Westerville City Schools
Geology
Course of Study
Course Number: SC411

Course Description

Geology focuses on Earth's history, materials, processes, and resources as integrated components in a larger system, including volcanoes, earthquakes, glaciers, oceanography, mountain building, weathering, erosion and plate tectonics. The course includes historical and structural geology; the impact of natural disasters on societies, as well as human impact on Earth's features and resources, will also be studied. Geology involves "learning by doing" and incorporates scientific practices such as inquiry, experimental design, the use of models, data analysis, critical thinking, and using evidence to construct and communicate explanations.

Recommended Grade Levels:	10, 11, 12
Course Length:	1 period; full year
Credit:	1.0 Physical Science or Advanced Earth Science
Course Weighting:	1.0

Course Rationale

To uphold the district's mission and foster college and career readiness, Geology provides opportunities to develop highly transferable skills in collaboration, communication, creativity, and scientific critical thinking which are relevant for any post-secondary coursework or career. This Geology curriculum will enhance students' content knowledge and inquiry-based problem solving skills while learning how geology affects their daily lives. It will improve students' abilities to innovate, deepen math and science skills, strengthen students' communication abilities and academic literacy skills, and foster interest in future advanced science courses.

Considerations for Cultural Relevancy, Inclusivity, and Diversity

Where possible teachers will create opportunities to incorporate the histories, values, beliefs and perspectives of people from different cultural backgrounds to meet the needs of all learners. Strategies for meeting the needs of all learners including gifted students, English Language Learners and students with disabilities can be found at this ODEW site.

Considerations for Intervention and Acceleration

This rigorous and highly relevant curriculum is built upon high quality, research-based instructional strategies.Teachers may need to provide targeted Tier II support (e.g., remediation of particular skills and concepts, as well as scaffolded or supplemental instruction) beyond the Tier I level of universal instruction to underachieving students. Intensive and individualized Tier III instruction (e.g., skill-specific intervention, one-on-one support).

Course Information

How and why is Earth constantly changing? How do Earth's surface processes and human activities affect each other?		
	Topics of Study	**Estimated Time (weeks)**
1	Geology Overview/Nature of Science	1-2
2	Mineralogy	3-5
3	Weathering, Erosion, and Sedimentary Rocks	2-3
4	Historical Geology	4
5	Structural Geology	2-3
6	Metamorphism and Metamorphic Rocks	2-3
7	Volcanism and Igneous Rocks	3
8	Glaciology	2
9	Oceanography	2-3
10	Geologic Resources and Economics	3-4

Topic of Study # 1 Geology Overview/Nature of Science
(Estimated time: 1-2 weeks)

Content Statements	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. Geology is the science that deals with the earth's physical structure and substance, its history, and the processes that act on it.
Content Elaborations	Science is a way of knowing about the world based on evidence from experimentation and observations. Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation. Scientific theories are based on a body of scientific evidence; science explanations can change based on new scientific evidence. Scientifically literate students ● know, use, and interpret scientific explanations of the natural world; ● generate and evaluate scientific evidence and explanations; ● understand the nature and development of scientific knowledge; and ● participate productively in scientific practices and discourse. The scientific practices allow students to <u>use</u> science content they have acquired. They involve doing something and learning something in such a way that the doing and learning cannot really be separated. Students learn <u>how</u> to do science while learning <u>about</u> science. When students engage in scientific practices, activities and lessons become the basis for learning about experiments, data and evidence, social discourse, models and tools, and mathematics and for developing the ability to evaluate knowledge claims, conduct empirical investigations, and develop explanations.
Essential Question	How do we know what we know about geology?
Enduring Understanding	Geologists ask questions, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations, engage in argument from evidence, and obtain, evaluate, and communicate information.
Vocabulary	constant, control, dependent variable, independent variable, inference, objective, observation
Learning Targets	I can ● Develop a testable question. ● Interpret models to help explain scientific concepts. ● Create and revise models to demonstrate science concepts. ● Explain and follow basic safety rules to perform lab activities. ● Select the correct pieces of equipment for a particular investigation. ● Identify the control, constants, independent and dependent variables in an experiment. ● Analyze charts and graphs for patterns and trends. ● Interpret charts and graphs looking for evidence to support claims. ● Create charts and graphs with collected data.

	• Use appropriate mathematics, tools and techniques to gather data and information. • Recognize and analyze alternative explanations and predictions. • Distinguish between an observation and an inference. • Explain why it is important to examine data objectively. • Explain why scientists can not allow bias to affect the interpretation of the results of an experiment. • Evaluate the credibility of scientific information from multiple sources. • Communicate scientific information through a variety of media.
Instructional Strategies	Scientific practices are included and incorporated with geologic content. The nature of science is intentionally integrated throughout content units rather than taught or experienced as a stand-alone unit.
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.

Topic of Study # 2 Mineralogy
(Estimated time: 3-5 weeks)

Content Statements	**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 Elaborations	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.
Essential Questions	How does understanding the properties of minerals help us to identify them? How are geographic location, formation environments, global economics related to our understanding of minerals?
Enduring Understanding	Understanding mineral properties and formation provides insight to natural resources' impact on global economics.
Vocabulary	cleavage, covalent bond, crystalline structure, fluorescence, luster, malleability, Moh's hardness scale, streak
Learning Targets	I can ● 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. ● Explain how crystalline structure relates to a mineral's properties as well as its use and application in daily life. ● Identify types of bonds present in each mineral group/family. ● Categorize crystalline shapes (7) and list what minerals would be found in each category. ● Explain why specific crystalline structures are different from each other. ● 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.

	● Differentiate between cleavage and fracture. ● Test a mineral for hardness (Mohs Scale), malleability and streak. ● Determine the best use of a mineral based on observable properties.
Instructional Strategies	● Conduct tests to differentiate between ionically and covalently bonded materials. ● Design a 3-D model of the different types of chemical bonding. ● 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). ● 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. ● Plan and conduct an investigation to determine the specific gravity of minerals.
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.

Topic of Study # 3 Weathering, Erosion, and Sedimentary Rocks
(Estimated time: 2-3 weeks)

Content Statements	**PG.IMS: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS** PG.IMS.3: Sedimentary • Division of sedimentary rocks and minerals (chemical, clastic/physical, organic) • Depositional environments
Content Elaborations	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 structures and features. 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 include the fossil fuels found in Ohio, nationally and globally. 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.
Essential Questions	What causes changes to landscapes where we live? How do we know what has happened to a landscape in the past?
Enduring Understandings	Interactions between Earth's systems have been and will continue to shape landscapes where we live. Understanding characteristics and features of sedimentary rocks provides insight into past environments.
Key Concepts/ Vocabulary	agents of erosion, biological weathering, chemical weathering, deposition, dissolution, erosion, exfoliation, fossil fuel, frost wedging, hydrolysis, oxidation, physical (mechanical) weathering, thermal expansion, weathering
Learning Targets	I can ● Identify and classify sedimentary rocks based on characteristics. ● Describe the depositional environment for various samples of sedimentary rocks. ● Use fossils found in sedimentary rock to determine changes in sea level over geologic time. ● Evaluate the ability of various sedimentary rocks to transport fluids (e.g., groundwater, oil, natural gas). ● Define sediment and sedimentary rocks. ● Explain the lithification process. ● Differentiate between cementation and compaction. ● Use particle size to distinguish between detrital sedimentary rocks. ● Describe the two ways in which chemical sediments are precipitated to form chemical sedimentary rocks. ● Discuss clastic texture as it pertains to detrital rocks.

	● Explain the classification system for chemical sedimentary rocks and identify common types. ● Describe how weathering, mass wasting, and erosion change geologic structures. ● Differentiate between mechanical vs chemical weathering. ● Identify factors contributing to the rate of weathering.
Instructional Strategies	● Create a dichotomous key allowing for the identification of various sedimentary rocks. ● Design a mining method (large or small scale) that allows material to be removed without collapse.
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.

Topic of Study # 4 Historical Geology
(Estimated time: 4 weeks)

Content Statements	**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 Elaborations	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.
Essential Questions	How does our understanding of geologic processes active today help us to understand Earth's past? How have gradual and catastrophic processes impacted Earth's historical biodiversity?

Enduring Understandings	Understanding geologic processes active in the modern world is crucial to interpreting Earth's past. Components of Earth's systems may appear stable, change slowly over long periods of time, or change abruptly with significant consequences on biodiversity.
Vocabulary	absolute age, cross-cutting, cross-section, eon, era, horizontality, isotope, radioactive decay, radiometric dating, regression, relative age, superposition, transgression
Learning Targets	I can ● 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. ● Justify why certain isotopes would be better than others 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. ● Explain why there could be differences in the absolute age determination of rock when different isotopes are used. ● Use historical and contemporary evidence to explain changes in Earth's climate.
Instructional Strategies	● Develop a 3D model that shows the geologic layers of the local area using data published by scientists. ● 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).
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.

Topic of Study # 5 Structural Geology
(Estimated time: 2-3 weeks)

Content Statements	**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 • 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 • 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 Elaborations	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.

Essential Question	How have scientists' use of instruments, observation, and prior knowledge helped us to understand Earth's internal processes and their impacts on Earth's external features?
Enduring Understanding	Knowledge of Earth's interior structure helps us to understand external features.
Vocabulary	asthenosphere, continental drift, continental plate, convection currents, convergent boundary, density, divergent boundary, epicenter, fault lines, isostatic, lithosphere, mantle plume, Mercalli scale, Mohorovicic boundary, oceanic plate, P wave, paleoclimatology, paleomagnetism, plate boundaries, reflection, refraction, S wave, sea floor spreading, seismic waves, transform boundary, triangulation
Learning Targets	I can ● 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. ● 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. ● 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. ● Explain how seismic wave behavior helps scientists determine where Earth's interior layers are located. ● Explain the cause of seafloor spreading and continental drift. ● Explain evidence to dispute the hypothesis that Earth is homogeneous throughout. ● Use data to investigate the magnetic reversals and the resulting magnetic striping that occurs at oceanic ridges. ● 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. ● 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. ● Use isotopic, petrological and/or geochemical evidence to identify motion at plate boundaries.
Instructional Strategies	● Create a marketing pamphlet describing features of an earthquake resistant building/structure. ● Construct a three-dimensional model that illustrates plate subduction using earthquake foci depth data. ● 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 the most effective design techniques. ● 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. ● 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. ● 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.
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.

Topic of Study # 6 Metamorphism and Metamorphic Rocks
(Estimated time: 2-3 weeks)

Content Statements	**PG.IMS: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS** PG.IMS.2: Metamorphic • Pressure, stress, temperature and compressional forces • Foliated (regional), non-foliated (contact), (coarse vs fine grained) • Parent rock and degrees of metamorphism • Metamorphic zones (where metamorphic rocks are found)
Content Elaborations	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 metamorphic 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 include the fossil fuels found in Ohio, nationally and globally. 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. 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.
Essential Questions	What causes changes to landscapes where we live? How do we know what has happened to a landscape in the past?
Enduring Understanding	Interactions between Earth's systems have been and will continue to shape landscapes where we live. Understanding characteristics and features of metamorphic rocks provides insight into past environments.
Vocabulary	coarse-grained, compressional force, fine-grained, foliated, metamorphism, non-foliated
Learning Targets	I can ● Identify characteristics of different classifications of metamorphic rocks. ● Sort metamorphic rocks by the grade of metamorphism. ● Describe the conditions under which various metamorphic rocks were formed from parent material. ● Use observational and analytical skills to identify metamorphic rocks.

Instructional Strategies	● Create a dichotomous key allowing for the identification of various metamorphic rocks. ● Construct a series of models to demonstrate the various ways metamorphic rocks form.
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.

Topic of Study # 7 Volcanism and Igneous Rocks
(Estimated time: 3 weeks)

Content Statements	**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, Mohorovičić discontinuity, crust) • Magnetic reversals and Earth's magnetic field • Thermal energy within Earth • Extrusive (volcanic activity, volcanoes: cinder cones, composite, shield) • Bowen's Reaction Series (continuous and discontinuous branches)
Content Elaborations	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 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. 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. 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.
Essential Questions	What causes changes to landscapes where we live? How do we know what has happened to a landscape in the past?
Enduring Understanding	Interactions between Earth's systems have been and will continue to shape landscapes where we live. Understanding characteristics and features of igneous rocks provides insight into past environments.

Vocabulary	basalt, batholith, Bowen's reaction series, cinder cone, composite volcano, dike, diorite, extrusive, felsic, gabbro, geode, granite, igneous, intrusive, limestone, mafic, Mohorovicic discontinuity, obsidian, pegmatite, pumice, quartzite, sandstone, scoria, shield volcano, sill
Learning Targets	I can • Identify characteristics of different classifications of igneous rocks. • Describe the conditions under which various igneous rocks were formed. • Use observational and analytical skills to identify igneous rocks. • Identify types of volcanoes and their impact on the environment around them
Instructional Strategies	• 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.
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.

Topic of Study # 8 Glaciology
(Estimated time: 2 weeks)

Content Statements	**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 Elaborations	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.
Essential Questions	How do glaciers shape the landscape with their movement and types? How can glaciology help us to understand historical climate?
Enduring Understandings	Ohio's geography and geology is heavily based on the movement of glaciers throughout time. The more we learn about glaciers the better understanding we have of Earth's climatic history.
Vocabulary	alpine glacier, cirque, continental glacier, erratic, esker, fjord, kettle lake, moraine, outwash, piedmont, striation, till
Learning Targets	I can ● 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.

	● 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. ● Examine a glacial map of Ohio to differentiate features found in northern and southern counties.
Instructional Strategies	● 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. ● 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.
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.

Topic of Study # 9 Oceanography
(Estimated time: 2-3 weeks)

Content Statements	**PG.IMS: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS** 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)
Content Elaborations	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. 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.
Essential Question	How do short and long term interactions between the lithosphere, hydrosphere, and atmosphere affect Earth's features today?
Enduring Understanding	The ocean helps shape Earth's features and plays a significant role in both historical and current climate and weather patterns.
Vocabulary	abyssal zone, alluvial fan, channel, cross-bedding, diurnal, ebb current, delta, deposition, El Nino, fetch, floodplain, flow current, La Nina, longshore current, neap tide, regression, ridge, rip current, semidiurnal, shelf, slope, spring tide, transgression, trench
Learning Targets	I can ● Compare and contrast continental crust versus oceanic crust. ● Explain why the age of oceanic crust increases with distance away from either side of a divergent plate boundary. ● Explain the origins of oceanic trenches and volcanic island arcs. ● Explain the significance of hot spots. ● Describe the development of a coral atoll. ● List some of the prominent geologic and topographic features of the ocean basins.

	- Sketch the cross-sectional profile of the continental margin. - Distinguish among the continental shelf, slope, and rise. - Identify the various features around and within a stream system using Google Earth. - Describe how the density of seawater varies with temperature and salinity. - Label the various components of an ocean wave. - Describe how fetch and wind duration affect the evolution of an ocean wave. - Compare and contrast deep-water waves and shallow-water waves. - Explain the origin of astronomical tides. - Explain how tides are predicted. - Describe the general pattern of wind-driven surface ocean currents in the Atlantic Ocean. - Explain why the direction of Ekman transport reverses between the Northern and Southern Hemispheres. - Distinguish between coastal upwelling and downwelling. - Describe the development of longshore currents. - Compare and contrast the characteristics of continental-margin deposits with those of deep-ocean deposits. - Describe how a delta forms.
Instructional Strategies	- 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. - Map major ocean currents and identify various types of currents. - Map major trenches, ridges and island systems in each ocean. - Construct a model to explain the development of an El Niño or La Niña event and explain how thermal energy shifts alter local and regional conditions. - Use aerial photos to explain changes in river paths.
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.

Topic of Study # 10 Geologic Resources and Economics
(Estimated time: 2-3 weeks)

Content Statements	**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 gasses 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 Elaborations	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, stormwater 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.
Essential Questions	How are humans and Earth's systems inextricably interconnected? How do our local decisions have a global impact on Earth's resources?
Enduring Understanding	Humans and Earth's systems are inextricably interconnected.
Vocabulary	contamination, desertification, energy, eutrophication, feedback loop, greenhouse gas, hypoxia, mass wasting, non-renewable, renewable, non-renewable, photochemical smog, potable
Learning Targets	I can ● Compare mineral uses versus availability and demand. ● Identify different energy resources as renewable and non-renewable. ● 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. ● 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. ● Deconstruct the events leading up to a fish kill in a local river, given data including times, locations, and eyewitness accounts. ● Use topographic maps to decide on an area to locate wells or a reservoir for drinking water for a city. ● Identify types of mass wasting that are present in the local area. ● Describe the steps of desertification and identify areas on a globe that represent each of the transitions.
Instructional Strategies	● 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. ● 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. ● 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. ● 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 stormwater runoff and construction mud.
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.

Ohio's Learning Standards for Literacy in Science

Teachers should incorporate Ohio's Learning Standards for Literacy in Science throughout the course.

Reading

By the end of the course, students should be reading, comprehending, and responding to science/technical texts in the appropriate grade level complexity band independently and proficiently.

Key Ideas

1. Cite specific textual evidence to support analysis of science and technical texts.
2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Craft and Structure

1. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to high school texts and topics.
2. Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g. force, friction, reaction force, energy).
3. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

Integration of Knowledge and Ideas

1. Translate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g. in a flowchart, diagram, model, graph, or table) and translate information expressed visually or mathematically into words.
2. Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
3. Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Writing

Text Types and Purposes

1. Write arguments focused on discipline-specific content.
   a. Establish a clear and thorough thesis to present an argument.
   b. Introduce precise claim(s), distinguish claims from alternate or opposing claims, and create an organization that establishes clear relationships among the claims, counterclaims, reasons, and evidence.
   c. Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline appropriate form and in a manner that anticipates the audience's knowledge level and concerns.
   d. Use words, phrases, and clauses to link major sections of text, create cohesion and clarify the relationships among claims, counterclaims, reasons, and evidence.
   e. Establish and maintain a formal style and objective tone.
   f. Provide a concluding statement or section that follows from and supports the argument presented.

2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
    a. Establish a clear and thorough thesis to present information.
    b. Introduce a topic clearly, previewing what is to follow; organize ideas, concepts, and information into broader categories as appropriate to achieving purpose, including graphics (e.g. charts, tables), formatting (e.g. headings), and multimedia when useful to aid in comprehension.
    c. Develop the topic with relevant, well-chosen facts, definitions, concrete details, quotations, or other information and examples.
    d. Use appropriate and varied transitions to create cohesion and clarify the relationships among ideas and concepts.
    e. Use precise language and domain-specific vocabulary to inform about or explain the topic.
    f. Establish and maintain a formal style and objective tone.
    g. Provide a concluding statement or section that follows from and supports the information or explanation presented.

Production and Distribution of Writing
1. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
2. Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
3. Use technology to produce, publish, and update writing.

Research to Build and Present Knowledge
1. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
2. Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
3. Draw evidence from informational texts to support analysis, reflection and research.
4. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

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