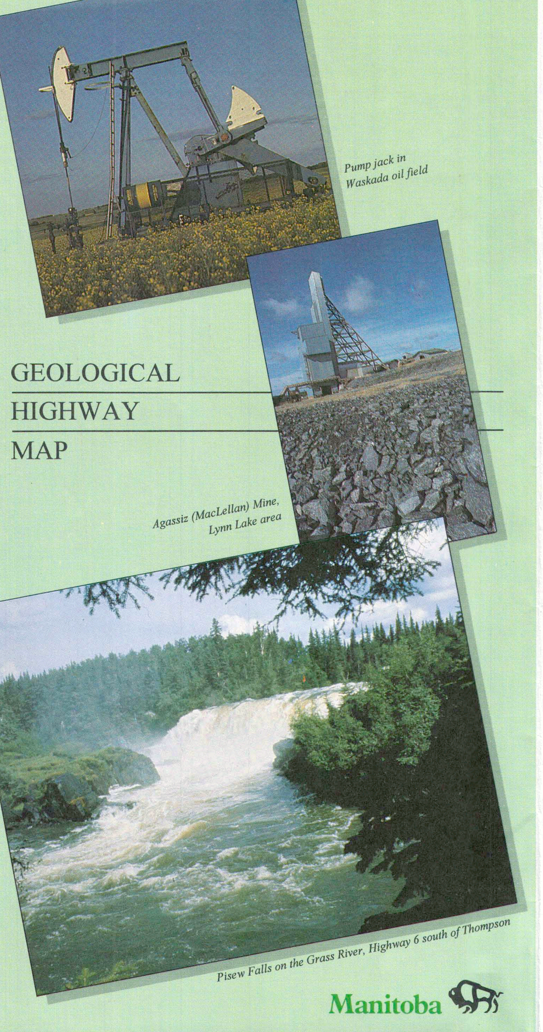
MANITOBA

GEOLOGICAL HIGHWAY MAP



Pisew Falls on the Grass River, Highway 6 south of Thompson

Canada

Manitoba

TRANS-CANADA HIGHWAY ROAD LOG

★1 Carberry Sand Hills. Sands in the area were deposited thousands of years ago as the upper delta of the Assiniboine River. Later north-westerly prevailing wind caused the sands to drift, forming the Carberry Sand Hills.

★2 For a distance of approximately 2 km east of Sidney the highway crosses the eastern edge of the upper Assiniboine delta, and for the next 3 km descends the shallowly sloping delta face.

★3 The highway crosses sand and gravel deposits of an abandoned beach just west of Squirrel Creek; the beach was formed by wave action on the shore of glacial Lake Agassiz.

★4 From Austin to Portage la Prairie the highway traverses the gently sloping sand deposits of the lower delta of the Assiniboine River. These deposits extend in an apron-like fashion toward the east.

★5 The lake at Island Park in Portage la Prairie was formed when a meander of the Assiniboine River was cut off from the main stream, forming an oxbow lake.

★6 From Portage la Prairie eastward the highway crosses clay and silt bottom lands of glacial Lake Agassiz.

★7 The highway leaves the thick clay and silt deposits of the fertile lake bed of glacial Lake Agassiz and enters rolling terrain consisting largely of abandoned beaches and bars formed at different levels in the glacial lake as its waters receded.

★8 A peat bog extends for approximately 16 km along the highway.

★9 First Precambrian granite outcrop after leaving the Lake Agassiz basin. Reference: Ecotour, Regina-Winnipeg, Winnipeg-Thunder Bay.

SELECTED BIBLIOGRAPHY

Bannatyne, B.B.
1983: Devonian potash deposits in Manitoba; Manitoba Mineral Resources Division, Open File Report OF83-3.

Berard, Real
1985: Canoe Routes (series of pictorial maps); Manitoba Natural Resources, Parks Branch.

Canadian Forestry Service
1980: Ecotour of the Trans-Canada Highway: Regina-Winnipeg; Environment Canada.
1981: Ecotour of the Trans-Canada Highway: Winnipeg-Thunder Bay; Environment Canada.

Chesterman, C.W.
1978: The Audubon Society field guide to North American rocks and minerals; Alfred A. Knopf, New York.

Galarnyk, A.
1986: Oil in Manitoba; Manitoba Petroleum Branch, Mineral Education Series.

Krason, Jan
1983: Geological environments favourable for petroleum and stratiform mineral deposits; Geoexplorers International, Inc., Denver.

Lahee, F.H.
1981: Field geology; Sixth Edition, McGraw-Hill Book Company, Inc., New York.

Lang, A.H.
1974: Guide to the geology of Riding Mountain National Park; Geological Survey of Canada, Miscellaneous Report 20.

Manitoba Energy and Mines
1985: The Manitoba Potash Project, May 1985; Winnipeg.

Manitoba Highways and Transportation
1986: Manitoba Official Highway Map, 1986/87; Winnipeg.

Manitoba Mineral Resources Division
1979: Geological map of Manitoba; scale 1:1 000 000, Map 79-2.
1980: Mineral map of Manitoba; scale 1:1 000 000, Map 80-1.
1981: Surficial geological map of Manitoba; scale 1:1 000 000, Map 81-1.

Manitoba Petroleum Division
1994: Well location map No. 7; Winnipeg.

Phillips, K.A.
1976: Common rocks in Manitoba; Manitoba Mineral Resources Division, Educational Series ES 76-1.
1978: Minerals of Manitoba: Volume I: Non-metallic and pegmatitic; Manitoba Mineral Resources Division, Educational Series ES 78-1.
1978: Minerals of Manitoba: Volume II: Metallic minerals; Manitoba Mineral Resources Division, Educational Series ES 78-2.

Pough, F.
1953: A field guide to rocks and minerals; Houghton Mifflin Co., Boston.

Prinz, M., ed,
1977: Rocks and minerals; Simon and Schuster, New York.

Sabina, A.P.
1964: Rock and mineral collecting in Canada: Volume I: Geological Survey of Canada, Miscellaneous Report 8.

Shimer, H.W. and Schrock, R.R.
1944: Index fossils of North America; M.I.T. Press, Cambridge.

Smith, D.G., ed.
1981: The Cambridge encyclopedia of earth sciences; Crown Publishers Inc./Cambridge University Press, New York.

Teller, J.T., ed.
1984: Natural Heritage of Manitoba: Legacy of the Ice Age; Manitoba Museum of Man and Nature.

Teller, J.T. and Bluemle, J.P.
1983: Bedrock geology of Lake Agassiz region; Figure 1 of Geological setting of the Lake Agassiz region; in: Glacial Lake Agassiz, J.T. Teller and L. Clayton, editors; The Geological Association of Canada, Special Paper 26. Also cited as: North Dakota Geological Survey, Miscellaneous Map 24.

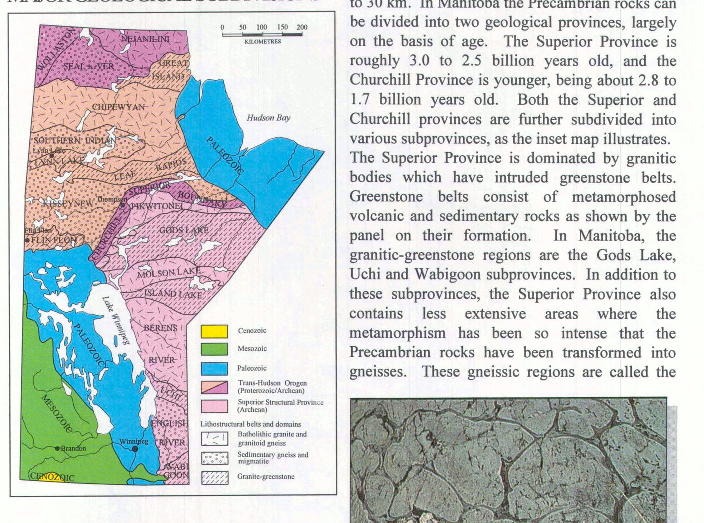
Thompson, I.
1981: The Audubon Society field guide to North American fossils; Alfred A. Knopf, New York.

Travel Manitoba
1994: Manitoba Vacation Guide '94; Manitoba Business Development and Tourism.

GEOLOGY OF MANITOBA

INTRODUCTION

MAJOR GEOLOGICAL SUBDIVISIONS



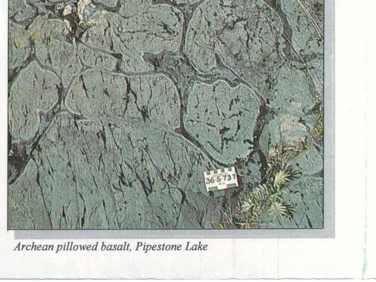
AIM OF THE MAP

The geological highway map of Manitoba is intended to be used as a general reference map to familiarize the reader with Manitoba's diverse and interesting geology. The extensive nature of the subject matter precludes any in-depth examination; the map is intended for information and to serve as a starting point to further research into Manitoba's geology. A selected bibliography with detailed and specific information has been provided for such research.

PRECAMBRIAN

The geologic characteristics and arrangements of these domains side by side suggest that they represent the roots of an ancient wide mountain system similar to that of present-day western North America. Within the Churchill Province, the last metamorphic, deformational and intrusive activity terminated about 1.6 billion years ago.

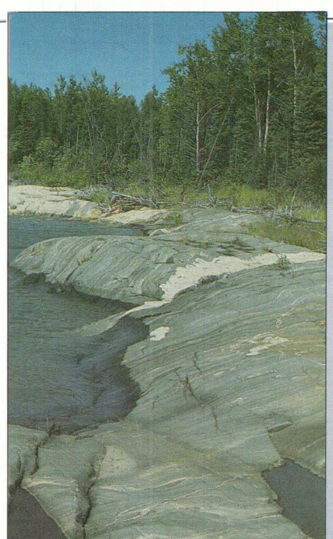
The greenstone belts of both the Superior and Churchill provinces have been important producers of copper, zinc and gold. The Churchill-Superior boundary zone marks the location of some of the world's largest nickel deposits; the best known is at Thompson.

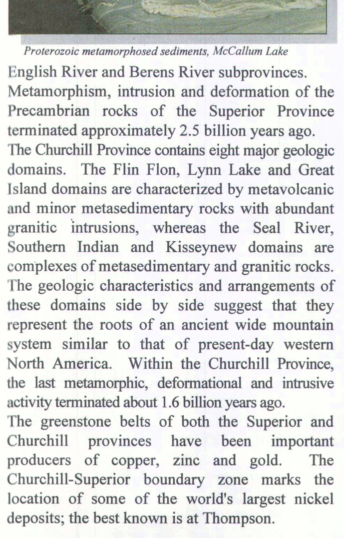


Archean pillowed basalt, Pipestone Lake

PHANEROZOIC

PALEOZOIC





Paleozoic dolomite, Grand Rapids quarry

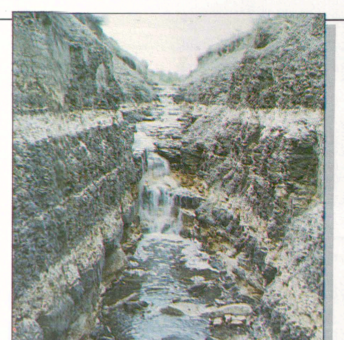
MESOZOIC

... Mesozoic Era. Large fossils of marine vertebrates such as mosasaurs and plesiosaurs are found in Mesozoic strata.

CENOZOIC

Only a small portion of Manitoba contains rocks of early Cenozoic time, which began about 64 million years ago. Paleocene strata of the Turtle Mountain Formation are limited to a relatively small isolated area capping the topographic high of Turtle Mountain, in southern Manitoba. These strata, consisting primarily of fine sandy, silty shales, rest directly on Mesozoic rocks.

PLEISTOCENE

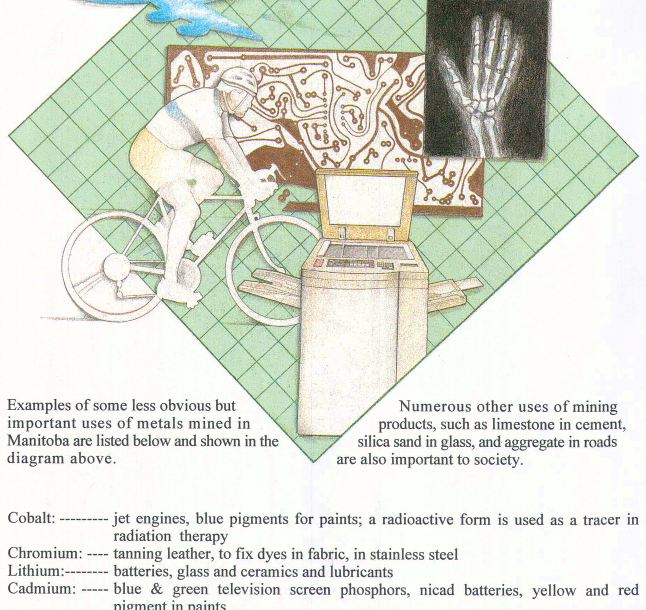


... structure. The Lake St. Martin structure is a cryptoexplosion crater, a descriptive term used to designate a roughly circular structure formed by the sudden release of energy, resulting in rock deformation with no relation to tectonic activity. The Lake St. Martin structure is probably a meteorite impact origin and is approximately Permian in age. The High Rock and Denby structures may also be the result of meteorite impact. Another crater structure is known in the Hartney area, 55 km southwest of Brandon; however, it is covered by Mesozoic sedimentary rocks.

MODERN SOCIETY AND THE MINERAL INDUSTRY

Minerals are indispensable in our daily lives and are often overlooked and underrated in public discussions of mining. They provide the raw materials for almost everything we own and use. They are one of the foundations of modern society.

The products of mining are not limited to obvious everyday materials such as steel in cars and nails, nickel in stainless and specialty steels, copper in plumbing and electrical wiring, and zinc in heating ducts and cans. More than 100 different minerals commodities are now used daily. For example titanium dioxide forms the basis for bright white pigments in paint and paper and is also the basis for modern sun screens to protect us from harmful ultraviolet radiation



Examples of some less obvious but important uses of metals mined in Manitoba are listed below and shown in the diagram above.

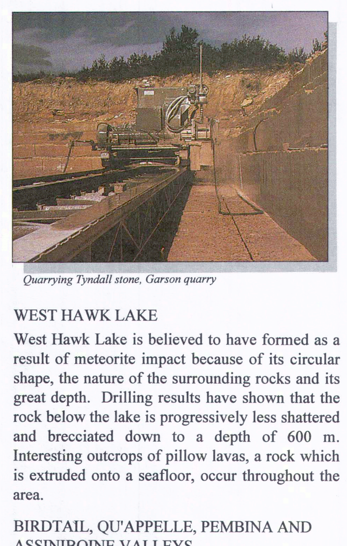
Numerous other uses of mining products, such as limestone in cement, silica sand in glass, and aggregate in roads are also important to society.

Cobalt: --------- jet engines, blue pigments for paints; a radioactive form is used as a tracer in radiation therapy
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 pigment in paints
Gold: ----------- printed circuits in electronics *i.e.* electronic games, computers, cameras; caps for teeth, medicine for arthritis
Zinc:------------ 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, photocopy machines
Spodumene: -- heat proof ceramic cookware (Corning Ware™)
Tantalum:------ surgical implants, glass for camera lenses, aircraft parts
Silver:---------- mirrors, jewellery, printed circuits, photography, batteries, and explosives

MANITOBA GEOLOGICAL HIGHLIGHTS

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, is the main source of aggregate material for the city. The deposit consists of a high narrow ridge which extends eastward from the town of Birds Hill for 6.5 kilometres. The ridge merges into a delta-like plateau of sand and gravel which extends over a broad area including Birds Hill Park.



Quarrying Tyndall stone, Garson quarry

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 area.

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'.

SETTEE MORAINE

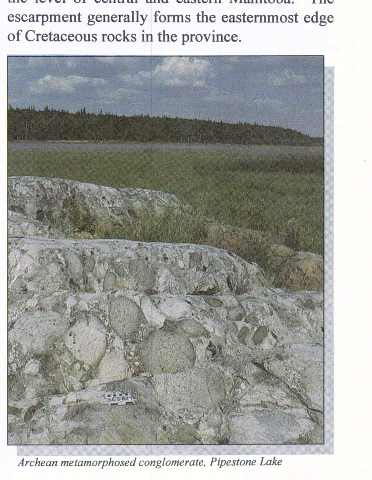
This moraine is located northwest of Thompson on Provincial Road 391 on the way to Nelson House. In the Leaf Rapids area the road travels upon an esker complex. These high, dry esker ridges from natural well drained roadbeds and trails.

SALT "MEADOW" WITH SALT SPRINGS

In the Dawson Bay area, along Pelican Rapids Road, and also along the roads on the southwest side of Lake Winnipegosis, large salt meadows with associated salt springs are abundant. They 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 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.

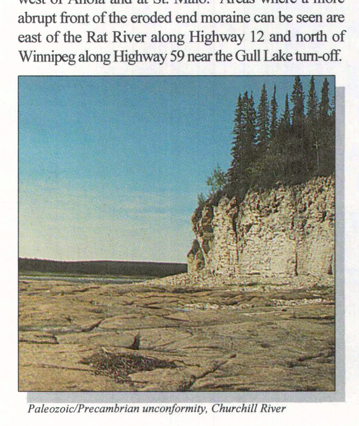


Archean metamorphosed conglomerate, Pipestone Lake

Abandoned beach ridges, Hudson Bay Lowland

BELAIR, MILNER AND SANDILANDS MORAINES

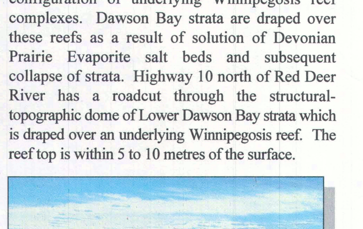
Belair interlobate moraine forms a series of ridges extending north from Beausejour to Lake Winnipeg, composed of till overlain by stratified clean sand and gravel derived from ice lobes on either side of the ridges. East of Winnipeg there is a complex series of sand end-moraine ridges which stretch 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 River valley onto the irregular topography of the old Sandilands end moraine. A similar gentle rise occurs west of Anola and at St. Malo. Areas where a more abrupt front of the eroded end moraine can be seen are east of the Rat River along Highway 12 and north of Winnipeg along Highway 59 near the Gull Lake turn-off.



Paleozoic/Precambrian unconformity, Churchill River

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 structural-topographic 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.



Esker, Nejanilini Lake area

RED RIVER PLAIN

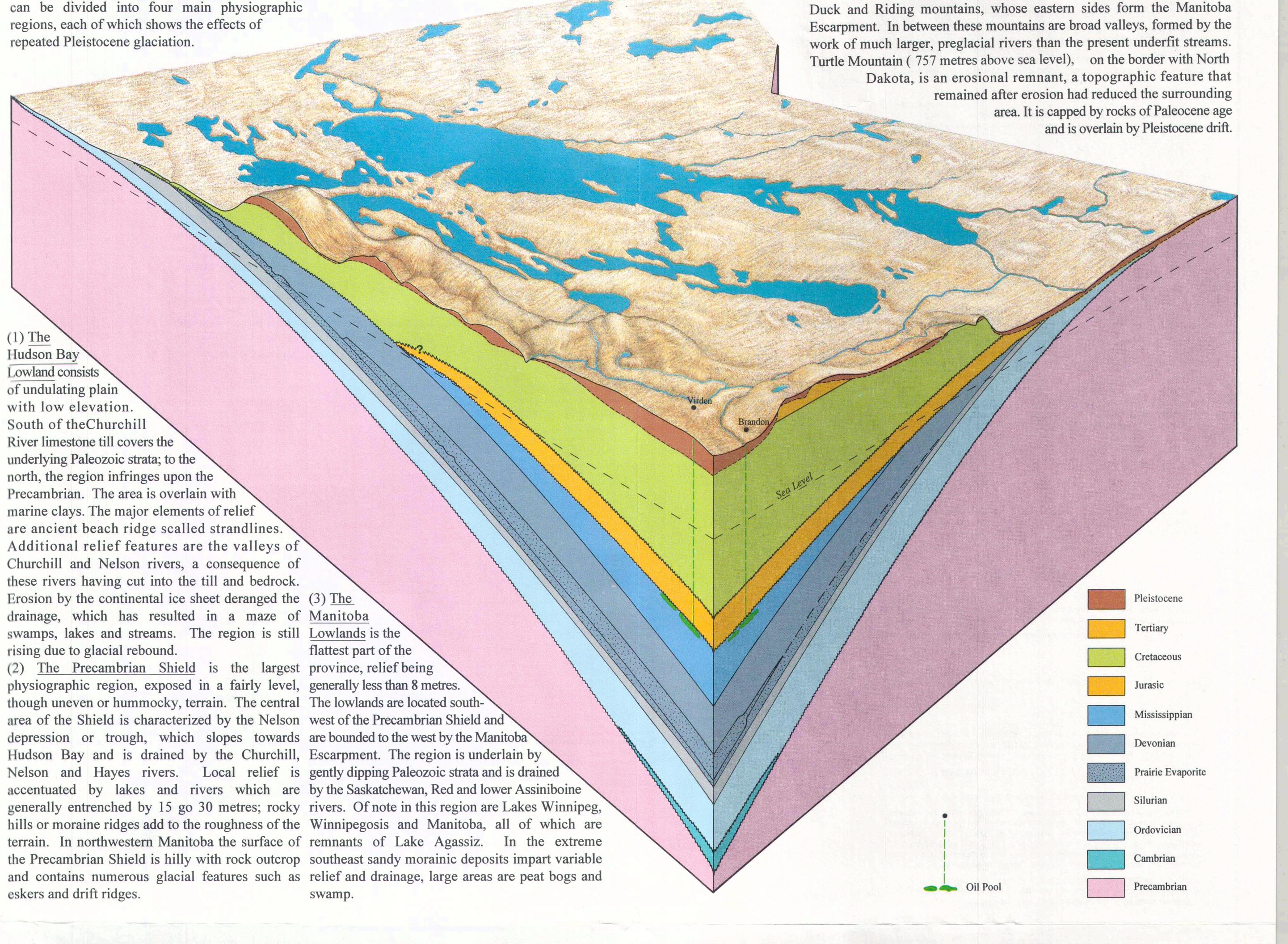
The Red River Plain, one the flattest regions in all of North America, formed as a result of glaciation and subsequent sedimentation in Lake Agassiz. Deposits of silt and clay settled onto the lake bottom. Such absence of surface relief in south-central Manitoba has led to extensive meandering of the Assiniboine and Red rivers and their tributaries.

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.

PHYSIOGRAPHY

Manitoba occupies an area of 650 000 km^2 and can be divided into four main physiographic regions, each of which shows the effects of repeated Pleistocene glaciation.



(1) The Hudson Bay Lowland consists of undulating plain with low elevation. South of theChurchill River limestone till covers the underlying Paleozoic strata; to the north, the region infringes upon the Precambrian. The area is overlain with marine clays. The major elements of relief are ancient beach ridge scalled strandlines. Additional relief features are the valleys of Churchill and Nelson rivers, a consequence of these rivers having cut into the till and bedrock. Erosion by the continental ice sheet deranged the drainage, which has resulted in a maze of swamps, lakes and streams. The region is still rising due to glacial rebound.

(2) The Precambrian Shield is the largest physiographic region, exposed in a fairly level, though uneven or hummocky, terrain. The central area of the Shield is characterized by the Nelson depression or trough, which slopes towards Hudson Bay and is drained by the Churchill, Nelson and Hayes rivers. Local relief is accentuated by lakes and rivers which are generally entrenched by 15 go 30 metres; rocky hills or moraine ridges add to the roughness of the terrain. In northwestern Manitoba the surface of the Precambrian Shield is hilly with rock outcrop and contains numerous glacial features such as eskers and drift ridges.

(3) The Manitoba Lowlands is the flattest part of the province, relief being generally less than 8 metres. The lowlands are located south-west of the Precambrian Shield and are bounded to the west by the Manitoba Escarpment. The region is underlain by gently dipping Paleozoic strata and is drained by the Saskatchewan, Red and lower Assiniboine rivers. Of note in this region are Lakes Winnipeg, Winnipegosis and Manitoba, all of which are remnants of Lake Agassiz. In the extreme southeast sandy morainic deposits impart variable relief and drainage, large areas are peat bogs and swamp.

(4) The Southwestern Uplands consist of gently dipping Mesozoic strata covered by Pleistocene moraine deposits. Drift thickness is greatest in the Southwestern Uplands. The region is characterized by the Porcupine, Duck and Riding mountains, whose eastern sides form the Manitoba Escarpment. In between these mountains are broad valleys, formed by the work of much larger, preglacial rivers than the present underfit streams. Turtle Mountain (757 metres above sea level), on the border with North Dakota, is an erosional remnant, a topographic feature that remained after erosion had reduced the surrounding area. It is capped by rocks of Paleocene age and is overlain by Pleistocene drift.

SUSTAINABLE DEVELOPMENT AND THE RESOURCE INDUSTRY

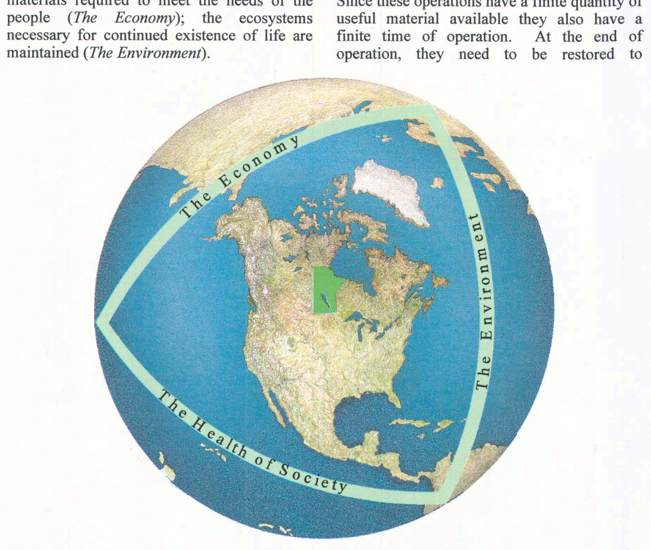
Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

A balance is required in which several criteria are met: the existing population and future generations can maintain a healthy quality of life (*The Health of Society*); an industrial, agricultural, and social system can produce the materials required to meet the needs of the ...

... medicine from these resources is currently irreplaceable.

In the production of minerals, decisions that minimize the impacts of developmental and operational disturbance are necessary. To reduce possible negative effects of projects, continuing advances in science and technology are applied in planning and monitoring all stages.

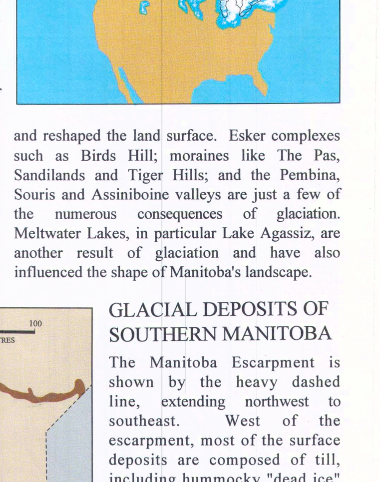
Since these operations have a finite quantity of ...



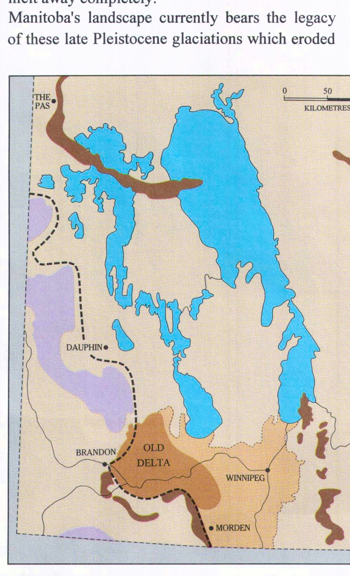
LATE PLEISTOCENE GLACIATION

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 figure at the right.

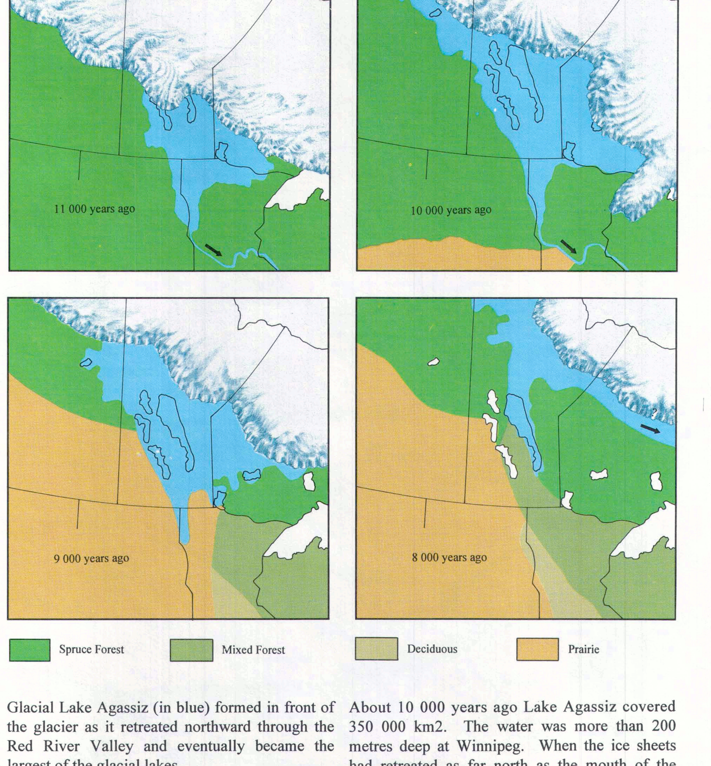
The most recent glaciation, called the Wisconsinan, started approximately 75 000 years ...



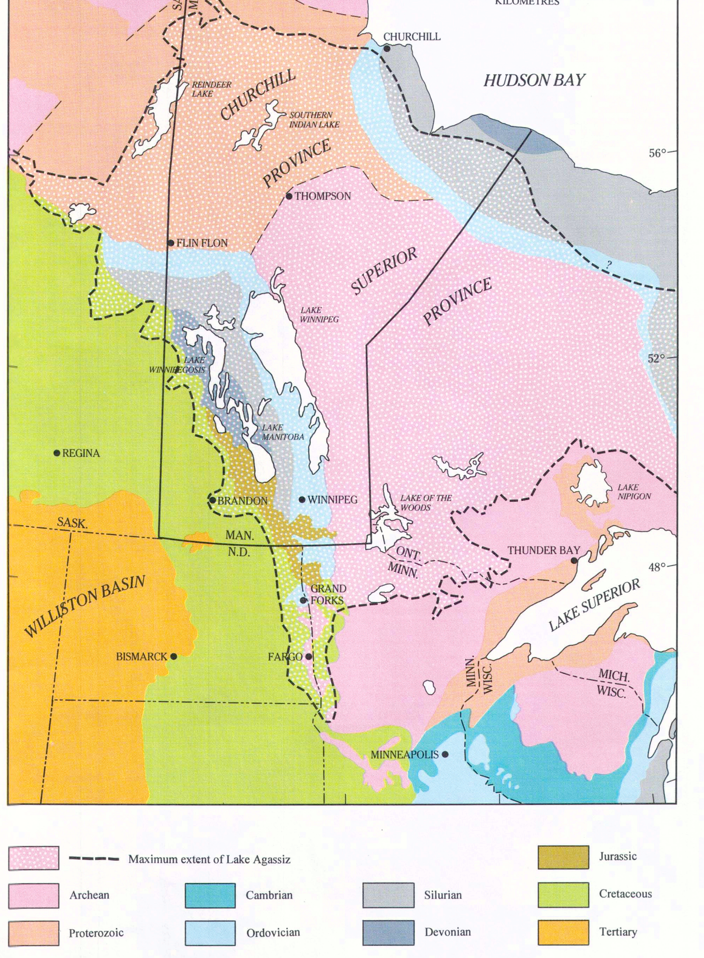
GLACIAL DEPOSITS OF SOUTHERN MANITOBA



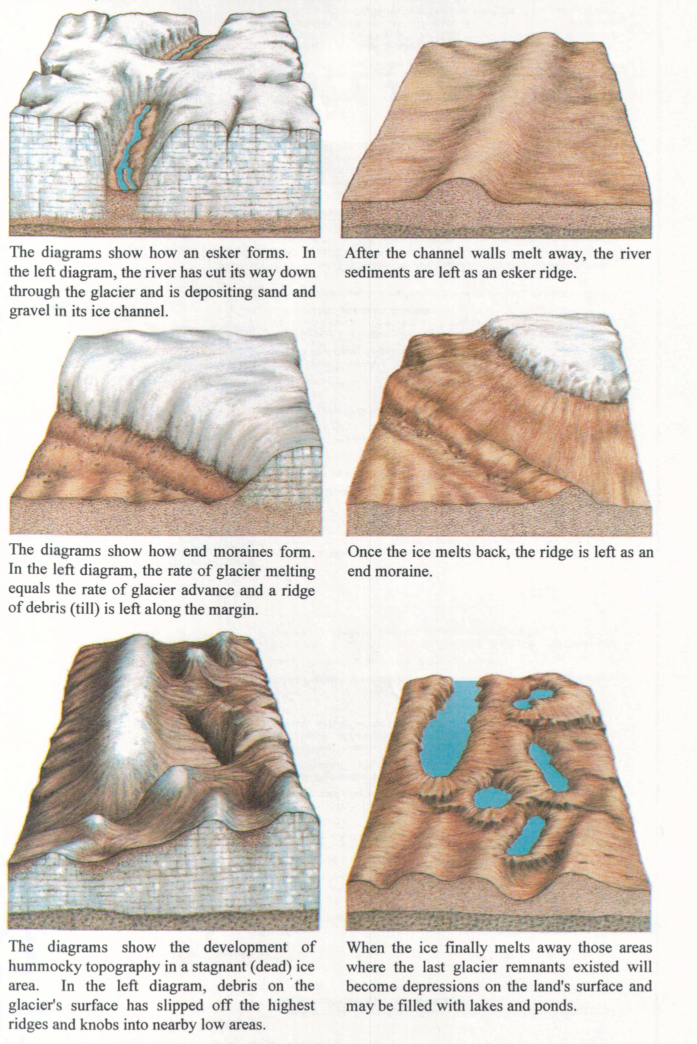
EXTENT OF LAKE AGASSIZ DURING DEGLACIATION



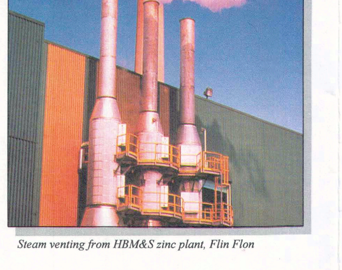
BEDROCK GEOLOGY OF GLACIAL LAKE AGASSIZ



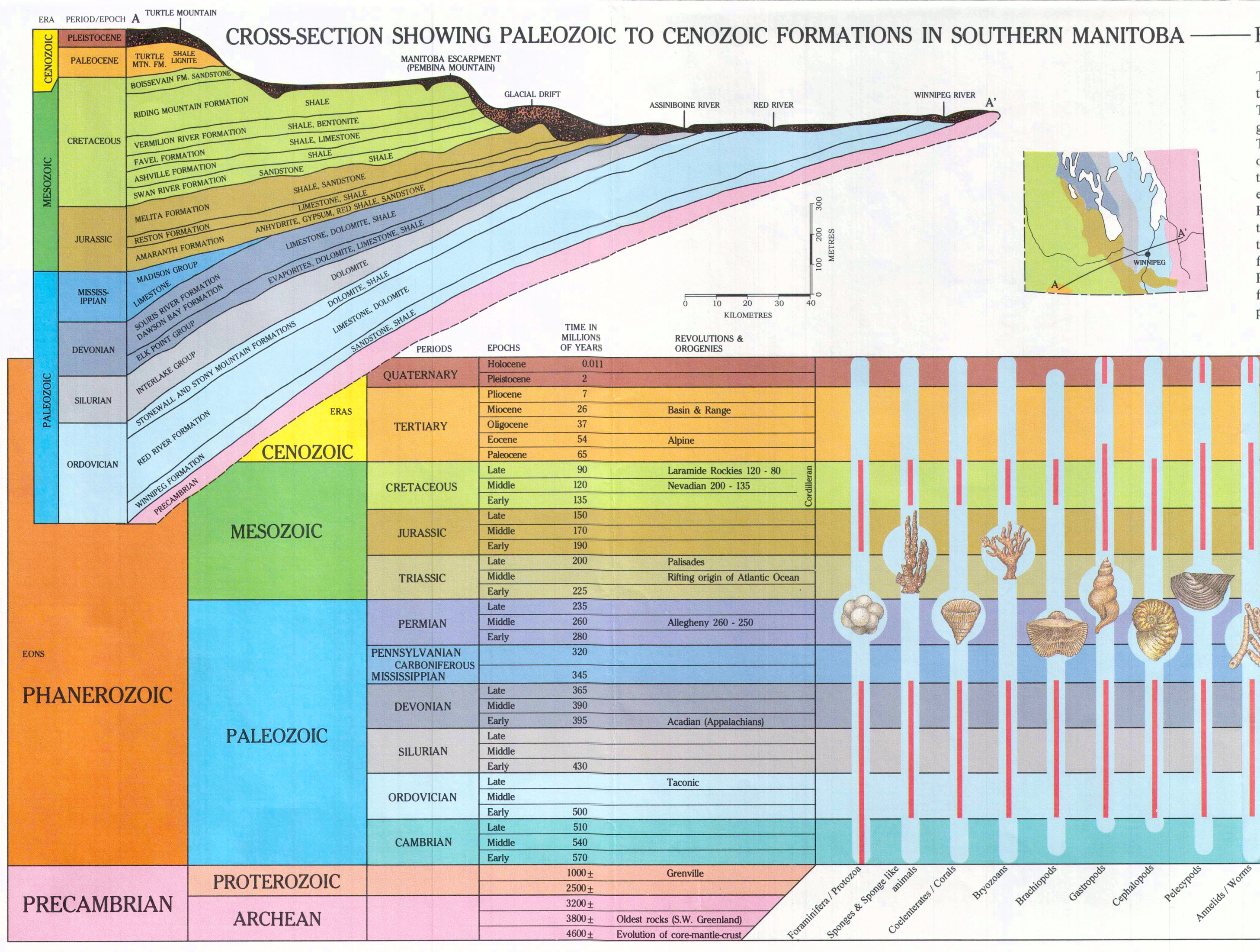
ESKERS, END MORAINES AND HUMMOCKY TOPOGRAPHY



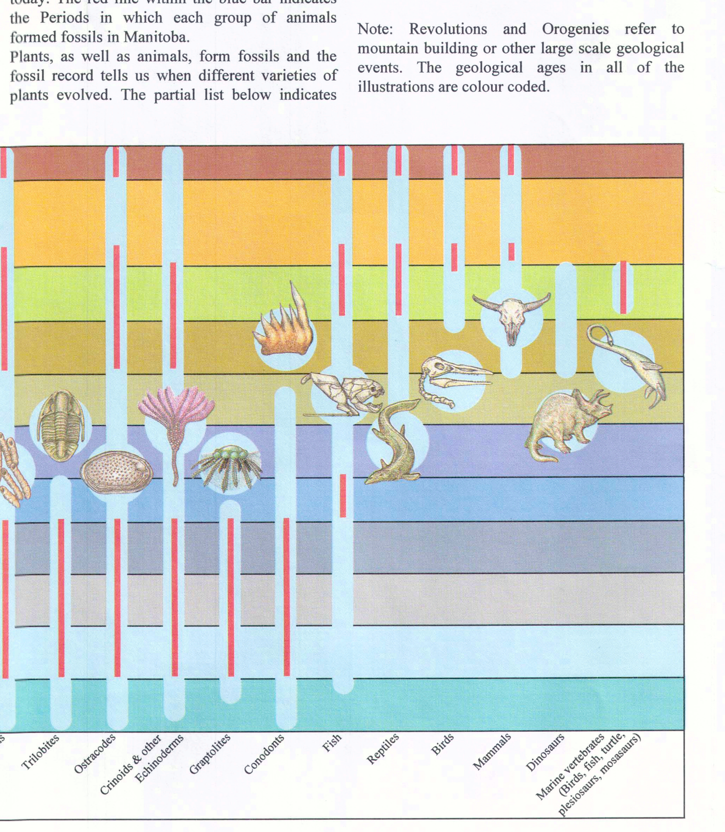
FUTURE DEMANDS ON NON RENEWABLE RESOURCES



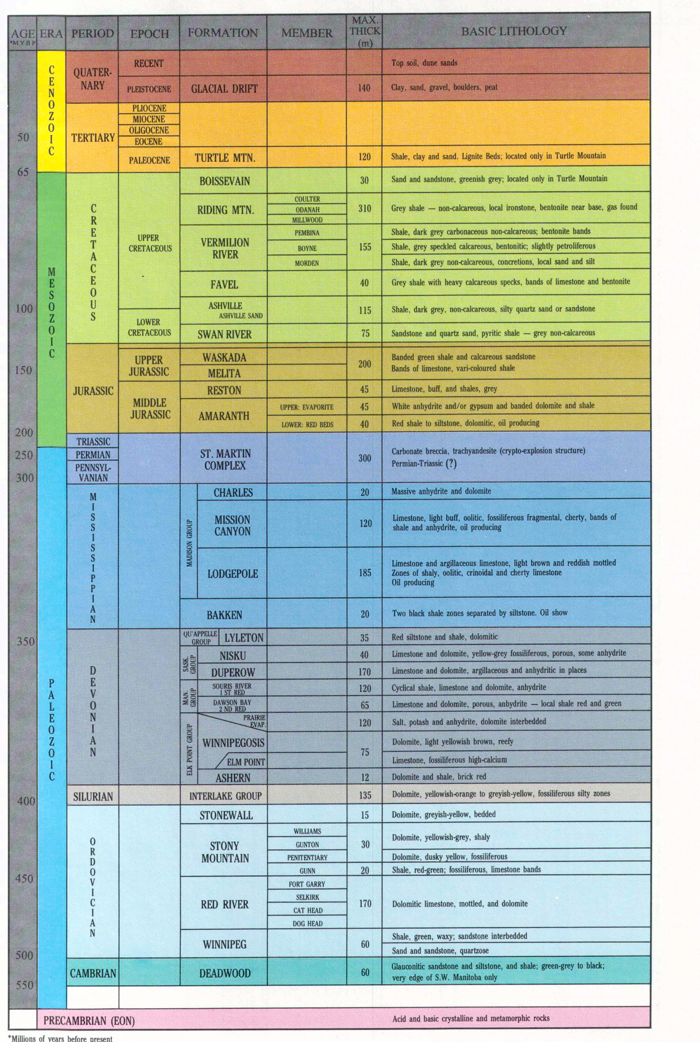
CROSS-SECTION SHOWING PALEOZOIC TO CENOZOIC FORMATIONS IN SOUTHERN MANITOBA



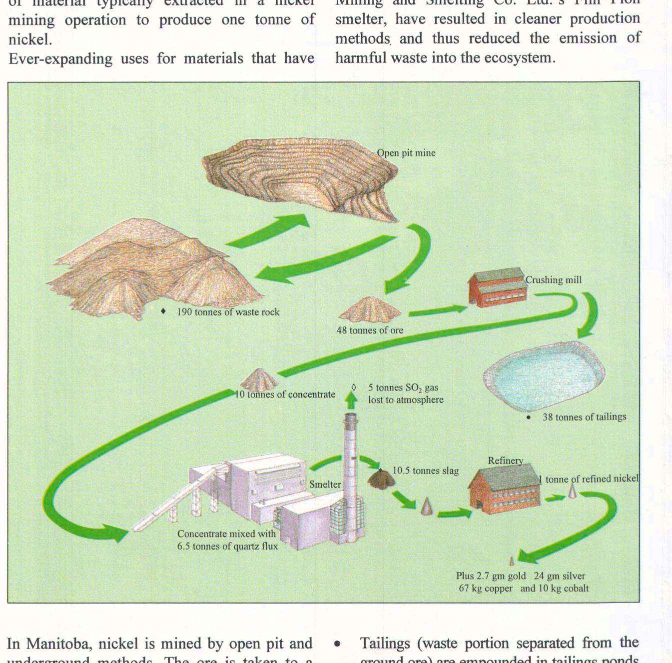
FOSSIL LIFE FORMS IN MANITOBA



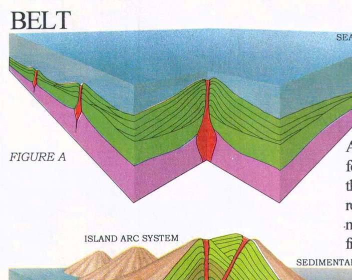
GEOLOGICAL FORMATIONS IN MANITOBA

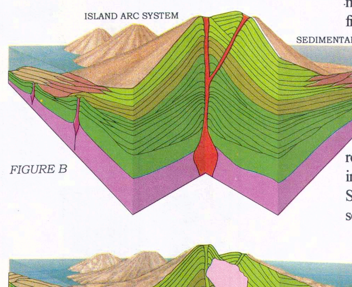


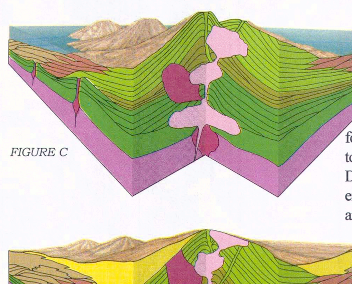
THE WORKINGS OF A MODERN MINE

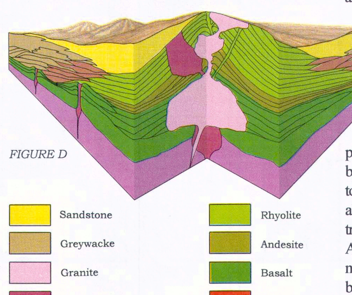


FORMATION OF A GREENSTONE BELT

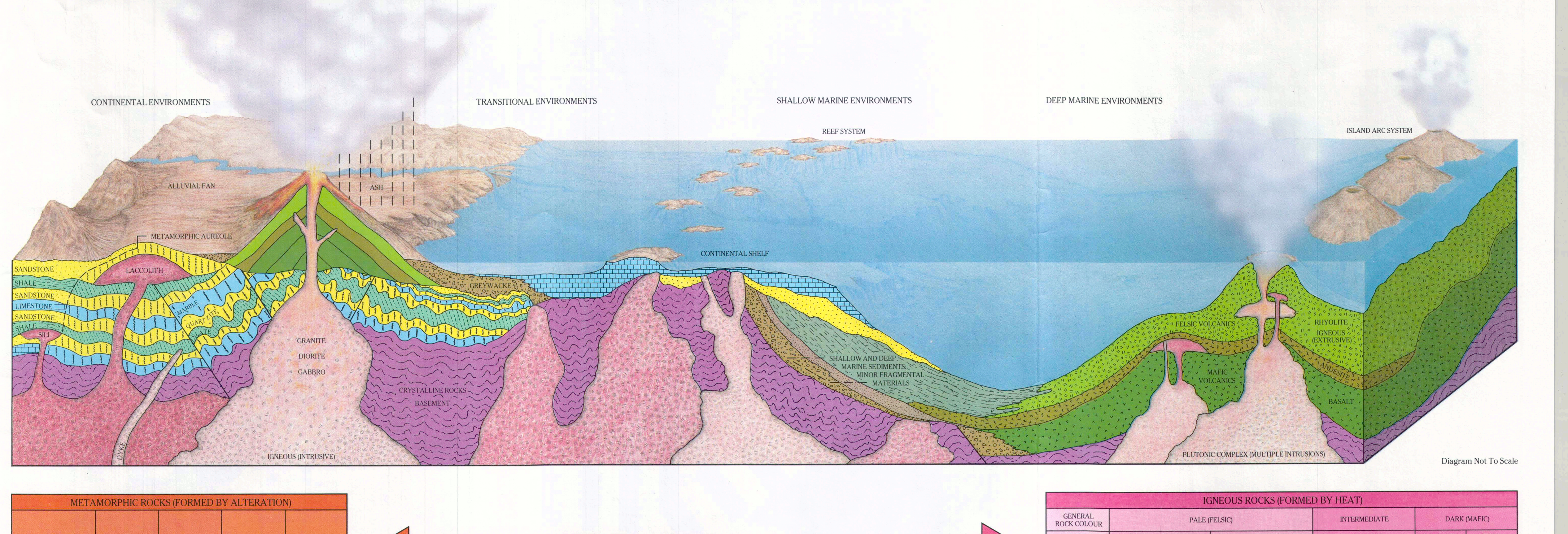


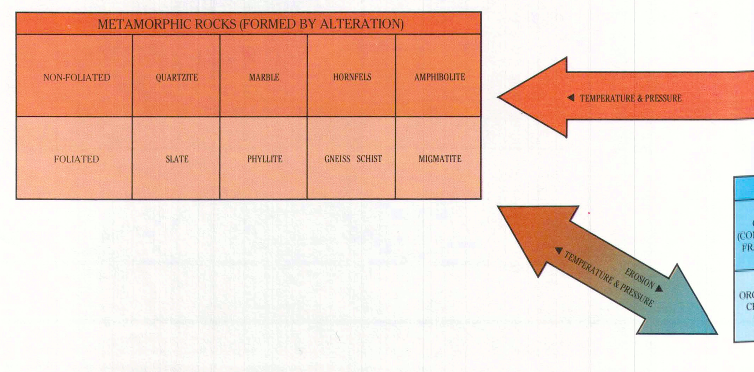


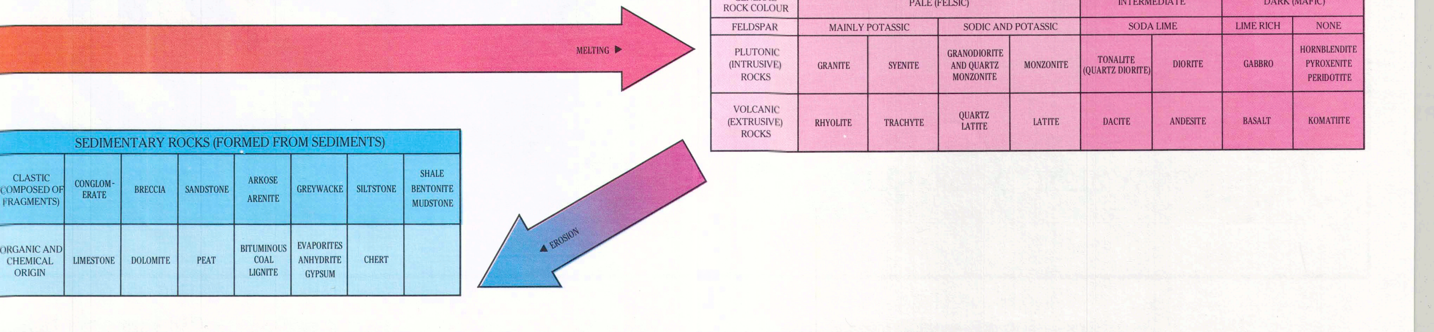




SIMPLIFIED ROCK CYCLE AND GEOLOGICAL ENVIRONMENTS







GEOLOGICAL HIGHWAY MAP OF MANITOBA 1994

Map Committee Chairman:
M. Timothy Corkery

Scientific Committee:
Brisbin, W.C.
Donachuk, D.A.
Lammers, G.E.
Lohrenz, J.R.

Technical Subcommittee
Baldwin, D.A.
Sales, R.J.
Stevenson, E.

Compiled by:
Lauhn-Jensen, D.M.

Cartography by:
Franceschet, T.

Design and Illustration by:
Hopper, D.J.

Assistance and financial support by the following organizations is gratefully acknowledged:

Natural Resources Canada
Sustainable Development Coordination Unit
Geological Association of Canada, Winnipeg Section
Manitoba Education and Training
Manitoba Energy and Mines
Manitoba Museum of Man and Nature
University of Manitoba

This second edition of the Geological Highway Map of Manitoba was funded in part through the Canada / Manitoba Partnership Agreement on Mineral Development (1990-1995), and coordinated by the Geological Association of Canada, Winnipeg Section

Geological Survey of Canada

Manitoba Minerals Division

KILOMETRES 10 5 0 10 20 30 40 50 60 70 80 90 100 KILOMETRES

Scale 1:1 000 000

LEGEND

PHANEROZOIC

Cenozoic

Tertiary

T — Turtle Mountain Formation (TM), Paleocene: bentonitic carbonaceous sand, silt and clay; thin lignite beds, silty shale

Mesozoic

Cretaceous

K — Boissevain Formation(B): impure sandstone; shale, in part kaolinitic

Riding Mountain Formation(RM): soft greenish bentonitic shale (m: Millwood Member)*; hard siliceous shale (o: Odanah Member); soft bentonitic siltstone and shale (c: Coulter Member)

Vermilion River Formation (VR): carbonaceous shale (Morden Member); speckled calcareous and carbonaceous shale (Boyne Member); thin bentonite beds, carbonaceous shale, and bentonitic shale (Pembina Member)

Favel Formation (F): calcareous speckled shale; minor limestone, bentonite, and lowgrade oil shale

Ashville Formation (A): carbonaceous shale; minor sand (including "Ashville sand"), silt, and bentonite

Swan River Formation(SR): quartzose sandstone, kaolinitic shale; minor lignite; glauconitic sandstone (including channel and karst fill in Mesozoic and Paleozoic outcrop belts)

Jurassic

J — Melita Formation: sandstone, variegated and red shale; minor limestone

Reston Formation: limestone, dolomite, shale

Amaranth Formation: red argillaceous dolomitic siltstone and sandstone (petroleum-bearing), gypsum and anhydrite

Paleozoic

Permian (?)

P — St. Martin Complex: trachyandesite and carbonate, granitic, and polymict breccias, in crypto-explosion (meteorite impact?) crater structure

Mississippian (subsurface only)**

M — Charles Formation: anhydrite, dolomitic anhydrite, dolomite

Mission Canyon Formation: limestone (petroleum-bearing), anhydrite

Lodgepole Formation: limestone (petroleum-bearing), argillaceous limestone, shale

Bakken Formation: black shale, pyritic siltstone, locally oil-stained

Devonian

D — Souris River Formation (SR): basal red shale, argillaceous and high-calcium limestone, dolomite

Dawson Bay Formation (DB): basal red shale, bituminous dolomite, high-calcium micritic limestone, calcareous shale, coral-stromatoporoid high-calcium limestone, dolomite

Prairie Formation (subsurface only): salt, potash, anhydrite; minor dolomite

Winnipegosis Formation (W): lower member—dolomite, platform facies, grades laterally to Elm Point Formation (EP) high-calcium limestone; upper member—thin interreef dolomitic and calcareous bituminous laminites, or thick reefal dolomite (W/r)

Ashern Formation (A): dolomitic shale, argillaceous dolomite

(HUDSON BAY BASIN AREA)
Upper Member of Kenogami River (KRu), Stooping River (STR), Kwataboahegan (K) and Moose River (MR) Formations: limestone, dolomitic limestone, argillaceous limestone and dolomite, bituminous limestone; minor chert and shale

Silurian

S — Interlake Group: Fisher Branch (FB), Inwood (I), Moose Lake (ML), Atikameg (A), East Arm (EA), and Cedar Lake (CL) Formations: micritic, fossiliferous, stromatolitic and biostromal dolomite; sandy/argillaceous marker beds

(HUDSON BAY BASIN AREA)
Severn River (SR), Ekwan River (ER), Attawapiskat (AT), and Lower and Middle Members of Kenogami River (KR l, m) Formations: limestone, dolomite, dolomitic limestone, siltstone, shale; some gypsum, minor anhydrite

Ordovician

O — Stonewall Formation (S): dolomite, medial sandy argillaceous marker may define Ordovician/Silurian boundary

Stony Mountain Formation (SM): calcareous shale, thin limestone beds, argillaceous dolomite (gp: Gunn and Penitentiary Members); dolomite and sandy argillaceous dolomite (gw: Gunton and Williams Members)

Red River Formation (RR): mottled dolomitic limestone, grades northward to dolomite (dh: Dog Head Member); dolomite, in part cherty and calcareous (ch: Cat Head Member); mottled dolomitic limestone (Tyndall stone), cherty high-calcium limestone, grades northward to dolomite (s: Selkirk Member); aphanic and cherty dolomite, shaly marker bed, high-calcium limestone beds (fg: Fort Garry Member)

Winnipeg Formation (W): quartzose sandstone; shale, kaolinitic, silty, and sandy

(HUDSON BAY BASIN AREA)
Bad Cache Rapids Group(BCR), Churchill River Group (CR), and Red Head Rapids Formation (RHR): basal sandstone and shale; limestone, dolomitic limestone, dolomite; minor shale, chert, and anhydrite

Cambrian (subsurface only)**

C — Deadwood Formation: glauconitic and quartzose siltstone and sandstone, shale

*Subdivisions within a grouping are described in ascending sequence

**Only subsurface units that have known or suspected economic potential are listed. Other subsurface units are present, e.g. Jurassic Waskada Formation, and Devonian Duperow, Nisku (Birdbear) and Lyleton Formations

PRECAMBRIAN

Churchill Province / Superior Province

7 — Granite and granitoid gneiss: (7a) fluorite granite; (7b) hypersthene-bearing granite; (7c) porphyritic granite; (7d) tonalite-granodiorite; (7e) tonalitic gneiss and minor amphibolite; (7f) layered migmatitic gneiss

6 — Gabbro: (6a) anorthositic gabbro; (6b) diorite; (6c) enderbite

5 — Metasediment, gneiss and migmatite derived from arkose, arenite, quartzite and minor greywacke and conglomerate: (5a) metaconglomerate with minor arkosic gneiss; (5b) migmatite dominant; (5c) felsic gneiss and migmatite of uncertain origin

4 — Metasediment, gneiss and schist derived from greywacke, mudstone and siltstone with local minor grit and conglomerate: (4a) highly metamorphosed and partly migmatitic derivative

3 — Felsic metavolcanic rocks, rhyolite and dacite