Impact of the Prairie Evaporite dissolution collapse on McMurray stratigraphy and depositional patterns, Shell Albian Sands Lease 13, northeast Alberta.

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Introduction

Throughout most of the Athabasca Oil Sands region, bitumen bearing sandstones associated with the Cretaceous McMurray Formation unconformably overlie Devonian carbonates and evaporates that have undergone extensive dissolution and collapse. Recent work indicates the dissolution and collapse took place beneath a relatively intact section of strata (Waterways Formation) and occurred in a progression of discrete phases that were active before, during, and after deposition of McMurray sediments (Stokes, 2014). The focus of this study is on how subsidence related to dissolution and collapse of the Devonian Prairie Evaporite impacted the stratigraphy and depositional patterns within the Cretaceous McMurray Formation. Understanding the relationship has a bearing on resource evaluation and mining through improvement in geologic models used to delineate ore and waste zones, as well as identifying focus areas for geo-hazard risk management.

Methodology

The interpretations presented in this work are based on detailed mapping of major stratigraphic packages within the McMurray Formation and to a lesser extent the underlying Devonian section. The mapping is based on borehole logs (gamma , dipmeter, etc) and core descriptions from over 3000 wells spaced at a distance of 100 m. Most wells extended a few meters (1-to-10 meters) into the underlying Devonian carbonates. However, six wells within the study area penetrated the entire Devonian section. A detailed discussion of those wells is provided by Mahood et al. (2012) and Stokes et al. (2014). Well to well stratigraphic interpretations were augmented by outcrop based interpretations from adjacent and evolving mine exposures as well as a series of 2D seismic lines located on the northern and eastern edge of the study area. The study area is roughly 200 square kilometers in areal extent encompassing the majority of Range 10W4 and R9W4 along Township 95.

Results

Sub-Cretaceous Unconformity

Topography on the surface is complex and composed of a series of orthogonally orientated ridges and troughs (SW-NE and SE-NW trend) that range in scale from a few hundred meters to a few kilometers in length /width. Relief on the sub-Cretaceous unconformity ranges from 150 m above sea level to 250 m above sea level and can vary by as much as 30 m between adjacent wells (100 m spacing). Small, circular, depressions, interpreted as surface karst features or sinkholes are rarely observed and occur around a small subset of wells.

Devonian Stratigraphy

Throughout the study area the sub-Cretaceous unconformity rest directly on top of the Devonian Waterways Formation. Marker beds within the Waterways formation show good correlation from well to well and parallel the sub-Cretaceous unconformity. With exception to small isolated areas interpreted as sinkholes the underlying Waterways Formation is generally intact and unbrecciated.

McMurray Stratigraphy

The McMurray Formation consists of an upward-deepening succession of fluvial, estuarine, and nearshore marine strata. Each major facies association is bounded at the base by a high relief erosion surface and referred to as lower McMurray (LM), middle McMurray (MM), and upper McMurray (UM), in ascending stratigraphic order.

The lower McMurray sequence is subdivided into a lower sand-rich fluvial system referred to as the LM1 and an overlying mud-rich unit, referred to as the LM2, which is composed largely of lacustrine mudstones, coals, and isolated channel deposits. The LM1 is a relatively continuous unit that ranges in thickness from 30 to 40 meters. Rather then onlapping the sub-cretaceous unconformity it extends uniformly across structural highs and lows except where it has been top truncated by the Middle McMurray unconformity.

In contrast to the LM1, the LM2 is largely confined to areas that overlie structural lows on the sub-Cretaceous unconformity. Thicknesses are usually between 20 and 40 meters but can reach 70 meters in places, especially in the eastern side of the study area. The unit tends to be thin or absent over structural highs on the sub-Cretaceous unconformity. The fill consist of a series of upward shoaling cycles that range in thickness from 5-10 meters and consist of a basal lacustrine mudstone/siltstone overlain by an upward coarsening succession of anastomosing fluvial deposits (levee, crevasse splay, channel), capped by a rooted mudstone or coal (paleosol).

The Middle McMurray sequence consists of a succession of tidally influenced estuarine deposits that ranges in thickness from 30 to 70 meters. Internal erosion surfaces subdivide the Middle McMurray sequence into units referred to as the MM1, MM2, and MM3 in ascending stratigraphic order. The MM 1 and 2 units consist of a transgressive succession of fluvial to estuarine channel deposits, where as the MM3 unit consists of a transgressive succession of estuarine channel to bay fill deposits. Incision of the MM1 unconformity is enhanced across areas where the LM2 is thin or absent.

Structure Features

A variety of faults, folds, and fluid injection features have been observed from mine exposures. Tilted strata are commonly observed within the Lower McMurray where the units drape across underlying Devonian highs. The degree of folding within the middle McMurray is much less severe but can be observed within the some of the MM3 bayfill deposits. Normal faults, displaying offsets from 1 to 10 m, have been seen in mine exposures. The usually occur within the LM2 and terminated within the basal part of the MM1.

Conclusions

Results from this work include the following findings:

1) Marker beds within the Waterways Formation demonstrate the complex morphology of the sub-Cretaceous unconformity is due to largely to differential subsidence within the underlying Devonian section rather than erosion associated with the overlying McMurray system.
2) Stratal relationships and thickness changes within the lower and middle McMurray indicate most the differential subsidence took place during LM2 time, a period which occurred after deposition of a basal fluvial deposit (LM1) but prior to the deposition of estuarine and marginal marine sediment associated with the middle McMurray (MM).
3) Structural features indicate differential subsidence during LM2 time occurred along a series of fault bounded blocks that were several hundred to several thousand meters in width and length. The finding is consistent with that proposed by Broughton 2013.
4) Total accommodation space created by salt removal and collapse during LM2 time was up to 80 meters in places.
5) Structural lows created by salt removal during LM2 time were filled by a system of lakes, swamps, and anastomosing fluvial deposits.
6) The distribution of coal- and mud-rich strata within the LM2 influenced the morphology of the overlying middle McMurray unconformity by inhibiting incision where the LM2 was thick and allowing incision where the LM2 was thin and easily erodible.

References

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