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Aptian Drainage Dynamics in the Alberta Basin Derived from Mapping McMurray Formation Paleo-Valleys

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Summary

Integrating measured bankfull flow depths, paleo-discharge estimates, catchment areas, and external valley dimensions from 3 McMurray channelized systems provides insight into the magnitude and organization of the drainage systems that operated in the McMurray sub-basin, and across the larger province of Alberta during the Aptian. In a focussed study area located in the southeastern portion of the Athabasca Oil Sands Region (AOSR), a series of valley fills are delineated using the stratigraphic scheme of Hein & Cotterill (2006). The youngest mapped drainage system (i.e., A2 valley) is best preserved, and consists of a northeast oriented tributary that joined a larger, North-South oriented main trunk valley. Based on the comparison of its internal fill characteristics and external valley width/depths ratios with those of two older, partially preserved channelized systems (i.e., B1 and B2 valleys), the two older systems are also considered to record tributaries to trunk systems. Bankfull channel measurements estimated from core and wireline logs are used to estimate paleo-drainage, and from these data we propose that the study area represented a major confluence for western Alberta sourced tributaries into the main, basin-axial oriented trunk of the continental McMurray drainage system.

Introduction

The Aptian McMurray Formation occurs along the eastern edge of the Alberta Foreland Basin and lies directly above the sub-Cretaceous angular unconformity. Paleo-drainage in the basin during the Early Cretaceous was dominated by three major basin-axis-parallel drainage systems separated by paleo-topographic ridges on the unconformity surface (Leckie & Smith, 1992; Ranger, 1984). Along the western edge of the basin, a northwest-southeast oriented valley system known as the Spirit River Paleo-valley drained large portions of western Alberta with paleo-flow directed towards the northwest (Jackson, 1984; Leckie & Smith, 1992). To the east, another major trunk valley system known as the Edmonton Paleo-valley was a conduit for northwesterly flow (Leckie & Smith, 1992), which had its headwaters in southeastern Alberta and southwestern Saskatchewan (Ranger & Pemberton, 1997). The Edmonton Paleo-valley was bounded to the East by resistant carbonate ridge known as the Grosmont High (Leckie & Smith, 1992). To the east of the Grosmont High, a third major trunk system known as the Assiniboia Paleo-valley (Christopher, 1997), or McMurray Valley (Ranger & Pemberton, 1997) persisted. This valley was bounded to the East by basement rocks of the Canadian Shield. Recent studies utilizing detrital zircons have indicated that the Assiniboia Paleo-valley hosted a continental scale river with a drainage area stretching from eastern Canada down to the southeastern United States (Benyon et al., 2014, 2016; Blum and Pecha, 2014). Benyon et al. (2016) used these data to propose that important tributaries headwatered in the Cordillera made their way across the basin and intersected the Assiniboia valley in the vicinity of the McMurray subbasin.

Repeated transgressive-regressive cycles led to deposition of Lower Cretaceous strata throughout the Aptian, resulting in the filling of the paleo-valleys, and healing of the regional topography on the unconformity (Ranger & Pemberton, 1997). This resulted in the reorganization of drainage systems in the McMurray subbasin during deposition of the McMurray Formation (Smith et al., 1984).

Methods

Applying a modified version of the Hein & Cotterill (2006) stratigraphic framework, regional scale mapping of 3 distinct McMurray Formation channelized systems using detailed drill core description and wireline log interpretation was performed across a 61 Township area in the southeastern portion of the AOSR. External valley dimensions, including widths and depths, were estimated from a 3D model built in Petrel using stratigraphic tops picked in 3000 wells across the study area. Over 650 wireline log based measurements of upward fining cycles in the various channelized systems were compiled to make estimates of maximum bankfull depths and channel belt thicknesses following the methods of Bridge and Tye (2000). Bankfull depths were used to estimate paleo-discharge and drainage areas for each system using the methods of Davidson & North (2009), allowing for the reconstruction of potential paleo-watersheds that existed during McMurray Formation deposition.

Results and Conclusions

Integrating external valley geometries, measured bankfull flow depths, interpreted paleo-discharge estimates, and catchment area estimates from McMurray valley systems provides insight into the dynamics and organization of the drainage systems that operated in the McMurray sub-basin, and across the larger province of Alberta during the late Aptian. Due to more complete preservation, both a tributary and trunk channel system are confidently mapped in the youngest A2 interval. Based on similarities between internal bankfull flow depths and external valley width/depth ratios of partially preserved B2 and B1 paleo-valleys and the A2 tributary, the two older systems are also considered to record tributary channel systems. Bankfull estimates indicate a paleo-drainage area of approximately 1,124,000 km^2 for the A2 axial trunk system, and between 409,000 km^2 and 110,000 km^2 for the A2, B1, and B2 tributary systems. In order to accommodate such a drainage area, all of the Aptian-aged tributary systems must have had headwaters to the West of the Grosmont High, likely headwatered in the incipient Cordillera. Based on mapping of McMurray (and equivalent) strata to the southwest of the study area, at least two possible paleo-topographic lows that cross the Grosmont High are identified that could have acted as conduits for Cordilleran-derived river systems, which would have enabled drainages to enter the Assiniboia Paleo-valley during McMurray time (Basiru, 2016). McMurray paleo-valleys are mapped across the Grosmont High and into the Edmonton Paleo-valley. Based on these observations, a revised paleo-geographic reconstruction of Aptian drainages are proposed to account for valley-confined reservoirs in the Athabasca sub-basin.

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