

CIPW Norm calculations

Level 2 Computing — Project 6:

Project Abstract

This project is an example of data handling and data plotting of mineral analyses that you can obtain from XRF and gravimetric analysis of rocks. The objectives are to calculate the norms for several basaltic rock compositions. In Project 6 you will:

- (1) use EXCEL to determine the CIPW norms of some basalts,
- (3) plot the proportions of some of the normative minerals on a ternary diagram using DeltaGraph,
- (4) edit the DELTAGRAPH file in ILLUSTRATOR.

You are supplied with an EXCEL file with mineral formulas — download from link on the Level 2 DIY Computing page.

You should produce: (1) a ternary diagram and (2) a page illustrating original matrix and the inverse matrix. References to CIPW norms can be found in every petrology textbook. These references:

Morse, S.A. (1994) *Basalts and Phase Diagrams*. Krieger Publishing Co. 491 p.
Rollinson. Hugh (1993) *Using Geochemical Data*. Longman Group UK. 352 p.

give complete calculation schemes.

Background

Probably all of you have heard of CIPW norms of rocks. The CIPW norms are calculations that are performed on major element analyses of magmatic rocks with the purpose of determining a normative mineralogy of a rock. This was a method developed early last century as means to compare the geochemistry of magmatic rocks. Like modal mineralogy, normative mineralogy can vary (*i.e.*, normative minerals will vary as a function of rock composition).

The basalt tetrahedron (Fig. 1) illustrates how CIPW norm calculations can be used to distinguish basaltic rock types. Three different volumes in the basalt tetrahedron indicate the extent of silica saturation of a basalt. Some of the rock names that can be represented on the basalt tetrahedron are shown in more detail below (Fig. 2).

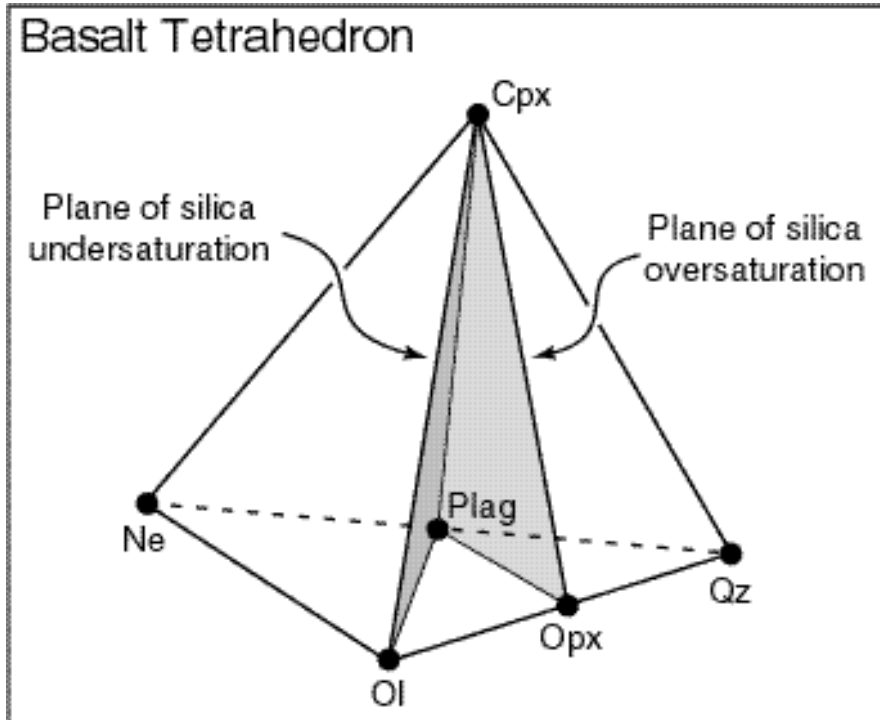


Figure 1. The basalt tetrahedron. Ol =olivine, Opx = orthopyroxene, Cpx = clinopyroxene, Qz = quartz, Ne = nepheline, Plag = plagioclase.

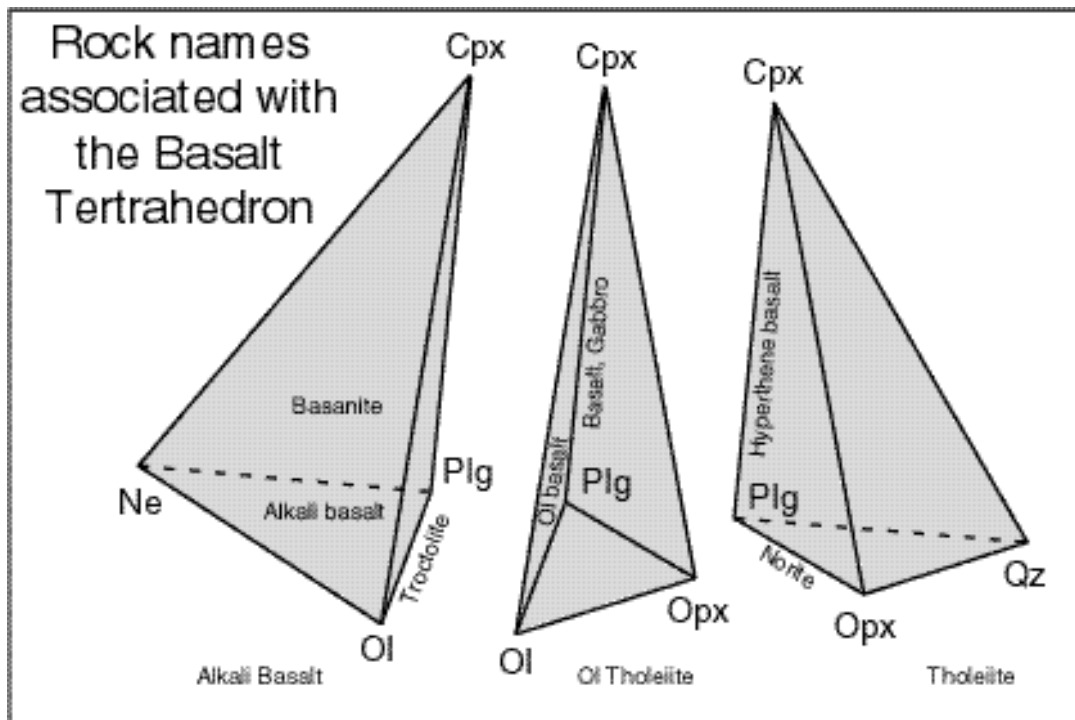


Figure 2. Three principal volumes of the basalt tetrahedron. These volumes represent varying degrees of silica saturation. Ol =olivine, Opx = orthopyroxene, Cpx = clinopyroxene, Qz = quartz, Ne = nepheline, Plag = plagioclase.

Project 6

By convention, norms are reported as Wt% of the normative minerals. To calculate a norm one must convert the Wt% oxides of the analyses to molecular proportions, determine the amounts of the minerals and convert the molecular proportions of minerals back to Wt% of the minerals. This is not as difficult as it sounds. We calculated molecular proportions of oxides in Project 4. This is simply the Wt% divided by the molecular weight (Wt%/mole wt). To convert the molecular proportions of the minerals back to weight proportion, multiply the molecular proportion of the mineral by the molecular weight of the mineral.

I hope that some of these procedures are becoming familiar to you by now.

You will need to do the following:

- (1) use EXCEL and the data in the file **proj6.xls** to determine the molecular proportions of the oxides of each basalt analysis.
- (2) in order to use the molecular proportions of the oxides to calculate the amounts of normative mineral, you will need to use the matrix inverse function in EXCEL. As in project 5, use this “new” set of components plus the molecular proportions of the oxides to calculate the normative minerals (see **proj6.xls** and below for setup).
- (3) plot these on a ternary diagram (see below) using DeltaGraph and export as an EPSF file for ILLUSTRATOR.
- (4) edit the ternary in ILLUSTRATOR.

You should produce the following results:

- (1) A labeled **ternary** figure.
- (2) A table of CIPW norms (the completed **results** sheet of the **proj6.xls** workbook)

Getting started

On the **data** sheet of the **proj6.xls** workbook you will need to convert the wt% oxides into molecular proportions (**wt% oxide/mol wt** - see **proj6.xls** for values for the molecular wt. Then add MnO to FeO.

In your project you will need to calculate the **new coordinates** in order to calculate the normative minerals from the molecular proportions of oxides. This requires inverting a matrix containing the compositions of the normative minerals expressed in terms of the oxide compositions (Fig. 3). Complete the starting matrix on the **calculations** sheet of the **proj6.xls** workbook. Note H₂O is not used. It will be added back to the analyses at the end.

		ne	il	an	mt	fa	fo	wo	ab	or	ap
6											
7	SiO2	1									
8	TiO2	0									
9	Al2O3	0.5									
10	Fe2O3	0									
11	FeO+MnO	0									
12	MgO	0									
13	CaO	0									
14	Na2O	0.5									
15	K2O	0									
16	P2O5	0									
17											

Figure 3. Starting matrix on the **calculations** sheet of the **proj6.xls**

The normative minerals for this project are:

ne = nepheline = NaAlSiO_4

il = ilmenite = FeTiO_3

an = anorthite (you should know this)

mt = magnetite (you should know this)

fa = fayalite (you should know this)

fo = forsterite (you should know this)

wo = wollastonite = CaSiO_3

ab = albite (you should know this)

or = orthoclase (you should know this)

ap = apatite = $\text{Ca}_5[\text{PO}_4]_3(\text{OH})$

Do a **MATRIX INVERSE** of the completed matrix in figure 3 into the space provided (Figure 4).

		SiO2	TiO2	Al2O3	Fe2O3	(Fe,Mn)OMgO	CaO	Na2O	K2O	P2O5
20										
21										
22	ne									
23	il									
24	an									
25	mt									
26	fa									
27	fo									
28	wo									
29	ab									
30	or									
31	ap									
32										

Figure 4. Results matrix on the **calculations** sheet of the **proj6.xls**

Copy a rock analysis from the **data** sheet of the **proj6.xls** workbook and place in the allotted cells in the **calculations** sheet of the **proj6.xls** workbook. As in project 5, use these coordinates plus the molecular proportions of oxides to calculate the amounts of the normative minerals (Fig. 5). The sums are the initial amounts of the normative minerals [e.g., $ne = (0.7987 \times -0.3994) + (0.0328 \times -0.0082) + \dots + (0.0044 \times -0.0074) = 0.0082$]. For these rock analyses all sums should be positive.

	SiO2	TiO2	Al2O3	Fe2O3	(Fe,Mn)O	MgO	CaO	Na2O	K2O	P2O5	Sum
ne	-0.3994	-0.0082	0.0949	-0.0091	0.0187	0.0272	0.0583	0.1847	0.0483	-0.0074	0.0082
il											
an											
mt											
fa											
fo											
wo											
ab											
or											
ap											

Figure 5. Calculation of the normative minerals on the **calculations** sheet of the **proj6.xls**

Conventional norm calculations go one step further. In order to make the normative minerals correspond more closely to the mineralogy of real magmatic rocks, you need to calculate a normative clinopyroxene composition (see below). We have not calculated *en* = enstatite or *fs* = ferrosilite (orthopyroxene end members) in the above matrix conversion. We will have to adjust the proportions of the normative minerals we have to obtain *en* and *fs*.

or
ab
an
ne
cpx *wo* ← Normative clinopyroxene
en
fs
ol *fo* ← Normative olivine
fa
mt
il
ap

Calculating clinopyroxene compositions

Although diopside is a pyroxene end member, lists of normative minerals from the geochemical literature commonly use the abbreviation *di* to represent the diopside - hedenbergite series. This can be a little confusing if you are not sure if *di* refers to the normative clinopyroxene composition or the end member composition. I will refer to diopside the end member as *di* and the normative clinopyroxene made up of *wo*, *en* and *fs* as *cpx*.

How much *en* and *fs* are needed

The amount of *wo* component determines this. The amount of normative *di* = diopside ($\text{CaMgSi}_2\text{O}_6$) + hedenbergite ($\text{CaFeSi}_2\text{O}_6$) = (*wo* + *en*) + (*wo* + *fs*), since $\text{CaMgSi}_2\text{O}_6 = \text{wo} + \text{en}$ and $\text{CaFeSi}_2\text{O}_6 = \text{wo} + \text{fs}$. As a consequence, $\text{wo} = \text{fs} + \text{en}$. By convention, all normative silicates have the same Fe-Mg ratio (*i.e.*, $X_{\text{Mg}} = \text{fo}/(\text{fo}+\text{fa})$) in the initial determination of the normative components. As a result,

$$\text{en} = X_{\text{Mg}} \times \text{wo} \quad (1)$$

$$\text{fs} = (1 - X_{\text{Mg}}) \times \text{wo} \quad (2)$$

How do we obtain *en* and *fs* from the original normative components?

We need to adjust the amounts of *fo*, *fa*, *ne* and *ab* to get enough SiO₂ to make *en* and *fs*. We can obtain *en* and *fs* from *fo* and *fa* via the following relationships:

$$en = 0.5 fo + 0.5 \text{ quartz} \quad (3)$$

$$fs = 0.5 fa + 0.5 \text{ quartz} \quad (4)$$

However, there is no quartz among the original norm components; since $ne + 2 \text{ quartz} = ab$,

$$\text{quartz} = 0.5 ab - 0.5 ne \quad (5)$$

Equation (5) can be combined with equations (3) and (4) to yield:

$$1.0 en = 0.5 fo + 0.25 ab - 0.25 ne \quad (6)$$

$$1.0 fs = 0.5 fa + 0.25 ab - 0.25 ne \quad (7)$$

Equations (1) and (2) give the amounts of *en* and *fs* for the norm and be used with equations (6) and (7) to adjust the *fo*, *fa*, *ne* and *ab* of the norm to obtain the required *en* and *fs*. For example, if equation (1) gives an *en* of 1.25, multiply equation 6 by 1.25, which gives:

$$1.25 en = 0.625 fo + 0.3125 ab - 0.3125 ne \quad (8)$$

The original amounts of *fo*, *ne* and *ab* will have to be adjusted using the values in equation 8. In this example, adjusted *fo* = original *fo* - 0.625; adjusted *ab* = original *ab* - 0.3125; but adjusted *ne* = original *ne* + 0.3125.

Lastly, since by convention, CIPW norms are reported as wt% of the normative minerals, you will need to convert the molecular proportions back to wt% (**mole prop. × mineral formula wt**). Note: after reconverting to wt % the sum should be within 5 relative % of the original analytical total if everything was done correctly.

There is space provided at the bottom of the **calculations** sheet of the **proj6.xls** workbook for adjusting the *fo*, *fa*, *ne* and *ab* of the norm to obtain the required *en* and *fs*, and to convert the molecular proportions of the normative minerals back into weight proportions. Copy these values into the **results** sheet of the **proj6.xls** workbook. Note that you will also need the wt % of H₂O from the **data** sheet of the **proj6.xls** workbook to complete the results page. Compare the totals of the norms with those of the original analyses—the totals should be close to the same.

See next page

Classification diagram:

Use your data to plot the basalt compositions on this diagram (values in wt proportions). Plot the diagram using DeltaGraph and export the results in EPSF format and polish the diagram in ILLUSTRATOR. By polish I mean make it look good! Hint, if you do not know what a feldspathoid is, then find out before you attempt to construct this diagram.

