GEOLOGICAL SURVEY OF CANADA
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Detailed outcrop measured sections of the Colorado Group in the Foothills of the Calgary region, Alberta, with reference to shale gas potential

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Abstract

In recent years, mudstones of the Colorado Group (and equivalents) have garnered attention as potential reservoirs for shale gas resources. However, the detailed stratigraphy, sedimentology and fracture patterns of most of this clastic wedge are currently not well known, and further geological research would enhance the outlook for potential resource identification and characterization. This report includes measured sections from three outcrops near Calgary and descriptions of the facies present. These facies, and their potential significance, include 1) dark grey laminated mudstone (the most likely potential shale gas reservoir), 2) grey bioturbated mudstone (possible shale gas reservoir), 3) thin siltstone to very fine grained sandstone (potential permeable carrier beds), and 4) ironstone horizons (possible permeability barriers).

Colorado Group Strata in the Calgary Region

In recent years, mudstones of the Colorado Group (and equivalents) have garnered attention as potential reservoirs for shale gas resources (both in shallow, biogenic and deeper thermogenic plays)(see Hamblin, 2006), as well as being long-recognized for their role as significant oil source rocks. These strata are present, in a westward-thickening wedge, over large tracts of the Western Canada Sedimentary Basin (WCSB), attain thicknesses up to 1200 m, have numerous well penetrations, and reside at relatively shallow depths through much of that area. Several discrete intervals within this unit of strata (Fish Scales Formation, Second White Specks Formation, First White Speckled Shale) are particularly organic-rich and prospective (see Bloch et al., 1999, and Hamblin, 2006 for further details and references). However, the entire mudstone package includes shales with elevated Total Organic Carbon, and may have shale gas, or shale oil, prospectivity locally.

An enormous amount of data regarding the organic richness and thermal maturity of the strata within the Colorado/Alberta/Smoky Groups throughout the surface and subsurface of WCSB have been collected. Addressing the Group-level unit as a whole, the GSC Rock-Eval Database includes 1141 samples of Colorado Group (primarily in the Alberta Plains, with some in Saskatchewan) with the following characteristics: TOC up to 11.99%, averaging 1.69%; T_{max} up to 477°, averaging 433°; S_1 up to 4.67, averaging 0.37; S_2 up to 50.04, averaging 2.74; S_3 up to 8.93, averaging 0.84; HI up to 533, averaging 139; OI up to 373, averaging 49 (M. Obermajer, 2006, pers. comm.). Likewise, the GSC Rock-Eval Database includes 155 samples from the Alberta Group (all in the Foothills of Alberta) with the following characteristics: TOC up to 9.34%, averaging 1.09%; T_{max} up to 487°, averaging 458°; S_1 up to 1.52, averaging 0.27; S_2 up to 54.22, averaging 1.93; S_3 up to 1.74, averaging 0.22; HI up to 581, averaging 111; OI up to 82, averaging 21 (M. Obermajer, 2006, pers. comm., see Hamblin, 2006, for further details). These data suggest that the Group as a whole has fair to good background levels of organic carbon, and is mature in the Plains, and mature to overmature in the Foothills.

Whereas the Colorado Group (and equivalents) provides excellent prospects for multiple shale gas(/oil) plays across the WCSB, the detailed stratigraphy, sedimentology and fracture patterns of most of this clastic wedge are currently not well known, and further geological research would enhance the outlook for potential resource identification and characterization. Studies by Leckie et al. (1994), Bloch et al. (1999), Nielsen et al. (2003), and Robinson (2009) have provided a baseline knowledge and understanding of the Colorado shales and their resource potential. In future, additional multidisciplinary studies, at multiple scales, and in both surface and subsurface occurrences, will be crucial in evaluating mudstones of the Colorado Group.

Facies Present in the Outcrops

The three outcrop measured sections included here are located along river courses in the Foothills west and southwest of Calgary (Table 1, Figs. 1, 2, 3 and 4), and are easily-accessible examples of the facies and depositional styles present in the Colorado Group. Due to their location in the Foothills Disturbed Belt, all outcrops show evidence of faulting and fractures. They encompass two short sections of Lower Colorado (Blackstone Formation) strata and one long section of Upper Colorado (Wapiabi Formation) strata. The information is presented as standard measured sections with text descriptions of units. The Colorado Group is typified by grey to dark grey, commonly bioturbated, mudstone to silty mudstone, with numerous thin, sharp-based, siltstone to very fine grained sandstone beds, all arranged into stacked thickening- and coarsening-upward sequences. These facies represent deposition in marine settings, of moderate to shallow depth, primarily below fairweather wave-base (except for the Jumping Pound Sandstone which represents nearshore deposition). Brief descriptions of these facies are included below.

Dark Grey Laminated Mudstone

Present in units up to 20 m thick (generally 1-5 m), especially at the bases of thickening- and coarsening-upward sequences, dark grey to black mudstone is prominent in some portions of the Colorado Group strata. It is typically uniform, organic-rich, and thinly laminated to papery, but may be partially burrowed in places with small, generally horizontal traces. Fractures are common to abundant, and larger-scale thrust faults are commonly localized in this facies. Minor mm-scale horizons of siltstone are common, and within any sequence, silt content, and interbedded siltstone to sandstone beds (described below), commonly increases upward. These mudstones are interpreted to represent deposition in distal, relatively deeper, dysoxic settings below both fairweather and storm wave bases. They represent the most likely shale gas reservoir.

Grey Bioturbated Mudstone

The most common facies in Colorado Group comprises thick units of grey to dark grey, moderately to thoroughly bioturbated, mudstone to silty mudstone to (rarely) sandy siltstone. This lithology constitutes the background deposits throughout much of the Group, and typically forms the dominant sediments in the upper half to two-thirds of thickening- and coarsening-upward sequences, where it is interbedded with thin siltstone to sandstone beds (described below). These rocks may be laminated, to thinly bedded, to more massive (primarily due to bioturbation) in aspect. Burrow traces are typically small and horizontal feeding traces, with some resting traces present. Within coarsening-upward sequences, the mudstones tend to be greyer, siltier, less laminated and more bioturbated upward. Fractures and thrust faults are common. Organic content is not as high as in the dark grey shales, but is still significant. These mudstones are interpreted to represent the primary background shallow marine deposition in

oxygenated settings, below fairweather, but above storm wave-bases. They represent a potential, but lesser quality, shale gas reservoir.

Thin Siltstone to Very Fine Grained Sandstone

The second most common facies of the Colorado Group is present as thin beds of rusty-weathering, calcareous/dolomitic grey siltstone, to sandy siltstone, to very fine to fine grained sandstone, up to 20 cm thick. Coarser grained beds are generally well sorted. These beds generally occur within the thickening- and coarsening-upward sequences where they increase in number and thickness upward. They also represent the dominant lithology of the Jumping Pound Sandstone (Second White Specks equivalent) at the Highwood River section, where burrows, three-dimensional interference ripples, trackways and wood fragments are also present. Within these sequences, the sandstone:mudstone ratio typically ranges from 1:15-20 at the base, to 1:3-5 at the top. Siltstone/sandstone beds have sharp, commonly erosional, bases with burrow casts and sole marks, and sharp to gradational burrowed tops. They are generally fairly to well sorted, and appear to fine upward within the narrow grain sizes present. Thinner examples may be laterally discontinuous. Fractures are common. Moderate bioturbation is ubiquitous. Internal sedimentary structures include horizontal lamination, commonly passing upward into ripple cross lamination, low-angle lamination, uncommon contorted lamination, hummocky cross stratification (near the tops of sequences), and preserved three-dimensional/symmetrical ripple forms or hummock forms on tops of some beds, especially at the tops of sequences. These thin beds of coarser sediment are interpreted as recording rapidly-emplaced, higher energy events (storm or flood events) in the shallow marine to nearshore setting, sourced from clastic input points at the adjacent shoreline. These deposits may provide higher permeability carrier beds for shale gas production. The several metres of thin bedded sandstones of the Jumping Pound Sandstone (Highwood River) are interpreted as nearshore to shoreline deposits.

Rusty Ironstone Horizons

In some intervals of the dark grey to black laminated mudstone facies and in the grey bioturbated mudstone facies, (especially in the Upper Colorado, as exposed at Benchlands, Fig. 2), horizons up to 20 cm thick of small to large, rusty-coloured sideritic concretions are conspicuous. Concretion horizons are typically discontinuous at outcrop scale, consisting of a series of disconnected, 5-50 cm diameter, flattened concretions lying along a single stratal horizon. Individual concretions have fairly sharp boundaries, and usually have vertical fractures. In addition, even in strata without discrete horizons, scattered small concretions may be present. These concretionary horizons are interpreted to represent periods of relative sediment starvation and non-deposition in distal, relatively deeper marine settings.

Paleocurrent Indicators

From the Highwood river and Ware Creek outcrops of Lower Colorado strata, a small data set with a total of 26 directional indicators (ripple cross lamination sets) and

20 trend indicators (4 solemarks, 16 ripple crest trends) were measured (see measured sections), tentatively suggesting sediment transport toward the west below the Jumping Pound Sandstone, and transport to the northeast during deposition of the Jumping Pound Sandstone nearshore-shoreline facies. In isolation, this data is ambiguous.

From the Benchlands outcrop of Upper Colorado strata, a small dataset of 6 directional indicators (ripple cross lamination) and 19 trend indicators (7 solemarks, 12 ripple crest trends) were measured (see measured section), tentatively suggesting sediment transport toward the east.

Acknowledgements

The manuscript was reviewed and improved by Jim Dixon. Elizabeth Macey patiently and professionally drafted the measured sections. Final production of the Open File was handled by Denise Then. Thanks to all of you.

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2. Detailed measured outcrop section of Benchlands.
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4. Detailed measured outcrop section of Ware Creek.

Table 1. Locations of measured sections.

References

Bloch, J.D., Schroder-Adams, C.J., Leckie, D.A., Craig, J., and McIntyre, D.J. 1999. Sedimentology, micropaleontology, geochemistry and hydrocarbon potential of shale from the Cretaceous lower Colorado Group in Western Canada. Geological Survey of Canada, Bulletin 531, 185p.

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Nielsen, K.S., Schroder-Adams, C.J. and Leckie, D.A. 2003. A new stratigraphic framework for the upper Colorado Group (Cretaceous) in southern Alberta and southwestern Saskatchewan, Canada. Bulletin of Canadian Petroleum Geology, v. 51, p. 304-346.

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SECTION	NTS MAP GRID	GPS LOCATION	LAT/LONG
Benchlands	15-5-27-6W5, 82O/7 Wildcat Hills, 528838 (NAD 27)	UTM Zone 11: 652 804E, 5 683 651N	51°17'01.2"N 114°48'31.9"W
Highwood River	16-28-18-3W5, 82J/9 Turner Valley, 881037 (NAD 27)	UTM Zone 11: 687 509E, 5 603 511N	50°33'12.3"N 114°21'10.4"W
Ware Creek	15-27-20-5W5, 82J/10 Mt. Rae, 688223 (NAD 27)	UTM Zone 11: 668 746E, 5 622 548N	50°43'50.2"N 114°36'31.1"W

Table 1. Location of Measured Outcrop Sections.

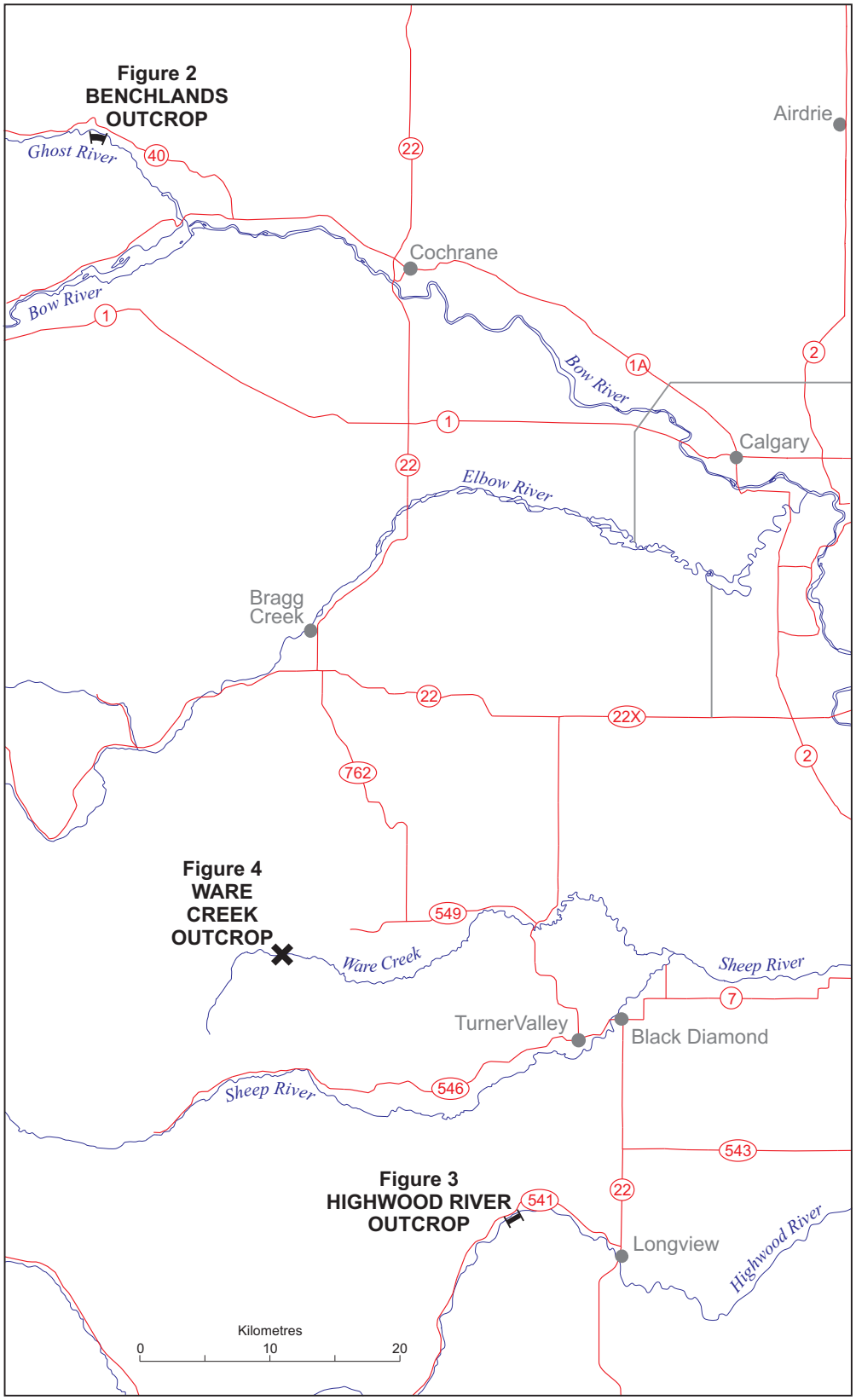

Figure 1. Location map for outcrop sections

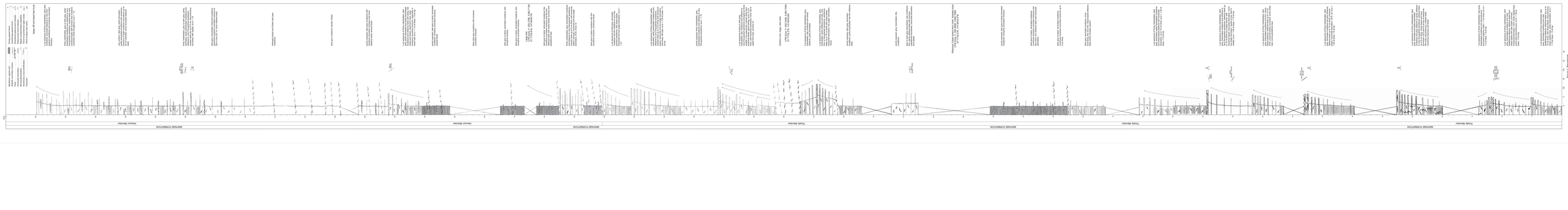
Figure 1 Mechanical Ventilation
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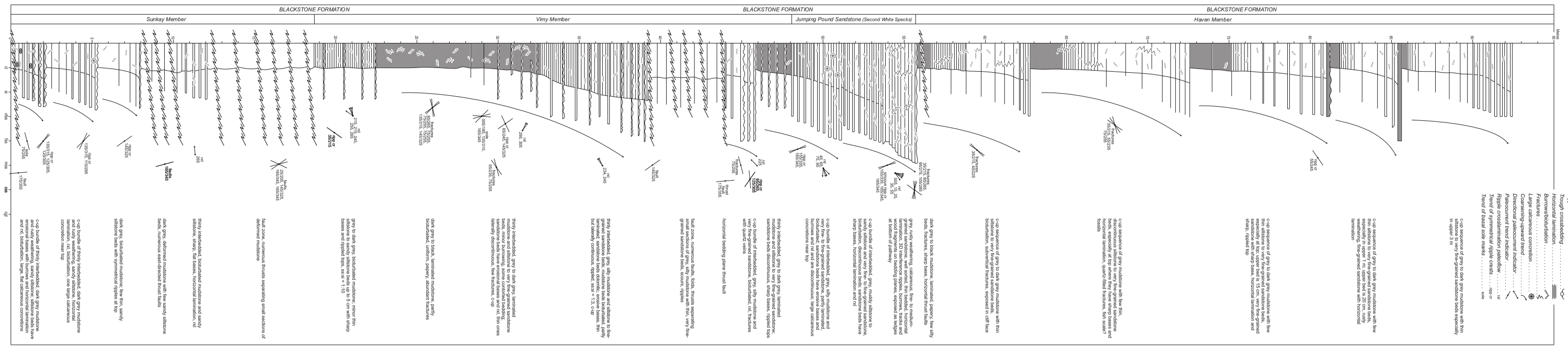
BLACKSTONE FORMATION
Sunkay Member
Vimy Member
Jumping Pound Sandstone (Second White Specks)
Haven Member
Metres
Fault
Ripple c
Trough c
Horizont
Burrows
Fractures
Large ca
Coarsen
Directio
Paleocu
Ripple c
Trend of
Trend of
c-up sequence of grey to dark grey mudstone with thin siltstone to very fine-grained sandstone beds, especially at top; upper bed is 15 cm; very fine-grained sandstone with ripple lamination, horizontal lamination and sharp, rippled top
c-up sequence of grey to dark grey mudstone with few thin siltstone to very fine-grained sandstone beds, especially at top; upper bed is 20 cm; very fine-grained sandstone with ripple lamination, horizontal lamination and weathering; fine-grained sandstone with horizontal lamination
c-up sequence of grey to dark grey mudstone with few thin siltstone to very fine-grained sandstone beds, especially at top; upper bed is 15 cm; very fine-grained sandstone with ripple lamination, horizontal lamination and sharp, rippled top
c-up sequence of grey mudstone with few thin discontinuous siltstone to very fine-grained sandstone beds, especially at top where they have sharp bases and bioturbation, horizontal lamination, quartz veins (fractures), fish (scale?) fossils
c-up sequence of grey to dark grey mudstone with thin siltstone to very fine-grained sandstone beds, especially at top; upper bed is 15 cm; very fine-grained sandstone with ripple lamination, horizontal lamination and bioturbation, subvertical fractures, exposed in cliff face
dark grey to black mudstone, laminated, papery, few silty beds, fractures, sharp bases, horizontal thrust faults
grey, rusty weathering, calcareous, fine- to medium-grained sandstone, 3D interference ripples, burrows, tracks and bioturbation, sharp bases, horizontal lamination, carbonized wood fragments on bedding planes, exposed as ledges at bottom of pathway
c-up bundle of interbedded, dark grey, muddy siltstone to sandy siltstone and very fine- to fine-grained sandstone, bioturbated, sandstone beds have sharp bases, horizontal lamination and ripples
c-up bundle of interbedded, grey, silty mudstone and sandstone beds, sandstone beds have sharp bases, bioturbated, sandstone beds have erosive bases and burrows and rip and are discontinuous, large calcareous concretions near top
thinly interbedded, grey to dark grey, laminated mudstone and siltstone to very fine-grained sandstone; sandstone beds discontinuous, sharp bases, rippled tops
c-up bundle of interbedded, grey, silty mudstone and very fine-grained sandstone, bioturbated, rx, fractures with quartz veins
sandstone beds discontinuous, bioturbated, rx, fractures
horizontal bedding plane thrust fault
dark brown, massive beds, blocky, friable, occasionally small sections of grey, silty mudstone with thin, very fine-grained sandstone beds, scours, ripples
thinly interbedded, grey, silty mudstone and siltstone to fine-grained sandstone, bioturbated, sandstone beds have sharp bases, lenticular sandstone beds, dolomite, erosive bases, thin but laterally continuous, rippled, sca = 1:3, c-up
thinly interbedded, grey to dark grey, laminated mudstone and siltstone to very fine-grained sandstone beds, minor burrowing, some concretion bedding, bioturbated, discontinuous, few fractures, c-up, thin coals
fault zone, numerous thrusts separating small sections of sediment mudstone
thinly interbedded, bioturbated mudstone and sandy siltstone, sharp, flat bases, horizontal lamination, rd
dark grey, bioturbated mudstone with few sandy siltstone beds, numerous sediment-directed thrust faults
dark grey to black, laminated mudstone, partly bioturbated, calcite, papery, abundant fossils
dark grey, bioturbated mudstone, few thin, sandy siltstone beds with symmetrical ripples at top
c-up bundle of thinly interbedded, dark grey mudstone and sandy siltstone, sandy siltstone beds have sharp bases, lamination, rd, bioturbation, one large calcareous concretion near top
c-up bundle of thinly interbedded, dark grey mudstone and sandy weathering, sandy siltstone, siltstone beds have sharp bases, lamination, rd, bioturbation, large, flat calcareous concretions
Blackstone Formation (Sunkay, Vimy, Jumping Pound (SSPK) Members)
Rio Alto Ranch
Rio Alto Ranch
Rio Alto Ranch

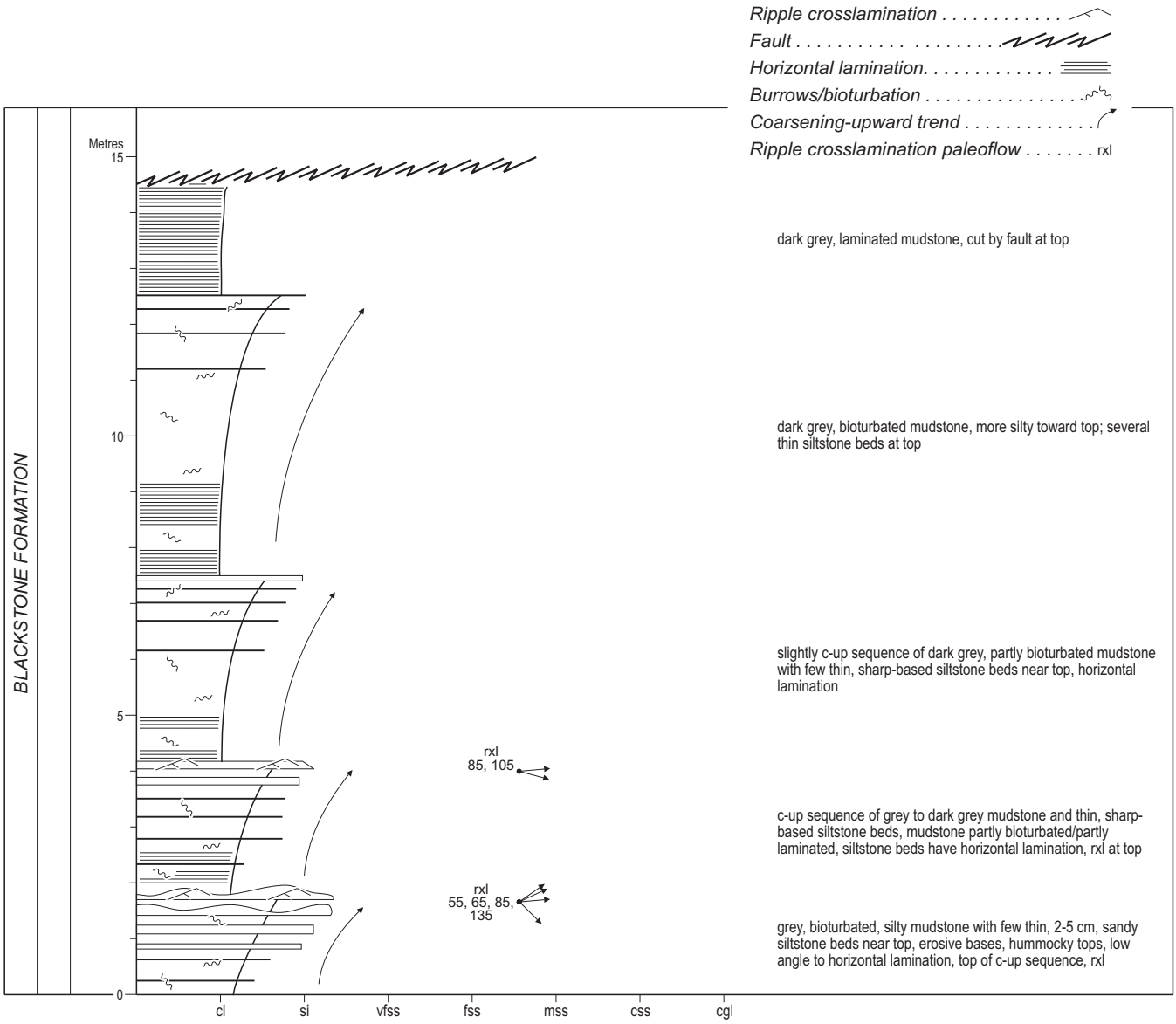

Figure 4. Ware Creek
22 km west of Millarville, off Hwy 549
Blackstone Formation, Lower Colorado Group (beneath Cardium Formation)
82J/10 (Mount Rae); 688223 (NAD27); LSD 15 Sec 27 Tp 20 R5W5
50°43'50.2"N, 114°36'31.1"W; UTM Zone 11: 668 746E, 5 622 548N