GEOSCAPE WHITEHORSE

Geoscience for a Yukon community

Aerial view of Whitehorse, Yukon Territory, in midwinter. Looking northwest from Schwatka Lake on the Yukon River (foreground), towards the Whitehorse Rapids dam and the hydroelectric generating facility (centre foreground), the airport and plowed runway (centre left), and downtown Whitehorse (centre right). The broad valley is drained by the Yukon River, which flows to the right.
Photo courtesy of W. Towriss

We live in the broad valley of the Yukon River amid the rounded mountains of the Yukon Plateau. This landscape is formed of clay, sand, gravel, and rock, and is continually shaped by earth processes – our geological landscape or geoscape.

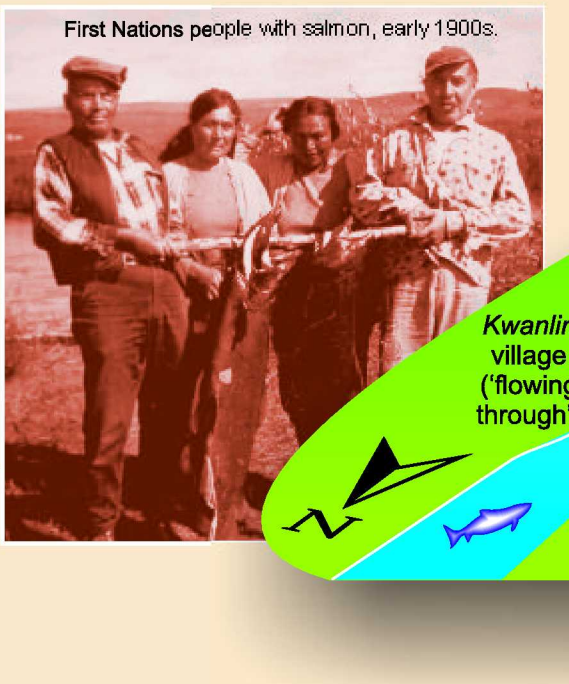
The earth materials in the Whitehorse valley tell the geological story from 250 million years ago to the present. The nearby mountains represent ancient limestone reefs, river deposits, granite magmas, and lavas. Glaciers and streams carved valleys and deposited sediment across the landscape; the Yukon River continues to wash away the sediment. Landslides displace rock and soil. Waters dissolve, transport, and deposit minerals, both at and below the Earth's surface.

By understanding our geoscape, we can promote its wise use: conserve water and energy resources, reduce natural hazards, and protect natural ecosystems that sustain life. Our quality of life and the sustainability of our community depend upon how we incorporate geological knowledge into land and resource decisions.

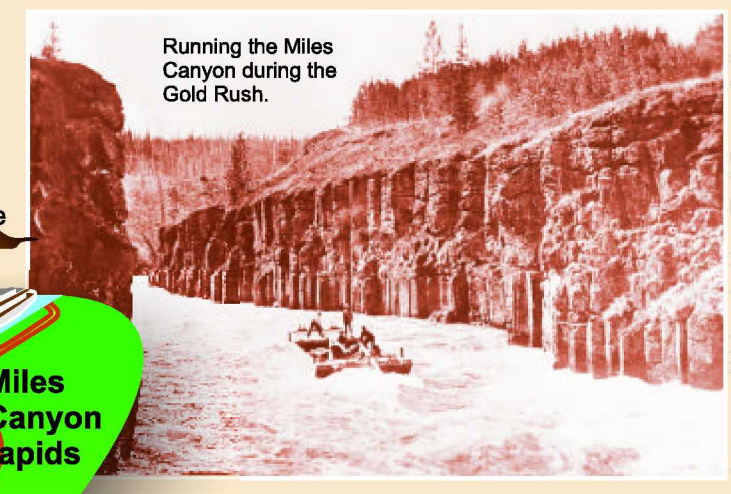
YUKON RIVER: Lifeline through time

Traditional fishing site

Rapids in the Yukon River have always focused human activity. *Klik-has* rapids impeded salmon migrating upstream to spawn in summer. (*Klik-has* means 'very bad' in the local First Nations language.) First Nations people speared salmon in the rapids and set their nets in the eddies below the rapids. Their seasonal camps were located downstream of the rapids.



First Nations people with salmon, early 1900s.
Courtesy of Yukon Archives/Richard Harrington Coll.



Running the Miles Canyon during the Gold Rush.
Courtesy of Yukon Archives/Emil Forrest Coll.

Transfer point during the Gold Rush

Miles Canyon and Whitehorse rapids were dangerous and famous obstacles to Gold Rush stampeders bound for the Klondike goldfields. To bypass these rapids, cargo was carried in horse-drawn carts on wooden rails, or 'tramlines', between transfer points at Canyon City and White Horse City. When the White Pass and Yukon Railway from Skagway was completed in 1900, a larger town (now Whitehorse) sprang up across the river around wharves where freight was transferred from rail cars to sternwheelers.

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Why Whitehorse?

Whitehorse owes its location to basaltic lava flows that constrict the Yukon River and give rise to the Miles Canyon and Whitehorse rapids. The Whitehorse Rapids were named for their resemblance to bounding white stallions. Today, the rapids are largely gone, due to diversion of river flow through the generating facility.

Today's hydroelectric power

The Whitehorse Rapids Generating Facility, built in 1957, supplies a major part of the Yukon Territory's electricity needs. This is where the gradient of the Yukon River is steepest, providing the 'head' for hydroelectric power generation. Water falls 18 m from the dam to spin the turbines, creating electricity.

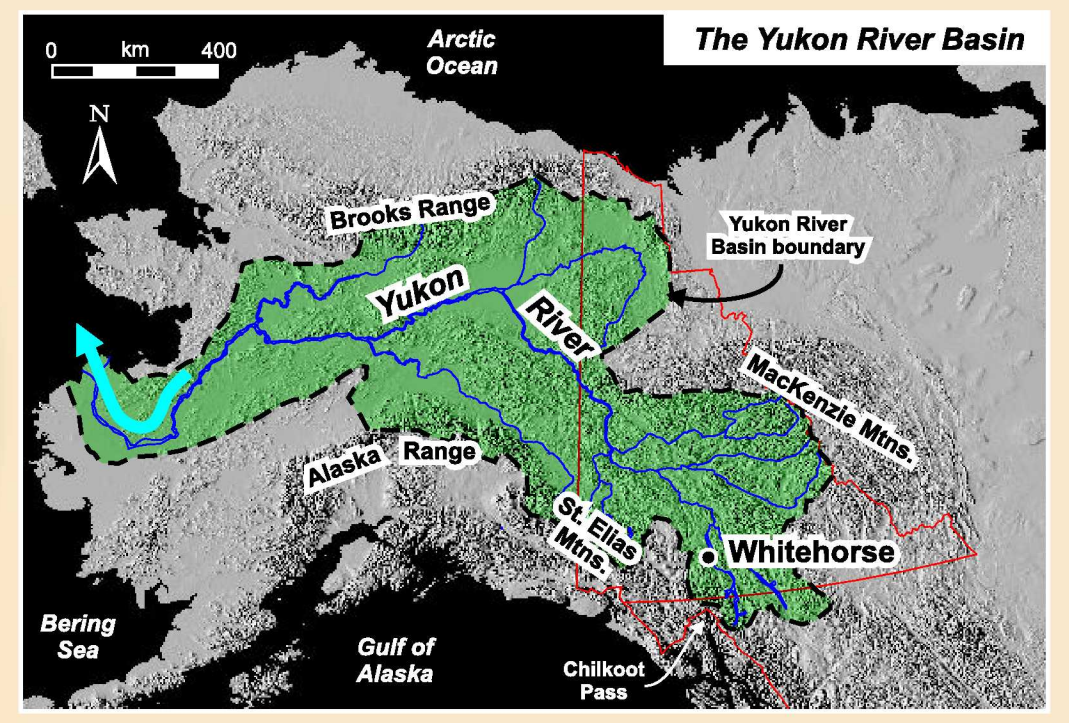
Another reason for building the dam at Whitehorse Rapids was that the basaltic lava flows that form the river banks provided an excellent foundation. Behind the dam, the Yukon River backed up to create Schwatka Lake, which in turn tamed the swift water at Miles Canyon.

Whitehorse Rapids Generating Facility.

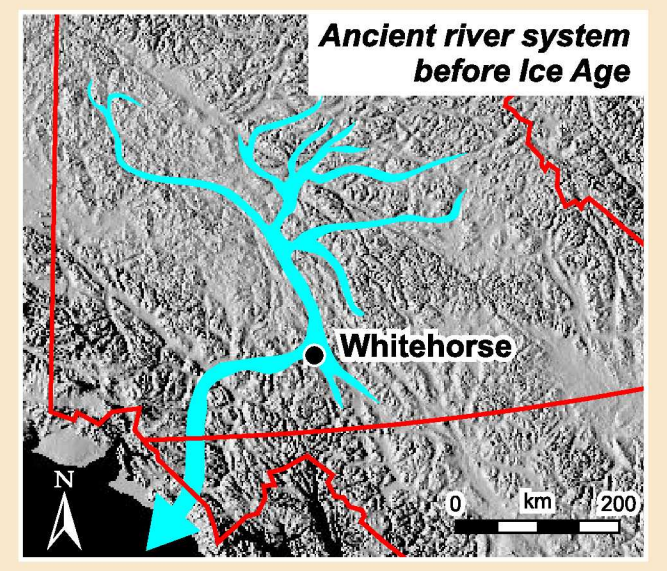
Courtesy of Yukon Energy Corporation

River piracy!

The head of the Yukon River, at Chilkoot Pass, is within sight of the Pacific Ocean – yet the river does not drain into the Pacific, but rather flows more than 3000 km to the Bering Sea. The present drainage pattern of the Yukon River is a relatively recent development. Many valleys and river terraces slope to the south, and geologists believe that much of the Yukon Territory may have once drained southwestward to the Gulf of Alaska. This drainage was blocked by glaciers during the Ice Ages, and waters in central Yukon Territory were forced to find a new and much longer route through the ice-free terrain of Alaska to the Bering Sea.



The Yukon River Basin

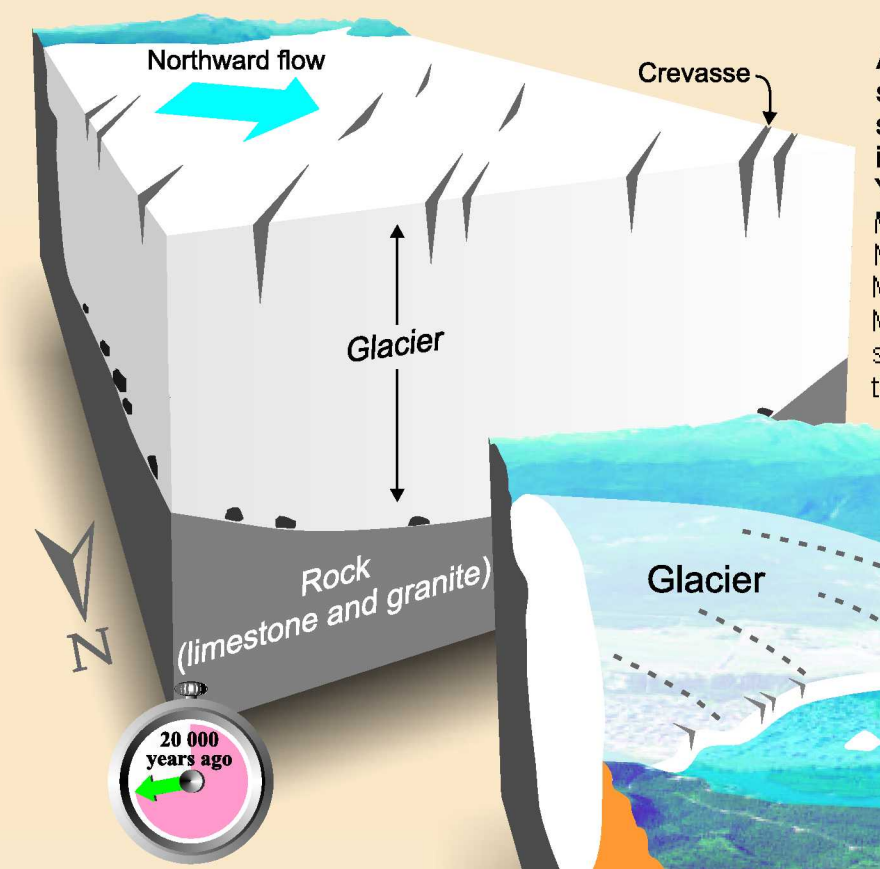


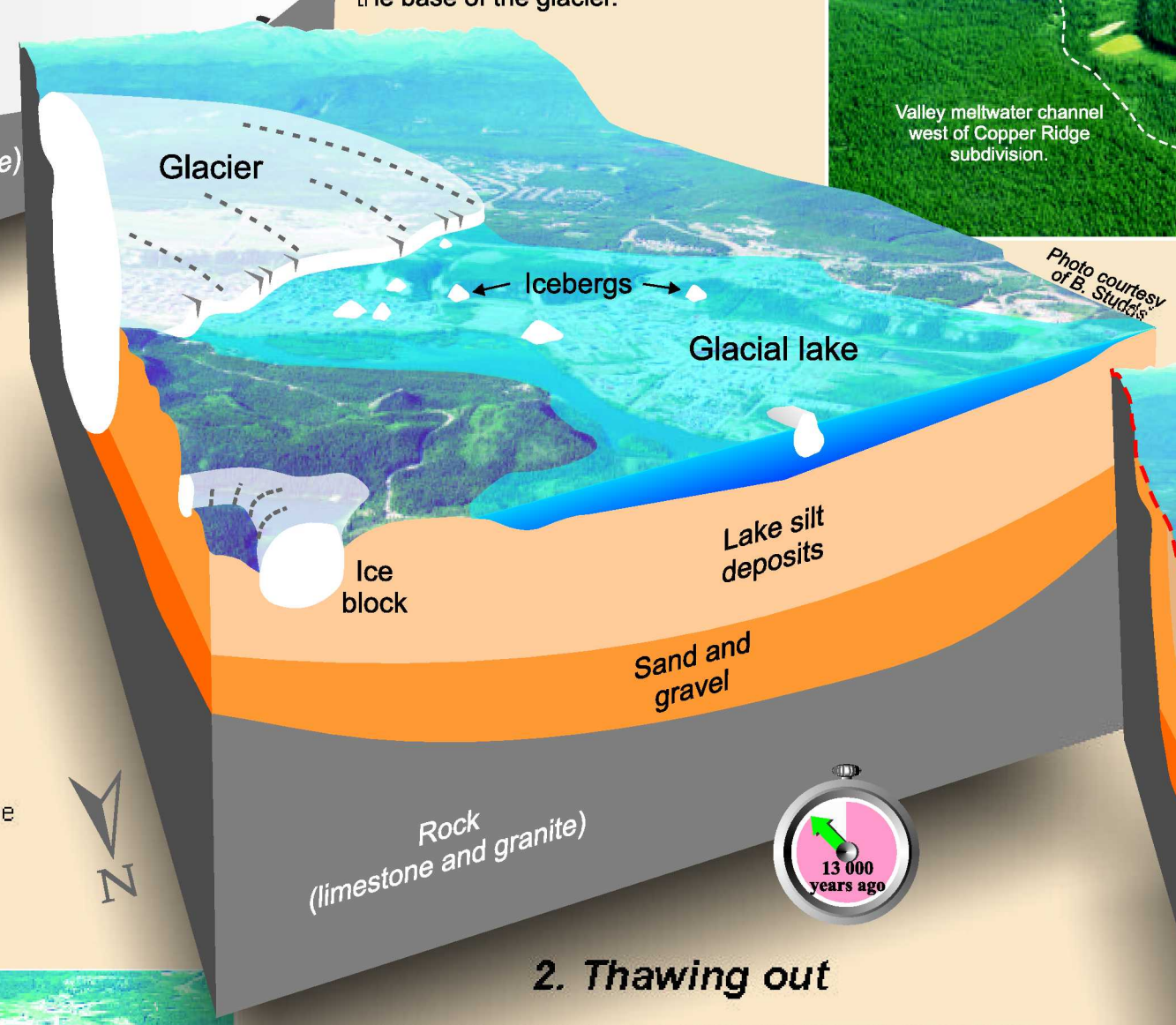
Ancient river system before Ice Age

GLACIERS AND STREAMS: Architects of our valley

1. The big chill

About 20 000 years ago, an ice sheet up to 2 km thick covered southern Yukon Territory. Glacier ice flowed northward along the Yukon River valley, overtopping Mount McIntyre, Canyon Mountain (locally known as Grey Mountain), and Golden Horn Mountain. Rock surfaces were scratched by stones frozen into the base of the glacier.





Buried ice cubes

Large blocks of stagnant ice that become isolated from the snout of a melting glacier may be partly or completely buried by silt, sand, or gravel. When the ice blocks melt, they leave depressions on the landscape, called **kettles**. Kettles deep enough to extend below the water table form kettle lakes.

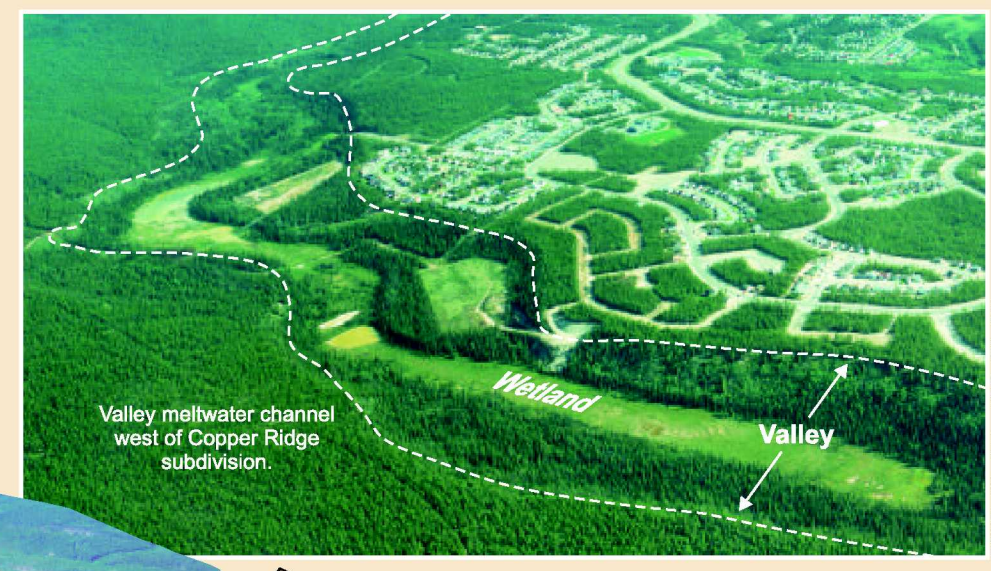
Hummocky landscape with kettles, Long Lake.
Photo courtesy of B. Studds

2. Thawing out

As the climate warmed, about 15 000 years ago, the glaciers covering southern Yukon Territory thinned and retreated to the south. Less than 2000 years later, glacier ice began to disappear from the Yukon River valley at Whitehorse. North-flowing meltwater, however, was dammed by a remnant mass of glacier ice near present-day Lake Laberge, and a large glacial lake developed in the Takhini and Yukon river valleys. Streams flowing from melting ice transported large amounts of silt and sand into the lake. The silt deposits accumulated on the lake floor, in some places to a thickness of more than 90 m. These deposits are exposed in bluffs which border the Yukon River and surround downtown Whitehorse. They form the flat surface on which the Whitehorse airport is located. Next time you are at the airport, imagine yourself on a muddy lake bottom with icebergs floating overhead!

Mysterious valleys

Long, narrow valleys on the sides of the Whitehorse valley are mysterious – they seem too large to have been carved by the small streams that now occupy them. Geologists believe that these valleys were carved by streams flowing from a melting glacier at the end of the Ice Age. The flat floors of these meltwater valleys contain wetlands that are an important plant and animal habitat.



Valley meltwater channel west of Copper Ridge subdivision.
Photo courtesy of B. Studds

Silt cliffs behind downtown Whitehorse.
C. Roots

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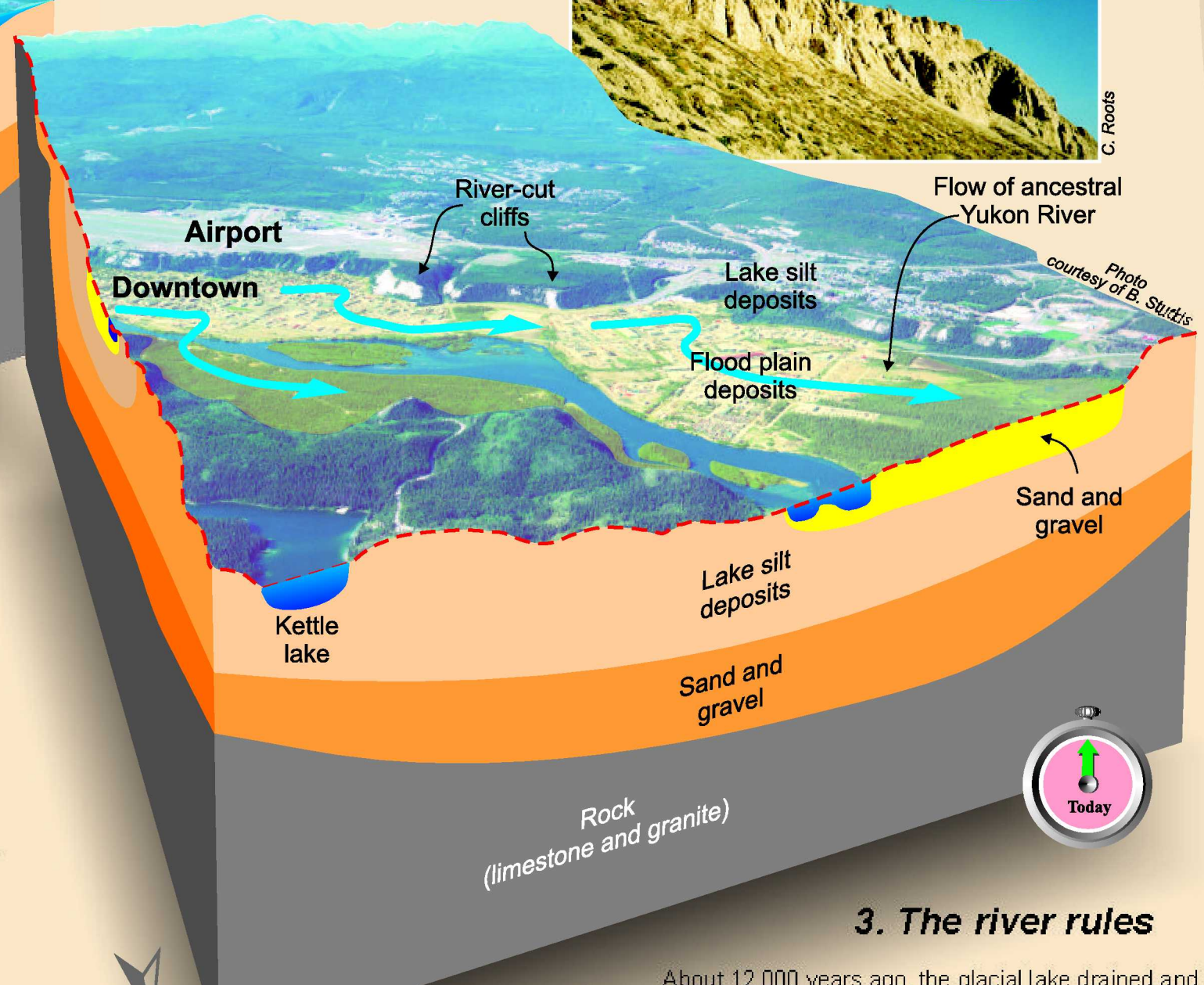
Did you know?

The silt cliffs along the Yukon River expose sediments deposited in a glacial lake at the end of the Ice Age.



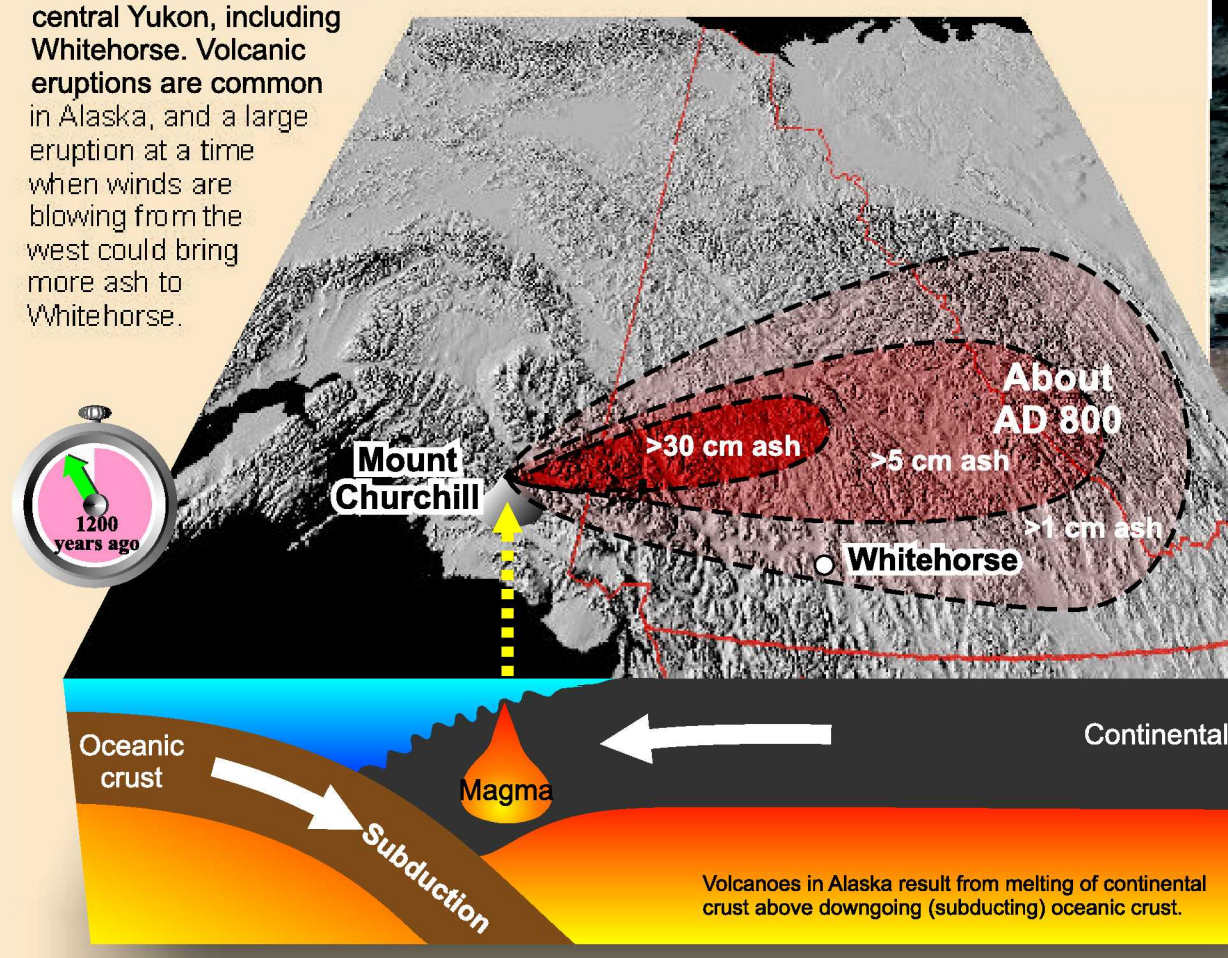
3. The river rules

About 12 000 years ago, the glacial lake drained and the Yukon River reclaimed the valley. The river eroded into the soft lake silt, creating the cliffs that border the downtown area. Downtown Whitehorse is built over sand and gravel that were deposited by the shifting channels and periodic floods of the Yukon River over thousands of years.

VOLCANIC ERUPTIONS!

Blast from the past

About 1200 years ago, in approximately 800 AD, an enormous eruption at Mount Churchill near the Alaska–Yukon border blanketed central and southern Yukon Territory with volcanic ash. The ash, referred to as the 'White River Ash', is visible in the soil layer throughout central Yukon, including Whitehorse. Volcanic eruptions are common in Alaska, and a large eruption at a time when winds are blowing from the west could bring more ash to Whitehorse.



Volcanoes in Alaska result from melting of continental crust above downgoing (subducting) oceanic crust.

Roadcut exposes White River Ash layer (white) in soil. The ash layer is about 10 cm thick.
Courtesy of P. Sinclair

Where did the people go?

Did people leave central Yukon Territory because the AD 800 volcanic eruption reduced their food supply? Some anthropologists have speculated that people displaced by that eruption were ancestors of Athapaskan-speaking peoples such as the Navajo in the southwestern United States, Tsuu T'ina in Alberta, and Dene in the MacKenzie River valley.

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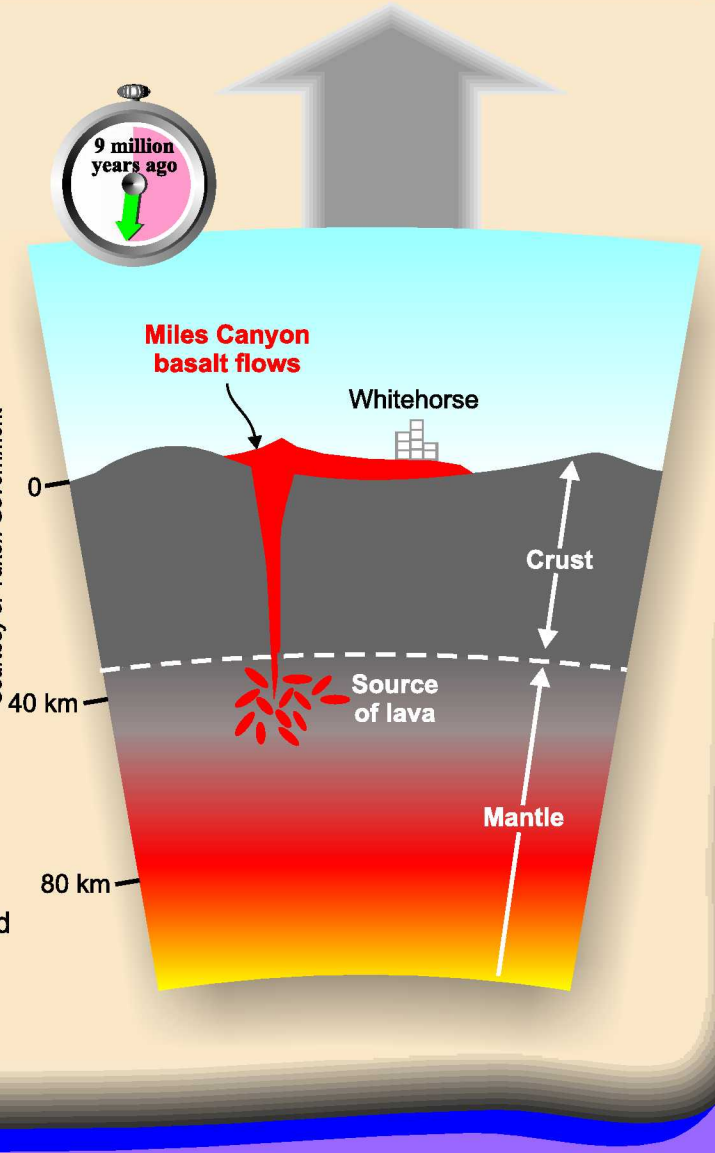
What would be the impact on Whitehorse if another volcanic ash eruption blanketed the region with ash?

Nine million years ago, lavas oozed into the valley

Several times between fifteen and nine million years ago, lava erupted quietly, as from a Hawaiian volcano, from a vent near the Mount Sima ski area. The lava flowed like a slow-moving river into the Yukon River valley, where it cooled to form basalt layers up to 15 m thick. Since then, the Yukon River has eroded a canyon through the basalt, exposing it to view at Miles Canyon and Whitehorse Rapids.

Lava fountain and flow at Kilauea Volcano, Hawaii.
Courtesy of U.S. Dept. of Interior, U.S. Geological Survey

Basalt columns, Miles Canyon.

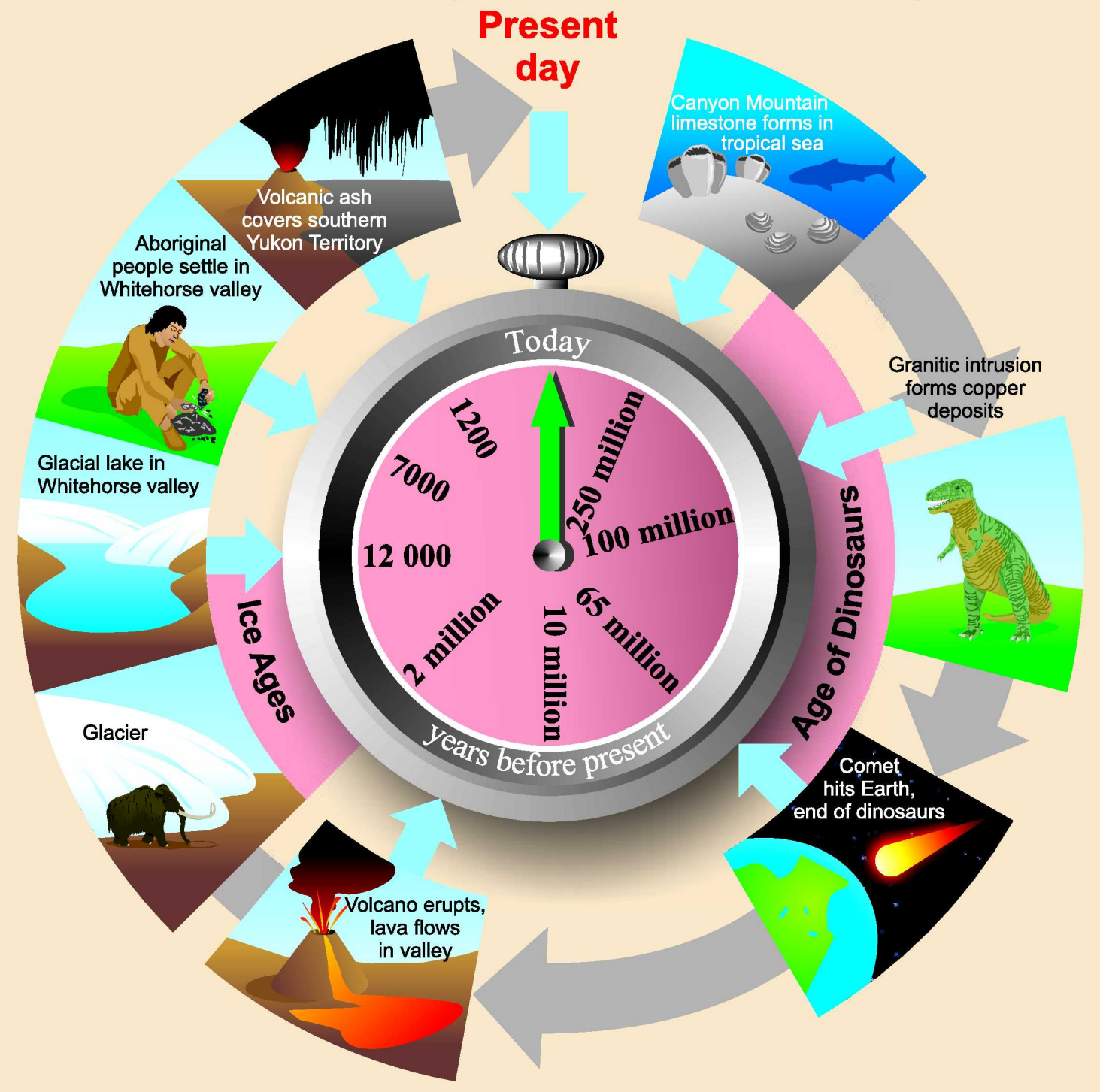


Courtesy of Yukon Government

The chilling tale of shrinking basalt

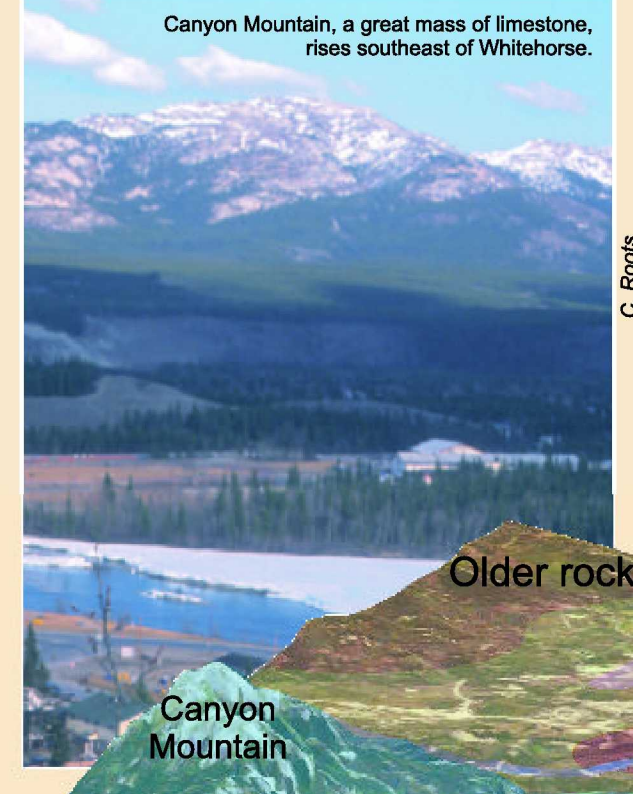
Lava shrinks as it cools, forming near-vertical fractures perpendicular to the surface of the flow. Columns formed from five or six intersecting cooling fractures are a distinctive feature of many basaltic flows.

YUKON TIME began 250 million years ago



An ancient tropical reef

Canyon Mountain (locally known as Grey Mountain) consists of limestone that formed as a reef in a tropical ocean about 250 million years ago. About 170 million years ago, the ocean basin closed, burying and squeezing the reef. Fossils of sponges and other reef animals were destroyed by the pressure and heat. In the recent geological past, water dissolved the limestone, creating crevices and shallow caves.

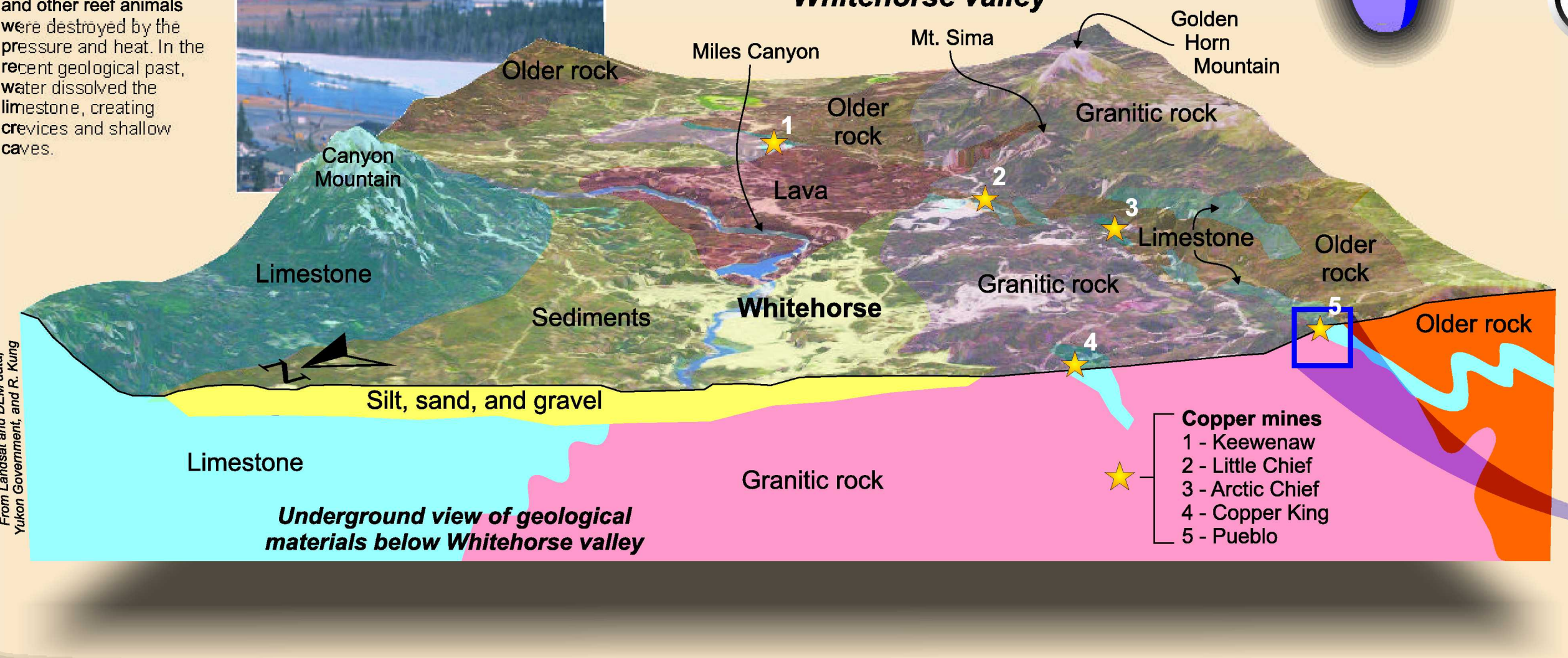


Canyon Mountain, a great mass of limestone, rises southeast of Whitehorse.
C. Roots

Vast geological time, diverse geological materials

The rocks and sediments of the Whitehorse valley have formed through the last 250 million years. They tell remarkable stories about tropical oceans and reefs, granite magmas and copper-rich fluids deep in the Earth, lava flows, violent volcanic ash eruptions, and great glaciations.

Geological materials in the Whitehorse valley



Copper mines
- 1 - Keewenaw
- 2 - Little Chief
- 3 - Arctic Chief
- 4 - Copper King
- 5 - Pueblo

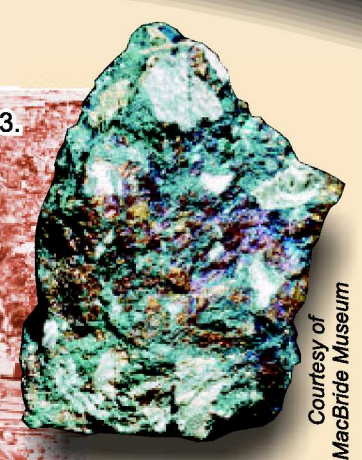
Underground view of geological materials below Whitehorse valley

From Landsat and DEM data, Yukon Government, and R. Kung

OUR BELT OF COPPER

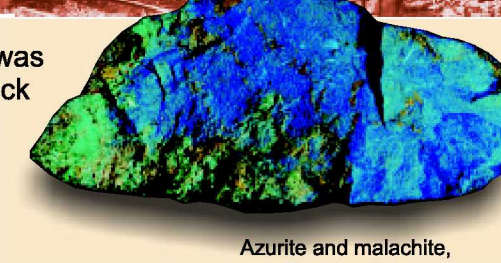
Malachite displaying botryoidal texture, Pueblo mine.
Courtesy of MacBride Museum

Pueblo open-pit mine, 1913.
Courtesy of Yukon Archives/MM Coll.



Bornite, Copper King mine.
Courtesy of MacBride Museum

Blue and green copper ore was hand-picked from blasted rock and shipped to a smelter on Vancouver Island.



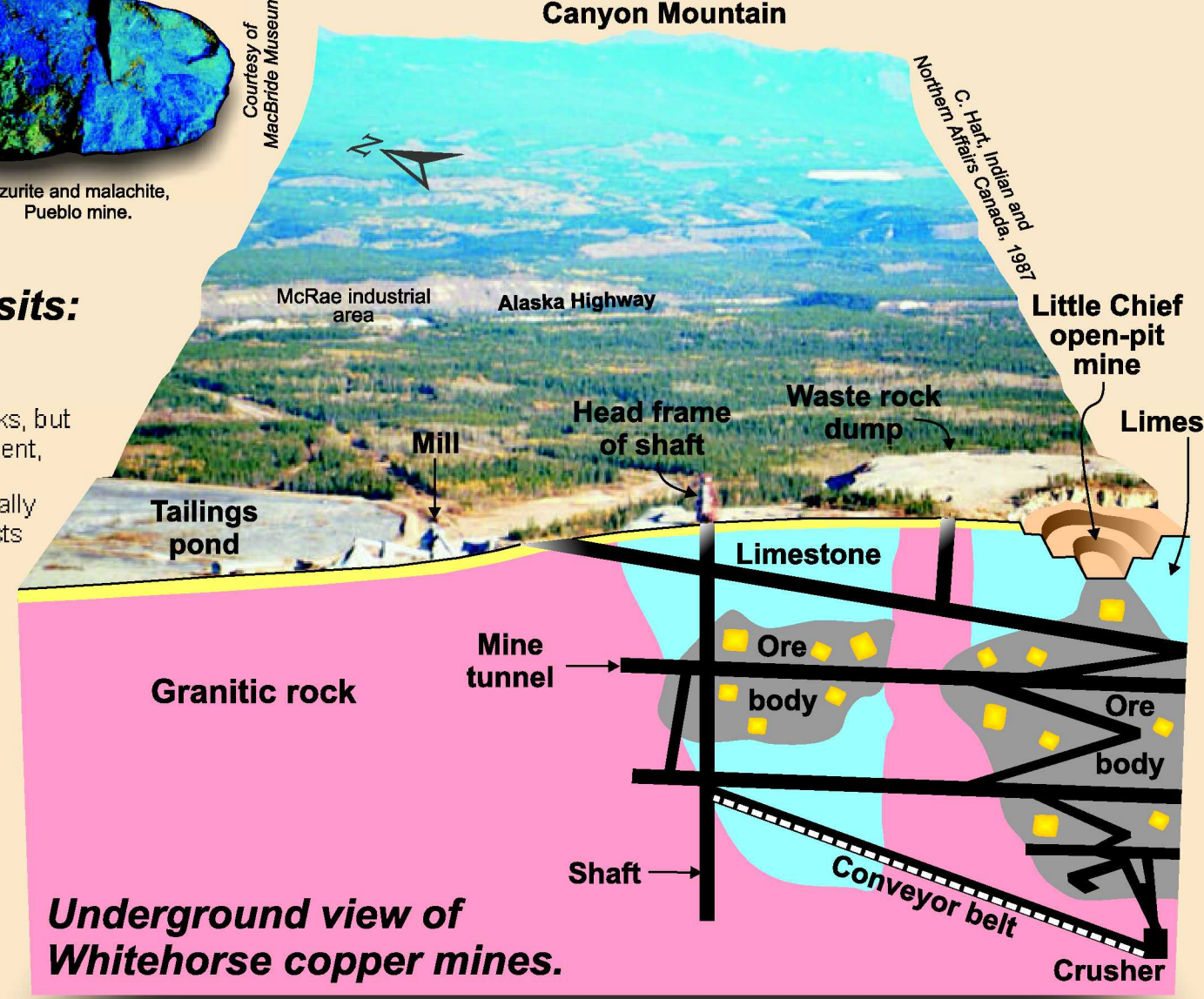
Azurite and malachite, Pueblo mine.
Courtesy of MacBride Museum

A half-billion dollars worth of ore

A belt of copper deposits lies along the western slopes of the Whitehorse valley. Surface ores were discovered by prospectors and mined between 1900 and 1919. Development of modern geophysical and geochemical exploration techniques that could detect buried deposits led to a second period of mineral production between 1967 and 1982. The total value of copper, silver, and gold mined near Whitehorse is almost 500 million dollars. Future exploration using modern techniques may lead to new discoveries and renewed mining.

Mines, ores, and deposits: what's in a name?

Copper is present in small amounts in all rocks, but some Earth processes concentrate this element, producing a copper **deposit**. The part of a copper deposit that can be mined economically is referred to as an **orebody**. A **mine** consists of tunnels, open pits, buildings, and waste dumps required to extract ore and dispose of waste rock. Preliminary separation of copper-bearing minerals from waste rock is performed through crushing and density flotation in the mill buildings. Pulverized waste rock from the mill (**tailings**) is stored behind rock dams.

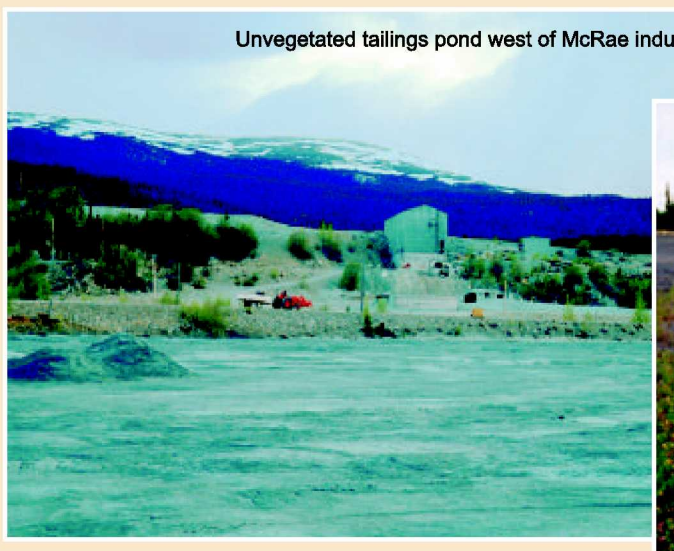


Underground view of Whitehorse copper mines.

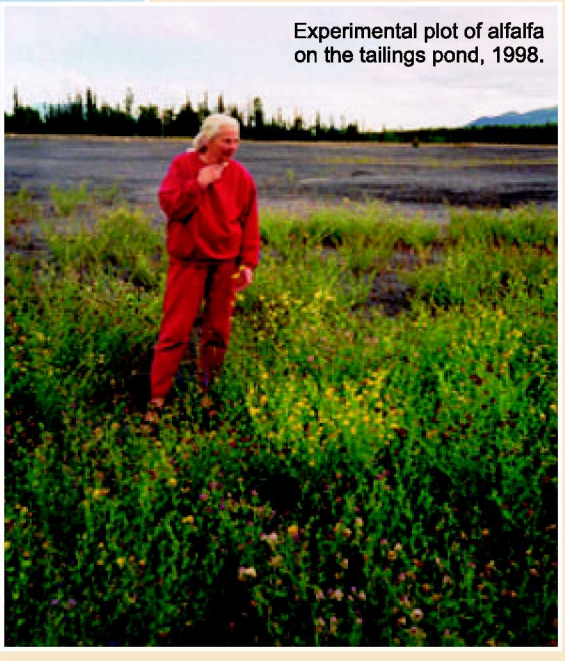
C. Hart, Indian and Northern Affairs Canada, 1987

Reclaiming old wastes

All mines close when the ore minerals are too sparse to be mined at a profit. Mine buildings are removed, mine shafts are blocked, and the mine site is reclaimed to the standards of government regulatory agencies. One problematic issue is reclamation of mine tailings. Plants have not revegetated the sandy tailings that cover a ten hectare area west of McRae industrial area near the site of the old Little Chief mine. The sandy tailings retain little moisture, while abundant calcite (a mineral made of calcium carbonate) makes the soil too alkaline for plants. The loose tailings, though not toxic to humans, animals, or plants, are blown about by strong winds. However, a pilot study has shown that, when mixed with compost, the tailings support healthy vegetation.

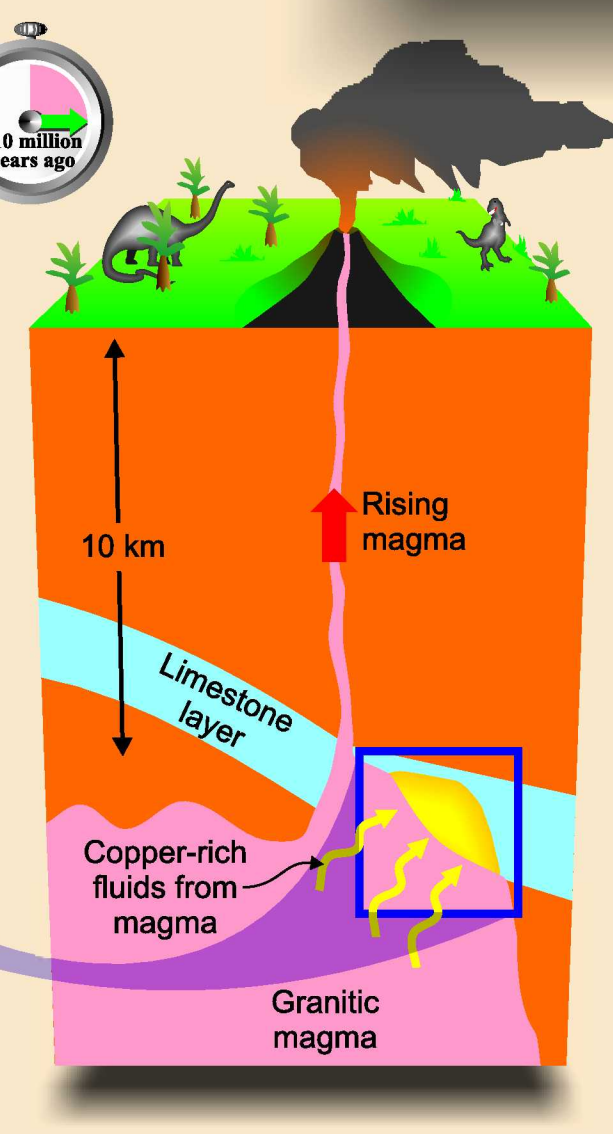


Unvegetated tailings pond west of McRae industrial area.
Courtesy of D. Craig



Experimental plot of alfalfa on the tailings pond, 1998.
Courtesy of D. Craig

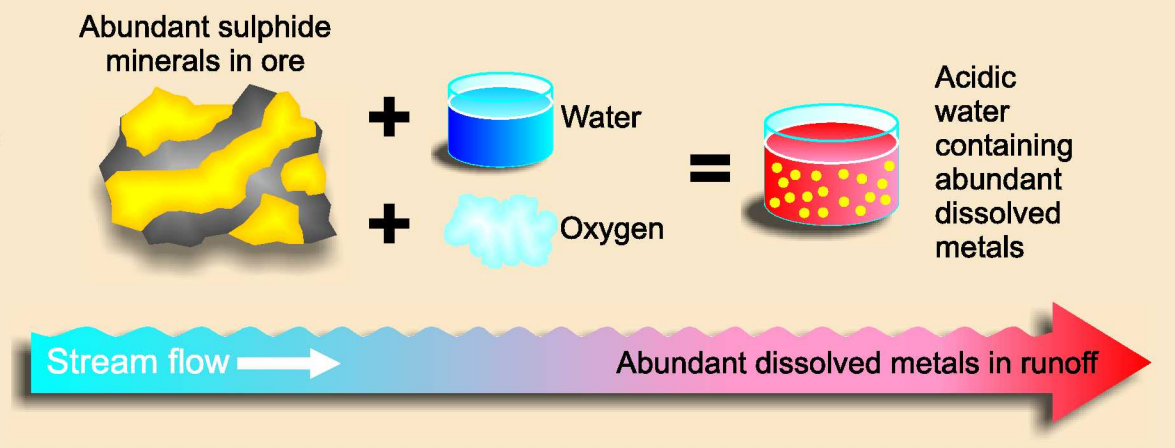
Birth of an orebody: 110 million years ago and 10 km down...



The copper deposits of the Whitehorse Copper Belt occur at the boundary between granite and limestone. Why is this so? Geologists explain it this way. The copper deposits formed about 110 million years ago, during the age of dinosaurs. Granitic magma moved upward through deeply buried crustal rocks, including layers of limestone. Copper-bearing fluids released from the crystallizing granite reacted vigorously with limestone, causing copper minerals to precipitate. Subsequent erosion of about 10 km of overlying rocks has brought these copper deposits near the surface, where they can be mined.

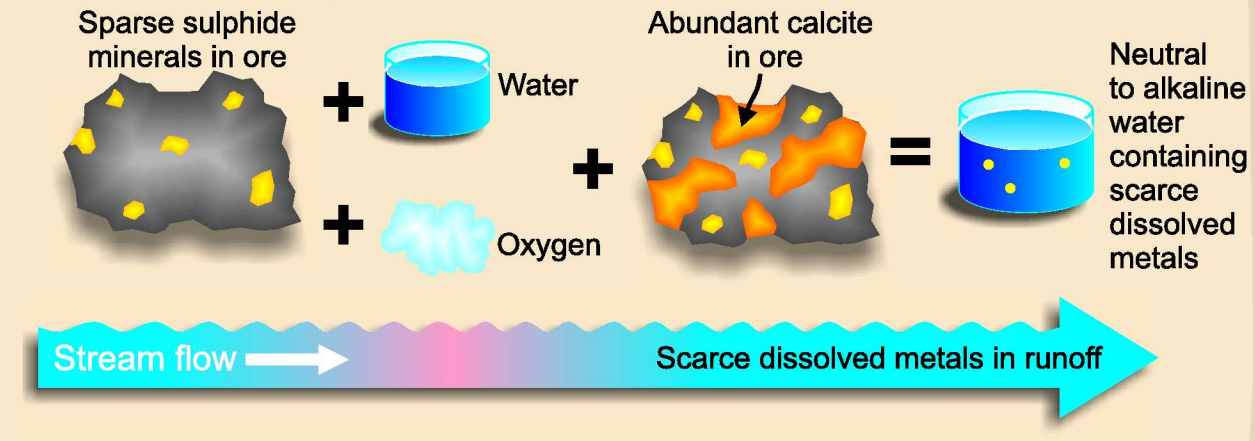
Q. Acid rock drainage?

Many mining operations must deal with the problem of acid rock drainage, which occurs when rock rich in sulphide minerals (commonly pyrite) reacts with water and atmospheric oxygen. Under these conditions, sulphide minerals dissolve, releasing metals and producing acidic waters. Acidic waters can transport high concentrations of metals, which can harm aquatic plants and animals.



A. Not here in Whitehorse Copper Belt!

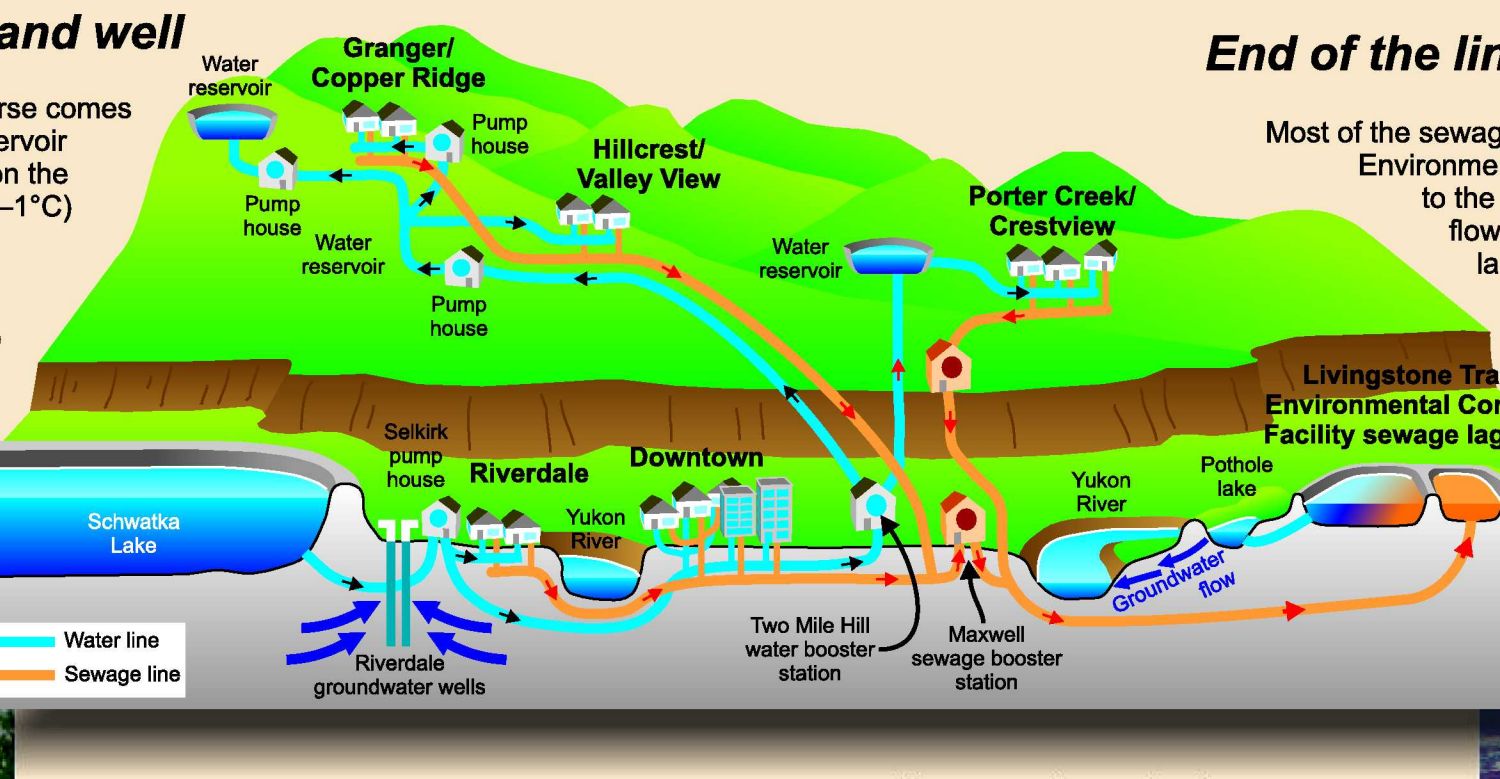
Acid rock drainage is not a problem in the Whitehorse Copper Belt, because sulphide minerals are sparse in the ore while calcite, which is derived from limestone, is abundant. When calcite dissolves in water, it consumes acid that has been generated by dissolution of sulphide minerals. As a result, waters flowing from the mine wastes do not transport metals.



WATER AND WASTE: Where it comes from, where it goes

Drawing from river and well

The water used to supply Whitehorse comes mostly from Schwatka Lake, a reservoir created by the hydroelectric dam on the Yukon River. In winter, the cold (0–1°C) lake water is mixed with warmer (4–6°C) groundwater from wells at Riverdale to prevent water lines from freezing. Chlorine is added to kill any bacteria that might be present in the water.



Water-well drill rig.
Courtesy of F. Pearson

End of the line — treating the sewage

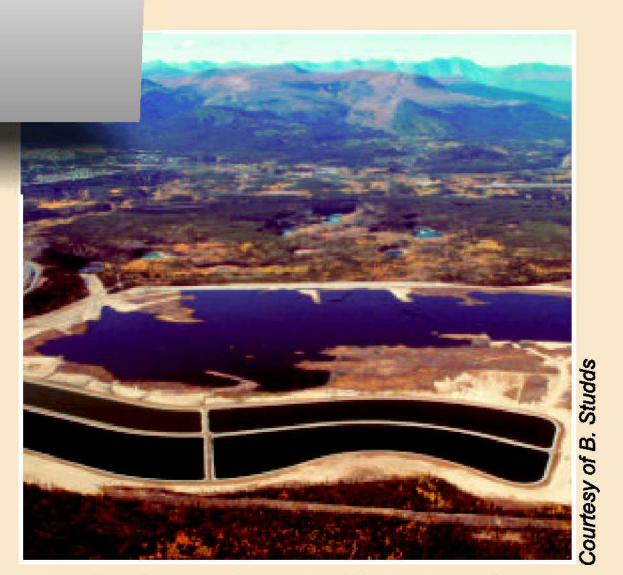
Most of the sewage ends up at the Livingstone Trail Environmental Control Facility. There, solid matter settles to the bottom of the primary lagoon, while effluent flows over into a series of larger secondary lagoons for treatment. Suspended or dissolved matter is then broken down by bacteria. After treatment, the effluent is stored in a large pond for one year. In the fall, when the effluent meets specified treatment standards, it is discharged into the Yukon River. Alternatively, the effluent is discharged to a 'pothole' lake, from which water seeps through soils to the river.

Getting water to you

Water is pumped from Schwatka Lake to a concrete storage reservoir in each Whitehorse neighbourhood. Each storage reservoir is situated on higher ground than the houses it serves, allowing water to flow by gravity throughout the neighbourhood.

Down the drain, and then where?

So where does the water go when we drain our baths or flush our toilets? Each house has a pipe for incoming drinkable water, and another for outgoing sewage. Household sewage pipes connect to main pipelines that carry sewage downhill by gravity. Where there are low points in the lines, booster stations pump the sewage to the treatment lagoon.

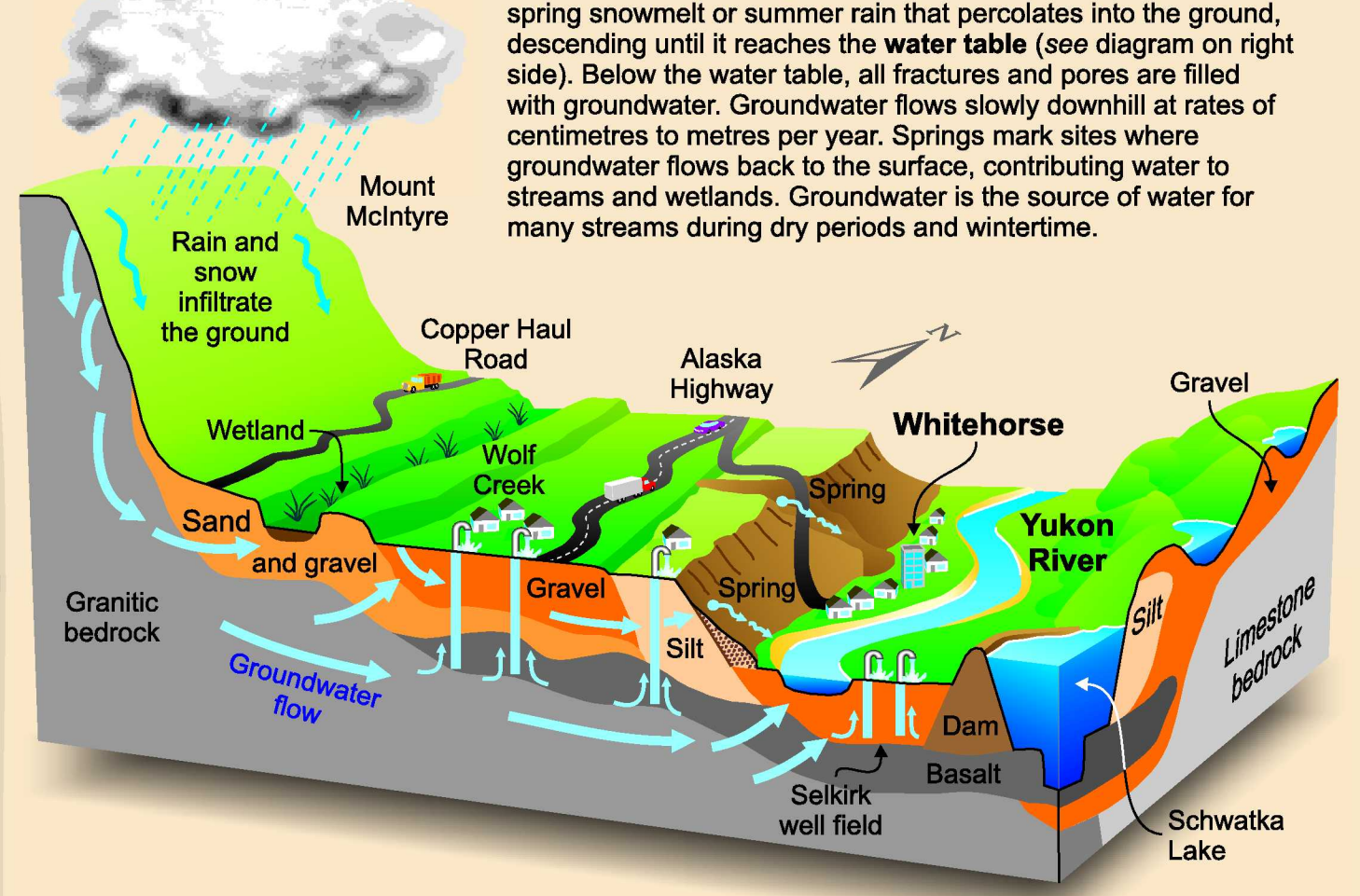


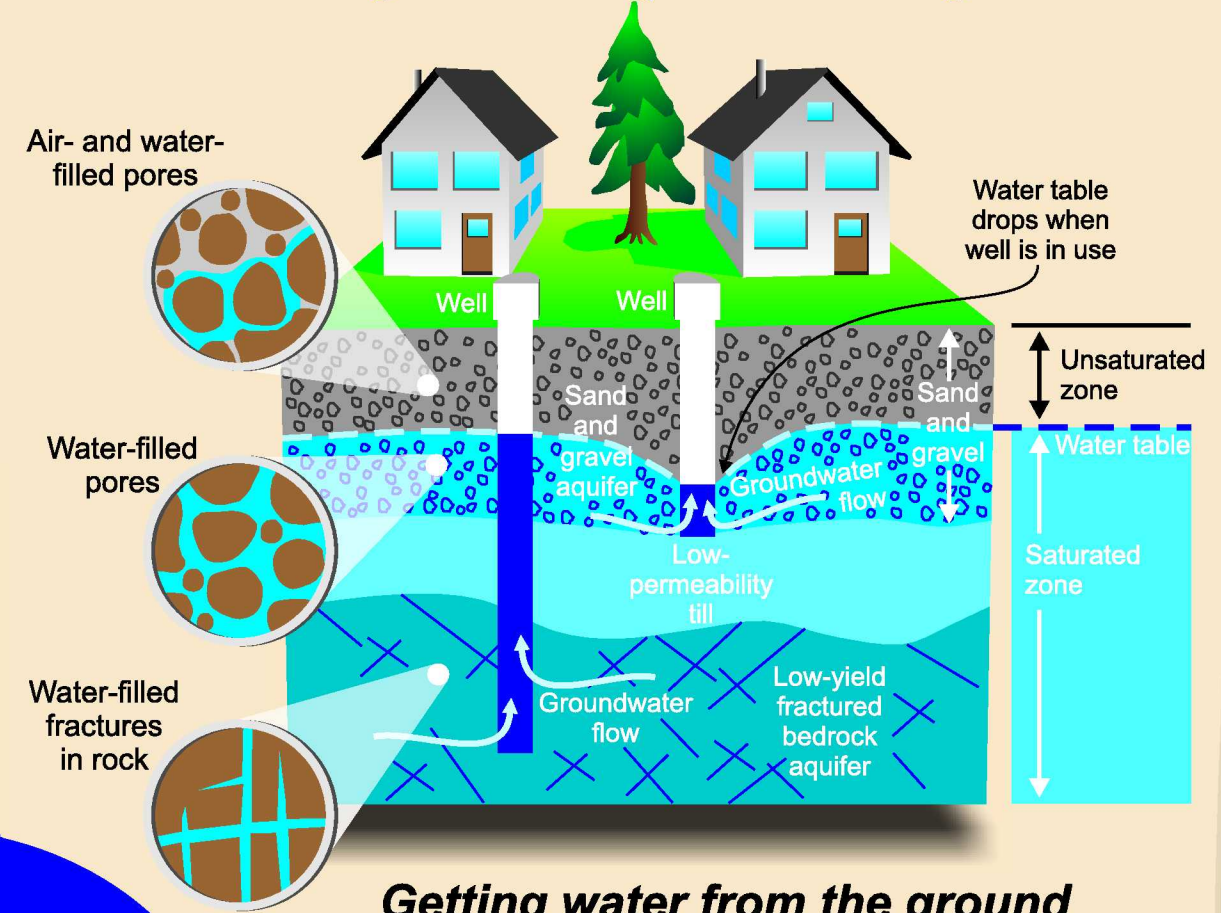
Treatment sewage lagoons and the one-year storage pond at Livingstone Trail Environmental Control Facility.
Courtesy of B. Studds

GROUNDWATER: Our vital underground plumbing

What goes down may come back up!

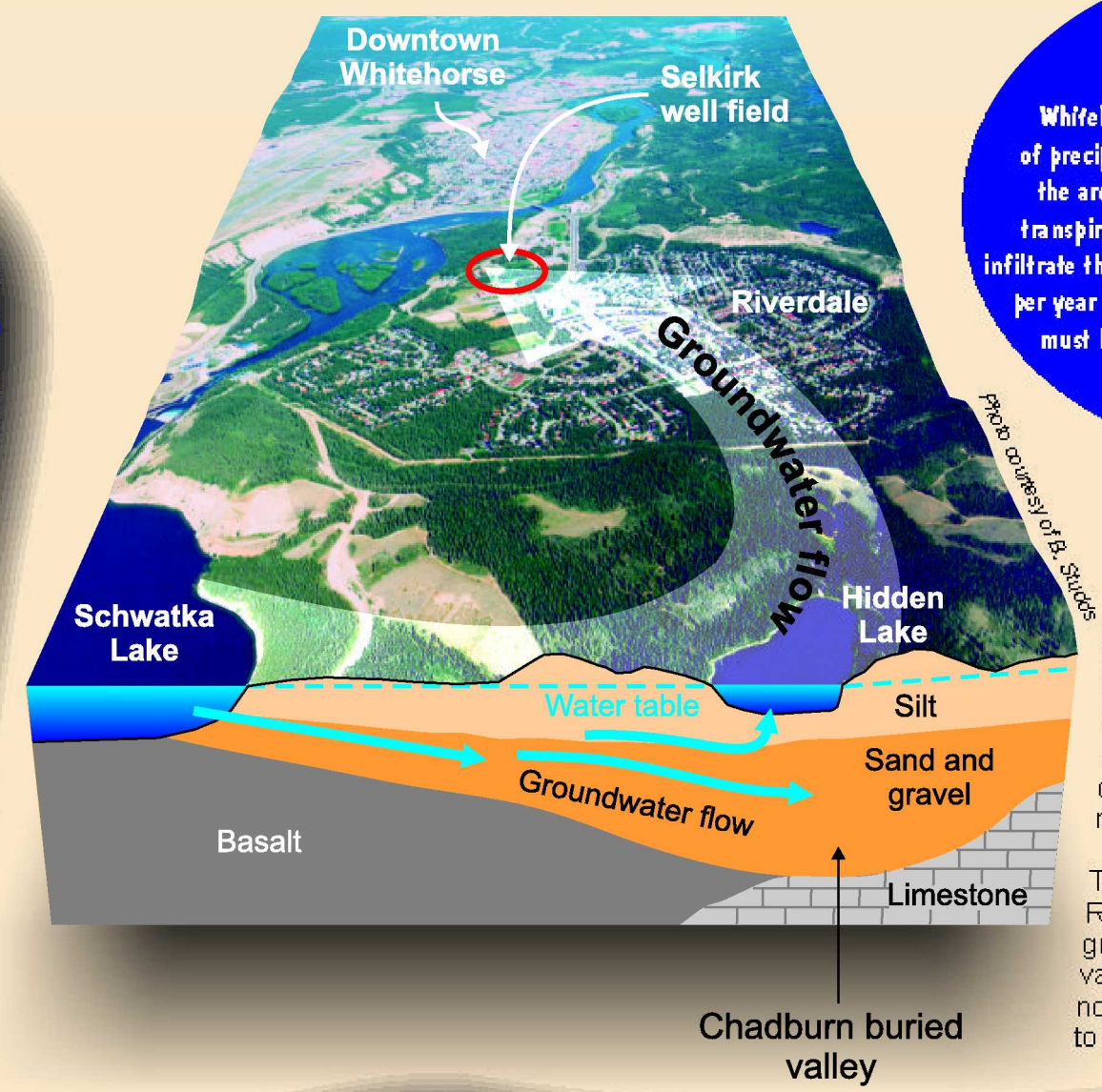
Water that resides in the spaces between grains in sand and gravel, and in fractures in rocks, is called groundwater. Groundwater starts as spring snowmelt or summer rain that percolates into the ground, descending until it reaches the **water table** (*see* diagram on right side). Below the water table, all fractures and pores are filled with groundwater. Groundwater flows slowly downhill at rates of centimetres to metres per year. Springs mark sites where groundwater flows back to the surface, contributing water to streams and wetlands. Groundwater is the source of water for many streams during dry periods and wintertime.





Getting water from the ground

Many rural residents in the Whitehorse valley obtain their water from wells. Wells must extend below the water table to water-bearing layers (**aquifers**). Sand and gravel layers are often excellent aquifers. Buried basalt has abundant fractures and porous zones, making it a good aquifer. In contrast, granite contains no pore space and few fractures, making it a typically poor aquifer.



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Did you know?

Whitehorse receives an average of 260 mm of precipitation per year. About 235 mm leave the area as stream runoff, evaporation, and transpiration by plants. The remaining 25 mm infiltrate the ground. Imagine – only an inch of water per year is added to our groundwater supply! We must be careful that we do not deplete this precious resource.

Careful! Drinking water below

Groundwater is less vulnerable to contamination than surface water, but is very difficult to clean once it is contaminated. A spill of a harmful substance such as gasoline or heating oil could contaminate your drinking water. We must be careful!

The Selkirk well field, in a greenbelt area of Riverdale, taps a water-bearing sand and gravel aquifer that fills an ancient buried valley. Groundwater percolates slowly northward from Schwatka and Hidden lakes to reach the well field.

The filling of Schwatka Lake caused a rise in the local water table, which raised levels in nearby lakes. These drowned shoreline trees record this rise in lake level.
C. Roots

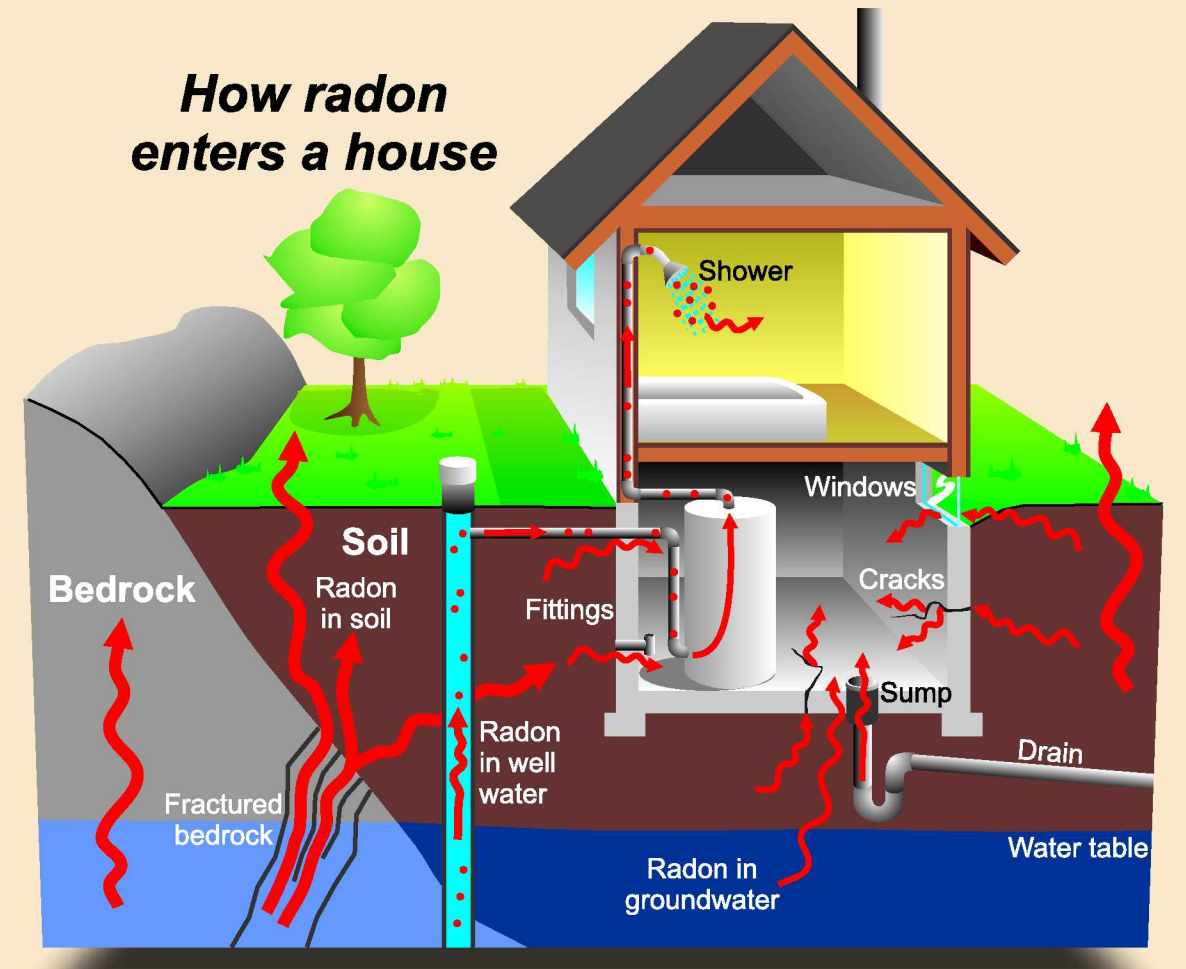
RADON GAS: Beware of the stuffy basement

Radon: gas from the Earth

What is radon?
Radon is an odourless, colourless, and tasteless gas produced by the radioactive decay of uranium that occurs naturally in rock, sediment, soil, and water. Radon gas seeps from the ground into the atmosphere and is dispersed and diluted to harmless levels. However, it can accumulate in poorly ventilated basements and crawl spaces, because it is more dense than air. Radon can also enter homes in water drawn from local groundwater wells. Radon dissolved in the water escapes to the indoor air as people take showers, and wash clothes and dishes. Long-term exposure to high levels of radon increases the risk of lung and throat cancer.

A survey of representative homes in the Yukon Territory found that radon emission from soils around Whitehorse is several times the national average. The radon comes from the granitic bedrock and overlying glacial sediments.

How radon enters a house



Coping with radon

Radon levels can vary greatly from house to house, depending on basement type, ventilation, and geological material on which the houses are built. To test radon levels, collectors can be signed out from the Yukon Housing Corporation, then returned for a reading. Seepage of radon into a home can be reduced by sealing holes in walls and floors, by installing small fans outside to reduce soil-gas pressure around the foundation, and by improving basement ventilation. The Yukon Territory's Building Code has provisions to ensure that new construction avoids potential gas buildup.

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Geoscape Whitehorse on the Internet

To view the Geoscape posters for Whitehorse and other Canadian communities, visit our web site at: www.geoscape.nrcan.gc.ca

Need more information?

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Geoscape Whitehorse – geoscience for a Yukon community

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