Utilizing Borehole Image Logs to Evaluate Depositional Trends in the Uinta Basin, Utah

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Abstract

Horizontal wells targeting deep-lacustrine deposits have been a primary driver of oil production growth in Utah's Uinta Basin over the past 10 years, with Estimated Ultimate Recoveries (EURs) that rank among the most prolific shale oil basins in the United States. The most well-known development target is the Uteland Butte member (UB) of the Eocene Green River Formation. The UB represents a large-scale transgression of Lake Uinta and exhibits a remarkably similar gamma-ray character from outcrop to basin center, allowing it to be easily mapped over a large area. The UB lacustrine depositional phase is underlain by the Wasatch Formation, interchangeably called the Colton or Castle Peak by previous authors. In outcrop, the Wasatch classically presents as a succession of distinctly red channel sandstones and mudstones which commonly contain pedogenic features, indicating a fluvial-deltaic depositional environment with periodic surface exposure and occasional intervening lacustrine phases. Utilizing public and proprietary whole-rock core, this study documents the multitude of depositional environments that can be identified within Wasatch Formation in the deepest parts of the Uinta Basin. Within the span of 10 miles, the same chronostratigraphic interval of the Wasatch Formation includes; 1) black, organic-rich shales; 2) dark gray micritic limestones; 3) organic-lean gray shales with root structures and pedogenic surfaces; 3) fine-grained salt-and-pepper lithic gray sandstones; and 4) red-beds and medium-grain alluvial sandstones. This collection of lithologies indicates that deep lacustrine depositional systems and proximal alluvial systems existed contemporaneously in different parts of the basin during the time of Wasatch deposition. The depositional period of the Wasatch was clearly a dynamic time and requires detailed study for resource evaluation.

References

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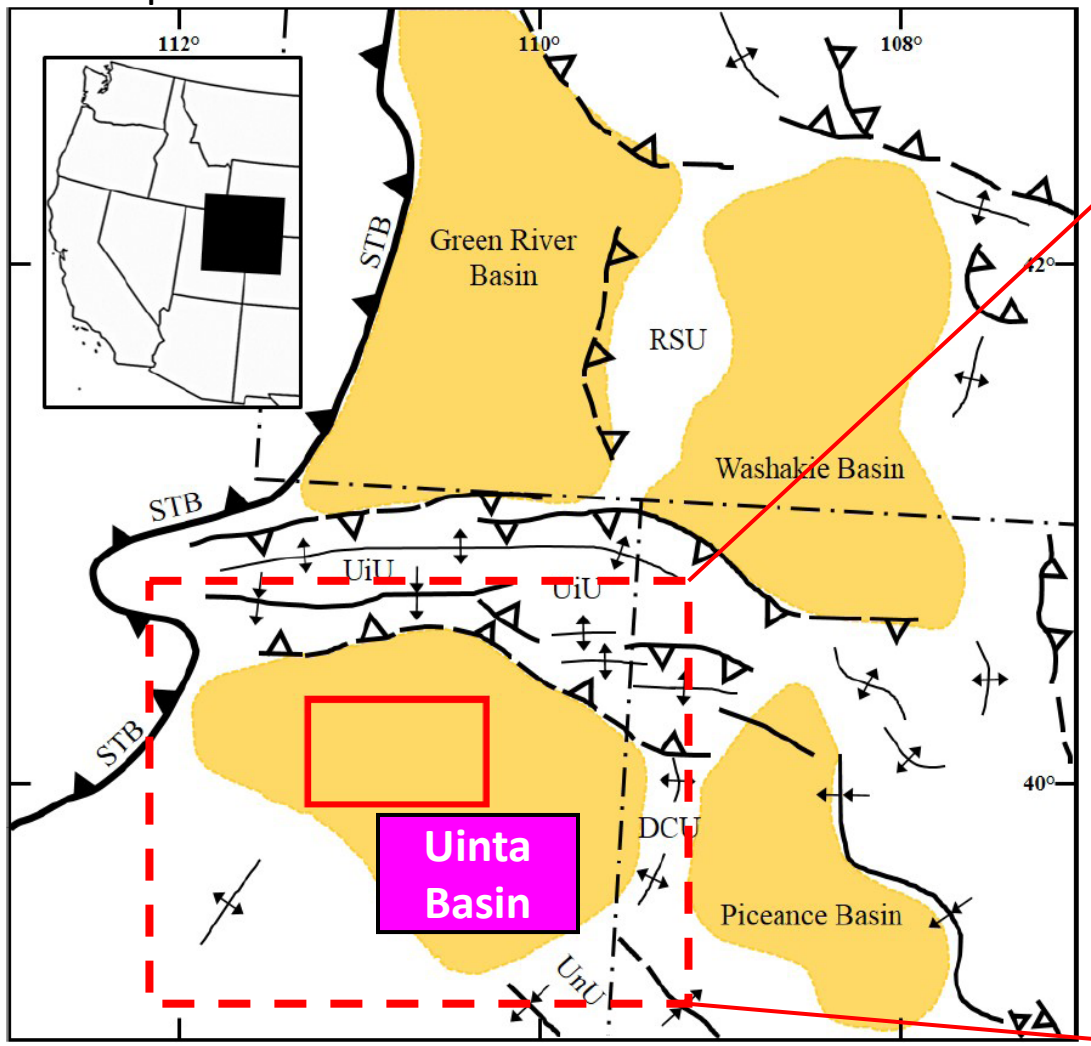
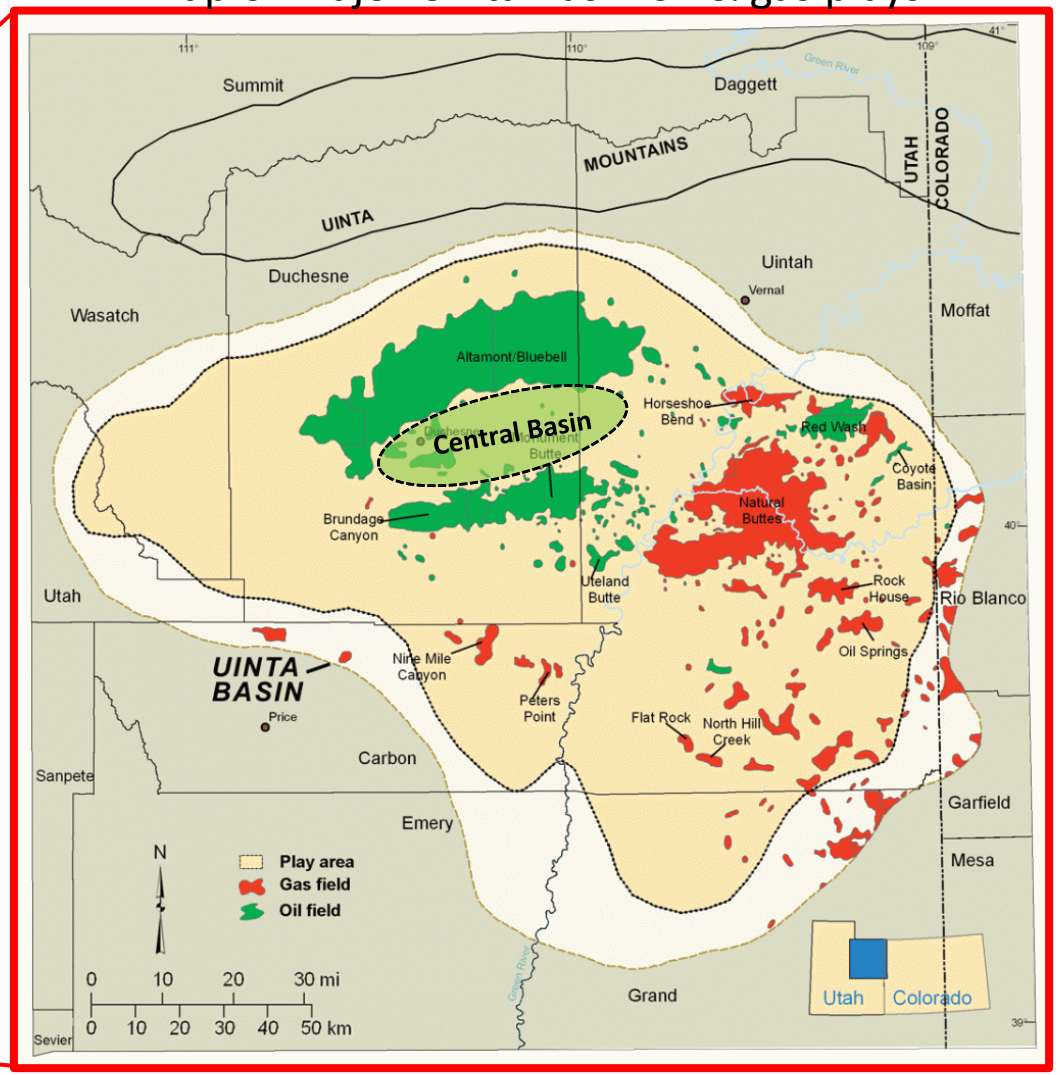
Uinta Basin Locator Slide

Map of western U.S. Laramide lacustrine basins



Modified from Rueda Chaparro 2019

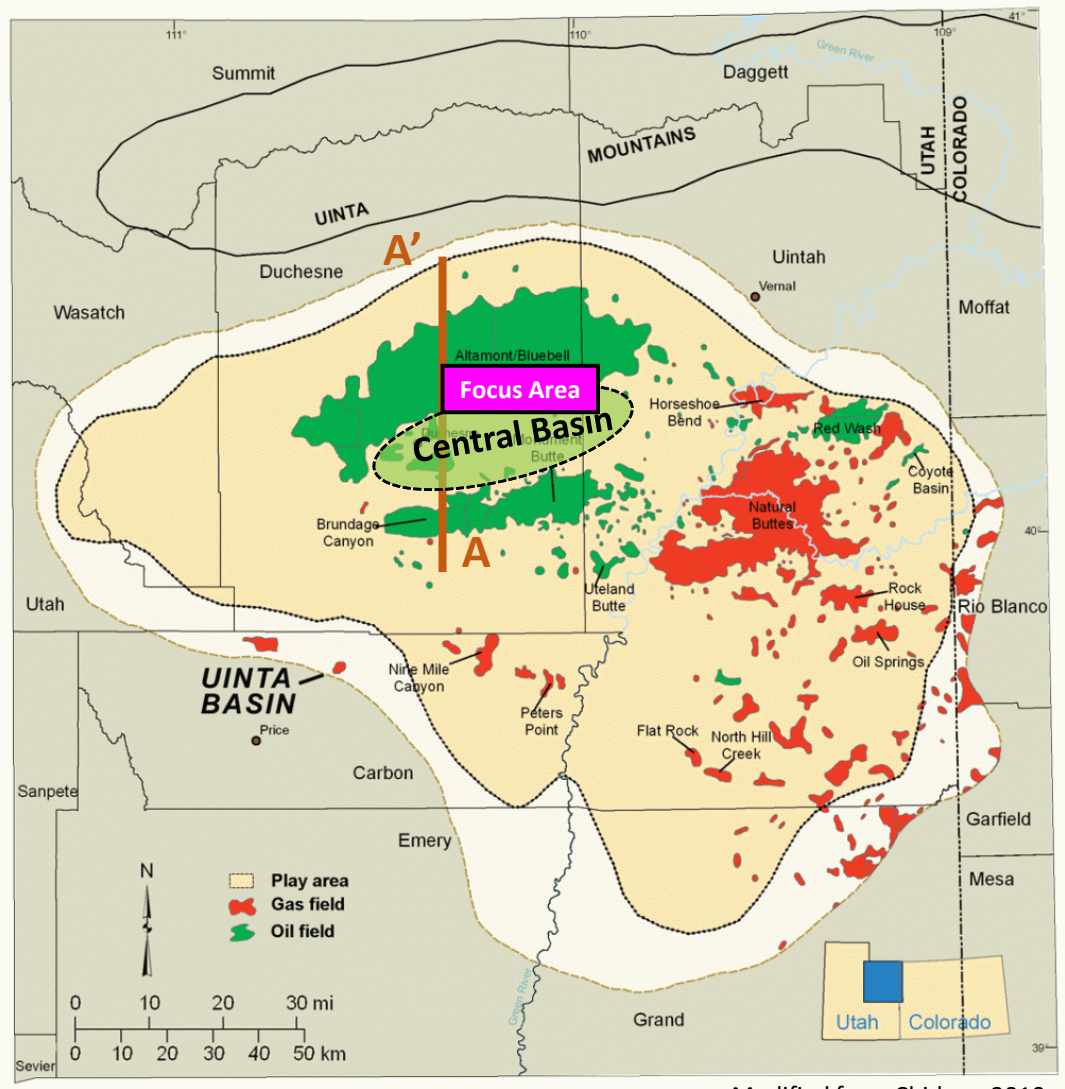
Map of major Uinta Basin oil & gas plays



Modified from Chidsey 2010

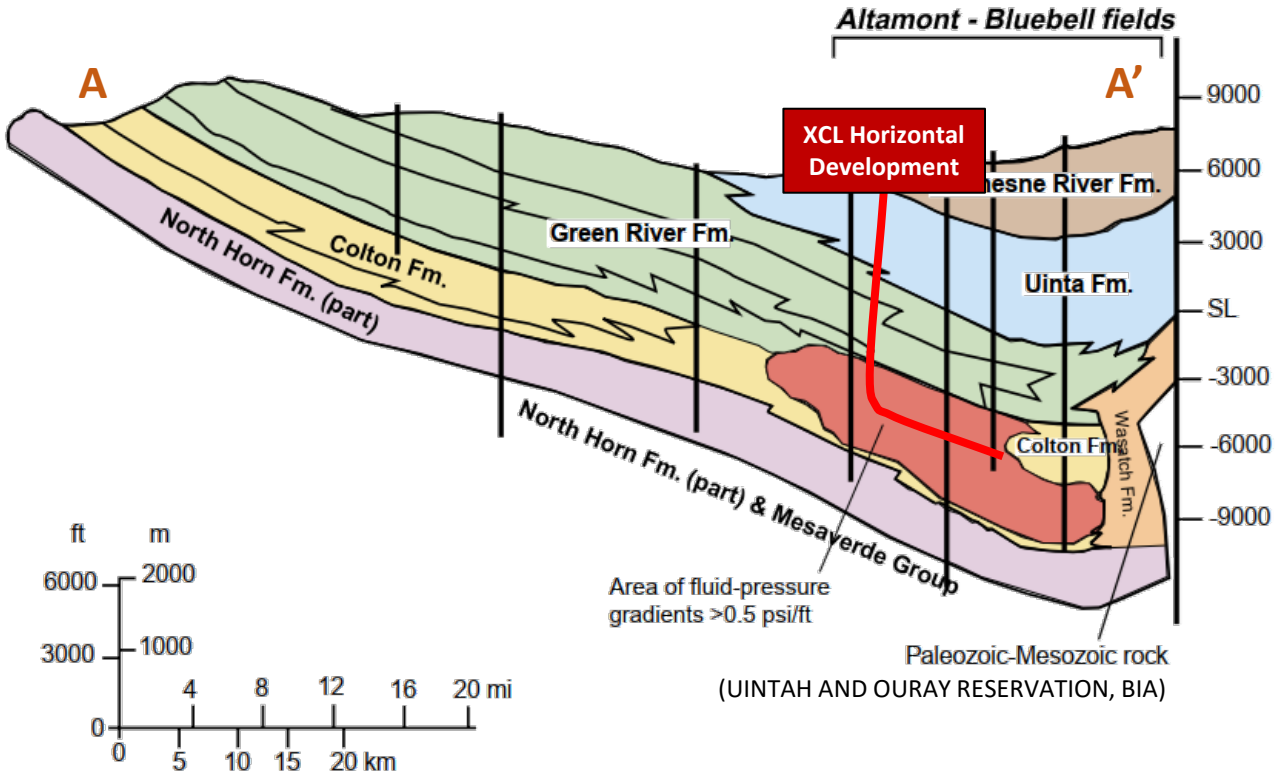
Uinta Basin Overview

Green River Fm - World Class Source Rock



Modified from Chidsey, 2010

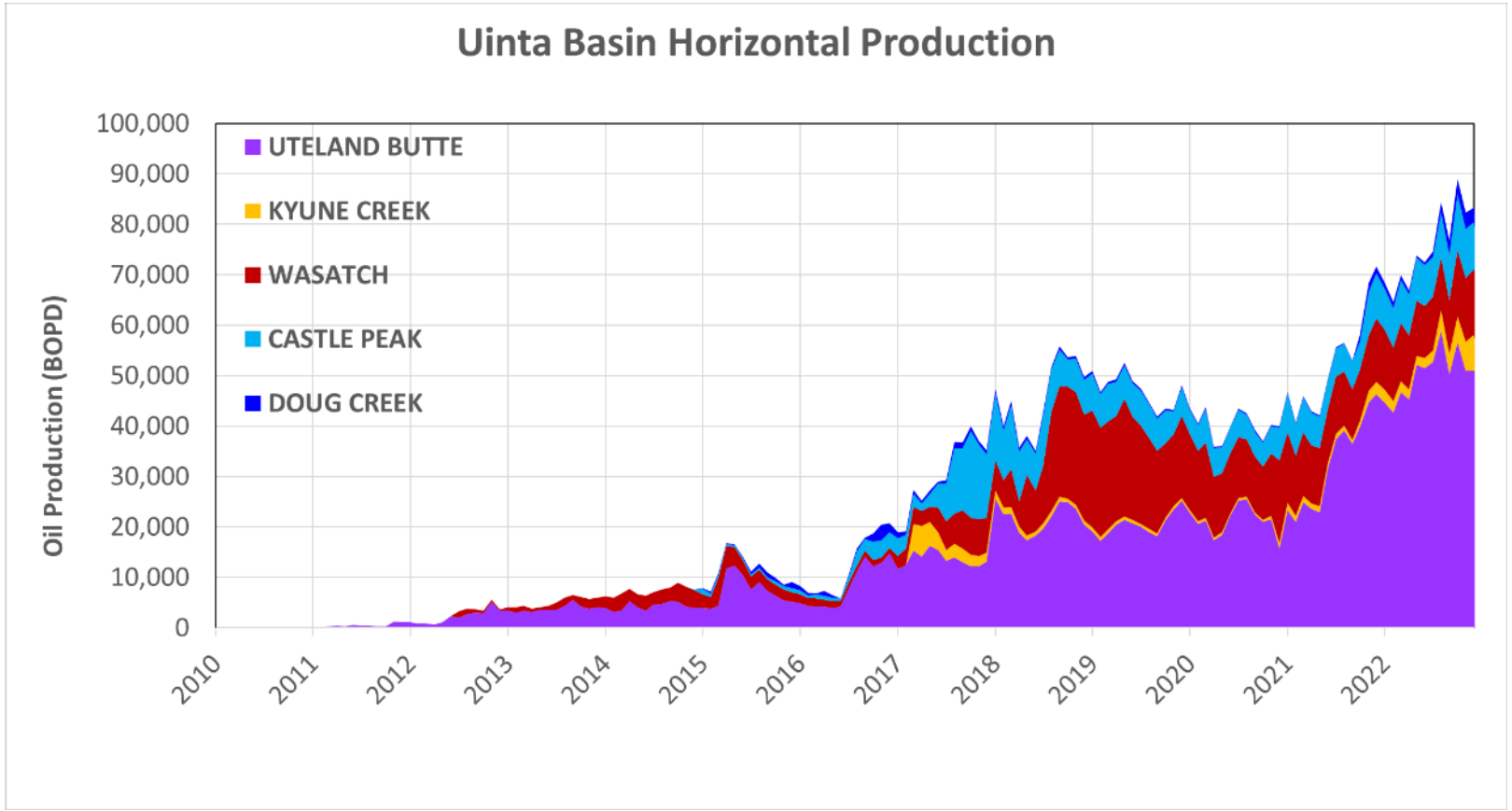
- Uinta Basin oil production at Altamont/Bluebell since 1970's and Monument Butte since 1980's
- Vertical production from Eocene Green River/Colton (Wasatch)/Flagstaff formations
- Modern Horizontal plays target lacustrine source rocks of Green River and Wasatch Formations
- Asymmetric basin configuration resulted in deepest lacustrine deposits stacked along northern margin of Uinta "Central Basin"

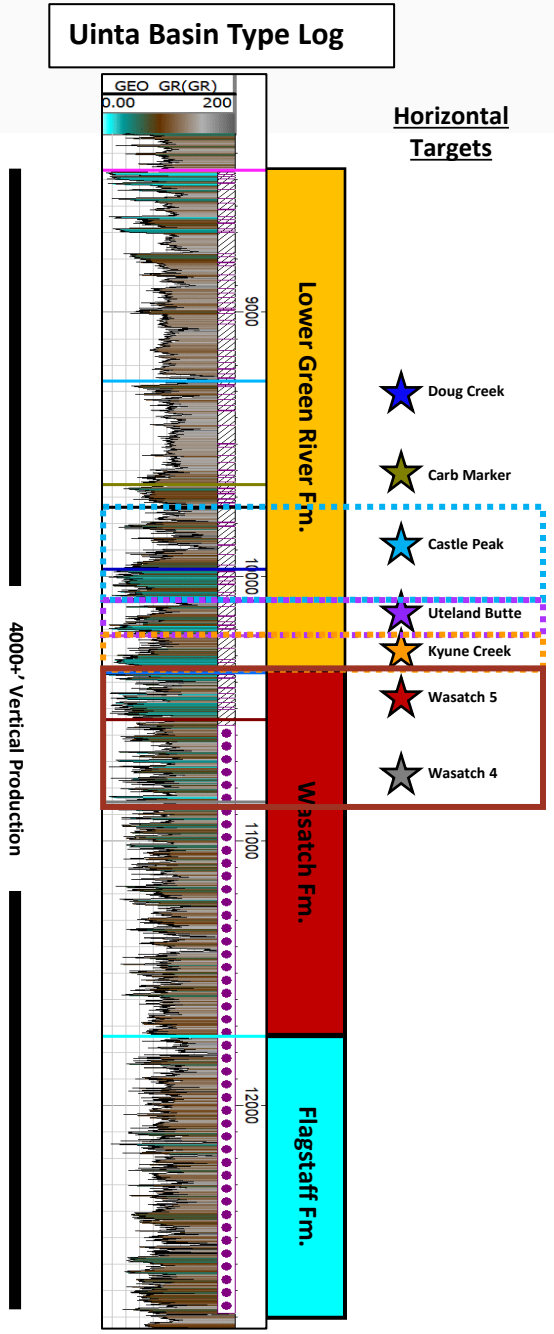


Uinta Basin Horizontal Production

Learning to Share Capex Dollars Within the Stack

- Uinta Basin horizontal drilling started in the Uteland Butte (UB)
- Some operators drill wells in 7+ benches of the Lower Green River and Wasatch Formations
- Significant production from Castle Peak and Wasatch benches but UB is king

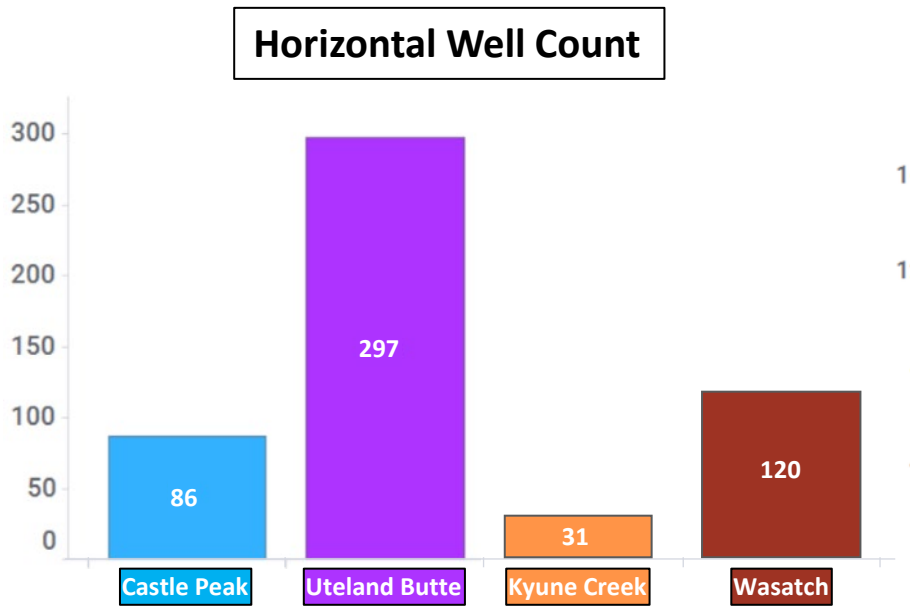


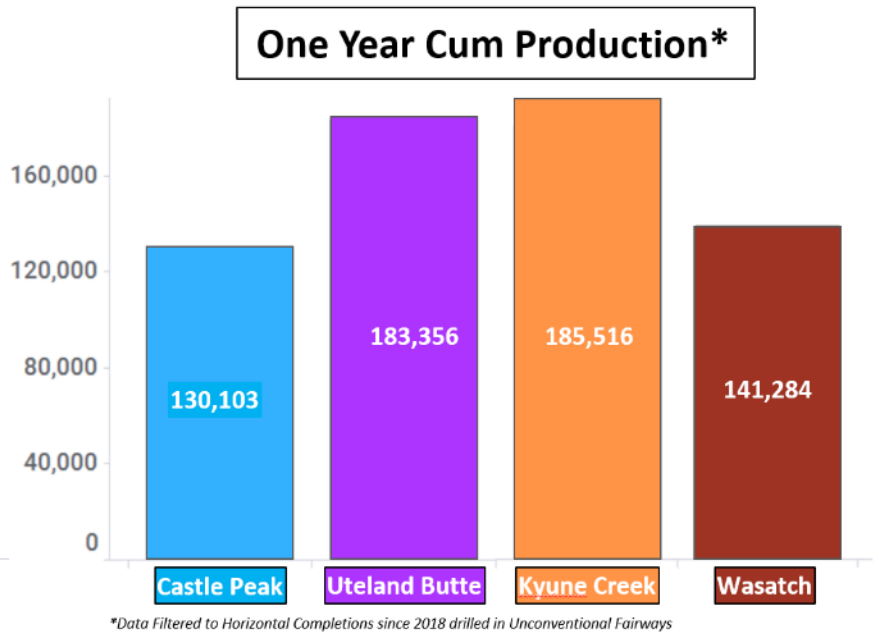


Uinta Basin Horizontal Production

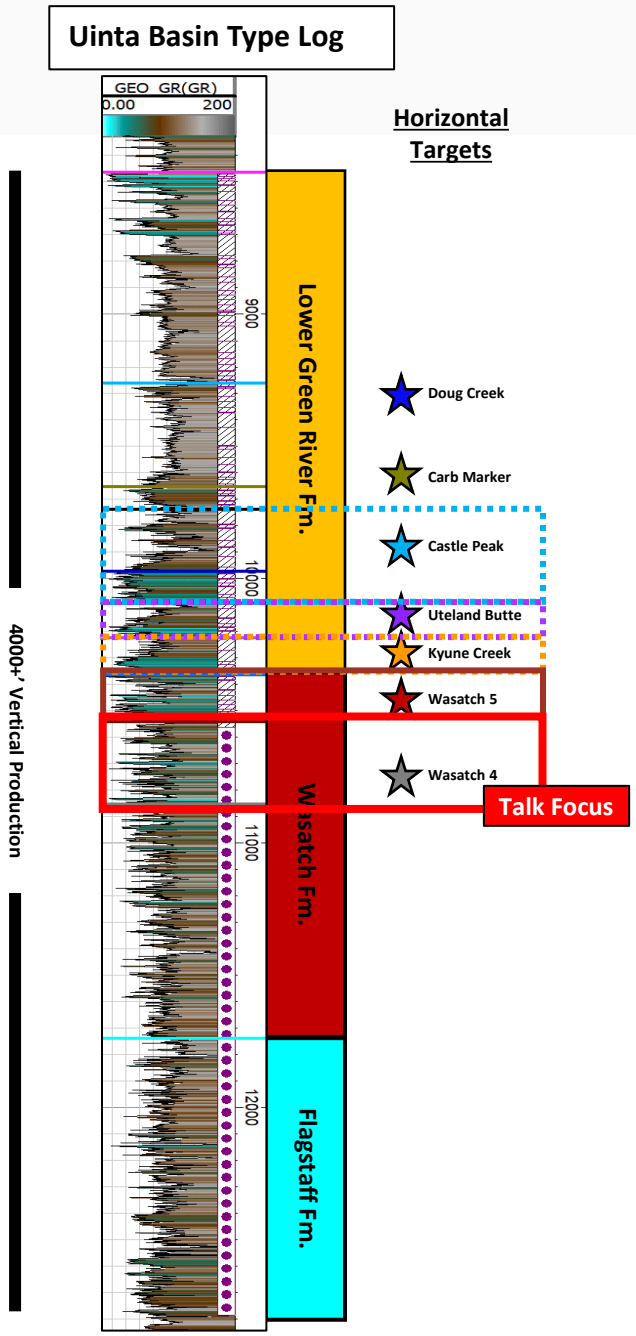
Learning to Share Capex Dollars Within the Stack

- Significant production from Castle Peak and Wasatch benches but UB is king
- UB & KC wells consistently outperform other benches yielding outsized capital budgets
- Other benches have to fight for capital
- Understanding reservoir distribution is critical to consistent success in CP and Wasatch
- How do we ensure secondary reservoir economics compete with UB?





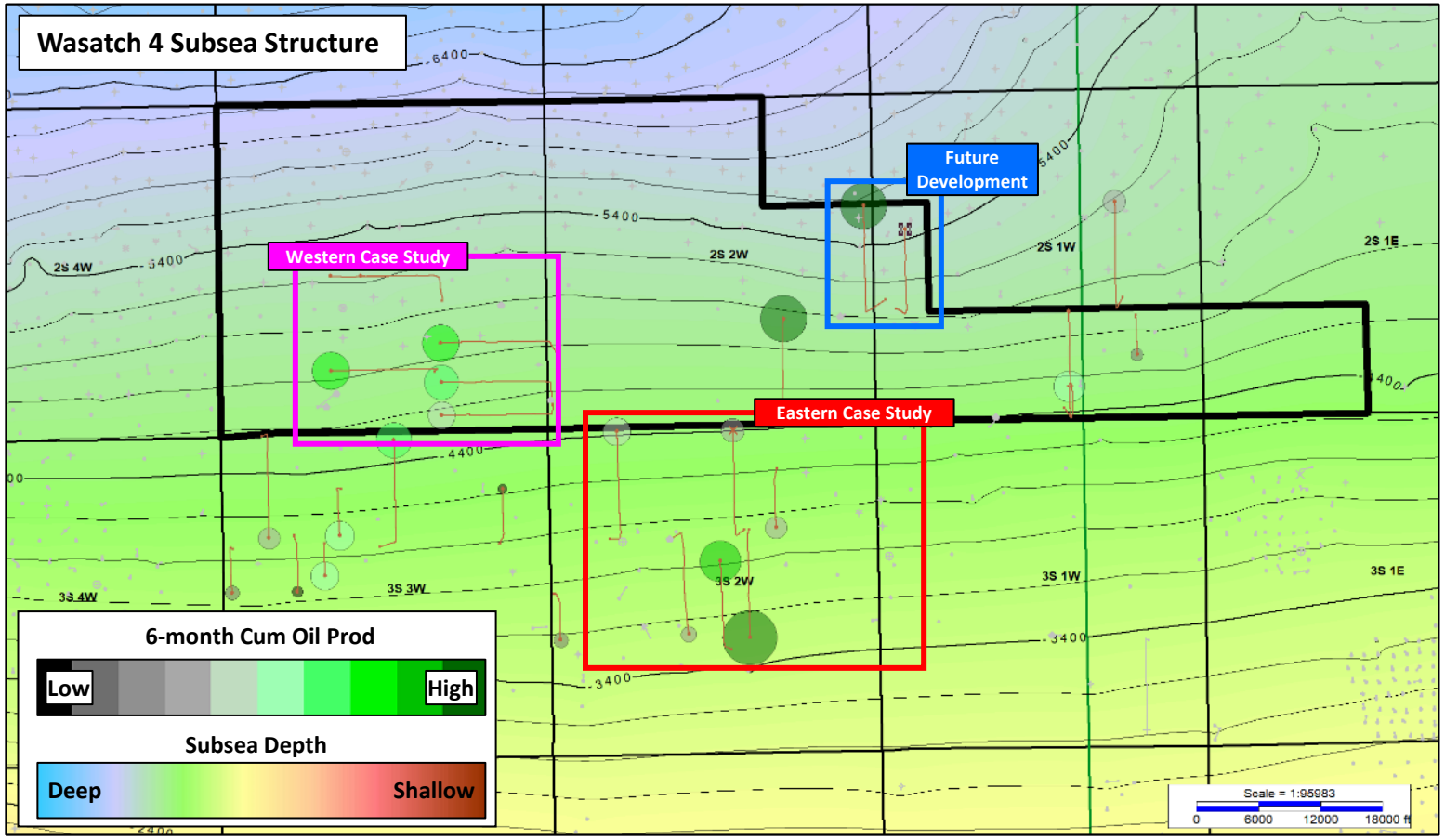
*Data Filtered to Horizontal Completions since 2018 drilled in Unconventional Fairways



Case Studies Teach Us Dos and Don’ts

Comparing Well Results in the Wasatch

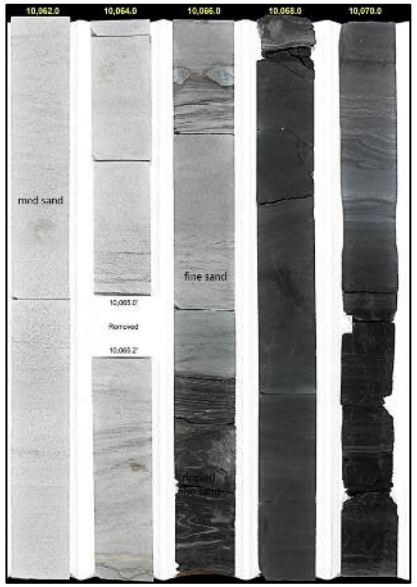
- XCL studied offset Wasatch wells to plan Wasatch cube well spacing
- Two major distributions of well results in these case studies western case study shows consistent well performance, eastern case study does not
- Staggering variation in well results over the course of ~1.5 miles between multiple wells in the east – **What causes this?**
- Reservoir depletion possible but seemed extreme
- Wasatch reservoirs contain numerous limestone and sandstone lenses – Could stratigraphic distribution be impacting well results?
- **This presentation outlines an XCL case study to attempt to understand Wasatch stratigraphy and its impact on development well spacing**



What's Your Perspective on the Wasatch?

Where Your Data Come From Informs Your View

Central Basin Deep Lacustrine Wasatch



Central Basin Wasatch

- Fine to rare med white sandstones
- Black to gray bioturbated and deformed mudstones

Red Wash Shallow Lacustrine Wasatch

Red Wash Wasatch

- Med to fine white to tan sandstones
- Minor gray to green silt to mudstone
- Extensive brecciation and reworking

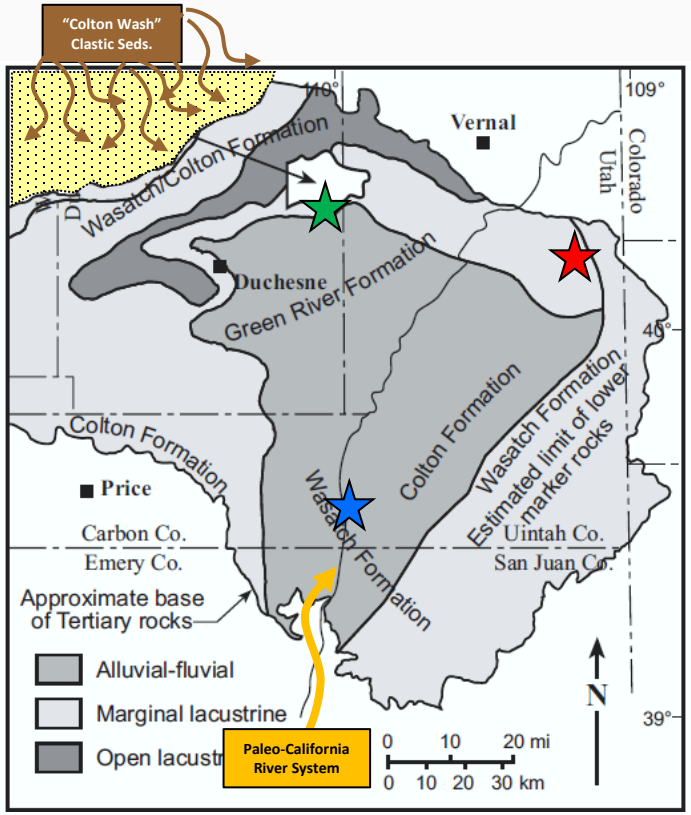
Desolation Canyon Fluvial Wasatch

Middle Wasatch

- High-net channel complexes of med – fine massive red-tan sandstones
- Minor intervening red to tan siltstones

Lower Wasatch

- Isolated med-fine massive red sandstones
- Extensive dark-red to tan siltstones and mudstones

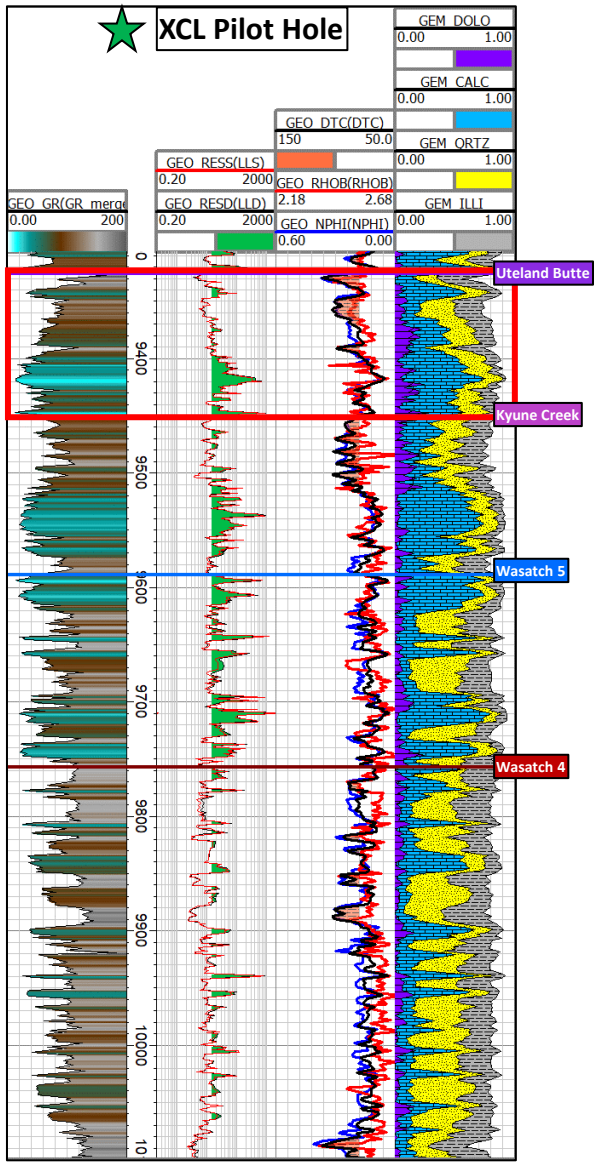


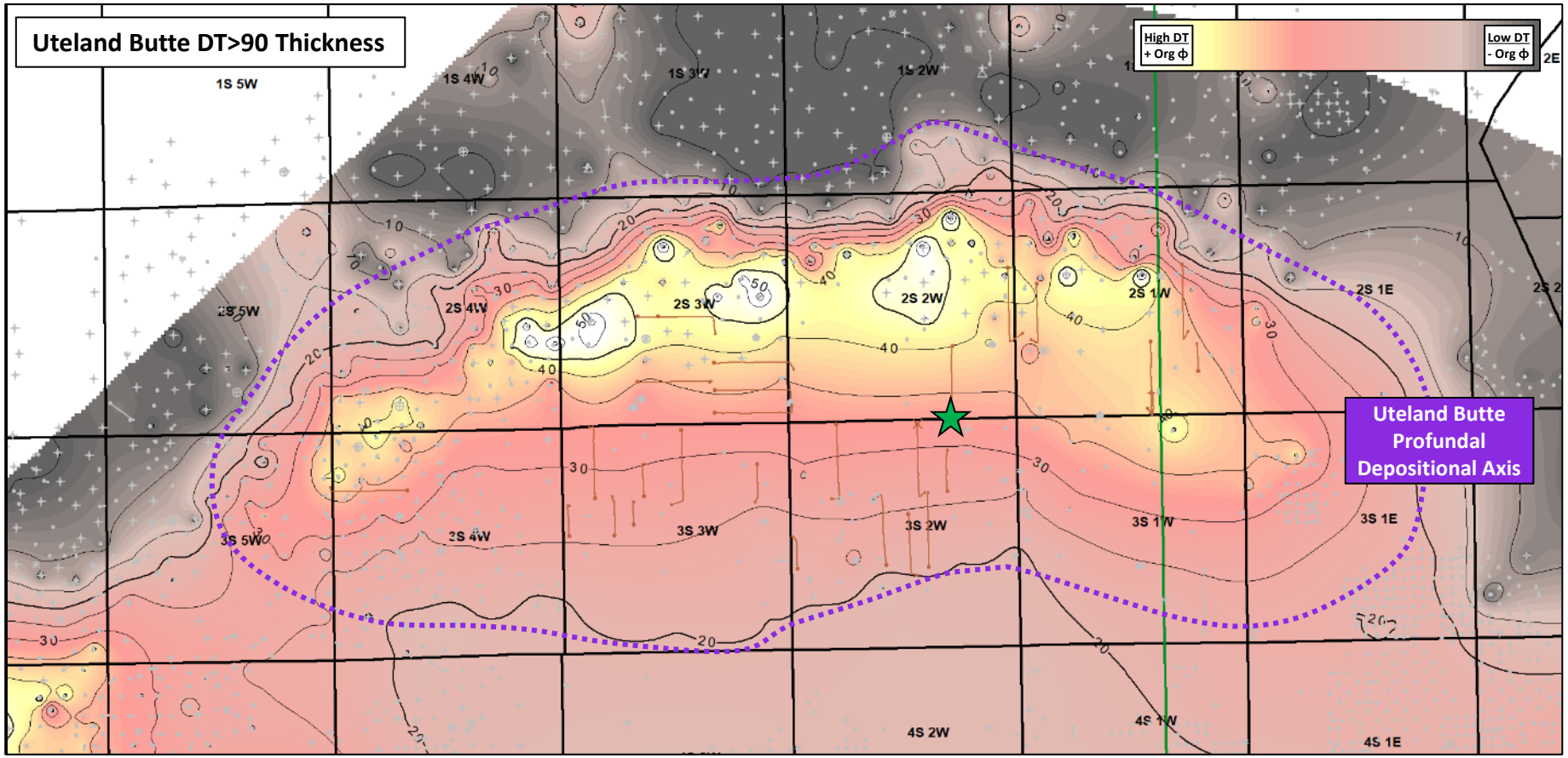
Modified from Morgan (2003)

- The names Wasatch and Colton have been used to describe several different clastic and carbonaceous depositional systems
- Wasatch/Colton clastic rocks sourced from both the S through the Paleo-California drainage (Dickenson ref) or from the NW from the Colton Wash sourced from the Uinta Mountains (Jones ref)
- In the Central Basin did sands come from the NW or S? Does it matter if everything is lacustrine?

One Map to Rule Them All

Building a Frame of Reference – Where was Lake Uinta Deep in Uteland Butte Time?

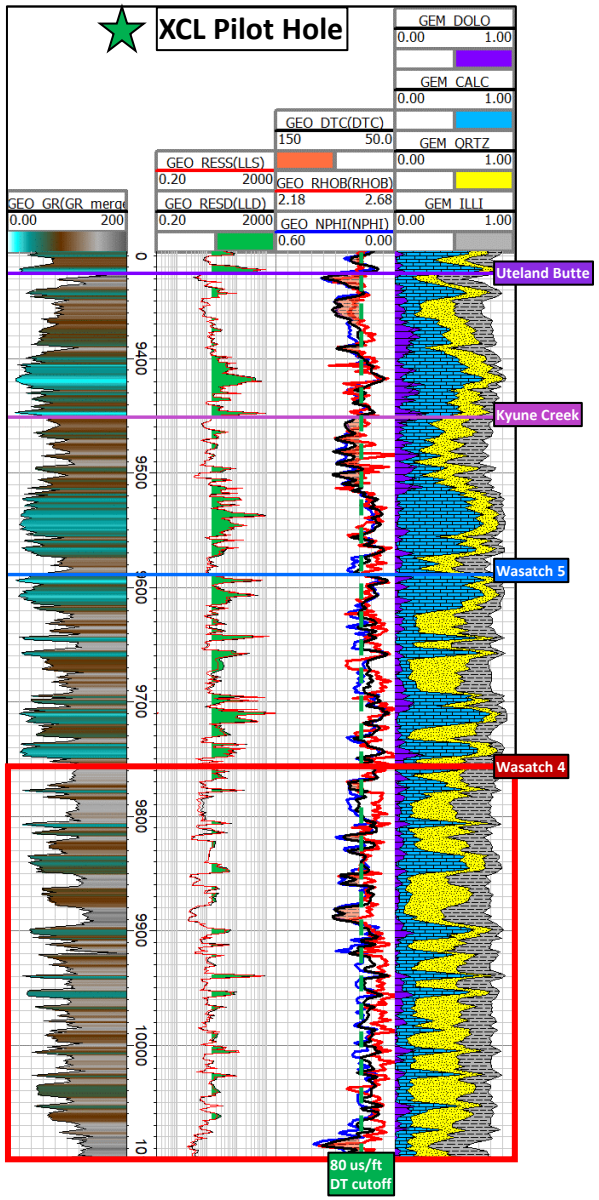


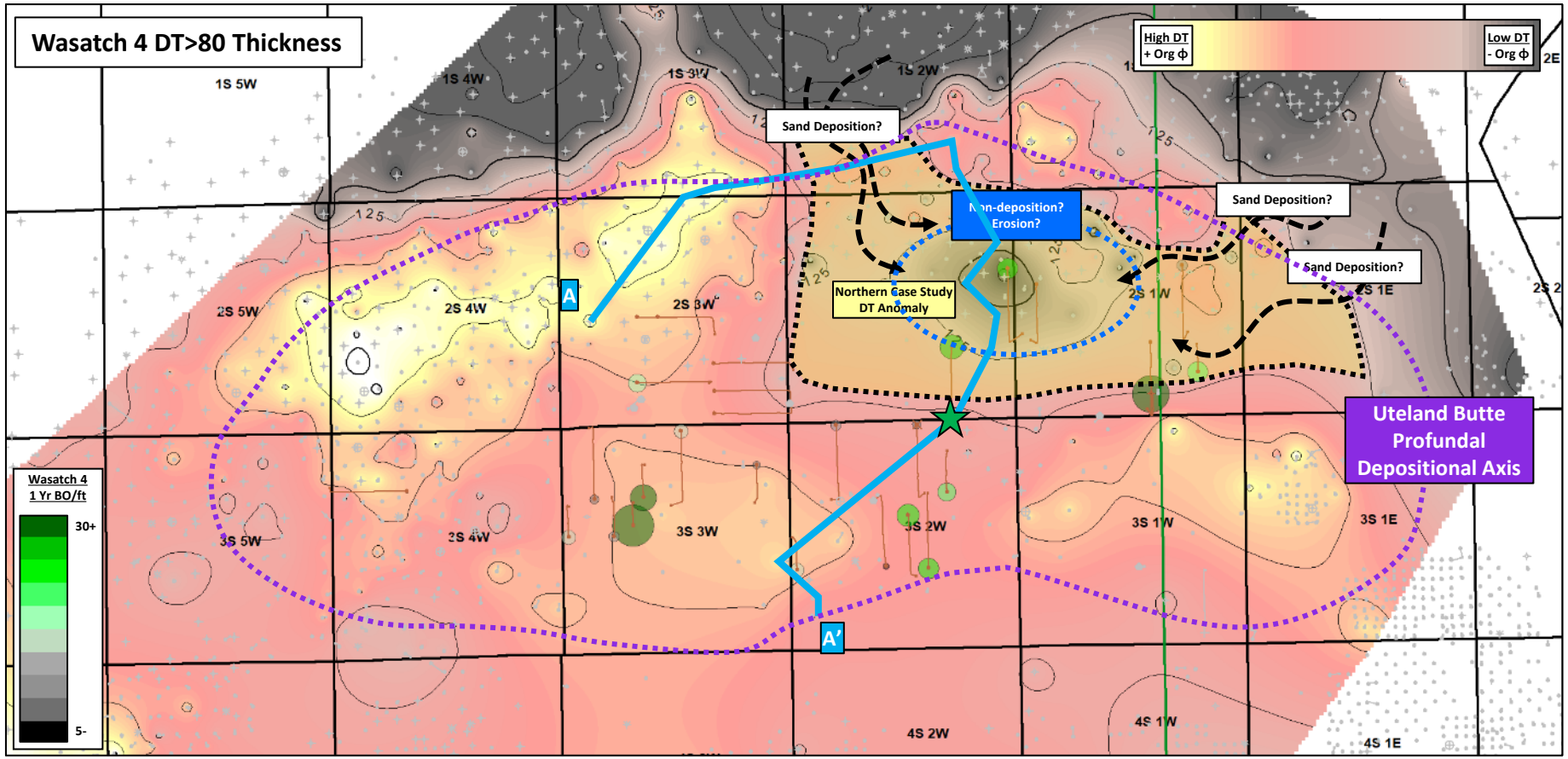


- Sonic response shown to be a proxy for organo-porosity by Fidler et al (2022), thus also potentially a proxy for profundal EODs
- The Uteland Butte EODs are reasonably well understood and may help identify profundal EODs in other intervals
- **<u>Can we use sonic logs to map similar depositional trends in the Wasatch 4?</u>**

Wasatch 4 Sonic Mapping

Building a Frame of Reference – Where was Lake Uinta Deep in Wasatch 4 Time?



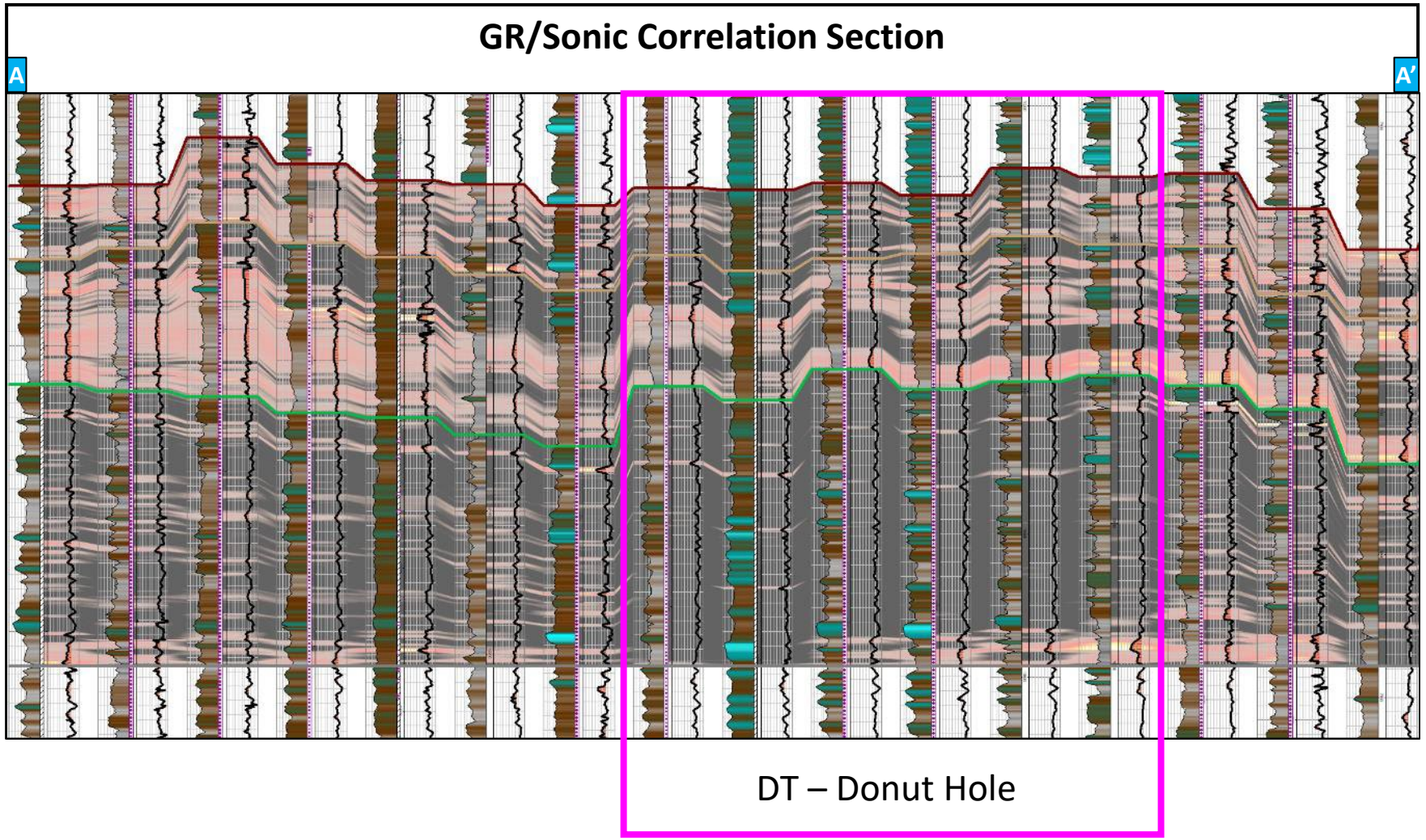


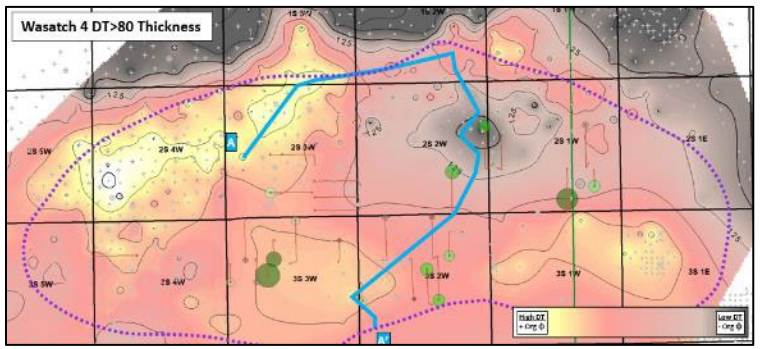
- Wasatch 4 sonic cutoff of 80 us/ft due to combo of compaction, Level of Maturity, and thin-bed logging (Fidler, personal comm.)
- Net sonic maps identify northern edge of source deposition but also identify a distinct drop in DT near northern case study wells
- **Drop in organo-porosity associated with good Wasatch 4 wells!**
- **Why?** Sand Depositional Axis? Paleo-high? Changing lake depositional systems?

Cross Section Analysis

Digging into the details – Sonic Log Analysis

- DT response is hard to analysis shows distinguish any trends – **Let's color fill it!**
- Interpretive color fill makes lower DT values pop
- DT – Donut Hole log response:
  - **Less consistent DT in the upper ½ of the W4**
  - **Dead DT response in the lower ½**

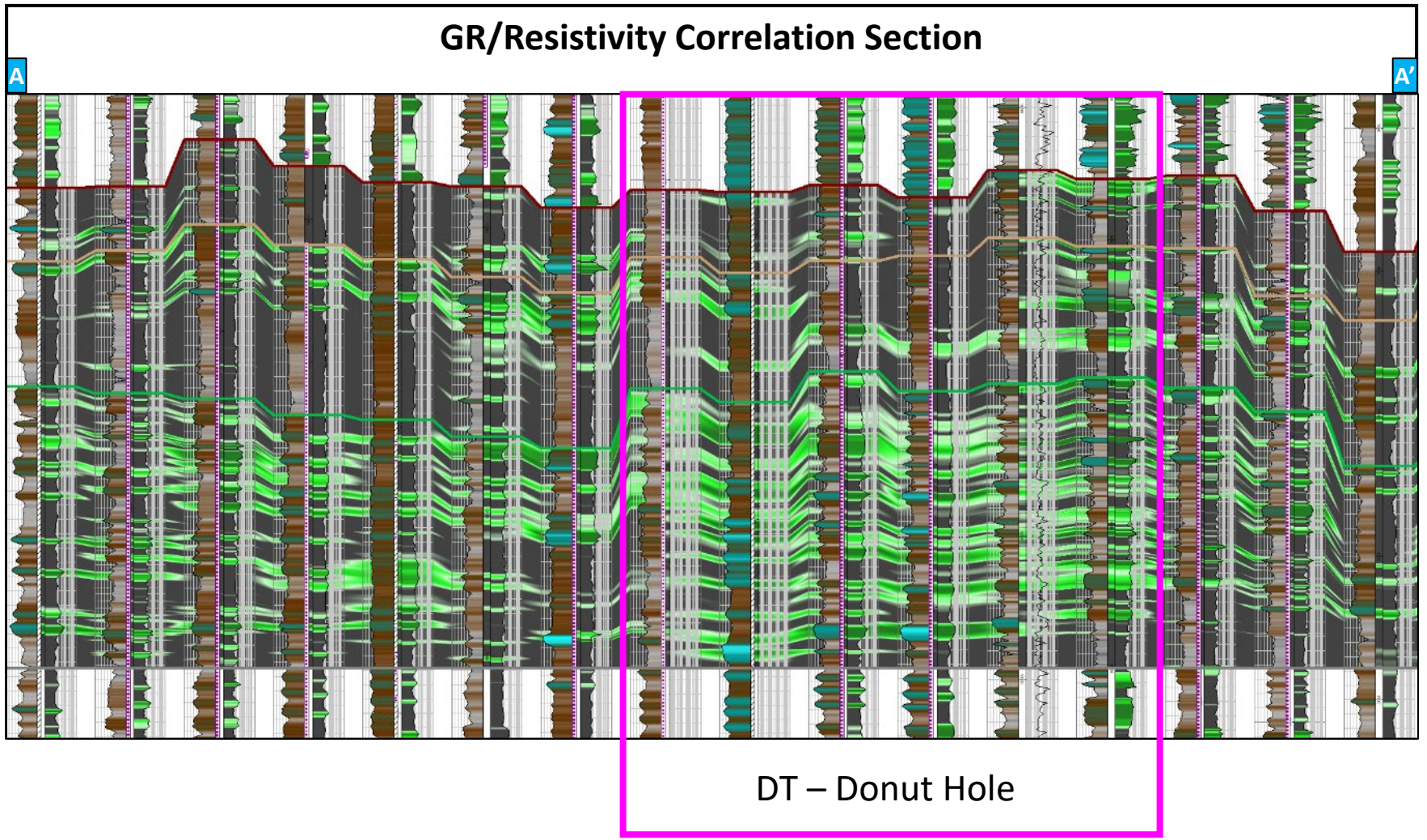


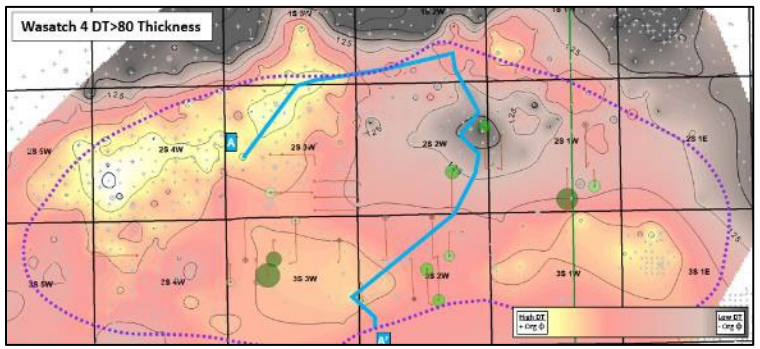


Cross Section Analysis

Digging into the details – Resistivity Log Analysis

- Resistivity pop a bit more, but l**et's color fill it anyway!**
- High Resistivity beds pop out where DT response was muted
- Indications of a depositional pattern in the DT – Donut Hole
- Since we notice high-resistivity, let's look at a Net-ResD map





Maybe One Map Doesn't Rule Them All

Depositional Trends from Resistivity Mapping?

- Net Resistivity maps seem are easily interpreted to show a depositional axis
- Conveniently XCL has core and image logs along this axis of deposition
- Can image logs and core demonstrate any trends?

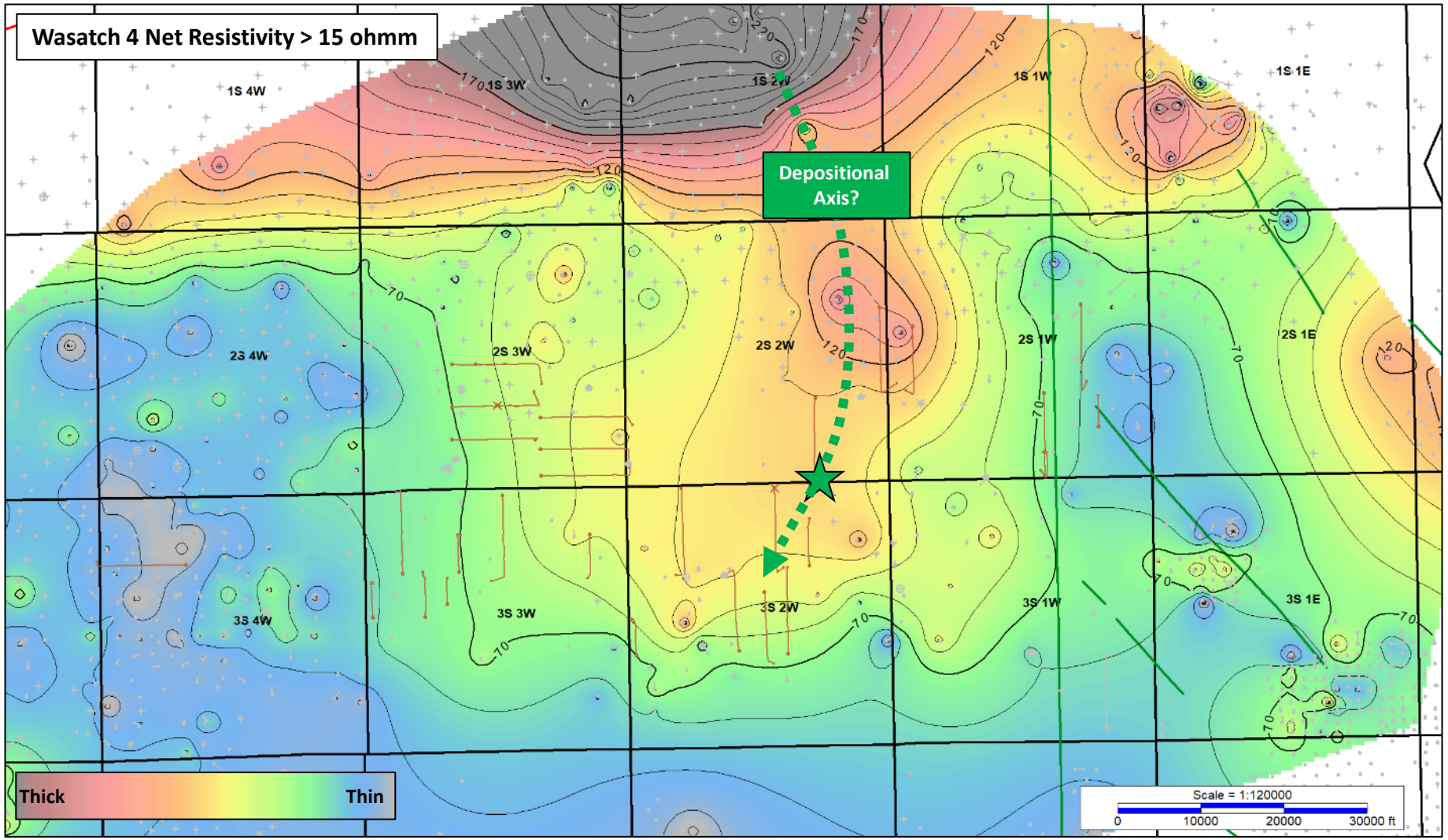
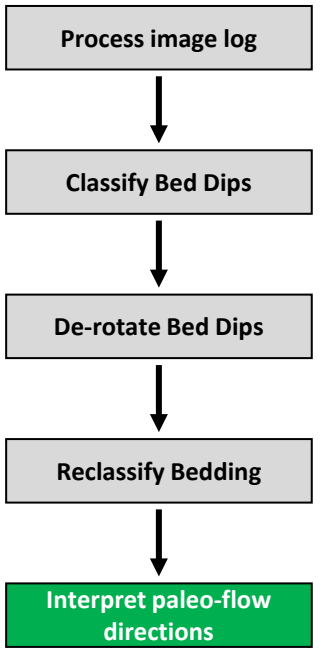
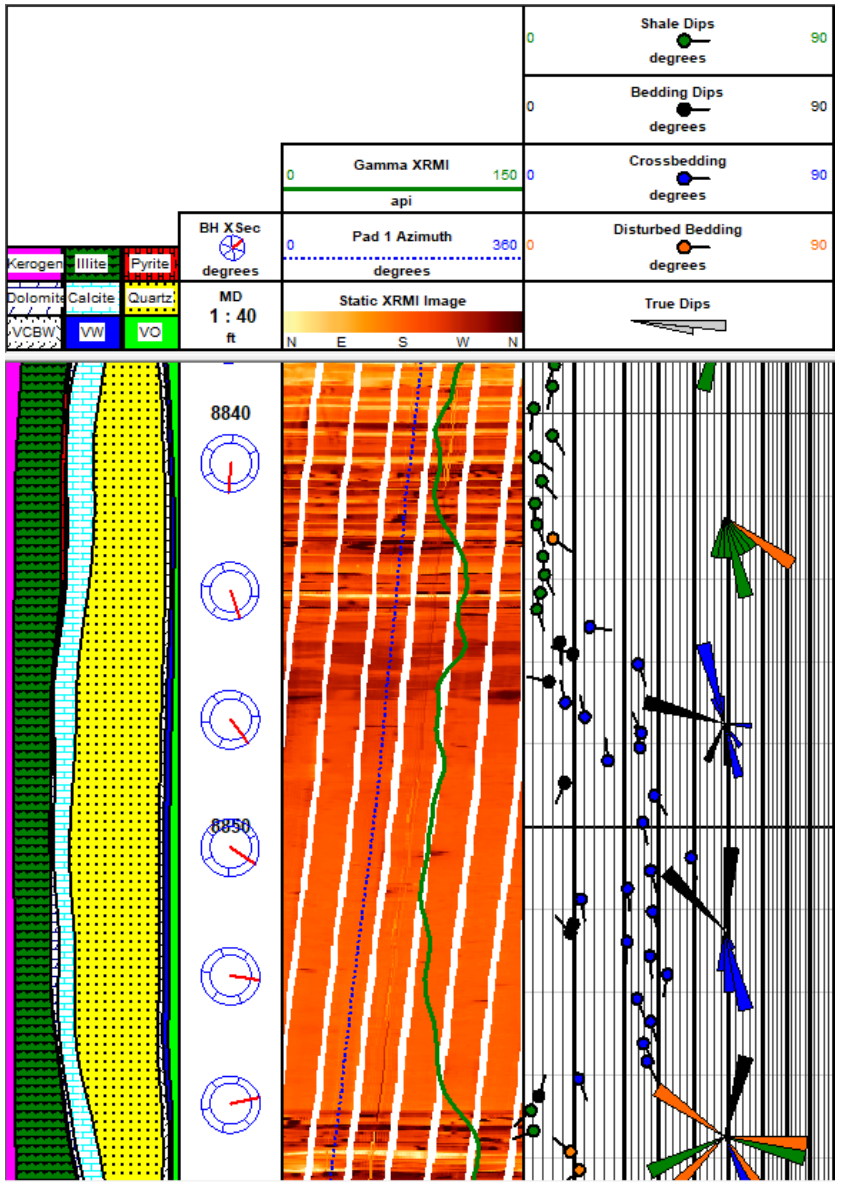


Image Log Dip Interpretation Workflow

- Utilizing previously processed image log
- Bed dips classified as follows:
  - Shale Dips
  - Disturbed Bedding – Soft sediment deformation
  - Crossbeds – Crossbeds that are apparent before de-rotation
  - Bedding Dips – Remaining dips to be reviewed after de-rotation
- Structural dip was determined from Shale Dips
- De-Rotate all bedding features using previously determined structural dip
- Reclassify any bedding dips as crossbeds revealed after applying the structural de-rotation.
- Discard Disturbed Bedding dips
- Schmidt plots of structural de-rotated cross beds to indicate possible paleo-flow directions

Borehole Image Log Paleo-flow Interpretation Workflow



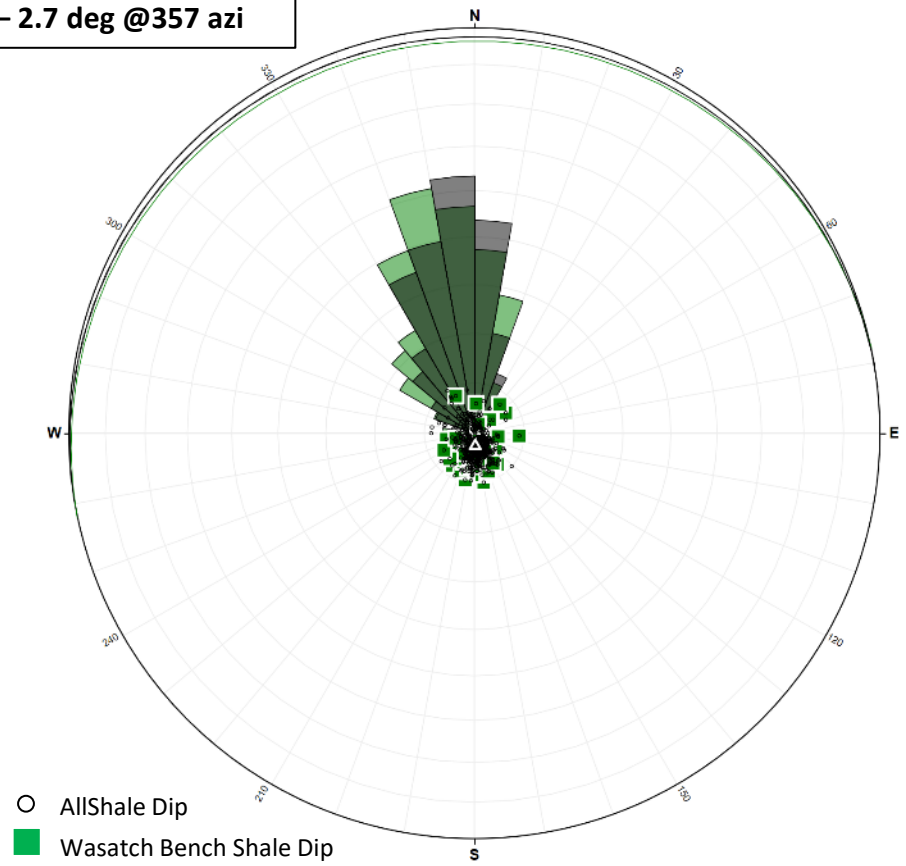


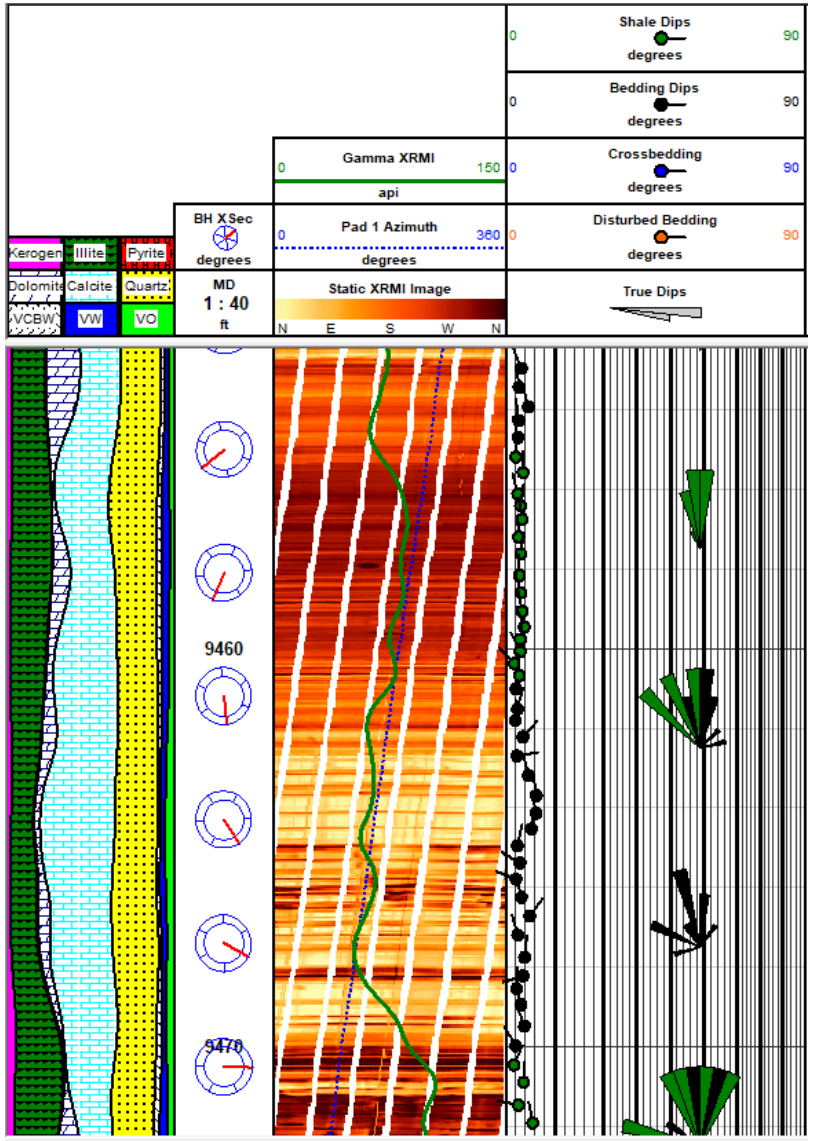
Structural Dip Determination

Identifying Our Plane of Rotation

- Wasatch shale beds and general bedding dips consistent with dip trends over entire log (Lower Green River)

Mean Dip Plane
Wasatch – 4 deg dip @ 350 azi
All Dips – 2.7 deg @357 azi

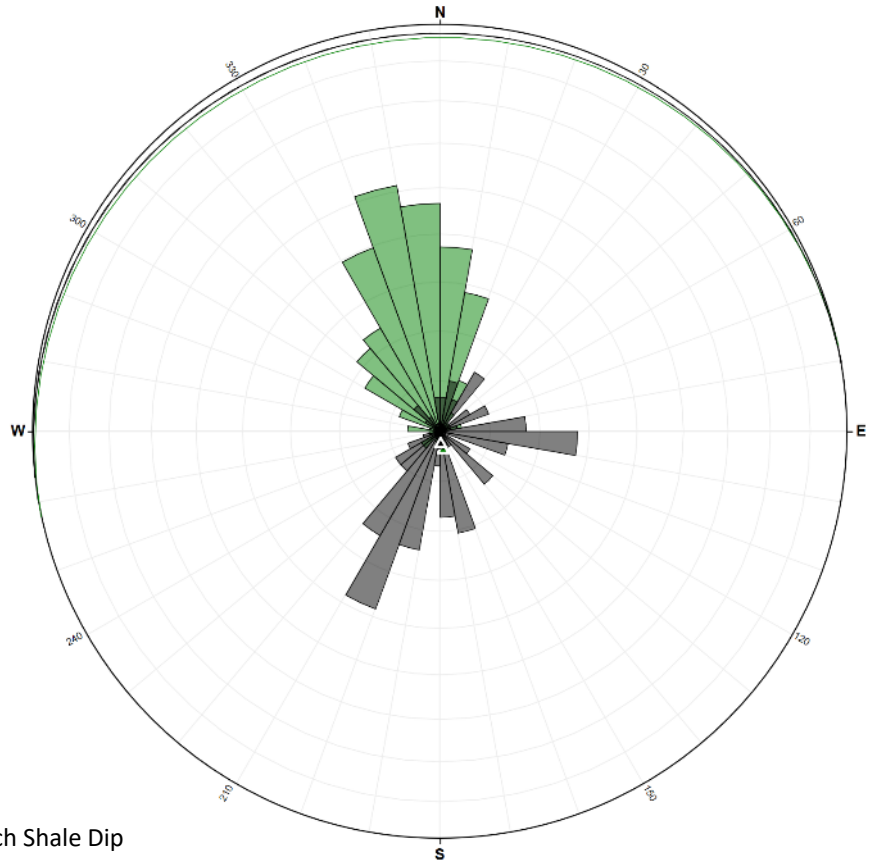




De-rotated Bench Crossbeds

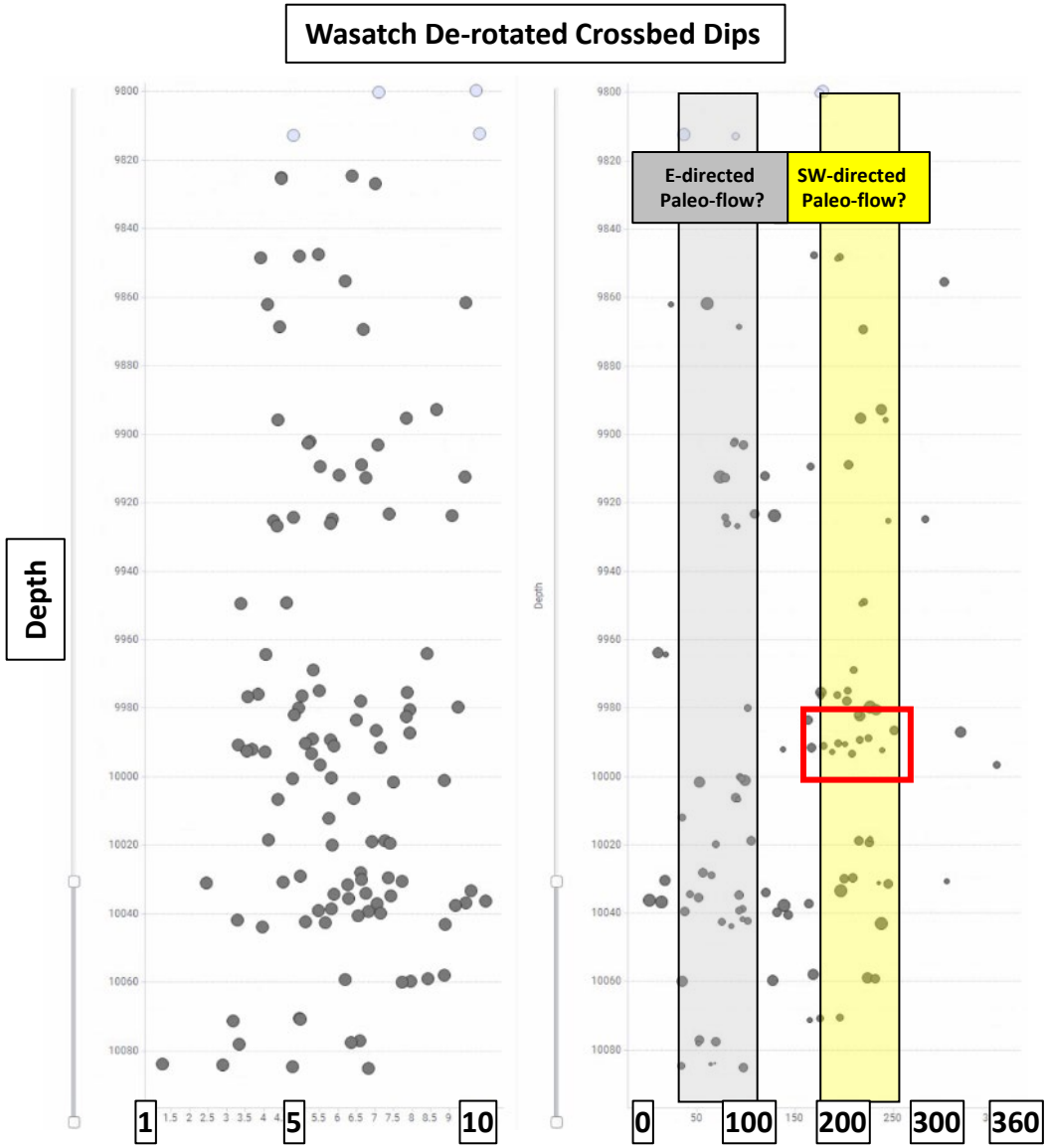
The Hunt for Paleo-Flow Directions

- De-rotated crossbeds show a bimodal trend, but strongest trend suggests SW-directed paleo-flow
- Strongest grouping of SW-directed Azimuths @ ~9990’



Wasatch Bench Shale Dip

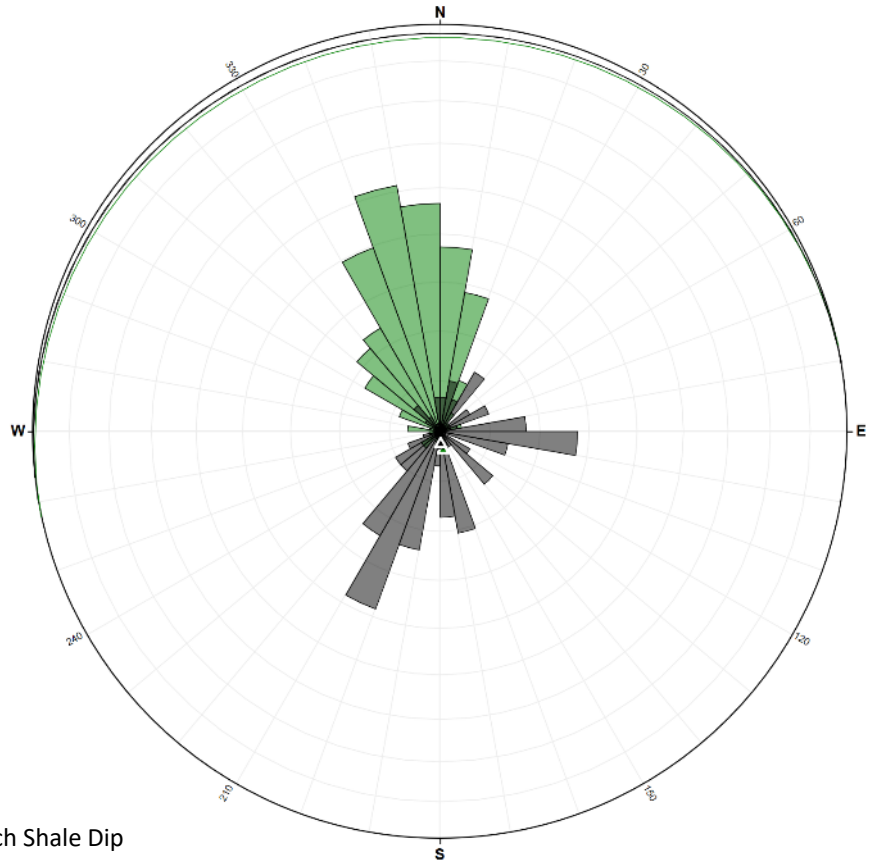
Wasatch Bench De-rotated Crossbeds



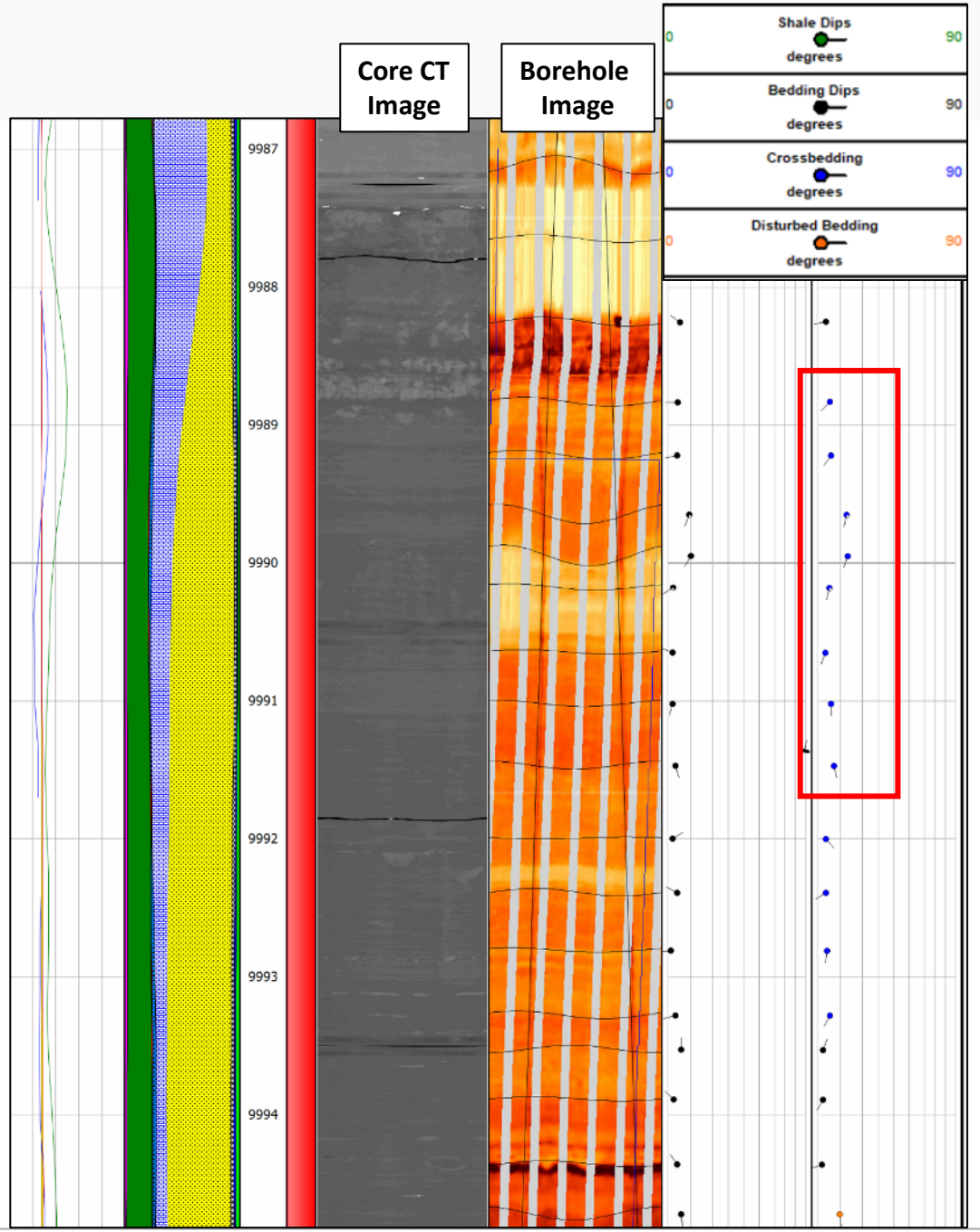
De-rotated Bench Crossbeds

Comparing Identified Crossbeds to Core CT Images

- De-rotated crossbeds show a bimodal trend, but strongest trend suggests SW-directed paleo-flow
- Strongest grouping of SW-directed Azimuths @ ~9990'



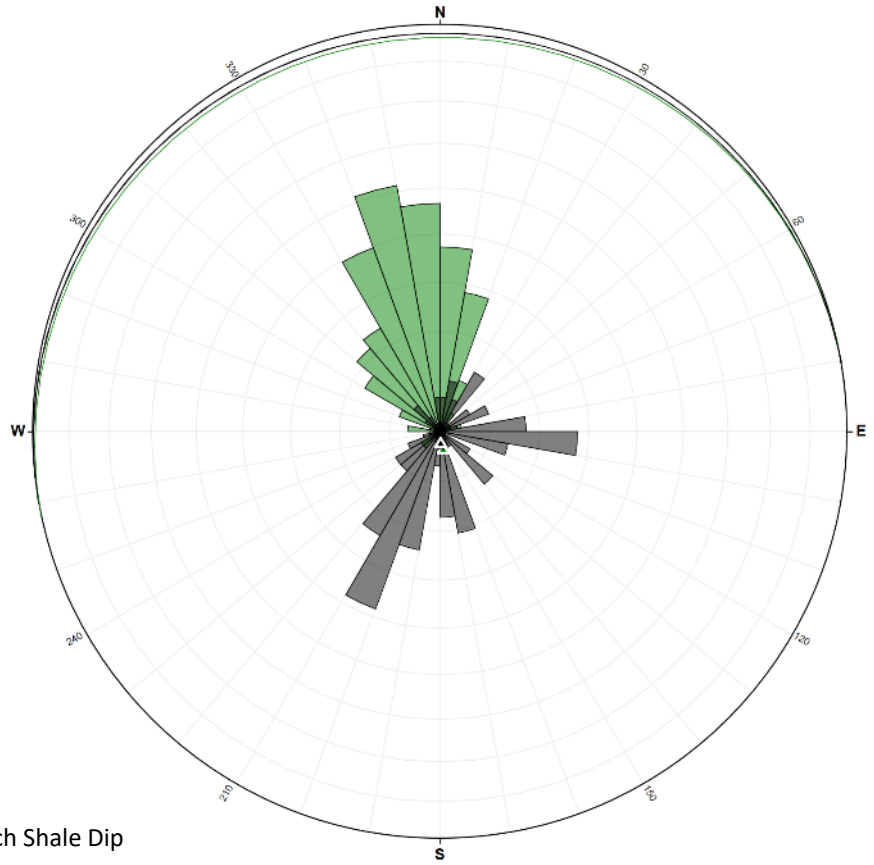
Wasatch Bench Shale Dip
Wasatch Bench De-rotated Crossbeds



De-rotated Bench Crossbeds

What does the Core Say?

- De-rotated crossbeds show a bimodal trend, but strongest trend suggests SW-directed paleo-flow
- Strongest grouping of SW-directed Azimuths @ ~9990’

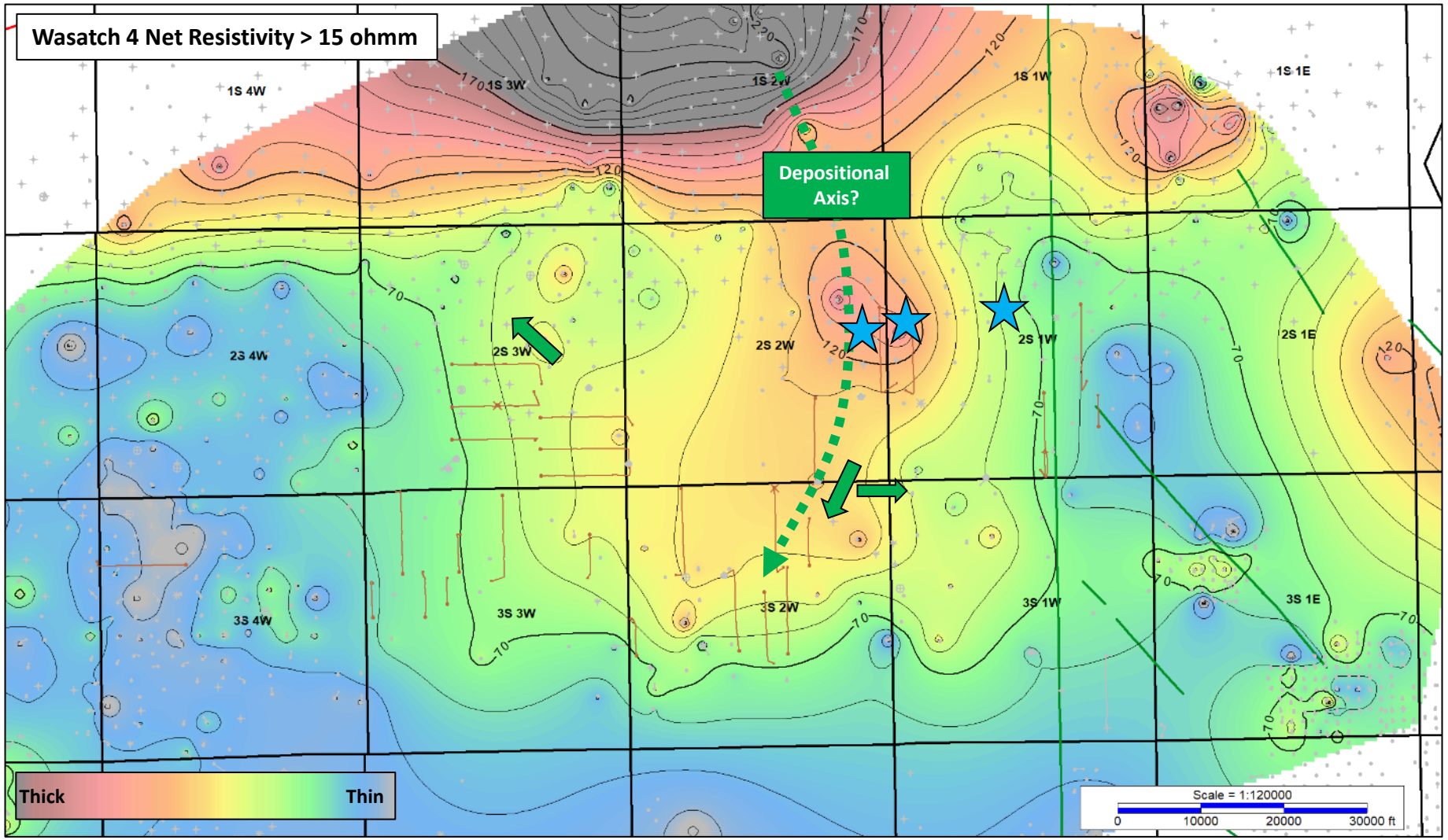


Certainly, some ripple laminations/cross beds but hard to see depositional patterns

Future Work

Identifying Additional Data Points

- When at first you don't succeed try more logs!
- 4 more logs identified for Paleo-flow analysis
- 1 well even included a vintage paleo-flow analysis showing NW directed flow
- Both currently identified paleo-flow indicators fit decently with map patterns but much work left to be done to put together a convincing story
- **Looking for industry partners for joint study!**



Acknowledgments

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UGS Staff

Riley Brinkerhoff

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