Alignment to Michigan Educational Standards-
Earth Science

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Standard E1	**INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS**						
Statement E1.1	**Scientific Inquiry** Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.						
E1.1A	Generate new questions that can be investigated in the laboratory or field.						
E1.1B	Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.						
E1.1C	Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).						
E1.1D	Identify patterns in data and relate them to theoretical models.						
E1.1E	Describe a reason for a given conclusion using evidence from an investigation.						
E1.1f	Predict what would happen if the variables, methods, or timing of an investigation were changed.						
E1.1g	Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation.						
E1.1h	Design and conduct a systematic scientific						

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	investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.						
E1.1i	Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.						
Statement E1.2	**Scientific Reflection and Social Implications** The integrity of the scientific process depends on scientists and citizens understanding and respecting the "Nature of Science." Openness to new ideas, skepticism, and honesty are attributes required for good scientific practice. Scientists must use logical reasoning during investigation design, analysis, conclusion, and communication. Science can produce critical insights on societal problems from a personal and local scale to a global scale. Science both aids in the development of technology and provides tools for assessing the costs, risks, and benefits of technological systems. Scientific conclusions and arguments play a role in personal choice and public policy decisions. New technology and scientific discoveries have had a major influence in shaping human history. Science and technology continue to offer diverse and significant career opportunities.						
E1.2A	Critique whether or not specific questions can be answered through scientific investigations.						
E1.2B	Identify and critique arguments about personal or societal issues based on scientific evidence.						
E1.2C	Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.						
E1.2D	Evaluate scientific explanations in a peer review process or discussion format.						

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E1.2E	Evaluate the future career and occupational prospects of science fields.						
E1.2f	Critique solutions to problems, given criteria and scientific constraints.						
E1.2g	Identify scientific tradeoffs in design decisions and choose among alternative solutions.						
E1.2h	Describe the distinctions between scientific theories, laws, hypotheses, and observations.						
E1.2i	Explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core knowledge.						
E1.2j	Apply science principles or scientific data to anticipate effects of technological design decisions.						
E1.2k	Analyze how science and society interact from a historical, political, economic, or social perspective.						
Standard E2	**EARTH SYSTEMS**						
Statement E2.1	**Earth Systems Overview** The Earth is a system consisting of four major interacting components: geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of geochemical cycles.						
E2.1A	Explain why the Earth is essentially a closed system in terms of matter.						
E2.1B	Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.						
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.						
Statement E2.2	**Energy in Earth Systems** Energy in Earth systems can exist in a						

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	number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth's systems, is driven by Earth's internal (radioactive decay and gravity) and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.						
E2.2A	Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).						
E2.2B	Identify differences in the origin and use of renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.						
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.						
E2.2D	Identify the main sources of energy to the climate system.						
E2.2e	Explain how energy changes form through Earth systems.						
E2.2f	Explain how elements exist in different compounds and states as they move from one reservoir to another.						
Statement E2.3	**Biogeochemical Cycles** The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different states and chemical forms; they move within and between the geosphere, atmosphere, hydrosphere, and biosphere as part of the Earth system. The movements can be slow or rapid. Elements and compounds have						

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	significant impacts on the biosphere and have important impacts on human health.						
E2.3A	Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life) within Earth systems and how those forms can be beneficial or harmful to humans.						
E2.3b	Explain why small amounts of some chemical forms may be beneficial for life but are poisonous in large quantities (e.g., dead zone in the Gulf of Mexico, Lake Nyos in Africa, fluoride in drinking water).						
E2.3c	Explain how the nitrogen cycle is part of the Earth system.						
E2.3d	Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.						
Statement E2.4	**Resources and Human Impacts on Earth Systems** The Earth provides resources (including minerals) that are used to sustain human affairs. The supply of non-renewable natural resources is limited and their extraction and use can release elements and compounds into Earth systems. They affect air and water quality, ecosystems, landscapes, and may have effects on long-term climate. Plans for land use and long-term development must include an understanding of the interactions between Earth systems and human activities.						
E2.4A	Describe renewable and nonrenewable sources of energy for human consumption (electricity, fuels), compare their effects on the environment, and include overall costs and benefits.						
E2.4B	Explain how the impact of human activities on the environment (e.g., deforestation, air pollution, coral reef destruction) can be understood through the analysis of interactions between the four Earth systems.						
E2.4c	Explain ozone depletion in the stratosphere and methods to slow human activities to						

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	reduce ozone depletion.						
E2.4d	Describe the life cycle of a product, including the resources, production, packaging, transportation, disposal, and pollution.						
Standard E3	**THE SOLID EARTH**						
Statement E3.p1	**Landforms and Soils *(prerequisite)*** Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruptions, and deposition of sediments transported in rivers, streams, and lakes through watersheds. Destructive forces include weathering and erosion. The weathering of rocks and decomposed organic matter result in the formation of soils. *(prerequisite)*						
E3.p1A	Explain the origin of Michigan landforms. Describe and identify surface features using maps and satellite images. *(prerequisite)*						
E3.p1B	Explain how physical and chemical weathering leads to erosion and the formation of soils and sediments. *(prerequisite)*						
E3.p1C	Describe how coastal features are formed by wave erosion and deposition. *(prerequisite)*						
Statement E3.p2	**Rocks and Minerals *(prerequisite)*** Igneous, metamorphic, and sedimentary rocks are constantly forming and changing through various processes. As they do so, elements move through the geosphere. In addition to other geologic features, rocks and minerals are indicators of geologic and environmental conditions that existed in the past. *(prerequisite)*						
E3.p2A	Identify common rock-forming minerals (quartz, feldspar, biotite, calcite, hornblende). *(prerequisite)*						

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E3.p2B	Identify common igneous (granite, basalt, andesite, obsidian, pumice), metamorphic (schist, gneiss, marble, slate, quartzite), and sedimentary (sandstone, limestone, shale, conglomerate) rocks and describe the processes that change one kind of rock to another. *(prerequisite)*						
Statement E3.p3	**Basic Plate Tectonics *(prerequisite)*** Early evidence for the movement of continents was based on the similarities of coastlines, geology, faunal distributions, and paleoclimatelogical data across the Atlantic and Indian Oceans. In the 1960s, additional evidence from marine geophysical surveys, seismology, volcanology, and paleomagnetism resulted in the development of the theory of plate tectonics. *(prerequisite)*						
E3.p3A	Describe geologic, paleontologic, and paleoclimatalogic evidence that indicates Africa and South America were once part of a single continent.						
E3.p3B	Describe the three types of plate boundaries (divergent, convergent, and transform) and geographic features associated with them (e.g., continental rifts and mid-ocean ridges, volcanic and island arcs, deep-sea trenches, transform faults).						
E3.p3C	Describe the three major types of volcanoes (shield volcano, stratovolcano, and cinder cones) and their relationship to the Ring of Fire.						
Statement E3.1	**Advanced Rock Cycle** Igneous, metamorphic, and sedimentary rocks are indicators of geologic and environmental conditions and processes that existed in the past. These include cooling and crystallization, weathering and erosion, sedimentation and lithification, and metamorphism. In some way, all of these processes are influenced by plate tectonics, and some are influenced by climate.						

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E3.1A	Discriminate between igneous, metamorphic, and sedimentary rocks and describe the processes that change one kind of rock into another.						
E3.1B	Explain the relationship between the rock cycle and plate tectonics theory in regard to the origins of igneous, sedimentary, and metamorphic rocks.						
E3.1c	Explain how the size and shape of grains in a sedimentary rock indicate the environment of formation (including climate) and deposition.						
E3.1d	Explain how the crystal sizes of igneous rocks indicate the rate of cooling and whether the rock is extrusive or intrusive.						
E3.1e	Explain how the texture (foliated, nonfoliated) of metamorphic rock can indicate whether it has experienced regional or contact metamorphism.						
Statement E3.2	**Interior of the Earth** The Earth can also be subdivided into concentric layers based on their physical characteristics: (lithosphere, asthenosphere, lower mantle, outer core, and inner core). The crust and upper mantle compose the rigid lithosphere (plates) that moves over a “softer” asthenosphere (part of the upper mantle). The magnetic field of the Earth is generated in the outer core. The interior of the Earth cannot be directly sampled and must be modeled using data from seismology.						
E3.2A	Describe the interior of the Earth (in terms of crust, mantle, and inner and outer cores) and where the magnetic field of the Earth is generated.						
E3.2B	Explain how scientists infer that the Earth has interior layers with discernable properties using patterns of primary (*P*) and secondary (*S*) seismic wave arrivals.						
E3.2C	Describe the differences between oceanic and continental crust (including density, age, composition).						
E3.2d	Explain the uncertainties associated with models of the interior of the Earth and how these models are validated.						

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Statement E3.3	**Plate Tectonics Theory** The Earth's crust and upper mantle make up the lithosphere, which is broken into large mobile pieces called tectonic plates. The plates move at velocities in units of centimeters per year as measured using the global positioning system (GPS). Motion histories are determined with calculations that relate rate, time, and distance of offset geologic features. Oceanic plates are created at mid-ocean ridges by magmatic activity and cooled until they sink back into the Earth at subduction zones. At some localities, plates slide by each other. Mountain belts are formed both by continental collision and as a result of subduction. The outward flow of heat from Earth's interior provides the driving energy for plate tectonics.						
E3.3A	Explain how plate tectonics accounts for the features and processes (sea floor spreading, mid-ocean ridges, subduction zones, earthquakes and volcanoes, mountain ranges) that occur on or near the Earth's surface.						
E3.3B	Explain why tectonic plates move using the concept of heat flowing through mantle convection, coupled with the cooling and sinking of aging ocean plates that result from their increased density.						
E3.3C	Describe the motion history of geologic features (e.g., plates, Hawaii) using equations relating rate, time, and distance.						
E3.3d	Distinguish plate boundaries by the pattern of depth and magnitude of earthquakes.						
E3.r3e	Predict the temperature distribution in the lithosphere as a function of distance from the mid-ocean ridge and how it relates to ocean depth. *(recommended)*						
E3.r3f	Describe how the direction and rate of movement for the North American plate has affected the local climate over the last 600 million years. *(recommended)*						
Statement E3.4	**Earthquakes and Volcanoes** Plate motions result in potentially catastrophic events (earthquakes, volcanoes, tsunamis, mass wasting) that						

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	affect humanity. The intensity of volcanic eruptions is controlled by the chemistry and properties of the magma. Earthquakes are the result of abrupt movements of the Earth. They generate energy in the form of body and surface waves.						
E3.4A	Use the distribution of earthquakes and volcanoes to locate and determine the types of plate boundaries.						
E3.4B	Describe how the sizes of earthquakes and volcanoes are measured or characterized.						
E3.4C	Describe the effects of earthquakes and volcanic eruptions on humans.						
E3.4d	Explain how the chemical composition of magmas relates to plate tectonics and affects the geometry, structure, and explosivity of volcanoes.						
E3.4e	Explain how volcanoes change the atmosphere, hydrosphere, and other Earth systems.						
E3.4f	Explain why fences are offset after an earthquake, using the elastic rebound theory.						
Standard E4	**THE FLUID EARTH**						
Statement E4.p1	**Water Cycle *(prerequisite)*** Water circulates through the crust and atmosphere and in oceans, rivers, glaciers, and ice caps and connects all of the Earth systems. Groundwater is a significant reservoir and source of freshwater on Earth. The recharge and movement of groundwater depends on porosity, permeability, and the shape of the water table. The movement of groundwater occurs over a long period time. Groundwater and surface water are often interconnected. *(prerequisite)*						
E4.p1A	Describe that the water cycle includes evaporation, transpiration, condensation, precipitation, infiltration, surface runoff, groundwater, and absorption. *(prerequisite)*						
E4.p1B	Analyze the flow of water between the elements of a watershed, including surface features (lakes, streams, rivers, wetlands) and groundwater. *(prerequisite)*						
E4.p1C	Describe the river and stream types,						

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	features, and process including cycles of flooding, erosion, and deposition as they occur naturally and as they are impacted by land use decisions. *(prerequisite)*						
E4.p1D	Explain the types, process, and beneficial functions of wetlands.						
Statement E4.p2	**Weather and the Atmosphere *(prerequisite)*** The atmosphere is divided into layers defined by temperature. Clouds are indicators of weather. *(prerequisite)*						
E4.p2A	Describe the composition and layers of the atmosphere. *(prerequisite)*						
E4.p2B	Describe the difference between weather and climate. *(prerequisite)*						
E4.p2C	Explain the differences between fog and dew formation and cloud formation. *(prerequisite)*						
E4.p2D	Describe relative humidity in terms of the moisture content of the air and the moisture capacity of the air and how these depend on the temperature. *(prerequisite)*						
E4.p2E	Describe conditions associated with frontal boundaries (cold, warm, stationary, and occluded). *(prerequisite)*						
E4.p2F	Describe the characteristics and movement across North America of the major air masses and the jet stream. *(prerequisite)*						
E4.p2G	Interpret a weather map and describe present weather conditions and predict changes in weather over 24 hours. *(prerequisite)*						
E4.p2H	Explain the primary causes of seasons. *(prerequisite)*						

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E4.p2I	Identify major global wind belts (trade winds, prevailing westerlies, and polar easterlies) and that their vertical components control the global distribution of rainforests and deserts. *(prerequisite)*						
Statement E4.p3	**Glaciers *(prerequisite)*** Glaciers are large bodies of ice that move under the influence of gravity. They form part of both the rock and water cycles. Glaciers and ice sheets have shaped the landscape of the Great Lakes region. Areas that have been occupied by ice sheets are depressed. When the ice sheet is removed, the region rebounds (see also climate change). *(prerequisite)*						
E4.p3A	Describe how glaciers have affected the Michigan landscape and how the resulting landforms impact our state economy. *(prerequisite)*						
E4.p3B	Explain what happens to the lithosphere when an ice sheet is removed. *(prerequisite)*						
E4.p3C	Explain the formation of the Great Lakes. *(prerequisite)*						
Statement E4.1	**Hydrogeology** Fresh water moves over time between the atmosphere, hydrosphere (surface water, wetlands, rivers, and glaciers), and geosphere (groundwater). Water resources are both critical to and greatly impacted by humans. Changes in water systems will impact quality, quantity, and movement of water. Natural surface water processes shape the landscape everywhere and are affected by human land use decisions.						
E4.1A	Compare and contrast surface water systems (lakes, rivers, streams, wetlands) and groundwater in regard to their relative sizes as Earth's freshwater reservoirs and the dynamics of water movement (inputs and outputs, residence times, sustainability).						
E4.1B	Explain the features and processes of groundwater systems and how the sustainability of North American aquifers has changed in recent history (e.g., the past						

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	100 years) qualitatively using the concepts of recharge, residence time, inputs, and outputs.						
E4.1C	Explain how water quality in both groundwater and surface systems is impacted by land use decisions.						
Statement E4.2	**Oceans and Climate** Energy from the Sun and the rotation of the Earth control global atmospheric circulation. Oceans redistribute matter and energy around the Earth through currents, waves, and interaction with other Earth systems. Ocean currents are controlled by prevailing winds, changes in water density, ocean topography, and the shape and location of landmasses. Oceans and large lakes (e.g., Great Lakes) have a major effect on climate and weather because they are a source of moisture and a large reservoir of heat. Interactions between oceanic circulation and the atmosphere can affect regional climates throughout the world.						
E4.2A	Describe the major causes for the ocean's surface and deep water currents, including the prevailing winds, the Coriolis effect, unequal heating of the earth, changes in water temperature and salinity in high latitudes, and basin shape.						
E4.2B	Explain how interactions between the oceans and the atmosphere influence global and regional climate. Include the major concepts of heat transfer by ocean currents, thermohaline circulation, boundary currents, evaporation, precipitation, climatic zones, and the ocean as a major CO2 reservoir.						
E4.2c	Explain the dynamics (including ocean-atmosphere interactions) of the El Niño-Southern Oscillation (ENSO) and its effect on continental climates.						
E4.2d	Identify factors affecting seawater density and salinity and describe how density affects oceanic layering and currents.						
E4.2e	Explain the differences between maritime and continental climates with regard to						

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	oceanic currents.						
E4.2f	Explain how the Coriolis effect controls oceanic circulation.						
E4.r2g	Explain how El Niño affects economies (e.g., in South America). *(recommended)*						
Statement E4.3	**Severe Weather** Tornadoes, hurricanes, blizzards, and thunderstorms are severe weather phenomena that impact society and ecosystems. Hazards include downbursts (wind shear), strong winds, hail, lightning, heavy rain, and flooding. The movement of air in the atmosphere is due to differences in air density resulting from variations in temperature. Many weather conditions can be explained by fronts that occur when air masses meet.						
E4.3A	Describe the various conditions of formation associated with severe weather (thunderstorms, tornadoes, hurricanes, floods, waves, and drought).						
E4.3B	Describe the damage resulting from and the social impact of thunderstorms, tornadoes, hurricanes, and floods.						
E4.3C	Describe severe weather and flood safety and mitigation.						
E4.3D	Describe the seasonal variations in severe weather.						
E4.3E	Describe conditions associated with frontal boundaries that result in severe weather (thunderstorms, tornadoes, and hurricanes).						
E4.3F	Describe how mountains, frontal wedging (including dry lines), convection, and convergence form clouds and precipitation.						
E4.3g	Explain the process of adiabatic cooling and adiabatic temperature changes to the formation of clouds.						
Standard E5	**THE EARTH IN SPACE AND TIME**						
Statement E5.p1	**Sky Observations *(prerequisite)*** Common sky observations (such as lunar phases) can be explained by the motion of solar system objects in regular and predictable patterns. Our galaxy, observable as the Milky Way, is composed						

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	of billions of stars, some of which have planetary systems. Seasons are a result of the tilt of the rotation axis of the Earth. The motions of the moon and Sun affect the phases of the moon and ocean tides. *(prerequisite)*						
E5.p1A	Describe the motions of various celestial bodies and some effects of those motions. *(prerequisite)*						
E5.p1B	Explain the primary cause of seasons. *(prerequisite)*						
E5.p1C	Explain how a light year can be used as a distance unit. *(prerequisite)*						
E5.p1D	Describe the position and motion of our solar system in our galaxy. *(prerequisite)*						
Statement E5.1	**The Earth in Space** Scientific evidence indicates the universe is orderly in structure, finite, and contains all matter and energy. Information from the entire light spectrum tells us about the composition and motion of objects in the universe. Early in the history of the universe, matter clumped together by gravitational attraction to form stars and galaxies. According to the Big Bang theory, the universe has been continually expanding at an increasing rate since its formation about 13.7 billion years ago.						
E5.1A	Describe the position and motion of our solar system in our galaxy and the overall scale, structure, and age of the universe.						
E5.1b	Describe how the Big Bang theory accounts for the formation of the universe.						
E5.1c	Explain how observations of the cosmic microwave background have helped determine the age of the universe.						
E5.1d	Differentiate between the cosmological and Doppler red shift.						
Statement E5.2	**The Sun** Stars, including the Sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. Solar energy is responsible for life processes and weather as well as phenomena on Earth. These and other						

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	processes in stars have led to the formation of all the other chemical elements.						
E5.2A	Identify patterns in solar activities (sunspot cycle, solar flares, solar wind).						
E5.2B	Relate events on the Sun to phenomena such as auroras, disruption of radio and satellite communications, and power grid disturbances.						
E5.2C	Describe how nuclear fusion produces energy in the Sun.						
E5.2D	Describe how nuclear fusion and other processes in stars have led to the formation of all the other chemical elements.						
Statement E5.2x	**Stellar Evolution** Stars, including the Sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. These and other processes in stars have led to the formation of all the other chemical elements. There is a wide range of stellar objects of different sizes and temperatures. Stars have varying life histories based on these parameters.						
E5.2e	Explain how the Hertzsprung-Russell (H-R) diagram can be used to deduce other parameters (distance).						
E5.2f	Explain how you can infer the temperature, life span, and mass of a star from its color. Use the H-R diagram to explain the life cycles of stars.						
E5.2g	Explain how the balance between fusion and gravity controls the evolution of a star (equilibrium).						
E5.2h	Compare the evolution paths of low- moderate-, and high-mass stars using the H-R diagram.						
Statement E5.3	**Earth History and Geologic Time** The solar system formed from a nebular cloud of dust and gas 4.6 Ga (billion years ago). The Earth has changed through time and has been affected by both catastrophic (e.g., earthquakes, meteorite impacts, volcanoes) and gradual geologic events (e.g., plate movements, mountain building) as well as the effects of biological						

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	evolution (formation of an oxygen atmosphere). Geologic time can be determined through both relative and absolute dating.						
E5.3A	Explain how the solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 Ga (billion years ago).						
E5.3B	Describe the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them.						
E5.3C	Relate major events in the history of the Earth to the geologic time scale, including formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.						
E5.3D	Describe how index fossils can be used to determine time sequence.						
Statement E5.3x	**Geologic Dating** Early methods of determining geologic time, such as the use of index fossils and stratigraphic principles, allowed for the relative dating of geological events. However, absolute dating was impossible until the discovery that certain radioactive isotopes in rocks have known decay rates, making it possible to determine how many years ago a given mineral or rock formed. Different kinds of radiometric dating techniques exist. Technique selection depends on the composition of the material to be dated, the age of the material, and the type of geologic event that affected the material.						
E5.3e	Determine the approximate age of a sample, when given the half-life of a radioactive substance (in graph or tabular form) along with the ratio of daughter to parent substances present in the sample.						
E5.3f	Explain why C-14 can be used to date a 40,000 year old tree but U-Pb cannot.						
E5.3g	Identify a sequence of geologic events using relative age dating principles.						
Statement E5.4	**Climate Change** Atmospheric gases trap solar energy that						

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	has been reradiated from the Earth's surface (the greenhouse effect). The Earth's climate has changed both gradually and catastrophically over geological and historical time frames due to complex interactions between many natural variables and events. The concentration of greenhouse gases (especially carbon dioxide) has increased due to human industrialization which has contributed to a rise in average global atmospheric temperatures and changes in the biosphere, atmosphere, and hydrosphere. Climates of the past are researched, usually using indirect indicators, to better understand and predict climate change.						
E5.4A	Explain the natural mechanism of the greenhouse effect including comparisons of the major greenhouse gases (water vapor, carbon dioxide, methane, nitrous oxide, and ozone).						
E5.4B	Describe natural mechanisms that could result in significant changes in climate (e.g., major volcanic eruptions, changes in sunlight received by the earth, meteorite impacts).						
E5.4C	Analyze the empirical relationship between the emissions of carbon dioxide, atmospheric carbon dioxide levels and the average global temperature over the past 150 years.						
E5.4D	Based on evidence of observable changes in recent history and climate change models, explain the consequences of warmer oceans (including the results of increased evaporation, shoreline and estuarine impacts, oceanic algae growth, and coral bleaching) and changing climatic zones (including the adaptive capacity of the biosphere).						
E5.4e	Based on evidence from historical climate research (e.g., fossils, varves, ice core data) and climate change models, explain how the current melting of polar ice caps can impact the climatic system .						
E5.4f	Describe geologic evidence that implies climates were significantly colder at times						

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	in the geologic record (e.g., geomorphology, striations, and fossils).						
E5.4g	Compare and contrast the heat-trapping mechanisms of the major greenhouse gases resulting from emissions (carbon dioxide, methane, nitrous oxide, fluorocarbons) as well as their abundance and heat trapping capacity.						
E5.r4h	Use oxygen isotope data to estimate paleotemperature. *(recommended)*						
E5.r4i	Explain the causes of short-term climate changes such as catastrophic volcanic eruptions and impact of solar system objects. *(recommended)*						
E5.r4j	Predict the global temperature increase by 2100, given data on the annual trends of CO2 concentration increase. *(recommended)*						