
Examination of Metamorphic petrology (337 G) for the
third level students (Special Geology), Jan. 2016.

Answer the following questions.

1- Write short notes about the followings

(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 600°C

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

Staurolite ($2*Al_2O_3*Fe(OH)_2$) = 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).

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

(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:
 $\text{Chl} + \text{Cal} \rightleftharpoons \text{Ep} + \text{Act} + \text{CO}_2\text{-H}_2\text{O fluid}$
- 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. Also biotite, chlorite and epidote could occur. Both Pl and hornblende may occur via the following reaction:
 $\text{Chl} + \text{ep} + \text{Qtz} \rightleftharpoons \text{Hbl} + \text{An-Pl} + \text{H}_2\text{O}$
- 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

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

- (b) Metamorphic facies of high pressure
Blueschist facies is a high-grade metamorphic facies typified by high pressures and associated with subduction. Also name glaucophane –lawsonite facies. The rocks of related to this facies occur along the plate tectonic boundaries where the pressure is maximum (8-6 Kbar, e. g. pacific orogenic belt and along Himalaya and Alps). These rocks are rare in the Arabo Nubian shield.
The metabasalt of the ophiolitic complexes represents good representative of this facies.

Glaucophane + Lawsonite ± Phengite, Omphacite	Meta Basic Rocks
Quartz + Jadite + Lawsonite ± Phengite, Galucophane	Metagrewackes
Aragonite)	Calcereous Rocks
Phengite + Paragonite + Quartz	Meta Pellitic Rocks

- (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)

3- Choose the best answers? (14 Marks)

- 1- 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.

- 2- Which list of metamorphic foliation types is in order from lowest to highest metamorphic grade?
c) Slaty cleavage, schistosity, gneissic foliation
- 3- What would you expect to find in rocks formed through contact metamorphism?
a) Minerals that are stable at high temperatures and low pressures
- 4- A geologist concludes that a particular metamorphic rock formed at high pressure. Which feature of the rock most likely led to this conclusion?
a) It contains dense minerals.
- 5- Why is metamorphism more rapid in deeply buried rocks than in rocks closer to the surface?
c) Increasing heat and pressure increase the rate of metamorphic chemical reactions.
- 6- Sedimentary rocks and metamorphic rocks can both be found on Earth's surface. Unlike sedimentary rocks, however, most metamorphic rocks:
d) Reach Earth's surface only through uplift of deeper rocks
- 7- Isograd A is the _____ isograd
c) biotite
- 8- Zone D should contain which of the following minerals?
d) kyanite
- 9- What metamorphic facies occurs at temperatures of 400°C and pressures of 6 kilobars?
a) greenschist
- 10- Which pressure-temperature regime represents the eclogite facies?
d) area G
- 11- Which index mineral indicates the highest temperature of formation in a metamorphic rock?
Choose one: Staurolite / **Sillimanite** / Biotite.
- 12- Gneiss can be distinguished from other metamorphic rocks by:
b) its dark and light mineral bands.
- 13- Which one of the following rock types would allow analysis of metamorphic index minerals for pressure and temperature of formation?
a) Schist.
- 14- A rock that has partially melted and is thus part igneous and part metamorphic is a:
c) migmatite.

4- **Match the numbers in the figure to the metamorphic facies listed on the right** (6 Marks)

- 15- Metamorphic facies #1: E) Hornfels
- 16- Metamorphic facies #2: A) Zeolite
- 17- Metamorphic facies #3: C) Prehnitepumpellyite
- 18- Metamorphic facies #4: F) Greenschist
- 19- Metamorphic facies #5: G) Amphibolite
- 20- Metamorphic facies #6: D) Blueschist

5- **True or False?**

(4 Marks)

- 21- Contact metamorphism results from the directed pressure that exists at the region of contact between two converging plates. True or **False**?
- 22- During contact metamorphism, pressure effects are extreme. True or **False**?
- 23- Foliation refers to a consistent orientation of the mineral grains perpendicular to the direction of greatest pressure. **True** or False?
- 24- Lithostatic pressure pushes in on rocks equally from all sides, while directed pressure acts in one principal plane. **True** or False?