FIELD GUIDE TO THE STRUCTURAL GEOLOGY OF THE NORDEGG AREA, ALBERTA

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INTRODUCTION

This field trip visits the Foothills and Front Ranges. Structures encountered can be characterized as folds, thrust faults, normal faults and tear faults (related to lateral ramps). A basal detachment above the Precambrian basement places the rocks in the thin-skinned style of deformation (McMechan and Thompson, 1989). A good overview of the structure of the Nordegg area is given by Jones and Workum (1978). Some of it will be summarized here. Folds are generally concentric and are underlain by detachment zones (generally thrusts), indicating that they are detachment folds as defined by Jamison (1987). Some fault-propagation and fault-bend folding is present as a result of the propagation of thrusts through folds that were detached during earlier stages of faulting.

This view is somewhat different from the one that sees the Rocky Mountains as a series of rigid thrust sheets, without much internal deformation other than fault-bend folding. The latter view is based on the Rich (1934) model of overthrusting and computer simulations such as described by Wilkerson et al. (1991). It is also the basis for fault-bend folding computer models used to characterize the Rocky Mountains by Jones (1987). In contrast, the importance of detachment folding in the deformation of the Rocky Mountains has been previously expressed by Dahlstrom (1970) and more recently by results from centrifuge experiments by Dixon and co-workers (e.g. Dixon and Liu, 1991).

The structure of the area can be described for the six major structural elements: Ancona Thrust sheet, Brazeau Thrust sheet, Bighorn Thrust sheet, McConnell Thrust sheet, Sulfur Mountain Thrust sheet and the Bourgeau Thrust sheet (figures 1 and 2). Some people argue that the Bourgeau Thrust sheet forms part of the Main Ranges, because of the presence of Precambrian strata. A cross section is shown in figure 3, the location of which is shown on figures 1 and 2. A cross section and seismic section through the Nordegg town site between the Stolberg Anticline and the Bighorn Thrust is shown in figure 4.

Ancona Thrust sheet (including Stolberg Anticline)

The Ancona Thrust sheet forms the Outer Foothills in the Nordegg area and includes the Stolberg Anticline, which is probably a Triangle Zone. The Stolberg Gas field is located along the Stolberg Anticline. The Tertiary Saunders coal deposits are situated on the northeast limb of the Stolberg Anticline.

Brazeau Thrust sheet

The Brazeau Thrust sheet forms part of the Inner Foothills and brings some Paleozoic rocks to the surface in the Brazeau Range. It includes the lower Cretaceous coal deposits of the Nordegg Coal field. On a regional scale the dip is rather uniform with a shallow angle to the southwest (see figure 4), but on a

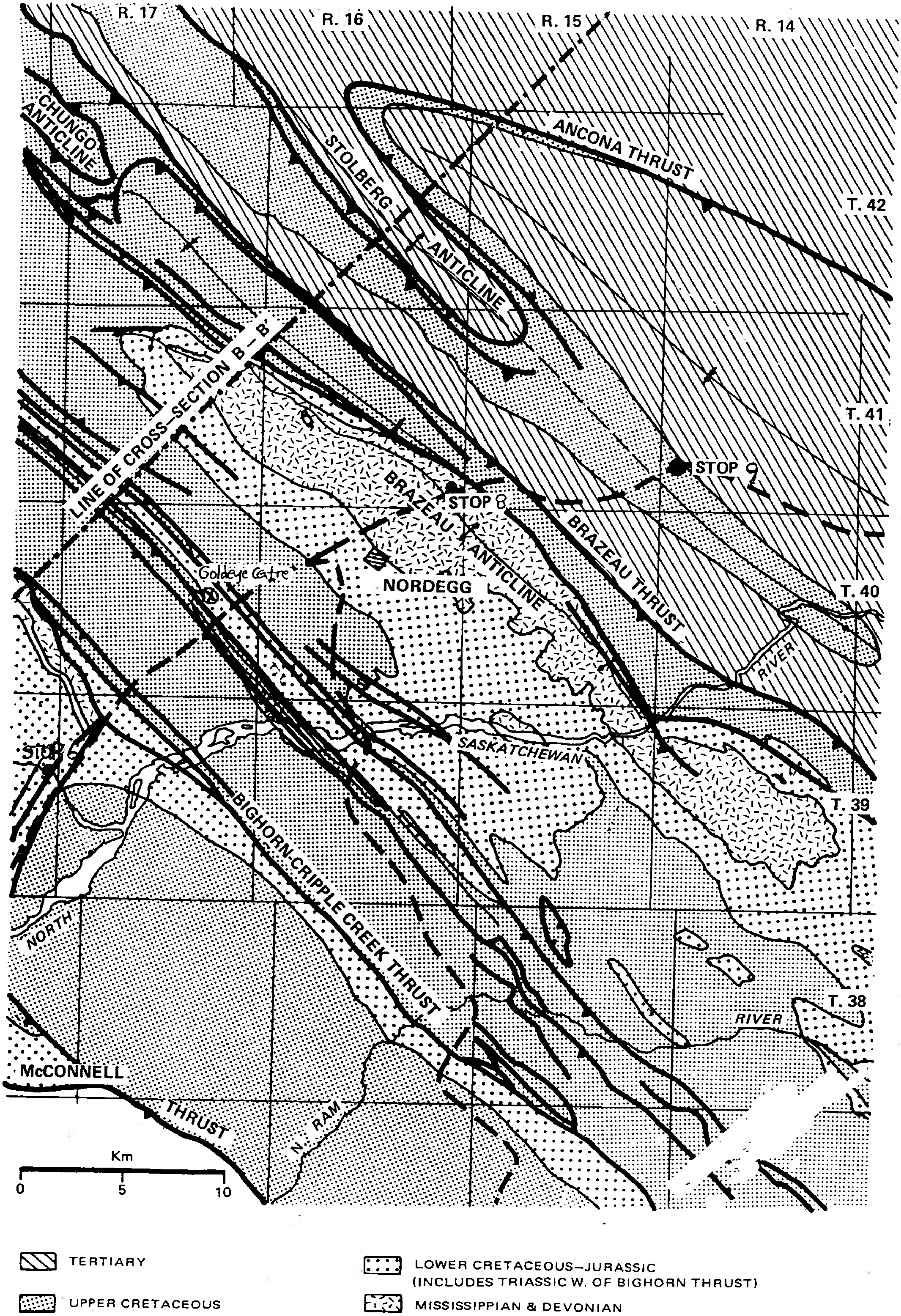

Figure 1. Geological map, Nordegg area, showing route. (After Jones and Workum, 1978)

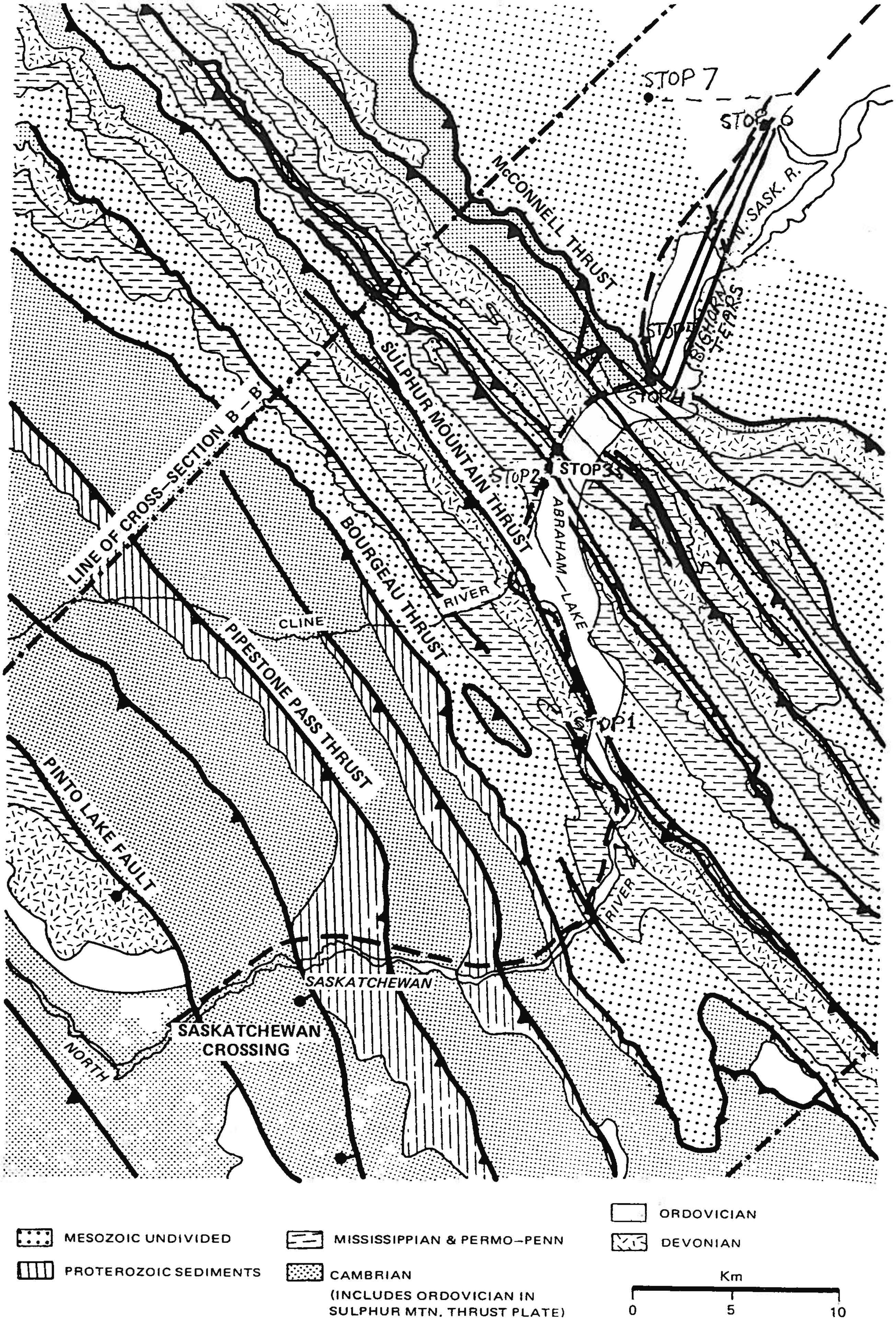

Figure 2. Geological map, Front Ranges and eastern Main Ranges, showing route. (After Jones and Workum, 1978).

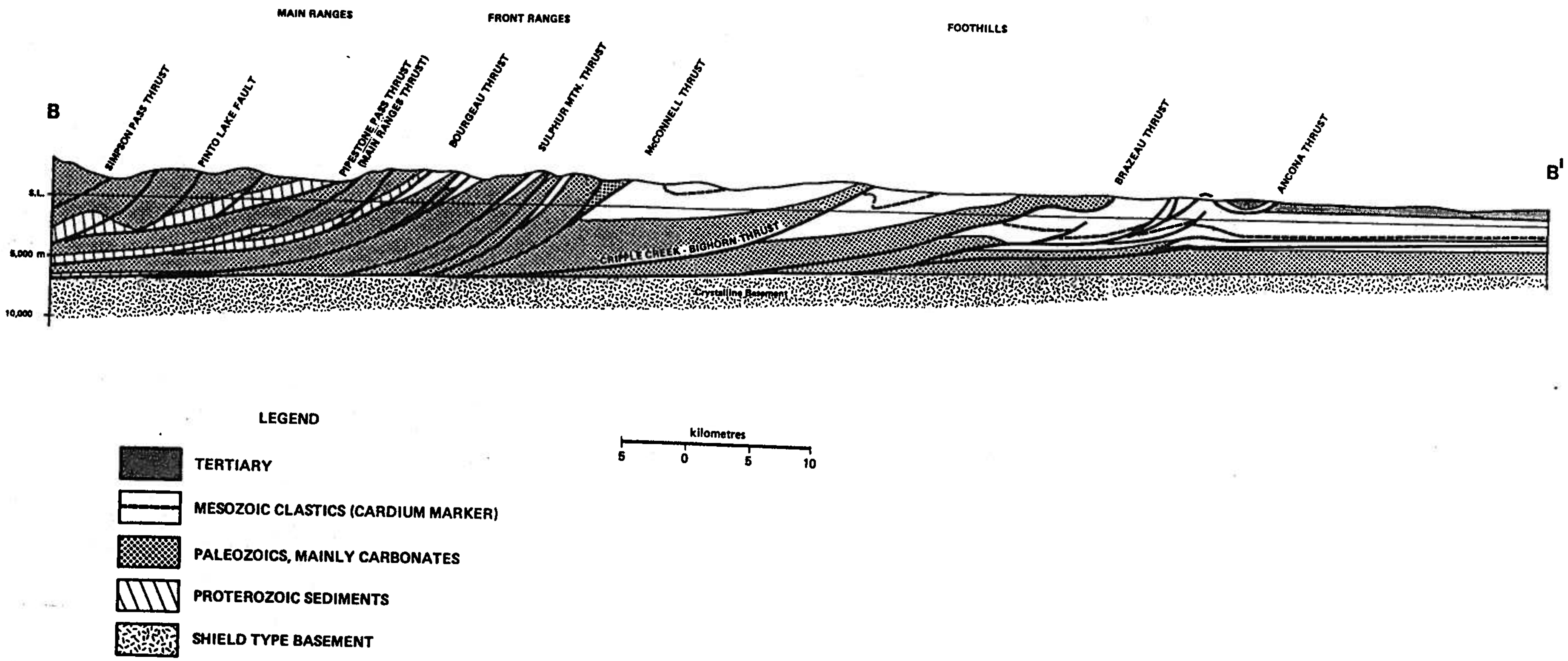

Figure 3. Cross section B-B' trough the Nordegg area (from Jones and Workum, 1978).

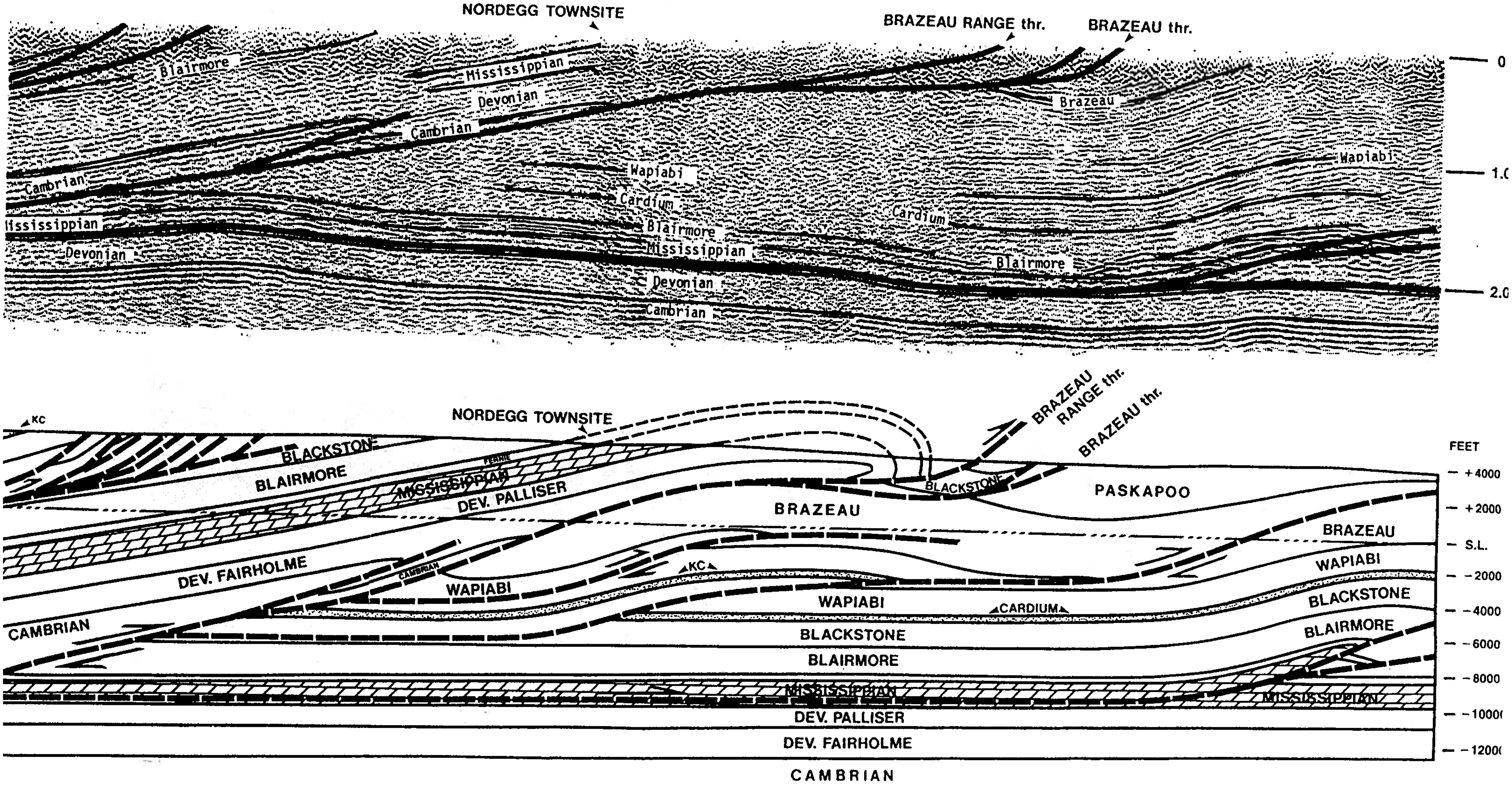

Figure 4. Seismic line and cross section through Nordegg Town site (from Perkins et al., 1984)

detailed scale folding and faulting is present as evidenced by shearing and structural thickening of the coal.

Bighorn Thrust sheet

The Bighorn Thrust sheet also forms part of the Inner Foothills, with Paleozoic rocks outcropping along the Bighorn Range. The lower Cretaceous coals of the Bighorn deposit form part of a syncline-anticline-syncline series with several thrusts (figure 3; see also Douglas, 1956). The Paleozoic carbonates seem to have a more uniform dip.

McConnell Thrust sheet

The McConnell Thrust sheet is the most eastern thrust sheet of the Front Ranges and shows a lot of internal deformation. It is largely composed of Paleozoic rocks, with minor Triassic rocks.

Sulfur Mountain Thrust sheet

This thrust sheet is very similar to the McConnell Thrust sheet. Interesting fold-thrust relationships will be viewed in these rocks.

Bourgeau Thrust sheet

This thrust sheet consists largely of Precambrian and Cambrian sediments and could be considered part of the Main Ranges.

FIELD TRIP STOPS

STOP 1: Fault-Propagation Fold in the Sulfur Mountain Thrust sheet

At 12.5 km South of the David Thompson Resort, at the bottom of the hill, there is a good view of a prominent anticline-syncline pair in Devonian and Mississsippian strata. At the level of the Palliser Formation, the fold is very tight and contains the tip line of a thrust whose displacement increases to the NW, indicating that this fold is a fault-propagation fold.

STOP 2: Folded and thrusted Missssissippian strata

Cambrian strata in the hanging wall of the Sulfur Mountain Thrust crop out at the bridge over the Cline River and the structurally complex McConnell Thrust sheet is entered north of there. Three kilometers North of the resort, anticlinally folded Banff and Rundle strata (Mississippian) are thrust over the Triassic. To the South, the same anticline is cored by Fairholme (Devonian) strata.

STOP 3: Abraham Lake viewpoint and Front Range folding

Devonian and Mississippian strata below the thrust of the previous stop have been thrown in a series of spectacular folds visible both to the SE and NW of this stop (6.7 km North of the resort). These folds owe their existance to the shaly nature of the Fairholme Group, as documented by Beattie (1984).

STOP 4: View of the McConnell Thrust and overlying strata

This stop provides a view across Lake Abraham of the McConnell Thrust underneath the First Range. The prominent peak consists of carbonates of the Palliser Formation.

The Second Range (including Mt. Michener) exposes Cambrian, Palliser and Banff formations. The Palliser formation displays strong folding (partly of similar style). This folding appears to be preferentially present when the underlying Fairholme Group is in the off-reef, shale facies (Beattie, 1984).

STOP 5: Flexural-slip detachment folding in the Gladstone Formation.

This exposure allows a splendid view of deformation in the Mesozoic rocks in the vicinity of the McConnell Thrust, which forms the boundary between foothills and front ranges. A sketch of this cross section is given in figure 5. It shows the style of deformation, with open to close flexural-slip folds and some thrust faulting. Notice the presence of flexural-slip duplexes (Tanner, 1991), hinge collapse of a chevron fold (Ramsay, 1974) and slickensided surfaces. This type of folding has been interpreted as drag folding beneath the McConnell Thrust in the past. However, it can be better described as fold-thrust interaction, whereby early detachment folds and later thrusting are closely related (Dixon and Liu, 1991).

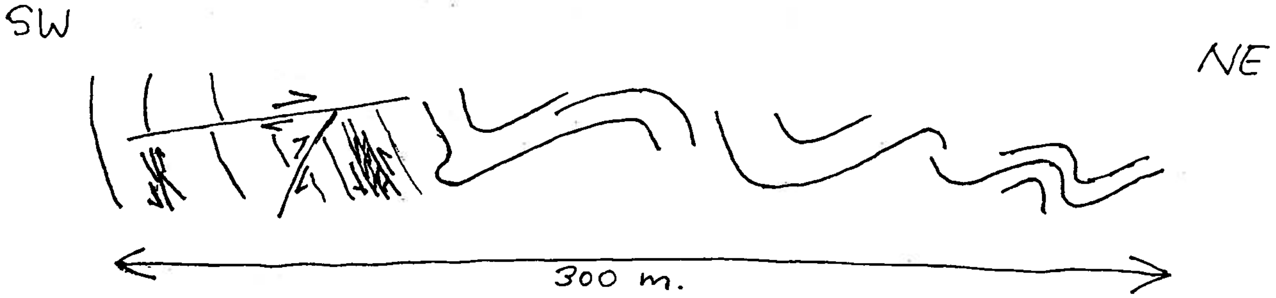

Figure 5. Sketch of outcrop.

STOP 6: Bighorn tear faults and lateral ramp

In the Bighorn Thrust sheet, the Paleozoic strata cropping out in the Bighorn Range NW of the Highway end to the SE against a NE striking fault system, the Bighorn tear faults. These faults are not exposed, however, there presence is further indicated by the presence of the Mountain Park sandstones and lineaments on map and aerial photos.

These faults were interpreted by Douglas (1956) as wrench faults such that displacement along it plus displacement along the Bighorn Thrust SE of the tears was equal to displacement along the Bighorn thrust NW of the tears (see also Dahlstrom, 1970). Another interpretation, that these tears are a surface expression of a lateral ramp in the underlying Bighorn Thrust, which is supported by the difference in depth to the top of the Paleozoic in nearby oil and gas wells on both sides of the fault system. The Paleozoic is at much higher elevation NW of the tears than SE of them.

STOP 7: Gladstone-Moosebar-Torrens section at Crescent Falls

The Crescent Falls section provides a superb exposure of the Gladstone-Moosebar-Torrens interval and has been well described in the literature by Taylor and Walker (1984) and Rosenthal (1988). It is the best and easiest accessible section of the Moosebar Formation in Central Alberta, south of Cadomin-Mountain Park (figure 6.).

Access

Take the walking path to the falls. After 50 m stay left on junction (do not descend to the lower falls) and continue on well marked trail for about 500 m. When the Bighorn river can be seen again, descend to a sandstone ridge, which provides an overview of the lower part of the section. From here one can descend to river level and return along the river to the main falls and examine units 5-8 (figure 6) from close-by.

Description

The measured section is shown in figure 6 and is from Taylor and Walker (1984). Units 1-8 were measured here at the Crescent Falls, units 9-11 were measured about 2.5 km West along the Bighorn River.

Units 1-4

Units 1-4 in the Gladstone Formation are well exposed on both sides of the river, but are difficult to access and will not be examined in detail. The base of the Gladstone (and

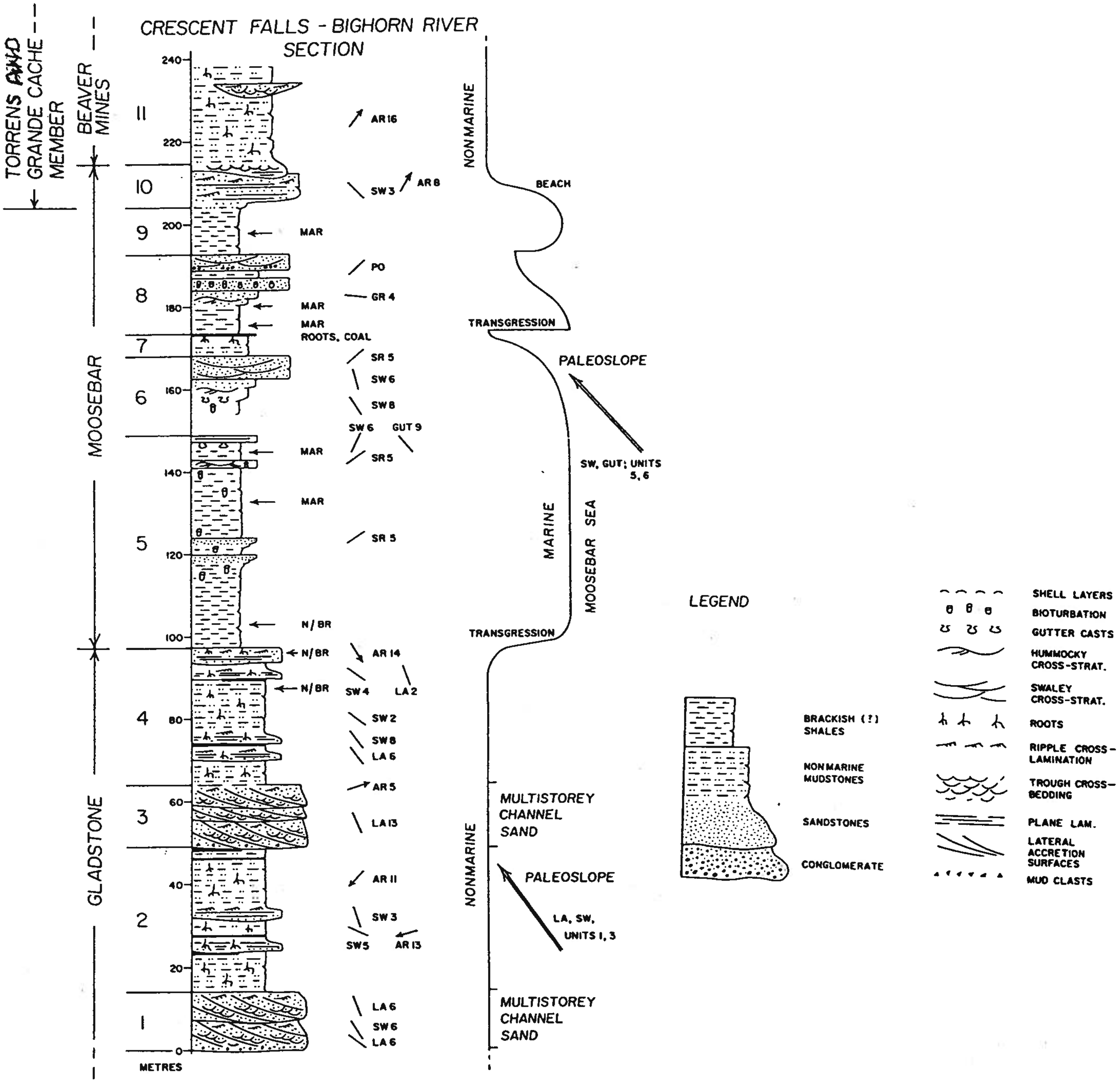

Figure 6. Measured section at Crescent Falls (from Taylor and Walker, 1984).

consequently also the Cadomin conglomerates) are not exposed because of faulting, which repeats the Gladstone. Units 1 and 3 are channel sands, which show excellent lateral accretion surfaces, which can be viewed from the ridge. Units 2 and 4 show (nonmarine) rooted overbank material with minor coals. However, brackish microfossils were found in the upper 10 m of unit 4 (Taylor and Walker, 1984), which might equate this interval to the Bluesky Formation of the subsurface.

Unit 5

The nonmarine Gladstone interval is abruptly overlain by dark grey fissile shales with interbeds of shell hash (coquina of gastropods and other pelecypods) of the Moosebar Formation. The contact is at the lower of the two water falls. At 103 m (near the base of this unit) a brackish fauna, similar to the upper part of unit 4, was found. At 133 m and at 145 m marine ostracods and foraminefera were found (Taylor and Walker, 1984). The sandstone at 142 m is largely bioturbated, but includes a sharp-based hummocky cross-stratified bed, about 1 m thick. Hummocks are 8-16 cm high with wavelength of 1.0 to 1.5 m. The top of the bed has symmetrical ripples 5 cm high with wavelength of 15-20 cm and a spectacular trace fossil assemblage. Trace fossils include *Diplocraterion, Rhizocorallium, Teichichnus, Planolites*, and others. These trace fossils can be viewed extensively on a bedding plane, below the main falls.

The marine shales probably represent quiet deep water. The hummocky cross beds may represent storm wave activity below fair weather wave base. The shell hash may have deposited from storm generated flows.

Unit 6

Unit 6 consists of a coarsening-up succession from mudstones to a prominent 6 m thick sandstone bed. This sandstone is the prominent marker horizon, that ties the lower part of the section to the upper part near the main falls. This sandstone is fine grained and sedimentary structures are not well displayed. It is overlying hummocky cross-stratified beds and shows some swaley cross stratified beds (with swales 20 cm to 1 m deep and up to 10 m in diameter, dips of the cross strata less than 15 degrees, according to Taylor and Walker, 1984). The base is sharp with local scours 30-40 cm deep and 2-3 m wide. The top is also sharp, with symmetrical ripples 3-5 cm high and wavelength of 20-30 cm.

This sandstone bed shows some interesting deformation near the beginning of this section (figure 7). Interaction of folds and faults can be observed (fold-thrust structures). No simple fault-bend or fault-propagation fold model can be used to explain these structures. Folding and faulting seems

Sketch from same outcrop as photograph:

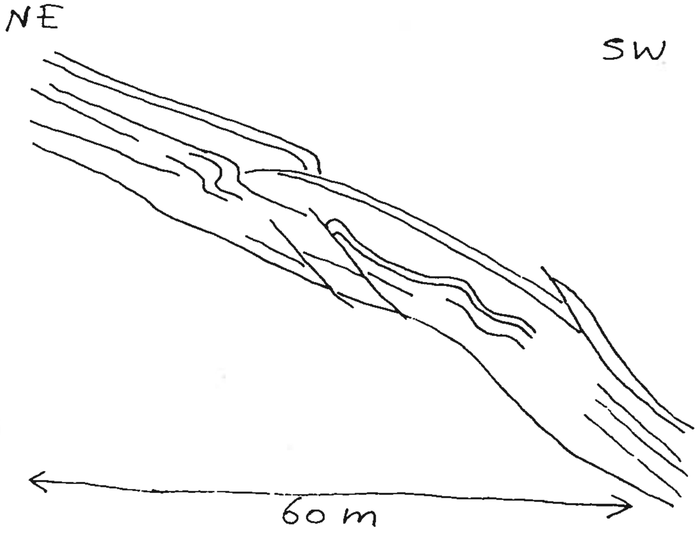

Figure 7. Deformation of Unit 6 sandstone beds. Notice zone of folding in thin bedded sandstone, grading into a fault in massive sandstone at top.

to be roughly contemporaneous and the structures might be described as modified detachment fold (see also Dixon and Liu, 1991).

Units 7-9

The prominent sandstone of unit 6 is sharply overlain by grey shales with plant fragment, which is capped by a thin, high ash coal seam at 173 m from the base. It represents a transition from marine to non-marine environments. The coal is overlain by silty shales of unit 8 with a marine fauna. Unit 8 is capped by two prominent sandstone beds (the twin sandstones). The lower sandstone forms the main water fall and is extensively bioturbated. The upper one shows swaley cross stratification (swales 20-30 cm deep and about 2 m in diameter). The base of the upper sandstone shows a pebble base, which is interpreted by Rosenthal (1988) as a sequence boundary, that record a major lowstand in sealevel, preceding a third major advance of the Clearwater (or Moosebar) sea. The upper sandstone is overlain by sandstones and shales of unit 9. It was not sampled at this location, but a correlative unit 2.5 km upstream yielded a marine fauna.

Unit 10

Unit 10 represents the base of the Torrens Member. It can not be examined at this locality because of difficult access, but 2.5 km upstream it is in a shoreface facies, with suggestions of beach sands. At the upstream locality it is overlain by non-marine sandstones and shales of unit 11 (figure 6).

STOP 8: Jurassic-Cretaceous section in NE limb of Brazeau Anticline

This section is divided in two parts by a covered interval of shales of the Fernie Formation and the lower part of the Nikanassin Formation. The top of the Rundle Group is exposed at the base of this overturned section in the NE limb of the Brazeau Range Anticline and is overlain by thin-bedded cherty carbonates of the Nordegg Member of the Fernie Formation. The top of the Rundle is an important petroleum reservoir (Turner Valley Formation) in the subsurface and this outcrop contains bitumen. The section is cut by several east dipping reverse faults. These faults are probably related to tectonic wedging (similar to a triangle zone) in a general east verging overall structure.

After a covered interval of about 100 m, the section continues with a succession of thin sandstones and shales of the Nikanassin Formation, abruptly overlain by conglomerates of the Cadomin Formation. The Cadomin Formation is about 10 m thick at this locality. The contact with the overlying

Gladstone Formation is gradational. The depositional environment of the lower part of the Gladstone is similar to the Cadomin, with fluvial sandstones deposited by braided rivers. However, the Cadomin is showing a higher energy level, resulting in coarser sediments.

STOP 9: Brazeau Range viewpoint and Stolberg Gas field

This stop is situated close to the axis of the Stolberg Anticline, which is the most easterly structure involving Paleozoic rocks at depth (figures 1 and 3). The Brazeau Range can be viewed from here with the frontal anticline nicely outlined by the carbonates of the Palliser Formation and overlying Banff shales. The NE limb of this fold is overturned. Work by Cruden (1966) shows that this anticline is cylindrical.

The Stolberg Gas field has been described earlier. The discovery well (Triad-BA Stolberg 6-10-42-15W5) is situated about 10 km to the NW. Gas from about 5 wells is treated in the nearby Husky Stolberg Gas dehydration facility. The existing gas line infrastructure may make coal-bed methane production from the near-surface Coalspur Formation coals feasible. The lower Cretaceous coals of the Gates Formation are at about 3 km depth, which is probably too deep for economic recovery of coal gas.

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