

Answer Key

The Great Lakes

Chapter 1: Niagara Falls

- 1.1.3 Roughly 1.5 metres
- 1.1.4 17 million litres per minute – the largest in the world
- 1.1.5 First place in the 19th century where there was a fairly accurate estimate of past time
- 1.1.6 36,000, a few thousand years old, 4.5 billion years
- 1.1.7 Continental and oceanic crust, mantle

Chapter 2: The Legacy of the Grenville Mountains

- 1.2.3 As a result of the collision of North America (known as Rodinia at the time) and another piece of oceanic crust
- 1.2.4 Huge – the size of the Himalayans; 10 kms high, covered with snow, glaciers draining away from the mountains
- 1.2.5 The crust rebounded when released from the weight of the ice causing further erosion. Eventually, the roots of the Grenville Mountains rose up and were exposed.
- 1.2.6 A combination of pressure and heat
- 1.2.7 All crustal rocks contain radioactive elements. When you put one layer on top of another, the heat is trapped and begins to build.
- 1.2.8 Few places in the world exist where you can actually view the Earth's building blocks; in this case, the very thick middle of a mountain belt.
- 1.2.9 The rocks contain no primary features. All we know for sure is that they were all hot.
- 1.2.10 Uranium-lead dating
- 1.2.11 The original age of the rock and the time of the melting
- 1.2.12 One grain of sedimentary rock, weighing much less than one gram
- 1.2.13 The rocks have been painted by some of the greatest painters in Canadian history, and contemporary artists continue to paint the rocks.

Chapter 3: Salt Mines: An Underground Laboratory

- 1.3.3 New volcanic mountains arose, creating a number of “sinks” all over the continent. About 400 million years ago.
- 1.3.4 It would be the same climate that exists in the Caribbean today
- 1.3.5 Created salt deposits that are mined today
- 1.3.6 400 million years old
- 1.3.7 The white horizontal lines indicate years of extreme heat. The black lines indicate cooler, rainier weather.
- 1.3.8 They drill cores.

Answer Key

The Great Lakes, continued

- 1.3.9 It was so valued that wars were fought over it. Soldiers used to be paid in salt. It was an important preservative for many years.
- 1.3.10 That there was a sudden flood
- 1.3.11 This is where the waves of the water lapped against the shoreline millions of years ago.

Chapter 4: Ice Sheets and Glaciers

- 1.4.7 They scoured out the Michigan basin (of salt) and created the other huge craters that became the Great Lakes.
- 1.4.8 A pink pebble from the Canadian Shield, far to the north of the bluffs
- 1.4.9 Glacial melt water
- 1.4.10 Twelve to 15 million years ago
- 1.4.11 The effect of climate change on water levels between Georgian Bay and Lake Huron
- 1.4.12 He believes it will contribute information about the climate 8 500 years ago.
- 1.4.13 Larger than Niagara Falls
- 1.4.14 Located between Georgian Bay and Lake Huron

The Rockies

Chapter 1: Plate Tectonics - Formidable Forces

- 2.1.1 Volcanism could have added some new rock from volcanoes (but not enough for all of the land that developed); areas below sea level could have been uplifted forming the land (we would see mostly deep sea sedimentary rocks, not the complex mixture of rock types, over the Cordillera if this were the case); strike slip faulting could have brought land from elsewhere (some was added this way). Most of the land west of the original western edge of North America is in fact "exotic" material added as a result of plates converging with the continent.
- 2.1.2 How were the Rockies made? Why are they folded? What kind of force was strong enough to bend solid rock? Why is there oil and gold trapped in the US Rockies and not in the Canadian Rockies? How much longer before the glaciers melt away?
- 2.1.3 Rock at the peaks of mountains was once at the bottom of oceans. The folded and faulted rocks in the jagged peaks were once as flat as the Prairies. The Rockies were once completely covered in ice.
- 2.1.4 Folding (plastic deformation) and faulting (brittle deformation)
- 2.1.5 Exotic rock: rock that did not form where it is now. Exotic rock has been moved from somewhere else and then scraped off a subducting plate. It will be quite different, over an abrupt contact, to the rocks that it ends up being next to.
- 2.1.6 Subduction: an oceanic plate that descends beneath a continental or another oceanic plate.
- 2.1.7 Basalts

Answer Key

The Rockies, continued

- 2.1.8 Extremely thick sequence of basalts (in some places on Vancouver Island. more than 6 kms thick). The rocks are dark coloured and here they have been eroded to form the sea caves and imposing coastal cliffs.
- 2.1.9 Formed from magma erupting repeatedly at volcanic islands in the middle of an ocean
- 2.1.10 Hawaii or ocean plateaus such as Hess Rise.
- 2.1.11 The basalts are a thick pile of lavas that were part of an oceanic volcanic island. The volcanic island was carried towards North America on a plate. The plate subducted beneath North America and when the volcanic island riding along on the plate collided with North America, it was scraped off and accreted to North America, forming the basalts at Hesquiat.
- 2.1.12
- The old North American margin was roughly where the Alberta/BC border is today.
 - Hesquiat is on the western edge of Vancouver Island, just North of the Pacific Rim National Park.
 - Wrangellia.
 - Sixteen accreted terranes.
 - They are typically long narrow, squished looking belts of rock.
- 2.1.13
- The ocean crust subducts because it is thinner and denser than the continental crust.
 - Earthquakes (there is almost one per day recorded on Vancouver Island), volcanoes (e.g. Mt Meager, Mt St. Helens), uplift and compression-producing mountains (accompanied by folding and faulting).
 - When terranes collide there are huge forces associated with the collisions. These compressional forces cause the sediments and rocks at the edge of the North American plate to buckle (fold) and break (fault) as they are compressed.
 - Every time a terrane is added, a new episode of folding and faulting associated with the collision occurs.
- 2.1.14
- The dark soft drink bubbles gently over the edge of the cup, while the corn syrup builds up pressure and then explodes out more dramatically.
 - The 'magmas' have different viscosities. The corn syrup magma has a higher silica content and is therefore thicker and flows less easily – high viscosity. The soft drink magma has a low viscosity because of the lower silica content. These low viscosity, more mafic (richer in iron and magnesium) magmas also tend to be hotter and less gas-rich than the higher silica (felsic) magmas. Viscous magmas tend to form highly explosive steep sided volcanos (e.g. Mt. Fuji) and magmas with low viscosities (runny) tend to form flat sheets (plateaus or volcanoes like Mauna Loa in Hawaii).
 - The low viscosity mafic magma would have formed the Hesquiat basalts.
 - The Hesquiat basalts weren't subducted because they are very thick (and not quite as dense as normal ocean crust). The ocean crust is on average around 6km thick. If ocean crust with an additional 5 or 6km thick pile of basaltic lavas reach the subduction zone, the basalts will be scraped off as terranes.
 - The Hawaiian Islands, Line Island Ridge, Hess Rise, Shatsky Rise (these last three are all ocean plateaus similar to what the Hesquiat basalts would have been like before they collided with North America).

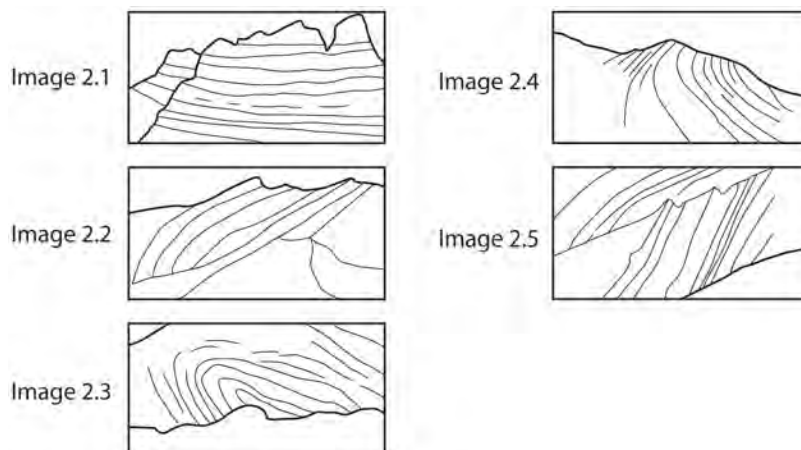
Answer Key

The Rockies, continued

Chapter 2: From Sea to Sky: Folding and Thrusting

- 2.2.1 One example would be to push at both ends of a pad of paper – the pad will buckle or fold. Another way would be to take a soft granola bar and squeeze the ends towards each other.
- 2.2.2 Pushing both ends of a stick with your hands (the stick will break) or dropping a cup or plate on the ground is another example of brittle deformation.
- 2.2.3 You would experience difficulties with reproducing the scale of the processes and also with the actual conditions in the Earth such as confining pressure, due to depth under the Earth's surface as well as temperature and the amounts of force involved.
- 2.2.4 All of the mountain topography shown in the Rockies is a result of folding and faulting. The vertical sedimentary layers are parts of folds, and many of the seemingly horizontal layers are parts of huge folds that toppled over and are now lying flat. The faults that are most common (e.g. in Mt Yamnuska) are thrust faults. These are very low angled faults, along which large blocks of rock moved towards the east as the North American plate collided with terranes and caused vast amounts of horizontal compression.
- 2.2.5 Rocks that break are brittle. Generally this is what happens to rocks near the surface when they experience stresses. When rocks are under a lot of confining pressure (because they are very deep in the crust) and also are a lot hotter, they tend to behave in a ductile way, like plastic.
- 2.2.6
- Image 2.1 – layers are lying flat
 - Image 2.2 – Layers are lying flat and you can see the crest or nose of the fold towards the left of the picture. Axis of the fold is close to horizontal (recumbent fold)
 - Image 2.3 – The layers again are folded and you can see the crest of the fold toward the top left of the photo. The axis of the fold is also horizontal, so this is a recumbent fold as well.
 - Image 2.4 – layers are tilted steeply
 - Image 2.5 – layers are almost vertical
 - The rock layers in the first three photos are bent into folds that are now lying flat or close to horizontal, except for the nose of the fold. The last two photos show rock layers that are steeply tilted and almost vertical.

2.2.8



Answer Key

The Rockies, continued

- 2.2.9 The first three photos would be from the Main Ranges and the last two from the Front Ranges.
- 2.2.10 The oldest are the Western Ranges, followed by the Main Ranges, then the Front Ranges, and the youngest are the Foothills east of the Front Ranges. The compressional force from the terranes colliding, bulldozing the Rockies, is coming from the west. All of the thrust faults (see cross section 2.1) show movement of the thick folded sequences of rock along the thrust planes from the west towards the east.
- 2.2.11
- The limestones were deposited approximately 520 million years ago. Much later (around 75 million years ago) the shale and sandstone were deposited on top of the limestone.
 - Compressional forces caused the limestone and shale/sandstone package to break (thrust fault) and a slab of the package was pushed over top of the sandstone along the thrust fault.
 - Erosion then wore away most of the top sandstone and shale leaving the older limestone lying on top of the younger shale and sandstone.
- 2.2.12 Limestone formed in a shallow warm ocean. Sandstone and shales formed from sediment eroding from rising mountains and terranes to the west. The limestone and overlying sandstone shale packages broke along a low angle fault or break (higher in the east and lower in the west) so the rock moved up the slope of the fault. The huge heights built up by this process were then worn away by erosion to form the mountains seen in the photos.
- 2.2.13 Sketches of the above.
- 2.2.14 The most important way that stratigraphers determine the age of specific rock units is by looking at the fossils they contain. Assemblages of fossils found at any age of Earth history (e.g. dinosaurs in the Mesozoic) are unique to that time so they can be used to relatively date rock units. To get a numerical age rocks must be radiometrically dated.
- 2.2.15 Limestone is most commonly made from the shells or hard parts of marine organisms such as corals, clams, sponges or plankton. Most limestones form in shallow, warm tropical or sub-tropical ocean areas. Limestones are forming today in places like the Great Barrier Reef, the Caribbean and Belize, as well as in the deep oceans from the accumulation on the ocean floor of the calcite shells of certain types of plankton.
- 2.2.16 For example, a sketch of a warm tropical reef and adjacent lagoon and beach.
- 2.2.17 The sketch of the original mountains would show some very high, jagged and steep mountains, while the present-day sketch would show much lower, more eroded mountains. The present-day sketch should include some erosional features associated with glacial processes since glacial erosion has been very important for the Rockies over the last 2 million years.
- 2.2.18
- It will vary every time you do the experiment, but the possible structures that you would produce are all the varieties of folds including anticlines, synclines and recumbent folds. You may also produce faults (normal if the plane of breakage is close to vertical) or thrust faults if it is a flattish break. The vertical layers of sand and flour are similar to the structures of the Front Ranges; others with more flat-lying

Answer Key

The Rockies, continued

layers or folds on top of thrust faults are similar to what you would see in the Main Ranges of the Rockies.

- With this experiment you will be able to produce both plastic deformation (folding) and brittle deformation (faulting) by manipulating the ooze in different ways.
- Gentle prolonged pressure will cause the ooze to flow (fold).
- More force over a short time will cause the ooze to break (fault).
- It hardens and breaks if force is applied quickly.
- Compressional forces applied to rocks over millions of years will cause the folding we see in the Rockies. The added forces associated with collisions of terranes will often cause major episodes of faulting, such as the thrust faults we see in the Rockies.

2.2.20 Earthquakes, hot springs

Chapter 3: Rocky Mountain Resources and Land Use

2.3.1 Suggestions may include their parks, natural beauty, resources, outdoor activity potential.

2.3.2 Proximity to the Rockies would mean they could easily access the parks and outdoor experiences that the Rockies offer. Provincially, the Rockies are important for revenue from tourism and resource extraction, and they also present significant barriers to transportation of goods from East to West. The further away one is, the less direct impact the Rockies would have, either on an individual, provincial or national level. However, regardless of proximity there will always be the recognition that the Rockies represent an important reserve of natural beauty and wilderness areas set aside for all Canadians.

- 2.3.3
- Rundle Rock – quarried from Mount Rundle near Banff; now quarried just East of Canmore / building stone, e.g. Banff Springs Hotel
 - Paskapoo Sandstone – quarried locally / building stone for schools, banks, churches and government buildings in Western Canada in the early 1900's.
 - Palliser Limestone – mined at Exshaw and Cadomin / cement making
 - Wapiabi Shale – mined from below Mount Yamnuska / used at Exshaw for the production of cement
 - Gypsum – mined at the Elkhorn quarry near Windermere and the Lussier River quarry near Canal Flats / used to make wallboard (drywall) and cement
 - Dolomitic shale – Banff Formation / used to make mineral wool near Exshaw.
 - Ordovician quartzite – mined near Golden, B.C. / used as a source of high-grade silica (e.g. For glass)
 - Ammolite – outer coating on some Jurassic and Cretaceous ammonites / used for jewellery
 - Coal – mined at Canmore from the late 1800's until 1979 / used by the Canadian Pacific Railway to fuel coal-powered locomotives, and today coal provides more than 80% of Alberta's electrical energy
 - Oil and Gas – Jumping Pound Foothills Gas Field, Elsworth Deep Basin Gas Field in the Rocky Mountain Foothills (most of Alberta's oil is from the plains to the east) /

Answer Key

The Rockies, continued

- natural gas, energy, fuel (e.g. Jumping Pound gasfield supplies over half the natural gas needs of Calgary)
- 2.3.4 Some ideas might be wilderness, nature, tourism, physical activities such as skiing and hiking, employment, vacationing, rock climbing, hot springs, viewing of wildlife, hunting, etc.
- 2.3.5 For example, downhill skiing. The contributing characteristics would be steep slopes, accessibility, high mountains for long runs. The potential impact on the Rockies would be from development (roads, hotels), more people, loss of pristine natural environment (ski runs, lodges etc.).
- 2.3.6 Designation of World Heritage Sites <http://whc.unesco.org/en/list/304> and creation of parks which limit development
- 2.3.7 Building of roads, houses, facilities, waste disposal, pollution, barriers to wildlife migration because of settlements, roads, railways, slope instabilities associated with railway cuts, logging, resource extraction
- 2.3.8 Pristine wilderness with no development will allow the natural environment, including the wildlife, to be preserved for future generations. Allowing development will alter the environment that drew people there in the first place, but will also provide jobs and allow people to enjoy and benefit from their experience of the wilderness directly.
- 2.3.9 Mines:
- Northwest B.C. Eskay Creek – gold, silver
Endako – molybdenum
Huckleberry – copper, molybdenum
Table Mountain – gold
 - Central B.C. Kemess South – copper
Gibraltar – copper, molybdenum
Mount Polley – copper, gold, silver
 - South Central B.C. Highland Valley – copper, molybdenum, gold, silver
 - Southwest B.C. Myra Falls – copper, zinc, silver, gold

Chapter 4: Erosion on a Grand Scale

- 2.4.1 The Himalayas are highest, steepest and most rugged. The Appalachians are lowest, most rounded and least rugged.
- 2.4.2 Mountains that are in the process of being formed, e.g. the Himalayas, will be steeper and higher because the tectonic forces that are pushing them up are still active. The longer ago a mountain range formed, the more time there has been for erosion to wear away the peaks by removing rock, grain by grain or pebble by pebble. Both the Appalachians and the Rockies when they first formed (~340my ago, and ~60my ago respectively) would have looked very much like the Himalayas today.
- 2.4.3 Criteria might be age of the mountains i.e. when they formed (Appalachians in the Paleozoic, the Rockies in the Mesozoic, and the Western Ghats in the Himalayas are still forming). Other criteria could be by the highest peak in each range or how rounded or rugged the mountains are, both of which are related to the age and the

Answer Key

The Rockies, continued

amount of time that erosion has been wearing the rocks away. Other criteria might be whether the mountains have glaciers or not (depends somewhat on height, rainfall as well as latitude), or the types of rocks the mountains are made of.

- 2.4.4
- Glaciation has shaped the Rockies through erosion as well as deposition.
 - Erosional features include: U shaped valleys, hanging valleys, cirques, arêtes, horns, glacial lakes, polished rock, grooves, roche moutonee. Glacial depositional features include moraines (terminal, recessional, lateral, medial), other deposits of till, drumlins, eskers, outwash plains, erratics.
- 2.4.5 Sketches of the depositional features noted above
- 2.4.7 The mudstone would likely be the least resistant, with the sandstone next and finally the limestone which is the most resistant. These results match up well with what you see in the video, since many of the highest peaks are made of limestone. The exposures of shale or mudstone are often covered with vegetation and appear more eroded and recessive. Sandstone is in between – harder than shale but softer generally than limestone.
- 2.4.8 They are measuring the thickness of the ice. This will enable them to estimate the total mass of the ice and over time see if the total mass is increasing or decreasing, and from this whether the ice sheet is melting away or growing. They are also measuring the thickness of the last winter layer of snow which, when compared over the entire ice sheet with the amount of meltwater lost, will tell them if the ice sheet is getting smaller.
- 2.4.9 Vast amounts of meltwater flowing away from the ice in rivers and waterfalls, and the huge crevasses in the glaciers, and the moulins. The moraines at the front edge of the Athabasca glacier are being deposited further and further up the valley and the ice is filling less of the valley as time goes on.
- 2.4.10 Little is known about the ice sheets in Canada between 2 million years and 135,000 years ago, however studies of ocean cores suggest that there were more than 50 glacial and interglacial cycles during that time. Research suggests that around 135,000 years ago there was a major ice sheet, again around 70,000 years ago, another advance around 20,000, and another around 1200 years ago.
- 2.4.11 There were major glaciations in the Earth's past: during the late Precambrian ~900 million years ago (Snowball Earth); in the late Ordovician ~ 430 million years ago; Carboniferous ~ 340 million years ago; and in the Pleistocene starting around 2 or 3 million years ago (the glaciations which affected the Rockies).
- 2.4.12 Scientists have to look at older rocks for evidence of these older glaciations. They would look for ancient hardened till deposits, evidence of glacial gouges and striations on the pebbles within these tills or diamicts, hardened sediments associated with the ancient meltwater streams flowing from the glaciers, as well as evidence of ancient glacial lakes that would have produced varves. Evidence comes from all over the world; for example, the effects of the Carboniferous glaciation (tills and old rock striations) are well exposed in the Sahara desert of Africa.

Answer Key

The Canadian Shield

Chapter 1: Meet the Torngats

- 3.1.2 Evidence of marine life can be found at the top of mountains. This happens over extremely long periods of time. The presence of zircon in the rock.
- 3.1.3 Provides an opportunity to learn how old the rocks are and understand the processes that formed them
- 3.1.4 The mineral zircon
- 3.1.5 Zircons contain small amounts of uranium that decay at a predictable rate giving the age of the mountain building events.
- 3.1.6 The existence of sandstone with ripples in it, and the mineral deposit of iron pyrite
- 3.1.7 Coal is derived from organic materials.
- 3.1.9 Prior to Pangaea there is the idea that the crust of the forming continents was too fragile to support the structure. As the planet cooled, larger masses of land could form.

Chapter 2: The Geology of Human Activity

- 3.2.1 Plate tectonics; subduction events
- 3.2.3 The Rama Chert was used to make tools.
- 3.2.4
- Human: tool making; sacred connection; found as far south as Maine (part of a trade system?)
 - Geologic: contains early, organic life; underwent a great amount of heat and cooled quickly
- 3.2.5 Higher altitude samples are less likely to be corrupted by younger volcanic rocks, and more likely to reveal an accurate age of the mountains.
- 3.2.6 using laser technology and analysing gases from the mineral
- 3.2.7 the presence of different layers in the crystal being analysed

Chapter 3: The Search for Gold

- 3.3.1 True; True; True; True; False; True
- 3.3.2 Highly deformed rocks, and evidence of gold bearing fluids moving through the rock (plumbing)
- 3.3.3 Gneiss formations are caused by hot plastic rock getting squeezed by tectonic plates ramming into each other.
- 3.3.4 It indicates fluids that would have moved gold through the rock.

Chapter 4: The Sudbury Basin and Manicouagan

- 3.4.3 Continental shield area that was formed during the Archean era

Answer Key

The Canadian Shield, continued

- 3.4.4 Meteorites hit the Earth and punched a hole into the Earth's crust allowing the mantle to fill up the basin. Shock waves shattered the rock and nickel-bearing minerals worked into the fractured surface and were buried under the pulverised rock.
- 3.4.5 Similar rock composition along the Shield would experience the same conditions during a meteorite impact. The size and the age of the impact would also define the potential wealth at other impact sites.
- 3.4.7 Core samples reveal the secrets of the underlying structure of the area and allow for models to be developed that would be useful in finding mineral deposits.

Chapter 5: Diamonds: The New Resource

- 3.5.2 The erosive action of the glaciers removed overburden and revealed showings of diamonds.
- 3.5.3 Disadvantage: takes a lot of time. Advantage: able to survey the area closely and understand the search area more directly.
- 3.5.4 Millions of years of glaciation and other erosive forces have distributed diamonds across the landscape.
- 3.5.5 The original source of the diamonds have been deformed and effectively erased from the landscape. Only clues exist and these must be found and interpreted correctly to locate the treasure.

The Appalachians

Chapter 1: Coal: Getting It Out of the Ground

- 4.1.1 The most likely sources would be natural gas, oil, electricity, solar, and wood.
- 4.1.2 The most likely sources would have been coal, wood, electricity, and oil.
- 4.1.3 The major reasons for shifting from coal to natural gas, probably the two most common urban energy sources, would include lower cost, cleaner burning (i.e. less dust and no ashes), less storage space needed, and easier to regulate the burning of the fuel (i.e. able to use thermostats).
- 4.1.4 Energy sources might move more to improving home insulation (the conservation option), solar heating, and greater use of electrical energy derived from solar, wind, and nuclear power.
- 4.1.5 From anthracite to lignite the major changes include a lower carbon content, reduced hardness, lower heating value per unit, and from use in home heating/water purification to electrical generation.
- 4.1.6 Anthracite had high carbon content which, after burning, resulted in harder waste and less ash. Anthracite could be more easily stored and handled without breaking up or giving off dust and contained more energy per unit of weight.
- 4.1.7 Three types of coal are: anthracite, low to medium volatile bituminous, and high volatile bituminous.

Answer Key

The Appalachians, continued

- 4.1.8 Anthracite in the folded region, bituminous in the unfolded region
- 4.1.9 The folding and compression caused when the Appalachians formed probably converted the coal from bituminous to anthracite in eastern Pennsylvania.
- 4.1.10 The anthracite region would be most difficult since the coal beds are folded instead of being level layers, making it harder, more expensive, and more difficult to mine since many different shafts would be needed to dig out the coal in folded rock. In unfolded rocks, it would be easier and cheaper to mine along level coal seams since fewer shafts or drifts would be needed to get at the coal.

4.1.11

Time Period	Type of Mine	Number of Miners	Human Risks	Environmental Risks
Early 20th Century	Drift/shaft	2000-3000	High death rates – 30 000 miners	Small – mines were underground
Early 21st Century	Strip	10-20	Low – truck drivers and crane operators work above ground	High – stripping rock layers off tops of mountains to get at coal

- 4.1.12 Changes resulted from increased mechanization reducing labour demands, and larger machines increasing the ability to strip large quantities of rock to get at coal seams.
- 4.1.13 Decision should be based on the numbers of deaths of miners in the 20th century due to mining (underground mining disasters still occur in the US, China, and other countries today) and the practice of stripping off whole mountaintops to get at coal seams in the 21st century.
- 4.1.14 Students should use the factual evidence provided by the video and their answers to earlier questions in their arguments. Accuracy and relevance of provided factual justifications should be in evidence.
- 4.1.15 Areas would still include the United States, China, Poland, Mexico and Australia. A good website to refer students to is http://en.wikipedia.org/wiki/List_of_disasters which has an extensive section listing Mining Disasters.

Chapter 2: Colliding Plates, Making Mountains

- 4.2.1 Moving plates colliding and separating from one another over geologic time
- 4.2.2 A collision of continents would crush, bend, and force up rocks along the edge of the plate to form high, rugged mountains due to folding, faulting, and volcanic activity.
- 4.2.3 Real-life simulations would include cars and/or truck colliding with each other or with poles or bridge abutments, or ships colliding at sea.
- 4.2.4 Two continents have moved towards one another due to plate movements and collided. The result was a bending and breaking of sedimentary of other rock layers and pushing up of tall, rugged mountains. As the leading edge of the one of the plates descended into the mantle, it melted and molten rock flowed upwards through

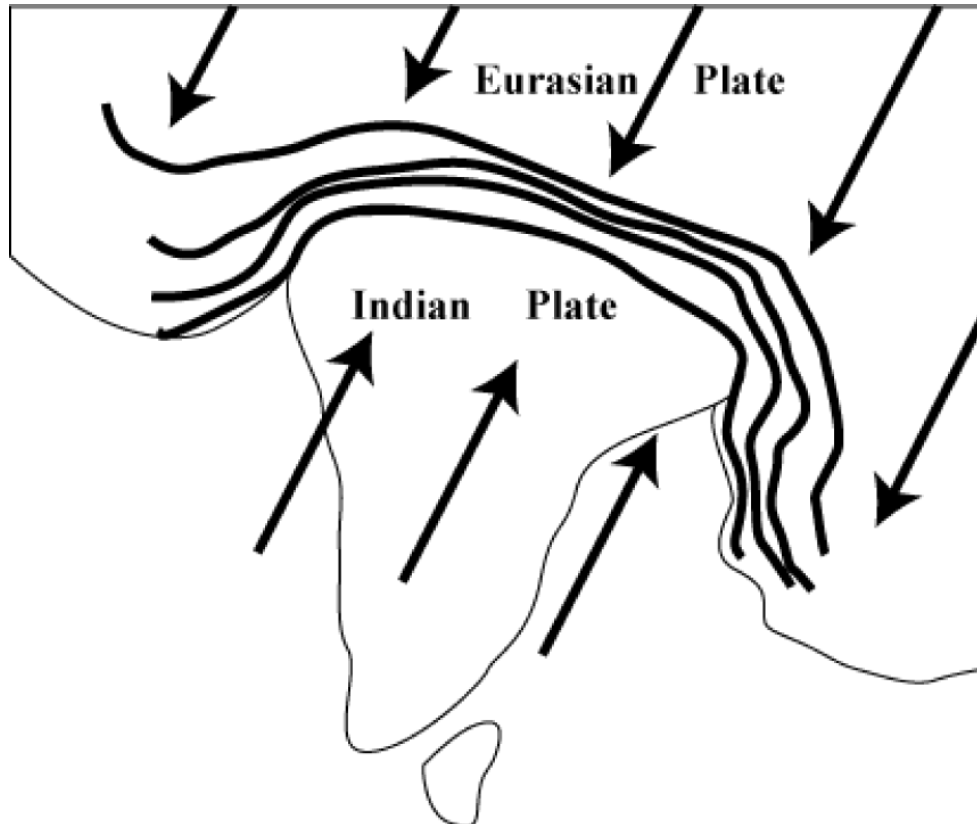
Answer Key

The Appalachians, continued

cracks in the crust, caused by the collision, to form volcanic features. These eruptions added even more height to the mountain chain formed by the collision. Eventually the continents were “welded” together along the length of the new mountain range.

4.2.5 They could be applied to the formation of the Himalaya Mountains where India is colliding with Asia.

4.2.6 Himalayas Collision Boundary Sketch Map



4.2.7 “Breakup of Pangaea” would be added to the chart in the Jurassic timeframe within the Mesozoic Era. “Formation of Pangaea and Appalachians” would be added to the chart in the Devonian timeframe in the Paleozoic Era.

4.2.8 The North American Plate collided with the Eurasian and African Plates, pushing up the rocks along their edges to form the Appalachian Mountains.

4.2.9 Mountains in northwest Africa, Greenland, and northwest Europe were also formed at the same time as the Appalachians.

4.2.10 The supercontinent of Pangaea started to separate or break up after a period of 200 million years.

4.2.11 Shenandoah Mountains are lower and rounded compared to the much higher and very rugged mountains that formed 370 million years ago.

4.2.12 The collision of the African and North American Plates

Answer Key

The Appalachians, continued

4.2.13 Evidence includes: folded rocks, ancient fossils found in sedimentary rocks on mountain tops, lack of rocks of a younger age than those of the mountains, and altered or metamorphosed rocks formed at great depth that are now found on, or very near, the surface of the Earth.

Chapter 3: New Technologies, New Theories

- 4.3.1 • Hypothesis – a proposed explanation made on the basis of available or limited evidence and used as a guide to future study or investigation to prove its accuracy or acceptability.
- Theory – a widely accepted explanation that has been verified using available and validated evidence, an explanation of events or processes that best fits known facts.

4.3.2

Case Study/ Researcher	Hypothesis	Technology In Use	Facts Collected Using Technology	Result of Hypothesis Testing
Montmorency Falls – Stephane Mazzotti	Moving apart of the plates along St. Lawrence Valley	Highly accurate GPS equipment	Plates are moving apart at a few mm per year	Proves that plate movement could cause earthquakes in future in this region
New Madrid – Martitia Tuttle	Major earthquakes occur approximately every 500 years instead of the formerly accepted 1 000 year time period in the New Madrid area	Helicopter flight, radio carbon dating,	Dates when sand blows occurred, indicating major earthquakes in the region	Proves that the major quakes occur approximately every 500 years on average
North Carolina/ Newfoundland – James Hibbard	Two microplates (Carolinia and Avalonia) collided with North America to form the Appalachian Mountains in North Carolina and Newfoundland	Laser technology to date zircons	Dates of collision to form mountains in N Carolina and Newfoundland were different	Proves two microplates were involved, rather than the formerly accepted idea that only one microplate was involved

Answer Key

The Appalachians, continued

- 4.3.3. It is referred to as a theory.
- 4.3.4 It is most likely that some theories will be thrown out or revised and that new hypotheses will be proposed and proven as a result of new evidence obtained through the use of new and more sophisticated technological devices.

Chapter 4: Want to be an Earth Scientist?

- 4.4.1 Students could suggest a wide variety of perceived traits, knowledge, and skills. Accept their answers if an acceptable justification is provided.
- 4.4.2 There are no right or wrong answers to this question. It is the discussion that provides students with a better understanding of what it takes to be a successful earth scientist.
- 4.4.3 The first task was to propose possible traits, knowledge, and skills based on general knowledge. The second task involved taking the major traits, knowledge, and skills suggested and investigating them by gathering evidence from the video. The third task was to test each hypothesis to see if it was verified or justified by evidence collected from the video. If there was evidence to support the hypothesis, it could be considered a theory; if not, it would be rejected and disregarded.
- 4.4.4 The most important aspect of this answer would be a set of reasons that were clearly outlined and were consistent with the student's position.

Chapter 5: Earthquake Hazard

- 4.5.1 Students are likely to suggest areas of recent earthquakes in the news such as southeast Asia, Japan, Peru, California, etc.
- 4.5.2 This answer will vary with their location in Canada. It is expected that B.C. residents would perceive a higher earthquake risk and magnitude than all but a few students from the St. Lawrence Valley, where the quake risk might be considered moderate and the magnitude rather low.
- 4.5.3 Rebound is linked closely to the theory of isostasy. When the term rebound is used by geologists, it refers to a rise in a block of Earth's crust that occurs when a weight is removed from its top or surface. Examples would be a rise in the centre of the Canadian Shield as a result of the melting of the continental glaciers that once covered it or, in the case of this video, the removal of the higher parts of the original Appalachian Mountains by erosion over the past 350+ million years. Earthquakes would result as these rebounding blocks of the crust move upwards along surrounding rocks.
- 4.5.4 Such quakes are often minor in magnitude and displacement.
- 4.5.5 They are most closely related to mountain belts along plate boundaries.
- 4.5.6 The Logan Line or Fault
- 4.5.7 Tuttle is looking for evidence in the soils of the region for "sand blows". These features occur when underground sand layers are liquefied during a major earthquake and move upwards through cracks in the soil caused by the quake to form sand fountains or blows. By finding and dating these features, Tuttle is able to date past major

Answer Key

The Appalachians, continued

- earthquakes in the New Madrid area thousands of years into the past. Her research indicates major earthquakes occur approximately every 500 years.
- 4.5.8 Students are likely to get the impression that the earthquake hazard in eastern North America is rather high.
- 4.5.9 Make certain students look at both maps to determine the magnitude of quakes in their community as well as the hazard level.
- 4.5.10 This will depend on your location within Canada.
- 4.5.11 To be acceptable, the answer must be supported by accurate and relevant evidence and a logical explanation. There is no right or wrong answer to the question.

The Atlantic Coast

Chapter 1: Tales from the Ocean Floor

- 5.1.2 The Tablelands are a leftover fragment of ancient ocean floor that pre-dates the modern Atlantic Ocean. When what geologists now call the Lapetus Ocean (“father of Atlantica”) opened up, these rocks were newly-formed on that ancient seafloor. When Pangaea was assembling, these rocks had a collision with what is now the African continent, and this old ocean floor was welded on to the new supercontinent. When Pangaea broke up and a new ocean emerged (the Atlantic Ocean), this slice of old ocean crust was ferried across the globe to become a part of eastern North America. The volcanic rocks found in the Tablelands are known to be abundant only in certain seafloor settings. To have them available above sea level gives us a chance to walk across an ancient piece of ocean floor and continue walking right down to the upper mantle.
- 5.1.3 The mineral was chromite, which is made up of about two-thirds chromium oxide (Cr_2O_3) and one-third iron oxide (FeO). It is a heavy, resistant mineral that commonly forms in Earth’s upper mantle and deep crust. Finding chromite crystals in the sedimentary rocks at Lobster Cove was unexpected.
- 5.1.4
- The presence of chromite indicated that the rocks of this area were not conventional igneous rocks, but had the hallmarks of being formed very deep in the Earth – more than 25 kms deep – as far down as Earth’s uppermost mantle. Plate tectonic forces placed the Tablelands in the location where it is found today, and is actually the remnant of an ocean floor that once separated North America from Africa and Europe. The new interpretation is that the Tablelands did not form where it is today, but had been brought there after a journey spanning 400 million years and the opening of two oceans!
 - The sequence of rocks in this part of Gros Morne National Park is what is known as an ophiolite sequence, which is a geologist’s term for a section of rocks that represents the top 30 kms of an ocean floor setting. Ophiolites tend to have lava flows at their tops, where the rocks were formed at the ocean floor where they met the water. Deeper down, the volcanic rocks tend to be made up of very iron-rich minerals, are heavy for their size. Since the ophiolite at Gros Morne was tipped

Answer Key

The Atlantic Coast, continued

up almost vertically by tectonic forces, we can literally walk from the lavas of the seafloor all the way on down to the rocks of the upper mantle. Imagine it as a slice of layer cake that has fallen over on its side, and an ant runs across the layers. We are that ant along the Tablelands' trails.

5.1.5 The following Web sites will provide information to complete this question:

- **This Dynamic Earth – the Story of Plate Tectonics**

<http://pubs.usgs.gov/gip/dynamic/dynamic.html> – An introductory-level treatment of most of the key ideas and classical principles of the Theory of Plate Tectonics. It also includes a link to the This Dynamic Planet Web site that provides a web-based version of the influential world map of global tectonics.

- **Ophiolites**

http://volcano.und.nodak.edu/vwdocs/vw_hyperexchange/ophiolites.html – This page from the popular Volcanoworld Web site outlines how slices of oceanic crust can sometimes be thrust onto the margins of continents as large ocean basins close up and collision of crustal blocks occurs. It provides “virtual” field trips to some of the world’s more outstanding examples of ophiolites, including those found in Oman, Cyprus, and Newfoundland.

- **Gros Morne Adventures – Newfoundland Adventure Tourism**

<http://www.grosmortheadventures.com/activities.html> – The relationships among geology, tourism, and the active lifestyle advocated today.

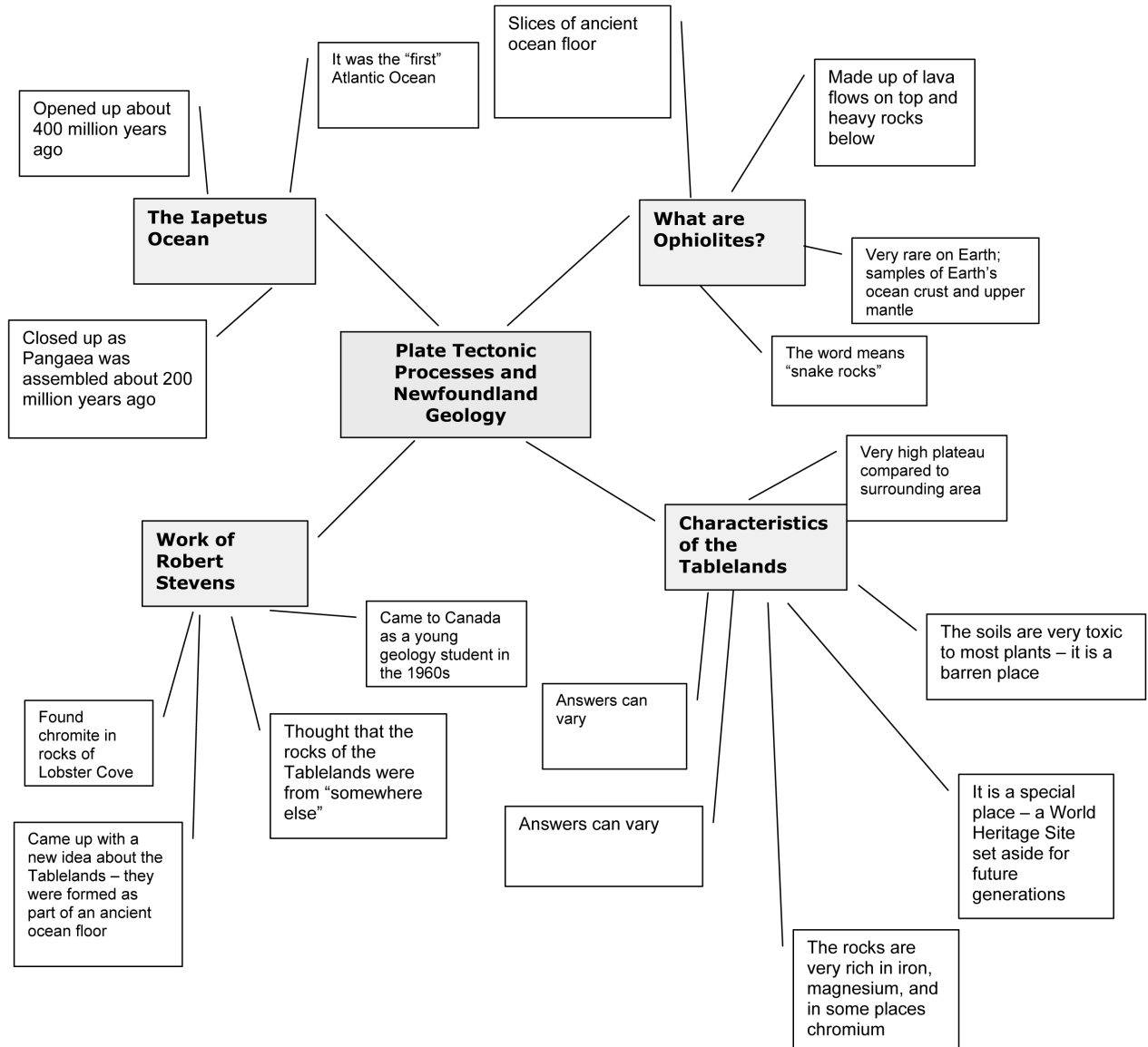
5.1.6 Since the volcanic rocks that make up ophiolites are usually born at mid-ocean ridges, it seemed simple to view these slices of ocean floor/upper mantle as being pieces of “fossil” spreading centres. Newer models actually point to ophiolites forming at spreading centres very close to subduction zones. This means that they are left stranded when a slice of the ocean floor collides with a continent. Students should first look for areas of the world where new ocean floor will likely be created, but quite close to known areas where the ocean crust is likely to be consumed at a plate boundary that is a trench.

The most likely places where future ophiolites will be generated would be along the west coast of Canada (Juan de Fuca plate boundary), the west coast of Central America, the Red Sea/Gulf of Oman, and over much of the western margin of the Pacific Plate.

Answer Key

The Atlantic Coast, continued

5.1.7 Geology of the Tablelands, Gros Morne National Park, Newfoundland



Answer Key

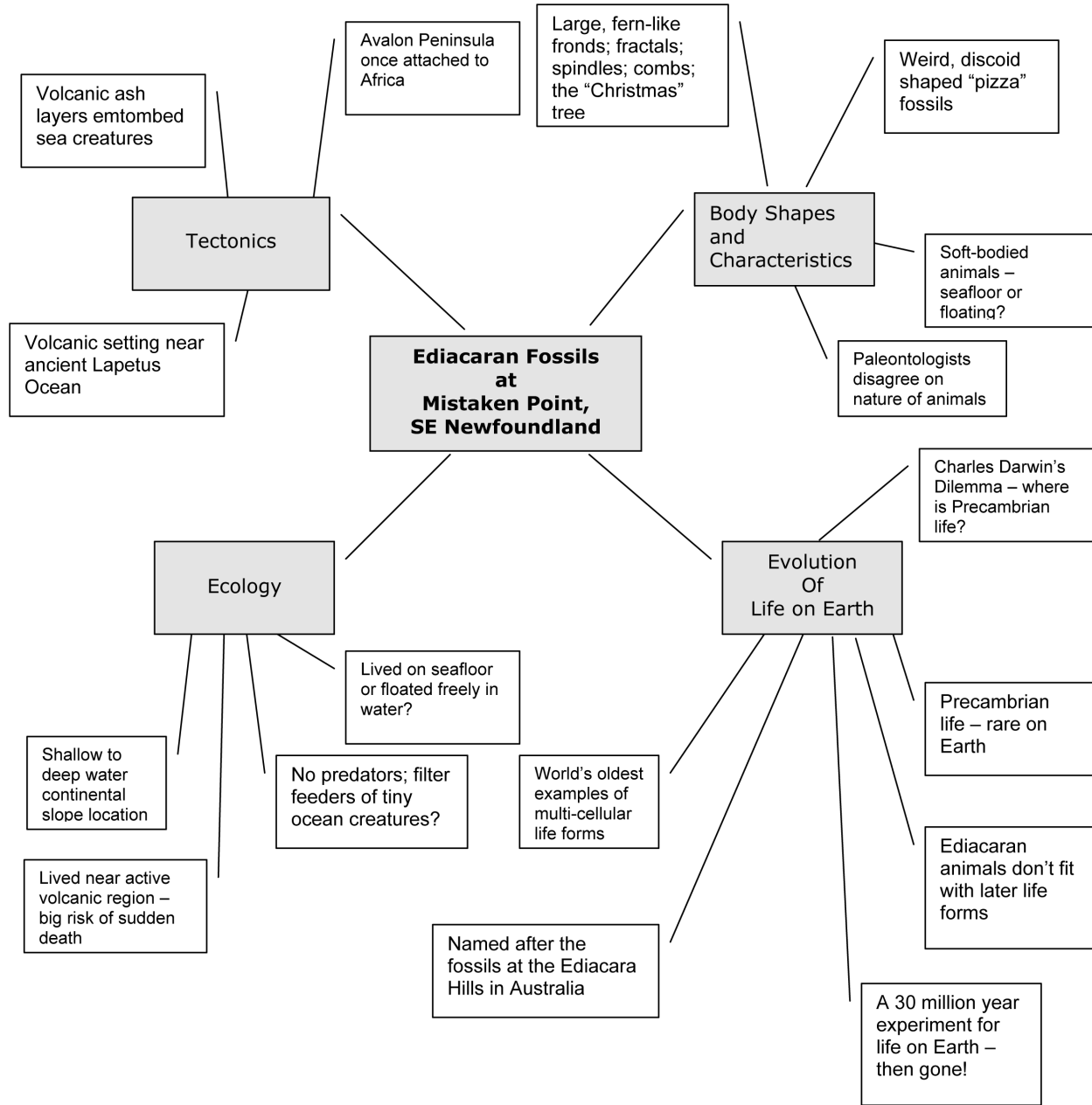
The Atlantic Coast, continued

Chapter 2: Experiment in the Precambrian Oceans

- 5.2.3 These fossilized creatures represent a very early example of what has been called “metazoan” life forms, meaning they were large, multi-cellular, and would be easily visible to the eye. Prior to their existence, any previously-known organisms — such as blue-green algae and bacteria — were microscopic in size.
- The body plans of these organisms have no modern-day counterparts, nor did they exist much beyond the beginning of the Cambrian period. This makes them a sort of “niche” collection that is a type of “experiment at life getting big” as Professor Jim Gehling puts it in this episode of Geologic Journey.
- 5.2.4 These fossils occur in rocks that were once sitting right next to Africa and then were “brought” to their current location as part of a “geologic journey” as the Atlantic Ocean opened up following the breakup of Pangaea. When the field party reached a particular outcropping of the fossils, everyone was asked to remove their footwear in order to not harm the surface of the rocks that contained the impressions. There are very few places in the world where Ediacaran-age animal fossils occur in such abundance; Mistaken Point is a rare find for paleontologists, and has been visited by interested people from around the world
- 5.2.5 The diamond reference speaks to something as being rare, valuable, difficult to find, occurring only in a few select areas on Earth, beautiful to the eye of the beholder. These thoughts can then be made analogous to the fossils at Mistaken Point, which are impressions of rare animals, hold great significance to the geologic history of Earth, and also have a certain beauty about them among those people who appreciate their existence and importance.
- 5.2.6
- According to the recreations seen in Geologic Journey, these animals were “sessile”, ie. attached to the sea bottom by a sort of holdfast, or anchor, structure. The manner in which they died suggests that small, localized “gardens” of Ediacaran animals lived in close proximity to one another. Since none had jaws, teeth, mobility, or a digestive system and were all filter feeders, predation was likely not occurring at all. These animals lived along a shallow-water slope adjacent to an ocean shoreline, but since they are preserved among shales (a rock type characteristic of depths below where sunlight penetrates), it seems that they lived in complete darkness all the time.
 - The Mistaken Point collection is capped on top by a thick layer of “tuff” (hardened volcanic ash). This indicates that this particular location was once under the direct influence of active volcanoes. Though the eruption itself would not have been fatal to them, the volcanic ash raining down on the sea would have drifted to the bottom and covered them.
- 5.2.7 The Ward family, living close to the fossil beds, recognize that they have an important volunteer role in assisting in the preservation of this unique site. One particular animal species among the collection bears the family name, and was first discovered by Mrs. Ward’s son.
- 5.2.8 Humans constitute the only known technological species in Earth history. We actually have the ability to eliminate ourselves rather than be extinguished by more natural means. It would be interesting to discover – from students’ views – whether this makes us a particularly fragile species that is perhaps the most unique experiment yet in life on Earth.

Answer Key

5.2.9 Concept Map: Mistaken Point Fossils



Answer Key

The Atlantic Coast, continued

Chapter 3: Mass Extinction...and Something New Out of Africa

5.3.1 – 5.3.4 Researching scientific information for a project involves different skills, thinking, and keyword approaches than looking up a movie trailer, a favourite musician, or sports-related information.

Using a variety of search engines that students can identify and have used (Yahoo, Infoseek, Google, Dogpile, Yahoo!igans, Ask Jeeves, Alta Vista, Raging Search, etc.), have students search “mass extinctions”, or any other topic relating to an episode of Geologic Journey. Record results of findings for each search engine on a class chart or table, noting the keyword search term(s), the number of hits obtained, the organization of hits (e.g., grouped by search engine type, ratings in percentages, etc.)

Do the results obtained by each student match their original predictions? How do the results compare for different search engines? Discuss possible reasons for the differences between their predictions and actual results, and between the different search engines.

Answers will vary, but characteristics such as the easily visible sedimentary character of the rocks (clear bedding), the abundance of fossils, action of the local tides, height of the cliffs, should emerge.

5.3.6 Eldon George has known the area since he was a child, and his keen interest in rocks, minerals and fossils stems from his having incurred an arm injury that did not heal completely. This kept him away from the activities most of the local boys engaged in while he was young. He has been collecting for decades, and has had the time to spend over the years with this fossil-rich area. Eldon has particular knowledge of the crocodile-like organisms, and recognizes the dinosaur footprints with an eye as good as that of any palaeontologist. Perhaps the greatest contribution he makes is through discussions with visitors to the area promoting the importance of understanding ancient life on Earth.

5.3.7 The geologic and scientific interest is with the age of the rocks that contain the fossils. One major extinction episode occurred at the transition from the Triassic to the Jurassic periods. Parrisboro Beach has rocks that date precisely to this time boundary. Therefore, the “rich treasure” is all about understanding what sorts of animals did and didn’t survive the extinction event. The Parrisboro rocks contain the fossil remains of the animals that repopulated the planet following the extinction that eliminated more than half of the world’s species (according to the fossil evidence). The small, mammal-sized reptiles found at Parrisboro were the precursors to the great giant reptiles that “ruled” the predator world in the Jurassic Period that followed some time later.

5.3.8 Dr. Paul Olsen and Dr. Jessica Whiteside are testing an idea that there is a connection among super-continent break up (Pangaea in this instance), volcanic activity, and large-scale extinction events. The rifting apart of large blocks of crust is accompanied by, or perhaps even driven by, significant periods of igneous (volcanic) activity. The increased volcanism may then cause dramatic climatic disruption which leaves vulnerable organisms at risk due to loss of habitat, scarcity of food, lower levels of sunlight, and even global cooling. Their recent work has been unable to establish a clear connection between the volcanic outpourings in the North Atlantic region at the end of the Triassic Period and the timing of the extinction event. More work needs to

Answer Key

The Atlantic Coast, continued

be done to test this hypothesis. Dr. Whiteside uses the ratio of two stable isotopes (meaning non-radioactive) of carbon – carbon-13 and carbon-12 – as a means of determining the type of atmospheric environment that organisms lived in long ago.

We use carbon isotope data for exactly the same reason that we use oxygen isotope data – to find out from where the atoms in a specific object (e.g., an animal or plant) are derived and what their history has been. The history of carbon atoms in living organisms involves how the organisms obtained these carbon atoms. For plants this means how their photosynthetic reactions worked; for animals, what they have been eating. Carbon isotopic records in carbonate rocks are of interest to paleo-ecologists because they help understand the functioning of the carbon cycle during earth history, and through the carbon cycle, the history of the biosphere.

What Dr. Whiteside is hoping to derive from the carbon isotope “fingerprints” in the carbonate rocks and fossils of the Atlas Mountains (as seen in Geologic Journey) is whether there is any evidence of a deviation from “normal” photosynthesis in plants, or some sort of a big disruption in the global carbon cycle. Disruptions in the carbon cycle could be a signal of some sort of global catastrophe that would explain the mass extinction event.

- 5.3.9 Humanity’s increasing population and demand for natural resources makes us potentially an unsustainable, almost predatory, species on this planet. By virtue of the large amounts of CO₂ we produce through burning fossil fuels, humans may eventually be contributors to changes in the world’s carbon cycling. That makes us a potential geological force that could end up contributing to yet another large extinction event on planet Earth.
- 5.3.11 Online information about the end Triassic extinction event (especially teacher background or for motivated students) can be found at:
- www.uky.edu/KGS/education/EndTriassic.htm
 - en.wikipedia.org/wiki/Triassic-Jurassic_extinction_event
 - palaeo.gly.bris.ac.uk/Palaeofiles/Triassic/triextict.htm
 - www.space.com/scienceastronomy/planetearth/jersey_dinosaurs_020516-1.html
 - www.space.com/scienceastronomy/planetearth/extinction_permian_000907.html