The Rock Cycle

The **rock** cycle is illustrated in Figure 1. **Igneous rocks** are produced when molten rock cools and solidifies. When the igneous rocks exposed at the earth's surface, the rock is broken down into tiny particles of sediment by weathering and erosion. This weathered material is carried by wind to form **sedimentary deposits** such as beaches, sand bars, or deltas. The sediment is gradually buried by more sediment and subjected to higher pressure and temperature. It eventually hardens into **sedimentary rock** (lithifies). If burial continues, the increasing pressure and temperature at depth recrystallizes the sedimentary rock into a **metamorphic rock**. The rock cycle is completed when the metamorphic rock becomes so hot that it melts and forms magma again. Igneous and sedimentary rocks can become metamorphic rocks if they are **buried deeply enough** or are affected by plate tectonic processes. Metamorphic rocks exposed at the surface will also weather to form sedimentary deposits.

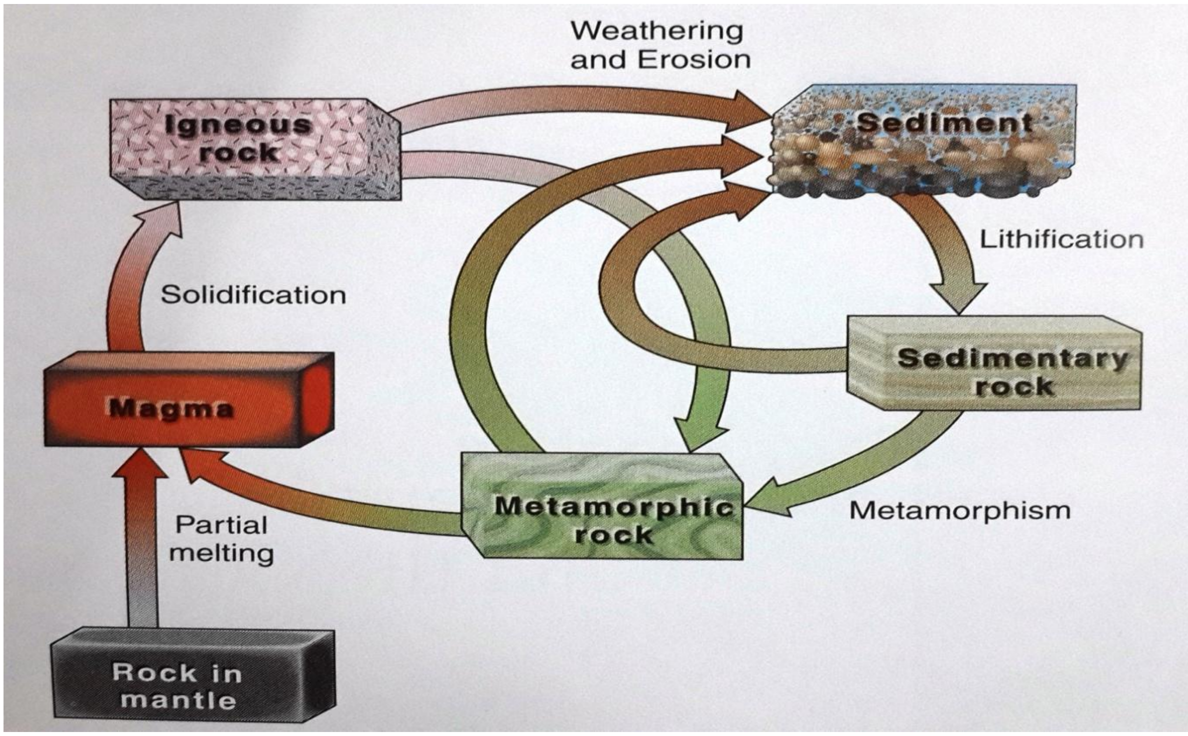


Fig. 1. Shows Rock Cycle

Igneous rock

Igneous rock (derived from the Latin word ignis meaning fire) is one of the three main rock types, the others being sedimentary and metamorphic. Igneous rock is formed through the **cooling** and **solidification** of **magma**. A **magma** is a body of molten rock that occurs below the surface of the earth. When magma rises along a deep fault and pours out on the earth's surface, it is termed **lava**.

Igneous rock may form with or without crystallization, either below the surface as **intrusive (plutonic)** rocks or on the surface as **extrusive (volcanic)** rocks. This magma can be derived from partial melts of pre-existing rocks in either a planet's mantle or crust.

Magma (from Greek μάγμα "mixture") is a mixture of molten or semi-molten rock, volatiles and solids that is found beneath the surface of the earth, and is expected to exist on other terrestrial planets. Besides **molten rock**, magma may also contain **suspended crystals**, **dissolved gas** and sometimes **gas bubbles**. Magma often collects in magma chambers that may feed a volcano or turn into a pluton. Magma is capable of intrusion into adjacent rocks (forming igneous dikes and sills), extrusion onto the surface as lava, and explosive ejection as tephra to form pyroclastic rock. The temperature of magma varies from about 600 to 1400 °C, depending on its **chemical composition** and the **depth** at which it forms. Generally, **basaltic magma** forms at great depth and has a temperature near the high end of this scale. **Granitic magmas**, which form at shallower depths, tend to lie near the cooler end of the scale. As a comparison, an iron bar turns red hot at about 600 C and melts at slightly over 1500 °C.

In addition to oxygen and silicon, they also contain lesser amounts of the six other common elements of the Earth’s crust: aluminum, iron, magnesium, calcium, potassium, and sodium.

Basaltic magma contains more iron and magnesium than granitic magma, but granitic magma is richer in silicon, potassium, and sodium. A few rare magmas are of carbonate composition.

PROCESSES THAT FORM MAGMA

Three different processes melt the asthenosphere rising temperature, decreasing pressure, and addition of water. We will consider these processes and then look at the tectonic environments in which they generate magma.

1-Rising Temperature

Everyone knows that a solid melts when it becomes hot enough. Butter melts in a frying pan, and snow melts under the spring sun. For similar reasons, an increase in temperature will melt a hot rock.

2-Decreasing Pressure

When a mineral melts, the atoms become **disordered** and **move freely**, taking up **more space** than when they were in the solid mineral. If a rock is heated to its melting point on the Earth's surface, it melts readily because there is little pressure to keep it from expanding. The temperature in the asthenosphere is more than hot enough to melt rock, but there, the high pressure prevents the rock from expanding, and it cannot melt. However, if the pressure were to decrease, large volumes of the asthenosphere would melt.

3-Addition of Water

A wet rock generally melts at a lower temperature than an otherwise identical dry rock. Thus, addition of water to rock that is near its melting temperature can melt the rock. Certain tectonic processes add water to the hot rock of the asthenosphere to form magma.

The composition of a rock may also be considered to include *volatile* phases such as water and carbon dioxide.

The presence of volatile phases in a rock under pressure can stabilize a melt fraction. The presence of even 0.8% water may reduce the temperature of melting by as much as 100 °C. Conversely, the loss of water and volatiles from magma may cause it to essentially freeze or solidify.

Magmatic Differentiation

When a magma cools, chemical reactions occur that create a series of different minerals. This process of differentiation occurs along two branches: discontinuous and continuous.

The discontinuous branch: The minerals that form in the discontinuous branch are all **ferromagnesian**—that is, they contain high percentages of **iron** and **magnesium**, which impart a **dark green** to **black** color. The branch is called discontinuous because the minerals form at discrete temperatures and not continuously during cooling. The first mineral to crystallize is **olivine**, followed by **pyroxene**, **amphibole**, and **biotite (fig 2)**.

The continuous branch: The continuous branch is made up of the **plagioclase feldspars**. The **calcium/sodium** ratio in this mineral type changes continuously as the magma cools. The first feldspars to form contain the highest amounts of calcium; subsequent feldspars have progressively less calcium and more sodium. These minerals tend to be **pink**, **tan**, **brown**, or **whitish**. Any magma left over after all these reactions have been completed crystallizes at the lowest temperature as **quartz**.

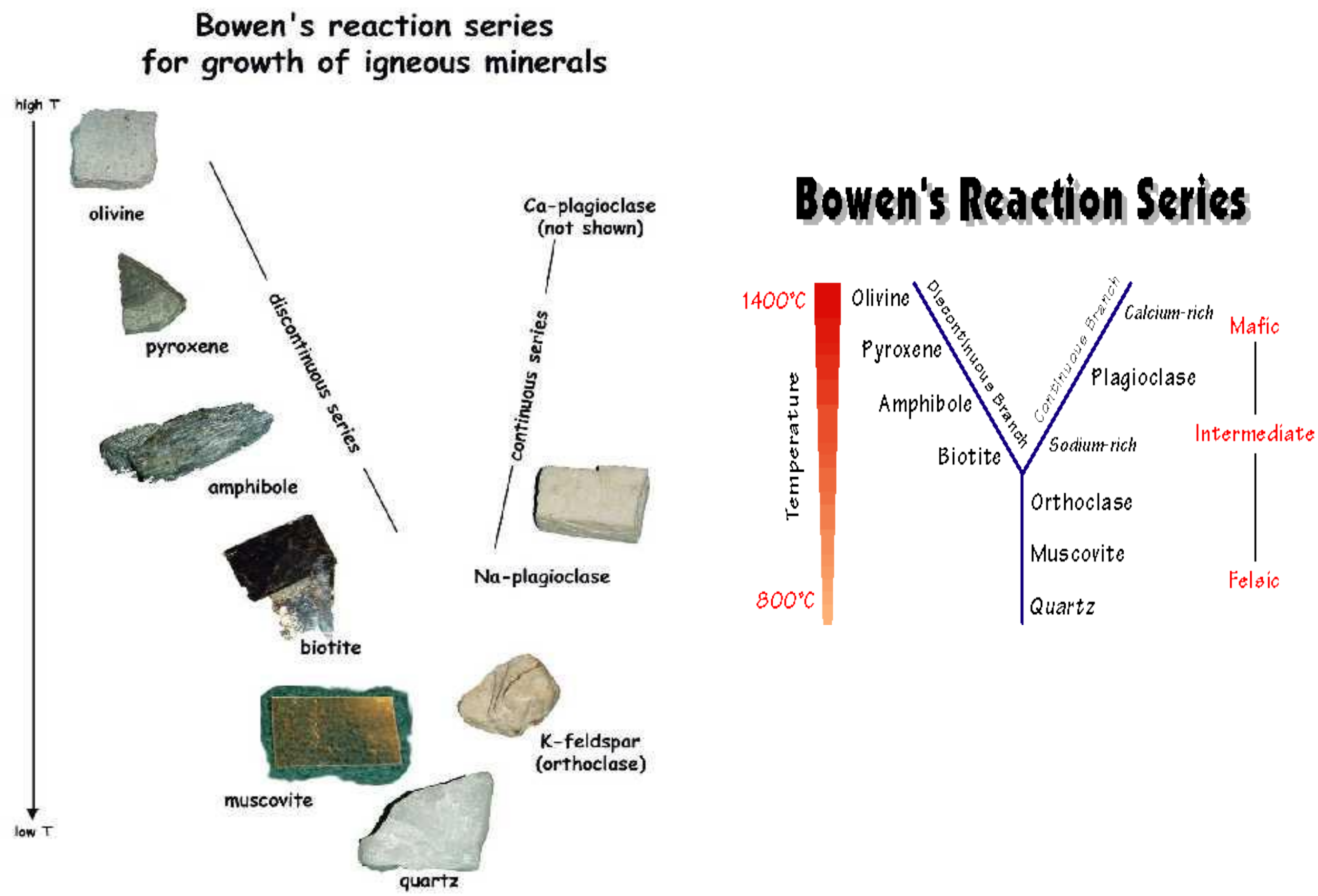


Fig. 2. Shows Bowen's reaction series

These theories known as **Bowen's reaction series**. The progression in the series explains why the first lavas from a volcanic vent are rich in iron, magnesium, and calcium, are low in quartz, and are dark green to black and why the later lavas are lighter colored and contain more quartz.

Extrusive Rock Types

The kind of rock an extrusive lava makes is largely dependent on the chemistry of the venting magma (Figure 3). **Basalt**, usually the first lava to form, contains a high percentage of ferromagnesian minerals and about **25 to 50** percent silica, making it dark green, gray, or black. **Andesite** is a lighter greenish-gray and has more silica and plagioclase feldspar and less ferromagnesian minerals than basalt. **Rhyolite** is the most silicious of the extrusive rocks, containing at least **65** percent silica (mostly in feldspar minerals and quartz) and few ferromagnesian minerals. This chemistry gives it a tan, pink, or cream color. **Dacite** has a composition that falls between those of andesite and rhyolite it has slightly less potassium feldspar and quartz and slightly more ferromagnesian minerals than rhyolite. Dacite is generally a light grayish-green and often difficult to distinguish from rhyolite in the field(Figure 3).

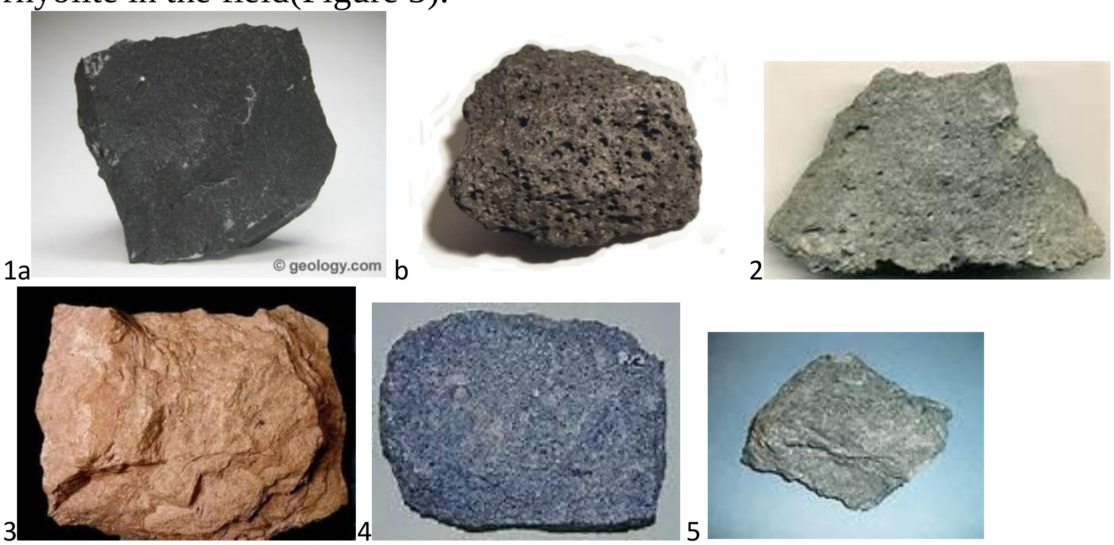


Fig. 3 Shows extrusive igneous rocks, 1 a& b Basalt, 2 Andesite, 3 Rayolite, and 4 Dacite, 5 komatiite

Mafic, felsic, and intermediate extrusive rocks.

More general terms for these rocks are mafic, felsic, and intermediate. **Mafic** rocks have about 50 percent silica and high amounts of iron, magnesium, and calcium and are dark in color. A common mafic rock is **basalt**. **Felsic** rocks are rich in silica, potassium, sodium, and aluminum and contain only small amounts of iron, magnesium, and calcium. Typical felsic rocks are **dacite** and **rhyolite**. Felsic magmas are the most **viscous** because of their high silica content. Intermediate rocks, such as andesite, fall between the mafic and felsic classifications.

Ultramafic extrusive rocks: A less common group is the ultramafic rocks, which consist almost entirely of ferromagnesian minerals and have no feldspars or quartz. They contain less than 45 percent silica, and are believed to originate from the mantle. These are some of the least viscous lavas because of their low silica content. A**komatiite** is a typical ultramafic extrusive rock that is mostly olivine and pyroxene, with lesser feldspar(Figure 3).

Intrusive Rock Types

When magma solidifies within the crust, the over lying rock insulates the magma like a thick blanket. The magma then crystallizes slowly, and the crystals may have hundreds of thousands or even millions of years in which to grow. As a result, most plutonic rocks are medium to coarse grained. **Granite**, the most abundant rock in continental crust, is a medium- or coarse-grained plutonic rock. The intrusive rock often contains **xenoliths**—fragments of the country rock that were torn away during the emplacement of the magma and that are generally most abundant near the contact with the country rock.

Mafic, felsic, and intermediate intrusive rocks: Intrusive rocks are classified the same way extrusive rocks are—according to the relative amounts of **feldspars, quartz**, and **ferromagnesian** minerals. **Gabbro** is a mafic rock and has the same chemistry and mineralogy as basalt; **diorite** is an intermediate rock equivalent to andesite; and **granite** is a felsic rock equivalent to rhyolite. For example, a magma that would form rhyolite if it vented at the surface would crystallize into a granite in a subterranean chamber kilometers below the surface. **Granite** is the most common intrusive rock on the continents; **gabbro** is the most common intrusive rock in oceanic crust(Figures 4, 5).

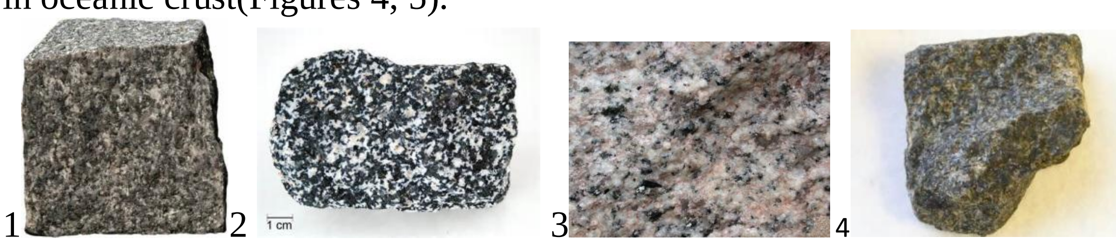
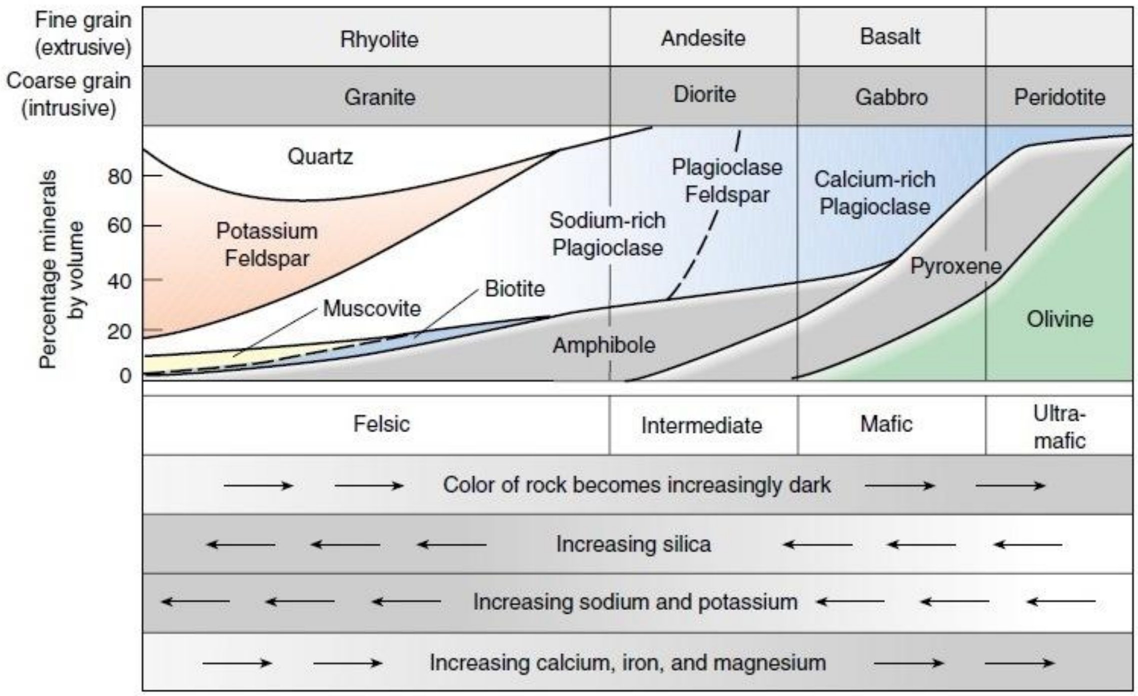


Fig. 4 shows samples of intrusive igneous rocks, 1 gabbro, 2 diorite, 3 granite, 4 peridotite.

Ultramafic intrusive rocks:

They are almost completely composed of ferromagnesian minerals, mostly olivine and pyroxene. They contain less than 45 percent silica and are thought to be derived from the mantle. A typical ultramafic intrusion is called a **peridotite (Figures 4, 5).**



The names of common igneous rocks are based on the minerals and texture of a rock. In this figure, a mineral's abundance in a rock is proportional to the thickness of its colored band beneath the rock name. If a rock has a fine grain texture, its name is found in the top row of rock names; if it has a coarse grain texture, its name is in the second row.

Fig. 5, Shows the name of common igneous rocks.

Rock Textures

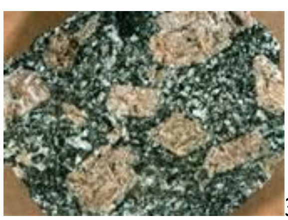
The origin of a rock can often be detected from its texture. The texture of a rock refers to the **size**, **shape**, and **arrangement of its mineral grains**, or **crystals**. Some igneous rocks consist of mineral grains that are too small to be seen with the naked eye; others are made up of thumb-size or even larger crystals. **Volcanic rocks** are usually fine grained, whereas **plutonic rocks** are medium or coarse grained. Most extrusive rocks are fine grained, meaning their mineral components (grains) are less than 1 millimeter in diameter. Lava flow rocks typically have a chilled margin that is very fine grained, or **aphanitic** (a = not, phaner = visible) rocks in contrast to phaneritic rocks, typically form from lava which crystallize rapidly on or

near the Earth' surface. Because extrusive rocks make contact with the atmosphere they cool quickly, so the minerals do not have time to form large crystals. The individual crystals in an aphanitic igneous rock are not distinguishable to the naked eye. Examples of aphanitic igneous rock include **basalt**, **andesite** and **rhyolite (Figure 3). Glassy or vitreous** textures occur during some volcanic eruptions when the lava is quenched so rapidly that crystallization cannot occur. The result is a natural amorphous glass with few or no crystals. Examples include **obsidian and pumice (Figure 6).**
Phaneritic (phaner = visible) textures are typical of intrusive igneous rocks, these rocks crystallized slowly below the Earth's surface. As magma cools slowly the minerals have time to grow and form large crystals. The minerals in a phaneritic igneous rock are sufficiently large to see each individual crystal with the naked eye. Examples of phaneritic igneous rocks are **gabbro, diorite and granite (Figure 4).** Grain size then increases progressively toward the center of the flow. Thicker flows can have medium- to coarse-grained centers. A **porphyritic** rock contains coarser-grained crystals (phenocrysts) that are supported in a matrix (groundmass) of finer grained minerals. *The larger minerals had already crystallized and were extruded with the magma, which then rapidly cooled to form the groundmass*.

Pegmatitic texture occurs during magma cooling when some minerals may grow so large that they become massive (the size ranges from a few centimeters to several meters). A **pegmatite** is a holo-crystalline, intrusive igneous rock composed of interlocking phaneritic crystals usually larger than 2.5 cm in size; such rocks are referred to as pegmatitic.

Most pegmatites are composed of quartz, feldspar and mica, having a similar basic composition as granite.

Pyroclastic (pyro = igneous, clastic = fragment) textures occur when explosive eruptions blast the lava into the air resulting in fragmental, typically glassy material which fall as volcanic ash, lapilli and volcanic bombs (Figure 6).

1 
2 
3 
4 

5 
6 
7 

Fig. 6 Shows 1, aphanitic texture, 2 porphyritic texture, 3 obsidian, 4 pahoehoe,5 volcanic ash, 6 lapilli, 7 bombs

Obsidian (volcanic glass) is a hard, super cooled, very fine-grained volcanic rock composed of silica. Basalt flows that have a ropy surface are called **pahoehoe** flow and form when the lava's exterior quickly solidifies into rock.

Magmas often contain dissolved gas because of higher pressures deep underground. When the magma is suddenly released and ventsat the surface, the gas "bubbles" out of the magma, creating numerous holes, cavities, or voids called **vesicles**. **Pumice** is a volcanic rock that has so much internal void space from gas bubbles that it floats in water. **Scoria** is a very vesicular basalt that contains more gas space than rock and has a very rough, irregular, and pocked exterior(Figure 7).

1 

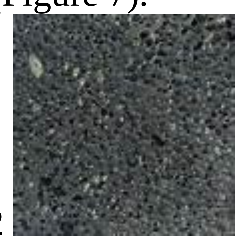
2 
3 
4 

Fig. 7 Shows 1 ah-ah texture, 2 vesicules texture, 3 pumice texture, and 4 scoria

Volcanoes

Volcanoes is the venting of liquid magma at the surface of the earth. Occasionally explosive, the process is important in producing continental and oceanic crust. Volcanoes are hills or mountains that form around the vent and consist of cooled magma, rock fragments, and dust from the eruptions (Figure 8).

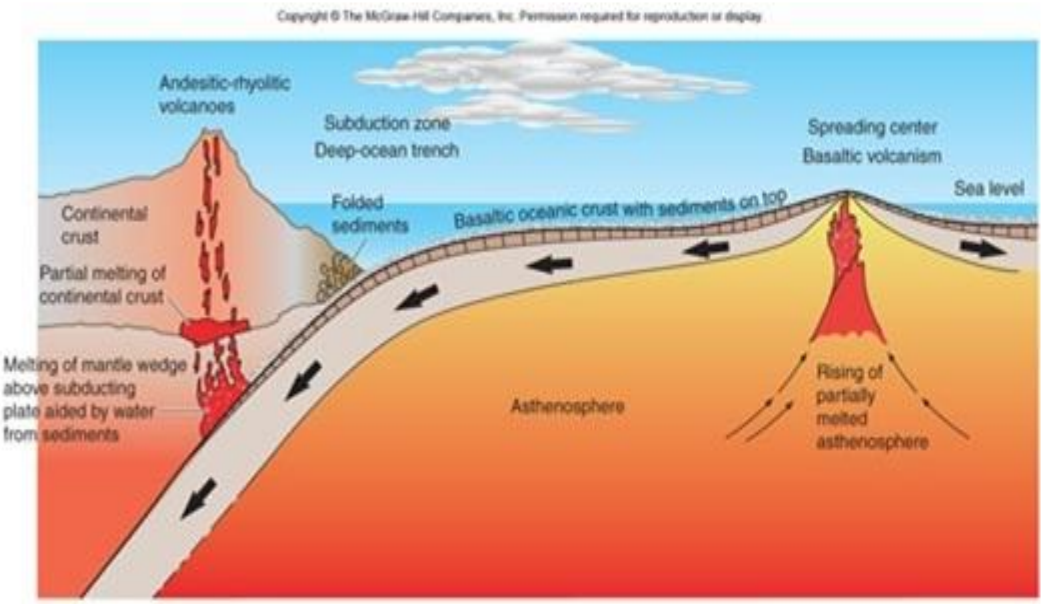


Figure 8 Shows the positions of volcanoes.

Craters and calderas . The crater is the circular depression at the top of the volcano. A caldera is a larger depression at least 1 kilometer in diameter that forms at the top of the volcano when the summit is destroyed during an eruption or when the crater floor collapses into the magma chamber below.

Types of volcanoes. There are three kinds of volcanoes: composite, shield, and cinder cone.

Composite volcanoes, (strato volcanoes) have been the sources of some of the more famous and destructive eruptions, such as those of Mount St. Helens, Vesuvius, and Krakatoa, they consist of alternating layers of lava and pyroclastic debris that can approach slopes as steep as 45 degrees. They are characterized by long periods of dormancy, or inactivity that can last for up to hundreds of thousands of years. How violent an eruption is depends on the temperature of the lava and the amounts of silica and dissolved gas in the lava (Figure 9).

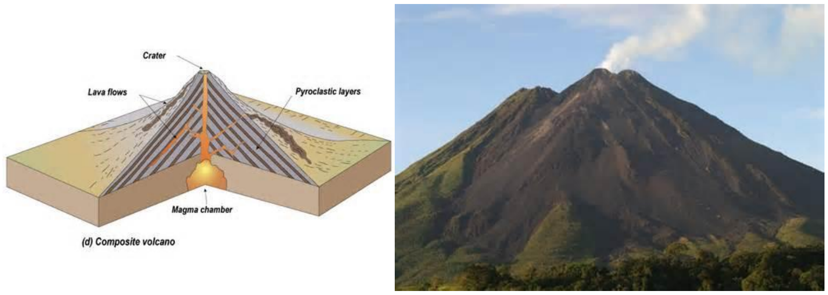


Fig. 9 Shows image and photoof composite volcano.

Shield volcanoes are broad, cone-shaped hills or mountains made from cooled lava flows. The sides are very gently dipping and rarely exceed 10 degrees from the horizontal because the lavas have a low viscosity and spread quickly after eruption. (Viscosity is defined as resistance to flow; a lava with high viscosity flows sluggishly.). The volcanoes of Hawaii are the typical example and the magma is form from the basalt, and the style of eruption is gentle (Figure 10).

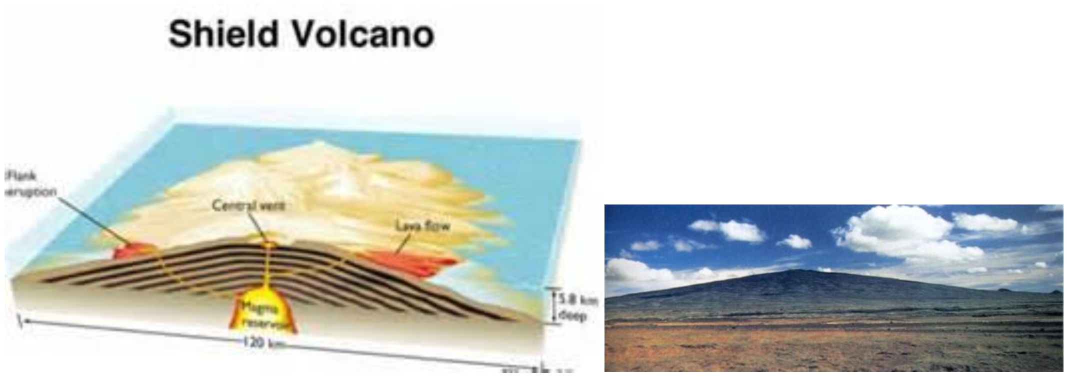


Fig. 10 Shows image and photo of Shield volcano.

A **spatter cone** is a smaller feature that usually develops on a cooling lava flow from a shield volcano. Gas and lava are ejected through a small vent, building up a steep-sided cone that resemblesan appendage (Figure 10).

A **cinder cone** (pyroclastic cone) is a small volcano composed of pyroclastic fragments(not lavas) ejected from a vent and commonly has slopes of about 30 degrees. A cinder cone forms when large amounts of gas accumulate in rising magma. When the gas pressure builds up sufficiently, the entire mass erupts explosively, hurling cinders, ash, and molten magma into the air. The particles then fall back around the vent to accumulate as a small mountain of volcanic debris. A cinder cone is usually active for only a short time because once the gas escapes, the driving force behind the eruption is gone. Most are less than 300 meters high, although a large one can be up to700 meters high. A cinder cone erodes easily and quickly because the pyroclastic fragments are not cemented together. About 350 kilometers west of Mexico City, numerous extinct cinder cones are scattered over a broad plain. Paricutin, in Mexico is a typical example of a cinder cone volcano (Figure 11).

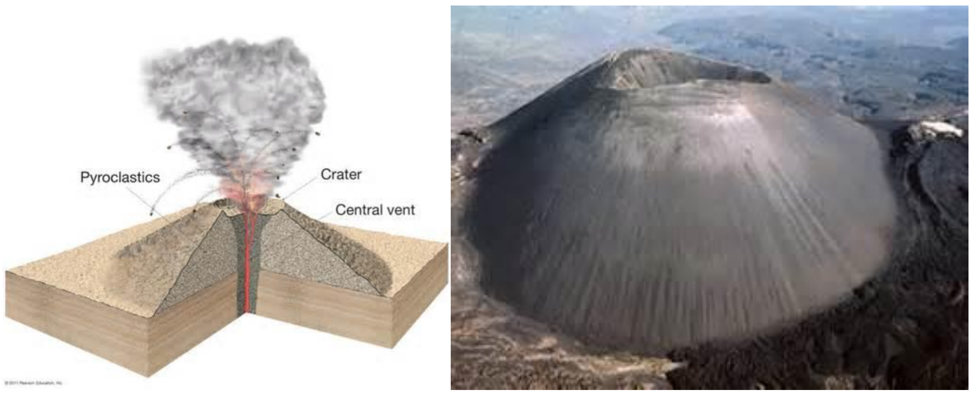


Fig. 11 Shows image and photo of cinder cone volcano.

CALDERAS

After the gas-charged magma erupts, nothing remains to hold up the overlying rock, and the roof of the magma chamber collapses (Fig. 12). Because most magma bodies are circular when viewed from above, the collapsing roof forms a circular depression called a **caldera**. A large caldera may be 40 kilometers in diameter and have walls as much as a kilometer high.

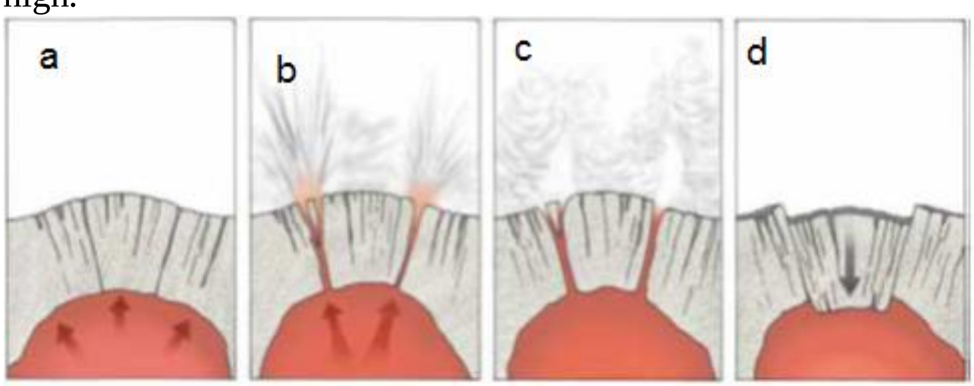


Figure 12 (a) When granitic magma rises to within a few kilometers of the Earth's surface, it stretches and fractures overlying rock. Gas separates from the magma and rises to the upper part of the magma body. (b) The gas-rich magma explodes through fractures, rising as a vertical column of hot ash, rock fragments, and gas. (c) When the gas is used up, the column collapses and spreads outward as a high-speed ash flow. (d) Because so much material has erupted from the top of the magma chamber, the roof collapses to form a caldera.

Intrusive Igneous Structures

Intrusions vary widely, from mountain-range-sized **batholiths** to thin vein like fracture fillings of aplite or pegmatite. When exposed by erosion, these cores called batholiths may occupy huge areas of Earth's surface. Large bodies of magma that solidify underground before they reach the surface of the crust are called **plutons (**Figure 13).

Intrusions are also classified according to size, shape, depth of formation, and geometrical relationship to the country rock. Intrusions that formed at depths of less than 2 kilometers are considered to beshallow intrusions, which tend to be smaller and finer grained thandeeper intrusions.

Dikes: A dike is an intrusive rock that generally occupies a discordant, or cross-cutting, crack or fracture that crosses the trend of layering in the country rock. Dikes are called pegmatite when they contain very coarse-grained crystals—a single such crystal can range in size from a few centimeters to 10 meters in diameter **(**Figure 13).

Sills: Sills are formed from magmas that entered the country rock parallel to the bedding (layering) and are thus concordant with the country rock. Sills can sometimes look like volcanic flows that were interbedded with sedimentary units **(**Figure 13).

Laccoliths: A laccolith resembles a sill but formed between sedimentary layers from a more viscous magma that created a lens -shaped mass that arched the overlying strata upward **(**Figure 13).

Plutons: Plutons are discordant intrusive rocks that formed at great depths. They tend to be large, coarse grained, and irregular in shape.

If the intrusion occupies less than 100 square kilometers (60 square miles) at the earth's surface it is called a **stock**; if it is larger than 100squarekilometers, it is termed a **batholith**. **Batholiths** are usually composed of granite. They have formed over long periods through the accumulation of smaller magma blobs called diapirs, which result from localized melting of the crust ; the diapirs then slowly move upward toward the surface and coalesce into a larger mass. **Granitic batholiths** usually form the cores of mountain complexes and are a result of plate tectonic action.

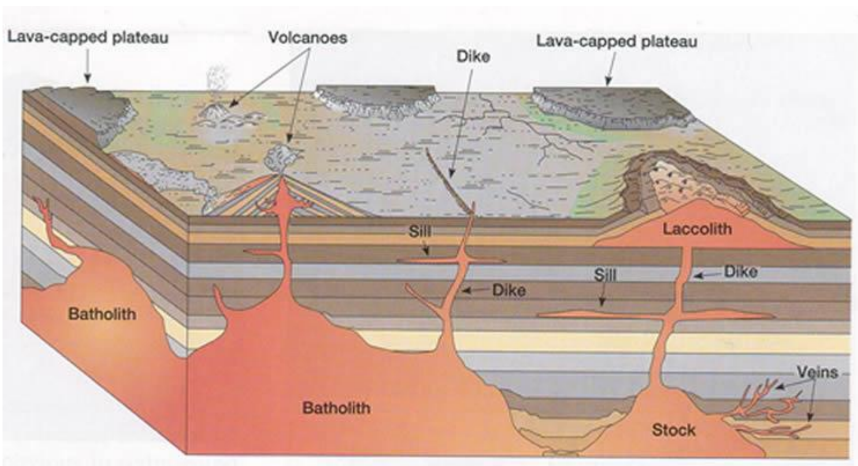


Fig. 13 Shows the types of intrusive igneous structures.

Sedimentary rocks

Sedimentary rocks cover about three-fourths of the surface of the continents. There are three kinds of sedimentary rocks: **clastic**, **chemical**, and **organic**. **Clastic sedimentary rocks** form from the consolidation of material such as gravel, sand, or clay (sediment) derived from the weathering and breakdown of rocks. **Chemical sedimentary rocks** result from biological or chemical processes, generally under water that crystallizes minerals that accumulate on the sea floor. **Organic sedimentary rocks**, such as coal, have as their major component accumulations of organic remains from plants or animals that make the rock distinctive.

Clastic Sedimentary Rocks

As rocks undergo weathering and erosion on the surface of the earth, they turn into grains of sediment. Clastic sediment is the solid bits and pieces of rocks and minerals that have broken down from the source rock by a combination of physical and chemical weathering. Clastic sedimentary rocks are classified according to the grain size of the sediment and the kinds of rock fragments that make up the sediment (Table 2). Grain size is largely a function of the distance the particle was transported. Clastic sedimentary rocks are composed of **silicate minerals** and rock fragments that were transported by moving fluids (as bed load, suspended load, or by sediment gravity flows) and were deposited when these fluids came to rest. Clastic rocks are composed largely of quartz, feldspar, rock (lithic) fragments, clay minerals, and mica; numerous other minerals may be present as accessories and may be important locally. In general, the greater the distance traveled the **smaller** and more **rounded** the sediment particles will be. This smoothing of rock fragments during transportation is called **rounding**. Clastic sediment, and thus clastic sedimentary rocks, are subdivided according to the dominant particle size (diameter). Most geologists use the **Udden-Wentworth** grain size scale and divide unconsolidated sediment into three fractions: 1**-gravel** (>2 mm diameter), 2**-sand** (1/16 to 2 mm diameter), **3-mud** (clay is <1/256 mm and **silt** is between 1/16 and 1/256 mm). The classification of clastic sedimentary rocks parallels this scheme; conglomerate and breccia are made mostly of gravel, sandstones are made mostly of sand, and mudstones are made mostly of mud. This tripartite subdivision is mirrored by the broad categories of rudites, arenites, and lutites, respectively, in older literature. Large, coarse, angular pieces of sediment will be deposited near the source.

Particle Sizes in Clastic Sedimentary Rocks			
Diameter (mm)	Particle Type	Sediment Name	Sedimentary Rock
More than 256	Boulder	Gravel	Conglomerate or Breccia
64 to 256	Cobble		
4 to 64	Pebble		
2 to 4	Granule		
$\frac{1}{16}$ to 2	Sand	Sand	Sandstone
$\frac{1}{256}$ to $\frac{1}{16}$	Silt	Mud	Siltstone, Shale, or Mudstone
Less than $\frac{1}{256}$	Clay		

■ Table 2 ■

Large, coarse, angular pieces of sediment will be deposited near the source area; well-rounded sand grains will have been transported a considerable distance before being deposited; silt, mud, and clay have been carried even farther. This process is called **sorting**.

Coarse-grained rocks. Sedimentary **breccia** contains an abundance of coarse, angular fragments of gravel that were deposited very near the source area. A **conglomerate** is formed from coarse-grained, rounded pieces of gravel. **Sandstone** is a medium-grained rock that contains rock particles (mostly quartz) about the size of sand. The grains in a quartz sandstone are at least 90 percent quartz **(**Figure 14).

1  2  3 

Fig. 14 Shows clastic sedimentary rocks, 1 conglomerate, 2 breccia, 3 sandstone

Graywackeis a poorly sorted sandstone with considerable quantities of silt and clay in its pores. Graywacke iscommonly dark in color because of fine clay that coatsthe sand grains. The grains are usually quartz, feldspar, and fragments of volcanic, metamorphic, and sedimentary rock is a type of "dirty" sandstone that consists of more than 15 percent silt-sized or clay-sized (finer-grained) material that imparts a darker or speckled appearance **(**Figure 15). If a coarse-grained sandstone consists of over 25 percent feldspar grains it is called an **arkose**.The sand grains in arkose are commonly coarse and angular. The high feldspar content and the coarse, angular nature of the grains indicatethat the rock forms only a short distance from itssource area, perhaps adjacent to granite cliffs **(**Figure 15).

1  2 

Fig. 15 Shows clastic sedimentary rocks, 1 Graywack, 2 Arkose.

Finer-grained rocks. The finer-grained clastic sedimentary rocks are called **shale, siltstone, and mudstone**. **Shale** is a smooth, thinly layered rock that is made up of fine-grained silt and clay particles .

Shale is considered a fissile rock because it splits very naturally alongits layers **(**Figure 16). A **siltstone** contains mostly silt grains and looks very similar to shale but is not as fissile. **Mudstone**, the finest-grained clastic rock, is not well layered, and contains more clay than does shale or siltstone **(**Figure 16). Most shales, siltstones, and mudstones are tan, brown, gray, or black.

1  2  3 

Fig.16 Shows clastic sedimentary rocks, 1 siltstone, 2 shale, 3 mudstone

2-Organic sedimentary rocks, such as chert and coal, form by lithification of the remains of plants and animals. Clams, oysters, corals, some types of algae, and a variety of other marine organisms convert dissolved calcium carbonate to shells and otherhard body parts. When these organisms die, waves andocean currents break the shells into small fragments, called **bioclastic sediment**. A rock formed by lithification of such sediment is called **bioclastic limestone**, indicating that it forms by both biological and clastic processes. Many limestones are bioclastic **(**Figure 17).

Coral and **algae** are especially important limestone builders. Oolitic limestones form in ocean shallows from the accumulation of oolites, sand-sized spheres of chemically precipitated calcite that develop in the tidal zone. Other variations of limestone result from the deposition and cementation of calcium-rich shells, shell fragments, corals, algae, and the remains of tiny marine organisms. **Coquina** is formed from the cementation of large pieces of broken shells. **Bioclastic** and **skeletal** limestones are fine- to coarse-grained accumulations of a wider variety of shell fragments and fossils. **Chalk** is a very fine-grained bioclastic limestone composed of accumulations of skeletal debris fromtiny marine organisms that drifted down to the ocean floor. All ofthese "redeposited" limestones could be considered clastic sedimentary rocks, as well as organic sedimentary rocks .

1 

2 

Fig. 17, shows 1- limestone, 2- chalk limestone.

Cherts. Chert (varieties of which are flint, agate, and jasper) is ahard, glassy sedimentary rock composed of pure silica that precipitated from water. **Chert nodules**, also known as geodes, are commonly found in limestones and less so in clastic sedimentary rocks . They form in pockets or voids that might have once been occupied by gasor organic material that has since been removed or decomposed. Cherts can also occur as **continuous layers** in sedimentary rocks. Chert usually composes at least half of a spectacular layered rock called iron formation, which crystallized in shallow seas around the world and is an important source of iron.

1  2 

Fig. 18 shows, 1- dolomite, 2- chert.

Coal

When plants die, their remains usually decompose by reaction with oxygen. However, in warm swamps and in other environments where plant growth is rapid, dead plants accumulate so rapidly that the oxygen is used up long before the decay process is complete. The undecayed or partially decayed plant remains form peat. As peat is buried and compacted by overlying sediments, it converts to **coal**, a hard, black, combustible rock **(**Figure 19).

Fig. 19, shows coal

3-Chemical Sedimentary Rocks

Chemical sedimentary rock forms when mineral constituents in solution become super saturated and inorganically precipitate. Common chemical sedimentary rocks include oolitic limestone and rocks composed of evaporite minerals such as halite (rock salt), sylvite, barite and gypsum.

Limestones. The most common chemical sedimentary rock is limestone. Composed mostly of the mineral calcite (CaCO3), some limestones can form by direct precipitation of calcium carbonate from marine or fresh water. Limestones formed this way are chemical sedimentary rocks. They are thought to be less abundant than biological limestones.

Dolomites. Limestones are frequently converted into dolomites, or dolostones, during the early stages of compaction, dewatering, and lithification of the limestone sediment. The process of dolomitization involves the removal of calcium from the limestone by magnesium-rich solutions and its replacement in the rock by magnesium. Dolomite's chemical formula is $CaMg(CO_3)2$ .Dolomite is very significant in the petroleum business because it forms underground by the alteration of calcite limestone. This chemical change is marked by a **reduction** in volume and by **recrystallization**, which combine to produce open space (porosity) in the rock strata. Porosity creates avenues for oil to travel and reservoirs for oil to collect. Naturally, this alteration of limestone is called dolomitization, and the reverse alteration is called dedolomitization. Both are still somewhat mysterious problems in sedimentary geology.

Evaporites. Evaporites are rocks that are composed of minerals that precipitated from evaporating sea water or saline lakes . Common evaporites are halite (rock salt), gypsum, borates, potassium salts, and magnesium salts. **Evaporites** form when evaporation concentrates dissolved ions to the point at which they precipitate from solution (Fig. 20). As the individual crystals precipitate, they interlock with each other to produce grain boundaries like those of an igneous rock.

1 

2 

Fig. 20, shows evaporate rocks, 1 halite, 2 gypsum.