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Salahaddin University

College of Science

Department of Earth Sciences & Petroleum

Subject: Metamorphic Petrology

Course Book: 3rd Year – 2nd Semester

Lecturer's names: Nihad Majeed Jameel (Ph.D.) (Theory) & Miss. Basna (M. Sc) (Practical)

Academic Year: 2022/2023- 2nd Semester

**Course Book**

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| **1. Course name** | Metamorphic Petrology |
| **2. Lecturer in charge** | Nihad Majeed Jameel (Ph.D.) |
| **3. Department/ College** | Department of Geology / College of Science |
| **4. Contact** | e-mail: nihad.jameel@su.edu.krdTel: 07504570536 |
| **5. Time (in hours) per week**  | Theory: 2 hours, Practical: 8 (2 Hours per group weekly) |
| **6. Office hours** | Sunday: 8:30-2:30Monday: 8:30-2:30Tuesday: 8:30-2:30Wednesday: 8:30-2:30Thursday: 8:30-2:30 |
| **7. Course code** |  |
| **8. Teacher's academic profile**  | \*Graduated at the Department of Geology, Salahaddin University/ College of Science (2004-2005).\* M.Sc. in Metamorphic petrology, Geology Department, College of Science, Salahaddin University-Erbil, Iraq.\*Assistant lecturer in Geology Department, Salahaddin University-Erbil, teaching practical to undergraduate students in the laboratory of subjects: optical mineralogy and metamorphic petrology.\* Ph.D. in Mineralogy, Institute of Earth and Environmental Science, Faculty of Science, University of Potsdam, Potsdam, Germany.\* Since 2015 I worked as Lecturer in the Geology Department at Salahaddin University-Erbil, teaching theoretical courses to undergraduate students in Optical mineralogy, igneous and metamorphic petrology, and mineral exploration |
| **9. Keywords** | Science, Petrology, Metamorphic |
| **10. Course overview:**This course will cover most important topics of metamorphic petrology, which focuses on the origin, occurrence, structure, and history of metamorphic rocks. The course will cover the structure of inner earth with a focus on continental crust, oceanic crust and upper mantle as the main metamorphic processes take place there. It will concentrate on metamorphic rocks, their classifications, textures and different rocks types, and metamorphic facies. |
| **11. Course objective:**Regular attendance is the best way to assure a good grade in this class. Different form of teaching is illustrated to gain best results, and it is much easier to absorb the information in lecture than to try and learn it on your own from the text. As an incentive to come regularly, quizzes will be given every 2 lectures.The students will be able to understand the petrology of igneous and metamorphic rocks in hand specimen. Physical properties of different minerals, is the aim for understanding the name and the texture of the rocks.  |
| **12. Student's obligation**In this course, the students will be required by two monthly exams, first at the middle of course, the second at the end of it. The student’s obligation during the course is attendance in the class for three hours for studying the practical part and applies it in the laboratory. There are many samples of both igneous and metamorphic rocks in the lab. Students also will be required by weekly report about former laboratory they had taken.You can expect us to: * be interested, excited, and enthusiastic about the course and the material
* take a new and innovative approach to teaching this course
* try to convince you that the material in this course is worth knowing
* assume you are familiar with the chapter before we discuss it in class
* include material that is not in the text and for which you will be responsible
* challenge you to think about the material and to evaluate situations
* involve you in the material through in-class and out-of-class exercises
* provide you with useful information on-line
* start and end class on time

We expect you to: * come to class regularly
* be willing to become involved in the course
* be an active and receptive learner
* read the chapter before class and consider specific concepts and questions
* complete on-line exercises and quizzes
* collaborate with your neighbours to exchange ideas and learn new concepts
* hand in your own work on the in-class exercises
* be courteous to me and to your classmates
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| **13. Forms of teaching**Different forms of teaching will be used to reach the objectives of the course: power point presentation will illustrate to show the main point slide titles and definitions and summary of conclusions, white board to clarify ideas, office work by designing work sheet to solve and analyse CIPW problems and homework’s, all figures that related to the lectures.  To get the best of the course, it is suggested that you attend classes as much as possible, read the required lectures before the time of lecture, teacher's notes regularly as all of them are foundations for the course. Try as much as possible to participate in classroom discussions.  |
| **14. Assessment scheme**‌ The students are required to do an one theoretical exam at the end of the semester. The semester has 15 marks, so we divided it like that: 5 for quizzes and the term exam have 10 marks. There will be a final exam on 50 so the final grade will be upon the following criteria: The course mark: 15Final exam for the semester: 50 Therefore the total mark will be 65The students are required to do a one practical exam at the end of the semester. The semester has 35 marks, so we divided it like that: home works count with quizzes 7.5 marks and weekly report has 7.5 marks, and the term exam has 20 marks.  |
| **15. Student learning outcome:**1. The student should be able to understand the different types of metamorphic rocks.
2. The student should be able to identify the different metamorphic rocks and their textures in hand specimens and under microscope.
3. The student should be able to identify the different metamorphic structure in the field.
4. The student should be able to understand different tectonic environments associated with the different metamorphic rocks.
5. The student should be able to know the distribution of metamorphic rocks in Iraq.
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| **16. Course Reading List and References‌:** Required books:Best, M.G., 2003. Igneous and metamorphic petrology. Blackwell Publishing company. 728p.Tracy R. and Owens B., 2005. Petrology: Igneous, Sedimentary, and Metamorphic.  Students are encouraged to search for the Journals and internet that may help them in this course, such as:1) Contributions to Mineralogy and Petrology*.*2) Journal of Petrology |
| **17. The Topics:** | **Lecturer's name** |
| In this section the lecturer shall write titles of all topics he/she is going to give during the term. This also includes a brief description of the objectives of each topic, date and time of the lecture Each term should include not less than 12 weeks  | The following subjects will cover the mentioned aims of the course (theoretical part):1. Introduction to metamorphic petrology
2. Types of metamorphism
3. Classification of metamorphic rocks
4. Textures of metamorphic rocks
5. Deformation and inclusions in metamorphic rocks
6. Triangular plot in metamorphic rocks
7. Metamorphic reactions
8. Phase diagrams, ACF and AFM diagrams
9. Thermodynamic of metamorphic reactions
10. Contact metamorphic facies
11. Regional metamorphic facies
12. Metamorphism and plate tectonics
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| **18. Practical Topics (If there is any)** |
| This syllabus may be subject to changes, i.e., we may take either longer or shorter time to finish topics, and if any changes happened you will be notified well in advance. | **Week 1:** Review of metamorphic rock forming minerals**Week 2:** Textures of egional metamorphic rocks**Week 3:** Regional metamorphic rocks **Week 4:** Regional metamorphic rocks**Week 5:** Regional metamorphic rocks**Week 6:** Regional metamorphic rocks**Week 7:** Textures of contact metamorphic rocks**Week 8:** contact metamorphic rocks**Week 9:** Hydrothermal metamorphic rocks**Week 10:** Dynamic metamorphic rocks**Week 11:** Phase rule**Week 12:** CIPW**Week 13:** KFM diagrams**Week 14:** Tectonic environment of different metamorphic rocks |
| **19. Examinations**: Theory Examples***Note: Answer all questions.*****Q1/ Are the following sentences right (√) or wrong (X)? Correct the wrong ones (you can only change underlined words, no marks without corrections). (8 Marks)**1. **Metamorphic assemblage** is a general term for describing the relative temperature and pressure conditions under which metamorphic rocks form.
2. According to the chemical classification of metamorphic rocks, rocks that are rich in Mn are termed **magnesian.**
3. In the post metamorphic textures, if the rock is highly strained and the matrix become glassy **mylonite**name is used.
4. In the regional metamorphism, if σ1> σ2 = σ3, **both foliation and lineation** will be formed.
5. **Eclogites** are rocks that contain an abundance of talc, forms from ultrabasic igneous protoliths by hydrothermal alteration.
6. In the **contact metamorphism** ultrahigh pressures can be generated which can produce minerals that are only stable at very high pressure, such as the SiO2 polymorphs coesite and stishovite.
7. The development of compositional layering or banding, usually evident as alternating discontinuous bands or layers of dark and lighter colored minerals, is called **metamorphic differentiation**.
8. **High-grade** metamorphism takes place at temperatures greater than 510oC and relatively high pressure.

**Q2/ Compare between three of the followings: (9 Marks)**1. Spotted hornfels and spotted slates
2. Granoblastic polygonal texture and decussate texture
3. Isochemical metamorphism and allochemical metamorphism
4. Blastoporphyritic texture and porphyroblastic textures

**Q3/ Answer the following questions:**1. What are the tectonic features of blue schist facies? **(6 Marks)**
2. There is a clear relationship between metamorphic facies and geothermal gradient, explain. **(5 Marks)**
3. During your field work to the Qala-Dezah area near Hero town, you found gabbroic igneous body intruded into a calcareous parent rock. Based on your field observations and your scientific background, answer the following questions: **(10 Marks)**

**Q3/ Define the phase rule then draw Al2O3 system of the pressure temperature phase diagram showing binvarient point, univarient line and invarient point by applying the phase rule. (8 Marks)****Q4/ List the name of contact metamorphic facies from low grade to high grade, then mention mineral assemblage for each facies (only for politic protoliths) with drawing AKF diagram for each facies? (15 Marks)****Answers****Q1/** 1. X **Metamorphic grade**
2. **X manganiferrous**
3. **X pseudotachylite**
4. **X foliation and no lineation**
5. **X Soapstones**
6. **X shock (compact)**
7. **/**
8. **/**

**Q2/****1-**If the orientation dependence is low (as in quartz or calcite), no particular faces are preferentially developed. Thus in *monomineralic* aggregates of structurally isotropic minerals (quartzites or marbles), grain boundary area reduction leads to an equilibrium texture in which grains meet along straight boundaries (resulting in low surface area for each grain). The texture is called **granoblastic** **polygonal** (or **polygonal mosaic**),Minerals becomes more plate-like. Low-energy surfaces in such minerals (e.g., the top and bottom of the plate) predominate in the final static recrystallization texture, even in monomineralic rocks, so that simple regular polygons are no longer abundant. The result is called **decussate** texture. Decussate (or diablastic) texture is a metamorphic rock texture comprising of equigranular, interlocking, randonly orientated platy, tabular, prismatic or elongate minerals. The texture arises to minimize surface energy in a rock with elongate crystals and is thus similar to a granoblastic texture.**2-** A field term for rocks that in hand specimen contain small porphyroblasts (usually ovoid, but not necessarily so) in a fine matrix is **spotted**. If the matrix is non-foliated the rock is commonly called a **spotted hornfels**. Contact metamorphism overprinting regional metamorphism is common (reflecting either post-orogenic magmatism or the time required for magmas to rise to shallow regions following an orogenic metamorphic- plutonic event). The result for low grade regional metamorphic rocks is **spotted slates** or **spotted phyllites** **3-*** Normal or isochemical metamorphism: involve no chemical changes in the bulk rock composition.
* Allochemical metamorphism: the metamorphism accompanied by chemical changes in the bulk rock composition.

**4-** blastoporphyritic texture is a porphyritic texture (Porphyritictexture is inequigranular magmatic texture made of two grain sizes; more or less euhedral larger crystals, called phenocrysts, are embedded in a finer grained or glassy matrix), original pre-metamorphic features which have not been obliterated by the metamorphism.. In metamorphic rocks it will be called.Porphyroblastic is porphyritic texure in which larger grains, are surrounded by a finer grained matrix of other phases. and produced by the metamorphism as a result of the minerals recrystalization. **Q3/**1. **mhtml:file://C:\Users\Nihad\Desktop\all\petrology\Types%20of%20Metamorphism.mht!http://www.tulane.edu/~sanelson/images/metafacies.gif**

**B-**1. The rapid subduction and rapid uplifting prevent the utmost heating of minerals of this facies
2. This facies is associated with active plate margin.
3. There are two types of metamorphism the high pressure and the low pressure which are associated with each other and isolated Benioff zone.

**Q4/****A**- The phase rule is an expression of the number of variables and equations that can be used to describe a system in equilibrium.  In simple terms, the number of variables are the number of chemical components in the system plus the extensive variables, temperature and pressure.  The general form of the phase rule is stated as follows: F = C + 2 - Pwhere F is the number of degrees of freedom or variance of the system., C is the number of components in the system, P is the number of phases in equilibrium, and the 2 comes from the two extensive variables, Pressure and Temperature.At point **A**: C= 1= Al2SiO5 , P= 1= KyaniteF= 2 We say that this area of kyanite stability on the phase diagram is a divariant fieldAt point **B**: C= 1= Al2SiO5 , P= 2= Kyanite and SillimaniteF= 1 univariant lineAt point **C**:C= 1 = Al2SiO5 , P= 3= Kyanite, Sillimanite and AndalusiteF= 0 invariant point |
| **20. Extra notes:**The course book lacks to the problems which affect the educational process. These problems include the large number of students in each stage, diminution of instruments, and absence of appropriate rooms for lecturers to develop themselves. Finally, about the department of Earth Sciences and Petroleum absence of financial support to carry out scientific trips and field course in a typical situation. |
| **21. Peer review** Assistant Prof. Dr. Ahmed Muhammed Aqrawi.‌‌  |