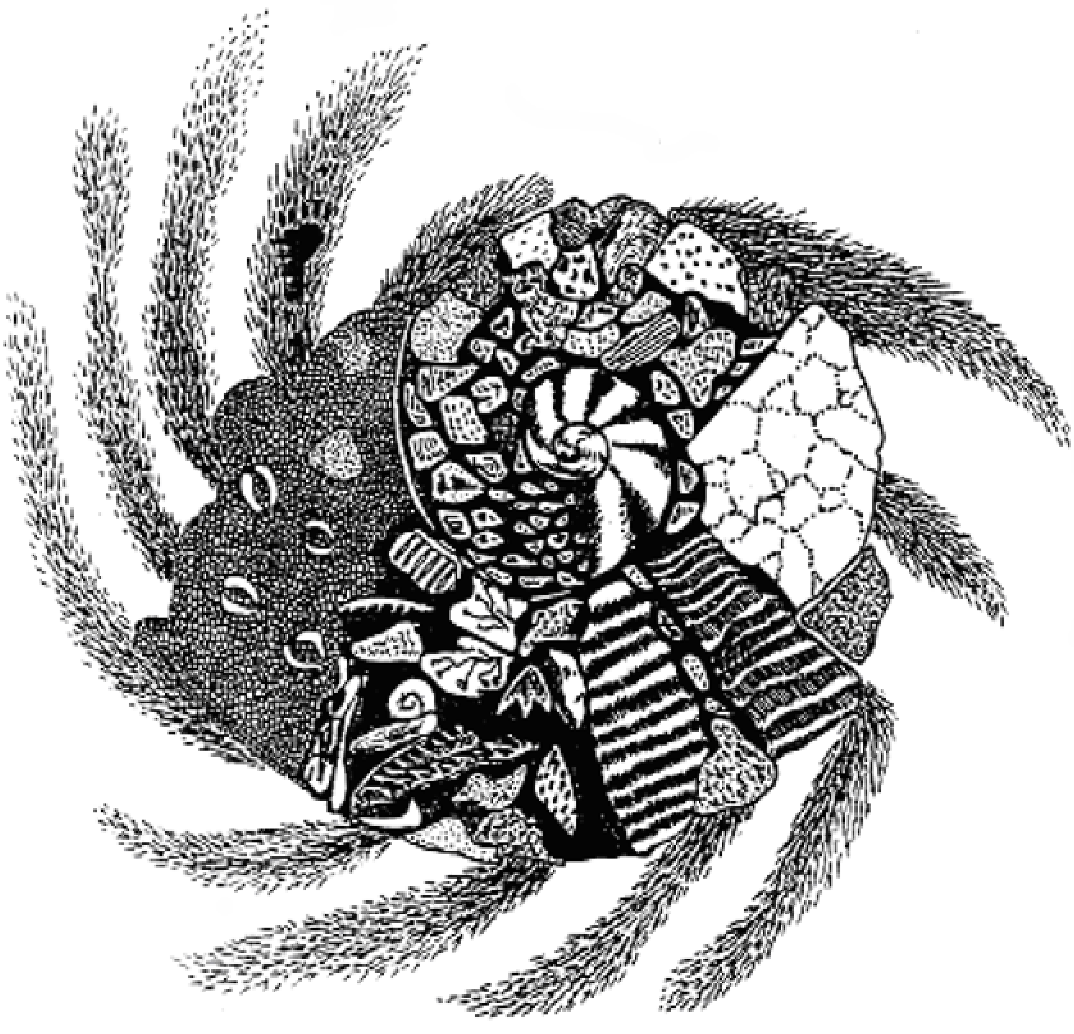
Royal Saskatchewan Museum



Saskatchewan
Ministry of
Parks, Culture
and Sport

For further information please contact:

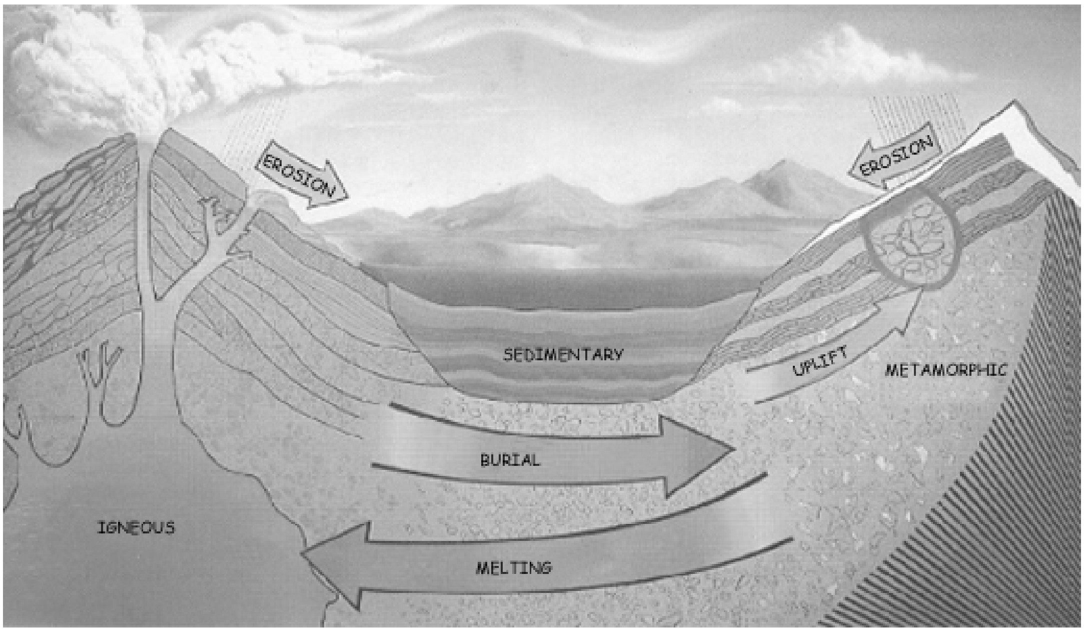
Public Programs
Royal Saskatchewan Museum
2445 Albert Street
Regina, Saskatchewan
S4P 4W7
Email: education@royalsaskmuseum.ca
Website: www.royalsaskmuseum.ca

This document has been created for students and teachers for use in research of Saskatchewan's geological and paleontological past.

Background Information

1. The Rock Cycle

The rock cycle is the process in which rocks are being formed, worn down and then formed again; they are constantly being altered or combined. Erosion is the main contributor to the rock cycle. It wears down the rocks, forming sediment. As sediment accumulates over the years, the older sediment gets pushed further down, eventually becoming sedimentary rock. Sedimentary rock is continually pushed down becoming exposed to great heat and pressure, eventually becoming metamorphic rock. The metamorphic rock continues to be pushed further into the earth and eventually gets so hot that it turns back into magma. The magma then returns to the earth's surface through volcanic activity to become igneous rock, at which point the cycle starts all over again. It takes thousands to millions of years for the cycle to be completed once.



Igneous Rocks

The earth is made of rocks and minerals. Minerals are the chemical compounds that combine to form rocks. For example, mica, feldspar, and quartz are all individual minerals that can be found together in granite.

The first rocks to form on the planet were igneous rocks. Geologists think this occurred approximately 4.5 billion years ago. These rocks formed when the molten material at the surface of the globe began to harden.

Beneath the solidifying rocks on the surface of the globe, minerals remain molten and under pressure. This substance called magma rises to the outer skin of the earth. Sometimes it breaks through the crust to reach the surface. This is volcanic activity.

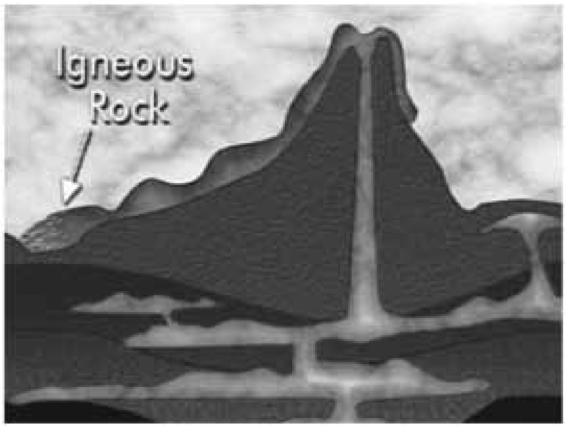
If the magma does not break through, it may harden and form intrusive rock. An *intrusive rock* is formed when magma cools slowly within the earth, whereas an *extrusive rock* is formed when the magma reaches the surface (lava) and cools more quickly.

Extrusive rock forms tiny crystals as a result of its quick cooling. Intrusive rock cools slowly and forms large crystals, like those seen in granite.

Igneous rocks can be classified by weight; the heavier, darker types such as basalt and gabbro, and the lighter-weight granites and rhyolites. The darker igneous rocks include iron and magnesium in their makeup, while the less heavy, lighter coloured rocks have elements of sodium and potassium.

Regions made of these heavier, darker rocks sink deeper into the earth's crust. These form the plates under the earth's oceans. The lighter granites and rhyolites "float" on top of the crust and form the foundations of the continents.

When a light plate and a heavier plate bump together, the heavier oceanic plate moves (subducts) under the continental plate. It eventually moves back into the mantle, where it becomes molten and the cycle begins again.



In Saskatchewan, igneous rocks are found at the surface only in the north where the Precambrian bedrock is exposed. The formation of volcanoes such as the Amisk volcano gives evidence of the tectonic activity that was going on in Saskatchewan 2 billion years ago.

Sedimentary Rocks

The rocks that remain on the earth's surface are exposed to the forces of nature, which eventually destroy the rocks. This process is called erosion or weathering. Water is the most powerful of these forces.

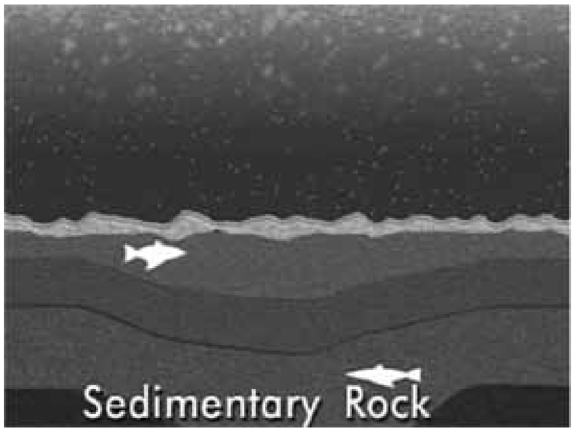
Two kinds of actions take place to create sedimentary rocks. The first is *clastic erosion and deposition*. In this process, rocks are broken apart into smaller pieces. These pieces are transported by water and deposited in layers where they eventually form sedimentary rocks. The largest particles come to rest first and the smallest last. This process of water sorting always leaves the largest particles closest to the source of the original rock.

The speed of the water and the size of the particle determine how far it is carried before being deposited. Fast flowing streams carry more material farther and faster than slower streams. Fast flowing rivers erode their streambeds while slow flowing rivers deposit sediments.

The other kind of action by which water creates sedimentary rock is called *chemical erosion and deposition*. Many minerals are water soluble and will readily dissolve in water. If dissolved minerals reach a saturation point, they will precipitate out of the water. The huge beds of potash being mined today formed when supersaturated ocean water in the deep basins of the mid-Devonian seas began to form crystals on the ocean floor.

Chemical erosion and deposition is also important for another reason. Some minerals such as silica dissolve in water. When animal bones or wood sit in groundwater full of dissolved silica, this mineral will eventually replace the organic material, thus forming a fossil.

The most common stone formed from chemical erosion is limestone. Most of limestone's substance is made of fossils. The fossils in limestone are of plants and animals that extracted calcium carbonate from the surrounding water to make their hard shells. Limestones are most often formed in oceans, although a few freshwater types are known.



The oldest sedimentary rock in the province comes from the Precambrian Period and is found in the Athabasca Formation. In this formation, the igneous rock that formed and cooled during the earlier Precambrian was eroded. The resulting sediments were deposited in layers that eventually formed sedimentary rock.

In the southern part of Saskatchewan, thick layers of sedimentary rock formed in the seas that covered the province from the late Precambrian to the end of the Cretaceous.

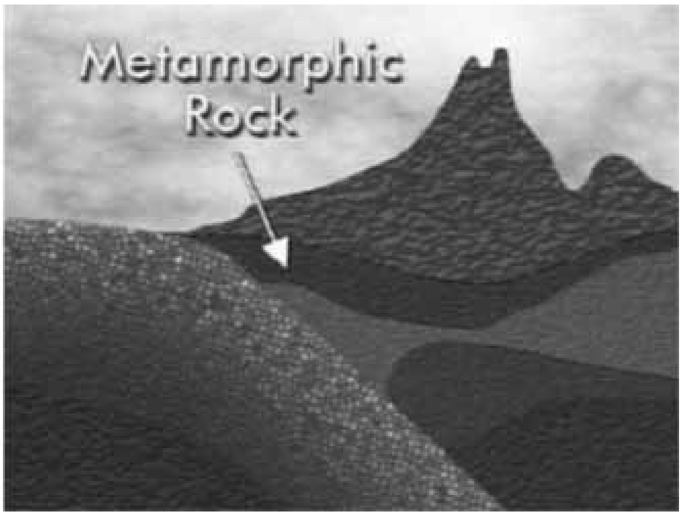
Metamorphic

Metamorphic is a Greek word that means *change* or *transformation*.
When igneous and sedimentary rocks are subjected to heat and pressure, their molecular structure changes. This change includes differences in the minerals and structure of the rock.

Heat and/or pressure must be present to produce changes to rock. This process most often occurs at zones of mountain building and intense folding, or near a volcanic intrusion.

Banding that is visible to the eye is often seen in metamorphic rock. When exposed to heat, some minerals in the rock will melt before others. When this situation occurs, the melted material will align itself in bands. These are known as *foliated* metamorphic rocks.

In Saskatchewan, metamorphic rocks represent the older periods of the province's geological history, when the land was subject to tectonic and volcanic activity. The metamorphic rocks found in the extreme northwesterly corner of the province represent ancient continental collisions. The north is the only place where metamorphic rock can be found on or close to the surface.



Rock Classification

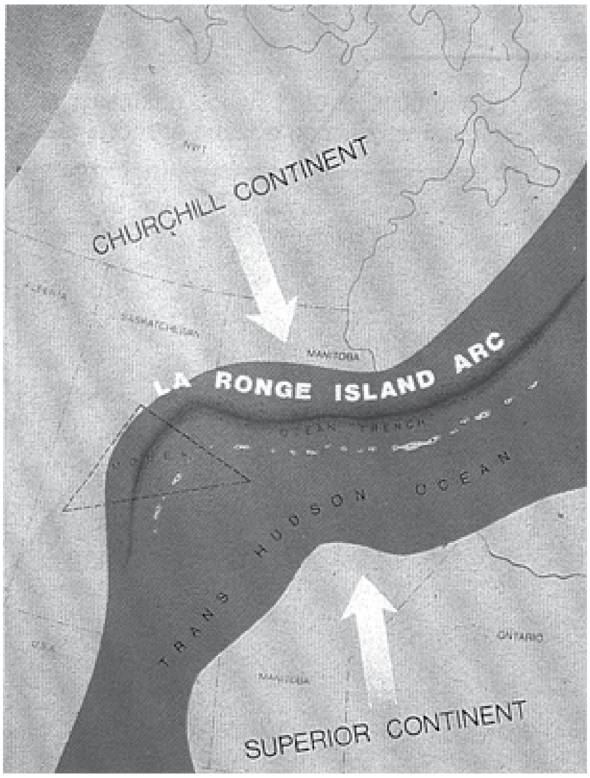
Sedimentary	*Igneous*	*Metamorphic*
1. Clastic	1. Intrusive	1. Foliated
Sandstone	Granite	Gneiss
Shale	Gabbro	Slate
Mudstone	Diorite	Schist
Siltstone	Granodiorite	
Breccia		2. Non-Foliated
Conglomerate	2. Extrusive	Marble
	Basalt	Quartzite
2. Chemical	Rhyolite	
Limestone	Dacite	
Dolostone	Andesite	
Evaporites		

2. Saskatchewan's Geology

Saskatchewan's Precambrian Rocks

In Saskatchewan, the Precambrian can be divided into different time periods. The older Precambrian is a time of intense mountain building and tectonic and volcanic activity.

At this time, there were two continents – the Superior and the Churchill Continents. The Superior Continent was gradually moving closer to the Churchill Continent. The Trans Hudson Ocean separated the two continents.



Volcanoes develop along the subduction zone of tectonic plates. This zone is where the oceanic plate is sliding under the continental plate. These volcanoes sometimes develop a feature called island arcs. The present day islands of Japan and Indonesia are examples of island arcs. In Saskatchewan two island arc formations lay in the Trans Hudson Ocean between the two continents. Today, these island arc formations are identified as the La Ronge belt and the Flin Flon belt.

Eventually, the two continents collided. The collision zone is another area of tectonic and volcanic activity. The Amisk volcano is an example of one such volcano. Today, the Himalayas are an example of mountains being built where continents collide.

The Amisk volcano is responsible for the copper and zinc deposits mined in northern Manitoba. The "black smokers" (tall, chimney-like projections from the ocean floor) associated with the volcanic activity also brought abundant minerals to the ocean floor. The shearing and metamorphism of the original igneous rocks created the gold deposits mined at the Star Lake and other similar gold mines in the north.

The early Precambrian was the last time that igneous and metamorphic rocks formed in Saskatchewan. The later layers of sedimentary formations covered these ancient rocks with deep layers of stone. Only in the north, where other deposits never covered the original Precambrian rocks or where the glaciers scraped the top layers off the bedrock, are the Precambrian formations exposed.

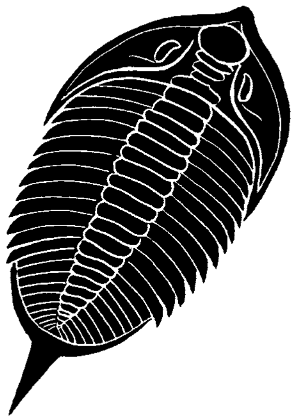
The Later Precambrian
Block faulting west of the mountains created rift valleys that filled with sediment during the early part of the late Precambrian. The oldest fossils found in Saskatchewan come from the sedimentary rocks filling these rifts. Stromatolites are formed by a kind of colonial blue-green algae that build mounds of calcareous material. The fossils look like spheres of different coloured rock.

This process of faulting and sedimentation caused the formation of uranium deposits. It is thought that uranium originates in some kinds of volcanic tuff (solidified volcanic ash). In northern Saskatchewan, these volcanic tuffs were deeply buried by later sedimentary layers. With the pressure that results from deep burial, changes occurred to these rocks and the uranium was released into groundwater. The water collected in chemical traps where the uranium precipitated to form very rich, highly radioactive deposits.

Saskatchewan's Palaeozoic Rocks and Fossils

Throughout the Palaeozoic era, Saskatchewan was covered by a series of warm, shallow seas. The water levels fluctuated, so that there were periods when land did emerge. Often these periods were marked by extensive erosion, so that little or no rock layers exist. This is the case with the Cambrian period. Saskatchewan has few or no rocks from the Cambrian period.

The Cambrian is best known for the appearance and evolution of strange sea creatures. These included early trilobites, arthropods, and soft-bodied animals. The Burgess Shale from the Kicking Horse Pass in British Columbia has an abundance of fossils left by some very bizarre animals. Although there is no fossil evidence of these strange creatures in Saskatchewan, we can surmise that the seas here also teemed with life.

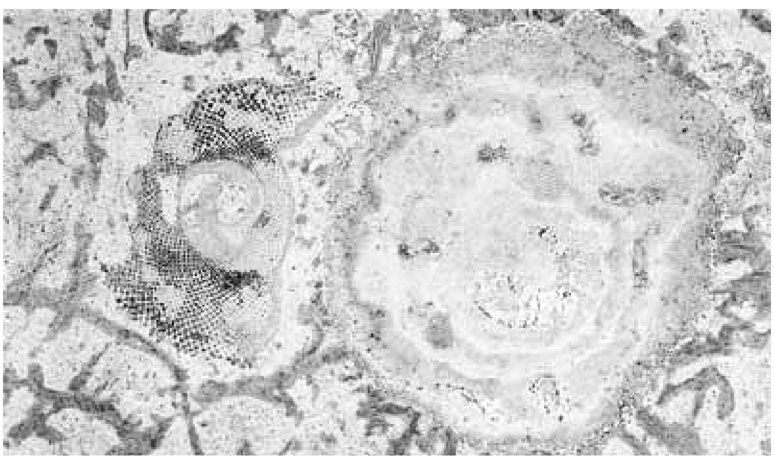


Trilobite

The Ordovician period followed the Cambrian. Most people in Regina have seen Ordovician fossils. The Tyndall stone facades of buildings in Regina are full of fossils of stromatolites, trilobites, corals, brachiopods, and nautiloids. Tyndall stone is limestone, which is a chemical sedimentary rock. It is formed when calcium carbonate is dissolved in water and later precipitates to form layers. While limestone contains calcium carbonate, it is mostly made up of fossils.

Tyndall stone contains another mineral called dolomite. The darker veins in the stone make it look like marble. These veins are fossilized burrows made by small marine organisms - probably a type of marine worm. The fossilized burrows have become dolomitized by the addition of magnesium ions. Dolomite is harder than limestone. If Tyndall stone is weathered, these burrows often are raised above the softer limestone.

Tyndall stone is quarried in Manitoba, but it was formed in the same seas that covered Saskatchewan. Some rocks of the same age have been exposed in northern Saskatchewan, and a few pieces dropped by glaciers have also been found in the south.



Fossils in Tyndall Stone

The lifeless Devonian seas yield few fossils. The level of dissolved mineral salts (saline) increased to a level that permitted few organisms to survive. Eventually, the deepest parts of the sea bed, inaccessible to new influxes of water, became so saline that the dissolved minerals began to precipitate out of the water.

Anhydrite (rock gypsum) precipitated out first, followed by halite (rock salt), and lastly potash.

The coral reefs that kept water circulation to a minimum were eroded after the formation of the mineral beds. Normal circulation resumed at the end of the Devonian as indicated by the occurrence of limestone and shale on top of potash deposits.

Elsewhere, the Devonian was a time of abundant life. Plants and varieties of marine life flourished. However, in Saskatchewan no fossils from the Devonian exist due to the saline conditions.

The end of the Devonian Period is also noted for the beginning of the tectonic mountain building that created the Rocky Mountains. This activity is still going on today.

The early Carboniferous in Saskatchewan is represented by limestone formations that have fragmentary fossils. These layers are capped by more anhydrite beds. There are no deposits for late Carboniferous and Permian periods.

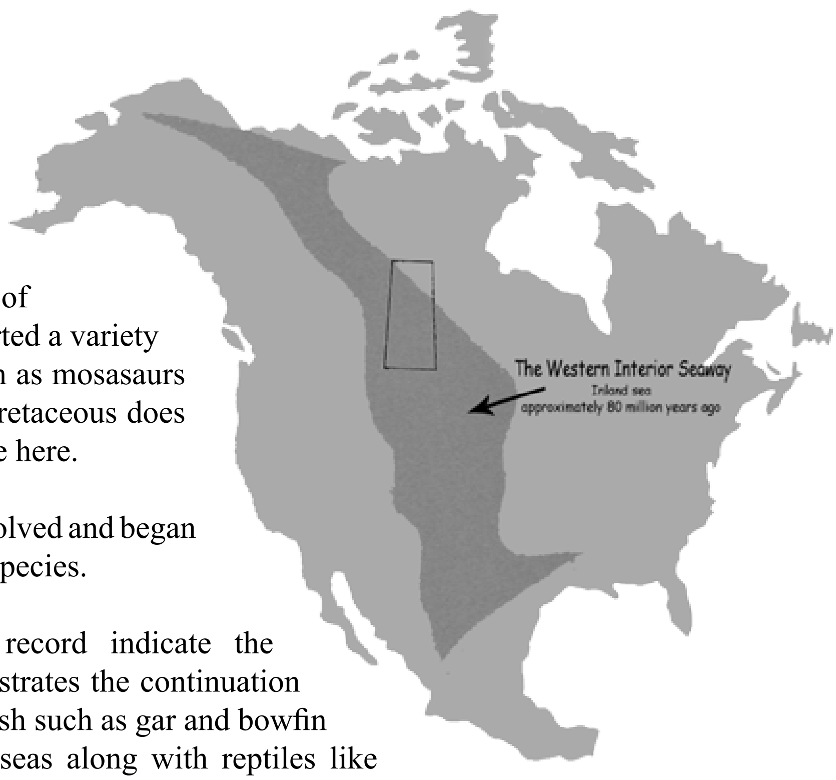
The Mesozoic Era

No fossils have been found for the Triassic Period in Saskatchewan. Elsewhere, mammals and dinosaurs first appeared during this time. The Jurassic Period again shows marine conditions and formation of limestone, dolomite, sandstone, and shale.

The Cretaceous Period

The Cretaceous is the last period of the Mesozoic era. For most of the Cretaceous period, Saskatchewan was covered by the Western Interior Seaway. This shallow inland sea connected what is now the Arctic Ocean with the Gulf of Mexico.

The formation of the Rocky Mountains continued and intensified in the Cretaceous. This activity caused the interior sea to move eastward, eventually uncovering dry land in Saskatchewan.



The Cretaceous in Saskatchewan reflects a marine environment for the greatest part of the time period. Warm muddy seas supported a variety of marine life including large reptiles such as mosasaurs and plesiosaurs. Only at the end of the Cretaceous does dry land appear and allow dinosaurs to live here.

During the Cretaceous, flowering plants evolved and began to replace the gymnosperms as dominant species.

Not only does Saskatchewan's fossil record indicate the appearance of new species, it also demonstrates the continuation and/or extinction of species. Sharks and fish such as gar and bowfin all swam in Saskatchewan's Cretaceous seas along with reptiles like mosasaurs and plesiosaurs. By the end of the Cretaceous, the marine reptiles became extinct while bowfin, gar, and sharks all survive today.

The geology and fossil records do not give proof of the causes of the extinction of the dinosaurs and large marine reptiles. Various theories and hypotheses which attempt to explain this extinction have been considered including climate change from an asteroid strike, climate change resulting from extreme volcanic activity, climate change due to the lowering of sea levels, and communicable diseases killing off all dinosaurs and many reptiles. None of these theories has been proven.

In recent years, new fossil finds from China have given credence to a theorized relation between birds and dinosaurs. These fossils are thought to be theropod dinosaurs with feathers. Many scientists support the idea that birds and dinosaurs are closely related – and some consider birds to be the direct descendants of the dinosaurs. If true, this means that not all the dinosaurs became extinct at the end of the Cretaceous and that they are still with us.

The Cenozoic Era (see NOTE on page 9)

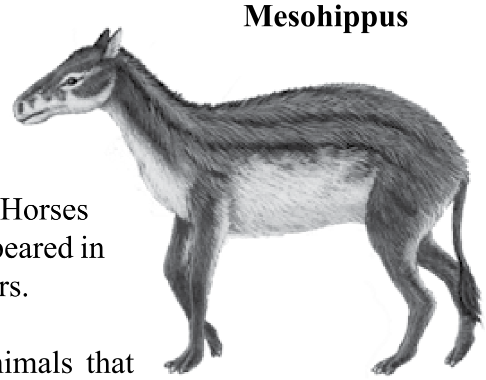
The Tertiary Period

The Tertiary is known as the Age of Mammals. Mammals are as old as dinosaurs, but when dinosaurs dominated, they stayed small and inconspicuous. When the big dinosaurs died out, the mammals could move into niches left empty by dinosaur extinction.

During the Paleocene Epoch (65-55 m.y.a.) at the beginning of the Tertiary, Saskatchewan was covered by moist rainforest. The rainforests of the Cretaceous-Tertiary resulted in the lignite coal deposits that are mined in southern Saskatchewan around Estevan. Fossil plants include ginkgo, sycamore, cypress, elm, and walnut trees as well as horsetails and other water plants.

Mammals at this time included primates such as Plesiadapis, rodent-like animals called multituberculates, and primitive ungulates called condylarths. All these early mammals were small in size.

Mesohippus



By the end of the Eocene Epoch (55-38 m.y.a.), the rainforest was receding and small mammals had developed into huge brontotheres, meat eaters called creodonts, various species of rhinoceros, a pig-like creature called an entelodont, and small dog-sized leaf-eaters called Mesohippus. Mesohippus is an early relative of modern-day horses. Horses evolved in North America. Eventually, they spread into Asia and disappeared in North America. They were re-introduced by the early Spanish explorers.

Things were not always as they appeared in the Tertiary. Many animals that resemble modern species are not closely related. In the Oligocene Epoch (38-25 m.y.a.), brontotheres resembled rhinoceros; sabre-toothed cats looked liked cougars and creodonts like bears. However, none of these look-alikes are closely related. On the other hand, Mesohippus does not closely resemble modern horses, but is related to today's species.

The Miocene Epoch lasted from 25 - 5 million years ago.

Miocene rodents included beavers, pikas, pocket gophers, and pocket mice. Grazing animals dominated the larger species. Miocene grazers included camels, early species of deer, giant pigs, Merychippus, and oreodonts. Oreodonts became extinct and left no modern descendants. Merychippus represents a later stage in the evolution of horses. Merychippus, was the size of a pony. It still had three hooves, but the middle one had become so large that the two outside hooves did not touch the ground. Merychippus had large grinding teeth that were able to chew tough grasses. The landscape and environment now had wet and dry seasons, and grass was more prevalent than forests.

As the Tertiary progressed, it became cooler and drier. Wet and dry seasons developed, but the temperature did not drop below freezing.

The last epoch in the Tertiary Period, the Pliocene (5-2 m.y.a.), is not well represented in the province's fossil record.

As grass became more prevalent during the course of the Tertiary period, some herbivores were able to switch from a diet consisting mainly of leaves (browsers) to one that was mostly grass (grazers). Grass is full of silica, which is very difficult to digest. Different strategies for digesting grass evolved. Ruminants for example use more than one stomach to digest grass. Browsers like mastodons could still find leaves to eat, but animals like Merychippus that made the switch to grass prospered.

The gradual progression from rainforest to savannah marked the last changes that took place before the Ice Age or Pleistocene Epoch. Much of the Tertiary record in Saskatchewan was destroyed by the glaciers that followed. Only in non-glaciated areas such as the Wood Mountain Plateau or the Cypress Hills can we find fossil evidence of the Age of Mammals in Saskatchewan.

The Quaternary Period

The Pleistocene Epoch began 2 million years ago. During this time, five separate ice sheets covered and retreated across North America. The last of the ice had retreated from Saskatchewan about 7,000 years ago. Scientists are still debating the possible causes of the growth and retreat of the glaciers.

NOTE: Science can change! Scientists discuss, debate and change - especially when new evidence is presented. Scientists have made some changes to how they divide the Cenozoic Era. While Tertiary and Quaternary are both still accepted (and used in many of the books and resources you may see), in your research you may also see reference to the Paleogene and Neogene. The Paleogene refers to the first part of the Tertiary and the Neogene refers to the last part of the Tertiary and Quaternary.

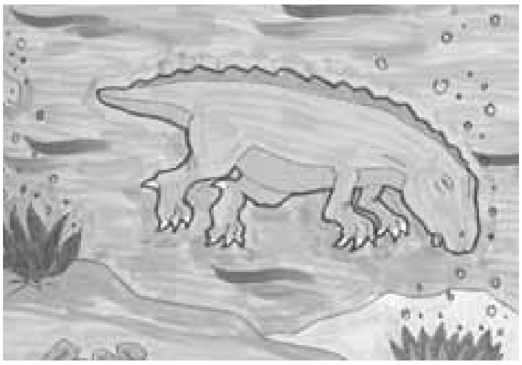
3. Fossils

Formation of Fossils

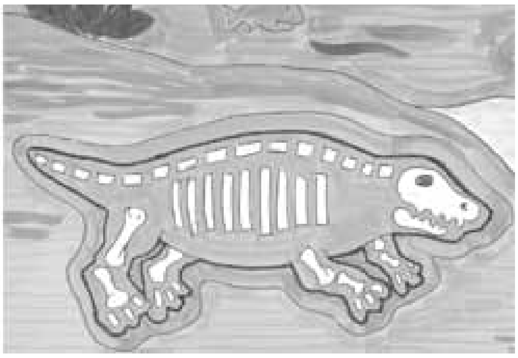
Fossils are either the remains of organisms or traces of their presence. Most organisms leave no trace of their lives behind because fossils will form only under certain conditions. This means that the picture we have of prehistoric life is incomplete.

Most of the world's fossils are found in sedimentary rock because the formation of sedimentary deposits allows for the creation of fossils. The forces that produce igneous and metamorphic rock destroy fossils. In rare cases, distorted fossils can sometimes be found in metamorphic rocks such as marble. There are some examples of this type of fossil in the red marble in the RSM.

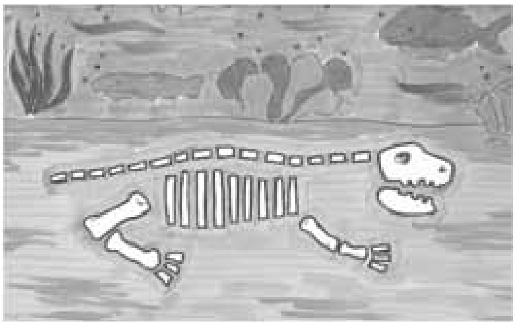
Fossils can take thousands to millions of years to form, undergoing a series of processes. However, the right conditions must be present for fossilization to occur. This process is as follows:

1. 

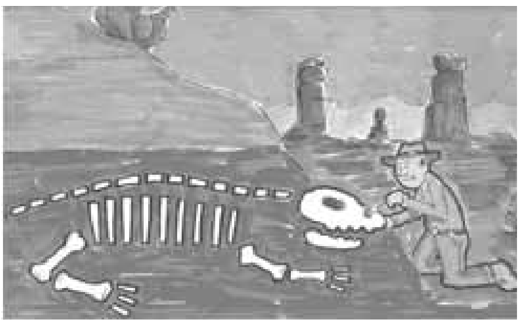
Once an organism (dinosaur, plant, etc.) dies, it must be buried quickly in sediment (dirt, mud, or sand) to prevent destruction of the organism by scavengers, bacteria, and weathering. The most suitable place for this to happen is underwater. Many fossils have been found in areas that were once covered by water.

2. 

The soft parts of the organism rot away, leaving behind only the hard parts, such as teeth, bones, shells, etc. Over time, more sediment covers the remains, burying the object deeper.

3. 

Minerals replace the original organic substances of an organism's remains. As a bone slowly decays, water infused with minerals seeps into the bone and replaces the organic matter with rock-like minerals.

4. 

Over thousands to millions of years, most of the original bone material has been replaced, forming a rock-like copy of the original organism. Through natural processes such as erosion and man-made activities like construction, the fossil may become partially exposed on the surface. Palaeontologists out prospecting (looking for fossils) will come across the exposed fossil and begin to excavate.

Trace Fossils

Trace fossils include tracks, track ways, and impressions (of skin, leaves, etc.). These are formed when a foot or a leaf etc. is pressed into mud. If the mud turns to rock without being disturbed, a trace fossil is left behind.

Mold and cast fossils are formed when layers of mud or sediment cover a dead organism. Eventually, the body rots away, leaving a mold of the organism. If minerals or sediments then fill in the cavity left after the body rots away, a cast fossil is formed. If the mold breaks up, the cast will be left behind. Sometimes both the mold and the cast remain intact.

Microfossils

When we think of fossils, we most often think of the huge bones of dinosaurs and other megafauna. However, in modern ecosystems, large animals such as bear, elk, and bison make up only a small portion of the animal species found within a habitat. Today, many palaeontologists are studying whole prehistoric ecosystems instead of focussing on just the large animals. The microfossils left behind by tiny animals have become an important tool in piecing together an understanding of ancient habitats and ecosystems.

Further Reading and Resources

Albert, Toni. Step-by-Step Science Series: Rocks & Minerals.Greensboro: Carson-Dellosa Publishing Co, 1994

Reader's Digest Pathfinders: Rocks and Minerals. San Francisco: Weldon Owen Inc., 1999

Reader's Digest Pathfinders: Earthquakes and Volcanoes. San Francisco: Weldon Owen Inc., 2000

Storer, John. Geological History of Saskatchewan. Saskatchewan Museum of Natural History (now, Royal Saskatchewan Museum), 1989

Symes, R.F. Eyewitness Books: Rocks & Minerals. New York: Dorling Kindersley, 2000

VanCleave, Janice. Earth Science for Every Kid. Toronto: John Wiley & Sons, Inc., 1991

VanRose, Susanna. Eyewitness Books: Earth. New York: Dorling Kindersley, 2000

Young, Ruth. Hands-On Minds-On Science: Rocks & Minerals. Huntington Beach: Teacher Created Materials Inc., 1994

Websites

Rocks for Kids [online] http://rocksforkids.com/RFK/TableofContents.html

Royal Saskatchewan Museum website: www.royalsaskmuseum.ca

Saskatchewan Industry and Resources: www.ir.gov.sk.ca/