Ashman Ridge Section Revisited: New Insights for the Evolution of the Bowser Basin, Northwestern British Columbia (NTS 93L/13)

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Introduction

The Bowser Basin is a large sedimentary basin deposited above basement of the Stikine Terrane in the Intermontane Belt of northwestern British Columbia (Figure 1). It was the site of deposition of a large volume of siliciclastic sedimentary rocks during Middle Jurassic through Early Cretaceous time. Approximately 6 km of marine to nonmarine sedimentary rocks, mainly assigned to the Bowser Lake Group, were deposited onto the Early to Middle Jurassic volcano-sedimentary assemblage of the Hazelton Group (Ricketts et al., 1992; Evenchick and Thorkelson, 2005). The boundary between these units marks a major change in depositional style, from a volcanic arc setting to a subsiding sedimentary basin. The transition zone hosts significant mineralization (e.g., Eskay Creek Au-Ag deposit; Anderson, 1993; Barrett and Sherlock, 1996; Roth et al., 1999) as well as dark organic shale with significant potential as a petroleum source rock (Ferri et al., 2004; Ferri and Boddy, 2005). A clear understanding of the nature of this stratigraphic transition at basin scale could provide new insights for both mineral and hydrocarbon exploration.

The aim of this study is to provide new detailed stratigraphic observations of the Ashman Ridge section, which exhibits continuous exposure across the Hazelton Group–Bowser Lake Group transition. In a future paper, this stratigraphic column will be integrated in a regional basin analysis study and compared with equivalent stratigraphic units previously described in the northern part of the Bowser Basin (Waldron et al., 2006; Gagnon et al., 2007).

Ashman Ridge is located approximately 40 km west of Smithers, BC (Figure 1). The section was originally described as part of a project involving regional stratigraphic mapping of north-central British Columbia by Tipper and Richards (1976), who defined the Ashman Formation of the Bowser Lake Group and proposed Ashman Ridge as the type section. Stratigraphically lower units of the Hazelton Group are also well exposed along the section and provide a complete record of the change in depositional environment.

Keywords: *stratigraphy, sedimentology, Hazelton Group, Smithers Formation, Ashman Formation, Bowser Lake Group*

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Stratigraphic Units

Volcanic Rocks

The lowest stratigraphic units exposed at Ashman Ridge consist of amygdaloidal andesitic to dacitic flows and associated pyroclastic rocks of the Hazelton Group. This predominantly volcanic succession was previously assigned to the Howson Subaerial Facies of the Late Sinemurian to Early Pliensbachian Telkwa Formation by Tipper and Richards (1976). According to them, the Howson Facies consists of a thick suite of calcalkaline basalt to rhyolite flows and derived pyroclastic rocks. The volcanic flows identified in the current study are typically 5–15 m thick, and autobrecciated near the top. Most are aphanitic, but the section contains minor amounts of feldspar-phyric andesite. The presence of highly indurated ignimbrite containing flattened pumice suggests that these volcanic rocks were mostly deposited in a subaerial environment (Figure 2). The occurrence of a unit of light grey packstone in the dominantly volcanic succession, however, indicates that marine conditions existed locally. This fossiliferous fine-grained limestone contains well-preserved silicified burrows and ooids, indicating deposition in a relatively warm shallow sea (Figure 3). These carbonate units are capped by a very thick rusty-weathered vesicular basalt flow with epidote-bearing quartz veins.

The uppermost dominantly volcanogenic unit of the section consists of maroon to bright red, fine-grained crystal-lithic tuff. Tipper and Richards (1976) included this unit in the Red Tuff Member of the Nilkitkwa Formation and estimated its age to be Middle Toarcian or younger, based on paleontological control in underlying and overlying units. On Ashman Ridge, units of the Red Tuff Member comprise well-bedded, welded ash flow tuff, poorly sorted rubbly lapilli tuff, and lahar. Rounded bombs up to 30 cm in diameter are common in a very fine grained matrix. In the Smithers area, this extensive subaerial pyroclastic unit con-

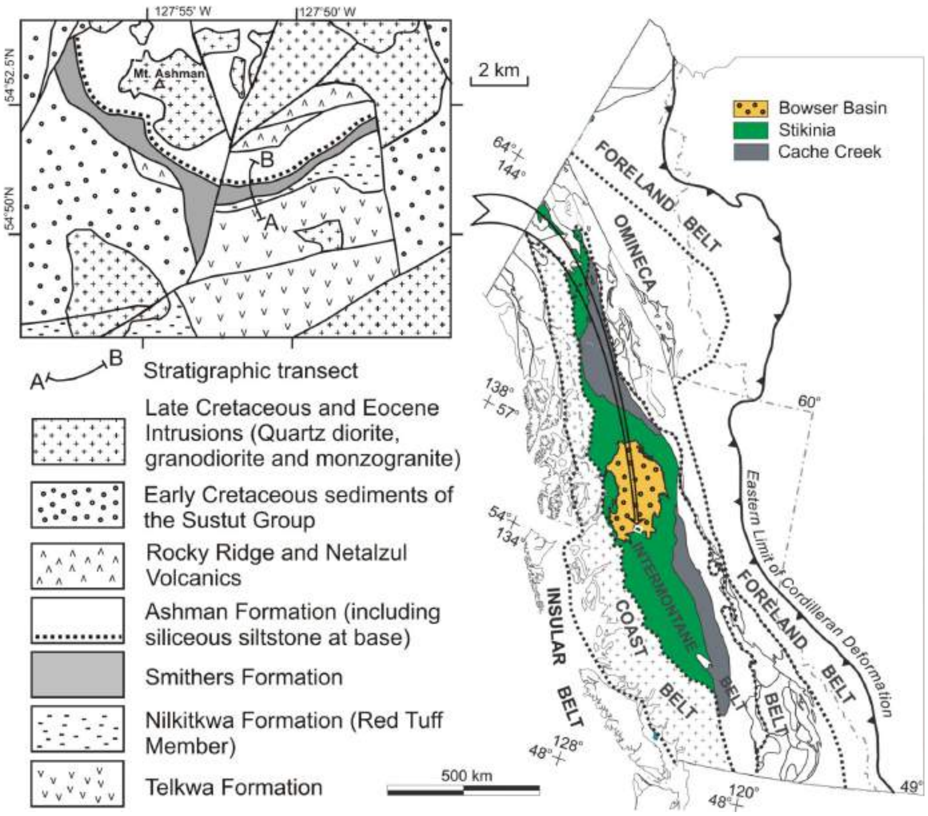

Figure 1. Simplified geology of the Ashman Ridge area, showing the location of the stratigraphic transect described in this study. Right side of the figure shows the location of the Bowser Basin in relation to principal tectonic belts of the Canadian Cordilleran Orogen (*modified from* Tipper and Richards, 1976; Evenchick and Thorkelson, 2005).

stitutes the last major preserved volcanic eruption related to the Hazelton arc before widespread sedimentation of the Smithers Formation was initiated.

Sedimentary Rocks

Establishment of a subsiding sedimentary basin on the Hazelton arc occurred around the Middle Toarcian and is recorded by the deposition of sandstone, assigned by Tipper and Richards (1976) to the Smithers Formation. As defined by these authors, the Smithers Formation consists of a mixture of fossiliferous, light grey-brown, lithic sandstone and tuffaceous siltstone.

At Ashman Ridge, the fossil-rich calcareous sandstone unconformably overlies the subaerial, oxidized pyroclastic units of the Red Tuff Member (Figure 4). The basal contact is erosive but no angular discordance was observed at the outcrop scale. A high concentration of volcanic-derived clasts in the tuffaceous sandstone suggests recycling of the

Figure 2. *Fiamme* structures in a unit of densely welded ignimbrite.

Figure 3. Silicified burrows in a unit of fine-grained oolitic limestone.

underlying Red Tuff Member and/or contemporaneous volcanism. Even though the hiatus associated with the unconformity remains poorly constrained due to the lack of precise dating of the Red Tuff Member, paleontological control below and above it suggests a gap of only a few million years.

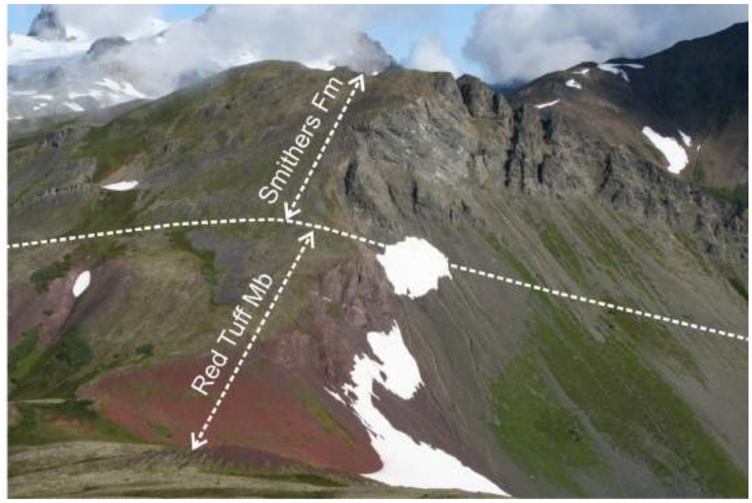

Figure 4. Stratigraphic contact between the Red Tuff Member and the Smithers Formation at Ashman Ridge.

Detailed stratigraphic observations of the lower, sandstone-dominated section taken along the exposed section at Ashman Ridge are shown in Figure 5, on which this interval is distinguished as unit A. The unit comprises mostly medium- to fine-grained, greenish brown sandstone with abundant marine fauna, including belemnites, gastropods, corals, ammonoids and a wide variety of ornate bivalves such as *Trigonia* (Figure 6). Bioturbation is omnipresent and tends to be particularly well displayed in occasional beds of green glauconitic sandstone (Figure 7). This rich faunal assemblage and common occurrence of wave-generated sedimentary structures suggest that the unit was deposited in relatively shallow marine conditions, confirming the previous interpretation of the Smithers Formation by Tipper and Richards (1976).

Fossiliferous calcareous sandstone of unit A is conformably overlain by a unit of thinly bedded blocky siliceous mudstone with recessive units, typically only millimetres to a few centimetres thick, of pale orange-weathered tuff (unit B in Figure 5). This unit contrasts with the underlying sandstone in that it lacks abundant bivalves, shows only sparse bioturbation and is significantly finer grained. The contact is easily mappable. Well-preserved ammonites, including *Kepplerites* sp. and *Cobbanites* sp., were collected during this study approximately 66.5 m below the top of the thinly bedded unit (Figure 8: corresponds to GSC location 85413; Tipper and Richards 1976). Belemnites and calcareous concretions are abundant in the upper half of this unit, which totals 221 m in thickness (Figure 5). The fine grain size, laterally continuous bedding, and lack of current-generated structures indicate that this unit accumulated mostly from suspension.

The siliceous, fine-grained succession is overlain with a sharp but apparently conformable boundary by brown- and white-weathering arkosic sandstone with thick limy concretions, marking the base of unit C (Figure 5). Even though the contact is conformable, field observations indicate that there is an ~10 m dextral offset along a steep normal fault close to the point where this contact crosses the crest of the ridge. The overlying medium-grained, arkosic sandstone contains abundant mud rip-up clasts at the bases of the 40–70 cm thick beds. Parallel horizontal laminations are common and there are local concentrations of fossil wood debris. The depositional environment for this sand-rich unit is interpreted to be one of high energy, contrasting with conditions that prevailed during the deposition of the underlying belemnite-rich, siliceous argillite of unit B.

Higher in unit C, a 50 m succession of finely laminated fine-grained sandstone and siltstone overlies the coarser feldspathic sandstone. It contains few belemnites and calcareous concretions. This recessive, fine-grained unit is capped by a thin bed of dark shale that probably corresponds to a flooding surface. Immediately above it, multiple coarsening-upward sequences were identified in fine-grained to pebbly sandstone. Hummocky cross-stratification, trough crossbedding and climbing ripples are common sedimentary structures in this unit. Abundant trace fossils are found in the finer grained sections and multiple *Trigonia* bivalves were also collected. At 760 m in the measured stratigraphic section, a coarsening-upward conglomerate interval is overlain by a 10 cm thick bed of wood debris. These regressive cycles could be interpreted as progradation of a deltaic system into a shallow marine environment. Recessive intervals of fissile shale and very fine silt are interbedded with the coarser progradational shoreface deposits and are interpreted by the authors to represent lateral embayments. Flaser laminations are common in the finer grained units, which suggests that the sediments were reworked by tidal processes. Occasional thin layers of reworked pale-weathering ash tuff at the base of sandstone beds attest to distal volcanism. Relatively good exposure enabled the authors to measure sedimentary strata up to 1145 m and no significant lithological change was observed.

Discussion

Tipper and Richards (1976) divided the Ashman Ridge section into a number of units. Above the predominantly volcanic rocks of the Telkwa and Nilkitkwa formations, they

Figure 5. Detailed stratigraphic section at Ashman Ridge, showing the different units identified in this study.

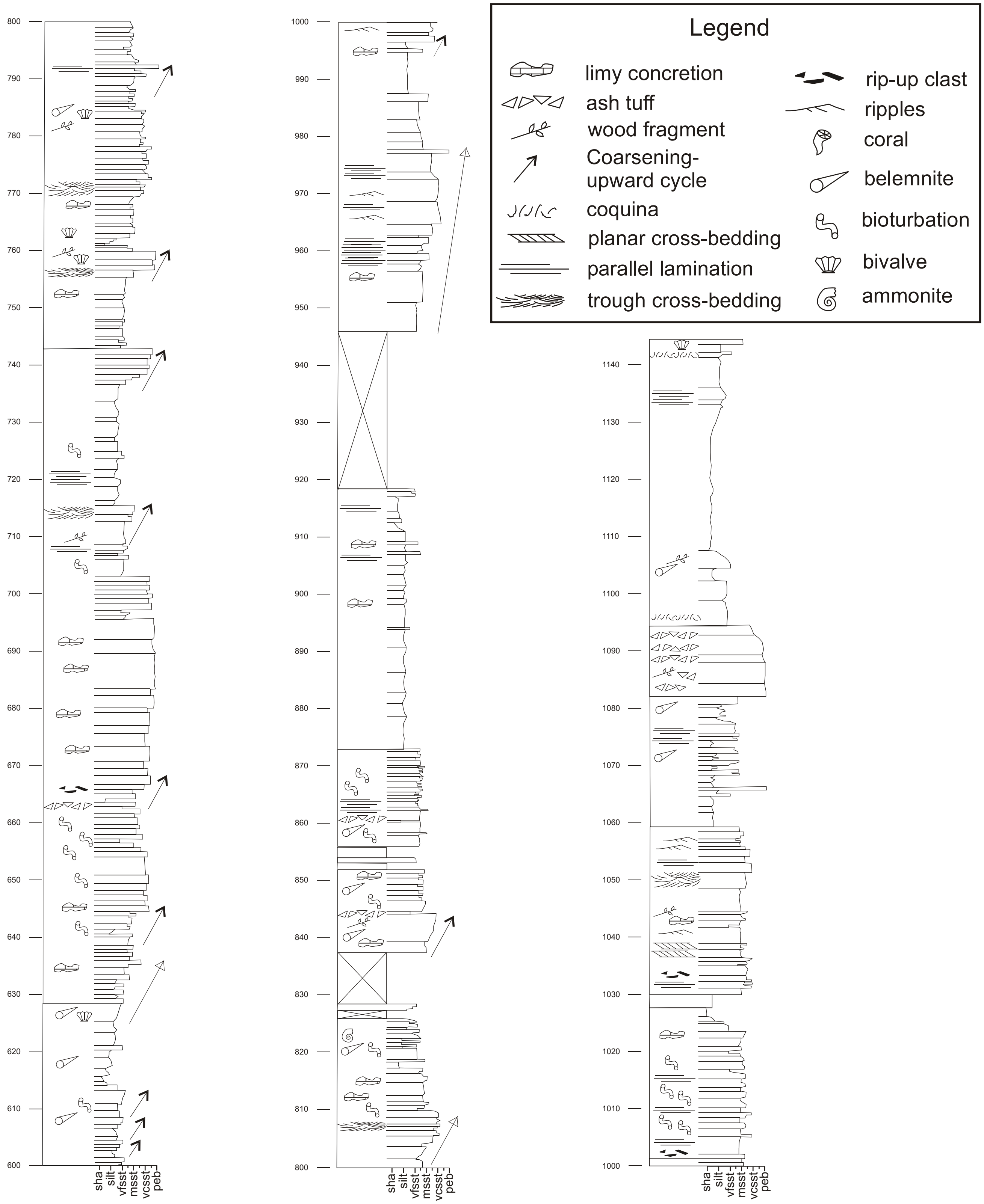

Figure 5 (continued)

Figure 6. *Trigonia* bivalve of the Smithers Formation, indicating deposition in a shallow marine environment. Observed at 102 m on the stratigraphic section.

Figure 7. Trace fossils in a glauconitic fine-grained sandstone of the Smithers Formation. Observed at 78 m on the stratigraphic section.

Figure 8. Well-preserved ammonite fossil collected near the top of the 'pyjama beds' unit. Observed at 463 m on the stratigraphic section.

assigned sandstone of unit A and the basal part of unit B of this study to their Smithers Formation. Most of the remainder of unit B of this study was assigned by Tipper and Richards to the Ashman Formation. The highest part of their section was assigned to undifferentiated Bowser Lake Group. Tipper and Richards (1976) placed the top of the Ashman Formation at the top of a 659 m thick unit, tentatively identified at 980 m in the section measured for this study, although they give no indication of the lithological criteria for distinguishing the Ashman Formation from undifferentiated units of the Bowser Lake Group.

Based on work by the current authors (Waldron et al., 2006; Gagnon et al., 2007), that of others farther north in the Bowser Basin (Thomson et al., 1986; Anderson and Thorkelson 1990; Greig 1991), and the definitions for the Smithers Formation of Tipper and Richards (1976), the authors suggest a different subdivision (Figure 9). Unit A is a clearly mappable unit of bioturbated fossiliferous sandstone that corresponds closely, in lithological character, to the Tipper and Richards (1976) definition of the Smithers Formation. The current study therefore suggests that the top of the Smithers Formation should be set at the top of the uppermost heavily bioturbated calcareous sandstone bed observed at 310 m in the section measured for this study (Figure 5).

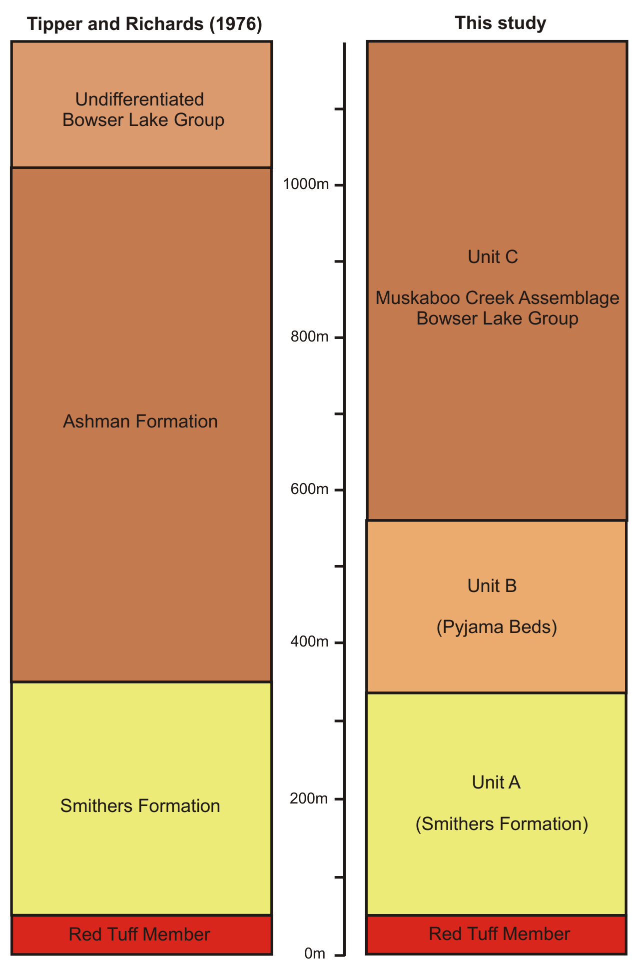

Figure 9. Stratigraphic correlations between the detailed section of this study and the original type section of the Ashman Formation (Tipper and Richards, 1976).

Following the same logic, the next important lithological boundary occurs at 531 m, where interbedded siliceous mudstone and tuff of unit B are overlain by laminated, medium- to very coarse grained arkosic sandstone beds with abundant mud rip-up clasts and wood fragments of unit C. This marks a significant change in depositional environment within the basin. Interbedded siltstone and thin tuff units similar (though not everywhere identical) to unit B are widespread in the Middle Jurassic of the Bowser Basin, though they are referred to by a variety of names. In the Joan Lake area, they are referred to as the Quock Formation of the Spatsizi Group by Thomson et al. (1986) The Quock Formation was later lowered to the Quock Member of the Spatsizi Formation by Evenchick and Thorkelson (2005). Elsewhere, similar units are referred to as the Troy Ridge Facies of the Salmon River Formation by Anderson and Thorkelson (1990). Informally, correlative units have been referred to widely as 'pyjama beds' (Anderson and Thorkelson, 1990; Anderson, 1993; Ferri et al., 2004; Ferri and Boddy, 2005; Evenchick and Thorkelson, 2005). The authors use this informal name pending future formal revision of the lithostratigraphy.

Overlying, nonsilicified clastic sedimentary rocks of unit C of this study, assigned to the Ashman Formation by Tipper and Richards (1976), bear a close field resemblance to widespread shallow marine units of the Bowser Lake Group assigned to the Muskaboo Creek assemblage of Evenchick et al. (2001). The upper boundary of this facies is not seen at Ashman Ridge, and the authors see no justification for placing an upper boundary at the top of the Tipper and Richards (1976) section.

The authors propose that the name Ashman Formation be abandoned, as it does not represent a clearly defined mappable unit. Instead, it is suggested that unit A of this study is equivalent to the Smithers Formation of the Upper Hazelton Group as regionally mapped. Unit B is yet to be formally named, but is correlative with the 'pyjama beds' mapped elsewhere as Upper Hazelton Group (Anderson, 1993; Waldron et al., 2006; Gagnon et al., 2007). The overlying unit C, equivalent to the bulk of the Ashman Formation as defined by Tipper and Richards (1976), is equivalent to the Muskaboo Creek Assemblage of the Bowser Lake Group (Evenchick et al., 2006).

The transition from unit A to unit B probably represents a deepening associated with subsidence at the onset of basin formation. The transition from the 'pyjama beds' of unit B to the Bowser Lake Group is unusual, because there is no interval of submarine fan or slope sediments (Ritchie-Alger or Todagin Assemblage) below shallow-marine sediments of the Muskaboo Creek Assemblage, as is typical of Bowser Basin successions farther north (Evenchick and Thorkelson, 2005). This suggests that the initial subsidence of the Bowser Basin was less profound at Ashman Ridge than elsewhere, and the accommodation space generated in basin formation was filled relatively rapidly by sediment in this area.

The new stratigraphic framework proposed in this study confirms the presence of a mappable 'pyjama beds' unit conformably underlying sedimentary rocks of the Bowser Lake Group at the basin scale. This has important implications for both petroleum and mineral exploration, as equivalent stratigraphic units in the northern part of the Bowser Basin host volcanogenic massive sulphide mineralization (Barrett and Sherlock, 1996; Roth et al., 1999) and have proven petroleum source rock properties (Ferri et al., 2004; Ferri and Boddy, 2005).

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