Unit 4
The Forces within Earth
Suggested Time: 30 Hours

Unit Overview

Introduction

This unit gives students an opportunity to learn about the internal dynamics of Earth and the subsequent changes witnessed on the surface. Plate tectonics, or the movement of crustal plates, is explored as something that results from mantle material rising and falling. Earthquakes, volcanism, folding, faulting, and mountain building are subsequently explained through the theory of plate tectonics.

Students are also give a change to explore the contributions made by Earth scientists who developed the plate tectonics theory.

Focus and Context

The focus of this unit is understanding the internal forces working within our planet. Our understanding of these forces helps us explain and define the resultant phenomena we experience and, to some degree, enhances our ability to predict the occurrence of such events.

Science Curriculum Links

Students have previously studied continental drift and plate tectonics in grade 7 Science. Volcanoes, earthquakes and folding and faulting were also included at the intermediate level. Earth Systems 3209 expands on this introduction to include the role of magma and lava, and the forces that drive these processes.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
Nature of Science and Technology 114-2 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge 115-3 explain how a major scientific milestone revolutionized thinking in the scientific community 115-7 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced **Social and Environmental Contexts of Science and Technology** 117-5 provide examples of how science and technology are an integral part of their lives and their community 117-7 identify and describe science- and technology-based careers related to the science they are studying 117-10 describe examples of Canadian contributions to science and technology 117-11 analyse examples of Canadian contributions to science and technology	**Analyzing and Interpreting** 214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots 214-10 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty 214-17 identify new questions or problems that arise from what was learned **Communication and Teamwork** 215-4 identify multiple perspectives that influence a science-related decision or issue 215-6 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise	330-12 use appropriate evidence to describe the geologic history of an area 331-9 describe methods of monitoring and predicting earthquakes, volcanic eruptions, and plate interactions 332-3 describe major interaction among the hydrosphere, lithosphere, and atmosphere 332-7 describe geological evidence that suggests life forms, climate, continental positions, and Earth’s crust have changed over time 332-8 analyse evidence for plate tectonics theory

Continental Drift: Birth of an Idea

Outcomes

Students will be expected to

- explain the roles of evidence, theories, and paradigms in the development of scientific knowledge (114-2)
  - describe the theory of continental drift
  - describe the evidence to support the theory of continental drift. Include:
    - (i) fit of continents
    - (ii) fossil evidence (fossil correlation)
    - (iii) rock types (shields)
    - (iv) structural similarities (e.g., folded mountains)
    - (v) paleoclimatic (e.g., striations, coal deposits, glacial deposits)

Elaborations—Strategies for Learning and Teaching

Students should know that a commonly held belief was that continents simply ‘drifted’ through the ocean floor pushing up material in front, forming mountain belts. Students should realize that this theory lacked a valid mechanism for driving the process. In 1915, Alfred Wegener believed the Earth’s rotation and lunar gravitational forces were responsible for the drifting of continents.

Teachers could use a map of the world or illustrations taken from the Internet to model the different pieces of evidence to support the theory of continental drift.

Students could use paper cut outs of continents as a jigsaw puzzle to assemble the continents as they are today as well as how they were assembled during the time of the Pangaea (200 million years ago).

A supplementary source of information is the Johnson GEO CENTRE Edukit, Topic 8 - Unit 3 – Demonstration 3.10 – Plate Tectonics.

Students should realize that while a significant volume of evidence supported the theory of continental drift, a mechanism to explain why they drifted did not exist.

Continental Drift: Birth of an Idea

Suggested Assessment Strategies

Paper and Pencil

- In your own words, explain what you know about the theory of continental drift.
- Create a foldable outlining the different pieces of evidence supporting the theory of continental drift. Include illustrations in your foldable.

Interview

- Interview a peer to determine their understanding of the theory of continental drift using self-constructed questions.

Performance

- Write and perform a song outlining the theory of continental drift and the evidence supporting it.
- Create a poster, brochure, or collage that represents the evidence supporting the theory of continental drift.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST p. 515

ST pp. 515-519

Edukit

Conventions used in Resources Column

ST = Student Text

Plate Tectonics: A Scientific Revolution

Outcomes

Students will be expected to

- explain how a major scientific milestone revolutionized thinking in the scientific communities (115-3)
  - describe the evolution of plate tectonic theory through the contributions of various scientists. Include:
    - (i) Frank Taylor
    - (ii) Alfred Wegener
    - (iii) Alexander DuToit
    - (iv) Arthur Holmes
    - (v) Harry Hess and Robert Deitz
    - (vi) Fredrick Vine and Drummond Matthews
    - (vii) J. Tuzo Wilson
    - (viii) Xavier Le Pichon and Dan McKenzie

Elaborations—Strategies for Learning and Teaching

Teachers could use the following table to briefly outline the contributions of each scientist to the evolution of the plate tectonics theory :

Frank Taylor	1910 – Explained the formation of the Himalayan Mountains by moving continents (no evidence given).
Alfred Wegener	1915 – Proposed the theory of continental drift (evidence given, but no mechanism provided).
Alexander DuToit	1937 – Proposed that Earth’s continents would fit more closely together at the continental margins.
Arthur Holmes	1950s – Proposed the existence of a mechanism for movement; mantle convection.
Harry Hess and Robert Deitz	1960s – Proposed the theory of seafloor spreading.
Fredrick Vine and Drummond Matthews	1963 – Proposed the idea of magnetic reversals as evidence to support the theory of seafloor spreading.
J. Tuzo Wilson	1965 - Proposed the existence of “plates” on Earth’s surface as a result of mapping the world’s volcanoes and earthquakes. He also proposed the existence of transform faults along plate boundaries; and that stationary hotspots in Earth’s mantle caused volcanism within plates.
Xavier Le Pichon and Dan McKenzie	1970s – Proposed the theory of plate tectonics

Plate Tectonics: A Scientific Revolution

Suggested Assessment Strategies

Paper and Pencil

- Write an essay incorporating the contributions made by various scientists to the evolution of the theory of plate tectonics.
- Explain the theory of plate tectonics in your own words.

Performance

- Create a foldable highlighting the contributions made by various scientists to the evolution of the theory of plate tectonics.
- Participate in a jigsaw activity where each student becomes an expert on the contributions of a single scientist and presents their findings to their home group. Students will learn about the contributions of other scientists by listening to their peers in the home group.

Presentation

- Create a presentation on one scientist or pair of scientists and the evidence they collected to support the theory of plate tectonics.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 523-524

Plate Tectonics: A Scientific Revolution (continued)

Outcomes

Students will be expected to

- explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced (115-7)
  - contrast the explanations provided by Wegener and Holmes for the mechanism of continental movement
  - describe the theory of plate tectonics

Elaborations—Strategies for Learning and Teaching

Alfred Wegener thought that the moon's tidal influence (gravity) was strong enough to cause a westward motion of the continents. He suggested that large, sturdier continents broke through the oceanic crust much like an ice breaker.

Arthur Holmes proposed that convection currents in the Earth's upper mantle (asthenosphere) were moving the continents.

Students should know that Hess and Deitz's concept of seafloor spreading provided the link between Holmes's mantle convection and plate tectonics theory.

Students should know that convection currents in the upper mantle drive the motion of plates. Students should observe Figure 19.17 on pages 528 -529 of the student text. This figure shows the plates that constitute Earth's outer shell (lithosphere) and that are moved by convection currents. Students should recognize that the edges of plates are called boundaries and that the type of boundary that exists in a given location is dependent on the motion of the plates. Students should know that some plates are made of oceanic crust only, whereas other plates are made of both oceanic and continental crust. It is important that students know that oceanic crust is largely casaltic in composition and as a result, mostly comprises the rocks basalt (lave) and gabbro (magma). Additionally, continental crust is largely granitic in composition as a result, mostly comprises of the rocks rhyolite (lava) and granite (magma). Students should know that magnetic reversals and the results of deep-ocean drilling serve as evidence of seafloor spreading.

Plate Tectonics: A Scientific Revolution (continued)

Suggested Assessment Strategies

Presentation

- Create computer animations that show the two different mechanisms for continental movement.
- Create a poster to contrast Wegener's mechanism with Holme's mechanism of plate motion.

Paper and Pencil

- Explain why Wegener couldn't adequately describe his drifting continents. What did this do to the acceptance of his theory?

Performance

- Develop and perform a role play (or dramatization) as a historical figure in the evolution of Earth science, presenting your evidence in support of a theory.
- Model convection currents in the science laboratory using laboratory materials (e.g., water, food colouring, and heater).

Interview

- Interview a peer to determine their understanding of the theory of plate tectonics using self-constructed questions.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 520-523

ST p. 525

Plate Tectonics: A Scientific Revolution (continued)

Outcomes

Students will be expected to

- explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced (115-7)

(continued)

- describe and give examples of convergent, divergent and transform plate boundaries

Elaborations—Strategies for Learning and Teaching

A divergent plate boundary is characterized by two plates moving away from one another as a result of tensional forces exerted on them by convection currents in the upper mantle. Hot molten upwells at the boundary forcing the edges of both plates upwards, creating a ridge. As ridge volcanism occurs, molten cools forming new oceanic crust. This process is referred to as seafloor spreading. Divergent plate boundaries are referred to as constructive margins since new oceanic crust is being formed there. The middle of the Atlantic Ocean is representative of a divergent plate boundary. As seafloor spreading occurs along the Mid-Atlantic ridge, the North American plate and the Eurasian plate move away or outwards from one another. The Mid-Indian ridge in the Indian Ocean is another example of a divergent plate boundary.

A convergent plate boundary is characterized by two plates moving toward one another as a result of compressional forces exerted on them by convection currents in the upper mantle. One of the plates is forced to subduct beneath the other where it is destroyed and/or melted. Remember that temperature increases with increasing depth inside Earth so the plate will melt as it subducts to a great enough depth. Surface expression created by descending plates are called trenches and these vary considerably in relation to depth and width. The planet is not growing larger due to ridge volcanism at divergent plates boundaries that creates new oceanic crust since older oceanic crust is constantly being destroyed in subduction zones at convergent plate boundaries.

A transform plate boundary is characterized by two plates grinding past one another without the construction or destruction of crust. The convection currents exert shear forces on both plates forcing them to slide past one another. The San Andreas fault in California, United States is an example of a transform fault and therefore, a transform plate boundary. The Alpine fault in New Zealand is another example of a transform fault. This type of plate boundary was discovered by J. Tuzo Wilson and will be covered in more detail further in the curriculum

Plate Tectonics: A Scientific Revolution (continued)

Suggested Assessment Strategies

Paper and Pencil

- Create a foldable to distinguish between the 3 types of plate boundaries.
- Create flip books to illustrate the movement of plates at convergent and divergent plate boundaries.
- Create a comic strip that illustrates plate movement at each of the 3 different types of boundaries.

Presentation

- Using computer animation, illustrate the difference between the 3 types of plate boundaries.
- Create a working model, using household items, to represent movement at transform plate boundaries.

Performance

- Create and perform a group interpretive dance to illustrate the movement of plates at each of the 3 types of plate boundaries.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 526-540

Plate Tectonics: A Scientific Revolution (continued)

Outcomes

Students will be expected to

- explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced (115-7)

(continued)

- describe and give examples of the different types of convergent plate boundaries. Include:
  - (i) oceanic-oceanic collisions
  - (ii) oceanic-continental collisions
  - (iii) continental-continental collisions

Elaborations—Strategies for Learning and Teaching

Students should know that there are three types of convergent plate boundaries, which are also referred to as collisions.

Oceanic-oceanic collisions involve two oceanic plates. Since both plates are made of the same rock and are of equal density, either plate could subduct forming a trench and the subduction zone. The volcanoes produced at this collision are island arc volcanoes; they form a curved arc on the surface (map view). The composition of the molten is largely andesitic (intermediate) since the melting basaltic (mafic) oceanic crust becomes mixed with melting sediments that were located on top of the subducting plate as a result of weathering and erosion from the nearest continent (granite-felsic). If the igneous rock is formed from a magma, it will be diorite, whereas if it is formed from a lava, it will be andesite. Global examples of oceanic-oceanic collions include: Japan arc (Japan); Mariana Arc (Philippines); and Aleutian Arc (Aleutian islands).

Oceanic-continental collisions involve an oceanic plate and a plate hosting a continent. Due to a greater density (basaltic vs. granitic), the oceanic plate will most likely subduct beneath the continent forming a trench and subduction zone. In a map view, a volcanic arc is created on the continent as a result of the collision. The composition of the molten will most likely be granitic (felsic) since the upwelling molten created by the melting oceanic crust and associated sediment has to burn through a granitic (felsic) continent. Global examples of oceanic-continental collisions include the Andes and Rocky mountains.

Continental-continental collisions involve the process of subduction, only while an ocean (high density oceanic crust) exists between them. Once the oceanic crust between the two continents has been entirely subducted and the continental shelves have nearly joined, the process of subduction ceases. As compressional forces continue, both continental shelves get uplifted and deformed, forming folded mountains. Global examples of continental-continental collisions include the Himalayan and Appalachian mountains.

Plate Tectonics: A Scientific Revolution (continued)

Suggested Assessment Strategies

Paper and Pencil

- Create a flip book to illustrate the collision of plates at each of the 3 types of convergent plate boundary.
- Create a comic strip that illustrates the collision of plates at each of the 3 different types of boundaries.
- Create a concept map for plate boundaries.

Presentation

- Using soft chocolate chip cookies, model the collisions at oceanic-oceanic or oceanic-continental convergent plate boundaries.
- Using computer animation, illustrate the collision that occurs at the boundary of continental-continental convergent plates.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 533-538

Plate Tectonics: A Scientific Revolution (continued)

Outcomes	Elaborations—Strategies for Learning and Teaching
Students will be expected to	
• explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced (115-7) **(continued)**	
- describe a rift valley and how it evolves into a divergent plate boundary	Students should refer to Figure 19.19 on page 533 of the student text. If tensional forces, due to the motion of convection currents in the upper mantle, begin beneath continents, it can cause continents to split into two or more smaller segments. A spreading center is formed and a rift valley is formed as a result of the associated faulting (normal) and thinning of the crust. Eventually the thinning becomes significant enough for ocean water to move into the rift valley. Ridge volcanism and seafloor spreading begin and a divergent plate boundary is produced. As both continue, the segments (i.e., landmasses) on both sides of the ridge continue to move apart from one another. A global example of a current rift valley is the East African rift valley.
• analyse evidence for plate tectonics theory (332-8) - describe the evidence which supports plate tectonic theory. Include: (i) paleomagnetism (ii) polar wandering (iii) magnetic reversals (iv) earthquakes (Wadati-Benioff zone) (v) deep-ocean drilling (vi) hot spots	Students should know that there is other evidence which supports plate tectonic theory. Examples include locations of and depths of earthquakes as well as the locations and hotspots. Student should link these examples to the contributing scientist.
• describe examples of Canadian contributions to science and technology (117-10)	John Tuzo Wilson is perhaps the best example to use for this outcome. Students should know that he was pivotal in the development of the plate tectonics theory. Students could represent his specific contributions on a timeline.

Plate Tectonics: A Scientific Revolution (continued)

Suggested Assessment Strategies

Paper and Pencil

- Create a comic strip to illustrate the formation of a rift valley and how it evolves into a divergent plate boundary.
- Explain how the world's next ocean could form in east Africa.

Performance

- In a mock courtroom, present your closing argument of evidence supporting the theory of plate tectonics.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 532-533

ST pp. 521-527, 540-544

ST p. 540

Plate Tectonics: A Scientific Revolution (continued)

Outcomes

Students will be expected to

- analyse examples of Canadian contributions to science (117-11)

Elaborations—Strategies for Learning and Teaching

In 1965, J. Tuzo Wilson proposed the existence of transform faults to explain the numerous narrow fracture zones and earthquakes found in the crust. He realized that ridges at divergent plate boundaries were not perfectly linear and came to the understand that transform faults exist where segments of ridges are offset. Students should observe Figure 19.24 on page 539 of the student text which shows a transform fault joining offset segments of a ridge. In making this discovery, Wilson was able to solidify his idea that Earth is covered by rigid plates. Wilson suggested that transform faults connect with divergent and convergent boundaries, and other transform faults, resulting in a network of plates that cover Earth's surface.

Wilson, along with other scientists, also proposed that there are places on Earth's surface, not on plate boundaries, where molten upwells creating volcanism. Wilson referred to these local, stationary plumes of upwelling molten as hotspots. Hotspot volcanism (also called intraplate volcanism), which explains the volcanoes in Hawaii and Yellowstone National Park, will be covered later in the curriculum,

- use appropriate evidence to describe the geologic history of an area (330-12)
  - describe the geology of the island of Newfoundland

This outcome and deliniation are addressed in detail in the CORE STSE "The Geology of Newfoundland and Labrador".

Students should know that there are three geological zones in relation to the island of Newfoundland, which include: western (North America); central (ocean crust/island arcs); and eastern (Africa).

Teachers could demonstrate the locations of the three geological zones of Newfoundland using a map. Teachers could also identify the Cape Ray – Baie Verte line fault on the map, which separates the western and central zones as well as the Hermitage – Dover fault, which separates the central and eastern zones.

Teachers should explain that Gros Morne National Park is recognized as a World Heritage Site since it hosts an ophiolite sequence; an ocean floor profile resting on land. Teachers could also mention the significance of pillow basalts in Tilt Cove.

Plate Tectonics: A Scientific Revolution (continued)

Suggested Assessment Strategies

Presentation

- Create a presentation outlining and/or demonstrating the supporting evidence for the theory of plate tectonics.

Performance

- Using a blank map of the island of Newfoundland, label the three geologic zones and two fault lines.
- Create a foldable of the geologic zones of the island of Newfoundland indicating the main features and characteristics of each zone.
- Develop and perform a role play (or dramatization) as a reporter in our geological past forecasting the geologic development of the island of Newfoundland.

Presentation

- Create a presentation on Gros Morne National Park and the reason for its designation as a World Heritage Site.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 539-540

Newfoundland and Labrador Heritage landscape website

Newfoundland and Labrador Department of Natural Resources website - Geology of Newfoundland and Labrador

Plate Tectonics: A Scientific Revolution (continued)

Outcomes

Students will be expected to

- provide examples of how science and technology are an integral part of their lives and their community (117-5)
- identify new questions or problems that arise from what was learned (214-17)

Elaborations—Strategies for Learning and Teaching

The CORE STSE component of this unit incorporates a broad range of outcomes. More specifically, it addresses, in whole or in part, outcomes 115-7, 117-5, 117-10, 117-11, 214-17, 332-8, and 330-12. The STSE component "The Geology of Newfoundland", can be found in Appendix A.

Teachers could show sections of the CBC learning episode "Geologic Journey - The Atlantic Coast" which pertain to Newfoundland and Labrador.

While the geology of the island of Newfoundland is easier to summarize, the geology of Labrador is quite complex due to the shear size of the region and the immense age of the Canadian Shield. Teachers could compare the geology of the island of Newfoundland to that of Labrador.

Plate Tectonics: A Scientific Revolution (continued)

Suggested Assessment Strategies

Presentation

- Research Canadian scientist Harold “Hank” Williams and create a presentation highlighting his connection to the development of the theory of plate tectonics.
- You have been hired by the NL Dept. of Tourism, Culture and Recreation to promote geotourism. Create a brochure or multi-media presentation to encourage geotourists to visit our province.

Paper and Pencil

- Describe the local evidence from the island of Newfoundland which supports the theory of plate tectonics.
- Having completed the STSE, use an exit card strategy for students to list any new questions that have arisen from what they learned.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

Core STSE #4: “The Geology of Newfoundland”, Appendix A

CBC learning “Geologic Journey - The Atlantic Coast”

Newfoundland and Labrador Dept. of Natural Resources website

Crustal Deformation: Folding and Faulting

Outcomes	Elaborations—Strategies for Learning and Teaching
Students will be expected to	
• describe geological evidence that suggests life forms, climate, continental positions, and Earth's crust have changed over time (332-7)	
- define crustal deformation	Deformation is a general term that refers to all changes in the original form and/or size of a rock body. It may also produce changes in the location and orientation of rocks. Students should know that most crustal deformation occurs along plate tectonic margins.
- define force	Teachers should limit the definition of force to that which tends to put stationary objects in motion or change the motion of moving bodies.
- define stress	For the purposes of this course, stress is defined as the amount of force applied to a given area. Students could take part in a think-pair-share activity to re-enforce the definitions of crustal deformation, force and stress.
- describe the types of forces/ stresses that produce crustal deformation. Include: (i) compressional (ii) tensional (iii) shear	Students should know that stresses that shorten a rock body are compressional in nature and those that elongate a rock body are tensional in nature. Students should know that stresses that cause sections of a rock body or two separate rock bodies to slide past one another are referred to as shear. Teachers could use a sponge or spring to model the types of forces/ stresses.
- describe the types of deformation. Include: (i) elastic (ii) brittle (iii) ductile	Students should know that elastic deformation is recoverable after stressing, brittle deformation results in fracturing and is permanent, and ductile deformation is a solid state flow and is permanent.

Crustal Deformation: Folding and Faulting

Suggested Assessment Strategies

Paper and Pencil

- Write a story documenting the evolution of the geology of the island of Newfoundland.

Paper and Pencil

- Develop illustrations showing elastic, brittle and ductile deformation.
- Create a comic strip where the main character is an Earth material undergoing ductile deformation.

Performance

- Demonstrate your understanding on the types of deformation using household items.
- Demonstrate how elastic rebound works using a piece of wood (note that shear forces can be demonstrated with wood like a meter stick).
- Using a sponge or spring demonstrate all three types of forces.

Paper and Pencil

- Write a song to demonstrate understanding of the three types of forces/stresses.
- Create a foldable on the three types of forces/stresses.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST p. 415

ST pp. 415-418

Crustal Deformation: Folding and Faulting (continued)

Outcomes

Students will be expected to

- describe geological evidence that suggests life forms, climate, continental positions, and Earth's crust have changed over time (332-7)

(continued)

- describe the factors that affect deformation. Include:
  - (i) temperature
  - (ii) confining pressure
  - (iii) rock type
  - (iv) time

- define faulting as the breaking of rock layers and their subsequent motion

- relate faulting to the factors that affect deformation

Elaborations—Strategies for Learning and Teaching

Students should know that temperature affects the type of deformation that occurs. The colder the Earth materials, the more brittle the deformation will be. The warmer the Earth materials, the more elastic or ductile the deformation will be.

Students should know that confining pressure will only result in elastic or ductile deformation. Brittle deformation typically occurs on the surface when there is no pressure from above.

Students should realize that all rock types can be deformed; however, sedimentary rocks could be more easily deformed since they are softer.

Students should know that rapid deformation tends to result in brittle deformation whereas deformation over longer periods of time tends to result in elastic or ductile deformation.

Students should know that rapid, continual, compressional (or tensional) forces, usually at shallower depths, result in brittle deformation (faulting).

Crustal Deformation: Folding and Faulting (continued)

Suggested Assessment Strategies

Presentation

- Create a presentation demonstrating compressional, shear and tensional forces and their effects on a rock body.
- Create computer animations to demonstrate the effects of the types of forces/stresses on a rock body.

Paper and Pencil

- Write a song (e.g. rap) that documents factors affecting the deformation of earth materials.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 415-419

ST p. 425

Crustal Deformation: Folding and Faulting (continued)

Outcomes	Elaborations—Strategies for Learning and Teaching
Students will be expected to	
• describe geological evidence that suggests life forms, climate, continental positions, and Earth's crust have changed over time (332-7) **(continued)**	
- describe the two major types of faults and associated forces/stresses. Include: (i) dip-slip - normal (tensional) - horst and graben (tensional) - reverse (compressional) - thrust (compressional) (ii) strike-slip (transform) - left-lateral (shear) - right-lateral (shear)	Teachers could use shoe boxes, pieces of cardboard or styrofoam to model the major types of faults. Teacher could describe the dip-slip faults in relation to the relative movements of hanging walls and footwalls. Note that the hanging wall is the block of rock above the fault line and that the foot wall is the block of rock below the fault line. Students could draw a vertical line down through the rock blocks in order to identify the hanging wall and the footwall. For normal faults as well as for horsts and grabens, the hanging wall moves down in relation to the footwall. For reverse and thrust faults, the hanging wall moves up in relation to the footwall. Teachers could describe the strike-slip faults by having students consider the movement of a rock block if standing on the opposite rock block and looking across the fault line. Movement to the right is a right-lateral strike-slip fault and movement to the left is a left-lateral strike-slip fault.
- define folding	Folding is defined as the bending of rock layers.
- relate folding to the factors that affect deformation	Students should know that slow, continual, compressional forces, usually at depth, results in ductile deformation (folding).
- describe the two common types of folds. Include: (i) anticline (ii) syncline	Teachers could have students determine whether a fold is an anticline or syncline by drawing a horizontal line across the structure. If it looks like an "A" then it is an anticline; otherwise, it is a syncline.

Crustal Deformation: Folding and Faulting (continued)

Suggested Assessment Strategies

Presentation

- Create a presentation displaying evidence of deformation of Earth materials.

Paper and Pencil

- Create a foldable highlighting the different types of faults. Include illustrations, either hand-drawn or from print sources, and information on the associated forces/stresses.
- Label diagrams provided by the teacher to demonstrate an understanding of the forces/stresses associated with major fault types.

Performance

- Label illustrations of folds as anticline or syncline.
- Create an illustration of an anticline and a syncline.
- Create a poster, brochure, collage or webpage demonstrating the type of forces/stresses associated with the major fault types.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 427-432

ST pp. 421-423

Earthquakes and Seismic Waves

Outcomes

Students will be expected to

- describe methods of analysing, monitoring and predicting earthquakes, volcanic eruptions, and plate interactions (331-9)
  - define earthquake
  - describe the causes of an earthquake. Include:
    - (i) moving magma
    - (ii) elastic rebound
    - (iii) faulting
  - define earthquake terminology. Include:
    - (i) seismic wave
    - (ii) focus
    - (iii) epicentre
    - (iv) foreshock
    - (v) aftershock
  - identify the location of earthquakes and relate them to their plate boundary. Include:
    - (i) divergent (shallow)
    - (ii) transform (shallow)
    - (iii) convergent (shallow, intermediate, and deep)

Elaborations—Strategies for Learning and Teaching

Teachers should note that the following objectives relate to seismic terminology meant to introduce students to these new concepts.

The intent of this delineation is for students to recognize that depending on the plate boundary, the location of an earthquake within the crust varies. Teachers should discuss the Wadati-Benioff zone when explaining the shallow, intermediate, and deep earthquakes along subduction zones.

Earthquakes and Seismic Waves

Suggested Assessment Strategies

Paper and Pencil

- Create a foldable vocabulary book for earthquake terminology and associated definitions.
- Demonstrate understanding by constructing sentences using earthquake terminology in context.

Performance

- Search earthquakes in the last week and display their locations on world map.
- Research locations where earthquakes exist. Using a world map, attach coloured stickers to the map to indicate whether earthquakes are shallow, intermediate or deep in relation to depth below the Earth's surface Students could be asked to formulate reasons why each type of earthquake exists where it does.
- Perform a song with a title or lyrics with a connection to earthquakes or earthquake waves and explain the connection, e.g., "Whole Lot of Shakin' Goin' On".
- Draw a cross-section through a subduction zone using a teacher-constructed table including numbers of earthquakes as well as their associated depths and distances from a deep-ocean trench. Students should relate the size of the earthquake to its depth down a subduction zone and degree of melting.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 440-443

ST pp. 448-451

Earthquakes and Seismic Waves (continued)

Outcomes

Students will be expected to

- describe methods of analysing, monitoring and predicting earthquakes, volcanic eruptions, and plate interactions (331-9)

(continued)

- describe properties of the different seismic waves. Include:
  - (i) surfaces waves (L waves)
  - (ii) primary waves (P waves)
  - (iii) secondary waves (S waves)

- distinguish between earthquake scales. Include:
  - (i) Richter
  - (ii) Modified Mercalli

Elaborations—Strategies for Learning and Teaching

Students should know that P waves and S waves are referred to as body waves since they travel through Earth's interior.

Teachers could use the following table when describing the properties of each type of wave.

	Other Names	**Movement Through States of Matter**	**Speed**	**Particle Motion**
Surface Wave (L wave)	long wave	Solid	slowest (10% slower than S wave)	shearing motion (horizontal only)
Primary Wave (P wave)	push-pull wave	Solid Liquid Gas	6 km/s	compressional (expansion & contraction)
Secondary Wave (S wave)	shear wave	Solid	3.6 km/s	shearing motion (horizontal only or vertical only)

Students should know the characteristics of each earthquake scale as shown in the table below.

Richter	magnitude (energy released)	uses instruments (seismographs)	uses Arabic values	open-ended scale
Modified Mercalli	intensity (amount of destruction)	uses human observations	uses Roman numerals	closed scale

Earthquakes and Seismic Waves (continued)

Suggested Assessment Strategies

Performance

- Use a “slinky” or other kind of spring to demonstrate the movement of each of the different seismic waves.
- In groups, use students to model the movement of each of the different seismic waves.

Presentation

- Create posters showing the Mercalli Intensity scale using images to represent damage.
- Search earthquakes in the last week and display their locations and magnitudes on world map.

Paper and Pencil

- Create a foldable of the different seismic waves and their associated properties.
- Create foldable of the different earthquake scales and their associated characteristics.
- Complete teacher-generated questions relating to amplitude on secondary waves for earthquakes of different magnitude.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 445-447

ST pp. 451-454

Earthquakes and Seismic Waves (continued)

Outcomes

Students will be expected to

- describe methods of analysing, monitoring and predicting earthquakes, volcanic eruptions, and plate interactions (331-9)

(continued)

- identify that the Richter scale increases in amplitude by a factor of ten for every increment of one
- identify in relation to the Richter scale, energy released increases by a factor of 30 (rounded down) for every increment of one

Elaborations—Strategies for Learning and Teaching

Teachers could use the following example as a guide.

Richter scale = 5.0

Richter scale = 6.0

The earthquake of 6.0 on the Richter scale has 10 times as much amplitude on the S wave as the earthquake of 5.0 on the Richter scale.

Teachers could use the following example as a guide.

Richter scale = 4.0

Richter scale = 5.0

The earthquake of 5.0 on the Richter scale has 30 times as much energy released as the earthquake of 4.0 on the Richter scale.

Earthquakes and Seismic Waves (continued)

Suggested Assessment Strategies

Paper and Pencil

- Complete teacher-generated questions relating to energy released from earthquakes of different magnitude.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST p. 453

Earthquakes and Seismic Waves (continued)

Outcomes

Students will be expected to

- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (214-3)
- identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty (214-10)
- identify multiple perspectives that influence a science-related decision or issue (215-4)
- work cooperatively with team members to develop and carry our a plan, and troubleshoot problems as they arise (215-6)
- describe methods of analysing, monitoring and predicting earthquakes, volcanic eruptions, and plate interactions (331-9)
  - describe how seismographs and resulting seismograms are used to measure seismic waves

Elaborations—Strategies for Learning and Teaching

Core Laboratory Activity: Locating an Earthquake Epicentre

The laboratory outcomes 214-3, 214-10, 215-4, 215-6, and 331-9 are addressed, in whole or in part, by completing **CORE LAB #5: "**Locating an Earthquake Epicentre".

Earthquakes and Seismic Waves (continued)

Suggested Assessment Strategies

Presentation

- Research and create a presentation on the 1929 Burin tidal wave.

Performance

- Create a collage of pictures from recent tidal wave disasters.
- Using a teacher, peer or self assessment rubric, assess group processes used in decision making and completing the assigned tasks.

Paper and Pencil

- Having completed the STSE, identify and describe the possible sources of error in mapping the location of the earthquake epicentre.

Observation

- Using a checklist or rubric, assess student ability to compile and display information in a table.
- Using a rubric or checklist, assess student ability to extrapolate from a graph.

Interview

- Using a rubric, assess student knowledge and understanding of how seismographs are used to measure seismic waves.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

Core Lab #5: "Locating an Earthquake Epicentre", Appendix B

ST pp. 447-448

The Nature and Products of Volcanic Eruptions

Outcomes

Students will be expected to

- describe methods of analysing, monitoring and predicting earthquakes, volcanic eruptions, and plate interactions (331-9)
  (continued)

  - describe factors affecting the nature of volcanic eruptions. Include:
    (i) magma temperature
    (ii) magma viscosity
    (iii) magma composition

  - define volcano

  - describe the three types of volcanoes:
    (i) shield
    (ii) ash and cinder
    (iii) composite cone

Elaborations—Strategies for Learning and Teaching

Teachers should refer to the following table of characteristics that relate to the three types of volcanoes.

	Base	Slope	Type of Material	Rock Types	Example
Shield	wide	< 5 degrees	lava flows (< 1% pyroclastic)	basalt	Mauna Loa, USA
Ash and Cinder	narrow	30 - 40 degrees	ejected lava and fragments (pyroclastic)	scoria basalt	Paricutin, Mexico
Composite	intermediate	> 40 degrees	both lava and pyroclastic	basalt andersite rhyolite	Mount St. Helens, USA

Students should be able to draw well-labelled diagrams of each of the volcanoes.

The Nature and Products of Volcanic Eruptions

Suggested Assessment Strategies

Performance

- Create models of the volcano types to give visual representations of relative shape and size.
- Compile YouTube videos to show characteristics of the three types of volcanoes.
- Use various liquids to demonstrate viscosity as a characteristic of fluids.

Paper and Pencil

- How important is magma composition to magma viscosity?
- Create a mind map to illustrate the distinguishing features and characteristics of each type of volcano.

Interview

- Conduct an interview of peers who are pretending to be different types of volcanoes. Interview questions could include:

  "Why do you erupt the way you do?"

  "What type of lava comes out of your vent?"

  "Are you able to interrupt aviation?"

  "Where are you most likely to form on Earth's surface?"

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 89-92

ST pp. 95-102

The Nature and Products of Volcanic Eruptions (continued)

Outcomes

Students will be expected to

- describe methods of analysing, monitoring and predicting earthquakes, volcanic eruptions, and plate interactions (331-9)

(continued)

- describe the type of eruption for each volcano type in relation to the different plate boundaries

- identify the rocks that form in relation to each type of volcano. Include:
  (i) shield – basalt
  (ii) ash and cinder – basalt and scoria
  (iii) composite – andesite, basalt, rhyolite

- distinguish between the types of lava. Include:
  (i) pahoehoe (ropy)
  (ii) aa (jagged, angular)

- describe intraplate volcanism as it relates to hotspots

- describe the formation of a lava plateau

Elaborations—Strategies for Learning and Teaching

Teachers should use the following table to aid understanding of the three types of volcanoes in relation to type of eruption.

Volcano Type	Silica Content	Viscosity	Gas Content	Eruption Style	Plate Boundary
Shield	least (~50%)	least	least (1-2%)	quiet, free-flowing lava	divergent
Ash and Cinder	greatest (~70%)	greatest	greatest (4-6%)	violent and explosive, pyroclastic	convergent and divergent
Composite	intermediate (~60%)	intermediate	intermediate (3-4%)	alternating quiet, free-flowing lava and violent and explosive, pyroclastic	convergent

Students should know that hotspots are stationary plumes of rising magma. Plates above hotspots move and the result, are chains of volcanoes on either the land or ocean floor.

Students should know that the Hawaiian island chain, in the middle of the Pacific Ocean plate, has been formed by a hotspot.

Students should know that Yellowstone National Park and the surrounding area, in the middle of the North American plate, host a chain of volcanoes due to the presence of a hotspot.

Students should know that the Yellowstone National Park and Hawaiian island chain examples differ based on volcano type, molten composition, and eruption style.

Students should know that a lava plateau forms from one or more fissures, which are fractures that extend to the depths of the mantle. These do not form from volcanic craters.

The Nature and Products of Volcanic Eruptions (continued)

Suggested Assessment Strategies

Performance

- Using layer cake, demonstrate the formation of a lava plateau and fissures.
- Research locations where volcanoes exist. Using a world map, place coloured stickers on the map to represent the type of volcano and their associated eruption style. Students should provide reasoning as to why each volcano erupts the way it does.
- Match rock samples with the type of volcano that formed them.
- Build a model to represent the development of volcanoes in either Yellowstone National Park or the Hawaiian Island chain.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 116-122

ST p. 93

ST pp. 121-122

ST pp. 108-109

The Nature and Products of Volcanic Eruptions (continued)

Outcomes

Students will be expected to

- describe major interactions among the hydrosphere, lithosphere, and atmosphere (332-3)
  - explain the global effects of volcanic activity

Elaborations—Strategies for Learning and Teaching

Students should realize that some global effects of volcanic activity will be short-term, whereas others will be long-term.

Short-term global effects of volcanic activity include:

1. Volcanic material can block out sunlight causing short-term cooling.
2. Volcanic material can disrupt air travel.
3. Erupting volcanic material can quickly create new land.
4. Volcanoes and associated material can be destructive (e.g., death to organisms, property damage, road damage).
5. Volcanoes release sulphur dioxides and nitrogen oxides which can mix with water vapour in the atmosphere leading to increased, short-term, acid precipitation.

Long-term global effects of volcanic activity include:

1. Volcanoes release gases like carbon dioxide and water vapour, which in large amounts, could contribute to global warming and climate change.
2. Volcanoes release sulphur dioxides and nitrogen oxides, which can mix with water vapour in the atmosphere leading to increased, long-term, acid precipitation.
3. Volcanoes create fertile soils which enhance agriculture.
4. Volcanoes, depending on number, frequency, and eruption size, could contribute to global cooling and the origin of ice ages, due to the blocking out of the sun. Plants failing to photosynthesize could result in total collapse of food webs and ecosystems.

The Nature and Products of Volcanic Eruptions (continued)

Suggested Assessment Strategies

Performance

- Create and perform a news report about the massive eruption of a large strato volcano and its potential impacts on global climate. Extrapolate potential short term and long term effects.

Paper and Pencil

- Create a mind map of the possible short-term and long-term effects of global volcanic activity.
- Write a story about the travels of a CO_2 molecule as it moves from one sphere to another. Include specific interactions within a sphere.

Presentation

- Create a digital portfolio of newspaper, magazine and/or on-line articles relating to global volcanic activity.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html

ST pp. 122-124

Careers in Earth Sciences

Outcomes

Students will be expected to

- identify and describe science and technology-based careers related to the science they are studying (117-7)
  - identify careers related to plate tectonics, earthquakes, and volcanoes. Include:
    - (i) structural geologist
    - (ii) volcanologist
    - (iii) seismologist
    - (iv) geomorphologist
    - (v) geochemist
    - (vi) geophysicist
    - (vii) petrologist
    - (viii) sedimentologist

Elaborations—Strategies for Learning and Teaching

Students could do a career based assignment to explore one of the careers. If time permits, a brief presentation of each could be made to the class.

Careers in Earth Sciences

Suggested Assessment Strategies

Presentation

- Come to class representing as a person working in a plate tectonics, earthquake, or volcano related career. Describe a typical day in the life of this person.
- Create a presentation, poster, collage or brochure about a plate tectonics, earthquake, or volcano related career.

Interview

- Role play a job interview for an Earth scientist in a plate tectonics, earthquake, or volcano related career.

Resources

http://www.ed.gov.nl.ca/edu/k12/curriculum/documents/science/highschool.html