

Answer Key

Passage I (Metamorphic Rock)

1. C
2. J
3. C
4. J
5. A

Passage II (comet vs. Asteroid)

6. J
7. B
8. G
9. D
10. H
11. A
12. G

Passage III (Elaiosome)

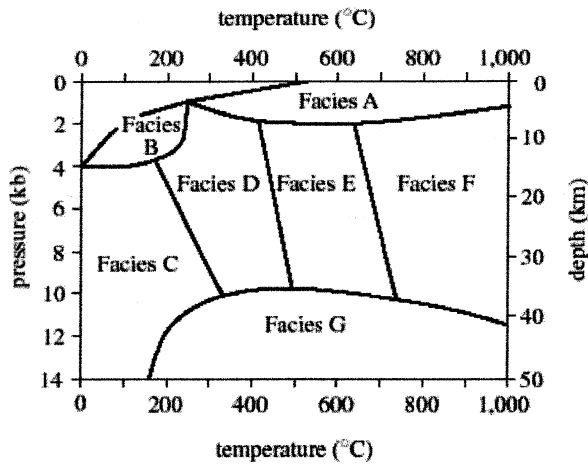
13. A
14. G
15. C
16. G
17. C
18. J

Passage I

Metamorphic rocks form when temperature and/or pressure cause changes in preexisting rock. Figure 1 shows the temperature and pressure conditions in which certain *facies* (categories of metamorphic rocks) are formed.

Passage I

Metamorphic rocks form when temperature and/or pressure cause changes in preexisting rock. Figure 1 shows the temperature and pressure conditions in which certain *facies* (categories of metamorphic rocks) are formed.



(Note: Boundaries are not actually sharp, distinct lines.)

Figure 1

Figure adapted from Sheldon Judson, Marvin Kauffman, and L. Don Leet, *Physical Geology*. ©1982 by Prentice-Hall, Inc.

A rock's *metamorphic grade* (a measure of the intensity of metamorphism) is classified on a scale of low (very similar to the original rock) to high (very different from the original rock). Table 1 lists the grades of Facies A–G from Figure 1. Figure 2 shows characteristic minerals that may be present in rocks of a given grade.

Table 1	
Facies	Metamorphic grade*
A	low
B	low
C	low to medium
D	low to medium
E	medium
F	medium to high
G	high

*Metamorphic grade is a measure of the intensity of metamorphism.

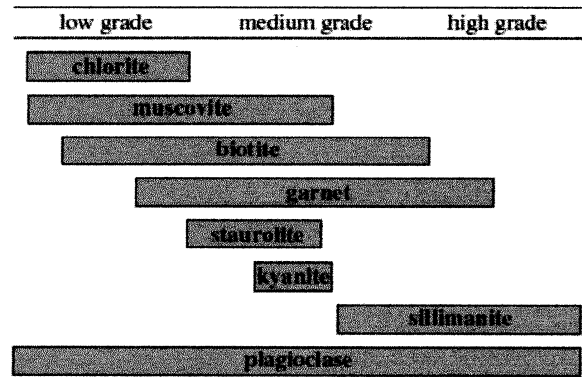


Figure 2

Figure 2 adapted from Frank Press and Raymond Siever, *Earth*. ©1986 by W. H. Freeman and Co.

Passage I (cont)

A rock's *metamorphic grade* (a measure of the intensity of metamorphism) is classified on a scale of low (very similar to the original rock) to high (very different from the original rock). Table 1 lists the grades of Facies A–G from Figure 1. Figure 2 shows characteristic minerals that may be present in rocks of a given grade.

1. According to Figure 2, which of the following minerals would most typically be found only in rocks of a medium grade?

- A. Muscovite
- B. Biotite
- C. Kyanite
- D. Plagioclase

2. According to Figure 1, a Facies G rock will most likely form under which of the following pressure and temperature conditions?

	Pressure	Temperature
F.	3 kb	800°C
G.	5 kb	400°C
H.	8 kb	1,000°C
J.	11 kb	600°C

3. Figure 1 indicates that as depth increases, pressure:

- A. decreases only.
- B. remains the same.
- C. increases only.
- D. increases, then decreases.

4. According to Figure 2, the presence of which of the following minerals in a metamorphic rock would be *least* helpful in determining that rock's grade?

- F. Chlorite
- G. Muscovite
- H. Staurolite
- J. Plagioclase

5. *Hornfels* is a metamorphic rock formed when *magma* (molten rock) heats sedimentary rocks on Earth's surface.

According to Figure 1, hornfels is most likely a member of which of the following facies?

- A. Facies A
- B. Facies C
- C. Facies E
- D. Facies G

Passage II

In 1908, an object from outer space devastated 2,000 km² of forest in Siberia. The object was between 10 m and 100 m in diameter and traveled at a maximum speed of 15 km/sec. It exploded at an altitude of 8 km and released energy equivalent to 20 million tons of TNT. Two scientists discuss whether this object was a comet or an asteroid.

Scientist 1

The object was a comet, a body made of ices (such as frozen water or methane) and dust. Most of this cometary material is *volatile* (easily vaporized) and low in density. Friction in Earth's atmosphere heated the comet to a temperature at which it exploded, high above the ground. The majority of the ices and dust were vaporized in the explosion, which explains why no crater was formed at the site and why no large, identifiable fragments of the object were found. An asteroid would not have been completely destroyed. Intact asteroid fragments that reached the ground would have created one or more craters upon impact and left behind recoverable pieces. Evidence shows that the object decelerated rapidly before it exploded. Because of their low density, comets are capable of such rapid deceleration, whereas high-density objects, such as asteroids, are not.

Scientist 2

The object was a stony asteroid. As it entered Earth's atmosphere, its high speed created a large air pressure difference between the area just in front of the asteroid and the area just behind the asteroid. The large pressure difference eventually exceeded the structural strength of the asteroid. The asteroid flattened, decelerated rapidly due to the dramatic increase in its surface area, and fragmented before reaching the ground. This fragmentation would have appeared like an explosion. Calculations show that a comet between 10 m and 100 m in diameter would explode at an altitude much higher than 8 km, but a stony asteroid of that size would fragment at or near an altitude of 8 km. Recovery of large asteroid fragments is difficult due to the area's boggy soil; however, small, glassy fragments were recovered and are believed to be melted and resolidified pieces of the asteroid.

6. Which of the following phrases best describes the major point of difference between the 2 scientists' hypotheses?

- F. The location of the event
- G. The speed the object was traveling
- H. The density of Earth's atmosphere
- J. The type of object that entered Earth's atmosphere

7. According to Scientist 2's viewpoint, compared to the altitude at which a stony asteroid would have exploded in Earth's atmosphere, a comet of similar size would most likely have exploded at:

- A. the same altitude.
- B. a higher altitude.
- C. a slightly lower altitude.
- D. a much lower altitude.

8. Scientist 1's viewpoint indicates that when the materials that compose most of a comet are sufficiently heated, they change to:

- F. solids.
- G. gases.
- H. liquids.
- J. a vacuum.

Passage II (cont)

9. Which of the following statements best describes how Scientist 2 would explain why no large, identifiable fragments of the object have been recovered?

- A. Any large, identifiable fragments that reached the ground have been removed from the area by erosion.
- B. Any large, identifiable fragments were thrown hundreds of kilometers from the site.
- C. No large, identifiable fragments of the object reached the ground.
- D. No large, identifiable fragments of the object have been recovered due to the soil conditions in the area.

10. How would the behavior of the asteroid differ from that described in Scientist 2's viewpoint if the asteroid had not been flattened by the air pressure difference?

The asteroid would:

- F. not have entered Earth's atmosphere.
- G. have struck another planet in the solar system.
- H. have decelerated more gradually.
- J. have frozen.

11. Which of the following statements would both scientists most likely use to explain the damage to the forest caused by the object's explosion? Energy from the explosion:

- A. traveled rapidly down to Earth's surface.
- B. dissipated in the upper atmosphere.
- C. was released less than 1 km above Earth's surface.
- D. was released as the object struck Earth's surface.

12. Scientist 1's viewpoint would be *weakened* by which of the following observations about comets, if true?

- F. Comets are composed mainly of frozen materials.
- G. Comets are much larger than 100 m in diameter.
- H. Comets often pass close enough to Earth to intersect Earth's atmosphere.
- J. Comets orbit the Sun.

Passage III

The seeds of some plants attract ants with a nutritious structure called an *elaiosome*. The ants carry the seeds to their nests, eat the elaiosomes, and then leave the seeds in a waste pile, where some seeds *germinate* (begin to grow). Three studies were conducted to examine this process.

Study 1

For 2 plant species (A and B), seed mass per seed in milligrams (mg), elaiosome mass per seed (mg), and percentage of seed mass composed of elaiosome were recorded (see Table 1).

Species	Seed mass (mg)	Elaiosome mass per seed (mg)	Percentage of seed mass composed of elaiosome
A	6.8	0.420	6.2
B	14.9	0.924	6.2

Site	Plant species absent	Number of seeds removed from seed dishes containing:	
		Species A	Species B
1	A	13	3
2	B	2	12
3	A and B	8	9

Tables 1 and 2 adapted from Brent H. Smith et al., "Frequency-Dependent Seed Dispersal by Ants of Two Deciduous Forest Herbs." ©1989 by the Ecological Society of America.

Study 2

Three study sites were established in order to determine the rate of seed collection by a single species of ant for the plants used in Study 1. In Site 1, Species A plants were absent; in Site 2, Species B plants were absent. Both plants were absent in Site 3. Two seed dishes were placed in each site: 1 containing 20 Species A seeds and 1 containing 20 Species B seeds. The dishes were left out for 48 hours and the number of seeds taken from each dish was recorded. The results appear in Table 2.

Study 3

The researchers planted 2,550 seeds from a third species, Species C. They also observed 2,550 Species C seeds that were planted by ants in similar environments. All seeds were observed for 2 years. Table 3 presents the results.

Maturation of Species C seeds	Results from:	
	hand-planted seeds	ant-planted seeds
Seeds that germinated	26	39
Plants alive after 1 year	9	20
Plants alive after 2 years	4	13
Seeds produced per plant after 2 years	2,187	2,163

Table 3 adapted from Frances M. Hanzawa, Andrew J. Beattie, and David C. Culver, "Directed Dispersal: Demographic Analysis of an Ant-Seed Mutualism." ©1988 by The University of Chicago.

Passage III (cont)

13. Based on the results of Study 3, one could generalize that compared to hand-planting of seeds, ant-planting of seeds results in:

- A. increased seed germination.
- B. increased seed production per plant.
- C. decreased plant survival after 1 year.
- D. decreased plant survival after 2 years.

14. Which of the following variables was controlled in the design of Study 2 ?

- F. The number of ants in each site
- G. The number of seed dishes placed in each site
- H. The mass of the elaiosome of each seed
- J. The type of seeds taken by the ants in each site

15. According to the results of the studies, Species A and Species B are most similar in that their:

- A. seed masses are the same.
- B. germination rates on ant waste piles are the same.
- C. percentages of elaiosome mass per seed are the same.
- D. rates of production of seeds after 1 year are the same.

16. In Study 2, Site 3 was used to study the:

- F. preference of a different ant species for the seeds of both plant species.
- G. seed preference of ants in an area in which both plant species were absent.
- H. growth and survival of both plant species in an area where ants were not present.
- J. effects of elaiosome mass on the seed preference of ants.

17. Which of the following is a weakness of the design of Study 2 ?

- A. Some plants were not present at each site.
- B. Some seeds were not present at each site.
- C. The seeds may have been removed from the dishes by animals other than ants.
- D. The plants may have been eaten by animals other than ants.

18. The results of Study 2 suggest that which of the following factors most affects the seed preference of ants?

- F. Seed mass
- G. Elaiosome mass
- H. Percentage of seed mass composed of elaiosome
- J. Abundance of a plant in a given area