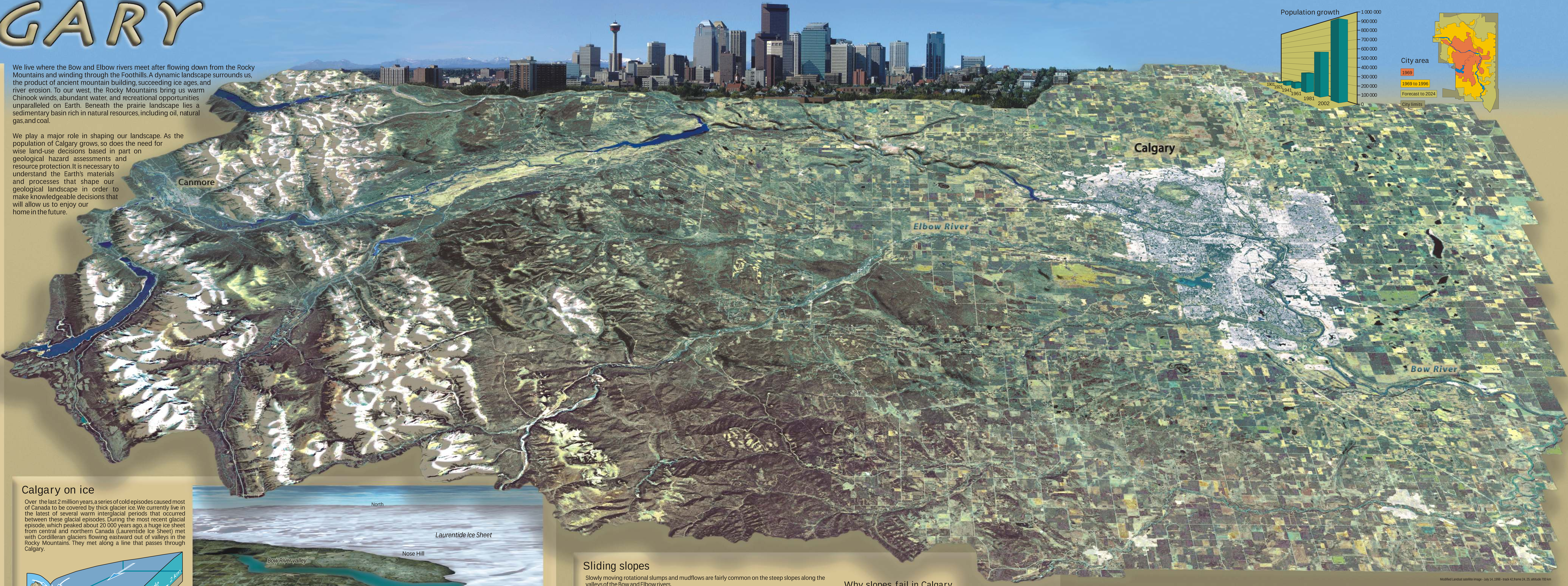
GEOSCAPE CALGARY

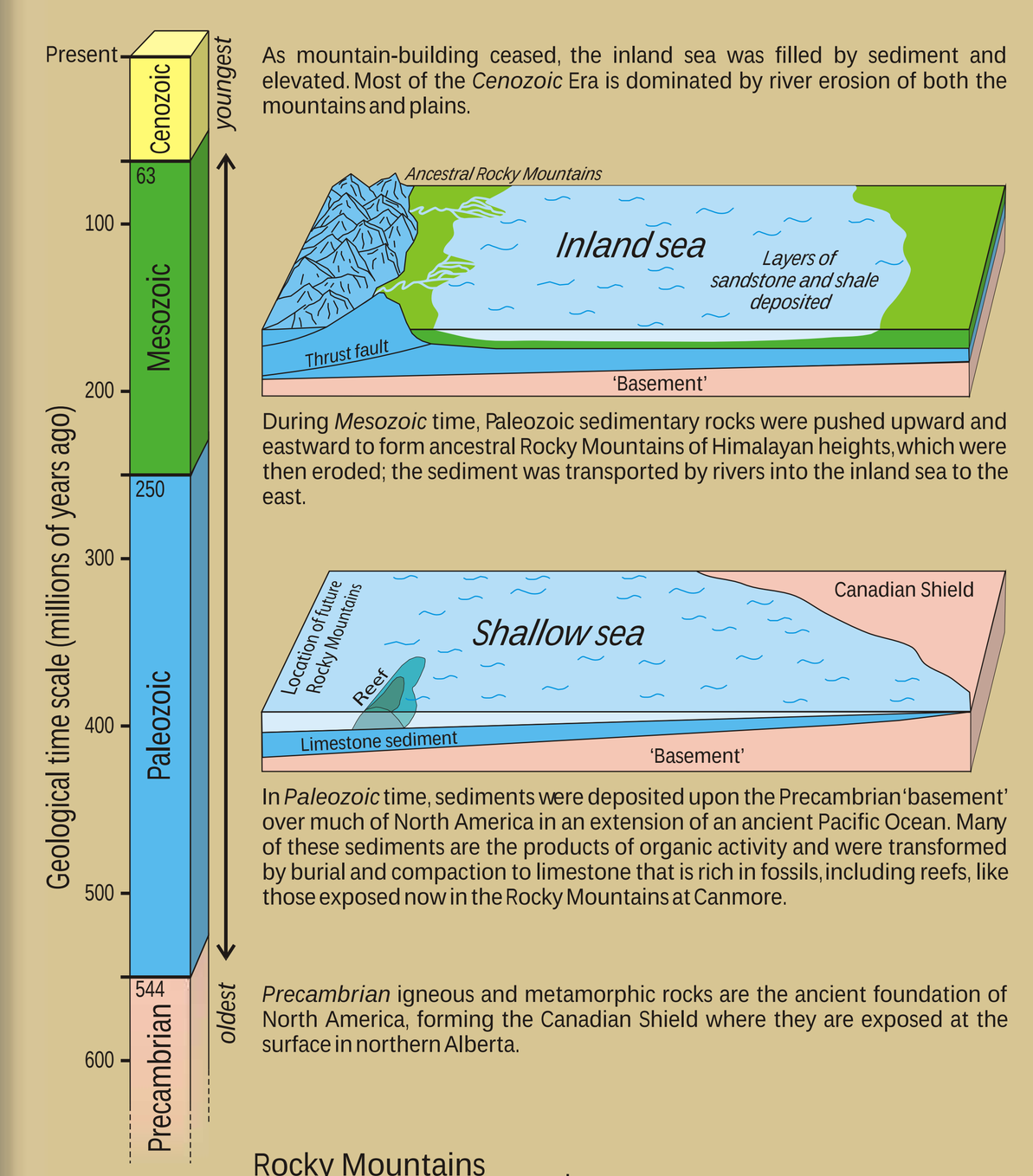


We live where the Bow and Elbow rivers meet after flowing down from the Rocky Mountains and winding through the Foothills. A dynamic landscape surrounds us, the product of ancient mountain building, succeeding ice ages, and river erosion. To our west, the Rocky Mountains bring us warm Chinook winds, abundant water, and recreational opportunities unparalleled on Earth. Beneath the prairie landscape lies a sedimentary basin rich in natural resources, including oil, natural gas, and coal.

We play a major role in shaping our landscape. As the population of Calgary grows, so does the need for wise land-use decisions based in part on geological hazard assessments and resource protection. It is necessary to understand the Earth's materials and processes that shape our geological landscape in order to make knowledgeable decisions that will allow us to enjoy our home in the future.

Landscapes then...

Geological time is divided into four eras (from youngest to oldest): Cenozoic, Mesozoic, Paleozoic, and Precambrian. The main events in the geological story of the Calgary region take place between 544 million years ago (the start of the Paleozoic Era) and the present. *The story begins in the Precambrian, at the bottom of the time scale.*



As mountain-building ceased, the inland sea was filled by sediment and elevated. Most of the *Cenozoic* Era is dominated by river erosion of both the mountains and plains.

During *Mesozoic* time, Paleozoic sedimentary rocks were pushed upward and eastward to form ancestral Rocky Mountains of Himalayan heights, which were then eroded; the sediment was transported by rivers into the inland sea to the east.

In *Paleozoic* time, sediments were deposited upon the Precambrian 'basement' over much of North America in an extension of an ancient Pacific Ocean. Many of these sediments are the products of organic activity and were transformed by burial and compaction to limestone that is rich in fossils, including reefs, like those exposed now in the Rocky Mountains at Canmore.

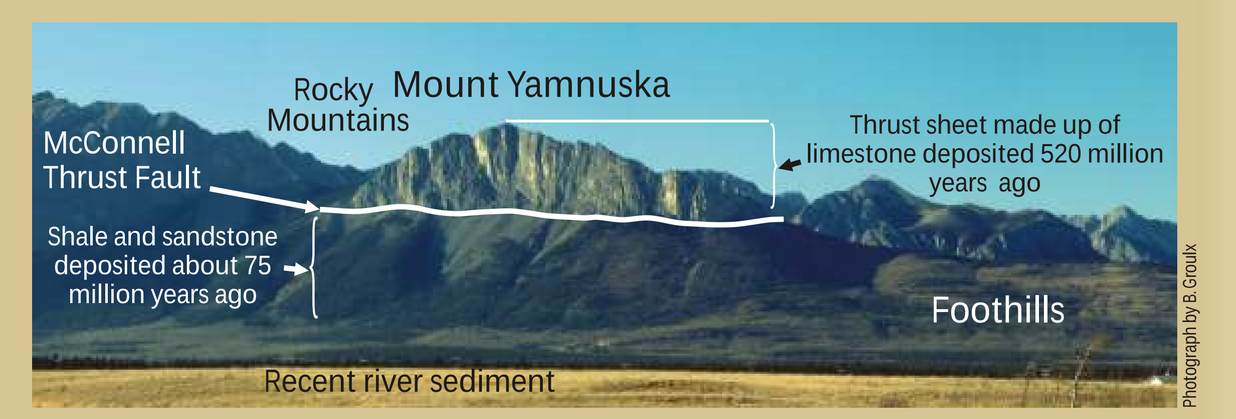
Precambrian igneous and metamorphic rocks are the ancient foundation of North America, forming the Canadian Shield where they are exposed at the surface in northern Alberta.

and now

Majestic mountains

Driving from Calgary to Canmore, it is hard to miss Mount Yamnuska, the most easterly peak north of the Trans-Canada Highway. It is a striking example of Paleozoic limestone, deposited about 520 million years ago, that was thrust on top of younger (Mesozoic) sandstone and shale deposited about 75 million years ago.

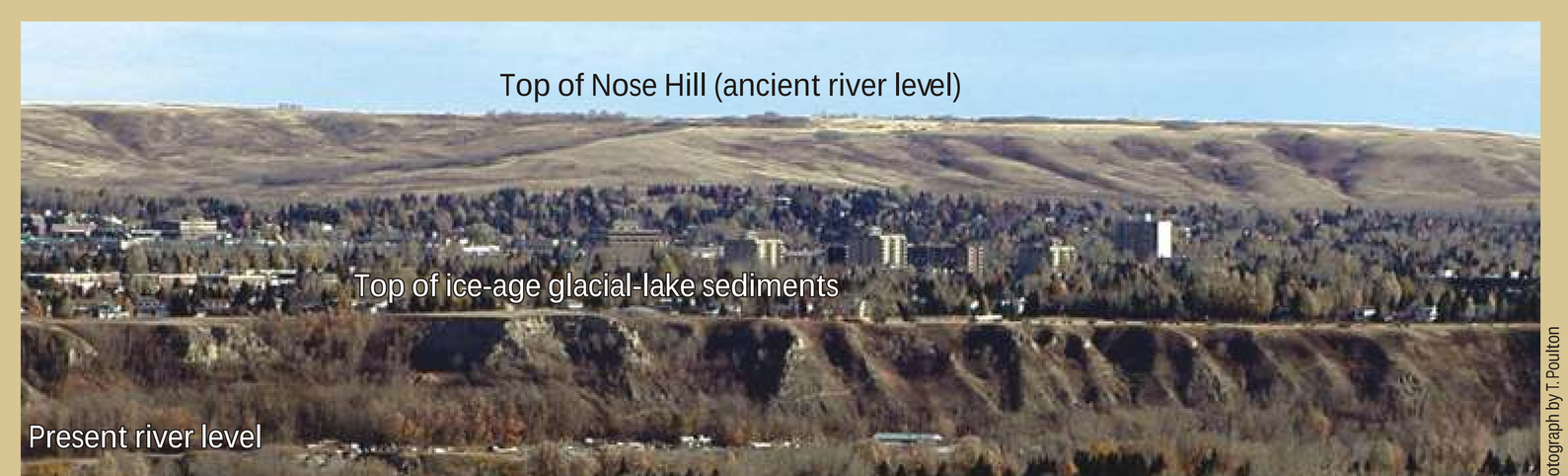
The paper-thin contact between the two rock formations is the McConnell Thrust Fault, one of the major faults of the eastern Rocky Mountains.

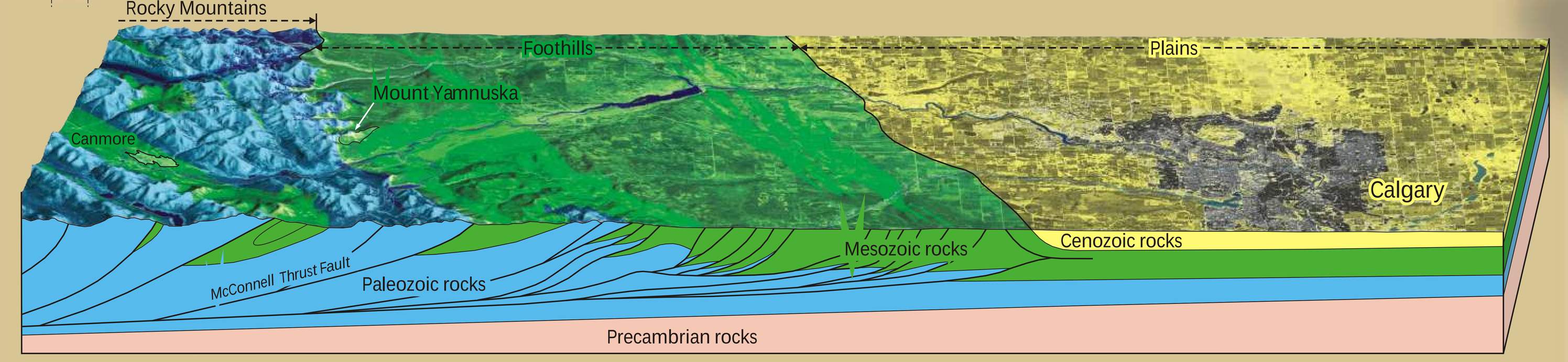


Peaceful plains

The Plains geological province, from Cochrane east to Manitoba, is made of sedimentary rocks not affected by mountain building and lies undeformed upon the original 'basement'.

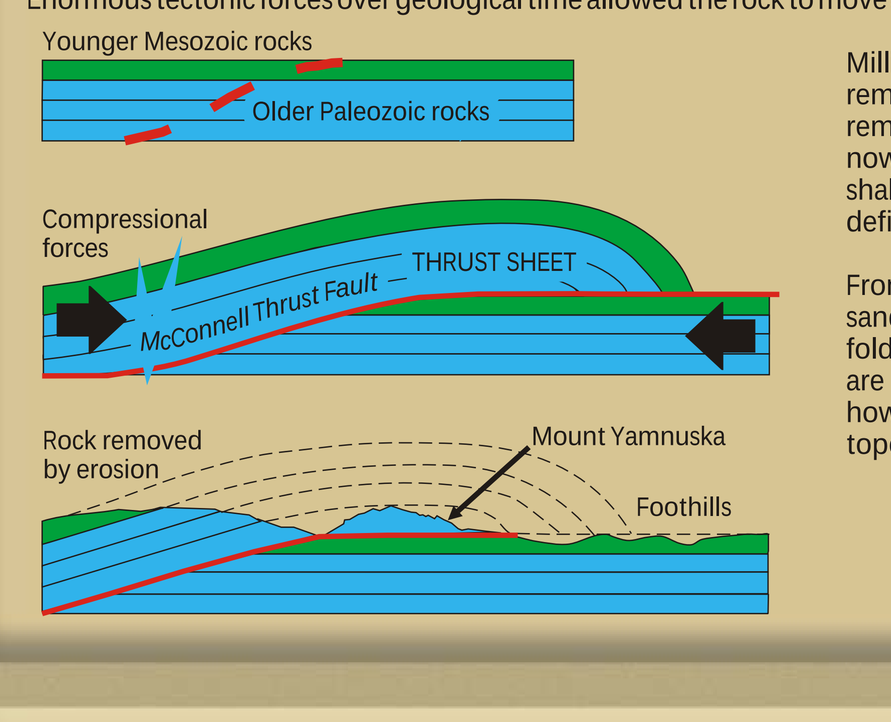
The main hills in the Calgary and Cochrane areas are remnants of a much higher plain from 1 million years ago, that has been largely removed by river erosion. The eroded land surface was modified by glacial erosion during the Ice Age, and the river valleys were the site of sediment deposition as the glaciers melted. Most recently, rivers in the last 10 000 years have cut down through ice-age sediments to their present levels.





Mountain building

During the building of the Rocky Mountains, from about 160 million to 60 million years ago, huge slabs of Paleozoic sedimentary rock ('thrust sheets') were shifted tens of kilometres northeastward and upward on top of much younger rock formations. Enormous tectonic forces over geological time allowed the rock to move and fold slowly, like a thick fluid.



Millions of years of erosion by water, wind, and ice have removed most of the original mountains, leaving only remnants — high cliffs of far-travelled hard limestone that now sit on top of much younger and softer sandstone and shale. Paleozoic limestone forming a rugged topography defines the Rocky Mountains geological province.

From the Rocky Mountains east to about Cochrane, the soft sandstone and shale of the Mesozoic were also faulted and folded during younger episodes of mountain building. They are not as hard as the limestone of the Rocky Mountains, however, and they have been eroded to form the gentler topography of the Foothills geological province.

If you just kept digging under Calgary...

Modern sediments

- *Soil, with organic content* — a rich agricultural resource
- *River-valley floodplain deposits* (including pebbles and boulders) derived in part from glacial deposits in the mountains
- *Volcanic ash layer* — from a huge eruption in Oregon 7700 years ago

Ice-age sediments

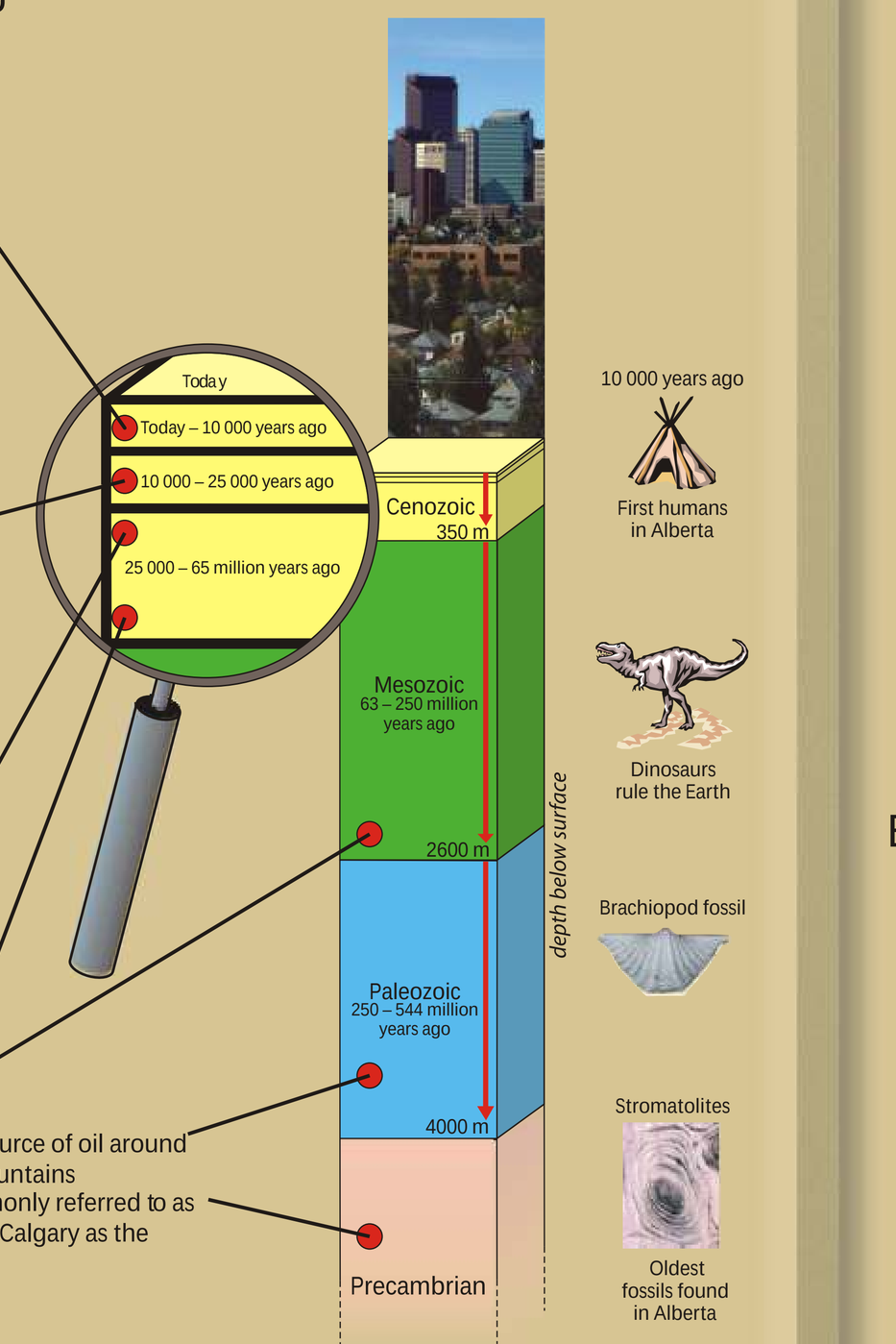
- *Till* — sediment deposited from melting glaciers, blanketing much of the higher ground in and around the city
- *Glacial-meltwater gravel and sand* — a source of aggregate
- *Glacial-lake silt* — subject to landslides

Pre-ice-age landscape

- *Bedrock topography* — formed by rivers cutting valleys into bedrock
- *Gravel beds of ancient rivers*, now preserved on the tops of the hills — a source of aggregate

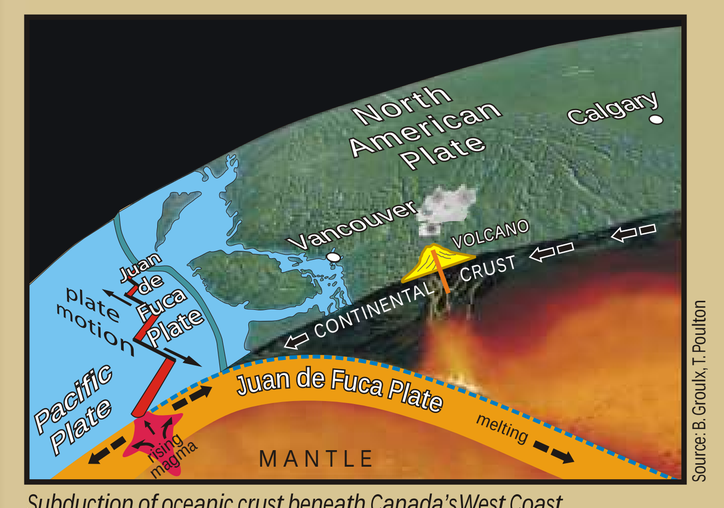
Bedrock

- *Paskapoo sandstone and shale* form the main hills in Calgary and Cochrane — a source of building stone and brick clay
- *Sandstone and mudstone* — a significant source of oil and natural gas
- *Limestone, including fossil reefs* — a source of oil around Calgary and rock resources from the mountains
- *Igneous and metamorphic rocks*, commonly referred to as 'basement', extend to over 20 km below Calgary as the continental crust



Location, location...

Calgary is located in a geologically stable setting, 800 km inland from active faults and volcanoes. The faults are related to the subduction of the Juan de Fuca Plate under the continental crust of North America and are a major source of earthquakes on the West Coast. As the oceanic crust on the plate descends, it melts and gives rise to some of the volcanoes in the west.

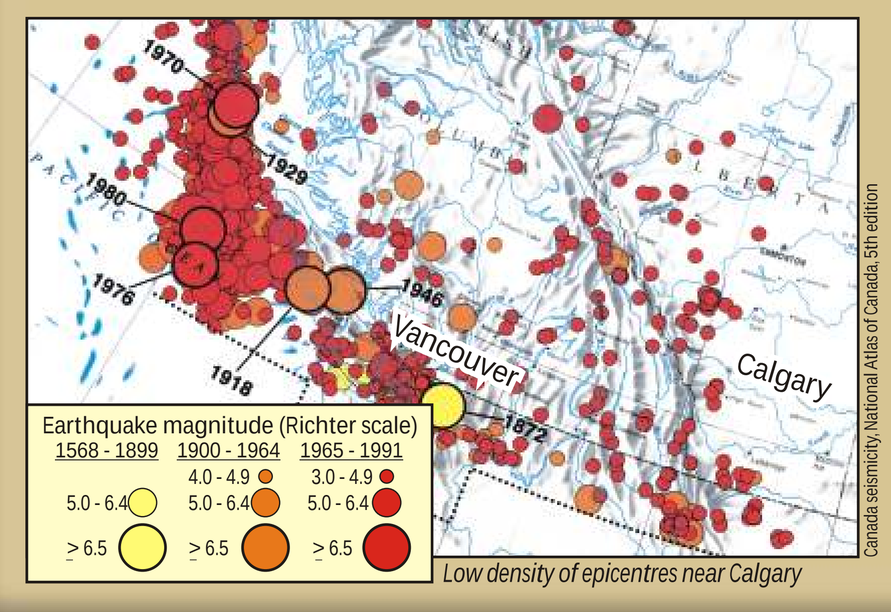


Subduction of oceanic crust beneath Canada's West Coast

Just a little bit shaky

Despite Calgary's location far from active faults, some small earthquakes have occurred in the region. Some of these result from the minor jostling and adjustments related to movement of geological plates. Others are caused by stresses in the rocks associated with removal of oil and gas from underground reservoirs, an effect taken into account by the industry.

The earthquake epicentre map shows the location, magnitude, and timing of earthquakes in historical times. Note the greater density and higher magnitude of earthquakes on the coast.



Low density of epicentres near Calgary

A blast from the past

Although Calgary is a long way from active volcanoes, many residents will remember the dusting of volcanic ash from the eruption of Mount St. Helens in 1980.

A much larger eruption occurred 7700 years ago, when Mount Mazama in southern Oregon erupted with such violence that much of the mountain was removed, creating the depression now occupied by Crater Lake. The eruption was so large that volcanic ash reached as far as Calgary and Edmonton. A layer of Mazama ash can be seen today in many places in southern Alberta and British Columbia.

Mazama ash layer exposed along Fish Creek in Calgary

Rock resources

Valuable building stone and aggregate materials are abundant in the mountains and along the Bow River valley, reducing the need for lengthy transport. Did you know that the Calgary Tower and the Banff Springs Hotel were built with materials from our own backyard?

Bow Valley mineral extraction and processing sites

Limestone quarry on Grotto Mountain

Cement

Sandstone and shale, trucked from quarries at Seebe near Mount Yamnuska, are combined with limestone at Exshaw, to produce cement. The process involves grinding and blending the rocks, and burning the mix in kilns.

Lime processing plant

Lime

Limestone, trucked from the Grotto Mountain quarry, is crushed, screened, and burned in kilns at about 1450°C to produce lime (calcium oxide). Lime is used in agriculture, in water treatment, in sugar refining, and in the manufacture of steel and paper.

Gravel extraction near Calgary

Concrete

Gravel is excavated from many pits around Calgary. It is combined with cement to form concrete, or with oil to form asphalt for building roads, bridges, sidewalks, and buildings. The Calgary Tower is a highly visible example of the use of concrete.

Rundle Rock

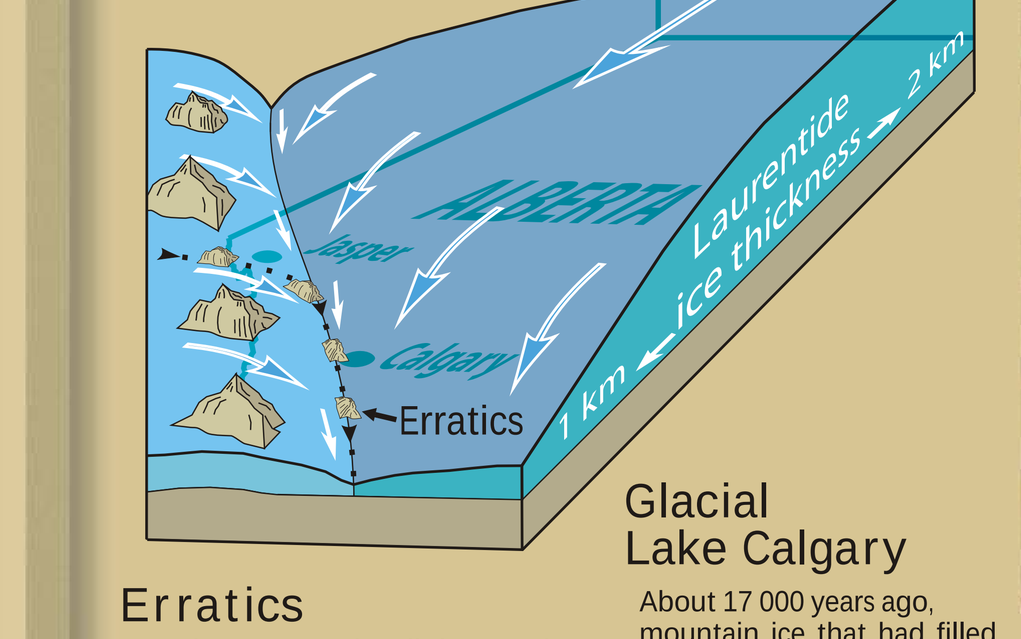
Rundle Rock is a blocky brown sandstone with flat, smooth surfaces. This popular decorative stone was first described by geologist R.G. McConnell in 1887. It was named by stonemasons quarrying the rock from the base of Mount Rundle near the town of Banff. Today this sandstone is quarried just east of Canmore. It originated as sand deposited on Early Mesozoic seafloors about 245 million years ago.

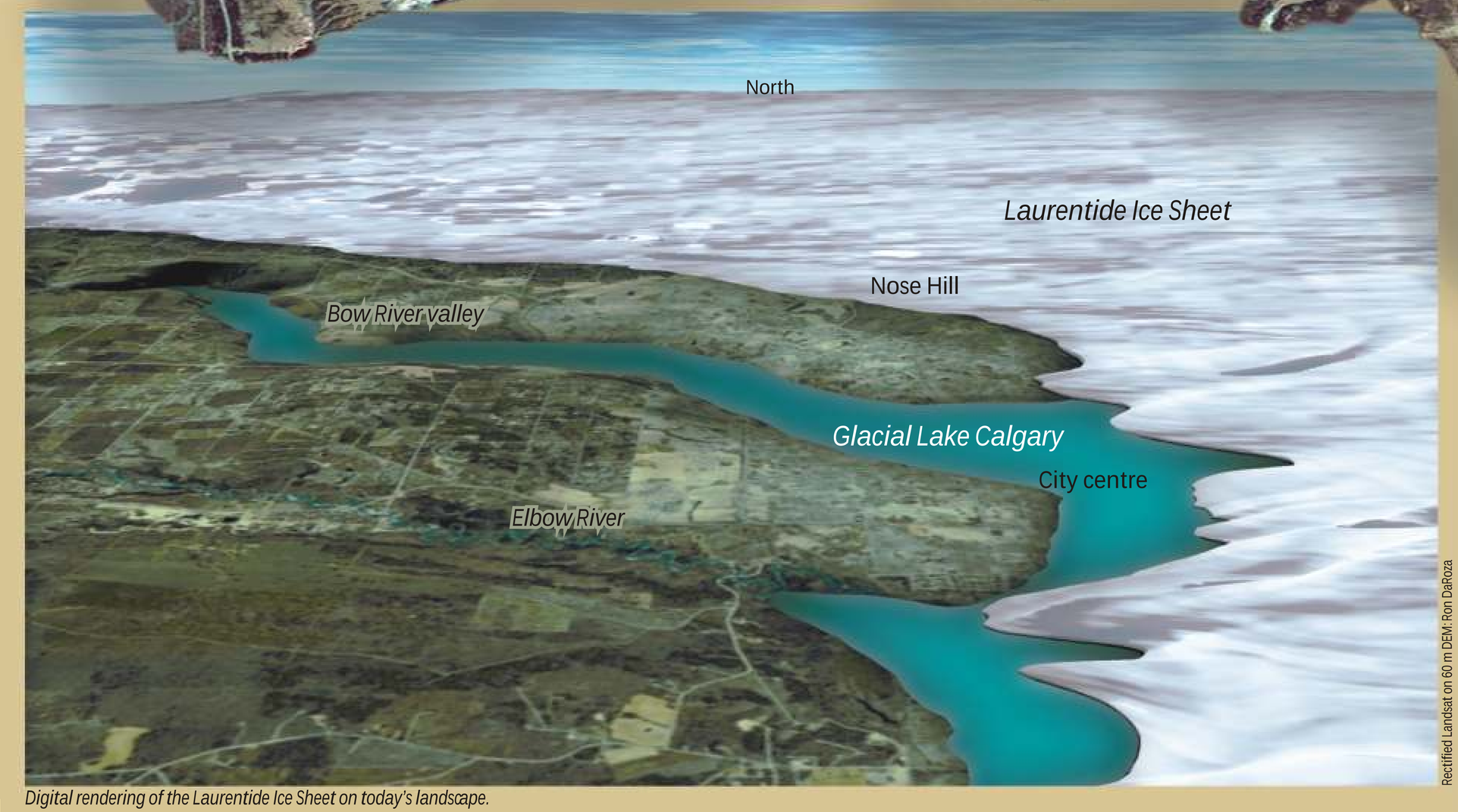
Rundle Rock on Banff Springs Hotel

Rundle Rock (left) was used to build the Banff Springs Hotel.

Calgary on ice

Over the last 2 million years, a series of cold episodes caused most of Canada to be covered by thick glacier ice. We currently live in the latest of several warm interglacial periods that occurred between these glacial episodes. During the most recent glacial episode, which peaked about 20 000 years ago, a huge ice sheet from central and northern Canada (Laurentide Ice Sheet) met with Cordilleran glaciers flowing eastward out of valleys in the Rocky Mountains. They met along a line that passes through Calgary.





Digital rendering of the Laurentide Ice Sheet on today's landscape.

Erratics

Erratics are exceptionally large rocks carried long distances by glaciers. A string of them, the Foothills Erratics Train, marks the junction of the Laurentide and Cordilleran glaciers. It includes the Big Rock near Okotoks and boulders on Nose Hill and Paskapoo Slopes. They are rocks that fell from mountain walls near Jasper and were carried eastward out of the Rocky Mountains by valley glaciers, then as far south as northern Montana along the line where the Laurentide and Cordilleran ice sheets met.

Glacial Lake Calgary

About 17 000 years ago, mountain ice that had filled the Bow River valley began to melt and its eastern edge receded westward. Meltwaters from the glacier were dammed by the Laurentide Ice Sheet in the central Calgary area, forming Glacial Lake Calgary. Fine-grained sediments deposited in this lake now underlie much of western Calgary. Remnants of the mountain ice remain today as glaciers on the highest peaks of the Rocky Mountains.

The 'Big Rock' is an erratic from the Jasper area that now rests near Okotoks.

Drumlin north of the Trans-Canada Highway at Morley Flats

Drumlins

Another curious landform created by the glaciers is the drumlin. The best place to see drumlins is at Morley Flats, 42 km west of Calgary on the Trans-Canada Highway. Debate continues as to whether these asymmetric mounds form by deposition at the base of a glacier or by erosion by meltwaters flowing at the base of a glacier. In general, drumlins indicate the ice-flow direction: the steep ends point in the direction from which the ice flowed (upstream) and the gentle, tapered ends point downstream.

Sliding slopes

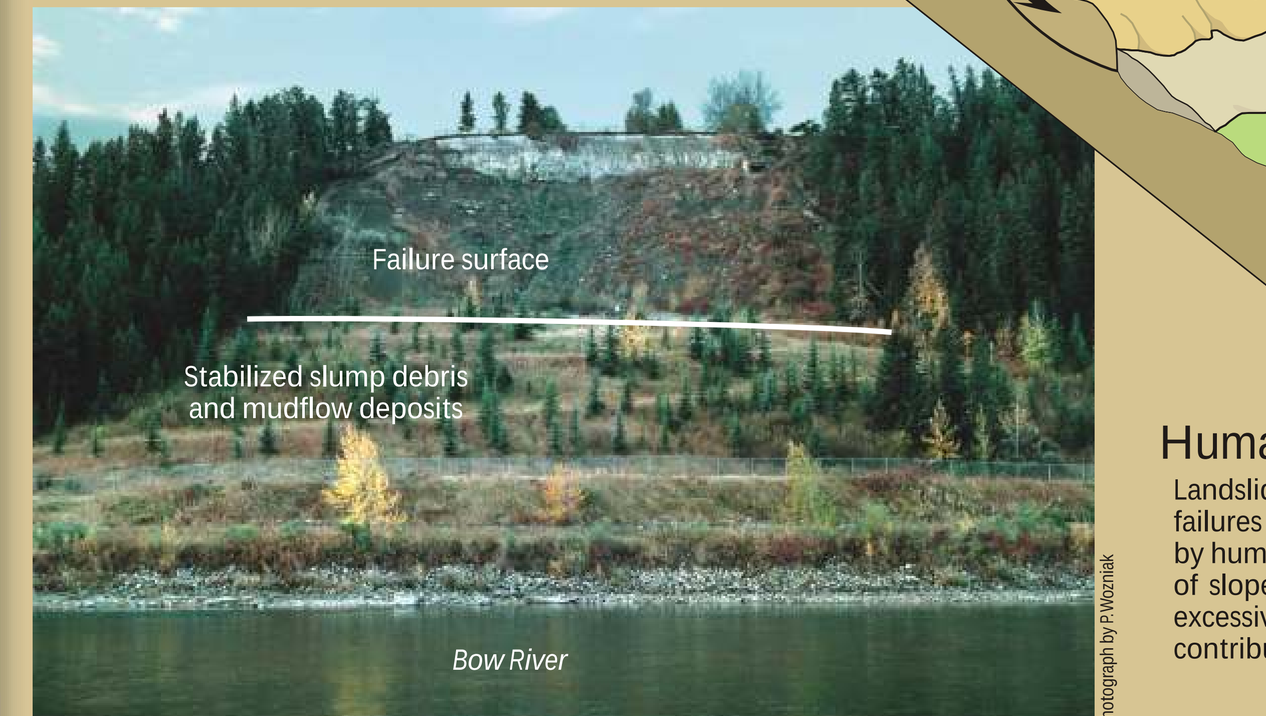
Slowly moving rotational slumps and mudflows are fairly common on the steep slopes along the valleys of the Bow and Elbow rivers.

The slides

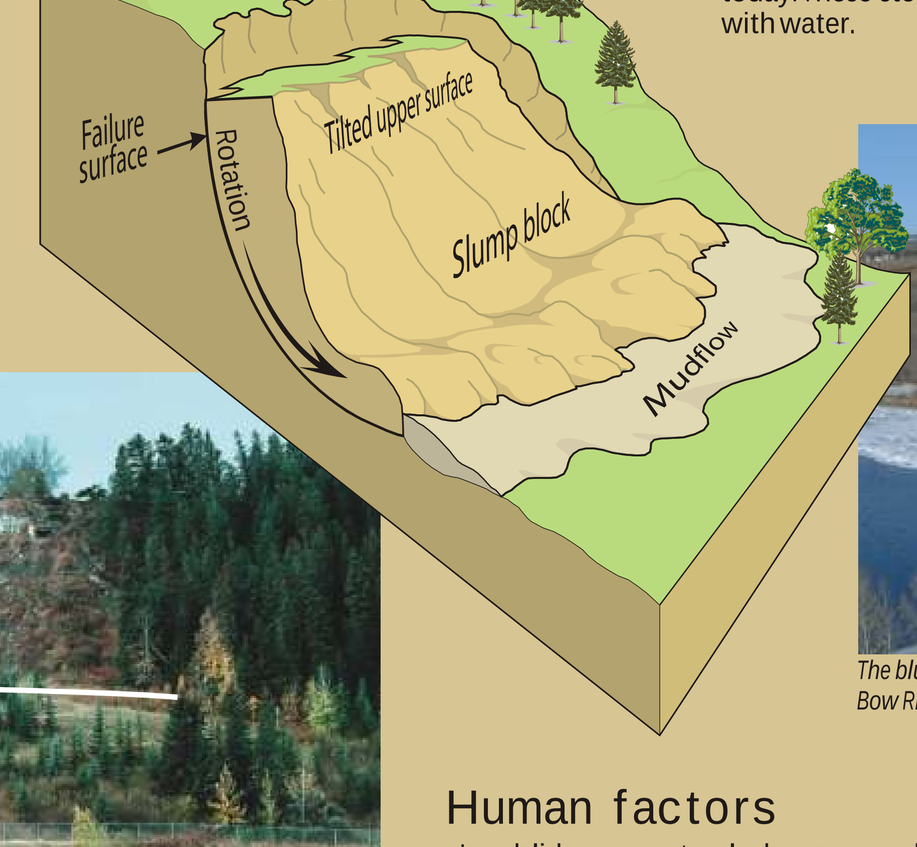
Rotational slumps are landslides that occur when a slumping block slides on a curved failure surface, causing the upper surface to tilt back.

Mudflows occur when unconsolidated materials become saturated with water during snowmelt or rainstorms and flow downslope.

At times, combinations of both types of landslide occur together, for example at the Wildwood slide site in north Calgary.

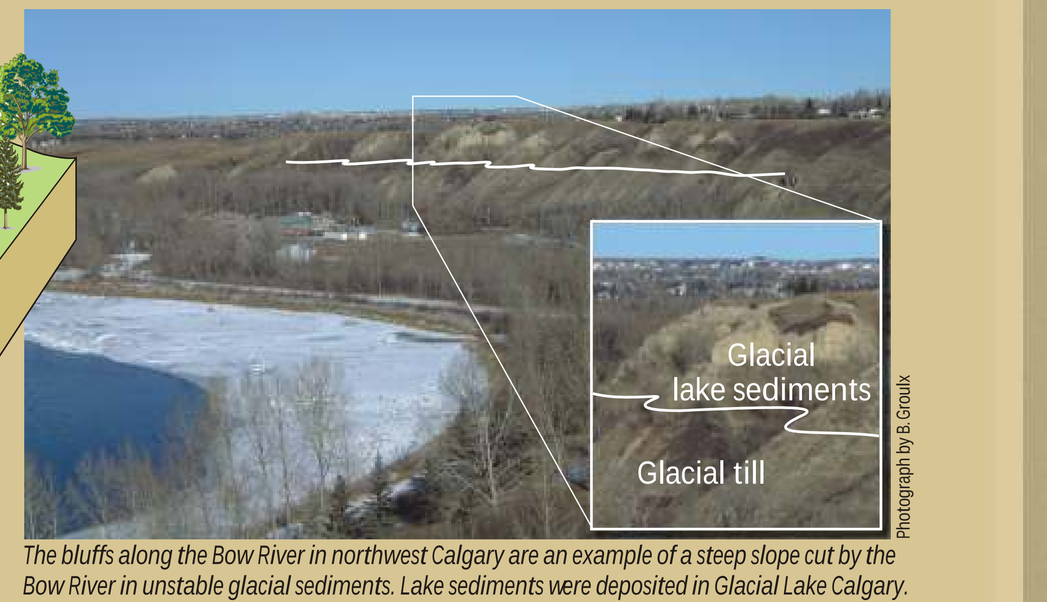


Wildwood slide



Why slopes fail in Calgary

The stage was set for failing slopes when large quantities of glacial and lake sediments were deposited during the Ice Age in the broad pre-glacial Bow and Elbow river valleys. The rivers cut down through these sediments to create the steep slopes that we see along the rivers today. These steep slopes are unstable and may fail when the ground becomes saturated with water.



The bluffs along the Bow River in northwest Calgary are an example of a steep slope cut by the Bow River in unstable glacial sediments. Lake sediments were deposited in Glacial Lake Calgary.

Human factors

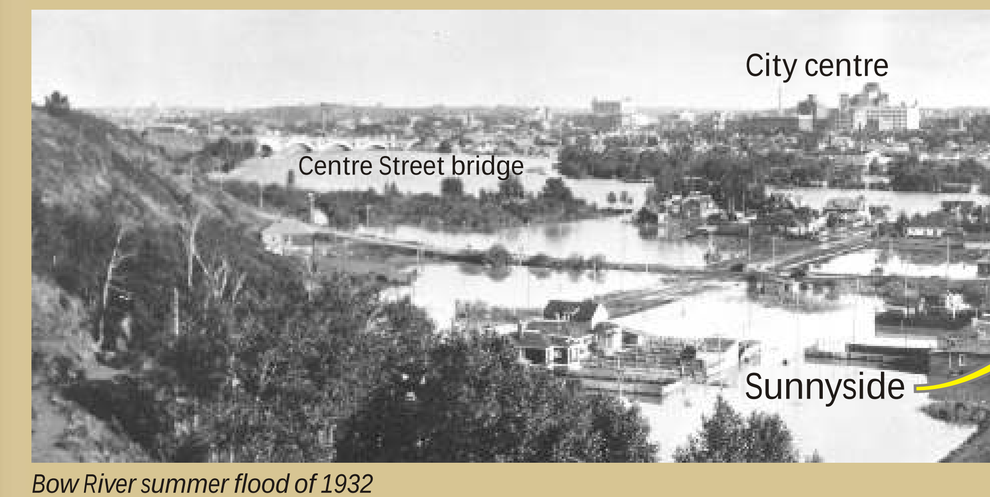
Landslides are natural phenomena, but some slope failures of the last several decades were caused in part by human activity. Removal of material from the base of slopes, placing earthfill at the top of slopes, and excessive lawn and garden irrigation on top of bluffs contribute to slope failures.

Slope safety

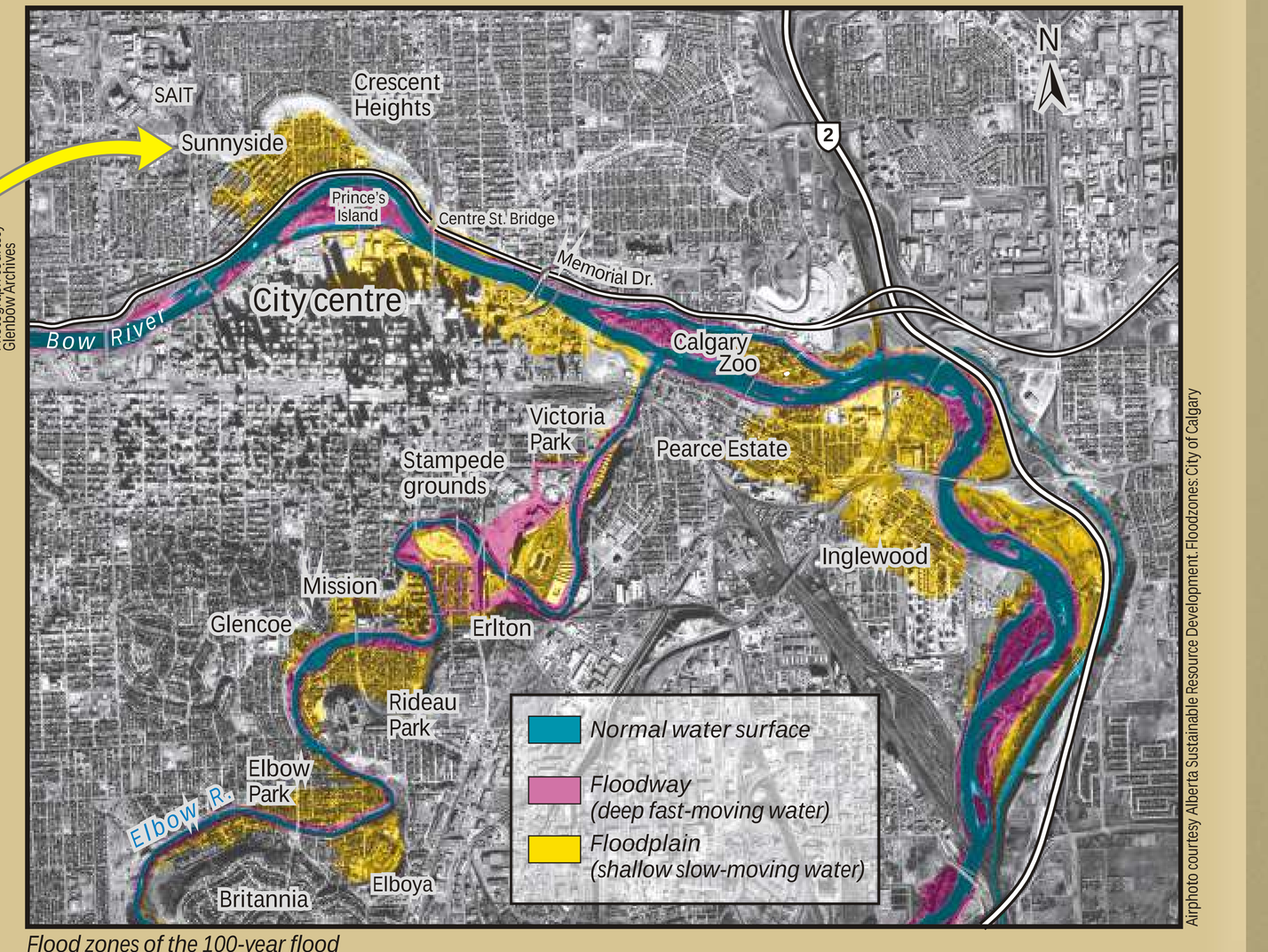
To minimize the occurrence of landslides in Calgary, the city has implemented land-use and engineering guidelines. Since 1978, an evaluation of slope stability by a qualified engineer must precede development at any site where final design slopes exceed 15% (about 9°).

Rivers... friend and foe

Water from the Bow and Elbow rivers meets the urban and agricultural needs of much of southern Alberta. Reservoirs along both rivers provide Calgarians with fresh water, and irrigation canals carry water to farms east of Calgary. The rivers also provide a natural retreat within Calgary and attract trout fishermen from around the world.



Bow River summer flood of 1932



Flood zones of the 100-year flood

Floods

Floods can occur during the summer when exceptionally heavy rainfalls combine with rapid snowmelt in the mountains. In June 1929, flooding on the Elbow River washed out the 25th Avenue SE bridge and created a lake where Victoria Park had been. The last major summer flood to hit Calgary was in 1932, when the Bow River inundated Sunnyside and other communities.

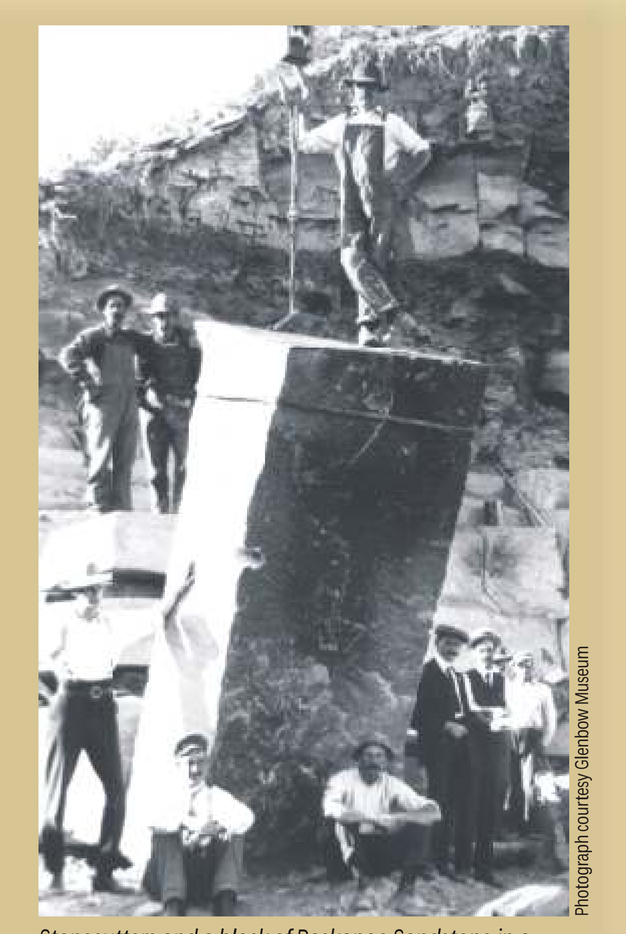
Ice jams form during spring breakup or during Chinook winds in midwinter. They are caused by surface ice breaking into floes, which pile up against obstructions and block the river's flow.

Future flooding?

The risk of flood damage has been reduced by the construction of dams on the Bow River upstream from Calgary and of dikes around the floodplain areas of the city. However, the dams are too far upstream and the storage capacity of the reservoirs is too small to prevent the largest spring or summer floods. A 1996 estimate of the damage to Calgary resulting from a '100-year flood' (a flood that has 1 chance in 100 of occurring in any given year) is $131 million.

Sandstone City

On November 7, 1886, a devastating fire destroyed many wooden buildings on the main street of Calgary. To avoid another catastrophe, Calgarians decided to rebuild the town with Paskapoo Sandstone, a more fireproof material. This decision marked the beginning of the 'sandstone era,' during which 15 quarries operated in and around Calgary. Sandstone was used to build schools, churches, and large private and public buildings, including the old part of City Hall, built in 1911 (800 Macleod Trail SE).



Stonecutters and a block of Paskapoo Sandstone in a quarry near Calgary

The old Customs Building (134-11 Avenue SE) was built with Paskapoo Sandstone from an Oliver Brothers quarry (grey blocks) and Brickburn brick.

Sandstone

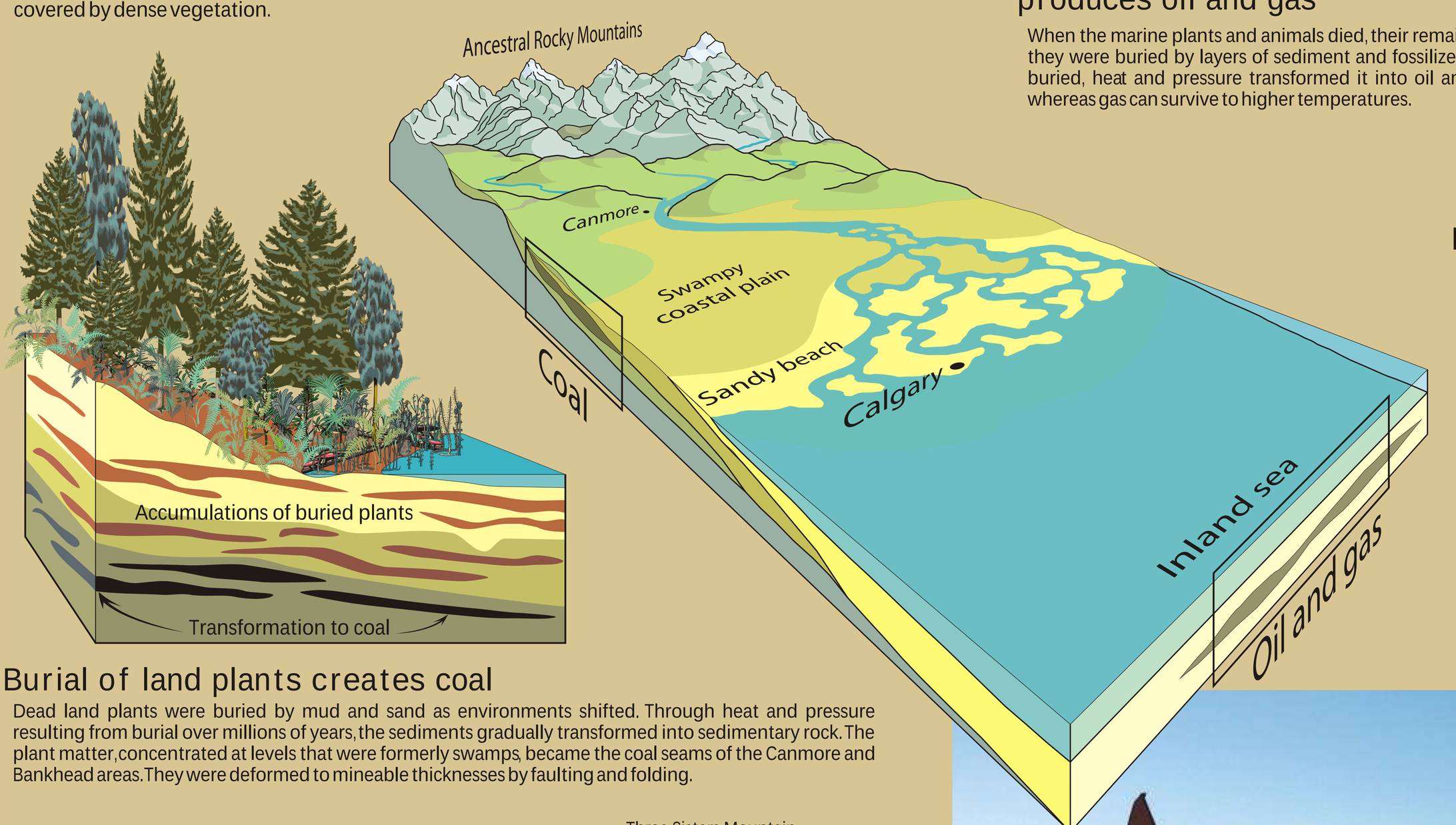
Paskapoo Sandstone consists of sand grains eroded from the ancestral Rocky Mountains and transported to the east by rivers 65 to 58 million years ago. Over time, the sands were buried under hundreds of metres of younger sediment, cemented with minerals precipitated from groundwater, and then slowly exposed by erosion to form the sandstone outcrops that can be seen today along our river valleys.

The brick boom

The 1886 fire also sparked a brick industry in Calgary. People began to build chimneys out of fireproof brick made from shale that is interlayered with Paskapoo Sandstone. From 1907 until 1912, brick homes were in vogue and the Calgary brickyards boomed. In 1914, however, the First World War brought an end to both industries as employees left to serve in the armed forces.

Fossil fuel energy

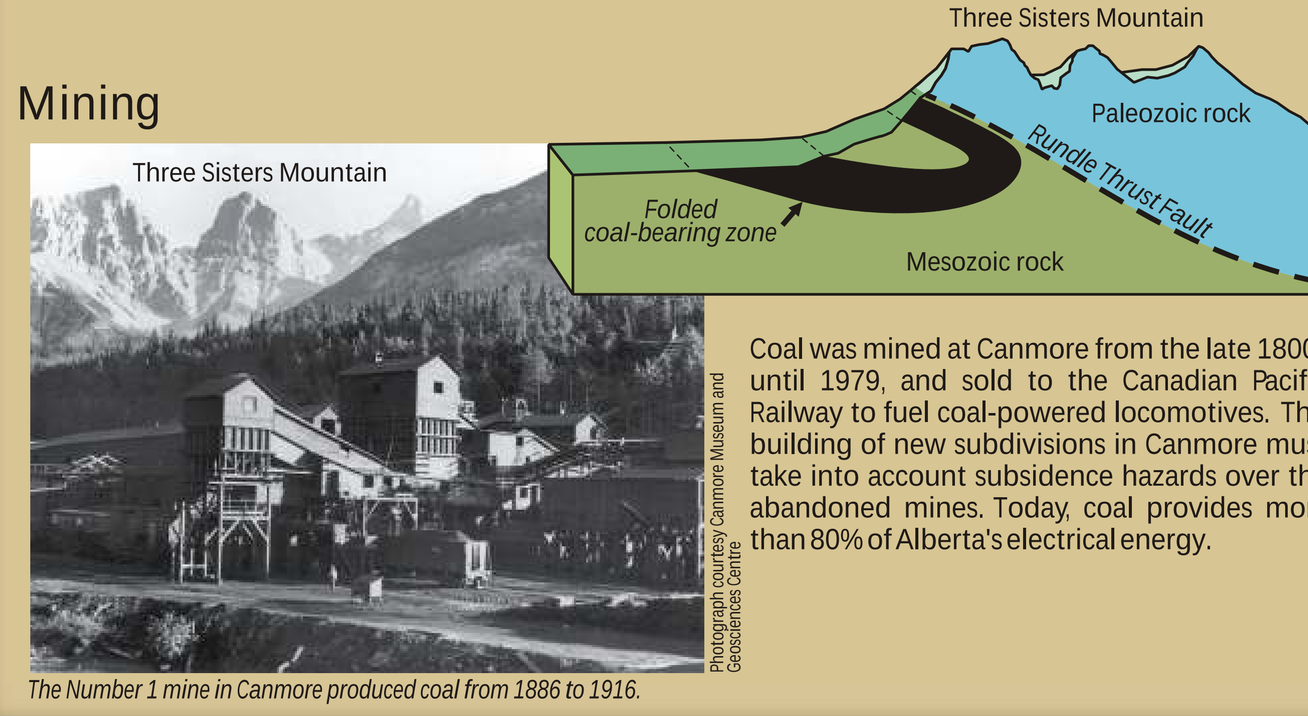
Millions of years ago, the region around Calgary was covered by an inland sea teeming with marine life. The land to the west featured rivers draining from the ancestral Rocky Mountains and swamps covered by dense vegetation.



Burial of land plants creates coal

Dead land plants were buried by mud and sand as environments shifted. Through heat and pressure resulting from burial over millions of years, the sediments gradually transformed into sedimentary rock. The plant matter, concentrated at levels that were formerly swamps, became the coal seams of the Canmore and Bankhead areas. They were deformed to mineable thicknesses by faulting and folding.

Mining

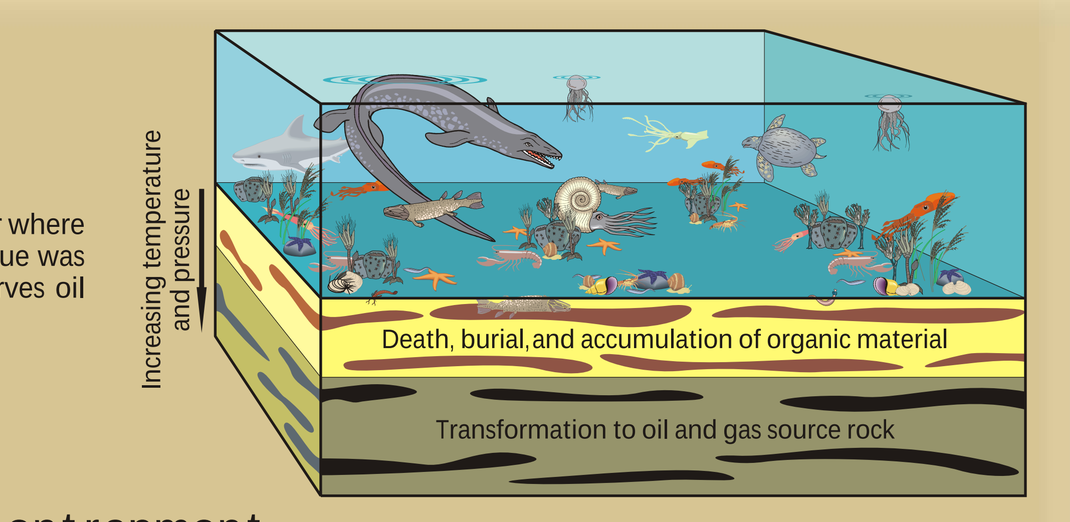


The Number 1 mine in Canmore produced coal from 1886 to 1916.

Coal was mined at Canmore from the late 1800s until 1979, and sold to the Canadian Pacific Railway to fuel coal-powered locomotives. The building of new subdivisions in Canmore must take into account subsidence hazards over the abandoned mines. Today, coal provides more than 80% of Alberta's electrical energy.

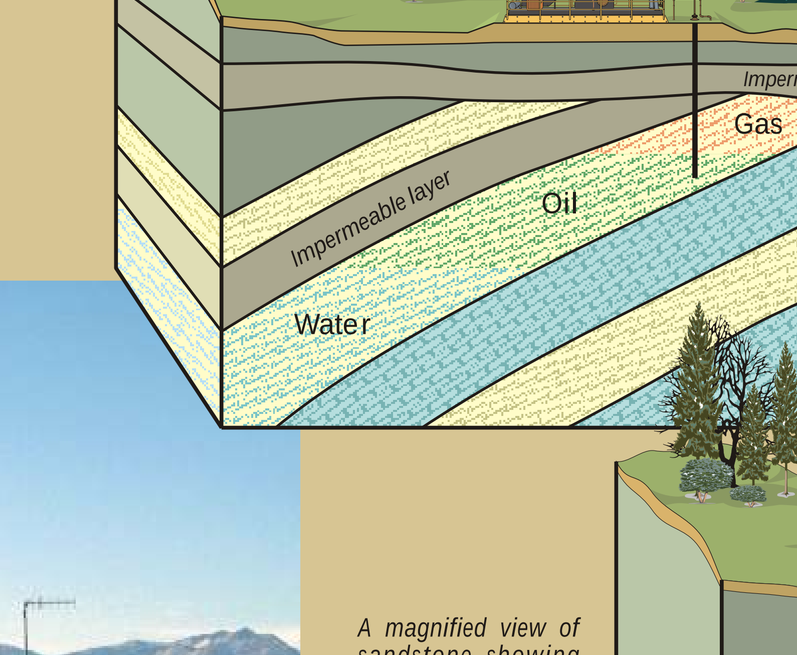
Burial of marine life produces oil and gas

When the marine plants and animals died, their remains settled on the seafloor where they were buried by layers of sediment and fossilized. As the soft organic tissue was buried, heat and pressure transformed it into oil and gas: lower heat preserves oil whereas gas can survive to higher temperatures.



Migration and entrapment

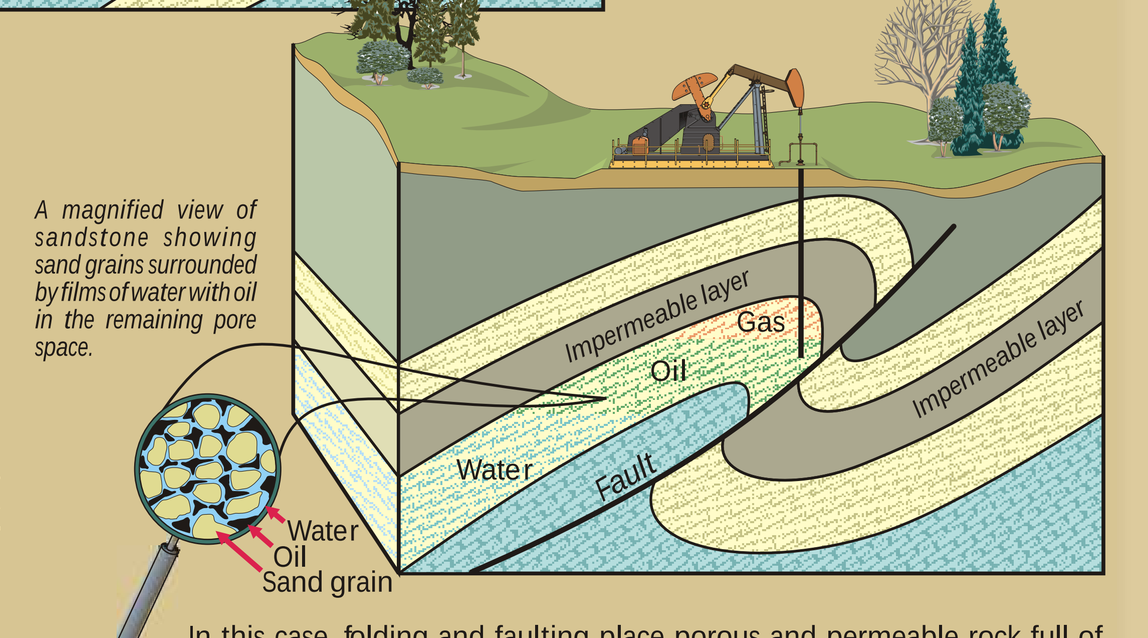
The rocks in which oil and gas form are called 'source rocks'. Due to the pressure of overlying rock layers, oil and gas seldom remain in the source rock. Instead, they migrate with water through the layers of rock until they either escape at the surface or are trapped by an impermeable barrier. There are two main types of traps: stratigraphic and structural.



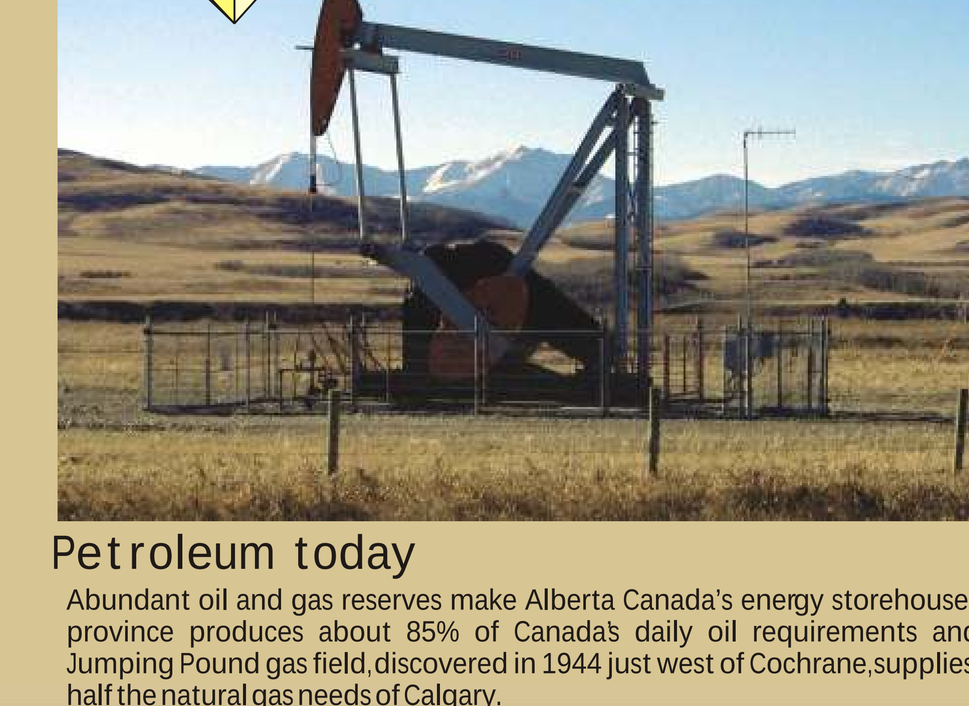
Stratigraphic trap

These occur when overlying impermeable layers act as a seal above the permeable strata below. The porous reservoir fills up with fluids. This is the kind of trap found commonly in the plains around Calgary. Gas and lighter fluids rise to the top.

Structural trap



In this case, folding and faulting place porous and permeable rock full of fluids next to impermeable rock. This kind of trap is found throughout the Foothills to the west of Calgary.

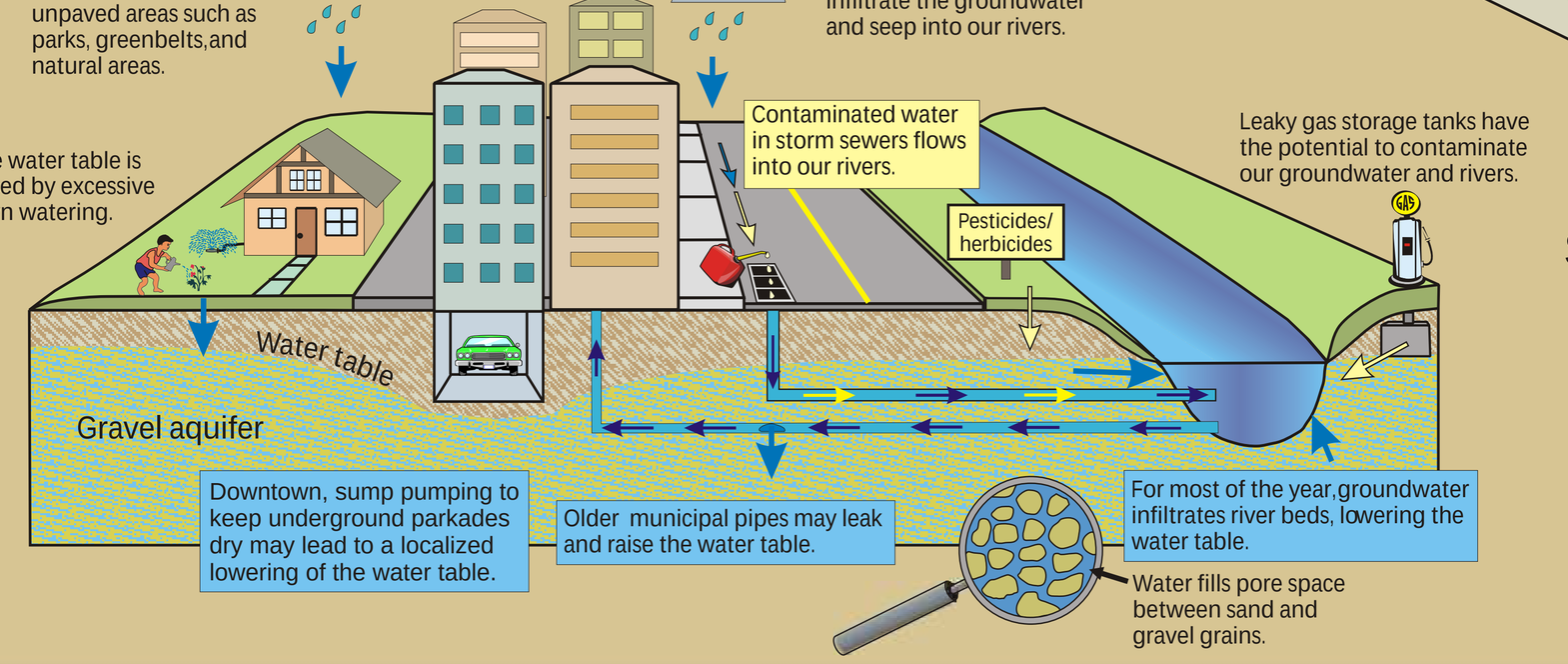


Petroleum today

Abundant oil and gas reserves make Alberta Canada's energy storehouse. The province produces about 85% of Canada's daily oil requirements and the Jumping Pound gas field, discovered in 1944 just west of Cochrane, supplies over half the natural gas needs of Calgary.

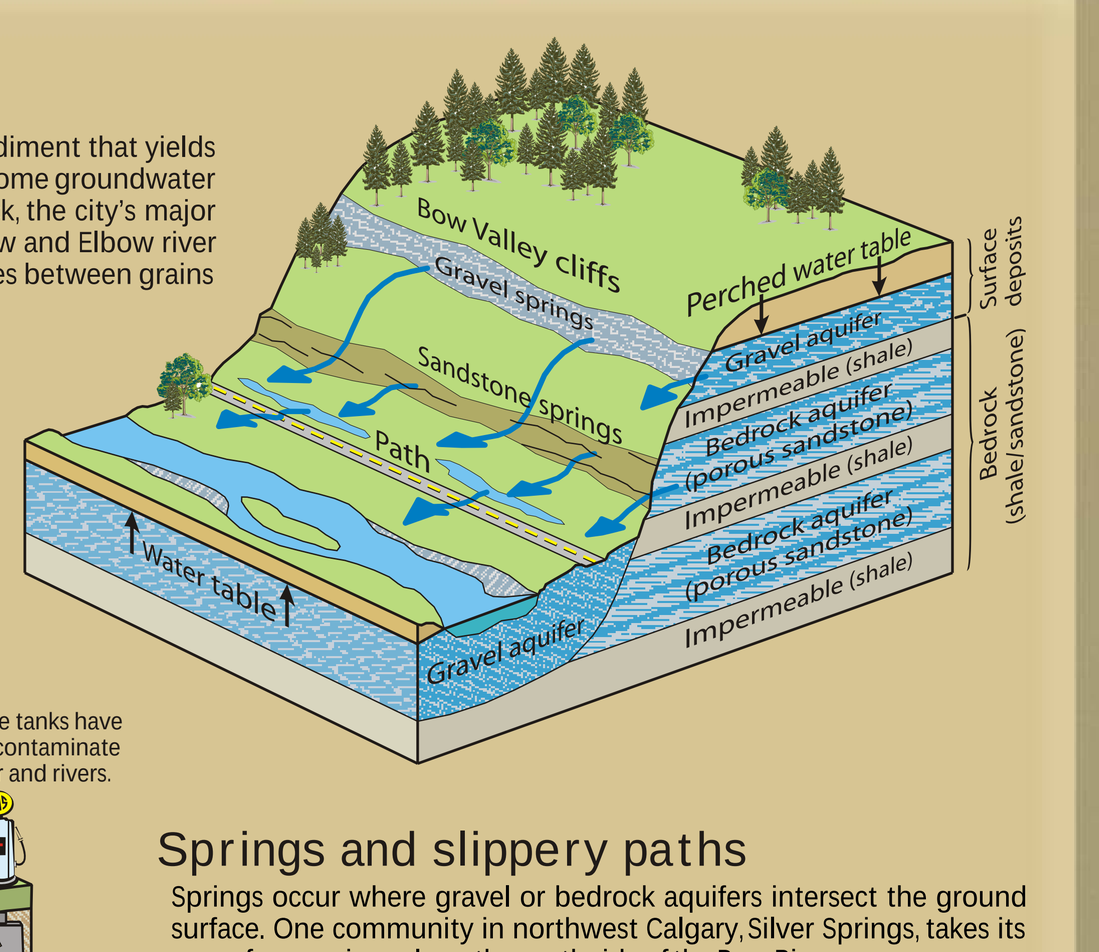
Water under our feet

Groundwater is something that few people think about. This abundant resource, however, is directly linked to our surface water supply in the Calgary valleys. When river levels are high, groundwater flows into the surrounding gravels, and during the rest of the year groundwater flows into the riverbeds. Because of this interconnection, contamination of either will affect the entire system. Sources of contamination within Calgary include leaky gas station fuel tanks, industrial activity, herbicides, pesticides, surface water runoff, and irresponsible storm sewer use.



Aquifers

An aquifer is a body of bedrock or sediment that yields water in usable quantities. Although some groundwater occurs in Calgary's sandstone bedrock, the city's major aquifer is the gravel that lines the Bow and Elbow river valleys. Groundwater is stored in pores between grains of sediment.



Springs and slippery paths

Springs occur where gravel or bedrock aquifers intersect the ground surface. One community in northwest Calgary, Silver Springs, takes its name from springs along the north side of the Bow River.

Some springs have proven to be an annual problem in Calgary. At the base of Spruce Cliff, southeast of Edworthy Park, water from numerous springs flows in small streams down to the Bow River, crossing a pedestrian and bicycle path. In winter the ice from these streams may build up to almost 2 m thick on parts of the path, making springtime walking and biking treacherous.

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Additional reading:

Huck B. and Whiteway, D., 1998. ***In Search of Ancient Alberta***; Heartland Associates Inc.

Karrow, P. and White, O. (ed.), 1998. ***The Urban Geology of Canadian Cities***; The Geological Association of Canada, Special Paper 42.

Mussieux, R. and Nelson, M., 1998. ***A Traveller's Guide to Geological Wonders in Alberta***; The Provincial Museum of Alberta.

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