Thickness Trends of J seam, and Its Split at the Falher D Shoreline, Wolverine River Area, Peace River Coalfield, Northeastern British Columbia (parts of NTS 093I, P)

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KEYWORDS: coal geology, middle Gates Formation, Peace River coalfield, NTS 093P, NTS 093I, Wolverine River, Murray River, Perry Creek pit, Falher D, Falher C, J seam, transgression, regression, J conglomerate, E conglomerate, COALFILE

INTRODUCTION

The area of study is located southwest of the town of Tumbler Ridge in northeast BC (Fig 1). It lies in an area of old, new and potential pits (Fig 2) that target coals of the middle Gates Formation of the Cretaceous (early to middle Albian).

Arguably J seam, at the base of the middle Gates Formation, is the important economic coal seam in the area. This report compiles the thickness trends of J seam between Bullmoose Mt. in the north and Babcock Mt. to the south (Fig 2). It details the thinning trend of this seam where it is overlain by nearshore deposits of J conglomerate (Falher D).

J seam is also split by J conglomerate with J1 ply extending over the northward-thickening wedge of nearshore deposits in the Perry Creek deposit area. The development of J seam peat spans a period of shoreline advance and retreat. It may represent a transgressive-regressive coal seam couplet as modelled by Diessel (1992) and Banerjee et al. (1996). Transgressive-regressive couplets explain why paralic coals are thick near the paleocoast (Fig 3).

Accommodation in the paralic environment is defined as the available space between the peat basin floor and sea level. The water table generally coincides with, or is influenced by sea level. A significant accommodation reversal in coastal peat (e.g., a change from a drying-up to a wetting-up trend) is often related to shoreline migrations. Accommodation reversal surfaces in J seam have been identified utilizing maceral analysis and petrographic indices such as tissue preservation and gelification (Lamberson et al., 1991; Diessel et al., 2000). This study provides supporting context to that work.

In the study area, onlap of nearshore J conglomerate involved wave erosion and reworking, sediment winnowing, stacking of nearshore deposits at high stand, loading and compaction of the adjoining coastal mire (J2 ply). A coastal lagoon formed at the margin of a barrier shoal and is represented by a thickened shale lens onlapping the conglomerate. A tentative model of the transgressive-regressive cycle is presented, drawing on relationships at Perry Creek pit and Mt. Spieker.

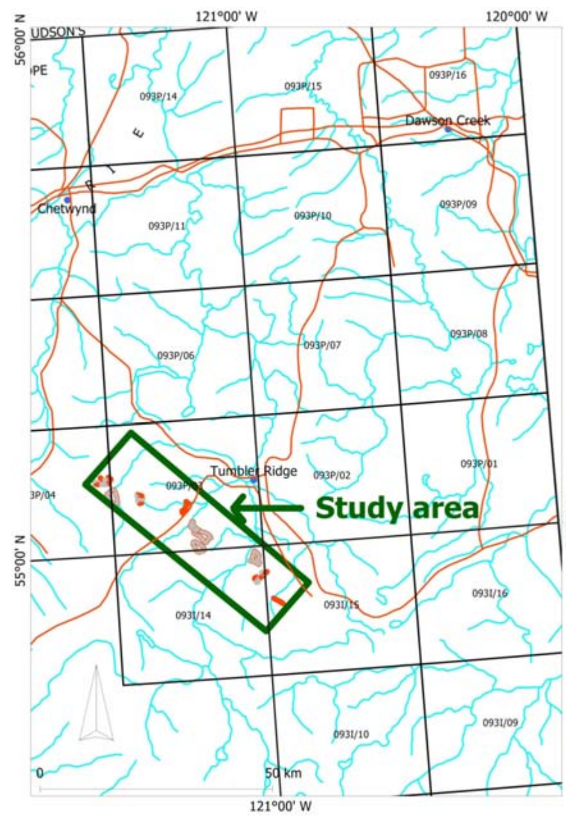

Figure 1. Location of study area, Tumbler Ridge, northeastern BC.

Other coal splits by marine tongues may be present in the area. A split in G seam in the Marmot area may be related to Falher C deposits nearby.

Some early aspects of this work are reported in Legun (2006a). Updates to the distribution of clean sandstone and conglomerate of Falher C and D are presented in Legun (2006b).

Wedge-like units of nearshore sedimentary rocks within the middle Gates Formation coal section affect aspects of coal extraction and pit planning in three ways: 1) they increase strip ratios and they include siliceous-rich conglomerate that influences the pH of waste rock drainage; 2) they indicate the probability of higher sulphur content in underlying or adjacent coal; and 3) they make com-

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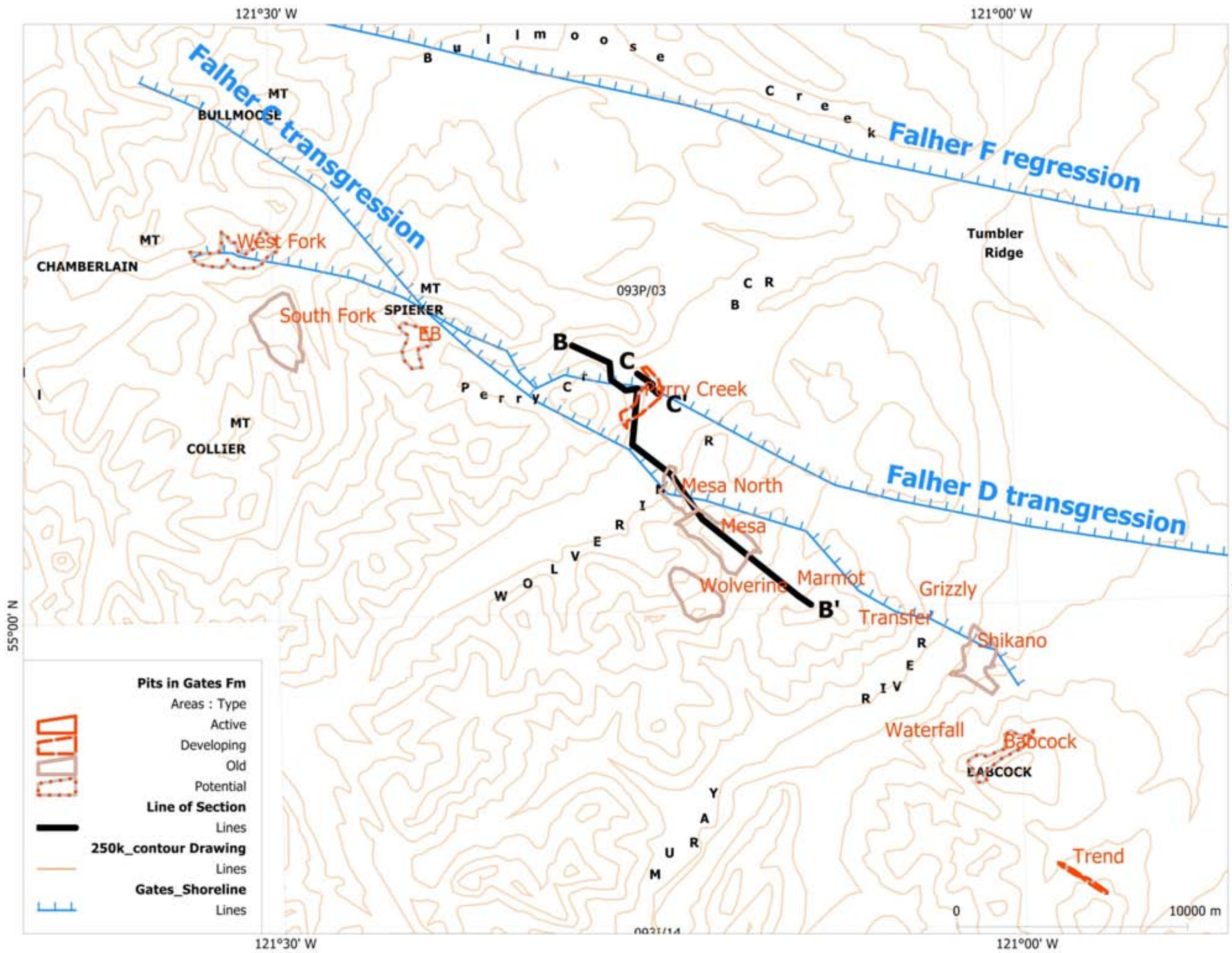

Figure 2. Coal pits, coal exploration areas, middle Gates Formation shoreline positions, and lines of section in the study area, northeastern BC.

petent roof rock for underground mining options or an excellent pit floor.

GATES FORMATION STRATIGRAPHY

The general stratigraphic framework of the Gates Formation is shown in Table 1. The Gates Formation is informally divided into lower, middle and upper members. The lower member is the Quintette sandstone, composed largely of clean sheet sandstone of shoreface and shallow shoal origin. It caps a transitional facies with Moosebar Formation shale below and underpins the middle Gates Formation coal measures, defined by geologists at Quintette Coal Ltd. as the interval bounded by K (lower) and D (upper) seams. Locally overlying D seam is a cap-rock sandstone and conglomerate unit, known as the Babcock (from extensive exposures on Babcock Mt.). These are estuarine shoal deposits of the upper Gates Formation that abruptly end the major coal-bearing period of the middle Gates Formation. Above the upper Gates Formation and below the overlying Hulcross Formation shale is an unnamed unit of thin coal and shale layers.

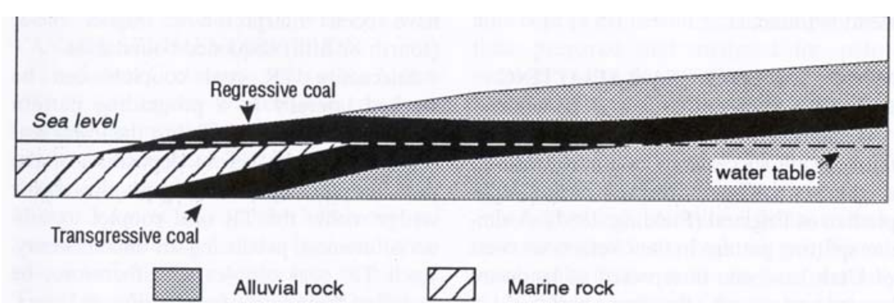

Figure 3. Model of transgressive-regressive coal couplet (*after* Diessel, 1992).

Middle Gates Formation

The J seam lies at the base of the middle Gates Formation coal section at Wolverine but K seam underpins it to the south at Murray River. The middle Gates Formation may contain up to 18 m of medium to low volatile coal in 60 m of section. Regional-scale correlations of middle Gates Formation coals indicate five to six seams that are laterally continuous and reach economic thickness over a

TABLE 1. STRATIGRAPHIC NOMENCLATURE OF THE GATES FORMATION AND ITS RELATION TO FALHER CYCLES, NORTHEASTERN BC.

	West Fork deposit	Teck Bullmoose pit (reclaimed), EB pit	Mt. Spieker Ridge	Perry Creek pit	Subsurface (oil and gas wells)	Carmichael regional study (1983)	Qunitette Coal Ltd. Mesa pit (reclaimed)
Upper Gates Formation	unit 5	upper seams'			Notikewan	unnamed	thin coals and shale
	unit 4			Fortress Mt. unit	Notikewan	Babcock member	Babcock member
Middle Gates Formation	**(E seam)**	**(E seam)**		**D seam**			**D seam**
	(D seam)	**(D seam)**		**E, F seams**			**E seam**
				Wolverine unit	Falher C		E conglomerate
	(C seam)	**(C seam)**	**C seam**	**G seam**			**G seam**
			C2 seam?	**J seam (J1 ply)**			
	unnamed		unnamed	J conglomerate	Falher D		
	conglomerate		conglomerate				
	A, B seams	**A, B seams**	**A, B seams**	**J seam (J2,3 plies)**			**J seam**
Lower Gates Formation	unit 1			Quintette sandstone	Falher F	Sheriff member	Quintette sandstone
					Falher G	Torrens member	

Note: ( ) indicate comparble stratigraphic position.

significant area. Of these, J and E seams show the thickest coal development. The J seam may exceed 7 m with low ash and could be mined as a single seam with no subplies and very thin partings. The E seam tends to be composite, formed of several closely spaced plies. Portions of these become very ashy (E1) or develop abundant partings (lower part of E3). The F seam, generally cleaner, is equivalent to E2/E3 where those plies separate from E1 in the Marmot (Hermann North) area, southeast of the reclaimed Mesa pit. Correlation and extents of middle Gates Formation coals are shown in summary figures of Quintette Coal Ltd. (COALFILE 753; COALFILE, 2007), Carmichael (1983) and Leckie (1983). Although major seams are often shown in a simple ordered sequence in a stratigraphic column, the seam architecture has some complexity. Correlations between pits indicate seams split or amalgamate, or stratigraphically approach each other. Approaches include D and E (Shikano and Mesa pits) and J and K (Babcock pit). The G seam is split in the Marmot area with the upper ply migrating stratigraphically to E4 seam in the Mesa pit area to the northwest. The seam architecture has not been adequately related to the geometry of nearby deltaic lobes and marine tongues.

FALHER CYCLES, MARINE TONGUES AND COAL

Cycles of marine regression, named Falher cycles, are distinguished by gamma log responses that indicate upward-coarsening sequences. The cycles are alphabetically named G (stratigraphically lowest) to A (highest). Ideally they comprise a basal transgressive lag deposit, upward-coarsening shale, sandstone to conglomerate with marine trace fossils followed by evidence of terrestrialisation (rootings, coal). Upper beds of cycle F correspond to the Quintette sandstone. At the top of the Falher F and C cycles are shoreface deposits that form the widespread floors to the J and E seams. Cycle G lies within the Moosebar transitional facies in the study area but is the Torrens sandstone floor to a major coal seam near the Alberta border.

J and E conglomerate in coalfield terminology correlates to the sandy and conglomeratic (i.e., non-shaly) nearshore deposits of Falher C and D. Wedge-like in geometry, Falher D directly overlies J seam while Falher C is above G seam and below E. Borehole QWD7115 in the Perry Creek pit area is key in tying Falher cycle correlations to J and E conglomerates in the Wolverine area. The E conglomerate develops and extends from Mesa North pit while J conglomerate develops in the northern half of Western Canada Coal Corp.'s (WCCC) Perry Creek pit, Mt. Spieker ridge and in the undeveloped West Fork deposit.

SHORELINES

Both Leckie (1983) and Carmichael (1983) produced maps of shoreline trends. The maximum regressive limit is the most northerly occurrence of coal or carbonaceous shale, capping a coarsening-upward sequence. The transgressive limit is marked by the southern limit (zero isopach) of clean sandstone and conglomerate of nearshore origin (zero edge of J or E conglomerate). During the Falher F regression, the shoreline migrated to a position north of Bullmoose Mt. (Fig 2). The subsequent transgression (Falher D) brought it to an east-west position near Mt. Spieker. It subsequently retreated well to the north and advanced again (Falher C) with a northwest-southeast shoreline position that lies close to a line from Bullmoose Mt. to Mesa North pit to Shikano pit. A portion of the middle Gates Formation outcrop section at Perry Creek is shown in Figure 4. This section lies south of the Falher D transgression line but north of Falher C.

J SEAM THICKNESS STUDY

Elements of J seam have a wide extent, though regional correlations may correspond to a coal interval rather than a discrete seam. It persists eastward to the Alberta deep basin as the 4th coal seam. Southeast of Wolverine, along the structural trend, it is split by a deltaic lobe at Monkman and continues as seams B4, B5 to the Belcourt area. In the southwest, along the trend of Five Cabin Creek syncline it is locally missing and replaced by fluvial conglomerate (Carmichael, 1983, Fig 6, 25). Some trends north of the Wolverine River are shown in Summary Figure 3.6 of Leckie (1983). Trends to the northeast, immediately outside the coalbelt, are poorly known due to few wells.

In the area of study, J seam has been mined at South Fork pit and a number of Quintette Coal Ltd. pits including Mesa, Wolverine and Shikano. It is currently mined at the Perry Creek and Trend pits. The J seam forms a significant resource at prospective pits that include EB, West Fork and Hermann North.

Over a large part of the study area, J seam has few and relatively thin (less than 0.5 m) rock splits. Where splits are present the seam is subdivided into local plies named J1, J2 and J3. In the Bullmoose area, J seam equates to two separate seams, locally named A and B. The basal J3 ply is probably equivalent to A seam as they both rest on Quintette sandstone. The B seam corresponds to J2 as both are locally overlain by Falher D conglomerate. The A and B seams are referred as J(A) and J(B) below.

Trends were compiled using group and individual borehole thickness data. Group data includes 'in pit' isopachs or seam averages. Individual thickness data is presented in seam intercept drilling summaries and in correlation charts. Thickness is often quoted as a fraction: coal thickness/seam thickness. Seam thickness and not coal thickness values were used in this study. These thicknesses are derived from picks of high resolution density logs in conjunction with gamma ray logs (and caliper). Additional thickness data is available in logs of petroleum wells though the geophysical logs have a coarser resolution.

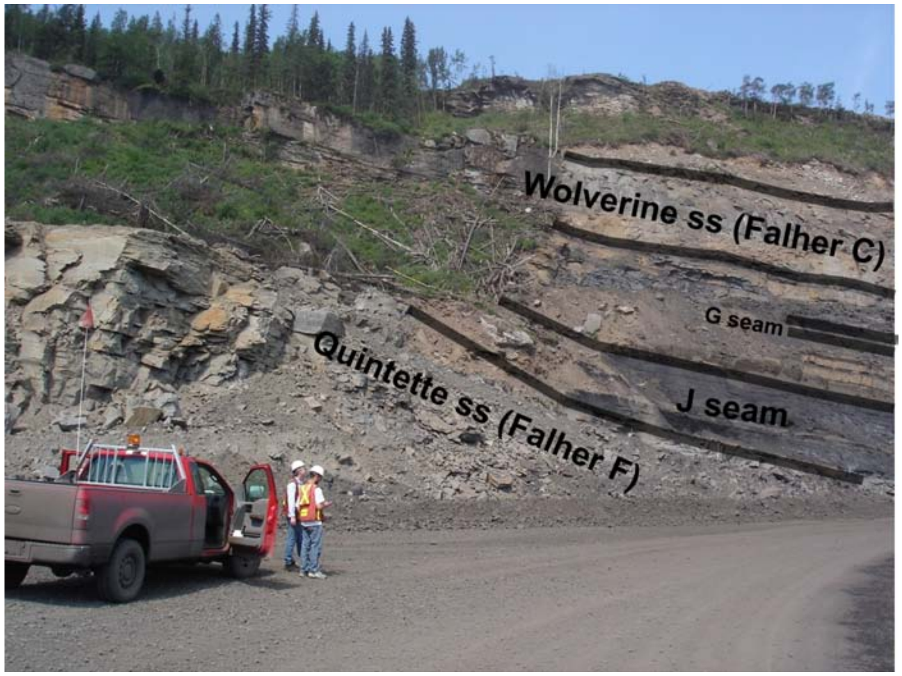

Figure 4. Outcrop section in the Perry Creek pit showing the base of middle Gates Formation (J seam) resting on clean Quintette sandstone (ss), northeastern BC.

The author employed a simple approach to assess trends. Seam thickness averages were used for densely drilled areas and point values where data was sparse. Values of separate plies (J1, J2, J3) were summed. The J(A) and J(B) seams were summed in the Bullmoose area.

Thickness trends are evaluated from data points in the folded terrain of the Rocky Mountain foothills. The data points and trends reflect crustal shortening of perhaps 15% and have not been palinspastically restored to original geographic position.

Results

Results of the thickness study revealed three thickness domains (Areas 1, 2, 3) of J seam (Fig 5). Seam thickness trends are superimposed on isopachs of J conglomerate (in metres). In the Perry Creek area, thicknesses that include J1 ply above the J conglomerate are shown in an inset.

Area 1 is a seaward area where J seam thins rapidly. The boundary follows the partially defined 4 m isopach of J seam. The thinning trend is normal to the linear trend of J conglomerate, and is particularly evident in the more densely drilled areas of West Fork and Perry Creek pit. The thinning trend continues east of the coalbelt in the subsurface and is recognizable in J seam and Falher D signatures in well logs. The J seam is thick south of the Falher D line. A possible exception occurs near well 15372 (Fig 5) where both J seam and J conglomerate are thick.

Area 2 is a large coastal area where J seam exceeds 4 m. Individual pit maps of J seam contours do not display any dominant trends that are normal or parallel to the shore. This domain extends east of the coalbelt into the subsurface.

Area 3 is an area where J seam is less than 4 m thick. This includes portions of Wolverine pit and Waterfall Creek drill areas. The seam thins due to thick rock splits. This area may border alluvial plains of the upper coast.

DETAILS OF THINNING TREND IN AREA 1 (NEAR FALHER D SHORELINE).

At the Mesa and Perry Creek pits, minor shale partings divide J seam into three coal plies (Fig 6). The partings thicken northward and the upper interseam rock (between J2 and J1 coal) is replaced by conglomerate. The logs from a line of development drillholes (Fig 7) show the separation of J1 ply from the main seam. The J conglomerate rapidly thickens northward to upwards of 40 m with the J1 ply above. Beyond the drillhole line, J1 thins to less than 0.5 m in drillhole QWD 7120 to the northwest (Fig 7 inset).

J2 coal ply has a clean upper contact suggesting it may be locally eroded below the conglomerate. Western Canada Coal Corp. (2003) reports that "Where J conglomerate forms the J2 roof, J2 is cleaner as it lacks the rock and/or high-ash coal bands in its upper part". In the line of section (C' to C), J2 thins from 4 to 2.7 m over 1 km. Further to the northwest, J2 splits into two plies, each of which thins and becomes shaly. The upper ply is not present in the last drillhole of this trend (PR 2006-24, Fig 7 inset).

In the Bullmoose area, both J(A) and J(B) seams thin northward to the West Fork area. In contrast to trends at Perry Creek, the interseam shale does not thicken. J(B) is locally eroded against J conglomerate, the contact is marked by chert pebbles in fine sand with coal fragments, some replaced by pyrite. This is very similar to observations at Mt. Spieker and the Perry Creek pit. Northward J(A) thins to a carbonaceous mudstone and J(B) persists to the northern parts of Bullmoose Mt.

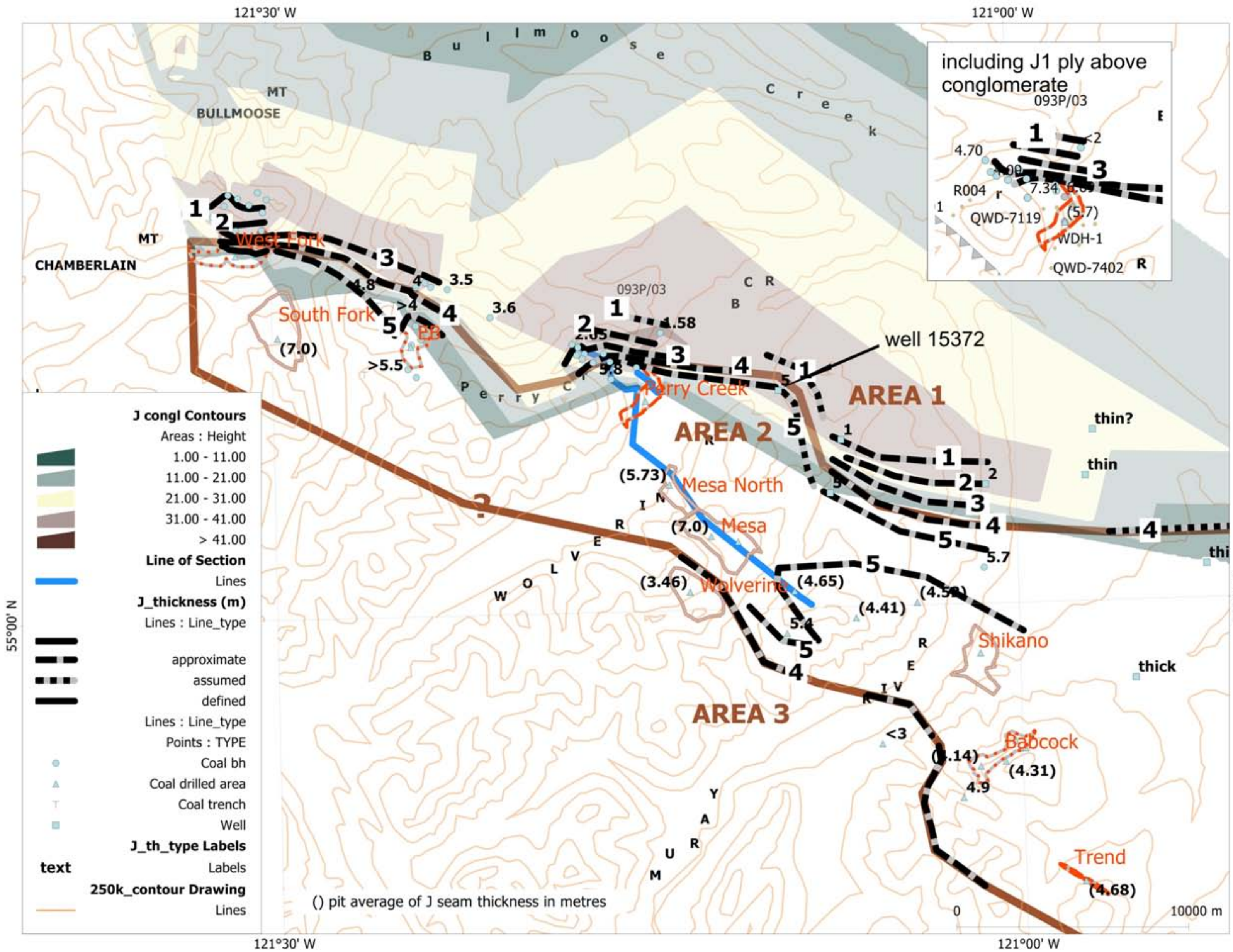

Figure 5. Relation of J (composite) seam thickness to isopach trends of J conglomerate (Falher D).

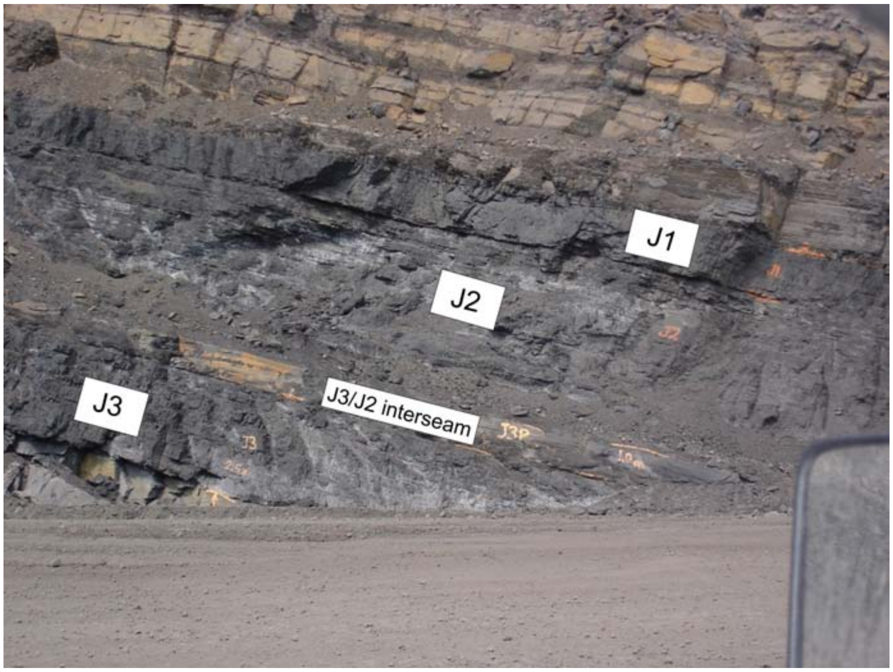

Figure 6. Exposure of J seam plies at Perry Creek pit, northeastern BC. The J2/J1 parting, barely apparent, passes northward to several metres of shale and then J conglomerate.

J(A) and J(B) have a combined thickness exceeding 5.5 m in the EB pit area but are separated by up to 15 m of interseam rock. The seam thickness is reduced to 4 m at the southwestern edge of adjoining Mt. Spieker ridge. On the ridge itself, the thinning trend of each seam continues with the combined thickness dropping to 2 m or less.

INTERPRETATION OF TRENDS AT THE PALEOSHORE

The thinning of the lower coal plies (JA or J3) is depositional as their roof shale is intact. The contact of ply J(B) or J2 with conglomerate marks a surface of marine erosion. The pebble lag on the coal surface is due to wave action (above storm wave base) during southern advance of the Falher D sea. On Mt. Spieker ridge, shale is locally present above B seam, even near the zero edge of the conglomerate (COALFILE 556, trench data). The erosion thus appears to be shallow and the thinning of upper plies is largely depositional.

On Mt. Spieker ridge, it is unclear whether the transgressive lag underpins the conglomerate to its zero edge, that is, whether the edge of the conglomerate coincides with the shoreline. Marine conditions are clearly documented a kilometre to the north with herringbone crossbedding, Rhizocorallium trace fossils and storm sheet facies of swaley cross-stratification (Leckie and Walker, 1982). In the Perry Creek valley, in a comparable position from the zero edge, tens of metres of massive sandstone lie above J2 coal at the creek's edge. It is loaded by sandstone pillows and intervening pockets of pebbly mudstone. The massive sandstone with basal flute casts suggests mass influx of sediment, possibly a baymouth splay below a distributary.

Toward the zero edge on Mt. Spieker ridge, Leckie (1983) suggested a fluvial regime based on the presence of a root horizon, large lateral accretion bedforms and a high proportion of conglomerate. Trench data in the area (COALFILE 556) suggests B seam thickness is maintained below the channel. The author suggested the accretion bedforms extending over 15 m in height may be the southern (coast facing) slope of a barrier shoal (Legun, 2006a). Well-washed, quartzitic sandstone occurs near the top of J conglomerate with current bedforms parallel to the shore. At Perry Creek, the well log for diamond-drill hole QPR 88003 (Fig 7) has density spikes that suggest the presence of carbonaceous shale lenses in J conglomerate. An estuarine environment with shore-parallel and shore-normal elements may be an inclusive description of sedimentation complexities at the coast/marine interface in both areas.

The source of nearshore sandstone and conglomerate is not readily evident. Channel bodies are not identified landward of the linear trend of J conglomerate — areas that include EB pit, South Fork (Bullmoose mine) and south Perry Creek pit. A thick, blocky gamma profile in a recent drillhole (COALFILE 901, PRC R003) near Fortress Mt. (Fig 7 inset) may represent a channel. It is south of the conglomerate line.

A shale interval between the top of J(B) and base of C2 seam can be traced from Mt. Spieker ridge (drillhole MS23) to the EB pit area (drillhole MS19). At Mt. Spieker, it is only a metre or so thick on top of J conglomerate while it is 16 m at the EB pit where the conglomerate is missing. It suggests the presence of a shale-filled lagoon landward of the coastal shoal or barrier. Overwash during storm events leads to sediment loading and compaction of adjoining mires creating accommodation space (i.e., a lagoon). An example of this in the modern historical record was reconstructed by Long et al. (2006).

Marine influence on coastal peat further south is indicated by fossils immediately above J seam in drillhole QWD 7402 (Fig 7 inset) and the sulphur content of J seam (D. McNeil, pers comm, 2007).

A model for J seam regressive couplet is presented in Figure 8, utilizing relationships at Mt. Spieker and Perry Creek.

PETROGRAPHIC INDICATOR STUDIES AND J SEAM SPLIT

The split of J seam provides improved context for petrographic indicator studies of J seam. Kalkreuth and Leckie (1989) suggested there was considerable transported (drifted) material in the J3 ply, given the high proportion of degraded vitrinite and inertodetrinite. With a falling sea level, a modest gradient was established on the new coastal plain. J3 began in a marsh environment subject to flood pulses that brought in abundant organic debris. The basal peat was part of the shoaling process and reflected a

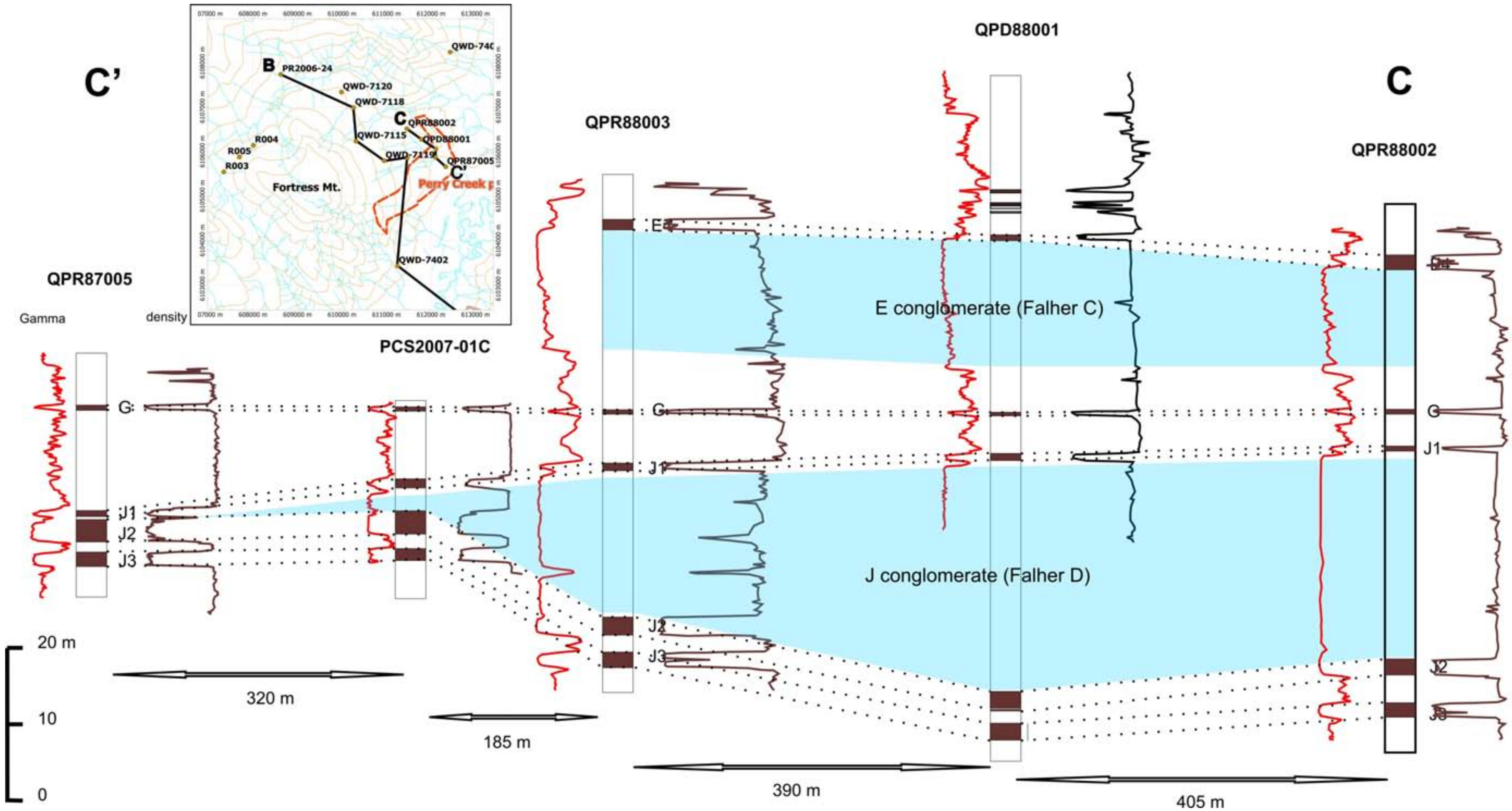

Figure 7. Line of development drillholes showing correlation of J1 ply above J conglomerate, northeastern BC.

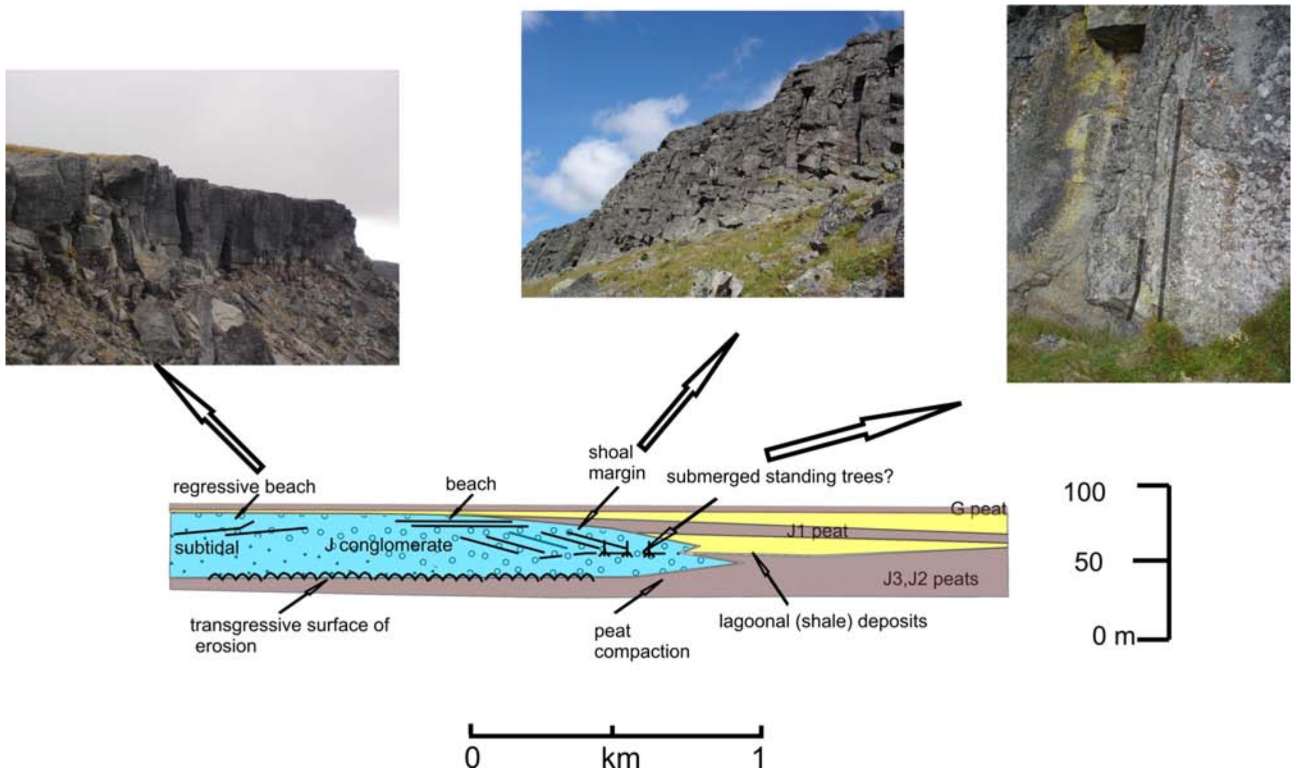

Figure 8. Precompaction model of transgressive-regressive coal couplet based on a composite of J seam and J conglomerate relationships at Perry Creek and Mt. Spieker, northeastern BC. Some elements of the figure are drawn from a sketch in Leckie and Walker (1982).

drying-up petrographic signature related to the retreat of the Falher F sea (Wadsworth et al., 2003). Middle portions of the seam (J2), in the lower part of J(B), indicate drier conditions, forested conditions and even wildfires (Lamberson et al., 1991). Very clean portions of J seam may represent ombrotrophic, raised mires. An accommodation reversal surface is identified in J(B) seam followed by increasing wetting and eventual drowning of the peat under fresh to brackish conditions. This drowning would correspond to the J2/J1 interseam split and highstand conditions. The J1 ply should have a regressive signature where it overlies Falher D.

SCOPE FOR FURTHER WORK

A line of section (B to B') across Falher C and D shoreline positions suggests another coal split related to the Falher C shoreline, though removed from it laterally (Fig 9). G1 ply separates from lower G plies and migrates to the base of E seam, forming E4 ply. Quintette Coal Ltd. geologists noted "the lower section of both E4 and Gl have a characteristic high ash zone….and…Gl disappears where E4 is identified" (COALFILE 746). Further to the southeast, G conglomerate occupies the interval between G and E4 seams in the Shikano pit and Grizzly areas. The G conglomerate may be a channel complex bordering Falher C. Falher C is recognizable in gamma ray logs of gas wells situated east of Shikano pit.

It is interesting to note in the line of section that G and J1 approach each other in Perry Creek North area. If E4 is a split of G seam then J and E are related in time. Peat formation probably occurred at one place or another during the entire interval of middle Gates Formation deposition. The marine wedges and depositional lobes represent local interludes of clastic deposition. J seam itself formed over one period of transgression but two periods of regression.

CONCLUSIONS

J coal seam is a regressive-transgressive coal couplet. The lower part of the seam corresponds to a shoaling up and general regression of the coastline. J2 includes an accommodation reversal surface and formed during sea level rise. There was coastal incision and deposition of abundant coarse clastics during highstand at a line marked by West Fork – Mt. Spieker and Perry Creek pits. Stacked shoreline facies in a barrier shoal (J conglomerate) mark the southernmost advance of the Falher D sea but marine influence extended further south. After shoreline retreat, peat formation (as J1 ply) extended over thick subsided nearshore deposits. Other coals splits may be related to the Falher C marine tongue.

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Dan McNeil of Western Canada Coal Corp. kindly provided key geophysical logs. David Lilly of the University of Victoria provided cheerful assistance in the field during a program of related mapping. Support by the BC Ministry of Energy, Mines and Petroleum Resources, director Brian Grant and chief geologist Dave Lefebure is gratefully acknowledged.

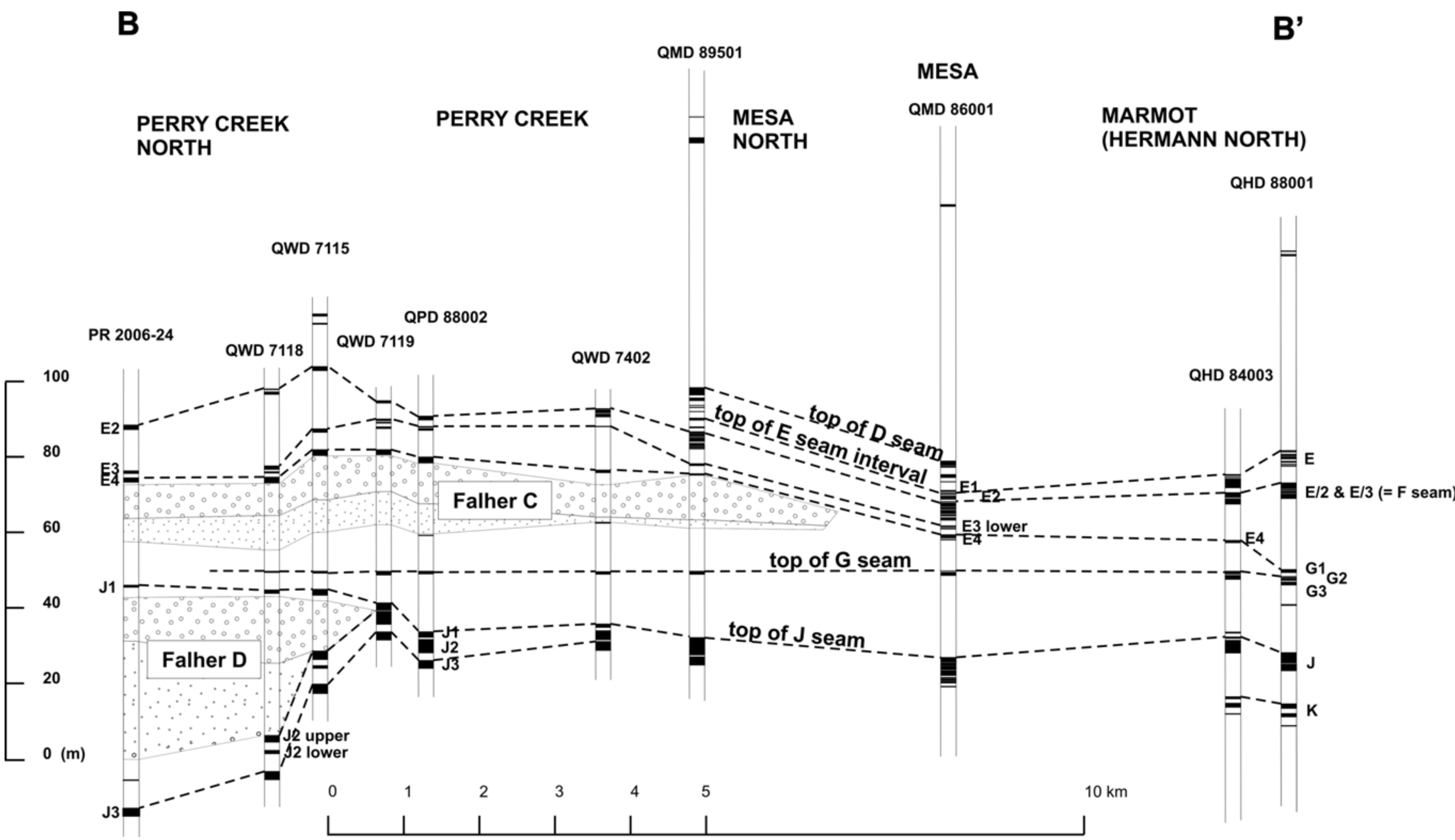

Figure 9. Line of section Perry Creek North pit to Marmot (Hermann North) areas, northeastern BC.

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