Bay de Verde
Field Trip

October 23-24, 1992

Contents

Overview of Newfoundland Geology

General Introduction

The Earth's crust is made of rock. There are many kinds of rock formed in different ways at different times. In any one area of Newfoundland and Labrador, rocks of different kinds and ages are found. These tell the story of the way in which the area grew geologically. This guidebook helps to illustrate that story and will show you how to learn from field observations about the rocks you can see around you.

400 million years ago the island of Newfoundland was part of a 5 000 kilometre long mountain chain that included the Appalachian Mountains of the eastern U.S.A., the Maritimes of Canada, Newfoundland, the Caledonian Mountains of Scotland and the mountains in Norway. The hills of Newfoundland now are just the eroded remnants of that range of mountains. The mountain range was formed during the collision of two continents which trapped the rocks of the intervening ocean between them. Present day mountain ranges form in the same way - due to a process known as plate tectonics which will be explained later.

In Labrador, the rocks are the remains of even older mountains. The oldest rocks there are between 3 000 and 4 000 million years old; nearly as old as the Earth itself, which formed about 4 600 million years ago.

Since the formation of the Appalachian Mountains, a new ocean - the Atlantic Ocean - split Europe from America and during this process the Grand Banks were formed at the new edge of the American continent. Under the Grand Banks are younger rocks than are found on land here. These younger rocks contain the oil fields such as Hibernia.

Before explaining the history of the area in detail, let us look at rocks - the different kinds and ages - and learn how to examine them and understand the way they formed.

Rocks

The rocks on the earth's surface can be divided into three major groups, all of which can be seen in Newfoundland and Labrador. These are igneous, sedimentary and metamorphic rocks. The names of the groups indicate the way in which the rocks were formed (See Figure 1).

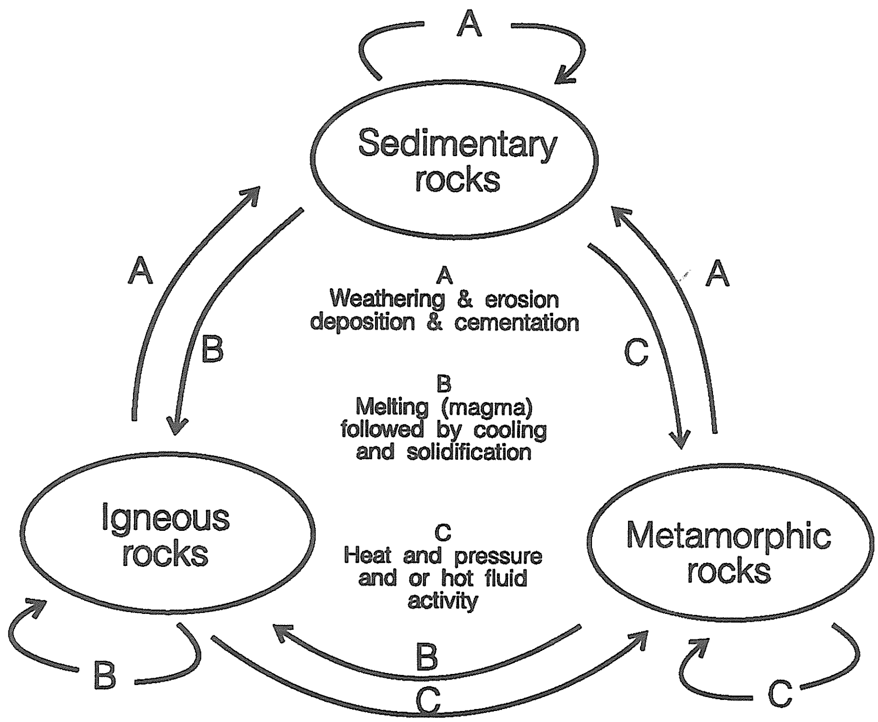


Figure 1. Rock Cycle

Igneous Rocks

Igneous rocks are so named because the word 'igneous' comes from the Latin word for fire. These rocks are formed from very hot melted rock called *magma*. If magma cools below the surface it gives rise to crystalline rocks with large crystals which can be seen with the naked eye. Large bodies are known as plutons or batholiths, and small intrusions that fill narrow cracks in existing rocks are known as dykes or sills. An example of an intrusive rock on the Avalon Peninsula is the Holyrood granite.

If the magma is extruded on the earth's surface, it is known as *lava* and the crystals are often so small a microscope is needed to see them. Pillow lavas found in Notre Dame Bay are good examples of extrusive igneous rock.

Sedimentary Rocks

When rocks are broken up and carried to rivers, lakes or the sea by ice or water, the rock fragments are laid down under water in layers. In deserts or near glaciers, small fragments can also be moved by wind. The fragments may be made of any kind of rock. When the fragments are loosely packed, they are known as sediments. Examples of these are silt and mud. If, after a long time, the fragments become buried and/or cemented together into solid rocks such as mudstone, shale or sandstone, they are known as sedimentary rocks. The layers in sedimentary rocks are known as beds. Good examples of these are found in Bell Island and areas around Manuels.

When carbonate material is precipated in the ocean by the action of animals or is a collection of animal shells such as clams and lobsters, it forms sedimentary rock called limestone. *Coral* reefs, which usually form in warm tropical water conditions, are modern examples of limestone formation. Ancient Cambrian reefs that are found near Forteau in southern Labrador and on the Northern Peninsula are formed by extinct animals called *archeocyathids.*

Metamorphic Rocks

Metamorphic rocks (literally those with changed form) are produced when any type of rock is subjected to heat and/or pressure (See Figure 1). The rock is changed so that the chemical elements are rearranged to form new *minerals*. These may indicate the direction from which the pressure was coming as the crystals often line up at right angles to the pressure, in layers of different minerals. Hot fluids moving through the rock can also cause changes. The new minerals are often very shiny so that some metamorphic rocks such as phyllite and schist, which include these minerals, can also be very shiny. Metamorphic rocks are typical of the Gander Zone and much of Labrador.

Figure 1 shows the processes to which rocks can be subjected. Notice that sedimentary rocks can be changed to igneous or metamorphic rocks but can also be eroded and redeposited to form new sedimentary rocks. Igneous and metamorphic rocks can also be reprocessed to form any of the three rock types. In this way all rocks can sometimes contain information about the older rocks that have been reprocessed to form younger rocks. It should also be noted that each time rocks are metamorphosed, most minerals have their chemical age reset to the time of the last metamorphism.

Geological Time

Geological time is measured on a different scale from everyday time. We usually measure time in seconds, minutes, hours, days, or years, whereas geological time is measured in thousands, millions, or billions of years. To help organize their thoughts when considering such long periods of time, geologists divide time into different segments, the larger ones being divided again into smaller ones. The largest division is the Precambrian which includes all time from the beginning of the Earth up to the time when animals with hard skeletons evolved. This makes up **87.5%** of the total age of the Earth.

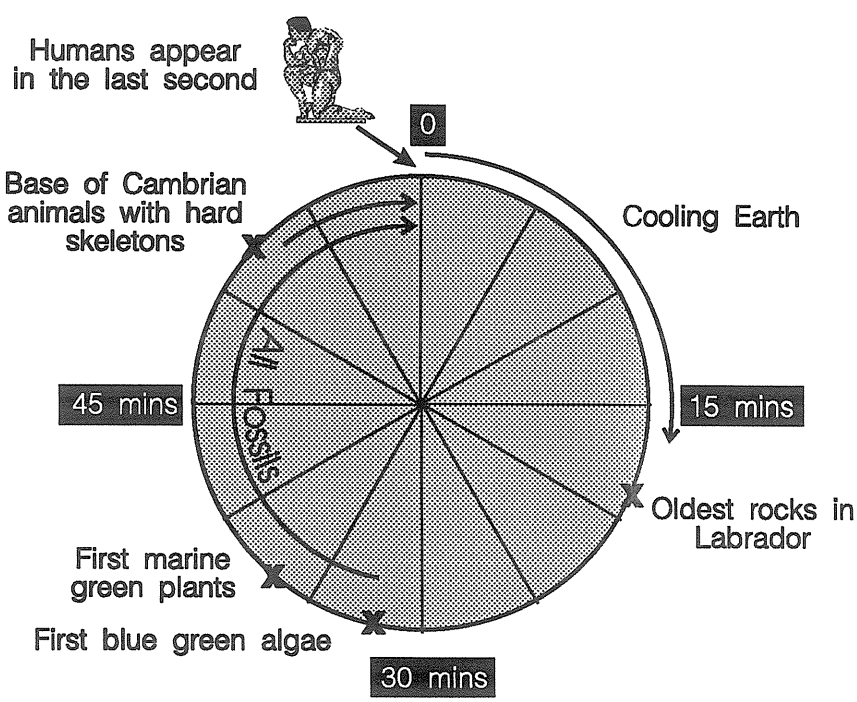


Figure 2. The age of the earth in terms of one hour.

If the age of the Earth is represented by one hour then the Precambrian lasted for 52.5 minutes. The last 7.5 minutes of the hour, or 12% of geological time, represents the whole of Phanerozoic time (See Figure 3). Phanerozoic time can be divided into eras. The oldest of these, the Paleozoic Era, lasted approximately 325 million years or 4.25 minutes on our clock. The Mesozoic Era lasted 175 million years or 2.5 minutes and the Cenozoic Era lasted 66 million years or 45 seconds! Humans only appear on earth in the last second of the hour. Originally the eras were divided up by the *fossils* which occurred in the rocks. Major changes in the types of fossils found were used to separate the different eras into periods and the periods into smaller divisions.

Animals and plants gradually change through time. This is known as evolution. It was evolution, or the rate at which populations and individuals change, that first enabled geologists to divide up the geological time scale. They used a 'guesstimate' of how long it would take for things to evolve to estimate the length of these time periods in millions of years. It is important to remember that all periods during the Phanerozoic Era were divided up and defined by fossils. Since that time, new techniques of dating, known as radiometric dating, have been developed. These depend on the time it takes for an element to decay from one isotope (parent isotope) to another (daughter isotope). These techniques can be used to date rocks such as igneous rocks that do not normally contain fossils. Together these two methods are giving us an evermore accurate time scale.

The age of the rocks in Newfoundland and Labrador spans the entire Geological time scale (See Figure 3). Some of the oldest rocks in the world, which are over 3.5 (3 500 000 000) billion years old, occur in the Nain Province of Labrador (See Figure 8). Rocks spanning the rest of the Precambrian Era are found in the rest of Labrador. Youngest Precambrian rocks are also found in the Long Range Mountains of the Great Northern Peninsula and on the Avalon Peninsula. The rocks located in the rest of insular Newfoundland formed during the Paleozoic Era, whereas the sediments on the Grand Banks, or the *continental shelf*, were deposited during the Mesozoic Era and later covered with glacial material during the Quaternary Period.

EON	ERA	PERIOD	Radiometric Age (MY)	LIFE FORMS	ROCKS PRESENT	MOUNTAIN BUILDING PERIODS (OROGENIES)
PHANEROZOIC	CENOZOIC	QUATERNARY	1.6	Homo sapiens	OFFSHORE NFLD.	
		TERTIARY	66	Mammals dominate *Extinction of dinosaurs*		Alpine
	MESOZOIC	CRETACEOUS	144	Flowering plants		
		JURASSIC	208	*Extinction of conodonts*		
		TRIASSIC	245	Dinosaurs and primitive mammals arise *Extinction of trilobites*		
	PALEOZOIC	PERMIAN	286	Mammal-like reptiles	ISLAND of NEWFOUNDLAND	Alleghenian/ Hercynian
		CARBON-IFEROUS: Pennsylvanian	320			
		CARBON-IFEROUS: Mississipian	360	*Extinction of graptolites* First Amphibians		Acadian
		DEVONIAN	408	First land plants		
		SILURIAN	438	Primitive fish		
		ORDOVICIAN	505			Taconian/ Penobscot
		CAMBRIAN	570	Marine invertebrates with hard parts	LABRADOR	Avalonian/ Pan African
PROTEROZOIC		Late	900	Soft bodied marine invertebrates		Grenvillian
		Middle	1600	Green algae		Hudsonian
		Early	2500			Kenoran
ARCHEAN			3800	Bacteria Blue-green algae		
		FORMATION of Earth	4600			

CORRELATION FOSSILS

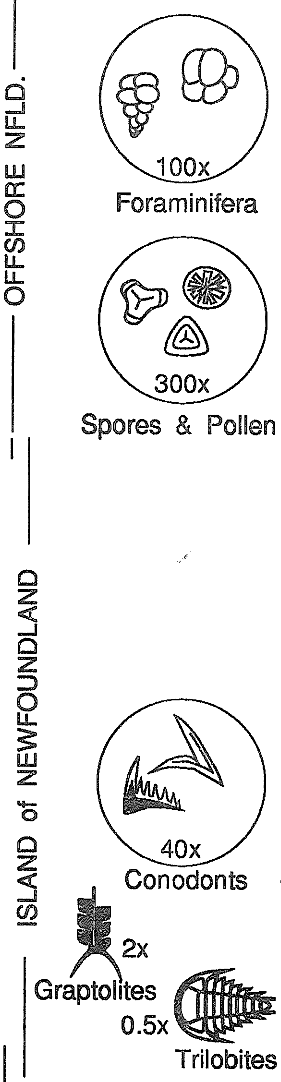


Figure 3: Geological time scale. (MY - millions of years) Emended from Hodych et al. 1991.

Formation of the Continental and Oceanic Crust of the Earth's Surface and Mountain Building.

The Earth formed about 4.6 billion (4 600 000 000) years ago and as it cooled initially a solid crust formed. The layer beneath it, the mantle, has remained mobile enough to develop *convection currents* which move heat from the interior of the earth to the exterior.

These currents cause stress in the solid *crust* so that it has broken into large continental *plates* which are moved about the surface of the Earth, floating on the hot mantle. The plates are moved by the mantle currents in the same way that sea ice is moved by ocean currents.

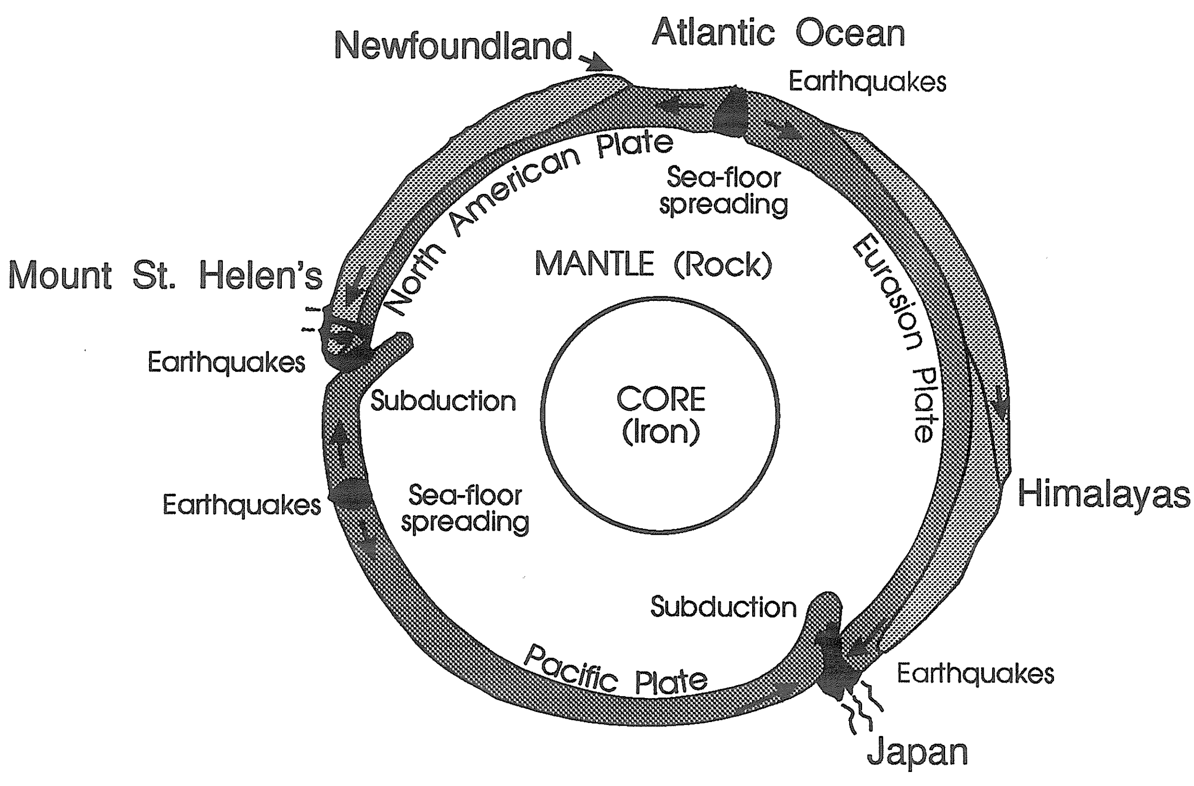


Figure 4. A cross-section through the Earth showing the relative position and movement of several of the Earth's present plates. Emended from Hodych et al, 1991. (not to scale)

There are five major types of plate boundaries.

1. As plates move apart, the gap between them is filled by lava welling up from below and solidifying, giving rise to oceanic crust (See Figure 5) such as the Atlantic Ocean. This usually occurs beneath the ocean but occasionally (such as in Iceland) it reaches the surface.

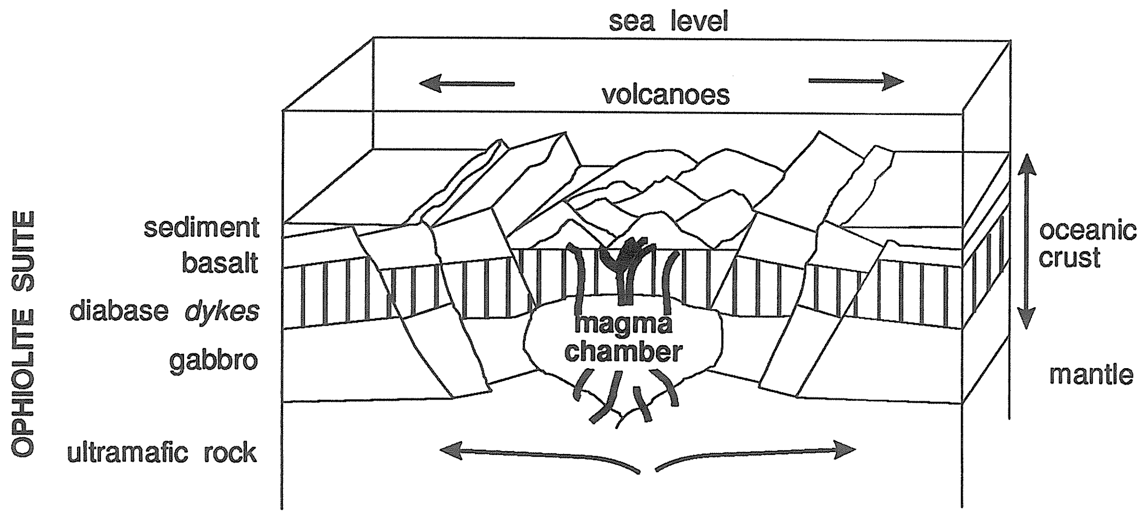


Figure 5. Cross-section through mid-ocean ridge showing layers which make up an ophiolite suite.

2. Where plates collide and one continental plate rides up over another continental plate, the crust thickens producing mountains such as the Himalayas.

3. Sometimes plates move past each other, as is happening on the west coast of North America, producing large faults, such as the San Andreas Fault. Earthquakes are the result of movement on these faults.

4. When ocean plates collide with continental plates, mountains such as the Applachians and the Andes are formed. Since continental rocks are lighter than oceanic rocks, oceanic plates tend to be forced beneath continental plates in a process called *subduction* (See Figure 7).

5. Oceanic plates can over-ride other oceanic plates causing the formation of island arcs such as the Japanese Island Arc (See Figure 4).

Wherever subduction takes place, the down-thrust rocks eventually melt and the magma (liquid rock) rises toward the surface to erupt as volcanoes. Sometimes it does not reach the surface but solidifies beneath the earth's surface as an igneous *intrusion*. Where plates pull apart, lava erupts to fill the gap and oceanic crust is formed (See Figure 5). These conditions will be considered in greater detail later in terms of Newfoundland geology during a discussion of the formation of the Appalachian Mountains.

The Island of Newfoundland

The island of Newfoundland is a geological 'laboratory' which exposes a cross-section of the Appalachian-Caledonian mountain belt of the North Atlantic. The rocks of this mountain belt record evidence of a previous opening and closing of the *Iapetus Ocean* during the Paleozoic Era.

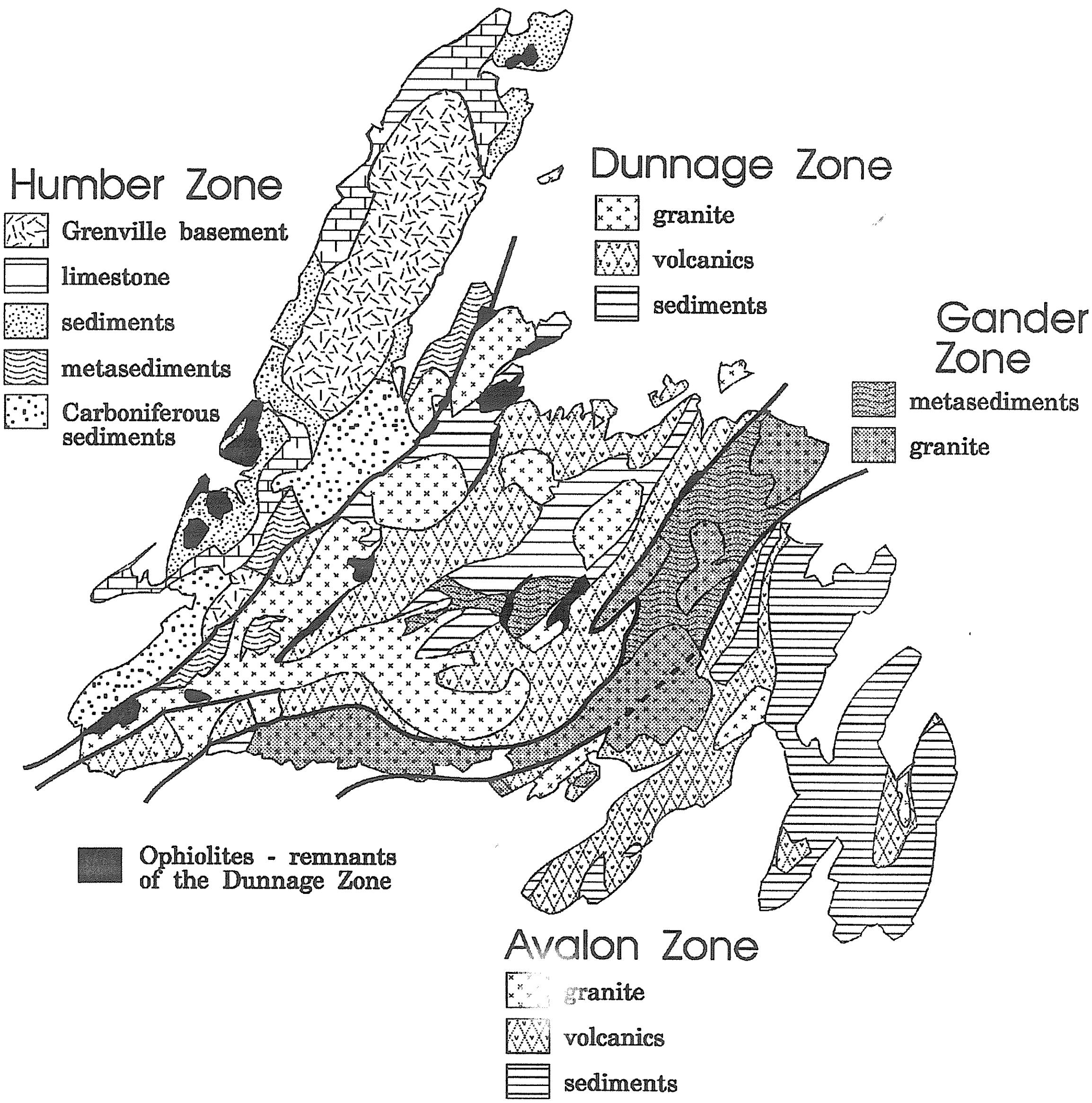


Figure 6. Simplified Geology of Newfoundland.

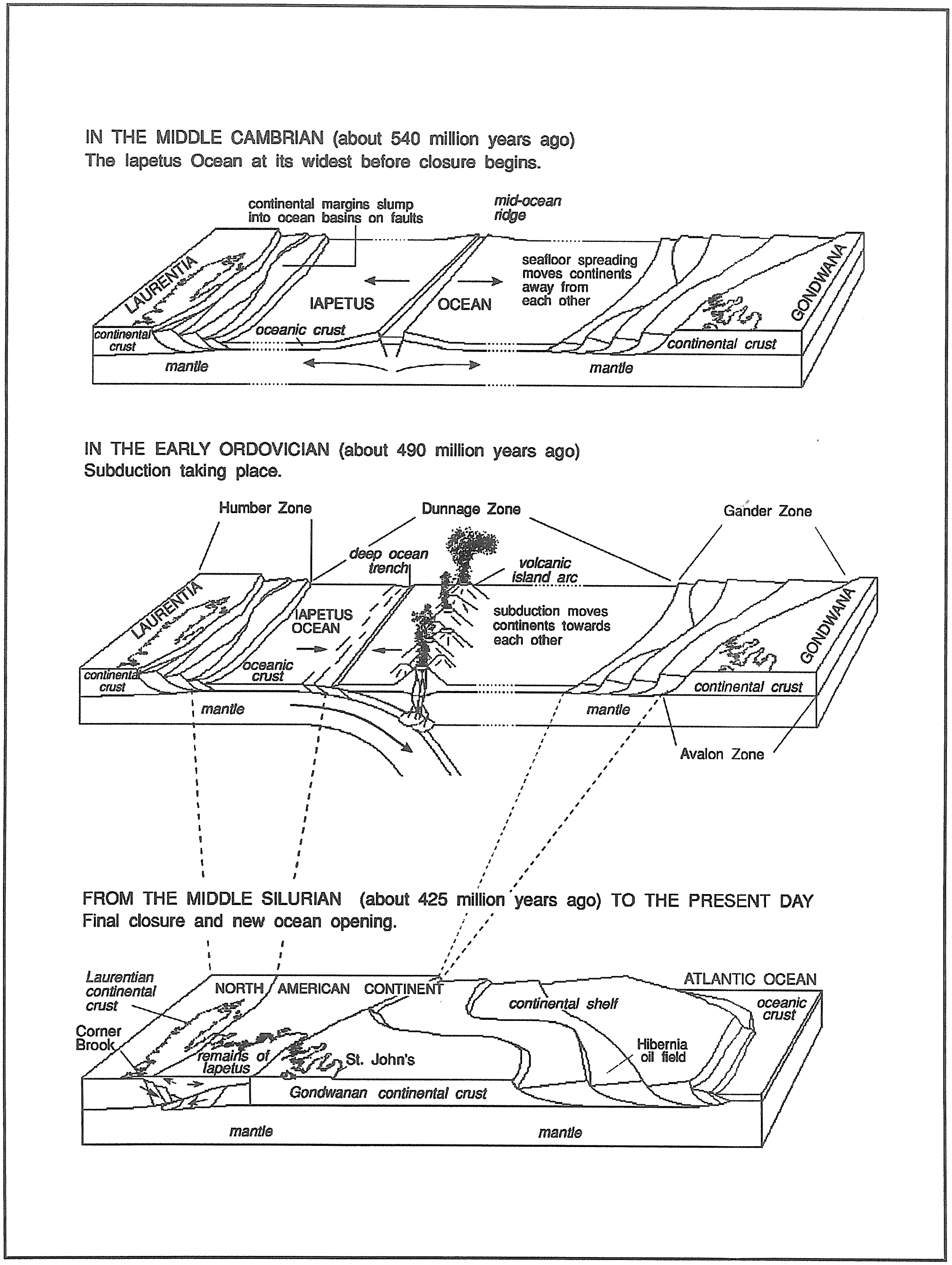


Figure 7. Plate Tectonic History of the Island of Newfoundland.

Since the beginning of the Mesozoic Era the Atlantic ocean has been reopening, in some places such as Iceland, as rapidly as three centimeters a year. Mesozoic rocks are now only found offshore on the continental shelf which surrounds Newfoundland and Labrador. These younger rocks preserve oil in sandstones. The oil fields like Hibernia are found in these rocks at depths of a few kilometres. Figure 7 shows the development of the geology of Newfoundland.

Geologically, the island is divided into four major zones:
(See Figures 6 and 7)

- The Humber Zone
  - The Humber Zone is composed of rocks that once made up the *continental margin* of the North American plate called Laurentia (The present continental margin of the North American Plate surrounding Newfoundland is known as the Grand Banks). Slabs of ophiolite (part of the Dunnage Zone) near Corner Brook and at the tip of the Northern Peninsula, were trapped on the continental margin.
- The Dunnage Zone
  - The Dunnage Zone is made up of rocks that formed the oceanic crust under the Iapetus Ocean. It contained at least one, and probably two, volcanic island arcs similar to the Japanese island arc of today. Gondwana was pushed under Laurentia when the Iapetus Ocean closed so that some ocean crust (Dunnage Zone) was torn from its roots in the mantle.
- The Gander Zone
  - The Gander Zone is the remains of sediments which were deposited from the Gondwana continental margin onto the oceanic crust of Iapetus and then were scraped off as the oceanic plate was subducted beneath Gondwana forming a sedimentary wedge of very metamorphosed rocks in front of the Avalon Zone.
- The Avalon Zone
  - The Avalon Zone was part of the continental margin of a plate on the other side of the Iapetus Ocean. The rocks around St. John's are very similar to those found in North Africa, which in the Paleozoic was part of a continental plate called Gondwana (See Figure 7).

Rocks contain within them a record of the stresses which caused slices of crust to be *thrust* or pushed towards the continents on both sides of the ocean during the closure of the Iapetus Ocean. This record also includes the chemistry and evidence of the age of the rocks as they formed and also the metamorphic changes caused by thrusting. Age of the rocks is recorded both chemically and by the fossils which they contain.

Once the Iapetus Ocean closed the thickened crust caused melting within the crust. This caused bodies of magma or molten rock to rise towards the surface. These large magma bodies crystallized beneath the earth's surface and are known as batholiths or plutons. These plutons or batholiths contain minerals indicating the presence of continental rocks beneath the Dunnage Zone. *Erosion* of the surface of the Appalachian Mountains in Newfoundland has worn the mountains down to such a depth that the granite batholiths are now seen at the surface, within and between the major geological zones. (See Figure 6).

During the Mezozoic Era, the modern Atlantic Ocean began to open. The same events that are seen in the early Cambrian during the opening of the Iapetus Ocean occur again. First, *rifting* began to occur and a large fault basin opened which began to fill with sediments. This eventually flooded, but since the climate was hot and dry at the time, it dried up to form thick deposits of salt. Subsequently the ocean began to develop with the eruption of lava at the mid-ocean ridge and the formation of ocean crust started (See Figure 5) which continues to this day. The shelf areas on either side of the ocean continued to receive sediments from the land and it is these thick sediments which contain the oil and gas fields of the Grand Banks and the Labrador continental shelf.

In the Quarternary Period an ice age enveloped the whole of northern North America. Several times ice sheets moved out from the Arctic and retreated during warmer interglacial periods only to move out again covering all of Labrador and Newfoundland. During the last extension of the ice, Newfoundland had its own ice sheet, moving from the centre of the island towards the ocean. This eventually broke up into smaller ice caps such as the one which was centred over the Avalon Peninsula. The ice finally melted from Newfoundland about 10 000 years ago, but it left behind ample evidence of its passage on the land surface. Large blocks of rock were carried by the ice sheets and, when the ice melted, they were left stranded far away from where they were originally picked up. These rocks are known as erratics. They give geologists information about the direction of movement of the ice sheets.

Other information on the direction of ice movement can be seen by the way hills have been smoothed by the ice. Rocks frozen into the base of the ice sheet acted like sandpaper and ground rock surfaces smooth. In some cases deep scratches known as striations were left across these smooth surfaces. The striations also indicate the direction the ice was moving. Although material such as gravel, sand and clay were dropped by the ice sheets when they melted, much of this material (including most of the soil which covered Newfoundland) was carried out and deposited on the Grand Banks. The soil now found in Newfoundland is very thin as, geologically speaking, it has had very little time to develop.

Labrador

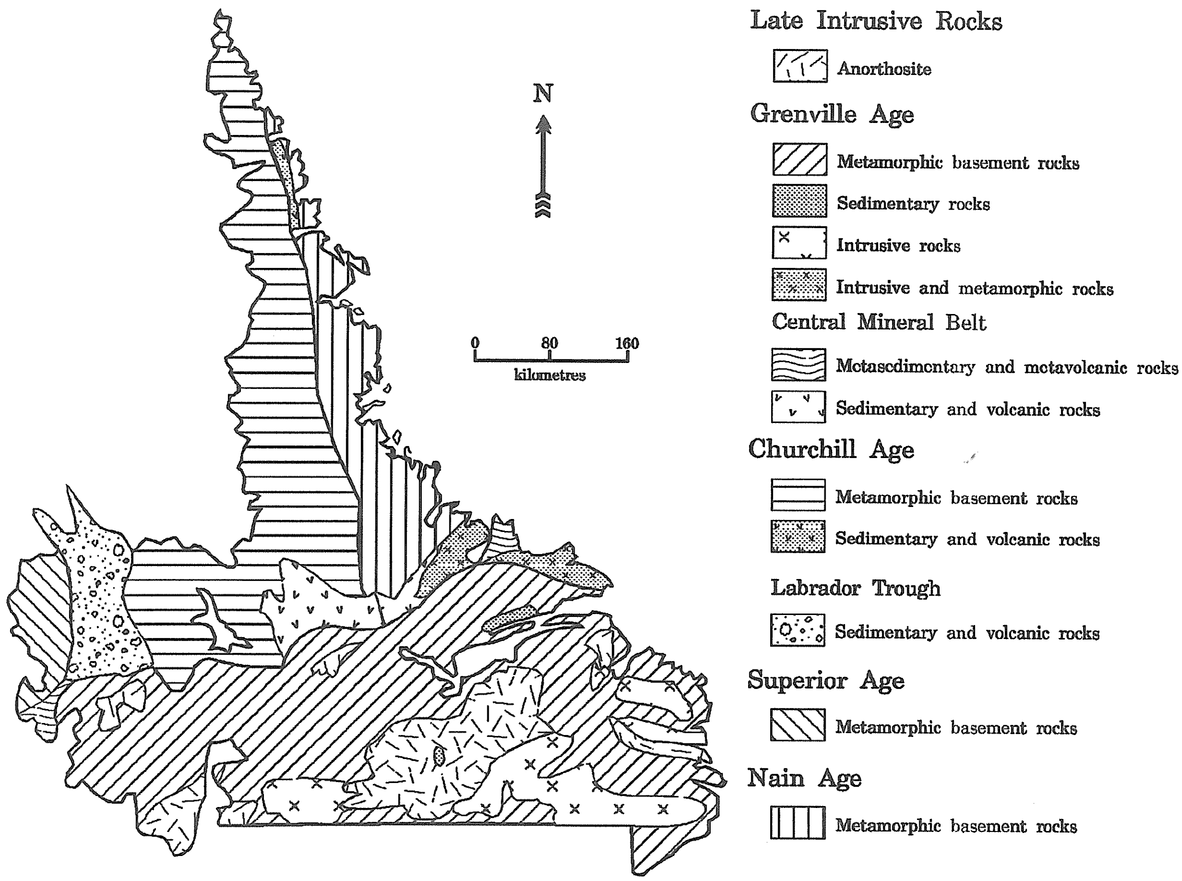


Figure 6. Geological Provinces of Labrador.

Labrador forms the eastern part of the Canadian Shield, the ancient Precambrian core of the North American continental plate. It is divided into several *geological provinces* as shown in Figure 6. Each province contains rocks which show particular *structures* and evidence of change (metamorphism) of a specific age produced during episodes of *mountain building*. (See Figure 3) These structures and metamorphism are the scars of plate collisions and divisions in the early history of the earth.

The oldest rocks in Labrador are found in the Nain and Superior Provinces which were both affected by the Kenoran *Orogeny* (2 500MY) (See Figure 3). Churchill Province and the southern edge of Nain Province, known as Makkovik Province, were both affected by the Hudsonian Orogeny (1 600MY). The western edge of the Churchill Province is bounded by the Labrador Trough, made up of volcanic and sedimentary rocks that were laid down on the continental margin of the Churchill Province. The Labrador Trough has since been affected by Hudsonian and Grenvillian (1 000M/Y) episodes of mountain building. The boundary between the Nain and Churchill Province is interrupted by large bodies of a rock called anorthosite containing a very beautiful mineral, labradorite (a kind of feldspar), the provincial gemstone of Newfoundland and Labrador. The youngest Precambrian Province is the Grenville Province in southern Labrador. On the southern coast of Labrador, near Forteau, there are outcrops of sediments of Cambrian age. These are the only rocks in Labrador which contain fossils. The rest are too old! Before the mining of iron ore in the Labrador Trough a small deposit of sediments of Cretaceous age, which contained plant fossils, was removed. All that remains of these fossils are now in collections at Memorial University of Newfoundland.

Glossary

Archeocyathid

- a colonial animal with a cup-shaped skeleton which formed the earliest reefs in the Cambrian.

Batholith

- a large body of igneous rock that solidified deep in the earth's crust.

Continental margin

- the edge of a continent extending from the water's edge across the continental shelf to the deep ocean floor.

Continental shelf

- a wide shallow platform sometimes extending as far as 200 miles from shore (eg. the Grand Banks) generally comprised of sediments washed down into the sea.

Convection currents

- heat is transmitted through a liquid due to a change in density. As the liquid is heated it becomes less dense and begins to rise while the colder denser liquid tends to sink due to gravity. This sets up a circular movement or cell, which allows heat to be moved from hotter to colder parts of the liquid. In the earth the most intense heat is at the centre and the coldest part is at the surface of the crust.

Coral

- small colonial animals which build colonies or reefs in warm shallow water. They became common in the Mesozoic Era as reef formers and continue to the present day.

Crust

- the crust of the earth is composed of solid rock formed as the outer surface of the earth cooled down. The composition varies from the base of the crust to the surface. The rocks of the continents tend to be lighter than those which form under the ocean.

Dykes

- intrusions of igneous rock which cut across previous rock structures.

Erosion

- the process of removal of rock material from the surface which has been broken down by weathering.

Fossils

- the remains of plants and animals, or the traces left by animals, such as tracks or droppings, which are preserved in rocks (usually sedimentary). Fossils are used to indicate the age of the rocks and also as indicators of the environment in which the rocks were deposited.

Geological Province

- an area which includes rocks of similar ages that have been subjected to the same geological or mountain building events.

Iapetus (eye - a - pe - tus) Ocean

- the ocean which opened during the Cambrian Period and existed during the Paleozoic Era in approximately the same position as the Atlantic is today. It was oriented parallel to the equator rather than north/south as the Atlantic Ocean is today and it separated Laurentia to the north and from Gondwana to the south. It had closed completely by the end of the Silurian Period.

Intrusion

- a body of igneous rock which was injected into the surrounding rock in a molten state but cooled and solidified below the earth's surface. It is visible at the surface now as the rocks above it have been removed by erosion.

Lava

- hot liquid rock that is erupted at the earth's surface. This can be on land or beneath the surface of the ocean. When it is beneath the ocean it usually forms as pillow lavas - deformed rounded or tube shaped lumps of lava that setlled while still hot and molded themselves into the gaps between other pillows.

Magma

- hot liquid rock that exists below the surface of the earth. Once it reaches the surface it is called lava.

Minerals

- crystals, large or small,the properties of which are controlled by the internal arrangement and chemical composition of their molecules. They have a precise chemical composition. Large crystals of mineral can be seen in some igneous rocks. Other mineral crystals can be seen in thin sections of rocks.

Mountain Building (Orogeny)

- the process by which mountains are built due to the collision of plates where one plate is forced up over another.

Plate

- an area of crust on the earth's surface which moves as a single piece. The most obvious examples of these are continental plates such as North America and Africa including their surrounding continental shelves. This movement is driven by subsurface currents.

Rifting

- faults caused by the pulling apart of basins, the first stage in the opening of an ocean where plates are moving apart.

Structures

- evidence of breaking (faults) or folding of rocks produced by movement during mountain building.

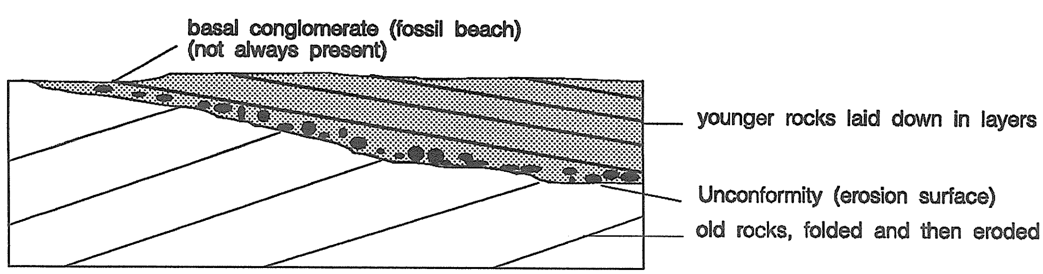
Subduction

- the process of one plate sinking beneath another and forcing the other over it. When it sinks far enough the leading edge of the subducting plate begins to melt producing a magma source which usually gives rise to volcanic eruptions (eg. Mount St. Helen's) if the over-riding plate is a continental plate. If the over-riding plate is an oceanic plate a volcanic island arc (eg. Japan) is formed.

Thrust Faults

- fault which occurs at a very shallow angle. Rocks can move great distances along thrust faults and become completely detached from their origin.

Unconformity



General Notes on Field Work

Characteristics of rocks which may be used to unravel their geological history
are those:

- visible to the naked eye
  - things which can be seen in a hand specimen
  - presence of folds, faults and/or unconformities

- visible in the laboratory
  - things which can only be seen with the aid of special equipment and techniques
    (eg. microscopes and geochemical analysis)

For example, minerals within a volcanic rock can indicate its origin, whether it formed in a continental setting or whether it was erupted under the ocean. If the crystals are too small to recognize it is necessary to cut a very thin section of the rock and look at it under a microscope. In the same way, fossils are sometimes big enough to see in a hand specimen but some very important ones, such as pollen and spores, can only be examined under very high powered microscopes.

For chemical dating of the rocks, the specimen has to be dissolved with acids. The proportions of individual chemical element isotopes are recorded using extremely sensitive machines. Because many of the characteristics of rocks can not be seen in the field, the geologist has to keep in mind what other tests the rocks will be subjected to on return to the laboratory. This makes a great difference to the way in which specimens are collected. Special care has to be taken in wrapping the samples to prevent damage to fossils or *contamination* of one sample by another. It is also very important to number each sample and record where it was collected.

The relationships between rocks in an outcrop are also very important in understanding the geological history of an area. Relative age can be worked out by determining which rocks are on top of which. Intrusions, such as dykes, must be younger than the rocks they intrude. Unless folding has overturned the rocks, the younger ones will be on top of the older ones. Faulting can also cause older rocks to be on top. It is often the study of fossils in rocks which allows *thrust faults* to be recognized. However, when rocks are lifted above sea level they are subjected to weathering and erosion. If after some time the rocks are moved below the sea, new rocks will be deposited on top of them - but there will be a time gap in deposition. If the rocks were folded before deposition began again, an *uncomformitiy* develops and can be seen in the field. If there is no change in the tilt of the rocks there will be a break in deposition, but it will not be easy to recognize in the field without the help of fossils or radiometric dating.

Hints for Field Trips

- **Before collecting specimens at a field stop, ensure collection is permitted.** Note: Both the use of hammers and collection of specimens of any type are banned in National Parks.
- Permission to visit sites on private land should be obtained when planning field trips.
- You should wear footwear and clothing appropriate for a variety of weather conditions.

What you will need to collect specimens:

- Safety glasses
- Hand lens
- Geological or brick hammer
- Chisel
- Newspaper and/or plastic bags to wrap and protect samples
- Permanent marker
- Notebook
- Pencil

Bag or bucket to carry samples

-
- Camera (Optional)

Things to consider when collecting samples:

- Is the sample typical of any part of the rock outcrop at which you're looking?
- Does it contain fossils?
- Does it contain a special mineral?
- Does the sample make up a part of the geological story expressed at this outcrop?

If you are collecting samples:

- Use a diagram of the rock outcrop and mark on it where your sample was collected.
- Mark the sample number on the diagram.
- Record the same number on the rock sample with a permanent marker
- Code your sample so that you can distinguish it from others. For example:

- **91-ABC-1-3** where

91 indicates the year

ABC indicates your initials

1 is the stop number

3 is the third sample from stop 1

- Keep a notebook and write anything special about the sample
under its assigned number

Following these suggestions will ensure you have a record of your field trip with which you can write a report or remind yourself of what you saw.

Safety

There are some safety rules which should be kept in mind by **students** and **teachers** at all times:

- If outcrops are near or alongside roads, be aware of traffic and do not cross the road or step back from the outcrop without looking first for traffic.

- Always be aware of overhanging cliffs - do not go too close to the edge if you are on top. Be very carefull,especially in quarries or on beaches, to see that the cliff above you is safe. If there is a talus slope always be aware someone above you can cause rocks to roll down. If you are on the slope, be aware if you dislodge rocks and warn those below.

- Always wear safety glasses when hammering rocks. It only takes one small rock splinter to blind you. Damage to one eye can often blind both!

- If possible wear a hard hat if you are working near cliffs.

Geology of the Bay de Verde Peninsula

The Avalon Zone of the Newfoundland Appalachians

During the Paleozoic Era, the Avalon Zone was part of the continental margin of the plate known as Gondwana. The Zone is composed of volcanic, intrusive igneous rocks and sedimentary rocks (see Figure 9). These rocks range in age from Late Proterozoic (760 MY) to Carboniferous (340 MY).

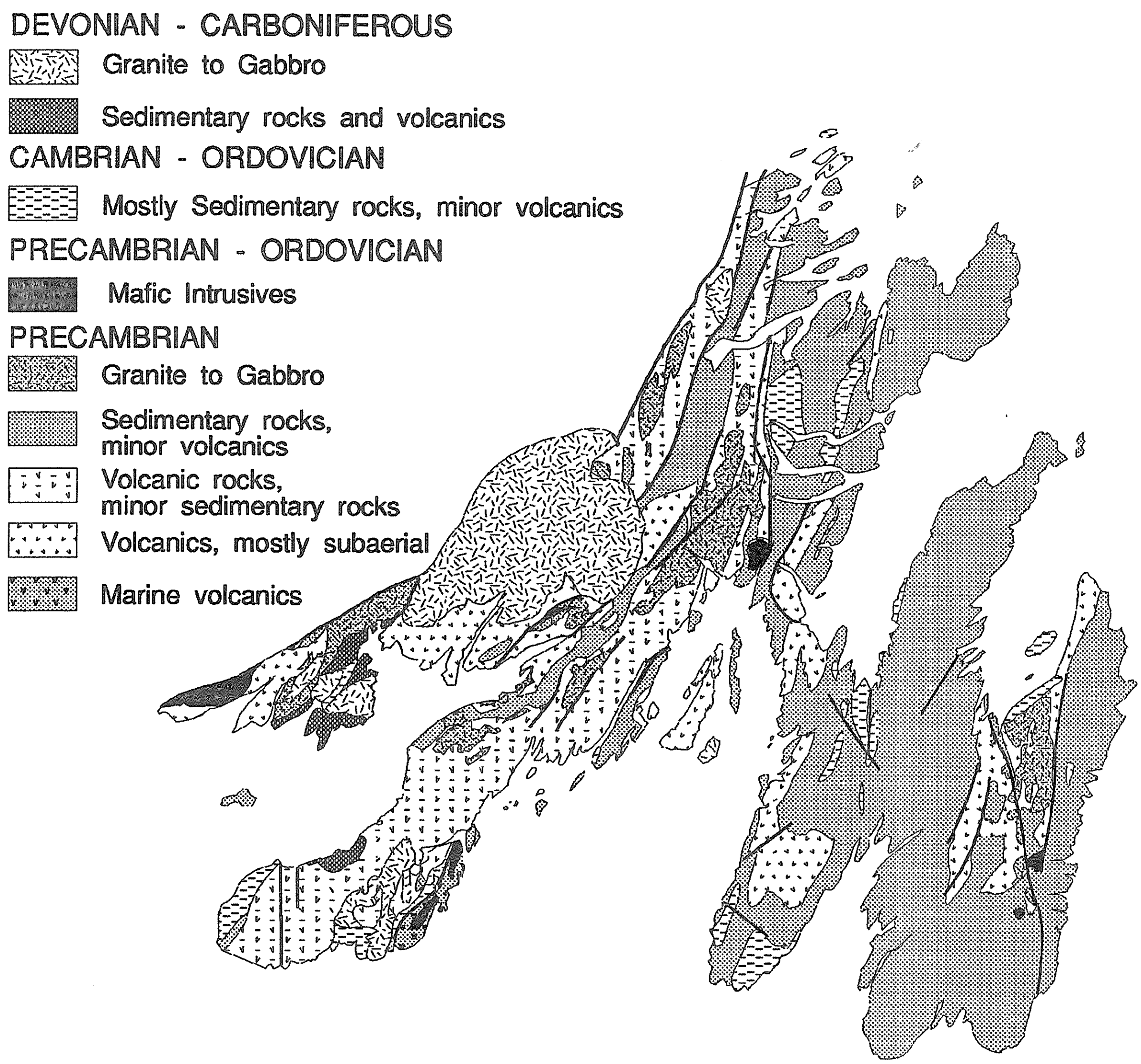


Figure 9. Simplified geology of the Avalon Zone.

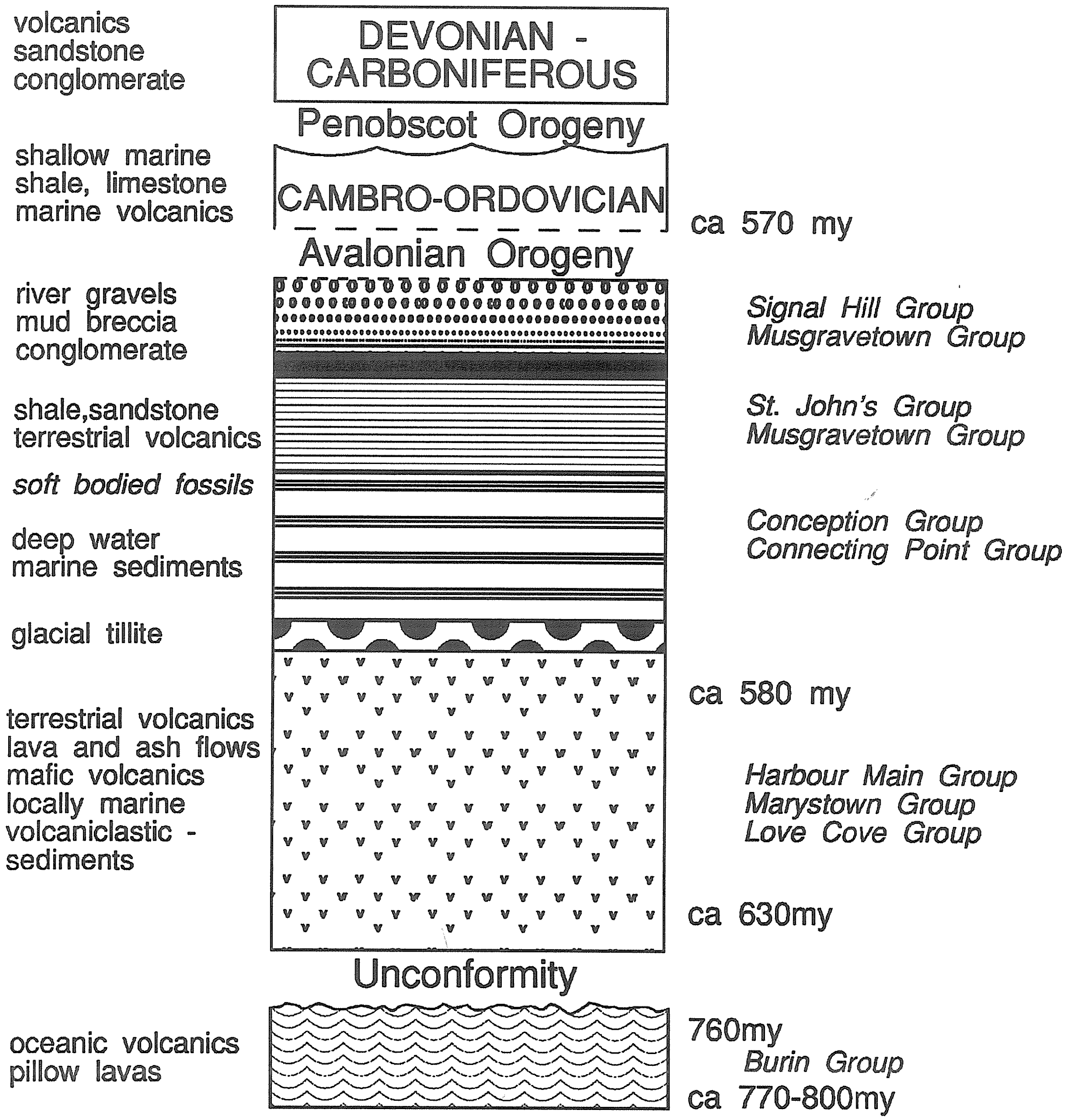


Figure 10. Stratigraphic section of the rocks of the Avalon Zone. It shows the order and kind of rocks which were deposited in the Avalon Zone. The oldest rocks are at the bottom of the section and the youngest are at the top.
Emended from Hiscott et al. 1988.

The oldest rocks are made up of pillow lavas, gabbro and associated sedimentary rocks composed of volcanic fragments and limestone blocks and are found on the Burin Peninsula along the coast from Marystown to St. Lawrence. There is a gap in deposition above these rocks and, since they are in fault contact with or unconformably overlain by rocks of Eocambrian age, there is no evidence of what happened during the next 80 million years.

Twice during the late Proterozoic (630 - 600 MY and 580 - 550 MY), volcanic islands developed along the northern edge of the Gondwanan continent.

630-600MY ago is the time during which the rocks of the Harbour Main and Conception groups and their equivalents, the Love Cove, Marystown and Connecting Point Groups, on the western part of the Avalon Zone were deposited (See Figure 11a and 11b).

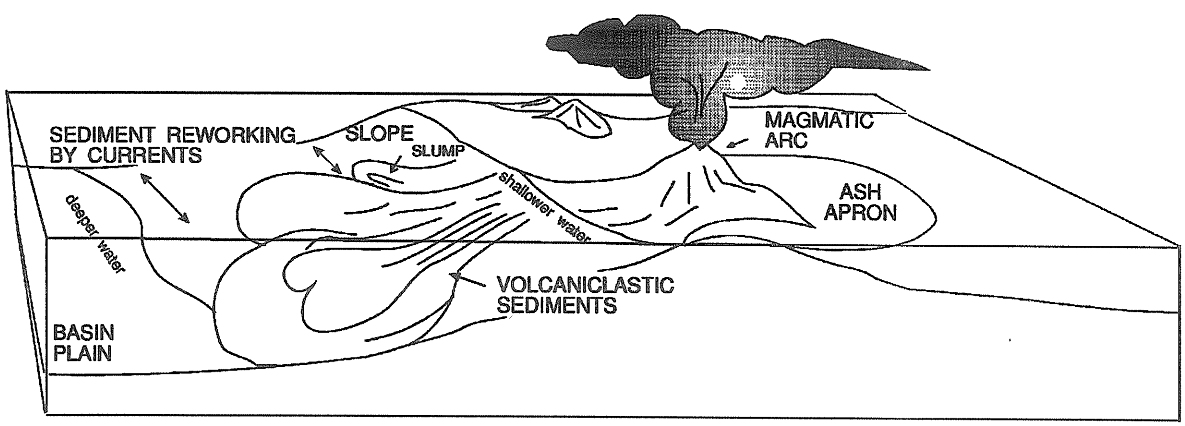


Figure 11a: Ancient depositional evironments of Harbour Main and Conception Groups After Hodych et al. 1991.

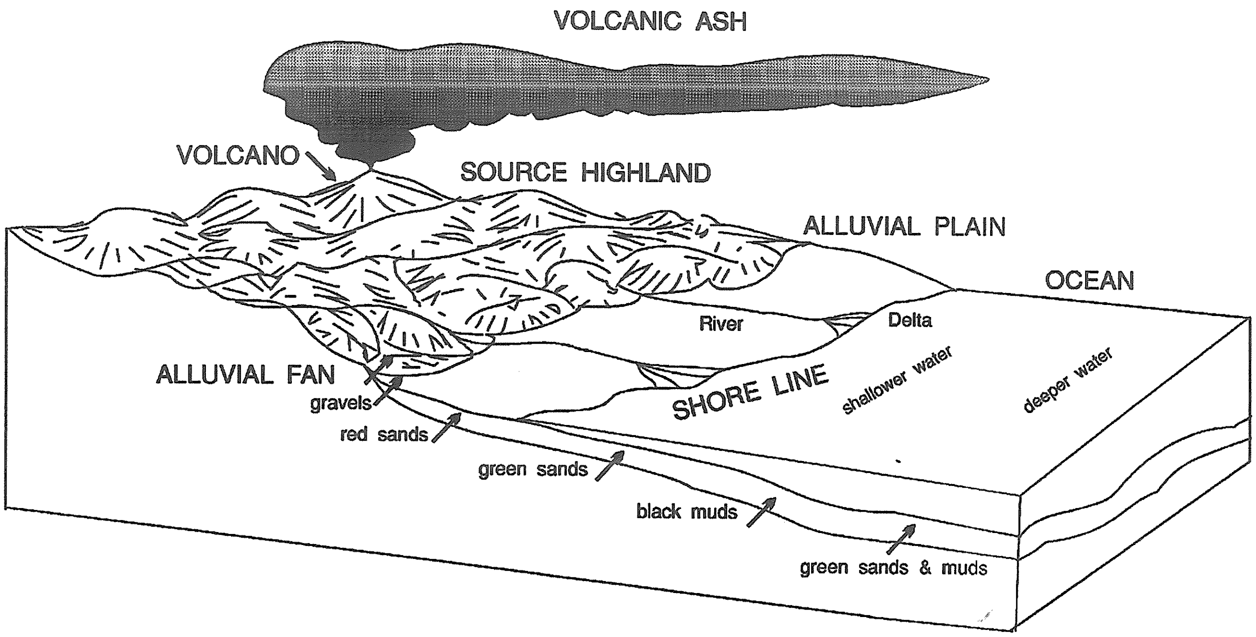


Figure 11b. Ancient depositional environments of St.John's and Signal Hill Groups. After Hodych et al.

The basins surrounding the volcanic islands gradually filled with sediment and the plains became continuous in front of the islands composed of sands and gravels that were deposited by the rivers which crossed them (See Figure 11a and 11b). The cores of these volcanic islands, or massifs, are composed of granites of similar age, which are typical of the Avalon Zone throughout the Appalachians. In other places these granites are very important because of the economic value of the minerals they contain.

The climate during the late Proterozoic in this part of Gondwana was hot and rather dry. Evidence of the hot climate can be seen in the red colour of the rocks caused by oxidation of the iron (to rust) in the rocks. The land was subjected to flash floods in the same way that desert areas in the Middle East are today. Mud breccias were formed when dried mud was ripped up by flood waters and mixed with the sand being carried by these waters. The flood waters must have sunk away rapidly because the mud clasts were not destroyed by the turbulent water, but must have been deposited very quickly as they are in quite large pieces with sharp, not rounded edges. All life at this time was in the ocean and, since the land surface had no plant cover, soil was easily washed into the river valleys by storms. The mud breccias and current bedding seen in the rocks of the Signal Hill and Marystown groups indicate this lack of vegetation and are good examples of sediments deposited in such conditions.

At the same time as the Signall Hill Group was being deposited, about 580-550MY ago, volcanoes were active in the area of the Isthmus of the Avalon Peninsula producing the Bull Arm Volcanics.

After the deposition of these sedimentary rocks, there is evidence of faulting and folding which took place during the Avalonian Orogeny about 570MY ago (See Figure 3). The eastern Avalon Zone was lifted above sea level, tilted and eroded before deposition started again in the Cambrian. The western side of the Avalon Zone was not lifted above sea level for as long, so that deposition started before the end of the Precambrian and continued across the Precambrian-Cambrian boundary. This continuous sequence of sedimentary rocks is well exposed in the Grand Bank - Fortune area.

The upper part of the Conception Group on the Avalon Peninsula contains beautifully preserved soft bodied fossils. On the Burin Peninsula these fossils are not present but fossils appear higher up the section which are used to identify the base of the Cambrian. In these areas the volcanic sediments contain trails known as trace fossils, left by creatures that crawled and burrowed in the sediments, and the limestones contain "small shelly fossils",indeterminate small shells which are used with the trace fossils to define the PreCambrian-Cambrian boundary. Deposition continued throughout the Cambrian in the Avalon Zone. In the area of Random Island, on the 'toe' of the Burin Peninsula and on the Bay de Verde Peninsula, the clean quartz sandstone of the Random Formation can be seen. In the Random Island area this formation sits unconformably on the eroded surface of the Late

Proterozoic sandstones but the base of the Cambrian is not seen. Above the quartzite, black shales contain trilobites and microfossils. These Cambrian rocks and fossils occur in isolated basins such as those in the areas of Conception Bay, Random Island and Fortune Bay.

The only Ordovician in the Avalon Zone rocks are seen on Bell Island in Conception Bay and in the Random Island area of Trinity Bay. These sandstones contain fossilized graptolites, brachiopods (kinds of sea shells), as well as trails and burrows of numerous animals, especially trilobites.These fossils are very different from those found in the rest of Newfoundland. Although graptolites, trilobites and brachiopods are found in the rest of Newfoundland, they are not closely related to those found in the Avalon Zone. Those of the Avalon Zone are more similar to those found in England, Wales, France and North Africa.

It was this difference in the fossils that first gave geologists the clue that the Avalon Zone was once part of Gondwana not Laurentia (North America).

The Avalon Zone was intruded by granites during Devonian and Carboniferous times (See Figure 3). In the western and central areas of the Avalon Zone, some Devonian - Carboniferous basins formed and filled with sediments containing plant fossils. These are exposed at Terrenceville, Spanish Room and on the west of the Burin Peninsula in sections along the road between Pools Cove and English Harbour West.

Geology of the Bay de Verde Peninsula.

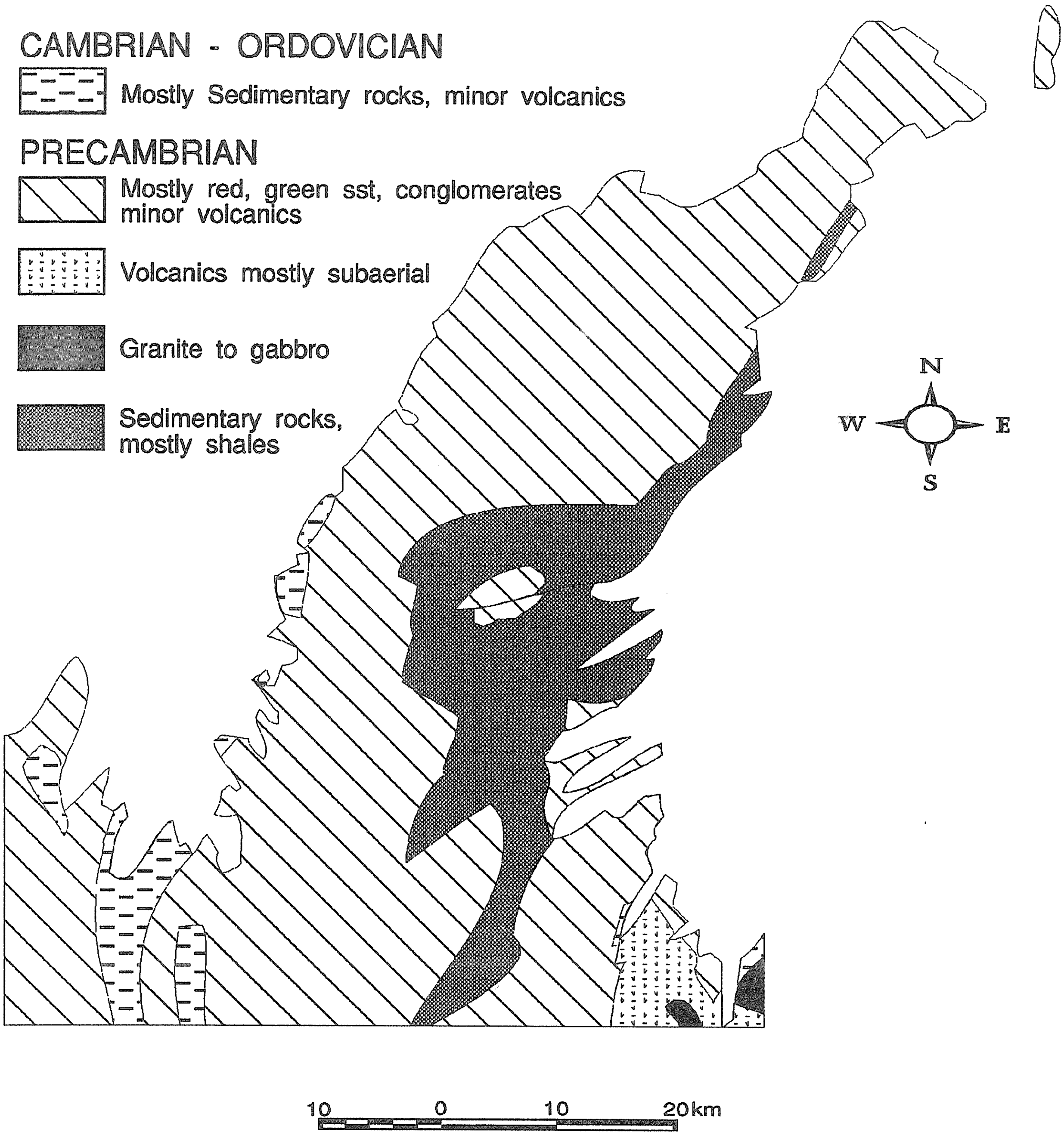
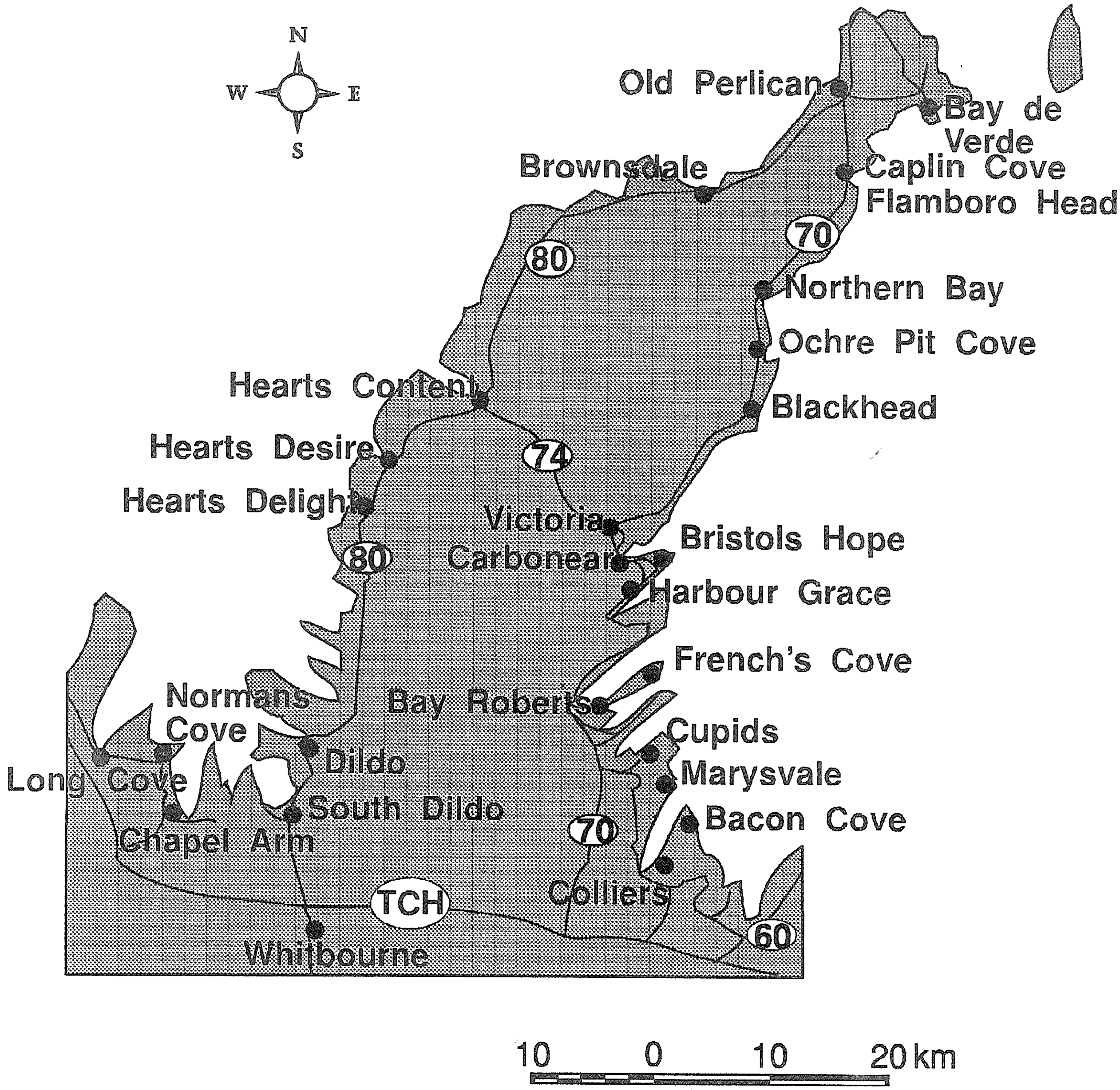


Figure 12. Simplified geological map of the Bay de Verde Peninsula. Emmended from King 1990

The geology of the Bay de Verde Peninsula is controlled by the development and destruction of the volcanic islands which make up most of the Avalon Zone. The sediments which were shed off the volcanic islands into the surrounding sea and eventually developed an extensive coastal plain make up most of the volcaniclastic sedimentary rocks which are seen on the peninsula. The whole area was subjected to the Avalon Orogeny at the end of the Proterozoic and in this area deposition stopped until well into the Cambrian Era. The peninsula is a showcase for many different sedimentary rocks which contain a variety of sedimentary structures. Vein development in joints and good examples of faults and folds can be seen. An excellent example of an angular unconformity developed between rocks of Proterozic and Cambrian age. The Cambrian shales also include good examples of pillow lavas and various limestones. Deformation of the Proterozoic rocks can be seen in varying degrees from simple folds in many places, to the development of slates near Cupids.

The Proterozoic volcanic rocks in the south east of the area show good examples of intusive relationships in Colliers Bay. Unconformities within the Proterozoic rocks can be seen with the development of boulder conglomerates such as those which can be seen at Turks Gut. The base of the Cambrian in this area is always marked by an unconformity between rocks of Proterozoic and Cambrian age. In many places the oldest Cambrian rocks are white sandstones or conglomerates known as the Random Quartzite. This is followed disconformably by red and green shales which pass up into conspicuous red limestones containing white algal nodules or layers. Above these are more red shales. In the Middle Cambrian black shales were deposited which contain trilobites and other fossils. Because the Cambrian rocks were filling an uneven Precambrian surface, deposition did not start at the same time everywhere. The age of the base of the Cambrian can be at any level in the Lower or Middle Cambrian. One thing which many places have in common is the development of a basal conglomerate at what ever level deposition started. Deposition at Bacon Cove started after the Random Quartzite was deposited in other areas. In the north west, in Chapel Arm, not only is the Random Quartzite present but in the Middle Cambrian black shales, there are pillow lavas which are not seen in other places.

Bay de Verde Field Stops - Location Map



The field trip will start by driving north on the Trans Canada Highway to the turn off for Chapel Arm (Route 201). From here we will proceed to Normans Cove.

Stop 1 - Normans Cove Beach

Take the next road after the school sign, the right turn after the bridge. Go 1km down to thebeach.

Cross the wooden bridge and walk to the right end of the beach in front of the cliffs.

The far headland is composed of Middle Cambrian black shales dipping steeply towards the north west. The near headland is composed of pillow lavas that were extruded under water. Close inspection of the pillow lavas shows the tops facing NW and the bases moulded against those beneath them. The contact between the black shales underneath and the pillow lavas on top can be seen at the top of the cliff. There is some alteration of the shales in places along the contact.

Stop 1a - Normans Cove Fish Plant

Return to the road, turn right and continue to the the small dirt road which crosses the beach and goes out onto the point to the fish plant and the dock.

On the left side of the road by the fish plant, it is possible to climb down onto loose blocks of the red limestone and see the algal layers close up. Its position in the sequence will be seen at stop 2.

Stop 2 - Long Cove

Return to road and turn right, continue as far as the sharp turn in the road by the gas station. Leave the main road and continue straight up the dirt road to the end. Go down onto the beach and go to the right.

The grey-white sandstones with conglomerate at the base are the oldest Cambrian rocks exposed in this area. They are known as the Random Quartzite. There is no exposure of what is beneath them at this site. Above the quartzite, red and green shales crop out in the beach. The base of the cliff is composed of green limestone which continues up into red limestone containing lighter algal nodules and layers. Above the limestone are red shales. All these rocks are of Lower Cambrian age.

Stop 3 - Dildo slate

Return to the road, turn left and return through Chapel Arm to the TCH. Turn left and drive to the Whitbourne intersection and turn left for Dildo (Route 80). Continue about 9 km to where The Perman Marine Building stands, the first building on the left side of the road after the group of buildings near the fish packing plant. Walk onto the headland to the right of the building.

This outcrop is deformed to slate at the south end of the exposure but at the north end, by the stream, the bedding of the shale can still be seen. The whole outcrop is dipping steeply to the NE.

Stop 4 - Hearts Desire Beach

Continue along Route 80 to Hearts Desire. Turn left onto Wharf Road and continue to the end of the road. Walk down the trail to the beach.

The first outcrop on the beach is composed of Proterozoic green sandstones. These show good bedding and other sedimentary features. Further down the beach are red sandstones which contain mud clasts and show good cross bedding. The red mud clasts indicate that these rocks were probably laid down in hot climatic conditions. The mud clasts cannot have been carried very far because they would have disintegrated very rapidly in water. They must have been picked up as cracked mud layers by flash floods which soaked away very rapidly into the sand beneath. At the far end of the beach the Cambrian Random Quartzite can be seen with the red shales and limestones above.

Stop 5 - Brownsdale

Continue on Route 80 to Brownsdale. Turn left into Marches Road. Go 0.7km from the highway. Turn left to the corner and walk down to beach. The white quartz vein on the far headland can be seen from here.

The red sandstone and mudstone contains well developed bedding that can be seen by close inspection of the beds. The flat, more obvious surfaces are joint planes which are made more conspicuous by the development of quartz veins in one set of joints. Good quartz crystals can be seen on these surfaces. Note the crossbedding and mud flakes in the red sandstones.

Watch the road cuts as we travel north from here. In one road cut between Lead Cove and Old Perlican, the sedimentary bedding is emphasized by red mudstone bands in white sandstones.

Stop 6 - Bay de Verde

Continue along Route 80, bypassing Old Perlican. Turn onto Route 70 towards Bay de Verde. At the top of the hill by the oil tanks, as you enter the community, at the beginning of the big road cut, stop and look at the outcrop on the left.

This outcrop is composed of coarse conglomerates that contain many different kinds of pebbles. Try to identify at least five different kinds of rock types in the pebbles. The area is folded into a large anticline. This folding has produced some fault brecciation that has been filled with quartz veins which can be seen at the north end of this outcrop.

Continue down into Bay de Verde, look at the strike and dip of the bedding and identify the anticline.

Stop 7 - Caplin Cove

Drive back to the main road and continue south on Route 70 on the east coast of the peninsula. Take the left turn to Caplin Cove and Low Point. Turn onto Main Street in Caplin Cove and turn down Wharf Road. Stop at the track that goes down to the beach and walk down past old fishing huts to the beach.

The stream beside the track falls over rapids where the bedding is very obvious. These dark grey shales show good bedding but have been faulted and folded. On the beach a large fault can be seen in the far cliffs, made obvious by the red beds on the top of the cliff. Decide which side of the fault has been moved up relative to the other side. Look at the relative positions of the red and grey rocks on either side of the fault. Note the stack at the end of the headland which has been produced by differential weathering (probably due to faulting of the grey shales and sandstones).

Look Out Point (north of Flamboro Head)

About 2.4 km from the Caplin Cove turn off on Route 70 there is a stretch of new road with a dirt section of the old road nearer to the coast. Take this dirt road and park when you can see the headland. Walk across the field to the top of the cliffs.

This headland shows the relationship of the different beds we will be looking at. It shows how the dip and strike of the rocks in combination with faulting has controlled the development of this headland. Presumably in a relatively short time (geologically speaking) this headland will be separated off as a small island by the erosive power of the waves.

Stop 8 - Northern Bay

Continue down Route 70 to Northern Bay Provincial Park. Walk onto beach and turn left and walk along to area by the waterfall.

Look at the cliffs at the back of the small bay before the waterfall. There are small caves at the base of the cliffs. Are they still within reach of the sea? Can you see any reason for them to have formed in the position they are in ?

Continue to the headland and determine which are the bedding planes. Search the surfaces for evidence of ripples and tool marks. Decide if the beds are right way up. The bedding of these sandstones is easily seen in the waterfall. Several features of waterfall development can be seen here. In particular look at the plunge pool and the development of potholes.

Stop 9 - Ochre Pit Cove

Continue down Route 70 to Ochre Pit Cove and turn down Brookside Road to the beach.

Just as you reach the beach, there are outcrops of hematite-rich shales on either side of the stream. These occur in every faulted and well jointed area along the beach to the north. There were efforts to follow this alteration band inland and to mine the iron but the quantities of ore were insufficient. Road building has since destroyed the old workings. Faulting can be observed at close quarters on the beach where the hematite occurs.

Return to the main road and turn onto Wharf Road and go onto the wharf.

From the end of the wharf the structure of the far cliffs is obvious. A series of normal and reverse faults can be seen, highlighted by the change in colour of the rocks. At the far end of the cliffs erosion has produced both an arch and a stack.

Stop 10 - Blackhead Wharf

Turn off Route 70 to Blackhead. At the bridge turn down to the wharf.

Beside the wharf, if the tide is out, there are good exposures of black shales which show ripples, current markings and very thin laminations (beds).

Walk up the paved drive, go down to the top of the cliffs and walk to the right.

At the base of the sandstone you can see contorted bedding, sandstone lenses and load casts. The bedding is uneven with thin muddy beds and thicker sandstone beds. Some beds are lenses (not continuous) some of which are calcareous and eroding.

Stop 11 - Hearts Content - Victoria Road

From the junction of Route 70 and Route 74 in Victoria, travel 6.1km on Route 74. The road cut is on both sides of the road.

The sandstones are very jointed making it difficult to distinguish bedding from cleavage at the eastern end of the outcrop. Close inspection of the rocks shows that the bedding varies in thickness. The sandier beds often show load casts at their bases. Other sedimentary structures make it easy to distinguish the "way up" of the outcrop.

Stop 12 - Carbonear/ Bristols Hope turnoff (on Route 70)

Return to Route 70 and proceed to Carbonear.

The road cut at the Bristols Hope turnoff, by the RCMP station, is in an outcrop of folded and faulted sandstones. The bedding is accentuated by quartz veins along the bedding. By following the gentle folds along the outcrop, it is easy to recognise at least one fault. Further along the outcrop there is a tighter anticlinal fold with well-developed cleavage through the centre of the fold.

Stop 13 - Frenchs Cove

Continue south along Route 70 to Bay Roberts. Turn left onto Water Street - the main road by Bay Roberts Harbour. Travel 3.1km beyond the Fire Station on Water Street towards Frenchs Cove. (The power pole on the right bears a yellow number 41).

This outcrop has been subjected to some metamorphism and shows well-developed slatey cleavage. Go round to the back of the outcrop. On this side the original bedding can be seen. In places this is emphasised by sandstone lenses which are less affected by the cleavage than the shales.

On the other side of the road there is a good example of glacial pavement. See how well the surface that has been protected by glacial till has been polished. It is best seen where the till has most recently been washed off. Where the surface has been subjected to weathering and erosion it has lost its high polish. Look for striations to indicate the direction in which the ice was moving.

Stop 14 - Cupids

Return to Route 70 and turn onto Route 60 at the junction. Turn left onto the road to Cupids at the National Historic Site sign. Drive 6.2km through Cupids almost to the end of the road along the coast.

The outcrop on the left (northwest) side of the road is composed of well-developed slate. The predominant layering is slatey cleavage. The shale bedding can still be seen in this outcrop. Samples from here are good examples for a school collection since the difference between bedding and slatey cleavage can be well illustrated.

Stop 15 - Turks Gut, Marysvale

Return to Route 60 and go through Brigus to Marysvale. Turn left onto Marysvale Road and continue to the end to the wharf. Look at the outcrop beside the road.

This boulder conglomerate has formed along the unconformity between the older Harbour Main Volcanics and the younger Conception Group sediments which are exposed on the other side of the Gut. The boulders in this conglomerate are mostly of porphyry with some amygdaloidal basalt (Basalt which had gas holes in it which have since been filled with another mineral such as quartz or calcite) and quartz pebbles.

There is very little cementing material in this deposit (only the spaces between the boulders are filled with cement) and the boulders are resting on each other. These boulders are large, up to 1.5m in diameter, with smaller ones between them and all are well rounded showing that they must have been deposited under water.

Stop 16 - Burkes Cove, Colliers Bay

Return to Route 60 and turn left to Colliers. Travel 2.2 km beyond the church and school in Colliers to the north end of Burkes Cove. A small beach curves out to an unnamed headland. Cross the beach to the headland.

Some of the beach rocks are worth collecting to start a school rock collection.

The small headland is composed of a rock called porphyrite. This rock obviously is igneous but contains large blocks. These are volcanic rocks. Look carefully at the size and distribution of the blocks in this outcrop.

The porphyrite is cut by dark green, fine-grained diabase. These intrusions are called dykes. The molten diabase forced its way into cracks and fissures in the porphyrite and when it cooled and crystallized left these unusual shaped intrusions. The edge of the intrusions cooled more rapidly than the centre so that in places a finer grained 'skin' is developed. Sometimes small pieces of porphyrite can be seen enclosed in the intrusion. These were broken off by the molten diabase as it forced its way into the porphyrite. These pieces are often altered by the heat of the molten rock so that they are changed and new minerals are formed. The yellow-green mineral is called epidote.

The surface of this outcrop has been smoothed and polished by the movement of ice sheets over it during the last Glacial Period. Scratches or striations indicate the direction in which the ice moved. The surface has been protected by glacial till on the edge of the outcrop so that the best polishing can be seen close to where the till is washing off.

Stop 17 - Bacon Cove

Return to Route 60 and continue south to Conception Harbour. Turn left on the road to Kitchuses and Bacon Cove. Follow the road through Bacon Cove to the wharf at Little Bacon Cove. Follow the trail which crosses the field from the end of the roadside barrier just before you reach the road that goes down to the wharf. If the tide is high you will not be able to get along the beach from the wharf. On the beach, walk south (to the right) until you get onto the headland.

The surface you are walking on is the very irregular outcrop of the Proterozoic (Precambrian) Conception Group siltstones. The irregular surface is filled in with small pockets of red shale and conglomerate. In some places there are limy lenses and algal structures. Go further along until you can look back towards the road. You will see flat-lying red and white sandstones and limestones lying on top of the folded, and in places, steeply dipping Proterozoic rocks. This is the unconformity between the Precambrian Proterozoic aged rocks and the Paleozoic Cambrian aged rocks above. For an angular unconformity such as this to develop, the Proterozoic rocks must have been subjected to a mountain building event, the Avalon Orogeny (see Figure 3). This uplifted them so that they were folded, weathered and eroded before the deposition of the Cambrian rocks began. A further indication of this erosion is the development of little pockets of conglomerate filling the hollows in the Proterozoic land surface before the flat lying beds were deposited.

To the north of the wharf is an exposure of a mixtite. This is an unsorted conglomerate which was deposited during glacial conditions at the end of the Proterozoic. It contains many different pebbles of different rock types which were deposited in a very muddy matrix so that the clast appear to "float" in the matrix and do not touch each other.

N.B. Student Exercises

Student exercises for Stops 15, 16 and 17 developed by Chris Woodworth Lynas are included with this field guide.