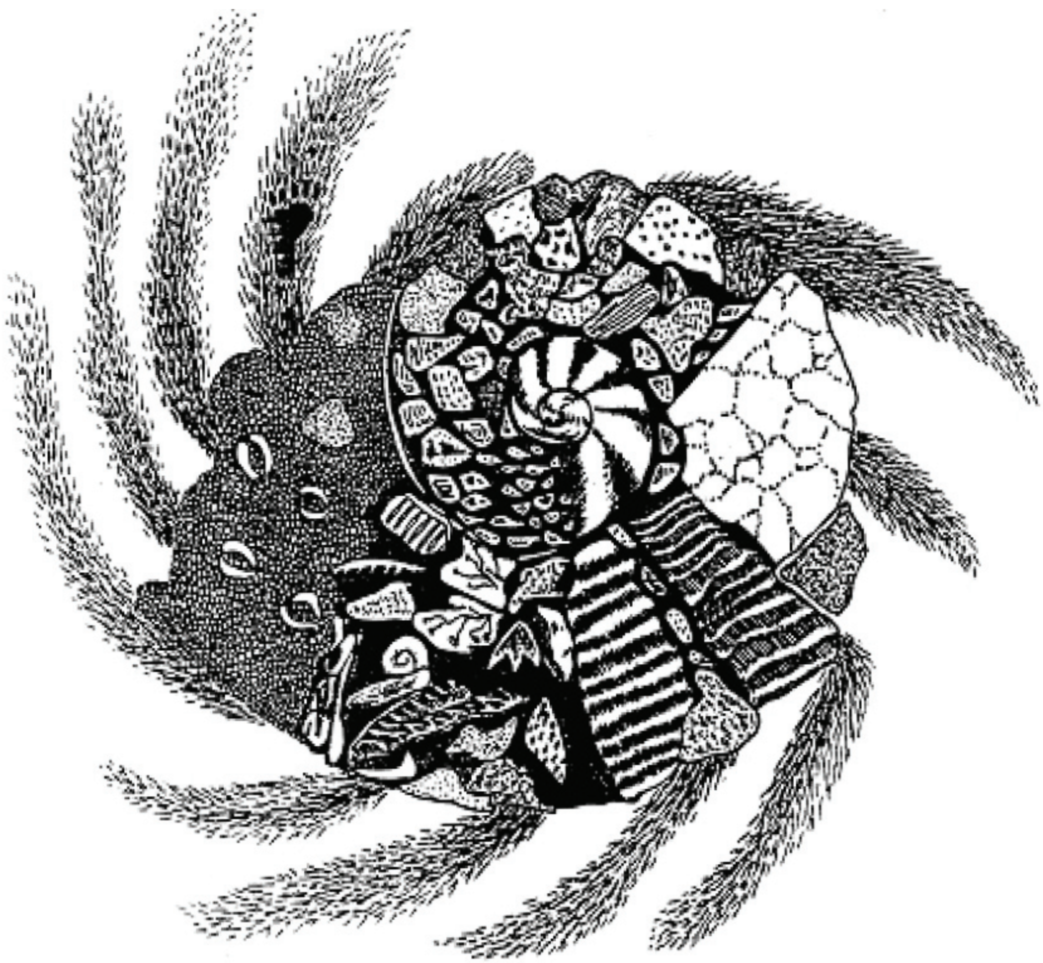
TIMETUNNEL

Earth Sciences Program
Teacher's Guide

Royal Saskatchewan Museum



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TIME TUNNEL
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For further information on this and other programs please contact:

Public Programs
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Time Tunnel

The Time Tunnel program is designed for Divisions three and four students. It consists of a 45-minute tour of the Earth Sciences Gallery with a Museum instructor. Classes are divided into two groups of 15 students. Each group has a 45-minute tour. Due to limitations of gallery space and museum staff, the program is limited to classes of 30 or fewer students.

To book this tour contact:

Public Programs
Royal Saskatchewan Museum
2445 Albert St.
Regina Saskatchewan S4P 4W7
Telephone (306) 787- 0814

Tour Objectives:

1. To introduce students to the geology and prehistory of Saskatchewan.

2. To show a continuum of events from the Precambrian to the modern topography and environment.

Vocabulary

plate tectonics
core
mantle
crust
sedimentary rocks
igneous rocks
metamorphic rocks

Background Information

The Layers of the Earth

Core:	The centre of the planet. Geologists separate the inner from the outer core. The outer is liquid and made of iron and sulfur. The inner core is solid and made mainly of iron and nickel.
Mantle:	The mantle of the planet is made of molten rock. The outer mantle which supports the crust is less molten than the inner mantle. The mantle is rich in iron, magnesium, and silicon.
Crust:	The crust is the outer shell of the earth.

Rocks

Although rocks and rock formations seem permanent, they are in a constant state of change. Rocks are constantly being formed, changed, and destroyed. There are three types of rock.

Igneous rock forms from very hot material from deep within the earth, below the earth's crust. These materials are brought to the surface by volcanoes, where they cool to form igneous rocks. Igneous rocks can be placed in two categories: heavy and light. The heavy igneous rocks include basalt and gabbros. Light igneous rocks include rhyolite and granite. The heavy igneous rocks sink farther into the mantle of the earth and for this reason usually form ocean floors. The lighter igneous rocks rise to sit on top of the heavier ocean floors and therefore form the foundations of the continents.

Sedimentary rock is made of particles eroded from existing rocks. The material can be either eroded by the action of water and wind (mechanical erosion) or by being dissolved in water (chemical erosion). In the process of mechanical erosion, the small particles are carried by water to another location where they are laid down in layers. Sandstone is a good example of this sort of rock. Alternatively, water may dissolve certain minerals from the original rock. If the water evaporates, the minerals are precipitated from the water to form rock. Limestone is a form of rock created through this chemical process.

Metamorphic rock is the result of changes made by heat and pressure to existing rock. Marble is limestone that has changed through pressure into a different form of rock.

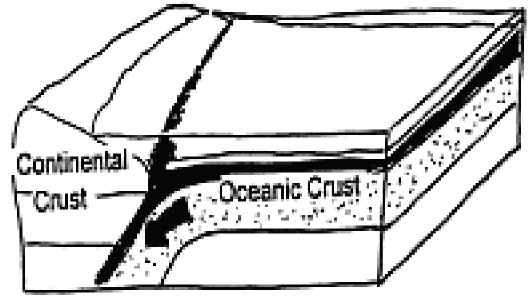
Plate Tectonics

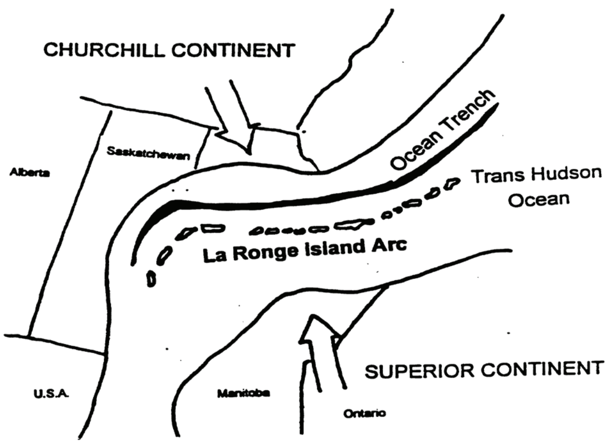
Like rocks, the earth itself is in a constant state of change. The vehicle for changes to the earth's crust is plate tectonics. Plate tectonics begins on the ocean floor. Trenches on the ocean floor are splits where magma is forced to the rock surface. As magma pours outward, it spreads the sea floor. The spread will at some point collide with a continent. Continents are made of rock that is lighter in weight than that of the sea floor. The sea floor is also thinner than the continents. Where the moving sea floor meets the continental shelf, it will do two things. First, the oceanic plate will slip underneath the lighter, thicker continental mass. Eventually this downward movement will force what was once ocean floor back into the molten magma. Secondly, the pull of gravity that takes the oceanic plate under the continental plate will also move the continental plate.

The meeting point of an oceanic plate and a continental plate is a restless place. The pressure of the two plates can shove the continental plate upward and build mountains. The friction of the oceanic plate also creates heat, which melts the heavier basalt. The lava finds it way to the surface through faults in the rock, forming a volcano. Often mountain ranges form on the coastal regions of a continental plate, at the subduction zone. The coastal mountains of western North America are examples of this action. The east side of the Rockies was made by the movement of the pacific plate under the continental plate. They are slabs of sedimentary rock broken and shoved upright. The coastal mountains are volcanic in origin. They formed as the oceanic plate slipped under the Pacific plate. Mount St. Helen's is an example of a coastal volcano.

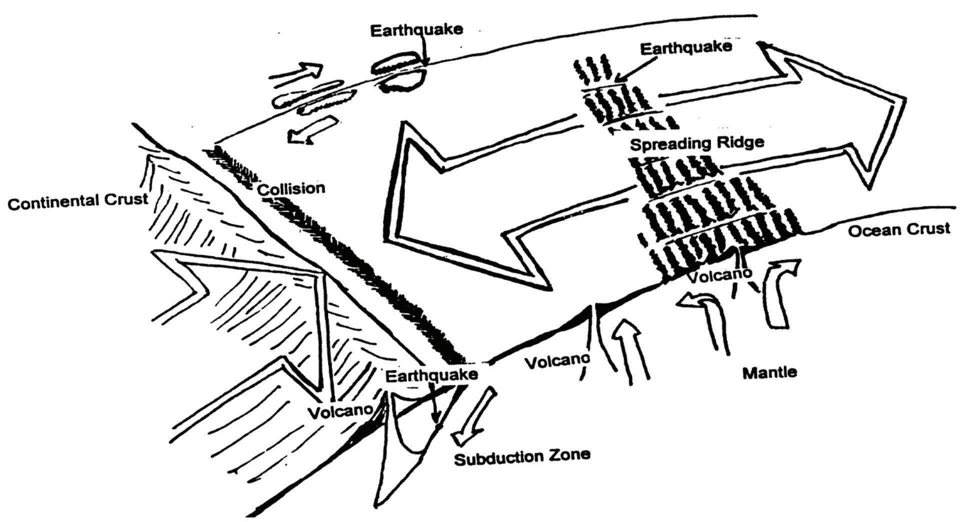
Mountain building also occurs where two continental plates collide. The Himalayas are the best example of this continental collision.

Subduction Zone
Oceanic crust is denser and heavier than continental crust. It usually sinks below the continental crust at plate edges. This is called the subduction zone.





1860 to 1850 Million Years Ago
The Arc Collision Stage
Two tectonic plates are moving towards each other. The La Ronge Island Arc is colliding with the Churchill Continent.

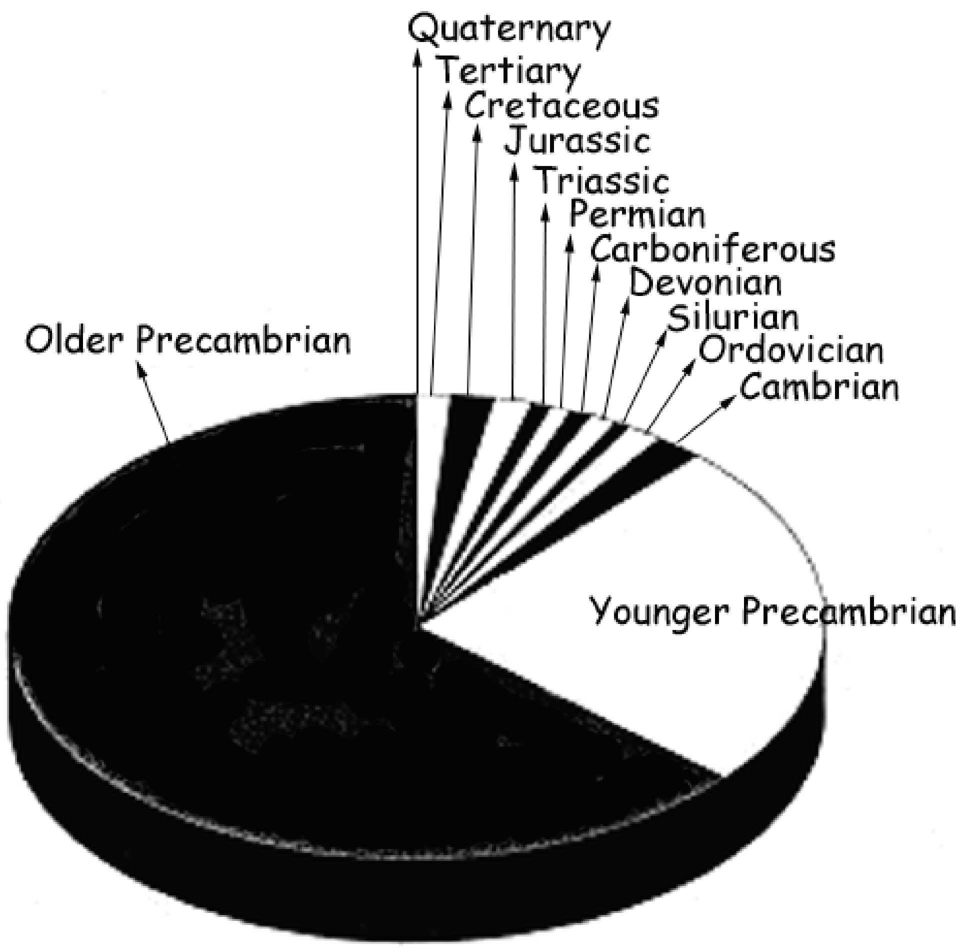


Dynamic Areas of the Earth's Crust
New crust is created at spreading ridges and volcanoes or hot spots. Ocean crust sinks downward at subduction zones along the edges of tectonic plates. This movement creates mountains and volcanoes.

Geological Time

As stated before, the earth's crust is constantly changing. However, barring catastrophic events such as earthquakes and volcanic eruptions, this change occurs slowly, over billions of years. the concept of geological time is difficult for anyone to grasp. While students might not understand the enormous length of time involved in the geology of the earth, they can learn the progression of events that have led to the world that is around us today.

To help understand this progression, palaeontologists and geologists divide the history of the planet into time periods.



The Precambrian

1. Archean Era
2.5 - 2.1 Billion Years Ago

Geologists believe that billions of years ago, a large ancient continent stretched from today's Canadian Arctic south to present day Colorado and Wyoming. About 2.1 billion years ago, this ancient Archean continent underwent rifting and breakup. The continent fragmented and ocean filled in between the island fragments. Continental drift then caused mountain building.

2. Passive Continental Edge
2,100 - 2,000 Million Years Ago

The area that is now northern Manitoba and Saskatchewan may have had many similar geological features to today's Atlantic Seaboard. At this time the ocean separated two major land masses, the Churchill continent (Manitoba and Saskatchewan) and the Superior continent (Manitoba and Ontario). Rivers flowing off the Churchill Continent brought large quantities of sediment into the ocean. These formed a broad continental shelf. In the ocean, a large ocean floor rift formed. Dense basalts erupted from this ridge, causing the sea floor to spread. On either side of this rift or trench, large volcanoes developed. Some may have been higher than the water level. Today, the same sort of situation can be found in Iceland. Sea floor spreading also caused faults to form off the original trench.

3. An Island Arc Forms
1,900 - 1,875 Million Years Ago

Sea floor spreading and subduction of the heavier oceanic plate under the lighter continental plate caused earthquakes and volcanic eruptions. As the volcanoes grew, they formed an island arc. This sort of activity is still going on today. The Aleutian Islands, Japan, and Indonesia are all examples of the development of island arcs. As in ancient times, these modern chains are also all volcanic.

An ancient island arc formed between the Churchill and Superior continents. Geologists call this group the La Ronge Island Arc. As the La Ronge Island Arc formed, the two continents moved closer together. The continued ocean floor sinking pulled the two continents together on a collision course.

4. Arc Collision
1,860 - 1,850 Million Years Ago

The movement of the ocean floor caused a collision between the Churchill Continent and the La Ronge Island Arc. The collision formed a mountain range that quickly eroded. With no vegetation, the rocks and soils could easily be washed away.

5. Continental Collision
1,830 - 1,800 Million Years Ago

Eventually, the same processes that led to the collision between the continental shelf and the La Ronge Island Arc caused the collision between the Churchill and Superior continents. The continental crusts were subjected to massive folding and faulting. At the same time, volcanic activity forced lava into the folds and faults in the base of the mountain range. Erosion of the mountain tops eventually uncovered these igneous intrusions. Today they form the Precambrian Shield.

6. Modern Situation
1,800 Million Years Ago - Present

The arc collision, followed by the collision of the continents, resulted in the formation of a new land mass. The remnants of this action can be found in the Precambrian (Canadian) Shield that covers most of northern Canada. After the mountains formed, the area was subjected to rifting and block faulting. This created gaps and sections that dropped to form basins. The erosion of the mountains that occurred after their formation stripped the top layers of rock from the underlying volcanic intrusions. Westward flowing rivers then deposited these sediments in the rifts and basins along the western edge of the mountains. These sandstones can be found in northern Saskatchewan today.

Since this last episode of volcanic activity and mountain building, Saskatchewan has been stable. Later mountain-building episodes such as the formation of the Rocky Mountains have not had volcanic or tectonic effects.

Occurrence of Mineral Ores

Mining is an important part of the economy of Saskatchewan. The presence of mineral ore is due to the forces of continental collision and volcanic activities.

Gold is one such example. At the Star Lake gold mine, the gold is held in a quartz ore body. The quartz was forced into areas of the original igneous rock that had been split and weakened by mountain building. As the molten quartz cooled, the gold carried within it crystallized.

Uranium is another mineral that owes its existence to ancient mountain building. Uranium is originally held within volcanic tuff. Tuff is volcanic ash that has turned to rock. When the tuff is deeply buried and pressurized, it undergoes changes that allow the uranium to be released in water. Uranium-bearing water is trapped in rifts and downfaults. These are sometimes called chemical traps. The uranium is precipitated from the water and laid down as a sedimentary deposit. The Cigar Lake Uranium mine is one such example of uranium caught in a chemical trap.

Palaeozoic Era: Early Life

The first organisms to leave fossils in Saskatchewan were stromatolites. Stromatolites are a type of blue-green algae that lives in colonies. Today living stromatalites can be found in parts of Australia. A shallow tropical sea covered Saskatchewan for most of the Palaeozoic. This was not a true ocean, for the inland sea rested on the continental land mass, not on a deep sea bed of heavy basalt. The bed of this inland sea was not subject to ocean floor spreading and volcanic eruptions.

Major advances in life forms were made during the Palaeozoic. The first hard-shelled organisms made their appearance early. These gradually evolved and diversified to include the first fish, insects, amphibians, and reptiles. Plants also made advances during the Palaeozoic. The first plants to take a foothold on dry land evolved early in the Palaeozoic.

1. Cambrian Period
590 - 505 Million Years Ago

The inland sea during the Cambrian Period laid down layers of sedimentary sandstones and shales. In Saskatchewan these are deeply buried, and there are no fossils from this time. However, the inland sea stretched as far as the present day Rocky Mountains. The shales and sandstones were exposed during the mountain building episode that formed the Rockies. It is from deposits such as the famous Burgess shales that life during the Cambrian Period can be studied.

2. Ordovician Period
505 - 438 Million Years Ago

During the Ordovician, Saskatchewan remained underwater. There are Ordovician limestones found in certain areas of the Province that give indications of the organisms and the conditions in which they lived.

The Ordovician seas were lively places. They were shallow, warm, and clear, much like the ocean surrounding the Great Barrier Reef in Australia. Solitary and colonial species of coral thrived. Creatures that remained on the sea bed were also abundant. These included sea lilies (crinoids) clams, snails, starfish, and trilobites. Free swimming varieties were ostracods and nautaloids, ancient relatives to modern squid.

One remnant of the Ordovician world is Tyndall stone. This limestone is quarried in Manitoba and used extensively throughout the Western Provinces as decorative building stone. It is Ordovician in age and full of fossils.

3. Silurian Period
438 - 408 Million Years Ago

Little is known of the Silurian Period in Saskatchewan. It probably looked very similar to the Ordovician. It is during the Silurian that the first land plants and the first jawed fish developed.

4. Devonian Period
408 - 360 Million Years Ago

During the middle Devonian massive coral reefs developed in the inland sea. Carbonate banks in the south-eastern part of the sea provided the base for massive pinnacle reefs, while in the north-west, the huge Presqu'ile Reef restricted the water exchange in the inland (Elk Point) sea. The reefs never completely cut off the Elk Point Sea, but they restricted water exchange enough to greatly raise salt levels. Once the water was saturated with dissolved salts, they started to precipitate out and collect on the bottom. Those that were the least water soluble came first. The first mineral salt to precipitate was rock gypsum. Next came halite or rock salt. The last was potash. The only place that potash is found is in the southern part of the Province, where the Elk Point Sea was the most restricted.

The pinnacle reefs in the south east part of the Elk Point Sea are also important today. It is from pinnacle reefs capped by limestone that Alberta gets most of its oil. These might also be a rich source of natural gas and oil for Saskatchewan.

No fossils of plants or animals are found in the evaporite minerals laid down during the Devonian. Fossils are abundant before and after the periods of high salt, but not during. No doubt, advanced organisms could not survive in the extremely salty water.

After the period of deposition of evaporite minerals, the reefs eroded and a fresh supply of water flowed into the Elk Point Sea.

The late Devonian also saw the beginning of mountain-building activity to the west. Tectonic activity began to shape the Rocky Mountains.

5. Carboniferous Period
360 - 286 Million Years Ago

Rocks from the early Carboniferous period are deeply buried in Saskatchewan.

The early Carboniferous rocks are limestones and dolomites and are oil-bearing. Carboniferous limestone in the south-eastern part of the Province contains oil and gas. The shale formation that these limestones sit on is an important source of oil and gas. During the Tertiary, the accumulation of sediments produced enough pressure to turn the micro-organisms trapped within the shale to gas (from tiny plants) and oil (from microscopic animals).

In other parts of the world, the first amphibians and later, the first reptiles made their appearance.

6. Permian Period
286 - 248 Million Years Ago

No Permian rocks have been found in Saskatchewan. This may have been a time when the sea level was dropping and extensive erosion taking place. The closest Permian rocks are in the Rocky Mountains.

Massive extinctions occurred during the Permian. Ninety percent of the living organisms of the planet died out. Creatures such as the trilobites, some types of coral, most ammonoids (a few species survived into the Cretaceous) and most brachiopods became extinct. The great extinction at the end of the Permian hit these marine invertebrates the hardest of all living creatures.

The Permian was a time of low seas and a dry climate. This drastically changed marine environment may account for the mass extinction of sea life.

Mesozoic Era: Middle Life

The Mesozoic was a period of incredible change on the earth. Plants rapidly developed, first ferns, then conifers and finally flowering plants. Birds and mammals evolved during the Mesozoic, while dinosaurs dominated and became extinct. In Saskatchewan, the inland seas drained and the North American continent moved from the equator to its present day location.

1. Triassic Period
248 - 213 Million Years Ago

No Saskatchewan fossils have been found for the Triassic Period. The Triassic rock formations are deeply buried. In other places, the Triassic was the time when dinosaurs first began to dominate. The first mammals also made their appearance during the Triassic. The other animals first known from the Triassic are birds. Archaeopteryx is the first known bird and it dates to this time.

2. Jurassic Period
213 - 144 Million Years Ago

Like the Triassic, Jurassic rock formations are deeply buried. They indicate that Saskatchewan existed under marine conditions, because they consist of thick beds of limestone. What we know of the Jurassic comes from potash mines and some oil drilling samples. Saskatchewan's Jurassic fossils include brachiopods, clams, snails, and fish.

3. Cretaceous Period
144 - 65 Million Years Ago

For most of the Cretaceous Period, Saskatchewan remained underwater. The Interior sea extended from what is now the Arctic Ocean to the Gulf of Mexico. During the Cretaceous, the plate tectonics that started the Rocky Mountains in the Devonian continued. Gradually, the land tilted and the inland seas drained from west to east.

Unlike the seas of the Ordovician, the Cretaceous seas were muddy. While many species of ammonoids, clams, and snails thrived, few corals found a niche. Some of the most spectacular residents of the Interior Sea were the vertebrates. These included fish, sharks, turtles, and marine reptiles - mosasaurs and plesiosaurs.

All species of mosasaur and plesiosaur (and there were many different species of each) were carnivorous. Mosasaurs were agile swimmers, propelling themselves with a strong tail. Paddles were used for steering. The long-necked plesiosaur (elasmosaur) had a different method. These creatures used their paddles to propel themselves. They probably were slower and less agile than mosasaurs, but could swim at great speed for long distances.

Terminonaris was another Cretaceous carnivore that lived in Saskatchewan. Terminonaris was a relative of today's crocodiles. Dated at 95 million years, the fossils found at Carrot River in Saskatchewan are the latest known for this genus. It is important, not only for its late date, but also because it gives researchers an idea of the location of sea shores. Terminonaris was a marine creature and probably hunted fish in the receding waters of the Cretaceous sea.

By the middle of the Cretaceous, land was emerging from the inland sea. Flowering plants were beginning to take over the land from the gymnosperms. The dominant animals of the time were dinosaurs. The dinosaurs in Saskatchewan were all from the late Cretaceous. The most common type included various species of hadrosaur or duck-billed dinosaur. Other herbivorous dinosaurs included Ankylosaurus, Triceratops, and Thescelosaurus.

Meat eaters included Tyrannosaurus rex, Dromaeosaurus, and Troodon. T. rex was the largest carnivorous dinosaur in North America (a recent discovery in South America is larger).

Although dinosaurs dominated, they were not the only animals around at this time. Reptiles, birds, and mammals all shared the landscape.

The end of the Cretaceous also marks the end of the dinosaurs. The dinosaurs may have disappeared, but they were not the only animals affected. The end of the Cretaceous also saw the end of many hard-shelled creatures such as ammonoids and belemnites.

Theories and hypotheses abound as to the cause of the extinction. The most widely known is the theory of the asteroid impact. Other theories include diseases spreading through the dinosaur population, and some palaeontologists think that the dinosaurs were in decline before the asteroid struck. They base this theory on evidence that the diversity of species had been greatly reduced by the end of the Cretaceous. Whatever the reasons, dinosaurs were gone by the end of the Cretaceous.

Cenozoic Era

The Cenozoic Era took Saskatchewan from the rainforest at the end of the Cretaceous to the modern environment familiar to us today.

1. Tertiary Period
65 - 2 Million Years Ago

During the Tertiary, Saskatchewan changed from the coal forests of the end of the Cretaceous to a landscape dominated by grasses. The diversity of animals during the Tertiary shows rapidly evolving fauna.

At the beginning of the Tertiary, small insectivores, lemur-like primates, condylarths, and multituberculates were the most common animals in the rainforests. Marsupials were already beginning to disappear in North America.

About 50 million years ago, the climate began to change. Continental drift changed the course of ocean currents and the continued mountain building to the west of Saskatchewan produced a cooler, drier climate. The rainforests gave way to meadows and more temperate forests. As the vegetation changed, so did the animals. Grass became a major food source for herbivores. The digestion of grass requires a different process than for leaves, which are much easier to digest. Many animals made the change from browsing on leaves to grazing grass.

The land connection linking North America and Europe may have increased the diversity of animal species.

As the Tertiary continued, the climate continued to become drier. By the end of the Tertiary, Saskatchewan resembled African savannas. Most of the animals living at the end of the Tertiary also seemed to fill many niches seen in Africa today.

During most of the Tertiary, the climate was seasonal. It was dry most of the year with one rainy season. Temperatures remained warm. This is proven by the existence of animals such as a species of land tortoise that cannot tolerate frost and cold temperatures.

The evolution of mammals throughout the Tertiary is a fascinating study of reaction to changes. Many Tertiary mammals that dominated at various times were in reality dead ends on the evolutionary tree. Early meat-eating creodonts, browsing titanotheres, pig-like entelodonts, and sabre-tooth cats are all animals that did not survive to the end of the Tertiary. Others, like condylarths and horses evolved to suit the changing environment. In so doing, they completely changed from their earliest form. Some others, like turtles, continued through the Tertiary without great evolutionary changes.

2. Quaternary Period
2 Million Years Ago - Present

The continental ice sheets of the Quaternary were the last occurrences to shape modern Saskatchewan. Ice sheets were not new phenomena. They have existed in various places throughout the geological history of the planet. For example, there are indications of an ice sheet in North America during the Precambrian.

Ice ages occur when the temperature during the summer does not become warm enough to melt all the winter snow. As the snow builds up, pressure at the centre of the mass has two effects. One is to turn snow to ice and the other to begin to force the edges of the accumulated snow outward. The accumulation now becomes a continental glacier.

Scientists do not agree on the causes of the cooling that formed the ice sheets, nor on the causes of the warming that melted them. Many hypotheses have been put forth, but none proven. Some scientists believe that we are living in an interglacial period - the time between ice sheets.

During the Quaternary Period, there were five continental ice sheets. The last one, the Wisconsin, covered North America as far south as Wisconsin. In Saskatchewan, the Cypress Hills and Wood Mountain Plateau were never glaciated. The ice sheet flowed around these two uplands, leaving them as islands of land in a sea of ice.

At the beginning of the Ice Age, the animals living in Saskatchewan did not seem all that different from those of the Tertiary. Species like the Bone-crushing Dog were late remnants of the Tertiary. Others like the Imperial Mammoth were early arrivals from other parts of the world. Horses were still abundant two million years ago and may have shared grazing space with camels, giant sloths, giant bison, and a bovid called a Shrub Ox.

The last glacier shaped modern Saskatchewan. Except for Wood Mountain and the Cypress Hills, all our familiar landforms are a result of the advance and retreat of the glacier. Glacial features that are found in Saskatchewan include terminal and lateral moraines, potholes, glacial lakes, outwash plains, glacial run-off valleys, drumlins, and eskers.

Studies of pollen left in peat bogs after the last glaciation give hints about the climate changes going on as the glacier retreated.

As the glaciers were melting starting 17, 000 years ago, Black Spruce was the dominant vegetation in southern Saskatchewan. About 10,000 years ago, prairie grassland replaced the spruce without any intermediate stages. This was a time of change for Saskatchewan. The first indications that man had come to this region are between 10,000 and 12,000 years old. About 10,000 years ago, a large number of megafauna that had survived the Ice Age disappeared. This included several species of horses, sloths, mammoths, glyptodonts, sabre-tooths, cheetahs, tapirs, and some species of camels. Although some species of camels and horses survived this extinction event, they died out in North America sometime later. Others like mastodonts and mammoths disappeared forever. The hypotheses for the causes of the extinction are an area of controversy and hot debate in scientific communities. So far no reason that gives a complete explanation has been discovered. It may never be truly understood.

With the development of grassland and the disappearance of the Ice Age megafauna, Saskatchewan's environment entered the modern era.

RECOMMENDED RESOURCES

Books:

Braithwaite, M. (1975). The Western Plains. Toronto: McClelland and Stewart.

Gordon, A. (1979). Geology of Saskatchewan. Regina: Western Extension College Educational Publishers.

Lambert, D. (1985). The Field Guide to Prehistoric Life. New York: Diagram Group.

Rhodes, F. H. (1962). Fossils. New York: Golden Press.

Storer, J. (1989). Geological History of Saskatchewan. Regina: Royal Saskatchewan Museum.

Films:

National Film Board of Canada: Continental Drift

National Film Board of Canada: Evolution

National Film Board of Canada: Face of the Earth

National Film Board of Canada: Five Billion Years

National Film Board of Canada: Moving Plates

National Film Board of Canada: This Was The Beginning

Saskatchewan Educational Media Services: Fossils: Clues to Prehistoric Times

Saskatchewan Educational Media Services: The Fossil Story

Royal Saskatchewan Museum. Glaciation.

Royal Saskatchewan Museum. 65,000,000 Years Ago