Detailled Architecture of Deepwater Sheet Sand and Associated Fine-Grained Sediments: Example from the Upper Kaza Group, British Columbia

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Deep Marine Sheet-Like Deposits

In recent years, exploration for hydrocarbon as shifted to the deep-sea realm. Although deep marine turbidites systems are known to contain large volume of oil and gas, little is known about the detailled architecture of the sheet sand deposited on the middle and outer part of a submarine fan.

There are numerous examples of sheet sand deposits in the literature, but our knowledge is limited by restricted outcrop exposure or by the resolution of seismic data. Even in areas where exposure of deep-sea or basin-floor sediment is deemed good, such as the Tanqua Fan (Wickens and Bouma, 2000) or the Jackfork Formation (Coleman *et al.* 1994), work is often limited to correlation between widely spaced stratigraphic logs or to continuous exposures well below the size architectural elements of modern fans.

Because the emphasis has been put on the wide-scale architecture, the distribution of mudstone beds and small-scale features such as injections and dewatering structures in sandbodies has been somewhat forgotten. However, they are of great importance as they dictate reservoir compartmentalization and hydrocarbon flow, and therefore recovery.

The Upper Kaza Group

The Upper Kaza Group is a deep-water, sand-rich succession included in the Neoproterozoic Windermere Supergroup (Meyer, 2004). Detailed architecture of a totally exposed, 650 m wide and 100 m thick section is at the head of the Castle Creek in the Cariboo Mountains of British Columbia was determined by bed-by-bed correlation of nine, 100 m long stratigraphic logs. In order to limit the correlation errors, 17 marker horizons were identified and traced on the outcrop. Several shorter logs were measured at a 25 to 30 meters spacing in some of the fine-grained intervals in order to evaluate bed continuity.

The sand-rich deposits of the studied section were divided in two type of intervals based on net-to-gross ratio: the sheet sands and the fine-grained intervals.

Sheet Sands

Sandstones in the studied part of the Upper Kaza Group were regrouped into 8 sheet sands ranging from 2 to 23 meter in thickness. Each sheet is composed of several stacked sandstone beds averaging 65 cm in thickness and have a N:G ratio between 94% and 99%. Sandstones are composed of moderately sorted medium sand. The majority of the sandstones beds are graded (Ta) with common planar laminations (Tb) indicating deposition by turbidity currents (Mulder and Alexander 2001). Less than 20% of the beds show the entire Bouma sequence. Structureless sandstone beds are also found and were deposited by hyperconcentrated density flow (Mulder and Alexander 2001). These massive beds grades laterally into turbidites and have a convex-upward shape. Mudstone fragments are ubiquitous and can be found at the base, middle (floating clasts) and top fo the beds. Dewatering structures were observed, but do not constitute a common feature in the sheet sands.

The different flows were erosive enough to enable scouring of the underlying beds. Therefore, the thin Td and Te are locally removed, resulting in sand-on-sand contacts. Although erosional features are common, there are no incisions deeper than 2 meters. Perfectly amalgamated beds are also present.

Fine-Grained Intervals

The sheet sands are interlayered with 7 fine-grained intervals that are continuous over the 650 m width of the outcrop, except for three that are locally brecciated. Thickness of the fine-grained intervals varies between 20 cm to 2 m and the N:G ratio between 5% and 36%. Where relatively thick, the fine-grained intervals are composed of several fine-grained turbidites dominated by Td and Te with few Ta, Tb and Tc and thin sandstone beds with entire or partial Bouma sequence. The sandstone beds are composed of fine to medium sand. Most of the sandstone beds are lenticular and become ripple train or sand layers thinner than 1 cm. Breccias are also common.

Most of the individual mudstone beds appear to be continuous for the width of the outrcop. There are however, few occurences of soft sediment deformation, brecciation and injections that breach, at least partially, what would otherwise be effective seals.

Implications for Reservoir Modelling and Future Work

Using seismic data, a 100 m thick sheet sand would show as fairly massive, but would look extremely complex when cored. In the Upper Kaza Group, only 10% of mudstone intervals are continuous, at least for 650 m (in 2D). However, it appears that fairly thin intervals (less than 1 m) can form continuous barrier.

In order to improve our ability to predict sandstone connectivity, a few more questions need to be answered. What controls mudstone thickness and continuity, lobe abandonment or sea-level rise? Can we differenciate the two processes? How do sedimentary processes affect sandstone stacking and removal of mud? How would such a complex deposit show up on seismic line? Can we develop a stochastic model to predict mud distribution and eventually hydrocarbon flow?

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