

# **FORMATION OF MAGMA AND IGNEOUS ROCKS**

**Smith and Pun, Chapter 4**

## **IGNEOUS PROCESSES**

**Igneous processes involve the melting of rock to form magma, molten material below the surface of the Earth.**

**Igneous products are formed where magma crystallizes below the surface of the Earth, or erupts as lava and other materials at the Earth's surface. The term lava refers to the molten material ejected from a volcano.**

## CLASSIFICATION OF IGNEOUS ROCKS

Igneous rocks are initially classified based on where they were formed (See Figure 4.2 on page 69) .

**Volcanic Rocks** – Rocks originating from the eruption of molten material at Earth's surface. These rocks are also referred to as *extrusive* rocks.

*Pyroclastic* materials are materials that are explosively ejected from an erupting volcano.

**Plutonic Rocks** – Igneous rocks that solidify below the surface of the Earth. These rocks are also referred to as *intrusive* rocks.

## CLASSIFICATION OF IGNEOUS ROCKS (2)

### COMPOSITION

1. Magma is rich in silica, present as  $\text{SiO}_2$ , except in rare cases. Silica content in most magma ranges from 45 to almost 80 percent by weight (see Figure 4.3, page 70).

Oxides of aluminum (Al), magnesium (Mg), iron (Fe), calcium (Ca), sodium (Na), potassium (K), and other elements in trace concentrations may also be present in magma.

## **CLASSIFICATION OF IGNEOUS ROCKS (3)**

### **COMPOSITION**

**2. Gases are also present in all magmas. The most abundant gases present are:**

- **Water vapor**
- **Carbon dioxide (CO<sub>2</sub>)**
- **Sulfur (S) compounds**

**As magma approaches or reaches the surface, gases escape and result in the formation of vesicles, that we observe in some volcanic rocks.**

## **CLASSIFICATION OF IGNEOUS ROCKS (4)**

### **COMPOSITION**

**One of the most significant differences between magma and lava is the entrapment of gas within magma at depth and its release during an eruption.**

**Magma is a mixture of liquid, crystals, and dissolved gases below the surface. Lava, in contrast, is magma at the surface from which most of the gases have escaped.**

**The composition of the magma determines the minerals that form and the appearance of the resulting rock.**

## **CLASSIFICATION OF IGNEOUS ROCKS (5)**

### **COMPOSITION**

**Based on the decreasing abundance of silica in the magma or in the rock-forming minerals, both magma and igneous rock compositions are further categorized as:**

- **Felsic** – Refers to feldspar and silica (as quartz)
- **Intermediate**
- **Mafic** – Derived from the names of the elements magnesium and iron (ferric) which are more abundant in magmas with lower silica contents
- **Ultramafic**

## **CLASSIFICATION OF IGNEOUS ROCKS (6)**

### **COMPOSITION**

- **Felsic rocks contain quartz, Na-rich plagioclase feldspar, and K-feldspar. The concentration of dark minerals, including hornblende, biotite, and pyroxene in felsic rocks is low. Felsic rocks are usually the lightest in color.**
- **Intermediate rocks typically contain hornblende, biotite or pyroxene, and plagioclase feldspar with nearly equal amounts of Ca and Na. Feldspar and Mg- and Fe-rich minerals are present in about equal proportions. These rocks tend to be darker than felsic rocks and lighter in color than mafic and ultramafic rocks; gray shades are most common.**

## **CLASSIFICATION OF IGNEOUS ROCKS (7)**

### **COMPOSITION**

- **Mafic and ultramafic rocks primarily contain Mg-rich and Fe-rich silicate minerals, olivine and pyroxene.**

**Ultramafic rocks are composed almost entirely of olivine and pyroxene. Mafic rocks also contain Ca-rich plagioclase feldspar.**

**These rocks tend to be dark gray to black in color, because the dark Mg- and Fe-rich minerals are more prevalent than the light-colored feldspar.**

## **CLASSIFICATION OF IGNEOUS ROCKS (8)**

### **TEXTURE**

**Crystal size is an important component of rock texture. The crystal size in igneous rocks is dependent on many factors; however, the cooling rate of the magma is generally the most important factor.**

**When magma cools quickly, the resulting rock consists of very small crystals which generally cannot be seen by the naked eye (Figure 4.2b, page 69). This fine-grained texture is called aphanitic (Figure 4.3, page 70).**

## **CLASSIFICATION OF IGNEOUS ROCKS (9)**

### **TEXTURE**

**If the cooling rate is so fast that few, if any, crystals have time to form, the melt solidifies into a noncrystalline glass (Figure 4.2e, page 69).**

**Obsidian is felsic volcanic glass with a dark gray to black color that seems uncharacteristic for a felsic rock. The dark color results because very tiny grains of magnetite and other minerals are widely dispersed throughout the rock.**

## **CLASSIFICATION OF IGNEOUS ROCKS (10)**

### **TEXTURE**

**In contrast, magma cools slowly beneath the surface because it is surrounded and insulated by warm rock. Mineral crystals grow slowly in this environment ultimately resulting in a coarse-grained texture called phaneritic (see Figure 4.2 a, page 69).**

**Aphanitic lava flows may cool within a few hours on the surface, whereas deep phaneritic intrusive rocks may require tens of thousands of years, or longer, to solidify completely.**

## **CLASSIFICATION OF IGNEOUS ROCKS (11)**

### **TEXTURE**

**In some cases, magma begins to crystallize slowly at depth, producing large crystals. Subsequent movement into colder environments at or near the surface results in rapid crystallization of the remaining melt.**

**The resulting igneous rock consists of large crystals surrounded by smaller crystals (see Figure 4.2d, page 69). The texture of such a rock is called porphyritic.**

## **CLASSIFICATION OF IGNEOUS ROCKS (12)**

### **TEXTURE**

**A special approach is necessary to classify the pyroclastic materials erupted from volcanoes, since most of them have glassy textures. Pyroclastic materials include pumice, ash, and any other erupted materials.**

**As a result, we distinguish these by the size of the fragments (see Figure 4.4 and Table 4.1 on page 72).**

## CLASSIFICATION OF IGNEOUS ROCKS (13)

### PYROCLASTIC MATERIALS

- Ash – Fragments that are less than 2 mm in size
- Lapilli – Small fragments from 2 to 64 mm in size
- Bombs – An irregular block of lava that is greater than 64 mm in size

## NAMING IGNEOUS ROCKS

The classification scheme for igneous rocks combines both composition and structure (see Figure 4.3, page 70).

- Ultramafic and phaneritic peridotite comprises the Earth's mantle. Pieces of this rock may be carried to the surface of the Earth by erupting volcanoes.
- Basalt and gabbro form from mafic magma and contain similar mineral assemblages, but differ in texture. Gabbro is the coarse-grained equivalent of basalt.

The oceanic crust is mostly composed of basalt and gabbro.

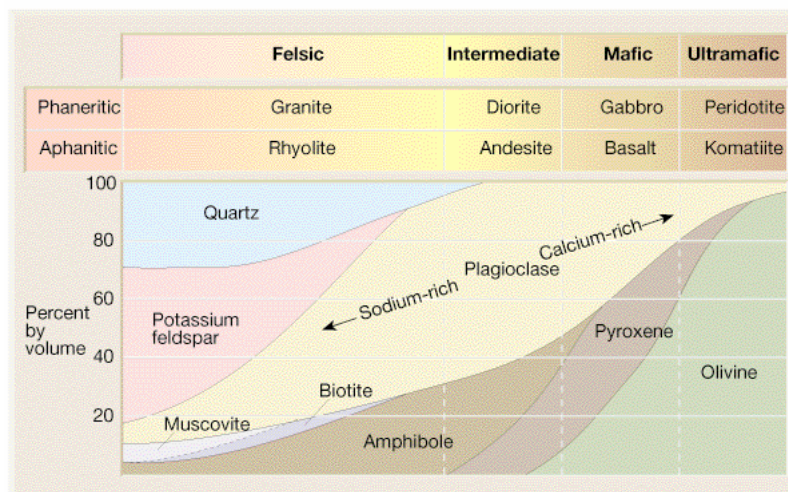


## NAMING IGNEOUS ROCKS (2)

- The igneous rocks **andesite** and **diorite** solidify from magmas with intermediate compositions.
- **Rhyolite** and **granite** form from magmas with the most felsic compositions.
- **Dacite** and its **phaneritic** equivalent tonalite have compositions that fall between andesite and rhyolite.

The continental crust is composed of a variety of intermediate to felsic igneous rocks. The most accessible rocks within the upper crust generally have an average tonalite composition.

## COMMON IGNEOUS ROCKS



### **NAMING IGNEOUS ROCKS (3)**

**Pyroclastic deposits are named on the basis of fragment size and whether the fragments are loose or consolidated into rock (Table 4.1, page 72). Compositional terms may be used as modifiers to complete the descriptive name of pyroclastic igneous rocks.**

- **Lightweight, highly vesicular lapilli is called pumice if it is dacitic or rhyolitic in composition.**
- **Lightweight, highly vesicular lapilli is called cinder or scoria if it is basaltic or andesitic in composition.**

### **ECONOMIC USES OF IGNEOUS ROCKS**

**Igneous rocks have a wide variety of uses in construction and industry. These uses include:**

- **Building stone, or when crushed, aggregate for highway and railroad bed construction.**
- **Volcanic ash and pumice are mixed into lightweight concrete. Pumice is also used as an abrasive in toothpaste and soap and is tumbled with denim to manufacture stonewashed jeans.**
- **Obsidian may be shaped into sharp tools and weapons; some plastic surgeons still use obsidian knives.**

## **WHERE DO IGNEOUS ROCKS OCCUR IN THE LANDSCAPE?**

**Extrusive and intrusive processes are revealed at the Earth's surface by:**

- **Earthquakes resulting from movement of magma beneath volcanoes**
- **Pieces of plutonic rocks ejected from volcanoes**
- **Presence of plutonic rocks exposed by erosion of volcanic rocks.**

**Most volcanoes are found at or near divergent and convergent plate boundaries; only a few occur within plates.**

## **WHERE DO IGNEOUS ROCKS OCCUR IN THE LANDSCAPE? (2)**

- **Seafloor volcanoes compose the mid-ocean ridges. Some rise to form islands, such as Hawaii, where magma rises below plate interiors at hot spots.**
- **Volcanoes appear within continents at points where plate divergence is beginning (East Africa), or at hot spot locations such as Yellowstone National Park in Wyoming.**

**Igneous activity today occurs in active tectonic settings; therefore, geologists infer that ancient volcanic rocks and their intrusive equivalents formed in active tectonic regions in the past.**

## **PLUTONIC ROCKS IN THE LANDSCAPE**

**When plutonic rocks are exposed at the surface by erosion, they are typically more resistant to erosion than the surrounding rocks. A wide variety of landforms may result whose shapes and sizes are determined by the:**

- **Volume of magma intruded**
- **Mechanism of intrusion**

**See Figure 4.6 on page 74 of the text.**

## **PLUTONIC ROCKS IN THE LANDSCAPE (2)**

**Tabular intrusions, referred to as dikes and sills are extensive in two dimensions, but relatively thin in the third dimension (see Figure 4.7, page 75). Dikes and sills form close to the surface, so they are the first to be revealed by erosion.**

**Dikes are long, steep tabular intrusions that occur along fractures in the surrounding rocks. Dikes cut across layers if the magma intrudes sedimentary rocks.**

**When magma moves at low angles to the ground surface, sills are formed.**

### **PLUTONIC ROCKS IN THE LANDSCAPE (3)**

**Volcanic necks also form close to the surface. Unlike dikes, which form when volcanic eruptions occur along elongate fissures, volcanoes may also be fed by nearly cylindrical pipes. When erosion eventually exposes the rocks filling the pipes, a volcanic neck is formed (see Figure 4.8, page 75).**