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Dynamic sedimentation in the Late Albian, south-central Alberta and Saskatchewan

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Summary

Across southern Alberta and Saskatchewan, rocks of Late Albian age (including the Joli Fou, Viking, Bow Island and Mill Creek formations) represent depositional environments ranging from alluvial to deltaic-nearshore to offshore marine. Because of radical facies changes, it is difficult to establish age relationships amongst these various lithostratigraphic formations. Building upon an existing allostratigraphic framework developed by Boreen and Walker (1991), Roca et al. (2008), Buckley and Plint (2013), and Vannelli (2016) have modified the original allostratigraphic scheme and extended correlation of Upper Albian strata to northern Alberta and NE British Columbia. The investigation reported here builds upon these allostratigraphic studies and extends across 56,000 km^2 of south-central Alberta and Saskatchewan. Preliminary results show that early Late Albian Joli Fou sediments form a subtly SE- thickening wedge whereas lower Viking allomembers VA and VB are approximately sheet-like, with local thickening to the SW reflecting local deltaic depocentres. Viking allomember VD contasts markedly with allomembers VA and VB because it forms a prominent, elongate SW-thickening wedge that extends across Alberta into Saskatchewan, within which, parasequences onlap towards the NE. The NE limit of the wedge is abrupt, defined by a prominent lineament, or hinge-line. To the south of the hinge, overlapping sandy deltaic lobes can be mapped whereas to the north of the hinge, the rocks are mudstone-dominated.

Introduction

The Viking Formation represents one of the most prolific hydrocarbon reservoirs in the Western Canada Foreland Basin, containing 5 to 8% of the total oil in Alberta (Reinson et al., 1994) and a total estimated oil reserve of 88.7 million m^3 (Alberta Research Council et al., 1994). As a result, it is one of the most well-studied formations in Western Canada (e.g. DeWiel, 1956; Beaumont, 1984; Boreen and Walker, 1991; Reinson et al., 1994; Walker, 1995; Burton and Walker, 1999; MacEachern et al., 1999a,b,c; Roca et al., 2008; Fig. 1). Major reservoirs at Willesden-Green, Joffre, Crystal, Gilby and other oil and gas fields, stimulated extensive research on the depositional environments and history of the Viking sandstones. Following the allostratigraphic approach developed for the Cardium Formation (Plint et al. 1986), Downing and Walker (1988) and Boreen and Walker (1991), amongst others, introduced an allostratigraphic framework for the Viking Formation. Although this approach was followed in many subsequent studies (e.g. Pattison and Walker, 1994; MacEachern et al., 1999b), little effort was made to apply a single, consistent allostratigraphic scheme across the basin.

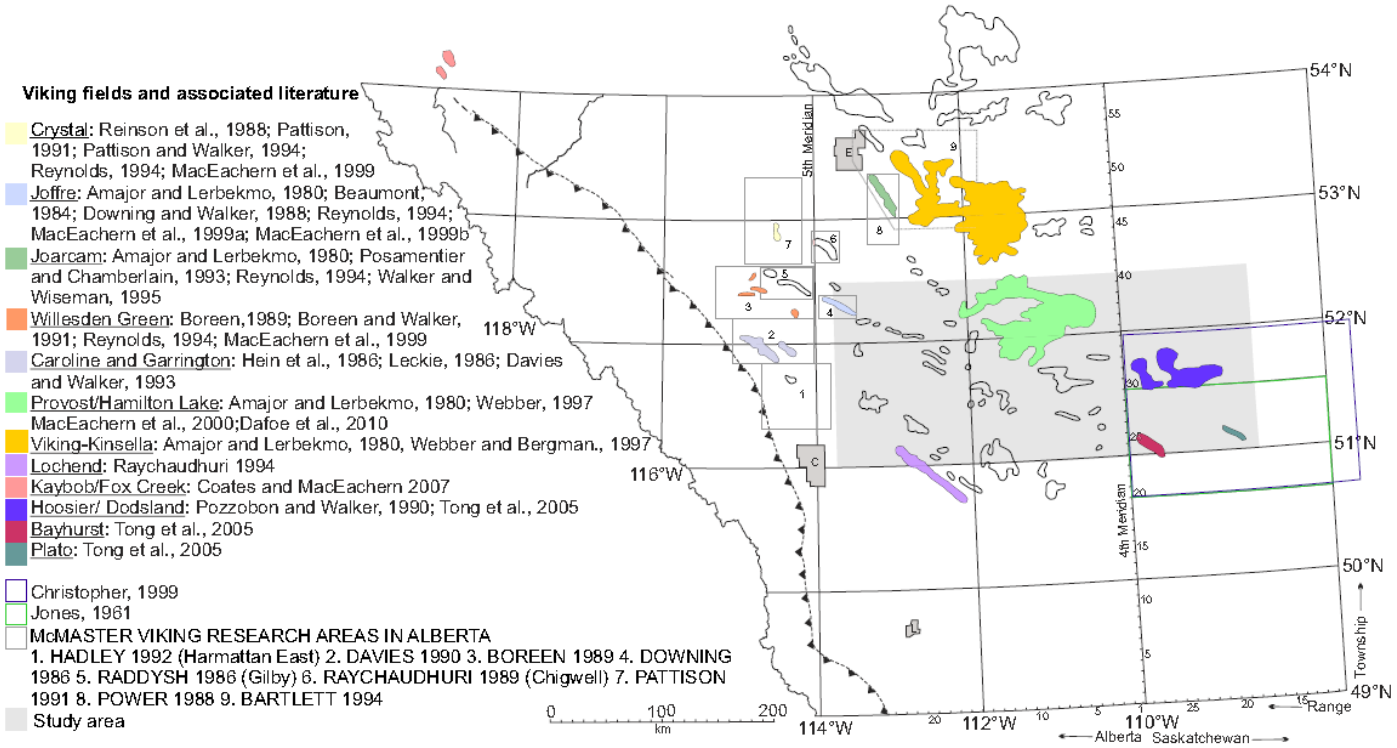

Figure 1: Map showing the distribution of previous studies of the Viking Formation. Map modified from Boreen and Walker (1991).

The current study integrates south- central Alberta and southwest Saskatchewan into the allostratigraphic framework developed by Roca et al. (2008).

Methods

Paired gamma ray and resistivity wireline logs from 1626 wells were correlated in a grid encompassing 56,000 km^2. Master marine flooding surfaces were traced on logs at persistent, but commonly subtle deflections that corresponded to an abrupt increase in clay content. Although marine flooding surfaces are diachronous to some degree (Christie-Blick and Driscoll, 1995; Van Wagoner, 1995) the diachroneity is low relative to the time represented by the rock packages bounded by the surfaces. Flooding surfaces can therefore be considered to approximate timelines; collectively, these surfaces have been traced for >1000 km in various studies at UWO. Sedimentary facies observed in core were used to calibrate wireline logs and interpret depositional environments. Collectively, logs and core were used to construct maps that illustrate the evolving paleogeography and subsidence patterns across the study area.

Results

Results are presented in terms of three main allostratigraphic units:

1. **Joli Fou alloformation:** Marine mudstone of the Joli Fou alloformation is bounded below by surface JE0 and above by surface VE0. The unit forms a wedge that thickens steadily across the study area, from ~ 20 m in the NW to > 40 m in the SE. In SW Alberta, Joli Fou mudstone grades laterally into sandy, marginal marine facies assigned to the lithostratigraphic Bow Island Formation (Reinson et al., 1994) whereas eastward across Saskatchewan, mudstone in the lower part of the Joli Fou alloformation grades laterally into the lithostratigraphic Spinney Hill Sandstone.
2. **Viking allomembers VA and VB:** Lower Viking allomembers VA and VB, collectively bounded by surfaces VE0 and VE3, exhibit an overall tabular geometry across the basin. Coeval marginal marine and alluvial facies of the Bow Island and Mill Creek formations occupy the most southern

part of Alberta. Viking allomember VB occupies a discrete depozone containing up to 40 m of sandy, deltaic and shallow-marine strata that grade laterally into mudstone to the NE.

3. **Viking allomember VD:** Viking allomember VD forms a prominant wedge, the NE margin of which is defined by a NW - SE trending lineament, mapped for > 500 km. The lineament forms a hinge across which sediment thickness increases rapidly. Overall, allomember VD thickens from ~10 m at the hinge to > 40 m at the southern margin of the study area. Although a very prominent feature, the 'hinge' described here appears to have been recognized previously only by Jones (1961) in south central Saskatchwan. Neither Jones nor ourselves have been able to identify the tectonic element that is presumed to have controlled differential subsidence across the hinge. Our isopach mapping of the overlying mudstone of the Westgate alloformation shows that Westgate strata thicken subtly to the NE across the hinge line, implying that the struture underwent a reversed pattern of subsidence between Viking allomember VD and Westgate allomember WC time.

Conclusions

Allostratigraphic correlation of genetic stratal packages, coupled with facies analysis, shows that Upper Albian strata reveal a dynamic pattern of changing accommodation across south-central Alberta and adjacent Saskatchewan. The Joli Fou records subtle differential uplift in the NW and subsidence in the SE whereas lower Viking allomembers VA and VB are essentially tabular and indicate regional tectonic quiescence, subtly overprinted by local deltaic depocentres in the SW. Marine sandy facies in Viking allomember VD form stacked, NE- onlapping parasequences that reach > 40 m thick and are confined to a wedge-shaped depocentre bounded to the NE by a linear hinge, > 500 km long. Coeval VD sediments to the NE of the hinge are <10 m thick and mudstone-dominated. In contrast to the pattern in allomember VD, latest Albian mudstone of the Westgate alloformation thickens to the NE across the hinge zone, implying that the sense of differential subsidence reversed between Viking VD and Westgate WC. A structural feature is assumed to have controlled the 'hinge', but has not yet been identified.

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