Facies Architecture of the Upper Mannville Group (Sparky, Waseca, and McLaren Formations), West-Central Saskatchewan

Alireza Morshedian, James A. MacEachern, and Shahin E. Dashtgard

ARISE, Earth Sciences, Simon Fraser University, Burnaby BC, V5A 1S6,
ama64@sfu.ca

The Lower Cretaceous (early to mid-Albian) Mannville Group (Sparky, Waseca, and McLaren formations) in west-central Saskatchewan is up to 60m thick, and consists of weakly consolidated sandstones, shales, mixed sands and shales forming heterolithic bedding, and minor coals. These units were deposited in shallow marine to coastal-plain environments. The study area is located in west-central Saskatchewan (Lloydminster area) from Townships 48 - 53, and Ranges 19W2 to 28W3, covering a total area of 5,400 km² (Fig. 1).

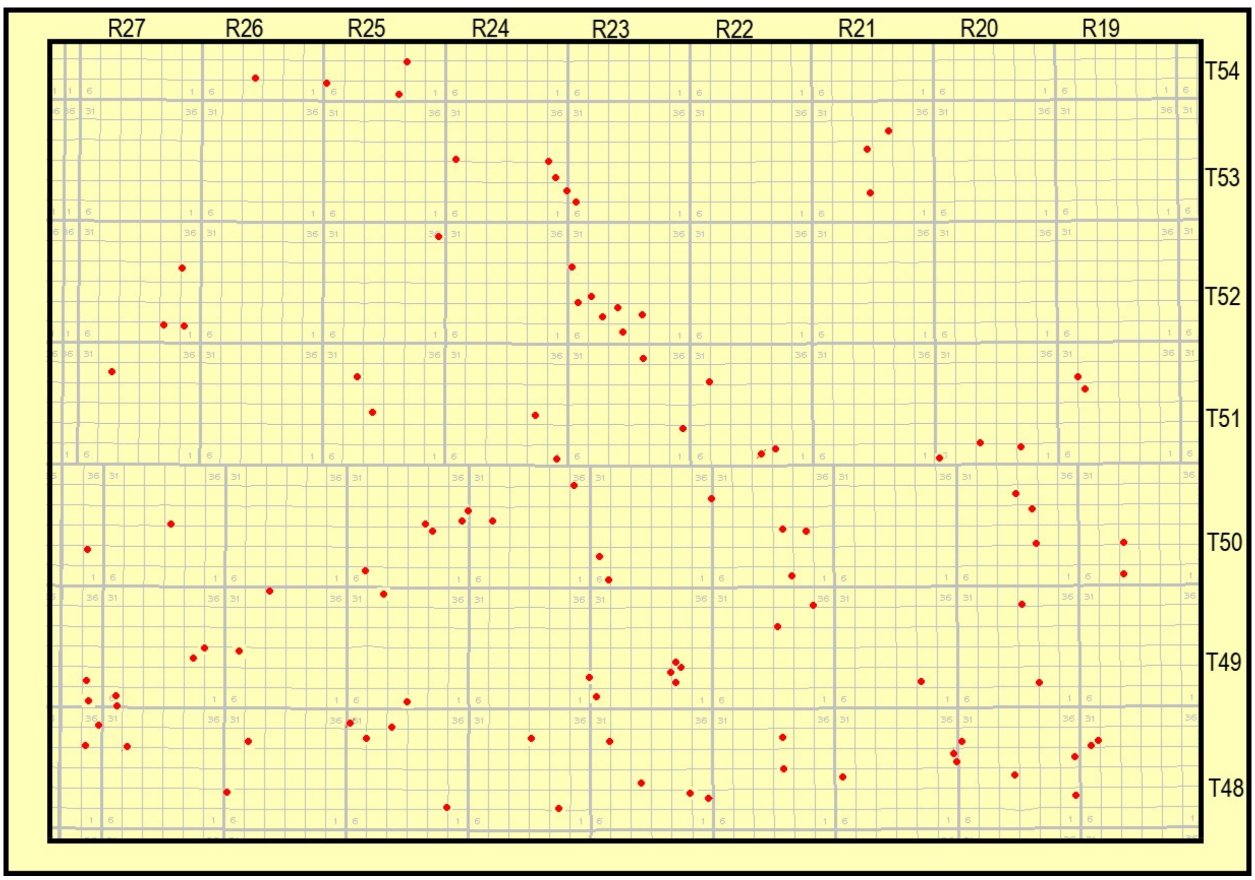

Figure 1: The study area is located in West-Central Saskatchewan, Canada, shown in the above figure. The figure illustrates the core distributions employed in this study.

The Upper Mannville (Fig. 2) was typified by generally low depositional gradients. Individual cycles are thin and represent multiple, small-scale relative sea-level changes. The low gradients facilitated pronounced shifts in depositional environment, reflected by the stacking of markedly different sedimentary facies. Variability in paleoshoreline orientations are reflected by pronounced changes in facies along depositional strike, which serves to inhibit reliable stratigraphic correlation. One hundred subsurface core intervals were analyzed from wells in the study area. The cored intervals were evaluated for trace fossils, sedimentary structures, lithological features, and the presence of stratigraphic discontinuities.

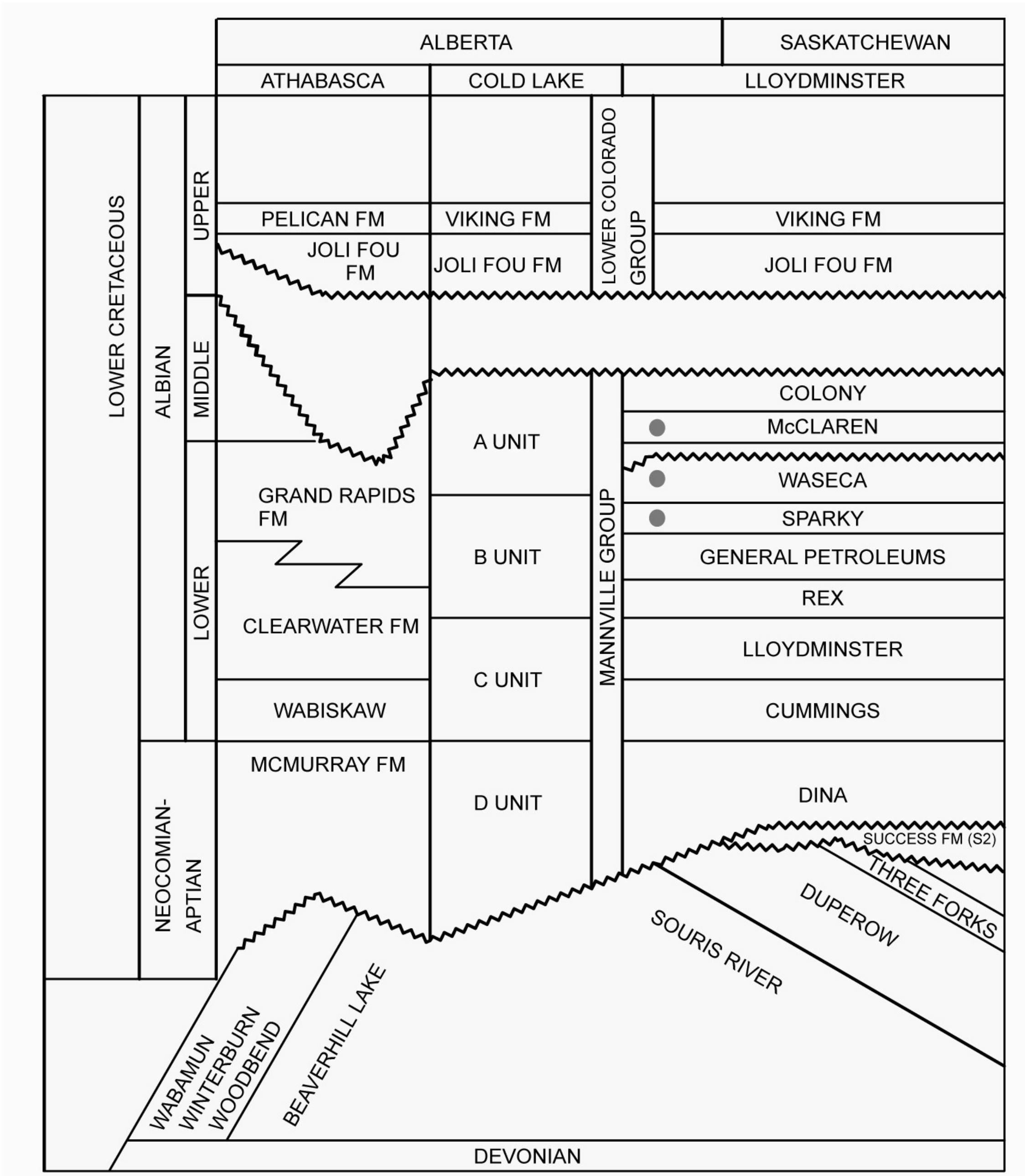

Figure 2: Correlation of Lower Cretaceous strata in eastern Alberta and western Saskatchewan (modified after Christopher, 2003). Dots indicate formations included in this study

Based on these criteria and their spatial distributions, ten recurring facies have been identified from the Sparky, Waseca, and McLaren formations (Morshedian *et al.,* 2009). These can be combined into 6 facies associations. Common depositional facies correspond to inclined heterolithic stratification (IHS), deltaic deposits (including bay-margin deltas), fluvio-estuarine valley fills, and channels associated with coastal-plain settings. Discrimination between these broadly similar depositional facies requires the integration of sedimentological and ichnological criteria.

Inclined heterolithic stratification (IHS) in the lower units are tidally influenced and accumulated as lateral accretion in channelized settings. These IHS units display an overall upward decrease in sediment calibre with variable sandstone-to-mudstone ratios. There is a corresponding upward decrease in the scale of bedforms, as inferred from the sedimentary structures. The facies shows BI (0-3), and commonly contains ichnological suites dominated by *Skolithos, Planolites, Gyrolithes, Cylindrichnus,* navichnia, and fugichnia, demonstrating brackish-water accumulation. Tidal rhythmicity is apparent in the IHS, demonstrating tidal-fluvial point bar accumulation in the estuarine part of the system. These paleochannel/point bars may correspond to estuaries or delta distributaries, depending upon the associated facies and associated discontinuities.

Deltaic deposits are dominated by abundant, organic-rich mudstone drapes of probable fluid-mud origin, syneresis cracks, soft-sediment deformation features, carbonaceous detritus, normally graded beds, and wave-, current- and combined flow-generated structures. Trace-fossil suites are of low diversity, with diminutive ichnogenera and highly variable bioturbation intensities (BI 0-5). Common ichnogenera include *Gyrolithes, Teichichnus, Planolites, Palaeophycus, Cylindrichnus, Skolithos, Thalassinoides,* and *Chondrites.* Additionally, rare occurrences of trace fossils interpreted to reflect the activity of organisms intolerant of stress (*e.g*., *Asterosoma, Phycosiphon, Helminthopsis, Rosselia,* and *Rhizocorallium)* are present, indicating that these environments were not persistently stressed. Brackish-water bay deposits display less overall physico-chemical stress and, as a result, demonstrate higher bioturbation intensities and ichnological diversities than do those of the bay-head deltas. Bedding contacts are pervasively bioturbated and only locally sharp. Bioturbation intensities range from (BI 0-5). Trace fossils include *Planolites, Cylindrichnus, Skolithos, Teichichnus, Palaeophycus, Thalassinoides, Rosselia, Chondrites, Asterosoma, Gyrolithes,* navichnia, and fugichnia. The setting is characterized by wave- and locally combined flow-generated structures, small-scale soft-sediment deformation features, and normally graded mud drapes. This is attributed to reduced fluvial influence in the bay.

Complete depositional cycles within the study area are capped by coastal plain deposits, subsequently terminated by renewed marine transgression. Deposits within this zone are characterized by coals, organic-rich sediments, and locally interstratified thin, fining-upward successions. Rooted paleosols with *Naktodemasis* (*i.e*., adhesive meniscate burrows*)* locally cap the coastal plain deposits, suggesting relative base level fall.

Valleys were incised some 10-15m deep, either during relative sea-level falls or by avulsion of deltaic distributary channels that cut into palimpsest deltaic sediments. The main fill of the incised valleys are estuarine deposits, which accumulated during the subsequent transgression. Facies within the valleys correspond to estuarine channel and bay-head delta deposits. Detailed ichnological evaluation of these valley fills demonstrate variable ichnological distributions and the dominance of simple structures of trophic generalists, consistent with the published brackish-water trace fossil model (*e.g*., Beynon *et al*. 1988, Pemberton and Wightman, 1992).

Correlation within the Upper Mannville has always been challenging. The stratigraphic succession indicates an overall transgressive event, supported by the movement of the shoreline south and east, producing a landward shift of facies. During the transgression, the morphology of the coastline changed significantly (*e.g.,* development of an increasingly embayed coast). This trend, however, is punctuated by periods of shoreline recovery, progradation, and channel/valley infill. The resulting irregularity in shoreline trend coupled with the low-gradient character of the setting is the principal cause of difficulty in stratigraphic correlation both downdip and along depositional strike.

Understanding the facies architecture (spatial and temporal distribution of the facies) and coastal evolution of transgressive deposits is essential, since these deposits have the potential to form abundant stratigraphic traps. Recognition and correlation of subtle stratigraphic discontinuities, coupled with comparisons to present-day strongly embayed coasts may assist in mapping the stratigraphic architecture and predicting the presence of such traps in these highly complex successions.

References

Beynon , B.M., Pemberton, S.G., Bell, D.D., and Logan, C.A., 1988, Environmental implications of ichnofossils from the Lower Cretaceous Grand Rapids Formation, Cold Lake oil sands deposit; Sequences, stratigraphy, sedimentology; surface and subsurface: Memoir - Canadian Society of Petroleum Geologists, v. 15, p. 275.

Beynon, B.M. and Pemberton, S.G. 1992: Ichnological signature of a brackish water deposit: an example from the Lower Cretaceous Grand Rapid Formation, Cold Lake oil sand area, Alberta; *in* Pemberton S.G. (ed), Applications of Ichnology to Petroleum Exploration, SEPM Core Workshop No 17, p199-221.

Christopher, J.E. (2003): Jura-Cretaceous Success Formation and Lower Cretaceous Mannville Group of Saskatchewan; Saskatchewan Industry and Resources, Report 223, CD-ROM.

Morshedian, Alireza, MacEachern, James A., and Dashtgard, Shahin E. (2009): Facies characterization of the Lower Cretaceous Sparky, Waseca, and McLaren formations (Mannville Group) of west-central Saskatchewan; *in* Summary of Investigations 2009, Volume 1, Saskatchewan Geological Survey, Sask. Ministry of Energy and Resources, Misc. Rep. 2009, Paper A-9, 14p

Pemberton, S.G., and Wightman, D.M., 1992, Ichnological characteristics of brackish water deposits *in* Pemberton S.G. (ed), Applications of Ichnology to Petroleum Exploration, SEPM Core Workshop No 17, p.141-167.