Differentiating Deep-Marine Overbank from Crevasse Splay Deposits in Outcrop: an Example from the Windermere Supergroup, Castle Creek, British Columbia

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Introduction

Deep-marine rocks are typically exposed in orogenic belts where mountain building processes commonly complicate or completely obliterate the primary sedimentary features and make stratal relationships equivocal. Mud-rich facies, such as interchannel deposits, are particularly susceptible to metamorphic and structural modification. Further complicated by surface cover and inaccessibility, good quality outcrop analogs for deep-marine interchannel deposits are uncommon in the sedimentary record. Castle Creek, however, is an easily accessed, thick succession of vertically dipping deep-water strata wherein interchannel deposits, including the fine-grained fraction, are superbly exposed. This outcrop presents a rare opportunity to make detailed millimetre- to decametre- scale sedimentological and stratigraphic observations. Although these strata are in fact metamorphic rocks, the low grade of metamorphism has had negligible effect on primary sedimentological attributes, and as a consequence the term used here.

Figure 1: At the Castle Creek study area, east-central BC Canada, deep-marine siliciclastic rocks of the Neoproterozoic Windermere Supergroup are well exposed adjacent to a rapidly retreating glacier. General direction of sediment transport was to the northwest.

Two architectural elements that comprise interchannel deposits are overbank and crevasse splay deposits. Both are typically observed on the outer bends of sinuous leveed-channel systems where energetic sediment gravity flows escape the confines of the channel. Anomalous large magnitude flows that overtop the levee and deposit in the distal levee form overbank splays whereas those that breach and incise the levee form crevasse splays. Based on seismic examples from the literature, overbank splays are typically an order of magnitude or more smaller than crevasse splays, being 100's of m² compared to several km², respectively (eg. Postmentier and Kolla, 2003).

Overbank Splay Deposits

Two end member kinds of overbank splays are recognized: isolated beds and multiple bed complexes. Isolated beds are well sorted, medium grained Tabcd, but more commonly Tbcd or Tbd turbidites. Typically the planar laminated division is generally ungraded, anomalously thick, comprising 75-90% of the bed, and capped by a single ripple cross-stratified set or formset. Isolated beds occur as a single or at most three bed assemblage of thick to very thickly bedded (40-200 cm) sandstone turbidites encased in thin to very thinly bedded turbidites. Bed bases are sharp, planar, non-erosive to shallowly scoured (less than 10 cm), and hence beds have a tabular geometry. Lateral thinning and a facies change from planar to ripple laminated sandstones is observed rarely. Multiple bed complexes extend up to 1000 m laterally, range from 2-4 m thick, and consist of amalgamated, normally graded, coarse to medium grained sandstone. These beds are commonly structureless or planar laminated. In addition, beds in the uppermost part of complexes are commonly capped by a single or few set thick ripple cross-stratified layer. Dune cross-stratified beds are less common within these features. Dispersed mudstone clasts and mud clast horizons occur in some beds. Although multiple bed complexes are laterally continuous over several hundreds of meters the individual beds within are laterally discontinuous, commonly being eroded by an overlying bed in less than 100 m. Multiple bed and isolated bed complexes have a low (10% or less) detrital mud matrix content.

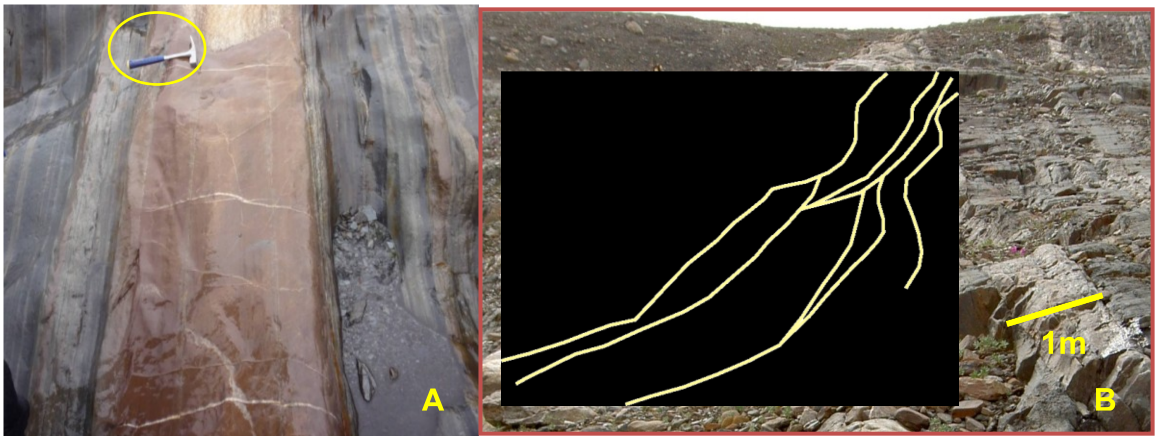

Figure 2: Overbank splay deposits: (A) isolated bed: thick-bedded (70 cm) Tbd turbidite. Note the anomalously thick planar laminated division, sharp non-erosive base and tabular morphology (B) multiple bed complex: stacked structureless sandstones. Note the scoured and amalgamated bed contacts (top is to the right)

Interpretation

Thick-bedded turbidites, occurring as isolated beds or multiple bed complexes, are interpreted to have been deposited on the distal part of a subaqueous outer bend levee. Along the outer bend, superelevation caused sedimentation rates to be higher, and accordingly levee growth greater, compared to its counterpart on the inner bend side (Straub et al., 2008). Moreover, flow stripping, which is the preferential loss (overspill) of the upper, more dilute part of the flow (while the coarse, lower part of the flow remains confined to the channel) is enhanced over the outer bend levee. In the case of isolated beds, upon exiting the confines of the channel, the flow bypassed the proximal levee, accelerated down its steep backside slope, and then, on the lower slope of the distal levee, deposited, under competence-driven conditions, the succession of planar laminated followed by ripple cross-stratified sand. Multiple bed complexes, on the other hand, are interpreted to be related to a partial breach in the levee that after some number of later flows became healed (infilled), or evolved into a full channel-margin breach with associated avulsion. Nevertheless, irrespective of the eventual outcome, a partial breach allowed coarser sediment carried in the lower part of the channelized flows to escape the confines of the channel. These more sand-rich and energetic flows, compared to those that deposited the isolated beds, would have also bypassed the proximal levee and become depositional on the more shallow-dipping distal levee. Here they experienced capacity- rather than competence-driven deposition, and emplaced the common graded, structureless beds. Note that flow deceleration was not accompanied by a hydraulic jump like in crevasse splays (see next). Also, the lack of lateral bed continuity, mudstone interbeds and paucity of traction structures is likely the result of erosion and rapid deposition that infilled topography on the distal levee.

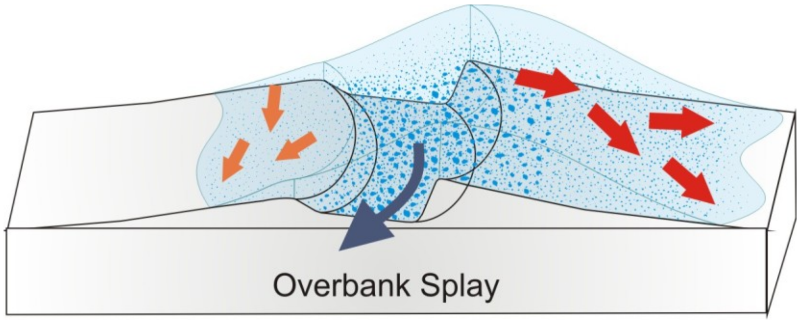

Figure 3: Schematic diagram of flow stripping over the outer bend of a sinuous channel-levee system. Note the preferential overbanking along the outer bend due to superelevation of the channelized flow.

Crevasse Splay Deposits

Crevasse splay deposits consist of poorly sorted, structureless and ungraded or coarse-tail graded, coarse or medium to fine grained sandstones with a high (30-50%) mud content. Two end member kinds are recognized: tabular and amalgamated, the former being more common. Tabular units range from 2-8 m thick and comprise beds 5-125 cm thick. Sandstones commonly contain a small number of large, isolated, tabular mudstone clasts. Soft sediment deformation features such as flame structures are observed locally. Beds generally show negligible change in facies or thickness laterally. Amalgamated units are approximately 4 m thick with beds from 25-100 cm thick. Mudclasts tend to be smaller (< 50 cm) but are more abundant, commonly forming breccia layers. Individual beds are discontinuous and cannot be traced for more than 150 m laterally. In large part this is related to intense scour at the base of most beds.

Figure 4: Crevasse splay deposits: (A) tabular crevasse splay: note the lateral continuity, tabular geometry, sharp non-erosive bedding contacts and, large flame structures (top is to the left) (B) amalgamated crevasse splay: note the deep scours at the base of most beds, which then are filled with matrix-rich, structureless sandstone (event beds are numbered, from oldest to youngest, 1-5.

Interpretation

The structureless sandstones described here are commonly mud-rich, poorly sorted, coarse-tail graded and lack fluid escape structures. Their poorly sorted texture and high mud content is interpreted to reflect extremely rapid capacity-driven deposition possibly immediately downflow of a plane-wall jet with jump (e.g., Leclair and Arnott, 2003). The jump is interpreted to have formed downflow of a major levee breach, and at an abrupt change in slope where supercritical flow (*Fr* > 1) passed through a hydraulic jump as it transformed quickly to subcritical flow (*Fr* <1). The levee breach allowed most of the thickness of the channelized turbidity currents to escape the channel and be diverted into the interchannel area. At some downflow break in slope, the now supercritical flow underwent an internal hydraulic jump with attendant intense turbulence generation. Here the bed was deeply scoured but then became draped with a rapidly deposited layer of sediment from the collapsing sediment cloud. It is here that the amalgamated crevasse splays accumulated. Downflow of the jump, much of the locally-generated turbulence was damped by the high sediment concentration and seafloor scour became negligible. In addition, sedimentation rate remained high as the dispersion continued to collapse, depositing the matrix-rich, tabular deposits of the tabular crevasse splay element.

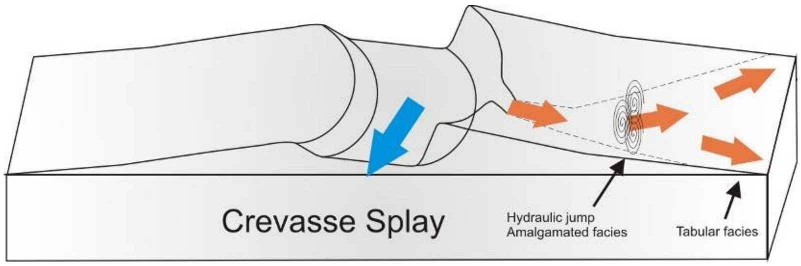

Figure 5: Schematic diagram of a crevasse splay. Note the breach in the levee, location of hydraulic jump, and spatial distribution of the amalgamated and tabular facies.

References

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