Chapter 3

Natural Heritage

The natural heritage values of the Ottawa River have provided the basis for the development of cultural heritage values as well as recreational opportunities. This section outlines the natural features of the Ottawa River using the following themes: geology, hydrology, river morphology, climate, flora, fauna, aquatic and terrestrial ecosystems, conservation, and land and water use. These chapters describe the natural values of the river as well as the conservation of these values, and current uses of the land and water.

The Ottawa River displays many interesting physical features. Its drainage basin offers an excellent, accessible display of geological heritage. The Ottawa River is the only Canadian River that crosses four major geological subdivisions. The sheer size of the Ottawa River is impressive: its 1271 kilometres and its high discharge volume make it the largest tributary to the St. Lawrence. The Ottawa River is Canada's 12th-longest river, and ranks 8th in terms of discharge volume.

The Ottawa River is home to many different ecosystems, each playing an important role in sustaining Canada's biodiversity. Unique wetlands and floodplain habitats along the river support species that are considered to be rare or at risk. The Ottawa River region hosts the most biologically diverse ecosystems in Quebec (Nature Conservancy of Canada: "Ottawa River Valley"). More than 300 species of birds have been inventoried along the river, and about half of these are migratory species that use the Ottawa as one of the continent's most important migratory halts. In addition, 33 species of reptiles and amphibians, 53 species of mammals, and 85 species of fish can be observed along the river. Within the watershed, there are at least 50 animal and plant species at risk (nationally or provincially), including the River Redhorse, American Shad and American Ginseng. The Ottawa River is also home to the threatened Least Bittern and the Eastern Spiny Softshell Turtle, one of the most rare turtles in Canada.

3.1 Geoheritage of the Ottawa River Drainage Basin

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The Ottawa River crosses distinctive segments of the lithosphere (the rigid, rocky, outer part of our planet) that are representative of all but one of the major time units through which 4.5 billion years (BY) of Earth's history can be traced: Archean, Proterozoic, Paleozoic, and Cenozoic (Table 3.1). An earlier unrepresented time unit, the Hadean, is nowhere preserved on Earth because it represents the interval of time between the origin of our universe, about 13 billion years ago, and the time of preservation of the oldest solid rock known on Earth: the Acasta Gneiss in Nunavut Territory, Arctic Canada, for which a minimum age of nearly 4 BY has been determined by radiometric methods.

Another unrepresented time unit within the Ottawa River drainage basin is the Mesozoic Era, best known as the time when dinosaurs "ruled our planet." The lack of dinosaur fossils within the region now traversed by the Ottawa River does not mean that dinosaurs did not wander over this part of Canada. In fact, they likely did, and the evidence for their existence has simply been removed by erosion. This same process of erosion is slowly revealing evidence for their existence elsewhere, as in the Badlands of Alberta, one of the most significant dinosaur burial grounds in the world.

Table 3.1 Geological Time Divisions[1]

Time Subdivisions		Millions of Years Ago
Phanerozoic Eon	Cenozoic Era	65 to present
	Mesozoic Era	250 to 65
	Paleozoic Era	545 to 250
Precambrian	Proterozoic Eon	2,500 to 545
	Archean Eon	4,500 to 2,500
	Hadean Eon	> 4,500

To gain an appreciation of the enormity of geological time, it is instructive to scale it to a single year, a unit readily comprehended (Table 3.2). On this condensed time scale, the Ottawa River has followed its present path for little more than a minute, having developed as a principal drainage pathway during the recession of the last continental ice sheet, 12,000 to 8,000 years ago (or about two minutes ago on our condensed time scale.)

Table 3.2 Geological Time Scale for Our Planet, Proportionally Compressed to One Year

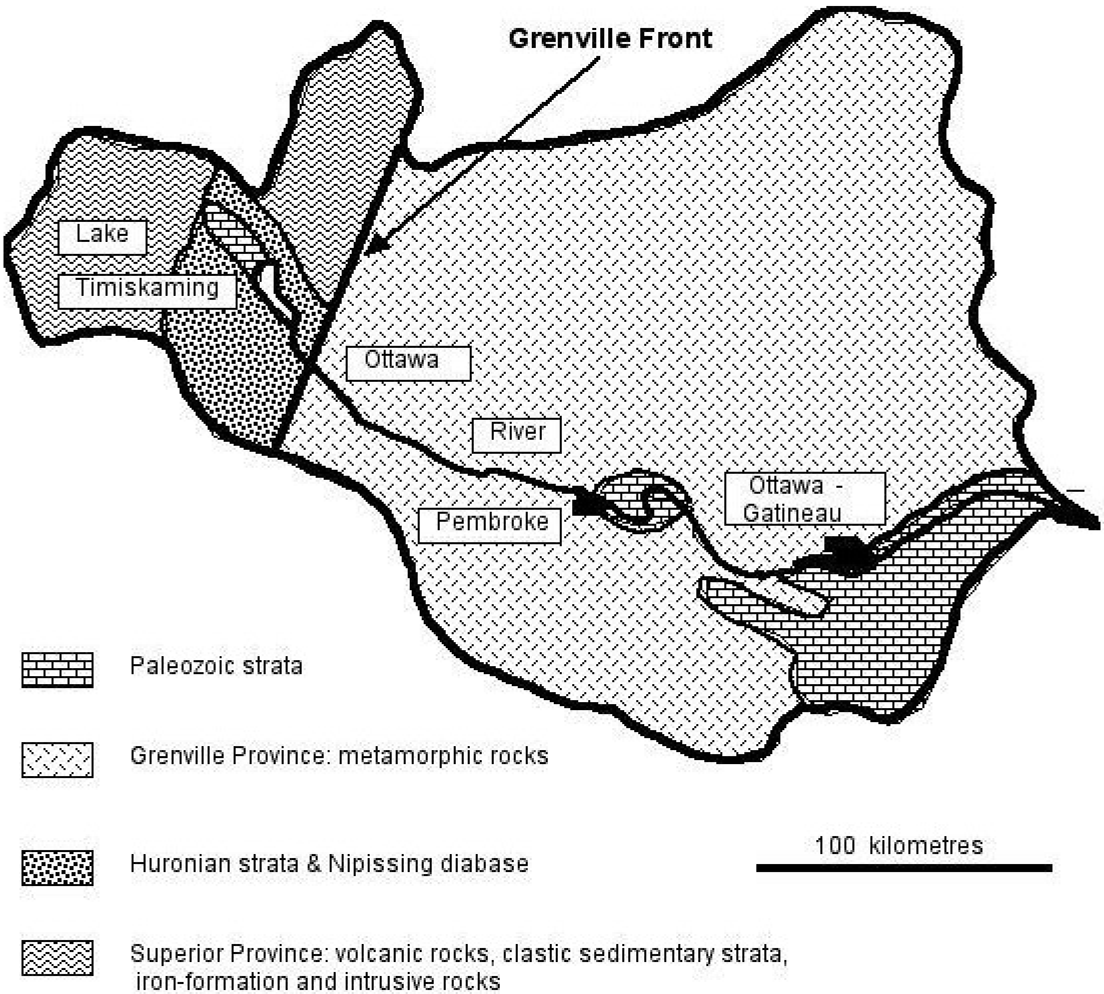
Compressed Time (1 yr.)	Geological Time Scale
1 second ago	Our lives
1 minute ago	Oldest written records
2 minutes ago	Last ice age
3 hours ago	First humans
1 week ago	End of dinosaurs
3 weeks ago	First dinosaurs
1.5 months ago	First metazoans
9.5 months ago	First stromatolites
10 months ago	Oldest rock
1 yr ago	Origin of Earth
3 years ago	Origin of Universe

The drainage basin of the Ottawa River now offers an excellent display of natural landscapes representative of a large part of our impressive geological heritage. Visits by road to selected segments of the river and environs offer appealing introductions to a variety of Ottawa River geoscapes. However, a trip down the river by raft, kayak or canoe is the ideal way to grasp the scope of events recorded in the rocks (Fig. 3.1) and in the overlying discontinuous blanket of unconsolidated sedimentary deposits: glacial till, drumlins, moraines and raised beaches; glacial outwash (sand and gravel in floodplains, deltas,

[1] Other designations of eras and eons are in current use. This simplified table matches common North American usage as shown at http://geology.er.usgs.gov/paleo/geotime.shtml and http://geoscape.nrcan.gc.ca/ottawa/time_e.php.

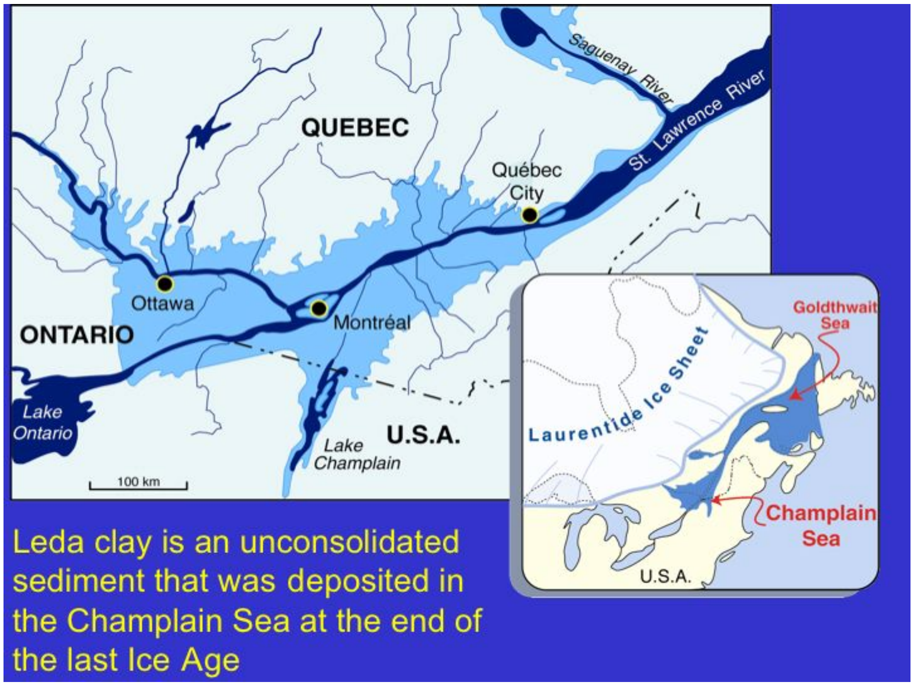
and eskers); and vast accumulations of silt and clay that were deposited during waning stages of the last Ice Age within both freshwater lakes and the Champlain Sea, a marine estuary of the Atlantic Ocean that extended up the Ottawa River beyond Pembroke (Fig. 3.2).

Figure 3.1 Distribution of Bedrock Units Underlying the Drainage Basin of the Ottawa River



Source : Dr. Allan Donaldson

Figure 3.2 Maximum Extent of the Champlain Sea, Approximately 12,000 Years Ago



Source : J.Aysworth, Terrain Sciences, Geological Survey of Canada

3.1.1 Our Geological Legacy

Sadly, few of our citizens or visitors to the Ottawa Valley have received formal training in the geosciences, in spite of the importance of the earth sciences to our very existence, let alone to our present standard of living. Nearly all products of modern society arise from the lithosphere, the upper solid component of our planet. Earth's bounties include a ready source of durable building materials, metallic and non-metallic ores, and also the coal and petroleum resources that provide vast quantities of fuel (and are also used to make plastics and other organic derivatives.)

Earth's lithosphere also provides sustenance for life as an outcome of the continual weathering of solid rock to produce soils essential to life on land. This is complemented by the relentless transport of waterborne mineral nutrients that support life in our rivers, lakes and oceans. The Ottawa River is a fine example of this interplay between geological and biological resources, arising in the hinterlands of the Canadian Shield, and terminating more than 1200 kilometres downstream, where it joins the St. Lawrence River. The St. Lawrence in turn drains the Great Lakes, the largest assemblage of linked lakes in the world, both in terms of area and of volume. One of the few publications that shows appreciation of the natural connection between biology and geology is a booklet by Paul Keddy (1999) that provides many interesting details about a key segment of the Ottawa Valley.

As discussed in Chapter 2.3: Algonquin History in the Ottawa River Watershed, the Ottawa River was an important pathway for First Nations inhabitants for many years. These people utilized the river's geological resources for thousands of years, and were familiar with much of its geological character. Although some geological observations were recorded by early explorers and missionaries, the first systematic geological survey was carried out in 1845 by Sir William Logan, founder of the Geological Survey of Canada (Smith and Dyck, in press; Zaslow 1970).

Art can function as a portal to geoheritage. Paintings by the artists such as Paul Kane, Tom Thomson and members of the Group of Seven have depicted the geology of the landscape in Algonquin Park and other parts of the Ottawa Valley quite well. More recently, artists such as George Cassidy and Muriel Newton-White have captured the essence of geological features along the rocky shores of Lake Temiskaming, often incorporating the famous history of the Cobalt silver mines through paintings of head frames and abandoned mining machinery.

Today, the geological legacy of the Ottawa River Valley is recognized in signage, such as that which has been erected by the National Capital Commission at the Champlain Lookout in Gatineau Park, a panel on the kiosk at Kitchissippi Lookout erected by the Ottawa Riverkeeper, the impressive RockWalk on the campus of Haileybury School of Mines in Haileybury, displays in the Museum of Nature (Ottawa), in the Écomusée (Gatineau) and in the Northern Museum of Mining (Cobalt).

Table 3.3 Introduction to the Three Types of Rock Present Along the Ottawa River[2]

Igneous Rock	Any rock that solidified from molten or partly molten material (such as magma).
Metamorphic Rock	Any rock derived from pre-existing rocks by mineralogical, chemical and/or structural changes, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally deep within the Earth's crust.
Sedimentary Rock	A layered rock resulting from the consolidation of sediment. Examples include clastic rocks such as sandstone, chemical rocks such as rock salt, and organic rocks such as low-rank coal.

3.1.2 The Precambrian Shield

The source of the Ottawa River lies within the Quebec portion of the Superior Structural Province of the Canadian Shield, one of two large blocks of Archean igneous and metamorphic rocks (Fig. 3.1 and 3.2) that contain the oldest rocks in North America. More than 2.5 BY old, these blocks consist of:

(1) Gneiss and large intrusions of granite and other igneous rocks;
(2) “Greenstone belts” that preserve volcanic edifices in which sea-floor eruptions are widely recorded by pillow structures (Fig. 3.3). The greenstone belts also contain thick accumulations of wackes and similar clastic sedimentary rocks (Fig. 3.5). The wackes commonly display graded bedding indicative of downslope resedimentation of unconsolidated sediment in response to earthquake-generated underwater landslides (turbidity currents). In addition, some tracts of Archean sedimentary rocks within the Ottawa Valley display large-scale cross-bedding suggestive of terrestrial deposition, as well as both textural and chemical maturity (well-rounded grains; high concentration of quartz sand) suggestive of multicycle origin; and
(3) Minor but economically significant deposits of banded iron-formation (chemically precipitated laminated rocks rich in silica and iron oxides, the prime source of iron ore (Fig. 3.4)).

In traversing this terrain, the Ottawa River is marked by numerous falls and rapids before it reaches Lake Temiskaming via Rapides des Quinze.

[2] For an explanation of other geological terms used within this section, please refer to Gary et al.

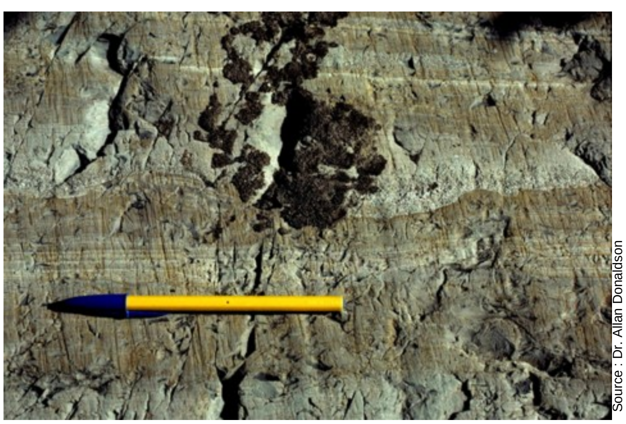
Figure 3.3 Pillow Structures

Pillow structures in a flow unit of Archean basalt that is more than 2.5 billion years old. Each pillow is actually a section through a lava tube, created when liquid rock material (magma) erupted under the sea, with the molten lava becoming instantly enshrouded in a glassy outer rim when the lava contacted cold sea water. Downward-pointing projections (keels) of the pillows were formed when the initially plastic lava tubes sagged to conform to the irregular surface created by the underlying, previously consolidated, lava tubes.
Location: 4 kilometres south of Cobalt, Ontario.

Figure 3.4 Block of Banded Iron Formation

Block of banded iron-formation in the RockWalk, Haileybury School of Mines, showing tabular beds that are alternately iron-rich (black) and iron-poor (red). This multi-tonne block came from the now inactive Sherman Mine, Temagami, Ontario.

Figure 3.5 Typical Stratified Archean Sedimentary Rock



Typical stratified Archean sedimentary rock showing graded bedding. Each layer represents deposition from a single downslope turbidity current (an underwater landslide generated by an earthquake).

At Lake Temiskaming, the Ottawa River encounters younger Precambrian strata of Proterozoic age. An ancient soil profile, known as a paleosol (Fig. 3.6) is locally preserved here beneath a major unconformity (a time gap in the rock record due to uplift and erosion - the lost interval in this case spans more than 300 million years). The paleosol lies between the older complexly folded and faulted Archean rocks and the generally flat-lying to gently undulating cover of overlying sedimentary strata assigned to the Huronian Supergroup.

Figure 3.6 Paleosol

Source : Dr. Allan Donaldson

Paleosol (ancient soil profile) at the base of the Gowganda Formation of the Huronian Supergroup. Formed by mechanical (freeze-thaw) weathering of Archean volcanic rock, it is overlain by a peggly conglomerate of the younger sedimentary strata.

Figure 3.7 Tillite Overlying a Laminated Siltsatone

Source : Dr. Allan Donaldson

Tillite overlying a lamiated siltsatone-claystone succession in the lower part of the Gowganda Formation. Road cut on north side of Highway 588, west of Haileybury.

These Proterozoic strata of the Huronian Supergroup have been subjected to only mild metamorphism, and only rarely do they display penetrative cleavage (deformation-induced layering). Most of the Huronian strata that border Lake Temiskaming belong to the world-renowned Gowganda Formation, universally regarded as a classic example of one of at least four episodes of continental glaciation that took place before the last Ice Age (Fig. 3.7). The ice sheet responsible for the deposition of the Gowganda sediments was at its maximum size more than 2.2 BY ago. This was established by the radiometric age of the Nipissing Diabase (Fig. 3.8), an igneous rock that intruded the Huronian strata as sills (bedding-conformable layers). Local intermixing of diabase and sedimentary units indicates that this widespread intrusive event took place before the sediments had completely lithified.

The Nipissing Diabase is a hard, weathering-resistant rock, responsible for much of the rugged topography north of the Grenville Front, which is the southern boundary of both the Superior Province and its overlying cover of Huronian strata (the latter geological unit is designated as the Cobalt Plate). One of the more striking examples of landscape created by the resistant Nipissing Diabase is Spirit Rock, which displays a spectacular cliff rising more than 100 metres above the west shore of Lake Temiskaming (Fig. 3.9). This vertical cliff presents a cross-section through one of the thicker sills of Nipissing diabase that was intruded as molten magma parallel to the bedding of enclosing, nearly flat-lying, sedimentary rocks of the Cobalt Group. The sill is transected by sets of near vertical joints that have controlled the mechanical weathering of this sill. The dark vertical lines spaced a few metres apart along the cliff mark the intersections of near-vertical joints.

Figure 3.8 Microscopic View of Nipissing Diabase

Source : Dr. Allan Donaldson

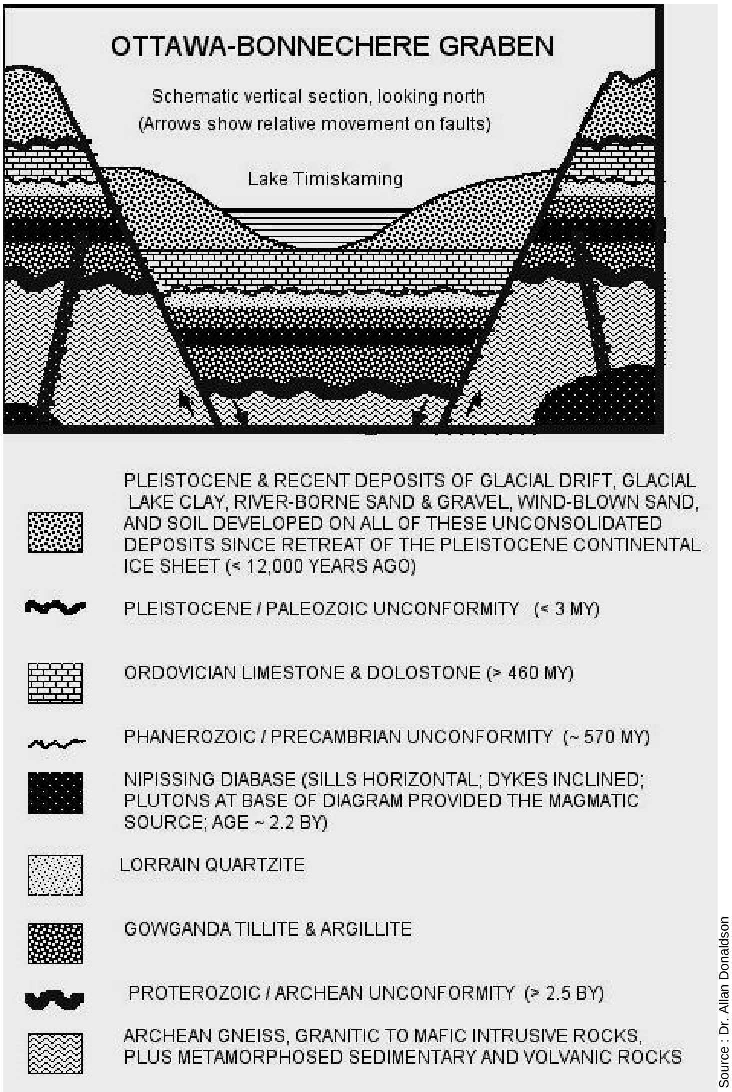
Microscopic view of Nipissing diabase, showing its characteristic intergrowth texture comprising randomly oriented elongate crystals of plagioclase feldspar (clear with dark linear stripes) and mafic minerals (more equant crystals that appear dark to opaque, reflecting their high content of iron and magnesium). Width of field of view is 4 millimetres.

Figure 3.9 Spirit Rock

Source : Dr. Allan Donaldson

The Ottawa River takes an abrupt southward turn along the linear south- to south-southeastward path of Lake Temiskaming, narrowing to again take up a route marked by intermittent rapids. This southward path is controlled by faulting that has down-dropped younger sedimentary strata of Paleozoic age within a keystone-like block or graben within, and extending north of, Lake Temiskaming (Fig 3.10: A graben is an elongate, down-dropped crustal unit that is bounded by faults along its roughly parallel sides (Bates and Jackson 217)). Unusually deep segments of Lake Temiskaming follow the trends of graben-parallel boundary faults.

Figure 3.10 Vertical Section, Looking Northward, Across the Ottawa-Bonnechere Graben



Vertical section, looking northward, across the Ottawa-Bonnechere Graben. This diagram illustrates how, as a result of east-west extension, the central fault-bounded block of rock (the graben) has subsided relative to the rocks on both sides.

3.1.3 The Grenville Province

At a point on the Ottawa River approximately due east of Temagami, Ontario, Archean rocks of the Superior Province are truncated by a block of Precambrian rocks intensely deformed, metamorphosed and uplifted more than 1 BY ago. These rocks, which belong to the Grenville Structural Province of the Canadian Shield, extend southward into southern Ontario and New York State, where they provide the basement to unmetamorphosed Paleozoic strata of the St. Lawrence Lowlands, and also form the Adirondack Mountains.

In contrast to the predominantly east-west alignment of greenstone belts in the Superior Province, the Grenville Province is characterized by large-scale, swirly patterns due to complex folding and intrusion of granitoid plutons. Interlocking crystalline texture (Fig. 3.11), and a wide range in size of their constituent mineral grains, are characteristic of both the Grenville metamorphic and intrusive rocks. Consisting mainly of gneiss and schist, these metamorphic rocks characteristically display a faint to distinct foliation (layered appearance) due to an alignment of minerals of different composition and colour. Typically, they are laced with networks of pegmatite and aplite dykes that were injected in a molten state along fractures in their metamorphic host rocks (Fig. 3.12). Their younger age is demonstrated by crosscutting relationships (the dykes truncate the metamorphic foliation).

Figure 3.11 Interlocking Crystalline Texture of Pegmatite

Source : Dr. Allan Donaldson

Interlocking crystalline texture of pegmatite, a coarse-grained igneous rock that commonly occurs in dykes injected into fractures opened in older solid rocks. Such ``jig-saw-puzzle`` textures, created by either crystallization from a magma (igneous rock) or recrystallization in the solid state while hot and under pressure (metamorphic rock), are typical of all igneous and metamorphic rocks of the Grenville Structural Province of the Canadian Shield. Roadcut on the east side of Highway 17, 15 kilometres north-west of Deep River.

Figure 3.12 Dykes of Pegmatite and

Source : Dr. Allan Donaldson

Dykes of pegmatite and aplite that were injected in a molten state along fractures in mafic metamorphic host rocks. Roadcut on the east side of Highway 17, 15 kilometres north-west of Deep River.

An imposing example of Grenville bedrock rises from the Ottawa River as Oiseau Rock, a site revered for many years by the First Nations Peoples of the area. Downstream from this locality, on both sides of Calumet Island, many fluvially eroded outcrops of Grenville age are exposed within and bordering the numerous river channels around Rocher Fendu. Especially striking are lichen-free water-scoured and polished sections of metamorphosed limestone (marble), which display spectacular folding in three dimensions (Fig. 3.13) when the water level is low. Early cultural development in these lower regions of the Ottawa River drainage basin was spurred by the development of numerous mines (lead, zinc, iron, mica and phosphorous) near the river, in both Quebec and Ontario.

Bordering the Ottawa River southward from a location just a few kilometres downstream from Pembroke, outcrops of unmetamorphosed sedimentary rock of Paleozoic age first appear, resting unconformably on the more-than-twice-as-old Grenville basement. Easily recognized by slightly inclined layering that marks the original beds, these strata include sandstone, limestone, dolostone, shale and minor conglomerate. Limestone and dolostone, the predominant rock types, are intermittently exposed downstream from their point of first appearance to Ottawa; from Ottawa south to the St. Lawrence River, the Grenville rocks are almost completely covered by these younger Paleozoic rocks.

Preserved in these rocks is a great variety of invertebrate fossils characteristic of the early Paleozoic Era. These record the evolution of lime-precipitating organisms that lived in warm tropical seas that covered much of Canada (which then was near the equator) from about 570 million to 440 million years ago. The fossils include corals, stromatoporoids, bryozoa, brachiopods, pelecypods, gastropods and cephalopods (mostly nautiloid orthocones: tapered and chambered shells up to 30 centimetres long, which housed soft bodies of the ancestors of our present-day squids). Many of these have been silicified (fossilized in such a way that their original components are replaced by quartz, chalcedony, or opal (Bates and Jackson 469)) (Fig. 3.14 and 3.15). These now stand out in relief due to dissolution of their enclosing matrix of soluble carbonate minerals.

Figure 3.13 Marble

Source : Dr. Allan Donaldson

Marble (metamorphosed limestone) containing interbedded layers of siliceous metasedimentary strata, displaying intense folding due to deformation at depths probably in excess of 15 kilometres. Ottawa River at the Paquette Rapids.

Figure 3.14 Ordovician Brachiopods and Gastropods

Source : Dr. Allan Donaldson

Silicified brachiopods and gastropods in Ordovician limestone. South shore of Ottawa River near Westmeath.

Figure 3.15 Ordovician Stromatoporoids

Source : Dr. Allan Donaldson

Silicified stromatoporoids in Ordovician limestone. South shore of Ottawa River near Westmeath.

The stratigraphy (sequential ordering of the strata) in the Ottawa Valley was initially established by Alice Wilson, the first female geologist to work for the Geological Survey of Canada. Her subdivisions, as well as her fossil identifications for the most part remain valid today (e.g. Wilson, 1946). In addition to bedding, primary structures characteristic of the environments within which the Paleozoic sedimentary strata were deposited include crossbedding, ripple marks, desiccation cracks (mudcracks) and intraclasts (pebbles of composition identical to their containing beds). Cyanobacteria (primitive bacteria, until recently classified as blue-green algae) were responsible for the synsedimentary growth of stromatolites, which can be seen in several places along both shores of the Ottawa River today. Their characteristics and some of their most accessible locations are described below.

Stromatolites: The Oldest Known Record of Life on Earth

The section of the Ottawa River between Pembroke and Ottawa offers the most easily accessible displays of stromatolites in Canada. Stromatolites are biosedimentary structures rather than true body fossils. They record departures from normal horizontal or rippled bedding occasioned by the presence of biofilm layers built up during sedimentation into domal to branching forms by cyanobacteria (primitive life forms such as bacteria and blue-green algae, which collectively are regarded as falling somewhere between the plant and animal kingdoms).

Figure 3.16 Oblique View of Ordovician Limestone

Source : Dr. Allan Donaldson

Oblique view of Ordovician limestone showing elongate, concentrically aminated domal stromatolites in a section parallel to bedding. Locality: North shore of the Ottawa River, immediately west of the Champlain Bridge, Gatineau.

Cyanobacteria thrive in a wide variety of environments, but fare best in warm aquatic waters where they build reefs in much the same way as do the corals. Through their life-related processes such as photosynthesis, cyanobacteria were likely responsible for transforming the Earth's initially reducing atmosphere (oxygen-poor) to its present oxygen-rich state. Although they were the predominant life form on Earth for over 2 billion years, cyanobacteria live in abundance in only a few localities worldwide, largely because numerous more advanced forms of life, such as snails, evolved in Early Paleozoic times, and remain in abundance today as voracious scavengers of biofilms.

Figure 3.17 Stromatolites

Source : Dr. Allan Donaldson

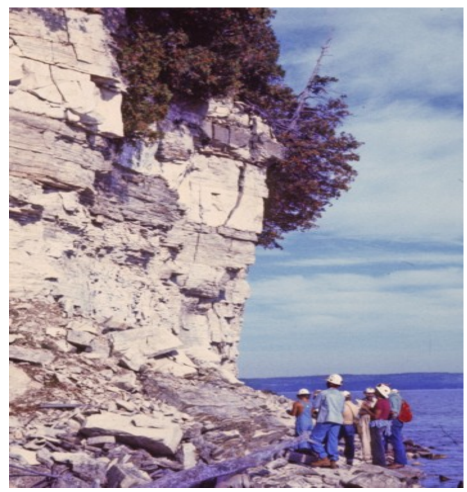
Bedding plane view of elongated, concentrically laminated stromatolites in Hamelin Pool, Shark Bay, Australia.

One of the places where cyanobacteria still live in abundance is Shark Bay, Australia. Here, hypersaline conditions (more than 3 times the salt content of normal marine water) provide an effectively scavenger-free environment that has enabled stromatolites to develop in profusion in subtidal, intertidal and supratidal zones.

Stromatolites are exposed along many stretches on the Ontario side of the Ottawa River (especially at times of low water levels). Some sites in Ontario include: the shore upstream of the bridge south of Pembroke; the shore immediately downstream from Port O'Call Marina near Dunrobin; Westboro Beach, Ottawa; the islands offshore from Fitzroy Provincial Park (where some attain diameters over 1.5 m). Small outcrops of stromatolites also occur in numerous other places in eastern Ontario, including Almonte and Appleton. The most spectacular place to view stromatolites, however, is in Gatineau, Quebec, less than 300 metres upstream from Champlain Bridge. During low water stages at this site, a platform of continuous exposure exceeds an area of more than 1500 m^2. These stromatolites (most of their tops have been eroded during glaciation and then by the river) are arrayed in parallel north-south lines (Fig. 3.16) that, by analogy with Hamelin Pool, Shark Bay, (Fig. 3.17) represent control of their growth by onshore winds and tides (Donaldson et al.). Smaller stromatolites show a distinct east-west elongation, and this, together with associated ripple marks, suggests the action of longshore currents in a warm, shallow-water saline environment, about 460 million years ago.

Since the Champlain Bridge stromatolite locality was drawn to public attention in 2001, more than 5000 people have visited it. The domal stromatolites so well displayed at this site on the shore of the Ottawa River closely resemble those in Lester Park and Petrified Sea Gardens near Saratoga Springs, New York State, the site where stromatolites were first recognized in North America (Hall).

Figure 3.18 Silurian Limestone



Source : Dr. Allan Donaldson

Cliff exposure of Silurian limestone at Dawson Point, on the north shore of Lake Temiskaming. Lying within the Ottawa-Bonnechere Graben, these nearly flat-lying coral- and brachiopod-rich strata are the youngest lithified sediments in the Ottawa River drainage basin. Their down-dropped position relative to the blocks on both sides of the graben can be appreciated by noting that the highlands on the horizon (at head-level of students viewing the Silurian strata) is composed of much older Precambrian rocks (mostly metamorphic and igneous rocks of Archean age).

At the north end of Lake Temiskaming and northward, strata of Silurian age overlie the Ordovician strata. These are the youngest lithified sedimentary rocks in the Ottawa River drainage basin. Dawson Point is an ideal place to grasp the three-dimensional relationship between the downdropped central block of the Ottawa-Bonnechere Graben and the uplifted blocks of much older Precambrian rock to both the east and to the west (Fig. 3.18).

3.1.4 Pleistocene Ice Age

During the past few million years, almost all of Canada was covered by continental ice sheets that advanced and receded several times. Each advance scoured the solid bedrock, and during the melting of the last ice sheet, 10,000 to 7,000 years ago, deposited vast quantities of glacial till, sand, gravel and clay. Because the ice was several kilometres thick and persisted for such a long time, the land became sufficiently depressed to allow the marine waters of the Champlain Sea to slowly encroach over the till, sand and gravel deposits, leading to the deposition of locally thick deposits of marine silt and clay (Leda clay) over the lower part of the present Ottawa River drainage basin. Much of the rich farmland of southeastern Ontario and southwestern Quebec is underlain by these unconsolidated fine-grained sediments.

Unstable clay slopes

Deposits of Leda clay, a potentially unstable material, underlie extensive areas of the Ottawa–Gatineau region. Leda clay is composed of particles of bedrock that were finely ground by glaciers and washed into the Champlain Sea. As the particles fell to the seafloor, they formed loose clusters. The resulting sediment had a loose but strong structure, making it capable of retaining large amounts of water. Following the retreat of the Champlain Sea, the salts that originally contributed to the bonding of the particles were leached by fresh water filtering through the ground, weakening the sediment's structure. If sufficiently disturbed, Leda clay can liquefy, producing dangerous landslides on unstable slopes. Triggers include river erosion, earthquakes, human activities such as excavation and construction, and increases in pore-water pressure (especially during periods of heavy rainfall or snowmelt.)

Because the southern region of the Ottawa River Valley contains deposits of Leda clay, the area is vulnerable to often catastrophic landslides. Over 250 landslides have been identified within 60 kilometres of the city of Ottawa. In spectacular cases, the sediment underlying large areas of flat land adjacent to unstable slopes liquefies instantaneously. The resulting debris may flow several kilometres, often damaging infrastructure and damming rivers, causing flooding, siltation, and water-quality problems. The most disastrous Leda clay landslide in eastern Canada occurred in 1908 at Notre-Dame-de-la-Salette, Quebec. It resulted in the death of 33 people. Geologists and geotechnical engineers today can identify potential landslide areas, and make land-use zoning recommendations in order to reduce the risk that landslides will harm people or property (Geoscape Canada).

High levels of glacial lakes are marked by raised boulder beaches (Fig. 3.20). Marine animals including barnacles, distinctive pelecypods (Fig. 3.19), and even some whale skeletons, were locally preserved in sandy and muddy deposits. These have since been exposed as the land once again was elevated above the sea due to rebound of the Earth's crust of as much as one centimetre per year, in response to melting of the continental ice sheets. This rebound continues today, but at a much slower rate.

Figure 3.19 Pelecypod Shells

Source : Dr. Allan Donaldson

Pelecypod shells collected from the top of sand beds beneath Leda clay. 10 kilometres south of Almonte, Ontario.

Figure 3.20 Boulder Beach

Abandoned boulder beach marking the highest level of post-glacial Lake Barlow-Ojibway. 8 kilometres west of Haileybury, Ontario.

3.1.5 Champlain Sea Sediments

Along the Lower Ottawa River Valley, clay is typically the most abundant unconsolidated sediment covering the lithified bedrock. Before and during the waning stages of the most recent episode of glaciation, commencing about 12,000 years ago, a vast freshwater lake extended across parts of this region as an extension of our present-day Lake Ontario. As the ice sheet continued to melt, the Atlantic Ocean crept up the Ottawa Valley, creating the Champlain Sea. Excavations created during construction commonly reveal horizontal stratification in these deposits, but after a few rainstorms, erosion masks this feature. Erosion may also release clam and barnacle shells that prove a marine origin. At the Ottawa Airport and at White Lake, the skeletons of marine mammals, including whales and seals, confirm that this region was covered by waters of the post-glacial Champlain Sea. The highest marine shoreline was just a few kilometres to the west of Almonte, almost bisecting Lanark County.

Whales of the Champlain Sea

Five species of whale have been reported to have once lived in the Champlain Sea. Belugas seem to have been most common in most parts of the sea as well as its eastern approaches. A record from Pontiac Point indicates that Harbour Porpoises, well adapted to freshwater conditions, reached the western part of the sea. Humpback and Bowhead whalebones show that these large species reached the western margins of the sea as well. The Common Finback was also found in the eastern portion of the sea (Harington 15).

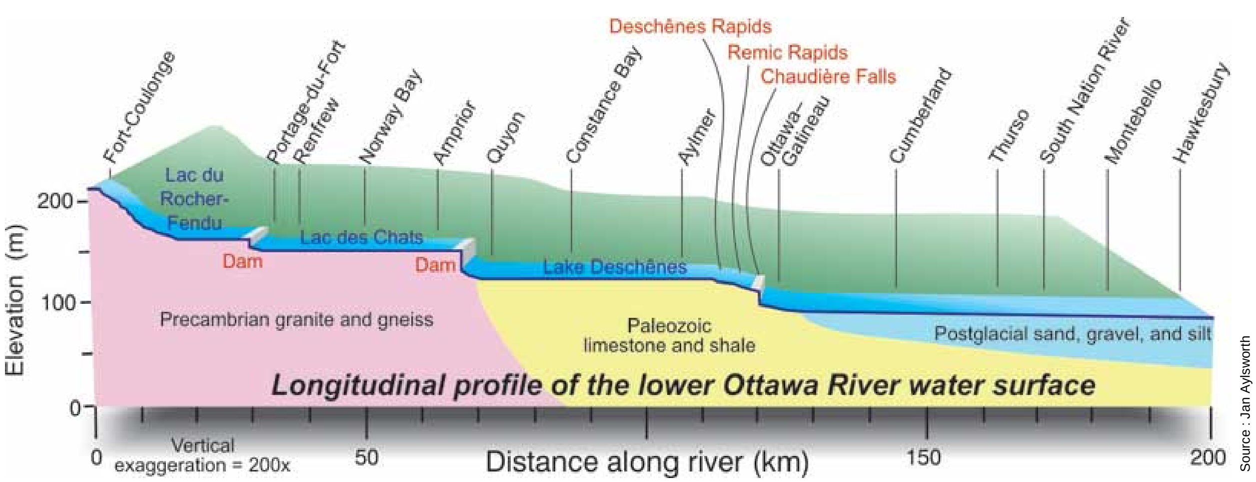
3.1.6 The Ottawa River Today

A fundamental link exists between rivers and geology, because the position of rivers, like lakes, is governed by the water table. Channelized bodies of water occur wherever the water table intersects irregular sloping landscapes; both the extent of a drainage basin and the direction in which a river travels are determined by topography, which in turn is controlled by composition, configuration, and distribution of the underlying bedrock. During geologically recent episodes of continental glaciation, when enormous ice sheets scoured southward across the ancient Precambrian heartland of the Canadian Shield, the eventual path of the present-day Ottawa River was modified by discontinuous deposits of unconsolidated glacial till, gravel, sand and clay - material derived by erosion of the underlying bedrock as a direct result of four major glacial advances during the last (Pleistocene) Ice Age.

The interplay between the Ottawa River and its rocky underpinnings has resulted in the exposure of features never before seen, as the river carries out its own more recent process of erosion, revealing vertical sections and near horizontal bedrock platforms along its generally rocky shores. A trip down the Ottawa River provides an ideal opportunity to view an impressive variety of intrusive plutons, dykes and sills more than 2.5 billion years old, all well displayed in the upper reaches of the river's drainage basin north of Lake Temiskaming. These ancient rocks extend almost to the south end of Lake Temiskaming, where more than 1 billion years ago the southern part of the Canadian Shield was raised more than 15 kilometres vertically along a world-famous fault zone known as the Grenville Front. Recent studies have shown that, at this time, the Grenville uplift caused rivers to flow northward from the Gatineau region to the present location of the Arctic Islands! The vast, now deeply eroded Grenville block, comprising a wide array of folded and highly contorted metamorphic and igneous rocks more than a billion years old, is exposed along the banks of the Ottawa River, from the shores of Lake Temiskaming east of Temagami, all the way south to Ottawa. Soon after the uplift of the Grenville Province about a billion years ago, fold-cored mountains south of the area now occupied by Lake Temiskaming may have risen higher than the present-day Himalayas.

From Pembroke southward, discontinuous plates of sandstone, limestone, dolostone and shale begin to take over the bedrock landscape. From Ottawa south to the St. Lawrence River, the Precambrian rocks are almost everywhere covered by these younger Paleozoic rocks, in which a great variety of fossils are preserved, recording the evolution of organisms that lived in seas that covered much of Canada from about 570 million to 440 million years ago. Throughout much of the subsequent time during which more advanced life forms developed, including dinosaurs, the land now traversed by the Ottawa River remained above the sea, and so was subjected to erosion. As a result, no strata containing dinosaur fossils occur within the Ottawa drainage basin.

Figure 3.21 Longitudinal Profile of the Lower Ottawa River



However, as explained for the last period of continental glaciation, the ice sheets became sufficiently thick to depress the land, resulting in marine flooding of much of the present Ottawa River drainage basin. As the ice melted, the Champlain Sea crept well up the Ottawa Valley, leaving clams, barnacles, and whale skeletons in local sandy deposits.

Shifting river channels during the post-glacial period

The modern river evolved when the ancestral Ottawa River and its tributaries adjusted to the retreat of the Champlain Sea. Between 10,000 and 8,000 years ago, there was a much greater flow of water through the ancestral Ottawa River than at present. Large glacial lakes in northern Ontario and the Prairie Provinces, as well as the upper Great Lakes, all drained into the Ottawa River. Several times during this period the Ottawa River shifted into new channels, but by about 8,000 years ago, the present modern drainage had become established.

Caves of Wonder!

The Ottawa River's Underwater Caves

In the township of Westmeath, just south of Allumette Island, lies an extensive series of caves that may well form Canada's largest cave diving system. Located under a large peninsula on the Ontario side of the river, under several large islands in the centre of the river belonging to Quebec, and under the river bed itself, this network includes over 4 kilometres of twisting passages (Sawatsky 6).

In this region, the Ottawa River is running over a bed of horizontally bedded limestone in which the caves are developing. The river generally runs in a NW/SE direction, but has, in this region, taken an "S" shaped turn to circumvent a large peninsula on the Ontario side. The peninsula is relatively flat, and about 1 to 4 metres above the normal river level. However, when the water level is high, half of the peninsula over the caves is submerged. Some of the water then flows under the peninsula along the fault lines and bedding planes in the limestones. It is this process that continues to form this complex series of caves (Sawatsky 1).

The Bonnechere Caves: A Recreational Opportunity

Near Eganville, just west of Renfrew, Ontario, a series of caves has developed in limestone strata that accumulated about 460 million years ago, when the area was covered by tropical seas. This privately-owned site offers guided tours of the many strange, twisting passages. Visitors can observe fossils of coral and other sea creatures that lived long before the dinosaurs, as well as stalactites - icicle-like structures that form by solution and reprecipitation of the limestone at a rate of about one cubic inch per year (Bonnechere Caves).

3.1.7 Heritage Designation for the Ottawa River in relation to Geological Highlights

The Ottawa River's unique geological features contribute significantly to its heritage value. Above all, the Ottawa River is readily accessible, unlike many extant Heritage Rivers in Canada's remote hinterlands. The Ottawa provides a tremendous outdoor laboratory for introducing our citizens and visitors to a vast range of geological features that have been created over more than 3 BY of geological time. Many stretches of the river remain little changed since the time when it first revealed many fundamental secrets to Sir William Logan during his epic canoe journey in 1845.

The Ottawa River is the only Canadian River that crosses these four major geological subdivisions of Canada: the Superior Province, Cobalt Plate (region underlain by Huronian strata of Proterozoic age), Grenville Province and St. Lawrence Lowlands. The river traverses many historic mining regions, the most famous being the Cobalt Mining Camp. The Ottawa River additionally provides a transect through a vast range of erosional features and unconsolidated glacial deposits. It even has a 1 kilometre-diameter structure formed by meteorite impact within its drainage basin (Brent Crater, less than 25 kilometres south of Deux-Rivières, within the northern limits of Algonquin Provincial Park). Numerous points of access, augmented by many stretches of water navigable by canoe, kayak or power boat, make visits possible to a vast array of sites where the geology behind the landscape can be observed, studied and appreciated. Many small museums and historic sites on both sides of the Ottawa River could contribute to, and benefit from, its elevation to heritage status. Some, such as Cobalt's Northern Ontario Mining Museum, already devote considerable attention to geological heritage. Others intend to provide new geoscientific displays. The Ottawa River is therefore an appealing and accessible pathway for all to gain a greater appreciation of Canada's geological heritage.

Scientists who studied the geoheritage of the region

Sir William Edmond Logan (1795-1875)
Few people are aware of the importance of the early work on the Ottawa River by Sir William Logan, named by a Canada-wide panel as the most important Canadian scientist. Logan traversed along the Ottawa River to the head of Lake Temiskaming and westward to Lake Nipissing to study ancient Canadian Shield rock. Like all early geologists, he was a well-rounded naturalist, collecting information on geology as well as biology, meteorology and ethnology (Ottawa Riverkeeper).

Willet Green Miller (1866 – 1925)
Willet Green Miller gave the town of Cobalt its name, and was responsible for recognizing the potential for silver, cobalt and precious metal resources that were recovered from numerous mines developed after his initial geological studies in the region. He was the first provincial geologist for the province of Ontario, and refined the methodology for identifying diamonds, emeralds and corundum by X-ray diffraction. The mining and geology building at Queen's University bears his name.

Alice Elizabeth Wilson (1881 – 1964)
Alice Wilson, the first woman to be awarded Fellowship in the Royal Society of Canada, was also a pioneer in advancing the recognition of women in science. As the first female paleontologist employed by the Geological Survey of Canada in 1909, she mapped the Paleozoic terrain of the Ottawa Valley, traveling by foot and by bicycle. On the basis of detailed studies of fossils, she established stratigraphic subdivisions for Paleozoic strata in much of the Ottawa Valley. These subdivisions remain almost the same today.

Robert Ferguson Legget (1904 – 1994)
Robert Legget was a geological engineer who was the head of the Division of Building Research, National Research Council of Canada, and for many years taught at both Queen's University and University of Toronto about geological hazards in the Ottawa Valley. He wrote and presented

extensively on the engineering contributions of Colonel By, builder of the Rideau Canal, which links the Ottawa River to Lake Ontario at Kingston. Legget was instrumental in having a plaque erected in 1997 on the River Thames in London, England, near the birthplace of Colonel By (for whom Ottawa was initially named Bytown).

Summary

The Ottawa River traverses segments of the lithosphere that represent the past 3 billion years of the Earth's history. The source of the Ottawa River lies within a portion of the Canadian Shield that contains the oldest rocks in North America: more than 2.5 billion years old. Strata bordering Lake Temiskaming contain sediments from a continental glaciation that took place more than 2.2 billion years ago.

Downstream of Pembroke, outcrops of younger, sedimentary rock border the river. Fossils dating from ancient tropical seas covering much of Canada from 570 million to 440 million years ago can be found in this sedimentary rock. Stromatolites, the oldest known record of life on earth, are easily viewed in the section of the Ottawa River between Pembroke and Ottawa.

The continental ice sheets that covered almost all of Canada during the past few million years weighed down the land. Unconsolidated glacial deposits are responsible for today's rich farmland in southeastern Ontario and southwestern Quebec. When the last ice sheet melted 10,000 to 7,000 years ago, the Atlantic Ocean crept up the depressed Ottawa Valley, creating the Champlain Sea, which was evidently once home to five species of whale.

Today's Ottawa River evolved when the ancestral Ottawa River and its tributaries adjusted to the retreat of the Champlain Sea. Between 10,000 and 8,000 years ago, much more water flowed through the Ottawa River, with large glacial lakes in northern Ontario and the Prairie Provinces as well as the upper Great Lakes, all draining through the Ottawa River. Several times during this period the Ottawa River shifted into new channels, but by about 8,000 years ago, the present modern drainage had become established. As the river continues to carry out its own, more recent process of erosion, it has exposed interesting features representing various different stages in its development, which can be viewed from the river or from shore. The accessibility of the geological features along the Ottawa River makes it an excellent and unique place to learn about our rich geoheritage.