The Good, the Bad and the Ugly: Reservoir Heterogeneity in the Athabasca Oil Sands, Northeast Alberta

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INTRODUCTION & BACKGROUND

Detailed sedimentological and stratigraphic analysis of over 80 outcrops, 140 cores and over 6000 well logs allows for a better understanding of the Athabasca oil sands deposit, hosted primarily by the McMurray Formation in northeastern Alberta. Revised informal stratigraphy includes the Lower McMurray fluvial succession, and the Upper McMurray estuarine and coastal plain succession. Facies mapping on a regional scale, involving lithofacies analysis of outcrops and cores, well log analysis, regional mapping, and comparisons with modern analogues, shows a marked reservoir heterogeneity within the formation.

Units within the Lower McMurray, interpreted as part of a fluvial lowstand systems tract, host rich bitumen- and water-sand reservoirs that accumulated as incised paleovalley-fills cut within the karstic pre-Cretaceous landscape. Lower McMurray bitumen reservoirs include braided channel-and-bar sands and mudstone intraclast breccias. Within paleolows along the pre-Cretaceous unconformity are laterally extensive basal water-sands. Elsewhere, are thick mudstone and clay-plug fills, as overbank, lacustrine and abandoned channel complexes.

The Upper McMurray succession of the overlying transgressive system tract contains rich bitumen reservoirs, hosted primarily within estuarine channel-and-point bar complexes that are often stacked above the Lower McMurray channel sands. Locally in some areas, other bay-fill and coastal plain successions are preserved within the Upper McMurray succession, particularly in South Athabasca. These bay-and-barrier island complexes are often mudstone

dominated at the base, coarsening upwards into wave-dominated lower shoreface, and parallel-laminated upper shoreface/shoreline sediments. Rich bitumen reservoirs occur within the coarser-grained, better-sorted, shoreline deposits.

Local water sands occur near the base of the Upper McMurray, along the disconformity between the Lower and Upper McMurray successions. Thick mudstones occur as abandoned channel fills, locally extensive basal bay-fills, and overbank sediments. More extensive coastal plain sediments are preserved in Athabasca North, some of which have laterally continuous coal markers; elsewhere thick, and less continuous coals are isolated in topographic lows associated with salt-collapse features. Gas reservoirs occur in the upper parts of the succession, particularly along the Prairie Salt Scarp, and associated with combined stratigraphic-structural traps.

RESERVOIR HETEROGENEITY & SAGD

The success of Steam-Assisted Gravity Drainage (SAGD) in the extraction and development of the bitumen resources at Northstar's Dover project (formerly called the AOSTRA Underground Test Facility, or UTF site) has led to the emplacement of a number of other SAGD pilot schemes in the oil sands of northeast Alberta. Other successful SAGD schemes have resulted in commercial production in the Tia Juana field of Venuzuela.

Some potential bitumen reservoirs, particularly in the Athabasca deposit, may be unsuitable or uneconomic for SAGD extraction. This is due to primarily to the presence of various reservoir heterogeneities within the oil sands deposit, including thin bitumen sands with low porosity and low permeability, basal water zones, top or internal thief zones, and mudstones, as interbeds or breccias, that may locally impede or baffle steam flow.

The following core display illustrates a number of reservoir heterogeneities that have been observed in core during regional assessment of the oil sands by both industry and government. The recognition of such reservoir heterogeneities should be considered when assessing an area for future SAGD schemes, both by industry for future exploration and by the government for future regulation of the growth of SAGD plants and other in-situ schemes.

RESERVOIR HETEROGENEITY AS SEEN IN CORE DISPLAY

This core display highlights the range of reservoir heterogeneity within the McMurray Formation (Athabasca oil sands deposit) and shows many of the features in core that have been successfully used by both the Alberta Geological Survey and industry in subsurface-outcrop correlation and prediction of regional trends. These include:

1. Cores near the salt scarp that have “apparently poor pay” on well logs, due to saline influx of formation waters, but in fact have very good to excellent bitumen pay when seen in core.

2. Bitumen channel sands in close proximity with mudstone plugs interpreted as vertical-accretion abandoned channel fills.

3. Poor reservoirs, with irregular bitumen-water contacts, within interbedded and chaotically bedded karstic fill of mixed sand and limestone associated with the pre-Cretaceous unconformity.

4. Continuous sand-on-sand contacts within good bitumen reservoirs (‘chimney wells”) interpreted as stacked estuarine channel fills of the McMurray Formation, overlain by gas reservoirs of the Wabiskaw/McMurray succession.

5. Mudstone intraclast breccia zones within the McMurray Formation that appear as poor to very poor reservoir on logs, but in fact are good to excellent bitumen pay as seen in core.

6. Water-sand trends as seen in core and log, including both basal and top water contacts with bitumen reservoirs.

CONCLUSION

In the past regional mapping schemes have not typically assessed possible effects of reservoir heterogeneities on the efficient recovery of bitumen or heavy oils in the oil sands areas. The recognition of such reservoir heterogeneity may have impacts on future reserve estimates for in-situ areas, as well as impacts dealing with improved methods for design and emplacement of SAGD plants.