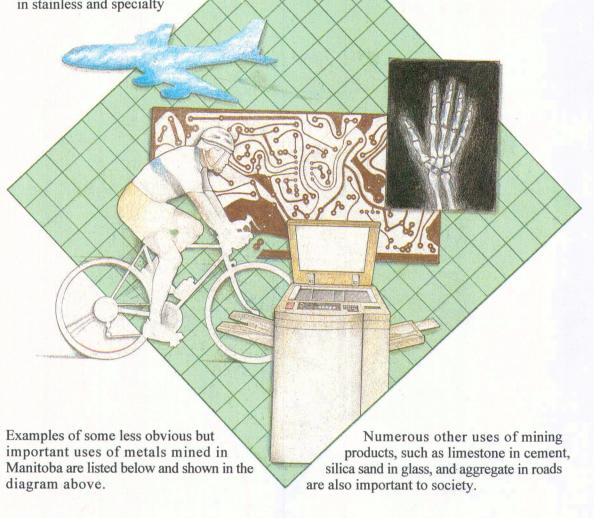


#### Travel Manitoba 1981: Surficial geological map of Manitoba; scale 1994: Manitoba Vacation Guide '94; Manitoba Business Development and Tourism

white pigments in paint and paper and is also the basis for modern sun screens The products of mining are not limited to protect us from harmful ultraviolet as steel in cars and nails, nickel in stainless and specialty



Cobalt: ----- jet engines, blue pigments for paints; a radioactive form is used as a tracer in Chromium: ---- tanning leather, to fix dyes in fabric, in stainless steel Lithium:----- batteries, glass and ceramics and lubricants Cadmium: ---- blue & green television screen phosphors, nicad batteries, yellow and red

- printed circuits in electronics i.e. electronic games, computers, cameras; caps for

teeth, medicine for arthritis --- paint, rubber, cosmetics, soap, medicines, textiles, x-ray and television screens, galvanized coatings for other metals Selenium: ---- photovoltaic cells for converting sun to electricity, electronic equipment, Spodumene: --- heat proof ceramic cookware (Corning Ware<sup>TM</sup>) Tantalum:---- surgical implants, glass for camera lenses, aircraft parts Silver: ----- mirrors, jewellery, printed circuits, photography, batteries, and explosives

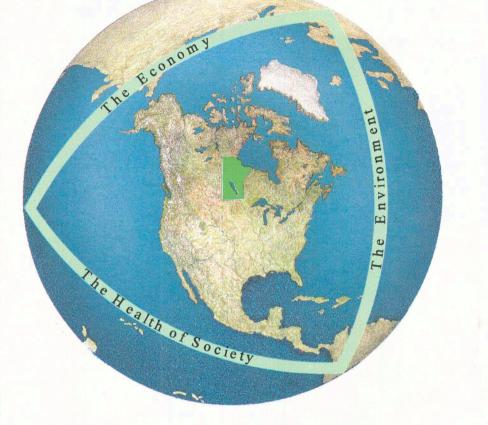
Sustainable development is a development that medicine from these resources is currently

#### SUSTAINABLE DEVELOPMENT AND THE — RESOURCE INDUSTRY

meets the needs of the present without irreplaceable. compromising the ability of future generations In the production of minerals, decisions that to meet their own needs. A balance is required in which several criteria operational disturbance are necessary. To are met: the existing population and future reduce possible negative effects of projects, generations can maintain a healthy quality of continuing advances in science and technology agricultural, and social system can produce the stages maintained (The Environment).

life (The Health of Society); an industrial, are applied in planning and monitoring all materials required to meet the needs of the Since these operations have a finite quantity of people (The Economy); the ecosystems useful material available they also have a necessary for continued existence of life are finite time of operation. At the end of operation, they need to be restored to

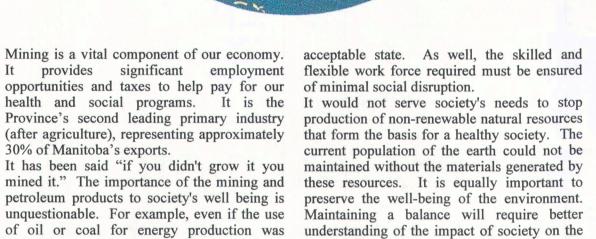
minimize the impacts of developmental and



opportunities and taxes to help pay for our of minimal social disruption. (after agriculture), representing approximately that form the basis for a healthy society. The 30% of Manitoba's exports. petroleum products to society's well being is preserve the well-being of the environment.

stopped, the need for plastic, fertilizer and natural system.

Mining is a vital component of our economy. acceptable state. As well, the skilled and It provides significant employment flexible work force required must be ensured



### MANITOBA GEOLOGICAL HIGHLIGHTS

Park; Geological Survey of Canada, Miscellaneous Teller, J.T., ed.

BIRDS HILL ESKER-DELTA COMPLEX Locally, meltwater channels which cut into the glacier became filled with sand and gravel. These former ice-walled valleys are expressed today as winding ridges of sand and gravel called eskers. An extensive deposit of sand and gravel located at Birds Hill, 16 kilometres northeast of Winnipeg, SALT "MEADOW" WITH SALT SPRINGS is the main source of aggregate material for the In the Dawson Bay area, along Pelican Rapids city. The deposit consists of a high narrow ridge Road, and also along the roads on the southwest which extends eastward from the town of Birds side of Lake Winnipegosis, large salt meadows Hill for 6.5 kilometres. The ridge merges into a with associated salt springs are abundant. They delta-like plateau of sand and gravel which extends over a broad area including Birds Hill Park.

deposited thousands of years ago as the upper

delta of the Assiniboine River. Later north-

westerly prevailing wind caused the sands to

Sidney the highway crosses the eastern edge of

the upper Assiniboine delta, and for the next 3

of an abandoned beach just west of Squirrel

lower delta of the Assiniboine River. These deposits

1983: Devonian potash deposits in Manitoba; Manitoba

1980: Ecotour of the Trans-Canada Highway: Regina-

1981:Ecotour of the Trans-Canada Highway: Winnipeg-

1978: The Audubon Society field guide to North American

1986: Oil in Manitoba; Manitoba Petroleum Branch,

Mineral Education Series.

nternational, Inc., Denver.

rocks and minerals; Alfred A. Knopf, New York.

1983: Geological environments favourable for petroleum

and stratiform mineral deposits; Geoexplorers

1981: Field geology; Sixth Edition, McGraw-Hill Book

1974: Guide to the geology of Riding Mountain National

1985: The Manitoba Potash Project, May 1985;

1986: Manitoba Official Highway Map, 1986/87;

1979: Geological map of Manitoba; scale 1:1 000 000,

1980: Mineral map of Manitoba; scale 1:1 000 000, Map

Winnineg.

Natural Resources, Parks Branch.

Winnipeg; Environment Canada.

Mineral Resources Division, Open File Report OF83-3.

1985: Canoe Routes (series of pictorial maps); Manitoba Phillips, K.A.

extend in an apron-like fashion toward the east.

km descends the shallowly sloping delta face.

on the shore of glacial Lake Agassiz.

drift, forming the Carberry Sand Hills.



**WEST HAWK LAKE** West Hawk Lake is believed to have formed as a result of meteorite impact because of its circular shape, the nature of the surrounding rocks and its great depth. Drilling results have shown that the rock below the lake is progressively less shattered and brecciated down to a depth of 600 m. Interesting outcrops of pillow lavas, a rock which is extruded onto a seafloor, occur throughout the

BIRDTAIL, QU'APPELLE, PEMBINA AND **ASSINIBOINE VALLEYS** As the glaciers retreated from Manitoba, huge volumes of debris-charged meltwater, which drained directly from the glacier, carved large valleys on the landscape, such as the Birdtail, Qu'Appelle, Pembina and Assiniboine valleys. When the glaciers disappeared, the present rivers in Manitoba established channels on the outwash surface. These rivers are much smaller than the former meltwater rivers which originally shaped

the valleys and are termed 'underfit streams'.

LATE PLEISTOCENE GLACIATION

The Pleistocene Epoch is often referred to as the Ice Age since continental ice sheets spread across Canada during this time. The effects of these

glaciations profoundly influenced Manitoba's

topography. Evidence suggests several major

periods of glaciation during the two million years

of the Pleistocene Epoch, each of which lasted for

thousands of years. The maximum extent of

glaciers during the Pleistocene is shown in the

The most recent glaciation, called the

Wisconsinan, started approximately 75 000 years

ago. The glaciers fluctuated back and forth

between northern and southern regions during this

time before they retreated about 8 000 years ago.

The load of the ice resulted in crustal depression.

Slow rebound of the crust followed the retreat of the glaciers and is still taking place in Manitoba.

ERA PERIOD/EPOCH A TURTLE MOUNTAIN

PALEOCENE TURTLE SHAI

SILURIAN

ORDOVICIAN

**PHANEROZOIC** 

**PRECAMBRIAN** 

FIGURE C

FIGURE D

Sandstone

Greywacke

Granite

Gabbro

Volcaniclastics

Though the climate began to warm about 16 and reshaped the land surface. Esker complexes 000 years ago, it took almost 5 000 years such as Birds Hill; moraines like The Pas, before the ice melted to expose large parts of the Sandilands and Tiger Hills; and the Pembina, land surface in southern Manitoba; the ice in Souris and Assiniboine valleys are just a few of northern Manitoba took another 3 500 years to the numerous consequences of glaciation.

Manitoba's landscape currently bears the legacy another result of glaciation and have also of these late Pleistocene glaciations which eroded influenced the shape of Manitoba's landscape.

Meltwater Lakes, in particular Lake Agassiz, are

GLACIAL DEPOSITS OF

**SOUTHERN MANITOBA** 

The Manitoba Escarpment is

shown by the heavy dashed

line, extending northwest to southeast. West of the escarpment, most of the surface deposits are composed of till, including hummocky "dead ice"

moraine shown in light purple. The old delta of the Assiniboine River (east of Brandon) formed

where the river entered glacial

Lake Agassiz. The thick clay

deposits of Lake Agassiz are

found mainly east of the delta,

in the Red River Valley (tan

colour). Elsewhere, the surface

is covered by a mixture of till,

clay, sand, gravel and peat,

with Precambrian bedrock

exposed over large areas east of

Lake Winnipeg. Major end

moraines are the irregular rust-

MILLIONS OF YEARS

**EPOCHS** 

PERIODS

QUATERNARY

TERTIARY

CRETACEOUS

TRIASSIC

PERMIAN

PENNSYLVANIAN

MISSISSIPPIAN

CARBONIFEROUS

DEVONIAN

SILURIAN

ORDOVICIAN

CAMBRIAN

Middle

Middle

3800±

FOLIATED

CENOZOIC

MESOZOIC

**PALEOZOIC** 

**PROTEROZOIC** 

ARCHEAN

coloured areas.

MANITOBA ESCARPMENT

9 000 years ago

largest of the glacial lakes.

unequal glacial rebound.

CROSS-SECTION SHOWING PALEOZOIC TO CENOZOIC FORMATIONS IN SOUTHERN MANITOBA -

10 20 30 KILOMETRES

**REVOLUTIONS &** 

figure at the right.

melt away completely.

SETTEE MORAINE This moraine is located northwest of Thompson on Provincial Road 391 on the way to Nelson House. In the Leaf Rapids area the road travels upon an esker complex. These high, dry esker ridges from natural well drained roadbeds and trails.

MORAINES

are believed to represent sites of Winnipegosis reefal structures where the overlying impervious Lower Dawson Bay rocks have been thinned or removed. Salt brines trapped within the reefs immediately below the surface are leaking out through salt springs. MANITOBA ESCARPMENT The Manitoba Escarpment is a preglacial feature and was not significantly eroded by glaciation due to the overlying deposits of hard grey Odanah

was formed when a meander of the

Assiniboine River was cut off from the main

★6 From Portage la Prairie eastward the highway

★ 7 The highway leaves the thick clay and silt

levels in the glacial lake as its waters receded.

\* 8 A peat bog extends for approximately 16 km

the Lake Agassiz basin. Reference: Ecotour,

Regina-Winnipeg, Winnipeg-Thunder Bay.

1994: Well location map No. 7; Winnipeg.

Educational Series ES 78-1.

Educational Series ES 78-2.

1978: Minerals of Manitoba: Volume II: Metallic

1953: A field guide to rocks and minerals; Houghton

1977: Rocks and minerals: Simon and Schuster, New York.

1964: Rock and mineral collecting in Canada: Volume I:

1944: Index fossils of North America: M.I.T. Press.

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in: Glacial Lake Agassiz, J.T. Teller and L.

1981: The Audubon Society field guide to North

of Geological setting of the Lake Agassiz region;

Clayton, editors; The Geological Association of

Canada, Special Paper 26. Also cited as: North

American fossils: Alfred A. Knopf, New York,

Dakota Geological Survey, Miscellaneous Map 24

Publishers Inc./Cambridge University Press, New York.

Geological Survey of Canada, Miscellaneous Report 8.

1976: Common rocks in Manitoba; Manitoba Mineral

Resources Division, Educational Series ES 76-1

pegmatitic; Manitoba Mineral Resources Division,

minerals; Manitoba Mineral Resources Division,

1978: Minerals of Manitoba: Volume I: Non-metallic and

crosses clay and silt bottom lands of glacial

deposits of the fertile lake bed of glacial Lake

Agassiz and enters rolling terrain consisting largely

of abandoned beaches and bars formed at different

stream, forming an oxbow lake.

Lake Agassiz.

along the highway.

traverses the gently sloping sand deposits of the 🔸 9 First Precambrian granite outcrop after leaving

Prinz, M., ed,

Shimer, H.W. and Schrock, R.R.

Teller, J.T. and Bluemle, J.P.

Cambridge.

shale. This shale, with its high silica content which was derived from volcanic activity, formed a resistant caprock of the Pembina and Riding mountains and the Manitoba Escarpment and prevented the escarpment from being eroded to the level of central and eastern Manitoba. The escarpment generally forms the easternmost edge of Cretaceous rocks in the province.



AIM OF THE MAP

provided for such research.

The geological highway map of Manitoba

ended to be used as a general reference map to

miliarize the reader with Manitoba's diverse and

teresting geology. The extensive nature of the

bject matter precludes any in-depth

mination; the map is intended for information

and to serve as a starting point to further research

ith detailed and specific information has been

into Manitoba's geology. A selected bibliograph

GEOLOGY OF MANITOBA

The rocks of Manitoba fall naturally into three

groups based on age and character. The most

ancient group is Precambrian in age and consists

of crystalline rocks of metamorphic and igneous

origin. The Precambrian rocks are overlain by a

seas during the Phanerozoic Eon. The Phanerozoic

is subdivided further into the Paleozoic, Mesozoic

MAJOR GEOLOGICAL SUBDIVISIONS

Trans-Hudson Orogei (Proterozoic/Archean)

Sedimentary gneiss and migmatite

younger group of sedimentary rocks deposited in of the age relationships between these groups.

and Cenozoic eras. The youngest Cenozoic Precambrian rocks record some of the earliest

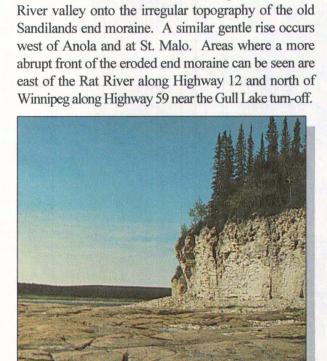
deposits form the third natural group. These events in the history of the earth. Additionally.

INTRODUCTION

Belair interlobate moraine forms a series of ridges extending north from Beausejour to Lake Winnipeg,

BELAIR, MILNER AND SANDILANDS

composed of till overlain by stratified clean sand and gravel derived from ice lobes on either side of the ridges. East of Winnipeg there is a complex series of sand end-moraine ridges which stretch from near Victoria Beach and Milner Ridge south through Sandilands Provincial Forest. Partly because of erosion by waves of Lake Agassiz, many parts of this once extensive end moraine are now low-lying hills. The original western edge of this end moraine system can be seen along the Trans-Canada Highway about 5 kilometres east of Ste. Anne turn-off (Highway 12). From there the road rises from the flat plain of the Red The Red River Plain, one the flattest regions in all River valley onto the irregular topography of the old of North America, formed as a result of glaciation Sandilands end moraine. A similar gentle rise occurs and subsequent sedimentation in Lake Agassiz. west of Anola and at St. Malo. Areas where a more Deposits of silt and clay settled onto the lake abrupt front of the eroded end moraine can be seen are bottom. Such absence of surface relief in southeast of the Rat River along Highway 12 and north of central Manitoba has led to extensive meandering Winnipeg along Highway 59 near the Gull Lake turn-off. of the Assiniboine and Red rivers and their



EXTENT OF LAKE AGASSIZ DURING DEGLACIATION

DAWSON BAY, HIGHWAY 10 Along the Pelican Rapids Road, Dawson Bay area, undulating bedding-plane surfaces of Lower Dawson Bay strata reflect closely the configuration of underlying Winnipegosis reef complexes. Dawson Bay strata are draped over these reefs as a result of solution of Devonian Prairie Evaporite salt beds and subsequent collapse of strata. Highway 10 north of Red Deer River has a roadcut through the structuraltopographic dome of Lower Dawson Bay strata which is draped over an underlying Winnipegosis reef. The reef top is within 5 to 10 metres of the surface.

Archean pillowed basalt, Pipestone Lake

deposits are sedimentary; however, their origin is

related to glaciers and glacial meltwater during

Pleistocene times. The glacial deposits occur

only at the surface and tend to cover the other two

rock groups. The geologic time scale shown

below will give the reader a more complete idea

they give geologist insight into processes that

occur far below the earth's surface, at depths of 10

to 30 km. In Manitoba the Precambrian rocks can

be divided into two geological provinces, largely

on the basis of age. The Superior Province is

roughly 3.0 to 2.5 billion years old, and the

Churchill Province is younger, being about 2.8 to

1.7 billion years old. Both the Superior and

Churchill provinces are further subdivided into

various subprovinces, as the inset map illustrates.

The Superior Province is dominated by granitic

bodies which have intruded greenstone belts.

Greenstone belts consist of metamorphosed

volcanic and sedimentary rocks as shown by the

panel on their formation. In Manitoba, the

granitic-greenstone regions are the Gods Lake,

Uchi and Wabigoon subprovinces. In addition to

these subprovinces, the Superior Province also

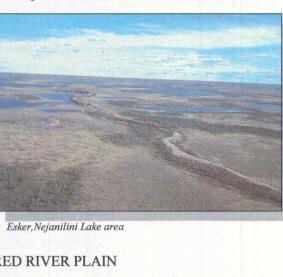
contains less extensive areas where the

metamorphism has been so intense that the

Precambrian rocks have been transformed into

gneisses. These gneissic regions are called the

**PRECAMBRIAN** 



8 000 years ago

had retreated as far north as the mouth of the

ancestral forms of Lakes Winnipeg, Manitoba and

Glacial Lake Agassiz (in blue) formed in front of About 10 000 years ago Lake Agassiz covered the glacier as it retreated northward through the 350 000 km2. The water was more than 200

Red River Valley and eventually became the metres deep at Winnipeg. When the ice sheets

Two stages, separated by an interval of low water, Nelson River approximately 5 000 years ago,

are recognized in the history of the lake. During access to the open sea became available. This

the recessional stage several types of deposits resulted in a sudden drainage of the remaining

were formed, such as outwash plains, deltas and part of Lake Agassiz, which left behind the

The ancient beaches of Lake Agassiz can be seen Winnipegosis. Deposits of silt and clay that were

today as nearly parallel sandy ridges or as wave- left on the lake bottom cover a large portion of

cut cliffs along the Manitoba Escarpment. These the province today.

beach ridges are higher to the north because of

CAMPBELL AND ARDEN BEACHES The Campbell and Arden beaches, ancient beaches of Lake Agassiz, form prominent topographic features in Manitoba. Ridges of sand and gravel deposits were formed by reworking of material along the shores of Lake Agassiz. Wave action resulted in erosion of headlands and winnowing out of clay and fine sands, while coarse sand and gravel were spread along the shore to form beaches. These beach ridges served as natural routes of travel for the early Indians and explorers. Many cemeteries were also located on these ridges because of their good drainage. They currently provide roadbeds for railroads and highways.

# Proterozoic metamorphosed sediments, McCallum Lake English River and Berens River subprovinces. Metamorphism, intrusion and deformation of the Precambrian rocks of the Superior Province terminated approximately 2.5 billion years ago.

The Churchill Province contains eight major geologic

domains. The Flin Flon, Lynn Lake and Great

Island domains are characterized by metavolcanic

and minor metasedimentary rocks with abundant

granitic intrusions, whereas the Seal River,

complexes of metasedimentary and granitic rocks.

The geologic characteristics and arrangements of

these domains side by side suggest that they

represent the roots of an ancient wide mountain

North America. Within the Churchill Province,

the last metamorphic, deformational and intrusive

The greenstone belts of both the Superior and

producers of copper, zinc and gold. The

Churchill-Superior boundary zone marks the

location of some of the world's largest nickel

activity terminated about 1.6 billion years ago.

sedimentation in Manitoba. These were the Hudson Bay Basin, centred in Hudson Bay, and the Williston Basin, centred in northwestern North Dakota. Within both of these areas the rocks dip gently towards the centre of the basin. The Paleozoic strata formed during a time span of about 570 million to 235 million years ago and comprise limestones, dolomites, shales, sandstones and some salt beds. All of these rocks were formed in ancient seas. The Paleozoic rocks of the Williston Basin contribute to Manitoba's mineral industry through mineral products such as silica sand, dolomitic limestone for building stone, dolomite, and high-calcium limestone for cement; subsurface deposits of salt and potash are potential products. In addition, some of the rocks serve as reservoirs for petroleum. Numerous fossils, such as corals, trilobites and brachiopods are found in Paleozoic rocks.

In Manitoba Paleozoic sedimentary rocks cover

the Precambrian Shield in the Hudson Bay

Lowland and in southwestern Manitoba. These

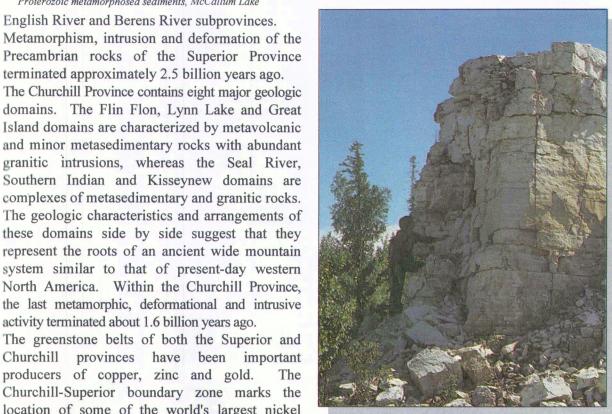
rocks accumulated in depressed areas in the

Two such sedimentary basins influenced

earth's crust known as sedimentary basins.

**PHANEROZOIC** 

**PALEOZOIC** 





**MESOZOIC** 

an unconformity. Mesozoic sediments were Another important process in Manitoba is deposited in ancient seas that covered Manitoba glacial rebound. Northern Manitoba is from about 225 million to 64 million years ago. gradually rising to its pre-existing level prior to These sediments include: red siltstones, glaciation, at a rate of about 60 cm per century. sandstones, shales and gypsum. Distant volcanic METEORITE IMPACT STRUCTURES activity, probably in western North America, spread volcanic ash across Manitoba; the ash was Manitoba has local, special structural features altered to beds of bentonite. Gypsum, bentonite, brick clay and shale are important mineral products from the rock formations of the High Rock Lake structure and the Denby Mesozoic Era. Large fossils of marine structure. The Lake St. Martin structure is a

found in Mesozoic strata. CENOZOIC

time, about 2 million years ago, the province was covered by repeated advances of the continental ice sheet, resulting in deposits which covered to various degrees all of the earlier rocks. The panels on glaciation highlight the nature of these deposits. Glacial material includes deposits laid down directly from the glacier, such as till, which is mixture of rock, sand and mineral particles that the glacier eroded from the various types of bedrock as it

During the Pleistocene Epoch in late Cenozoic

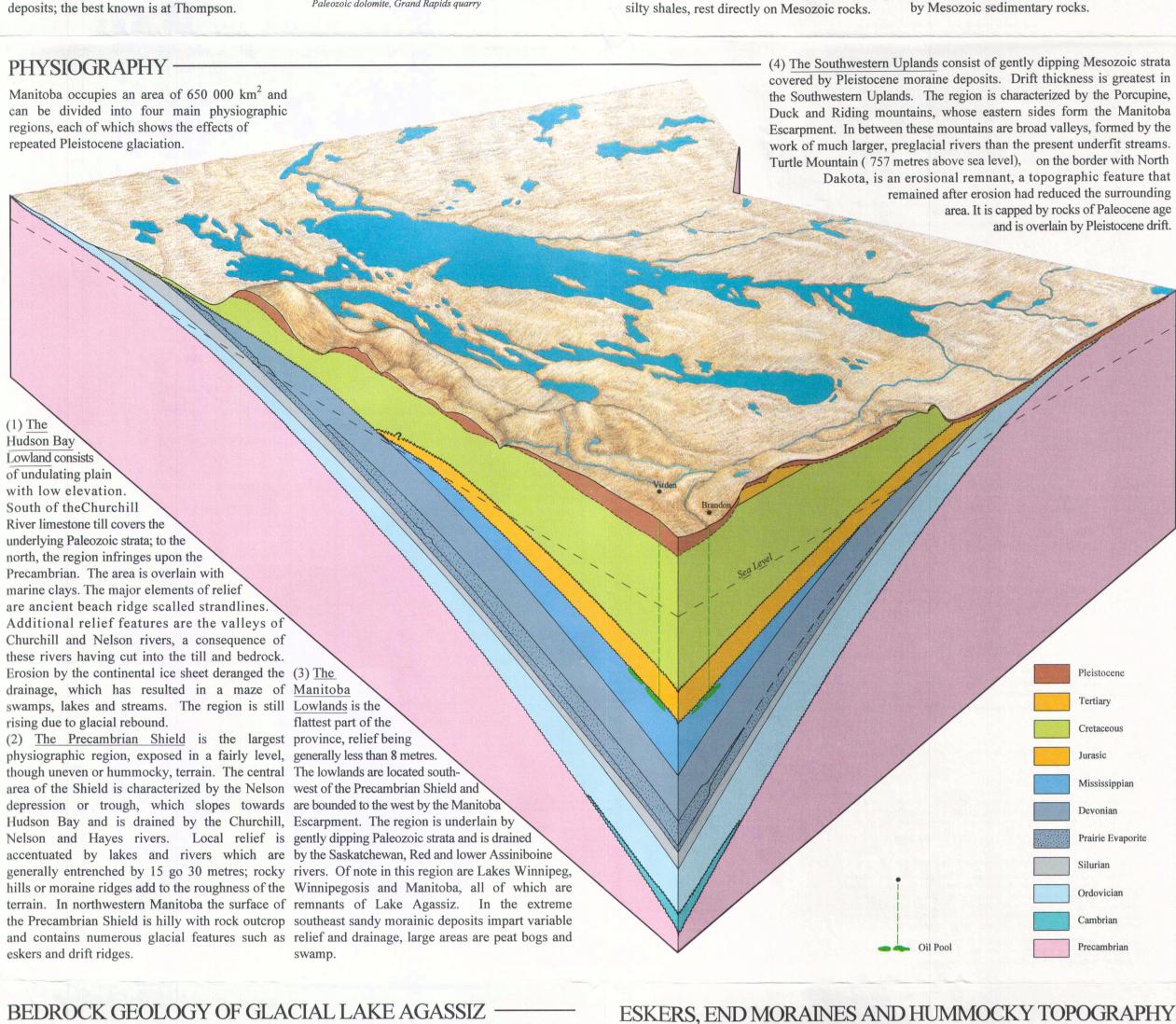
**PLEISTOCENE** 

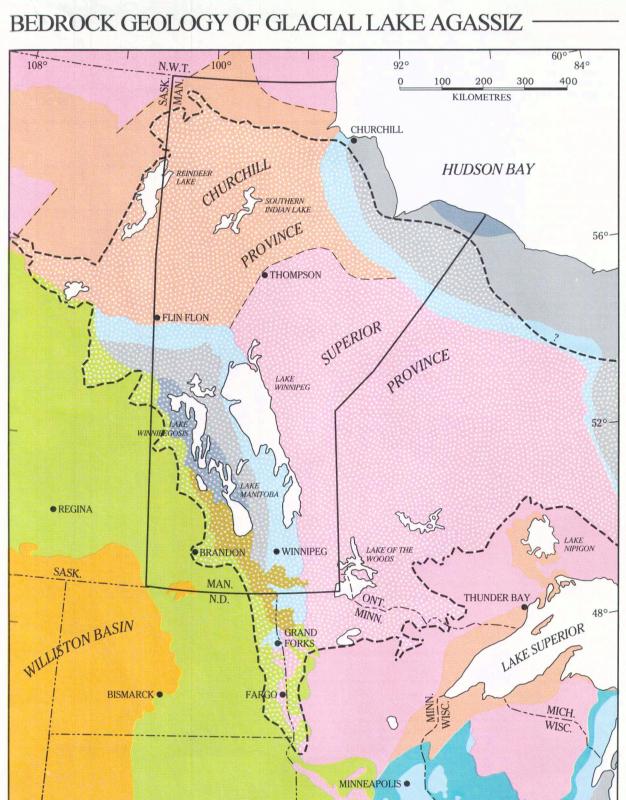
passed over the land. Glacial material also includes outwash deposits composed of sands and silts and lake deposits such as clays. These glacial deposits are economically important for Manitoba: sand and gravel is used in the construction industry and clay is used in the production of brick, tile and Portland cement. At the conclusion of the Paleozoic Era, the The main process of Recent time that is marine sedimentary rocks were raised above sea apparent to the traveller in Manitoba is level and eroded. This erosional surface was erosion, primarily through the action of rivers characterized by the development of sinkholes and streams and along shorelines. Wind and caves in limestone, and by the development erosion also occurs where the vegetation cover of hills and valleys. Later, downward movement is less established. The results of wind action of the earth's crust led to the accumulation of can be seen in the sand dunes at Grand Beach Mesozoic sediments on the erosional surface. The and along the western edge of the Lake contact between the eroded Paleozoic rocks and Agassiz plain in the Old Assiniboine Delta, the base of the Mesozoic rocks is an example of where sand dunes are constantly shifting.

such as the West Hawk Lake crater, Poplar Bay crater, the Lake St. Martin crater, the

vertebrates such as mosasaurs and plesiosaurs are cryptoexplosion crater, a descriptive term used to designate a roughly circular structure formed by the sudden release of energy, Only a small portion of Manitoba contains rocks to tectonic activity. The Lake St. Martin of early Cenozoic time, which began about 64 structure is probably a meteorite impact origin million years ago. Paleocene strata of the Turtle and is approximately Permian in age. The Mountain Formation are limited to a relatively High Rock and Denby structures may also be small isolated area capping the topographic high the result of meteorite impact. Another crater of Turtle Mountain, in southern Manitoba. structure is known in the Hartney area, 55 km

resulting in rock deformation with no relation These strata, consisting primarily of fine sandy, southwest of Brandon; however, it is covered





——— Maximum extent of Lake Agassiz

The chart below shows selected groups of animals important developments of some common plants.

the world, and the top of the bar the time of its • Early Triassic - abundant cycads and conifers

The blue bar indicates the Periods in which each • Middle Silurian - first terrestrial plants

extinction. Those bars that extend to the top of the Late Cretaceous- first flowering plants

that have formed fossils in rocks in Manitoba. • Archean - earliest known bacteria and algae

- FOSSIL LIFE FORMS IN MANITOBA

group of animals, depicted in the circle, lived.

The base of the bar indicates the oldest know

occurrence of fossilized remains of the group in

Holocene indicate that this group of animals lives

today. The red line within the blue bar indicates

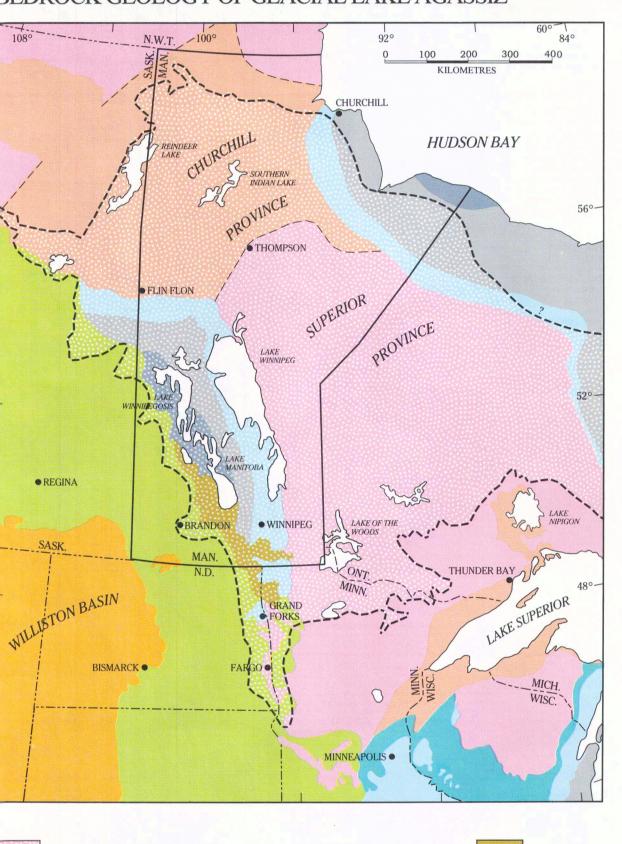
the Periods in which each group of animals

Plants, as well as animals, form fossils and the

fossil record tells us when different varieties of

plants evolved. The partial list below indicates

formed fossils in Manitoba.



Pennsylvanian - coal forming forests

Oligocene - abundant grasses

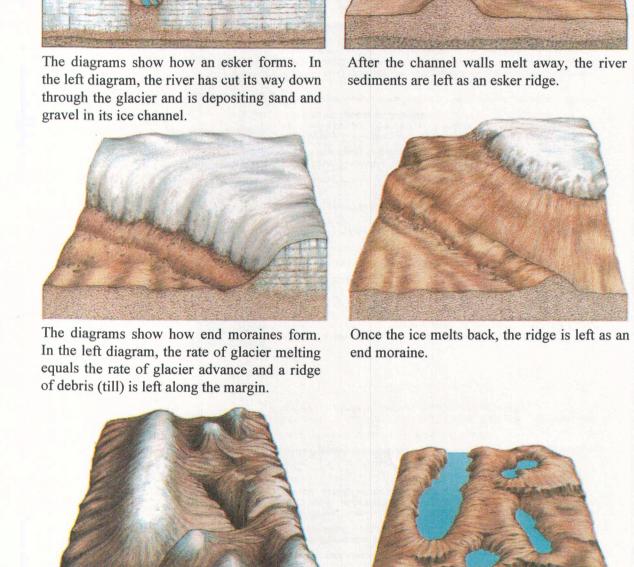
illustrations are colour coded.

• Late Permian - development of conifers

Note: Revolutions and Orogenies refer to

mountain building or other large scale geological

events. The geological ages in all of the



ridges and knobs into nearby low areas.

RECENT

NARY | PLEISTOCENE | GLACIAL DRIFT

E ERA PERIOD EPOCH FORMATION MEMBER

TURTLE MTN.

RIDING MTN

FAVEL

AMARANTH

BAKKEN

NISKU

DUPEROW

INTERLAKE GROUP

STONEWALL

MOUNTAIN

WINNIPEG

DEADWOOD

PENITENTIARY

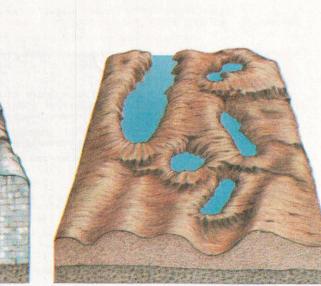
FORT GARRY CAT HEAD

DOG HEAD

SILURIAN

PRECAMBRIAN (EON

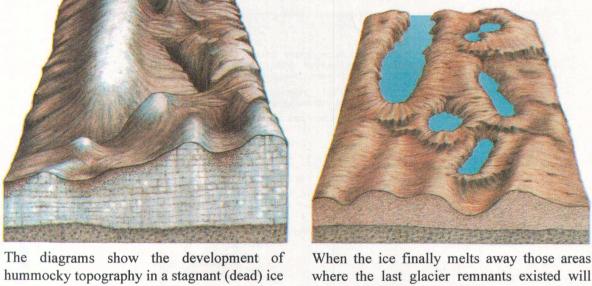
GEOLOGICAL FORMATIONS IN MANITOBA-



hummocky topography in a stagnant (dead) ice area. In the left diagram, debris on the become depressions on the land's surface and

Top soil, dune sands

140 Clay, sand, gravel, boulders, peat



## where the last glacier remnants existed will glacier's surface has slipped off the highest may be filled with lakes and ponds.

BASIC LITHOLOGY

120 Shale, clay and sand, Lignite Beds; located only in Turtle Mountain

30 Sand and sandstone, greenish grey; located only in Turtle Mountain

Shale, dark grey carbonaceous non-calcareous; bentonite bands

Shale, dark grey non-calcareous, concretions, local sand and silt

40 Grey shale with heavy calcareous specks, bands of limestone and bentonite

115 Shale, dark grey, non-calcareous, silty quartz sand or sandstone

Banded green shale and calcareous sandstone

Limestone, buff, and shales, grey

300 Permian-Triassic (?)

Sandstone and quartz sand, pyritic shale — grey non-calcareous

White anhydrite and/or gypsum and banded dolomite and shale

Carbonate breccia, trachyandesite (crypto-explosion structure)

Limestone, light buff, oolitic, fossiliferous fragmental, cherty, bands of shale and anhydrite, oil producing

Limestone and argillaceous limestone, light brown and reddish mottled Zones of shaly, colitic, crinoidal and cherty limestone Oil producing

20 Two black shale zones separated by siltstone. Oil show

170 Limestone and dolomite, argillaceous and anhydritic in places

120 Cyclical shale, limestone and dolomite, anhydrite

120 Salt, potash and anhydrite, dolomite interbedded

Dolomite, light yellowish brown, reefy

Limestone, fossiliferous high-calcium

12 Dolomite and shale, brick red

15 Dolomite, greyish-yellow, bedded

Dolomite, yellowish-grey, shaly Dolomite, dusky yellow, fossiliferous

20 Shale, red-green; fossiliferous, limestone band

Shale, green, waxy; sandstone interbedde

Acid and basic crystalline and metamorphic rocks

Glauconitic sandstone and siltstone, and shale; green-grey to black

40 Limestone and dolomite, yellow-grey fossiliferous, porous, some anhydr

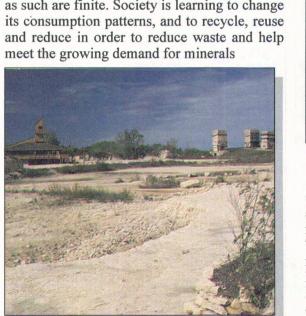
65 Limestone and dolomite, porous, anhydrite — local shale red and green

Dolomite, yellowish-orange to greyish-yellow, fossiliferous silty zones

35 Red siltstone and shale, dolomitic

## FUTURE DEMANDS ON NON RENEWABLE RESOURCES

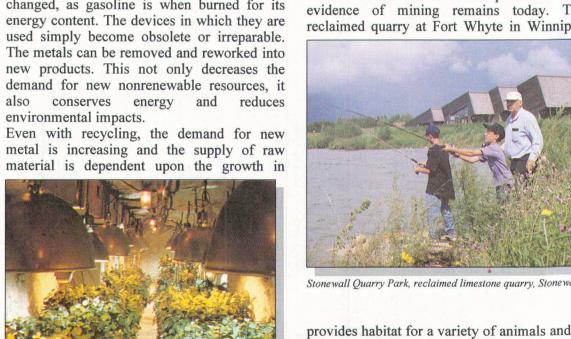
Demand for material things increases not only with population growth but also with development of Third World countries. One way to satisfy such demand is to increase production. However, materials from mining and petroleum are nonrenewable resources and as such are finite. Society is learning to change meet the growing demand for minerals



Fort Whyte Centre for Environmental Education, Winning

environmental impacts.

mining in the future Many metals such as copper, zinc and iron in steel are not consumed or irreversibly



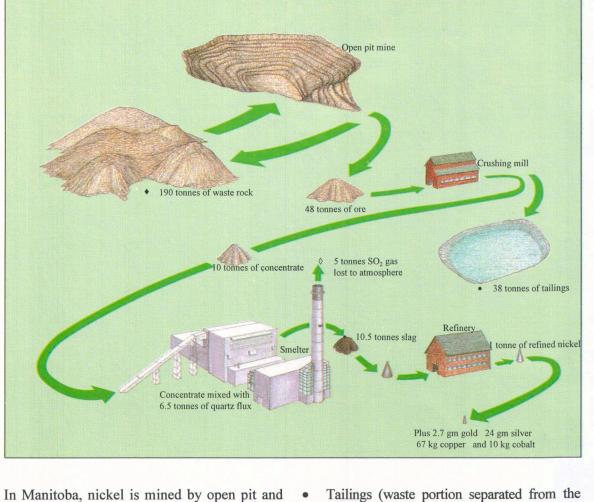
provides habitat for a variety of animals and is enjoyed by thousands of visitors to its park and nature centre. Lands that have been ehabilitated to a condition that is environmentally safe, ecologically sound, and valuable to society

#### THE WORKINGS OF A MODERN MINE

Because recycling cannot replace the need for typically been waste, as well as improved new production, the mining industry will extraction technology, can increase the yield continue to apply new technology to enhance and products from an operation. Environmentally production and reduce environmental impacts benign systems, such as the two stage pressure and waste. The diagram indicates the amount leach system of zinc extraction in Hudson Bay of material typically extracted in a nickel Mining and Smelting Co. Ltd.'s Flin Flon mining operation to produce one tonne of smelter, have resulted in cleaner production Ever-expanding uses for materials that have harmful waste into the ecosystem.

Underground garden in HBM&S Flin Flon mine

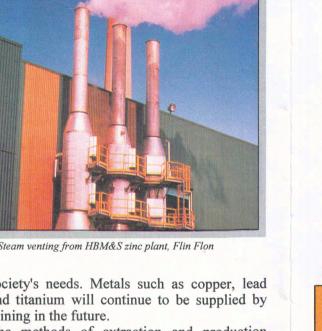
methods and thus reduced the emission of



underground methods. The ore is taken to a electrolytically.

crushing mill where metal bearing minerals are separated from waste rock. The concentrated ore is smelted with quartz flux. In this process iron and some sulphur impurities concentrate in slag and the remaining sulphur is vented up the stack. The nickel is then further refined Waste rock is used: to backfill underground mines, for road construction, as railway

ground ore) are empounded in tailings ponds with dams designed to be "maintenance free." Slag (solidified glassy waste separated from the metal in the furnace) is sold for a nominal fee for roofing materials (aggregate) and as a sand blasting medium. ♦ Half of the sulphur in the ore is fixed as pyrrhotite and in the slag. In the future, scrubbers will be added to the stacks to remove SO<sub>2</sub> from the hot gases being ballast and for dam construction.



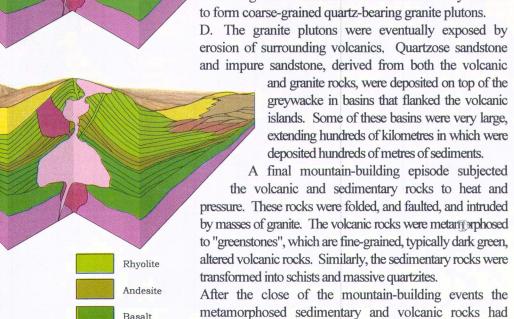
society's needs. Metals such as copper, lead and titanium will continue to be supplied by The methods of extraction and production must continue to become more sustainable. For example, new technology in the Flin Flon smelter allows production of zinc in a way that eliminates sulphur dioxide as an air pollutant from the process. The only emission into the Mine sites such as Centennial Mine near Flin Flon have been reclaimed to a point that little evidence of mining remains today. The reclaimed quarry at Fort Whyte in Winnipeg



disturbed by mineral development shall be

FORMATION OF A GREENSTONE Greenstone belts in the Precambrian Shield BELT are elongate areas of metamorphosed volcanic and sedimentary rocks lying within broad areas of granite and gneiss. The hypothetical model for the formation of one such belt, in the Snow Lake area, typifies a possible mode of origin for these economically important areas. A. During the early history of the earth, the crust was formed by upward separation of lighter rock material from the dense, mafic material in the layer below the crust, referred to as the mantle. This pre-existing crust contained many fractures or cracks. Mafic lavas poured out of the ISLAND ARC SYSTEM fractures onto the seafloor and solidified as black basalt. As MENTARY TROUGH this process continued, a thick platform of volcanic rocks built up gradually on the ocean floor. B. As volcanic activity continued, the lavas underwent a change in chemical composition from mafic to more felsic lavas, such as andesites

and rhyolites. The platform of accumulated volcanic rocks eventually built up to the surface of the ocean and individual volcanoes rose above sea level. Subsequent erosion of these new land masses produced sediments called greywacke, a dark, coarse-grained sandstone derived by weathering of volcanic rocks. Continued volcanic activity produced fragmental material called volcaniclastics which, together with the greywacke, were deposited in basins flanking the volcanoes. C. Gabbro, compositionally similar to basalt, intruded the volcanics. Large bulbous masses of felsic magma also intruded the volcanics and crystallized



been transformed into a solid, stable portion of the

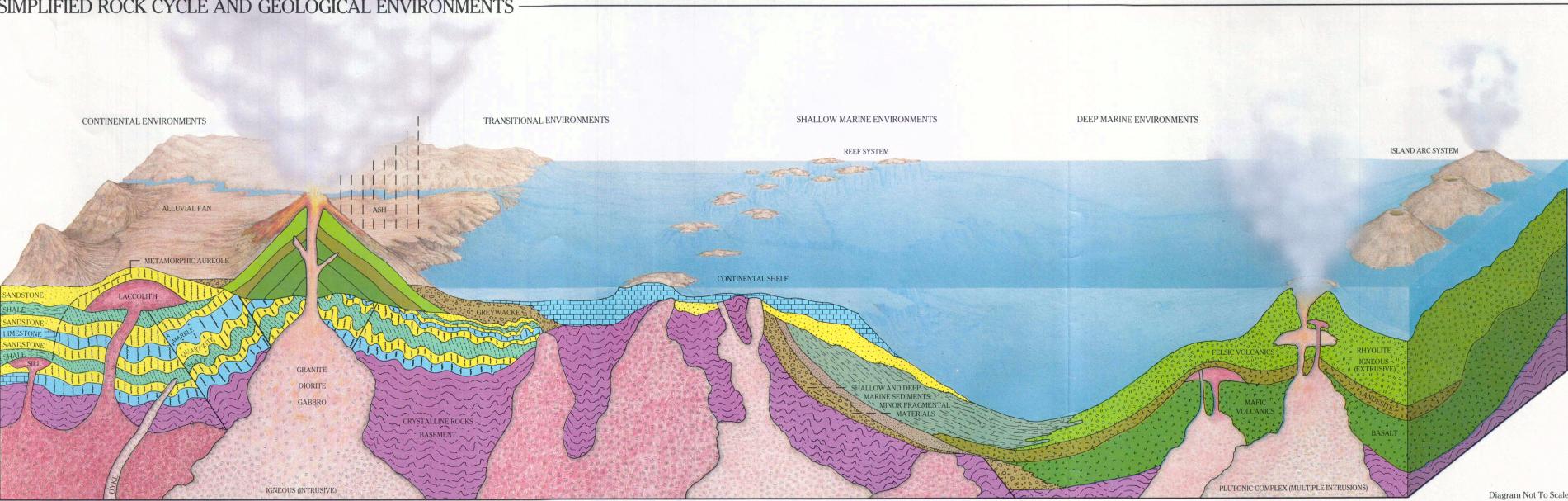
continental crust. Erosion continued uninterrupted for

almost one billion years, reducing the landscape to the

undulating surface of low relief that we observe today.

# Basin & Range Laramide Rockies 120 - 80 Nevadian 200 - 135 Rifting origin of Atlantic Ocean Allegheny 260 - 250

### SIMPLIFIED ROCK CYCLE AND GEOLOGICAL ENVIRONMENTS



IGNEOUS ROCKS (FORMED BY HEAT) METAMORPHIC ROCKS (FORMED BY ALTERATION GENERAL ROCK COLOUR INTERMEDIATE DARK (MAFIC) PALE (FELSIC) SODIC AND POTAS (INTRUSIVE) ROCKS AND QUARTZ MONZONITE PYROXENIT PERIDOTI SLATE PHYLLITE GNEISS SCHIST MIGMATITE QUARTZ LATITE (EXTRUSIVE) ROCKS LATITE DACITE RHYOLITE TRACHYTE SEDIMENTARY ROCKS (FORMED FROM SEDIMENTS) GREYWACKE SILTSTONE BENTONITE

COAL ANHYDRITE
LIGNITE GYPSUM

CHEMICAL ORIGIN

