Geology of the Frank Slide and southwestern Alberta

Leaders: D. Cruden, W. Langenberg and R. Paulen
September 19-21, 2003
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ITINERARY

Friday, Sept 19
5:00     Drive south to Okotoks, Dinner stop in Red Deer

Saturday, Sept 20
7:45     Board bus
8:00 – 8:30     STOP 1     Okotoks Erratic
8:30 – 9:30     STOP 2     Turner Valley Gas Seep
11:30 – 12:45   STOP 3     Lundbeck Falls / Lunch
1:00 – 2:00     STOP 4     Bellevue Coal Mine Tour
2:00 – 5:30     STOP 5/6/7 Various Sites within Crowsnest Pass

• Duplex
• Cold Sulphur Springs
• Crowsnest Volcanics
5:30 – 6:30     Drive west in to BC to Sparwood

Sunday, Sept 21
7:45 - 8:45       Board bus and drive east to Frank Slide Interpretive Centre
9:00 – 12:30     STOP 7     Frank Slide
12:30 – 8:00     Return to Edmonton, Dinner stop in Airdrie/Red Deer
Geological Stops

1. Big Rock (Okotoks Erratic)
2. Turner Valley Gas Seep
3. Lundbreck Falls
4. Bellevue Coal Mine
5. Duplex Structure
6. Turtle Mountain Sulphur Spring
7. Crowsnest Pass Geology
8. Frank Slide
Disclaimer:

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2003 Field Trip Leaders

Dave M. Cruden
Willem Langenberg
Roger C. Paulen (editor)
Introduction

This past year marked the 100th anniversary of the Frank Slide. On 30 April 1903, a day after the Frank Slide, the Superintendent of Mines in the Canadian Department of the Interior instructed two senior staff of the Geological Survey of Canada (R.G. McConnell and R.W. Brock) to investigate the catastrophe. Their report (McConnell and Brock 1904) was published in 1904 and has been out-of-print for a long time. The Edmonton Geological Society (EGS) decided to reprint this report on the occasion of the centennial of the Frank Slide in 2003. The careful contemporary account of the landslide's impact on Frank is still one of the very few available for risk assessment studies. The book is a must for anybody interested in landslides. The book includes a reproduction of the original geological map. For those who have not purchased a copy of this book, several will be available for purchase on the bus, please talk to EGS Treasurer Heather Budney or Publications Director Matt Grobe for further information.

This year the EGS decided to mark the centennial of the Frank Slide by making it the focal point of our annual field trip. Several stops of interest of varying geological and historical interest are also included. The Crowsnest Pass region has a long history of coal mining and many historical sites associated with it. During the early part of the previous century coal mines operated at Passburg, Bellevue, Hillcrest and Frank. Leitch Collieries at Passburg was one of the largest and most ambitious local mines. Hillcrest Collieries marks the site of one of Canada's worst mine disaster that claimed the lives of 189 men. The Bellevue mine operated into the early 1960s and offers an underground tour that we will embark upon. Lastly, the coalmine at the town of Frank operated for a short time until the “day that the mountain fell”. The Frank Slide is of unique geologic and historic interest. It is known to earth scientists from around the world. Three generations of geology students have read and studied pictures of the slide and many of them have visited the site.

The Crowsnest pass is also home to some of the few exposures of volcanic rocks in Rocky Mountains. Stops will include visits at these outcrops, the duplex structures and sedimentary structures at Lundbreck Falls. Field trip participants are to remember that several of the planned stops occur along busy roadways, so exercise extreme caution when exiting the bus and walking along the shoulders of the highways.

Stop 1: The Okotoks Erratic

The Big Rock is a house-sized quartzite block and is the largest and best known glacial erratic in Alberta; even an Alberta brewery is named after it (Big Rock Beer). This is the largest rock in a group of rocks that were carried by valley glaciers of Cordilleran Ice Sheet, which then coalesced with the Laurentide Ice Sheet in the Late Wisconsin (Jackson et al. 1997) and flowed southeastward, perpendicular to regional glacial trends for almost 800 km, creating the Foothills Erratics Train (Stalker 1956; Jackson 1980). The erratics lie in a narrow band extending from Jasper National Park to northern Montana (Fig 1). The Foothills Erratics Train is narrow, ranging in width from 22 km to less than 1 km.
The name of the erratic was derived from the Blackfoot word for rock, "okatok". The Okotoks Erratic is 9 metres high, 41 metres long and 18 metres wide and weighs 16,500 tons! The rock has been eroded into pieces, but is still a large landmark on the flat prairie (Fig 2). If you look closely at the rock, you can see something vaguely familiar, a piece of quartzite seen in outcrop last year on the EGS field trip in Jasper! It is a piece of the thick bedded, micaceous, feldspathic quartzite of the Lower Cambrian Gog Group (Price et al. 1972). About 18,000 years ago, a rockslide crashed Gog Group onto the surface of a valley glacier in the present day Athabasca River valley. The flowing glacier slowly carried this debris eastward to the plains, where the continental ice sheet deflected it southward.

One interesting feature of Big Rock is the large split down the middle. Ethnographer George Bird Grinnell recorded a story in the 1800s of Napi, the supernatural Trickster of the Blackfoot who sat upon the rock to rest:

One hot summer day, Napi, the supernatural trickster of the Blackfoot peoples, rested on the rock because the day was warm and he was tired. He spread his robe on the rock, telling the rock to keep the robe in return for letting Napi rest there. Suddenly, the weather changed and Napi became cold as the wind whistled and the rain fell. Napi asked the rock to return his robe, but the rock refused. Napi got mad and just took the clothing. As he strolled away, he heard a loud noise and turning, he saw the rock was rolling after him. Napi ran for his life. The deer, the bison and the pronghorn were Napi's friends, and they tried to stop the rock by running in front of it. The rock rolled over them. Napi's last chance was to call on the bats for help. Fortunately, they did better than their hoofed neighbours, and by diving at the rock and colliding with it, one of them finally hit the rock just right and it broke into two pieces.

Not only does this story explain why the rock is in two pieces, but also why bats have squashed-looking faces. The tale provides helpful caution against taking back what you have given away.

In the 1970s, the Big Rock was the first "natural feature" to be designated as an official provincial historic site. The Big Rock was located on private land until 1987 when the province purchased the land on which the Big Rock now sits.

Quartzite is slippery to climb and although it is hard, pieces can break off in climbers' hands. Please do not climb the rock, as tempting as it looks. Also, there are aboriginal pictographs on the rock, and these could easily be damaged by climbers. Enjoy the beautiful colours, textures and feel of the rock, but stay on the ground.
Fig. 1. Movement of some glacial erratics in southern Alberta. The Foothills Erratics Train (Stalker 1956) is shown along A-B (from Klassen 1989, p.144).

Fig. 2. The Big Rock (photo by Jill Weiss, Alberta Geological Survey)
Stop 2: Turner Valley Gas Field and Hell’s Half Acre

The 1914 discovery of the Turner Valley oil and gas field, 45 km southwest of Calgary, was Alberta’s first major oil strike. Turner Valley provided the impetus for the development of Alberta’s multi-billion dollar petroleum industry. The historical importance of this site was recognized in 1989 when the Royalite gas plant, built in the early 1920s, was designated a Provincial Historic Site by the Government of Alberta (Fig. 3). Several buildings can be visited on guided tours. Its museum, presently occupying part of the Town Hall, has exhibits and models interpreting the spectacular boom and bust history of the area. Here, visitors can find out the significance of oilfield terms with the assistance of a fine historical video.

Discovery and History

In 1906, a settler from Montana named Michael Stoos had purchased homestead lands from the Canadian Pacific Railway (CPR) along the Sheep River in the Turner Valley area of Alberta. The CPR had retained the rights to petroleum. The shale beds along the banks of the Sheep River as it passes through the lands acquired by Mr. Stoos form an anticline and gas naturally seeps from these shale beds. This gas seep attracted the interest of William S. Herron who has been referred to as the "father of the petroleum industry in Alberta" (Breen 1984). Herron applied to both the CPR and to the Dominion Government for leases in the area. In 1911, Herron reportedly fried eggs over the gas seep with R.B. Bennett (Kerr 1988), a lawyer who then acted as the CPR's Calgary solicitor (RP - You decide if you would have enjoyed a breakfast cooked over this flare!). That same year, Herron purchased Stoos' land for $18,000. In 1912, a group of prominent Calgary citizens, including Bennett, A.E. Cross, W. H. McLaws, J. A. Lougheed, and W. Pearce purchased a majority interest in Herron's company, Calgary Petroleum Products Co. Ltd., and committed to spend $50,000 developing the properties that Herron had transferred to the company (Kerr 1988).

On May 14, 1914, Calgary Petroleum Product's first well, Dingman No. 1, discovered 'wet gas' on a Dominion Government lease adjacent to the Sheep River seep. Unlike dry gas, wet gas in the subsurface contains significant quantities of normally liquid hydrocarbons dissolved in gaseous solution. When the temperature drops as wet gas is produced at surface, measurable quantities of hydrocarbon liquids condense from gaseous solution. Dingman No. 1 initially produced approximately 1 million cubic feet per day of wet gas which, when passed through a surface separator yielded what Calgary newspapers described as "practically pure gasoline" (Breen 1993). The next day, P.L. Naismith, manager of the CPR's Department of Natural Resources, described these hydrocarbon liquids as "oil" in a telegram to the CPR's Montreal headquarters. In another telegram, three days later, Naismith (1914) described the scene in downtown Calgary as follows: "for two or three days the police have had to take charge of the crown on First Street west, the street being practically overcrowded with people endeavoring to get into various offices to purchase stock". This discovery triggered an oil boom and later that year 226 oil companies were listed in Calgary’s city directory (Mussieux and Nelson 1998).

Alberta's first 'oil' boom dissipated with the outbreak of World War I. Calgary Petroleum Products drilled a successful follow-up well (Dingman No. 2). The second well was on the geologically highest part of the anticline, where Upper Cretaceous Cardium Formation
sandstones outcrop on the banks of the Sheep River (Fig. 4). The seep at Dingman No. 2, combined with a gas leak from the old well, is constantly ignited to prevent the hazardous accumulation of methane gas in the valley bottom. It is visible from the Hell's Half Acre Bridge on Decalta Road. A third well (Dingman No. 3) was planned, but was unable to secure the financing necessary to fully develop its properties. Disaster struck the company in 1920 in the form of a fire that destroyed the plant it had built to strip gasoline from the gas produced from Dingman No. 1 and No. 2. R. B. Bennett then approached A. M. McQueen, Vice-President of Imperial Oil Limited, and arranged for the assets of Calgary Petroleum Products to be transferred into a new corporation called Royalite Oil Company. The former shareholders of Calgary Petroleum Products acquired 25% of the shares of Royalite, Imperial retained 75% and committed to spend $400,000 rebuilding the plant and drilling two further wells. Royalite Oil Company was incorporated in January of 1921 (Kerr 1988).

Production and Royalties

Calgary Petroleum Product's drilling in Turner Valley had been on leases of Dominion Government lands. Royalite intended to drill on the split-title lands that Michael Stoos had purchased from the CPR. The title to these lands, which Royalite had acquired from Herron, included "all mines and minerals except coal and petroleum". But Royalite also had acquired a 1915 lease from the CPR to Calgary Petroleum Products on these same lands and the lease called for a royalty of 10% on gas and gasoline to be paid to the CPR. In the summer of 1922, Imperial approached the CPR to amend the terms of this lease (Breen 1993).

In a July 3, 1922 memo to the President of the CPR, Sir Augustus Nanton, who was a member of the railway company's Board of Directors and Chairman of the Board's Advisory Committee, advised that the question may be raised as to whether Gas is a Petroleum product or not and recommended that the 1915 lease be canceled and a new lease be issued with "the royalty to be paid the Canadian Pacific being 5% on Gas and Gasoline as these commodities come from the absorption plant" (CPR 1922). A new lease was issued on August 1, 1922 and, in September of 1922 Royalite No. 4 was drilled on the split-title lands formerly owned by Mr. Stoos.

In 1924, Alberta's first giant field was discovered when Royalite No. 4 blew in while drilling in limestone beds stratigraphically below the productive zone encountered in Dingman No. 1. When Royalite No. 4 was brought under control it produced approximately 20 million cubic feet per day of wet gas. The gas produced from Royalite No. 4 was very rich in hydrocarbon liquids and, when passed through a surface separator, produced 600 barrels per day of naphtha, a light, clear liquid petroleum. Most of the gas recovered was not used, however, but flared off in a nearby ravine known as Hell’s Half Acre because of the constant fire. At night, the light from these fires could be seen as far away as Calgary.

In March of 1925, the Department of Natural Resources sought the advice of the CPR's Law Department in Montreal. The CPR's General Solicitor, W.H. Curle, advised that "Petroleum' does not include dry natural gas", but the "oil which is being recovered at Okotoks by the Imperial Oil Company, is, in my opinion, oil and not gas" (Kerr 1988). Curle apparently
Fig. 3. Royalite gas plant at Turner Valley. Note the burning natural gas at left (from Mussieux and Nelson 1998, p. 174)

Fig. 4. Accumulation of petroleum in the crest of the anticline consisting of Mississippian-age limestone. The anticline was faulted and moved eastwards to its present location (figure by Dan Magee, Alberta Geological Survey).
understood that a royalty of 10% was due on both gas and oil and his opinion that "it makes no difference for the Imperial Oil Company to argue about this distinction" must be taken in context. Nevertheless, the issue of whether the CPR actually owned all of the gas which Royalite was contractually obligated to pay it a royalty on appears to have been irrelevant to the CPR's General Counsel.

In a chilling harbinger of what was to come for individual freehold owners of natural gas on split-title lands, R.B. Bennett, representing Royalite, met with the Manager of the CPR's Department of Natural Resources in April of 1925 and agreed that Royalite would pay a 10% royalty to the CPR. If a subsidiary of what was then the world's largest oil company, represented by a lawyer who 5 years later would become Canada's 11th Prime Minister, could not stand up to the CPR, who could?

Although the Royalite No. 4 controversy had apparently been resolved to the CPR's satisfaction, Imperial sought further petroleum leases from the CPR on split-title lands in the Turner Valley area where title to all mines and minerals except coal and petroleum was held by individuals and not Imperial or its subsidiaries. In November of 1926, P.L. Naismith wrote to A. M. McQueen of Imperial advising that the CPR's Board of Directors was concerned with the CPR's potential legal exposure in such situations and asking whether Imperial was aware of any court rulings in similar circumstances. In McQueen's letter of response, he states (Naismith 1926):

"... if the arrangement is agreeable to you that we should apply to Mr. (omitted) for a lease of the gas rights to the land in question and pay him any royalties on gas due thereon. We presume that under such an arrangement the gas, whether dry as it comes from the well or naphtha bearing, would belong to Mr. (omitted) and that the naphtha would belong to your company"

Perhaps in the context of a "little dispute", Mr. McQueen's reference to paying a royalty to the presumed rightful owner of the gas is a subtle indication that Imperial would not be prepared to pay royalties to the CPR on this same gas, as it was required to do in the form of lease prescribed by the CPR on Royalite No. 4. McQueen's letter (1926) does not address the CPR's potential legal liability under this form of petroleum lease, but a December 7, 1926 memorandum of law in the CPR files at the Glenbow Museum does. This memorandum concludes:

"The Canadian Pacific Railway Company having conveyed to (omitted) the natural gas cannot derogate from its own grant and confer on a lessee the right to drill for petroleum so as to destroy or injure the natural gas on the Lessee's land.

It would seem that while the petroleum lessee would not be enjoined from drilling for petroleum he would be under obligation, if in the course of such drilling he struck natural gas, to take such steps as would prevent the gas from escaping or compensate (omitted) for the interference with the natural gas.

Under no circumstances would the oil lessee be justified in appropriating the natural gas. The form of petroleum lease used by the Company seems to contemplate such a contingency as the present by the language of paragraph 17."
It is implicit in this legal memorandum, as it was explicit in W.H. Curle's 1925 legal opinion, that the CPR did not believe that it's right to petroleum on split-title lands included the right to all natural gas. Curle apparently recognized no problem in the CPR demanding a royalty on something it didn't own, whereas the unknown author of the 1926 memorandum of law was clearly of a different view. How the CPR resolved this potential legal liability while still demanding a royalty on something it didn’t own appears to have had a profound impact on the oil and gas industry's view of how ownership should be determined on split-title lands. It is also implicit in these legal opinions and throughout the correspondence between the CPR and Imperial that, during the 1920's, both parties held the view that ownership determination on split-title lands should be based on the phase condition of the hydrocarbons as they were produced at surface from time to time. A quarter of a century later, the CPR and Imperial changed their tune at Leduc (Kerr 1991).

Implications

Turner Valley was exploited in such a manner that an estimated 88% of the oil remains in the reservoir. Crowding of wells and the flaring of natural gas depleted the gas pressure in the reservoir and the remaining reserves are now unrecoverable by present-day technology (Mussieux and Nelson 1998). The lessons learned at Turner Valley led to the formation of what is now the Alberta Energy and Utilities Board.

Stop 3: Lundbreck Falls

At the eastern edge of Crowsnest Pass, the Crowsnest River plunges 17 m over a sandstone cliff to form Lundbreck Falls, a Provincial Recreation Area. Located 12 km west of Pincher Creek, these falls are near the eastern margin of the Foothills. A fine spot for a picnic lunch! Enjoy the magnificent scenery where you can get a true taste of the prairie rising up into mountain majesty, and marvel at the falls themselves. The train trestle over the river lends a sense of atmosphere to the scenery (Fig. 5). Looking towards the west from this site, you can see the folded and faulted Paleozoic limestones of the Front Ranges. Lundbreck Falls marks the western boundary of the Plains.

Geology

Lundbreck Falls is formed where the Crowsnest River plunges over a resistant sandstone cliff of the Belly River Formation (Tozer 1956), deposited after an early Late Campanian period of marine inundation (Pakowki/Nomad Sea). Belly River Formation (and their equivalent rocks) represents a major influx of clastic detritus from the Cordillera that pushed the coastlines eastward across the foreland basin (Smith 1994). Rivers flowing from the rising mountains brought great quantities of sand and dumped them in many deltas, such as the Belly River Delta. The cliff that forms Lundbreck Falls contains numerous sedimentary structures (Fig. 6), such as ripple marks and worm borrow traces, which indicate a shallow shoreline environment (Lerbekmo 1963; Baturin-Pollock 1992; McLaren 1992).
Also of interest in this area is the excavation of “Black Beauty” in 1982. Black Beauty is a beautifully preserved, rich-black *Tyrannosaurus rex* that was discovered about 5.5 km east of Lundbreck along the Crowsnest River (Mussieux and Nelson 1998). The dinosaur was prepared for display at the Royal Tyrrell Museum of Palaeontology in Drumheller.

![Scenic photos at Lundbreck Falls.](image1)

**Fig. 5.** Scenic photos at Lundbreck Falls.

![Sketch of interdistributary bay succession.](image2)

**Fig 6.** A sketch of the interdistributary bay succession of the Connelly Creek delta at Crowsnest River Rapids near Lundbreck Falls. 1 to 5: (1) crevasse channel sequence composed of large-scale trough cross-stratified in-channel sandstone bars; (2) overbank limestone; (3 to 4) heterolithic cross-stratified to small-scale trough crossbedded to ripple-drift laminated point bar deposits; and (5) bay mudstone. 6 to 8: (6) mouth-bar sequence composed of an intensively bioturbated fine grained sandstone and siltstone bed; (7) a coquina lag composed of chaotically arranged shells of unionid bivalves in the “escaping” position in the middle, and bulbous-shaped burrows at the base; and (8) a low-angle stratified to wave-ree worked upper bed. (9) Bay mudstone with a single crevasse-splay sandstone sheet. (10) Large-scale trough cross-stratified sandstone of the next crevasse-channel (*RP* - ask Willem Langenberg for source of this figure).
Stop 4: Bellevue Coal Mine

The Crowsnest Pass encompasses a number of once-bustling coal-mining towns. The tumultuous history of these communities of one of strikes and tragedies, and in 1988, the Pass became Alberta’s first designated Ecomuseum and Historic District. It is quite fitting that the Edmonton Geological Society visits and tours the Bellevue Coal Mine at the onset of the “Year of the Coal Miner” – September 2003 to September 2004.

The foundation of many communities in southern Alberta and southeastern British Columbia is the coal that lies beneath the prairie and mountain landscape. From Canmore to Drumheller to Lethbridge to the Crowsnest Pass, coal has played, and continues to play a fundamental role in the development of our region.

Crowsnest Pass and Coal - Historical Notes

Prior to the mid 1800's the only people travelling the Crowsnest Pass were First Nations Peoples. The First Nations Peoples had moved their campgrounds further south (to the Waterton area) many years before the European Explorers arrived in the area. An expedition setting out in 1857 didn't travel the pass because their Aboriginal Guide described the Crowsnest pass as "a very bad trail" (Crowsnest Pass Historical Society 1979).

Coal was first noted by Father Jean de Smet, a missionary on the Elk River in 1845. It isn't known for certain but settlement, by other than First Nations Peoples, in the valley itself could have been as early as 1865. The valley was definitely settled in by 1870. In 1873 ex-Hudson Bay Traders Michael Phillips and John Collins had so much difficulty travelling upstream of the Elk River that they didn't return via the same route. In 1877 a trail was cut up the Elk Valley to what is now called Phillipps Pass.

George Dawson, of the Geological Survey of Canada, visited the Pass in 1878 and reported that there were large quantities of coal in the area and that it would be an ideal route for the CPR (Dawson 1883; Dawson and McConnell 1883). The politics of the day coupled with Crowsnest Pass proximity to the US border vetoed his suggestion of sending the CPR line through that pass and instead, the rail line went through the Kicking Horse Pass.

Ironically, the Federal Department of Mines and Minerals, for nearly 50 years, issued statistics showing the number of tons of coal mined per serious injury or fatality. The nearby Hillcrest
Mine, located in Crowsnest Pass and site of Canada's worst mine disaster, was considered to be the safest mine in the area.

*Bellevue Mine*

The Bellevue town and mine, named for its beautiful view high in the mountains, was opened by West Canadian Collieries Ltd. (based in Lille, France) in 1903. The above ground portion of the operation, and the thickest coal seam, was conveniently located next to the Canadian Pacific Railway branch line (Mussieux and Nelson 1998). Bellevue became the first coal town in southern Alberta solely providing fuel for the railways during the steam era. Coal extraction at the site proved to be difficult. Although the coal seam was 3.5 m thick, it was steeply dipping usually discontinuous (Fig. 7). It also contained pockets of explosive methane gas.

Active development on the Bellevue Mine and Townsite began in 1903 and the mine was in production by 1904 (Fig. 8). Construction of 40 houses, a tipple, hotel and general store were begun in 1905 and 1906. The community had an excellent water system and power. The Bellevue Mine operated for seven years with a strong safety record. Then, on December 9, 1910, at 8:00pm there was an underground explosion. It was suspected that a rock fall generated sparks, ignited methane gas that in turn caused a coal dust explosion - destroying the mine's only ventilation fan. Likely, rock falls from the roof ignited some methane gas which then produced a coal dust explosion. This chain of events resulted in high concentrations of carbon dioxide and carbon monoxide. There were 42 men working in the mine that night. Thirty died, most as a result of the deadly gasses. It was fortunate that the explosion had not taken place during the day shift when 200 workers would have been in the mine (Crowsnest Pass Historical Society 1979).

The Bellevue Mine reopened a few weeks after the tragedy and reached its peak operations about 70 years ago when a work force of 500 men produced 2500 tons of coal each day (Crowsnest Pass Historical Society 1979). Tragedy struck again in 1917 when a fire demolished all but 3 buildings in the Bellevue business section. The town rebuilt but fire struck twice more, once in 1921 and again in 1922. Concrete gables (entries to the mine), which can be seen from Highway 3, were added in 1929 (Fig. 9). West Canadian's coal processing plant was situated next to the mine's main entrance. A second mine at Byron Creek was brought into production in 1945 called the Adanac. It had the distinction of being "the only bituminous coal mine in Alberta that was fully electrified." (Crowsnest Pass Historical Society 1979). The mine extended 850 m into the mountain and coal was extracted on nine different levels of workings. Various methods were used to load and transport the coal to the surface but the actual extraction of the coal from the seam was done mostly by hand. This was quite a feat when we consider that this mine produced 1,364,000 tonnes of coal in its 60-year history!

Expanded use of gas and oil for domestic and industrial fuel, however, led to a gradual decline in the market for coal. The mine closed in 1962 (Fig 10). Bellevue is now a quiet and beautiful residential community.

The mine tour gives an authentic 'coal miner' experience as you don a miner's lamp, battery pack and hard hat, then walk into the dark, damp, chilly depths of the original tunnel. Your lamp is the only light by which to see the artifacts and the various sections of the mine, including the coal
seam, a coal room and loading chute. Guides explain the mine operation and the love the miner and for his work - despite the dangers and conditions.

Fig. 7. A section of the Bellevue Mine, published in 1913, showing the folded and faulted nature of the coal seams (from Mussieux and Nelson 1998, p. 203).

Fig. 8. West Canadian Collieries mine entrance, Bellevue, Alberta, 1905 (Glenbow Archives)
Fig. 9. Concrete gables leading into the mine, 1929 (Provincial Archives of Alberta).

Fig. 10. Bellevue coal mine in full operation, 1951 (Provincial Archives of Alberta).
Stop 5: Duplex Structure

Willem Langenberg will discuss this part at the outcrop (i.e. take notes!).

NOTES:

Fig. 11. Detailed cross-section through the Lewis thrust sheet along Highway No. 3 at Crowsnest Lake, Crowsnest Pass, Alberta. The plane of the cross-section is sub-parallel to the regional tectonic transport direction (ask Willem Langenberg for source of this figure).
Fig. 12. A: Photograph of an antiformal stack within the Middle Banff Formation. B: Detailed section through the antiformal stack shown above and the associated stacked duplexes in the Middle Banff Formation (ask Willem Langenberg for source of this figure).
Stop 6: Turtle Mountain Sulphur Spring

The occasional whiff of hydrogen sulphide in the air here is borne downwind from the Turtle Mountain Sulphur Spring at the north end of Turtle Mountain. This spring discharges a 9°C flow, up to 10 litres a second of calcium sulphate and bicarbonate water from the low point exposed on the Turtle Mountain Thrust, a few metres above the Crowsnest River. Fractured Palaeozoic limestones have been thrust over Mesozoic clastics. This karst spring (Borneuf, 1983) is probably fed by precipitation south of the Crowsnest River and west of the Turtle Mountain Fault (Van Everdingen, 1972) and demonstrates that Turtle Mountain is part of an active karst.

Stop 7: Crowsnest Volcanics

The Crowsnest volcanics are one of the few exposures of volcanic rocks in the Rocky Mountains and considerably younger than the nearby Mark diatreme cluster (Upper Devonian to Lower Mississippian) at the Alberta-BC border to the west (Pell 1987). The Crowsnest Formation volcanics consist mainly of pyroclastic and epiclastic deposits, with rare flows and intrusive rock that are restricted to southern Alberta in the vicinity of Coleman (Adair 1986). The volcanics are sodic-rich trachytes to phonolites (Peterson and Currie 1993). The reported age for the Crowsnest volcanics is 96 Ma (Folinsbee et al. 1957) and the volcanic unit is 450m thick north of Coleman (Fig. 13).

The explosive nature of the Crowsnest eruptions resulted in debris ranging from fine ash to blocks several metres across. Particularly noticeable are the bedded layers, where the volcanic debris was deposited in a subaqueous environment (Adair and Burwash 1996). There are a great variety of rock types in the Crowsnest volcanics. One type is made up mainly of the mineral analcime and the rock is named analcimite (Peterson and Currie 1993). This rock was once named blairmorite, after the town of Blairmore (Mussieux and Nelson 1998). Standard naming practices for igneous rocks now require names after the major mineral, instead of localities where they are found. Other minerals to look for are crystals of pink sanidine feldspar and small lustrous black melanite garnets.
Fig. 13. Type section of the Crowsnest Formation along Highway 3 (from Adair and Burwash 1996)
Stop 8: Frank Slide

This rockslide has become the classic example of mass movement because it is one of the largest slides to have eyewitness descriptions as well as numerous detailed geological reports. The portion of the guidebook is a slightly modified version of “A Guide to the Frank Slide” by D.M. Cruden, prepared for the 54th Canadian Geotechnical Conference, Calgary, September 2001.

The rock layers of Turtle Mountain are folded into a large anticline with a steeply dipping east limb that lies on a fault (Fig. 14). A large display at the Frank Slide Interpretive Centre shows the slide in a detailed three-dimensional relief model with the coal seams and faults projected to surface.

![Fig. 14. Turtle Mountain annotated with geology.](image)

Location

The Frank Slide lies at the east end of the Municipality of Crowsnest Pass, in the valley of the Crowsnest River in the Front Ranges of the Canadian Rockies in southwestern Alberta. Alberta Highway 3 crosses the slide and, immediately north of the slide debris at the bridge over Gold Creek, an access road leaves the highway for the Interpretive Centre, 1.7 km to the northeast (Figure 15). The Centre, an excellent starting point for a tour of the slide, provides a superb view of Turtle Mountain, the slide scar on its eastern flank, and the immense accumulation of shattered limestone on the valley floor.
Significance of the Site

For many years, the Frank Slide was the only well-described, historic example in the English language literature of what Varnes, (1978) has called a rockfall avalanche. The importance of the Frank Slide has been reinforced by nearly every North American textbook of physical geology or rock mechanics. Recent investigations have increased our knowledge of the geological factors contributing to the occurrence of the landslide, but what triggered its motion and what explains its travel across the valley floor is still being discussed. Terminology follows the Transportation Research Board's (Cruden and Varnes, 1996).

Frank Slide Interpretive Centre

The Frank Slide occurred at 4:10 on the morning of April 29, 1903. An enormous wedge of rock moved down the east face of Turtle Mountain, across the entrance to the Frank Mine of the Canadian American Coal and Coke Company and the Crowsnest River, obliterated the southeastern end of the town of Frank, and buried the main road and Canadian Pacific Railway through the Crowsnest Pass. Rising ground to the east absorbed the momentum of much of the debris, but huge boulders of limestone covered the Lille spur railway line then under construction in the lower valley of Gold Creek. In about 100 seconds, 3 km$^2$ had been submerged by an average of 14 m of rubble. Thirty million m$^3$ of rock had moved. Dust thrown up from the debris caused violent electrical discharges during the landslide and settled like a pall over the valley. At least 70 people were killed (Kerr, 1990). A death toll of 83 with 23 injured is documented by Anderson (1986).

The high bedrock bench on which the Interpretive Centre stands is one of the few localities, all elevated, where the debris has a sharply defined edge of boulders. Below the bench, to the left and east, the deposit has two edges. The outer one is steep but not much over 1 m in height. Inwards is a low area with small, frequent hummocks about 1 m high and littered with scattered boulders. The dense cover of brush and tress indicates a substantial proportion of fines in the debris. This is the "splash area", up to 100 m wide, hypothesized to have formed as the more fluid fines at the base of the debris ran ahead of the coarser material, which was left behind to form a second scarp up to 8 m high (Cruden and Hungr, 1986, and Figure 16).

So the steep lateral margins of the slide described by McConnell and Brock (1904, p. 9), and taken by Shreve (1968, p. 38) to be evidence of debris transport on an air cushion, are probably caused by this marginal high ground catching only the uppermost layers of the moving material. W. Pearce, Chief Inspector of Surveys, Department of the Interior, who interviewed survivors and eyewitnesses only a few days after the event, commented: "There was apparently no very great rush of wind with the slide except immediately in front of it.... On the edge of the slide, some very peculiar movements are discernible. Thus a portion would strike a bank or ridge and would curve off to one side or another until its course would be deflected perhaps 120° from its original direction. This and the action which this deflection took in the way of throwing mud, gravel and sticks...led many to believe that a large amount of this slide had been hurled through the air" (Pearce, 1903, p. 490). However, McConnell and Brock (1904, p. 7) stated that
survivors of the event described the noise of the slide as "resembling that of steam escaping from under high pressure".

Figure 15. Map of the Frank Slide and its vicinity from McConnell and Brock (1904).

Returning to Highway 3 from the Interpretive Centre and turning south for 300 m brings a closer view of the structure of Turtle Mountain.
The Canadian Department of the Interior's Report attributed "the primary cause" of the slide to "the form and structure of Turtle Mountain (McConnell, Brock, 1904, p. 17). Interpretation of the bedrock structure has changed since the Report, but the basic conclusion has not. From this site, the structure of Turtle Mountain can conveniently be reviewed.

This structure is summarized in Figure 17, a vertical section across the north-south trending ridge. The beds of limestone that form the ridge have been folded into a great arch, the Turtle Mountain Anticline, and thrust eastwards along the Turtle Mountain Thrust Fault during the Rocky Mountain orogeny (Norris, 1993). They now overlie vertical to over-turned, younger, coal-bearing rocks. In the area of the slide, the east limb of the anticline moved out along a splay of the fault upslope from the coal mine (Cruden and Krahn, 1977).

Looking south from the highway sign, some of the structure shown in Figure 17 may be seen in the eastern flank of the mountain where it slopes precipitously from South Peak, the prominent summit to the left. The crest of the Turtle Mountain Anticline is about 50 m below South Peak. Limestone beds dipping eastwards, parallel to the slope and partially exposed by removal of the slide mass, can be followed almost to a distinct break in slope below the trace of the Turtle Mountain Thrust. Immediately above the break in slope, the limestones are over-turned and dipping westwards. The splay of the Turtle Mountain Thrust, which formed the toe of the rupture surface of the slide, is not exposed beyond the south margin of the slide. The splay can be seen at the north margin, better viewed from Stop 3.

It is apparent that the bulk of the displaced material, mainly Palaeozoic carbonates of the Livingstone Formation, moved on steeply eastward-dipping bedding planes, rather than on joint planes and across the bedding as McConnell and Brock (1904, p. 12) suggested. Joints probably controlled the form of the scarp and crown of the slide.

Reconstruction of the Canadian Pacific Railway line required a deep cut visible to the south through nearly the full depth of the displaced material. Assuming the surface of separation is within 2 m of the new track, the maximum thickness here is about 20 m, 6 m more than the estimated average for the slide. The section shows a distinct upward coarsening of the displaced material.

Cruden and Hungr (1986) have distinguished "base" material identifiable in at least the lowest 5 m of the cut. This sandy gravel is made up dominantly of angular limestone fragments and contains only a few boulders. Occasional rounded pebbles, probably derived from till or Crowsnest River alluvium, and traces of dark, organically-stained sand have been found. Grain size distributions of the base material are similar to those of sediment in the splash areas, which also contains rounded pebbles. Clearly the rock displaced in the landslide-eroded soil and the river gravels as it traversed the valley floor. So this flow of rock was in contact with the ground along, at least, part of its path.
Figure 16. Splash areas of the Frank slide deposits Numbers 1-4 are locations of molards.
The coarsest displaced material is at the top of the cut, dominated by boulders, which form the surface of the accumulation. Such reverse grading has been observed in some debris flows and may be a consequence of dispersive pressures in the flows. Other sedimentary structures, molards, conical mounds of displaced material, were illustrated by McConnell and Brock (1904, Plates 9 and 10) and located by Cassie et al. (1988). They can be glimpsed on the way to Stop 3. They are a later stage in the size segregation processes shown in the cut (Figure 16).

To reach Stop 3, continue eastwards on Highway 3 for 2 km and turn right on the road to Hillcrest. Immediately after the level crossing of the Canadian Pacific Railway, 0.5 km down the Hillcrest road, and before the bridge over the Crowsnest River, take the right turn signposted "7 Avenue". Follow this old highway for 2 km past abandoned lime kilns to the right at 0.8 km and into the slide debris.

Following reports in 1930 of movements from the South Peak of Turtle Mountain, the Provincial Government offered residents half the cost of moving their homes to new sites away from the southern margin of the slide. The Government also relocated Highway 3 to its present position to the east of the railroad, (Allan, 1933).

**Crest of Old Road through the Slide Debris**

From here, we can see the abandoned approach to the Frank Mine, on the west bank of the Crowsnest River just above river level, at the northern edge of the slide (Fig. 4). Mining was from a horizontal adit into the near-vertical seam and drew down coal from large rooms extending upwards to within 10 m of the ground surface. The displaced material moved rapidly over the limits of the mine but apparently damaged only the surface and near-surface workings.

Men working inside the mine during the landslide recalled to McConnell and Brock (1904, p. 7) that although some coal was dislodged, no really significant movement of the mine workings occurred. Discovering the mine entrance to be blocked by debris, they dug their way to the surface through an up-raise. Production was resumed shortly after the landslide and continued until 1918. The subsidence visible on the south margin of the slide clearly post-dates deposition of the debris. The last episode of mining extended the underground workings more than 2 km beyond the south margin of the slide.

There was considerable controversy at the time about the role of mining in triggering the movements (Pearce, 1903). A more recent analysis suggested that the movements resulting from mining were not likely to have been significant factors in the slide. Reasonable assumptions about rock mass strength in the slope before mining now indicate that it was unstable even then (Cruden and Krahn, 1977).

At the north margin of the landslide, the belt of minor folds forming the "contorted beds" noted by McConnell and Brock (1904, p. 15) can be clearly seen (Fig. 4). Its upper margin is the splay of the Turtle Mountain Fault, which can be followed northwards into a talus beyond the north margin of the slide. Immediately above the talus is the "hoodoo area" of McConnell and Brock (1904, p. 15). The hoodoos are isolated blocks of the muddy carbonates of the Banff Formation, which dip westwards and stratigraphically underlie the limestones of the Livingstone Formation.
The peculiar pattern of weathering is caused by intense deformation around the fault and in the hinge zone of the Turtle Mountain Anticline. The crest of the Anticline in the Banff Formation is about 50 m higher. Clearly, the anticlinal crest is plunging northwards, and the east limb of the Anticline is not exposed to the north. The mass of light grey weathering limestone protruding from the talus is overturned westerly dipping Livingstone Formation, deformed in the thrust slice above Turtle Mountain Fault, which also plunges northwards.

![Diagram of Turtle Mountain and surrounding geology](image)

Figure 17. Cross section along the line shown in Figure 15.

Continuing north, the old highway passes over the buried channel of Gold Creek, by a memorial to the slide victims and then over the diverted Gold Creek brings us, after 1.2 km, onto Dominion Avenue, former main street of the original town of Frank.

**Northeast End of the Old Town of Frank**

The antique fire hydrant immediately west of the road here may have been illustrated in McConnell and Brock's report (1904, Plate 5). Basements of buildings along Dominion Avenue are the only other obvious remains of the old townsite. At the recommendation of the Commission of 1911 (Daly, Rice and Miller, 1912), most of the buildings were moved to the
present townsite north-east of the highway. The Commission believed that the geological structure of Turtle Mountain was essentially similar in sections through the South and North Peaks and north of the North Peak. Because slopes are steeper north of the North Peak, slide risk was assumed to be greater there.

The monitoring program begun in 1933 has established that rock falls from the crown of the slide continue. A recent upgrading of the monitoring network made large-volume movements from the South Peak more perceptible, (Kostak, Cruden, 1990). Rates of movement are less than a millimetre a year.

Some of the natural processes that contributed to the slide – the destruction of cohesion along bedding planes by limestone solution and by freeze and thaw weathering, for instance – have probably been accelerated by the movement-induced fracturing of rock in the crown of the slide. Other processes, such as the removal of lateral support for the rock mass by slush avalanches down the steeply inclined gullies on the east face of the mountain, are probably less important because the slide itself reduced the mass requiring support.

The major source of concern today is the possibility of a sudden collapse of the 1903-1918 workings of the abandoned Frank mine. The 2 m or so of horizontal movement that might take place could be transferred up the slope and result in some loosening of rock around the South Peak, triggering further movements. The fire burning in the mine in 1918 has probably been extinguished.

Continuing north westwards, Dominion Avenue crosses the Canadian Pacific Railway tracks and rejoins Highway 3,200 m north of the Gold Creek Bridge.

**Review**

At least two aspects of the Frank Slide remain incompletely understood. First, the trigger that set the landslide in motion has not been positively identified. Mining at the base of Turtle Mountain may not have been the direct cause of the slide, the literal trigger, although removal of a large volume of coal must have lead to a further weakening of an already unstable structure. A small earthquake, undetected by the sparse seismic network then in operation, might have provided the trigger. But there were no reports of earthquake activity in the area on the morning of April 29, 1903.

A more likely cause was the local weather. As noted by McConnell and Brock (1904, p. 14), "The night of the slide was excessively cold.... Those outside say the temperature was down to zero (°F). The day before and the preceding days had been very hot, so that the fissures in the mountain must have been filled with water..."Since the month of March, 1903, had been wet in the southern Alberta Rockies, a probable source of the water was copious melt from a heavy snowpack on Turtle Mountain. Given appropriate meteorological conditions, deep freezing might have produced sufficient stresses within the fissures to have wedged or pried loose a large prism of rock. Indeed, McConnell and Brock concluded (1904, p. 17): "The heavy frost on the morning of the slide...appears to have been the force which severed the last thread and precipitated the unbalanced mass."
Figure 18. Sketch of the slide scarp from the old road through the debris.

Second, the mechanisms of movement that enabled the landslide to spread so widely have been the subjects of considerable discussion. McConnell and Brock (1904, p. 17) wrote: "The motion of the slide was complex in detail, but as a whole resembled that of a viscous fluid." They also stated (p. 8) that a shelf of rock in the basin of the slide apparently "...hurled most of the material over the coal mine at the base of the mountain into the river bed, or beyond."

The 1995 Learning Channel/BBC TV video variously titled "Runaway Mountains" or "Landslides" has illustrated the ways large landslides are believed to travel. Melosh (1987) and Campbell et al. (1995) have provided more rigorous reviews. Van Gassen and Cruden (1989) demonstrated that "An assumption of 30° for the friction angle of the (land)slide debris reproduces the debris profiles generated by...the Frank Slide and "the problem of the extreme mobility of some dry rock-fall debris flows appears to be solved". The reviewers don't disagree.

In retrospect, controversy arose from the assumption that the behaviour of many millions of colliding rock fragments could be represented by the movement of a single fragment as Heim (Skermer, 1989, p. 126-135) had suggested. Heim's visualization of the motion of the displaced mass of a rock avalanche described a process very different from the single sliding block his mathematics contemplated.

"The highest detached block wants to be foremost. It rushes and hits one detached a little further down that blocks its way. The exact amount of kinetic energy that the first block has over the second is lost in the contact with the second, and the first one stays behind. It remains in this position; it cannot overtake the second one. Thousands and thousands of times this behaviour is repeated in the rubble stream. No rock is independent: all are united in the shooting stream, and have to abide by the order imposed by their common assault. But this does not mean that the additional potential energy of the higher fall has been lost. It was transmitted further a field."
The whole body of the plunge stream is filled with kinetic energy to which each rock has added its share." (Skermer, 1989, p. 99).

New formulations of the differential equations of particle motion (Van Gassen and Cruden, 1989) and sophisticated computer simulations (Campbell et al., 1995) allow a much closer approach to Heim's vision of rock particle motion. It may be true enough.

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