Quadrant III – Notes

Programme : Bachelor of Science (Third Year)

Subject : Geology

Course Code : GEC-109

Course Title : Metamorphic Petrology

Unit : IV

Module Name :ACF and AFM (AKFM) diagrams, their advantages and limitations.

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Notes:

Introduction:

- From over 30 commonly occurring metamorphic minerals, the ones likely to occur in metamorphic rocks would essentially depend o the chemical composition of the parent rock, besides P-T conditions during metamorphism.
- The number of minerals that can appear in a metamorphic rock is governed by the Gibb's Phase Rule.
- According to the rule, modified by Goldschmith for the metamorphic rocks, the number of Phases (P) i.e minerals present in a rock are always less than or equal to the number of Components (C). i.e $P \leq C$
- For a better study of metamorphic facies, the equilibrium mineral assemblages for rocks of various compositions are graphically represented on ACF and AFM diagrams.

- These triangular phase diagrams are used to depict stable mineral assemblages representing a facies.
- This is so because, different assemblages in rocks of the same bulk composition from adjoining regions represent different conditions of metamorphism and hence, different facies, subfacies, zones or grades of metamorphism.

The ACF diagram:

- The ACF diagram is a triangular diagram used to plot mineral assemblages in metabasites and impure carbonate rocks.
- Each of the three corners of the diagram represents moles of a particular major element oxide or group of oxides.
- The oxides SiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO and CaO are accounted for in the diagram, but inorder to plot seven oxides on a three-component diagram, adjustments must be made.
- First, all assemblages are assumed to be saturated with silica i.e quartz must be present in all assemblages for which the diagram is used.
- Next, $Fe^{2+,}$ Mg and Mn are assumed to substitute freely for one another, because they occupy the same sites in mineral structures.
- The F-corner represents moles of the oxides of these three cations.
- Similarly, Al and Fe^{3+} are assumed to substitute freely for one another and they are lumped together.
- The sum Na_2O+K_2O is subtracted from the sum Al_2O_3 + Fe_2O_3 as the former combine with Al to make feldspar.
- The molecular value remaining after this subtraction is plotted at the A corner.
- The C-corner represents the moles of CaO.

- In summary, the three corners of the diagram are represented by the molecular values.

  $A = Al_2O_3 + Fe_2O_3 – (Na_2O + K_2O)$

  $C = CaO$

  $F = FeO + MgO + MnO$

Certain corrections are applied to take care of minor elements:

- *FeO is reduced to allow TiO_2 and Fe_2O_3 in ilmenite and magnetite respectively.*
- *CaO is corrected to allow for combination with P_2O_5 to form apatite.*
- *The % of Na_2O and K_2O are subtracted from the A-components, as these oxides are presumed to unite with equal amounts of Al_2O_3 in the alkali feldspars.*
- *The quantity of 3.3 P_2O_5 is subtracted from CaO because all of the P_2O_5 is assumed to be utilised in the mineral apatite.*

The ACF components are then calculated as follows:

$A = Al_2O_3 – (Na_2O + K_2O)$

$C = CaO – 3.3\ P_2O_5 – CO_2$

F = MgO + FeO (corrected)   [FeO (corrected) Fe2O3TiO2 fe2O3]

- Before plotting data on the diagram, these values must be normalised by making A+C+F = 100%.
- From the positions of the bulk rock chemistries, one can easily determine which minerals might be expected in the metamorphic rocks.

- For example: calcite, dolomite, lawsonite, anorthite and grossular are among the minerals expected in metamorphosed limestones (i.e carbonate rocks).
- Metabasites might contain diopside, hornblende, Actinolite, glucophane, hypersthenes, olivine, epidote, lawmontite, pumpellyite or anorthite whereas
- Kyanite, sillimanite, cordierite and anorthite are minerals that might appear in an aluminous rock such as metapelite.

The AFM diagram:

- The AFM diagram is a true phase diagram.
- Developed by J B. Thompson (1957), it is used to depict the mineral assemblages present in metapelites, some metasandstones, metaigneousroch and any other containing quartz and muscovite.
- In this diagram, FeO and MgO are treated as separate components (as they should be).
- The diagram is derived from a 4-component plot, the AKFM tetrahedron.
- Six major element components are accounted for in the system SiO_2-Al_2O_3-FeO-MgO-K_2O-H_2O which serves as the foundation for the AFM diagram.
- Adjustments may be made for the additional components TiO_2, Fe_2O_3, Na_2O and P_2O_5.
- The diagram is used only for systems saturated in silica i.e quartz is always present and need not be depicted other than o be listed adjacent to the diagram.
- Similarly, H_2O is considered to be available where needed, either because the system will be saturated with it or because the external environment can provide adequate water, if it is needed to form a particular phase.

- Adjustments made to account for the presence of ‘additional’ components listed leaves only the four remaining components Al_2O_3, FeO, MgO and K_2O – to be plotted.
- Any aluminoius or ferromagnesium mineral or rock composition may be plotted in the AFM diagram.
- Mineral or rock compositions that lack K_2O (like garnet) plot directly on the basal AFM plane. [refer fig 4]
- Projecting from the composition of muscovite (point M), one may plot any point lying within the volume of the tetrahedron onto the basal AFM plane or its projection to infinity.
- Minerals like biotite (point B) that are K-rich project beyond the FeO-Mg line (outside of the AFM triangle)
- Actual plotting of compositions in the AFM diagram is done using calculated co-ordinate values derived from the chemical analysis.
- The co-ordinate axes, are the molecular values MgO/(MgO + FeO) and $(Al_2O_3 – 3K_2O) / (Al_2O_3 – 3K_2O + MgO + FeO)$.
- Pelitic rock compositions may plot anywhere within the diagram, but most commonly fall in the lower centre.
- Similarly, sandstone compositions are variable.
- Quartz arenites plot near the A-corner because they consist of quartz and aluminous clays, whereas lithic wackes and arenites have compositions that plot near the base (the M-F line), because they contain Fe-Mg bearing minerals and volcanic rock fragments.

$A = Al_2O_3 - 3K_2O$.

F = $FeO-TiO_2$

M = MgO

Utility of the ACF/AFM diagrams:

- ACF and AFM diagrams are useful to study compositional variations of mineral assemblages and metamorphic grades. Thus, a more complete study of metamorphic facies can be done from standard diagrams, which are already available and several deductions are possible.
- By noting the mineral composition of a rock and observing the diagram, the grade of metamorphism and the approximate chemical composition of the rock can be visualised, depending upon the modal % of different minerals.
- Alternately, the rock can be chemically analysed and the composition can be plotted for accurately establishing the ideal mineral assemblages.
- Thus, the rocks of different grades but similar composition will yield different assemblages at different temperatures of formulation.
- Such situations can be easily verified or established through the use of these diagrams.

Offline Resources:

- Raymond, Loren: Igneous and Metamorphic Petrology, John Wiley Sons
- Winter John: Igneous and Metamorphic Petrology.
- Best M. G.: Igneous and Metamorphic Petrology.

- Yardly, V.M.; An introduction to Metamorphic Petrology.
- Philpots, A.R. Principles of Igneous and Metamorphic Petrology.

Online Resources: