Large-Type Edition

The University of the State of New York
REGENTS HIGH SCHOOL EXAMINATION

EARTH AND SPACE SCIENCES

Thursday, June 18, 2026 — 1:15 to 4:15 p.m., only

Student Name _____

School Name _____

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

Print your name and the name of your school on the lines above.

Use your knowledge of **Earth and Space Sciences** to answer all questions in this examination. Before you begin this examination, you must be provided with the ***2024 Edition Reference Tables for Earth and Space Sciences***. You may need to use these reference tables to answer some of the questions.

You are to answer all questions in this examination. You may use scrap paper to work out the answers to the questions, but be sure to record your answers on your answer sheet and in your test booklet. A separate answer sheet for multiple-choice questions has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers for the constructed-response questions in your test booklet.

All answers in your test booklet should be written in pen, except for graphs and drawings, which should be done in pencil.

When you have completed the examination, you must sign the declaration printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and test booklet cannot be accepted if you fail to sign this declaration.

NOTICE …

A four-function or scientific calculator and a copy of the ***2024 Edition Reference Tables for Earth and Space Sciences*** must be available for you to use while taking this examination.

Note that diagrams are not drawn to scale unless otherwise noted.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

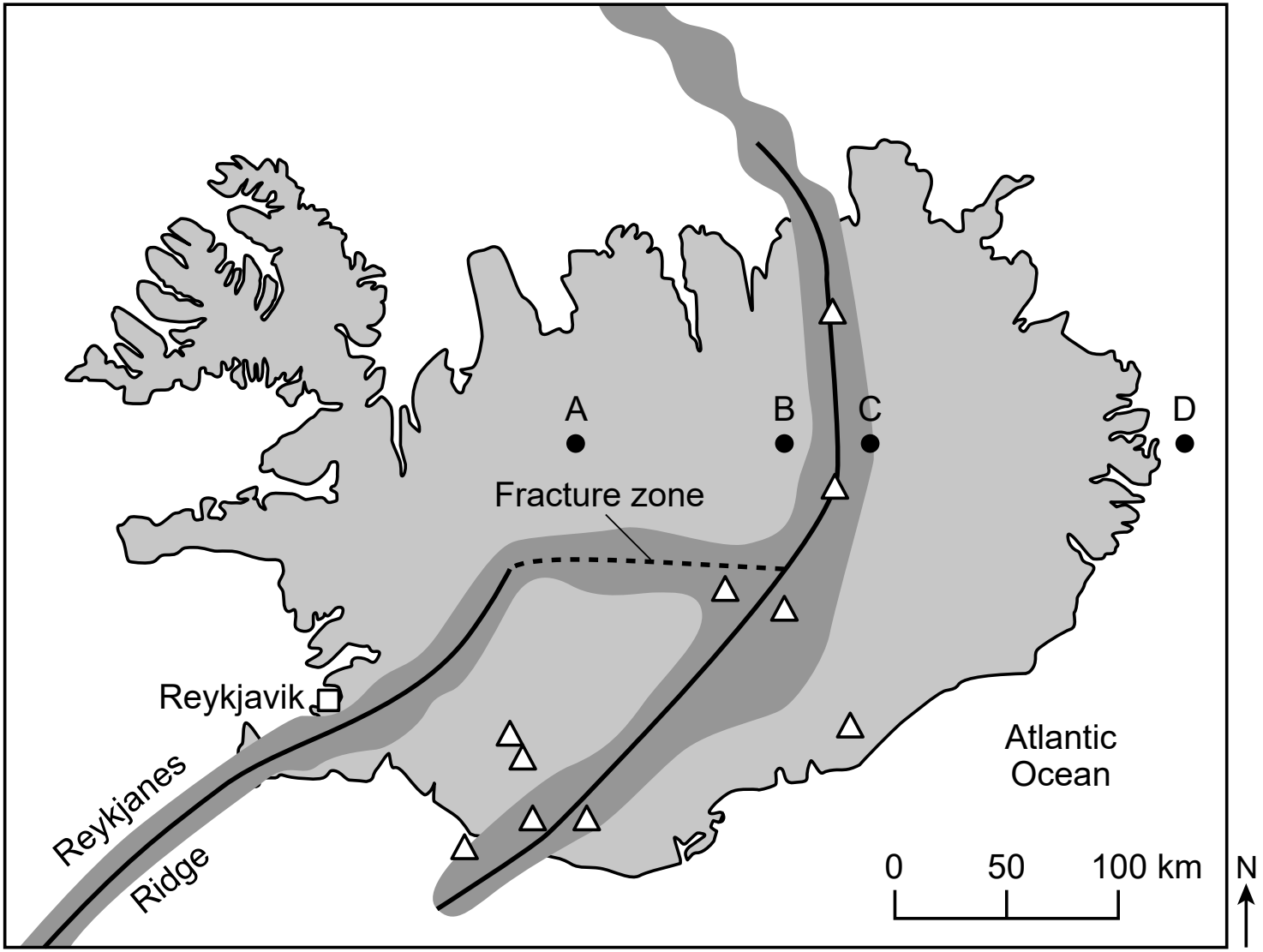
Base your answers to questions 1 through 4 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the ***2024 Edition Reference Tables for Earth and Space Sciences***. Be sure to record your answers for multiple-choice questions on the separate answer sheet provided. Record your answers for constructed-response questions in your test booklet.

Iceland Hotspot

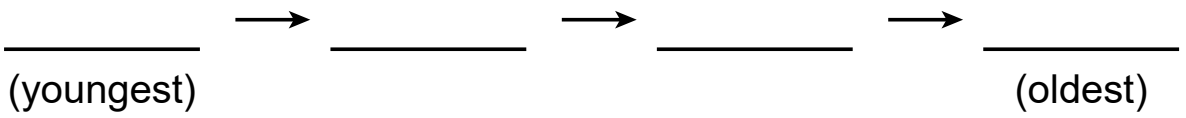
Iceland is one of the most active volcanic regions on Earth. It is a hotspot in the north Atlantic Ocean near the Reykjanes Ridge. The island formed by a combination of seafloor spreading and volcanism.

The map below shows some information about the tectonic setting of Iceland. Points *A* through *D* represent locations on Earth's surface.

Tectonic Map of Iceland



1 Place the letters representing locations *A*, *B*, *C*, and *D* in the spaces below to show the pattern in the ages of rock from youngest to oldest. [1]



2 Which statement correctly compares the rate of seafloor spreading at the ridge in Iceland to the rate of seafloor spreading at another plate boundary?

(1) Iceland's approximate rate of spreading is faster than the Southeast Indian Ocean Ridge.

(2) Iceland's approximate rate of spreading is slower than the East Pacific Rise.

(3) Iceland's approximate rate of spreading is faster than the boundary between the Cocos Plate and the Nazca Plate.

(4) Iceland's approximate rate of spreading is slower than the Southwest Indian Ocean Ridge.

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Eyjafjallajökull Volcano is located on the south coast of Iceland. On April 14, 2010, an explosive eruption occurred in the ice-covered crater. The mixing of the glacial water and magma resulted in a massive ash cloud that went approximately 11 km into the atmosphere. The cloud consisted of large amounts of microscopic particles of hard volcanic rock.

The map below shows some information about the movement of the ash cloud during the Eyjafjallajökull Volcano eruption in 2010. The key indicates the distribution of the ash cloud over time as a result of the eruption event.

3 Which statement, based on evidence found on the map below, describes how the movement of the Eyjafjallajökull ash cloud influenced humans?

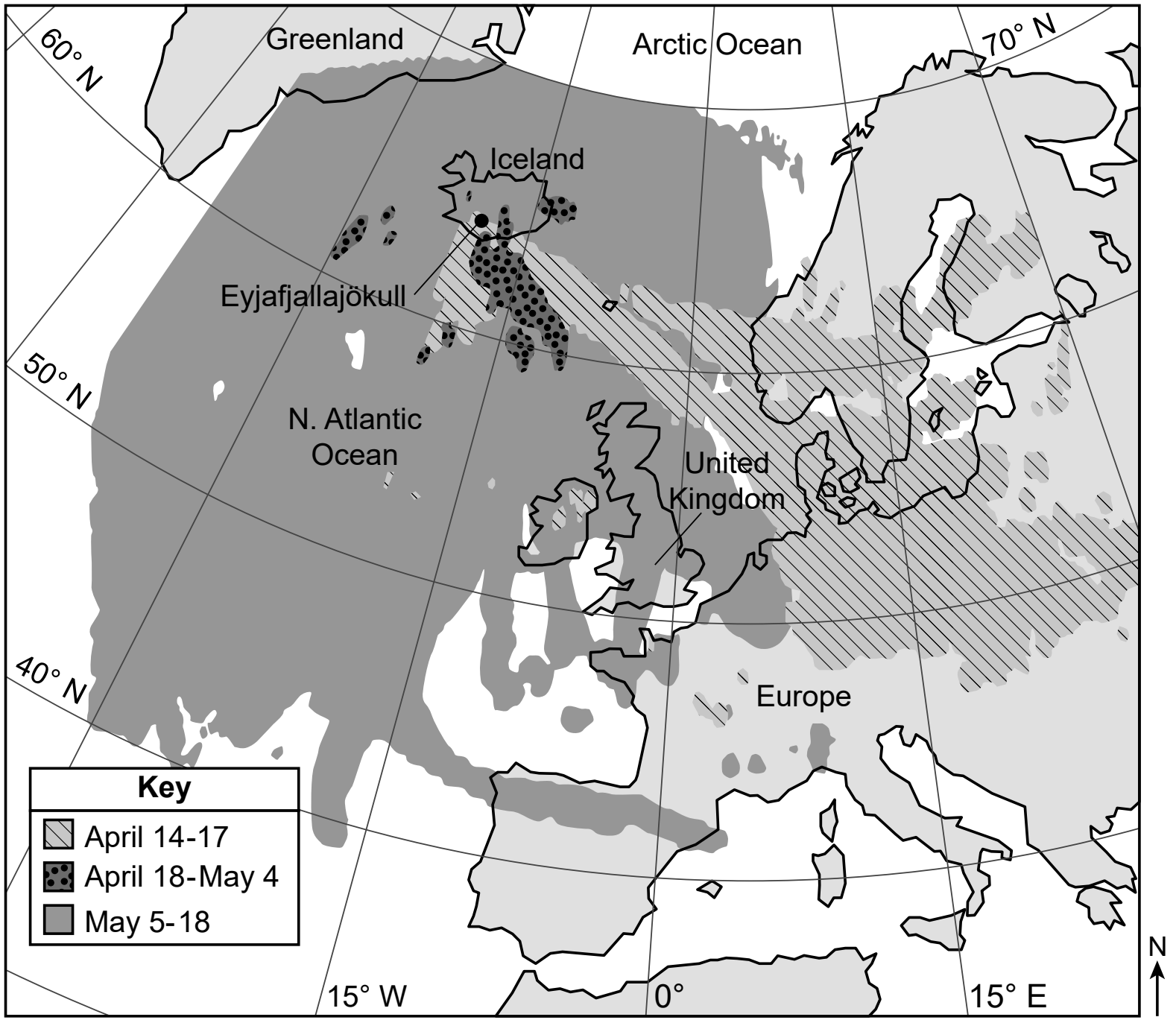
(1) Between May 5 and May 18, all of Iceland was most likely experiencing poor air quality.

(2) By April 18, the southern tip of Greenland was most likely experiencing poor air quality.

(3) On April 23, residents within southern Europe experienced total darkness due to the ash cloud.

(4) On April 15, residents in the United Kingdom experienced increased atmospheric visibility due to the ash cloud.

Eyjafjallajökull Volcanic Ash Cloud



Managing and mitigating lava flows from volcanic eruptions is a challenge due to the intense heat and fluid dynamics of lava. In Iceland, several solutions have been applied or proposed to address the impacts of lava flows.

The table below lists different methods that all require equipment to address the impact of lava flows on communities.

4 Which proposed solution from the table below would best protect an Icelandic community from a lava flow when considering constraints such as costs and equipment?

(1) Solution *A*, lava diversion

(2) Solution *B*, seawater cooling

(3) Solution *C*, lava flow barrier

(4) Solution *D*, explosions

Possible Lava Flow Solutions

	Solution	Description	Constraint
A	Lava diversion	Construct channels to redirect lava	– Costly – Time-consuming – Lava may breach – Redirects flows instead of stopping them
B	Seawater cooling	Use pumps to draw seawater to spray lava to cool and harden	– Need constant water supply – Demand for energy to run multiple costly pumps
C	Lava flow barrier	Build earthen barriers to dam the lava and stop its flow	– Need machinery/equipment to build barrier – Lava could breach the barrier
D	Explosions	Detonate explosives to disrupt the lava flow and redirect its path	– Could cause further damage and loss of life – Not precise and lava returns to its original path

Base your answers to questions 5 through 8 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***.

Stars and Stellar Evolution

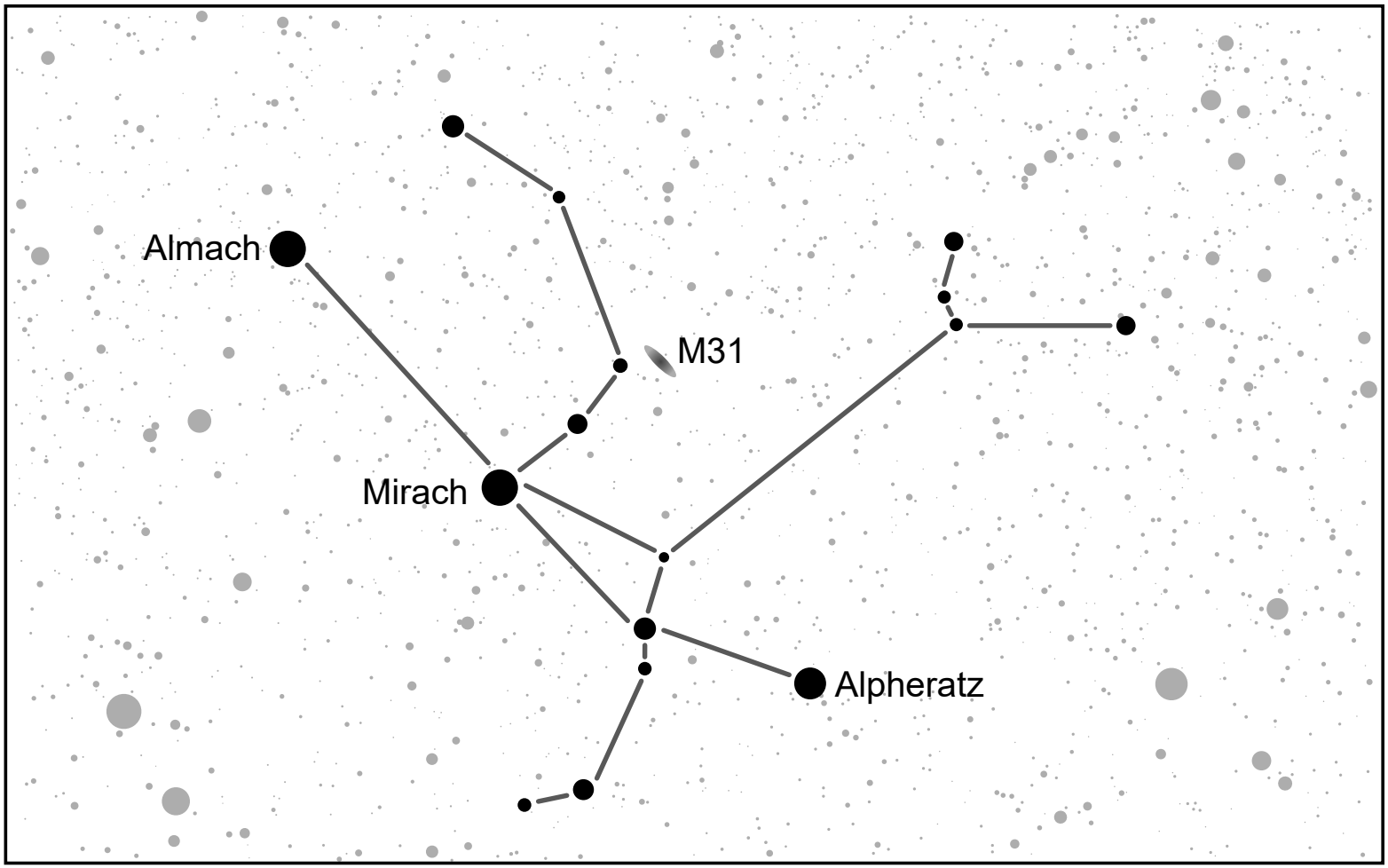
The Andromeda constellation contains several stars including three of the brightest stars in the sky: Almach, Mirach, and Alpheratz. Almach is a multiple-star system located 350 light years (ly) from Earth. A light year is defined as the distance that light travels in one year, about 6 trillion miles or 9.5×10^{12} km. The Almach system is the third brightest object in the constellation. Mirach is a red giant star located 200 ly from Earth, and it is approximately 2000 times brighter than the Sun. Alpheratz is a sub-giant star located 97 ly from Earth, and it is approximately 200 times brighter than the Sun.

The Andromeda Galaxy, known as M31, is also within the Andromeda constellation. It is 2.5 million ly away from Earth.

The Andromeda constellation is visible in both the northern and southern hemispheres of Earth, but is not visible at latitudes greater than 40° S. In the northern hemisphere, this constellation is best observed from August to February. In the southern hemisphere, it is only visible from October to December.

The model below shows some information about a constellation.

Model of the Andromeda Constellation



(Not drawn to scale)

5 Which row correctly lists the factors that influence nuclear reactions in stars and lists the types of elements in the core of some of the stars named in the Andromeda constellation?

Row	Factors That Influence Nuclear Reactions in Stars	Elements of Giant Stars in Andromeda
(1)	• Mass of star • Stage in lifetime	He and C
(2)	• Brightness of star • Stage in lifetime	H and He
(3)	• Mass of star • Distance from Earth	He and C
(4)	• Brightness of star • Distance from Earth	H and He

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The model below shows some information about the zodiac constellations visible from Earth. The ecliptic is the Sun's apparent path among the constellations as viewed from Earth.

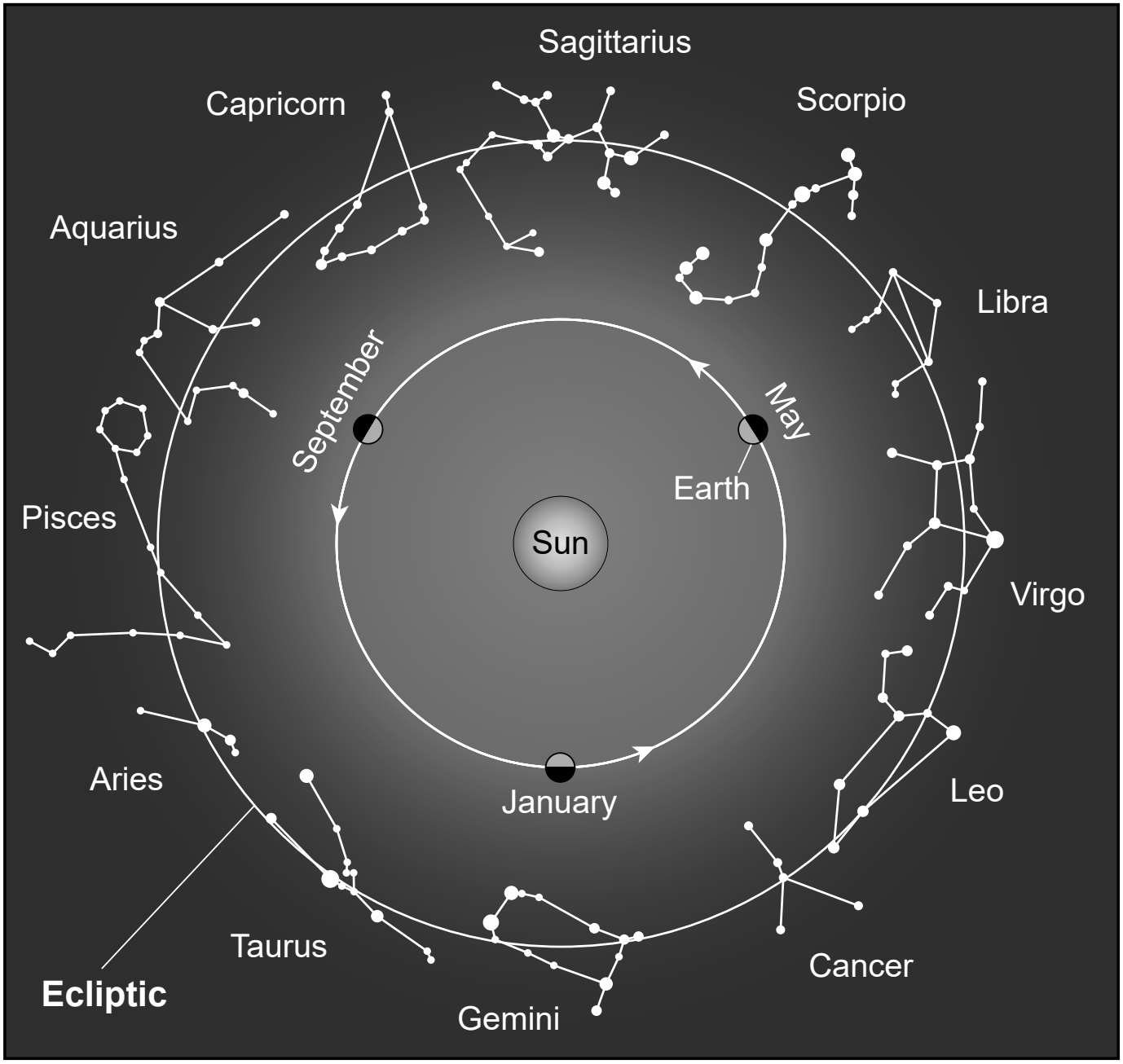
6 Identify the name and motion of the celestial object shown in the model below that is responsible for the pattern of different constellations that are visible to an observer in the northern hemisphere. Then, identify the name of **one** constellation that would most likely be highest in the night sky at the same time that the Andromeda constellation would also be visible in the night sky at midnight in January in New York State. [1]

Name and description of motion: _____

_____

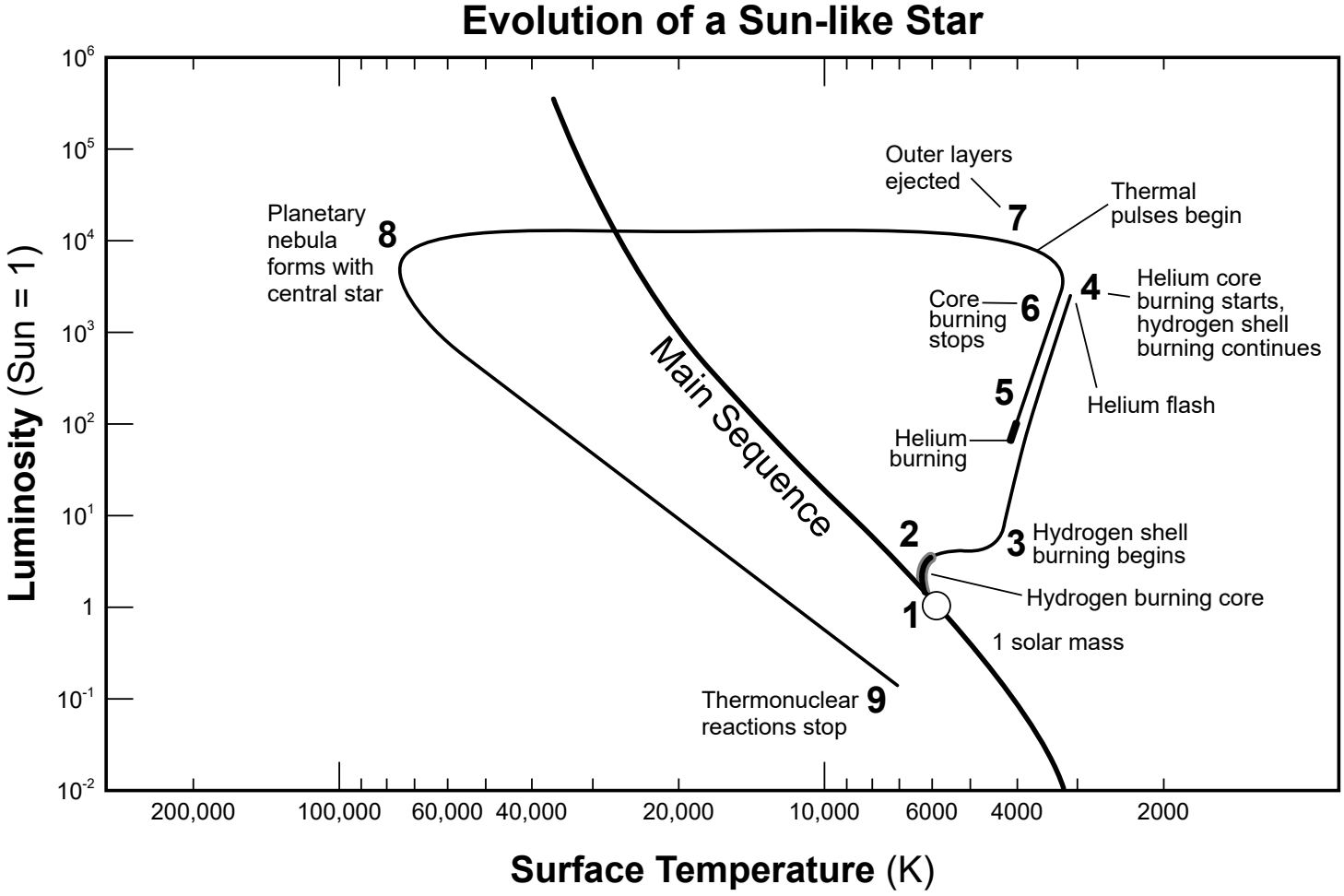
Constellation name: _____

Model of Some Constellations Visible from Earth



(Not drawn to scale)

The graph below shows the evolution of a Sun-like star. Numbers 1 through 9 represent the steps in the sequence of a star's evolution and its position on a H-R Diagram. Luminosity is the total amount of energy radiated by a star, compared to our Sun. The term "burning" refers to fusion.



7 Which piece of evidence in the *Evolution of a Sun-like Star* graph could be used to support the claim that nuclear fusion is the process responsible for energy generation in stars like our Sun and Mirach?

(1) In Step 4, helium burns in the core, then helium burns in the shell.

(2) In Step 7, outer layers of the star are ejected and become a planetary nebula in Step 8.

(3) From Step 2 to Step 5, hydrogen burning changes to helium burning in the core.

(4) From Step 1 to Step 3, hydrogen core burning stops and thermal pulses begin.

In 1924, Edwin Hubble studied the Andromeda Galaxy, along with many other galaxies, and found that there is a pattern in the speeds that galaxies are receding from Earth. Hubble's finding had important implications for theories related to understanding the universe.

The *Galaxy Data Table* below shows some information about galaxies, including their distances and recessional velocities (speed relative to Earth). Black arrows below the spectra indicate how far the two darkest absorption lines have shifted in wavelength (λ).

Four statements about the universe, labeled *A*, *B*, *C*, and *D*, are shown in the table below.

A	The farther away a galaxy is from Earth, the more light is red-shifted, indicating an accelerating galaxy velocity.
B	The greater the distance a galaxy is from Earth, the more recessional velocities decrease (along with blue-shifted spectra data).
C	The closer galaxies are to Earth, the recessional velocity decreases, indicating the presence of cosmic microwave background radiation.
D	As distance of galaxies increases from Earth, the recessional velocity increases, shifting spectra to include longer wavelengths.

8 Which pair of statements supports the Big Bang theory, based on the given astronomical evidence of light spectra, galaxy distances, and galaxy velocities?

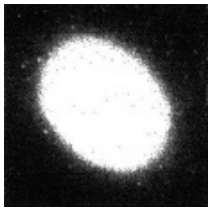
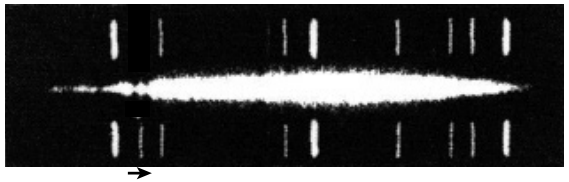
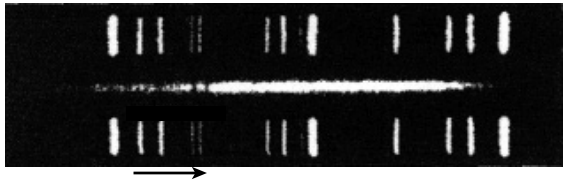
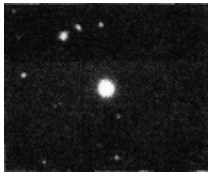
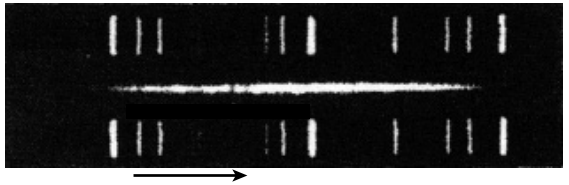
(1) *A* and *B*

(2) *B* and *C*

(3) *C* and *D*

(4) *D* and *A*

Galaxy Data Table

Cluster Galaxy in	Approximate Distance in Light-Years from Earth	Spectra Recessional Velocities blue Shorter λ — red Longer λ
 Virgo	52 million	 1200 KM/SEC
 Ursa Major	60 million	 15,000 KM/SEC
 Corona Borealis	1 billion	 22,000 KM/SEC

Base your answers to questions 9 through 13 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 Slow Carbon Cycle

The slow carbon cycle is controlled by various geologic processes that move carbon between Earth's spheres. Carbon takes millions of years to move between rocks, soil, the ocean, and the atmosphere through a series of chemical reactions.

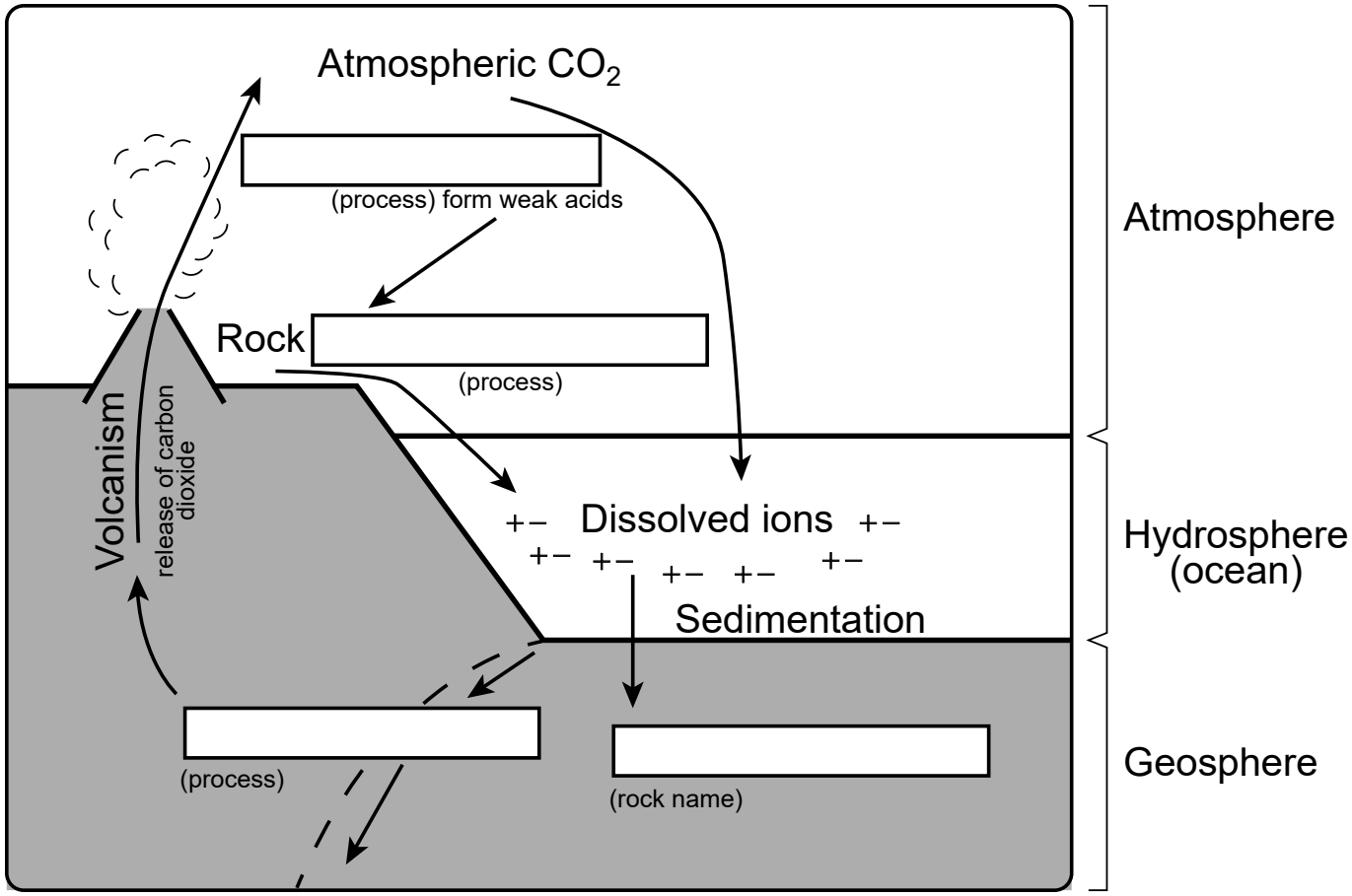
The movement of carbon from the atmosphere into rocks begins when atmospheric carbon (CO_2) combines with rain water (dissolution) to form a weak acid (carbonic acid). This weak acid dissolves rock, releasing ions that are carried to the ocean. These ions combine to form calcium carbonate. Over time, this calcium carbonate builds up on the ocean floor, creating sedimentary rock layers.

Carbon dioxide can be returned to the atmosphere through crustal plate movement and volcanic activity.

9 Complete the model by placing the correct terms, from the choices below, in the boxes to describe the cycling of carbon between three Earth spheres. Not all terms will be used. [1]

Choices:
– subduction
– erosion
– limestone
– shale
– dissolution
– divergence
– weathering

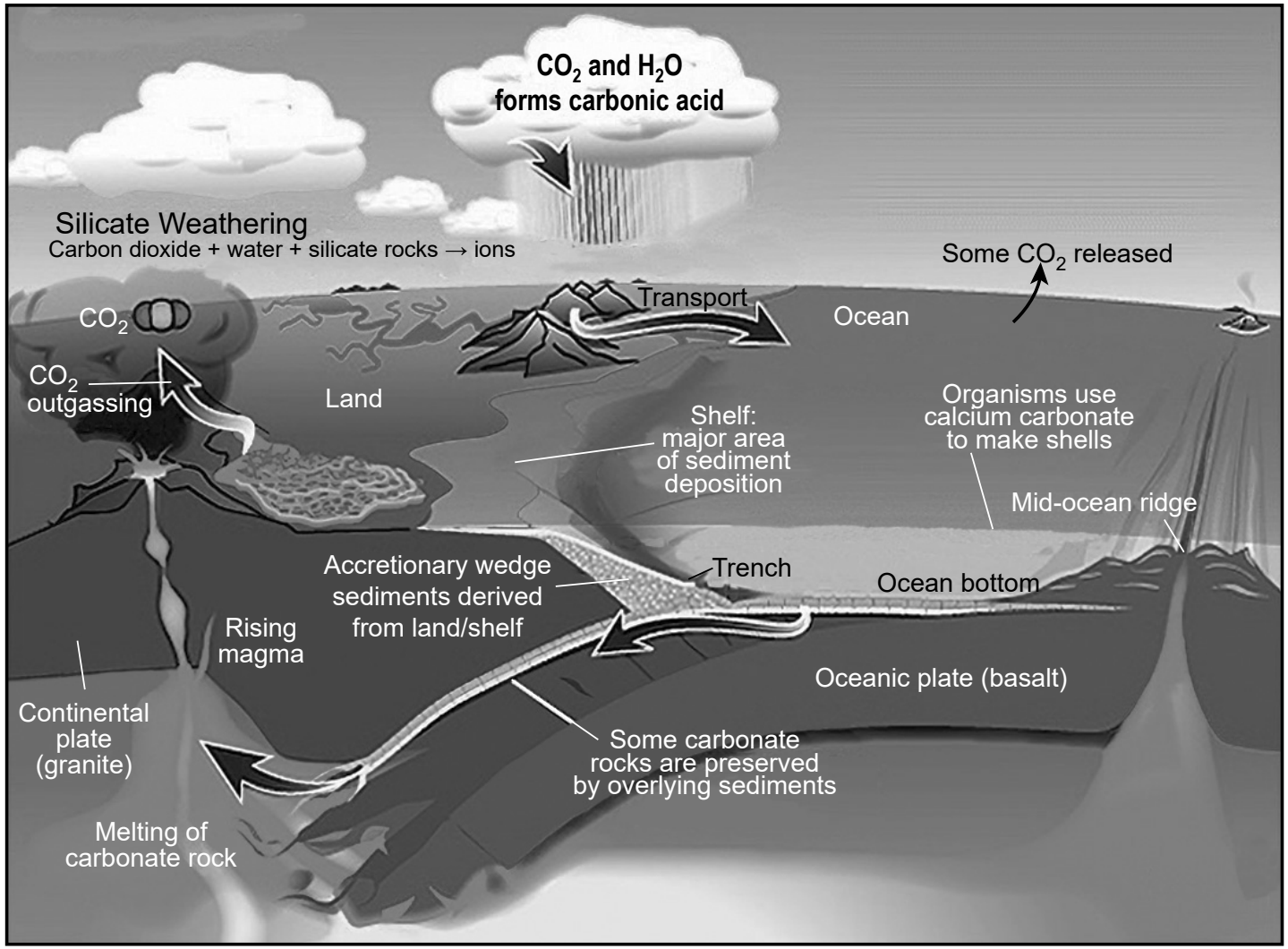
Model of Slow Carbon Cycle



(Not drawn to scale)

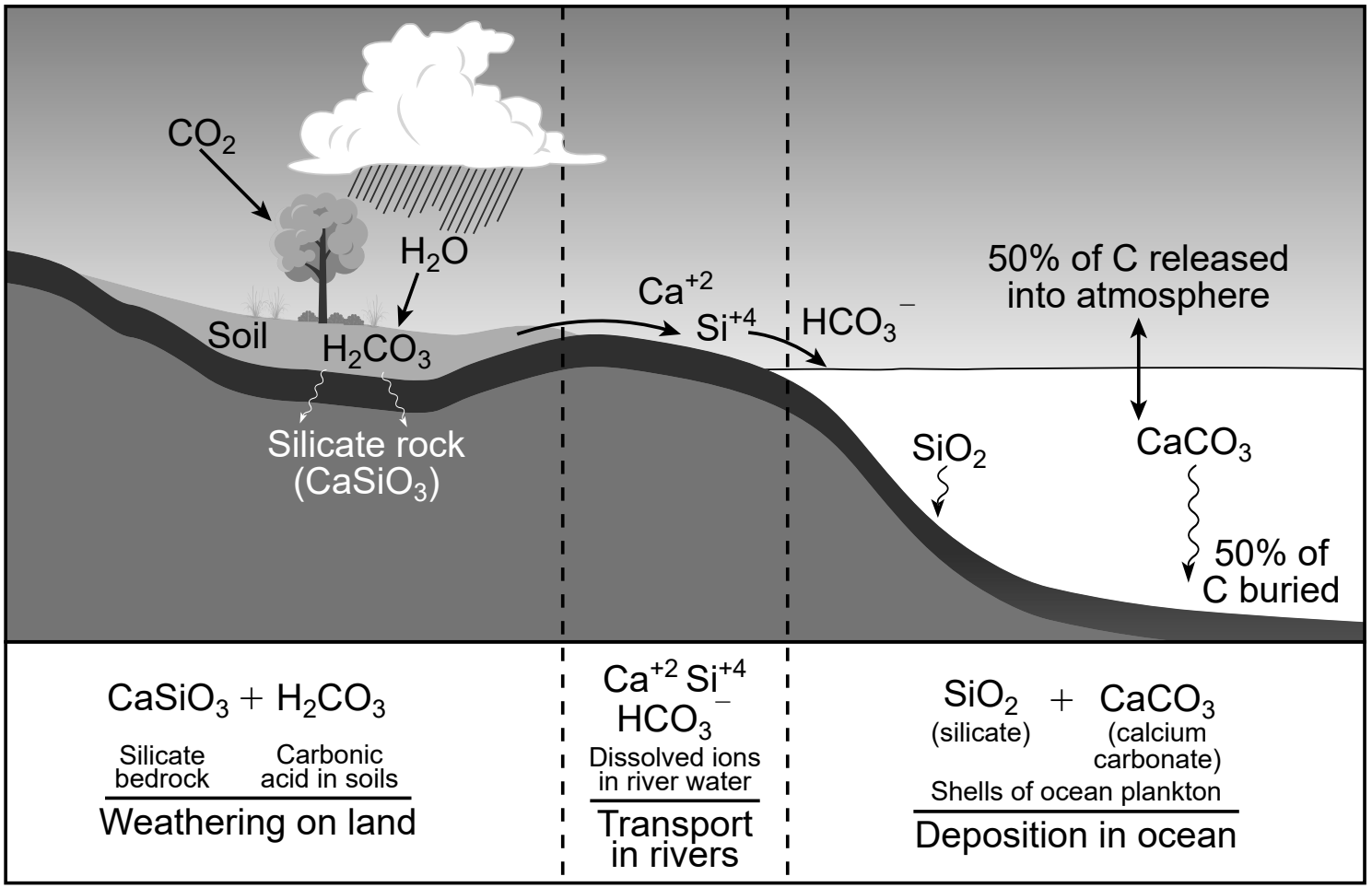
The models below show some information about how silicate rocks are weathered to produce carbonate rocks that cycle carbon among Earth's spheres.

How Silicate Rocks are Transformed into Carbonate Rocks Model



(Not drawn to scale)

Model of Chemical Weathering of Silicate Rocks on Earth



(Not drawn to scale)

10 Describe how plate convergence cycles carbon in carbonate rocks by thermal convection from the lithosphere to the atmosphere. [1]

11 Which statement identifies how the silicate rocks that have been chemically changed by water produced carbonate rocks in Earth's oceans?

(1) Water carries dissolved ions of silicate rocks to the ocean where they are used to form carbonate rock layers.

(2) Water combines with carbonic acid to weather the silicate rocks, which directly break down to form carbonate rocks.

(3) River water transports silicate rocks to the ocean where they form carbonate rocks.

(4) Ocean water combines silicate rocks with calcium ions to form calcium carbonate rocks.

12 Based on the models, which table correctly identifies the processes that form carbonate rock from silicates and the distribution of these materials?

(1)

Material	Process	Distribution
Carbonate rock	Mechanical weathering	Mid-ocean ridge
Silicate	Crystallization	Deep ocean

(2)

Material	Process	Distribution
Carbonate rock	Subsidence	Oceanic trenches
Silicate	Mineral precipitate	Ocean surface

(3)

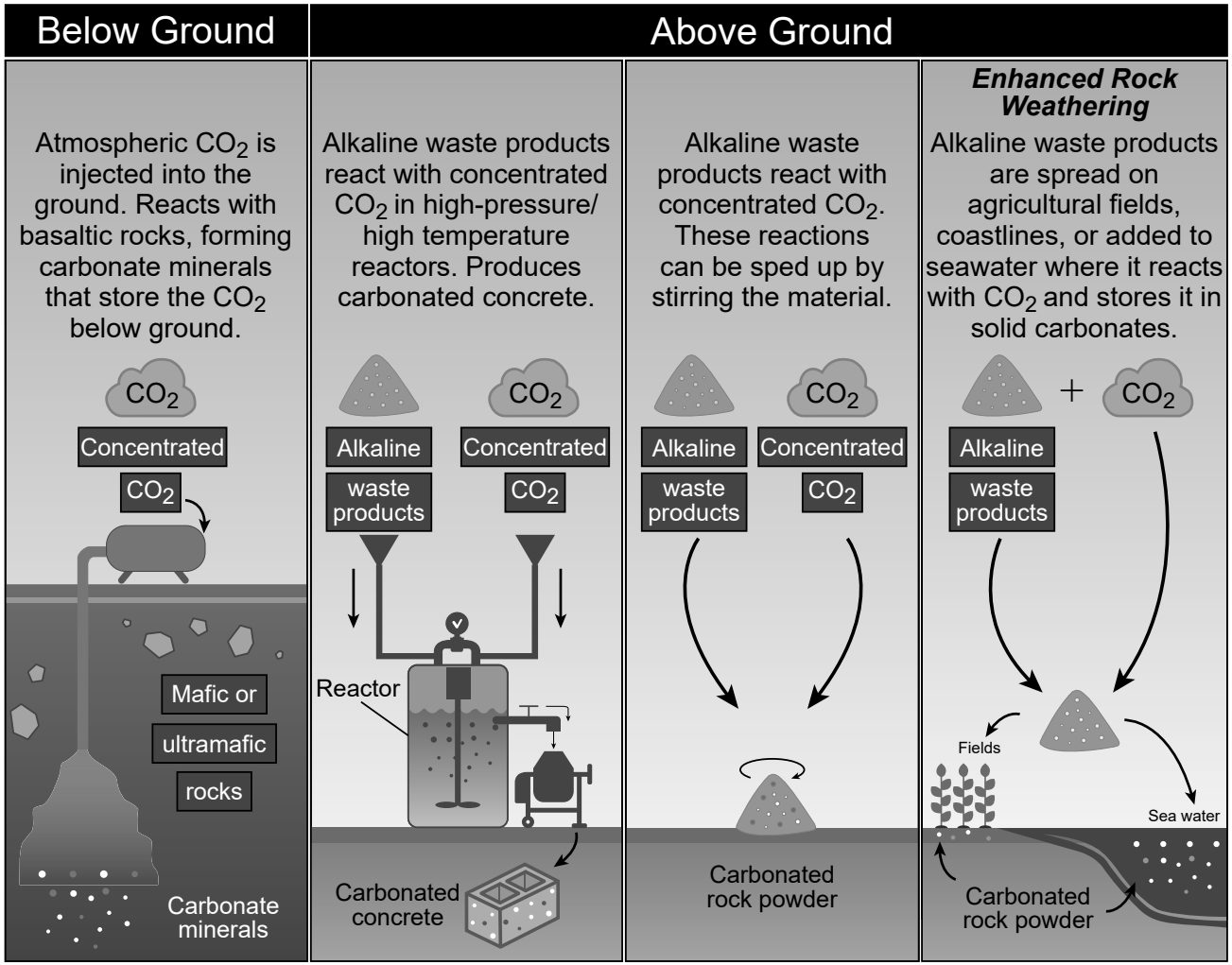
Material	Process	Distribution
Carbonate rock	Lithification	Continental shelf
Silicate	Weathering	Earth's surface

(4)

Material	Process	Distribution
Carbonate rock	Chemical weathering	Deep beneath Earth's surface
Silicate	Recrystallization	Volcanoes at the surface

Scientists are developing solutions to reduce atmospheric carbon dioxide (CO_2). Carbon mineralization is a process that speeds up the formation of carbonate rocks. Three of the four carbon mineralization processes listed below take alkaline waste products (calcium ions) from the production of batteries and steel, and use these ions to combine with atmospheric CO_2 to form the carbonate material.

Carbon Mineralization Processes



13 A student made claims about the four carbon mineralization processes. Which claim correctly evaluates a solution and describes how that solution reduces impacts of human activities on a natural system?

(1) Enhanced rock weathering stores alkaline waste products and increases the amount of calcium ions being transported to the ocean to form carbonate rocks.

(2) The below ground process removes CO_2 in Earth's atmosphere using metamorphic and mafic rocks to create carbonate concrete.

(3) An above ground process combines alkaline waste products and atmospheric CO_2 to make carbonate rock powder, which decreases the amount of atmospheric CO_2 that can be dissolved in seawater.

(4) Alkaline waste products combine with CO_2 in reactors, creating concrete which removes CO_2 from the atmosphere.

Base your answers to questions 14 through 18 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***.

Conditions of a Polar Vortex Event

A polar vortex is a large area of low pressure and cold air surrounding the North Pole. When the polar vortex is especially strong, the polar jet stream stays farther north. The polar jet stream is a fast-moving belt of westerly winds in the atmosphere. The polar vortex keeps the cold air contained over the Arctic. When the polar vortex weakens, it can cause the polar jet stream to change. A notable polar vortex occurred in January 2014.

The model below represents conditions of the polar vortex that determine the extent of the polar jet stream affecting the Northern Hemisphere during winter.

14 Describe how the pattern of movement of the polar jet stream changed when the polar vortex changed from stable to disrupted. Also, describe how **one** weather condition most likely changed for New York State residents. [1]

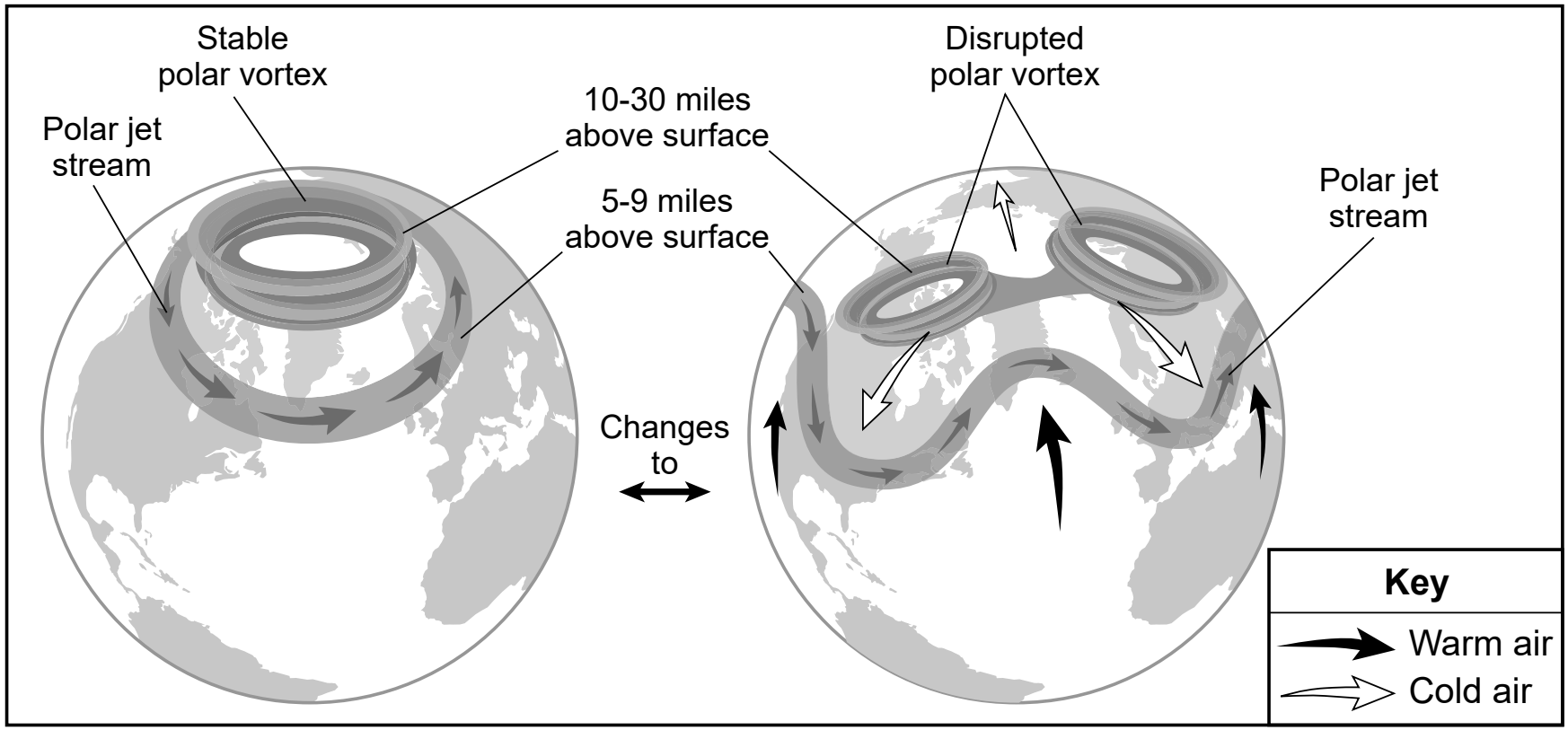
Change in polar jet stream pattern: _____

_____

Change in weather condition: _____

_____

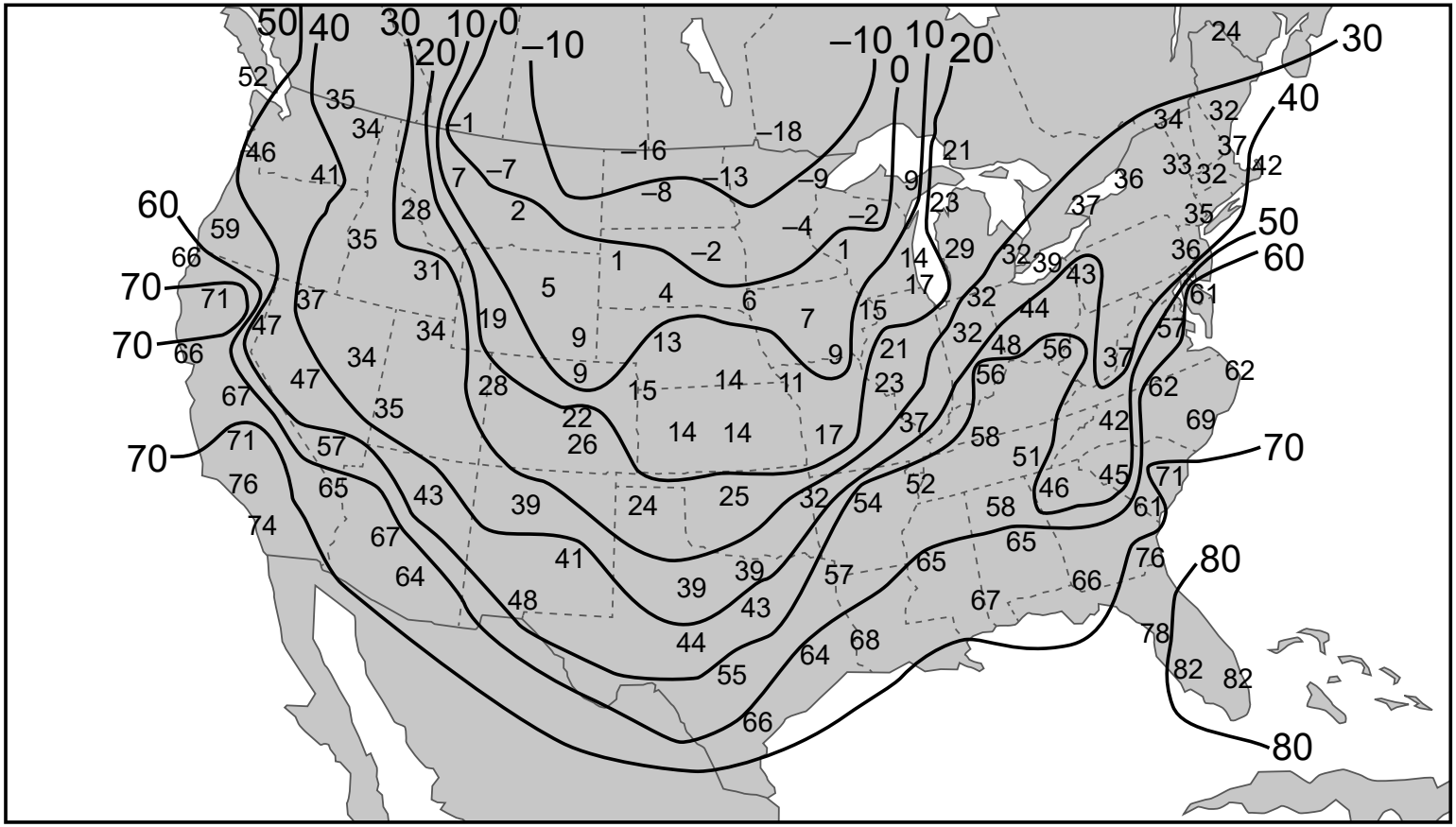
Model of Polar Vortex Conditions



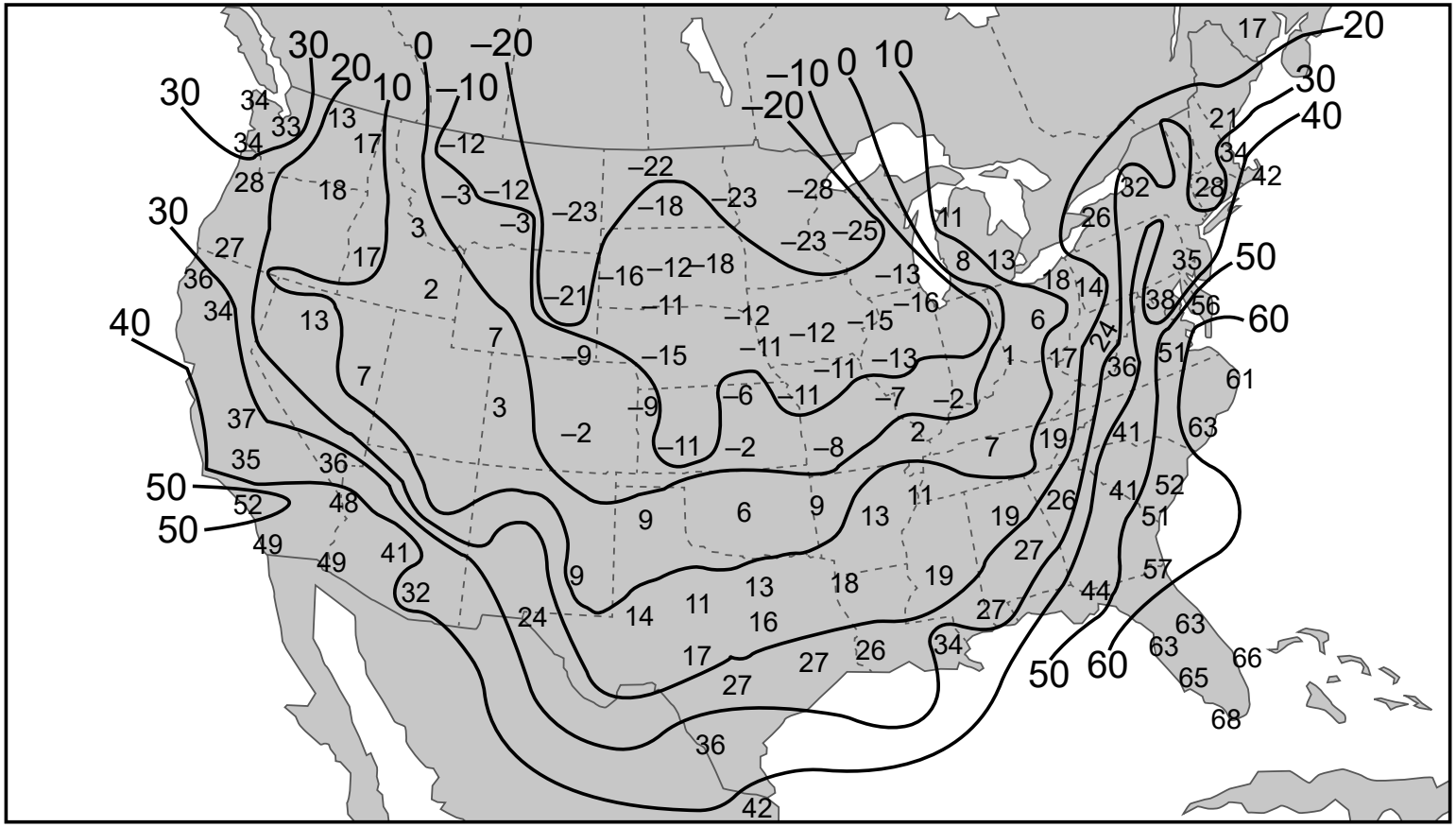
(Not drawn to scale)

The weather maps below show the maximum and minimum temperatures (°F) for January 6, 2014, when the United States was experiencing a polar vortex event.

Maximum Temperatures: Monday, January 6, 2014



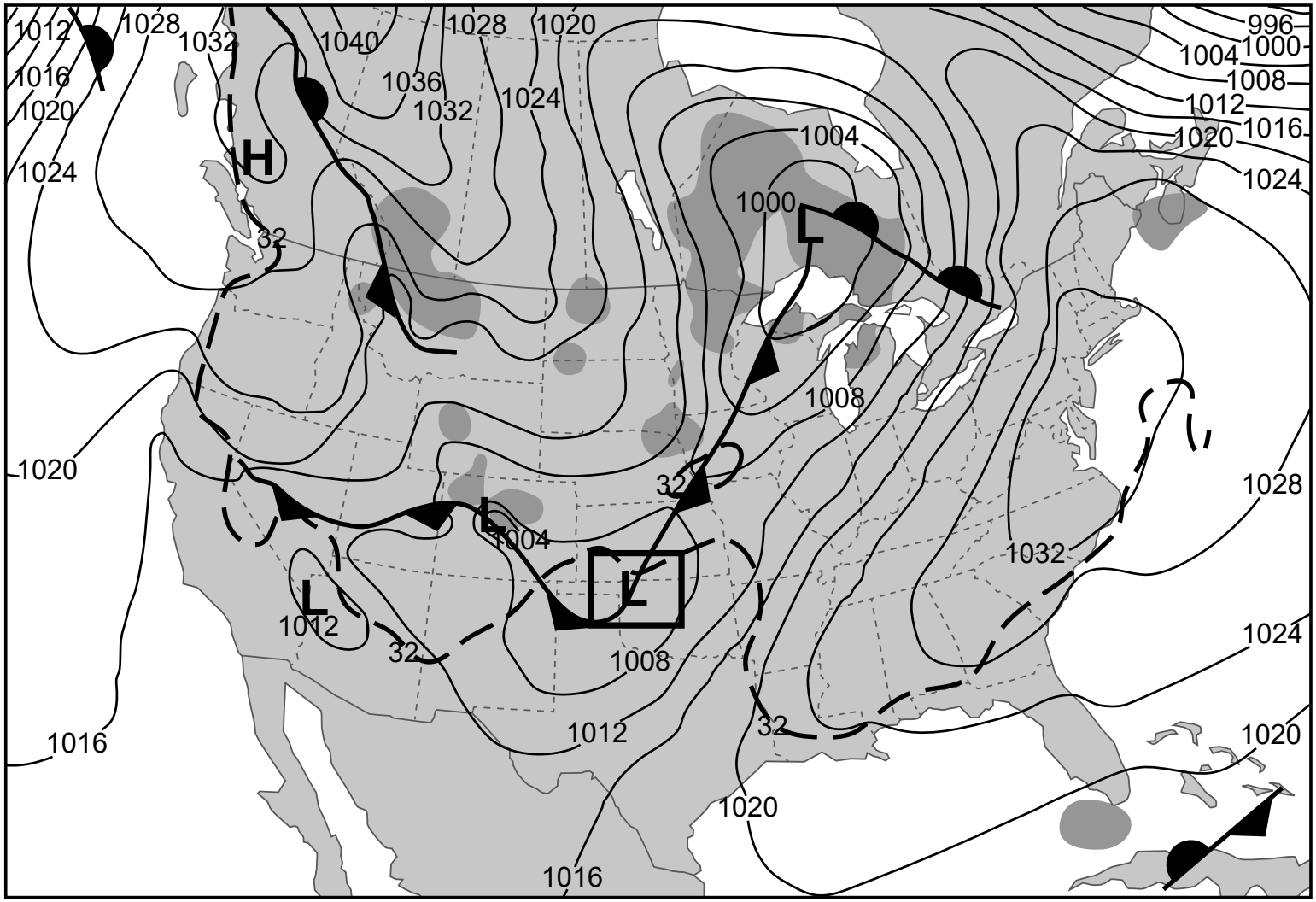
Minimum Temperatures: Monday, January 6, 2014



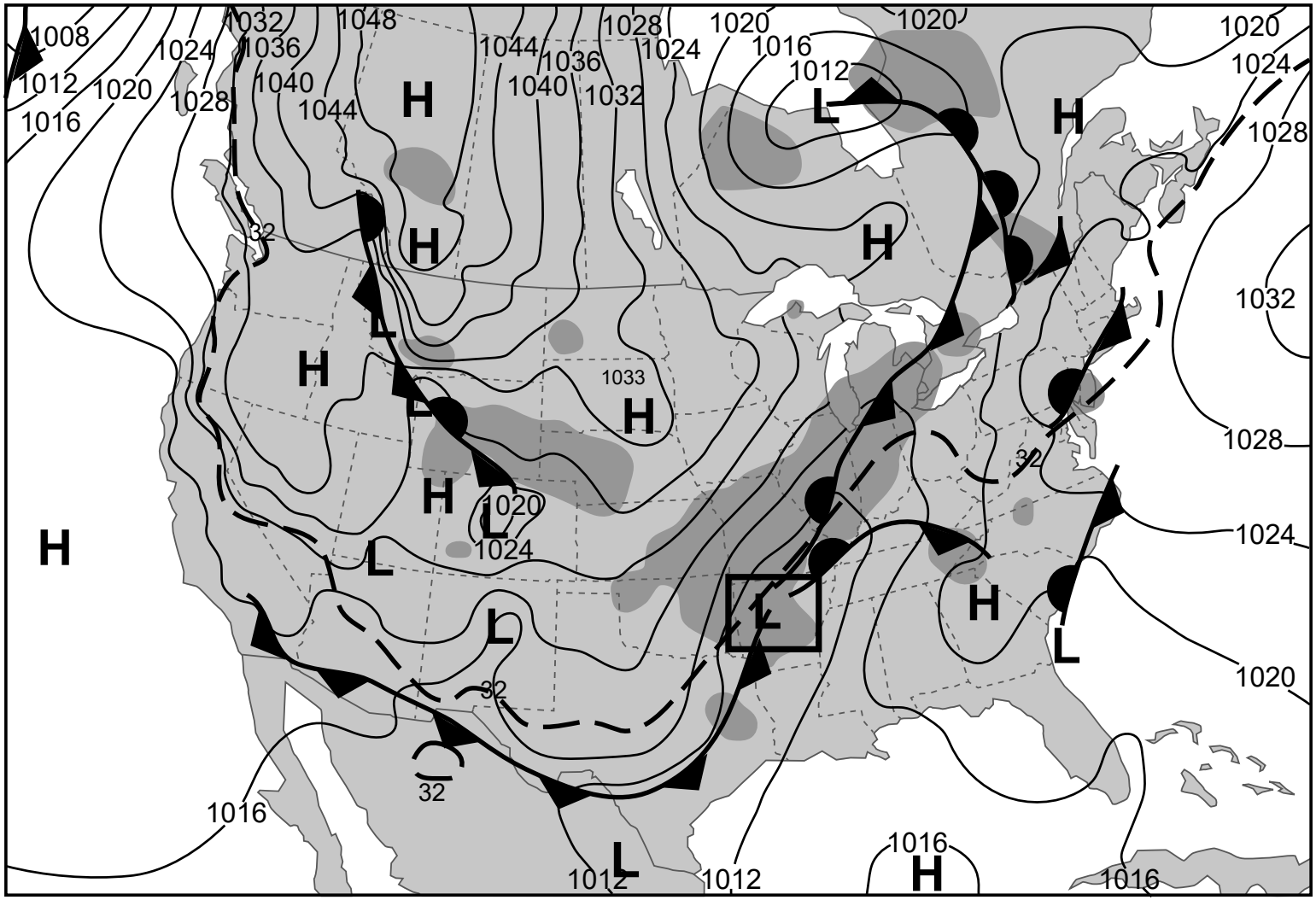
15 Explain how the maximum and minimum temperature maps on January 6, 2014 provide evidence for the claim that the central United States was most likely experiencing a polar vortex event on this date. [1]

The maps below show weather information for January 4, 2014 and January 5, 2014. The dashed line indicates the 32°F isotherm at 7 a.m. eastern standard time on each day. Areas of precipitation are shown in dark gray.

Saturday, January 4, 2014 Weather Map



Sunday, January 5, 2014 Weather Map



16 Which statement identifies the pattern of movement of the low pressure center and weather condition, indicated on the map with an **L**, from January 4 to January 5, 2014?

(1) The low moved west, and precipitation occurred in this area.

(2) The low moved east, and precipitation occurred in this area.

(3) The low moved north, bringing cold, dry weather to the area.

(4) The low moved south, bringing warm, dry weather to the area.

17 The movement of the cold front associated with the low pressure system from January 4 to January 5 is a result of

(1) unequal heating of Earth's surface and ocean circulation

(2) unequal heating of Earth's surface and prevailing global winds

(3) reflection of electromagnetic radiation and absorption of atmospheric energy

(4) reflection of electromagnetic radiation and release of atmospheric energy

18 Based on evidence from the maps, weather conditions in high pressure system (**H**) areas are generally clear because high pressure systems are usually

(1) not near frontal boundaries or near areas of precipitation

(2) only located near cold frontal boundaries that point east

(3) only located near warm frontal boundaries that point west

(4) located where isobars are closely spaced together

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Base your answers to questions 19 through 23 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 James Webb Space Telescope (JWST)

The James Webb Space Telescope (JWST) orbits the Sun in a complex path. This path allows the JWST to maintain a fixed location beyond Earth at an average distance of 1.5 million km from Earth. The JWST specializes in the study of infrared radiation. Many celestial objects, such as extrasolar planets, radiate large amounts of energy in the infrared range. Other objects, such as neutron stars, are hidden by dust. Visible light from these objects in the universe is stretched into the infrared range. Infrared radiation can easily pass through this dust.

On Earth, observing the infrared spectrum from celestial objects is difficult. Earth's atmosphere blocks some of the infrared spectrum from space. This makes outer space the best place to observe the infrared spectrum.

The model below shows some information about the orbital positions of Earth and the JWST.

19 From the Sun, the JWST average orbital distance and orbital velocity is approximately

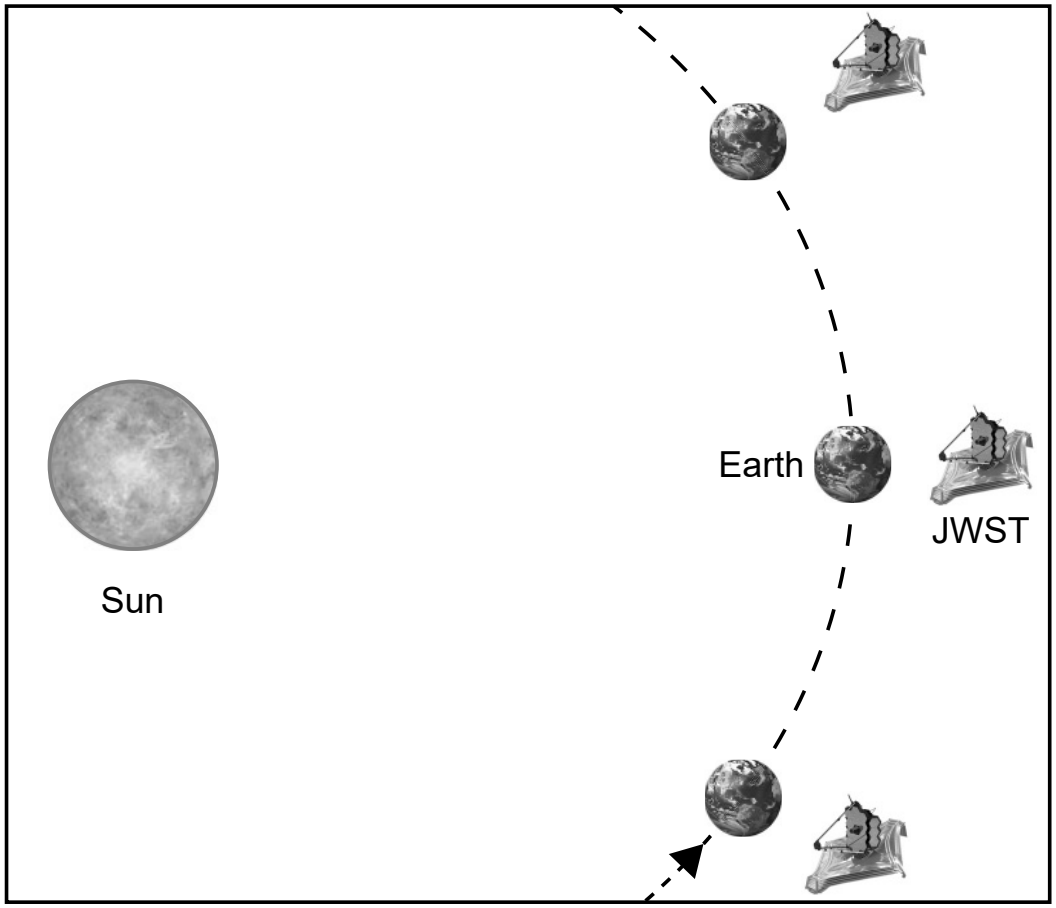
(1) 149.6 million km with the same orbital velocity as Earth to maintain a fixed location

(2) 149.6 million km with a faster orbital velocity than Earth to maintain a fixed location

(3) 151.1 million km with the same orbital velocity as Earth to maintain a fixed location

(4) 151.1 million km with a faster orbital velocity than Earth to maintain a fixed location

Model of Some Orbital Positions of Earth and JWST



(Not drawn to scale)

20 Place a check mark (✓) in each row to identify whether each design criteria or constraint is a positive or negative trade-off of the development and use of the JWST. [1]

Design Criteria or Constraints	Positive Trade-off	Negative Trade-off
Ability to Detect Older, More Distant Objects		
Access for Repair		
High Development Cost		
Quality of Infrared Imagery		

21 Which explanation uses evidence from the JWST to support the Big Bang Theory?

(1) The universe must still be expanding because the JWST observed that the visible light from distant galaxies has been moved into the infrared range.

(2) The universe must still be expanding because the JWST observed the infrared radiation from distant neutron stars that formed from the supernovas caused by the Big Bang.

(3) The universe must be stable and static because the JWST observed the infrared radiation from distant extrasolar planets that formed after the Big Bang.

(4) The universe must still be contracting because the JWST observed that the visible light from distant galaxies is compressed into the infrared range.

The JWST and the Hubble Space Telescope (HST) allow scientists to observe stars at various stages of stellar evolution. The table below shows some information for several stars observed by these two telescopes.

Stars Observed by the James Webb Space Telescope

Name	Spectral Class	Estimated Luminosity	Approximate Temperature (K)
WD 1202-232	A	1.0×10^{-3}	8400
21 Lyncis	A	1.0×10^{2}	9692
Quyllur	M	1.0×10^{6}	3500

22 Complete the model below by placing the names of all three stars in order of their relative ages. Then, label their correct H-R Diagram classification. [1]

Relative age 1. _____ (youngest) → 2. _____ → 3. _____ (oldest)

Classification 1. _____ → 2. _____ → 3. _____

The James Webb Space Telescope was used with other telescopes to observe a very bright gamma-ray burst. The release of gamma rays was evidence of two stars merging together. Spectral data allowed scientists to determine that elements more massive than iron were formed during this event. Elements more massive than iron may also form in some stars at one point in their life cycles.

23 Which statement about the formation of these elements during this event is correctly supported by the evidence from telescopes?

(1) Elements heavier than iron are usually formed during the destruction of massive stars.

(2) Elements heavier than iron are commonly fused together in main sequence stars.

(3) Gamma rays are necessary for the formation of elements heavier than iron.

(4) Merging stars absorbed the gamma rays, forming the elements heavier than iron.

Base your answers to questions 24 through 27 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 Influence of Volcanoes on Earth's Systems

Two of Earth's major volcanic eruptions occurred in 1883 at Krakatoa in Indonesia and in 1991 at Mt. Pinatubo in the Philippines. Both of these major eruptions produced large plumes of rock, ash, and gases that extended upward into Earth's stratosphere. Global winds circulated the ash and gases around Earth producing impacts for years. The model below shows some information about the tectonic setting of Southeast Asia.

24 Based on the model below, which plate tectonic interaction led to the formation and eruption of Mt. Pinatubo?

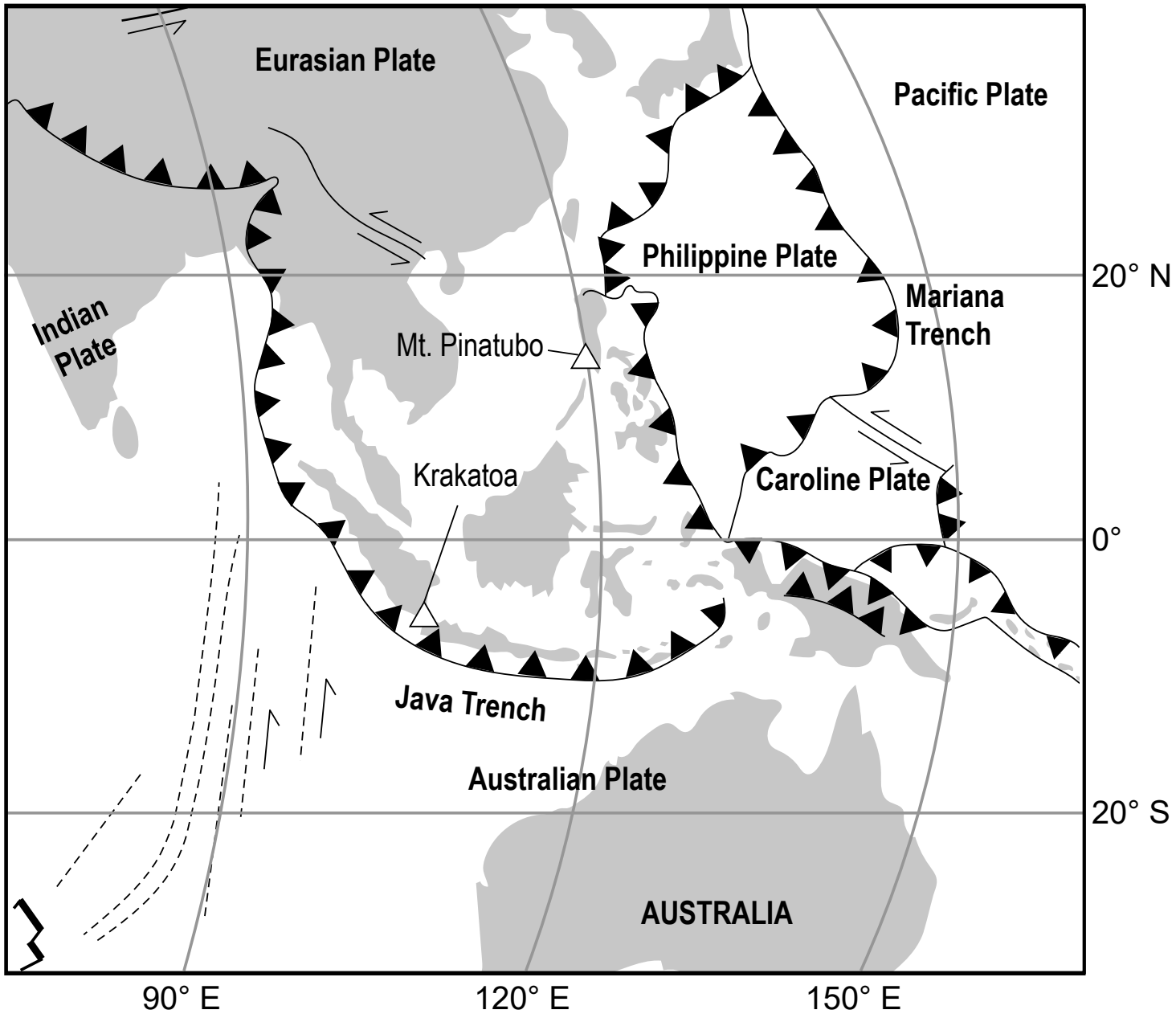
(1) divergence between the Philippine Plate and the Pacific Plate

(2) transform movement at the Mariana Trench

(3) convergence between the Australian Plate and the Eurasian Plate

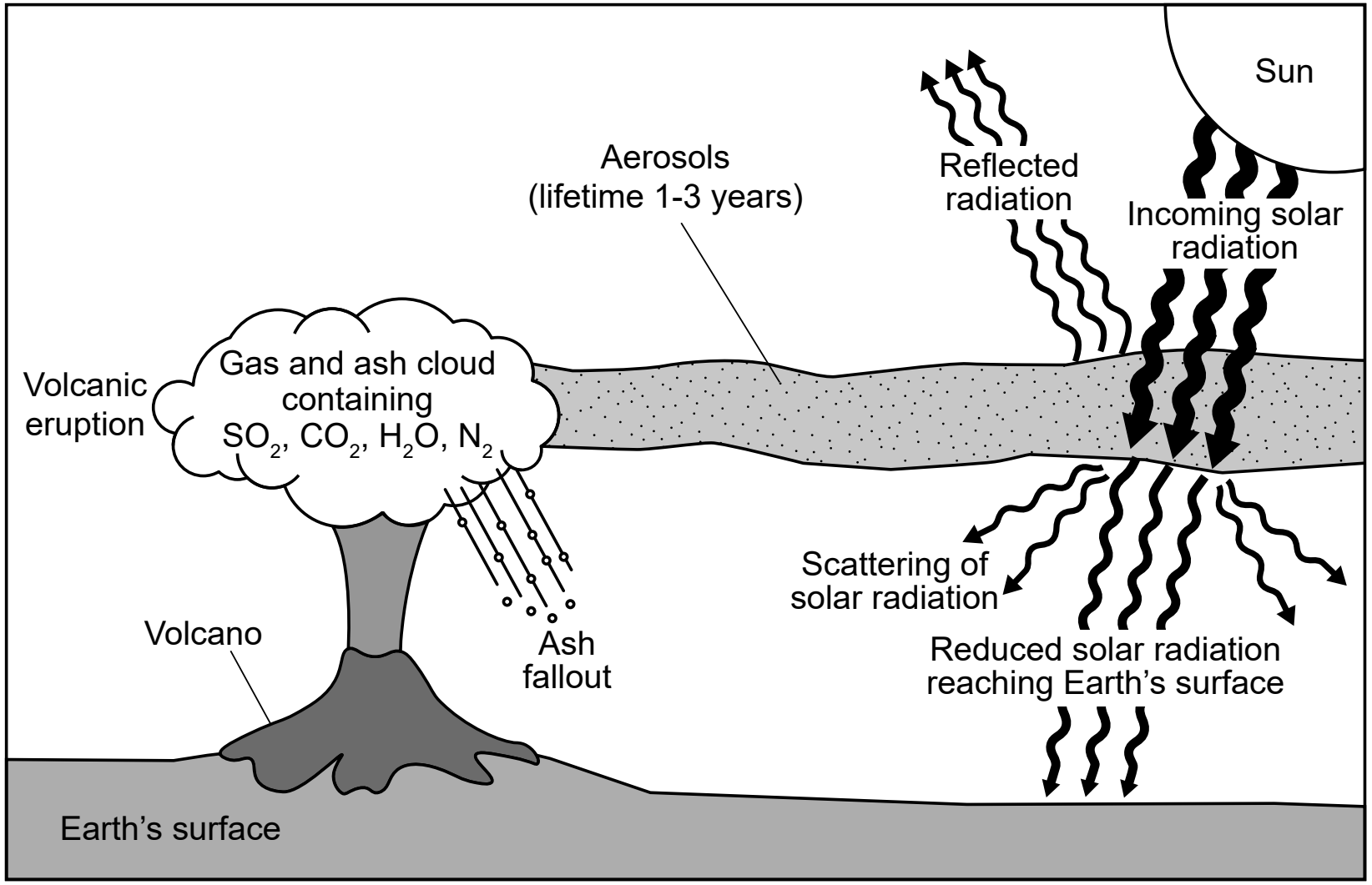
(4) convergence between the Eurasian Plate and the Philippine Plate

Model of Plate Motions in Southeast Asia



Volcanic eruptions cause changes to several Earth systems. The model below shows the effects that large volcanic eruptions, like those that occurred at Krakatoa and Mt. Pinatubo, have on the atmosphere. Very small solid or liquid particles (aerosols) ejected from volcanoes become suspended.

Volcanic Eruption Model



(Not drawn to scale)

25 Use information from the *Volcanic Eruption Model* to describe how aerosols ejected from volcanoes affect energy flow into *and* out of Earth's system. Also, describe the change in climate in the years following volcanic eruptions that most likely results from this change in energy flow. [1]

Effect of aerosols on energy flow: _____

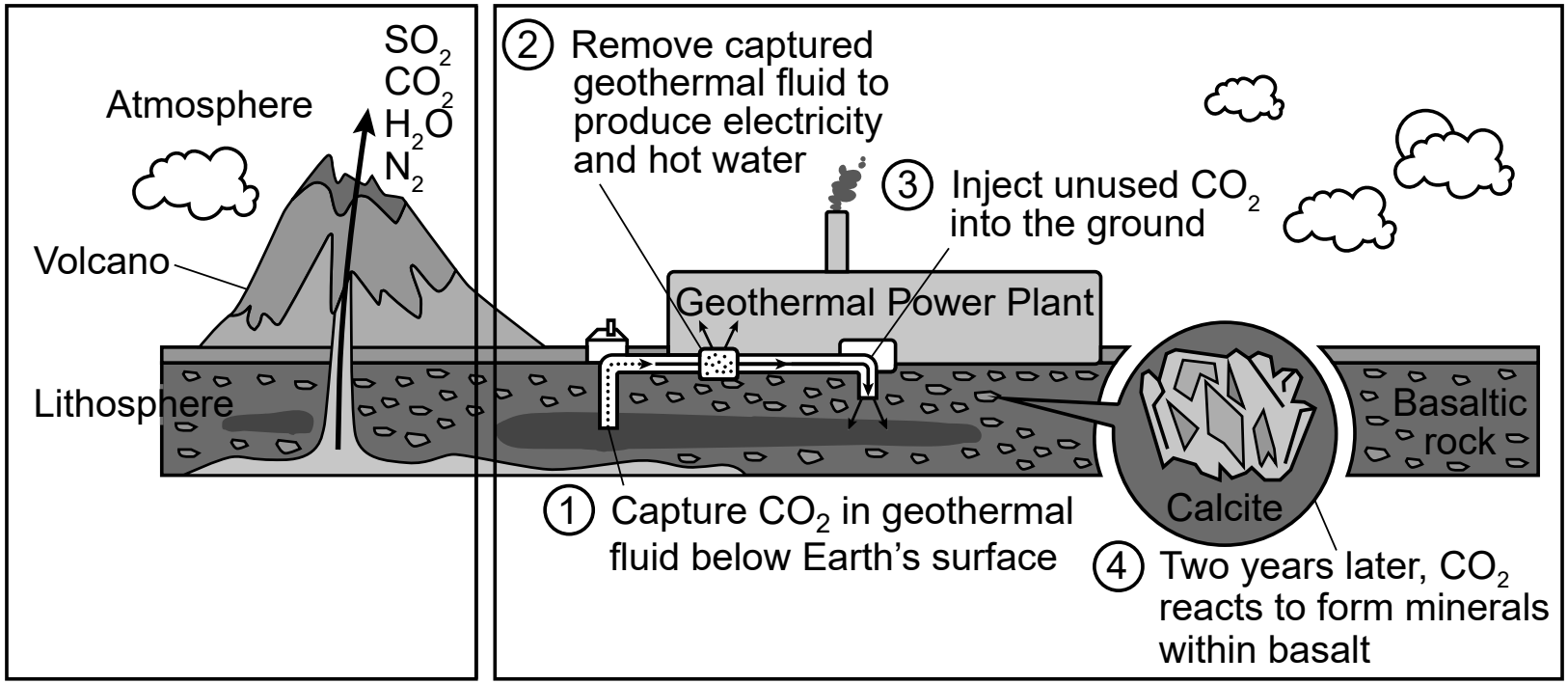
_____

Change in climate: _____

_____

Although volcanic activity can cause problems for humans, it can also provide benefits. The model below shows a four-step process of converting geothermal energy into usable energy, which includes mitigation of a cause of climate change.

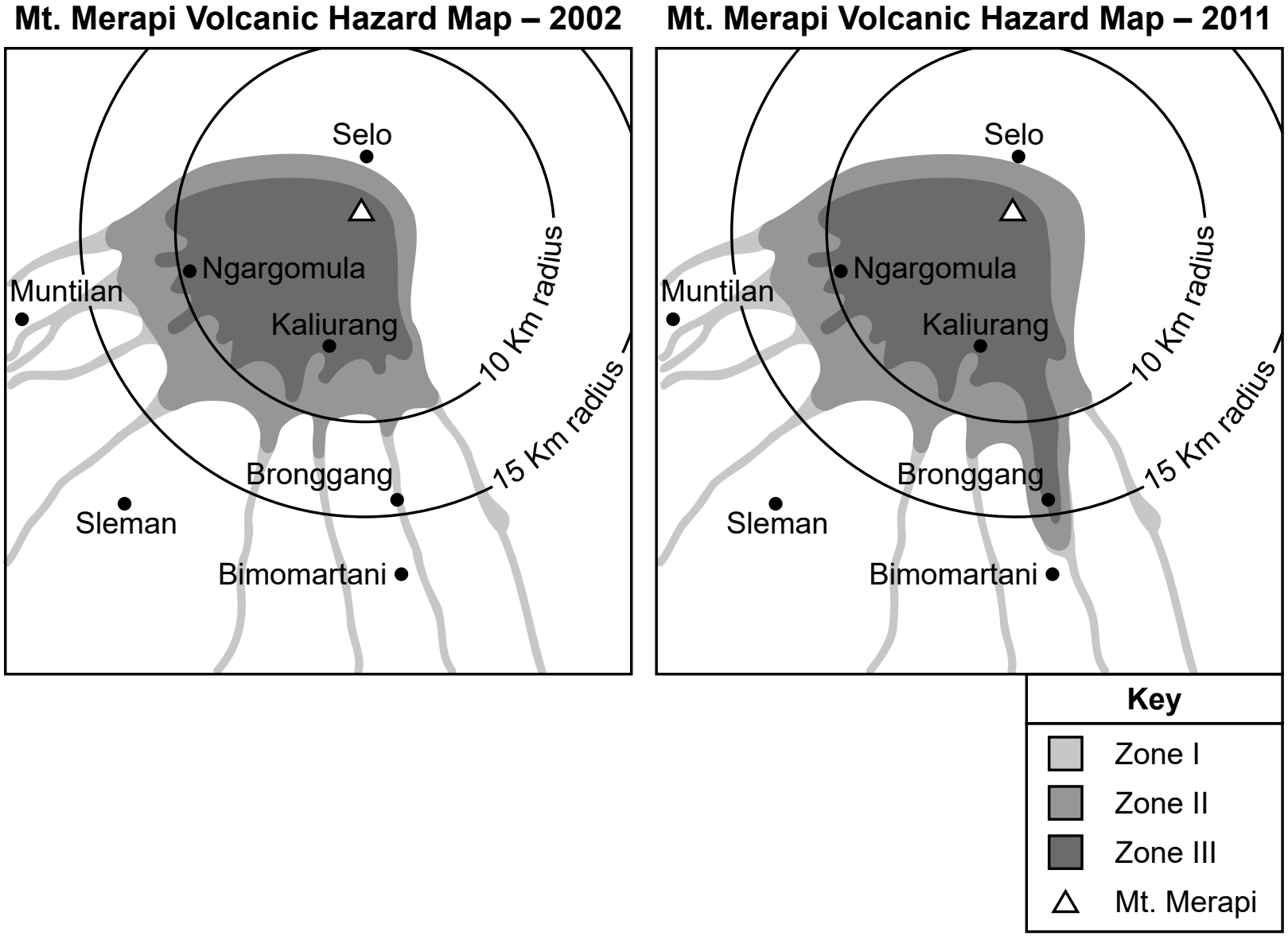
Model of Geothermal Power Plant with Mitigation Components



26 Based on the *Model of Geothermal Power Plant with Mitigation Components*, which row in the table correctly identifies the step during which energy flows out of an Earth system and a step that mitigates climate change?

Row	Step of Energy Flow Out	Mitigation Step
(1)	3	2
(2)	4	1
(3)	1	4
(4)	2	3

The Mount Merapi volcano hazard maps were made to identify areas of potential impact from pyroclastic flows as a result of previous eruptions. Locations in Zone I have a lower probability of being impacted by a pyroclastic flow (fast-moving hot ash and gas), while areas in Zone III have the highest probability of being impacted by pyroclastic flows.



27 Which statements correctly identify the probability of how these natural hazards have influenced human activity?

Statement 1: Residents of Bronggang downgraded their probability of experiencing a pyroclastic flow after the 2011 hazard map was created.

Statement 2: Residents in Bronggang should install an early warning system sooner than the residents of Selo due to the predicted direction of pyroclastic flow.

Statement 3: An early warning system is needed in Munitilan because it is within 15 km of Mt. Merapi.

Statement 4: Evacuation zones were developed based on the probabilities of pyroclastic flow directions.

Statement 5: Residents in Ngargomula should always evacuate when Mt. Merapi erupts because the community has the highest probability of being impacted by pyroclastic flows.

(1) Statements 1, 3, and 4

(2) Statements 2, 4, and 5

(3) Statements 2, 3, and 5

(4) Statements 1, 3, and 4

Base your answers to questions 28 through 31 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***.

New York's Concrete Industry

The production of concrete starts by mixing limestone and clay together, which are heated and dried in a kiln to produce clinker. Clinker is then pulverized into a fine powder and mixed with gypsum to make Portland cement. Aggregates, such as crushed stone and sand, are added to the Portland cement along with water to make a new product called concrete.

28 Mineral resources in New York State have allowed for the construction of facilities that produce cement. Which resource is correctly matched with the location where the resource is found and used to produce cement products?

(1) clay from the Manhattan Prong

(2) limestone from the Adirondack Mountains

(3) carbonate rock from the Hudson River Valley

(4) gypsum from the St. Lawrence Valley Province

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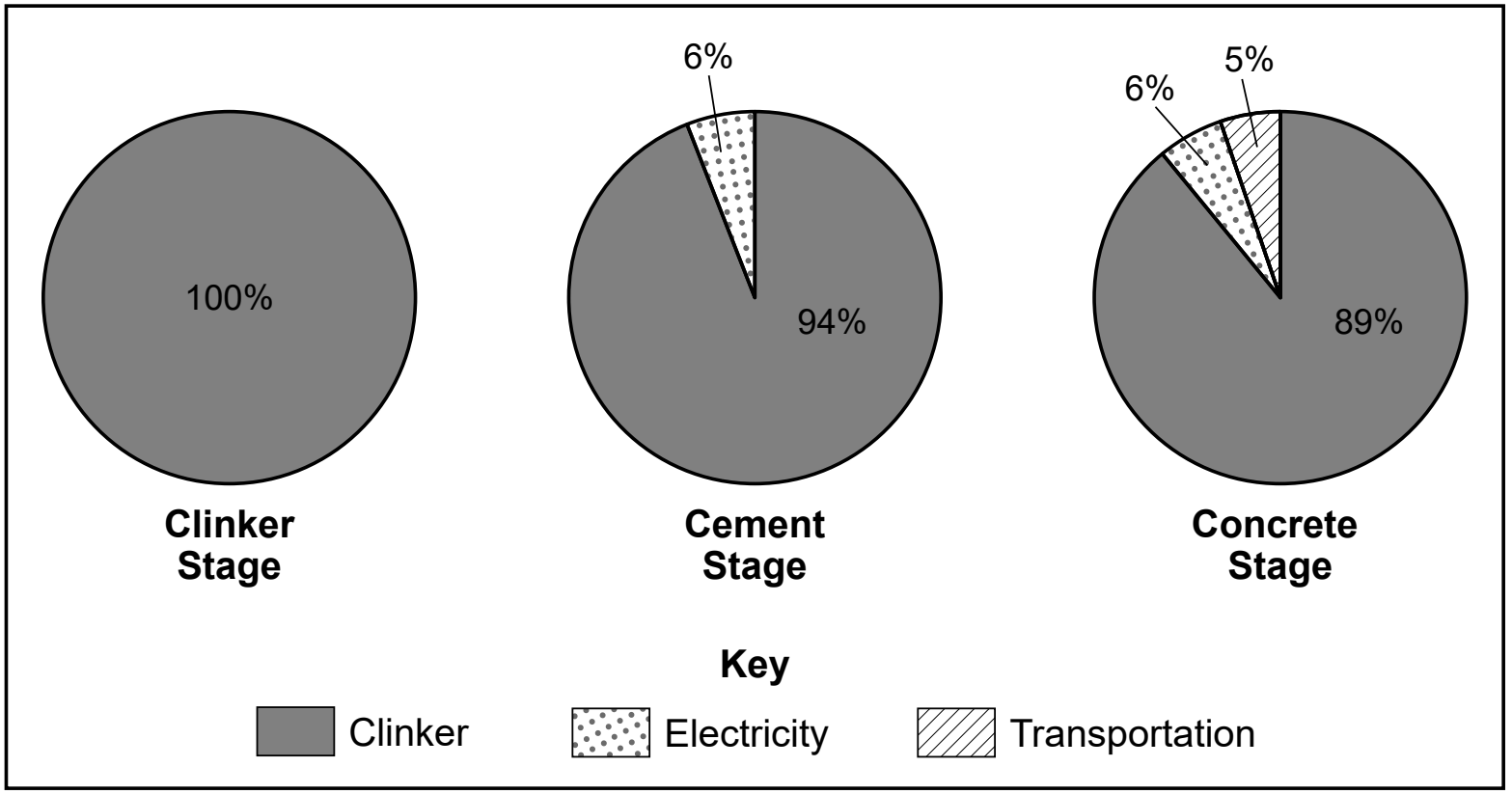
The pie charts below show some information about the carbon footprint of the three stages of concrete production. Carbon footprint is the percent of carbon emissions generated at each stage.

Carbon Footprint of Each Stage of Concrete Production



29 Which statement identifies the relationship between two Earth systems that are affected by the production of concrete?

(1) During the concrete stage, 11% of emissions are released from the geosphere into the hydrosphere from transportation.

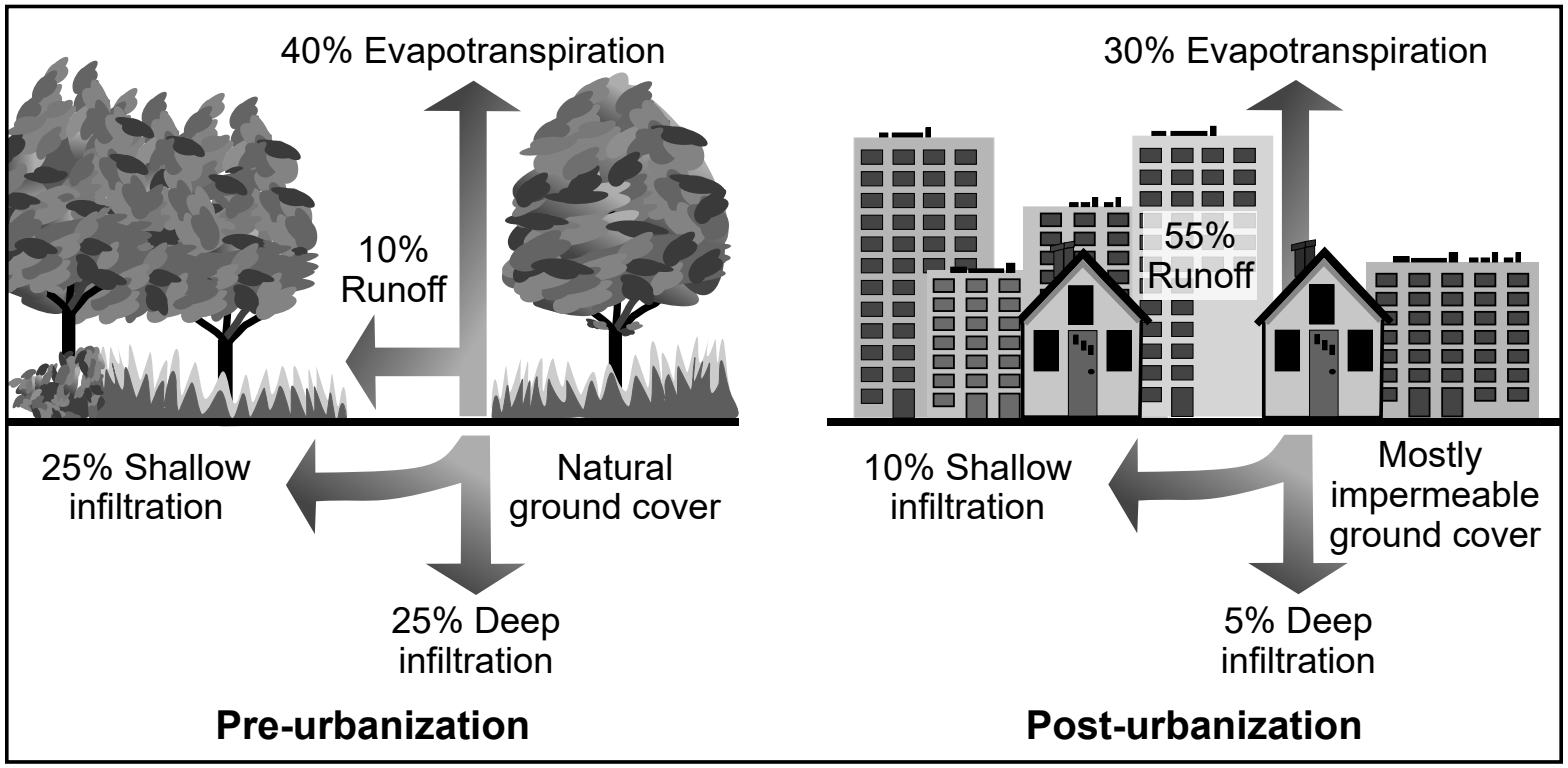
(2) During the cement stage, 100% of emissions are released from the geosphere into the atmosphere from the production of clinker.

(3) During the concrete stage, 5% of emissions are released from the atmosphere into the geosphere from transportation.

(4) During the cement stage, 94% of emissions are released from the geosphere into the atmosphere from the production of clinker.

Concrete has been used for centuries in the development of urban areas. The model below shows some information about urbanization.

Urbanization Impact on Earth's Spheres



30 Circle **two** of the three Earth systems below that are influenced by the use of concrete in the development of urban areas. Then, describe **one** impact of urbanization on the water cycle of each of the **two** chosen Earth systems. [1]

Earth System	Impact
Circle one: Atmosphere Hydrosphere Geosphere	_____ _____
Circle one: Atmosphere Hydrosphere Geosphere	_____ _____

Engineers have developed a newer type of concrete, called porous concrete, to address some environmental issues that accompany urbanization. An investigation was completed by an engineer in northern New York using the properties of water to determine water's impact on porous concrete. The tables below show some information on the properties of concrete and water. The photographs show the results of the engineer's investigation.

Porosity

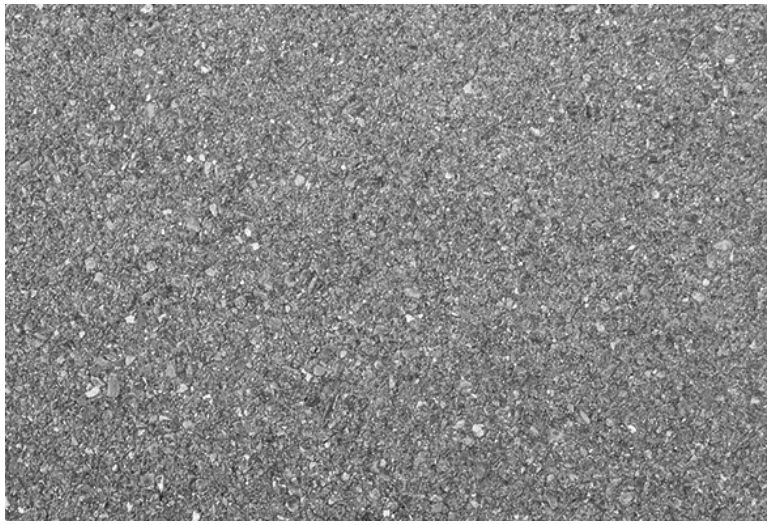
Concrete Type	**Open Space** (%)
Traditional	3-5
Porous	15-22

Properties of Water

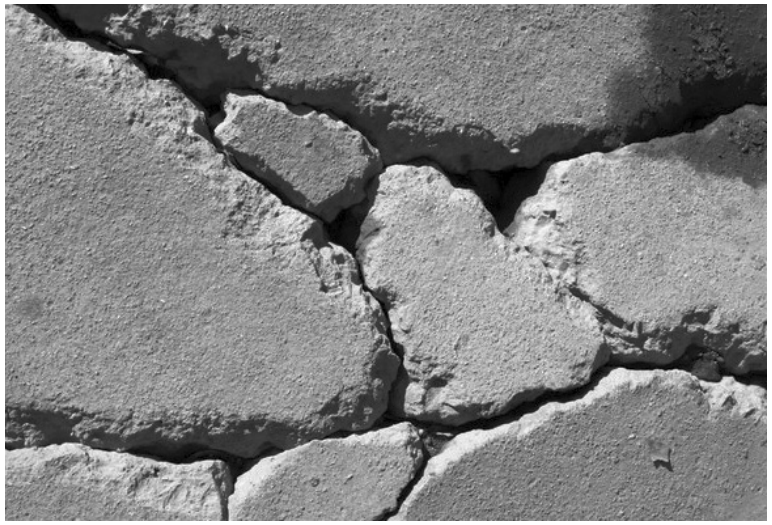
Phase	**Temperature** (°C)	**Density** (g/mL)
Liquid	4	1.0
Solid	0	0.92

Porous Concrete

New Installation



After Several Years



The six factual statements below describe some considerations for the use of porous concrete throughout New York State.

I – Sand cannot be used on new porous concrete for ice control.

II – Porous concrete typically has a cooler surface temperature during the summer.

III – Porous concrete has a higher cost for installation and maintenance.

IV – Porous concrete cannot be used for roads, bridges, dams, and buildings.

V – Porous concrete filters sediments from runoff.

VI – Porous concrete has a rougher surface and provides better traction during the winter.

31 Which two statements identify constraints that would support the choice of traditional concrete over porous concrete?

(1) Claims I and V

(2) Claims II and V

(3) Claims III and VI

(4) Claims III and IV

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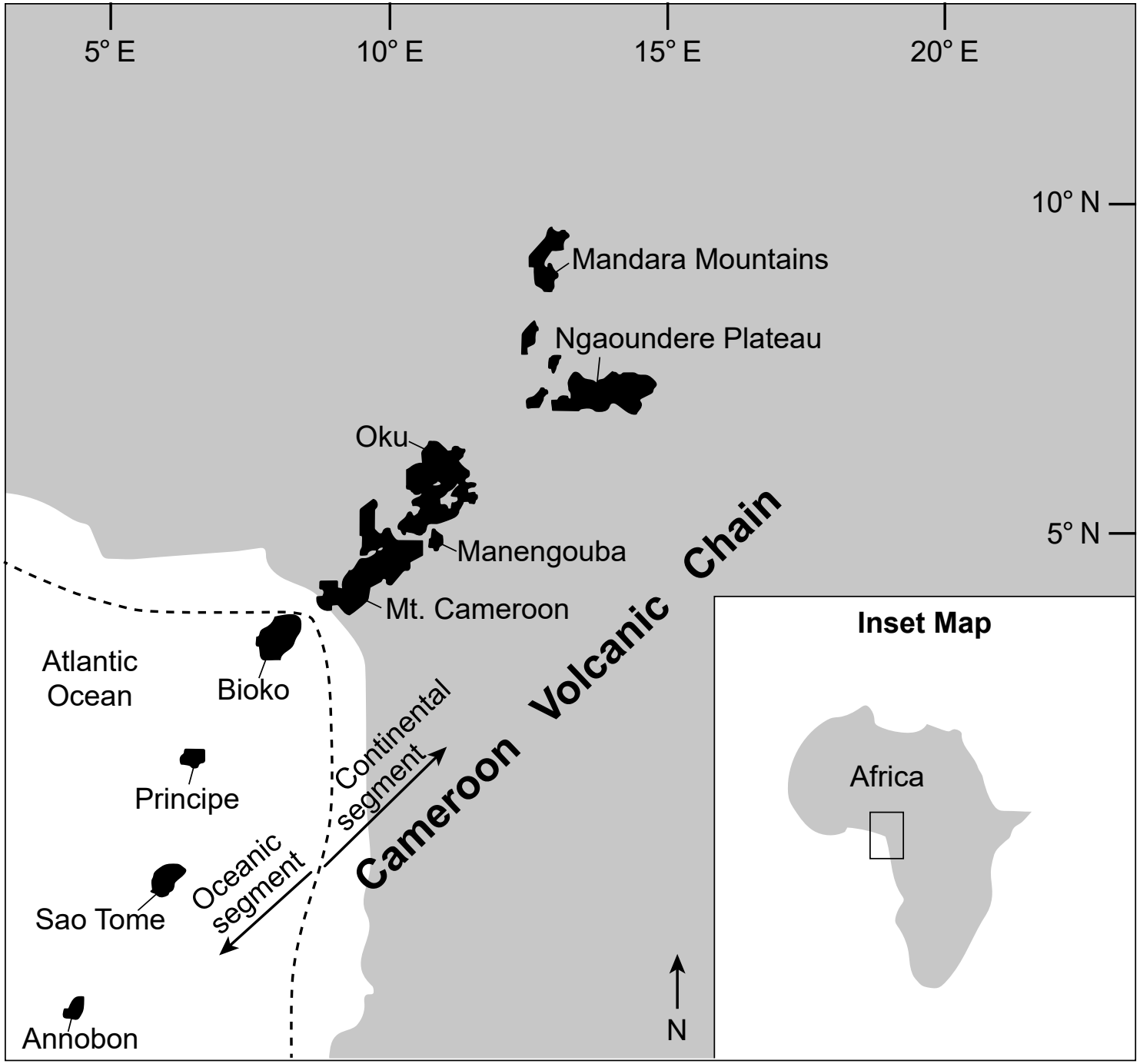
Base your answers to questions 32 through 36 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the ***2024 Edition Reference Tables for Earth and Space Sciences***.

Lake Nyos

Lake Nyos sits in the crater of an inactive volcano in northwestern Cameroon, Africa, within the Oku Volcanic Field. Lake Nyos has almost no convection. A layer of warm water always sits on top of a deep layer of cold water. In 1986, a large bubble of carbon dioxide that was trapped at the bottom of the lake rose to the surface. The carbon dioxide then moved down into the valley killing 1800 people and 3500 livestock.

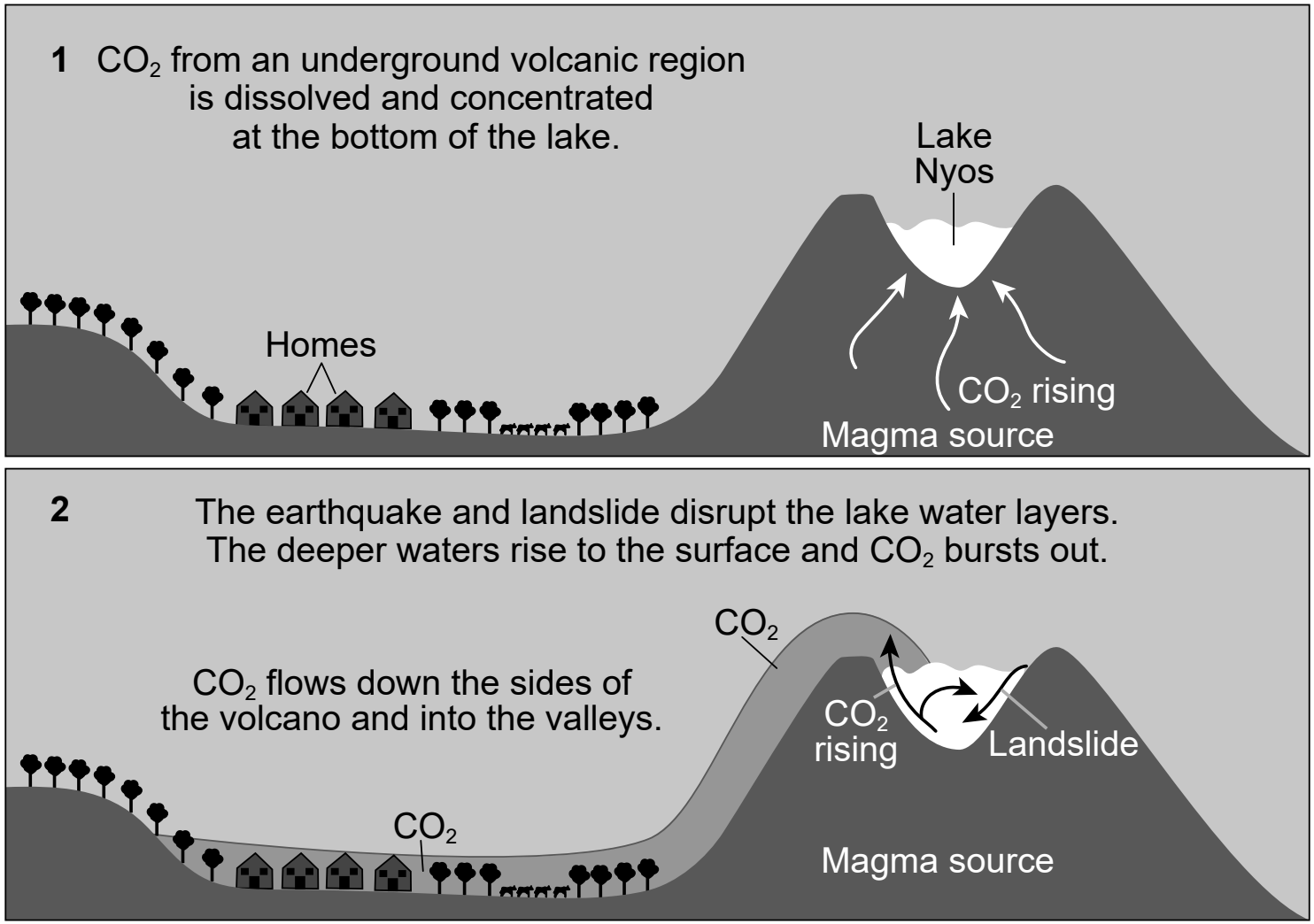
The map below shows the locations and names of the volcanic features that include Lake Nyos. The inset map shows the location of the Cameroon Volcanic Chain in Africa.

Map of Cameroon Volcanic Chain



The infographic below shows some information about the Lake Nyos event.

Process of Carbon Dioxide Emission in Lake Nyos



(Not drawn to scale)

32 Which factor most likely caused the movement of carbon dioxide gas from the lake downhill into the valley?

(1) Air temperature on top of the mountain increased, causing the carbon dioxide gas to sink and flow into the valley.

(2) Atmospheric pressure decreased as the carbon dioxide gas flowed down the sides of the volcano.

(3) Atmospheric density increased over the lake because the carbon dioxide gas was more dense than the surrounding air, causing it to flow down the volcano.

(4) Relative humidity was higher at the surface of the lake than in the valley, causing carbon dioxide gas to flow into the valley.

33 Using evidence from the infographic, which statement describes the best human response that would reduce loss of life due to a future release of the trapped carbon dioxide in Lake Nyos?

(1) Relocate the homes to higher ground above the valley floor.

(2) Plant more trees along the slope of Lake Nyos to absorb carbon dioxide.

(3) Drain Lake Nyos to remove the source of carbon dioxide.

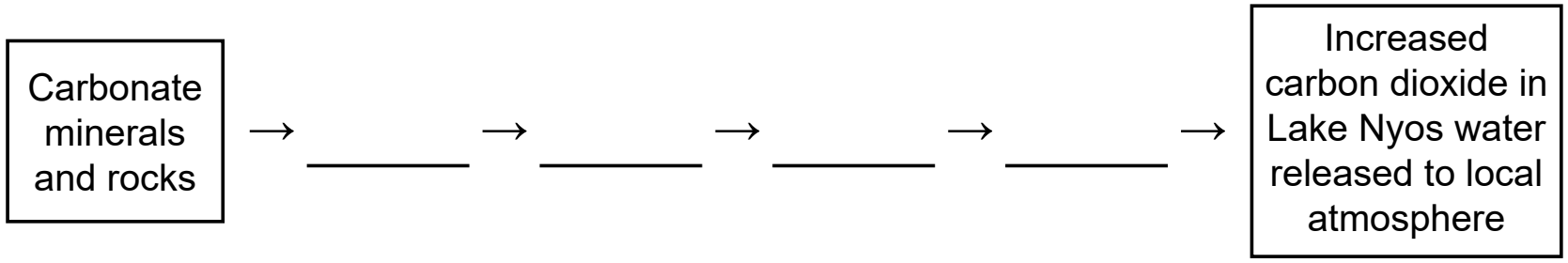
(4) Relocate homes to a different part of the valley floor.

The magma creating the Cameroon Volcanic Chain is rich in carbon dioxide. Two sources of carbon dioxide in the magma are found in surface and mantle minerals and rocks. Carbonate minerals and rocks (containing carbon and oxygen) located on Earth are broken down and melted.

34 Complete the qualitative model below by writing the letter for each choice in the correct space in the model to represent one pathway for the movement of carbon that was responsible for the increased levels of carbon dioxide in Lake Nyos water. [1]

Choice	A	B	C	D
Description	Carbon dioxide dissolves into magma	Carbon dioxide is released from carbonate minerals and rocks	Carbon dioxide leaks from rising magma and dissolves into the lake	Heat is applied to carbonate minerals and rocks

Model of Carbon Movement



35 Describe how the minerals within the rocks of the continental segment are different than those found in the oceanic segment of the region around the Cameroon Volcanic Chain. Use at least **one** specific mineral to support your description. [1]

After several studies in the 1980s and early 1990s, scientists and engineers proposed installing degassing pipes in Lake Nyos to prevent further loss of life. These pipes function in two stages. In stage one, carbon dioxide would be removed by using a powered pump to pull small amounts of cold water from the bottom of the lake to the surface.

In stage two, the bubbling from the carbon dioxide coming out of the water (carbonated water) creates suction and makes the process self-sustaining. The first degassing pipe was installed in 2001 with additional pipes installed in 2011. The carbon dioxide now comes to the surface under its own pressure with no pump required.

The model below shows some information about degassing pipes installed in Lake Nyos.

36 Which description best explains why self-sustaining degassing pipes are the best solution for reducing the risk of future outgassing events at Lake Nyos?

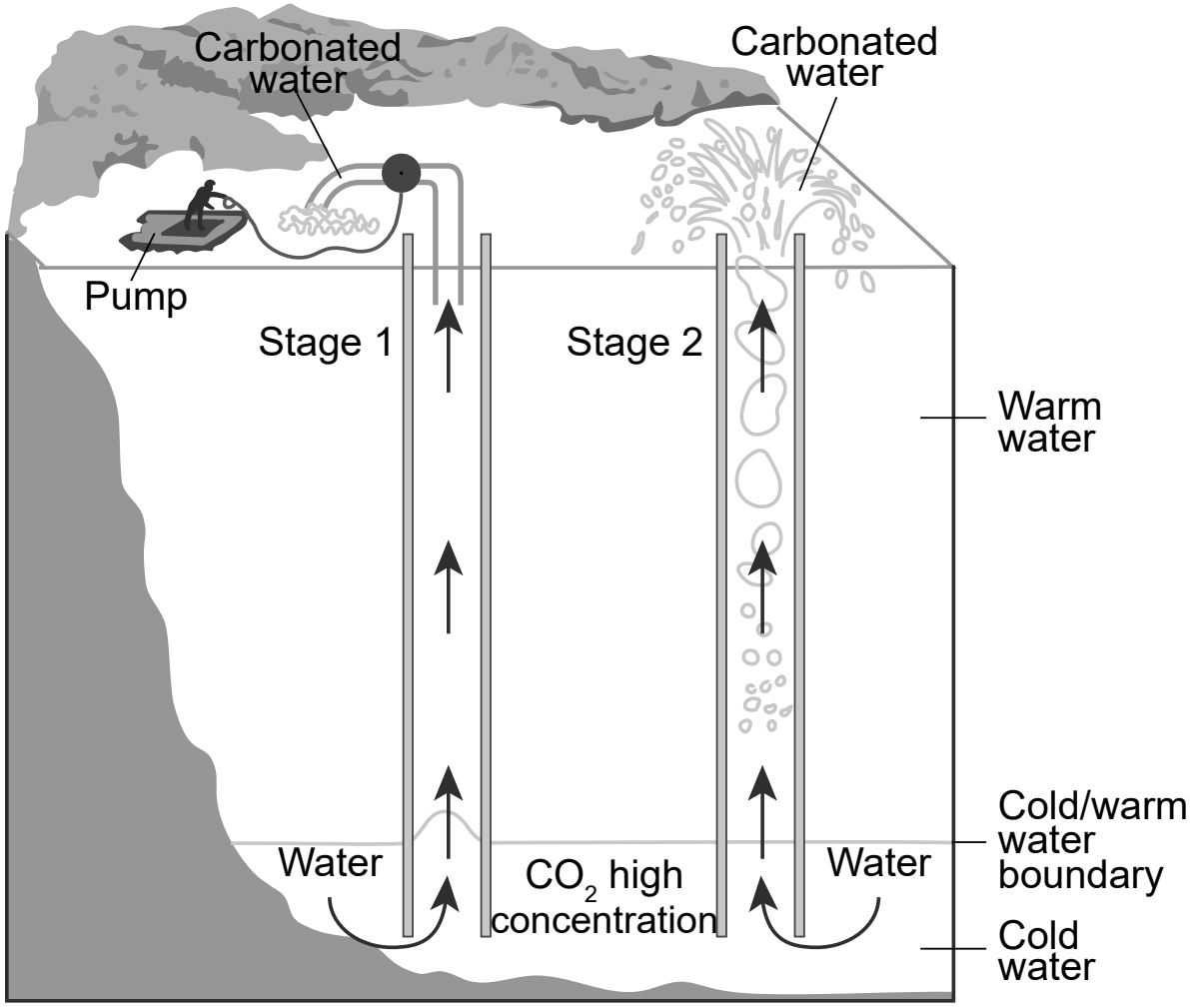
(1) Self-sustaining degassing pipes leave the cold water at the bottom of Lake Nyos undisturbed. This allows the natural processes to continue without disrupting the natural system.

(2) The self-sustaining pipes allow the residents of rural Cameroon to be less dependent on scarce fossil fuels or electricity needed to operate the pipes.

(3) The self-sustaining degassing pipes reduce the risk of future volcanic eruptions by removing the carbon dioxide from the magma underneath Lake Nyos.

(4) The self-sustaining pipes allow the warm and cold water layers of Lake Nyos to mix. This process removes the carbon dioxide from the lake.

Degassing Pipes Model



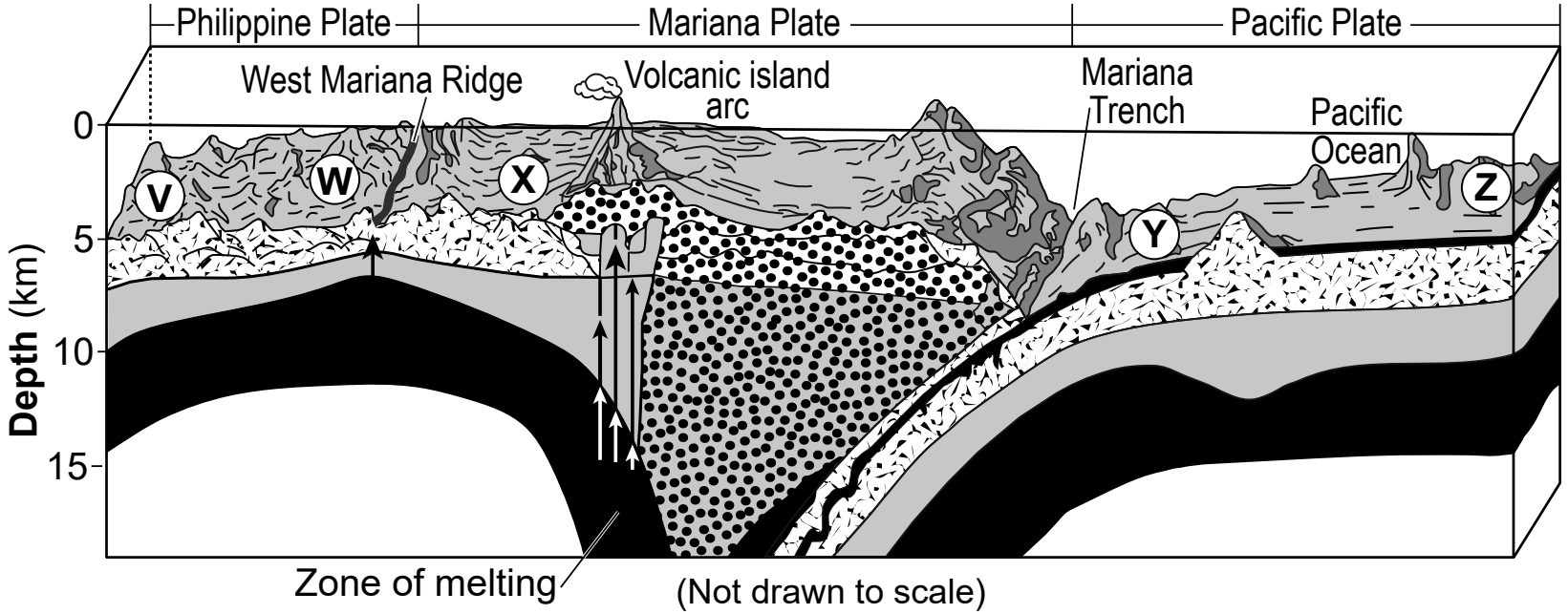
(Not drawn to scale)

Base your answers to questions 37 through 41 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 Complex Tectonics of the Western Pacific

The Mariana Plate is a microplate that is located west of the Mariana Trench. Geologic activity caused a section of the Philippine Plate to break off and become the Mariana Plate. This microplate is surrounded by many geologic features and complex plate boundaries. Letters *V* through *Z* represent locations on Earth's surface.

Model of Area Surrounding the Mariana Trench



37 Which statement correctly describes the pattern of ages in the crustal rocks found in the model?

(1) Location *Y* is younger than location *V* because location *Y* is closer to the convergent boundary.

(2) Location *W* is older than location *X* because location *W* is closer to the divergent boundary.

(3) Location *Y* is older than location *Z* because location *Y* is closer to the convergent boundary.

(4) Location *V* is younger than location *W* because location *V* is located farther away from the divergent boundary.

38 Plate interactions that cause plates to move also form features on Earth's surface. Which table accurately identifies the process associated with the complex features found in the model?

Features	Process
Divergent boundary	Constructive
Volcanic island arc	Constructive
Mariana Trench	Destructive

(1)

Features	Process
Divergent boundary	Constructive
Volcanic island arc	Destructive
Mariana Trench	Constructive

(3)

Features	Process
Divergent boundary	Destructive
Volcanic island arc	Constructive
Mariana Trench	Destructive

(2)

Features	Process
Divergent boundary	Destructive
Volcanic island arc	Destructive
Mariana Trench	Constructive

(4)

39 Four tectonic processes listed below describe one stage in the cycling of Earth materials in the Mariana region.

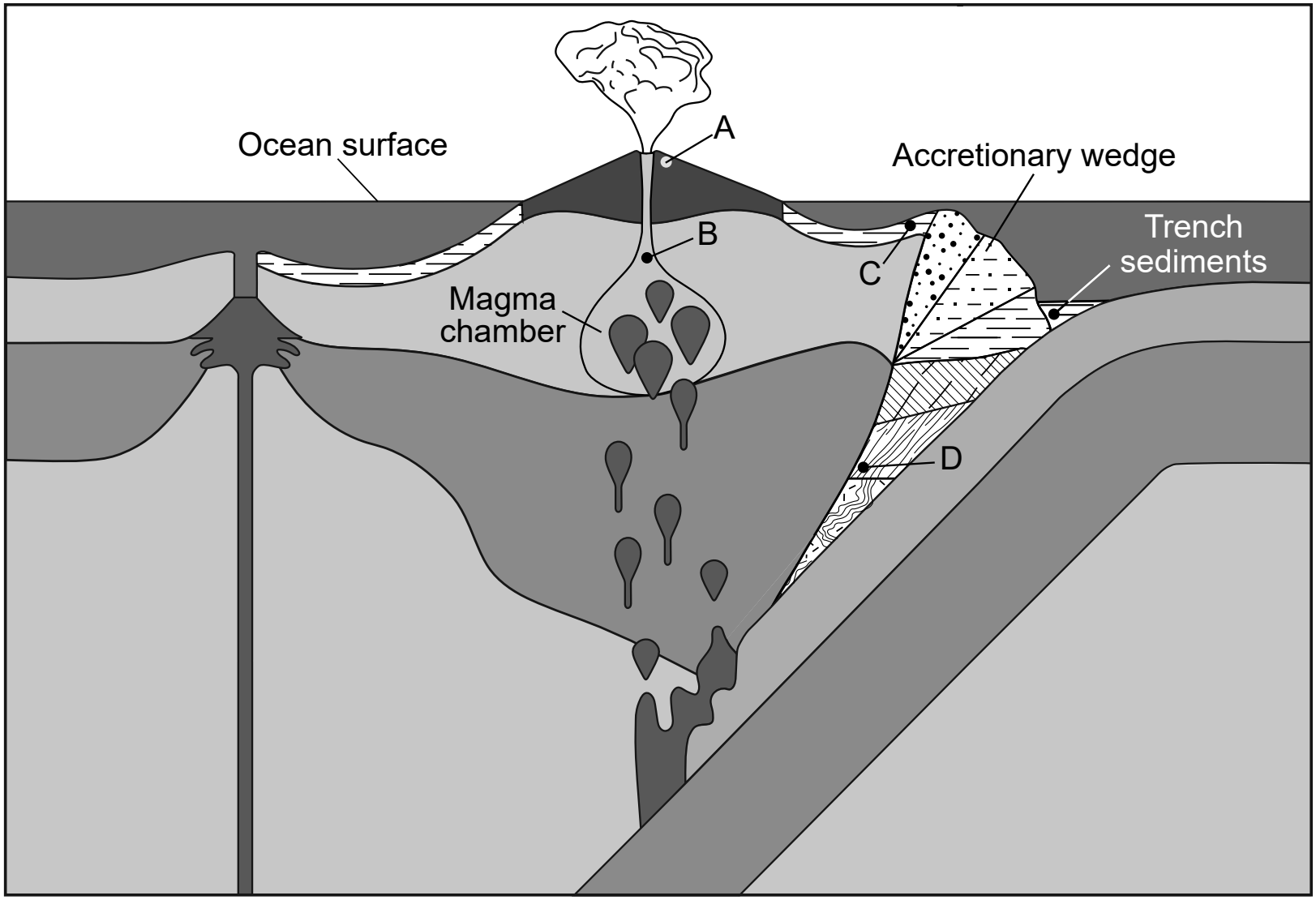
A	Eruption and solidification of lava
B	Partial melting of oceanic crust
C	Rising magma
D	Subduction of the Pacific Plate

Write the letter of each tectonic process in the correct sequence to describe the cycling of Earth materials from location *Y* to location *X*. [1]

_____ → _____ → _____ → _____

The model below shows some information about rock formation in the area surrounding the Mariana microplate.

Model of Rock Formation Environments Along Plate Boundary

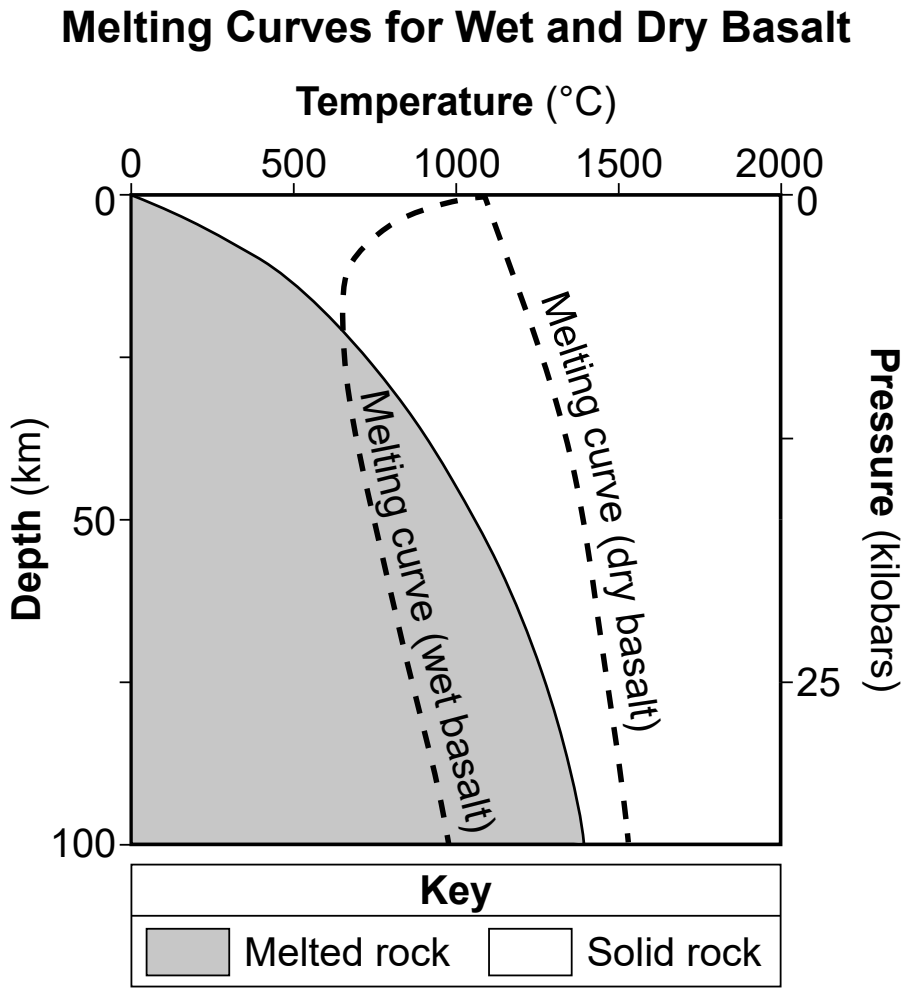


(Not drawn to scale)

40 Based on the model, which row in the data table below identifies the correct combination of location of formation, rock forming process, and rock name?

Row	Location of Formation	Rock Forming Process	Rock Name
(1)	A	Eruption	Granite
(2)	B	Solidification	Peridotite
(3)	C	Compaction	Conglomerate
(4)	D	Heat/pressure	Schist

At the Mariana trench, water-bearing minerals are brought into the mantle, altering the melting point temperature. The graph below shows some information about melting of basalt. Pressures on the graph are in kilobars (one kilobar is equivalent to one thousand times Earth's average surface air pressure).



41 Name **one** tectonic feature that forms in an area above melting oceanic crust. Then use evidence from the graph to describe how the presence of water affects the melting point of basalt. [1]

Tectonic feature: _____

Evidence: _____

_____

_____

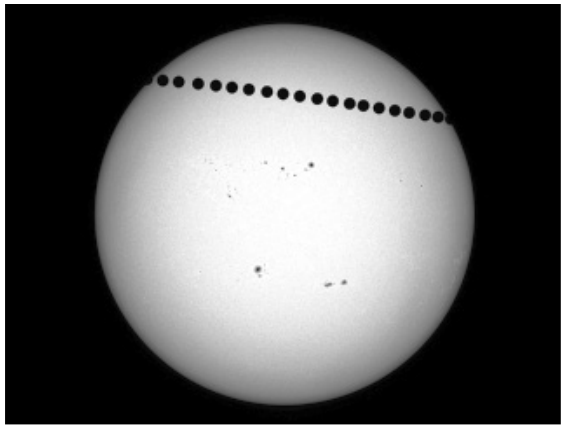
Base your answers to questions 42 through 46 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the ***2024 Edition Reference Tables for Earth and Space Sciences***.

Planetary Transits

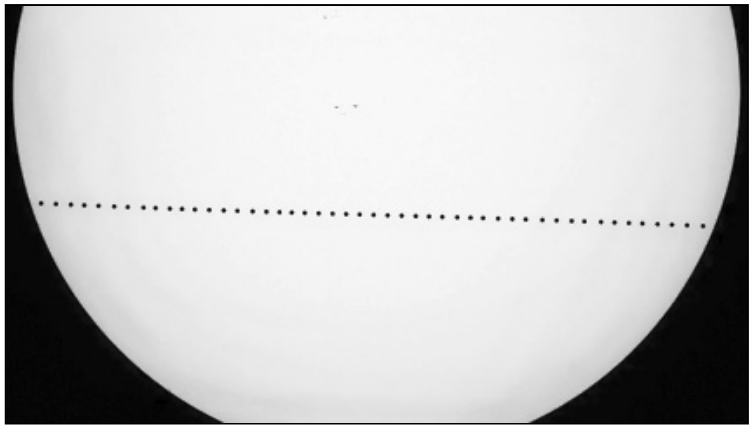
The transit of a planet across the disk of the Sun may be thought of as a special kind of eclipse. A transit occurs when a planet passes across the disk of the Sun.

The time-lapse photographs below show two planetary transits across the Sun.

2012 Venus Transit Composite Photo



2016 Mercury Transit Composite Photo



The data table shows some information about the transits of Mercury and Venus.

Dates of Planetary Transits

Transits of Mercury	Transits of Venus
May 7, 2003	June 8, 2004
November 8, 2006	June 6, 2012
May 9, 2016	December 10, 2017
November 11, 2019	December 8, 2125
November 13, 2032	
November 7, 2039	
May 7, 2049	

42 Which piece of evidence explains why Mercury and Venus are the only planets in our solar system that transit when viewed from Earth?

(1) Mercury and Venus have smaller equatorial diameters than Earth.

(2) Mercury and Venus both have axial tilts greater than Earth's axial tilt.

(3) Mercury and Venus are the only planets between Earth and the Sun.

(4) Mercury and Venus have orbits with the greatest eccentricities in the solar system.

43 Which evidence-based statement explains why Mercury has more transits of the Sun than Venus for the same time period, as viewed from Earth?

(1) Mercury orbits the Sun approximately 2.6 times faster than Venus, resulting in a greater probability of a transit being viewed from Earth.

(2) Venus orbits the Sun approximately 2.6 times faster than Mercury, resulting in a greater probability of a transit being viewed from Earth.

(3) Mercury orbits the Sun approximately 2.6 times faster than Earth, resulting in a greater probability of a transit being viewed from Earth.

(4) Venus orbits the Sun approximately 2.6 times faster than Earth, resulting in a greater probability of a transit being viewed from Earth.

The Kepler space telescope used planetary transits to find planets outside our solar system. Kepler-16b was the first planet discovered in a binary star system. Binary star systems contain two stars. In this solar system, the stars Kepler-16A and Kepler-16B orbit each other.

Some Characteristics of Kepler-16 Stars

Star	Approximate Surface Temperature (K)	Luminosity
Kepler-16A	4500	0.14
Kepler-16B	3300	0.005

44 Describe the **two** characteristics of the Kepler-16 stars compared to our Sun. Then, describe how these characteristics affect the lifetime of these stars compared to our Sun. [1]

Characteristics: _____

_____

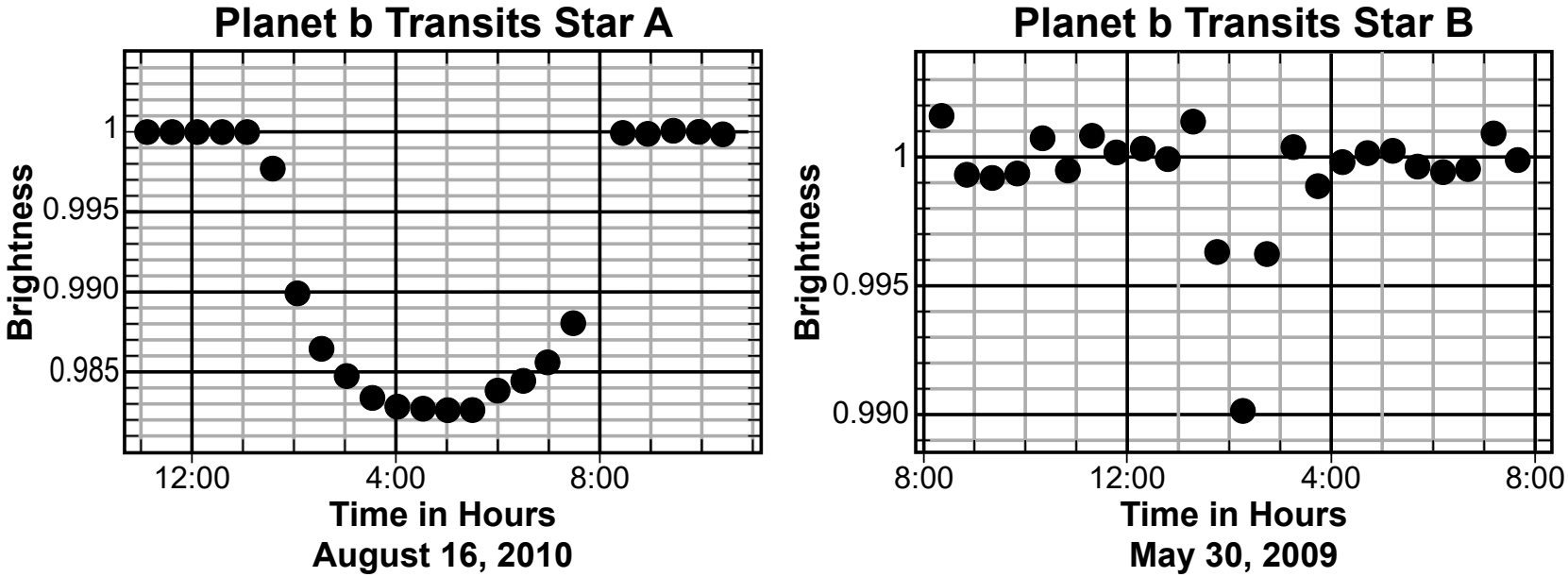
Lifetime: _____

_____

45 Based on the characteristics of Kepler-16A, which row best describes the nuclear fusion occurring within this star, and correctly identifies a star that has similar characteristics?

Row	
(1)	Fusion of helium directly to hydrogen; similar to Lacaille 9352
(2)	Fusion of hydrogen directly to helium; similar to Cygni B
(3)	Fusion of hydrogen directly to carbon; similar to Alpha Centauri B
(4)	Fusion of hydrogen directly to helium; similar to Gliese 725 B

The graphs below show some information about the apparent dimming of the stars Kepler-16A and Kepler-16B as planet Kepler-16b transits them.



46 Calculate how long it takes planet Kepler-16b to transit both stars, and provide **one** reason why the planet's transit takes a longer period of time to cross the star Kepler-16A compared to the star Kepler-16B. [1]

Transit time for Kepler-16A: _____ **hours**

Transit time for Kepler-16B: _____ **hours**

Reason: _____

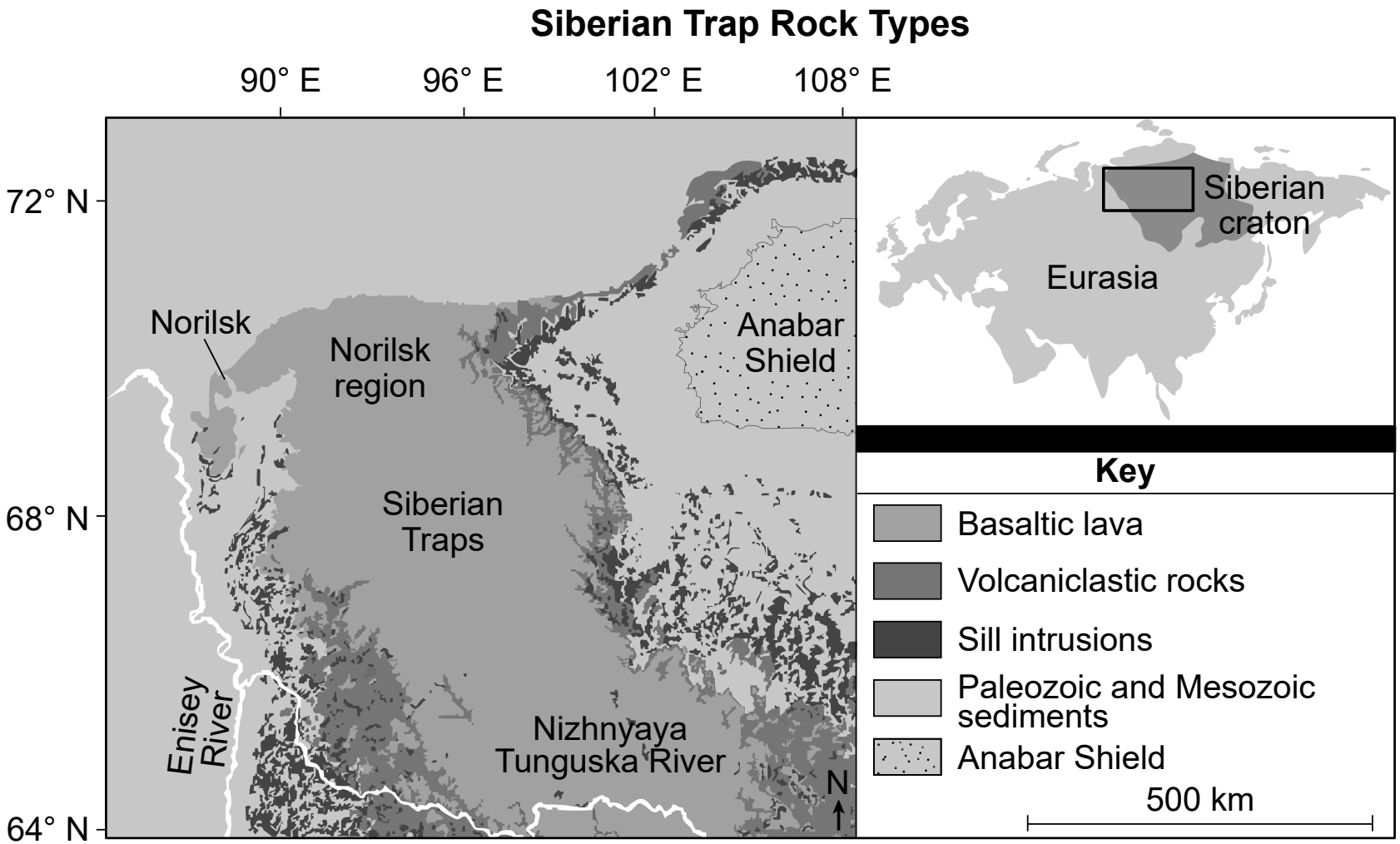
_____

Base your answers to questions 47 through 50 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 Siberian Traps

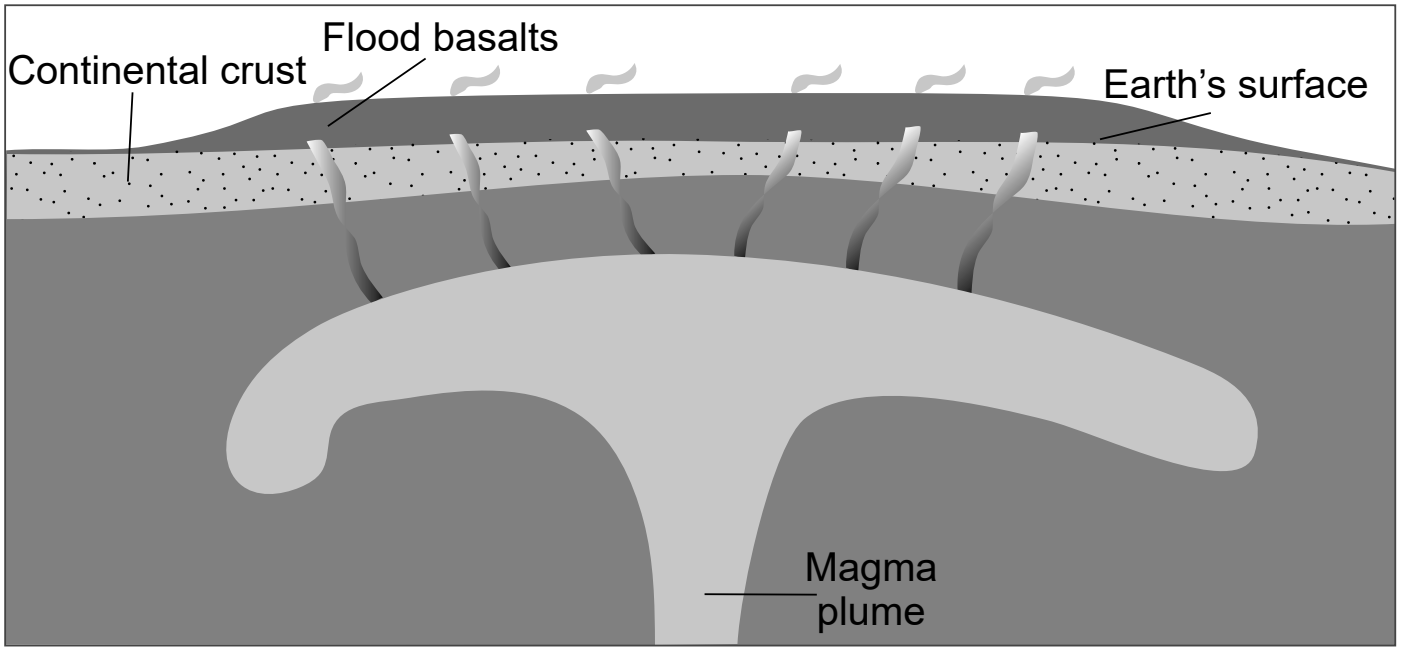
The Siberian Traps are one of the largest igneous features on Earth. The Siberian Traps did not form at a plate boundary or hotspot. Rising magma spread horizontally below the boundary of the crust and upper mantle. This formed a mushroom-shaped mantle plume. Magma pulses, lasting about 10,000 years each, erupted over a period of about one million years. The main volcanic pulse occurred about 252 million years ago. It is estimated that four million cubic kilometers of magma erupted to form the three-kilometer-thick structure. The Siberian craton includes the Anabar shield, which is the oldest original bedrock in the region.

The map below shows some information about the location and rock types associated with the Siberian Traps.



47 Develop the model in the space provided that indicates how the Siberian Traps were formed. Your model must include a minimum of **two** arrows to represent the movement of magma within the magma plume. [1]

Siberian Traps Model



(Not drawn to scale)

48 Which statement correctly describes the physical and chemical properties of the basalt in the Siberian Traps?

(1) The basalt has large mineral crystals and contains high amounts of iron and magnesium.

(2) The basalt has large mineral crystals and contains high amounts of potassium and sodium.

(3) The basalt has small mineral crystals and contains high amounts of iron and magnesium.

(4) The basalt has small mineral crystals and contains high amounts of potassium and sodium.

Norilsk, Russia, is a mining town on the western edge of the Siberian Traps. Norilsk has large deposits of nickel-bearing ore. Processing this ore releases the pollutant sulfur dioxide. Sulfur dioxide causes breathing issues from the creation of aerosols, which are small particles in the atmosphere that reflect sunlight. Worldwide, Russia ranks number three in nickel production and number one in sulfur dioxide emissions.

49 Which table identifies the correct relationship between two Earth systems and how they are changed as a result of the mining for nickel?

(1)

Earth System	Change
Atmosphere	Warmer temperatures
Hydrosphere	An increase in acid rain from increased sulfur dioxide concentrations

(2)

Earth System	Change
Geosphere	Increased chemical weathering of rocks by acid rain
Atmosphere	Cooler temperatures

(3)

Earth System	Change
Hydrosphere	A decrease in acid rain from increased sulfur dioxide concentrations
Biosphere	Decreased plant extinction due to less acid rain

(4)

Earth System	Change
Biosphere	Increased plant growth due to more acid rain
Geosphere	Increased physical weathering of rocks by acid rain

50 The nickel deposits in Norilsk are found in the same mine with large deposits of copper, cobalt, and platinum. Nickel is rarely found as a resource in New York State. Which row correctly identifies the mineral deposits that are found with the nickel deposits in New York State and the processes that most likely formed these deposits in New York and in Norilsk, Russia?

Row	Mineral Deposits Found with Nickel	Geoscience Process	Norilsk, Russia Process
(1)	Zinc and lead	Recrystallization	Lithification
(2)	Wollastonite and rare-earth elements	Lithification	Recrystallization
(3)	Iron and rare-earth elements	Recrystallization	Crystallization
(4)	Talc and carbonate rock	Crystallization	Recrystallization