GLY4310 68 points 18 took exam Name\_\_\_\_\_ March 24, 2010

## 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)

- 2 <u>F</u> 1. The seismic Moho and the petrologic Moho are the same depth below the surface.
- 5 <u>T</u> 2. Heavy isotopes like those of strontium or neodymium are not likely to mass fractionate significantly during either partial melting or fractional crystallization.
- 3 <u>T</u> 3. If a melt is fluid saturated, any increase in volatile content will produce one or more additional phases.
- 3 <u>T</u> 4. The dry peridotite solidus has a positive P/T slope. Thus, lowering the pressure at constant T would eventually produce melting.
- 7 <u>F</u> 5. Fast-spreading ridges have a pronounced axial valley, 30 to 50 kilometers in width, and 1-5 kilometers in depth. Inward facing fault scarps are seen, a feature shared with continental rift zones. An inner rift valley is often present, 3-9 kilometers in width, with a flat floor. This is the definition of a slow-spreading ridge.
- 2 <u>F</u> 6. Heat-flow at slow-spreading ridges is much higher than at fast-spreading ridges.
- 8 <u>F</u> 7. Carbon dioxide solubility is very high in silicate melts. Just the opposite
- 3 <u>T</u> 8. At a given depth of melting, fractional crystallization is simply the reverse of partial melting.
- 3 <u>F</u> 9. The first crystals formed in a magma are more likely to be anhedral than crystals formed later in the crystallization
- 5 <u>F</u> 10. Basaltic magma generally contains more water than granitic magmas.
- 5 <u>T</u> 11. The olivine in the upper gabbro layers of a Gabbro Ophiolite complex is richer in fayalite than the olivine in the peridotite layer.
- 6 T 12. Augite is a higher temperature mineral in Bowen's Reaction Series than hornblende.
- 4 <u>T</u> 13. Tholeiites are far more voluminous than alkaline rocks.

- 5 <u>F</u> 14. Ultramafic rocks like those in the mantle ordinarily contain volatiles
- 1 <u>T</u> 15. Garnet, spinel, and plagioclase lherzolites all have the same composition, but melting will not begin at the same temperature, since garnet, spinel, and plagioclase all have different melting points.
- 4 <u>T</u> 16. LIL and HFS data for N-MORB and OIB show that the K/Ba and Zr/Nb ratios are much higher for the N-MORB's than for OIB, suggesting at least two separate mantle reservoirs.
- 9 <u>F</u> 17. Basaltic magmas have much higher volatile contents, on average, than granitic magmas. Granites are wet, basalts dry.
- 1 <u>F</u> 18. In terms of total rock volume, stratovolcanoes like those in the Cascades are much larger than the shield volcanoes of Hawaii.
- 2 <u>T</u> 19. The following reaction is an example of a discontinuous reaction.

 $Melt = Mineral_1 + Mineral_2$ 20. If  $P_f = P_{total}$ , the melt 4 is saturated with volatiles.

- 8 <u>T</u> 21. Rocks form an alkaline magma series may be found within both continental and oceanic plates, but are only associated with convergent plate margins.
- 5 <u>T</u> 22. Under adiabatic conditions, decompressive melting can turn up to at least 30% of a rock body into magma.
- 5 <u>F</u> 23. Fractional crystallization under low pressures (at a shallow depth) is likely to produce a silica-undersaturated magma, leading to a rock like nephelinite.
- 7 <u>F</u> 24. A mush zone contains more liquid than a magma lens.

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

- 5 <u>C</u> 1. Granite belongs to what silica classification?
  - A. Ultramafic
  - B. Intermediate
  - C. Felsic
  - D. Mafic

- 2 <u>A</u> 2. When early-formed, dense crystals settle to the bottom of a magma chamber without further reaction, the process is called:
  - A. Fractional crystallization
  - B. Anatexis
  - C. Forceful injection
  - D. Zone melting
- 4 <u>D</u> 3. The Columbia River and Deccan Plateaus are:
  - A. Gabbroic layered intrusions
  - B. Carbonatites
  - C. Anorthosite plutons
  - D. Flood Basalts
- 1 <u>D</u> 4. We have never successfully drilled into the upper mantle. Nevertheless, sample fo the upper mantle are thought to be available. Which of the following sources might provide upper mantle rock samples?
  - A. Dredged samples from oceanic fracture zones
  - B. Nodules in basalt
  - C. Xenoliths in kimberlites
  - D. All of the above
- 4 <u>B</u> 5. The work of the late A.E. Ringwood on the melting and crystallization of the synthetic mantle material called pyrolite failed to show the formation of which of the following minerals at any depth?
  - A. Plagioclase
  - B. Spinel
  - C. Garnet
  - D. Olivine
- 1 <u>D</u> 6. A magma formed by melting at depth, without any subsequent modification process, is a:
  - A. Derivative magma
  - B. Parental magma
  - C. Primitive magma
  - D. Primary magma
- 5 <u>A</u> 7. Normalizing the observed concentrations of elements in REE and spider diagrams relative to C1 chondrites helps to eliminate:
  - A. The Oddo-Harkins effect
  - B. Partial melting effects
  - C. Fractional crystallization effects
  - D. All of the above

- 0 <u>C</u> 8. Gabbro, presumably from shallow magma chamber near the ridge axis, makes up this layer of the ocean. The upper sublayer has isotropic gabbro on top of transitional gabbro. The lower sublayer is layered gabbro with cumulate textures. Which layer is this?
  - A. Layer 1
  - B. Layer 2
  - C. Laager 3
  - D. Layer 4
- omitC9. Gabbro, presumably from shallow magma chamber near the ridge axis, makes up this<br/>layer of the ocean. The upper sublayer has isotropic gabbro on top of transitional gabbro.<br/>The lower sublayer is layered gabbro with cumulate textures. Which layer is this?
  - A. Layer 1
  - B. Layer 2
  - C. Layer 3
  - D. Layer 4
- 7 <u>B</u> 10. In the Hawaiian Island sequence of basaltic eruptions, alkaline basalt is seen in all of the following stages except:
  - A. Pre-shield
  - B. Shield-building
  - C. Post-shield
  - D. Post-erosional
- 1 <u>A</u> 11. Which of the following lead isotopes does not have a radiogenic source?
  - A. <sup>204</sup>Pb
  - B. <sup>206</sup>Pb
  - C. <sup>207</sup>Pb
  - D. <sup>208</sup>Pb
- 5 <u>C</u> 12. The following set of characteristics describes plutons of what depth of emplacement? Partially concordant, partially discordant, contacts sharp to gradational Country rock 300-500°C
  - Low grade regional metamorphism

Planar foliation, sometimes with lineation, is generally present, especially near the contact Contact metamorphic aureole is usually present

- No relation to volcanoes
- No chilled border zone (or very minor)
- Most major batholiths are mesozonic

Generally late stage syn-tectonic, or post-tectonic

Spotted slates and phyllites are common

- A. Catazone
- B. Epizone
- C. Mesozone
- D. None of the above

- 3 <u>D</u> 13. Which of the following are potential sources of upper mantle rocks?
  - A. Dredge samples from oceanic fracture zones
  - B. Ophiolites
  - C. Xenoliths in kimberlites
  - D. All of the above
- 9 <u>C</u> 14. Lherzolites are a type of:
  - A. Clinopyroxenite
  - B. Orthopyroxenite
  - C. Peridotite
  - A. All of the above
- 0 <u>C</u> 15. In a Fenner diagram, the wt. % oxides of various elements are plotted versus which element.
  - A. Ca
  - B. Fe
  - C. Mg
  - D. Ni

3 <u>A</u> 16. In Bowen's Reaction Series, which branch or branches are continuous?

- A. Felsic
- B. Mafic
- C. Both
- D. Neither
- 0 <u>C</u> 17. In the two-layer mantle model, where is the separation between layers thought to occur? A. At the Moho
  - B. At 100 kilometers
  - C. At 660 kilometers
  - D. At 2900 kilometers
- 13 <u>C</u> 18. The lack of HREE depletion excludes which of the following as a source for MORB? A. Plagioclase lherzolite
  - B. Spinel lherzolite
  - C. Garnet lherzolite
  - D. None of the above
- 10 <u>A</u> 19. MORB's do not show a Eu anomaly. Which of the following layers would likely produce a Eu anomaly if it were the source of MORB.
  - A. Plagioclase lherzolite
  - B. Spinel lherzolite
  - C. Garnet lherzolite
  - D. None of the above

7 <u>B</u> 20. Element ratios are sometimes useful for discriminating different rock types. On the is frequently used is K/Ba. For which of the following rock types is this ration very high? A. E-MORB B. N-MORB C. OIA D. OIT

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

- 9 1. If a rising diapir were to follow adiabatic (without loss of heat) conditions, then the rock temperature would follow the adiabat.. This curve is a loss of about 12 C/GPa. It is impossible to follow a true adiabat, but rapidly rising masses would come close. The melting curve is decreasing about 130 C/GPa, so it is possible for the rock to initiate melting. Once melting begins, the heat of fusion will consume energy, and keep the adiabatic path to a shallow slope. Melting will occur, but slowly, and with limited quantities of melt. The process is called <u>DECOMPRESSION MELTING</u>.
- 6 2. A study by Rhodes showed that clinopyroxene removal is necessary for mass balance to be maintained in models of MORB fractionation, despite the fact that clinopyroxene is not a liquidus phase in them. This is called the <u>PYROXENE PARADOX</u>.
- 1.5 3. Cann proposed a name for a model of axial model chambers. The model envisioned narrow, shallow magma chambers into which magma was injected. Fractional crystallization began to produce MORB. Dikes might emanate upward, to produce sheeted dike complexes. They would also feed pillow flows. Crystallization along the walls, top and bottom of the magmas would produce gabbro. Periodic injections of fresh magma, together with divergent plate motion, would continually expand the magma chamber, preventing crystallization from filling it up. Cann called this model <u>THE INFINITE ONION MODEL</u>.
- 5 4. Despite the attractiveness of the model outlined in the previous question in explaining many physical features of the ocean crust at a divergent boundary, it was discarded because of one fatal flaw. What was the flaw?

THE AXIAL MAGMA CHAMBERS SHOULD BE READILY DETECTED SEISMICALLY, BUT THEIR PRESENCE IS NEVER SEEN

5. The elements Th, U, Ce, Zr, Hf, Nb, Ta, ane Ti are known as HFS elements. HFS stands for <u>HIGH-FIELD STRENGTH</u>. 14 6. When petrologists attempt to determine the average chemistry of MORB, they extract glass from the basalt, and measure the chemistry. Why?

### GLASS IS UNSOLIDIFIED MAGMA THAT HAS NOT UNDERGONE ANY MAGMATIC DIFFERENTIATION PROCESSES .

7-8. Why are divergent boundaries more likely to be found in oceans than on a continent? Discuss two reasons for this.

- 8 7) <u>ONE REASON IS THAT OCEANS COVER 70% OF THE EARTH'S CRUST, CONTINENTS</u> 30%.
- 12 8)ANOTHER IS THAT THE OCEANIC LITHOSPHERE IS MUCH THINNER (10 KM) THAN CONTINENTAL LITHOSPHERE. THIS RESULTS IN RIFTS ON LAND EITHER OPENING, SPLITTING A CONTINENT AND CREATING A NEW OCEAN, OR FAILING, AND BECOMING AN AULACOGEN. SINCE A RIFT ON THE OCEAN FLOOR IS NO LONGER CONTINENTAL, CONTINENTAL RIFTS SIMPLY DO NOT LAST FOR LONG.
- 5 9-10. Consider the reaction:

# $H_2O_{(vapor)} + albite = liquid_{(aa)}$

This reaction has a large negative  $\Delta V$  on going from left to right. In a plot of pressure versus temperature under H<sub>2</sub>O saturated conditions, will the slope of the line be negative or positive? <u>NEGATIVE</u>. 10. Why?

- 12 THE CLAPEYRON EQUATION SAYS THAT THE CHANGE IN PRESSURE WITH RESPECT TO TEMPERATURE EQUALS THE CHANGE IN ENTROPY DIVIDED BY THE CHANGE IN VOLUME. THE CHANGE IN ENTROPY GOING FROM A SOLID TO A LIQUID IS ALWAYS POSITIVE, SO THE NEGATIVE VOLUME CHANGE MAKES THE SLOPE OF THE LINE NEGATIVE
- 7 11. A <u>MAGMA SERIES</u> is a group of rocks that share some chemical, and sometimes mineralogical, characteristics.
- 0 12. MORB stands for <u>MID-OCEAN RIDGE BASALT</u>

- 13. Why is lead thought to be a good indicator of contamination of mantle rocks? <u>THE MANTLE CONTAINS VERY LITTLE LEAD, SO MANTLE SAMPLES WITH HIGH</u> <u>LEAD CONCENTRATIONS ARE PROBABLY CONTAMINATED BY NON-MANTLE</u> <u>ROCKS.</u>
- 10.514. Where are the DUPAL volcanoes located? 14)DUPAL VOLCANOES ARE LOCATED INTHE SOUTHERN HEMISPHERE, CLUSTERED AROUND THE 30°S LATITUDE LINE.
- 4 15. What is the NHRL (name and description)? <u>NHRL STANDS FOR THE NORTHERN</u> <u>HEMISPHERE REFERENCE LINE, WHICH IS A LINE DRAWN BETWEEN THE DM AND</u> <u>HIMU RESERVOIRS IN A PLOT OF <sup>208</sup>Pb/<sup>204</sup>Pb VS. <sup>206</sup>Pb/<sup>204</sup>Pb.</u>

**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)

- 1 <u>B</u> 1. The photo shows which of the following features?
  - A. Columnar joints
  - B. Lava tube
  - C. Pillow basalt
  - D. Tephra
- 3 <u>D</u> 2. The photo shows what feature? A. Dike B. Laccolith
  - B. Laccolith C. Lopolith
  - C. Lopoli
  - D. Sill
- 10 <u>T</u> 3. (T-F) At point B in the diagram,  $G_s > G_l$ . The stable state is the one with the lowest free energy.
- 4. The equation shown in the diagram is the <u>CLAPEYRON EQUATION</u>
- 9.5 5. What do the symbols labeled 1atm, 1GPa, 2 GPa, and 3 GPa represent? (Note: The question does **not** ask what the abbreviations atm and GPa stand for.)

# THE SYMBOLS ARE THE POSITION OF THE TERNARY EUTECTICS AT THE RESPECTIVE PRESSURES SHOWN.

6-8 At low pressure (~0.3 GPa) , what would be the order of crystallization as the temperatures decreased from 1300° to 1100°C?

#### 8 6) <u>OLIVINE, FOLLOWED BY PLAGIOCLASE, THEN CLINOPYROXENE</u>

At high pressure (1.0 GPa), what would be the order of crystallization as the temperatures decreased from  $1300^{\circ}$  to  $1100^{\circ}$ C?

#### 8 7) <u>CLINOPYROXENE, THEN PLAGIOCLASE, THEN OLIVINE</u>

Under what conditions would you get simultaneous crystallization of olivine, plagioclase, clinopyroxene, and orthopyroxene?

## 5.5 8) THE QUARTERNARY EUTECTIC IS LOCATED AT ABOUT 0.8 GPA AND APPROXIMATELY 1260°C.

9. Both the solidus and liquidus lines become nearly vertical as depth increases. Why?
ΔV APPROACHES ZERO ON GOING FROM SOLID TO LIQUID AS PRESSURE

INCREASES, WHICH CAUSES BOTH SOLIDUS AND LIQUIDUS TO CHANGE SLOPE AS DEPTH INCREASES.

**Short Answer -** Write a complete, concise answer to **two** of the following **three** questions. Diagrams (labeled) may be used to supplement your written answers, where appropriate. 4 points each

1. The terms derivative magma, parental magma, and primary magmas were discussed in lecture and the textbook. Define each type, and discuss their interrelationships.

A PRIMARY MAGMA IS ONE THAT FORMS AT DEPTH, WITHOUT ANY LATER MODIFICATION. A DERIVATIVE MAGMA IS ONE THAT HAS BEEN MODIFIED BY SOME MAGMA DIFFERENTIATION PROCESS AS IT IS RISING. SUCH PROCESSES CAN PRODUCE A MAGMA SERIES. WITHIN A GIVEN SERIES, THE MOST PRIMITIVE MAGMA MAY BE CALLED THE PARENT MAGMA. PARENT MAGMAS MAY OR MAY NOT BE PRIMARY. 2. The ocean crust and upper mantle structure is composed of layers 1, 2A, 2B AND 2C, 3A and 3B, and 4. Describe the rock types and structures found in each layer and sublayer.

LAYER 1 IS A THIN LAYER, GRADUALLY INCREASING IN THICKNESS AWAY FROM THE SPREADING CENTER, WHICH CONSISTS OF PELAGIC SEDIMENTS. LAYER 2A AND 2BCONSISTE OF PILLOW BASALTS, WITH INFILLING OF MATERIALS BETWEEN THE PILLOWS. LAYER 2C IS A VERTICAL SHEETED-DIKE COMPLEX. LAYER 3A CONSISTS OF ISOTROPIC TO SOMEWHAT FOLIATED (AS DEPTH INCREASES) GABBROS, WHILE 3B IS MORE LAYERED, WITH CUMULATE TEXTURES. LAYER 4 IS OPHIOLITES, WEHRLITE INTRUDING INTO CUMULATE GABBROS, FOLLOWED BY CUMULATE DUNITE WITH INTRUDED XENOLITHIC HARZBURGITE, AND FINALLY TECTONITE HARZBUGITE/DUNITE, A RESIDUUM OF UNMELTED MANTLE.

3. Which of the following ratios is the most sensitive indicator of mantle contamination?

<sup>206</sup>Pb/<sup>204</sup>Pb, <sup>207</sup>Pb/<sup>204</sup>Pb, <sup>208</sup>Pb/<sup>204</sup>Pb.

Why is this ratio the best? How does <sup>204</sup>Pb differ from <sup>208</sup>Pn, <sup>207</sup>Pb, and <sup>206</sup>Pb? The HIMU reservoir is characterized by a high value of  $\mu$ . What is  $\mu$ ? How is the HIMU reservoir different isotopically from other reservoirs?

<sup>206</sup>Pb/<sup>204</sup>Pb IS THE MOST SENSITIVE, BECAUSE THE RADIOACTIVE PRECURSOR OF <sup>206</sup>Pb IS <sup>238</sup>U, WHICH IS FAR MORE COMMON THE <sup>235</sup>U OR <sup>232</sup>Th. <sup>204</sup>Pb IS NON-RADIOGENIC, WHILE ALL THE OTHERS HAVE A RADIOACTIVE PRECURSOR ISOTOPE.  $\mu = {}^{238}$ U/<sup>204</sup>Pb. THE HIMU RESERVOIR IS QUITE DISTINCTIVE IN THE Pb SYSTEM, HAVING A VERY HIGH <sup>206</sup>Pb/<sup>204</sup>Pb RATIO, SUGGESTIVE OF A SOURCE WITH HIGH U, YET NOT ENRICHED IN Rb, AND OLD ENOUGH (> 1 Ga) TO DEVELOP THE OBSERVED ISOTOPIC RATIOS BY RADIOACTIVE DECAY OVER TIME

Question #	Times Answered	Points Missed	Average Missed
1	12	10	0.8
2	14	9.5	0.7
3	8	11.5	1.4

**EXTRA-CREDIT** - Answer the following question for up to four points extra credit.

18 Explain what a deuteric autometamorphic process is. Name and describe what is happening in one example of a deuteric process.

AS INTRUSIVE IGNEOUS ROCKS COOL SLOWLY, THEY WILL PASS THROUGH A RANGE OF TEMPERATURES USUALLY ASSOCIATED WITH METAMORPHOSIS, ROUGHLY 300-800°C. THE MINERALS IN THE ROCK MAY BE ALTERED. IF THE REACTIONS INVOLVE WATER, THEY ARE TERMED DEUTERIC. EXAMPLES:

1)URALIZATION, IN WHICH PYROXENE IS CONVERTED TO AMPHIBOLE

2) BIOTITIZATION, IN WHICH EITHER PYROXENE OR AMPHIBOLE IS CONVERTED TO BIOTITE

3) CHLORITIZATION IN WHICH A MAFIC MINERAL IS CONVERTED TO CHLORITE

4) SERITIZATION IF THE CONVERSION OF FELSIC MINERALS TO VERY FINE-GRAINED WHITE MICA

5) SAUSSURIZATION IS THE REACTION OF CALCIC PLAGIOCLASE TO FROM NEARLY PURE ALBITE PLUS EPIDOTE

6) SERPENTINIZATION IS THE BREAKDOWN OF ANHYDROUS MAFIC MINERALS TO FORM SERPENTINE MINERALS

## Midterm 2 Results

<u>66.5</u>	A+	
64.0	A	
62.0	<u>A-</u>	
<u>59.5</u>	B+	
58.5 - 2		
57.0	B	
56.0		
55.0		
54.5	B-	$\mathbf{MEDIAN} = 54.8$
52.5	C+	MEAN =53.3 (78.3%)
51.0	С	× ,
49.0		
48.5	C-	
47.0 - 2	D+	
41.0	D-	
38.5	F	
Spring 2010	Mean = 78.3	3%
Spring 2008 Mean = 70.8%		8%
Spring 2006	Mean = 81.7%	
Fall 2001	<b>Mean = 83.</b>	1%

Exams	to	Date
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<u>113.5</u>	A	
111.5		
109.0	<u>A-</u>	
104.5	B+	
102.5		
101.5	B	
98.5		
<u>98.0</u>	<u>B-</u>	
95.5		MEDIAN = 95.3
95.0	<u>C+</u>	MEAN = 92.9 (77.4%)
90.0		
88.5	С	
86.5		
85.0		
84.5	_C-	
80.5	D+	
77.0	D	
69.0	F	
Spring 2010	Mean = 77.4%	)
Spring 2008	Mean = 76.3%	
Spring 2006	Mean = 79.2%	
Fall 2001 Mean = 78.2%		, D

+