

# **PS Tidal and Deltaic Influence in Storm-Dominated Prograding Shoreline Deposits – Implication Toward Reservoir Characterization\***

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## **Abstract**

The Upper Cretaceous Pictured Cliffs Sandstone of northern San Juan basin represents a storm-dominated prograding shoreline sequence deposited during the last regressive cycle of the Western Interior Seaway. The unit produces unconventional stratigraphic traps with the underlying Lewis Shale (offshore mudstone) and overlying Fruitland Formation (non-marine coal). Most of the sandstone units show evidences of tidal effects and distal deltaic deposits. In these instances, architectural element analysis of these reservoir sandstones reveals variations in internal architecture and petrophysical characters of the sandstone units.

Outcrop investigation of the Pictured Cliffs Sandstone reveals 14 different lithofacies. These lithofacies are grouped into 4 common lithofacies assemblages: 1) tempestite, 2) turbidites, 3) flood deposits, and 3) tidalites. In tempestites and flood deposit sequences, heterolithic sandstones and mudstones are noticed by cyclic and sharp grain size variation and are identified as rhythmites. These rhythmites are asymmetric which are commonly identified as mud-drapes produced by daily tidal cycles. Thin and thick tidal bundles also identify monthly tidal cycles (spring and neap tides). Increased fine grained particles in these sandstone units would greatly reduce porosity (by 50%) and permeability. Evidence for such reduction in porosity is revealed from thin section analysis which shows iron-rich clay rims filling the pore spaces.

Evidences of distal deltaic plain deposits were also found in the lower section of the Pictured Cliffs Sandstone. These deposits are identified by non-erosional base overlain by planar-laminated sandstone (Sl) or massive sandstone (Sm) often with soft-sediment deformation structures like load casts (Sld and Smd). There is no direct evidence of a delta in the Pictured Cliffs Sandstone in the study area. But, provenance analysis and paleocurrent study suggest that there was a fluvial system and a wave dominated delta located in close proximity, northeast of the study area. These flood deposits are generally homogenous, quartz rich sandstones and have a fairly high porosity and permeability.



# Tidal and Deltaic Influence in Storm-Dominated Prograding Shoreline Deposits – Implication towards

## Reservoir Characterization

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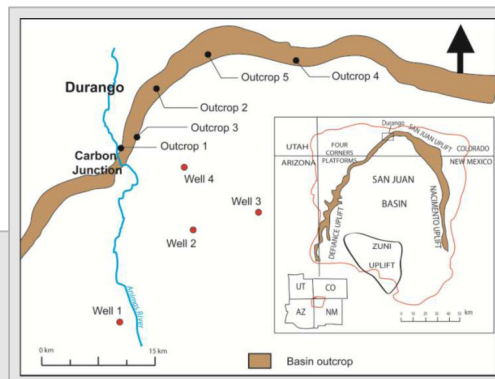
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### Introduction

The Upper Cretaceous Pictured Cliffs Sandstone of the northern San Juan basin represents a storm-dominated prograding shoreline sequence deposited during the last regression of the Western Interior Seaway. The unit produces unconventional stratigraphic traps with the underlying Lewis Shale (offshore mudstone) and overlying Fruitland Formation (non-marine coal). The sandstone units show evidences of tidal effects and distal deltaic deposits. In these instances, architectural element analysis of these tidal deposits and deltaic deposits reveals variation in internal architecture and petrophysical characters of the sandstone units.

Figure 1. Study area showing the outcrop sections and well locations, and structural features in San Juan Basin. Modified from Law (1992).



### Outcrop Investigation

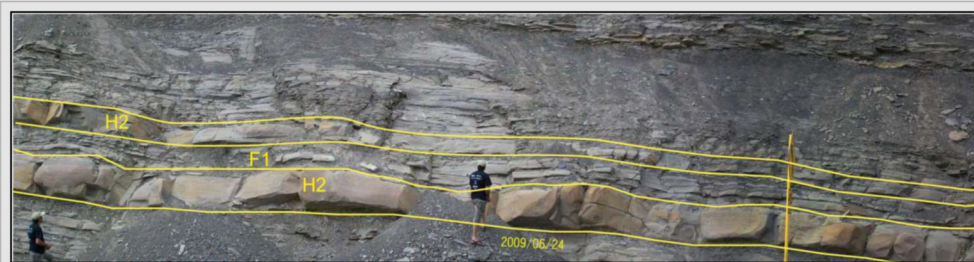


Figure 2. Photomosaic of part of outcrop 1 showing the two dimensional architecture of H2 (distal tempestite) and F1 (flood deposit) architectural elements representing offshore deposits below fair weather wave base. Notice that these are mostly sheet deposits.

- Outcrop investigation of the Pictured Cliffs Sandstone reveals 14 different lithofacies.
- These lithofacies are grouped into 4 common lithofacies assemblages.
- Eleven architectural elements are identified based on bounding surfaces and variation in lithofacies assemblages.



Figure 3. Hummocky stratification (*Sh*) the most predominant lithofacies.

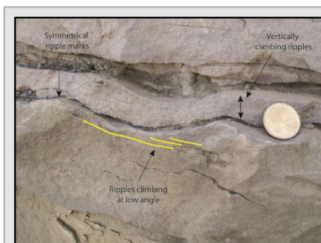


Figure 4. Symmetrical ripple marks and vertically climbing ripples (*Sr*).

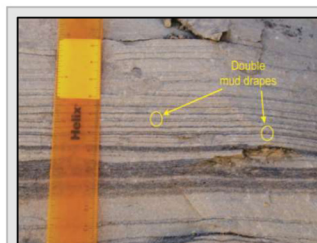


Figure 5. Heterolithic planar-laminated (*Sml*) lithofacies.

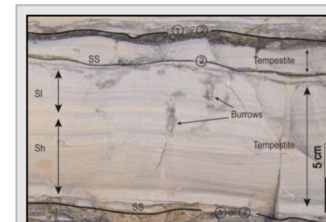


Figure 6. A tempestite (storm deposit) architectural element with numbers in circles representing the order of bounding surfaces.

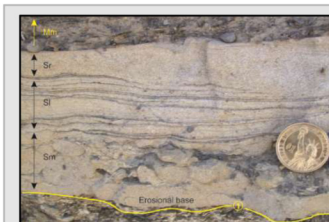


Figure 7. Turbidite lithofacies assemblage (architectural element) showing part of the Bouma sequence (Bouma, 1962).

### Evidence for Tidal Influence

- Heterolithic sandstones and mudstone are noticed by cyclic and sharp grain size variation identified as rhythmites.
- These rhythmites are asymmetric which are commonly identified as mud-draper produced by daily tidal cycles.
- Monthly tidal cycles (spring and neap tides) are also recognized by thin and thick tidal bundles.

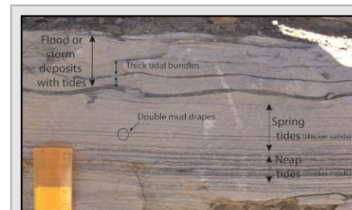


Figure 8. Tidalite deposit showing trends in thickness of sandstone and mudstone couplets interpreted to represent spring and neap tidal cycle (scale = 5 cm).



Figure 9. Storm deposit with a scour surface (yellow line) showing tidal influence. Notice the hematite staining due to sharp grain size variation (scale = 15 cm).

### Evidence for Distal Deltaic Influence

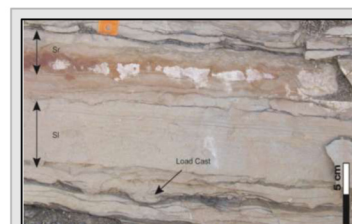


Figure 10. Planar-laminated sandstone (*Sl*) and ripple laminated sandstone (*Sr*) with load casts interpreted as flood deposits.



Figure 11. Planar-laminated sandstone (*Sl*) and climbing ripple-laminated sandstone (*Sr*) with non-erosional base interpreted as flood deposits.

- Though there is no direct evidence of a delta in the Pictured Cliffs Sandstone, evidences of distal deltaic deposits were found in the lower section of the Pictured Cliffs Sandstone.
- These are identified by non-erosional base overlain by planar-laminated sandstone or massive sandstone, often with soft-sediment deformation structures (load casts).
- This interpretation is supported by little grain size variation and angular nature of fine-grained sand (little reworking) of these deposits.

### Thin Section Analysis

- Point counts of thin section reveal flood deposits (massive or planar-laminated sandstones) and storm deposits (hummocky-stratified sandstone) have a porosity of 15 – 18%.
- Porosity of tidal-influenced flood and storm deposits range from 7 – 9.5% with fine grained mud filling in the pore space.
- Most of the quartz grains of the tidalites show iron-rich clay rims occupying the pore spaces.

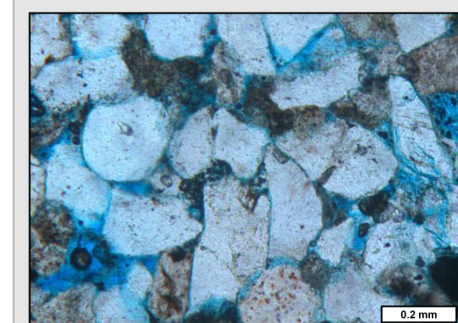


Figure 12. Thin section of a flood deposit. Notice that the void spaces are highlighted by the blue dye.

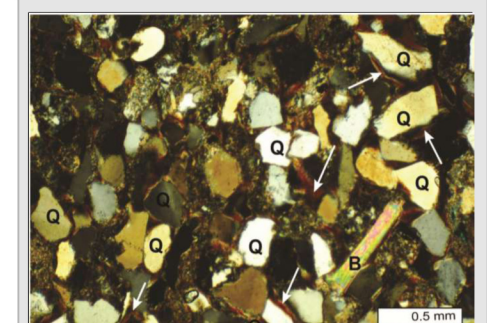


Figure 13. Thin section of a tidalite. Notice that most of the quartz grains are surrounded by clay rims (arrows).

### Conclusion

- Recognition of tidal rhythmites in tempestite and flood deposit sequences reveals higher level of stratigraphic complexity of the storm-dominated prograding Pictured Cliffs Sandstone.
- Provenance analysis and paleocurrent study along with distal deltaic plain deposits suggest that there was a fluvial system and a wave-dominated delta located in close proximity, northeast of the study area.
- In general, tempestite and flood deposit sequence show higher porosity, but tidal influences in these deposits can reduce the porosity by 50% by the inclusion of fine grained particles.

### Acknowledgments

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