GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

Facies analysis of thin-bedded reservoirs in mixed-influenced deltaic systems and implications for halo plays

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Summary

Detailed millimetric to centimetric, bed-by-bed facies analysis allows quantification of the relative importance of depositional processes in prodelta heterolithic deposits as well as the along-strike variation in ancient delta systems. These thin-bedded heterolithic deposits contain significant sandstone and are volumetrically important zones of bypassed unconventional pay surrounding many conventional deltaic reservoirs. The nature of these halo-plays may vary lateral and systematically within a parasequence, especially in mixed river and wave influenced asymmetric deltas, but can also vary between parasequences within clastic wedges, such as the Dunvegan Formation, where wave-dominated shorefaces alternate with lobate, river-dominated deltas. Examples of varying heterogeneity in thin-bedded reservoirs are illustrated from storm, river, and tide influenced deltaic systems.

Introduction

Despite the historical assumptions that most marine “shelf” mud is deposited by gradual fallout from suspension in quiet water, recent studies of modern muddy shelves show that they are dominated by hyperpycnal fluid mud (e.g. Bhattacharya and MacEachern, 2009). Flume work shows that bedload transport is critical in the deposition of mud, and storm-wave aided hyperpycnal flows are common on many modern muddy shelves (Schieber and Southard, 2009). These ideas have been applied to the interpretation of mud-rich prodelta deposits of the Cretaceous Western Interior Seaway depositional systems of North America to evaluate the variability of processes and facies both within and between parasequences. This has implication for variability and heterogeneity of halo plays in the Western Canada Sedimentary Basin associated with conventional deltaic reservoirs, such as the Dunvegan, Belly River, Cardium etc.

Method

Detailed millimetric to centimetric, bed-by-bed facies analysis of cores and outcrop data allow individual beds to be characterized according to their sedimentary structures, lithology, and degree of bioturbation. Sedimentary structures or sequences of structures can be used to distinguish process that deposit beds. The bioturbation index can be used as a proxy for sedimentation rate and typically decreases with increasing river influence. These processes can in turn be lumped such that a given prodeltaic facies succession can be characterized according the degree of wave, river, and tidal influence. These differences are quantified across a number of study areas to evaluate lateral facies variability in a given parasequence. Detailed measured sections, at centimeter-scale, allow the relative proportion of sedimentary and biogenic structures generated by each depositional process/event to be calculated. These were measured from a series of stratigraphic sections within a mixed wave and fluvial dominated parasequence, exposed continuously exposed along depositional strike. Outcrop examples allow continuous tracking of lateral heterogeneity at interwell distances and may be useful for characterization of halo-play reservoirs.

Examples

Examination of prodeltaic parasequences in outcrops of the Upper Cretaceous Ferron Sandstone in Utah shows deposition by ignitive turbidity currents, hyperpycnal flows, storm surges, as well as complete bioturbation in areas away from river-influence (Li, 2013, Seepersad, 2012). Ignitive turbidites show fining upward Bouma sequence, hyperpycnites show either inverse or normal grading, and storm deposits (tempestites) fine upward and contain hummocky cross stratification (HCS) capped by wave ripples. Ignitive turbidity currents and hyperpycnal flows indicate fluvial-dominated depositional environments, whereas tempestites are linked to storm-wave dominated environments. In the Ferron Sandstone outcrop examples, parasequence shows marked along-strike variation with a completely wave-influenced shoreface environment in the north, that contains minimal thin-beds, passing abruptly, over a few kilometers, into a fluvial-dominated area, that covers a lateral distance of about 10 km, with a thick heterolithic prodelta, and this then passes into an environment with varying degrees of fluvial and wave influence southward, and back to a wave-dominated environment further to the southeast. The depositional model of the parasequence is therefore interpreted as a storm-dominated symmetric delta with a large river-dominated bayhead delta system with consequent depositional variation in the associated inner shelf prodeltaic facies.

Core examples from the Dunvegan Formation in Alberta show a dominance of river-derived turbidites and hyperpycnites with some tempestites, especially in more wave-dominated parasequences. The Frewen's Allomember in Wyoming shows an abundance of prodeltaic tidalites that have a relatively uniform character across several kilometers. The tidal example shows thin beds with alternating fine-to medium grained rippled sandstones alternating with claystones, which may represent fluid muds.

Conclusions

It is practical to quantify the relative importance of depositional processes and determine the along-strike variation within thin-bedded heteroliths in ancient delta system using thin-bedded facies analysis, which has implications for along-strike heterogeneity of thin-bedded reservoirs. Thin-bedded heterolithic deposits contain significant sandstone and are volumetrically important zones of bypassed unconventional pay surrounding many conventional reservoirs. The nature of these halo-plays may vary laterally and systematically within a parasequence, especially in mixed river and wave influenced asymmetric deltas, but can also vary between parasequences within clastic wedges, such as the Dunvegan Formation, where wave-dominated shorefaces alternate with lobate, river-dominated deltas.

Acknowledgements

This work was funded by the McMaster-UH Quantitative Sedimentology Laboratories Consortium, including BP, Ecopetrol and Inpex and an NSERC Discovery Grant to Bhattacharya.

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