

Metamorphic Rocks

S=slide

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Metamorphism is the transformation of one rock type into another

Metamorphic rocks are produced from igneous, sedimentary, and metamorphic rock

Parent rock – the rock from which it was formed

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Folded and Metamorphosed rock from the Anza-Borrego Desert

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Metamorphism – change form

Process that leads to changes in the mineralogy, texture, and sometimes chemical composition

Occurs where the preexisting rock is subjected to a physical or chemical environment that is significantly different from where it formed

temperature

pressure (stress)

introduction of chemically reactive fluids

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Example of Low Grade Metamorphism

From shale to slate

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High Grade Metamorphism

Identity of parent is difficult to determine and cannot be done with a hand sample alone

Temperatures may approach those at which rocks melt

During metamorphism rocks remain essentially solid

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Temperatures, pressures, and depths at which metamorphism occurs

Low-grade – slight changes metamorphism occurs at low T and P.

High-grade –substantial changes

metamorphism occurs at high T and P.

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Heat as a Metamorphic Agent

Heat provides the energy to drive chemical reactions – recrystallization of minerals or new minerals

clays and chemical precipitates
higher heat leads to change in mineral
stability ranges

Heat source – radioactive decay and residual heat from formation of Earth –
geothermal gradient

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Variations in crustal geothermal gradients in different settings near the surface.
About 200 degrees C clay minerals begin to recrystallize – Quartz and feldspar
stable

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Estimated temperature increase with depth within Earth (geothermal gradient).

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Rocks carried to great depth occur at convergent boundaries and they can be deeply
buried in large basins where gradual subsidence results in thick accumulations of
sediment.

Heat can be transferred by igneous intrusions

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Confining Pressure and Differential Stress

Confining pressure – forces are equal in all directions – deeper the rock the greater
the pressure

Pressure may cause minerals to recrystallize with more compact structure

Differential pressure – stresses are greater in one direction – rocks shortened in
direction of greatest stress and elongated in direction perpendicular to that stress

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Confining pressure – such as the Gulf of Mexico – Mississippi River deposits
sediment in layers – bottom layers are confined in all directions

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Differential stress - convergent boundaries – rocks are folded and flattened at depth
where the rock is ductile (can flow due to heat) and the rock breaks near the surface
where it is brittle and colder.

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Distribution in the upper 30 km of Earth's crust of metamorphic rocks produced by
regional and associated contact metamorphism.

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Increasing temperature -> expansion - bonds spread out or break

Increasing pressure-> compression - bonds are compressed or break.

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Chemically Active Fluids

Fluids are water, CO₂, and volatiles – from pore spaces, late stage igneous, and hydrated minerals

Fluids surround mineral grains and act as catalysts to promote recrystallization through ion migration (diffusion)

Hotter environments more reactive

Metasomatism -Fluid from plutons reacts with host rock

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Solid state changes, bonds break and reform, ions move by diffusion

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Metamorphic Textures

Texture – size, shape, and arrangement of grains in a rock

Foliation – planar (nearly flat) arrangement of mineral grains or structural features in a rock

Compressional stresses shorten rock units – mineral grains develop parallel, or nearly parallel, alignments

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Development of Foliation

1. Rotation of platy (i.e., clay or mica) and/or elongated (i.e., pyroxene) into a new orientation

2. Recrystallization of minerals to form new grains growing in the direction of preferred orientation (i.e., clay to mica or chlorite)

3. Changing shape of equidimensional grains into elongated shapes that are aligned in a preferred orientation

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Foliated Textures

Slaty cleavage- closely spaced planar surfaces where the rock splits into thin sheets

Schistosity- mica and chlorite grains are large enough to be seen with unaided eye

Gneissic texture- banded appearance

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Differential stress perpendicular to bedding caused the platy grains in shale and related rocks to bend into microfolds where the sides of the fold are aligned.

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Other Textures

Nonfoliated – minimal deformation and/or the parent rock is composed of all equidimensional minerals such as calcite or quartz

Porphyroblastic texture – large grains are surrounded by a fine-grained matrix – the large grains are called porphyroblasts
(garnet, stauralite, andalusite)

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Muscovite schist with porphyroblasts of garnet

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Tourmaline quartzite, with porphyroblastic texture.

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metaconglomerate: composed of former pebbles that have been stretched, deformed, and fused

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Foliated Rocks

Slate – fine grained foliated rock composed of minute mica grains – parent rocks: shale, mudstone, siltstone, or volcanic ash

Phyllite – intermediate between slate and schist

Schist – medium to coarse-grained rock where platy minerals predominate and may have other minerals, accessory minerals can be garnet, stauralite, sillimanite

Gneiss – medium to coarse-grained banded rock with granular and elongated minerals, common minerals include quartz and plagioclase, and include some micas, and amphiboles, parent rock same as above and granite

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Slate.

Forms by low-grade metamorphism of mudstones, shales, and claystones.

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Muscovite schist.

Forms by intermediate-grade metamorphism of phyllite.

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schist: a coarse-grained, foliated rock dominated by mica or amphibole.

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Gneisses are medium to coarse grained banded metamorphic rocks

Composed of granular and elongated minerals

Can have accessory minerals such as garnet – garnet gneiss or

amphibole - amphibolite

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gneiss: a coarse-grained, foliated rock composed of feldspar, quartz, mica, and amphibole.

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Nonfoliated Rocks

Nonfoliation –grains are equidimensional

marble – coarse, crystalline metamorphic rock – parent was a limestone, can have accessory minerals

quartzite – coarse grained metamorphic rock – parent was a quartz sandstone

hornfels – contact metamorphism of any rock

serpetinite – parent is basalt

anthracite – parent is coal

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marble: a coarse to fine-grained, nonfoliated rock composed mainly of calcite or dolomite.

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Marble.

Forms by intermediate to high-grade metamorphism of limestone or dolostone.

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Quartzite.

Forms by metamorphism of quartz sandstone.

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quartzite: a coarse-grained, nonfoliated rock composed mainly of quartz.

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Hornfels.

Forms by contact metamorphism of any rock type.

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Serpentinite with asbestos.

S39

Anthracite coal.

Forms by low to intermediate-grade metamorphism of bituminous coal.

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Metamorphic Environments

1. Contact or thermal metamorphism

2. Hydrothermal metamorphism
 3. Burial and subduction zone metamorphism
 4. Regional metamorphism
 5. Impact metamorphism
 6. Cataclastic metamorphism – along faults
- There is overlap over most of these types

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The five types of metamorphism and the settings where they occur.

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Metamorphic Environments

Contact or Thermal Metamorphism

Host rock around igneous rock is 'baked' or altered – zone is called an aureole

Size of aureole depends on size of the intrusion – small or narrow intrusions have very narrow aureoles and batholiths have large aureoles

Composition of host rock and amount of water present affects the size of the aureole

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Hornfels.

Forms by contact metamorphism of any rock type.

Marble and quartzite can be produced in contact metamorphism as well

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Contact metamorphism occurs due to heating of the country rock that borders a magma intrusion or lava flow.

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Contact metamorphism in a dolomitic limestone with quartz and clay impurities caused by a granite pluton.

Each change in mineralogy is a zone of metamorphism

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Parent rocks, metamorphic grade and type, and the resulting metamorphic rocks.

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Metamorphic Environment

Hydrothermal Metamorphism

Hot iron-rich fluids circulate through fissures and cracks in the rock

Hydrothermal metamorphism is a chemical alteration

Associated with igneous activity, such as the emplacement of plutons where ions in solution not incorporated into the pluton circulate through the host rock

also found along mid-ocean ridges where hot magma reacts with seawater

