Elemental Analysis as a Tool in Determining Wellbore Stability Issues: Marcellus Shale Play, SW Pennsylvania*

Charles Moyer[1], Milly Wright[2], and Nahysa Martinez[2]

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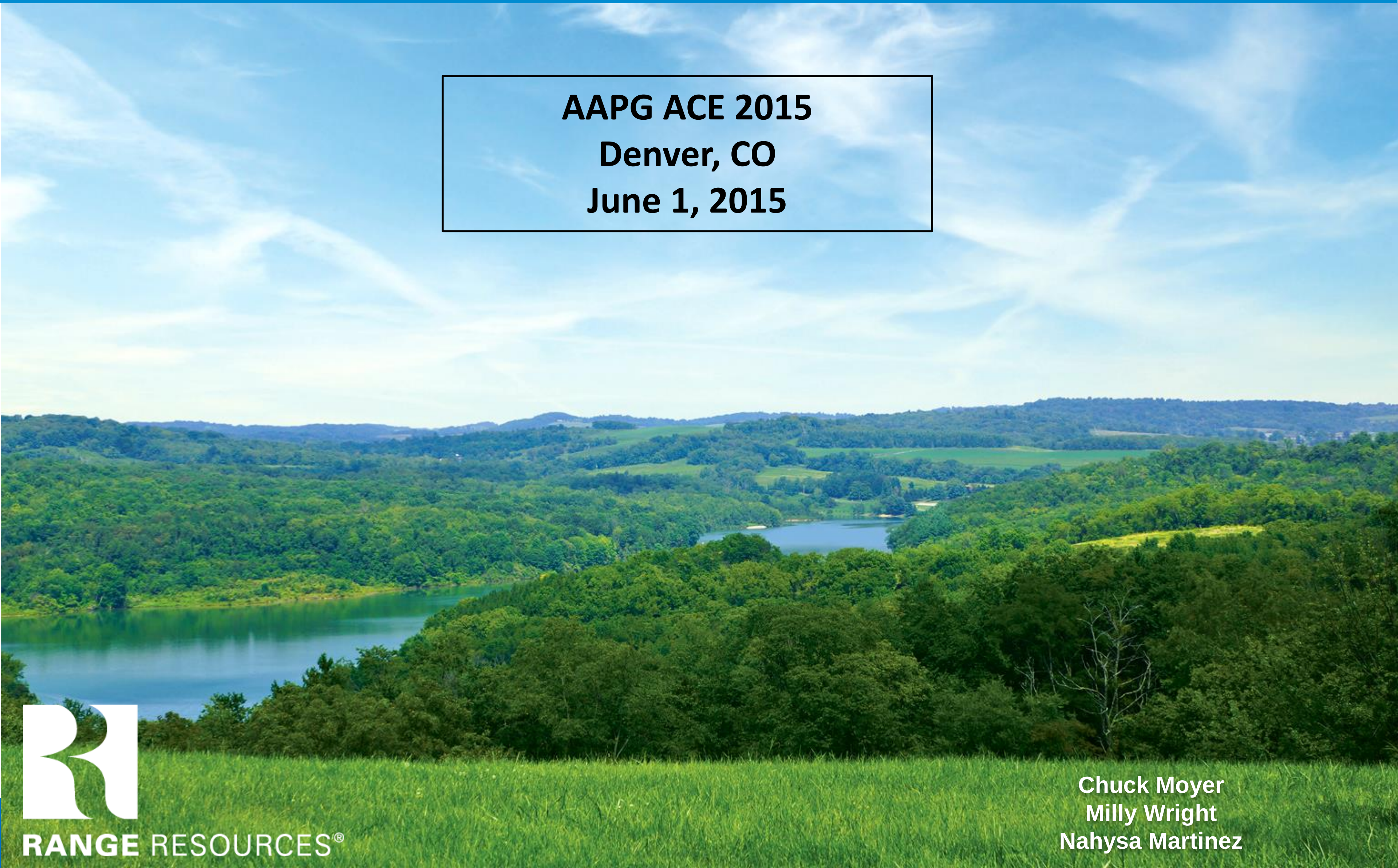
[1]Geology, Range Resources Corporation, Canonsburg, Pennsylvania, USA (cmoyer@rangeresources.com)
[2]Chemostrat, Inc., Houston, Texas, USA

Abstract

Solutions to deviated and horizontal wellbore stability issues can be complex. Problems such as lost circulation, stuck pipe, pack off, tight hole and enlarged cuttings can occur while drilling. Drilling techniques, mud pump pressure surges, mud type, weights and additives, cleanup cycle design, borehole azimuth, structure, anisotropic stresses and formation characteristics may be contributing factors in any combination. Determining a wellbore's failure point is a critical first step toward finding a solution to a stability issue. Borehole imaging-while-drilling tools help but can be costly since an operator would need to routinely run the tools in wellbores in order to “catch” a wellbore failure. Analysis of breakdown/breakout mud weight failure envelopes help as predictive tools but may not be definitive in an actual wellbore failure situation. Wellbore “rubble” (enlarged rocks exiting the well that were not caused by cutting action from the drill bit) can be elementally/compositionally analyzed more precisely to determine where in the rock column the failure occurs. X-Ray Diffraction (XRD) works well to determine bulk mineralogy; however, this technique can fall short when trying to differentiate various organic shale sequences and parasequences. Elemental analysis and chemostratigraphy offer a more in-depth analysis to determine sequence stratigraphic units in mud rocks where type sections are available. This paper details a case study where the utilization of elemental analysis and chemostratigraphy to successfully pinpoint a series of wellbore failure events in the Marcellus Shale Play in southwestern Pennsylvania.

ELEMENTAL ANALYSIS AS A TOOL IN DETERMINING WELLBORE STABILITY ISSUES

MARCELLUS SHALE PLAY, SW PENNSYLVANIA



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Chuck Moyer
Milly Wright
Nahysa Martinez

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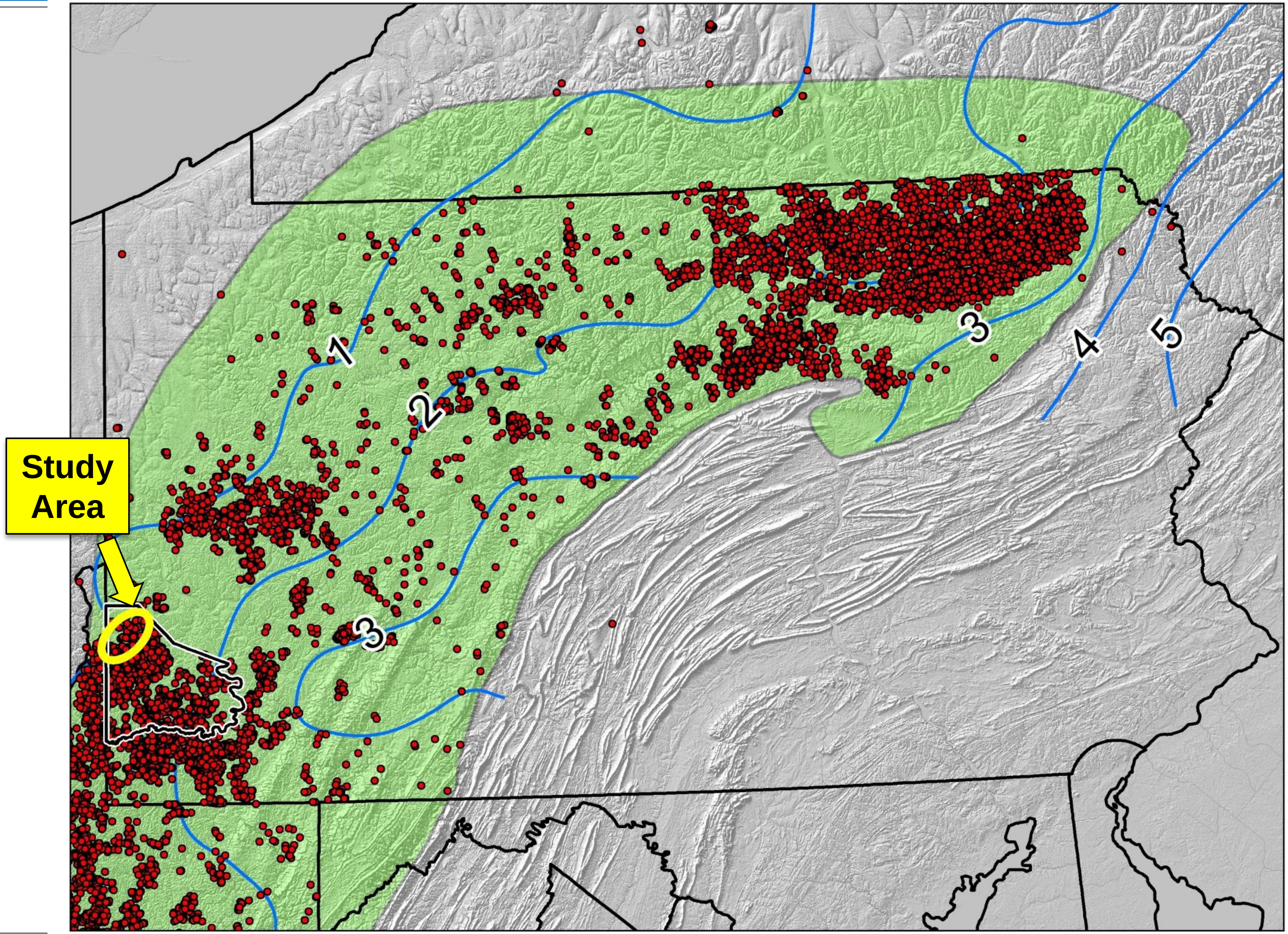
AREA OF INTEREST – SW PA MARCELLUS PLAY



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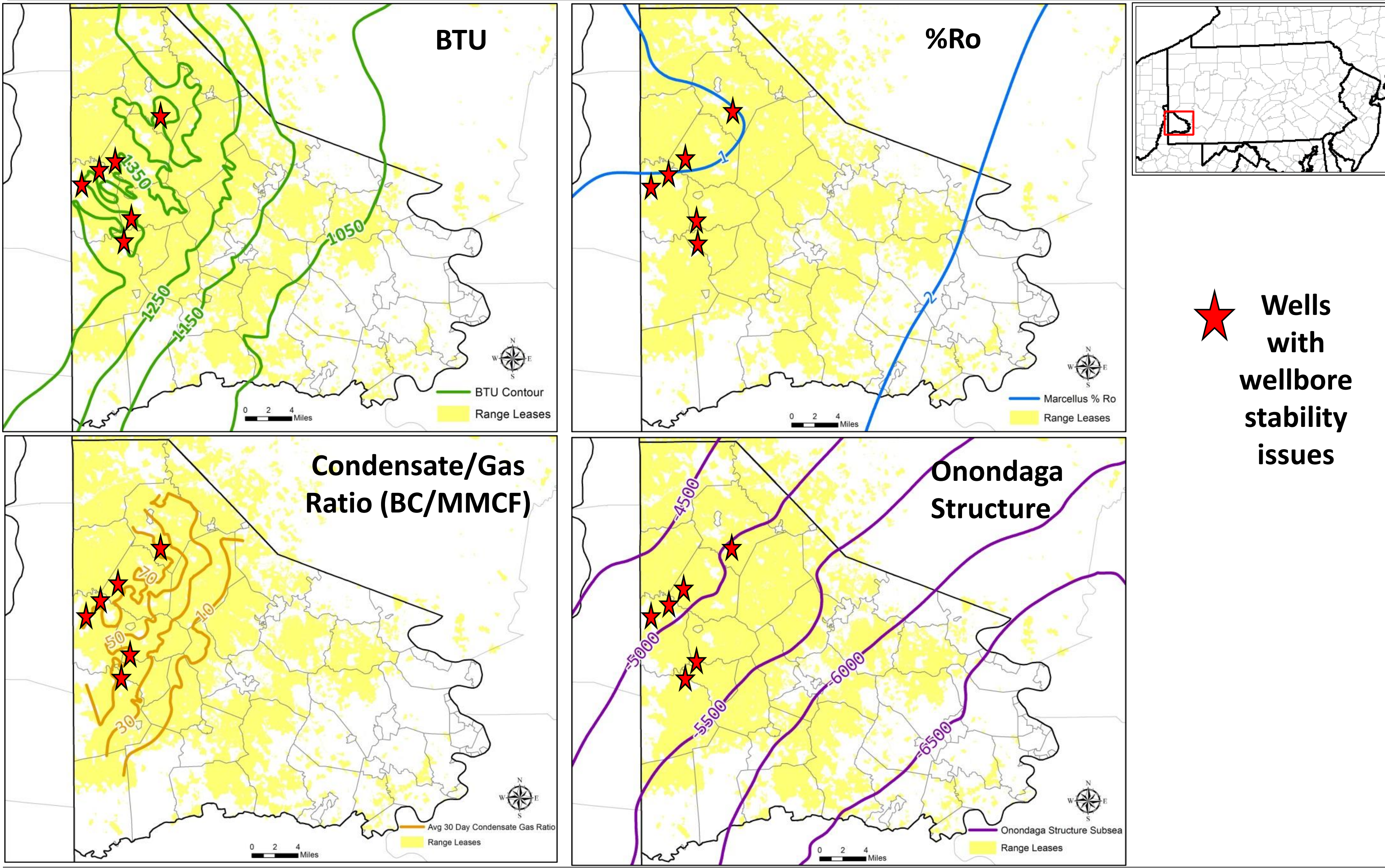
GEOLOGIC VARIATIONS WITHIN THE MARCELLUS SHALE, WASHINGTON COUNTY, PA



TYPICAL RUBBLE FROM A FAILED WELLBORE

Tabular Marcellus rubble. Scale 1 block = 1/4". Large triangle piece at lower left is 3" long.

PROBLEM-SOLUTION-APPLICATION

1) PROBLEM – Increased rubble events occurring while drilling in condensate-rich Marcellus area.

2) PROBLEM - Preconceived bias as to where the rubble originated.

3) SOLUTION - Geology Team needed to perform lab and geosteering analysis to determine the role the rocks were playing in wellbore failures.

4) SOLUTION - Drilling Team needed to review drilling equipment and procedures and make revisions as necessary.

5) APPLICATION - Reconvene and determine an action Plan.

6) DRILLING AND GEOLOGY TEAMS WORK TOGETHER TO SOLVE WELLBORE STABILITY PROBLEMS.

Summary of Geology, Landing Zone and Drilling Changes Concurrent with the move to the Condensate-Rich Area

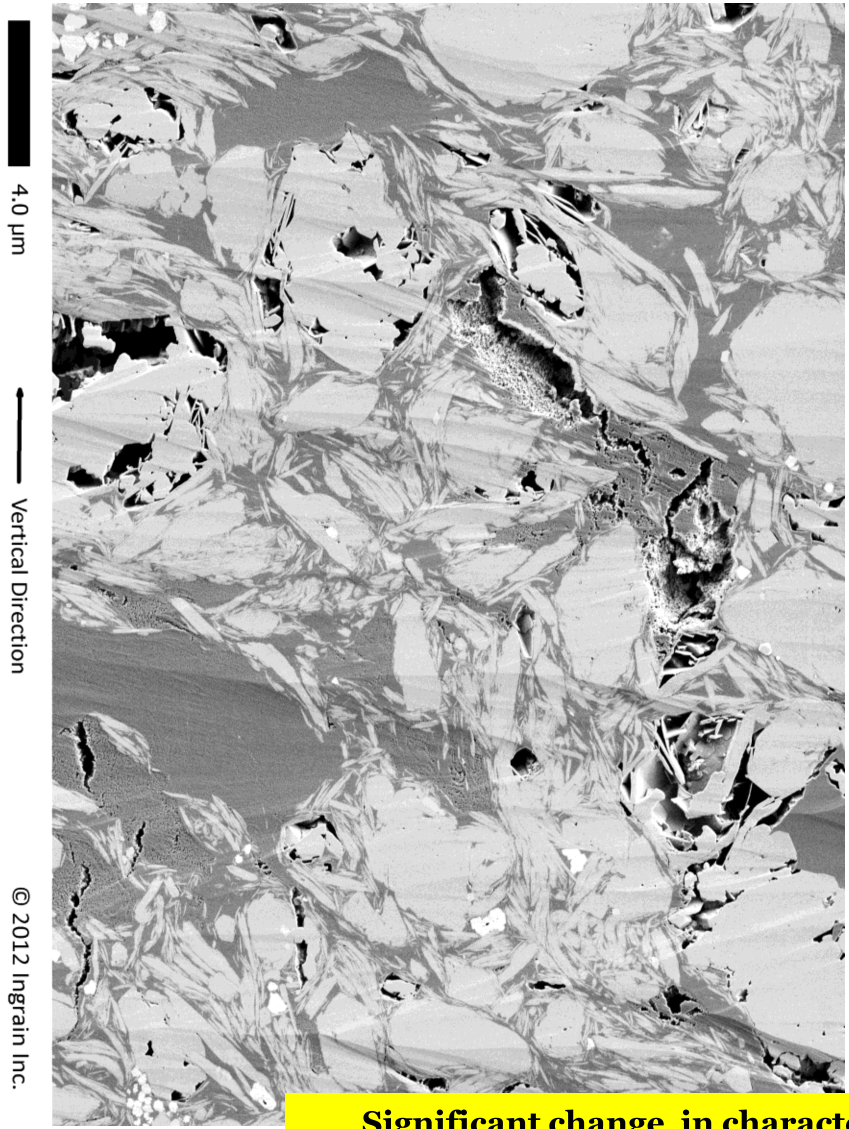
1) DECREASE IN THERMAL MATURITY – Rocks change character in an updip direction: increasing TOC, condensate yield and ductility, decreasing thermal maturity, depth, thickness and pressure gradient.

2) LANDING ZONES – Due to variations in BTU and condensate content, the geology dept. altered landing zones and target intervals within the Marcellus to seek larger pores.

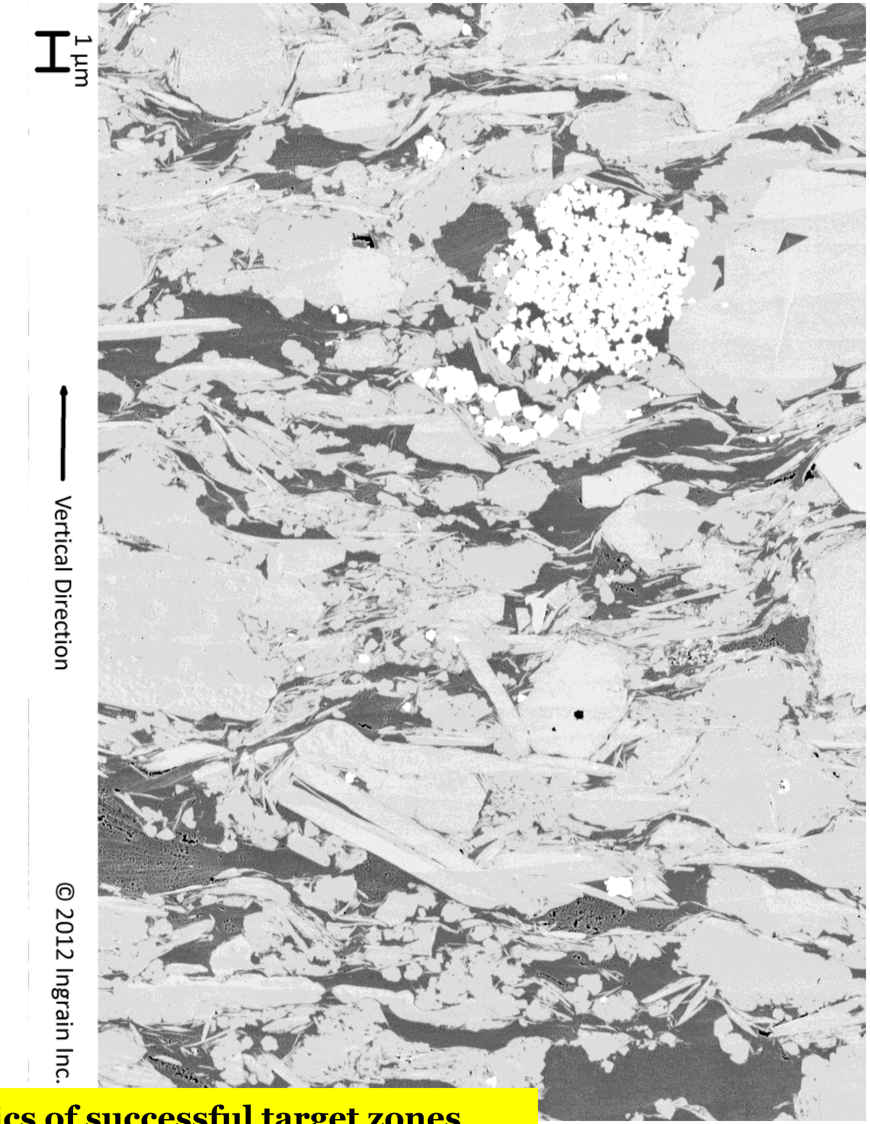
3) DRILLING RIGS – Range contracted two Super Single drilling rigs at about the same time we moved into the condensate rich area. These rigs were equipped with smaller ID drill pipe (4 ½"), smaller mud pumps and hook load. (Also less expensive, smaller footprint and faster moving).

VARIABLE PORE THROATS WITHIN THE MARCELLUS

High BTU Area



Low BTU Area



Significant change in characteristics of successful target zones

Pores in the 1,500 to 2,000 nm range

Pores in the 10 to 20 nm range

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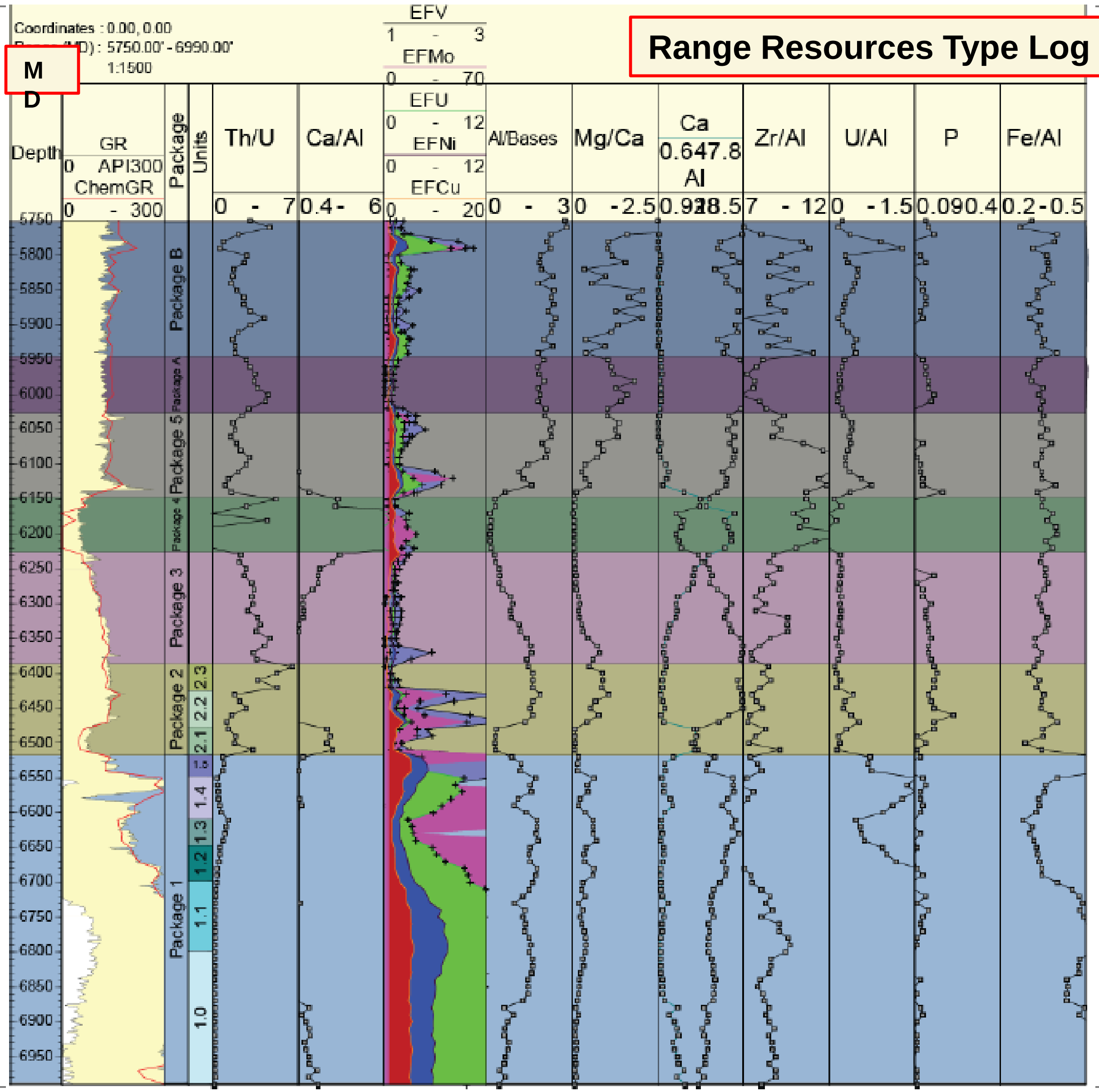
Chemostratigraphic Nomenclature



NOTE: Type log was landed in Oatka Creek and did not penetrate Union Springs.

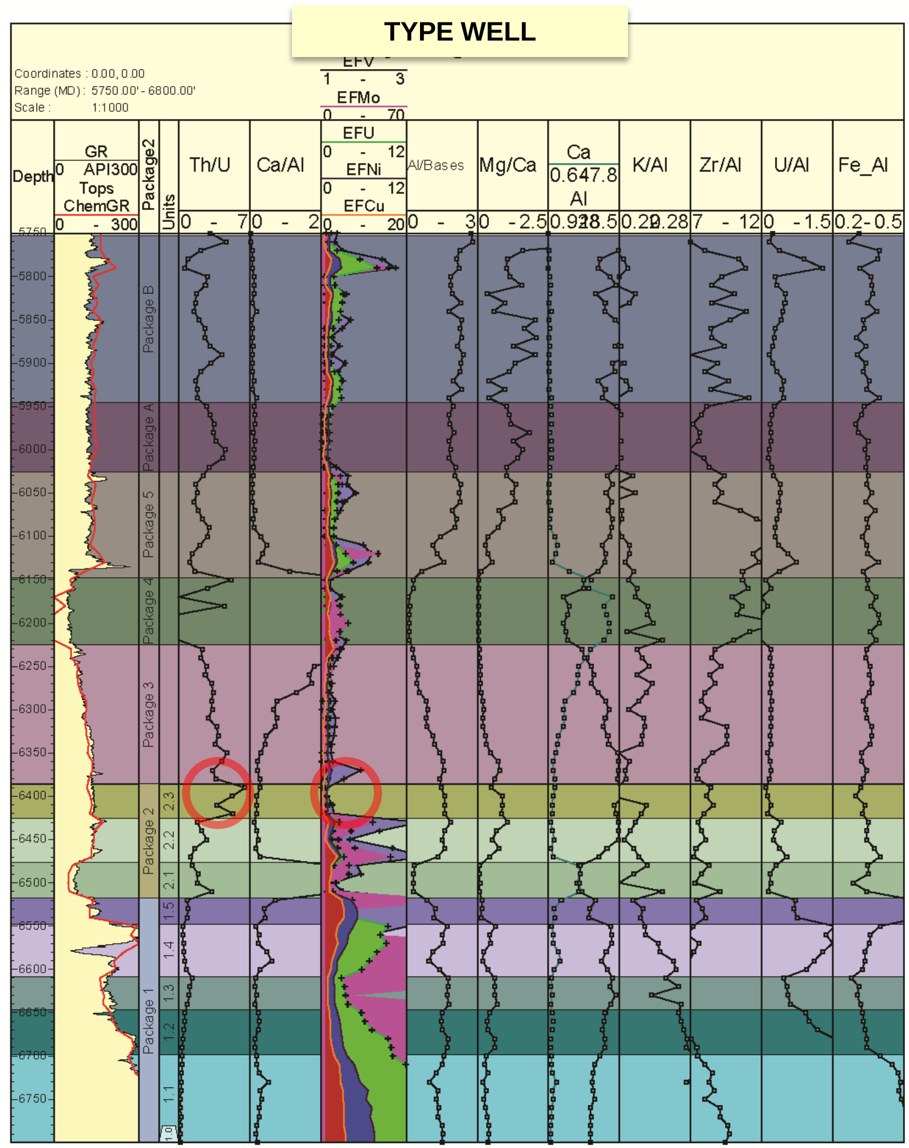
RUBBLE ZONE "A" IDENTIFIERS

RUBBLE ZONE A, Package 2, Unit 2.3 – Lower Mahantango (above Purcell)

1) **Higher Th/U - (less organics, not Marcellus)**
2) **Higher P (phosphorous)**
3) **Higher Th/Al**
4) **Lower EF (enrichment factor, not Marcellus)**
5) **Lower U (not Marcellus)**
6) **Lower Si/Al (not Package B, Rhinestreet)**

Rubble Zone A

Suspect zone



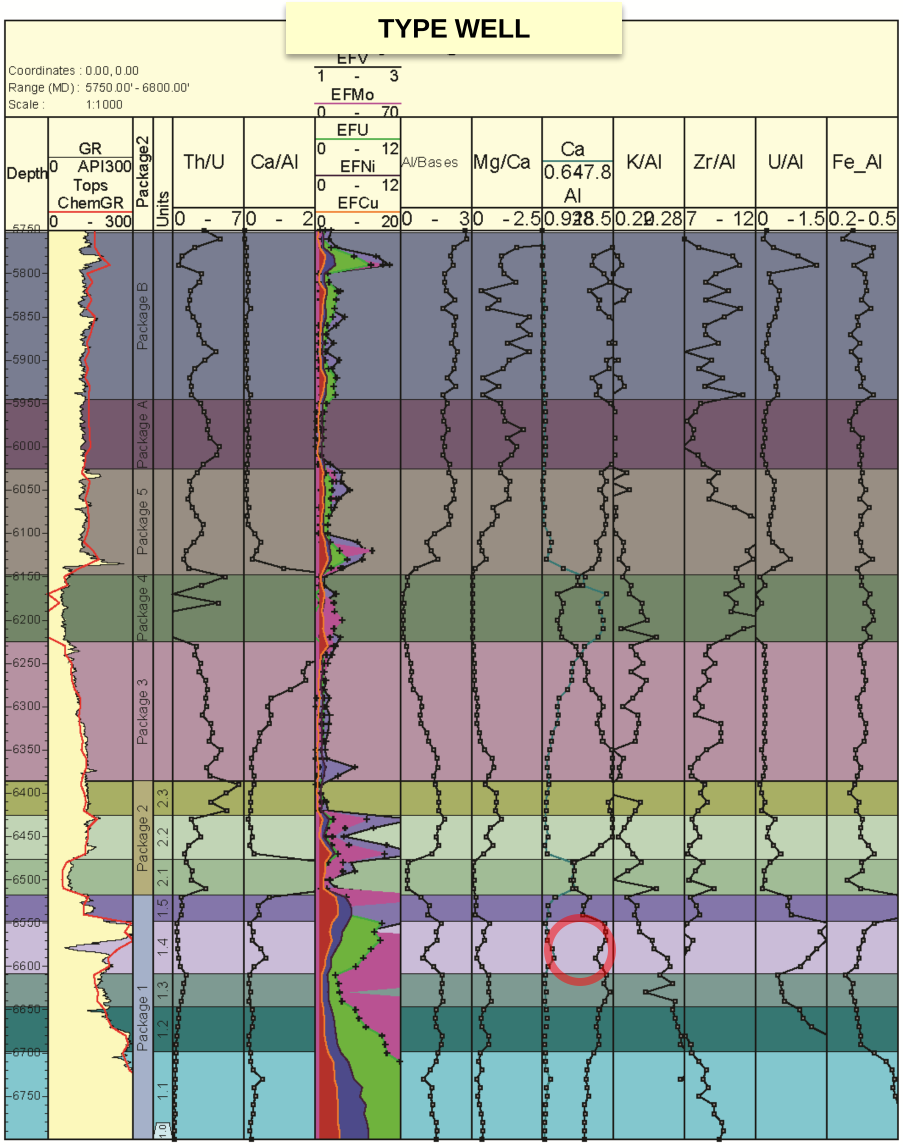
RUBBLE ZONE "B" IDENTIFIERS

RUBBLE ZONE B, Package 1, Unit 4, Cherry Valley

1) **High Ca - Limestone**
2) **High Ca/Al - Limestone**
3) **Mg and Mn values – Cherry Valley is more similar to these values than the Tully or Purcell.**

Suspect zone

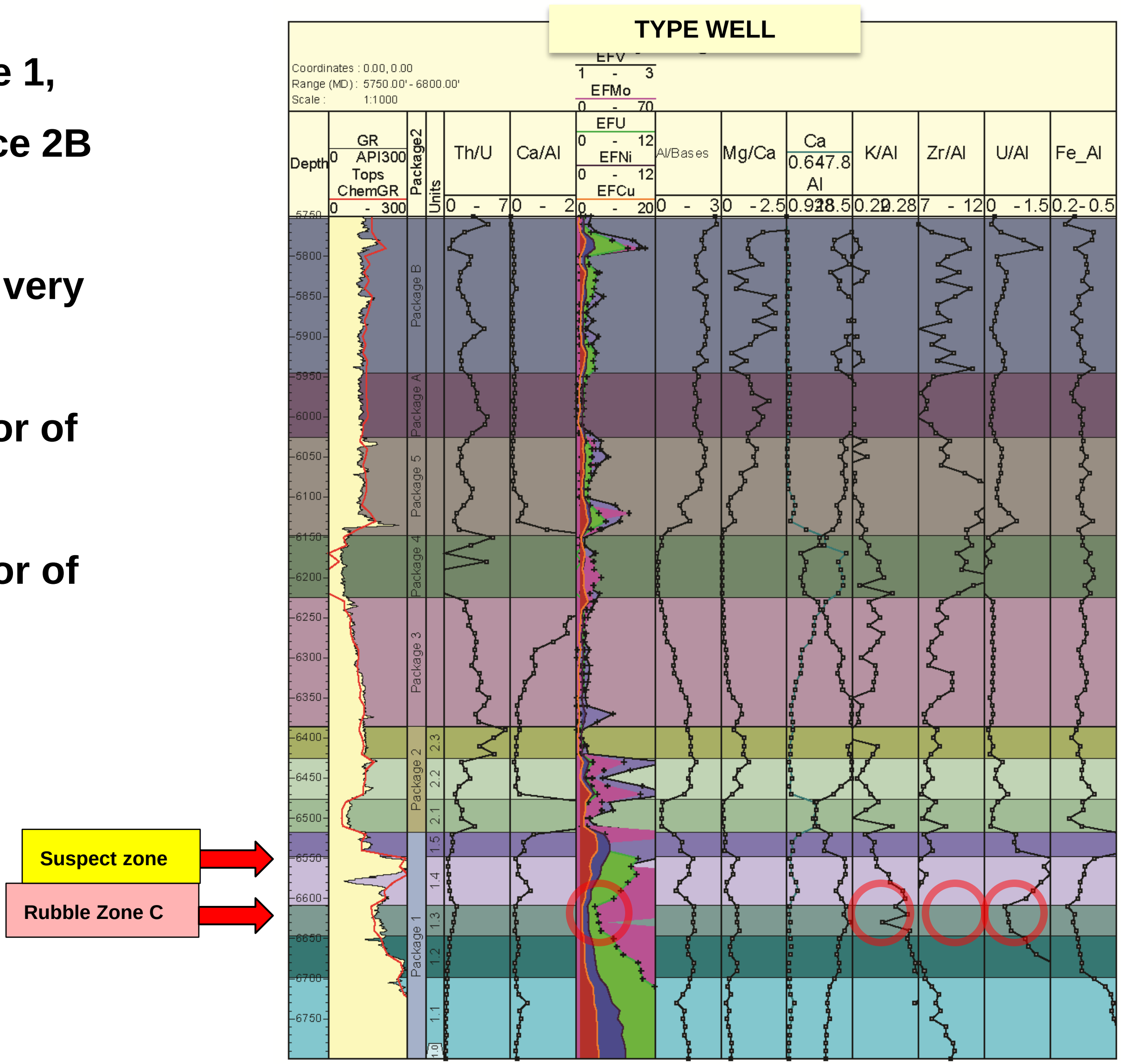
Rubble Zone B



RUBBLE ZONE "C" IDENTIFIERS

RUBBLE ZONE C, Package 1, Unit 3 – Middle of Sequence 2B

1) **EF - Intermediate. Not very good indicator.**
2) **K/Al – High, an indicator of Package 1, Unit 3.**
3) **Zr/Al – Low, an indicator of Package 1, Unit 3.**
4) **U/Al – High, Marcellus source rocks.**

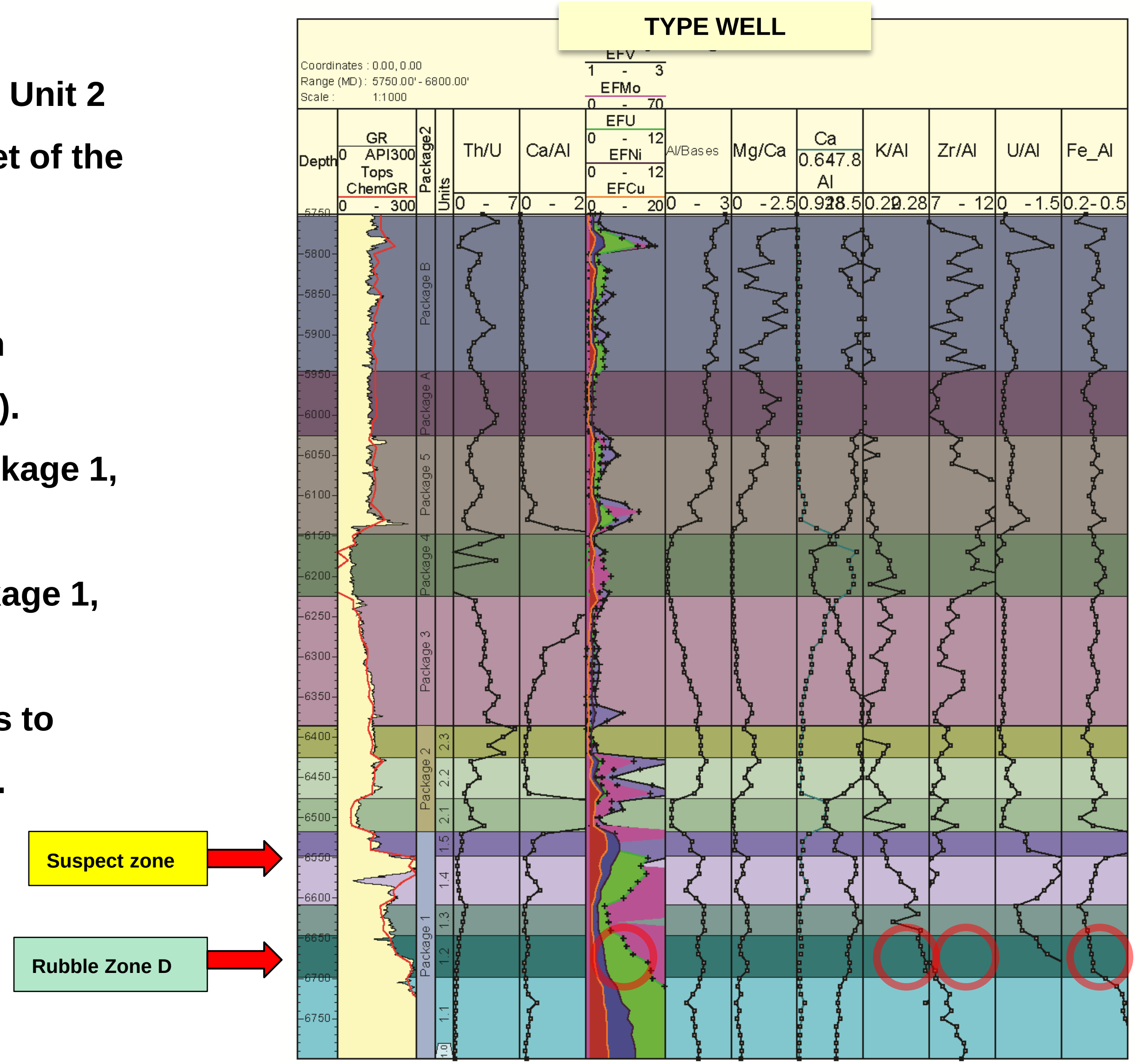


RUBBLE ZONE "D" IDENTIFIERS

RUBBLE ZONE D, Package 1 Unit 2 – Sequence 2A, and a few feet of the base of 2B

(Enrichment Factor – Vanadium)

1) **EFV and U/Al – Very high (Marcellus, source rocks).**
2) **K/Al – High, suggest Package 1, Units 2 and 4.**
3) **Zr/Al – Low, tags to Package 1, Units 2 and 4.**
4) **Fe/Al – Intermediate, tags to Package 1, Units 2 and 4.**



CHEMOSTRAT "RUBBLE ZONES"

Chemostrat Lab packaging of like rocks

Package B
Rhinestreet

Package A
Cashaqua

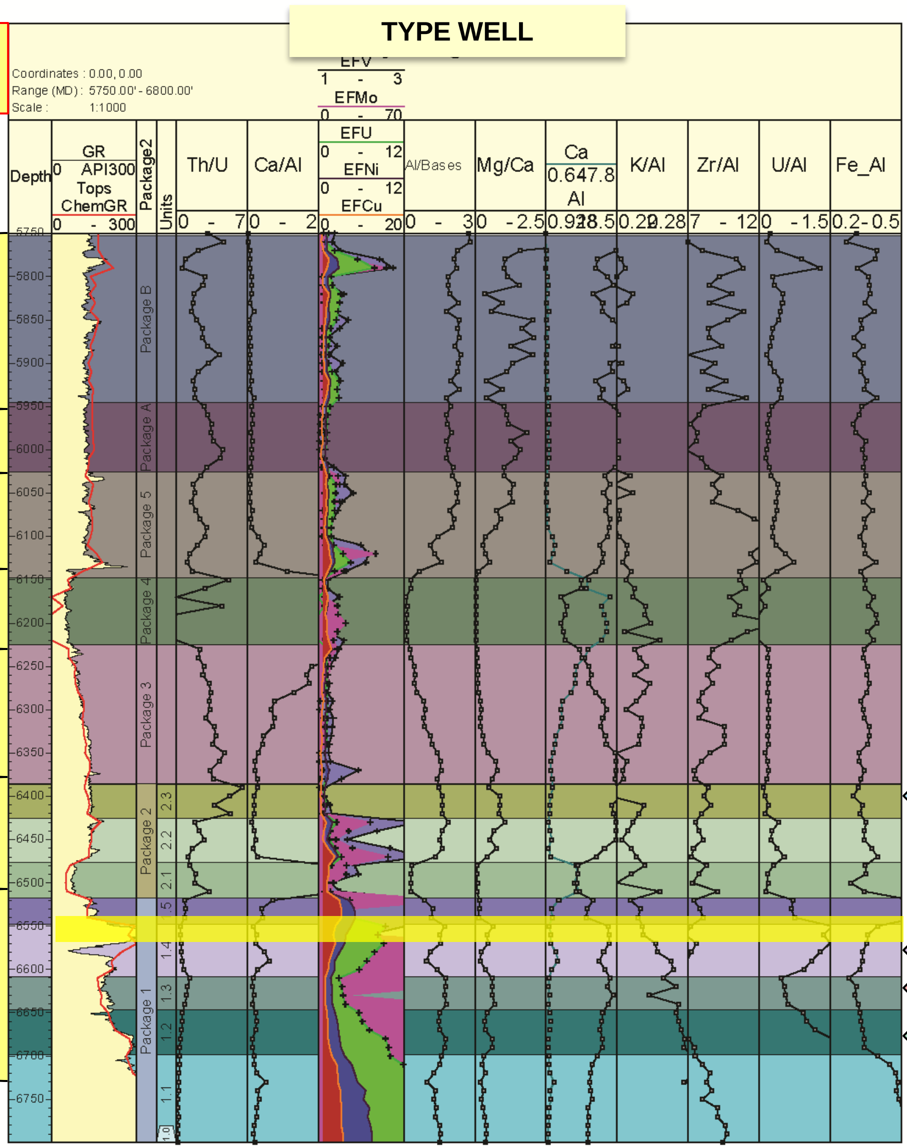
Package 5
Burkett-Middlesex

Package 4
Tully Ls

Package 3
Upper Mahantango

Package 2
Lower Mahantango,
Purcell Ls

Package 1
Oatka
Creek and
above



Typing of rubble to Chemostrat Packages.

Next step is to match Packages to geosteering.

RUBBLE ZONE A

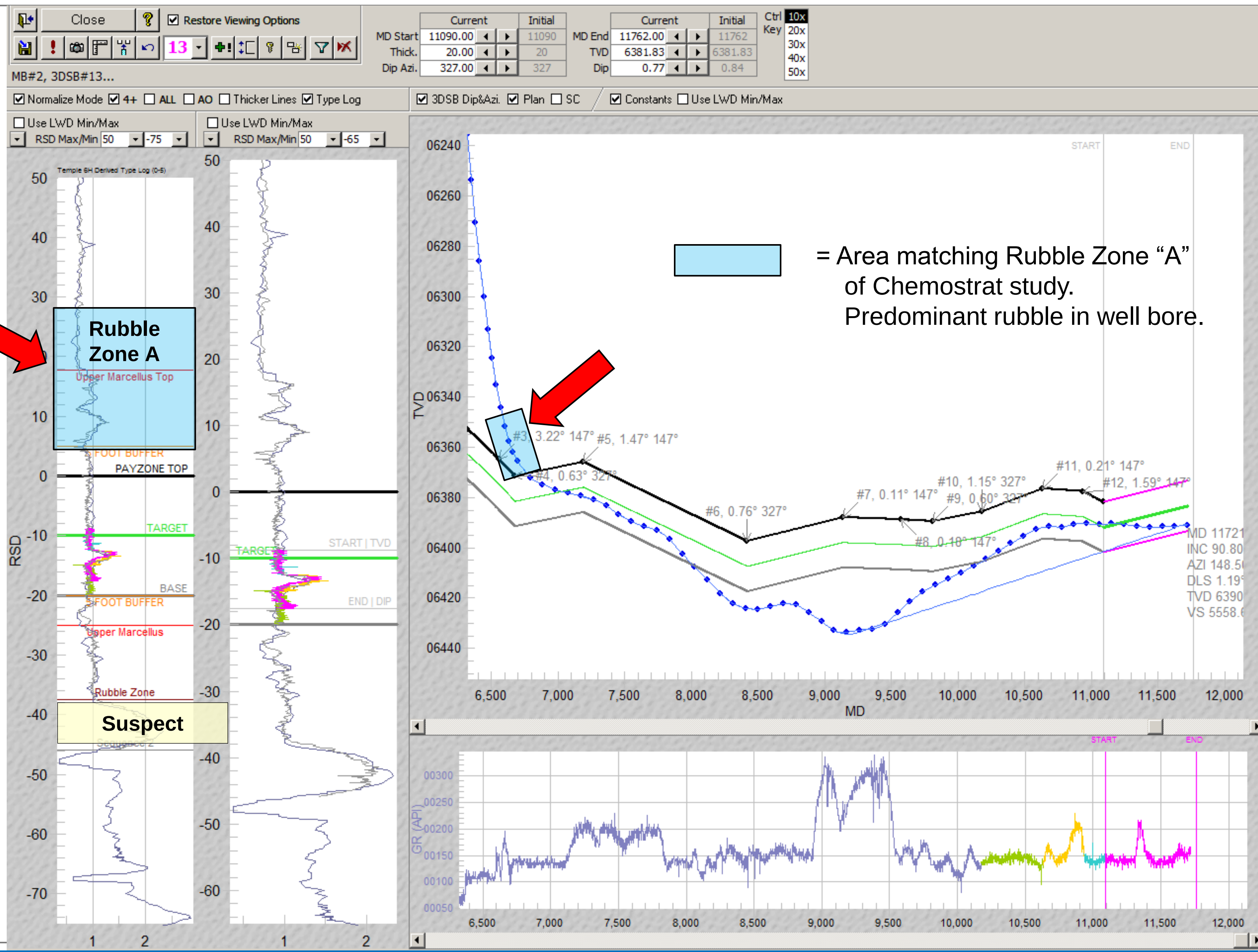
ORIGINAL "RUBBLE ZONE"

RUBBLE ZONE B
Cherry Valley

RUBBLE ZONE C

RUBBLE ZONE D

Rubble "A" Example – SM1B land (Purcell Ls)



Suspect zone not "failure" interval. Failure interval at base of the curve. Suspect zone was penetrated in the middle of the lateral and was originally blamed for the well failure.

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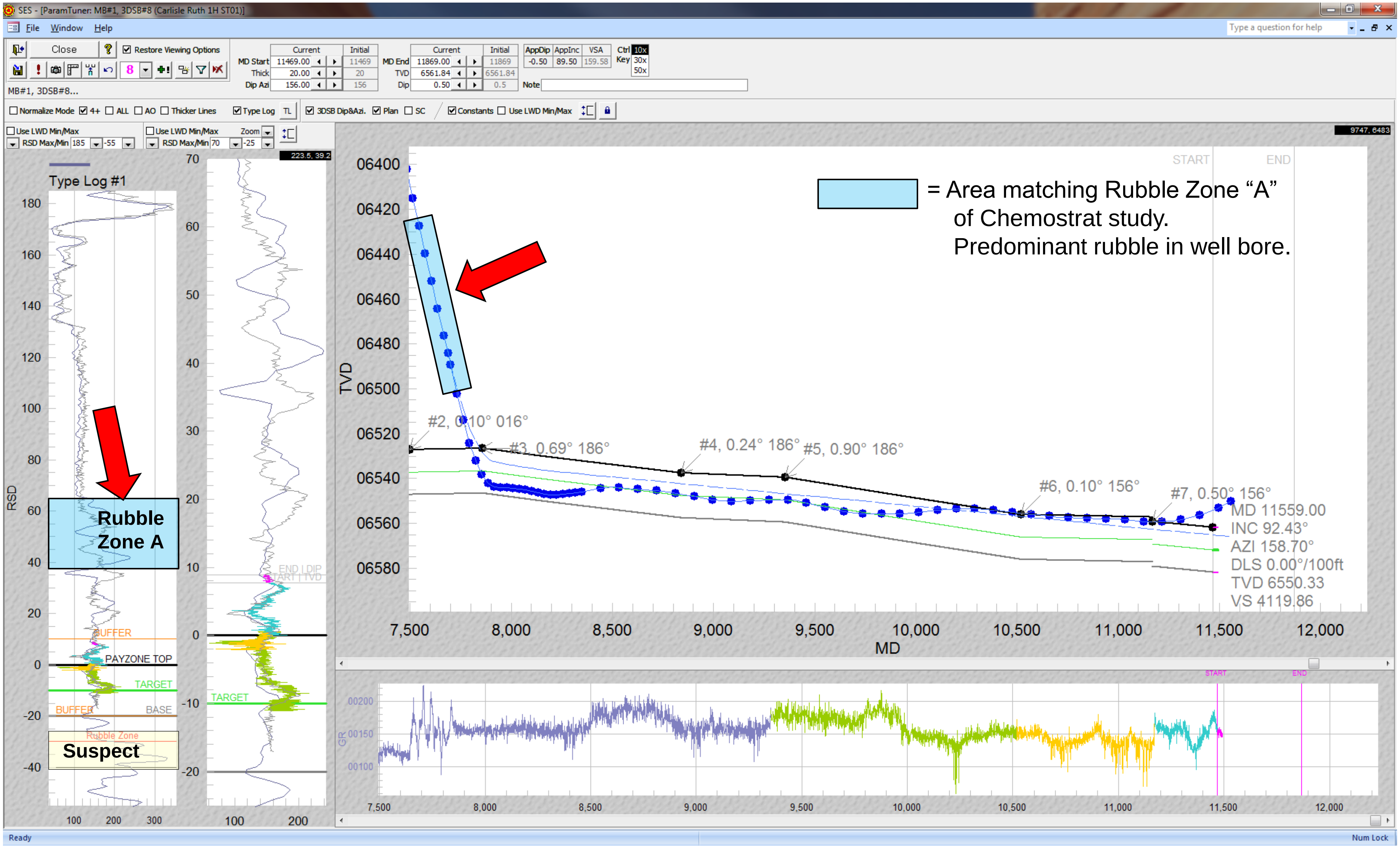
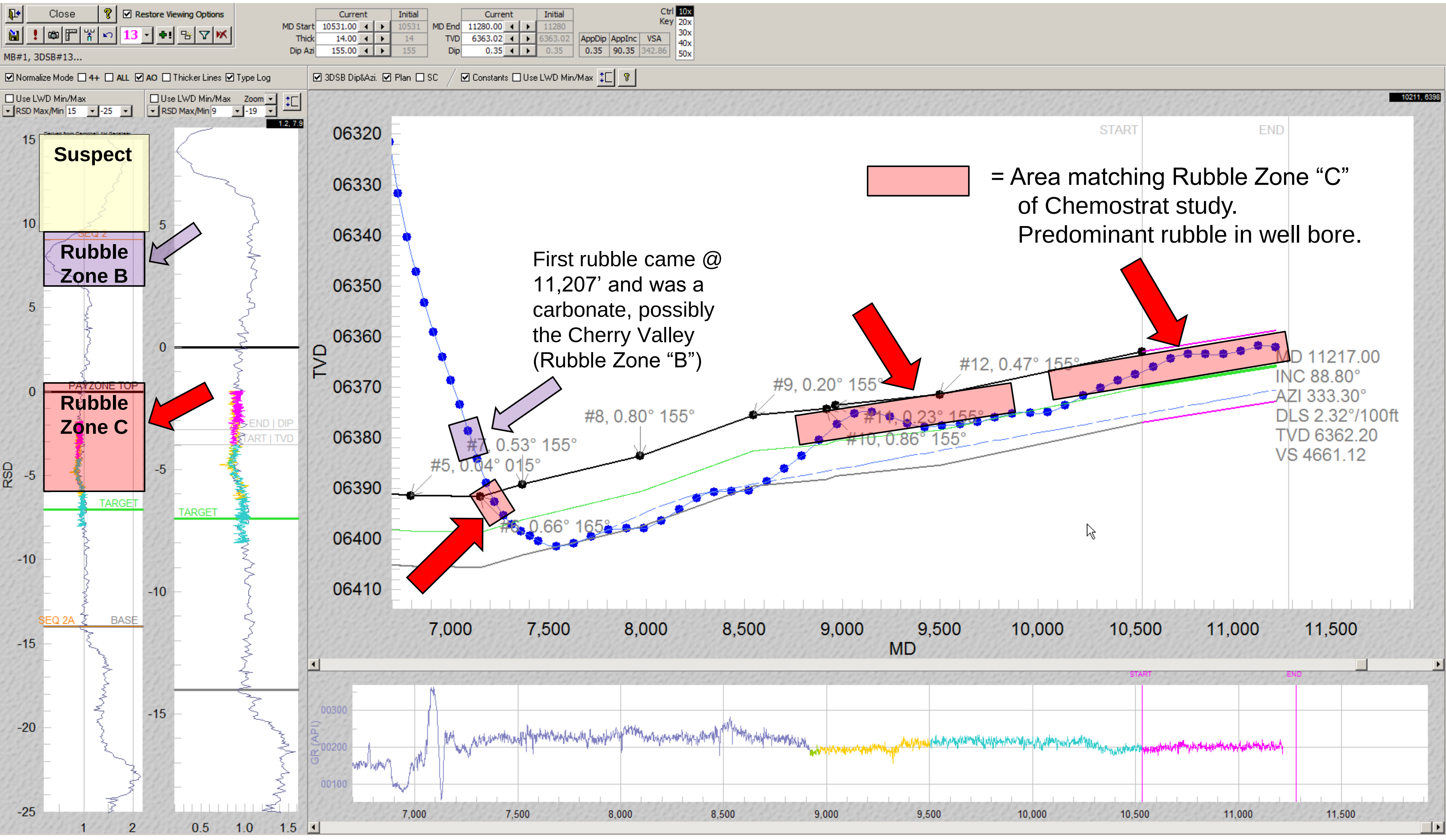
Rubble "A" Example – SM1B land (Purcell Ls)



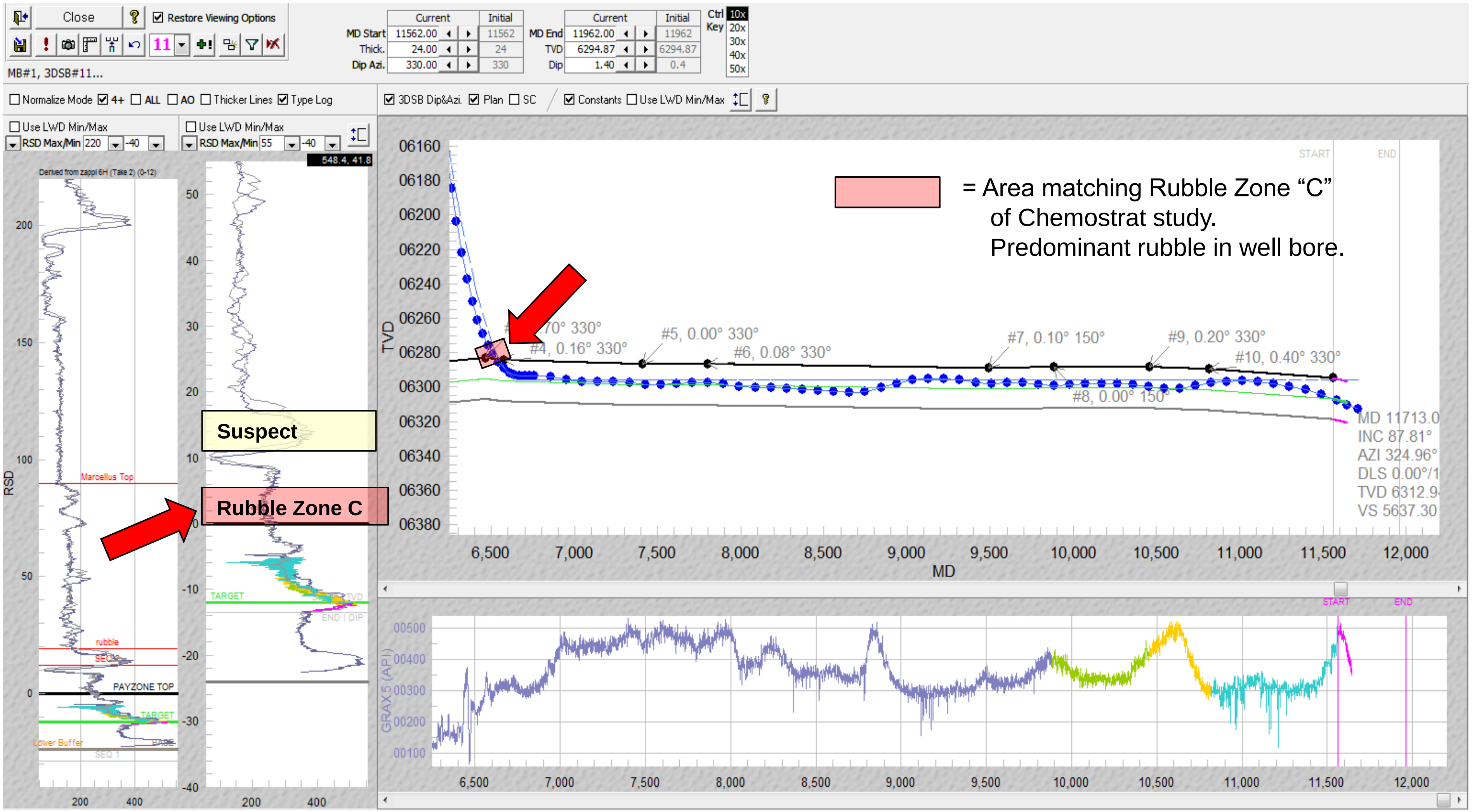
Suspect zone not "failure" interval. Failure interval at base of the curve. Suspect zone was not penetrated in the wellbore.

Rubble "B" Example – S2B Land



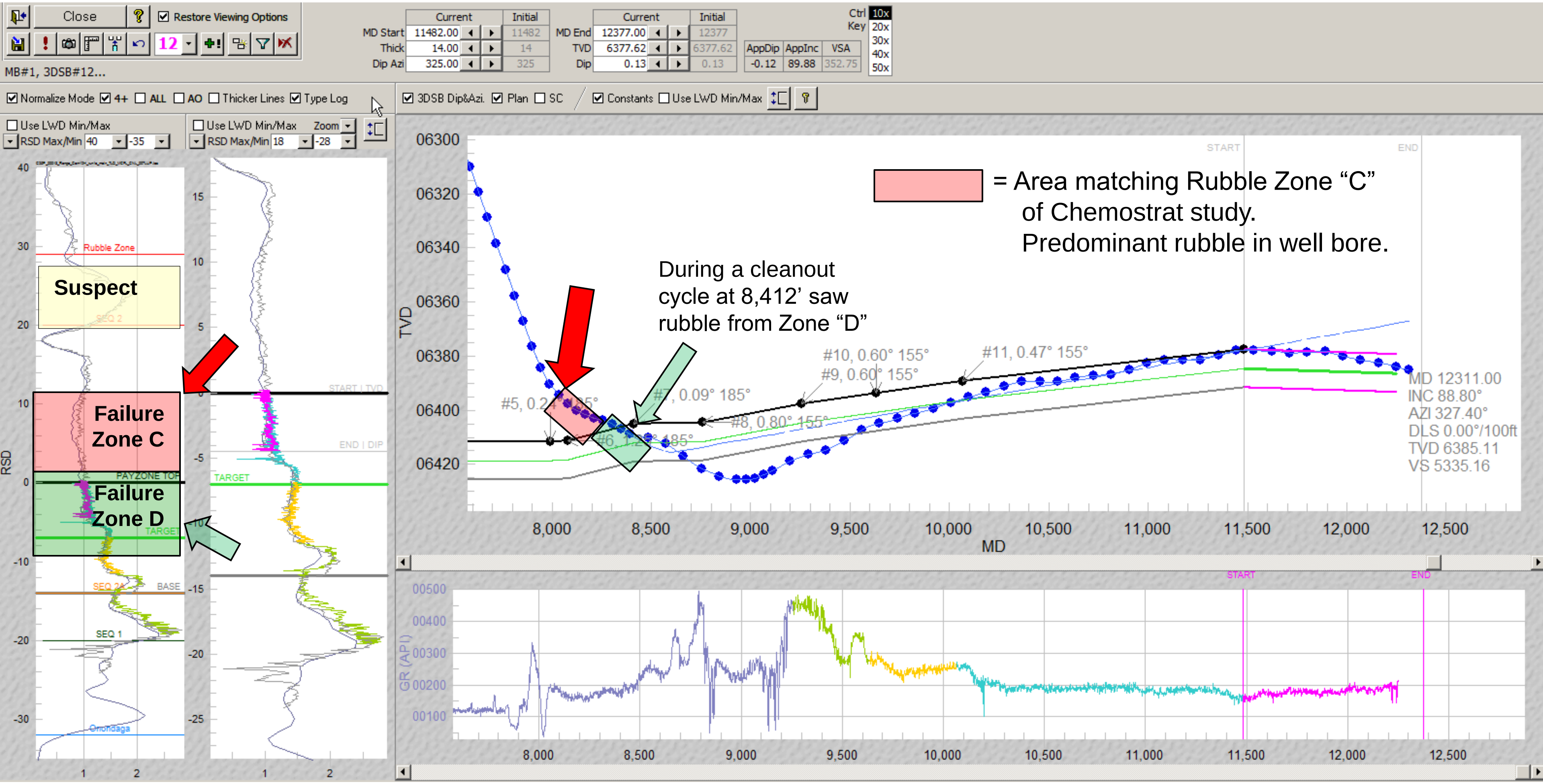
Suspect zone not "failure" interval. Note position of failure zone at the base of the curve and in the lateral.

Rubble "C" Example – S2A land



Suspect zone not "failure" interval. Note position of failure zone at the base of the curve.

Rubble "C" and "D" Example - S2A/B land



Suspect zone not "failure" interval. Note position of failure zone at the base of the curve.

CONCLUSIONS

1) Due to past experiences, the Geology and Drilling Teams suspected the "Rubble Zone" (above Oatka Creek) as the main zone of failure in wellbores in the condensate-rich Marcellus area. This is the uppermost consistant organic layer of the Marcellus.

2) With cuttings from a type well and from multiple failed wellbores, elemental analysis was utilized as a relatively inexpensive tool to identify zones of failure.

3) Four separate packages were cataloged as rubble zones. The study determined that the wellbores were failing in the base of the curve and not in any particular geologic sequence. The "Rubble Zone" is no longer termed the "Rubble Zone"!

4) Armed with this information the Company was able to forge ahead with solutions, including bigger OD drill pipe and revisions to clean-up procedures.