# Answers for Section A: Earth Materials (Introduction to Geology)

1. Describe geology as a discipline.
   *Geology is a broad based discipline as it incorporates many other sciences. Knowledge of physics allows geologists to understand the earth's interior, rock structures and deformations. Chemistry provides a thorough understanding of minerals and their structure. Biology is the study of life, an important part of earth's history. Mathematics allows the geologist to quantify many processes.*

2. Describe at least three aspects of geology that make it different from other sciences.
   *1) Geology makes use of physics, chemistry and biology.*

   *2) The earth is the subject*

   *3) The time scale for many geologic processes is very slow. It may therefore be impossible to duplicate some geologic processes in the laboratory.*

   *4) The size of some geological processes is very large which may limit reproduction in the laboratory.*

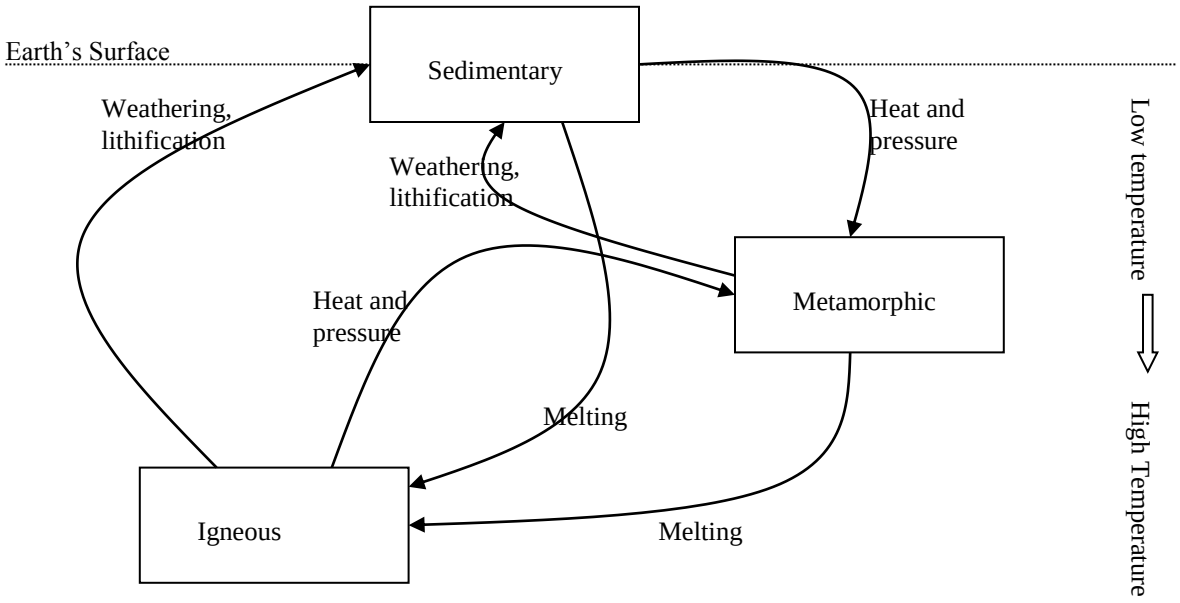
   *5) Natural geologic processes are rarely simple, instead they are too complex to be performed in the laboratory.*

3. Differentiate between rocks and minerals.
   *A mineral has definite chemical composition, solid, naturally occurring, inorganic, with a crystalline structure. A rock is a mixture or minerals. An important note to consider is that rocks will only have certain combinations of minerals. There are over 3000 different minerals within the Earth's crust yet only a few are very common, most are rare. Therefore, a rock will only have a few different minerals and its composition will rarely change. In every rock, there is a combination of minerals that gives the rock its character and identity. The are called essential minerals. But rocks often contain traces of other minerals called accessory minerals.*

4. Describe the formation of igneous, sedimentary, and metamorphic rocks, and classify rocks as igneous, sedimentary, or metamorphic.

| | | |
|---|---|---|
| ***Igneous Rocks*** | *Formed from the cooling and solidification of melted lava or magma.* | *Interlocking crystals. Size of crystals depends on the cooling rate.* |
| ***Sedimentary Rocks*** | *Formed from the lithification of loose weathered rock particles.* | *Fragments of weathered particles, often rounded fragments or fossils.* |
| ***Metamorphic Rocks*** | *Formed when heat and pressure alter the rock.* | *Mineral grains may look flattened and altered. Can be foliated.* |

5. Draw and label a rock cycle diagram.




6. Research and briefly describe 3 careers associated with geological technologies and sciences.

*An important geologic career, albeit less so in North America, is **mining**. We rely on various metals and energy reserves for our everyday needs and it is up to the geologist to find these and determine if it is economically feasible to mine the area. Another area in which we rely on geologists is **natural hazards** such as earthquake prediction and analysis, volcano prediction and analysis, floods, and landslides etc. **Hydrologists** analyze ground water, an important source of drinking water for billions. **Paleontologists** study Earth's past to seek a better understanding of evolution. **Planetary geology** has proved to be a valuable science to help understand our solar system and for the NASA trips to the moon.*

*The Department of Natural Resources run by the federal government supports the Geological Survey of Canada. The Survey provides basic scientific information to the public and the different levels of government on the geological architecture of the national territory. This enables Canada to fully realize its economic mineral potential, formulate policies on the best way to utilize the land surfaces and assess the types of natural hazards that might arise. Many Geologists work for the Survey all across the country.*

7. Why is the study of geology important?
   1. *All of the resources that we use today are either mined or grown. By studying geology, resources, such as metals and petroleum, can be discovered and mined. When geologists have a better understanding as to how minerals and petroleum form they know where to look for potential resources.*
   2. *By studying geology earth hazards, such as volcanoes, earthquakes, floods, landslides etc., can be assessed and possibly predicted thus saving lives and possibly property.*
   3. *We are stewards of our own planet, so it is our responsibility to take care of our environment.*

8. How are each of the following sciences involved in Geology?
   a. *Astronomy – in Geology we study the planets and solar system's formation to better understand Earth.*
   b. *Biology – fossil phyla, and biological weathering*
   c. *Chemistry – in the mineral and rocks sections chemistry is involved*
   d. *Physics – radiometric dating, plate motions*

9. Why are sedimentary rocks so abundant at the Earth's surface when igneous rocks make up most of the crust?

   *The weathering process occurs at the Earth's surface. Rivers are the most important agent of erosion and deposition, so sedimentary rocks form at the Earth's surface. Igneous rocks are formed from the melting of previously existing rock material. The source of heat to melt the rock is within the Earth, so igneous rocks make up most of the crust*

10. How does the Principle of Uniformitarianism help us understand the history of the Earth?

    *The same processes that are occurring now on the Earth are the same processes that have occurred throughout Earth's history. The present is the key to the past.*

11. What exceptions are there to uniformitarianism?

    *The exceptions include meteorite impacts large or small, the largest have been responsible for mass extinctions. Volcanic eruptions are also intermittent and can affect the Earth on a global scale. But these events by themselves cannot be responsible for all the landforms and contours of the Earth's surface that have ever existed throughout time.*

12. What geologic processes occur relatively slowly and which geologic processes would occur relatively quickly?

| ***Slow geologic processes*** | ***Fast geologic processes*** |
|---|---|
| *Chemical and physical weathering (cm per century).* | *Volcanic eruptions (lava flows - 1 cm/hour to 50 km per hour). (Explosions – hundreds of km per hour).* |
| *Some types of erosion. River down-cutting may be 1 to 10 cm per year or much slower depending on the rock type, uplift, etc.* | *Catastrophic erosional events – e.g., debris flows (hundreds of km per hour).* |
| *Soil creep (mm to cm per year).* | *River flood deposition (cm to metres per day).* |
| *Tectonic plate movement (mm to cm per year on average)* | *Earthquake (energy) release and propagation (km per second).* |
| *Mountain building (mm to cm per year on average).* | *Fault movement (metres per second).* |
| *Sedimentary deposition (mm to cm per year).* | *Meteorite impact (very fast).* |

13. Describe how the time factor complicates our attempts to understand geologic processes.

    *Many processes are extremely slow, some barely noticeable such as glacier movement, and other processes difficult to monitor even with sensitive equipment such as tectonic movement and mountain building. Even the idea that the Earth formed 4.5 billion years ago is an incomprehensible number. We humans have been on the Earth for a brief instant when compared with geologic processes that have shaped the Earth. Our concept of time is very different than a geologic concept of time.*

14. According to Hutton's "Principle of Uniformitarianism" the Earth's sedimentary rocks

    a) were all formed recently

    b) are continuously being formed

    c) ceased being formed billions of years ago

    d) were deposited when the planet first formed.

15. Which statement below would be most consistent with a uniformitarian view of the Earth?
    a) Entire plant and animal populations have been destroyed and created many times.
    b) Violent volcanic eruptions have created the mountains we see today.
    c) By studying modern day volcanic eruptions we can understand those of the past.
    d) Fossils of marine animals are found high in the mountains today because the oceans once covered all the mountains.

16. Which statement below is most inconsistent with how we now understand uniformitarianism?
    a) Catastrophic geologic events occasionally happen.
    b) Irreversible changes may occur on the Earth
    c) The chemical and physical laws operating today happened in the same way in the geologic past.
    d) The processes which formed rocks in the geologic past no longer occur today.

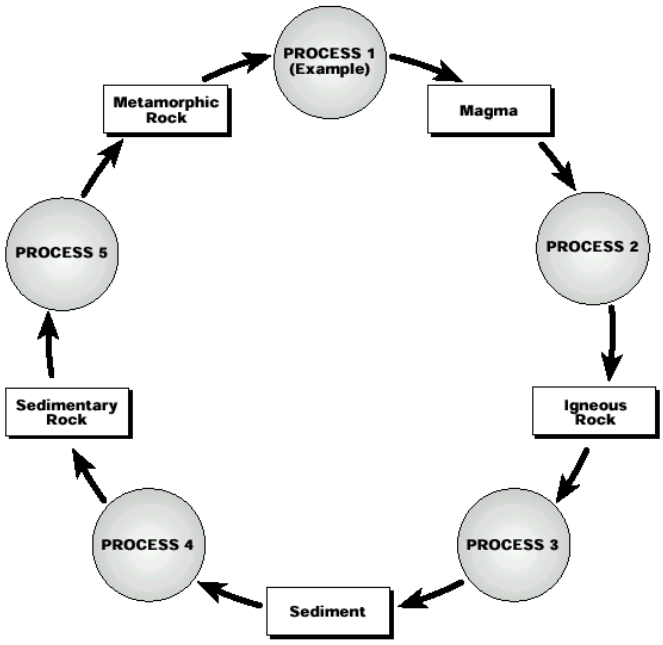
17. Differentiate each of the following as either a rock or mineral:

| | | |
|---|---|---|
| slate rock | hematite mineral | shale rock |
| pumice rock | gneiss rock | feldspar mineral |
| sandstone rock | basalt rock | quartz mineral |
| hornblende mineral | limestone rock | granite rock |

18. Although the Scotsman James Hutton first put the concept forth, it was Charles Lyell who gave a name to **uniformitarianism**. In the years since, it has been recognized as a fundamental principle in Geology. Using the principle of uniformitarianism, explain the occurrence of ripple marks in Precambrian sandstone.
    *The present is the key to the past. If ripple marks can be found on Precambrian rocks, it means that the process of running water that forms ripple marks must have been occurring then as it does now. The same processes of erosion occur now as they did during the Precambrian times.*

19. Describe the Nebular Model of the formation of the Solar System.
    *About 5 billion years ago there was a rotating cloud of dust and gas (nebula) where our Solar System now is. A nearby star exploded (went supernova) which caused a disturbance in space so that the nebula began to contract (pull together.) The sun (99.99% of the mass) formed in the centre and the remaining dust and gas, still rotating around the sun, contract due to gravity and formed the planets. The heavier elements, with higher melting temperatures, formed the planets near the sun and the lighter elements, that would be gasses on Earth, condensed into the outer planets. Everything rotates around the sun since the original cloud was rotating too.*

**Use the following rock cycle diagram to answer question 20.**




20.

| | Name and description of the process | Geologic details about the environment where the process would occur |
|---|---|---|
| **EXAMPLE PROCESS 1** | ***Fusion and Melting*** *The rock has been heated to such a high temperature that it has started to melt.* | *The process occurs deep in the earth's crust or in the upper mantle where the temperature is sufficient for melting.* |
| **PROCESS 2** | *Magma rises up through the crust and **cools, solidifies and crystallizes**. Some magma may emerge as lava and solidify on the surface.* | *Lower crust, upper crust and surface of the earth. May cool in batholiths, dikes, sills, and volcanoes.* |
| **PROCESS 3** | ***Physical and chemical weathering and erosion** during transportation break down the solid rock to sediment. The sediments are usually eventually deposited in marine environments.* | *These processes occur on the earth's surface where the rocks are exposed to surface processes.* |
| **PROCESS 4** | ***Lithification.** Sediments are buried, compacted and cemented.* | *Just below the earth's surface in areas where the sediment is buried. Large deltas would be the most important environment for the formation of sedimentary rocks.* |
| **PROCESS 5** | ***Metamorphism.** As any type of rock is subjected to an increase in temperature and/or an increase in pressure, it is likely to recrystallize to form a metamorphic rock. Contact metamorphism occurs when intruded rock is heated by intruding magma.* | *Within the earth, where the temperatures and pressures are sufficient to make the minerals recrystallize. Metamorphism usually accompanies mountain building.* |

21. A geologist collected four rock samples in the land area shown in diagram 1. Unfortunately, the labels fell off each sample. All that was left to identify each sample were field-note descriptions and a magnified view showing the microscopic make-up of each rock.

**Diagram 1**

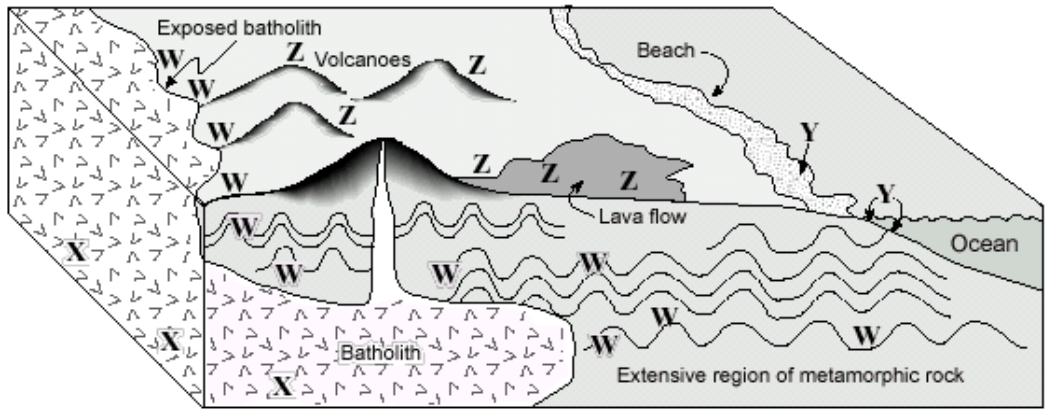
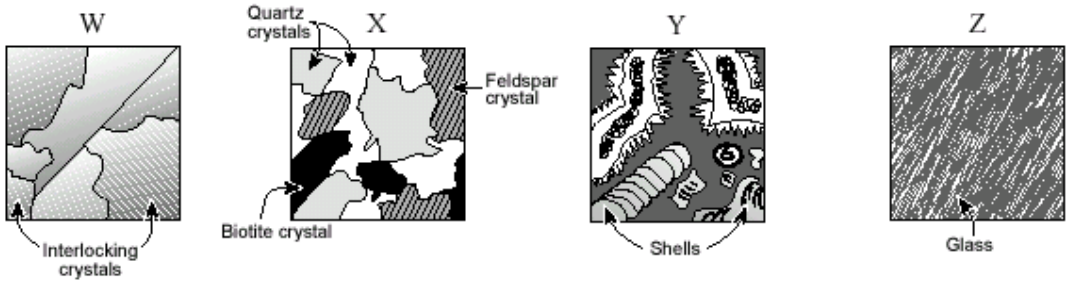



**Diagram 2**

Magnified view (x30) of rock samples



*a) Complete the following table using information from diagram 2 and the description of each rock sample below.*

| SAMPLE | EXAMPLE | W | X | Y | Z |
|---|---|---|---|---|---|
| **Description** | large pebbles in a fine-grained matrix<br>rounded pebbles | tightly interlocking crystals<br>hardness of 7<br>crystalline<br>granular texture | large interlocking crystals<br>light-coloured<br>clear, beige, pink and black crystals | made from shells and shell fragments cemented together<br>reacts with dilute acid | glassy texture<br>dark<br>slightly opaque<br>conchoidal fracture |
| **Type of rock** | sedimentary | *metamorphic* | *igneous* | *sedimentary* | *igneous* |
| **Specific rock name** | conglomerate | *quartzite* | *granite* | *limestone (fossiliferous)* | *obsidian* |

b) For each rock sample, place its corresponding **letter** on diagram 1 in a location where it would **most likely** form.

*See diagram on the previous page*

c) The texture of a rock tells a great deal about how that rock was formed. Pick **two** of the rocks from a) and, with reference to **textur**e, describe how each rock was formed.

*W: Quartzite:* *was formed from the metamorphism of sandstone, i.e., sandstone was subjected to sufficient heat and pressure to recrystallize it as quartzite. The porosity of the original sandstone was reduced.*

*X: Granite:* *the large crystals suggest a magma cooled and crystallized over a long period of time under the earth's surface.*

*Y: Limestone:* *shells and shell fragments were subjected to lithification which caused dissolved calcite (probably from the shells) to cement the shells together.*

*Z: Obsidian:* *magma reached the surface of the earth and cooled extremely rapidly, resulting in its glassy texture. On the other hand, a glassy texture may result from slow cooling of a silicic magma that is too viscous to allow the nucleation and growth of crystals. (In this situation, the rate of cooling is less significant.)*

22. If you were given a few rock samples to identify, briefly describe how would you distinguish between the igneous, sedimentary and metamorphic rocks?

*Igneous rocks can be identified by having interlocking crystals. Sometime the crystals can be as large as a few centimeters. Igneous rocks may also contain vesicles, or bubbles. Extrusive igneous rocks have a smooth, or aphanitic, texture, which means the crystals are too small to be seen. Sedimentary rocks look like they have been made up of fragments of other rocks, and that is exactly what they are. They may contain fossils. Metamorphic rocks have crystals that look flattened and the texture can be rather sparkly. Certain metamorphic rocks exhibit foliation, where the minerals are aligned parallel to one another.*

## Answers to Section B: Earth Materials (Minerals)

23. Outline the importance and abundance of various elements in the earth's crust.
*Oxygen, silicon, aluminum, iron, calcium, magnesium, potassium, and sodium make up more than 98% of the Earth's crust. These eight elements combine in only a few ways, thus only nine rock-forming minerals make up most of the Earth's crust (quartz, feldspars, micas, augite(pyroxene), hornblend(amphibole), garnet, olivine, calcite.)*

24. Define and explain how to use the following properties used in identifying minerals:

| | |
|---|---|
| ***Simple crystal shape*** | *A crystal is any substance whose atoms are arranged in a regular, orderly and periodically repeated pattern. Crystal shape and habit refers to the shape of the individual crystals and how they grow together in aggregates.* |
| ***Cleavage*** | *Cleavage refers to the tendency to break along certain flat crystal planes. A mineral will cleave where the atomic bonds are weakest.* |
| ***Fracture*** | *Fracture is when the mineral does not break along any crystal planes. I.E. quartz has conchoidal fracture.* |
| ***Hardness*** | *The hardness of a mineral is its ability to be scratched by other minerals or scratch other minerals. It is controlled by the strength of the bonds in the mineral.* |
| ***Specific gravity (relative density)*** | *Density is mass divided by volume. A mineral of a high density will be heavy for its size.* |
| ***Colour*** | *The colour of opaque minerals is due to the reflection of a specific colour.* |
| ***Streak*** | *The streak test is done by rubbing the mineral across an unglazed piece of porcelain and observing the colour of the powder.* |
| ***Lustre*** | *Lustre is how light is reflected from the surface of a mineral. It describes the way the mineral shines.* |
| ***Special properties, such as reaction to dilute HCl*** | *The acid test determines if the mineral reacts with a dilute solution of hydrochloric acid. Only carbonate minerals will do so.* |
| ***Magnetism*** | *A few minerals are strongly attracted to a magnet.* |
| ***Double Refraction*** | *The arrangement of atoms in calcite causes some of the light to bend as it enters and leaves the crystals so that you can see two images of the object on the other side.* |
| ***Taste*** | *Halite tastes like salt.* |
| ***Radioactivity*** | *Some minerals spontaneously emit radiation. I.E. potassium feldspar* |
| ***Fluorescence*** | *Occurs when the mineral glows in optical light when exposed to ultra-violet light.* |

25. Give the definition of a mineral.
*A naturally occurring, inorganic, solid, element or compound that has a definite chemical composition and crystal shape.*

26. Distinguish between an element and a compound.
*A compound is made up of two or more elements chemically combined.*

27. Explain how to identify a mineral. What diagnostic tests must be done to identify a mineral?
*Perform each of the diagnostic tests on the mineral sample, and systematically eliminate all possible choices until the mineral can be identified. A data sheet will be vital to compare your results with known results to identify the mineral. The diagnostic tests include: hardness, streak, cleavage, colour, lustre, reaction to HCl, magnetic, crystal shape, radioactive, fluorescent, density, etc.*

28. Why is colour a poor diagnostic test to identify a mineral? Why is streak a better test? Which mineral is a good example of this?
*Many minerals have the same colour, and the colour may be difficult to determine. But the streak is more identifiable and reliable. Hematite is a good example: the mineral can be various but the streak is always red-brown.*

29. What are some important uses of minerals?
*Minerals are used as rock-forming minerals, ores, or gemstones. See mineral lab uses too.*

30. Which of the following is the most common element in the Earth's crust?
a. Silicon
b. Oxygen
c. Aluminum
d. Iron

31. Which one of the following statements is true about the property of cleavage in minerals?
a) All minerals, except quartz, have cleavage.
b) The type of cleavage a mineral possesses depends on its composition; ferromagnesian minerals do not have cleavage.
c) The directions of cleavage is always parallel to the faces or planes of well-formed crystal shapes
d) The directions of cleavage correspond to planes of weakness in the crystal structure of a mineral

32. Why does mica break in thin sheets, yet quartz has no cleavage?
a) Mica forms at lower temperatures than does quartz
b) The silica tetrahedra in mica are arranged in a different pattern than in quartz.
b) Mica has larger silica tetrahedra than does quartz
c) Mica contains more iron and magnesium than does quartz.

33. Which mineral group is the most common in the Earth's crust?
a) oxides
b) carbonates
c) sulphates
d) silicates

34. Which of the following can be best used to distinguish between calcite and quartz?
a) Streak
b) Colour
c) Hardness
d) Specific Gravity

35. Halite and calcite can both occur as clear crystals. The best property to distinguish between the two minerals would be

a) cleavage
b) hardness
c) colour
d) streak.

*Calcite has rhomdohedral crystals and halite has cubic crystals*

36. Two minerals X and Y look very similar. Both have a metallic lustre and a golden yellow colour. Mineral Y can scratch glass, while mineral X cannot. Mineral Y is most likely

a) chalcopyrite
b) galena
c) hematite
d) pyrite

37. A certain mineral has a vitreous lustre and some of it is coloured purple. Its hardness is less than 5, and is usually identified by its large number of cleavage planes. The mineral is most likely

a) quartz
b) calcite
c) fluorite
d) apatite

38. Imagine that you have been given samples of ten index minerals of the Mohs hardness scale. The samples are labeled with code letters. Use the following clues to determine the identity of each mineral.

Mineral A scratches minerals E and I but can be scratched by mineral J
Mineral C can be scratched by every other mineral
Mineral E can scratch mineral I
Mineral F can scratch only mineral C
Mineral B can scratch mineral F, but it can be scratched by all other minerals
Mineral H can scratch every other mineral
Mineral D can be scratched only by mineral H
Mineral G can be scratched by minerals H and D; it can scratch mineral J

| | |
|---|---|
| *Mineral A* | *Feldspar* |
| *Mineral B* | *Calcite* |
| *Mineral C* | *Talc* |
| *Mineral D* | *Corundum* |
| *Mineral E* | *Apatite* |
| *Mineral F* | *Gypsum* |
| *Mineral G* | *Topaz* |
| *Mineral H* | *Diamond* |
| *Mineral I* | *Fluorite* |
| *Mineral J* | *Quartz* |

39. This mineral appears somewhat transparent and thin and it can be scratched by a fingernail and is very common in metamorphic rocks. The mineral is

a) quartz.
b) calcite.
c) gypsum.
d) muscovite mica.

40. The minerals gypsum and talc are very similar in appearance. Which of the following mineral properties **best** distinguishes them from each other?
    a) Streak
    b) Colour
    c) Hardness
    d) Reaction to acid

*Gypsum is harder than talc*

41. A soft black mineral breaks off in flakes. This mineral is most likely
    a) hornblende
    b) galena
    c) biotite mica
    d) olivine

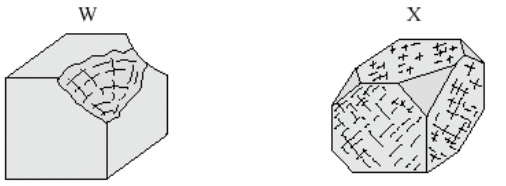
*Mica has cleavage in one plane. Look at mineral Y in the diagram below.*

42. Which of the following can best be used to distinguish between hematite and pyrite?
    a) Streak
    b) Lustre
    c) Hardness
    d) Hydrochloric acid

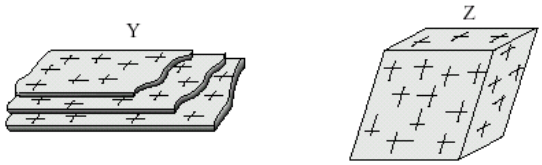
*Hematite has a red brown streak and pyrite has a greenish black streak*

**Use the diagram to the right to answer questions 43 to 45.**

43. Which of the diagrams to the right **best** illustrates the mineral calcite?
    a) W
    b) X
    c) Y
    d) Z



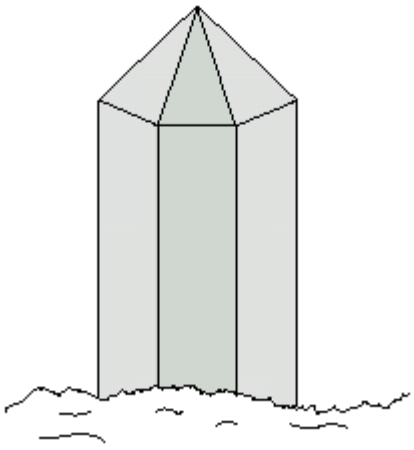

44. Which of the diagrams to the right best illustrates the mineral mica?
    a) W
    b) X
    c) Y
    d) Z




45. Which of the following statements best describes how mineral W breaks?
    a) Conchoidal fracture
    b) Cleavage in one plane
    c) Cleavage in 6 planes
    d) Cleavage in multiple planes

*Fracture is when the mineral does not break along any crystal planes. All the other minerals exhibit smooth and definite cleavage.*

46. The mineral shown in the diagram can easily scratch glass and has a conchoidal fracture. The mineral is
    a) quartz.
    b) calcite.
    c) galena.
    d) feldspar.



47. In how many directions does quartz have perfect cleavage?
    a) none
    b) 3
    c) 4
    d) 6

## Answers for Section C: Earth Materials (Igneous Rocks and Processes)

48. Describe and demonstrate factors affecting cooling rate and crystal size.
*Igneous rocks that are allowed to cool for a long period of time will exhibit larger crystals than those rocks that cool faster. A rock that cools more slowly will have crystals that will grow to a larger size, they will have sufficient time to grow and accrete more material. Lava that is exposed to the Earth's surface will cool more quickly and the mineral crystals will not have time to grow.*

49. Relate texture to rate of crystallization for extrusive (volcanic) and intrusive (plutonic) igneous rocks.
*Extrusive (volcanic) rocks cool faster than extrusive (plutonic) rocks so the crystal size will be smaller.*

| ***Where formed*** | ***Texture*** |
|---|---|
| *Extrusive (volcanic) faster cooling* | *small or no crystals visible, fine grained* |
| *Intrusive (plutonic) slower cooling* | *visible crystals, course grained* |

50. Identify and classify the following igneous rocks according to their texture (coarse or fine grained, vesicular, glassy, fragmental-pyroclastic), cooling rate and composition (felsic, intermediate, mafic): granite, diorite, gabbro, peridotite, andesite, tuff, rhyolite, basalt, volcanic breccia, obsidian, pegmatite, pumice, porphyry.

NOTE:

| ***Felsic/Granitic*** | ***Mafic/Basaltic*** |
|---|---|
| *70% silicate minerals* | *50% silicate minerals*<br>*More Aluminum, Magnesium, Iron oxides* |
| *Quartz*<br>*Potassium Feldspar*<br>*Sodium Feldspar*<br>*Mica* | *Calcium Feldspar*<br>*Pyroxene*<br>*Olivine* |
| *High viscosity (Doesn't flow easily)* | *Low viscosity (flows easily)* |

***Vesicular*** *refers to gas bubbles present in the rock.*
***Glassy*** *texture occurs when the rock cools so fast that it has no chance to form a crystalline structure.*
***Fragmental – pyroclastic*** *rocks of those formed from the lithification of ash and other materials ejected during a volcanic explosion.*

| **Name** | **Texture** | **Cooling Rate** | **Composition** |
|---|---|---|---|
| Granite | Coarse grained | Slow | Felsic |
| Diorite | Course grained | Slow | Intermediate |
| Gabbro | Course grained | Slow | Mafic |
| Peridotite | Course grained | Slow | Ultra mafic |
| Andesite | Fine grained | Fast | Intermediate |
| Tuff | Fragmental-pyroclastic | Fast | Varies |
| Rhyolite | Fine grained | Fast | Felsic |
| Basalt | Fine grained | Fast | Mafic |
| Volcanic breccia | Fragmental-pyroclastic | Fast | Varies |
| Obsidian | Glassy | Fast in thick magma | Usually felsic (thicker ) |
| Pegmatite | Very course grained | Slow in thin residual magma | Felsic |
| Pumice | Vesicular | Fast | Varies |
| Porphyry | Fine and course grained | Slow then fast | Large felsic crystals surrounded by mafic |

51. Describe and explain the order of crystallization of minerals from a magma (Bowen's reaction series)
*The first to crystallize from a magma melt is olivine, then pyroxene, amphibole, biotite, potassium feldspar, muscovite, and finally quartz. Olivine has the highest melting point and the lowest silica content. Quartz has the lowest melting point and the highest silica content.*

52. A fine-grained igneous rock, when examined using a microscope, is found to contain 30% dark ferromagnesian minerals. Which other minerals would you expect to find in this rock?
a) plagioclase feldspar only
b) plagioclase feldspar and muscovite
c) potassium feldspar, muscovite and quartz
d) plagioclase feldspar, potassium feldspar and quartz

53. Which mineral would most likely be the last to crystallize from a silicate melt?
a) Quartz
b) Olivine
c) Amphibole
d) Biotite mica

The last mineral of the Bowen's reaction series.

54. Which rock has the same mineral content as granite (is its compositional equivalent)?
a) Basalt
b) Quartz
c) Rhyolite
d) Gabbro

55. In order to produce a granitic composition from an initially basaltic magma through the process of fractional crystallization, which must occur?
a) Basaltic magma must assimilate rocks of intermediate composition
b) Silica must be removed from the melt through crystal settling, leaving the melt enriched in Fe, Mg, and Ca
c) The basaltic magma must cool very slowly and evenly, with removing any components.
d) Fe, Mg, and Ca must be removed from the melt through crystal settling, leaving the melt enriched in silica.

56. If pressure is held constant and water (or any mineral) is added, what will happen to the melting temperature of igneous material of any composition?
a) Nothing; them melting temperature will not change.
b) The melting temperature will increase if water is added.
c) The melting temperature will decrease if water is added.
d) The direction of change in melting temperature varies depending on the composition.

57. a) The chemical composition of molten rock from a deep magma chamber may be changed by a number of different processes as it moves upward toward the surface. Describe how two of these, Wall Rock Assimilation and Fractional Crystallization can change the chemical composition of the magma.

Wall Rock Assimilation:
*During this process, magma incorporates and melts bits of surrounding country rock thus changing the composition of the magma to be more like the country rock than it previously was..*

Fractional Crystallization:
*This process involves crystallization of magma of early formed crystals which are removed and isolated so they are unable to react with the remaining melt. This is because some minerals crystallize before others. It is the mafic crystals, such as olivine and pyroxene, which settle out first to deplete the melt; what remains behind is a more felsic magma.*

58. Distinguish among the following:

| | Composition | Flow Behaviours | Where formed | Rock/Feature Formed |
|---|---|---|---|---|
| **Lahar** | Mud and water | Rapid motion downhill | Snow capped erupting volcano | Wider river valley |
| **Pyroclastics** | Various | Flying through the air out of volcano | Explosive volcanic eruption | Tuff, volcanic breccia |
| **Ash Flow** | Hot ash and gas | Rushing down side of volcano | Composite volcano | Also called nuée ardente |
| **Pillow Lava** | Basaltic | Oozes out | Underwater | Obsidian on outside of bulbous shape |
| **Aa Lava** | Basaltic with slightly higher viscosity | Bit jumbled, doesn't flow quite as easily | Basaltic volcano | Sharp, blocky, hurts to walk on |
| **Pahoehoe Lava** | Basaltic | Skin forms, flowing lava causes it to wrinkle | Basaltic volcano | Smooth, ropey, wrinkled texture |
| **Columnar Joints** | Basaltic usually | Shrinks as cools causing cracks to form | Lava flow | Polygonal columns |

59. Draw a diagram distinguishing between batholiths, sills, dikes, xenoliths, stocks, and plutons.

*A **dike** is an intrusion that has flowed through different layers of country rock. (Cuts across the layers.)*

*A **sill** is an intrusion that has flowed between different layers of country rock. (Flows parallel to the layers.)*

*A **stock** is a small pluton exposed at the Earth's surface.*

*A **batholith** is a large pluton, more than 100km$^2$ exposed at the Earth's surface.*

**Xenolith** literally means foreign rock. Xenoliths are igneous rocks cemented into larger igneous rocks. When magma rises within the Earth it often breaks off pieces of the surrounding country rock. These pieces fall into the magma chamber, but before they have a chance to melt the entire magma chamber starts to cool.

60. Distinguish among the following volcanic features:

| Feature | Magma Composition | Type of Eruption | Magma Viscosity | Shape of Feature | Location Relative to Plates | Other Details |
|---|---|---|---|---|---|---|
| **Shield Volcano** | Mafic (Basaltic) | Smooth flowing | Thin | Low, flat, wide | Mid-plate: Over a hot spot usually | |
| **Cinder Cone** | Basaltic usually, may be felsic | Explosive, pyroclastic | If thin (mafic) has water mixed in; otherwise thick | Steep sided | Various, anywhere volcanoes can occur | |
| **Composite Volcano** | Felsic (granitic) or intermediate (andesitic) | Explosive | Thick | Steep sided; Layers of lava and ash | Subduction zones i.e. Cascades | Also called: Stratovolcano |
| **Volcanic Dome** | Felsic (granitic, rhyolitic) | Can be explosive | Very thick | Steep sided | In craters of composite volcanoes | Oozes out and piles up like toothpaste |
| **Lava Plateau** | Basaltic | Smooth flowing | Thin | Flat | Rifts, fissures, cracks in plates | Also called: Flood basalt, Fissure eruption |

61. Distinguish between a sill and a buried lava flow:

| *Sill* | **Lava Flow** |
|---|---|
| ○ Layers above and below will both be contact metamorphosed<br>○ No vesicles<br>○ Sill may contain fragments (xenoliths) from layers above and below | ○ Only layer below will be contact metamorphosed<br>○ Vesicles near top of flow<br>○ Lava flow will only contain fragments from layer below |

62. Describe pyroclastic material. What various materials may be ejected from an explosive volcano?
*Pyroclastics are rock fragments that were explosively ejected from a volcano. From smallest particles to largest: volcanic ash, cinders and bombs.*

63. Distinguish between lava and magma. (Which is where? Which has dissolved gas? Why?)
*Lava is liquid rock on the surface. It contains less dissolved gas since it is not under pressure. Lava rock will often contain vesicles as the bubbles of gas are trapped in the solidified rock.*
*Magma is liquid rock underground. It contains more dissolved gas due to the pressure that keeps the gas dissolved in the magma.*

64. What clues do vulcanologists look for to predict future volcanic eruptions?

Many volcanic eruptions are preceded by small earthquakes, smaller eruptions of ash and noxious gases. Often the mountain will bulge. Previous eruptions are also a clue. If these occur evacuation may be ordered.

65. Explosive volcanoes such as Mt St. Helens and Mt Fuji often erupt lava which is

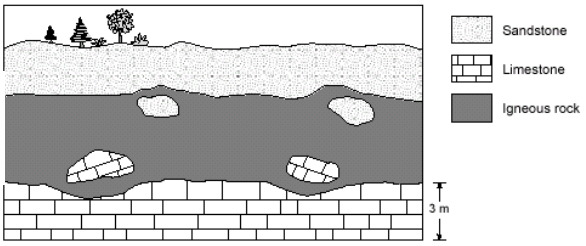
a) mafic and has a low viscosity.
b) felsic and has a low viscosity.
c) mafic and has a high viscosity.
d) felsic and has a high viscosity.

High viscosity means the lava does not flow easily.

66. The igneous layer in the cross section of the picture above is best described as a

a) sill.
b) dike.
c) stock.
d) buried lava flow.

*Incorporates rock fragments above and below*




67. The rough, jumbled blocky or jagged surface of a lava flow is called:

a) aa
b) pahoehoe
c) lahar
d) nuee ardente

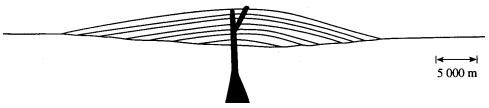
68. Why does more viscous lava generally erupt more violently and explosively than does less viscous lava?

a) Because more viscous lava erupts less frequently than less viscous lava.
b) Because more viscous lava tends to be cooler than less viscous lava
c) Because more viscous lava trap gases so pressure builds up in the magma chamber
d) Because more viscous lava contains very little gas and other volatile materials.

**Use the following sketch of a cross section of a volcano to answer questions 69 and 70.**

69. What type of volcano is shown in the diagram above?

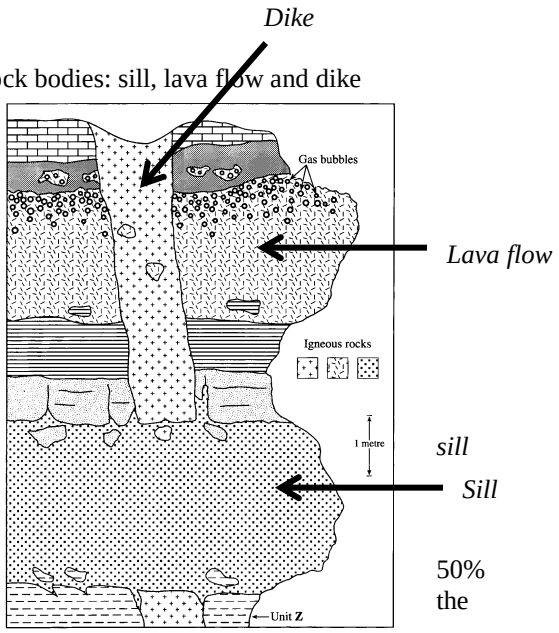
a) Cinder cone
b) Shield volcano
c) Volcanic dome
d) Composite volcano




70. This type of volcano most commonly forms at

a) mid-ocean ridges
b) island arc volcanoes
c) subduction at continents
d) hot spots, or mantle plumes

**Use the following sketch of a rock cross section to answer question 71.**




71. a) On the cross section sketch, label the following igneous rock bodies: sill, lava flow and dike

*See diagram to the right*

b) Describe two features shown on the cross section which distinguish the sill from the buried lava flow.

*The sill contains fragments of rocks from above and below, whereas the flow contains only fragments from below.*
*The lava flow contains bubbles at its top that illustrates typical degassing of a flow.*
*The inclusion of lava flow fragments in layer above, with inclusions from layers above and below.*

c) The rock which composes the sill is mostly coarse-grained and contains 50% dark-grey plagioclase and dark ferromagnesian minerals. What is the name of rock?

*Gabbro (use Minerals in Igneous Rocks chart!)*

d) Describe the variation in crystal size that would be found in the sill from top to bottom.

*The sill would be fine-grained at the top and bottom (where cooled more quickly next to the cooler country rock) and course-grained in the middle (since was insulated some and had time to form larger crystals.)*