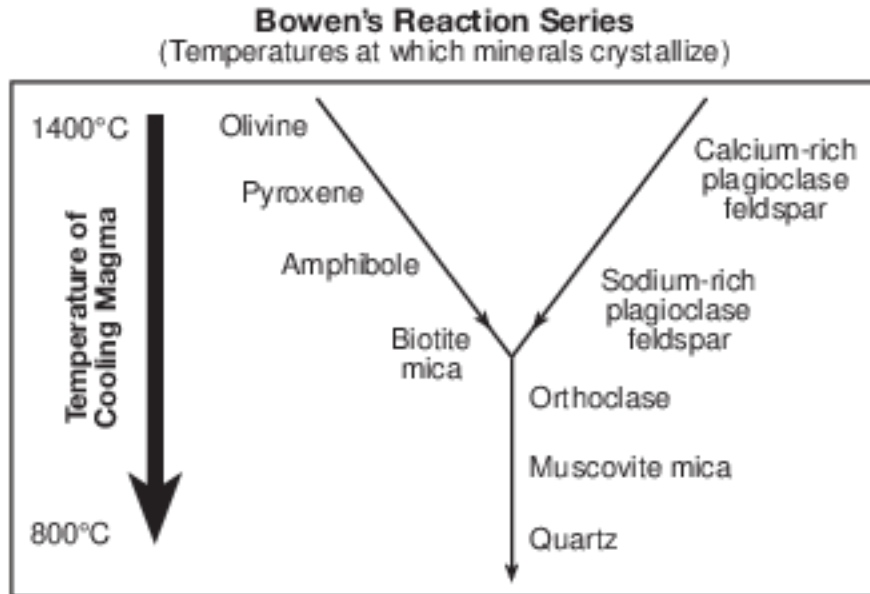


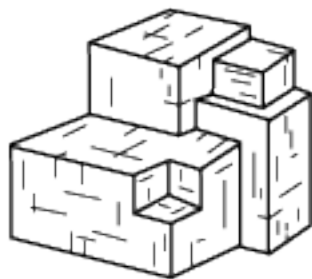
## Formation Of Minerals

- 1 The diagram of Bowen's Reaction Series below indicates the relative temperatures at which specific minerals crystallize as magma cools.

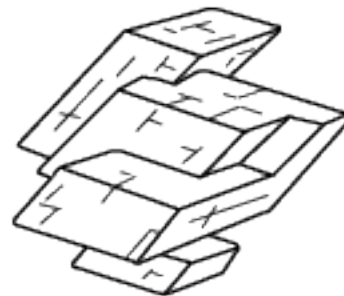


Which statement is best supported by Bowen's Reaction Series?

- (1) Most minerals crystallize at the same temperature.
  - (2) Most felsic minerals usually crystallize before most mafic minerals.
  - (3) Muscovite mica and quartz are the last minerals to crystallize as magma cools.
  - (4) Biotite mica is the first mineral to crystallize as magma cools.
- 2 The diagrams below represent the crystal shape and type of cleavage of two different minerals.



Crystal shape: cubic  
Cleavage: three directions  
– all at right angles

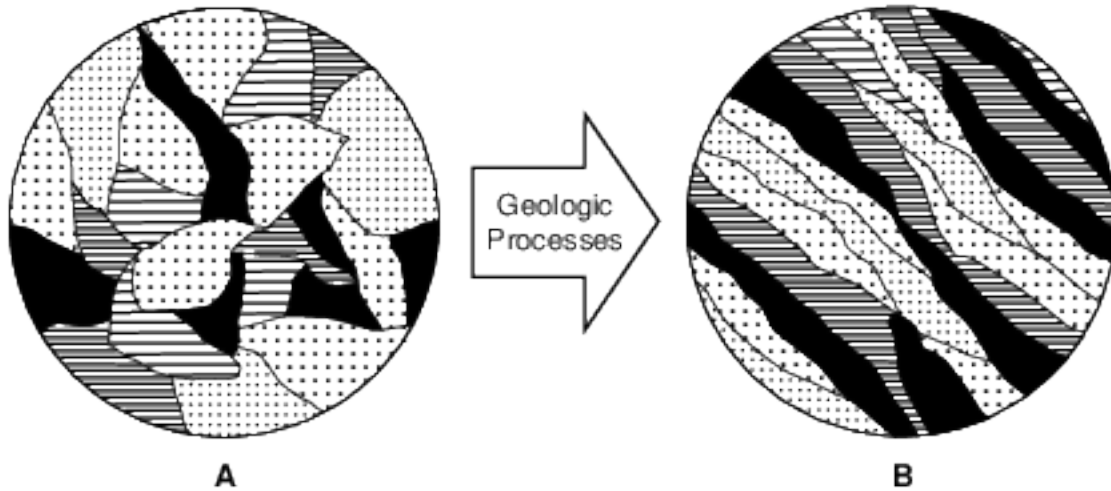


Crystal shape: rhombohedral  
Cleavage: three directions  
– not at right angles

The crystal shape and type of cleavage of these two minerals are determined mainly by the minerals'

- (1) color and type of luster
- (2) streak and hardness
- (3) composition and atomic arrangement
- (4) density and magnetism

- 3 Diagrams A and B represent magnified views of the arrangement of mineral crystals in a rock before and after being subjected to geologic processes.



Which geologic processes are most likely responsible for the banding and alignment of mineral crystals represented in diagram B?

- |                                     |                                |
|-------------------------------------|--------------------------------|
| (1) melting and solidification      | (3) compaction and cementation |
| (2) heating and increasing pressure | (4) weathering and erosion     |
- 4 Mineral crystals of quartz, biotite mica, and amphibole are produced primarily by the
- |   |  |
|---|--|
| (1) chemical reaction of elements in seawater | (3) deposition of sediments by a glacier |
| (2) cooling and solidification of magma       | (4) metamorphism of bituminous coal      |

Base your answers to questions 5 on the passage below and on your knowledge of Earth science.

### Waimea Canyon

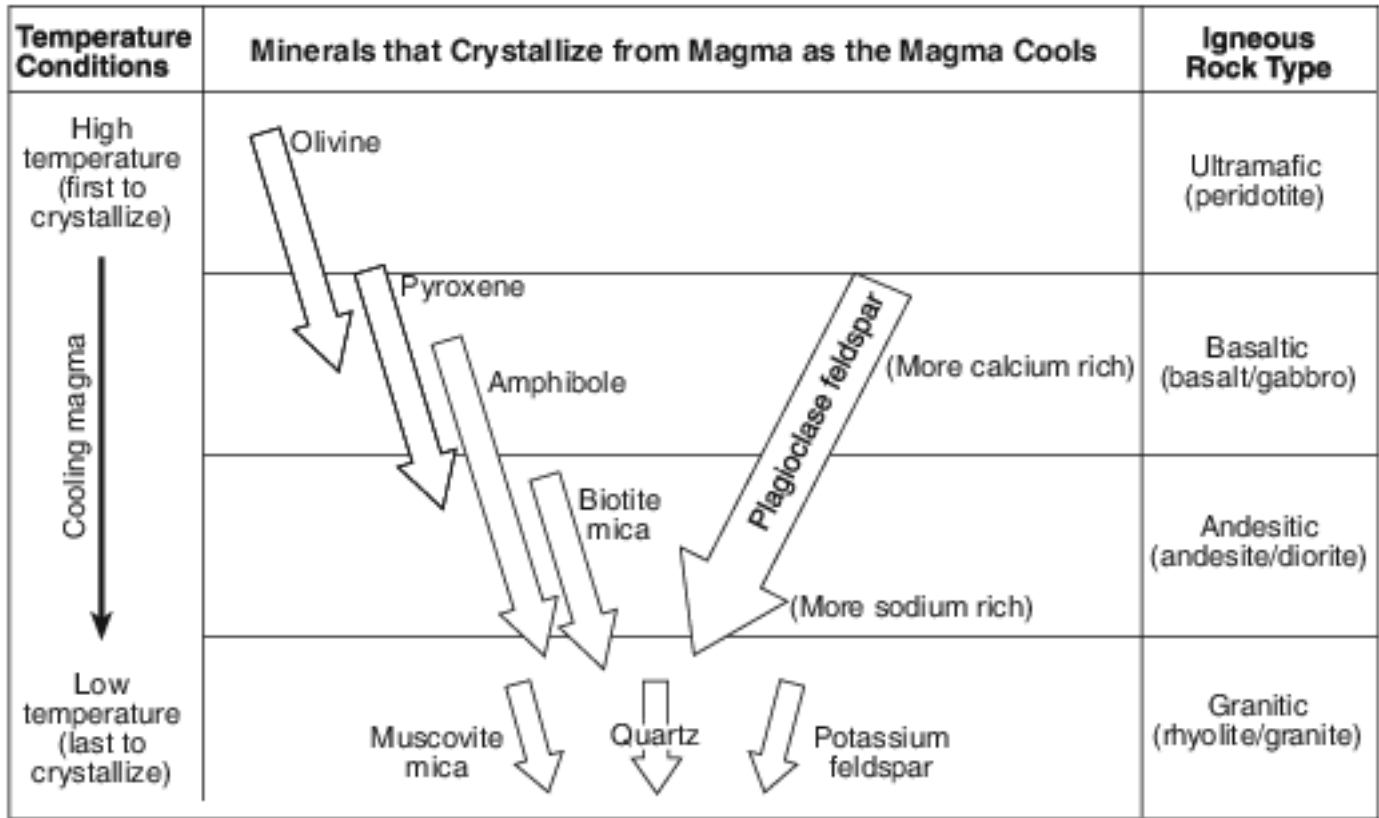
Waimea Canyon is located on the west side of the island of Kauai, Hawaii. Waimea Canyon has been referred to as the “Grand Canyon of the Pacific.” But unlike the Grand Canyon, which was carved through horizontal layers of sedimentary rocks, Waimea Canyon was cut through basalt. The formation of this igneous rock began about 4 million years ago. Numerous lava flows followed as magma rose from deep within Earth. The canyon then was formed over time by erosional agents, causing deep, V-shaped valleys that exposed the basalt layers along the canyon walls.

Over time, the composition of the basalt, where it was exposed at the surface, was changed due to oxidation (rusting) of iron-bearing minerals, such as pyroxene and olivine. The result is a canyon with red rocks and soils.

- 5 In addition to pyroxene and olivine, identify the name of one other mineral commonly found in basalt that could oxidize to produce red soils. [1]

Base your answers to questions 6 on the diagram of Bowen’s Reaction Series below, which shows the sequence in which minerals crystallize as magma cools and forms different types of igneous rocks from the same magma. The arrow for each mineral represents the relative temperature range at which that mineral crystallizes.

**Bowen’s Reaction Series**



6 According to Bowen’s Reaction Series, how is the chemical composition of plagioclase feldspar found in basaltic rock different from the chemical composition of plagioclase feldspar found in granitic rock? [1]

Base your answers to questions 7 on the passage below and on your knowledge of Earth science.

**The Mica Family**

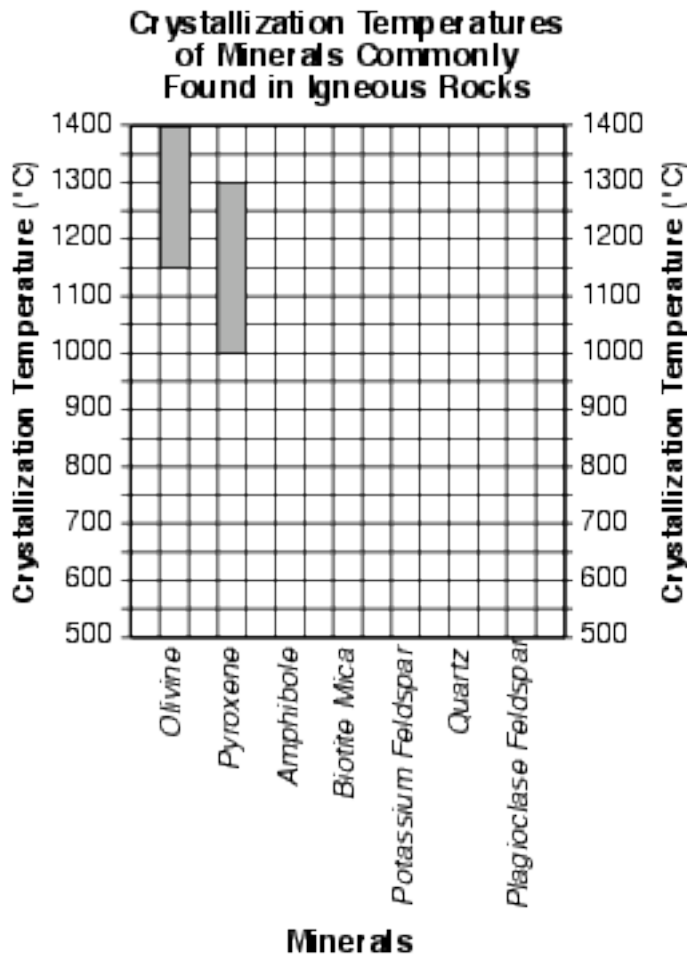
The familiar term “mica” is not the name of a specific mineral, but rather the name for a family of more than 30 minerals that share the same properties. All members of the mica family have high melting points and are similar in density, luster, hardness, streak, type of breakage, and crystal shape. As a result, telling the micas apart can be difficult. However, some common members of the family can be identified by color. For example, biotite is black to dark brown while muscovite can be light shades of several colors, or even colorless. When less common members of the mica family have any of these colors, or have similar colors, chemical tests are needed to tell them apart.

7 Identify the two chemical elements present in biotite mica that are not present in muscovite mica. [1]  
 and \_\_\_\_\_

Base your answers to questions 8 on the data table below and on your knowledge of Earth science. The data table shows the range of temperatures at which different minerals crystallize as molten magma cools and solidifies.

Mineral	Range of Temperatures at Which Each Mineral Crystallizes (°C)
Olivine	1400 to 1150
Pyroxene	1300 to 1000
Amphibole	1100 to 800
Biotite Mica	950 to 750
Potassium Feldspar	800 to 600
Quartz	550 to 500
Plagioclase Feldspar	1300 to 600

- 8 Complete the graph in the image provided by drawing a bar to represent the range of temperatures at which each mineral crystallizes. Shade in each bar drawn. The bars for the range of temperatures at which olivine and pyroxene crystallize have already been drawn. [1]



## Answer Keys

- 1 3
- 2 3
- 3 2
- 4 2
- 5 Allow 1 credit for amphibole/hornblende or biotite mica/biotite.
- Note: Do not accept “mica” alone because some micas, such as muscovite mica, do not contain iron.
- 6 Allow 1 credit. Acceptable responses include, but are not limited to:
- — The plagioclase feldspar in the basaltic rock is more calcium rich.
  - — The plagioclase feldspar in the granitic rock contains more sodium.
  - — less sodium in basaltic plagioclase feldspar
  - — The basaltic rock is more calcium rich.
- 7 Allow 1 credit for magnesium/Mg and iron/Fe.
- 8 Allow 1 credit if all five student-drawn bars are drawn in the correct columns and the ends of the bars are within or touch the rectangular areas shown at the end of each bar.
- Note: It is recommended that an overlay of the same scale as the student answer sheet be used to ensure reliability in rating.. Do not allow credit if any bar is not directly in the column above the mineral name.