

Examination of Igneous and metamorphic petrology (331 G) for the third level students (Geology & Chemistry), Jan. 2016.

Igneous Rocks

Answer two questions only from the following:

1- Discuss the following points:

(12 Marks)

(a) The general characteristics of igneous rocks.

Some of the main minerals in igneous rocks are feldspar, quartz, olivine and mica. The size of the minerals depends on the depth of the magma that formed the rock. Deeper magma cools more slowly and forms larger crystals. Rocks that cool over a few months have microscopic mineral grains and are called extrusive. Rocks that cool over thousands of years have small to medium grains and are called intrusive. Rocks that cool over millions of years have large pebble sized grains and are called plutonic.

Granite and basalt make up the majority of igneous rocks. Basalt is dark and fine-grained with minerals rich in magnesium and iron. It is either extrusive or intrusive and is the primary rock on the ocean floor. Granite is light and coarse-grained and rich in feldspar and quartz. It is plutonic and less dense than basalt. Granite is found nearly everywhere beneath the continents.

The word "igneous" comes from the Latin word "fire" and is related to the melting process that forms these rocks.

(b) Textures and structures of gabbroid rocks.

Ophitic texture - laths of plagioclase in a coarse grained matrix of pyroxene crystals, wherein the plagioclase is totally surrounded by pyroxene grains. This texture is common in diabases and gabbros.

Subophitic texture - similar to ophitic texture wherein the plagioclase grains are not completely enclosed in a matrix of pyroxene grains.

Poikilitic texture - smaller grains of one mineral are completely enclosed in large, optically continuous grains of another mineral.

Intergranular texture - a texture in which the angular interstices between plagioclase grains are occupied by grains of ferromagnesium minerals such as olivine, pyroxene, or iron titanium oxides.

Intersertal texture - a texture similar to intergranular texture except that the interstices between plagioclase grains are occupied by glass or cryptocrystalline material.

Hyalophitic texture - a texture similar to ophitic texture except that glass completely surrounds the plagioclase laths.

Hyalopilitic texture - a texture wherein microlites of plagioclase are more abundant than groundmass, and the groundmass consists of glass which occupies the tiny interstices between plagioclase grains.

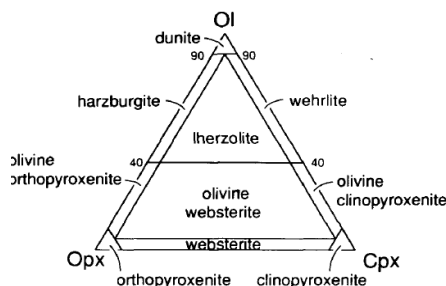
Coronas or reaction rims - often times reaction rims or coronas surround individual crystals as a result of the crystal becoming unstable and reacting with its surrounding crystals or melt. If such rims are present on crystals they should be noted in the textural description.

Patchy zoning - This sometimes occurs in plagioclase crystals where irregularly shaped patches of the crystal show different compositions as evidenced by going extinct at angles different from other zones in the crystal.

Oscillatory zoning - This sometimes occurs in plagioclase grains wherein concentric zones around the grain show thin zones of different composition as evidenced by extinction phenomena.

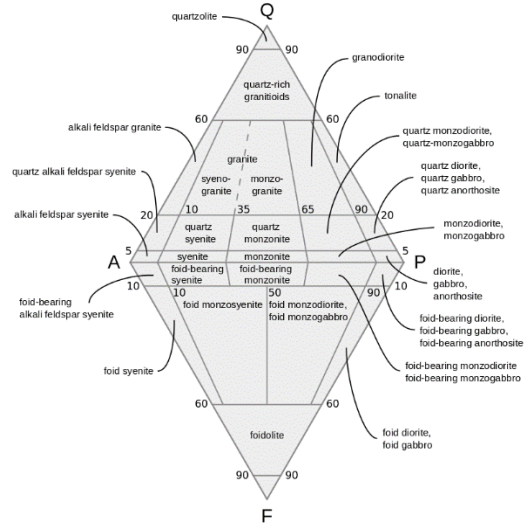
Moth eaten texture (also called *sieve texture*) - This sometimes occurs in plagioclase wherein individual plagioclase grains show an abundance of glassy inclusions.

2- Explain the Streckeisen's classification of the ultramafic rocks, when they consist mainly of olivine, orthopyroxene and clinopyroxene? (12 Marks)



- 3- Write in detail about the four types of granitoid rocks?
 Granite is classified according to the QAPF diagram for coarse grained plutonic rocks and is named according to the percentage of quartz, alkali feldspar (orthoclase, sanidine, or microcline) and plagioclase feldspar on the A-Q-P half of the diagram. True granite according to modern petrologic convention contains both plagioclase and alkali feldspars. When a granitoid is devoid or nearly devoid of plagioclase, the rock is referred to as alkali feldspar granite. When a granitoid contains less than 10% orthoclase, it is called tonalite; pyroxene and amphibole are common in tonalite. A granite containing both muscovite and biotite micas is called a binary or two-mica granite. Two-mica granites are typically high in potassium and low in plagioclase, and are usually S-type granites or A-type granites.

(12 Marks)



Metamorphic Rocks

Answer the following questions.

- 1- Write short notes about the followings

(Marks)

- (a) Different types of metamorphism.

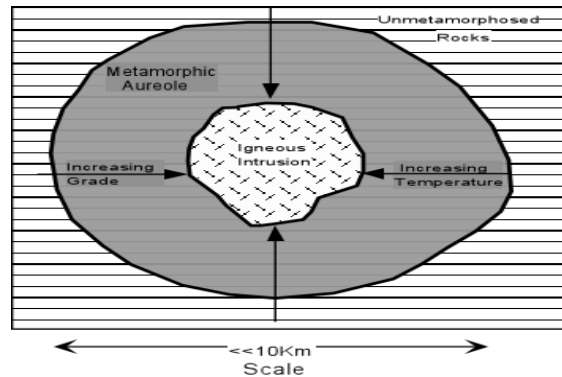
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Types of Metamorphism

Contact Metamorphism

Contact metamorphism occurs adjacent to igneous intrusions and results from high temperatures associated with the igneous intrusion.

Since only a small area surrounding the intrusion is heated by the magma, metamorphism is restricted to the zone surrounding the intrusion, called *ametamorphic* or *contact aureole*. Outside of the contact aureole, the rocks are not affected by the intrusive event. The grade of metamorphism increases in all directions toward the intrusion. Because the temperature contrast between the surrounding rock and the intruded magma is larger at shallow levels in the crust where pressure is low, contact metamorphism is often referred to as high temperature, low pressure metamorphism. The rock produced is often a fine-grained rock that shows no foliation, called *hornfels*.



Regional Metamorphism

Regional metamorphism occurs over large areas and generally does not show any relationship to igneous bodies. Most regional metamorphism is accompanied by deformation under non-hydrostatic or differential stress conditions. Thus, regional metamorphism usually results in forming metamorphic rocks that are strongly foliated, such as slates, schists, and gniesses. The differential stress usually results from tectonic forces that produce compressional stresses in the rocks, such as when two continental masses collide. Thus, regionally metamorphosed rocks occur in the cores of fold/thrust mountain belts or in eroded mountain ranges. Compressive stresses result in folding of rock and thickening of the crust, which tends to push rocks to deeper levels where they are subjected to higher temperatures and pressures.

Cataclastic Metamorphism

Cataclastic metamorphism occurs as a result of mechanical deformation, like when two bodies of rock slide past one another along a fault zone. Heat is generated by the friction of sliding along such a shear zone, and the rocks tend to be mechanically deformed, being crushed and pulverized, due to the shearing. Cataclastic metamorphism is not very common and is restricted to a narrow zone along which the shearing occurred.

Hydrothermal Metamorphism

Rocks that are altered at high temperatures and moderate pressures by hydrothermal fluids are hydrothermally metamorphosed. This is common in basaltic rocks that generally lack hydrous minerals. The hydrothermal metamorphism results in alteration to such Mg-Fe rich hydrous minerals as talc, chlorite, serpentine, actinolite, tremolite, zeolites, and clay minerals. Rich ore deposits are often formed as a result of hydrothermal metamorphism.

Burial Metamorphism

When sedimentary rocks are buried to depths of several hundred meters, temperatures greater than 300°C may develop in the absence of differential stress. New minerals grow, but the rock does not appear to be metamorphosed. The main minerals

produced are often the Zeolites. Burial metamorphism overlaps, to some extent, with diagenesis, and grades into regional metamorphism as temperature and pressure increase.

Shock Metamorphism (Impact Metamorphism)

When an extraterrestrial body, such as a meteorite or comet impacts with the Earth or if there is a very large volcanic explosion, ultrahigh pressures can be generated in the impacted rock. These ultrahigh pressures can produce minerals that are only stable at very high pressure, such as the SiO₂ polymorphs coesite and stishovite. In addition they can produce textures known as shock lamellae in mineral grains, and such textures as shatter cones in the impacted rock.

(b) Different types of protoliths

Six Common Types:

1. Pelitic (shale, mudstone)
2. Quartzo-feldspathic (sandstone, rhyolite, granite, chert)
3. Calcareous (limestone, dolomite, marls)
4. Basic (basalt, andesite, gabbro, diorite)
5. Magnesian (peridotite, serpentine)
6. Ferruginous (ironstone, umbers)

1. **Pelitic Protoliths** = Rocks enriched in clay minerals

- High Al₂O₃, K₂O, lesser amounts Ca

- Micas favored because of Al content

- Also aluminosilicates: Al₂SiO₅ - sillimanite, andalusite, kyanite.

Kyanite: Highest density (smallest volume) forms at higher pressures.

Andalusite: Lowest density, largest volume, forms at low pressures.

Sillimanite: Intermediate density, volume; forms at moderate T, P.

Alumino-silicate triple point = 5.5 kb at 600°C

Wet granite solidus: Shows where anatexis occurs in sillimanite zone.

Staurolite (2*Al₂O₃*Fe(OH)₂) = Common metamorphic mineral

Need an Al and Fe-rich protolith

2. **Quartzo-feldspathic Protoliths**: High SiO₂, low Fe and Mg

- “Psammitic” is a general term for sandstone

- Quartz-rich sandstones with varying % feldspars (“arkose”)

- Felsic igneous rocks (rhyolites, tuffs, granites)

- If protolith >50% quartz then probably a sandstone or chert.

- Gneiss: Fine-grained at low grade, coarser with increasing grade.

3. **Calcareous Protoliths**: High CaO, CO₂

- Limestones and dolomite form MARBLES

- Impure limestones (with clay, silt) form Calc-silicates:

[tremolite, diopside, wollastonite, forsterite, epidote, et cetera]

4. **Basic Protoliths**: Low SiO₂ moderate CaO, MgO, FeO

- Basalts, andesites, gabbros - mafic igneous rocks.

- Some shale-limestone mixtures.

- Minerals depend on grade: chlorite, actinolite, hornblende, plagioclase, epidote, garnet.

5. **Magnesian Protoliths**: Very low SiO₂, high MgO

- Peridotites >> serpentine, magnesite.

- Serpentine (low T) >> antigorite (high T serpentine), olivine.

6. **Ferruginous Protoliths**: High Fe₂O₃

- Ironstones = Precambrian iron formations (Fe-rich cherts).

- Umbers = Fe-rich cherts, shales associated with MOR.

(c) Metamorphism of carbonate rocks

Metamorphism of pure carbonate rocks yielded calcite and/or dolomite marbles. Many marbles are composed only of calcite and/or dolomite with minor quartz and phyllosilicates, originally of detrital origin.

A- Calcite marble

The grade of metamorphism is function in grain size, where grain size increases with grade increase.

At very HP, the polymorph aragonite becomes stable and aragonite marble is known from high pressure terrains.

At HT/LP (>600°C) calcite and quartz react to produce wollastonite and CO₂. The reaction occurs only at high temperature thermal aureole, and is inhibited by high fluid pressures of CO₂.

CaCO₃ + SiO₂ → CaSiO₃ + CO₂

B- Dolomite marble

At HT/LP, dolomite marble loses CO₂ to form periclase (MgO) in condition <900 °C, and consequently reacts with water to form brucite (MgO(OH)₂). Therefore, the common result of decarbonation of dolomite or dolomitic marble is a mixture of brucite and calcite.

Quartz bearing dolomitic marbles (calcite + dolomite + quartz) develop a characteristic sequence of Ca- and/or Mg-silicate as follows:

- (i) talc

dolomite + quartz + H₂O = talc + calcite + CO₂

(ii) tremolite in the greenschist facies,

talc + calcite + quartz = tremolite + H₂O + CO₂ (quartz rich)

talc+calcite = tremolite + dolomite + CO₂ + H₂O (quartz poor)

(iii) diopside and/or forsterite in the amphibolite facies

tremolite+calcite+quartz = diopside+H₂O +CO₂

tremolite + dolomite = forsterite + calcite + H₂O + CO₂

And,

(iv) diopside + forsterite at higher grade.

tremolite + calcite = diopside + forsterite + H₂O+CO₂

Sheet-silicate impurity in calcite and dolomite marble adds variety by the following Al-bearing minerals to feature in the assemblage: typically they include zoisite, epidote and Ca-rich garnet in the greenschist facies and anorthite in the amphibolite facies.

2- Choose the best answers?

(12 Marks)

1- Which list of metamorphic facies is in order from lowest to highest grade?

D. Zeolite, greenschist, amphibolite, granulite

2- Which type of metamorphism creates the majority of metamorphic rocks?

A. regional

3- Fluid activity _____.

C. brings new ions into a rock which react to form new minerals

4- Along which type of plate boundary is metamorphism most common?

A. convergent

5- Metamorphic zones _____.

D. All of the above.

6- Metamorphic facies are groups of metamorphic rocks characterized by _____.

B. particular mineral assemblages formed under the same broad P-T conditions

7- A _____ forms at very high pressures and moderately low temperatures associated with subduction of oceanic crust and sediments.

B. Blueschist

8- During metamorphism, what is the major effect of chemically active fluids?

B. Aid in the movement of dissolved silicate constituents and facilitate growth of the mineral grains

9- In which setting would regional metamorphism be most likely?

C. At great depths in the crust where two continents are colliding

10- If you knew the metamorphic facies of a metamorphic rock (example: Zeolite), what can you deduce about the rock?

D. All of the above

11- _____ is characterized by segregation of light-and dark-colored minerals into thin layers or bands.

A. Granitic gneiss

12- Why can studying the mineral assemblage in a metamorphic rock give information about the temperature and pressure conditions under which it formed?

C. As pressure and temperature change, unstable minerals react to form minerals that are stable under the new conditions.