

ROCKS AND ROCK-FORMING PROCESSES

Smith and Pun, Chapter 3

CLASSIFYING ROCKS

Scientists, including geologists, often group features or other phenomena based on similarities to provide explanations for their origins.

Descriptive Classifications – Group items of similar appearance

Genetic Classifications – Group features or phenomena based on similarities in the processes that result in, or create the observed features or phenomena.

Historically, the principal groupings of rocks have emphasized the origin of the rocks.

THE THREE CLASSES OF ROCK

Geologists utilize a three-category rock classification scheme, based on rock forming processes (see Table 3.1 on page 54 of the text). The three rock types are:

Sedimentary – Rocks formed by deposition and precipitation of products formed by the breakdown of older rocks under the typical conditions of Earth's surface environment

Igneous – Rocks that crystallize from molten material called *magma*.

THE THREE CLASSES OF ROCK (2)

Metamorphic – Rocks resulting from changes of preexisting rocks. These changes typically occur at temperatures in excess of 200 °C. *However, metamorphism does not include very high temperatures where melting occurs.*

SEDIMENTARY ROCKS

Any rock exposed at the Earth's surface will undergo deterioration by physical and chemical processes of *weathering* (see Figure 3.5 on page 54).

Physical weathering – Results in disintegration of rocks into smaller rocks or smaller mineral grains.

Chemical weathering – Involves reactions between minerals and water to produce dissolved ions and new minerals.

SEDIMENTARY ROCKS (2)

Minerals or rock fragments produced by weathering are called clastic sediment. Clastic is derived from the Greek *clastos*, which means broken.

Mineral constituents dissolved in water by chemical weathering may subsequently precipitate as new mineral crystals depending on changes in the existing temperature, pressure, and/or changes in the elements present. These precipitates form chemical sedimentary rocks.

SEDIMENTARY ROCKS (3)

Precipitated minerals may also cement particles of loose clastic sediment to form clastic sedimentary rocks. Clastic sedimentary rocks are comprised of particles generated during weathering and then transported to a depositional site by water, wind, or glaciers.

Compaction under the weight of accumulated sediment and precipitation of cementing minerals between grains transform loose sediment into consolidated sedimentary rocks. This transformation is referred to as lithification, which is derived from the Greek *lithos* meaning rock.

SEDIMENTARY ROCKS (4)

Sedimentary rocks are most often recognized from a distance by their distinctive layering, called bedding.

Bedding originates from the sequential deposition of different sedimentary materials at Earth's surface.

IGNEOUS ROCKS

The root for “igneous” is the Latin word *igneus*, which means “fiery” (see Figure 3.6 on page 55).

Magma may erupt:

- At volcanoes
- As lava and volcanic ash
- Underground where it solidifies

Volcanic Rocks – Solidify at the Earth’s surface (also referred to as *extrusive*)

Plutonic Rocks – Solidify beneath the Earth’s surface (also referred to as *intrusive*)

IGNEOUS ROCKS (2)

Experiments have demonstrated that fast solidification of magma generally produces small crystals. In contrast, slower crystallization favors the formation of larger crystals.

Fine-grained rocks, therefore, result from rapid cooling of magma and other materials following volcanic eruptions (see Figures 3.4b and c, page 52).

Coarser-grained rocks form from the slow solidification of magma underground (see Figure 3.4d, page 52).

IGNEOUS ROCKS (3)

The composition of magma is dominated by the elements composing silicate minerals.

As a result, igneous rocks consist mostly of silicate minerals. The composition of igneous rocks also helps to differentiate them from chemical sedimentary rocks.

Accumulation of successive lava flows or other volcanic materials at the Earth's surface produces layers that may resemble bedding in sedimentary rocks (see Figure 3.7a, page 56).

Plutonic rocks, however, rarely accumulate in successive layers (see Figure 3.7b, page 56).

METAMORPHIC ROCKS

Metamorphic rocks result from alteration of preexisting rocks. The term metamorphic comes from the Greek *meta* meaning "change" and *morphe* meaning "form".

Change in the appearance of a rock requires:

- **Change in the minerals composing the rock, and/or**
- **Rearrangement of the existing minerals.**

The processes resulting in these changes are referred to as metamorphism, and typically occur at temperatures and pressures found within the Earth and not at the surface.

METAMORPHIC ROCKS (2)

Field observations and laboratory experiments demonstrate that metamorphism nearly always occurs at elevated temperatures (see Figure 3.8, page 56).

High pressure and chemical reactions between minerals are also important in metamorphism.

- **Pressure increases with depth in the Earth because of the increasing weight of overlying rock (overburden).**
- **Temperature measurements in deep wells show that the interior of the Earth is hotter than the surface, and that temperature increases with increasing depth.**

METAMORPHIC ROCKS (3)

Metamorphism may impact large areas, particularly at convergent plate boundaries.

At convergent plate boundaries rocks originally at or near the surface are forced down to great depths and are altered by high, near horizontal pressure exerted on them. Additionally, the vertically directed weight of overlying rock and sediments contributes to metamorphism.

These rocks are called regional metamorphic rocks (see Table 3.1, page 54) and include rocks with minerals oriented preferentially in layers or bands (see right side of Figure 3.4d, page 52).

METAMORPHIC ROCKS (4)

Metamorphism may also occur on a local scale. An example of local metamorphism is the intrusion or extrusion of magma baking the adjacent rocks. The rocks that result from this type of process are referred to as contact metamorphic rocks.

Contact metamorphic rocks may be viewed at the bottom of some lava flows or adjacent to large igneous intrusions.

METAMORPHIC ROCKS (5)

Hydrothermal metamorphic rocks form where fluids with elevated temperatures react with rock during metamorphism. These rocks may occur separately, or with either regional and contact metamorphic rocks.

Hydrothermally metamorphosed rocks often host important deposits of metal ores.

METAMORPHIC ROCKS (6)

The minerals occurring in metamorphic rocks depend on the minerals present in the original rock and the nature of the metamorphic processes that occur.

Metamorphic rocks commonly contain abundant silicate minerals; many of these silicate minerals are minor or nonexistent in rocks crystallizing from magma. This fact is also used to help distinguish metamorphic rocks from igneous rocks.

COMPETING VIEWS OF ROCK-FORMING PROCESSES

Two competing views of rock forming processes were proposed by geologists during the late 1700s. Although neither group turned out to be completely correct, a brief review of their debate helps illustrate how observations, inference, and critical review help to evolve scientific knowledge over time.

The Neptunist View emphasized that Earth was cold and that virtually all rocks form by chemical precipitation from water (see Figure 3.10, page 58). Abraham Werner (1749-1817) was responsible for development of the Neptunist View.

COMPETING VIEWS OF ROCK-FORMING PROCESSES (2)

Opposing the Neptunists, was the Vulcanist View. The Vulcanists believed that the Earth was an inherently hot planet and that rocks formed from the fusing of particles by heat, or from solidification of magma rising from the molten interior of the Earth (see Figure 3.11, page 59).

The man who was ultimately labeled as the champion of the Vulcanists was James Hutton (1726-1797), a Scottish gentleman farmer. Hutton was also responsible for developing the Principle of Uniformitarianism (see Section 1.4, page 11).

COMPETING VIEWS OF ROCK-FORMING PROCESSES (3)

The debate between the Neptunist and Vulcanist views was ultimately resolved by observations and additional studies performed by many geologists.

French geologists, in particular, were among the first to recognize that volcanoes played a greater role in rock formation than permitted by the Neptunist View.

One of the components of the Neptunist View that was proven to be true is the origin of chemical sedimentary rocks and the cementing minerals in clastic sedimentary rocks to precipitation in water. Heat is not required for this process to occur.

THE ROCK CYCLE

The three classes of rock, igneous, sedimentary, and metamorphic have relationships to one another in the changing Earth (see Figure 3.12, page 61).

Sedimentary rocks are derived from the weathering of preexisting igneous, metamorphic, or other sedimentary rocks.

Metamorphic rocks originate from alteration of the form and nature of minerals in a preexisting igneous, sedimentary, or other metamorphic rock.

Igneous rocks crystallize from magmas that form by melting of preexisting rocks, typically of igneous or metamorphic origin.