Depositional History of the Createceous Dina-Cummings Interval: Implications for Reservoir Development, Winter Pool, West-Central Saskatchewan

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Summary

A significant heavy oil reservoir is hosted in Lower Cretaceous strata (Winter Heavy Oil Pool) in west-central Saskatchewan (Townships 42 and 43, Ranges 25 and 26 W3M; Fig. 1). The Winter Pool is estimated to originally have contained 566,044 mbbl of 11 to 13° API oil within the Lower Cretaceous Dina and Cummings members of the Mannville Group (Vigrass et al., 1994). This succession unconformably overlies Paleozoic carbonates and is conformably overlain by the Lloydminster Member. Lower Cretaceous deposition in the Winter area was influenced by topography on the regional sub-Cretaceous unconformity, including the Unity uplands south of the study area and major paleovalleys opening to the north-northwest (Fig. 1). The main objectives of this investigation were to (1) build a predictive depositional model for the Winter area through detailed core and wire-line log evaluation; and (2) integrate the pool-scale reservoir geology into the established regional geological setting in order to reconstruct the depositional history of Lower Cretaceous heavy oil-bearing rocks. The Winter Heavy Oil Pool study area contains 200 vertical wells from which data were analyzed, including 10 cores that were examined in detail (Fig. 1). Sedimentologic and stratigraphic characteristics were documented from analysis of grain size, sedimentary structures, biogenic structures, palynology, and wire-line log data. Eight sedimentary facies were defined and four facies associations interpreted based on genetic characteristics and lithogical relationships assessed during core analysis.

The overall depositional framework can be simplified into five main stages, which consist of: 1) lowstand and transgressive fluvial sandstone deposits (Dina Member; Fig. 2A); 2) evolution to a brackish embayment system (Cummings Member; Fig. 2A, 2B and 2C); 3) incision of a linear valley into the embayment deposits due to sea level fall (Fig. 2A); 4) filling of the incised valley with sandstone during a subsequent sea-level rise (Cummings Member; Fig. 2A and 2D); and 5) continued transgression and widespread deposition of organic-rich shale and coal followed by marine shale of the Lloydminster Member (Bauer 2008; Fig. 2A).

The linear trend of incised valley fill that makes up the Winter reservoir is characterized by a distinctly different depositional pattern and architecture relative to the underlying brackish embayment-estuarine deposit. Recognition and mapping of the brackish embayment back-barrier system (Stage 2, Fig. 2A) and the subsequent valley incision and fill (Stages 3 and 4, Fig. 2A) within the stratigraphic interval of interest is vital for interpreting the distribution of reservoir sandstones and heterolithic non-reservoir deposits in the prolific Cummings–Dina interval of west-central Saskatchewan. The incised valley fill is likely associated with late Aptian to early Albian base level fluctuations that caused incision into Barremian and early Aptian deposits across the Western Canada Sedimentary Basin (cf., Gross, 1980; Smith, 1994; Terzouli and Walker, 1997).

Numerous sedimentological similarities exist between Cummings–Dina strata in the Lloydminster area and lithostratigraphically equivalent heavy oil-bearing units in Alberta, including the McMurray Formation and the Bluesky–Gething interval. Firstly, like the more studied lithostratigraphic equivalents in Alberta, the Cummings–Dina deposits are characterized by brackish-water dominated units. A complex stratigraphic architecture typical of these marginal marine settings is mapped at Winter and therefore continued detailed sedimentological and stratigraphical analysis is essential for the identification of future development opportunities in the region. Furthermore, an underlying topographic control associated with the pre-Cretaceous unconformity influenced sediment distribution in the Winter area, consistent with that recognized in the Athabasca and Peace River oil sands regions. In particular, significant reservoir sandstone bodies in all three areas are commonly aligned with underlying mapped paleotopographic lows on the pre-Cretaceous unconformity. The linkage between paleotopography and sandstone distribution provides further insight into future exploration and reservoir delineation in the Lloydminster region.

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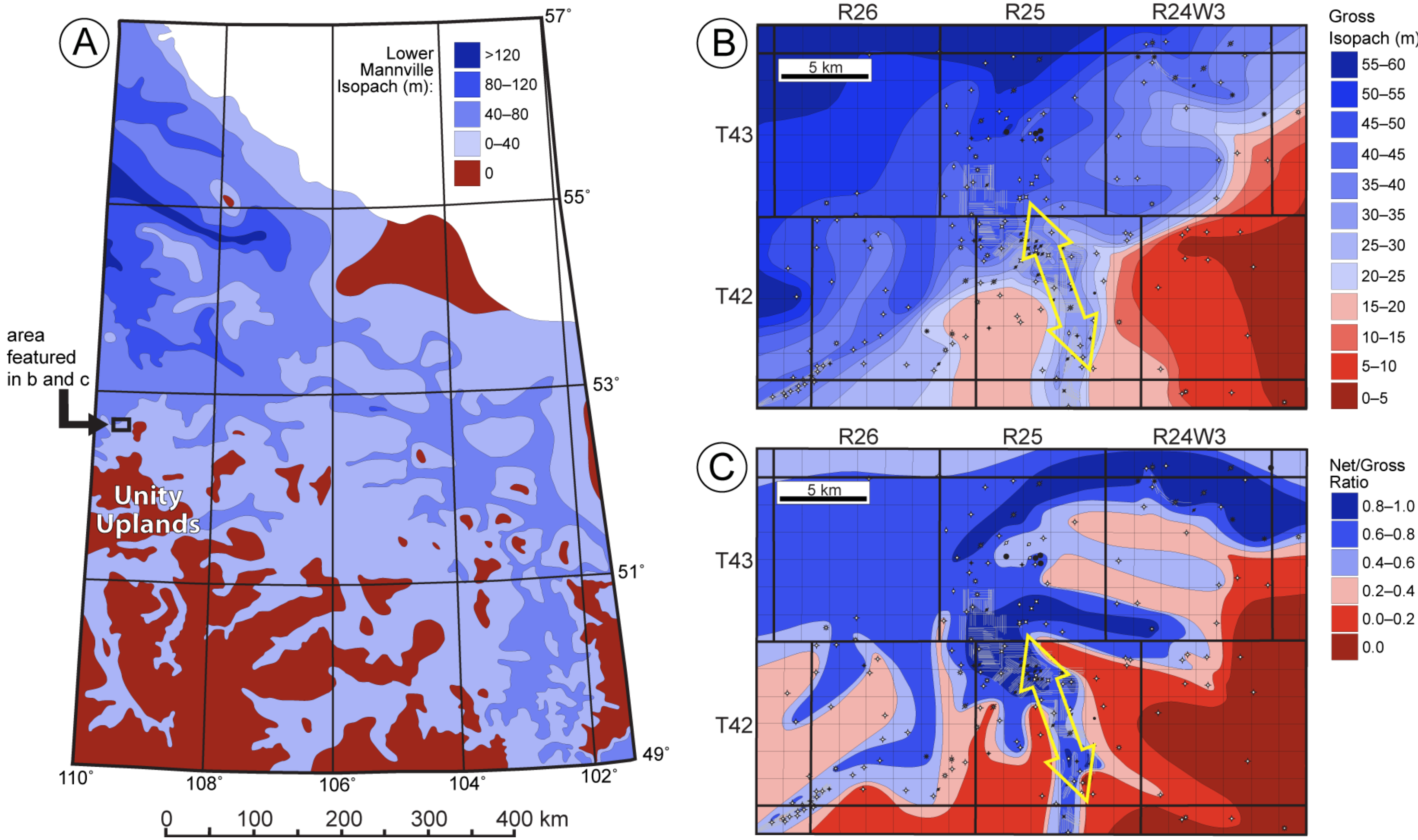

Fig. 1. A) Regional isopach map of Lower Mannville strata, including the Dina and Cummings members and the lithostratigraphically equivalent McCloud Member (modified from Christopher, 1997). B) Isopach and C) net/gross ratio maps of Dina and Cummings members in the Winter area. Yellow double-headed open arrows indicate trend of linear sandstone thick. Horizontal development well trajectories shown, roughly aligned with this trend.

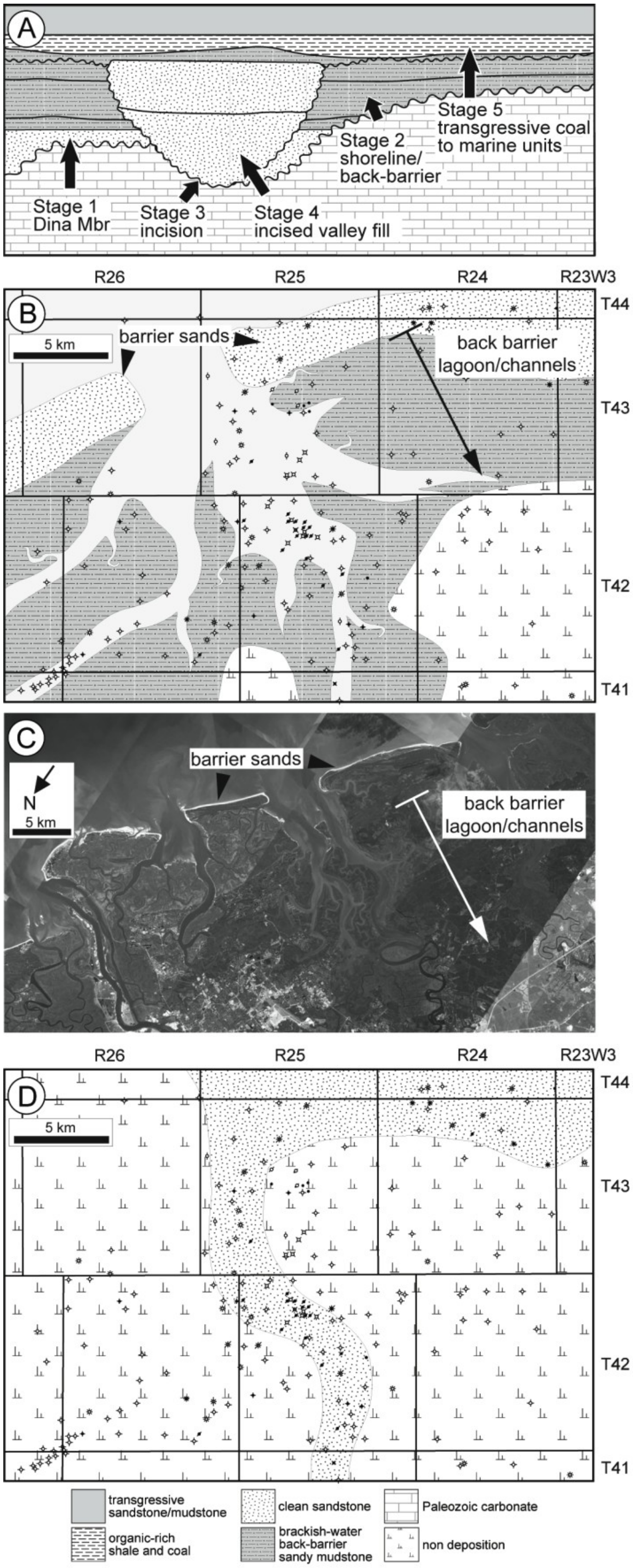

Fig. 2. Interpreted depositional environments for the strata studied. A) Schematic study area cross-section showing stages of depositional history including 1) Dina Member fluvial sandstone deposition on unconformity surface; 2) transgression resulting in barrier-bar complex (back-barrier facies prominent) across map area; 3) Sea-level fall and valley incision; 4) fill of valley primarily with sandstone on transgression; 5) deposition of shoreline and open marine units on continued transgression. B) Map-view interpretation of brackish-water back-barrier depositional environment of study area based on facies mapping, net/gross mapping (Fig. 1C) and sedimentological analysis. C) Modern analogue of Ogeechee River, Georgia Coast, U.S.A. (e.g., Dorjes and Howard, 1975; Howard and Frey, 1985) demonstrating a similar facies architecture and distribution as Part B. D) Incised valley interpretation of study area for reservoir sandstone that eroded through the brackish-water back-barrier deposits (Part B).