

Geology 533
Metamorphism and Lithosphere Evolution

Metapelites:

Petrogenetic grid, AFM diagrams, bulk compositions, isograds and grade!

using the Gibbs program of F.S. Spear

You are provided with a 'map' representing four different stratigraphic units going upgrade towards a diorite intrusion. The horizontal axis on the 'map' is in T (°C), which you can think of as roughly equivalent to distance away from the intrusive contact. The four different stratigraphic units maintain constant bulk composition going upgrade.

The bulk compositions of the four units, in terms of coordinates in an AFM diagram projected from Ms, Qtz and H₂O, are:

Unit	Name	A	F	M
1	High-Al pelite	0.4	0.3	0.3
2	Low-Al intermediate Fe-Mg pelite	0.1	0.45	0.45
3	Low-Al Fe-rich pelite	0.1	0.8	0.1
4	Low-Al Mg-rich pelite	0.1	0.1	0.8

You are to use the AFM routine in *Gibbs* to record stable mineral assemblages and isograds that are encountered in each lithological unit going upgrade towards the intrusion. The metamorphic field gradient you are to examine ranges from 405 to 700 °C at a uniform pressure of 3.8 kbar.

The mineral assemblages will contain two or three minerals plus the excess phases Ms, Qtz and hydrous fluid. These will include variously biotite, chlorite, chloritoid, staurolite, cordierite, andalusite, sillimanite and kyanite. Look at the attached AFM diagram to see where these plot relative to one another.

Isograds are here defined as lines on a map across which there is a change in mineral assemblage. The isograds may be of two types:

1. Continuous reactions, in which three phase fields on the AFM diagram sweep through the bulk composition as P-T conditions change. These reactions involve changes between divariant (3-phase) and trivariant (2-phase) assemblages. In these reactions, you either (a) gain a phase, ie, go from two to three phases stable, as a triangle is entered, or (b) lose a phase, ie go from three to two phases stable, as a triangle is exited. The first type is a mineral-in isograd, the second type a mineral-out isograd.

Rarely you may encounter a 1-phase region (quadravariant), which may also be involved in mineral-in or mineral-out isograds.

2. Discontinuous reactions, in which a tie line change occurs across a univariant reaction. In these reactions, the number of phases on either side of the isograd is the same (generally three = divariant, unless crossing a degenerate univariant reaction – see below), but the mineral assemblage changes. These reactions involve both the loss of one phase and gain of another, so they are simultaneously a mineral-in/mineral-out isograd.

There are three types of discontinuous reactions: (a) crossing tie-line reactions; (b) ‘internal’ phase disappearance or appearance reactions; and (c) degenerate reactions. An example of a crossing tie-line reaction (in which the four phases lie at the points of a quadrilateral) is $\text{St} + \text{Chl} = \text{Al}_2\text{SiO}_5 + \text{Bt}$, whereas an example of an internal phase disappearance reaction (in which one phase lies within a triangle defined by the other three) is $\text{Chl} = \text{Al}_2\text{SiO}_5 + \text{Crd} + \text{Bt}$ (remember that the projected phases Ms, Qtz and H_2O are also involved). Look at an AFM diagram.

Some examples of degenerate univariant reactions are $\text{Ky} = \text{And}$, $\text{And} = \text{Sil}$ and $\text{Ms} + \text{Qtz} = \text{Sil} + \text{Kfs} + \text{H}_2\text{O}$ (they are degenerate because they proceed in a smaller chemical subsystem than in the full KFMASH system, and univariant because within these smaller chemical subsystems, they involve one more phase than component – eg, the 5-phase $\text{Ms} + \text{Qtz} = \text{Sil} + \text{Kfs} + \text{H}_2\text{O}$ reaction is univariant in the Fe&Mg-absent 4-component KASH system).

Exercise

Start the Gibbs program and follow the directions in the Instructions attached to this lab. Choose the SPaC 2000 data base. Go to the ‘Plotting menu’ and choose the P-T diagram that gives a P range of 0-10 kbar, 400-800 °C, and draw the (new) axes. Return to the ‘Main menu’ and select ‘MakeMyGrid’. Choose ‘KFMASH system (Spear, Pattison & Cheney 2000)’. Choose ‘AFM diagram routines’. Choose ‘P&T dialogue box’. Input Start T and P of 405 °C, 3800 bars; delta T and P of 5°C, 0 bars, and End T and P of 700 °C, 3800 bars. Press ‘Calculate AFM’. The AFM diagram for 405 °C, 3800 bars will be displayed.

At this point, you need to add your bulk compositions to the AFM diagram. Hit ‘Done’. Move the AFM window over to the right and expand it, if necessary, so that you can see the whole thing (normally it will largely obscure the P-T grid but don’t worry – you have a hard copy of the grid to look at). Using a felt pen, mark as accurately as you can on a clear overlay the positions of your four bulk compositions on the AFM diagram on the screen.

Go back to the Command window and choose ‘P&T dialogue box’ again. The same box as before will appear. Hit ‘Calculate AFM’ and the diagram for 410, 3800 bars will appear. Again make note of the mineral assemblage for each of the four bulk compositions. Hit ‘Calculate AFM’ again and the one for 415, 3800 bars will appear.

Continue doing this, recording all mineral assemblages and isograds for each bulk composition. Note whether the isograd is a continuous or discontinuous isograd, and the mineral-in or mineral-out.

** For each P-T point, look at your P-T diagram so you can link what is going on in the grid with what is happening with the AFM diagram. In particular, when you cross one of the coloured red or blue lines on the grid (corresponding to end member KFASH or KMASH reactions), you will notice that a skinny three phase triangle emanates from the Fe-rich or Mg-rich side of the AFM diagram, respectively, and migrates and enlarges as temperature is increased. These are continuous Fe-Mg reactions. When you cross one of the black univariant lines, you will get a tie-line flip involving the four phases labelled on the reaction.**

You may need to reduce the T-interval in places to figure out exactly what is happening when things change markedly over small temperature intervals.

Complete the map and comment on the different isograds observed for each bulk composition. Are all bulk compositions affected by all the grid reactions?

Isograds for different bulk compositions



