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EARTH & SPACE SCIENCES
REFERENCE TABLES WORKBOOK
3rd Edition
Next Generation Learning Standards

Each table has its own section.

- Each section contains: *An Overview*, in-depth explanation of the *Topic*, detailed *Diagram* section, and two sets of *Practice Questions*.

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Cover Photograph – The cover photo was taken by the Hubble Space Telescope and is labeled NGC 1333. It is a photo of a nebula—a star forming region—in the Perceus molecular cloud, located approximately 960 light-years away. Embedded within and behind the dark dust cloud are several hundred newly forming stars. The section at the bottom right captures the reddish glow of ionized hydrogen shooting out from newly forming stars. The Hubble Space Telescope has the unique capability of obtaining images from ultraviolet to near-infrared light. This range has allowed Hubble to deliver stunning images of stars, nebulae, galaxies and other astronomical objects. For more information and stunning picture go to science.nasa.gov.

EARTH & SPACE SCIENCES REFERENCE TABLES WORKBOOK

3rd Edition

Based on 2026 New York State Reference Tables

The Introduction – Overview, The Chart, Additional Information, and Diagrams – In these sections you will find the essential information about a specific part of the reference table. These areas contain much information, so read each section carefully to achieve full comprehension of the material.

SET 1 – Questions and Answers – Set 1 group of questions will test your understanding of a specific section of the reference table. It is highly recommended that you first read and have a good knowledge of the introduction pages. Once you have mastered this, the correct answer to each question will be apparent. Try all questions in Set 1, and then correct your work by going to the Answers for Set 1, which are located at the end of the section. The explanation should be clear enough to help you understand any mistakes you have made. If not, ask your teacher for more assistance.

SET 2 – Questions – The answers to these questions are provided in a separate answer key. It's "Show Time"; time to prove to yourself and to your teacher that you know the information for this part of the reference chart. You and your teacher will interact to see how well you have done in this area.

CLUSTER QUESTIONS – These questions are designed to assess your understand of a key topic. Each cluster group includes a series of multiple-choice and open-ended questions that might involve interpreting a reading passage, diagram, data table or graph. Carefully study the given information, apply the Earth and Space Sciences concepts you have learned, while engaging your critical thinking skills. The answers to these questions are in a separate answer key.

All of us at Topical Review Book Company hope that by mastering the 2026 NYS Earth and Space Sciences Reference Tables, your understanding of Earth and Space will be more complete and your grades will improve.

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Retired Earth Science Teacher

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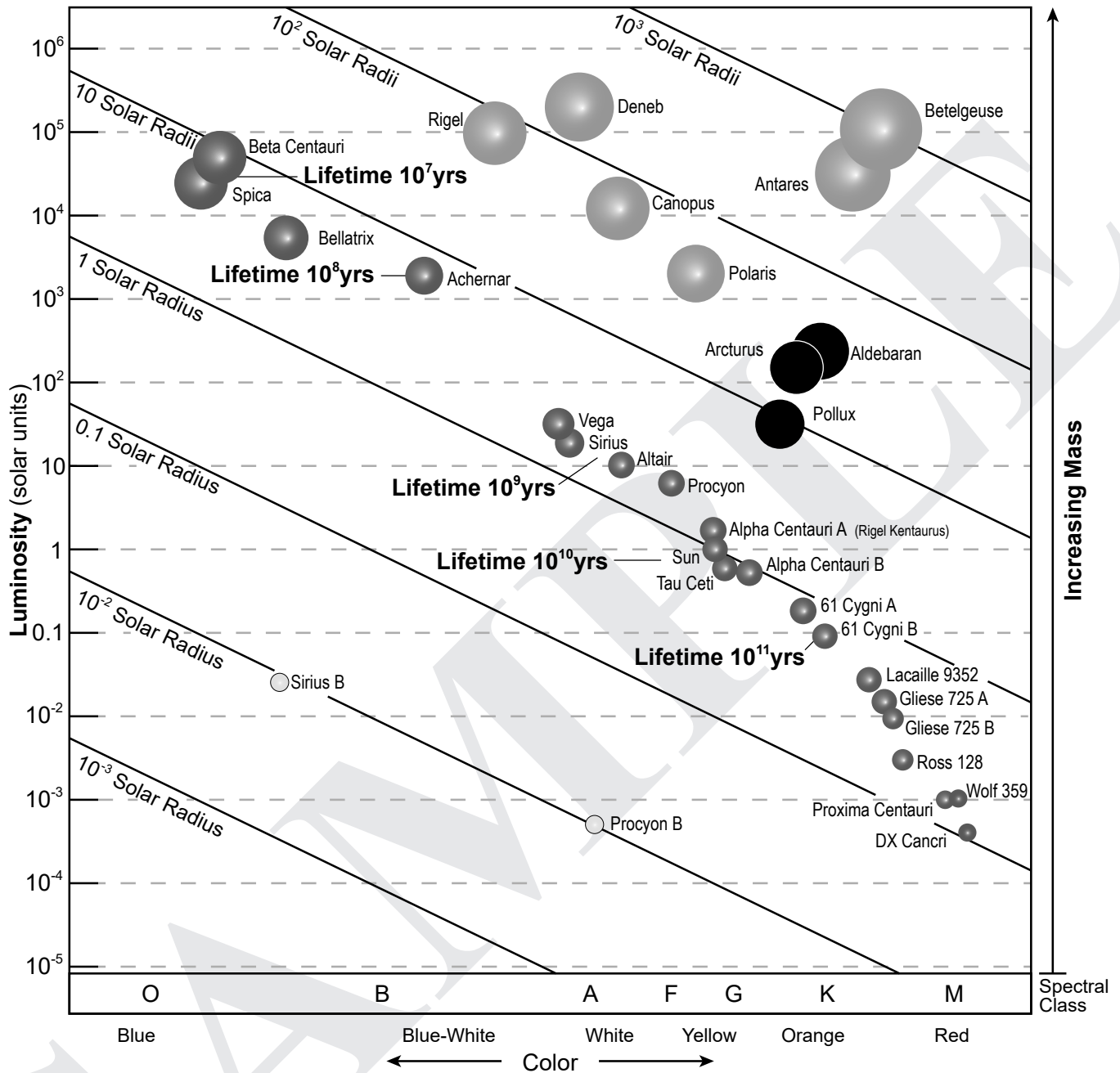
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H-R Diagram



Approximate Surface Temperature Range (K) of Stars

O	$\geq 28,000$
B	10,000 – 27,999
A	7500 – 9999
F	6000 – 7499
G	5000 – 5999
K	3500 – 4999
M	2000 – 3499

Key

	SUPERGIANTS
	WHITE DWARFS
	MAIN SEQUENCE
	GIANTS

Overview:

When the temperature and luminosity (brightness) of stars, all within our Milky Way galaxy, were plotted on a graph, a pattern emerged. Most of the stars fell within a specific region that ran diagonally across the graph, later to be named the “main sequence”. Stars off the main sequence fell mainly into three other groups: giants, supergiants, and white dwarfs. Astronomers discovered that this pattern revealed stellar evolution according to the group that the stars were positioned in. The two scientists that independently produced this graph, Hertzsprung and Russell, are credited for making a tremendous contribution to astronomy. Thus, this graph is referred to as the H-R diagram.

The Graph:

The X-axis – This axis has two scales: Color and Spectral Class. Spectral class is a classification system of seven letters that represent a range of star’s surface temperatures from hotter stars, O, to cooler stars, M. The approximate surface temperature range in K degrees is given in the separate chart. The surface temperature of a star determines its color. A star that radiates above 30,000 K, spectral class O, would be blue, while a star that radiates below 3,500 K, would be red, spectral class M. Our Sun is a spectral class G star, having a surface temperature in the range of 5,000 K to 5,999 K. The H-R graph shows that on the main sequence O stars are the hottest but the least common, while the M stars are the coolest but most common. On a clear moonless night, look for the different star’s color.

The Y-axis – The left-side of the y-axis is the Luminosity scale. This scale represents the relative brightness of a star compared to our Sun, if that star and our Sun were placed side by side at a given distance from Earth. Our Sun is assigned the luminosity value of 1. Brighter stars have a luminosity value greater than 1, and duller stars have a luminosity value less than 1. On the right side of the y-axis is the Increasing Mass scale. The more massive stars are at the top. The luminosity value of a star is mostly based on its size rather than its temperature. For example, Betelgeuse is a massive cool red star but has a high luminosity value (10^5) caused by its tremendous size. This red star is easily observed in the winter constellation Orion.

Lifetime Scale – The lifetime values represent how long a star would remain as a main sequence star. The more massive a star is, the faster it consumes its fuel, resulting in a shorter lifespan compared to a smaller star. Locate the star 61 Cygni B. This smaller star is shown to have a lifespan of 10^{11} years. Now, locate the star Spica. Being a massive star, its lifetime is far shorter at only 10^7 years.

Solar Radius – The solar radius is a unit used to express the size of stars relative to our Sun, which has a value of 1. A star that falls on the 10 solar radii line, like Beta Centauri, has a radius ten times that of our Sun. Betelgeuse, a true giant, has a solar radii 1,000 times that of our Sun.

The Key: Star classifications

Main Sequence Stars – The main sequence stars run diagonally across the graph. When nuclear fusion of $H \rightarrow He$ occurs forming a star, forces (gravity and nuclear) become balanced and the star becomes a main sequence star. Stars spend most of their lives as main sequence stars. Some examples of these early-stage stars, as shown on the graph, are Alpha Centauri B, our Sun, Altair, Vega, and Spica.

Supergiant and Giant Stars – When a star’s hydrogen fuel becomes limited, it greatly expands, causing its surface temperature to cool. This repositions the star off the main sequence into the giants or supergiants region. The mass of the star determines whether it becomes a giant or supergiant. The most massive stars become supergiant stars. Only these stars will form all the heavier nuclei that are shown on the Nucleosynthesis chart (see page 12). All of these stars are now in their intermediate stage of life.

White Dwarf Stars – When low to medium-mass stars exhaust their nuclear fuel, they enter their late stage of existence become white dwarf stars. These stars are very dense, small, hot stars. All nuclear fusion has ceased in these stars, but they still radiate much residual energy that initially give them a high temperature value. Their luminosity is low because of their small size. Over billions of years, they cool and become a cold, inert, stellar remnant referred to as a black dwarf. Both Sirius B and Procyon B are white dwarf stars.

Additional Information:

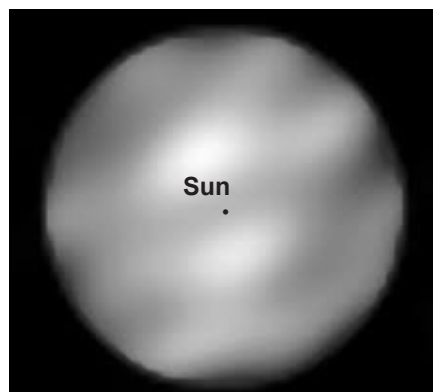
- The Sun’s energy is the result of nuclear fusion – an energy producing process. The equation for the fusion reaction of hydrogen is:
- $$\begin{array}{ccccccc} \text{Hydrogen} & + & \text{Hydrogen} & \rightarrow & \text{Helium} & + & \text{Energy} \\ (\text{lighter element}) & & (\text{lighter element}) & & (\text{heavier element}) & & \end{array}$$
- Our Sun is estimated to be 4.6 billion years old. Our universe is estimated to be 13.7 billion years old.
 - Roughly 97% of all the stars in our galaxy, the Milky Way, will become white dwarf stars.

Diagrams:

Stars	Temperature		Luminosity	
	Hotter	Cooler	Brighter	Dimmer
<i>Procyon B</i>	X			X
<i>Wolf 359</i>		X		X
<i>Spica</i>	X		X	

- Characteristics of Stars** – This chart shows the comparison of temperature and luminosity of three stars to our Sun. Massive stars located on the main sequence (Spica) has a greater luminosity and a hotter temperature than our Sun. Smaller stars (i.e., Wolf 359) on the main sequence tend to be cooler with lower luminosity values. White dwarf stars (i.e., Procyon B) tend to be hotter but because of their small size they are dimmer.

- Betelgeuse and our Sun** – Betelgeuse is a late-stage, massive supergiant star. It is close to 1,000 times as large as our Sun. Yet it is relatively young, for large stars use up their fuel faster than smaller stars. In time, this star will supernova, exploding most of its material deep into space. The dot is the relative size of our Sun compared to Betelgeuse.



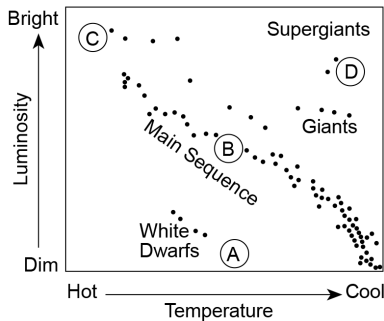
Set 1 — H-R Diagram

1. Which star color indicates the hottest star surface temperature?

(1) blue (3) yellow
(2) white (4) red

1 _____

2. The graph represents the brightness and temperature of stars visible from Earth.



Which location on the graph best represents a star with average brightness and temperature?

(1) A (2) B (3) C (4) D 2 _____

3. Which star is more massive than our Sun, but has a lower surface temperature?

(1) Procyon B (3) Sirius B
(2) Aldebaran (4) Alpha Centauri B

3 _____

4. Which star is hotter and 100,000 times brighter than Earth's Sun?

(1) Barnard's Star (3) Rigel
(2) Betelgeuse (4) Antares 4 _____

5. Compared with our Sun, the star Betelgeuse is

(1) smaller, hotter, and less luminous
(2) smaller, cooler, and more luminous
(3) larger, hotter, and less luminous
(4) larger, cooler, and more luminous

5 _____

6. Which two stars have the most similar luminosity and temperature?

(1) Betelgeuse and Barnard's Star
(2) Rigel and Betelgeuse
(3) Alpha Centauri A and the Sun
(4) Sirius B and Procyon B

6 _____

7. Compared to the temperature and luminosity of the star Achernar, the star Sirius B is

(1) hotter and more luminous
(2) hotter and less luminous
(3) cooler and more luminous
(4) cooler and less luminous

7 _____

8. In nuclear fusion what occurs?

(1) Lighter elements are converted to heavier elements.
(2) Lighter elements are converted to even lighter elements.
(3) Heavier elements are converted to lighter elements.
(4) Heavier elements chemically combine with lighter elements.

8 _____

9. Betelgeuse and Canopus are both red-giant stars. Give a statement comparing their luminosity and temperature values.

10. A star located off the main sequence indicates what? _____

Set 2 — H-R Diagram

11. Compared to the surface temperature and luminosity of massive stars in the Main Sequence, the smaller stars in the Main Sequence are
- (1) hotter and less luminous
 - (2) hotter and more luminous
 - (3) cooler and less luminous
 - (4) cooler and more luminous
- 11 _____
12. The star Phecda has a surface temperature of approximately 9500 K and a luminosity of 10^2 . Of the following stars, which has nearly the same values as Phecda?
- (1) Sirius B
 - (2) Rigel
 - (3) Vega
 - (4) Pollux
- 12 _____
13. To an observer on Earth, the Sun appears brighter than the star Rigel because the Sun is
- (1) hotter than Rigel
 - (2) more luminous than Rigel
 - (3) closer than Rigel
 - (4) larger than Rigel
- 13 _____
14. Which star is hotter, but less luminous, than Altair?
- (1) Deneb
 - (2) Aldebaran
 - (3) Procyon B
 - (4) Pollux
- 14 _____
15. The Sun revolves around the center of
- (1) Polaris
 - (2) Aldebaran
 - (3) solar system
 - (4) the Milky Way Galaxy
- 15 _____
16. A newly discovered star has a spectral class of F and a luminosity of 10^5 . The classification of this star would be
- (1) white dwarf
 - (2) main sequence
 - (3) giant
 - (4) supergiant
- 16 _____
17. The inferred temperature at the boundary of the inner and outer core of Earth is 5500 K. Which star radiates close to this temperature and has a solar radius of 1?
- (1) Canopus
 - (2) Polaris
 - (3) Tau Ceti
 - (4) Procyon
- 17 _____
18. Which star is projected to continue its nuclear reaction for the longest duration?
- (1) our Sun
 - (2) Spica
 - (3) Ross 128
 - (4) Achernar
- 18 _____
19. Which object in space emits light because it releases energy produced by nuclear fusion?
- (1) Earth's Moon
 - (2) Halley's comet
 - (3) Venus
 - (4) Polaris
- 19 _____
20. In about 500 million years Vega is expected to enter its intermediate stage and become a giant star. When this occurs, which of the following values would be expected for Vega?
- (1) luminosity of 10^2 , spectral class A, solar radii 3
 - (2) luminosity of 10^3 , spectral class K, solar radii 20
 - (3) luminosity of 0.1, spectral class B, solar radius 10^{-2}
 - (4) luminosity of 10^5 , spectral class K, solar radius 10^3
- 20 _____

21. Compared to the luminosity and surface temperature of red main sequence stars, blue supergiants are

- (1) less luminous and have a lower surface temperature
- (2) less luminous and have a higher surface temperature
- (3) more luminous and have a lower surface temperature
- (4) more luminous and have a higher surface temperature

21_____

22. Which table includes data that are characteristic of the surface temperature and luminosity of some white dwarf stars?

(1)

Surface Temperature	5000 K
Luminosity	100

(3)

Surface Temperature	10,000 K
Luminosity	100

(2)

Surface Temperature	5000 K
Luminosity	0.001

(4)

Surface Temperature	10,000 K
Luminosity	0.001

22_____

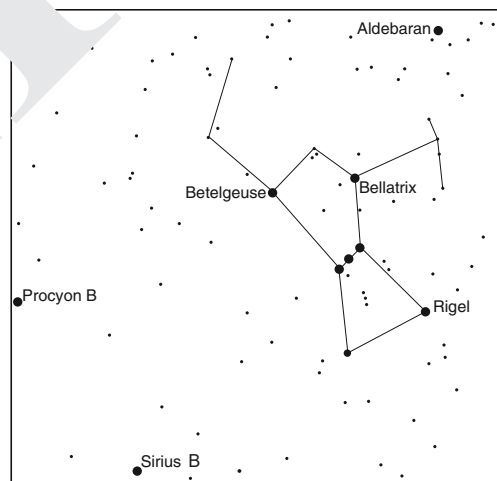
23. Explain why a giant star that is cooler than our Sun, similar to Aldebaran, has a greater luminosity than our Sun.

The star chart shows part of the winter sky visible from New York State. Some of the brighter stars are labeled and the constellation Orion is outlined.

24. a) Identify the color of the star Bellatrix, having a spectral class of *B*. _____

b) Which star on the chart would be classified the youngest?

c) In the accompanying chart, list the stars, other than Bellatrix, found on the chart in order of decreasing luminosity. Rigel, the most luminous star, has been listed.



Most luminous ↓ Least luminous	(1) Rigel
	(2) _____
	(3) _____
	(4) _____
	(5) _____

25. Give a statement on the relationship between temperature and luminosity of the main sequence stars.

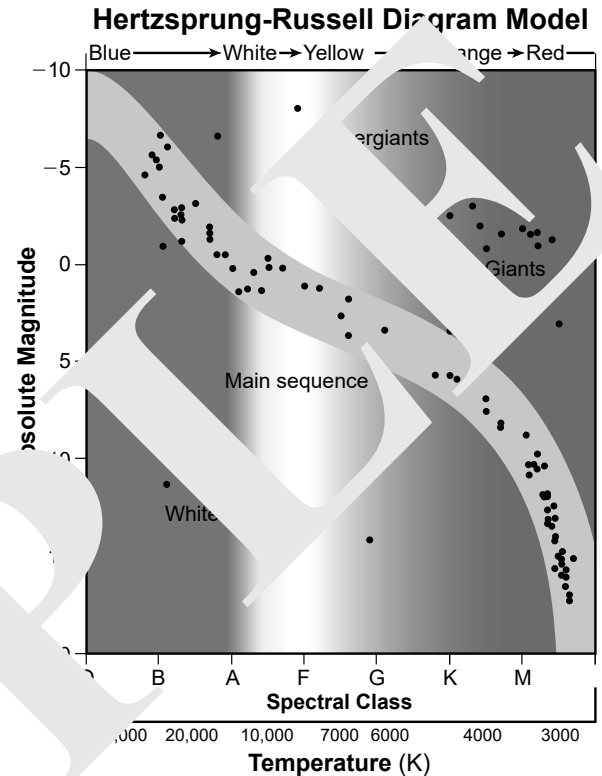
Our Sun – A Star

The Hertzsprung-Russell (H-R) diagram was developed from star charts by two scientists in different countries independently of each other in 1911. It classified stars based on their surface temperatures, observable color, and magnitude. Absolute magnitude is a measurement of how bright a star would appear if all stars are the same distance from Earth. On this scale, the brighter the star, the *lower* the absolute magnitude value.

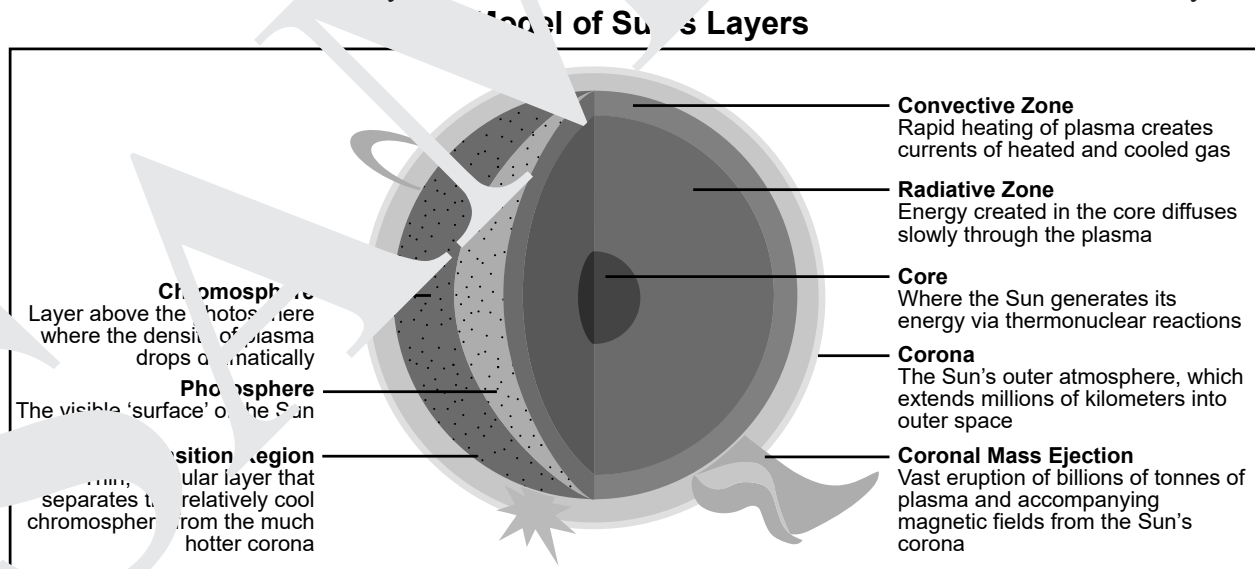
26. Our Sun is classified as a spectral class G star with a surface temperature between 5000 to 6000 K and an absolute magnitude of about five. Based on this information, complete the H-R diagram model by placing one **X** to indicate where the Sun is located. Also, identify the relative temperature and relative absolute magnitude of the Sun as it transitions to a red giant.

Change in relative temperature: _____

Change in relative absolute magnitude: _____



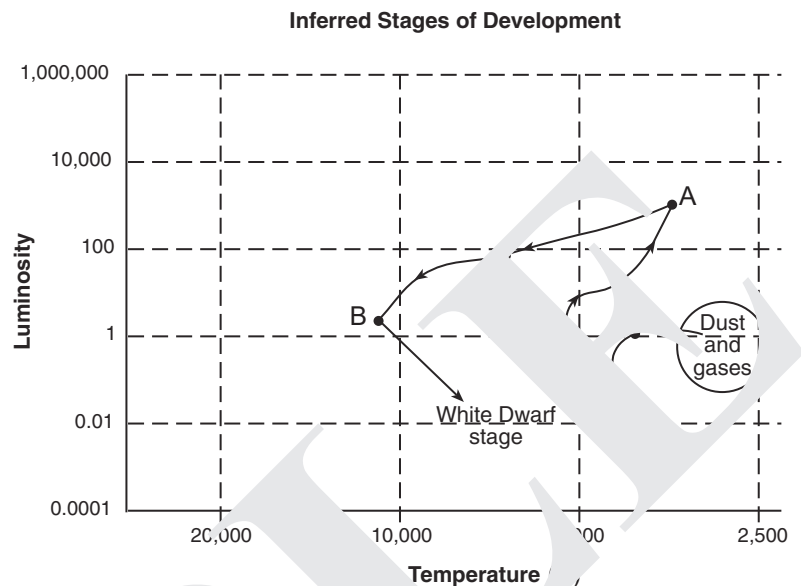
The model below shows the layers of the Sun and information about some features of each layer.



27. Based on the information in the model, which list of five of the Sun's layers are in the correct sequence to allow energy generated by fusion to eventually reach the Sun's surface as radiation?
- (1) core → chromosphere → photosphere → transition region → corona
 - (2) core → radiative zone → transition region → photosphere → corona
 - (3) core → photosphere → corona → transition region → chromosphere
 - (4) core → radiative zone → convective zone → photosphere → chromosphere

27 _____

Base your answers to question 28 on the on the accompanying graph. The graph shows the inferred stages of development of the Sun, showing luminosity and surface temperature at various stages.



28. a) Describe the changes in luminosity of the Sun that will occur from its current Main Sequence stage to its final White Dwarf stage.

b) Identify the process that produces the Sun's energy.

c) Why does the Sun's luminosity increases and its temperature decreases at position A?

d) At position A, what color star would be observed?

29. Identify two stars that are at the same life-cycle stage as the Vega but have a greater luminosity.

1) _____ 2) _____

30. Both Sirius B and Procyon B are classified as white dwarfs. Describe one characteristic of the star Sirius B that causes it to have a greater luminosity than Procyon B.

31. Describe how the relative surface temperature and the luminosity of Aldebaran would change when it becomes a white dwarf.

Surface temperature: _____ Luminosity: _____

32. List the following astronomical features, in order of relative size, from smallest to largest.

Sun

Deneb

Milky Way Galaxy

Bellatrix

Proxima Centauri

Pollux

Smallest _____

↓

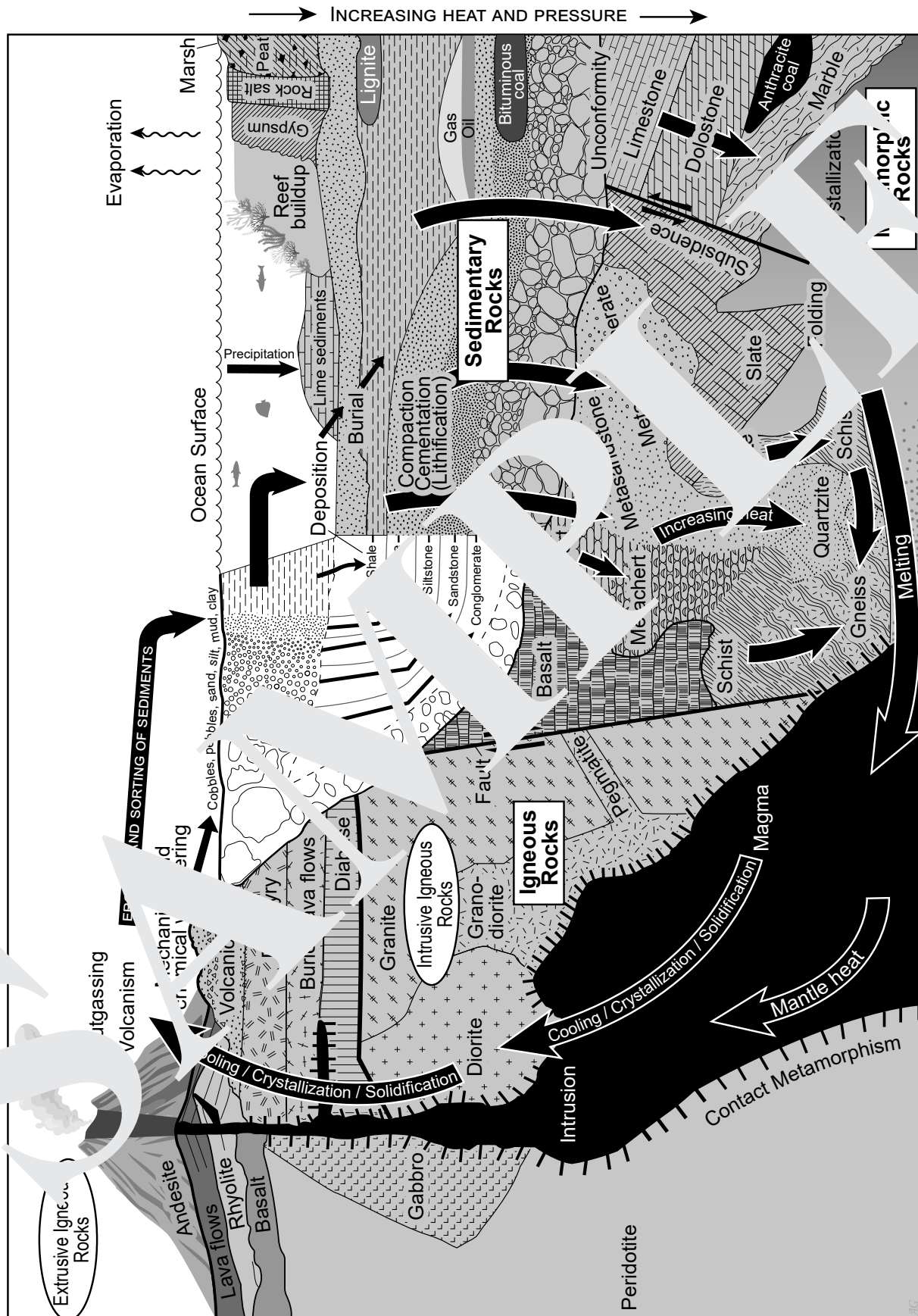
Largest _____

H-R Diagram

Set 1 – Answers

1. 1 In the H-R Diagram, go to the Temperature axis. Blue stars have the hottest surface temperatures, over 30,000 K (spectral class O).
2. 2 An average star would be located on the main sequence and have the same luminosity and temperature as our Sun. Locate our Sun on the diagram. Location *B* is close to where our Sun is positioned.
3. 2 On the H-R Diagram, Aldebaran is classified as a giant star, which is more massive than our Sun. Aldebaran has a spectral class of K (around 4,000 K), which is cooler than our Sun.
4. 3 Locate Rigel on the H-R Diagram. As shown, the luminosity of this star is (10^5) greater than that of our Sun. Its spectral class is B, while the Sun's spectral class is G, just under 6,000 K.
5. 4 Betelgeuse has a spectral class of M, which is cooler than our Sun. It has a greater luminosity than our Sun because it is a supergiant star.
6. 3 Alpha Centauri A and the Sun are positioned next to each other.
7. 2 Sirius B is positioned lower on the Luminosity scale than Achenar. The temperature of Sirius B is hotter than that of Achenar, as shown by the surface temperature scale.
8. 1 By the process of nuclear fusion, lighter nuclei are joined to produce a heavier nucleus, while releasing massive amounts of energy.
9. Betelgeuse has a slightly higher luminosity; Canopus has a higher temperature.
10. In stellar evolution, when a star is off the main sequence it may indicate that:
 - a) it is in its dying stage.
 - b) its fuel is running out.
 - c) it is expanding, causing its temperature to cool.
 - d) it has collapsed and is a white dwarf.
 - e) it has entered the intermediate or late stage of its existence.

Rock Cycle Infographic



Rock Cycle Infographic

Overview:

All rocks can be classified as igneous, metamorphic or sedimentary. As permanent as rocks appear, eventually geologic forces act on them, causing changes. These changes may alter the rock to be reclassified into a different family of rocks. Even rocks that have been melted back within the mantle, forming magma, may one day surface as lava, solidifying only to be exposed again to the forces of the “Rock Cycle.”

Rock Families:

This chart is packed with information on the different processes and environments that create, alter and reform new rocks. The chart has three main sections, based on the different families of rocks. First, let's review each rock family.

Igneous Rocks – All igneous rocks started as molten rock. As the magma or lava cools, it undergoes solidification, changing the molten rock to a solid. The crystallization of magma produces intrusive igneous rocks, usually with visible crystals. Lava produces extrusive igneous rocks that cool relatively rapidly, producing small or no visible crystals. The rate of cooling and the composition of the magma or lava will create different rocks, but because they originated from molten material, all are igneous rocks.

Sedimentary Rocks – Rocks at or near the surface will undergo weathering, producing smaller sediments. These smaller rocks can be transported mainly by wind and water. Many sediments are eventually deposited in a quiet body of water. These buried sediments become compacted and undergo cementation, forming sedimentary rocks. The accumulation of dead organic substances can be compressed, producing a rock in this family. Minerals that are precipitated (released) from a solution can accumulate forming a sedimentary rock. This usually occurs when a shallow sea undergoes evaporation.

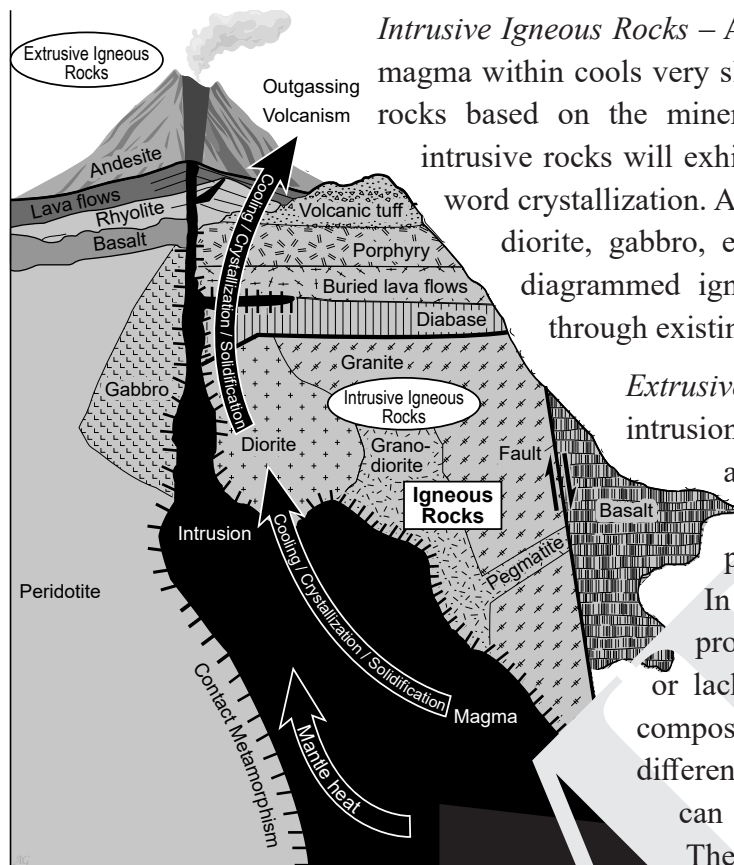
Metamorphic Rocks – Heat and/or pressure applied to rocks may change them into metamorphic rocks, if they don't melt. When there is enough heat or pressure, the minerals within a rock can be altered (recrystallization), producing a new rock classified as a metamorphic rock. Plate tectonics is the major force that produces the needed heat/pressure of metamorphism. Mountain ranges that form from colliding plates will have a high percentage of metamorphic rocks.

The Chart:

To help understanding this detailed chart, I've elected to separate the chart into each rock family. Remember though that in the rock cycle, forces producing a rock in one family may also create a rock in another family.

Igneous Rock Section:

The igneous rocks were the first rocks ever formed. This occurred as melted molten rock cooled and solidified. Magma produces intrusive rocks, while lava produces extrusive igneous rocks.

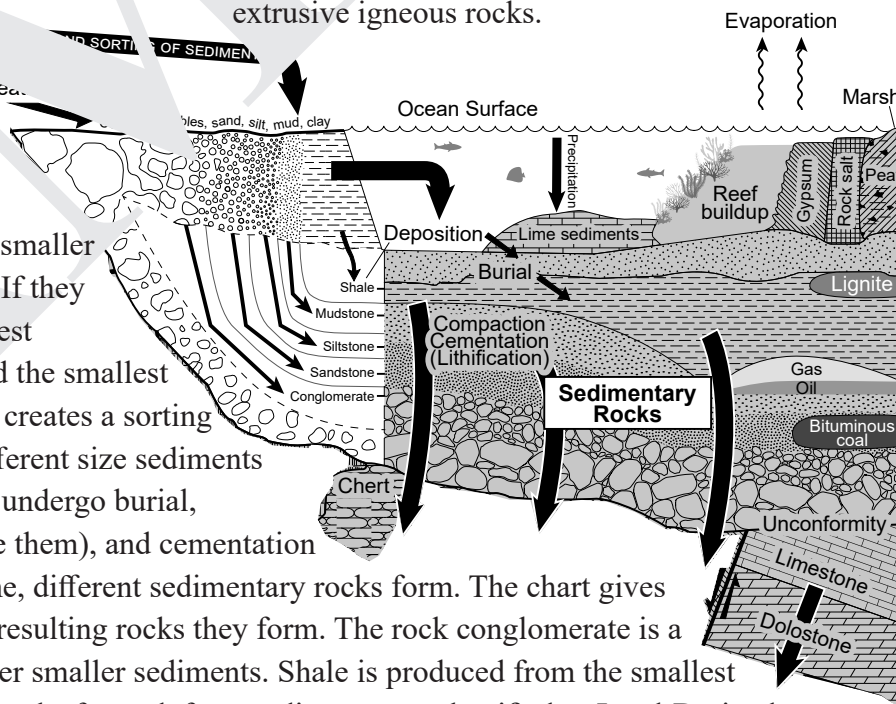


Intrusive Igneous Rocks – A magma chamber is a large pool of magma. The magma within cools very slowly and eventually may form different igneous rocks based on the mineral composition of the magma. These formed intrusive rocks will exhibit visible crystals. This is illustrated around the word crystallization. Above this are some of the intrusive rocks (granite, diorite, gabbro, etc.) that may form in a magma chamber. The diagrammed igneous intrusion is a seam of magma that cuts through existing rocks.

Extrusive Igneous Rocks – As shown in the diagram, intrusions bring magma to the surface, and now it's known as lava. Lava can be violently ejected by volcanic eruptions or ooze out of a deep crustal opening producing a lava flow, slowly spreading outward. In all cases, lava cools relatively quickly, either producing very small crystals, having a fine texture, or lacking any crystals, having a glassy texture. The composition of the lava and its cooling rate can form different extrusive igneous rocks. Later volcanic eruptions can cover lava flows and other extrusive rock layers. The diagram shows two buried lava flows and four extrusive igneous rocks.

Sedimentary Rock Section:

Mechanical (physical) and chemical weathering forces act on rocks at or near the surface. These forces break down solid bedrock to smaller sediments that can be eroded away. If they enter a quiet body of water, the largest sediments will be deposited first and the smallest deposited last and farthest out. This creates a sorting process by size and density. The different size sediments will produce different rocks as they undergo burial, compaction, (from the weight above them), and cementation (from dissolved minerals). Over time, different sedimentary rocks form. The chart gives the names of six sediments and the resulting rocks they form. The rock conglomerate is a mixture of cobbles, pebbles and other smaller sediments. Shale is produced from the smallest sediment– clay particles. These six rocks formed from sediments are classified as Land-Derived Sedimentary rocks. The three other classifications of sedimentary rocks are the following:



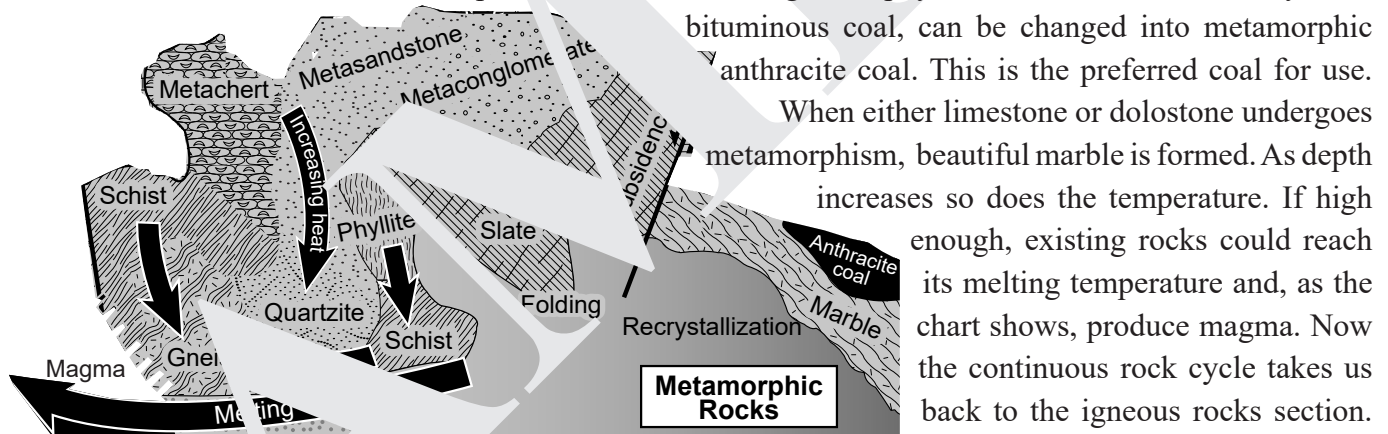
Mineral Sedimentary Rocks – As water evaporates concentrated dissolved minerals can be released or precipitated out of a solution and accumulate on the bottom of the water source. When these “released” minerals become cemented, they become a sedimentary rock such as gypsum and rock salt.

Organic Sedimentary Rocks – Dead organic material can accumulate in bogs or swamps/marshes. Over time this material gets compressed to form first peat, then lignite and then sedimentary bituminous coal—all of which are different grades of coal. The upper right side of the chart shows “Reef buildup.” Coral is a type of organic biochemical rock produced by coral polyps secreting layers of calcium carbonate. Lime sediments are mostly composed of calcium carbonate (CaCO_3) derived from skeletal remains of shelled organisms. This mineral will precipitate (be released) out of the water settling to the ocean floor producing limestone. Oil and natural gas are produced from the decay of organic matter that lived millions of years ago. Impermeable sedimentary layers can trap these fossil fuel resources.

Chemically Formed Sedimentary Rocks – Limestone and dolostone are chemically (or biochemically) formed sedimentary rocks. Both contain the mineral calcite, which reacts to an acid.

Metamorphic Rock Section:

Rocks can be subjected to heat and pressure from Earth’s forces. If these forces do not melt the rocks, they can alter them, changing the original rock into a metamorphic rock. Thus, all metamorphic rocks are made from preexisting rocks. The chart shows that the metamorphism of sandstone produces metasandstone and with additional heat and pressure quartzite forms. Locate slate. It is a low-grade metamorphism of shale. With an increase of heat and pressure, slate can change into phyllite and schist. Sedimentary coal,



Types of Metamorphism:

Contact Metamorphism – The heat of an igneous intrusion can cause the surrounding rocks to undergo metamorphism. This is called contact metamorphism. In the igneous section, this is diagrammed by hash-marks on the edges of the intrusion as it comes into contact with preexisting rocks.

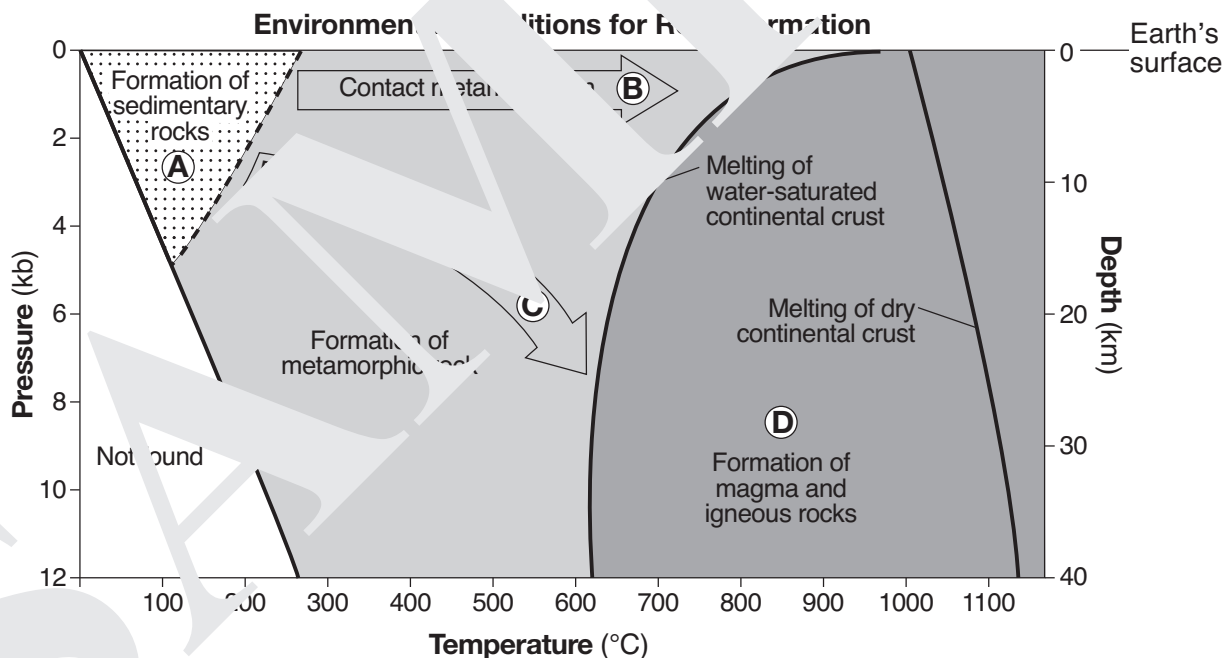
Regional Metamorphism – This is a very large area that has undergone metamorphism. Plate collisions produce regional metamorphism, forming folded mountains.

Remember, each family of rocks has its unique processes to produce them: igneous rocks → molten rock that solidifies; metamorphic rocks → rocks altered by heat and/or pressure, but never melts; sedimentary rocks → the compaction and cementation (lithification) of sediments along with organic material and chemicals precipitated out of a solution.

Additional Information:

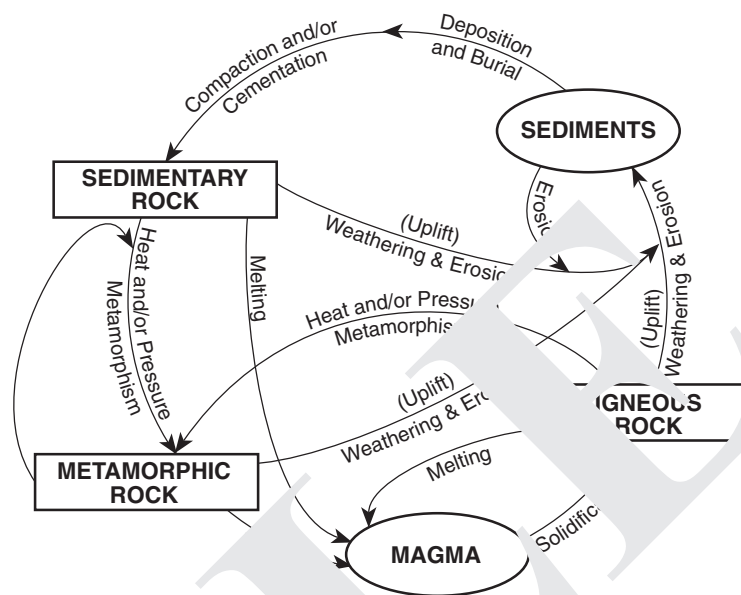
- Outgassing is the release of Earth's interior gases by volcanism.
- Pressure and heat of metamorphism can alter the minerals. This is known as recrystallization. (See lower section of the Metamorphic chart.)
- Sedimentary rocks are the most common rocks found on the Earth's surface. The evidence of fossils indicates a sedimentary rock.
- On the Sedimentary model is the term unconformity. This is an area of missing layer(s), making a time gap in the geologic history of the area. It was caused by uplifted layers that were eroded away. Then, sometime later the land subsided (sank) and new layers were deposited over the eroded layer.
- An extrusion will cause contact metamorphism to the layer it rests on. Any layer that develops on top of the extrusion will not show contact metamorphism because the extrusion has cooled to a solid.
- Mount Rushmore was carved from mostly granite that solidified deep in a magma chamber and was later uplifted, exposed to the Earth's surface.

Diagrams:



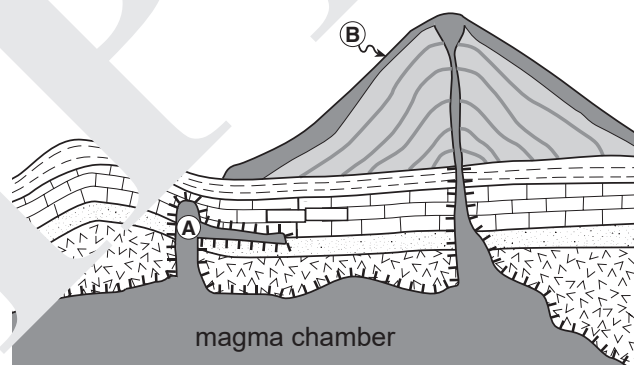
1. **Environmental Conditions for Rock Formation** – The graph shows the temperature, pressure, and depth environments for the formation of the three major rock families. Letters *A* through *D* identify different environmental conditions for rock formation. Sedimentary rocks form on or near the surface, while metamorphic rocks need much heat/pressure, but the temperature cannot reach the rock's melting point. Magma exists at the highest temperature and pressure; upon cooling, igneous rocks form.

2. **Rock Cycle in Earth's Crust** – The outside circle shows the processes and steps that change rocks from one family to another. This chart also shows many other paths represented by inner arrows.

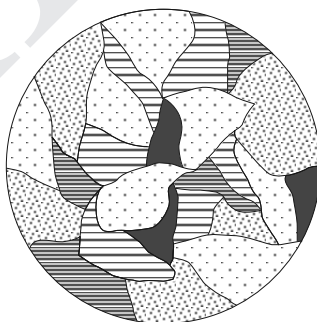


Igneous Rocks

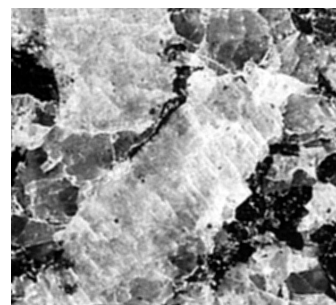
3. **Igneous Environments** – A magma chamber is a deep underground pool of molten rock. If the outer part of this chamber (A) cools enough to solidify, the resulting intrusive igneous rocks will have a coarse texture exhibiting large interlocking crystals. If the magma surfaces, the lava (B) will cool quickly, producing an extrusive igneous rock with a fine, glassy texture.



4. **Igneous Rock**
- | | |
|--|-----------|
| | Amphibole |
| | Biotite |
| | Feldspar |
| | Quartz |
- Scale: 0 2 4 mm



(1)



(Actual size)

(2)

Intrusive Igneous Rock – Figure 1 shows the magnified drawing of minerals found in an intrusive igneous rock. Based on the size of its intergrown crystals, the environment of formation must have been intrusive (plutonic). Figure 2 is an actual photograph of such an intrusive igneous rock that cooled slowly, growing large crystals.

5. **Extrusive Igneous Rocks** – Rock *A* has gas pockets, showing it cooled rapidly, trapping air as lava was ejected from a volcano.

Rock *B* shows a glassy texture, making it non-crystalline. A lava flow on the Earth's surface cooled quickly, producing this texture.



A

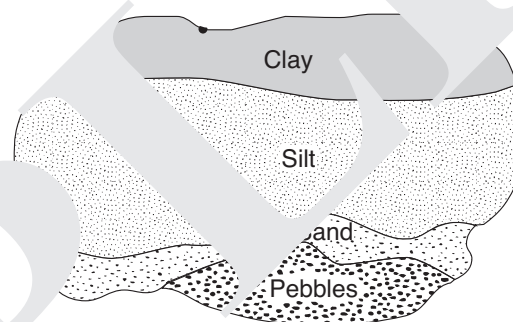


Glossy black rock that breaks with a shell-shape fracture

B

Sedimentary Rocks

6. **Sediments to Rocks** – This diagram represents the deposition of sediments when a river enters a lake. Over years and with compaction and/or cementation, these sediments of different sizes produce different sedimentary rocks. Clay and mud form shale, silt becomes siltstone, sand becomes sandstone and a mixture of pebbles and smaller sediments produce the sedimentary rock known as conglomerate.



7. **Identification of a Sedimentary Rock** – The diagram represents a sedimentary rock composed of cemented pebbles and sand. This rock is a conglomerate because it contains many sized sediments. Remember, inorganic land-derived sedimentary rocks are based on grain size, not composition.



8.

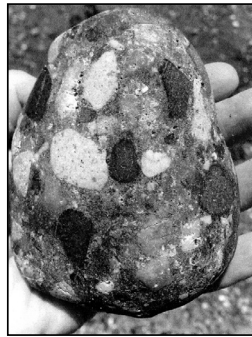


Sedimentary Rocks and Fossils – Most sedimentary rocks were formed under water. When marine organisms die, some impressions are preserved in the marine sediments and fossilized as the sediments become cemented and/or compacted, changing into a sedimentary rock. A great clue that a rock is sedimentary is the presence of fossils – like this Paleozoic brachiopod.

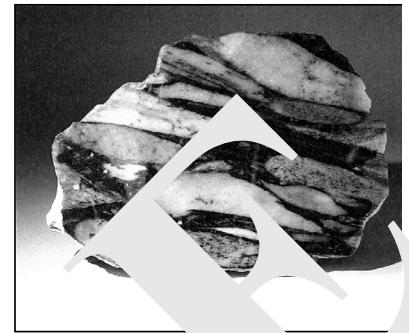
Metamorphic Rocks

9. Sedimentary to Metamorphic –

This conglomerate rock (A) was subjected to Earth's forces that increased the temperature and pressure enough to cause metamorphism to the sedimentary rock producing a metaconglomerate (B).

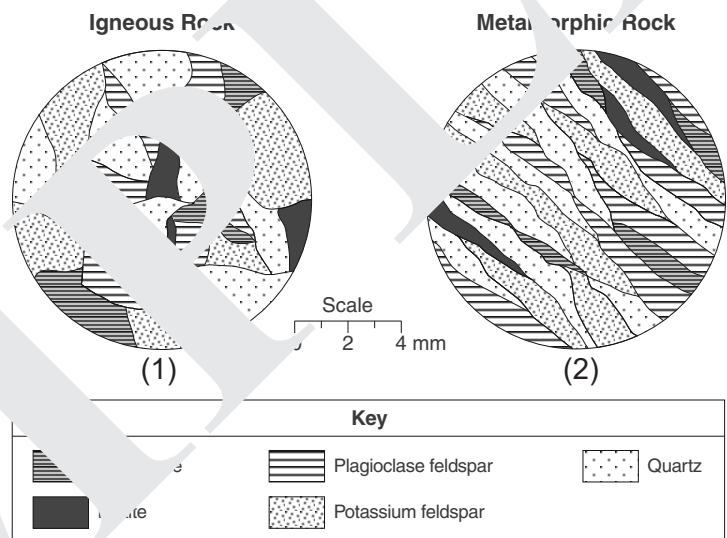


Rock A

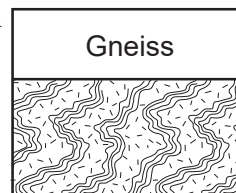


Rock B

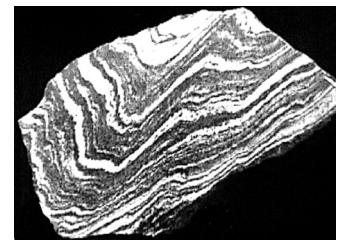
10. **Recrystallization** – Figure 1 represents the igneous rock granite, having interlocking crystals of five minerals. When it undergoes metamorphism, the increase of heat and pressure causes minerals to undergo recrystallization and become aligned (figure 2).



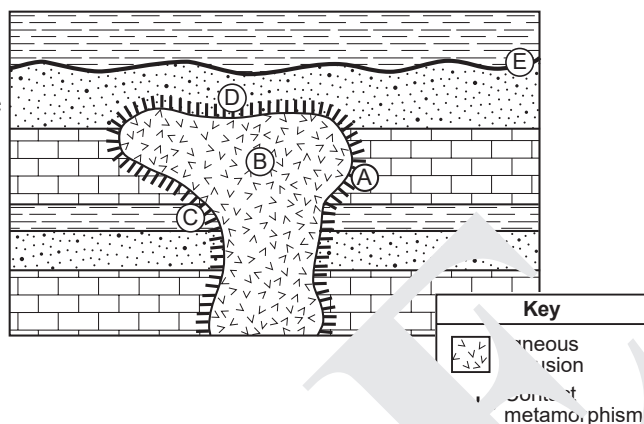
11. **Gneiss** – Gneiss is a metamorphic rock that formed from a preexisting rock that had been subjected to great pressure and heat due to regional metamorphism. These conditions caused the minerals to segregate into “wavy” bands.



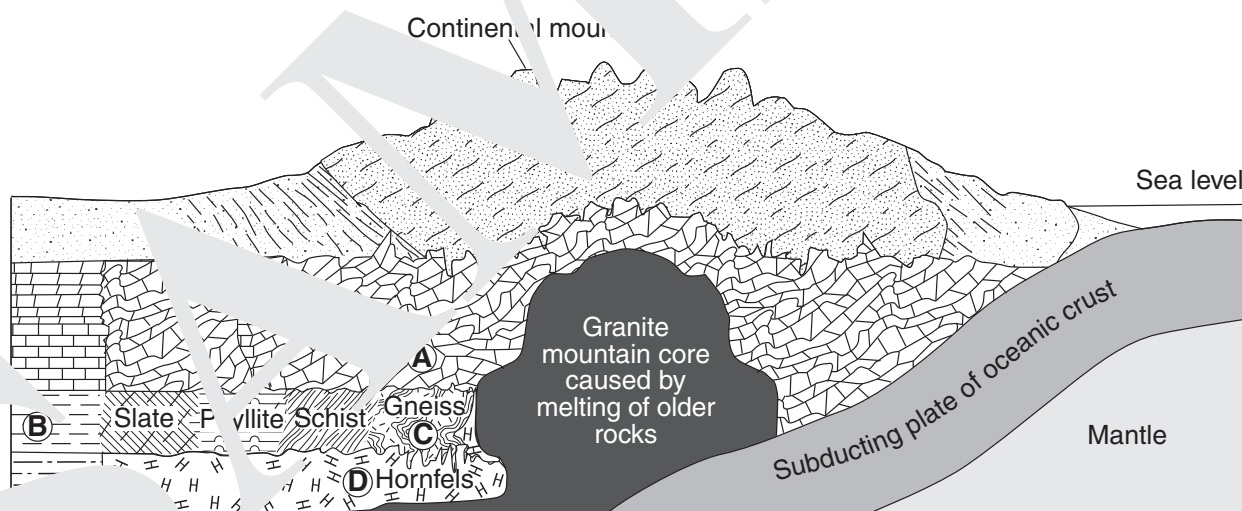
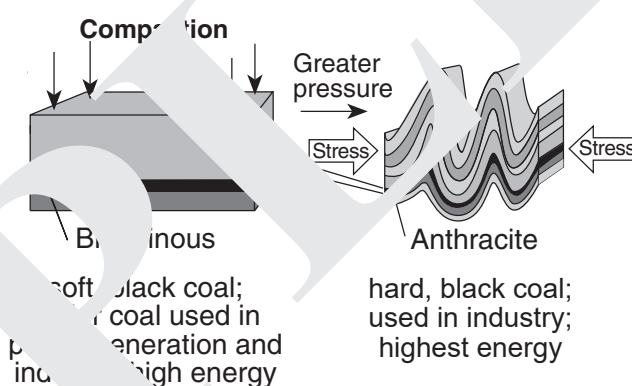
Banding



12. **Contact Metamorphism** – Letter *B* represents an intrusion of magma that solidified into an igneous rock. When the magma intruded the rock layers, the heat of the magma caused contact metamorphism to the previously existing rocks. In the contact area, letter *D*, sandstone, is now quartzite; letter *C*, shale, is now slate; and letter *A*, limestone, has been metamorphosed to marble. The wavy line, *E*, represents an unconformity where layers were eroded away producing a geologic time gap.



13. **Sedimentary to Metamorphic** – Bituminous coal is a sedimentary rock formed by compaction of organic matter. If this rock layer is subjected to an increase of heat and pressure, the soft bituminous coal changes into hard anthracite coal. This metamorphic coal is the highest grade of coal.

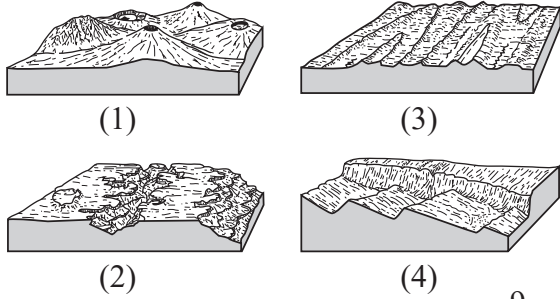


14. **Regional Metamorphism** – Regional metamorphism is a type of metamorphism that affects a large area by the force of plate tectonics. The above model details where and how different metamorphic rocks (*A*, *C*, *D*) are made by the build up of heat and pressure as an oceanic plate moves into a continental plate. The granite, an igneous rock, will form when the molten rock crystallizes. Notice *B*, shale, becomes different types of metamorphic rocks, slate → phyllite → schist → gneiss, as the pressure and temperature increase. The Continental mountains may have uplifted sedimentary strata.

Set 1 — Rock Cycle Infographic

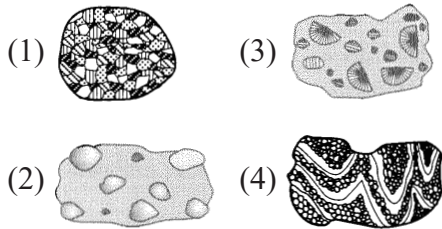
1. Rocks are classified as igneous, sedimentary, or metamorphic based primarily on their
 - (1) texture
 - (2) crystal or grain size
 - (3) method of formation
 - (4) mineral composition1 _____
2. When gneiss melts and then solidifies, it becomes
 - (1) a sedimentary rock
 - (2) an igneous rock
 - (3) a metamorphic rock
 - (4) sediments2 _____
3. Which statement about the rock cycle is *not* true?
 - (1) Cementation is a process that leads to sedimentary rocks.
 - (2) When heat is applied to a rock and it melts, it may form a metamorphic rock.
 - (3) A sedimentary rock in the future may change into another type of sedimentary rock.
 - (4) Solidification is always needed to form an igneous rock.3 _____
4. The burial process involving sedimentary rocks is usually
 - (1) deep within the Earth.
 - (2) on the surface of the Earth.
 - (3) within a water environment.
 - (4) at an ocean ridge.4 _____
5. The solidification of magma produces
 - (1) igneous and metamorphic rocks.
 - (2) sedimentary rocks and igneous rocks.
 - (3) only igneous rocks.
 - (4) only metamorphic rocks.5 _____
6. Which statement about a metamorphic rock is not supported by the rock cycle?
 - (1) A metamorphic rock may one day become sediments.
 - (2) Metamorphic rocks may one day undergo melting.
 - (3) A metamorphic rock has undergone cementation.
 - (4) A metamorphic rock may eventually become another type of metamorphic rock.6 _____
7. A primary difference between sedimentary rocks and nonsedimentary rocks is that
 - (1) nonsedimentary rocks contain an abundance of fossils
 - (2) nonsedimentary rocks originate in regions of great heat and/or pressure
 - (3) sedimentary rocks usually make up most mountains
 - (4) sedimentary rocks are formed at plate boundaries7 _____
8. Which rock has once melted deep inside the Earth, and slowly, over time its temperature dropped below its melting point?
 - (1) siltstone
 - (2) schist
 - (3) peridotite
 - (4) slate8 _____

9. Which diagram represents a landscape where fine-grained igneous bedrock is most likely to be found?



9 _____

10. Which diagram best represents a sample of an igneous rock?



10 _____

11. Most rock salt is formed by the

- (1) heating of previously existing bedrock
- (2) cooling and solidification of lava
- (3) compaction and cementation of shells and skeletal remains
- (4) chemical precipitation of minerals from seawater

11 _____

12. Which sedimentary rock may form as a result of biologic processes?

- (1) shale
- (2) siltstone
- (3) fossil limestone
- (4) gypsum

12 _____

13. Andesite is a type of rock that forms from the process of

- (1) solidification deep within the Earth
- (2) solidification close to the Earth's surface
- (3) erosion of sediments then became cemented together
- (4) being subjected to much heat and pressure without melting

13 _____

14. Which rock was subjected to intense heat and pressure but did not solidify from magma?

- (1) phyllite
- (2) porphyry
- (3) gabbro
- (4) rhyolite

14 _____

15. A large exposed formation of gabbro was primarily formed by

- (1) metamorphism of layered sandstone
- (2) solidification of magma
- (3) compaction of precipitated gypsum
- (4) cementation of sediments

15 _____

16. Most sedimentary rocks were formed by

- (1) volcanic eruptions and crystallization
- (2) compaction and/or cementation
- (3) heat and pressure
- (4) melting and/or solidification

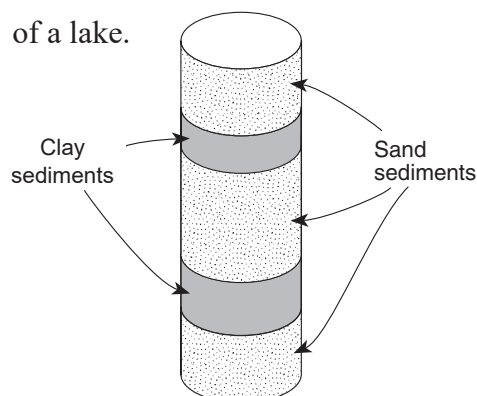
16 _____

17. Which type of rock most likely contains fossils?

- (1) volcanic tuff
- (2) gabbro
- (3) schist
- (4) shale

17 _____

18. The diagram below shows a drill core of sediment that was taken from the bottom of a lake.



Which types of rock would most likely form from compaction and cementation of these sediments?

- (1) conglomerate and siltstone
- (2) sandstone and shale
- (3) shale and bituminous coal
- (4) shale and rock salt

18 _____

19. Which statement about an igneous rock is not supported by the rock cycle?

- (1) All igneous rocks eventually become sedimentary rocks.
- (2) An igneous rock may be remelted and solidified into another type of igneous rock.
- (3) All igneous rocks must have been a liquid at one time.
- (4) An igneous rock can undergo metamorphism.

19 _____

20. Wavy bands of light and dark minerals visible in gneiss bedrock probably formed from the

- (1) cementing together of individual mineral grains
- (2) cooling and crystallization of magma
- (3) evaporation of an ancient ocean
- (4) heat and pressure during metamorphism

20 _____

21. The precipitation of the mineral halite would form a layer of

- (1) limestone
- (2) rock salt
- (3) coal
- (4) dolostone

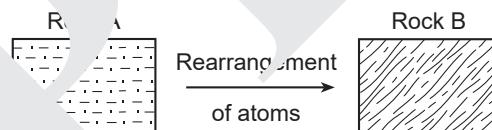
21 _____

22. A mixture of rounded pebbles and sand was deposited in a river. Over time, these sediments were compacted and cemented together to form the sedimentary rock

- (1) conglomerate
- (2) sandstone
- (3) megaconglomerate
- (4) shale

22 _____

23. The diagram below represents rock *A* changing into rock *B*.



Which process causes rock *A* to change into rock *B*?

- (1) melting
- (2) solidification
- (3) precipitation
- (4) metamorphism

23 _____

24. Which metamorphic rock is composed mostly of the same minerals as sandstone?

- (1) gneiss
- (2) marble
- (3) quartzite
- (4) schist

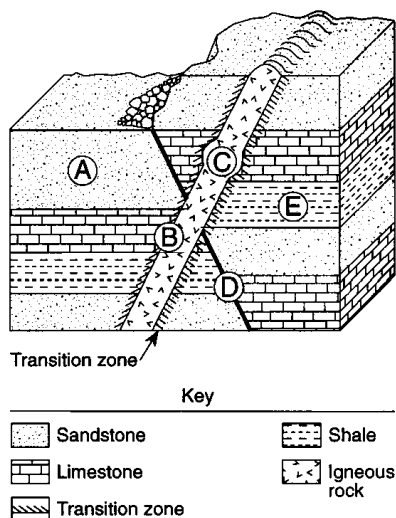
24 _____

25. Which rock would most likely be produced by the metamorphism of limestone and dolomite?

- (1) quartzite
- (2) slate
- (3) marble
- (4) gneiss

25 _____

26. The diagram below shows a portion of the Earth's crust. Letters *A*, *B*, *C*, and *D* indicate different types of rock.



At which location is metamorphic rock most likely to be found?

- (1) *A* (3) *C*
(2) *B* (4) *D* 26 _____

27. Which rock was organically formed and sometimes contains fossilized plant impressions?

- (1) bituminous coal (3) shale
(2) rock salt (4) mudstone 27 _____

28. Which rock was made from the smallest sediment?

- (1) sandstone (3) shale
(2) mudstone (4) siltstone 28 _____

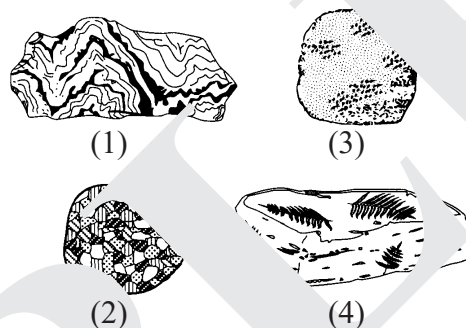
29. Which form of organic matter burns the cleanest and has the highest BTU value—a measurement of heat energy?

- (1) anthracite coal (3) lignite
(2) bituminous coal (4) peat 29 _____

30. Of the following pairs of sedimentary rocks, which choice contains an inorganic and an organic rock?

- (1) sandstone and gypsum
(2) sandstone and shale
(3) shale and reef buildup
(4) shale and siltstone 30 _____

31. Which rock sample is most likely metamorphic rock?



31 _____

32. The photograph below shows the large-scale eruption of volcanic ash from Mount Kelud in Indonesia in 2014.



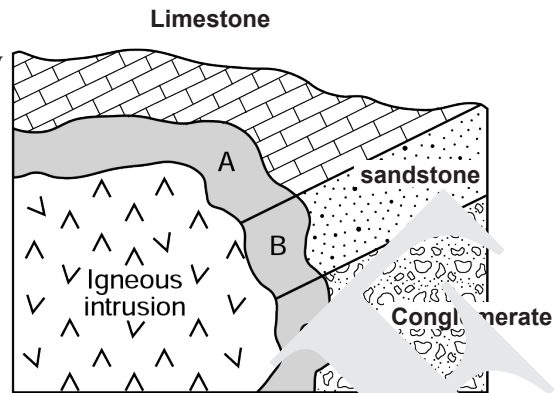
Which igneous rock would most likely to be found at the base of the volcano?

- (1) diorite (3) andesite
(2) peridotite (4) gabbro 32 _____

33. The cross section represents an igneous intrusion into sedimentary bedrock layers. Letters *A*, *B*, and *C* identify different rocks within the shaded zone of contact metamorphism.

Which metamorphic rocks are most likely formed in zones *A*, *B*, and *C*?

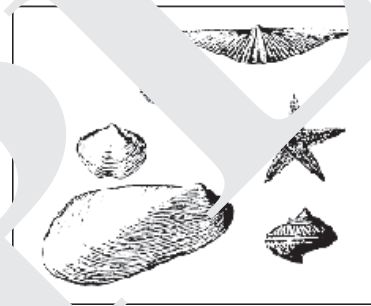
- (1) *A* = marble, *B* = gneiss, *C* = schist
- (2) *A* = marble, *B* = quartzite, *C* = metaconglomerate
- (3) *A* = metaconglomerate, *B* = quartzite, *C* = marble
- (4) *A* = metaconglomerate, *B* = schist, *C* = gneiss



33 _____

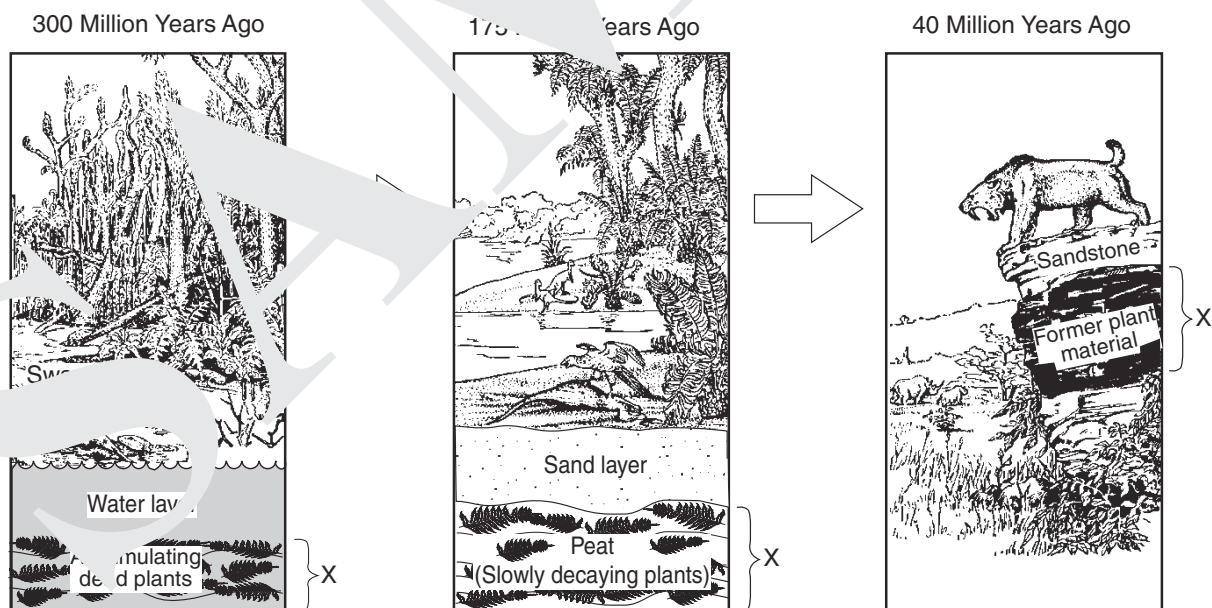
34. The accompanying diagram represents the fossils found in a bedrock formation located in central New York State. In which type of rock were the fossils most likely found?

- (1) sedimentary rock that formed in a marine environment
- (2) sedimentary rock that formed in a land environment
- (3) igneous rock that formed in an ocean environment
- (4) igneous rock that formed in a land environment



34 _____

35. The sequence of diagrams below represents the gradual geologic changes in layer **X**, located just below Earth's surface.

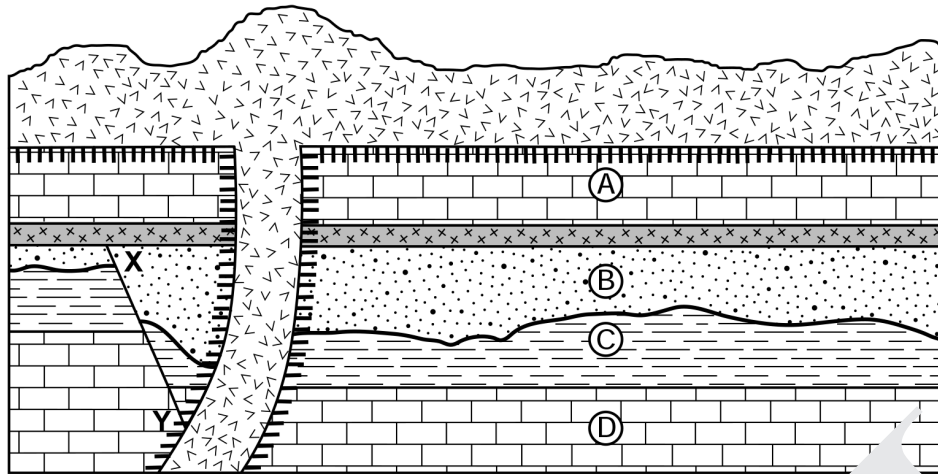


Which type of sedimentary rock was formed at layer **X**?

- (1) conglomerate
- (2) shale
- (3) rock salt
- (4) coal

35 _____

Base your answers to 36 through 39 on the diagram below.



Key	
	Basalt
	Volcanic ash
	Contact metamorphism

36. Layer *A* is limestone. State the name of the metamorphic rock that formed in the zone of contact metamorphism in this layer? _____

37. Layer *B* is sandstone. State the name of the metamorphic rock that formed in the zone of contact metamorphism in this layer? _____

38. Between *C* and *B* is an unconformity. What occurred to produced this?

39. What is the age of the basalt compared to the age of the fault line?

(circle one) younger older

40. How does contact metamorphism occur?

41. List two processes that would change accumulated sediments in a delta into sedimentary rocks.

1) _____ 2) _____

42. Give one reason that fossils are rarely found in metamorphic rocks.

43. When water evaporates, the minerals get concentrated and can start precipitating out building an evaporate. What rock family are evaporates placed in? _____

Rock Cycle Infographic

Set 1 — Answers

1. 3 The three rock families are based on how they were formed. Each family, sedimentary, igneous and metamorphic, has different conditions that produced them.
2. 2 Any rock that undergoes melting and solidifies is classified as an igneous rock.
3. 2 The key word here is “melt.” Metamorphic rocks were made by the conditions of heat and pressure, but they did not melt.
4. 3 The Rock Cycle Infographic chart shows that most sedimentary rocks are deposited in a water environment where they underwent compaction and cementation.
5. 3 The Rock Cycle chart shows: Cooling and Solidification → Igneous rocks.
6. 3 Heat and pressure are the processes that change an existing rock to a metamorphic rock. Cementation is involved in sedimentary rocks.
7. 2 Nonsedimentary rocks are igneous or metamorphic rocks. Heat and pressure, without melting the rock, will change the rock structure, changing it to a metamorphic rock.
8. 3 These conditions are for the igneous rock family. Choice 3, peridotite, is situated on the left side of the Igneous Rock Cycle chart.
9. 1 Volcanoes eject lava, which quickly cools, producing extrusive, fine grain igneous rocks.
10. 1 An intrusive igneous rock cools slowly, forming crystals. This is shown in choice 1.
11. 4 Locate Rock Salt in the Sedimentary Rock section. Notice it is positioned in a water environment—as a shallow sea. The water is a solution of minerals, of which halite (salt) is a major part of its composition. If the solution gets too concentrated or the water evaporates, the minerals become concentrated and start to precipitate out. This process can develop a layer of sedimentary rock salt.
12. 3 A biological sedimentary rock is one whose origin is organic—once living. Fossil limestone would have evidence of shells within the limestone rock.
13. 2 Andesite is located at the top left side of the Igneous Rock Cycle chart. It is positioned just below the volcano. Andesite is an extrusive igneous rock that solidified from lava.
14. 1 Intense heat and pressure produce metamorphic rocks. In the Metamorphic section of the Rock Cycle, phyllite is listed.
15. 2 Gabbro is positioned on the left side of the intrusion in the igneous section. All igneous rocks have undergone solidification—changing from a liquid to a solid.
16. 2 These are the conditions that produce sedimentary rocks. They are also stated in the Rock Cycle chart.
17. 4 Fossils are almost exclusively found in sedimentary rocks. The Sedimentary Rock section shows that clay and mud will undergo compaction and cementation (called lithification) and form shale.

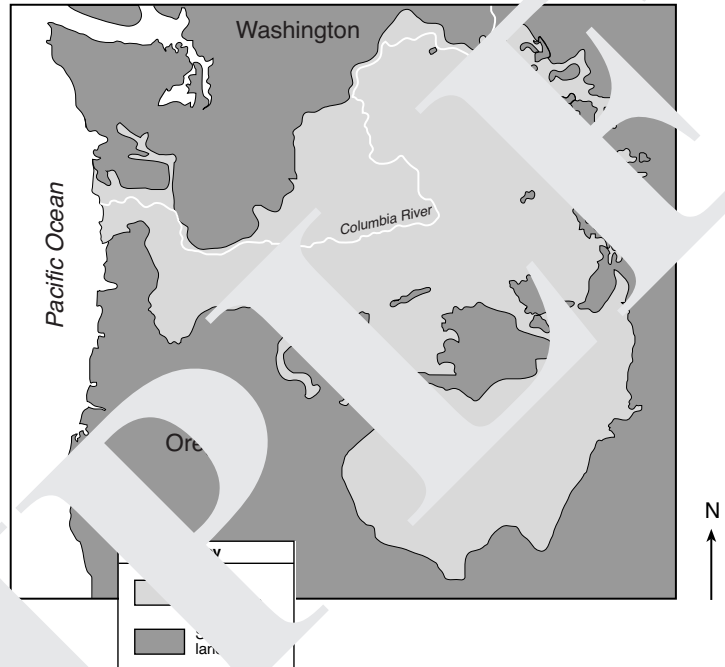
GROUP 3

Some questions may require the use of the *2026 Edition Reference Tables for Earth and Space Sciences*.

Base your answers to questions 1 through 7 on the passage and map below, and on your knowledge of Earth and Space Sciences. The map of the northwestern United States shows the location of the Columbia River Basalts.

Columbia River Basalts

The Columbia River Basalts are a formation of several horizontal lava flows from eruptions that took place between 6 million and 17 million years ago. The magma originated deep in the Earth and flow upward through a magma plume producing a hotspot. The lava erupted from this hotspot and flowed westward toward the Pacific Ocean. This large area of basalt was created when the North American Plate moved over the hot spot. These horizontal basalt layers are currently about 1200 meters above sea level.



1. The mantle plume, the hotspot, and the lava flows of the Columbia River Basalts are inferred to have risen from the boundary between the solid mantle and the outer core. Give the depth at this boundary and state the name of this hotspot.

Depth: _____ Hotspot: _____

2. Compared to the surrounding mantle material the mantle plume rose toward Earth's surface from the boundary between the solid mantle and the outer core because the mantle plume

(1) cooler and less dense (3) hotter and less dense
(2) cooler and denser (4) hotter and denser

2 _____

3. The basaltic rock that forms the Columbia river basalt where mantle plumes reach Earth's surface is usually composed of

(1) fine-grained, dark-colored felsic minerals
(2) interlocking crystals, light-colored felsic minerals
(3) fine-grained, dark-colored mafic minerals
(4) interlocking crystals, light-colored mafic minerals

3 _____

4. A small percentage of komatiite has also been found within this basalt flow. The identification of komatiite was done by comparing the mineral composition of basalt and komatiite. State a mineral that could be present in basalt but absent in komatiite. _____

5. Identify two elements that increase when comparing composition of the igneous mafic basalt to the igneous ultramafic komatiite. _____ and _____
6. Identify the geologic epoch when the first lava flow produced the initial Columbia River Basalts.
_____ Epoch
7. Today the coordinates of this hotspot is 44°26'N, 110°40'W. 17 million years ago, the coordinates of this hotspot was
- (1) 30 degrees of latitude east and 30 degrees of longitude north of the present coordinates
 - (2) 30 degrees of latitude west and 30 degrees of longitude south of the present coordinates
 - (3) 30 degrees of latitude north and 30 degrees of longitude west of the present coordinates
 - (4) approximately the same coordinates
- 7 _____

Base your answers to questions 8 through 12 on the passage below and on your knowledge of science.

Dimension Stone: Granite

Dimension stone is any rock mined and cut for specific purposes, such as kitchen countertops, monuments, and the curbing along city streets. Examples of rock mined for use as dimension stone include limestone, marble, sandstone, and slate. The most important dimension stone is granite; however, not all dimension stone sold as granite is actually granite. Two examples of such rock sold as “granite” are syenite and anorthosite. Syenite is a crystalline, light-colored rock composed primarily of potassium feldspar, plagioclase feldspar, biotite, and amphibole, while anorthosite is composed almost entirely of plagioclase feldspar. Like actual granite, both syenite and anorthosite have large, interlocking crystals.

8. Explain why syenite is classified as an igneous intrusive rock.

9. State one reason why anorthosite is a darker dimension stone compared to granite.

10. The igneous rock gabbro is sometimes sold as “black granite.” Compared to the mineral composition of granite, describe how the mineral composition of gabbro are different.

11. Being igneous rocks, granite and gabbro both crystallized out as magma cooled. Of these two rocks, which crystallized out first? _____
12. Identify one dimension stone mentioned in the passage that is of metamorphic origin.

13. Which sequence of formation is possible?

- (1) clay → sedimentary slate → metamorphic phyllite → metamorphic schist
- (2) clay → metamorphic slate → metamorphic quartzite → metamorphic gneiss
- (3) clay → sedimentary sandstone → metamorphic metasandstone → metamorphic quartzite
- (4) clay → metamorphic slate → metamorphic phyllite → metamorphic schist

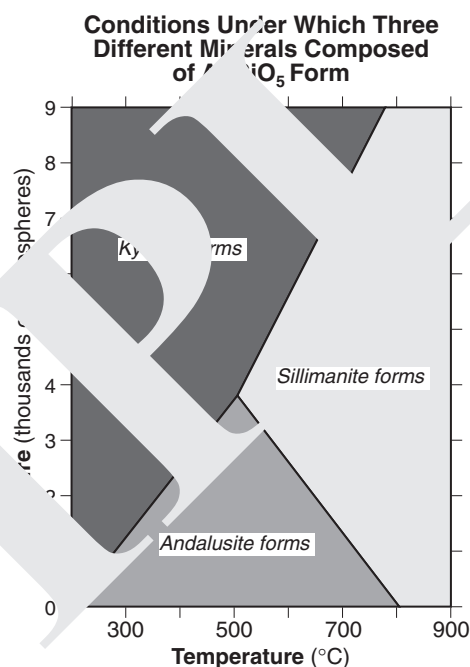
13 _____

14. 310 million years ago, extensive forests existed. The decaying organic remains built up in marshes and swamps tens of feet thick. Over time they were compacted to an average of 4 to 8 feet while forming a sedimentary rock. State the name of this rock. _____

Base your answers to question 15 on the graph, which shows the crustal temperature and pressure conditions under which three different minerals with the same chemical composition (Al_2SiO_5) crystallize.

15. Under which crustal temperature and pressure conditions will andalusite form?

- (1) 300°C and 6000 atmospheres
- (2) 500°C and 2000 atmospheres
- (3) 600°C and 4000 atmospheres
- (4) 700°C and 8000 atmospheres



15 _____

16. The pie chart shows the percentage of each mineral found in a sample of an igneous rock that formed deep underground.

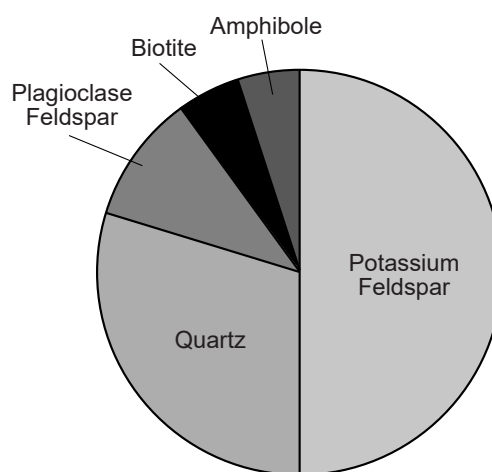
a) Which igneous rock is represented by the chart?

b) State the composition of this rock.

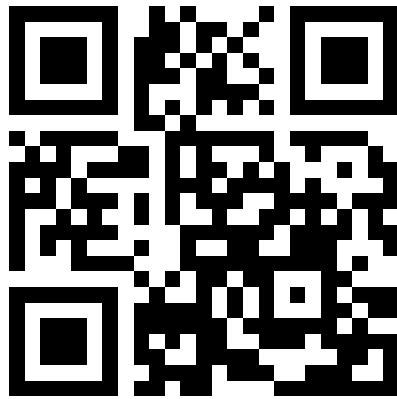
c) Other than plagioclase feldspar, complete the chart below showing the order that the remaining four minerals crystallized out to form this rock.

Minerals 1) _____ 2) _____ 3) _____ 4) _____

Highest temperature -----> Lowest temperature
to crystallize out to crystallize out



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