

PS Reservoir Architecture and Economic Implications of the Trail Member Fluvial Sandstones, Ericson Sandstone, Mesaverde Group*

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Abstract

The Trail Member of the Cretaceous Ericson Sandstone, exposed near Dry Canyon on the southeast flank of the Rock Springs Uplift, represents a low-accommodation fluvial system, with a high net-to-gross relative to both underlying and overlying strata. It is dominated by trough-cross stratified sandstone with frequent, but often discontinuous, mud and silt interlayers. Individual beds are laterally discontinuous and pinch out regularly, but both lateral and vertical amalgamation of sandy fluvial channel elements is common. Though this strata is overwhelmingly sand-rich in the study area, measured sections and photogrammetric modeling of this fluvial system show both spatial and temporal variations in the character and connectivity of these sands that have important implications in this and analogous systems in the subsurface. The studied outcrops are only 15 miles from the Trail Unit, which produces from this and other intervals of Cretaceous strata, and the high resolution variability seen in outcrops can better inform models of the subsurface in this and other fields.

Near the top of the Trail Member in the field area, sands are more laterally accreting and less vertically stacked, suggesting that accommodation was lowest at this time, leading to frequent avulsion and lateral migration of channels. In contrast, the majority of the stratigraphic section is composed of multi-story channel complexes sands that are vertically thick but generally less laterally extensive. Both of these configurations have very different reservoir implications, and ongoing work shows that these trends extend more regionally throughout the Rock Springs Uplift. In addition, within the exposed potential reservoir sands of the field area, key facies identified in outcrop show variability in both porosity and permeability. Through both large-scale observation of architectural elements and much finer-scale investigation of rock properties and facies relationships, it is shown that effective reservoir connectivity and drainage patterns can be much more complex than anticipated, even in a sandy high net-to-gross systems such as this.

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ABSTRACT

The Trail Member of the Cretaceous Ericson Sandstone, exposed along the length of the Rock Springs Uplift, represents a low-accommodation fluvial system, with a very high net-to-gross relative to both underlying and overlying strata. It is dominated by trough-cross stratified sandstone with frequent, but often discontinuous, mud and silt interlayers. Individual beds are laterally discontinuous and pinch out regularly, but both lateral and vertical amalgamation of sandy fluvial channel elements is common. Though this strata is overwhelmingly sand-rich in the study area, measured sections and photogrammetric modeling of this fluvial system show both spatial and temporal variations in the character and connectivity of these sands that have important implications in this and analogous systems in the subsurface. Near both the base and the top of the section in the field area, sands are more laterally accreting and less vertically stacked, suggesting that accommodation was lowest at this time, leading to frequent avulsion and lateral migration of channels. In the middle of the stratigraphic section, sands are generally less laterally extensive, and multi-story, vertically-stacked channel complexes are more common. The distribution of these multi-story sands is not random, but can be shown to be statistically clustered - we attribute this to autogenic processes. Detailed study of fluvial architecture within the Trail Formation shows that both autogenic and allogenic processes exert important controls on the distribution and connectivity of reservoir sands, and ongoing work shows that these trends extend more regionally throughout the Rock Springs Uplift. In addition, within the exposed potential reservoir sands of the field area, key facies identified in outcrop show important variability in both porosity and permeability. Through both large-scale observation of architectural elements and much finer-scale investigation of rock properties and facies relationships, it is shown that effective reservoir connectivity and drainage patterns can be much more complex than anticipated, even in sandy high net-to-gross systems such as this.

BACKGROUND



Figure 1. The age of the Trail Member is Late Cretaceous, ~85 Mya. The distance from the Western Interior Seaway is between 10-100 km. There is major influence from the Sevier Orogeny during this time as well.

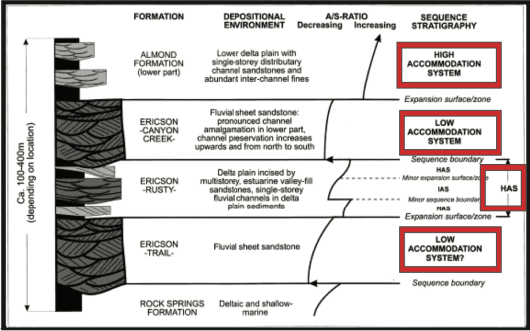


Figure 3. Stratigraphic model specifying type of accommodational system in Ericson Sandstone modified from Martinsen et al., (1999).

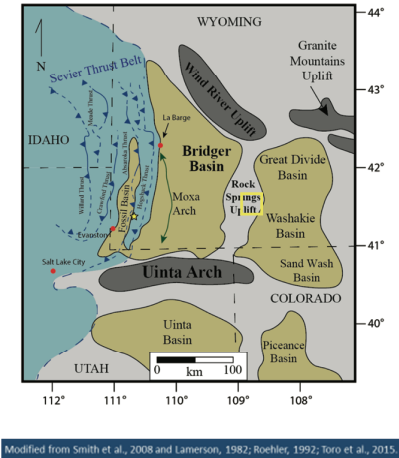


Figure 2. This regional map focuses on the orogenic induced basins near/around the Rock Springs Uplift contemporaneous with the Laramide orogeny. The location of our studies is in the southeast portion of the uplift (outlined in the map). The preferential drainage of the fluvial systems during this time was east-southeast to the Western Interior Seaway. Tectonic activity can be interpreted as a major factor in the interplay between high accommodation fluvial systems and low accommodation systems (see fig. 3). Low accommodation sands manifest as laterally accreting amalgated sands, whereas high accommodation sands are vertically stacking and less laterally extensive. The Trail Member shows both of these types of accommodation.

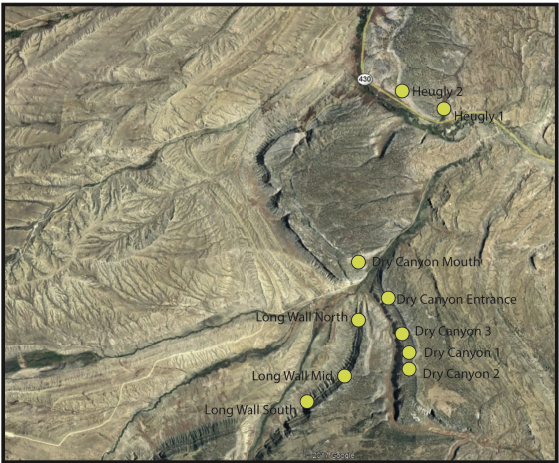


Figure 4. Google Earth image showing stratigraphic column locations.

FACIES INTERPRETATIONS

Facies 1: Massive Sandstone



Grain size: Fine - medium
Interpretation: Axial flow of channel with possible splays

Facies 2: Trough Cross Stratified Sandstone



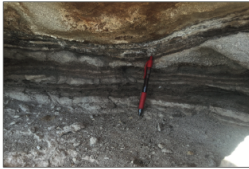
Grain Size: Predominately medium, occasionally fine grained
- Fluid escape structures and convolute bedding
Interpretation: Point bar laterally accretion

Facies 3: Heterolithic Sandstone/Mudstone



Grain Size: Medium sand with interbedded silt
- Laterally continuous interlayers range from 5 - 20 cm thick
- Rip up clasts in margins of underlying beds
Interpretation: Marginal setting of river

Facies 4: Laminated Mudstone



Grain Size: Mud - silt
- Represented by slope formers
- Iron concretions
Interpretation: Overbank mud deposits

Facies 5: Protosol/Paleosol



Grain Size: Powdery mess
- Rare occurrences of coal beds
Interpretation: Sub-aerial exposure

STRATIGRAPHIC CORRELATION PANEL

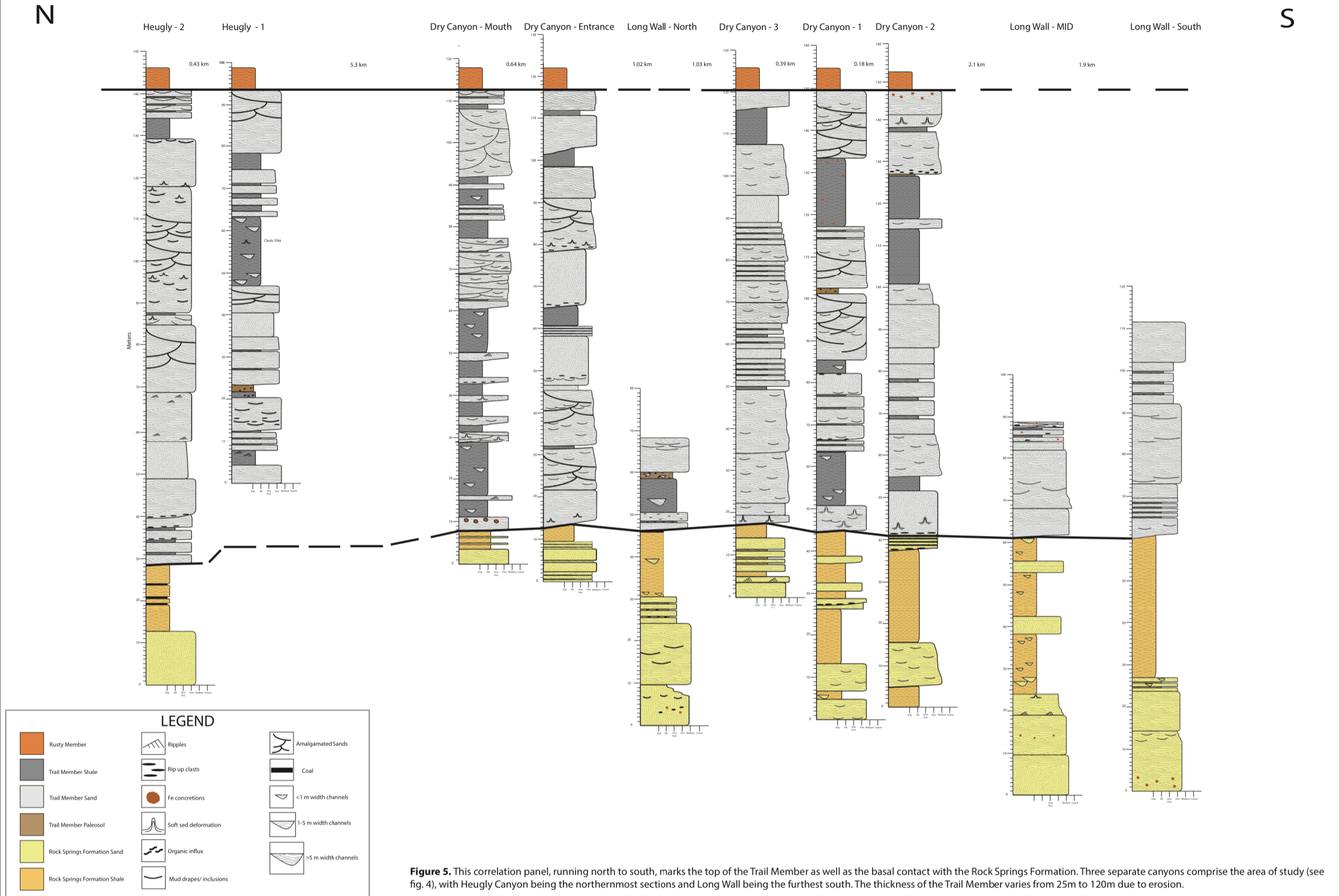


Figure 5. This correlation panel, running north to south, marks the top of the Trail Member as well as the basal contact with the Rock Springs Formation. Three separate canyons comprise the area of study (see fig. 4), with Heugly Canyon being the northernmost sections and Long Wall being the furthest south. The thickness of the Trail Member varies from 25m to 120m due to erosion.

NET TO GROSS STATISTICS

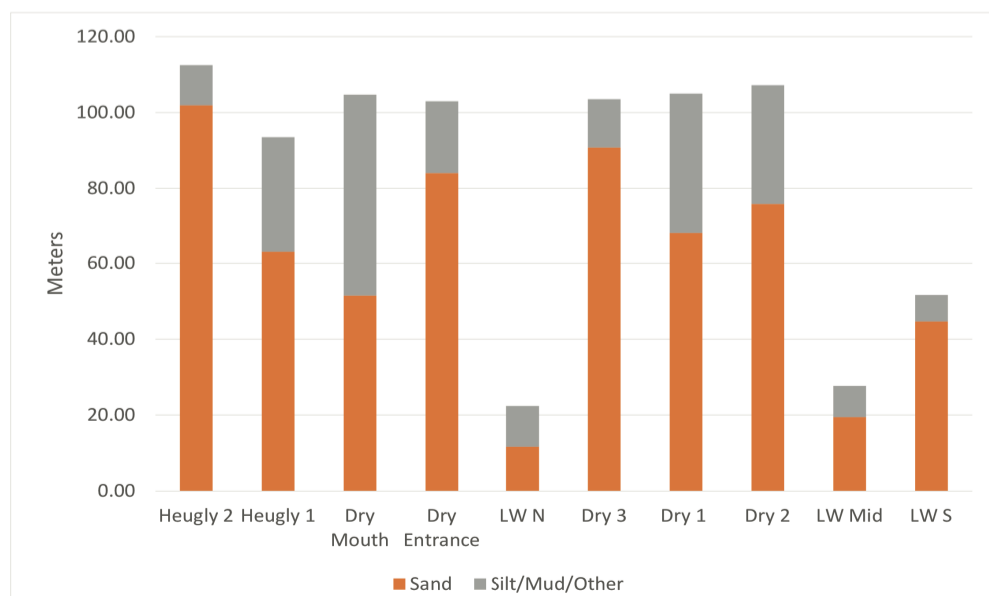


Figure 6. Net to gross on a multikilometer scale is variable with area's such as Dry Canyon Mouth and Dry Canyon Entrance contrasting each other (50%-80% respectively), even with their close proximity. Generally speaking the Net to Gross is high (50% or higher).

WIDTH/DEPTH STATISTICS

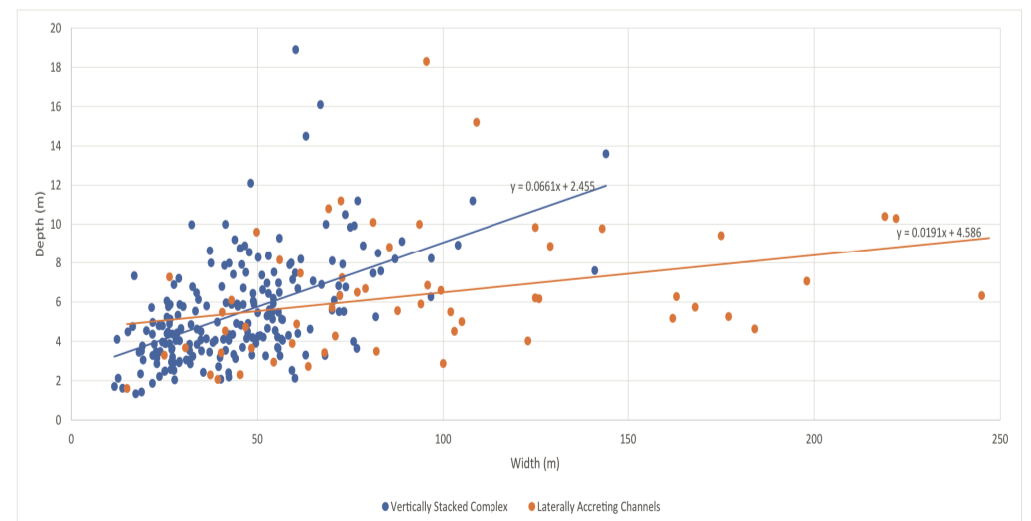


Figure 7. This width to depth chart combines both the northern and southern portion of Dry Canyon. The measurements were based on the photogrammetric analysis. These measurements represent 210 channels from the vertically stacking high accommodation section (blue), and 59 channel measurements from the low accommodation laterally accreting sands (orange). The trend shows that the width to depth ratio of the laterally accreting channels is higher than the ratio of the vertically stacked channels.

PHOTOGRAMMETRIC PANELS

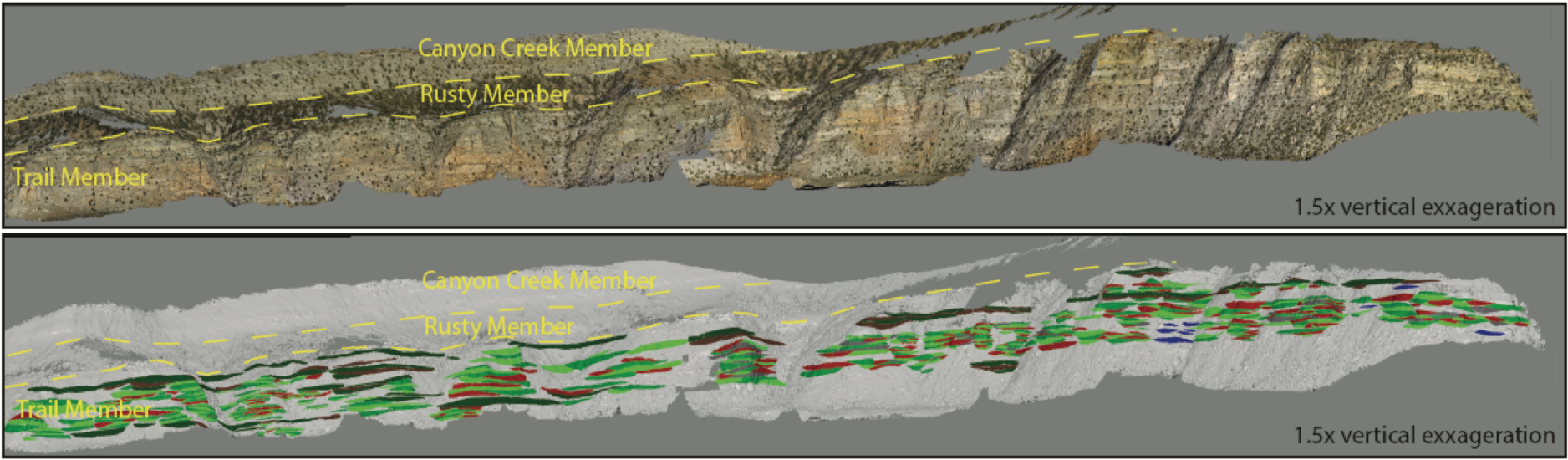


Figure 8. These two panels (1.5x exaggeration) represent the outcrop at Dry Canyon. The bottom photo panel shows both vertically stacked channels (light green, red) as well as the laterally accreting channels (dark green, brown). These and other photogrammetric panels were used to better understand spatial characteristics in the study areas as well as the data for width to depth statistics (see fig. 8). It was observed that the vertically stacked channels are spatially isolated while the low accommodation sands connect laterally with greater consistency.

DRY, HEUGLY CANYON CHANNEL CLUSTERING

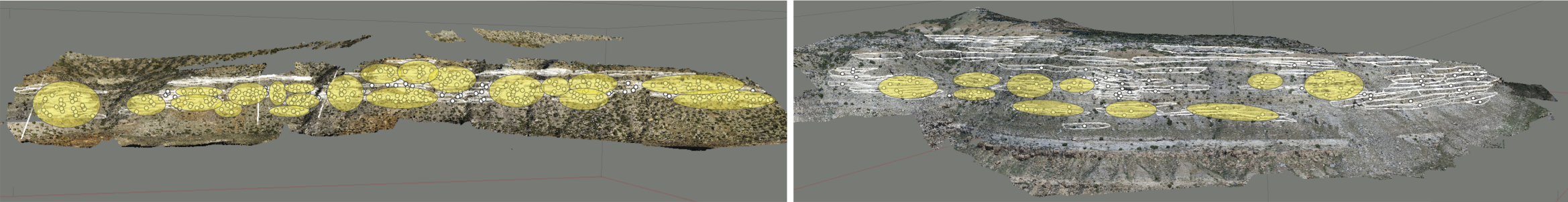


Figure 9. Both photogrammetric images shown (Northern Dry Canyon to the left, Heugly Canyon to the right) show preferential channel clustering patterns. Each cluster is outlined in a yellow ellipse and basic statistics were recorded based on the number of clusters, number of channels per cluster, total number of channels, and distance between each cluster (see statistics below).

CHANNEL CLUSTER STATISTICS FOR DRY, HEUGLY CANYONS

South Dry Canyon		North Dry Canyon		Dry Canyon (Composite)	
# Clusters	21	# Clusters	18	# Clusters	39
# Channels per cluster	10 to 22	# Channels per cluster	3 to 18	# Channels per cluster	3 to 22
Total # of Channels	335	Total # of Channels	221	Total # of Channels	556
Distance between Clusters (m)	20 to 70	Distance between Clusters (m)	10 to 80	Distance between Clusters (m)	10 to 80

Outside Heugly Canyon		Inside Heugly Canyon		Heugly Canyon (Composite)	
# Clusters	13	# Clusters	7	# Clusters	20
# Channels per cluster	3 to 15	# Channels per cluster	3 to 21	# Channels per cluster	3 to 21
Total # of Channels	108	Total # of Channels	96	Total # of Channels	204
Distance between Clusters (m)	10 to 90	Distance between Clusters (m)	20 to 60	Distance between Clusters (m)	10 to 90

CHANNEL CLUSTER INTERPRETATIONS

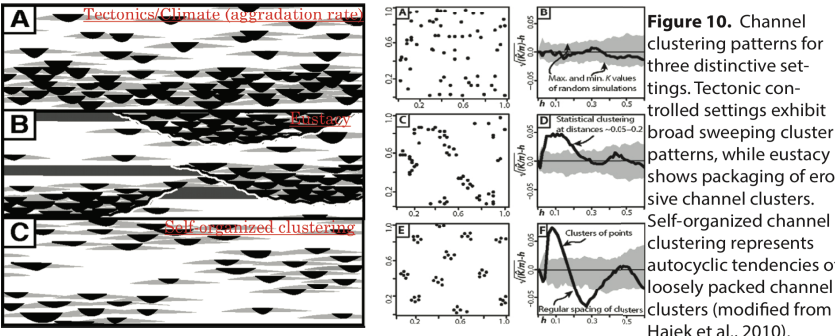


Figure 10. Channel clustering patterns for three distinctive settings. Tectonic controlled settings exhibit broad sweeping cluster patterns, while eustasy shows packaging of erosive channel clusters. Self-organized channel clustering represents autocyclic tendencies of loosely packed channel clusters (modified from Hajek et al., 2010).

CONCLUSIONS

- 1) The upper stratigraphic section shows lateral accretion of stream beds indicating a lower accommodation setting, while the middle section shows a higher accommodation setting with thicker, more isolated stacked channel systems.
- 2) Observations indicate a good reservoir rock, but silty interlayers could inhibit fluid flow.
- 3) The Trail Member of the Ericson sandstone is characterized by multi-story channel complexes, which show possible self-organized clustering patterns based off of cluster analysis.
- 4) However, important differences exist within different units most likely due to tectonic influence:
 - i) Low accommodation sands (during lower tectonic activity) are laterally continuous, but thin.
 - ii) High accommodation sands (during higher tectonic activity) are thick, but potentially more spatially isolated.
- 5) There is an observable change in Net-to-Gross on a multi-kilometer scale (Heugly and Dry).

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