# DOWNLOAD PDF METAMORPHIC ROCK (GEOLOGY ROCKS!)

## Chapter 1 : How Metamorphic Rocks are Formed

*Metamorphic rocks have been modified by heat, pressure, and chemical processes, usually while buried deep below Earth's surface. Exposure to these extreme conditions has altered the mineralogy, texture, and chemical composition of the rocks.*

See Article History Metamorphic rock, any of a class of rocks that result from the alteration of preexisting rocks in response to changing environmental conditions, such as variations in temperature , pressure , and mechanical stress , and the addition or subtraction of chemical components. The preexisting rocks may be igneous , sedimentary , or other metamorphic rocks. Metamorphism comprises changes both in mineralogy and in the fabric of the original rock. Minerals within the original rock, or protolith, respond to the changing conditions by reacting with one another to produce a new mineral assemblage that is thermodynamically stable under the new pressure-temperature conditions. These reactions occur in the solid state but may be facilitated by the presence of a fluid phase lining the grain boundaries of the minerals. In contrast to the formation of igneous rocks, metamorphic rocks do not crystallize from a silicate melt, although high-temperature metamorphism can lead to partial melting of the host rock. White bands have undergone partial melting and recrystallized into granite. Dark bands represent material composed predominantly of biotite and minor hornblende. The vast region of the Pacific margin, for example, with its seismic and volcanic activity, is also an area in which materials are being buried and metamorphosed intensely. In general, the margins of continents and regions of mountain building are the regions where metamorphic processes proceed with intensity. But in relatively quiet places, where sediments accumulate at slow rates, less spectacular changes also occur in response to changes in pressure and temperature conditions. Metamorphic rocks are therefore distributed throughout the geologic column. When tectonic forces thrust sedimentary and metamorphic rocks into the hot mantle, they may melt and be ejected as magma, which cools to form igneous, or magmatic, rock. Created and produced by QA International. Mantle rocks are seldom observed at the surface because they are too dense to rise, but occasionally a glimpse is presented by their inclusion in volcanic materials. Such rocks may represent samples from a depth of a few hundred kilometres, where pressures of about kilobars 3 million inches of mercury may be operative. Experiments at high pressure have shown that few of the common minerals that occur at the surface will survive at depth within the mantle without changing to new, high-density phases, in which atoms are packed more closely together. Thus, the common form of $SiO_2$, quartz , with a density of 2. In general, temperatures increase with depth within Earth along curves referred to as geotherms. The specific shape of the geotherm beneath any location on Earth is a function of its corresponding local tectonic regime. Metamorphism can occur either when a rock moves from one position to another along a single geotherm or when the geotherm itself changes form. The former can take place when a rock is buried or uplifted at a rate that permits it to maintain thermal equilibrium with its surroundings. This type of metamorphism occurs beneath slowly subsiding sedimentary basins and also in the descending oceanic plate in some subduction zones. The latter process occurs either when hot magma intrudes and alters the thermal state of a stationary rock or when the rock is rapidly transported by tectonic processes e. Regardless of which process occurs, the result is that a collection of minerals that are thermodynamically stable at the initial conditions are placed under a new set of conditions at which they may or may not be stable. If they are no longer in equilibrium with one another under the new conditions, the minerals will react in such a way as to approach a new equilibrium state. This may involve a complete change in mineral assemblage or simply a shift in the compositions of the preexisting mineral phases. The resultant mineral assemblage will reflect the chemical composition of the original rock and the new pressure-temperature conditions to which the rock was subjected. Because protolith compositions and the pressure-temperature conditions under which they may be placed vary widely, the diversity of metamorphic rock types is large. Many of these varieties are repeatedly associated with one another in space and time , however, reflecting a uniformity of geologic processes over hundreds of millions of years. For example, the metamorphic rock associations that developed in the Appalachian Mountains of eastern North America in response to the collision between the North

American and African lithospheric plates during the Paleozoic Era million to million years ago are very similar to those that developed in the Alps of south-central Europe during the collision between the European and African plates that occurred during the Mesozoic and Cenozoic eras million years ago to the present. Likewise, the metamorphic rocks exposed in the Alps are grossly similar to metamorphic rocks of the same age in the Himalayas of Asia , which formed during the continental collision between the Indian and Eurasian plates. Metamorphic rocks produced during collisions between oceanic and continental plates from different localities around the world also show striking similarities to each other see below Regional metamorphism yet are markedly different from metamorphic rocks produced during continent-continent collisions.

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## Chapter 2 : 6 Metamorphic Rocks â€“ An Introduction to Geology

*HomeÂ» Rocks. Rocks: Igneous, Metamorphic and Sedimentary Rocks hold the history of the earth and the materials that will be used to build its future.*

Metamorphic rocks are the rocks formed from other rocks. They are sedimentary or igneous rocks that have undergone changes as a result of extreme pressure and heat. The changes that occur in the process of metamorphism are because of the changes in the physical pressure and temperature, which alters the mineral composition and texture of the pre-existing igneous and sedimentary rocks to form metamorphic rocks. So, all metamorphic processes involve solid-state changes of the minerals. The protolith may be a sedimentary rock, an igneous rock or another older metamorphic rock. Pressure from the overlying rocks also increases the process of transformation. Heat from magma and friction along fault lines is the major contributor of the heat that brings about the rock changes. Even though the rocks do not actually melt, some mineral groupings redistribute the elements within the original minerals to form new compositions of minerals that are more stable at the new temperatures and pressures. The intense temperature gradient between the country rocks and the surrounding molten magma is the driving factor for the changes in texture and chemical composition. As a result, the original rocks are transformed into metamorphic rocks. Metamorphic rocks formed from direct magma heating and intrusions are termed as thermal or contact metamorphic rocks. Those formed as a result of widely distributed pressure and temperature changes induced by tectonic movements are known as regional metamorphic rocks. Metamorphic rocks are largely grouped into foliated and non-foliated rocks. Types of Metamorphic Rocks There are two main types of metamorphic rocks. These are Foliated metamorphic rocks and Non-foliated metamorphic rocks. Foliated Metamorphic Rocks Foliated metamorphic rocks are formed from direct exposure to pressure and heat. They are the most vital and largest groupings of metamorphic rocks. Foliated metamorphic rocks have four distinguishable types of aligned textures and they normally have a banded or layered appearance. Examples include slate, gneiss, phyllite, and schist. Non-foliated are formed as a result of tectonic movements or direct pressure which makes their formation highly dependent on their pre-existing conditions. Non-foliated Metamorphic Rocks Non-foliated metamorphic rocks do not have a banded or layered appearance. The extensively known example of non-foliated metamorphic rock is marble. Other examples include quartzite, hornfels, and novaculite. Examples of Metamorphic Rocks There are hundreds of metamorphic rocks across the face of the earth with different compositions and textures. The best way of learning their various types is by handling and seeing them in reality. Here is a list of the most known types of metamorphic rocks. It has a non-foliated metamorphic rock that has no specific composition. Hornfels are heated when near heat source such as a sill, dike, or magma chamber. Amphibolite Amphibolite is non-foliated metamorphic rock that is composed chiefly of plagioclase and amphibole hornblende , frequently with very little quartz. Amphibolite forms under conditions of directed pressure and high viscosity through the process of recrystallization. Gneiss Gneiss is a foliated metamorphic rock made up of granular mineral grains. It contains a lot of feldspar minerals and bands of quartz and sometimes mica. It normally has a banded appearance and is sort of laminated. It appears similar to granite. Novaculite Novaculite is a hard, fine-grained, dense, siliceous rock. It is non-foliated metamorphic rocks known to break with a conchoidal fracture. It forms in marine environments from sediment deposits where organisms like diatoms plentiful in water â€” the single-celled algae that secret hard shells made up of silicon dioxide. Marble Marble is among the non-foliated metamorphic rocks produced from the metamorphism of dolostone or limestone. It takes high polish and is often used for sculpture and as building material. Marble is mainly composed of calcium carbonate. Phyllite Phylite is mostly made up of very fine-grained mica and sometimes chlorite. It is a foliated metamorphic rock and its surface is generally lustrous and in certain cases wrinkled. Geologists say it represents the intermediate state between slate and schist. Lapis Lazuli Lapis Lazuli is one of the rarest metamorphic rocks, especially because of its blue color. Thus, Lapis Lazuli is famously known for its blue gem material and they are used for decoration and to make beads in the form of round small stones. It is a non-foliated metamorphic rock formed during the metamorphism of sandstone. It is a type of foliated metamorphic rock that is produced by the metamorphism of shale. Slates are predominantly realigned clay minerals. Schist Schist is a foliated metamorphic rock that is well developed and contains substantial amounts of mica. Because of the high concentrations of mica, schist can readily split into thin layers. Geologists say it represents the intermediate metamorphic grade between gneiss and phyllite. Sometimes schist might contain high amounts of chlorite. Soapstone Soapstone is a metamorphic rock primarily made up of talc with a soapy feel and varying amounts of other minerals such as chlorite, pyroxenes, micas, carbonates, and amphiboles. It is also a highly dense, soft, and heat resistant rock with high heat capacity. Because of its properties after metamorphism, it is considered highly used in a wide range of artistic and architectural works.

## Chapter 3 : What are metamorphic rocks?

*In the large outcrop of metamorphic rocks in figure 1, the rocks' platy appearance is a result of the process metamorphism. Metamorphism is the addition of heat and/or pressure to existing rocks, which causes them to change physically and/or chemically so that they become a new rock.*

It is composed primarily of hornblende amphibole and plagioclase , usually with very little quartz. The specimen shown above is about two inches five centimeters across. What are Metamorphic Rocks? Exposure to these extreme conditions has altered the mineralogy, texture, and chemical composition of the rocks. There are two basic types of metamorphic rocks. Foliated metamorphic rocks such as gneiss , phyllite , schist , and slate have a layered or banded appearance that is produced by exposure to heat and directed pressure. Non-foliated metamorphic rocks such as hornfels , marble , quartzite , and novaculite do not have a layered or banded appearance. Pictures and brief descriptions of some common types of metamorphic rocks are shown on this page. Hornfels is a fine-grained nonfoliated metamorphic rock with no specific composition. It is produced by contact metamorphism. Hornfels is a rock that was "baked" while near a heat source such as a magma chamber, sill, or dike. Gneiss is a foliated metamorphic rock that has a banded appearance and is made up of granular mineral grains. It typically contains abundant quartz or feldspar minerals. Marble is a non-foliated metamorphic rock that is produced from the metamorphism of limestone or dolostone. It is composed primarily of calcium carbonate. Phyllite is a foliated metamorphic rock that is made up mainly of very fine-grained mica. The surface of phyllite is typically lustrous and sometimes wrinkled. It is intermediate in grade between slate and schist. Novaculite is a dense, hard, fine-grained, siliceous rock that breaks with a conchoidal fracture. It forms from sediments deposited in marine environments where organisms such as diatoms single-celled algae that secrete a hard shell composed of silicon dioxide are abundant in the water. The specimen shown above is about three inches across. Lapis Lazuli , the famous blue gem material, is actually a metamorphic rock. Most people are surprised to learn that, so we added it to this photo collection as a surprise. Blue rocks are rare, and we bet that it captured your eye. Quartzite is a non-foliated metamorphic rock that is produced by the metamorphism of sandstone. It is composed primarily of quartz. The specimen above is about two inches five centimeters across. Slate is a foliated metamorphic rock that is formed through the metamorphism of shale. It is a low-grade metamorphic rock that splits into thin pieces. Schist is a metamorphic rock with well-developed foliation. It often contains significant amounts of mica which allow the rock to split into thin pieces. It is a rock of intermediate metamorphic grade between phyllite and gneiss. The specimen shown above is a "chlorite schist" because it contains a significant amount of chlorite. It is about two inches five centimeters across. The best way to learn about rocks is to have a collection of specimens to examine while you study. Seeing and handling the rocks will help you understand their composition and texture much better than reading about them on a website or in a book. Mineral collections and instructive books are also available. Soapstone is a metamorphic rock that consists primarily of talc with varying amounts of other minerals such as micas, chlorite , amphiboles, pyroxenes, and carbonates. It is a soft, dense, heat-resistant rock that has a high specific heat capacity. These properties make it useful for a wide variety of architectural, practical, and artistic uses.

## Chapter 4 : Metamorphic Rock Facts: Fascinating Types of Metamorphic Rocks

*Metamorphic rocks are those that form by the effects of heat, pressure, and shear upon igneous and sedimentary rocks. Some form during mountain-building by forces of others from the heat of igneous intrusions in regional metamorphism others from the heat of igneous intrusions in contact metamorphism.*

Check new design of our homepage! Fascinating Types of Metamorphic Rocks Metamorphic rocks are formed when other types of rocks change because of the enormous pressure and heat they experience deep within the earth. Keep reading to know more ScienceStruck Staff Last Updated: Jan 25, Metamorphism is a geological process involving rocks changing their form. The process requires millions of years in transformation. Earlier, the transformed rocks could either have been igneous, sedimentary, or even older metamorphic rocks. The new texture that develops is through the process of recrystallization. The texture and the kinds of minerals they consist of are how these rocks are classified. Here, we will have a look at some related facts, and also the various types of metamorphic rocks. Interesting Facts Metamorphic rocks can be divided on the basis of their metamorphism - regional, thermal, hydrothermal, and fault zone metamorphism. This phenomenon affects a very large area. The transformation is also affected by the thermal intensity. More pressure leads to major changes in the texture of the rock. The more the heat, the more changes will occur to the rocks. Hydrothermal metamorphic rocks are formed when hot fluids from hot springs circulate between the rocks. Most classifications of metamorphic rocks involve first separating the rocks into two categories by their texture -foliated rocks and non-foliated rocks. The foliation or layering that occurs in these rocks is because of the immense directional pressure they undergo deep within the Earth, usually along the boundary of a converging tectonic plate. In this environment, over an enormous time period, flat crystals of minerals as well as fragments, like stream pebbles and volcanic pyroclasts, progressively become perpendicular to the direction of the pressure. Apart from the effects of the pressure, the increase of the temperature can also result in minerals such as chlorite and mica re-crystallizing into bigger crystals that are more visible. These rocks are termed as foliated rocks. The rocks which do not have planar patterns of strain or stretching are termed as non-foliated metamorphic rocks. These rocks are most often deduced from single mineral sedimentary rocks. High temperature and pressure erases out the fossils of the metamorphic rocks. Metamorphic rocks do not have pores or openings, and may be accompanied with visible layers of crystals. Basalt The rock consists of amphiboles, is generally dark-colored and heavy, with a weakly foliated structure. It is used for used for construction purposes, building facings and paving. It is easily available and has attractive textures. Basalt This rock derives its name from its color. The metamorphism is generally accompanied by high pressure and low temperature. The presence of the mineral glaucophane imparts blue color to this rock. Limestone or dolomite Both dolomite and limestone contain calcium carbonate in large concentrations. Compared to its parent rock, marble is much harder. This enables it to get polished, and makes it popular as a building material. It is also used in bathtubs, floor tiling, sink tops, kitchen countertops, and so on. Artists do use it as a carving material. Marble is made up of various sized crystals, and also has many variances in color because of the impurities that are present during the formation process. Hence, marble can be white, gray, black, red, green, pink, banded and mottled. Peridotite This rock is formed under great pressure and temperatures. It consists of pyroxene and red garnet, along with small amounts of stable minerals. The color of eclogite is red-green, which makes it quite beautiful to look at. Basalt This rock is formed under low temperatures and pressure. The rock gets its color from the presence of chlorite, epidote, or actinolite. Shale The rock is fine-grained, containing perfect cleavage, which enables splitting it into fine sheets. Slate generally contains dark- to light-brown streaks. It is formed because of comparative low pressures and temperatures, and is referred to as low-grade metamorphism. It has been used in various ways over the years; for example, as grave markers or headstones. However, one of the problems with slate is the perfect cleavage it has, which resulted in gravestones splitting and cracking along the cleavage lines. It is also commonly used for chalkboards. Nowadays, due to its cracking and splitting, and its weight, slate is not used much. Shale This metamorphic rock is classified as medium grade, which means it has been formed by more pressure and heat compared to slate. This rock is coarse-grained, with the individual grains of the minerals that it is made up of being visible to the naked eye. Most of the original minerals are transformed into flakes, and since it has experienced far more pressure, it is usually found crumpled or folded. Usually, schists are named according to the main mineral they have been formed from. For example, talc schist, garnet mica schist, hornblende schist, and biotite mica schist. Granite or shale This rock is classified as high grade, which means that compared to schist, it has been subjected to more pressure and heat. Gneiss is distinctly banded and is coarser than schist. The banding comprises alternating layers, which are made up of different minerals. One of the most important minerals that gneiss is made up of is feldspar, along with quartz and mica. Gneiss can also form from the metamorphosis of sedimentary rocks like shale or sandstone, or from igneous rocks like granite. Gneiss is used as a building stone and for paving. Basalt, limestone and shale This rock does not appear in crystalline form, but the small grains enclosed fit in as a mosaic. Hornfel is non-foliated and its texture is banded. Its color is variable and largely depends on the source of rock it has metamorphosed from. Quartz sandstone When sandstone is metamorphosed it turns into quartzite. It becomes more harder than its parent rock. It is formed when sandstone comes into contact with magma that is deeply buried. Quartzite appears quite similar to sandstone, and the best way to tell the difference is to break both the rocks. While sandstone shatters into many grains, quartzite breaks across the grains. Peridotite This rock is mainly composed of serpentine minerals - antigorite, lizardite and chrysotile. The color can be green to dark-green or reddish-brown to black. It is very finely grained, and its texture is variable. It is used as a decorative stone in architecture. It was used to make chimneys earlier, due to its heat-resisting property. Peridotite This rock is primarily composed of talc and contains small amount of chlorite, mica and amphiboles. Soapstone is used for countertops in kitchens, making bowls and plates, electrical panels, and also as wall tiles and floor tiles. Shale or pelite Shale being the parent rock, is metamorphosed to become a fine grained phyllite, consisting of clay minerals. This rock is subjected to a greater degree of heat and pressure than slate, and also has larger crystals. The chief composition of phyllite consists of quartz, sericite mica, and chlorite.

## Chapter 5 : OneGeology - eXtra - OneGeology Kids - Rocks and minerals - Metamorphic rocks

*Metamorphic rocks started out as some other type of rock, but have been substantially changed from their original igneous, sedimentary, or earlier metamorphic form.. Metamorphic rocks form when rocks are subjected to high heat, high pressure, hot mineral-rich fluids or, more commonly, some combination of these fa.*

After decades of debate, geologists have found it most convenient to divide metamorphic rocks into two fundamental classes: Each class contains several rock types. We distinguish foliated rocks from each other partly by their component minerals and partly by the nature of their foliation, whereas we distinguish non-foliated rocks from each other primarily by their component minerals. Foliated metamorphic rocks can be distinguished from one another according to their composition, their grain size, and the nature of their foliation. The most common types include Slate is a foliated metamorphic rock that forms at relatively low temperature and pressure. The finest-grained foliated metamorphic rock, slate, forms by metamorphism of shale or mudstone rocks composed dominantly of clay under relatively low pressures and temperatures. Slaty cleavage develops when pressure solution removes portions of clay flakes that are not perpendicular to the compression direction, while clay flakes that are perpendicular to the compression direction grow. During the process, some flakes passively rotate into parallelism with the cleavage plane, pushed into the new orientation by compression. Commonly, such compression also causes the layers to bend into curves called folds. Examples of foliated metamorphic rocks formed at high temperatures and pressures. Phyllite is a fine-grained metamorphic rock with a foliation caused by the preferred orientation of very fine grained white mica. The word comes from the Greek word phyllon, meaning leaf, as does the word phyllo, the flaky dough in Greek pastry. Phyllite forms by the metamorphism of slate at a temperature high enough to cause neocrystallization of white mica. Under the metamorphic conditions that produce slate or phyllite, a protolith of conglomerate becomes metaconglomerate. Specifically, pressure solution and plastic deformation flatten pebbles and cobbles into pancake-like shapes. Schist forms at a higher temperature than does phyllite. The formation of gneiss, which takes place at very high temperatures and pressures. Gneiss is a compositionally layered metamorphic rock, typically composed of alternating dark-coloured and light-coloured layers that range in thickness from millimetres to meters. How does the banding in gneiss form? Some evolved directly from the original bedding in a rock. For example, metamorphism of a protolith consisting of alternating beds of sandstone and shale produces a gneiss consisting of alternating beds of quartzite and mica. Such flow stretches, folds, and smears out pre-existing compositional contrasts in the rock and transforms them into aligned sheets. Finally, banding in some gneisses can develop by an incompletely understood process called metamorphic differentiation. Under certain conditions, gneiss may begin to melt, producing felsic magma and residual, still solid, mafic rock. If the melt freezes again before flowing out of the source area, a mixture of igneous rock and relict metamorphic rock forms. This mixture is called migmatite. In effect, a migmatite is part metamorphic and part igneous. Nonfoliated Metamorphic Rocks Nonfoliated metamorphic rocks contain minerals that recrystallized or grew during metamorphism, but have no foliation. The lack of foliation means either that metamorphism occurred in the absence of compression and shear, or that most of the new crystals can only grow in an equant form. We list below some of the rock types that can occur without foliation. Examples of quartzite and marble typically, but not always, these are non-foliated. Hornfels is a fine-grained nonfoliated rock that contains a variety of metamorphic minerals. The specific mineral assemblage in a hornfels depends on the composition of the protolith and on the temperature and pressure of metamorphism. Quartzite forms by the metamorphism of pure quartz sandstone. During metamorphism, pre-existing quartz grains recrystallize, creating new, larger grains. In the process, the distinction between cement and grains disappears, open pore space disappears, and the grains become interlocking. When quartzite cracks, the fracture cuts across grain boundaries in contrast, fractures in sandstone curve around grains. Depending on the impurities it contains, quartzite can vary in colour from white to gray, purple, or green. The metamorphism of limestone yields marble. During the formation of marble, calcite composing the protolith recrystallizes, so fossil shells, pore space, and the distinction between grains and cement disappear. Thus, marble typically consists of a fairly uniform mass of interlocking calcite crystals. Marble comes in a variety of colours white, pink, green, and black depending on the impurities it contains. Not all marble is non-foliated. For example, rocks carried to a great depth beneath a mountain range undergo more intense metamorphism than do rocks closer to the surface. Geologists use the term metamorphic grade in a somewhat informal way to indicate the intensity of metamorphism, meaning the amount or degree of metamorphic change. Different grades of metamorphism yield different metamorphic mineral assemblages. Geologists discovered that the presence of certain minerals, known as index minerals, in a rock indicates the approximate metamorphic grade of the rock. All points along an isograd have approximately the same metamorphic grade. Metamorphic zones are regions between two isograds; zones are named after an index mineral that was not present in the previous, lower-grade zone. To compare rocks of different grades, you could take a hike from central New York State eastward into central Massachusetts in the eastern United States. Your path starts in a region where rocks were not metamorphosed, and it takes you into the internal part of the Appalachian Mountain belt, where rocks were intensely metamorphosed. Metamorphic Facies In the early years of the 20th century, geologists working in Scandinavia, where erosion by glaciers has left beautiful, nearly unweathered exposures of rocks once buried very deeply in the crust, came to realize that metamorphic rocks, in general, do not consist of a hodgepodge of minerals formed at different times and in different places, but rather consist of a distinct set of minerals that grew in association with each other at a certain pressure and temperature. It seemed that such mineral assemblages more or less represent a condition of chemical equilibrium, meaning that the chemicals making up the rock had organized into a group of mineral grains that were to anthropomorphize a bit comfortable with each other and their surroundings, and thus did not feel the need to change further. A metamorphic facies is a set of metamorphic mineral assemblages indicative of a certain range of pressure and temperature. Geologists recognize several facies, of which the major ones are zeolite, hornfels, greenschist, amphibolite, blueschist, eclogite, and granulite. The names of the different facies are based on a distinctive feature or mineral found in some of the rocks of the facies. The common metamorphic facies. The boundaries between the facies are depicted as wide bands because they are gradational and approximate. Note that some amphibolite-facies rocks and all granulite-facies rocks form only if the protolith is dry. We can represent the approximate conditions under which metamorphic facies formed by using a pressure temperature graph figure above. Each area on the graph, labeled with a facies name, represents the approximate range of temperatures and pressures in which mineral assemblages characteristic of that particular facies form. For example, a rock subjected to the pressure and temperature at Point A 4. We can also portray the geothermal gradients of different crustal regions on the graph. Beneath mountain ranges, for example, the geothermal gradient passes through the zeolite, greenschist, amphibolite, and granulite facies. In contrast, in the accretionary prism that forms at a subduction zone, temperature increases slowly with increasing depth, so blueschist assemblages can form. Stephen Marshak Essentials of Geology.

## Chapter 6 : Metamorphic Rocks: Formation, Types and Examples | Earth Eclipse

*Metamorphic rocks (meta =change and morphos =form) are one of the three rocks in the rock cycle and represent material that has been changed due to heat, pressure, and/or fluids. The rock cycle shows that both igneous and sedimentary rocks can become metamorphic rocks.*

These minerals, known as index minerals , include sillimanite , kyanite , staurolite , andalusite , and some garnet. Other minerals, such as olivines , pyroxenes , amphiboles , micas , feldspars , and quartz , may be found in metamorphic rocks, but are not necessarily the result of the process of metamorphism. These minerals formed during the crystallization of igneous rocks. They are stable at high temperatures and pressures and may remain chemically unchanged during the metamorphic process. However, all minerals are stable only within certain limits, and the presence of some minerals in metamorphic rocks indicates the approximate temperatures and pressures at which they formed. The change in the particle size of the rock during the process of metamorphism is called recrystallization. For instance, the small calcite crystals in the sedimentary rock limestone and chalk change into larger crystals in the metamorphic rock marble ; in metamorphosed sandstone, recrystallization of the original quartz sand grains results in very compact quartzite, also known as metaquartzite, in which the often larger quartz crystals are interlocked. Both high temperatures and pressures contribute to recrystallization. High temperatures allow the atoms and ions in solid crystals to migrate, thus reorganizing the crystals, while high pressures cause solution of the crystals within the rock at their point of contact. Foliation geology The layering within metamorphic rocks is called foliation derived from the Latin word folia, meaning "leaves" , and it occurs when a rock is being shortened along one axis during recrystallization. This causes the platy or elongated crystals of minerals, such as mica and chlorite , to become rotated such that their long axes are perpendicular to the orientation of shortening. This results in a banded, or foliated rock, with the bands showing the colors of the minerals that formed them. Textures are separated into foliated and non-foliated categories. Foliated rock is a product of differential stress that deforms the rock in one plane, sometimes creating a plane of cleavage. For example, slate is a foliated metamorphic rock, originating from shale. Non-foliated rock does not have planar patterns of strain. Rocks that were subjected to uniform pressure from all sides, or those that lack minerals with distinctive growth habits, will not be foliated. Where a rock has been subject to differential stress, the type of foliation that develops depends on the metamorphic grade. For instance, starting with a mudstone , the following sequence develops with increasing temperature: Another important mechanism of metamorphism is that of chemical reactions that occur between minerals without them melting. In the process atoms are exchanged between the minerals, and thus new minerals are formed. Many complex high-temperature reactions may take place, and each mineral assemblage produced provides us with a clue as to the temperatures and pressures at the time of metamorphism. Metasomatism is the drastic change in the bulk chemical composition of a rock that often occurs during the processes of metamorphism. It is due to the introduction of chemicals from other surrounding rocks. Water may transport these chemicals rapidly over great distances. Because of the role played by water, metamorphic rocks generally contain many elements absent from the original rock, and lack some that originally were present. Still, the introduction of new chemicals is not necessary for recrystallization to occur. Types of metamorphism Contact metamorphism A contact metamorphic rock made of interlayered calcite and serpentine from the Precambrian of Canada. Contact metamorphism is the name given to the changes that take place when magma is injected into the surrounding solid rock country rock. The changes that occur are greatest wherever the magma comes into contact with the rock because the temperatures are highest at this boundary and decrease with distance from it. Around the igneous rock that forms from the cooling magma is a metamorphosed zone called a contact metamorphism aureole. Aureoles may show all degrees of metamorphism from the contact area to unmetamorphosed unchanged country rock some distance away. The formation of important ore minerals may occur by the process of metasomatism at or near the contact zone. When a rock is contact altered by an igneous intrusion it very frequently becomes more indurated, and more coarsely crystalline. Many altered rocks of this type were formerly called hornstones, and the term hornfels is often used by geologists to signify those fine grained, compact, non-foliated products of contact metamorphism. A shale may become a dark argillaceous hornfels, full of tiny plates of brownish biotite ; a marl or impure limestone may change to a grey, yellow or greenish lime-silicate-hornfels or siliceous marble , tough and splintery, with abundant augite , garnet , wollastonite and other minerals in which calcite is an important component. A diabase or andesite may become a diabase hornfels or andesite hornfels with development of new hornblende and biotite and a partial recrystallization of the original feldspar. Chert or flint may become a finely crystalline quartz rock; sandstones lose their clastic structure and are converted into a mosaic of small close-fitting grains of quartz in a metamorphic rock called quartzite. If the rock was originally banded or foliated as, for example, a laminated sandstone or a foliated calc- schist this character may not be obliterated, and a banded hornfels is the product; fossils even may have their shapes preserved, though entirely recrystallized, and in many contact-altered lavas the vesicles are still visible, though their contents have usually entered into new combinations to form minerals that were not originally present. The minute structures, however, disappear, often completely, if the thermal alteration is very profound. Thus small grains of quartz in a shale are lost or blend with the surrounding particles of clay, and the fine ground-mass of lavas is entirely reconstructed. By recrystallization in this manner peculiar rocks of very distinct types are often produced. Thus shales may pass into cordierite rocks, or may show large crystals of andalusite and chiastolite , staurolite , garnet , kyanite and sillimanite , all derived from the aluminous content of the original shale. A considerable amount of mica both muscovite and biotite is often simultaneously formed, and the resulting product has a close resemblance to many kinds of schist. Limestones, if pure, are often turned into coarsely crystalline marbles; but if there was an admixture of clay or sand in the original rock such minerals as garnet, epidote , idocrase , wollastonite, will be present. Sandstones when greatly heated may change into coarse quartzites composed of large clear grains of quartz. These more intense stages of alteration are not so commonly seen in igneous rocks, because their minerals, being formed at high temperatures, are not so easily transformed or recrystallized. In a few cases rocks are fused and in the dark glassy product minute crystals of spinel , sillimanite and cordierite may separate out. Shales are occasionally thus altered by basalt dikes , and feldspathic sandstones may be completely vitrified. Similar changes may be induced in shales by the burning of coal seams or even by an ordinary furnace. There is also a tendency for metasomatism between the igneous magma and sedimentary country rock, whereby the chemicals in each are exchanged or introduced into the other. Granites may absorb fragments of shale or pieces of basalt. Sometimes an invading granite magma permeates the rocks around, filling their joints and planes of bedding, etc. This is very exceptional but instances of it are known and it may take place on a large scale. Dynamic metamorphism Regional metamorphism, also known as dynamic metamorphism, is the name given to changes in great masses of rock over a wide area. Much of the lower continental crust is metamorphic, except for recent igneous intrusions. Horizontal tectonic movements such as the collision of continents create orogenic belts , and cause high temperatures, pressures and deformation in the rocks along these belts. If the metamorphosed rocks are later uplifted and exposed by erosion , they may occur in long belts or other large areas at the surface. Recrystallization of the rock will destroy the textures and fossils present in sedimentary rocks. Metasomatism will change the original composition. Regional metamorphism tends to make the rock more indurated and at the same time to give it a foliated, shistose or gneissic texture, consisting of a planar arrangement of the minerals, so that platy or prismatic minerals like mica and hornblende have their longest axes arranged parallel to one another. For that reason many of these rocks split readily in one direction along mica-bearing zones schists. In gneisses , minerals also tend to be segregated into bands; thus there are seams of quartz and of mica in a mica schist, very thin, but consisting essentially of one mineral. Along the mineral layers composed of soft or fissile minerals the rocks will split most readily, and the freshly split specimens will appear to be faced or coated with this mineral; for example, a piece of mica schist looked at facewise might be supposed to consist entirely of shining scales of mica. On the edge of the specimens, however, the white folia of granular quartz will be visible. In gneisses these alternating folia are sometimes thicker and less regular than in schists, but most importantly less micaceous; they may be lenticular, dying out rapidly. Gneisses also, as a rule, contain more feldspar than schists do, and are tougher and less fissile. Contortion or crumbling of the foliation is by no means uncommon; splitting faces are undulose or puckered. Schistosity and gneissic banding the two main types of foliation are formed by directed pressure at elevated temperature, and to interstitial movement, or internal flow arranging the mineral particles while they are crystallizing in that directed pressure field. Rocks that were originally sedimentary and rocks that were undoubtedly igneous may be metamorphosed into schists and gneisses. If originally of similar composition they may be very difficult to distinguish from one another if the metamorphism has been great. A quartz-porphyry , for example, and a fine feldspathic sandstone, may both be metamorphosed into a grey or pink mica-schist.

## Chapter 7 : Rocks: Pictures of Igneous, Metamorphic and Sedimentary Rocks

*In metamorphic rocks some or all of the minerals in the original rock are replaced, atom by atom, to form new minerals. Types of metamorphic rocks include gneiss, quartzite, marble, schist, soapstone, and phyllite.*

List of top sixteen metamorphic rocks: Slate is formed from low grade regional metamorphism of fine grained sedimentary mudrocks. It is a homogeneous fine grained rock which can be split into thin or thick sheets with relatively smooth surfaces. The presence of these parallel planes of weakness makes this rock distinct from original sedimentary bedding. Fossils may be preserved though they may be deformed or replaced by pyrite. When subjected to additional heat during contact with large igneous intrusions, additional minerals like andalusite can give the slate a spotted appearance. Since slate is very resistant to weathering it tends to be exposed in rough and craggy hills and breaks as brittle splinters along its cleavage planes. Due to its high resistance to weathering it is used for roofing. Tiles can be quarried, split and installed on roofs easily and hence it is an inexpensive building material. Another popular use is for writing slates and blackboards. It has also been used for the tops of billiards tables where weight and flatness are essential. Slate quarries produce table tops and floor tiles. At some locations coloured slate occurs in red, brown, green and yellow often with attractive streaking and texture. The grey and black colours are generally due to carbonaceous material in the original rock, the carbon compounds having changed to graphite. The red and purple shades are due to iron and manganese oxides and the green colour due to ferrous iron silicates. Mica, Chlorite, Quartz, Feldspar Other minerals: Dark grey, Greenish, Bluish grey Textural features: Even textured rock with distinctive uniform cleavage can split to thin flakes. Schists are foliated metamorphic rocks of medium to coarse texture. They are recognized by their strong foliation and ease of parting. The mineral grains are generally large enough to be seen with the naked eye. This rock often has a flaky plate-like appearance. This rock represents metamorphosed shale or basaltic rock and is largely formed from minerals that grow during metamorphism such as muscovite mica and the semiprecious mineral garnet. Schists are the product of the same processes of rock flow and recrystallization that produce slates, but carried to a higher degree. While in slates, the foliation is called Slaty cleavage, the foliation of schists is called Schistosity. Slaty cleavage and Schistosity differ only in perfection and size of grains. The perfection of schistosity varies. In some schists it is excellent while in some it is relatively poor. The schists which show most perfect foliation are those with the highest proportion of the micas. The common minerals whose dimensional parallelism determines schistosity are muscovite, biotite, chlorite and hornblende. Quartz is present in most schists but feldspars is present only in subordinate amount. Schists are of little use. They are weak due to foliation. Due to the high mica content schists may weather to subdued landscapes. There are many varieties of schists based on the minerals. Mica Schist containing abundant muscovite, biotite or chlorite is the usually recognized type which shows shiny surfaces if broken. Garnet-mica schist is a variety which is dark red or brownish. Platy minerals like Mica, Chlorite, Amphibole or Talc. Pale grey, Greenish Textural features: Parallel fabric of platy minerals â€" Rock cleaves into platy pieces. Phyllite is a finely laminated, finely micaceous rock of nearly uniform composition, with a distinct silky lustre on the foliation surfaces. It contains a number of other flaky minerals whose parallel alignment produces sheets-like foliation. It differs from slate by its lustre, due to the presence of crystalline mica flakes. The tiny glistening flakes of mica can be seen on close observation. The mineralogy of phyllite is similar to that of slate and the rock is a product of more intense and longer continued metamorphism. Mica, Quartz Other minerals: Biotite, Feldspar, Chlorite, Graphite Colour: Pale silvery grey, Pale greenish Textural features: Even textured rock Flaky Sericite wraps around other granular crystals, strong alignment and fine-scale wavy fabric. Phyllites have little use. They are too soft for crushed stone and too weak for structural uses. Gneiss is a banded metamorphic rock of medium to coarse texture and commonly with some degree of foliation or schistosity. Most gneisses are coarser than most schists and carry considerable feldspar. The alternating bands or layers are commonly of unlike mineral composition. In most gneisses, feldspar is a prominent constituent. In many cases, the presence of large feldspar crystals serves to distinguish a gneiss from a schist. There are many varieties of gneiss corresponding to several modes of origin. The bands of the rock are generally of contrasting mineral composition. The banding may be due to differences in the original sedimentary rock, due to segregation and recrystallization of the material of igneous rocks or due to a crude foliation resulting from shearing and recrystallization. Feld spathic or granitic material introduced along bedding or foliation planes or vein material similarly introduced or segregated form gneisses. During the movement under very high pressure, the feldspar crystals of a granite may be forced to rotate so that they are made to lie with their long axes aligned in the direction of least pressure. The micas too are recrystallized and made to lie with their leaves parallel to the long axes of the crystals. Gneisses also have been formed from arkose sands by the granulation and cementation of the fragments of feldspar and other minerals that make up the sands. Some gneisses are used as building and dimension stone. If foliation is not strong it may be used for crushed stone. Generally this rock is not widely used. Many gneisses are rich in biotite. Strong preferred orientation of the biotite leads to a preferred breaking direction. It is named according to the characteristic mineral like garnet gneiss, cordierite gneiss etc. It is also named by textural features like augen gneiss, which are eye shaped large alkali feldspar crystals. Alkali feldspar, Plagioclase, Quartz, Biotite. Hornblende, Garnet, Muscovite, Sillimanite. Prominent discontinuous banding due to repeated variation in proportion of dark and light minerals. Quartzites are metamorphic rocks of sedimentary origin composed largely or wholly of quartz. These rocks are derived from quartz sandstones and siltstones and differ from them in their crystallinity and strength. They are formed by both thermal as well as dynamic metamorphism. A third type of origin of quartzites may also be noted. In the course of cementation by silica, quartz sandstones or siltstones may become so completely cemented with quartz that porosity is practically eliminated. The crystalline quartz precipitated as cement between quartz fragments of the sediment is as strong as the grains it crystallized against. Thus the rock becomes a real quartzite. Because quartzite is very resistant to erosion and rarely supports vegetation, it forms exposed rocky landscapes and rugged ridges. It can often be seen in road cuts, stream channels and on hill tops and usually stands out from the intervening schists. Pure quartzite, containing more than 97 per cent silicon dioxide is used to make silica firebrick and other refractories. High silica content quartzite if crushed and ground may be used in fillers and abrasives as a substitute for quartz taken from sedimentary rocks. Any rock forming minerals â€” Feldspar, Mica, Chlorite, Garnet. White, Grey, Brownish, Reddish Textural features: Acid Metamorphic Rock 6. It is produced by contact as well as dynamic metamorphism. Marbles range in texture from fine to relatively coarse varieties in which the grains are clearly visible to the unaided eye. Marble is more compact than limestone since its porosity is reduced by pressure and recrystallization. Pure marble is white but impurities may give it a variety of colours. Due to presence of varying proportions of iron, red, yellow and brown marbles are present. Carbonaceous organic matter produces black and grey colours. Serpentine and chlorite give green colour to marble. Marble develops smooth, sometimes grooved, weathered surfaces and is sparkling or granular in broken surfaces. Its even strength makes it a popular stone for buildings and ornamental purposes. It has long been valued as a stone for sculpting. It can be distinguished from limestone by its lack of cavities, lack of fossils and coarse grained texture of shining calcite grains. Marbles are also used for floor blocks, walls, columns, stairways and counters Marble is also used as a source for lime and it is pulverised for whiting.

## Chapter 8 : Rock (geology) - Wikipedia

*Metamorphic rock, any of a class of rocks that result from the alteration of preexisting rocks in response to changing environmental conditions, such as variations in temperature, pressure, and mechanical stress, and the addition or subtraction of chemical components.*

Identify and describe the three principal agents of metamorphism. Describe what recrystallization is and how it affects mineral crystals. Explain what foliation is and how it results from directed pressure and recrystallization. Explain the relationship among slate, phyllite, schist and gneiss in terms of metamorphic grade. Explain how metamorphic facies relate to plate tectonic processes. The rock cycle shows that both igneous and sedimentary rocks can become metamorphic rocks. This is why metamorphic rocks are important. They can record how long-term tectonic processes shape our planet. Rock cycle showing the five materials such as igneous rocks and sediment and the processes by which one changes into another such as weathering. The changes in composition and texture occur without melting the rock. In general, the chemistry of the protolith can be changed by heat, a type of pressure called confining pressure, and fluids. While the texture is changed by a type of pressure called directed stress. The following sections will discuss each metamorphic process in more detail. This may be the heat of a body of igneous rock trapped within a volcano, or the heat of ocean water. On the other hand, temperature is the measure of the vibrational kinetic energy of a substance. Therefore, as the temperature of a body increases, the vibrational energy rises. At the atomic scale, high temperatures cause atoms in the crystal structure to vibrate so vigorously that the atoms can jump from one position to another in the crystal. So, temperature can affect the chemical makeup of minerals in a rock by affecting the chemical equilibrium, or balance of cations in minerals. Since temperature increases with increasing depth with the Earth geothermal gradient , metamorphic rocks are affected by depth and these rocks can record these temperature changes within their minerals. Metamorphic rocks lie in between sedimentary rocks and magma in the rock cycle diagram above. However, the temperature at which a mineral melts is dependent on the pressure. Pressure Pressure is the force exerted over a unit area on a material. Like heat, pressure can affect the chemical equilibrium. The pressure that affects metamorphic rocks can be grouped into confining pressure and directed stress. Strain is the result of this stress, including metamorphic changes within minerals. Confining Pressure Difference between pressure and stress and how they deform rocks. Under directed stress, some stress directions forces are stronger than others, and this can deform rocks. When pressure is exerted from rocks above, it is balanced from below and sides, and is called confining or lithostatic pressure. These chemical reactions will cause new minerals to form. Confining pressure is measured in bars and ranges from 1 bar at sea level to around 10, bars at the base of the crust. Directed Stress Pebbles in quartzite deformed by directed stress Directed stress, or differential or tectonic stress, is an unequal balance of forces on a rock in one or more directions see figure above. In contrast to confining pressure that cause chemical reactions, the magnitudes of directed stress are much lower and do not cause chemical reactions to occur. Directed stresses are ultimately caused by the physical motion of large-scale plates of lithosphere. Most importantly, while minerals are being mechanically manipulated, they are not melted, and do not need to change chemically or compositionally at all. Just the arrangement of crystals. This mineral arrangement is called texture such as foliations and lineations discussed below. An igneous rock granite left and foliated high-temperature and high-pressure metamorphic rock gneiss right illustrating a metamorphic texture. Peter Davis Directed stresses can produce rock textures in many ways. Stress can cause minerals to rotate and change their orientation in space, reduce their grain-size by physically breaking them, can deform their shape, and can make minerals actually grow in size. These processes rely on the fact that minerals can change shape through recrystallization. Dissolution recrystallization occurs when a mineral responds to a directed stress by dissolving from the part of a mineral with the highest stress and precipitates or regrows on a surface with lower stress. Rocks can also recrystallize to make their grain-size larger, much like soap bubbles that increase in size by absorbing smaller adjacent bubbles. Rocks can also recrystallize by allowing the grain-size to reduce, but not allow the rock to break. In this case rocks deform much like silly putty, and are very important in understanding how rock faults work in the deep earth. These reactive fluids are made of mostly water $H_2O$ and carbon dioxide $CO_2$ , and smaller amounts of elements such as potassium K , sodium Na , iron Fe , magnesium Mg , calcium Ca , and aluminum Al. These fluids react with minerals in the protolith causing compositional changes because the fluid is out of chemical equilibrium with the minerals. This is similar to equilibrium reactions driven by heat and pressure discussed above. This process uses elements from the existing chemistry of the protolith or new elements from the fluids to contribute to the growth of new minerals. One example of a compositional change is emplacement of economically important mineral deposits and ores in veins surrounding magma bodies. For example, the mining districts in the Cottonwood Canyons and Mineral Basin of northern Utah resulted from the Little Cottonwood Stock granite intruding limestone and dolostone country rock. The circulating fluids easily react or dissolve the limestone and precipitate minerals such as gold native element , argentite silver sulfide , galena lead sulfide , and chalcopyrite copper iron sulfide. General alteration of surrounding rocks by these hot fluids is called hydrothermal metamorphism and accompanies igneous activity wherever it occurs. This process is discussed in detail in Chapter  An example of hydrothermal fluids that remove elements rather than deposit them are mid-ocean spreading centers where new crust is forming and interacting with seawater. As seawater circulates down through fractures in the fresh basalt, fractures act like a channel system that allows seawater to interact with the hot basalt and picks up ion in solution. Deposits from black smokers include ores of important metals. Ancient black smokers are responsible for copper ores mined on Cyprus as early as BCE and later by the Romans , an important contribution to the development of human civilization.

## Chapter 9 : Types of Metamorphic Rocks ~ Learning Geology

*Metamorphic rock structure is either foliated (has a definite planar structure) or nonfoliated (massive, without structure). Foliated Metamorphic Rocks Slate: Slate is fine grained, dense, and brittle and is a metamorphosed form of shale.*

Rocks are composed of grains of minerals, which are homogeneous solids formed from a chemical compound arranged in an orderly manner. The types and abundance of minerals in a rock are determined by the manner in which it was formed. Many rocks contain silica SiO2 ; a compound of silicon and oxygen that forms This material forms crystals with other compounds in the rock. The proportion of silica in rocks and minerals is a major factor in determining their names and properties. These physical properties are the result of the processes that formed the rocks. This transformation produces three general classes of rock: Those three classes are subdivided into many groups. There are, however, no hard-and-fast boundaries between allied rocks. By increase or decrease in the proportions of their minerals, they pass through gradations from one to the other; the distinctive structures of one kind of rock may thus be traced gradually merging into those of another. Hence the definitions adopted in rock names simply correspond to selected points in a continuously graduated series. Igneous rock Sample of igneous gabbro Igneous rock derived from the Latin word igneus, meaning of fire, from ignis meaning fire is formed through the cooling and solidification of magma or lava. Typically, the melting of rocks is caused by one or more of three processes: Igneous rocks are divided into two main categories: A common example of this type is granite. Volcanic or extrusive rocks result from magma reaching the surface either as lava or fragmental ejecta, forming minerals such as pumice or basalt. Most major igneous rocks are found along this scale. Granites and similar rocks, known as meta-granitoids, form much of the continental crust. These have diverse properties, depending on their composition and the temperature and pressure conditions in which they were formed. This process causes clastic sediments pieces of rock or organic particles detritus to settle and accumulate, or for minerals to chemically precipitate evaporite from a solution. The particulate matter then undergoes compaction and cementation at moderate temperatures and pressures diagenesis. Before being deposited, sediments are formed by weathering of earlier rocks by erosion in a source area and then transported to the place of deposition by water , wind , ice , mass movement or glaciers agents of denudation. Sedimentary rocks form under the influence of gravity and typically are deposited in horizontal or near horizontal layers or strata and may be referred to as stratified rocks. A small fraction of sedimentary rocks deposited on steep slopes will show cross bedding where one layer stops abruptly along an interface where another layer eroded the first as it was laid atop the first. Metamorphic rock Metamorphic banded gneiss Metamorphic rocks are formed by subjecting any rock typeâ€" sedimentary rock , igneous rock or another older metamorphic rockâ€"to different temperature and pressure conditions than those in which the original rock was formed. This process is called metamorphism , meaning to "change in form". The result is a profound change in physical properties and chemistry of the stone. The original rock, known as the protolith , transforms into other mineral types or other forms of the same minerals, by recrystallization. An intrusion of magma that heats the surrounding rock causes contact metamorphismâ€"a temperature-dominated transformation. Pressure metamorphism occurs when sediments are buried deep under the ground; pressure is dominant, and temperature plays a smaller role. This is termed burial metamorphism, and it can result in rocks such as jade. Where both heat and pressure play a role, the mechanism is termed regional metamorphism. This is typically found in mountain-building regions. Those that possess a texture are referred to as foliated ; the remainders are termed non-foliated. The name of the rock is then determined based on the types of minerals present. Schists are foliated rocks that are primarily composed of lamellar minerals such as micas. A gneiss has visible bands of differing lightness , with a common example being the granite gneiss. Other varieties of foliated rock include slates , phyllites , and mylonite. Familiar examples of non-foliated metamorphic rocks include marble , soapstone , and serpentine. This branch contains quartzite â€"a metamorphosed form of sandstone â€"and hornfels.