

GLY4310
88 points
10 took exam

Name _____
April 25, 2019

Florida Atlantic University

PETROLOGY -- FINAL EXAMINATION KEY

Scores to the left of the answer in red are the number of incorrect responses. Instructor comments and answers are in blue.

True-False - Print the letter T or F in the blank to indicate if each of the following statements is true or false. Illegible answers are wrong. (1 point each)

- 2 T 1. The geothermal gradient be lower than average in a subducting plate.
- 0 F 2. New minerals will growth during deformation, parallel to σ_1 .
- 0 T 3. The effects of contact metamorphism are most evident in shallow, low-pressure environments.
- 2 F 4. Relict structures are not preserved in hornfels and granofels.
- 3 T 5. Cordierite has a large molar volume, which indicates it is stable at low pressures.
- 4 F 6. Ordinary prograde metamorphic reactions are common in high-temperature mafic igneous rocks. **Ordinary prograde metamorphic reactions are not possible in these rocks, since they cannot be dehydrated**
- 0 F 7. In the low-grade mafic assemblages, complete alteration of the protolith minerals occurs, and it is easy to define new characteristic mineral assemblages
- 2 F 8. In a Barrovian sequence, oligoclase appears before hornblende.
- 0 T 9. In most P-T-t paths, P_{max} and T_{max} do not occur at the same time.
- 4 F 10. Greenschist-amphibolite facies, such as those of Western North Carolina, require an average continental crustal geotherm to form.
- 2 T 11. Generally the study of coal, petroleum, and ore deposits are excluded from petrology.

Exam Total _____/208 _____% Grade _____

- 8 F 12. A facies should contain no more than six essential minerals. [Mineral assemblages should contain no more than six essential minerals](#)
- 2 F 13. Barrow found a much greater change in the sandstones he studied, compared to the pelitic rocks .
- 1 T 14. The presence of garnet in a facies indicates it did not form at low pressures.
- 3 T 15. Reactions for which the sole metamorphic agents are temperature, pressure, or both, are isochemical.
- 0 T 16. A metamorphic facies may be defined as a set of repeatedly associated mineral assemblages. [Knowing this should help with question 12](#)
- 3 T 17. Cataclasis refers to mechanical crushing and grinding, with no recrystallization. Rocks exhibiting this behavior have undergone brittle deformation.
- 2 F 18. Carbon dioxide solubility is very high in silicate melts.
- 3 T 19. Metamorphic recrystallization often leads to an increase in grain size.
- 1 T 20. At very low metamorphic grade, the preservation of original igneous textures and minerals is common.
- 2 F 21. The extrapolated near-surface geotherm provides a good basis for estimating the geothermal gradient from the surface to the core.
- 5 F 22. Isotopes fractionate during both partial melting and fractional crystallization. [There isn't enough mass difference among isotopes of interest \(¹⁴³Nd, ¹⁴⁴Nd, ⁸⁷Rb, ⁸⁷Sr, etc.\) for significant fractionation to occur.](#)
- 4 T 23. The Mid-Ocean Ridge (MOR) averages about 2000 km in width on the ocean floor.
- 6 F 24. Eclogites occurring as bands or lens-shaped deposits in blueschist belong to the high-temperature group. [They are low-temperature](#)

Multiple-Choice - Choose the best response to each statement or question. Print the letter corresponding to your choice in the blank. (1 point each)

- 0 C 1. What is the agent associated with fault-zone metamorphism?
A. Fluid alteration
B. Load pressure
C. Shear stress
D. Increased temperature due to proximity to magma
- 1 B 2. Parallel belts like the Sanbagawa and Ryoke belts, usually separated by a fault, are seen in a number of regions around the Pacific Ocean. The name paired metamorphic belts was suggested by whom?
A. Alfred Harker
B. Akiho Miyashiro
C. C.E. Tilley
D. Peter Wyllie
- 5 C 3. Phyllonites are foliated cohesive rocks rich in what mineral?
A. Chlorite
B. Enstatite
C. Mica [Phyllonites sould like phyllites, which are rich in mica](#)
D. Olivine
- 2 A 4. Who proposed the addition the zeolite and prehnite-pumpellyite facies to Eskola's original set of five facies?
A. D.S. Coombs
B. P. Eskola
C. W. Fyfe
D. All of the above
- 5 D 5. Where might a low P/T baric series be found?
A. Contact metamorphic zone
B. High heat flow orogenic zone
C. Rift zone
D. All of the above
- 2 B 6. The Barrovian type of metamorphic trajectory is characteristic of which baric series?
A. High P/T
B. Medium P/T
C. Low P/T
D. May be any of the above

2 C 7. Metabasites in the blueschist facies are characterized by the presence of a sodic, blue amphibole. Normally this is:
A. Actinolite
B. Cummingtonite
C. Glaucophane
D. Hornblende

5 D 8. Chemically the eclogites are equivalent to which rock type?
A. Granite
B. Rhyolite
C. Quartzite
D. Basalt

5 C 9. Which of the following groups of minerals would be most representative of the zeolite facies?
A. Calcite, prehnite, pumpellyite
B. Chlorite, microcline, muscovite, and quartz
C. Wairakite, calcite, and laumontite
D. Hornblende, plagioclase, biotite, epidote, sphene

9 A 10. Which of the following rock types is not associated with the greenschist facies?
A. Gneiss **Only in higher facies**
B. Quartzite
C. Schist
D. Slate

7 B 11. Given the following reaction:



Suppose P_{water} is increased. The reaction will:

Have we forgotten Le Chatelier?

- A. Proceed to the right
- B. Proceed to the left
- C. Must know P_{CO_2} also
- D. Impossible to ascertain - the reaction depends on P_{fluid} , not P_{water}

2 C 12. Which of the following minerals is likely to form porphyroblasts?
A. Biotite
B. Chlorite
C. Garnet
D. Quartz

- 9 A 13. This facies has two zones. The lower grade zone contains hydrous minerals, whereas the higher grade zone contains only anhydrous minerals.
A. Granulite
B. Greenschist
C. Prehnite-pumpellyite
D. Zeolite
- 2 C 14. The Buchan type of metamorphic trajectory is characteristic of which baric series?
A. High P/T
B. Medium P/T
C. Low P/T
D. May be any of the above
- 6 B 15. In the English Lake District, Ordovician Skiddaw Slates are intruded by granite and granodiorite bodies. The metamorphic aureole is divided into the inner, middle, and outer zones. The basis for this classification within the zones is:
A. Mineralogy
B. Structure
C. Temperature
D. All of the above
- 1 C 16. Which of the following describes tension? **Tension mean pulling apart, hence σ_3 is negative**
A. $\sigma_1 > \sigma_2 > \sigma_3$
B. $\sigma_1 > \sigma_2 \approx \sigma_3$
C. $\sigma_1 > \sigma_2$, both + ; σ_3 is negative
D. Either A or B
- 2 B 17. What are the principal agents of metamorphism involved with ocean-floor metamorphism?
A. Metasomatism and pressure
B. Metasomatism and temperature
C. Pressure and temperature
D. Any of the above
- 0 C 18. The starting material from which a reaction or recrystallization begins is called what?
A. Granofels
B. Isograd
C. Protolith
D. Spillite

- 3 D 19. Why are divergent boundaries more likely to be found in oceans than on a continent?
A. Oceans cover 70% of the earth's surface, so the statistical chance of a rift forming in the ocean is greater
B. Ocean crust is thinner than continental crust, and therefore easier to split
C. Continental rifts may split a continent, creating an ocean, and thus converting themselves to an oceanic rift
D. All of the above
- 3 A 20. Which type of meteorite is believed to correspond to the core of a broken planet?
A. Irons
B. Stones
C. Stony-irons
D. All of the above
- 5 D 21. Which of the following minerals would not be enriched in a mafic rock?
A. Augite
B. Forsterite
C. Hornblende
D. Sanidine
- 4 C 22. If a mineral contains 30-60% dark minerals, it is:
A. Leucocratic
B. Melanocratic
C. Mesotype
D. None of the above
- 2 D 23. If P + M is greater than which of the following percentages, the QAPF diagram should not be used.
A. 50%
B. 65%
C. 80%
D. 90%
- 4 C 24. The process of conversion of feldspars to a very fine-grained white mica (essentially muscovite) is called:
A. Biotitization
B. Chloritization
C. Seritization
D. Uralitization

- 2 D 25. The SiO_4 group has what shape?
 A. Cube
 B. Octahedron
 C. Square planar
 D. Tetrahedron
- 6 C 26. Which of the following minerals is not typically associated with alkaline-rich rocks?
 A. Aegirine
 B. Glaucophane
 C. Hornblende
 D. Riebeckite
- 0 C 27. The DUPAL group, first identified by Dupré and Allègre, are located where?
 A. Arctic Ocean
 B. Atlantic Ocean
 C. Indian Ocean
 D. Pacific Ocean
- 2 C 28. Decay of which element increases the $^{87}\text{Sr}/^{86}\text{Sr}$?
 A. K
 B. Na
 C. Rb ^{87}Rb is the source of ^{87}Sr
 D. Sm
- 3 A 29. Pb is perhaps the most sensitive measure of crustal (including sediment) components in mantle isotopic systems. What lead ratio will be the most sensitive to a crustal-enriched component?
 A. $^{206}\text{Pb}/^{204}\text{Pb}$ $^{238}\text{U} \rightarrow ^{234}\text{U} \rightarrow ^{206}\text{Pb}$ Since 99.3% of all U is ^{238}U , this is the most sensitive
 B. $^{207}\text{Pb}/^{204}\text{Pb}$
 C. $^{208}\text{Pb}/^{204}\text{Pb}$
 D. Either B or C
- 3 B 30. Eclogites associated with migmatitic gneisses are usually associated with which temperature group?
 A. Low
 B. Medium
 C. High
 D. Any of the above

Diagrams - Examine the following diagram. Identify the metamorphic facies associated with each of the following regions in Figure 1 (1 point each)

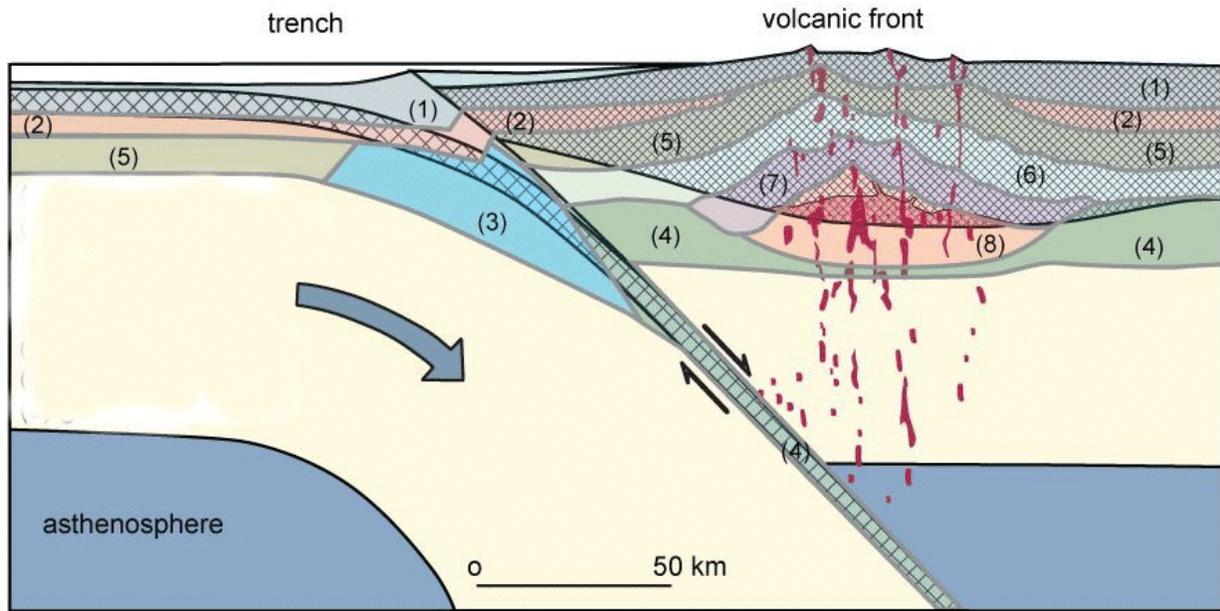


Figure 1

- 1 1 ZEOLITE
- 0 3 BLUESCHIST
- 2 5 GREENSCHIST
- 3 8 GRANULITE

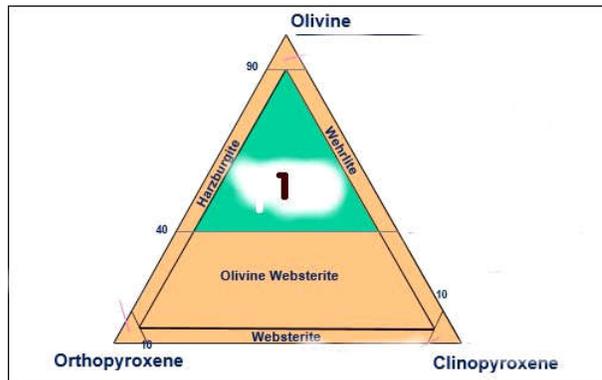


Figure 2

- 3 The region labeled 1 in Figure 2 represents what rock type? LHEROZOLITE

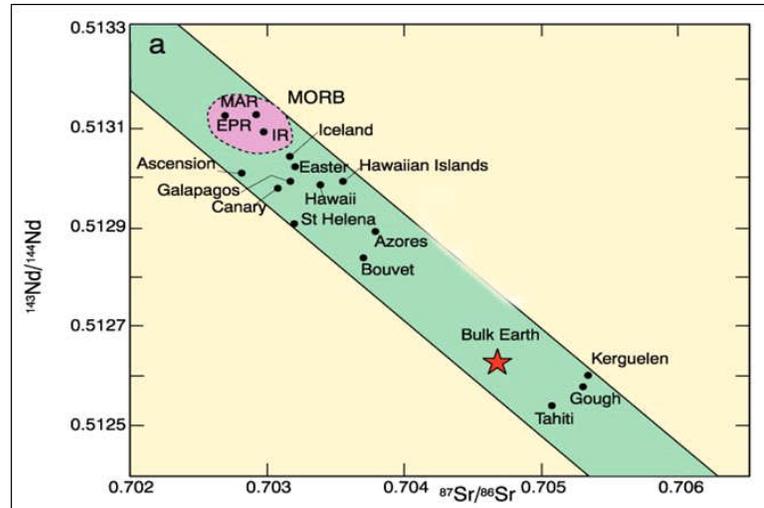


Figure 3

5 The area shown in green in Figure 3 is known as what? (Also the name of the diagram)

MANTLE ARRAY

Fill-Ins - Write in the word or words which best completes each statement or answers each question. (1 point per blank)

0 1. What organization established SCMR?

THE INTERNATIONAL UNION OF GEOLOGICAL SCIENCES (IUGS)

2-3. Under what two conditions does intense heat promote recrystallization?

1 2) WHEN THE PROTOLITH IS FINE-GRAINED

3.5 3) When the environment is static, since shear stresses typically reduce grain sizes

1 4. What type of stress is produced by tectonic forces? DEVIATORIC

5 5. Basalt, altered by ocean-floor metamorphism, often retains the structures of basalt, including vesicles and pillow structures. The altered rock is called what? SPLITITE

1 6. In metamorphic assemblages, the symbol \pm is short for what phrase?

WITH OR WITHOUT

2.5 7. What is an immature graywacke?

AN IMMATURE GRAYWACKE IS ONE THAT HAS UNDERGONE AT MOST LIMITED WEATHERING. THE MAFIC MINERALS HAVE NOT BEEN COMPLETELY WEATHERED OUT.

2 8. A metamorphic rock will typically be buried, metamorphosed, possibly with orogenic forces acting on it, then brought to the surface through uplift and erosion. The path that it follows is called a P-T-t path.

0 9. What does the symbol X_{H_2O} represent?

X_{H_2O} REPRESENTS THE MOLE FRACTION WATER IN THE FLUID PHASE

4 10. Metabasites is a term applied to? METAMORPHOSED MAFIC ROCKS

9 11. A schist of sedimentary origin is called a(n) PARASCHIST.

7 12. The metamorphic equivalent of pure limestone is MARBLE.

If you missed question 12, and anyone asks what university you attended, please answer Podunk!

3 13. Preferred orientation of prismatic or tabular minerals due to flow is known as FOLIATION.

14-15. Silicon is the second most abundant element in the crust of the earth. What two elements are virtually tied for second most abundant when the whole earth is considered?

3, 2 14) MAGNESIUM and 15) IRON.

5 16. The most common volatile gas associated with magma is WATER VAPOR.

6.5 17. For an isobaric system, complete the following equation.

$$(\delta G / \delta T)_p = \underline{-S}$$

18-19 Name two sources of metamorphic fluids.

0 18 -19 METEORITIC WATER, JUVENILE WATER, WATER ASSOCIATED WITH SUBDUCTED MATERIAL, SEDIMENTARY BRINES, WATER FROM METAMORPHIC DEHYDRATION REACTIONS, OR DEGASSING OF THE MANTLE

Problems - SHOW ALL WORK - there will be no credit for answers not supported by sufficient work to justify your answer. Show the formula used in your calculation, and identify all parameters, including units, used in the formula. Clearly label your answer, including units if any. Be sure to express your answer to the correct number of significant figures.

- 20.5 1. A reaction takes place with a constant energy barrier of 842 cal/mol. Calculate K at 684 K. (3 points)

$$\ln K = \ln e^{-\frac{E}{RT}} = -\frac{E}{RT} \quad (1)$$

$$\ln K = -\frac{842}{1.987 \cdot 684} = -\frac{842}{1359.1} = -0.6195 \quad (2)$$

$$K = e^{-0.6195} = 0.240$$

- 19.5 2. For a constant energy barrier of 538 cal/mol calculate the temperature in °C at which the amount of products should equal the amount of reactants. (3 points)

If the amount of products should equal the amount of reactants, then $k = 0.5$

$$T = -\frac{E}{R \cdot \ln K} = -\frac{538}{1.987 \cdot \ln 0.5} = -\frac{538}{1.987 \cdot -0.6931} = 390.6 \quad (4)$$

Convert to °C :

$$T(^{\circ} C) = 390.6 - 273.15 = 117(^{\circ} C)$$

Discussion Questions - Answer all of the following questions completely but concisely. Points as indicated. Diagrams (labeled) may be used to supplement your written answers, where appropriate.

- 2.5 1. What is a major difference between orogenic metamorphism and burial metamorphism? (1 point)
The largest difference is the lack of significant structural deformation during burial metamorphism
- 0.5 2. What is the difference between fault gouge and fault breccia? (2 points)
Fault breccia is broken, crushed rock filling in along the fault. Gouge is a clayey alteration of the breccia, produced by groundwater percolating down the fault zone.
- 4.5 3. Retrograde metamorphic reactions are usually exothermic, but often proceed very slowly. Why? (1 point)
Prograde reaction drive off water and carbon dioxide. If the volatiles are lost, the retrograde reactions will be impossible.
- 2.5 4. Hydrous pelitic and quartzo-feldspathic rocks do not reach granulite grade. Why? (1 point)
When aqueous fluids are present, pelitic and quartzo-feldspathic rocks will be above the solidus at low to medium pressure. Melting will begin. Migmatites may form.
- 1.0 5. Granulites are thought to form in regions of crustal thickening. Why? (1 point)
Areas of crustal thickening have very high geotherms, which allows granulites to reach the 700-1000°C range they require to form.

- 9.5 6. What is the difference between a group of minerals (i.e. pyroxene group) and a series of minerals (i.e. olivine series)? (2 points)
- Groups of minerals are related species which share some common chemical properties and having structural similarities, such as a chain of SiO_4 tetrahedra in the pyroxenes. A series are related species which are part of a solid solution series, from forsterite (Mg_2SiO_4) to fayalite (Fe_2SiO_4) in the olivine series. In this series, Mg^{2+} and Fe^{2+} can freely substitute for each other.
- 8.0 7. Both augite and hornblende often occur as small black crystals. In hand specimen, how might they be distinguished? What common field tool is often necessary in this regard? (2 points)
- Augite is a pyroxene, with 2D cleavage near 90° , whereas hornblende is an amphibole, with 2D cleavage near 60° . A hand lens is often required to see the cleavage.
- 14.5 8. At 2 GPa, carbon dioxide solubility is 5-6% in the system Albite- H_2O - CO_2 , 18% in the system Enstatite- H_2O - CO_2 , and 35% in the system Diopside- H_2O - CO_2 . Explain why. (2 points)
- Mysen and Virgo (1980) suggested that the carbon dioxide dissolves by forming carbonate complexes in silicate melts, particularly when calcium is available to form CaCO_3 . The carbon dioxide steals one oxygen, and converts another to a bridging oxygen. Diopside contains Ca, whereas albite and enstatite do not. Since carbon dioxide is soluble in less polymerized melts, it is more soluble in enstatite (a pyroxene) than in albite (a tectosilicate).

Questions 6-9 were review, and the results were not good.

- 17 9. In the phase diagram for Nepheline-Forsterite-Silica, as pressure increases from 1 atm to 3 GPa, toward which apex does the ternary eutectic move? Will alkaline basalts be favored at shallow depths or deep within the earth? Why? (3 points)

Increased pressure moves the ternary eutectic minimum from the oversaturated tholeiite field to the under-saturated alkaline basalt field. Since alkaline basalts are undersaturated, they will be favored by greater depth of melting, deep within the earth.

**HAVE A GREAT SUMMER AND ENJOY
SFC IF YOU ARE GOING ON IT.
IT'S BEEN FUN!**

Final Examination Results

<u>89.5</u>	A+	
<u>73.0</u>	B	
69.5 - 2		
<u>68.5 - 2</u>	C+	MEDIAN = 68.5 (77.8%) C+
<u>62.5</u>	C-	MEAN = 66.8 (75.9%) C
59.5		
<u>59.0</u>	D+	
<u>48.5</u>	F	

Overall Exam Results

<u>220.5</u>	A+	
<u>169.0</u>	B-	
<u>161.5</u>	C+	
158.0		
<u>157.3</u>	C	MEAN = 155.8 (79.2%) C+
150.8		MEDIAN = 154.1 (74.1%) C
<u>150.3</u>	C-	
<u>133.8</u>	D	
129.5		
<u>127.0</u>	D-	

Previous Final Exam Results

Spring, 2019	Mean = 66.8 (75.9%)
Spring, 2018	Mean = 74.9 (85.1%)
Spring, 2017	Mean = 60.8 (69.0%)
Spring, 2016	Mean = 74.5 (84.7%)
Spring, 2015	Mean = 79.0 (89.8%)
Spring, 2014	Mean = 63.9 (72.7%)
Spring 2013	Mean = 67.1 (76.3%)
Spring 2012	Mean = 73.6 (83.7%)
Spring 2011	Mean = 76.4 (86.8%)
Spring 2010	Mean = 79.5 (90.3%)
Spring 2008	Mean = 76.2 (86.6%)
Spring 2006	Mean = 81.3 (92.4%)
Fall 2001	Mean = 76.4 (86.8%)

Exams Overall

Spring, 2019	Mean = 79.2%, C+
Spring, 2018	Mean = 83.4%, B
Spring, 2017	Mean = 81.8%, B-
Spring, 2016	Mean = 79.9%, C+
Spring 2015	Mean = 83.4%, B
Spring 2014	Mean = 77.4%, C+
Spring 2013	Mean = 78.1%, C+
Spring 2012	Mean = 80.3%, B-
Spring 2011	Mean = 83.0%, B
Spring 2010	Mean = 82.9%, B-
Spring 2008	Mean = 80.7%, B-
Spring 2006	Mean = 84.8%, B
Fall 2001	Mean = 81.9%, B-

