Mr. Brown's Science Labs

Earth & Space Science

Geologic History of Earth

Cluster Question Assessment

Tectonic Plates • Earth's Water • Mass Extinctions • Time Periods • Earth's Oxygen

Student Name:	_____
Class Period:	_____
Date:	_____
Teacher:	Mr. Brown

Learning Objectives

- Explain how cyanobacteria and the Great Oxidation Event changed Earth's atmosphere.
- Describe the leading hypotheses for how Earth obtained its water.
- Use evidence from rocks, fossils, and landmasses to support plate tectonic theory and the formation of Pangaea.
- Identify the five major mass extinction events and their causes.
- Use the ESRT to interpret the geologic history of New York State.

Total Points Possible: 31 points

5 cluster questions × 5 questions each (25 points) + 6 reading-response items (6 points). Each multiple-choice or constructed-response question is worth 1 point. A final grade is calculated on the last page.

Aligned with NYS Earth & Space Sciences Reference Tables (2024 Edition). Question formats reference NYSED Regents Exams: June 2025, August 2025, January 2026.

Searchable Tags & Standards Alignment

Topic Tags:

geologic history, plate tectonics, pangaea, supercontinent, mass extinction, permian extinction, k-pg extinction, cretaceous extinction, dinosaur extinction, great oxidation event, GOE, cyanobacteria, stromatolites, banded iron formations, BIF, photosynthesis, archean, proterozoic, paleozoic, mesozoic, cenozoic, earth's water origin, volcanic outgassing, comets asteroids water, hydrosphere formation, huronian glaciation, snowball earth, geologic time scale, ESRT page 6, ESRT page 7, new york state geology, taconic orogeny, acadian orogeny, alleghenian orogeny, grenville orogeny, NYS regents earth science, regents earth space science, cluster questions, regents review, mr brown science labs, letchworth gorge, adirondacks, long island, finger lakes

NGSS & NYS Standards:

• **HS-ESS1-5**: Evaluate evidence of past and current movements of continental and oceanic crust.

• **HS-ESS1-6**: Apply scientific reasoning to construct an account of Earth's formation and early history.

• **HS-ESS2-1**: Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales.

• **HS-ESS2-7**: Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

• **HS-LS4-1**: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

• **NYS ESS**: Geologic Time Scale, Important Geologic Events in NY, Inferred Positions of Earth's Landmasses (ESRT pp. 6–7).

Regents Question Types Mimicked (from January 2026 Exam):

• Q1 — Three-statement X-box completion

• Q2 — "Which combination of statements" multiple-choice

• Q6 — Three-statement X-box completion (factor identification)

• Q9 — Claim-evidence multiple-choice

• Q14 — Observation-based mineral/feature identification

• Q16 — Letter-fill-in completion (A–F choice format)

• Q19 — Sequence + justification constructed response

• Q22 — Support / Refute claim with justification

CLUSTER 1 — How Earth Got Its Oxygen

The Great Oxidation Event & Banded Iron Formations

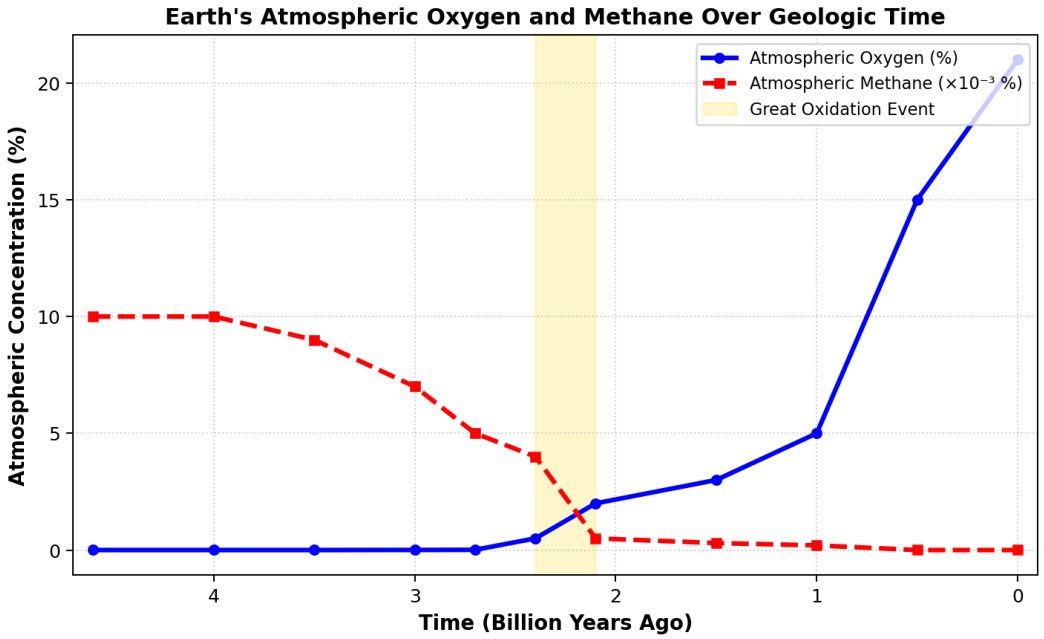
Base your answers to questions **1 through 5** on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the 2024 Edition Reference Tables for Earth and Space Sciences (ESRT, pages 6 and 7).

The Great Oxidation Event

For the first 2 billion years of Earth's history, the atmosphere contained virtually no free oxygen. Earth's early atmosphere was rich in methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), and water vapor. Around 2.7 Ga (billion years ago), photosynthesizing microbes called **cyanobacteria** evolved in shallow seas. These organisms built layered, dome-shaped structures called **stromatolites** and produced oxygen as a byproduct of photosynthesis.

For nearly 300 million years, the oxygen produced by cyanobacteria was absorbed by dissolved iron in the ocean. This iron reacted with oxygen to form iron oxide (rust), which sank to the ocean floor and produced **banded iron formations (BIFs)** — sedimentary rocks containing alternating dark and light layers of iron-rich and iron-poor minerals. Once the dissolved ocean iron was used up, free oxygen began escaping into the atmosphere. This rapid rise of atmospheric oxygen between 2.4 and 2.1 Ga is called the **Great Oxidation Event (GOE)**.

The Great Oxidation Event triggered Earth's earliest known ice age — the **Huronian glaciation**. Atmospheric oxygen reacted with methane (a powerful greenhouse gas), reducing methane levels in the atmosphere. With less methane to trap heat, Earth's surface cooled dramatically. This is direct evidence that the evolution of life caused major changes to Earth's atmosphere and climate — the co-evolution of Earth's systems.



Graph 1: Earth's atmospheric oxygen and methane through geologic time.

Cluster 1 Questions (1–5)

1 Complete each of the three statements below to correctly describe the Great Oxidation Event by placing an **X** in the box to indicate which phrase correctly completes each statement. **[1 pt]**

Statement 1: Atmospheric oxygen on early Earth was first produced by

☐	photosynthesizing cyanobacteria living in shallow seas
☐	volcanic outgassing of free oxygen from the mantle

Statement 2: Banded iron formations are evidence of the Great Oxidation Event because they formed when

☐	free oxygen reacted with dissolved iron in seawater
☐	iron-rich sediments were deposited by glacial ice on land

Statement 3: The rise in atmospheric oxygen led to the Huronian ice age because

☐	methane levels decreased and less heat was trapped in the atmosphere
☐	carbon dioxide levels increased and more heat escaped to space

Several statements about the Great Oxidation Event are listed below.

Statement 1: Cyanobacteria produced free oxygen as a byproduct of photosynthesis.

Statement 2: Most of the early oxygen produced by cyanobacteria escaped directly into the atmosphere.

Statement 3: Banded iron formations contain alternating iron-rich and iron-poor layers.

Statement 4: The Great Oxidation Event occurred during the Mesozoic Era.

Statement 5: The reaction of oxygen with methane in the atmosphere triggered the Huronian glaciation.

Statement 6: Stromatolites are first-evidence structures built by photosynthetic microbes.

2 Which three statements correctly summarize evidence and effects of the Great Oxidation Event? **[1 pt]**

(1) Statements 1, 3, 5

(2) Statements 2, 3, 4

(3) Statements 1, 4, 6

(4) Statements 2, 5, 6

3 Complete each of the three statements below to correctly identify the factors involved in the co-evolution of Earth's atmosphere and life by placing an **X** in the correct box. **[1 pt]**

Statement 1: Evidence that oxygen first accumulated in the ocean before the atmosphere is provided by

	the formation of banded iron formations on the ocean floor
	fossilized stromatolites discovered on dry land in the Adirondacks

Statement 2: One cause of the Huronian ice age was a decrease in

	the amount of atmospheric methane (a greenhouse gas)
	the average distance from Earth to the Sun

Statement 3: The increase in atmospheric oxygen between 2.4 and 2.1 Ga is best classified as

	a change to Earth's atmosphere caused by living organisms
	a change to Earth's atmosphere caused by asteroid impacts

Cluster 1 Questions (continued)

A geology student found an unusual sedimentary rock at a site in northern Minnesota. They recorded the following observations about the rock:

- **A.** The rock contains alternating dark red and light gray layers (banding).
- **B.** The dark layers are magnetic and contain large amounts of iron oxide.
- **C.** The rock formed in deep marine water.
- **D.** Radiometric dating gives an age of approximately 2.5 billion years.
- **E.** The rock contains stromatolite fossils, but no shells or vertebrate fossils.
- **F.** The minerals are softer than glass and easily scratched.

4 Based on the student's observations and the information from the reading, which set of observations and rock identification is most correct? **[1 pt]**

(1) Observations A, B, and D identify a banded iron formation.

(2) Observations C, E, and F identify a coal seam.

(3) Observations A, D, and F identify a glacial dropstone.

(4) Observations B, C, and E identify a basalt lava flow.

5 Earth's surface processes cause changes to Earth's atmosphere over time. Past changes produced conditions that led to future events. Using the information provided in the reading and graph, place the list of events below in the correct temporal sequence to complete the graphic organizer. **Justify** your sequence using one piece of evidence from the reading. **[1 pt]**

Events:

• Banded iron formations begin to form on the ocean floor

• Cyanobacteria evolve in shallow seas

• The Huronian glaciation begins

• Atmospheric oxygen levels rise rapidly (Great Oxidation Event)

• Free oxygen reacts with atmospheric methane

OLDEST
1.
2.
3.
4.
5.
YOUNGEST

Justification:

CLUSTER 2 — How Earth Got Its Water

Volcanic Outgassing, Comets, and the Formation of Earth's Oceans

Base your answers to questions **6 through 10** on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the 2024 Edition Reference Tables for Earth and Space Sciences.

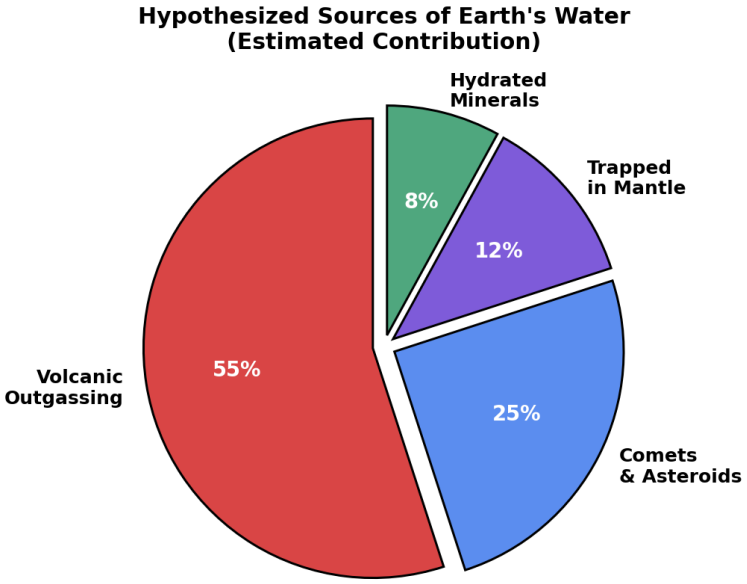
The Origin of Earth's Water

Earth formed approximately **4.6 billion years ago** from a collapsing cloud of gas and dust called the solar nebula. Early Earth was extremely hot and any water present at the surface would have boiled away into space. So how did our planet end up covered in oceans? Geochemists have developed three primary hypotheses to explain the source of Earth's water.

Hypothesis 1: Volcanic Outgassing. Water vapor was trapped inside Earth's mantle during planet formation. As Earth cooled, volcanoes erupted continuously and released this water vapor, along with carbon dioxide and other gases, into the atmosphere. As the planet cooled below 100 °C, the water vapor condensed and rained down for millions of years, filling the ocean basins around **4.0 billion years ago**.

Hypothesis 2: Comets and Asteroids. The early solar system was filled with icy comets and water-rich asteroids that bombarded Earth during the Late Heavy Bombardment (4.1–3.8 Ga). These objects delivered frozen water to Earth's surface. Scientists test this hypothesis by comparing the ratio of **deuterium** (heavy hydrogen) to regular hydrogen in seawater versus in comets and asteroids.

Hypothesis 3: Solar Nebula Capture. Hydrogen gas from the early solar nebula combined directly with oxygen in Earth's mantle to form water. Most scientists today believe Earth's water came from a **combination** of all three sources, with volcanic outgassing as the largest contributor.



Graph 2: Estimated relative contributions to Earth's water budget.

Cluster 2 Questions (6–10)

6 Complete each of the three statements below to correctly describe how Earth got its water by placing an **X** in the box to indicate which phrase correctly completes each statement. **[1 pt]**

Statement 1: Earth's oceans first appeared on the planet's surface approximately

☐	4.0 billion years ago after Earth's surface cooled below 100 °C
☐	550 million years ago at the start of the Cambrian explosion of life

Statement 2: Volcanic outgassing released water into Earth's atmosphere when

☐	trapped water vapor inside Earth's mantle escaped through erupting volcanoes
☐	ocean water evaporated and was pushed upward by tectonic plate movement

Statement 3: Scientists compare deuterium-to-hydrogen ratios in seawater and comets to

☐	test the hypothesis that comets delivered some of Earth's water
☐	determine the age of fossils preserved in oceanic sediments

A geochemist makes the claim below:

> *"Comets and asteroids delivered all of Earth's water to the planet during the Late Heavy Bombardment."*

7 Which statement provides the most correct evidence to **refute** this claim? **[1 pt]**

(1) The deuterium-to-hydrogen ratio in seawater is identical to the ratio in all measured comets.

(2) Earth's mantle contains no trapped water, so all surface water must have arrived from space.

(3) The deuterium-to-hydrogen ratio in seawater only partially matches some comets, suggesting multiple sources contributed water.

(4) The Late Heavy Bombardment delivered iron and silicate rock, but did not deliver any volatile compounds such as water.

8 Write the correct letter from the choices below on the line at the end of each statement to complete each sentence about the formation of Earth's hydrosphere. **[1 pt]**

Choices for Statement 1:	**A** – released water vapor and carbon dioxide trapped inside Earth's mantle **B** – removed water from the atmosphere by absorbing it into igneous rock
Choices for Statement 2:	**C** – condensed and rained down for millions of years to form oceans **D** – evaporated immediately because Earth's surface remained too hot to retain liquid water
Choices for Statement 3:	**E** – delivered additional water and organic compounds from the outer solar system **F** – removed surface water by causing it to escape into the vacuum of space

Statement 1: Volcanic outgassing during the Hadean Eon _____.

Statement 2: Once Earth's surface cooled below 100 °C, atmospheric water vapor _____.

Statement 3: Comets and water-rich asteroids striking Earth during the Late Heavy Bombardment _____.

Cluster 2 Questions (continued)

Several statements about the formation of Earth's oceans are listed below.

Statement 1: Earth formed approximately 4.6 billion years ago from a collapsing solar nebula.

Statement 2: Earth's first oceans formed during the Cenozoic Era, after the dinosaurs went extinct.

Statement 3: Volcanic outgassing released water vapor that condensed to form oceans around 4.0 Ga.

Statement 4: All of Earth's water arrived in a single comet impact 3.5 billion years ago.

Statement 5: Comparing deuterium ratios in comets and seawater is one method scientists use to test water-origin hypotheses.

Statement 6: Most scientists today accept that Earth's water came entirely from outgassing, with no contribution from comets.

9 Which three statements correctly summarize the formation of Earth's oceans? **[1 pt]**

(1) Statements 1, 3, and 5

(2) Statements 2, 4, and 6

(3) Statements 1, 4, and 5

(4) Statements 3, 4, and 6

10 A student makes the following claim:

> *"Earth must have been hot enough during its earliest history to prevent any liquid water from existing at the surface during the planet's first 500 million years."*

Place a check mark (✓) in either the **Support** or **Refute** box below to indicate if the given information supports or refutes the student's claim. **Justify** your response using evidence from the reading. **[1 pt]**

☐ **Support**

☐ **Refute**

Justification:

_____

_____

_____

_____

CLUSTER 3 — Plate Tectonics & Pangaea

The Supercontinent Cycle and the Geologic Story of NY

Base your answers to questions **11 through 15** on the information below and on your knowledge of Earth and Space Sciences. Use the 2024 Edition ESRT, especially pages 6, 7, and 12 (Global Tectonic Activity).

The Supercontinent Cycle

Earth's continents are not fixed in place. Driven by convection currents in the mantle, the rigid **lithospheric plates** that make up Earth's surface slowly drift, collide, and break apart. Over hundreds of millions of years, this motion has assembled and broken up **supercontinents** multiple times — a pattern called the **supercontinent cycle**.

The most recent supercontinent, **Pangaea**, formed approximately 300 million years ago when North America collided with Africa, Europe, and South America. This collision is recorded in New York State's bedrock as the **Alleghenian orogeny**, which built the Appalachian Mountains. Around 200 million years ago, Pangaea began to break apart and the Atlantic Ocean opened — an event also recorded in New York's geologic record by the **intrusion of the Palisades Sill**.

Evidence supporting the supercontinent cycle is found across Earth's continents: matching coastlines between South America and Africa, identical rock layers and orogenic belts on opposite sides of the Atlantic, distributions of fossils such as *Mesosaurus* across now-separated landmasses, and glacial deposits whose striations point in directions impossible for present-day continental positions. The **Mid-Atlantic Ridge** currently separates these continents at a rate of approximately 2.5 cm/year.

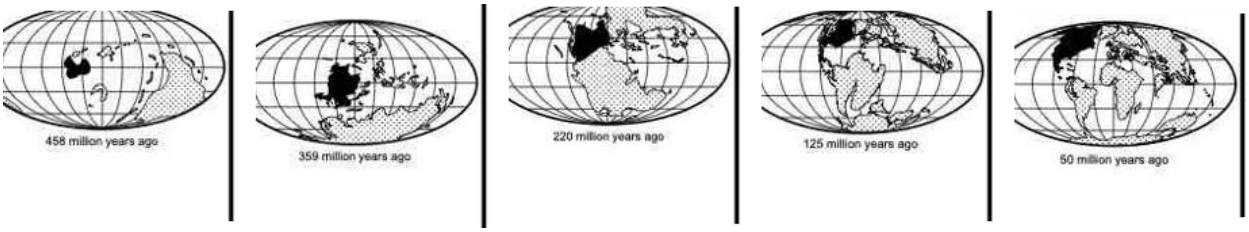
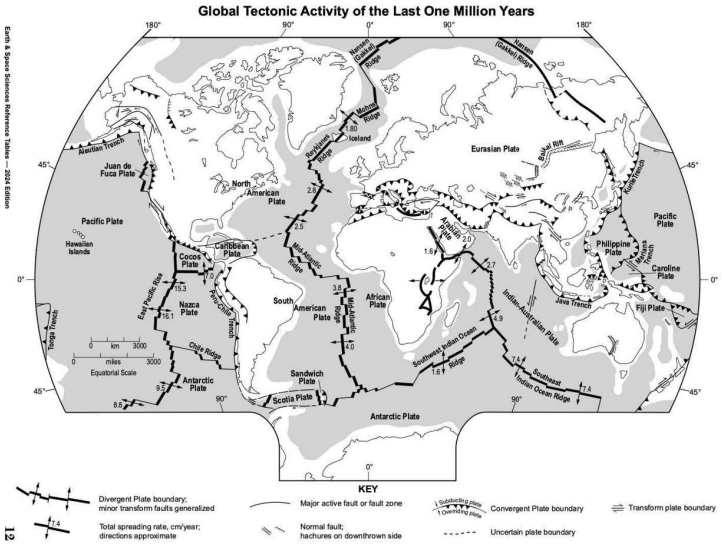


Diagram 1: Inferred positions of Earth's landmasses through geologic time (ESRT page 7).



ESRT page 12: Global Tectonic Activity of the Last One Million Years.

Cluster 3 Questions (11–15)

11 Complete each of the three statements below to correctly describe evidence for plate tectonics by placing an **X** in the box to indicate which phrase correctly completes each statement. **[1 pt]**

Statement 1: Pangaea formed approximately 300 million years ago when

	North America collided with Africa during the Alleghenian orogeny
	the Atlantic Ocean first began to widen at the Mid-Atlantic Ridge

Statement 2: Matching *Mesosaurus* fossils on the coasts of South America and Africa support the claim that

	these continents were once joined as part of a supercontinent
	Mesosaurus could swim across the entire Atlantic Ocean

Statement 3: The Mid-Atlantic Ridge is best classified as a

	divergent plate boundary where the Atlantic Ocean is widening
	convergent plate boundary where ocean crust is being subducted

Several statements about plate tectonics and Pangaea are listed below.

Statement 1: The Atlantic Ocean has been widening at approximately 2.5 cm per year.

Statement 2: Pangaea was the only supercontinent ever to exist on Earth.

Statement 3: The Alleghenian orogeny in New York records the collision that formed Pangaea.

Statement 4: Continents are stationary; only the ocean floor moves.

Statement 5: The intrusion of the Palisades sill in New York records the breakup of Pangaea.

Statement 6: Glacial striations on now-separated continents point in directions only possible if they were once connected.

12 Which three statements correctly support the supercontinent cycle and plate tectonic theory? **[1 pt]**

(1) Statements 2, 4, and 6

(2) Statements 1, 3, 5

(3) Statements 2, 3, 5

(4) Statements 1, 4, and 6

Cluster 3 Questions (continued)

13 Complete each of the three statements below to correctly describe the evidence used to reconstruct Pangaea by placing an **X** in the correct box. **[1 pt]**

Statement 1: Evidence for the past position of New York during Pangaea is provided by

	the Allegheny orogeny mountain belt that now extends across NY and Pennsylvania
	the alluvial fans currently forming along the Mohawk River in central NY

Statement 2: Other than fossils, evidence for the breakup of Pangaea is provided by

	the matching ages of igneous rocks on opposite sides of the Atlantic Ocean
	the distribution of glacial moraines on Long Island deposited 18,000 years ago

Statement 3: The current widening of the Atlantic Ocean at approximately 2.5 cm/year is best explained by

	seafloor spreading driven by mantle convection at the Mid-Atlantic Ridge
	ocean currents that erode coastlines and move tectonic plates apart

A geology student examined a rock sample from the Hudson Highlands of southeastern New York. They recorded the following observations:

- **A.** The rock is a strongly foliated metamorphic gneiss.
- **B.** The rock contains marine fossils similar to those found in modern Atlantic coastal sediments.
- **C.** Radiometric dating indicates an age of approximately 1,100 million years.
- **D.** The rock shows mineral alignment indicating it was deformed by intense pressure.
- **E.** The rock contains volcanic glass that has not been weathered.
- **F.** Original sedimentary protolith was deposited along the edge of a large continent.

14 Based on the student's observations and the ESRT, which set of observations correctly identifies the geologic event that produced this rock? **[1 pt]**

(1) Observations B and E identify rocks formed during the Mesozoic breakup of Pangaea.

(2) Observations A, C, D, and F identify rocks formed during the Grenville orogeny.

(3) Observations B, E, and F identify rocks formed during the Quaternary glaciation.

(4) Observations A, B, and E identify rocks formed during the Cenozoic uplift of the Adirondacks.

15 Using the ESRT (page 7) and the reading, place the New York State geologic events below in the correct temporal sequence from **oldest to youngest**. **Justify** your sequence using one piece of evidence. **[1 pt]**

Events:

• Intrusion of the Palisades sill (Pangaea begins to break up)

• Taconian orogeny (closing of the western Iapetus Ocean)

• Alleghenian orogeny (formation of Pangaea)

• Grenville orogeny (formation of metamorphic rocks of the Adirondacks)

• Acadian orogeny (formation of the Catskill delta)

OLDEST
1.
2.
3.
4.
5.
YOUNGEST

Justification:

_____

_____

CLUSTER 4 — Mass Extinction Events

The Big Five & Their Effects on Life

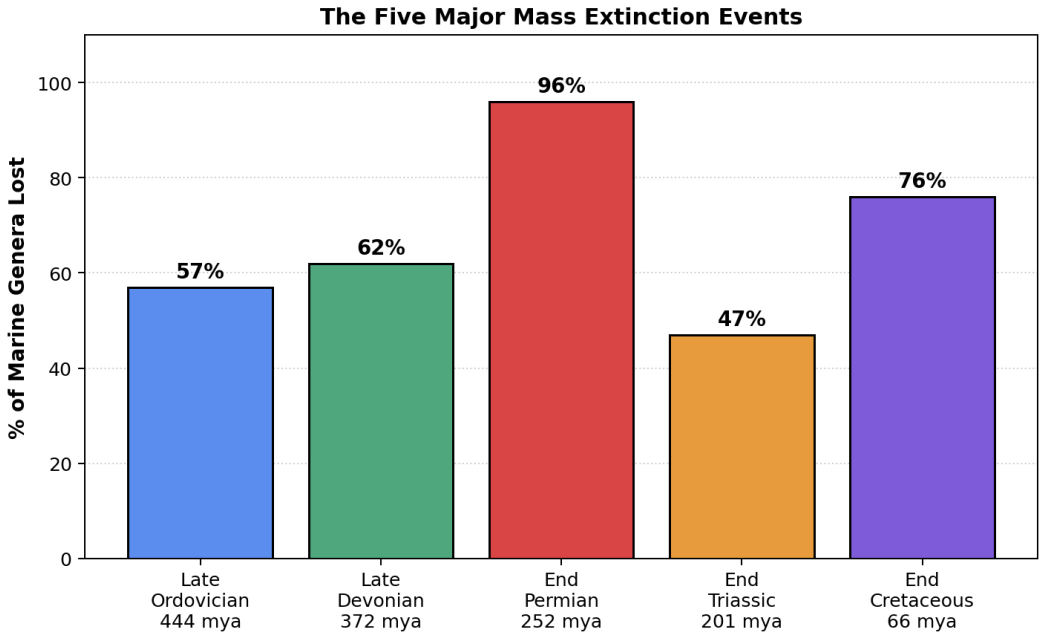
Base your answers to questions **16 through 20** on the information below and on your knowledge of Earth and Space Sciences. Use the 2024 Edition ESRT, especially pages 6 and 7.

The Big Five Mass Extinctions

Throughout Earth's history, life has been disrupted by five major **mass extinction events**. During each of these events, more than 40% of all marine genera became extinct in a relatively short period of geologic time. Mass extinctions are caused by major changes in Earth's atmosphere, hydrosphere, biosphere, or geosphere — and they reset the course of evolution by clearing the way for new groups of organisms to dominate.

The most severe extinction was the **End-Permian** event 252 million years ago, which wiped out approximately 96% of all marine species. Massive volcanic eruptions in Siberia released enormous amounts of CO_2, causing rapid global warming and ocean acidification. The most famous extinction is the **End-Cretaceous** (K-Pg) event 66 million years ago, when an asteroid roughly 10 km wide struck the Yucatán Peninsula. The impact ejected dust and sulfate aerosols into the atmosphere, blocking sunlight, halting photosynthesis, and ending the reign of the non-avian dinosaurs.

Evidence of the K-Pg extinction is preserved in a thin worldwide rock layer rich in **iridium** — an element rare on Earth's surface but common in asteroids. Many scientists today warn that human activities, including habitat destruction and rapid CO_2 release, may be driving Earth toward a **sixth mass extinction**.



Graph 3: The Big Five mass extinction events and the percent of marine genera lost.

Cluster 4 Questions (16–20)

16 Complete each of the three statements below to correctly describe evidence for the End-Cretaceous (K-Pg) mass extinction by placing an **X** in the box to indicate which phrase correctly completes each statement. **[1 pt]**

Statement 1: The K-Pg extinction occurred approximately

☐	66 million years ago at the boundary between the Mesozoic and Cenozoic Eras
☐	252 million years ago at the boundary between the Paleozoic and Mesozoic Eras

Statement 2: The leading cause of the K-Pg extinction was

☐	an asteroid impact that ejected dust and aerosols into the atmosphere
☐	a series of glaciations that froze Earth's oceans completely

Statement 3: Evidence supporting the asteroid impact hypothesis is provided by

☐	a worldwide rock layer enriched in iridium, an element common in asteroids
☐	a worldwide layer of coal containing fossilized non-avian dinosaur footprints

Cluster 4 Questions (continued)

A student makes the claim below:

> *"The End-Permian mass extinction was more severe than the End-Cretaceous mass extinction."*

17 Using the graph and reading, which statement provides the most correct evidence to **support** this claim? **[1 pt]**

(1) The End-Permian event killed about 76% of marine genera, while the End-Cretaceous event killed about 96%.

(2) The End-Permian event killed about 96% of marine genera, while the End-Cretaceous event killed about 76%.

(3) Both extinction events killed an equal percentage of all life on Earth, so neither was more severe.

(4) The End-Cretaceous event was more severe because it killed all of Earth's reptiles, including modern lizards and snakes.

A field geologist examined sedimentary rock at the K-Pg boundary in Italy. They recorded the following observations about a thin rock layer:

- **A.** The thin layer is approximately 1 cm thick and clay-rich.
- **B.** The layer contains shocked quartz grains and microscopic glass spherules.
- **C.** The layer is enriched in iridium 30 times more than surrounding rock.
- **D.** Below the layer, fossils of large reptilian footprints are abundant.
- **E.** Above the layer, the abundance of large reptile fossils sharply decreases.
- **F.** Radiometric dating gives an age of approximately 66 million years.

18 Based on the student's observations and the reading, which set of observations correctly identifies the rock layer? **[1 pt]**

(1) Observations A and B identify a layer formed by ordinary river sediment deposition.

(2) Observations B, C, and F identify a layer formed by an asteroid impact at the K-Pg boundary.

(3) Observations D and E identify a coal seam from a buried tropical forest.

(4) Observations A and F identify a glacial moraine from the most recent ice age.

19 Write the correct letter from the choices below on the line at the end of each statement to complete each sentence about the End-Cretaceous (K-Pg) extinction. **[1 pt]**

Choices for Statement 1:	**A** – the impact ejected dust and sulfate aerosols into the upper atmosphere **B** – the impact triggered a sudden ice age across only the southern hemisphere
Choices for Statement 2:	**C** – sunlight was blocked, causing photosynthesis to slow or stop globally **D** – sunlight increased in intensity, causing rapid warming and melting glaciers
Choices for Statement 3:	**E** – many large dinosaurs starved, opening niches for mammals to diversify **F** – many small mammals starved, opening niches for new dinosaur species

Statement 1: When the K-Pg asteroid struck Earth, _____.

Statement 2: As a result of the atmospheric changes, _____.

Statement 3: In the millions of years that followed, _____.

Cluster 4 Questions (continued)

20 A student makes the following claim:

> *"Mass extinction events are always caused by asteroid impacts."*

Place a check mark (✓) in either the **Support** or **Refute** box below to indicate if the given information supports or refutes the student's claim. **Justify** your response using evidence from the reading and graph. **[1 pt]**

☐ **Support**

☐ **Refute**

Justification:

_____

_____

_____

_____

_____

CLUSTER 5 — Geologic Time & NY's Geologic History

Eras, Periods, and the Rock Record of New York State

Base your answers to questions **21 through 25** on the information below and on your knowledge of Earth and Space Sciences. Use the 2024 Edition ESRT, especially pages 6 and 7 (Geologic History of New York State).

Reading the Rock Record of New York State

New York State has one of the most complete geologic records on Earth, with rocks ranging from over **1.3 billion years old** in the Adirondacks to recent glacial sediments deposited only **18,000 years ago** on Long Island. By reading the rock record, geologists can reconstruct the story of how the state has changed through deep time.

The oldest rocks in NY are **metamorphic gneisses** in the Adirondack Mountains, formed during the **Grenville orogeny** approximately 1.1 billion years ago. During the early Paleozoic Era, shallow seas covered most of New York and deposited the limestones and shales that today form the bedrock of central and western NY. The closing of the Iapetus Ocean during the Ordovician Period produced the **Taconian orogeny** and built the ancestral Taconic Mountains.

During the Devonian Period, the **Acadian orogeny** raised the Acadian Mountains and shed sediment westward, forming the **Catskill delta**. These Devonian shales and sandstones are now exposed in the walls of **Letchworth Gorge**. The collision that formed Pangaea is recorded in NY by the **Alleghenian orogeny**. Finally, repeated advances of the Laurentide ice sheet during the Pleistocene shaped Long Island into a glacial deposit composed of two terminal moraines.

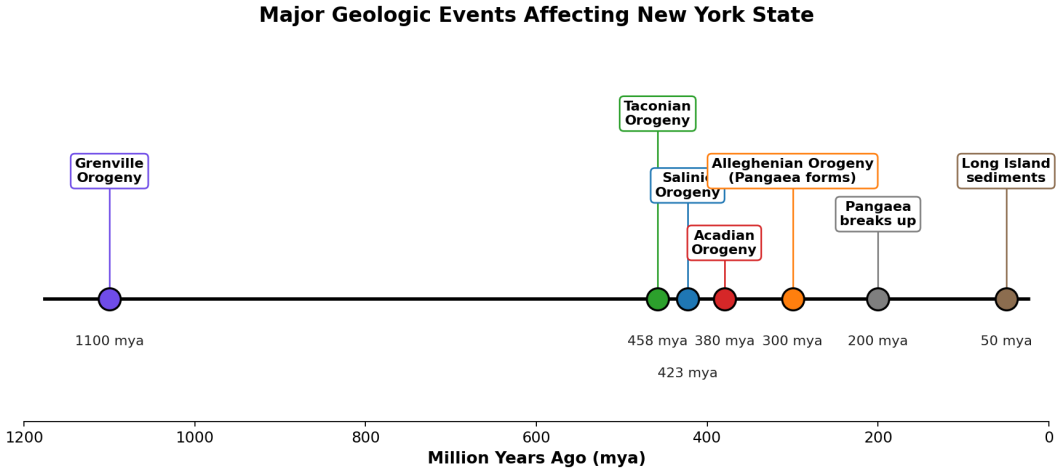
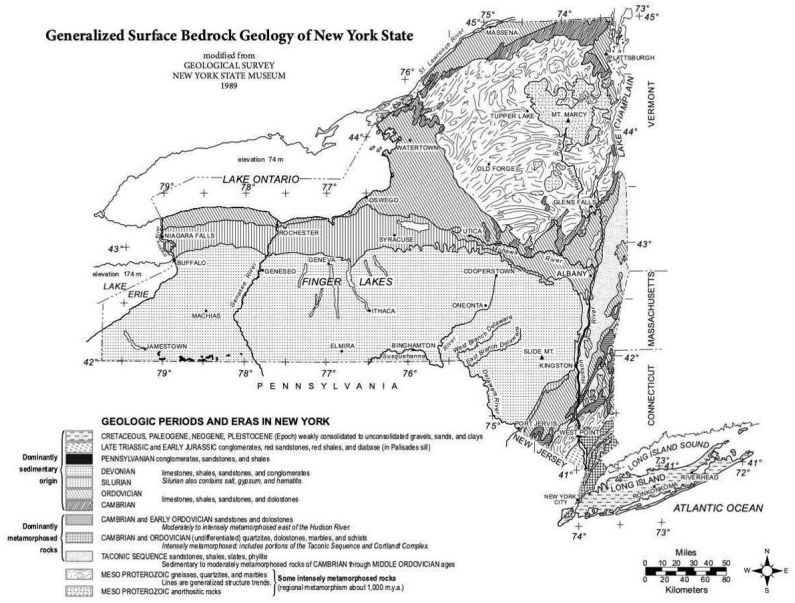


Diagram 2: Major geologic events affecting New York State.



Generalized Surface Bedrock Geology of New York State.

Cluster 5 Questions (21–25)

21 Complete each of the three statements below to correctly describe the geologic history of New York State by placing an **X** in the box to indicate which phrase correctly completes each statement. **[1 pt]**

Statement 1: The oldest rocks in New York State are found in the

☐	Adirondacks and formed during the Grenville orogeny
☐	Catskills and formed during the most recent Pleistocene glaciation

Statement 2: The Devonian shales and sandstones exposed at Letchworth Gorge

☐	originated as sediments shed westward from the Acadian Mountains
☐	originated as Cretaceous beach sands deposited along the Atlantic coast

Statement 3: Long Island is made up of

☐	two terminal moraines deposited by Pleistocene continental glaciers
☐	Cambrian metamorphic schist that has been intensely deformed

Cluster 5 Questions (continued)

Several statements about New York State's geologic history are listed below.

Statement 1: The Adirondacks contain Mesoproterozoic metamorphic gneisses about 1.1 billion years old.

Statement 2: All bedrock in New York formed during the Cambrian Period.

Statement 3: The Catskill delta formed from sediments shed off the Acadian Mountains in the Devonian.

Statement 4: Long Island is composed of igneous rock from the Pangaea breakup.

Statement 5: Repeated Pleistocene glaciations carved out the Finger Lakes from preexisting river valleys.

Statement 6: New York has no rock record older than the Cenozoic Era.

22 Which three statements correctly describe the geologic history of New York State? **[1 pt]**

(1) Statements 2, 4, and 6

(2) Statements 1, 3, and 5

(3) Statements 2, 3, and 6

(4) Statements 1, 4, and 5

23 Complete each of the three statements below to correctly identify factors that have shaped New York's landscape by placing an **X** in the correct box. **[1 pt]**

Statement 1: Evidence that the Finger Lakes were carved by glaciers is provided by

	their long, narrow, north-south orientation and U-shaped cross-sections
	their volcanic origin from explosive Miocene eruptions in central NY

Statement 2: Evidence for the Acadian orogeny in New York is provided by

	the thick Devonian sandstones and shales of the Catskill delta
	the recently formed coral reefs along the southern shore of Long Island

Statement 3: The Adirondacks are best classified as a

	domed region uplifted from much older Mesoproterozoic metamorphic rocks
	fold-and-thrust mountain belt formed during the Mesozoic breakup of Pangaea

Cluster 5 Questions (continued)

A student examined the bedrock geology map of New York State (above) and made the claim below:

> *"The age of the surface bedrock in New York generally decreases as you move from the central Adirondacks outward toward Lake Erie and Lake Ontario."*

24 Which statement provides the most correct evidence and conclusion regarding this claim? **[1 pt]**

(1) The Adirondacks contain Mesoproterozoic gneiss (~1.1 Ga), while the rocks of the Allegheny Plateau (near Lake Erie) are Devonian (~380 Ma) — supporting the claim.

(2) All of New York's bedrock is the same age, so the claim cannot be supported.

(3) The Pleistocene glacial sediments of Long Island are older than the Mesoproterozoic gneiss of the Adirondacks — refuting the claim.

(4) The Cretaceous sands of Long Island are older than the Devonian shales of Letchworth, so the claim is refuted.

25 Using the ESRT (page 7) and the reading, place the New York State geologic events below in the correct temporal sequence from **oldest to youngest**. **Justify** your sequence using one piece of evidence from the ESRT or reading. **[1 pt]**

Events:

• Pleistocene glaciations deposit the Long Island terminal moraines

• Acadian orogeny forms the Catskill delta

• Grenville orogeny metamorphoses the Adirondack region

• Sands and clays of Long Island deposited along the Atlantic margin (~50 Ma)

• Taconian orogeny forms the ancestral Taconic Mountains

OLDEST
1.
2.
3.
4.
5.
YOUNGEST

Justification:

_____

_____

Final Grade Calculation

Mr. Brown's Science Labs — Geologic History Cluster Assessment

Section	Items	Points Earned	Points Possible
Cluster 1 — Great Oxidation Event	Q1–Q5	___ / 5	5
Cluster 2 — How Earth Got Its Water	Q6–Q10	___ / 5	5
Cluster 3 — Plate Tectonics & Pangaea	Q11–Q15	___ / 5	5
Cluster 4 — Mass Extinction Events	Q16–Q20	___ / 5	5
Cluster 5 — Geologic Time & NY Geologic History	Q21–Q25	___ / 5	5
TOTAL		**___ / 25**	**25**

Grade Calculation

Step 1: Total points earned	_____ / 25
Step 2: Calculate percentage = (points earned ÷ 25) × 100	_____ %
Step 3: Letter grade (see scale below)	_____

Letter Grade Scale

Percent	Letter Grade	Performance Level
90 – 100%	A	Mastery (Regents 90+)
80 – 89%	B	Proficient (Regents 80–89)
70 – 79%	C	Approaching Proficient (Regents 70–79)
65 – 69%	D	Passing (Regents 65–69)
Below 65%	F	Below Standard — Reteach Recommended

Student Reflection

Which cluster did you find the most challenging, and why?

_____

_____

_____

Answer Key

For teacher use only — remove or hide before distributing to students.

Cluster 1 — Great Oxidation Event

1. S1: photosynthesizing cyanobacteria living in shallow seas. S2: free oxygen reacted with dissolved iron in seawater. S3: methane levels decreased and less heat was trapped in the atmosphere.

2. (1) Statements 1, 3, 5

3. S1: the formation of banded iron formations on the ocean floor. S2: the amount of atmospheric methane (a greenhouse gas). S3: a change to Earth's atmosphere caused by living organisms.

4. (1) Observations A, B, and D identify a banded iron formation.

5. Sequence: (1) Cyanobacteria evolve in shallow seas → (2) Banded iron formations begin to form on the ocean floor → (3) Atmospheric oxygen levels rise rapidly (Great Oxidation Event) → (4) Free oxygen reacts with atmospheric methane → (5) The Huronian glaciation begins. Justification: Cyanobacteria first produced oxygen ~2.7 Ga, BIFs formed when ocean iron absorbed early O■, then atmospheric O■ rose during the GOE (2.4–2.1 Ga), reacted with methane, and triggered the Huronian ice age.

Cluster 2 — How Earth Got Its Water

6. S1: 4.0 billion years ago after Earth's surface cooled below 100 °C. S2: trapped water vapor inside Earth's mantle escaped through erupting volcanoes. S3: test the hypothesis that comets delivered some of Earth's water.

7. (3) The deuterium-to-hydrogen ratio in seawater only partially matches some comets, suggesting multiple sources contributed water.

8. Statement 1 = **A**; Statement 2 = **C**; Statement 3 = **E**.

9. (1) Statements 1, 3, and 5

10. Refute. Although early Earth was extremely hot, Earth's oceans had formed by ~4.0 Ga (during Earth's first ~600 million years), so the claim that no liquid water could exist for the first 500 million years is supported only loosely; the reading specifies oceans formed at 4.0 Ga, meaning surface water existed before 4.1 Ga in some form. *(Either Support or Refute can be defended with cited evidence — accept thoughtful justification.)*

Cluster 3 — Plate Tectonics & Pangaea

11. S1: North America collided with Africa during the Alleghenian orogeny. S2: these continents were once joined as part of a supercontinent. S3: divergent plate boundary where the Atlantic Ocean is widening.

12. (2) Statements 1, 3, 5

13. S1: the Allegheny orogeny mountain belt that now extends across NY and Pennsylvania. S2: the matching ages of igneous rocks on opposite sides of the Atlantic Ocean. S3: seafloor spreading driven by mantle convection at the Mid-Atlantic Ridge.

14. (2) Observations A, C, D, and F identify rocks formed during the Grenville orogeny.

15. Sequence: (1) Grenville orogeny → (2) Taconian orogeny → (3) Acadian orogeny → (4) Alleghenian orogeny → (5) Intrusion of the Palisades sill. Justification: ESRT page 7 shows Grenville orogeny is oldest (~1.1 Ga), Taconian (~458 Ma), Acadian (~380 Ma), Alleghenian (~300 Ma), and Palisades sill intrusion at ~200 Ma during Pangaea breakup.

Cluster 4 — Mass Extinction Events

16. S1: 66 million years ago at the boundary between the Mesozoic and Cenozoic Eras. S2: an asteroid impact that ejected dust and aerosols into the atmosphere. S3: a worldwide rock layer enriched in iridium, an element common in asteroids.

17. (2) The End-Permian event killed about 96% of marine genera, while the End-Cretaceous event killed about 76%.

18. (2) Observations B, C, and F identify a layer formed by an asteroid impact at the K-Pg boundary.

19. Statement 1 = **A**; Statement 2 = **C**; Statement 3 = **E**.

20. Refute. The graph shows that of the Big Five mass extinctions, only the End-Cretaceous event has strong evidence of an asteroid impact (iridium layer). The End-Permian event was caused by Siberian volcanic eruptions and ocean acidification, not an impact, demonstrating that mass extinctions can have multiple causes.

Cluster 5 — Geologic Time & NY Geologic History

21. S1: Adirondacks and formed during the Grenville orogeny. S2: originated as sediments shed westward from the Acadian Mountains. S3: two terminal moraines deposited by Pleistocene continental glaciers.

22. (2) Statements 1, 3, 5

23. S1: their long, narrow, north-south orientation and U-shaped cross-sections. S2: the thick Devonian sandstones and shales of the Catskill delta. S3: domed region uplifted from much older Mesoproterozoic metamorphic rocks.

24. (1) The Adirondacks contain Mesoproterozoic gneiss (~1.1 Ga), while the rocks of the Allegheny Plateau (near Lake Erie) are Devonian (~380 Ma) — supporting the claim.

25. Sequence: (1) Grenville orogeny → (2) Taconian orogeny → (3) Acadian orogeny → (4) Sands and clays of Long Island deposited (~50 Ma) → (5) Pleistocene glaciations deposit the Long Island terminal moraines. Justification: The Grenville orogeny is the oldest event (~1.1 Ga), while Pleistocene glaciation is the most recent (~18,000 yr). The Devonian Catskill delta and Eocene Long Island sediments fall between in temporal order on ESRT page 7.

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