

Recognition of a Sequence Boundary at the top of the Mississippian Midale Beds, Williston Basin of southeast Saskatchewan;

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The upper portion of the Midale Beds of southeast Saskatchewan were deposited in a Tidal Flat environment and show a great deal of variation in reservoir quality. They were vulnerable to erosion as a result of an extended period of exposure. Our model of deposition suggests that the carbonates prograded laterally as clinoforms and built up to sea level (Kent and Lake, 2012). The potential for preservation depends on the duration of exposure and the stability of the platform and sea level. This explains the thinning of the Midale Beds as we move eastwards from Weyburn - Midale towards Steelman Pool (Lake, 2001).

The cores on display give us an opportunity to review the evidence.

The top of the Midale Beds represents a Sequence Boundary since the package built up to sea level and was subject to exposure and erosion, similar to the modern Sabkha Faishakh in Qatar, Persian Gulf. (Illing and Taylor, 1993). The overlying Midale Evaporite represents the initial flooding event on the Sequence Boundary and was sourced from restricted circulation of sea water! (Harris and Kowalik, 1993). (Figure 2).

Early Mississippian Midale Beds (Visean) represents the initiation of Icehouse conditions as evidenced by glaciations in Gondwana (the present South America, South Africa, Antarctica, India and Australia) Crowell, 1999, Lopez-Gamundi and Butois, 2012. In addition, the continents of Laurasia and Gondwana were on a collision course to creating Pangaea. The timing was right for sea level changes by both Glacial and Eustatic/Orogenic origins. The collision of the continents created compressive conditions and stress which are recorded in the Midale Beds of southeast Saskatchewan. Northeast-trending lineaments were interpreted from the Top-Midale to Top-Mississippian Isopach map (figure 1) and show horizontal sinistral offset when superimposed on the Oilfields Map of Nickel and Yang, (2008). The fault system trends northeast with sinistral wrench faulting observed on the west side of Steelman Pool (displacement of approximately 20km.). This stress regime deviates from the north-trending Precambrian basement magnetic lineaments (Nemeth, et al, 2005; Morosov and Li, 2012) but is consistent with stress regimes in place since the Proterozoic. The lineaments of Oilfields follow the northeast orientation, including Post-Mississippian erosional Alida Formation remnants at Alida-Rosebank-Nottingham Pools and confirms they existed prior to the Laramide Orogeny. The thinning of the Midale Beds west of Steelman Pool resulted from differential vertical movement of this block. There is a low potential for preservation of Midale tidal flat dolomite reservoirs in areas of uplift.

In contrast to the subtle relief over much of Midale Beds Sequence Boundary, the Frobisher Sequence Boundary underwent severe erosion with significant section missing. If we assume similar thickness of facies in the Frobisher and Midale cycles, there is 15 meters of section not accounted for in the Frobisher at 11-32-4-4W2M. We attribute this to rapid sea level change from tectonic uplift (figure 4). The tidal flat package of the Frobisher (State A) underwent considerable erosion and is reduced to 1 meter in thickness. The Frobisher Evaporite represents the initial flooding event of the Midale Beds and represents a forced regression of facies towards the basin. Exposed and oxidized anhydrites overlie the sequence boundary. Shark Bay, Western Australia (Hamelin basin) is the depositional model (Harris and Kowalik, 1994) (figure 3). Erosion of the Frobisher Beds is much more severe in terms of the rapidity of the exposure. We go from an open marine platform to an abbreviated tidal flat with extensive erosion. This abbreviated Frobisher is attributed to tectonic uplift rather than sea level fluctuations from glacial activity because of the amount of section missing. The erosion at the sequence boundary proves that the overlying Evaporites are in fact the initial flooding events of the overlying sequences.

Conclusions:

The Tidal Flat and Sabhka Reservoirs of both the Frobisher (State A) and Upper Midale (Marly) are susceptible to erosion due to their vulnerability to exposure and hence represent sequence boundaries. The Frobisher and Midale Evaporites do in fact represent the initial flooding events of the Midale and Midale Evaporite sequences. Deposition of the Frobisher and Midale was influenced by sea level fluctuations associated with both tectonics (Laurasia-Gondwana collision) as well as the initiation of glaciation in the Icehouse conditions in Gondwana (Crowell, 1999; Lopez-Gamondi and Butois, 2010). The idea of preservation potential versus depositional models for tidal flat dolomite reservoirs gives us a different perspective for exploration. These ideas resulted from modelling depositional environments in conjunction with looking at the rocks.

The northeast-trending sinistral offsets occurred contemporaneously with sedimentation and are part of the continental collision history which has been going on since early Proterozoic. The Post-Archean collision of Superior-Churchill Craton with the Proterozoic Vavapai-Mazatzal-Grenville trend parallels the Laurentia-Gondwana collision, suggesting the stress pattern we see in the Williston Basin is older than Mississippian and is susceptible to reactivation. The Post-Mississippian Absaroka Unconformity event (Sloss, 1963) occurred at the Permian docking of Laurasia and Gondwana resulting in the supercontinent of Pangaea (which coincides with the Permian mass extinctions).

Acknowledgements

Thanks to Melinda Yurkowski and her staff at the Ministry of Energy and Resources, Saskatchewan Geological Survey, for their friendly help with cores and mapping. Thanks to Robert Norris (Straterra Inc.) for use of their digital core logging programme. Also, thanks to Alexis Anastas and the volunteers for organizing the CSPG Core Conference this year.

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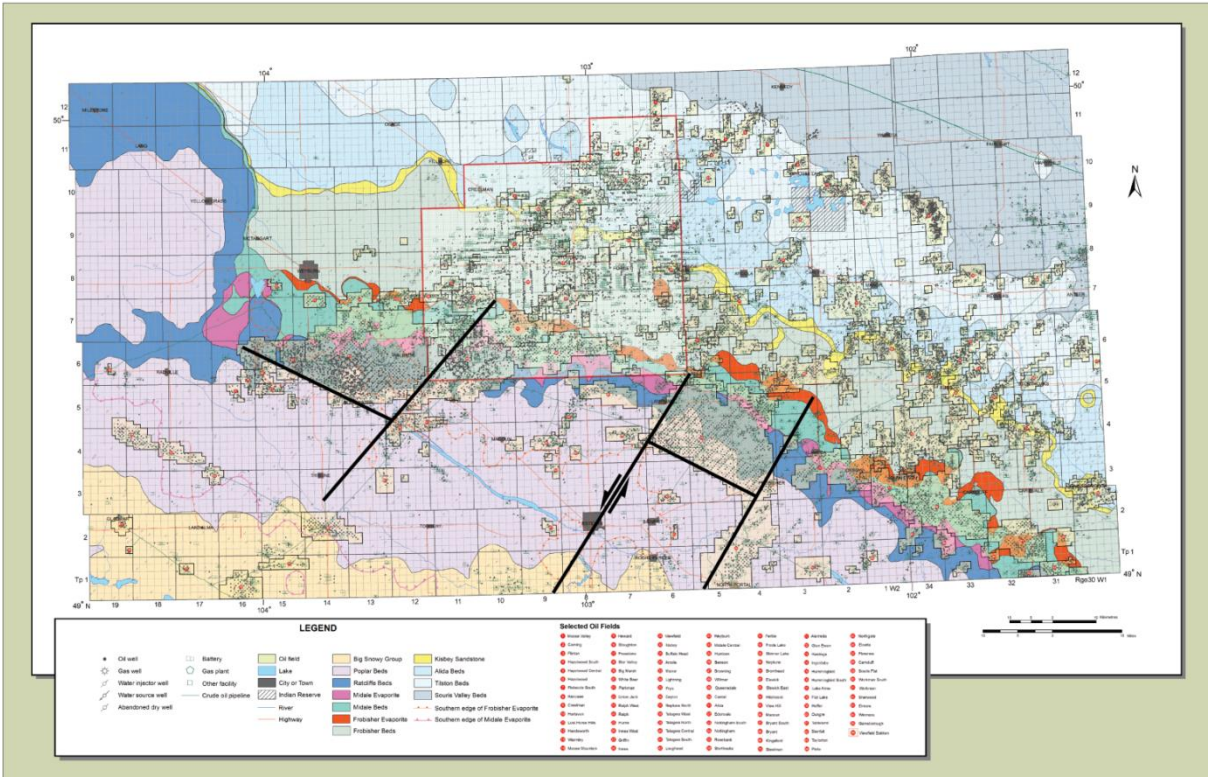


Figure 1
Lineaments superimposed on Oilfield Map of southeast Saskatchewan (Nickel and Yang, 2008). Sparse Midale production between Weyburn and Steelman Pools is caused by erosion at the Midale Sequence Boundary due to contemporaneous uplift.

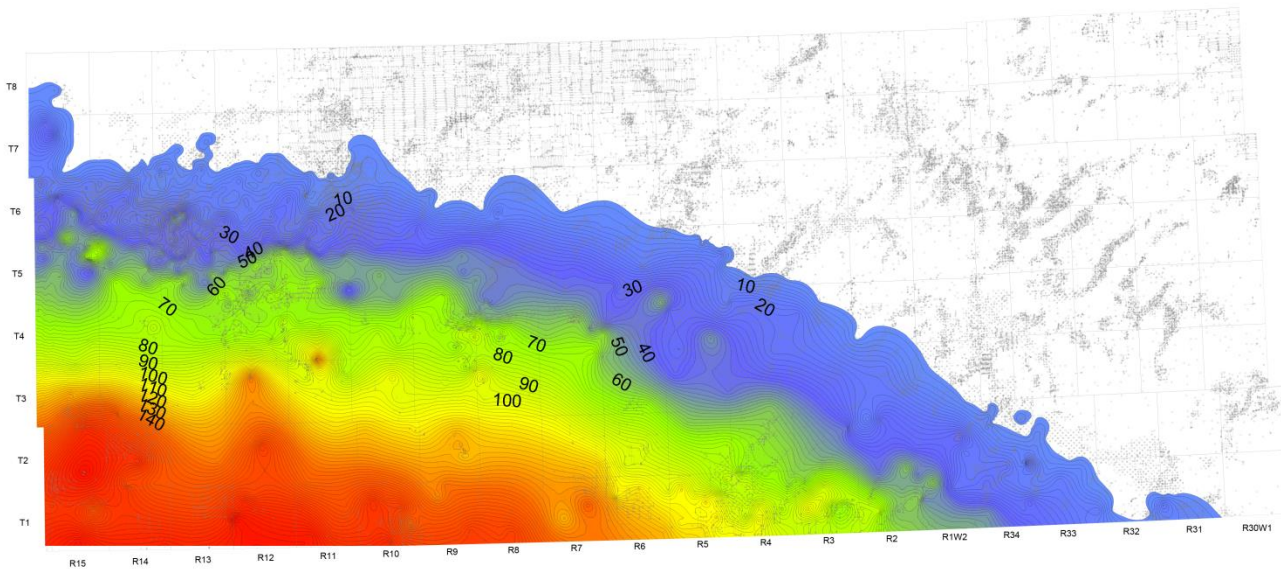


Figure 2
Upper Midale to Top of Mississippian Isopach Map of southeast Saskatchewan demonstrating significant lineaments. (2m contour interval- using TGI2 data tops.

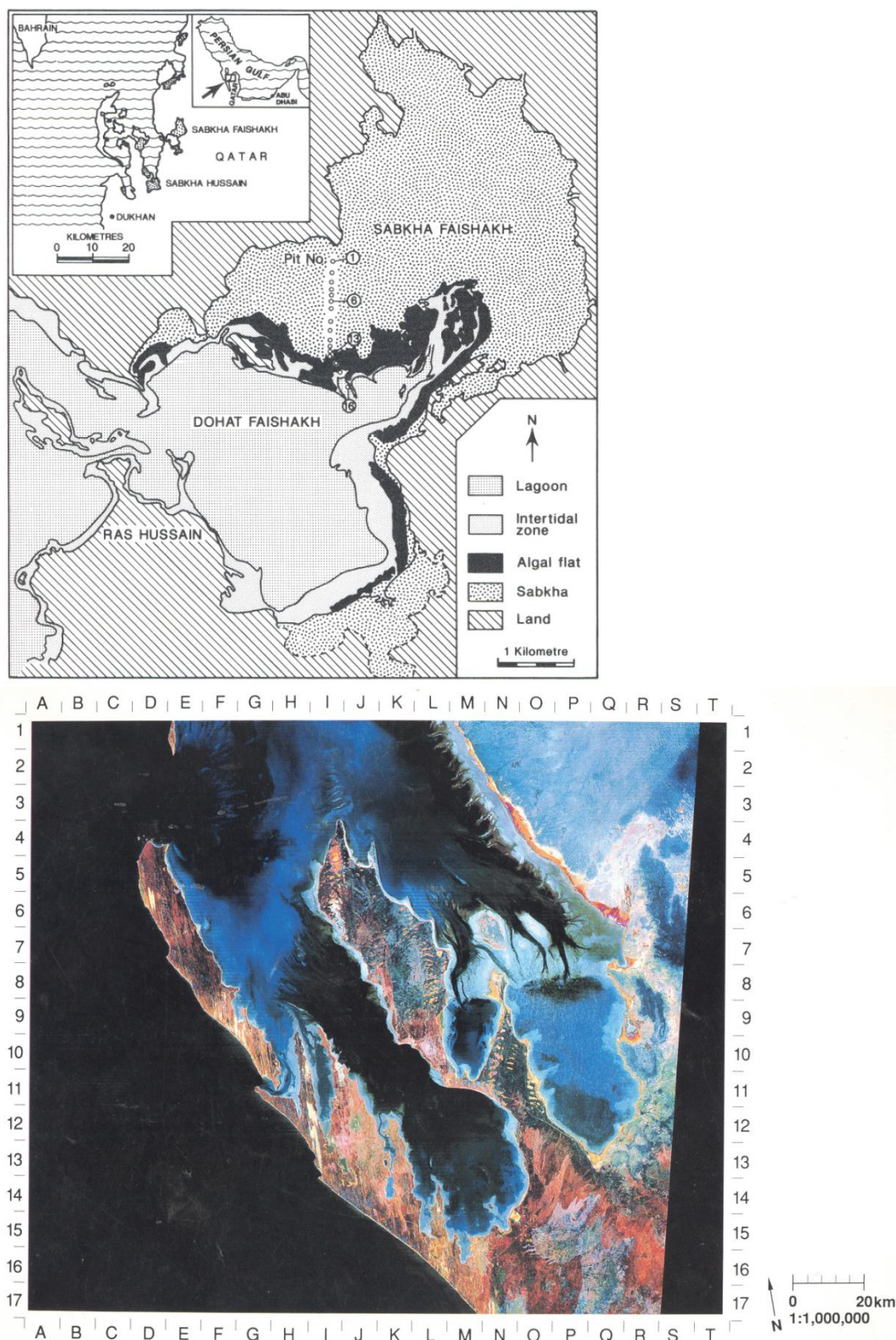


Figure 3

Map of Sabkha Faishakh, Qatar Peninsula is a modern analogue for the Midale carbonate tidal sequence boundary. The satellite image of Shark Bay, western Australia, emphasizes that flooding of the sequence boundary is mandatory for evaporate deposition.

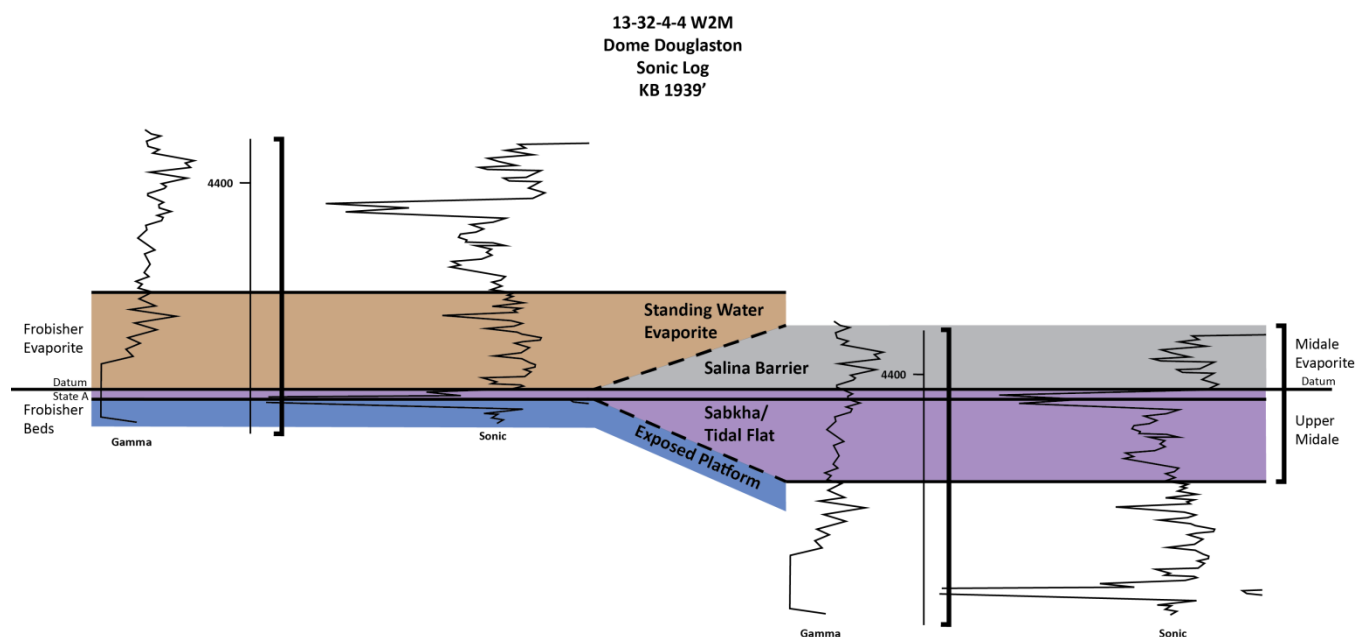


Figure 4

Comparison of Frobisher (left) and Midale (right) sections from the 13-32-4-4W2M Douglaston well. The Frobisher (State A) is missing about 15 meters of section in comparison to the Midale as a result of exposure and erosion on this sequence boundary.

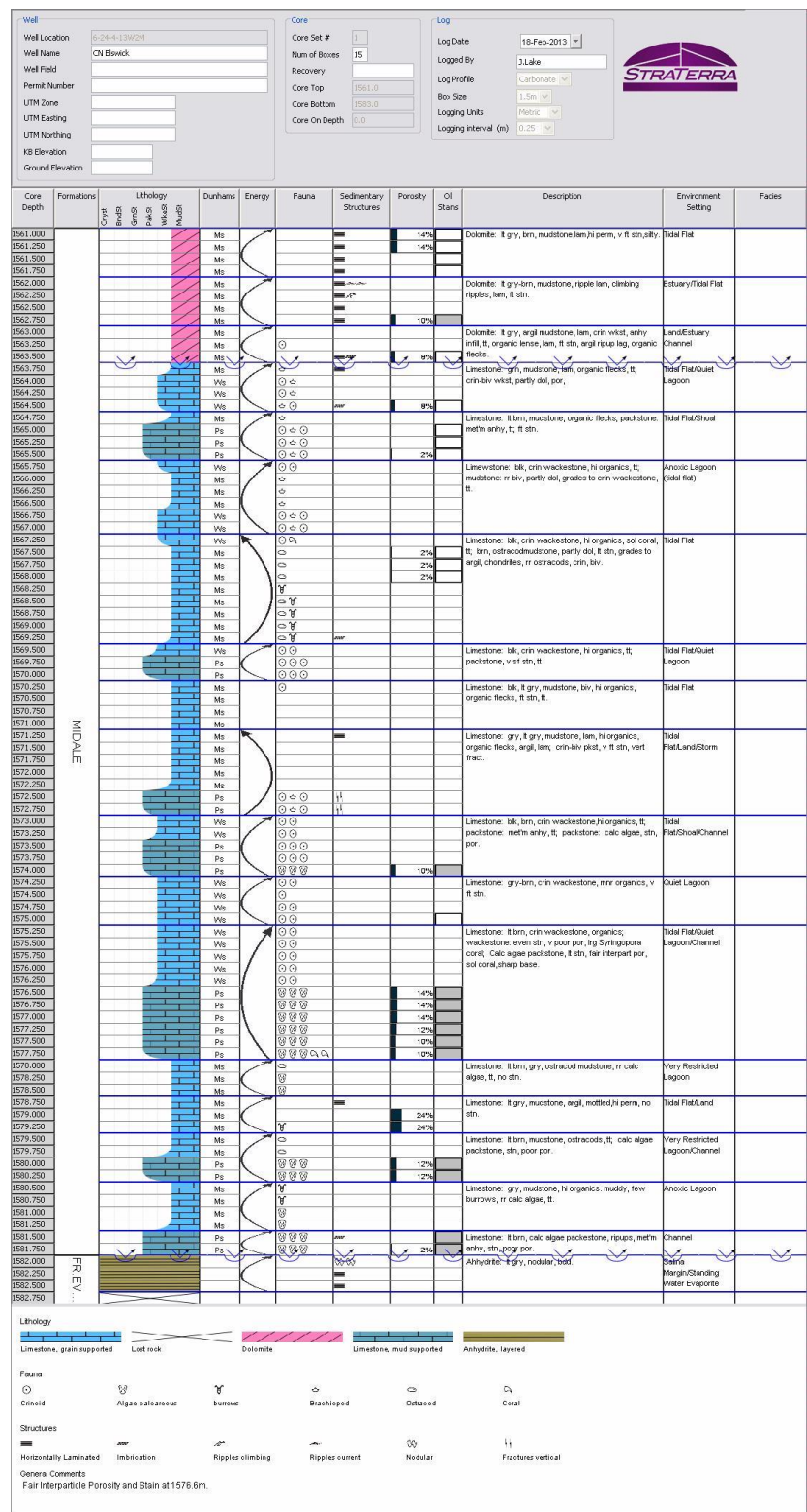


Figure 5
Core Description of 6-24-4-13W2M Elswick. showing continuous flooding from Frobisher Evaporite by channel facies of Lower Midale.. Sequence progrades (shallows up) to Tidaal Flat/ Sequence Boundary.

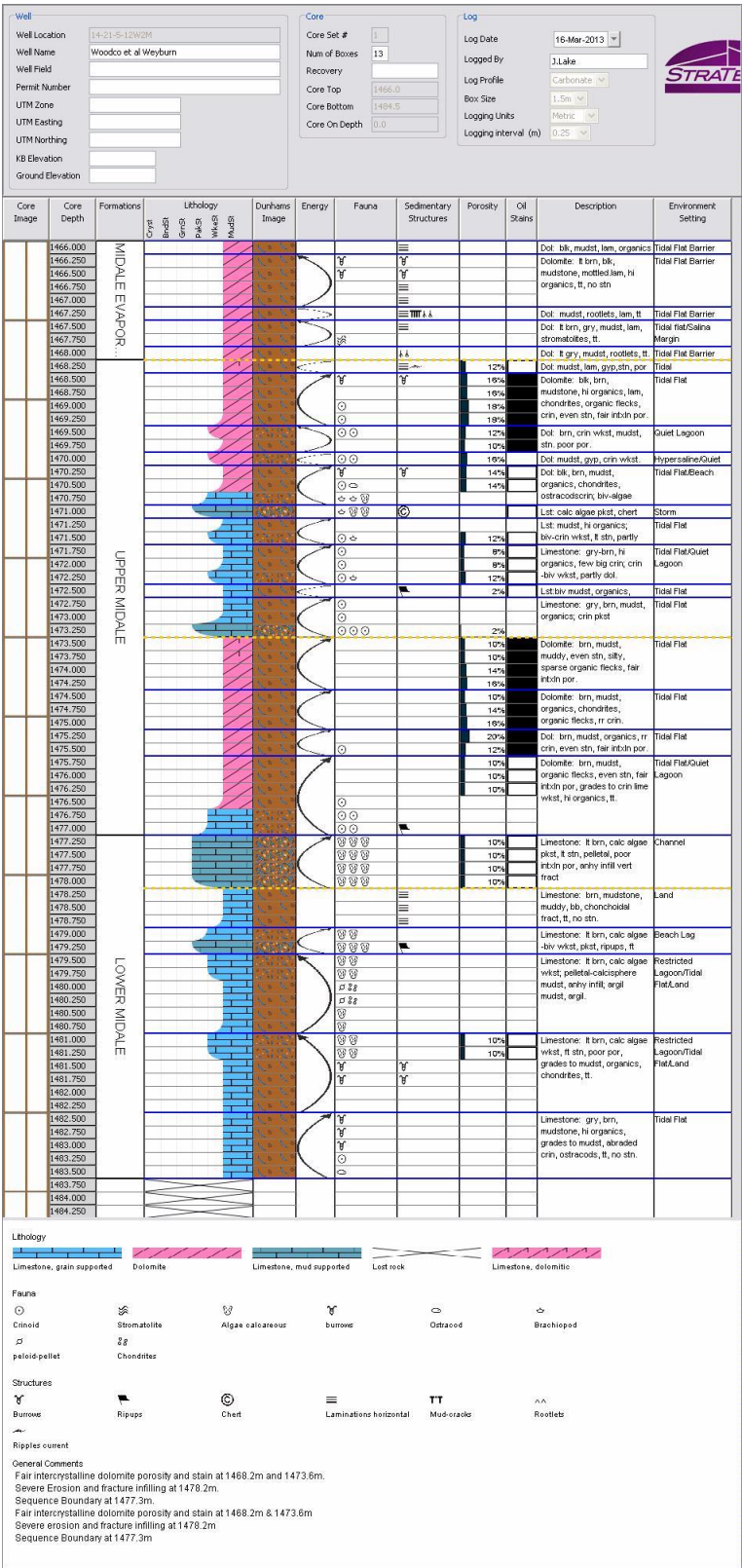


Figure 6

Core description for 14-21-5-12W2M Weyburn well showing subtle nature of Upper Midale Sequence Boundary. Overlying Midale Evaporite represents the initial flooding event of the overlying cycle.

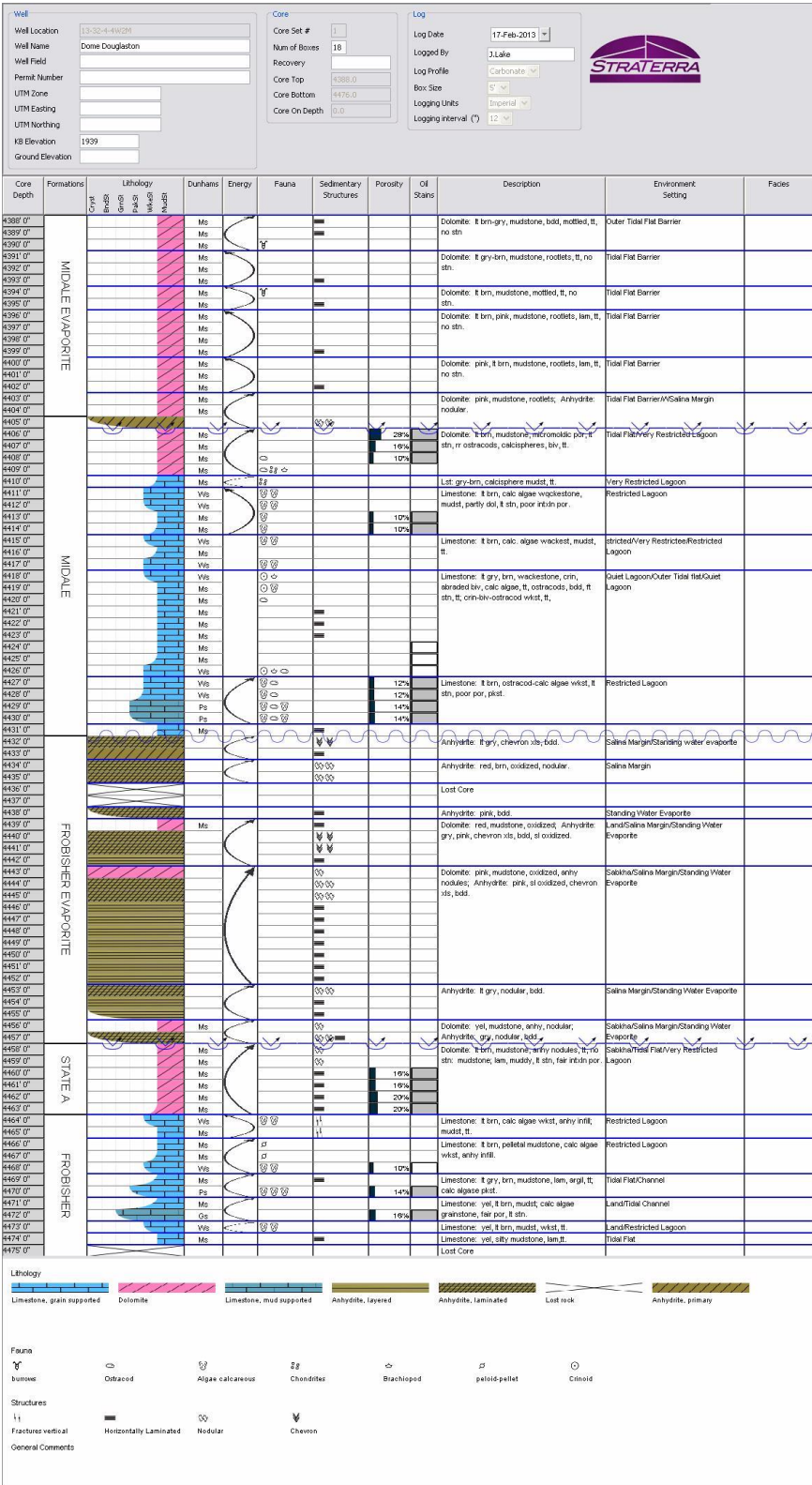


Figure 7
Core Description for the 13-32-4-4W2M Douglaston well. Section includes the Sequence Boundaries for both the State A and Upper Midale.