ERCB/AGS Open File Report 2012-20

Outcrops of the La Loche, Contact Rapids, and Keg River Formations (Devonian) on the Clearwater River: Alberta (NTS 74D/9) and Saskatchewan (NTS 74C/12)

Energy Resources Conservation Board

Alberta Geological Survey

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Abstract

The Middle Devonian Elk Point Group outcrops along the Clearwater River near the Alberta–Saskatchewan border. In this area, sedimentary rocks of the Elk Point Group rest directly on crystalline Precambrian basement rocks.

In this report, we describe outcrops of the La Loche, Contact Rapids, and Keg River formations visited during the 2010 field season. At a previously undescribed outcrop at Contact Rapids, located on the Clearwater River in Saskatchewan, we observed the nonconformable contact between a paleotopographic high in the Precambrian basement and the La Loche Formation. In addition, we describe in this report the conformable contact between the Contact Rapids and Keg River formations, which had previously been unobserved at the described locality. At Whitemud Falls on the Clearwater River in Alberta, we observed the contact between the La Loche and Keg River formations where the intervening Contact Rapids Formation is absent. This contact is evidence that the outcrop is close to an unexposed paleotopographic basement high that remained exposed during the early stages of Keg River Formation carbonate deposition.

1 Introduction

Sedimentary rocks of the Middle Devonian Elk Point Group outcrop in two areas of northeastern Alberta: the northeasternmost portion of Wood Buffalo National Park and along the Clearwater River near the Alberta-Saskatchewan border. We present data collected during the 2010 field season along the Clearwater River in Alberta and Saskatchewan, where the rocks of the La Loche, Contact Rapids, and Keg River (Methy) formations outcrop sporadically along the river valley (Figure 1).

In most of Alberta, initial Devonian sedimentation was primarily halite and marine to marginal-marine carbonate. The Peace River and Athabasca arches remained exposed during the accumulation of Lotsberg Formation halite, Ernestina Lake Formation carbonate, and Cold Lake Formation halite. Near the end of the deposition of the lower Elk Point Group, the Athabasca Arch, oriented approximately parallel to the present-day Clearwater River, was flooded by marine water, which reworked La Loche Formation sands and led to the deposition of the silty shale to argillaceous carbonate of the Contact Rapids Formation.

In northeastern Alberta, the Elk Point Group directly overlies Precambrian basement (Figure 2). The La Loche Formation granite wash locally includes a basal regolith. Once the Athabasca Arch was fully flooded, the silty shale, argillaceous carbonate, and minor anhydrite of the Contact Rapids Formation accumulated on top of La Loche Formation sandstone. With continued transgression, open marine conditions led to the accumulation of thick Keg River Formation carbonate, which is laterally contiguous with the Keg River Formation of Law (1955) in northwestern Alberta and the Winnipegosis Formation of Baillie (1953) of southern Alberta, Saskatchewan, and Manitoba.

In the vicinity of the Clearwater River in northeastern Alberta, the topography of the Precambrian basement is irregular (Norris, 1963). The La Loche and Contact Rapids formations are thickest above paleotopographic lows in the basement surface and thinnest over paleotopographic highs. At Whitemud Falls, an outcrop of Keg River Formation biostromal carbonate is in direct contact with underlying sandstone of the La Loche Formation, indicating that some of the basement knolls remained exposed until the deposition of the Keg River Formation.

In the study area, Devonian sedimentation presumably continued after the deposition of the Keg River Formation. Pre-Cretaceous tilting and erosion of Devonian strata combined with Neogene glacial erosion resulted in the complete removal of younger Devonian rocks. Downcutting of the Clearwater River valley into Devonian and basement rocks resulted in sporadic exposure of Elk Point Group strata along the river banks from Cascade Rapids in Alberta to Contact Rapids in Saskatchewan.

In the Middle Devonian, northeastern Alberta was situated in the southern tropics, under arid climate conditions (Wendte, 1992). Towards the end of the Eifelian, a rise in relative sea level led to the incursion of marine water from the Panthalassia Ocean to the paleo north-northwest. As a result, shallow marine depositional environments existed in northeastern Alberta, ranging from restricted to normal marine conditions. With the establishment of the extensive carbonate platform of the Keg River and Winnipegosis formations, paleoenvironments included reefs, mounds, and biostromes. A barrier reef, known as the Presqu'île Barrier, extended from northeastern British Columbia through the southern Northwest Territories and separated a vast inland sea, located to the southeast, from the open ocean in the north. The reef restricted circulation; carbonate accumulation in the back-reef basin ceased during evaporite deposition of the Muskeg and Prairie formations.

In this report, occurrences of granite wash sandstone and conglomerate are referred to as the La Loche Formation, a name introduced by Norris (1963) for detritus derived locally from exposed basement in northeastern Alberta.

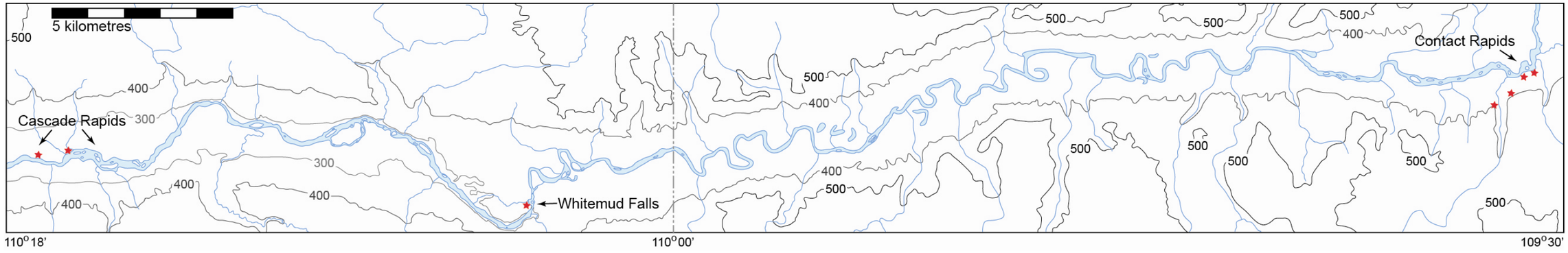


Figure 1. Map of Elk Point Group localities described in this report along the Clearwater River.

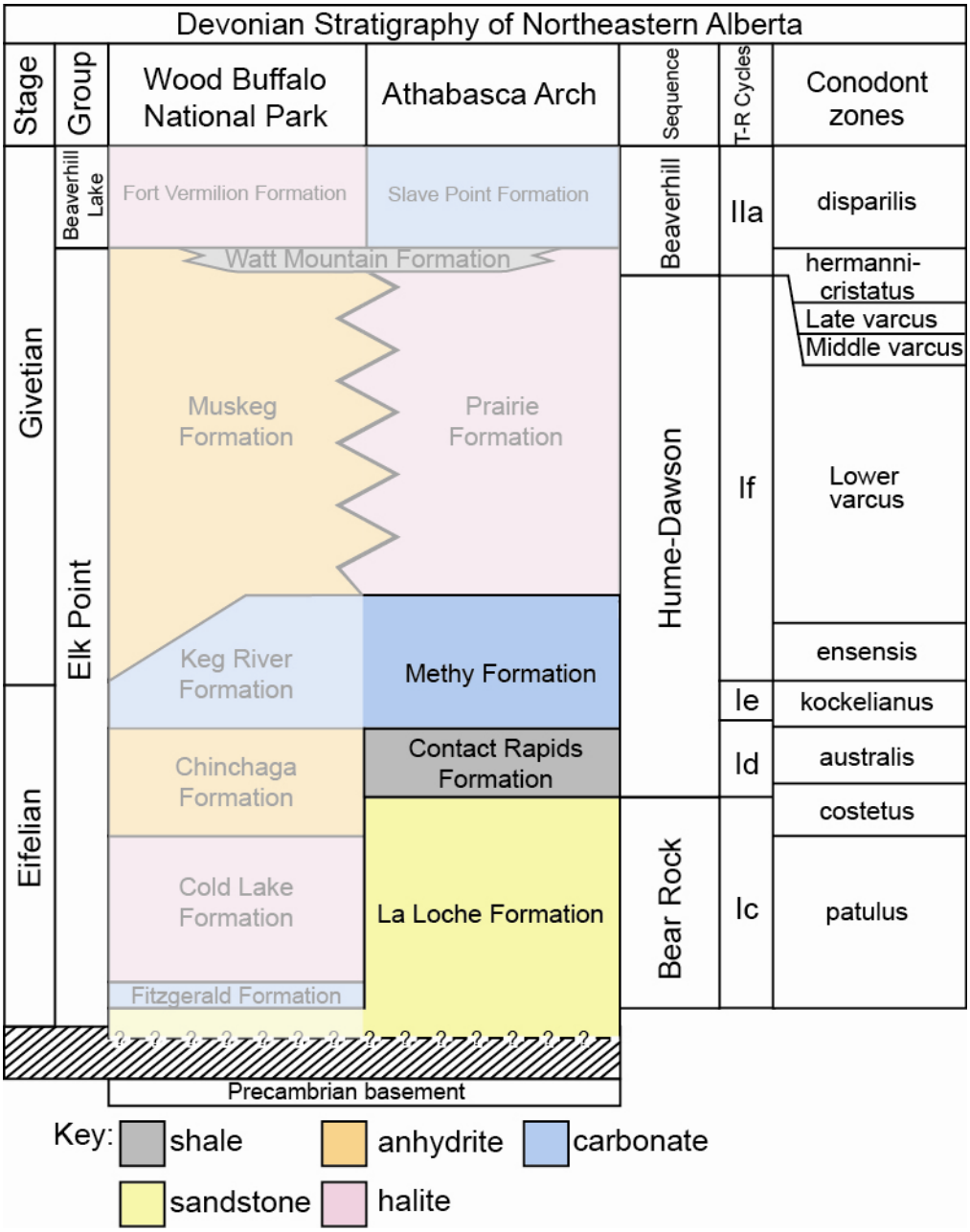


Figure 2. Stratigraphic chart for the Elk Point Group of northeastern Alberta. Units described in this report are highlighted. Sequences are from Moore (1988, 1993). Conodont zones and T-R cycles are from Johnson et al. (1985).

The Keg River Formation outcrops as erosional remnants and massive cliffs along the Clearwater River. The carbonate is a distinct beige colour with black and orange-red staining. Outcrops have conspicuous horizontal cleavage that does not necessarily parallel bedding. At some outcrops, the carbonates are vuggy.

Herein, we use Dunham's (1962) classification for the texture of carbonate rocks. We use the term 'lime mudstone' to differentiate carbonate from siliciclastic mudstone, and use the term 'shale' to denote a terrigenous mud lithology.

2 Previous Investigation of Outcrops

2.1 La Loche Formation

The earliest mention of the La Loche Formation comes from Bell's 1882 exploration of the Athabasca River basin in the (then) Northwest Territories (Bell, 1884). He made reference to a "red sandstone" occurring along the Clearwater River near Keg River Portage, but made no reference to younger Devonian rocks occurring along the river.

Sherwin (1962) included the lowermost beds of the La Loche Formation within the Contact Rapids Formation. His brief description of the outcrop at Contact Rapids included a basal feldspathic sandstone.

Norris (1963) named the La Loche Formation for the lowermost unit of detrital sandstone and conglomerate overlying Precambrian basement. He considered the La Loche Formation to be Early Devonian or older, as it underlies the early Middle Devonian Contact Rapids Formation and overlies Precambrian basement.

In Norris's (1963) type section, the La Loche Formation is located at the lower end of Contact Rapids and is described as a pale brown, thin-bedded to irregularly lenticular, fine- to medium-grained, hematite-cemented, arkosic sandstone containing coarse, angular to sub-rounded feldspar and quartz fragments. At Contact Rapids, the La Loche Formation reaches a maximum thickness of 5 feet (1.5 m), with the thickest sections occurring within paleotopographic lows in Precambrian basement. In the subsurface near Fort McMurray, Norris (1963) measured the thickest La Loche Formation section at 98 feet (29.9 m) in the Bear Westmount no. 2 well at L.S. 8, Sec. 36, Twp. 88, Rge. 8, W 4th Mer. (abbreviated 08-36-088-08W4), presumably occurring within a basement paleotopographic low. Norris did not observe the upper and lower contacts in the field and instead described gradational La Loche contacts with the basement rock and the overlying Contact Rapids Formation from core.

The La Loche Formation does not outcrop along the Alberta portion of the Clearwater River; outcrops of La Loche sandstones can only be seen along the river banks at Contact Rapids in Saskatchewan. However, the La Loche Formation outcrops along the Slave River in Alberta, north of Lake Athabasca.

2.2 Contact Rapids Formation

Sherwin (1962) named the Contact Rapids Formation from strata intersected by Canadian Seaboard Ernestina Lake well no. 10-13 and from an outcrop located at Contact Rapids. At the type locality, the Contact Rapids Formation is characterized by greenish-grey dolomitic shale. Sherwin (1962) also included the underlying sandstone of the La Loche Formation in his description.

A year later, Norris (1963) proposed the name "McLean River Formation" for the same Contact Rapids outcrop on the Clearwater River. Norris (1963) excluded the La Loche Formation from his description of the unit, limiting the formation to the greenish shale. Norris's composite description of his McLean River Formation, based on outcrop at Contact Rapids, includes the following units (from base to top):

1) 12 feet (3.7 m) of light brownish grey, medium to thickly bedded, occasionally vuggy, very fine grained, sandy, calcareous dolostone interbedded with thin beds of olive-green, sandy, calcareous shale.
2) 5 feet (1.5 m) of medium greenish-grey, silty and sandy, calcareous shale, from which Norris (1963) recovered a mould of the brachiopod *Emanuella* sp.
3) 16 feet (4.9 m) of recessive, olive-green, sandy, calcareous shale.
4) 8 feet (2.4 m) of light grey, medium-bedded, finely crystalline dolostone with olive-green shale partings.
5) 7 feet (2.1 m) of recessive, green, sandy, calcareous shale containing *Tentaculites* sp. and small spores.

Norris did not observe upper or lower contacts at Contact Rapids, but, from subsurface wells, he described a gradational contact with the underlying La Loche Formation and a gradational to sharp but conformable contact with the overlying Keg River Formation.

Outcrops of the Contact Rapids Formation are not known from Alberta but can be observed at Contact Rapids on the Clearwater River in Saskatchewan.

2.3 Keg River Formation

In 1877, Macoun published the notes from his Northwest Territories expedition, which covered the Alberta-Saskatchewan border area along the Clearwater River. He described outcrops of "cream-coloured limestone" lining the river banks, many of which contained caves. He also noted the thick-bedded nature of the limestone as well as moulds of unidentified fossils.

Sproule (in Ells, 1932) described two distinct units from Keg River Formation–equivalent outcrops on the Clearwater River. The lower unit contained thinly "banded" limestone and shale and rubbly-bedded, argillaceous limestone with an abundant fauna. From the upper unit, a massive dolostone and thinly bedded limestone, Sproule collected a sparse fauna consisting of poorly preserved gastropods, bivalves, and brachiopods.

Bassett (1952) briefly observed the Keg River Formation at Cascade Rapids on the Clearwater River. He described the Keg River Formation as 28 feet (8.5 m) of brownish to yellowish-grey, platy dolostone.

Norris (1963) described several outcrops of Keg River (Methy) Formation carbonate between Contact Rapids and Cascade Rapids. At Contact Rapids, Norris (1963) described two members: a "lower thin-bedded member" and an "upper massive member." The "lower thin-bedded member" is a 40 foot (12.2 m) thick, light brown, finely crystalline, partly vuggy, calcareous dolostone that locally contains crenulated silty laminae and grey chert nodules. The "upper massive member" is a cliff-forming 42 feet (12.8 m) of light brown to mottled light and medium brown, irregularly thick-bedded to massive, finely crystalline, vuggy dolostone containing light greenish-grey chert in its basal portion.

At Whitemud Falls, Norris (1963) measured a composite Keg River Formation section. His lowermost unit is 4.5 feet (1.4 m) of light cream-brown to medium brown, irregularly very thin-bedded, finely crystalline dolostone with prominent silty laminae and a few atrypide brachiopod moulds in the basal beds. Norris's middle unit is a 20.5 foot (6.2 m) thick, light brownish-grey, irregularly medium-bedded, finely crystalline, vuggy dolostone with irregular, light cream-brown chert nodules along some beds. After a 5 foot (1.5 m) thick covered interval, Norris's upper unit is approximately 50 feet (15.2 m) of medium brownish grey, irregularly thick-bedded to massive, finely crystalline, scarp-forming, vuggy dolostone containing fragments of the brachiopod *Atrypa* sp. cf. *A. arctica* and crinoid columnals.

Along Cascade Rapids, Norris (1963) noted many erosional remnants of Keg River Formation dolostone, including some the "size of a small house." The tallest of these outcrops rises to about 60 feet (18.3 m)

above river level. Norris reported two sections from the Cascade Rapids area: one at the rapids' midpoint and one just past the lower end of the rapids.

At the midpoint of Cascade Rapids, Norris (1963) described four lithologies, from base to top:

6) 5 feet (1.5 m) of pale brown, irregularly very thinly bedded, porous, fine to medium-crystalline, fossiliferous, calcareous dolostone.
7) 27 feet (8.2 m) of light brown, massive, finely crystalline, silty and calcareous dolostone.
8) 1.5 feet (0.5 m) of light brown, thinly bedded, medium- to coarse-grained and sucrosic, brecciated, calcareous dolostone.
9) 1.5 feet (0.5 m) of light brown, thinly bedded, finely crystalline dolostone containing small blebs of gypsum.

Approximately 600 m downstream from Cascade Rapids, Norris (1963) described five lithologies, from base to top:

10) 5 feet (1.5 m) of medium brown, even to irregular, very thin-bedded, very fissile, calcareous dolostone.
11) 4 feet (1.2 m) of resistant, massive, coarsely brecciated, calcareous dolostone.
12) 8 feet (2.4 m) of medium brown, thin-bedded, fissile, very finely crystalline dolostone.
13) 2 feet (0.6 m) of light brown, irregularly medium-bedded, calcareous dolostone, brecciated into angular to rounded clasts.
14) 2 feet (0.6 m) of resistant, light brown, thickly bedded, fissile, calcareous dolostone.

Buschkuehle (2003) revisited the Keg River Formation at Whitemud Falls. Rather than Norris's (1963) three lithologies, Buschkuehle (2003) described four units, from base to top:

1) 1 to 2 m of sucrosic dolomitic limestone containing occasional crinoids.
2) 3.5 m of very porous dolostone, interpreted as a reef deposit.
3) 2 m of yellow-grey, calcareous dolostone containing crinoid columnals near the base and bulbous to tabular stromatoporoids throughout.
4) resistant, light grey, dolomitic and fossiliferous limestone, interpreted as a bank of unknown thickness.

Buschkuehle (2003) interpreted the paleoenvironment of the Keg River Formation at Whitemud Falls as fore-reef to reef facies deposited under moderate to high-energy conditions.

The Keg River Formation intermittently outcrops along the Clearwater River from Contact Rapids in Saskatchewan to shortly downstream of Cascade Rapids in Alberta.

3 Current Investigations of the Clearwater River Outcrops: La Loche, Contact Rapids, and Keg River Formations

During the summer of 2010, we investigated one La Loche Formation outcrop and one Contact Rapids Formation outcrop, both at Contact Rapids in Saskatchewan. We also examined the Keg River Formation at Contact Rapids, Whitemud Falls, and Cascade Rapids. We accessed the outcrops by helicopter, except those at Cascade Rapids, which could be reached by boat.

The Whitemud Falls and Cascade Rapids localities were described by Norris (1963). Buschkuehle (2003) also described the Keg River Formation from Whitemud Falls. At Contact Rapids in Saskatchewan, Norris (1963) examined several outcrops of the La Loche, Contact Rapids, and Keg River formations, but only one of his Keg River Formation stations was re-described in the present study (Figure 3). Two localities of the La Loche Formation—one described and one photographed from the air (Figure 4)—are

newly described, as is the single Contact Rapids Formation locality. Norris's (1963) Contact Rapids Formation stations were not located during the 2010 field season and were presumably covered by talus.

3.1 La Loche Formation, Contact Rapids, Clearwater River (Saskatchewan)

3.1.1 Locality Description and Access

lat 56°44′04″N, long 109°29′37″W (NAD83)

By helicopter, land on the island at 56°43′58″N and 109°30′06″W. Be cautious traversing the small island, as vegetation hides large boulders and low spots. Wade the river to the south bank. Walk upstream through the woods to the next bend in the river and the upstream rapids. Beware of submerged rocks, slick surfaces, and a strong current.

The granite basement forms the rapids at Contact Rapids. The contact between the Precambrian basement and the La Loche granite wash outcrops on the south bank of the easternmost rapids. The La Loche Formation is mostly hidden by vegetation. At this location, Precambrian basement dips southward beneath the La Loche Formation towards a basement topographic low. La Loche sandstone fills this topographic low, thinning over the high area at the rapids and thickening over the low area just to the south of the rapids.

3.1.2 Stratigraphy

The outcrop contains the following units, beginning from the top of the basement, or base of the La Loche Formation outcrop (Figure 5):

1) 70 cm, regolith: red-brown weathering and fresh, with in situ angular granitoid clasts ranging from pebble to cobble size.
2) 115 cm, sandstone and conglomerate: brown weathering, brown to brownish-red to grey , moderately sorted, sub-angular to sub-rounded, poorly cemented, dominantly coarse-grained, arkose with graded conglomerate beds (Figure 6). Cross-bedding and lenticular bedding are present, especially within graded beds. A 5 cm thick, red and green shale bed occurs at 85 cm above the base of the unit (strike: 150^{o} dip: 15^{o}NW).
3) Unmeasured, sandstone: brown weathering, brown to brownish-red, moderately sorted, sub-rounded to rounded, poorly cemented, dominantly coarse-grained, porous arkose.

The outcrop is capped by soil and tree roots.

Ten metres downstream from the rapids, away from the basement topographic high, the La Loche Formation thickens to approximately 3.5 m, with the thickening occurring mostly within units 2 and 3.

3.1.3 Fossils

None.

3.1.4 Paleoenvironmental Interpretation

The La Loche Formation was deposited or reworked within a fluvial environment. Bedding and lithology suggest a prograding point bar deposit composed of arkosic sand and gravel.

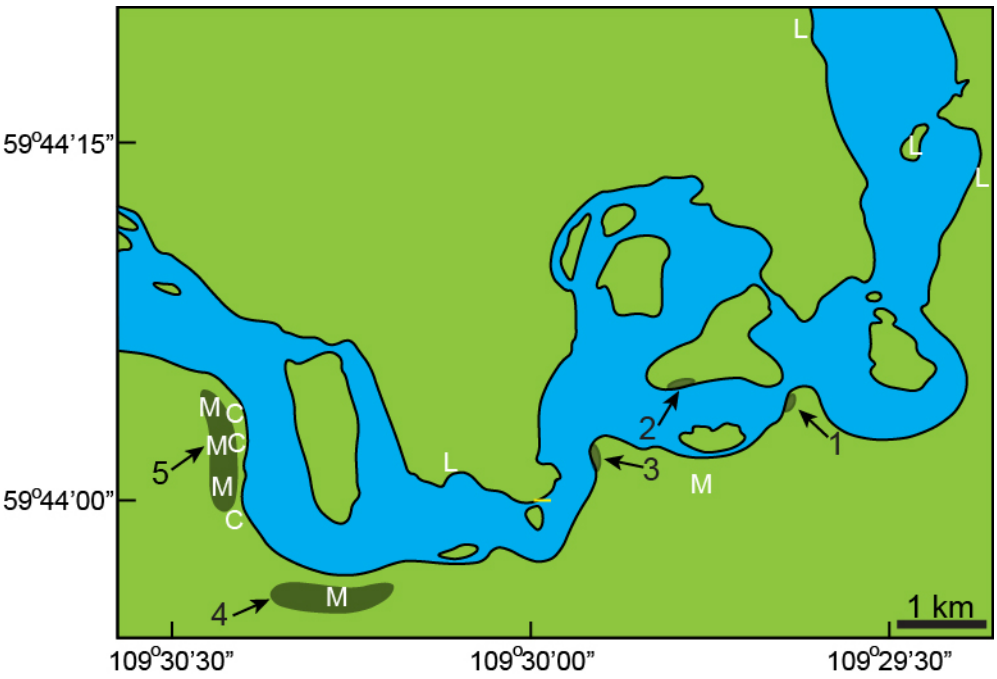


Figure 3. Map of outcrops at Contact Rapids on the Clearwater River in Saskatchewan. Grey areas represent outcrops of the La Loche, Contact Rapids, and Keg River formations observed during the 2010 field season. (1) La Loche Formation, described herein; (2) La Loche Formation, observed from the helicopter; (3) Contact Rapids and Keg River formations, described herein; (4) Keg River Formation, described herein; (5) Keg River Formation, observed from station 4, but not described; (L) Norris (1963) La Loche Formation stations; (C) Norris (1963) Contact Rapids Formation stations; and (M) Norris (1963) Keg River Formation stations.

Figure 4. Outcrop of the La Loche Formation (station 2), observed from the helicopter.

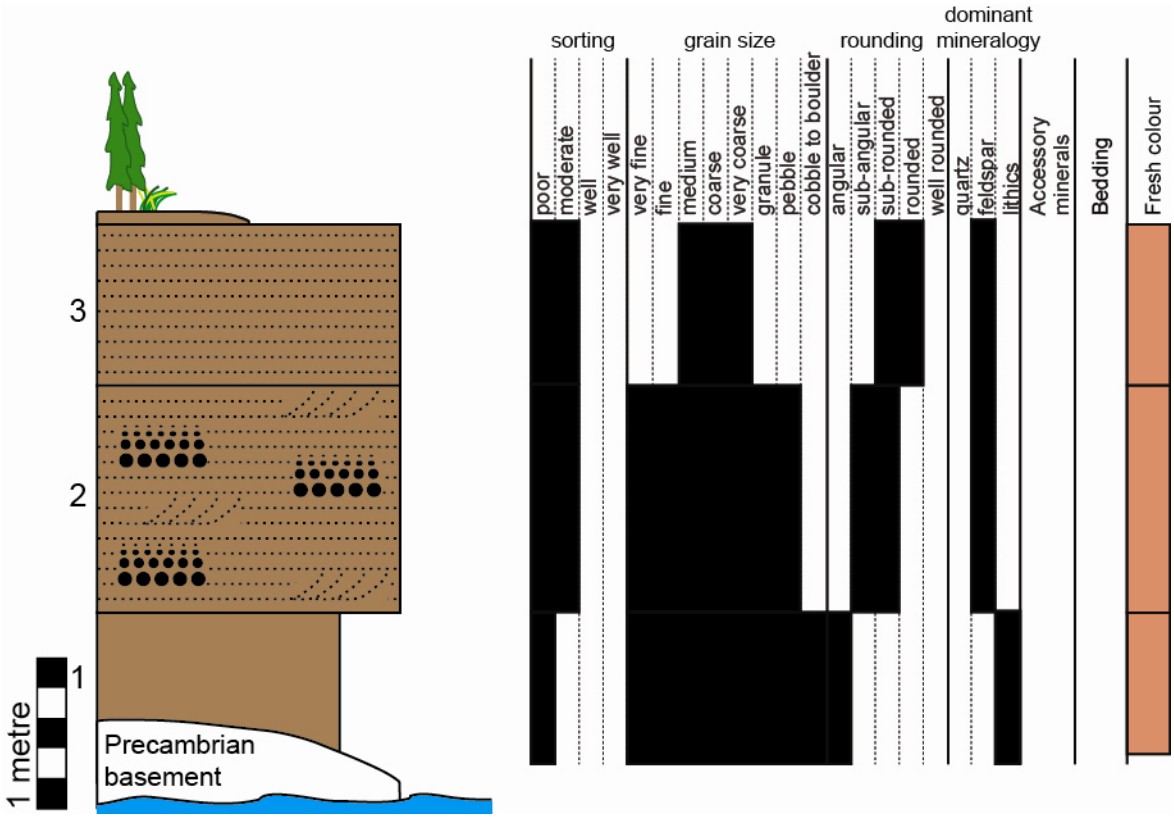


Figure 5. Stratigraphic section of the La Loche Formation at the upper falls of Cascade Rapids, Clearwater River, Saskatchewan (station 1). Numbers to the left of the section correspond to units described above.

Figure 6. Unit 2 sandstone of the La Loche Formation at the upper falls, Contact Rapids, Clearwater River, Saskatchewan (station 1). Recessive beds between thick, resistant sandstone beds are more friable, either because of increased shale in that horizon or decreased cementation. Note head of rock hammer for scale (lower right, with orange survey tag).

3.2 Contact Rapids and Keg River Formations, Contact Rapids, Clearwater River (Saskatchewan)

3.2.1 Locality Description and Access

lat 56°44′02″N, long 109°29′52″W

By helicopter, land on the island at 56°43′58″N and 109°30′06″W. Be cautious traversing the small island, as vegetation hides large boulders and low spots. Wade the river to its south bank. Walk upstream through the woods around the bend in the river. Beware submerged rocks, slick surfaces, and a strong current.

The Contact Rapids Formation forms a steep slope of greenish-grey and calcareous shale at a single locality on the south bank of the Clearwater River (Figure 7). At the top of the section, a dense grey dolostone of the Contact Rapids Formation conformably underlies a brown, bedded, vuggy dolostone of the Keg River Formation. The lower boundary with the La Loche Formation is not seen at this outcrop.

3.2.2 Stratigraphy

Beginning at the river's edge, the outcrop includes the following units, from base to top (Figure 8):

1) 175 cm, shale, Contact Rapids Formation: slumped and greenish-grey, containing siltstone chips.
2) 175 cm, siltstone: greenish-grey and shaly with shale seams and lenses. In the top 50 cm, the siltstone becomes the most resistant bed in the river bank.
3) 325 cm, shale: greenish-grey, chippy to platy weathering, and silty.
4) 65 cm: beige-weathering, grey, dense dolostone and greenish shale in three sub-units:
   a) 35 cm thick lower massive dolostone.
   b) 10 cm thick middle greenish shale.
   c) 20 cm thick upper massive dolostone.
5) 9 cm, dolostone, Keg River Formation: beige-weathering, brown, wavy bedded (average 5 cm thick) with wispy laminae, medium-crystalline mudstone with occasional vugs up to 2 cm in diameter. The contact with unit 4 is sharp.

Above this basal Keg River Formation bed, recessed in the woods, are the following units:

6) 800 cm, cover.
7) 600 cm, dolostone, Keg River Formation: beige-pink weathering, medium-crystalline, crinoidal floatstone. Partings occur at 5–10 cm intervals. This dolostone block is rotated slightly out of place.

3.2.3 Fossils

None.

3.2.4 Paleoenvironmental Interpretation

The Contact Rapids Formation was deposited in a marginal marine environment, as indicated by abundant sand and silt, as well as the gradational vertical transition with the overlying marine carbonate rocks of the Keg River Formation.

Figure 7. Contact Rapids Formation at Contact Rapids, Clearwater River, Saskatchewan (station 3). Note the beige dolostone at the top of the river bank near the boundary between the Contact Rapids and Keg River formations. Photo was taken from the helicopter.

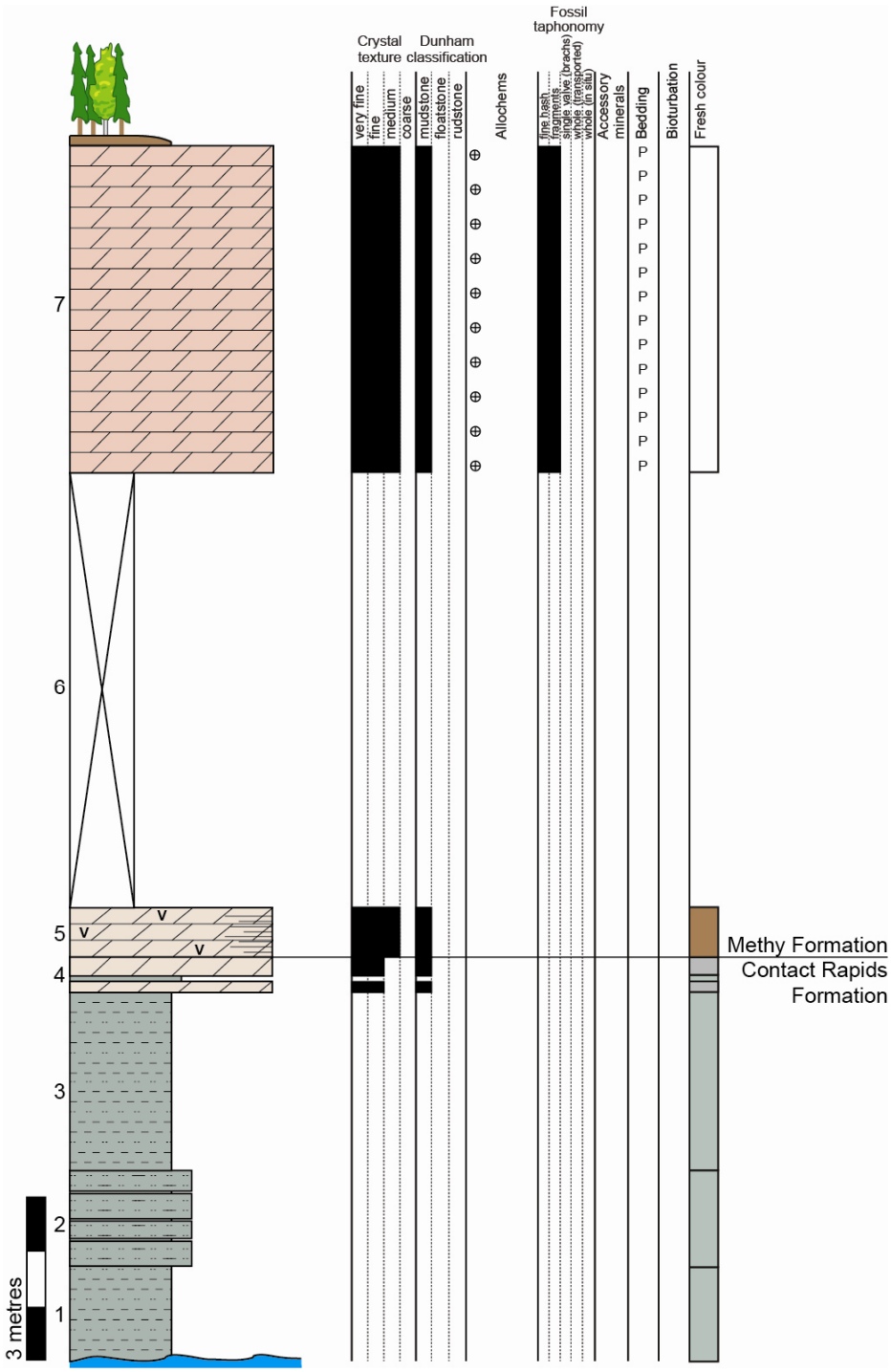


Figure 8. Stratigraphic column of the Contact Rapids and Keg River formations from Contact Rapids, Clearwater River, Saskatchewan (station 3). The base of the Contact Rapids Formation was not observed, but the contact with the overlying Keg River Formation occurs between the uppermost dense dolostone bed of the Contact Rapids Formation and the bedded, vuggy dolostone of the basal Keg River Formation. Numbers to the left of the section correspond to units described above.

3.3 Keg River Formation, Contact Rapids, Clearwater River (Saskatchewan)

3.3.1 Locality Description and Access

lat 56°43′55″N, 109°30′10″W

By helicopter, land on the island at 56°43′58″N and 109°30′06″W. Be cautious traversing the small island, as vegetation hides large boulders and low spots. Wade the river to its south bank. Walk downstream and scramble upwards through woods on moss-covered dolostone blocks to a cliff at the top of the river valley. Beware of submerged rocks, slick surfaces, and a strong current in the river and loose blocks and deep holes beneath the slippery and springy moss on the scree slope.

The Keg River Formation forms the steep cliffs lining the upper walls of the Clearwater River valley at Contact Rapids (Figures 9 and 10). Beige dolostone outcrops are stained reddish-orange and black. The contact with the underlying Contact Rapids Formation was not encountered at either of the south bank cliffs, although G. Prior found a green, argillaceous siltstone in the rubbly slope below the easternmost cliff at Contact Rapids. The southernmost of these steep cliffs is the outcrop described below.

3.3.2 Stratigraphy

The outcrop description starts from the lowest point of in situ Keg River Formation dolostone. From base to top, the outcrop contains the following units (Figure 11):

1) 120 cm, dolostone: brown-purple- to grey-weathering, brown, coarsely crystalline, sucrosic, crinoid floatstone with wavy partings at 2 to 8 cm intervals, 0.5 cm-scale dark brown laminae, and intercrystalline porosity (Figure 12).
2) 140 cm, dolostone: beige-weathering, brown, sucrosic, crinoid floatstone, with partings at 5 to 25 cm intervals (Figure 13).
3) 40 cm, dolostone: beige-weathering, dark brown, 2 to 5 cm flaggy bedded, coarsely crystalline, sucrosic, crinoid floatstone with mottled dark grey and white chert nodules, 1 to 20 cm in diameter (Figures 13 and 14).
4) 570 cm, dolostone: beige-weathering, grey to brown, coarsely crystalline becoming medium-crystalline in the top 2.9 m, sucrosic, crinoid floatstone with micromouldic to mouldic (after crinoids) porosity and partings at 5 to 10 cm intervals.

3.3.3 Fossils

Crinoids are abundant; less common brachiopods are faintly visible in the recrystallized dolostone or are dissolved, leaving moulds. Crinoid columnals and pleuricolumnals range from 1 to 10 mm in diameter.

3.3.4 Paleoenvironmental Interpretation

Fossils from this outcrop suggest a sublittoral, open marine paleoenvironment. Laminae in unit 1 may indicate quiet water conditions, such as a lagoon or other low-energy, non-bioturbated, and periodically dysoxic to anoxic environment.

Figure 9. Keg River Formation outcrop at Contact Rapids, Clearwater River, Saskatchewan (station 4).

Figure 10. Keg River Formation outcrop at Contact Rapids, Clearwater River, Saskatchewan (station 5). Note person wearing red vest (about half way up the left side of scree slope) for scale.

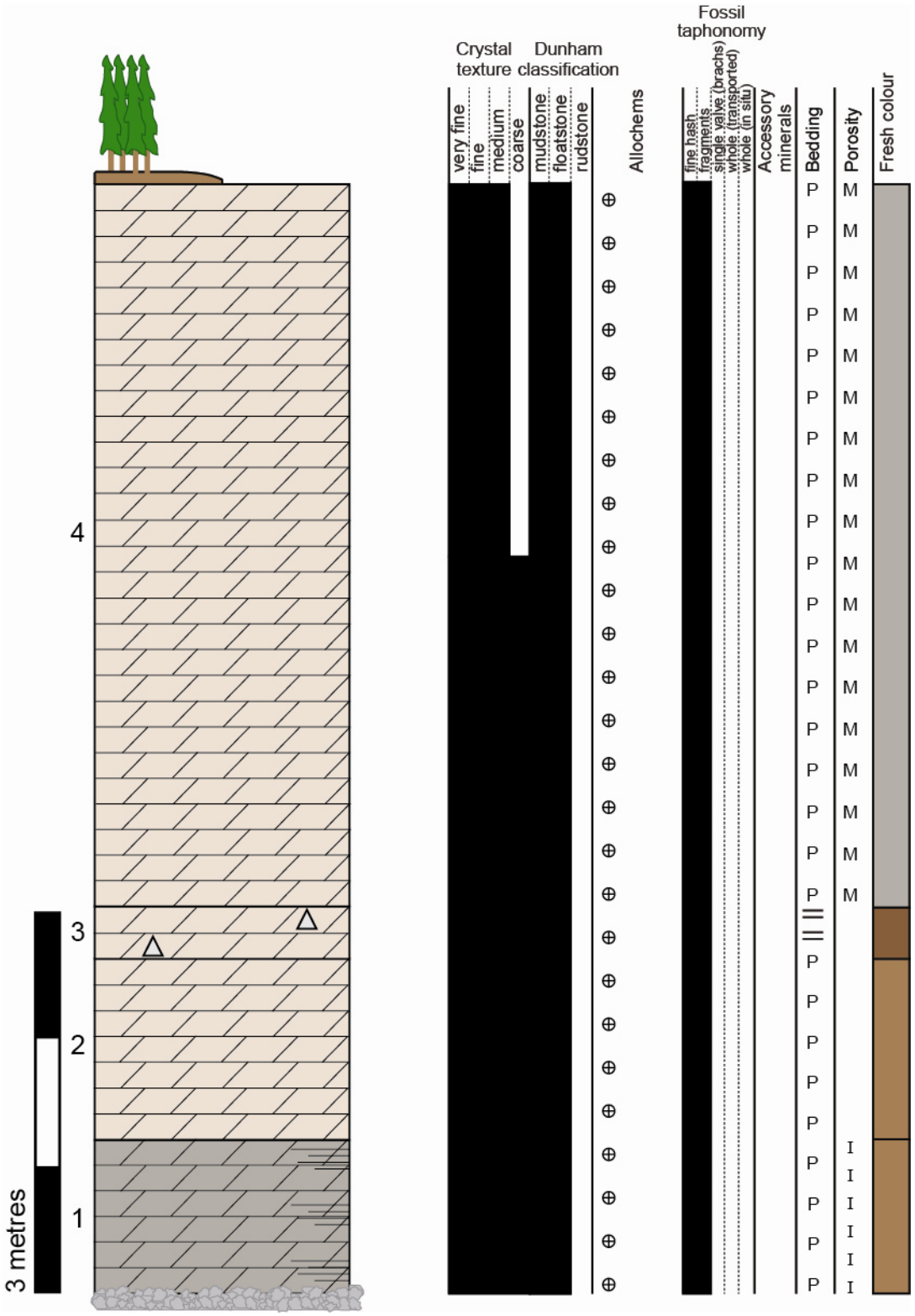


Figure 11. Keg River Formation at Contact Rapids, Clearwater River, Saskatchewan (station 4). The entire section is crinoidal dolo-floatstone; each unit is differentiated by minor changes in partings or the presence of chert nodules. Numbers to the left of the section correspond to units described above.

Figure 12. Unit 1 of the Keg River Formation at Contact Rapids, Clearwater River, Saskatchewan (station 4).

Figure 13. Units 2 and 3 of the Keg River Formation at Contact Rapids, Clearwater River, Saskatchewan (station 4).

Figure 14. Chert nodules from unit 3 of the Keg River Formation at Contact Rapids, Clearwater River, Saskatchewan (station 4).

3.4 Keg River Formation, Whitemud Falls, Clearwater River

3.4.1 Locality Description and Access

lat 56°41′29″N, long 110°03′35″W

By helicopter, land in the camping area north of Whitemud Falls. Foot trails are located riverwards of the camping spot in any location. Follow the footpaths along the edge of the river (and the top of the Keg River Formation cliffs) to the locality. Carefully make your way down the side of the outcrop through the cave to the river's edge. The measured section starts at the upstream edge of the cliff; the contact with the La Loche Formation is near the downstream edge of the cliff and may be covered if the water level is high.

This outcrop forms a small amphitheatre along the river's edge and faces other Keg River Formation cliffs across the water (Figure 15). At the downstream end of this small amphitheatre, Keg River Formation dolostone is eroded enough that a small patch of La Loche Formation lithic sandstone is exposed. As the Contact Rapids Formation is not present, this sandstone presumably overlies the flank of a basement topographic high that remained exposed during Contact Rapids deposition. Several small, domal stromatolites, up to 15 cm in diameter, initiated and grew on top of the sand of the La Loche Formation.

Near the sandstone, several bands of greenish argillaceous material occur between Keg River beds or along paleo-karsted fissures. White, abraded crinoid columnals and Keg River Formation carbonate clasts also appear in these karst features.

The outcrop contains at least three phases of karst: (1) syndepositional karst that occurred during a short sea level drop, which exposed the lower Keg River Formation carbonate overlying the Precambrian basement–La Loche Formation topographic high; (2) post-depositional karst that formed breccia-filled sinkholes or caves—this phase was possibly related to uplift and exposure prior to deposition of the Cretaceous succession in northeast Alberta; and (3) modern karst indicated by solution-enlarged fractures, a cave, calcite flowstone, and cavity-lining, popcorn-textured calcite deposits.

3.4.2 Stratigraphy

The outcrop was measured upstream from the falls. Because the rock forms a steep wall, the outcrop was described in several sections using beds that were traceable throughout the outcrop to correlate between sections.

At river level, at the downstream end of amphitheatre, the Keg River Formation is in direct contact with the La Loche Formation. La Loche sandstone and related karst-filling sediment both underlie and fill cavities in the Keg River dolostone. From base to top, the Keg River–La Loche area of the outcrop contains the following units:

1) Keg River Formation dolostone with fissures filled with sediment from unit 4.
2) La Loche Formation sandstone: dark grey, coarse to very coarse grained, rounded, moderately sorted, lithic sandstone.
3) Grey, stromatolitic, finely crystalline dolostone. Stromatolites encrusted the sand of unit 2 and aggraded into low domes.
4) Dark blue-grey, sandy shale containing (a) pyrite and marcasite crystals, white, (b) abraded crinoid pleuricolumnals, (c) scattered lithic coarse sand to pebbles, and (d) dolostone fragments. This unit fills fissures and solution chimneys in unit 1.
5) Keg River Formation dolostone.

The Keg River Formation outcrop was measured starting from the upstream end of the amphitheatre (Figure 16). From base to top, the outcrop contains the following units:

1) 75 cm, dolostone: beige-brown weathering, medium grey, massive, fine- to medium-crystalline, cherty mudstone containing solution vugs up to 2 cm in diameter.
2) 100 cm, dolostone: beige-weathering, brown-grey, massive, medium-crystalline, stromatoporoid and brachiopod rudstone with sparse vugs (Figure 17).
3) 165 cm, dolostone: beige-weathering, grey, tabular bedded (average 30 cm thick), fine- to medium-crystalline, stromatoporoid, solitary rugose coral, and brachiopod rudstone with sparse vugs, most of which are 5 to 10 cm in diameter.
4) 300 cm, dolostone: beige-weathering, medium-grey, massive, fine- to medium-crystalline, cherty, crinoidal rudstone with sparse vugs. In situ domal stromatoporoids and branching corals occur at the base of the unit.

Measurements continue near the cave in the south end of the outcrop:

5) 200 cm, dolostone: beige-weathering, grey breccia and flowstone. Clasts are mudstone.

Measurements continue past the cave, at the top and south end of the outcrop:

6) 600 cm, dolostone: beige-weathering, brown, massive, medium-crystalline, crinoid floatstone.

3.4.3 Fossils

Most fossils are dolomitized or preserved as moulds. Brachiopods and crinoid columnals occur throughout most of the section. Stromatoporoids and corals are common in the lower beds of the section, but most stromatoporoids are dissolved, leaving spherical vugs. A layer at the base of unit 4 contains an in situ biohermal community of corals and stromatoporoids, including one branching coral attached to the side and top of a domal stromatoporoid.

On the south end of the outcrop, near water level, small domal stromatolites grew on top of the La Loche Formation.

3.4.4 Paleoenvironmental Interpretation

At the Whitemud Falls locality, the Keg River Formation records the establishment of a reef ecosystem followed by a somewhat deeper, open marine, shallow platform (below fair-weather wave base) environment in which crinoids thrived. Evidence of at least two episodes of subaerial exposure were found in the outcrop: near the base of the outcrop—where La Loche Formation sediment filled crevices in the Keg River Formation (Figure 18)—and in the middle of the outcrop where extensive brecciation and flowstone deposits point to a younger period of paleo-karstification. The older exposure event was syndepositional with Keg River carbonate accumulation; the timing of the younger event is unknown and could postdate the Devonian.

Based on the nature of the contact with the La Loche Formation, carbonate of the Keg River Formation exposed at Whitemud Falls likely formed near an exposed basement topographic high. From this evidence, the events at the Whitemud Falls outcrop, from oldest to youngest, are as follows (Figure 19):

1) Transgressing seas during the deposition of the Contact Rapids left the highest basement knolls exposed. La Loche Formation sands formed thin drapes over these exposed knolls while silty shale of the Contact Rapids Formation filled the areas around the knolls.
2) With further transgression, deposition in the vicinity of the submerged Athabasca Arch became fully marine. Open marine carbonates of the Keg River Formation began to accumulate and encroached onto the basement knolls.

3) Brief subaerial exposure interrupted the deposition of the Keg River Formation and karst developed in the carbonates. Sand of the La Loche Formation washed off the knoll and combined with green clay, reworked crinoid columnals, and Keg River carbonate breccia to fill fissures and other karst features located near the basement knoll (Figures 18 and 20).
4) Transgression resumed and stromatolites encrusted the sandy sediment covering the knoll in a marginal marine paleoenvironment (Figure 21).
5) Further transgression led to the establishment of a coral-stromatoporoid reef over the knoll.
6) Continued transgression drowned the reef and crinoids flourished in the deeper-water environment.
7) All of the carbonate seen at the Whitemud Falls locality was deposited. Sedimentation continued but has since been lost to erosion.
8) The Keg River Formation was buried and dolomitized. Stromatoporoids were dissolved, leaving vugs. Brachiopods and crinoid columnals were recrystallized.

Figure 15. Keg River Formation outcrop on an island in Whitemud Falls, Clearwater River, Alberta. The view is from the described locality across the river to the island.

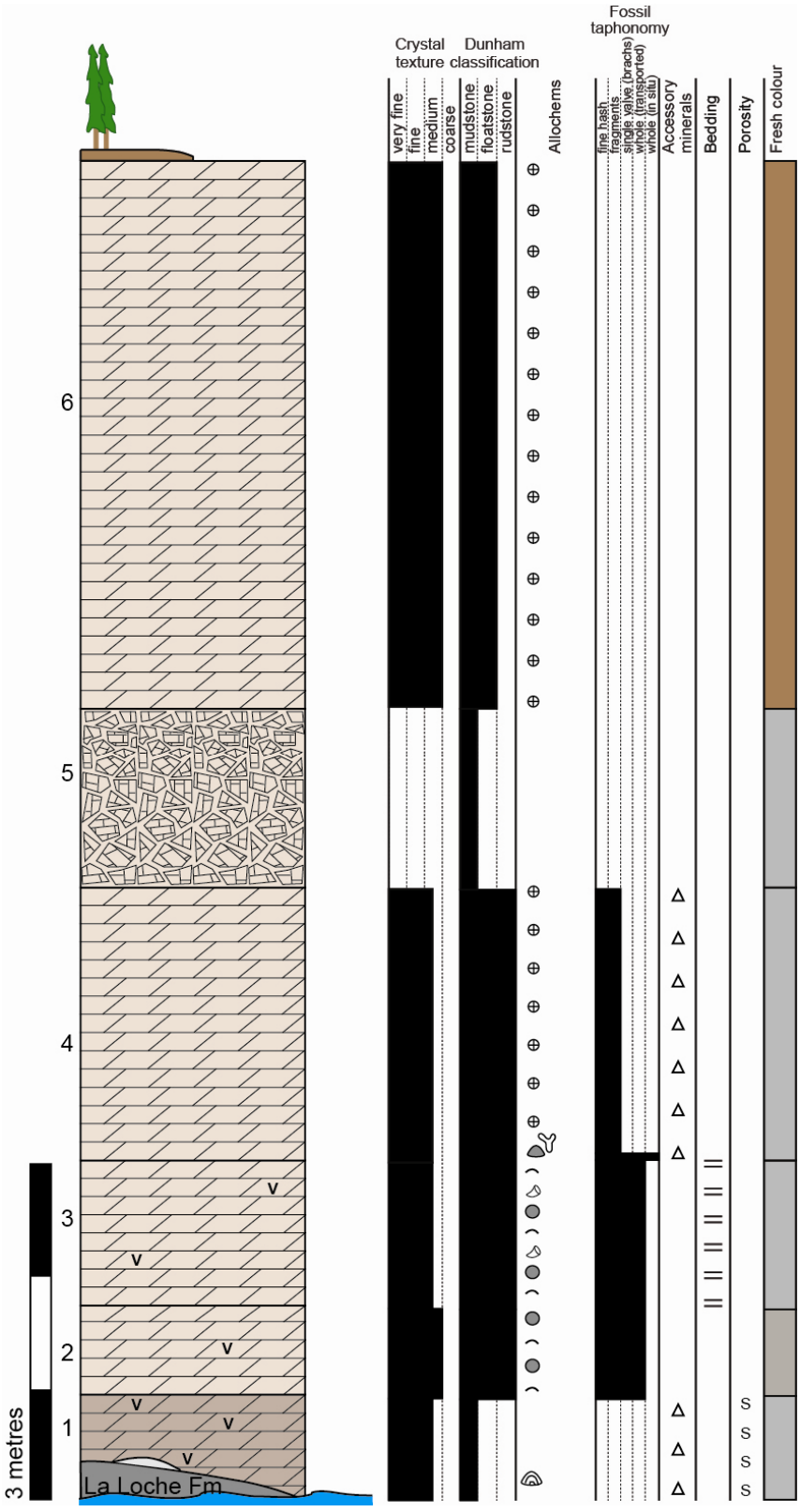


Figure 16. Stratigraphic column of the Keg River Formation at Whitemud Falls. Numbers on the left of the column correspond to Keg River descriptions, not to La Loche–Keg River contact descriptions

Figure 17. Unit 2 of the Keg River Formation at Whitemud Falls, Clearwater River, Alberta.

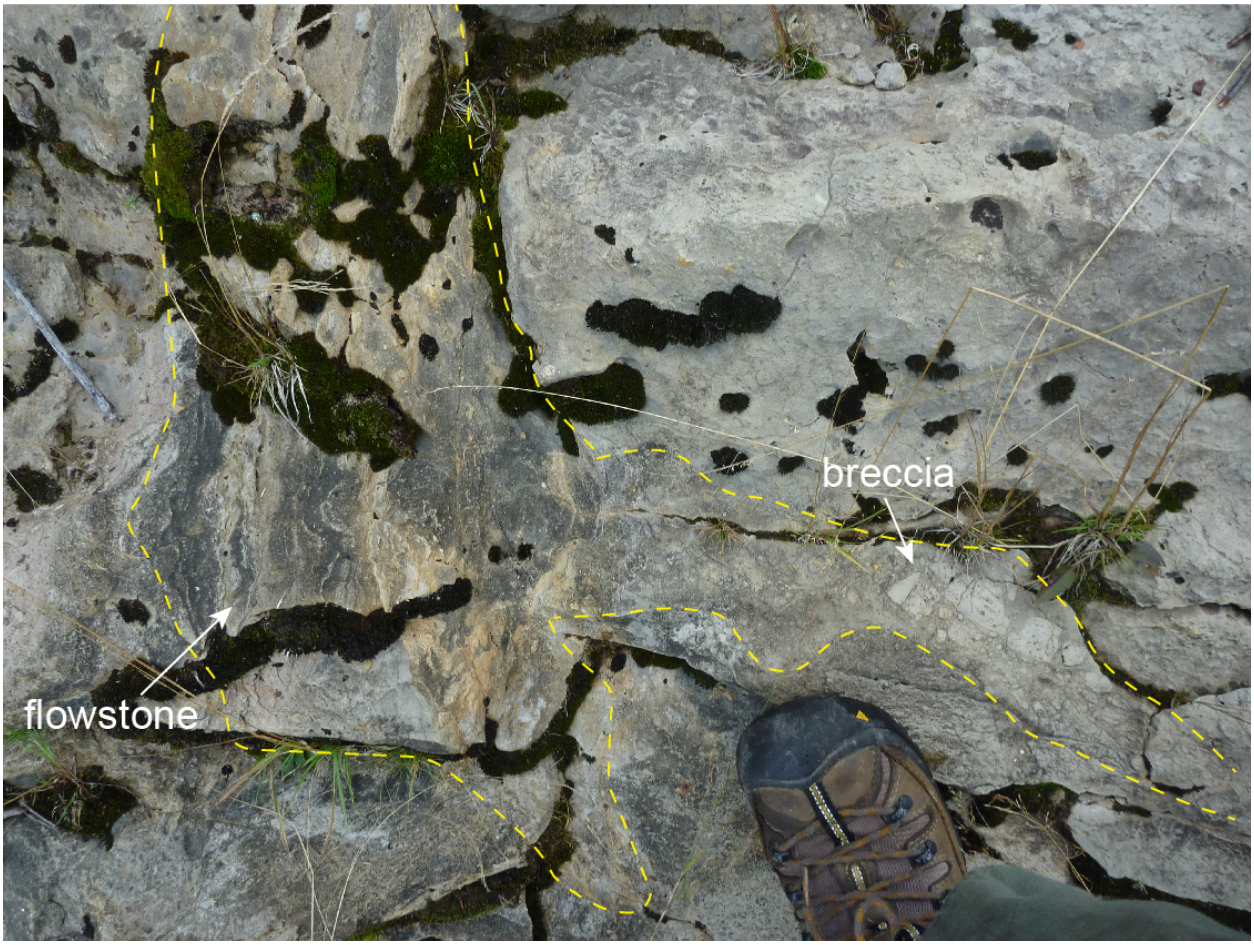


Figure 18. Paleokarst in the Keg River Formation at Whitemud Falls, Clearwater River, Alberta, outlined with a dashed yellow line. Photo is near vertical. To the upper left of the boot is a near-vertical chimney filled with layers of argillaceous material and possible flowstone. Some small white specks in the chimney are abraded crinoid columnals; others are quartz granules. Above and to the upper right of the boot is a nearly horizontal fissure containing breccia, argillaceous carbonate, quartz granules, and abraded crinoid columnals.

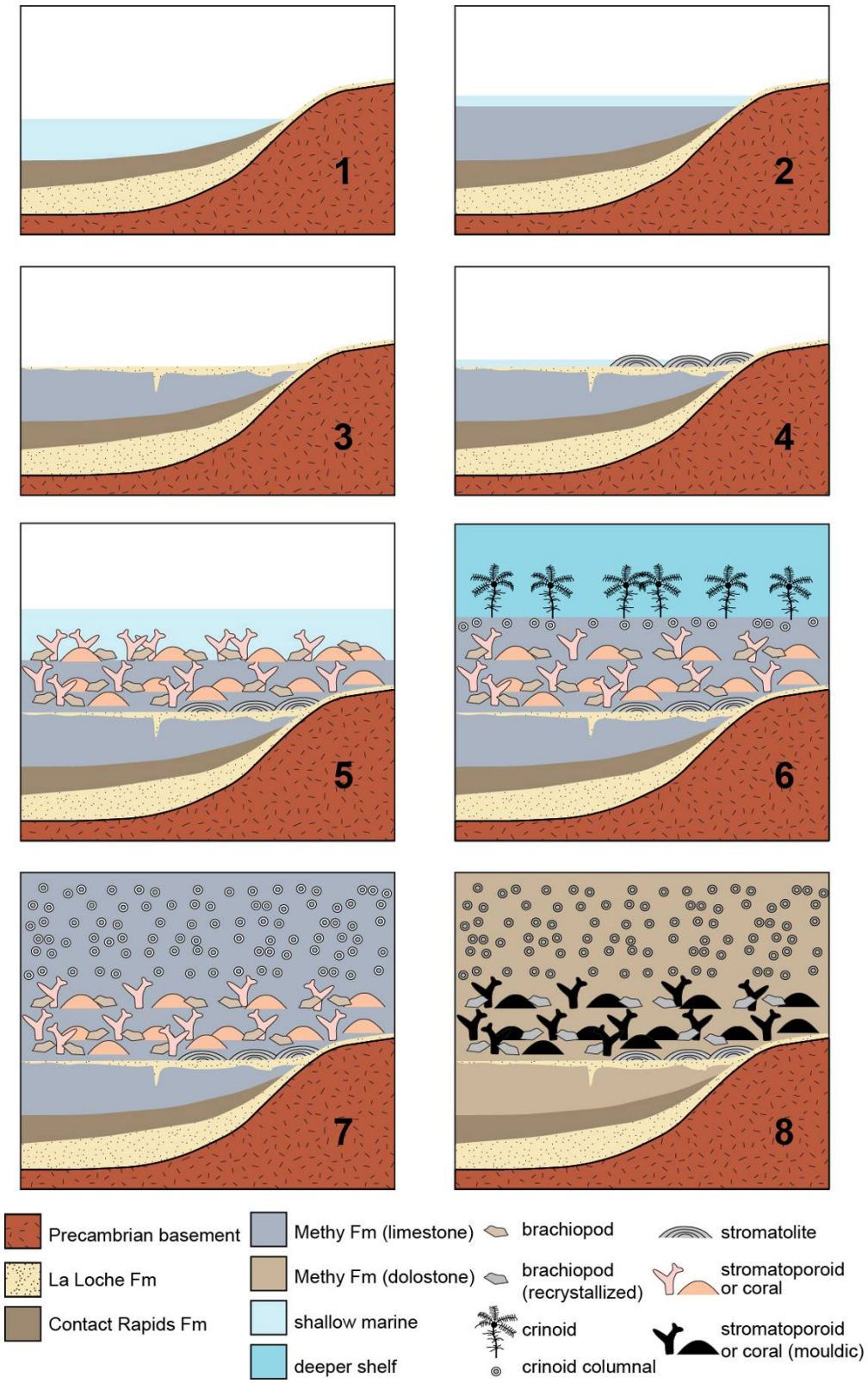


Figure 19. Cartoon of the geological history of the Whitemud Falls outcrop, as described in the Paleoenvironmental Interpretation section.

Figure 20. Contact between the La Loche and Keg River formations. La Loche granite wash fills a horizontal cavity or extends onto a horizontal surface in the Keg River dolostone. One foot is on brownish-grey weathering La Loche Formation sandstone and the other is on the light to medium grey-weathering Keg River Formation dolostone.

Figure 21. Contact between the La Loche Formation (brownish-red) and Keg River Formation stromatolites (light grey).

3.5 Keg River Formation, Cascade Rapids, Clearwater River

3.5.1 Locality Description and Access

lat 56°42′14″N, long 110°17′27″W

Take a boat to Cascade Rapids on the Clearwater River. Disembark at Cascade Rapids Recreational Area on the north bank of the river and walk upriver using the ATV trail to the next recreational area, about a five-minute hike through gently rolling terrain. Keg River Formation tidal flat facies outcrop along the river here. To get to the cliff-face outcrop described below, either return to the trail and walk upriver a short distance before walking through the forest (listen for the second set of rapids at the outcrop) or carefully scramble along the river's edge.

Because the outcrop dips gently upstream, the first outcrop encountered on the north bank of the river is equivalent to the lower portion of the upstream cliff face. At this first outcrop, the Keg River Formation dolostone comprises a series of algal laminites grading from nearly horizontal laminae through more complex laminae to domal stromatolites. Some exposed bedding planes contain oncolites and mudcracks.

Upstream, at the cliff-face outcrop described below, this tidal flat facies is abruptly terminated by subaerial exposure. A caliche bed overlies the topmost domal stromatolites of the tidal flat facies and can be traced laterally to a laminated or chaotic, flat-pebble rudstone. A pisolitic rudstone caps the subaerial exposure interval. The top of the outcrop is a return to tidal flat facies algal laminites.

3.5.2 Stratigraphy

From base of the outcrop by the river to the top, the outcrop contains the following units (Figures 22 and 23):

1) 140 cm, dolostone: beige-weathering, medium grey, 1–5 cm tabular-bedded, millimetre-scale laminated, medium- to coarsely crystalline, algal bindstone. Mouldic and intercrystalline porosity is to 10 per cent. The top 10 cm contains undulatory, anastomosing domal stromatolites (Figure 23).
2) 97 cm, dolostone: sharp contact with unit 1. This unit can be divided into sub-units of variable thickness (Figure 24):
   a) 15 to 23 cm thick, beige-weathering, medium grey, spongy textured, dolomitized caliche with 20–25 per cent millimetre-scale porosity.
   b) (laterally contiguous with unit c) 64 to 72 cm thick, beige-weathering, medium grey, laminated, medium- to coarsely crystalline, algal bindstone.
   c) (laterally contiguous with unit b) 0 to 72 cm thick, beige-weathering, medium grey, chaotically bedded, intraclastic rudstone of a possible channel infill.
   d) 10 cm thick, beige-weathering, medium grey, oncolitic rudstone (Figure 25).
3) 250 cm, dolostone: beige-weathering, medium grey, tabular bedded (at 1–5 cm intervals), millimetre-scale laminated, medium- to coarsely crystalline, algal bindstone. Mouldic and intercrystalline porosity is 5–10 per cent (Figure 26).

3.5.3 Fossils and Allochems

Alga and cyanobacteria formed stromatolites, tidal flat laminae, and oncolites.

3.5.4 Paleoenvironmental Interpretation

The units at this outcrop were deposited in a marginal marine, intra- to supralittoral tidal flat paleoenvironment. From base to top, the outcrop records a basal regression which extends through the peritidal carbonates up to the subaerial exposure surface and an upper initially transgressive but later regressive sequence:

1) Algal laminites formed in the upper intertidal zone. As sea level rose, algal laminae became undulose and ultimately developed into domal stromatolites in the lower intertidal zone.
2) Regression, exposure, weathering, and formation of caliche horizon.
3) Transgression caused the return to upper tidal flat facies. Meanwhile, the marginal marine or tidal flat channel incised and filled with storm-generated rip-up clasts from nearby tidal flat facies.
4) Further transgression into high-energy, shallow (above fair-weather wave base) lagoon facies optimal for oncolite formation.
5) Regression and return to upper tidal flat facies.

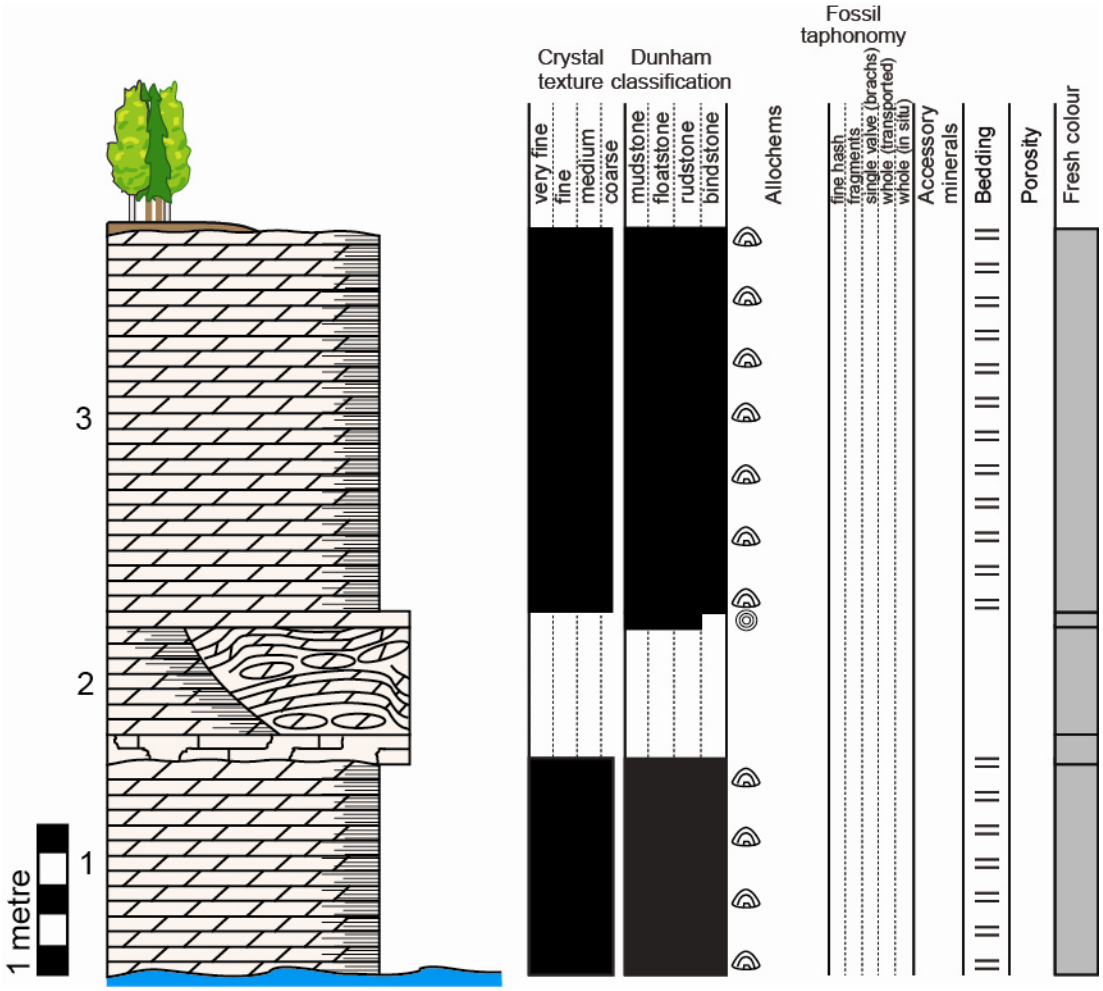


Figure 22. Stratigraphic section of the Keg River Formation at Cascade Rapids on the Clearwater River. Numbers to the left of the section correspond to described units above.

Figure 23. Keg River Formation at Cascade Rapids, north bank of the Clearwater River, Alberta.

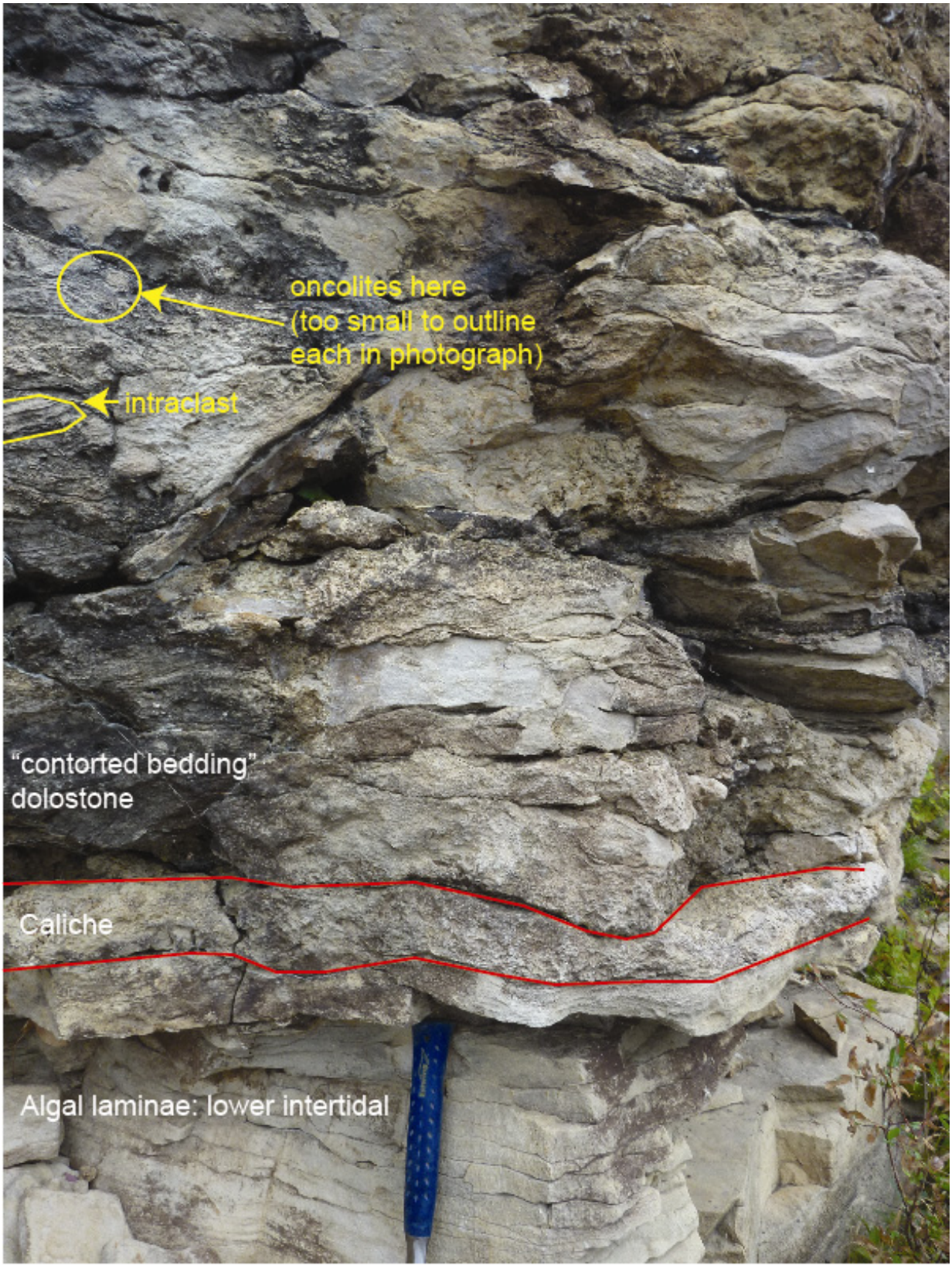


Figure 24. Detail of the relationship between intertidal algal laminae and supratidal caliche in the Keg River Formation at Cascade Rapids, north bank of the Clearwater River, Alberta.

Figure 25. Close-up of oncolites along a bedding plane in the intertidal facies of the lower Keg River Formation at Cascade Rapids, north bank of the Clearwater River, Alberta.

Figure 26. Succession of horizontal algal laminae upwards to domal stromatolites in the lower Keg River Formation at Cascade Rapids, north bank of the Clearwater River, Alberta.

4 Summary

At the Contact Rapids locality described above, the La Loche Formation includes a basal regolith, red arkosic sandstone, and minor silty to sandy shale, all of which are devoid of fossils. In outcrop, the colour of the La Loche Formation differs little from the underlying basement granitoid. From a distance, bedding planes in the coarse sandstones are the most conspicuous indication of the presence of the La Loche Formation.

The Contact Rapids Formation is a green-grey, silty shale with dolomitic and anhydritic beds and occasional fossils. Presently, only one outcrop is known for the Contact Rapids formation. Norris's (1963) locality is buried beneath Keg River Formation talus.

The Keg River Formation consists of grey-beige to brown dolomite and calcareous dolomite. Keg River outcrops are numerous and conspicuous along the Clearwater River valley from Cascade Rapids in Alberta to Contact Rapids in Saskatchewan. At all locations, the Keg River Formation is a beige to brown dolostone, often with conspicuous orange and black staining on its vertical surfaces and forming vertical cliffs along the river. The contact between the Contact Rapids and Keg River formations, previously only described from core, occurs near the top of the Contact Rapids Formation outcrop at the Contact Rapids locality. The Keg River Formation that forms the upper cliffs of the river valley is a beige-weathering, crinoidal dolo-floatstone containing locally abundant chert nodules.

La Loche Formation sands formed thin drapes over basement paleotopographic highs. Contact Rapids Formation dolomitic and silty shale filled the low areas but are absent from the tallest of the basement knolls. Over these exposed knolls, Keg River Formation carbonate was deposited directly on top of La Loche Formation sand. The Whitemud Falls outcrop described herein is an example of the Keg River Formation surrounding and abutting a basement knoll and is the only described example from outcrop. During Keg River Formation deposition, a period of subaerial exposure led to the development of karsted fissures and chimneys around the basement knoll. These karst features were filled with an argillaceous mix of La Loche sand and granules, crinoid columnals, and Keg River carbonate breccia. The Devonian sea later transgressed the knoll, allowing the formation of a stromatoporoid and coral reef. Further transgression led to the demise of the reef, resulting in the deposition of open shelf, crinoid-rich limestone. The Keg River Formation limestone was later dolomitized and contains evidence of another period of subaerial exposure and karstification, seen in the thick breccia in the cliff side.

At Contact Rapids and Whitemud Falls, the Keg River Formation is an open-marine, shallow-shelf crinoidal floatstone to biohermal rudstone. At Cascade Rapids, Keg River Formation facies fall entirely within the intertidal to supratidal range and include algal laminites, stromatolites, oncolites, subaerial exposure surfaces, and caliche. As this is the easternmost and, given the regional dip, stratigraphically highest section visited, the Keg River Formation goes through an overall shallowing-upwards trend, starting with the crinoid-rich and biohermal, shallow shelf environment below fair-weather wave base and terminating in a marginal marine paleoenvironment.

Overall, the La Loche–Contact Rapids–Keg River succession along the Clearwater River represents a complete transgressive-regressive sequence that starts with the initial flooding of the Athabasca Arch. La Loche sandstones formed during subaerial weathering of the basement into a regolith and the reworking of sands and gravels, possibly in a fluvial to shoreline paleoenvironment. Further transgression led to the deposition of dolomitic and silty shales of the Contact Rapids Formation, which formed in the near-shore to shallow marine environment. Keg River dolostone at Contact Rapids and Whitemud Falls records further transgression into an open marine, carbonate platform environment, and contains two major facies: a crinoid-rich, low- to moderate-energy paleoenvironment that formed beneath fair-weather wave base, and a shallower stromatoporoid-coral biostrome that likely experienced higher-energy conditions. The Keg River Formation at Cascade Rapids captures the regressive portion of the La Loche–Contact Rapids–Keg River sequence, when the sediments capping the Athabasca Arch experienced regression and, at times, subaerial exposure.

5 References

Baillie, A.D. (1953): Devonian System of the Williston Basin area; Manitoba Mines and Natural Resources; Mines Branch, Publication 52-5, 105 p., 5 maps.

Bassett, H.G. (1952): Correlation of Devonian sections in northern Alberta and Northwest Territories; Ph.D. dissertation, Princeton University, 313 p.

Bell, R. (1884): Report on part of the basin of the Athabasca River, North-west Territory, 1882–3; Geological and Natural History Survey of Canada Report of Progress 1882-83-84, part CC, p. 1–37.

Buschkuehle, B.E. (2003): Sedimentology and stratigraphy of Middle and Upper Devonian carbonates in northern Alberta: a contribution to the carbonate-hosted Pb-Zn (MVT) Targeted Geoscience Initiative; EUB-AGS Geo-Note 2002-14, 14 p.

Dunham, R.J. (1962): Classification of carbonate rocks according to depositional texture; *in* Classification of carbonate rocks, W.E. Ham (ed.), American Association of Petroleum Geologists (AAPG) Memoir 1, p. 108–121.

Ells, S.C. (1932): Exploration of bituminous sand areas in northern Alberta; Department of Mines, Canada, Mines Branch, Report 727, p. 107–134.

Johnson, J.G., Klapper, G. and Sandberg, C.A. (1985): Devonian eustatic fluctuations in Euramerica; Geological Society of America Bulletin, vol. 96, no. 5, p. 567–587.

Law, J. (1955): Geology of northwestern Alberta and adjacent areas; Bulletin of the American Association of Petroleum Geologists, 39, p. 1927–1975.

Macoun, J. (1877): Geological and topographical notes on the lower Peace and Athabasca Rivers; Geological Survey of Canada, Report on Progress 1875–1876, p. 87–95.

Moore, P.F. (1988): Devonian geohistory of the Western Interior of Canada; *in* Devonian System of the World, N.J. McMillan, A.F. Embry and D.J. Glass (ed.), Canadian Society of Petroleum Geologists, Second International Symposium on the Devonian System, memoir 14, v. 1, p. 67–84.

Moore, P.F. (1993): Devonian; Subchapter 4D *in* Sedimentary Cover of the Craton of Canada, D.F. Scott and J.D. Aitken (ed.) Geological Survey of Canada, Geology of Canada, no. 5, p. 150–201.

Norris, A.W. (1963): Devonian stratigraphy of northeastern Alberta and northwestern Saskatchewan; Geological Survey of Canada, Memoir 313, 168 p.

Sherwin, D.F. (1962): Lower Elk Point section in east-central Alberta; Journal of the Alberta Society of Petroleum Geologists, vol. 10, no. 4, p. 185–191.

Wendte, J.C. (1992): Overview of the Devonian of the Western Canada Sedimentary Basin; *in* Devonian-Early Mississippian Carbonates of the Western Canada Sedimentary Basin: A Sequence Stratigraphic Framework, J. Wendte, F.A. Stoakes and C.V. Cambell (ed.), Society for Sedimentary Geology (SEPM) Short Course no. 28, p. 1–25.

Appendix: Key to Stratigraphic Sections

Lithology


silty shale


shaly siltstone


sandstone


dolostone


breccia


contorted beds and intraclasts


caliche


cover

Colours

beige

beige-brown

pink

red-brown

brown

dark brown

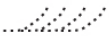
brown-grey

grey

green-grey

unknown

Structures


Cross-bedding


Graded bedding

Laminae

v Vug

Δ Chert nodule

Allochems


stromatolite


oncoid


massive stromatoporoid


bulbous stromatoporoid


branching coral


solitary rugose coral

brachiopod


crinoid

Accessory minerals

Δ Chert

Bedding

= Tabular beds

P Partings

Porosity

M Mouldic

I Intercrystalline

S Solution vugs