

# The CIPW Norm

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*Simplified by JFM (feb. 06), by removing most of the accessory minerals, and the steps needed only in rare case. Skip the crossed-out steps for the simplified version (which we'll use in this practical)!*

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The CIPW norm is named for the four petrologists, Cross, Iddings, Pirsson and Washington, who devised it in 1931

## What is a Norm and Why is it Needed?

A norm is a means of converting the chemical composition of an igneous rock to an ideal mineral composition. It often reveals similarities in rocks that have quite different *modes*, or observed mineral assemblages. Some of the factors that can cause such variations are:

- Disequilibrium (for example, zoned minerals or reaction rims isolating the interiors of grains)
- Temperature
- Pressure
- Alteration
- Water content (otherwise identical rocks might contain biotite, amphibole, or pyroxene, depending on water content)
- Other minor constituents. For example, excess sulfur or chlorine might cause scapolite to form instead of feldspar. Boron typically causes tourmaline to form.

The CIPW norm calculates mineral composition as if the magma were anhydrous (water is simply treated as a separate phase) and at low pressure. Other more complex norms have been devised for high-pressure or very hydrous situations. In an ideal world, a norm would match the observed mineral phases perfectly. To create such a norm, we would have to understand magma crystallization perfectly (and we don't), and the norm would be extremely complex to calculate.

## Logic of Calculation

The logic of calculating a norm is simple even if the steps are tedious. Deal with the simplest and most predictable minerals first, then apply corrections if the rock is silica-deficient.

- Allocate the most predictable elements

- Allot Common Substitution Elements to Major Elements  
Nickel and manganese are combined with ferrous iron, strontium and barium with calcium.
- Allot Minor Elements to Accessory Minerals. These include P (Apatite), S, (Pyrite), Cr (Chromite), F, (Fluorite), CO<sub>2</sub> (Calcite) and Zr (Zircon)
- Allot Titanium to ilmenite or sphene. Later on, Ti may need to be alloted to perovskite or rutile.
- Allot Calcium and Aluminum to anorthite.
- Provisionally form silica-saturated silicates
  - Provisionally allot Alkalis and Aluminum
  - Begin alloting Iron and Magnesium
  - Create Provisional Pyroxenes
  - Silica Excess forms Quartz
  - If there is no silica deficit, calculation is complete.
- Convert Provisional Minerals to Remove Silica Deficit
  - Convert Hypersthene to Olivine
  - ~~Convert Sphene to Perovskite~~
  - Convert Albite to Nepheline
  - Convert Orthoclase to Leucite
  - ~~Convert Wollastonite and Diopside to Calcium Orthosilicate (Rare)~~
  - ~~Convert Orthoclase to Kaliophilite (Rare)~~

## Calculating the Norm

### Preliminary Comments

- **Convert all weight percentages to molecular percentages.**
- All quantities are running amounts; that is, use the quantity remaining after any previous calculations.
- Formulas follow common computer program syntax. For example, FeO = FeO + MnO + NiO means sum FeO, MnO and NiO, then replace the value of FeO with the calculated value.
- Provisional calculations are denoted by P\*; for example, P\*Albite means a provisional quantity for albite, which may be converted later on to nepheline. Any provisional amounts remaining at the end become final amounts.

### Allot Common Substitution Elements to Major Elements

- FeO = FeO + MnO + NiO
- ~~CaO = CaO + BaO + SrO~~

### Allot Minor Elements to Accessory Minerals

- Apatite = P<sub>2</sub>O<sub>5</sub>, CaO = CaO - (10/3)P<sub>2</sub>O<sub>5</sub>, P<sub>2</sub>O<sub>5</sub> = 0
- ~~Pyrite = S, FeO = FeO - S/2, S = 0~~

- ~~Chromite = Cr<sub>2</sub>O<sub>3</sub>, FeO = FeO - Cr<sub>2</sub>O<sub>3</sub>, Cr<sub>2</sub>O<sub>3</sub> = 0~~
- ~~Fluorite = F, CaO = CaO - F, F = 0~~
- ~~Calcite = CO<sub>2</sub>, CaO = CaO - CO<sub>2</sub>, CO<sub>2</sub> = 0~~
- ~~Zircon = ZrO<sub>2</sub>, SiO<sub>2</sub> = SiO<sub>2</sub> - ZrO<sub>2</sub>, ZrO<sub>2</sub> = 0~~

## Allot Titanium

- If FeO exceeds Titanium then Ilmenite = TiO<sub>2</sub>, FeO = FeO - TiO<sub>2</sub>, TiO<sub>2</sub> = 0
- ~~If TiO<sub>2</sub> exceeds FeO then:~~  
~~P\*Spheue = TiO<sub>2</sub>, CaO = CaO - TiO<sub>2</sub>, SiO<sub>2</sub> = SiO<sub>2</sub> - TiO<sub>2</sub>, TiO<sub>2</sub> = 0~~

## Provisionally Allot Alkalis and Aluminum

- P\*Orthoclase = K<sub>2</sub>O, Al<sub>2</sub>O<sub>3</sub> = Al<sub>2</sub>O<sub>3</sub> - K<sub>2</sub>O, SiO<sub>2</sub> = SiO<sub>2</sub> - 6 K<sub>2</sub>O
- If Al<sub>2</sub>O<sub>3</sub> exceeds Na<sub>2</sub>O then:  
P\*Albite = Na<sub>2</sub>O, Al<sub>2</sub>O<sub>3</sub> = Al<sub>2</sub>O<sub>3</sub> - Na<sub>2</sub>O, SiO<sub>2</sub> = SiO<sub>2</sub> - 6 Na<sub>2</sub>O, Na<sub>2</sub>O = 0
- If Na<sub>2</sub>O exceeds Al<sub>2</sub>O<sub>3</sub> then:
  - Albite = Al<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O = Na<sub>2</sub>O - Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> = SiO<sub>2</sub> - 6 Na<sub>2</sub>O, Al<sub>2</sub>O<sub>3</sub> = 0
  - Aegerine = Na<sub>2</sub>O, Fe<sub>2</sub>O<sub>3</sub> = Fe<sub>2</sub>O<sub>3</sub> - Na<sub>2</sub>O, SiO<sub>2</sub> = SiO<sub>2</sub> - 4 Na<sub>2</sub>O
  - ~~In the very rare case where Na<sub>2</sub>O is left over due to insufficient Fe<sub>2</sub>O<sub>3</sub>, allot it to sodium metasilicate. SiO<sub>2</sub> = SiO<sub>2</sub> - Na<sub>2</sub>O.~~
- If Al<sub>2</sub>O<sub>3</sub> is left after alloting orthoclase and albite, then:  
Anorthite = Al<sub>2</sub>O<sub>3</sub>, CaO = CaO - Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> = SiO<sub>2</sub> - 2 Al<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub> = 0
- If Al<sub>2</sub>O<sub>3</sub> exceeds CaO in the preceding calculation, then:
  - Anorthite = CaO, Al<sub>2</sub>O<sub>3</sub> = Al<sub>2</sub>O<sub>3</sub> - CaO, SiO<sub>2</sub> = SiO<sub>2</sub> - 2 CaO
  - Corundum = Al<sub>2</sub>O<sub>3</sub>, CaO = 0, Al<sub>2</sub>O<sub>3</sub> = 0

## Begin Alloting Iron and Magnesium

- If FeO exceeds Fe<sub>2</sub>O<sub>3</sub> then:  
Magnetite = Fe<sub>2</sub>O<sub>3</sub>, FeO = FeO - Fe<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> = 0
- If Fe<sub>2</sub>O<sub>3</sub> exceeds FeO then:  
Magnetite = FeO, Fe<sub>2</sub>O<sub>3</sub> = Fe<sub>2</sub>O<sub>3</sub> - FeO, FeO = 0, Hematite = Fe<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> = 0
- From here on, all FeO and MgO go to pyroxene plus olivine, but their relative proportions are maintained in all minerals. The sum of MgO plus FeO is designated FM in what follows.

## Create Provisional Pyroxenes

- If FM exceeds CaO then:
  - P\*Diopside = CaO, FM = FM - CaO, SiO<sub>2</sub> = SiO<sub>2</sub> - CaO, CaO = 0
  - P\*Hypersthene = FM, SiO<sub>2</sub> = SiO<sub>2</sub> - FM
- If CaO exceeds FM then:
  - P\*Diopside = FM, CaO = CaO - FM, SiO<sub>2</sub> = SiO<sub>2</sub> - 2 CaO, FM = 0
  - P\*Wollastonite = CaO, SiO<sub>2</sub> = SiO<sub>2</sub> - CaO

## Deal With Silica Excess or Deficit

- If  $\text{SiO}_2$  is still positive then: Quartz =  $\text{SiO}_2$ ,  $\text{SiO}_2 = 0$ , **Calculation Finished**
- If  $\text{SiO}_2$  is negative, then we must convert some of the P\*minerals. Call the silica deficit D ( $D = -\text{SiO}_2$ ) and proceed as follows. Whenever  $D = 0$ , the calculation is done.

## Convert Provisional Minerals to Remove Silica Deficit

### Form Olivine

- If D is less than  $1/2$  of P\*hypersthene, then:  
Olivine = D, Hypersthene = P\*Hypersthene - 2D,  $D = 0$ , **Calculation Finished**
- If D is greater than  $1/2$  of P\*hypersthene, then:  
Olivine = P\*Hypersthene,  $D = D - 1/2(\text{P*Hypersthene})$ , Hypersthene = 0,

### Form Perovskite

- ~~If D is less than P\*Spheue, then:  
Perovskite = D, Spheue = P\*Spheue - D,  $D = 0$ , **Calculation Finished**~~
- ~~If D is greater than P\*Spheue, then:  
Perovskite = P\*Spheue,  $D = D - \text{P*Spheue}$ , Spheue = 0~~
- ~~Any excess  $\text{TiO}_2$  is accounted as Rutile~~

### Form Nepheline

- If D is less than  $4(\text{P*Albite})$  then:  
Nepheline =  $D/4$ , Albite = P\*Albite -  $D/4$ , P\*Albite = 0,  $D = 0$ , **Calculation Finished**
- If D is greater than  $4(\text{P*Albite})$  then:  
Nepheline = P\*Albite,  $D = D - 4(\text{P*Albite})$ , Albite = 0

### Form Leucite

- If D is less than  $2(\text{P*Orthoclase})$  then:  
Leucite =  $D/2$ , Orthoclase = P\*Orthoclase -  $D/2$ , P\*Orthoclase = 0,  $D = 0$ , **Calculation Finished**
- If D is greater than  $2(\text{P*Orthoclase})$  then:  
Leucite = P\*Orthoclase,  $D = D - 2(\text{P*Orthoclase})$ , Orthoclase = 0

### Form Calcium Orthosilicate (Rare)

- ~~If D is less than  $(1/2)(\text{P*Wollastonite})$  then: Calcium Orthosilicate = D,  
Wollastonite = P\*Wollastonite - 2D,  $D = 0$ , **Calculation Finished**~~
- ~~If D is greater than  $(1/2)(\text{P*Wollastonite})$  then: Calcium Orthosilicate =  
P\*Wollastonite,  $D = \text{P*Wollastonite}/2$ , Wollastonite = 0~~

- ~~If there is *still* a deficit, convert Diopside to Olivine + Calcium Orthosilicate as follows:~~
  - ~~If D is less than P\*Diopside then:  
Additional Calcium Orthosilicate = D/2, Additional Olivine = D/2. Add these amounts to the previously formed minerals. Diopside = P\*Diopside - D, D = 0, **Calculation Finished**~~
  - ~~If D is greater than P\*Diopside then:  
Additional Calcium Orthosilicate = P\*Diopside/2, Additional Olivine = P\*Diopside/2. Add these amounts to the previously formed minerals. D = D - P\*Diopside, Diopside = 0~~

### **Form Kaliophilite (Rare)**

~~If there is *still* a deficit, convert Leucite to Kaliophilite: Kaliophilite = D/2, Leucite = Leucite - D/2, D = 0, **Calculation Finished**~~

Convert all remaining provisional minerals, if any, to final quantities

## **Reference**

Myron G. Best; *Igneous and Metamorphic Petrology*, Freeman, 1982, Appendix E, pp. 616-619

<http://www.uwgb.edu/dutchs/petrology/cipw01.htm>