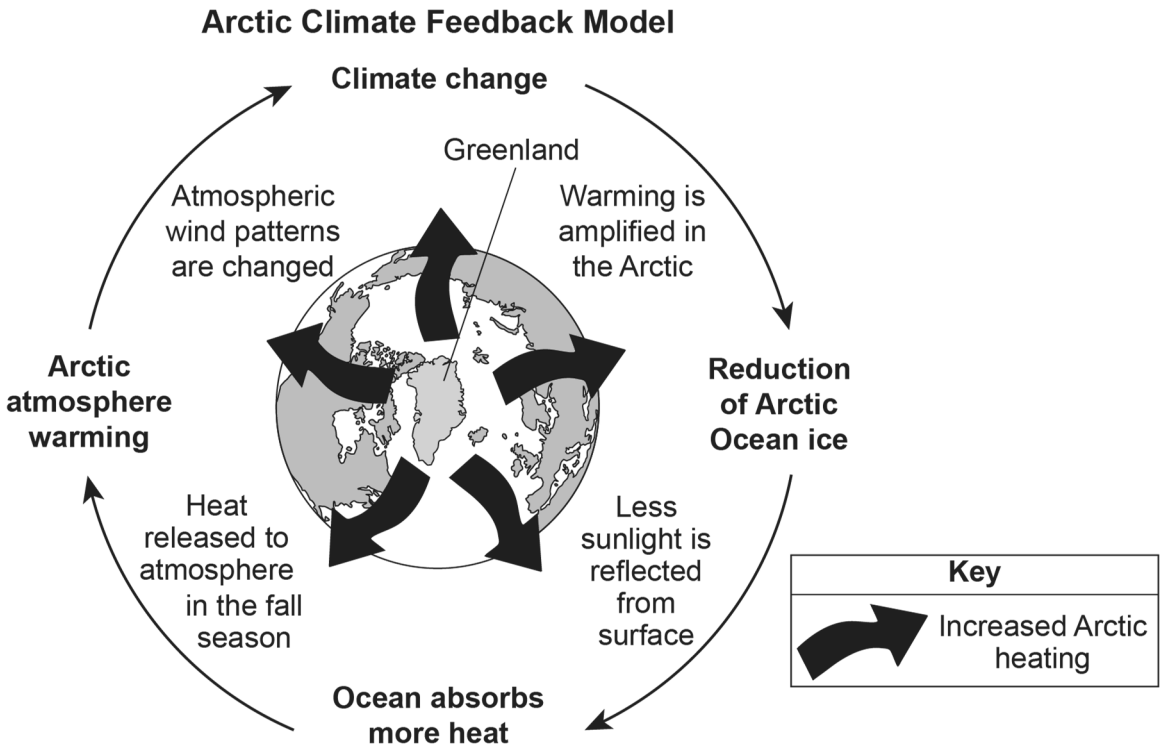
Base your answers to questions 1 through 5 on the information below and on your knowledge of Earth and Space Sciences.

Earth's Climate

Earth's climate is the result of energy interacting with the substances and surfaces that make up Earth's spheres. While Earth's spheres have different properties and characteristics, they are not isolated from each other. Interactions between these spheres have caused feedbacks that have changed Earth's climate over decades.

The model below shows information about the Arctic climate.



1 Use evidence from the climate model to describe how a reduction of Arctic Ocean ice will cause a change in average atmospheric pressures above the Arctic Ocean, and how this change in pressure results in a change of climate. [1]

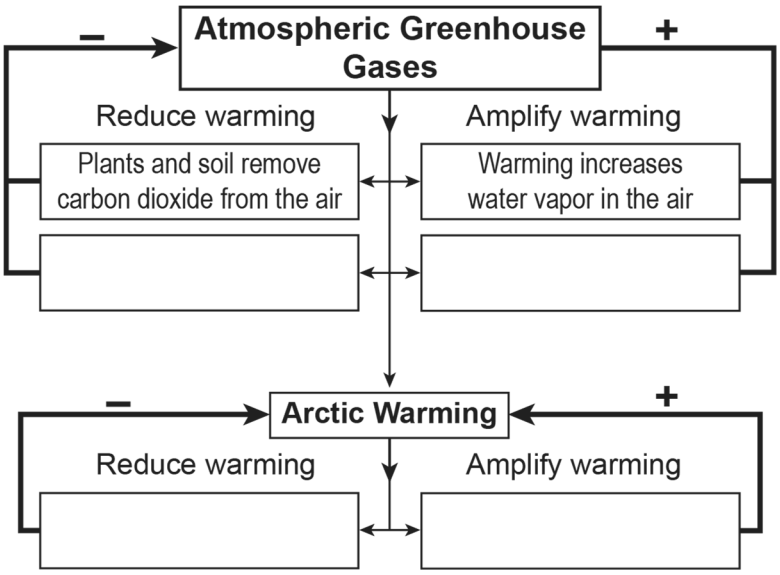
_____

_____

_____

The model below shows some information about positive and negative climate changes that occur in the Arctic. Four processes have been removed from the model and are listed below.

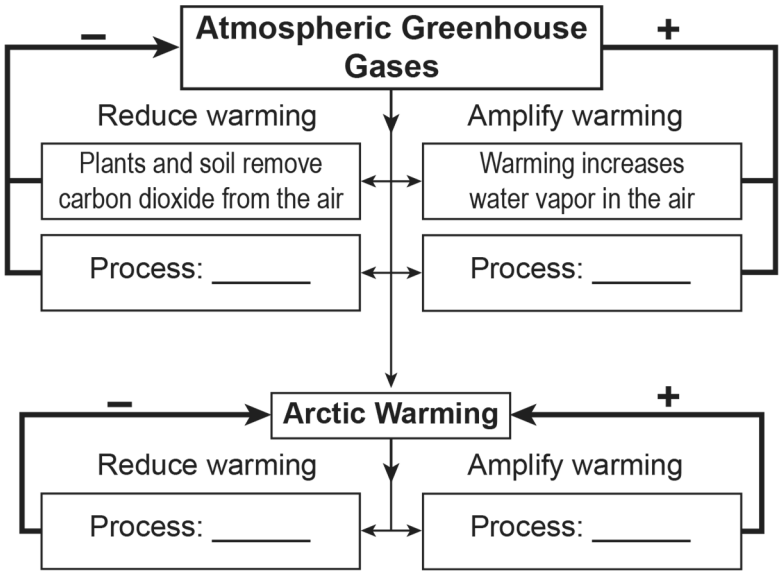
Model of Positive and Negative Arctic Climate Factors



Process 1 — Earth, as it warms, radiates more infrared energy that passes through Earth's atmosphere into space.
Process 2 — Wetlands and thawing permafrost release carbon dioxide and methane to the atmosphere.
Process 3 — Oceans remove carbon dioxide from the air.
Process 4 — Decrease in snow cover and sea ice reduce reflection of sunlight.

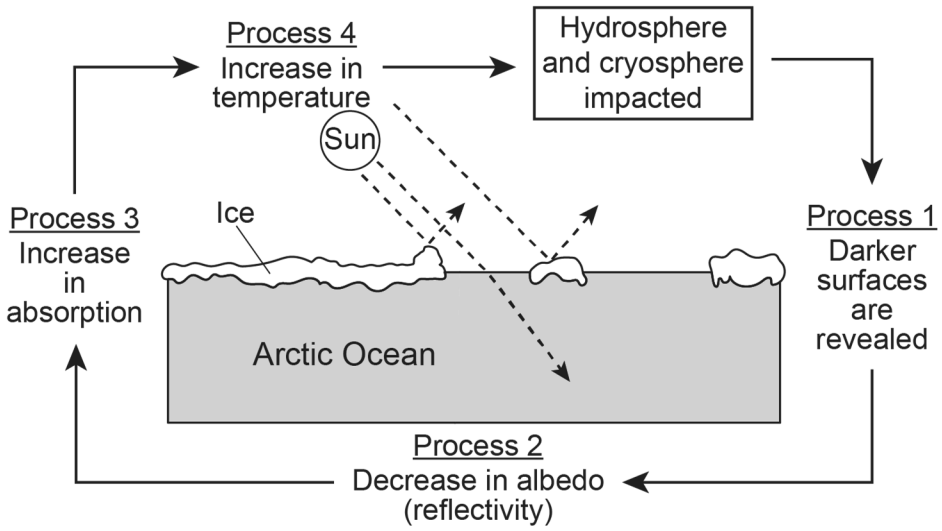
2 Complete the model by placing the correct process number into each of the *four* boxes to indicate how variations in the flow of energy into and out of Earth's systems influence either arctic warming or atmospheric greenhouse gases. [1]

Model of Positive and Negative Arctic Climate Factors



The model below shows a climate feedback loop.

Arctic Ocean Coastline Climate Feedback Loop



(Not drawn to scale)

3 Which table correctly identifies associated future impacts to the cryosphere and hydrosphere from the Arctic Ocean Coastline Climate Feedback Loop?

(1)

Cryosphere	Snow and ice in Arctic areas will melt and break apart, decreasing albedo.
Hydrosphere	Sea level in the Arctic will increase, covering existing coastline areas.

(2)

Cryosphere	Temperatures in the Arctic Ocean will increase, causing Arctic Ocean water density to increase.
Hydrosphere	Snow and ice in Arctic areas will break apart, increasing albedo at Earth's surface.

(3)

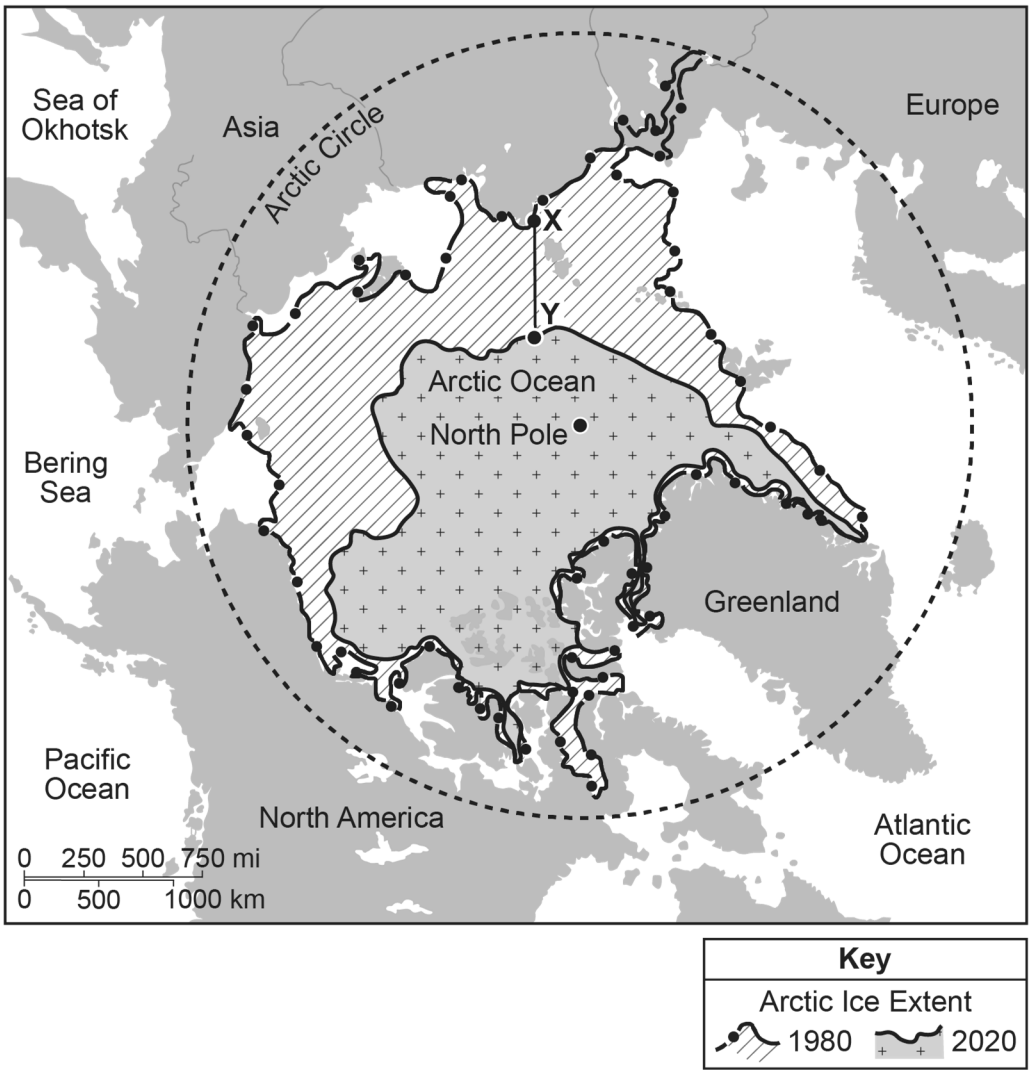
Cryosphere	Sea level in the Arctic Ocean will decrease, exposing more of the geosphere along the coastline.
Hydrosphere	Snow and ice in Arctic areas will melt, increasing albedo.

(4)

Cryosphere	Snow and ice in Arctic areas will melt, decreasing albedo at Earth's surface.
Hydrosphere	Salinity of the Arctic Ocean water will increase as snow and ice melt.

The map below shows some information about the change in Arctic Ocean ice extent. Line *X*–*Y* is a reference line.

Decline in Minimum Arctic Ice Extent: 1980-2020



4 Which claim identifies the current rate of Arctic ice change along line *X*–*Y* and its effect on the North Pole?

(1) In the next two years, the North Pole will most likely be ice-free because the rate of decline in the last 40 years is 12.5 mi/yr.
(2) In the next five years, the North Pole will still be covered in ice because the rate of decline in the last 40 years is approximately 12.5 mi/yr.
(3) In the next ten years, the North Pole will most likely be ice-free because the rate of decline in the last 40 years is 12.5 km/yr.
(4) In the next fifty years, the North Pole will most likely still be covered in ice because the rate of change over the last 40 years is approximately 12.5 km/yr.

5 Which piece of evidence best supports the claim that there is less sea ice formation in the Eastern Arctic Ocean off the coast of Northern Europe?

(1) The Polar Easterlies push sea ice to the eastern side of the Arctic Ocean.
(2) The East Greenland Current causes regional warming of the Arctic Ocean.
(3) The Norwegian Current causes regional warming of the Arctic Ocean.
(4) The Polar Front Jet Stream clears sea ice from the eastern side of the Arctic Ocean.

Base your answers to questions 1 through 5 on the information below and on your knowledge of Earth and Space Sciences.

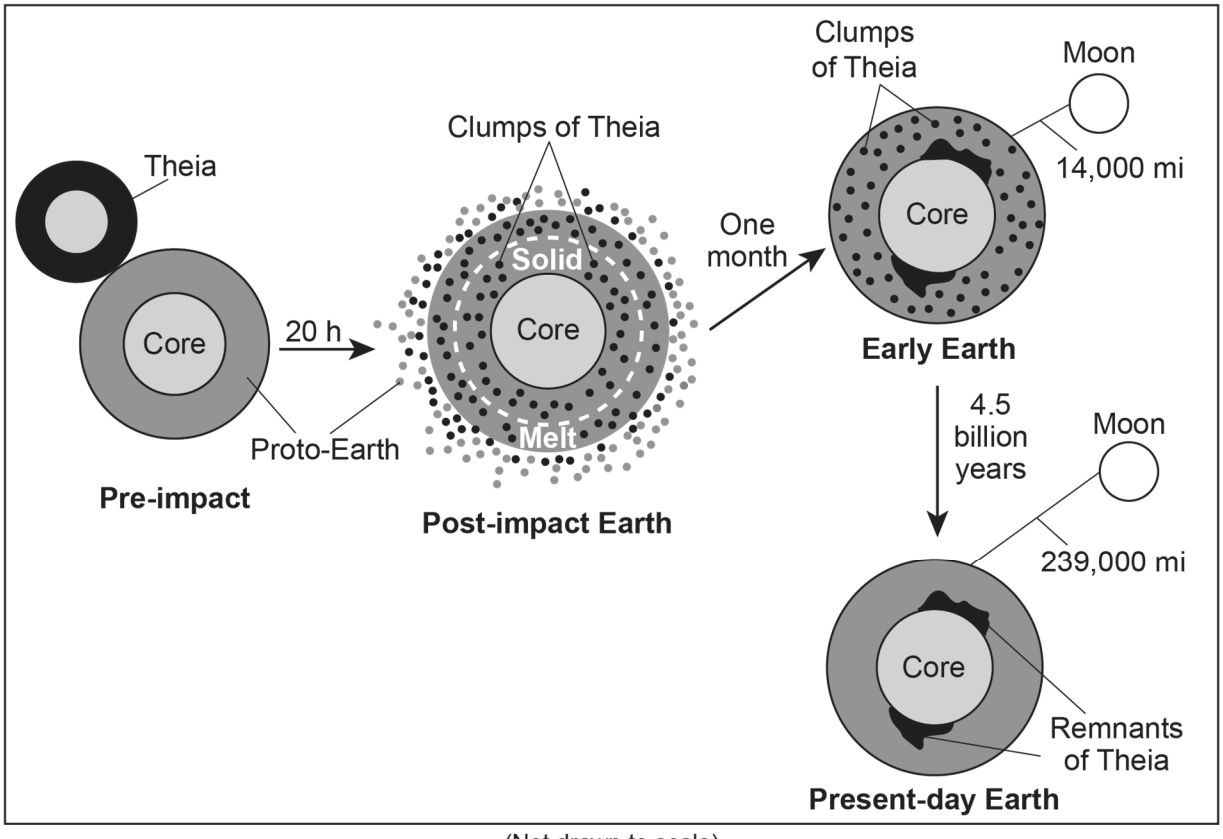
Theia and the Moon

The Giant Impact hypothesis is the most widely accepted theory for the formation of the Moon. Shortly after Earth formed, a small planetary body called Theia collided with Earth. Some remains of Theia were included into Earth's interior. Other remains formed into a ring of vapor, dust, and molten rock. Eventually, the pieces clumped together (accreted), forming the Moon.

The Late Heavy Bombardment is a period of time when Earth, the Moon, and the other inner planets experienced intense impact activity from asteroids and comets. These impacts created cratered surfaces on both Earth and the Moon. The Late Heavy Bombardment is believed to have peaked about 3.9 billion years ago.

The model below shows some information about the impact of Theia with Earth, an event that eventually led to the Moon's formation.

Model of Impact of Theia with Earth which Formed the Moon



(Not drawn to scale)

1 Use the model to explain how the collision of Theia, which eventually formed the Moon and changed Earth's composition, occurred at different spatial and temporal scales at any point from pre-impact to present-day. Use numerical evidence in your explanations. [1]

Spatial change: _____

_____

_____

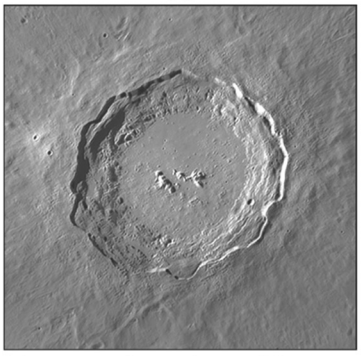
Temporal change: _____

_____

_____

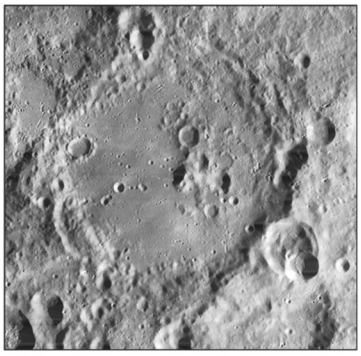
Information about the Moon's early history can be obtained from observations of craters on the Moon's surface. The photographs below show four different impact craters.

A



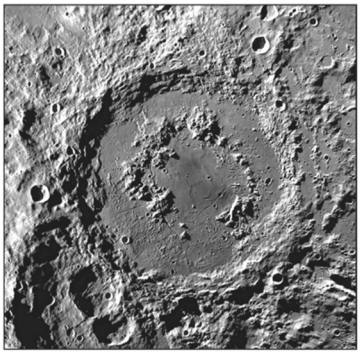
Uneven rim edge with shallow middle depression in crater bottom.

C



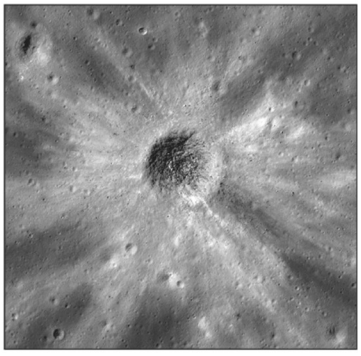
Missing parts of rim edge with multiple smaller craters inside crater bottom.

B



Smaller craters visible on weathered, less-distinct rim edge.

D



Distinct rim of crater surrounded by ejected material with deep middle depression.

2 Which table identifies the correct relative ages of two craters and a piece of evidence that supports the hypothesis for the Late Heavy Bombardment?

(1)

Oldest Crater	Youngest Crater	Evidence for the Late Heavy Bombardment
B	A	Craters of all ages cover most of the Moon's surface.

(2)

Oldest Crater	Youngest Crater	Evidence for the Late Heavy Bombardment
B	D	Multiple smaller craters are found inside the bottoms of larger craters.

(3)

Oldest Crater	Youngest Crater	Evidence for the Late Heavy Bombardment
C	A	The rims of the smaller craters are surrounded by younger ejecta materials.

(4)

Oldest Crater	Youngest Crater	Evidence for the Late Heavy Bombardment
C	D	A large proportion of craters were determined to have formed over a short period of time.

3 Construct an account, using radioactive elements and their decay products, to support the Giant Impact Hypothesis, which provides evidence that zircons found in Moon rocks formed at approximately the same time as Earth. [1]

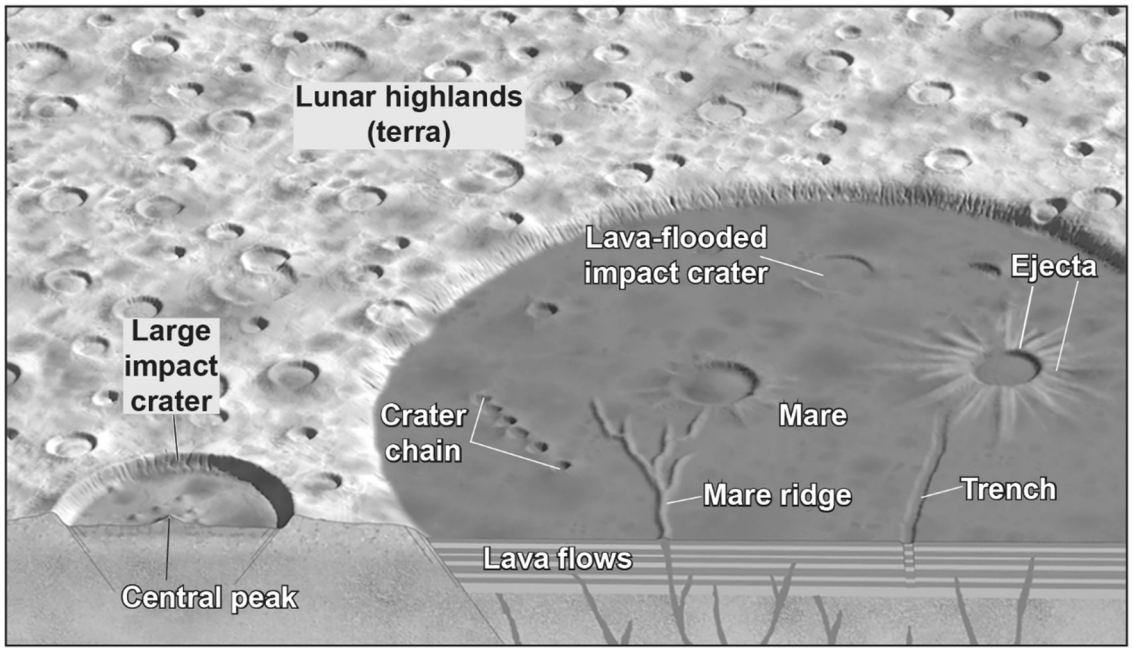
_____

_____

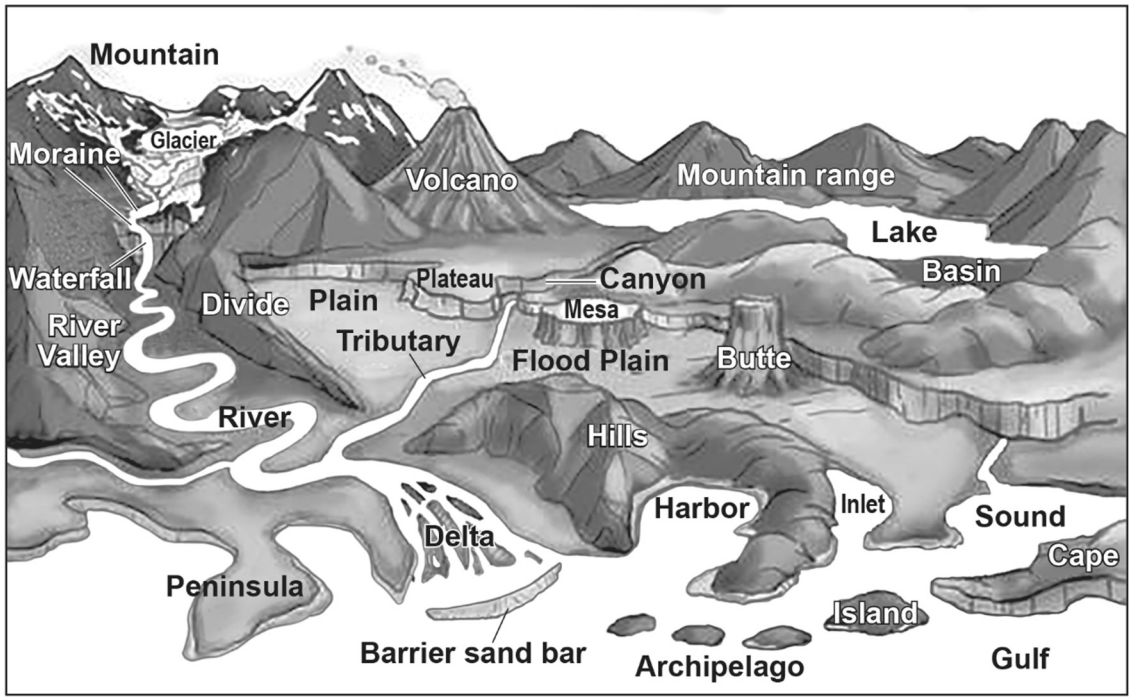
_____

The models below show some information about surface features found on the Moon and Earth.

Surface Moon Features Model



Surface Earth Features Model



4 A student made a chart of constructive and destructive geologic processes represented in the *Model of Impact of Theia with Earth Which Formed the Moon* and the two models of surface features on the Moon and Earth.

Constructive	Destructive
• The Moon forms from Theia's impact with Earth. • Lava flooded and filled some impact craters on the Moon. • Flood basalts partially fill in a crater on the Moon's surface.	• Theia collides with Earth. • The glacier eroded the valley sides widening the area on Earth. • Lunar crust collapses forming a surface trench on the Moon.

Which table below shows an additional process that is correctly classified for either the Moon or Earth, and could be added to the table above?

(1)

Constructive
The waterfall weathers rocks and moves sediment along the river valley.

(2)

Destructive
The upward flow of lava created the mare ridge.

(3)

Constructive
A delta formed from sediments transported by a river on Earth.

(4)

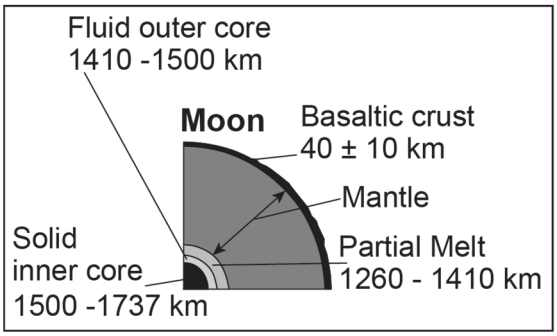
Destructive
Lava flows out of a volcano onto a planetary surface.

5 Which two geologic processes have provided information about Earth's formation and early history by altering or destroying most of the very early rock record on Earth, while 4.2 billion year old craters on the Moon still remain?

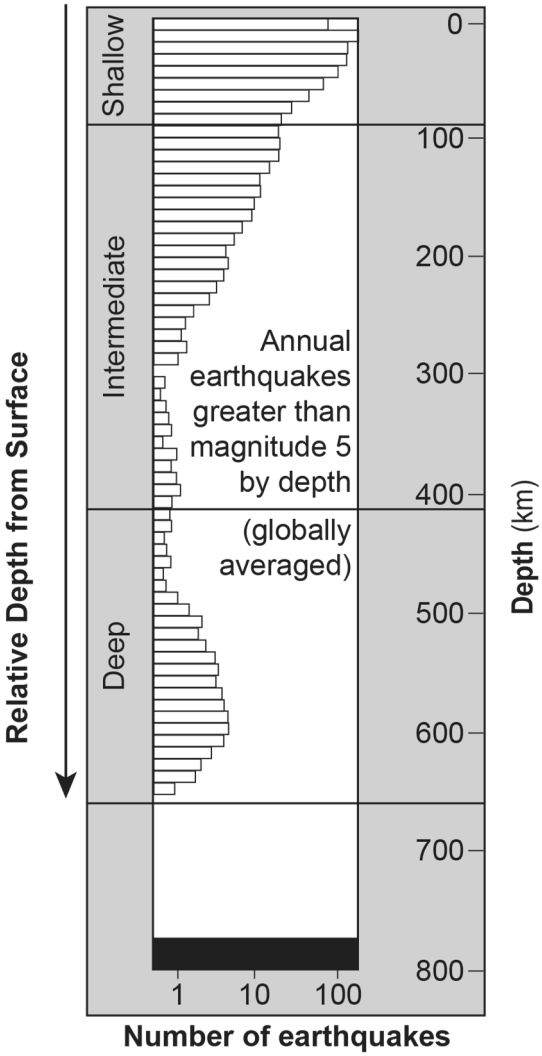
(1) plate tectonic activity and erosion of Earth's surfaces by water
(2) weathering of Earth's surface and accretion of vapor, dust, and molten rock
(3) lava flows from erupting volcanoes and frequent earthquakes
(4) radioactive decay of Earth's crust and decay of Earth's crustal minerals

The model below shows some information about the Moon. The graph shows some information about seismic activity that occurs on Earth (earthquake data). The data table summarizes some information about seismic activity that occurred on the Moon (moonquake occurrences from 1969-1977).

Model of the Moon's Surface and Interior Layers



Number of Earthquakes Occurring at Different Depths



Data for Different Types of Moonquakes (1969-1977)

Moonquake Category	Number	Comments and Layer of Occurrence
Artificial impacts	9	• Satellite-rocket substages • Exact time of events known • Crust
Meteorite impacts	1743	• Asteroids and comets • Crust
Shallow Moonquakes	28	• Probably shallower than 200 km • Approximately 200 km or less in depth • Crust and mantle
Nested deep Moonquakes	7083	• Mostly 700-1200 km deep • Occur in regional clusters referred to as nested • Lower solid mantle
Deep Moonquakes (not nested)	317	• Similar to above but not nested • Lower solid mantle
Other Thermal events	555	• Very local, shallow, low magnitude events associated with thermal contraction and expansion during periods of night and day • Crust
Unclassified	3323	
Total	**13,058**	

6 Complete each of the statements below to correctly describe geological processes related to the surface and interior layers of Earth and the Moon. Place an **X** in the box to indicate which phrase correctly completes each statement. [1]

Statement 1
A comparison of earthquake depths and moonquake depths indicates

☐ all earthquakes occur at depths less than 700 km in Earth's crust and upper mantle

☐ all moonquakes occur at depths between 700-1200 km in the moon's lower solid mantle

Statement 2
Locations of circulation by thermal convection occur

☐ in the Moon's lower solid mantle

☐ in Earth's upper mantle and crust

Statement 3
The best evidence for the Moon's formation from a collision with a planetary body called Theia is

☐ the basalts on Earth and the Moon are made from the same minerals

☐ the Moon and Earth both have a crust, mantle, and solid inner core