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A high resolution sedimentological assessment : Niton Member of the Fernie Formation, west-central Alberta subsurface

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Summary

The Niton Member, is a distinctive and regionally mappable, unconformity-bounded, unit in the upper Fernie Formation in the subsurface of west-central Alberta. This member is Late Jurassic (Oxfordian) in age and consists predominantly of glauconitic sublitharenites to quartz arenites with rare shales. It is readily distinguished from the underlying Rock Creek Member (Bajocian) as well as the overlying “Upper Fernie” shale (Oxfordian-Kimmeridgian), and serves as a regional marker in a sequence below the Mannville Group that has long been difficult to interpret. The Niton Member accumulated as a prograding, shallow marine sandbody following a 7 Ma (Late Bajocian to Callovian) hiatus. Concomitant with progradation, the member was overprinted by vadose processes.

Introduction

Jurassic and Cretaceous strata of the Western Canadian Sedimentary Basin (WCSB) have been the focus of many geological studies over the years since the discovery of economically significant oil and gas reserves. However, interpretation in distinguishing sandstones within the interval between clearly Jurassic strata below and the Cretaceous strata above has proven to be both challenging and difficult and any distinctive unit could potentially be a useful stratigraphic tool.

The Niton Member of the Fernie Formation is one unit that lies in this enigmatic interval. It can be separated from underlying and overlying strata based on the presence of glauconite, trace fossils, age, regional extent, and bounding unconformities. Its regional correlatability with other glauconitic units is important as these strata occur within the interval between obvious Jurassic strata below and Cretaceous strata above. Although the Niton Member is a somewhat thin blanket-like unit, its disproportionate value as a stratigraphic horizon is remarkable for its age and glauconite content.

The Niton Member is Late Jurassic (Oxfordian) in age based on palynology (Kramers and Dolby, 1993). It is a synthemic unit, as it is bound by unconformities, and stratigraphically overlies the Middle Jurassic Rock Creek Member, while underlying the “Upper Fernie” shale. The lithology of the Niton Member is predominantly glauconitic sublitharenites and quartz arenites with rare shales. Its correlatability with other glauconitic units is important as they occupy an interval between a passive margin, platformal basin succession and the subsequent orogenic foredeep fill succession resulting from exotic terrane accretion to the west (Poulton et al., 1994).

Similar to the Niton Member, the Green Beds of the Fernie Formation in northern Alberta and northeastern British Columbia overlie a widespread regional unconformity below which are older Jurassic strata. The Green Beds are also a basal transgressive sandstone below the “Upper Fernie” shale (Poulton et al., 1990; Stott, 1998). Identification of the Niton Member contributes to the revision and understanding of the regional geology of west-central Alberta and for the Jurassic depositional history of the WCSB.

Methods

Our study area is located in west-central Alberta, encompasses 3000 km^2 between Townships 52 to 56 and Ranges 11W5 to 16W5, and includes the Niton, Carrot Creek, and McLeod oil and gas fields (Figure 1). More than 3000 wells have been drilled in this area and at least 2000 wells intersect the Fernie Formation. Here, the Fernie Formation includes the Nordegg, Poker Chip Shale, Rock Creek, former “Niton B”, and “Upper Fernie” members (Figure 2). The study uses data collected from core logging and analysis completed at the Energy Resources Conservation Board, Core Research Centre, located in Calgary, Canada. Thirty cores were selected within the study area and analysed using the core logging methods and symbols of Swanson (1981). These cores were used as stratigraphic control for correlation with geophysical well log data from 284 other wells to create 25 stratigraphic cross-sections, and isopach maps for the Jurassic units within the study area.

Pertinent rock samples were removed from each core, and 40 thin sections were cut and analyzed by petrographic light microscopy. Mineralogy was compared in 8 thin sections from throughout the Niton Member sandstones, and 600 grains were counted per thin section using a Swift Model F point counter to determine composition. The parameters for the counter include a stage interval of 2 (horizontal shift) and a vertical adjustment increment of 1.5 mm. The counts were conducted using a petrographic light microscope at 100X magnification.

Representative thin sections were further characterised via scanning electron microscopy (SEM) at the Instrumentation Facility for Analytical Electron Microscopy (IFFAEM), University of Calgary, Department of Geoscience. Instrumentation used consisted of an FEI Quanta FEG 250 field emission SEM equipped with a Bruker Quantax 5030 SDD-type energy dispersive X-ray spectrometry system and a Gatan MonoCL4 Elite cathodoluminescence (CL) system. Thin sections were carbon-coated and examined under high vacuum conditions. Imaging modalities used included backscattered electron (BSE) imaging, elemental X-ray emission mapping, and CL imaging. BSE imaging and X-ray mapping were conducted at an accelerating voltage of 20 kV, while CL acquisitions were performed at 7.5 kV.

Results

Recognition: The Niton Member is light to medium grey and occasionally brown in patches, and is composed of very fine- to coarse-grained (62.5–1000 µm, 177–250 µm avg.) glauconitic sublitharenites and quartz arenites with rare dark grey to black shales. Niton Member sandstones are almost always well bioturbated to churned with a mixture of horizontal and vertical macroburrows. The most commonly observed trace fossils are *Phoebichnus* isp., *Rhizocorallium* isp., and *Diplocraterion* isp. Where not disrupted by bioturbation, the rocks are observed to be originally very thinly to thinly bed. Physical sedimentary structures when present consist of 2-D and 3-D ripple- and dune-scale structures, plane-parallel beds, and low-angle inclined stratification (LIS) (Krause and Nelson, 1984). Iron sulphides and siderite are observed throughout the member, but are more common at the bounding unconformities.

Unconformities: The Niton Member while resting mainly on the Rock Creek Member can also rest on the Poker Chip Shale. Erosion before or during accumulation of the Niton Member not only removed parts of the Rock Creek Member across most of the study area, but removed it completely in the northwest corner of the study area. As a result, the time gap at this lower unconformity is variable ranging between 7–15 Ma. In contrast, the upper unconformity separating the Niton Member from the

“Upper Fernie” shale is of much shorter duration and may span the Late Oxfordian and extend into the Early Kimmeridgian. In addition the Niton Member can be further truncated by younger unconformities that resulted from down-cutting, erosion, and deposition of Lower Cretaceous units (Figure 2).

Petrology: Niton Member sandstones are very fine- to coarse-grained sublitharenites that on average are fine- to medium-grained. Based on 600-grain point counts of seven thin sections, the majority of framework grains are monocrystalline quartz (87–93%) and glauconite (4–10%) with a lesser fraction of chert, polycrystalline quartz, feldspars, and lithic rock fragments (LRF) that include phosphatic and carbonate grains, and very rare epidote, tourmaline, and zircon. Notably, glauconite grains increase in abundance (greater than 50%) at the top bounding unconformity based on point counting of the eighth thin section. To highlight the compositional differences at the upper bounding unconformity between the Niton Member and the transgressive deposits that cap the member, we have modified the ternary Folk et al. (1970) diagram to accommodate glauconite in the feldspar pole. With this modification the different abundances of glauconite above and below the unconformity are immediately apparent as rocks below this boundary are subglaucoses and above the boundary they are glaucoses. In the standard Folk et al. (1970) classification, these rocks are sublitharenites and litharentites, respectively. On the other hand, phosphatic grains are infrequent to rare, only occurring at or near the bounding unconformities. Cementation, while variable throughout the unit, comprises mainly silica with minor amounts of clay, siderite, and rare calcite. Megaquartz overgrowths are common and the central cores of the quartz grains are usually rounded to well-rounded. At or near the bounding unconformities, iron sulphides, siderite, calcite, and illuvial, circumgranular and birefringent clay fabrics are more common.

Clays have commonly translocated sub-vertically to vertically between the framework grains producing characteristic illuvial textures. Throughout the member, this distribution is patchy. Within these patches brown illitic clays drape grains and fill interparticle spaces. Birefringent translocation and paleosol pressure realignment fabrics are visible with crossed-polarised light (Fitzpatrick, 1993, p. 107–111; Retallack, 2001, p. 188–189). These fabrics include circumgranular clays and birefringent-strial patterns. Below the bounding unconformities, these birefringent fabrics are particularly common.

Siderite and iron sulphides are present throughout the Niton Member with increased concentrations at the bounding unconformities. In core, highly sideritised regions (up to 35 cm thick) are accompanied by discontinuous subhorizontal iron sulphide precipitates along platy to subangular peds as observed for example in well 100/5-21-55-16W5/00 at 2272.60 m. Thin sections of some mudstones that were cemented early with siderite contain early sedimentary textures that include grains that are either in point contacts with other grains or floating in the mudstone matrix. Floating grains have crystalline “halos” that are former circumgranular cavities, now filled with crystalline carbonate. These circumgranular cavity infills are crystallaria that are indicative of formation under vadose conditions, as periods of wetting and drying provided for the expansion and contraction of the surrounding mudstone (Wright, 1990; Fitzpatrick, 1993).

Green sedimentary grains with a knobby pelletal outline are dispersed in the arenites. Morphologically, these green grains are variably smooth, fractured, layered, or zoned; all these features are similar to the ones described by Odin and Matter (1981) as glauconite. Under reflected light these grains are mostly greenish-grey and dark greenish-grey (Munsell colours 5G4/1, 5G6/1, 5G7/1, 5GY4/1, 5GY6/1) (Munsell Soil Color Charts (Revised Edition), 1994). In thin section under transmitted light the grains exhibit a very weak light yellow-brown to pale green pleochroism. Energy dispersive X-ray (EDX) chemical element maps and back-scattered electron (BSE) images of the grains indicate enrichment in potassium and aluminum with lesser amounts of iron, magnesium, and sodium (Figure 3). Thus, the ranges of features that we note are all indicative of glauconite (Meunier, 2005). Glauconite particles have also been reported in cuttings in commercial lithological logs, but our study provides the first conclusive determination of the mineral in the public record for this member. Thus, polished thin sections of cuttings can be used to identify the Niton Member in the absence of core using light microscopy and EDX techniques.

Previous reports of glauconite in the Rock Creek Member are taken to refer to the Niton Member instead, as the Niton Member has not been differentiated from the unconformably underlying Rock

Creek Member in most studies, databases, and charts. Some publications since Stronach (1981), including the "Atlas" (Poulton et al., 1994), have referred to berthierine or chamosite in the Niton-equivalent Green Beds of the Fernie Formation, without providing documented identifications for the green minerals. Chemical element maps of green grains from the Green Beds collected at the Coal Mountain Mine 30 km southeast of Sparwood, British Columbia are very similar to the glauconitic grains that we have identified in the Niton Member. Our experience with the Niton Member and Green Beds now suggests that earlier publications contain misidentifications of glauconite. Correct identification of the green mineral in the Niton Member and equivalent strata regionally is important, because of its status as a stratigraphic indicator in this Jurassic section.

Conclusions

The Niton Member is an unconformably bounded synthemic interval of glauconite-bearing, sublitharenite to quartz arenites and rare shales that is regionally mappable in the subsurface of west-central Alberta. The discrimination of this unit, and of the major regional unconformity below it, clarifies ambiguities that have existed with stratigraphic separation from the underlying and significantly older Rock Creek Member. The Niton Member is also in unconformable contact with the overlying "Upper Fernie" shale. The recognition and interpretation of this unit are important for regional correlations within a broad area of west-central Alberta. This is a significant and distinctive marker unit that will contribute to future understanding of the enigmatic interval immediately below the "sub-Cretaceous unconformity" and its relationships within western Canada foredeep development. The Niton Member appears to be a shallow marine glauconitic sandstone, with vadose imprintings, developed by progradation possibly as a strand plain over a broad surface following a major hiatus that spanned the Late Bajocian through Callovian stages.

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Figures

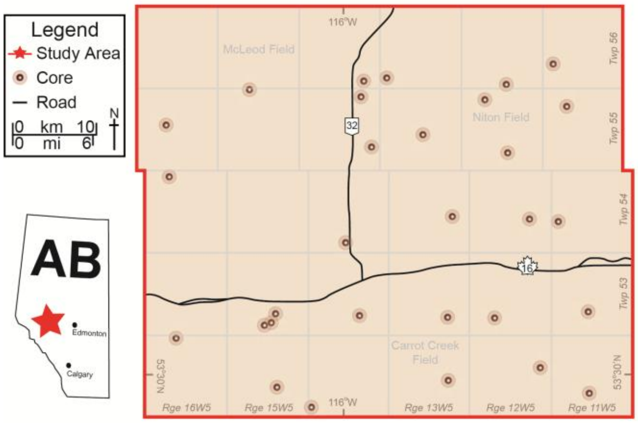

Figure 1. Study area. The location of the study area outlined in red is illustrated as a red star on the index map of Alberta. Tan and maroon double circles are well locations of logged cores. The general location of the McLeod, Niton, and Carrot Creek hydrocarbon fields are noted.

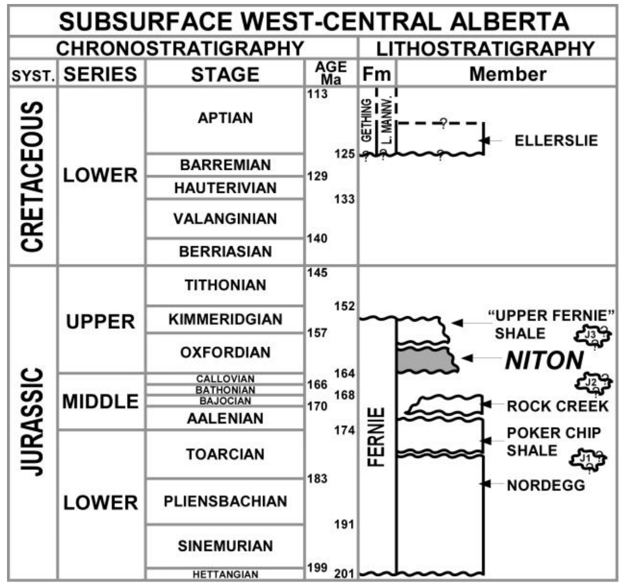

Figure 2. Summary chronostratigraphic and lithostratigraphic chart for Lower Cretaceous and Jurassic strata in west-central Alberta. Stage intervals are scaled to age, but age boundaries are rounded off. L.MAN = Lower Mannville Formation. The Niton Member may include strata as old as latest Callovian (Dolby, in Poulton et al., 1990; Kramers and Dolby, 1993). Chart compiled from Hall (1990b, 1990c, 1990d); Losert (1990); Poulton et al. (1990); Putnam and Burnett (1990); Kramers and Dolby (1993); Hayes et al. (1994) and Poulton et al. (1994); Asgar-Deen et al. (2004); Hall (2006); Gradstein et al. (2012).

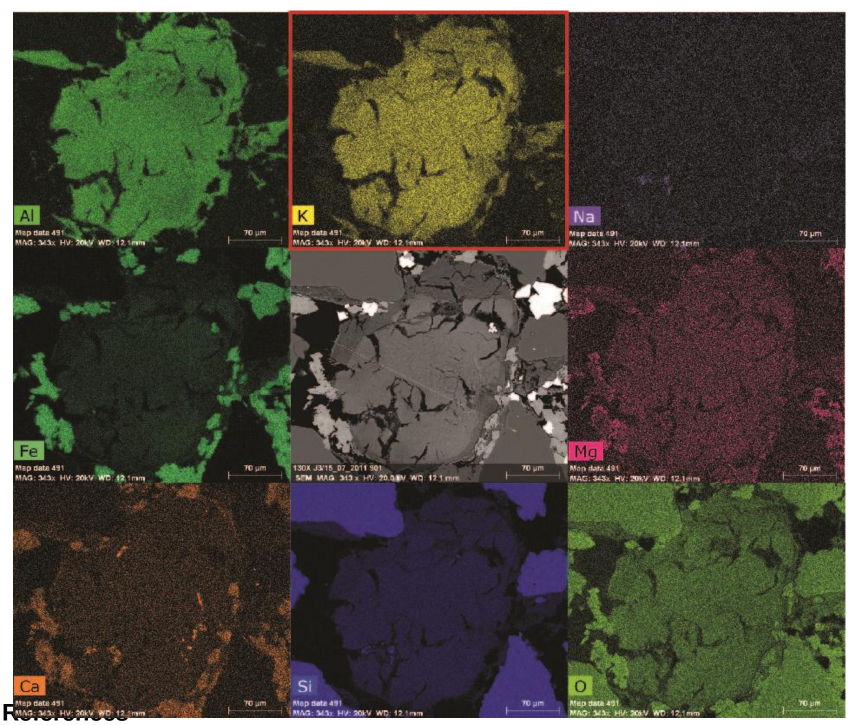

Figure 3. Energy dispersive x-ray (EDX) chemical element maps for Al, K, Na, Fe, Mg, Ca, Si, and O and back-scattered electron (BSE) image (Center) of a glauconitic grain from the Niton Member. The presence of potassium (K elemental map with rectangular red outline) eliminates the possibility of a chlorite mineralogy. Magnification = 343X. HV = 20 kV. This grain was analysed from thin section T-14, sampled from well 100/12-15-055-13W5 at 1966.00 m.

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