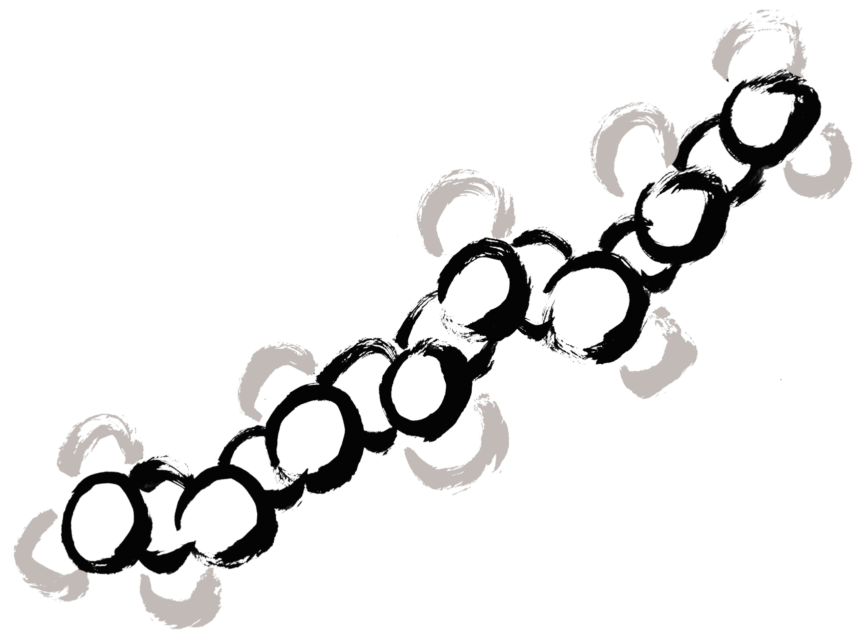
The Commission on Higher Education
in collaboration with the Philippine Normal University

Teaching Guide for Senior High School

EARTH SCIENCE

CORE SUBJECT

This Teaching Guide was collaboratively developed and reviewed by educators from public and private schools, colleges, and universities. We encourage teachers and other education stakeholders to email their feedback, comments, and recommendations to the Commission on Higher Education, K to 12 Transition Program Management Unit - Senior High School Support Team at k12@ched.gov.ph. We value your feedback and recommendations.



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***Chairperson:* Patricia B. Licuanan, Ph.D.**

Commission on Higher Education
K to 12 Transition Program Management Unit
Office Address: 4th Floor, Commission on Higher Education, C.P. Garcia Ave., Diliman, Quezon City
Telefax: (02) 441-0927 / E-mail Address: k12@ched.gov.ph

Consultants

This project was developed with the Philippine Normal University.
University President: Ester B. Ogena, Ph.D.
VP for Academics: Ma. Antoinette C. Montealegre, Ph.D.
VP for University Relations & Advancement: Rosemarievic V. Diaz, Ph.D.

Ma. Cynthia Rose B. Bautista, Ph.D., *CHED*
Bienvenido F. Nebres, S.J., Ph.D., *Ateneo de Manila University*
Carmela C. Oracion, Ph.D., *Ateneo de Manila University*
Minella C. Alarcon, Ph.D., *CHED*

Gareth Price, *Sheffield Hallam University*
Stuart Bevins, Ph.D., *Sheffield Hallam University*

Development Team

Team Leader: Leopoldo de Silva, Ph.D.

Writers: Alfonso Vincent A. Guzman II, Ernesto Ancheta Dizon Jr., Zoraida S. Dizon, Eddie L. Listanco, D.Sc., Catherine C. Abon, Ph.D.

Technical Editors: Maria Ines Rosana Balangue-Tarriela, Ph.D., Rene Juna R. Claveria, Ph.D.

Copyreader: Sarah Mae U. Penir

Illustrator: Patricia G. De Vera

Cover Artists: Paolo Kurtis N. Tan, Renan U. Ortiz

Senior High School Support Team

CHED K to 12 Transition Program Management Unit

Program Director: Karol Mark R. Yee

Lead for Senior High School Support:
Gerson M. Abesamis

Course Development Officers:
John Carlo P. Fernando, Danie Son D. Gonzalvo, Stanley Ernest G. Yu

Lead for Policy Advocacy and Communications:
Averill M. Pizarro

Teacher Training Officers:
Ma. Theresa C. Carlos, Mylene E. Dones

Monitoring and Evaluation Officer:
Robert Adrian N. Daulat

Administrative Officers:
Ma. Leana Paula B. Bato, Kevin Ross D. Nera, Allison A. Danao, Ayhen Loisse B. Dalena

Printed in the Philippines by EC-TEC Commercial, No. 32 St. Louis Compound 7, Baesa, Quezon City, ectec_com@yahoo.com

Table of Contents

Introduction

As the Commission supports DepEd's implementation of Senior High School (SHS), it upholds the vision and mission of the K to 12 program, stated in Section 2 of Republic Act 10533, or the Enhanced Basic Education Act of 2013, that "every graduate of basic education be an empowered individual, through a program rooted on...the competence to engage in work and be productive, the ability to coexist in fruitful harmony with local and global communities, the capability to engage in creative and critical thinking, and the capacity and willingness to transform others and oneself."

To accomplish this, the Commission partnered with the Philippine Normal University (PNU), the National Center for Teacher Education, to develop Teaching Guides for Courses of SHS. Together with PNU, this Teaching Guide was studied and reviewed by education and pedagogy experts, and was enhanced with appropriate methodologies and strategies.

Furthermore, the Commission believes that teachers are the most important partners in attaining this goal. Incorporated in this Teaching Guide is a framework that will guide them in creating lessons and assessment tools, support them in facilitating activities and questions, and assist them towards deeper content areas and competencies. Thus, the introduction of the **SHS for SHS Framework.**

SHS for SHS Framework

The SHS for SHS Framework, which stands for "Saysay-Husay-Sarili for Senior High School," is at the core of this book. The lessons, which combine high-quality content with flexible elements to accommodate diversity of teachers and environments, promote these three fundamental concepts:

SAYSAY: MEANING

Why is this important?

Through this Teaching Guide, teachers will be able to facilitate an understanding of the value of the lessons, for each learner to fully engage in the content on both the cognitive and affective levels.

HUSAY: MASTERY

How will I deeply understand this?

Given that developing mastery goes beyond memorization, teachers should also aim for deep understanding of the subject matter where they lead learners to analyze and synthesize knowledge.

SARILI: OWNERSHIP

What can I do with this?

When teachers empower learners to take ownership of their learning, they develop independence and self-direction, learning about both the subject matter and themselves.

About this Teaching Guide

Earth Science is a Core Subject taken in the first semester of Grade 11. This learning area is designed to provide a general background for the understanding of the Earth on a planetary scale. It presents the history of the Earth through geologic time. It discusses the Earth's structure and composition, the processes that occur beneath and on the Earth's surface, as well as issues, concerns, and problems pertaining to Earth's resources.

Implementing this course at the senior high school level is subject to numerous challenges with mastery of content among educators tapped to facilitate learning and a lack of resources to deliver the necessary content and develop skills and attitudes in the learners, being foremost among these.

In support of the SHS for SHS framework developed by CHED, these teaching guides were crafted and refined by biologists and biology educators in partnership with educators from focus groups all over the Philippines to provide opportunities to develop the following:

Saysay through meaningful, updated, and context-specific content that highlights important points and common misconceptions so that learners can connect to their real-world experiences and future careers;

Husay through diverse learning experiences that can be implemented in a resource-poor classroom or makeshift laboratory that tap cognitive, affective, and psychomotor domains are accompanied by field-tested teaching tips that aid in facilitating discovery and development of higher-order thinking skills; and

Sarili through flexible and relevant content and performance standards allow learners the freedom to innovate, make their own decisions, and initiate activities to fully develop their academic and personal potential.

These ready-to-use guides are helpful to educators new to either the content or biologists new to the experience of teaching Senior High School due to their enriched content presented as lesson plans or guides. Veteran educators may also add ideas from these guides to their repertoire. The Biology Team hopes that this resource may aid in easing the transition of the different stakeholders into the new curriculum as we move towards the constant improvement of Philippine education.

Parts of the Teaching Guide

This Teaching Guide is mapped and aligned to the DepEd SHS Curriculum, designed to be highly usable for teachers. It contains classroom activities and pedagogical notes, and is integrated with innovative pedagogies. All of these elements are presented in the following parts:

1. **Introduction**
   - Highlight key concepts and identify the essential questions
   - Show the big picture
   - Connect and/or review prerequisite knowledge
   - Clearly communicate learning competencies and objectives
   - Motivate through applications and connections to real-life
2. **Motivation**
   - Give local examples and applications
   - Engage in a game or movement activity
   - Provide a hands-on/laboratory activity
   - Connect to a real-life problem
3. **Instruction/Delivery**
   - Give a demonstration/lecture/simulation/hands-on activity
   - Show step-by-step solutions to sample problems
   - Give applications of the theory
   - Connect to a real-life problem if applicable
4. **Practice**
   - Discuss worked-out examples
   - Provide easy-medium-hard questions
   - Give time for hands-on unguided classroom work and discovery
   - Use formative assessment to give feedback
5. **Enrichment**
   - Provide additional examples and applications
   - Introduce extensions or generalisations of concepts
   - Engage in reflection questions
   - Encourage analysis through higher order thinking prompts
6. **Evaluation**
   - Supply a diverse question bank for written work and exercises
   - Provide alternative formats for student work: written homework, journal, portfolio, group/individual projects, student-directed research project

On DepEd Functional Skills and CHED College Readiness Standards

As Higher Education Institutions (HEIs) welcome the graduates of the Senior High School program, it is of paramount importance to align Functional Skills set by DepEd with the College Readiness Standards stated by CHED.

The DepEd articulated a set of 21st century skills that should be embedded in the SHS curriculum across various subjects and tracks. These skills are desired outcomes that K to 12 graduates should possess in order to proceed to either higher education, employment, entrepreneurship, or middle-level skills development.

On the other hand, the Commission declared the College Readiness Standards that consist of the combination of knowledge, skills, and reflective thinking necessary to participate and succeed - without remediation - in entry-level undergraduate courses in college.

The alignment of both standards, shown below, is also presented in this Teaching Guide - prepares Senior High School graduates to the revised college curriculum which will initially be implemented by AY 2018-2019.

College Readiness Standards Foundational Skills	DepEd Functional Skills
Produce all forms of texts (written, oral, visual, digital) based on: 1. Solid grounding on Philippine experience and culture; 2. An understanding of the self, community, and nation; 3. Application of critical and creative thinking and doing processes; 4. Competency in formulating ideas/arguments logically, scientifically, and creatively; and 5. Clear appreciation of one's responsibility as a citizen of a multicultural Philippines and a diverse world;	Visual and information literacies, media literacy, critical thinking and problem solving skills, creativity, initiative and self-direction
Systematically apply knowledge, understanding, theory, and skills for the development of the self, local, and global communities using prior learning, inquiry, and experimentation	Global awareness, scientific and economic literacy, curiosity, critical thinking and problem solving skills, risk taking, flexibility and adaptability, initiative and self-direction
Work comfortably with relevant technologies and develop adaptations and innovations for significant use in local and global communities	Global awareness, media literacy, technological literacy, creativity, flexibility and adaptability, productivity and accountability
Communicate with local and global communities with proficiency, orally, in writing, and through new technologies of communication	Global awareness, multicultural literacy, collaboration and interpersonal skills, social and cross-cultural skills, leadership and responsibility
Interact meaningfully in a social setting and contribute to the fulfilment of individual and shared goals, respecting the fundamental humanity of all persons and the diversity of groups and communities	Media literacy, multicultural literacy, global awareness, collaboration and interpersonal skills, social and cross-cultural skills, leadership and responsibility, ethical, moral, and spiritual values

Grade: 11
Core Subject Title: Earth Science

Semester: 1
No. of Hours: 80 hours
Prerequisite (if needed):

Core Subject Description: This learning area is designed to provide a general background for the understanding of the Earth on a planetary scale. It presents the history of the Earth through geologic time. It discusses the Earth's structure and composition, the processes that occur beneath and on the Earth's surface, as well as issues, concerns, and problems pertaining to Earth's resources.

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
I. ORIGIN AND STRUCTURE OF THE EARTH 1. The Universe and Solar System 2. Earth Systems	*The learners demonstrate an understanding of…* 1. the formation of the universe and the solar system 2. the subsystems (geosphere, hydrosphere, atmosphere, and biosphere) that make up the Earth	*The learners shall be able to...* make a concept map and use it to explain how the geosphere, hydrosphere, atmosphere, and biosphere are interconnected	*The learners…* 1. describe the historical development of theories that explain the origin of the Universe	**S11ES-Ia-1**
			2. compare the different hypotheses explaining the origin of the Solar System	**S11ES-Ia-2**
			3. describe the characteristics of Earth that are necessary to support life	**S11ES-Ia-b-3**
			4. explain that the Earth consists of four subsystems, across whose boundaries matter and energy flow	**S11ES-Ib-4**
II. EARTH MATERIALS AND RESOURCES 1. Minerals and Rocks 2. Mineral Resources 3. Energy Resources 4. Water Resources 5. Soil Resources 6. Human Activity and the Environment	1. the three main categories of rocks 2. the origin and environment of formation of common minerals and rocks 3. the various sources of energy (fossil fuels, geothermal, hydroelectric)	1. make a plan that the community may use to conserve and protect its resources for future generations 2. prepare a plan that the community may implement to minimize waste when people utilize materials and resources	1. identify common rock-forming minerals using their physical and chemical properties	**S11ES-Ib-5**
			2. classify rocks into igneous, sedimentary, and metamorphic	**S11ES-Ic-6**
			3. identify the minerals important to society	**S11ES-Ic-7**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
	4. the amount of usable water resources on Earth 5. the distribution of arable land on Earth 6. waste generation and management		4. describe how ore minerals are found, mined, and processed for human use	**S11ES-Ic-d-8**
			5. cite ways to prevent or lessen the environmental impact that result from the exploitation, extraction, and use of mineral resources	**S11ES-Id-9**
			6. describe how fossil fuels are formed	**S11ES-Id-10**
			7. explain how heat from inside the Earth is tapped as a source of energy (geothermal) for human use	**S11ES-Ie-11**
			8. explain how energy (hydroelectric) is harnessed from flowing water	**S11ES-Ie-12**
			9. cite ways to address the different environmental concerns related to the use of fossil fuels, geothermal energy, and hydroelectric energy	**S11ES-Ie-f-13**
			10. recognize how water is distributed on Earth	**S11ES-If-14**
			11. identify the various water resources on Earth	**S11ES-If-g-15**
			12. explain how different activities affect the quality and availability of water for human use	**S11ES-Ig-16**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
			13. suggest ways of conserving and protecting water resources	**S11ES-Ig-16**
			14. identify human activities, such as farming, construction of structures, and waste disposal, that affect the quality and quantity of soil	**S11ES-Ih-17**
			15. give ways of conserving and protecting the soil for future generations	**S11ES-Ih-i-18**
			16. describe how people generate different types of waste (solid, liquid, and gaseous) as they make use of various materials and resources in everyday life	**S11ES-Ii-19**
			17. explain how different types of waste affect people's health and the environment	**S11ES-Ii-j-20**
			18. cite ways of reducing the production of waste at home, in school, and around the community	**S11ES-Ij-21**
III. EARTH PROCESSES 1. Exogenic Processes 2. Endogenic Processes 3. Deformation of the Crust 4. Plate Tectonics	1. geologic processes that occur on the surface of the Earth such as weathering, erosion, mass wasting, and sedimentation (include the role of ocean basins in the formation of sedimentary rocks) 2. geologic processes that occur within the Earth 3. folding and faulting of rocks	1. make a simple map showing places where erosion and landslides may pose risks in the community 2. using maps, diagrams, or models, predict what could happen in the future as the tectonic plates continue to move	1. describe how rocks undergo weathering	**S11ES-IIa-22**
			2. explain how the products of weathering are carried away by erosion and deposited elsewhere	**S11ES-IIa-b-23**
			3. explain how rocks and soil move downslope due to the direct action of gravity	**S11ES-IIb-22**
			4. explain why the Earth's interior is hot	**S11ES-IIb-c-23**
			5. describe how magma is formed	**S11ES-IIc-24**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
	4. the internal structure of the Earth 5. continental drift 6. seafloor spreading		6. describe what happens after magma is formed	**S11ES-IIc-25**
			7. describe the changes in mineral components and texture of rocks due to changes in pressure and temperature (metamorphism)	**S11ES-IIc-d-26**
			8. describe how rocks behave under different types of stress such as compression, pulling apart, and shearing	**S11ES-IId-27**
			9. identify the layers of the Earth	**S11ES-IId-28**
			10. differentiate the layers of the Earth from each other	**S11ES-IIe-29**
			11. describe the continental drift theory	**S11ES-IIe-30**
			12. discuss evidence that support continental drift	**S11ES-IIe-31**
			13. explain how the seafloor spreads	**S11ES-IIf-32**
			14. describe the structure and evolution of ocean basins	**S11ES-IIf-33**
			15. explain how the movement of plates leads to the formation of folds, faults, trenches, volcanoes, rift valleys, and mountain ranges	**S11ES-IIg-h-34**
IV. HISTORY OF THE EARTH	1. relative and absolute dating 2. the major subdivisions of	describe the possible geologic events that occurred in a certain area	1. describe how layers of rocks (stratified rocks) are formed	**S11ES-IIh-35**

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
Major Events in Earth's Past	geologic time (including index fossils) 3. how the planet Earth evolved in the last 4.6 billion years	based on the rock layers found therein	2. describe the different methods (relative and absolute dating) of determining the age of stratified rocks	**S11ES-IIh-i-36**
			3. explain how relative and absolute dating were used to determine the subdivisions of geologic time	**S11ES-IIi-37**
			4. describe how index fossils (also known as guide fossils) are used to define and identify subdivisions of the geologic time scale	**S11ES-Ii-j-38**
			5. describe the history of the Earth through geologic time	**S11ES-IIj-39**

CODE BOOK LEGEND

Sample: S11ES-Ia-1

LEGEND		SAMPLE	
First Entry	Learning Area and Strand/ Subject or Specialization	Science	**S11**
	Grade Level	Grade 11/12	
Uppercase Letter/s	Domain/Content/ Component/ Topic	Earth Science	**ES**
			-
Roman Numeral **Zero if no specific quarter*	Quarter	First Quarter	**I**
Lowercase Letter/s **Put a hyphen (-) in between letters to indicate more than a specific week*	Week	Week one	**a**
			-
Arabic Number	Competency	State the different hypotheses explaining the origin of the universe	**1**

Earth Science

Universe and the Solar System

60 MINS

Content Standard
The learners demonstrate an understanding of the formation of the universe.

Performance Standard

Learning Competency
Describe the historical development of theories that explain the origin of the universe **(S11ES-Ia-1).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- describe the structure and composition of the Universe;
- state the different hypothesis that preceded the Big Bang Theory of the Origin of the Universe;
- explain the red-shift and how it used as proof of an expanding universe; and
- explain the Big Bang Theory and evidences supporting the theory.

LESSON OUTLINE

Introduction	Communicating learning objectives	10
Motivation	Question&Answer	10
Instruction	Lecture	30
Enrichment	Assignment	
Evaluation	Report and Summary Questions	10

Materials
Projector or print-out of figures

Resources
Lesson Plans/Materials/Teaching Guides

(1) http://imagine.gsfc.nasa.gov/educators/lesson_plans.html
(2) http://imagine.gsfc.nasa.gov/educators/materials.html
(3) http://www.astro.princeton.edu/~dns/teachersguide/website.pdf
(4) http://map.gsfc.nasa.gov/universe/WMAP_Universe.pdf (accessed 3 October 2015)
(5) https://en.wikipedia.org/wiki/Universe (accessed 4 October 2015)
(6) https://www.youtube.com/watch?v=RPVvgJoddO4&list=PLrhG2NtyHAZuPW5HP3cyenGGTUqUhumeQ (accessed 25 October 2015)
(7) Steinhardt P and N Turok. Endless Universe, http://www.physics.princeton.edu/~steinh/endlessuniverse/askauthors.html(accessed 13 October 2015)
(8) http://science.nasa.gov/astrophysics/focus-areas/how-do-stars-form-and-evolve/ (accessed: 12 october 2015)
(9) http://csep10.phys.utk.edu/astr161/lect/solarsys/solarsys.html (accessed 12 October 2015)

Additional resources at the end of the lesson

INTRODUCTION (10 MINS)

Communicating learning objectives

1. Introduce the following learning objectives.
    a. Describe the structure and composition of the Universe;
    b. Explain the red-shift and how it used as proof of an expanding universe
    c. State the different hypothesis that preceded the Big Bang Theory of the Origin of the Universe
    d. Explain the Big Bang Theory

2. Introduce the following important terms
    a. Baryonic matter - "ordinary" matter consisting of protons, electrons, and neutrons that comprises atoms, planets, stars, galaxies, and other bodies
    b. Dark matter - matter that has gravity but does not emit light.
    c. Dark Energy - a source of anti-gravity; a force that counteracts gravity and causes the universe to expand.
    d. Protostar- an early stage in the formation of a star resulting from the gravitational collapse of gases.
    e. Thermonuclear reaction - a nuclear fusion reaction responsible for the energy produced by stars.
    f. Main Sequence Stars - stars that fuse hydrogen atoms to form helium atoms in their cores; outward pressure resulting from nuclear fusion is balanced by gravitational forces
    g. light years - the distance light can travel in a year; a unit of length used to measure astronomical distance

Teacher tip
Alternatively, these terms can be defined during the instruction/delivery.

MOTIVATION (10 MINS)

Connect the lesson to a real-life problem or question.

1. The teacher tells the students that the Universe is at least 13.8 billion of years old and the Earth/ Solar System at least 4.5-4.6 billions of years old. But how large exactly is a billion? Ask the students how long will it take them to spend 1 billion pesos if they spend 1 peso per second.

- 11 billion/(60 s/min*60 min/hr*24 hr/day*365days/year)
- ~32 years
- How long is 13.8 billion years?

2. Show students the series of photographs as follows:

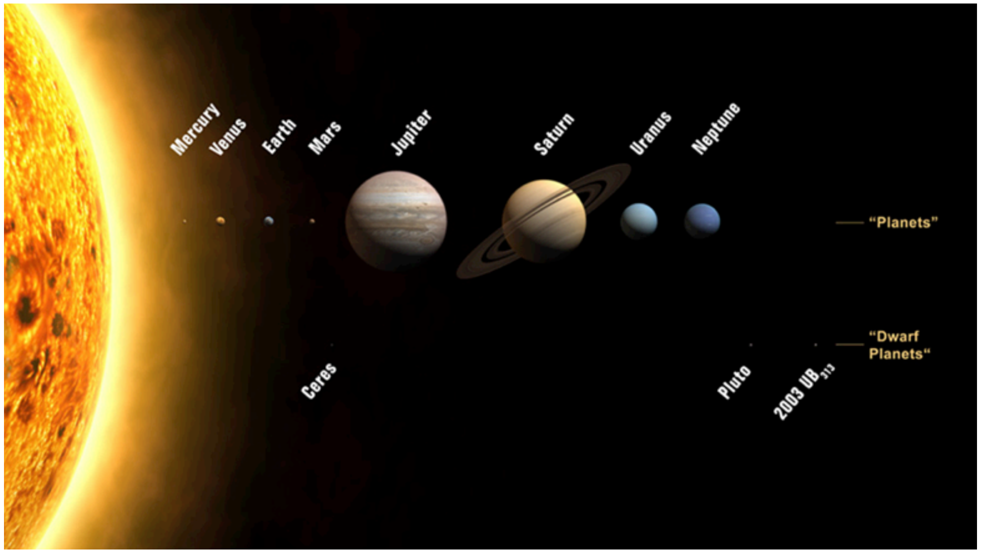
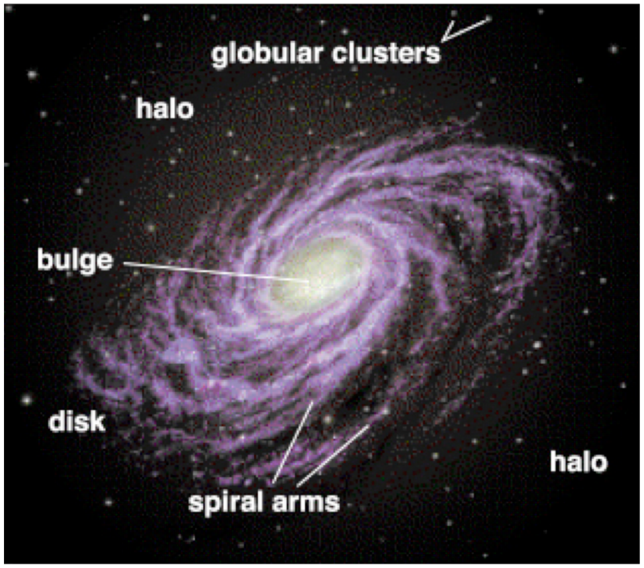


Figure 1: Solar System (Source: https://upload.wikimedia.org/wikipedia/commons/thumb/c/cb/Planets2013.svg/2000px-Planets2013.svg.png)



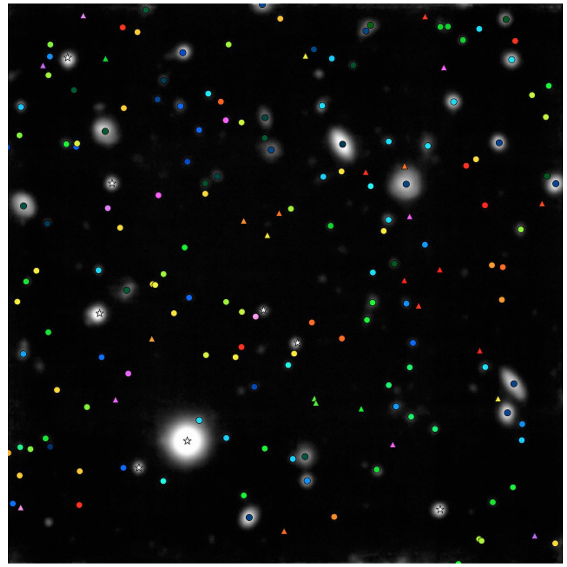


Figure 2: Milky Way Galaxy
(Source: http://physics.highpoint.edu/~mdewitt/phy1050/images/week6/milky-way-top-view.png)

Figure 3: View from Hubble. The Milky Way is but part of billions of galaxies in the universe.
(Source: http://astronomynow.com/wp-content/uploads/2015/03/eso1507b_640x646.jpg)

INSTRUCTION (30 MINS)

Give a demonstration/lecture/simulation

Lecture proper (outline)

A. Introduction

- Any explanation of the origin of the Universe should be consistent with all information about its **composition**, **structure**, **accelerating expansion, cosmic microwave background radiation** among others.

B. Structure, Composition, and Age

- The universe as we currently know it comprises all space and time, and all matter & energy in it.

- It is made of **4.6% baryonic matter** ("ordinary" matter consisting of protons, electrons, and neutrons: atoms, planets, stars, galaxies, nebulae, and other bodies), **24% cold dark matter** (matter that has gravity but does not emit light), and **71.4% dark energ**y (a source of anti-gravity)
- Dark matter can explain what may be holding galaxies together for the reason that the low total mass is insufficient for gravity alone to do so while dark energy can explain the observed accelerating expansion of the universe.
- **Hydrogen**, **helium**, and **lithium** are the three most abundant elements.
- **Stars** - the building block of galaxies born out of clouds of gas and dust in galaxies (fig. 4). Instabilities within the clouds eventually results into gravitational collapse, rotation, heating up, and transformation to a **protostar**-the core of a future star as **thermonuclear reactions** set in.
- Stellar interiors are like furnaces where elements are synthesized or combined/fused together. Most stars such as the Sun belong to the so-called "**main sequence stars**." In the cores of such stars, hydrogen atoms are fused through **thermonuclear reactions** to make helium atoms (fig. 4). Massive main sequence stars burn up their hydrogen faster than smaller stars. Stars like our Sun burnup hydrogen in about 10 billion years.

Teacher tip

Hydrogen and Helium as the most abundant elements in the universe. Having the lowest mass, these are the first elements to be formed in the Big Bang Model of the Origin of the Universe.

- A star's energy comes from combining light elements into heavier elements by fusion, or "nucler burning" (nucleosynthesis).
- In small stars like the sun, H burning is the fusion of 4 H nuclei (protons) into a He nucleus (2 protons + 2 neutrons).
- Forming He from H gives off lots of energy(i.e. a natural hydrogen bomb).
- Nucleosynthesis requires very high T. The minimum T for H fusion is $5x10^{6o}C$.

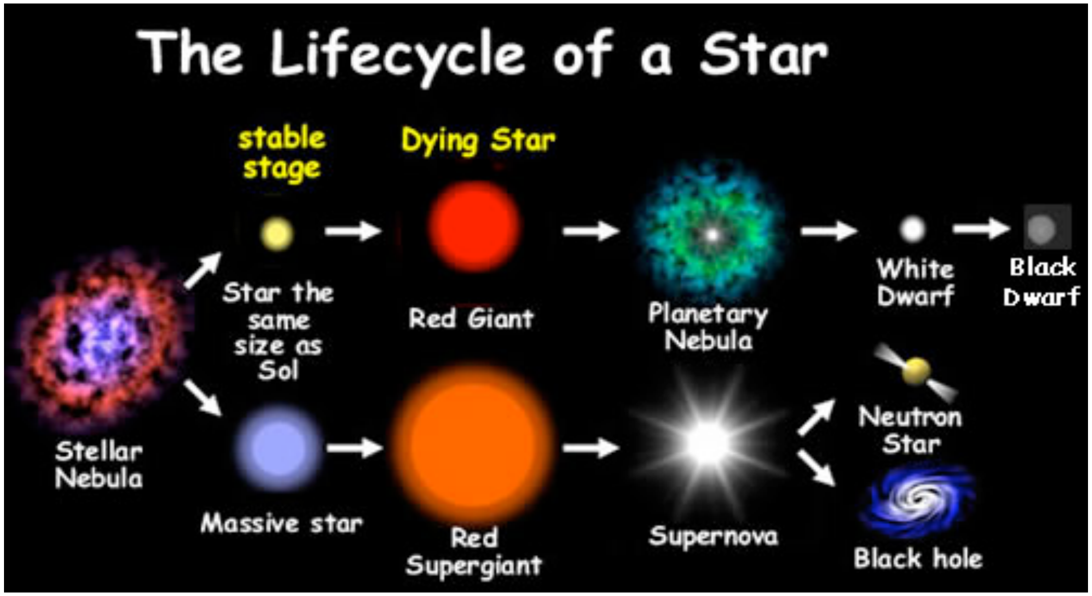


Figure 4: Birth, evolution, death, and rebirth of stars
Image Source: http://www.cyberphysics.co.uk/graphics/diagrams/space/lifecycle_of_star.jpg

- The remaining dust and gas may end up as they are or as planets, asteroids, or other bodies in the accompanying planetary system.

- A **galaxy** is a cluster of billions of stars and clusters of galaxies form superclusters. In between the clusters is practicallyan empty space. This organization of matter in the universe suggests that it is indeed clumpy at a certain scale. But at a large scale, it appears homogeneous and isotropic.

- Based on recent data, the universe is **13.8 billion years old**. The diameter of the universe is possibly infinite but should be at least 91 billion light-years (1 light-year = 9.4607 × 10^{12} km). Its density is 4.5 x 10^{-31} g/cm^3.

Teacher tip

- Isotropic - having physical properties that are the same when measured in different directions
- Two ways by which astronomers estimate the age of the universe :1) by estimating the age of the looking oldest stars; and 2) by measuring the rate of expansion of the universe and extrapolating back to the Big Bang.

  http://map.gsfc.nasa.gov/universe/uni_age.html

C. Expanding Universe

- In 1929, Edwin Hubble announced his significant discovery of the **"redshift"** (fig. 5) and its interpretation that galaxies are moving away from each other, hence as evidence for an expanding universe, just as predicted by Einstein's **Theory of General Relativity**.
- He observed that spectral lines of starlight made to pass through a prism are shifted toward the red part of the electromagnetic **spectrum**, i.e., toward the band of lower frequency; thus, the inference that the star or galaxy must be moving away from us.

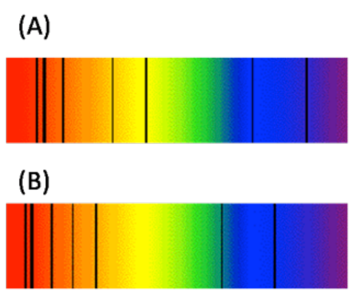


Figure 5. Red shift as evidence for an expanding universe. The positions of the absorptions lines for helium for light coming from the Sun (A) are shifted towards the red end as compared with those for a distant star (B).

(Source: http://www.cyberphysics.co.uk/Q&A/KS4/space/diagrams/spectra.png)

This is similar to the **Doppler effect** for sound waves: to a stationary observer, the frequency or pitch of a receding source decreases as it moves away.

- This evidence for expansion contradicted the previously held view of a static and unchanging universe.

D. Activity: Doppler Effect and Interactive (http://molebash.com/doppler/horn/horn1.ht)

Ask the students to watch two short video clips filmed inside a car. Try to determine where the horn is coming from. Is it coming from inside the car or outside the car? If outside the car, where?

- Video 1 - horn is coming from the inside of the car. There is hardly any change in the volume and pitch of the horn.
- Video 2 - horn is coming from outside of the car. Specifically, the horn is coming from another car travelling in an opposite direction. Notice how the pitch and volume of the car varies with distance from the other car. Pitch and volume increases as the other car approaches.

- If there is internet access, teacher can play these two movie clips directly from the website; (http://molebash.com/doppler/horn/horn1.htm)
- Alternatively, the movie clips can be downloaded (also saved in the CD)

The Doppler Effect: An Interactive Lesson

Credits

Web site content	Randy Bell Philip Molebash Gerriy Swan
Web site design	Philip Molebash
Honking horn videos	Randy Bell Philip Molebash
Java applets	Davidson College Physlets Page Fu-Kwun Hwang, Dept. of physics, National Taiwan Normal University
Flash movies	Philip Molebash

E. Cosmic Microwave Background

- There is a pervasive cosmic microwave background (CMB) radiation in the universe. Its accidental discovery in 1964 by Arno Penzias and Robert Woodrow Wilson earned them the physics Nobel Prize in 1978.
- It can be observed as a strikingly uniform faint glow in the microwave band coming from all directions-blackbody radiation with an average temperature of about 2.7 degrees above absolute zero (fig. 6).

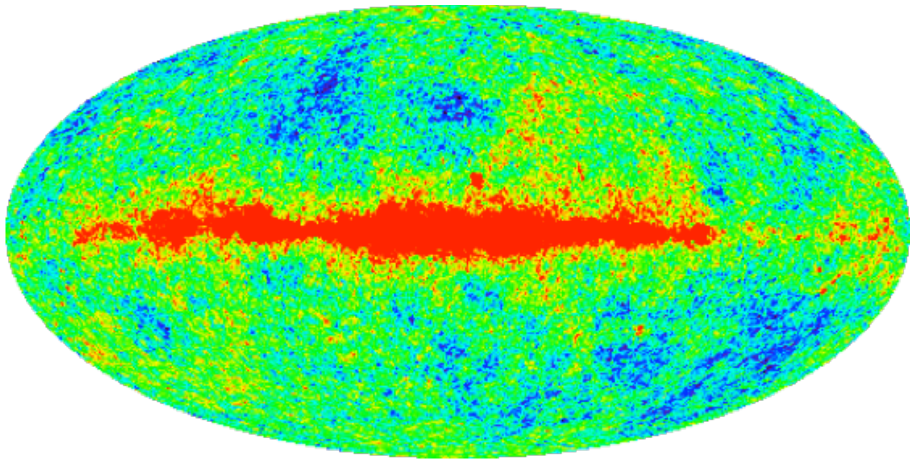


Figure 6: Cosmic microwave background radiation map showing small variations from WMAP (Wilkinson Microwave Anisotropy Probe).
(Source: http://wmap.gsfc.nasa.gov/media/ContentMedia/map_model_2.gif)

A. Origin of the Universe

Non-scientific Thought

- Ancient Egyptians believed in many gods and myths which narrate that the world arose from an infinite sea at the first rising of the sun.
- The Kuba people of Central Africa tell the story of a creator god Mbombo (or Bumba) who, alone in a dark and water-covered Earth, felt an intense stomach pain and then vomited the stars, sun, and moon.
- In India, there is the narrative that gods sacrificed Purusha, the primal man whose head, feet, eyes, and mind became the sky, earth, sun, and moon respectively.
- The monotheistic religions of Judaism, Christianity, and Islam claim that a supreme being created the universe, including man and other living organisms.

Teacher Tip
Unlike hypotheses in the sciences, religious beliefs cannot be subjected to tests using the scientific method. For this reason, they cannot be considered valid topic of scientific inquiry.

Steady State Model

- The now discredited steady state model of the universe was proposed in 1948 by Bondi and Gould and by Hoyle.It maintains that new matter is created as the universe expands thereby maintaining its density.
- Its predictions led to tests and its eventual rejection with the discovery of the cosmic microwave background.

The uniform nature (even in all direction) of the CMB precludes propagation from a point source (i.e. from ancient stars as explained by the steady state model).

Big Bang Theory

- As the currently accepted theory of the origin and evolution of the universe, the Big Bang Theory postulates that 13.8 billion years ago, the universe expanded from a tiny, dense and hot mass to its present size and much cooler state.
- The theory rests on two ideas: General Relativity and the Cosmological Principle. In Einstein's General Theory of Relativity, gravity is thought of as a distortion of space-time and no longer described by a gravitational field in contrast to the Law of Gravity of Isaac Newton. General Relativity explains the peculiarities of the orbit of Mercury and the bending of light by the Sun and has passed rigorous tests. The Cosmological Principle assumes that the universe is homogeneous and isotropic when averaged over large scales. This is consistent with our current large-scale image of the universe. But keep in mind that it is clumpy at smaller scales.
- The Big Bang Theory has withstood the tests for expansion: 1) the redshift 2) abundance of hydrogen, helium, and lithium, and 3) the uniformly pervasive cosmic microwave background radiation-the remnant heat from the bang.

Misconception:
The "bang" should not be taken as an explosion; it is better thought of a simultaneous appearance of space everywhere. The theory does not identify the cause of the "bang."

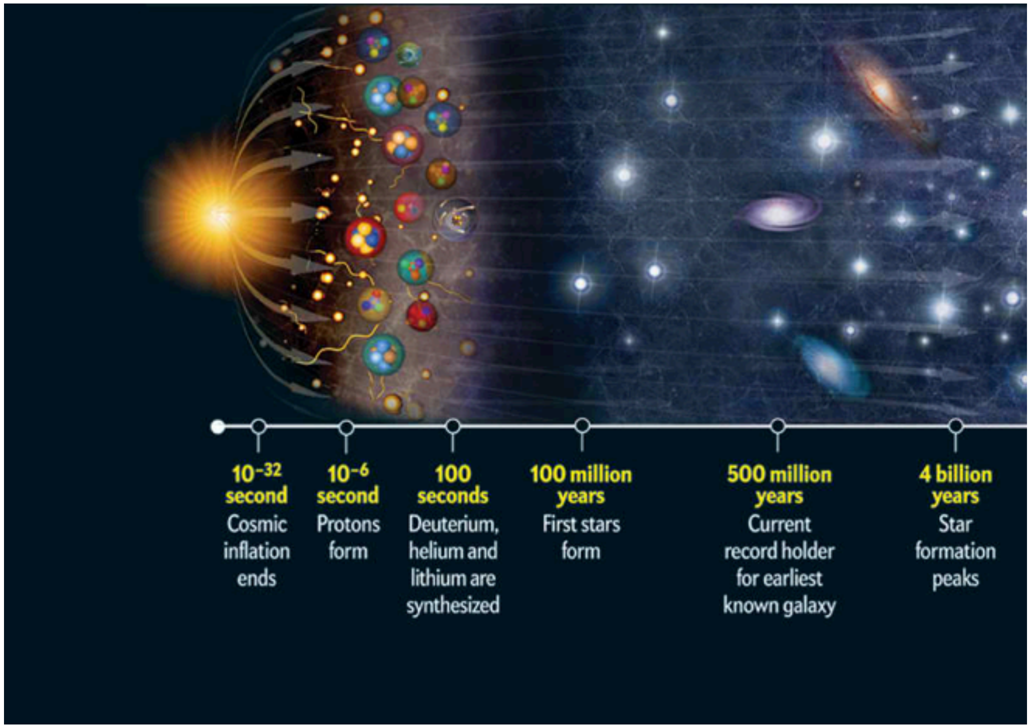


Figure 7: Big Bang Timeline

(Source: http://futurism.com/wp-content/uploads/2015/11/big-bang-theory-timeline1.jpg)

6. **Evolution of the Universe according to the Big Bang Theory**
    - From time zero (13.8 billion years ago) until 10^{-43} second later, all matter and energy in the universe existed as a hot, dense, tiny state (fig. 7). It then underwent extremely rapid, exponential inflation until 10^{-32} second later after which and until 10 seconds from time zero, conditions allowed the existence of only quarks, hadrons, and leptons.
    - Then, Big Bang nucleosynthesis took place and produced protons, neutrons, atomic nuclei, and then hydrogen, helium, and lithium until 20 minutes after time zero when sufficient cooling did not allow further nucleosynthesis.
    - From then on until 380,000 years, the cooling universe entered a matter-dominated period when photons decoupled from matter and light could travel freely as still observed today in the form of cosmic microwave background radiation.

- As the universe continued to cool down, matter collected into clouds giving rise to only stars after 380,000 years and eventually galaxies would form after 100 million years from time zero during which, through nucleosynthesis in stars, carbon and elements heavier than carbon were produced.
- From 9.8 billion years until the present, the universe became dark-energy dominated and underwent accelerating expansion. At about 9.8 billion years after the big bang, the solar system was formed.

ENRICHMENT

Ask the students to submit a brief report on the following topic/questions.

- What is the fate of the universe? Will the universe continue to expand or will it eventually contract because of gravity?

Teacher tip

It was previously thought that the gravity would eventually stop the expansion and end the universe with a "Big Crunch" and perhaps to generate another "bang". This would occur if the density of the universe is greater than the critical density. But if it is lower, there would be not enough gravitational force to stop or reverse the expansion---the universe would expand forever leading to the "Big Chill" or "Big Freeze" since it cools during expansion. The recent observation of accelerating expansion suggests that the universe will expand exponentially forever.

Submitted work may be evaluated using the following criteria:

- Logical discussion of scientific concepts used for the argument (egeffects of gravity, expansion), consistent discussions of pros and cons

- Logical build up of reasoning to support the choice.

EVALUATION (20 MINS)

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Enrichment report				
Summary questions				
Explains the concept of the Red Shift and how it used as an evidence for an expanding universe.				
Applies understanding of the Doppler effect to differentiate between source of sound in two movie clips				
Describes the cosmic microwave background radiation and its significance.				
States the different hypotheses that preceded the Big Bang Theory of the origin of the universe				
Explain the origin and evolution of the Universe according to the Big Bang Theory.				

ADDITIONAL RESOURCES

Lesson Plan/Materials/Teaching Guides

1. https://en.wikipedia.org/wiki/History_of_Solar_System_formation_and_evolution_hypotheses#Classification_of_the_theories (accessed 13 October 2015)
2. "The Origin of the Universe, Earth, and Life." National Academy of Sciences. *Science and Creationism: A View from the National Academy of Sciences, Second Edition*. Washington, DC: The National Academies Press, 1999. http://www.nap.edu/read/6024/chapter/3#8 (accessed 2 October 2015)
3. http://science.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/ (accessed 5 October 2015)

Activities for teaching of the Universe

1. http://www.nuffieldfoundation.org/science-society/activities-universe
2. http://molebash.com/doppler/horn/horn1.htm

Short Article

1. http://www.scholastic.com/teachers/article/?origin-universe

Earth Science

Universe and the Solar System

60 MINS

Content Standard
The learners demonstrate an understanding of the formation of the universe and the solar system.

Performance Standard

Learning Competency
Compare the different hypotheses explaining the origin of the Solar System. **(S11ES-Ia-2).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- identify the large scale and small scale properties of the solar system; and
- discuss the different hypotheses explaining the origin of the solar system.

LESSON OUTLINE

Introduction	Communicating learning objectives	10
Motivation	Prelection	5
Instruction	Lecture	35
Enrichment	Short Research Assignment	
Evaluation	Pen & Paper Assignment	10

Materials
Projector or print-out of figures

Resources

(1) http://csep10.phys.utk.edu/astr161/lect/solarsys/solarsys.html (accessed 12 October 2015)

(2) https://en.wikipedia.org/wiki/History_of_Solar_System_formation_and_evolution_hypotheses#Classification_of_the_theories (accessed 13 October 2015)

(3) "The Origin of the Universe, Earth, and Life." National Academy of Sciences. *Science and Creationism: A View from the National Academy of Sciences, Second Edition*. Washington, DC: The National Academies Press, 1999. http://www.nap.edu/read/6024/chapter/3#8 (accessed 2 October 2015)

(4) http://science.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/ (accessed 5 October 2015)

(5) http://abyss.uoregon.edu/~js/ast121/lectures/lec24.html (accessed 27 March 2016)

(6) http://discovery.nasa.gov/education/pdfs/Active%20Accretion_Discovery_508.pdf (accessed 27 March 2016)

(7) http://www.pbslearningmedia.org/resource/nsn11.sci.ess.eiu.solarorigins/origins-of-the-solar-system/ (accessed 27 March 2016)

(8) http://dawn.jpl.nasa.gov/DawnClassrooms/pdfs/ActiveAccretion_Dawn.pdf (accessed 27 March 2016

INTRODUCTION (10 MINS)

Communicating learning objectives

1. Introduce the following learning objectives and important terms
   a. Identify the large scale and small scale properties of the solar system;
   b. Discuss the different hypotheses explaining the origin of the solar system;

2. Help students recall what they have learned about the solar system by drawing a model on the board. Ask the students for the correct sequence (from the inner planets to the outer planet).

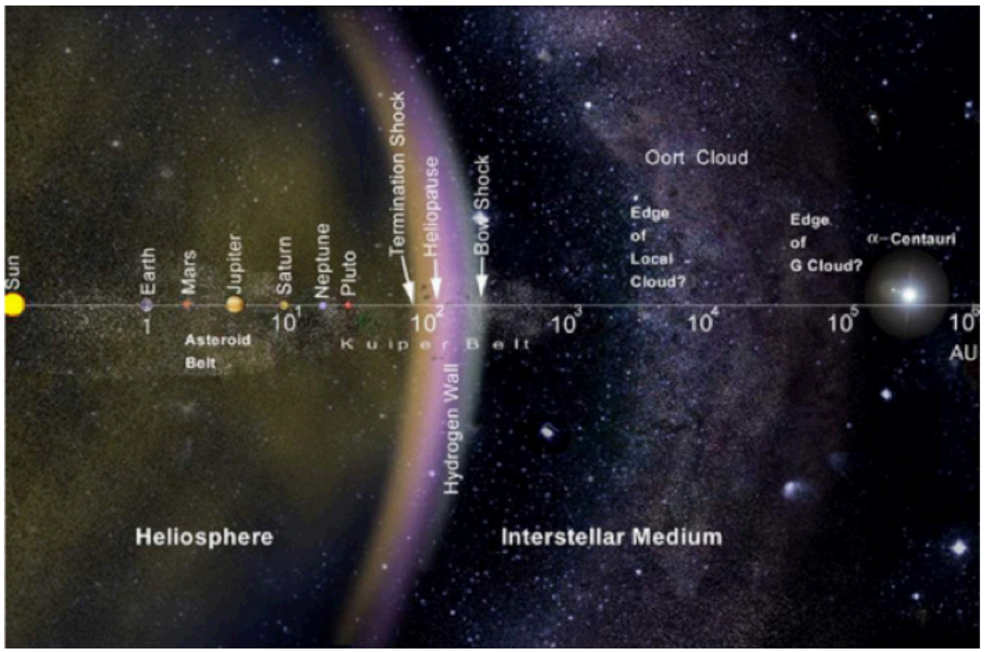


Figure 1. Layout of the solar system comprising mainly the Sun, planets and their satellites, asteroids, and icy bodies such as dwarf planets and comets.
(http://www.universetoday.com/wp-content/uploads/2011/02/oort-cloud-nasa.jpg)

Teacher tip

- *The Solar System and its components have been discussed in Grade 6 and Grade 8 (astronomy)*
- The solar system comprises the Sun, eight planets, dwarf planets such as Pluto, satellites, asteroids, comets, other minor bodies such as those in the Kuiper belt and interplanetary dust.
- The asteroid belt lies between Mars and Jupiter. Meteoroids are smaller asteroids. They are thought of as remnants of a "failed planet"—one that did not form due to disturbance from Jupiter's gravity.
- The Kuiper belt lies beyond Neptune (30 to 50 AU, 1 AU = Sun-Earth distance = 150 million km) and comprise numerous rocky or icy bodies a few meters to hundreds of kilometers in size.
- The Oort cloud marks the outer boundary of the solar system and is composed mostly of icy objects

MOTIVATION (5 MINS)

The Earth, the planet we live on, is part of the Solar System. If we want to know how the Earth formed, we need to understand the origin and evolution of the Solar System.

INSTRUCTION (30 MINS)

Give a demonstration/lecture/simulation

Lecture proper (outline)

Show to the class the photos of the Milky Way galaxy and discuss the highlights.

SOLAR SYSTEM

A. Overview

- The solar system is located in the Milky Way galaxy—a huge disc- and spiral-shaped aggregation of about at least 100 billion stars and other bodies (fig. 2);
- Its spiral arms rotate around a globular cluster or bulge of many, many stars, at the center of which lies a supermassive blackhole;
- This galaxy is about 100 million light years across (1 light year = 9.4607×10^{12} km;
- The solar system revolves around the galactic center once in about 240 million years;
- The Milky Way is part of the so-called Local Group of galaxies, which in turn is part of the Virgo supercluster of galaxies;
- Based on on the assumption that they are remnants of the materials from which they were formed, radioactive dating of meteorites, suggests that the Earth and solar system are 4.6 billion years old.on the assumption that they are remnants of the materials from which they were formed..

Teacher tip

Age of Solar System is at **4.6 billion** years old based on radioactive dating of meteorites (Solar System is much younger than the Universe);

Figure 2: The Solar System position with respect to the Milky Way Galaxy.
http://www.basicknowledge101.com/photos/earthinmilkyway.jpg

B. Large Scale Features of the Solar System

- Much of the mass of the Solar System is concentrated at the center (Sun) while angular momentum is held by the outer planets.
- Orbits of the planets elliptical and are on the same plane.
- All planets revolve around the sun.
- The periods of revolution of the planets increase with increasing distance from the Sun; the innermost planet moves fastest, the outermost, the slowest;
- All planets are located at regular intervals from the Sun.

Teacher tip

- **Any hypothesis regarding the origin of the solar system should conform to or explain both large scale and small scale properties of the solar system**. Natural forces created and shaped the solar system. The same processes (condensation, accretion, collision and differentiation) are ongoing processes .

C. Small scale features of the Solar System

- Most planets rotate prograde
- Inner terrestrial planets are made of materials with high melting points such as silicates, iron , and nickel. They rotate slower, have thin or no atmosphere, higher densities, and lower contents of volatiles - hydrogen, helium, and noble gases.
- The outer four planets - Jupiter, Saturn, Uranus and Neptune are called "gas giants" because of the dominance of gases and their larger size. They rotate faster, have thick atmosphere, lower densities, and fluid interiors rich in hydrogen, helium and ices (water, ammonia, methane).

D. Element Abundance on Earth, Meteorites, and Universe

Table 1 shows the abundance of elements across bodies in the solar system as compared to abundance in the universe.

- Except for hydrogen, helium, inert gases, and volatiles, the universe and Earth have similar abundance especially for rock and metal elements.

- The orderly structure of the Solar System (planets located at regular intervals) and the uniform age of the point to single formation event.
- It would help if there is a table to show these features..comparing and contrasting the different planets.
- Review the learners on of rotation vs revolution.
- **Prograde** - counterclockwise when viewed from above the Earth's North Pole.
- Mercury's orbit around the sun does not conform with the rest of the planets in the solar system. It does not behave according to Newton's Laws.
  - The precession or rotation of the orbit is predicted by Newton's theory as being caused by the pull of the planets on one another. The precession of the orbits of all planets except for Mercury's can, in fact, be understood using Newton;s equations. But Mercury seemed to be an exception.
  - As it orbits the Sun, this planet follows an ellipse, but only approximately: it is found that the point of closest approach of Mercury to the sun does not always occur at the same place as in other planets but that it slowly moves around the sun

Earth's origins known mainly from its compositional differences with the entire Universe. Planet- making process modified original cosmic material.

Elemental abundances in Earth vs. Universe (atoms per 10,000 atoms Silicon)

		Continental crust	Universe	Meteorites	Whole Earth
Rock makers	Si	10,000	10,000	10,000	10,000
	Al	3,000	950	740	740
	Fe	960	6,000	9,300	11,500
	Mg	940	9,100	9,700	9,700
	Ca	1,020	490	520	520
	Na	1,040	440	460	460
	K	540	30	40	40
	Mn	18	70	70	70
	Ti	104	20	20	20
	Ni	13	270	450	750
	P	35	100	60	60
	Cr	19	80	90	90
Volatiles	H	1,400	4.0×10^{8}		84
	O	29,000	215,000	34,300	34,000
	N	1	66,000		0.2
	C	18	35,000		70
	S	9	3,750	990	1,100
	F	34	16		3
	Cl	4	90		30
Inert Gases	He		3.1×10^{7}		3.5×10^{-7}
	Ne		86,000		12×10^{-7}
	Ar		1,500		$5{,}900 \times 10^{-7}$
	Kr		0.51		0.6×10^{-7}

Teacher can choose to skip this part (abundance of elements) if pressed for time.

Teacher tip

If teacher decides to discuss this part, he/she can show th table and solicit observations from the students as to the differences/similarities in terms of element composition (Not necessarily absolute amounts). Students may also provide explanations/implications for their observations.

Expected responses may include:

- a difference between the composition of the Earth's continental crust and the Whole Earth (average composition of the Earth) Þ The Earth differentiated into compositional layers - crust, mantle, and the core
- Very similar rock and metal elements for Universe and Earth Þ easy to make Earth if most H and He are removed; sun and large planets have enough mass and gravity to retain H and He
- Inert gases rare on Earth Þ too light for Earth's gravity to hold
- Some volatile elements remain Þ ingredients from which Earth formed were "cold" and solid particles; if hot, would have been lost
- Recall that meteorites are believed to be remnants of materials from which the solar system was derived

Table 1: Abundance of Elements.

- The sun and the large planets have enough gravity to retain hydrogen and helium. Rare inert gases are too light for the Earth's gravity to retain, thus the low abundance.
- The sun and the large planets have enough gravity to retain hydrogen and helium. Rare inert gases are too light for the Earth's gravity to retain, thus the low abundance.
- Retention of volatile elements by the Earth is consistent with the idea that some materials that formed the Earth and the solar system were "cold" and solid; otherwise, the volatiles would have been lost. These suggest that the Earth and the solar system could be derived from materials with composition similar to that of the universe.
- The presence of heavy elements such as lead, silver, and uranium on Earth suggests that it was derived from remnants of a supernova and that the Sun is a second-generation star made by recycling materials.

E. Origin of the System

- Any acceptable scientific thought on the origin of the solar system has to be consistent with and supported by information about it (e.g. large and small scale features, composition). **There will be a need to revise currently accepted ideas should data no longer support them**.

F. Rival Theories

- Many theories have been proposed since about four centuries ago. Each has weaknesses in explaining all characteristics of the solar system. A few are discussed below.

1. Nebular Hypothesis

- In the 1700s Emanuel Swedenborg, Immanuel Kant, and Pierre-Simon Laplace independently thought of a **rotating gaseous cloud that cools and contracts** in the middle to form the sun and the rest into a disc that become the planets.
- This nebular theory failed to account for the distribution of angular momentum in the solar system.

Teacher can ask students for what theories/ explanations they know about the origin of the solar system.

Teacher Tips:

- This is the nature of scientific inquiry. As new data is generated from observations/experimentation, a hypothesis can be revised or even replaced by a new one.
- Present the different hypotheses on the origin of the Solar System in table form. The first column is a summary of the hypothesis. Second column - flaws/ drawbacks of the hypothesis.
- Teacher can draw this simple diagram on the board to explain the Nebular Hypothesis.

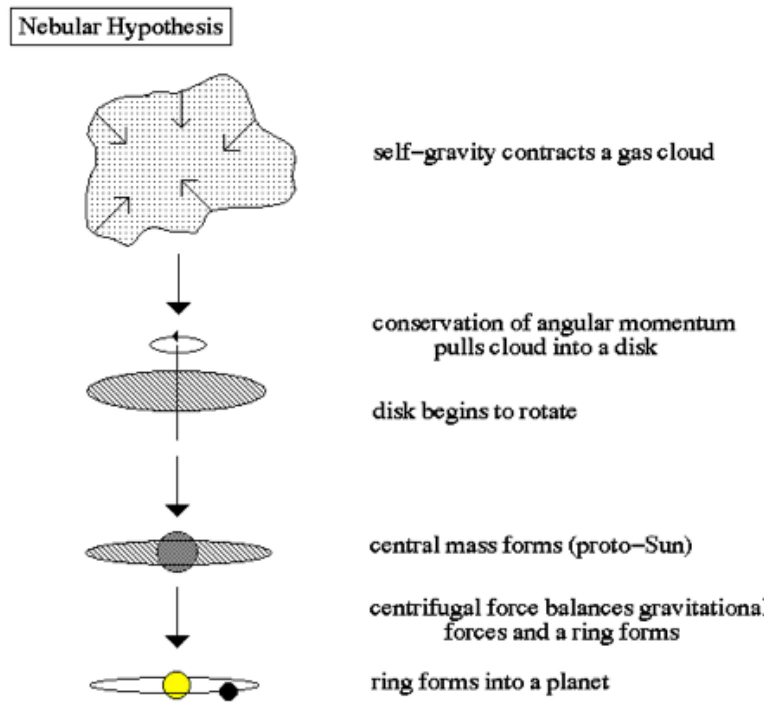


Figure 3. Nebular Hypothesis.
(Source: http://abyss.uoregon.edu/~js/images/nebular_hypothesis.gif)

2. Encounter Hypotheses:

- Buffon's (1749) **Sun-comet** encounter that sent matter to form planet;
- James Jeans' (1917) **sun-star** encounter that would have drawn from the sun matter that would condense to planets,
- T.C. Chamberlain and F. R. Moulton's (1904) **planetesimal hypothesis** involving a **star much bigger than the Sun passing by the Sun** and draws gaseous filaments from both out which planetisimals were formed;

- The common theme of these hypotheses involves an **unlikely encounter** between the Sun and another celestial body (e.g. comet, star, protoplanet, interstellar cloud);
- The two major flaws of this type of hypothesis include: 1) fails to explain how planets are formed (hot gas from the sun/star expands and will not form planets); 2) this type of encounters are extremely rare

- Ray Lyttleton's (1940) sun's companion star colliding with another to form a **proto-planet** that breaks up to form Jupiter and Saturn.

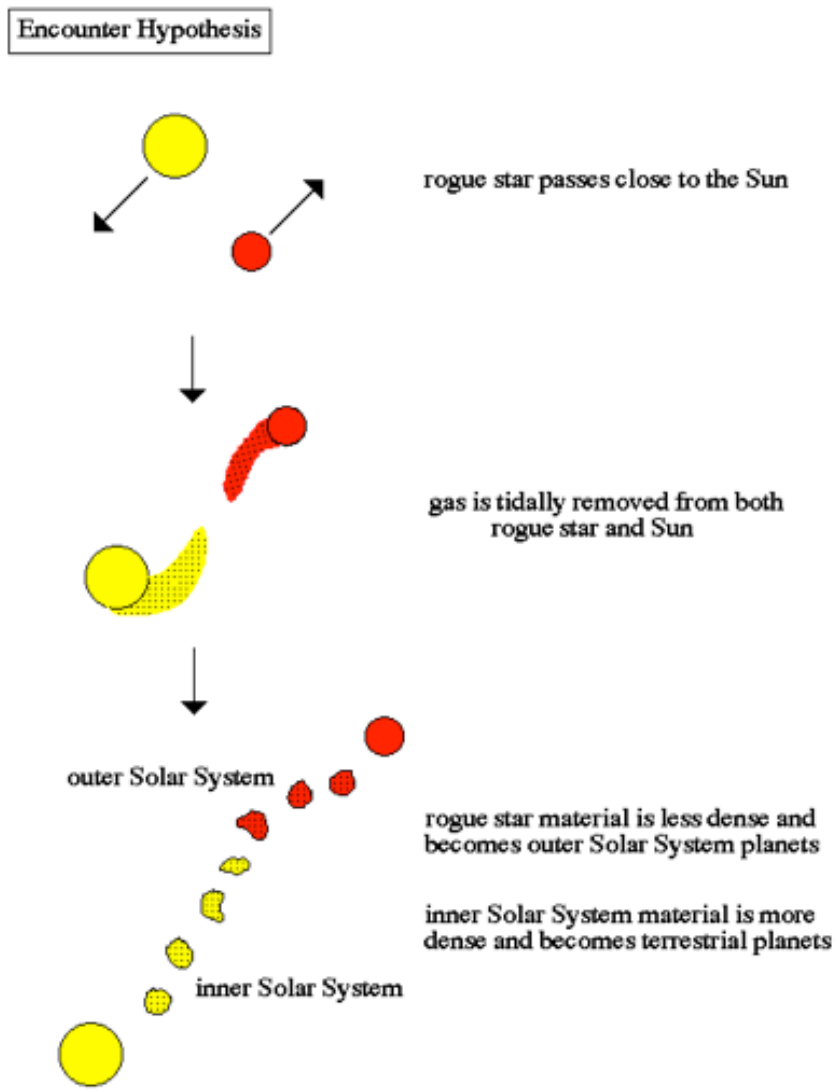


Figure 4: Sun - Star Interaction

Image Source: http://abyss.uoregon.edu/~js/images/encounter_hypothesis.gif

- Otto Schmidt's accretion theory proposed that the Sun passed through **a dense interstellar cloud** and emerged with a dusty, gaseous envelope that eventually became the planets. However, it cannot explain how the planets and satellites were formed. The time required to form the planets exceeds the age of the solar system.
    - M.M. Woolfson's capture theory (Figure 4) is a variation of James Jeans' near-collision hypothesis. In this scenario, the Sun drags from a near proto-star a filament of material which becomes the planets. Collisions between proto-planets close to the Sun produced the terrestrial planets; condensations in the filament produced the giant planets and their satellites. Different ages for the Sun and planets is predicted by this theory.
    - Nobel Prize winner Harold Urey's compositional studies on meteorites in the 1950s and other scientists' work on these objects led to the conclusion that **meteorite constituents have changed very little since the solar system's early history and can give clues about their formation**. The currently accepted theory on the origin of the solar system relies much on information from meteorites.

3. Protoplanet Hypotheses - Current Hypothesis

- About 4.6 billion years ago, in the Orion arm of the Milky Way galaxy, a slowly-rotating gas and dust cloud dominated by hydrogen and helium starts to contract due to gravity (fig. 5).
- As most of the mass move to the center to eventually become a proto-Sun, the remaining materials form a disc that will eventually become the planets and momentum is transferred outwards.
- Due to collisions, fragments of dust and solid matter begin sticking to each other to form larger and larger bodies from meter to kilometer in size. These **proto-planets** are **accretions** of frozen water, ammonia, methane, silicon, aluminum, iron, and other metals in rock and mineral grains enveloped in hydrogen and helium.
- High-speed collisions with large objects destroys much of the mantle of Mercury, puts Venus in retrograde rotation.
- Collision of the Earth with large object produces the moon. This is supported by the composition of the moon very similar to the Earth's Mantle
- When the proto-Sun is established as a star, its solar wind blasts hydrogen, helium, and volatiles from the inner planets to beyond Mars to form the gas giants leaving behind a system we know today.

Teacher Tip

- importance of meteorites in determining the age and the origin of the solar system.
- An improvement of the nebular hypothesis based on current knowledge of fluids and states of matter.
- remind the learner of the comparison of the elemental abundance among the Universe, Meteorites, and the whole Earth
- accretion and bombardment generate heat (kinetic energy is transformed to heat)which was partly retained by the Earth as **internal heat**;

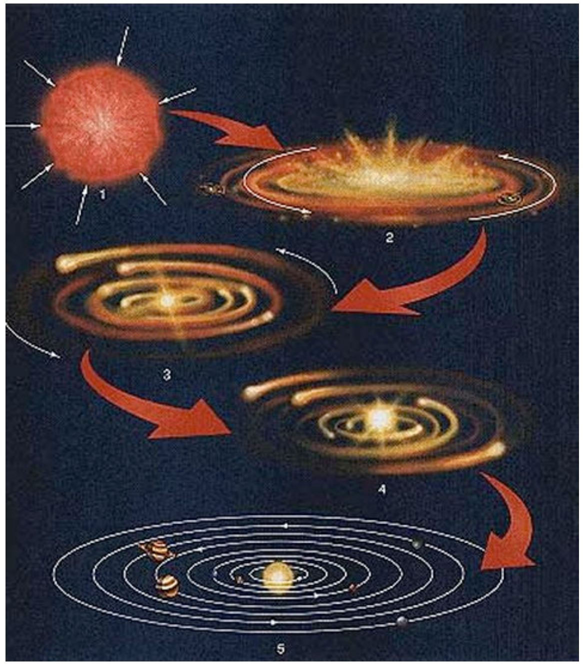


Figure 5: . Cartoon showing the origin of the solar system

(Source: https://puserscontentstorage.blob.core.windows.net/userimages/52dd5b0a-2db6-4a81-bca7-5ee3a4c3c05c/aa8d4f1a-b99d-42ed-8c70-a104ca40ec3eimage6.jpeg)

G. Activity (Optional)

Let's Volt In.

Activity/game based on Active Accretion NASA's Discovery and New Frontiers Program: http://dawn.jpl.nasa.gov/DawnClassrooms/pdfs/ActiveAccretion_Dawn.pdf

Download or print from CD.

Teacher Tip

The activity/game can be very brief but it would entail preparation and a lot of space (ideally and outdoor activity)

ENRICHMENT

Is the Solar System unique or rare? What is the possibility of finding a similar system within the Milky Way Galaxy? What about an Earth like planet?

Teacher tip

- Recent works are reporting presence of a solar system in the other part of the galaxy. Ask students to think about the questions and do some research. This can also be used to transition to the next topic - Earth as habitable planet.
- Criteria for assessment of this task may include:
  - Logical discussion on answering the questions with supporting statements based on scientific concepts.

EVALUATION (10 MINS)

EVALUATION (PEN AND PAPER ASSIGNMENT)				
	1. (NOT VISIBLE)	**2. (NEEDS IMPROVEMENT)**	**3. (MEETS EXPECTATIONS)**	**4. (EXCEEDS EXPECTATIONS)**
Name the different components of the solar system.				
Name the large scale and small scale features of the solar system.				
Discuss the different hypotheses regarding the origin of the solar system and recognizing their weaknesses.				
Discuss the origin and evolution of the solar system based on the most current hypothesis (Proto Planet Hypothesis)				

Earth and Life Science

Earth Systems

90 MINS

Content Standard
The learners demonstrate an understanding of the subsystems (geosphere, hydrosphere, atmosphere, and biosphere) that make up the Earth.

Performance Standard
The learners shall be able to make a concept map and use it to explain how the geosphere, hydrosphere, atmosphere, and biosphere are interconnected.

Learning Competency
The learners explain that the Earth consists of four subsystems, across whose boundaries matter and energy flow **(S11ES-Ib-4).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- define the concept of a system; and
- recognize the Earth as a system composed of subsystems.

LESSON OUTLINE

Introduction	Communicating learning objectives	35
Motivation	Recall the concept of El Niño	5
Instruction	Lecture	30
Practice	Diagram Analysis	20
Enrichment	Essay	
Evaluation	Essay	

Materials
Pencil or any drawing material; A4 or letter size paper; clip board or any flat surface that can be used for drawing

Resources

(1) Carleton College. (n.d.). Earth System Science. Retrieved from http://serc.carleton.edu/Earthlabs/climate/index.html

(2) National Oceanic and Atmospheric Administration. (n.d.). Teaching Activity: The Hydrologic Cycle. Retrieved from http://www.esrl.noaa.gov/gmd/outreach/lesson_plans/The%20Hydrologic%20Cycle.pdf

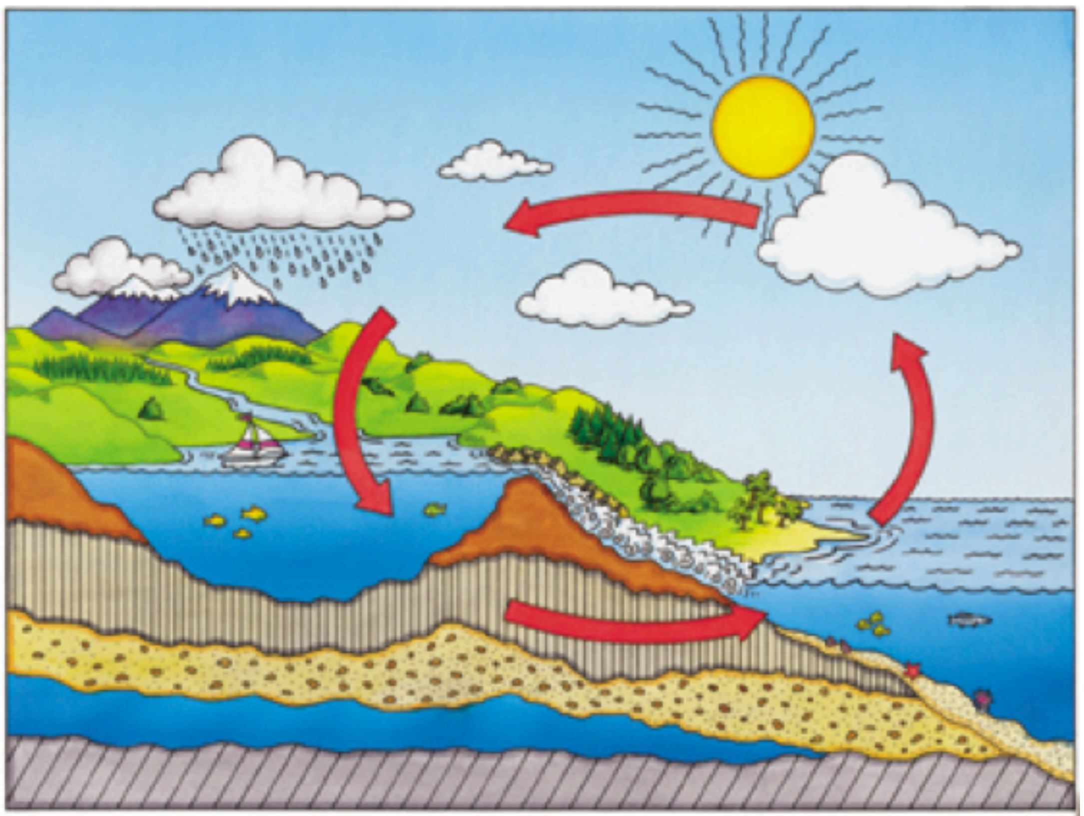
(3) National Oceanic and Atmospheric Administration. (n.d.). The Major Earth Spheres. Retrieved from http://www.esrl.noaa.gov/gmd/outreach/lesson_plans/Teacher%20Background%20Information-%20The%20Major%20Earth%20Spheres.pdf

(4) National Oceanic and Atmospheric Administration. (n.d.). El Niño, La Niña, and ENSO. Retrieved from http://www.esrl.noaa.gov/gmd/obop/mlo/educationcenter/students/brochures%20and%20diagrams/noaa%20publications/El%20Nino%20Fact%20Sheet.pdf

INTRODUCTION (35 MINS)

Communicating learning objectives

1. Perform either one of the following pre-class activities (30 minutes).
   - Option 1 (This option is recommended for schools in a non-urban setting.)
     - Using a pencil and a piece of paper, have the learners draw or illustrate the field area. Take note of the presence of vegetation, soil cover, wildlife, rockout-crops, and bodies of water. Ask the learners to think how energy and mass are transferred in the different components of the area.
   - Option 2 (This option is recommended for schools in an urban setting.)
     - Together with the learners, label the different processes and phases of water involved in the water cycle.



Teacher tip

- Check your immediate surrounding for an appropriate field area, preferably with trees or vegetation, and pond, lake, or stream.
- Before bringing the learners to the field area, check for potential hazards. If applicable, the learners should be properly warned about safety precautionary measures.
- For schools in urban areas without open spaces, choose option 2.

Teacher tip

- The concept of ecosystems has been discussed in pre-SHS biology. Emphasize the definition of the word interaction.
- Most of the terms in this lesson have been introduced in previous science subjects.
- Help the learners integrate the concepts that will be introduced.

Figure 1: Hydrologic Cycle (w/o labels)
Image Source: http://3.bp.blogspot.com/_YTb6ZblJu0o/TPMzp32R5aI/AAAAAAAAALg/vnul9ZgWt0M/s1600/WaterCycleArt.jpg

- Use the following terms to complete the cycle:
  - condensation
  - precipitation
  - evaporation
  - transpiration
  - infiltration
  - surface run-off

2. Introduce the following specific learning objectives:
   - Define the concept of a system.
   - Recognize the Earth as a system composed of subsystems.
3. Ask the learners what they remember about the concept of ecosystems.

MOTIVATION (5 MINS)

1. Ask the learners what they know about or have experienced regarding El Niño.
2. Use the Figure 2, briefly explain the El Niño phenomenon. Emphasize that it starts with the unusual warming of the central Pacific Ocean accompanied by the weakening of the trade winds. The warming of the central Pacific Ocean results to an eastward shift of the low pressure area (away from the Indo Pacific).

Teacher tip

- Most of the answers will describe the atmospheric conditions during El Niño (e.g. hot and dry, no rain, water crisis, etc.)
- Emphasize that El Nino is not limited to atmospheric conditions. It is the result of hydrosphere (ocean)-atmosphere interaction.
- The subsystems of the Earth (atmosphere, hydrosphere, biosphere, and lithosphere) interact with each other.

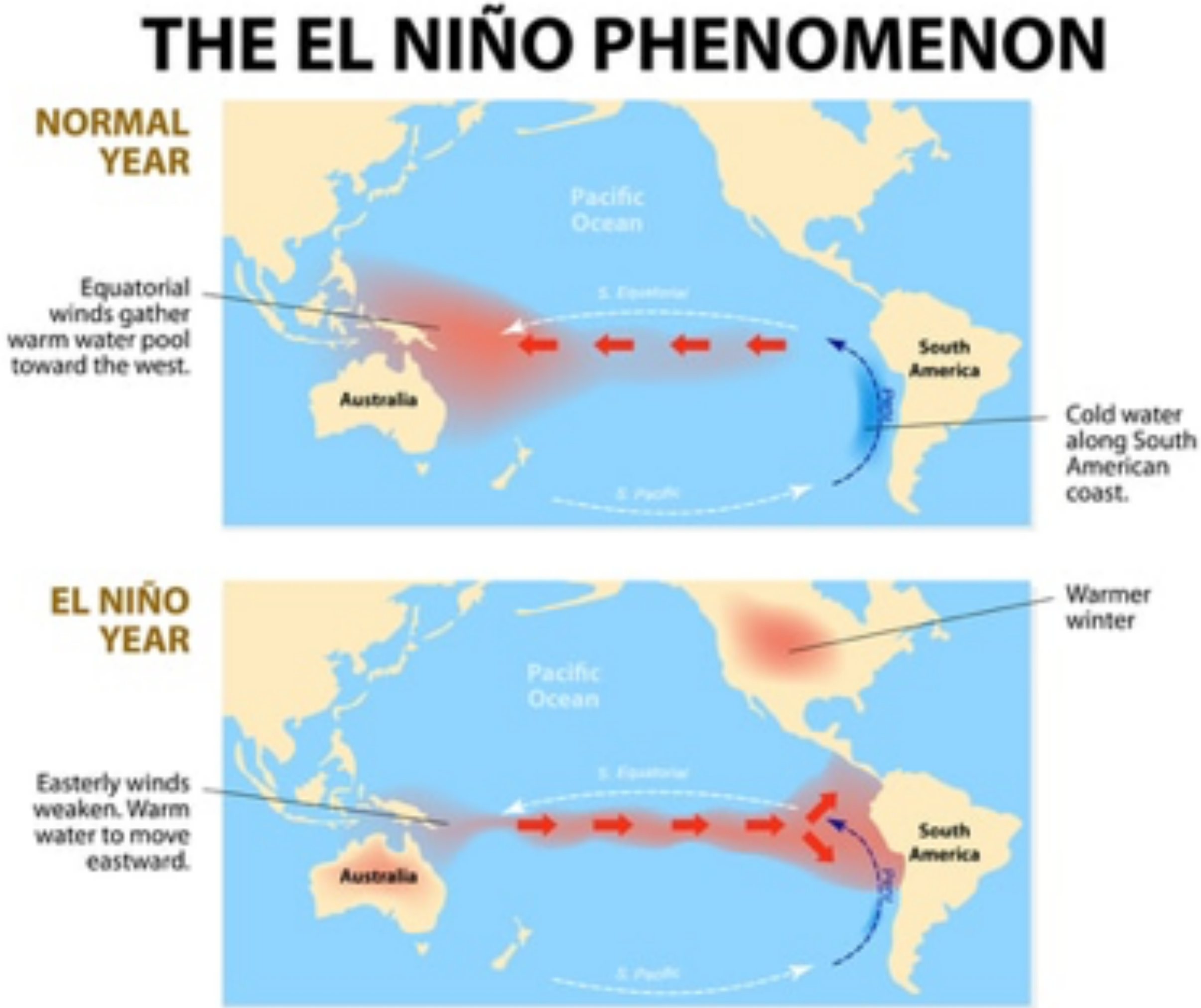


Figure 2. El Niño phenomenon

Source: http://images.listlandcom.netdna-cdn.com/wp-content/uploads/2015/09/The-El-Nino-Phenomenon-explained-in-a-nice-little-graphic.jpg

Teacher tip

- Most of the answers will describe the atmospheric conditions during El Niño (e.g. hot and dry, no rain, water crisis, etc.)
- Emphasize that El Nino is not limited to atmospheric conditions. It is the result of hydrosphere (ocean)-atmosphere interaction.
- The subsystems of the Earth (atmosphere, hydrosphere, biosphere, and lithosphere) interact with each other.

3. Explain the origin of the term '**El Niño**' as a decrease in fish catch off the coast of Peru near Christmas time. Emphasize that this is a biologic response.

INSTRUCTION (30 MINS)

1. Define the term **system** as a set of interconnected components that are interacting to form a unified whole.
2. Present this diagram that enumerates the subsystems of the Earth.

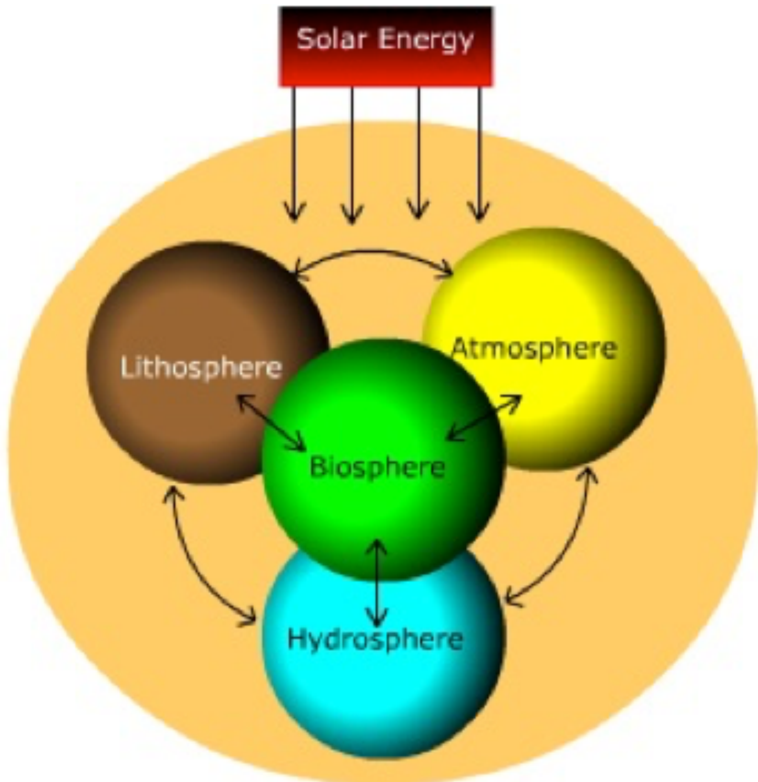


Figure 3: The Earth system.

(Source: https://www.earthonlinemedia.com)

Teacher tip

- Give the government as an example. Inquire about the three branches of the government (executive, judiciary, and legislative). Explain that these three branches are independent and have their respective mandates or functions. A government can only succeed if all three branches are able to perform their respective functions.

- The arrows in the diagram indicate the interaction among the components.

- A closed system is a system in which there is only an exchange of heat or energy and no exchange of matter.

3. Explain that the Earth system is essentially a closed system. It receives energy from the sun and returns some of this energy to space.
4. Introduce the term **atmosphere.**
   - The atmosphere is the thin gaseous layer that envelopes the lithosphere.
   - The present atmosphere is composed of 78% nitrogen (N), 21% oxygen (O2), 0.9% argon, and trace amount of other gases.
   - One of the most important processes by which the heat on the Earth's surface is redistributed is through atmospheric circulation.
   - There is also a constant exchange of heat and moisture between the atmosphere and the hydrosphere through the hydrologic cycle.
5. Introduce the term **lithosphere**.
   - The lithosphere includes the rocks of the crust and mantle, the metallic liquid outer core, and the solid metallic inner core.
   - Briefly discuss the Plate Tectonics as an important process shaping the surface of the Earth. The primary driving mechanism is the Earth's internal heat, such as that in mantle convection.
6. Introduce the term **biosphere**.
   - The biosphere is the set of all life forms on Earth.
   - It covers all ecosystems—from the soil to the rainforest, from mangroves to coral reefs, and from the plankton-rich ocean surface to the deep sea.
   - For the majority of life on Earth, the base of the food chain comprises photosynthetic organisms. During **photosynthesis**, CO_2 is sequestered from the atmosphere, while oxygen is released as a byproduct. The biosphere is a CO_2 sink, and therefore, an important part of the **carbon cycle**.
   - Sunlight is not necessary for life.
7. Introduce the term **hydrosphere**.
   - About 70% of the Earth is covered with liquid water (hydrosphere) and much of it is in the form of ocean water (Figure 3).
   - Only 3% of Earth's water is fresh: two-thirds are in the form of ice, and the remaining one-third is present in streams, lakes, and groundwater.
   - The oceans are important sinks for CO_2 through direct exchange with the atmosphere and

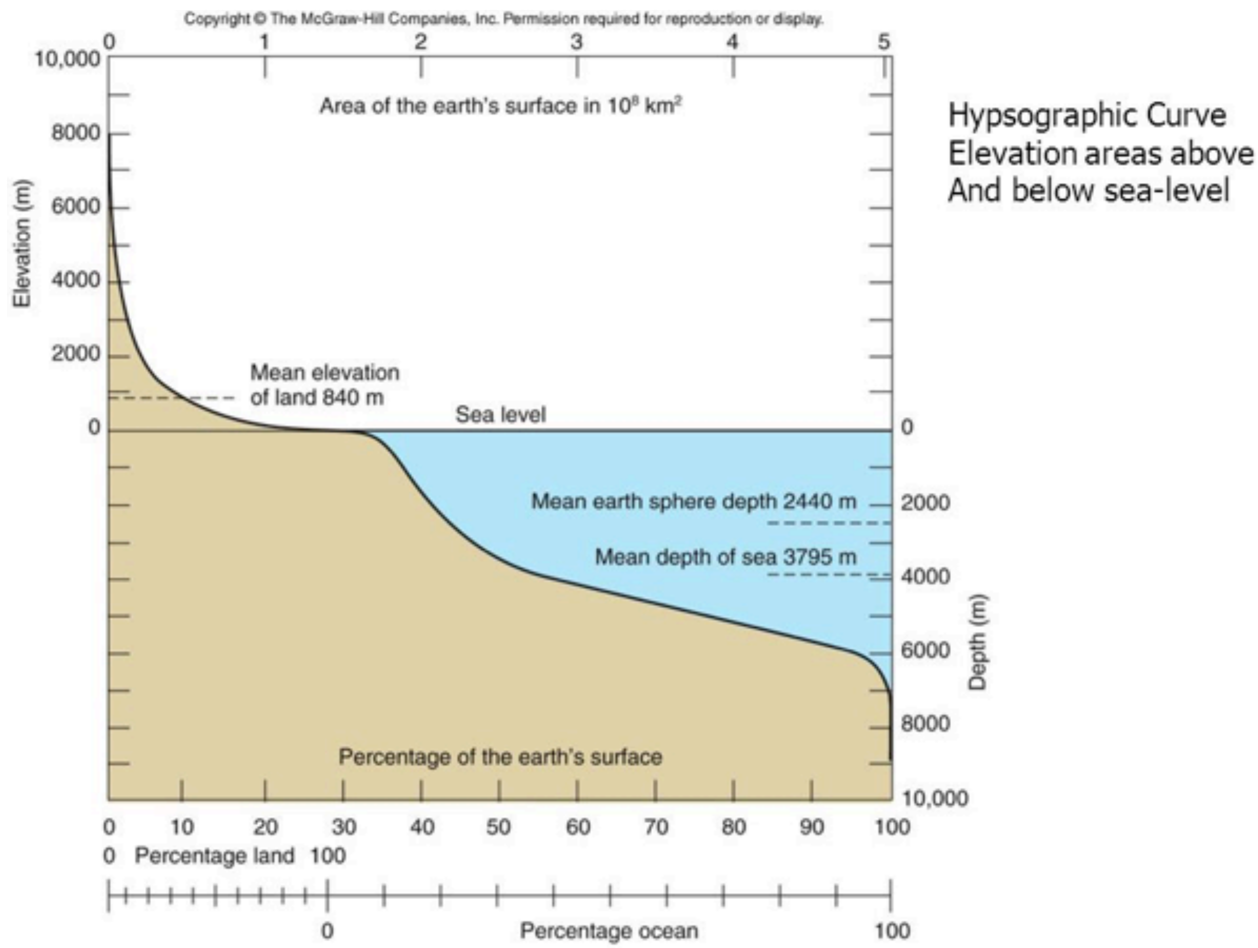
- Describe each subsystem of the Earth.

- Warm air converges and rises to form low-pressure zones. Low-pressure areas are associated with increased precipitation. By contrast, cold air descends to form high-pressure regions (dry regions).

- The concept of Plate Tectonics will be discussed in detail in the succeeding lessons (Internal Structure of the Earth)
- The carbon cycle is the process by which carbon is transferred among the atmosphere, oceans, soil, and living organisms.

- Isolated and complex ecosystems thrive in the deep sea floor at depths beyond the reach of sunlight. The base of the food chain for such ecosystems is called **chemosynthetic** organisms. Instead of sunlight, these organisms use energy from **hydrothermal vents** or **methane seeps** (methane seeping through rocks and sediments) to produce simple sugars.

- indirectly through the weathering of rocks.
- Heat is absorbed and redistributed on the surface of the Earth through ocean circulation.



- The hypsographic curve is a graphical representation of the proportion of land at various elevations (meters above or below sea level)
- Ensure that the learners understand what the X and Y axes represent. To test their comprehension, ask the leaners what proportion of the Earth's surface is about 4000 m below sea level (Answer Key: ~ 60%).
- The hydrologic cycle (water cycle) has been partly discussed in Grade 4 (water in the environment) and Grade 8 (Ecosystems).
- Through the process of weathering and erosion, the hydrologic cycle is another important process contributing to the shaping and reshaping of the surface of the Earth. This is an important link among the hydrosphere, atmosphere, and lithosphere that the learners should be able to identify themselves.

Figure 3: Hypsographic curve

(Source: http://images.slideplayer.com/10/2857469/slides/slide_11.jpg)

PRACTICE (20 MINS)

1. Using either the illustration on Figures 1 or 4, identify how energy and mass is exchanged among the subsystems. Use different types of lines and boxes to differentiate between matter or materials and energy.
2. Use arrows to indicate the interaction among components.

Teacher tip
Use the pre-lecture drawing exercise for schools with open spaces (option 1); else, use the hydrologic cycle diagram

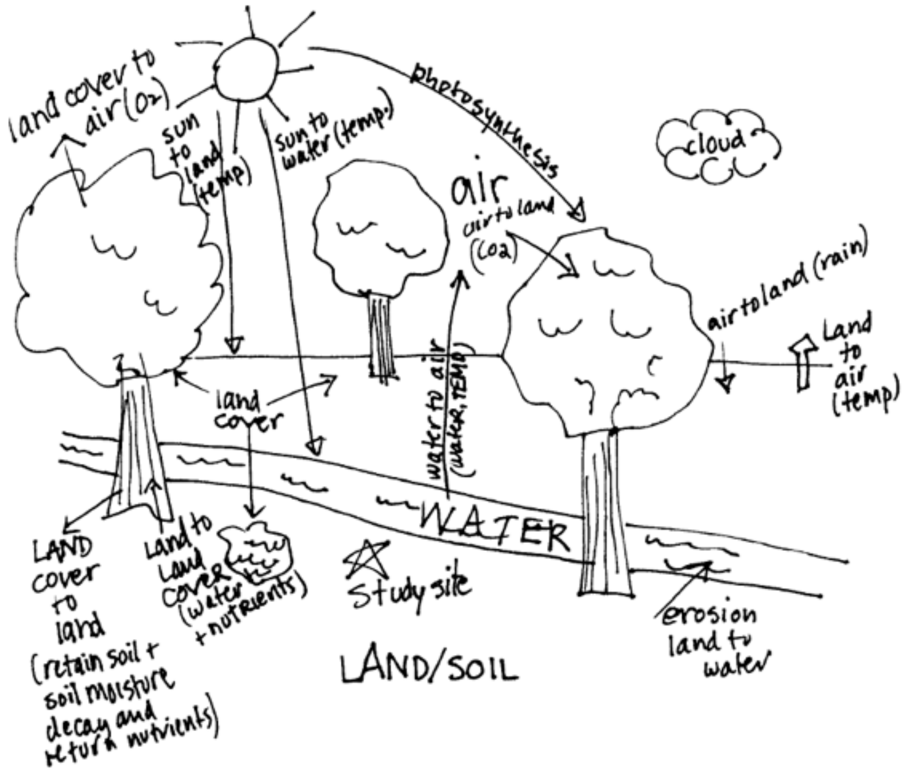


Figure 4: Exchange of energy and mass among subsystem (without labels).

ENRICHMENT

1. The impact of man to the environment has become so massive that scientists are proposing the addition of man or the '**anthroposphere**' to the Earth system.

2. Write an essay not exceeding 200 words on how man has altered the atmosphere, biosphere, hydrosphere, lithosphere, and as a consequence, the Earth System as whole.

Teacher tip

Possible responses may include but are not limited to:

- Changes in land use
- Deforestations lead to erosion, flooding, decrease in CO_2 sequestration (hence increase in greenhouse gases), and loss of habitat (extinction).
- Industrialization and development of technology may lead to pollution and over-hunting (extinction).
- The use of renewable energy sources reduces pollution and greenhouse gases.

EVALUATION

EVALUATION				
	1. (NOT VISIBLE)	**2. (NEEDS IMPROVEMENT)**	**3. (MEETS EXPECTATIONS)**	**4. (EXCEEDS EXPECTATIONS)**
Understands the concept of a system.				
Can describe the different components or subsystems of the Earth System.				
Can identify and explain how mass and energy is exchanged among the components of a system.				
Essay is relevant to the assigned topic and written logically and clearly.				

The Universe and Solar System

60 MINS

Content Standard
The learners demonstrate an understanding of the formation of the universe and the Solar System.

Performance Standard
The learners shall be able to make a concept map and use it to explain how the geosphere, hydrosphere, atmosphere, and biosphere are interconnected.

Learning Competency
The learners describe the characteristics of Earth that are necessary to support life **(S11ES-Ia-b-3)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- recognize the difference in the physical and chemical properties between the Earth and its neighboring planes; and
- identify the factors that allow a planet to support life.

LESSON OUTLINE

Introduction	Communicating learning objectives	10
Motivation	Puzzle	5
Instruction/ Practice	Lecture and Data Interpretation	45
Enrichment	Terraforming Mars (Assignment)	
Evaluation	Data Interpretation	

Materials
Projector; hard copy of figures

Resources

(1) Montana State University. (n.d.). Interstellar Real Estate - Defining the Habitable Zone. Retrieved from https://btc.montana.edu/ceres/html/Habitat/habitablezone.htm

(2) National Aeronautics and Space Administration. (2015). Planetary Fact Sheet. Retrieved from http://nssdc.gsfc.nasa.gov/planetary/factsheet/

(3) National Science Foundation. (n.d.). Crash Landing! Student Activity Sheet. Retrieved from http://www.voyagesthroughtime.org/planetary/sample/lesson5/pdf/5_3_1sas_crashland.pdf

(4) National Science Foundation. (n.d.). Goldilocks and the Three Planets. Retrieved from http://www.voyagesthroughtime.org/planetary/sample/lesson5/pdf/goldilocks.pdf

(5) National Science Foundation. (n.d.). Lesson 5: Activity 3: Habitable Worlds. Retrieved from http://www.voyagesthroughtime.org/planetary/sample/lesson5/z_act3.htm

(6) https://btc.montana.edu/ceres/html/Habitat/habitablezone.htm

(7) http://nssdc.gsfc.nasa.gov/planetary/factsheet/

INTRODUCTION (10 MINS)

Communicating learning objectives

1. Introduce the following specific learning objectives:
    - Recognize the difference in the physical and chemical properties between the Earth and its neighboring planets
    - Identify the factors that allow a planet to support life.
2. Review the previous lessons on the Solar System.
    - Origin
    - Components
    - Terrestrial vs Gas Planets

MOTIVATION (5 MINS)

1. Using the letters provided in Figure 1, ask the learners the four-letter word that describes the following images.

Teacher tip

Teacher can create his or her own 4 Picture 1 Word puzzle. Use images that the learners can easily relate to.

Image source: whats-theword.com

Answer Key: LIFE

Figure 1. Finding the four-letter word that describes the image above

2. The humanity's failure to protect the environment and **life** here on Earth is likely due to the following:
    - Inability to recognize the full consequence of his/her actions
    - Lack of appreciation of how truly unique the Earth is

Teacher tip

The concept of the Earth as a system and the interconnectivity of its components will be discussed in the succeeding lesson.

INSTRUCTION/PRACTICE (40 MINS)

Activity 1: Compare and Contrast the Planets

1. Print and cut-out photographs of three terrestrial planets, namely Venus, Earth, and Mars. Place the photographs side by side.

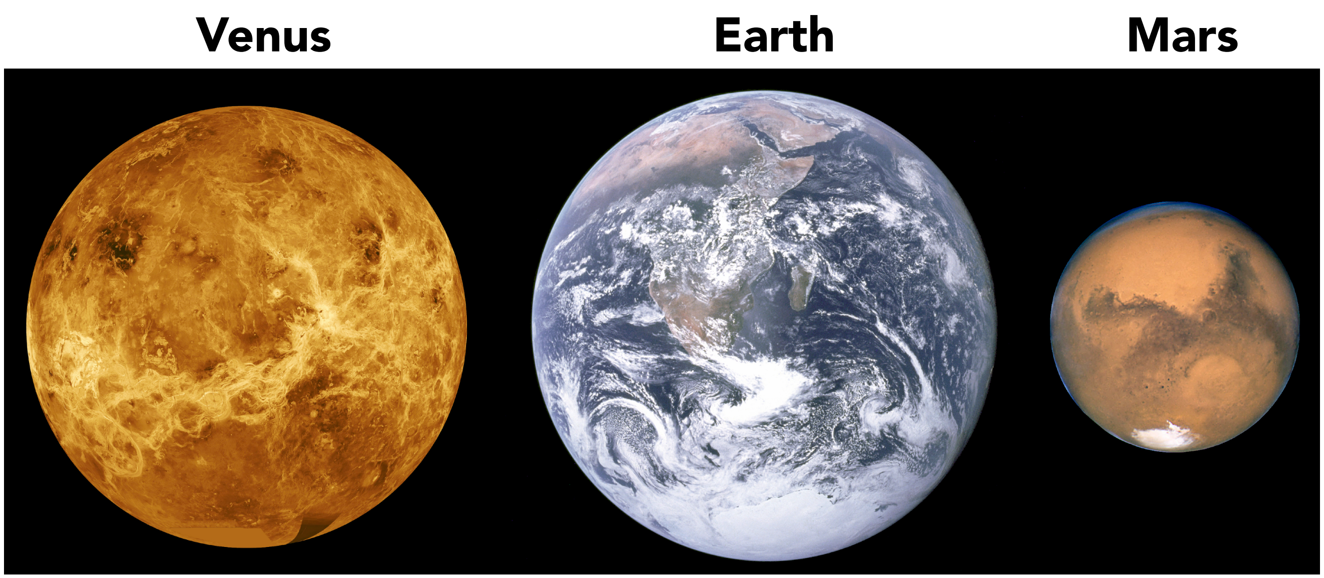


Figure 2: Venus, Earth, and Mars. Images from NASA
https://upload.wikimedia.org/wikipedia/commons/2/25/Terrestrial_planet_sizes.jpg

Teacher tip

- To save time, prepare the materials before the class starts.
- Try to print colored photographs in hard paper so it can be reused several times. Print the photographs in the correct scale.
- Alternatively, the teacher may opt to post on the blackboard the contents of Table 2, instead of giving out copies to the learners.

- Possible responses may include:
    - The blue coloration of the Earth is very apparent due to the presence of water. The size of the planets is also important to note.
    - The size and mass of Venus and Earth are very similar. Mars is about half the Earth's size.
    - The three planets have a spheroidal shape.

-

2. Divide the class into groups of three to five. Give each group a copy of Table 1 for reference. Ask each group to write down on a piece of paper the similarities and differences among the planets. Give the learners 15 minutes to complete the task.

3. Ask the learners to provide possible explanations for their observations using the information in Table 2 and their prior knowledge on the planets.

Table 1: Comparison of the features of Venus, Earth, and Mars

(National Aeronautics and Space Administration, 2015)

	VENUS	EARTH	MARS
Mass (1024kg)	4.87	5.97	0.642
Diameter (km)	12,104	12,756	6792
Density (kg/m3)	5243	5514	3933
Gravity (m/s2)	8.9	9.8	3.7
Escape Velocity (km/s)	10.4	11.2	5
Surface Pressure (bars)	92	1	0.01
Composition of Atmosphere	96% CO_2 3.5% N	77% N 21% O_2 1% Ar	95% CO_2 2.7% N 1.6% Ar
Major Greenhouse Gases (GHG)	CO_2	CO_2 H_2O	CO_2
Mean Temperature (°C)	464	15	-65
Temperature if no greenhouse gases are present	-46	-18	-57
Change in Temperature (°C) due to greenhouse gases	+ 523	+ 33	+ 10
Distance from Sun (106 km)	108.2	149.6	227.9
Orbital Period (days)	224.7	365.2	687
Orbital Velocity (km/s)	35	29.8	24.1
Length of Day (hours)	2802	24	24.7
Global Magnetic Field	No	Yes	No

Teacher tip

- The rows are color coded according to their relationship with respect to each other.
- **Escape velocity** is the minimum speed an object needs to escape a planet's pull of gravity.
- **Surface pressure** is the atmospheric pressure at a location on the surface of the planet. It is proportional to the mass of air above the location.
- **'Temperature if no greenhouse gases are present'** indicates the temperature of the planet without the warming effect of greenhouse gases. Note that the temperature of the Earth would be around 18 °C lower without greenhouse warming.
- Emphasize that the greenhouse effect is not necessarily undesirable. It is run-away greenhouse effect which we would like to avoid (e.g. Venus).

Ask the students what is the consequence if greenhouse gases are not present

- **Length of day** is a function of rotational speed.
- The ability of a planet to retain its **internal heat** is proportional to its **size**. Mars may have lost much of its internal heat very early in its evolution.
- A planet's **temperature** is a function of its distance from the Sun. However, this factor can be modified by the intensity of greenhouse warming.
- **Water** in liquid form is one of the most important prerequisites for life. There is recent evidence that liquid water, in the form of brine (salty water) flows intermittently on the surface of Mars.

4. After the task, ask a representative from each group to present their observations.
    - Venus, Earth, and Mars are part of the inner terrestrial or "rocky" planets. Their composition and densities are not too different from each other.
    - Venus is considered to be the Earth's twin planet. It has a very similar size and mass with the Earth. Mars is about half the Earth's size.
    - Orbital period and velocity are related to the planet's distance from the sun. Among the three planet, Venus is the nearest and Mars is the farthest from the Sun.
    - Rotational speed of Earth and Mars are very similar. Rotational speed of Venus is extremely slow.
    - Abundance of liquid water on Earth, hence the blue color. The Earth is a habitable planet.

Activity 2: Interstellar Crash Landing (National Science Foundation, n.d.,)
(http://www.voyagesthroughtime.org/planetary/sample/lesson5/pdf/5_3_1sas_crashland.pdf)

1. Ask students what factors would a planet habitable. Learners should try to elaborate on their responses.

2. Provide a copy of Table 2 - "Factors that Make a Planet Habitable" to each of the group (can be the same grouping as Activity 1). Ask students to read the document carefully and compare their answers they have given at the start of the activity

Table 2: Factors that make a planet habitable (National Science Foundation, n.d.,)
http://www.lpi.usra.edu/education/explore/our_place/hab_ref_table.pdf

- **Water** - in the liquid form, turns out to be one of the most important prerequisites for life as we know it.

- *There is recent evidence that liquid water, in the form of brine (salty water) flows intermittently on the surface of Mars.*

- **thermophiles** - bacteria that can tolerate extreme temperatures (41 to 122 ^{0}C) commonly associated with hot springs and deep-sea hydrothermal vents. Life, in general can tolerate a wide range of temperature conditions. The temperature range that allows water to exist in the liquid state is the over-riding factor.
- planets should have **sufficient size** to hold a **significant atmosphere**. The composition of the atmosphere, specifically the amount of **green house gases**, influences the planet **surface temperature**.
- the amount of **solar radiation** that a planet receives is primarily a function of distance from the sun. **Sunlight** is essential for **photosynthesis** but some organism are able to extract energy from other sources (**chemosynthetic organisms**).
- a system that will be able to constantly supply nutrients to organisms is important to sustain life. On Earth, nutrients are cycled through the hydrologic cycle and plate tectonics (volcanism)
- Internal heat drives plate tectonics. The ability of a planet to maintain internal heat is related to size.

Factors that make a Planet Habitable	Not Enough of the Factor	Just Right	Too Much of the Factor	Situation in the Solar System
Temperature influences how quickly atoms and molecules move.	Low temperatures cause chemicals to react slowly, which interferes with the reactions necessary for life. It can also cause the freezing of water, making liquid water unavailable.	Life seems to be limited to a temperature range of -15ºC to 115ºC. In this range, liquid water can still exist under certain conditions.	At about 125ºC, protein and carbohydrate molecules, and the genetic material (e.g., DNA and RNA) start to break apart. Also, high temperatures cause the quick evaporation of water.	Surface: only the Earth's surface is in this temperature range. Sub-surface: the interior of the solid planets and moons may be in this temperature range.
Atmosphere	Small planets and moons have insufficient gravity to hold an atmosphere. The gas molecules escape to space, leaving the planet or moon without an insulating blanket or a protective shield.	Earth & Venus are the right size to hold a sufficient-sized atmosphere. Earth's atmosphere is about 100 miles thick. It keeps the surface warm & protects it from radiation & small- to medium-sized meteorites.	Venus's atmosphere is 100 times thicker than Earth's. It is made almost entirely of greenhouse gasses, making the surface too hot for life. The four giant planets are completely made of gas.	Of the solid planets & moons, only Earth, Venus, & Titan have significant atmospheres. Mars' atmosphere is about 1/100th that of Earth's, too small for significant insulation or shielding.

The document/table can be downloaded from http://www.lpi.usra.edu/education/explore/our_place/hab_ref_table.pdf or from the accompanying CD.

Energy	When there is too little sunlight or too few of the chemicals that provide energy to cells, such as iron or sulfur, organisms die.	With a steady input of either light or chemical energy, cells can run the chemical reactions necessary for life.	Light energy is a problem if it makes a planet too hot or if there are too many harmful rays, such as ultraviolet. Too many energy-rich chemicals is not a problem	Surface: The inner planets get too much sunlight for life. The outer planets get too little. Sub-surface: Most solid planets & moons have energy-rich chemicals.
Nutrients Used to build and maintain an organism's body.	Without chemicals to makeproteins & carbohydrates, organisms cannot grow. Planets without systems to deliver nutrients to its organisms (e.g., a water cycle or volcanic activity) cannot support life. Also, when nutrients are spread so thin that they are hard to obtain, such as on a gas planet, life cannot exist.	All solid planets & moons have the same general chemical makeup, so nutrients are present. Those with a water cycle or volcanic activity can transport and replenish the chemicals required by living organisms.	Too many nutrients are not a problem. However, too active a circulation system, such as the constant volcanism on Jupiter's moon, Io, or the churning atmospheres of the gas planets, interferes with an organism's ability to get enough nutrients.	Surface: Earth has a water cycle, an atmosphere, and volcanoes to circulate nutrients. Venus, Titan, Io, and Mars have nutrients and ways to circulate them to organisms. Sub-surface: Any planet or moon with sub-surface water or molten rock can circulate and replenish nutrients for organisms

3. Ask the students to imagine themselves in an interstellar voyage. Their spaceship suffers mechanical problems and will be forced to land. Fortunately they are passing through the Yanib System , which is composed of a sun-like star surrounded by seven planets, some of which have moons . The profiles of planets and moons of the Yanib System are listed on Table 3 (Provide each group a copy of Table 3). Students are to decide the best place to land their ship.
4. Ask students to write down on a piece of paper their choice of planet or moon . Reasons for their choice should also be written down. Reasons why they did not choose the other planets should also be included.

Table 3 Profiles of Planets and Moons of Yanib System. Modified from**:** http://www.voyagesthroughtime.org/planetary/sample/lesson5/pdf/5_3_1sas_crashland.pdf

Planet 1 (closet to the star) Mass: 1.5 (Earth = 1) Tectonics: Active volcanoes and seismic activity detected Atmosphere: CO_2, N, and H_20 Ave. Temperature: 651°C Description: Thick clouds surround the planet. No surface is visible through the clouds.	**Planet 4** Mass: 1.5 Tectonics: Active volcanoes and seismic activity detected Atmosphere: N, O_2, and ozone layer Average Temperature: 2°C Description: Cold oceans, covered with ice along much of the globe, some open water around equator
Planet 2 Mass: 0.5 Tectonics: No activity detected Atmosphere: Thin CO_2 atmosphere detected Average Temperature: 10°C Description: Polar ice caps, dry riverbeds	**Planet 5** Gas Giant with one large moon. Moon: Sulfur dioxide (SO_2) atmosphere. Many volcanoes and hot springs on surface. Temperatures in hot spots can be up to 600°C. Other spots away from volcanic heat can get as low in temperature as 145°C.

Planet 3 Mass: 1 Tectonics: Active volcanoes and seismic activity detected. Atmosphere: CO_2, H_2O Temperature: 30 ^{O}C Description: Liquid water oceans cover much of the surface. Volcanic island chains make up most of the dry land.	**Planet 6** Gas giant with four large, rocky satellites (moons). Moons have no appreciable atmosphere. Ice detectable on one.
	Planet 7 (furthest from the star) Gas giant with two large moons. **Moon 1**: Thick methane atmosphere with pressure high enough to keep a potential methane ocean liquid underneath. Temperature: -200 ^{o}C **Moon 2**: Covered in water ice. Ice appears cracked and re-frozen in parts, indicating a potential liquid ocean underneath. Surface temperature -100 ^{o}C.

Teacher Tip

You may also require the learners to include a sketch/diagram of how they think their habitable planet/moon would look like based on the factors for habitable planet/moon.

ENRICHMENT

Terraforming Mars

Have the learners write a 200 word report/essay on the following topic: 'Can man alter Mars environment to make it more suitable for human habitation? How?'

Teacher tip

- To **terraform** means to transform another planet to resemble the Earth in several aspects, specifically the ability to support life.
- Use the following criteria in assessing this assignment:
  - Logic and consistency in the arguments
  - Valid and consistent scientific concepts to support the answer

EVALUATION

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Identify similarities and differences among the three planets, namely Venus, Earth, and Mars.				
Explain the impact of planet size to gravity, internal heat, and atmosphere of the planet.				
Identify factors that influence a planet's temperature.				
Explain factors that make a planet habitable.				
Explain why the presence of liquid water is important to life				

Earth Science

Minerals and Rocks

60 MINS

Content Standard
The learners demonstrate an understanding of the three main categories of rocks.

Performance Standard
The learners shall be able to make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competency
The learners will be able to identify common rock-forming minerals using their physical and chemical properties **(S11ES-Ib-5).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- demonstrate understanding about physical and chemical properties of minerals and will be able to identify certain minerals using specific tests;
- identify some common rock-forming minerals; and
- classify minerals based on chemical affinity.

LESSON OUTLINE

Introduction	Communicating learning objectives	3
Motivation	Mineral Identification Video	10
Instruction	Lecture	27
Practice	Mineral Identification	20
Enrichment	Assignment	
Evaluation	Summary Questions	

Materials
Mineral Decision Tree; Mineral Identification Charts; manila paper; markers; media player; internet connection (optional)

Resources

(1) Identifying Minerals by Michael Sammartano https://www.youtube.com/watch?v=32NG9aeZ7_c (8/29/2015).

(2) Laboratory Manual for Physical Geology – Mineral Identification https://gln.dcccd.edu/Geology_Demo/content/LAB03/LAB_Man_03.pdf (8/29/2015).

(3) The Mineral Identification Key http://www.minsocam.org/msa/collectors_corner/id/mineral_id_keyq1.htm (8/29/2015).

(4) Calcite Cleavage by Steven Newton https://www.youtube.com/watch?v=bYiT2qgD8zQ&feature=youtu.be (8/30/2015).

INTRODUCTION (3 MINS)

Communicating learning objectives

1. Introduce the following learning objectives using the suggested protocols (Verbatim, Own Words, Read-aloud)
    a. I can describe how much minerals are part of our daily lives
    b. I can describe minerals as a life-long hobby (gemstone collectors)
    c. I can describe the importance and use of minerals to human development
    d. I can develop a systematic way of identifying minerals

Understanding key concepts

2. Define what a mineral is. Give emphasis to the five requirements for a material to be considered a mineral (i.e. naturally occurring is not man-made or machine-generated, inorganic is not a by-product of living things, etc.).

Review

3. Ask the learners: Do you consider water a mineral? How about snowflake or tube ice?

Teacher tip

- Cite examples of mineral use in our daily lives:
    1. halite (salt) for cooking
    2. graphite (pencil) for writing
    3. diamond and gold as jewelry
- Mineral - naturally occurring, inorganic solid with orderly crystalline structure and a definite chemical composition. These are the basic building blocks of rocks.
- Water is not a mineral since it is not solid and crystalline. Tube ice is not because it is not naturally occurring. Snow flake meets all requirements in defining a mineral.

MOTIVATION (10 MINS)

Options: video (for lectures), power point slides (pictures), specimens (if available)

Show a video on minerals (general) with discussions on the different chemical and physical properties of minerals. This will guide the students on how to identify minerals. Tell the students that the video will only be played once and that they need to take notes for discussion. (8:33 minutes)

Teacher tip

- Make sure that the learners are ready to watch before playing the video.
- With no available specimen or tangible sample to describe, the teacher can use a video.

INSTRUCTION (27 MINS)

A. Mineral Properties

Ask the students to identify the different mineral properties described in the video. Encourage class participation by specifically using table salt or halite in demonstrating these properties. Tabulate the answers on the board.

Mineral Name	**HALITE (TABLE SALT)**
Chemical Composition	NaCl
Luster	non-metallic – vitreous; transparent to translucent
Hardness	soft (2-2.5)
Color	white
Streak	white
Crystal Form / Habit	cubic
Cleavage	perfect cubic
Specific Gravity	light (2.2)
Other Properties	salty taste; very soluble; produces reddish spark in flame

Teacher to discuss the different mineral properties.

1. Luster – it is the quality and intensity of reflected light exhibited by the mineral
   a. Metallic – generally opaque and exhibit a resplendent shine similar to a polished metal
   b. Non-metallic – vitreous (glassy), adamantine (brilliant/diamond-like), resinous, silky, pearly, dull (earthy), greasy, etc.

2. Hardness – it is a measure of the resistance of a mineral (not specifically surface) to abrasion.

Teacher tip

- Give the government as an example. Inquire about the three branches of the government (executive, judiciary, and legislative). Explain that these three branches are independent and have their respective mandates or functions. A government can only succeed if all three branches are able to perform their respective functions.

- The arrows in the diagram indicate the interaction among the components.

Teacher tip

- Explore with the students a systematic way of identifying minerals.

a. Introduce students to the use of a hardness scale designed by German geologist/mineralogist Friedrich Mohs in 1812 (Mohs Scale of Hardness). The test compares the resistance of a mineral relative to the 10 reference minerals with known hardness. It is simply determining the hardness of a mineral by scratching them with common objects of known hardness (e.g. copper coin -3.0-3.5).

Moh's scale of Hardness

RATING	DESCRIPTION	MINERAL EXAMPLE
1: VERY SOFT	EASILY CRUMBLES. CAN BE SCRATCHED WITH A FINGERNAIL (2.2)	TALC
2: SOFT	CAN BE SCRATCHED WITH A FINGERNAIL (2.2)	GYPUSM
3: SOFT	CAN BE SCRATCHED WITH A COPPER PENNY (3.5)	CALCITE
4: SEMI-HARD	CAN BE SCRATCHED WITH A NAIL (5.2)	FLUORITE
5: HARD	CAN BE SCRATCHED WITH A NAIL (5.2)	APATITE
6: HARD	MINERAL WITH HARDNESS OF 6 OR MORE CAN SCRATCH GLASS	FELDSPAR
7: VERY HARD	CAN BE SCRATCHED WITH A COCRETE NAIL (7.5)	QUARTZ
8: VERY HARD		TOPAZ
9: EXTREMELY HARD	USED IN INDUSTRIAL TOOLS FOR CUTTING AND GRINDING	CORUNDUM
10: THE HARDEST	DIAMOND IS USED TO CUT ALL MINERALS	DIAMOND

Source: http://www.instructables.com/id/How-to-identify-a-Mineral/step3/Hardness/ (8/30/2015)

- Explore with the students a systematic way of identifying minerals.
- It is recommended that the mineral properties be discussed in the correct sequence :
  1 and 2 (in any order): Luster, Hardness
  3: Color and Streak
  4. Crystal Form/ Habit
  5. Cleavage
  6. Fracture
  7. Specific Gravity
  8. Other Properties
- Common everyday objects that can be used for hardness test

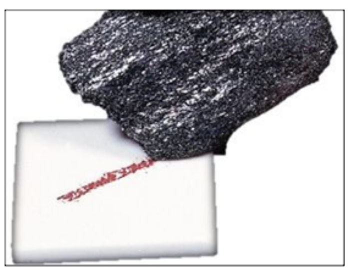
Object	Hardness
Fingernail	2 – 2.5
Copper coin/wire	3-3.5
Nail	5-5.5
Glass	5.5
Steel knife	6.5 - 7

b. What are the pros and cons in using the Mohs scale of hardness?

PROS	**CONS**
Easy to do the test	The scale is qualitative and not quantitative
Can be done anywhere, anytime as long as the place is not dark	Cannot be used to test accurate hardness of industrial materials
Mohs scale is highly relevant for field geologists to roughly identify minerals using scratch kits	
Can be done without or few kits – handy	

3. Color and streak – Color maybe a unique identifying property of certain minerals (e.g. malachite – green, azurite – blue). There are also lots of minerals that share similar or the same color/s. In addition, some minerals can exhibit a range of colors. The mineral quartz for example, can be pink (rose quartz), purple (amethyst), orange (citrine), white (colorless quartz) etc. **Streak** on the other hand is the color of a mineral in powdered form. Note that the color of a mineral could be different from the streak. For example, pyrite (FeS_2) exhibits golden color (hence the other term of pyrite which is Fool's Gold) but has a black or dark gray streak. Streak is a better diagnostic property as compared to color. Streak is inherent to almost every mineral. Color maybe unreliable for identification as impurities within the minerals may give the minerals a different color.

- The different colors and varieties of Quartz is the result of impurities within the crystal structure. The color of some minerals can also be modified by weathering.



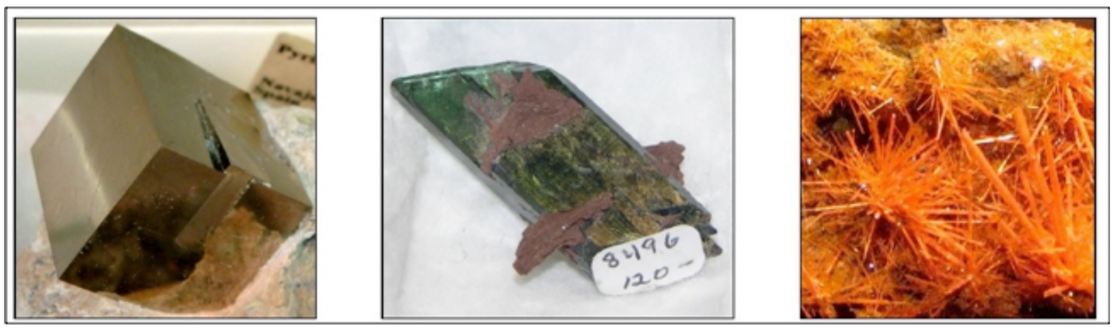
Color vs streak of a hematite (Fe_2O_3). Source: http://www.instructables.com/id/How-to-identify-a-Mineral/step6/Streak/ (8/30/2015)

4. Crystal Form/Habit –The external shape of a crystal or groups of crystals is displayed / observed as these crystals grow in open spaces. The form reflects the supposedly internal structure (of atoms and ions) of the crystal (mineral). It is the natural shape of the mineral before the development of any cleavage or fracture. Examples include prismatic, tabular, bladed, platy, reniform and equant. A mineral that do not have a crystal structure is described as amorphous.

Teacher tip
Use Figure 4 for schools with open spaces. Otherwise, use Figure 1.

The crystal form also define the relative growth of the crystal in 3 dimension which are its length, width and height

Activity: Show the pictures to the learners and try to identify the crystal forms / habits. Provide more pictures if needed.



Crystal form / habit. Source: http://www.slideshare.net/davidprestidge/earth-lecture-slide-chapter-five page 46 of 74 (8/30/2015)

Answer: Left picture: blocky/cubic or equant (it has equal growth rate in three dimensions). Middle picture: bladed habit (it resembles a blade, with varied growth rates in 3 dimensions). Right picture: needle-like habit (rapid growth of crystals in one dimension while slow in other dimensions).

5. Cleavage – It is the property of some minerals to break along parallel repetitive planes of weakness to form smooth, flat surfaces. These planes of weakness are inherent in the bonding of atoms that makes up the mineral. These planes of weakness are parallel to the atomic planes and appear to be repeating within the mineral. When minerals break evenly in more than one direction, cleavage is described by the number of cleavage directions and the angle(s) between planes (e.g. cleavage in 2 directions at 90 degrees to each other).



Mineral cleavage. Left photo shows one cleavage direction (biotite). Middle photo has cleavage in 2 directions at 90° (orthoclase). Right photo has 3 cleavage directions at 74° (calcite). Source: https://commons.wikimedia.org License: Creative commons (attribution: Rob Lavinsky, iRocks.com – CC-BY-SA-3.0)

Show a video of a calcite crystal being hit with a hammer (https://www.youtube.com/watch?v=bYiT2qgD8zQ&feature=youtu.be).

Note how the crystal breaks into smaller pieces and still manifest the same rhombic shape. Where the crystal breaks (the flat surfaces) are called cleavage planes. For the calcite crystal, there are three cleavage planes at 120 and 60 degrees.

It is important to clearly differentiate a crystal habit from cleavage. Although both are dictated by crystal structure, crystal habit forms as the mineral is growing, therefore relies on how the individual atoms in the crystal come together. Cleavage on the other hand is the weak plane that developed after the crystal is formed.

6. Fracture – Some minerals may not have cleavages but exhibit broken surfaces that are irregular and non-planar. Quartz for example has an inherent weakness in the crystal structure that is not planar. Examples of fracture are conchoidal, fibrous, hackly, and uneven among others.

7. Specific Gravity – It is the ratio of the weight of a mineral to the weight of an equal volume of water. A bucket of silver (SG 10) would weigh 10 times more than a bucket of water (SG 1). It is a measure to express the density (mass per unit volume) of a mineral. The specific gravity of a mineral is numerically equal to density.

8. Others – There are certain unique properties of minerals that actually help in their identification (e.g. magnetism, odor, taste, tenacity, reaction to acid, etc.). Magnetite is strongly magnetic; sulfur has distinctive smell; halite is salty; calcite fizzes with acid as with dolomite but in powdered form.

B. Mineral Groups

In a manner of exploring and discovering systematic ways of identifying minerals, the teacher can ask the students if they can think of a way to group minerals together.

The teacher can now proceed synthesizing the suggested "systematic ways" by the students.

A more stable and less ambiguous basis for classification of minerals is by chemical composition.

Element	Element + SiO_4	Element + O_2	Element + SO_4	Element + S_2	Element + CO_3	Element + Halogens
Native	Silicate	Oxide	Sulfate	Sulfide	Carbonate	Halide
Gold	Quartz	Hematite	Gypsum	Pyrite	Calcite	Chlorine
Bismuth	Olivine	Magnetite	Barite	Galena	Dolomite	Fluorine
Diamond	Talc	Chromite	Anhydrite	Bornite	Malachite	Halite

Teacher tip

The most likely response would be on the grouping basis of physical properties. Although physical properties are useful for mineral identification, some minerals however may exhibit wider range of properties to include chemical compositions.

1. Silicates – minerals containing 2 of the most abundant elements in the Earth's crust, namely, silicon and oxygen. When linked together, these two elements form the silicon oxygen tetrahedron - the fundamental building block of silicate minerals. Over 90% of the rock-forming minerals belong to this group. Aside from Si (46.6 % by wt.) and O (27.7%), the other most common elements that make the earth's crust are Al (8.1), Fe (5.0), Ca (3.6), Mg (3.1), Na (2.8) and K 2.6).
2. Oxides – minerals containing Oxygen anion (O_2^-) combined with one or more metal ions
3. Sulfates – minerals containing Sulfur and Oxygen anion $(SO_4)^-$ combined with other ions
4. Sulfides – minerals containing sulfur anion $(S_2)^-$ combined with one or more ions. Some sulfides are sources of economically important metals such as copper, lead and zinc.
5. Carbonates – minerals containing the carbonate anion $(CO_3)^{2-}$ combined with other elements
6. Native Elements – minerals that form as individual elementsa.
    a. Metals and Inter-metals – minerals with high thermal and electrical conductivity, typically with metallic luster, low hardness (gold, lead)b.
    b. Semi-metals – minerals that are more fragile than metals and have lower conductivity (arsenic, bismuth)c.
    c. Nonmetals – nonconductive (sulfur, diamond)
7. Halides – minerals containing halogen elements combined with one or more elements

The teacher to provide a list of the common rock-forming minerals containing NAME and CHEMICAL COMPOSITION ONLY.

PRACTICE (20 MINS)

Activity 1. For the whole class, try to identify 5 minerals by testing their properties using the mineral identification charts provided by Mineralogical Society of America (http://www.minsocam.org/msa/collectors_corner/id/mineral_id_keyq1.htm). Click on "Yes" or "No" to questions regarding Luster, Hardness and Streak (The "program" narrows down the options by the process of elimination). The program will direct you to the correct part of the mineral chart if the correct answers are supplied.

Teacher tip

- Compounds formed with the silicate ions and the other common elements are called silicates which are associated to be common rock forming minerals
- The other mineral properties are not to be provided because these will be used in the Practice portion.
- The first activity can only be done with an internet connection. If time permits and if the learners enjoy the activity, the teacher can continue with the activity using some other minerals. Otherwise, proceed to the next activity. If there is no internet connection, then only the second activity can be done

Activity 2. Group the students into 3-4 teams. The teacher to print and provide each team a copy of the Mineral Decision Tree and Mineral Identification Charts (https://gln.dcccd.edu/Geology_Demo/content/LAB03/LAB_Man_03.pdf). Based on the discussed topics and examples, select ten (10) different rock-forming minerals (known or unknown to students) and determine the different properties that can be used to identify them. Write the data in a Manila paper using markers. Include which chemical family group these minerals belong. The team will then select a leader to present their output to the class.

ENRICHMENT

Homework to be submitted on next meeting. Think of 5 minerals and their common uses and identify the specific property/properties that made them for that purpose (e.g. graphite, having a black streak and hardness of 1-2, is used in pencils due to its ability to leave marks on paper and other objects).

EVALUATION

A. Summary questions related to the lesson (Questions in bold font are difficult questions):

1. What are the characteristics that define a mineral?

   Answer: inorganic, naturally occurring, crystalline, solid and must have a consistent chemical composition
2. Which among the following mineral groups, if any, contain silicon: halides, carbonates or sulfides? Explain.

   Answer: None. The identified mineral groups are non-silicates
3. Which is more abundant in the Earth’s crust: silicates or all the other mineral groups combined?

   Explain.

   Answer: Silicates. Silicon and oxygen are the main components of silicates and these are the two most abundant elements in the Earth’s crust.

4. An unknown opaque mineral has a black streak and has a density of 18g/cm3. Is the mineral metallic or non-metallic?

   Answer: The mineral is more likely to be metallic because it is opaque and metallic minerals are usually heavy and with dark streaks

5. **What is the difference between a mineral's streak and color? Why is streak more reliable for rock identification?**

   Answer: Streak is the color of a mineral in powdered form. It is more reliable because it is inherent to most minerals. Color is not reliable because mineral can be formed with varieties of color, an effect of impurities and weathering.

6. **Differentiate habit and a cleavage plane.**

   Answer: Habit is the external shape of a crystal that is developed during the formation of the mineral. Cleavage plane is a plane of weakness that maybe formed in a crystal after the crystal formation.

7. **Is it possible for a mineral to have a prismatic habit without having any cleavage? Why or why not? If yes, give an example.**

   Answer: Yes, the prismatic habit is simultaneously developed while the mineral is growing. During the process, there is no repetitive plane of weakness being created which makes the mineral break only by fracturing. An example of this scenario is quartz.

B. Practice identifying minerals if samples are available (optional).

	1. (NOT VISIBLE)	**2. (NEEDS IMPROVEMENT)**	**3. (MEETS EXPECTATIONS)**	**4. (EXCEEDS EXPECTATIONS)**
A. Summary Questions	Correctly answered ≤2 easy questions	Correctly answered all easy questions	Correctly answered all easy questions and one difficult question	Correctly answered all questions
B. Mineral Identification (optional)	Cannot identify any mineral	Can identify 1 or 2 minerals	Can identify 3-5 minerals	Can identify more than 5 minerals

Earth Science

120 MINS

Minerals and Rocks

Content Standards
The learners demonstrate an understanding of

1. the three main categories of rocks, and
2. the origin and environment of formation of common minerals and rocks

Performance Standard
The learners shall be able to make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competency
The learners will be able to classify rocks into igneous, sedimentary and metamorphic **(S11ES-Ic-6).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- identify and describe the three basic rock types;
- establish relationships between rock types and their mode of origin and environments of deposition/formation; and
- understand the different geologic processes involved in rock formation.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Mineral Identification Video	15
Instruction	Lecture	60
Practice	Mineral Identification	40
Enrichment	Assignment	
Evaluation	Summary Questions	

Materials
Manila paper; marker pen; media player; laptop/computer; projector; Internet connection

Resources

(1) 3 Types of Rocks by Smart Learning for All (Accessed 09/20/2015) https://www.youtube.com/watch?v=17l2LrjZi9o

(2) The Rock Cycle by Kelly Dunham (Accessed 09/20/2015) https://www.youtube.com/watch?v=9lyCYXXIHT0

(3) The Rock Cycle by Annennberg Learner (Accessed 09/18/2015) http://www.learner.org/interactives/rockcycle/diagram.html, http://www.learner.org/interactives/rockcycle/diagram2.html, http://www.learner.org/interactives/rockcycle/testskills.html

(4) Mr. Mulroy's Earth Science: How do We Idendity Sedimentary Rocks? (Accessed 09/22/2015) http://peter-mulroy.squarespace.com/how-do-we-idendity-sedimentary-rocks/

(5) Tarbuck, Lutgens, and Tasa. Earth An Introduction to Physical Geology 11thed, 2014

Additional Resources at the end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objectives

1. Introduce the following learning objectives using the suggested protocols (Verbatim, Own Words, Read-aloud)
   a. I can identify and describe the three basic rock types;
   b. I can describe how and define what type of environment each of these rock types are formed;
   c. I can describe how rocks are transformed from one rock type to another through the rock cycle;
   d. I can identify and describe the different geologic processes that operate within the rock cycle.

Understanding key concepts

The Rock Cycle provides us a comprehensive understanding how the 3 dominant rock types are formed. Based on their physical and chemical properties, what could be the possible conditions of formation for each rock type?

Review

- The teacher discusses in review of minerals the 8 elements comprising almost 99% of the minerals making up the Earth's crust.

Element	Symbol	% by wt. of the Earth's crust	% atoms
Oxygen	O	46.6	62.6
Silicon	Si	27.7	21.2
Aluminum	Al	8.1	6.5
Iron	Fe	5.0	1.9
Calcium	Ca	3.6	1.9
Sodium	Na	2.8	2.6
Potassium	K	2.6	1.4
Magnesium	Mg	2.1	1.8
All other elements		1.4	<0.1

Teacher tip

- *Igneous rocks* –rocks that are formed from the solidification of molten rock material. The process of solidification involves the formation of crystalline solids called minerals. Molten rock material can solidify below the surface of the earth (plutonic igneous rocks) or solidify at the surface of the Earth (volcanic igneous rocks)
- *Sedimentary rocks* – rocks that form through the accumulation, compaction, and cementation of sediments. Sedimentary rocks form at surface or near surface conditions.
- *Metamorphic rocks* – are rocks that form through the transformation of pre-existing rocks (igneous, sedimentary, or metamorphic rocks) through the process of metamorphism. Metamorphism can involve changes in the physical and chemical properties of rocks in response to heat, pressure, and/or chemically active fluids.

Teacher tip

- Make sure that the learners are ready to watch before playing the video.
- With no available specimen or tangible sample to describe, the teacher can use a video.

(The total abundances do not add up to exactly 100% because of round-off errors)

- Approximately 85% of the Earth's crust is composed of oxygen and silicon. Together they form the silicon oxygen tetrahedron, which is the basic building block of silicate minerals. Silicates are also termed as (common) rock forming minerals.

- As a review the teacher can ask the students to recall the definition of a mineral.

  - Rocks are an aggregate of minerals. A rock can be composed of a single mineral (e.g. Quartzite is a metamorphic rock composed predominantly of Quartz) or more commonly composed of an aggregate of two or more minerals.

  - Teacher can ask the students: Can a name of a mineral be also used as a rock name.

- Yes, a rock composed predominantly of the mineral Gypsum ($CaSO_4$) is called Gypsum Rock.

MOTIVATION (15 MINS)

1. Show a video of the different rock types. Tell the students that the video will only be played once and that they need to be attentive for the upcoming discussion (8:05 minutes).

2. After the discussion of the different types of rocks and their properties, show a short video about the rock cycle, in preparation for the discussions on the rock cycle (2:15 minutes).

Teacher tip

- Make sure that the learners are ready to watch before playing the video.

INSTRUCTION (60 MINS)

A. Rock Classifications

- Show video #1 (under motivation).
- Review: Defining minerals: inorganic, naturally occurring solid with definite internal structure and chemical composition. These are the building blocks of rocks.

Ask the students: How can we classify rocks? Would it be by color, hardness, texture, density or other physical properties? Is it by chemical composition?

- Enumerate and discuss the three rock types.

Teacher tip

- Generally rocks are classified on the basis of the mode of formation and that some of these physical and chemical properties are inherent on how the rocks are formed.

1. **Discuss Igneous Rocks.**
    - these are rocks that are derived from the cooling and solidification of magma or lava
    - from solidified molten rock materials, usually hard and crystalline
    - rate of cooling as one of the most important factors that control crystal size
    - solidification can occur along the surface of the earth or beneath the surface of the earth

- Differentiating magma and lava. Magma is a molten rock material beneath the surface of the earth. Lava is molten rock material extruded to the surface of the earth through a central vent (volcano) or as fissure eruption.

- Teacher should be able to describe plutonic or intrusive rocks and be able to discuss the processes of their formation and observable textures. Give examples.
    - from solidified magma underneath the earth
    - gradual lowering of temperature is indicated by the movement of magma from depth to surface causing slow cooling /crystallization
    - Phaneritic textures
    - Examples: granite, diorite, gabbro

- Slow cooling forms large interlocking crystals, a texture called **phaneritic**.

- Teacher should be able to describe volcanic or extrusive rocks and be able to discuss their processes of formation and their observable textures. Give examples.
    - from solidified lava at or near the surface of the earth
    - fast rate of cooling/crystallization due to huge variance in the temperature between Earth's surface and underneath
    - common textures: aphanitic, porphyritic (define groundmass vs phenocrysts), vesicular

- Fast cooling does not promote the formation of large crystals.

- examples: rhyolite, andesite, basalt
- pyroclastic rocks: fragmental rocks usually associated with violent or explosive type of eruption. Examples tuff and pyroclastic flow deposits (ignimbrite)

- Igneous rocks are also classified according to silica content and relative amounts of K, Na, Fe, Mg and Ca. They can be classified as felsic, intermediate, mafic and ultramafic, practically based on presence of light and dark colored minerals. The relatively dark minerals are olivine, pyroxene, hornblende and biotite. The relatively light colored minerals are plagioclases, K-feldspars, quartz and muscovite.
- felsic: granitic: >65% silica, generally light-colored
- intermediate: andesitic: 55-65% silica, generally medium colored (medium gray)
- mafic: basaltic: 45-55% silica, usually dark colored
- ultramafic: <45% silica, generally very dark colored

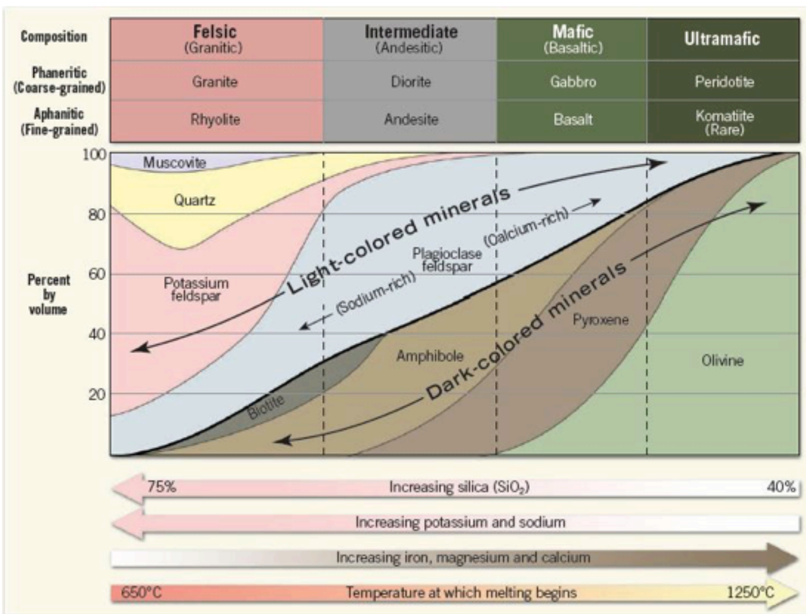


Table from Tarbuck, Lutgens, and Tasa. Earth An Introduction to Physical Geology 11thed, 2014, p 122

- **Porphyritic** texture: formed through two stages of crystallization where in magma partly cooled below the surface of the earth providing time for the large crystals to grow (phenocrysts) before it is extruded to the surface forming the fine-grained matrix (groundmass).

- **Aphanitic** texture: fine-grained texture; minerals not visible to the naked eye; relatively fast rates of cooling/ solidification prevent the formation of large crystals.

- Special textures would include: vesicular, glassy and porphyry

- **Vesicular** texture: voids created by rapid cooling which causes air bubbles to be trapped inside.

- Show photos of common intrusive rocks with their extrusive counterparts (TO BE REPLACED WITH OUR OWN SAMPLES):

- Granite and Rhyolite have the same chemical composition however Granite on le exhibits phaneritic texture and rhyolite on the right has aphanitic and porphyritic textures.

- Diorite and Andesite have the same chemical composition but different textures. Diorite (left) is coarse grained (phaneritic) and andesite (right) is fine grained (aphanitic and porphyritic).

- Gabbro and Basalt are of the same chemical composition but differ in texture. Gabbro (left) has larger crystals than basalt (right) which has finer crystals.

2. Discuss sedimentary rocks

- these are rocks that are formed at or near the surface of the Earth
- sedimentary processes include: weathering of rocks, erosion, sediment transport and deposition (compaction and cementation)
- common sedimentary features: fossil assemblages and stratification
- fossil assemblages: remains and traces of plants and animals that are preserved in rocks
- stratification or layering (strata which is >1cm is called bedding and < 1cm is called lamination): layering is the result of a change in grain size and composition; each layer represents a distinct period of deposition

- Temperature and pressure at the Earth's surface are low, allowing for the sedimentary processes to happen

- Sediments: solid fragments of organic or inorganic materials from weathered and eroded pre-existing rocks and living matters

Photo of the Kapurpurawan Formation located at the coastal town of Burgos, Ilocos Norte, courtesy of riderako.com. shows series of sedimentary strata

Photo from http://riderako.com/2013/07/16/kapurpurawan-rocks-the-most-famous-sedimentary-rock-in-the-philippines/.

- Clastic sedimentary rocks
  - grains, matrix and cement are the components of clastic rocks
  - clastic rocks are commonly classified based on particle size
  - clastic rocks with volcanic origin (e.g. pyroclastics) and may have undergone some stages in the sedimentary processes could be classified as sedimentary rock (e.g. volcanoclastic rocks).
  - the presence of variable grain sizes (including matrix and cement) is indicative of sedimentary differentiation which is actually a function of processes happening in different sedimentary environments.

- Grains: greater than sand-sized minerals and/or rock fragments.
- Matrix: fine-grained (clay to silt sized) minerals.
- Cement: minerals precipitated from solution that binds the grains and matrix together

- Table below shows the different clastic rocks

Clast / Sediment Size (mm)	Sediment Group	Sediment Name	Rock Name	Rock Group	Comment
>256	Gravel	Boulders	Conglomerate (rounded clasts); Breccia (angular clasts)	Rudaceous Rocks	Identifiable clasts
64-256		Cobbles			Clasts visible to naked eye; often identifiable.
4-64		Pebbles			
2-4		Granules			
1-2	Sand	Very coarse sand	Sandstone	Arenaceous Rocks	Clasts visible to naked eye; often identifiable.
0.5-1		Coarse sand			
0.25-0.5		Medium sand			Grains not visible to naked eye.
0.125-0.25		Fine sand			
0.063-0.125		Very fine sand			
0.032-0.063		Silt	Siltstone	Argillaceous Rocks	Grains not visible to naked eye.
<0.032		Clay	Mudstone, Claystone, Shale		Grains not visible to naked eye.

- Non-clastic sedimentary rocks
  - evaporation and precipitation from solution or lithification of organic matter
  - classified as evaporites (halite, gypsum and dolostone), precipitates (limestone) and bioclastics (coal, coquina)
  - chart below summarizes the features of the non-clastic rocks

CHEMICALLY AND/OR ORGANICALLY FORMED SEDIMENTARY ROCKS					
TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Crystalline	Fine to coarse crystals	Halite	Crystals from chemical precipitates and evaporites	Rock salt	
		Gypsum		Rock gypsum	
		Dolomite		Dolostone	
Crystalline or bioclastic	Microscopic to very coarse	Calcite	Precipitates of biologic origin or cemented shell fragments	Limestone	
Bioclastic		Carbon	Compacted plant remains	Bituminous coal	

- Rudaceous Rocks: (rudites) >50% clasts diameter >2mm made up of primarily rock fragments

- Arenaceous Rocks: (arenites) >50% sediments diameter between 0.063-2mm can contain high quartz %.

- Argillaceous Rocks: (argillites) >50% sediments diameter <0.063mm and made up mainly of clay minerals and quartz grains to a much lesser extent

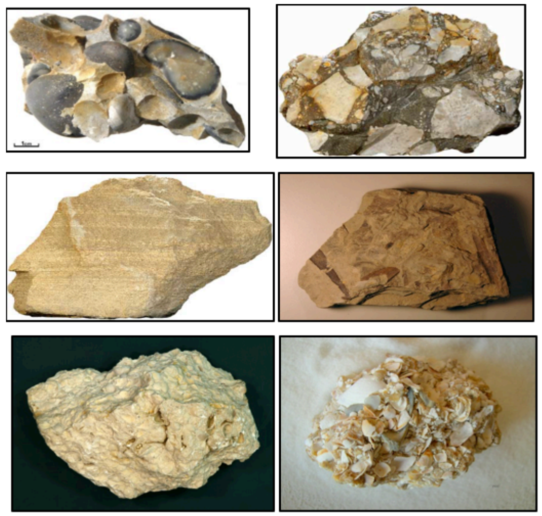
- Evaporites: rocks formed from the evaporation of water leaving the dissolved minerals to crystallize

- Precipitates: rocks formed when minerals from a mineral supersaturated waters start to crystallize at the bottom of the solution

- Bioclastic: rock formed from compacted organic matter

Source: http://peter-mulroy.squarespace.com/how-do-we-idendity-sedimentary-rocks/; accessed 09/25/2015

- Several photos of sedimentary rocks:



- Conglomerate (left) relatively large and rounded clasts as compared to the angular clasts of the breccia on the right
- Sandstone (left) with visible grains and prominent layering or; claystone (right) with several embedded fossils
- Non-clastic sedimentary rocks limestone (left) and coquina (right)

3. Discuss metamorphic rocks

- formed below the surface of the earth through the process of metamorphism with the recrystallization of minerals in rocks due to changes in pressure and temperature conditions
- contact and regional metamorphism

- Contact metamorphism

- heat and reactive fluids as main factors: occurs when a pre-existing rock gets in contact with magma which is the source of heat and magmatic fluids where metamorphic alterations and transformations occur around the contact / metamorphic aureole of the intruding magma and the rock layers. The aureole occurs on different scales depending on the sizes of the intruding magma and the amount of water in the intruded rocks and the reactive fluids coming from the magma.
- creates non-foliated metamorphic rocks
- example: hornfels

- Imagine magma forcing its way up through rock layers under the crust. The magma will bake the surrounding rocks due to the differences in temperature (rock layers are cooler than the magma) causing them to metamorphose.
- Deformed rocks exhibit foliation/ lineation/ banding of mineral grains, brought about by pressure and recrystallization of minerals while undergoing regional metamorphism

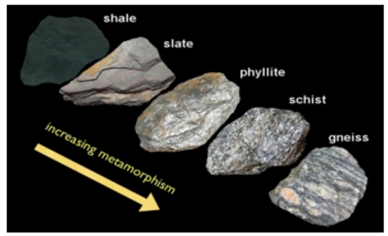
- Regional metamorphism

- pressure as main factor: occurs in areas that have undergone considerable amount of mechanical deformation and chemical recrystallization during orogenic event which are commonly associated with mountain belts
- occurs in a regional/large scale
- creates foliated metamorphic rocks
- examples: schist, gneiss
- non-foliated rocks like marble also form through regional metamorphism, where pressure is not intense, far from the main geologic event

- Below is a table of the different common metamorphic rocks.

TEXTURE		GRAIN SIZE	COMPOSITION	TYPE OF METAMORPHISM	COMMENTS	ROCK NAME	MAP SYMBOL
FOLIATED	MINERAL ALIGNMENT	Fine	MICA	Regional (Heat and pressure increases)	Low-grade metamorphism of shale	Slate	
FOLIATED	MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET	Regional (Heat and pressure increases)	Foliation surfaces shiny from microscopic mica crystals	Phyllite	
FOLIATED	MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET	Regional (Heat and pressure increases)	Platy mica crystals visible from metamorphism of clay or feldspars	Schist	
FOLIATED	BAND-ING	Medium to coarse	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increases)	High-grade metamorphism; mineral types segregated into bands	Gneiss	
NONFOLIATED		Fine	Carbon	Regional	Metamorphism of bituminous coal	Anthracite coal	
NONFOLIATED		Fine	Various minerals	Contact (heat)	Various rocks changed by heat from nearby magma/lava	Hornfels	
NONFOLIATED		Fine to coarse	Quartz	Regional or contact	Metamorphism of quartz sandstone	Quartzite	
NONFOLIATED		Fine to coarse	Calcite and/or dolomite	Regional or contact	Metamorphism of limestone or dolostone	Marble	
NONFOLIATED		Coarse	Various minerals	Regional or contact	Pebbles may be distorted or stretched	Metaconglomerate	

- Some photos of common metamorphic rocks:

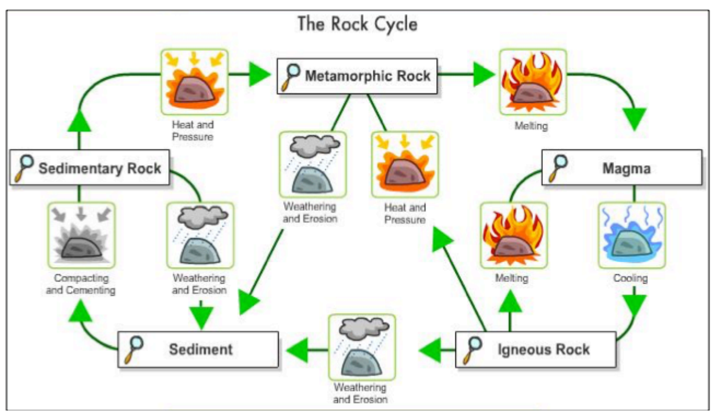


- Non-foliated rocks: Hornfels (left), a fine-grained rock that forms through contact metamorphism of non-carbonate rocks. Marble (right), a recrystallized rock that forms from the metamorphism of limestone or dolostone

- Foliated rocks: Slate, phyllite, schist and gneiss from shale as precursor rock. The stages of transformation are manifestations of increasing metamorphic grade with increasing pressure

B. The Rock Cycle

- The teacher to show the quick video on rock cycle
- rock cycle diagram:
  - constant recycling of minerals
  - illustrates how geologic processes occurring both underneath and on the Earth's surface can change a rock from one type to another..

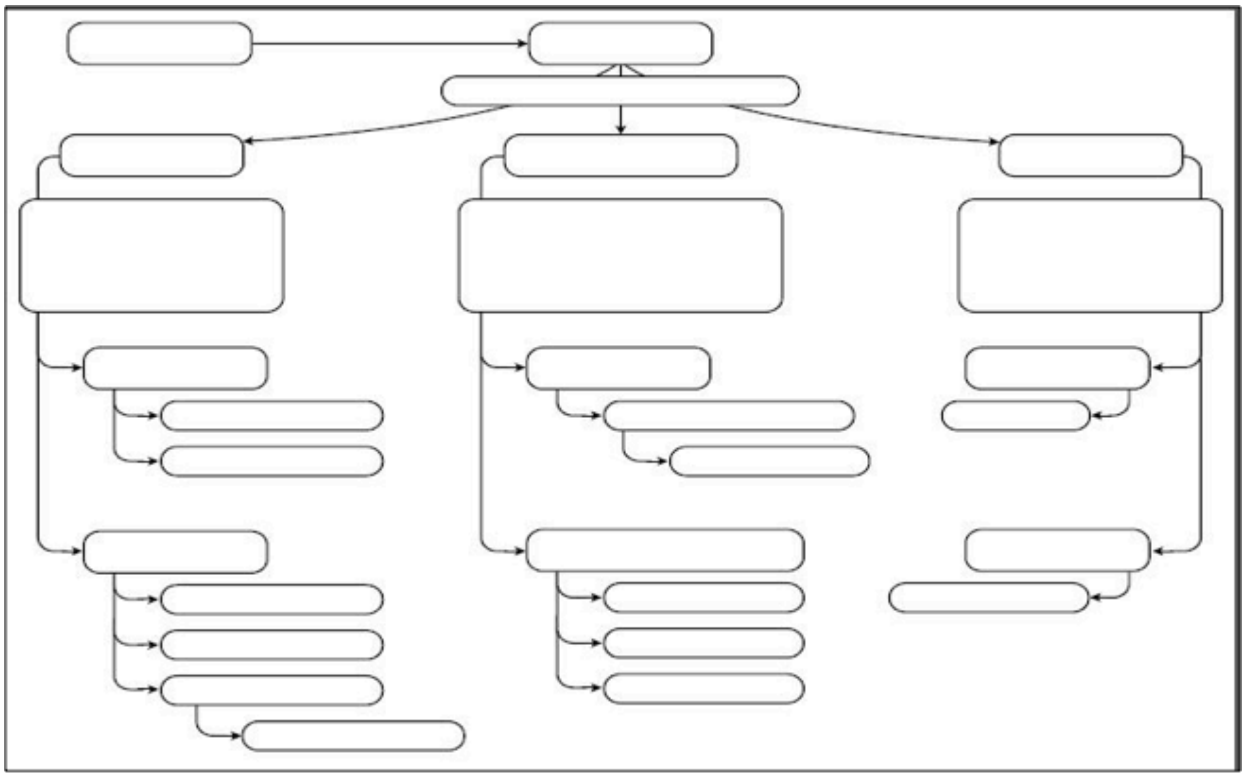


Source: http://www.learner.org/interactives/rockcycle/diagram.html

PRACTICE (40 MINS)

1. Concept Mapping – Types of Rocks (20 minutes: 10 minutes filling up the table, 3 minutes presentation per team, 1 minute wrap up)

Group the class into three teams, each electing their leader. Provide each team a blank chart similar to the one below, written in a Manila paper. Each team will fill up portions of the chart which correspond to the list of words provided to choose from. Group 1 to fill up the left side of the chart (igneous rocks), Group 2 the middle portion (sedimentary rocks) and Group 3 to fill up the right side of the chart (metamorphic rocks). When done, the team leaders will present their work to class.



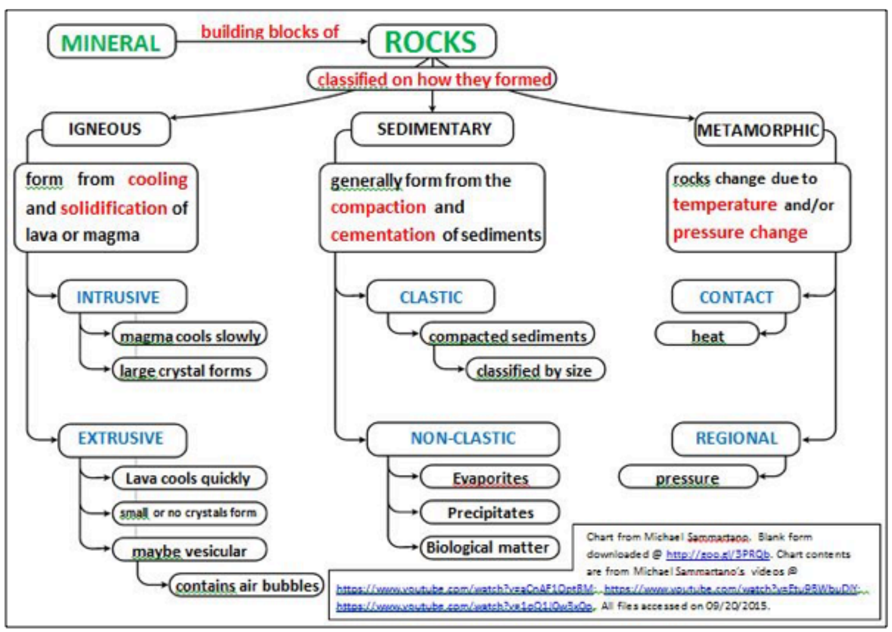
Teacher tip

- The teacher will go around checking on the different teams and check on the works done and how the learners are doing.

Words/phrases to choose from:

pressure	biological matter	lava cools quickly
clastic	maybe vesicular	compacted sediments
extrusive	classified by size	contains air bubbles
rocks	large crystals form	small or no crystals forms
heat	evaporites	magma cools slowly
contact	metamorphic	classified on how they are formed
intrusive	building blocks of	precipitates
mineral	non-clastic	sedimentary
igneous	regional	generally forms from the compaction and cementation of sediments
forms from cooling and solidification of lava or magma	rocks change due to temperature and/or pressure change	

Answer: The completed chart should look like this:



2. Interactive quiz for the whole class – Rock Cycle (20 minutes)

Answer the interactive quiz provided by Annenberg Learner in their website http://www.learner.org/interactives/rockcycle/diagram2.html. The first set, to be completed in five minutes, utilizes the learners' knowledge about rock types and geologic processes to map out the rock cycle. When done, the site will be automatically direct you to the second part of the quiz (http://www.learner.org/interactives/rockcycle/testskills.html) for 15 additional questions. There is no time limit for the second part but set a maximum of 1 minute to answer each question to include some class discussions. Correct answers are automatically provided by the site once the quiz is completed.

ENRICHMENT

Homework to be submitted on next meeting. Each student to research on 3 rocks (one for each rock type). Include in the discussion the following:

1. history of formation
2. common environment of formation
3. common textures
4. common use of the rock

EVALUATION

A. Summary questions related to the lessons (Questions in regular font are easy questions while the ones in bold are hard):

1. How does a vesicular texture in a volcanic rock develop?

   Answer: As magma rises up to the surface, it is subjected to decreasing pressure, allowing dissolved gases to come out of the solution forming gas bubbles. When the magma reaches the surface (as lava) and cools, the rock solidifies around the gas bubbles. The bubbles are then preserved as holes or vesicles. Also, the texture can also be formed thru the rapid escape of gases.

2. **Explain why vesicular texture is not associated with peridotites.**

   Answer: Peridotites are intrusive rocks formed beneath the earth's surface and the high pressure conditions prevent gases from forming and escaping.

3. How do clastic rocks differ from non-clastic rocks in terms of process of formation?

   Answer: Clastic rocks form from rock fragments transported away from their source by wind, water, gravity or ice rather than by chemical processes such as precipitation or evaporation.

4. **Explain how the physical features of sediments change during transport.**

   Answer: The farther the sediment is transported, the longer the transport takes, and the smaller, more rounded and smoother the sediment becomes.

5. Differentiate between a foliated and non-foliated rock.

   Answer: Foliated rocks has a texture in which the mineral grains are arranged in bands or grains, which is absent in a non-foliated rock.

6. **What do butterflies and metamorphic rocks have in common?**

   Answer: Butterflies and metamorphic rocks both undergo change from an earlier form (caterpillar for butterfly, parent rock for metamorphic rock) to a new one.

7. Heat is a major agent in metamorphism and igneous rock formation, but not in sedimentary rocks. Why?

   Answer: Sedimentary processes occur in surface conditions - low temperature and pressure conditions.

8. **Does every rock go through the complete rock cycle, i.e. changing from igneous to sedimentary rock to metamorphic then back to igneous rocks? Explain.**

   Answer: No. Rocks can change into any type of rock or even reform as the same kind of rock for several cycles.

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
A. Summary Questions	Correctly answered ≤2 easy questions	Correctly answered all easy questions	Correctly answered all easy questions and one difficult question	Correctly answered all questions

ADDITIONAL RESOURCES:

(1) Rock flowchart by Michael Sammartano (Accessed 09/18/2015) blank template: http://www.hmxearthscience.com/Sammartano/Rocks%20Flow%20Chart.pdf filled up template by combining data from the following videos:

a. Introduction to Igneous Rocks https://ww.youtube.com/watch?v=aCnAF1Opt8M
b. Introduction to Sedimentary Rocks https://www.youtube.com/watch?v=Etu9BWbuDlY
c. Metamorphic Rocks Video https://www.youtube.com/watch?v=1oQ1J0w3x0o

Mineral Resources

60 MINS

Content Standard
The learners demonstrate an understanding of the origin and environment of formation of common minerals and rocks.

Performance Standard
The learners shall be able to make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competency
The learners will be able to identify the minerals important to society **(S11ES-Ic-7).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- understand the importance of the different minerals to the society; and
- understand the different ways on how the mineral deposits are formed.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Video	5
Instruction	Lecture	50
Practice	Activity	
Enrichment	Assignment	

Materials
Mineral cards (to be prepared by the teacher), masking tape, *Ground Rules* film, reference books and/or internet access

Resources

(1) https://www.youtube.com/watch?v=xmXT1YgfoTA. Accessed 11 Nov 2015

(2) https://mining.cat.com/cda/files/2786351/7/GroundRules-MineralsEverydayLife-15-18.pdf Accessed 10 Nov 2015

(3) http://www.tulane.edu/~sanelson/eens1110/minresources.htm. Accessed 01 Nov 2015

(4) http://encyclopedia2.thefreedictionary.com/hydrothermal+solution. Accessed 31 Oct 2015

(5) http://www.britannica.com/science/hydrothermal-solution. Accessed 31 Oct 2015

(6) http://earthsci.org/mineral/mindep/depfile/vei_dep.htm. Accessed 31 Oct 2015

(7) http://geology.com/rocks/pegmatite.shtml. Accessed 01 Nov 2015

(8) Frank, D., Galloway, J., Assmus, K., The Life Cycle of a Mineral Deposit – A Teacher's Guide for Hands-On Mineral Education Activities, USGS General Information Product 17, 2005

Additional resources at the end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objectives

1. Introduce the following learning objectives using the suggested protocols (Verbatim, Own Words, Read-aloud)
   a. I can identify the importance of minerals to the society
   b. I can describe how ore minerals are formed.

MOTIVATION (5 MINS)

a. Show the students the short video "Mining and the Modern World" of the Ground Rules film (2 minutes) (https://www.youtube.com/watch?v=xmXT1YgfoTA).

b. The teacher can bring out items from his or her bag such as cell phone, keys, coins, pencil/pen, make-up, powder, glasses, etc. and identify the minerals involved in the manufacture of each item.

Teacher tip

- Make sure that the learners are ready to watch before playing the video.
- An alternative in case the video cannot be shown in class.

INSTRUCTION (50 MINS)

A. Minerals in Everyday Life

The video clip in the Motivation section shows that even the simplest household items are made up of different minerals. Enumerate a few examples of household items mentioned in the video and discuss with the class the minerals (and their properties) that make up each of the selected household items.

Teacher tip

- List few household items mentioned in the video except for the ones that will be in the activity in the Practice section

Perform the Activity "Minerals In My House" (See Practice Section)

B. Mineral Deposits

- Define some significant terms listed in the "Life Cycle of a Mineral Deposit – A Teacher's Guide for Hands-On Mineral Education Activities".

  Mineral Occurrence – concentration of a mineral that is of scientific or technical interest

  Mineral Deposit – mineral occurrence of sufficient size and grade or concentration to enable extraction under the most favorable conditions

  Ore Deposit – mineral deposit that has been tested and known to be economically profitable to mine.

Aggregate – rock or mineral material used as filler in cement, asphalt, plaster, etc; generally used to describe nonmetallic deposits

Ore – naturally-occurring material from which a mineral or minerals of economic value can be extracted.

- Most rocks of the Earth's crust contain metals and other elements but at very low concentrations. For example, the average concentration of Gold in rocks of the Earth's crust is about 0.005 ppm (parts per million) which is roughly 5 grams of gold for every 1000 tons of rock. Although valuable, extracting Gold at this concentration is not economic (the cost of mining will be too high for the expected profit). Fortunately, there are naturally occurring processes (geologic processes) that can concentrate minerals and elements in rocks of a particular area.

- ppm: a dimensionless value that represents a part of a whole number in units of 1/1000000; 1ppm is one part by weight (or volume) of a solute that is in a 1 million parts by weight (or volume) solution

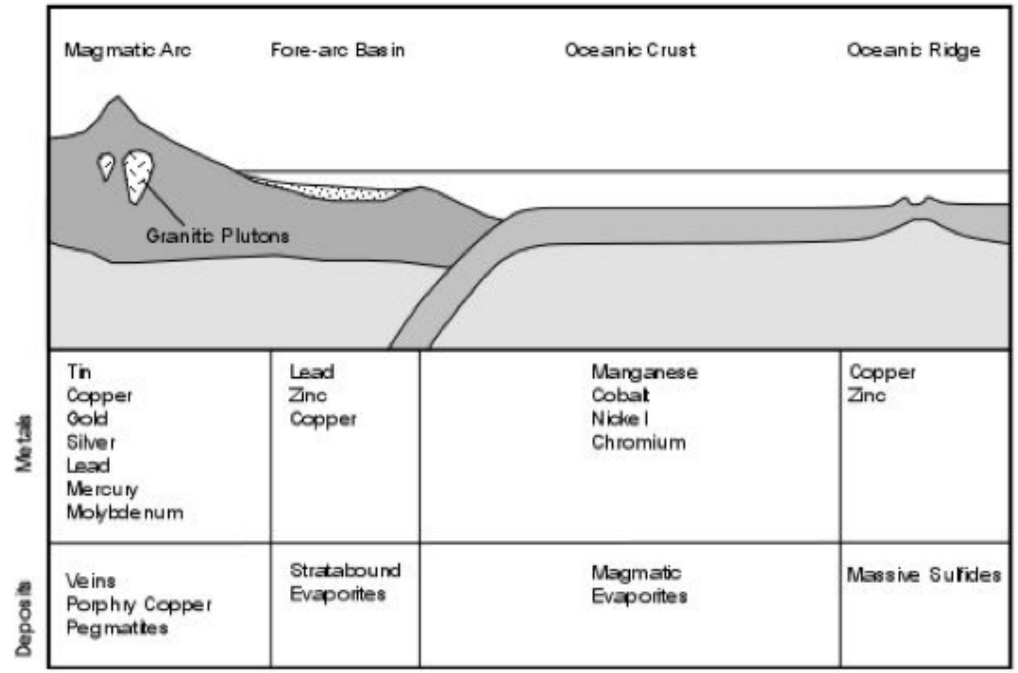
- Differentiate the types of mineral resources. Discuss with students and give examples.

  Types of mineral resources: metallic and nonmetallic

  Metallic mineral deposits: gold, silver, copper, platinum, iron

  Non-metallic resources: talc, fluorite, sulfur, sand, gravel

- Discuss the occurrence of a mineral resource. Relate it to the rock cycle and plate tectonics
  - The geologic processes involved in the rock cycle play major role in the accumulation and concentration of valuable elements/ minerals.
  - Plate tectonics: the Earth's crust is broken into a dozen or more plates of different sizes that move relative to one another (lithosphere). These plates are moving slowly on top of a hot and more mobile material called the asthenosphere. The diagram below shows the different mineral deposits that usually occur in different tectonic environments.



- Enumerate the different mineral resources and discuss their origins. Give examples for each.
  - Mineral resources can be classified according to the mechanism responsible for concentrating the valuable substance.

1. Magmatic Ore Deposits

- valuable substances are concentrated within an igneous body through magmatic processes such as crystal fractionation, partial melting and crystal settling.
- magmatic processes can concentrate the ore minerals that contain valuable substances after accumulating elements that were once widely dispersed and in low concentrations within the magma.

Examples:

- Crystal settling: as magma cools down, heavier minerals tend to crystallize early and settle at the lower portion of the magma chamber
- From a basaltic magma, chromite ($FeCr_2O_4$), magnetite (Fe_3O_4) and platinum (Pt) can be concentrated through crystal settling
- Fractional crystallization: the residual melt contains high percentage of water and volatile substances that are favorable for the formation of pegmatites. Pegmatites are enriched in Lithium, Gold, Boron, rare elements and some other heavy metals
- Fractional crystallization of granitic magmas can concentrate rare earth elements (such as cesium and uranium) and heavy metals. This can also form pegmatites (large crystals of quartz, feldspars and muscovite)which may contain semi-precious gems such as beryl, topaz, and tourmaline

2. Hydrothermal Ore Deposits

- concentration of valuable substances by hot aqueous (water-rich) fluids flowing through fractures and pore spaces in rocks
- hydrothermal solutions - are hot, residual watery fluids derived during the later stages of magma crystallization and may contain large amount of dissolved metals. These can also originate from the ground water circulating at depth that is being heated up by a cooling and solidifying igneous body or along depths with known geothermal gradient.
- Such hot water can dissolve valuable substances (at low concentrations) from rocks. As the metal enriched hot waters move into cooler areas in the crust, the dissolved substances may start to precipitate
- There are numerous hydrothermal mineral deposits as compared to the different types of deposits

Examples:

- Vein type deposits - A fairly well defined zone of mineralization, usually inclined and discordant and typically narrow. Most vein deposits occur in fault or fissure openings or in shear zones within the country rock. Sometimes referred to as (metalliferous) lode deposits, many of the most productive deposits of gold, silver, copper, lead, zinc, and mercury occur as hydrothermal vein deposits

- Magma chamber – a reservoir or pool of magma within the upper mantle or lower crust
- Pegmatite – an igneous rock formed during the latter stages of magma's crystallization that has exceptionally large crystals (several centimeters or even a few meters in length). Most pegmatites are granitic.
- Feldspar - used in production of ceramics
- Muscovite - used for electrical insulation and glitter
- Discordant - cuts across existing structures.

- Disseminated deposits - Deposits in which the ore minerals are distributed as minute masses (very low concentration) through large volumes of rocks. This occurrence is common for porphyry copper deposits
- Massive sulfide deposit (at oceanic spreading centers) - Precipitation of metals as sulfide minerals such as sphalerite (ZnS) and chalcopyrite ($CuFeS_2$) occurs when hot fluids that circulated above magma chambers at oceanic ridges that may contain sulfur, copper and zinc come in contact with cold groundwater or seawater as it migrate towards the seafloor.
- Stratabound ore deposits (in lake or oceanic sediment) – This deposit is formed when the dissolved minerals in a hydrothermal fluid precipitate in the pore spaces of unconsolidated sediments on the bottom of a lake or ocean. Such minerals may contain economic concentrations of lead, zinc and copper, usually in sulfide form like galena (PbS), sphalerite (ZnS) and chalcopyrite ($CuFeS_2$).

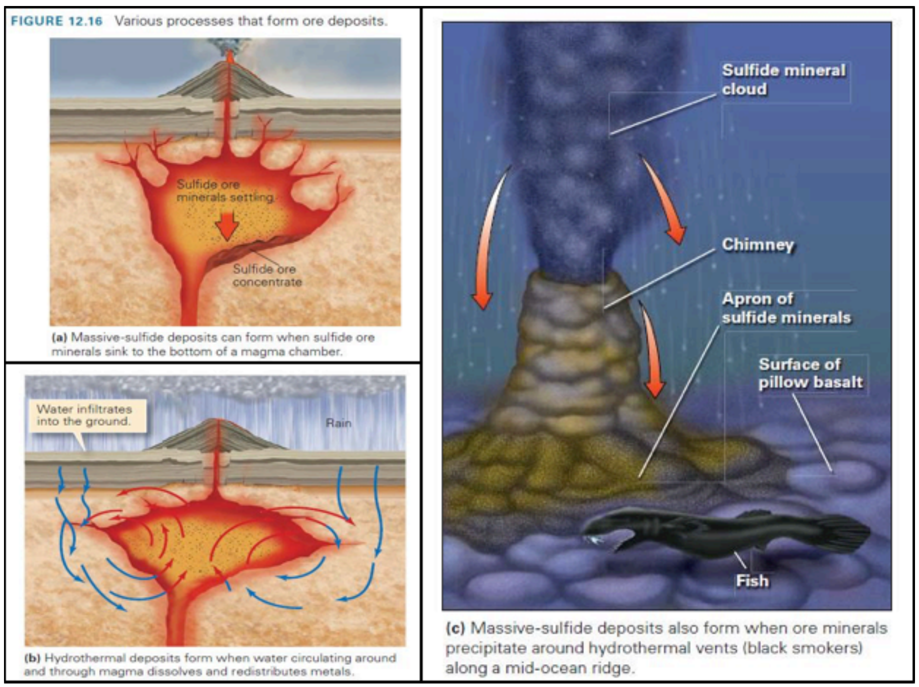


FIGURE 12.16 Various processes that form ore deposits.

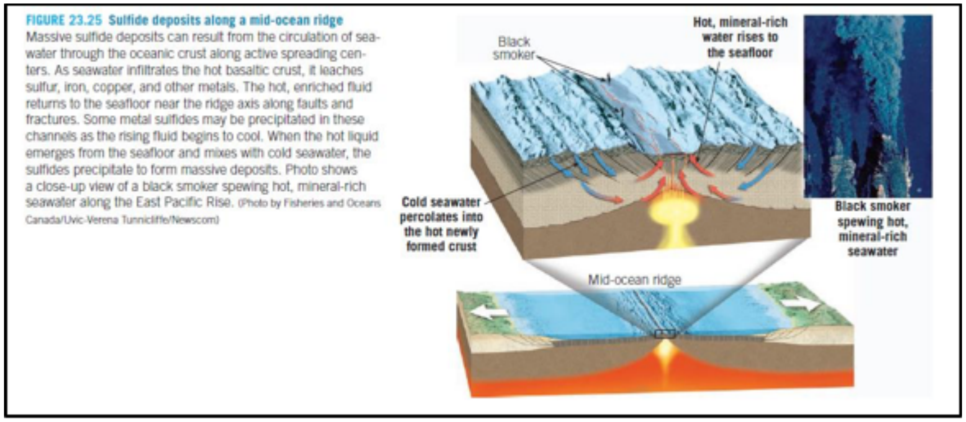
(a) Massive-sulfide deposits can form when sulfide ore minerals sink to the bottom of a magma chamber.

(b) Hydrothermal deposits form when water circulating around and through magma dissolves and redistributes metals.

(c) Massive-sulfide deposits also form when ore minerals precipitate around hydrothermal vents (black smokers) along a mid-ocean ridge.

Various processes that form ore deposits. Photos taken from Essentials of Geology by Stephen Marshak, 4th ed., 2013, p377

- **Porphyritic** texture: formed through two stages of crystallization where in magma partly cooled below the surface of the earth providing time for the large crystals to grow (phenocrysts) before it is extruded to the surface forming the fine-grained matrix (groundmass).
- **Aphanitic** texture: fine-grained texture; minerals not visible to the naked eye; relatively fast rates of cooling/ solidification prevent the formation of large crystals.
- Special textures would include: vesicular, glassy and porphyry
- **Vesicular** texture: voids created by rapid cooling which causes air bubbles to be trapped inside.



Massive sulfide deposit along mid-oceanic ridge. Photo taken from Earth An Introduction to Physical Geology by Tarbuck et al, 11th ed., 2014, p. 804

3. Sedimentary Ore Deposits

- Some valuable substances are concentrated by chemical precipitation coming from lakes or seawater (http://www.tulane.edu/~sanelson/eens1110/minresources.htm)

Examples:

- Evaporite Deposits: This type of deposit typically occurs in a closed marine environment where evaporation is greater than water inflow. As most of the water evaporates, the dissolved substances become more concentrated in the residual water and would eventually precipitate. Halite (NaCl), gypsum ($CaSO_4 \cdot 2H_20$), borax (used in soap) and sylvite (KCl, from which K is extracted for fertilizers) are examples of minerals deposited through this process.
- Iron Formation: These deposits are made up of repetitive thin layers of iron-rich chert and several other iron bearing minerals such as hematite and magnetite. Iron formations appear to be of evaporite type deposits and are mostly formed in basins within continental crust during the Proterozoic (2 billion years or older).

4. Placer Ore Deposits
- Deposits formed by the concentration of valuable substances through gravity separation during sedimentary processes.
- Usually aided by flowing surface waters either in streams or along coastlines.
- Concentration would be according to the specific gravity of substances, wherein the heavy minerals are mechanically concentrated by water currents and the less-dense particles remain suspended and are carried further downstream.
- Usually involves heavy minerals that are resistant to transportation and weathering.
- Common deposits are gold and other heavy minerals such as platinum, diamonds and tin;
- The source rock for a placer deposit may become an important ore body if located.

5. Residual Ore Deposits
   - A type of deposit that results from the accumulation of valuable materials through chemical weathering processes.
   - During the process, the volume of the original rock is greatly reduced by leaching.
   - Important factors for the formation of residual deposit include parent rock composition, climate (tropical and sub-tropical: must be favorable for chemical decay) and relief (must not be high to allow accumulation)
   - Common deposits are bauxites and nickeliferous laterites.
   - Bauxite, the principal ore of aluminum, is derived when aluminum-rich source rocks undergo intense chemical weathering brought by prolonged rains in the tropics, leaching the common elements that include silicon, sodium and calcium through leaching.
   - Nickeliferous laterites or nickel laterites are residual ore deposits derived from the laterization of olivine-rich ultramafic rocks such as dunite and peridotite. Like in the formation of bauxite, the leaching of nickel-rich ultramafic rocks dissolves common elements, leaving the insoluble nickel, magnesium and iron oxide mixed in the soil.
   - Secondary Enrichment Deposits are derived when a certain mineral deposit becomes enriched due to weathering.

- Leaching – the removal of soluble materials in rocks or ore body through the percolation of water
- Relief – the configuration of an area that pertains to the elevation and slope variations and the irregularities of the land surface
- Laterization – conditions of weathering which leads to the removal of alkalis and silica, resulting in a soil or rock with high concentrations of iron and aluminum oxides.

PRACTICE (40 MINS)

"Minerals In My House" (adapted from the activity "Minerals in My House") 20 minutes https://mining.cat.com/cda/files/2786351/7/GroundRules-MineralsEverydayLife-15-18.pdf pp 12-14)

The objective of the activity is to determine the mineral content of common household items.

Pre-activity (to be accomplished by the teacher):

1. List 5 common household items on the board.
    1. Prepare a set of cards containing the minerals used to make those 5 items. One mineral should be written on each card.

Activity:

1. Show one mineral card at a time and ask the students to identify which household item they think contains that mineral. Attach the card with a masking tape beside the household item. Remind the class that several minerals may be associated in one household item.
2. Repeat the procedure until all the mineral cards are used (except for the joker mineral card).
3. Together with the class, go through and review all the answers. Invite students to explain if they think the mineral placed beside the household item is incorrect. Also ask the possible use of the joker mineral.

Household Items and Minerals (from Chapter 3 of Ground Rules)

Wallboard - gypsum, clay, perlite, vermiculite, aluminum hydrate, borates
Paint - titanium dioxide, kaolin, calcium carbonate, mica, silica, wollastonite
Glass - silica, quartz, lead, titanium, sodium carbonate
Door Knob - nickel
Speakers - aluminum, cobalt, silver, silica, iron, titanium, graphite, mica, carbon, strontium, neodymium
Plastic - calcium carbonate, talc, wollastonite, barium sulfate, clay, mica
Keys - nickel
Stainless steel - iron, nickel, molybdenum, chrom
Non-stick coating - fluorite
Ceramic tiles - clay, feldspar, fluorite, lithium, silica, talc
Countertop - titanium dioxide, calcium carbonate, aluminum hydrate
Knife - chromium
Table salt - halite, iodine
Sugar - limestone, lime
Toothpaste - calcium carbonate, limestone, sodium carbonate, fluorite, mica, zinc
Cosmetics - calcite, hematite, kaolinite, mica, silica, talc, titanium, zinc
Carpet - calcium carbonate, limestone
Textiles - antimony, feldspar, tungsten
Dish soap - halite, sodium carbonate
Can opener - iron, nickel, chromium, molybdenum
Incandescent light bulbs - tungsten
Window panes - silica, lime, sodium carbonate, calcium carbonate, halite, feldspar
Brick - kaolin, shale, barium, manganese
Jewelry - gold, silver, platinum, diamonds
Soda cans - aluminum

Others

Baby powder - talc
Cement - limestone
Insulation - vermiculite
Matches - sulfur
Sun block - zinc
Thermometer - mercury
Utensils - nickel, iron, silver

Teacher tip

- Add a joker mineral card (one that is not used in any of the 5 household items) to encourage class participation.
- The table on the left is for the use of the teacher only.

Discussion:

Discuss the importance of minerals in our daily lives. Different minerals are important for different purposes: from household items, construction, energy sources, communication, travels, recreation, food processing and even in multivitamins.

With the reference books and/or internet access on hand, group the class into two. Each group has to select one particular mineral from the activity and prepare answers for the following questions, to be presented in the class:

1. What properties of that mineral make it important in creating the item?
2. How is this specific mineral formed?
3. Is this a renewable or non-renewable resource?

ENRICHMENT

The following activity for Enrichment is adapted from "What Parts of a Computer are Mined?" of Ground Rules (https://mining.cat.com/cda/files/2786351/7/GroundRules-MineralsEverydayLife-15-18.pdf).

1. Divide the class into 5 groups.
2. Assign the following computer parts for each group to work on:

   Group 1: computer monitor

   Group 2: computer chip

   Group 3: computer circuitry

   Group 4: computer case

   Group 5: electrical cords
3. Have each group prepare a short report about the designated component of the computer. Report should answer the following:
   - Identify the minerals and metals used to build the computer component
   - Identify the properties of each mineral/metal that makes it useful to the function of that computer part.
   - Select one specific mineral/metal from the computer part. Discuss how the mineral is formed (what are the ore minerals and the most realistic origin of the ore resource)

- Based on the list, hypothesize what minerals would be useful for another electronic item (television, media player, mobile phone, etc.)
- Discuss environmental implications of disposing outdated computer equipment. Should it be landfilled? Why is computer waste one of the biggest waste issues facing the world? Discuss the global implications of computer waste.

4. Reports to be submitted on the next class meeting.

Minerals and Metals in a Computer

Computer Monitor:
- Silicon, lead, strontium, phosphorus, boron, indium, barium

Computer Chip:
- Silicon, gallium

Computer Case:
- Calcium carbonate, clays, mica, talc, sulfur

Computer Circuitry:
- Gold, aluminum, lithium, chromium, silver, nickel, gallium, lead, zinc, copper, steel, tungsten, titanium, cobalt, germanium, tin, tantalum

Electrical cords:
- Copper

EVALUATION

Summary questions (Questions in regular font are easy questions while the ones in bold are hard):

1. Differentiate metallic and non-metallic resources. Give examples.

   Answer: Metallic resources are those minerals that contain metals in their chemical composition (a product obtained when the mineral was melted). These usually have bright and metallic luster. Examples include iron ore, chromite and bauxite. Non-metallic resources such as sand, gravel, gypsum, halite, talc, are those resources that do not yield new products when melted. These do not have metallic luster.

2. Can a mineral be formed in more than one process? If yes, give example. If no, explain why.

Answer: Yes. (Examples may vary) Gypsum can form as a precipitate from evaporating water, but also associated with volcanic regions where limestone and sulfur gases from the volcano have interacted. Copper may commonly be deposited as a disseminated hydrothermal deposit but can also be formed as a stratabound ore.

3. Other than as a jewelry, why is gold important to society?

Answer: Statistically worldwide, approximately 50% of produced gold is used in jewelry. The remaining 40% is used for financial investments and the remaining 10% in industry. Due to its limited supply and high value, gold has been long used as a medium of exchange or money. Many governments use gold bars or bullion as a financial backing for currencies. A country's gold bullion reserve is equated to the wealth of the country.

Several properties of gold including its malleability, good conductivity and general resistance to corrosion and oxidation made it very important in the electronics industry, primarily as connectors, switch and relay contacts, soldered joints and connecting strips. These can be found in almost every sophisticated electronic device such as GPS, cellphones, MP3 players, calculators, laptop computers and televisions.

4. Discuss the most common origin of chromite ore. How is this ore important to society?

Answer: Chromite ore is formed from a magmatic process called crystal settling. Its relatively high density makes it settle at the lower portion of the magma chamber and solidifies ahead than most of the basaltic magma. Chromium is the ore mineral for the element chromite, which is used in chrome plating and also for alloying stainless steel. Chromium is also used as pigment in many types of paint inks, dyes and even cosmetics.

5. Discuss the difference between a magmatic ore deposit and a hydrothermal deposit.

Answer: Magmatic ore deposits are formed from different magmatic processes such as crystal settling or crystal fractionation.

6. **Explain how mineral veins form.**

   Answer: Mineral veins form when the hydrothermal solution containing dissolved substances flows through cracks in rocks. The solutions deposit solid mineral particles and fill in the cracks.

	1. (NOT VISIBLE)	**2. (NEEDS IMPROVEMENT)**	**3. (MEETS EXPECTATIONS)**	**4. (EXCEEDS EXPECTATIONS)**
Enrichment report	Report not submitted on time	Report submitted on time; identified minerals is less than 50% and only managed to answer half of the questions	Report is submitted on time; completely answered all question asked	Report is submitted on time and complete with illustrations; very elaborate explanation/ discussion of answers especially the last question of the discussion part
Summary questions	Only ≤ 2 easy questions were correctly answered	Only easy questions were correctly answered	All easy questions and 1 difficult question were correctly answered	All easy and difficult questions were correctly answered

ADDITIONAL RESOURCES

1. Carlson, D. H., Plummer, C. C., Hammersley L., Physical Geology Earth Revealed 9thed, 2011, pp 560-563
2. Marshak, S., Essentials of Geology, 4th ed., 2013, pp 375-379
3. Tarbuck, E. J., Lutgens, F. K., Tasa, D., Earth An Introduction to Physical Geology, 11thed, 2014, pp 802-806

90 MINS

Mineral Resources

Content Standard
The learners demonstrate an understanding of the origin and environment of formation of common minerals and rocks.

Performance Standard
The learners shall be able to make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competencies
The learners will be able to describe how ore minerals are found, mined, and processed for human use **(S11ES-Ic-d-8)**, and

cite ways to prevent or lessen the environmental impact that result from the exploitation, extraction, and use of mineral resources **(S11ES-Id-9).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- understand the life cycle of mineral resources; and
- understand the impact of mining.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Participation/Photo/Video	5
Instruction	Lecture/Demonstration	50
Practice	Activity	30
Enrichment	Assessment	

Materials
For Demonstration#1 (Core Sampling)
- Yellow clay representing gold-rich vein, Blue clay representing copper-rich vein; Blue clay representing copper-rich vein; Brown clay representing country / host rock, ruler; 1 opaque, wide bowl, colored chalks (brown, yellow and blue); 3 transparent (colorless), sturdy drinking straw (i.e. the ones used in milk teas)

For Demonstration#2 (Flotation)
- Dry roasted peanuts; Raisins; Clear soda water; Drinking water; 2 clear drinking glasses

For Practice (Operating a Mine)
- Sand representing country rock; iron filings representing metallic ore; salt representing other valuable material; macaroni for other valuable material; saw dust representing the surface top soil; 1 page old newspaper; ice bag/plastic; filter paper; magnet, spoon; beakers/ containers; 500ml bowl, water; tweezers

Resources

(1) Carlson, D. H., Plummer, C. C., Hammersley L., Physical Geology Earth Revealed 9thed, 2011, pp564-566

(2) Frank, D., Galloway, J., Assmus, K., The Life Cycle of a Mineral Deposit – A Teacher's Guide for Hands-On Mineral Education Activities, USGS General Information Product 17, 2005

(3) Marshak, S., Essentials of Geology, 4th ed., 2013, pp 379-383

Additional resources at the end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objectives

1. Introduce the following learning objectives using the suggested protocols (Verbatim, Own Words, Read-aloud)
   a. I can describe how ore minerals are found, mined, and processed for human use.
   b. I can cite ways to prevent or lessen the environmental impact that result from the exploitation, extraction, and use of mineral resources

Review

- Remind the students how minerals are incorporated to our daily lives by citing one or two examples.
- Review some processes how mineral resources are formed.

MOTIVATION (5 MINS)

Encourage class discussion by asking the questions like: "We already know how mineral resources are formed, but are we aware of how they end up in the things we use?"

Answers may vary but expected answers must include ideas or concepts about mineral exploration, mining and metallurgy or milling process

Teacher tip

- The teacher may present (if available) a video on mining and utilization.

INSTRUCTION (50 MINS)

A. Mineral Exploration

- Discuss major stages involved in mineral exploration (https://www.cde.int/sites/default/files/documents/mineral_exploration_part_1.pdf and part2.pdf)
- The steps enumerated below are used or considered based on how they are needed during exploration. These steps are written within the context of a general exploration project where some activities may vary depending on the type of commodity being explored.

1. **Project Design**: This is the initial stage in formulating a project. This involves review of all available data (geologic reports, mining history, maps, etc.), government requirements in acquiring the project, review of social, environmental, political and economic acceptability of the project, and budget and organization proposals.
2. **Field Exploration:** This stage involves physical activities in the selected project area. This can be subdivided into three phases:
   A. R*egional Reconnaissance:*The main objective is to identify targets or interesting mineralized zones covering a relatively large area (regional). In general, the activities involve regional surface investigation and interpretation.
   B. *Detailed Exploration*: This involves more detailed surface and subsurface activities with the objective of finding and delineating targets or mineralized zones.
   C. *Prospect Evaluation*: The main objective is to assess market profitability by (1) extensive resource, geotechnical and engineering drilling (2) metallurgical testing and (3) environmental and societal cost assessment.
3. **Pre-production Feasibility Study**: The feasibility study determines and validates the accuracy of all data and information collected from the different stages. The purpose is for independent assessors to satisfy interested investors to raise funds and bring the project into production.

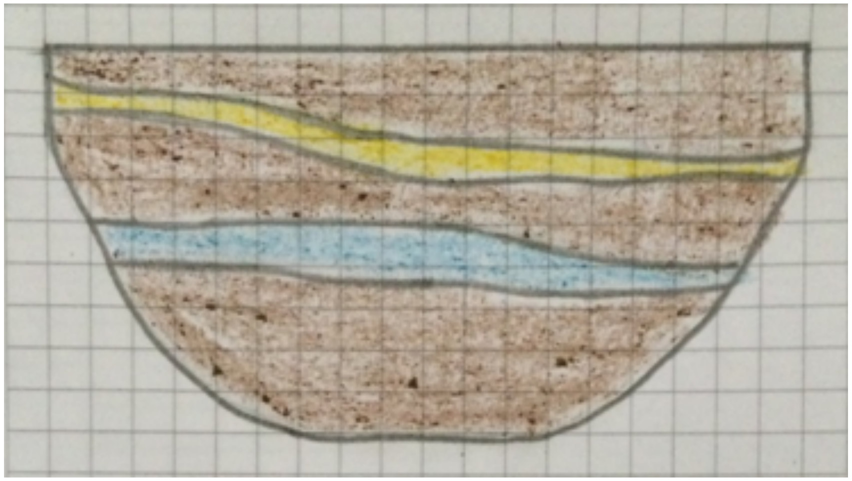
- This is a *Stop-Go* process that controls risk for the investor and of which is done by providing geological and economic considerations in producing a mine. Each stage has to be evaluated before the investor can proceed to the next stage.If not feasible,the project has to be reviewedagain using other assessment techniques.

- Demonstration 1 (core sampling)
- The teacher will demonstrate how geologists delineate mineral deposits beneath the Earth's surface (modified from the activity "Cupcake Core Sampling"; source:The Life Cycle of a Mineral Deposit – A Teacher's Guide for Hands-On Mineral Education Activities)

Instruction

A. *Pre-class preparation (teacher):*

Mold the clay into several layers from bottom to top: thick brown, thin blue, thick brown, thin yellow, thick brown. Differences in thickness with irregularities in the layers are encouraged. Put the molded clay in abowl so that the students will not be able to see the thicknesses of each layer (in the same way that a geologist cannot see the interior of the Earth).



A sample illustration of how the clay is molded in the bowl

B. During Class:

Draw a scaled representation of the bowl on the board.

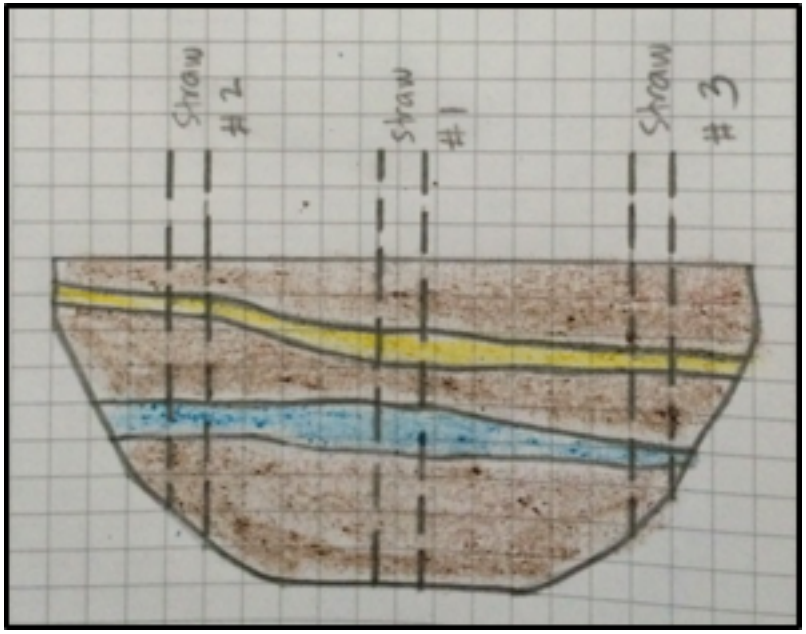
Bring the student closely to the model.

The teacher can ask the students how they might get information about what is inside the bowl by just using the straw without removing the clay from the bowl. (*Some students may suggest using the straw to take a core sample).*

Demonstrate to students how to rotate and push (in one direction only) a sturdy straw into the clay and pull it out. The clay accumulated in the straw represents a core sample. The process represents core drilling, a method done to investigate how the rocks underneath the Earth's surface look like.

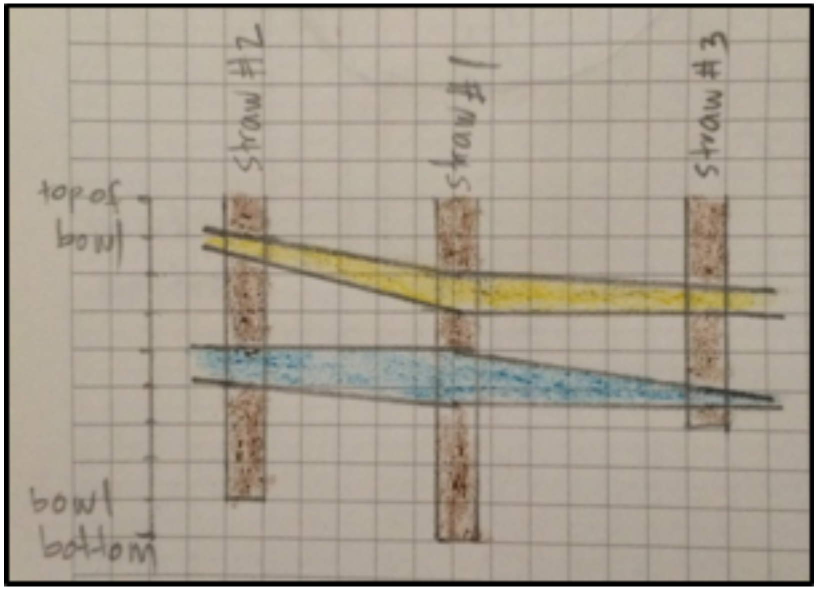
Get one straw, position it in the middle of the bowl and drill (push in rotating manner) vertically down the bottom. Pull the straw out. Ask the students to measure the thickness of each clay layer collected from the straw. In reality, the sample collected in the straw is comparable to a core sample.Ask another student to include the observations in the drawings on the board. Make sure to have the drawing representation on scale of each layer similar to the bowl.

Drill the second and third holes in the left side and right side of the bowl, respectively. Include the findings in the drawing.



Sample illustration of the location of the three straws drilled into the molded clay.

Ask the students to make correlation of the different layers they discovered from the drill holes by connecting the layers of the same color.



Sample illustration on how the correlation of the 3 drill holes would look like. Observe how the layers (or veins) differ from the actual set-up. This would imply that with more drill holes the correlation would appear more accurate.

Discussion:

Students should be able to answer the following questions after the demonstration:

1. Are the mineral deposits (represented by the yellow clay for gold and blue clay for copper) evenly distributed in the bowl? Explain its relevance.

Answer: No.This is a representation of the actual mineral deposition -they are not deposited in an even thickness and concentration.

2.Can the drill cores indicate how deep the mineral deposits are?

Answer: Yes. Cores are representatives of what is in the drilling area. With proper measurements, the different layers underneath the surface can be identified.

- The questions under the activity can be given orally or in a short quiz. If given as a quiz, it is recommended that the discussions of the answers be done after the submission of papers.

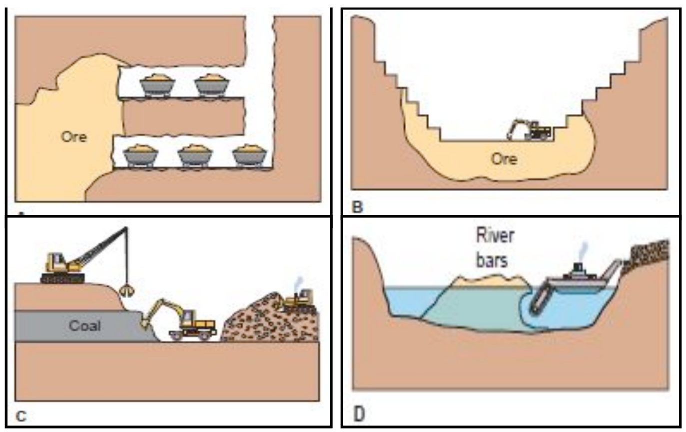
3.How can additional drillholes affect geological interpretations?

Answer: More drillholes could provide a clearer picture of what is underneath the surface and makes the interpretation more accurate.

B. Mining Methods

- Identify and explain some of the vital considerations needed to know on the different methods to mine a mineral deposit.
  - For example, upon knowing the geometry of the ore body, there are appropriate safety ways to mine the minerals and proper assessment of maximizing profit.

- Teacher should be able to identify the 2 main methods of mining.
  - Surface and underground mining



Types of mines: (A) Underground, (B) Surface (Open pit), (C) Strip, (D) Placer (being mined by a floating dredge) (Source: Physical Geology Earth Revealed by Carlson, 2011, p 564)

1. Surface Mining

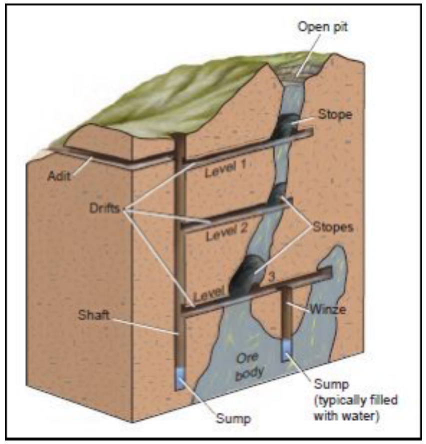
- Utilized to extract ore minerals that are close to Earth's surface
- Different types include open pit mining, quarrying, placer mining and strip mining.

600m deep open pit diamond mine (Source: CK12 Earth Science)

Limestone Quarry in northern Illinois(source: Physical Geology Earth Revealed by Carlson, 2011)

2. Underground Mining

- Utilized to extract ore minerals from the orebody is that is deep under the Earth's surface



A 3-D view of an underground mine showing the ore body at subsurface(source: Physical Geology Earth Revealed by Carlson, 2011 p565)

C. The Milling Process

- Explain to the students that the materials extracted or "mined" are rocks composed of both ore and waste material (part of the rock which contain very little or no element or mineral of economic value). The extracted rocks will undergo processes of mineral (e.g. metal) separation and recovery.
- Recovering the minerals from the oreand waste materials can involve one or more processes where in the separation is usually done in a mill.
- Crushing and screening are the first stages of controlled size reduction followed by grinding where the rocks are pulverized

- Discuss some examples of milling or recovery methods or processes

1. **Heavy media separation:** The crushed rocks are submerged in liquid where the heavier/denser minerals sink thus are separated from the lighter minerals. This is commonly used to separate chalcopyrite from quartz before the refining processes of extracting copper.

2. **Magnetic separation:** If the metal or mineral is magnetic, the crushed ore is separated from the waste materials using a powerful magnet.

3. **Flotation:** The powdered ore is placed into an agitated and frothy slurrywhere some minerals and metals based on physical and chemical properties may either sink to the bottom or may stick to the bubbles and rise to the topthus separating the minerals and metals from the waste.

4. **Cyanide heap leaching:** This method used for low-grade gold ore where the crushed rock is placed on a "leach pile" where cyanide solution is sprayed or dripped on top of the pile. As the leach solution percolates down through the rocks, the gold is dissolved into the solution. The solution is processed further to extract the gold.

The waste material is either used as a backfill in the mine or sent to a tailings pond, while the metals are sent for further processing

- Demonstration 2 (Flotation)

Teacher to demonstrate the concept of flotation process (copied from https://www.mineralseducationcoalition.org/sites/default/files/uploads/molybdenum.pdf, page 7).

Instruction:

Mix ½ cup of dry roasted peanuts with ½ cup raisins. Add ½ of the mixture to each of the 2 drinking glasses. Fill the first drinking glass to 2/3 full with plain water. Observe what happens. Fill the second drinking glass to 2/3 full with soda water. Observe and compare results to the first drinking glass.

Discussion:

1. Explain what happens to glass 1.

Answer: Both the raisins and peanuts sink to the bottom of the drinking glass containing plainwater. This is because the densities of these objects are both heavier than water.

- Bring the students closer to the demonstration area. Make sure everybody is attentive before starting the activity.

2. Explain what happens to glass 2.

Answer: Bubbles from the soda water were notably attached with raisins and peanuts, altering the densities of the 2 objects.The raisinsthat sink indicated that its density is heavier than the soda water. On the other hand, the peanuts float implying a lighter density as compared to the soda water.

Conclusion: Flotation is one method used in the industry for mineral extraction. Frothers are added to the solution to lower the surface tension of the water. The froth must be strong enough to support the mineral but weak enough to break down in launders. Common frothers are alcohols and glycols.

D. Environmental Impacts

- Enumerate the possible environmental impacts of irresponsible mining:
  - Improper mining can cause flooding, erosion, subsidence, water and air pollution, damage to wildlife and habitat.
- Discuss measures to prevent or mitigate the harmful effects of irresponsible mining:
  - Topsoil replacement using uncontaminated soil; reintroduction of flora and fauna; neutralizing acidic waters; backfilling and sealing of abandoned underground mines; stabilizing the slope of impacted area to reduce erosion, etc.
- Highlight the role of the government (environmental laws) and other organizations in the implementation of environmental programs:
  - Identify the functions and programs of the Mines and Geosciences Bureau (MGB), Environmental Management Bureau (EMB), Philippine Mine Safety and Environment Association (PMSEA), other environmental, non-government organizations that promote environmental awareness and protection in relation to mining.

PRACTICE (40 MINS)

Operating a Mine (modified combination of two activities, namely, Operating a Mine and Physical Separation of Minerals. Source: Bringing Earth Science to Life – Using Natural Resources pp15-19 and 31-33 http://www.edgeo.org/images/pdf/bringing-earth-science-to-life/natural-resources.pdf)

Groupings: 5 members per group

Instruction:

1. Each group will prepare their own surface mine model following the procedure below:
   a. In the 500ml bowl/container, thoroughly mix 350ml of sand, 50ml salt, 50ml iron filings, 50ml elbow macaroni.
   b. Put a thin layer of sawdust (about 10ml) all over the top of the bowl.

2. Ask the students to draw a picture of their model to have a record of how it looks like before mining.

3. Have the students mine the model by using a spoon as the mining equipment. In the newspaper, make 5 mounds of mined materials, placed side by side. Each mound must contain four scoops of mined material. (Explain to students that in reality, these mounds are called stock piles, which are collected eventually by trucks and delivered to the mill for processing).

4. Draw a picture of the model after mining.

5. Get one stockpile and extract the minerals in it. In case the extractable materials are not enough, add another stockpile.

6. Bring out the things to be used in separating the different materials from each other (e.g. magnet, ice bag/plastic, beaker/container, filter paper, tweezers and water). Promote discussions among groups on the methods to extract the different materials in the most productive way. Write the steps in the activity report.

Sample Separation Method:

1. *Use tweezers to pick up the elbow macaroni.*
2. *Wrap a magnet in a plastic bag and pass it through the mixture. When all iron filings have been collected, turn the bag inside out to contain iron filings.*
3. *Add water to the mixture. Mix thoroughly to dissolve the salt. Filter the solution to separate the salt (in liquid form) from the sand and sawdust. Allow the liquid to evaporate to collect the salt crystal (Note: Due to time constraint, evaporation may not be done. It can be assumed that salt can be collected as residue after evaporation).*
4. *Add new water to the sand and sawdust mixture. The sawdust will float and the sand will sink. Decant off the top part of the liquid containing the sawdust. Filter to collect the sawdust.*
5. *Filter the remaining liquid to collect the sand.*

7. Have students rehabilitate the surface of the mine by returning all of the country rock materials minus the valuable minerals (make assumptions that the other stockpiles are already processed and do not contain minerals anymore) into the pit.

Discussion:

1. From personal experiences and observations in the activity, describe the properties of the different materials used in the mixture.

	Density	**Solubility**	**Magnetism**	**Other Properties**
Sand				
Iron filings				
Macaroni				
Salt				
Sawdust				

2. Based on the above properties, design the steps that will separate the mixture.

Step	**Substance Separated**
1.	
2.	
3.	
4.	
5.	

3. What factors did you consider in selecting where to start mining the rocks?

   Possible answers include slope stability, closeness to facility (the place for stockpiling, etc.)

4. How has mining change the land?

   Possible answers include, change in elevation and slope, removal of topsoil and vegetation, etc.

5. What have you done to rehabilitate the land after mining?

ENRICHMENT

Special Report to be submitted in 2 weeks (group report, 5 members per group):

Research on a local mine (location, mining history in the area, ore type, mineral product, separation process, annual production, etc.); include the company's existing social, environmental and rehabilitation projects.

EVALUATION

Summary questions (Questions in regular font are easy questions while the ones in bold are hard):

1. What is the importance of the different stages of exploration?

   Answer: The different stages of mineral exploration allow the investor to systematically evaluate the potential and marketability of having a mineral project. Knowledge about the project is increased at every stage, and this knowledge serves as the basis whether to proceed with the project or not.

2. **In a newly acquired mineral project for exploration, is it possible to immediately drill in the area even without any subsurface investigation (e.g. geophysics and trenching)?**

   Answer: Yes, especially if the property has a good mineralized outcrops or exposure of mineralization on the surface. However, this is a bit risky for projects without surface manifestations of mineralization.

3. Describe some methods used in surface mining.

   Answer: Open pit creates big hole in the ground from which the ore is mined. Quarry is a type of open pit mine usually associated with the mining of non-metallic resources such as limestone, sand and gravel. Ore is removed in strips in a strip mining method. Ore can be extracted in strips as in strip mining.

4. **An open-pit mine may in the future be converted into an underground mine. Why would this happen?**

   Answer: When all the minerals at or near the surface have been extracted, and when the lateral extent of the project area cannot hold the stability of slopes as mining gets deeper, the only way to mine the deeper extent of the orebody is to go underground.

5. Enumerate several ways to rehabilitate a mined-out area.

   Answer: Topsoil replacement using uncontaminated soil; reintroduction of flora and fauna; neutralizing acidic waters; backfilling and sealing underground mines; changing the slope of impacted area to reduce erosion; etc.

6. **How is it possible for materials presently considered as waste become economically mineable in the future?**

   Answer: Economics play a great role in mining and mineral/metal prices are usually dictated by supply and demand. When supply is high and demand is low, metal prices drop, hence the need to mine only high grade ores. But when demand is high, even the low grade ores are being mined or are mixed to high grade ores to achieve economically profitable product.

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Practice Activity	Did not complete the activity and did not answer any of the questions	Activity completed on time and only correctly answered 1- 2 questions	Activity completed on time and correctly answered 3-4 questions	Activity completed on time; correctly answered all questions
Enrichment Project	Did not submit report on time; report is not complete	Report is submitted on time but is lacking of substance; report not well presented	Report is submitted on time; report is well-presented (organized flow of discussion with few instances straying from the topic) authors demonstrate acceptable understanding of topic (few corrections and misconceptions)	Report submitted on time; report is excellently presented (highly organized flow of discussion); authors demonstrate excellent level of understanding of the topic
Summary questions	Only 2 of the easy questions are correctly answered	Correctly answered the easy questions	Correctly answered the easy questions and 2 hard questions	Correctly answered all questions

ADDITIONAL RESOURCES:

1. Freudenrich C., Benner, J., Bethel, D. et al, Earth Science CK-12, 2009, p 77-80
2. https://www.cde.int/sites/default/files/documents/mineral_exploration_part_1.pdf (Accessed 25 Nov 2015)
3. https://www.cde.int/sites/default/files/documents/mineral_exploration_part_2.pdf(Accessed 25 Nov 2015)
4. http://www.edgeo.org/images/pdf/bringing-earth-science-to-life/natural-resources.pdf (Accessed 24 Nov 2015)
5. https://www.mineralseducationcoalition.org/sites/default/files/uploads/molybdenum.pdf (Accessed 23 Nov 2015)
6. https://www.mineralseducationcoalition.org/sites/default/files/uploads/copper_more_than_a_metal.pdf (Accessed 23 Nov 2015)

Earth Science

280 MINS

Earth Materials and Resources - Energy Resources

Content Standard
The learners demonstrate an understanding of the various sources of energy (fossil fuels, geothermal, hydroelectric).

Performance Standard
Make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competencies
Describe how fossil fuels are formed **(S11ES-Id-10)**,

explain how heat from inside the earth is tapped as a source of energy (geothermal) for human use **(S11ES-Ie-11)**, and

explain how energy (hydroelectric) is harnessed from flowing water **(S11ES-Ie-12)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- describe how fossil fuels are formed;
- explain how heat from inside the earth is tapped as a source of energy (geothermal) for human use;
- explain how energy (hydroelectric) is harnessed from flowing water; and
- create individual models explaining how fossil fuels are formed, and how geothermal and hydroelectric energy are harnessed for human use.

LESSON OUTLINE

Introduction	Communicating learning objectives	10
Motivation	Reflection Question	10
Instruction	Lecture	30
Practice	Group Activity	60
Enrichment	Group Activity	90
Evaluation	Group Case Study	80

Materials
Projector; LCD; Computer

Resources

TEXTBOOK:

(1) Carlson, D.H., Carlson, Plummer, C.C., and Hammersley, L., 2011. Physical Geology: Earth Revealed. McGraw-Hill. 645 p.

(2) Desonie, D., 2015. CK-12 Earth Science High School . http://www.ck12.org/earth-science/

(3) Junine, J.I., 2013. Earth Evolution of a Habitable World. Second Edition. Cambridge University Press. 304 p.

(4) Kirkland, K. 2010. Earth Science: notable research and discoveries. Facts on File, Inc., 212 p.

(5) Lutgens, F.K., Tarbuck, E.J. and Tassa, D., 2013. Essentials of Geology. 11th Edition. Pearson Prentice Hall, 554 p.

(6) Tarbuck, E.J. and Lutgens, F.K., 2008. Earth – An Introduction to Physical Geology. 9th Edition Pearson Prentice Hall, 703 p.

INTERNET RESOURCE:

(1) http://www.doe.gov.ph/doe_files/pdf/01_Energy_Situationer/2012-2030-PEP.pdf

(2) http://www.doe.gov.ph/doe_files/pdf/01_Energy_Situationer/2012-2030-PEP-Executive-Summary_revised.pdf

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following learning objectives using any of the suggested protocols (Verbatim, Own Words, Read-aloud)
   a. I can describe how fossil fuels are formed.
   b. I can explain how heat from inside the earth is tapped as a source of energy (geothermal) for human use
   c. I can explain how energy (hydroelectric) is harnessed from flowing water
   d. I can create a model explaining how fossil fuels are formed, and how geothermal and hydroelectric energy are harnessed for human use

- State the importance of energy and it's various sources and uses
- Initiate an opening discussion on the importance of energy to humans.
- Enumerate the different sources of energy, general, and identify which ones we utilize in the country.
- Cite some examples of highly developed (1st world) countries and relate how critical energy self-sufficiency is to their development and advancement.

- Enumerate the various energy sources which can be broken down into 2 broad categories: Non-renewable and Renewable. (Reference: Republic Act 9513 - Renewable Act of 2008)
  Non-Renewable Sources
  1. Coal
  2. Oil
  3. Natural Gas
  4. Nuclear

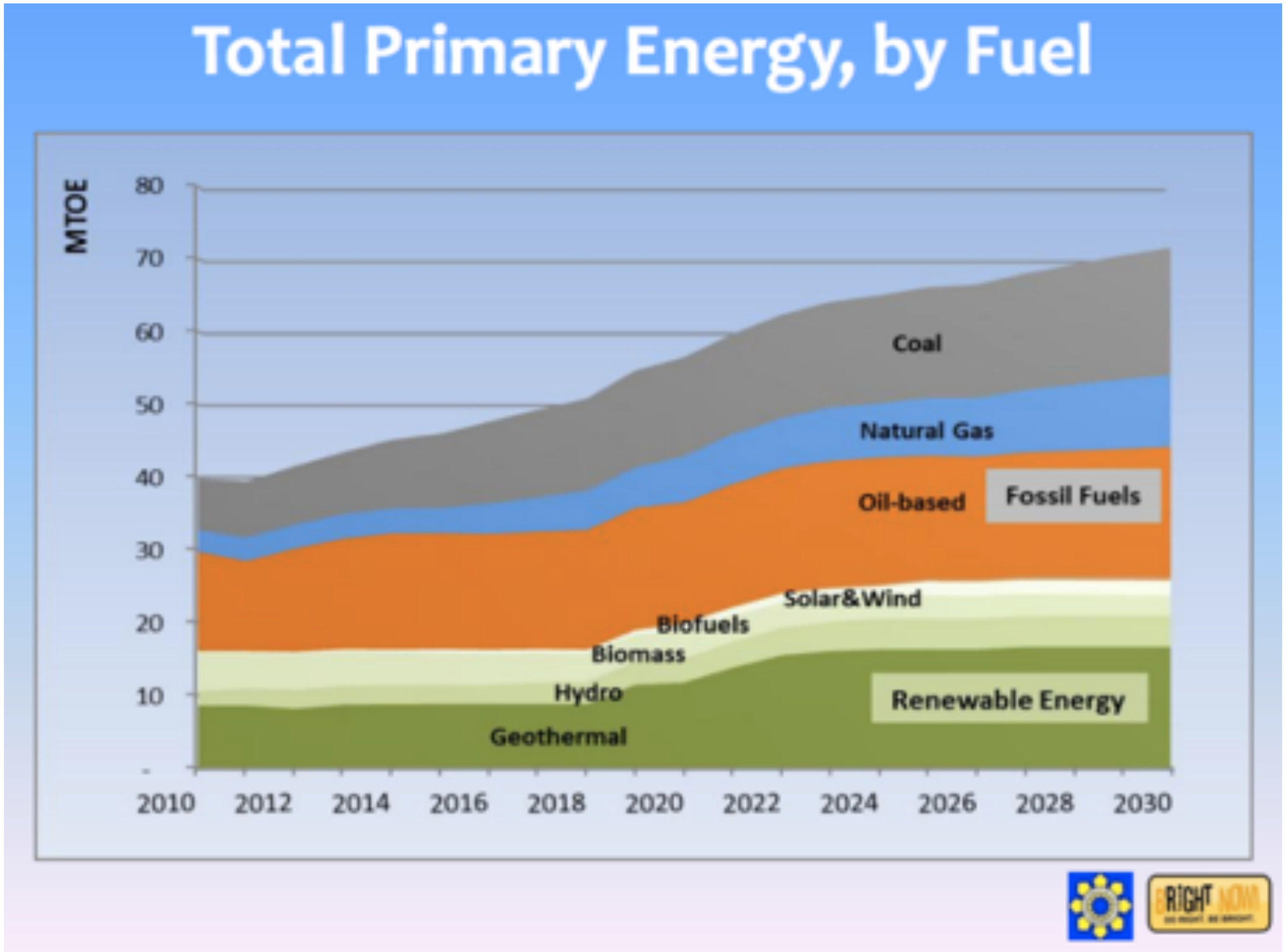
  Renewable Energy Sources
  1. Solar
  2. Wind
  3. Hydroelectric

Teacher tip

- Display the learning objective/s prominently on one side of the classroom and refer to them frequently during discussions. You may place a check mark once a lesson is done to give the learners an idea of their progress and create a sense of accomplishment as they progress through the lessons.
- The initial discussion on the importance of energy to a developing country like ours serves to stress the relevance of the key concepts that they will learn throughout the lesson.
- Display the charts and run through the total distribution of the various energy sources identified by the Philippine Department of Energy (DOE). Start a discussion by asking the class what is the biggest source of energy. Note that the ideal energy plan is to reduce reliance on imported energy sources and increase reliance on indigenous energy sources.
- Ask the class if they think reliance on indigenous energy sources is important for energy self-sufficiency and why.

4. Biomass
5. Geothermal

- The graph below was lifted from the Total Primary Energy Demand Forecast from Phil DOE Philippine Energy Plan 2012-2030. It shows the total primary energy demand, by fuel type, in MTOE (million tonnes of oil equivalent).

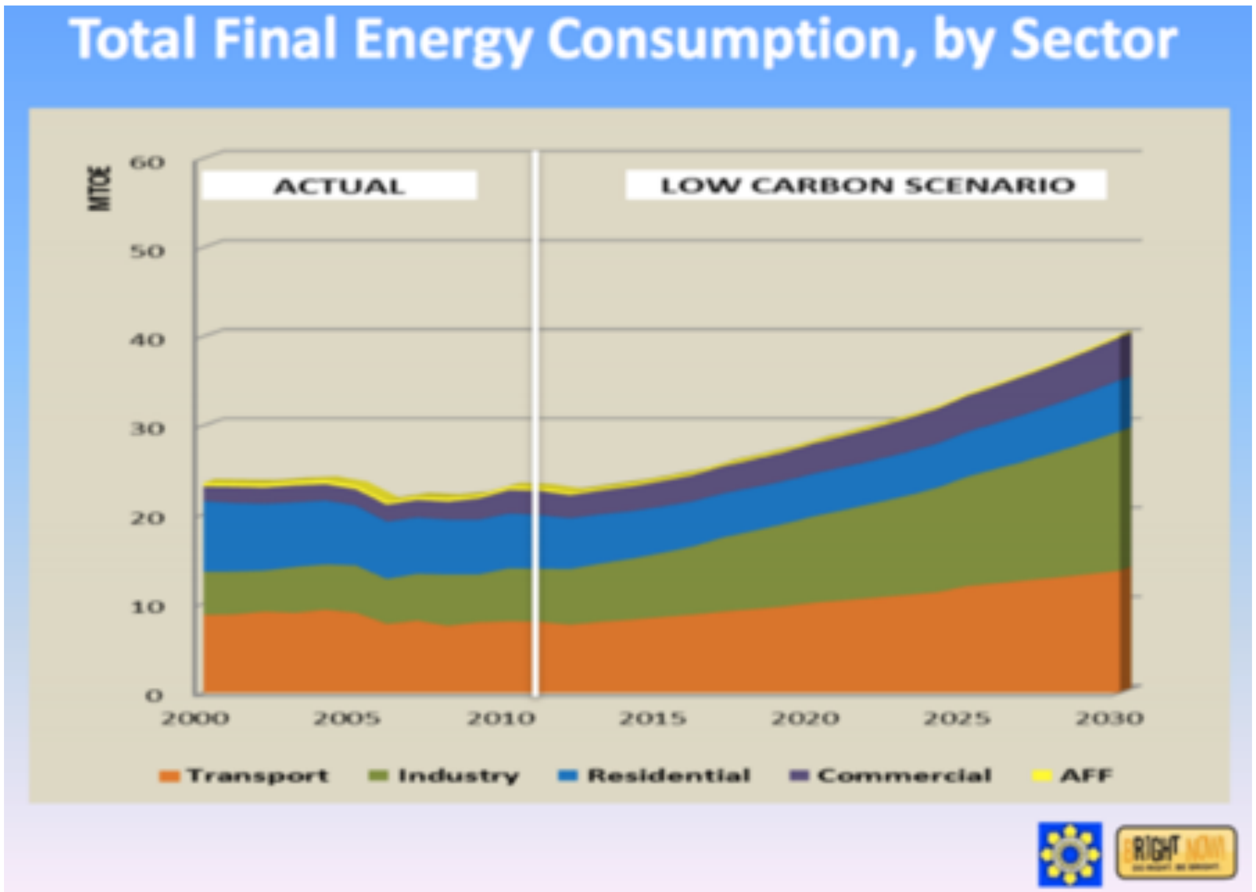


Teacher tip

- NOTE: MTOE (million tonnes of oil equivalent) or TOE (tonne of oil equivalent) is a unit of energy defined as the amount of energy released by burning one tonne of crude oil. It is approximately 42 gigajoules, although as different crude oils have different calorific values, the exact value is defined by convention; several slightly different definitions exist. The toe is sometimes used for large amounts of energy.
- Just like the previous activity, encourage class discussion by making sense of the graph. The most basic observation is that energy demand increases with population (even though population statistics is not presented).

- Enumerate the following uses of energy:
  1. Agricultural
  2. Transportation
  3. Residential
  4. Commercial
  5. Industrial

The graph below was lifted from the Total Primary Energy Demand Forecast from Phil DOE Philippine Energy Plan 2012-2030. It shows the Total Final Energy Consumption, by sector, in MTOE.



MOTIVATION (10 MINS)

- Ask the class this reflection question.

  "How important is energy to the advancement of society and how do we ensure self-sufficiency for the current and future generations (energy independence)?" The aim of this reflection question is for the learners to think about energy and its role in the advancement of society and come up with ideas on how energy indepence can be achieved. There are no wrong answers at this point. Note that this will be discussed in full in the Evaluation section where the Philippine Energy Plan 2012-2030 will be discussed through the case studies project. After about 5-6 minutes of idea sharing among the group members, ask for group volunteers to share their ideas on the subject. The important thing to establish after the discussions is the importance of energy in the advancement of society. All the other points will be discussed during the evaluation section.

Teacher tip

The class may be divided into small groups of twos or threes to facilitate idea sharing.

Note that this is a reflection question that doesn't need to be answered fully at this point. Its purpose is to stimulate thinking among the learners and for them to draw from what they already know and more importantly, to give real-life relevance to the lesson itself.

INSTRUCTION (10 MINS)

- Prior to the lecture proper, have the students recall previous lessons from junior high school on fossil fuels, geothermal and hydroelectric energy

- **Fossil Fuels**

  Q: What are fossil fuels and what are the different kinds?

  - Fossil fuels are fuels formed by natural processes such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels contain high percentages of carbon and include coal, petroleum and natural gas. Other more commonly used derivatives of fossil fuels include kerosene and propane.

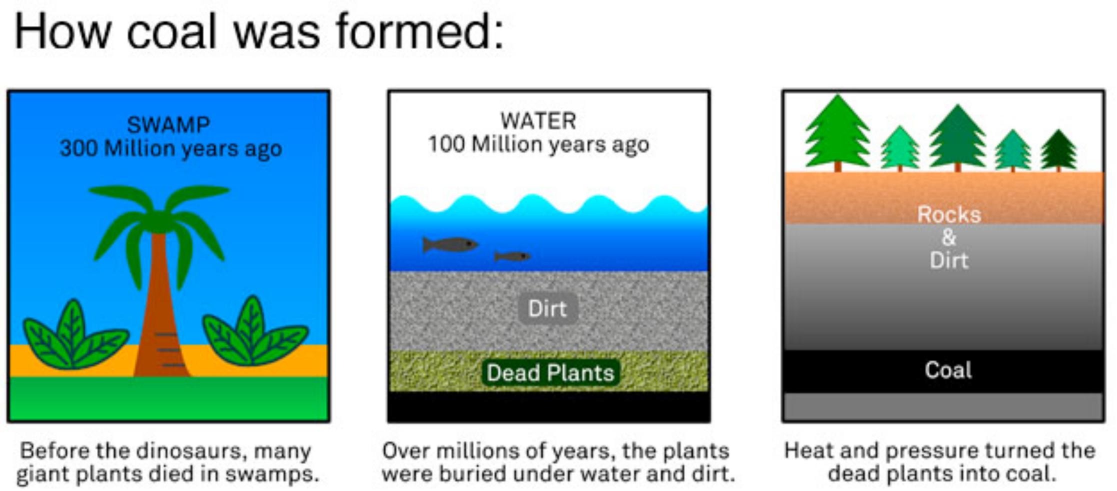
  Q: What is coal and how is it formed?

  - Like oil and natural gas, coal is a fossil fuel. It started forming over 350 million years ago, through the transformation of organic plant matter.

Teacher tip

Before the lecture proper, ask for volunteers to share what they recall from their previous lessons on energy from junior high school. List on the board key words that will arise from the discussion. You can add to this initial list more key words or phrases as you go through the class lessons. This is quite useful in showing the students how much they have learned in class.

Use of visual aids is strongly encouraged to enhance understanding of key concepts.



(Source: https://empoweryourknowledgeandhappytrivia.files.wordpress.com/2015/02/how-coal-was-formed.jpg)

- Coal is a combustible black or brownish-black sedimentary rock usually occurring in rock strata in layers or veins called coal beds or coal seams. The harder forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. Coal is composed primarily of carbon along with variable quantities of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen.

- Coalification is the formation of coal from plant material by the processes of diagenesis and metamorphism. Also known as bituminization or carbonification. It all starts with a swamp on the edge of a sedimentary basin, such as a lagoon or a lake. Tectonic activity raises sea levels, covering and killing vegetation. Plant debris accumulates and is buried under layers of mud and sand in a process known as sedimentation. This protects the debris from the air and slows down the decomposition process. The vegetation grows back, until the next flooding. The sedimentary basin gradually sinks under the weight of the sediments, and the layers of dead plants are subjected to rising temperatures that gradually "cook" them, leading to their transformation. The different stages of sedimentation turn cellulose, the main component of wood, from peat to lignite (brown coal), then sub-bituminous coal, followed by bituminous coal and, finally, anthracite. Anthracite has the highest carbon content.

Geological Time For The Formation of Coal

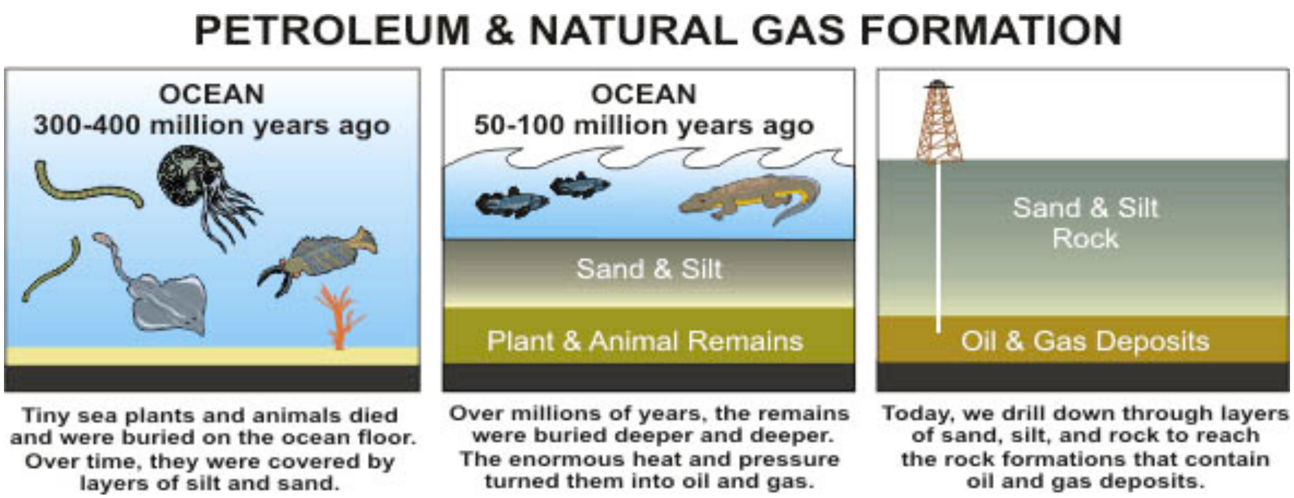
- The most favorable conditions for the formation of coal occurred 360 million to 290 million years ago, during the Carboniferous ("coal-bearing") Period. However, lesser amounts continued to form in some parts of the Earth during all subsequent periods, in particular the Permian (290 million to 250 million years ago), and throughout the Mesozoic Era (250 million to 65 million years ago).
- The accumulated plant matter buried during the Tertiary Era — less than 65 million years ago — is generally less mature. It is often in the form of lignite, which still contains a high content of volatile matter (bitumen and decayed wood) and has a lower carbon content. However, there is also some higher rank coal from the Tertiary Era, coal that matured early, heated by plate tectonics. Examples of this include Paleocene coal (65 to 55 million years ago), found in Columbia and Venezuela, and Miocene coal (20 million years ago), found in Indonesia. In Indonesia, where the geothermal gradient is very high, anthracite lies close to the surface.
- However, the deposits in the Moscow Basin have never gone beyond the lignite stage as it is too cold. Finally, recent accumulations (from 10,000 years ago to today) are very rich in fibrous debris known as peat, in which the shapes of branches and roots can still be discerned. This material was not buried deep enough to contain elemental carbon.

The Different Types of Coal

- There are several different types of coal. They are ranked according to their carbon and volatile matter content.
  - Anthracite is 86 to 98% pure carbon and 8 to 3% volatile matter. It is an excellent fuel that is still used to heat homes.
  - Bituminous coal contains 70 to 86% carbon and 46 to 31% volatile matter. It is used to make coke, used in metallurgy.
  - Sub-bituminous coal is 70 to 76% carbon and 53 to 42% volatile matter. It is burned in industrial boilers.

- Lignite is 65 to 70% carbon and 63 to 53% volatile matter. It is a low-grade fuel with a high moisture content that is used in industrial boilers.
- Peat consists of partially decomposed vegetation. Technically speaking, it isn't coal. It has a carbon content of less than 60% and is composed entirely of volatile matter. A poor fuel that was once used throughout Europe in the form of dried briquettes for heating, today it is used only in a few regions, such as Ireland.

What is petroleum (oil and gas) and how is it formed?



(Source: http://www.openlearningworld.com/World_Geography/imgs/figure_7.3.3.jpg)

How Oil and Gas Deposits are Formed

- Deep in the Earth, oil and natural gas are formed from organic matter from dead plants and animals. These hydrocarbons take millions of years to form under very specific pressure and temperature conditions.

- When a living organism dies, it is generally recycled in one of two ways:
  - It is eaten by predators, scavengers or bacteria.
  - Through exposure to ambient air or oxygen-rich water, it oxidizes. That means that the hydrogen, carbon, nitrogen, sulfur and phosphorus contained in the matter combine with oxygen atoms present in the air. The organic matter breaks down into water (H2O), carbon dioxide (CO2), nitrates, sulfates and phosphates that nourish new plants.

The Slow Formation of Source Rock

- A tiny proportion of this organic matter — about 0.1% — escapes this fate. Transported by water, it sometimes sinks to the bottom of the sea or large continental lakes. It is partly preserved in these poorly oxygenated environments, well away from tidal currents. It mixes with inorganic matter, such as clay particles and very fine sand, and with dead marine plankton (microscopic organisms). This mixture is transformed into dark, foul-smelling mud by anaerobic bacteria.
- Over time, this mud accumulates and hardens. Mud that contains at least 1 to 2% organic matter may be transformed into source rock, which eventually produces oil and gas deposits. This percentage may seem low, but that is because one or more specific requirements are necessary to enable the process to take place:
  - A hot climate that is conducive to the growth of large quantities of plankton.
  - A location near the mouth of a major river carrying a lot of plant debris.
  - No nearby mountains that could limit the volume of inorganic sediment within the rock.

Source Rock Subsidence

- The weight of accumulating sediment very slowly pushes the source rock further under the Earth's crust, by a few meters to a few hundred meters every million years or so. This gradual sinking is called subsidence and leads to the formation of sedimentary basins.

As it sinks below ground, the source rock is subjected to increasingly high temperatures, the organic matter that makes up the rock is crushed by the weight of the accumulating sediments, and the pressure increases by 25 bar every 100 meters on average. At one kilometer underground, the temperature is 50°C and pressure is 250 bar.

Under these physical conditions, the nitrogen, sulfur and phosphorus atoms are gradually converted into kerogen, an intermediate material made up of water, carbon dioxide, carbon and hydrogen, which is then transformed into oil or gas.

How Oil and Gas Forms

- At a depth of 2,000 meters, when the temperature reaches 100°C, kerogen starts to release hydrocarbons:
- Between 2,000 and 3,800 meters, it turns into oil. This depth interval is known as the oil window.
- When the source rock sinks further, to between 3,800 and 5,000 meters, production of liquid hydrocarbons peaks. The liquids produced become increasingly lighter and gradually turn into methane gas, the lightest hydrocarbon. This depth interval is known as the gas window.
- There are no hydrocarbons below a depth of 8 to 10 kilometers, because they are destroyed by the high temperature.
- The proportion of liquids and gas generated in this way depends on the type of source rock. If the organic debris is composed mostly of animal origin, it will produce more oil than gas. If it is composed mainly of plant debris, the source rock will produce mostly gas.
- With an estimated average sedimentation of 50 meters every million years, it takes 60 million years for dead animals to become liquid hydrocarbons. It is hardly surprising, therefore, that oil is classified as a non-renewable energy source.

How Oil and Gas Migrate

- Starting out from the source rock where they are formed, hydrocarbon molecules, which are light, set off on an upward journey to the surface. They accumulate in porous rock and are blocked by impermeable rock, thereby creating oil and gas deposits.

The Slow Rise to the Surface of Oil and Gas

- In the source rock, hydrocarbons are present in greater volumes under higher pressures than the initial kerogen. Little by little, they are expelled into the water-containing rocky layers located adjacent to the source rock. Because hydrocarbons are lighter than water, gas and oil rise upward by circulating between the mineral grains of the rock. This slow, constant movement away from the source rock is called migration.
- Migration is a complicated process. The rate depends on the permeability of the rocks they cross and the size of the molecules: gas molecules rise more quickly than oil molecules, because they are smaller and more mobile. Some hydrocarbon molecules are prevented from moving upward, either because they dissolve in the water contained in the rock they encounter (this affects gas much more often than oil) or because they adhere to the grains that make up the rock. This phenomenon is known as migration loss. These losses can be significant, especially if the oil and gas have a long way to travel. This is why some source rock hydrocarbons will never be suitable for development.

The Formation of Deposits in Reservoir Rock, Under Cap Rock

- A hydrocarbon deposit can only form in reservoir rock. Hydrocarbon molecules may accumulate in large quantities in this porous, permeable rock.
- Sedimentary rock is formed of solid particles deposited in seas, oceans, lakes or lagoons. The appearance of the rock is different depending on the size of these particles: very large grains form rock consisting of gravel, small grains bond together to form sand, and the smallest grains of all form clay or mud.
- There are also empty spaces within the rock that determine its porosity. The higher the percentage of space within the rock, the more porous the rock, which can contain large quantities of fluids such as water, oil or gas. Pumice is an example of a porous rock. These spaces, or pores, may be connected. Their connectivity is known as permeability, which is what allows fluids to circulate within the rock. Not all rock is both permeable and porous. Oil exploration engineers look for reservoir rocks — also known as reservoirs — that combine good porosity (large quantities of hydrocarbons) and good permeability (which makes it easy to extract these hydrocarbons because they flow unimpeded inside the rock).

- However, a hydrocarbon deposit will only form if the reservoir rock is capped by a layer of impermeable rock that prevents the oil or gas from rising vertically to the surface and forms a closed space that prevents the oil or gas from rising laterally. This cap rock forms a barrier and traps the hydrocarbons. While clay and crystallized salt (evaporite) layers form the best cap rock, any rock that is sufficiently impermeable — such as highly compact carbonates — can serve as a cap rock

Absence of Cap Rock

- If the hydrocarbon molecules are not prevented from rising, they will move through the reservoir rock and cannot accumulate.
- Oil or gas that reaches the surface at the end of its migration is exposed to bacteria and ambient air. This triggers complex chemical reactions that convert them into water and carbon dioxide. However, when significant quantities of hydrocarbons arrive at the surface more quickly than the final degradation process, the heaviest molecules may remain in the ground in the form of viscous, almost solid bitumen, buried at depths of a few meters. But these bitumen deposits will quickly disappear when the hydrocarbons stop arriving at the surface to replenish them.

From Traps to Commercial Deposits

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From Traps to Commercial Deposits

- Commercial oil and gas deposits occupy closed spaces created by deformations in geological layers. These spaces, known as traps, must be large enough to make developing the deposit economically viable. Reservoir rock, which is both porous and permeable, can hold a given quantity of hydrocarbons. Cap rock, which seals these reservoirs, stops the hydrocarbons from migrating upwards to the surface.
- But before a deposit can be formed, these hydrocarbons must also be sealed in a closed space called a trap.

About Oil and Gas Traps

- There are two main types of trap:
- Structural traps, which are formed by changes in geological layers caused by the movement of tectonic plates. Reservoir rock is sometimes deformed until it forms a completely sealed

space. These anticlinal traps are dome-shaped and the most common type of structural trap.

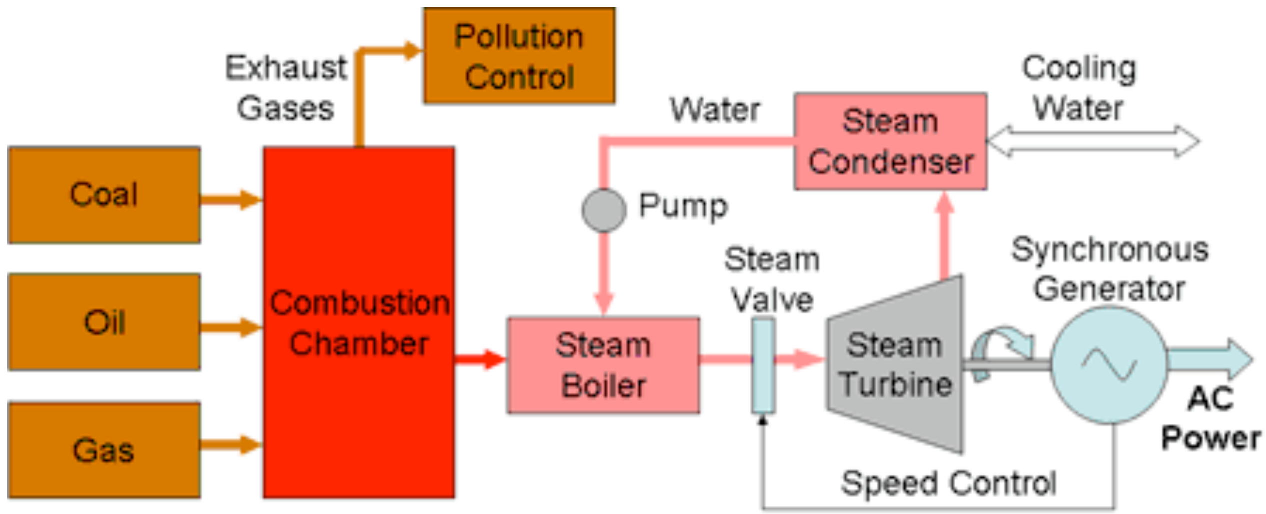
- Stratigraphic traps are made up of sedimentary layers that have not undergone tectonic deformation. In this case, a cap rock completely seals off the reservoir rock. For example, salt domes can act as cap rocks in this type of trap.
- The trap contains hydrocarbons, but also residual water. Because they are lighter than the water, the hydrocarbons migrate above the water table.
- Hydrocarbon traps can contain:
  - Oil, with significant quantities of dissolved gas.
  - Gas, with light liquid hydrocarbons known as condensate.
  - Both oil and gas. In this case, the gas, which is lighter than the oil, accumulates in the upper part of the trap.
- If the reserves are developed, the gas dissolved in the crude oil will be turned into liquefied petroleum gas (LPG), used primarily as fuel. Condensate will be refined to produce naphtha, used as a feedstock in the petrochemical industry, or kerosene, a fuel used in aviation.

Conserving Hydrocarbons

- Once trapped, the hydrocarbons are still at risk of deterioration that could prevent the formation of a commercial deposit.
- At depths of less than 1,000 meters, the accumulation can be infiltrated by meteoric water (precipitation). This water contains bacteria and oxygen that come into contact with the gas and oil, triggering chemical reactions that separate them into water and carbon dioxide.
- Bacteria and oxygen start by attacking light and medium hydrocarbon molecules. After a period of time, the initial oil is significantly degraded, leaving only viscous, solid hydrocarbons that are more difficult to extract than non-degraded oil or gas.
- Below 1,000 meters, the temperature is in most cases higher than 50°C and the bacteria that cause the degradation cannot survive. Although no longer threatened by bacteria or oxygen, traps located deep underground can be affected by tectonic activity — some traps have even been created this way. This can cause fractures and faults in the rock, breaking the seal and letting the hydrocarbons leak out of the trap. More violent tremors can even destroy the trap by substantially reducing or destroying the seal.

Fossil Fuel Power Generation

- Electrical energy generation using steam turbines involves three energy conversions, extracting thermal energy from the fuel and using it to raise steam, converting the thermal energy of the steam into kinetic energy in the turbine and using a rotary generator to convert the turbine's mechanical energy into electrical energy.



Fossil Fuel Powered Steam Turbine Electricity Generation

(Source: http://www.mpoweruk.com/images/fossil_fuel.gif)

Geothermal Energy

- As you descend deeper into the Earth's crust, underground rock and water become hotter. This heat can be recovered using different geothermal technologies depending on the temperature. But the heat resources in geothermal reservoirs are not inexhaustible.

(Source: https://d30y9cdsu7xlg0.cloudfront.net/png/2070-200.png)

Thermal Gradient

- The adjective geothermal comes from the Greek words ge (earth) and thermos (heat). It covers all techniques used to recover the heat that is naturally present in the Earth's subsurface, particularly in aquifers, the rock reservoirs that contain groundwater. About half this thermal (or "heat") energy comes from the residual heat produced when the planet was formed 4.5 billion years ago and about half from natural radioactivity.
- The temperature of geothermal water increases with depth, depending on the thermal gradient — the average rate at which the temperature rises with depth — of the region where it is found. The average value of the gradient worldwide is 3°C per 100 meters of depth, but it varies between 1°C and 10°C per 100 meters depending on the physical conditions and geology of the region.

The Different Types of Geothermal Energy

- Geothermal technologies differ with the temperature of geothermal water, which determines what can be done with it:
  - At 20°C to 90°C, geothermal heat and water are used for geothermal heating. This is called low-temperature geothermal energy (see Close-Up – "Low-Temperature Geothermal Energy: Heating”).
  - At 90°C to 160°C, the water is used on the surface in liquid form. It transfers its heat to another fluid, which vaporizes at low temperature and drives a turbine to generate power. This is called medium-temperature geothermal energy (see Close-up – "High-Temperature Geothermal Energy: Power”).
  - At temperatures above 160°C, the water turns into steam when it reaches the Earth’s surface. It drives turbines to generate power. This is called high-temperature geothermal energy.
- The different temperature ranges are general, and practices may vary according to the economic conditions of the particular location.

Availability of Geothermal Resources

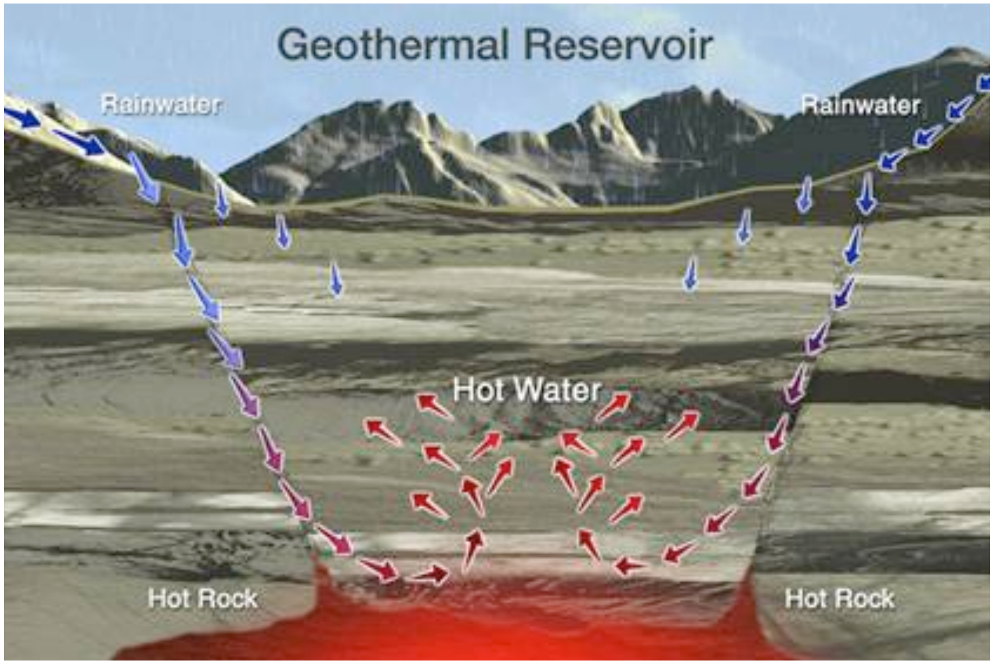
- This heat varies in different areas. The average geothermal heat flow — the energy available for any given surface area and period — on the surface is low. It averages 0.06 watts per square meter per year, or 3,500 times less than the solar energy flow received in a single year by the same surface area. This is why priority is given to using heat resources in those areas that are most likely to provide significant amounts of energy. These “geothermal reservoirs” are found in all the Earth’s sedimentary basins, but high-temperature geothermal energy is most likely to be found near volcanoes. In volcanic areas, geothermal heat flow can reach 1 watt per square meter.
- Geothermal reservoirs tend to be depleted with use, some faster than others. Their replenishment capacity depends on:
  - Heat sources within the Earth’s crust, mainly radioactivity and residual heat.
  - Energy from outside the reservoir (solar heat) for very low-temperature applications using heat pumps. Ensuring that these reservoirs will be reheated is especially crucial for geothermal heat pumps: external factors, such as low winter temperatures, cool the subsurface, meaning that less heat is available to be harnessed.

- The circulation of groundwater that is reheated on contact with heat sources located away from the reservoir before returning to the reservoir.

- Therefore, these heat resources must be replenished to use a reservoir in a sustainable manner. This involves capping the amount of heat used and putting a time limit on the operation of the site.
- In addition, the availability of geothermal energy is geographically limited. Significant losses occur when heat is transported over long distances. This can cause problems, because production sites cannot always be located close enough to the place of consumption to meet energy needs.

How is heat from inside the earth tapped as a source of energy for human use?

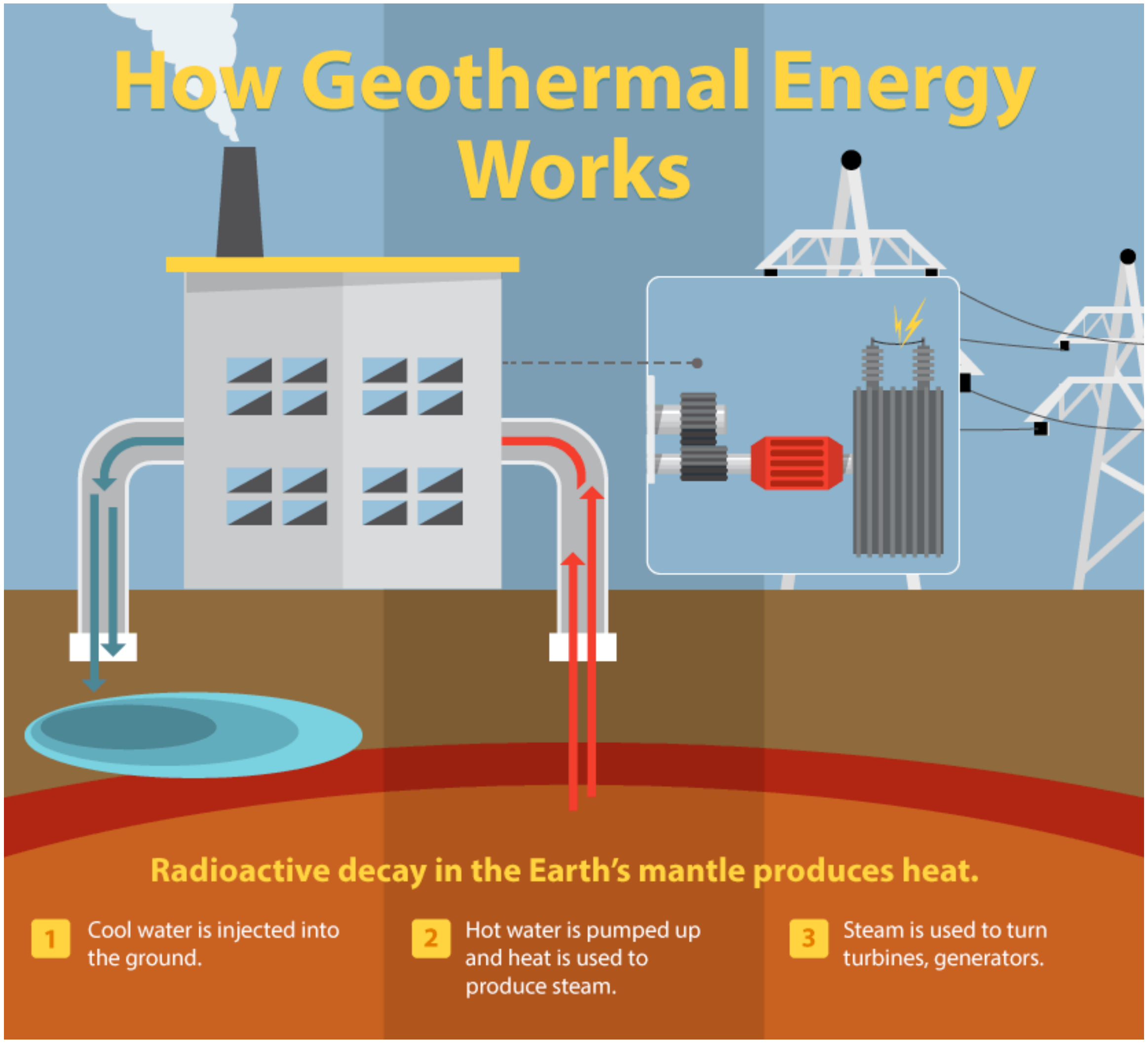
- Thermal energy, contained in the earth, can be used directly to supply heat or can be converted to mechanical or electrical energy.



(Source: http://geo-energy.org/images/basics_clip_image002_0006.jpg)

Teacher Tip

The picture shows the Negros (Palinpinon) Geothermal Power Plant, operated by the Energy Development Corporation, located at Valencia, Negros Oriental, Philippines



(Source: https://www.fix.com/assets/content/15694/geothermal-energy.png)

High-Temperature Geothermal Energy: Power

- Medium and high-temperature geothermal energy harnesses extremely hot water and steam from beneath the Earth to generate electricity in dedicated power plants.

(Source: http://www.energy.ca.gov/geothermal/images/geysers_unit_18.jpg)

Global Resources

- Global high-temperature geothermal energy resources used for power generation are found in a relatively few countries, in areas characterized by volcanic activity. They are mainly located in Asia, the Pacific islands, the African Great Lakes region, North America, the Andean countries of South America, Central America and the Caribbean.

- Around 20 countries in the world produce geothermal power, for a total installed capacity of 10.93 GW. It plays an essential role in some countries like the Philippines, where it accounts for 17% of electricity produced, and Iceland, where it represents 30%. Global installed capacity is projected to double by 2020.

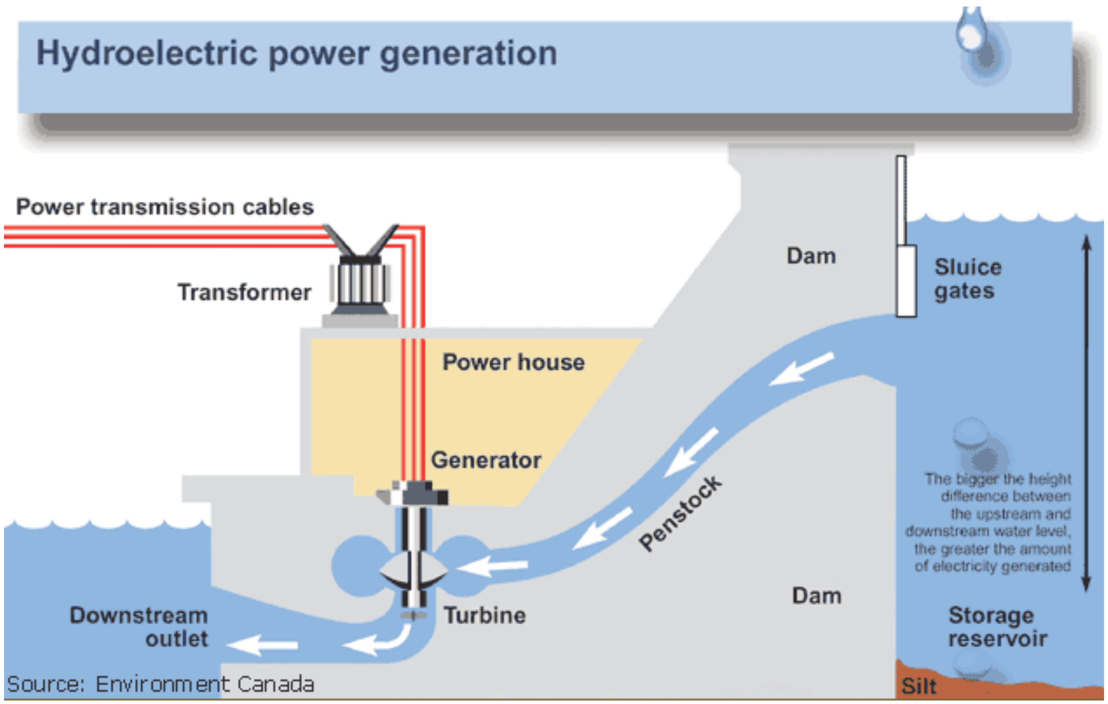
Medium-Temperature Geothermal Power Plants

- Geothermal water at temperatures of 90 to 160°C can be used in liquid form to generate power; this is called medium-temperature geothermal energy.
- This technology involves power plants that harness groundwater via geothermal wells. This type of power plant is built near aquifers located at depths of 2,000 to 4,000 meters. In volcanic areas ("hotspots"), where the subsurface holds more heat, the water used by the power plants is sometimes found closer to the surface, at depths of less than 1,000 meters.
- In these plants, water that has been pressurized to stop it boiling circulates through a heat exchanger. This equipment contains pipes filled with geothermal water that are in contact with pipes filled with another fluid, generally a hydrocarbon. When it comes into contact with the water-filled pipes, the fluid heats up, boils and vaporizes. The steam obtained drives a turbine that generates power. In the process, the steam cools, returning to its liquid state before being reused in another production cycle.

High-Temperature Geothermal Energy in Volcanic Areas

- If the geothermal water is hotter than 160°C, it can be used directly in the form of steam to drive turbines and generate power. This is called high-temperature geothermal energy. This principle was applied as long ago as 1913 in the world's very first geothermal power plant, in Larderello, Italy.

- This type of power plant uses water from water tables in volcanic regions, at depths of 1,500 to 3,000 meters. On very rare occasions, the water is present in the reservoir in the form of steam. In 95% of cases, the water is liquid. The drop in pressure experienced by the liquid in the wells as it flows to the surface causes some of the liquid to become vapor.
- At the surface, the liquid water is separated from the dry steam in a separator. The dry steam is fed to the turbine, while the liquid water can be vaporized again by reducing its pressure even further. The residual liquid water is injected back into the reservoir.
- Medium and high-temperature geothermal energy is used in a wide variety of applications. In industry, for example, geothermal water and steam can be used to wash and dry wool. They can also be used to manufacture pulp or treat biomass.



(Source: http://water.usgs.gov/edu/graphics/wuhytypicalplant.gif)

Hydropower, the Leading Renewable Energy

- Water energy encompasses both plants installed on land — on rivers and lakes — and ocean energy, which is still being developed and harnesses the force of waves, tides and currents. Widely used for decades, hydropower plants are the world's leading renewable energy source, producing 83% of renewable power.

(Source: http://www.eco-business.com/media/uploads/ebmedia/fileuploads/shutterstock_168301589_hydro_news_featured.jpg)

- The kinetic energy generated by moving water has been used by humankind for centuries, to drive watermills that produce mechanical energy. Modern hydropower, sometimes referred to as "white coal," is harnessed in plants where electricity is generated. Around 40 countries use hydropower to produce more than a fifth of their electricity1. Hydropower accounts for 16% of electricity worldwide, behind coal and gas, but ahead of nuclear.

From Dams to Plants

- A hydroelectric power plant has three main components:
  - A dam that creates a large waterfall and stores enough water to supply the plant at all times. As well as producing and storing energy, a dam also helps to regulate flooding.
  - A penstock that channels water from its natural environment (river or lake) to supply the dam reservoir. It may be an open channel, a tunnel or pipeline.
  - A powerhouse that houses the turbines driven by the waterfall and the generator driven by the turbines.

Types of Hydropower Plant

- The type of plant varies with the site's configuration, the waterway and the intended use. Run-of-river plants produce energy using the flow of the river. With dams less than 25 meters high, these "small hydro" plants generate power continuously to meet daily needs.
- Off-stream plants are modular, meaning that energy can be produced on demand, with dams used to create reservoirs that can be released as required. On lakes, water falls from a significant height (over 300 meters); on locks, from between 20 and 300 meters.
- Pumped storage power plants are specifically designed for modular operation. They have two reservoirs at different heights. When demand requires, water is released from the higher reservoir to the lower reservoir. When there is excess production — for example, from wind or solar sources — the surplus electricity is used to pump water into the higher reservoir.

Site Selection and Financing

- First, the right topographical, geological and hydrographical conditions are required. The biggest hydropower producers are countries crossed by fast-flowing rivers and mountainous countries. Gorges in rivers are good places for building dams. Similarly, a large flat valley is ideal for holding water. There must be sufficient rainfall in the catchment area (all upstream water).
- Large and medium-size dams are very expensive to build. Governments are increasingly trying to obtain funding from private sources or large international organizations such as the World Bank for these projects. But because the payback period is seen as too long, hydropower projects have difficulty attracting investors. The future of hydropower depends to a large extent on the persuasiveness of states and potential public-private partnerships.

The Advantages of Hydropower

- The water used to generate hydropower is renewable and storable, meaning it can be used at peak consumption times and then reused. This way of storing potential energy is particularly efficient as a hydro plant can reach its maximum rated capacity in just a few minutes. By way of comparison, a thermal energy plant takes around 10 hours to reach full capacity and a nuclear reactor takes four times longer than that.
- Hydropower is extremely efficient, with 90% of the water's energy converted into electricity. In addition, hydropower plants do not generate greenhouse gases and other emissions.
- While construction is a capital intensive, operating and maintenance costs are low. Plants have an extremely long life and the technology is highly reliable. In France alone, of the 60-odd large dams still in use, many were built before 1960. The oldest, located in the Nièvre region, began operating in 1858.
- With all these advantages, developing hydropower can only be beneficial. However, it still presents difficulties.

PRACTICE (120 MINS)

Group Activity

- Discussion and presentation on current energy situation (Primary Energy Supply, Fuel Input Mix for Power Generation, Power Generation Mix and Final Energy Consumption).
- Provide the learners with web links to the Phil DOE Philippine Energy Plan 2012-2030
  - (http://www.doe.gov.ph/doe_files/pdf/Researchers_Downloable_Files/EnergyPresentation/PEP_2012-2030_Presentation_(Sec_Petilla).pdf
  - http://www.doe.gov.ph/doe_files/pdf/01_Energy_Situationer/2012-2030-PEP.pdf).
- If internet is not available, print outs of the same should be made available.
- The figures below will serve to guide the discussion. These were lifted from the Philippine Energy Plan 2012-2030.
- This serves as a follow up exercise for the learners after learning the fundamental concepts on the different types of energy and how they are formed and harnessed for human use. It also serves as a build up exercise prior to the Evaluation exercise which serves to address the performance standard of making a plan that the community may use to conserve and protect its resources for future generations.

Teacher Tip

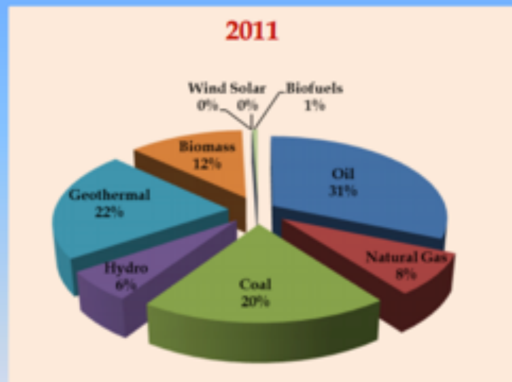
- The Philippine Energy Plan 2012-2030 will serve as the primary resource material to guide the discussion.
- The 2012-2030 Executive Summary (Revised) can also be used as a supplementary material, if necessary. Link: http://www.doe.gov.ph/doe_files/pdf/01_Energy_Situationer/2012-2030-PEP-Executive-Summary_revised.pdf

Where Are We Now

Primary Energy Supply

	2011
Total Energy (MTOE)	**39.4**
Self-sufficiency (%)	**60.0**
Shares (%)	
Renewable Energy (RE)	**40.7**
Green Energy (RE + Natural Gas)	**48.7**

Note:
MTOE – Million Tons of Oil Equivalent

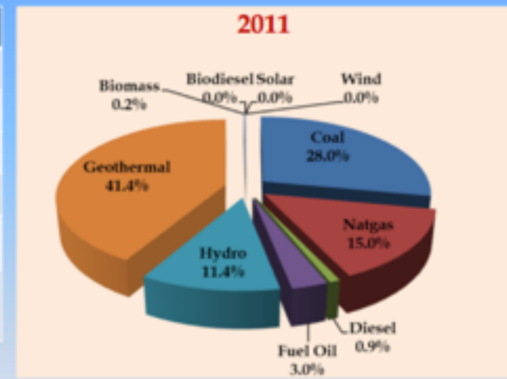


Where Are We Now

Fuel Input Mix for Power Generation

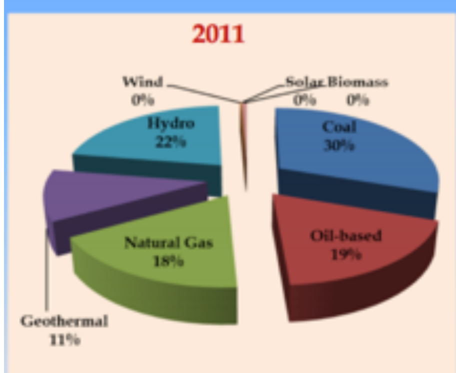
	2011
Total Energy (MTOE)	**20.6**
Share to TPES (%)	**52.4**
Self-sufficiency (%)	**68.1**
Shares (%)	
Renewable Energy (RE)	**53.0**
Green Energy (RE + Natural Gas)	**68.1**

Note:
MTOE – Million Tons of Oil Equivalent
TPES – Total Primary Energy Supply



Where Are We Now

Power Generation Mix



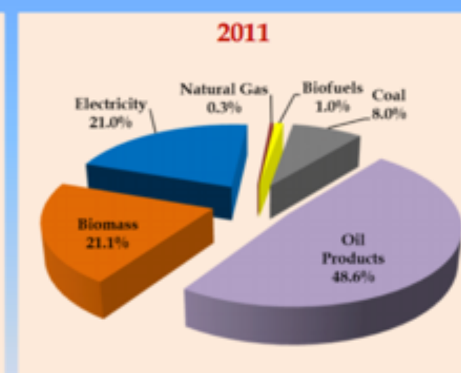
Installed Capacity (MW) – 16,162

Total Generation (GWh) – 69,050

Where Are We Now

Final Energy Consumption

By Sector



By Fuel

Total Energy Consumption (MTOE) – 23.0

Teacher Tip
It is good practice to conduct a debrief after each class activity. This gives an opportunity to fill any knowledge gaps in the discussion, correct misconceptions and answer any lingering questions.

ENRICHMENT (90 MINS)

- Debrief of the previous class activity. Supplement knowledge gaps (not captured during class activity). (10 minutes)

- Group Activity - Creating individual models as learning aids to demonstrate how fossil fuels (coal, oil and natural gas) are formed, how geothermal and hydroelectric energies are tapped for human use. This could be given as homework so as not to consume classroom time. Each group will be given 15 minutes to present - for a total of 60 minutes. (60 minutes)

- The models will serve as a learning reinforcement of the knowledge they have acquired during the lecture. It enhances assimilation. Since each group will only get to work on one model, each group can always spend time on their own to examine models created by other groups. These models will be displayed in the classroom for the duration of the quarter and as such may serve as a review aid.

Rubrics for assessing models:

1. Completeness of model (visual aid) in detailing how fossil fuels are formed/how geothermal and hydroelectric energies are tapped for human use - 40%
2. Conciseness and clarity of presentation/explanation of the model - 30%
3. Creativity and resourcefulness in creating the model - 20%
4. Group's effective use of the allotted 15 minutes to fully explain the model. - 10%

Total Mark = 100%

- Review session covering learning outcomes (20 minutes)
- Go through the learning outcomes one by one and ask the students if they feel that the learning activities proved sufficient in achieving each learning outcome. If everyone is satisfied and there are no further questions, proceed to the Evaluation section. Otherwise, this review session will serve to fill any knowledge gaps or any questions from the lessons covered so far.

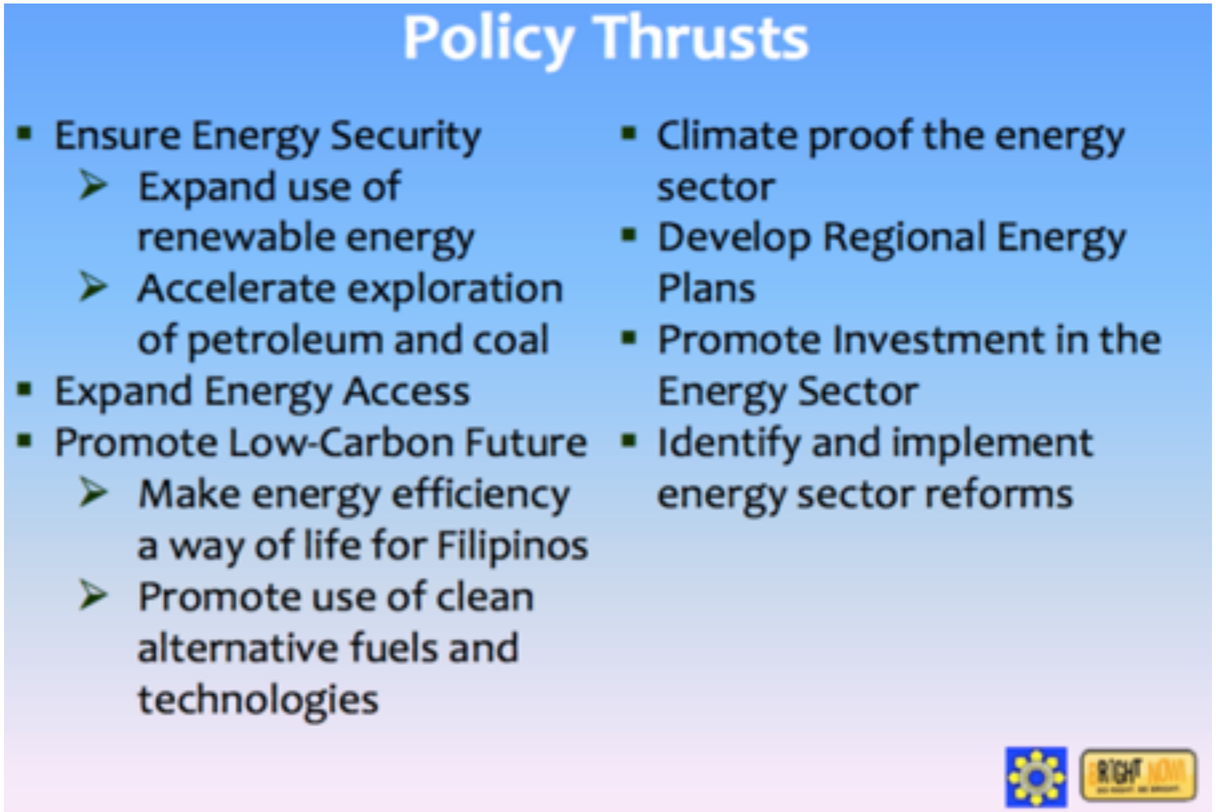
EVALUATION (90 MINS)

- Written Assessment covering theory questions to evaluate the learners’ understanding of key concepts and definitions of fossil fuels (coal, oil and natural gas), geothermal and hydroelectric energy, and the processes by which they are harnessed for human use. This written assessment serves to check whether the learners' have fully achieved the learning outcomes.

- Case Study - The objective of the case study is to make the learners fully grasp, not just the “how” - how are these different sources of energies formed and how they are harnessed/processed for human use, but also the “why” - the importance of energy to humans and its integral role in the development of nations. Although the case study may seem disconnected with the learning outcomes, it actually serves as a concluding activity that is directly tied to the performance standard
  - Make a plan that the community may use to conserve and protect its resources for future generations. Essentially, it synthesizes the theoretical foundation lessons and extends them into the field of "application", which makes their learning experience a truly real world one.
  - The case study should be assigned right after the instruction session covering how the different energy sources are formed and how they are harnessed for human use.
  - Using the previous groupings during the enrichment activity, divide the class into groups and conduct research on how the Philippines, through the Department of Energy, will ensure energy self-sufficiency while safeguarding the environment for future generations. This may seem like a daunting exercise for junior high school students but the goal is to get them to think outside of the classroom environment and relate what they learn in a classroom environment to the “real world”. This gives more meaning and importance to what they learn inside the classroom as it stresses its direct impact to our society. Make sure to assess each group’s progress as early as two days after the case study has been assigned. This will ensure that they are on track with the exercise. In the event that they struggle with the exercise, ask them to start their research by looking up the DOE’s Philippine Energy Plan 2012-2030. Below is an excerpt of the Philippine DOE’s policy trusts that will guide their conduct of their case studies:

Teacher Tip

The case study should be assigned right after the instruction session covering how the different energy sources are formed and how they are harnessed for human use.



Teacher Tip

The case study should be assigned right after the instruction session covering how the different energy sources are formed and how they are harnessed for human use.

- Review the learning outcomes one last time to round up the class session. This will reaffirm to the students that they have fully learned what they set out to learn.
  - Describe how fossil fuels are formed.
  - Explain how heat from inside the earth is tapped as a source of energy(geothermal) for human use
  - Explain how energy (hydroelectric) is harnessed from flowing water
  - Create individual models explaining how fossil fuels are formed, and how geothermal and hydroelectric energy are harnessed for human use

Earth Science

Energy Resources: Human Activity and the Environment

Content Standard
The learners demonstrate an understanding of waste generation and management.

Performance Standard
Prepare a plan that the community may implement to minimize waste when people utilize materials and resources

Learning Competency
Cite ways to address the different environmental concerns related to the use of fossil fuels, geothermal and hydroelectric energies **(S11ES-Ie-f-13).**

Specific Learning Outcome
At the end of the lesson, the learners will be able to:

1. identify ways to address the different environmental concerns related to the use of fossil fuels, geothermal and hydroelectric energies.

255 MINS

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Video	10
Instruction	Lecture	30
Practice	Short Quiz and Group Activity	120
Enrichment	Group Activity Reflection	30
Evaluation	Student-Directed Project	60

Materials
Internet access; computer; LCD or projector

Resources

TEXTBOOK:
(1) Carlson, D.H., Carlson, Plummer, C.C., and Hammersley, L., 2011. Physical Geology: Earth Revealed. McGraw-Hill. 645 p.
(2) Desonie, D., 2015. CK-12 Earth Science High School . http://www.ck12.org/earth-science/
(3) Junine, J.I., 2013. Earth Evolution of a Habitable World. Second Edition. Cambridge University Press. 304 p.
(4) Kirkland, K. 2010. Earth Science: notable research and discoveries. Facts on File, Inc., 212 p.
(5) Lutgens, F.K., Tarbuck, E.J. and Tassa, D., 2013. Essentials of Geology. 11th Edition. Pearson Prentice Hall, 554 p.
(6) Tarbuck, E.J. and Lutgens, F.K., 2008. Earth – An Introduction to Physical Geology. 9th Edition Pearson Prentice Hall, 703 p.

INTERNET RESOURCE:
(1) http://www.eia.gov/
(2) http://environ.andrew.cmu.edu/m3/s3/11sources.shtml

VIDEO LINKS
(1) https://www.youtube.com/watch?v=gvuzuyEKLd8

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following learning objective:
    a. Identify ways to address the different environmental concerns related to the use of fossil fuels, geothermal and hydroelectric energies

Teacher tip

Display the learning objective/s prominently on one side of the classroom and refer to them frequently during discussions. You may place a check mark once a lesson is done to give the learners an idea of their progress and create a sense of accomplishment as they progress through the lessons.

MOTIVATION (10 MINS)

- Deepwater Horizon-BP Oil Spill Video Playback. (Duration: 2 minutes)
  This is the largest marine oil spill in history, caused by an April 20, 2010, explosion on the Deepwater Horizon oil rig - located in the Gulf of Mexico, approximately 41 miles (66 km) off the coast of Louisiana—and its subsequent sinking on April 22.
- Although not a local example, being the worst marine disaster in recent history, it allows them to connect to a real-life problem that we face in the process of searching for much-needed energy for development. It sets the tone for the next section that discusses the ways to address different environmental concerns related to the use of fossil fuels, geothermal and hydroelectric energies.
- Video link: https://www.youtube.com/watch?v=gvuzuyEKLd8
- The teacher may allot 5-8 minutes to elicit any reactions on the video.

Teacher tip

The video link is provided. A copy of the video is also provided, in case internet connection is not available.

INSTRUCTION (30 MINS)

- Lecture Proper: Lecture and discussion on ways to address different environmental concerns related to the use of fossil fuels, geothermal and hydroelectric energies
- All energy production and use has environmental impacts. Fossil fuels and nuclear produce more solid, liquid and gaseous wastes, while renewables (geothermal and hydroelectric) face challenges of land and water use, visual and noise pollution. Making energy cleaner is usually more expensive, and these costs are passed along to the consumer.
- The table listed summarizes the various environmental impacts of each of the various sources of energy.

Energy Resources and related information

Energy Source	Energy production	Usage	Environmental Impact
Oil, Petroleum	Non renewable	· 38% of world's consumption in 2000 · Easily transported · Large portion in transportation industry	**Refining and consuming produce air, water, and solid waste pollutants**
Natural Gas	Non renewable	· 20% of world's consumption in 2000 · Flexible for use in industries, transportation, power generation	**Produces fewer pollutants than oil and coal, and less CO_2**
Coal	Non renewable	Primary resource for electricity	**Produces CO_2 and other air, water and solid waste pollutants**
Biomass: Wood and organic waste including societal waste	· Renewable · In terms of timber, it is easily harvested and abundant in certain areas; but it takes a long time to grow a tree.	Low energy potential relative to other resources	**· Burning emits CO_2 and other pollutants** **· Possible toxic byproducts from societal waste** **· Loss of habitat when trees harvested, unless sustainable tree farms**
Hydro-electric	· Renewable · Clean resource with high efficiency · Influenced by climate and geography	Low economic cost, though high start up costs	**Destruction of farmlands, dislocation of people, loss of habitat, alteration of stream flows**

Teacher tip

Age of Solar System is at **4.6 billion** years old based on radioactive dating of meteorites (Solar System is much younger than the Universe);

Solar Power (photo-voltaics)	· Renewable	· Technology is already in use for remote applications and non-centralized uses where it is economically competitive with alternatives	**Large land use**
	· High economic cost particularly in terms of start-up	· Unlimited resource that is clean, efficient, safe, and renewable	
	· Dependent on climate and geographical location		
	· Need a storage system for the energy to ensure reliability		
	· Not advanced enough for global use		
Solar Power - (solar thermal)	· Renewable	· Solar energy technology not advanced enough for global use	
	· Central-thermal systems to convert solar energy directly to heat	· Many industrial plants use solar	
	· More competitive economically than photovoltaics		
	· Dependent on climate and geographical location		

Geo-thermal	· Extracts heat from underground masses of hot rock.	· Consumption is localized	**Disrupts natural geyser activity**
	· Technology is still undeveloped.	· Efficient	
	· Can be geographically dependent		
Wind Power	· Renewable	· Economic cost comparable to current technologies	**· Aesthetic issues**
	· Unlimited resource that is a very clean process, no pollutants	· System must be designed to operate reliably at variable rotor speeds	**· Needs lots of land**
		· Technology not advanced enough for global societal us	**· Possible impacts on birds and their migration patterns**
			· Some noise pollution
Nuclear Fission	· Non renewable resource U-235 (uranium)	Currently accounts for 10-12% of the world's electricity	**· Byproduct is highly radioactive and highly toxic**
	· Highly technological infrastructure necessary for safe operation		**· Produces radioactive wastes that have a long lifetime**
	· Production of nuclear energy has a high cost due in part to regulations		**· Disposal solution complex technically and politically**
	· High water usage for cooling		**· Safety issues in terms of operating a facility with the potential to release radiation to the atmosphere**
			· Public perception problem in terms of radiation, etc.

Nuclear Fusion	· Technology is not yet viable and requires research investment · Technology still not developed enough to make this a viable source		**Possibility high for water pollution because of radioactive tritium**

Energy Information Administration, International Energy Annual 1999, DOE/EIA-0219(99) (Washington, DC, January 2001.)

Energy Information Administration, International Energy Outlook 2001, DOE/EIA-0484(2001) (Washington, DC, March 2001.)

- A successful energy future will depend on managing environmental impacts while keeping energy affordable. And this can only be achieved by formulating and implementing comprehensive energy and environmental policies with the cooperation of the international community in the form of treaties like the Kyoto Protocol.

- The following are considered priority solutions advocated by international communities, led by the United States of America, that are addressed in these international treaties:

1. **Curbing Global Warming**

Climate change is the single biggest environmental and humanitarian crisis of our time. We must act now to spur the adoption of cleaner energy sources at home and abroad.

Climate change is the single biggest environmental and humanitarian crisis of our time. The Earth's atmosphere is overloaded with heat-trapping carbon dioxide, which threatens large-scale disruptions in climate with disastrous consequences. We must act now to spur the adoption of cleaner energy sources at home and abroad.

2. **Creating the Clean Energy Future**

Dependence on fossil fuels threatens our national security and is a major contributor to global warming and toxic air pollution. By investing in renewable energy sources such as the sun, wind and biomass, we can help solve the energy and climate crises.

Our best weapon against global climate change is clean energy. Renewable power, conservation, energy efficiency in buildings and elsewhere, more efficient vehicles and clean fuels -- these are the solutions that will reduce the impacts on our climate, revive our economy, and create jobs.

3. **Reviving the World's Oceans**

The world's oceans are on the brink of ecological collapse. We can restore marine vitality by ending overfishing, creating marine protected areas and improving the way we govern our oceans.

Powerful forces have pushed the world's oceans to the brink of ecological collapse. Marine vitality can be restored by ending overfishing, creating marine protected areas, improving oceans governance, and combating emerging threats like ocean acidification. By focusing on these solutions, we can achieve the broadest, most long-lasting benefits for our oceans and those who rely on oceans-related jobs.

4. **Defending Endangered Wildlife and Wild Places**

The destruction of our last remaining wildlands means the loss of vast troves of biological diversity, critical regulators of global climate, and irreplaceable sanctuaries.

Our government joins forces with NGOs and other environment activists to defend some of our country's most imperiled species and their habitats.

Teacher can ask students for what theories/ explanations they know about the origin of the solar system.

Teacher Tip

This can be delivered as a straight lecture or alternatively, the teacher can assign the learning materials and have the students present the same as a group. Knowledge gaps should filled by the teacher and misconceptions should be corrected after the group presentations.

5. **Protecting Our Health By Preventing Pollution**

We must reduce or eliminate the dangerous chemicals in the products we buy, the food we eat and the air we breathe. Toxic chemicals in our environment, such as mercury, lead, and certain manmade chemicals, have been linked to cancer, birth defects and brain impairments. Reducing or eliminating the load of these dangerous chemicals in the products we buy, the air we breathe, the food we eat and the water we drink can help reduce the toll of human disease and suffering.

6. **Ensuring Safe and Sufficient Water**

Clean and plentiful water is the cornerstone of prosperous communities. Yet as we enter the 21st century, swelling demand and changing climate patterns are draining rivers and aquifers and pollution is threatening the quality of what remains. Our government is integrating our expertise in pollution prevention, water efficiency and climate change to sustain Philippines' precious water resources, working to advance smart water efficiency policies to ensure that communities get the water they need while keeping our lakes, rivers, and streams full and healthy.

7. **Fostering Sustainable Communities**

The choices we make for where and how we live have enormous impacts on our well-being, economy, and natural environment. The government develops and advocates sustainable solutions for our communities.

The Philippines, through the Department of Energy, will work on ensuring the implementation of the following plans and programs to contribute to the attainment of these broad policy and program frameworks. These plans and programs are embodied in DOE's Energy Reform Agenda (ERA).

D. National Renewable Energy Plan

- With the global trend towards a clean energy future, the Renewable Energy Act was passed in 2008 to fully harness the country's renewable energy potential such as geothermal, hydro, wind, solar, biomass and ocean. To guide the full implementation of the law, the National Renewable Energy Program (NREP) was launched on 14 June 2011 by President Aquino. The PEP includes the targets set under the NREP to strengthen its energy security plan. Specifically, the NREP seeks to increase the country's renewable energy-based capacity by 2030.

E. Energy Efficiency and Conservation Program

- With the escalating prices of imported fuels, the call for energy efficiency and conservation has graduated from merely just a personal virtue to that of a national commitment. The PEP includes the National Energy Efficiency and Conservation Program (NEECP) as one of the centerpiece strategies in pursuing energy security of the country and looks into it as a major solution to the energy challenges of the future. To lay the groundwork for a national energy efficiency plan, the PEP recognizes the need for an energy conservation law as a critical measure in managing the country's energy demand. The proposed legislation aims to incorporate policies and measures to develop local energy auditors and energy managers, establish the ESCO industry, encourage the development of energy efficient technologies and provide incentives for the effective promotion of efficiency initiatives in the energy market sector.

F. Natural Gas Master plan

- A complementary initiative to ensure the country's energy security is the review and update of the Master Plan Study for the Development of the Natural Gas Industry in the Philippines. Said update includes an evaluation of the natural gas infrastructure requirements in the Visayas and Mindanao regions in view of the DOE's plan to implement a Natural Gas Infrastructure Development Plan in these regions. The Masterplan, with technical assistance from Japan International Cooperation Agency (JICA) and World Bank, evaluates the opportunities, critical infrastructures and required investments for the development of the natural gas industry.

A. Power Sector Development

- The development plans on power systems, transmission highways, distribution facilities and missionary electrification provide the platform to put in place long-term reliable power supply, improve the country's transmission and distribution systems and attain nationwide electrification. Specifically, the PEP highlights the implementation of critical power infrastructures to address possible power outages. Based on the Plan, the government will concentrate its efforts on the completion of committed power projects, as well as attract local and foreign investors to venture into indicative and potential power projects to include electrification projects.

B. Fuelling Sustainable Transport Program

- As one of the biggest user of energy, the energy sector is mainly concerned on other alternative options to fuel the transport sector. Thus, the PEP will pursue the implementation of the Fueling Sustainable Transport Program (FSTP) which seeks to convert public and private vehicles from diesel and gasoline to compressed natural gas (CNG), liquefied petroleum gas (LPG) and electric power. Under the program, CNG buses are envisioned to ply throughout the country. It also includes the promotion of electric vehicles for public transport and the increase in biofuels blends to 20.0 percent. With the FSTP, the government hopes to reduce the carbon footprint from road transport in the Philippines. It has been estimated that road transportation accounts for around 50.0 percent of the total air pollutants in the country.

C. Indigenous Energy Development Program

- As energy demand is anticipated to grow significantly over the indicated planning period, it is incumbent for the energy sector to pursue all means to develop the country's indigenous resources. In view of this, the Plan looks into a highly diverse energy mix to fuel the Philippine economy within the planning period. Even with the dawning of renewable energy development, the DOE recognizes the fact that the country will remain dependent on conventional fuels for many years to come to address its growing energy requirements. The Plan programs the conduct of energy contracting rounds as an effective strategy to bring in critical investments for the exploration, development and production of local energy resources.

Teacher Tips

- importance of meteorites in determining the age and the origin of the solar system.
- An improvement of the nebular hypothesis based on current knowledge of fluids and states of matter.
- remind the learner of the comparison of the elemental abundance among the Universe, Meteorites, and the whole Earth
- accretion and bombardment generate heat (kinetic energy is transformed to heat)which was partly retained by the Earth as **internal heat**;

PRACTICE (120 MINS)

- Give a short quiz on the topics covered in the previous lecture session to gauge learners' knowledge retention. (30 minutes)

  Name and briefly explain the 6 policy programs embodied in the DOE's Energy Reform Agenda (ERA). Each correct policy will be given 5 points. Each sufficient explanation will be given 10 points, for a total of 90 points.

- Group Activity - Divide the class into suitable group size (will depend on the size of the class) and conduct a research on local environmental disasters or damages related to the use of energy. The groups will be given 30 minutes to search the internet for local examples and each group will be given 10 minutes to present (90 minutes - assuming a total of 6 groups).

  The presentation will cover 1) what went wrong? 2) could it have been prevented? and 3) if the answer is yes, what could have been done to prevent the incident from happening? Alternatively, for very large class sizes, this can be given as a homework to be presented the following class session.

Teacher Tips

- Point deductions will be at the discretion of the teacher.
  Alternatively, the assessment can be given as a matching type, with the policy program on one side and the policy description on the other. This is preferred if the class is pressed for time.
- Alternatively, for very large class sizes, the group activity can be given as homework to be presented the following class session

ENRICHMENT (30 MINS)

- Debrief of the previous class activity. Supplement knowledge gaps (not captured during class activity). (10 minutes)

- Reflection Question - Is there an energy source that is free of some type of environmental impact? Ask the question to the class and allow them 5 minutes to reflect on the question. Conclude the reflection by giving the following answer. The answer really is, no energy source is free of some type of environmental impact. So what do we do address energy security while minimizing the negative effects of energy production and use to the environment? In the end, we must accept that current patterns of energy production and use have widespread and widely known negative impacts on the environment. As President Jimmy Carter once remarked when addressing the US Congress in 1976,

Teacher Tip

It is good practice to conduct a debrief after each class activity. This gives an opportunity to fill any knowledge gaps in the discussion, correct misconceptions and answer any lingering questions.

to avoid a cycle of energy and climate crises: "We must face the prospect of changing our basic ways of living. This change will either be made on our own initiative in a planned way or forced on us with chaos and suffering by the inexorable laws of nature."   It would be far better to implement carbon taxes, to incorporate the cost of negative environmental consequences into energy prices, to pass feed-in tariffs, and to harness the powers of energy efficiency now in a proactive way rather than a few decades from now when forced to by crises. In short, the problem of environmental impact can only be solved by matter of policy. Environmental care initiatives must be formulated in conjunction with our nation's energy policy, consistent with international conventions. (20 minutes)

EVALUATION (90 MINS)

- Written Assessment covering theory questions to evaluate the learners' understanding of the different environmental concerns related to the use of fossil fuels, geothermal and hydroelectric energies. This can be given as an enumeration type or matching type exam. The students will have to match the environmental impact with the associated energy source. Use the summary table in the instruction section as answer key. (30 minutes)

- Group Activity - Divide the class into suitable group size (will depend on the size of the class) and conduct a research on international treaties/conventions on safeguarding the environment that the Philippines is party to. Discuss amongst the groups, if you feel that the Philippines is doing enough towards fulfilling the agreements made in these international treaties. The teacher may assign one treaty per group if time permits. Otherwise, the teacher can assign the Kyoto Protocol that aims to reduce greenhouse gases emissions, based on the premise that (a) global warming exists and (b) man-made CO_2 emissions have caused it.

- Since conducting a research requires time, this may be assigned as a take home exercise to be given as early as practicable.

Teacher Tip

This is a student-directed project, and although this may not be a graded exercise, that aims to impress upon the students the gravity of the inherent ill effects of the production and use of energy, how we utilize energy in the country not only affects our own local environment but also contributes towards global climate change. Exposing the students to international treaties impresses upon them the utmost importance of working alongside international communities in ensuring care of our environment not only for our sake but also for the sake of future generations.

Earth Science

Earth Materials and Resources - Water Resources

145 MINS

Content Standard
The learners demonstrate an understanding of the amount of usable water on earth.

Performance Standard
Make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competencies
The learners will be able to describe how water is distributed on earth **(S11ES-If-14)**,

identify the various water resources on earth **(S11ES-If-g-15)**,

explain how different activities affect the quality and availability of water for human use **(S11ES-Ig-16(a))**; and

suggest ways of conserving and protecting water resources **(S11ES-Ig-16(b))**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- describe how water is distributed on earth;
- identify the various water resources on earth;
- explain how different activities affect the quality and availability of water for human use; and
- suggest ways of conserving and protecting water resources.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Video	10
Instruction	Lecture	30
Practice	Short quiz	10
Enrichment	Reflection	30
Evaluation	Group research	60

Materials
Internet access; computer; LCD projector; unlabelled hydrologic cycle illustration

Resources
Textbook

(1) Carlson, D.H., Carlson, Plummer, C.C., and Hammersley, L., 2011. Physical Geology: Earth Revealed. McGraw-Hill. 645 p.

(2) Desonie, D., 2015. CK-12 Earth Science High School . http://www.ck12.org/earth-science/

(3) Junine, J.I., 2013. Earth Evolution of a Habitable World. Second Edition. Cambridge University Press. 304 p.

(4) Kirkland, K. 2010. Earth Science: notable research and discoveries. Facts on File, Inc., 212 p.

(5) Lutgens, F.K., Tarbuck, E.J. and Tassa, D., 2013. Essentials of Geology. 11th Edition. Pearson Prentice Hall, 554 p.

(6) Tarbuck, E.J. and Lutgens, F.K., 2008. Earth – An Introduction to Physical Geology. 9th Edition Pearson Prentice Hall, 703 p.

Additional resources at the end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objectives

- Communicate learning outcomes and state the importance of water to life on earth. (5 minutes)
- Introduce the following learning objectives using any of the suggested protocols (Verbatim, Own Words, Read-aloud)
    A. I can describe how water is distributed on earth.
    B. I can identify the various water resources on earth
    C. I can explain how different activities affect the quality and availability of water for human use
    D. I can suggest ways of conserving and protecting water resources

Teacher tip
Display the learning objective/s prominently on one side of the classroom and refer to them frequently during discussions. You may place a check mark once a lesson is done to give the learners an idea of their progress and create a sense of accomplishment as they progress through the lessons.

MOTIVATION (10 MINS)

- Why Care About Water? Video Playback - A National Geographic video that talks about water as a scarce resource and its vital role in sustaining life on earth. (3 minutes)

- There is the same amount of water on Earth today as there was when the dinosaurs roamed. And just less than one percent of the planet's water is available to meet the daily drinking water, sanitation and food needs of nearly 7 billion people and millions of other species. Learn more about water in all its forms and how you can make a difference.

- https://www.youtube.com/watch?v=Fvkzjt3b-dU

- The teacher may allot 5-7 minutes to elicit any reactions on the video - how important it is as a resource. Round up the discussion by telling the class that the lessons that they will be learning will highlight how important water is as a resource.

The video link is provided. A copy of the video is also provided, in case internet connection is not available.

INSTRUCTION (30 MINS)

Lecture and discussion on distribution of earth's water and the various water resources on earth. (30 minutes)

A. Mineral Exploration

Water is a simple compound, made of two atoms of hydrogen and one atom of oxygen bonded together. More than any other substance on the Earth, water is important to life and has remarkable properties. Without water, life could probably not even exist on Earth. When looking at Earth from space, the abundance of water on Earth becomes obvious — **see Figure 1.** On land, water is also common: it swirls and meanders through streams, falls from the sky, freezes into snow flakes, and even makes up most of you and me. In this section, we'll look at the distribution of water on Earth, and also examine some of its unique properties.

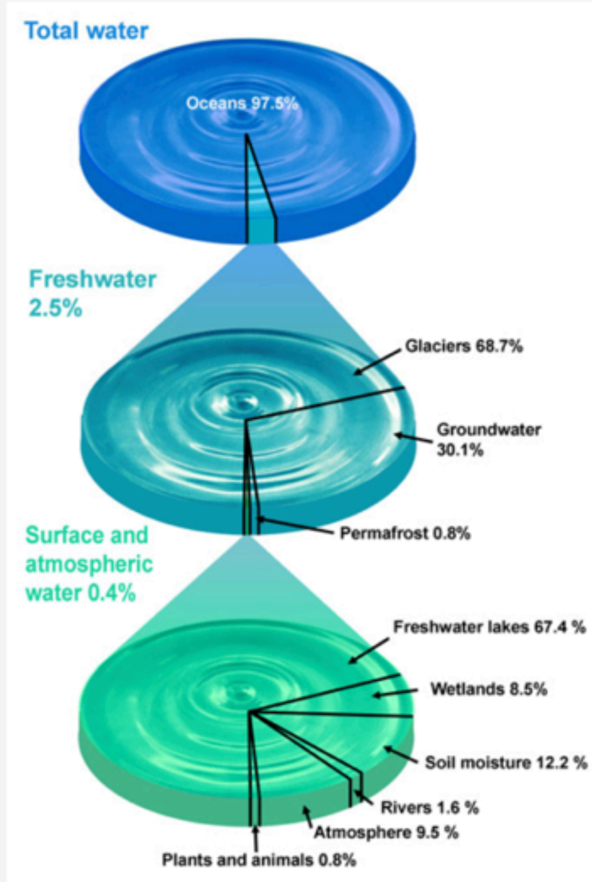
Figure 1: Earth, the "Blue Marble," can be seen in this photograph to be mostly covered with liquid water.

(*Source:* http://en.wikipedia.org/wiki/Earth, *License:* GNU-FDL)

B. Distribution of Water on earth

As Figure 1 makes clear, water is the most abundant substance on the Earth's surface. About 71% of the Earth's surface is covered with water, most of which is found in the oceans. In fact, 97.5% of Earth's water, nearly all of it, is in the Earth's oceans. This means that just 2.5% of Earth's water is fresh water, water with low concentrations of salts. Most freshwater is found as ice in the vast glaciers of Greenland and the immense ice sheets of Antarctica. That leaves just 0.4% of Earth's water that is freshwater that humans can easily use. Most liquid freshwater is found under the Earth's surface as groundwater, while the rest is found in lakes, rivers, and streams, and water vapor in the sky.

Figure 1: Global distribution of the world's water



Data from Shiklomanov and Rodda, 2003. Freshwater has a global volume of 35.2 million cubic kilometres (km^3).

Source: UNESCO The United Nations World Water Development Report 2
Section 2: Changing Natural Systems,
Chapter 4, Part 1. Global Hydrology and Water Resources, p.121

C. Where and in what forms is water available on Earth?

The world's water exists naturally in different forms and locations: in the air, on the surface, below the ground and in the oceans.

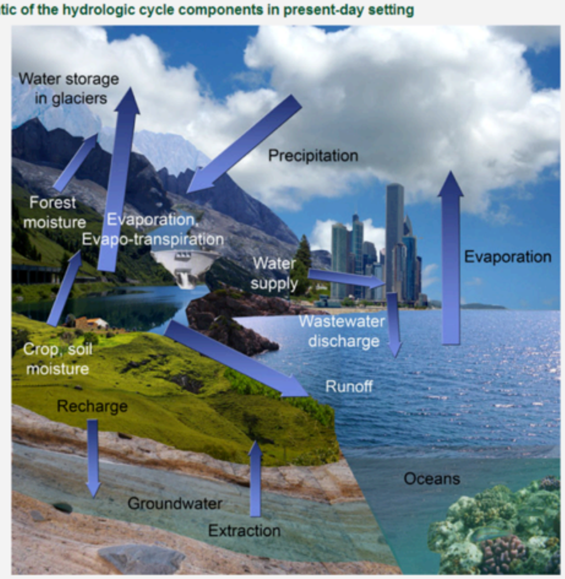
Just 2.5% of the Earth's water is freshwater, and most is frozen in glaciers and ice sheets. About 96% of all liquid freshwater can be found underground. The remaining small fraction is on the surface or in the air.

Knowing how water cycles through the environment can help in determining how much water is available in different parts of the world. The Earth's water cycle (Figure 2) is the global mechanism by which water moves from the air to the Earth (precipitation) and eventually back to the atmosphere (evaporation).

The principal natural components of this cycle are precipitation, infiltration into the soil, runoff on the surface, groundwater discharge to surface waters and the oceans, and evapotranspiration from water bodies, the soil, and plants.

"Blue water"— the water in rivers, lakes, and aquifers— can be distinguished from "green water" — which feeds plants and crops, and which is subsequently released into the air. This distinction may help managers focus on those areas which green water feeds and passes through, such as farms, forests, and wetlands.

Figure 2: Schematic of the hydrologic cycle components in present-day setting



Source: UNESCO The United Nations World Water Development Report 2
Section 2: Changing Natural Systems,
Chapter 4, Part 1. Global Hydrology and Water Resources, p.122

D. How does water move from the atmosphere to the ground and back?

About 10% of the Earth's freshwater that is neither frozen nor underground is found in the atmosphere. Precipitation, in the form of rain or snow, for instance, is an important form of available freshwater. About 40% of precipitation has previously evaporated from the oceans; the rest from land. The amount of precipitation varies greatly around the world, from less than 100 mm a year in desert climates to over 3,400 mm a year in tropical settings.

In temperate climates, about a third of precipitation returns to the atmosphere through evaporation, a third filters into the ground and replenishes groundwater and the remainder flows into water bodies. The drier the climate, the higher the proportion of precipitation that returns to the atmosphere and the lower the proportion that replenishes groundwater.

A large part of the freshwater that returns to the atmosphere passes through soil and plants. Reliable figures are available only for some regions. Soil moisture is important for plant growth. Finding out how much moisture soil contains is important for such activities as farming and "river-flow forecasting", and for understanding climate and natural and water systems. Satellite data are increasingly complementing measurements of soil moisture taken on the ground to provide a broader and more up-to-date picture to decision-makers.

E. How much freshwater is found at the Earth's surface?

About three-quarters of the world's freshwater is frozen in ice sheets and glaciers. Most remains inaccessible, located in the Arctic, Antarctica or Greenland. Land-based glaciers and permanent snow and ice, however, supply water in many countries, releasing water in amounts that vary seasonally and over longer time periods. Because of climate change, glaciers are now being more closely monitored.

Surface waters, including lakes, ponds, reservoirs, rivers, streams and wetlands hold only a small volume of the Earth's total fresh water (0.3%). Still they represent about 80% of the renewable surface water and groundwater that is available in a given year. These water bodies perform many functions in the environment, and provide people with the prime source of drinking water, energy and recreation, as well as a means of irrigation and transport.

Lakes and other reservoirs counteract fluctuations in river flow from one season to the next because they store large amounts of water. Lakes contain by far the largest amount of fresh surface water. But the hydrology of only about 60% of the largest lakes has been studied in detail, leaving much to be learned.

River basins are a useful "natural unit" for the management of water resources, though they often extend across national borders. International river basins have drainage areas covering about 45% of the Earth's land surface (excluding the polar regions). Some of the largest basins are the Amazon, which carries 15% of all water returning to the oceans, and the Congo-Zaire Basin, which carries one-third of all river water in Africa.

River flows can vary greatly from one season to the next and from one climatic region to another. In tropical regions, large flows are witnessed year round, whereas in drylands, rivers are often ephemeral and only flow periodically after a storm. Drylands make up about 40% of the world's land area and have only 2% of all water runoff.

Past data records for river flow and water levels help to predict yearly or seasonal variations, though it is difficult to make accurate longer-term forecasts. Some records in industrialised countries go back up 150 to 200 years. By contrast, many developing countries started keeping records only recently and data quality is often poor.

Wetlands, including swamps, bogs, marshes, and lagoons, cover 6% of the world's land surface and play a critical role in the conservation of water resources. Many wetlands were destroyed or converted to other uses during the last century. Those that remain can play an important role in supporting ecosystems, preventing floods, and increasing river flows.

F. How much freshwater can be found underground?

Ninety-six percent of liquid fresh water can be found underground. Groundwater feeds springs and streams, supports wetlands, helps keep land surfaces stable, and is a critical water resource.

About 60% of the water that is taken from the ground is used for farming in arid and semiarid climates, and between 25% and 40% of the world's drinking water comes from underground. Hundreds of cities around the world, including half of the very largest, make significant use of groundwater. This water can be especially useful during shortages of surface water.

Groundwater aquifers vary in terms of how much water they hold, their depth, and how quickly they replenish themselves. The variations also depend on specific geological features.

Much of the water underground is replenished either very slowly or not at all, and is thus termed "non-renewable". The largest aquifers of non-renewable water are found in North Africa, the Middle East, Australia, and Siberia. There is some debate about how and when to use this water. Many aquifers that contain non–renewable groundwater resources are shared by more than one country and need to be managed in common for the benefit of all administrative entities concerned.

If the infiltration of precipitation recharges the aquifer, the groundwater is considered "renewable" and can be used for irrigation, domestic and other purposes. While most renewable groundwater is of a high quality and does not require treatment, it should be analysed before it is used to avoid possible health impacts. However, few countries measure the quality of underground water or the rate at which it is being withdrawn. Monitoring is being improved in Europe and India, but remains minimal in many developing countries, and is deteriorating in many industrialised ones. This makes it hard to manage underground water resources sustainably.

Teacher tip

This will be delivered as a straight lecture.

PRACTICE (10 MINS)

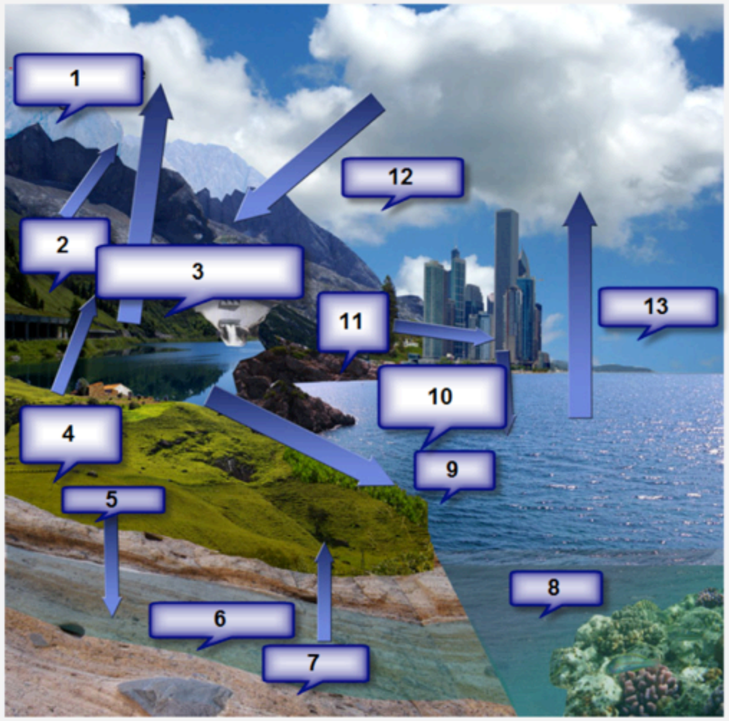
Give a short quiz on the topics covered in the previous lecture session to gauge learners' knowledge retention. (10 minutes)

Fill in the blanks. Handout the water cycle digram and have them write the cycle component words or phrases on the blank boxes to complete the diagram.

Teacher tip

- This is formative assessment to monitor student learning to provide ongoing feedback that you can use as an instructor to improve your teaching and by the students to improve their learning. It helps students identify their strengths and weaknesses and target areas that need work and helps faculty recognize where students are struggling and address problems immediately.

Schematic of the hydrologic cycle components in present-day setting



Source: UNESCO The United Nations World Water Development Report 2
Section 2: Changing Natural Systems,
Chapter 4, Part 1. Global Hydrology and Water Resources, p.122

- This is a low stakes exercise, which means that they have low or no point value. This is essentially a concept map to represent their understanding of the water cycle

ENRICHMENT (30 MINS)

Reflection Activity: Ask the class what and how different activities affect the quality and availability of water for human use (30 minutes)

As answers come in, write them down on the board. Hopefully, you will end up with a good list. Regardless, you will have a chance to fill gaps on the list. When the class runs out of answers, debrief the activity by using this United States Geological Survey publication as reference - Effects of Human Activities on the Interaction of Groundwater and Surface Water. This may be supplemented by Section D of the 2007 report on the state of water resources in the Philippines by Greenpeace which discusses the major problems concerning water use and scarcity.

Teacher tip

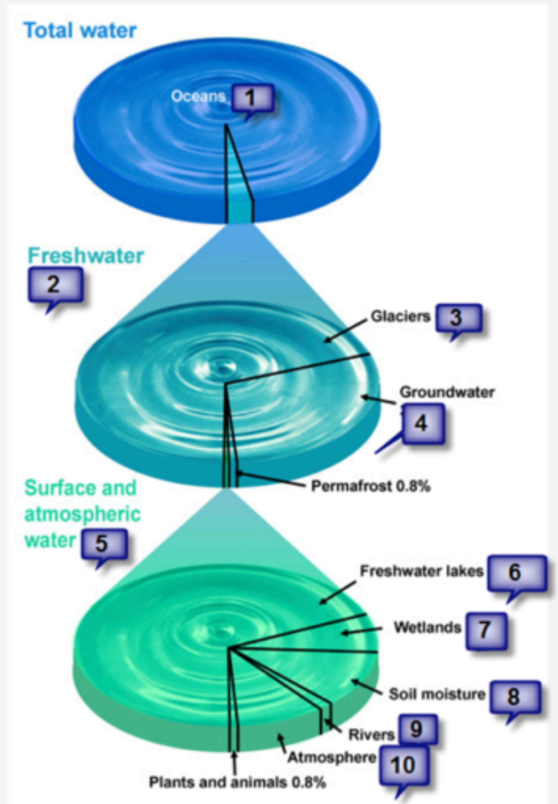
- Deviate from the teacher-driven lecture type content delivery and encourage active learner participation by allowing them to verbalize their ideas. Ask them to reflect on day-to-day activities (real-life experiences) that affect the quality and availability of water for human use. Learner-driven exercises yields optimum satisfaction from the learner.

EVALUATION (60 MINS)

Written Assessment covering theory questions to evaluate the learners' understanding of the distribution of water on earth and the various water resources on earth. (30 minutes)

Fill in the blanks. Hand out the diagram below and have them fill in the percentages on the empty numbered boxes to gauge their knowledge of the global water distribution.

Figure 1: Global distribution of the world's water



Data from Shiklomanov and Rodda, 2003. Freshwater has a global volume of 35.2 million cubic kilometres (km^3).

Source: UNESCO The United Nations World Water Development Report 2
Section 2: Changing Natural Systems,
Chapter 4, Part 1. Global Hydrology and Water Resources, p.121

- This is a low stakes exercise, which means that they have low or no point value. This is essentially a concept map to represent their understanding of the water cycle

Teacher tip

- Deviate from the teacher-driven lecture type content delivery and encourage active learner participation by allowing them to verbalize their ideas. Ask them to reflect on day-to-day activities (real-life experiences) that affect the quality and availability of water for human use. Learner-driven exercises yields optimum satisfaction from the learner.

Group Activity - Divide the class into suitable group size (will depend on the size of the class) and ask the groups to conduct a research on ways to conserve and protect water resources.

This is a student-directed research project that aims to solicit answers directly from students, that they may reflect on their daily activities and ask themselves if they have contributed to the conservation and protection our water resources.

Although, Integrated Water Resources Management (IWRM) holistic approach has now been accepted internationally as the way forward for efficient, equitable and sustainable development and management of the world's limited water resources and for coping with conflicting demands, individuals and families can make a huge difference in the state of the world's water resources by avoiding waste and pollution. Ask the students to reflect on what they can do daily to conserve and protect water resources. (30 minutes)

Note: Integrated Water Resources Management is a collaborative process which promotes the coordinated development and management of water, land and related resources within hydrological boundaries, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

You may use the list below to check mark their answers.

Here are some simple ways we can help to conserve and protect water sources.

1. Use less water. Turn off the water while you brush your teeth and shave. Take shorter showers. Run the clothes washer and dishwasher only when they're full. If you wash dishes by hand, fill the sink or dishpan with water, rather than running the tap continuously as you scrub. Wash your car by hand, and sweep, rather than hose down, your sidewalk and driveway.

2. Keep harmful substances out of the water. Don't put hazardous materials, pesticides, oil, prescription drugs, or personal care products down the drain or toilet -- they'll wind up in the bay and other local waterways. Of course, it's better to use nontoxic products when you can. For examples of safe substitutes for toxic household products. Animal waste also causes pollution in stormwater runoff, so it's important to clean up after your pets. Dispose of their waste in the garbage.

- This is a low stakes exercise, which means that they have low or no point value. This is essentially a concept map to represent their understanding of the water cycle

3. Keep pipes and appliances in good condition. Fix leaks and drips. Even a small drip can waste hundreds of gallons a month. Maintain your septic system -- fecal matter from malfunctioning systems can contaminate beaches or groundwater. Have the septic tank cleaned out every three to five years.

4. Use water-efficient appliances. If you're stretching the life of an old toilet, you can save more than a gallon of water per flush if you put a plastic milk jug filled with water or pebbles in the toilet tank to reduce the amount of water used. And next time you buy a clothes washer, choose a high-efficiency model, which uses up to 20 gallons less water per load. Quick but effective fixes include low-flow showerheads (showers account for 32 percent of home water use) and flow restrictor aerators, which can save three to four gallons per minute when you turn on the tap (but still keep the water pressure feeling strong).

5. Use water efficiently outdoors. Landscape your yard with native and drought-tolerant plants. And direct water runoff from your roof to strategic spots of your lawn or garden.

6. Drive less. Yes, even driving affects water quality. That's because exhaust eventually settles out of the air, often into waterways. By choosing alternatives to driving (public transit, biking, walking, carpooling) and bundling your errands, you'll reduce vehicle emissions and help protect our waters. Keeping your car in good shape helps too: a well-maintained vehicle is more efficient. And remember: Never pour used motor oil down the drain -- that's a huge source of water pollution.

Teacher tip
The list provided is just a guide. The class could very well come up with a longer, more exhaustive list. Hence, the list may be expanded as you hold more classes.

ADDITIONAL RESOURCES:

Internet Resources
http://pubs.usgs.gov/circ/circ1139/pdf/part2.pdf

http://www.unwater.org/publications/publications-detail/en/c/396246/

Video Links
https://www.youtube.com/watch?v=Fvkzjt3b-dU

Earth Science

60 MINS

Earth Materials and Resources - Soil Resources

Content Standard
The learners demonstrate an understanding of the distribution of arable land on earth.

Performance Standard
Make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competencies
Identify human activities, such as farming, construction of structures, and waste disposal, that affect the quality and quantity of soil **(S11ES-Ih-17)**, and Give ways of conserving and protecting the soil for future generations **(S11ES-Ih-i-18).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

1. identify human activities, such as farming, construction of structures, and waste disposal, that affect the quality and quantity of soil; and
2. give ways of conserving and protecting the soil for future generations.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Group Game Activity	10
Instruction	Lecture	15
Practice	Group Discovery Exercise	10
Enrichment	Reflection Activity	10
Evaluation	Class Activity	10

Resources

TEXTBOOK:

(1) Carlson, D.H., Carlson, Plummer, C.C., and Hammersley, L., 2011. Physical Geology: Earth Revealed. McGraw-Hill. 645 p.

(2) Desonie, D., 2015. CK-12 Earth Science High School . http://www.ck12.org/earth-science/

(3) Junine, J.I., 2013. Earth Evolution of a Habitable World. Second Edition. Cambridge University Press. 304 p.

(4) Kirkland, K. 2010. Earth Science: notable research and discoveries. Facts on File, Inc., 212 p.

(5) Lutgens, F.K., Tarbuck, E.J. and Tassa, D., 2013. Essentials of Geology. 11th Edition. Pearson Prentice Hall, 554 p.

(6) Tarbuck, E.J. and Lutgens, F.K., 2008. Earth – An Introduction to Physical Geology. 9th Edition Pearson Prentice Hall, 703 p.

INTERNET RESOURCE:

(1) http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/edu/

VIDEO LINK

(1) http://study.com/academy/lesson/soil-erosion-effects-prevention.html

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following learning objective using any of the suggested protocols (Verbatim, Own Words, Read-aloud):
   a. identify human activities, such as farming, construction of structures, and waste disposal, that affect the quality and quantity of soil; and
   b. give ways of conserving and protecting the soil for future generations.

Teacher tip

Display the learning objective/s prominently on one side of the classroom and refer to them frequently during discussions. You may place a check mark once a lesson is done to give the learners an idea of their progress and create a sense of accomplishment as they progress through the lessons.

MOTIVATION (10 MINS)

- Group Game Activity - List down all human activities that may affect the quality and quantity of soil. (5 minutes)

- Divide the class into 3-5 groups, depending on the class size. This is a quick, 3-minute exercise. Ask each group to list down all human activities that they could think of that could adversely affect the quality and quality of soil. It is expected that they will come up with similar answers. Once the 3-minute mark is up, each group should stop writing further. Go through the answers of each group and cross out answers that are similar. The group that ends up with the most answers wins the game.
- Round up the activity by filling in the gaps - identifying human activities that have not been mentioned. Use the guide list below.

Guide List:

1. Agricultural Depletion
2. Overgrazing Animals
3. Deforestation
4. Mining
5. Development and Expansion
6. Recreational activities, like driving vehicles off-road or hiking

Teacher tip

Games or any movement activities are good motivational pieces. They are fun and engaging and serve to raise the energy level of the class, especially, if it precedes a traditional formal lecture.

INSTRUCTION (15 MINS)

- Lecture and discussion on human activities that affect the quality and quantity of soil. (10 minutes)
- Soil is especially vulnerable to erosion if it is bare or exposed. Plants therefore serve a tremendous role in preventing soil erosion. If the soil is covered with plants, erosion is slowed down. But when soil is bare, the rate of erosion speeds up tremendously. Here are some human activities that leave the soil exposed and speed up erosion. We speed up erosion through the following actions.

Teacher tip
This will be delivered as a straight lecture.

1. Agricultural Depletion - Farming can degrade the topsoil and lead to an increase in erosion. To plant a field, a farmer must first till the soil, breaking it up and loosening it so the new plants can take root. Once the plants are harvested, the loose soil remains and wind or rain can easily wash it away. In the 1930s, much of the American plains suffered greatly from erosion due to non-sustainable farming practices, creating the Dust Bowl and leading to widespread poverty and migration to the west coast. Planting cover crops in the fall can help maintain the soil through the winter months, reducing the amount of erosion. In addition, rotating the crops planted can help return nutrients to the soil to prevent its degradation.

2. Overgrazing Animals - Grazing animals are animals that live on large areas of grassland. They wander over the area and eat grasses and shrubs. They can remove large amounts of the plant cover for an area. If too many animals graze the same land area, once the tips of grasses and shrubs have been eaten, they will use their hooves to pull plants out by their roots

3. Deforestation - Deforestation is another practice that can greatly increase the rate of erosion in a region. One of the most important barriers to erosion is plant life, as long-lived trees and other species put down roots that literally help hold the soil together. Logging kills these plants, and even if the operation plants new trees to replace the old ones, the younger plants require years to put down the kind of root system that once protected the soil. Timber companies utilize a variety of different techniques, such as partial clearing and replanting, to prevent soil degradation and erosion in their work zones.

4. Mining operations are major contributors to erosion, especially on a local level. Many mining techniques involve shifting large amounts of earth, such as strip mining or mountaintop removal. These operations leave large amounts of loose soil exposed to the elements, and they often

require large amounts of water, which can exacerbate the erosion process. Even once the mining operation is completed and the company replaces the earth, it lacks the established vegetation that helped it maintain its coherency before removal, and until plants can re-establish themselves, erosion will continue to be a problem.

Teacher tip
This will be delivered as a straight lecture.

5. Development and Expansion - Urban and suburban development can also exacerbate erosion, especially if the developers ignore the natural state of the land. Construction of a building often begins by clearing the area of any plants or other natural defenses against soil erosion. In addition, some landscapers replace natural ground cover with plant species unsuited to the climate, and these plants may not be as effective at preventing erosion.

6. Recreational activities, like driving vehicles off-road or hiking - Humans also cause erosion through recreational activities, like hiking and riding off-road vehicles. An even greater amount of erosion occurs when people drive off-road vehicles over an area. The area eventually develops bare spots where no plants can grow. Erosion becomes a serious problem in these areas.

PRACTICE (10 MINS)

- As a discovery exercise, divide the class into suitable-sized groups (depending on the class size), and ask the groups to list down examples (of local places they know of) where any of the above-mentioned human activities have been observed or still being observed. Give them 5 minutes to work in their groups then ask the elected group leaders to present their examples to the class. Each group will be given 2 minutes to present. (10 minutes - 2 minutes per group x 5 groups)

Teacher tip
This is a low stakes exercise, which means that they have low or no point value. This is essentially an exercise for the students to connect to real-life problems.

ENRICHMENT (15 MINS)

- Reflection Activity: Ask the class how soil can be conserved and protected for future generations (15 minutes)
- Draw a table on the board with 2 columns. Label the first column "Source of Erosion" and the second "Strategies for Prevention". Ask for volunteers to populate the second column. You may opt to have them fill up the first column too, for review/recall purposes. Use the table to fill gaps on the list. Allot 10 minutes for the class to fill the table and another 5 minutes for you to complete it.

Teacher tip
Deviate from the teacher-driven lecture type content delivery and encourage active learner participation by allowing them to verbalize their ideas. Ask them to reflect on day-to-day activities (real-life experiences) that serve to prevent soil erosion. Learner-driven exercises yield optimum learner participation/interaction.

Source of Erosion	Strategies for Prevention
Agricultural Depletion	Leave leaf litter on the ground
	Grow cover crops, special crops grown in the dry season to cover the soil
	Plant tall trees around fields to buffer the effects of wind
	Drive tractors as little as possible
	Use drip irrigation that puts small amounts of water in the ground frequently
	Avoid watering crops with sprinklers that make big water drops on the ground
	Keep fields as flat as possible to avoid soil eroding down hill
Overgrazing Animals	Move animals throughout the year, so they don't consume all the vegetation in one spot
	Keep animals away from stream banks, where hills are especially prone to erosion
Deforestation and Mining	Reduce the amount of land that we log and mine
	Reduce the number of roads that are built to access logging areas
	Avoid logging and mining on steep lands
	Cut only small areas at one time and quickly replant logged areas with new seedlings
Development and Expansion	Reduce the amount of land that we turn into cities, urban areas, parking lots, etc.
	Keep as much "green space" in cities as possible, such as strips of trees where plants can grow
	Invest in and use new technologies for parking lots that make them permeable to water in order to reduce runoff of water
	Avoid building on steep hills
	Grade surrounding land to distribute water rather than collecting it in one place
	Where water collects, drain to creeks and rivers
	Landscape with plants that minimize erosion
Recreational Activities	Avoid using off-road vehicles on hilly lands
	Stay on designated trails

EVALUATION (10 MINS)

- Written Assessment to gauge the learners' understanding of the causes of soil erosion and prevention strategies. (10 minutes)

- Fill in the blanks. Hand out the table below and have them identify which source of erosion matches the prevention strategies given on the left column.

Teacher tip
Alternatively, you may give out the source of erosion and ask them to identify the corresponding prevention strategy/ies or a mix of both.

Strategies for Prevention	Source of Erosion
Keep animals away from stream banks, where hills are especially prone to erosion	
Plant tall trees around fields to buffer the effects of wind	
Drive tractors as little as possible	
Use drip irrigation that puts small amounts of water in the ground frequently	
Reduce the amount of land that we log and mine	
Reduce the number of roads that are built to access logging areas	
Avoid logging and mining on steep lands	
Cut only small areas at one time and quickly replant logged areas with new seedlings	
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Avoid using off-road vehicles on hilly lands	
Stay on designated trails	
Avoid watering crops with sprinklers that make big water drops on the ground	
Keep fields as flat as possible to avoid soil eroding down hill	
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Avoid building on steep hills	
Grade surrounding land to distribute water rather than collecting it in one place	

Earth Science

Human Activity and the Environment

60 MINS

Content Standard
The learners demonstrate an understanding of waste generation and management.

Performance Standard
Make a plan that the community may use to conserve and protect its resources for future generations.

Learning Competencies
Describe how people generate different types of waste (solid, liquid, and gaseous) as they make use of various materials and resources in everyday life **(S11ES-Ii-19)**,

Explain how different types of waste affect people's health and the environment **(S11ES-Ii-j-20)**, and

Cite ways of reducing the production of waste at home, in school, and around the community **(S11ES-Ij-21)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

1. describe the type of waste generated by a typical household;
2. enumerate and describe the environmental and health impact of the improper disposal of household waste;
3. appreciate the enormity of the problem of waste disposal in the Philippines;
4. propose ways to reduce the volume of municipal waste; and
5. describe the wastes produced from different sources and their effect on human health and the environment

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Discussion	10
Instruction	Lecture	45
Enrichment	Short Report	
Evaluation	Short Report	

Materials
Computer; LCD; projector

Resources

(1) Alameda County Waste Management Authority & Source Reduction and Recycling Board. (1997). Do The Rot Thing: A Teacher's Guide to Compost Activities. Retrieved from http://www.cvswmd.org/uploads/6/1/2/6/6126179/do_the_rot_thing_cvswmd1.pdf

(2) Asian Development Bank. (2004). The Garbage Book. Retrieved from http://www.adb.org/sites/default/files/publication/29301/garbage-book.pdf

(3) Biology Discussion. (n.d.). Wastes: Sources, Classification and Impact. Retrieved from http://www.biologydiscussion.com/wastes/wastes-sources-classification-and-impact/70

(4) Carlson, D. H., Plummer, C. C., & Hammersley, L. (2011). *Physical Geology: Earth Revealed*. McGraw-Hill.

(5) Department of Environment and Natural Resources. (2003). *Metro Manila Solid Waste Management Project* (1). Retrieved from http://119.92.161.2/portal/Portals/38/adb/Report%201%20-%20Summary.PDF

(6) Desonie, D. (2015). CK-12 Earth Science High School. Retrieved from http://www.ck12.org/earth-science/

Additional resources at the end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following learning objective using any of the suggested protocols (Verbatim, Own Words, Read-aloud):
   a. Describe the type of waste generated by a typical household.
   b. Enumerate and describe the environmental and health impact of the improper disposal of household waste.
   c. Appreciate the enormity of the problem of waste disposal in the Philippines.
   d. Propose ways to reduce the volume of municipal waste.
   e. Describe the wastes produced from different sources and their effect on human health and the environment.
2. Introduce the following terms:
   a. Solid, liquid, and gaseous waste
   b. Leachate
   c. Eutrophication
   d. Siltation
   e. Acid mine drainage

Teacher tip

Write down these words on the board. Define each of these terms during the course of the lesson.

MOTIVATION (10 MINS)

Figure 1: Payatas dumpsite
Image Source: https://upload.wikimedia.org/wikipedia/commons/thumb/9/97/Payatas-Dumpsite_Manila_Philippines02.jpg/500px-Payatas-Dumpsite_Manila_Philippines02.jpg

- Show a picture of Payatas, one of the many garbage dumpsite in Metro Manila. On the 10th of July 2000, a landslide of garbage killed 218 people living on the dumpsite with 300 people still missing. The dumpsite covers an area of about 13 hectares.
- Ask the learners the following question: 'Why is there a need for dumpsites, such as the Payatas dumpsite?'

Region	Volume (2007)	2007 % of Total	Volume (2010)	2010 % of Total	Rank (2007)
NCR	2.86	23.54	3.14	22.97	1
CAR	0.21	1.73	0.21	1.5	15
I: Ilocos Region	0.57	4.69	0.63	4.61	8
II: Cagayan Valley	0.37	3.05	0.4	2.9	13
III: Central Luzon	1.21	9.96	1.32	9.66	3
IV: Southern Tagalog	1.69	13.91	2.11	15.4	2
V: Bicol Region	0.62	5.10	0.65	4.75	7
VI: Western Visayas	0.9	7.41	1	7.3	5
VII. Central Visayas	0.87	7.16	1.01	7.39	4
VIII. Eastern Visayas	0.49	4.03	0.51	3.7	10
IX. Western Mindanao	0.46	3.79	0.53	3.88	9
X. Northern Mindanao	0.56	4.61	0.47	3.4	11
XI. Southern Mindanao	0.6	4.94	0.97	7.10	6
XII: Central Mindanao	0.45	3.70	0.41	3.0	12
XIII. CARAGA	0.29	2.39	0.31	2.27	14
National	**12.15**	100	**13.67**	100	

Waste Generation Estimates, 2007 and 2010 (million tons/year)

Table 1: Regional waste generation estimates (in million tons) in 2007 and 2010 in the Philippines (Environmental Management Bureau, n.d.).

- Table 1 shows the estimated waste generated per region in the Philippines. Determine the amount of waste (in million tons/year) being generated by your region. Emphasize that there is a huge volume of waste being generated per year. Waste disposal has always been a big problem for the Philippines.
- It is estimated that, in the next 30 years, Metro Manila alone will generate approximately 230 million cubic meters of solid waste– **enough to fill the country's largest shopping mall** over 175 times (Asian Development Bank, 2004). This then leaves us with this important question: 'what are we going to do with this situation?'

INSTRUCTION (45 MINS)

ITEM	Amount (Number, estimated volume or weight)
Plastic bags	
Plastic bottles	
Plastic containers	
Glass bottles	
Paper/carton	
Metal cans	
Wood	
Battery	
Cooking oil	
Food scraps	
Kitchen and food waste	
Detergent (How much detergent is used for washing clothes and dishes)	
Others	

Table 2: Weekly record of the type and amount of garbage in the household.

Pre-Class Assignment

- Using Table 2, ask each learner to monitor the type and amount of garbage their respective household generates for a period of one week.

Teacher tip

Assign this activity a week or more in advance. The exact number or volume per item is not too important. Instead, the learners should become aware of the type of waste their individual households generate.

Lecture Proper

1. Call on one or more learners to present their data to the class. Ask the learners if they are able to recycle some of these items.
2. Ask each learner to imagine how much waste their household generates in a year. Inquire if they know how often the city government is able to collect their garbage, and where all of their garbage end up in.
3. Present the chart below:

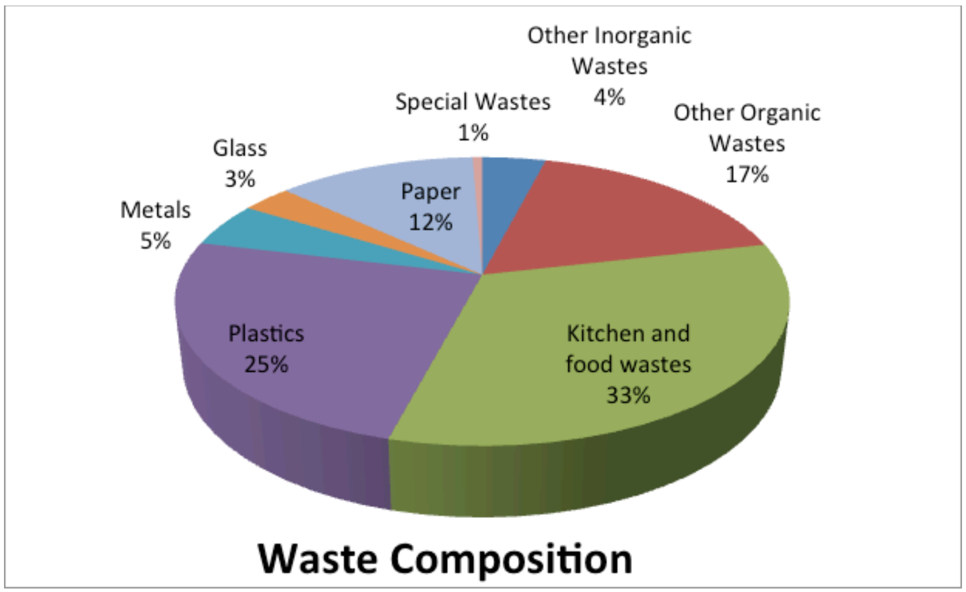


Figure 2: Waste composition of Metro Manila garbage (Asian Development Bank, 2004).

4. Ask the learners if this is comparable to the data they generated from their household waste.

Activity (20 mins)

Break up the class into suitable number of groups. Ask each group to brainstorm on the following questions:

1. How much of the waste in figure 2 is considered biodegradable?
   Answer Key: ~ 54 %

2. How do nations normally dispose of dispose of large volume of waste?
   Answer Key: sanitary land fill, incineration

3. Given the composition of the garbage, propose how we can reduce the volume of waste.
   Answer Key: A large volume of the waste is biodegradable. This can be used for composting. An equally large proportion of the waste can be recycled. Waste generation can also be minimized.

4. What possible hazards are associated with improper waste disposal? Are there government regulations to control this?

   Answer Key:
   - Some of the possible hazards associated with improper waste disposal:
   - Pollution of bodies of waters, such as rivers, lakes, the marine environment, and ground water
   - Loss of habitat from pollution of environment
   - Clogging of waterways /drainage system (canals, rivers, and streams) which can cause flooding
   - Unsanitary conditions leading to the spread of disease and pests that carry disease
   - Burning of waste can release toxic gases (formaldehyde, hydrogen chloride, sulfur dioxide, dioxins, and furans)
   - Unsightly and destroys the natural beauty of the environment

Teacher tip

Alternatively, you may give out the source of erosion and ask them to identify the corresponding prevention strategy/ies or a mix of both.

- Some government regulations that control improper waste disposal:
  - Republic Act No. 9003 is an act providing for an ecological solid waste management program, creating the necessary institutional mechanism and incentives, declaring certain acts prohibited and providing penalties, appropriating funds therefor, and for other purposes. Prohibited acts include:
    - Littering, throwing, dumping of waste matters in public places
    - Undertaking activities in violation of sanitation operation
    - Open burning of solid waste
    - Causing non-segregated waste
    - Squatting in open dumps and landfills
    - Open dumping, burying of biodegradable materials in flood-prone areas
    - Unauthorized removal of recyclable material
    - Mixing of source-separated recyclable material with other solid waste
    - Establishment or operation of open-dumps
    - Manufacturing, distributing, using, and importing consumer products that are non-environmentally-friendly materials
    - Importing toxic wastes misrepresented as 'recyclable' or 'with recyclable content'
    - Transporting and dumping in bulk in areas other than facility centers
    - Site preparation, construction, expansion or operation of waste management facilities without an Environmental Compliance Certificate and not conforming with the land use plan of LGUs
    - Construction of establishment within 200 meters from dump sites or sanitary landfills
    - Operation of waste disposal facility on any aquifer, groundwater reservoir or watershed area
  - Municipality ordinances

5. Can landfills cause pollution to the local environment?
   Answer Key: Leachate from landfills can contaminate groundwater if not properly managed. Moreover, it can cause soil contamination and the production and release of methane (a greenhouse gas) from the decomposition of organic matter.

Teacher tip
Highlighted are the prohibitions that are most relevant. Point out that littering, dumping of wasted matters in public places is punishable by law. Burning waste (e.g." pagsisiga") is also prohibited.

Most of the waste in landfills are classified as 'municipal waste' or waste collected from residential houses, markets, among others (mostly in urban areas). However, there are other sources of waste.

Other Sources of Wastes and their Environmental Impact

1. Industrial waste
    - Waste released from manufacturing plants, such as chemical plants, cement production, textile industries, metallurgical plants, textile, food processing, power plants, etc

Table 17.3 Industrial products and hazardous waste

Products	Hazardous Wastes
Medicines	Organic solvents and residues, heavy metals (mercury and zinc)
Metals	Heavy metals, fluorides, cyanides, acids and alkaline cleaners, solvents, pigments etc.
Paints	Heavy metals, pigments, solvents, organic residues
Leather	Heavy metals, organic solvents
Oil, Petroleum products	Oils, phenols, organic compounds, heavy metals etc.
Pesticides	Organic chlorine compounds, organic phosphate compounds.
Plastics	Organic chlorine compounds
Textiles	Heavy metals, dyes, organic chlorine compounds, solvants

Figure 3: Industrial products and hazardous waste (Biology Discussion, n.d.).

Teacher tip

- A **leachate** is a liquid that has dissolved or entrained environmentally harmful substances (contaminated fluid).
- Electronic waste (e.g. batteries) is a source of hazardous elements, such as mercury, cadmium, PVC, solvents, acids, and lead. Remind learners not to throw electronic items, such as batteries, into the regular household bins. PVC or Polyvinyl Chloride generates toxic byproducts, such as dioxin.

- This part can be delivered as a straight lecture.

- **Eutrophication** - excessive richness of nutrients can cause algal blooms (dense growth of plant life), which can be detrimental to animal life due to lack of oxygen.
- **Siltation** - pollution of water by silt or clay. Siltation can have a negative impact on flora and fauna. It can cause smothering of filter feeders, as well as an increase in the turbidity of waters (decrease light penetration).

2. Agricultural waste
    - Excess use of fertilizers and pesticides can cause land and water pollution.
    - Rice paddies release methane to the atmosphere.
    - Excess excrement from poultry and other livestock can cause eutrophication of bodies of water.

3. Mining waste
    - Waste generated from the exploitation of mineral resources
    - **Overburden material** - ground (soil and rock) that is removed to extract the mineral deposit. Release of overburden material to the environment as a result of improper management can cause siltation of bodies of water.
    - **Acid mine drainage** - water that has come to contact with oxidized rock or overburden that contains sulphide material (coal, zinc, copper, and lead). When acid mine drainage is not properly managed, it can find its way into waterways and the ground water. High pH waters can be detrimental to plant and animal life. Acid mine drainage is also associated with the release of heavy metals to the environment.

4. Biomedical Waste
    - Waste generated by hospitals and other health care institutions
    - This type of hazardous waste includes infectious waste and chemical waste dangerous to people and the environment.

ENRICHMENT

- Republic Act (RA) 9003 provides for the establishment of the Provincial Solid Management Board. Among the functions of the board is the development of a provincial solid management plan. As an individual or group assignment, ask the learners to interview or find out from the municipal officers the province's or municipality's solid waste management plan and how it is being implemented. Ask the learners to submit a short report on their research.
- Divide the class into an appropriate number of groups. Ask each group to develop materials (e.g. posters, video presentation, etc.) that can be used to promote recycling in their community.

Teacher tip
Choose among the three proposed enrichment activities the most appropriate for the learners. The activity can be a long-term project.

- If not yet implemented in the school, ask the learners or group of learners to study and implement the use of compost bins. The activity should include executable plans to promote the use of compost bins by the school community.

EVALUATION

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Can enumerate and classify the waste generated by a typical household				
Can differentiate between biodegradable and non-biodegradable waste				
Can enumerate and explain the negative impact of improper waste disposal				
Familiarity with the composition of municipal waste in the Philippines and ability to propose ways to reduce the volume of waste				
Familiarity with the health and environmental hazards associated with landfills				
Can identify other sources of wastes and the hazards associated with each				

ADDITIONAL RESOURCES

1. Environmental Management Bureau. (n.d.). *State of the Philippine Environment: Solid Wastes.* Retrieved from Department of Environment and Natural Resources website: http://pcw.gov.ph/sites/default/files/documents/efiles/webmaster/gwpf_sofe_solid_wastes.pdf
2. Junine, J. I. (n.d.). *Earth Evolution of a Habitable World* (2nd ed.). Cambridge University Press.
3. Kirkland, K. (2010). Earth sciences: Notable research and discoveries. New York, NY: Facts on File.
4. Lutgens, F. K., Tarbuck, E. J., & Tassa, D. (2013). *Essentials of geology* (11th ed.). Upper Saddle River, NJ: Prentice Hall.
5. McCarthy, James E. (2005). *Clean Air Act: A summary of the act and its major requirements.* Retrieved from Library of Congress website: http://fpc.state.gov/documents/organization/47810.pdf
6. Republic of the Philippines. (2001). *Ecological Solid Waste Management Act of 2000*. Retrieved from National Solid Waste Management Commission website: http://www.gov.ph/2001/01/26/republic-act-no-9003-s-2001/
7. Soriano, R. (n.d.). How to Compost in the Philippines l eHow. Retrieved from http://www.ehow.com/how_7798538_compost-philippines.html
8. Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Prentice Hall.

Earth Science

60 MINS

Exogenic Processes (Weathering)

Content Standard
The learners demonstrate an understanding of geologic processes that occur on the surface of the Earth such as weathering, erosion, mass wasting, and sedimentation

Performance Standard

Learning Competency
Describe how rocks undergo weathering **(S11ES-IIa-22)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- define weathering and distinguish between the two main types of weathering; and
- identify the factors that affect the rate of weathering.

LESSON OUTLINE

Introduction	Communicating learning objectives	2
Motivation	Bell-ringer Question	3
Instruction	Lecture	25
Enrichment	Laboratory Activity	20
Evaluation	Think-Pair-Share Activity	10

Materials
Nail (new and rusted); antacids (sodium bicarbonate); clear plastic cups; mortar and pestle; vinegar, timer (for the enrichment activity)

Resources

(1) ES550 Geomorphology Lab. https://www.google.com.ph/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBsQFjAAahUKEwjFsMLNhozJAhUiq6YKHe6QAso&url=http%3A%2F%2Fwww.koofers.com%2Fohio-state-university-main-campus-osu%2Fearthsci%2F550-geomorphology%2F&usg=AFQjCNEyqaox1jqT4KGdYVGKVhsF2bWLKA&sig2=2vxi43PiIYdHroNCOMj0QQ Accessed 10/17/2015

(2) Breaking it down. http://www-tc.pbs.org/wnet/nature/files/2008/12/breaking-it-down.pdf Accessed 9/22/2015

(3) https://www.uwgb.edu/dutchs/planets/moon.htm (Accessed 10/10/2015)

(4) http://science.opposingviews.com/weathering-moon-vs-earth-22633.html (Accessed: 10/10/2015)

(5) Tarbuck, E.J., F.K. Lutgens, and Tasa, D. 2014. Earth An Introduction to Physical Geology. Eleventh Edition. Prentice Hall.

(6) Monroe, J.S., Wicander,R., and Hazlett, R. 2007. Physical Geology: Exploring the Earth 6th edition. Thomson Brookes/Cole.

INTRODUCTION (2 MINS)

Communicating learning objective

1. Introduce the following learning objectives and important terms.
    a. Describe the type of waste generated by a typical household.I can define weathering and distinguish between the two main types of weathering
    b. I can identify the factors that affect the rate of weathering.
2. Introduce the list of key terms that learners will encounter.
    a. Weathering
    b. Mechanical weathering
    c. Abrasion
    d. Frost wedging
    e. Chemical weathering
    f. Hydrolysis
    g. Carbonation
    h. Oxidation
3. Copy the key terms on the board. Have the students write the definitions in their own words.

Teacher Tip

Students have had prior exposure to most of these terms in pre SHS science. Have students revise their definitions after the lecture.

MOTIVATION (3 MINS)

- Show students a sample of a large rock. Ask them the possible natural agents and/or processes that can break down the rock into smaller pieces. Write their responses on the board and briefly discuss each.

Teacher Tip

Students' answers may vary. Some typical answers may be water, wind, physical impact, waves, temperature changes, etc.

INSTRUCTION /DELIVERY/PRACTICE (25 MINS)

- **Give a demonstration/lecture/simulation**
- **Lecture proper (Outline)**
    1. After collecting their ideas about the topic in the motivation part, ask someone to define weathering in their own words. From then on, formally define weathering. Name the two main categories of weathering processes (physical and chemical). Briefly describe each, and

point out their main difference. Describe how rocks disintegrate through weathering processes. Explain that weathering usually occurs *in situ* (in place).

2. Discuss the processes by which mechanical weathering takes place. To demonstrate physical weathering, place an effervescent antacid tablet on the table and break or crush it with a spoon. Explain that, assuming the tablet is a rock, the process in which it is **physically broken into smaller pieces due to any force (natural or anthropogenic) without any alteration of its composition** exemplifies physical weathering. Discuss the following processes that lead to the mechanical disintegration of rocks:
    a. Frost wedging- when water gets inside the joints, alternate freezing and thawing episodes pry the rock apart.
    b. Salt crystal growth- force exerted by salt crystal that formed as water evaporates from pore spaces or cracks in rocks can cause the rock to fall apart
    c. Abrasion – wearing away of rocks by constant collision of loose particles
    d. Biological activity – plants and animals (including humans) as agents of mechanical weathering
3. Describe the processes that contribute to chemical weathering. Teacher may demonstrate chemical weathering by simply dissolving an antacid in water. Teacher may also have students examine and compare a new nail and a severely rusted nail. Show students how the rusted nail can be crumbled by bare hand (Note: one should obtain a thoroughly rusted nail to use for this demonstration). Ask the students what they can infer from the reddish coloration seen on the surface of some rocks (Answer: this shows that the constituent minerals contain iron and that the rock has been subjected to chemical weathering by oxidation).

    Discuss the following major processes of chemical weathering :
    a. Dissolution – dissociation of molecules into ions; common example includes dissolution of calcite and salt
    b. Oxidation- reaction between minerals and oxygen dissolved in water
    c. Hydrolysis- change in the composition of minerals when they react with water
4. Enumerate and discuss the factors that affect the type, extent, and rate at which weathering takes place:

Teacher Tip

- During the instruction (lecture or powerpoint presentation) students must take notes in their notebook. The teacher will monitor as the lesson progresses and randomly call on students to read what they have written for a particular topic
- Physical weathering (or mechanical weathering) disintegrates rocks, breaking them into smaller pieces. Chemical weathering decomposes rocks through chemical reactions that change the original rock-forming minerals. Weathering occurs as a response to the low pressure, low temperature, and water and oxygen-rich nature of the Earth's surface. Point out that physical weathering and chemical weathering almost always occur together in nature and reinforce each other. An example scenario would be, when a rock is physically broken down into smaller pieces, the amount of surface area exposed to weathering agents increases. Hence, chemical weathering is enhanced. As an effect of the chemical weathering, the rock weakens, thus becoming more susceptible to physical weathering.

a. Climate – areas that are cold and dry tend to have slow rates of chemical weathering and weathering is mostly physical; chemical weathering is most active in areas with high temperature and rainfall.
b. Rock type – the minerals that constitute rocks have different susceptibilities to weathering. The susceptibility of minerals (from high to low) roughly follows the inverse of the order of crystallization of minerals in the Bowen's reaction series. Thus, olivine which crystallizes first is the least resistant whereas; quartz which crystallizes last is the most resistant.
c. Rock structure- rate of weathering is affected by the presence of joints, folds, faults, bedding planes through which agents of weathering enter a rock mass. Highly-jointed/fractured rocks disintegrate faster than a solid mass of rock of the same dimension
d. Topography- **physical weathering** occurs more quickly on a steep slope than on a gentle one. On a gentle slope, water may stay longer in contact with the rocks, hence chemical weathering is enhanced.
e. Time- length of exposure to agents of weather determines the degree of weathering of a rock

Teacher Tip

- Write down on the board the chemical equations for each of the processes to easily illustrate the product of each weathering reaction. Have students summarize the chemical reactions in their own words.
- Ask the students on how and why the factors such as climate, rock type, rock structure, topography and time specifically affect the type, extent and rate of weathering.

- Use the following table to support the processes on how factors above affect weathering

Factor	How does it affect weathering?
Climate: Cold and dry = slow rate of chemical weathering High temperature and high rainfall = high rate of chemical weathering	If you go back to the chemical weathering processes, most if not all are chemical reactions involving water. Hence, the presence of water which is an important chemical weathering agent increases the rate of weathering. High temperature enhances chemical reactions.

Factor	**How does it affect weathering?**
Rock Type: Weathering rates roughly follow the inverse of the order of c	Recall that temperature is an important factor of mineral formation/ crystallization. Olivine crystalizes at high temperature while quartz at the lowest temperature as compared to the other minerals. Therefore, quartz is the most stable on surface conditions (low temperature conditions), while the other minerals in the series would be less stable. Olivine would be least stable. Limestone however will have a high susceptibility to weathering even though it is formed at surface temperature, because it can be easily dissolved by water (cite Bohol chocolate hills for example).
Rock Structure: The presence of cracks where agents of weathering (water, plant roots, etc.) can enter enhances weathering	These cracks/structures facilitate the entry of weathering agents.
Topography: Physical weathering occurs more quickly on a steep slope than on a gentle one	Be careful on this because this is a very tricky factor. Physical weathering occurs faster when the slope is steep due to the higher slope's susceptibility to mass wasting and the higher rate at which new materials are exposed to agents of mass wasting (rainwater can easily wash away weathered materials downslope). However in gentle slopes, the rate of chemical weathering may be higher. This is due to the fact that water which is an agent of weathering may stay longer in the gentle slopes.
Time: Longer time of exposure to agents of weathering means higher rate of weathering.	Longer time of exposure to weathering agents could mean higher degree of weathering processes have occurred. The rock has been weakened, therefore easier to be break.

ENRICHMENT (20 MINS)

Break Me Down.

This activity will focus on the types of weathering and the factors that influence the rate of weathering.

1. Divide the class into three groups. Give each group three antacid (sodium bicarbonate) tablets, and three clear plastic cups. Explain to the students that they will be preparing nine set-ups for this activity: whole, broken, and crushed antacid tablets each added to assigned liquid --room temperature water, hot water, and room temperature vinegar.
2. Each group will be assigned a liquid in which to dissolve the antacid tablets. Instruct the groups to label the cups according to the particle size of the antacid they will be dissolving: whole, broken, crushed. Use a mortar and pestle to break and crush the two tablets while leaving one of the tablets whole.
3. Put equal volume (100ml) of assigned liquid to the cups. Drop the tablet (whole, broken, crushed) into the appropriate cups and record the time from when the tablet is added to the liquid until when the tablet has completely dissolved and no traces of the tablet is visible. Have the groups assign two students for each setup, one to drop the tablet into the cup and one to record the time.
4. Have each group fill the table with dissolution times (in seconds) they have recorded. The data should be posted in front where the class can see.

	Room temperature water	Hot water	Room temperature vinegar
Whole tablet			
Broken tablet			
Crushed tablet			

5. Direct students to plot the dissolution times in a bar graph where Y axis is the dissolution time (s) and X axis is the Particle size (whole, broken, crushed). They should use different colors to represent the different liquids used in the activity.

Teacher Tip

- The class may use chalk cut into 1 inch sticks to replace antacid tablets. Just make sure that the chalk sticks are of equal volume.
- Point out that breaking or crushing the antacid illustrates physical weathering.
- Expected answers to discussion questions:
  a. Crushed tablet in vinegar exhibited the fastest dissolution rate
  b. The larger the surface area the faster reaction will proceed. In nature, smaller rocks weather faster than large rocks. Cracked and pitted surfaces will weather faster than smooth surfaces.
  c. Breaking and crushing the tablet exposes more surface area. As mechanical weathering breaks rocks into smaller pieces, more surface area is exposed which renders the rock more susceptible to attack by agents of chemical weathering. Chemical weathering can speed up physical disintegration by weakening the bonds between grains, loosening them to fall out physically. Placing a few drops of water on the tablet would soften it making breaking/ crushing a lot easier.
  d. Faster dissolution times in hot water. Chemical weathering proceeds more rapidly in higher temperature.

6. Ask the students to answer the following questions. Discuss the answers with the class.
   a. Which tablet size and liquid combination resulted in fastest dissolution times?
   b. What is the relationship between particle size and time it takes for the tablet to dissolve? How does this relationship apply to weathering in nature?
   c. Using the activity as a model, explain how mechanical weathering (breaking or crushing) contribute to chemical weathering (dissolution)? How can you demonstrate that chemical weathering can hasten mechanical weathering?
   d. Compare dissolution times in room temperature water and hot water. Using this as a model, what can you deduce about the relationship between temperature and weathering rate?
   e. Is there marked difference in the dissolution rate in water and vinegar both at room temperature? What caused the difference? What does dissolution in vinegar simulate in nature?
   f. In what environment would weathering rate be fastest? Slowest? Explain your reasons based on the observations from this lab activity.

e. Crushed tablet in vinegar exhibited the fastest dissolution rateChemical reactions tend to occur faster in vinegar than in room temperature water. Dissolving antacid in vinegar represents the effect of chemical weathering by acid rain. This can be shown in the equation:
   $CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2CO3$.
   Carbonic acid breaks down further into. Similarly, acid rain is produced when water in the atmosphere combines with sulfur and nitrogen compounds to form acids which cause accelerated weathering.

f. From the results of this activity, it can be concluded that weathering is fastest in a combination of hot, wet environment and fractured rocks.

EVALUATION (10MINS)

- Ask the students to get together in pairs and answer the following questions. Have 2 or 3 pairs discuss their answers in front of the class.

	1. (NOT VISIBLE)	**2. (NEEDS IMPROVEMENT)**	**3. (MEETS EXPECTATIONS)**	**4. (EXCEEDS EXPECTATIONS)**
Break me down lab activity 1. Followed procedure throughout the activity and successfully completed tasks. 2. Data and observations are recorded accurately 3. Graphs are drawn accurately and clearly labelled 4. Answers to discussion questions are complete and written correctly and accurately				

1. Which rock is more susceptible to chemical weathering in humid environment, granite or gabbro? Explain. (Expected answer: Gabbro. It has an abundance of high-temperature minerals like olivine and pyroxene which break down rapidly in moist environments.)
2. Why does groundwater in arid regions tend to be alkaline whereas in humid regions it tends to be acidic? (Expected answer: In humid areas, respiration of organisms plus decaying organic matter produce carbon dioxide in the soil which renders the groundwater slightly acidic. In arid region however, vegetation is sparse so there is a limited source of carbon dioxide.)

c. Does weathering occur in the moon? If so, has the moon surface been weathered mechanically and/or chemically? (Expected answer: Mechanical weathering on the surface of the moon occurs through meteorite bombardment which breaks down rocks into smaller pieces over time. Chemical weathering is absent on the moon due to the fact that the moon has no atmosphere or flowing water on it.)

Earth Science

Exogenic Processes (Mass Wasting)

60 MINS

Content Standard
The learners demonstrate an understanding of geologic processes that occur on the surface of the Earth such as weathering, erosion, mass wasting, and sedimentation

Performance Standard
1. Make a simple map showing places where landslides may pose risks in the community

Learning Competency
Explain how rocks and soil move downslope due to the direct action of gravity **(S11ES-IIb-22)**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:
1. identify the controls and triggers of mass wasting; and
2. distinguish between different mass wasting processes

LESSON OUTLINE

Introduction	Communicating learning objectives	2
Motivation	Mass Wasting Analogy	3
Instruction	Lecture	25
Enrichment	News Broadcast	20
Evaluation	Area Identification	10

Materials
Paper cup; paper plate; sand; water

Resources

(1) http://www.tulane.edu/~sanelson/eens1110/massmovements.htm (Accessed: 12/29/2015)
(2) http://www.glencoe.com/ebooks/science/9780078957222/EGEU_Florida_OSE/PDF/docs/192_221_C08_874636.pdf (Accessed 12/10/2015)
(3) http://landslides.usgs.gov/learn/prepare.php (Accessed: 1/15/2015)
(4) http://serc.carleton.edu/NAGTWorkshops/environmental/activities/64246.html (Accessed: 12/27/2015)
(5) http://www.teacherstryscience.org/lp/mass-wasting-all-comes-tumbling-down (Accessed: 12/27/2015)
(6) http://www.discoveryeducation.com/teachers/free-lesson-plans/landslides.cfm (Accessed: 12/27/2015)
(7) http://www.miracosta.edu/home/MEggers/MRE%20MassWastingCh7.pdf (Accessed: 01/11/2016)
(8) Rodolfo, K., 2000. The hazard from lahars and jokulhaups. Encyclopedia of Volcanoes. https://www.academia.edu/16339753/The_hazard_from_lahars_and_j%C3%B6kulhlaups (Accessed: 02/26/2016)

Additional resources at the end of the lesson.

INTRODUCTION (2 MINS)

Communicating learning objective

1. Introduce the following learning objectives and important terms.
   a. I can identify the controls and triggers of mass wasting.
   b. I can distinguish between different mass wasting processes.
2. Introduce the list of key terms that learners will encounter.
   a. Mass wasting
   b. Landslide
   c. Regolith
   d. Angle of repose
   e. Debris flow
   f. Creep
   g. Slump
   h. Rock slide
   i. Submarine slump
3. Copy the key terms on the board. Have the students write the definitions in their own words.

Teacher Tip

Students have had prior exposure to most of these terms in pre SHS science. Have students revise their definitions after the lecture.

MOTIVATION (3 MINS)

- Show students a photo of a person sliding down a water slide. Have students brainstorm the factors that determine how fast one can go on a water slide. Write their responses on the board. Discuss answers briefly and tell students that similar to sliding down a waterslide, rocks and rock debris can also move downslope due to gravity, a process called mass wasting.

Teacher Tip

Students' answers may vary. Some typical answers may be the slope of the slide, material of the slide, amount of water flowing through the slide, friction between the body and the slide, how water interacts with the slide, weight of the person, air resistance, etc.

INSTRUCTION /DELIVERY/PRACTICE (25 MINS)

- **Give a demonstration/lecture/simulation**
- **Lecture proper (Outline)**
  1. Show some mass wasting photos and short clips or animated videos.
  2. Ask the students to define mass wasting based on what you have shown. Summarize their own definition and then define mass wasting as the downslope movement of rock, regolith,

and soil under the direct influence of gravity (Tarbuck, et.al. 2014). Emphasize gravity as the main immediate agent in mass movement. Discuss that mass movements are an important part of the erosional processes whereby mass wasting moves materials from higher to lower elevations where streams or glaciers can then pick up the loose materials and eventually move them to a site of deposition.

3. Clarify to the students the meaning of the word landslide.

- Landslide is a common term used by many people to describe sudden event in which large quantities of rock and soil plunge down steep slopes. This term encompasses all downslope movement whether it be bedrock, regolith, or a mixture of these. Emphasize that strictly speaking, this term was not originally an "official" word in the mass wasting lexicon; it only became popular due to consistent (but erroneous) use by the media and general public.

4. Discuss the controlling factors in mass wasting.
    a. Slope Angle : Use a blackboard eraser (as a rock debris/rock) and a cardboard (as the surface) to illustrate this. Ask the students to observe as you put the eraser on top of the cardboard and tilt it at different angles with respect to the horizontal.
        1. Component of gravity perpendicular to the slope which helps hold the object in place (Fig. 1)
        2. Component of gravity parallel to the slope which causes shear stress and helps move objects downslope (Fig. 1)

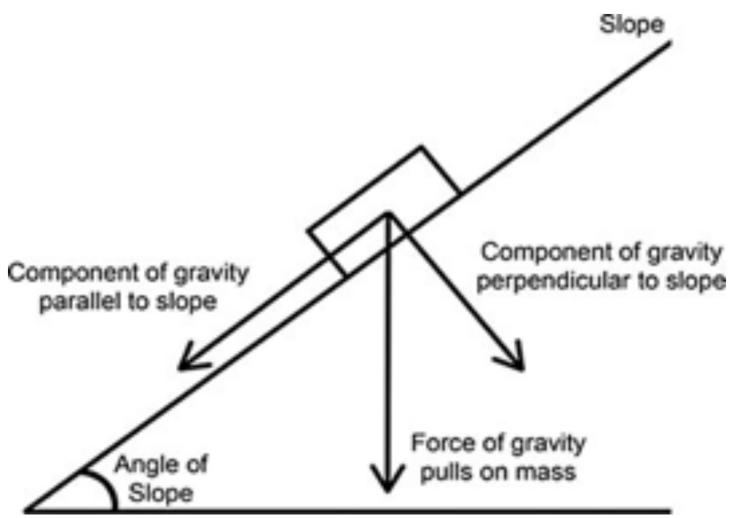


Figure 1. The components of gravity acting on a mass resting on a tilted surface. (Source: http://www.sciencebuddies.org/science-fair-projects/project_ideas/EnvEng_p035.shtml#background)

Teacher Tip

- During the instruction (lecture or powerpoint presentation) students must write down notes in their notebook. The teacher will monitor as the lesson progresses and randomly call on students to read what they have written on the topic currently being discussed.
- Point out that weathering, mass wasting, and erosion constitute a continuum of interacting processes.

As the slope increase, the slope-parallel component increases while the slope perpendicular component decreases. Thus the tendency to slide down the slope becomes greater.

All forces resisting movement downslope can be grouped under the term ***shear strength***. This is controlled by frictional resistance and cohesion of particles in an object, amount of pore pressure of water, and anchoring effect of plant roots. When ***shear stress > shear strength*** , downslope movement occurs

b. Role of water.

1. Water has the ability to change the angle of repose (the steepest slope at which a pile of unconsolidated grains remain stable). To demonstrate this concept, the teacher will create a sand hill using dry, damp, and water-saturated sand by flipping a paper cup full of the sand material upside down on a paper plate. Note that dry, unconsolidated grains will form a pile with slope angle determined by its angle of repose. For slightly wet sand, a high angle of repose will be observed while a very low angle of repose will be observed for water-saturated sand. Ask the students why this is so. Emphasize that it is surface tension that holds the grains together and helps them stick more than they do when they are dry. The opposite happens for sand with too much water. In saturated sand, all the pore spaces are filled with water eliminating grain to grain contact. Water in the interconnected pores exerts pressure which then reduces the shearing force between the particles. Thus the angle of repose is also reduced.
2. Addition of water from rainfall or snowmelt adds weight to the slope.
3. Water can reduce the friction along a sliding surface

c. Presence of clays.

1. Expansive and hydrocompacting soils – contain a high proportion of smectite or montmorillonite which expand when wet and shrink when they dry out,
2. Sensitive soils – clays in some soils rearrange themselves after dissolution of salts in the pore spaces. Clay minerals line up with one another and the pore space is reduced.

- Write down on the board the chemical equations for each of the processes to easily illustrate the product of each weathering reaction. Have students summarize the chemical reactions in their own words.
- Ask the students on how and why the factors such as climate, rock type, rock structure, topography and time specifically affect the type, extent and rate of weathering.

- This demonstration, similar to building a sandcastle on the beach, shows that there is an optimum dampness in the sand which results in stable shapes. If the sand is totally dry it is impossible to build steep-faced walls as the material easily crumbles. If sand is wet, it can build a vertical wall. With water-saturated sand, the material flows like a fluid.

3. Quick clays – water-saturated clays that spontaneously liquefy when disturbed

d. Weak materials and structures – become slippage surfaces if weight is added or support is removed (bedding planes, weak layers, joints and fractures, foliation planes). Make sure that the teacher explains all the enumerated terms.

5. Classify mass wasting processes. Collect sample visual aids (images, illustrations, photos, video clips etc.) as an example of each type of mass wasting process.

a. Slope failures- sudden failure of the slope resulting in transport of debris downhill by rolling, sliding, and slumping.

1. Slump – type of slide wherein downward rotation of rock or regolith occurs along a curved surface

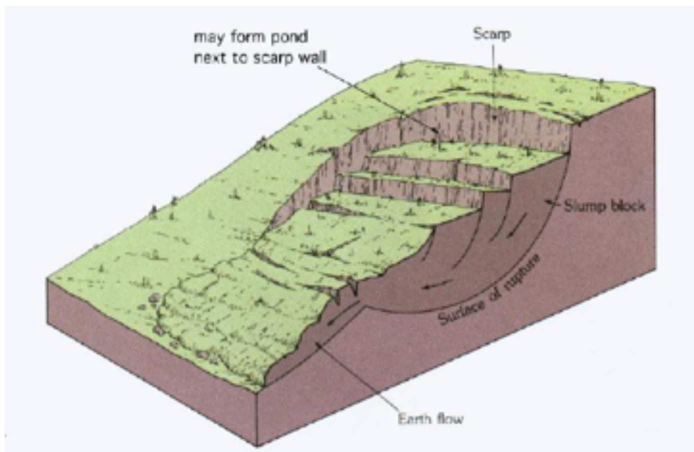


Figure 2. A schematic diagram of a slump. (Source: http://classes.colgate.edu/bselleck/geol210/lab2/images/SLUMP.JPG Accessed: 26 April 2016.)

2. Rock fall and debris fall– free falling of dislodged bodies of rocks or a mixture of rock, regolith, and soil in the case of debris fall

3. Rock slide and debris slide- involves the rapid displacement of masses of rock or debris along an inclined surface

b. Sediment flow- materials flow downhill mixed with water or air; Slurry and granular flows are further subdivided based on velocity at which flow occurs

1. Slurry flow – water-saturated flow which contains 20-40% water; above 40% water content, slurry flows grade into streams

- Before discussing in detail the mass wasting classification, write down on the board the different mass wasting processes (slump, rock fall, debris fall, mudflow, grain flow, etc.). Emphasize that the terms are very descriptive and that it is fairly simple to figure out where these terms come about. Have the students predict based on the terms the type of material and how the material moves. For example, in the term rock fall, the word "rock" indicates the type of material and "fall" indicates the movement involves falling.
- Most mass wasting processes grade into one another without clear boundaries between them making classification into types somewhat difficult. There is not one universal classification scheme for mass wasting processes. Even the term "mass wasting" is not universal as some writers prefer the term "mass movement". The classification used in this teaching guide divides the processes into two broad categories: slope failures and sediment flow.

- Solifluction – common wherever water cannot escape from the saturated surface layer by infiltrating to deeper levels; creates distinctive features: lobes and sheets of debris
- Debris flow – results from heavy rains causing soil and regolith to be saturated with water; commonly have a tongue-like front; Debris flows composed mostly of volcanic materials on the flanks of volcanoes are called lahars. Rodolfo, K.S. (2000) in his paper "The hazard from lahars and jokulhaups" explained the distinction between debris flow, hyperconcentrated flow and mudflow: debris flow contains 10-25 wt% water, hyperconcentrated stream flow has 25-40 wt% water, and mudflow is restricted to flows composed dominantly of mud
- Mud flow – highly fluid, high velocity mixture of sediment and water; can start as a muddy stream that becomes a moving dam of mud and rubble; differs with debris flow in that fine-grained material is predominant;

2. Granular flow - contains low amounts of water, 0-20% water; fluid-like behavior is possible by mixing with air
   - Creep – slowest type of mass wasting requiring several years of gradual movement to have a pronounced effect on the slope ; evidence often seen in bent trees, offset in roads and fences, inclined utility poles. Creep occurs when regolith alternately expands and contracts in response to freezing and thawing, wetting and drying, or warming and cooling.
   - Earth flow – involves fine-grained material such as clay and silt and usually associated with heavy rains or snowmelt; tend to be narrow tongue-like features that that begin at a scarp or cliff
   - Grain flow – forms in dry or nearly dry granular sediment with air filling the pore spaces such as sand flowing down the dune face
   - Debris avalanche – very high velocity flows involving huge masses of falling rocks and debris that break up and pulverize on impact; often occurs in very steep mountain ranges. Some studies suggest that high velocities result from air trapped under the rock mass creating a cushion of air that reduces friction

- Usually, one "landslide" event would involve a combination of two or more types of mass movement. It should be noted that one type of mass wasting can evolve into another type as the body of rock/sediments move downslope. For example, a slump would have a flow component near its toe.
- Collect more photos of mass wasting processes and show these to the students after discussing the classification. Make them guess the type of mass wasting in the photos and ask them the key features that they used in classifying.

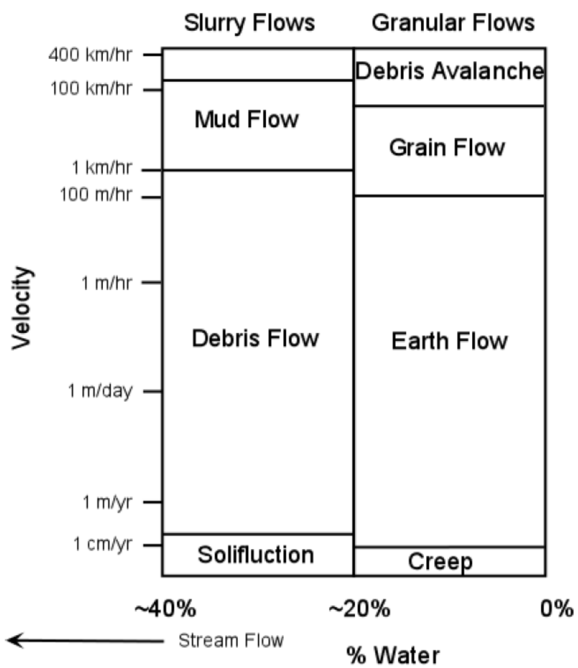


Figure 3. A schematic diagram of a slump. (Source: Nelson, S.A., 2015. http://www.tulane.edu/~sanelson/eens1110/massmovements.htm)

6. Describe subaqueous mass wasting. Subaqueous mass movement occurs on slopes in the ocean basins. This may occur as a result of an earthquake or due to an over-accumulation of sediment on slope or submarine canyon. 3 types:
    a. Submarine slumps - similar to slumps on land
    b. Submarine debris flow – similar to debris flows on land
    c. Turbidity current – sediment moves as a turbulent cloud
7. Discuss the events that trigger mass wasting processes.
    a. Shocks and vibrations – earthquakes and minor shocks such as those produced by heavy trucks on the road, man-made explosions
    b. Slope modification – creating artificially steep slope so it is no longer at the angle of repose
    c. Undercutting – due to streams eroding banks or surf action undercutting a slope
    d. Changes in hydrologic characteristics – heavy rains lead to water-saturated regolith increasing its weight, reducing grain to grain contact and angle of repose;

e. Changes in slope strength – weathering weakens the rock and leads to slope failure; vegetation holds soil in place and slows the influx of water; tree roots strengthen slope by holding the ground together
f. Volcanic eruptions - produce shocks; may produce large volumes of water from melting of glaciers during eruption, resulting to mudflows and debris flows

8. Enumerate and discuss some landslide warning signs
    a. Springs, seeps, or saturated ground in areas that have not typically been wet before.
    b. New cracks or unusual bulges in the ground, street pavements or sidewalks.
    c. Soil moving away from foundations.
    d. Ancillary structures such as decks and patios tilting and/or moving relative to the main house.
    e. Tilting or cracking of concrete floors and foundations.
    f. Broken water lines and other underground utilities.
    g. Leaning telephone poles, trees, retaining walls or fences.
    h. Offset fence lines.
    i. Sunken or down-dropped road beds.
    j. Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content).
    k. Sudden decrease in creek water levels though rain is still falling or just recently stopped.
    l. Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb.
    m. A faint rumbling sound that increases in volume is noticeable as the landslide nears.
    n. Unusual sounds, such as trees cracking or boulders knocking together, might indicate moving debris.

- In considering these landslide warning signs, one must put observations into perspective. One aspect may not always tell the whole story.

9. Discuss how landslide hazard can be reduced. Relate these to the triggers discussed in No. 7.
    a. Hazard zone mapping. One of the most important step in hazard mitigation is the

production of a landslide hazard map. These maps should serve to reduce hazard by keeping people away from the most vulnerable slopes.

b. Proper land use
    - Areas covered by degraded natural vegetation in the upper slopes should be afforested and existing natural vegetation preserved
    - Developmental activity should be taken up only after a detailed study of the area
    - Proper care to be taken to avoid blockage of natural drainage
    - Mandatory total avoidance of settlement in the risk zone
    - Building codes that limit the steepness of slope when building in hilly areas
    - Relocate settlements and infrastructures that are in the possible path of a landslide

c. Engineering mitigation techniques
    - Anchoring the footings of a structure in solid bedrock. This is a simple mitigation method for creep.
    - Drainage systems (e.g. installation hydrauger holes, drainage ditches, or planting vegetation) that drain water from the surface and/or subsurface
    - Buttress fills and retaining devices to stabilize slope. Example includes retaining walls, shotcrete, metal mesh, and rockbolts.
    - Building deflection walls to send flows around a structure

ENRICHMENT (20 MINS)

- Have students read the article " The 17 February 2006 rock slide-debris avalanche at Guinsaugon, Philippines: a synthesis" by Guthrie et. al. as a pre-class reading assignment. Provide a copy of the paper to those who do not have access to it. Encourage students to write notes describing the event and the conditions that have led to its occurrence. Emphasize that they will be using those notes for an in-class activity. If possible have students research a different viewpoint on the subject and bring it to class.

- In class, divide students into groups of 3-4. Instruct students to create a news broadcast about the Guinsaugon landslide based on the article they have read. Set a time limit of 15 minutes and have students discuss the assigned article and the secondary source, if any. The presentation should discuss the following information:
  1. Classification of the landslide event
  2. What happened? Describe the chronology of events that led to the catastrophe. Include eyewitness accounts.
  3. Why did the landslide occur? Discuss possible trigger mechanisms and contributory factor
  4. Follow-up measures to prevent or lessen the impact of reoccurrence of the disaster

- Also, based on lecture notes, general information about landslides should be included in the presentation:
  1. Natural and anthropogenic causes of landslide
  2. Factors that determine slope stability

- Give each group an opportunity to present their news broadcast.

EVALUATION (10MINS)

- Prior to class, have students locate areas around their community that are prone to mass movement. Ask them to take a photo or make an annotated sketch of the area they have chosen. They should take note of structures present, vegetation, extent of weathering, rock type, geometry of slope, etc.
- In class, have students pair up and discuss with their partners the possible changes, natural conditions or human interventions, that could occur on the slope to reduce its stability and allow mass movement to take place. Each student is required to submit a short essay.

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
News Broadcast 1. Accurately explains all the necessary information required and uses supporting details in the discussion. 2. Presents information clearly and creatively. Mapping landslide prone areas 3. Correctly identifies areas prone to mass movement. Explains with supporting information the possible triggers and contributory factors that might lead to mass movement				

Earth Science

90 MINS

Exogenic Processes (Erosion and Deposition)

Content Standard
The learners demonstrate an understanding of geologic processes that occur on the surface of the Earth such as erosion, deposition and sedimentation

Performance Standard
Make a simple map showing places where landslides may pose risks in the community

Learning Competency
Explain how the products of weathering are carried away by erosion and deposited elsewhere **(S11ES-IIa-b-23)**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

1. identify the different agents of erosion and deposition; and
2. describe characteristic surface features and landforms created and the processes that contributed to their formation.

LESSON OUTLINE

Introduction	Communicating learning objectives	3
Motivation	Sediment Jar Analogy	5
Instruction	Lecture	40
Enrichment	Modeling	30
Evaluation	Review Questions	12

Materials
For class demo: Jar with lid; sand; gravel; salt; board eraser; double-sided tape
For group activity: Large rectangular pan/tray; 3 paper cups; sediment mixture; pebbles; sand and powdered clay; wooden scraper; thick cotton towel; acetate transparency; ruler; sponge or old newspapers; 2-3 books; bucket

Resources

(1) http://www.csuchico.edu/~abykerk-kauffman/courses/nsci342/1101packet/S11%20NSCI%20342%20Packet%20Part%20B.pdf (Accessed 11/27/2015)

(2) https://www.gvsu.edu/cms4/asset/DE36066F-E528-CF94-8F079306A8293D59/take_a_tumble.pdf (Accessed 11/27/2015)

(3) http://web.crc.losrios.edu/~jacksoh/lectures/rivers.html (Accessed 11/27/2015)

(4) http://www.tulane.edu/~sanelson/eens1110/index.html#Lecture%20Notes (Accessed 11/25/2015)

(5) http://www.geographynotes.com/geomorphology/the-fluvial-landforms-and-cycle-of-erosion/757 (Accessed 11/25/2015)

(6) http://ijolite.geology.uiuc.edu/07FallClass/geo101/101%20Lectures/101_L37_GlaF07.html (Accessed 11/28/2015)

(7) https://geogondotnet.files.wordpress.com/2013/09/lessonmv.pptx (Accessed 11/27/2015)

Additional resources at the end of the lesson.

INTRODUCTION (3 MINS)

Communicating learning objective

1. Introduce the following learning objectives and important terms.
   a. I can identify the different agents of erosion and deposition.
   b. I can describe characteristic surface features and landforms created and the processes that contributed to their formation.
2. Introduce the list of key terms that learners will encounter.
   a. Erosion
   b. Deposition
   c. Abrasion
   d. Alluvial fans
   e. Oxbow lake
   f. Glacier
   g. Arete
   h. Drumlin
   i. Dune
   j. Deflation
   k. Ventifacts
   l. Barrier island
   m. Spit
3. Copy the key terms on the board. Ask the students to construct a table with four columns labelled: ***Key Terms, Can Define It, Have heard/read about It, No Idea about It. I***nstruct them to rate their knowledge of the terms by writing a check on the corresponding column. Ask the students to write the definitions in their own words, if they can.

Teacher Tip
Let the students revise their definitions after the lecture.

MOTIVATION (5 MINS)

- Show the students a jar with sediments in it. Tell them that you have previously filled the jar with a handful of sand, gravel, salt, and water. Make sure that the lid is screwed on tightly. Ask the students to shake the jar vigorously at least three times, and then pass it to the next. Make at least five of this "shake-and-pass" activity. Afterwards, take the jar back and set it down on the table. Let the students observe of what they see and notice. Write down their answers on the board.

a. What happened to the sediments as the jar was set down on the table after shaking?

   Expected answer: The particles started to settle out. Salt is dissolved in the water.

b. What happened to the water the sediments are in?

   Expected answer: The water became murky with some visible particles floating.

c. Do the smallest grains land on top or bottom of the jar? Why?

   Expected answer: The larger particles are generally heavier and quickly settled to the bottom with smaller grains landing on top of them. Tinier particles stay suspended in the water.

d. What environment and processes does the sediment jar demo represent? Which part in the demo simulates weathering? How about erosion and deposition?

   Expected answer: This demo is akin to rocks grinding and colliding as they are carried by stream flows or waves. Physical abrasion of the rocks hitting each other or the wall of the jar represents mechanical weathering while salt dissolving in water simulates chemical weathering. Constant tumbling and swirling of rocks in the water simulates erosion or transport. Salt carried in solution by moving water also represents erosion.

Teacher Tip

Teacher should prepare the sediment jar prior to class. To make a sediment jar, get a clear plastic jar or soda bottle with a lid and fill it about one-thirds full with sediments (gravel, sand, a teaspoon of salt). Fill the jar/bottle the rest of the way with water and screw on the lid. You may substitute gravel with angular fragments of terracotta pot to see if vigorous shaking will wear the sharp corners down.

INSTRUCTION /DELIVERY/PRACTICE (40 MINS)

- **Give a demonstration/lecture/simulation**
- **Lecture proper (Outline)**

   1. Explain the distinction between weathering and erosion. Define deposition and describe the general conditions that commonly lead to deposition of sediments. Highlight the thread connects these processes. Briefly review the hydrologic cycle to illustrate the role of the sun and gravity in driving these processes.

   - Definitions from Tarbuck et. al.,2014:

      a. Weathering- the disintegration and decomposition of rock at or near the Earth surface

      b. Erosion- the incorporation and transportation of material by a mobile agent such as water, wind, or ice

- Weathering occurs in situ, that is, particles stay put and no movement is involved. As soon as the weathering product starts moving (due to fluid flow) we call the process erosion.
- Point out that weathering, erosion/transportation, deposition are exogenic processes that act in concert but in differing relative degrees to bring about changes in the configuration of the Earth's surface.

2. Discuss the various agents of erosion.

   1. Running Water

   a. Explain that running water encompass both overland flow and stream flow. Differentiate overland flow and streamflow. Briefly describe how streamflow begins as moving sheet wash. (*splash erosion->overland flow->rills->gulleys->stream*)

   b. Discuss the factors that affect stream erosion and deposition
      - Velocity – dictates the ability of stream to erode and transport; controlled by gradient, channel size and shape, channel roughness, and the amount of water flowing in the channel
      - Discharge- volume of water passing through a cross-section of a stream during a given time; as the discharge increases, the width of the channel, the depth of flow, or flow velocity increase individually or simultaneously

   c. Summarize how various properties of stream channel change from its headwaters to its mouth.
      - From headwaters to mouth: Channel slope ↓, Channel roughness ↓, Discharge ↑, Channel size↑, Flow velocity↓

   d. Explain how streams erode their channels, transport, and deposit sediments. (Go back to students' answers to questions in Motivation part. Briefly discuss their answers.)
      - Styles of erosion: Vertical erosion (downcutting), lateral erosion, headward erosion
      - Streamflow erosion occurs by : Hydraulic action, abrasion, solution
      - Streams transport their sediment load in three ways: in solution **(dissolved load)**, in suspension **(suspended load),** sliding and rolling along the bottom **(bed load)**
      - A stream's ability to transport solid particles is described by: **Competence**

Teacher Tip

- During the instruction (lecture or powerpoint presentation) students must take notes in their notebook. The teacher will monitor as the lesson progresses and randomly call on students to read what they have written for a particular topic
- Teacher may explain the processes of weathering, erosion, and deposition in the context of systems to help students understand that the landscape can be imagined as a series of intimately linked components. Point out that exogenic processes are essentially driven by forces generated by the Sun-Earth system and by the pull of gravity. The sun's energy drives the water cycle and gravity controls rock and water movements downslope.
- The teacher may use the sediment jar to demonstrate sediment sorting. By this time most of the particles have settled to the bottom of the jar.

(size of the largest particle that can be transported by the stream) and **Capacity** (maximum load a stream can transport under given conditions)

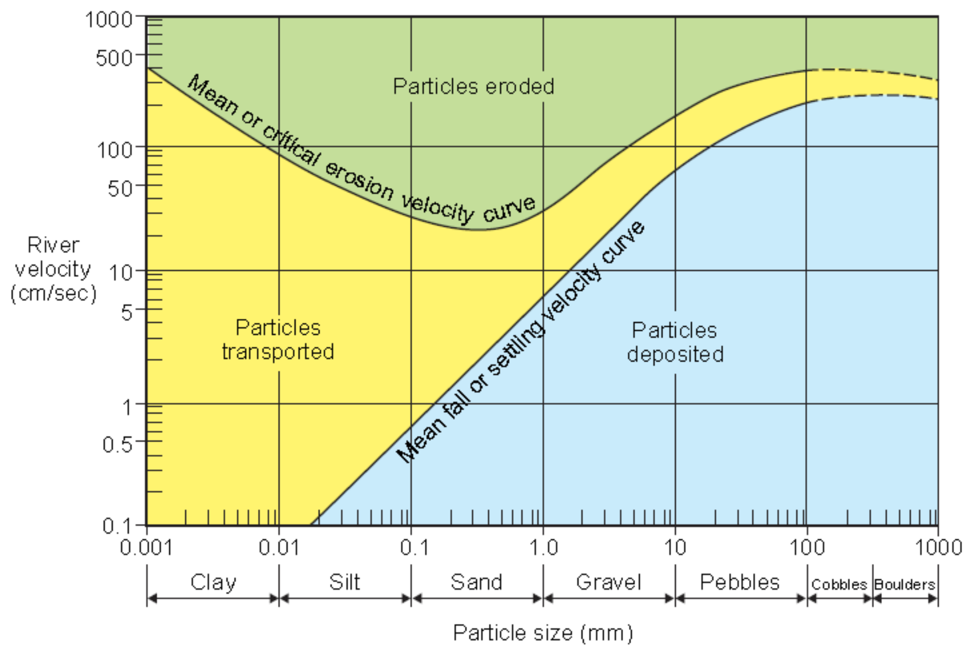
✦ **Activity: Interpreting Graphs**. With the teacher's help, have the students interpret the Hjulstrom diagram.

- Hjulstrom curve is used to determine whether a river will erode, transport or deposit sediment.
- Describe the x and y axes. Why do you think the graph uses logarithmic scale? (x-axis shows particle size(mm), y-axis represents mean flow velocity (cm/sec). Both the x and y axes are logarithmic in scale to accommodate a wide range of data in one graph.)
- Describe the upper and lower curves. (Upper curve shows the **mean or critical erosion velocity,** which is the **minimum velocity** needed to erode particles of varying sizes from the streambed. The region above the curve indicates erosion. Lower curve shows the **mean fall or settling velocity** which is the **maximum velocity** in which particles of different sizes are deposited. The region below this curve indicates deposition. Beyond this curve BUT below the minimum erosion velocity, particles are transported (the region between the two curves= transport)
- Describe the general trend of each curve. (Upper curve: In general, the mean velocity to erode a particle increases with particle size. However, for the small end of grain size (~0.001-0.03 mm), the velocity required for erosion actually increases. Clay particles tend to have planar structures and contain charged ions. Hence, they stick together making them harder to erode. Lower curve: As particle size increases, the **maximum velocity** at which the river drops its load increases).
- What does the area between the two curves represent? (Small particles are transported as suspended load while larger particles are transported as bed load.
- What does the diagram show about the settling velocity for clays? (The diagram illustrates that within the given range of stream

velocities, clays will remain suspended. Clay deposition occurs very slowly. The river should be almost stationary (~0 cm/sec) before clay settles down from suspension.

- What do you think are the weaknesses of the Hjulstrom curve? (Some problems with Hjulstrom curve: a. depends on average values. Velocity varies within the channel, b. velocity is not the physically correct variable for calculating whether a particle will move—shear stress, which takes into account depth and slope, is more important, c. does not take into account the density and shape of the grains, d. does not take into account turbulent flows which are important for sediment movement

Figure 1



Source: http://filestore.aqa.org.uk/subjects/AQA-GEOG1-QP-JAN13-CR.PDF

- Base level is the limit to how low the stream can erode. In general, lowering the base level leads to downward erosion. Raising it results to deposition.
- Deposition occurs when river loses energy and can no longer transport such a large load. With decrease in velocity and competence, sediments start to settle out. River deposits are sorted by particle size.

e. Explain how straight, braided, and meandering channels form.

f. Enumerate and describe erosional and depositional landforms created by a stream

- Erosional landforms: River valleys, Waterfalls, Potholes, Terraces, Gulley/ rills, Meanders (exhibit both erosional and depositional features), Oxbow lake, Peneplane
- Depositional landforms: Alluvial fans/cones, Natural levees, Deltas

2. Ocean or sea waves

a. Define wave. Identify the parameters by which a wave is described.

- Crest and Trough, Wave length (L), wave height (H), steepness (H/L), period (T), velocity (C=L/T)
- Waves are classified by the generation force: wind-generated waves, tsunami, tides, seiches (We'll focus on wind-generated waves)

b. List and discuss the factors that influence the height, length, and period of a wave and describe the motion of water within a wave. Describe how wave's velocity, length, and height change as the wave move into shallow water.

- Wind speed, Wind duration, Fetch (the distance the wind has travelled across water)
- Orbital motion of water in waves. In deep water, there is little or no orbital motion at depths greater than half the wavelength. As wave moves into shallower water, it starts to 'feel the bottom' at a depth equal to the wave base (D=L/2). C (velocity)↓, L ↓, H↑, T does not change as wave moves into shallow water.

c. Explain how waves erode and move sediment along the shore

- Shoreline erosion processes: Hydraulic action, abrasion, corrosion

- Transport by waves and currents: Longshore current, beach drift

d. Describe the features created by wave erosion and deposition
   - Erosional features: wave-cut cliff, wave-cut platform, marine terrace, headland, stacks and sea arches
   - Depositional features: beach, spit, baymouth bar, tombolo, barrier island

3. Glaciers

a. Define glacier. Identify and describe the characteristics of different types of glaciers.
   - Glacier is defined as a moving body of ice on land that moves downslope or outward from an area of accumulation (Monroe et. al., 2007)
   - Types of glaciers:
     1. Valley (alpine) glaciers are bounded by valleys and tend to be long and narrow.
     2. Ice sheets (continental glaciers) cover large areas of the land surface and unconfined by topography. Modern ice sheets cover Antarctica and Greenland.
     3. Ice shelves are sheets of ice floating on water and attached to the land. They usually occupy coastal embayments.

b. Explain how glaciers are formed. Discuss the mechanisms that account for glacial movement.
   - Glaciers are formed in regions where more snow falls than melts. Snow accumulates then goes through compaction and recrystallization to form firm and eventually transforms into glacial ice.
   - Glaciers move to lower elevations by plastic flow due to great stress on the ice at depth, and basal slip facilitated by meltwater which acts as lubricant between the glacier and the surface over which it moves.
   - The velocity of a glacier is lowest next to the base and where it is in contact with valley walls; the velocity increases toward the top center of the glacier.

c. Discuss the processes and the features created from glacial erosion.
   - Ice cannot erode the bedrock on its own. Glaciers pick up rock fragments and use them to abrade the surfaces over which they pass.

- Processes responsible for glacial erosion: Plucking (lifting pieces of bedrock beneath the glacier) and abrasion (grinding and scraping by sediments already in the ice). Plucking is responsible for creating roche moutonnee. Abrasion yields glacial polish and glacial striations. (Teacher may demonstrate glacial erosion by sticking double-sided tape on one side of a board eraser, press down and push the eraser with tape side down along the length of a paper sprinkled with a mixture of fine and coarse-grained sand. The particles are picked up and pushed to a different location. This left indentations and parallel grooves on the paper)
- Landforms created by valley glacier erosion: cirque, tarn, arête, horn, hanging valley, u-shaped valley, pater noster lakes, fjord
- Landforms created by continental glaciers: roche moutonnee

d. Distinguish between the two types of deposits by glaciers. Describe the landforms associated with each deposit.

- All glacial deposits are called glacial drift and comprised of two types: (1) till, deposited directly by ice, unsorted, and composed of many different particle sizes; (2) stratified drift, deposited by the glacial meltwater and thus has experienced the sorting action of water. As its name suggests, deposits are layered and exhibit some degree of sorting.
- Moraines are ridges of till and classified according to their position relative to the glacier: lateral moraine (edge of valley glaciers), end moraine (front or head of glacier), ground moraine (base of glacier), and medial moraine (middle). Medial moraines form when lateral moraines join as tributary glaciers come together. Other till features are erratics and drumlins.
- Features associated with glacial drift: kames(steep-sided hill of stratified drift), eskers(deposited in meltwater tunnels), kettle lakes (depression formed from melting of buried ice blocks), outwash plain.

4. Wind

a. Describe the processes associated with erosion and transportation by wind.

- Wind erodes by: deflation (removal of loose, fine particles from the surface), and abrasion (grinding action and sandblasting)

- Deflation results to features such as blowout and desert pavement. Abrasion yields ventifacts and yardangs.
- Wind, just like flowing water, can carry sediments as: (1) bed load which consists of sand hopping and bouncing through the process of saltation, and (2) suspended load (clay and silt-sized particles held aloft).

b. Identify features associated with Aeolian (wind –related) erosion and deposition. Describe their characteristics and the processes by which they are formed.

   - Features created by wind erosion: blowout and desert pavement created by deflation, ventifacts and yardangs resulting from abrasion
   - Two types of wind deposits: (1) dunes which are hills or ridges of wind-blown sand, and (2) loess which are extensive blankets of silt that were once carried in suspension
   - The size, shape, and arrangement of dunes are controlled by factors such as sand supply, direction and velocity of prevailing wind, and amount of vegetation. There are six major kinds of dunes: barchan dunes, transverse dunes, barchanoid dunes, longitudinal dunes, parabolic dunes, star dunes.
   - Primary sources of sediments contributing to loess deposits are deserts and glacial deposits.

5. Groundwater

a. Describe how groundwater erodes rock material.

   - The main erosional process associated with groundwater is solution. Slow-moving groundwater cannot erode rocks by mechanical processes, as a stream does, but it can dissolve rocks and carry these off in solution. This process is particularly effective in areas underlain by soluble rocks, such as limestone, which readily undergoes solution in the presence of acidic water.
   - Rainwater reacts with carbon dioxide from atmosphere and soil to form a solution of dilute carbonic acid. This acidic water then percolates through fractures and bedding planes and slowly dissolves the limestone by forming soluble calcium bicarbonate which is carried away in solution.

b. Describe karst topography and its associated landforms.

- Karst topography is a distinctive type of landscape which develops as a consequence of subsurface solution. It consists an assemblage of landforms that is most common in carbonate rocks but also associated with soluble evaporate deposits.
  - Cave/Cavern – forms when circulating groundwater at or below the water table dissolves carbonate rock along interconnected fractures and bedding planes. A common feature found in caverns is dripstone which is deposited by the dripping of water containing calcium carbonate. Dripstone features are collectively called speleothems and include stalactites, stalagmites, and columns
  - Sinkholes (Dolines) – circular depressions which form through dissolution of underlying soluble rocks or collapse of a cave's roof
  - Solution valleys – closed depressions which form from coalescing sinkholes
  - Disappearing streams – surface streams that flows and "disappears" into solution cavities and at other places may re-emerge as a spring
  - Tower karst – tall, steep-sided hills created in highly eroded karst regions;

6. Gravity

a. Define mass wasting and summarize the factors that control mass wasting processes.

- Mass wasting is the downslope movement of soil, rock, and regolith under the direct influence of gravity
- Factors that control mass wasting processes include:
  - Slope angle – as slope angle increases, the tendency to slide down the slope becomes greater
  - Role of water: adds weight to the slope, has the ability to change angle of repose, water pore pressure reduces shear strength of materials, reduces friction on a sliding surface
  - Presence of clays that expand when wet and shrink when dry
  - Weak materials and structures that can become slippage surfaces if weight is added or support is removed

ENRICHMENT (30 MINS)

- The students will explore features created by erosion and deposition by rivers using a stream table.
- Break the class into small groups. Students should work in groups of 3-4 or as materials allow.

- Building a Model of the river system

  Materials:

  - Large rectangular pan/tray: Plastic tub or aluminum roasting pan may be used. Punch a 1cm diameter hole into the edge of the pan (downstream end)
  - Water source containers: 3 paper cups with hole at the bottom. Water flow is regulated by punching a hole at the bottom, 0.3cm diameter for low discharge, 0.4cm for medium discharge, and 0.6cm for high discharge
  - Sediment mixture: pebbles, sand, and powdered clay (if not available use baking soda or flour). Put in more sand in the mixture
  - Wooden scraper: For molding the sediment in the tray
  - Thick cotton towel
  - Acetate transparency
  - Ruler
  - Sponge or old newspapers for mopping up spills
  - 2-3 books to prop up the tray
  - Bucket to catch excess water

Setting up the model:

1. Partially fill the tray with the sediment mixture. Moisten the sediment by adding water. Mix well. Make sure that the sediment mixture is not too watery.
2. Use the wooden scraper to push the damp sediments to one side of the tray without drainage hole, leaving approximately half of the tray empty. The empty half of the tray will represent the ocean.
3. Mold the sediment into a hillside by gently patting the sediment with your hand to create a wedge shape.

Teacher Tip

- To save time, have the students do the setting up part prior to the class. Remember that each group will have to work on 4 setups: (1) low discharge, (2) high discharge, (3) medium discharge & low slope angle, (4) medium discharge & high slope angle.

Procedure:

1. Elevate the end of the tray by propping it up using a book. This will create a gradient where the water flows downhill on a slope.
2. Place a ruler across the width of the tray, far enough from the edge such that the paper cup (water source container) that will be sitting on top of it will have the hole between the ruler and tray's edge. Secure the ruler with a tape.
3. Cover the hole at the bottom of the paper cup (low discharge cup with 0.3cm hole at the bottom) with a finger and fill it with water. Remove the finger to release water and watch as the water sculpt features on the surface of the hillside over a 5-minute period. Make sure to position a bucket below the tray's drainage hole to catch water and sediment. Refill the paper cup before it is completely empty.
4. Measure stream velocity by timing the movement of a small piece of toothpick over a measured length of channel.
5. Remix the sediment and set up the tray as described above. Repeat steps 1 to 4 but this time using the high discharge cup.
6. Remix the sediment and set up the tray as described above. Repeat steps 1 to 4 but this time using the medium discharge cup. Measure the slope using a protractor.
7. Repeat step 6 on a high slope angle by adding another book under the tray. Make sure to measure velocity and slope angle.

Discussion:

1. Describe what happens when you first pour water on the stream table. Do channels form right away? Which particles get eroded first? What determines the path which river follows?
2. Compare the stream velocity in each discharge scenario. Under which discharge scenario does more erosion occur?
3. Does more runoff occur in high or low angle topography? In which topography is velocity greatest? Where does more erosion take place?
4. What process dominates in the headwaters? In the mouth? What landforms or features do you observe forming in different locations on the stream? Make a labelled sketch of the

- To save time, have the students do the setting up part prior to the class. Remember that each group will have to work on 4 setups: (1) low discharge, (2) high discharge, (3) medium discharge & low slope angle, (4) medium discharge & high slope angle.
- If setting up the models cannot be done ahead of time, remind students that the **sediments must be remixed** and not just reshaped for each scenario.
- Remind the students not to oversaturate the sediments. They should mix just enough water to make the sediments damp. If the mixture is too soppy, they should sponge off excess water otherwise the data will show a high level of runoff at the start instead of gradual change over time.
- If cameras are available, let the students take a video or snapshots of the hillside/sediment wedge at frequent intervals during each run to better observe how fluvial features develop.
- Give the discussion questions to the students before they conduct the experiments. This will serve as their guide into which features/processes they have to observe. If pressed for time, discussion of the questions may be sent as homework.

features in your stream. Show where erosion and deposition occur.

5. Explain how stream gradient and velocity relate to transportation and deposition of sediments. Cite observation from the experiment to support your answer.

Ideas for extension/Homework:

1. Ask the students to use a map to locate a river or coastline nearest their community. Direct them to identify locations of erosion and deposition by making an annotated sketch of the river or coast. Explain how the different erosional and depositional features may have formed. Predict how the river/coast may change shape in the future and identify areas susceptible to fluvial/coastal erosion. (A satellite image from Google Earth of the lower and middle course of Agno River provided in this teaching guide may be used for this activity).
2. Let the students experiment with their stream tables.
   a. Explore the effect of permeable and impermeable surfaces to runoff.

      Students will use the thick cotton towel to represent dense vegetation and drape this o the upper one- third of their sediment hill. Water will be poured using the medium discharge cup in a duration of 5mins. They have to take note of the time the first runoff appears. Repeat the procedure using an acetate transparency to represent concrete pavements in urban areas.
   b. Assess house and infrastructure placement near rivers.
   c. Students will place their house where they think it is safe. Flood the river and see if their house survives.

      Explore the effect of base level change and varying discharge levels on the features or landforms created.

      Run the setup for 30 minutes, changing the discharge levels and base level during this duration while observing the landforms/features that emerge. Note where erosion and deposition occur. Students may create a time-lapse video using their mobile phones.

EVALUATION (12 MINS)

- Have each student formulate three review questions that cover the content of the lesson. Break the class into pairs and instruct the students that they will quiz their partners with the questions they have prepared and discuss between them the answers. Each pair should submit their questions and corresponding answers.

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Building a river model 1. Followed procedure throughout the activity and successfully completed tasks. 2. Data and observations are recorded accurately 3. Sketches are drawn accurately and clearly labelled 4. Answers to discussion questions are complete and written correctly and accurately Question and Answer 1. Questions are pertinent to the topic and stimulate thought and inquiry. The questions encourage students to evaluate and analyze in order to arrive to an answer. 2. Answers are accurate and complete. Response is correct and demonstrate understanding of concepts.				


Dagupan
Lingayen
Binmaley
Calasiao
Google


PNR Bayambang
Bayambang
Google

ADDITIONAL RESOURCES

Internet sources:

http://serc.carleton.edu/integrate/teaching_materials/energy_and_processes/activity_2.html (Accessed 12/06/2015)

http://serc.carleton.edu/files/nagt/jge/abstracts/Lillquest_v50n5p583.pdf (Accessed 12/06/2015)

Textbook sources:

Tarbuck, E.J., F.K. Lutgens, and Tasa, D. 2014. Earth An Introduction to Physical Geology. Eleventh Edition. Prentice Hall.

Monroe, J.S., Wicander,R., and Hazlett, R. 2007. Physical Geology: Exploring the Earth 6th edition. Thomson Brookes/Cole.

Endogenic Processes (Erosion and Deposition)

90 MINS

Content Standard
The learners demonstrate an understanding of the geologic processes that occur within the Earth

Performance Standard
The learners will be able to make a simple map showing places where erosion and landslides may pose risks in the community.

Learning Competencies
Explain why the Earth's interior is hot **(S11ES-IIb-c-23)**, and describe how magma is formed **(S11ES-IIc-24)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- recognize the sources and significance of the Earth's internal heat; and
- explain the requirements for magma generation.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Class Participation	5
Instruction	Lecture and Demonstration	50
Practice	Activity	30
Enrichment	Report	

Materials
For demonstration#1 (Convection current)
burner; beaker; water; coffee or tea
For "Chocolate Mantle Convection" Activity (Practice section)
1 flat pan or 500 mL tin ice cream can; 3 small candles; pan holder (higher than the candle); clean water; 1 cup chocolate/cocoa powder (to represent the lithosphere - this should not be mentioned before the activity)

Resources

(1) Carlson, D. H., Plummer, C. C., Hammersley L., Physical Geology Earth Revealed 9thed, 2011, pp46-47.

(2) Kirkland, K., Earth Sciences Notable Research and Discoveries, 2010, pp 18-21.

(3) Marshak, S., Essentials of Geology, 4th ed., 2013, pp99-100.

(4) Tarbuck, E. J. et al Earth An Introduction to Physical Geology, 2014, p 134-136.

(5) http://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Geophysics8%20-%20Thermal%20evolution/Heat.htm (Accessed 3Dec 2015).

(6) http://www.tulane.edu/~sanelson/eens211/earths_interior.htm(Accessed: 3 Dec 2015).

(7) http://www.geol.umd.edu/~jmerck/geol100/lectures/10.html (Accessed 3Dec 2015).

(8) https://www.youtube.com/watch?v=PdWYBAOqHrk (Accessed 07 Dec 2015).

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following learning objectives using the suggested protocols (Verbatim, Own Words, Read-aloud)
   a. I can identify the sources of the Earth's internal heat and describe the different processes responsible for the transfer of heat.
   b. I can explain the different conditions required in the generation of magma.

Review

- Review the parts of the different layers of the Earth – layering based on physical and chemical properties.
- Review the rock cycle and definition of magma.

MOTIVATION (5 MINS)

- Encourage class participation by asking a question that will guide the students' focus to the topics to be discussed:
- For example what are the materials that come out of an erupting volcano? Are they hot? If so, why?

Teacher Tip

The teacher can show a video or a photo of an erupting volcano. Then ask the students what materials come out of the volcano. The students may have different answers, but ask questions that would lead them to realize that hot gases, hot rocks, or other hot materials come out of volcanoes.

INSTRUCTION /DELIVERY/PRACTICE (50 MINS)

A. Heat in Earth's Interior

- Discuss the two categories of the internal heat sources of the Earth (http://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Geophysics8%20-%20Thermal%20evolution/Heat.htm).
  - Introduce the concept of primordial heat by briefly reviewing the process of earth formation. Specifically, the heat generated during the Earth's formation came from the following sources: accretion energy, adiabatic compression, core formation energy and decay of short-lived radio-isotopes.
  - Discuss radioactive heat (the heat generated by long-term radioactive decay): main sources are the four long-lived isotopes (large half- life), namely K^{40}, Th^{232}, U^{235}

Teacher Tip

- Teacher can ask the students what they learned about isotopes and Earth's formation.
- To illustrate heat generated from accretion, take a piece of metal/nail. Let the students feel and take note of the relative temperature of the nail. Take piece of metal and hammer it several times (using a hammer or a piece of rock). Then let the students feel it again. They would feel that it is significantly warmer than prior to hammering.

and U^{238} that continuously produces heat over geologic time.

- Explain geothermal gradient (Kirkland, K., Earth Sciences Notable Research and Discoveries, 2010,pp 18-21; Carlson, D. H. et al, Physical Geology Earth Revealed, 2011, pp 46-47; and http://www.tulane.edu/~sanelson/eens211/earths_interior.htm).
  - Geothermal gradient or geotherm: the temperature increase with depth into Earth (the non-linear temperature/depth curve) (Fig. 1).

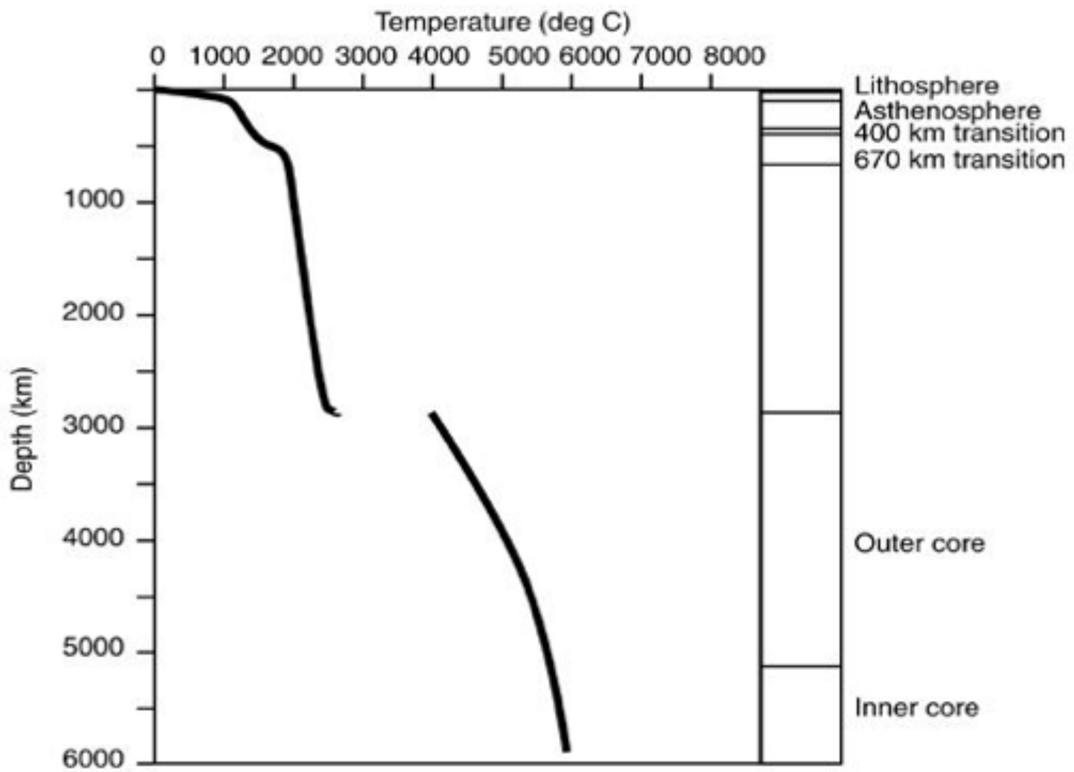


Figure 1. The geothermal gradient (source: http://www.geol.umd.edu/~jmerck/geol100/lectures/10.html)

- Adiabatic compression-compression in which no heat is added to or subtracted from the air and the internal energy of the air is increased by an amount equivalent to the external work done on the air. The increase in temperature of the air during adiabatic compression tends to increase the pressure on account of the decrease in volume alone; therefore, the pressure during adiabatic compression rises faster than the volume diminishes (http://www.mindat.org/glossary/adiabatic_compression).

- Non-linear: the increase in one variable (e.g. depth) is not proportional to the increase in the other variable (e.g. temperature)

- To further explain the concept of geothermal gradient and it's trend, ask the students to identify the temperature range of different Earth layers (e.g. Inner Core, Outer Core...). Use Fig. 1 for this exercise.

- Temperature gradient in the crust: ~25°C/km
- Some areas exhibit a much higher gradient as a result of a greater concentration of heat at relatively shallow depths. These areas (areas of anomalously high temperature gradient) are exploited for geothermal energy.
- If temperature was simply a linear function of depth (linear relationship), we should expect that at depths below 100 km (the average thickness of the lithosphere), temperature could reach as much as 2500°C. Partial melting of rocks can occur at this temperature yet we know that, except for the outer core, the rest of the Earth is essentially solid. Most of the rocks beneath the surface of the Earth is solid due to the fact that the geothermal gradient drops sharply a short distance into the earth and that increasing confining pressure with depth counteracts the effect of increasing temperature.
- Temperature gradient at the mantle: between 0.5°C/km to 1°C/km.

- Discuss the estimated internal temperature of the Earth (Carlson, D. H. et al, Physical Geology Earth Revealed, 2011, p 47 and http://www.geol.umd.edu/~jmerck/geol100/lectures/10.html)
  - Based on the geotherm curve above, it can be deduced that the mantle is considerably hotter than the crust, and the core is much hotter than the mantle.
  - Core-mantle boundary: 3,700°C
  - Inner-core – outer-core boundary: 5,000°C±500°C
  - Earth's center: 6,400°C±600°C

- Discuss how the Earth's internal heat is redistributed:
  - Simultaneous conduction, convection and radiation
  - Convection occurs at the mantle but not between the core and mantle or even between the asthenosphere and lithosphere (except at sea-floor spreading zones).The only heat transfer mechanism in these transition zones is through conduction.

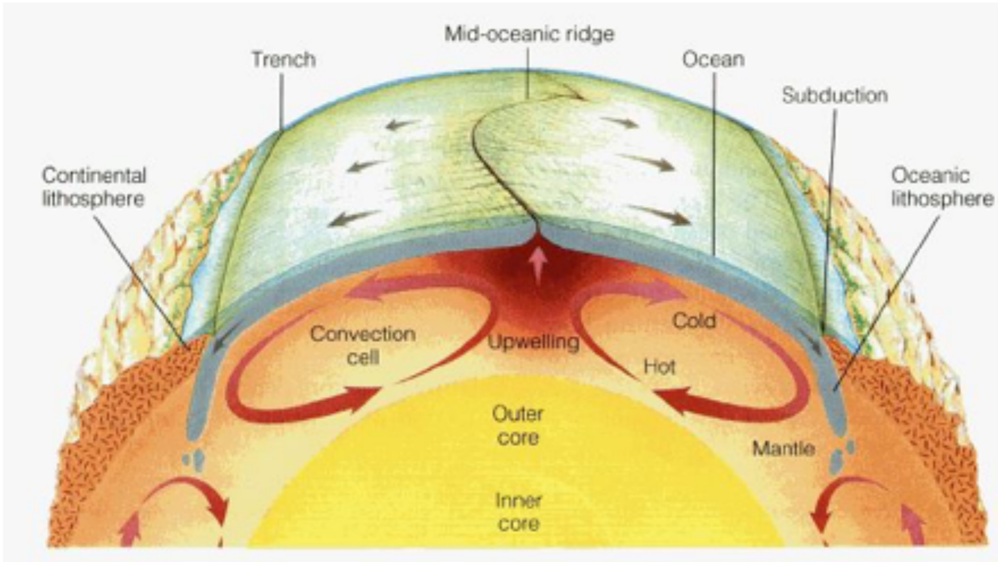


Figure 2. Diagram illustrating how heat is transferred in the Earth's interior. (source: http://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Geophysics8%20-%20Thermal%20evolution/Heat.htm).

Review the concepts of conduction, convection and radiation

- Demonstrate convection current (activity is based on the examples sourced from http://www.geol.umd.edu/~jmerck/geol100/lectures/10.html).

Instruction

Heat water in the beaker until it boils. Pour coffee or tea into it.

Discussion

1. Explain and guide the students in understanding the concept of convection by enumerating the mechanisms that occur when boiling the water.
   a. There is a heat source at the bottom of the water.
   b. The heat is rising to the top from the bottom.

Bring the students closer to the demonstration area. Make sure everybody is attentive before starting the activity.

c. The surface water becomes hot, and it radiates its heat into the air and then cools.

d. The cooler water sinks into the space vacated by the ascending warmer water. This cooler water starts to warm again while the one that rises starts to cool.

e. The process goes on, forming a top to bottom circulation of water.

Convection cell – the unit of a convective circulation

2. Observe what happens to the coffee or tea, especially the top portion. Explain what happens. The top portion has a relatively lighter color relative to the lower portion and represents the top of a convection cell. Condensing water vapor marks the top of rising columns of warm water. Dark line separating them marks the location of sinking cooler water.

Figure 3. An illustration of a convection process. Source: http://www.geol.umd.edu/~jmerck/geol100/lectures/10.html

Teacher Tip

- To save time, have the students do the setting up part prior to the class. Remember that each group will have to work on 4 setups: (1) low discharge, (2) high discharge, (3) medium discharge & low slope angle, (4) medium discharge & high slope angle.

B. Magma Formation

- Discuss the special conditions required for the formation of magma (Marshak, et al, Essentials of Geology, 2013, pp 99-100).

- Crust and mantle are almost entirely solid indicating that magma only forms in special places where pre-existing solid rocks undergo melting.

  A. Melting due to decrease in pressure (decompression melting): The decrease in pressure affecting a hot mantle rock at a constant temperature permits melting forming magma. This process of hot mantle rock rising to shallower depths in the Earth occurs in mantle plumes, beneath rifts and beneath mid-ocean ridges.

  B. Melting as a result of the addition of volatiles—compounds that have low boiling points (flux melting): When volatiles mix with hot, dry rock, the volatile decreases the rock's melting point and they help break the chemical bonds in the rock to allow melting.

  C. Melting resulting from heat transfer from rising magma (heat transfer melting): A rising magma from the mantle brings heat with it and transfer heat to their surrounding rocks at shallower depths which may melt.

- Identify the places where magma can form (http://www.geol.umd.edu/~jmerck/geol100/lectures/10.html).

  - ***Mid-oceanic ridges***:the rising magma in mantle convection cell brings heat to the surface, transferring heat to the overlying rocks. The transfer of heat due to convection is accompanied by a decrease in pressure or "decompression" associated with the spreading of the lithospheric plates. These two work in tandem promoting the partial melting of rocks along the spreading center.

  - ***Mantle plumes (hot spots)***: Similar to mid-oceanic ridges, the transfer of heat and decompression result to magma generation. The source of heat for mantle plumes is much deeper.

  - ***Subduction zones***: Oceanic crustal rocks are formed along spreading centers, typically beneath several kilometers of seawater. The presence of water during generation results to the formation of hydrous minerals. As the oceanic slab is down-thrusted along subduction zones, the change in temperature and pressure conditions brings about mineral instability (e.g. hydrous minerals) and the release of water to the surrounding hot rocks.

- At this point, emphasize that indeed heat is essential for magma formation (or melting of rocks). But other factors and processes can also induce melting such as decompression and addition of volatiles,

- Ask why decompression induces melting of rocks. In order to melt a rock, the bonds between the particles should be broken. Under intense pressure, this is not possible even when the temperature is high. When pressure is decreased, melting can occur because the bonds between the particles can be broken down and move farther away from each other.As an analogy example: Water under 1Gpa (Giga Pascal)pressure can remain solid even at 100ºC.

- To introduce the topic on where magmas can form, ask the students first in which environments or regions on earth where the three necessary conditions to induce melting (discussed earlier) can be found.

The introduction of water effectively lowers the melting temperature of rocks and therefore causes partial melting or magma generation.

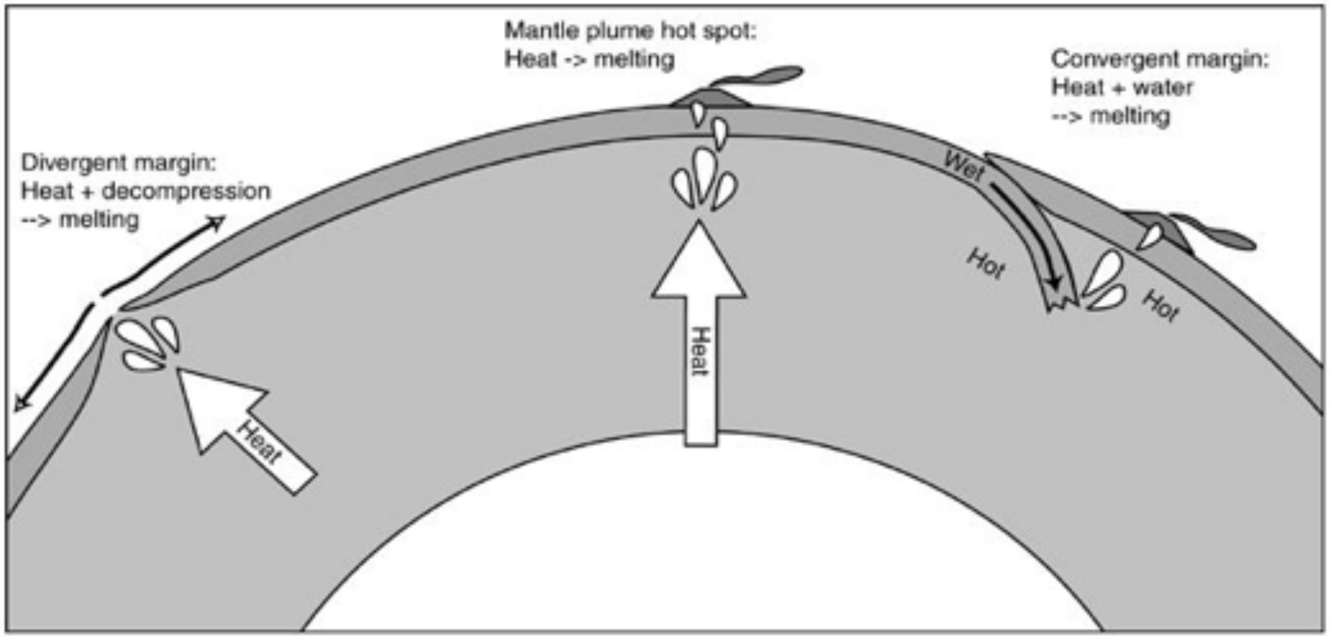


Figure 4. Schematic diagram showing different zones where melting occurs (source: http://www.geol.umd.edu/~jmerck/geol100/lectures/10.html)

PRACTICE (30 MINS)

- Divide the class into groups of 5 and perform the activity Chocolate Mantle Convection (adapted from the videoHot Chocolate Mantle Convection Demonstration. Source: https://www.youtube.com/watch?v=PdWYBAOqHrk).

Objective: To illustrate how heat works in the mantle.

Instruction:

- Put water in the pan. Sprinkle it with chocolate powder until the top is thickly covered with dry powder. Slowly put it on the pan holder. Light one of the candles and place it under the center of the pan. When it starts to boil, light the other two candles and put them in opposite sides of the pan. Observe what happens.

Discussion:

1. How is heat transferred in the activity? State evidence.

   Answer: Convection is shown by the presence of mounds and cracks in between the mounds, radiation is illustrated by the emitted gas directly above the heat source and conduction is evidenced by the submerging chocolate powder along the rims of the pan.

2. Describe what happens to the powder when the water starts to boil. Explain why this occurs.

   Answer: The chocolate powder starts to rise forming a conical shape then cracks and emits gas. Slowly, the chocolate powder around it starts to subside and get wet. The heat source is directly beneath this zone so the hotter water is rising in that area. But since the chocolate powder traps the water, the hot water starts to move laterally under the chocolate powder forming the conical shape, before it manages to create a crater where the water is released as gas.

3. Describe what happened after boiling is achieved in the other two candles. Explain why this occurs.

   Answer: The other two candles will create the same thing as the first candle. However somewhere in between the two candles, a crack starts to form and the chocolate powder sinks slowly in these regions. This occurs because these are the zones where the colder water goes down.

4. How does this activity relate to the formation of magma?

   Answer: The water represents the asthenosphere, the chocolate powder represents the lithosphere and the candles represent heat sources. Magmas are formed directly above the heat sources due to relatively higher temperature. Through convection, heat is transferred to other places. And since there are more than one heat sources, several convection cells develop. Where the colder portions of two convection cells meet, cracks form because the materials are being pulled downwards by the subsiding colder water. These zones represent subduction zones.

ENRICHMENT

A simple report to be submitted on the next day:

Draw a schematic cross section of the earth, showing the different layers of the earth. Include and label (when necessary) the following in the illustration:

1. different tectonic settings where magma is generated

2. type of melting that is usually associated with the settings identified in # 1
3. heat transfer mechanisms and the direction of heat transfer (thru arrows)

Below the drawing, make a simple research on the different zones where magma is formed and cite one known location of each.

EVALUATION

Summary questions related to the lessons. Questions are classified as described in the table below.

Question Format	**Type of Question**
In regular font	Questions that test whether the student can recall, recognize, define, describe or give examples (knowing).
In bold	Questions that test whether the students understand a concept and apply it in new situations, classify, compare, contrast, relate, use models, interpret information, or explain (applying).
Italicized and bold	Questions that test whether the students can analyze, generalize, integrate, predict, justify, design or draw conclusions (reasoning).

1. What are the two categories of the source of Earth's internal heat? Give examples.

   Answer: Primordial heat source: accretion energy, adiabatic compression, core formation energy and decay of short-lived radio-isotopes.

   Radioactive heat source: decay of long-life isotopes such as K^{40}, Th^{232}, U^{235} and U^{238}.

2. How is the Earth's internal heat redistributed?

   Answer: Magma transfers the heat from the Earth's interior to the surface when it rises.

3. Differentiate decompression melting and flux melting.

   Answer: Decompression melting is the process of creating magma by reducing the pressure at a constant temperature. Flux melting occurs upon the introduction of volatiles which breaks the chemical bond in rocks and at the same time lowers the melting temperature of the rocks.

4. Describe how magma is formed.

   Answer: Magma is formed when hot rocks in the Earth partially melt which occurs when (1) the pressure decreases, (2) when volatiles are added to hot rocks and (3) when heat is transferred by a magma rising from the mantle into the crust.

5. Cite three tectonic settings where magma is formed.

   Answer: mid-oceanic ridges, hot spots and subduction zones

6. Cite an example of a tectonic setting where two melting processes occur simultaneously to generate magma.

   Answer: (May vary) In mid-oceanic ridges, the rising hot rocks in mantle convection cell bring heat to the surface, transferring heat to the overlying rocks. Simultaneously occurring in these rocks is decompression melting. While the lithospheric plates move further away from the mid oceanic ridge, the pressure decreases resulting to more melting.

7. Are there any significance or relations of magmatic formation and their eventual rise to the shallower depths to our daily lives?

   Answer: There are a lot of relationships between magmatic processes and our daily lives. One example is that the mineral deposits that we extract from the earth are carried by magma to shallower depths where we people can mine them out. The extractions of mineral deposits have tremendously changed our lifestyles, civilizations, state of technology and so on.

Classification of Competency Measurements

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Practice Activity	Did not complete the activity and did not answer any of the questions	Activity completed on time; correctly answered 1- 2 questions; answers are not presented well	Activity completed on time; authors demonstrate acceptable understanding of topic in answering the question; and answered 3- questions correctly	Activity completed on time; authors demonstrate excellent level of understanding of topic in presenting the answers; correctly answered all questions
Enrichment Project	Did not submit report on time; report is not complete	Report is submitted on time but is lacking of substance; report not well presented	Report is submitted on time; report is well-presented (organized flow of discussion with few instances straying from the topic) authors demonstrate acceptable understanding of topic (few corrections and misconceptions)	Report submitted on time; report is excellently presented (highly organized flow of discussion); authors demonstrate excellent level of understanding of the topic
Summary Questions	Only 2 of the easy questions are correctly answered	Correctly answered the easy questions	Correctly answered the easy questions and 2 hard questions	Correctly answered all questions

75 MINS

Endogenic Processes (Erosion and Deposition)

Content Standard
The learners demonstrate an understanding of the geologic processes that occur within the Earth

Performance Standard
The learners will be able to make a simple map showing places where erosion and landslides may pose risks in the community.

Learning Competency
Describe what happens after a magma is formed **(S11ES-IIc-25)**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- explain how and why magma rises up;
- understand the concept of Bowen's reaction series; and
- identify, understand and explain magmatic differentiation mechanisms operating beneath the surface of the Earth.

LESSON OUTLINE

Introduction	Communicating learning objectives	10
Motivation	Class Participation	5
Instruction	Lecture and Demonstration	30
Practice	Concept Mapping	15
Enrichment	Report	

Materials
For demonstration#1 (Partial Melting)
2 small beakers (50 or 100 mL); chopped candlewax; fine gravel
For demonstration#2 (Magma mixing)
media player
For Practice
Manila paper; cardboards (for flash cards); marking pen; masking tape
For tips on introducing new concepts:
Density difference - a coin; piece of rock; piece of styrofoam; glass or pail of water
Viscosity - 1/8 cup of water; oil; honey (or water and sugar thick solution)

Resources

(1) Monroe, J. S., et al, Physical Geology Exploring the Earth, 6th ed., 2007, pp107-113.

(2) Carlson, D. H., Plummer, C. C., Hammersley L., Physical Geology Earth Revealed 9thed, 2011, pp289-292.

(3) Marshak, S., Essentials of Geology, 4th ed., 2013, pp102-105.

(4) Tarbuck, E. J. et al Earth An Introduction to Physical Geology, 2014, pp137-140.

(5) http://www.colorado.edu/geolsci/courses/GEOL3950/class_notes/Lecture%20%239%20notes%202006.pdf): (Accessed 15Dec 2015).

Additional resources at end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following learning objectives using the suggested protocols (Verbatim, Own Words, Read-aloud)
   a. I can identify and explain the different magmatic processes occurring beneath the surface of the Earth.

Review

- Review the processes and conditions for magma generation and the areaswhere magma is generated.

MOTIVATION (5 MINS)

- Encourage class participation by asking a question that will guide the students' focus to the topics to be discussed, such as:
  - What happens to magma after it is formed?

Teacher Tip

The teacher can guide the students by asking some questions that lead to the expected answers.
Example leading questions:

1. Do you think magma rises or stays in place?
2. What happens to the composition of magma as it rises up?

INSTRUCTION /DELIVERY/PRACTICE (50 MINS)

A. Discuss why and how magma rises up

- **Density contrast:** magma is less dense than the surrounding country rock. Magma rises faster when the difference in density between the magma and the surrounding rock is greater.
  - **At deeper levels**, magma passes through mineral grain boundaries and cracks in the surrounding rock. When enough mass and buoyancy is attained, the overlying surrounding rock is pushed aside as the magma rises. Depending on surrounding pressure and other factors, the magma can be ejected to the Earth's surface or rise at shallower levels underneath (Fig. 1).

Teacher Tip

- To introduce the concept of density difference, the teacher can make a demonstration on how materials of different densities behave when placed in a medium (e.g. water). The teacher can put a coin, a piece of rock, and a piece of Styrofoam on a pail/glass of water, and let the students observe what happens to these materials. A guide question will be: Which materials sink and which ones float? Let the students explain their observation.
- To illustrate viscosity, the teacher can make a demonstration using at least three different liquids: honey, oil, water.

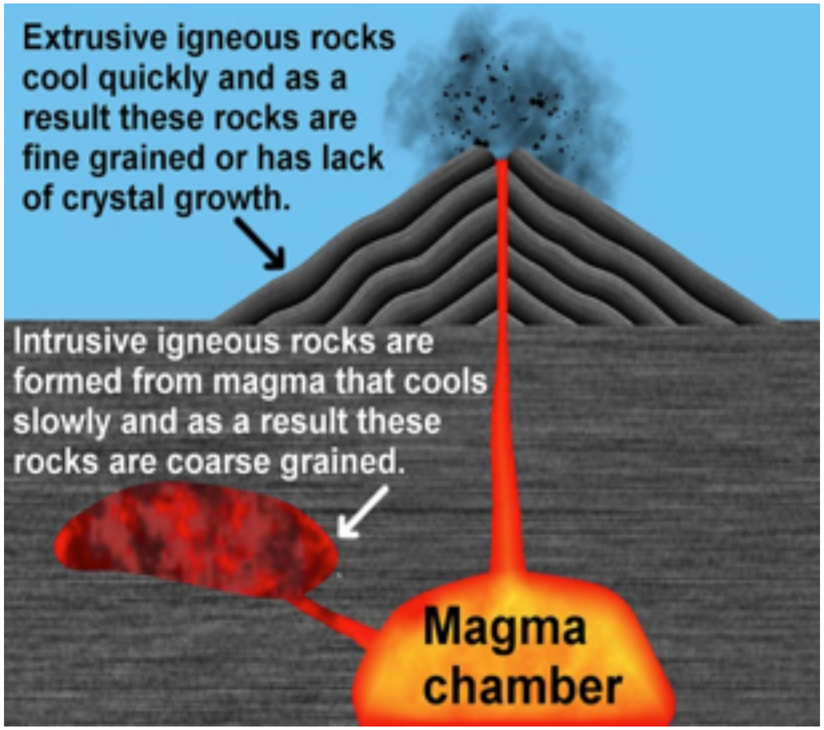


Figure 1. Two processes as magma rises up: (1) ejected out to the surface through volcanoes (2) solidifies within the shallower levels. Source: http://en.wikipedia.org/wiki/Igneous_rock#/media/File:Igneous_rock_eng_text.jpg. Accessed: May 2, 2016

- Using a pan, the teacher can ask a student to pour the liquid on the pan.
- Ask the students to observe how the different liquids flow (e.g. very fast, fast, slow etc.) on the pan.

- **At shallower levels**, magma may no longer rise because its density is almost the same as that of the country rock. The magma starts to accumulate and slowly solidifies (Fig. 2).

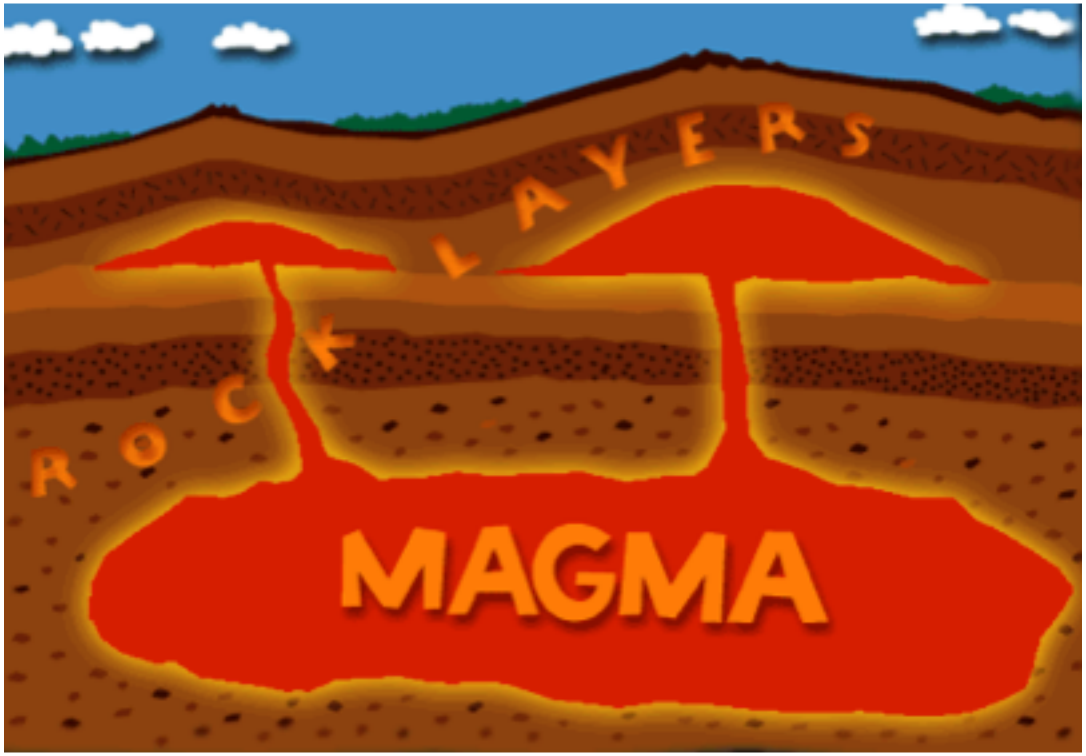


Figure 2. The magma chamber and rising magma. Magma chamber: Source : http://www.windows.ucar.edu/tour/link=/earth/geology/images/batholith_gif_image.html

- Viscosity: a measure of a fluid's resistance to flow. Magmas with low viscosity flow more easily than those with high viscosity. Temperature, silica content and volatile content control the viscosity of magma. Use the table below to clarify the effects of different factors on magma viscosity.

Table 1. Different factors that affect magma's viscosity.

Factor	Effect to Viscosity
↑ temperature	↓ viscosity
↑ Silica content (SiO2)	↑ viscosity
↑ dissolved water (H2O)	↓ viscosity

- Mafic magma is less viscous than silicic (felsic) magma because it is hotter and contains less silica. Also, the volatiles in magma decreases viscosity.

B. Introduce the Bowen's reaction series

(Fig. 3.)(Carlson, D. H., Plummer, C. C., Hammersley L., Physical Geology Earth Revealed 9th ed., 2011, pp289-290).

- Certain minerals are stable at higher melting temperature and crystallize before those stable at lower temperatures.
- Crystallization in the continuous and discontinuous branches takes place at the same time.
- Continuous branch: contains only plagioclase feldspar, with composition changing from calcium-rich to sodium rich as temperature drops.
- Discontinuous branch describes how ferromagnesian minerals in the magma are transformed as temperature changes. The early formed crystals, olivine in this case, reacts with the remaining melt as the magma cools down, and recrystallizes into pyroxene. Further cooling will transform pyroxene into amphibole. If all of the iron and magnesium in the melt is used up before all of the pyroxene recrystallizes to amphibole, then the ferromagnesian minerals in the solid rock would be amphibole and pyroxene and would not contain olivine or biotite.

- To introduce the Bowen's reaction series, convey the anecdote on how the proponent NormanL. Bowen came up with the Bowen's reaction series. The teacher can refer to this excerpt :

- Norman L. Bowen explained why certain minerals tend to occur together while others are almost never associated with one another. In the early 1900s, he heated powdered rock material until it melted. He allowed the molten material to cool down and observed the minerals that formed in the rocks. He repeated this process with progressively lower temperatures and the results he got led him to the now called Bowen's reaction series.Up to this day, the series is still accepted as the idealized progression of minerals produced by cooling magma. Based upon his work, one can infer from the minerals present in a rock the conditions (temperature and pressure) under which the rock had formed.

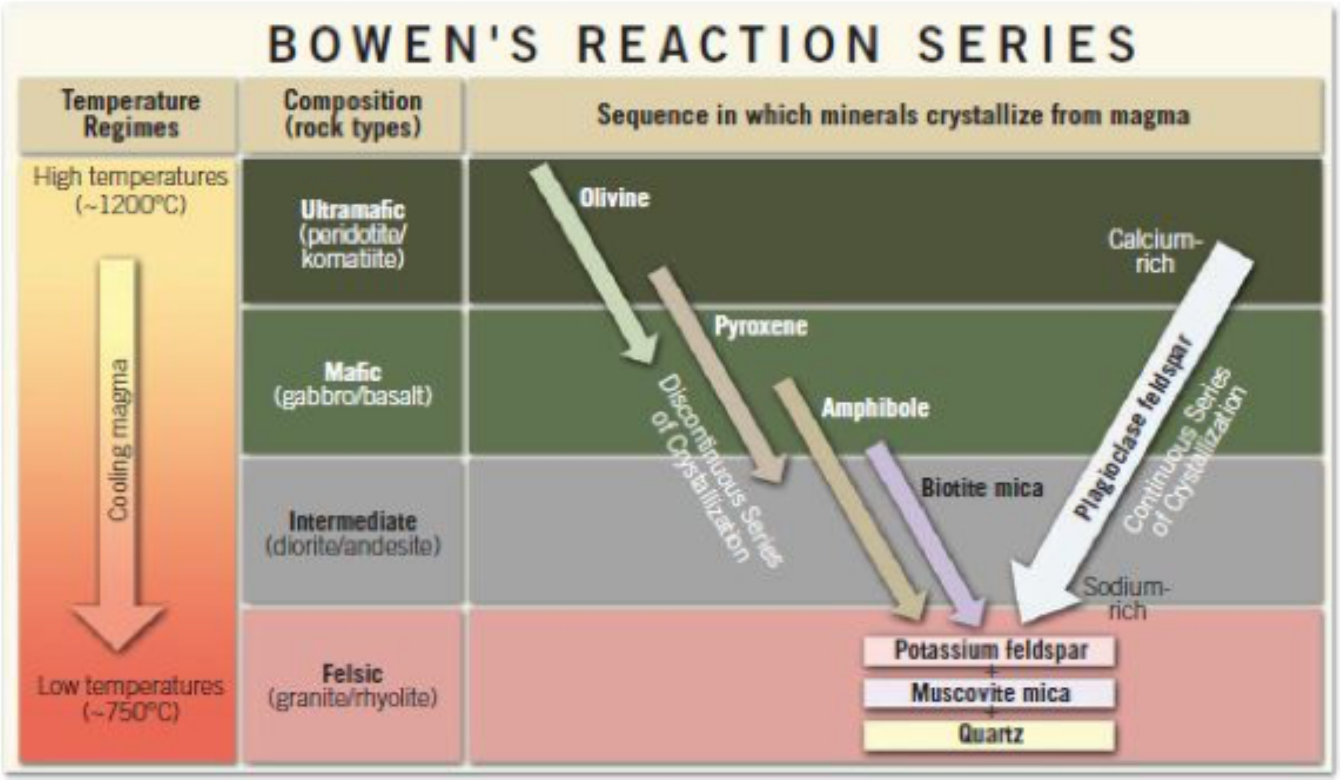


Figure 3. Generalized Bowen's reaction series. Sourced from Tarbuck, E. J. et al Earth An Introduction to Physical Geology, 2014, p137.

- Important concepts derived from the Bowen's reaction series:
  - A mafic magma will crystallize into pyroxene (with or without olivine) and calcium-rich plagioclase —that is, basalt or gabbro —if the early formed crystals are not removed from the remaining magma. Similarly, an intermediate magma will crystallize into diorite or andesite, ifearly formed minerals are not removed.
  - If minerals are separated from magma, the remaining magma is more silicic than the original magma. For example, if olivine and calcium-rich plagioclase are removed,the residual melt would be richer in silicon and sodium and poorer in iron and magnesium.

- When rocks are heated in high temperatures, minerals will melt in reverse order, going up the series in the Bowen's reaction series diagram. Quartz and potassium feldspar would melt first. If the temperature is raised further, biotite and sodium-rich plagioclase would contribute to the melt. Any minerals higher in the series would remain solid unless the temperature is raised further.

C. Discuss the different processes by which the composition of magma may change (magmatic differentiation).

- Magmatic differentiation is the process of creating one or more secondary magmas from single parent magma (Tarbuck, E. J. et al Earth An Introduction to Physical Geology, 2014, p138).

1. **Crystal Fractionation**–a chemical process by which the composition of a liquid, such as magma, changes due to crystallization (https://wwwf.imperial.ac.uk/earthscienceandengineering/rocklibrary/viewglossrecord.php?gID=00000000159). There are several mechanisms for crystal fractionation. One that is directly related to the Bowen's reaction series is crystal settling.
   - Crystal settling - denser minerals crystallize first and settle downwhile the lighter minerals crystallize at the latter stages.Bowen's reaction series shows that denser minerals such as olivine and Ca-rich plagioclases form first, leaving the magma more silicic(Tarbuck, E. J. et al Earth An Introduction to Physical Geology, 2014, p138).
2. **Partial Melting**- as described in Bowen's reaction series, quartz and muscovite are basically formed under low temperature conditions, making them the first ones to melt from the parent rock once exposed in higher temperature and/or pressure. Partial melting of an ultramafic rock in the mantle produces a basaltic magma(Carlson, D. H., Plummer, C. C., Hammersley L., Physical Geology Earth Revealed 9th ed, 2011, p292).

- Note that there are other mechanisms in crystal fractionation such as filter pressing, inward crystallization and flow segregation. The teacher can mention these briefly, but does not necessarily discuss. These topics require more advanced understanding of other natural processes.

Demonstration#1: Partial Melting (copied from http://www.earthlearningidea.com/PDF/82_Partial_melting.pdf):

- The teacher should prepare the models at least few hours before the class starts.

Instructions:

- Prepare the two beakers shown in the left photo below (Fig. 4). In each beaker, put about 1 cm depth of fine gravel mixed thoroughly with about 2 cm depth of candlewax that has been cut into fragments about the same size as the pieces of gravel. Warm one of the beakers over a Bunsen until the candlewax melts. At this stage, the gravel sink to the bottom, leaving a layerof pure candlewax at the top. Leave the beaker to cool and the wax to solidify.
- Show the students the beaker containing the mixture of gravel and chopped candlewax before heating; ask what will happen if the beaker is heated until the wax melts. Most will realize that the gravel will sink to the bottom to form a mixed gravel/wax layer, whilst pure wax will flow to the top to form another layer. Then use the second beaker to show that this is what happens.
- Explain that this shows the results of partial melting. When solids made of mixed materials start to melt, the substances with the lowest melting point melt first – giving a partial melt. The substances with the highest melting points often don't melt, but sink through the partially molten material to the bottom. The material that flows to the top cools and solidifies; it is composed only of the lower melting point material.

Figure 4: Beaker Setup

Underlying principles about the demonstration:

- When solid mixtures partially melt, it is the lower melting point materials that melt first.
- Separation can occur in partial melts, with the high melting point materials sinking to the bottom and the liquid from the lower melting point materials flowing to the top. These two different materials, that have different chemical compositions and different physical properties, may then be further separated, e.g., by the liquid rising further through overlying materials, leaving the solid behind.

Additional information on the depletion and enrichment of certain elements that occur during partial melting can be discussed after the demonstration #1.

- Oxygen/silicon-rich rock-forming minerals have lower melting points than iron/magnesium-rich minerals.
- Each stage of partial melting produces rocks enriched in oxygen/silicon (and depleted in iron/magnesium)

3. **Magma mixing** – this may occur when two different magma rises up, with the more buoyant mass overtakes the more slowly rising body. Convective flow then mixes the two magmas, generating a single, intermediate (between the two parent magmas) magma (Tarbuck, E. J. et al Earth An Introduction to Physical Geology, 2014, p139).

Demonstration # 2: Magma Mixing (copied from http://www.eos.ubc.ca/resources/webres/concepts/igneous/magma/magexper.html). The downloadable video clip can be found at(http://www.eos.ubc.ca/resources/webres/concepts/igneous/magma/magmovie.html).

- If time and resources are available, the activity can be done in the class (takes about 15 minutes).

Overview

- A container is used to simulate a compositionally stratified magma chamber. The bottom opening allows fluid at a constant pressure to enter the system. This causes the fluid already in the chamber to be forced out the top opening. The top opening is analogous to the volcanic neck of an erupting volcano.
- The layers within the container dividedinto materials with a lower density and higher viscosity layer on the top, (eg: rhyolite), and ahigher density and lower viscosity layer on the bottom, (eg: basalt). By controlling the density and viscosity contrast between the two layers, magmas with different compositions in the same chamber, can be simulated. i.e: a rhyolite overlaying a basalt.
- The experimental setup is illustrated on the right.
    1. Top layer: this layer consists of water mixed with CMC, an organic polymer. Mixing with CMC increases the viscosity with little to no effect on the density. Different ratios of water to CMC can be used to obtain the desired viscosity whilst keeping the density constant. Metal filings are added to this layer so that motion can be detected.

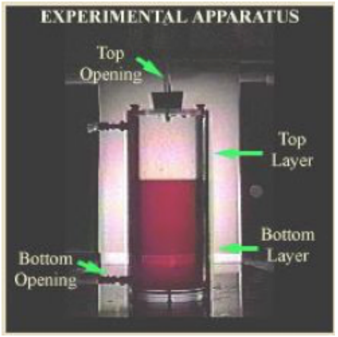
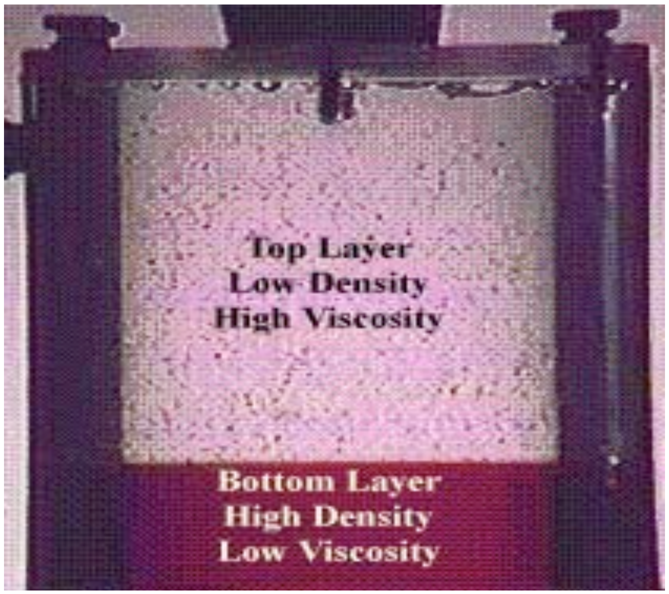
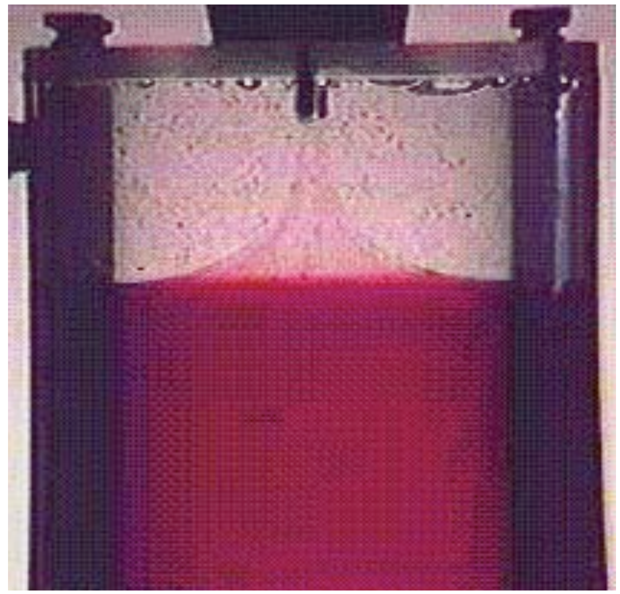


Figure 5: Experimental Setup

2. Bottom layer: this layer is composed of water mixed with salt. The addition of salt increases the density while having little effect on the viscosity. Thus the density of the fluid can be controlled. Red food coloring was added so that the two layers could be easily distinguished.

Experiment Stages





- The video clip shows several stages which correspond to changes in geologically significant processes. Two stills are collected from the movie to illustrate these stages.
- Stage1 (Left photo): As fluid enters the bottom of the chamber, fluid is expelled through the conduit at the top of the chamber. As this process proceeds convection cells develop in the top layer.

- Note the semicircular arrangement of the metal filings. In the movie, some parts of the chamber are affected by this convection, and others are not.

- Stage 2 (Right photo): A critical level is reached where the denser bottom layer, being less viscous, is more readily forced up through the top layer, and a cone structure develops.

- At this point both magmas are being tapped at the same time and mixing of the magmas can proceed in the conduit. The extent to which the two magmas mix in the conduit relates to differences in the densities and viscosities of the fluids. If the viscosity contrast is high, blending is retarded and mingling dominates. If the fluids have similar viscosities then blending is facilitated.

4. **Assimilation/contamination of magma by crustal rocks -** a reaction that occurs when the crust is mixed up with the rising magma. As magma rises to the surface, the surrounding rocks which it comes in contact with may get dissolved (due to the heat) and get mixed with the magma. This scenario produces change in the chemical composition of the magma unless the material being added has the same chemical composition as the magma (http://www.tulane.edu/~sanelson/eens212/magmadiff.htm).

PRACTICE (15 MINS)

Conceptual mapping of the Bowen's reaction series.

- Pre-activity: Before the class starts, the teacher has to prepare two sets of blank diagram of the Bowen's reaction series in a Manila paper, flash cards for the different parameters, minerals and rock types (Refer to the Bowen's reaction series diagram provided in the Instruction delivery section).

- During the activity: Group the class into two. Give the teams five minutes to paste the flash cards into the diagram in their correct places. Make sure that the students do not refer to their notes and just dwell on how much they learned and understood during the class discussions. Each group to present their answers in front of the class (five minutes each).

Teacher Tip:
The activity may be modified depending on the resourcefulness of the teacher.

ENRICHMENT

- A simple report to be submitted on the next day.
- Explain the role of magmatic differentiation in plate tectonics.

Question Format	Type of Question
In regular font	Questions that test whether the student can recall, recognize, define, describe or give examples (knowing).
In bold	Questions that test whether the students understand a concept and apply it in new situations, classify, compare, contrast, relate, use models, interpret information, or explain (applying).
Italicized and bold	Questions that test whether the students can analyze, generalize, integrate, predict, justify, design or draw conclusions (reasoning).

Teacher Tip:
Review the concepts of conduction, convection and radiation

EVALUATION

Summary questions related to the lessons. Questions are classified as described in the table below.

1. Define viscosity.

   Answer: Viscosity is the measure of a substance's resistance to flow.

2. Identify the three major factors controlling the viscosity of magma/lava.

   Answer: The three major factors controlling the viscosity of magma and/or lava are temperature, silica content and volatile content.

3. **Describe how viscosity affects the movement of magma. Compare the viscosity of basaltic and granitic magmas.**

   Answer: Viscosity is the measure of fluid's resistance to flow. Mafic or basaltic magma, when compared to a felsic or granitic magmais more mobile and flows faster as it is less viscous due to its higher temperature and less silica content. Granitic magmadoes not reach the Earth's surface as often due to its higher viscosity, but in case, it tends to be thick, slow-moving and can only flow short distances.

4. True or False: Magmatic differentiation is the process of creating one or more secondary magmas from single parent magma.

   Answer: True.

5. **How does magma composition change during crystallization?**

   Answer:Magma becomes progressively more silica-enriched as crystallization progresses.

6. What are the two branches of the Bowen's reaction series? Give one mineral example for each branch.

   Answer: Continuous and discontinuous branches. Olivine belongs to the discontinuous branch.

   Plagioclase feldspar is the mineral in the continuous branch.

7. **What is the Bowen's reaction series?**

   Answer: Bowen's reaction series describes the sequence of mineral crystallization in a cooling magma. The two branches of theseries are the continuous and discontinuous branches. As the temperature drops, the discontinuous branch describes how minerals are transformed into another type of mineral while the continuous branch shows how calcium-rich plagioclase feldspar is progressively changed into sodic plagioclase. The reverse of Bowen's reaction series describes the melting of rock.

8. **Rising magma assimilates crustal rocks but does not result in any change in the composition of the resulting magma. In what condition/s can this occur?**

   Answer: When the composition of crustal rock and magma are the same, then the composition of a rising magma will not be altered even when assimilation occurs.

9. True or False: The different mechanisms through which crystal fractionation occurs are crystal settling, filter pressing, inward crystallization and flow segregation.

   Answer:True.

10. **What will happen to the cooling magma when a new batch of hot magma is injected in it?**

Answer: This can cause extreme fractional crystallization due to several effects from the newly injected magma. Existing minerals can be remelted and incorporated into the magma, and therefore new higher temperature minerals can begin crystallizing. The crystallizing minerals may also change composition due to the fresh injection.

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Enrichment Project	Did not submit report on time; report is not complete	Report is submitted on time but is lacking of substance; report not well presented	Report is submitted on time; report is well-presented (organized flow of discussion with few instances straying from the topic) authors demonstrate acceptable understanding of topic (few corrections and misconceptions)	Report submitted on time; report is excellently presented (highly organized flow of discussion); authors demonstrate excellent level of understanding of the topic
Summary questions	Only 4 of the easy questions are correctly answered	Correctly answered the easy questions	Correctly answered the easy questions and 4 hard questions	Correctly answered all questions

ADDITIONAL RESOURCES

1. https://wwwf.imperial.ac.uk/earthscienceandengineering/rocklibrary/viewglossrecord.php?gID=00000000159(Accessed: 14 Dec 2015).
2. (http://www.tulane.edu/~sanelson/eens212/magmadiff.htm(Accessed 3Dec 2015).
3. http://www.science.marshall.edu/elshazly/Igmet/Differentiation.doc (Accessed 18 Dec 2015).
4. http://www.eos.ubc.ca/resources/webres/concepts/igneous/magma/magexper.html(Accessed 20 Dec 2015).
5. http://www.eos.ubc.ca/resources/webres/concepts/igneous/magma/magmovie.html(Accessed 20 Dec 2015).

Endogenic Processes (Erosion and Deposition)

Content Standard
The learners demonstrate an understanding of the geologic processes that occur within the Earth

Performance Standard
The learners will be able to make a simple map showing places where erosion and landslides may pose risks in the community.

Learning Competency
Describe the changes in mineral components and texture of rocks due to changes in pressure and temperature (metamorphism) **(S11ES-IIc-d-26)**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- understand the different metamorphic facies; and
- understand the processes and factors that cause the metamorphic texture.

60 MINS

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Class Participation	5
Instruction	Lecture and Demonstration	30
Practice	Simulation Activity	20
Enrichment	Report	
Evaluation	Answering of Summary Questions	

Materials
Box of matchstick or short lengths of uncooked pasta noodles; two rulers; piece of slate, preferably with color bands from the original bedding or photograph; modelling clay; disposable plastic; stirring rod; seashell (e.g. cockle shell); plaster of paris or melted candle; water

Resources

(1) Imperial College London. (2013). Rock Library. Retrieved from https://wwwf.imperial.ac.uk/earthscienceandengineering/rocklibrary/viewglossrecord.php?Term=pelite

(2) Monroe, J. S., Wicander, R., & Hazlett, R. W. (2007). *Physical geology: Exploring the Earth* (6th ed.). Belmont, CA: Thomson Brooks/Cole.

(3) Nelson, S. A. (2011). Metamorphic Mineral Assemblages. Retrieved from http://www.tulane.edu/~sanelson/eens212/metaminerals.htm

(4) Nelson, S. A. (2011). Types of Metamorphism. Retrieved from http://www.tulane.edu/~sanelson/eens212/typesmetamorph.htm

(5) Nelson, S. A. (2012). Metamorphic Textures. Retrieved from http://www.tulane.edu/~sanelson/eens212/metatexture.htm

(6) Royal Society of Chemistry. (n.d.). Metamorphic modelling: simulating metamorphic processes: teacher's notes. Retrieved from http://www.rsc.org/education/teachers/resources/jesei/meta/index.htm

(7) Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Prentice Hall.

Additional resources at end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following specific learning objectives:
   - Understand the different metamorphic facies
   - Understand the processes and factors that cause the metamorphic texture

Review

2. Review the following concepts:
   - Review the rock cycle. Highlight where metamorphic rocks occur in the rock cycle and how it is related to other types of rocks.
   - Review metamorphic rocks and how they are formed.

MOTIVATION (5 MINS)

1. Encourage class participation by asking questions such as the following:
   - What do we mean when we say metamorphic rocks?
   - How are metamorphic rocks formed?
2. Metamorphic rocks are similar to sedimentary rocks in the sense that they are both "recycled" rocks (derived from pre-existing rocks). Whereas sedimentary processes (weathering, erosion, and deposition) occur at surface or near surface conditions, metamorphism (the process through which pre-existing rocks are transformed into metamorphic rocks) normally occur at subsurface conditions (resulting from but not limited to deep burial). Unlike igneous rocks, there is no melting involved in metamorphism.

Teacher Tip

Emphasize that, in metamorphism, all changes (physical or chemical) that rocks undergo occur in the solid state (no melting involved).

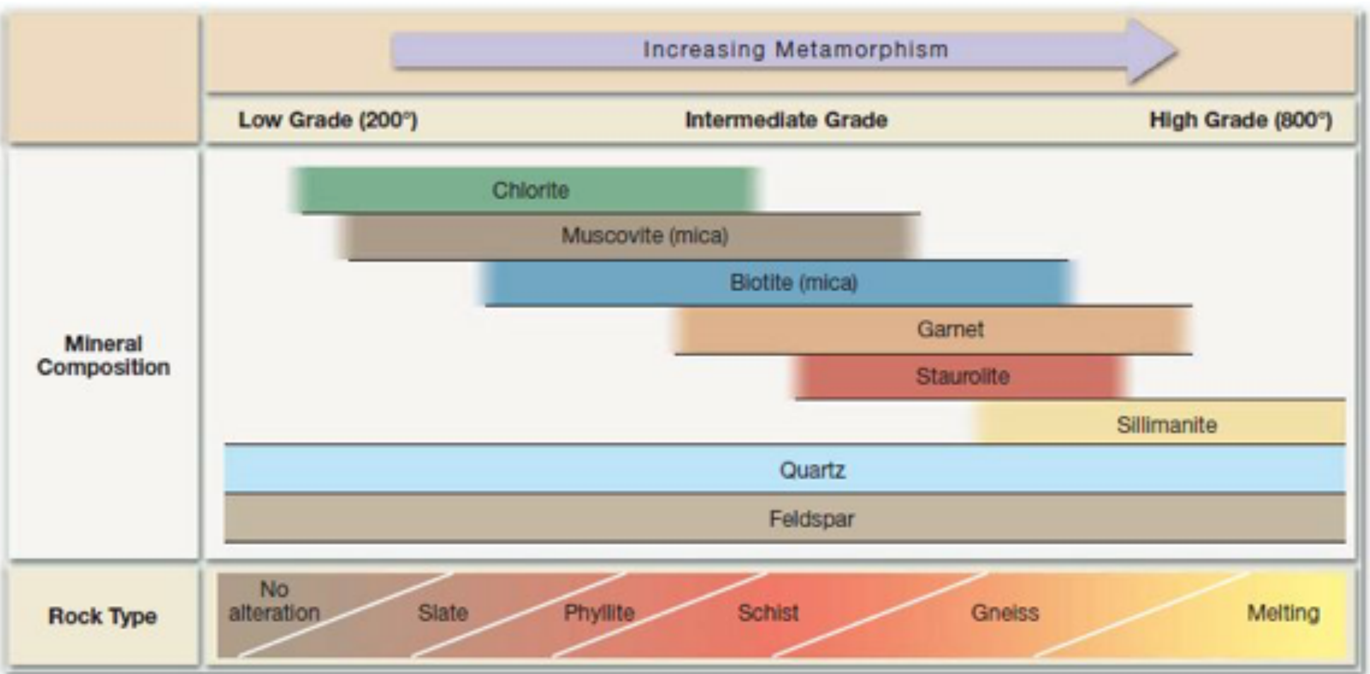
INSTRUCTION (50 MINS)

1. **Define metamorphism.**
   - As a response to heat, pressure, and chemically active fluids, minerals become unstable and change into another mineral without necessarily changing the composition. For example, coal, which is composed entirely of carbon, will turn into a diamond (also composed of carbon) when subjected to intense pressure.
   - The mineral composition of the resulting metamorphic rock is influenced by the following:
     - Mineral composition of the original or parent rock

- Composition of the fluid that was present
- Amount of pressure and temperature during metamorphism

2. Discuss the index minerals for metamorphic rocks.

- Factors controlling the mineral assemblage of metamorphic rocks include:
  - Bulk composition of the original rock
  - Attained **pressure** during metamorphism
  - Attained **temperature** during metamorphism
  - **Composition of fluid phase** that was present during metamorphism (Nelson, 2011).
- Certain minerals identified as index minerals are good indicators of the metamorphic environment or zone of regional metamorphism in which these minerals are formed (Tarbuck and Lutgens, 2008).



Teacher Tip

- In general, metamorphism does not drastically change the chemical composition of the original rock. However, changes in the mineral composition of the resulting rock can be useful in determining the degree of metamorphism. The occurrence of certain minerals ('index minerals') is associated with a specific range of temperature and pressure conditions during metamorphism.
- **Pelitic rock** - or 'pelite' is a term applied to metamorphic rocks derived from a fine-grained (<1/16 mm) sedimentary protolith. The term usually implies argillaceous, siliciclastic sediments as opposed to carbonate mudstones (Imperial College London, 2013).
- The resulting metamorphic rock is also dependent on the original or 'parent' rock. No amount of metamorphism will transform shale into marble. Marble can only be formed from the metamorphism of limestone (where heat is the main agent of metamorphism).

Figure 1: Typical transition of mineral content resulting from the metamorphism of shale (Tarbuck and Lutgens, 2008).

- Emphasize that Figure 1 is a representation of the progressive metamorphism of shale. It is not necessarily applicable to all types of parent rocks. Pelitic rocks (e.g. shale) more faithfully preserve the effects of increasing grade of metamorphism. **Some rocks, however, such as pure quartz sandstone or limestone, provide very little clue as to the intensity of metamorphism** (Monroe et al., 2007).
- Shale can be transformed into a series of metamorphic rocks (slate, phyllite, schist, and gneiss, respectively) with increasing temperature and pressure conditions. Shale can also be transformed directly into schist or even gneiss if the change in metamorphic conditions is drastic.

3. Discuss the textural changes that occur to rocks when they are subjected to metamorphism.

- In general, the grain size of metamorphic rocks tends to increase with increasing metamorphic grade. With the increasing metamorphic grade, the sheet silicates become unstable and mafic minerals, such as hornblende and pyroxene, start to grow. At the highest grades of metamorphism, all of the hydrous minerals and sheet silicate become unstable and thus there are few minerals present that would show preferred orientation. This is because the fluids from these hydrous minerals are expelled out due to the high temperature and pressure.
- Most metamorphic textures involve foliation, which is generally caused by a preferred orientation of sheet silicates (silica minerals with sheet-like structures), such as clay minerals, mica and chlorite. Slate, phyllite, schist, and gneiss are foliated rocks, are texturally distinguished from each other by the degree of foliation. Hornfels and granulite are examples of non-foliated metamorphic rocks. In hornfels, the individual mineral grains are too small, whereas in granulites, the grains are large enough to be identified in hand specimens (visible without the use of microscopes) (Nelson, 2011).

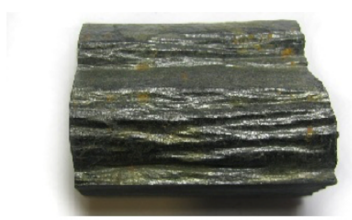


Figure 2: Aphyllite rock showing foliations. Brighter bands are composed of aligned muscovite (Imperial College London, 2013).

- Differential stress is formed when the pressure applied to a rock at depth is not equal in all directions. If present during metamorphism, effects of differential stress in the rock's texture include the following (Nelson, 2012):
  - Rounded grains can be flattened perpendicular to the direction of the maximum compressional force (Figure 3).

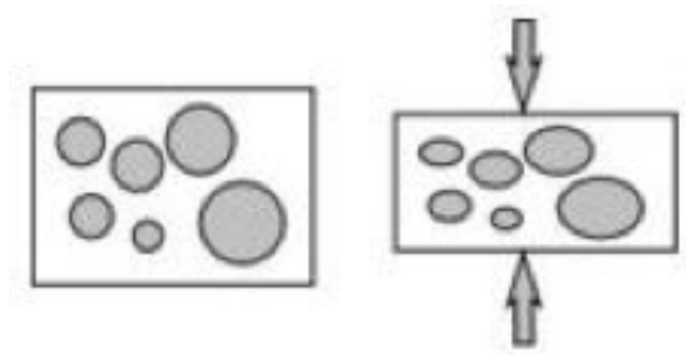


Figure 3: The effect of differential stress to the rounded grains
(Image Source: http://www.tulane.edu/~sanelson/images/flatening.gif)

- **Foliation -** pervasive planar structure that results from the nearly parallel alignment of sheet silicate minerals and/or compositional and mineralogical layering in the rock (Nelson, 2012). This is brought about by the preferred alignment of sheet silica minerals with respect to the stress being applied.

  - When subjected to differential stress field, minerals may develop a preferred orientation. Sheet silicates and minerals that have an elongated habit will grow with their sheets or direction of elongation perpendicular to the direction of maximum stress (Figure 4).

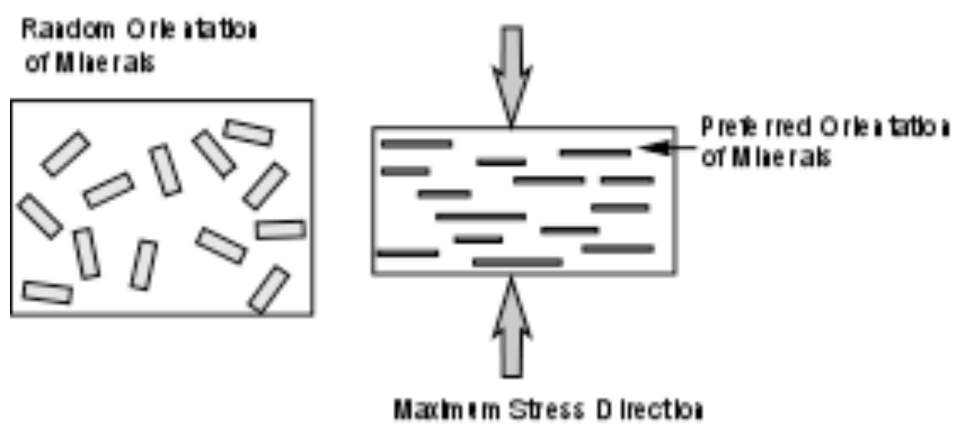


Figure 4. The effect of differential stress to sheet silicates or minerals with elongated form.
(Image Source: http://www.tulane.edu/~sanelson/images/preforient.gif)

4. **Use Table 1 to summarize the metamorphic processes involved under the agents of metamorphism (temperature and pressure).**

Table 1: Agents of metamorphism and the associated metamorphic processes.

Agents of Metamorphism	Metamorphic Processes
High temperature	• Minerals convert to new high temperature minerals • Fluids are released (e.g. clay = mica + H2O) • Crystals grow larger • Rocks become weaker and easier to deform
High pressure	• Minerals may recrystallize into more compact/stable forms • Platy or elongate minerals may align in a preferred direction

5. **Non-foliated metamorphic rocks are formed when heat is the main agent of metamorphism. Generally, non-foliated rocks are composed of a mosaic of roughly equi-dimensional and equigranular minerals.**

Figure 5: An example of a non-foliated metamorphic rock- quartzite (Image Source: https://4.bp.blogspot.com/-XRs4y5EZHjk/VP9A10CZKzI/AAAAAAAAAKw/_IeHz9vdauA/s1600/gneiss.jpg)

Table 2: Some common metamorphic rocks.

Classification	Metamorphic Processes	Parent Rock	Common Minerals
Foliated (Banded)	Slate	Shale, mudstone	Quartz, clay minerals (feldspars)
	Schist	Shale, slate, basalt, or granite	Mica, chlorite, talc, quartz
	Gneiss	Shale, schist, granite, sandstone and other rock types	Quartz, feldspars
Non-Foliated (Non-Banded)	Quartzite	Sandstone	Quartz
	Marble	Limestone, dolomite	Calcite
	Anthracite coal	Bituminous coal	Crystalline carbon

Activity

The activity simulates the formation of foliation when a rock is compressed or squeezed (Royal Society of Chemistry, n.d.).

1. Pour some matchsticks, or short pieces of spaghetti onto the bench, so that they lie in all directions. These represent the microscopic, flaky clay minerals in mudstone or shale.
2. Take two rulers and place one on either side of the matchsticks and push the rulers together, trapping the matchsticks and forcing them to line up parallel to the moving rulers.
3. Discuss the following:

- The activity simulates the formation of foliation, where the tiny, flaky clay minerals in the original (or 'parent') rock are made to line up at right angles to the maximum forces (exerted on the ruler).
- An example of such a rock is slate. When struck, slate will split along the planes made by the new minerals more easily than along the original bedding. This property is called rock cleavage (Figure 6). You can use the matchsticks/spaghetti to show how such rocks can split along the cleavage by using a ruler to separate the aligned 'minerals'. Simply slide a ruler between the aligned pieces of matchsticks/spaghetti and move them apart.
- Try to match the way the pieces are lying with a piece of roofing slate. Sometimes, slate shows different colored bands lying at an angle to the cleavage (Figure 7). This is the remains of the bedding layers of the original mudstone or shale.

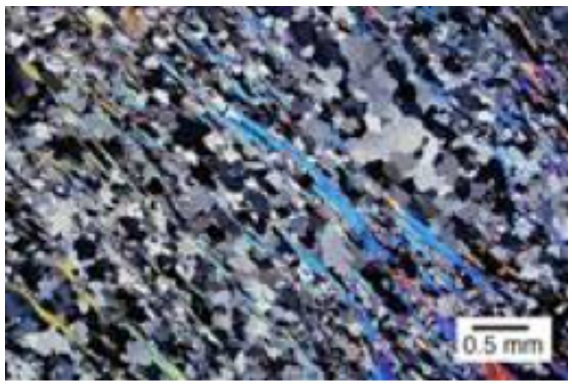


Figure 6: A piece of slate, cut thinly, under the microscope showing the cleavage running from top left to bottom right formed by the aligned minerals. (Image Source: http://www.rsc.org/education/teachers/resources/jesei/meta/h1.jpg)

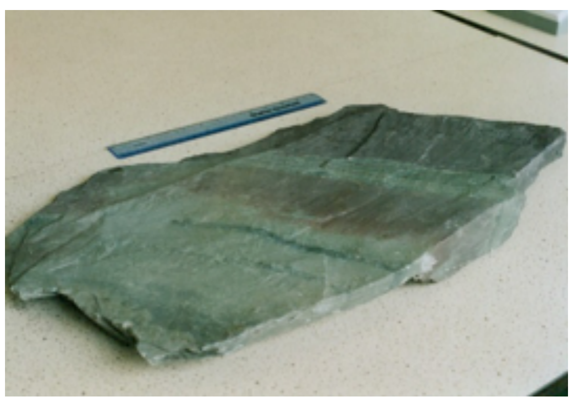


Figure 7: This sample of slate shows colored layers at about 50º inclination to the cleavage. The colored layers show the bedding of the original shale. (Image Source: http://www.rsc.org/education/teachers/resources/jesei/meta/h2.jpg)

PRACTICE (20 MINS)

This activity is a simulation of the distortion of fossils under pressure (Royal Society of Chemistry, n.d.). Many metamorphic rocks, such as slate, are formed deep below ground under great pressure. They sometimes contain fossils which have been badly squashed. The result of the squashing gives clues about the directions of the pressures which squeezed the rocks. The concept of this activity is also applicable to minerals that are subjected to pressure (metamorphism).

1. Wear eye protection when doing the activity.

2. Make a mold by pressing the outside of a shell carefully into the clay. Make a rim around the mold to contain the plaster.

3. Carefully remove the shell to leave the imprint in the clay.

4. Squeeze the mold so as to change the shape of the shell imprint by first choosing whether to squeeze it from top and bottom or from the sides. Alternatively, you could push one side up and the opposite side down. This sort of twisting is called shearing. Whichever you choose, do not distort the shape too much. Note down how you squeezed the mold as it will be important later.

5. Mix up some plaster of Paris in a disposable plastic cup. Place less than 1 cm of water in the cup and stir in enough plaster to make a runny cream.

6. Pour the plaster into the distorted mold and leave it for a few minutes to set.

7. Leave any remaining plaster to set in the cup. Wash the stirring rod.

8. When your plaster fossils have set, take your 'fossil cast' out of the modeling clay and then carefully scratch your initials on the base.

Teacher Tip
The activity may be modified depending on the resourcefulness of the teacher.

9. Pass your fossil on to a nearby group. See if they can work out the directions of the pressures which you used to distort the fossil. Do the same for theirs.

Discussion

Discuss the following questions to identify how the same distortion has been produced by forces acting in different directions (Royal Society of Chemistry, n.d.).

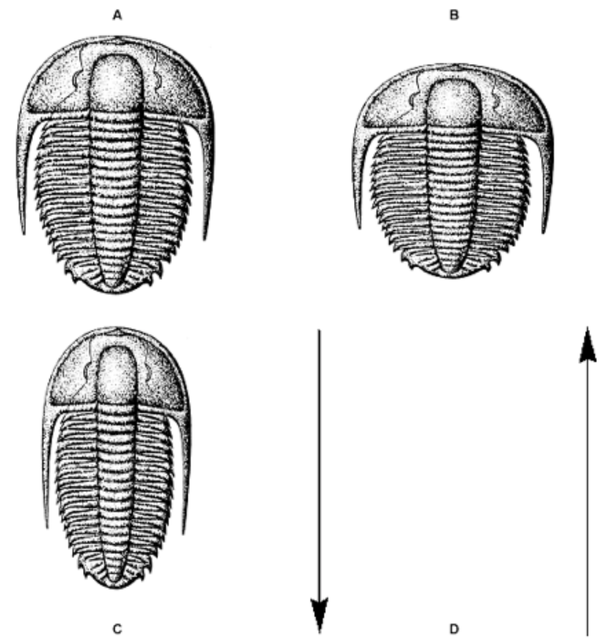


Figure 8: The effects of pressure on fossil. (A) undistorted trilobite, (B) and (C) are distorted trilobites, and learners will fill in the shape of the distorted trilobite in (D).

1. Fossils of a marine invertebrate (called trilobites) are shown in Figure 8. Compared to fossil A, fossils B and C have been distorted by moderate pressures, which have changed the mudstone they were found in to a slate. What might have happened to the fossils if the pressures had been much greater?

   Answer Key: The fossils would have been even more distorted, perhaps to the point of being completely destroyed. (Further distortion might have been caused by recrystallization of the rock but learners are unlikely to come up with this unless it had been discussed in class.)

2. In what direction were the forces that squeezed fossil B? Based on the original length, estimate how much distortion the fossil has undergone. Give your answer as a percentage.

   Answer Key: The forces acted downwards from the top of the paper and upwards from the bottom. The trilobite has been distorted by about 15-20%.

3. In what direction were the forces that squeezed fossil C? Based on the original length, estimate how much distortion the fossil has undergone. Give your answer as a percentage.

   Answer Key: The forces acted leftwards from the right of the paper and rightwards from the left. The trilobite has been distorted by about15-20%.

4. What do your answers suggest about how much the rock in the region in which the fossils were found has been squeezed? How might this scale of deformation have been caused?

   Answer Key: This suggests that the rocks that contain the fossils have been distorted in about the same ratio. The same might well apply to the whole region. This could have happened when the rock was at the site of a destructive plate margin.

5. Another similar fossil has been distorted by shearing forces acting in the directions shown by the arrows in figure D. Sketch the shape that this fossil might have.

   Answer Key: The following presents a fossil distorted by shearing forces acting in the directions shown by the arrows in figure D.

Figure 9: A trilobite fossil distorted by shearing forces (or alternatively by the left-right squeezing of a fossil tilted to the left). (Image Source: http://www.rsc.org/education/teachers/resources/jesei/meta/fig4.gif)

ENRICHMENT

Have the learners prepare a simple report explaining the relationship of metamorphism and plate tectonics (i.e. expected metamorphic grade in a specific tectonic setting). The report has to be submitted after three days (or over the weekend).

Summary Questions

The following summary questions are related to the content. Questions in regular font are of easy difficulty, whereas those in bold are of hard difficulty.

1. True or false: Chlorite is commonly found in high grade metamorphic rocks

   Answer Key: False. Chlorite is usually associated with low to medium grade metamorphism.

2. **Other than the attained temperature and pressure during metamorphism, what are the other two factors that control the mineral composition of a metamorphic rock?**

   Answer Key: Other factors that control the mineral composition of a metamorphic rock include the bulk composition of the parent rock and the composition of fluid present during metamorphism.

3. Define metamorphism.

   Answer Key: Metamorphism is the recrystallization of minerals in rocks due to a change in pressure and temperature conditions.

4. **Define metamorphic grade.**

   Answer Key: Metamorphic grade pertains to the temperature and/or pressure condition(s) to which a rock has been subjected during metamorphism.

5. Define foliation.

   Answer Key: Foliation is the pervasive planar structure that results from the nearly parallel alignment of sheet silicate minerals and/or compositional and mineralogical layering in the rock.

6. **Define the role of stress in the formation of foliation?**

   Answer Key: Foliation can occur when a differential stress develops in rocks, wherein the pressure acting on all sides of the rock is not equal. Rounded grains will flatten perpendicular to the direction of the maximum compressional stress. In addition, sheet silicates and minerals that have an elongated habit will grow with their sheets or direction of elongation perpendicular to the direction of maximum stress.

7. True or false: There is a direct correlation between the grain size of metamorphic rocks and the metamorphic grade.

   Answer Key: True

8. **Is it possible to find fossils in metamorphic rocks?**

   Answer Key: Yes, it is possible to find fossils in metamorphic rocks especially in low-grade metamorphic rocks. However, the fossils are expected to be not in the original form due to the effect of the change in temperature and pressure.

EVALUATION

	1. (NOT VISIBLE)	2. (NEEDS IMPROVEMENT)	3. (MEETS EXPECTATIONS)	4. (EXCEEDS EXPECTATIONS)
Enrichment Project	Did not submit report on time; report is not complete	Report is submitted on time but is lacking of substance; report not well presented	Report is submitted on time; report is well-presented (organized flow of discussion with few instances straying from the topic) authors demonstrate acceptable understanding of topic (few corrections and misconceptions)	Report submitted on time; report is excellently presented (highly organized flow of discussion); authors demonstrate excellent level of understanding of the topic
Summary questions	Only 4 of the easy questions are correctly answered	Correctly answered the easy questions	Correctly answered the easy questions and 4 hard questions	Correctly answered all questions

90 MINS

Endogenic Processes (Continental Drift)

Content Standard
The learners demonstrate an understanding of continental drift.

Performance Standard
The learners shall be able to, using maps, diagrams, or models, predict what could happen in the future as the tectonic plates continue to move.

Learning Competencies
Describe the continental drift theory **(S11ES-IIe-30)** and discuss evidence that support continental drift **(S11ES-IIe-31)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- discuss the history behind the continental drift theory;
- describe the continental drift theory; and
- enumerate and explain the evidence used to support the idea of drifting

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Identification of Continents	10
Instruction	Lecture and Demonstration	50
Practice	Activity - Puzzle	25
Enrichment	Activity - Rate of Movement	
Evaluation	Answering of Summary Questions	

Materials
Globe or world map; Internet connection; media player; puzzle print-outs; scissors; glue; blank paper; pencil; crayons

Resources

(1) Carlson, D. H., Plummer, C. C., & Hammersley, L. (2011). *Physical Geology: Earth Revealed.* McGraw-Hill.

(2) Earle, S. (n.d.). Geological Renaissance of the Mid-20th Century. Retrieved from https://opentextbc.ca/geology/chapter/10-3-geological-renaissance-of-the-mid-20th-century/

(3) Earth Reference Data and Models. (n.d.). Continental Drift Activity. Retrieved from https://Earthref.org/ERDA/1541/

(4) Monroe, J. S., Wicander, R., & Hazlett, R. W. (2007). *Physical geology: Exploring the Earth* (6th ed.). Belmont, CA: Thomson Brooks/Cole.

(5) Roose-Snyder, B. (2002). The Caledonides Mountain Range. Retrieved from http://legacy.earlham.edu/~roosebe/Earlham%20College%20-%20Geology%20211%20-%20Caledonides.htm.

(6) Salmingo, E. (2010). *Pangaea Animation* [Video file]. Retrieved from https://vimeo.com/14258924.

(7) Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Prentice Hall.

Additional resources at end of the lesson.

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following specific learning objectives:
   - Discuss the history behind the continental drift theory
   - Describe the continental drift theory
   - Enumerate and explain the evidence used to support the idea of drifting continents

MOTIVATION (10 MINS)

1. Present a globe or a world map (preferably a big one).

2. Have the learners identify the different continents.

3. Ask the learners the following questions:
   - How much of the Earth is covered by water?
   - What are the ocean basins of the world? What is the largest ocean basin?
   - Is there anything peculiar with the shape of the continents on the opposite sides of the Atlantic Ocean?

Teacher Tip

Test whether the learners can recognize the remarkable fit between the eastern coast of South America and the western coast of Africa.

INSTRUCTION (50 MINS)

1. Introduce the continental drift hypothesis.

- Discuss how the concept of continental drift came about.
  - The idea that continents fit together like pieces of a jigsaw puzzle has been around since the 1600s, although little significance was given to it.
  - The continental drift hypothesis was first articulated by Alfred Wegener, a German meteorologist, in 1912. He proposed that a single supercontinent, Pangaea, separated into the current continents and moved across Earth's surface to their present locations. He published his work through a book entitled 'The Origin of Continents and Oceans' in 1915.
  - Until the 1950s-60s, it was still widely held that that continents and ocean basins had

Teacher Tips

- Pangaea - an ancient Greek word meaning 'all land' or 'entire Earth'.
- Alfred Wegener thought that continents drifted due to the tides formed by the gravitational forces of the moon and sun. He also believed that the larger and sturdier continents cut through the thinner oceanic crust, although there is no proof that the ocean floor is weak enough to allow passage of the continents without significantly deforming them in the process.

fixed geographic positions. As such, scientists were reluctant to believe that continents could drift.

- In the 1960s, the post-war boom in oceanography generated a lot of new data about the ocean floor. It turned out that the ocean floor was not as flat and featureless as they had originally thought. The ocean floor was characterized by deep depressions called trenches and a network of ridges that encircled the globe. These topographic data, together with heat flow measurements, led to the emergence of the Seafloor Spreading Hypothesis which revived interest in Alfred Wegener's idea of drifting continents.

- Show an animation of continental drift.
  - The animation is for the learners to visually understand how continental drift occurred.
  - One example is the Pangaea Animation (Salmingo, 2010): https://vimeo.com/14258924

2. Enumerate and discuss the evidence supporting continental drift.

- The fit of the continents
  - Opponents of Wegener's idea disputed his continental fit evidence, arguing that the fit of the continents' margins was crude, and that shorelines were continuously being modified by wave erosion and depositional processes.

Figure 1: Continents fitted together to form supercontinent Pangaea

- There several other animations available online.

- Several scientists worked on continental drift prior to Wegener but the distinction was awarded to him because of the overwhelming lines of evidence that he presented.

- The oceanographic data later on revealed that a much better approach was to fit the continents together along the continental slope, where erosion would be minimal. In 1965, Sir Edward Bullard, an English geophysicist, and two of his associates demonstrated that the best fit between the continents occurs at a depth of approximately 2000 m.
- Even with this method, a perfect fit could not be achieved. The process of stretching and thinning of the continental margins and sedimentary processes (e.g. erosion, delta formation, etc.) could explain some of the overlaps.

- Similarity in geological units and structure
  - Wegener discovered that rocks on both sides of the Atlantic Ocean were identical in terms of type and age. He also matched up mountain ranges with the same rock types, structures, and ages, that were now on opposite sides of the Atlantic Ocean. The Appalachians of the eastern United States and Canada, for example, were just like mountain ranges in eastern Greenland, Ireland, Great Britain, and Norway. Wegener concluded that they formed a single mountain range that became separated as the continents drifted.

Figure 2: Map showing how mountain belts and rock types connect across continents (Roose-Snyder, 2002).

- Fossil match
  - Similar fossils of extinct plants and animals in rocks of the same age were found on different continents, which are now separated by large bodies of water. Wegener recognized that organisms were adapted to a specific type of environment and their dispersal could be limited by biogeographic boundaries (e.g. oceans, mountain ranges, etc.) Wegener argued that these organisms could not have physically crossed the oceans; rather, the continents were in fact part of a large contiguous landmass which later on broke apart and drifted.

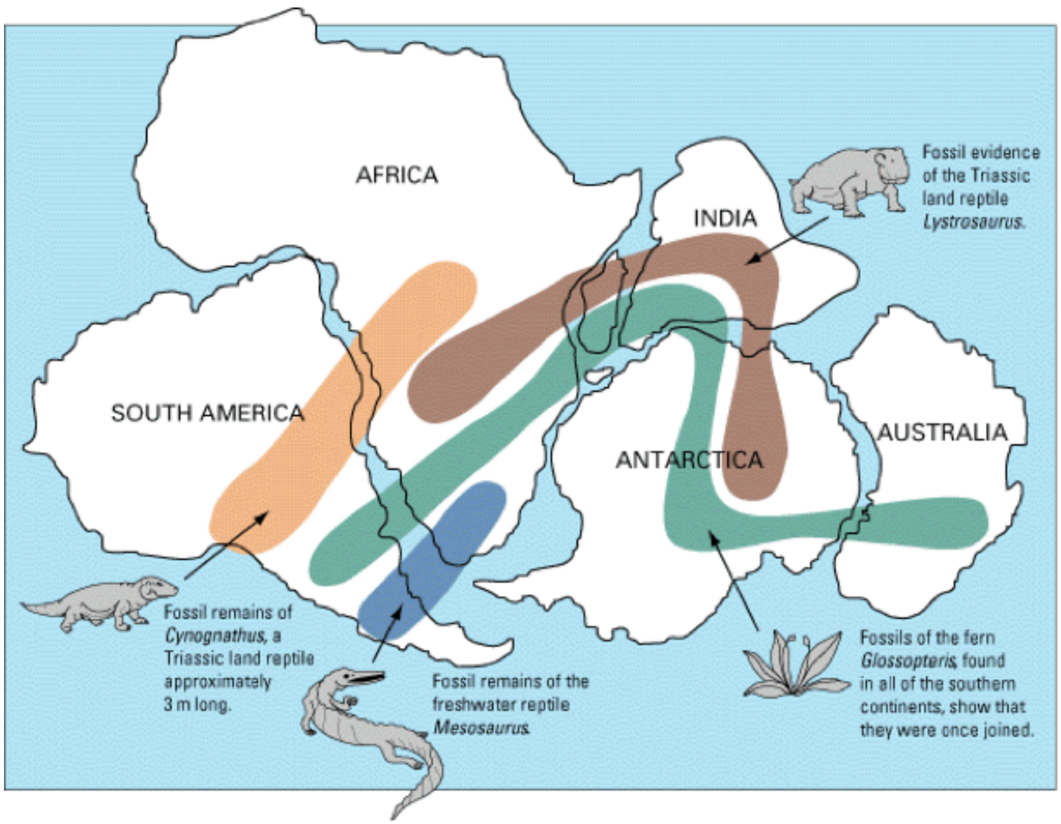


Figure 3: Fossils discovered and used by Wegener to support his continental drift hypothesis.

- ✦ *Glossopteris flora* – 'seed fern' that grew only in a subpolar regions, fossils of which were widely distributed over Australia, Africa, India, and South America (later on discovered in Antarctica). Seeds were too large to be blown away by wind to different continents.
- ✦ *Mesosaurus* - a freshwater reptile whose fossils were found only in black shales about 260 million years of age (Permian) in South Africa and Brazil. This land-based reptile could not have crossed the Atlantic Ocean.
- ✦ *Lystrosaurus* and *Cynognathus* - land reptiles whose fossils were found across South America, Africa, India, and Antarctica. With their inability to swim and the continents' differing climates, the organisms must have lived side by side and that the lands drifted apart after they became extinct and fossilized.

- Glacial and paleoclimate evidence
  - A glacier is a slowly moving mass or river of ice formed from the accumulation and compaction of snow on high mountains or in polar areas. As it flows, it carries sediments of different shapes and sizes, which are then deposited and slowly compacted into a soft sedimentary rock called till (glacial till). It also creates grooves or scratches called striations in the underlying bedrock.
  - Wegener analyzed glacial tills and striations of ancient times and found out that glaciers of the same period (late Paleozoic age, around 300 million years ago) are located in Australia, South America, Africa, India, and Antarctica. Except for Antarctica, these countries did not have subpolar climate that allowed glaciation. Putting the continents together in accordance to Wegener's Pangaea shows that the glaciation only occurred in a small region in Gondwana (around the South Pole) which then moved outward to the aforementioned continents.
  - Figure 4a illustrates the direction of the glacial striations in rocks from South America, Africa, India, and Australia. At first glance, they would hardly make sense until we rearrange the continents to form Wegener's Gondwana.
  - Reconstructing the location of ancient glaciers led Wegener to discover that the location of the current poles was not the same as the ancient ones. His studies showed that South Africa was originally at the South Pole (300 million years ago), which explains the flow direction of the ancient glaciers. Fitting the continents together places the northern half

of Pangaea closer to the tropics and was proven correct by fossil and climatological evidences.

Figure 4: (A) Present location of the different continents showing the ancient (Paleozoic) glaciers. Arrows indicate the direction of ice flow. (B) Rearranging the continents based on Wegener's Pangaea gives a better picture of the glacial body and how it melted (Carlson et al., 2011).

- Paleomagnetism and polar wandering
  - This group of evidence emerged relatively much later (1950s) with the development of new technology and the boom in oceanographic studies**.**
  - **Paleomagnetism** - As magma cools down it starts forming minerals. Some minerals are strongly magnetic (e.g. magnetite). Below a certain threshold temperature, some of these minerals attain magnetic properties. The magnetic minerals start to align with the surrounding magnetic field. The alignment of these minerals becomes fixed once the lava or magma solidifies. Rocks therefore can potentially preserve or record magnetic polarity (normal vs. reverse), direction or location of magnetic poles, and the strength of the magnetic field.
  - Magnetism of geologically recent rocks is generally consistent with the Earth's current magnetic field.When the location of the Earth's magnetic poles are plotted based on the paleomagnetism of rocks of different ages, their positions appear to be "wandering" through time (Figure 5) if we assume a fixed position of the continents. In reality, the magnetic poles have a relatively fixed position, and it is actually the continents which are moving.

- **Paleomagnetism** - the residual magnetism in ancient rocks showing direction and intensity of Earth's magnetic field at the time of the rock's formation.
- **Polar wandering** - pertains to the slow movement of the Earth's magnetic poles relative to the geographic poles.

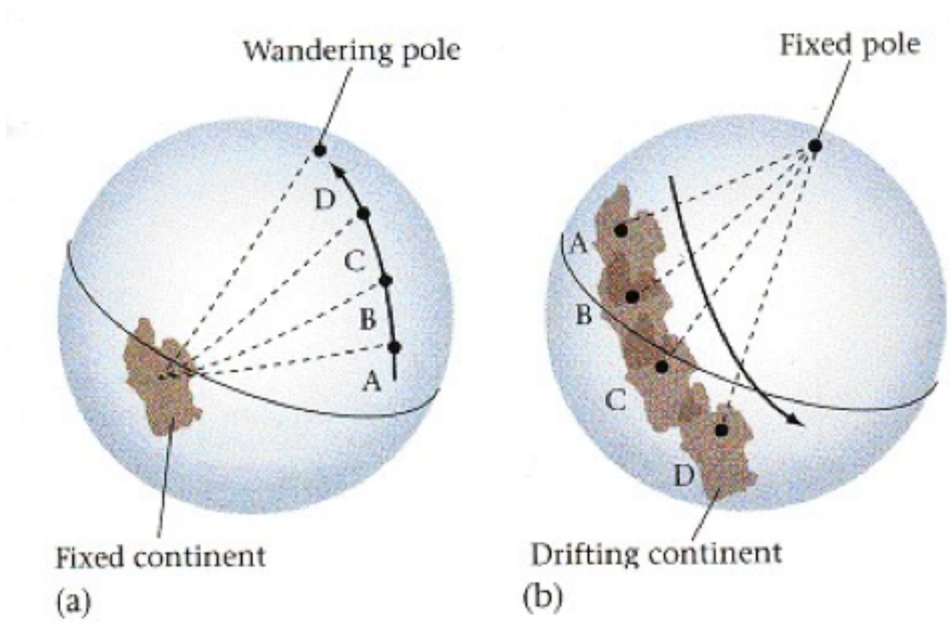


Figure 5: Paleomagnetism of rocks of different ages suggest either (A) the varying position of the magnetic poles through time, or (B) the fixed position of the poles and the movement of the continents.

PRACTICE (25 MINS)

This activity entitled 'Continental Jigsaw Puzzle' was modified from (Earth Reference Data and Models, n.d.): https://Earthref.org/ERDA/1541/).

1. Print copies of the puzzle enough for all groups.
2. Divide the class into groups of two to five. Each group is provided with the activity materials.
3. In the legend, assign different colors for each type of fossil and geologic structure. Use these colors to represent the identified areas within the landmasses.
4. Cut along the borders of the continents using a pair of scissors.
5. On another sheet of paper, place the continent cut-outs and try to reconstruct Pangaea using the given clues (fossils and mountain ranges).
6. Finalize the positions of the continents by gluing them on a sheet of paper. Draw a circle around to represent the Earth.
7. Cut out the legend and paste it in the lower portion of the paper.
8. Randomly select few teams to discuss their findings in front of the class.

Teacher Tip

- Expect imperfect fit of the cut-outs as these are only approximations of the shapes of the continents after the Pangaea split up.

Discussion

Discuss the answers to the following questions.

1. What criteria or basis did you consider in piecing together the 'jigsaw puzzle'?

   Answer Key: The following were considered in piecing together the 'jigsaw puzzle': the shapes of coast lines, distribution of fossils, and mountain ranges.

2. Look at the resulting map. What can you conclude with regard to the location of the different fossils? What about the mountain range?

   Answer Key: The distribution of fossils and mountain ranges will 'line up' in the reconstructed map. They will form continuous belts or areas.

- It is suggested that the discussion portion of the activity be performed after the instruction section. Have each learner submit answers as an attachment to their group's Pangaea puzzle.

3. Give your thoughts on why the cut-outs do not perfectly fit with each other.

   Answer Key: The imperfect fit is most likely due to the modification of the coastlines as a result of weathering and erosion, and collisions and movement of plates. Fitting together the continental slopes will provide a much better fit.

For better resolution, it is suggested that the activity material be downloaded directly from the source.

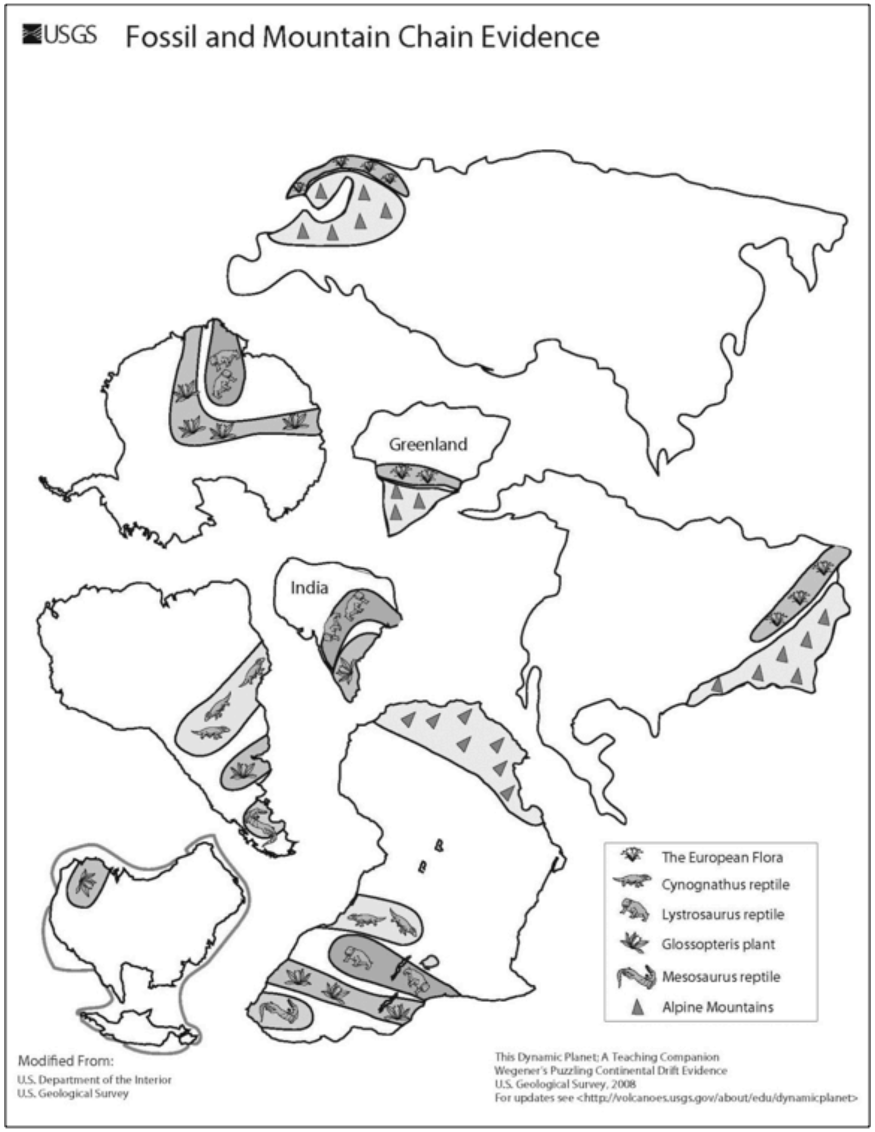


Figure 6: Fossil and mountain chain evidence

(Earth Reference Data and Models, n.d.).

ENRICHMENT

This activity was modified from (Teaching Engineering, n.d.): https://www.teachengineering.org/collection/cub_/activities/cub_natdis/cub_natdis_lesson02_activity2_worksheetnew.pdf

Other related studies that came out after the continental drift hypothesis has been proven and accepted by the scientific community. One of these studies led to the identification of the speed of the continents' movement. Table 1 shows the rate of movement of some of the continents.

Table 1: Rate of movement of the continents.

Continent	**Speed**
Antarctic	2 cm/yr
African	2.2 cm/yr
South American	1.5 cm/yr
North American	1.2 cm/yr

Discussion

1. Compute, in meters, how far these continents will travel in (a) 100 years, (b) 500,000 years and (c) 1 million years. Tabulate the answers.

   Answer Key: Using the formula of velocity/speed, distance is computed as: Distance = Speed x Time.

2. Which continent moves the fastest? Where will it be in 50,000 years?

   Answer Key: The African continent moves the fastest. In 50,000 years, it will be 1.1 km away from its current location.

Table 2: Distance traveled by the continents

Continent	Speed	Distance traveled (in meters)		
		100 years	50,000 years	1 million years
Antarctic	2 cm/yr	2m	1,000m	20,000m
African	2.2 cm/yr	2.2m	1,100m	22,000m
South American	1.5 cm/yr	1.5m	750m	15,000m
North American	1.2 cm/yr	1.2m	600m	12,000m

3. Which continent moves the slowest? Where will it be in 1 million years?

   Answer Key: The North American continent is the slowest moving continent with a speed of 1. 2cm/yr. In 1 million years, it will be displaced from its current location by 12km.

4. Is there a chance that the continents will collide with each other? Explain your answer. If yes, give an example.

   Answer Key: Yes, continents can collide with each other since they are moving in different directions. India, for example, has collided and is still colliding with the Asian continent. Reconstructing the Pangaea shows that India was originally part of the southern half of Pangaea that gradually moved northwards.

EVALUATION

The following summary questions are related to the content. Questions in regular font are of easy difficulty, whereas those in bold are of hard difficulty.

1. Why do the continents fit roughly along their coastlines?

Answer Key: Because these were once joined together; they just drifted apart through time.

2. **Define the concept of continental drift.**

   Answer Key: Continental drift is the theory that the continents move. From a single landmass called Pangaea, the continents broke apart and drifted to their current positions.

3. What made early scientists reject Wegener's continental drift idea?

   Answer Key: Although Wegener presented a lot of evidence supporting continental drift, he was not able to convincingly explain how the continents moved.

4. What were the lines of evidence supporting continental drift?

   Answer Key: The evidence of the continental drift hypothesis include (1) continental fit, (2) similarities of geologic units and structures across continents, (3) fossil match across continents, and (4) glacial and paleoclimate evidences.

5. True or False: Mountain ranges on the opposite sides of the Atlantic were used by Wegener to support his continental drift idea.

   Answer Key: True

6. **What evidences can prove that two mountain ranges separated by ocean were part of a single mountain range and that these were once joined together?**

   Answer Key: The mountain ranges should be aligned from one continent to another. The rock types and their ages should be similar for both landmasses. If there are fossils in the area, they should be similar as well.

7. Give an evidence of continental drift that was discovered after the time of Wegener.

   Answer Key: Paleomagnetic evidence only surfaced in the 1950s.

8. **Define paleomagnetism.**

   Answer Key: Paleomagnetism is the residual magnetism in ancient rocks showing direction and intensity of Earth's magnetic field at the time of the rock's formation.

	1. (NOT VISIBLE)	**2. (NEEDS IMPROVEMENT)**	**3. (MEETS EXPECTATIONS)**	**4. (EXCEEDS EXPECTATIONS)**
Enrichment Project	Did not submit report; did not answer any question correctly	Correctly answered two or less questions	Correctly answered three questions	Correctly answered all questions
Summary questions	Correctly answered two or less of the easy questions	Correctly answered all the easy questions	Correctly answered all the easy questions and two hard questions	Correctly answered all questions

ADDITIONAL RESOURCES

1. Teaching Engineering. (n.d.). Drifting Continents – Math Extension Worksheet. Retrieved from https://www.teachengineering.org/collection/cub_/activities/cub_natdis/cub_natdis_lesson02_activity2_worksheetnew.pdf
2. The Nuffield Foundation. (2001). Theoretical Models: Continental Drift. Retrieved from http://www.nuffieldfoundation.org/sites/default/files/files/teacherguidance_continentaldrift.pdf

60 MINS

Deformation of the Earth's Crust - Folding and Faulting

Content Standard
The learners demonstrate an understanding of folding and faulting of rocks

Performance Standard
The learners shall be able to, using maps, diagrams, or models, predict what could happen in the future as the tectonic plates continue to move.

Learning Competencies
Describe how rocks behave under different types of stress such as compression, pulling apart, and shearing **(S11ES-IId-27).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- understand how rocks are deformed by stress and undergo solid deformation (strained); and
- explain how tension, compression, and shear stresses produce geological structures.

LESSON OUTLINE

Introduction	Communicating learning objectives	3
Motivation	Word Illustration	12
Instruction	Lecture/Discussion	35
Enrichment	Illustration Interpretation	10
Evaluation		

Materials
Projector; transparency/printout; clay; rubber band; metal wires or paper clip; clay; and small metal springs.

Resources

(1) http://www.nature.com/scitable/topicpage/lesson%AD3%ADproperties%ADof%ADearth%ADmaterials%AD86769282/4 (Accessed: 9/23/2015)

(2) http://www.tulane.edu/~sanelson/eens1110/deform.htm (Accessed: 9/23/2015)

(3) Marshak, Stephen. 2008. Earth: Portrait of a Planet, 3rd Edition. W.W. Norton & Company,Inc.

INTRODUCTION (3 MINS)

Communicating Learning Objectives

1. Introduce the following learning objectives:
    - I can explain how rocks are deformed by stress and undergo solid deformation (strained).
    - I can identify and explain the different kinds of stress and the resulting geological structures.

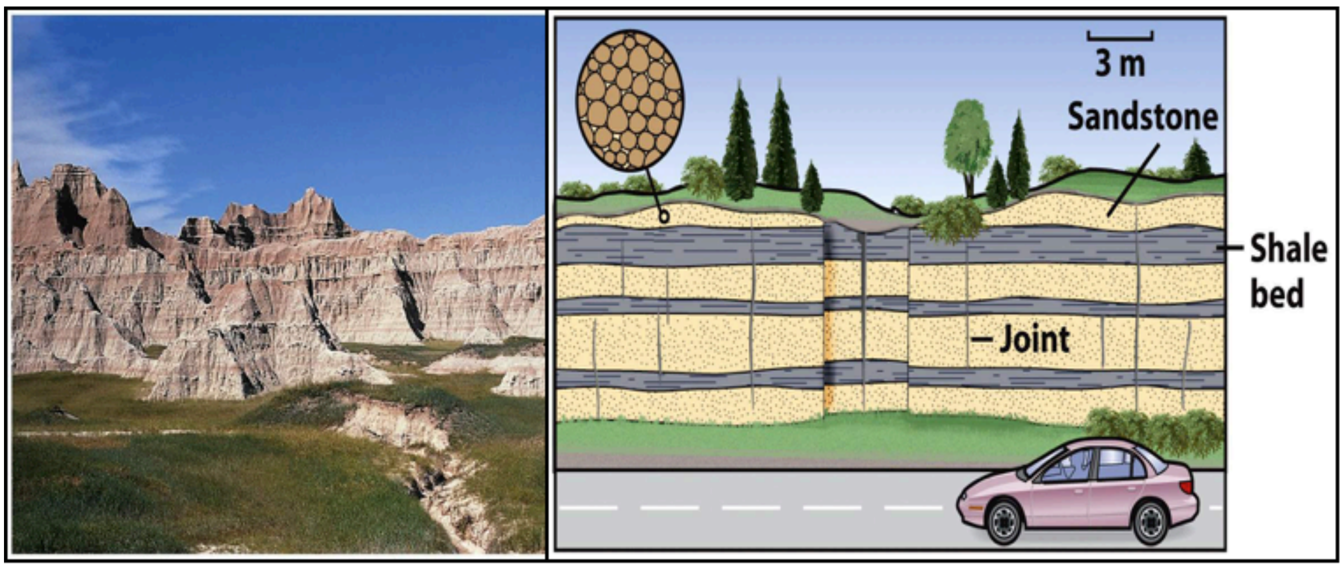
MOTIVATION (12 MINS)

"Deformed vs Undeformed"

1. Show students the illustrations below (Fig.1). Have them create groups of 3-4 and report:

a. What they observe

b. What they think has happened



Teacher Tips

- Illustrations lifted from Earth: Portrait of A Planet, 3rd Edition, by Stephen Marshak. Chapter 11: Crags, Cracks and Crumples: Crustal Deformation and Mountain Building
- The first illustration (Fig. 1 a) shows an "undeformed" or "unstrained" sequence.
    - Strata occurs in horizontal layers
    - Sand grains are spherical (inset)
    - No folding or faulting, no metamorphic rocks, a few joints observed

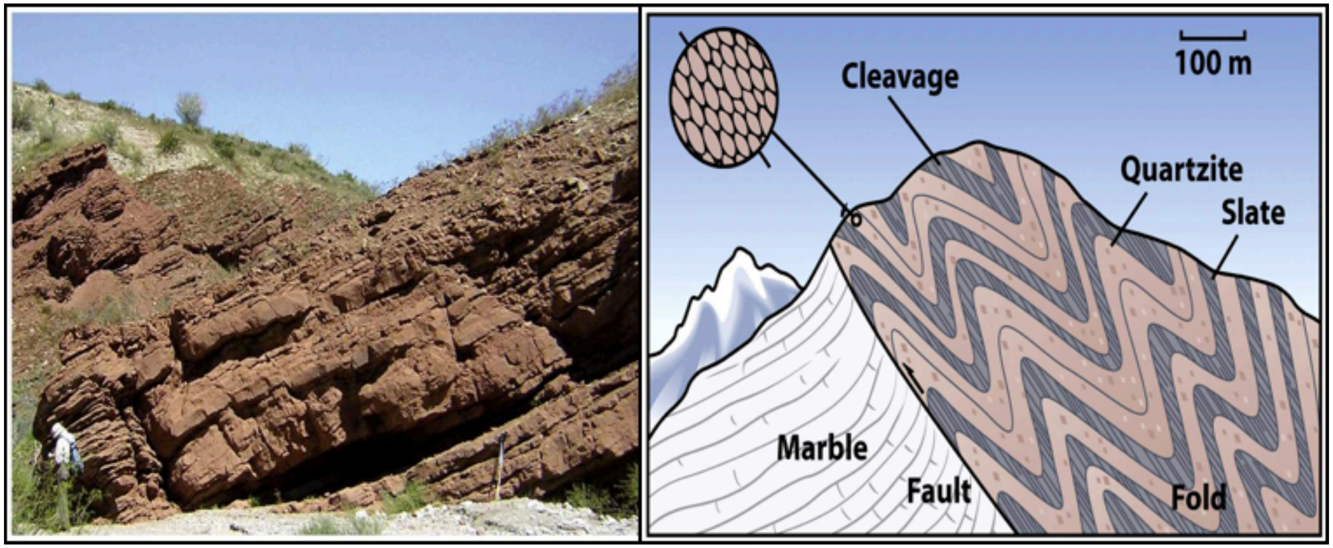


Figure 1. Examples of unstrained (a) and strained rocks (b). (Source: Earth: Portrait of A Planet, 3rd Edition, by Stephen Marshak. Chapter 11: Crags, Cracks and Crumples: Crustal Deformation and Mountain Building)

2. Show students the illustrations below (Fig.1). Have them create groups of 3-4 and report:

INSTRUCTION (35 MINS)

Lecture Proper

1. Define the term **Deformation**. Relate to earlier observations in "Deformed vs Undeformed" Motivation activity
2. Contrast **stress** and **strain**.
3. Identify and describe three fundamental kinds of stress to which rocks are subjected: **compressional** (squeezing), **tensional** (stretching), and **shear** (wrenching) stress.

- "Deformed/strained" sequence (Fig. 1.b)
  - Layers are tilted
  - Rocks are highly folded and possibly metamorphosed (sand->quartzite, clay->slate); grains are squashed/ distorted
  - Fault with large offset juxtaposed different rocks side by side

Teacher Tips

- The term deformation encompasses any change in shape, position, and/or volume of a rock in response to stress. When layers of rocks are found tilted, folded, or displaced, this indicates that deformation has occurred.
- Explain briefly that Stress is the force per unit area applied on the rock, whereas, Strain is the change in shape or volume of the rock that experienced stress. Thus, Stress=cause, Strain=Effect
- Point out that the magnitude of stress is not simply a function of the amount of stress but also relates to the area over which the force is applied.

- To help students visualize the types of stress, take a block of clay 5cm long, 5cm wide, 2 cm thick. Demonstrate compression by slowly pushing on opposite ends of the short side of the block. Have students sketch what they have observed. (Answer: clay thickened in the middle). Reshape the clay and demonstrate tension by gently pulling the sides of the clay in opposite directions. Again, have students sketch what they have observed. (Answer: clay thinned in the middle). Reshape the clay yet again and demonstrate shear stress by placing your hand flat on opposite sides of the clay block and slowly moving your hands in opposite directions past each other. Have the students draw what they have observed. (Answer: clay is offset at the edges). Below is an illustration for reference

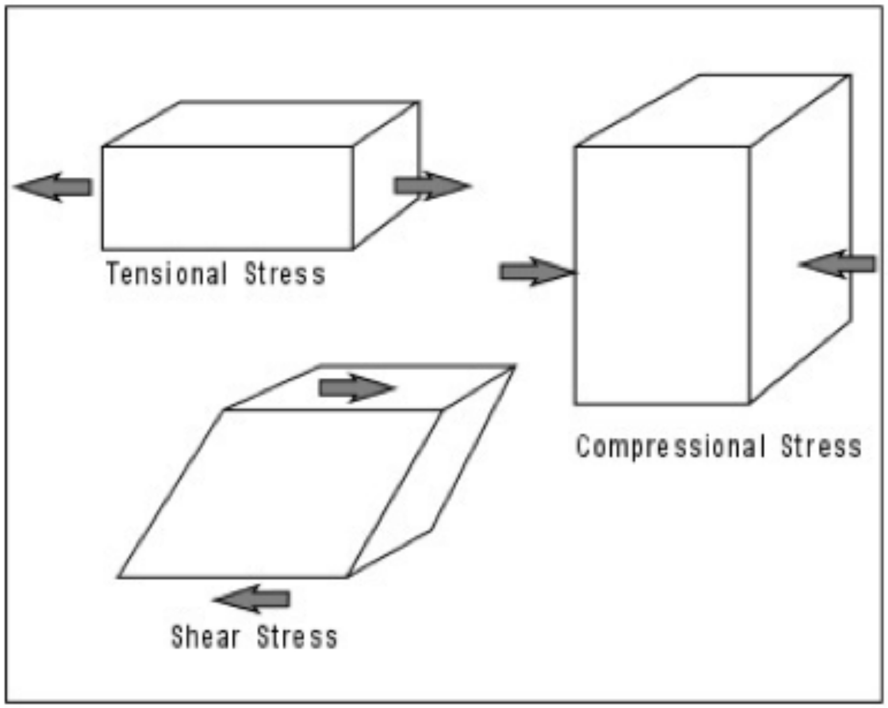


Figure 2. Kinds of stress and their corresponding deformation type. Source : Modified from http://www.tulane.edu/~sanelson/images/stress1.gif

4. Describe the differences between elastic, ductile, and brittle deformation. To help students better grasp the concept of deformation of materials, perform with students a short activity as described below:
    - Organize four areas within the room. At each area, put out a rubber band, metal wires or paper clip, clay, and small metal springs.
    - Explain to students the meaning of the following words:
        a. **Elastic**: describes a material that returns to its original shape once the stress that deforms it is removed
        b. **Inelastic**: describes a material that does not return to its original shape after it is deformed. Inelastic materials can be categorized into **brittle** (materials respond to stress by breaking and fracturing), and **ductile** (materials respond to stress by bending or deforming without breaking).
    - Have the students spend a few minutes at each area. Ask them the following questions for each material:
        a. Is the material elastic or inelastic?
        b. If inelastic, is it brittle or ductile?
        c. What other materials are similar to this material?
    - After everyone has had some time at each material, go over the students' responses and classify each material.
    - Explain to the students that rocks can deform like the materials they have just experimented with.
5. Discuss the 3 stages of deformation a rock passes through when it is subjected to increasing stress: Elastic deformation -> Ductile deformation-> Fracture. Explain using the stress strain curve (Figure 4).
6. Explain how factors such as confining pressure, temperature, strain rate, and composition affect deformation. Use the following graph as a guide (Fig. 3) to illustrate the effect of confining pressure. Similar graphs can be found in the internet when necessary.

- Students' answers should be similar to this:

Material	Property
rubber band	elastic
metal wire	inelastic, ductile
clay	inelastic, ductile (some will say inelastic, brittle if stress is applied suddenly)
metal spring	elastic (some may say ductile if the spring is stretched too far

- Emphasize that low temperature, low confining pressure, and high rate of strain enhance the brittle properties of rock. High temperature, high confining pressure and low rate of strain enhance the ductile behavior of rocks. The composition of a material determines the point at which brittle-ductile transition occurs.

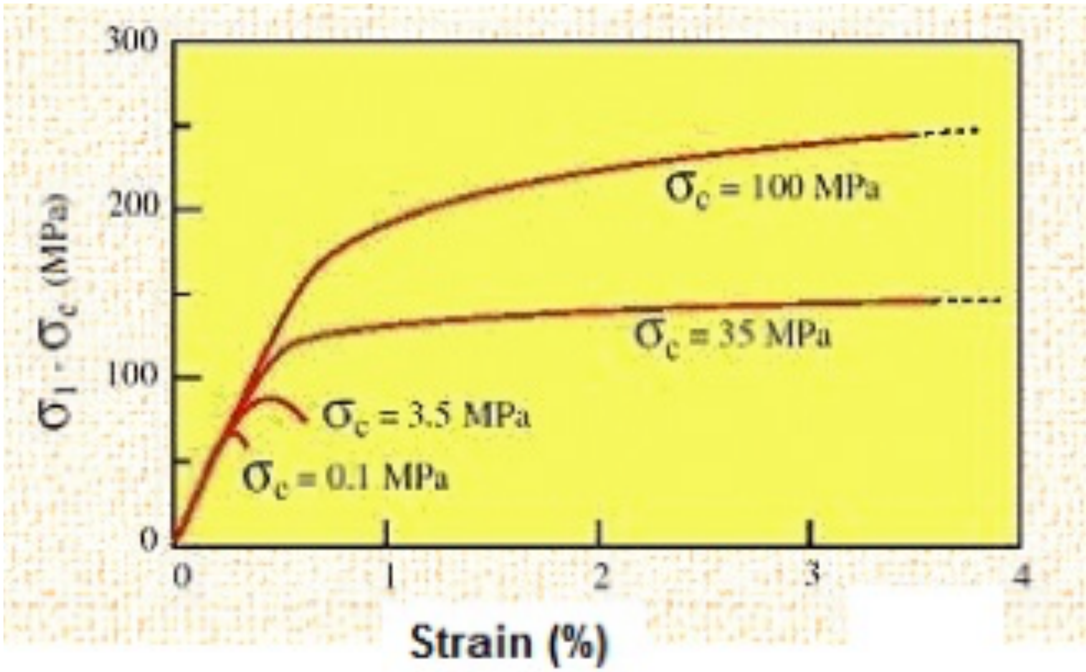


Figure 3. The graph shows the relationship between confining pressure and strain. Y-axis is the amount of pressure to deform a material (MPa). X-axis is the amount of strain/deformation (%). Each curve has an indicated amount of confining pressure (σ_c = 0.1MPa…). When the confining pressure is higher, it requires higher amount of pressure to deform a material. (Image Source: http://structuralgeology.50webs.com/pconf.htm)

7. Define strike and dip
8. Discuss features of brittle deformation: joints and faults
    - Contrast joints and faults
    - Discuss the different types of faults and kinds of stress associated with each type (dip slip->tension or compression; strike slip-> shearing; oblique slip ->combination of shearing and tensional or compressional stress)
9. Discuss features of ductile deformation: folds

- Define and describe the basic type of folds: monoclines, anticline, synclines
- Give some examples of landscapes that are created from folding

ENRICHMENT (10 MINS)

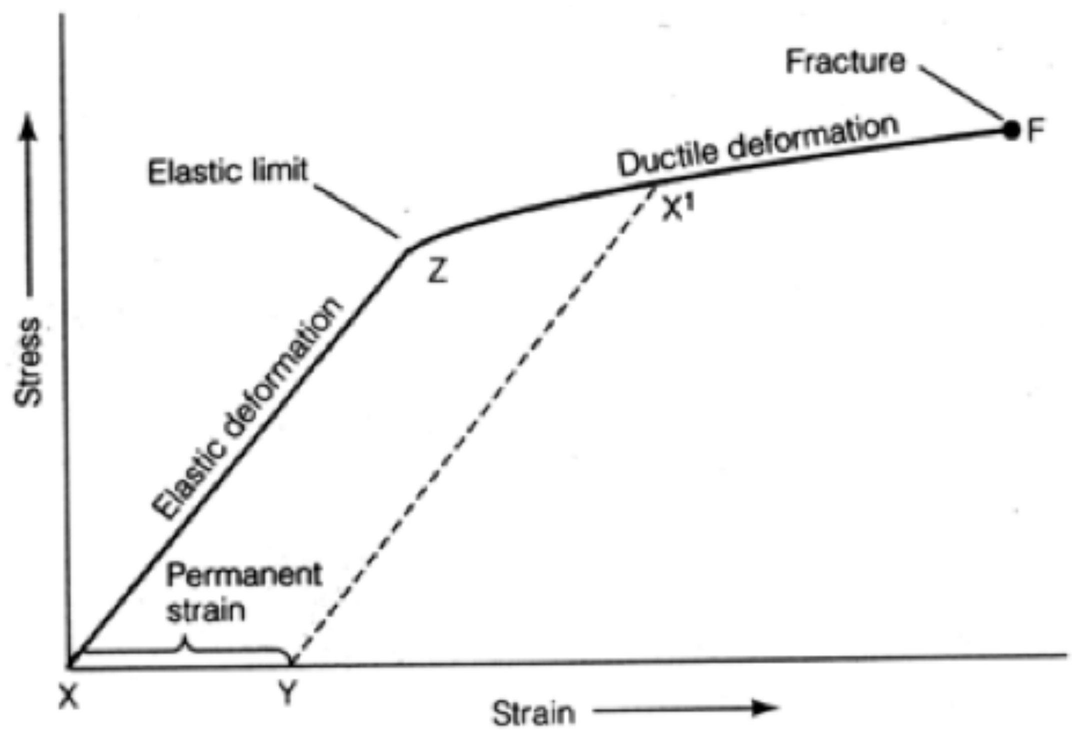


Figure 4. The Stress-Strain Curve. (Source: http://darkwing.uoregon.edu/~drt/Classes/201_99/Rice/Seismology.html)

Teacher Tip
Expected answer: The rock on the photo (Fig. 5) exhibits both brittle and ductile deformation. The light-colored layer at the top and dark-colored layer at the bottom have been deformed by brittle fracture with very minimal internal deformation. This corresponds to point F on the diagram. Other layers have not fractured but have flowed and underwent ductile deformation, corresponding to a point along FZ. These layers have been subjected to the same stress regime so composition must be a factor in the way the layers deform.

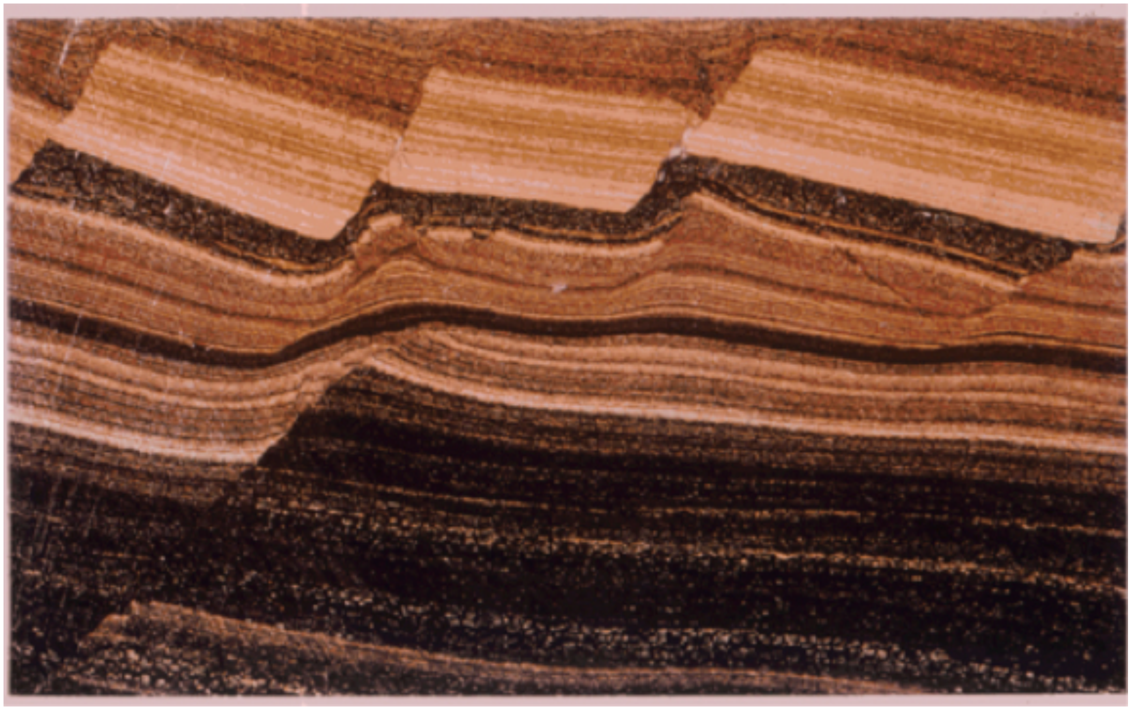


Figure 5. A photo of deformed rock layers.
(Source: http://www.rci.rutgers.edu/~schlisch/structureslides/slides.html)

1. Ask the students to explain the deformation they can observe in the photo.
2. On the stress-strain curve above, have them plot where the deformation occurs.

EVALUATION

Have the students research areas in the Philippines where faulting and/or folding is present. The students should submit a short written report identifying the kind of deformation and describing how the deformation has contributed to the topography of the area.

	1 (NOT VISIBLE)	2 (NEEDS IMPROVEMENT)	3 (MEETS EXPECTATIONS)	4 (EXCEEDS EXPECTATIONS)
Identify and sketch the three fundamental types of stress.				
Identify the types of deformation using an illustration.				
Collect at least five photos (from the internet or other sources) of deformed rocks and identify the type of deformation (fold, joint or fault) as well as the type of stress that have caused such.				

160 MINS

Deformation of the Earth's Crust: The Internal Structure of the Earth

Content Standard
The learners demonstrate an understanding of the internal structure of the Earth.

Performance Standards
The learners shall be able to:

- make a simple map showing places where erosion and landslides may pose risks in the community.
- using maps, diagrams, or models, credit what could happen in the future as the tectonic plates continue to move.

Learning Competencies
The learners identify the layers of the Earth **(S11ES-IId-28)**; and differentiate the layers of the Earth from each other **(S11ES-IIe-29)**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- Describe and differentiate the layers of the Earth;
- develop an understanding of the structure of the Earth's interior and its relationship to plate tectonics; and
- develop an understanding of the relationship between mathematics and science by creating a model that is made to scale the interior of the Earth.

LESSON OUTLINE

Introduction	Communicating learning objectives	10
Motivation	Inquiry and Review	20
Instruction	Lecture	50
Enrichment	Laboratory Activity	60
Evaluation	Drawing/Writing a Story	20

Materials
Paper; pencil; ruler; calculator; compass

Resources

(1) Berkley School District. (n.d.). *Making a Scale Model of the Earth's Interior*. Retrieved from http://www.berkleyschools.org/NorthstarMedia/download/122532?token=OCaRojCyVwc%3D

(2) Braile, L. (2005). *Three-D Earth Structure Model*. Retrieved from http://web.ics.purdue.edu/~braile/edumod/threedearth/threedearth.htm

(3) Busch, R. (2012). *Laboratory Manual in Physical Geology*. (9th ed.). New Jersey: Prentice Hall.

(4) Kirkby, K. (2008). *On The Cutting Edge: Strong Undergraduate Geoscience Teaching*. Retrieved from http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html

INTRODUCTION (10 MINS)

Communicating learning objectives

1. Introduce the following specific learning objectives:
    - Describe and differentiate the layers of the Earth.
    - Develop an understanding of the structure of the Earth's interior and its relationship to plate tectonics
    - Develop an understanding of the relationship between mathematics and science by creating a model that is made to scale the interior of the Earth.

2. Introduce the list of important terms the learners will encounter.
    - **Crust** - thin, outermost layer of the Earth made up of two different types, namely continental crust and oceanic crust
    - **Mantle** - middle layer of the Earth between the crust and the core which makes up about 83% of Earth's interior
    - **Core** - innermost layer of the earth; outer core is in a liquid state, whereas inner core is in a solid state
    - **Lithosphere** - rigid outer layer of the Earth which is made up of the brittle crust and the upper mantle
    - **Asthenosphere** - layer of weak, ductile rock in the mantle situated below the lithosphere
    - **Moho** - boundary separating the crust and the mantle
    - **Seismic wave** - an elastic shock wave that travels outward in all directions from an earthquake source
    - **Convection** - transfer of heat by mass movement or circulation of a substance
    - **Plate tectonics** - theory which proposes that the crust and upper mantle of the Earth are composed of several large, thin, and relatively rigid plates that move relative to one another
3. Have the learners define in their own words what they know of the important terms. Write their responses on the board. Leave learners' responses and refer to these throughout the lesson.

Teacher tip

- You may create a customized puzzle as you see fit. Use images that the learners can easily relate to.

MOTIVATION (20 MINS)

1. Connect the lesson to a real-life problem or question.

2. To gauge the prior knowledge of the learners, have them answer a bell work question: if you dig down all the way into the center of the Earth, what would you see?

3. Have the learners sketch their ideas of what the interior of the Earth looks like within 10 minutes. Ask them to include and label the following in their drawing:
    - Characteristics of the materials (temperature, composition, and physical state)
    - Boundaries between regions with different types of materials
    - Changes that take place as you go deeper into the center of the Earth (change in temperature, pressure, and density)

4. Elicit answers by having the learners present their diagrams and descriptions in front of the class.

Teacher tip

- The teacher may prompt the learners with the following questions:
    - Is the inside of the Earth completely solid?
    - What materials or substances are could be present in the interior of the Earth?
    - What do you think is the temperature like inside the Earth?
- If the class is more on the passive side, division of the class into small groups of two or three may facilitate sharing. Call on two or three groups to share if pressed for time.
- Possible misconceptions on the Earth's structure include the following (Kirkby, 2008):
    - Crust and lithosphere (or plates) are synonymous terms
    - Asthenosphere is liquid (most learners are only familiar with liquid convection, not solid convection)
    - Lower mantle is liquid
    - Earth's core is hollow or large hollow spaces occur deep within the Earth (a mainstay of popular literature and Hollywood movies)
- Explain why the abovementioned misconceptions are false.

INSTRUCTION (50 MINS)

Give a demonstration/lecture/simulation using the following lecture proper outline:

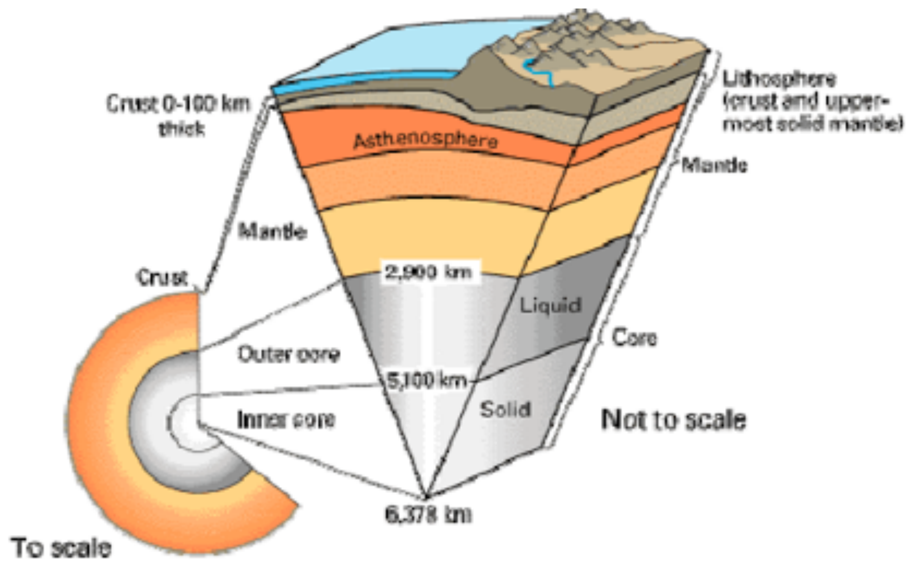


Figure 1: Cutaway view showing the internal structure of the Earth.

1. Earth's layered structure
    - There are two ways the layers of the Earth are classified and labeled. Discuss and compare layering defined by composition (crust, mantle, and core) and layering defined by physical properties (lithosphere, asthenosphere, outer core, and inner core).
    - Describe how temperature, pressure, and density change as you travel deeper down the Earth's interior.
    - Contrast continental crust and oceanic crust.
    - Discuss the crust-mantle boundary (Moho) and how it was discovered
    - Introduce the idea of the lithosphere being broken into smaller pieces called plates, which move about on top of the asthenosphere.
    - Describe the layering within the mantle.

Teacher tip

- During the instruction (lecture or PowerPoint presentation), the learners must take notes in their notebooks. Monitor the learners as the lesson progresses and randomly call them to read what they have written for a particular topic.

- Discuss what the inner core is made up of and why it is solid. Differentiate the inner and outer core.

2. How geologists look into the Earth's interior
    - Most knowledge on the Earth's interior came from the study of the earthquake waves that travel through the Earth.
    - Explain how the materials in the Earth's interior affect seismic waves.
    - Describe the behavior of P and S waves as they travel through the interior of the Earth.
    - Define seismic discontinuities.
    - Explain how scientists inferred the liquid state of the outer core.

3. Other methods by which scientists look into the interior of the Earth
    - Briefly discuss other tools scientists/geologists use to study the deepest parts of the Earth.
    - Explain how meteorites provided important clues to the composition of the Earth's interior.

ENRICHMENT (60 MINS)

Facilitate a laboratory activity on constructing a scale model of the Earth's interior.

1. Learners will need pencil, crayons, compass and drawing paper for this activity.
2. Recall that the rocky body of the Earth has an average radius of 6,371 km, and consists of the crust, upper mantle, lower mantle, outer core, and inner core. If the Earth had the radius of a basketball (119 mm), calculate the thickness of each layer.
3. Fill out the table below with appropriate values. Round the numbers to the nearest whole number. The thickness of each layer is listed in the table below:
4. Draw a dot on the center of a blank sheet of paper. Use a compass to draw a circle that represents the scale thickness of the inner core.
5. Adjust the width of the compass to account for the scale distance (mm) of the outer core. Place the point of the compass on the center dot and draw a circle. It will be wider than the inner core circle by the thickness of the outer core.
6. Repeat the above procedure to construct circles for the mantle and for the crust.

Teacher tip

- To compute for the ratio scale of the basketball model, divide the radius of the Earth (6,371km) by the radius of the basketball (119mm). Thus, 1.0 mm = 53.5 km.
- As an extension of this activity, a similar exercise on calculating the relative volume of the layers of the Earth may be sent as homework. Using the formula for the volume of a sphere ($V=4\pi R^3$) and given the radius of the bottom Rb and radius of the top Rt of the spherical shell, the volume of the layer is $V=4\pi(Rt^3-Rb^3)$.

7. Color each layer and label them with their characteristics (name of layer, actual thickness, elemental composition, and state of matter).

Layers of the Earth	Actual Thickness (km)	Thickness (mm) if the Earth is the size of a basketball
Crust	25	
Mantle	2,900	
Outer Core	2,250	
Inner Core	1,196	22

8. Divide the class into groups and have them answer and discuss the following questions:
    - What is the thickest layer of the Earth? What is the thinnest layer of the Earth?
    - If you were to use an egg as a scale model of the earth, which would represent the crust, mantle, and core?
    - How does this drawing compare to the sketch you made earlier in the class? Does a scale model give you better information than a rough sketch?
    - Examine the model and determine the layer on which life exists. Describe the thickness of this layer relative to the radius of the Earth.

Teacher tip

- The answers of the learners may vary. In general, in the egg analogy, the eggshell corresponds to the crust, the white to the mantle, and the yolk to the core. Other learners may answer that the shell corresponds to the lithosphere, the thin membrane underneath the shell to the asthenosphere, the white part to the mantle, and yolk to the core.
- The scale model gives an accurate depiction of the relative size of the actual layers. In a drawing that is not to scale, parts may be too large or small relative to the other parts.

EVALUATION (20 MINS)

Ask the learners to draw two cross-sections of the Earth from memory. Divide the Earth by physical properties in one and by composition in the other. Have the learners discuss and check each other's work OR Ask the learners to write a short story in which the main character travels to the center of the Earth. The story should describe the conditions and changes the character would encounter at different depths in his journey. Assure that the information about the layers of the Earth's interior are accurate.

	1. (NOT VISIBLE)	**2. (NEEDS IMPROVEMENT)**	**3. (MEETS EXPECTATIONS)**	**4. (EXCEEDS EXPECTATIONS)**
Constructing a scale of the Earth's interior				
Short story about taking a journey to the centre of the Earth				

Earth Science

Plate Tectonics

75 MINS

Content Standard
The learners demonstrate an understanding of plate tectonics.

Performance Standard

Learning Competencies
Explain how the seafloor spreads **(S11ES-IIf-32)**,

Describe the structure and evolution of ocean basins **(S11ES-IIf-33)**, and

Explain how the movement of plates leads to the formation of folds and faults **(S11ES-IIg-h-34).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- identify major physiographic features of ocean basins;
- describe the process of seafloor spreading; and
- demonstrate understanding of the theory of plate tectonics and how plate tectonic processes lead to changes in Earth's surface features.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Activity: Map Navigation	10
Instruction	Lecture/Discussion	30
Enrichment	Activity: Map Interpretation	15
Evaluation	Pair Quiz	15

Materials
book, unlined paper

Resources

A. Websites

(1) http://www.cosee-se.org/files/southeast/Introduction%20to%20the%20Seafloor%20Teacher.pdf (Accessed: 27/04/2016)

(2) http://oceanworld.tamu.edu/resources/ocng_textbook/chapter03/chapter03_04.htm ((Accessed: 27/04/2016)

(3) Seafloor Spreading Centers: The Life Cycle of the Seafloor Lesson Plan by Ashlee Henig and Stephen Halpern

(4) https://earthref.org/SCC/lessons/2011/seafloorspreading/#day4 (Accessed: 26/04/2016)

(5) https://opentextbc.ca/geology/chapter/10-3-geological-renaissance-of-the-mid-20th-century/ (Accessed: 25/04/2016)

(6) http://www.mrkscience.com/planbook/Earth%20Science/Jan202010/Sea%20Floor%20Spreading%20Made%20Easy-%20Pages%204%205%2010%2011.pdf (Accessed: 28/04/2016)

(7) http://serc.carleton.edu/NAGTWorkshops/intro/activities/65696.html (Accessed: 20/04/2016)

(8) http://serc.carleton.edu/NAGTWorkshops/intro/activities/25297.html (Accessed: 20/04/2016)

Additional resources at the end of the lesson

INTRODUCTION (5 MINS)

Communicating Learning Objectives

1. Introduce the following learning objectives and important terms:
    - I can identify major physiographic features of ocean basins
    - I can describe the process of seafloor spreading
    - I can demonstrate an understanding of the theory of plate tectonics and how plate tectonic processes lead to changes in Earth's surface features
2. Introduce the list of important terms that learners will encounter:
    a. Mid-ocean ridges
    b. Abyssal plains
    c. Trench
    d. Passive margin
    e. Continental drift
    f. Seafloor spreading
    g. Lithosphere
    h. Asthenosphere
    i. Magnetic anomaly
    j. Plate tectonics
    k. Plate boundary
    l. Subduction
    m. Island arc
    n. Transform fault

MOTIVATION (10 MINS)

Connect the lesson to a real-life problem or question.

1. Ask students: What would the ocean floor look like if we drain away all the seawater? Instruct students to sketch a picture of what they think the ocean bottom may look like. Have the students compare their sketches with their classmates.

2. Show students a topographic map of the Earth (attached with this teaching guide or may be downloaded at http://d32ogoqmya1dw8.cloudfront.net/images/NAGTWorkshops/structure/SGT2012/activities/noaa_global_topographic_map.jpg)
3. Ask students to locate the continents and identify arcuate and linear features on the continents (ex. Major mountain chains like Andes and Himalayas; linear lakes in Africa)
4. Help students identify the major ocean basins: Pacific, Atlantic, Indian, Arctic.
5. Ask students to describe the ocean floor. (Probable answers: The seafloor is not flat!; Seafloor topography is as varied and rugged as that on land; Middle of the seafloor is not the deepest part.) As with the continents ask them to point on the map arcuate and linear features on the ocean floor (ex. seamount chains, volcanic islands, mid-oceanic ridge, trenches).
6. Ask students to locate Iceland. What feature in the Atlantic Ocean can be observed slicing through Iceland? (The mid-Atlantic ridge, an example of an underwater mountain range. It is a part of the most extensive chain of mountains that wraps around the globe for more than 65,000 km!)
7. Explain to students that prior to the 1940s, very little was known about the deep oceans. During the WWII, with the advances in electronics and sonar, it became technologically possible to map the ocean floor in great detail. This provided the databases to construct the first detailed maps of the important features of the ocean floor such as mid-oceanic ridges and trenches.

Teacher Tip

Encourage all students to participate. If a student finds a feature, ask him to point to the map and trace it with his finger to ensure that everybody in class could identify the feature.

INSTRUCTION (30 MINS)

Give a demonstration/lecture/simulation.

Lecture proper (Outline)

1. SEAFLOOR BATHYMETRY
   - **Briefly discuss the various methods of measuring ocean depths**
     A. Sounding line – weighted rope lowered overboard until it touched the ocean bottom; this old method is time-consuming and inaccurate
     B. Echo sounding– type of sonar which measures depth by emitting a burst of high frequency sound and listening for the echo from the seafloor. Sound is emitted from

Teacher Tips

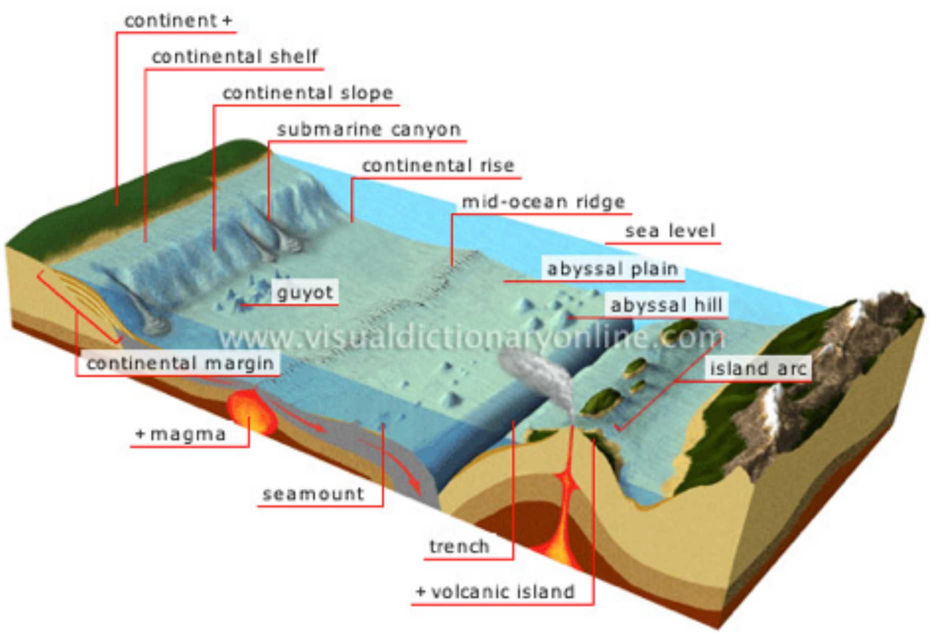
- Some common misconceptions that can be addressed in this lesson:
  - The seafloor is flat or bowl-shaped and the deepest portion is in the middle.
  - The seafloor is the same age as the continents.
  - The entire seafloor is the same age
  - The Earth is expanding; seafloor is created but never destroyed.
  - Continents drift through the ocean and oceanic currents are responsible for continental drift.
  - “Plate” is synonymous to “continent”.

a source on the ship and the returning echo is detected by a receiver on the ship. Deeper water means longer time for the echo to return to the receiver.

C. Satellite altimetry – profiles the shape of the sea surface by measuring the travel time of a radar pulse from the satellite to the ocean surface and back to the satellite receiver. The shape of the sea surface approximates the shape of the sea floor.

(Source: https://earthref.org/SCC/lessons/2011/seafloorspreading/#day2)

- Discuss with students these statements and **explain why these statements are false**.



(Image source: http://www.visualdictionaryonline.com/earth/geology/ocean-floor.php)

- **Describe the different features of the ocean floor.**

A. Continental margin – submerged outer edge of the continent where continental crust transitions into oceanic crust

- Passive or Atlantic type – features a wide, gently sloping continental shelf (50-200m depth), a steeper continental slope (3000-4000m depth), and a flatter continental rise.

- Active or Pacific type – characterized by a narrow shelf and slope that descends into a trench or trough

B. Abyssal plains and abyssal hills – abyssal plain is an extremely flat, sediment-covered stretches of the ocean floor, interrupted by occasional volcanoes, mostly extinct, called seamounts. Abyssal hills are elongate hills, typically 50-300m high and common on the slopes of mid oceanic ridge (Note: figure above is not a very good representation of abyssal hill). These hills have their origins as faulted and tilted blocks of oceanic crust.

C. Mid-ocean ridges – a submarine mountain chain that winds for more than 65,000 km around the globe. It has a central rift valley and rugged topography on its flanks. Mid-ocean ridges are cut and offset at many places by transform faults. The trace of a transform fault may extend away from either side of the ridge as a fracture zone which is older and seismically inactive.

D. Deep-ocean trenches- narrow, elongated depressions on the seafloor many of which are adjacent to arcs of island with active volcanoes; deepest features of the seafloor.

E. Seamounts and volcanic islands – submerged volcanoes are called seamounts while those that rise above the ocean surface are called volcanic islands. These features may be isolated or found in clusters or chains.

2. SEAFLOOR SPREADING

- **Review of Continental drift theory**

A. Remind students of the evidences for Continental drift:
   - Fit of the continents
   - Matching of rock units across ocean basins
   - Distribution of fossils
   - Paleoclimate evidence (evidence of tropical climates and past glaciations)

B. Briefly discuss why many scientists rejected Wegener's Continental drift.
   - Wegener could not conceive of an acceptable mechanism for moving the continents around.

- **Enumerate the different observations/evidences that led to the proposal of**

- Point out that these arguments for continental drift can also be evidences to support seafloor spreading. The continents were once joined together but now separated. This implies that something had to be put between the continents for them to move apart.

seafloor spreading by Hess

A. Distribution of seafloor topographic features – distribution of mid-ocean ridges and depth of the seafloor

B. Sediment thickness – fine layer of sediment covering much of the seafloor becomes progressively thicker away from mid-ocean ridge axis; seafloor sediment not as thick as previously thought

C. Composition of oceanic crust – consists primarily of basalt

D. High heat flow along mid-ocean ridge axes – led scientists to speculate that magma is rising into the crust just below the mid-ocean ridge axis

E. Distribution of submarine earthquakes – earthquakes do not occur randomly but define distinct belts (earthquake belts follow trenches, mid-oceanic ridges, transform faults)

- **Describe the seafloor spreading hypothesis. Discuss the different lines of evidence for seafloor spreading**

A. Seafloor spreading hypothesis

- In 1960, Harry Hess advanced the theory of seafloor spreading. Hess proposed that seafloor separates at mid-ocean ridges where new crust forms by upwelling magma. Newly formed oceanic crust moves laterally away from the ridge with the motion like that of a conveyor belt. Old oceanic crusts are dragged down at the trenches and re-incorporated back into the mantle.
- The process is driven by mantle convection currents rising at the ridges and descending at the trenches. This idea is basically the same as that proposed by Arthur Holmes in 1920.

B. Proof for seafloor spreading

- Magnetic stripes on the seafloor: detailed mapping of magnetism recorded in rocks of the seafloor shows that these rocks recorded reversals in direction and strength of the Earth's magnetic field. Alternating high and low magnetic anomalies run parallel to mid ocean ridges. Pattern of magnetic anomalies also matches the pattern of magnetic reversal already known from studies of continental lava flows.

• Review with students the concept of mineral magnetism. Point out that ferromagnetic minerals within partially molten rock can align with the ambient magnetic field. But why do these minerals do not realign themselves when the next magnetic reversal occurs? When rocks cool below the Curie temperature (around 500°C), the minerals retain the direction of magnetization. Thus, unless the magnetized rock is heated beyond the Curie temperature, it will retain its original magnetism.

    - Deep sea drilling results: Age of seafloor forms a symmetric pattern across the mid-oceanic ridges, age increases with distance from the oceanic ridge; no seafloor older than 200 million years could be found, indicating that seafloor is constantly being created and destroyed.

- **Seafloor spreading demonstration** (activity instructions as attachment)

  For this demonstration, the class will need 4 books, 4 identical strips of unlined paper, 2 different colored markers or crayons. Place two books on the table with the spines almost touching. Have a student take 2 strips of paper and insert them back to back into the gap between the books. Make sure the ends of the paper strips are sticking up. Repeat this setup adjacent to the first two books but offset the center of the second setup slightly to the right.

  Assign one student per setup to pull on the edges of the paper strips evenly on opposite directions while the class observes. While two students very slowly pull out the paper strips at the same rate, have one student use a marker or crayon to mark across the paper strips where they exit the gap. This will create a stripe of color along the gap that grows wider as more paper is pulled out. Explain that this color represents the rocks with normal polarity, that is, the rocks cooled and solidified when Earth's magnetic polarity is similar to what we have today.

  Afterwards, announce that a magnetic reversal has occurred, that is, the magnetic polarity has flipped or is now oriented in the opposite direction. At the same time, the student takes the other colored marker/crayon and begins coloring the paper strip along the gap. Continue switching polarity but vary the timing between each switch so that each setup will result in two strips of paper that are mirror image of each other with alternating stripes of color of varying widths. When the entire length of the paper strips are pulled out, ask students to tape together the paper strips down at the center where the last stripes are.

  Demo Questions

  Ask students to identify the following:

  (a) spreading center/mid ocean ridge

(b) strips with normal polarity and strips with reversed polarity

(c) where the oldest and youngest rocks are

Q: How does this activity model seafloor spreading?

3. THEORY OF PLATE TECTONICS

- **Outline the main principles Plate Tectonics**

A. The Earth's outermost rigid layer (lithosphere)is broken into discrete plates each moving more or less as a unit.

B. Driven by mantle convection, the lithospheric plates ride over the soft, ductile asthenosphere.

C. Different types of relative motion and different types of lithosphere at plate boundaries create a distinctive sets of geologic features.

- **Review the concept of lithospheric plate**

A. The lithosphere consists of the crust and the uppermost mantle.

- Average thickness of continental lithosphere :150km
- Average thickness of old oceanic lithosphere: 100km

B. Composition of both continental and oceanic crusts affect their respective densities.

C. The lithosphere floats on a soft, plastic layer called asthenosphere.

D. Most plates contain both oceanic and continental crust; a few contain only oceanic crust.

E. A plate is not the same as a continent.

- Answers to Demo Questions:
  1. (a) the center where the two strips are held together
     (b) Normal polarity, stripes of one color (e.g. blue); reverse polarity, stripes of another color (e.g. orange)
     (c) youngest rocks are along the spreading center on both sides, oldest rocks are on the outer edges of the paper strip

  2. The paper strips represent the oceanic crust created at the mid ocean ridge. The newly formed oceanic crust "spreads" laterally. The alternating stripes represent the episodes of magnetic reversals. It is important to note that the mirror image implies that the rocks on either side of the spreading center are formed at the same time. (This model, however, does not account for the destruction of old oceanic crust at trenches.)

- Using a white board or transparency film (if using overhead projector) get students to draw with you the different features associated with each type of plate boundary. This will help students easily visualize shapes, motion, and spatial relationships related to the plate boundaries.

- **Identify and describe the three types of plate boundaries**

Types of Plate Boundaries				
Plate Boundary		**Plate movement**	**Description**	**Example**
Divergent	Oceanic-Oceanic	Plates moving away from each other	Forms elevated ridge with rift valley at the center; submarine volcanism and shallow earthquakes	Mid-Atlantic ridge; East Pacific rise
	Continental-Continental		Broad elevated region with major rift valley; abundant volcanism and shallow earthquakes	East African Rift valley; Red Sea
Convergent	Oceanic-Continental	Plates moving toward each other	Dense oceanic plate slips beneath less dense continental plate; trench forms on the subducting plate side and extensive volcanism on the overriding continental plate; earthquake foci becoming deeper in the direction of subduction	Western South America
	Oceanic-Oceanic		Older, cooler, denser plate slips beneath less dense plate; trench forms on subducting plate side and island arc on overriding plate; band of earthquakes becoming deeper in the direction of subduction	Aleutians; Marianas
	Continental-Continental		Neither mass is subducted; plate edges are compressed, folded, and uplifted resulting in the formation of major mountain range	Himalayas; Alps
Transform		Plate sliding past each other	Lithosphere is neither created nor destroyed; most offset oceanic ridge systems while some cut through continental crust; characterized by shallow earthquakes	mid-ocean ridge; San Andreas fault

- **Briefly discuss the Wilson Cycle**
  A. Plate tectonics is cyclic. In 1966, J. Tuzo Wilson proposed a cycle that includes continental break-up, drifting, collision and re-assembly of the continent.
  B. Main phases of the Wilson Cycle
     - Rifting within the supercontinent leads to the opening of new ocean basin and formation of oceanic crust.
     - Passive margin cools and sinks, and sediment accumulates along the edge.
     - Convergence begins, initiating subduction and eventual ocean closure.
     - Continent-continent collision forms the next supercontinent.
- **Explain the driving forces for plate motion**
  A. Convection in the mantle (the sinking of denser material and rising of hot, less dense material) appears to drive plate motion.
  B. Gravity-driven mechanisms such as slab-pull and ridge-push are thought to be important in driving plate motion. Slab-pull develops when cold, dense subducting slab of lithosphere pulls along the rest of the plate behind it. Ridge-push develops as gravity pushes the lithosphere off the mid-ocean ridges and toward the subduction trenches.

ENRICHMENT (15 MINS)

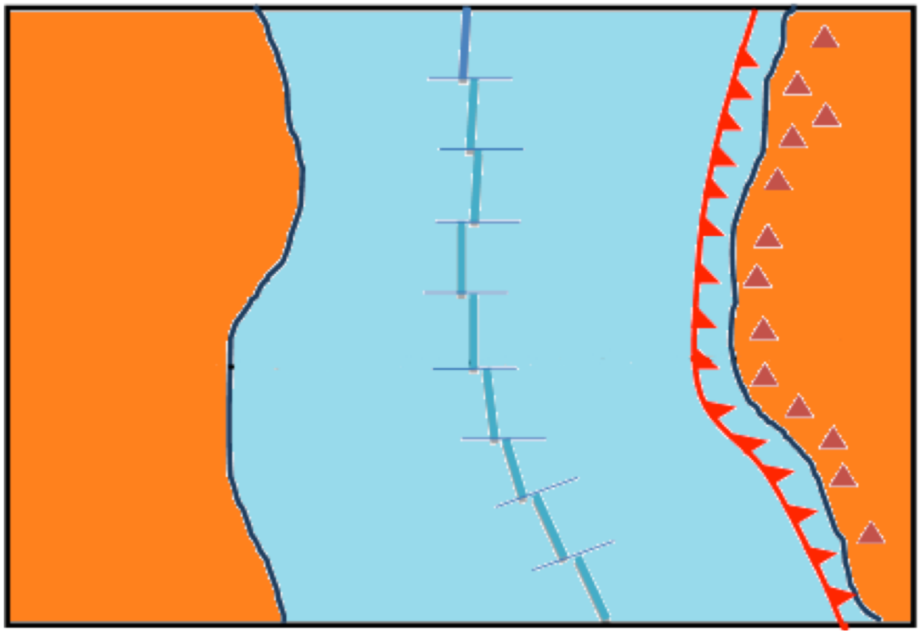
Idealized Plate Boundary Map and Cross Section

1. Refer to the hypothetical plate map below showing continents A and B separated by an ocean. Answer the following questions:
   a. How many plate portions are shown?
   b. Draw arrows on the map to show the relative direction the plates are moving.
   c. Draw a triangle (Δ) where volcanic activity is likely to occur.
   d. Draw a circle (o) where earthquake is likely to occur.
   e. Indicate with an arrow the younging direction of the lithosphere.

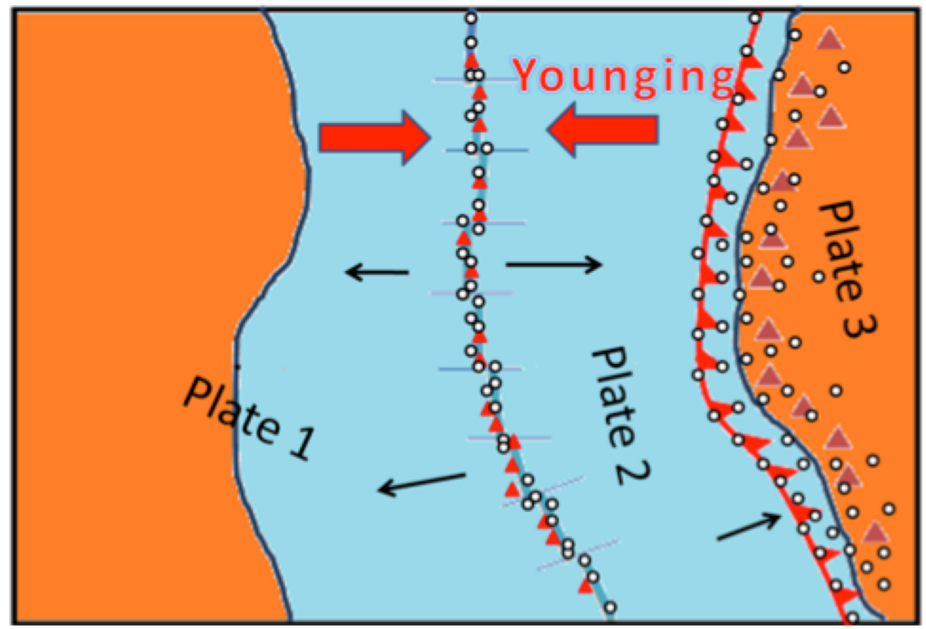
f. Mark the location and type of each plate boundary shown in the map.

g. If the ocean is opening at a rate of 3cm/yr, how wide will the ocean be in 100 million yrs? Give your answer in kilometers.

Hypothetical plate map



Answers



- Black arrows indicate direction of movement of plates; large red arrows indicate younging direction of the oceanic lithosphere; white circles and red triangles represent location of earthquakes and volcanoes
- Mid-ocean ridge represents a divergent plate boundary (boundary between plates 1 and 2); saw teeth pattern represents a subduction zone which is a convergent type of plate boundary (boundary between plates 2 and 3)
- Volcanism and seismicity are associated with plate boundaries
- At 3 cm/yr spreading rate, ocean basin would be 3,000 km wider in 100 million years (assuming subduction continues along the boundary between plates 2 and 3 and that no subduction is developed within plate 1)

EVALUATION (15 MINS)

Have each student formulate 3 review questions that cover the content of the lesson. Break the class into pairs and instruct students that they will quiz their partners with the questions they have prepared and discuss between them the answers. Each pair should submit their questions and corresponding answers.

	1 (NOT VISIBLE)	**2 (NEEDS IMPROVEMENT)**	**3 (MEETS EXPECTATIONS)**	**4 (EXCEEDS EXPECTATIONS)**
Idealized Plate Boundary Map 1. Questions are answered accurately 2. Map is properly labelled				
Question and Answer 1. Questions are pertinent to the topic and stimulate thought and inquiry. The questions encourage students to evaluate and analyze in order to arrive at an answer. 2. Answer is accurate and complete. Response is correct and demonstrate understanding of concepts.				

ADDITIONAL RESOURCES

B. Textbook sources:

1. Tarbuck, E.J., F.K. Lutgens, and Tasa, D. (2014). Earth An Introduction to Physical Geology. Eleventh Edition. Prentice Hall.
2. Marshak, Stephen (2013). Essentials of Geology (4th ed.). W.W. Norton.

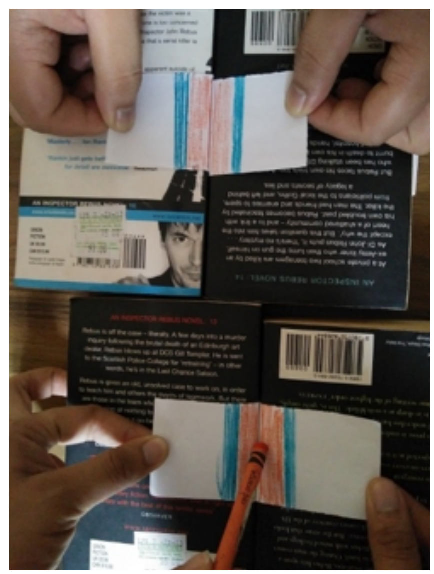
Seafloor Spreading Demonstration Instructions

Step 1. Prepare the materials.

Step 2. Set up the book and insert paper strips back to back along the gap between the books.

Step 3. Pull on the edges of the paper strips in opposite directions. Use a crayon or marker to mark across the gap as the strips are being pulled out slowly.

Step 4. Announce magnetic reversal and at the same time a student takes a different colored crayon/marker and begins marking along the gap. Continue switching polarity but vary the timing between each switch until all the paper has been pulled out.



Earth Science

40 MINS

Major Events in Earth's Past

Content Standard
The learners demonstrate an understanding of how the planet Earth evolved in the last 4.6 billion years.

Performance Standard

Learning Competency
Describe how layers of rocks (stratified rocks) are formed **(S11ES-IIh-35)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- identify and describe sedimentary layering; and
- describe how layers of rocks (stratified rocks) are formed.

LESSON OUTLINE

Introduction	Communicating learning objectives	10
Motivation	Discussion	5
Instruction	Discussion	25
Enrichment	Assignment	
Evaluation	Assigment	

Materials
Large clear plastic bottles (e.g. 2-liter soda bottle); modelling clay (preferably brown in color); soil; sand; small pebbles with rounded edges; small angular pebbles; small marine shells; small wood fragments; water; plastic

Resources

(1) Annenberg Learner. (n.d.). *Sedimentary Rock Formation* [Video file]. Retrieved from https://www.learner.org/series/modules/express/pages/scimod_07.html

(2) Carlson, D. H., Plummer, C. C., & Hammersley, L. (2011). *Physical Geology: Earth Revealed*. McGraw-Hill.

(3) Desonie, D. (2015). CK-12 Earth Science High School. Retrieved from http://www.ck12.org/earth-science/

(4) Environment Agency - Abu Dhabi. (n.d.). Lesson Plan: Sedimentation. Retrieved from http://edu.environmentalatlas.ae/downloads/Lesson%20Plan_Sedimentation.pdf

(5) *GCSE Science Revision - Formation of Sedimentary Rock layers* [Video file]. (n.d.). Retrieved from https://www.youtube.com/watch?v=Yf4YtDlA1oQ

(6) Hastings Cave and Thermal Springs. (n.d.). Activity Sheet - How do Sedimentary Rocks Form? Retrieved from http://www.parks.tas.gov.au/file.aspx?id=30422

Additional resources at the end of the lesson

INTRODUCTION (10 MINS)

Communicating learning objective

1. Introduce the following specific learning objectives:
   - Identify and describe sedimentary layering
   - Describe how layers of rocks (stratified rocks) are formed

2. Review the definition of the following terms:
   - **Bedding, Stratification, Lamination** - refers to layering that occurs in sedimentary rocks. Igneous rocks can also exhibit layering especially when formed at the surface of the Earth (volcanic rocks).
   - **Stratification** - general term for layering in sedimentary rocks.
   - **Beds** - layering in sedimentary rocks, which are greater than 1 cm thick.
   - **Lamination** - layering in sedimentary rocks, which are less than 1 cm thick.

Teacher Tip

- A layer is a three dimensional feature (not simply lines on the surface of the rock) common in sedimentary rocks.
- Each bed or layer is bounded at the bottom and top by normally planar surfaces (bedding planes).
- Thickness of beds may vary (lamination vs bedding).
- Each bed or layer represents an interval of time or a depositional event.

MOTIVATION (5 MINS)

1. Bring an old diary to class (can be fictitious). Tell the class that you faithfully record events in your life in your diary. Flip through your diary and pick a date. Read or pretend to read events that happened during that day.

2. Show a picture of a bedded sedimentary rock unit (Figure 1). Based on the previous discussion, ask the learners if they can point out bed or beds in the picture.

3. Explain to the class that each bed represents a 'page' in the Earth's history. The succession of layers or beds in a sedimentary sequence represents the successive time intervals in the Earth's history—the bottom layer being the oldest and the topmost representing the youngest time interval.

Figure 1: Clastic Sedimentary rock outcrop exhibiting distinct layering.

(Image Source: http://lh3.googleusercontent.com/-JgUgp-AGZL8/VlL_reIZzCI/AAAAAAAAM8c/12d7qB3UlWc/s720/00188%252520IMG_0633%252520tuff.jpg)

Teacher Tip

- A layer is a three dimensional feature (not simply lines on the surface of the rock) common in sedimentary rocks.
- Each bed or layer is bounded at the bottom and top by normally planar surfaces (bedding planes).
- Thickness of beds may vary (lamination vs bedding).
- Each bed or layer represents an interval of time or a depositional event.

INSTRUCTION (25 MINS)

Pre-class Preparation

Prepare several units of a sedimentary layering model using the procedure outlined below.

1. Cut off the top of the clear transparent plastic bottle to form a cylinder.
2. Mix together sand (~80%) and rounded pebbles (~20%). Pour the mixture into the plastic cylinder to form the first layer. Press to flatten the surface.
3. Pour pure sand into the plastic cylinder to form the second layer. Press to compact and flatten the surface.
4. Form a thin third layer using modeling clay.
5. On a small plastic bag, mix together sand, soil, angular pebbles, and small wood fragments. Pour the mixture into the clear plastic bottle to form the fourth layer. Press down on sediment mixture to form a flat surface.
6. Mix together sand and small shells. Pour the mixture into the plastic cylinder to form the fifth layer.
7. In a separate container, mix together sand and soil in equal proportions. Pour water into the mixture. Cover the cylinder with a lid and shake the mixture thoroughly. Pour the mixture slowly so as not to disturb the lower layers already in the cylinder. Allow the sediments to settle to form the sixth and final layer.

Figure 2: Sample of a 'sedimentary layering model'. Note that the sedimentary layering model that will be produced using the procedure outlined above will not be the same as the model represented in the image.

(Image Source: https://s-media-cache-ak0.pinimg.com/236x/e6/94/c9/e694c9ed6cdadc85650024d06b904fb3.jpg)

Teacher Tip

- Make several 'units' of the sedimentary layering.
- The amount of materials needed depends on the desired thickness of each layer.
- The number of units that needs to be prepared will depend on how many groups the class will be subdivided into.
- The preparation can be done well ahead of time. The prepared units can be re-used for different classes.
- For the sixth and final layer, check that the change in grain size from the lower to the upper parts of the layers is recognizable. This can be tested by allowing the sediments to settle first in a separate container and by shaking the container prior to pouring into the cylinder. If the change in grain size is not recognizable, it is advisable to change the grain size of the sand and soil.

Lecture Proper

1. Review of sedimentary rocks and processes:
    - Ask the learners to enumerate and define sedimentary processes of weathering, erosion, transport, deposition, and lithification.
    - Have the learners differentiate sedimentary processes from igneous and metamorphic processes. What is the fundamental difference among them?

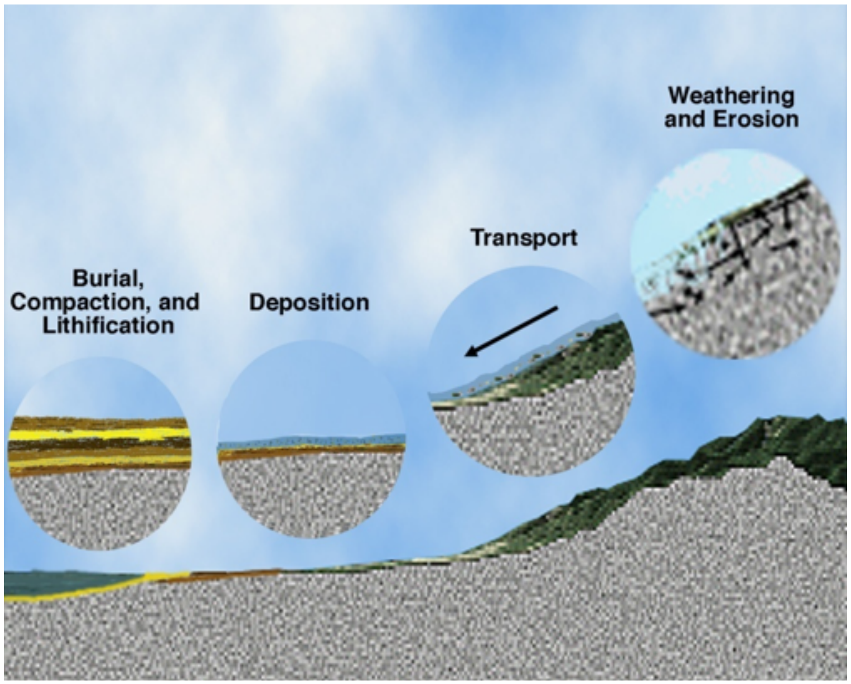


Figure 3: Sedimentary processes, namely weathering, erosion, transport, deposition, and lithification. (Image Source: http://www.indiana.edu/~g103/theinteractiveearth/5-Sedimentary%20Rocks/erostranspdep.jpg)

2. When sediments accumulate (either through deposition of clastic sediments or precipitation from solution), they tend to blanket the surface of accumulation. The surface of accumulation is generally topographically low and flat. Sediments therefore tend to form tabular layers. Not only

- Call on learners to define each of the sedimentary processes (covered in previous lessons)
- Guide the learners to the desired answers by asking them to identify where weathering, erosion, and deposition occur.
- Sedimentary processes are essentially surficial processes (processes that occur at or near the surface of the Earth at low temperature and low pressure conditions).

- Use Figure 3 to help learners recall and describe the different sedimentary process.
- In topographically high areas, the dominant sedimentary processes are erosion and transport.
- Water is an important agent of sediment transport. Weathered and eroded materials are transported and deposited to low lying areas.

do sediments form layers, they also tend to cover an extensive area.

3. If conditions on the surface do not change (e.g. constant rates of weathering, erosion, deposition), only thick, homogenous, and undifferentiated sedimentary rocks will form. Bedding or layering in sedimentary rocks is a reflection of the changing conditions during deposition. Each layer represents an interval of time where conditions have remained uniform.

Figure 4: Interbedded mudstone (left) and limestone (right).
(Image Source: http://earthwise.bgs.ac.uk/images/f/fe/P219226.jpg)
(Image Source: (http://imgc.allpostersimages.com/images/P-473-488-90/64/6455/MFJH100Z/posters/gerald-buff-corsi-tilted-sedimentary-rock-strata-of-sandstone-interbedded-with-mudstone.jpg)

- It is preferable to show learners an actual outcrop or exposure of the sedimentary rock with obvious layering. Use Figure 4 if no outcrop is accessible.

4. What defines a bed or layer? How do you distinguish one bed to another?
   - In Figure 4, the beds are clearly defined by a change in color or shade. A change in color can reflect differences in grain size and/or composition.
   - Grain size in sedimentary rocks is commonly a function of the energy of the environment of deposition. Fine grained sediments generally reflect low energy quiet settings (protected from waves and strong currents).

- A change in climate influences rates of weathering (dry vs. wet conditions), as well as rates and mechanism of erosion and transport.
- Ask the learners to recall how the atmosphere, hydrosphere, and biosphere interact with the lithosphere (lesson on Earth system).

- A variety of factors influence the composition of sedimentary rocks: source rocks, length and duration of transport, climate, volcanism, etc.

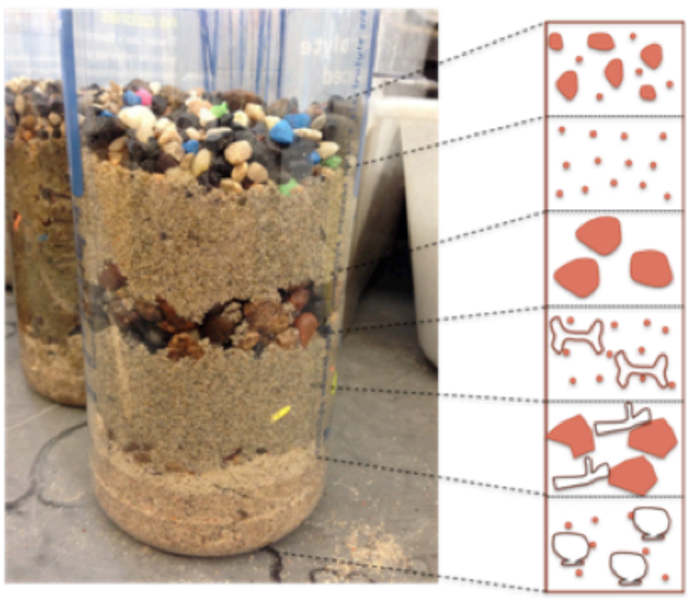
Activity

1. Break the class into several groups. Provide each group with a sedimentary layer model.

2. Have the learners make a representative drawing for each of the sediment layer (see Figure 2). Drawings should graphically show the grain sizes, grain size distribution, and 'fossil content' (e.g. shells, wood fragments).

- Figure 4 shows the evolution of life through time.

3. Measure the thickness of each layer. Have them provide a short description for each layer in terms of color, grain size and components.



Description	Origin
Small sub-rounded pebbles with a few sand grains.	
composed of well sorted sand sized sediments	
Sub-angular pebbles	
Well sorted sand sized sediments with fossils	

Figure 5: An example of a sedimentary layer model, and representative drawing and description.

4. When the learners have completed their drawings and descriptions, the teacher demonstrates how the sedimentary model was made using the procedures outlined in the pre-class preparation. For each layer, the teacher explains how similar sediments or rocks form in the natural environment. After the discussion, have the learners fill in the required information in the 'origin' column in their respective worksheets (Figure 5).

    - **Layer 1** - mixture of sand and rounded pebbles. This layer suggests transport and deposition by running water. The coarse-grained nature of the sediment rules out wind as a transporting medium. The **rounded** pebbles indicate the considerable duration of transport. River sedimentation can produce similar deposits.

    - **Layer 2 -** pure sand layer. The absence of coarser material (pebbles) in this layer compared with Layer 1 suggests the following: (a) the absence of a source for the coarser materials or (b) the transporting medium does not have the capacity to transport sediments with sizes coarser than sand. The uniform grain size (well-sorted) also suggests a transporting medium that effectively segregates or sorts sediments into separated grain sizes. Well sorted sand/sandstone can also be associated with river sedimentation.

    - **Layer 3** - the modelling clay layer represents very fine grained sediments (silt to clay size). Very fine grained sediments are more commonly transported as suspended materials. Rivers, especially during flood events, carry a lot of suspended load. When flooding recedes, the suspended load (mostly silt and clay) can settle down or be deposited as blanket of mud and silt.

    - **Layer 4** - mixture of sand, soil, pebbles, and wood fragments. Poorly sorted sediment materials containing relatively large floating debris (in this example, pebbles and wood fragment) or surrounded by fine grained material are typical of debris flow deposits.

    - **Layer 5** - sands with marine shells. The presence of marine shells indicates marine conditions. This layer could represent a period in time when the sea level was high (the area was below sea level).

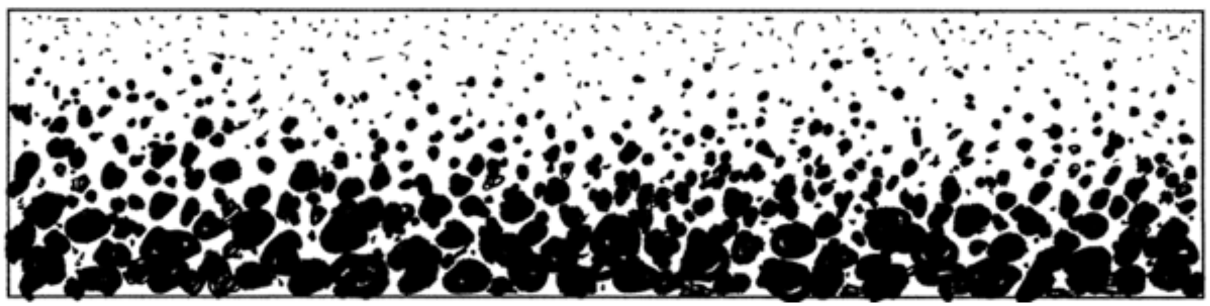
- **Roundness** is defined as the degree of smoothing of the surface of a sediment due to abrasion. The longer the duration of transport, the greater chance for abrasion, and therefore, greater degree of roundness.
- **Sorting** is a description of the distribution of sediment sizes. Well sorted sediments have uniform grain sizes. Poorly sorted sediments exhibit a wide range of sediment sizes.
- If there is a river nearby, ask the learners if they have observed the color of the river during periods of heavy rainfall. Yellowish brown - brown coloration suggests that the river is carrying a lot of suspended load.
- Recall that a debris flow is a form of mass wasting process.
- Introduce the concept of **fossils.** Fossils are the remains and traces of ancient plants and animals preserved in rocks.

- **Layer 6 -** when sediments are deposited from suspension, coarser and denser materials settle first, followed by progressively finer grained material. The resulting sedimentary structure is called **graded bedding** (Figure 6). In extreme conditions, the suspended load of a flooded river may consist of pebbles, sand, silt, and clay. As flooding recedes, the suspended load will be progressively deposited according to grain size, forming graded bedding.

Assignment

Using the same grouping, ask each group to make their own sedimentary layer model. The sedimentary layer model should be accompanied by a description of each layer.

Top



Bottom

Figure 6: Illustration of graded bedding.

(Image Source: https://commons.wvc.edu/rdawes/g101ocl/basics/gradedbedding.gif)

ENRICHMENT

Superposition is a fundamental principle in stratigraphy (the study of stratified/layered rocks). It states that, in an undisturbed (not faulted or folded), the bottom layer was formed before the top layer. However, rocks may be subjected to deformation (folding and faulting), and sedimentary layers or beds may be overturned. With this is mind, we need to ensure that the rock layers are in the correct sequence and position to correctly interpret the geologic history of an area. Have the learners explain how graded bedding would help in determining the correct sequence of layers (which is the top and which is the bottom?).

Teacher Tip

- Possible response: The bottom layer contains the coarser particles.

EVALUATION

	1 (NOT VISIBLE)	**2 (NEEDS IMPROVEMENT)**	**3 (MEETS EXPECTATIONS)**	**4 (EXCEEDS EXPECTATIONS)**
Can identify layering or bedding in sedimentary rocks				
Can describe sedimentary layers in terms of thickness, grain size, and sorting				
Can explain the origin of layering or bedding in sedimentary rocks				
Can explain the observed physical properties of sedimentary rocks and sedimentary process				

ADDITIONAL RESOURCES

1. Junine, J. I. (n.d.). *Earth Evolution of a Habitable World* (2nd ed.). Cambridge University Press.
2. Kirkland, K. (2010). Earth sciences: Notable research and discoveries. New York, NY: Facts on File.
3. Lutgens, F. K., Tarbuck, E. J., & Tassa, D. (2013). *Essentials of geology* (11th ed.). Upper Saddle River, NJ: Prentice Hall.
4. Math/Science Nucleus. (2001). Sedimentary Rocks. Retrieved from https://www.msnucleus.org/membership/html/jh/earth/sedimentary/jhsedmentary.pdf
5. National Earth Science Teachers Association. (n.d.). Classroom Activity: Making Sedimentary Rocks. Retrieved from http://www.windows2universe.org/teacher_resources/teach_makerock.html
6. Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Prentice Hall.
7. The Society for Mining, Metallurgy, and Exploration, Inc. (n.d.). Sedimentary Rock Activities. Retrieved from http://www.coaleducation.org/lessons/sme/elem/6.pdf
8. University of Leeds. (n.d.). Sedimentary Rocks and the Origin of Sedimentary Strata. Retrieved from http://www.see.leeds.ac.uk/fileadmin/Documents/geolog-mapping/Lecture_7.ppt

Earth Science

Major Events in Earth's Past

60 MINS

Content Standard
The learners demonstrate an understanding of how the planet Earth evolved in the last 4.6 billion years.

Performance Standard

Learning Competency
Describe the different methods (relative and absolute dating) of determining the age of stratified rocks **(S11ES-IIh-36)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- differentiate between relative dating and absolute dating; and
- demonstrate an understanding of the principle of relative dating by being able to reconstruct the sequence of events in a given formation.

LESSON OUTLINE

Introduction	Review	5
Motivation	Activity: Relative and Absolute Age	15
Instruction	Discussion	30
Practice	Activity: Relative Dating and Absolute Dating	10
Enrichment	Short Report: Dating of Artifacts	
Evaluation	Short Report: Dating of Artifacts	

Materials
Laptop; metacards; pentel pens; rock sample with a plant imprint (fossil); clay bars of different colors

Resources

(1) Allaby, M., & Garratt, R. (2009). Earth science: A scientific history of the solid Earth. New York: Facts on File.

(2) Botkin, D. B., & Keller, E. A. (2011). Environmental science: Earth as a living planet (8th ed). Hoboken, N.J: Wiley.

(3) Carlson, D. H., Plummer, C. C., & Hammersley, L. (2011). *Physical Geology: Earth Revealed*. McGraw-Hill.

(4) Edu2000. (2008). *Carbon 14 Decay* [Video file]. Retrieved from http://www.youtube.com/watch?v=81dWTeregEA.

(5) Jordan, V. (n.d.). Radiometric Dating Lab. Retrieved from http://www.nsta.org/images/news/legacy/scope/0604/jordanradiometrics.pdf.

(6) Kirkland, K. (2010). Earth sciences: Notable research and discoveries. New York, NY: Facts on File.

(7) Lunine, J. I. (2013). *Earth: Evolution of a habitable world* (2nd ed). Cambridge: Cambridge University Press.

Additional resources at the end of the lesson

INTRODUCTION (5 MINS)

Review

1. Prompt learners to recall what they have learned from the previous lesson: how rock layers are formed. Understanding this fundamental concept in stratigraphy is essential in understanding and applying the different techniques to be discussed in this lesson.

2. Introduce the following terms:
   - relative dating
   - absolute dating
   - unconformity

Teacher Tip

Write on the board these three new words and concepts. Define each of these words as the lesson progresses.

MOTIVATION (15 MINS)

Demonstrate the difference between relative age and absolute age with this activity (adapted from: http://www.esrl.noaa.gov/gmd/outreach/lesson_plans/Using%20Radioactive%20Decay%20to%20Determine%20Geologic%20Age.pdf) (National Oceanic and Atmospheric Administration, n.d.).

Present to the class three or more people (ideally of widely varying ages). Ask them to introduce themselves to the class. The introduction should ideally include the type of work they do, years in service, and clues to their age (e.g. favorite T.V. show when they were growing up).

1. Once they have left the class, list their names on the board in random order.

2. Ask the learners to guess who is the oldest and who is the youngest among the list of persons on the board. Ask the learners to justify their answers by enumerating their criteria. List the criteria on the board.

3. Ask the learners to guess the respective ages of the persons on the list. If the persons on the list have given their prior consent, list their ages on the board.

4. Point out that some of the criteria they have used can indeed provide clues to the 'relative' ages

Teacher Tip

- If possible, use people working in the same school. Use this opportunity to allow the learners to know more about the people in their school.
- Emphasize the roles that these persons play in the functionality of the school.
- Make sure to correct the learner's behavior if they make fun of the ages of the people involved.

of people (if a person is older or younger than the rest). However, none of these can provide us their exact ages.

5. Similarly, we can use several criteria or techniques to determine the **relative ages of rocks**. Ultimately, can we determine the exact or **absolute ages of rocks**?

INSTRUCTION (30 MINS)

In earth science, there are different methods and principles that are used to determine the relative ages of rocks.

1. **Relative Dating**
    - Principle of Original Horizontality
        - When sediments are deposited, they form essentially horizontal or flat layers (Figure 1). A corollary of this principle is that tilted sedimentary rocks were originally horizontal and that they must have been subjected to rock deformation (i.e. folding).
        - Try to relate this principle with the activity on the rock layering model. Ask the learners to recall how sediments from suspension formed a horizontal sediment layer.
        - Relate the tilting of beds to the lesson on rock deformation, particularly folding.

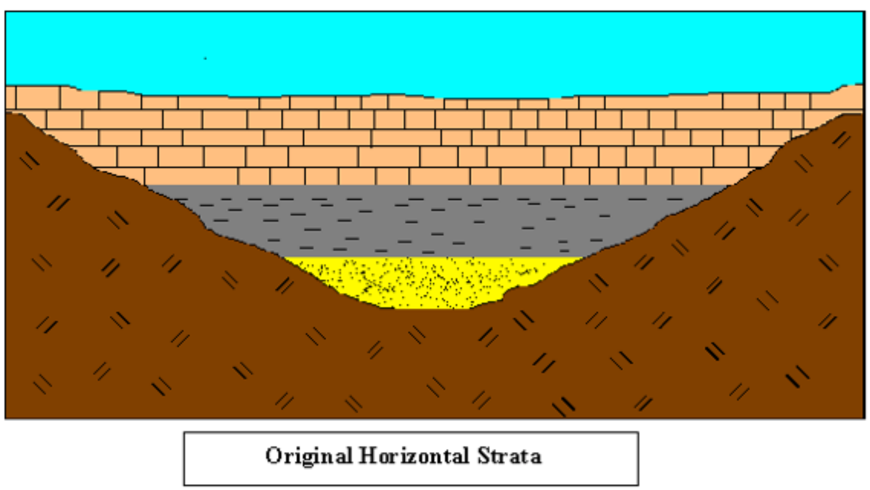


Figure 1: Layering or bedding as a result of sediment deposition.

(Image Source: http://www.sci.ccny.cuny.edu/~mcesaire/horizontalstrata.gif)

- **Law of Superposition**
  - New rock layers are always deposited on top of existing rock layers (Figure 2). Therefore, deeper layers must be older than those closer to the surface.
  - The sediments poured into the pail of water settles into horizontal layers. The bottommost layer is the oldest and the topmost layer is the youngest.

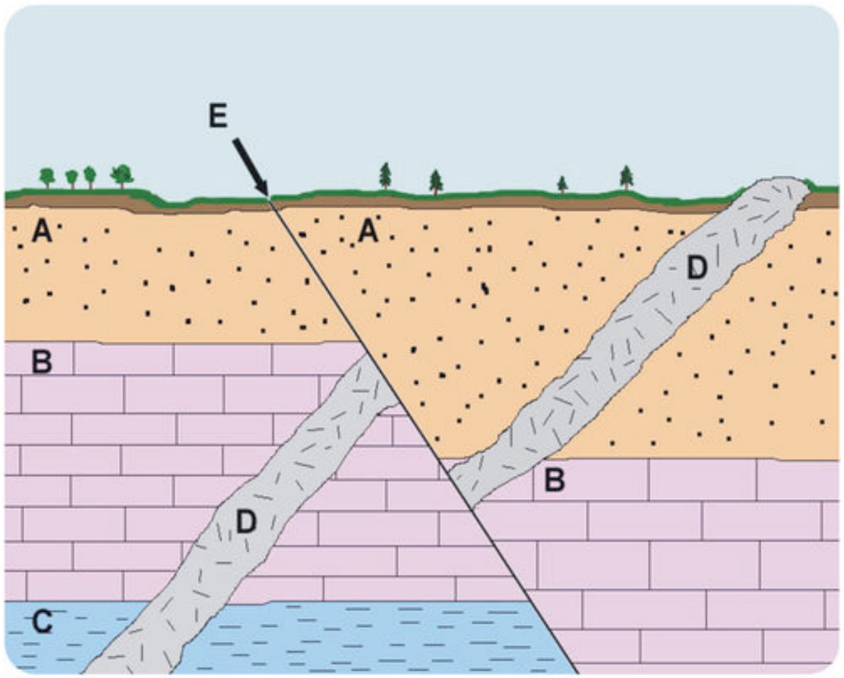


Figure 2: Illustration of the law of superposition

(Image Source: https://dr282zn36sxxg.cloudfront.net/datastreams

- **Principle of Lateral Continuity**
  - Rock layers extend laterally and cover very broad areas, especially if they formed at the bottom of ancient seas. As long as there is sufficient supply of sediments, the layer will continue to extend further.

Teacher Tip

- Use the rock layer model used in the previous lesson to demonstrate the Law of Superposition.
- As a review, ask the learners to explain how each of the successive layers were formed.

- If a geologist studying the distribution of rocks will encounter the same rock types on the opposite side of the river valley in Figure 3b, upon applying the Principle of Lateral Continuity, he can conclude that these rocks previously formed a continuous layer and that the part of the original layer of rock must have been eroded by the river.
- Layers of the same rock type are found across canyons at the Grand Canyon (Figure 4). Take note of the white layer on the top that is continuous throughout despite the presence of gaps in between.

- Ask the learners to recall the evidence used by Alfred Wegener to prove the Continental Drift Theory. He was able to correlate rock layers on the opposite side of the Atlantic Ocean by applying the Principle of Lateral Continuity.

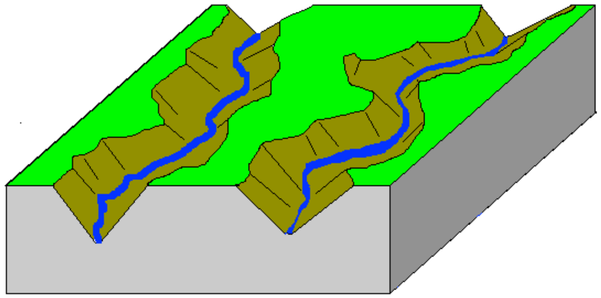


Figure 3: A landscape that undergoes stream erosion. As the river cuts down the underlying layers, it progressively erodes older layers.

Figure 4: Panorama of the Grand Canyon from the south rim (Photo by Roger Bolsius). (Image Source: https://upload.wikimedia.org/wikipedia/commons/8/85/Grand_Canyon_Panorama_2013.jpg)

- **Principle of Lateral Continuity**
  - This principle states that a layer or stratum must always be older than any feature that cuts or disrupts it. For example, if a layer is cut by a fault, the layer is older than the fault that cuts across it.

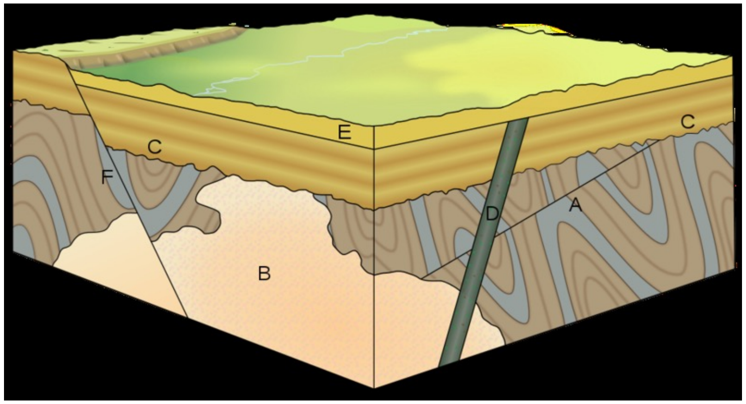
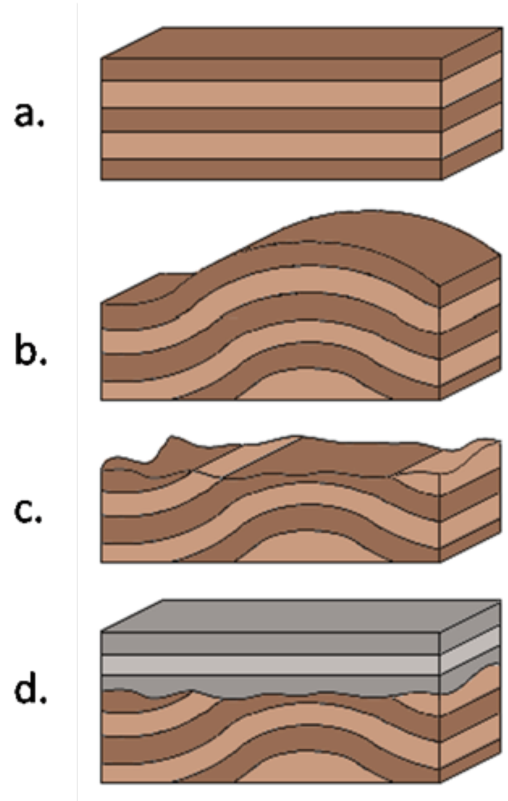


Figure 5: Hypothetical cross section/block model of an area underlain by different rock types (Illustration by Woudloper). F is a fault that cuts through layers C and igneous rock B, therefore F is younger than C and B. Rock D is a dike that cuts across all the other rocks. It is therefore younger than the other rocks. If you will look closely, Rock E is younger than rock D because rock D was not able to cut through Rock E. E was then deposited after the intrusion of Rock D. Fault, F, on the other hand is the youngest of all because it was able to cut through Rock E. However, E was eroded out on the other side of the fault block (left side of the fault).

- **Principle of Unconformity**
  - An **unconformity** is a surface of non-deposition or erosion. Accumulation of sediments continues until the supply of sediments is cut off or if the area is subject to uplift and erosion. Uplift to the surface (e.g. from the bottom of the ocean to the surface) exposes rocks to the agents of weathering and erosion.
  - Figure 6 illustrates the sequence of events that can lead to the formation of an angular unconformity.

- The horizontally layered sedimentary unit on top is separated from the underlying folded rocks by an unconformity. **Rocks above an unconformity are younger than the rocks below.**



- There is more than one type of unconformity. In an angular unconformity, the attitude or dip of the layers above and below the erosional surface are different.

Figure 6: Formation of an angular uniformity (Illustration by Actualist). Sediments are initially deposited as horizontal layers (a). The resulting rocks layers are then subject to folding (b). Rock deformation (folding) is often associated with uplift. Exposure of the folded rock layers to the surface results to erosion (c). Finally, the folded and eroded rocks undergo subsidence allowing the resumption of deposition (d). The unconformity (represented by the undulating surface) represents a period of erosion.

- Types of unconformities
  - ✤ **Angular Unconformity -** attitude of beds above and below the surface of erosion or unconformity are not the same (beds are not parallel to each other).

  - ✤ **Nonconformity -** the layer below the erosional surface is either a metamorphic rock or an igneous rock. The layer above the erosional surface is a sedimentary rock.
    - Ask the learners why igneous rocks (specifically plutonic rocks) or metamorphic rocks which are overlain by sedimentary rocks are usually separated by an erosional surface.

      Answer Key: Plutonic rocks and metamorphic rocks form below the surface of the Earth. Sedimentary rocks form at the surface. The plutonic rocks or metamorphic rocks will have to be uplifted (and therefore subject to erosion) before the deposition of the sedimentary rocks.

    - Is it possible for plutonic igneous rock or metamorphic rock to be overlain by sedimentary rocks without an erosional surface?

      Answer Key: Yes, if the contact between the two is a fault.

  - ✤ **Disconformity -** sedimentary rock strata above and below the surface of erosion are parallel to each other.

  - ✤ **Paraconformity -** strata or beds are parallel to each other. There is no discernable erosional surface; however, there is a gap in the ages between the rock units. A paraconformity represents a period of non-deposition.

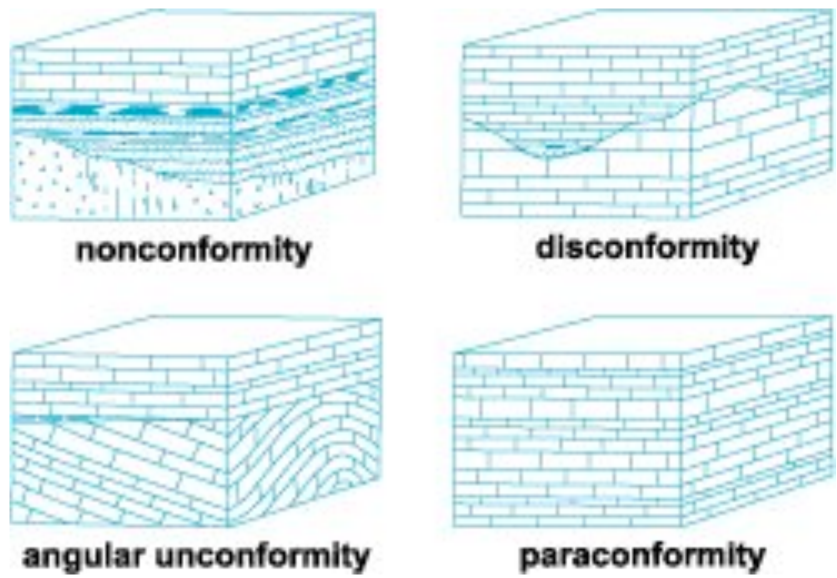


Figure 7: Types of Unconformities. (Image Source: https://s-media-cache-ak0.pinimg.com/564x/7f/9e/ca/7f9eca0770d4b6f0e8cd457454173a77.jpg)

2. Absolute Dating

- With the discovery of radioactivity in the late 1800s, scientists were able to measure the absolute age or the exact age of some rocks in years. Absolute dating allows scientists to assign numbers to the breaks in the geologic time scale and get an absolute age of a rock or fossil.
- Methods used in the absolute dating of rock layers:
  - Radiocarbon Dating
    - ✤ This is used to find the age of once living materials between 100 and 50,000 years old. It is usually used to determine ages of human fossils and habitation sites.
    - ✤ A video of carbon-14 decay is available here (Edu2000, 2008): http://www.youtube.com/watch?v=81dWTeregEA

- A longer explanation of carbon-14 decay is available here (The Science Channel, 2009): http://www.youtube.com/watch?v=udkQwW6aLik

- Potassium-Argon Dating
  - Potassium is common in many minerals, such as feldspar, mica, and amphibole. With its half-life, the technique is used to date rocks from 100,000 years to over a billion years old.
  - Potassium-40 decays to argon-40 with a half-life of 1.26 billion years.
  - Argon is a gas, allowing it to escape from molten magma. Thus, any argon that is found in an igneous crystal probably formed as a result of the decay of potassium-40. Measuring the ratio of potassium-40 to argon-40 yields a good estimate of the age of that crystal.
- Uranium-Lead Dating
  - Two uranium isotopes are used for radiometric dating:
    - Uranium-238 decays to lead-206 with a half-life of 4.47 billion years.
    - Uranium-235 decays to form lead-207 with a half-life of 704 million years.
  - Uranium-lead dating is usually performed on zircon crystals. When zircon forms in an igneous rock, the crystals readily accept atoms of uranium but reject atoms of lead. If any lead is found in a zircon crystal, it can be assumed that it was produced from the decay of uranium.

PRACTICE (10 MINS)

Relative Dating Activity

Have the learners work on this diagram (Figure 8).

1. Ask them to list down the sequence of events from the oldest to the youngest.
2. Ask them to write down the principles in stratigraphy that they used.

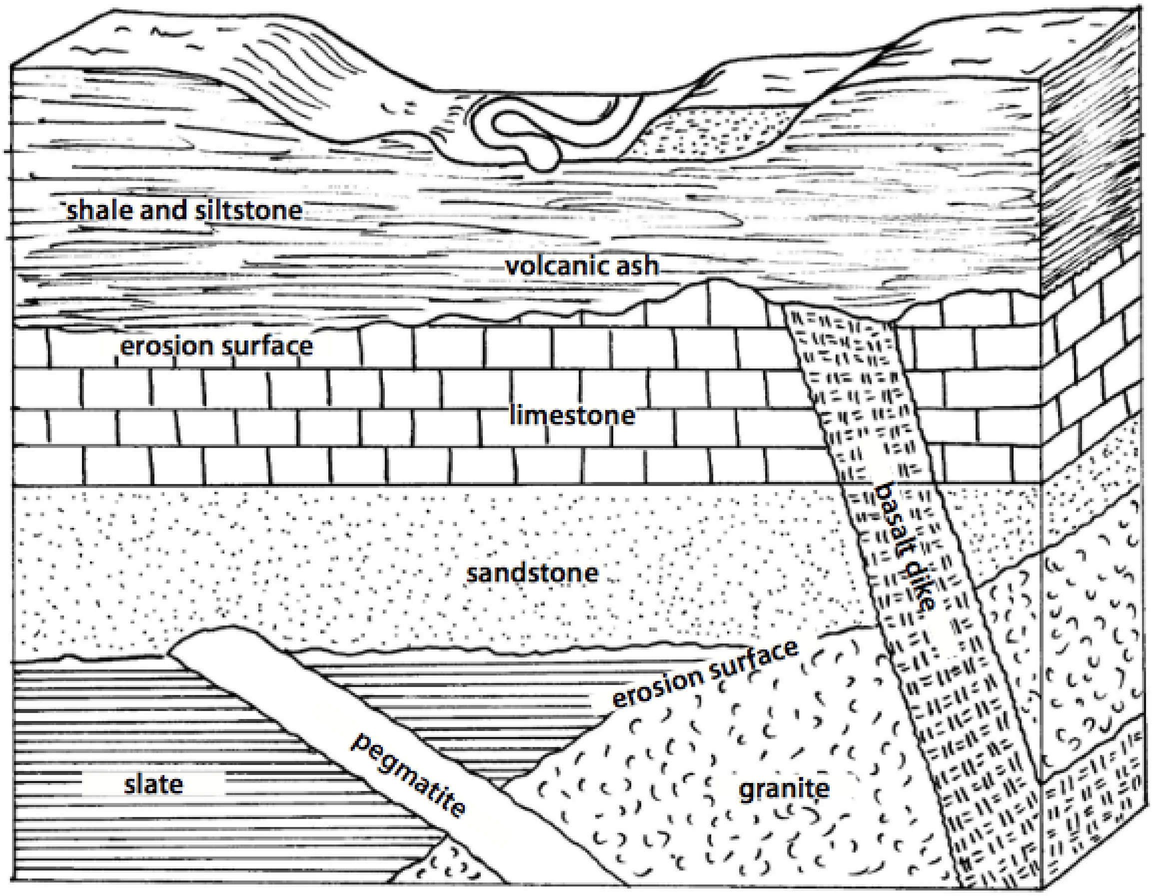


Figure 8: Hypothetical cross-section of sedimentary strata.

Answer Key:

From oldest to youngest:

1. Formation of slate
2. Formation of sandstone
3. Intrusion of granite

4. Formation of limestone
5. Intrusion of basaltic dike
6. Erosion (unconformity)
7. Deposition of the volcanic ash
8. Deposition of shale and siltstone
9. Intrusion of the pegmatite dike; however, the pegmatite dike may also have occurred after together with the intrusion of the basaltic dike or together with the deposition of the limestone. Absolute dating of these rocks will solve the problem.

Absolute Dating Activity

This activity was adapted from: http://www.nsta.org/images/news/legacy/scope/0604/jordanradiometrics.pdf (Jordan, n.d.).

A bottle soda cap or any other small and flat material with two distinct sides may be used instead of a 5-centavo coin.

1. Start with 100 pieces of 5-centavo coins inside a container. Each 5-centavo coin represents an atom in the radioactive element Carbon-14.

2. Dump out all of the 5-centavo coins and spread them out on the table.

3. Move all the coins that show tails to the side. These are atoms that have 'decayed' and are no longer radioactive.

4. Record the number of 5-centavo coins with heads in Table 1. These represent the atoms that are still radioactive.

5. Put the 5-centavo coins that had heads up back in the container. Mix them and spread them out on the table. Repeat the abovementioned process until all the coins are gone or until you have completed 15 trials.

6. Graph the data in your data chart on the graph provided (Figure 9).

Table 1: Empty table for the absolute dating activity.

Flip No. (Time Elapsed)	No. of 50-centavo coins w/ heads (radioactive atoms remaining)
0	100
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

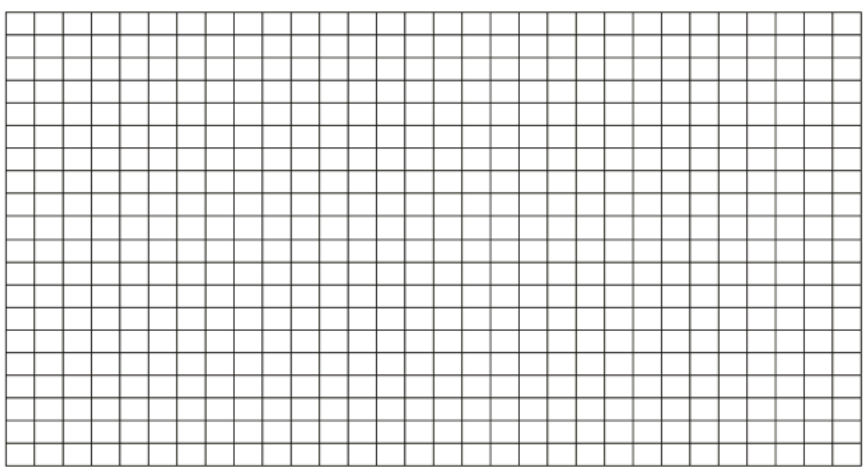


Figure 9: Empty graph for the absolute dating activity plot.

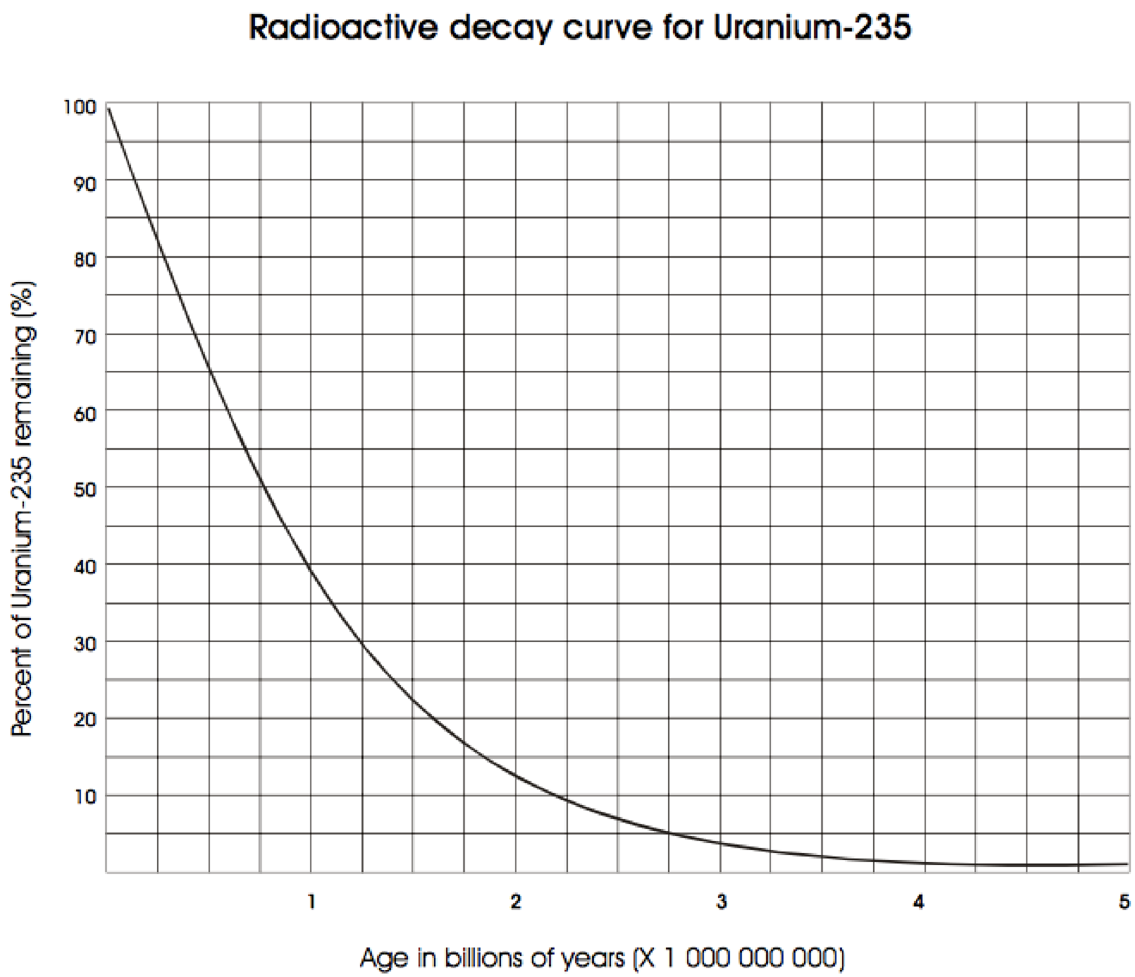


Figure 10: Example radioactive decay curve of Uranium-235.

(Image Source: http://www.felloweducators.com/brick/ear/images/eari_radioisotope_n13_small.png

7. Discuss the following questions:
    - What is the half-life of the 100 atoms of Carbon-14 (represented by the 5-centavo coin)?
    - If each flip represents 5730 years, how many years would it have taken for all of your Carbon-14 5-centavo coins to become Nitrogen-14 5-centavo coins?

Teacher Tip

- An artifact is a man-made object of cultural or historical significance.
- This is an opportunity for the learners to know more about other fields of study.

ENRICHMENT

Archaeologists use techniques developed in geology to determine the age (relative and absolute) of artifacts unearthed from the ground. Research and write a short report (200 to 300 words) on this topic.

EVALUATION

	1 (NOT VISIBLE)	**2 (NEEDS IMPROVEMENT)**	**3 (MEETS EXPECTATIONS)**	**4 (EXCEEDS EXPECTATIONS)**
Diagram in the relative dating activity shows understanding of the topic	Cannot come up with any sequence.	Around 50% correct	Around 75% correct (usually it takes time to fully understand and grasp the concept)	100% and can explain the principles
Use the graph in the absolute dating activity to evaluate the following: • Ability to demonstrate the relationship between the amount of daughter isotope and elapsed time • Understanding of the concept of half-life				

ADDITIONAL RESOURCES

1. Lutgens, F. K., Tarbuck, E. J., & Tassa, D. (2013). *Essentials of geology* (11th ed.). Upper Saddle River, NJ: Prentice Hall.
2. National Oceanic and Atmospheric Administration. (n.d.). Teaching Activity: Using Radioactive Decay to Determine Geologic Age. Retrieved from http://www.esrl.noaa.gov/gmd/outreach/lesson_plans/Using%20Radioactive%20Decay%20to%20Determine%20Geologic%20Age.pdf
3. Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Prentice Hall.
4. The Science Channel. (2009). *Carbon Dating: (How) Does It Work?* [Video file]. Retrieved from http://www.youtube.com/watch?v=udkQwW6aLik.

Earth Science

Major Events in Earth's Past

30 MINS

Content Standard
The learners demonstrate an understanding of how the planet Earth evolved in the last 4.6 billion years.

Performance Standard

Learning Competencies
Explain how relative and absolute dating were used to determine the subdivisions of geologic time **(S11ES-IIi-37)**; and

describe how marker fossils (also known as guide fossils) are used to define and identify subdivisions of the geologic time scale **(S11ES-Ii-j-38)**.

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- acquire familiarity with the geologic time scale;
- show the contributions of different personalities in the establishment of the geologic time scale;
- describe how relative and absolute dating were used to subdivide geologic time; and
- explain how fossils have been used to define and identify subdivision of the geologic time scale.

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Activity - Geological Time Scale	5
Instruction	Discussion	20
Enrichment	Research	
Evaluation	Research	

Materials
Manila paper; projector; several sets of cards/print-outs of fossil *Foraminifera assemblages*

Resources

(1) Carlson, D. H., Plummer, C. C., & Hammersley, L. (2011). *Physical Geology: Earth Revealed*. McGraw-Hill.

(2) Desonie, D. (2015). CK-12 Earth Science High School. Retrieved from http://www.ck12.org/earth-science/

(3) Florida State University. (n.d.). Back to the Past with the Geologic Time Scale -. Retrieved from http://www.cpalms.org/Public/PreviewResourceLesson/Preview/43470

(4) Florida State University. (n.d.). Geologic Time Scale. Retrieved from http://www.cpalms.org/uploads/Resources/final/43470/Document/18185/Geologic%20Time%20Scale%20worksheet(1).docx

(5) Haywick, D. (2008). Geological Time. Retrieved from http://www.usouthal.edu/geology/haywick/GY111/111-25.pdf

(6) Junine, J. I. (n.d.). *Earth Evolution of a Habitable World* (2nd ed.). Cambridge University Press.

(7) Kirkland, K. (2010). Earth sciences: Notable research and discoveries. New York, NY: Facts on File.

Additional resources at the end of the lesson

PRE-CLASS PREPARATION

1. Write the geologic time scale on the board or on a Manila paper.
2. Prepare several sets of fossil foraminifer cards (paper or cardboard print-outs): http://216.166.82.105/sites/default/files/Faunal_Succession/Foraminifera_Cards.pdf (Olson, 2011).

Teacher Tip
Use a projector if applicable.

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following specific learning objectives:
   - Acquire familiarity with the geologic time scale
   - Show the contributions of different personalities in the establishment of the geologic time scale
   - Describe how relative and absolute dating were used to subdivide geologic time
   - Explain how fossils have been used to define and identify subdivision of the geologic time scale
2. Introduce or review the definition of the following terms:
   - Fossils
   - Relative vs absolute dating
   - Stratigraphy

MOTIVATION (5 MINS)

1. Ask the learners if they like watching TV shows with themes of criminal investigation or detective work. Ask the learners to name their favorite show.
2. In evaluating a suspect of a crime, investigators need to establish the following details: **means** (ability to commit the crime), **motiv**e (reason for the crime), and **opportunity** (chance to do the crime). In evaluating **opportunity**, it often important to determine the sequence of events or the **timeline** (exact occurrence of the events).
3. On the other hand, in investigating the history of the Earth, it is just as important to establish

Teacher Tip

- Inform the learners that the dinosaurs are but one of a large group of organisms (both on land and at sea) that became extinct during this mass extinction event. (The proposed cause should be capable of worldwide destruction).
- Possible answers for the cause of the extinction of the dinosaurs include asteroid impact, volcanic eruption, climate change, disease, etc.

the chronology or the events in order of occurrence in time. The **geologic timescale** is used by scientist to describe the timing and relationship between past events in Earth's history.

4. Ask the learners the following question: 'What killed the dinosaurs?' Evaluate the 'suspects' in terms of means and opportunity.

- Inform the learners that scientists believe that the mass extinction event that wiped out the dinosaurs occurred around 65 millions of years ago

INSTRUCTION /DELIVERY/PRACTICE (20 MINS)

Age of the Earth

The Earth has a very long history—4.6 billion years of history. The age of the Earth is based from the radioactive isotopic dating of **meteorites**. The oldest dated rock from the Earth is only ~3.8 billion years old. Why?

Rocks and Fossils

1. The **history of the Earth** is **recorded in rocks** but the rock record is **inherently incomplete**. Some 'events' do not leave a record or are not preserved. Some of the rock record may have also been lost through the recycling of rocks (recall the rock cycle).
2. Preserved in rocks are **fossils** or the remains and traces of plants and animals that have lived and died throughout the Earth's history. The fossil record provides scientists with one of the most compelling evidence for **Charles Darwin's Theory of Evolution** (increasing complexity of life through time).

Figure 1: Fossil leaves preserved in Gondwanaland rocks of Australia.

Teacher Tip

- The rock record is not a video documentary of the Earth's history. A large amount of analysis and interpretation is required to extract information from rocks.
- The oldest known fossils are simple single-celled organisms found in rocks that are 3.8 billion years old. The first multi-cellular organism evolved around 600 million years ago.

Image Source: http://www.antarctica.gov.au/__data/assets/image/0020/48134/varieties/antarctic.jpg

Rocks, Fossils, and the Geologic Time Scale

1. The geologic time scale (Figure 2), which is the timeline of the history of the Earth, is based on the **rock record**.
2. Geologic time is subdivided into hierarchal intervals, the largest being **eon**, followed by **era**, **period**, and **epoch**, respectively. The subdivision of geologic time is based on the **significant events** in the Earth's history as interpreted from the rock record.
3. The mass extinction event, which led to the extinction of the dinosaurs occurred around 66.4 million years ago, marks the boundary between the Mesozoic era (age of the reptiles) and the Cenozoic era (age of mammals). This mass extinction event may have been pivotal in the rise of the dominance of the mammals during the Cenozoic era.

- Introduce the geologic time scale by presenting Figure 2. A more detailed discussion of the geologic time scale in relation to Earth's history will be given in the next lesson.
- Use the extinction of the dinosaurs as an example of a significant geologic/ biological event in the history of the Earth.

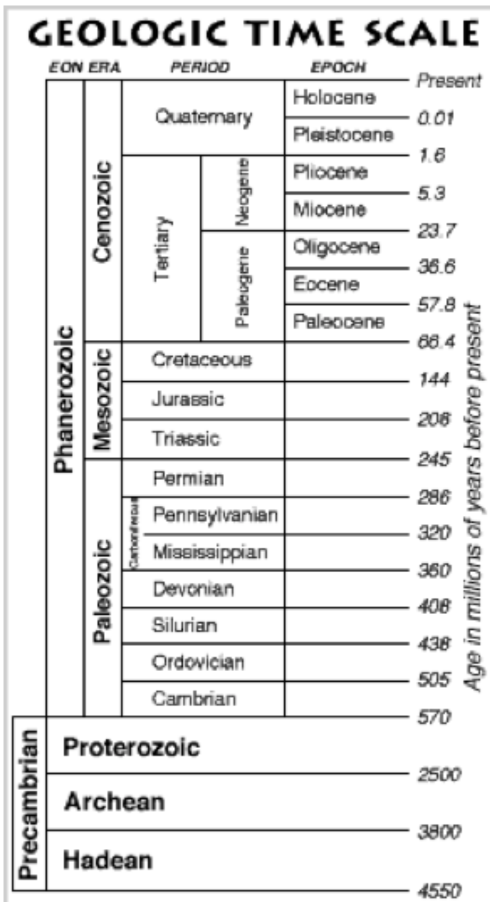


Figure 2: The geologic time scale (USGS, 1997).

Image Source: http://geomaps.wr.usgs.gov/parks/gtime/geoltimebw.gif

4. Perform the following activity (adapted from http://www.cpalms.org/uploads/Resources/final/43470/Document/18185/Geologic%20Time%20Scale%20worksheet(1).docx) (Florida State University, n.d.).
   1) Have the learners complete Table 1.
   2) Create a pie chart to represent the percentage of each division of time with respect to the geologic time scale in Table 1.

Table 1: Relative proportion of the major subdivisions of geologic time

Divisions of Geologic Time		Time Interval (in millions of years)	Duration (in millions of years)	% of Geologic Time
Cenozoic Era		*66.4 - Present*	*66.4*	*1.46*
Mesozoic Era		*245 -66.4*	*178.6*	*3.93*
Paleozoic Era		*570 -245*	*325*	*7.14*
Pre-Cambrian	Proterozoic	*2500 -570*	*1930*	*42.42*
	Archean	*3800 - 2500*	*1300*	*28.57*
	Hadean	4550 - 3800	750	16.48

5. One of the first to recognize the correspondence between rocks and time is **Nicholas Steno** (1638-1686). Steno's principles, namely superposition, original horizontality, and lateral continuity, became the foundation of stratigraphy, the study of layered rocks.

6. Since the geologic time scale is based on the rock record, the first order of business is to establish the correct succession of rocks. Initially, this was done using **relative dating techniques**.

- This activity will help the learners get familiar with the subdivisions of the geologic time scale.
- Check if the learners are able to calculate percentages and present their data in the form of a pie chart.
- In Table 1, the texts in red are the information which will be supplied by the learners.

- The Law of Superposition and other of Steno's Principles have been covered in previous lesson (S11/12ES-Ie-25).

7. One of the earliest attempts to subdivide the rock record into units of time was made by **Abraham Gottlob Werner**, a German geologist. Werner divided the rock record into the following rock-time units (from oldest to youngest): **primary**, **secondary**, **tertiary**, and **quaternary**. Werner extensively used the **Principle of Superposition** to establish temporal relationship among the rock units.

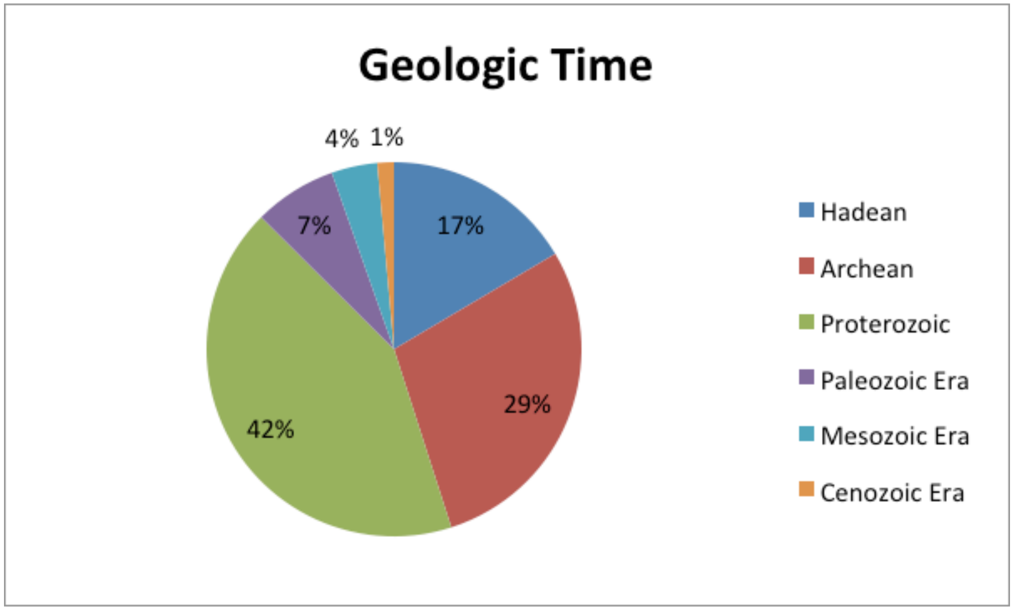


Figure 3: Pie chart showing relative proportion of the major subdivisions of geologic time.

8. **Fossils** are also useful in determining relative ages of rocks. While working in a coal mine, **William 'Strata' Smith** (1769-1839) observed that each layer or strata of sedimentary rock contains a **distinct assemblage of fossils**, which can be used to establish equivalence (**correlation**) between rock units separated by long distances. Moreover, he observed that these fossils succeed each other vertically in a definite order.

9. In contrast to William Smith, who primarily used fossils to identify rock layers, **Charles Lyell** (1797-1875), a British lawyer and geologist, recognized the utility of fossils in subdividing

- Using the pie chart, point out that the Pre-Cambrian (Hadean, Archean, and Proterozoic) represents a disproportionately large part of the Geologic Time (> 87%); yet we know very little of what happed during this period (incomplete/imperfect rock record).

- Call on learners to explain the principles of superposition, cross-cutting relationship, inclusion, and unconformities (was covered in lesson S11/12ES-Ie-26).

- Abraham Werner is (1749-1817) is considered to be the father of German Geology. He is also the proponent of **Neptunism**, the idea that all of the Earth's rocks were formed from an all-encompassing ocean (now a discarded theory used to interpret the history of the Earth).

- **Tertiary Period** - part of the Cenozoic Era, from 66.4 to 1.5 millions of years ago (see Table 1. Geologic Time Scale).
- Younger layers will contain a greater proportion of fossils with living representatives.

geologic time on the basis of fossils. He was able to subdivide the tertiary by examining the proportion of living vs. extinct fossils in the rocks.

10. The underlying reason for this definite and orderly succession of fossils in the rock record is organic evolution.

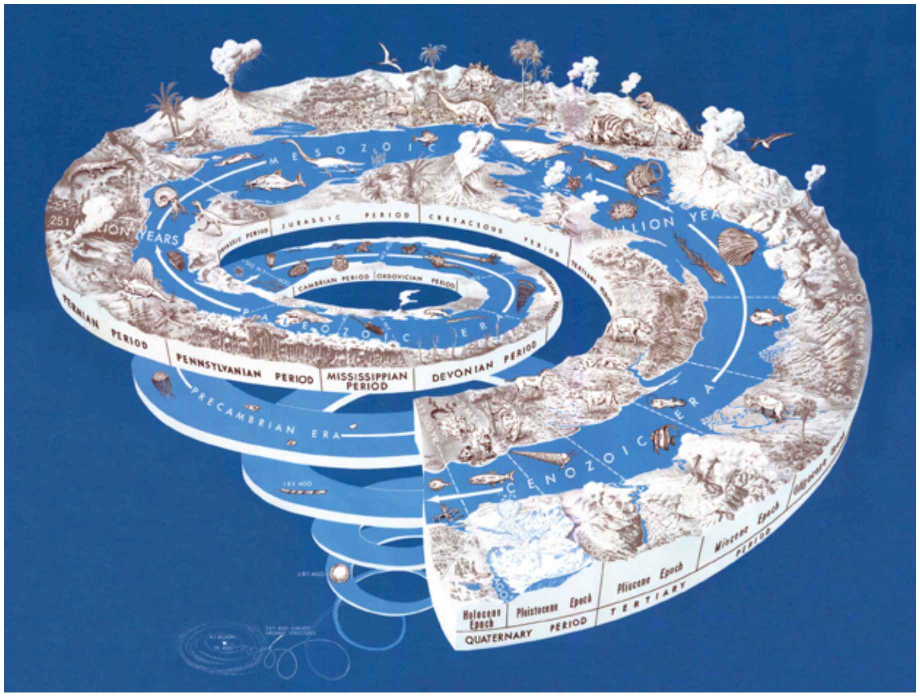


Figure 4: Evolution of life through Earth's history (USGS, 1997).

- Figure 4 shows the evolution of life through time.

11. Fossils are an essential in the subdivision of the geologic time.

12. **Biostratigraphy** is a sub-discipline of stratigraphy, which deals with the use of fossils in the correlation and establishments the relative ages of rocks.

13. **Index fossils** are marker fossils used to define periods of geologic time. Ideally, index fossils are distinctive (can easily be identified and distinguished from other fossils), widespread (distribution is not confined to a few locality), and have limited geologic time range.

14. Ultimately, the geologic time scale was assigned numerical dates (absolute dating) through the radiometric dating of rocks.

15. As an introduction to the next class activity, the teacher can bring out a box containing mementos of his or her life. Bring out various objects, and for each object, explain the significance, and more importantly, the time each object represents (e.g. a piece of pencil the teacher used when he or she was still learning to write). After each introduction, place the object at a random position on the teacher's desk. When all the objects have been placed on the table, have the learners arrange the objects according to 'age' from left to right. Explain that fossils are similar to the 'objects' or mementos of his or her life, as each is associated with a particular period of time.

16. Perform the following activity: Stratigraphy and Evolution - Using Fossils to Tell 'Deep Time' (Olson, 2011).
    1) Divide class into groups of three to five learners.
    2) Provide each group a set of cards/print-outs representing fossil assemblages from different rock layers.
    3) Explain that the actual sizes of the fossils represented in the illustrations are much smaller. Foraminifera are mostly marine, microscopic, single-celled organisms that have calcareous shells. When the organism dies, the shells or tests become part of the sediment record. Foraminifers are important index fossils, as they are abundant, widespread, distinctive, and have relatively limited geologic time range.
    4) Ask each group to arrange the cards in order from oldest to youngest.

- The box of mementos can either be fictional or made-up.
- For maximum effect, the teacher should prepare at least ten objects.
- This is an effective way to test if the learners have been paying attention.
- The teacher can opt to give a token gift to the first learner who can arrange the objects correctly
- If the school is near a coast, collect beach sand and examine them using a binocular microscope. Specimens of Foraminifers are most likely in the sediments. Have the learners see the actual specimens of Foraminifers.
- Apply the Principle of Faunal Succession in arranging the cards/assemblage of fossils from oldest to youngest.
- While the learners are arranging their stack of cards, the teacher goes around and asks the learners their reasons for their arrangements of the cards.
- Guide the learners by suggesting that they start from the oldest (E) and work their way to the youngest (J). Compare the cards in terms of similarity of fossil content. Keep in mind that some fossils become extinct and new species may emerge.

Figure 5: Foraminiferal fossil assemblages from a stratigraphic section (Olson, 2011).

(Image Source: http://www.txessrevolution.org/sites/default/files/Faunal_Succession/Foraminifera_A-F_Oldest.jpg

- Answer: In order of decreasing age (oldest to youngest): E, B, I, H, F, L, K, C, D, G and I.

ENRICHMENT

Ask the learners to do research on the index fossils of the Philippines. Name at least one index fossil. Indicate what division of the geologic time scale the index fossil represents and where the index fossil has been reported.

EVALUATION

	1 (NOT VISIBLE)	2 (NEEDS IMPROVEMENT)	3 (MEETS EXPECTATIONS)	4 (EXCEEDS EXPECTATIONS)
Can enumerate the major subdivisions of the geologic time scale				
Can correctly calculate and presents the relative percentages of the major subdivisions of the geologic time scale in a pie chart				
Can explain how relative and absolute dating techniques were used to establish the geologic time scale				
Can describe the historical development of the subdivision of geologic time and the contribution of important personalities				
Ability to define marker or index fossils.				
Can explain the Principle of Faunal Succession				

Can explain the underlying reason why there is a definite and determinable succession of fossils in the rock record				
Ability to apply the Principle of Faunal Succession for the relative dating of stratigraphic sequences				

ADDITIONAL RESOURCES

1. Lutgens, F. K., Tarbuck, E. J., & Tassa, D. (2013). *Essentials of geology* (11th ed.). Upper Saddle River, NJ: Prentice Hall.
2. Math/Science Nucleus. (2001). Stratigraphy. Retrieved from https://www.msnucleus.org/membership/html/jh/earth/stratigraphy/jhstratigraphy.pdf
3. NASA Earth Observatory. (n.d.). William Smith (1769-1839). Retrieved from http://earthobservatory.nasa.gov/Features/WilliamSmith/page3.php
4. Olson, H. C. (2011). Stratigraphy and Evolution: Using Fossils to Tell "Deep Time". Retrieved from www.txessrevolution.org/FaunalSuccession
5. Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Prentice Hall.
6. United States Geological Survey. (1997). Geologic Time: Contents. Retrieved from http://pubs.usgs.gov/gip/geotime/contents.html

Earth Science

Major Events in Earth's Past

Content Standard
The learners demonstrate an understanding of

1. how the planet Earth evolved in the last 4.6 billion years.

Performance Standard

Learning Competency
The learners describe the history of the Earth through geologic time **(S11ES-IIj-39).**

Specific Learning Outcomes
At the end of the lesson, the learners will be able to:

- appreciate the immensity of geologic time and recognize that the Earth has a very long history;
- identify the timing and duration of the major events in Earth's history; and
- recognize how short human history is in relation to the history of the Earth.

30 MINS

LESSON OUTLINE

Introduction	Communicating learning objectives	5
Motivation	Activity - 24-hr Earth Clock Projection	5
Instruction	Activity - Geological timeline	20
Enrichment	Report	
Evaluation		

Materials
5-10 m measuring tape; masking tape; marking pens or colored chalk; significant event tags (Evolutionary events - light blue, Extinction events - red, Geologic events - yellow); plastic straw; cartolina paper

Resources

(1) Aurelio, M. A. (2008). Shear partitioning in the Philippines: Constraints from Philippine Fault and global positioning system data. *Island Arc*, *9*(4), 584-597. doi:10.1111/j.1440-1738.2000.00304.x

(2) Briais, A., Patriat, P., & Tapponnier, P. (1993). Updated interpretation of magnetic anomalies and seafloor spreading stages in the south China Sea: Implications for the Tertiary tectonics of Southeast Asia. *J. Geophys. Res*, *98*(B4), 6299. doi:10.1029/92jb02280

(3) Carleton College. (n.d.). Geologic Time Scale. Retrieved from http://serc.carleton.edu/files/introgeo/interactive/examples/bgeotime.pdf

(4) Carlson, D. H., Plummer, C. C., & Hammersley, L. (2011). *Physical Geology: Earth Revealed*. McGraw-Hill.

(5) Desonie, D. (2015). CK-12 Earth Science High School. Retrieved from http://www.ck12.org/earth-science/

(6) Florida State University. (n.d.). Back to the Past with the Geologic Time Scale -. Retrieved from http://www.cpalms.org/Public/PreviewResourceLesson/Preview/43470

(7) Haywick, D. (2008). Geological Time. Retrieved from http://www.usouthal.edu/geology/haywick/GY111/111-25.pdf

Additional resources at end of the lesson.

PRE-CLASS PREPARATION

1. Scout for an area or location that is around 50 m long (e.g. a hallway, gym, multipurpose hall, open area). Assess for hazards, especially if the chosen area is outdoors (e.g. interaction with vehicles).
2. Cut cartolina (four different colors) into notebook size pieces. Using a permanent marker, write down on the cartolina the significant events in Earth's history. Use a separate color per event type (Event Tags).
3. Print out several copies of the blank geologic time scale, which can be downloaded from: http://serc.carleton.edu/files/introgeo/interactive/examples/bgeotime.pdf (Carleton College, n.d.).

Teacher Tip

- The area is preferably around 50 m long, but it can be shorter.
- If the chosen area is unpaved, the teacher can attach event tags to barbecue sticks, which can be pegged into the ground.
- Make several copies of event cards to be distributed to the number of intended groups.

INTRODUCTION (5 MINS)

Communicating learning objective

1. Introduce the following learning objectives using the suggested protocols (Verbatim, Own Words, Read-aloud)
   a. Appreciate the immensity of geologic time and recognize that the Earth has a very long history
   b. Identify the timing and duration of the major events in Earth's history
   c. Recognize how short human history is in relation to the history of the Earth

MOTIVATION (5 MINS)

1. Draw a 24-hour clock on the board. Ask the learners the following question: 'How old is the Earth?'
2. When the correct age of the Earth has been established, compare geologic time to the 24-hour clock. Mark some important events in the Earth's history in the 24-hour clock:
   - First prokaryotes
   - First eukaryotes
   - First multicellular organisms
   - Extinction of the dinosaurs

Teacher Tip

- As stated in the previous lesson, the age of the Earth is around 4.6 billion years.
- Prokaryotes are single-celled organisms without nuclei. Eukaryotes are characterized by cells with nuclei.
- Emphasize that, during the first two-thirds of the Earth's history, the planet was inhabited by only single-celled organisms.
- Humans appeared during the last few seconds of the last minute of the 24-hour clock.
- Emphasize how seemingly insignificant human history is in relation to Earth's history.

3. Remind the learners that modern humans emerged during the last ~200,000 years. Have the learners place the emergence of man in the 24-hour clock of Earth's History. Emphasize that we are relatively 'new' to the Earth, and yet our impact to the Earth system has already been profound.

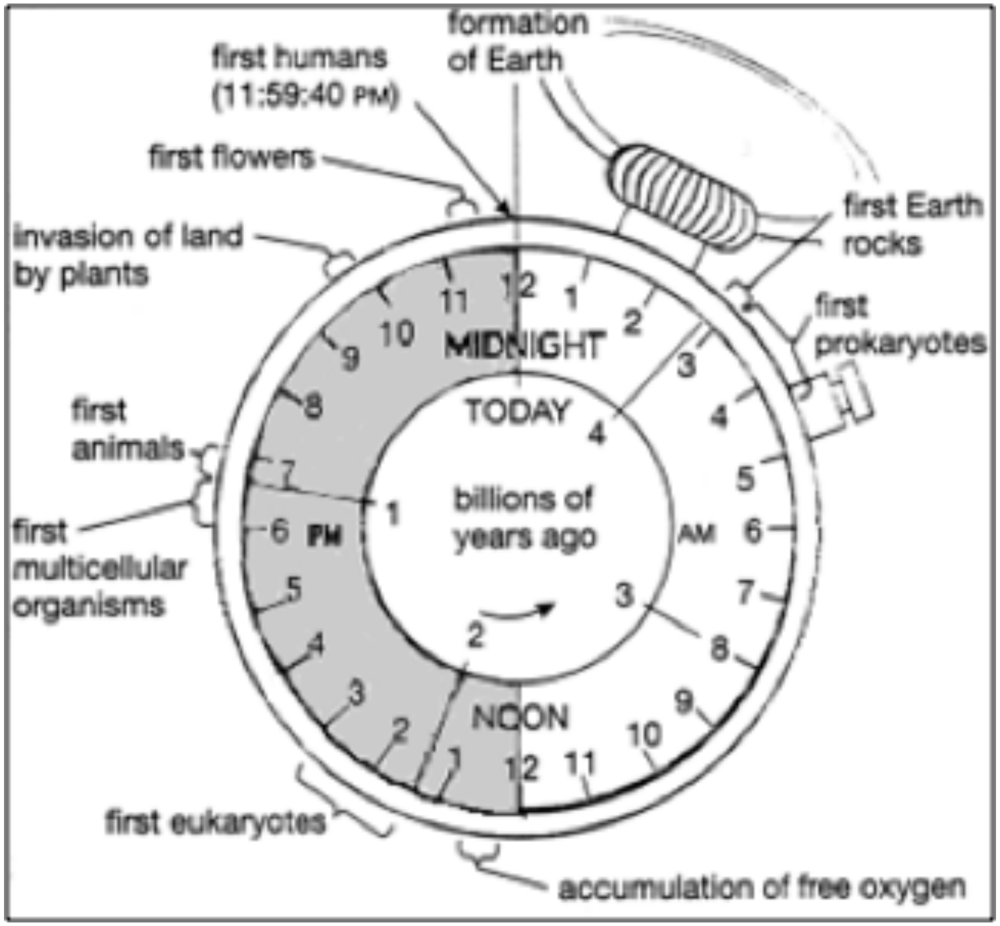


Figure 1: History of the Earth projected on a 24-hour clock. Image source: http://www.counterbalance.org/media/earthist.gif

INSTRUCTION /DELIVERY/PRACTICE (20 MINS)

This lesson was adapted from: http://www.teachersdomain.org/resource/tdc02.sci.life.div.lp_divdeeptime/ (PBS Learning Media, n.d.).

Activity

1. Divide class into groups of five to ten learners. Distribute the blank geologic time scale to each student. Each group will create their own time scales.
2. In the preselected area, use a measuring tape to lay-out a line measuring 46 meters. Use a plastic straw or draw a line using colored chalks (if the ground surface allows). Mark one end as 'Today' and the other end as 4.6 billion years.
3. Subdivide the line into 46 one meter sections each representing 100 million years. Mark each subdivision with a masking tape or with colored chalk.
4. Have the learners arrange the event cards along their respective time scales according to their date.
5. Optional: have the learners represent some of the significant events by means of drawings (if the surface allows) using colored chalk.

Evolutionary Events (light blue):

- First evidence of life (3,850 Ma)
- Photosynthesizing bacteria (3,700 Ma)
- Oldest fossils (3,500 Ma)
- First eukaryotes (2,700 Ma)
- Ediacaran fauna (600 Ma)
- The Cambrian explosion (530 Ma)
- First land plants and fish (480 Ma)
- Arthropods on land (420 Ma)
- First insects (407 Ma)
- First amphibians land vertebrates (375 Ma)
- First seed plants (360 Ma)

Teacher Tip

- If the space is limited, cut the total length to 26 meters. Subdivide the 26-meter length into half meter sections (half a meter = 100 million years).

- Most of the dates for the significant events were taken from: http://www.pbs.org/wgbh/evolution/change/deeptime/index.html (Public Broadcasting Service, n.d.).
- Discussions will be at the end of the construction of their respective geologic time scale.

- Early life forms most likely adapted to anoxic conditions (free of oxygen).
- Point out the significance of the emergence of photosynthesis with regards to the evolution of the Earth's atmosphere (an example of how components of the Earth system interact).
- The Ediacaran fauna represents the first metazoans, which are organisms with more than one type of cell.
- The Cambrian explosion is an evolutionary bust of animal origin. Most of the major phyla originated from the Cambrian explosion.

- First reptiles (350 Ma)
- First dinosaurs (220 Ma)
- Early mammals (220 Ma)
- First birds (150 Ma)
- First flowering plants (130 Ma)
- Early primates (60 Ma)
- First hominids (5.2 Ma)
- Modern humans (0.2 Ma)

Extinctions (red):

- Vendian - some single celled algae and soft-bodied animals went extinct (543 Ma)
- Cambrian - some reef builders and other shallow water organisms become extinct (520 Ma)
- End Ordovician - 25% of marine vertebrates families and 57% of genera become extinct (443 Ma)
- Devonian - 50-55% of marine invertebrate genera and 70-80% of species went extinct (364 Ma)
- Permian - greatest extinction event; 90% of all species became extinct (250 Ma)
- End Cretaceous - extinction of the dinosaurs; 60-80% of all species became extinct (65 Ma)
- Late Triassic - ~50% marine invertebrate genera, possibly land vertebrate went extinct (206 Ma)
- Late Eocene - 50-90% of species in certain land and marine group went extinct (33 mya)
- Miocene - many woodland plant-eating herbivores went extinct (9 Ma)
- Late Pleistocene - nearly all large mammals and birds (>45 pounds) became extinct (.01 Ma)

- There had been many (>> 7) mass extinction events in the Earth's history. Mass extinction is a rule rather than the exception. Mammals would not have become dominant if the dinosaurs did not become extinct.
- Probable cause for mass extinction events include meteor/bolide impact, large scale volcanism, and climate change. Some of these may have acted in concert with each other.

Geologic events (yellow):

- Formation of the great oceans (4,200 Ma)
- Continents begin shifting (3,100 Ma)
- Oxygen levels reach 3% of the atmosphere (1.9 Ma)
- Supercontinent Rodinia forms (1100 Ma)
- Protective ozone in place (600 Ma)

- Emphasize the interaction among the components of the Earth system in the evolution of the atmosphere and hydrosphere.
- The biosphere 'infected' the atmosphere with O_2 through photosynthesis.

- Gondwana forms (500 Ma)
- Oxygen nears present day concentration (400 Ma)
- Formation of the Pangaea supercontinent (280 Ma)
- Pangaea supercontinent breaks up (200 Ma)
- Continents near present-day positions (40 Ma)
- Initiation of seafloor spreading of South China Sea (32 Ma)
- Initiation of the Philippine fault (4 Ma)
- Global ice ages begin (2 Ma)

- Evolution of the atmosphere (from oxygen poor to oxygen rich) had a significant impact on the evolution of life. Certain organisms were able to take advantage of the new oxygen-rich environment, while the primitive organisms that used to thrive in oxygen-poor environment may have been forced to retreat to specific environments that are oxygen poor (e.g. animal guts).
- The ozone protects life on the surface from harmful ultraviolent rays from the sun. The development of the ozone may have allowed life to emerge from the seas.
- Pangaea is not the only supercontinent that existed in the past. Continents have broken apart and re-assembled several times in the past. The underlying process is plate tectonics (movement of lithospheric plates). As to where the continental lithosphere breaks and initiates rifting is still subject to speculation.
- The South China Sea (SCS) is a marginal sea – partially enclosed by islands and archipelagos. SCS formed as a result of rifting and seafloor spreading.
- The initiation of the Philippine fault is part of the geologic evolution of the Philippine archipelago. It is related or "paired" with the initiation of subduction along the Philippine Trench. (SCS and the Philippine Fault were included to add regional/local geologic events in the mix.
- Global climate over the last 2 million years has oscillated between Ice Age (glacial periods) and non-Ice Age (interglacial periods). The Earth is currently in the tail end of an interglacial period.

History of the Earth

1. Select one of the time scales made by the learners and leads the discussion to the history of the Earth.
2. Ask the learners to recall how the solar system formed at around 4.6 billion of years ago.
3. Discuss the geologic time scale:
   - **The Precambrian or Cryptozoic Era (4.6 Ga - 540 Ma)**
     - Represents 80% of Earth's history
     - Also known as the eon of "hidden life" due to obscure fossil records. (Ask the learners why there is very little record of life during the Precambrian era.)
   - **Hadean Eon (4.56 - 3.8 Ga)**
     - From "Haedes", Greek god of the underworld
     - Chaotic time because of several meteorite bombardment
     - Atmosphere reduction (methane, ammonia, carbon dioxide)
     - Start of the hydrologic cycle and the formation of the world oceans
     - Life emerged in this "hostile" environment
   - **Archean Eon (3.8 - 2.5 Ga)**
     - Anaerobic (lack of oxygen)
     - No ozone
     - Photosynthetic prokaryotes (blue green algae) emerged and started releasing oxygen to the atmosphere.
     - Life forms are still limited to single-celled organisms without nuclei (prokaryotes) until 2.7 Ga when Eukaryotes emerged.
   - **Proterozoic Eon (2.5 Ga - 540 Ma)**
     - Oxygen level reaches ~3% of the atmosphere
     - Rise of multicellular organisms represented by the Vendian fauna
     - Formation of the protective ozone layer
   - **Phanerozoic Eon (540 Ma - present)**
     - Eon of "visible life"
     - Diversification of life

- Global climate over the last 2 million years has oscillated between Ice Age (glacial periods) and non-Ice Age (interglacial periods). The Earth is currently in the tail end of an interglacial period.
- Make sure that the learners are taking down notes during the discussion.
- Start from one end (4.6 Ga) and literally walk through the history of the Earth.

- There is very little record of life during the Precambrian era due to the following reasons: (1) not much life during this period; (2) only simple life forms that do not have preservable hard parts may have existed; and (3) the rocks containing the fossils would have already been obliterated over time.
- There are many theories on how life on Earth began. Assign this as a topic of research.

- The ozone layer protects life on the surface of the Earth from harmful UV rays. This may have allowed life to emerge from the oceans.

- Many life forms are represented in fossil records (with preservable hard parts).

- **Paleozoic Era (540 - 245 Ma)**
  - Age of “ancient life”
  - Rapid diversification of life as represented by the Cambrian fauna (Cambrian explosion)
  - ○Dominance of marine invertebrates
  - Plants colonize land by 480 Ma
  - Animals colonize land by 450 Ma
  - Oxygen level in the atmosphere approaches present day concentration
  - Massive extinction at the end (end of Permian extinction)
- **Mesozoic Era (245 - 65 Ma)**
  - Age of reptiles
  - Dominance of reptiles and dinosaurs
  - Pangaea starts to break-apart by 200 MA
  - Early mammals (220 Ma)
  - First birds (150 Ma)
  - First flowering plants (130 Ma)
  - Mass extinction at the end of the Cretaceous (65 Ma)
- **Cenozoic Era (65 Ma - present)**
  - Age of mammals
  - Radiation of modern birds
  - Early primates (60 Ma)
  - Continents near present-day positions (40 Ma)
  - First hominids (5.2 Ma)
  - Modern humans (0.2 Ma)
  - Global ice ages begin (2 Ma)

4. At the end of the activity, ask the learners to fill-in the blank geologic time scale with important events in Earth’s history using their notes.

- The term ‘dinosaurs’ is used for land reptiles that lived from 230 to 65 ma. The term is not used for flying and marine reptiles that lived during the same period.

- Ask the learners if the rise in dominance of the mammals during the Cenozoic would have occurred if not for the mass extinction event at the end of the Mesozoic.
- Mass extinction events are important drivers in the evolution of life on Earth.

ENRICHMENT

Ask the learners to write a report (200 to 300 words) on one of the following topics:

- Theories on the origin of life
- Possible causes of mass extinction events
- How mankind is driving the next mass extinction event
- How the ozone layer was formed

EVALUATION

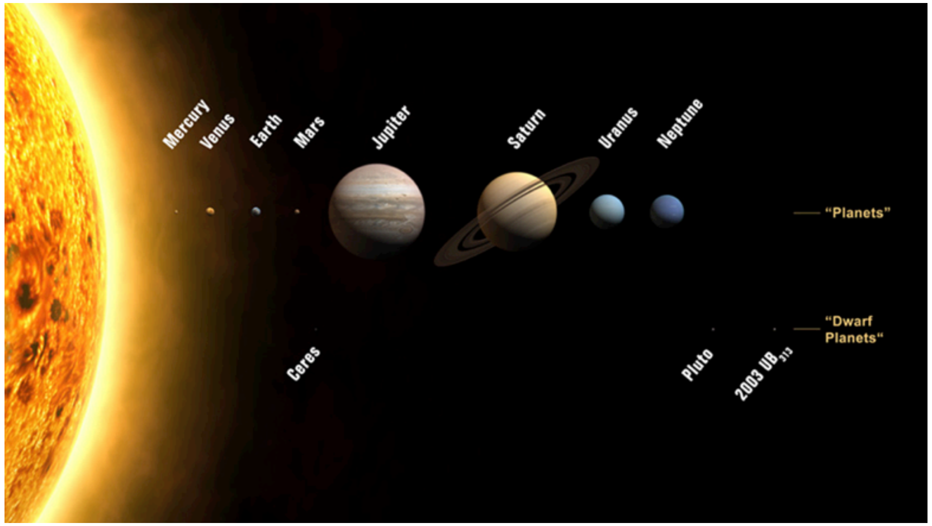
Summary questions related to the lessons. Questions are classified as described in the table below.

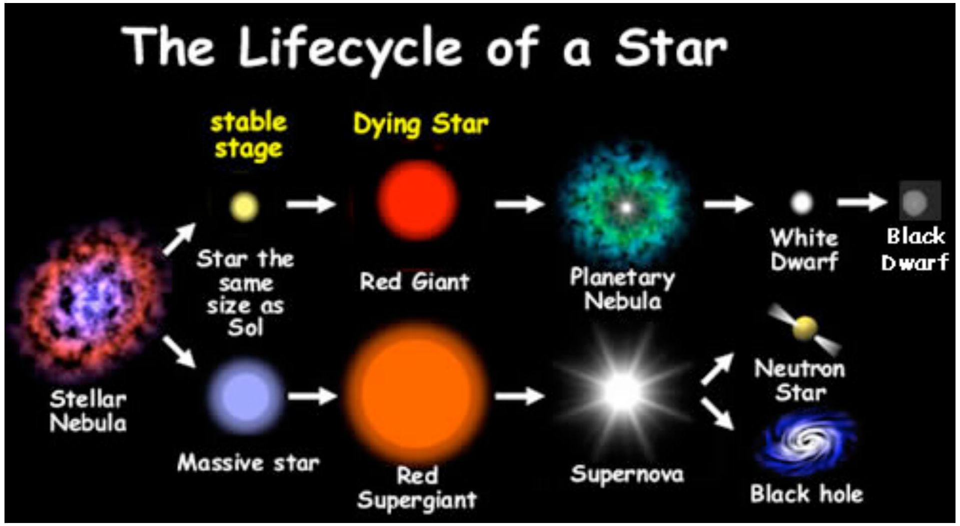
	1 (NOT VISIBLE)	**2 (NEEDS IMPROVEMENT)**	**3 (MEETS EXPECTATIONS)**	**4 (EXCEEDS EXPECTATIONS)**
Knowledge on the age of the Earth				
Familiarity with the timing and duration of the important biologic and geologic events in Earth's history				
Can enumerate some of the most important mass extinction events				
Can explain the significance of the mass extinction events on the evolution of life on Earth				
Can give examples of how the components of the Earth system have interacted over time				

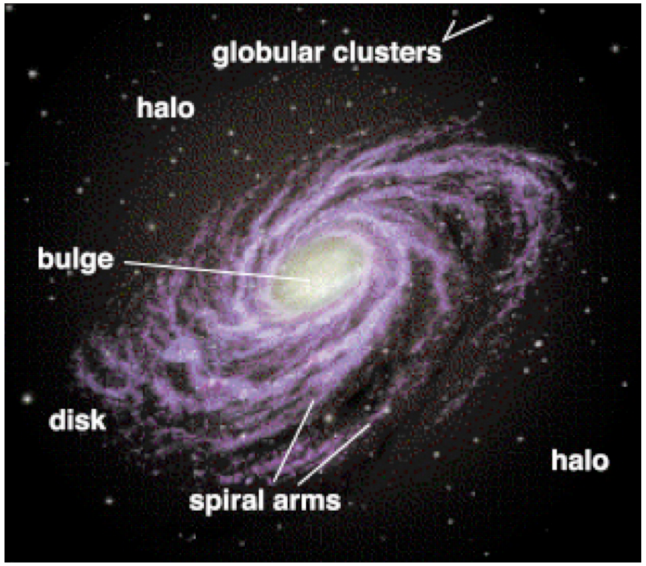
ADDITIONAL RESOURCES

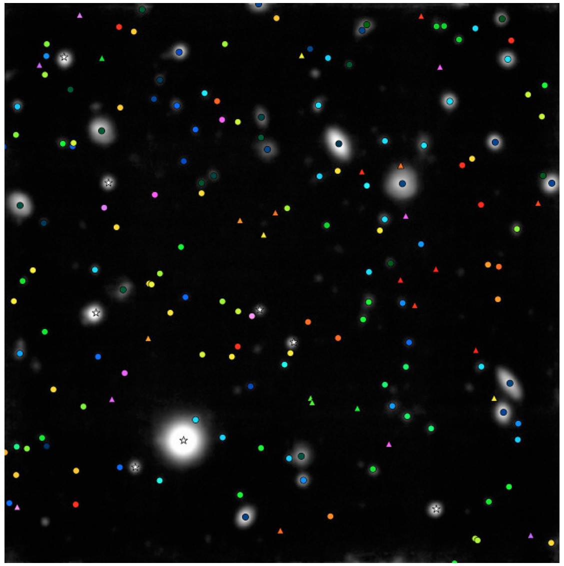
1. Junine, J. I. (n.d.). *Earth Evolution of a Habitable World* (2nd ed.). Cambridge University Press.
2. Kirkland, K. (2010). Earth sciences: Notable research and discoveries. New York, NY: Facts on File.
3. Lutgens, F. K., Tarbuck, E. J., & Tassa, D. (2013). *Essentials of geology* (11th ed.). Upper Saddle River, NJ: Prentice Hall.
4. PBS Learning Media. (n.d.). Deep Time and the History of Life. Retrieved from http://www.teachersdomain.org/resource/tdc02.sci.life.div.lp_divdeeptime/
5. Public Broadcasting Service. (n.d.). Evolution: Change: Deep Time. Retrieved from http://www.pbs.org/wgbh/evolution/change/deeptime/index.html
6. Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Prentice Hall.
7. United States Geological Survey. (1997). Geologic Time: Contents. Retrieved from http://pubs.usgs.gov/gip/geotime/contents.html
8. University of California, Berkeley. (n.d.). Geologic Time. Retrieved from http://www.ucmp.berkeley.edu/education/explorations/tours/geotime/gtpage1.html

Earth Science - Colored Images

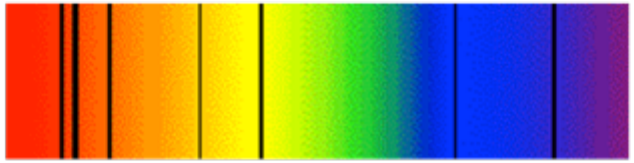




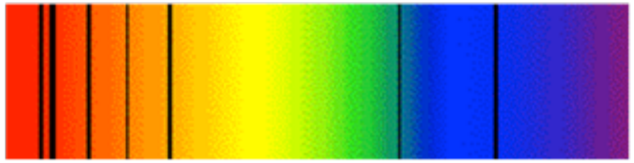




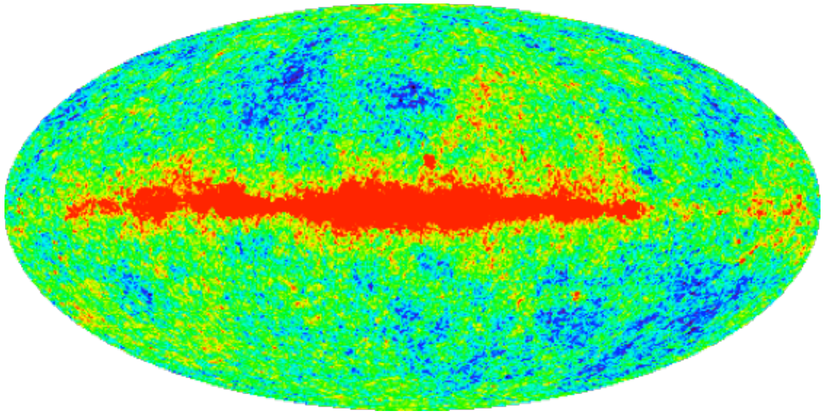
(A)

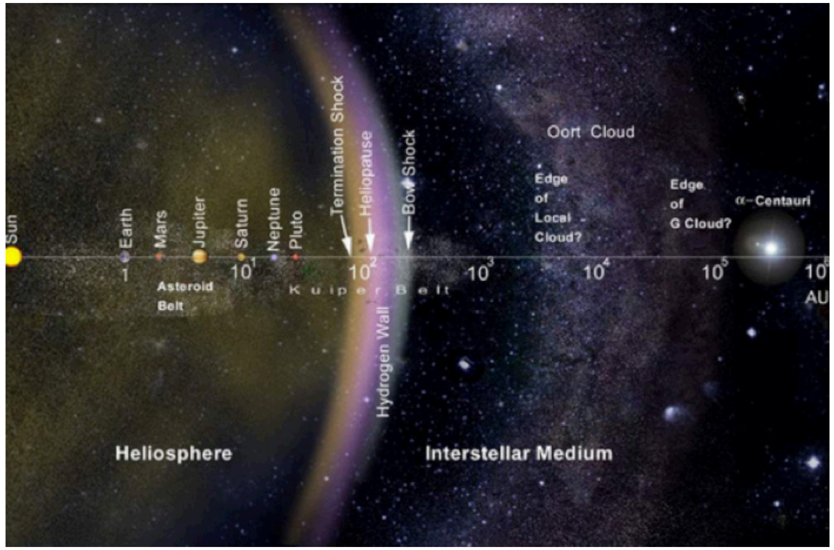


(B)



Lesson 1: The Universe and the Solar System




Sun
Earth
Mars
Jupiter
Saturn
Neptune
Pluto
Termination Shock
Heliopause
Bow Shock
Hydrogen Wall
Oort Cloud
Edge of Local Cloud?
Edge of G Cloud?
α-Centauri
1
10^1
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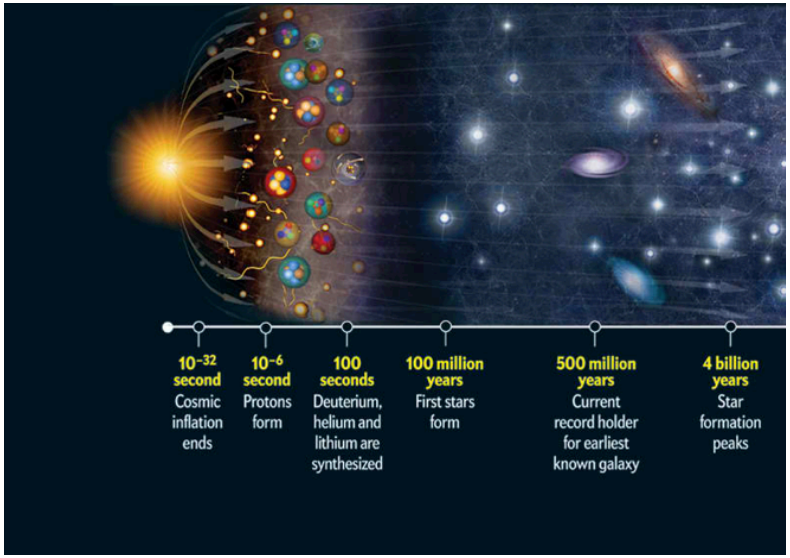
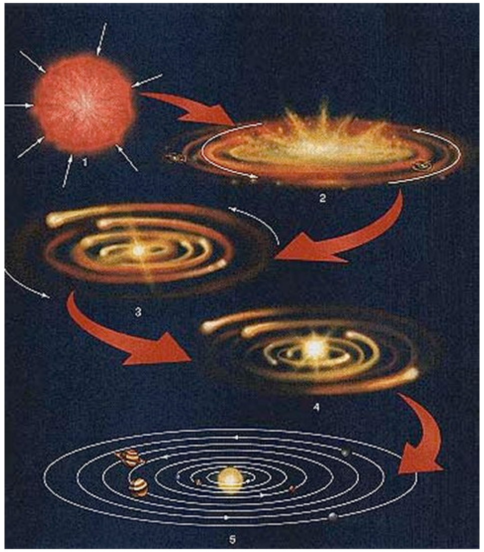
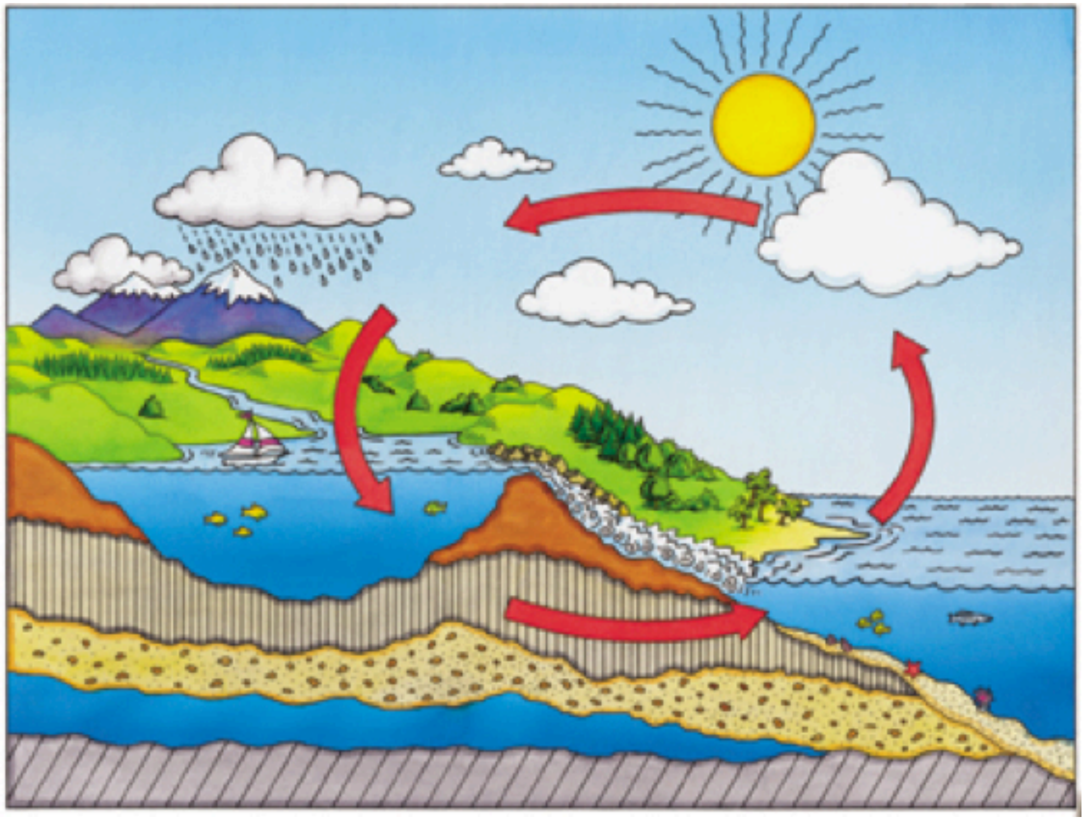
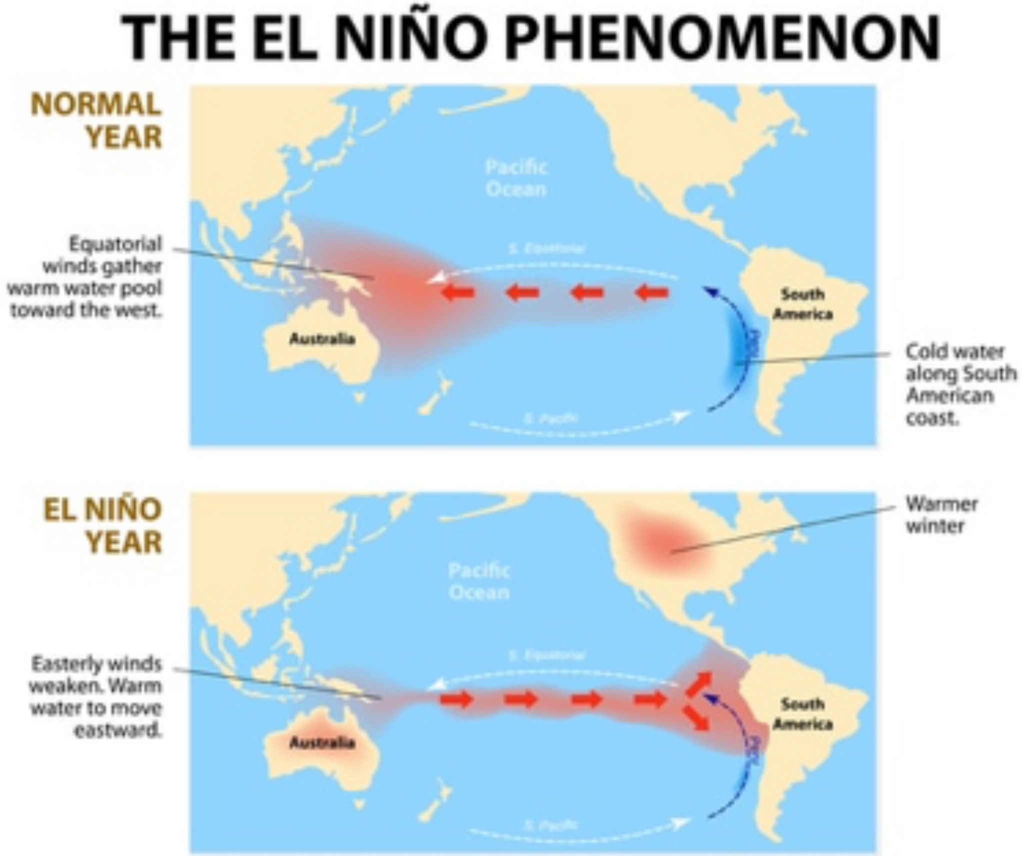
AU
Asteroid Belt
Kuiper Belt
Heliosphere
Interstellar Medium


10^{-32} second
Cosmic inflation ends
10^{-6} second
Protons form
100 seconds
Deuterium, helium and lithium are synthesized
100 million years
First stars form
500 million years
Current record holder for earliest known galaxy
4 billion years
Star formation peaks

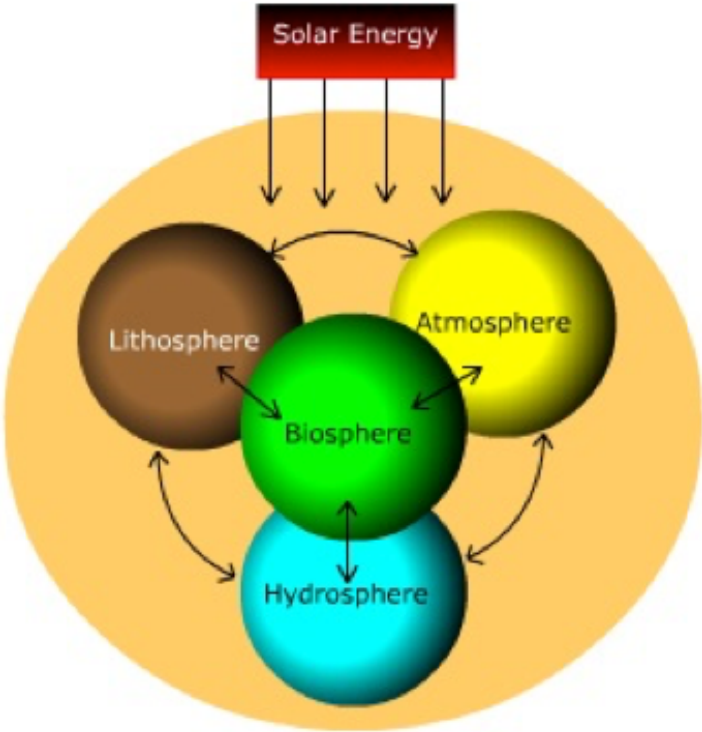

1
2
3
4
5

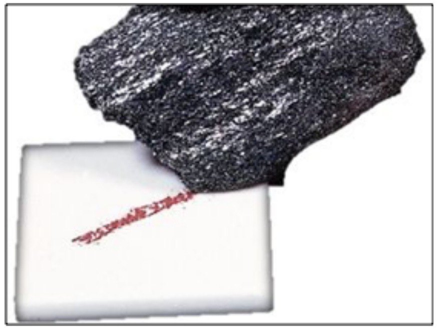

We live here in the Milkyway

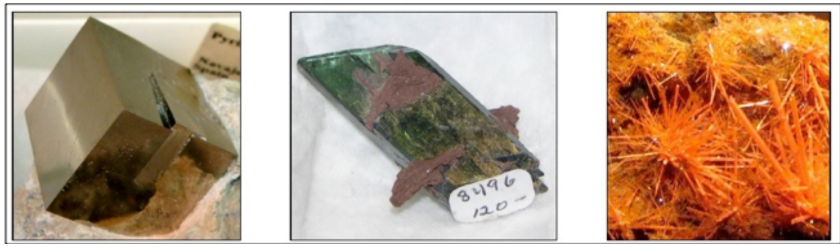


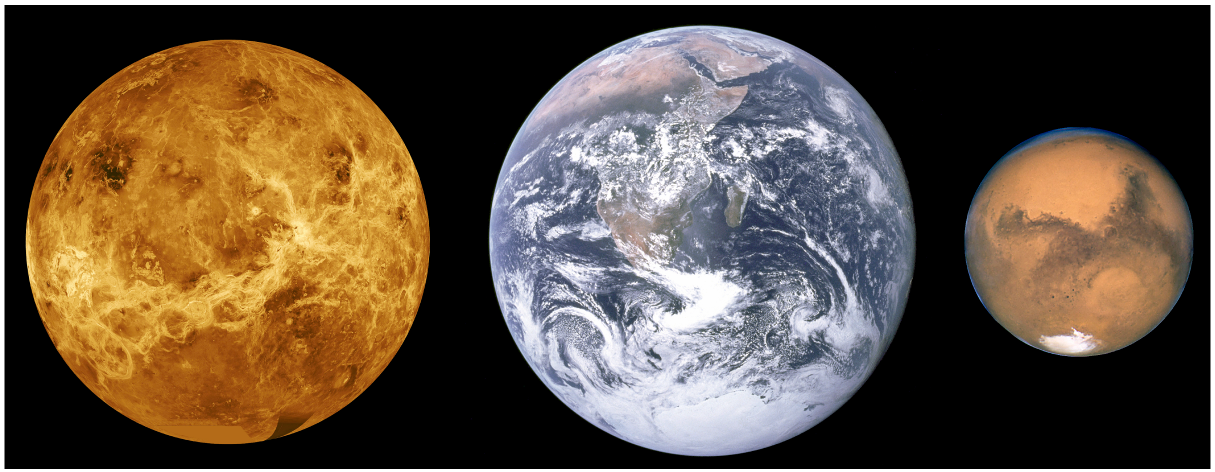


Lesson 2: Earth Systems

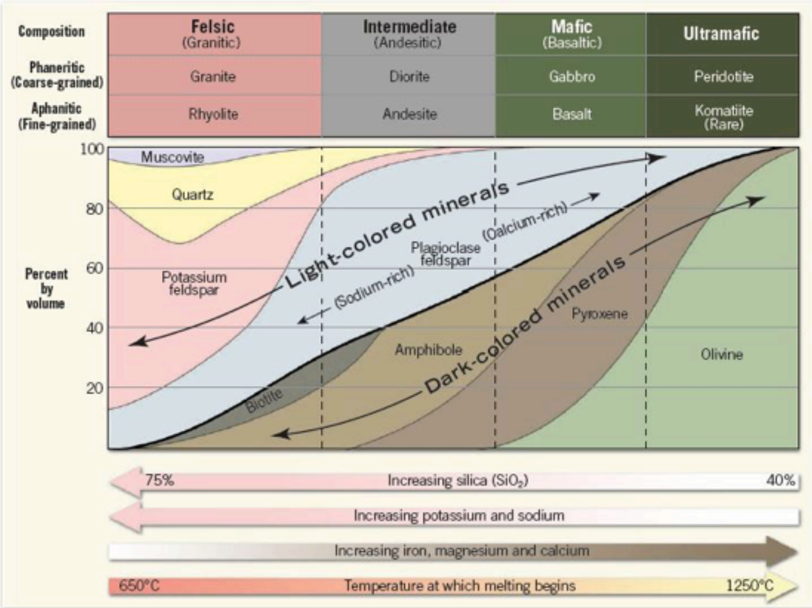




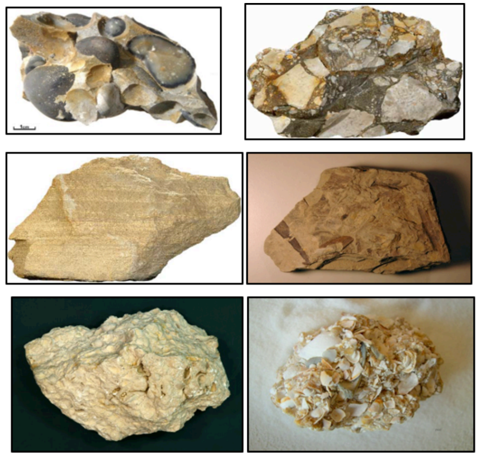




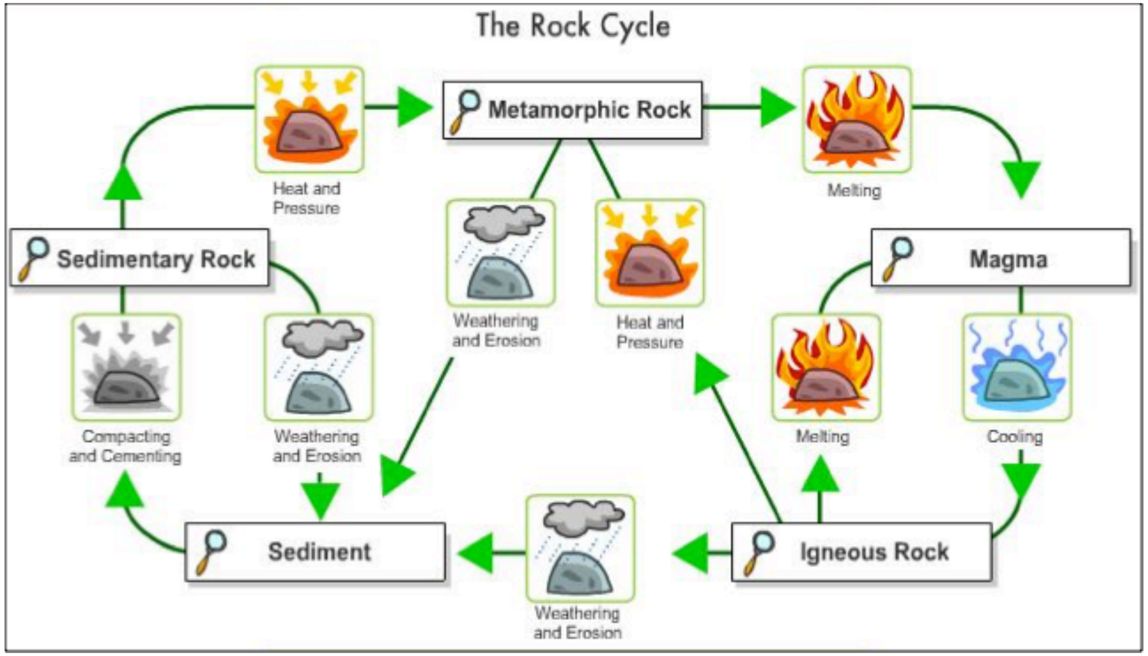
Lesson 2: Mineral Resources

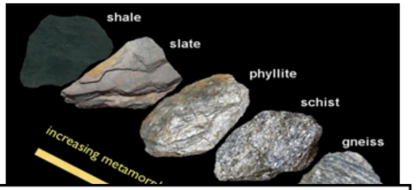

Composition
Felsic (Granitic)
Intermediate (Andesitic)
Mafic (Basaltic)
Ultramafic
Phaneritic (Coarse-grained)
Granite
Diorite
Gabbro
Peridotite
Aphanitic (Fine-grained)
Rhyolite
Andesite
Basalt
Komatiite (Rare)
Percent by volume
100
80
60
40
20
Muscovite
Quartz
Potassium feldspar
Light-colored minerals
Plagioclase feldspar
(Sodium-rich)
(Calcium-rich)
Biotite
Amphibole
Dark-colored minerals
Pyroxene
Olivine
75%
Increasing silica (SiO_2)
40%
Increasing potassium and sodium
Increasing iron, magnesium and calcium
650°C
Temperature at which melting begins
1250°C


riderako




© geology.com


The Rock Cycle
Heat and Pressure
Metamorphic Rock
Melting
Weathering and Erosion
Heat and Pressure
Sedimentary Rock
Magma
Compacting and Cementing
Weathering and Erosion
Melting
Cooling
Sediment
Weathering and Erosion
Igneous Rock



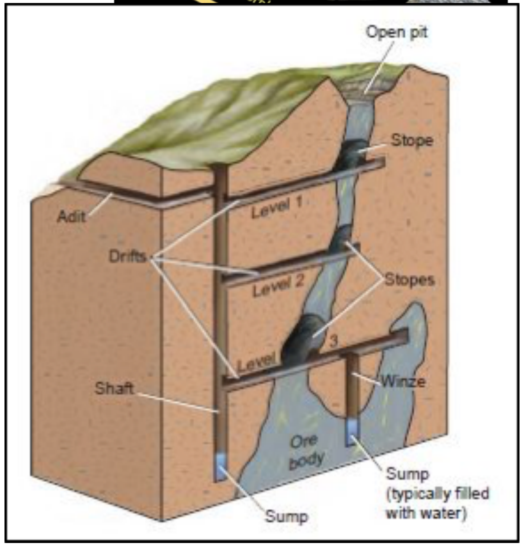
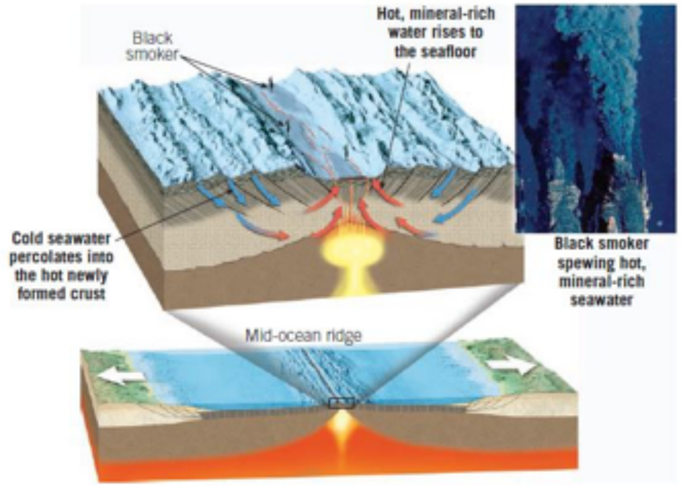
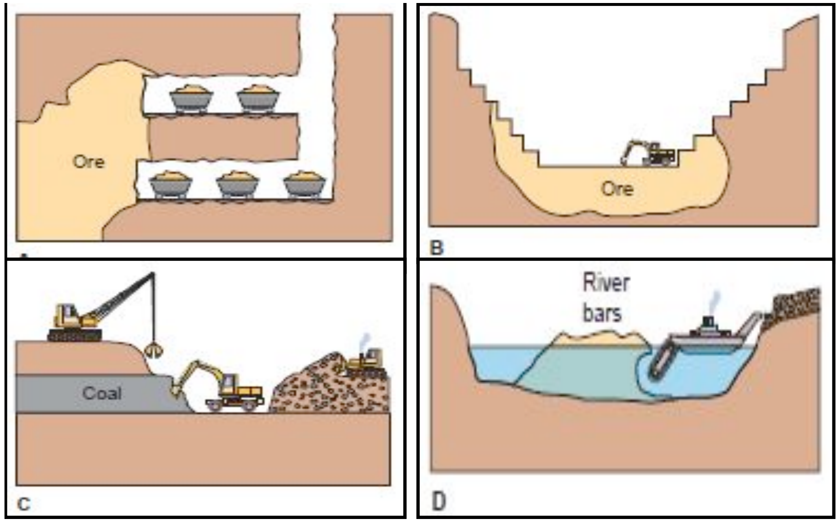
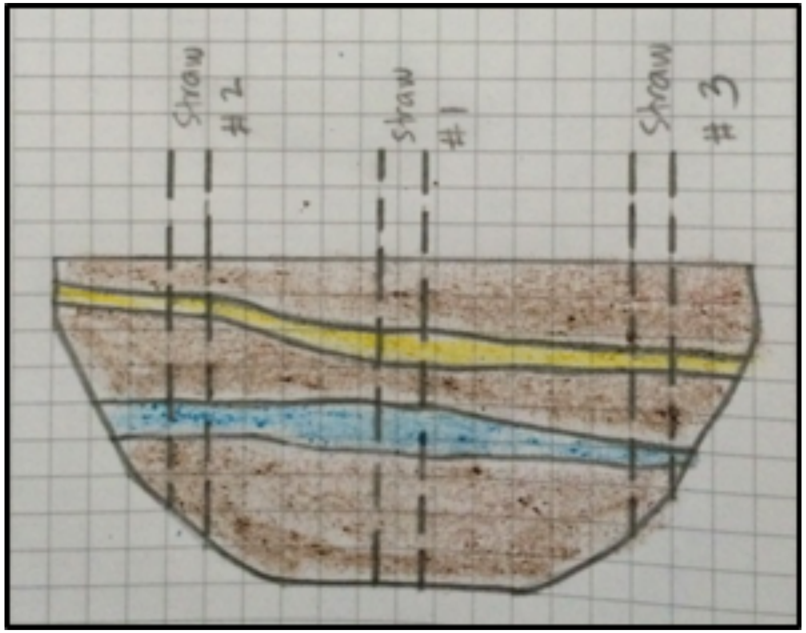
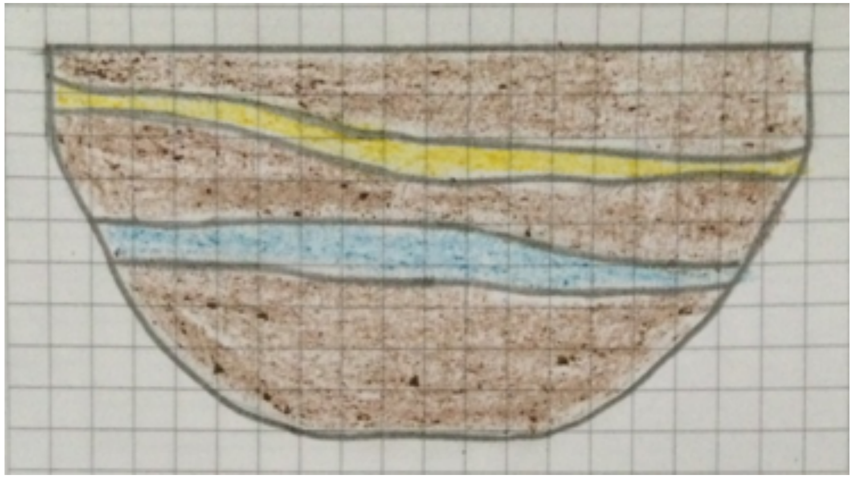


FIGURE 23.25 Sulfide deposits along a mid-ocean ridge
Massive sulfide deposits can result from the circulation of seawater through the oceanic crust along active spreading centers. As seawater infiltrates the hot basaltic crust, it leaches sulfur, iron, copper, and other metals. The hot, enriched fluid returns to the seafloor near the ridge axis along faults and fractures. Some metal sulfides may be precipitated in these channels as the rising fluid begins to cool. When the hot liquid emerges from the seafloor and mixes with cold seawater, the sulfides precipitate to form massive deposits. Photo shows a close-up view of a black smoker spewing hot, mineral-rich seawater along the East Pacific Rise. (Photo by Fisheries and Oceans Canada/Uvic-Verena Tunnicliffe/Newscom)









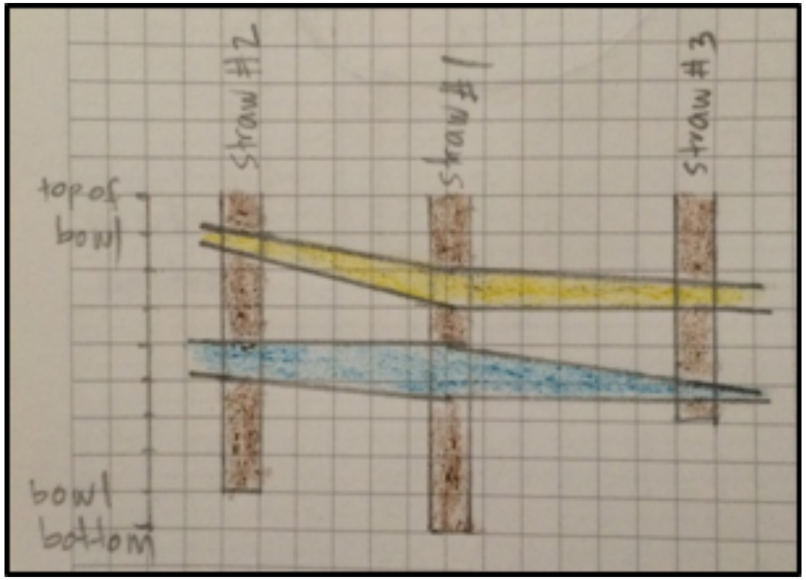
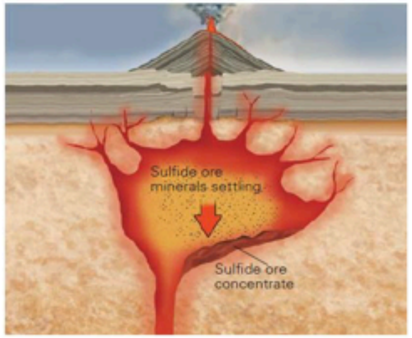
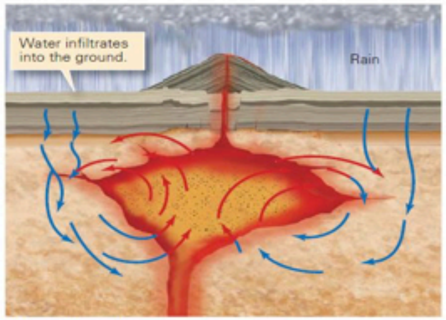


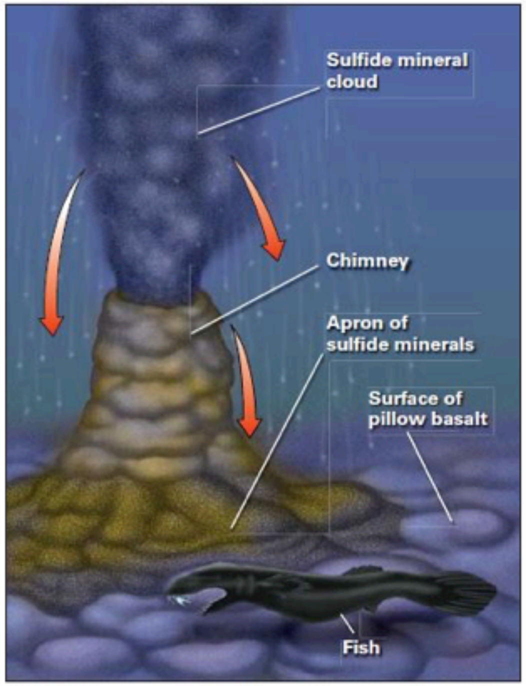
FIGURE 12.16 Various processes that form ore deposits.



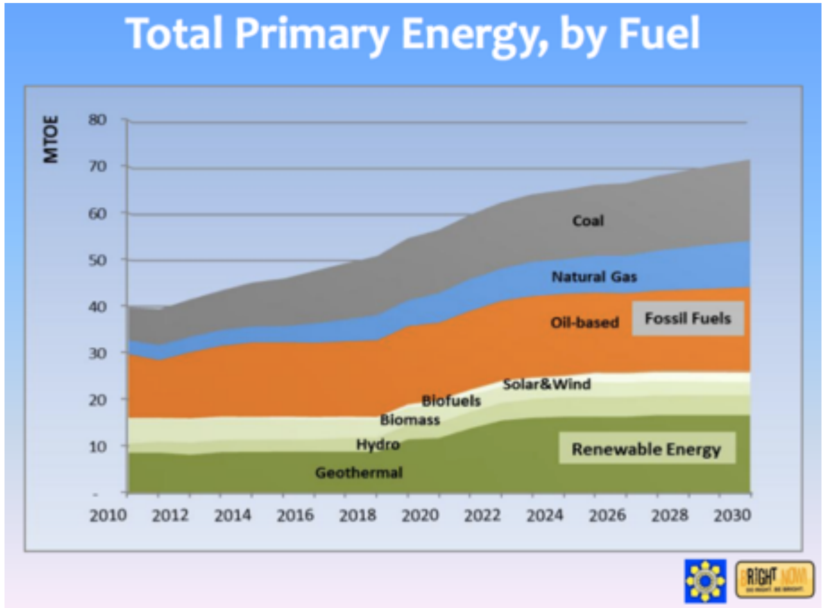
(a) Massive-sulfide deposits can form when sulfide ore minerals sink to the bottom of a magma chamber.

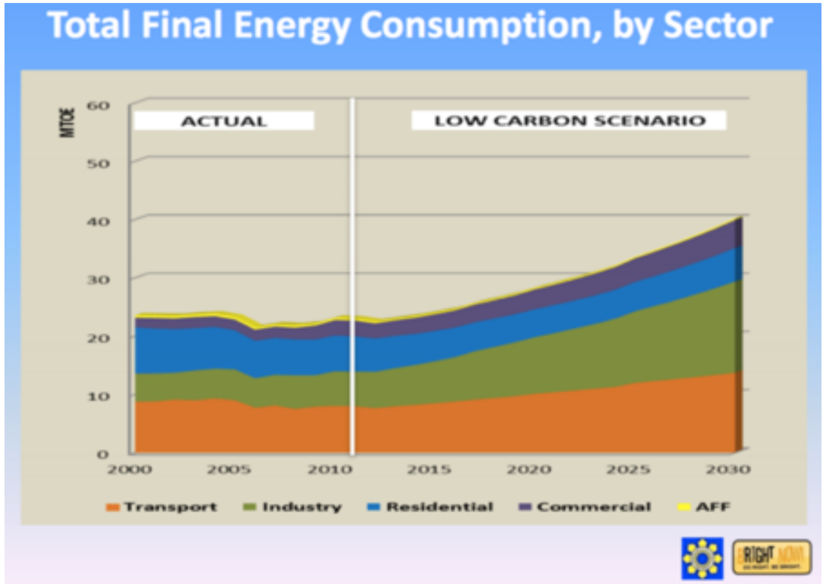


(b) Hydrothermal deposits form when water circulating around and through magma dissolves and redistributes metals.



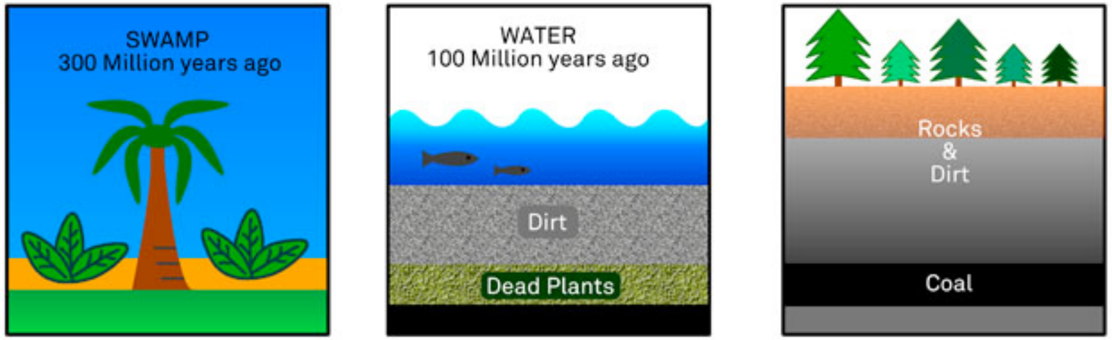
(c) Massive-sulfide deposits also form when ore minerals precipitate around hydrothermal vents (black smokers) along a mid-ocean ridge.





Lesson 2: Energy Resources

How coal was formed:

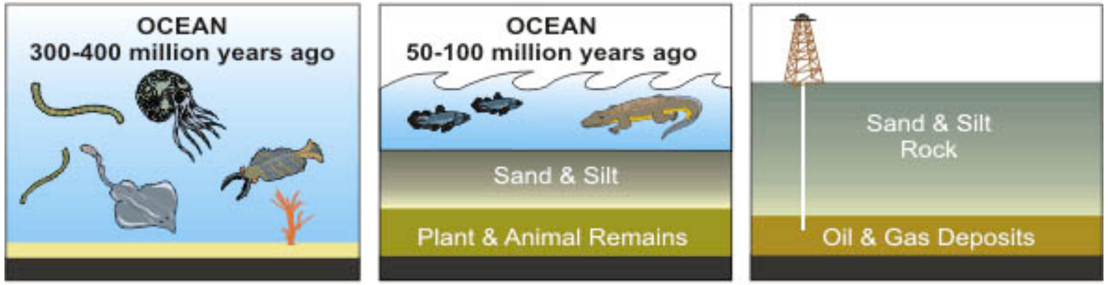


Before the dinosaurs, many giant plants died in swamps.

Over millions of years, the plants were buried under water and dirt.

Heat and pressure turned the dead plants into coal.

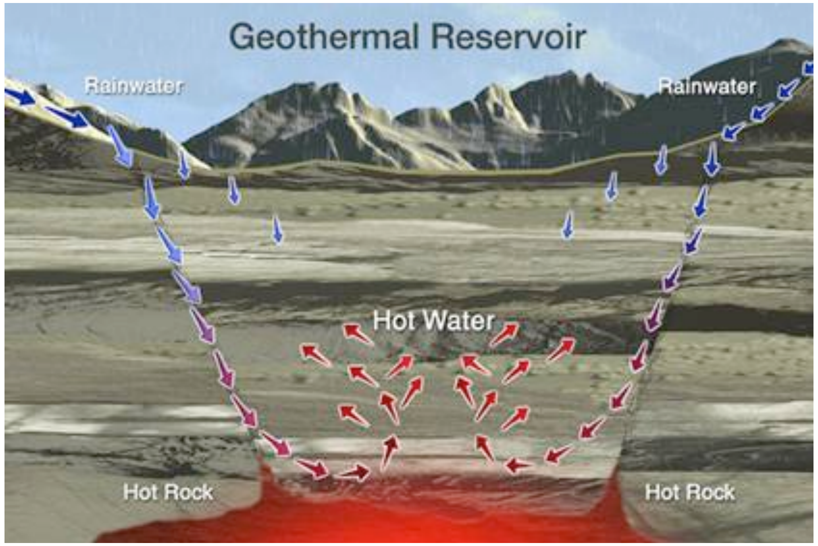
PETROLEUM & NATURAL GAS FORMATION

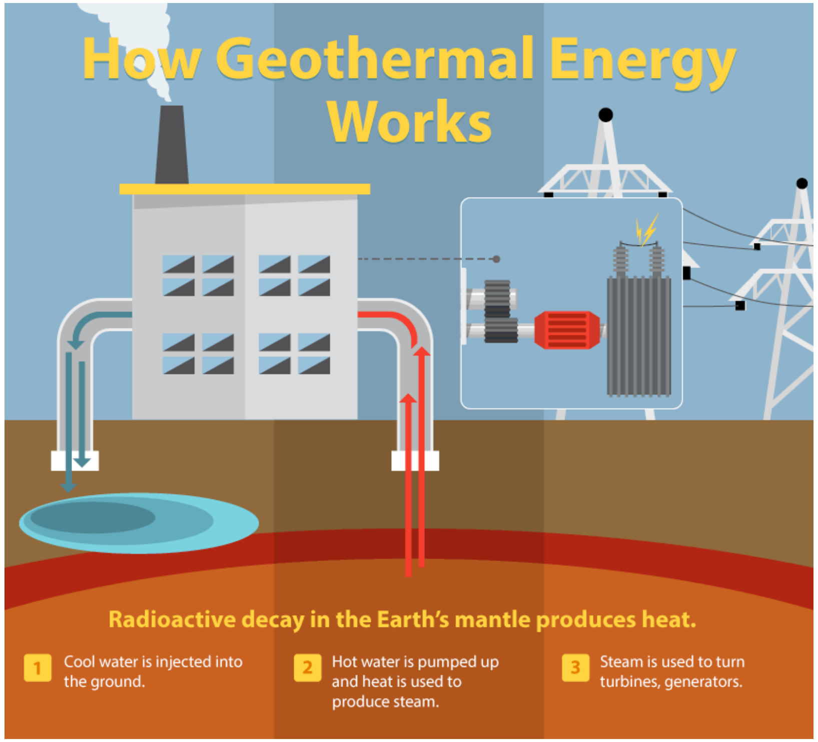


Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

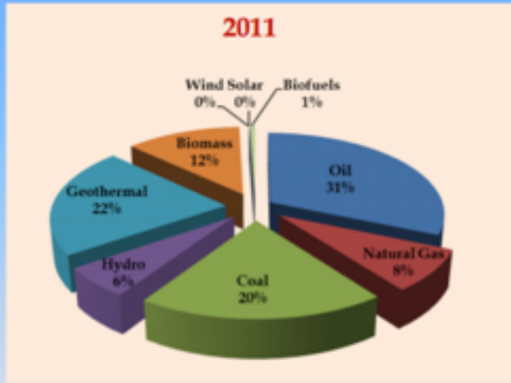

Geothermal Reservoir
Rainwater
Rainwater
Hot Water
Hot Rock
Hot Rock


How Geothermal Energy Works
Radioactive decay in the Earth's mantle produces heat.
1 Cool water is injected into the ground.
2 Hot water is pumped up and heat is used to produce steam.
3 Steam is used to turn turbines, generators.

Where Are We Now
Primary Energy Supply

	2011
Total Energy (MTOE)	39.4
Self-sufficiency (%)	60.0
Shares (%)	
Renewable Energy (RE)	40.7
Green Energy (RE + Natural Gas)	48.7

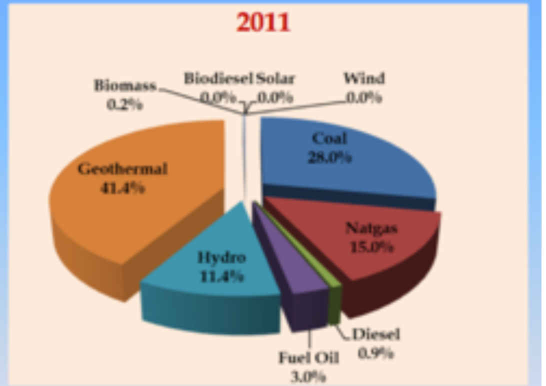
Note:
MTOE – Million Tons of Oil Equivalent



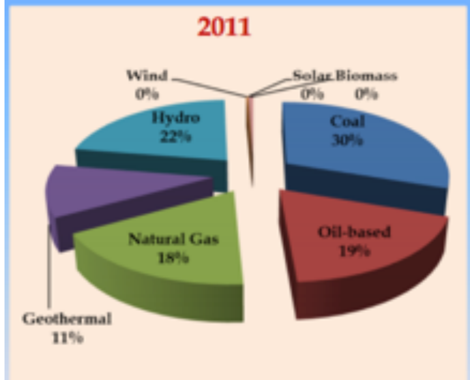
Where Are We Now
Fuel Input Mix for Power Generation

	2011
Total Energy (MTOE)	20.6
Share to TPES (%)	52.4
Self-sufficiency (%)	68.1
Shares (%)	
Renewable Energy (RE)	53.0
Green Energy (RE + Natural Gas)	68.1

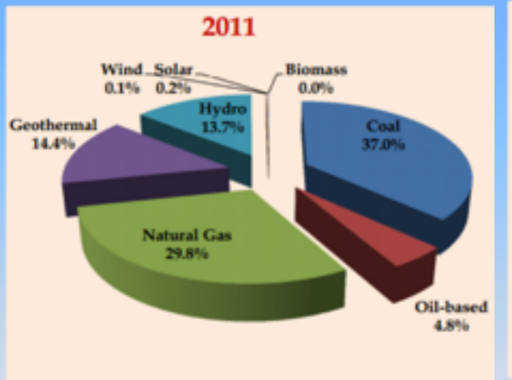
Note:
MTOE – Million Tons of Oil Equivalent
TPES – Total Primary Energy Supply



Where Are We Now
Power Generation Mix



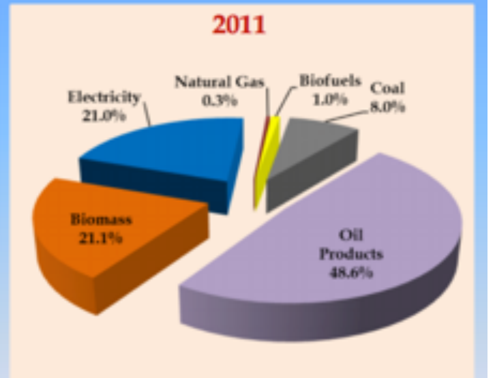
Installed Capacity (MW) – 16,162



Total Generation (GWh) – 69,050

Where Are We Now
Final Energy Consumption

By Sector



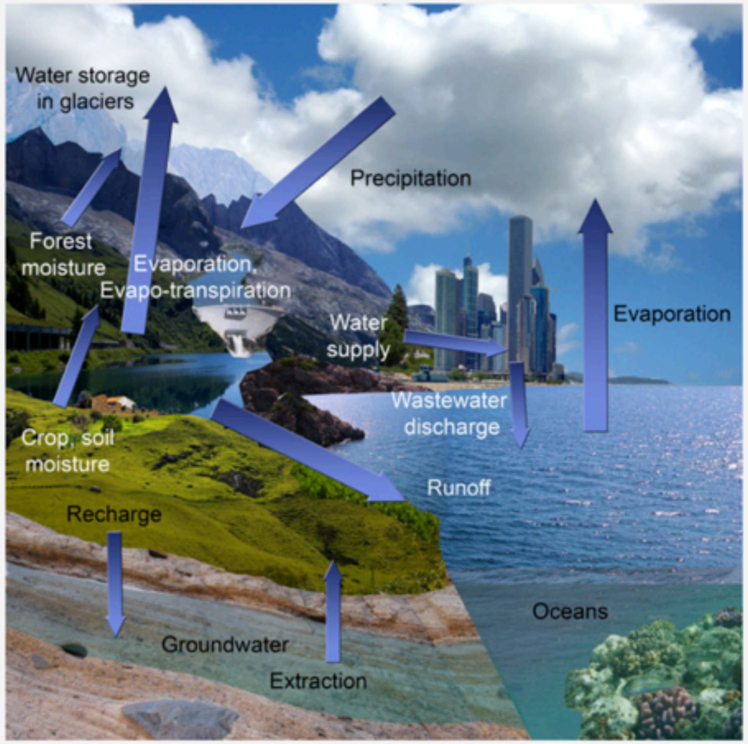
By Fuel

Total Energy Consumption (MTOE) – 23.0

Figure 1: Earth, the "Blue Marble," can be seen in this photograph to be mostly covered with liquid water.

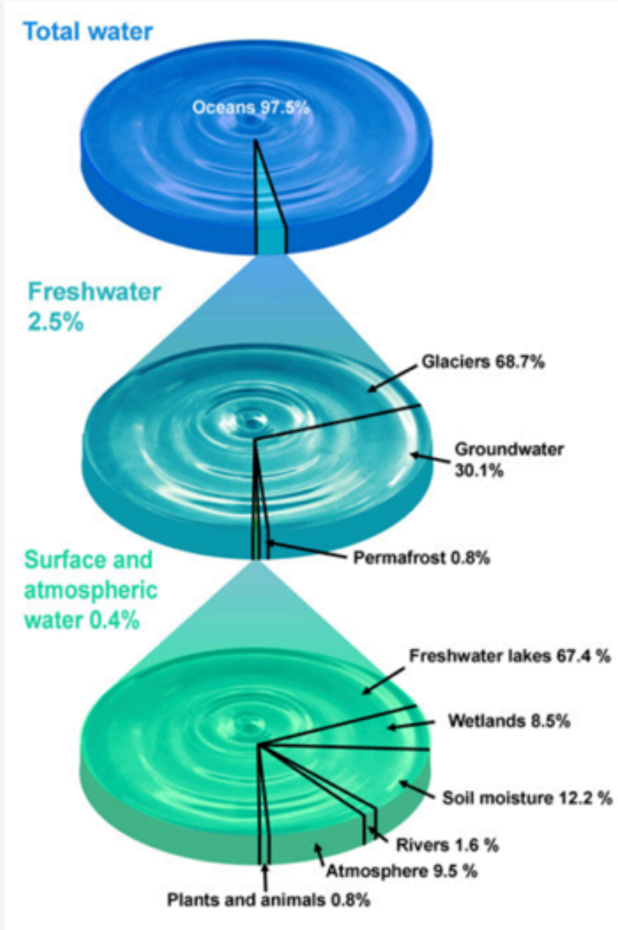
(*Source:* http://en.wikipedia.org/wiki/Earth, *License:* GNU-FDL)

Figure 2: Schematic of the hydrologic cycle components in present-day setting



Source: UNESCO The United Nations World Water Development Report 2
Section 2: Changing Natural Systems,
Chapter 4, Part 1. Global Hydrology and Water Resources, p.122

Figure 1: Global distribution of the world's water



Data from Shiklomanov and Rodda, 2003. Freshwater has a global volume of 35.2 million cubic kilometres (km^3).

Source: UNESCO The United Nations World Water Development Report 2
Section 2: Changing Natural Systems,
Chapter 4, Part 1. Global Hydrology and Water Resources, p.121

Lesson 2: Water Resources

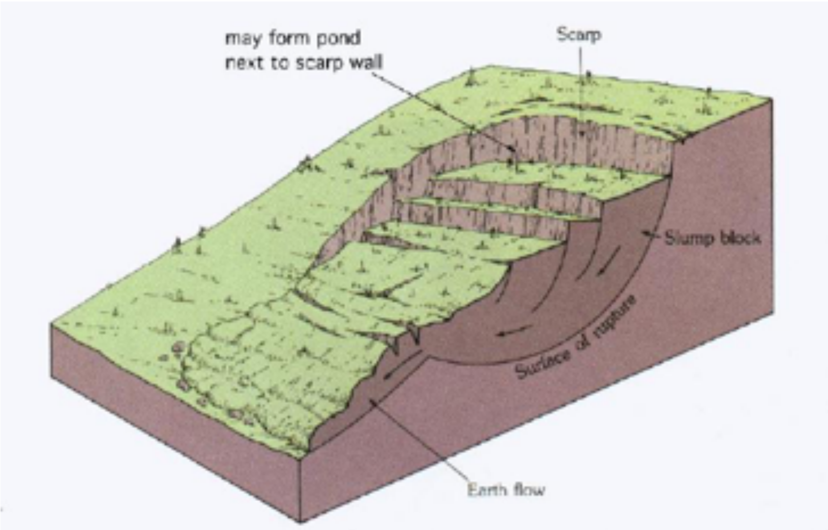
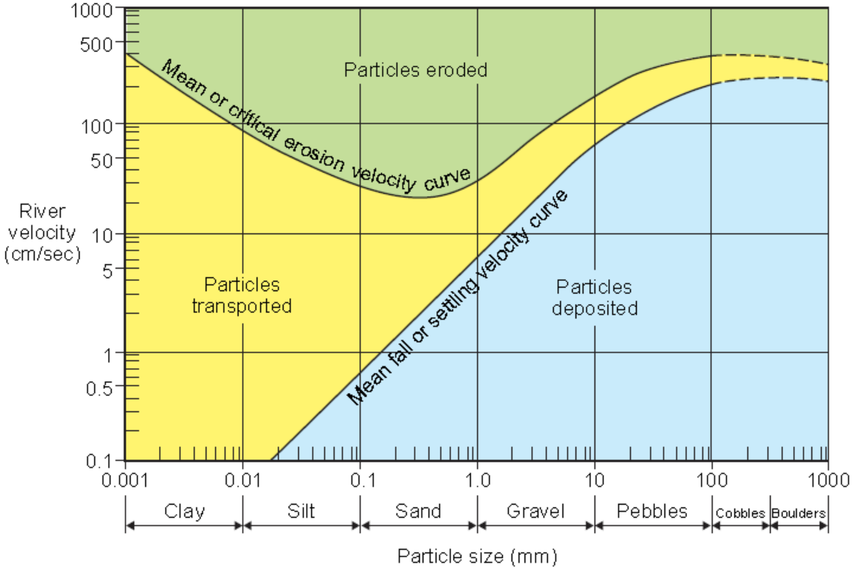
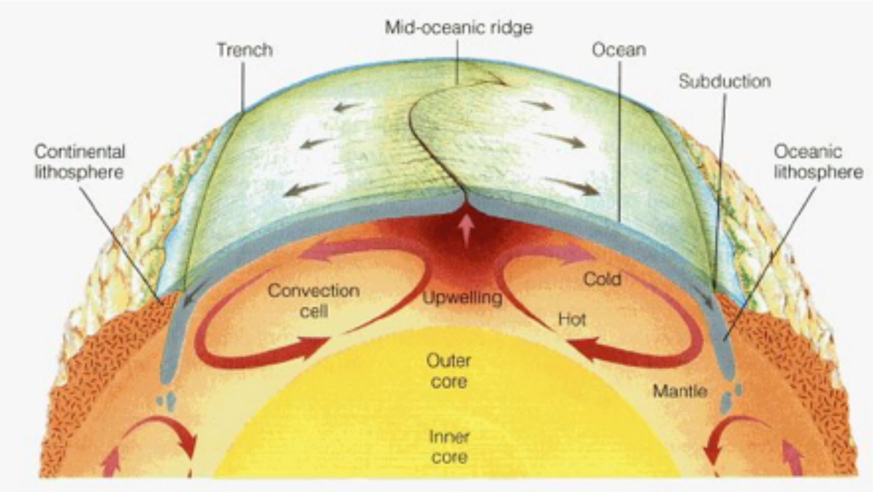
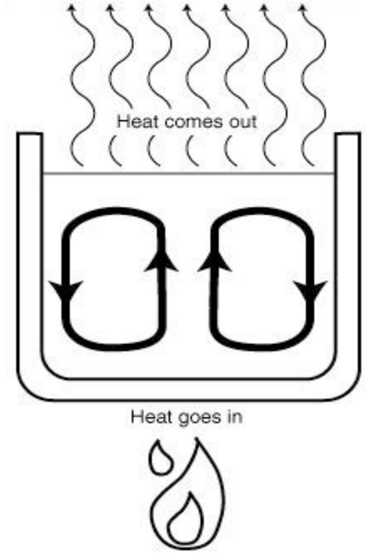


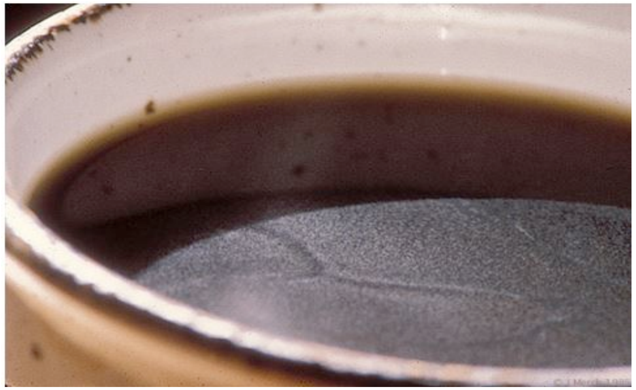
Figure 1

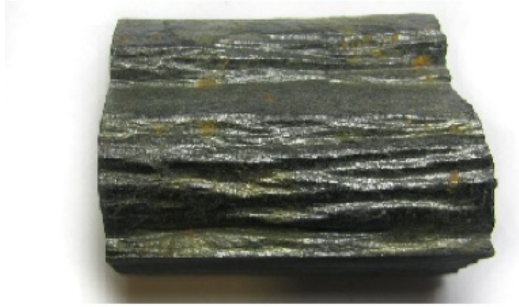


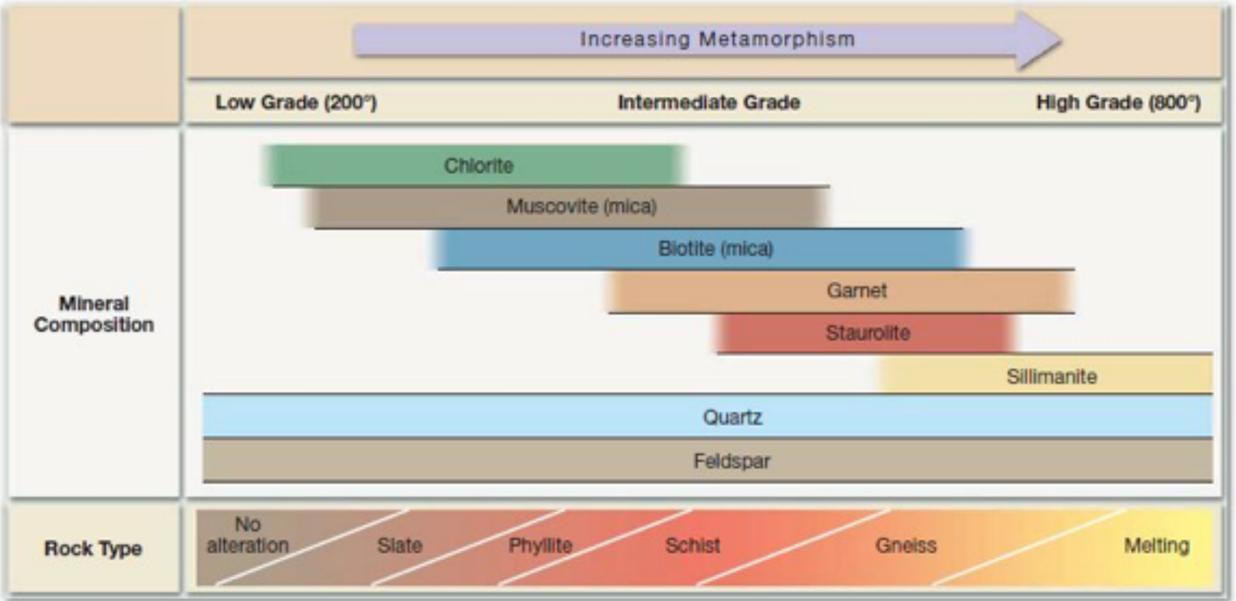
Lesson 3: Exogenic Processes



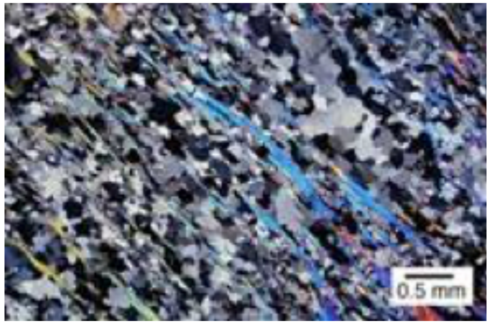


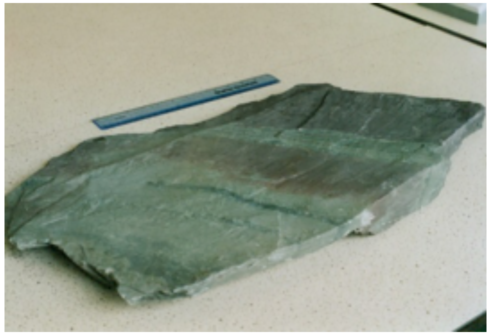






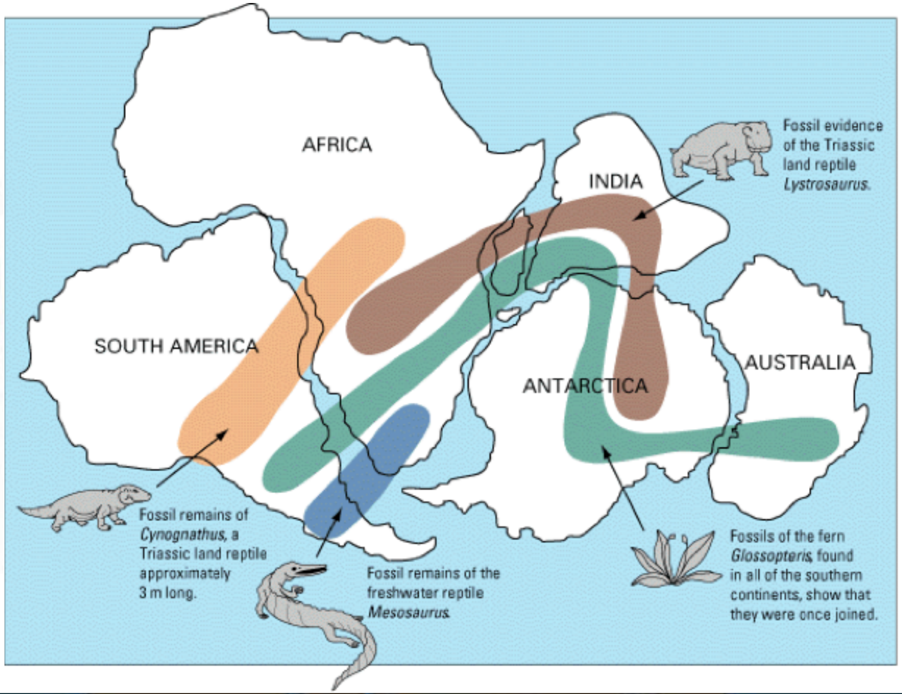
Lesson 3: Endogenic Processes

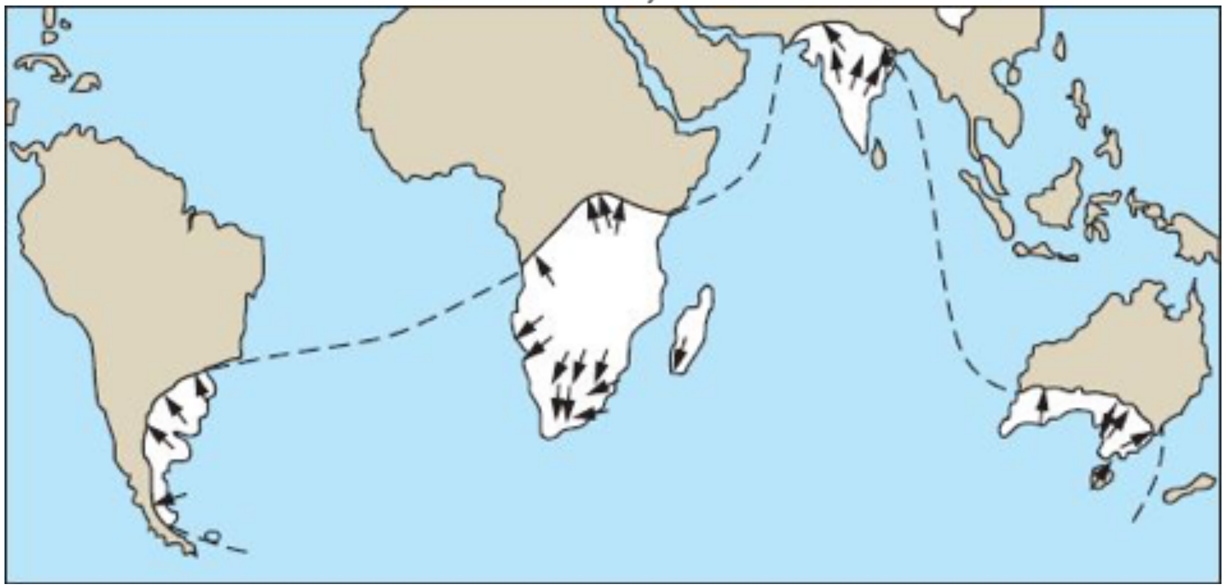

0.5 mm

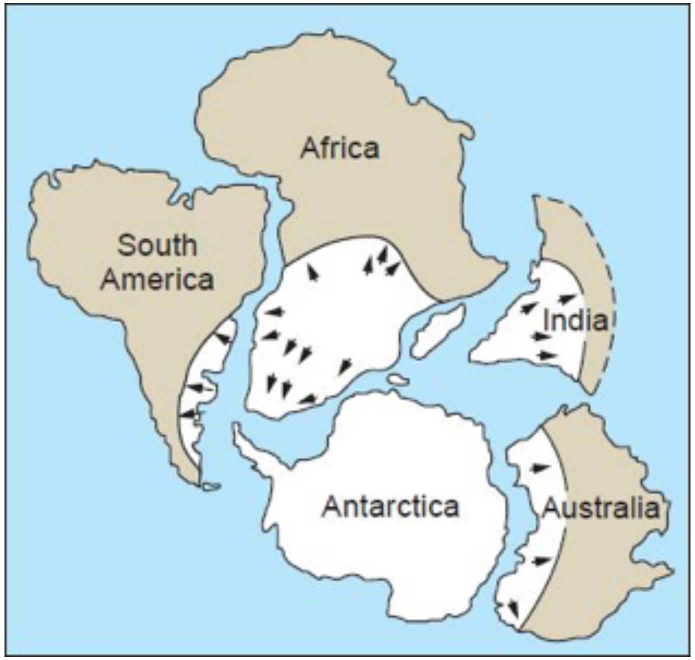


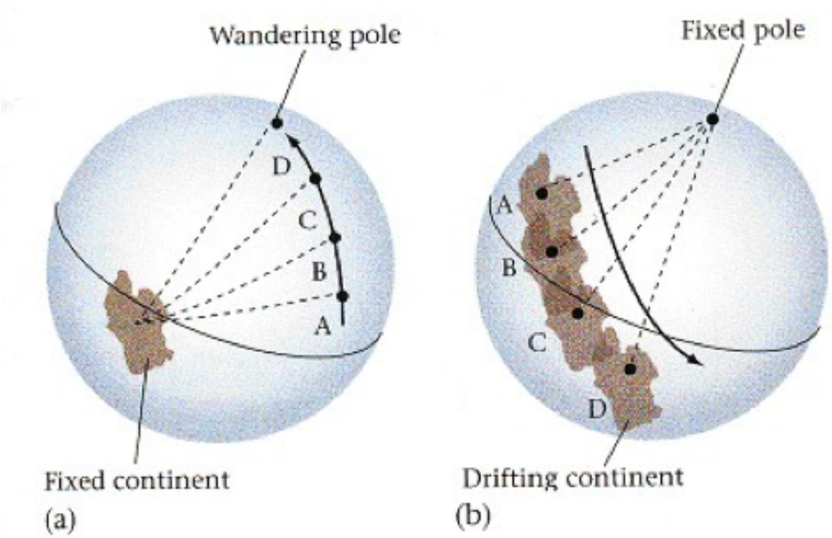

Eurasia
North America
Africa
South America
India
Antarctica
Australia

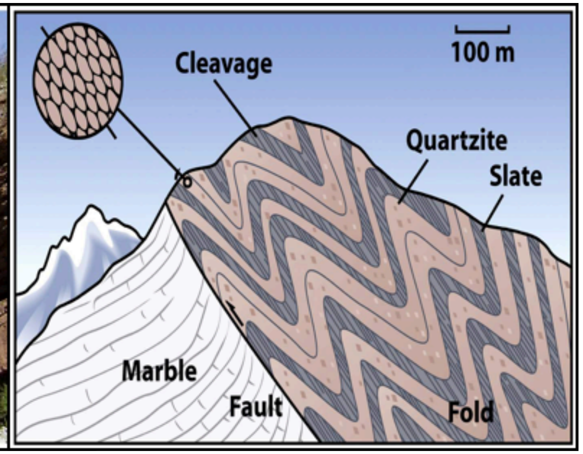

Uralian belt
Hercynian belt
Mauritanide belt
Panthalassa Ocean
Cordilleran belt
Andean belt
Transantarctic belt
Tasman belt

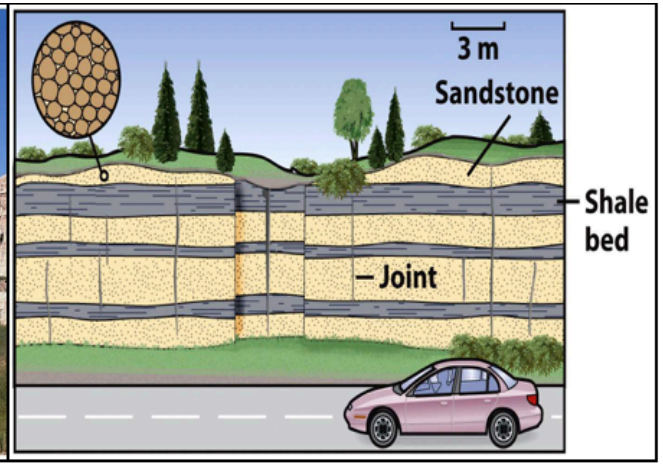

AFRICA
INDIA
SOUTH AMERICA
ANTARCTICA
AUSTRALIA
Fossil evidence of the Triassic land reptile *Lystrosaurus*.
Fossil remains of *Cynognathus*, a Triassic land reptile approximately 3 m long.
Fossil remains of the freshwater reptile *Mesosaurus*.
Fossils of the fern *Glossopteris*, found in all of the southern continents, show that they were once joined.



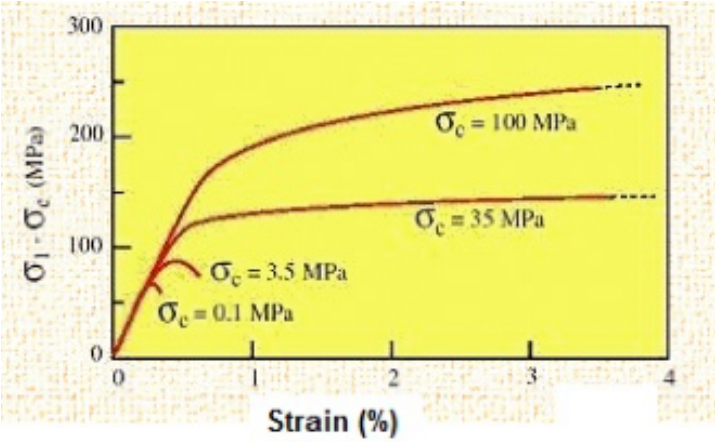


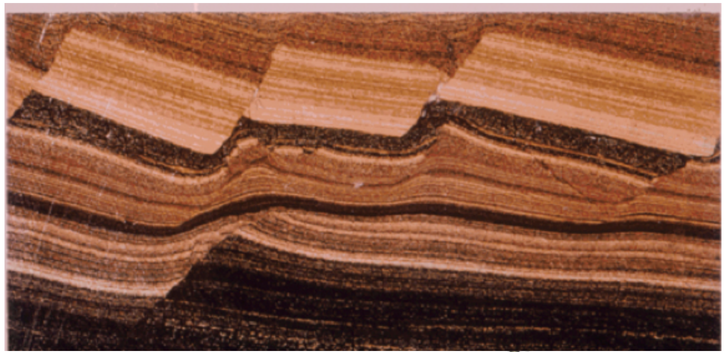


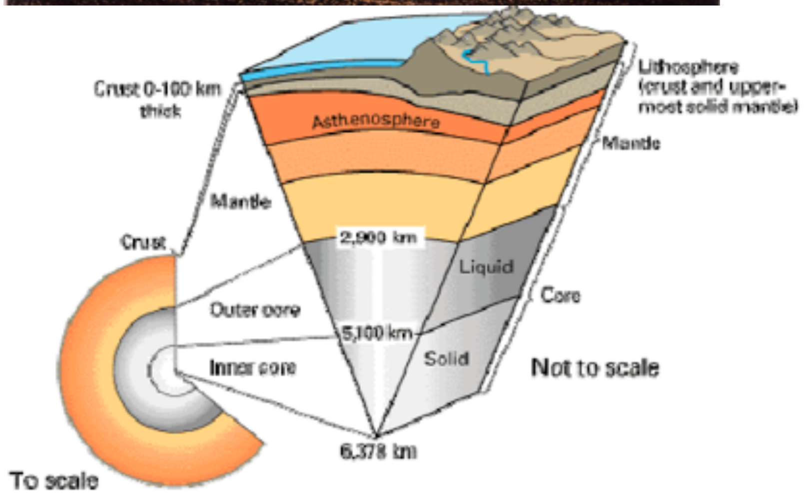


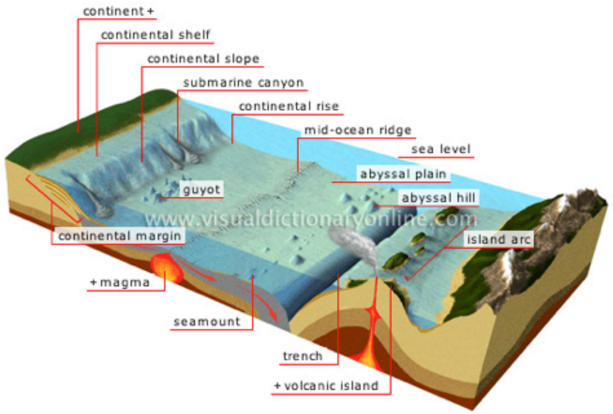


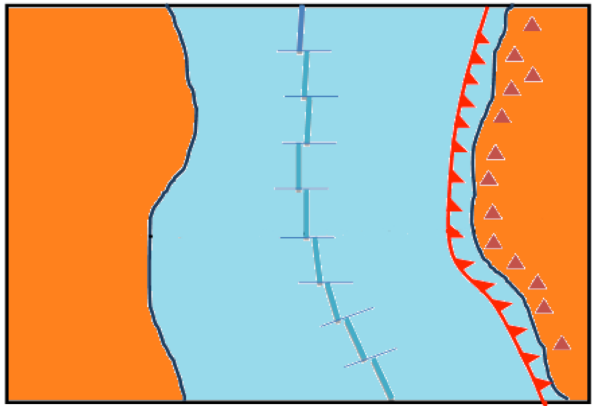
Lesson 3: Deformation of the Earth's Crust

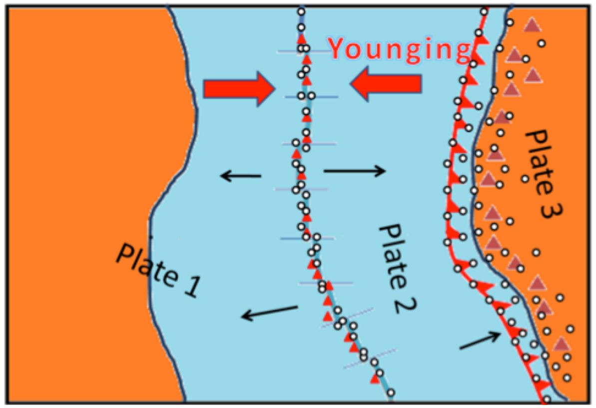




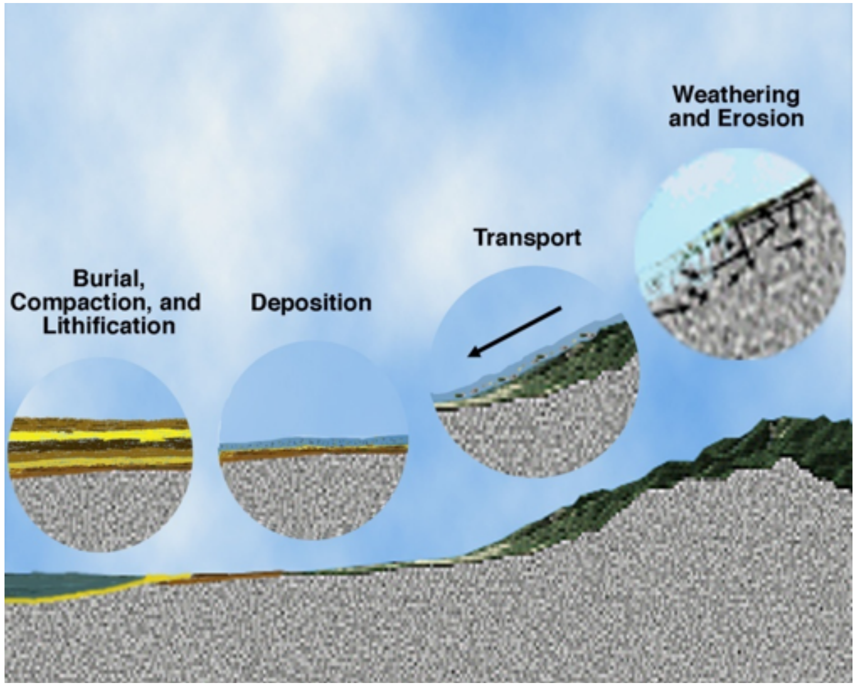




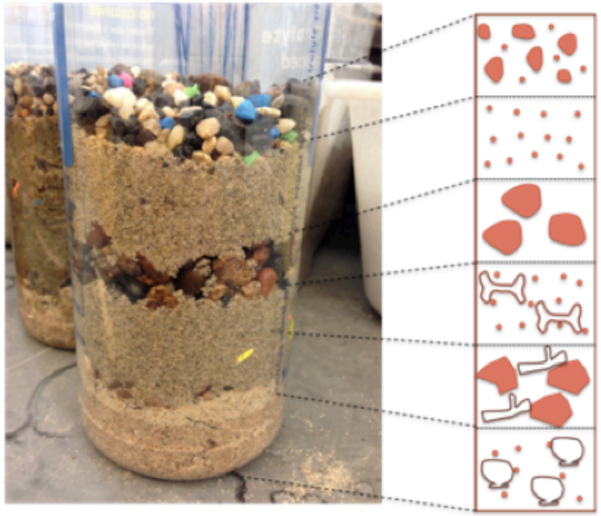




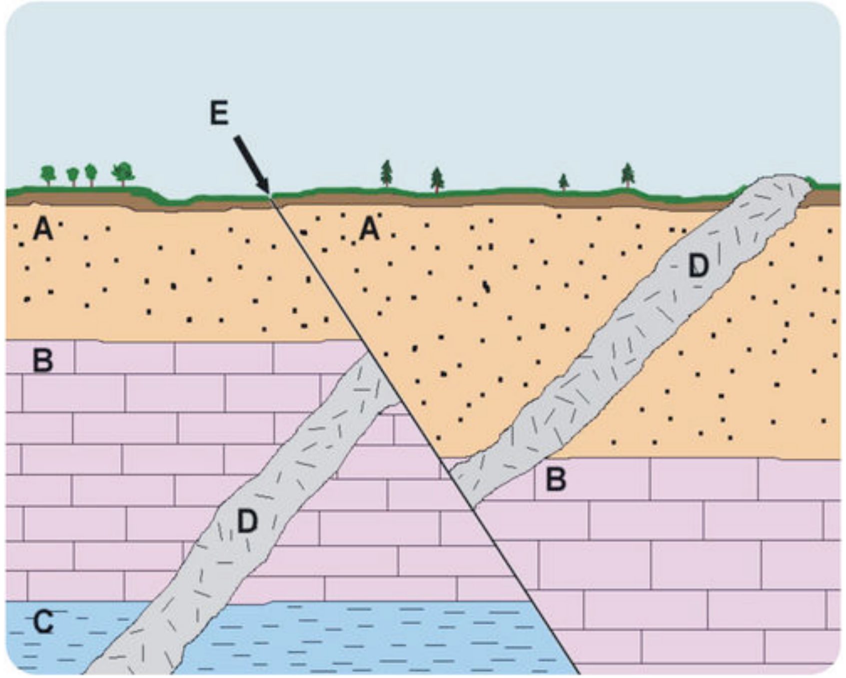
Lesson 3: Plate Tectonics

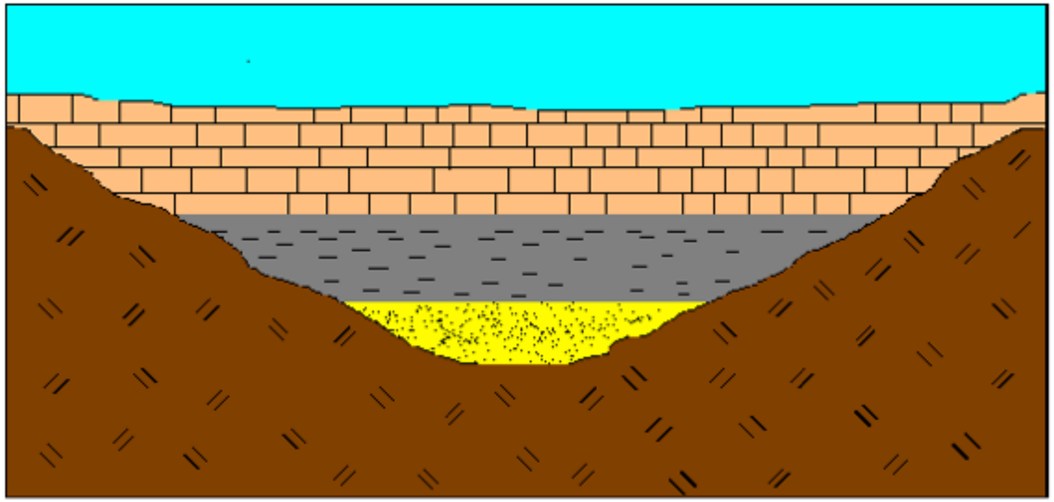


Lesson 4: History of the Earth

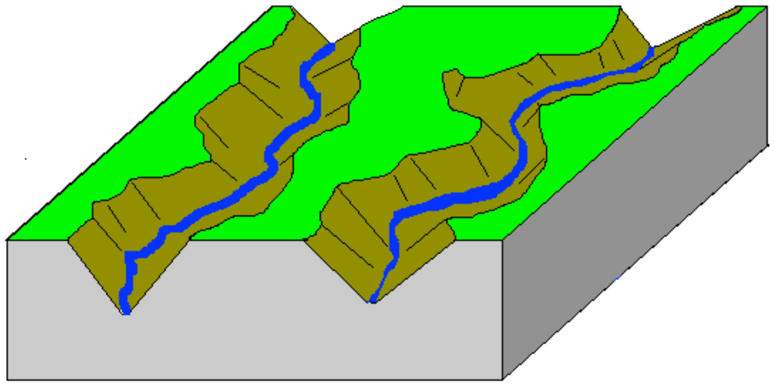


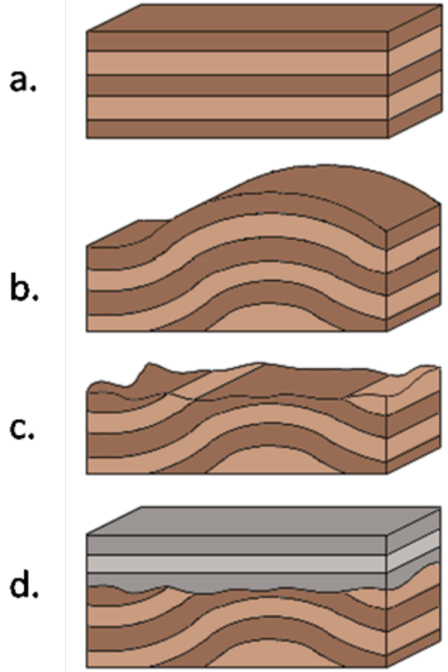
Description	Origin
Small sub-rounded pebbles with a few sand grains.	
composed of well sorted sand sized sediments	
Sub-angular pebbles	
Well sorted sand sized sediments with fossils	

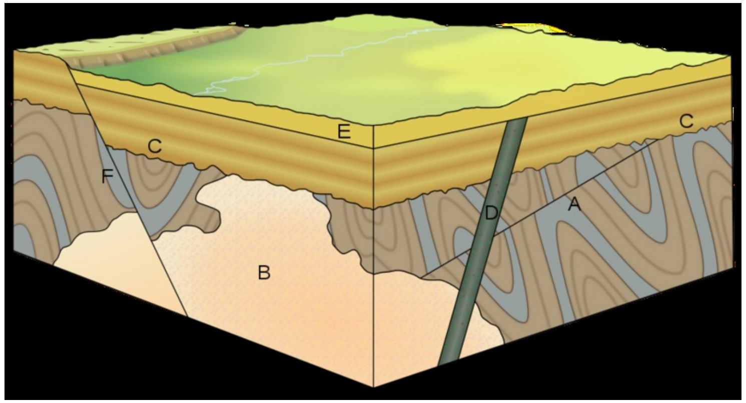


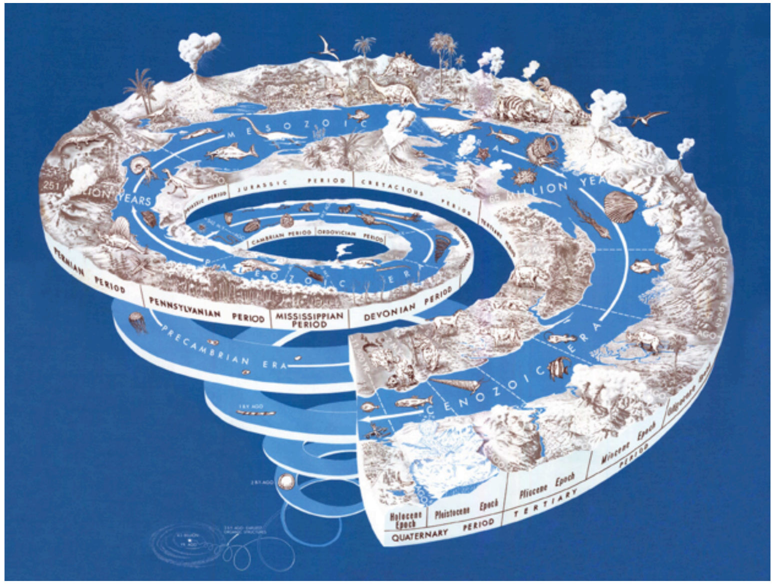


Original Horizontal Strata




a.
b.
c.
d.


E
C
C
F
D
A
B


PENNSYLVANIAN PERIOD
MISSISSIPPIAN PERIOD
DEVONIAN PERIOD
QUATERNARY PERIOD