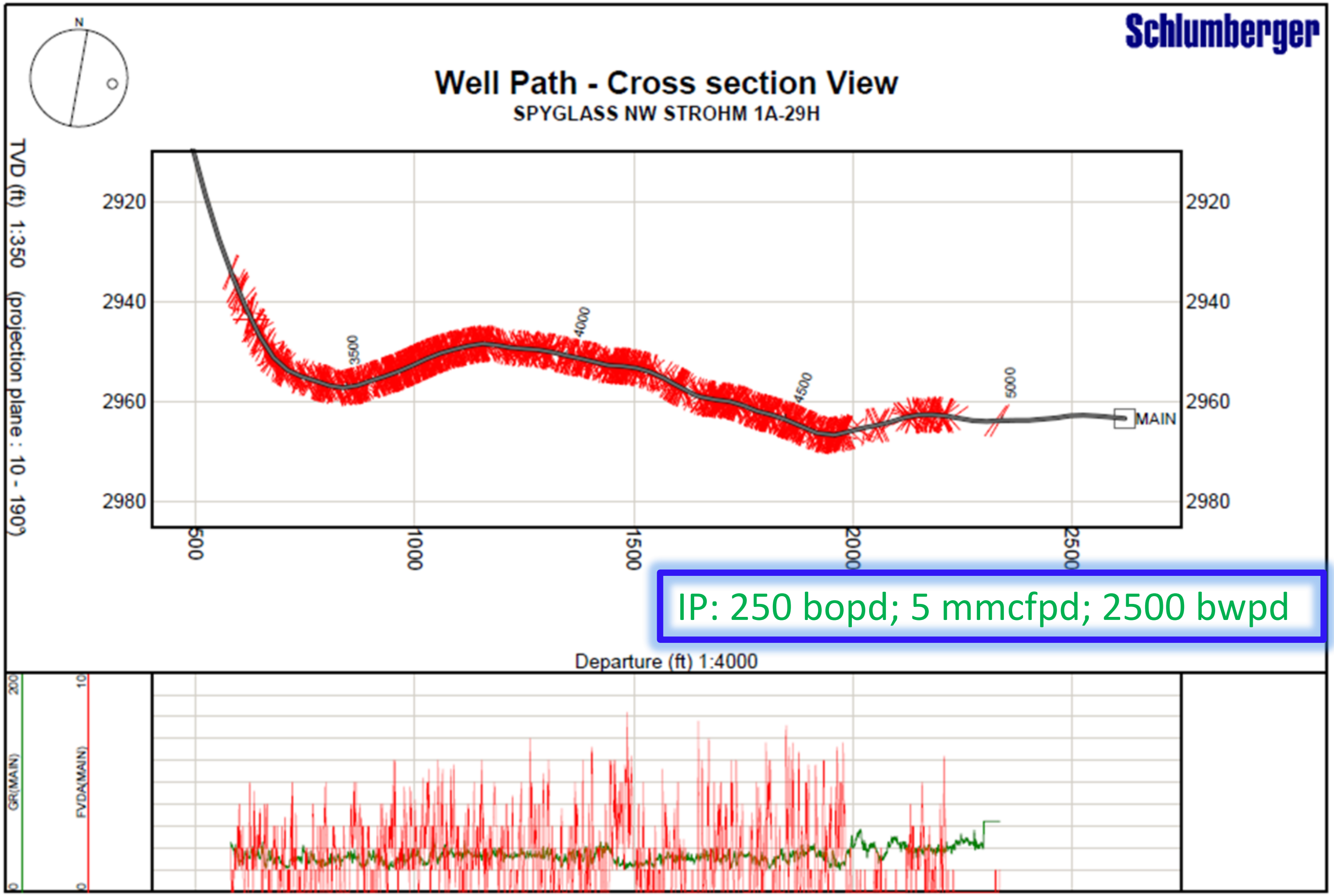
# Case #4: Image Log and Interpretation Results



# Case #4: IP Results




IP: 250 bopd; 5 mmcfpd; 2500 bwpd

# Conclusion

**Stay Away from Large Fault !**