

# ORIGIN, TEXTURE, AND CLASSIFICATION OF METAMORPHIC ROCKS

**Teklewold Ayalew**

*Addis Ababa University, Ethiopia*

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## Summary

Metamorphic rocks are igneous, sedimentary, or other metamorphic rocks whose texture and composition has been changed by metamorphism. Metamorphism occurs as a response to changes in the physical or chemical environment of any pre-existing rock, such as variations in pressure or temperature, strain, or the infiltration of fluids. It involves recrystallization of existing minerals into new grains and/or the appearance of new mineral phases and breakdown of others. Metamorphic processes take place

essentially in the solid state. The rock mass does not normally disaggregate and lose coherence entirely; however small amounts of fluids are frequently present and may play an important catalytic role.

Metamorphic rocks occur in a number of geological environments, including orogenic areas, aureoles of igneous intrusive bodies, sea floor, and most parts of the lower and intermediate crust and the upper mantle.

Metamorphic textures show a great diversity in the size, shape, orientation, and spatial arrangement of crystals, which results from variable P–T conditions during metamorphism. Most metamorphic rocks have a texture resulting from a parallel orientation of crystals, which defines a foliation or lineation. Others have a more isotropic arrangement of mineral grains.

The nomenclature of metamorphic rocks is classified according to various criteria, especially texture, composition, and P–T conditions of metamorphism. Metamorphic rocks that are classified according to texture include slate, phyllite, schist, and gneiss. Amphibolite, marble, and quartzite are defined according to their composition. Skarn, hornfels, and migmatite are classified according to their genesis.

Metamorphic minerals include a large variety of types (for instance, quartz, calcite, amphibole, pyroxene, alkali-feldspars, plagioclase, muscovite, biotite, andalusite, and garnet), some of which are typical or exclusive of metamorphic rocks (for instance, andalusite, kyanite, sillimanite, cordierite, staurolite, and chloritoid.). Some of these minerals are stable over narrow ranges of pressure and temperature, and their occurrence in a given rock furnishes important information on condition of metamorphism suffered by the rock.

## **1. Introduction**

Metamorphic rocks are igneous, sedimentary, or other metamorphic rocks that have been changed by heat, pressure, and chemical reactions with fluids and gases (see *Igneous and Metamorphic Petrology; Pressure, Temperature, Fluid Pressure Conditions of Metamorphism*). The textures and composition of the original rock are changed during metamorphism. The effects of metamorphism can form new crystalline structures in rocks, cause the formation of new minerals, and produce the coarsening of texture and layering of minerals.

Metamorphic petrology is the study of the solid-state chemical changes that take place in minerals and rock. Abundant evidence now exists to indicate that the mineral assemblages of the common sedimentary and volcanic rocks, when buried and subjected to high temperatures and pressures, become thermodynamically unstable, resulting in the production of new minerals and new textures. Bedding, amygdules, and other structures are often preserved, and the mineral changes are therefore presumed to be essentially solid-state reactions, rather than changes resulting from melting and crystallization from the melt (see *Ultrametamorphism and Crustal Anatexis*).

Some metamorphic rocks, particularly those buried to depths of several kilometers, contain numerous veins rich in quartz and feldspar. These may have formed by the diffusion and segregation of matter in the solid rock, or by partial melting, with subsequent segregation of the melt.

Chemical analyses indicate that, apart from the addition or removal of H<sub>2</sub>O and CO<sub>2</sub>, metamorphism commonly occurs with little or no addition of material; locally, however, K, Si, and other elements have been added or removed during metamorphism, a process known as “metasomatism.”

Metamorphic rocks are extremely abundant in Earth’s crust, and presumably also in the mantle. They are well exposed in mountain belts such as the Appalachians and the Alps, and in Precambrian shield areas such as the Arabian-Nubian, Canadian, and Fennoscandian shields. However metamorphism, when defined as a solid-state reaction, also occurs in many igneous rocks, including gabbro and granite, as they cool below liquidus temperatures. Besides, evidence for metamorphism, including shock metamorphism, is found in some meteorites and lunar rocks, and metamorphism is no doubt an important process in the history of other planetary bodies.

Metamorphic rocks are also important because they provide us with a remarkable demonstration of the laws of nature. The multitudes of chemical changes taking place when a mudstone is transformed to schist, for example, all proceed in the direction of lower energy, as required by the laws of thermodynamics. The importance of kinetics is displayed in the remarkable diversity that exists in the texture of metamorphic rocks, resulting from variation in the mechanisms of and rates of crystal nucleation and growth.

## **2. Occurrence**

The occurrences of metamorphic rocks can be defined on the basis of geological settings. The types of occurrences include orogenic, ocean-floor, burial, contact, cataclastic, impact, and hydrothermal. The subdivisions are often distinct, but others overlap, or transitional forms exist between the various genetic occurrences and the main occurrences, which are reviewed below.

### **2.1. Orogenic Metamorphism**

This is characteristic of orogenic belts where deformation accompanies recrystallization. The processes involved are lithospheric thickening, compression, and heating associated with subduction followed by thermal relaxation. The rocks have a penetrative fabric (foliation, lineation, folds, and so on) with a preferred orientation of the mineral grains, generally associated with polyphase deformation.

### **2.2. Contact Metamorphism**

This takes place in rocks in proximity to shallow igneous intrusions, where concentric heated rock, or an aureole, of a few meters to a km width develops. The width of aureole depends on the volume, nature, and intrusion depth of a magmatic body, as well

as on the properties of the country rock. The resulting rocks are generally fine-grained and lack attitudinal features.

### 2.3. Ocean Floor Metamorphism

This is transformation in the oceanic crust in the vicinity of midocean ridges that are moved laterally by ocean floor spreading, covering large areas of the oceanic crust. Basalt produced at the spreading ridges is porous and is cooled by the converting seawater, and often characterized by extensive veining.

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#### Biographical Sketch

**Teklewold Ayalew** Ph.D. is an Associate Professor of Geology in the Department of Geology and Geophysics at the Addis Ababa University, Ethiopia. He obtained his Ph.D. in Geology from the Ottawa-Carleton Geoscience Centre, Carleton University, Ottawa, Canada, and specialized in metamorphic petrology and geochronology. His fieldwork has been mainly on the Precambrian geology of western Ethiopia.