# GEOLOGY, COAL MINING AND COAL-BED METHANE POTENTIAL OF THE NORDEGG AREA, ALBERTA

**Leaders: Willem Langenberg and Rick Richardson**

**Alberta Geological Survey**
**Alberta Research Council**

**THIRTY-THIRD ANNUAL FIELD TRIP**

**EDMONTON GEOLOGICAL SOCIETY**

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## PREFACE

This is the second Edmonton Geological Society field trip to the Nordegg area. The 7th annual EGS field trip was organized in 1965 shortly after the David Thompson Highway was extended into Banff National Park. That trip concentrated on the geology of the Front and Main Ranges, which are largely comprised of Paleozoic rocks. The present field trip will concentrate more on the Foothills and consequently on Mesozoic rocks, and explain the economically important occurances of coal and gas. It will also discuss the history of coal mining, which has recently added to the tourist appeal of the Nordegg area.

We hope you will enjoy the field trip and that it will stimulate you into further geological explorations of the Nordegg area. Enjoy!

## ACKNOWLEDGEMENTS

Craig Siemens and Rudy Strobl are thanked for helping with the logistics. The Alberta Geological Survey, Alberta Research Council is thanked for providing transportation and facilities for the production of the guide book. Gail Mazza of the Nordegg Historic Heritage Interest Group is thanked for coordinating the tour of the Nordegg mine site.

CONTENTS

## INTRODUCTION

The objective of this field trip is to examine the geology of the Nordegg area of central Alberta. Participants will have an opportunity to observe at first hand the lithology and complex structural relationships of the rock succession. Examples of deposition related to deep marine, shallow marine, coastal plain, swamp, alluvial flood plain and alluvial channel environments will be observed and the evidence for this interpretation will be discussed. The structure of the area will be explained with some excellent exposures and accompanying cross sections.

The Nordegg area is situated in west-central Alberta (figure 1) and forms part of the Nordegg (83C/8), Saunders (83B/5) and Harlech (83B12) 1: 50 000 mapsheets.

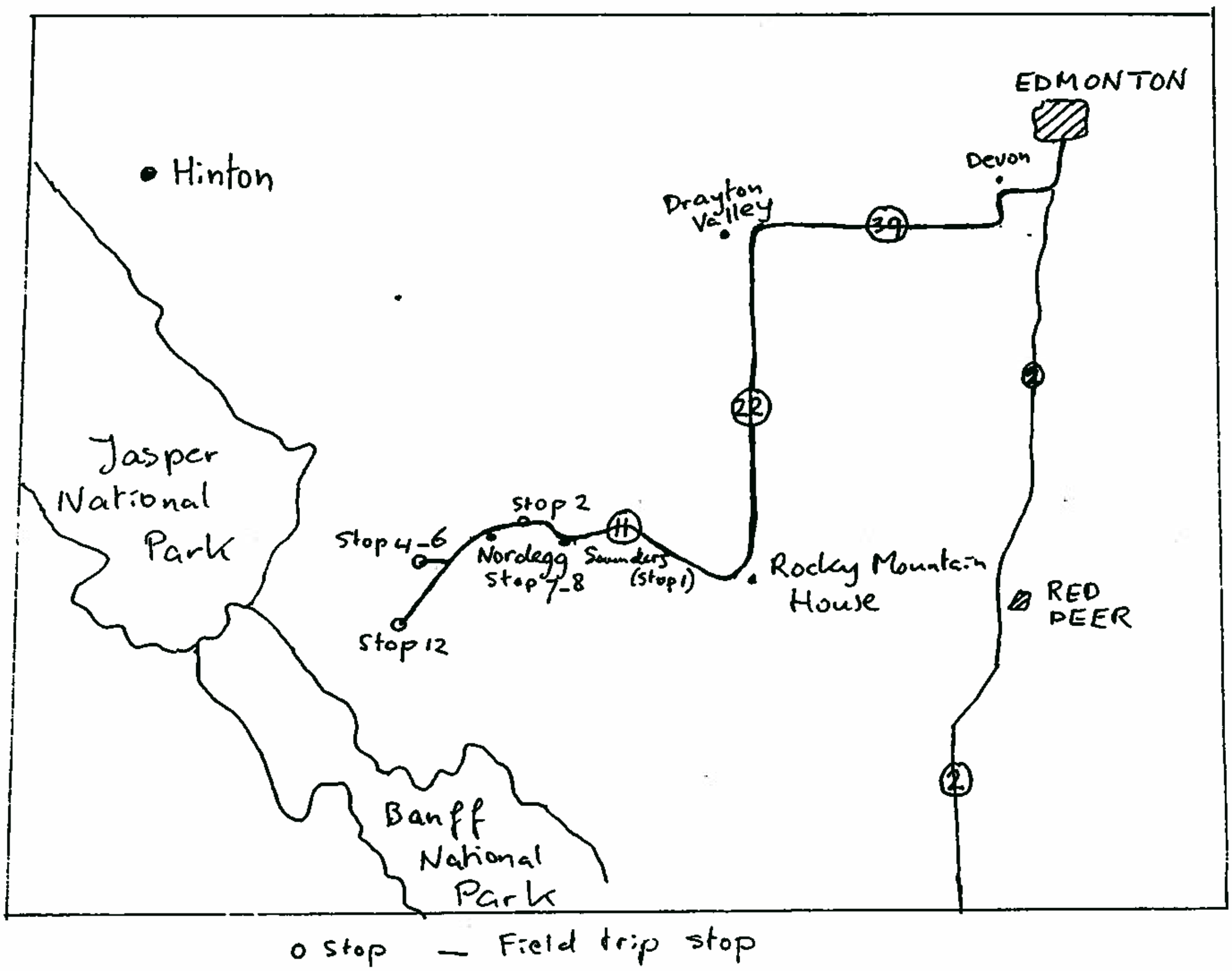



Figure 1. Field trip route and major stops.

Coal seams were discovered in 1906 in the Bighorn River area by Dowling of the Geological Survey of Canada and subsequently staked by Martin Nordegg. Coal was discovered near the present town of Nordegg in 1911 by an exploration crew sent by Martin Nordegg (Green, 1958). By 1914 the coal mine and the town of Nordegg were established and between 1914 and 1955 about 20 million tons of coal were produced. Production problems were encountered in the 1920's because of the large percentage of fine particles in the often highly sheared coal of the Nordegg area. Experimental work was performed by the Alberta Research Council (ARC) on the bricketting of coal (Stansfield and Lang, 1928). Additional confidential ARC reports helped convince Brazeau Collieries to establish a briquetting plant in 1936 (Lang, 1950; Green, 1958). This is an early example of successful technology transfer from the Alberta Research Council to the private sector.

The first oil exploration well in the area was drilled between 1937 and 1940 (Home Brazeau #1 16-7-43-17W5), but was abondonned after negative test results. At present the Stolberg gas field is well established with pipe lines and a gas plant in place.

After early geological explorations by the Geological Survey of Canada (Dowling, 1914), the Nordegg coal field was mapped by the Alberta Geological Survey (Allan and Rutherford, 1923). The Nordegg (83C/8) mapsheet was mapped by the GSC (Douglas, 1956). Guidebooks of CSPG field trips give additional information on the geology of the Nordegg area (Jones and Workum, 1978; Perkins et al., 1984).

## STRATIGRAPHY

Rocks of the Foothills in the Nordegg area comprise a sequence of an about 7500 m thick succession of carbonates and clastics, consisting of 1200 m of competent Paleozoic carbonates and shales and 6300 m of less competent Mesozoic and Cenozoic clastic rocks. The Paleozoic rock units will only be discussed briefly, because the emphasis is on Mesozoic rocks. A more complete discussion is provided by Jones and Workum (1978).

### CAMBRIAN

Cambrian carbonates are present in the First Range of the Front Ranges above the McConnell Thrust at Windy Point.

### DEVONIAN

The Devonian is divided into two major units, the Fairholme Group and the overlying Palliser Formation. The Alexo Formation is a thin intermediate unit. In the Fairholme Group a reef/platform facies (with many different formation names such as Southesk and Cairn in outcrop and Leduc and Cooking Lake in the subsurface) and off-reef facies (Mt. Hawk and Perdrix in outcrop, Ireton and Duvernay in subsurface) can be distinguished. In addition, other units such as the Nisku Formation are present in the Fairholme Group.

The Palliser Formation consists of a competent succession of carbonates.

**CARBONIFEROUS**

The Carboniferous consists of shales of the Banff Formation and carbonates of the Rundle Group. The Rundle Group comprises in ascending order the Pekisko, Shunda, Turner Valley and Mount Head formations.

**TRIASSIC**

Siltstones and shales of the Spray River Group are exposed on the Bighorn Range and further west in the Front Ranges.

**JURASSIC**

Two units are recognized in the Jurassic of the Nordegg area, the Fernie Formation and overlying Nikanassin Formation. The Fernie consists of basal cherty limestones (Nordegg Member) and overlying, poorly exposed, dark marine shales. The Nikanassin consists of marine and non-marine sandstones and shales.

**CRETACEOUS**

The largely Albian Luscar Group consists of the Cadomin, Gladstone, Moosebar and Gates formations (Langenberg and McMechan, 1983). This group, which is equivalent to the Mannville Group of central Alberta (figure 2), shows both marine and non-marine sedimentary environments.

**Cadomin Formation**

The Cadomin Formation was deposited in alluvial fans and on braided river pediment plains with chert pebble conglomerates, and is unconformably overlying the Nikanassin Formation. Much of the Cadomin that developed in the west as alluvial fans was transported and reworked into the northwest trending Spirit River channel that developed parallel to the mountain front during the early Aptian. The Cadomin likely represents a major drop in sea level and a major sequence boundary. The Cadomin Formation is an excellent marker horizon, both at the surface and in the subsurface.

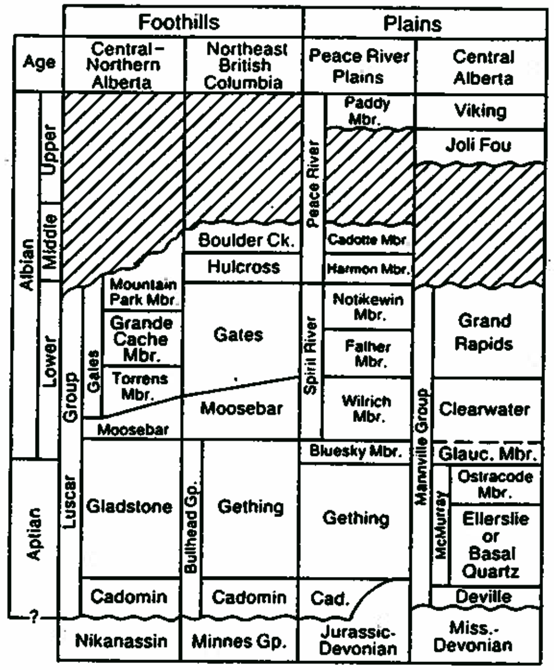



Figure 2. Stratigraphic nomenclature of the Luscar Group.

## Gladstone Formation

The Lower Cretaceous (Aptian-Albian) Gladstone Formation is equivalent to the coal-bearing Gething Formation in northeastern British Columbia and the oilsands-bearing McMurray Formation in northeastern Alberta. The formation lies conformably on the Cadomin with no apparent major stratigraphic break. The section at Cadomin shows a transition from well drained alluvial plain deposits with thin coals near the base, to coastal plain deposits with thicker coals near the top.

## Moosebar Formation

Several marine cycles can be recognized in the Albian Moosebar/lower Gates succession (Macdonald et al., 1988). The fully marine succession includes offshore to lower shoreface (with storm deposits) and shoreface to foreshore (and possibly beach). The Moosebar to Gates transition of the Nordegg area has been described from the Crescent Falls section by Taylor and Walker (1984) and Rosenthal (1988).

The lower Moosebar Formation consists of a series of fine-grained mudstones interbedded with sharp based siltstones and thin sandstones. It is interpreted to have formed in an offshore environment in which storm events periodically deposited thin sand units.

In the upper Moosebar more sandstones (often with hummocky cross stratification) are found. The hummocky cross stratification supports the storm deposited origin and has been found in other locations of the Moosebar to Gates transition. A glauconitic, sharp based pebble conglomerate bed is found in the upper Moosebar and is interpreted as an offshore transgressive deposit. It may in part represent very slow deposition of a condensed section. The boundary between Moosebar and Gates is gradational in a coursening-up succession.

**Gates Formation**

The Albian Gates Formation consists of the Torrens, Grande Cache and Mountain Park members. Both shallow marine and non-marine sedimentary environments are deduced for this formation.

**Torrens Member**

The offshore/transgressive deposits of the Moosebar give way upsection to lower shoreface and finally foreshore sediments of the Torrens Member. The trace fossil assemblage is consistent with this interpretation.

The Torrens member consists of massive (though occasionally thinly bedded), fine to very fine grained sandstone. Faint parallel laminations are the predominant structures, with some trough cross bedding and hummocky cross stratification also present. Scour surfaces, with pebble lag deposits, are also common in the unit. Mudstone is a very minor lithology in this cycle and is usually associated with the hummocky cross stratification. Trace fossils may be present. The Torrens is interpreted to be a succession of prograding shorelines sequences, with upper shoreface to foreshore environment transitions being present.

**Grande Cache member**

The base of the Grande Cache Member is often a thick coal seam (for example the 10 m thick Jewel seam in the Cadomin area), which may represent a major drop in relative sea level. It is probable that some of the coal seams of the Nordegg area are in an equivalent stratigraphic position as the Jewel seam of the Cadomin area, but more work is needed to establish this relationship.

The low-lying Okefenokee Swamp, which is some distance from active shoreline processes, is a modern day model for these Cretaceous coals. From maceral data it can be shown that these peats were dominantly planar, low-lying and were formed under seasonable wet (relatively dry) conditions.

The lower part of the Grande Cache Member is often brackish until the first major fluvial sandstones are encountered. A brackish water interpretation is based on the presence of trace fossils and the presence of lenticular bedding throughout this interval. Specimens of the siliceous foraminifera *Hippocrepina (?) sp.*, *Miliammina (?) sp.* and *Saccammina sp.* have been recovered from three locations above the Jewel seam in the Cadomin area and are indicative of a shallow brackish (not normal marine) marine environment (John Wall, pers. comm.).

The upper part of the Grande Cache member is largely non-marine and contains fining-upward sequences. Major coal seams may be present.

**Mountain Park Member**

The base of the Mountain Park Member is generally defined at the base the first major greenish colored sandstone encountered going upsection from the major coal seams. These sandstones are interpreted to be large scale fluvial deposits and may occur at various stratigraphic levels, making this field mapping criteria somewhat arbitrary.if only limited exposure is available.

The contact between the Mountain Park Member and the overlying dark grey shales of the Blackstone Formation (Shaftesbury) is generally sharp.

**Blackstone Formation**

The Blackstone Formation is characterized by dark marine shales. The base of the formation usually contains a thin transgressive pebble lag deposit. Thin upward-coarsening cycles are occasionally seen in the lower part of the Blackstone Formation. The Blackstone transgression is related to the accretion of terranes during the Columbian Orogeny and the onset represents a sequence boundary.

**Cardium Formation**

The Cardium Formation consists of approximately 100 m of competent sandstone and some interbedded shales. The lower sandstone unit (the Ram Member) is the most continuous and is the Cardium sand of subsurface geologists. Much recent work on the Cardium has been done by Roger Walker and his students (e.g. Plint et al., 1988).

**Wapiabi Formation**

The Wapiabi consists of dark marine shales overlying the Cardium. At the top there is a marine sandstone of about 30m thickness (Chungo Member), that can be mapped in both surface and subsurface. This member has trace fossils and bedforms characteristic of its marine origin.

### Brazeau Formation

The Brazeau Formation consists of fluvial sandstones, shales and some coal seams above the marine shales of the Wabiabi Formation and below the basal Entrance Conglomerate of the Coalspur Formation. Some exploration for coal has been done in this formation in the Cadomin and Coalspur areas.

## CRETACEOUS/TERTIARY

### Coalspur Formation

The Coalspur Formation contains a thick continental succession of interbedded sandstones, mudstones and thick economic coal seams. The base of the Coalspur Formation is the so-called Entrance Conglomerate. Thick coal seams interbedded with coaly shales and numerous bentonites occur in the upper part of the formation. This interval is known as the Coalspur coal zone. The Cretaceous-Tertiary boundary is at the base of the Mynheer coal seam in the Coalspur area. The precise location of the Cretaceous-Tertiary boundary in the Nordegg area is unknown, but in analogy with the Coalspur area it seems likely that the thick coal seams near Saunders are Tertiary. The Coalspur Formation represents a nonmarine, fluvially dominated environment of deposition.

## TERTIARY

### Paskapoo Formation

The Paskapoo Formation consists of thick alluvial sandstones and mudstones above the uppermost thick coal seam of the Coalspur Formation.

## STRUCTURAL GEOLOGY

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 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 everywhere 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, in press).

The structure of the area can be described for the four major structural elements: Ancona Thrust sheet, Brazeau Thrust sheet, Bighorn Thrust sheet and McConnell Thrust sheet (figures 3 and 4). A cross section is shown in figure 5, the location of which is shown on figures 3 and 4. A cross section and seismic section through the Nordegg town site between the Stolberg Anticline and the Bighorn Thrust is shown in figure 6.

**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 east 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 6), but on a 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 5; see also Douglas, 1956). The Paleozoic carbonates seem to have a more uniform dip.

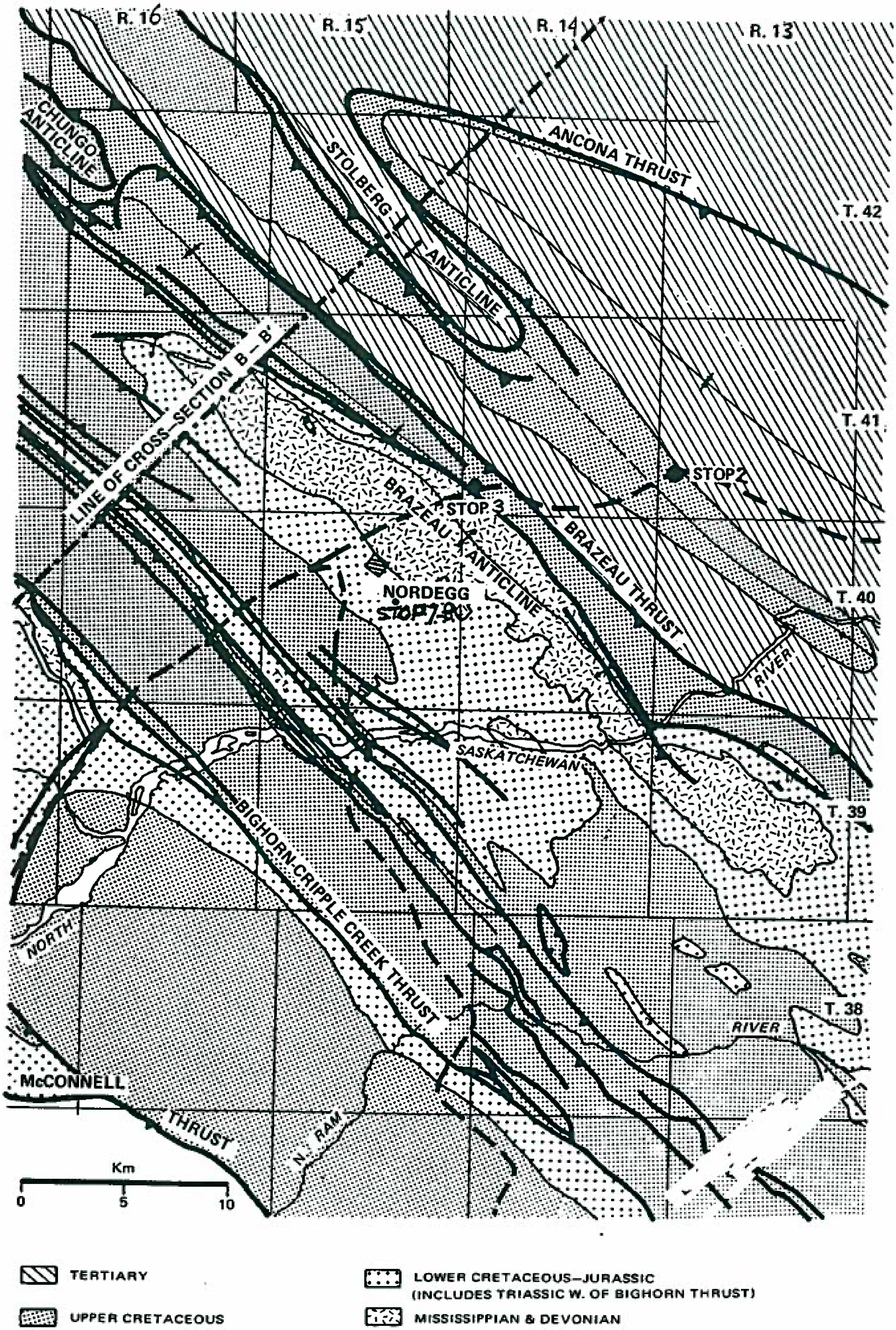



Figure 3. Geological map, Nordegg area, showing route (After Jones and Workum, 1978)

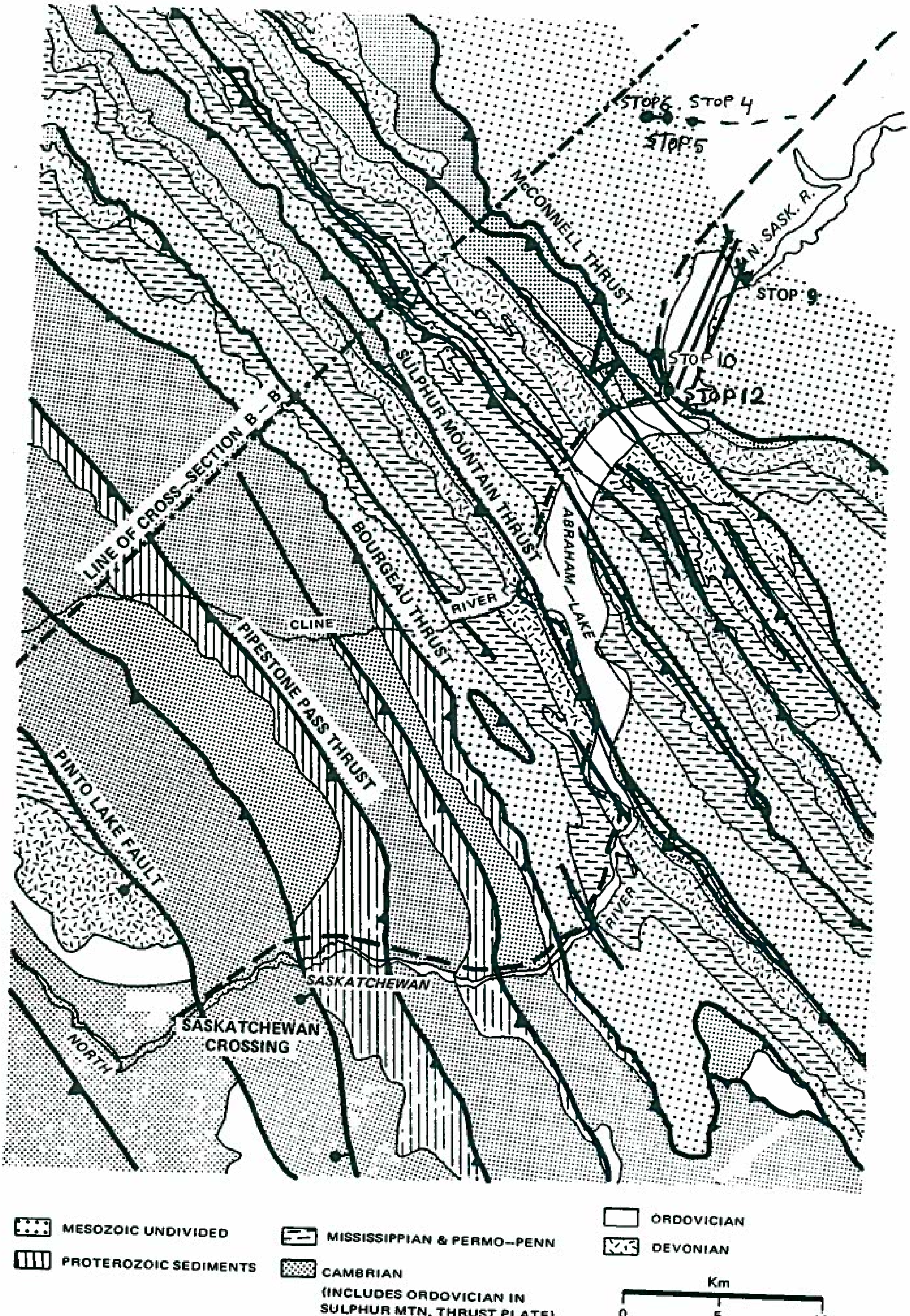



Figure 4.. Geological map, Front Ranges and eastern Main Ranges, showing route. (After Jones and Workum, 1978).

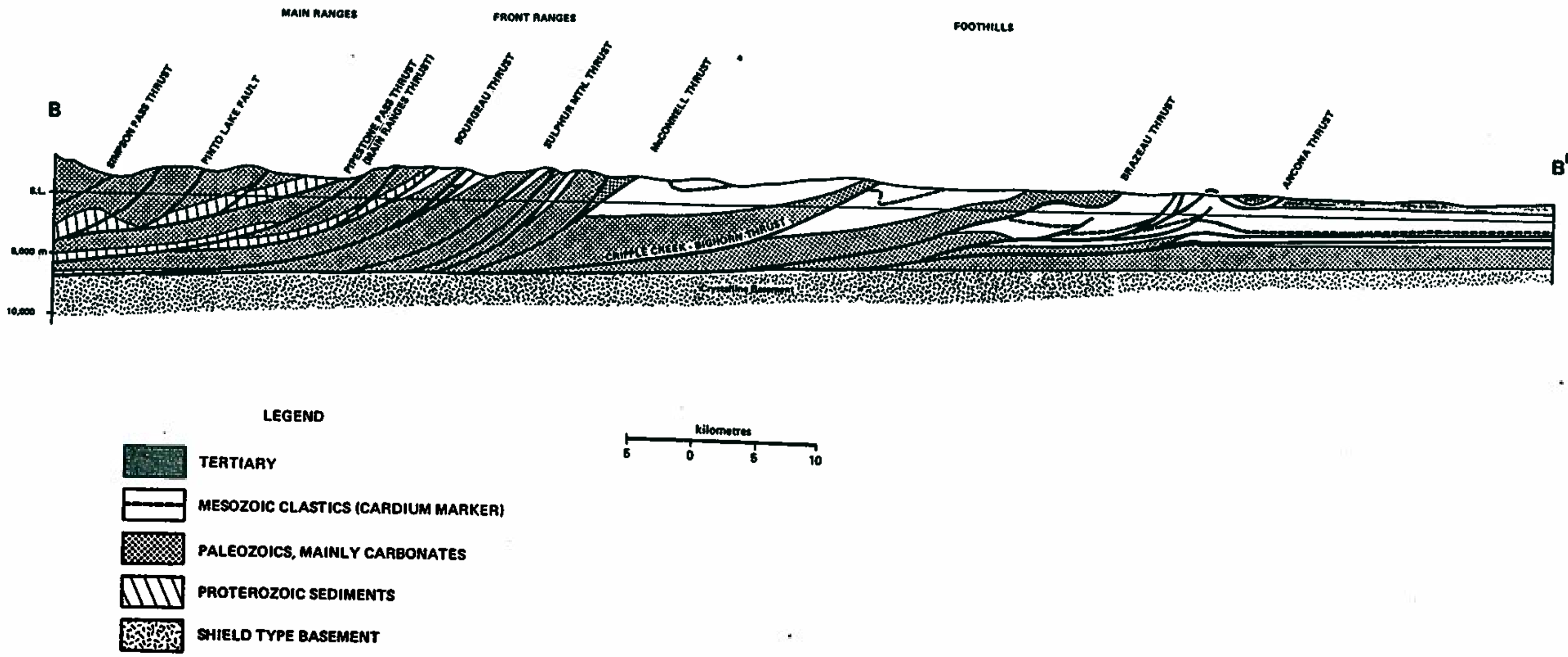



Figure 5. Cross section B-B' trough the Nordegg area (from Jones and Workum, 1978).

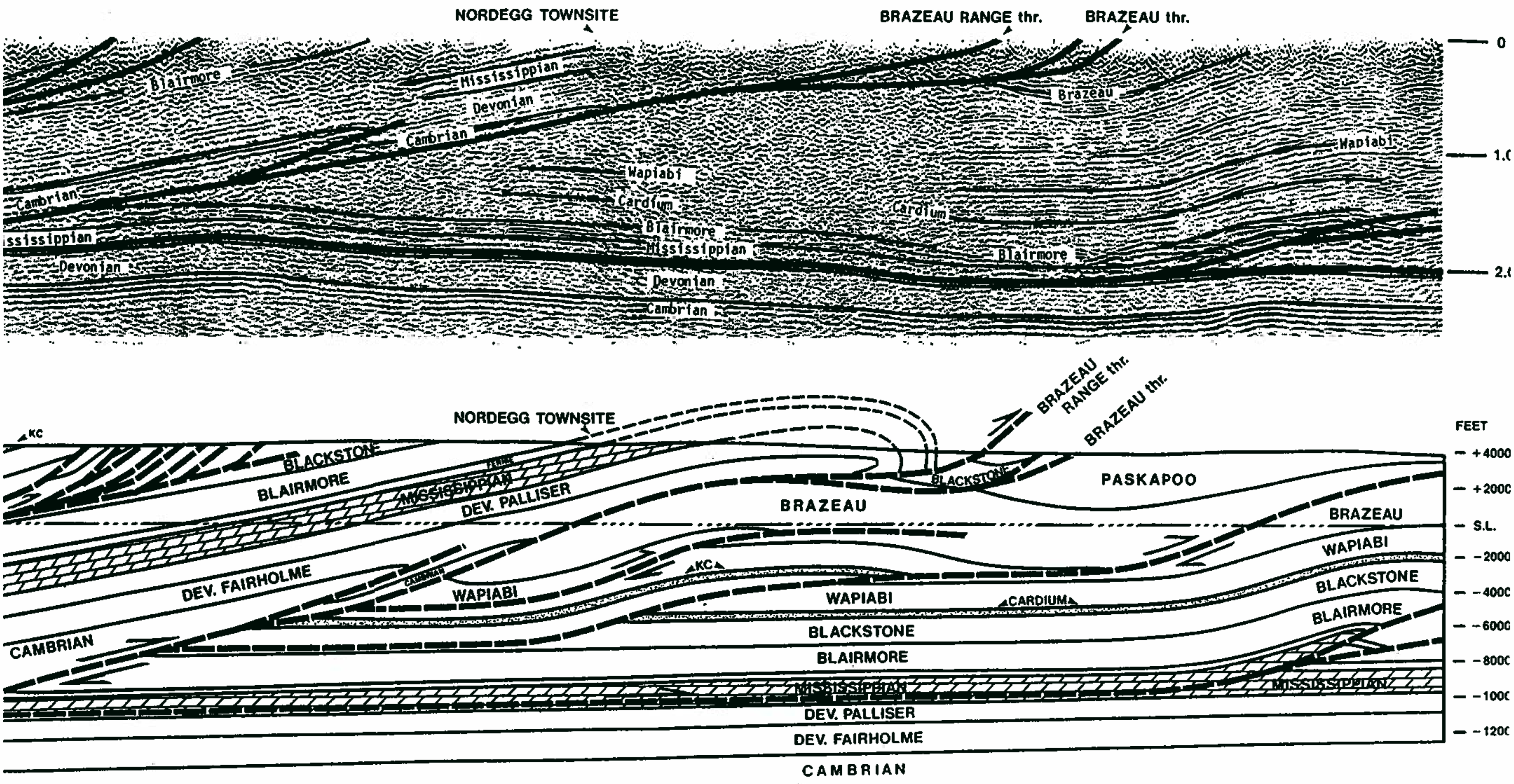



Figure 6. Seismic line and cross section through Nordegg Town site (from Perkins et al., 1984)

**McConnell Thrust sheet.**

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

## COAL DEPOSITS

Three areas with economically important coal deposits will be visited: the Saunders Coal deposits, the Nordegg Coal field and the Bighorn Falls Coal deposit (ERCB, 1989)

### SAUNDERS COAL DEPOSITS

The Saunders Creek Mine near Saunders operated from 1913 to 1952 and produced from Coalspur Formation (probably Tertiary) coals. The Alexo Coal Mine in nearby Alexo operated in approximately the same time. The Jack Fish Lake Mine near Jack Fish Lake was abandoned in 1941.The Saunders Creek deposit is situated about 1.6 km northeast of the crest of the Stolberg Anticline and the strata dip from 5 to 20 degrees The rank of the coal is high volatile C bituminous (Erdman, 1950).

### NORDEGG COAL FIELD

The coals of the Nordegg Coal field belong to The Grande Cache Member of the Gates Formation of the Luscar Group. An exploration report by Consol mentions 7 coal seams (Consol, unpublished report). Green (1958) mentions 5 coal seams, which were reported by Dowling (1914). Two seams were mined by Brazeau Collieries: i.e. the No.2 and No.3 seam (see cross section of figure 7). Seam 2 has an average thickness of 2.4 m and Seam 3 an average thickness of 3.4 m. The rank of the coal is low volatile bituminous (W. Kalkreuth, pers.comm. and Stewart, 1917).

### BIGHORN FALLS DEPOSIT

Thick coals can be seen in outcrop and are reported from drilling by Consol in strata stratigraphically above the Torrens Member of the Crescent Falls section. The rank of these coals is medium volatile bituminous (W. Kalkreuth, pers.comm.).

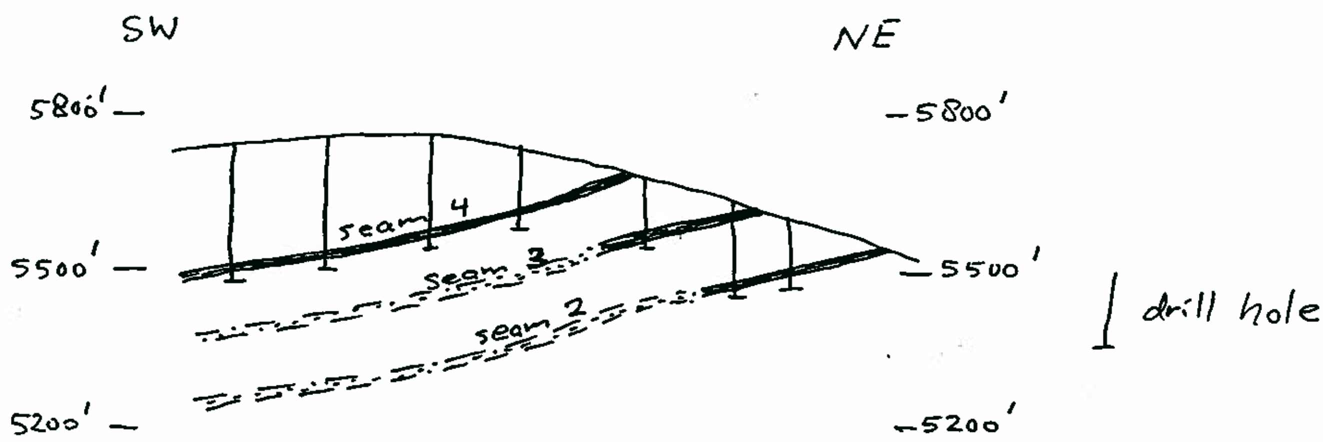



Figure 7. Cross section through Nordegg Coal field, 750m southeast of the No 12 level entrance (Consol report, unpublished).

## GAS FIELDS

Two gas fields are present in the Nordegg area, the Stolberg and Nordegg gas fields.

### Stolberg gas field

This gas field is producing from the Carboniferous in up to five thrust slices in the Paleozoic. This is the most eastern structure bringing the Paleozoic above regional elevation. The surface expression of these structures is the Stolberg Anticline, which is probably a triangle zone (see Mc Mechan and Thompson, 1989). This surface structure is exposed along Shunda and Colt creeks (Douglas, 1958) and was drilled in 1945 (Stolberg No.1 3-22-41-14W5, about 4 km north of the highway). This well defined the deeper strucure. Gas was encountered at the top of the Gates Formation, but the Carboniferous was tight. The discovery well was drilled in 1958 (Triad-BA Stolberg 6-10-42-15W5, about 10 km NW of the Highway) and gave good gas production from the Mississippian. In May 1980 5 wells went into production, with reserves of about 500 BCF. The gas is treated at the Husky Stolberg Gas Plant.

### Nordegg gas field

The Nordegg gas field is situated in the Brazeau Range Thrust sheet northwest of Nordegg, near Wapiabi and Sturrock creeks (TP41-R16,17). Gas reserves are both in the Carboniferous (Turner Valley Formation) and the Triassic. In 1980 this gas was still shut-in.

## COAL-BED METHANE POTENTIAL

The three economically important coal deposits (described above) extend into the subsurface where conditions are suitable for the production and "trapping" of methane.

### SAUNDERS COAL DEPOSITS

Although the rank of these coals are relatively low (major themogenic gas production begins at ranks of High volatile C bituminous, McBane and Schraufnagel, 1989, their figure 22) for the generation of large quantities of coal-bed methane, the coals are thick and continuous and may contain economic quantities of gas. In addition, the coals are at a depth shallow enough for inexpensive drilling (200-1000 m) while deep enough to maintain pressures to contain the gas in the coal structure. The western limb of the Stolberg Anticline towards and under the Brazeau thrust (figure 6) has coal-bed methane potential. Part of that area may be overpressured but little is known of the coal deposits at depth. To the east the broad area above the Ancona thrust (figure 3), termed the Ancona Syncline, may also contain coal-bed methane gas in the Coalspur coals (Saunders coal deposit equivalents). The finding and extraction costs as well as more moderate environmental concerns may make this area an attractive coal-bed methane play. A coal-bed methane test pilot site that could examine these coals has been proposed by the Alberta Geological Survey to the north in Twp. 43 Rgn. 13. In general the low rank of the Coalspur coals make these coals a less attractive coal-bed methane target than coals to the west. Equivalent Upper Brazeau coals beneath the Coalspur coal zone in the Ancona Syncline, may also contain coal-bed methane and (only where shallow) may provide coal-bed methane plays.

### NORDEGG COAL FIELD

These coals with ranks in the low volatile bituminous range are prime coal-bed methane targets and have been known for years as "gassy coals" during mining at the Brazeau Collieries. The seams have been sheared and thickened which may enhance or provide problems (eg. coal fines) for the commercial production of coal-bed methane. However the many seams available in the area and the varied structural situations present may result in excellent plays. In general these coals should be regarded as prime coal-bed methane prospects.

### BIGHORN FALLS DEPOSIT

The medium volatile bituminous coals are also known to be optimal coal-bed methane producers. The thick coals in this area (lateral extent is unknown) may contain large volumes of gas. The local geological, geographical (mainly topography), and environmental situation will make the commercial production of coal-bed methane from this area a challenge. A coal-bed methane test pilot site has been proposed by the Alberta Geological Survey to the north in Twp. 39 Rgn. 17. The focus of this pilot site would be on the technical solutions to the challenges listed above with a view to establish procedures critical for environmental responsible coal-bed methane production from similar and less challenging areas.

**Road log between Edmonton and Nordegg**

Kms.

0 Terrace Plaza. Notice glacial drumlin across the street. Proceed south along Highway 2.

16.3 Turn east towards Devon along Highway 19.

25.9 Whitemud Creek with exposure of the Upper Cretaceous Horseshoe Canyon Formation.

29.3 ARC Devon facility; turn south along Highway 60.

30.1 **Leduc No.1 discovery well.** This historical well location has been made an historical site by the erection of this 1940's rig, which operated originally on a barge in the Gulf Coast region (the original Leduc No. 1 rig is now situated near the Edmonton Information Centre on Highway 2). This well was the discovery well for the Leduc Oilfield. The Leduc Oilfield forms part of a series of oil fields trending along Devonian reef complexes. The discovery in 1947 was based on seismic information and the first well was completed in the Upper Devonian Nisku Formation. A follow-up well penetrated through the Nisku Formation and discovered the oil and gas pools in the Devonian Leduc Formation. The main pool is in the reefal dolomites of the Leduc Formation. A second reservoir is developed in the dolomites of the Nisku Formation. Since the discovery in 1947 some 1000 wells have been drilled and several billion barrels of oil have been produced. The oil is believed to be sourced from the Devonian Duvernay Formation.

Kms.

37.4 Junction Highway 39, proceed west.

42 Town of Calmar.

55 Weed Creek with exposure of the Scollard Formation. The outcrop trace of the Battle Formation is north of the highway.

83 Junction Highway 770. The Genesee coal-fired power plant and open pit coal mines are situated 20 km north along this highway. Continue west on Highway 39.

91 Town of Alsike. Start of the Pembina Oil and Gasfield, as evidenced by storage tanks of the Pembina Oil Company. The discovery well for the Pembina Oilfield is located near Drayton Valley and was completed in 1953. Reservoir rocks are the sandstones of the Upper Cretaceous Cardium Formation, which will be seen in outcrop near Nordegg during this field trip.

104.3 Modeste Creek with exposure of the Tertiary Paskapoo Formation. Surficial sediments on top.

118.3 Junction with Highway 22, turn south. Drayton Valley, which is the centre of the Pembina Oilfield, is 7km west of here. Notice the many oil wells.

| | |
|---|---|
| 134.7 | Many oil wells of the southern part of the Pembina Oilfield are noticeable. |
| 149.7 | Junction with Highway 13. |
| 163 | Outcrop of flat-lying Paskapoo sandstone. |
| 183 | View of the Brazeau Range and its Paleozoic rocks. |
| 184 | Oil well, forming part of the Willesden Green Oil field, which has mainly Cardium reservoir rocks. |
| 197 | Start of the gradual slope towards the valley of the North Saskatchewan River. |
| 210.6 | Junction with David Thompson Highway (#11). |
| 212.2 | Bridge over North Saskatchewan River. Horizontal Paskapoo sandstone exposed. |
| 214.6 | Dune field of post-glacial eolian sands. |
| 237.5 | Chambers Creek. |
| 241.1 | Brazeau Dam access road. |
| 243.6 | Till |
| 254.1 | Till |
| 257.8 | Jackfish Creek. First clear evidence of tectonic deformation. Southwest dipping sandstone of the Coalspur Formation in the hanging wall of the Ancona Thrust (figure 2). Southwest dipping faults can be seen. |
| 262.1 | View of Brazeau Range straight ahead. |
| 272.8 | Turnoff to Saunders and **STOP 1** |

Follow road to Saunders for 3.5 km. Keep left on turn after old railroad crossing in large clearing of the forest and park vehicles in what used to be downtown Saunders.

**STOP 1: Tertiary coals of the Saunders Coal deposit**

**Estimated arrival: 10:45 am**
**Departure:11.45 am**

The town of Saunders was closed in 1954, after the Saunders Creek mine had operated from 1913-1952. Walk towards the clear water of Big John's Spring (a Russian immigrant, who died in Saunders in 1949) and proceed up Saunders Creek. There is good exposure of the coals and surrounding rocks just north of the old railroad bridge.

The section shows a 3m thick coal seam, underlain by an interlayered succession of sandstone, shale and thin coal seams and overlain by a channel sandstone with coal stringers.

The coal is solid and blocky, showing good cleating. The bedding shows a dip of about 20 degrees to the NNE (NE limb of the Stolberg Anticline, which is a triangle zone). Face cleats are the most continuous cleats, which dip 84 degrees to the SE (perpendicular to the mountain front). Butt cleats are less continuous and dip 83 degrees to the SW (parallel to the mountain front). These cleat orientations are similar to those in the plains and are important in establishing permeability in coal-bed methane reservoirs. The rank of this coal (high volatile bituminous B/C) indicates a good coal-bed methane potential for these coals, where they are buried between 200 and 1000 m.

Return to Highway 11 and continue road log

Kms.
284 Harlech Recreation Area and **STOP 2**

**STOP2: Brazeau Range viewpoint and Stolberg Gas field**

**Estimated arrival: 12:00 pm**
**Departure (after lunch): 1:00 pm**

This stop is situated close to the axis of the Stolberg Anticline, which is the most easterly structure involving Paleozoic rocks at depth (figures 3 and 5). 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 (figure 8). 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 Plant. The existing gas line infrastructure may make coal-bed methane production from the 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.

Kms.
285.4 Husky Stolberg Gas Plant.
290.4 Shunda Creek and **STOP 3.**

**STOP 3: Jurassic-Cretaceous section in NE limb of Brazeau Anticline**

**Estimated arrival: 1:15 pm**
**Departure: 1:45 pm**

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 (figure 9). The section is cut by several east dipping reverse faults. These

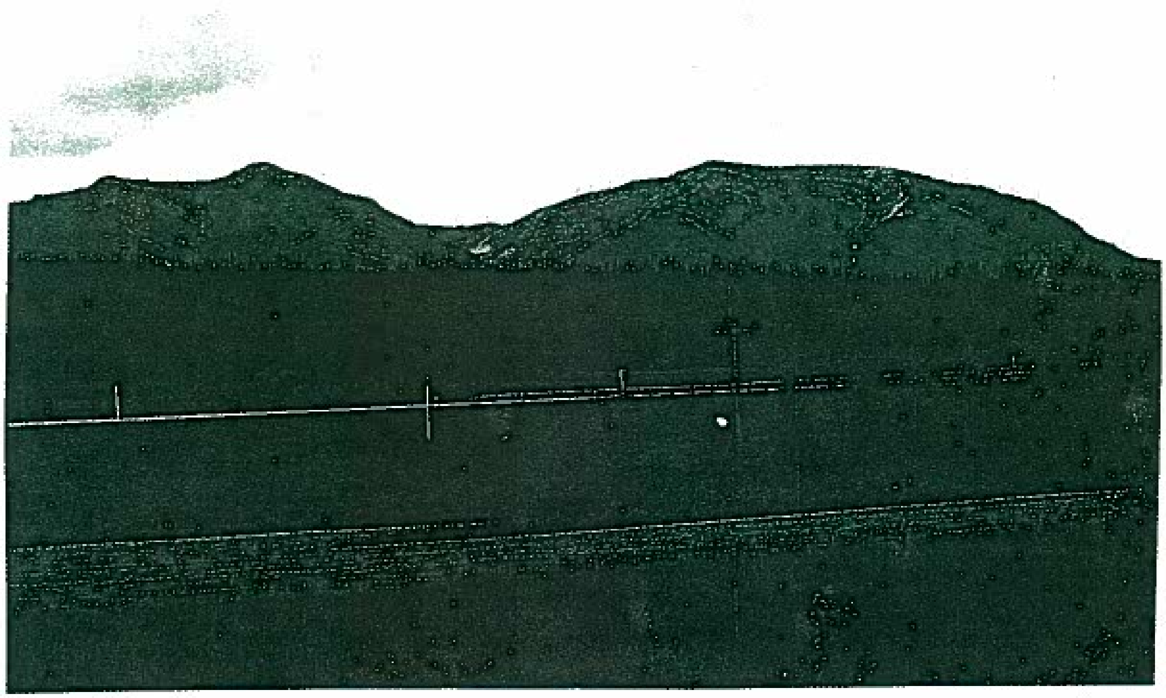


Figure 8. View of Brazeau Range from Harlech.

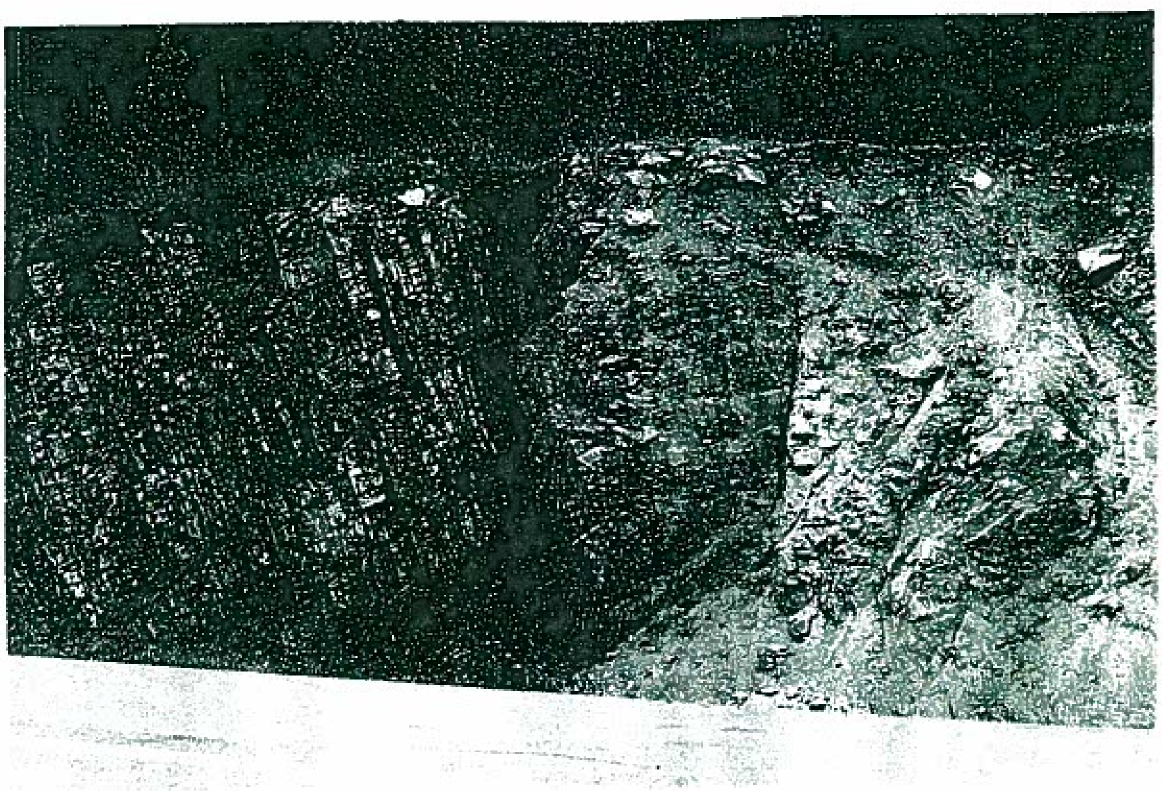


Figure 9. Nordegg Member cherty dolomites (on left) overlying Rundle Group massive limestone.

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. A measured section is shown in figure 10.

| Kms. | |
|---|---|
| 291.6 | Carbonates of the Devonian Fairholme Group and overlying Alexo Formation are exposed in the core of the Brazeau Range Anticline. |
| 292.2 | Location of Shunda Oils No.1 (15-36-40-15W5), which was drilled from 1944-1947. This well proved that the Brazeau Range is underlain by a low-angle thrust fault by encountering Cretaceous clastics at 736 m (figure 6 and 7). |
| 295.9 | Nordegg turnoff. |
| 298.3 | Junction with Forestry Trunk road. Continue straight ahead. |
| 300.4 | Road to Shunda Lake, good campsites. |
| 303.4 | Outcrop of sandstones of the Mountain Park Member. This member is repeated by a number of thrust slices for the next 1.7 km. |
| 304.4 | Turnoff to Goldeye Centre, owned and operated by the United Farmers of Alberta. |
| 306 | Culvert over Haven Creek |
| 308 | Good view ahead of the Bighorn Range, which exposes Carboniferous carbonates thrusted over Cretaceous clastics. |
| 310.4 | Outcrop of Blackstone shales and Cardium conglomerates and sandstones on right of road. |
| 312.2 | Road into Bighorn Indian Reserve. |
| 313.8 | Bioturbated sandstones and shales of the Nikanassin Formation. |
| 314.4 | Crescent Falls turnoff. Turn right along gravel road. |
| 315.4 | Outcrop of Gladstone sandstones and shales. |
| 318 | Scenic viewpoint and **STOP 4** |

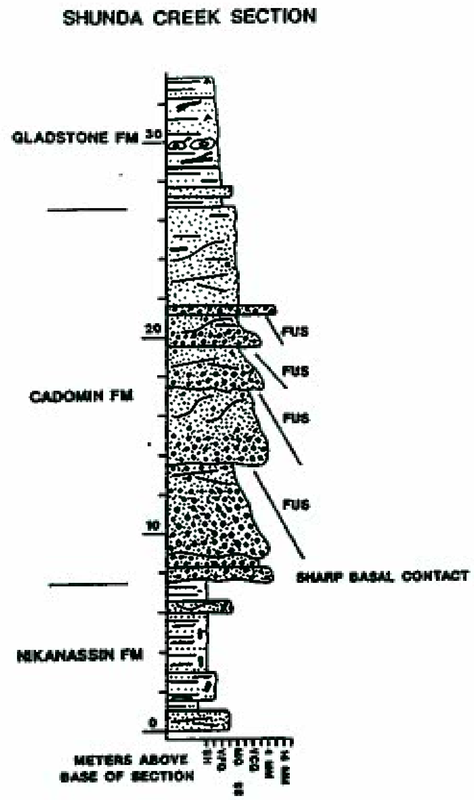



Figure 10. Measured section, Shunda Creek (from Rosenthal, 1988).

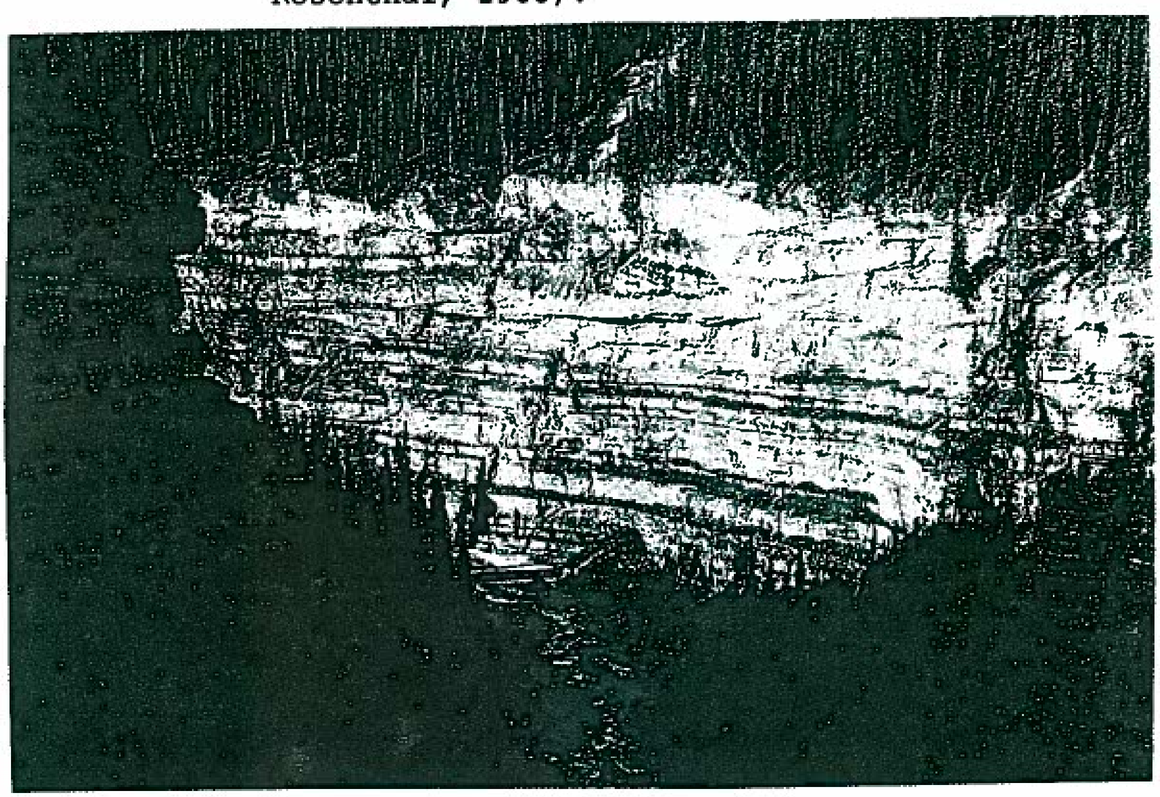


Figure 11. Gladstone Formation exposed in Bighorn River gorge.

**STOP 4: Gladstone Formation canyon**
**Estimated arrival: 2:15 pm**
**Departure: 2:25 pm**

This short scenic stop provides a nice exposure of the Gladstone Formation (figure 11). The interval consists of channel sandstones with lateral accretion beds, interbedded with thin coals and carbonaceous shales.

| Kms. | |
|---|---|
| 319 | Junction, turn left. |
| 319.4 | Outcrop of sandstones, shales and thin coal seams. Probably Gladstone Formation. |
| 320.5 | Crescent Falls and **STOP 5** |

**STOP 5: Gladstone-Moosebar-Torrens section at Crescent Falls**

**Estimated arrival: 2:30 pm**
**Departure: 5:00 pm**

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.

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 12) from close-by.

Description

The measured section is shown in figure 12 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 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

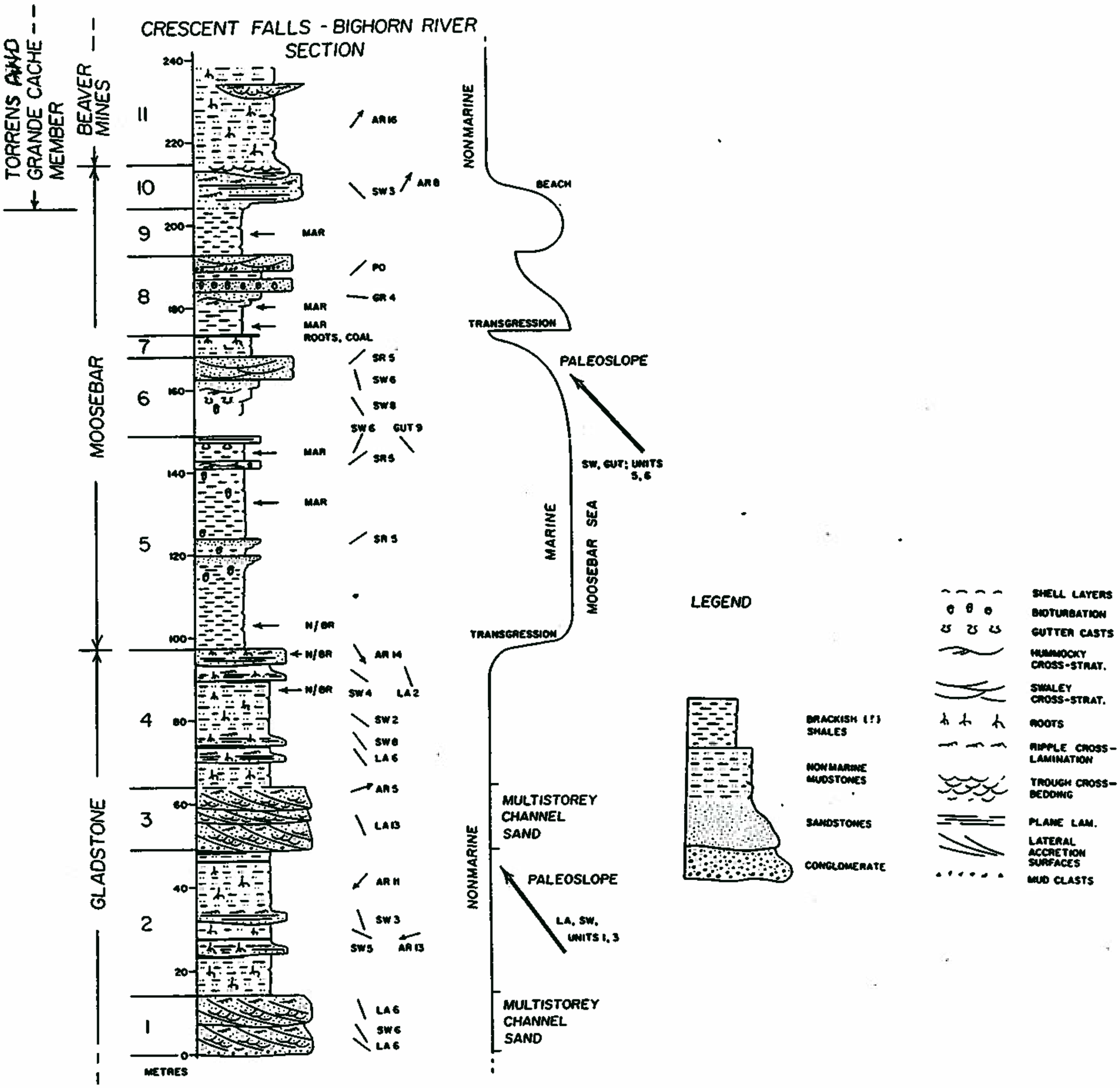



Figure 12. Measured section at Crescent Falls (from Taylor and Walker, 1984).

(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 (see figure 13). 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 14). 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

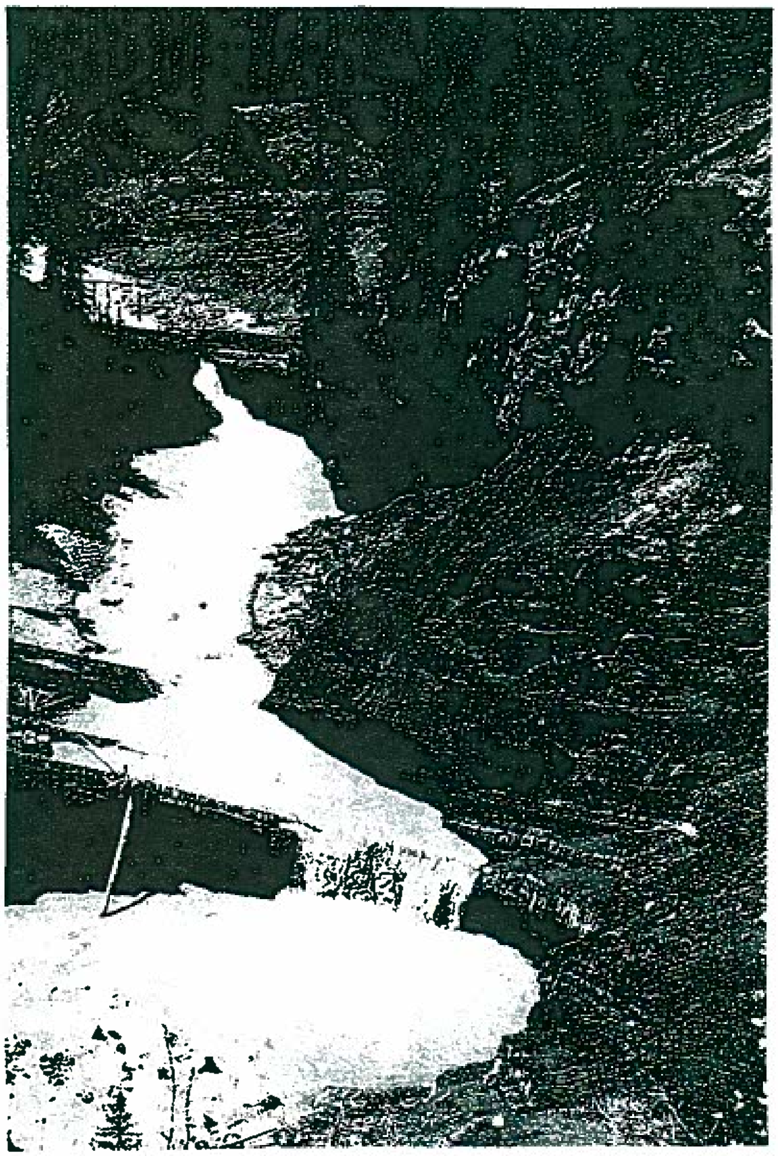
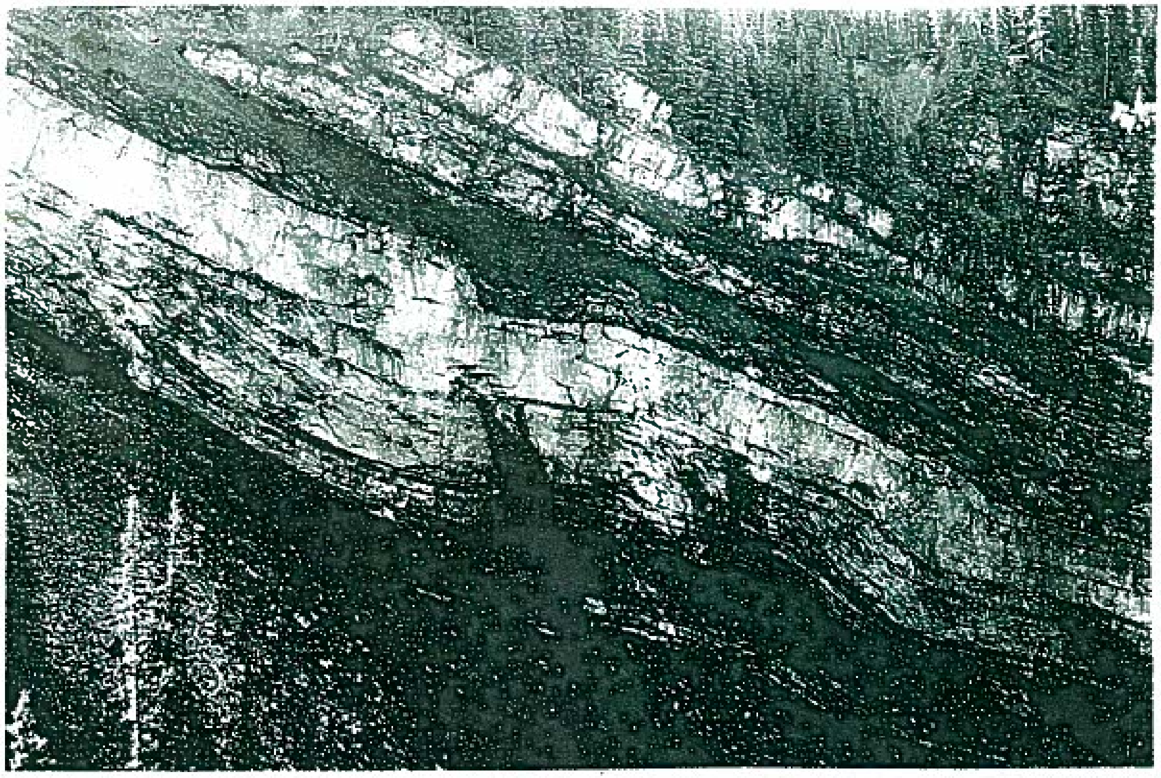


Figure 13. Gladstone-Moosebar contact (units 4 and 5) at lip of lower falls along the Bighorn River, about 750m. down-stream from main falls.



Sketch from same outcrop as photograph:

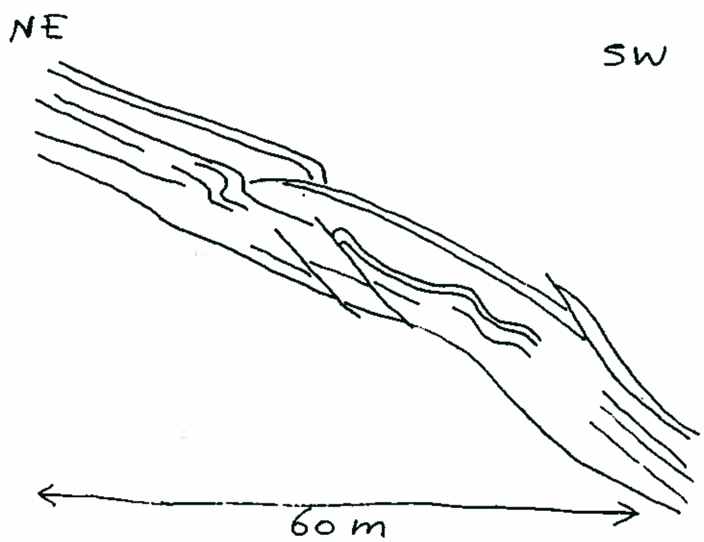



Figure 14. Deformation of Unit 6 sandstone beds. Notice zone of folding in thin bedded sandstone, grading into a fault in massive sandstone at top.

structures. Folding and faulting seems to be roughly contemporaneous and the structures might be described as modified detachment fold (see also Dixon and Liu, in press).

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 (figure 15) 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 12).

Return to the vehicles, drive about 1 km east along the river through the campsite and park near the good exposure of thick coal of **STOP 6**.

**STOP 6: Thick Gates Formation coal**

**Estimated arrival: 5:15 pm**
**Departure: 5:30 pm**

This exposure shows the main prospect of coal in the Bighorn Falls coal deposit. It has been reported by Douglas (1956) and Melnyk (1959) and figure 16 is from the latter report. Some faulting is present in this outcrop and it is uncertain if No.1 seam is a fault repeat of No.2 seam. However, it is clear that considerable thickness of coal is present. The exact stratigraphic position of this coal is not known. The coal is underlain by 10 m of interlayered sandstone and shale, which are underlain by a 30 m thick sandstone

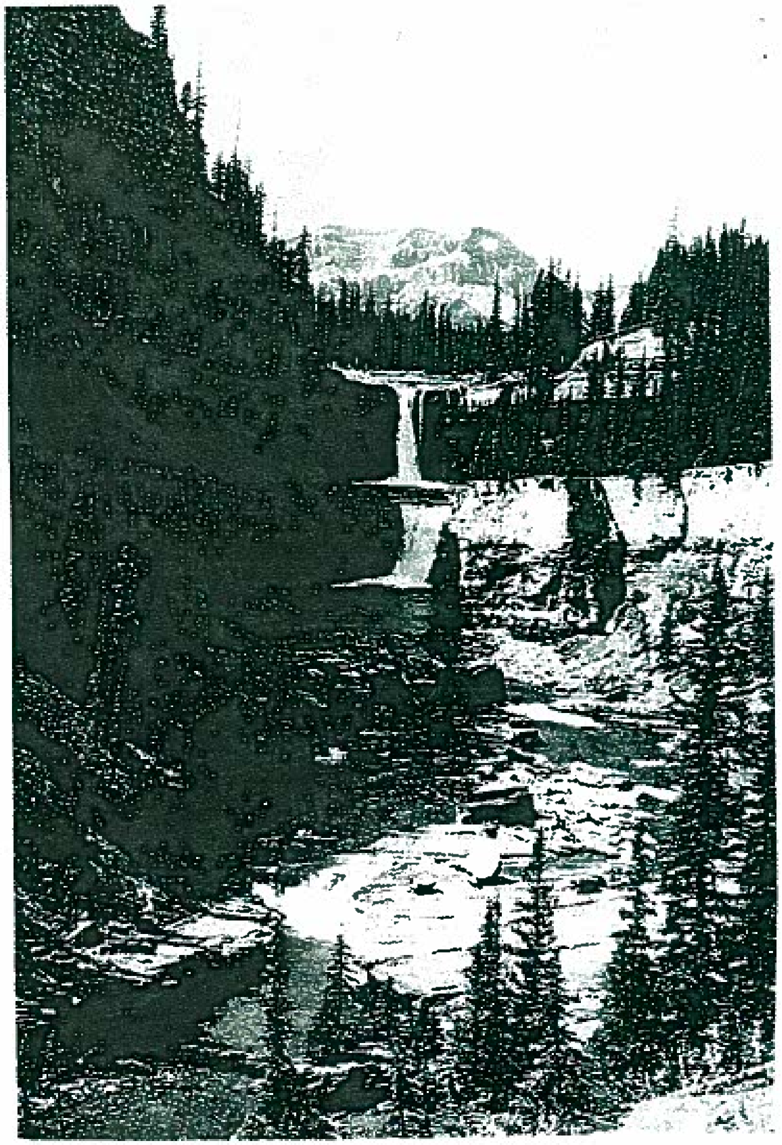


Figure 15. Main Crescent Falls. Upper falls at lower of twin sandstones of Unit 8. Middle falls at top of Unit 6. Lower falls at bioturbated sandstone of Unit 5 (notice prolific trace fossils).

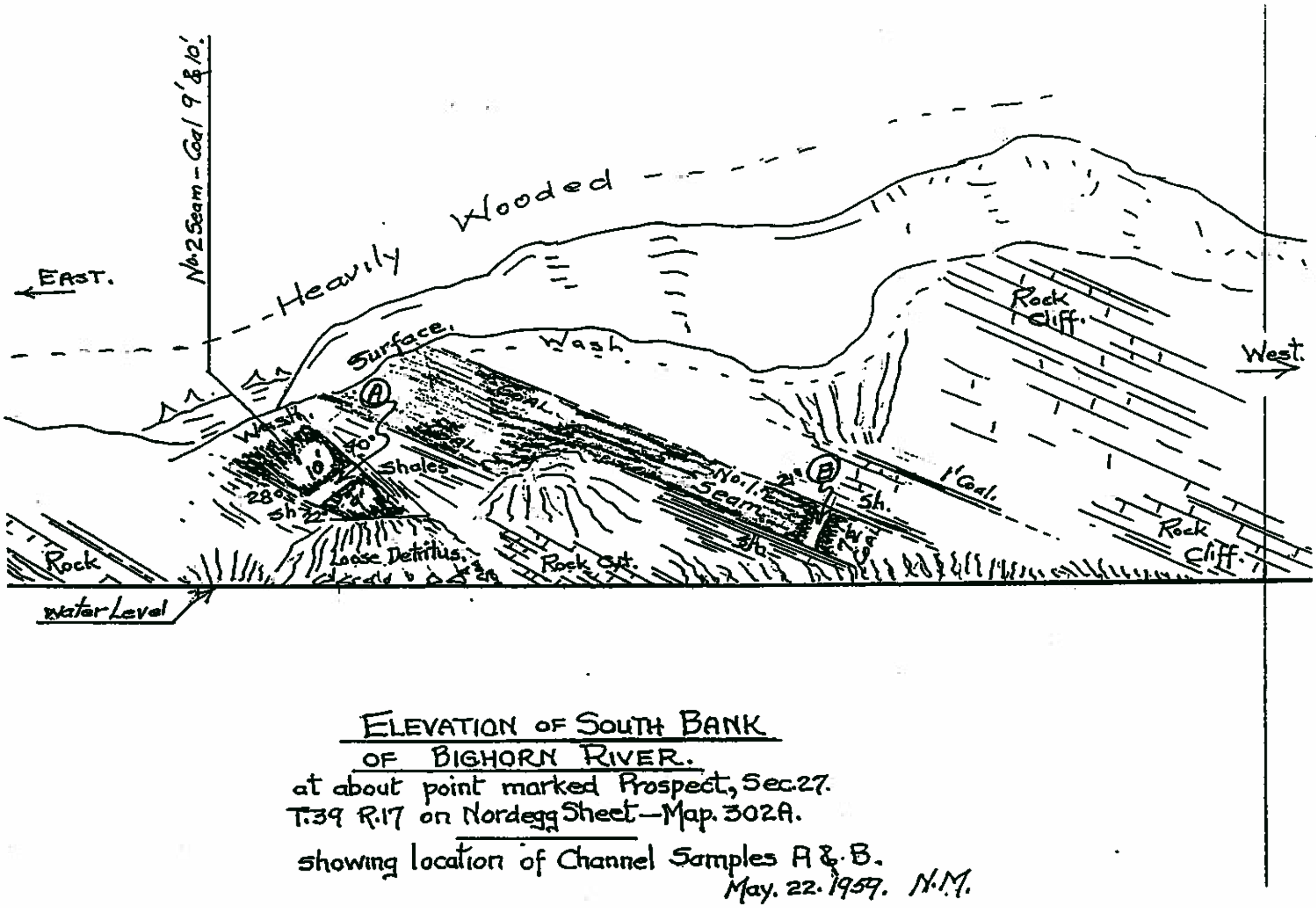



Figure 16. Outcrop of thick coal across river at STOP 6 (from Melnyk, 1959).

unit, medium grained, with few cross beds, rip-up clasts and plant hash. This sandstone could be a beach sand and belongs to the Torrens member. The covered interval between the Crescent Falls and the thick sandstone unit probably contains a fault. In addition, Douglas (1956) postulates a thrust fault at the base of the coal seam.

The rank of the coal is medium volatile bituminous, which may indicate good coal-bed methane potential, if sufficient tonnage is present in the subsurface.

Return to Nordegg. Supper at 7 p.m.

**SECOND DAY**

The morning of the second day will be spend on the geology, coal mining and coal-bed methane potential of the Nordegg Coal field. From 8 to 10 a.m. a tour will be given by the Nordegg Historic Heritage Interest Group. They will show us remnants and artifacts of the coal mining, which took place in Nordegg from 1914 to 1955. The mine entrances to the No. 2 and No. 3 seam will be visited, as well as the briquetting plant. This plant is a remnant of early technology transfer (from 1928 to 1936) of the Alberta

Research Council to the private sector. The Alberta Research Council publication by Allan and Rutherford (1923) on the Nordegg Coal field was for a long time the most importance reference to the geology of this area.

Road log to coal exposures:

| Kms. | |
|---|---|
| 0 | Nordegg school and information centre. Take road through town site |
| 1.9 | Tipple to right, washhouse to left, turn left |
| 2.1 | No.2 seam entance |
| 2.4 | Turnoff to South Pit, go straight. Do not take turnoff. |
| 2.5 | Gates Formation sandstone, showing dip of 15 degrees to southwest. |
| 4.8 | Beginning of North Pit |
| 5.3 | Coal exposure **(STOP 7)**. |

**STOP 7: Coal exposure in South Pit**

**Estimated arrival: 10:30 am**
**Departure: 11:00 am**

The No.3 seam is exposed in this open pit. There is 2.3 m of coal partly exposed, below an 8 m succession of alternating sandstone and shale. The succession is fining upwards and fluvial. The coal is very much deformed (sheared). No cleats are present in this coal and consequently the permeability of this coal is difficult to estimate. More work has to be done to determine the permeability of sheared coal. It is still uncertain how this sheared coal will behave in production tests for coal-bed methane in the area southwest of the area of exposure, where the coal is buried and still contains its gas.

Continue on road

| Kms. | |
|---|---|
| 6 | Old mine entrance and **STOP 8** |

**STOP 8: Coal section at upper level of mine (No. 12 level).**

**Estimated arrival: 11:15 am**
**Departure: 11:45 am**

This is an old mine entrance to the upper levels of the mine in the No. 3 seam. This area was generally referred to as No. 12 level. Figure 17 shows what was left of the mine entrance in July 1991 and the surroundings of the coal section. Figure 18 shows the measured section of the No. 3 seam and the overlying strata.

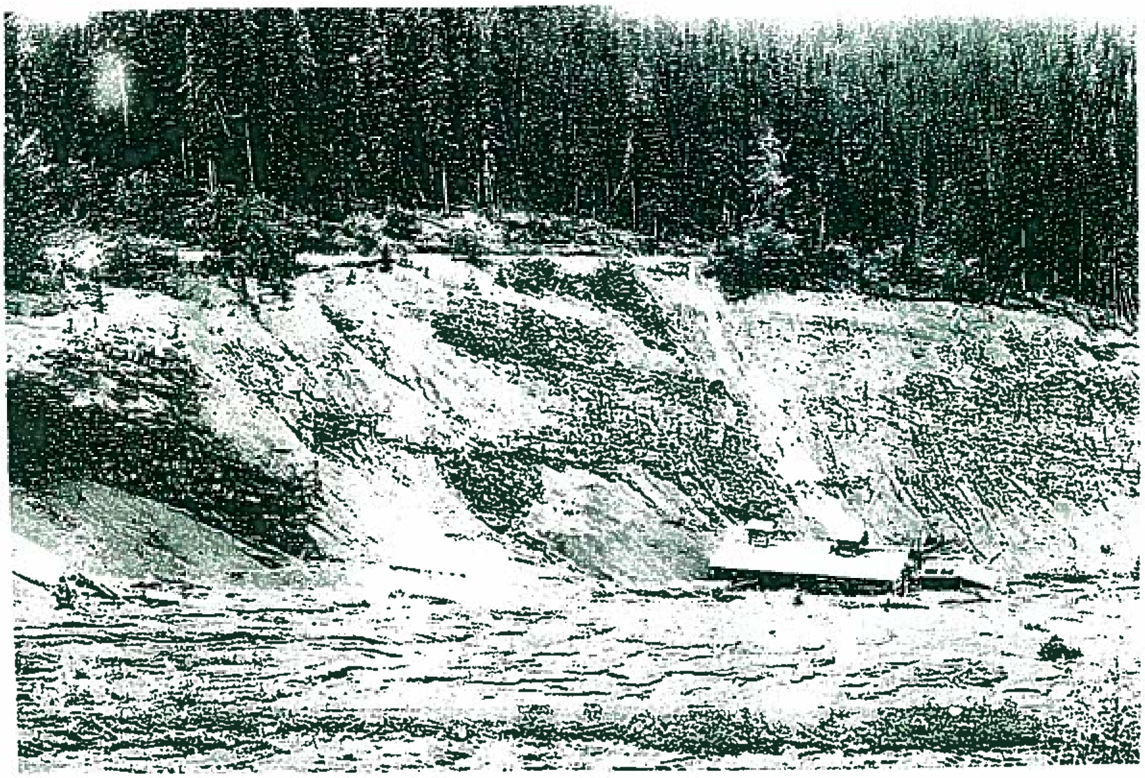


Figure 17. Coal and overburden section near old mine entrance at No.12 level (STOP 8).

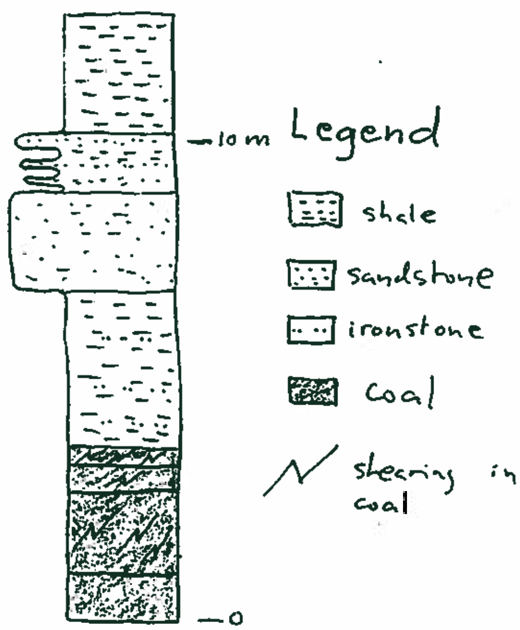



Figure 18. Measured section of coal and overburden at No.12 level (STOP 8).

Part of the coal seam is sheared and part is blocky with cleats. It might be advantageous to test coal-bed methane wells in this type of coal in the blocky interval, because the sheared coal might not hold up in the sides of the well (caving problems). This will have implications for the area down-dip from the mine, where the coal is buried at favorable depths.

Return to Nordegg and proceed along the David Thompson Highway to the Crescent Falls turnoff. A lunch stop will be taken on route. Road log continues along this highway.

| Kms. | |
|---|---|
| 0 | Crescent Falls turnoff. |
| 1 | Mountain Park sandstone. |
| 1.7 | Mountain Park sandstone. |
| 2.3 | Bighorn River crossing. Outcrop of Mountain Park sandstone near Bighorn Tear. |
| 2.9 | Shales of the Blackstone Formation. |
| 5.1 | Turnoff to Bighorn Dam. Proceed towards this dam. |
| 6.4 | Mountain Park sandstone |
| 8.2 | Mountain Park sandstone |
| 9.9 | View of shales of the Wapiabi Formation across the river. |
| 10.6 | Turn right and park near gate. Walk about 100 m to outcrop of the Cardium Formation **(STOP 9)** |

**STOP 9: Cardium Formation**
**Estmated arrival: 1:30 pm**
**Departure: 2:00 pm**

This stop provides some good exposure of the Cardium Formation, which is the reservoir rock in the Pembina and Willisden Green Oil fields, that were traversed on the way to Nordegg. The sandstones, that are exposed form part of the Cardium sands and may correlate with the Ram Member of Stott (1963). Notice the sandstone beds with hummocky cross beds and interlayers of more shaley character. Scour features of this outcrop have been described by Krause and Nelson (1984), which include rib and furrow structure and the base of a conglomerate of small chert pebbles and large sideritized clasts (including a large carbonate cemented sandstone boulder). Subsurface sections of the Cardium generally show a larger percentage of conglomerates.

Return to David Thompson Highway and continue road log

| Kms. | |
|---|---|
| 0 | Bighorn Dam turnoff. |
| 3.6 | Tershishner Creek. |
| 3.7 | Road to recent Canterra 4-9-39-17W5 well (was a dry well). |
| 6.4 | Sandstone of the Luscar Group. |

8.3 Allstones Creek. Both upstream along the creek and along the Highway the Gladstone Formation is exposed. We will be looking at the section along the highway, because the exposure is more continuous and easier accessible.

8.4 Beginning of section (**STOP 10**).

**STOP 10: Gladstone Formation at Allstones Creek.**
**Estimated arrival: 2:30 pm**
**Departure:3:00 pm**

The strata are steeply dipping NE and consist of non-marine interbedded sandstones, shales and coal. the thickness of discrete sandstone beds varies from 0.1 to 3 m. The thicker, sharp based sandstones are interpreted as point-bar sandstones, whereas the thinner units, often exhibiting loaded bases, are interpreted as crevasse splay and overbank deposits. Vertical roots are found in many parts of the section. Trough cross stratification and lateral accretion beds are characteristic for the thicker sandstones. The coals are too thin to be economically important. This is the easiest accessible section of the Gladstone Formation in the Nordegg area (the sections along the Bighorn River are very precipitous).

Kms.
8.8 Folded sediments of the Gladstone formation.
10.2 Mt. Michener view point and **STOP 11.**

**STOP 11: Folded and thrusted Gladstone Formation.**
**Estimated arrival: 3:05 pm**
**Departure: 3:30 pm**

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 20. It shows the style of deformation, with

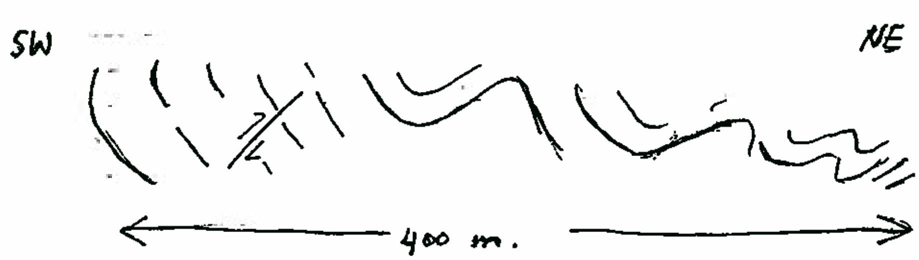



Figure 20. Sketch of outcrop in STOP 11.

open to close folds and some thrust faulting. 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.

11.2 Overturned, bioturbated sandstone and shale of either Fernie passage beds or the Nikanassin Formation (was mapped as Luscar Formation by Douglas, 1956).

11.5 Trace of McConnell Thrust.

12.3 Windy Point and **STOP 12**

**STOP 12: View of the McConnell Thrust and overlying strata**

**Estimated arrival: 3:35 pm**
**Departure: 4:15 pm**

This stop provides a view across Lake Abraham of the McConnell Thrust underneath the First Range (figure 21). The prominent peak consists of carbonates of the Palliser Formation.

The Second Range (including Mt. Michener) exposes Cambrian, Palliser and Banff formations (figure 22). 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.

Return to Edmonton. Dinner at Alder Flats golf course at 6:00 p.m. Return at Terrace Plaza at 8:30 p.m.