

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH KOLKATA
End-semester Examination, Autumn 2018

Course: ES4101 – Igneous and metamorphic petrology

Full marks: 50

Time: 3 hours

Date: 30/11/2018 FN

Instructions:

- **Section A (10 marks): Answer ALL questions.**
- **Section B (30 marks): Answer ALL questions.**
- **Section C (10 marks): Answer 1 out of 2 questions.**
- **The question paper needs to be submitted along with the answer script.**

Section A: Answer ALL questions.

Question 1. Marks: 10

- a) What is the rate of nucleation and rate of growth in plutonic conditions? (in terms of high/low) (1)
- b) What is the difference between a shield volcano and a composite volcano in terms of the shape and the composition of the magma erupted? (1)
- c) What would be the name of the rock containing 40% quartz, 30% K-feldspar, 20% plagioclase 6% biotite and 4% hornblende by weight and having a fine-grained interlocking texture? Justify your answer in a sentence. (1)
- d) Define prograde metamorphism. What is the difference between metamorphism and metasomatism? (2)
- e) What is meant by Isothermal Decompression (ITD) and Isobaric cooling (IBC) P-T paths? (1)
- f) What is the sequence of facies that commonly occur along a medium P/T series? (1)
- g) In which type of tectonic settings are tholeiitic and calc-alkaline basaltic magma normally generated? (1)
- h) Define Gibbs free energy and entropy of a system? Write the equation by which Gibbs free energy it is related to enthalpy and entropy of the system. (2)

Section B: Answer ALL questions.

Question 2. Marks: 6

- a) Define metamorphic facies. (1)
- b) What would be the formula of the resulting molecule after tremolite ($\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$) has undergone pargasite substitution? Show the substitution. (2)
- c) What change does plagioclase undergo from greenschist to amphibolite facies? (1)
- d) What is the typical mineral assemblage of a granulite and an eclogite-facies metamorphosed rock of mafic bulk composition? What is the characteristic difference in the mineral assemblage of the two facies? (2)

Question 3. Marks: 6

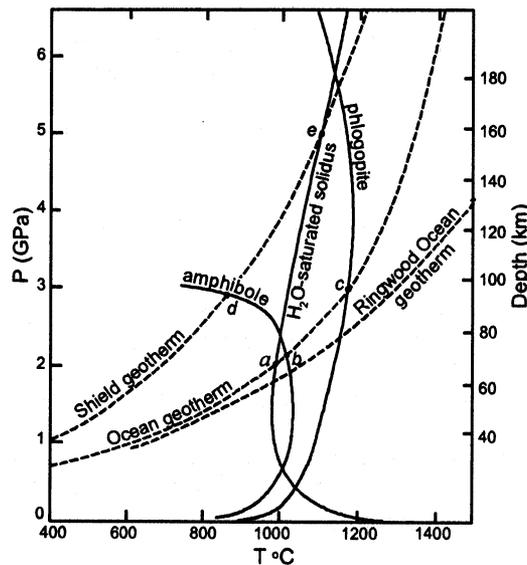
- a) What are paired metamorphic belts? Where and how do they form? (2)

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- b) Describe the tectonic-petrologic evolution of a rock along a typical clockwise P-T-t path with the help of a suitable diagram. In which tectonic setting would you expect such a P-T-t path? (3)
- c) What type of metamorphism will be experienced by the surrounding country rocks when a hot basaltic magma is emplaced at very shallow depths? Draw a schematic P-T path for the country rocks. (1)

Question 4. Marks: 6

- a) If melting of mantle is not a 'normal process', under what circumstances can it be accomplished? Give examples of regions on earth where such circumstances occur. (2)
- b) A H₂O-undersaturated rock composed of only diopside + anorthite + phlogopite is heated by burial along ocean geotherm. At which point (diagram below) will melt be generated and why? (2)
- c) The same rock as above, but H₂O-saturated, is heated along the shield geotherm. What will happen at point 'd' and 'e', and why? (2)



Question 5. Marks: 6

The temperature-composition (T-X) Diopside (CaMgSi₂O₆)-Anorthite (CaAl₂Si₂O₈) binary phase diagram at 1 atmosphere pressure is shown below (last page).

- a) Begin with a melt of composition X_{Di} = 80 at 1500°C. Plot the composition on the diagram and calculate the F at this condition. (1)
- b) If the melt is cooled isobarically, at what temperature (roughly) will F change and what occurs at this point? (1)
- c) On further cooling, at what temperature does F change again? Write the reaction involved at this point. (1)
- d) Considering ideal fractional crystallization, what would be the ratio of the solid phases (by weight) when both the solid phases crystallize together? (1)
- e) Mark on the figure the solid and the liquid evolution path for ideal fractional crystallization. (1)
- f) If the Diopside-Anorthite binary phase diagram is constructed for 1 GPa pressure, how will the eutectic point shift from that in the given diagram? (1)

- iii. Consider that the rock is then rapidly uplifted to a depth of about 7 km below the surface and stayed there for a much longer time. Draw and explain the likely P-T path followed by the rock from the onset of metamorphism in a calibrated P-T space. (3)

Question 8. Marks: 10

- a) Based on the mineral assemblage of the 2 different metamorphic rocks in the table below, for each rock answer the following questions:
- An appropriate metamorphic name. (1)
 - The possible parent rock (protolith). (1)
 - The corresponding metamorphic facies. (1)
 - Assuming that all the minerals in both rocks are in equilibrium, indicate the possible geobarometers and geothermometers you can use to determine the P –T conditions of equilibrium of the minerals assemblages in each rock. (2)

Rock 1 Plagioclase (25%), Hornblende (15%), Clinopyroxene (10%), Orthopyroxene (20%), Garnet (15%) with some quartz (10%) and opaque minerals (5%).
Rock 2 Garnet (10%), Biotite (25%), Kyanite (10%), Staurolite (20%), Quartz (25%) and Plagioclase (10%).

PS: Your answer must be presented under the following format.

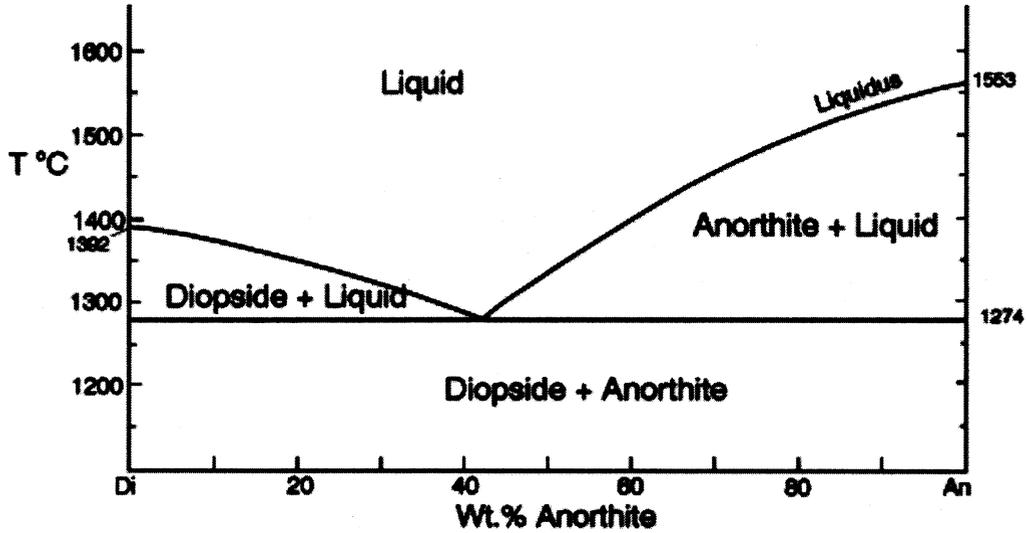
Rock No.	Rock name	Metamorphic facies	Possible parent rock (protolith)	Thermometer	Barometer
Rock 1					
Rock 2					

- b) The temperature-composition (T-X) Forsterite-Silica binary phase diagram at 1 atmosphere pressure is shown below (last page).
- Starting with a melt of composition 90wt.% forsterite at 2000°C, briefly describe what happens with cooling till the entire melt crystallizes. Consider ideal fractional crystallization. Draw and label the solid evolution path on the figure? (4)
 - If a rock composed of enstatite and quartz starts melting, at which point will the first melt be produced? Write the melting reaction taking place at this point. (1)

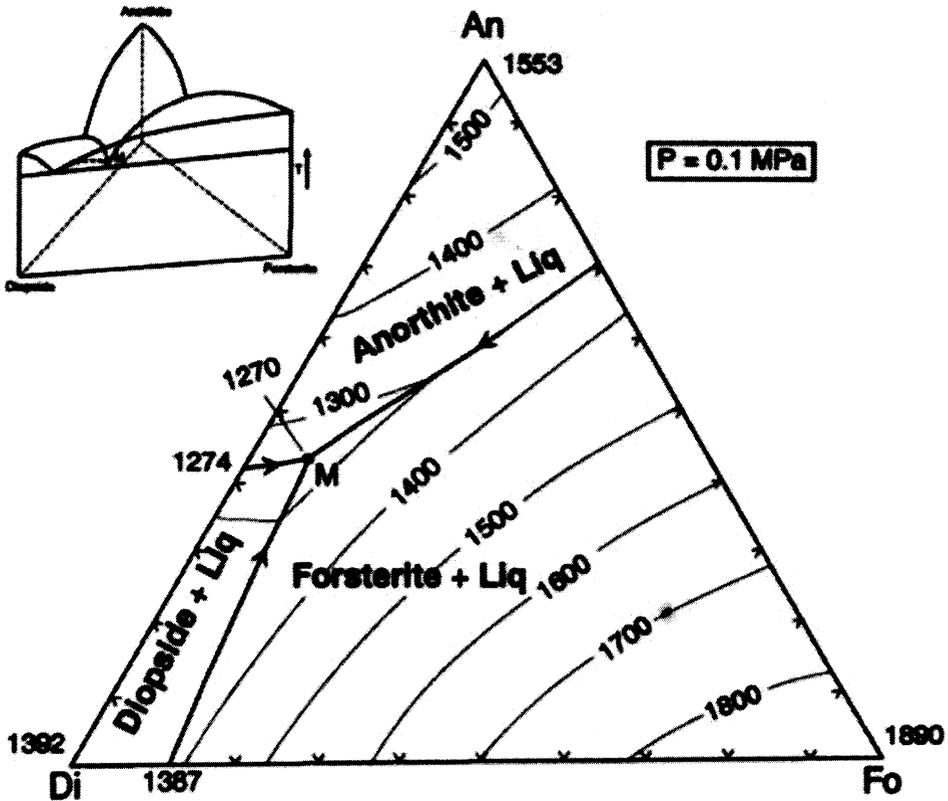
This page should be submitted along with the answer script

Name: _____ Roll no. _____

Q.5



Q. 7a



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Q. 8b

