Deposition of the Peavine Sandstone on the Peace River Arch and its Relationship to Transgressive-Regressive Cycles within the Beaverhill Lake Group, North-Central Alberta*

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Abstract

Strata of the Beaverhill Lake Group in north-central Alberta were mapped using wireline logs and core. Primary lithostratigraphic mapping was supplemented with sequence stratigraphic methods to relate the timing of events between distinct depositional realms within the Beaverhill Lake Group across the province. Transgressive-regressive (T-R) cycles within the Waterways Formation in the east were correlated westward across the province to the southern flank of the Peace River Arch and northern Swan Hills area. Here, T-R cycles downlap or onlap Slave Point or Swan Hills carbonate complexes. Younger T-R cycles interfinger with siliciclastics shed from the Arch. During a period of relative sea-level fall, one such T-R cycle merges with a marked regressive sandstone package, known in industry reports as the Peavine sandstone (also the Beaverhill Lake sandstone). This particular T-R cycle is significant because its upper contact displays evidence for subaerial exposure on the Eastern Platform and has been correlated to similar exposures within the carbonate complexes of the Swan Hills area. On the Eastern Platform, evidence for subaerial exposure occurs at the top of a T-R cycle within the Moberly Member carbonates of the Waterways Formation. In the study area, this event is recognized as one of a few times during which sea level fell low enough to subaerially expose Frasnian-aged Beaverhill Lake Group carbonates. Evidence for lowering of relative sea level is further supported by linking this event with the Peavine sandstone regressive pulse on the Peace River Arch.

Introduction

The Middle to Upper Devonian Beaverhill Lake Group in the subsurface of Alberta is a regionally extensive succession of carbonates, argillaceous carbonates, calcareous shales, evaporites, and areally restricted sandstones. The Alberta Basin, during Beaverhill Lake Group time, records an important phase of bioherm and biostrome development in the form of extensive platforms, banks, and isolated reef successions. Linking depositional events tied to relative sea-level history in the Beaverhill Lake Group has been an ongoing research topic since hydrocarbon discoveries were made in Swan Hills strata as early as 1957 (Oldale and Munday, 1994).

Some of the more recent research has moved beyond lithostratigraphy to employ sequence stratigraphic methods to more fully understand the evolution and stratal architecture of Beaverhill Lake Group strata (e.g., Campbell, 1992; Potma et al., 2001; Wendte and Uyeno, 2005). Recognition of cyclicity within carbonate complexes both in the Swan Hills area and in Slave Point strata on the Peace River Arch brought understanding of the evolution of these two distinct carbonate systems (Fischbuch, 1968; Gosselin et al., 1989; Wendte, 1992). Understanding the relationship between these two systems has been difficult in part due to a general paucity of useful biostratigraphic elements within reefal successions (Braun et al., 1988). Moving beyond the western carbonate complexes, gains were made in understanding the relationship between western carbonate depositional systems with biostrome and terrigenous basin-filling strata of the eastern part of the province (i.e., Eastern Platform; Waterways Formation) (Sheasby, 1971; Moore, 1993; Potma et al., 2001; Wendte and Uyeno, 2005). Linking eastern and western depositional systems has benefited from correlation of sequence stratigraphic packages, namely transgressive-regressive cycles supported with biostratigraphy, originating from the Eastern Platform (Wendte and Uyeno, 2005). This study aims to enhance the understanding of stratigraphic relationships in Beaverhill Lake Group strata across the province in north-central Alberta, and place in context a distinct, regressive siliciclastic pulse from the Peace River Arch with respect to relative sea-level history in the basin.

Geological Setting

The Beaverhill Lake Group in Alberta comprises, in ascending stratigraphic order, the Fort Vermilion Formation, the Slave Point Formation, the Swan Hills Formation, and the Waterways Formation (Figure 1). The Slave Point and Swan Hills formations are partly equivalent shallow-water and open-marine carbonates. In general, the Waterways Formation has been used to describe argillaceous-rich carbonates associated with the Eastern Platform (Crickmay, 1957). The Waterways Formation displays a number of alternating shaley and carbonate-rich units recognizable on wireline logs that have been subdivided into a series of members: in ascending stratigraphic order, these are the Firebag, Calumet, Christina, Moberly, and Mildred. Along the southern flank of the PRA a distinct sandstone unit, known in industry reports as the Peavine sandstone, is found within the argillaceous carbonates of the Waterways Formation (Figure 1 and Figure 2). Preliminary mapping indicates that feldspathic Peavine sandstones were deposited in a marginal-marine, likely deltaic, setting.

The distribution of strata in the study area is complicated by the presence of the Peace River Arch (PRA). Within the Alberta Basin, the PRA is a complex basement structure that has influenced depositional patterns from at least the time of the early Paleozoic (O'Connell et al., 1990). During Devonian deposition, the PRA was continuously onlapped as sediments accumulated in the basin. It remained emergent throughout Beaverhill Lake Group time, and was a continuous source of siliciclastic sediment. These sediments were shed in an apron around the margin of the structure, forming what is commonly known as the Granite Wash. These siliciclastics are therefore diachronous and interfinger in a complex manner with the onlapping Beaverhill Lake Group strata (Figure 1). Depositional pinch-out is complicated by local antecedent paleotopography, such as monadnocks, and lateral facies changes resulting from interbedding with nearshore sandstones shed from the PRA.

A number of transgressive-regressive (T-R) cycles can be correlated from the Eastern Platform westward to the Swan Hills area and PRA. T-R cycles vary in hierarchical significance, but there is one T-R cycle within the Moberly Member that shows evidence of an unconformity at its upper bounding surface in the form of subaerial exposure on the Eastern Platform. Wendte and Uyeno (2005) correlated this surface with a similar surface identified in Swan Hills carbonate complexes (e.g., Judy Creek of Wendte and Muir, 1995). In this study, this same surface is shown to correlate from the Eastern Platform westward toward the PRA and merges with a pronounced regressive sandstone unit originating from the southern flank of the Arch, known as the Peavine sandstone (also known as the Beaverhill Lake sandstone). A fall in relative sea level subsequent to deposition of this T-R cycle resulted in exposure of isolated carbonate complexes in the Swan Hills region, similar exposure in carbonate complexes of the Eastern Platform, and regressive lowstand siliciclastic deposition on the flank of the PRA. Other T-R cycle boundaries within the Waterways Formation do not show evidence for subaerial exposure, suggesting that the amplitude of this fall may have been the most significant during deposition of the Beaverhill Lake Group.

The position of this particular correlative T-R cycle boundary within the Beaverhill Lake succession across the basin has implications for the timing of Slave Point Formation deposition over much of the southern and eastern flanks of the Peace River Arch in relation to the Swan Hills carbonate complexes. Portions of the isolated Swan Hills buildups that post-date the subaerial exposure surface are younger than many of the Slave Point carbonate complexes fringing the Peace River Arch, which underlie the T-R cycle boundary within the Waterways Formation at the base of the Beaverhill Lake sandstone unit, and within the Moberly Member of the Eastern Platform (Figure 1).

Methods

This work is part of a larger project that contributes to the Alberta Geological Survey goal of modeling in three dimensions the distribution of Paleozoic strata across the Province of Alberta. The present study area encompasses the southern and eastern flank of the PRA; south to the northernmost part of the Swan Hills carbonate complexes, and east to the Eastern Platform near the subcrop belt of the Beaverhill Lake Group. Fifteen cores were reviewed for verifying presence or absence of mapped strata, and to verify log response for the purpose of wireline log correlation. Several cores spanning the T-R cycle boundary at the base of the Beaverhill Lake sandstone on the Peace River Arch and in the Moberly Member on the Eastern Platform were described, to discern the nature of the contact and the over- and underlying facies. Correlation within the Beaverhill Lake Group was accomplished using ~1500 wells and a suite of wireline logs—gamma ray, density-neutron, bulk density, resistivity, photoelectric effect, and sonic—within the computer program Petra from IHS. Tops data are then gridded within Petra and contoured for structure and isopach mapping.

Examples

Figure 2 is an east-west stratigraphic cross-section showing mapped lithostratigraphy within the Beaverhill Lake Group. The stratigraphy of some of the underlying Elk Point Group and overlying Woodbend Group is shown for reference. The cross-section runs from the Eastern Platform in Twp. 70, Rge. 16, W 4th Mer. to a location near the depositional termination of Beaverhill Lake Group strata on the southern flank of the PRA in Twp. 75, Rge. 25, W 5th Mer., a total distance of 345 kilometres. The cross-section includes wells that penetrate the northern part of the Swan Hills Platform and the overlying Snipe Lake isolated buildup.

The correlation of upper bounding surfaces of three transgressive-regressive cycles is shown (Figure 2). Other T-R cycles were mapped during the course of this study, but are not shown here. T-R cycles C and D display onlapping relationships with the eastern margin of the Swan Hills Platform. The younger T-R cycle E correlates westward to a position underlying the Peavine sandstone on the southern flank of the PRA. Subsequent to the deposition of T-R cycle E, a lowering of relative sea level in the study area resulted in exposure of carbonate complexes on the Eastern Platform and some isolated buildups in the Swan Hills carbonate complex. On the PRA, this lowering of sea level is associated with deposition of the Peavine sandstone, which is interpreted as a lowstand siliciclastic wedge.

Conclusions

The distribution of Beaverhill Lake Group strata has been mapped lithostratigraphically in north-central Alberta. Correlation of T-R cycles within Waterways Formation strata enhances the understanding of the relationship between carbonate complexes on the west and east side of the basin. Additionally, a pulse of regressive siliciclastic sedimentation along the southern flank of the Peace River Arch is related to T-R cyclicity, linking relative sea-level history recorded in carbonate complexes with siliciclastic deposition along the PRA. Evidence for subaerial exposure at the upper bounding surface of a T-R cycle in the Moberly Member of the Waterways Formation can be linked to lowstand deposition of the Peavine sandstone. Subaerial exposure in isolated buildups of the Swan Hills Formation has been correlated to the same event.

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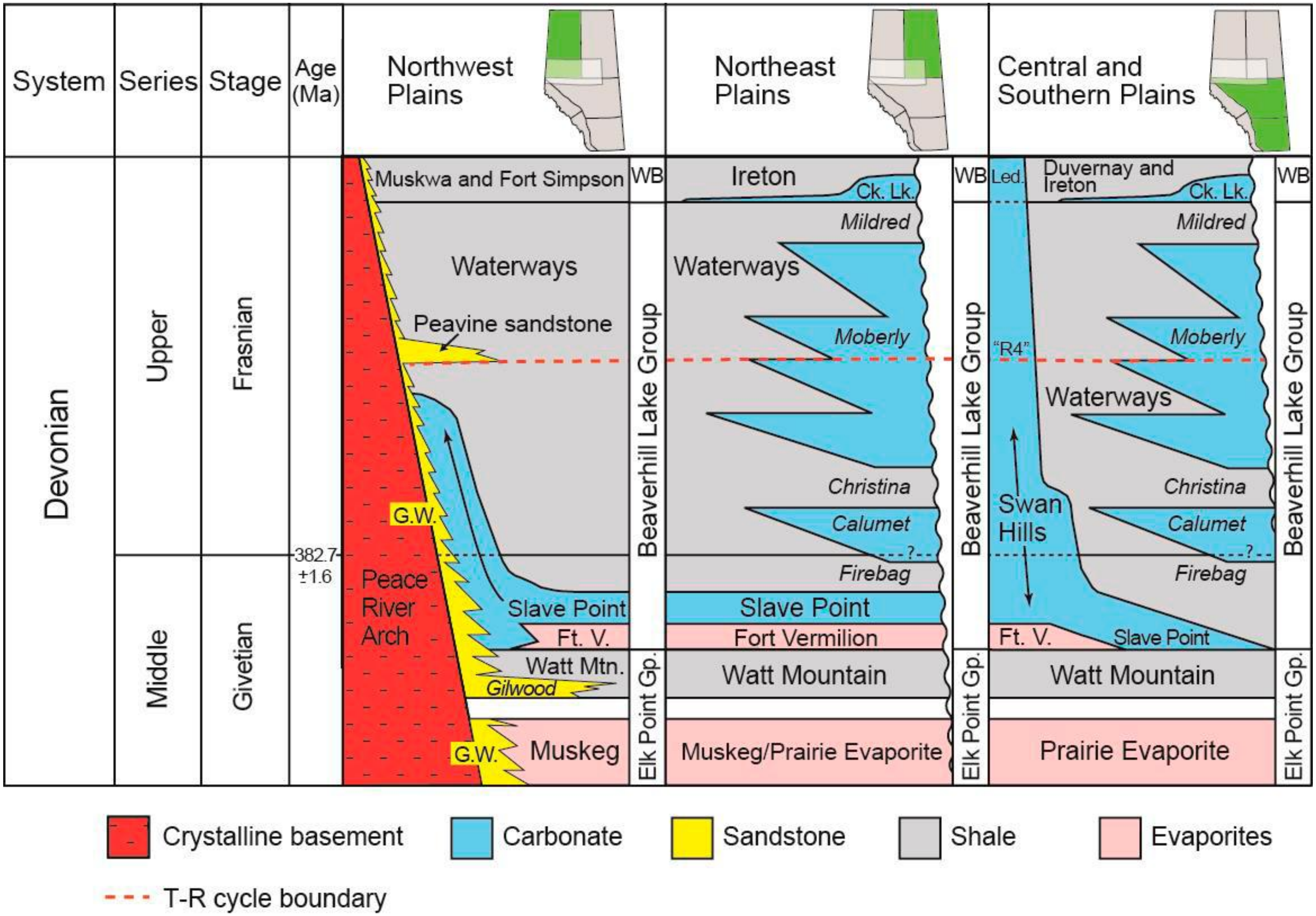

Figure 1. Schematic lithostratigraphic column showing the distribution of upper Givetian to lower Frasnian strata in the Alberta Basin. The T-R cycle boundary associated with the deposition of the Beaverhill Lake sandstone is shown. The study area is shown as the transparent box at top. Member nomenclature in italics. Abbreviations: WD, Woodbend Group; G.W., Granite Wash (lithosome); Ft. V., Fort Vermilion; Ck. Lk., Cooking Lake; Led., Leduc; Mtn., Mountain; Ma, millions of years. The age for the Givetian-Frasnian boundary from the International Stratigraphic Chart www.stratigraphy.org.

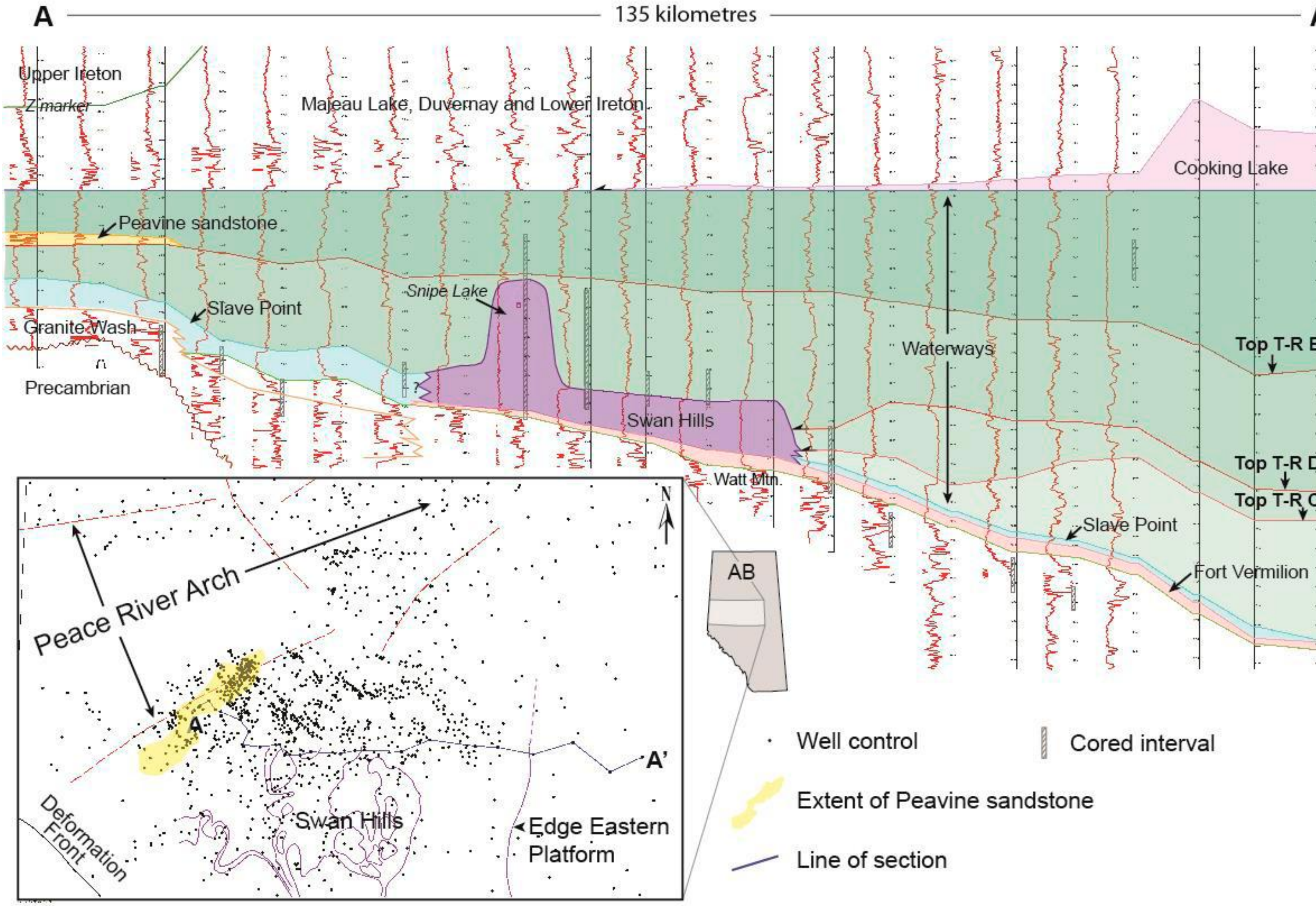

Figure 2. Stratigraphic cross-section A-A' (datum = top Beaverhill Lake Group) showing lithostratigraphy and the correlation of three transgressive-regressive cycles within the Waterways Formation (not all mapped T-R cycles are shown). The T-R cycle E, associated with subaerial exposure on the Eastern Platform, correlates westward to a position underlying the Peavine sandstone on the southern flank of the Peace River Arch. The extent of the Peavine sandstone is shown in yellow on the map. Digital gamma-ray logs are shown where available (unavailable in older wells in the east). The edges of the Swan Hills and Eastern platforms are from Wendte and Uyeno (2005).