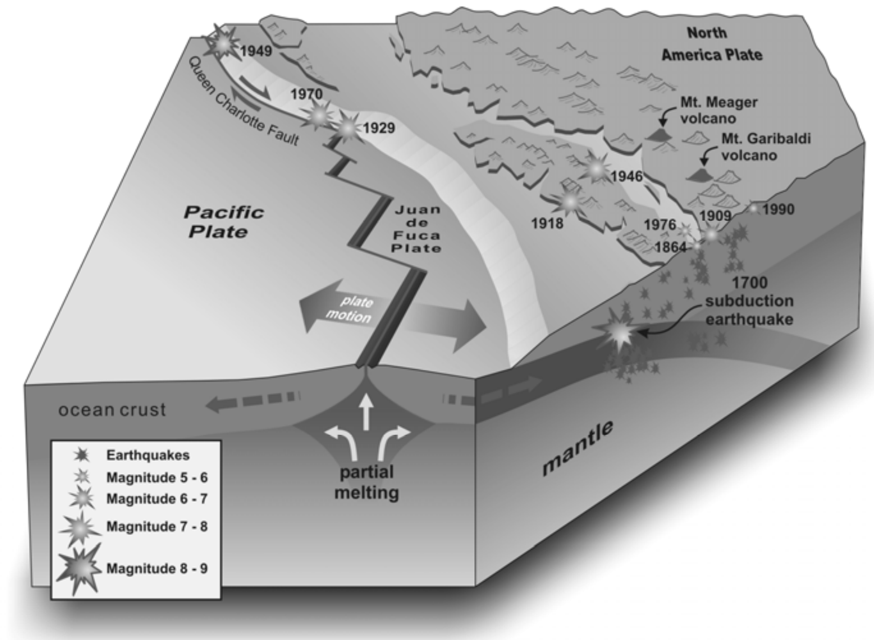
Earth Science for Grade 10 Teachers

EdGEO Workshop Manual



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Earth Science for Science 10 Teachers

An EdGEO-sponsored workshop at Catalyst 2008

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SCHEDULE

1. Rocks and their structures – how geologists use rocks to learn about the Earth
   10G1
   Activity 1 Classifying rocks and understanding the stories they tell

2. Fossils and Geological Time – fossils are our evidence for how life forms have changed over time
   10G2
   Activity 2a The Earth's time line
   Activity 2b How fossils form and what they tell us about the history of life
   Activity 2c Reconstructing ancient geography using fossils

3. Plate tectonics and the Pacific Northwest
   10G4
   Activity 3a Foamies and plates of the Pacific Northwest
   Activity 3b Identifying plates and features on the Juan de Fuca Plate map

RESOURCES
Rock Kit
Field Guide to the Identification of Pebbles
Fossil Kit
BC Fabulous Fossils Poster
Earth History Clock
South Vancouver Island Earth Science Fun Guide
Juan de Fuca Plate Relief Map
Colour transparencies - Plates of the Pacific NW

Activity 1 Classifying Rocks and Understanding the Stories they Tell

Start by Exploring!

- Encourage the group to look closely at and classify a set of rocks
- Listen to what they say as they work (shape, colour, use, beauty …)
- Gather them together after a few minutes and talk about how every one of these ways of classifying is valid
- Introduce the idea that geologists classify rocks by how they formed
- Talk about how different rocks might form. This is an opportunity to hear about what they might already know and also about misconceptions they hold

Then Discuss …

- Ask how they think igneous rocks form? And what kinds of things would we see in the rock because of this? Crystals that interlock and are randomly oriented, generally no layers or bands
- What about sedimentary rocks? – fossils, layers, particles that look like they have been carried by rivers or wind (rounded), hardened sand, gravel, mud.
- Metamorphic? – squished looking, minerals aligned on flattish, shiny surfaces, folded layers
- Now, get the groups to reclassify their rocks by origin

Do your students Understand?

- See if they have understood by giving them a mystery rock or two to classify. It's amazing how well they do and how confident they are about it.

KEY THINGS:

We are building on existing knowledge and using very little jargon

We are making observations (discipline specific ones)

And relating the observations to the story of how the rock formed, so the observations are immediately relevant

Rock Samples Catalyst 08 EdGEO workshop

Igneous rocks

Form from cooled magma (melted rock)

Interlocking crystals
Usually hard
Homogenous and uniform (no obvious structures)
Speckled appearance
If you can see the crystals – plutonic (cooled deep inside the earth), if not – volcanic (cooled at the Earth's surface)

RI 1 Granite

Granite is made up of interlocking crystals of creamy feldspar, glassy quartz and black mica minerals. The crystals are easily visible which means that the rock cooled slowly from hot magma (leaving plenty of time for the crystals to form and grow). This is called a plutonic igneous rock. The minerals are mostly light coloured so the rock is compositionally felsic – lots of feldspar and less Fe and Mg (as opposed to the darker mafic minerals in basalt which contain lots of Fe and Mg). Granite is a very common rock on the continents - e.g. the Coast Mountains of B.C.

RI 2 Basalt

Basalt is the most common volcanic igneous rock. It has very small crystals that you can't readily be seen with the naked eye, which means that the rock cooled quickly from magma that erupted at the surface of the Earth. The holes are where there were gas bubbles in the magma. Basalt makes up the top layer of rock in the ocean crust. You find basalt (old ocean floor) in the Metchosin/Sooke area e.g. at Widdy's Lagoon Park.

RI 3 Pumice

Here's a rock that floats! It is very light in weight, because it cooled from a very gassy felsic (light coloured) magma, so the rock is full of holes. These kinds of magmas usually erupt very violently from volcanoes like Crater Lake in Oregon or Lake Taupo in New Zealand.

Sedimentary Rocks

Form form eroded gravel, sand, mud and carbonaceous material that has been carried by water, wind or ice, and then settled at the bottom of rivers, lakes or oceans. The loose sediments are deposited in layers that are slowly buried and harden due to pressure and chemical changes, becoming sedimentary rocks.

Usually layered
Often contain fossils
Grains are usually somewhat rounded (from being carried in rivers etc)
Often softer than igneous or metamorphic rocks

RS 1 Conglomerate
Contains gravel-sized, rounded grains (larger than 2mm) that have been transported by rivers (or at beaches) and then deposited, along with the finer sediment in between, by the current as it slowed down.

RS 2 Sandstone
Sandstones are made of sand-sized grains. Many of the grains are quartz, and the rock has a gritty feel. The sand grains were cemented together when the sediment was buried by many more layers of sediment. The fossils fragments in this sandstone suggest that it was deposited in the ocean, offshore of a beach environment. The sand grains were washed there from the continent.

RS 3 Shale
This smooth, soft rock is simply hardened (or lithified) mud. It is dark because there is some organic C present. When you see this kind of rock, it suggests a very quiet water environment such as a deep ocean floor or floodplain of a river. Shale or mudstone is often layered.

RS 4 Limestone
The main mineral in limestone is calcite. It reacts (fizzes) with acid and dissolves easily (caves etc form when rain water with dissolved CO_2 dissolves the calcite forming underground tunnels and caverns). Most limestones are accumulations of the hard parts of marine organisms such as clams, corals, sponges etc. so they usually have obvious fossils within them. Limestones are very important reservoir rocks for oil and gas.

Metamorphic rocks

From when an existing rock (igneous, sedimentary or metamorphic) is changed when subjected to extreme temperatures and pressures because of deep burial or the stresses of plate interacting. The original character of the rock changes - mineral grains tend to align along surfaces and new metamorphic minerals such a garnet grow.

Often greenish in colour
Shiny micas are often very obvious
The minerals look 'lined up' giving these rocks shiny surfaces
May have a banded appearance
Many have small folds

RM 1 Phyllite
A fine grained 'slatey-looking' rock, with a silky sheen on the surfaces from mica and chlorite minerals lining up parallel to these surfaces. A phyllite forms when a mudstone or shale is metamorphosed (i.e. subjected to higher temperatures and pressures) and the new metamorphic minerals line up at right angles to the pressure.

RM 2 Schist
The minerals in a schist are somewhat coarser than in a phyllite, indicating that the pressure and temperature were a bit higher (more severe metamorphism). The mica minerals are visible with their shiny surfaces.

RM 3 Gneiss (pronounced 'nice')
This is a banded metamorphic rock that was subjected to even higher temperatures and pressures than the schist. The layers of light and dark minerals are smeared and folded from the pressures they were subjected to. There are lots of gneisses around Victoria. They formed when pieces of crust collided with North America resulting in very high temperatures and pressures.

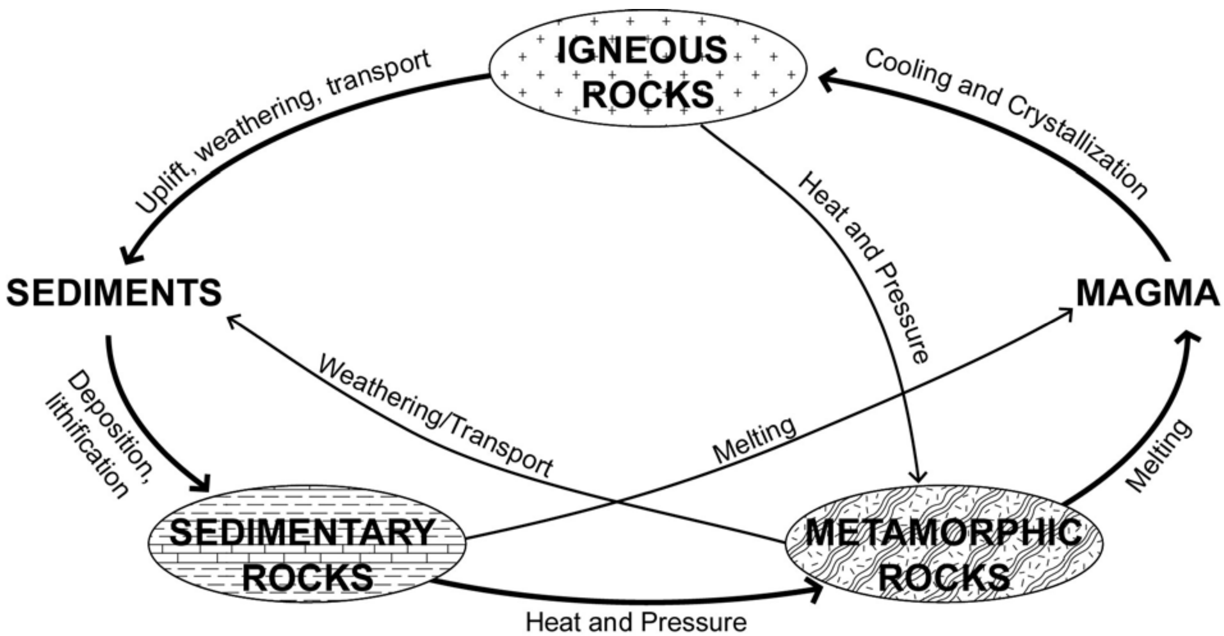
Background Information—Rock Cycle and Igneous Rocks

ROCK IDENTIFICATION

When we think about what makes up Earth, rocks usually come to mind. We constantly observe rocks in our environment as we hike in and gaze at the mountains, walk along a stream or riverbed, visit the beach, or notice attractive building stone.

Rocks are made of minerals and usually have one or more mineral within them. The best indicator of a rock's identification is the way these mineral grains or crystals are arranged in the rock. Rocks are grouped into three types based on their origin: IGNEOUS, SEDIMENTARY, and METAMORPHIC. Characteristics that are easily observed in rocks, especially the arrangement of mineral grains, help us classify rocks.

<u>The Rock Cycle</u>



The ***ROCK CYCLE*** describes how rocks pass from one form to another. A more accurate terms might be the "Rock Recycle". Throughout geological time, any of the three rock types can be transformed into another in this ongoing cycle. Remember our Earth is dynamic so the rocks you will hold in your hands today are not final products, but will ultimately transform into other rocks through time. The Rock Cycle is important for understanding rock classification and identification based on the stages of this rock cycle that share characteristics.

The outside path of the cycle shows us that MAGMA (molten rock) forms IGNEOUS ("formed by fire") rocks, which then undergo uplift, weathering and transport to forms SEDIMENTS as pieces of rock are carried away by various processes and deposited elsewhere and lithify into SEDIMENTARY ("settling") rocks. If these rocks are buried deeply enough, they transform into METAMORPHIC ("changed") rocks that will melt into magma and be reborn into igneous rocks.

The internal pathways show other transformations such as and igneous rock becoming buried and transforming into a metamorphic rock.

Revisiting the Rock Cycle

Recall that rocks are simply stages along a continuum of the Rock Cycle (see Fig. 5.4). We now want to review the dominant processes in each general rock classification (melting and cooling in igneous rocks, weathering and transportation in sedimentary rocks, etc.).

The term "rock cycle" only tells part of the story.

Although one pathway is Magma ⇒ Igneous rocks ⇒ Sedimentary rocks ⇒ Meta-morphic rocks, there can be many others.

For example, an igneous rock may be buried even deeper and metamor-phosed without ever going through uplift, erosion, and weathering at the surface.

Thus a more accurate term might be the Rock "Recycle".

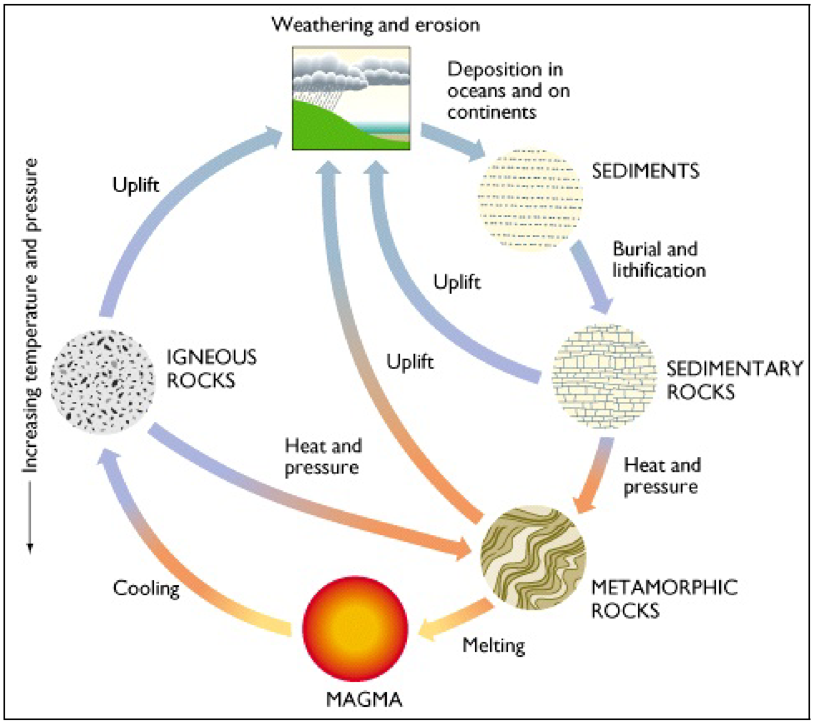


Figure 5.4 The Rock Cycle.

Activity 2a The Earth's Time Line

Background: Comparing the magnitude of geological time with time spans in a person's lifetime is difficult. Geologists estimate the age of the Earth as 4.6 Billion years old by studying the rocks and minerals and by dating radioactive isotopes contained within them. Earth has constantly changed through its history. Continents have moved around, come together and broken apart. There have been many mass extinctions and evolutionary changes in the history of life. In this activity, your students will make a timeline from the earth's birth to present day that they can actually walk along in order to get a better idea of how old our planet really is. Many analogies or metaphors have been used to help us conceptualize the immensity of geological time.

Materials

- 46 metres or 4.6 metres of adding machine paper, wallpaper, or rope
- metre stick or measuring tape
- markers
- clothes pins (if using the rope)

Procedure

1. Use the 4.6m of paper or rope to represent 4.6 billion years of Earth history. One cm will equal 10 million years.
2. Using the annotated geological time scale, mark the major events in Earth history onto the paper or peg them onto the rope. (The table is based on using 46 metres, so you'll have to adjust the measurements). Your students could make pictures of the events on paper, but for today, we'll just get the events on as words. These are major events and students could research other dates. You'll need lots of wallspace if you go for the 46m version!

Extensions

A group project can include making a geological time-line for your classroom, using distances equaling 4.6 metres or 46 metres if you have lots of space, that are analogies for geological time. Examples include:

1. 4.6 or 4 metres of adding machine tape, marked with key events.

2. Variation is Geologic Time (Clothes) Line: A similar length of rope or clothesline could have illustrated events attached by clothes pegs for students to peg where they think the events should lie. This is a more participatory form of the exercise. Having the key marker for the start of the Phanerozoic as only 15% of the rope is a good visual.

3. Another participatory variation is to have the timeline (paper or rope) on the floor and designate students as events. They then have to stand where their event occurs, so anyone within the 15% of the Phanerozoic will have to vie for space (especially the Cenozoic).

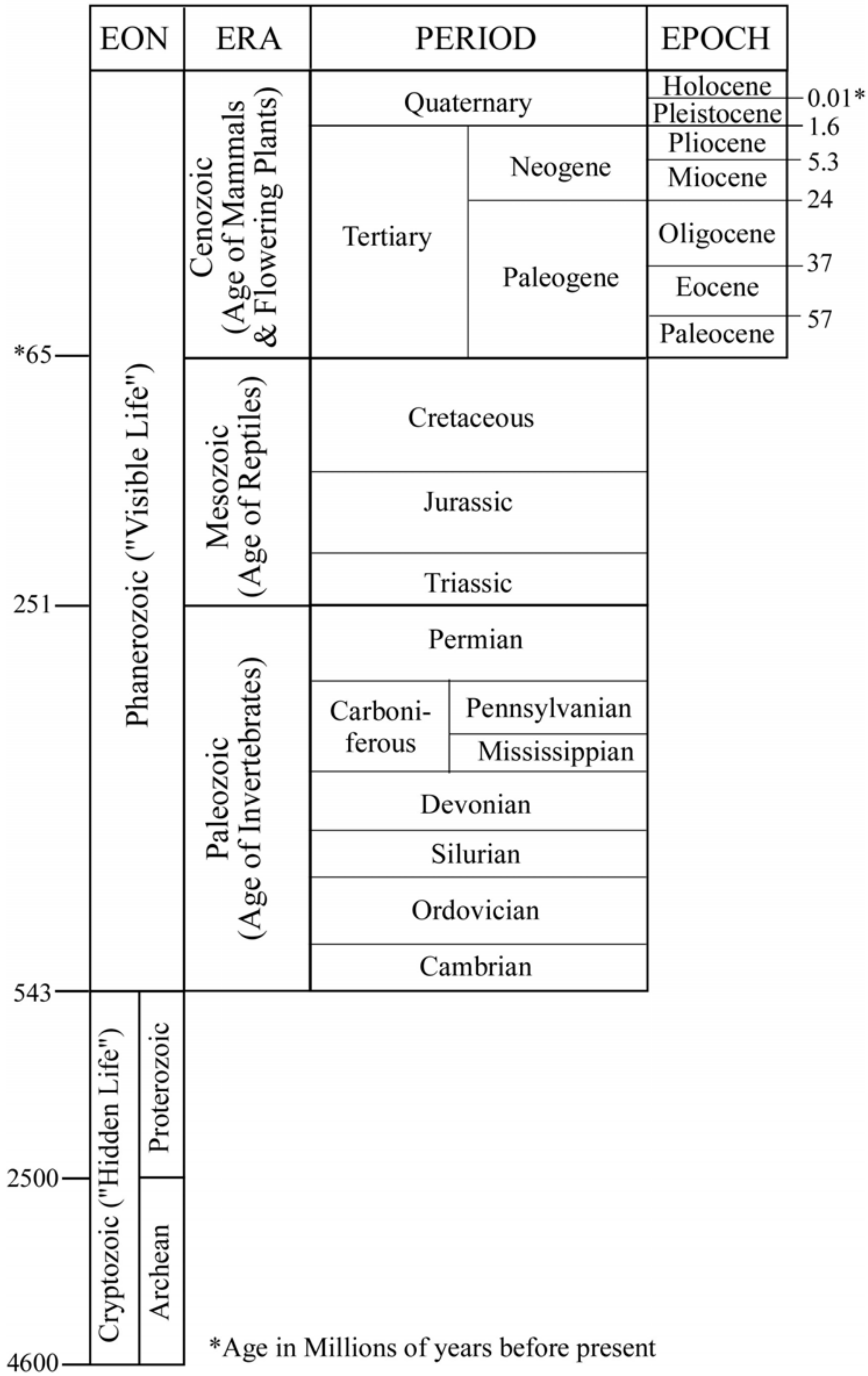
4. Divide 4.6 Billion years into a 12 hour clock (in Appendix B and colour on CD). The colour version of this is coloured to match the colour scheme of different aged rocks on

Map 1860A called the Geological Map of Canada, available from the GSC Bookstores in either Vancouver or Calgary.

5. Use a calendar year.

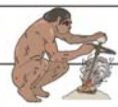
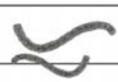
6. Have students come up with their own metaphors (e.g.length of Canada or of a hallway in the school).

The Geologic Time Scale



*Age in Millions of years before present

EARTH'S TIME LINE

Era	Event	Millions of years ago	Centimetres added on
Cenozoic	Present Day 	0	Start
	Homo Sapiens appear	1	+1
	 Ice Age	2	+1
	First Primate	3	+1
	Mass extinction (dinosaurs, many marine species), possible meteorite?	65	+62
Mesozoic	 Dinosaurs decline 	70	+5
	Rocky Mountains form, first flowers	136	+66
	Pangea splits apart, continents begin to separate	190	+54
	 Flying reptiles, birds, small mammals appear	200	+10
	First dinosaurs appear 	210	+10
	Mass extinction (75% of species wiped out)	225	+15
Paleozoic	 First reptiles, trees, insects appear	350	+125
	First land plants, first amphibians	395	+45
	First fish 	400	+5
	Horseshoe crabs, sharks appear	500	+100
	 Trilobites, first shell-bearing organisms appear	545	+45
Precambrian	Major mountain building	1000	+455
	 Oldest forms of life appear (algae, bacteria)	3400	+2400
	Formation of Earth from gaseous cloud	4600	+1200

Fossil Samples Catalyst 08 EdGEO Workshop

Bivalves	Pleistocene	
Sea Urchin	Eocene	*Cenozoic Era*

Petrified Wood	Cretaceous/(Tertiary)	
Dinosaur bone	Cretaceous	
Shark teeth	Cretaceous	
Gastropod	Cretaceous	*Mesozoic Era*
Ammonite	Jurassic/Cretaceous	
Belemnite	Jurassic	

Coral	Mississippian	
Brachiopod	Devonian	*Paleozoic Era*
Trilobite	Middle Cambria	

Activity 2b How Fossils Form and what they tell us about the History of Life

PRESERVATION OF FOSSILS

The fossil record preserves less than 1% of all the species that have ever existed on the earth. Preservation requires special conditions and is enhanced by:

- **Presence of hard parts**—soft-bodied organisms such as worms are rarely fossilized, but organisms with shells, bones and teeth are more resistant to stresses of burial and chemical change through time.
- **Favourable preservation environment**—marine organisms are more likely to be fossilized than terrestrial organisms, as they may be buried quickly before they can be eaten or decomposed. Areas of low oxygen levels (peat bogs, swamps) may also enhance preserve because bacterial decomposition is impeded.

TYPES OF PRESERVATION

1. Original Material

- **Unchanged.** Examples are: bivalve shells, Pleistocene animals from the La Brea tar pits, insects preserved in amber, mammoths "freeze-dried" in glaciers or Arctic permafrost, and mummified ground sloths in dry caves in the American southwest.
- **Carbonization.** Volatile elements (N, S, O etc.) are lost, leaving only carbon. This process preserves delicate and soft-bodied worms, jellyfish, insects and leaves. Unique organisms of the Burgess Shale were preserved by carbonization.

2. Replacement of Primary Material—Original organic material has been dissolved away by circulating groundwater and is replaced by minerals that precipitate out of solution.

- Carbonate skeletons may be replaced by **pyrite**, **hematite** or **limonite**.
- Shell, bone or wood is often replaced by microcrystalline **quartz**.

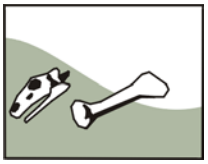
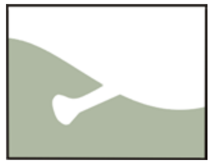
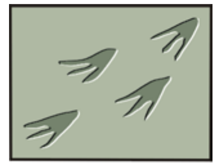
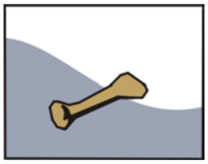
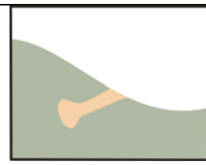
This process can occur on a fine scale so that delicate features of the structures are retained.

3. Molds, Impressions, and Casts

Surface characteristics of an organism can be preserved as an **external mold** or **impression**. An **internal mold** reflects, for example, the internal surface of shell valves. Molds only preserve surface markings: neither the original material that composed the hard part nor the internal structures remain. When an organism is completely dissolved away, the space that it occupied in the sediment may be filled with other materials such as mud or clay. This forms a **cast** of the organism.

4. Trace Fossils (Ichnofossils)

The study of *trace fossils* is called **ichnology**. Trace fossils may be tracks, trails, burrows, footprints, grazing patterns, and coprolites (fossilized fecal matter). Trace fossils can tell us a great deal about the size, lifestyle, and environment of an organism.

	Original material: Unchanged hard parts		Mold in the shape of original fossil		Trace fossils: Tracks &
	Replacement of original material		Cast forms as mold is filled in		Trails

IMPORTANCE OF FOSSILS

1. **History and evolution of life**

   The fossil record is a record of evolutionary change. Paleontology helps us understand catastrophic events such as mass extinctions that mark drastic changes in the history of life.

2. **Geologic dating and correlation**

   The Principle of Fossil Succession states that all organisms eventually become extinct, and they are replaced by newly-evolved, related forms in an orderly succession through time.

   Certain organisms, called **zonal fossils**, are characteristic to specific time periods, and thus the geologic age of a bed can be determined by its fossil content. In addition, rocks in one area can be correlated with those at great distances (even on other continents) because they contain identical fossil assemblages.

   In order to qualify as a zonal fossil, the organism should have the following characteristics:

   - It should have existed for only a short period of geologic history.
   - It should have distinctive features that make it easy to recognize.
   - It should be abundant enough that it is well represented in the fossil record.
   - It should have a large geographical distribution.

3. **The study of ancient environments**

   Each type of organism has specific environmental needs. Fossils in sedimentary rocks give us important information about climates and environments of the past.

Activity 2c Reconstructing Ancient Geography Using Fossils

Background

There are many applications and uses of fossils. As we have seen in the previous exercise, fossils help us tell geological time, and understand the history of life on Earth. They also help us reconstruct ancient geography **(paleogeography)** and ancient environments **(paleoecology)**.

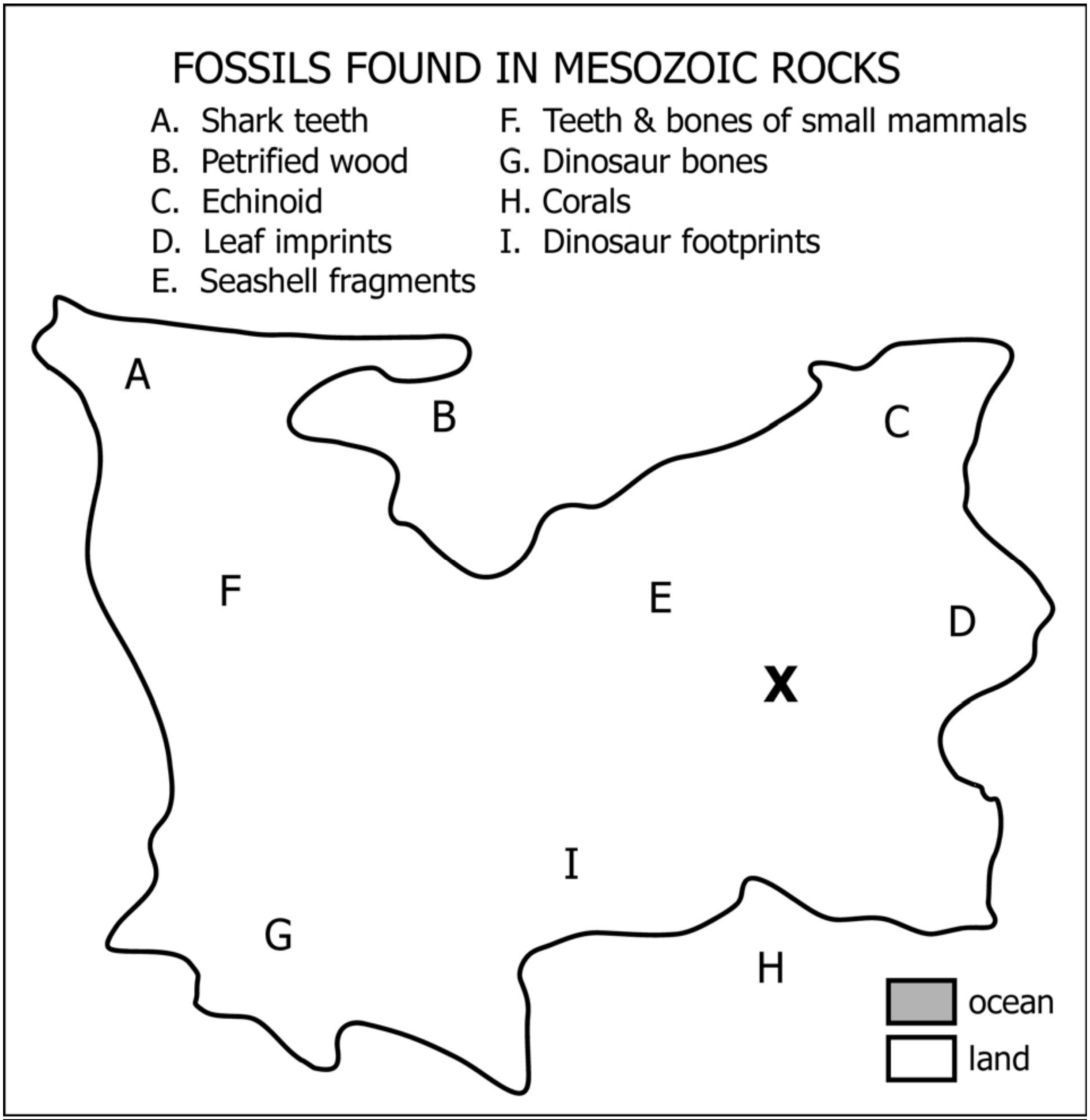
One of the main objectives in studying sedimentary rocks is the reconstruction of the environment in which the sediments that formed the rocks were deposited. Accurate reconstruction of environments can lead to the discovery of natural resources such as coal, many metals, salt, oil and gas. A study of the environmental requirements of organisms that become fossils provides the most accurate information on the ancient environment in which they lived. Studies of this type are referred to as **paleoecology.**

Materials

- Large-scale handout of map (see next page)
- Overhead of map, overhead pens
- Crayons or coloured pencils
- Fossil kits

Procedure

1. Pass out the maps. Have a large-scale version to display and use in Step 3. Explain that this is a map of an imaginary continent. Locations A through I are places where fossils have been found in rocks of Mesozoic age (the "Age of Dinosaurs", roughly 65 million-250 million years ago). The object of the activity is to make a map of what the continent looked like during Mesozoic time, i.e. where the land and ocean areas were at that time.
2. Have students select colours for land and water and make a key for the map.
3. The table at the top of the handout shows which fossils were found at each location. (Locations and fossil types are arbitrary and can be adjusted to suit your needs or preferences.) First have students place the appropriate fossil on the large-scale format of the map. Then have students colour each locality as either land or ocean. With elementary students it would work better to provide this information orally rather than to give them the written table. (For example, "At location A we found shark teeth. Was this land or ocean? O.K. colour that area with your colour for ocean.")
4. Ask the students to colour all the areas around and between the localities as either land or ocean (interpolate between data points). Emphasize that the outline of the modern continent may have no relationship to the Mesozoic boundary.
5. Ask students whether location X was land or ocean in the Mesozoic, according to their maps.


FOSSILS FOUND IN MESOZOIC ROCKS
A. Shark teeth
B. Petrified wood
C. Echinoid
D. Leaf imprints
E. Seashell fragments
F. Teeth & bones of small mammals
G. Dinosaur bones
H. Corals
I. Dinosaur footprints
A
B
C
F
E
D
X
I
G
H
ocean
land

Activity 3a Foamies and Plates of the Pacific NorthWest

Background: We can use foamies to model the plate interactions of the Pacific Northwest. The Pacific plate and the Juan de Fuca plate diverge from each other at the Juan de Fuca Rideg, where new ocean floor is created as the plates move away from the ridge. The convergent margin off the west coast of Vancouver Island is where the thin (7 km thick) Juan de Fuca Plate and the thick (20-40 km thick) continental plate of North America collide. The thinner, more pliable, and dense plate (Juan de Fuca plate) is being over-ridden and subducted beneath the leading edge of the North American plate.

Materials

- 2 Thinsulate foamies, about 2 m long
- 1 piece of 4 inch foam rubber, about 50x80 cm
- 3 small laminated arrows (25 cm long) and masking tape
- labels for Pacific Plate, Juan de Fuca Plate, North American Plate, Juan de Fuca Ridge, Cascadia Subduction Zone
- Plasticene
- Overheads of the plates of the Pacific Northwest

Procedure

Sketch each stage of this or have your team take digital images of the set up:

1. Drape thin foamies over the backs of two chairs (backs of chairs put together), with the long sides tucked down between the chairs. Label one Pacific Plate and one Juan de Fuca Plate
2. Pull the leading edge of the foamies up (vertically) and move them away from each other (horizontally). This models the creation of new oceanic material at the ridge and the conveyor-belt motion of the oceanic plate away from the ridge.
3. Show the thick foamie (North American continental plate) converging with the leading edge of the Juan de Fuca Plate to model subduction. Label the ridge (where new oceanic plate material is created as the Pacific and Juan de Fuca plates spread apart) and the subduction zone (where the plate is consumed). The angle of the Juan de Fuca plate as it subducts under North America is about 45^{o}.
4. Place volcanoes on the North American Plate above the descending oceanic plate.

Activity 3b Identifying plates and features on the Juan de Fuca Plate Map

The three main plates which affect us on southern Vancouver Island are the

North American plate (we're on it)
Juan de Fuca plate (it's out to sea)
and the Pacific plate (on the other side of the Juan de Fuca plate towards the west)

1.Using the Juan De Fuca Plate Relief Map, construct a topographic cross section from one side of the map to the other going roughly east west across the Juan de Fuca or Gorda Ridge. Place the graph paper along the line of the cross section and mark off each contour (and record it's height or depth) on the top edge of the paper. Draw a horizontal line below and a vertical scale at each end. The scale will extend above and below the cross section line. Transfer the contour heights to points on the cross section and the join the points.

2. Label the features you have drawn the cross section through.

3. a) Draw in the plates (Juan de Fuca, North American and Pacific) below the surface topographic line.
b) Show the subducting Juan de Fuca plate and where you think rising magma occurs.
c) Label the plate boundaries.
d) Use arrows to show the directions of plate movement.
e) Mark in where you would expect to have earthquakes occurring.

(As an extension exercise - find out where the latest earthquakes have been in the region (www.pgc.nrcan.gc.ca) and locate them on the map). How does this fit in with what you have just drawn?

4. What do you see?
From west to east. Juan de Fuca or Gorda Ridge (diverging plate boundary), with a rift at the centre of the ridge
Topography slopes away from the ridge to the east (Juan de Fuca plate) and west (Pacific plate) as the new crust cools
There is no trench above the subduction zone (it is filled with sediment scraped off the subducting plate as well as sediment from the adjacent continental area)
Steep continental slope
Shallow fairly narrow continental shelf
Mountains and volcanic peaks on the edge of the continent (from convergence of the Juan de Fuca and North American plates)

5. What else to notice on the map?

Where are the diverging, converging and transform plate margins/boundaries?
Follow the trace of the Juan de Fuca and Gorda Ridges - notice where they are offset by Transform faults
Volcanic seamounts - where there is a local hot spot producing volcanoes
Fans of sediment coming off the continental shelf into the ocean floor (e.g. Nitinat Fan)
Follow the chain of volcanoes up the continental margin - how many can you pick out?

6. What are the different characteristics on the ocean floor compared with those on land?