Benha university	**Third Level**
Faculty of science	**Geol. & chemistry**
Geology Dept.	**Igneous and Metamorphic Petrology (331G)**
10 / 1 /2017	**Time: Two Hours**

Examination of Igneous and Metamorphic petrology (331G) for the third level students (Geol & chemistry), Jan. 2017.

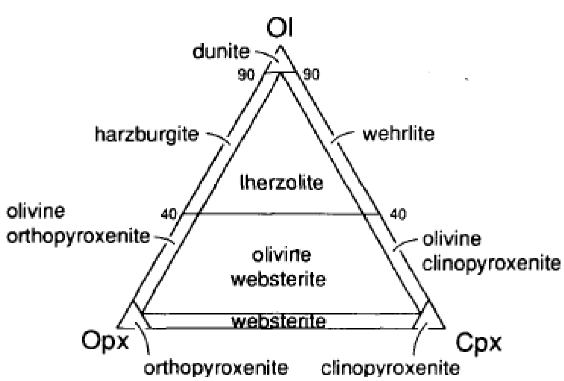
Igneous Petrology

Answer two questions only from the following:

1- What are the general characters of igneous rocks? (12 Marks)

1- Volcanoes and related lava flows.
2- Cross-cutting relations to surrounding rocks, as in dikes, veins, stocks and batholiths.
3- Thermal effects on adjacent rocks, such as recrystallization, colour changes, and reaction zone.
4- Chilled (finer-grained) borders against adjacent rocks.
5- Lack of fossils and stratification.
6- Generally, structure less rocks composed of interlocking grains.
7- Typically located in Precambrian or orogenic terranes.
8- Characterstics shapes and sizes as laccoliths, lopoliths, sills, stocks, batholiths and lava flows.
9- Have several textures such as amygdaloidal, graphic, ophtic, pyroclastic or interlocking aggregates.
10- Have characteristic minerals amphibole, feldspar, leucite, mica, nepheline olivine, pyroxene, quartz and glass.

2- Explain the Streckeisen`s classification of ultramafic rocks: when the minerals are: olivine, orthopyroxene and clinopyroxene? (12 Marks)



When the felsic minerals component falls below 10% of the mode, triangular plots involving olivine, pyroxene and hornblende satisfactorily classify the peridotitic, pyroxenitic and hornblenditic ultramafic rocks. The prefixes leuco- and mela- can be applied to all the rocks in the QAPF fields.

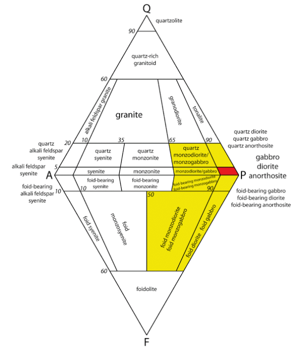
3- Write on the mineral composition and textures of gabbroic rocks? (12 Marks)

Gabbro is a dense, mafic intrusive rock. It generally occurs as batholiths and laccoliths and is often found along mid-ocean ridges or in ancient mountains composed of compressed and uplifted oceanic crust. Gabbro is the plutonic equivalent of basalt.

Group - plutonic.

Colour - dark grey to black.

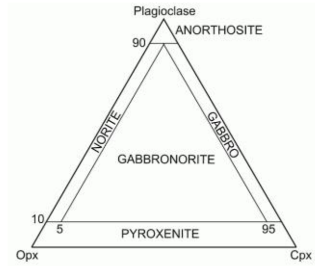
Texture - phaneritic (medium to coarse grained).



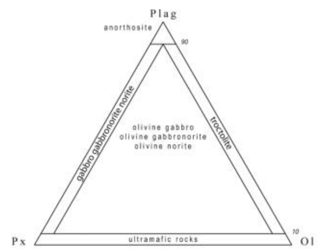
Mineral content - predominantly plagioclase and pyroxene (augite) with lesser olivine.

Silica (SiO2) content - 45%-52%.

The most important mineral groups that make up this rock type are plagioclase and pyroxene. Plagioclase usually predominates over pyroxene. Plagioclase is sodium-calcium feldspar. It contains more calcium than sodium in gabbro. If there is more sodium in the plagioclase, then the rock type is named diorite. Diorite is usually lighter in color and contains more amphiboles than pyroxenes.



“Gabbro” in the strict sense of the term is an intrusive rock that is chiefly composed of monoclinic pyroxene (clinopyroxene, abbreviated Cpx) and plagioclase. If more than 5% of Cpx is replaced with orthorhombic pyroxene (orthopyroxene, abbreviated Opx), the rock is named gabbronorite. If more than 95% of the pyroxene is Opx, then we have norite. These rocks are all collectively called gabbroic rocks. Sometimes the term “gabbro” is used loosely to include them all. Rocks that contain more than 90% pyroxene is pyroxenite. Gabbroic rocks may contain small amounts of quartz (up to 5%). If there is more quartz present, the rock must be named quartz gabbro. If quartz makes up more than 20%, then the rock is one of granitoids.



There are even more varieties possible. Olivine can be present or feldspathoids just like in basalt. Hence, rock names like nepheline-bearing gabbro or olivine norite are possible. Anorthosite and troctolite are similar rocks also. Anorthosite is almost monomineralic rock — more than 90% of the plagioclase-pyroxene pair is plagioclase. Troctolite contains mostly olivine and plagioclase, pyroxene again forms no more than 10% of the composition. Saussuritized version can be named metagabbro nowadays because its original composition has clearly been altered by metamorphism. Diallage is not defined as a mineral now, but it is monoclinic pyroxene anyway (either diopside or augite). So we can say that von Buch used the term roughly as we use it today.

Gabbros form in the crust. This is the magma that did not break to the surface to cool as a basalt. These rocks are not as widespread as granitoids, but they are definitely not rare. Gabbroic rocks are usually equigranular (composed of similarly sized grains) mixtures of black, brown or greenish pyroxene and white, gray, or greenish plagioclase. Pyroxenite and other ultramafic rocks are darker- and diorite is lighter-colored.

Metamorphic Petrology

Answer the following questions:

1- Write short notes about the following: (12 Marks)

(a) **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 Al_2O_3, K_2O, lesser amounts Ca
• Micas favored because of Al content
• Also aluminosilicates: Al_2SiO_5 - 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 600oC
Wet granite solidus: Shows where anatexis occurs in sillimanite zone.
Staurolite ($2*Al_2O_5*Fe(OH)_2$) = Common metamorphic mineral
Need an Al and Fe-rich protolith

2. Quartzo-feldspathic Protoliths: High SiO_2, 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, CO_2
• Limestones and dolomite form MARBLES
• Impure limestones (with clay, silt) form Calc-silicates:
[tremolite, diopside, wollastonite, forsterite, epidote, et cetera]

4. Basic Protoliths: Low SiO_2 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 SiO_2, high MgO
• Peridotites >> serpentine, magnesite.
• Serpentine (low T) >> antigorite (high T serpentine), olivine.

6. Ferruginous Protoliths: High Fe_2O_3
• Ironstones = Precambrian iron formations (Fe-rich cherts).

(b) **Metabasites at the greenschist and amphibolite facies conditions.**

Most of the metamorphic sequences contain mixture of sedimentary and igneous rocks. Comparable mineral assemblage in the greenschist and amphibolite of the metabasites to the metapelites include the following mineral zones:

1- **Chlorite and biotite zone**

   Metabasite in this zone may preserve the original texture, but mineral assemblage is entirely metamorphic.

   Ca-plagioclase will be replaced by albite, and a minerals Chl, Ep, pale green actinolite and quartz should be present. Biotite and calcite may be occur.

   Both epidote and actinolite could be generated through the following reaction:

   Chl + Cal Ep + Act + CO2-H2O fluid

2- **Garnet zone**

   Grt appears at lower conditions than that in the in the metapelites

   Garnets are typically Mg- and Ca-rich (slide 108).

   Mineral assemblage of this zone include: blue-green Hbl + Grt + Ca-rich Pl. In addition, biotite, chlorite and epidote could occur. Both Pl and hornblende may occur via the following reaction:

   Chl + ep + Qtz Hbl + An-Pl + H2O

3- **Staurolite and kyanite zone**

   In this zone, Bt and chl are absent

   Mineral assemblage include Green Hbl and Ca-rich plagioclase, and scarce of Epidote.

4- **Sillimanite zone**

   The rock is dominated by brownish-green hornblende and Ca-plagioclase. No epidote remain in this zone

(c) **Foliated and non-foliated metamorphic rocks**

1. FOLIATED ROCKS

In general, foliations in non-high-strain rocks are caused by orogeny and regional metamorphism, and the type of foliation varies with metamorphic grade. In order of increasing grade, they are: *Cleavage.* Traditionally: the property of a rock to split along a regular set of subparallel, closely spaced planes.

A more general concept adopted by some geologists is to consider cleavage to be any type of foliation in which the aligned platy phyllosilicates are too fine grained to see individually with the unaided eye.

Schistosity. A preferred orientation of inequaint mineral grains or grain aggregates produced by metamorphic processes.

Aligned minerals are coarse grained enough to see with the unaided eye. The orientation is generally planar, but linear orientations are not excluded.

Gneissose structure. Either a poorly developed schistosity or segregation into layers by metamorphic processes.

Gneissose rocks are generally coarse grained.

The rock names that follow from these textures are given

below. Again, these names are listed in a sequence that generally corresponds with increasing grade:

Slate. A compact, very fine-grained, metamorphic rock with a well-developed cleavage. Freshly cleaved surfaces are dull. Slates look like shales, but have a more ceramic ring when struck with a hammer.

Phyllite. A rock with a schistosity in which very fine phyllosilicates (sericite/phengite and/or chlorite), although rarely coarse enough to see unaided, impart a silky sheen to the foliation surface. Phyllites with both a foliation and lineation (typically crenulated fold axes) are very common.

Schist. A metamorphic rock exhibiting a schistosity. By this definition, schist is a broad term, and slates and phyllites are also types of schists. The more specific terms, however, are preferable. In common usage, schists are restricted to those metamorphic rocks in which the foliated minerals are coarse enough to see easily in hand specimen.

Gneiss. A metamorphic rock displaying gneissose structure. Gneisses are typically layered (also called banded), generally with alternating felsic and darker mineral layers.

Gneisses may also be lineated, but must also show segregations of felsic-mineral-rich and dark-mineral-rich concentrations.

Gneissic layers or concentrations need not be laterally continuous.

2. NON-FOLIATED ROCKS

This category is simpler than the previous one.

Again, this discussion and classification applies only to rocks that are not produced by high-strain metamorphism. A comprehensive term for any isotropic rock (a rock with no preferred orientation) is a granofels. Granofels(ic) texture is then a texture characterized by a lack of preferred orientation.

An outdated alternative is *granulite*, but this term is now used to denote very high-grade rocks (whether foliated or not) and is not endorsed here as a synonym for granofels.

A hornfels is a type of granofels that is typically very fine grained and compact, and it occurs in contact aureoles.

2- Discuss the following: (12 Marks)

(a) Contact metamorphism of argillaceous rocks

Argillaceous rocks which have undergone metamorphism are referred to as Pelites

- Low Grade – Spotted Rock
- Medium Grade – Chiastolite Rock
- High Grade – Hornfels

Argillaceous rocks undergo most change as they are composed of chemically complex clay minerals such as kaolinite, illite, smectite, bentonite and montmorillianite.

Increased temperature to 300 – 400 degrees centigrade.

Partial recrystallization occurs

New minerals occur as oval spots 2 – 5mm in diameter. Cordierite or iron oxides

Spots show sieve or poikiloblastic texture Spots have overgrown and included grains of the original argillaceous rock

Relic structures such as bedding/lamination and fossils may be evident

- Increase in temperature to 400 – 500 degrees centigrade, results in coarser grained rock
- Extensive recrystallization occurs
- Needles of chiastolite develop and show porphyroblastic texture. Up to 2cm long, 3mm in diameter, square cross section often with iron inclusions. Groundmass is mainly micas

- Needles show random orientation, having crystallised in the absence of pressure
- No relic structures are evident
- Increase in temperature 500–600 degrees centigrade, results in grain size >2mm
- Hornfels shows hornfelsic texture-a tough, fibrous and splintery-looking rock with a crystalline texture
- Andalusite often occurs as porphyroblasts
- No evidence of any relic structures

(b) Deviatoric Stress

Only when the pressure is unequal in various directions will a rock be deformed. Unequal pressure is usually called deviatoric stress (whereas lithostatic pressure is uniform stress).

Stress is an applied force acting on a rock (over a particular cross-sectional area)

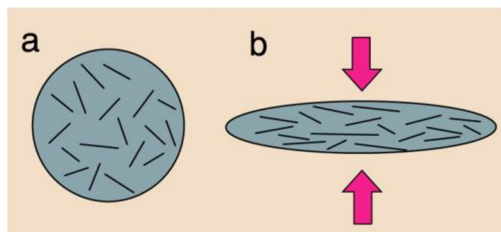
Strain is the response of the rock to an applied stress (= yielding or deformation)

Deviatoric stress can be maintained only if application keeps pace with the tendency of the rock to yield

This occur most often in orogenic belts, extending rifts, or in shear zones. (i.e. generally at or near plate boundaries)

Deviatoric stress affects the textures and structures, but not the equilibrium mineral assemblage

- We can envision deviatoric stress as being resolvable into three mutually perpendicular stress (s) components:
  s_1 is the maximum principal stress
  s_2 is an intermediate principal stress
  s_3 is the minimum principal stress



- In hydrostatic situations all three are equal
- Foliation is a common result, which allows us to estimate the orientation of s_1
- $s_1 > s_2 = s_3 \rightarrow$ foliation and no lineation
- $s_1 = s_2 > s_3 \rightarrow$ lineation and no foliation
- $s_1 > s_2 > s_3 \rightarrow$ both foliation and lineation

(c) Major mineralogical changes in the transition from greenschist to amphibolite facies.

Greenschist to amphibolite facies transition involves 2 major mineralogical changes

1. Transition from albite to oligoclase (increased Ca-content of stable plagioclase with T)
2. Transition from actinolite to hornblende (amphibole becomes able to accept increasing amounts of aluminum and alkalis at higher T)

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