GeoTour Guide

for the East Kootenay, British Columbia

Geology, Landscapes, Mines, Ghost Towns, Gold, Dinosaur Tracks, and Hot Springs

Geological Survey of Canada Open File 6477, British Columbia Geological Survey Geofile 2010 - 07

R.J.W. Turner and R.G. Anderson, Geological Survey of Canada; R. Franklin, D. Grieve, BC Ministry of Energy, Mines, and Petroleum Resources; Cranbrook; R. Franklin, North Saanich

East Kootenay Chamber of Mines

TGI 3 Cordillera

Fort Steele Heritage Town

Fernie Museum

British Columbia Ministry of Energy, Mines and Petroleum Resources

Natural Resources Canada

Ressources naturelles Canada

Cover (Figure 1). Highway 93/97 in the Rocky Mountain Trench north of Fort Steele. Billion year old rocks in the Purcell Mountains rise above wetlands on the floodplain of the Kootenay River.

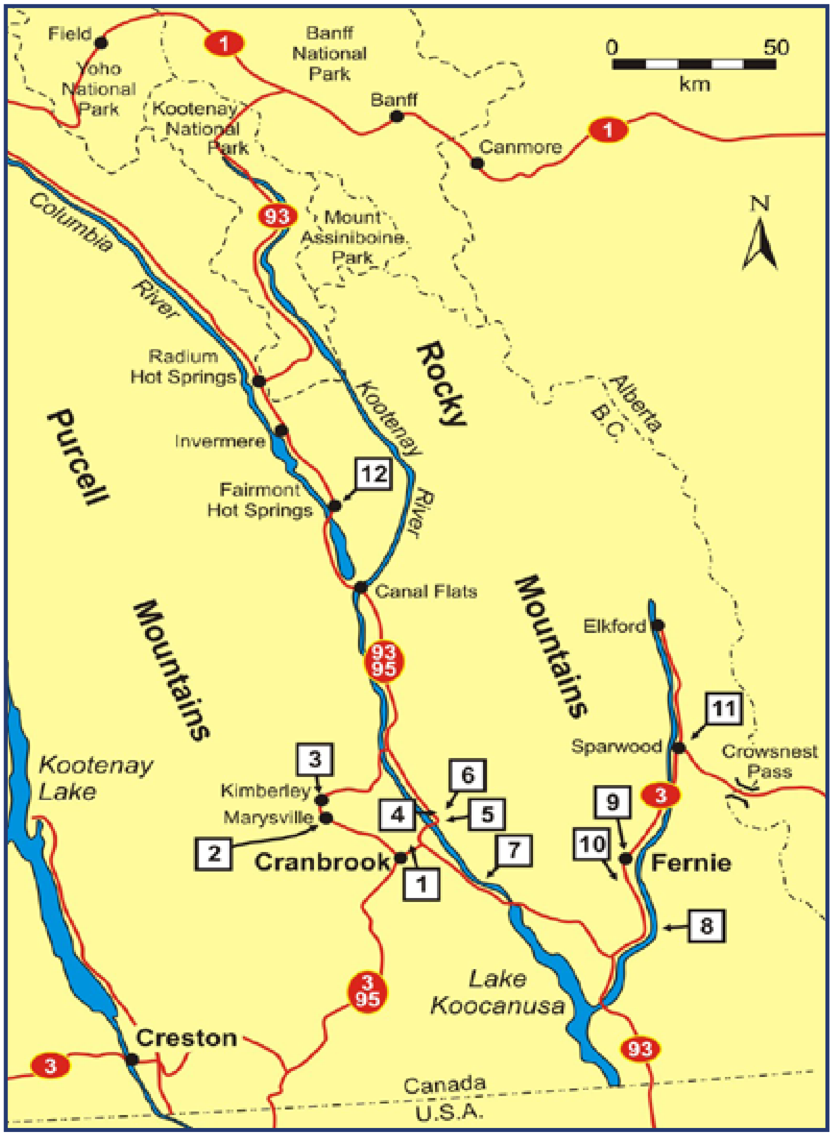


Figure 2. The location of GeoTour sites in the East Kootenay region.

GeoTour Guide Sites

1. **Eager Hills Trail and Lookout** – A big view of the big valley.
2. **Marysville Falls Walk** – BC's oldest seafloor.
3. **Sullivan Mine Tour** – The richest hill in BC.
4. **Fort Steele Heritage Town** – built on an ancient river bed.
5. **Wild Horse River Viewpoint** – Reading the mountains from river gravels.
6. **Wild Horse River Historic Site** - Ghosts of a gold rush .
7. **Norbury Lake Provincial Park** – Two curious lakes.
8. **Highway 3 Tunnel Pullout** – Where limestone peaks meet hills of coal.
9. **A Walking Tour of Fernie** – Geological stories in a heritage coal-mining town.
10. **Fernie Alpine Resort** – How the mountains come to be.
11. **Elk Valley Coal Mine Tour** - How BC's energy giant formed in the footsteps of dinosaurs.
12. **Fairmont Hot Springs** - Mysterious waters from the deep Earth.

East kootenay – A Landscape Full of Questions

__Figure 3.__ A collage of East Kootenay scenery and features. ***(Top Left)*** *Pinnacle-like hoodoos rise near Fairmont Hot Springs (Photograph by R. Anderson).* ***(Top Right)*** *The Rockies rise above Rocky Mountain Trench grasslands east of Kimberley.* ***(Middle left)*** *The bright green waters of Peckham's Lake.* ***(Middle Right)*** *The Lizard Range at Fernie.* ***(Bottom Left)*** *Trilobite fossil in East Kootenay rock that once was ancient sea floor.* ***(Bottom Middle)*** *Greenhills coal mine near Elkford.* ***(Bottom Right)*** *Fort Steele Heritage Town.*

East Kootenay is a landscape full of contrasts: from dry grasslands of the Rocky Mountain Trench to high glacier peaks of the Purcell and Rocky Mountains; and from the big Kootenay River and great forested valleys to desert-like hoodoos near Fairmont and Kimberley.

To the curious mind, the East Kootenay is also a landscape full of questions. Why is the East Kootenay mountainous, while nearby Alberta is flat? Why are fossils of ancient sea life found high on mountain peaks? Why are some lakes so green? Where was the gold rush that created Fort Steele? Why do they find dinosaur footprints in coal mines near Sparwood? Why does the East Kootenay have so many hot springs? What wealth financed the fine heritage buildings in Fernie?

This guide explores these and other questions. Is there logic to the landscape? Can geologists explain some of these puzzles? Let's go take a look!

FIRST, LET'S TALK GEOLOGY

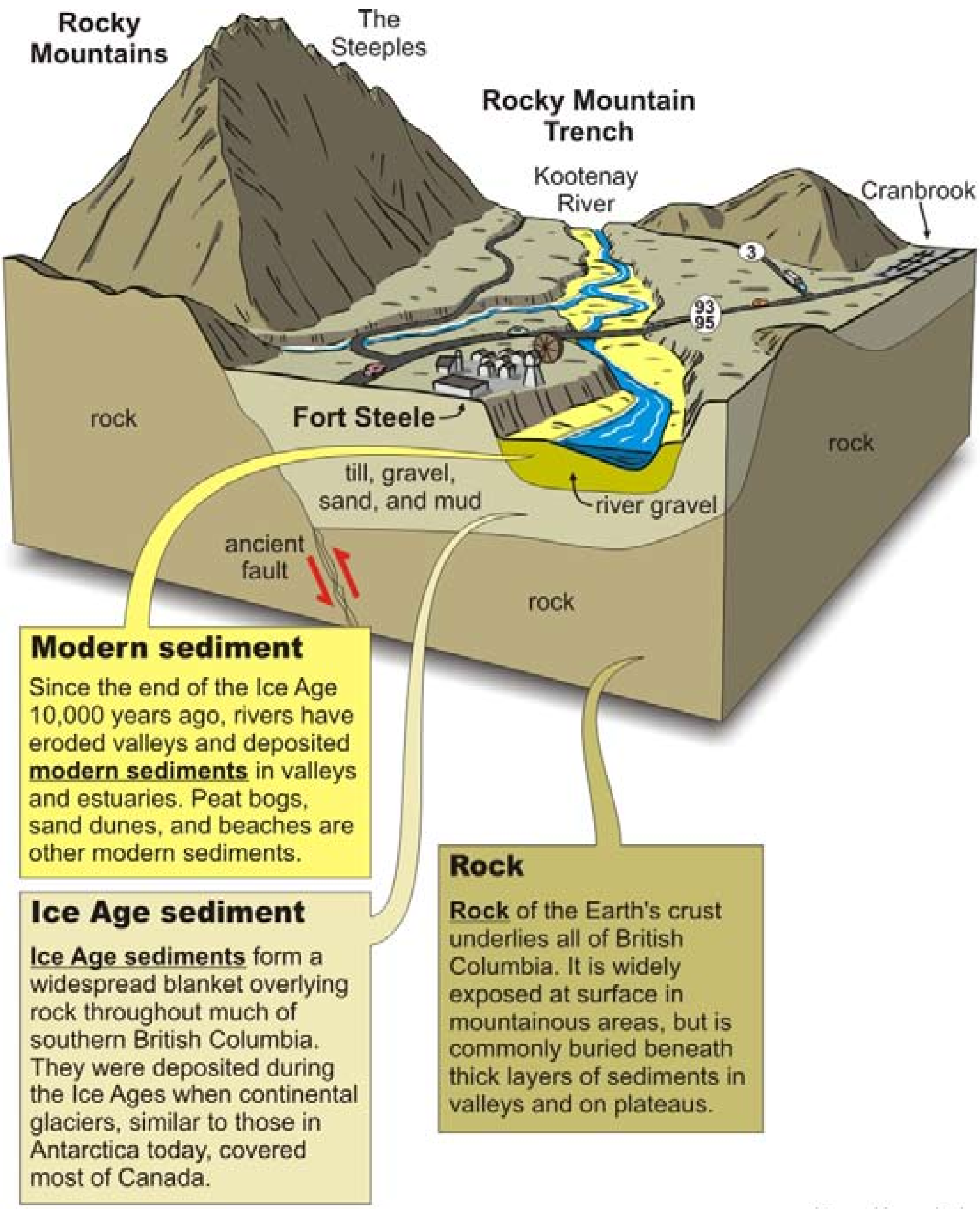


Figure 4. *This diagram of the Fort Steele and Cranbrook area illustrates the typical distribution of three main geological materials in the East Kootenay.*

WHAT'S UNDER THE FORESTS AND SOIL?

The geological materials that underlie the East Kootenay, as well as all of British Columbia, fall into three basic types (Figure 4). ***Rocks*** of the Earth's crust underlie the entire East Kootenay and are commonly exposed in mountain peaks, rocky cliffs, river canyons, and in rock cuts along highways. ***Ice Age sediments***, deposited during the Ice Ages, form a widespread blanket that covers much of the underlying rock. This blanket is typically thin on mountain slopes and thick in valleys. Over the 10,000 years since the end of the last Ice Age, rivers have eroded valleys into rock and Ice Age sediments and deposited ***modern sediments*** of sand, gravel, and mud as river plains, river bars, and beaches.

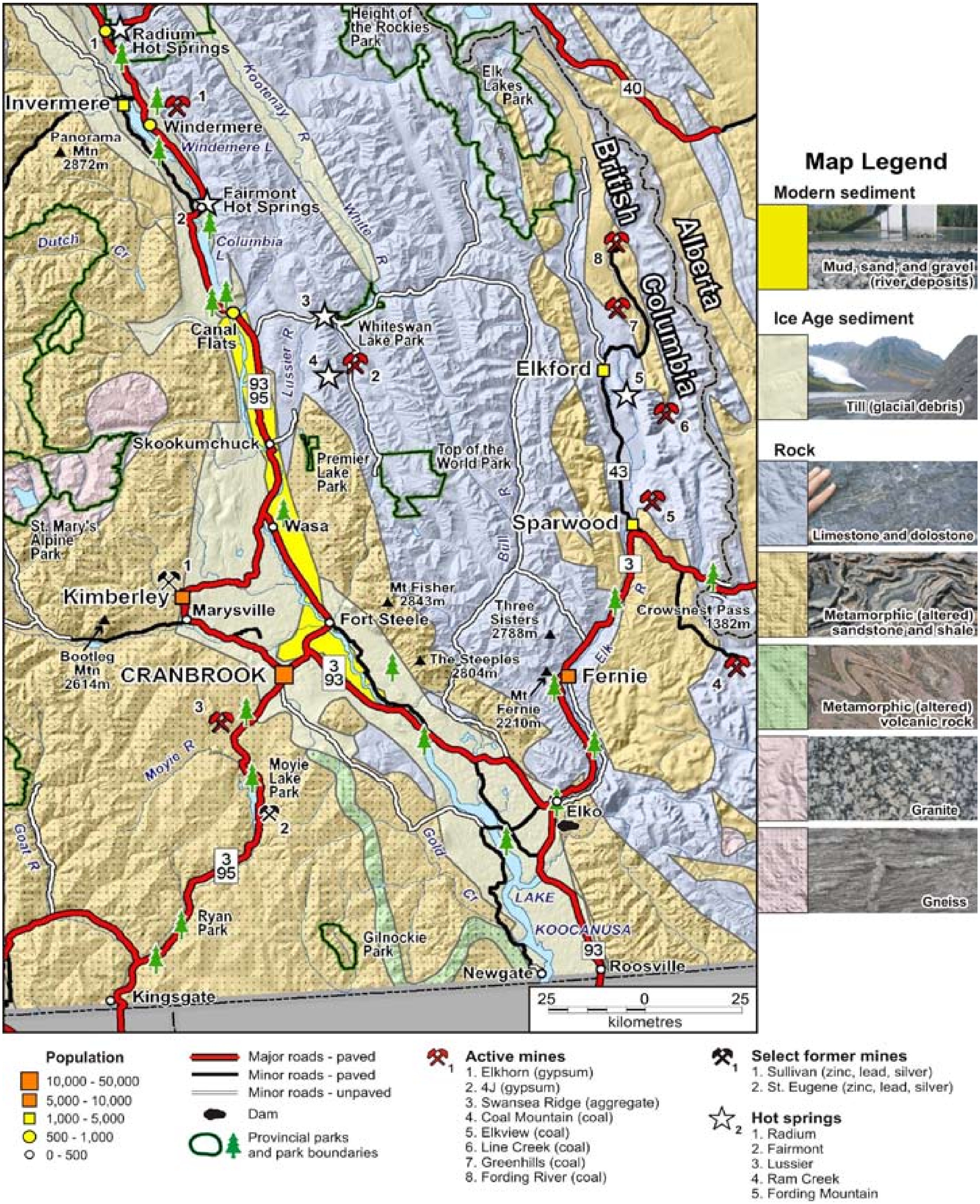


Figure 5. *This is a map of the geological materials that underlie the forests and soils of the East Kootenay. Highway 93 follows the Rocky Mountain Trench, the biggest valley in the region. The Trench contains extensive deposits of Ice Age and Modern sediment. Metamorphic (altered by high temperature and pressure deep in the earth) sandstone and shale shown in stippled gold underlie much of the area west of the Trench, while limestone (blue) and sandstone and shale (gold) dominate the Rocky Mountains to the east.*

HOW DID ALL THESE GEOLOGICAL MATERIALS FORM?

A QUICK TOUR THROUGH GEOLOGIC TIME

How old is the East Kootenay? There are several answers to that question. We know that European settlement of the East Kootenay goes back to the mid 1800s. First Nations settlement in the region is much older and goes back thousands of years. The land however is much, much older – millions and billions of years in fact. We're talking deep time; a span of time that challenges our comprehension and that contains a quite fantastic history. What follows is a brief summary of that geological history of the East Kootenay, pieced together by the work of geologists over the past century.

The region is carved from a mosaic of diverse geological materials illustrated in Figure 5. The clock in Figure 6 reminds us that each material in this mosaic has a unique age and that the entire story ranges across more than 1.4 billion years of time.

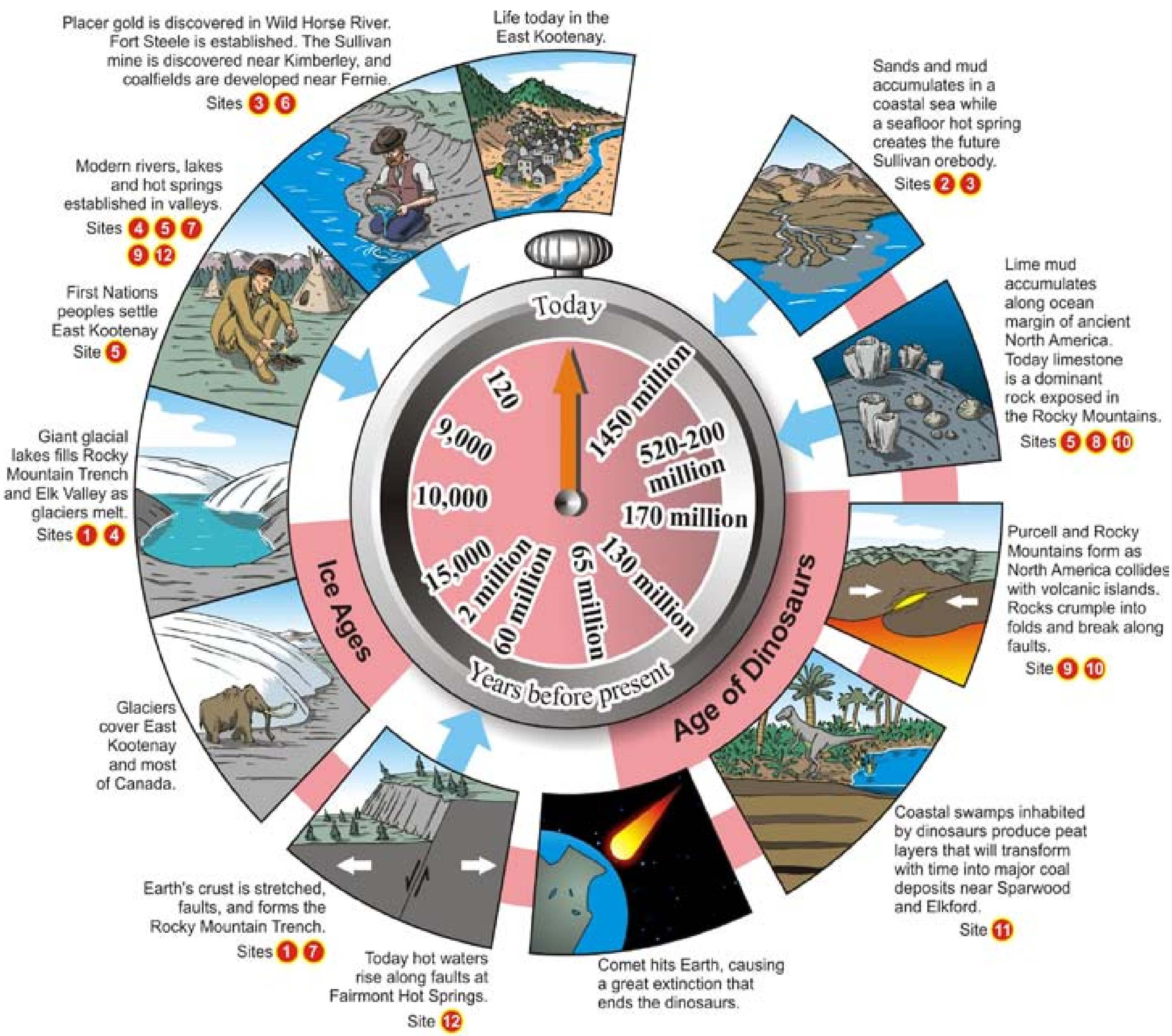


Figure 6. *This geological history of the East Kootenay region is presented as a clock. Note that equal divisions of the clock face represent highly unequal periods of time. Each geological material has a history of formation. Geologists use fossils and radioactive elements contained in each geological material to determine its age. Much of this ancient history has been destroyed by erosion over geological time, leaving many gaps in our understanding.*

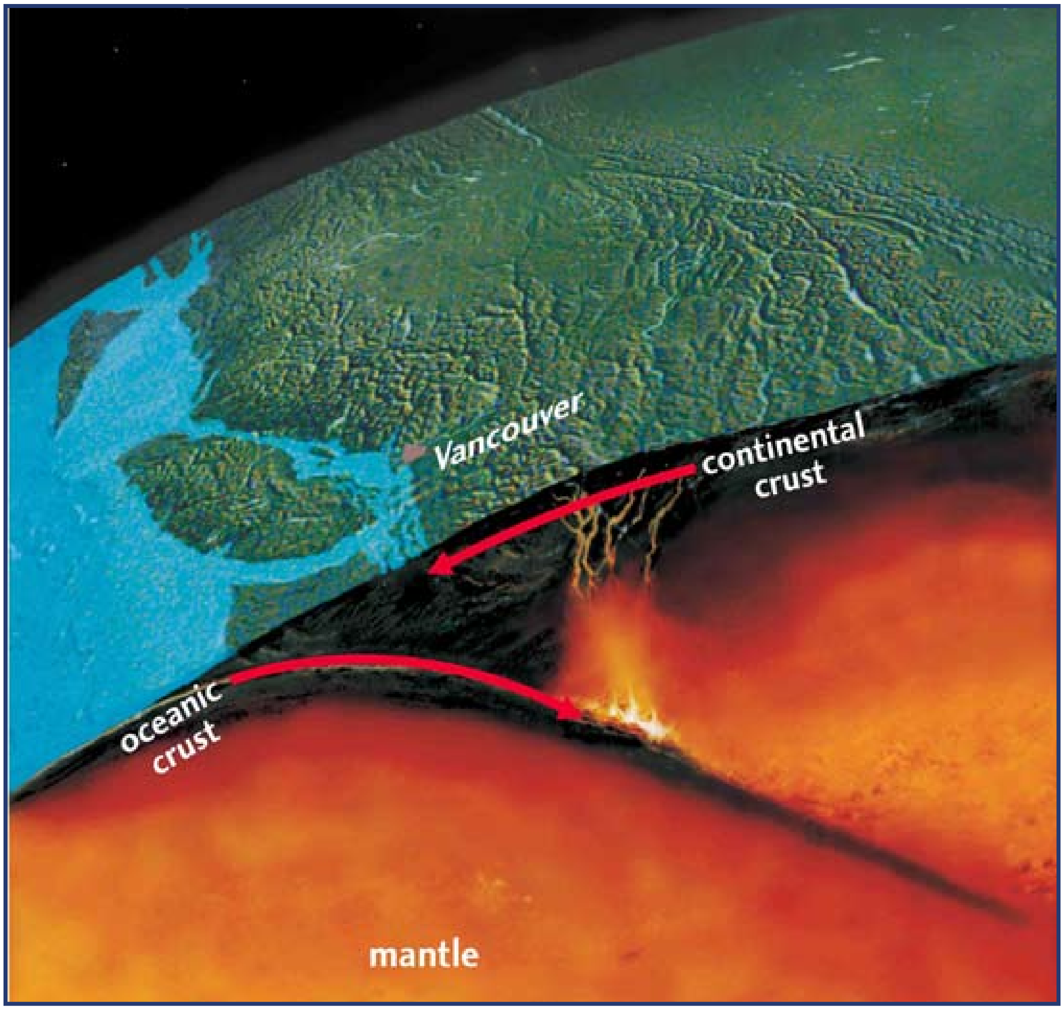


Figure 7. Coastal British Columbia sits above a collision zone between two tectonic plates.

COASTAL BC IS A COLLISION ZONE

We all know that British Columbia lies along Canada's West Coast. But coastal British Columbia is also at the leading edge of the westward-moving North American tectonic plate. This is one of many vast plates, each tens of kilometers thick and thousands of kilometers broad, that make up the segmented rigid skin of our planet. Driven by flow in the Earth's mantle, the North American plate, with British Columbia as part of its leading edge, is overriding the oceanic plate at the toe nail-growing speed of 4 cm per year. This is a slow-moving collision that has created and continues to create the mountains, earthquakes, and volcanoes for which coastal British Columbia is known.

When you next visit Vancouver, consider this thought. Seventy kilometers below your feet, former Pacific Ocean seafloor and underlying oceanic plate is slowly moving eastwards on a downward dive into the mantle. The rock you stand on, part of the North American plate, is in compression and periodically faults slip under the stress. Earthquakes are the creaks and groans of this collision. Caught in this tectonic vise, the compressed edge of North America landmass rises. Rivers and glaciers, relentless carvers of the landscape, have cut valleys that create the mountain scenery. Deep below, the descending oceanic plate transforms under pressure, releasing liquids that melt adjacent rock. Liquid rock works its way to the surface, erupting as volcanoes. Rising heat warms the North American plate in the process, expanding the crustal rocks and adding to the rise of mountains.

COLLISION BUILT BC

The collision taking place below coastal British Columbia today has been going on for the past 170 million years. Over this time, the North American plate has been pushing westwards, driving over tens of thousands of kilometers of oceanic plates. Volcanic islands built on those oceanic plates have collided with, and been plastered to, this moving front of North America. These plastered bits of volcanic islands have added land, extending North America's land mass westwards. This 'new' land includes most of what we today call British Columbia.

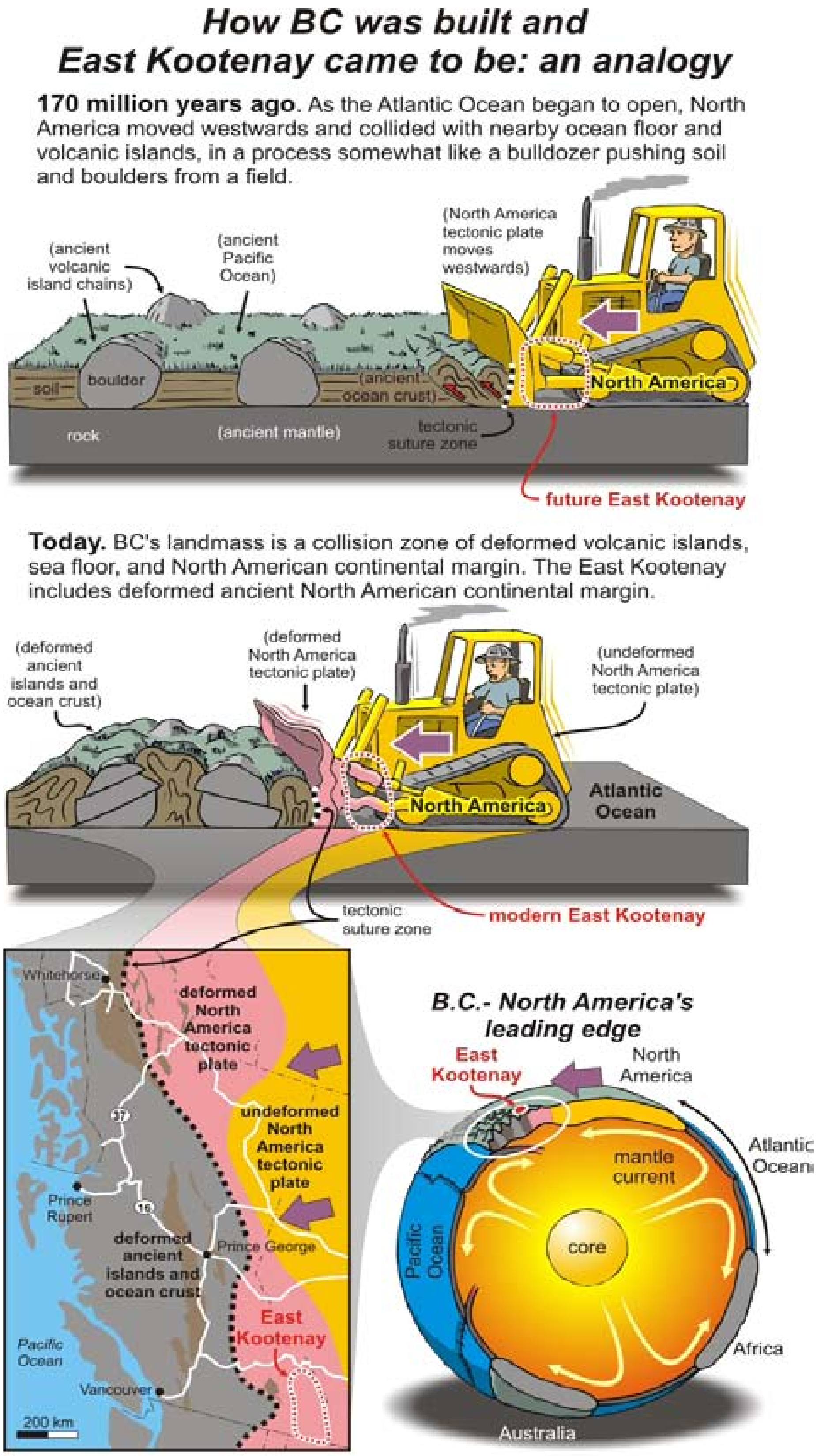


Figure 8. Here is an analogy for the ancient origin of British Columbia. A tractor is plowing a field with scattered boulders. The tractor represents the North American plate, the soil is ocean floor, and boulders are volcanic islands. As the tractor moves forward, its blade pushes together soil and boulders, deforming the soil and breaking the boulders. The tractor blade is also damaged. The rock of modern British Columbia represents the combination of broken boulder, deformed soil, damaged blade, and tractor

The rocks of the East Kootenay are a part of the ancient North American plate that collided with offshore islands and ocean crust. The layered rocks that had been deposited on the seafloor along the edge of the continental margin for over half a billion years were broken and folded during tectonic collision to create the Purcell and Rocky Mountains. Today, the tilted and folded layers of these rocks are visible in the high peaks of the Rockies (Figure 9).

First, let's consider the seafloor sediments deposited off the shores of ancient North America. The high peaks of the Purcell Mountains west of the Rocky Mountain Trench are carved from sandstone formed almost 1.5 billion years ago. The Sullivan mine and Marysville Falls occur within these rocks (Sites 2 and 3). A younger belt of limestone, sandstone, and shale make up the Rocky Mountains further east, and these rocks formed from 550 to 125 million years ago. Limestone mountains near Fernie (Sites 8, 9, and 10) and the coal mines near Sparwood (Site 11) occur within these rocks.

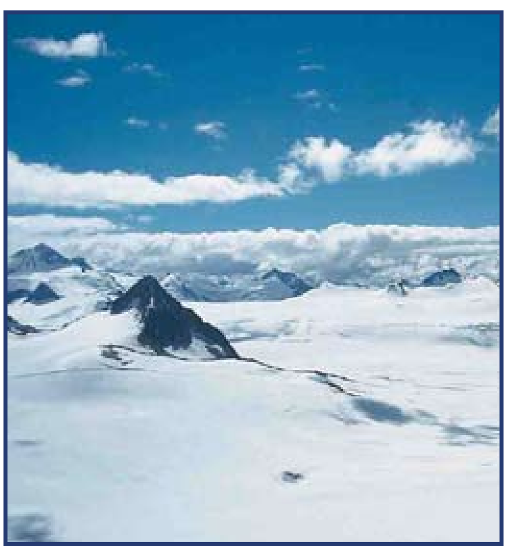
Figure 9. ***(Top left)*** *Folded limestone strata north of Greenhills coal mine, Elkford are a testament to the Earth forces that created the Rocky Mountains.*

(Top right) *A fossil of a coral, found in rock high in the Rocky Mountains, attest to the fact that most of the Rocky Mountains were once seafloor but have been raised thousands of metres during mountain-building.*

THE BIG CRUNCH

One hundred and seventy million years ago, the western edge of North America started to collide with offshore volcanic islands and seafloor (Figure 8). Today, the boundary between ancient North America and these offshore rocks lies west of East Kootenay near Kootenay Lake and the town of Nelson. This collision welded these rocks to North America, adding landmass and causing North America's coastline to jump westwards. A high plateau rose as the rock was squeezed into folds and broken by faults. This collision was slow and lengthy – at the toe-nail growing rate, but it continued for millions of years. Former continental margin seafloor was squeezed and piled into a thick stack of fault-bound slivers, creating a mountain belt 200 kilometres narrower than the continental margin from which it formed.

For millions of years erosion carved the mountains, deepening valleys. Then fifty million years ago, the land pulled apart along great north-trending faults, creating long trough-like valleys. Largest of all was the great valley of the Rocky Mountain Trench (Site 1). No where is this fault scarp more dramatic than east of Cranbrook near Norbury Lake Provincial Park (Site 7).



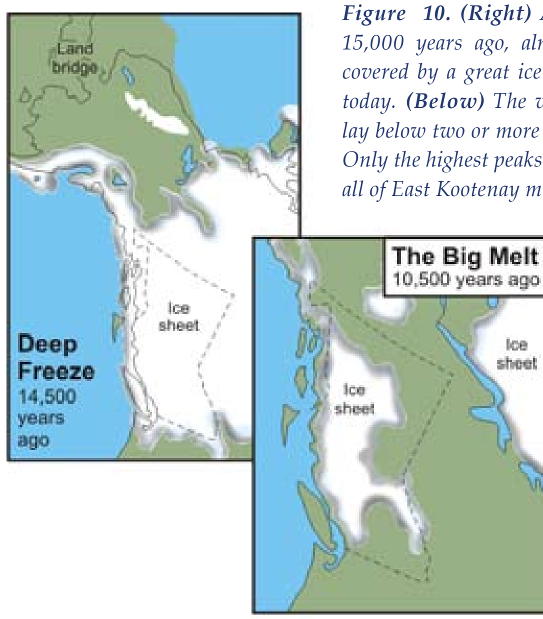
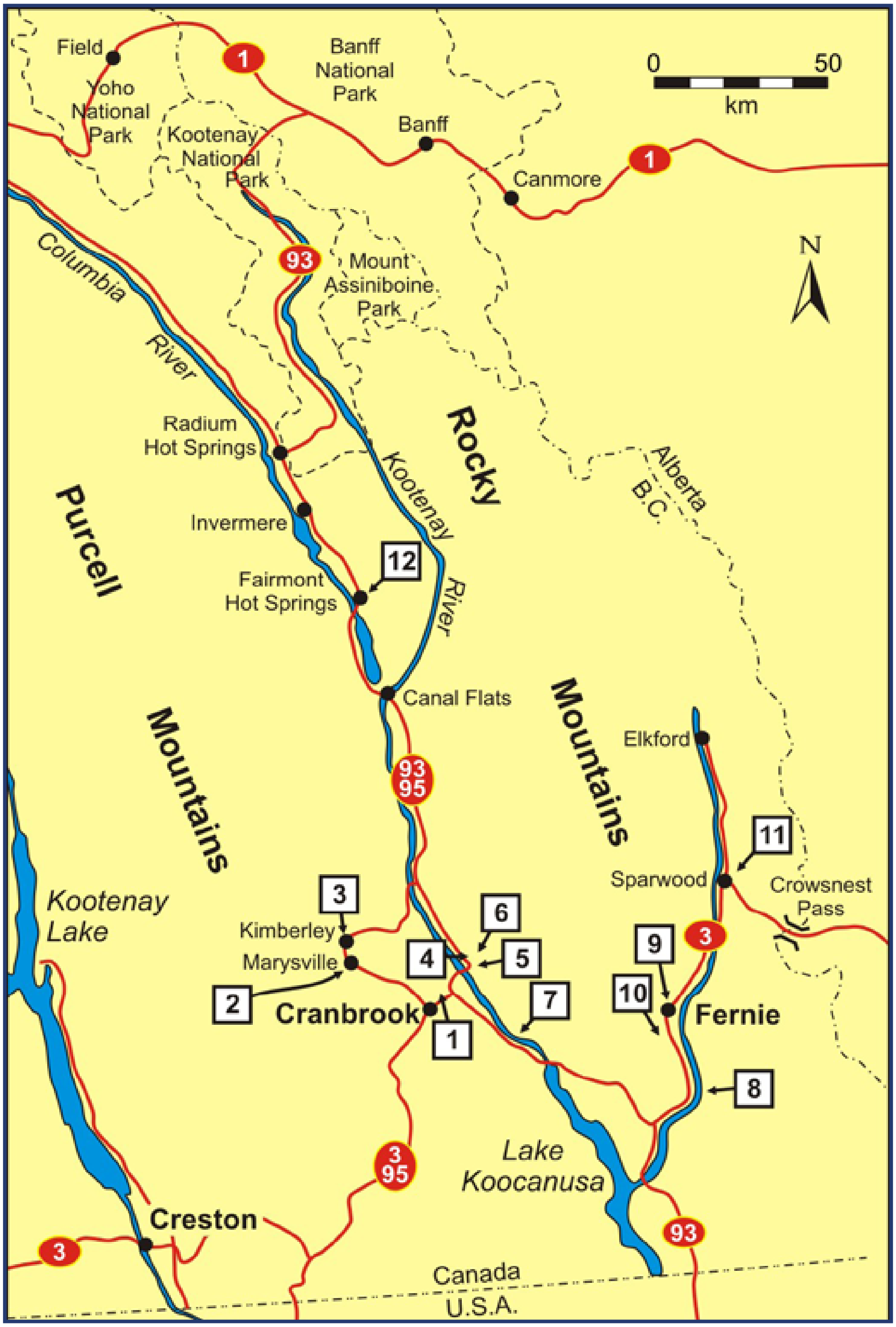


Figure 10. (Right) *At the peak of the last ice advance 15,000 years ago, almost all of British Columbia was covered by a great ice sheet similar to that of Greenland today.* ***(Below)*** *The valleys of the east Kootenay region lay below two or more kilometers of south-flowing glacier. Only the highest peaks poked above this vast ice cover, and all of East Kootenay must have looked similar to ice fields in today's highest mountains (Photograph courtesy of J. Clague).*

THE BIG FREEZE

During the Ice Age, glacier ice further carved and deepened these valleys, rounding the tops of hills and lower mountains. Only the highest peaks that poked up above the 2 km thick glacier retained their craggy profile. As the glaciers melted, lakes formed where plugs of glacier ice and local glacial debris dammed the valleys. Plants and animals re-colonized the land as the glaciers melted, and First Nations peoples followed, hunting game, foraging plants, and fishing for salmon. Settlers came later, first as fur traders and prospectors, and later as miners, farmers, and business people, building the villages and towns of the East Kootenay.

A QUICK PREVIEW OF THE GEOTOUR



Our GeoTour starts with a great view of valley and mountains near Cranbrook (Site 1). We then head west to nearby Kimberley to view BC's oldest seafloor rocks and tour the former giant Sullivan mine (Sites 2 and 3). Site 4 is Fort Steele Heritage Town, rich with gold rush history. Nearby are two stops on Wild Horse River that examine river gravels, and the gold rush ghost town of Fisherville (Site 5 and 6). The Fort Steele-Wardner Road takes us to beautiful Norbury Lakes Provincial Park below a great mountain wall (Site 7). Rejoining Highway 3, we enter the Rocky Mountains through a narrow gap in a ridge of limestone (Site 8). At Fernie, we walk the historic downtown and along the Elk River (Site 9). Fernie Alpine Resort provides us a hike in the alpine with panoramic views (Site 10). Further east at Sparwood, there are tours to arrange of Elk Valley coal mines (Site 11). Returning once again to Cranbrook, we head north on Highway 93/95, to our final stop at the intriguing Fairmont Hot Springs (Site 12).

Figure 11. A map of the East Kootenay with the location of GeoTour sites.

(Site 1) Eager Hills Lookout: the Big View of the Big Valley

The Rocky Mountain Trench is the biggest valley in the East Kootenay, home to many of its communities, and a vital transportation corridor. So we start our tour here.

THE VIEW FROM THE TOP

The lookout at Eager Hills lies just east of Cranbrook and has a lovely walk up a open grass slope to the top. There are views of the Rocky Mountain Trench, Rocky Mountains, and Purcell Mountains. Together, these are the three major geographic and geologic elements of the East Kootenay region.

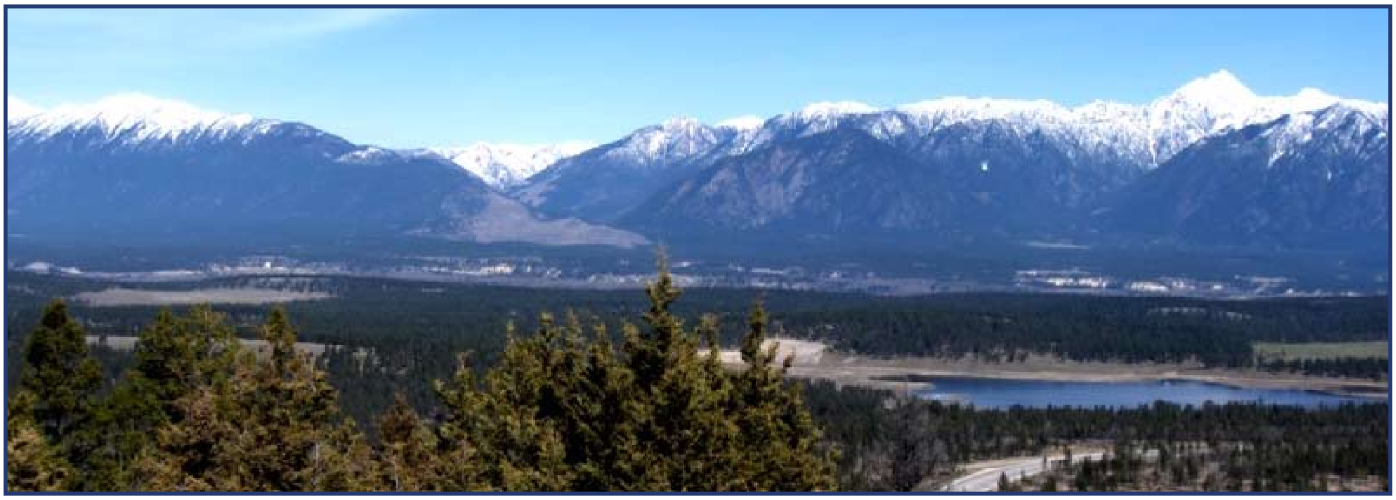


Figure 12. (Above) *View to the east across Rocky Mountain Trench to the Rocky Mountains. The valley floor is underlain by Ice Age sand, gravel, and clay (Photograph by D. Grieve).*

Figure 13. (Left) *View to the southeast across the Rocky Mountain Trench to the Steeples, part of the Rocky Mountains. The steep mountain wall was created by fault movement that uplifted the mountains and lowered the valley.* ***(Below)*** *View to the north across the St. Mary River valley (left) and the Rocky Mountain Trench (centre) to the Purcell Mountains (left) and Rocky Mountains (right). The junction of the St. Mary River valley and Rocky Mountain Trench has created abroad lowland. Photographs by D. Grieve*

FAULTY HISTORY OF THE BIG VALLEY

The Rocky Mountain Trench is North America's longest valley, extending from Alaska to Montana. It is a geographic feature large enough to be seen from space. Much of the valley was formed by fault movement 10 to 50 million years ago when the crust of British Columbia stretched and broke along faults. Near Cranbrook, a fault raised the Rockies and dropped the floor of the Rocky Mountain Trench. Over time, more rapid erosion of softer in rocks in the valley, relative to the hard rocks in the Rockies, increased the relief (Figure 15). Similar faults further north provide the plumbing system for hot waters deep in the Earth that form hot springs at Fairmont Hot Springs (Site 12) and Radium. The formation of this north-south valley diverted the flow of ancient rivers that previously flowed from the Purcell Mountains eastwards across the Alberta plains, and redirected their flow along the Trench.

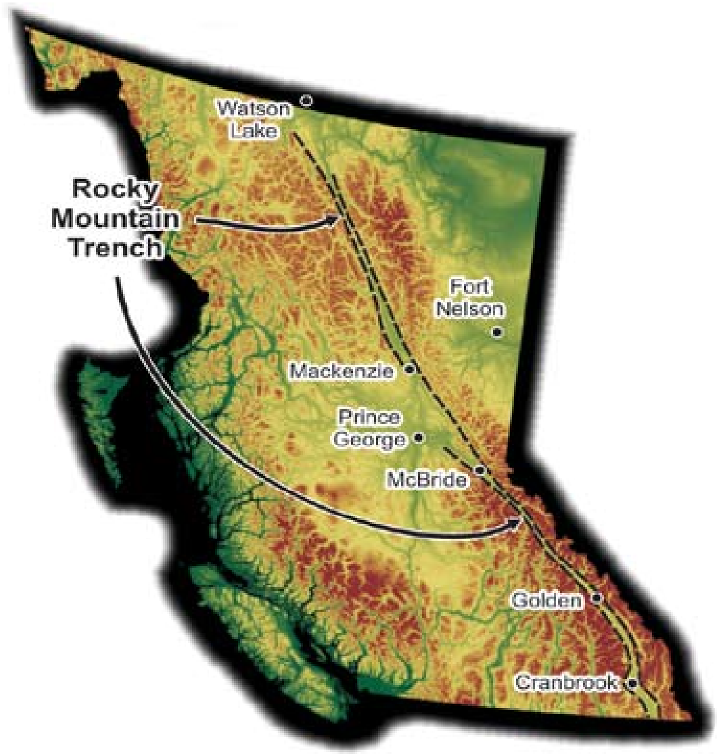


Figure 14. The Rocky Mountain Trench valley extends the length of British Columbia.

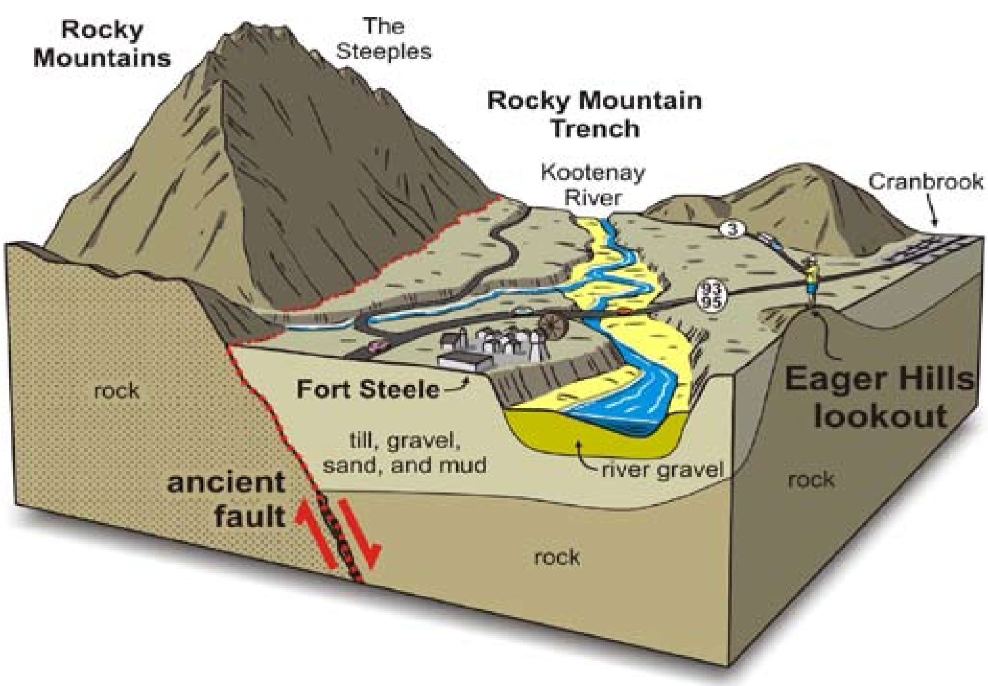


Figure 15. An ancient fault lies below the Rocky Mountain Trench, and a thick layer of Ice Age sediment blankets the valley. Eager Hills lookout is bedrock knob that pokes up through the Ice Age sediment.

How to Get There. The turnoff to the Eager Hills lookout trail is on Highway 3 about 4 km east the junction with Highway 95A , on the outskirts of Cranbrook. Look for an unmarked gravel road on the north side of the highway, immediately below an orange-coloured rock cliff, and just west of the highway summit. A short gravel road leads to the trailhead. Rusty blocks of ore from the Sullivan Mine (Site 3) line the parking area. Leave yourself at least an hour and a half for the return walk.

(Site 2) Marysville Falls: BC's Oldest Seafloor

Figure 16. A road side sign marks the entrance.

It is likely that few realize that the East Kootenay mountains are largely carved from ancient seafloor rocks. Even fewer may know that the oldest ancient seafloor rocks in BC make up the southern Purcell Mountains. The best place to take a look at these very ancient rocks, almost a billion and a half years old, is along the pleasant walk to Marysville Falls near Kimberley.

WHAT'S AT YOUR FEET? ANCIENT SEAFLOOR!

You are standing on ancient seafloor! It is an astonishing fact that most of the Purcell and Rocky Mountains are made of rocks that were once ancient seafloor. Today, these seafloor rocks are thousands of metres above sea level, thousands of kilometers from the sea, and form the highest parts of southern Canada. This remarkable fact can only be explained by tremendous Earth forces that created the mountains of the East Kootenay.

Figure 17. (Above) Pale-coloured sandstone layers and dark mudstone layers along Mark Creek each represent the position of an ancient seafloor at a point in time. The rock wall has been smoothed by the grinding action of sand and silt grains carried by creek waters.

The walls of Mark Creek are striped with layers of sandstone and mudstone. Each layer represents sand or mud that accumulated on the floor of an ancient sea. Over millions of years, thousands of metres of sand and mud were deposited on this seafloor. During deep burial and under tremendous pressure, these sediments consolidated to rock as ground waters added mineral cement that glued the grains together.

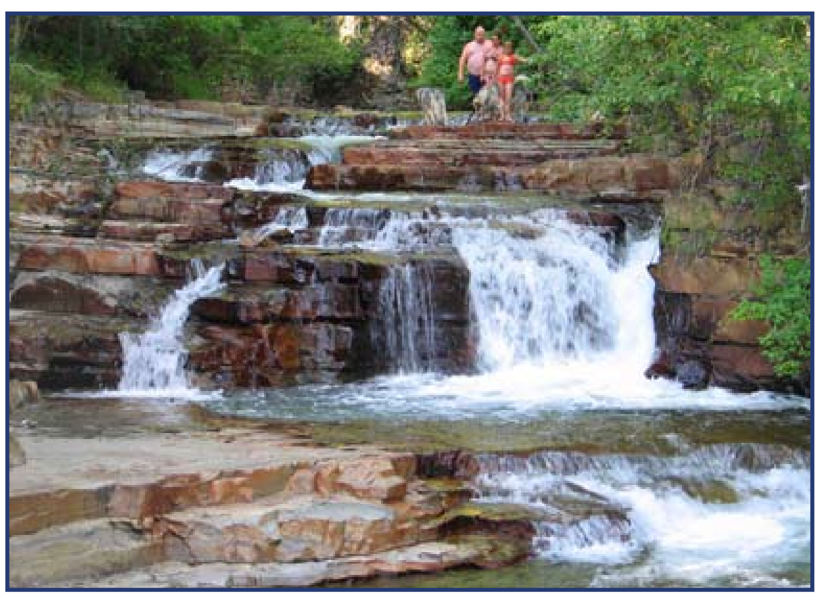


Figure 18. Mark Creek tumbles over the flat-lying layers sandstone and mudstone, forming pools and swimming holes. This stack of layers was deposited from the bottom up, with the youngest at the top and oldest at the bottom. As you descend the trail along the creek, you are walking down through the layers and therefore through older and older rock.

BC`S OLDEST SEAFLOOR

The Purcell Mountains extend from the Rocky Mountain Trench to Kootenay Lake. Most of the southern Purcell Mountains, including those exposed along Mark Creek, are sandstone and mudstone interpreted by geologists to be over 1.4 billion years old. These are the oldest sedimentary rock in British Columbia. At this ancient time, a giant continent was splitting, pulled apart along faults by slow-moving currents within the underlying Earth's mantle. An inland sea filled a valley along this break in the continent. Hundreds of millions of years later, the western half of this broken continent, now a separate tectonic plate, floated away on the Earth's mantle current below. The remaining eastern half of the continent became North America, and the ancient rocks of Marysville Falls and the Purcell Mountains now formed part of its western edge. Geologists suspect that the departed tectonic plate is now either part of Australia or Siberia.

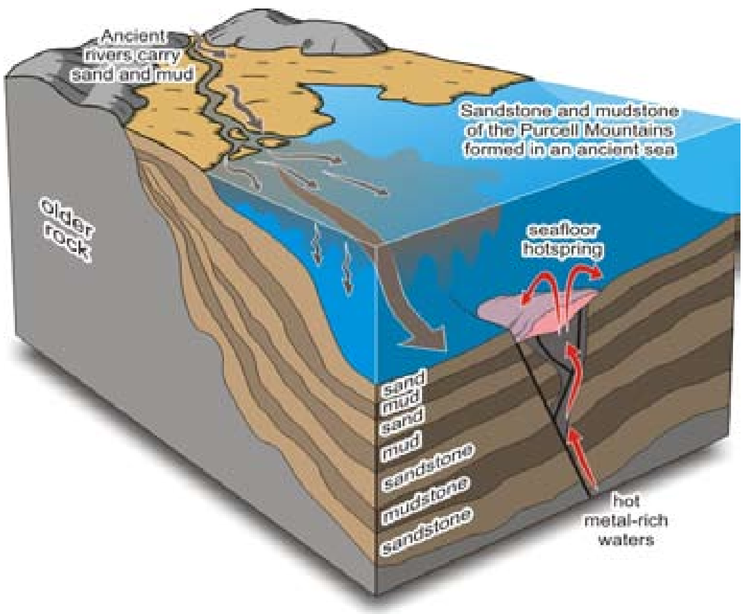


Figure 19. *This is a geological interpretation of the ancient sea, a billion and a half years ago, where the rocks at Marysville Falls and southern Purcell Mountains formed. Mud carried by rivers slowly settled to the deep seafloor. Sand carried by rivers accumulated along the shores and occasionally collapsed as undersea landslides, spreading a layer of sand across the deep seafloor and interrupting the mud accumulation. The ore at the Sullivan Mine formed at this time, near a hot spring that deposited metal on the seafloor* ***(Site 3).***

Figure 20. *At Marysville Falls, Mark Creek flows from a shallow valley into a narrow canyon that extends downstream to the St. Mary River. The original position of the waterfall was near the St. Mary River; over the last 10,000 years it has eroded upstream, leaving the canyon in its wake. At some time in the geological future, the waterfall and canyon will extend to the location of the highway bridge.*

HOW TO GET THERE. Highway 95 crosses Mark Creek on the western outskirts of Marysville, near Kimberley. Upstream, the Mark Creek EcoPark protects Mark Creek and its adjacent stream-side forests. Downstream, the Al Fabro Walkway leads to Marysville Falls. There is parking along Highway 95 and on 303 Street. The walkway to the falls takes 5 to 10 minutes. A trail continues downstream from the falls to the St. Mary River, a walk of 10 to 15 minutes.

(SITE 3) SULLIVAN MINE TOUR: THE RICHEST HILL IN BC

The former Sullivan Mine lay within Sullivan Hill that rises above the town of Kimberley. It may be that Sullivan Hill was the richest hill in BC. The Sullivan Mine produced billions of dollars of metal during its century of operation. Today the mine is closed and the site is undergoing environmental clean up and monitoring. But you can still learn the story of this remarkable mine, its history, and its people. The Mining Railway and Interpretive Center provides a narrow-gauge rail tour that includes a stop at underground mine workings that showcase mining techniques. There are also views of the old mine site and its environmental reclamation, and a small museum that explains its history and geology. The train tour runs throughout the summer, and on weekends during the late spring and early fall.

Figure 21. *Narrow-gauge train tours of the Sullivan Mine depart from a station on the outskirts of Kimberley.*

Figure 22. *A guide explains mining techniques on the underground tour.*

BILLION DOLLAR BONANZA

For 90 years, the Sullivan mine, and the Trail smelter which was primarily fed by the ore of the Sullivan mine, created an economic cornerstone to the economy of the Kootenays. The mine was discovered in the 1892, went into large scale production before World War I, and finally closed in 2001. During its life it produced ore worth $19 billion dollars, which today would be worth $60 billion. During its peak it was among the largest zinc-lead mines in the world. Geologists continue to scour the East Kootenay region in search of another Sullivan mine.

Figure 23. *The site of the former Sullivan Mine on Sullivan Hill lies in the middle ground and is partly obscured by the trees in the foreground. This view is from the Kimberley Alpine Resort.*

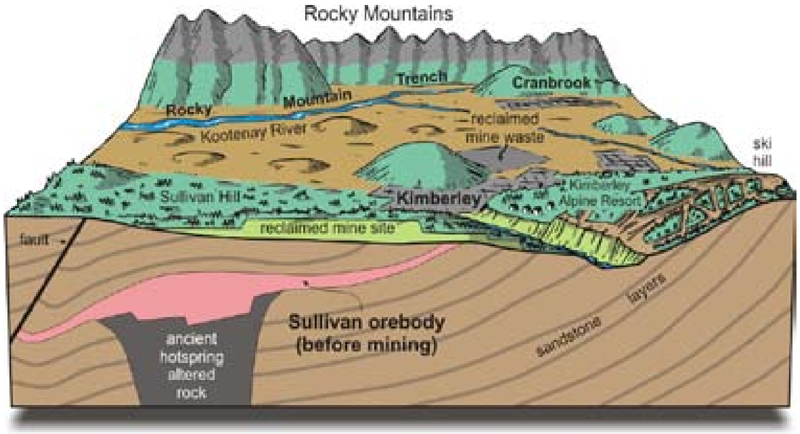


Figure 24. *The Sullivan ores lay within layered sandstone and mudstone that underlies Sullivan Hill. The same rocks are exposed at Marysville Falls* ***(Site 2).***

Figure 25. *A view of the Sullivan Mine buildings during the 1980's and looking towards Kimberley. Photograph courtesy of Teck Metals Ltd.*

DIGGING RICHES: FROM ORE TO METAL

The Sullivan ores were a giant mass of metal-rich sulphide. It extended more than a kilometer by a kilometre and covered an area equivalent to 300 football fields. It contained the metals iron, zinc, lead, and silver. Ore was blasted free and removed from the mine, leaving large underground openings that were filled with gravel to prevent collapse. Ore was carried by rail cars several kilometers to a mill where the ore was crushed and ground to particles the size of fine sand, allowing metal sulphides to be separated from waste material. A concentrate of metal sulphide was shipped by train to the smelter in Trail where zinc, lead, and silver metal was produced. Fine waste rock or tailings were stored in large storage ponds behind low dams. Waste rock was dumped in piles near the mine entrances.

A 1.5 BILLION YEAR OLD HOT SPRING

Geologists are always trying to figure out how and why ores formed where they did. This knowledge can predict where similar conditions might have occurred elsewhere, and therefore lead to the location of a yet-to-be-discovered ores. Because the Sullivan ores were a supergiant deposit, and contained billions of dollars worth of metal, there has been sustained effort company and government geologists to understand its origin. Nonetheless, similar giant ores have yet to be found.

Figure 26. *The ores of the Sullivan mine are composed of fine layers of zinc and lead sulphide (silver) and mud (black). Geologists interpret that these layers formed on a sea floor near a submarine hot spring. The layers were originally flat. During mountain building starting 170 million years ago, the layers were deformed into folds.*

Geologists interpret that the Sullivan ore body formed at a hot spring on a seafloor 1.4 billion years ago. Hot waters rich in iron, zinc, and lead rose from the deep Earth along faults to the seafloor. Dissolved metals combined with sulphur in the sea water to form particles of metal sulphides that accumulated on the seafloor as layers. Over thousands of years, the deposits of metal sulphide covered an area equivalent to 300 football fields, and, near the hot springs, reached thicknesses of 60 m. Then the hot springs waned. Over millions of years, thousands of meters of sediment accumulated over the deposit, raising the seafloor to the surface of the sea. Compression and mountain building, a billion years later, folded the ore layers.

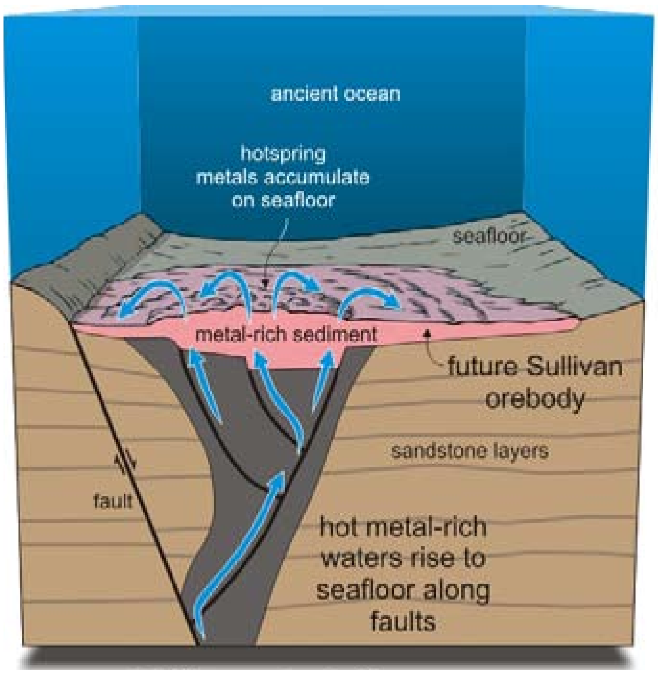


Figure 27. (Left) The Sullivan ores formed beside a seafloor hot spring 1.4 billion years ago.

ENVIRONMENTAL CLEAN UP: A BIG JOB

Cleaning up the Sullivan mine at the end of its life has been a big job. Because the mine was a very large and long-lived, the extent of its waste materials was larger than most mines. Its long history also meant that much of the mining was done prior to the modern era of good environmental mine management. In addition, the ores of the Sullivan mine are rich in reactive iron sulphide, making them prone to acid rock drainage, a major environmental concern. And finally, the stakes are high – Mark Creek flows through the Sullivan mine area and then into the St. Mary River, a clear-water river famous for pristine nature and trout fishing.

METALS ON THE MOVE: MANAGING ACID ROCK DRAINAGE

Acid rock drainage (also known by its abbreviation ARD) is an important issue for many mines. Acid rock drainage enables metals to move and enter streams where they can damage stream life.

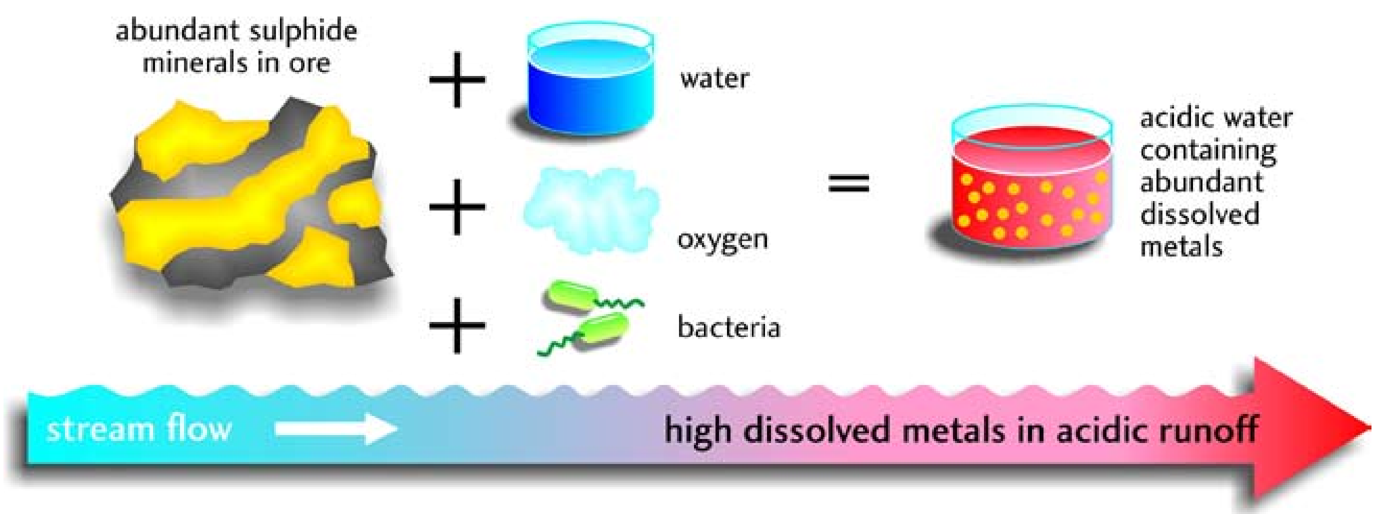


Figure 28. (Left) The formula for the formation of acid rock drainage.

So how does ARD form? It occurs when rainwater and snow melt flow through rock that are rich in iron sulphide. Water and oxygen from the atmosphere react with iron sulphide, causing sulphuric acid to form. Bacteria living on rock surfaces can enhance this reaction. This acid dissolves other metals in the rock such as zinc and lead. Once in this acid solution, these metals are on the move.

Figure 29. (Left) An aerial view of mine waste rock along Mark Creek prior to reclamation. The area is upstream of the hairpin turn in the road to the Kimberley Ski Resort, visible in the lower left corner of the photo. Photograph courtesy of Teck Metals Ltd.

***Figure 30. (Upper right)** Today, the reclaimed waste rock along Mark Creek have been covered with soil and planted with grasses. The soil is clay-rich and limits water from reaching the buried waste rock. Drainage that does flow through the waste rock is captured and sent to a water treatment plant to remove metals. The railway tour crosses Mark Creek on the bridge in the lower left corner of the photo. **(Bottom right)** A view of Mark Creek and reclaimed waste rock from the rail tour. Since reclamation efforts started, levels of zinc in the waters of Mark Creek have fallen dramatically.*

At Sullivan mine, the remediation plan recognized that ARD could mobilize zinc, and that at high concentrations zinc damages stream ecosystems including fish, insects, and plants. Because Mark Creek flows through the mine site, a priority was to keep ARD out of Mark Creek. Major sources of potential ARD included the mine workings, waste rock piles, and fine waste rock in tailings. The strategy was to limit the formation of ARD, and capture and treat any ARD that did form. The deeper parts of the mine were allowed to flood with groundwater. This underground lake prevents oxygen in the atmosphere from reaching and reacting with ore in the deep mine. Overflow from this underground lake is piped to a treatment plant where metals are removed.

How to Get There: Follow Highway 95A to Kimberley. Once in Kimberley, follow signs to the Kimberley Ski Resort. The turnoff to the Sullivan Mine Interpretive Centre is on the edge of the downtown and just before road starts to climb steeply. You can book a ticket at the railway station for the train tour. While you are waiting for the tour, walk over to the museum where there are displays and videos about the Sullivan mine. The train tour takes about 2 hours and returns you to the station. The Sullivan Mine Interpretive Centre is operated by the Sullivan Mine and Rail Historical Society.

(SITE 4) FORT STEELE HERITAGE TOWN: BUILT ON AN ANCIENT RIVER BED

Fort Steele is a heritage town full of living history. You can poke around the gold rush RCMP post, watch blacksmiths at work, pan for gold, and watch live theatre. The spirit of the 1860's gold rush era is alive at the town's assay office, miner's cabin, and museum. While you are there, take some time to marvel at the town's remarkable geography. The town lies on a flat plain within the Rocky Mountain Trench, on bluffs above the Kootenay River, and nearby to the dramatic mountain front of the Rockies. So there is a geological history to explore as well.

Figure 31. *A street scene during a quiet moment at Fort Steele.*

GOLD RUSH TOWN

Fort Steele figured large in the early settlement of the East Kootenay. When gold was discovered on nearby Wild Horse River (locally known as Wild Horse Creek), the governor of British Columbia commissioned construction of a trail across southern BC to connect to the Wild Horse goldfields and so exert colonial authority over the lands and tax revenues. The Northwest Mounted Police were sent to quell tensions between First Nations and settlers, and they established their first post west of the Rockies at Fort Steele. A town grew around the post that served the miners on the nearby Wild Horse River. But the gold ran out, and when the Canadian Pacific Railway chose Cranbrook rather than Fort Steele as its local waypoint, Fort Steele slowly withered. Life returned when the site became a heritage tourist attraction.

WHY IS FORT STEELE SO FLAT?

Sam Steele picked the site for Fort Steele on a flat terrace overlooking the Kootenay River. You might ask why this land, high above the river, is flat? After all, much of the valley floor in the Rocky Mountain Trench is rolling hills.

Figure 32. *A view of Fort Steele sitting on a flat terrace above the Kootenay River, from Buckman Road north of Fort Steele. Underlying Ice Age sediments are exposed in river-cut cliffs.*

Fort Steele sits on a river terrace, a type of feature common along rivers in British Columbia. Castlegar, Lillooet, and Terrace are all built on flat terraces above major rivers. How do terraces form? Note that the western bank of the Kootenay River is a flat floodplain at the Highway 93/95 bridge by Fort Steele. Most rivers are flanked by a river plain, created by the back-and-forth migration of the river channel over time. Over time, the river will cut down, leaving the old river plain high and dry as it creates a new lower plain. The abandoned plain, or terrace, is a remnant of the former river channel.

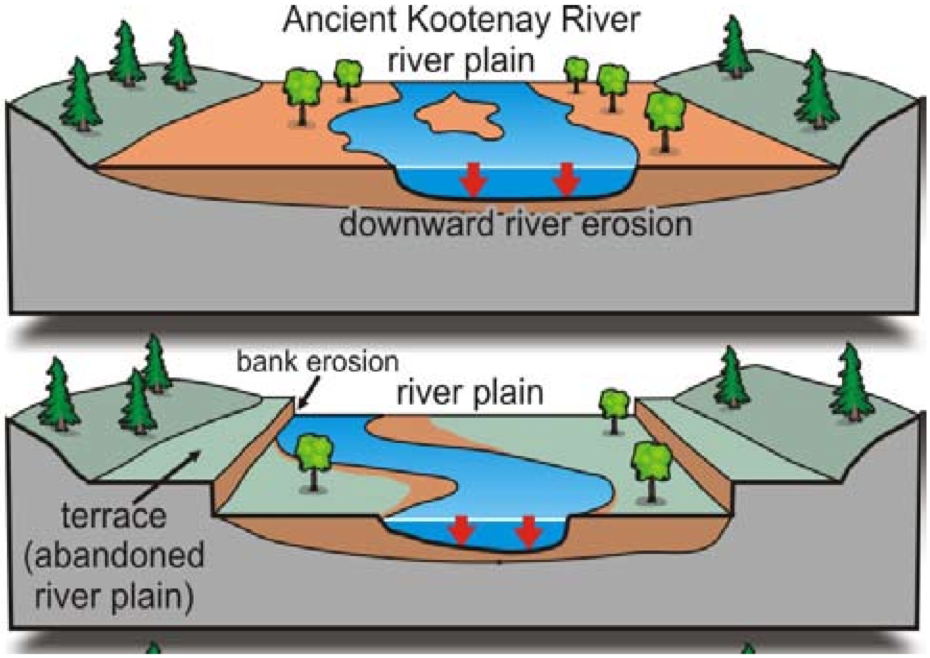


Figure 33. (Right) *The origin of a river terrace. As the river cuts downward, remnants of former river plains can be left high and dry as a terrace, and the river creates a new river plain at a lower level.*

SUBTERRANEAN EVIDENCE FOR A GEOLOGICAL HISTORY

Figure 34. (Left) *Fort Steele Heritage Town sits on a flat terrace above a cliff along the Kootenay River. This view is from the Highway 93/95 bridge across the Kootenay River.* ***(Right)*** *A closer view of the cliff reveals that the terrace is underlain by a layer of river gravel several metres thick (grey). Below the gravel layer is tan-coloured silt left behind by an ancient glacial lake.*

If you want to know the recent geological history of Fort Steele, take a look at the cliffs along the river. There the history is recorded in its subterranean geology. Near the highway bridge, two geological layers are exposed. The upper layer is gravel that is very similar to gravel on bars in the Kootenay River. This upper layer is a remnant of the ancient Kootenay River plain. Below the gravel is a thick layer of tan-coloured silt. The silt is ancient rock flour, fine rock particles created by grinding glaciers thousands of years ago. Similar silt deposits are widespread throughout the southern Rocky Mountain Trench and are interpreted to have accumulated in a large glacial lake that filled the valley during the waning stages of the Ice Age.

Modern rock flour gives the Kootenay River its opaque grey to olive colour. This rock flour comes from glacier meltwaters in the Rocky Mountains that drain into the Kootenay River.

As you stand on the streets of Fort Steele, think of the two layers. First imagine yourself standing on the bottom of a cold glacial lake, perhaps 50 m deep. Next imagine yourself standing on a broad gravel flats with a river coursing through bars and islands, and on the river bank nearby, a wooly mammoth.

PANORAMA FROM THE TOWER

There is a 360° view from the top of the water tower in the northwest corner of town. Don't miss it! From the tower, you see that the Fort Steele lies above a bend in the Kootenay River. Upstream there are cliffs with pinnacle-like hoodoos. Across the river is an extensive lush forest growing on a flat floodplain where the St. Mary River joins the Kootenay River. The St. Mary River flows clear from a large lake upstream that acts as a giant settling pond. This contrasts with the Kootenay River whose grey muddy waters reflect the glaciers that feed its headwaters. The confluence of the two rivers is just upstream of Fort Steele; look for evidence of the clear St. Mary waters along the far bank of the Kootenay River.

Figure 35. (Top, left) *Climb the stairs inside the Fort Steele Waterworks Company Ltd. water tower views of Fort Steele and its surrounding scenery. The tower provides a panorama of the steep wall of Rocky Mountains to the east.* ***(Bottom, left)*** *Lush cottonwood forests cover a floodplain across the Kootenay River from Fort Steele. A gravel and sand fan of the St. Mary River is hidden below this lush forest and acts as a partial dam to the Kootenay River. This causes the gradient of the Kootenay River upstream of this natural dam to be very flat, creating extensive wetlands that extend north to Wasa.* ***(Bottom, right)*** *Hoodoos occur in river-side cliffs of glacial lake silts upstream along the Kootenay River. Hoodoos form by erosion of gullies in weakly cemented sediments.*

GOLD FEVER, THEN AND NOW

Fort Steele started as a gold rush outpost. So be sure you try your hand at panning for gold. Fort Steele celebrates its connection to the gold rush, and displays many of the tools used by gold miners.

***Figure 36. (Far left)** A gold prospector walks a boardwalk in Fort Steele. **(Left)** Panning for gold at Fort Steele. **(Below)** A small vial containing gold nuggets found in East Kootenay streams.*

***Figure 37. (Left)** A 15 m high water wheel was used in the 1930's at placer gold mining claims on Perry Creek west of Cranbrook. Creek water turned the wheel, that in turn powered pumps that dewatered underground mine workings below the creek. **(Right)** A sluice box, common tool of gold miners, was used to separate gold from gravel.*

HOW TO GET THERE: Fort Steele Heritage Town is 16 km northest of Cranbrook on Highway 93/95. The site is open year round. Visit their website at www.fortsteele.ca or call 250 426 7352 for hours of operation and other information.

(SITE 5) WILD HORSE RIVER BRIDGE VIEWPOINT: READING THE MOUNTAINS FROM RIVER GRAVELS

BACK ROAD GEOLOGY

The Fort Steele-Wardner Road connects Fort Steele to Highway 3 further south by way of the eastern side of the Rocky Mountain Trench and Kootenay River. This road is scenic and provides access to many interesting features. Starting at historic Fort Steele, the road passes the access road to the Wild Horse gold diggings, Wild Horse River, vistas of the Kootenay River valley and mountain wall of the Steeples, Norbury Lake Provincial Park, and Bull River trout hatchery.

THE VIEWPOINT: ANCIENT CAMPSITE

Figure 38. *The broad gravel flats of Wild Horse River below the viewpoint.*

Several hundred metres along the Wardner-Fort Steele Road from its junction with Highway 93/95 is a viewpoint overlookingWild Horse River. It was the discovery of gold upstream on Wild Horse River in 1864 that led to the building of Fort Steele. At the viewpoint, Wild Horse River flows out of a narrow valley walled by cliffs of gravel and glacial till, flows under the bridge and out across a broad expanse of gravel bars on its way to join the Kootenay River.

The site of this viewpoint, with its commanding vista of Wild Horse River, was an important hunting camp site for the Ktunaxa peoples. An interpretive sign describes the results of archeological excavations at this site. The deepest layer encountered in the shallow excavation was a glacial age river bed, similar to the gravel layer described under Fort Steele (Site 4). An overlying layer contained evidence of intensive use of the site as a riverside hunting camp, with abundant deer bone dated by radiocarbon methods at about 4000 years old. A younger layer of sand dunes was overlain by remains of another hunting camp, with bones of butchered bison that were dated as about 500 years old.

READING THE ROCKS – RIVER PEBBLES

Mountains continually fall apart, breaking into fragments that roll down hill. Streams erode these fragments, rounding them to a smooth shape as they carry and tumble them downstream. Every mountain stream is filled with such rounded rocks. A geologist or prospector will look at the pebbles in a stream to get an understanding of the geology of the land drained by that stream. So if you want to get a quick idea of the local geology, go to a river and take a look at its pebbles.

To take a closer look at pebbles in Wild Horse River, continue south on the road past the bridge and pull over on the wide shoulder. Except during high water in the spring, you can easily access the river's gravel bars. Wild Horse River has very broad gravel bars. This is due to historic hydraulic gold mining that occurred upstream and that washed large volumes of gravel into the creek. Site 6 visits these old hydraulic placer workings.

Figure 39. Pebbles in Wild Horse River. ***(Upper Left)*** *Grey limestone and tan dolomite limestone (a knife can scratch these rocks).* ***(Upper Centre)*** *Layered quartz-grain sandstone or quartzite (a knife cannot scratch this rock).* ***(Upper Right)*** *Layered sandstone.* ***(Middle Left)*** *Layered siltstone.* ***(Middle Centre)*** *Granitic rock.* ***(Middle Right)*** *Lava with former gas bubble holes filled with white quartz.* ***(Lower Left)*** *White quartz veins in green-altered sandstone.* ***(Lower Rightt)*** *Rusty iron carbonate and quartz veins in green-altered sandstone.*

There is a variety of pebble types on the gravel bars: grey, white, tan, pale green, pale purple, rusty brown. Some have parallel layers, others contain a criss-cross of veins. You can scratch some pebbles easily with a knife; other not.

Where did these pebbles come from? Well, upstream for sure. One obvious place is erosion of the nearby mountains. Wild Horse River drains a large area within the Rocky Mountains. The dominant rock types in these mountains are sandstone, shale, limestone, and quartzite (very hard quartz-rich sandstone) with lesser amounts of volcanic lava and granite. Pebbles of all these rocks can be found on the bars.

Another source of gravel is erosion of ancient river gravels or Ice Age glacier deposits. An example of such erosion is just upstream of the bridge over Wild Horse River where gravels are being eroded in river-cut cliffs. These are Ice Age sediments, deposited by Ice Age glaciers and rivers, and carried from sources that may be far away and well outside the drainage basin of Wild Horse River.

HOW TO GET THERE: The turn off to the Fort Steele-Wardner Road from Highway 93/95 is just north of Fort Steele Heritage Town. The viewpoint over Wild Horse River is 200 metres from the highway junction. There are pull-outs along the Wild Horse River just south of the bridge.

(SITE 6) WILD HORSE RIVER HISTORIC SITE: GHOSTS OF A GOLD RUSH

It is safe to say that discovery of gold on Wild Horse River in 1864 was a pivotal event in the history of the East Kootenay. The site of the gold rush, variously known as Wild Horse Creek or Fisherville, remains a fascinating place to poke.

Figure 40. (Above) *The cemetery for the Wild Horse miners greets the visitor at the entrance to the historic area.* ***(Right)*** *Little is left of the original buildings of Fisherville along Wild Horse River.*

GOLD!

In the 1860's, a party of prospectors camped on the Wild Horse River. Part of the party went north to investigate gold reported near Canal Flats. Those remaining to tend the camp were surprised to pan some gold from the river. They followed the river upstream, through a canyon and around a waterfall, to a wider valley. There the gravel bars in the river were rich with gold. News got out and the gold rush was on.

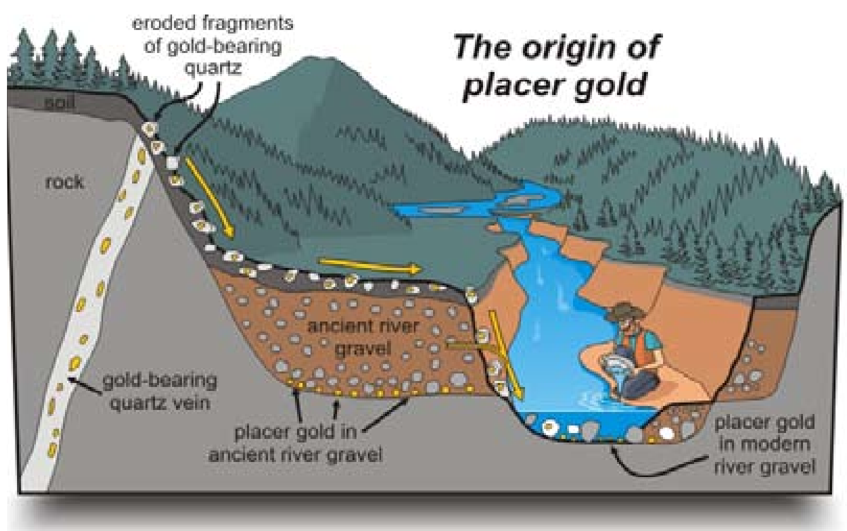


Figure 41*. Placer gold is eroded from gold-bearing rock. Rivers concentrate gold particles, because the heavy gold settles together in the river bed. Both modern and ancient river gravels can contain gold. At Wild Horse, much of the gold mined by hydraulic washing lay in ancient river gravels, and in the fissured top of bedrock below those gravels.*

Within a year 5000 men filled the narrow valley. A rough village was built near the river. When miners discovered the town sat on gold-bearing gravels, the buildings were burned or moved and the gravels dug. Within another year, all the gravels that could be mined by the simple methods of pan, shovel, rocker box, and sluice box had been exhausted, and most of the gold seekers moved on. But already, this gold rush had changed BC history. Fearing loss of sovereignty and revenues, the government in Victoria quickly built the Dewdney Trail to connect steamships on the Fraser River to the Wild Horse diggings. Settlers followed, and conflict with local Indians required a detachment of North West Mounted Police and construction of Fort Steele. The East Kootenay was on the map.

WASHING MOUNTAINS INTO RIVERS: HYDRAULIC MINING

But gold mining wasn't over; the techniques changed. Canals were built to carry water from upstream to power giant water cannons that washed the gold-bearing gravels from valley slopes. This was hydraulic mining – washing the gold-bearing sediment with powerful hoses into sluice boxes. Hydraulic mining was lucrative on Wild Horse River and continued into the 1920's. However, it left a legacy of barren scars on the valley sides, and flooded Wild Horse River with gravel and mud.

*Figure 42. **(Top)** Historic photo of hydraulic mining on Wild Horse Creek. Photograph FS 31.132 courtesy of Fort Steele Heritage Town Archives. **(Bottom left)** Sign to the historic hydraulic mining areas. **(Bottom Right)** Scars left by hydraulic placer mining along Wild Horse River.*

WALKING THE HISTORIC SITE

Figure 43. (Left) Boulders on a gravel bar by Wild Horse River near the former site of Fisherville. These gravel bars have been panned many times, and large boulders have been set aside into piles during this work. (Right) Fissured bedrock, underlying the gravels, is exposed locally in the hydraulic workings. Miners dug into this bedrock to find gold that had lodged in the crevices.

Today, Wild Horse Creek is a protected historic site. There is a cemetery near the parking lot, and trails lead off in all directions through the forest to various historic features such as a former water ditch, relict portions of the Dewdney Road, and the former site of Fisherville near the river. To the west is a viewpoint that looks out over the former hydraulic workings that remain largely unvegetated scars. Steep trails descend into this badlands landscape and are well worth the effort.

Signs direct the visitor throughout the large site, and explain features. A good half day or more could be spent exploring. Gold panning is allowed with pan and shovel only; no other equipment is allowed. Farther upstream and on the far bank, modern placer mining operations are still active. No significant gold-bearing rock source for the gold has been found, though geologists continue to prospect for this mother lode.

HOW TO GET THERE. From Highway 93/95 near Fort Steele Heritage Town, turn on to the Fort Steele-Wardner Road. Just before the bridge over Wild Horse River, turn left (east) on the Wildhorse Forest Service Road. Follow the road for 6 km up the Wild Horse River valley and canyon to the marked turnoff (right or down slope side) to the Wild Horse River Historic Site. Follow the access road past the cemetery to the parking area where there is an orientation map of the historic site. Trails lead to all the historic features.

(Site 7) Norbury Lake Provincial Park: Two Curious Lakes

Small Norbury Lake Provincial Park combines open grassland and parkland forest, a view of one of the most dramatic mountain walls in BC, and two lakes with a beautiful turquoise colour. Peckham's Lake has day-use picnic tables, and beach and dock for swimming and boating (no motors allowed). Norbury Lake, only partly in the park, is adjacent to the campgrounds. A trail leads from the picnic area around the shores of Peckham's Lake and through a pine forest to the campground. Another short trail links the campground to the shores of Norbury Lake.

Figure 44. *T he turquoise waters of Peckham's Lake reflect the Rockies that rises over 2000 m above the lake.*

WHY ARE THE LAKES SO GREEN?

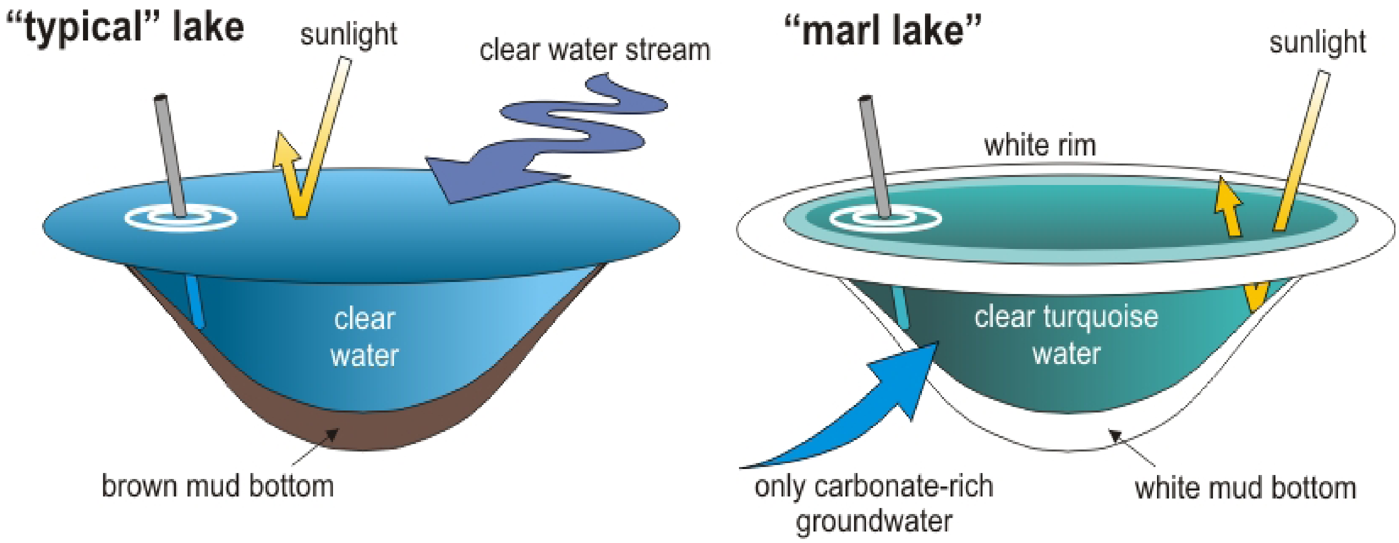
Figure 45. (Left) *At low water, the floor of Peckham's Lake is exposed, displaying white lime-crusted pebbles and grey mud.* ***(Below)*** *A close up of white lime-covered rock on the lake floor.*

Glacial lakes in the Rockies are famous for their beautiful turquoise or green colour. These lakes are fed by glacial streams with abundant fine glacial rock flour suspended in their waters. However, there are no glacial streams that feed the lakes in Norbury Lake Provincial Park. So why are these lakes green?

Typically, lake water looks blue because water absorbs the longer red, orange, and yellow wavelengths of sunlight while it reflects or transmits the shorter blue wavelengths. If the water overlies a light-coloured bottom, blue wavelengths are absorbed while blue-green light is reflected back to your eyes – think of a swimming pool or a tropical ocean with a white sand bottom. However, most lakes have dark organic mud on their bottoms that reflect little light, and therefore are a blue colour.

If you swim in the Peckham's Lake or Norbury Lake with a face mask, or walk its shores during low water, you will notice that the lake floor is covered by a pale grey mud. This mud is largely calcium carbonate, or lime, and the same composition as limestone.

Figure 46. Marl lakes with reflective white or pale grey lime mud bottoms give lake waters a bright green or turquoise colour while lakes with darker mud bottoms result in a darker and bluer water colour. Marl is a geological term for lime-rich mud.



RECIPE FOR A WHITE-BOTTOM LAKE

Where then does the pale grey lime mud come from? Formation of lime-mud or marl lakes is favoured in broad flat valleys with few streams, and underlain by limestone-rich gravel and sand. Marl lakes typically lack feeder streams and instead are fed by groundwater springs. Groundwater flowing through the limestone gravel leaches lime and therefore contains high levels of dissolved lime. When the groundwater rises through springs into the lake, the lime precipitates as mud on the lake floor..

MELTED ICE-CUBE LAKES

The campground and lakes at Norbury Lake Provincial Park sit on a plain. Below the grass and forest is gravel and sand. This was an ancient river bed at the end of the Ice Ages. As the glaciers melted, giant blocks of ice separated from the glacier snout and were buried by river gravel. Both Peckham's and Norbury lakes fill depressions created when giant blocks of glacier ice were buried by gravel. When these giant ice cubes melted, great depressions formed on the plain. Groundwater later filled these depressions to form the lakes.

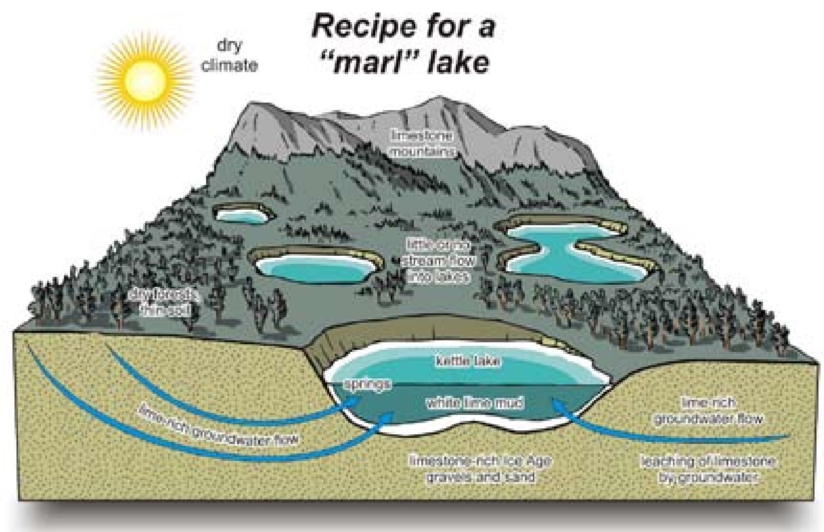


Figure 47. Conditions for the formation of white-bottom marl lakes

WHERE DOES THE LAKE WATER COME FROM?

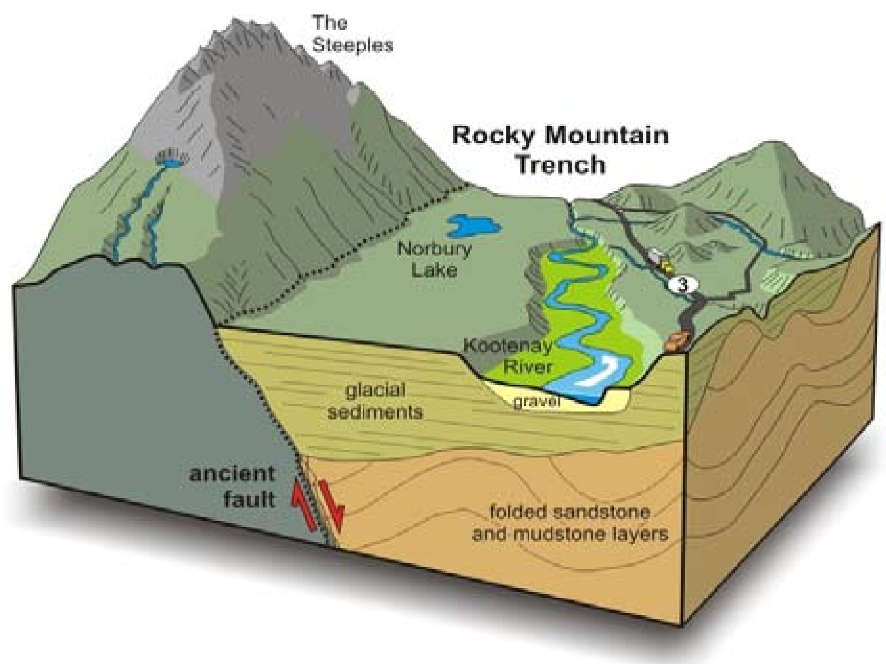
Peckham's Lake is curious. It has a stream flowing out (at least during high water), but none flowing in. Where does the lake water come from? One has to conclude that groundwater springs feed the lake. The best place see springs is on the shores of the Norbury Lake beside the campground. Follow the short Norbury Lake Trail from the south end of the campground down to the shores of Norbury Lake. Here the lake shore has a fringe of lush meadow that is distinctly soggy. Look closely and you will see water flowing from the grasses into the lake. These are groundwater springs.

__Figure 48. (Left)__ Groundwater springs line the shores and shallows of Norbury Lake along its shoreline adjacent to the campground. Spring waters rise through gravels that are surrounded by brown mosses and green grass. ***Figure 49. (Right)*** *Springs below the shallow waters of Norbury Lake are identified by round areas of dark grey gravel surrounded by pale lake-floor mud. Rising spring waters wash away mud, leaving clean gravel at the site of the spring.*

THE GREAT FAULT WALL

Norbury Lake Provincial Park sits at the base of the Steeples, a part of the Rocky Mountains that forms a dramatic mountain wall. This wall formed when an ancient fault broke the crust and lifted the mountain range. Rock exposed on the mountain is layered tan and grey coloured sandstone and shale and dark-coloured igneous intrusions. All these rocks are over a billion years old

Figure 50. (Left) *The Steeples near Norbury Lake.* ***(Right)*** *An ancient fault formed the Steeples.*



HOW TO GET THERE: Norbury Lake Provincial Park is about 14 km south along the Fort Steele-Wardner Road from Highway 93/95. The day use area on Peckham's Lake has picnic benches, a boat launch and a dock. The campground is adjacent to Norbury Lake. Trails from the campground access both lakes.

(Site 8) Highway 3 Tunnel Pullout: Where Limestone Peaks Meet Hills of Coal

YOU ARE IN LIMESTONE COUNTRY

Highway 3 crosses the Rocky Mountains from the Rocky Mountain Trench at Elko to the foothills in Alberta. Limestone is abundant here, and mountains of limestone dominate the scenery. There is a good place to stop and take a look at a pullout between Elko and Fernie near the only tunnel on Highway 3.

Figure 51. *Tilted layers of limestone rise above Highway 3 just west of the tunnel pullout. The tunnel allows the highway to pass through the lower end of this limestone ridge.*

LIMESTONE – A MOST PECULIAR ROCK

The entire length of the eastern Rocky Mountains from Yukon to Montana is limestone country. Limestone is an unusual rock. It is best known because it dissolves slowly in water, and therefore contains caves. Limestone lacks clay minerals necessary for good soil formation and therefore limestone slopes are often bare of vegetation. As a result, limestone mountains have great barren rock peaks. This, along with their distinctive grey colour and prominent layering make the Rockies a striking mountain landscape.

Figure 52. (Left) *Site 8 is a pullout just east of the tunnel on Highway 3 that cuts through a ridge of tilted limestone layers. The Elk River has cut a narrow valley across this range.*

Figure 53. (Right) *Across from the pullout is a cliff of tilted layers of limestone. Each layer is a former seafloor of lime mud, stacked one above the other. The seafloor beds were tilted when they were pushed up during mountain building.*

ANCIENT SEAFLOOR MUD

Most limestone was once mud on an ancient tropical seafloor, formed by the accumulation of billions of tiny shells from plankton animals that lived in the overlying warm waters. These tiny animals extracted lime (calcium carbonate) from seawater to form their shells. When the animals died, their shells accumulated as lime mud on the seafloor.

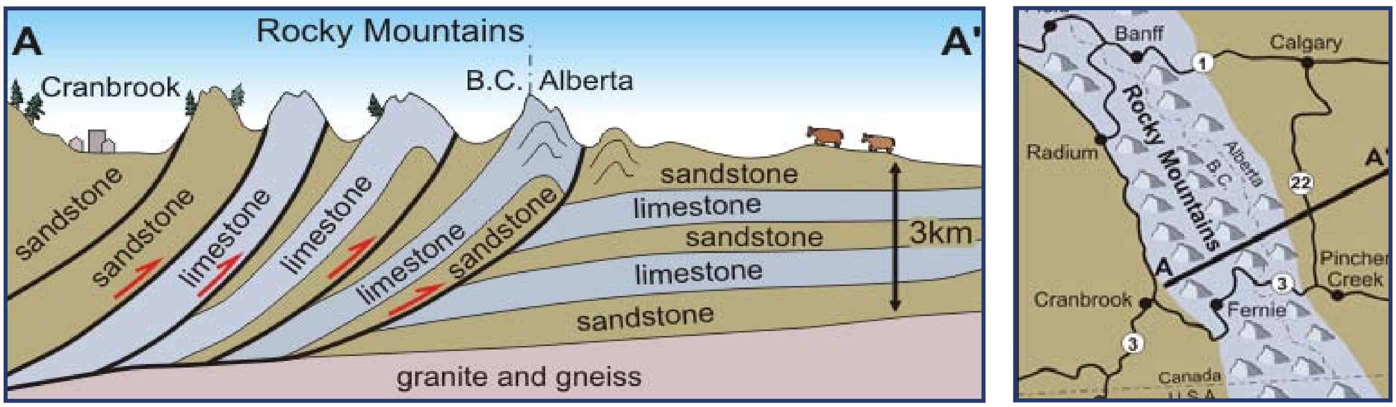
LIME ON THE MOVE

Limestone forms from seawater, and so readily dissolves back into water. This is why caves are common in limestone rock. As a result, groundwater within limestone terrain often carries a high load of dissolved lime. In dry limestone country, such as the southern Rockies, you will often find a white coating of lime on the underside of pebbles that lie in soil. This lime is precipitated as lime-rich groundwater seeps to the surface, evaporates, and drops its dissolved load of lime. Where groundwater flows to the surface as springs, mound-like deposits of limestone can form (see Site 12). Lime-mud lakes such as Norbury Lake are created by lime-rich groundwater (Site 7).

SUBTERRANEAN ALBERTA LAID BARE

It might surprise you to learn that geologists come to the Rockies to learn about the rocks that contain oil and gas reservoirs buried deep below the plains of Alberta and northeastern BC. This is because the same layers exposed in the Rocky Mountains also underlie the plains of Alberta. Mountain building has thrust these horizontal layers into a series of tilted and folded panels, and have exposed layers that otherwise would be deeply buried.

Figure 54. The Rockies contain the same rock layers as those that underlie the plains of Alberta to the east.



COAL COUNTRY!

Site 8 sits at the boundary between two different geological landscapes. To the south and west are high grey barren ridges and peaks of limestone. To the east, across the Elk River, are lower forested ridges underlain by sandstone and shale. These rocks erode more easily than limestone and form more subdued mountains. Though they form less dramatic landscapes, these sandstone and shale rocks contain vast resources of coal and are of great historic and economic importance. These rocks and the coal they contain are a focus of discussion at our stop in Fernie (Site 9) and at the Elk Valley coal mines (Site 11).

Figure 55. The view east across the Elk River to the coal-bearing forested ridges of sandstone and shale.

(Site 9) A Walking Tour of Fernie: Geological Stories In A Heritage Coal-Mining Town

Fernie is a great place to walk with its heritage downtown, riverside trails, and dramatic mountain backdrop. The town is built on low terraces along the Elk River, and trails along the river offer opportunities to examine river gravels, river dykes, and a nearby Nature Centre.

Figure 56. *Victoria Avenue in downtown Fernie is lined with heritage buildings that reflect the wealth created by nearby coal mining at the turn of the last century. The limestone peaks of the Lizard Range, site of the Fernie Alpine Resort, rise above the town. The rock strata in the Lizard Range is upside down, with older rocks lying above younger rocks. This upside-down mountain is due to colossal Earth forces that compressed, folded, and faulted the region millions of years ago.*

THE TOWN THAT COAL BUILT

The best place to start a tour is at the museum run by the Fernie & District Historical Society on Victoria Avenue in downtown Fernie. The museum has great historic photographs of Fernie and nearby coal mines. Pick up the guide to historic buildings in the downtown.

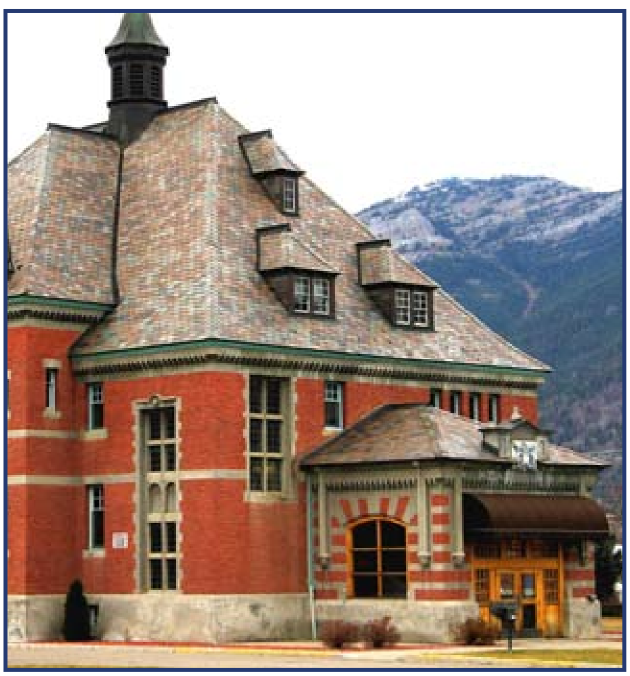


Figure 57. (Left) *Fernie town hall reflects the wealth created by early coal mining in the area.*

Figure 58. (Right) *Historic photo of coal miners at work, timbering underground workings to support the overlying rock as the coal seam is mined. Photograph courtesy of Fernie & District Historical Society.*

The dominant building material is a reddish brick, imported from Calgary. However, some walls are built of a yellow brick, produced from glacial lake clays quarried on the outskirts of town. Other walls are made of river rock, rounded sandstone from nearby Coal Creek or the Elk River. These rocks were eroded from the nearby sandstone ridges that rise near town.

Figure 59. (Left) *The building on the corner of Victoria Avenue and Wood Street contains a mix of red and yellow brick, with a honey-coloured sandstone blocks as trim. Both the red brick and sandstone were imported from Calgary. Yellow brick was produced locally but was not favoured because of its colour. The yellow colour reflects the low iron content and high lime content of local clay deposits that were quarried for brick making. The clay was quarried on the outskirts of town from deposits of an ancient glacial lake that filled the valley about 12000 years ago at the end of the Ice Age.*

Figure 60. (Right) *River rock was used to construct the Fernie Livery and Transfer building on Victoria Avenue just east of Wood Street. Most river cobbles are sandstone and taken from nearby Coal Creek or the Elk River.*

Figure 61. (Left) *Close-up of sandstone river rock in the building above. This rock was deposited as sand about 130 million years ago in an ancient river that flowed across a swampy plain. Those ancient swamps accumulated thick layers of peat that over time and deep burial became coal, the economic backbone of the Elk Valley.*

THE MOUNTAINS ABOVE

The high limestone peaks that rise above Fernie are visible from anywhere in the downtown. However, there is an unobstructed panorama of these mountains across the railway tracks at the large lawn in front of the Aquatic Centre.

Figure 62. *An evening view from Fernie of Mt. Fernie* ***(left),*** *the Three Sisters (centre), and Mt. Proctor* ***(right)****. These are limestone peaks that lie above lower forested slopes underlain by shale. The older limestone rocks have slid on a great flat fault over the younger shale rocks during compression and mountain building over 100 million years ago. Photograph by R. Anderson.*

Figure 63. *Mount Hosmer dominates the skyline above Fernie to the northeast. This view is from Highway 3 east of Fernie. Limestone and shale beds tilted on end make up the top of the mountain. A flat fault separates these upper rocks from younger shale rocks that underlie the lower forested slopes of the mountain. Tectonic compression during mountain building pushed the older rocks up and over the younger rocks.*

A SECOND WALK: MAIDEN LAKE TO FERNIE NATURE CENTRE

Figure 64. *Fernie Ridge rises above Maiden Lake on the outskirts of Fernie. The ridge is underlain by sandstone, shale, and coal layers that are less resistant than limestone and therefore form a more subdued landscape than limestone peaks.*

Another interesting geology walk is from Maiden Lake on the eastern edge of town, across the Elk River, to the Visitor Information Centre. There are great views of the limestone peaks and sandstone ridges. Follow the path along Maiden Lake towards the Elk River. The path follows the top of a flood protection dyke, and connects to another dyke trail along the Elk River. The dykes are constructed of local sandstone blocks that display features such as layering, and fossil vegetation. Near the bridge, there are good views of the gravel bars and channels of the Elk River. At low water, the gravel bar under the bridge is an interesting place to get a close look at the pebbles carried by the Elk River. Limestone and sandstone pebbles are abundant and reflect the geology of the region drained by the Elk River. Across the bridge, you can walk along the shoulder of the highway. Here there are outcrops of shale, a rock that underlies the entire valley but is rarely seen because it erodes so easily and therefore it is commonly covered by thick soil. Further along the highway is the Visitor Centre featuring a huge wooden oil drilling derrick. Inside the Visitor Centre is a Nature Centre with displays on the geology and ecology of the area.

Figure 65. *Dykes built of sandstone blocks help to prevent flooding of low lying areas along the Elk River. The dykes also prevent the river channel from migrating into the town.*

Figure 66. (Left) Sandstone blocks that make up the dykes contain layering and (Right) carbonized plant fragments.

Figure 67. (Below) An outcrop of grey shale lines Highway 3 just north of the Elk River bridge. This highly fractured rock is easily eroded and is usually hidden below soil and forest. This soft rock has been eroded by the Elk River and Ice Age glaciers into a broad Elk River valley.

Figure 68. (Right) This wooden oil derrick outside the Visitor Centre was used to drill oil wells in the Flathead Valley before World War I.

Figure 69. (Right) The Fernie Nature Centre inside the Visitor Centre has displays on the origin of mountains, local fossils, and ecology. (Far right) A fossil sponge in limestone is an example of ancient marine life that has been found on the highest peaks in the region, indicating uplift of seafloor by as much as three to four kilometers!

(SITE 10) FERNIE ALPINE RESORT:
HOW THE MOUNTAINS CAME TO BE

Figure 70. The Lizard Range is a ridge of limestone. A Fernie Alpine Resorts chair lift provides access to the alpine and a trail that climbs to the ridge.

During the summer, Fernie Alpine Resort operates the Timber Bowl ski lift to a restaurant high on the mountain, with tremendous views of the Elk River valley and surrounding mountain peaks. You can explore the alpine area around the restaurant, or, if ambitious and prepared, take the Polar Peak trail that climbs to the limestone ridgeline of the Lizard Range. You won't forget the experience.

Figure 71. The view of Fernie and the Elk River valley from the restaurant at the top of the Timber Bowl ski lift.

TO THE TOP

The Polar Peak hike follows a switch back road from the restaurant towards a saddle in the ridge. Look for a trail rising up the east (right) side of the saddle, marked with red dots or rock cairns. The trail is rough, climbing over irregular limestone for much of its length, and in one short section, descends a steep slope with the assistance of a fixed cable. The ridge has a series of small peaks, with Polar Peak as its high point.

Figure 72. (Left) Trail sign for the Polar Peak hike, which is a 5 to 6 hour round trip from the restaurant..

Figure 73. (Right) Limestone near the restaurant is a good place to find fossils. Look for crinoids – barrel-shaped segments of the stalks of ancient plant-like animals that anchored themselves to the seafloor. In cross-section, the stalks are circular with a hollow centre.

The ridgeline of the Lizard Range follows beds of steeply tilted limestone. The limestone has features that suggest it is slowly dissolving in rainwater. The surface of the limestone is pitted. Cracks that allow water to seep into the rock have dissolved into wider cracks. Some widened cracks have coalesced into small caverns. Large depressions along the ridge suggest that underlying caves have collapsed and caused the overlying land surface to sag.

Figure 74. ***(Left)*** *Steeply tilted layers of grey limestone form the ridgeline of the Lizard Range.* ***(Right)*** *Limestone on the ridge line shows evidence that it is slowly dissolving. The limestone surface is pitted with small pockets, and fractures have widened.*

Figure 75. *The view of the northern Lizard Range and the steeply tilted limestone layers that make up the high peaks.*

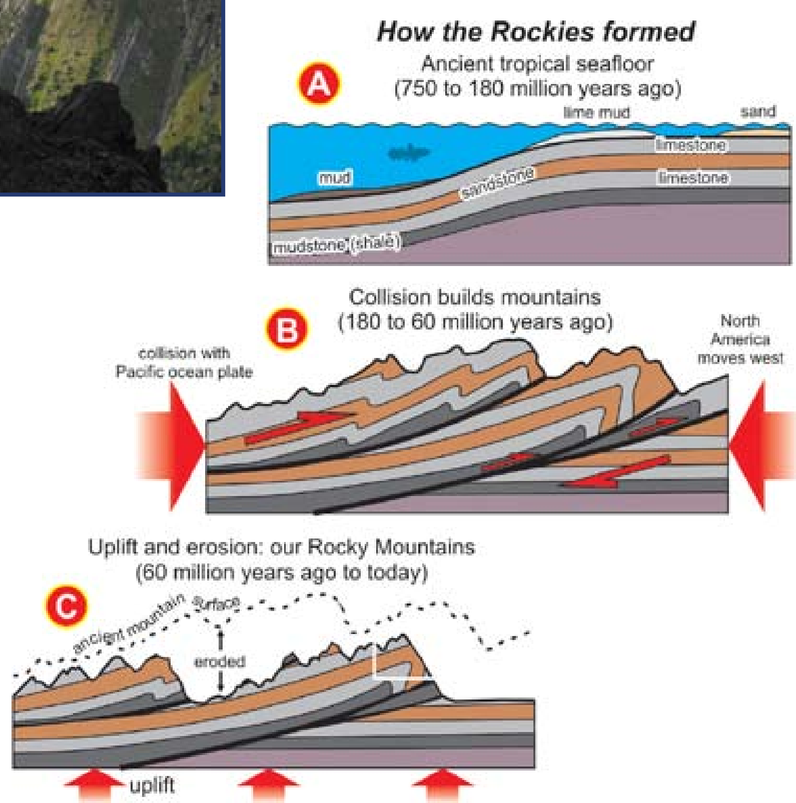


Figure 76. *Marine fossils in the Rocky Mountains indicate that these rocks formed in a shallow ocean along the west coast of North America. For half a billion years, this continental margin accumulated deposits of lime mud, mud, and sand. About 180 million years ago, offshore volcanic islands collided with the continental margin, resulting in compression, uplift, folding and faulting. A mountain belt formed as the rocks buckled into folds, broke along faults, and were piled into a stack of giant rock slices. Rivers carved valleys into these mountains, digging deep into softer layers while more resistant rock remained as ridges and mountains.*

(Site 11) Elk Valley Coal Mines:
How BC's Energy Giant Formed In The Footsteps Of Dinosaurs

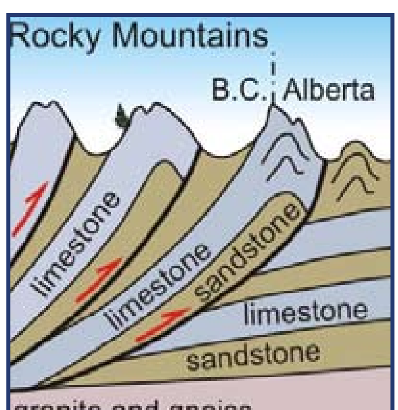
Figure 77. The dark ridge of coal-bearing rock on the skyline is the site of the Elkview mine, high above Sparwood. The terraced grassy slope (lower left) is crushed waste rock from the mine that has been planted with grass. This view is from Highway 43 just north of Sparwood.

The Elk River valley, from Fernie to Sparwood and Elkford, is coal country. Prospectors in the 1800's came looking for gold, but quickly found coal. The history of this Crowsnest region has largely been the history of coal mining. Today, the Crowsnest region is Canada's largest producer of metallurgical coal, a vital ingredient in the making of steel. To get an insight into this vast industrial enterprise set high in the Rockies, visit the Sparwood Visitor Centre and arrange a tour of a coal mine. Tours are run daily throughout the summer months.

***Figure 78. (Below Left)** A giant coal mine truck marks the Visitor Centre in Sparwood.*

***Figure 79. (Below Center)** The local Rocky Mountains are made up of hard layers of limestone that form rugged mountains (blue) while softer layers of coal-bearing sandstone and shale (gold) are eroded into valleys and ridges.*

***Figure 80. (Far Right)** A geological map of the Crowsnest coal country. Areas underlain predominantly by coal-bearing sandstone and shale are coloured gold, while limestone areas are coloured blue. Coal mines are located with a red cross-hammers symbol. Most of the coal mines lie north of Sparwood.*



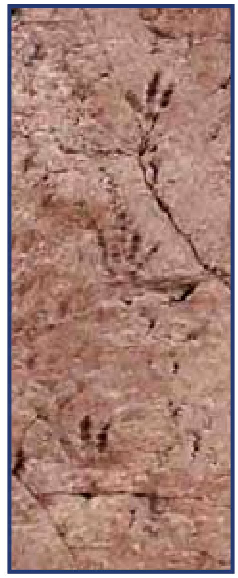
MINING MOUNTAINS OF BLACK ENERGY

Figure 81. (Left) *Tilted layers of grey sandstone and shale and black coal seams are exposed in a wall of the Greenhills coal mine north of Elkford. Horizontal lines are benches cut into the wall. The giant coal truck in the bottom of the mine provides a scale.*

Figure 82. *Giant trucks carry coal from the bottom of the open pit mine to the mill.*

Figure 83. (Below) *The Greenhills coal mine has carved large open pits into a high ridge of coal-bearing sandstone and shale. The coal mines occur on ridges of sandstone and shale where the coal is near surface and can be mined by large open pits. The mine is surrounded by the high limestone peaks of the Rockies.*

THE FOOTSTEPS OF DINOSAURS

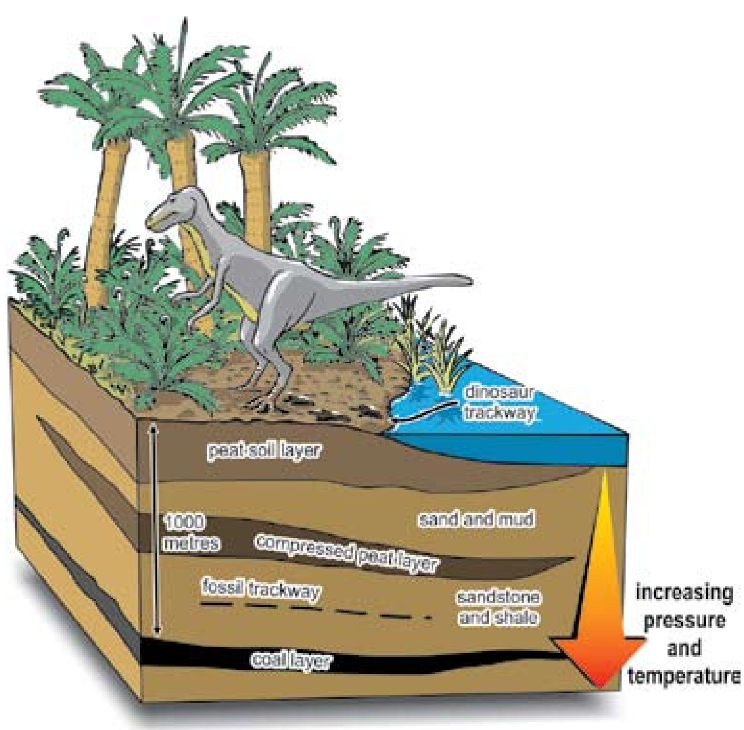


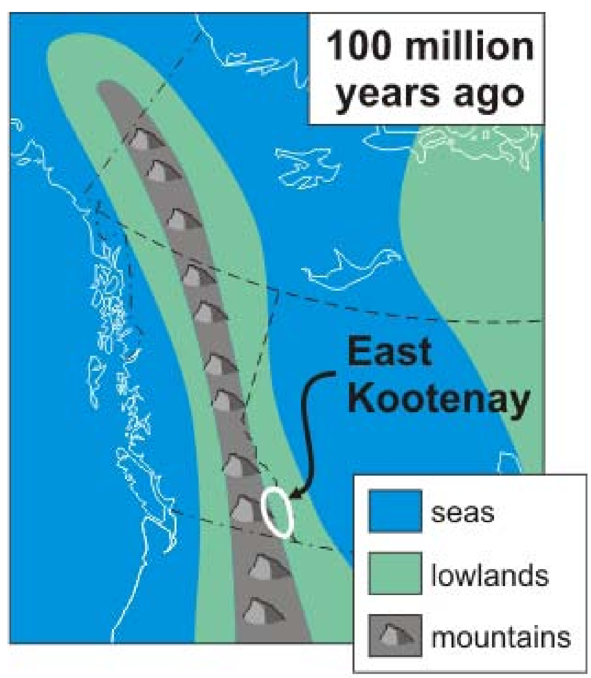
Dinosaur tracks were discovered in the Line Creek coal mine north of Sparwood in 2008. These tracks were made by a 40 tonne sauropod dinosaur, often called Brontosaurus. The animal was about 4 metres tall and over 20 metres from head to tail, and excited paleontologists who study dinosaurs. Tracks provide clues as to how dinosaurs walked, and add information to what can be learned from fossil dinosaur skeletons.

Figure 84. (Left) *Dinosaur tracks were found on a tilted layer of sandstone in the Line Creek coal mine. The tracks form a vertical path above the stick held by the miner. Each track measured about half a metre long. Photograph courtesy of Teck Coal Limited.*

Figure 85. (Below Right) *The East Kootenay region was once a broad coastal lowland on the east side of a mountain range. Vast coal-forming swamps covered this lowland and bordered a shallow inland sea.*

Figure 86. (Below) *The coal-bearing sandstone and shale rocks found in the coal mines and throughout the Elk Valley formed 130 million years when the region was a swampy lowland. Rivers flowed from nearby mountains, depositing sand and mud. Rotting vegetation accumulated below swamps. Dinosaurs roamed these swamps and river beds, leaving behind tracks. Over millions of years, ongoing accumulation of sediment buried the sand, mud, and peat to great depths. Deep in the Earth, the sand, mud, and peat were transformed by heat and pressure into sandstone, shale, and coal.*





(Site 12) Fairmont Hot Springs:
Hot Waters From The Deep Earth

East Kootenay is well known for its hot springs. Fairmont Hot Springs is perched on the side of the Rocky Mountain Trench and its famous hot pools are the centre of a large resort. Over millennia, lime-rich hot spring waters have deposited extensive limestone (travertine) mounds that are fascinating to explore.

Figure 87. (Above) *A large mound of white limestone or travertine just above the resort complex has been deposited from lime-rich hot spring water over thousands of years. A weak flow of hot waters continues to flow out of the mound. The mound also provides a panoramic view across the Rocky Mountain Trench to the Purcell Mountains.*

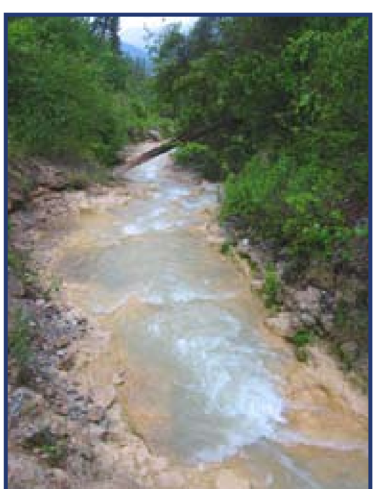


Figure 88. (Above Left) *Colourful algae and bacteria coat the channels of the hot spring waters. Freshly deposited limestone is bright white; older limestone has a pale grey colour.*

Figure 89. (Above Right) *Hot spring waters are diverted into a popular swimming pool at the resort.*

Figure 90*.(Left) Pale-coloured limestone coats the bed of Fairmont Creek below the hot springs.*

WHAT MAKES A SPRING HOT?

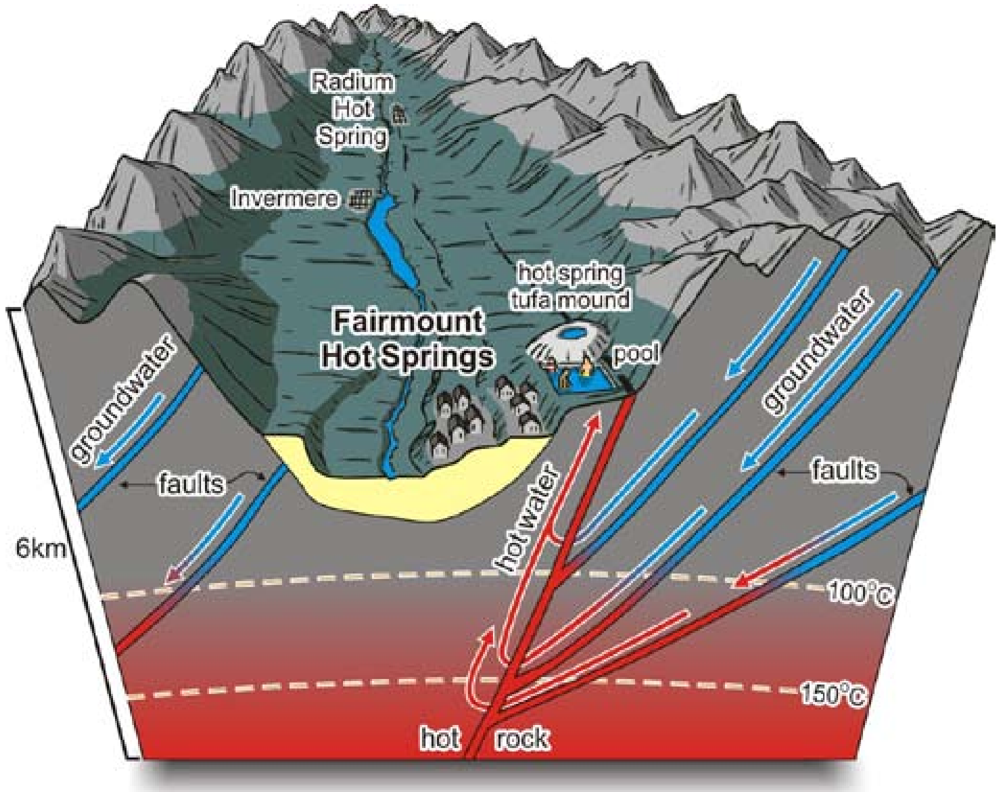


Figure 91. *The natural geological plumbing system for Fairmont Hot Springs.*

The Kootenays are famous for hot springs - Radium, Fairmont, Ainsworth and Nakusp to name just a few. In Canada, hot springs are only found in its western mountains. Why is this so?

Chemical analysis indicates that hot spring waters originate as rain or snow melt. To gain heat, waters must circulate deep into the hot Earth. Mountains are riddled with fractures that allow rain and snow melt waters to leak downwards. The weight of this descending water pushes down on water deeper in the fracture network, pressurizing it. If there is a steep and permeable fault underlying a nearby valley, deep pressurized waters can be pushed to the surface as a hot spring. This is why most Kootenay hot springs are in valleys.

EVERY HOT SPRING NEEDS A PUSH

To better understand how this works, imagine that you fill a garden hose with water and stand on top of your house holding both ends. A loop of hose dangles thirty feet below you. When you raise one end of the hose slightly above the other (i.e. the mountain), water flows out the lower end (i.e. in the valley). As long as one end is higher than the other, the length of the loop doesn't matter, it's just the relative height difference of the input and output ends.

Such a "loop" of deep Earth water is the plumbing system required for a hot spring to function. The temperature of a hot spring depends on how deep into the Earth the loop goes, and how much the heated waters cool as they rise back to the surface. At Fairmont, waters enter the Rocky Mountains high above the resort and likely descend about five kilometers into the Earth, heating as they descend, before encountering the ancient fault that allows them to rise.

HOW TO GET TO THERE: Fairmont Hot Springs Resort is on Highway 93/95 between Cranbrook and Radium. At Fairmont Hot Springs, drive up the road to the resort. The old bathhouse sits above the parking lot on top of a white hill of travertine, and is an easy walk. To visit Fairmont Creek, walk down the access road to the RV park. Follow the graveled trail downstream along Fairmont Creek.

SOME OTHER POPULAR READINGS OF LOCAL INTEREST

British Columbia: A Natural History, by Richard and Sydney Cannings. Published by Greystone Books in 1996 (310 pages). This well written summary includes a chapter on the geology of British Columbia.

Canadian Rockies Geology Road Tours, by Ben Gadd. Published by Corax Press in 2008 (576 pages). This is the definitive geological road guide to the Rockies with hundreds of annotated photographs of road cuts and mountain landscapes.

GeoTour Guide of the West Kootenay, British Columbia. Geology, Landscapes, Mines, Ghost Towns, Caves, and Hot Springs, by Bob Turner, Bob Anderson, Richard Franklin, Lesley Anderton, and Frank Fowler. Published by the Geological Survey of Canada (Open File 6135 or British Columbia Geological Survey Geofile 2009-06), 43 pages (available as a free download on the internet). This is the companion guide to the *East Kootenay GeoTour Guide*.

Handbook of the Canadian Rockies, by Ben Gadd. Published by Corax Press in 1995 (831 pages). This is the definitive guide to the Canadian Rockies.

In Search of Ancient British Columbia, Volume I: Southern B.C., by Barbara Huck. Published by Heartland Associates Inc. (304 pages). This book reviews sites and features including hot springs, Kootenay First Nations and history, and the Kootenay River.

Roadside Geology of southern British Columbia, by Bill Mathews and Jim Monger. Published by Mountain Press Publishing Company in 2005 (403 pages). A well written but somewhat technical description of roadside geology along major East Kootenay highways as well as a comprehensive discussion of plate tectonic and terrane history of British Columbia.

The B.C. Roadside Naturalist, by Richard and Sydney Cannings. Published by Greystone Books in 2002 (230 pages). This is a delightful guide to the natural history, including geology, along major highways in British Columbia, including the East Kootenay.

CREDITS

AUTHORS

Bob Turner, *Natural Resources Canada, Vancouver;*
Bob Anderson, *Natural Resources Canada, Vancouver;*
Dave Grieve, *British Columbia Ministry of Energy, Mines, and Petroleum Resources, Cranbrook;*
Richard Franklin, *North Saanich.*

PHOTO CREDITS

Photographs are by Bob Turner unless otherwise noted.

RESOURCE PEOPLE THAT PROVIDED HELP – THANK YOU!

Bruce Dawson, *Teck Metals Ltd., Kimberley;* Robin Gold, *Teck Coal Ltd.;* Nick Guiliano, *Fernie & District Historical Society;* Steve Grasby, *Natural Resources Canada, Calgary;* Dave McMichael, *Chamber of Mines of Eastern BC, Nelson;* Mike Pennock, *Fernie & District Historical Society;* Brandy Dunnebacke, *Friends of Fort Steele Society;* Brandon Scott, *Teck Coal Ltd.;* John Sciarra, *Teck Coal Ltd.;* Ross Stanfield, *East Kootenay Chamber of Mines, Cranbrook;* Laura Williams, *Friends of Fort Steele Society;* Malaika Ulmi, *Natural Resources Canada, Vancouver.*