

Read the chapter on metamorphic rocks before you begin

Metamorphic minerals

The first two minerals to learn are low grade metamorphic minerals, both of which are **green**. *Epidote* is common in metamorphosed basalt (known as greenstone), as well as in veins and joint fillings in some granitic rocks. *Chlorite* (a mica) is a common low-grade index mineral of both shale and basalt protoliths.

1. Identify these two green minerals from sample numbers 23 -28 in *drawer 1* (25 is dolomite) _____ epidote (1 cleavage, hardness = 6-7) _____ chlorite (1 cleavage, hardness = 2)

Examine **sample A** from the tray in the lab. This rock is called "unakite," which in this case is a granitoid rock from the Blue Ridge that has been hydrothermally altered.

2. What is the metamorphic mineral that unakite contains? _____
3. What does hydrothermal metamorphism entail? _____
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Three common metamorphic minerals that show increasing metamorphic grade, and two of which have the same chemistry but different crystal form (polymorphs) due to changes required by pressure and temperature, are: **Staurolite** forms during medium-grade metamorphism. It generally has a resinous luster, red-brown to brown color, and is often found in X or cross-shaped twins. **Kyanite** is usually found in long, tabular crystals, displays 1 perfect plane of cleavage, and has a blue color. It is only stable in high-pressure, low-temperature conditions and is a good indicator of blueschist facies metamorphism. **Sillimanite** is a polymorph of kyanite that is stable at high pressures and temperatures. It has a vitreous luster and generally forms white slender white crystals that are often aligned in parallel groups. These minerals occur during moderate to high grade metamorphism. See examples in the tray then try your hand at the samples below.

4. Identify each of the following three minerals in your drawer and the grey tray.

Sample 26 _____ Sample 28 _____ Sample B _____

5. Look at Sample C from the supplemental tray. This sample features large *porphyroblasts* of the mineral garnet.

--Which of your minerals from the 1st minerals lab is garnet? _____

--Identify by number which sample (23-28) is the euhedral garnet crystal. _____

What is a porphyroblast? (Check your book for a definition.) What samples in the metamorphic rock drawer (samples 70-82) have porphyroblasts?

porphyroblast containing sample (s) _____

Metamorphic rocks

A major division of metamorphic rocks depends on the presence of *foliation*. Foliation is defined as a set of flat or wavy planes that form during deformation. These planes are not necessarily parallel to original bedding, and often can be identified by ease of fracture or change in mineralogy. Rocks that lack a foliation are referred as *granoblastic*.

6. Identify whether each of the rocks in the metamorphic drawer are foliated or non-foliated.

Foliated _____ Non-foliated _____

Granoblastic (non-foliated) metamorphic rocks

Granoblastic rocks form in the absence of a foliation-producing deformation, and therefore are often the product of burial or contact metamorphism. They have equant crystals, cubes or spheres, rather than platy or elongate shapes. Increase of grain size and mineralogical changes do occur. Some granoblastic rocks do form under differential pressure, but a homogenous mineralogy prevents the development of foliation.

Granoblastic metamorphic rocks

Parent rock (protolith)	Metamorphic rock	Comments
Limestone	Marble	Often shows a "swirly" texture; pyrite is common
Quartz sandstone	Quartzite	Breaks <i>through</i> grains, not around them
Basalt (or gabbro)	Greenstone	Low grade; contains epidote and chlorite; also can be foliated
Any Rock	Hornfels	Contact metamorphism; original minerals replaced by epidote, staurolite, chlorite, etc
Basalt or Shale	Blueschist	High-P, low-T metamorphism; glaucophane (green) for basalt or kyanite for sediments: may be weakly foliated
Limestone	Skarn*	Calcite plus silicate minerals; variously colored; generally formed by hydrothermal metamorphism
Coal	Anthracite*	Hard, silvery, breaks in conchoidal fracture

*Not present in sample drawers

Marble can be distinguished from limestone by the increased size of the crystals and the deformed bedding. Quartzite is distinguished from marble by hardness and from quartz arenite sandstone by its tendency to break through grains – in contrast to a sandstone breaking around the grains – the cement in a quartzite is just as hard as the grains themselves.

7. Examine the samples D through G and determine the rock name.

D. _____ E. _____ F. _____ G. _____

8. Identify by number and name five granoblastic samples in the metamorphic rocks drawer.

1. _____ 2. _____ 3. _____
4. _____ 5. _____

Foliated metamorphic rocks

These rocks are characterized by the alignment of mineral grains perpendicular to the direction of the maximum stress. Thus, the mica and amphibole minerals make textural and color variations apparent. As metamorphic grade increases, the grain size tends to increase until quartz begins to melt.

Foliated metamorphic rocks with a shale protolith

Rock name	Description
Slate	Black to green; breaks in thin planar layers not necessarily along bedding; slaty rock cleavage
Phyllite	Shiny or velvety looking; mica grains just visible by eye; non-parallel planes of fracture
Schist	Large mica grains often in wavy layers; commonly contains garnet and other minerals
Gneiss	Alternating layers of white minerals (quartz and feldspar) and ferromagnesian minerals (biotite, hornblende); banding is often distorted or folded

Note: the rock names of schist and gneiss should be modified to include the major mineral (e.g., a “biotite schist”) or an important indicator mineral if one exists (e.g., a “garnet gneiss”)

Foliated metamorphic rocks with a mafic protolith

Rock name	Description
Greenstone	Black to green; breaks in thin planar layers not necessarily along bedding; slaty rock cleavage; forms at low-grade metamorphic conditions
Amphibolite*	Rock dominated by hornblende and plagioclase; can be foliated or granoblastic ; forms at medium-grade metamorphic conditions
Eclogite*	Coarse grained rock that often contains garnet porphyroblasts and a bright green pyroxene; granoblastic texture; formed at low temperatures and very high pressures that indicate an origin from mantle depths

9. Put the foliated samples from the metamorphic rock drawer and arrange them in order of increasing metamorphic grade. This means the samples should increasingly large grain size and degree of mineral segregation. Now, name each of the samples. Some are “on the fence” between two types; use your best judgment. (Note that all of these samples have a shale protolith.)

Slate _____

Phyllite _____

Schist _____

Gneiss _____

Deformation

Metamorphism is often accompanied by deformation of previous sedimentary layering or other rock features. *Ductile deformation* results in bending and folding as the atoms rearranged themselves to accommodate the pressure. *Brittle deformation* occurs in stronger rocks or at lower temperatures and results in the formation of breaking and crushing. Fractures that result from brittle deformation can often be transformed into *veins* by the precipitation of minerals from fluids traveling through the fractures.

10. Look at samples H and I in the supplemental rock tray. Indicate whether each sample experienced *ductile* or *brittle* deformation

Sample H _____

Sample I _____

Answers:

1. 23 = epidote (often brighter green, like olivine), 24 = chlorite
2. epidote
3. A change of the chemical and mineralogical composition of a rock due to water-rock interactions driving by nearby intrusions or fluid migration during tectonics.
4. 26 = kyanite, 28 = staurolite, B = sillimanite
5. A porphyroblast is a large crystal surrounded by finer-grained minerals in a metamorphic rock. They grow as metamorphism proceeds.
 - mineral from drawer one = 20 (Garnet)
 - euhedral crystal sample = 27 (a garnet called "almandine")
 - Samples with porphyroblasts: 70
6. Foliated Samples = 70, 71, 72, 74, 75, 76, 77, 80
Granoblastic (non-foliated) = 73, 78, 79, 81, 82
7. D. marble E. greenstone F. quartzite G. antracite
8. 73 = quartzite, 78 = greenstone, 79 = marble, 81 = hornfels (epidote bearing),
82 = blueschist
9. 74 = slate
71 = phyllite
70 = garnet schist, 72 = schist, 80 = schist
75 = gneiss, 76 = gneiss, 77 = gneiss
10. Sample H shows brittle deformation caused by fracturing and filling of dikes.
Sample I shows ductile deformation of the gneiss banding.