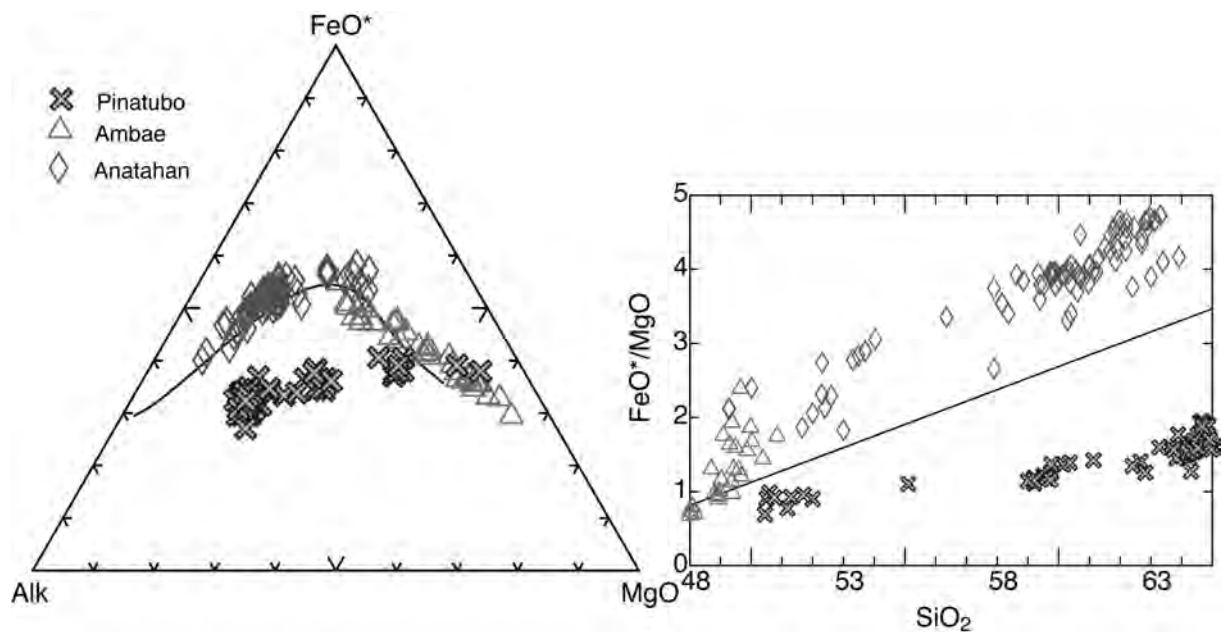


QUESTION 1 (5+5 = 10 marks)

- Explain which melt would have the higher viscosity, if we compare them at the same temperature: a melt of albite, or a melt of nepheline?
- What is the difference between a pyroclastic fall deposit and a pyroclastic flow deposit (=ignimbrite), in terms of the type of clasts, clast sizes, clast size variation, and mode of formation?

QUESTION 2 (2+2+4 = 8 marks)



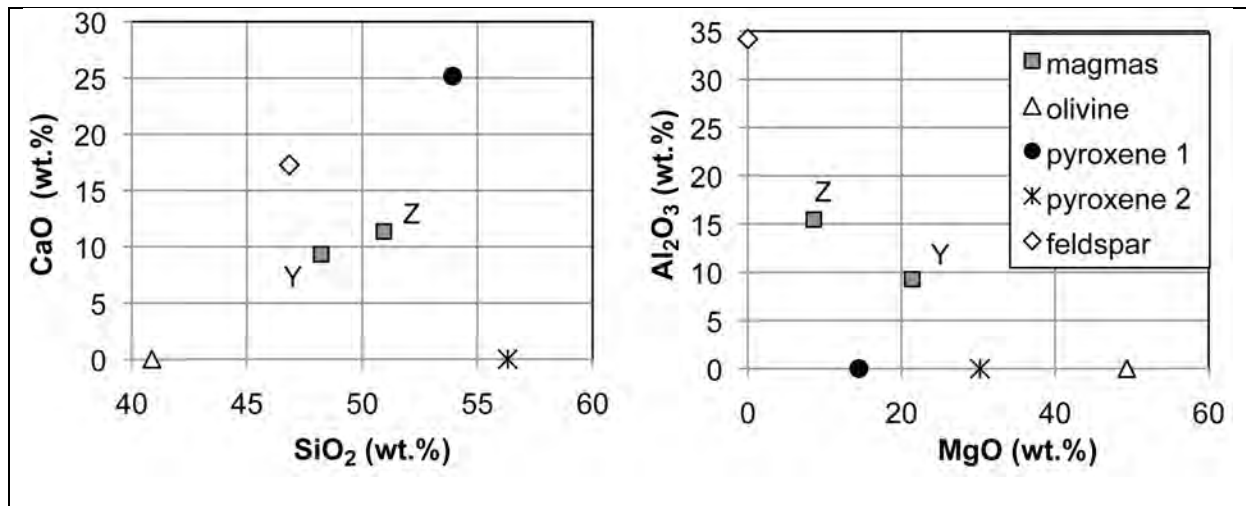
The two diagrams above show data for three different volcanoes, Pinatubo, Ambae and Anatahan. The datasets for the two diagrams are of course the same.

- In the left diagram what does 'Alk' stand for?
- In the right diagram, what does the little star next to FeO mean?
- Discuss whether the magmas from these three volcanoes show calc-alkaline or tholeiitic differentiation trends.

QUESTION 3 (8 marks)

A lava sample contains 15% plagioclase phenocrysts, and 85% glass. The glass that is in equilibrium with the plagioclase phenocrysts contains 200 ppm Sr. The plagioclase/melt distribution coefficient for Sr is 3. What is the Sr concentration of this lava sample?

QUESTION 4 (2+4+2+2 = 10 marks)



The two diagrams above show the composition for two magmas, and some minerals. Use these diagrams to answer the following questions.

- The two magmas are related to each other by fractional crystallisation. Explain which one is the more evolved one, Y or Z.
- Two minerals fractionate to produce the more evolved magma from the more primitive magma. Which two minerals, in which proportions?
- There are two pyroxenes shown on the diagram. What is the most likely mineral name for the one with the lower MgO content?
- Is the feldspar that is shown on the diagram rich in anorthite, albite or orthoclase component?

QUESTION 5 (6*2 = 12 marks)

Give the most appropriate names for the intrusive rocks with the following minerals:

Sample	quartz	plagio- clase	microc line	sodalite	other	biotite	amphi- bole	augite	ortho- pyroxene	olivine
A		63						17	15	5
B		2	5	12	58 leucite	10		13		
C	20	50	8					12	10	
D			49	32	2 eudialyte	5	12			
E	6	14	71			9				
F								38	42	20

QUESTION 6 (5*2 = 10 marks)

Fill in the blanks:

a. Dolerites often display a texture in thin section, whereby plagioclase is wholly enclosed by clinopyroxene.

b. A can be described as a mafic igneous rock, which is rich in potassium, and which often occurs as dykes. This rock type does not feature in either the QAPF or TAS classification.

c. When you look at a thin section of a komatiite under the microscope, you expect to see its characteristic texture.

d. Crystals that are shaped like a needle, are also called

e. A texture is typical for a vesicular pyroclastic rock, which has a felsic composition, and a very high number of very small vesicles.

QUESTION 7 (6*2 = 12 marks)

	A	B
SiO ₂	43.22	73.77
TiO ₂	0.97	0.37
Al ₂ O ₃	12.20	13.23
Fe ₂ O ₃ *	10.38	2.98
MnO	0.17	0.04
MgO	14.54	0.81
CaO	10.92	2.84
Na ₂ O	2.04	3.87
K ₂ O	4.76	2.03
P ₂ O ₅	0.82	0.05
Quartz	0.00	35.14
Plagioclase	10.21	45.60
Orthoclase	0.00	12.06
Nepheline	9.40	0.00
Leucite	22.24	0.00
Diopside	18.77	0.88
Hypersthene	0.00	4.85
Olivine	28.50	0.00
Larnite	4.83	0.00
Ilmenite	1.86	0.70
Magnetite	2.28	0.65
Apatite	1.92	0.12

The table to the left shows the geochemical analyses (in weight%) for two lavas, with their calculated normative minerals.

A. Explain whether all iron was assumed to be divalent when the normative mineralogy was calculated.

B. What kind of basalt would lava A be, based on its position in the basalt tetrahedron?

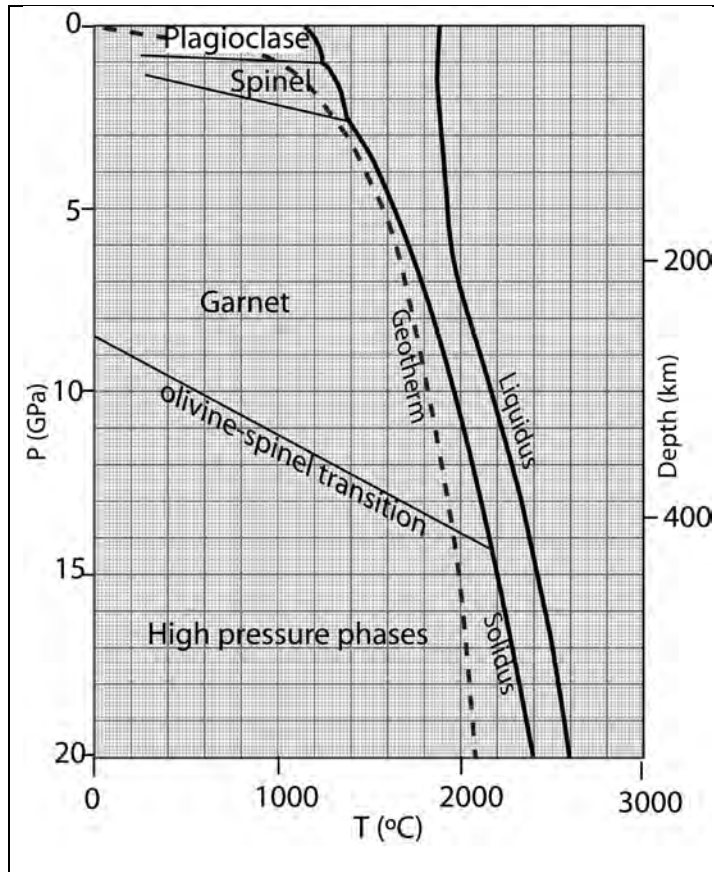
C. Do you think it is appropriate to also plot sample B in the basalt tetrahedron? Explain.

D. What are the names of these two samples based on the TAS diagram?

E. What are the names of these two samples if we assume that they are intrusive rocks, and that the normative minerals represent the modal mineralogy of these samples?

F. In what tectonic setting is lava A most likely to have been generated: mid-ocean ridge, oceanic island, or island arc? Explain.

QUESTION 8 (4*3 = 12 marks)



The diagram to the left shows the solidus and liquidus for the mantle, the geotherm, and the stability fields for selected minerals.

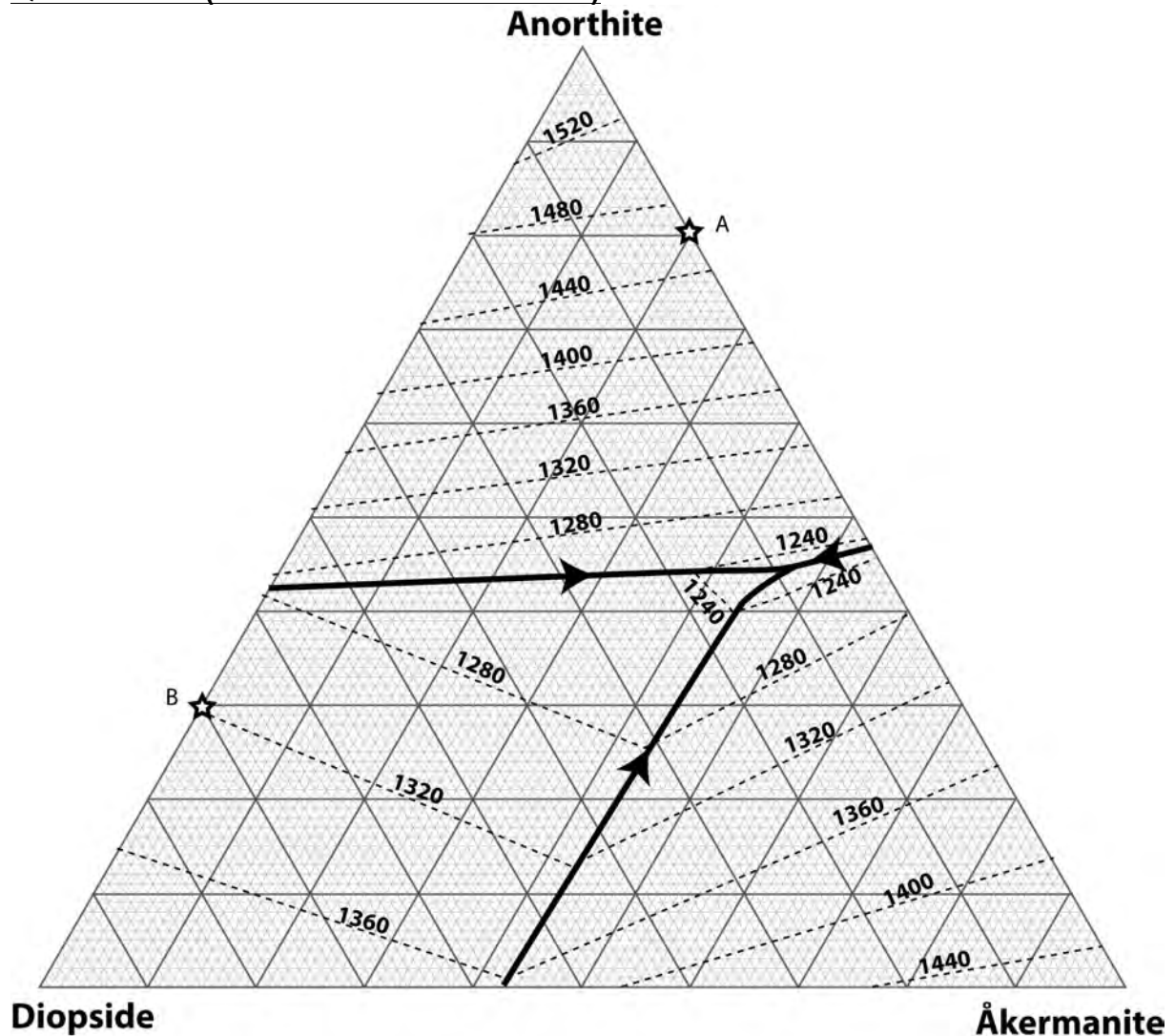
A. At what temperature does the mantle start melting at a pressure of 20 kbar?

B. Which aluminium-bearing phase is stable in the mantle at 1273 K and 5 GPa, and what is its mineral formula?

C. Is the mantle that lies on the geotherm at 4 GPa completely solid, partially molten or completely molten? Explain.

D. If the mantle ascends adiabatically from the geotherm at 4 GPa, will the percentage of melt increase, decrease or stay the same? Explain.

QUESTION 9 (2+2+1+1+4+4+4=18 marks)



The diagram above gives the phase diagram for the ternary system diopside-anorthite-åkermanite at 1 atmosphere pressure. The mineral formula for åkermanite is $\text{Ca}_2\text{MgSi}_2\text{O}_7$. The thin lines with numbers are the isotherms (degrees C). The thicker lines are the boundaries to the primary phase fields.

- We consider compositions A and B, plotted in the diagram above. How many grams of which minerals would we need to mix together to get ten grams of composition A, and ten grams of composition B?
- At which temperatures would compositions A and B start melting?
- We now mix together the ten grams of solid A and B, and thereby obtain a mixture that we call C. Draw the composition of C in the diagram above.
- At what temperature would composition C start melting?
- Of which phases, and in which percentages does composition C consist at 1240 °C?
- Of which phases, and in which percentages, does composition C consist at 1280 °C?
- Of which phases, and in which percentages, does composition C consist at 1360 °C?

Handy equations and other things:

$$\Delta_{rx}G = \Delta_{rx}H - T\Delta_{rx}S$$

$$\frac{dG}{dP} = V$$

$$\frac{dG}{dT} = -S$$

$$\Delta G_{rx, T', P'} = \Delta G_{rx, T_{ref}, P_{ref}} + \Delta V_{rx} (P' - P_{ref}) - \Delta S_{rx} (T' - T_{ref})$$

$$d\Delta G = \Delta V dP - \Delta S dT$$

$$P + F = C + 2$$

$$D_i^{a/b} \text{ (or } Kd_i^{a/b}) = C_i^a / C_i^b$$

$$\frac{C_l}{C_0} = \frac{1}{F + D - FD}$$

$$\frac{C_l}{C_0} = F^{(D-1)}$$

