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GEOLOGY AND FOSSILS

CRAIGLEITH AREA

ONTARIO

Ministry of
Natural
Resources
Ontario

The Geology and Fossils of the Craigleith Area

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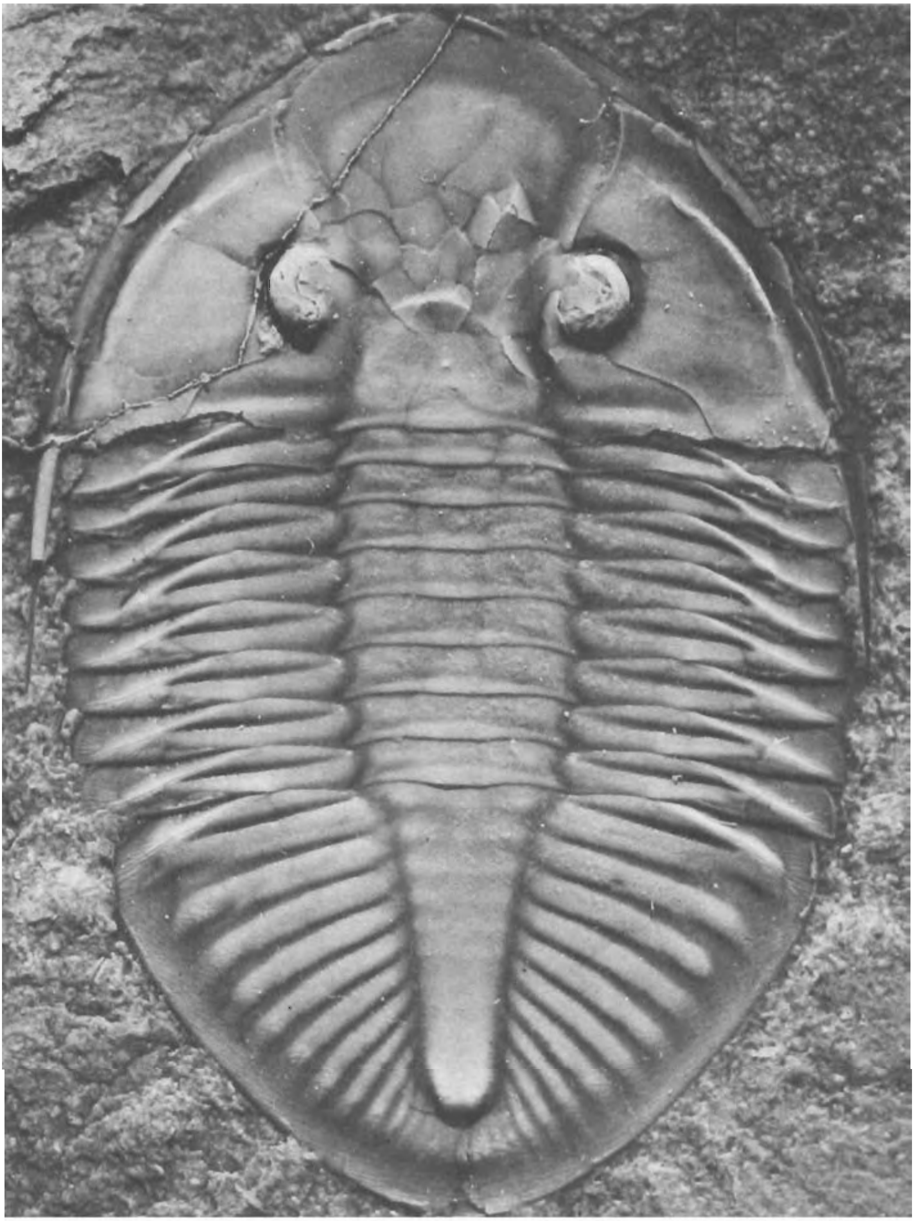
Much of the country away from the roads is not public property. Visitors must respect the rights of property owners and permission should be obtained from them before entering private property. All safety precautions against accidents should be observed.

Collection of fossils is prohibited by law in Provincial and National Parks in order to allow everyone to see, appreciate and enjoy these natural objects.

Please do not smoke or light fires in the bush because of the hazard of forest fire.

Cover: A large variety of fossils is found on the rocks exposed along the shoreline of Nottawasaga Bay. A curious visitor examining a rock slab showing fossil imprints.



Frontispiece: Latex cast of young individual of trilobite *Pseudogygites latimarginatus* x4 (courtesy Dr. Rolf Ludvigsen, Department of Geology, University of Toronto).

GEOLOGY AND FOSSILS

CRAIGLEITH AREA ONTARIO

by
Harish M. Verma

Ontario Geological Survey
Guidebook No.7

Ontario

Ministry of Natural Resources

Hon. James A.C. Auld
Minister

Dr. J.K. Reynolds
Deputy Minister

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“Black Bituminous Shales”

Mr. Ross, who surveyed Barrie Township gave me a specimen found in the 2nd concession of Collingwood township north of the Blue Mountains, on the shore of Lake Huron. This specimen and the strata of Windsor are identical in their fossil content and mineralogy. Therefore one can conclude that the formation extends from one lake to the other.... In the outcrop the rock is jet black shale. It is hard, fissile and breaks easily. It exfoliates into thin sheets and the surfaces of these sheets are covered with a very thin bituminous skin.... Under weathering conditions the rock disintegrates rapidly and finally becomes a blackish shale that forms a good soil. Fossils described by American geologists as characteristic of the Utica shale in New York State are abundant in this rock. In Whitby I found specimens of the trilobite called [Triarthrus beckii] with shells of genera avicula and [orthoceras]. The shales found in Collingwood township contain similar organic remains.

Alexander Murray
Assist. Provincial Geologist, 1845

Translated from French: Mesage de son Excellence Le Gouverneur Général avec Rapports sur une Exploration Géologique de la Province de Canada, Présenté a la Chambre, le 27 Janvier, 1845. lmprimé par de L’Assemblée Legislative Montréal. De L’Imprimerie de Lovell et Gibson, Rue St. Nicoles. 1845, p.65-66.

PART 1

Geological Background

Introduction

The landscape of southern Ontario that we see today, its rolling hills and valleys, steep rock scarps, meandering rivers, and numerous lakes, has changed very little since the glaciers that sculptured it receded from the area about 12,000 years ago. The few changes that have occurred are mostly due to streams cutting through unconsolidated glacial deposits to bedrock, or to wave action exposing the underlying bedrock around the shores of the Great Lakes. Southern Ontario's bedrock mainly consists of a variety of stratified rocks: sandstones, shales, limestones, and dolostones. These strata were originally deposited as sand, mud, and limy oozes at the bottom of a shallow sea covering this part of Ontario between 360 and 450 million years ago. Since then, the soft sediments have hardened and have been uplifted by geological forces to form the bedrock of today.

In southern Ontario the surficial (glacial) deposits as well as the underlying sedimentary strata are exposed in roadcuts and quarry walls, and along riverbanks, creeks, and lakeshores. At such places it is possible to learn much about the past natural history by studying the rock formations, minerals, and fossils.

Around Craigleith, Ontario, on the southern shore of Georgian Bay, the exposed bedrock consists of slightly tilted layers of limestone and of shale originally deposited about 445 million years ago. The weathered surface of these rocks reveals fossils – skeletons or impressions of animals that once lived in the warm shallow sea that covered the Georgian Bay region so long ago. These rocks and fossils tell us a great deal about the life and the environment that prevailed; they represent pages from Nature's diary in which are recorded events of the distant past.

Visitors to the Craigleith area, including amateur collectors of fossils, are usually curious about the nature and variety of organisms that inhabited this area hundreds of millions of years ago. Common questions are:

- What were these animals like when they were alive?
- What did they eat?
- How did they move about?
- What kind of environment did they live in?
- Have these animals left any descendants?

- How long did this environment last?
- How do animals on the same rock slab differ from one another?
- Are there any differences between animal populations on successive (underlying and overlying) slabs?

In order to find answers to these and similar questions, one must turn to a paleontologist – one who studies the remains of past life. The science of paleontology deals with past forms of life; their classification and nomenclature, life habits, evolutionary history, migration patterns, distribution in space and time, and the relationships among the life forms.

Those who are familiar with fossils know that, besides being objects of beauty and variety in form, these remains of past life are our only clues to the past history of this planet. In many places fossils are the only available tools for determining the age of the more recent rocks, as rocks of each period of the Earth's history since Cambrian times are characterized by a distinctive suite of fossils. The usefulness of the study of fossils was admirably summed up by Sir William Logan, the first Director of the Geological Survey of Canada and one of the pioneers of Canadian geology. In his introduction to the Geology of Canada, published in 1863, he stated:

> "But independent of the instruction derived from fossils as guides to ourselves, and proofs to others in regard to the succession of our rocks, there is a higher consideration attached to them than their mere utilitarian application. For, as remarked by Conybeare,[1] they bring us supplementary information of numerous species which have long vanished from the actual order of things; and by their resurrection they unexpectedly extend our views of the various combinations of organic forms. In many instances they supply links otherwise wanting, in uniting the different terms of the series in an unbroken chain, and thus aid in elucidation of those general laws of natural history, the investigation of which is always of so much interest to enlightened minds."

This guidebook deals with the geology and fossils found along the shores of Nottawasaga Bay and the creeks in the vicinity of Craigleith. It is written for all those who have expressed curiosity and interest about the abundant fossils found in this area. The early sections of the guidebook dealing with the geological framework of Ontario, the Earth's calendar and ages of rocks will provide the reader with the background necessary to understand the

---

[1] William Daniel Conybeare (1787-1857) Renowned British geologist and paleontologist.

latter sections dealing with the local geology and types of fossils found here. It is hoped that the readers will find the guidebook useful in gaining an insight into the environment and history of this part of Ontario. References listed at the end will be useful to those who wish to pursue the subject further. Technical terms used in this guidebook are explained in the appended Glossary.

LOCATION AND NEIGHBOURHOOD

The location of the Craigleith area is shown in Figure 1. Nearby there are three Provincial Parks which display unique geological features of interest to students of natural history. Surrounding Wasaga Beach Provincial Park, about 16 km east of Collingwood, are interesting sand dune formations that originated along the shores of ancient Lake Nipissing almost 6,000 years ago. Devil's Glen Provincial Park, situated about 15 km south of Collingwood, is an ideal area to study the rock formations that make up the Niagara Escarpment, a major landscape feature of southern Ontario. Craigleith Provincial Park lies on the southern shore of Nottawasaga Bay about 10 km west-northwest of Collingwood and provides a unique opportunity to examine the fossilized remains of a variety of creatures that lived in this part of Ontario about 445 million years ago. The Craigleith area displays an outstanding variety of well preserved fossils and is among one of the very few fossil-rich localities in Ontario within easy reach of urban centres.

HISTORICAL AND GEOLOGICAL INTEREST IN THE CRAIGLEITH AREA

In historical times, the area around the southern shore of Georgian Bay has attracted the attention of a variety of workers, each dedicated to a different cause. Among them were missionaries, industrial entrepreneurs, and geologists.

In the early seventeenth century, the Craigleith area was inhabited by the "Petuns", who accepted Christianity from the French missionaries. Later, owing to disease and wars with the Iroquois, the Petun people were completely obliterated.

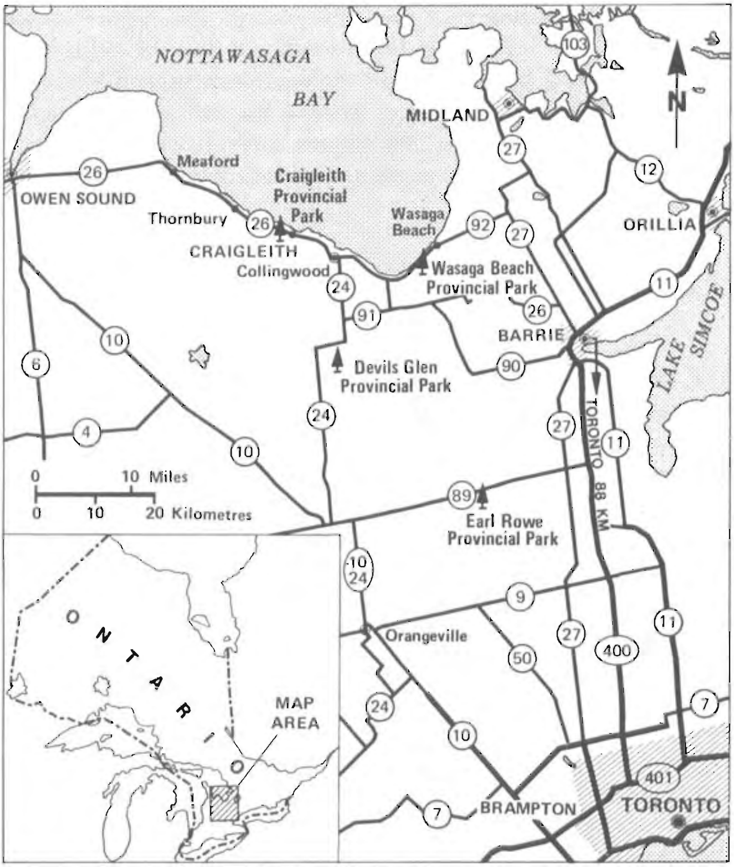
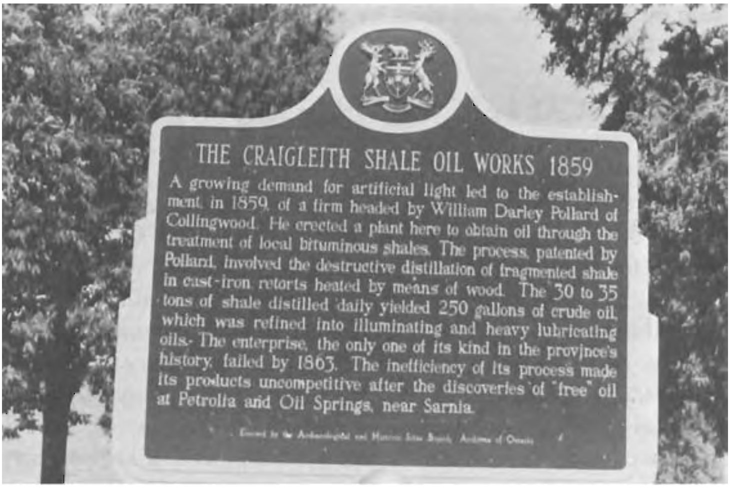


Figure 1 Location and neighbourhood of the Craigleith area.

Collingwood has an interesting industry-based history. It was a shipbuilding centre in 1850. The bituminous-smelling shales, the fossils of which are the subject of the present booklet, were also the basis of an interesting industrial experiment between 1859 and 1863. A plant for the extraction of oil from these shales was established at the Craigleith Park site. The project proved economically unprofitable and was soon abandoned. A plaque at the east end of the park commemorates this historical event (Photo 1).


THE CRAIGLEITH SHALE OIL WORKS 1859

A growing demand for artificial light led to the establishment in 1859, of a firm headed by William Darley Pollard of Collingwood. He erected a plant here to obtain oil through the treatment of local bituminous shales. The process, patented by Pollard, involved the destructive distillation of fragmented shale in cast-iron retorts heated by means of wood. The 30 to 35 tons of shale distilled daily yielded 250 gallons of crude oil, which was refined into illuminating and heavy lubricating oils. The enterprise, the only one of its kind in the province's history, failed by 1863. The inefficiency of its process made its products uncompetitive after the discoveries of "free" oil at Petrolia and Oil Springs, near Sarnia.

Photo 1 Commemorative plaque at Craigleith.

Systematic geologic exploration of what was then known as "The Province of Canada" began in 1843 when the Geological Survey of Canada was instituted. It was carried out by geologists and a number of explorers, some trained by the geologists. Geological descriptions of the land area surrounded by Georgian Bay, Lake Huron, and Lake Erie appear in several reports of the Geological Survey of Canada published between 1844 and 1863. Alexander Murray's account of the "Black Bituminous Shales" (1845, p.65-66), reproduced on p.viii, is the earliest of these descriptions.

In the early and middle part of the twentieth century, the Lake Simcoe area was to receive a great deal of attention from prominent geologists, including A.F. Foerste, W.A. Parks, W.S. Dyer, M.A. Fritz, G.W. Sinclair, and A.E. Wilson. The first comprehensive report on the geology of the area was published by Foerste in 1916, followed by a detailed account of the fauna in 1924. A comprehensive and updated synopsis of the geology and fauna, including descriptions of new species, was provided in 1928 by W.A. Parks, the first Director of the Royal Ontario Museum, Toronto. The latest comprehensive work on the subject is that of B.A. Liberty, who chose to study the geology and paleontology of the Lake Simcoe District for his doctoral thesis submitted to the University of Toronto in 1953. Liberty's memoir titled "Paleozoic Geology of the Lake Simcoe Area, Ontario" embodying the results of several years of studies, was published by the Geological Survey of Canada in 1969.

GEOLOGICAL FRAMEWORK OF ONTARIO

The geological setting of the rocks exposed on the shores of Nottawasaga Bay can be best understood in the context of Ontario's geological framework.

A look at the generalized geological map of Ontario (Figure 2) shows that the province is underlain by rocks of two main geological ages. About two-thirds of Ontario's bedrock surface is Precambrian in age. These rocks are older than 570 million years and make up part of the Canadian Shield. A complex variety of rock types occurs in the Shield. These include various sedimentary

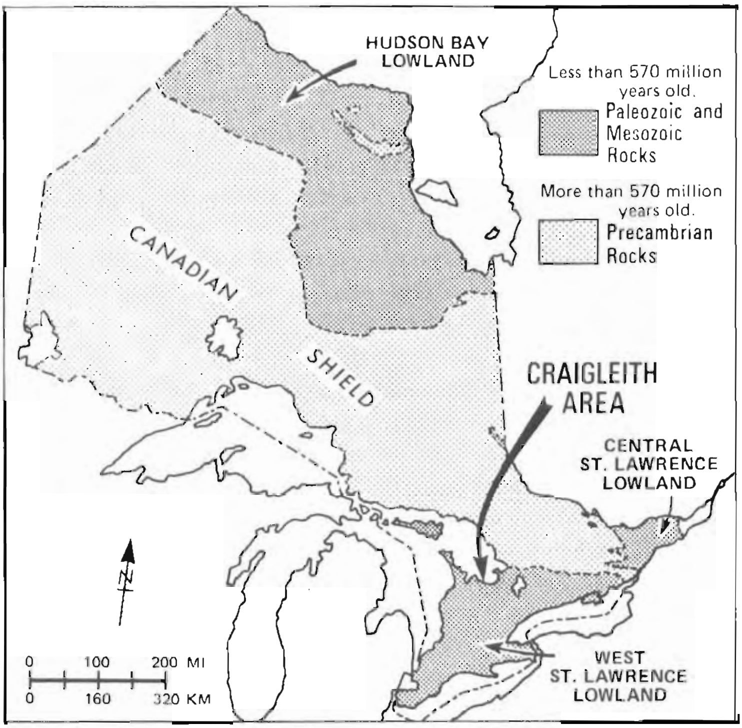


Figure 2 Generalized geological map of Ontario.

rocks as well as both intrusive and volcanic igneous rocks. To add to the variety, varying degrees of metamorphism have affected most of these Shield rocks. More significantly still, these rocks are the source of many economic minerals, including ores of nickel, copper, iron, gold, silver, and zinc. These Shield rocks constitute a vital basis of Ontario's mining industry. However, other than traces of ancient algae preserved in some rocks as old as 2,100 million years, the Shield rocks are devoid of recognizable fossils.

Rocks younger than 570 million years, known as Phanerozoic rocks, surround and cover parts of the Canadian Shield, as seen in Figure 2. These Phanerozoic rocks were deposited as sediments in seas that lapped onto the Canadian Shield which, 570 million years ago, was largely a rolling lowland. In Ontario, the Phanerozoic rocks occur in three separate areas:

(i) *The Hudson Bay Lowland,* occupying a large tract of northern Ontario south of Hudson Bay and west of James Bay;
(ii) *The West St. Lawrence Lowland,* south of a line extending from Midland to Kingston and bounded by Lakes Huron, Ontario, and Erie; and
(iii) *The East St. Lawrence Lowland,* east of the Canadian Shield and between the Ottawa and St. Lawrence Rivers.

The Phanerozoic Eon extends from 570 million years ago to the present and is further subdivided into three smaller subdivisions of time called Eras. Thus we have the Paleozoic Era or "age of ancient life" (from 570 to 235 million years), the Mesozoic Era or "age of middle life" (from 235 to 65 million years), and the Cenozoic Era, "age of recent life" (from 65 million years to the present). The uppermost part of the Cenozoic Era is termed the Quaternary Period and ranges from about 2 million years ago to the present. Although we have so far referred to the rocks of the St. Lawrence Lowland as Phanerozoic rocks, it is important to remember that rocks of only the lower Paleozoic Era and unconsolidated deposits of the Quaternary Period are represented in this area. During the upper Paleozoic, the Mesozoic, and a large part of the Cenozoic Eras, the seas regressed in this area and therefore no sediments were deposited; or if deposited have since been eroded away. Most sedimentary rocks containing record of past life are deposited by water in rivers, lakes or oceans; some sedimentary deposits are formed by action of wind, particularly in desert areas.

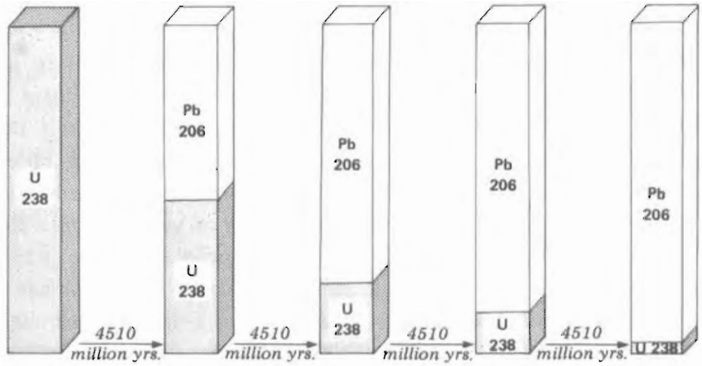
Before we take a closer look at the geology of the West St. Lawrence Lowland, which is our primary concern, we should digress for a moment to try and understand the immensity of geological time and discover how geologists determine the age(s) of rocks.

THE EARTH'S CALENDAR AND AGES OF ROCKS

Most geologists believe that this planet was formed about 4,500 million years ago from a primordial dust cloud. Through these many years of Earth's history, slow natural processes have produced spectacular results. A gigantic mountain chain may be worn to a flat plain through millions of years of erosion by water, wind, and ice. Conversely, sediments from the bottom of an ocean may be compressed and uplifted to form a mighty mountain system. Of course, these long periods of gradual change also included sudden catastrophic events similar to the volcanic eruptions and devastating earthquakes of recent times.

The immense length of geologic time is far beyond our comprehension when personal experience is limited to only a few score years. One possible way of viewing the past events in the Earth's history is to imagine all these events to have taken place within the span of a single calendar year. Taking the 1st of January as the beginning of the Earth and the midnight of December 31st as the present, the oldest rocks known to us were formed in the middle of March. Life first appeared on this planet in the middle of May. The first recognizable marine animals appeared in the third week of November. On this scale, the rocks that you see on the shores of Nottawasaga Bay were formed towards the end of November. Dinosaurs ruled the world between 15th and 26th of December, when they suddenly became extinct. Our ape-like ancestors first appeared late on the evening of December 31st. The vast ice sheets that covered much of northern North America began to recede from this area about one minute and fifteen seconds before midnight on December 31st. Mankind's written history began about 15 seconds before midnight. In this imaginary year, comprising the entire history of the Earth, the Roman Empire lasted only five seconds, from 11:59:45 to 11:59:50, and *Columbus discovered America about 3 seconds before midnight of December 31st.*

How do geologists determine the ages of rocks? Like detectives, they look for clues to the events taking place when the rock was formed. If the rock is igneous in origin (i.e. formed by cooling from a molten state either deep inside or on the surface of the Earth) the clue to its age is provided by radioactive elements (like uranium and thorium) that were incorporated in the rock in minute quantities at the time of its formation. In the early 1900s, it was discovered that radioactive elements, from the moment they come into existence, spontaneously break down to form other lighter elements, some of which may be radioactive and also suffer the same fate. This process of spontaneous disintegration, called radioactive decay, continues until a stable, nonradioactive element is formed that does not decay any further. For example, uranium-238 (one variety of uranium found in nature) eventually transforms into lead-206, a nonradioactive element. A convenient way of visualizing the transformation or decay process is to consider how much time is taken by one half of the original radioactive element to change to a nonradioactive element. This time is called the half life period and is different for different radioactive elements. In the case of uranium-238, the half life is 4,510 million years. In other words, if we start with one gram of uranium-238, one-half gram will change to lead-206 in 4,510 million years. The other one-half gram will still be uranium-238. In another 4,510 million years, one-half of one-half (one-fourth) of the original uranium-238 will be converted to lead-206, so that, after 9,020 million years, the sample will contain one-fourth gram of uranium-238 and three-fourths gram of lead-206 (see Figure 3).



At origin | *After One half life* | *After Two half lives* | *After Three half lives* | *After Four half lives*

Figure 3 Diagram illustrating radioactive disintegration of uranium 238 through four half-lives.

Let us turn the situation around. If, today, we found a one gram sample of uranium-lead mixture which, upon analysis, revealed a composition of one-half gram U-238 and one-half gram Pb-206, we would conclude that the sample had originated 4,510 million years ago, at which time all of it was U-238. Thus, by analyzing for the amount of a radioactive element present in a rock, and comparing this to the amount of nonradioactive decay products, the period of decay can be determined. This provides an absolute age, in years, for the rock. As shown in Figure 3, at the end of four half lives, one-sixteenth of the original radioactive element is left, the remainder having decayed. In theory, a given amount of radioactive element never completely decays. At any one time, it will always have one-half left to decay.

The above is a rather simplified explanation of the principle behind the technique used to determine the ages of rocks. For further study, including details of other radiometric methods, the reader is referred to an excellent book, "Geologic Time" by Don Eicher (see bibliography).

On the other hand, if the rock is sedimentary in origin (i.e. formed by compaction of small particles of sand, silt, clay or lime at the bottom of a body of water), the clue to the age of the rock is commonly supplied by the skeletal remains of organisms that lived in the water. Upon death, the bodies of some of these organisms become buried in the bottom sediment, and, over long periods of time, the hard parts are preserved as fossils. The use of fossils in determining the age of rocks is based upon the discovery, in the early nineteenth century, that rocks of different geological periods are characterized by different fossils. Knowing that in an undisturbed sequence of sedimentary rocks, each rock layer is younger than the one below it and older than the one above it, the fossil contents of rocks of adjacent areas can be compared. However, using fossils provides only a relative time scale; it merely tells us which rock formations are relatively older or younger than the surrounding rock formations. But, once a relative sequence of sedimentary rocks is reconstructed, it is possible to attach absolute ages to the sequence by determining, with the help of radiometric methods, the absolute age of any igneous rocks found in association with the sedimentary rocks. In this manner, for a given area, geologists can construct a stratigraphic scheme showing the types of rocks, their ages, and the types of fossils contained in the rocks. Such a scheme enables us to determine the ages of unknown sedimentary rocks merely by examining their fossil contents.

Radiometric methods are generally used to determine ages of Precambrian rocks, whereas the fossiliferous Phanerozoic rocks are dated by knowledge of fossils and their ages. One method can be used as a check and counter-check on the other.

One of the principal tasks of a geologist is to study rock formations in the field and in the laboratory to determine their origin, relative positions, and ages in the context of the local as well as world-wide geological record. The picture that emerges from this slow painstaking work is documented in the form of a geological map that incorporates all the information about the geology of an area. The Paleozoic geology of the Craigleith area is shown by Telford (1976).

PALEOZOIC GEOLOGY OF THE WEST ST. LAWRENCE LOWLAND - A BIRD'S EYE VIEW

Southwestern Ontario is underlain by rocks of the Lower and Middle Paleozoic Era, ranging from 570 million years to 360 million years in age. These are further subdivided by age, as seen in Figures 4 and 5, into rocks of the Cambrian, Ordovician, Silurian, and Devonian Periods.

The areal distribution of Cambrian, Ordovician, Silurian, and Devonian rocks in southwestern Ontario is shown in the simplified geological map (Figure 4). These layered rocks form roughly parallel belts trending in a northwesterly direction. The rock layers are slightly tilted southwestward and the belts are successively younger from northeast to southwest.

The bedrock geology of southwestern Ontario can best be understood with reference to the Niagara Escarpment. This prominent feature extends from Queenston Heights near Niagara Falls to Tobermory on the Bruce Peninsula. Bedrock occurring to the east and north of the Escarpment, including some in the lower part of the Escarpment, is Ordovician in age. Westward from Kingston to the Niagara Escarpment, one comes across belts of successively younger Ordovician rocks. Thus, the area extending from Kingston, past Lake Simcoe, to Nottawasaga Bay is underlain by limestones of Middle Ordovician age. Next westerly is the younger Upper Ordovician grey and black shales of the Whitby Formation, dealt with in detail later (p.16). Toronto, farther westward, is situated on top of still younger Upper Ordovician shales and limestones called the Georgian Bay Formation.

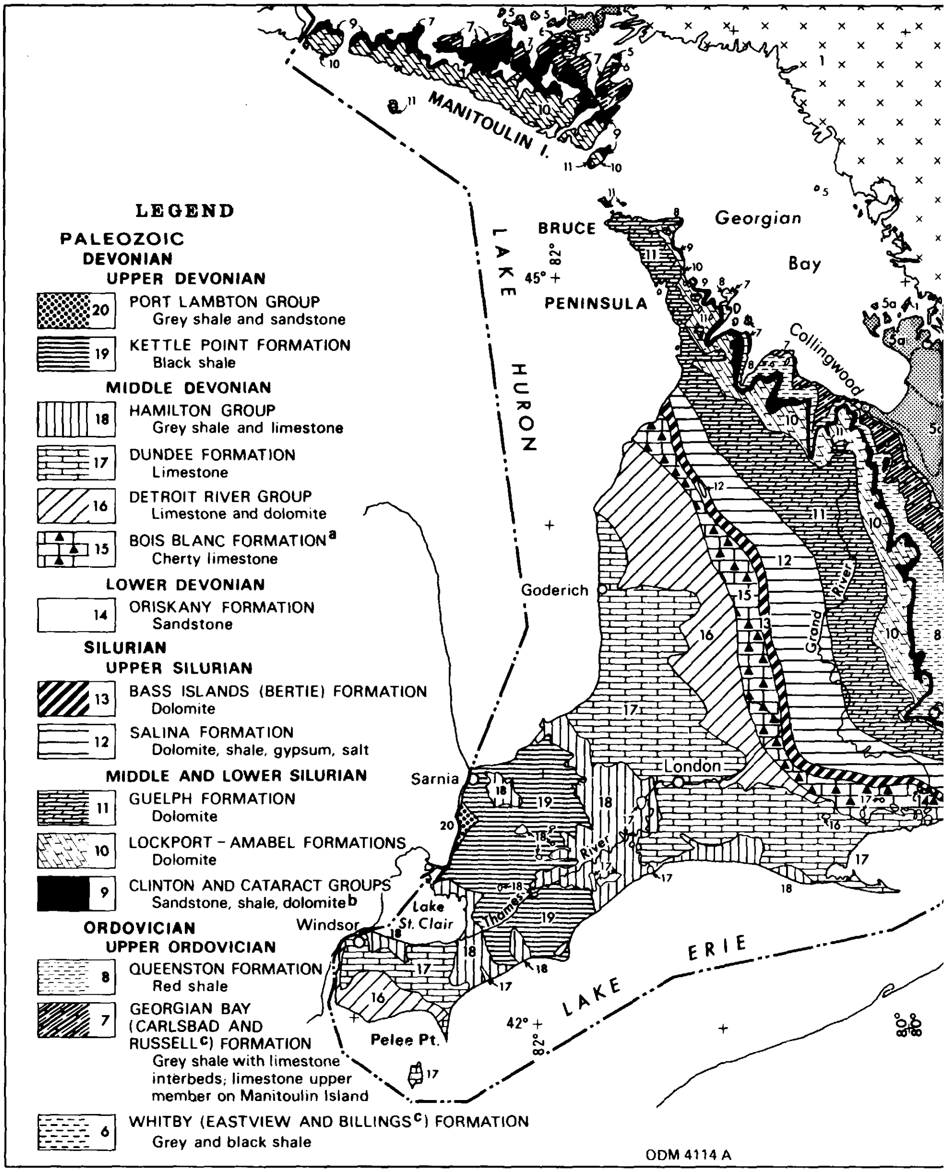
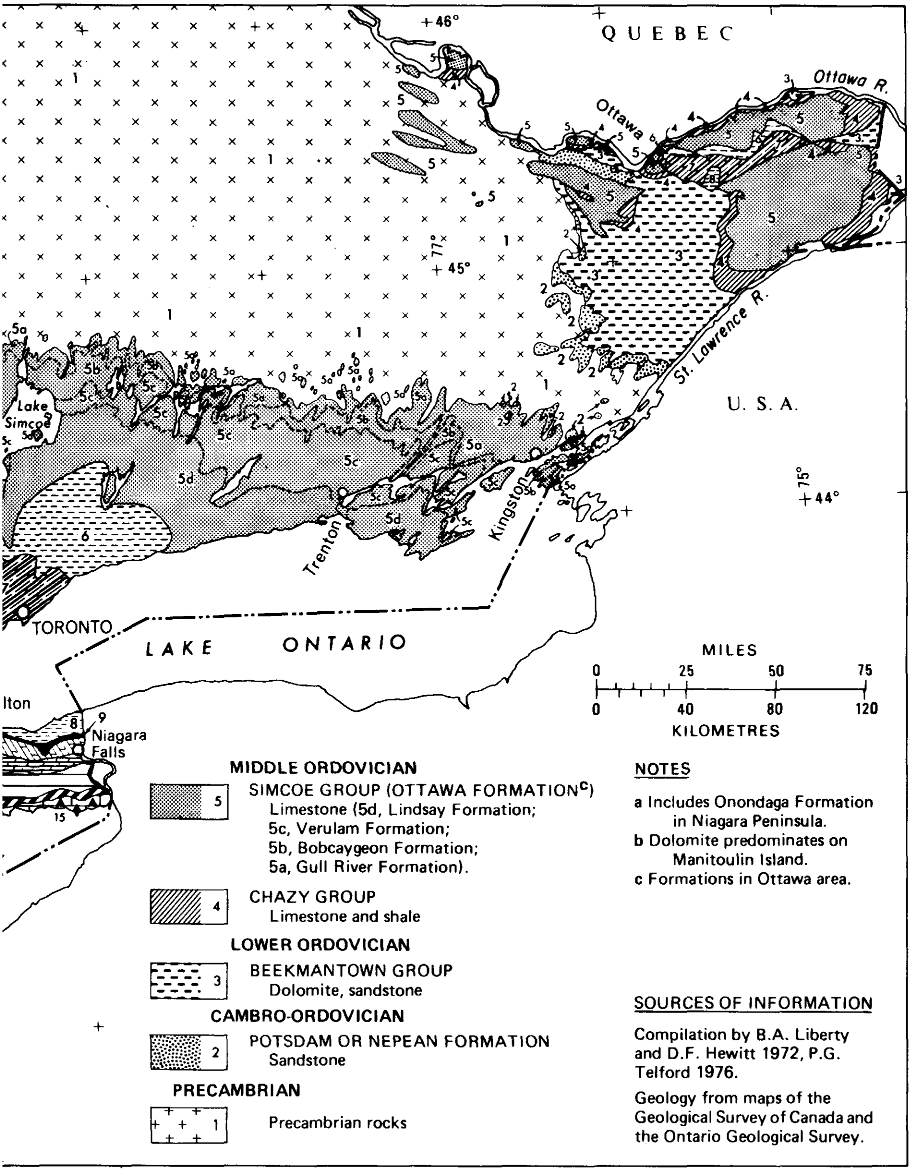


Figure 4 Simplified geological map of the West and Central St. Lawrence Lowlands.



MIDDLE ORDOVICIAN

▩ 5 SIMCOE GROUP (OTTAWA FORMATION[c])
Limestone (5d, Lindsay Formation;
5c, Verulam Formation;
5b, Bobcaygeon Formation;
5a, Gull River Formation).

▨ 4 CHAZY GROUP
Limestone and shale

LOWER ORDOVICIAN

▤ 3 BEEKMANTOWN GROUP
Dolomite, sandstone

CAMBRO-ORDOVICIAN

▒ 2 POTSDAM OR NEPEAN FORMATION
Sandstone

PRECAMBRIAN

+ 1 Precambrian rocks

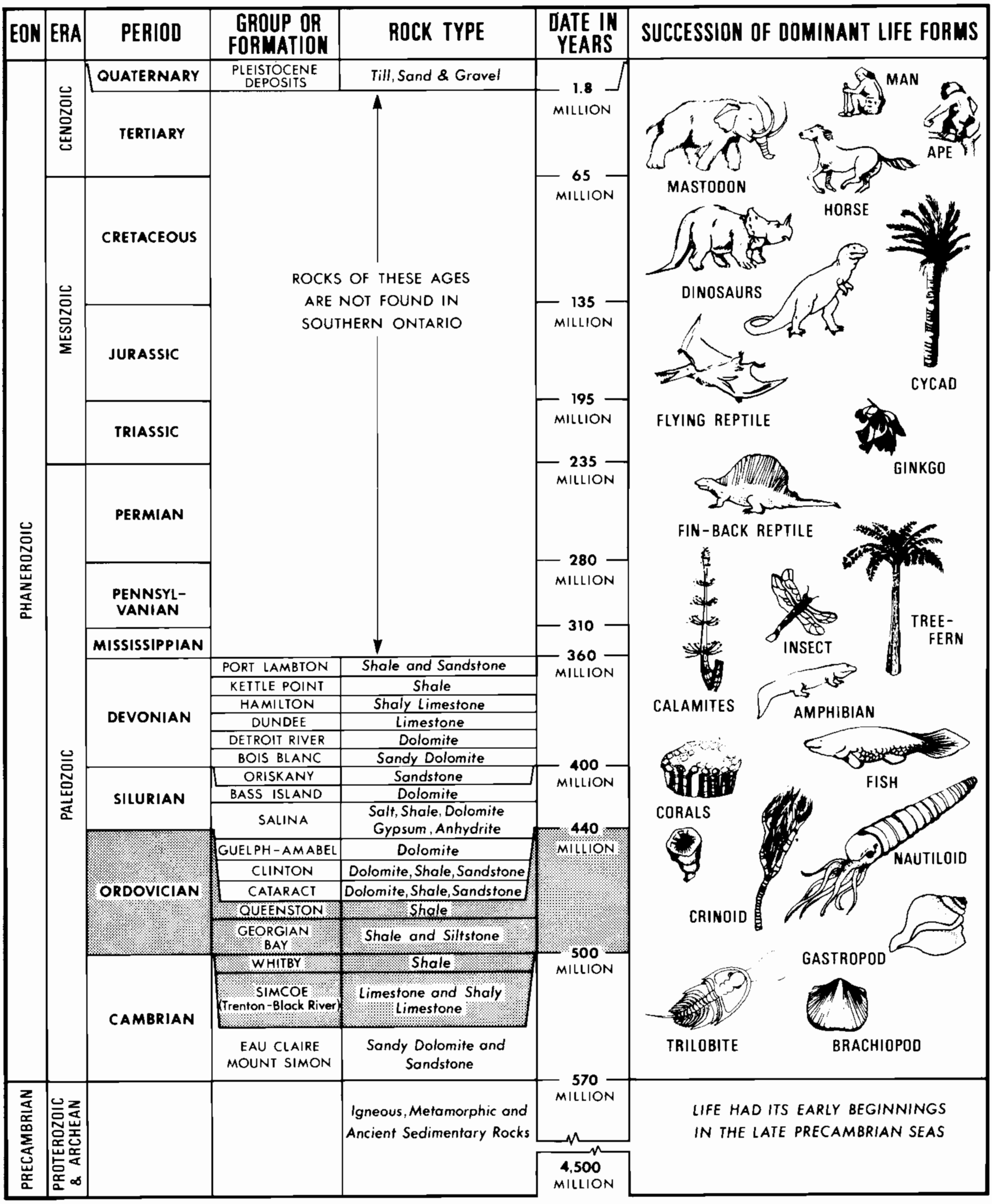
NOTES

a Includes Onondaga Formation in Niagara Peninsula.
b Dolomite predominates on Manitoulin Island.
c Formations in Ottawa area.

SOURCES OF INFORMATION

Compilation by B.A. Liberty and D.F. Hewitt 1972, P.G. Telford 1976.

Geology from maps of the Geological Survey of Canada and the Ontario Geological Survey.



EON	ERA	PERIOD	GROUP OR FORMATION	ROCK TYPE	DATE IN YEARS
PHANEROZOIC	CENOZOIC	QUATERNARY	PLEISTOCENE DEPOSITS	*Till, Sand & Gravel*	1.8 MILLION
		TERTIARY	ROCKS OF THESE AGES ARE NOT FOUND IN SOUTHERN ONTARIO		65 MILLION
	MESOZOIC	CRETACEOUS			135 MILLION
		JURASSIC			195 MILLION
		TRIASSIC			235 MILLION
	PALEOZOIC	PERMIAN			280 MILLION
		PENNSYLVANIAN			310
		MISSISSIPPIAN			360 MILLION
		DEVONIAN	PORT LAMBTON	*Shale and Sandstone*	
			KETTLE POINT	*Shale*	
			HAMILTON	*Shaly Limestone*	
			DUNDEE	*Limestone*	
			DETROIT RIVER	*Dolomite*	
			BOIS BLANC	*Sandy Dolomite*	400 MILLION
		SILURIAN	ORISKANY	*Sandstone*	
			BASS ISLAND	*Dolomite*	
			SALINA	*Salt, Shale, Dolomite Gypsum, Anhydrite*	440 MILLION
			GUELPH-AMABEL	*Dolomite*	
			CLINTON	*Dolomite, Shale, Sandstone*	
			CATARACT	*Dolomite, Shale, Sandstone*	
		ORDOVICIAN	QUEENSTON	*Shale*	
			GEORGIAN BAY	*Shale and Siltstone*	500 MILLION
			WHITBY	*Shale*	
			SIMCOE (Trenton-Black River)	*Limestone and Shaly Limestone*	
		CAMBRIAN	EAU CLAIRE MOUNT SIMON	*Sandy Dolomite and Sandstone*	570 MILLION
PRECAMBRIAN	PROTEROZOIC & ARCHEAN			*Igneous, Metamorphic and Ancient Sedimentary Rocks*	4,500 MILLION

Figure 5 Geological time chart - southern Ontario.

Most of the Niagara Escarpment itself, as well as a large belt of bedrock on top of the Escarpment to the west and south, is composed of Silurian dolostones and shales, as well as beds of gypsum and salt. The remainder of southwestern Ontario, extending up to the shores of Lake Huron and Lake Erie, contains bedrock of Devonian age. The break in the rock record since Devonian times spans nearly 360 million years. This type of break is called an unconformity. Marked by an erosional surface between two rock units, an unconformity represents an interruption in continuity of deposition between the eroded rock unit and the overlying unit. Thus, the Quaternary glacial deposits dating back several hundred thousand years rest, like a mantle directly on top of the eroded Paleozoic rocks. The distribution pattern of the Paleozoic rocks, as shown in Figure 4, has been reconstructed on the basis of natural and man-made exposures, as well as from geological records of oil and water wells drilled at many places in Ontario.

The reader should bear in mind the distinction between the *time stratigraphic* terms, such as Paleozoic or Ordovician, and the *rock stratigraphic* terms, such as Georgian Bay Formation or Queenston Formation. The former refer to a certain time period of Earth's history and are applicable over the entire Earth. The latter terms refer to a distinct group of rocks occurring in a certain area. Thus, the Ordovician rocks of Ontario may carry a different name than rocks of the same age in New York State.

The geological time chart (Figure 5) shows the position and geological ages of the various rock formations of southwestern Ontario and the rock types that constitute the individual formations. Also included is a sampling of the dominant animal and plant life that existed during those past ages. During the Ordovician Period, there were no land animals or plants and life in the seas was dominated by invertebrates (animals without backbones) similar to the modern day corals, clams, snails, lobsters, sea lilies, and squids.

ROCK FORMATIONS IN THE VICINITY OF CRAIGLEITH

The landforms and geological structure in the vicinity of Craigleith may be seen in Figure 6.

Limestones: Exposed along the shore of Nottawasaga Bay from Collingwood to Craigleith are limestones belonging to the Middle Ordovician Lindsay Formation. These limestones, composed of calcium carbonate, are grey to greenish grey in colour, are very fine textured, and very hard. Due to their hardness, the limestones that extend into the water now show up as prominent rock ledges. Such ledges are visible at the eastern end of Craigleith Provincial Park and along the shore to Craigleith. The limestones contain abundant fossils which are in places difficult to remove from the rock because of its hardness. Some limestone beds are separated by thin shale seams.

Shales: Westward from Craigleith, the limestones gradually become interbedded with shale beds so that shale becomes the dominant rock type along the shore all the way to Thornbury. These shales constitute the Whitby Formation and were earlier known by the name of Collingwood Shales or Craigleith Formation. These fine-grained shales are black to dark grey in colour, and can be easily split into thin slabs. They give an oily smell; hence the name “Bituminous Shales” used by the geologist Alexander Murray in 1845.

The most remarkable feature of these black shales is the abundance and diversity of fossils present in them. Generally, the fossils appear as broken shells or darker or lighter blotches or areas of slight relief best observed in an oblique light. Rarely, one may come across slabs that are entirely covered with one type of fossil, or slabs with one or more complete skeletons (see photos 2 and 3). These fossils give us a glimpse of the rich and diverse marine life that existed in the shallow sea that covered this area about 445 million years ago.

Fossilization is a highly selective process. Only a small fraction of any animal population living in a particular area ever gets fossilized, and a still smaller fraction of the fossilized remains may become available for observation. To be fossilized, animals must possess hard parts that withstand processes of decay, the wrath of predators and wave action, and be quickly buried upon death. The sediments which entomb the hard parts must be suitable for fossilization and many centuries must elapse before the mineral of the hard parts is replaced by a more stable mineral. Finally, the

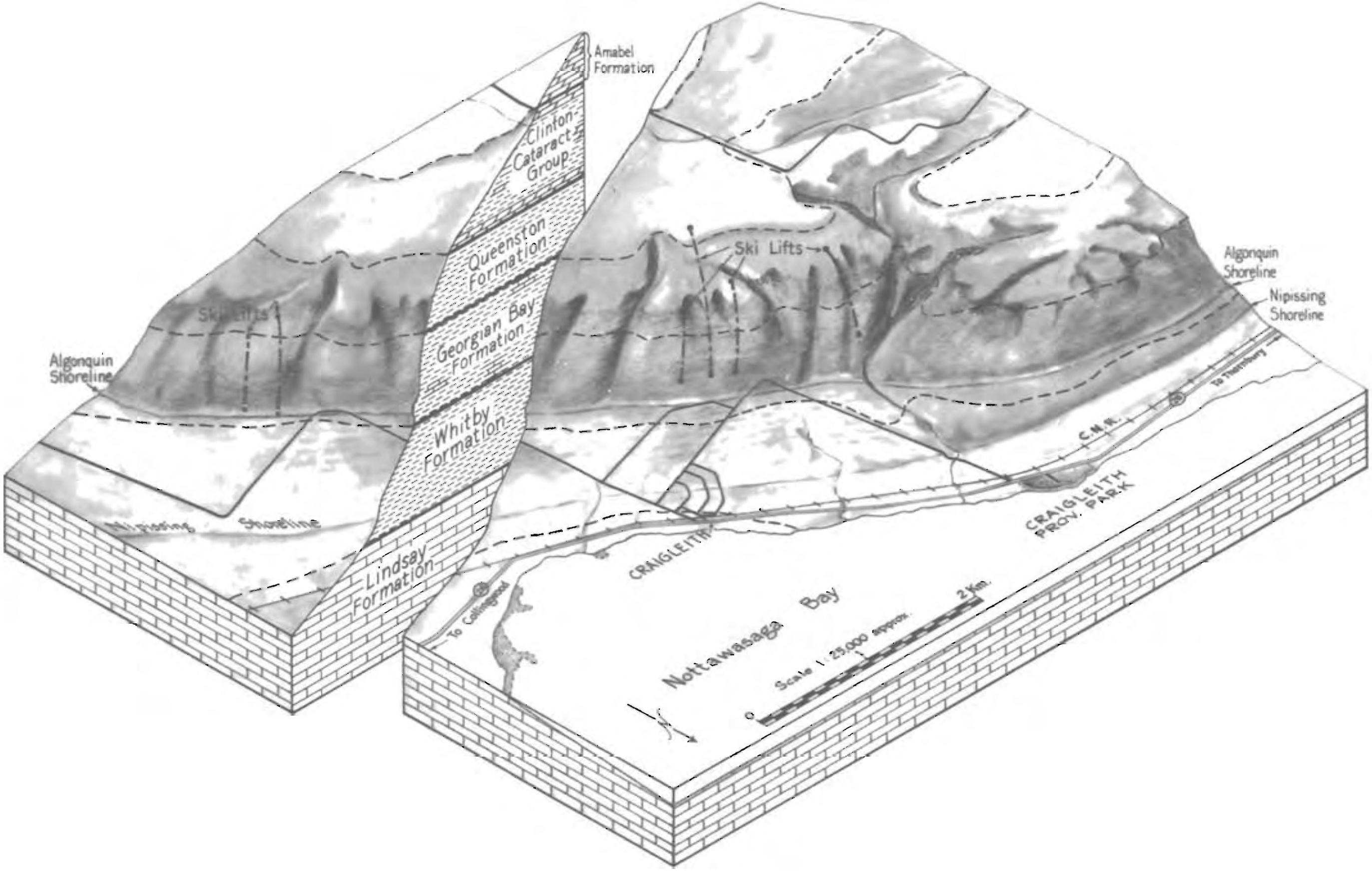


Figure 6 Block diagram showing topography and geology in the vicinity of Craigleith.

Photo 2 A rare slab of shale from Craigleith showing a cluster of *Pseudogygites latimarginatus* x1.5 (specimen courtesy Royal Ontario Museum).

rocks containing the fossils must become exposed at the surface and be collected before erosional processes destroy them. Since a fossil represents only the hard skeletal parts, reconstruction of the entire animal, including the soft fleshy parts, must be made on the basis of comparison with modern day descendants or other indirect evidence.

Fossilization of soft bodied animals occasionally occurs, but is an extremely rare circumstance with only a few examples known.

Among the very few examples of preservation of soft-bodied organisms are the famous fossils of Burgess Shale, exposed on the steep slope of Mount Wapta, British Columbia. The fossils consist of over a hundred different species of delicate soft-bodied animals and plants of Middle Cambrian age (515 to 545 million years old). They are seen as very thin carbonaceous films best observed in reflected light. The preservation is so complete that even the finer details of the anatomy can be easily reconstructed. These fossils were discovered, reportedly by accident, by Dr. Charles Walcott of the Smithsonian Institution, who spent nearly twenty years collecting and studying them. Another outstanding Canadian example of soft bodied animals is found in the cliffs near Cape Race, southeastern Newfoundland. These fossils look like sea-pens, jelly fish, and worms, and are believed to be about 700 million years old.

Bearing in mind that the fossils in the shale beds on the shore of Nottawasaga Bay constitute a very small sample of the actual life that prevailed here in the distant past, let us examine more closely the remains of these ancient inhabitants of Ontario.

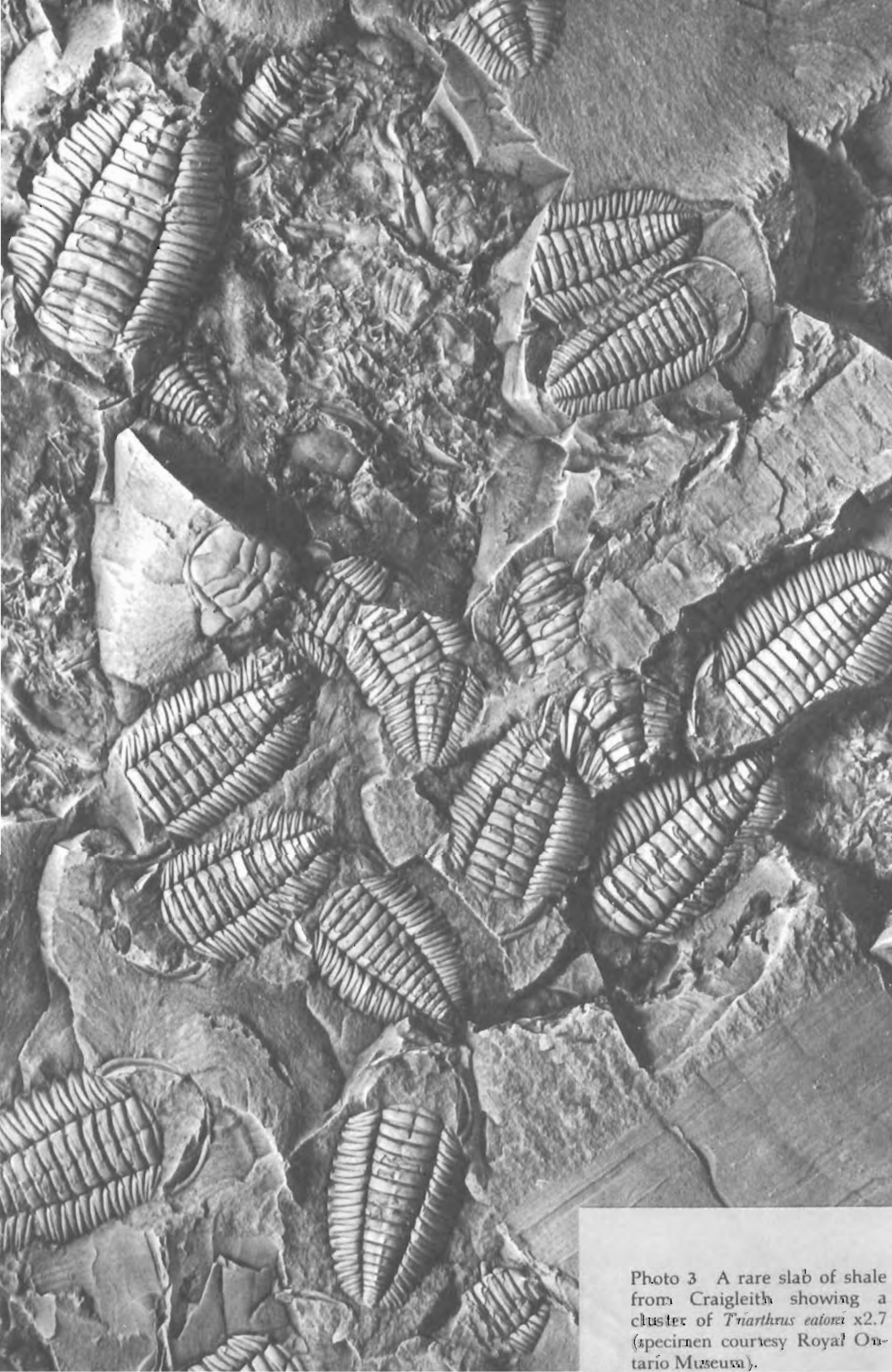


Photo 3 A rare slab of shale from Craigleith showing a cluster of *Triarthrus eatoni* x2.7 (specimen courtesy Royal Ontario Museum).

PART 2

Paleontology

CLASSIFICATION AND NOMENCLATURE OF ANIMALS

To those who are not familiar with the shapes of fossils and the kinds of animals they represent, the mixture of assorted and commonly fragmented shapes found on the slabs of shale can be puzzling. This confusion can be resolved by separating the fossils into groups of similar looking forms and then searching for small differences within each group.

A group of animals (or plants) having identical features and representing a distinct population is called a *species.* More precisely, a species is considered as a population of individuals capable of interbreeding to produce similar looking offspring. All the members of a species show identical features and have a similar mode of life. Since we have no way of knowing whether members of a fossil population actually interbred or not, we look for identical features as a means of grouping together members of a particular species.

To bring organization into the scheme and to facilitate communication among scientists, species showing close similarities are grouped together into a *genus,* similar genera into a *family,* similar families into an *order,* orders into *a class,* and classes into a *phylum.*

A species is the basic natural grouping of fossil populations. The groupings of species into genera, genera into families, and so on are based upon the information and judgement of the person studying the population. Availability of new information at a later time may make it necessary to transfer a species from one genus grouping to another. Such transfers are common in paleontology.

A system of naming organisms corresponding to the above scheme of classification is universally followed by those engaged in the study of different forms of life. Each species carries a unique two-word Latin name. The first word, a noun, is the name of the genus and the second word, an adjective, is loosely referred to as the name of the species. It is the combination of both the generic and the specific name that uniquely identifies a species. The generic name can be used for naming more than one species, but the specific name can only be used once for a single species. For example the human species is called *Homo sapiens.* A closely related species that lived in South Africa about 1,000,000 years ago is called *Homo erectus.* In scientific publications, the name of a species is followed by the name of the person who first named it and the year in which the first description appeared in print; this helps to track down original descriptions.

COMMON FOSSILS OF THE CRAIGLEITH AREA

The remarkable fossils of Craigleith range from tiny filamentous worms to giant look-alike ancestors of modern squids. One of these squids is reported to have been 5 m long, making it the largest creature living on Earth at that time! Also among the fauna are intriguing creatures, like graptolites and conulariids, whose ancestry and relationships with other forms of life are uncertain. Then there are abundant "lamp shells" called brachiopods. One of these, *Lingula,* still exists today and is known as a "living fossil" because it has remained essentially unchanged through about 500 million years; while most other animals have slowly changed through millions of years of evolution and a large majority have become extinct, *Lingula* lives in the oceans of today as it did 500 million years ago. Scattered on the surface of shales are carapaces (shells) of segmented animals called trilobites, most prolific in the waters during Lower Paleozoic times.

Among the Craigleith fossils, 11 different major groups of invertebrate animals, distributed into some 67 species, are present. The more abundant groups are:

— Trilobites
— Brachiopods
— Graptolites
— Cephalopods
— Pelecypods
— Gastropods and
— Conulariids

The rare groups include:

— Bryozoans
— Crinoids
— Annelids and
— Ostracodes

Let us now look at each of the abundant groups and some of the rare ones.

Trilobites

Trilobites (see frontispiece) are by far the most abundant and common of the fossils among the Craigleith fauna. They usually appeared as disjointed semicircular or oval mounds or depressions bearing several thin furrows. Complete specimens are rare.

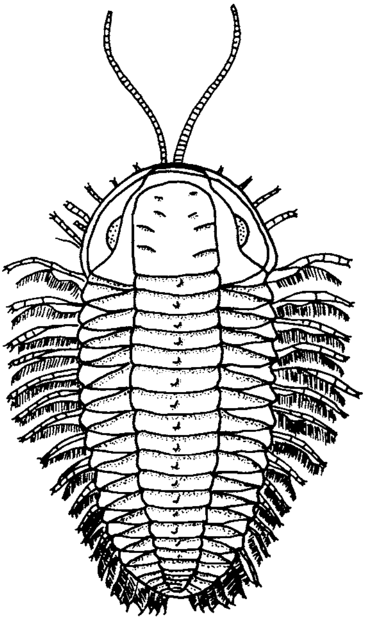
Trilobites constitute a class within the phylum Arthropoda (animals with jointed limbs) which includes crabs, lobsters, shrimps, spiders, and insects. The phylum Arthropoda is the largest among the phyla of the animal kingdom; 80 percent of all known living and fossil animal species belong to this phylum. Most arthropods are made up of a series of somewhat similar segments, paired jointed limbs on the underside and an external rigid skeleton with flexible joints. They have highly developed digestive, circulatory, reproductive, and nervous systems, including compound eyes. Members of the phylum are adapted to live in a variety of environments from the deep seas to high mountains.

Trilobites were marine animals. They suddenly appeared in the geological record at the beginning of the Cambrian Period and were the dominant form of life during the Cambrian and Ordovician Periods. Of all known Cambrian fossils, 60 percent are trilobites. They reached their climax of development in the mid-Ordovician, declining in numbers and diversity during the Devonian period, to become extinct at the end of the Permian. Due to their rapid evolution, trilobites are geologically very important and useful in comparing lower Paleozoic rocks all over the world.

As the name trilobite implies, the body is divided lengthwise into three lobes by two furrows which extend from front (head) to back (tail); the axial lobe in the middle and two lateral (pleural) lobes, one on each side. Transversely the trilobite body consists of three parts consisting of head shield (cephalon), body (thorax), and tail shield (pygidium). The eyes vary in size, shape, and location on the cephalon. During growth, the animal periodically shed its external skeleton by moulting. The moults, broken into cephalon, thorax, and pygidium, litter the sea floor. Sorting by wave action commonly resulted in a concentration of head, tails, and broken segments of the body in different areas. If the skeleton is found complete, it is probably the result of death of the animal rather than a moult stage. Some trilobite fossils are even found curled up with the head touching the tail.

Trilobites were scavengers and predators feeding on organic debris. They crawled or swam close to the sea bottom, and crawl tracks of trilobites are found in a few places preserved on bedding

1. Triarthrus eatoni x3
(ROM 34505)
Fossilized carapace.



2. Triarthrus eatoni x3
Restoration showing
appendages.

3. Flexicalymene meehi x1.5
(ROM 841 U)

4. Isotelus maximus x1.5
(ROM 30841)

Plate 1. Trilobites found in the Craigleith area.

surfaces of rocks.

Of the ten different species of trilobites recorded from the Whitby Formation of Craigleith, two are extremely abundant. These are *Pseudogygites latimarginatus* (frontispiece) and *Triarthrus eatoni* (see Plate 1). The former is large with an oval outline tapering at both ends. It has prominent eyes and approximately eight segments in the body (thorax). Isolated tails with a prominent axial lobe are extremely common. *Triarthrus eatoni* is smaller, elongate, and tapers at the tail. Its axial lobe is wider than the pleural lobes. The body has approximately 13 segments. Isolated head shields bearing horizontal furrows in the middle part are fairly common. A few other species of *Triarthrus,* differing in minor details from above, are also known to occur. Among the less common trilobites are *Isotelus maximus* and *Flexicalymene meeki.* All other trilobite species are extremely rare, commonly represented by a single specimen only.

Brachiopods

Although trilobites are the most abundant fossils in the Craigleith area, brachiopods or "lamp shells" form the most diverse group of fossils. Seventeen different species are known to occur in the Craigleith area. They appear as small oval to rounded mounds or depressions, usually carrying fine radiating or concentric striations. Unlike the trilobites, brachiopods are still living today; over 200 species thrive in the western Pacific. The fossil forms, however, greatly outnumber the recent ones; some 30,000 species have been recorded from post-Cambrian rocks. The climax of brachiopod development was reached in the Upper Paleozoic Era and their variety and abundance has continued to decline since that time.

Superficially, brachiopods resemble the common clams in that the soft parts of the animals are encased in a shell composed of two parts called valves. But the similarity ends there. Clams and brachiopods are two entirely different groups of animals. Clams are pelecypods, with the two valves similar to each other, and these are described later in greater detail on pages 37 and 38. The two valves in a brachiopod shell are dissimilar; the larger one is always convex and the smaller may be convex, flat, or concave (Figure 8). In certain brachiopods, called inarticulates, the two valves made up of phosphatic material are held together by muscles. In the second larger group, called articulates, the valves made up of calcium carbonate are held together by muscles as

Plate 2. Brachiopods found in the Craigleith area.

1. *Resserella emacerata* x2
   (ROM 34499)

2. *Lingula cobourgensis* x2
   (ROM 24897)

3. *Zygospira modesta* x2
   (ROM 27290)
   Pedicle and Brachial views.

4, 6. *Lingula cobourgensis* x1.5
   (ROM 219U)
   Pedicle view and cross section showing both Pedicle and Brachial valves.

5. *Rafinesquina deltoidea* x1.5
   (ROM 316T)

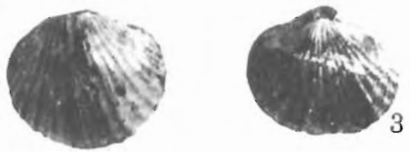
7. *Leptaena rhomboidalis* x2
   (ROM 25055)

8. *Sowerbyella sericea* x2
   (ROM 27279)

9. *Resserella rogata* x1.6
   (ROM 25057)

1

2



3

4

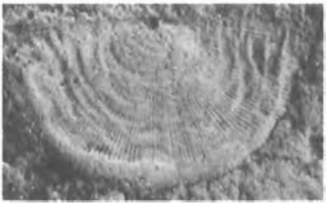
Pedicle View

5

Brachial Valve

6

Pedicle Valve



7

8

9

well as by teeth that fit into sockets on the opposite valve, forming a hinge mechanism. In most species, a long muscle protruding through an opening in the large valve is used by the animal to attach itself to the sea bottom. In the larval stage, however, the animal is free swimming.

The mode of life of brachiopods is known mainly from a study of living species. The animals live attached to the sea bottom, or other shells, and feed by filtering minute particles and small animals from the water. The water currents are guided in and out of the shell by the vibrating action of thin hair-like filaments which line two coiled arms of an internal organ which occupies a large part of the space between the valves.

The most interesting brachiopods in the Craigleith area are the several species of *Lingula* which, as mentioned above, live in the oceans of today just as they did 500 million years ago. Here is a striking example of an animal whose mode of life is so well suited to its environment that few changes have occurred in its biological design. *Lingula* lives peacefully in a burrow at the bottom of the ocean with the edges of its valves protruding to allow water currents to filter through. Because of its limited physical needs and protection from predators, the ravages of changing environments, and passing time have failed to obliterate this species.

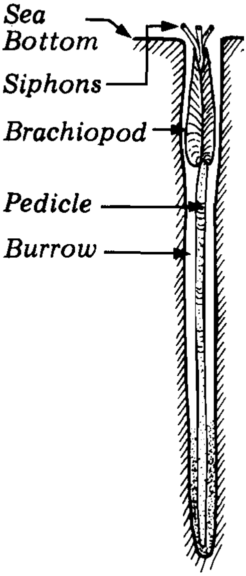
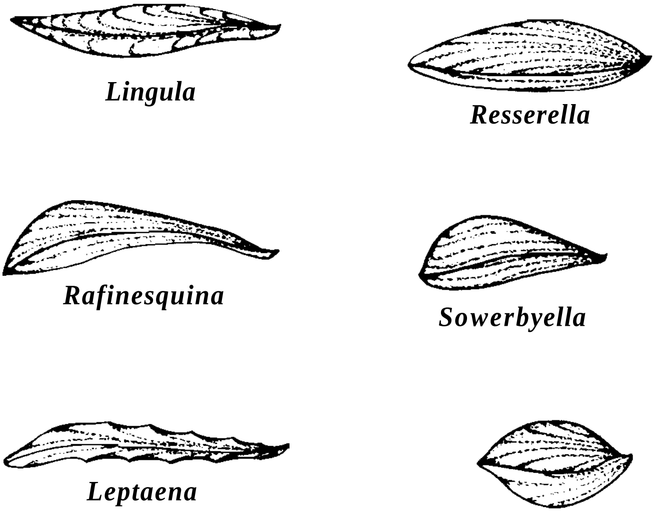


Figure **7**

Lingula (life position).

Other brachiopods that may be found in the Craigleith area (see Plate 2) are species of the following genera: *Resserella,* characterized by coarse ribs radiating from the apex of the anterior hinge edge; *Rafinesquina,* with a large, flat, semicircular shell composed of one extremely convex and the other flat or concave valve; *Sowerbyella,* with a broad and short shell having a straight hinge margin; *Leptaena* identified by concentric wrinkles on valves and a sharp right angle bend on each valve; and the tiny *Zygospira,* usually found with both valves strongly ribbed and convex. A comparison of section through the two valves of the above genera is shown in Figure 8.



Lingula

Resserella

Rafinesquina

Sowerbyella

Leptaena

Zygospira

Figure 8 Sketch illustrating the variety of curvature of the two valves of some of the brachiopods found in the Craigleith area.

Graptolites

What appear to be thin, black, pencil markings on the surface of the shales are in fact the former living quarters of an entire colony of mysterious animals known as graptolites (see Plate 3). The name, translated from Greek, means “writings on stone”. Like the trilobites, graptolites are extinct and geologically extremely useful. But, unlike the trilobites, each black pencil line is a colony and usually the entire colony drifted in the ocean waters attached to sea weed or a “floatation device”.

A closer examination, preferably with the help of a magnifying glass, will reveal that the edges of the graptolites have serrations like the teeth of a saw blade. Each tooth of the blade is, in fact, a compressed cup-like structure which housed the individual animal. Well preserved three dimensional skeletons showing great detail of structure have been obtained from limestones after dissolving the carbonate matrix. The shape, orientation, and arrangement of the cups varies in different genera and species, resulting in a large variety of forms. We know nothing about the soft

1. *Climacograptus typicalis* x2 *(ROM 24973)*

2. *Glossograptus quadrimucronatus* x2 *(ROM 24999)*

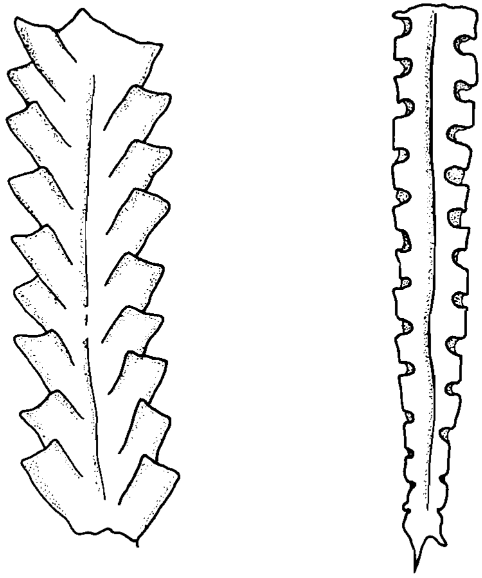
3. *Dictyonema arbusculum* x2 *(ROM 27289)*

4. *Diplograptus sp. x2 (ROM 30018)*

Plate 3. Graptolites found in the Craigleith area.

parts of the individual graptolites, as only their housing colonies are preserved.

Graptolites consist of two main groups, the dendroids and the graptoloids. The dendroids consist of branched interconnected chains, each composed of three distinct types of cups forming a regular alternating series. They are believed to have lived attached to the sea bottom.



Diplograptus sp. *Climacograptus prolificus*

Figure 9 Graptolites, *Diplograptus* sp., and *Cllmacograptus prolificus* (note curved nature of cups).

The second group, the graptoloids, show greater diversity and are extremely important to geologists as indicators of the age of rocks, especially those of the Ordovician and Silurian Periods. Because of their mode of life, floating on surface waters, they were distributed widely by wind and water currents. They also evolved rapidly into different forms. Consequently,
different types of graptolites follow one another in a rapid succession almost uniformly all over the world, enabling geologists to compare the ages of rocks from widely separated areas of the globe. Graptolites were dominant and widespread from early Or-

dovician to middle Silurian time, when they began to decline in numbers and diversity and became extinct in the early Devonian. Graptolites are outstanding examples of index fossils—fossils that, on account of their world wide distribution and restricted time span, have proved to be extremely useful in comparing rocks of identical ages all over the world.

The most abundant graptolites at Craigleith are species of *Climacograptus*, characterized by two rows of sharply curved cups facing upwards, the outer walls being somewhat parallel to the central line. The differences between the three known species are subtle. Another closely related form is *Diplograptus*, with the overlapping cups facing outwards (see Figure 9). Rare forms include *Glossograptus quadrimucronatus*, with sharply serrated edges, and *Dictyonema arbusculum*, a branching dendroid.

Cephalopods

Straight, conical molluscs called cephalopods are the largest fossils in the Craigleith area. *Endoceras proteiforme*, one of the Craigleith cephalopods, measuring about 5 m in length and 25 cm in diameter, was the largest sea creature known in Ontario's early Paleozoic world! Due to compaction, the specimens show only a faint tapering outline with parallel transverse ridges. Great care is needed to locate and extract individual specimens, as the rock is extremely friable. Sometimes, it may be necessary to cut around the specimen with a pavement saw and remove the whole slab rather than attempt to extract the specimen from the rock.

Cephalopods constitute only one class among the highly prolific and successful phylum Mollusca, which also includes such well known classes as pelecypods (clams, oysters, scallops and mussels) and gastropods (snails, limpets, whelks). Among the molluscs, the cephalopods are the most highly organized, largest, fastest-swimming predaceous carnivores. They are represented in the modern seas by squid, octopus, cuttlefish, and the pearly *Nautilus*.

In the geologic past, cephalopods were extremely abundant; several thousand species have been reported from rocks of all ages. They are now long past their climax of diversity. Some 600 species exist in the present oceans. Except for *Nautilus*, the modern cephalopods differ from the ancient ones in not having an external shell. Squids and cuttlefish have an internal skeleton; the octopus has no skeleton at all.

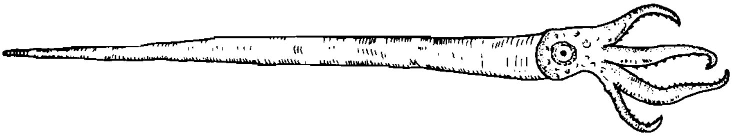


Figure 10 Sketch showing the life position of the cephalopod *Endoceras.*

The straight conical shell type is the common cephalopod in the Craigleith area (see Figure 10) and, as in all cephalopods, the shell is partitioned into several chambers by curved saucer-shaped walls called septa. As the animal grew, it secreted larger and larger chambers each time the living animal moved from its last chamber into the newly formed one. In life the animal occupied the last chamber (the body chamber) but carried the rest of the shell with it. When threatened, the animal withdrew into the body chamber and covered the front opening with a muscular hood. The chambers were connected to each other by a tube, called the siphuncle, that ran from the floor of the body chamber to the first formed chamber through a hole in the septa (see Figure 11). The septa strengthened the shell so that it was able to

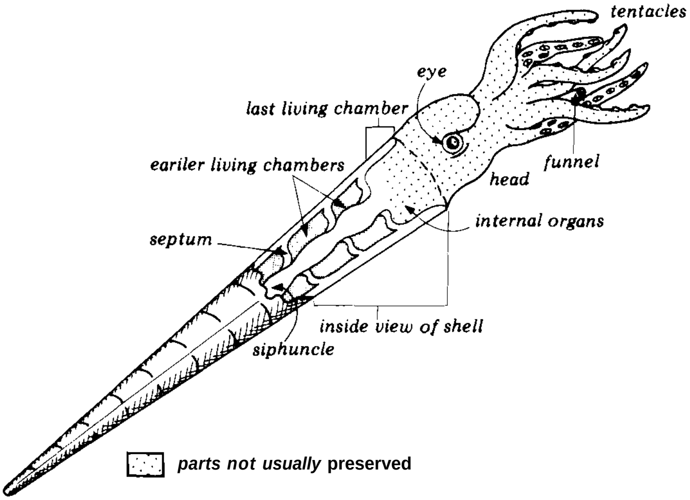


Figure 11 Schematic drawing of various parts of a cephalopod.

withstand the tremendous water pressures encountered at depth. The chambers between the septa provide buoyancy very much like the air chambers in a modern submarine. The surface of the shell commonly bore a variety of relief features, including ridges, knobs, and spines. Swimming was accomplished by ejecting water from a funnel-shaped organ located below the mouth. In this manner the cephalopods were able to propel their streamlined shell through the water. The bottom dwelling octopus, however, moves by crawling.

The cephalopods are subdivided into three main groups. These are: i) the nautiloids, ii) the ammonoids, and iii) the coleoids. The Craigleith cephalopods belong to the nautiloid category, ancestral to the living *Nautilus,* containing simple or slightly undulating septa. These primitive cephalopods appeared in the late Cambrian, became extremely prolific in mid-Silurian times, and declined nearly to extinction at the end of the Triassic Period. The second category, ammonoids, were an off-shoot of the nautiloids and are known, among other structures, by their complexly folded septa. They became extremely diverse during the entire Mesozoic Era and constitute important index fossils of the Triassic, Jurassic, and Cretaceous Periods. The third group, coleoids, include the modern squids, octopi and cuttlefish. The bullet-shaped internal skeletons of ancient coleoids, abundant in Mesozoic rocks are called belemnites.

Two species of straight- coned nautiloids are abundant in the Craigleith area. Of these, some specimens of *Endoceras proteifome* reached a length of over 3 m. Funnel-shaped chambers toward the open end are typical of this species. The fossilized remains have a large siphuncle lined inside with conical calcareous deposits. These calcareous deposits helped to counter-balance the shell, enabling the animal to swim in a horizontal position very much like the modern squids. The other common nautiloid, *Geisonoceras tenuistriatum,* is generally smaller and bears transverse ridges on the shell (see Photo 4). A third rare species, *Spyroceras bilineatum,* has transverse ridges on the shell as well as very fine longitudinal striations.

The conical markings on the shales at Craigleith are all that remain of the once formidable carnivorous “giant squids” that lived in the Ordovician sea.

Photo 4 Fossil nautiloid *Geisonoceras tenuistriatum* that lived in the Ordovician sea. x0.6 ROM 34503.

Pelecypods

The groups of animals described have become almost entirely extinct, but were extremely abundant in Ordovician times. In contrast, the pelecypods are one of the dominant groups today, being in the early phase of their development in the Ordovician. Some writers prefer to call them lamellibranchs or bivalves. They are the least abundant among the common fossils found in the Craigleith area. Occurring about the size and shape of lima beans, they lie scattered on the surface of the shales.

Like the brachiopods, pelecypods are encased in a shell made up of two curved plates called valves. However, as stated previously, brachiopods and pelecypods are two entirely different groups of animals with completely different anatomies, modes of life, and geological histories. A careful look at the shell shape of the two groups (Figure 12) reveals that, while the two valves of a brachiopod shell are unlike each other in most specimens, those of a pelecypod shell are generally identical mirror images. Also, each brachiopod valve is bilaterally symmetrical, whereas a pelecypod valve cannot be divided into two symmetrical halves.

Other important differences between the pelecypods and brachiopods are the manner in which the two valves are attached to each other and the manner in which they open and close their valves. Both valves in pelecypods carry teeth and sockets between adjacent teeth. The teeth of one valve dove-tail into the sockets of the opposite valve. In brachiopods, all the teeth are located on

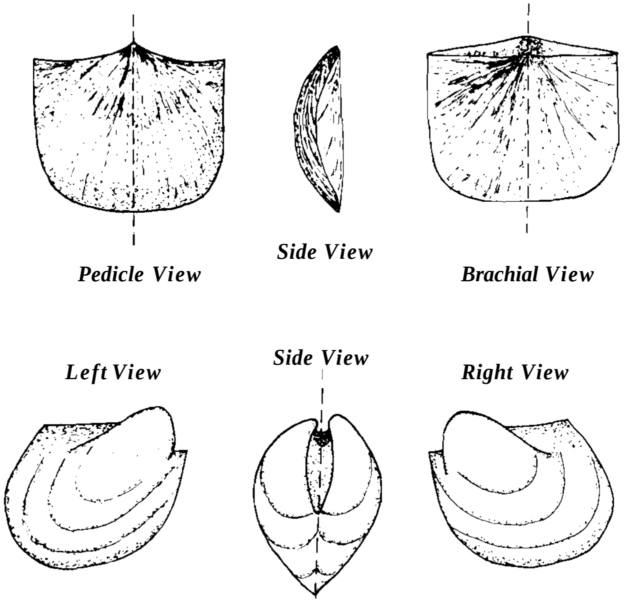


Figure 12 Diagram showing differences in shell shape of brachiopods and pelecypods.

one valve, and all the sockets on the other. The brachiopods have two sets of muscles, one for opening and the other for closing. Pelecypods have only one pair of very powerful muscles used for closing by contraction and for opening by relaxation. In the pelecypod, the opening is further aided by the spring-like action of an elastic cushion sandwiched in a cavity in the area of attachment of the two valves.

The modes of life of brachiopods and pelecypods are also quite different. Most brachiopods lead a sedentary (stationary) life attached to the sea bottom by a stalk-like muscle. Whereas some pelecypods attach themselves to the sea bottom, others burrow into soft sediment; still others crawl or “swim” by flapping their valves. Some show even greater versatility, having adapted themselves to life in fresh water.

The overall shape of the shell in pelecypods generally is an indication of the way in which the animal lived. Crawling pelecypods generally have a triangular shell, about as long as it is thick. Burrowing pelecypods have an elongate and narrow shell which facilitates burrowing. Sedentary pelecypods are attached to the bottom by means of a clump of threads extending from the foot.

The common oysters have an unusual mode of life. They live firmly cemented to the rocky sea bottom. The two valves in such pelecypods are extremely irregular.

The earliest pelecypods appeared in middle Cambrian times but the class did not become prolific until mid-Silurian. Many new genera appeared during the Mesozoic and today they are more numerous than they have ever been.

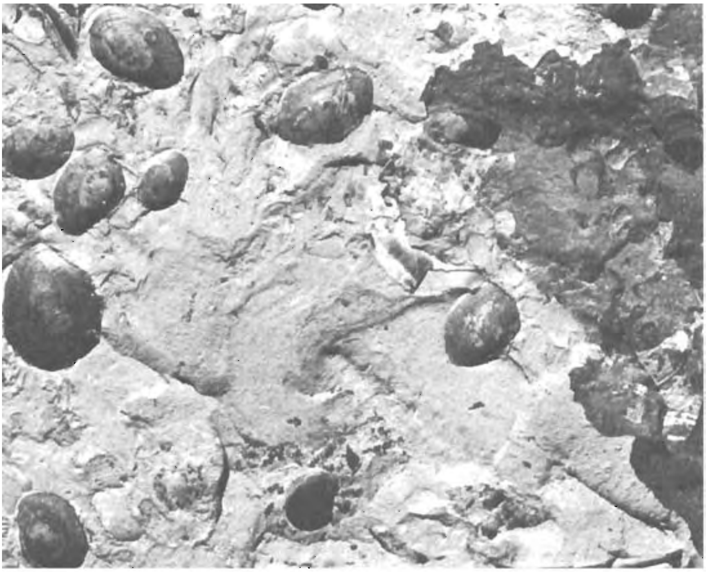
Almost all the Craigleith pelecypods belong to the genus *Ctenodonta.* The valves are oval in shape with faint concentric striations on the shell surface. Where the hinge line is preserved, it shows a series of small almost equal teeth. It appears to have been a form that ploughed through soft sediment in search of food. Five species are known to occur at Craigleith. The slight differences between them can only be determined by an expert. A somewhat larger pelecypod, *Modiolopsis brevis,* may be rarely found and is identified by a sinuous oval margin, a beak extending above the hinge line, and a well marked ridge extending from the beak to the posterior margin (see Figure 13).

Gastropods

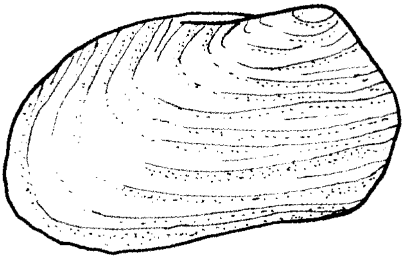
This group of molluscs, well known to modern shell collectors as snails, limpets, and whelks, are extremely abundant in the limestones in the Craigleith area (26 species). In the shales, only 2 or 3 species are found.

Gastropods are commonly characterized by the coiled spiral shape of their shell. The surface of the shell commonly has a variety of colour patterns and is covered with ribs, knobs and, in some specimens, long straight or curved spines. The most outstanding feature of the living animal is the broad muscular foot which enables the animal to creep “at a snail’s pace” by continuous waves of muscular contractions. The name gastropod refers to the belly-side position of the foot. A well developed head with eyes and a mouth containing a long armoured tongue are located above the foot (see Figure 14). Searching for food, the animal carries its shell as a refuge. Upon sensing danger the gastropod withdraws its entire body into the shell, closing a lid behind it.

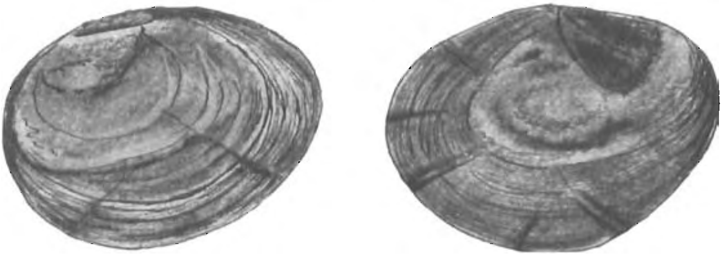
Although most gastropods are marine, some have adapted themselves to live in other environments including rivers, ponds, lakes, and even on land. The land snails have air breathing gills. This last adaptation makes the gastropods unique among the invertebrates considered above.



1. *Ctenodonta elongata* x2
(ROM 74DC4)



2. *Modiolopsis brevis*



3. *Ctenodonta georgina* x3
(ROM30024)

Figure 13 Sketches showing pelecypods, *Ctenodonta elongata, and Modiolopsis brevis,* and *Ctenodonta georgina.*

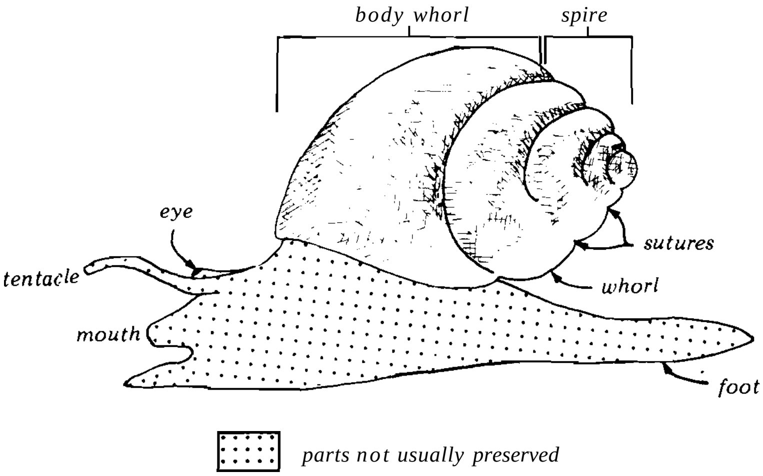


Figure 14 Sketch showing various parts of a gastropod.

Gastropods were first recorded in the Cambrian and many families evolved during the Paleozoic and Mesozoic. They became highly diversified during the Tertiary Period and today they are the most abundant class of molluscs. It is of interest to note that most of the Paleozoic gastropod fossils are found as mud-filled infillings (moulds). The shell material has been dissolved away. The Mesozoic and Cenozoic gastropods are better preserved, in some cases retaining the original colour markings.

Of the 26 species of gastropods recorded from the limestones of the Lindsay Formation, 6 belong to the genus *Hormotoma,* distinguished by high spires with many rounded whorls separated by deep notches and devoid of any ornamentation. Other important genera are: *Fusispira,* with a moderately high spire and inflated whorls; *Lophospira,* still lower spired with a ridge in the middle of the coiled whorls; and *Liospira,* with a much depressed acutely conical shell having marked ornament. There is great scarcity of gastropods in the Whitby shales. Rarely, one may come across *Ecculzomphalus,* coiled in one plane (see Figure 15) or *Trochonema,* another depressed spire, somewhat resembling *Lophospira* or *Pleurotomaria.*

1. *Ecculiomphalus ottawaensis x2 (ROM 303U)*

Top View

2. *Murchisonia trentonensis x0.7 (ROM 24916)*

Figure 15 Sketch of the coiled gastropod *Ecculiomphalus ottawaensls* and a photograph of the high spired *Murchisonia trentonensis.*

Conulariids

Another group of animals with ancestry just as enigmatic as that of the graptolites is the conulariids. Large numbers of individuals of a single species, *Conularia trentonenis latior,* are commonly found in the Craigleith area (see Photo 5). On the surface of the shale slabs, these fossils generally show up as two adjoining triangles with a series of parallel v-shaped grooves. In three dimensions, each specimen has the shape of a slender four-sided pyramid, each side being an isosceles triangle. Due to compaction generally two sides appear on the rock surface. Each plate is ornamented with ridges, grooves, and striations. Specimens of conulariids found elsewhere show what appear to be tentacles at the open end of the pyramid.

The absence of any similar living forms has led different paleontologists to group these mysterious creatures along with different animal groups. Some place them among worms. Others think they might be early forms of snails. The presence of tentacles supports the currently held majority view that these animals may be distantly related to the jellyfish, which has an umbrella shaped body from which hang tentacles and mouth parts.

Photo 5 *Conularia trentonensis latior* commonly found in the Craigleith area. xl ROM 30021.

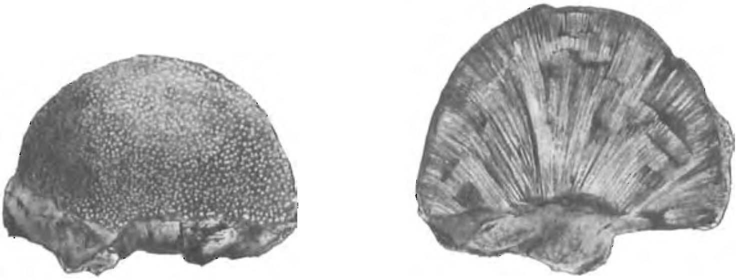
RARE FORMS AMONG CRAIGLEITH FOSSILS

The rare fossils encountered at Craigleith include bryozoans (moss animals), crinoids (sea lilies), annelids (worms) and ostracodes (crustaceans).

Bryozoans

Bryozoans are small animals that live in colonies. They lead a stationary life and occur as encrustations on sea weeds, shells, and rocks. Modern bryozoans include "sea mats" and "sea mosses".

Successive encrustations result in a globular, hemispherical, or irregular mass commonly resembling a coral colony. Bryozoan colonies may also grow as dendritic or fan-like branches or stems. Each box or tube-like chamber of the colony houses one animal, which feeds on microscopic organisms collected by tentacles extending from an opening in the chambers.



Side View *Oblique View*

Figure 16 Sketch showing the mound-shaped colony of the bryozoan *Mesotrypa prolifica.* x1.3 ROM 467U.

Bryozoans are common as fossils in all rocks from the Ordovician Period to the present day. Careful search at Craigleith may reveal a small mound-shaped colony of *Mesotrypa prolifica* (see Figure 16). Another bryozoan found at Craigleith belongs to the genus *Paleschara,* which generally occurs as thin encrustations showing polygonal openings. The limestones contain a greater variety of bryozoans than the shales.

Crinoids

Owing to their resemblance to flowers and attachment to the sea bottom with a long stem, crinoids were originally mistaken for flowers. Hence the name sea lilies. Actually they belong to the animal phylum called Echinodermata (animals with spiny skins), which includes such familiar forms as star fish and sea urchins.

The soft parts of the animal are encased in a cup-shaped structure called a calyx, made up of hard plates. The mouth, at the top of the cup, is surrounded by five long branched arms which gently sway in the water, gathering food. The long stalk is made up of several small discs strung end to end, very much like a beaded necklace (see Figure 17). Some crinoids have a system of roots at the base of the stalk. Others have a free swimming mode of life.

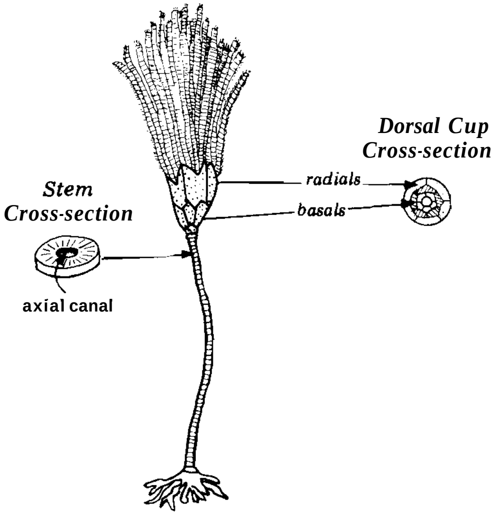


Figure 17 Sketch of a crinoid (life position) with accompanying cross-sections of stem and dorsal cup.

First appearing in the Upper Cambrian, crinoids are still represented by about 800 living species, mainly in the Pacific and Indian Oceans. They were fairly abundant during the Ordovician, Silurian, and Mississipian Periods.

Upon death, the skeletal parts disintegrate quickly. Preservation of an entire skeleton, including the calyx, stem and root, is therefore a very rare circumstance. At Craigleith, one may find parts of stems belonging to *Schizocrinus.*

Annelids

The occurrence of soft-bodied worms (annelids) in the geological record is generally deduced from the presence of bore holes in which they lived. In the Craigleith area, however, they are found as very thin, branching or parallel lines arising from a common point. They belong to the genus *Serpulites.* Two species have been recorded; *Serpulites serratus* and *Serpulites isolatus.*

Ostracodes

Ostracodes are tiny animals (2 mm or less) belonging to the class Crustacea. Modern crustaceans include crabs, lobsters, and crayfish. The ostracode body is enclosed within two oval plates hinged on one margin. The plates have pits, ridges, and spines. Fossilized plates or their moult stages occur fairly commonly in rocks of all ages. Only one species, *Primitiella ulrichi,* has been reported to occur in the Craigleith area.

PART 3

Paleoecology

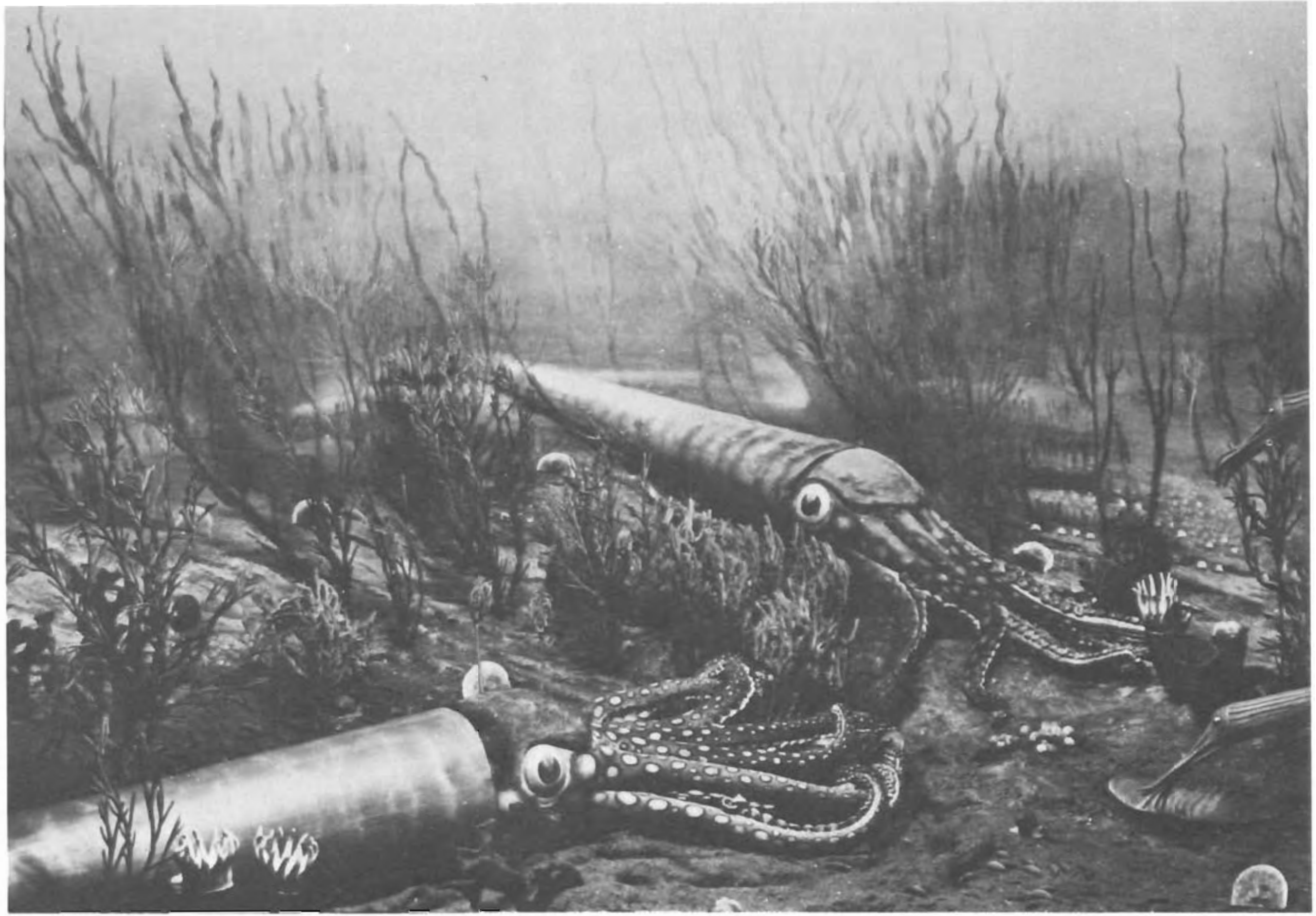


Photo 6 Life as it may have been in the shallow Ordovician sea (Photograph courtesy Royal Ontario Museum).

ORDOVICIAN ENVIRONMENT: A LOOK AT NORTH AMERICA 445 MILLION YEARS AGO

Having learned some facts about the nature of rocks and the kinds of animals found fossilized in them, let us try to reconstruct the environment that might have existed in the Craigleith area in late Ordovician times, 445 million years ago.

We know from radiometric dating that the last major period of metamorphism (rock alteration) and uplift in the Canadian Shield occurred about 1,000 million years ago. Therefore, by the beginning of Ordovician times, 500 million years ago, the exposed Canadian Shield would have been worn down by millions of years of erosion to a relatively flat and barren plain.

Evidence from the sediments of the ensuing Paleozoic Periods suggests that, although most of the North American continent was a stable landmass, it was repeatedly flooded by large shallow inland seas whose boundaries fluctuated with time in a somewhat cyclical manner. At the beginning of each cycle, the oceans flooded large continental areas, at times covering as much as half the present continent as seen in Figure 18. The predominance of so much water would have created a uniform climate. After ocean flooding had reached its peak, uplift of the Earth's crust caused the seas to retreat, as seen by the occurrence of smaller and more restricted marine sedimentary deposits. Following a period of continental emergence, the cycle was to repeat itself, although not exactly in the same manner as before.

Since the beginning of the Ordovician, the Earth's crust has been undergoing change of another kind. Large continent-size blocks called plates have moved vast distances over numerous geological periods and hundreds of millions of years. In Ordovician times, the North American continent was located in a far more southerly position, as indicated by the position of the equator in Figure 18. The southerly position of the continent has been deduced from evidence from a variety of sources and is further confirmed by the abundant paleontological evidence in the form of fossils of warm subtropical animals present in the rocks of that age.

During the Ordovician Period, the margins of the continental platform were bordered by deep elongate ocean troughs called geosynclines (Figure 18). Such a trough along the Atlantic margin was called the Appalachian Geosyncline. Toward the close of the Ordovician Period, unrest in the Earth's crust caused continental

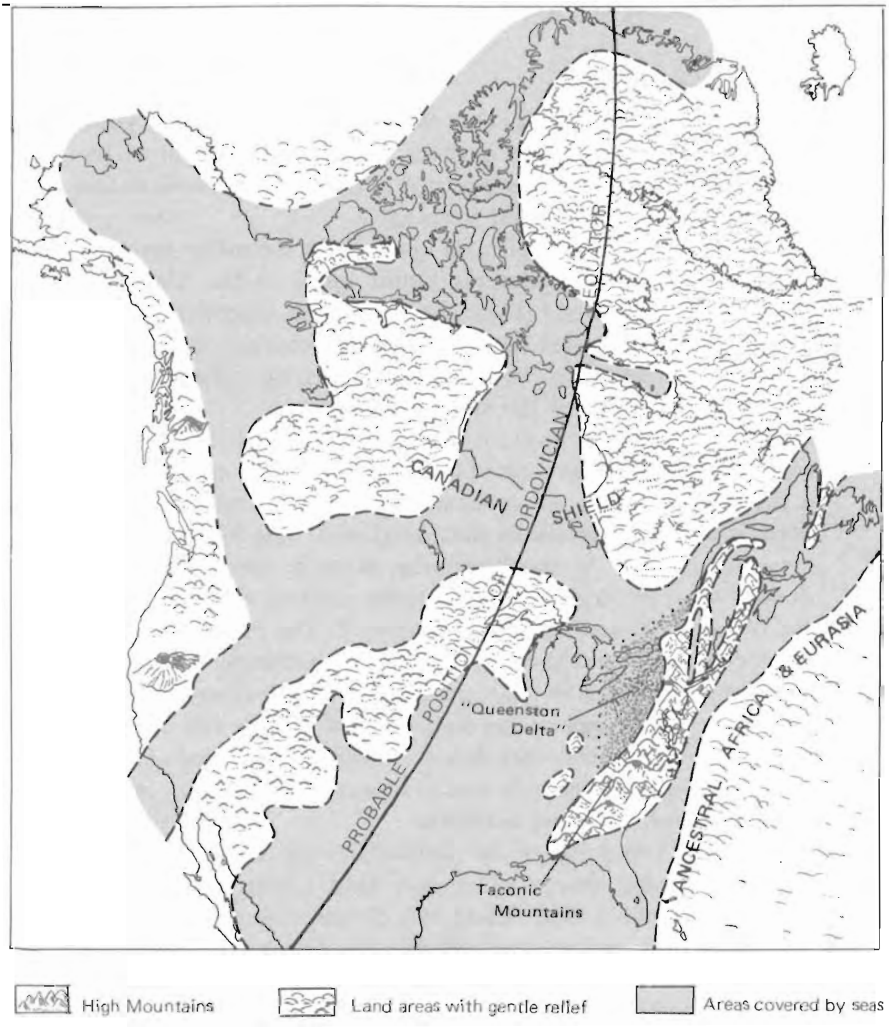


Figure 18 Geography of North America during upper Ordovician times.

drifting (movement of the plates) and, along the Atlantic border of North America, initiated a period of uplift and metamorphism called the Taconic Orogeny. This event is named after the Taconic Range which was created at this time; the Taconic Range is located today at the junction of Vermont, New York, and Massachusetts. At this time, about 445 million years ago, the Craigleith area was part of a shallow inland sea occupying a depression now called the Michigan Basin. Rivers issuing from the Taconic highlands deposited sediment west and northwest to build a broad tidal delta, usually called the Queenston Delta, which extended to the Michigan Basin. The sediments deposited in this and other marine basins of North America provide us with an almost complete fossiliferous record of the Cambrian, Ordovician, Silurian, and Devonian Periods. A diagrammatic cross-secton of the rock formations from the Taconic Mountains to the Michigan Basin is shown in Figure 19.

The kind of sediment deposited in a sea is generally determined by nearness to shore and the nature of the eroding land. Coarser sandy sediment is deposited near shore and in deltas, whereas the finer clay particles are winnowed out and deposited farther from shore. In places where sediments eroded from land could not reach, limy oozes may be deposited as chemical precipitates. In time, these layers or fans of sediment harden into rock: sand to sandstone, clay to shale, and limy ooze to limestone. If the position of the shoreline fluctuates, then so too will the types of sedi-

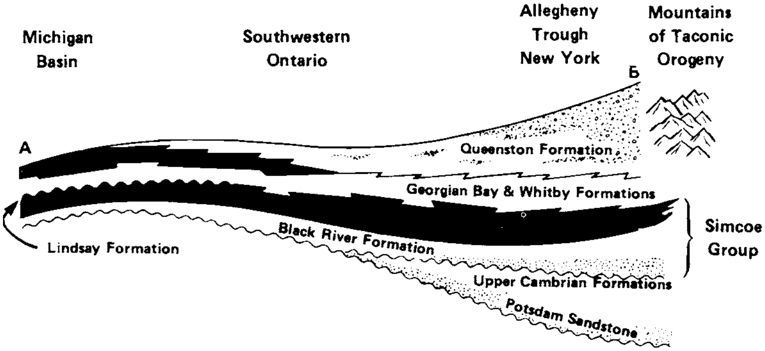


Figure 19 Cross-section of Cambrian and Ordovician formations in southwestern Ontario and northern New York State (modified from Figure VI-8, Geology and Economic Minerals of Canada).

ment. Thus, an area initially receiving sand may have layers of clay deposited on top when the sea deepens.

The Lindsay Formation, exposed on the shores of Nottawasaga Bay, is made up of limestones. From this we may conclude that during Middle Ordovician times this area was under sea, a considerable distance away from the shore. As we go upward in the rock sequence, a few shale beds start to appear. The shales increase in thickness and become the predominant rock type of the overlying Whitby Formation. This indicates infilling of the sea by increasingly coarser material related to erosion of the highlands created by the Taconic Orogeny.

The various types of invertebrate animals discussed in this guidebook either lived in the quiet muddy bottom of this inland sea or in shoals. In general, the limestones contain the remains of invertebrates bearing limy shells, including articulate brachiopods and gastropods, whereas the shales contain remains of animals whose skeletons were made up of chitinophosphatic material. Trilobites crawled on these muddy bottoms searching for food. *Lingula* lived a quiet life in burrows protected from predators while schools of giant cephalopods, the look-alike ancestors of the modern squids, cruised in the waters above looking for prey. Elsewhere in the deeper areas of the sea, swarms of sea lilies gently swayed while bryozoans encrusted rocks and dead shells. The minute graptolites floated attached to sea weeds. Buffeted by winds and currents, they were scattered far and wide. After death, their housing colonies gently fell to the sea bottom.

Such was life in the sparkling subtropical warm shallow sea that covered Ontario 445 million years ago. The variety and diversity of life in this sea was a sharp contrast to the barren rocks of the Canadian Shield and the rising Taconic highlands to the east.

CONCLUSIONS

In this guidebook, we have attempted to show how a closer look at what might appear as uninteresting pieces of rock can yield a wealth of information about the geologic history of an area.

With a clearer understanding about the nature of rocks and of the skeletal remains contained in them, the rocky shore of Nottawasaga Bay springs back into a myriad of exotic life forms that lived in a warm subtropical sea existing here a long time ago.

The study of fossils provides the clues to the ancient history of our planet. Once we understand how these "silent witnesses to yesterday" lived and became entombed in sedimentary rocks, the history of the Earth unfolds like the pages of a history book. Fossils help us reconstruct the ancient geography and climates of the different parts of the Earth. We become aware of the awesome forces that have acted on the Earth's crust, causing large continents to move, mountains to rise from the oceans, and highlands erode to flatlands.

Search and study of the past forms of life helps us understand the intricate pathways of evolution of life on this planet from the earliest microscopic single-celled animals to the highly developed human species of today. The picture, however, is far from complete. We are just beginning to understand the patterns of these evolutionary changes. There are enormous gaps in our present knowledge and numerous unsolved puzzles remain. But each new find brings us a small step closer to knowing the realities of the past.

Besides increasing our knowledge of the past, fossils allow geologists to correlate and date sedimentary rock sequences from widely separated areas, whether at the Earth's surface or underground. Oil geologists, by comparing the shells of tiny microscopic animals contained in rock layers, are able to correlate underground formations and locate possible oil-bearing rocks. Petroleum itself was formed by the underground burial over millions of years of the soft tissues of microscopic marine animals. Coal, another fossil fuel, was also formed by burial of vast swamps and forests. Thus, the process of fossilization is responsible for producing our natural resources of oil, gas and coal. Remembering that it took millions of years of natural processes to produce these vital resources, we ought to make renewed efforts to conserve and use these resources wisely.

The study of remains of ancient life can be a fascinating hobby. With the increase in leisure time, greater numbers of amateurs are getting interested in it. The search for fossils will take you out of doors and to many places not frequented by other students of natural history. Sedimentary rocks containing fossils are found in a variety of places. The people of Ontario are particularly fortunate in having a large part of the province underlain by fossil-bearing sedimentary rocks. There are many interesting localities close to urban areas. The most suitable places to look are shorelines, road cuts, riverbanks, and quarries.

ACKNOWLEDGMENTS

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The fossil specimens illustrated here are housed among the collections of the Royal Ontario Museum, Toronto. The author is grateful to Dr. Peter H. von Bitter, Dr. D.H. Collins, Mrs. Janet Waddington and Mr. David Rudkin, of the Department of Invertebrate Palaeontology, Royal Ontario Museum, for providing access to the collections and allowing the use of museum facilities. Dr. M.A. Fritz and Dr. Rolf Ludvigsen provided valuable advice.

All photographs were taken and prepared by the author. Line drawings were made by the author and Mr. A. Guthrie of the Regional Geologist's Office, Ontario Ministry of Natural Resources, London. The remaining figures were prepared by the drafting unit of the Scientific Review Office, Ontario Geological Survey.

GLOSSARY

Annelids - Worm-like animals having a segmented body with a distinct head and appendages.

Bedrock - Solid rock underlying vegetation, soil or loose surface material.

Bilateral symmetry - Exists when an organism or its parts can be divided into right and left halves so that one half is the mirror image of the other.

Brachiopods - Organisms with an external shell consisting of two dissimilar curved plates or valves. Each valve is bilaterally symmetrical. Also known as "Lamp Shells".

Bryozoans - A colony of animals usually encrusting sea weeds, shells, and bottom rocks. May also occur as globular or irregular masses or as fan-shaped or branched stems. Also known as sea mats, sea mosses, or moss animals.

Cambrian - The span of geologic time and corresponding rocks from about 570 to 500 million years ago; named after Cambria, the Roman name for Wales, where rocks of this age were first studied.

Cephalopods - Free swimming marine molluscs characterized by well-developed head, foot, mouth, eyes, and tentacles; commonly living in the outermost chamber of a multichambered straight or coiled shell.

Chitinophosphatic - Composed of chitin, a resistant organic compound and/or calcium phosphates. Chitin is a skeletal forming material in some animals e.g. trilobites.

Class - A grouping comprising one or more smaller subgroupings of organism called orders.

Clastic - Containing fragments (clasts) of pre-existing rocks. cf. detrital.

Conulariids - Extinct marine animals of uncertain affinities, characterized by a cone- or pyramid-shaped body commonly having longitudinal markings.

Correlation - The determination of the position or place of a geologic formation or phenomenon in space or time with respect to a similar formation or phenomenon from another area.

Crinoids - Marine animals resembling flowers. They possess a system of roots, a long beaded stem, a cup-shaped head containing soft parts, and five branched arms extending outwards from the head. Also known as sea lilies.

Dendritic - A branching pattern, as that of a deciduous tree.

Detrital- Formed from loose rock materials (detritus) moved from their place of origin. cf. clastic.

Devonian - The span of geologic time and corresponding rocks from about 400 to about 360 million years ago; named after Devonshire county, England, where rocks of this age were first studied.

Dolostone - A variety of limestone consisting mainly of the mineral dolomite ($CaMg(CO_3)_2$).

Eon - A subdivision of geological time, next in order of magnitude above an Era, e.g. Precambrian Eon, Phanerozoic Eon.

Era - A geological time unit comprising several smaller time units called Periods, e.g. Paleozoic Era, Mesozoic Era.

Evolution - Gradual change, with time, of life forms.

Family - A grouping of (one or more) closely resembling genera. Ranks above *genus* and below *order*.

Friable - A rock or mineral that is easily crumbled or reduced to powder is said to be friable.

Gastropods - Molluscs characterized by a head with eyes and tentacles; living in a conical, spirally coiled, “unpartitioned” shell. Commonly known as snails.

Genus - A grouping of species which closely resemble each other.

Graptolites - Extinct colonies of marine organisms consisting of one or more strands lined up with cup-like structures, each cup housing one animal. Ancestry and relationships of these animals are uncertain. .

Limestone - Sedimentary rock consisting of calcium carbonate; primarily as calcite ($CaCO_3$).

Metamorphism - Processes whereby rocks undergo change within the Earth’s crust in their mineralogy and appearance mainly through the action of chemical solutions or changes in pressures and/or temperatures. The altered rock attains a new structure and often a new mineral assemblage.

Metavolcanic - Metamorphosed rocks of volcanic origin.

Molluscs - A group of animals (phylum) with a wide range of form and life habits but sharing the following common characteristics: bilaterally symmetrical non-segmented body with an anterior mouth and a posterior anus; principal sense organs grouped around a distinct head; soft parts of the body encased in a sheath called the mantle, with which it secretes its shell, and locomotion is generally by means of a foot-like muscular extension of the body.

Ordovician - Span of geologic time and corresponding rocks ranging in age from 500 to about 440 million years ago; named after a

Celtic tribe called “Ordovices”, who lived in the area where rocks of this age were first studied.

Order - A grouping of several families of organisms.

Ostracodes - Very small organisms possessing a bivalved shell containing a segmented body with appendages including antennae.

Outcrop - That part of bedrock exposed at the Earth’s surface.

Pelecypods - Sea-bottom dwelling molluscs having a hatchet-shaped foot, sheet-like gills and an external shell consisting of two generally similar convex plates or valves. Commonly known as clams. Also known as lamellibranchs or bivalves.

Phanerozoic - All geologic time and the corresponding rocks younger than about 570 million years before present.

Phylum - A major taxonomic unit of closely related animals within the animal kingdom. Ranks above class and below *kingdom*.

Precambrian - All geologic time and the corresponding rocks occurring before the Cambrian Period, older than about 570 million years before present.

Radiometric dating - Techniques of determining rock ages by analysing radioactive elements and their decay products.

Sandstone - Consolidated sedimentary rock consisting of mineral or rock grains between 0.1 and 2.0 millimetres in diameter firmly united by a cementing material.

Sediment - Fragmental material (such as sand, gravel, silt, limy mud, and till) resulting from the weathering and erosion of rocks forming unconsolidated layers on the Earth’s surface.

Shale - Sedimentary rock, commonly showing fine laminations, formed by compaction and consolidation of clay, silt, or mud.

Silurian - The span of geologic time and corresponding rocks from about 440 to about 400 million years ago; named after the Celtic tribe called “Silures”, who lived in the area where rocks of this age were first studied.

Species - A population of animals or plants capable of interbreeding to produce similar looking offspring.

Stratigraphy - The branch of geology dealing with the nature, extent and characteristics of rock strata, mainly those of sedimentary nature.

Tentacle - A flexible elongate organ of invertebrate animals. Commonly used as a sensory or food gathering organ.

Trilobites - An extinct group of sea-bottom dwelling animals characterized by a three-lobed body consisting of a large head, a segmented body and a tail.

Whorl - One complete turn through 360 degrees of a spiral or coiled shell.

ANNOTATED BIBLIOGRAPHY

A large number of publications dealing with the subject of paleontology are presently available. The following annotated bibliography will enable the readers to equip themselves with further knowledge on the subject of fossils. Some publications are particularly related to fossiliferous rocks of Ontario. Works marked with an asterisk (*) are of a more technical nature.

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