Physical Geology

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Physical Geology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Physical geology incorporates chemistry, physics and environmental science and introduces students to key concepts, principles and theories within geology. Investigations are used to understand and explain the behavior of nature in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

PG.M: MINERALS

PG.M.1: Atoms and elements
PG.M.2: Chemical bonding (ionic, covalent, metallic)
PG.M.3: Crystallinity (crystal structure)
PG.M.4: Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition)
PG.M.5: Properties of minerals (hardness, luster, cleavage, streak, crystal shape, fluorescence, flammability, density/specific gravity, malleability)

PG.IMS: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS

PG.IMS.1: Igneous
- Mafic and felsic rocks and minerals
- Intrusive (igneous structures: dikes, sills, batholiths, pegmatites)
- Earth's interior (inner core, outer core, lower mantle, upper mantle, Mohorovicic discontinuity, crust)
- Magnetic reversals and Earth's magnetic field
- Thermal energy within the Earth
- Extrusive (volcanic activity, volcanoes: cinder cones, composite, shield)
- Bowen's Reaction Series (continuous and discontinuous branches)

PG.IMS.2: Metamorphic
- Pressure, stress, temperature and compressional forces
- Foliated (regional), non-foliated (contact)
- Parent rock and degrees of metamorphism
- Metamorphic zones (where metamorphic rocks are found)

PG.IMS.3: Sedimentary
- Division of sedimentary rocks and minerals (chemical, clastic/physical, organic)
- Depositional environments

PG.IMS.4: Ocean
- Tides (daily, neap and spring)
- Currents (deep and shallow, rip and longshore)
- Thermal energy and water density
- Waves
- Ocean features (ridges, trenches, island systems, abyssal zone, shelves, slopes, reefs, island arcs)
- Passive and active continental margins
- Transgressing and regressing sea levels
- Streams (channels, streambeds, floodplains, cross-bedding, alluvial fans, deltas)

PG.EH: EARTH'S HISTORY

PG.EH.1: The geologic rock record
- Relative and absolute age
- Principles to determine relative age
  - Original horizontality
  - Superposition
  - Cross-cutting relationships
- Absolute age
  - Radiometric dating (isotopes, radioactive decay)
  - Correct uses of radiometric dating
- Combining relative and absolute age data
- The geologic time scale
  - Comprehending geologic time
  - Climate changes evident through the rock record
  - Fossil record

PG.PT: PLATE TECTONICS

PG.PT.1: Internal Earth

- Seismic waves
  - S and P waves
  - Velocities, reflection, refraction of waves

PG.PT.2: Structure of Earth (Note: specific layers were part of grade 8)

- Asthenosphere
- Lithosphere
- Mohorovicic boundary (Moho)
- Composition of each of the layers of Earth
- Gravity, magnetism and isostasy
- Thermal energy (geothermal gradient and heat flow)

PG.PT.3: Historical review (Note: this would include a review of continental drift and seafloor spreading found in grade 8)

- Paleomagnetism and magnetic anomalies
- Paleoclimatology

PG.PT.4: Plate motion (Note: introduced in grade 8)

- Causes and evidence of plate motion
- Measuring plate motion
- Characteristics of oceanic and continental plates
- Relationship of plate movement and geologic events
- Mantle plumes

PG.ER: EARTH'S RESOURCES

PG.ER.1: Energy resources

- Renewable and nonrenewable energy sources and efficiency
- Alternate energy sources and efficiency
- Resource availability
- Mining and resource extraction

PG.ER.2: Air

- Primary and secondary contaminants
- Greenhouse gases

PG.ER.3: Water

- Potable water and water quality
- Hypoxia, eutrophication

PG.ER.4: Soil and sediment

- Desertification
- Mass wasting and erosion
- Sediment and contamination

PG.GG: GLACIAL GEOLOGY

PG.GG.1: Glaciers and glaciation

- Evidence of past glaciers (including features formed through erosion or deposition)
- Glacial deposition and erosion (including features formed through erosion or deposition)
- Data from ice cores
  - Historical changes (glacial ages, amounts, locations, particulate matter, correlation to fossil evidence)
  - Evidence of climate changes throughout Earth's history
- Glacial distribution and causes of glaciation
- Types of glaciers – continental (ice sheets, ice caps), alpine/valley (piedmont, valley, cirque, ice caps)
- Glacial structure, formation and movement

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.

Science is a Way of Knowing
Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.
	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method).
	  ○ Make observations and look for patterns.
	  ○ Determine relevant independent variables affecting observed patterns.
	  ○ Manipulate an independent variable to affect a dependent variable.
	  ○ Conduct an experiment with controlled variables based on a question or hypothesis.
	  ○ Analyze data graphically and mathematically.
	• Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews.
	  ○ Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings.
	  ○ Logical arguments should be evaluated with open-mindedness, objectivity and skepticism.
	• Science arguments are strengthened by multiple lines of evidence supporting a single explanation.
	• The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.

Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Physical Geology continued

PG.M: MINERALS
PG.M.1: Atoms and elements
PG.M.2: Chemical bonding (ionic, covalent, metallic)
PG.M.3: Crystallinity (crystal structure)
PG.M.4: Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition)
PG.M.5: Properties of minerals (hardness, luster, cleavage, streak, crystal shape, fluorescence, flammability, density/specific gravity, malleability)

CONTENT ELABORATION: MINERALS

This unit builds upon the Earth and Space Science strand in grade 6, where common minerals are defined, tested and classified. It also incorporates knowledge of mineral properties and crystalline structures (chemical compositions and bonding) included in the chemistry sections of other high school courses.

The emphasis in this course is to relate the chemical and physical components of minerals to the properties of the minerals. This requires extensive mineral testing, investigations, experimentation, observation, use of technology and models/modeling. The focus is on learning the ways to research, test and evaluate minerals, not in memorization of mineral names or types.

Properties such as cleavage and hardness are connected to the chemical structure and bonding of the mineral. In addition, the environment in which minerals form should be part of the classification of the mineral, using mineral data to help interpret the environmental conditions that existed during the formation of the mineral.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.M.1: Atoms and elements			
Evaluate the appropriateness of extracting minerals such as uranium, platinum, copper, phosphorus, aluminum, sodium or iron in populated areas.	Develop a system to recycle used minerals from a product (e.g., tin cans, aluminum foil, copper pipes).	Explain how crystalline structure relates to a mineral's properties as well as its use and application in daily life. Represent the chemical compositions of common minerals with a drawing and/or 3D model. Explain what is represented in the depiction of the chemical formula.	Classify the groups of minerals by chemical composition. Compare minerals and ores and identify their uses. Given a chemical formula for a mineral, identify the elemental composition and relate this to its properties.
PG.M.2: Chemical bonding (ionic, covalent, metallic)			
		Conduct tests to differentiate between ionically and covalently bonded materials. Design a 3-D model of the different types of chemical bonding.	Identify types of bonds present in each mineral group/family.
PG.M.3: Crystallinity (crystal structure)			
		Explain why specific crystalline structures are different from each other. Use crystal or atomic models to illustrate the crystal structure of common minerals. Relate the structure to a specific quantifiable property (e.g., cleavage, hardness).	Categorize crystalline shapes (7) and list what minerals would be found in each category.
PG.M.4: Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition)			
Design a method to use GIS to target mineral exploration or evaluate mining conditions and extraction methods. Then, construct a model of a site which has minimal environmental impact.	Plan and conduct an investigation to determine the specific gravity of minerals.	Construct a graphic model depicting how minerals are classified into groups by chemical composition and crystal formation. Create an atom building game that demonstrates how elements combine to build minerals.	Identify and classify a mineral based on tested properties. Use a variety of rock samples to identify the minerals present. Examine mineral samples for crystalline structure and cleavage/fracture.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.M.5: Properties of minerals (hardness, luster, cleavage, streak, crystal shape, fluorescence, flammability, density/specific gravity, malleability)			
Research social issues relating to conflict minerals (e.g., coltan, tungsten, gold). Determine whether there are alternative sources for these minerals.	Develop a method to determine the difference between pyrite and gold using tools available to early gold prospectors.	Determine the best use of a mineral based on observable properties. Select a consumer product. Determine the minerals used in the product and the reason(s) for their use.	Differentiate between cleavage and fracture. Test a mineral for hardness (Mohs Scale), malleability and streak.

Physical Geology continued

PG.IMS: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS

PG.IMS.1: Igneous

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- Earth's interior (inner core, outer core, lower mantle, upper mantle, Mohorovičić discontinuity, crust)
- Magnetic reversals and Earth's magnetic field
- Thermal energy within Earth
- Extrusive (volcanic activity, volcanoes: cinder cones, composite, shield)
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PG.IMS.2: Metamorphic

- Pressure, stress, temperature and compressional forces
- Foliated (regional), non-foliated (contact)
- Parent rock and degrees of metamorphism
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PG.IMS.3: Sedimentary

- Division of sedimentary rocks and minerals (chemical, clastic/physical, organic)
- Depositional environments

PG.IMS.4: Ocean

- Tides (daily, neap and spring)
- Currents (deep and shallow, rip and longshore)
- Thermal energy and water density
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- Passive and active continental margins
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- Streams (channels, streambeds, floodplains, cross-bedding, alluvial fans, deltas)

CONTENT ELABORATION: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS

This unit builds upon a variety of topics studied in middle school. In the Earth and Space Science strand, sedimentary, igneous and metamorphic rocks are introduced. Rocks and minerals are tested and classified. Plate tectonics, seismic waves and the structure of Earth are studied and the geologic record is introduced (including the evidence of climatic variances through Earth's history). In the Life Science strand, fossils and depositional environments are included as they relate to the documented history of life in the geologic record. In the Physical Science strand, waves, thermal energy, currents, pressure and gravity are presented.

In this course, geologic, topographic, seismic and aerial maps are used to locate and recognize igneous, metamorphic and sedimentary structures and features. Technological advances permit the investigation of intrusive structures and the interior of Earth. Connections between the minerals present within each type of rock and the environment formed are important. The processes and environmental conditions that lead to fossil fuel formation (**Note:** *this links to the energy resources section below*) includes the fossil fuels found in Ohio, nationally and globally.

Bowen's Reaction Series is used to develop an understanding of the relationship of cooling temperature, formation of specific igneous minerals and the resulting igneous environment. The focus is on knowing how to use Bowen's Reaction Series, not to memorize it. Virtual demonstrations and simulations of cooling magma and crystallization of the igneous minerals found on the series can be helpful in conceptualizing the chart.

The magnetic properties of Earth are examined through the study of real data and evidence. The relationship of polar changes, magnetic striping, grid north, true north and the North Pole are included in the study of Earth's magnetic properties.

Features found in the ocean include all types of environments (igneous, metamorphic or sedimentary). Using models (3-D or virtual) with real-time data to simulate waves, tides, currents, feature formation and changing sea levels to explore and investigate the ocean fully is recommended. Interpreting sections of the geologic record to determine sea level changes and depositional environments, including relative age, is also recommended.

Technological advances can be used to observe and record the physical features of the Earth, including the ocean floor. Interpreting geologic history using maps of local cross-sections of bedrock can be related to the geologic history of Ohio, the United States and Earth.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	PG.IMS.1: Igneous		
Determine the feasibility of building a tunnel or road in a specific location based on the type of rocks present.		Create a dichotomous key allowing for the identification of various igneous rocks. Use Bowen's reaction series to identify the origins of several rocks. Provide evidence to support the identification.	Identify characteristics of different classifications of igneous, metamorphic, and sedimentary rocks.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		PG.IMS.2: Metamorphic	
Create a building construction task based on student criteria. Analyze the pros and cons of different rock types to determine the most appropriate rock(s) for various aspects of the project.		Create a dichotomous key allowing for the identification of various metamorphic rocks.	Sort metamorphic rocks by the grade of metamorphism. Describe the conditions under which various metamorphic rocks were formed from parent material.
		PG.IMS.3: Sedimentary	
Design a mining method (large or small scale) that allows material to be removed without collapse.	Evaluate the ability of various sedimentary rocks to transport fluids (e.g., groundwater, oil, natural gas).	Create a dichotomous key allowing for the identification of various sedimentary rocks. Use fossils found in sedimentary rock to determine changes in sea level over geological time.	Identify and classify sedimentary rocks based on characteristics. Describe the depositional environment for various samples of sedimentary rocks.
		PG.IMS.4: Ocean	
Design and engineer a method to use ocean waves, tides or currents to produce energy. Research historic changes in the course of the Mississippi River. Discuss the pros and cons of the engineering methods being used to maintain its current course.		Trace the development of an El Niño or La Niña event and explain how thermal energy shifts alter local and regional conditions. Analyze why the Colorado River no longer flows into the Sea of Cortez. Use aerial photos over the last century to explain what happened to the delta. Analyze how neap and spring tides impact coastal regions, especially during storm events and other natural occurrences.	Identify the various features around and within a stream system using Google Earth. Map major ocean currents and identify various types of currents. Map major trenches, ridges and island systems in each ocean.

Physical Geology continued

PG.EH: EARTH'S HISTORY
PG.EH.1: The geologic rock record

- Relative and absolute age
- Principles to determine relative age
  - Original horizontality
  - Superposition
  - Cross-cutting relationships
- Absolute age
  - Radiometric dating (isotopes, radioactive decay)
  - Correct uses of radiometric dating
- Combining relative and absolute age data
- The geologic time scale
  - Comprehending geologic time
  - Climate changes evident through the rock record
  - Fossil record

CONTENT ELABORATION: EARTH'S HISTORY

This unit builds upon a variety of topics studied in middle school. In the Earth and Space Science strand, sedimentary, igneous and metamorphic rocks are introduced. Rocks and minerals are tested and classified. Plate tectonics, seismic waves and the structure of Earth are studied and the geologic record is explored (including uniformitarianism, superposition, cross-cutting relationships and the evidence of climatic variances through Earth's history). In the Life Science strand, fossils and depositional environments are included as they relate to the documented history of life in the geologic record. In the Physical Science strand, radiometric dating, seismic waves, thermal energy, pressure and gravity are presented.

In this course, the long-term history of Earth and the analysis of the evidence from the geologic record (including fossil evidence) are investigated.

Using actual sections of the geologic record to interpret, compare and analyze can demonstrate the changes that have occurred in Ohio, in North America and globally. The emphasis for this unit is to explore the geologic record and the immensity of the geologic record. The analysis of data and evidence found in the variety of dating techniques (both absolute and relative), the complexity of the fossil record, and the impact that improving technology has had on the interpretation and continued updating of what is known about the history of Earth are investigated. Geologic principles are essential in developing this level of knowledge. These principles can be tested and experienced virtually, or through modeling, field studies, research and in-depth investigations.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.EH.1: The geologic rock record			
	Design and conduct a field study in a local area to locate fossil evidence that can be combined with other rock evidence to interpret the geologic history of the area. Document the fieldwork and steps of the investigation. Present an analysis of the data and the interpretation of the geologic history.	Use a geologic cross-section (or conduct a field investigation) for a specific location to analyze/interpret geologic history (e.g., rock type, formation, fossils or minerals present) and environmental conditions (e.g., volcanic activity, transgressing and regressing sea levels). Use evidence (e.g., glacial maps) to describe climate changes which occurred in Ohio. Develop a 3D model that shows the geologic layers of the local area using data published by scientists. Research the glacial history of a specific location using data from the rock record, contemporary field data (research conducted and published by scientists) and/or glacial features that can be documented (e.g., maps, virtual aerial documentation, remote sensing data). Relate the history to contemporary evidence of changing climate. Examine a glacial map of Ohio to compare the northern counties with the southern counties. What features would you expect to find in each location? Explain why there could be differences in the absolute age determination of rock when different isotopes are used.	Describe fossils that are common to the local area and relate them to the geologic history of that region of Ohio. Explain how absolute age is determined using different radioactive isotopes. Select which isotopes would be best for dating rock in a particular location (e.g., bottom of Grand Canyon, rocks in a dinosaur dig). Describe the different divisions of geologic history and what specific events can be found within each division.

Physical Geology continued

PG.PT: PLATE TECTONICS
PG.PT.1: Internal Earth

- Seismic waves
    - S and P waves
    - Velocities, reflection, refraction of waves

PG.PT.2: Structure of Earth

- Asthenosphere
- Lithosphere
- Mohorovičić boundary (Moho)
- Composition of each of the layers of Earth
- Gravity, magnetism and isostasy
- Thermal energy (geothermal gradient and heat flow)

PG.PT.3: Historical review

- Paleomagnetism and magnetic anomalies
- Paleoclimatology

PG.PT.4: Plate motion

- Causes and evidence of plate motion
- Measuring plate motion
- Characteristics of oceanic and continental plates
- Relationship of plate movement and geologic events and features
- Mantle plumes

CONTENT ELABORATION: PLATE TECTONICS

This unit builds upon a variety of topics studied in middle school. In the Earth and Space Science strand, plate tectonics is studied in grade 8. Topics include plate motion (evidence and causes, characteristics of oceanic and continental plates), seismic waves, continental drift, seafloor spreading, the structure of Earth's surface and interior (including specific layers) and paleomagnetism. In the Life Science strand, fossils and depositional environments are included. In the Physical Science strand, density, convection, conductivity, motion, kinetic energy, radiometric dating, seismic waves, thermal energy, pressure and gravity are explored.

In this course, Earth's interior and plate tectonics are investigated at greater depth using models, simulations, actual seismic data, real-time data, satellite data and remote sensing. Relationships between energy, tectonic activity levels and earthquake or volcano predictions, and calculations to obtain the magnitude, focus and epicenter of an earthquake are included. Evidence and data analysis are key in understanding this part of the Earth system. For example, GIS/GPS and/or satellite data provide evidence for moving plates and changing landscapes (due to tectonic activity).

The causes for plate motion, the evidence of moving plates and the results of plate tectonics must be related to Earth's past, present and future. The use of evidence to support conclusions and predictions pertaining to plate motion is an important part of this unit.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.PT.1: Internal Earth			
Design model buildings to withstand earthquakes. Use shake tables to test the models. Refine designs based on test results. Compare designs within the class to evaluate to most effective design techniques.	Construct a three-dimensional model that illustrates plate subduction using earthquake foci depth data. Determine how an earthquake can cause the reversal of flow in a river using a project-based approach.	Determine the distance of an epicenter from a seismic station using travel time curves. Locate the epicenter of an earthquake by triangulation. Calculate the time of origin of an earthquake based on seismic data. Create a marketing pamphlet describing features of an earthquake resistant building/structure. Given earthquake and damage data (e.g., photos, reports, eyewitness accounts), rate each occurrence on the Mercalli scale. Create an approach for using this data to pinpoint the epicenter of the earthquake. Determine the rating of the earthquake on the Richter Scale using historic descriptions of earthquake occurrences.	Identify P, S, and surface waves on three-component seismograms. Identify the difference between reflection and refraction of seismic waves. Perform basic velocity calculations related to P and S wave speed.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.PT.2: Structure of Earth			
Research a specific area with active geologic processes or events. Develop a plan to harness the available energy (e.g., heat from magma, water movement) from the process. Build a working model using specific data from the location. Evaluate the efficiency of the type of energy chosen.		Provide evidence to dispute the hypothesis that Earth is homogeneous throughout.	Explain how seismic wave behavior helps scientists determine where Earth's interior layers are located.
PG.PT.3: Historical review			
		Use data to investigate the magnetic reversals and the resulting magnetic striping that occurs at oceanic ridges. Create a model demonstrating how paleomagnetic stripes on the seafloor provided clues to magnetic reversals of the planet. Create a seafloor profile using maps and depth charts to illustrate seafloor spreading. Create a chart or table using evidence from the rock record to document the pattern of climate change that has occurred throughout geologic time. Use scientific data to document periods of climate fluctuation. Evaluate patterns and cause and effect that may be evident in the research. Assemble a puzzle based on Pangaea and use it to explain the processes that separated Pangaea. Project future plate movement.	Explain the cause of seafloor spreading and continental drift.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Evaluate various methods used to map and collect samples from the seafloor. Explain how ancient ice, pollen and tree ring samples provide evidence of ancient climate changes on Earth.	
G.PT.4: Plate motion			
		Identify specific geologic features using LANDSAT or other remote sensing data. Identify the factors required to create the specific features. Create a 3-D working model of a real landform created by plate tectonics (e.g., faults, fault block mountains, volcanoes, rift valleys). Create a digital bulletin board or a 360 Google Map tour of a geologic feature created by plate tectonics. Use isotopic, petrological and/or geochemical evidence to identify motion at plate boundaries. Research the most recent measurements of North America. Using this data and the movement of North America throughout geologic time, predict where North America will be in 600 million years or more. Create a model to demonstrate that movement.	Identify characteristics of oceanic and continental plates using data. Correlate locations of volcanoes and earthquakes with plate boundaries. Identify plate motion as a cause for construction and destruction of landforms and surface features on Earth's crust. Explain how heat transfer causes plate motion. Explain the causes and evidence of plate motion.

Physical Geology continued

PG.ER: EARTH'S RESOURCES
PG.ER.1: Energy resources
- Renewable and nonrenewable energy sources and efficiency
- Alternate energy sources and efficiency
- Resource availability
- Mining and resource extraction

PG.ER.2: Air
- Primary and secondary contaminants
- Greenhouse gases

PG.ER.3: Water
- Potable water and water quality
- Hypoxia, eutrophication

PG.ER.4: Soil and sediment
- Desertification
- Mass wasting and erosion
- Sediment contamination

CONTENT ELABORATION: EARTH'S RESOURCES

This unit builds upon a variety of topics studied in previous courses. In elementary school, renewable/nonrenewable energy, soils, the atmosphere and water are introduced. In middle school, Earth's spheres, Earth's resources and energy resources are explored. At the high school level, water, air, chemistry and energy topics are studied. In this course, the Earth Resources topic should be looked at through the lens of geology when referring to renewable/non-renewable resources, air, water, soil, and energy.

In this course, renewable and nonrenewable energy resources topics investigate the effectiveness and efficiency for differing types of energy resources at a local, state, national and global level. Feasibility, availability and environmental cost are included in the extraction, storage, use and disposal of both abiotic and biotic resources. Modeling (3-D or virtual), simulations and real-world data are used to investigate energy resources and exploration. The emphasis is on current, actual data, contemporary science and technological advances in the field of energy resources.

Relating Earth's resources (e.g., energy, air, water, soil) to a global scale and using technology to collect global resource data for comparative classroom study is recommended. In addition, it is important to connect industry and the scientific community to the classroom to increase the depth of understanding. Critical thinking and problem-solving skills are important in evaluating resource use and conservation.

Smaller scale investigations, such as a field study to monitor stream quality, construction mud issues, storm water management, nonpoint source contamination problems (e.g., road-salt runoff, agricultural runoff, parking lot runoff) or thermal water contamination, can be useful in developing a deeper understanding of Earth's resources.

Earth systems are used to illustrate the interconnectedness of each of Earth's spheres (hydrosphere, lithosphere, atmosphere and biosphere) and the relationship between each type of Earth's resources.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.ER.1: Energy resources			
Design and build (virtual, blueprint or 3-D model) an Eco-House that uses green technology and allows the house to be off-grid. Select a specific location and evaluate the different options that would be efficient and effective for that area.			Compare mineral uses versus availability and demand. Identify different energy resources as renewable and non-renewable.
PG.ER.2: Air			
Design a technology to remove either particulate or chemical pollutants from air. Collect samples of air to investigate a local contamination issue. Recommend ways to reduce or prevent contamination based on scientific data and research.	Determine the amount and size of particulate matter in the air at the school or community. Analyze the results using information from the Environmental Protection Agency and the Department of Health (e.g., lung diseases, including emphysema and asthma). Locate specific Ohio data for comparative analysis. Report class findings and recommendations orally or in written form to school administrators or community leaders. Survey the indoor school environment for the presence of ozone using Schoenbein's papers prepared in class.	Describe the components and processes involved in the generation of photochemical smog. Describe positive and negative feedback loops that impact the greenhouse effect and climate change.	Describe the characteristics of each layer of the atmosphere, including any benefits to or uses by humans. Describe how the atmosphere and the oceans interact to sequester atmospheric carbon.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.ER.3: Water			
Investigate different methods (e.g., aeration, filtration) for removing pollutants from water. Design, build and test water filters. Collect samples of water to investigate a local contamination issue. Recommend ways to reduce or prevent contamination based on scientific data and research.		Deconstruct the events leading up to a fish kill in a local river, given data including times, locations, and eye-witness accounts. Use topographic maps to decide on an area to locate wells or a reservoir for drinking water for a city.	
PG.ER.4: Soil and sediment			
Collect samples of soil to investigate a local contamination issue. Recommend ways to reduce or prevent contamination based on scientific data and research. Build a model construction site and use it to develop techniques to manage storm water runoff and construction mud.	Construct a model to explore how soil type (e.g., sand, silt, clay), water content and slope affect severity of landslides. Create a topographic, soil or geologic map of the school or community using actual data collected from the field (e.g., GPS/GIS readings, field investigation, aerial maps). Present a final map in a poster session, along with data used in the development of the map and an analysis of the data.	Describe the steps of desertification and identify areas on a globe that represent each of the transitions.	Identify types of mass wasting that are present in the local area.

Physical Geology continued

PG.GG: GLACIAL GEOLOGY
PG.GG.1: Glaciers and glaciation

- Evidence of past glaciers (including features formed through erosion or deposition)
- Glacial deposition and erosion (including features formed through erosion or deposition)
- Data from ice cores
  - Historical changes (glacial ages, amounts, locations, particulate matter, correlation to fossil evidence)
  - Evidence of climate changes throughout Earth's history
- Glacial distribution and causes of glaciation
- Types of glaciers – continental (ice sheets, ice caps), alpine/valley (piedmont, valley, cirque, ice caps)
- Glacial structure, formation and movement

CONTENT ELABORATION: GLACIAL GEOLOGY

This unit builds upon a variety of topics previously studied. In fourth grade, Earth's surface (landforms and features, including glacial geology) is introduced. In middle school, igneous, metamorphic and sedimentary rocks, sediment and soils, the geologic record and Earth's history are studied. The cryosphere and the relationship of the analysis of ice cores in understanding changes in climate over thousands of years is also introduced. Fossils and fossil evidence within the geologic record is found in the Life Science strand, building from second grade through high school biology.

An emphasis for this unit is tracing and tracking glacial history and present-day data for Ohio, the United States and globally. Scientific data found in the analysis of the geologic record, ice cores and surficial geology should be used to provide the evidence for changes that have occurred over the history of Earth and are observable in the present day. New discoveries, mapping projects, research, contemporary science and technological advances are included in the study of glacial geology. The focus should be on the geologic processes and the criteria for movement. Modeling and simulations (3-D or virtual) can be used to illustrate glacial movement and the resulting features.

Field investigations to map and document evidence of glaciers in the local area (if applicable) or virtual investigations can help demonstrate the resulting glacial features and the impact that ice has had on the surface of Earth throughout history. Real-time data (using remote sensing, satellite, GPS/GIS, aerial photographs/maps) can help support this topic.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.GG.1: Glaciers and glaciation			
	Design an investigation to determine/evaluate how changes in slope, substrate and temperature affect glacial flow dynamics.	Use Google Earth to identify locations of features created by glaciers. Take or find pictures of the features and add them to Google Earth in the correct locations. Develop a model to reconstruct glacial history that includes resulting features (e.g., U-shaped valleys, moraines, tills, kettles, eskers, erratics, outwash). Use the model to explain the processes.	Recognize and identify different types of glaciers and glacial features using aerial photographs, LANDSAT data, surficial geology maps or topographic maps. Identify topographic features in Ohio and explain the geological processes involved in creating those features.