Depositional Architecture of a Mixed River-Wave Influenced Asymmetric Delta Lobe: Upper Cretaceous Basal Belly River Formation, Central Alberta, Canada

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Introduction

Cycle G of the Upper Cretaceous (Campanian) basal Belly River Formation in central Alberta provides one of the first documented subsurface examples of an ancient prograding asymmetric delta lobe. Detailed facies mapping, utilizing both core and geophysical well logs, records a striking asymmetry to this mixed-influence delta lobe. The studied succession illustrates those features proposed by the process-based model of Bhattacharya and Giosan (2003) that can be expected to survive into the rock record. In addition, this ancient example greatly enhances the predictability of facies characteristics and facies architecture of asymmetric delta successions, especially with respect to delta-front and prodelta deposits.

The basal Belly River Formation comprises a series of overlapping and offlapping deltaic lobes. Although the internal stratigraphy of the unit was mapped regionally more than a decade ago (Power, 1993: Power and Walker, 1996), few detailed studies have addressed the individual deltaic cycles. Coates (2001) described the sedimentology and ichnology of a number of the cycles, and identified facies ranging from wave to river dominated. Cycle G was identified as a lobe characterized by both wave and river influence, and is penetrated by a substantial core database, making it an ideal candidate for a detailed study focused on the facies characteristics and depositional architecture of an ancient mixed river-wave influenced delta lobe.

Facies Associations

Based on the analysis of 56 cored intervals within the study area (Townships 43-47 and Ranges 27W4-02W5), Cycle G is differentiated into two mappable facies associations (FA1 and FA2; Hansen, 2007). FA1 comprises uniformly coarsening-upward successions with abundant wave- and storm-generated physical structures (HCS, oscillation ripples and combined flow ripples). In contrast, FA2 forms variable and markedly heterolithic coarsening-upwards successions, dominated by current-generated structures, convolute bedding, normally graded layers, structureless siltstones, dark claystone drapes, syneresis cracks, and sediment-gravity deposits. Both facies associations yield sporadically distributed trace fossil suites, attributable to stressed expressions of the *Cruziana* Ichnofacies. Nevertheless, the relative abundance and diversity of ichnogenera constituting the suites differ markedly. FA1 contains moderate-abundance and moderate-diversity trace fossil suites, whereas FA2 displays low-abundance and typically very low-diversity suites comprising predominantly facies-crossing deposit-feeding structures. FA1 shows bioturbation intensities ranging from sparse to moderate (BI 1-3) with some locally abundant (BI 5) intervals. FA1 successions include moderate to abundant numbers of *Planolites*, *Chondrites*, *Helminthopsis*, *Cosmorhaphe*, *Teichichnus*, *Thalassinoides*, *Rosselia*, *Macaronichnus* isp., and fugichnia, in addition to complex and specialized fully marine forms such as *Phycosiphon* and *Rhizocorallium*. FA2, on the other hand, records very low bioturbation intensities (BI 0-1). Facies-crossing elements such as *Planolites*, *Teichichnus*, *Thalassinoides*, *Chondrites*, and fugichnia comprise the dominant biogenic structures.

Based on the integration of ichnological, sedimentological, and lithological characteristics, FA1 is interpreted to represent deltaic conditions dominated by wave and storm processes, whereas FA2 records the predominance of river-generated processes (*e.g.*, buoyant mud plumes, salinity fluctuations, elevated deposition rates, and possible hyperpycnal flows).

Lobe Architecture

The asymmetric delta model of Bhattacharya and Giosan (2003) is based on a number of modern mixed river-wave influenced deltas characterized by strong longshore drift (*e.g.*, the Danube delta). Their model indicates that a strong groyne effect is generated at the distributary mouth, which impedes sediment movement alongshore leading to a pronounced asymmetry of the resulting depositional facies. Amalgamated beach ridges mimicking shoreface successions accumulate on the updrift side of distributaries, whereas more heterolithic, stressed facies develop downdrift in response to elevated river influence. Barrier bars are formed on the downdrift side as well, which create protected lagoons that act as sediment traps for fine-grained sediment and progradation of bay-head deltas.

The more homogeneous coarsening-upward architecture of FA1 reflects the higher sand contents and stronger wave influence expected along updrift portions of the delta (SSE part of the study area; Figures 1 and 2). Intervals in the updrift position are broadly similar to non-deltaic strandplain shoreface deposits. Reduced river influence in these successions is reflected by more pervasive bioturbation, higher trace fossil diversities and broader ethological ranges. Vertical dwelling structures of presumed suspension/filter-feeding infauna are more common within FA1 owing to generally reduced water turbidity (MacEachern et al., 2005). In contrast, the facies architecture of FA2 is markedly heterolithic, reflecting the river-induced processes that predominate in positions downdrift of the distributary channel mouths. Indeed, FA2 also encompasses deposits of the distributary channel/mouth-bar complex. Heightened river-sediment influx leads to elevated physico-chemical stresses on infaunal communities in these downdrift positions. Such stresses are reflected by the dominance of soft-sediment deformation, normally graded bedding, syneresis cracks, and organic-rich claystone drapes of inferred hypopycnal and hyperpycnal origin. Bioturbation is less pervasive compared to updrift counterparts, and trace fossil diversities are reduced. The structures of inferred suspension-feeding organisms are virtually absent in FA2 successions. Finally, the presence of restricted bay and bay-head delta deposits completes the expected downdrift stratigraphic architecture within an asymmetric mixed river-wave influenced delta.

References

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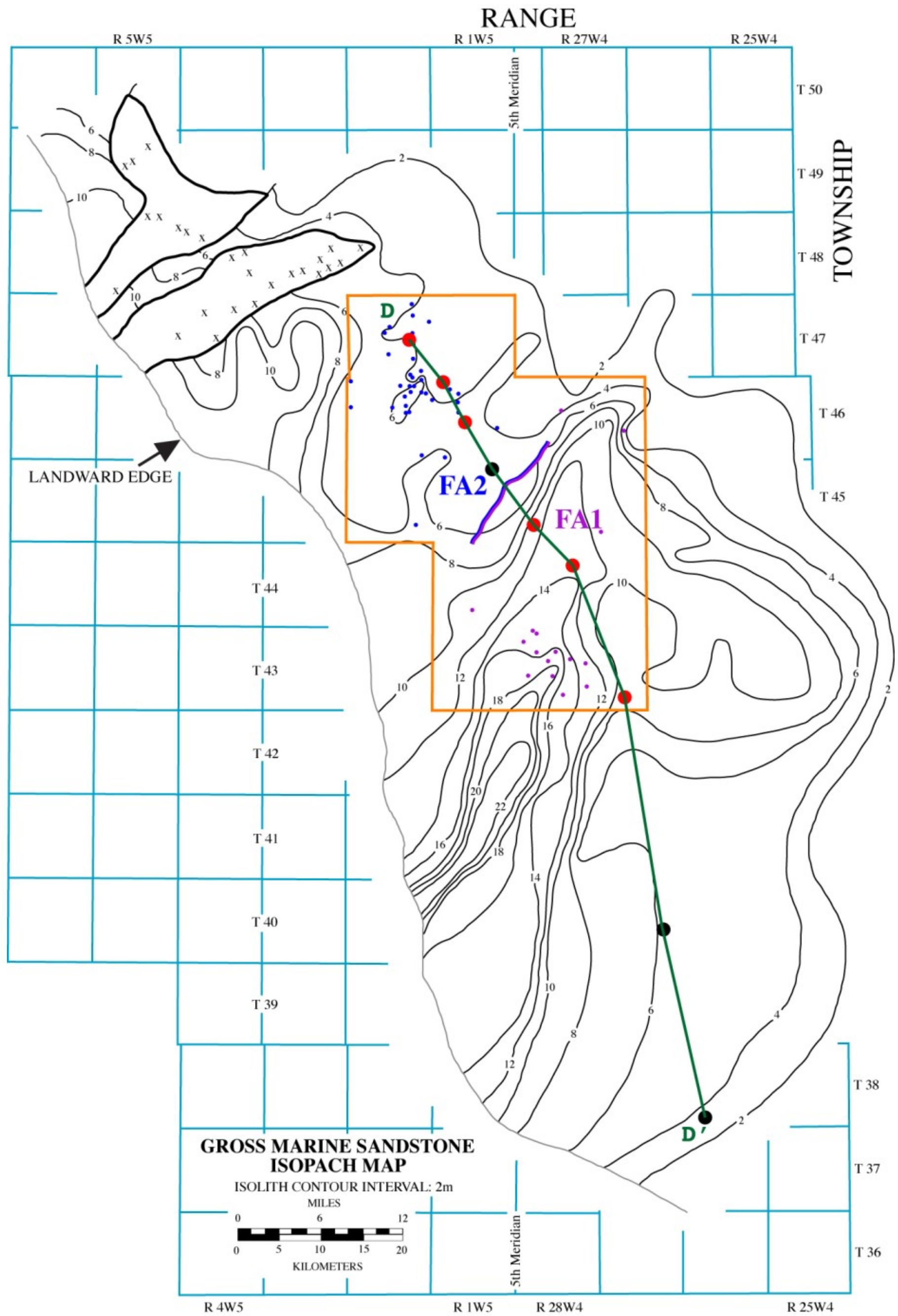

Figure 1: Gross sand isopach map of the Cycle G proximal delta-front sandstones. Contours are 2m. The distribution boundary between FA1 and FA2 is shown in addition to the line of section (D-D'), indicating the location of the along-strike litholog cross-section featured in Figure 2.

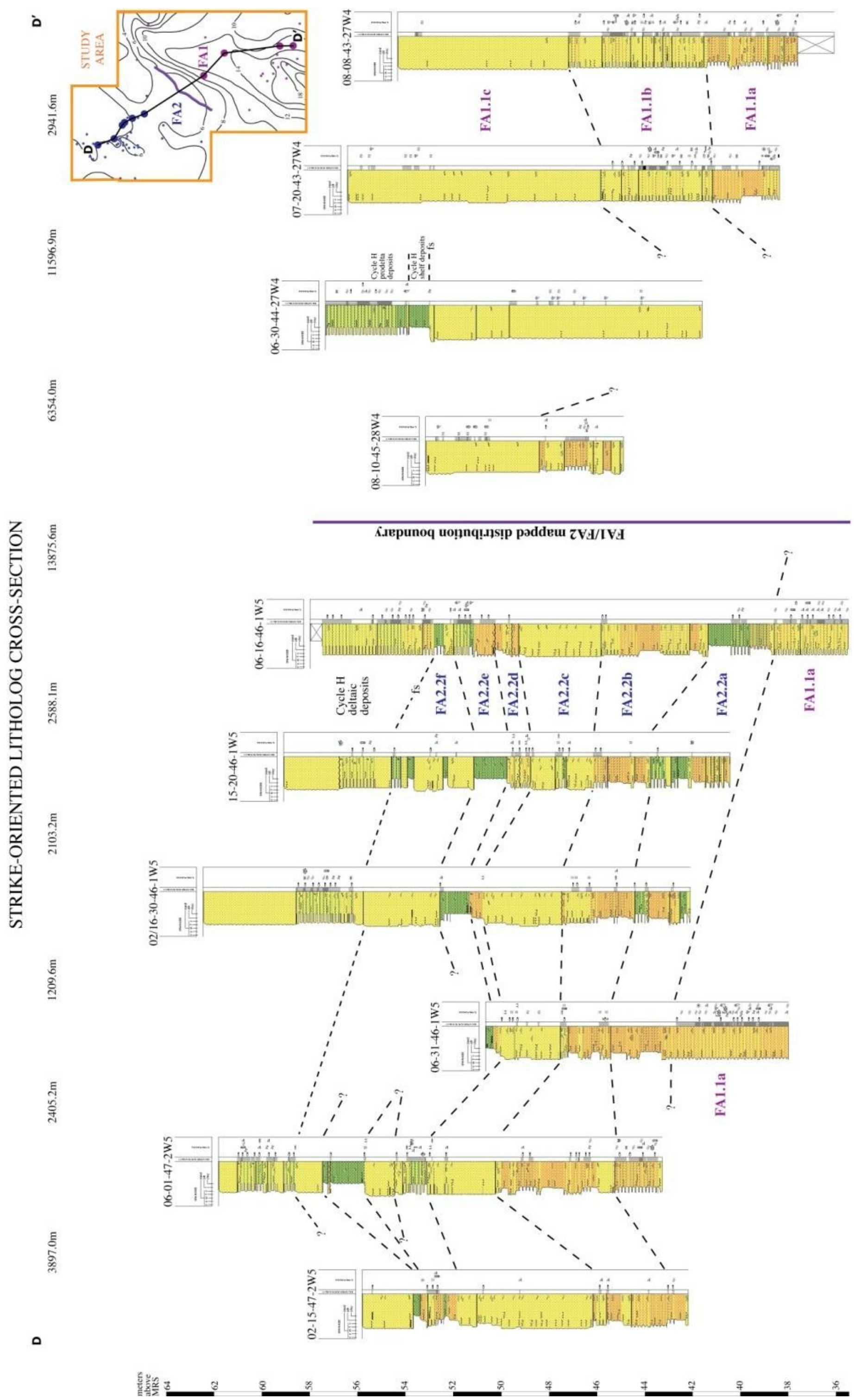

Figure 2: Along-strike litholog cross-section D-D' across the Cycle G lobe (see Fig 1 for location). Facies associations comprise discrete occurrences, with the exception of wells lying near the mapped FA1/FA2 boundary, which show FA1 underlying distal deposits of FA2. Wells are aligned to the Milk River Shoulder (datum is not shown, as it lies 35 to 45 m below the cored intervals).