The Association of
Professional Engineers and Geoscientists
of the Province of British Columbia

Association Examination: **December 2005**

94-Geocom – A5 Introduction to Petrology

Time Available: 3 hours **Total Points: 100**

Closed Book Examination/Non-programmable calculators and a ruler are allowed.

Answer all questions directly on the following pages.

Question 1 (17 points)

Answer **all** of the following short answer questions.

a. Blueschist facies rocks are restricted to what sort of tectonic setting?

b. True or False (Circle one). Magma mixing is an igneous process that is responsible for the formation of Cu-Ni sulfide deposits in layered intrusions such as the Bushveld Complex of South Africa.

c. What is the range of SiO_2 contents in mafic magmas?

d. Briefly state the difference between the seismic and the petrologic Moho.

e. Which of the following three minerals is most likely to be an alteration product of plagioclase? (Circle one only). epidote actinolite chlorite

f. True or False (Circle one). The protolith of an amphibolite is basalt.

g. Which igneous rock series is most common at mid-ocean ridges?

h. ____________________ and ____________________facies series are representative of the two dominant geothermal gradients found in paired metamorphic belts. (Give one example from each gradient in each blank).

i. What is the <u>petrologic</u> significance of the Low Velocity Zone (LVZ)?

j. 1 GPa = ______ kb ≈ ______ km depth.

k. An initial $^{87}Sr/^{86}Sr = 0.7100$ in a lava indicates that the source for the magma is where?

l. If $T_{country\ rock} > T_{magma}$, what differentiation process (if any) will occur?

m. Chlorite is not stable at amphibolite facies P-T conditions. Why then is chlorite present in some amphibolite facies rocks?

n. Which of the metamorphic driving forces is the **least** important for rocks of facies such as hornblende hornfels and pyroxene hornfels?

o. As the temperature rises, which rock will melt first, gabbro or quartz diorite?

Question 2 (8 points)

Listed below are petrogenetic histories of four rocks that exist in outcrop. For each, use the petrogenetic history to give the rock a name based on its chemical composition and texture.

a. A magma formed from partial melting of peridotite beneath an oceanic spreading ridge, followed immediately by transportation to the surface and eruption as a pillow lava. The rock was then subducted to the P-T conditions of greenschist facies, but it was not affected by deformation in a directed stress field. Finally, it was faulted back to the surface where it crops out on a roadside.

name:

b. This sample originated as a crustal melt in a continental setting. It cooled slowly at depth and formed a phaneritic rock containing quartz + plagioclase + K feldspar + biotite. Then it was buried to very great depths in the crust, in the region of amphibolite to granulite facies metamorphism. Further tectonic activity uplifted this sample to the surface where we can observe it today.

name:

c. First a large volume of magma formed by partial melting of peridotite. This magma rose into the continental crust, where it stagnated at 6 km depth. Olivine and Ca-rich plagioclase began to crystallize and settle to the bottom of the magma chamber. When hornblende appeared as a liquidus phase, it did not settle out. When the remaining magma had 5% hornblende phenocrysts and 61% SiO_2 overall, it erupted as a lava flow.

name:

d. Mafic mantle stagnated in the continental crust and provided the heat to melt a high volume of crustal material. A few crystals of sanidine and quartz formed in the crustal melt during initial cooling at depth. This crustal melt rose towards Earth's surface and erupted explosively due to fragmentation when the percentage of gas bubbles in the magma reached >75%. The rock formed as part of a thick deposit surrounding and partly infilling a caldera.

name:

Question 3 (4 points)

Discuss both the lower and upper limits of metamorphism. Which is better defined?

Question 4 (9 points)

Compare and contrast epizonal, mesozonal, and catazonal intrusions in terms of depth of emplacement, shape, contact relationships, and rock characteristics, including distinctive textures and structures characteristic of each.

Question 5 (8 points)

What is an ophiolite? Where and how do ophiolites form?

Question 6 (13 points)

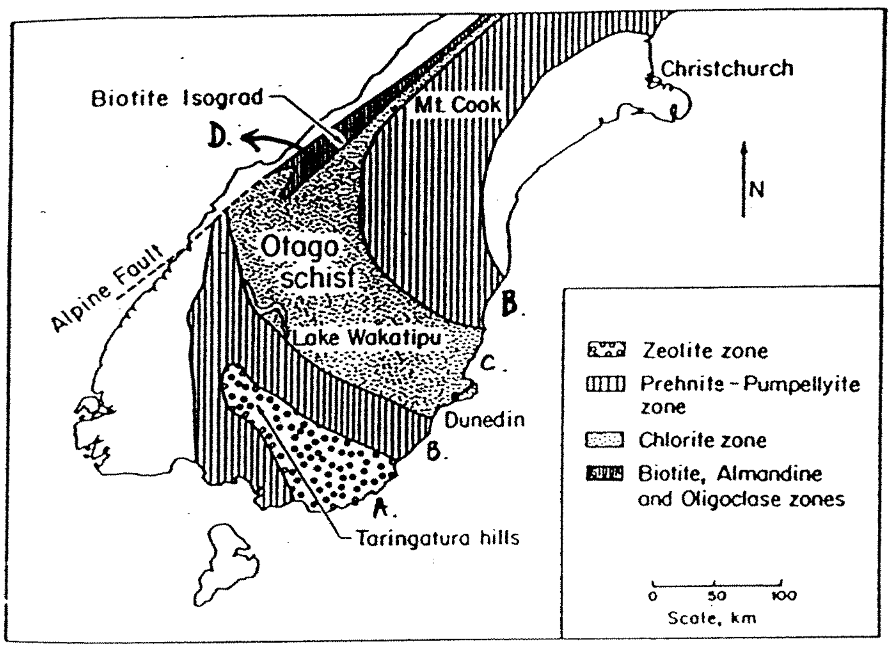
Fill in the blanks in the following table. There may be more than one possible correct answer per row, but only one answer is necessary for each blank, and your answers must be consistent across each row of the table.

Structure or texture	Definition	Petrogenetic significance
e.g., phaneritic	*Igneous texture describing rock with interlocking crystalline grains, all visible to the naked eye*	*Indicates slow cooling of magma underground in an intrusive environment*
Porphyro-aphanitic		
		Indicates dynamic metamorphism at deep crustal levels
	Sausage-like forms	Indicates tensional deformation in a metamorphic rock
porphyroblast		
trachytic		
	Large eye-shaped crystal in a metamorphic rock	
	Cone-shaped edifice made up of alternating layers of lava flows, pyroclastic deposits, and volcanic domes erupted mostly from a central vent	

Question 7 (7 points)

Below is a map of southern New Zealand showing metamorphic zones in greywackes. The following partial metamorphic mineral assemblages are reported:

A. laumontite (a zeolite) + calcite + albite
B. prehnite + pumpellyite + chlorite + albite
C. epidote + chlorite + actinolite
D. biotite + garnet + oligoclase + sillimanite + muscovite + quartz



a. What metamorphic facies do these assemblages represent?

A.
B.
C.
D.

b. What *facies series* is represented here?

c. Is the parent rock for assemblage "D" any different than for the other rocks? If so, how?

Question 8 (12 points)

Answer all of the following questions that refer to the T-X diagram for plagioclase.

a. Use point form to describe all of the steps that take place during equilibrium crystallization of a melt of composition An_{70}. Be sure to illustrate the paths of the liquid and solid phases on the diagram.

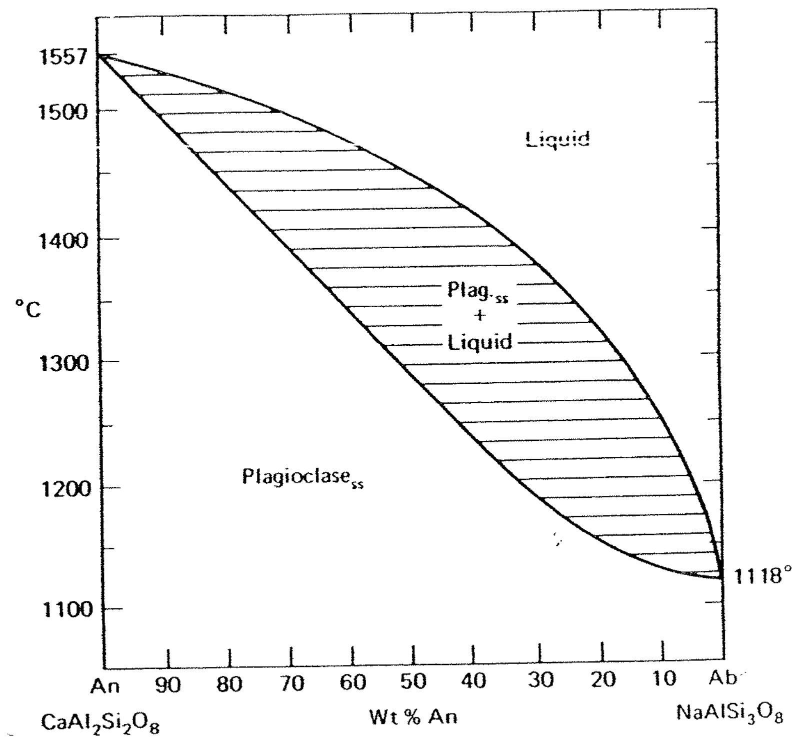


FIGURE 10-12 System $CaAl_2Si_2O_8$ (anorthite)–$NaAlSi_3O_8$ (albite) at 1 atm pressure. [After Bowen (1913) and Weill et al. (1980).]

b. What is the composition of plagioclase in a. at 1450°C?

c. What is the percentage of plagioclase in a. at 1450°C?

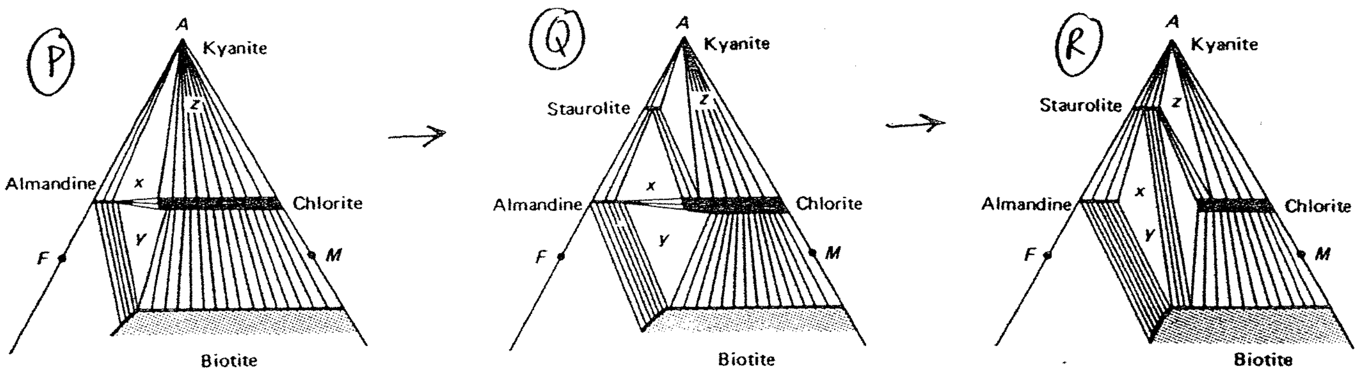
d. What is the T at which the last drop of liquid is crystallized in a.?

e. What is the composition of the final drop of liquid in a.?

f. If, at 1450°C, all of the plagioclase crystals in a. were removed from the system and the remaining liquid was allowed to crystallize in equilibrium, what would the composition be of the final solid plagioclase?

Question 9 (12 points)

Study the following three AFM diagrams (labelled P, Q, and R going up in temperature) carefully and answer all of the following questions.



a. What three phases are assumed to be present in this system at all P-T conditions, even though they are not shown on the diagram?

b. Fill in the following table of mineral assemblages present in rocks x, y, and z at the temperatures of P, Q, and R. (No need to restate the assumed phases referred to in a. above.)

Rock ⇓	Mineral assemblage present at P	Mineral assemblage present at Q	Mineral assemblage present at R
x			
y			
z			

c. Write the (unbalanced) reaction that takes place between P and Q.

d. Write the (unbalanced) reaction that takes place between Q and R.

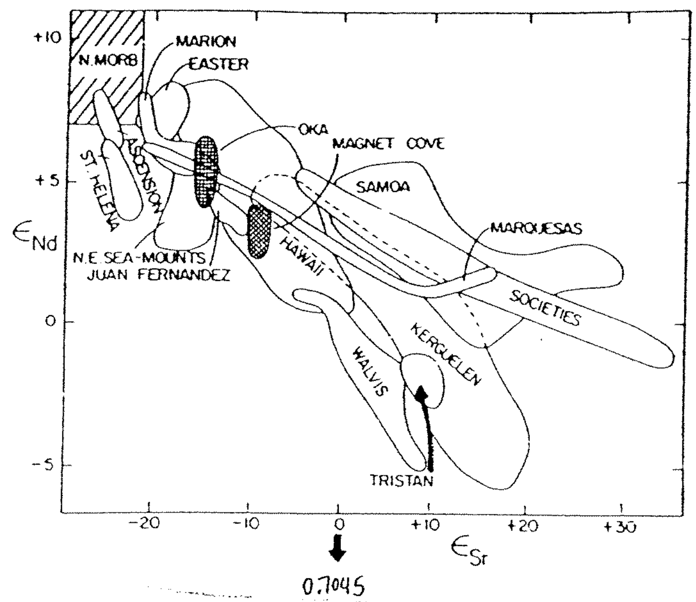
Question 10 (4 points)

Examine the plot of isotopic data (Fig. 3 below) for volcanic rocks from a variety of oceanic tectonic settings, including N-MORB (normal mid-ocean ridge basalt) and a variety of ocean "hot spot" basalt localities (e.g. Hawaii, Easter Island, Samoa, Marquesas, Kerguelen, Societies, etc).

Note the **dark hachured fields** labelled Oka (Quebec) and Magnet Cove (Arkansas). In the Cretaceous, both Oka and Magnet Cove erupted carbonatites, rare magmas with >50% carbonate minerals and that originate in the mantle. Nd and Sr isotopic data can be used to help understand the petrogenesis of these odd magmas.

Note that an εSr of 0 is equal to a $^{87}Sr/^{86}Sr$ of 0.7045. Negative values of εSr are <0.7045 and + values of εSr are >0.7045.

Fig. 3. $\varepsilon_{Sr}(T)-\varepsilon_{Nd}(T)$ anti-correlation diagram. Fields for oceanic basalts from White and Hofmann (1982) and Hart et al. (1986).



a. Indicate the position of "bulk earth" on the diagram with an upper case "B".

b. Note the field for Easter Island basalts (Easter) and compare it to the field for volcanic rocks from Tristan de Cunha (Tristan). Easter Island is a hot spot volcano in the south Pacific whereas Tristan de Cunha is a hot spot volcano in the Atlantic Ocean. Which of these two localities has a more depleted mantle source?

c. What type of mantle source did Oka and Magnet Cove carbonatites come from, depleted or enriched?

d. Draw an arrow on the diagram that points in the direction that the Oka and Magnet Cove isotopic analyses would be displaced if the magmas were contaminated by Precambrian crust of the Canadian Shield.

Question 11 (6 points)

For the three volcanic rock samples (#s 2, 9, and 10) for which major element chemical analyses and normative analyses are given below, name each sample using the IUGS classification scheme (below). Explain the method that you use, show your calculations, and plot each sample as a labelled point on the IUGS diagram.

	2	10
SiO_2	51.98	67.62
TiO_2	1.21	0.84
Al_2O_3	14.48	12.31
Fe_2O_3	1.37	5.66
FeO	8.92	3.04
MnO	0.16	0.11
MgO	7.59	0.32
CaO	10.33	2.52
Na_2O	2.04	2.92
K_2O	0.84	3.38
P_2O_5	0.14	0.24
H_2O^+	0.88	0.68
H_2O^-	0.16	0.62
Total	100.10	100.26
Q	2.80	32.46
or	4.73	20.02
ab	16.92	24.63
an	28.23	10.56
di	18.19	0.86
hy	23.60	0.40
ol		
mt	2.03	7.98
il	2.28	1.52
ap	0.32	0.55
Total	99.10	98.98

	9
SiO_2	43.15
TiO_2	2.70
Al_2O_3	13.46
Fe_2O_3	4.52
FeO	8.22
MnO	0.11
MgO	10.80
CaO	9.80
Na_2O	3.47
K_2O	1.63
P_2O_5	0.75
H_2O^+	1.21
H_2O^-	0.15
Total	99.97
Q	
or	9.63
ab	9.67
an	16.34
ne	10.67
di	22.23
hy	
ol	16.76
mt	6.55
il	5.13
ap	1.64
Total	98.62

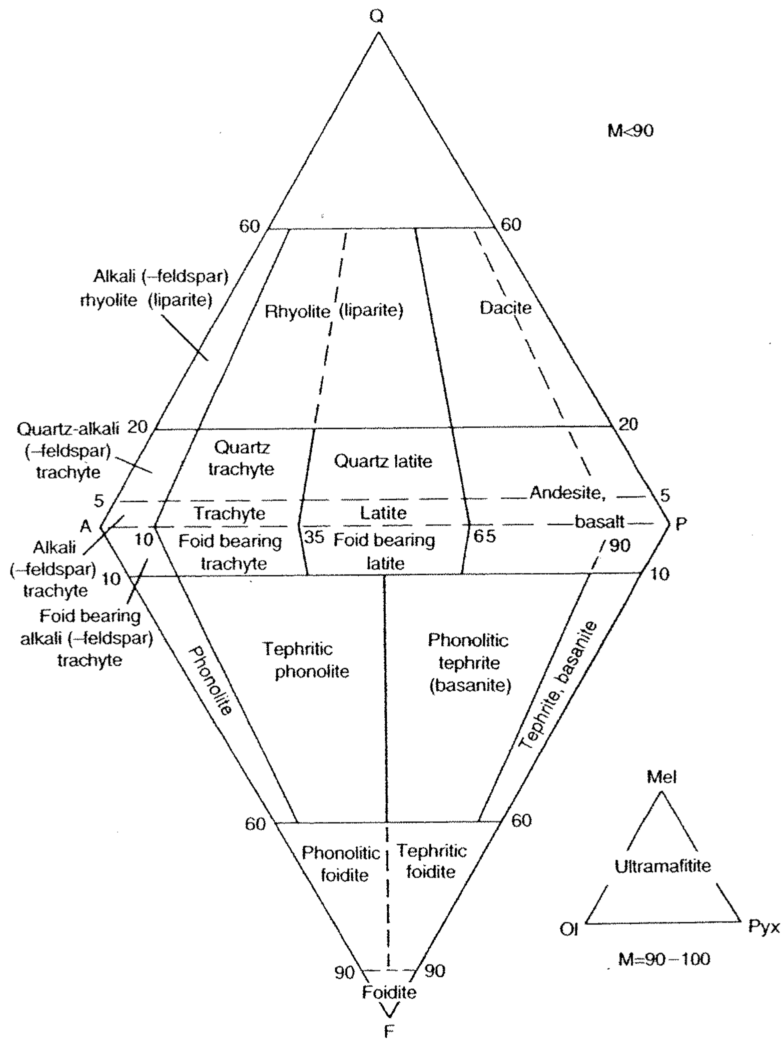


Figure 3.17
The IUGS classification of volcanic rocks (a).
(Source: From Streckeisen, 1979.)