Integrated Ichnology and Sedimentology of Mixed River- and Wave-Influenced Delta Complexes, Upper Cretaceous Basal Belly River Fm, Central Alberta, Canada

Brittan M. Jones*, Applied Research in Ichnology and Sedimentology (ARISE) Group, Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada

brittanj@sfu.ca

and

James A. MacEachern, Applied Research in Ichnology and Sedimentology (ARISE) Group, Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada

Introduction

The Upper Cretaceous (early-mid Campanian) basal Belly River Formation (Fig. 1) of central Alberta comprises eight progradational, mixed river- and wave-influenced delta lobes (cycles A-H). Successive cycles intertongue with the underlying marine shales of the Lea Park Formation, and young to the east-northeast (Power and Walker, 1996). A detailed subsurface analysis of cycles E-G was initiated within the Ferrier, Willesden Green, Gilby and Wilson Creek fields of central Alberta (Fig. 2), to complement a previous study in the Ferrybank and eastern Pembina/Keystone fields (*cf*. Hansen, 2007; Hansen and MacEachern, 2007). Expansion of the study area and study interval will serve to enhance our understanding of facies characteristics and depositional architectures within ancient, mixed river- and wave-influenced deltaic systems. Such refinements in the facies model will shed light on the degree of predictability in reservoir heterogeneities within such settings.

Methods

Fifty subsurface cores were selected, with the aim of optimizing spatial coverage and the cycles intersected. Cored intervals were evaluated using sedimentology and ichnology, establishing a high-resolution facies framework. Sedimentological analysis focused on textures, physical sedimentary structures, bed thicknesses, bedding contacts, and lithologic accessories. Ichnological evaluation concentrated on bioturbation intensities, trace fossil distributions, ichnogenera identification, and assessment of trace fossil diversities. Bioturbation intensities were given as a Bioturbation Index (BI) measurement, with 0 corresponding to unburrowed deposits and 6 reflecting complete homogenization.

Results

Integration of the preserved physical sedimentary structures with ichnology reveals 14 discrete facies; each defined by unique combinations of lithologic, physical, and biogenic characteristics, differentiating them from facies above, below, and laterally adjacent to them (*cf*. Walker, 1992). The facies are grouped into 4 distinct facies associations: FA1 (storm-dominated, mixed river- and wave-influenced delta deposits); FA2 (river-dominated, storm-influenced delta deposits); FA3 (fluvio-estuarine distributary channel deposits); and FA4 (delta plain/coastal plain deposits).

FA1: Storm-Dominated, Mixed River- and Wave-Influenced Delta Deposits

FA1 comprises coarsening-upwards successions, characterized by relatively sand-rich, fully marine to marginal marine facies, which pass upwards from interstratified sandstones and siltstones into laminated and apparently structureless (massive) sandstones. The successions are dominated by an abundance of wave- and storm-generated physical sedimentary structures, with subordinate amounts of river-generated features such as current-generated structures, syneresis cracks, soft-sediment deformation, and drapes of inferred fluid mud origin. Bioturbation is sporadically distributed and characterized by low to moderate intensities (BI 0-4), with low to moderate diversities. Overall, the ichnological suite is interpreted to represent a stressed, distal to proximal expression of the *Cruziana* Ichnofacies.

FA2: River-Dominated, Storm-Influenced Delta Deposits

FA2 consists of coarsening-upwards successions characterized by markedly heterolithic, fully marine to marginal marine deposits. Facies pass upwards from interstratified clayey siltstones and sandstones into cross-stratified and current ripple-laminated sandstones. Successions are characterized by an abundance of river-generated features, such as current-generated structures, normally graded bedding, syneresis cracks, soft-sediment deformation features, and drapes of inferred fluid mud origin (e.g., MacEachern et al., 2005). Lesser amounts of wave- and storm-generated physical sedimentary structures are also locally present. Bioturbation is sporadically distributed, with intensities ranging from absent to moderate (BI 0-3), but more typically, absent to rare (BI 0-2). Trace fossil suites display low diversities with abundant facies-crossing elements, and are attributable to a stressed, distal to proximal expression of the *Cruziana* Ichnofacies (MacEachern and Bann, 2008).

FA3: Fluvio-Estuarine Distributary Channel Deposits

FA3 comprises erosionally based and fining-upwards successions. Pebble conglomerates and pebbly sandstones locally overlie the basal erosion surface, and pass upwards into coarse-grained sandstones and interstratified sandstones and siltstones. Successions are dominated by current-generated structures, which includes planar tabular and trough cross-stratification, current-ripple lamination, and horizontal planar parallel lamination. Bioturbation is generally absent (BI 0) in lower to middle portions of the succession. The uppermost, heterolithic deposits display sporadically distributed bioturbation with low intensities (BI 0-1). Trace fossil suites display low diversity, and are indicative of a periodically brackish-water setting.

FA4: Delta Plain / Coastal Plain Deposits

FA4 constitutes lithologically variable successions, consisting of stratified mudstones, siltstones, sandstones and coals. Overall, successions are dominated by mudstones and siltstones characterized by anomalously high concentrations of intercalated carbonaceous debris, coal fragments, and siderite-cemented nodules. Horizontal laminations, apparently structureless (massive) intervals, and convolute bedding are common within mud- and silt-rich facies. Sand stringers are locally intercalated, and exhibit curvilinear laminations and current ripples. With the exception of root traces, biogenic structures are exceedingly rare. Trace fossil suites display low diversity and are attributable to the *Scoyenia* and *Psilonichnus* Ichnofacies.

Conclusions

FA1 and FA2 share similar traits, which makes their differentiation challenging. Careful integration of sedimentological and ichnological characteristics allows the two associations to be identified, and facilitates an assessment of along-strike variations in facies distribution. At any single location within a mixed river- and wave-influenced delta complex, the relative influence of river versus wave processes is directly related to the proximity of the distributary mouth. The fluvial signal is strongest at the distributary mouth and diminishes outwards and along-strike, as wave energy mitigates the river-induced stresses. As a result, facies deposited proximal to the distributary mouth exhibit the strongest fluvial characteristics, whereas facies deposited along strike display progressive reductions in fluvial influence as the depositional setting becomes increasingly open marine. Thus, differentiation between FA1 and FA2, combined with subsequent mapping of their spatial distributions, can serve as a predictive tool for determining distributary channel proximity.

Preliminary evaluations indicate that the sandier, more wave- and storm-influenced deposits of FA1 are concentrated in updrift positions, whereas the more heterolithic, fluvially influenced deposits of FA2 prevail in positions downdrift of distributary channels (FA3). These distributions compare favorably with those predicted by the asymmetric delta model of Bhattacharya and Giosan (2003), and corroborate research completed by Hansen (2007) on the Belly River cycles in the Ferrybank, Keystone, and eastern Pembina fields (Fig. 2). Continued research will focus on delineating the along-strike variations in facies distributions for these Belly River lobes, in order to construct a paleogeographically accurate depositional model for the study area.

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Figures

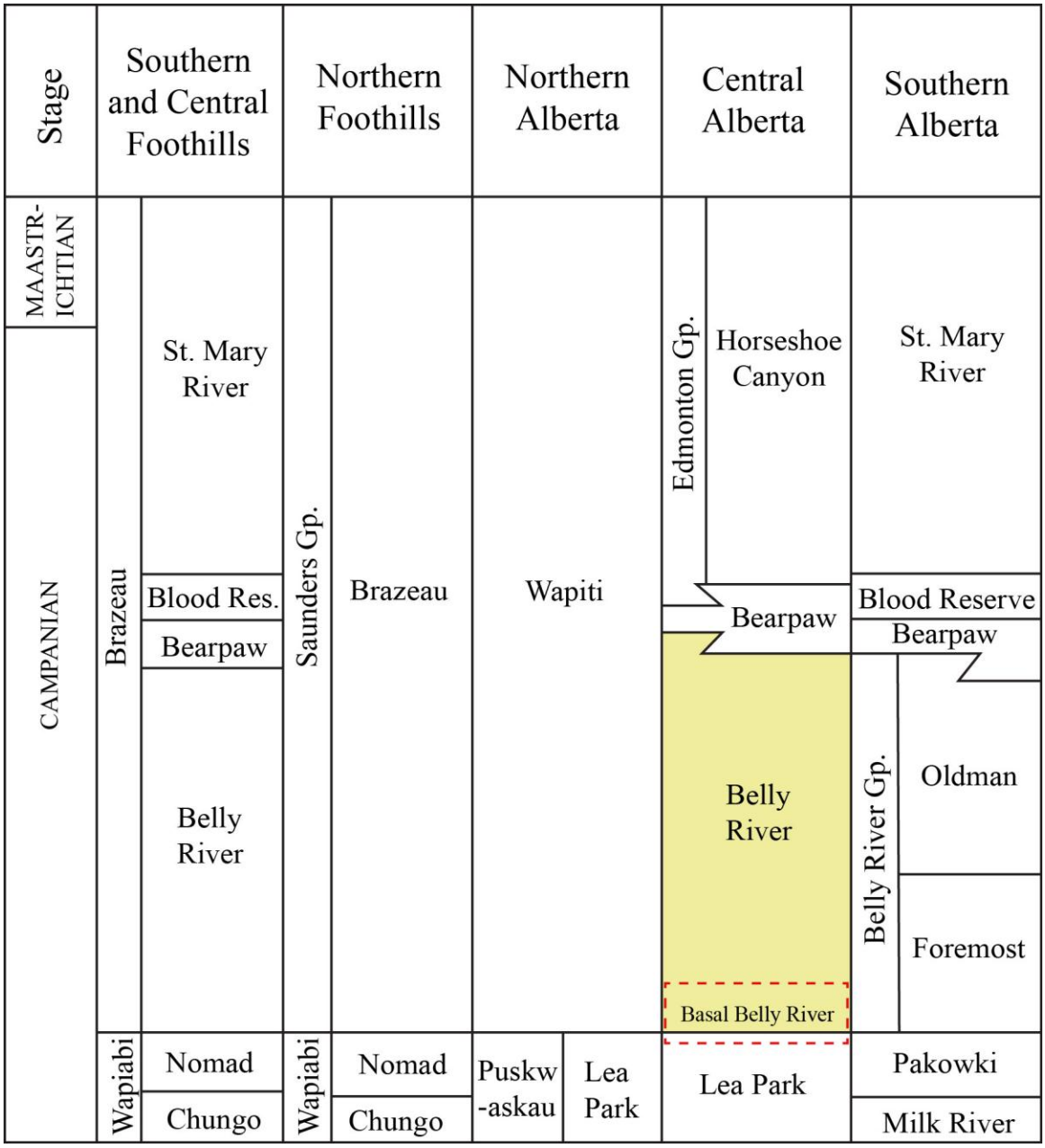

Figure 1: Lithostratigraphy of the Belly River and Lea Park formations (modified after Power and Walker, 1996; Hansen, 2007). The red, dashed border outlines the interval of interest in this study.

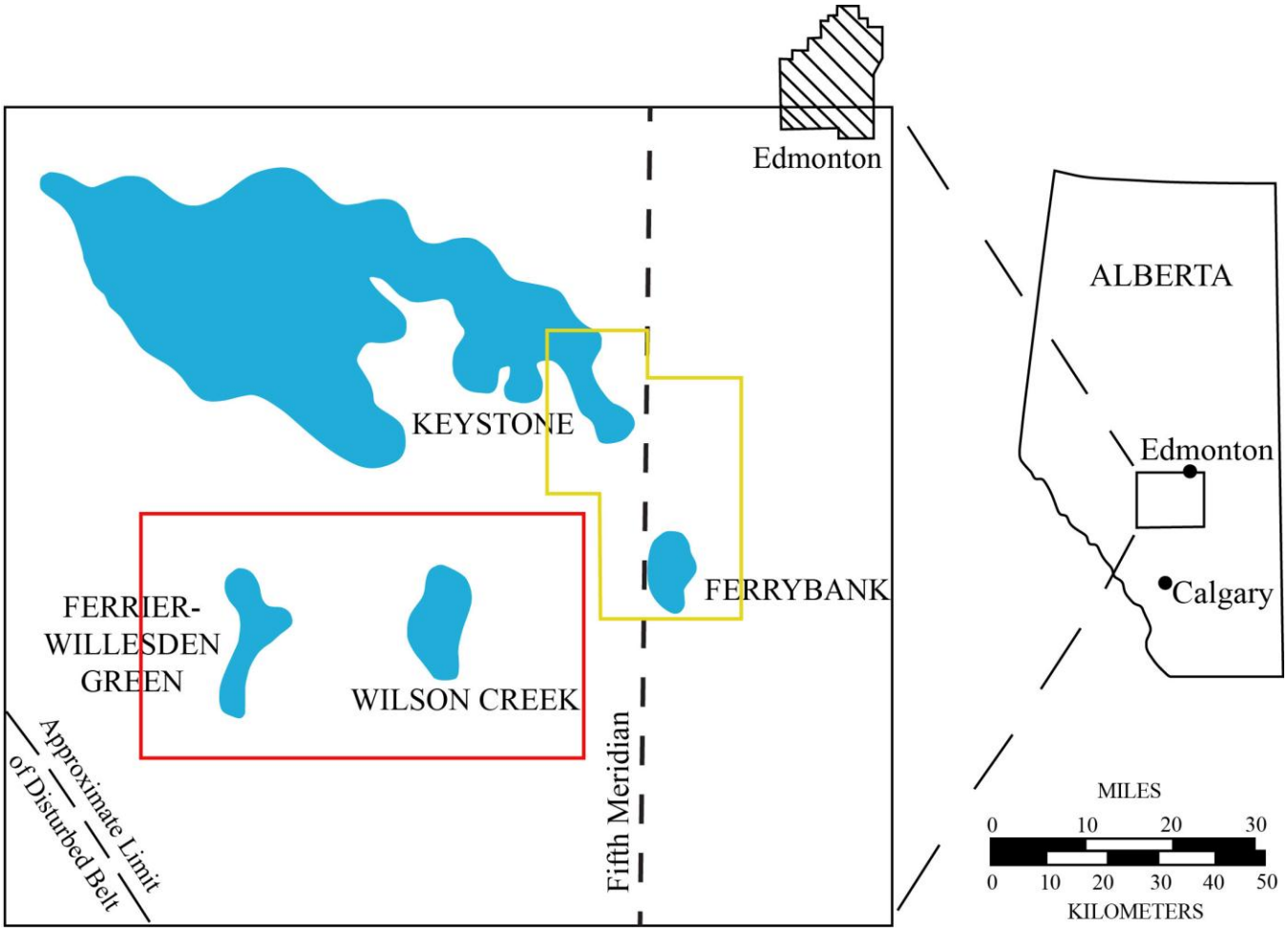

Figure 2: Location map of major Belly River fields in central Alberta (modified after Power and Walker, 1996; Hansen, 2007). The red border outlines the current study area. The yellow border outlines the study area of Hansen (2007).