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. A system in which the pressure is constant is known as an isobaric system.
0   T    2. If $P_f = 0$, a melt is said to be dry.
0   F    3. Parental magmas are always primary.
2   F    4. Slow spreading ridges have persistent magma chambers, whereas fast spreading ridges have small, ephemeral magma bodies
1   T    5. Most of the fastest spreading rates observed are along the East Pacific Rise.
0   T    6. If a plume is centered on a ridge, it may create two aseismic ridges, one on each divergent plate.
0   T    7. Magma series share patterns on chemical variation diagrams which share a genetic relationship.
1   F    8. In the system Forsterite-Nepheline-Silica as pressure increases the eutectic shifts toward the silica apex.
3   F    9. In terms of total rock volume, stratovolcanoes like those in the Andes are much larger than the shield volcanoes of Hawaii.
2   F   10. N-MORB’s form from the deep, incompatible rich mantle below 660 km.
5   T   11. The composition of fast-spreading ridges are more varied than those of slow-spreading ridges, and show either a larger proportion of evolved liquids or a greater degree of partial melting.
0   T   12. In a plot of rare earth element concentrations normalized to chondritic chondrite values, E-MORB’s will show a negative La to Sm slope, despite the fact that E-MORB’s are LREE enriched.
13. Water solubility is greater in felsic minerals like feldspar and quartz, which have bridging oxygens, than in olivine, which doesn’t.

14. Alkaline basalt magmas have more CO₂ but less water than tholeiitic magmas.

15. 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.

16. Blocks are often angular to subangular.

17. Rhyolite grades into basalt as quartz content decreases. In the QAPF diagram, trachyte is below rhyolite.

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

1. Which type of extrusive igneous rock did Bowen do most of his work on?
   A. Basalt
   B. Dacite
   C. Granite
   D. Rhyolite

2. On the continuous side of Bowen’s Reaction Series, what solid solution series is crystallizing?
   A. Olivine
   B. Plagioclase feldspar - this is the continuous side
   C. Potassium feldspar
   D. Amphiboles

3. In a classic paper called "The Origin of Igneous Rocks", written in 1892, magmas were first divided into two series, the alkaline and the sub-alkaline. Who was the author of this paper?
   A. N.L. Bowen
   B. A.E. Ringwood
   C. C.E. Tilley
   D. J.P. Iddings
4. In 1967, the late A.E. Ringwood and colleagues at the Australian National University performed a series of experiments on a synthetic material called pyrolite. Pyrolite is a mixture of olivine, clinopyroxene, orthopyroxene, plagioclase, and small amounts of other phases. What part of the earth was pyrolite supposed to represent.
A. Continental crust
B. Oceanic crust
C. Mantle
D. Core

5. Which of the following conditions indicates that a magma may be primary?
A. The presence of dunite or peridotite nodules
B. Cr content > 1000 ppm, and nickel content > 400 ppm
C. Olivine with a very Mg-rich composition, in the range Fo$_{86-91}$
D. All of the above

6. The coordination number of Si$^{4+}$ below 660 kilometers depth is thought to be what?
A. III
B. IV
C. VI
D. VIII

7. This layer consists of two sublayers, both composed of basalt. The upper layer, shows pillow structures, while the lower sublayer is composed of vertical sheeted dikes shallowly emplaced in extensional openings. Many of the dikes have a single chilled margin, probably because latter dikes split earlier ones, intruding them. Which layer is this?
A. Layer one
B. Layer two
C. Layer three
D. Layer four

8. 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
9. The dominant type of magma in the Hawaiian Islands is:
A. OIT - tholeiite is about 98% of the magma erupted
B. OIA, silica undersaturated
C. OIA, slightly silica saturated
D. There is no dominant type, because the composition varies substantially over time

10. LIL elements are all enriched in OIB relative to MORB. They can be used to evaluate which of the following?
A. Source composition
B. Degree of partial melting and residual phases
C. Subsequent fractional crystallization
D. All of the above

11. Ni and Cr both are accommodated in the olivine structure. OIA rocks are depleted in both Ni and Cr relative to OIT and MORB. This indicates the OIA’s have experienced fractional crystallization of olivine:
A. Prior to eruption
B. At the time of eruption
C. After eruption
D. Either B or C

12. The calc-alkaline series is found in which setting?
A. Convergent plate margin
B. Divergent plate margin
C. Within an oceanic plate
D. Within a continental plate

13. Which of the following lherzolite phases occurs at the shallowest depths?
A. Garnet
B. Plagioclase
C. Spinel
D. None of the above

14. The ultimate source rock of a plume is believed to be:
A. The spinel lherzolite field
B. The plagioclase lherzolite field
C. Decompressive melting in the asthenosphere
D. Below 660 km, in enriched mantle material
15. Which isotope of lead does not have a radiogenic precursor?
   A. $^{204}\text{Pb}$
   B. $^{206}\text{Pb}$ $^{232}\text{Th}$
   C. $^{207}\text{Pb}$ $^{235}\text{U}$
   D. $^{208}\text{Pb}$ $^{238}\text{U}$

16. Which of the following minerals is an alkaline pyroxene?
   A. Aegirine
   B. Albite
   C. Nepheline
   D. Riebeckite

17. Which of the following minerals is an orthopyroxene?
   A. Augite
   B. Diopside
   C. Enstatite
   D. Hornblende

18. Which of the following is NOT a phyllosilicate?
   A. Chlorite
   B. Fayalite
   C. Kaolin
   D. Phlogopite

19. Which of the following minerals is hydrous?
   A. Albite
   B. Augite
   C. Hornblende
   D. Labradorite

20. In the terminology used in the United States, the major minerals of diabase are
   A. Quartz and plagioclase
   B. Plagioclase and pyroxene
   C. Olivine and calcic plagioclase
   D. Nepheline and pyroxene
**Fill-Ins** - Write in the word or words which best completes each statement or answers each question. (1 point per blank)

2. For the equation, \( \Delta V = V_L - V_S \), is positive on going from solid to liquid. Name a substance, which is very significant in geology, for which \( \Delta V \) is negative. **WATER**

2. State the Clapeyron Equation. \( (dP/dT) = (\Delta S/\Delta V) \)

5. What is the Mg #? \( \text{Mg#} = \left(\frac{\text{MgO}}{\text{MgO} + \text{FeO}}\right) \times 100 \)

0.5. Persistent magma chambers just below the ridge axis were postulated as narrow (5 km) and not too deep (up to 9 km). Magma was injected and began to fractionally crystallize to produce derivative MORB's. Dikes could emanate upward to create sheeted dike complexes, and feed the pillow flows. Crystallization along the walls, top, and bottom of the chamber could create gabbros. Periodic injections of fresh magma, together with divergent plate movement, would continually expand the chamber, preventing the crystallization from completely filling the chamber. Indeed, Cann called this model the "INFINITE ONION", since layers would be added from the inside. The dense ol and opx would settle toward the floor, producing the ophiolite layers of level 3, and suspected to be present in layer 4.

0.5. Why are bombs rounded to sub-rounded? **THEY WERE VISCIOUS LIQUIDS WHEN Erupted, AND WERE ROUNDED IN FLIGHT**

1. What does MAR stand for? **MID-ATLANTIC RIDGE**

5. Upward movement of magma under nearly adiabatic conditions would produce a type of melting known as **DECOMPRESSIVE** melting

8. The \( \text{Al}_2\text{O}_3/\text{TiO}_2 \) is about 20 in MORB, but close to 5 in OIT. Olivine is the only mineral removed early. Does this suggest fractional crystallization is at work? 8a) **NO** Why or why not? 8b) **OLIVINE DOES NOT CONTAIN EITHER Al OR Ti, SO REMOVAL OF OLIVINE WILL NOT AFFECT THIS RATIO, THEREFORE FRACTIONAL CRYSTALLIZATION IS NOT AFFECTING THE RATIO.**

Knowing the major elements of olivine would help - learn your minerals!
9. PREMA (Prevalent Mantle) is another proposed reservoir which corresponds to several oceanic islands, including Easter Island, Hawaii, the Galapagos Islands, and Iceland. But it is in the middle of the mantle array, and can be made but mixing of other reservoirs. Why is it considered by some to be a separate reservoir?

THE FREQUENT OCCURRENCE OF THIS COMPOSITION, IN GEOGRAPHICALLY DIVERSE LOCATIONS, SUGGESTS TO SOME THAT IT IS A SEPARATE RESERVOIR.

8 10. What is the major difference between dacite mineralogy and andesite mineralogy?

IN DACITE, QUARTZ IS AN ESSENTIAL MINERAL, OFTEN OCCURRING AS PHENOCRYSTS. QUARTZ IS GENERALLY ABSENT IN ANDESITE.

12.5 11. What is the P/(A+P) range for quartz latite? 35-65 What are the boundaries within the QAPF diagram?

12. Diabasic texture is (name and describe): OPHITIC TO SUBOPHITIC TEXTURE IN WHICH LATH-SHAPED PLAGIOCLASE CRYSTALS ARE PARTIALLY OR COMPLETELY INCLUDED IN PYROXENE CRYSTALS, TYPICALLY AUGITE

7,3 13-14. A lithic fragment is 13) CRystalline, while a vitric fragment is 14) GLASSY.

15-16. Basalts displaying a “pillow” structure are believed to have formed in one of two ways. These are:

15. BY SUBMARINE OR SUBLACUSTRINE ERUPTION.

16. BY SUBAERIAL ERUPTION, FOLLOWED BY FLOW INTO THE OCEAN.
**Problem** - Use the figure below. You should be able to get within 10°C.

1. Start at a pressure of 0.3 GPa, with a melt containing 10% \( \text{H}_2\text{O} \). At what temperature will the first liquid appear? 810°C

2. At what temperature will there be 25% melt? 925°C

3. At what temperature will there be 50% melt? 1060°C

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**Figure 7–22** Pressure-temperature projection of the melting relationships in the system albite-\( \text{H}_2\text{O} \). From Burnham and Davis (1974). Reprinted by permission of the American Journal of Science.
Short Answer - Write a complete, concise answer to the following two questions. Diagrams (labeled) may be used to supplement your written answers, where appropriate. 5 points each

32.5 1. Hawaii is by far the best studied of the oceanic islands. A typical sequence of four stages of eruption has been discovered, beginning before the shield volcano has formed. Name and describe these four stages of eruption. Which stage(s) brings a wide variety of xenoliths to the surface?

1. PRE-SHIELD STAGE - SUBMARINE ERUPTIONS OF ALKALINE BASALT AND HIGHLY ALKALINE BASANITES, FOLLOWED BY THOLEIITIC BASALT. LOIHI SEAMOUNT, SITUATED ABOUT 35 KM SOUTHEAST OF THE ISLAND OF HAWAII, IS AT THIS STAGE. THE ALKALINE BASALTS REPRESENT LOW DEGREES OF PARTIAL MELTING.

2. SHIELD-BUILDING STAGE - TREMENDOUS OUTPOURINGS OF THOLEIITE BEGIN TO BUILD A SHIELD VOLCANO. THE ISLAND OF HAWAII IS COMPRISED OF FIVE SHIELDS. MAUNA LOA AND KILAUEA, THE MOST ACTIVE SHIELDS, ARE PRESENTLY IN THIS STAGE. MAUNA LOA ALREADY REPRESENTS 40,000 KM3 OF BASALT. 98-99% OF ALL LAVA IN HAWAII RESULTS FROM THIS STAGE.

3. POST-SHIELD STAGE - MAUNA KEA, HUALALAI, AND KOHALA, THE REMAINING THREE SHIELDS ON THE ISLAND OF HAWAII, HAVE REACHED THIS STAGE. ACTIVITY SLOWS, BECOMES EPISODIC (AS OPPOSED TO NEARLY CONTINUOUS), ALKALINE, AND MORE VIOLENT. LAVAS ARE MUCH MORE VARIED AS THE RESULT OF SHALLOW FRACTIONATION. ACTIVITY FADES, ENTERING A PERIOD OF DORMANCY FOR ABOUT 0.5 TO 2.5 M.Y.

4. POST-EROSIONAL STAGE - HIGHLY-ALKALINE, SILICA UNDERSATURATED MAGMAS ERUPT. ROCK TYPES INCLUDE ALKALI BASALTS, BASANITES, NEPHELINITES, AND NEPHELINE MELILITES.

THE ALKALINE STAGES BRING A WIDE VARIETY OF XENOLITHS TO THE SURFACE.
2. Crustal contamination of mantle rocks can lead to erroneous conclusions about the origin and subsequent history of the mantle rocks. Lead isotopic systems are often thought to provide useful information about crustal contamination. Why? Which of the following ratios is the most sensitive indicator of mantle contamination? Why?

\[
\frac{^{206}\text{Pb}}{^{204}\text{Pb}}, \quad \frac{^{207}\text{Pb}}{^{204}\text{Pb}}, \quad \frac{^{208}\text{Pb}}{^{204}\text{Pb}}.
\]

(Provide a detailed answer)

Lead is a large, incompatible ion. It will quickly segregate itself into a liquid phase, and will migrate upward to become incorporated in oceanic or continental crust. Thus, there is relatively little lead in the mantle. Radioactive isotopes are concentrated in felsic rocks. Continental crust has high concentrations of lead, and develops high concentrations of radiogenic daughter nuclei over time. Oceanic crust has elevated U and Th content, relative to the mantle, as well as a sedimentary cover derived from continental and oceanic crust, and will also develop increased levels of radiogenic daughter nuclei over time. One isotope of lead, \(^{204}\text{Pb}\), has no radioactive precursor. Ratios of \(^{206}\text{Pb}/^{204}\text{Pb}\), \(^{207}\text{Pb}/^{204}\text{Pb}\), and \(^{208}\text{Pb}/^{204}\text{Pb}\) will all increase with time. Since 99.3% of natural uranium is currently \(^{238}\text{U}\), the dominate radiogenic daughter will be \(^{206}\text{Pb}\). Pb is the most sensitive measure of crustal components in mantle isotopic systems.

Mixing of mantle material with crustal material will greatly change the observed lead-lead isotopic ratios, with \(^{206}\text{Pb}/^{204}\text{Pb}\) being the most sensitive to crustal contamination, because the radioactive precursor of \(^{206}\text{Pb}\) is \(^{238}\text{U}\), which is far more common than \(^{235}\text{U}\) or \(^{232}\text{Th}\). PLOTS of \(^{207}\text{Pb}/^{204}\text{Pb}\) versus \(^{206}\text{Pb}/^{204}\text{Pb}\) can thus yield information about possible contamination. If no contamination of mantle material has occurred, the data should plot along the geochron, with the ratio depending only on the age of the sample.
Midterm 2 Results

61.0
59.0  A+
52.5  B+
51.0
49.5  B
49.0 - 2  B-
44.0 - 2  C
42.5  C-
41.5
40.5  D+
38.5
38.0  D

Mean = 47.1 (78.6%)
Median = 47.5

Previous Results

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%
### OVERALL RESULTS

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**Previous Overall Results**

- **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%