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The Eastern Flank: Predicting the Architecture of the McMurray Formation Beyond its Subcrop Edge

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Introduction

A detailed subsurface study was conducted on the Lower Cretaceous McMurray Fm with the intention of resolving the eastern flank of the McMurray Sub-Basin towards and beyond the unit's subcrop edge. Lower Cretaceous sediment was delivered to the McMurray Sub-Basin, probably via a continental-scale drainage system with headwaters in the Canadian Shield, Appalachians, and Cordillera of North America (Blum and Pecha, 2014; Benyon et al., 2016). Towards the mouth of the continental-scale drainage, a series of tributaries drained the Canadian Shield, although the number, scale, and position of tributaries is poorly constrained. Herein, the McMurray paleodrainage system is mapped from the main fairway east towards the sparsely drilled and erosionally truncated subcrop edge. Linear and exponential regression is then used to map the McMurray Fm to its theoretical eastern extent. To do this, 23 cross-sections and 164 hypothetical wells were defined, and structural elevations for the Top_Wabiskaw, Top_McMurray, and Sub-Cretaceous Unconformity (SCU) were calculated along lines of section using both linear regression and exponential regression. From these tops, unit thicknesses were calculated at hypothetical well locations, and contour mapping was used to map the hypothetical depositional edge of the McMurray Fm.

Methodology

Linear regression was applied to all 23 cross-sections and indicated the McMurray subcrop edge was located further towards the east. Using linear regression, 103 hypothetical wells were created to increase the number of data points in a region lacking well control. Discriminating linear regression data based on R^2 resulted in two additional sets of data – alternate mapping method A and alternate mapping method B.

Exponential regression was applied to all 23 cross-sections, with 21 sections indicating that the McMurray subcrop edge was located further toward the east. Using exponential regression, 61 hypothetical wells were created to increase the number of data points in a region lacking well control. Discriminating exponential data based on R^2 (same as linear regression) resulted in two additional sets of exponential data – alternate mapping method A and alternate mapping method B.

In total, six different isopach maps were created using hypothetical well data. The first used all hypothetical wells derived from linear regression. The second used linear regression data refined using mapping method A and utilized 92 of the original 103 hypothetical wells. The third used linear regression data refined after mapping method B was applied and yielded in 82 hypothetical wells. The fourth map was created using all 61 wells generated using exponential regression. The fifth map employed mapping method A to refine the exponential regression data, resulting in 54 usable hypothetical wells of the 61 total. The sixth and final map used mapping method B to refine exponential regression well data, resulting in the use of 48 hypothetical wells. Several features are defined in all maps regardless of which type of regression and data culling methodology was employed. The features that are evident on all maps include several Paleo-highs and Tributary systems.

Results, Discussion, and Conclusions

Three paleovalleys are identified, which appear to have drained the Canadian Shield and debouched into the Assiniboia Valley within the McMurray Sub-Basin. These include (from north-to-south) Firebag Tributary, Buffalo River Paleovalley, and Choiceland Paleovalley (Fig. 1). The extent of the drainage basins and architectures of these valleys are based on projections of surfaces to the east, and comparison of isopach maps based on hypothetical well data to previously published studies (e.g., Christopher 1997; Ranger and Pemberton 1997; Macdonald and Slimmon, 1999; Ranger 2006; Bauer et al., 2009; Kohlruss et al., 2013; Broughton, 2015; Hauck et al., 2017).

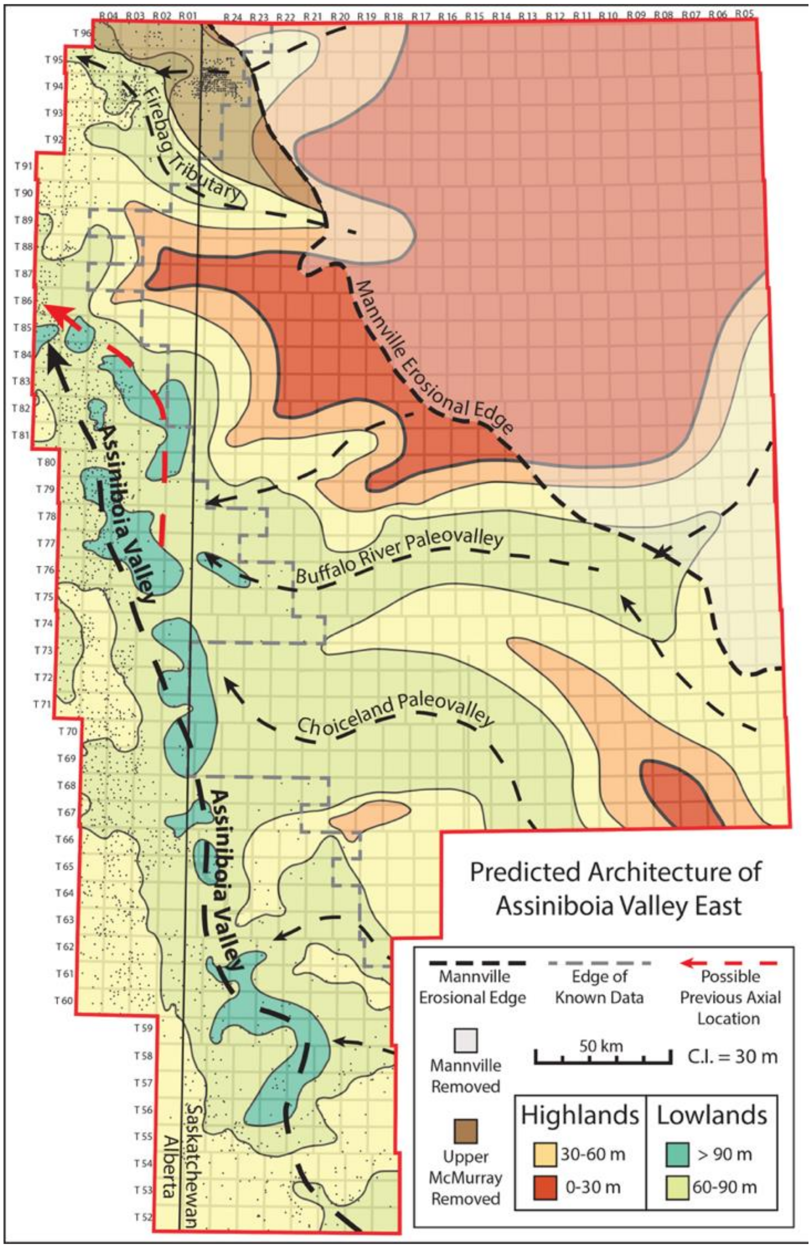

Figure 1:Summary map indicating the most probable paleodrainage pattern for the eastern flank of the McMurray Sub-Basin. Three separate drainages occur on all maps: Firebag Tributary, Buffalo River Paleovalley and Choiceland Paleovalley. Red arrow indicates a possible additional axial location for the Assiniboia Valley.

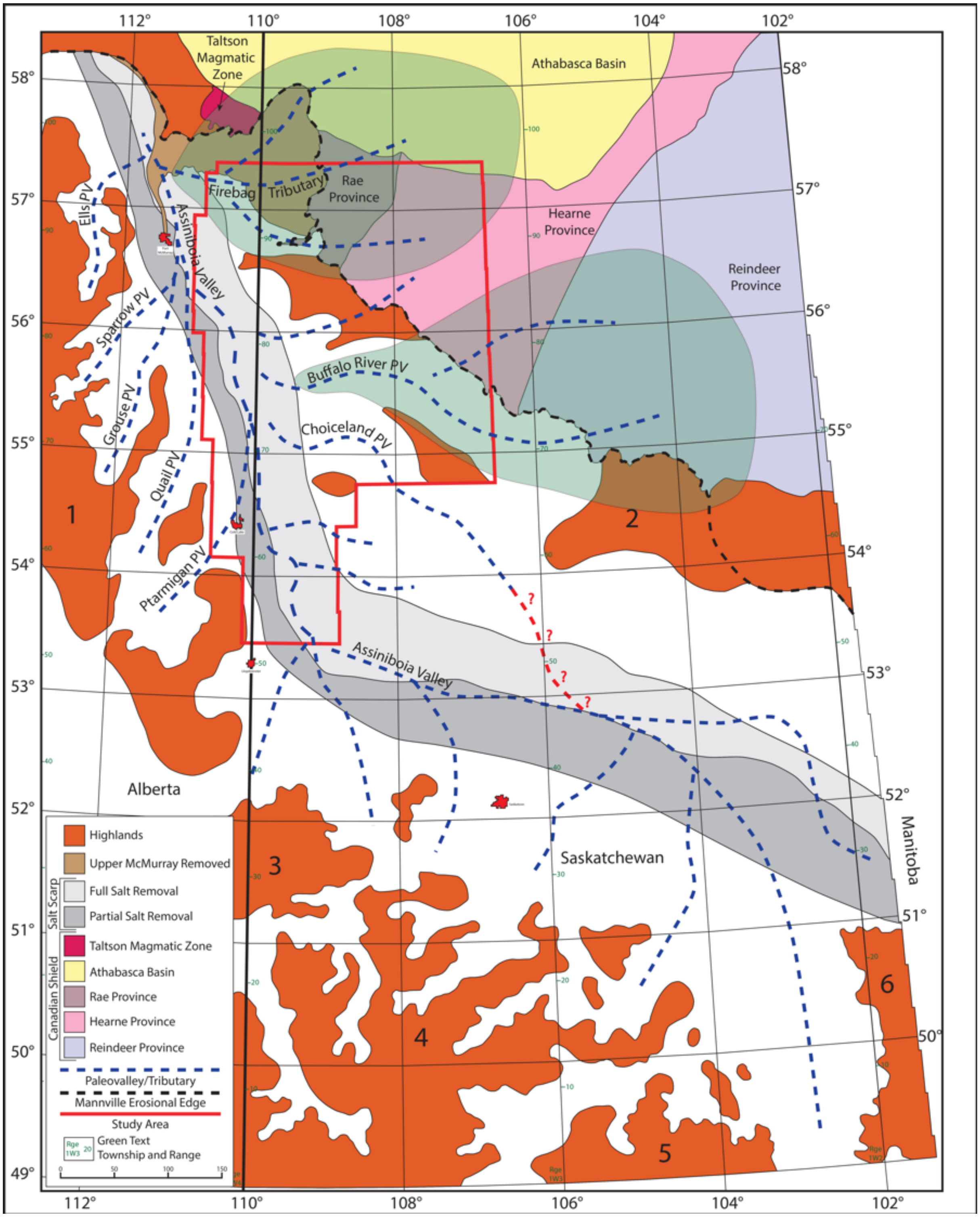

Figure 2:Map of eastern Alberta, Saskatchewan and western Manitoba, illustrating Lower Cretaceous drainage patterns and potential source terrains. The partly translucent green areas represent the possible catchment areas of each paleovalley/tributary. Orange represents highlands that influenced the paleodrainage system: 1) Grosmont High/ Wainwright Ridge; 2) Molanosa; 3) Kindersley Paleo-upland; 4) Swift Current Paleo-upland; 5) Willowbunch; and 6) Moosomin Paleo-upland (Christopher, 1997; Ranger and Pemberton, 1997). Location of Grouse, Quail, and Ptarmigan Paleovalleys (Basiru et al., in press) are illustrated west of the study area. Approximate location of Prairie Evaporite Salt Scarp is illustrated with partial and full removal of salt indicated (Broughton, 2015; Hauck et al., 2017). Potential source rock regions from the Canadian Shield are highlighted (Macdonald and Slimmon, 1999; Prior et al., 2013).

Figure 2 shows the expected extents of the various paleovalleys and the geological provinces in their source areas, it also shows the trend between salt dissolution and the orientation of Assiniboia Valley. Firebag Tributary extends east with head waters sourcing sediment from the Athabasca Basin, Rae and Hearne provinces. The catchment area of Firebag Tributary is considered small to moderate, encompassing an area of >10,000 km^2, with a river system capable of producing sand bodies up to 10 m thick along a river 100 km to 750 km long (Somme et al., 2009; Blum et al., 2013). Buffalo River Paleovalley extends east toward the Canadian Shield likely sourcing sediment from the Hearn and Reindeer Provinces. The thickness of Buffalo River Paleovalley reaches 60–90 m, and likely had a moderately sized catchment basin covering between 10,000 km^2 and 100,000 km^2. The river in Buffalo River Paleovalley is interpreted as capable of producing sand bodies up to 15 m thick along a river extending up to 750 km east (Somme et al., 2009; Blum et al., 2013). Like Assiniboia Valley, Choiceland Paleovalley recycled previously deposited sediment from stratigraphically older units. Thickness of sediment in Choiceland Paleovalley is very similar to Buffalo River Paleovalley, ranging from 60–90 m and indicating a catchment basin between 10,000 km^2 and 100,000 km^2. In this case the main tributary in Choiceland Paleovalley would extend up to 750 km southeast and could deposit sand bodies up to 15 m thick (Somme et al., 2009; Blum et al., 2013). Alternatively, Choiceland Paleovalley possibly represents a previous axial position of the continental scale drainage system (Fig. 2). In this case, the westward migration of salt dissolution created a paleo-low creating accommodation space and forcing the river to change course (Fig. 2; Schneider et al., 2014; Stoakes et al., 2014). These three drainage systems collected sediment from a large region of the Canadian Shield contributing significant amounts to the McMurray Sub-Basin.

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