Benha university
Faculty of science
Geology Dept.
15 / 6 /2019

2nd Semester Exam

Geochemistry (334 G)
Time: Two Hours

Examination of Geochemistry of Igneous and Metamorphic Rocks (334 G) for the 3rd level students (Geology and Chemistry), June. 2019.

<u>Answer three the questions only from the following.</u>

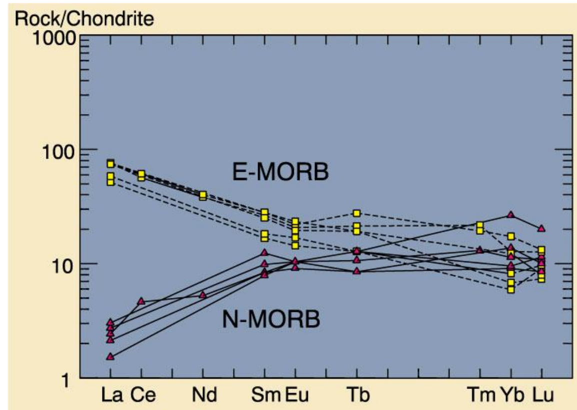
1. a) Discuss the general characteristics of A-, S-, M- and I-type granites? (8 Marks)

Type	SiO_2	K_2O/Na_2O	Ca, Sr	A/(C+N+K)*	Fe^{3+}/Fe^{2+}	Cr, Ni	□^{18}O	$^{87}Sr/^{86}Sr$	Misc	Petrogenesis
M	46-70%	low	high	low	low	low	< 9‰	< 0.705	Low Rb, Th, U Low LIL and HFS	Subduction zone or ocean-intraplate Mantle-derived
I	53-76%	low	high in mafic rocks	low: metal-uminous to peraluminous	moderate	low	< 9‰	< 0.705	high LIL/HFS med. Rb, Th, U hornblende magnetite	Subduction zone Infracrustal Mafic to intermed. igneous source
S	65-74%	high	low	high peraluminous	low	high	> 9‰	> 0.707	variable LIL/HFS high Rb, Th, U biotite, cordierite Als, Grt, Ilmenite	Subduction zone Supracrustal sedimentary source
A	high □□77%	Na_2O high	low	var peralkaline	var	low	var	var	low LIL/HFS high Fe/Mg high Ga/Al High REE, Zr High F, Cl	Anorogenic Stable craton Rift zone

b) Write a summary of the MORB petrography and their major and trace element chemistry? (8 Marks)

A "typical" MORB is an olivine tholeiite, with low K_2O (< 0.2%) and low TiO_2 (< 2.0%) compared to most other basalts. This makes MORBs chemically distinctive from basalts of other petrogenetic associations.
Textures range from glassy to phyric, and rarely to gabbroic among seabed samples. Glass samples are very important chemically, because they represent *liquid* compositions, whereas the chemical composition of phyric samples can be modified by crystal accumulation processes. Common phenocrysts are plagioclase (An_{40}-An_{88}), olivine (Fo_{65}-Fo_{91}), and a Mg-Cr spinel . Ca-rich clinopyroxene phenocrysts are much less common, and usually occur in rocks with abundant olivine and plagioclase, suggesting that clinopyroxene is most commonly a late crystallizing phase. The groundmass mineralogy of MORBs is dominated by plagioclase and clinopyroxene microlites and a Fe-Ti oxide phase. From textures and experiments on natural samples at low pressure, the common crystallization sequence is:

olivine (± Mg-Cr spinel) —» olivine + plagioclase (± Mg-Cr spinel) —> olivine + plagioclase + clinopyroxene.
N-MORB ("normal" MORB), which taps the depleted, or incompatible-poor mantle and **E-MORB** ("enriched" MORE, also called **P-MORB** for "plume") which taps the deeper, incompatible-richer mantle.



N-MORBs with Mg# > 65 have $K_2O < 0.10$, and $TiO_2 < 1.0$, whereas E-MORBs have $K_2O > 0.10$ and $TiO_2 > 1.0$ for the same Mg#. Of course, major element chemical composition is not the best way to make these distinctions, which must be substantiated by trace element and isotopic differences.
.Highly compatible elements, such as Ni and Cr, decrease with decreasing Mg#, as we would expect with olivine fractionation. Highly incompatible elements, such as V, concentrate in the evolved liquids. If we want to address the distinction between P-MORB and E-MORB, however, we are best served by proceeding directly to the rare earth elements.
The LREE patterns show a negative slope for the E-MORB's, but overall LREE enrichment. This is very similar to the enriched mantle xenoliths and basalts seen previously.
The N–MORB shows a large LREE depletion, and a positive slope. The HREE patterns for both types are similar. Since samarium is about halfway between lanthanum and lutetium, and is not plagued with anomalous behavior like europium, it has been suggested that the La/Sm ratio might be a useful distinguishing factor among basalts.

2. Write short notes for the following: (16 Marks)

a) Goldschmidt's Classification

b) Silica saturation classification

c) Alumina (Al_2O_3) Saturation

d) An incompatible element

a) Goldschmidt recognized four broad categories: atmophile, lithophile, chalcophile, and siderophile.
Atmophile elements are generally extremely volatile (i.e., they form gases or liquids at the surface of the Earth) and are concentrated in the atmosphere and hydrosphere.
Lithophile, siderophile and chalcophile refer to the tendency of the element to partition into a silicate, metal, or sulfide liquid respectively.
Lithophile elements are those showing an affinity for silicate phases and are concentrated in the silicate portion (crust and mantle) of the earth.
Siderophile elements have an affinity for a metallic liquid phase. They are depleted in the silicate portion of the earth and presumably concentrated in the core.
Chalcophile elements have an affinity for a sulfide liquid phase.

Siderophile	Chalcophile	Lithophile	Atmophile
Fe*, Co*, Ni*	(Cu), Ag	Li, Na, K, Rb, Cs	(H), N, (O)
Ru, Rh, PdZn, Cd, Hg	Be, Mg, Ca, Sr, Ba	He, Ne, Ar, Kr, Xe	
Os, Ir, Pt	Ga, In, Tl	B, Al, Sc, Y, REE	
Au, Re†, Mo†	(Ge), (Sn), Pb	Si, Ti, Zr, Hf, Th	
Ge*, Sn*, W‡	(As), (Sb), Bi	P, V, Nb, Ta	
C‡, Cu*, Ga*	S, Se, Te	O, Cr, U	
Ge*, As†, Sb†	(Fe), Mo, (Os)	H, F, Cl, Br, I	
	(Ru), (Rh), (Pd)	(Fe), Mn, (Zn), (Ga)	

b) Silica saturation classification

If a magma is oversaturated with respect to Silica then a silica mineral, such as quartz, cristobalite, tridymite, or coesite, should precipitate from the magma, and be present in the rock. On the other hand, if a magma is undersaturated with respect to silica, then a silica mineral should not precipitate from the magma, and thus should not be present in the rock. The silica saturation concept can thus be used to divide rocks in silica undersaturated, silica saturated, and silica-oversaturated rocks. The first and last of these terms are most easily seen.

Silica Undersaturated Rocks

In these rocks, we should find minerals that, in general, do not occur with quartz. Such minerals are:

Nepheline- $NaAlSiO_4$

Leucite - $KAlSi_2O_6$

Forsteritic Olivine - Mg_2SiO_4

Sodalite - $3NaAlSiO_4 \cdot NaCl$

Nosean - $6NaAlSiO_4 \cdot Na_2SO_4$

Haüyne - $6NaAlSiO_4 \cdot (Na_2,Ca)SO_4$

Perovskite - $CaTiO_3$

Melanite - $Ca_2Fe^{+3}Si_3O_{12}$

Melilite - $(Ca,Na)_2(Mg,Fe^{+2},Al,Si)_3O_7$

Silica Oversaturated Rocks.

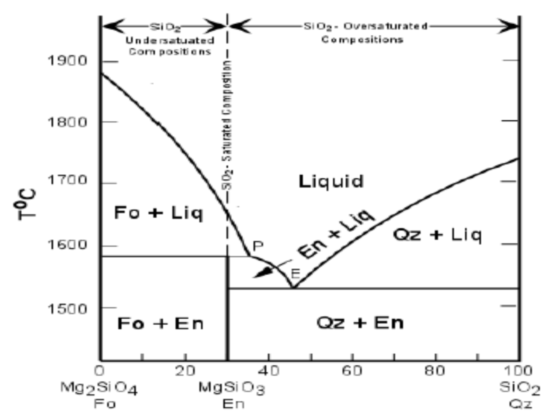
These rocks can be identified as possibly any rock that does not contain one of the minerals in the above list.

If we calculate a CIPW Norm, silica oversaturated rocks will contain normative quartz.

Silica Saturated Rocks.

These are rocks that contain just enough silica that quartz does not appear, and just enough silica that one of the silica undersaturated minerals does not appear.

In the CIPW norm, these rocks contain olivine, or hypersthene + olivine, but no quartz, no nepheline, and no leucite.



c) Alumina (Al2O3) Saturation

After silica, alumina is the second most abundant oxide constituent in igneous rocks. Feldspars are, in general, the most abundant minerals that occur in igneous rocks. Thus, the concept of alumina saturation is based on whether or not there is an excess or lack of Al to make up the feldspars. Note that Al2O3 occurs in feldspars in a ratio of 1 Al to 1 Na, 1K, or 1 Ca:

$KAlSi_3O_8$ -- $1/2K_2O : 1/2Al_2O_3$

$NaAlSi_3O_8$ -- $1/2Na_2O : 1/2Al_2O_3$

$CaAl_2Si_2O_8$ -- $1CaO : 1Al_2O_3$

Three possible conditions exist.

1. If there is an excess of Alumina over that required to form feldspars, we say that the rock is ***peraluminous***. This condition is expressed chemically on a molecular basis as:

$Al2O3 > (CaO + Na2O + K2O)$

In peraluminous. rocks we expect to find an Al2O3 rich mineral present as a modal mineral such as muscovite, corundum, topaz, or an Al2SiO5 mineral like kyanite, andalusite, or sillimanite.

Peraluminous rocks will have corundum in the CIPW norm and no diopside in the norm.

2. ***Metaluminous*** rocks are those for which the molecular percentages are as follows:

$Al2O3 < (CaO + Na2O + K2O)$ and $Al2O3 > (Na2O + K2O)$

These are the more common types of igneous rocks. They are characterized by lack of an Al2O3 rich mineral and lack of sodic pyroxenes and amphiboles in the mode.

3. ***Peralkaline*** rocks are those that are oversaturated with alkalis (Na2O + K2O), and thus undersaturated with respect to Al2O3. On a molecular basis, these rocks show:

$Al2O3 < (Na2O + K2O)$

Peralkaline rocks are distinguished by the presence of Na rich minerals like aegirine, riebeckite, arfvedsonite, or aenigmatite in the mode.

d) An incompatible element

Incompatible elements are defined as those elements that partition readily into a melt phase when the mantle undergoes melting.

3. Discuss in detail the geochemical characteristics of the different types of primary magmas? (16 Marks)

A primary magma: Is the "first melt" produced by partial melting within the mantle, and which has not yet undergone any differentiation.

A primary magma may therefore evolve into a parental magma by differentiation. For a melt to qualify for the definition of primary magma, it must fulfill the following conditions:

(1) have a higher liquidus T compared to its differentiation products,

(2) be richer in minerals removed by fractional crystallization compared to its differentiation products,

(3) have a composition in equilibrium with the mantle phases from which it was produced by partial melting at high pressure.

All primary magmas must have > 10% MgO by weight.

When a rock melts to form a liquid, the liquid is known as a primary melt. Primary melts have not undergone any differentiation and represent the starting composition of a magma. In nature, primary melts are rarely seen. Some leucosomes of migmatites are examples of primary melts. Primary melts derived from the mantle are especially important and are known as primitive melts or primitive magmas. By finding the primitive magma composition of a magma series, it is possible to model the composition of the rock from which a melt was formed, which is important because we have little direct evidence of the Earth's mantle

Types of primary magmas

Unlike parental magmas, primary magmas, which are ones produced by partial melting in the mantle, and which have not differentiated, can only be of two types: basic or ultrabasic. Basic primary magmas are simply basaltic, which by definition, have to yield Cpx + Plag upon crystallization. However, not all basalts are the same.

4. Write a summary of the differences (Geochemical characterization) between calc-alkaline and tholeiitic fractionation trends? (16 Marks)

Geochemical characterization

Rocks from the calc-alkaline magma series are distinguished from rocks from the tholeiitic magma series by the redox state of the magma they crystallized from (tholeiitic magmas are reduced, and calc-alkaline magmas are oxidized). When mafic (basalt-producing) magmas crystallize, they preferentially crystallize the more magnesium-rich and iron-poor forms of the silicate minerals olivine and pyroxene, causing the iron content of tholeiitic magmas to increase as the melt is depleted of iron-poor crystals. (Magnesium-rich olivine solidifies at much higher temperatures than iron-rich olivine.) However, a calc-alkaline magma is oxidized enough to (simultaneously) precipitate significant amounts of the iron oxide magnetite, causing the iron content of the magma to remain more steady as it cools than with a tholeiitic magma.

-Best Wishes-

Dr. M. M. Mogahed