

GLY4310

60 points

10 took exam - Numbers to the left of the question number in red are the number of incorrect responses. Instructor comments are in blue.

Name _____

March 21, 2019

Florida Atlantic University
PETROLOGY -- MIDTERM TWO KEY

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)

- 0 T 1. As the temperature of a magma increases, the viscosity of the magma will decrease.
- 1 F 2. The volatile gas content of basaltic magmas is higher than rhyolitic magmas.
- 0 T 3. If $P_f = P_{total}$, the melt is saturated with volatiles.
- 3 T 4. Partial melting experiments on depleted magmas are unable to generate alkaline basalts under any conditions.
- 3 F 5. The Mid-Ocean Ridge (MOR) averages about 500 km in width on the ocean floor.
- 7 F 6. Isotopes fractionate during both partial melting and fractional crystallization. *There isn't enough mass difference among isotopes of interest (^{143}Nd , ^{144}Nd , ^{87}Rb , ^{87}Sr , etc.) for significant fractionation to occur.*
- 1 T 7. In the Hawaiian Islands, OIA is seen in the pre-shield and post-erosional stages, but not in the shield building and post-shield phases.
- 1 T 8. E-MORBs are LREE enriched, whereas N-Morbs are LREE depleted.
- 3 T 9. The composition of most MORB's is near the low-pressure cotectic for olivine-plagioclase-clinopyroxene, suggesting that fractional crystallization occurred in shallow magma chambers
- 2 F 10. Slow spreading ridges have persistent magma chambers, whereas fast spreading ridges have small, ephemeral magma bodies

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 D 1. Which type of volcano has the largest surface area?
A. Cinder cone
B. Composite
C. Dome
D. Shield
- 1 D 2. The term coulée in geology means:
A. In the western United States, tongue-like protrusions of solidified lava, forming a sort of canyon.
B. The dry, braided channels formed by glacial drainage of the Scablands of eastern Washington, such as Grand Coulee and Moses Coulee.
C. Canyons characterized by steep walls that have been shaped by erosion
D. Any of the above
- 0 A 3. A Canadian geologist who was one of the most important pioneers in the field of experimental petrology, he was widely recognized for his phase-equilibrium studies of silicate systems as they relate to the origin of igneous rocks. He formulated the Reaction principle, recognizing two types of reaction, continuous and discontinuous.
A. N.L. Bowen
B. B.P.E. Clapeyron
C. A.E. Ringwood
D. P.J. Wyllie
- 0 B 4. In a classic paper called "The Origin of Igneous Rocks", who, in 1892, first divided magmas into two series, the **alkaline** and the **sub-alkaline**.
A. N.L. Bowen
B. J.P. Iddings
C. C.E. Tilley
D. P.J. Wyllie
- 4 A 5. The fastest spreading plates are found where?
A. EPR
B. IOR
C. MAR
D. Both B and C

- 1 C 6. Ocean layers 2A and 2B are composed of what?
A. Gabbro (3)
B. Peridotite (4)
C. Pillow basalts
D. Sheeted dikes (2C)
- 3 A 7. Which reservoir is thought to be the source of N-MORB?
A. Depleted Mantle
B. Enriched Mantle I
C. High mu Mantle
D. Prevalent Mantle
- 6 C 8. The high $^{87}\text{Sr}/^{86}\text{Sr}$ in EMI and especially in EMII require enrichment of which element?
A. K
B. Na
C. Rb ^{87}Rb is the source of ^{87}Sr
D. Sm
- 3 A 9. 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
- 6 C 10. The DUPAL group, first identified by Dupré and Allègre, are located where?
A. Arctic Ocean
B. Atlantic Ocean
C. Indian Ocean
D. Pacific Ocean
- 1 A 11. The presence of P in magma usually produces what mineral in granitic rocks?
A. Apatite
B. Ilmenite
C. Plagioclase
D. Sphene

- 3 D 12. The seismic velocities in this layer match that of ultramafic rock. The boundary between this layer and the next highest layer is the Moho. The upper part of this layer is layered, with cumulate texture. It consists of olivine and pyroxene, settled from the bottom of axial magma chambers. Below this is an unlayered, residual mantle material. Which layer is this?
- A. Layer one
 - B. Layer two
 - C. Layer three
 - D. Layer four

Diagrams and Figures - A series of slides will be shown. Each of these is a photo or a diagram previously seen in class. Diagrams may have been altered to remove labels, etc. Answer each question as the slide is shown. (1 point each)

- 4 B 1. The diagram depicts which of the following?
- A. Maar
 - B. Scoria cone
 - C. Tuff cone
 - D. Tuff ring

- 4 C 2. The diagram depicts which of the following?
- A. Maar
 - B. Scoria cone
 - C. Tuff cone
 - D. Tuff ring

- 1 C 3. The photo shows what feature?
- A. Columnar joints
 - B. Lava tube
 - C. Pillow basalt
 - D. Tephra

- 1 A 4. The diagram depicts which of the following?
- A. Laccolith
 - B. Lopolith
 - C. Sill
 - D. Vein

- 1 F 5. (T-F) This video is an example of a pahoehoe flow.

0 A 6. The picture shows what feature?
A. Columnar joints
B. Lava tube
C. Pillow basalt
D. Tephra

7 7. The region labeled **1** in the diagram represents what rock type? Lherzolite

1 D 8. What type of diagram is this?
A. Fenner
B. Pearce
C. REE
D. Spider

1 A 9. What type of diagram is this?
A. Fenner
B. Pearce
C. REE
D. Spider

5.5 10. Why is the abscissa plotted decreasing from left to right?
MgO is a component of very high-temperatures minerals, such as forsterite and enstatite. It decreases as magma temperatures drop because these minerals are the first to crystallize, so plotting decreasing MgO corresponds to what is happening as magma crystallizes.

7.5 11. Why do calcium and alumina concentrations drop?
Because Ca-rich plagioclase also crystallizes early.

10 12. The area shown in green 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)

- 2, 0 1-2. The two most common volatile gases associated with magma are:
1) WATER VAPOR and 2) CARBON DIOXIDE.
- 1 3. The formation of a large depression by the removal of large quantities of magma from beneath a volcano, causing the ground to collapse into the empty space produces a CALDERA.
- 2 4. Most solids are denser than their liquids at the melting point, so ΔV is positive on going from solid to liquid. A geologically very important substance which is an exception to this rule is WATER.
- 4 5. For an isobaric system, complete the following equation.
 $(\delta G/\delta T)_P =$ -S
- 5 6. For an isothermal system, complete the following equation.
 $(\delta G/\delta P)_T =$ V
- 4.5 7. A FLUID-SATURATED melt contains the maximum amount of dissolved volatile species possible at a given set of P-T-X conditions. Any increase in volatile content will produce one or more additional phases. **It is necessary to specify what is saturated.**
8. LIL includes elements K, Rb, Cs, Ba, Pb²⁺, and Sr. 8) What does LIL stand for? They are incompatible with silicate minerals, except for Ba and Sr. 9) Which major mineral do Ba and Sr occur in? **They follow Ca**
- 1 8. LARGE-ION LITHOPHILE ELEMENTS
- 8 9. PLAGIOCLASE
- 3, 3 10-11. Which type of extrusive igneous rock may be confused with which type of intrusive rock?
10) LAVA FLOW may be confused with 11) HYPABYSSAL rock.
- 5,4 12-13 How is the mafic mineralogical composition likely to change on going from a granodioritic magma to a granitic magma? 12) From hornblende to biotite
Why? 13) Granodiorites form at slightly higher temperatures than granite, and are therefore
10-13 came from the homework, and were identified in class as answers many students had trouble with

Discussion Questions - Write a complete, concise answer to the following questions. Diagrams (labeled) may be used to supplement your written answers, where appropriate.

- 12.5 1. Plutonic emplacement is often related to other events, especially orogenesis. Name and describe the terms used to denote emplacement before, during, or after orogenesis. What features seen in the pluton will help select the correct age association? (3 points)

Pre-tectonic plutons - Emplacement occurs before major tectonic movements. The orogenic events impart both a tectonic and a metamorphic imprint on the pluton. Internal foliation is established, and it parallels that of the country rock. Regional metamorphism may curve around the pluton, particularly if there are ductility differences. Pre-tectonic plutons are relatively cold, and likely to be mechanically strong. Most deformation will be concentrated at the border zone.

Syn-tectonic plutons - When the pluton is formed during orogenesis, it is syn-tectonic. Like the pre-tectonic pluton, it will be affected by orogenic tectonic, often to a greater degree. The syn-tectonic pluton is very warm and therefore ductile. Deformation will be seen throughout the pluton, not limited to the margins. Syn-tectonic plutons may elongate more than pre-tectonic plutons, in the direction of foliation.

Post-tectonic plutons - Emplaced after the tectonic movement and its associated metamorphism, the plutons lack foliation. Any regional deformation fabrics in the country rock will end discordantly at the pluton, or may end concordantly if a significant contact metamorphic aureole and schlieren exist.

- 17 2. At 2 GPa, carbon dioxide solubility is 5-6% in the system Albite-H₂O-CO₂, 18% in the system Enstatite-H₂O-CO₂, and 35% in the system Diopside-H₂O-CO₂. 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 CaCO₃. 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).
- 7 3. Name and briefly describe three terrestrial sources of rock believed to be samples of the mantle available on the surface of the earth. (3 points)
1. Ophiolites - Sheet-like mafic to ultramafic rocks, sometimes thrust onto continental borders or incorporated into continental mountain ranges. They are composed of oceanic crust and upper mantle. Erosion has exposed these rocks in some areas. The ultramafic rocks in the lower portion of the ophiolite sequences are believed to represent the upper mantle. In the mountains, we sometimes find slivers referred to as alpine peridotites. These also contain ultramafic portions. The ultramafic rocks in both regions contain peridotites, usually harzburgite and dunite, and subordinate rocks such as wehrlite, lherzolite, and pyroxenite.
 2. Dredge samples from oceanic fracture zones - The fracture zones are transform faults, and significant fault scarps are sometimes found there. At the base of the scarps, broken rocks accumulate. In the 1960's and 70's, much dredging of these samples occurred. These samples, like the ophiolites on the continents, are restricted to the uppermost mantle. The rocks seen are very similar.
 3. Nodules in basalts - Nodules are found in some basalts, usually fist-sized or smaller. They are xenoliths, rocks that fell into the magma and survived. They are found only in alkaline basalts, never in tholeiites. Many types of nodules are found. They include gabbro, dunite, and harzburgite, which are common rocks in the crust and upper mantle. There are also lherzolite in three varieties (spinel, plagioclase, and garnet) and eclogite. Nodules may be autoliths, rocks genetically related to the magma, rather than picked up from the wall or roof rocks. Restites, which are refractory residuum left by partial melting, are also found. (Picture next slide) The garnet lherzolites are of the most interest, because they are high-pressure rocks found in the most alkaline, silica-deficient rocks. This suggests their origin in deep in the mantle, and that they rose very quickly to the surface.
 4. Xenoliths in kimberlites - Kimberlite pipes are always found in continental areas. They appear to tap upper mantle sources between 250-350 km in depth, with the magma rising very rapidly to the surface. Along the way, xenoliths of both upper mantle and crustal rocks are incorporated. The least altered deep samples are composed of spinel or garnet lherzolites.

- 18 4. 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.

- 12 5. The late A.E. Ringwood did a series of experiments on the synthetic substance he called pyrolite. What type of magma fractionation was he considering? What was the most notable outcome of his work? P.J. Wyllie built on Ringwood's work by adding which other magma fractionation process? (3 points)

Ted Ringwood considered the effects of partial melting. The most notable aspect of the work was the lack of a separate spinel phase at any depth. Peter Wyllie added the effects of fractional crystallization. He allowed the substance to partially melt, with the magma then rising within the earth to an area of lower pressure, where it then fractionally crystallized.

- 3 6. The infinite-onion model, with periodic injections of fresh magma, appeared to nicely explain features seen at and below the mid-ocean ridge, and was widely accepted. What eventually caused this model to be rejected? (1 point)

Shallow magma chambers, full of liquid, should be readily detectable by seismic wave studies. But seismic studies have failed to locate magma chambers of any significant size beneath the axial ridges. So, as any model which fails to fit new data must, this model was discarded.

Problem - Use Figure 7-22 to answer the questions. You should be able to get within 10°C. (1 point each)

- 3.5 1. Start at a pressure of 0.7 GPa, with a melt containing 7% H₂O. At what temperature will the first liquid appear? 750°C
- 6 2. At what temperature will there be 25% melt? 1080°C
- 6.5 3. At what temperature will there be 75% melt? 1210°C

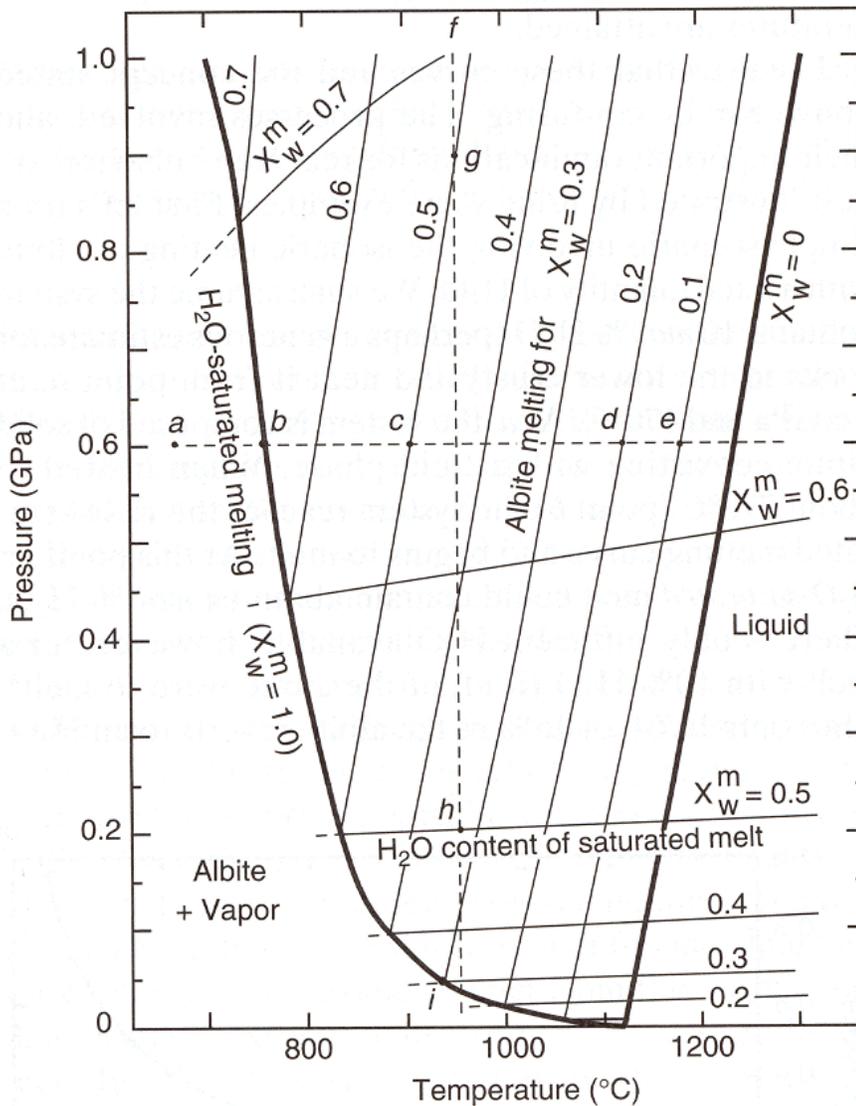


Figure 7-22 Pressure-temperature projection of the melting relationships in the system albite-H₂O. From Burnham and Davis (1974). Reprinted by permission of the American Journal of Science.

Previous Results, Midterm 2

Spring 2019	Mean = 72.0%
Spring 2018	Mean = 78.1%
Spring 2017	Mean = 89.8%
Spring 2016	Mean = 75.0%
Spring 2015	Mean = 78.6%
Spring 2014	Mean = 87.2%
Spring 2013	Mean = 81.0%
Spring 2012	Mean = 74.9%
Spring 2011	Mean = 78.6%
Spring 2010	Mean = 78.3%
Spring 2008	Mean = 70.8%
Spring 2006	Mean = 81.7%
Fall 2001	Mean = 83.1%

Previous Overall Results

Spring 2019	Mean = 70.4%
Spring 2018	Mean = 75.8%
Spring 2017	Mean = 87.5%
Spring 2016	Mean = 77.0%
Spring 2015	Mean = 76.1%
Spring 2014	Mean = 81.5%
Spring 2013	Mean = 84.9%
Spring 2012	Mean = 77.8%
Spring 2011	Mean = 75.9%
Spring 2010	Mean = 77.4%
Spring 2008	Mean = 76.3%
Spring 2006	Mean = 79.2%
Fall 2001	Mean = 78.2%