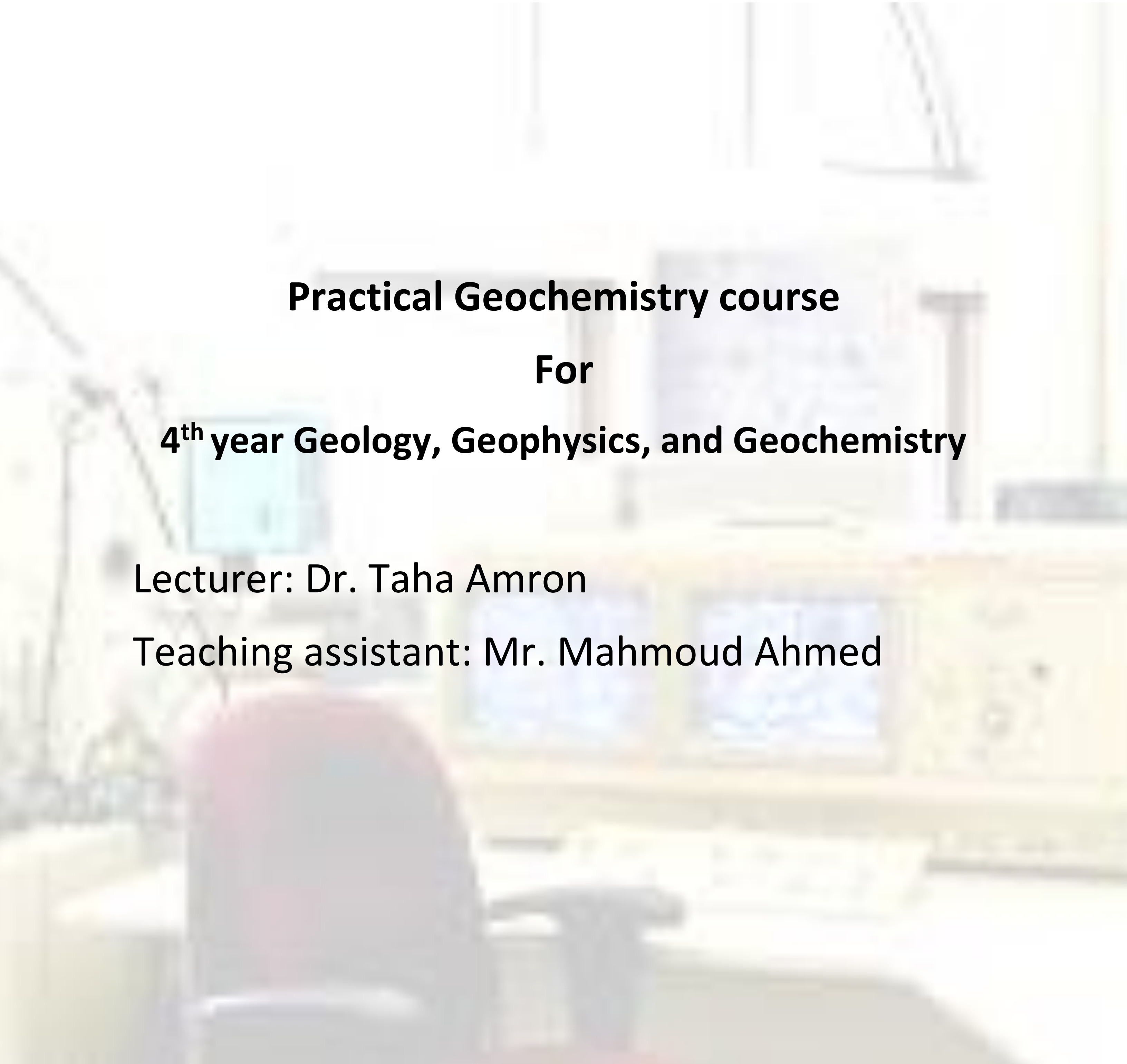
South Valley University

Faculty of Science

Geology Department



Practical Geochemistry course

For

4^{th} year Geology, Geophysics, and Geochemistry

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Plan of practical Geochemistry course

week	Content
Week one	Introduction
Week two	Using major element data (Classifying igneous rocks using oxide-oxide plots)
Week Three	Using major element data (Classifying igneous rocks using cations)
Week four	Using major element data (Classifying igneous rocks using norms)
Week five	Using major element data (Classifying igneous rocks using norms)
Week six	Using major element data (Classifying igneous rocks using norms)
Week seven	Mid-semester exam
Week eight	Variation diagrams
Week nine	Using trace element data (Discrimination diagrams for rocks of basaltic and andesitic composition)
Week ten	Using trace element data (Discrimination diagrams for rocks of granitic composition
Week Eleven	Presenting and Analysis of geochemical data using GCDKIT software.
Week Twelve	Presenting and Analysis of geochemical data using GCDKIT software.

Week *one*

Introduction

***Geochemistry*:** is the science that uses the tools and principles of chemistry to explain the mechanisms behind major geological systems such as the Earth's crust and its oceans.

Geochemical data: major elements, trace elements, radiogenic isotopes, and stable isotopes.

Major elements: are the elements that predominate in any rock analysis. They are Si, Ti, Al, Fe, Mg, Mn, Ca, Na, K, and P, and their concentrations are expressed as the weight percent of oxides.

Trace elements: those elements which are present at less than 0.1 % and their concentrations are expressed as part per millions.

Analytical techniques in geochemistry:

1- X-RAY Fluorescence (XRF)
2- Neutron activation analysis
3- Inductively coupled plasma emission spectrometry (ICP)
4- Atomic absorption spectrophotometry (AAS)
5- Mass spectrometry
6- Electron microprobe analysis

Preparation of samples for geochemical analysis:

1- Collecting samples from the field with emphasis on the freshness of samples.
2- Preparing thin sections of the collected samples.
3- Microscopic examination of the samples and choosing the freshest samples.
4- Crushing the samples with avoiding contamination during the process.
5- Grinding the crushed products to get a suitable powder that can be used for geochemical analysis.

Table 1.5 Elements readily analysed by XRF, INAA, IDMS, AAS, ICP and ICP-MS

Atomic Symbol Element No.			XRF	INAA	IDMS	AAS	ICP	ICP-MS
1	H	Hydrogen						
2	He	Helium						
3	Li	Lithium				x	x	x
4	Be	Beryllium				x		
5	B	Boron						x
6	C	Carbon						
7	N	Nitrogen						
8	O	Oxygen						
9	F	Fluorine						
10	Ne	Neon						
11	Na	Sodium	x			x	x	
12	Mg	Magnesium	x			x	x	
13	Al	Aluminium	x			x	x	
14	Si	Silicon	x			x	x	
15	P	Phosphorus	x				x	
16	S	Sulphur	x					
17	Cl	Chlorine	x					
18	Ar	Argon						
19	K	Potassium	x			x	x	
20	Ca	Calcium	x			x	x	
21	Sc	Scandium	x	x			x	x
22	Ti	Titanium	x			x	x	
23	V	Vanadium	x			x	x	
24	Cr	Chromium	x	x		x	x	
25	Mn	Manganese	x			x	x	
26	Fe	Iron	x			x	x	
27	Co	Cobalt	x	x		x	x	
28	Ni	Nickel	x	x		x	x	
29	Cu	Copper	x			x	x	
30	Zn	Zinc	x			x	x	
31	Ga	Gallium	x					
32	Ge	Germanium	x					
33	As	Arsenic	x					
34	Se	Selenium						
35	Br	Bromine						
36	Kr	Krypton						
37	Rb	Rubidium	x		x	x		x
38	Sr	Strontium	x		x	x	x	x
39	Y	Yttrium	x				x	x
40	Zr	Zirconium	x				x	x
41	Nb	Niobium	x				x	x
42	Mo	Molybdenum						
43	Tc	Technetium						
44	Ru	Ruthenium		x				
45	Rh	Rhodium						
46	Pd	Palladium		x				
47	Ag	Silver		x				
48	Cd	Cadmium						
49	In	Indium						
50	Sn	Tin	x					
51	Sb	Antimony						
52	Te	Tellurium						
53	I	Iodine						
54	Xe	Xenon						

Table 1.5 Continued

Atomic No.	Symbol	Element	XRF	INAA	IDMS	AAS	ICP	ICPMS
55	Cs	Caesium	x					x
56	Ba	Barium	x			x	x	x
57	La	Lanthanum	x	x	x		x	x
58	Ce	Cerium	x	x	x		x	x
59	Pr	Praseodymium					x	x
60	Nd	Neodymium	x	x	x		x	x
61	Pm	Promethium						
62	Sm	Samarium	x	x	x		x	x
63	Eu	Europium		x	x		x	x
64	Gd	Gadolinium		x	x		x	x
65	Tb	Terbium		x				x
66	Dy	Dysprosium		x	x		x	x
67	Ho	Holmium					x	x
68	Er	Erbium			x		x	x
69	Tm	Thulium		x				x
70	Yb	Ytterbium		x	x		x	x
71	Lu	Lutetium		x	x		x	x
72	Hf	Hafnium		x				x
73	Ta	Tantalum		x				x
74	W	Tungsten						
75	Re	Rhenium		x				
76	Os	Osmium		x				x
77	Ir	Iridium		x				
78	Pt	Platinum		x				
79	Au	Gold		x				
80	Hg	Mercury						
81	Tl	Thallium						
82	Pb	Lead	x		x	x		x
83	Bi	Bismuth						
84	Po	Polonium						
85	At	Astatine						
86	Rn	Radon						
87	Fr	Francium						
88	Ra	Radium						
89	Ac	Actinium						
90	Th	Thorium	x	x	x			x
91	Pa	Proactinium						
92	U	Uranium	x	x	x			x

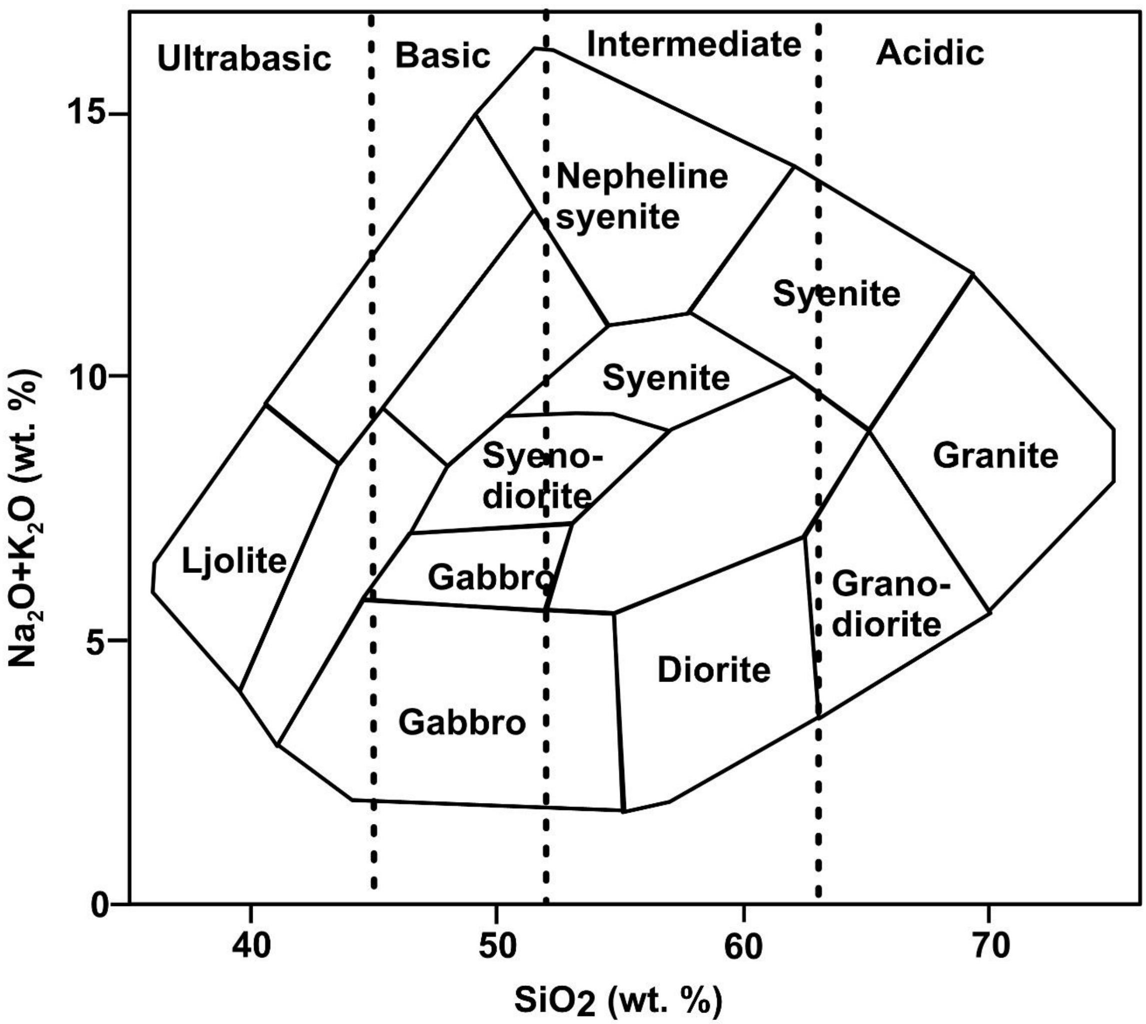
Week two

Classifying igneous rocks using oxide-oxide plots

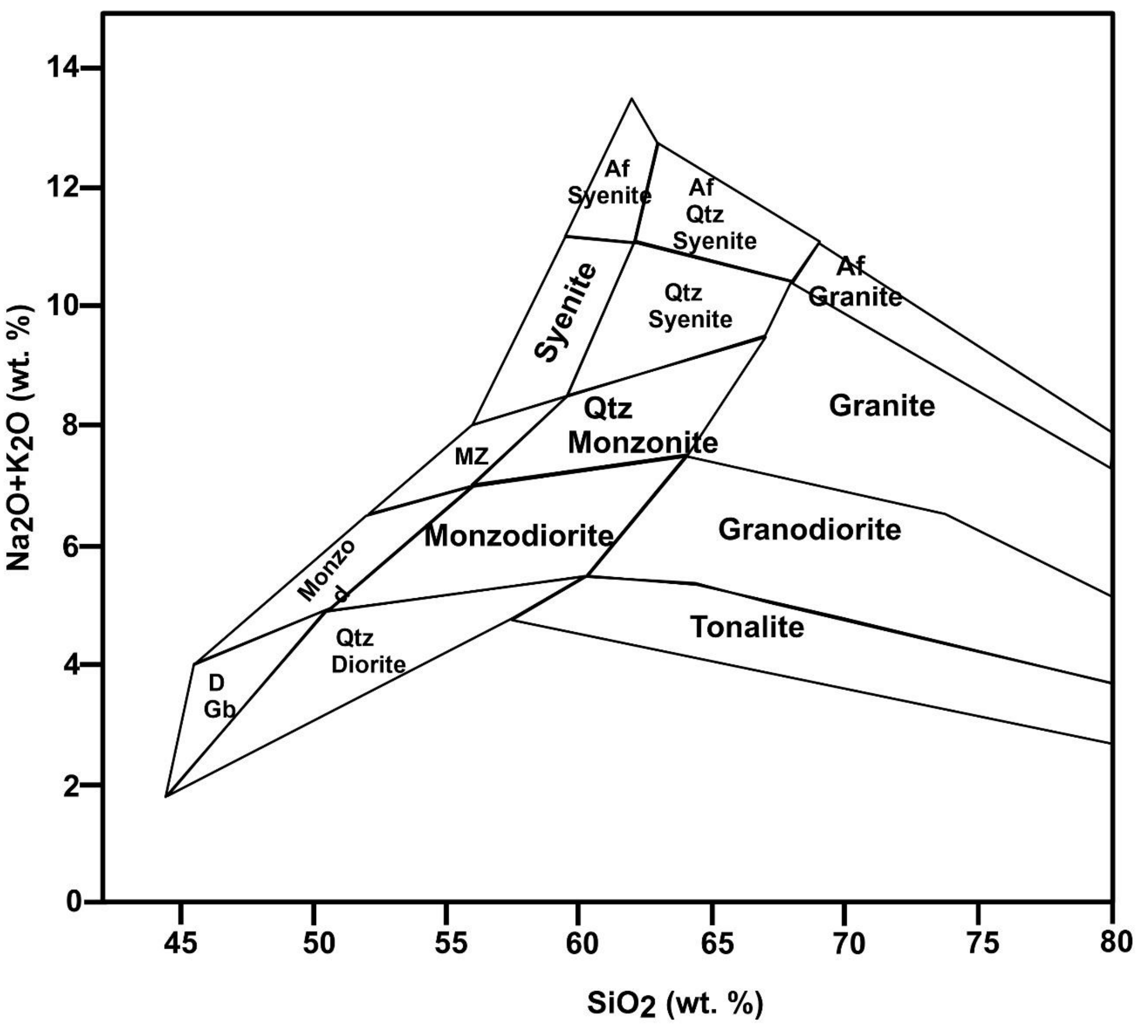
Problem1: You have the major element data for some samples in the table below. Plot the samples using the attached classification diagrams and write a brief geochemical report.

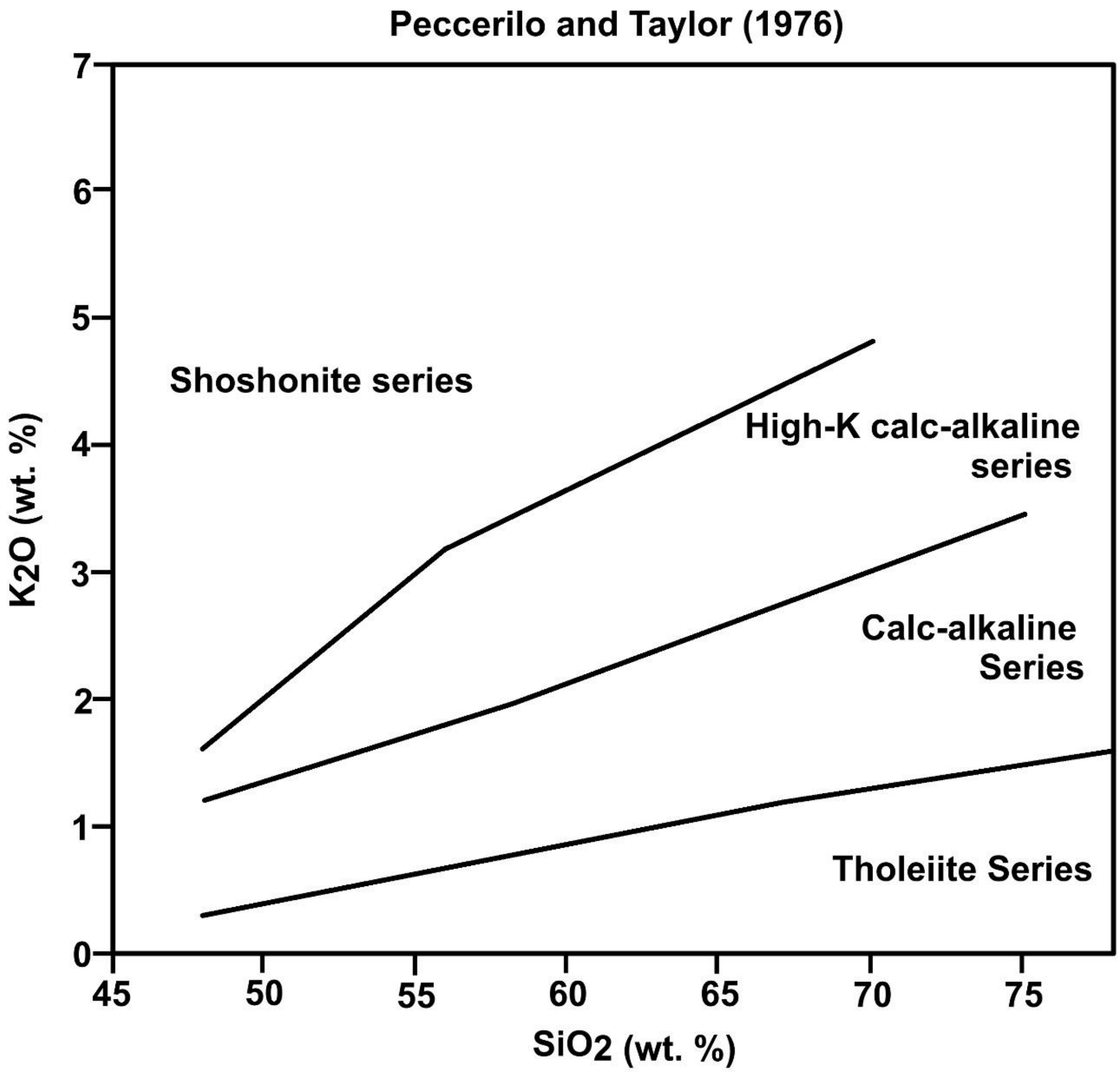
	1	2	3	4	5	6	7	8	9
SiO_2	73.27	72.19	70.04	51.96	51.62	53.41	65.8	66.9	66.4
Al_2O_3	13.84	14.11	14.62	17.08	16.74	16.80	15.2	15.9	15.1
Fe_2O_3	2.13	2.47	3.23	7.72	8.15	7.02	4.28	4.33	5.11
MgO	0.42	0.45	0.58	5.72	6.05	6.75	1.5	1.64	2.04
CaO	0.69	0.87	1.44	9.85	10.06	8.41	4.15	4.17	4.31
Na_2O	4.69	4.99	4.89	3.53	3.40	4.01	4.3	4.49	4.11
K_2O	3.50	3.33	3.00	0.72	0.72	0.65	1.85	1.62	1.72
TiO_2	0.33	0.38	0.43	0.99	1.07	0.79	0.46	0.47	0.57
P_2O_5	0.05	0.05	0.10	0.11	0.11	0.12	0.121	0.14	0.113
MnO	0.03	0.05	0.06	0.14	0.15	0.14	0.08	0.08	0.08
Na_2O+K_2O									

TAS (Cox etal. 1979)



Middlemost (1985)





Peccerilo and Taylor (1976)
Shoshonite series
High-K calc-alkaline series
Calc-alkaline Series
Tholeiite Series
K2O (wt. %)
SiO2 (wt. %)
0
1
2
3
4
5
6
7
45
50
55
60
65
70
75

Geochemical report

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Week three

Classifying igneous rocks using cations

De la Roche et al. (1980) proposed a classification scheme for volcanic and plutonic igneous rocks based upon their cationic proportions expressed as millications.

R1= (4Si-11(Na + K)-2(Fe + Ti)) on the X-axis

R2= (Al+ 2 Mg + 6 Ca) on the Y-axis.

Jensen (1979) suggested a ternary classification scheme for sub-alkaline volcanic rocks according to their cationic percentages Al, (Fe^{tot}+ Ti) and Mg

How to calculate cationic proportions and cationic percentages

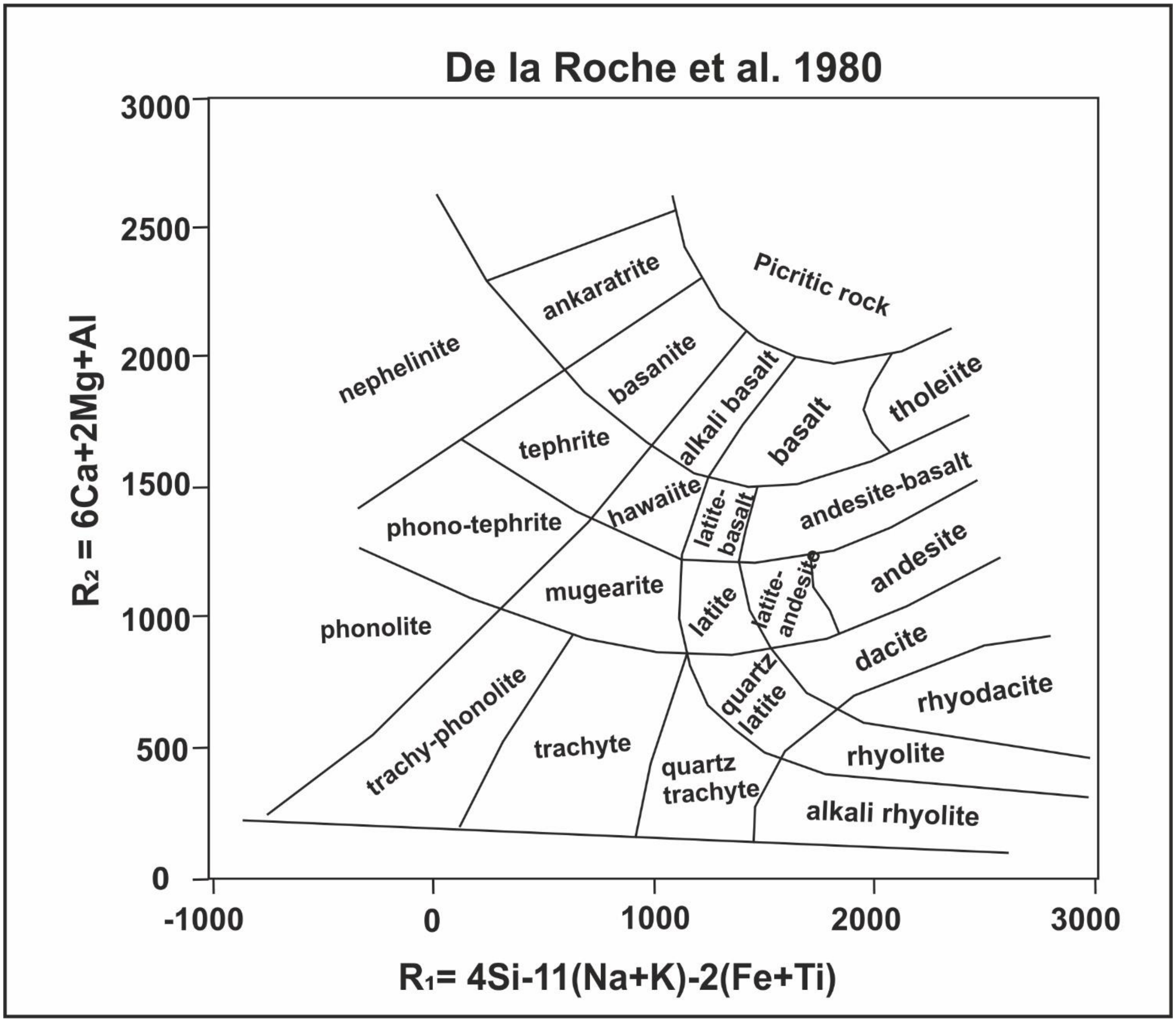
(You are given the weight percent of the oxides and molecular weight)

1- Calculate the molecular proportions by dividing the weight percent of oxides by molecular weight.
2- Determine the number of cations for each oxide (e.g. SiO_2 No. of cations =1 and Fe_2O_3 No.=2 etc.).
3- Calculate the cationic proportions by multiplying the number of cations by molecular proportions
4- Calculate millications (used for De La Roche diagram) by multiplying cationic proportions by 1000
5- Calculate the cationic percentage (used for Jensen classification) by dividing the cationic proportions by its sum and multiplying by 100.

Problem 2: You have the major element data for two samples in the table below.

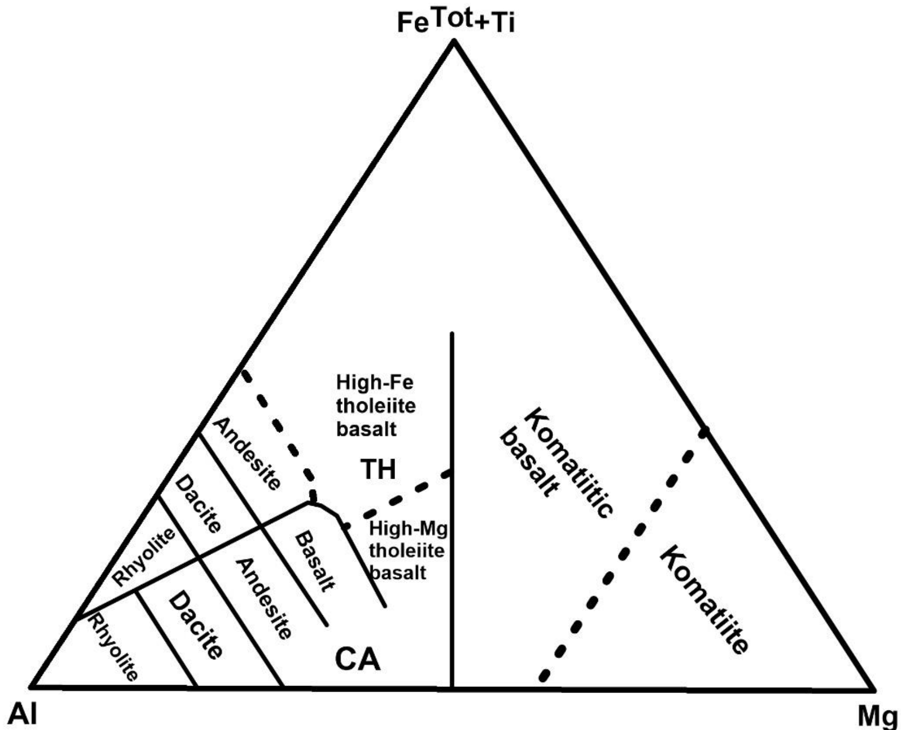
1- Calculate the R1 and R2 cationic proportions for the two samples and plot them using the classification diagram of De La Roche et al. (1980).
2- Calculate the cationic percentage for the two samples and plot them using the classification diagram of Jensen (1976).

No	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO
1	68.03	14.83	3.79	1.20	2.65	4.53	2.72	0.56	0.11	0.09
2	51.96	17.08	7.72	5.72	9.85	3.53	0.72	0.99	0.11	0.14
Mol. Wt	60	102	160	40	56	62	94	80	142	71



Geochemical report: -

Jensen (1976)



Geochemical report: -

Week four

Classifying igneous rocks using norms

The norm calculation is a way of working out the mineralogy of rock from chemical analysis.

Norms are commonly calculated for glassy or fine-grained volcanic rocks that are otherwise difficult to classify, and for metamorphosed igneous rocks that no longer have their original igneous mineralogy. The normative 'minerals' are calculated to represent, in some ways, the actual minerals that might crystallize if the rock were cooled under perfect dry equilibrium conditions at low pressure. The calculation is based on the following assumptions:

1- The magma from which the rock is derived is assumed to be "dry" so hydrous phases such as amphibole and mica are ignored by the calculation.
2- The ferromagnesian minerals are assumed to be free of Al2O3 so that the amount of that component can be used to fix the abundance of feldspar and feldspathoid in the norm.
3- The magnesium/iron ratio of all of the ferromagnesian minerals is assumed to be the same.
4- Several mineral pairs are considered to be incompatible, such as feldspathoids and quartz, and therefore never appear together in the norm although in real rocks that may be present.

Norm: the calculated mineralogy

Mode: the observed mineralogy

The sequence of normative mineral formation in silica-saturated magma

1-	Apatite	$CaO.3.33\ P_2O_5$
2-	Ilmenite	$FeO.TiO_2$
3-	Orthoclase	$K_2O.Al_2O_3.6SiO_2$
4-	Albite	$Na_2O.Al_2O_3.6SiO_2$
5-	Acmite	$Na_2O.Fe_2O_3.4SiO_2$
6-	Anorthite	$CaO.Al_2O_3.2SiO_2$
7-	Sphene	$CaO.TiO_2.SiO_2$
8-	Rutile	TiO_2
9-	Corundum	Al_2O_3
10-	Magnetite	$Fe_2O_3.FeO$
11-	Hematite	Fe_2O_3
12-	Diopside	$CaO.(Fe, Mg)O.2SiO_2$
13-	Wollastonite	$CaO.SiO_2$
14-	Hyperthene	$(Fe, Mg)O.SiO_2$
15-	Quartz	SiO_2

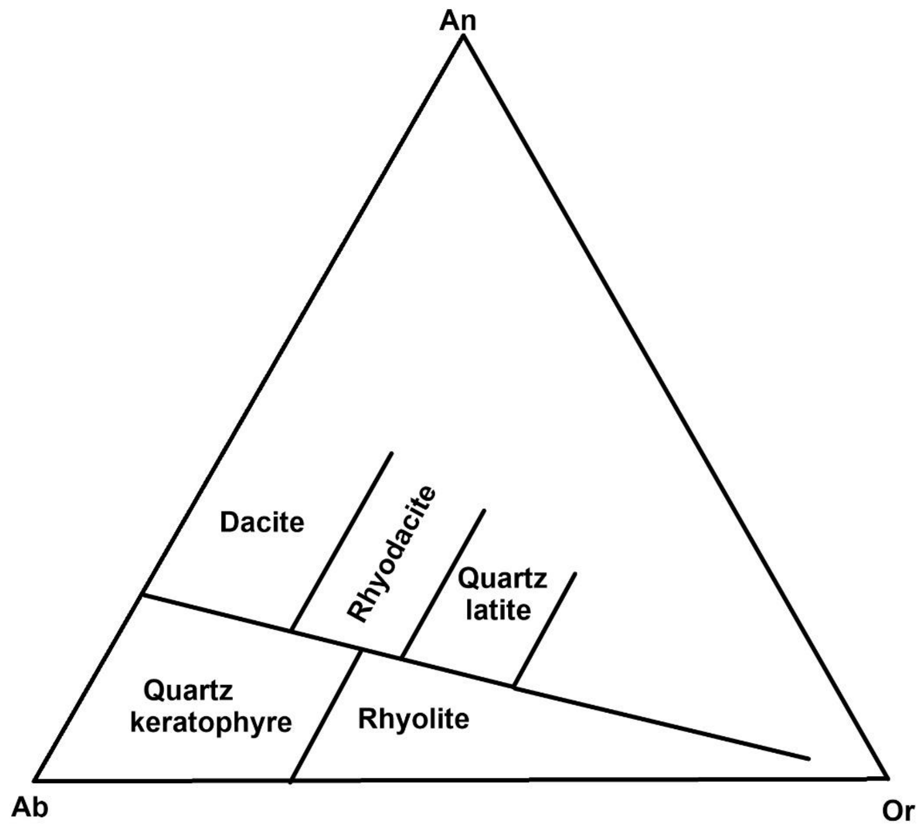
Problem 4: You have the major element data for a sample in the table below.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Total
Wt %	73.27	13.84	2.13	0.42	0.69	4.69	3.50	0.33	0.05	0.03	
Mol. Wt	60	102	160	40	56	62	94	80	142	71	
Mol.prop											

It's required to

1- Calculate the normative minerals.
2- Calculate the weight percent of the normative minerals
3- Give a brief comment on the nature of the magma based on the presence of characteristic normative minerals assemblage.
4- Give the suitable nomenclature for the sample using the attached classification diagrams (O'Conner 1965).

O'Connor (1965)



Geochemical report: -

Week five

Classifying igneous rocks using norms

Problem 5: You have the major element data for a sample in the table below.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Total
Wt %	51.96	17.08	7.72	5.72	9.85	3.53	0.72	0.99	0.11	0.14	
Mol. wt	60	102	160	40	56	62	94	80	142	71	
Mol. prop											

It's required to

1- Calculate the normative minerals.
2- Calculate the weight percent of the normative minerals
3- Give a brief comment on the nature of the magma based on the presence of characteristic normative minerals assemblage.

Week six

Classifying igneous rocks using norms

When the calculated silica is greater than the total silica, this means that the rock is silica undersaturated. In this case, the lately formed silicate minerals will be decomposed to new silicates consuming less silica than the previously formed silicates.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Total
Wt % (1)	44.52	10.54	13.45	15.28	9.76	2.12	1.15	2.65	0.34	0.18	
Wt % (2)	49.38	11.65	10.54	5.06	15.47	3.94	0.48	1.11	0.14	0.22	
Mol. wt	60	102	160	40	56	62	94	80	142	71	
Mol. prop											

Problem 6: You have the major element data for a sample in the table below.

It's required to

1- Calculate the normative minerals.
2- Calculate the weight percent of the normative minerals
3- Give a brief comment on the nature of the magma based on the presence of characteristic normative minerals assemblage.

Week seven

Mid-semester exam

Week eight

Variation diagrams

A diagram was constructed by plotting the chemical compositions of rocks in an igneous rock series to show the genetic relationships and the nature of the processes that have affected the series. Also known as the Harker diagram.

Problem 7: You have the major element data for ten samples in the table below.

wt.%	1	2	3	4	5	6	7	8	9	10
SiO_2	45.51	47.36	48.35	49.00	50.09	52.45	56.17	56.87	61.01	61.22
TiO_2	3.52	3.30	2.82	2.73	2.48	2.29	1.61	1.40	0.68	1.00
Al_2O_3	15.24	16.32	16.01	16.33	16.83	16.09	17.13	16.96	17.14	17.10
Fe_2O_3	3.64	4.64	5.87	2.35	1.65	5.02	2.91	3.88	5.09	2.03
FeO	8.84	6.89	5.37	8.67	8.80	4.19	4.79	3.93	1.21	4.06
Fe_2O_{3t}										
MgO	5.80	4.82	4.30	4.00	3.31	2.67	1.73	1.57	0.76	0.92
CaO	10.40	9.30	9.04	8.70	8.50	7.49	5.20	4.83	3.33	3.28
Na_2O	4.54	4.63	5.32	4.98	5.31	6.11	6.33	6.47	7.07	6.61
K_2O	1.09	1.49	1.14	1.66	1.39	1.64	2.22	2.43	2.87	3.05
P_20_5	0.20	0.38	0.46	0.54	0.63	0.68	0.73	0.80	0.94	1.00

It's required to

1- What is the Peacock alkali-lime index for this group of rocks?
2- Calculate the solidification index for each sample.
3- Construct variation diagrams.
4- What can you conclude about the magmatic evolution of this group of rocks?

Week nine

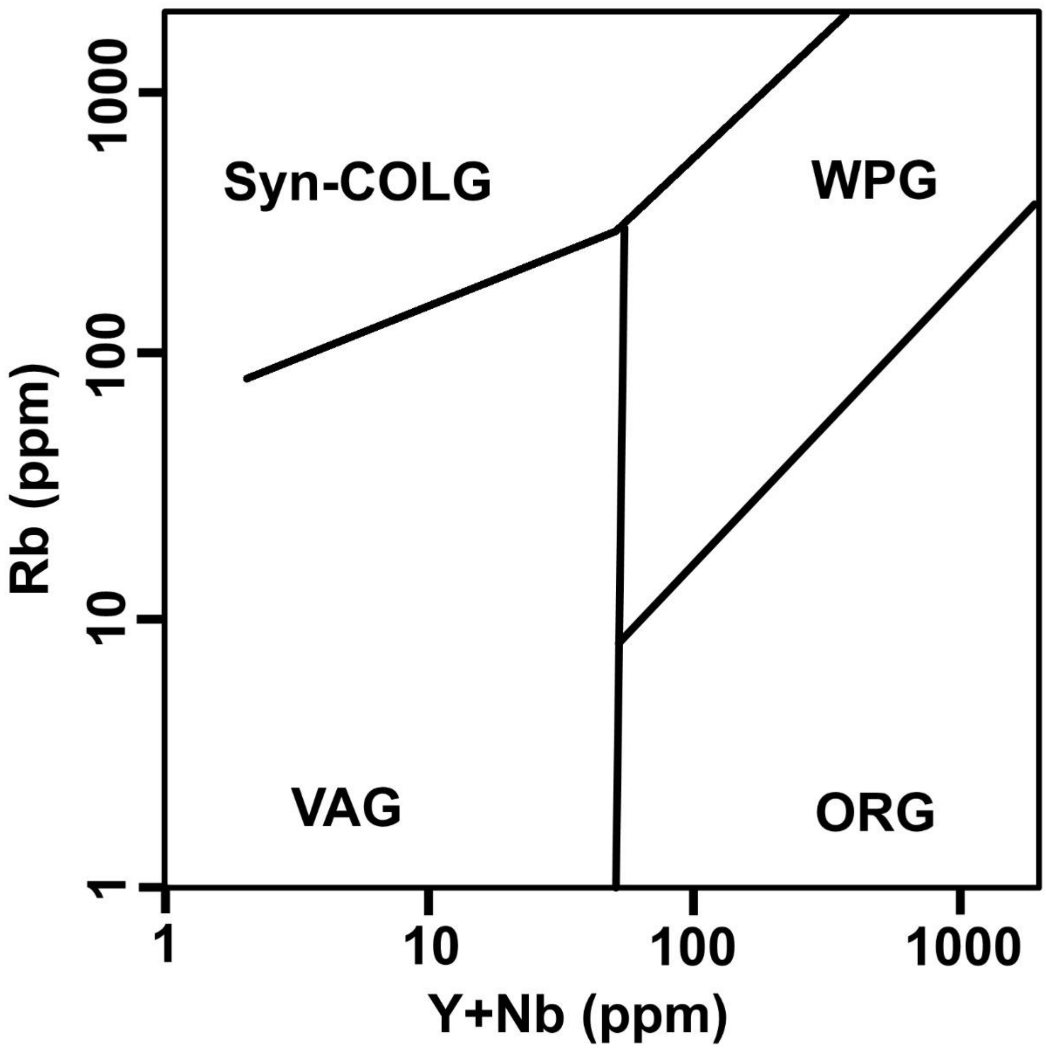
Discrimination diagrams for tectonic environments

Problem 7: You have the trace element data for six granitic rocks in the table below.

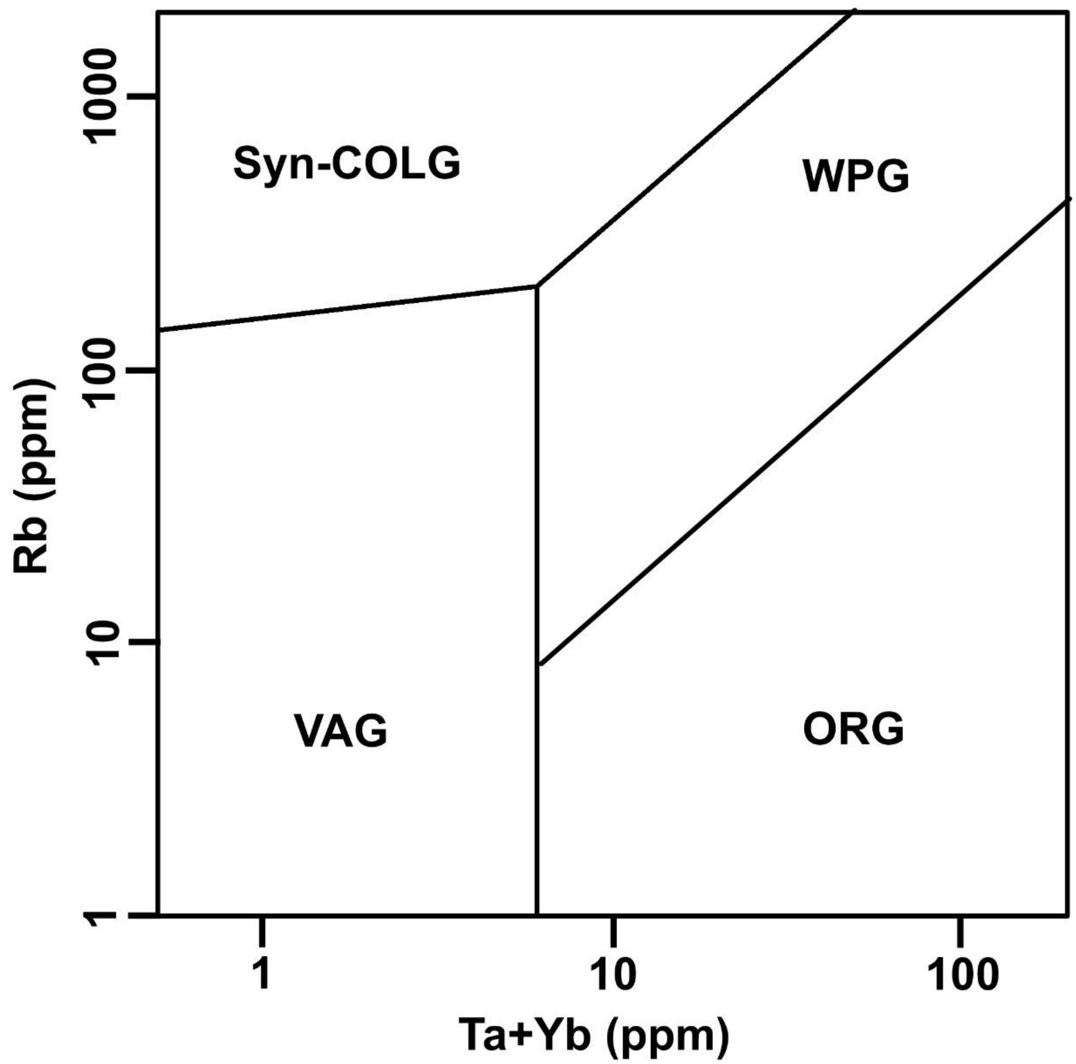
Sample	Be	Co	Cs	Ga	Nb	Rb	Sn	Sr	Ta	Th	U	W	Zr	Y	La
1	2	2.2	0.9	20.3	12.4	37.7	4	110.3	1.2	7.4	3.6	0.5	321.3	42.9	28.9
2	2	2.0	0.7	17.9	12.2	34.6	3	103.5	0.8	5.8	2.0	<0.5	336.1	38.0	30.6
3	4	1.9	0.5	19.5	12.9	37.8	4	110.7	0.9	6.8	2.8	1.0	339.5	43.0	33.2
4	3	4.1	1.0	18.0	11.2	31.5	2	273.5	0.7	4.8	1.8	0.5	400.1	36.2	26.4
5	2	3.3	0.5	18.3	10.2	36.3	2	150.4	0.7	5.0	2.2	<0.5	327.6	34.9	24.3
6	2	6.7	0.8	17.4	8.3	39.5	2	270.5	0.7	4.0	1.5	0.8	266.2	30.1	23.0

It's required to determine their tectonic environments by using the attached discrimination diagrams. (Pearce et al.,1984).

Pearce et al. (1984)



Pearce et al. (1994)



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