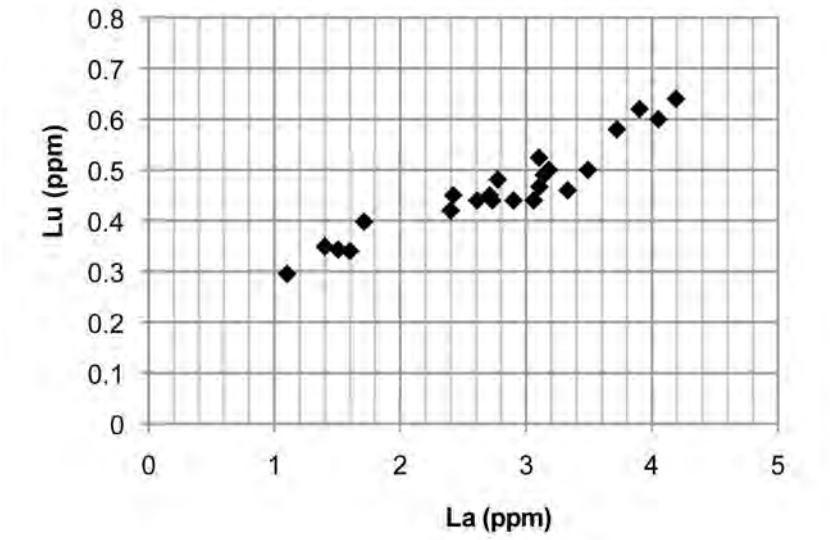
QUESTION 1 (5+5 = 10 marks)

A. Explain which melt would have the higher viscosity, if we compare them at the same temperature: a melt of anorthite, or a melt of orthopyroxene? Anorthite is more polymerised than opx, so An would have the higher viscosity

B. Explain the difference between a crater and a caldera, in their size and mode of formation. A crater is much smaller than a caldera, and is formed when a volcano 'blows its top'. A caldera is formed when a magma chamber underneath a volcano empties itself, and the roof collapses downwards. Can be 10-100 km diameter, whereas a crater would be a few hundred meters.

QUESTION 2 (10 marks)



The diagram above shows whole rock data for samples from the Mid-Atlantic Ridge. It is thought that the different samples are related to each other by fractional crystallisation. Use these data to explain which of these two elements is more incompatible: lanthanum or lutetium. La goes from 1.1 to 4.2 ppm, so 3.8-fold enrichment, and lutetium only 2.17 times enriched. The more incompatible, the more enriched an element becomes during fractional xtallisation, so La is more incompatible, and this is logical as it is a bigger ion than Lu, and thus fits more poorly in minerals such as olivine and the pyroxenes.

QUESTION 3 (5*2=10 marks)

Fill in the blanks:

A. When a plagioclase is zoned from an albite-rich core to an anorthite-rich rim, it is said to have reverse zoning.

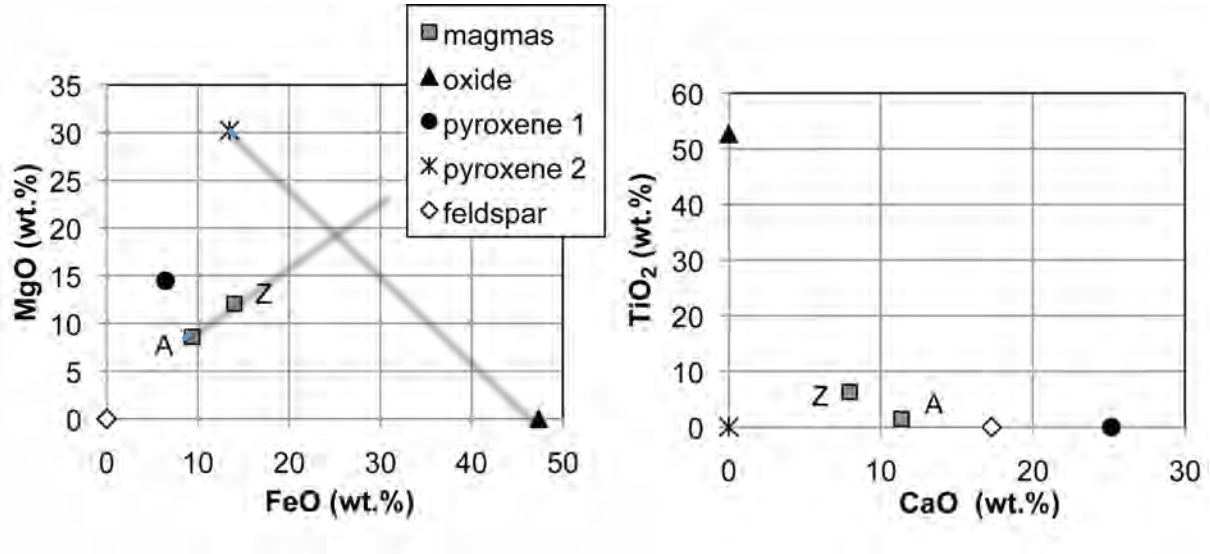
B. An embayed quartz crystal has a rounded shape, and often also contains holes within the crystal. This shape is a result of redissolution of the crystal into the melt.

C. A rock of which the texture is idiotopic consists of crystals that are mostly euhedral in shape.

D. In a poikilitic texture,the host crystal, which contains numerous inclusions, is called an oikocryst.

E. When glass occupies the spaces between plagioclase, the texture is called intersertal

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



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

A. The two magmas are related to each other by fractional crystallisation. Explain which one is the more evolved one, A or Z. A is more evolved as it has the lower MgO content.

B. Two minerals fractionate to produce the more evolved magma from the more primitive magma. Which two minerals, in which proportions? 33% oxide, 67% px2

C. Explain whether this fractionation process will cause a calc-alkaline or a tholeiitic differentiation trend. FeO decreases together with MgO, so this is a calc-alkaline trend.

QUESTION 5 (6*2 = 12 marks)

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

Sample	quartz	plagio-clase	ortho-clase	nephe-line	other	biotite	amphi-bole	augite	ortho-pyroxene	olivine
A		55			19 nosean		2	12		12
B	34	42					24			
C			49	32	2 aenigmatite	5	12			
D	2	39	45				2	12		
E	6	14	71			9				
F	25	23	42			7	3			

A; nosean gabbro

B: tonalite

C nepheline syenite

D monzonite

E quartz syenite

F Granite

QUESTION 6 (6*2 = 12 marks)

	A	B
SiO_2	49.68	64.61
TiO_2	0.70	0.10
Al_2O_3	17.30	20.61
Fe_2O_3*	7.69	1.94
MnO	0.10	0.04
MgO	10.36	0.07
CaO	11.36	0.74
Na_2O	2.39	5.25
K_2O	0.40	6.57
P_2O_5	0.02	0.06
Quartz	0.00	6.29
Plagioclase	55.90	47.84
Orthoclase	2.36	38.89
Corundum	0.00	3.64
Diopside	16.93	0.00
Hypersthene	8.80	2.58
Olivine	12.94	0.00
Ilmenite	1.33	0.19
Magnetite	1.68	0.42
Apatite	0.05	0.14

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

A. What tells you that not all the iron was taken to be trivalent when the normative mineralogy was calculated? Ilmenite and hypersthene in the norm, which both contain only Fe2+

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

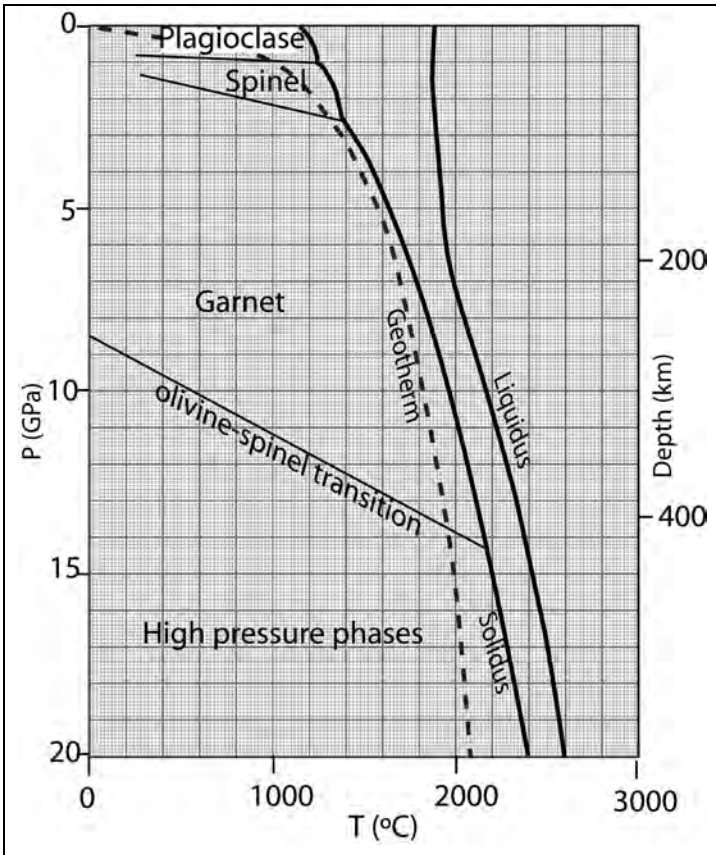
C. Do you think it is appropriate to also plot sample B in the basalt tetrahedron? Explain. No, it isn't a basalt.

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

E. What are the names of these two samples if we assume that the normative minerals represent the phenocrysts in these lavas? Basalt, latite

F. In what tectonic setting is lava A most likely to have been generated: mid-ocean ridge, oceanic island, or island arc? Explain. MOR: ol-tholeiite, shallow, H2O-free melting.

QUESTION 7 (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 5 GPa? 1620 ˚C

B. Which aluminium-bearing phase is stable in the mantle at 1273 K and 20 kbar, and what is its mineral formula? Spinel $(Mg,Fe)(Al,Cr,Fe^{3+})_2O_4$

C. Is the mantle at 2200˚C and 13 GPa completely sold, partially molten or completely molten? Explain. Partially molten; point lies between solidus and liquidus

D. If the mantle ascends adiabatically from 2200˚C and 13 GPa, will the percentage of melt increase, decrease or stay the same? Explain. Pressures decreases as temperature stays almost the same, so the point is moving closer to the liquidus, and thus the amount of melt increases.

QUESTION 8 (1+1+4 = 6 marks)

	olivine	plagioclase
Rb	0.00018	0.1
Ta	0.01	0.02

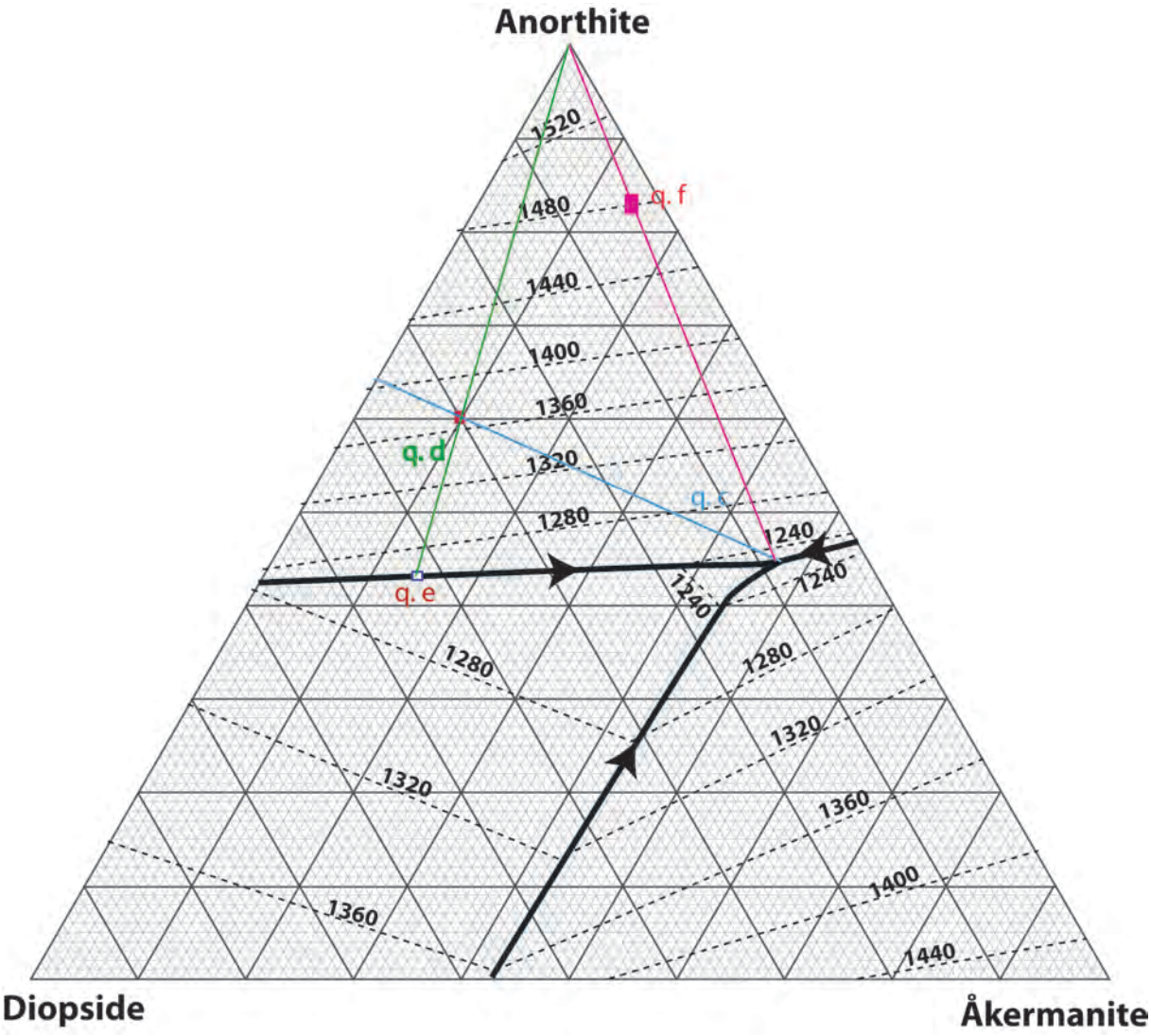
A basalt crystallizes 10% olivine and 20% plagioclase to produce an andesite. Relevant mineral/melt distribution coefficients for two trace elements are given in the table above.

A. What are the names of the elements with the abbreviations Rb and Ta? Rubidium and tantalum

B. To which group(s) of elements do Rb and Ta belong? LILE and HFSE resp.

C. If the basalt contained 5 ppm Rb and 0.1 ppm Ta, then what are the concentrations of these two elements in the andesite that is produced? DRb = 0.06673, 1.3949 times enrichment, so 6.97 ppm Rb; DTa = 0.0166, so 1.42 times enrichment, 0.142 ppm Ta.

QUESTION 9 (2+2+4+4+3+3 = 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 $Ca_2MgSi_2O_7$. The thin lines with numbers are the isotherms (degrees C). The thicker lines are the boundaries to the primary phase fields.

a. We mix 12 g anorthite with 2 g åkermanite and 6 g diopside. Plot this composition in the diagram above.

b. At what temperature will this mixture start melting, and what is the composition of this melt (expressed as $An_{xx}Åk_{yy}Di_{zz}$, with the subscripts referring to the percentage of the components in the melt)? Ca. 1230 ˚C, $An_{45}Åk_{47}Di_{08}$

c. During the melting process, one of the three minerals will be the first one to be completely consumed. At the moment that this first mineral has disappeared, what are the phases present, and in which percentages do they occur? 20% melt, 80% solids of which 65%An and 35%Di, so 52% An, 28% Di

d. At the moment that the second mineral has just disappeared, what are the phases present, and in which percentages do they occur? 31% An, 69% melt.

e. What is the composition of the melt, expressed as $An_{xx}Åk_{yy}Di_{zz}$, at the moment that the second mineral has just disappeared? $An_{43}Åk_{15y}Di_{41}$

f. There are compositions in this system for which, during the meting process, not ONE, but TWO phases run out at the same time at the eutectic temperature. Draw the composition that would be wholly liquid at 1480˚C, and for which two phases would be completely consumed in the melting process at the eutectic temperature, while anorthite would still remain..