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Mineral compositions,
Water = H_2O, pyrophyllite (py) = $Al_2Si_4O_{10}(OH)_2$, quartz (q) = SiO_2, K-feldspar (Kfs)= $KAlSi_3O_8$, muscovite (mu) = $KAl_3Si_3O_{10}(OH)_2$, kyanite (Ky) = Al_2SiO_5, and Sillimanite (sill) = Al_2SiO_5

Construct a molar compositional phase diagram for each metamorphic zone. Five chemical components are needed to describe the compositions of all of the minerals. Reduce these to three significant components. This can be done by using $KAlSi_3O_8$ SiO_2 and Al_2O_3 as the components and projecting the mineral composition of pyrophyllite and muscovite from H_2O. Write balanced reactions that describe the changes in mineral assemblages between the metamorphic zones.

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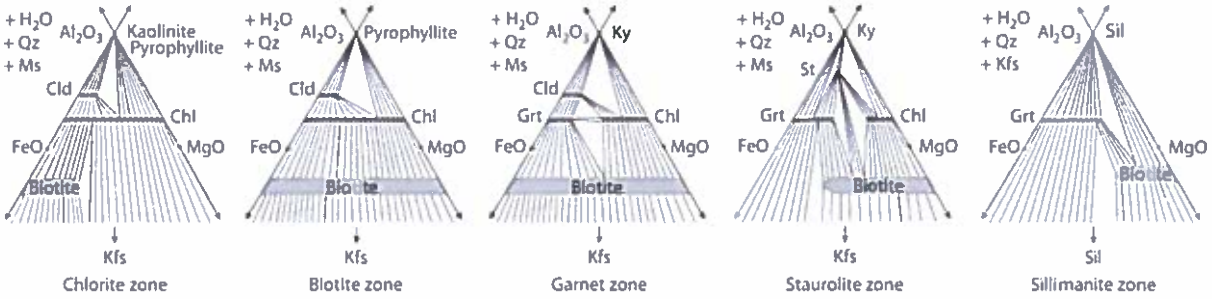
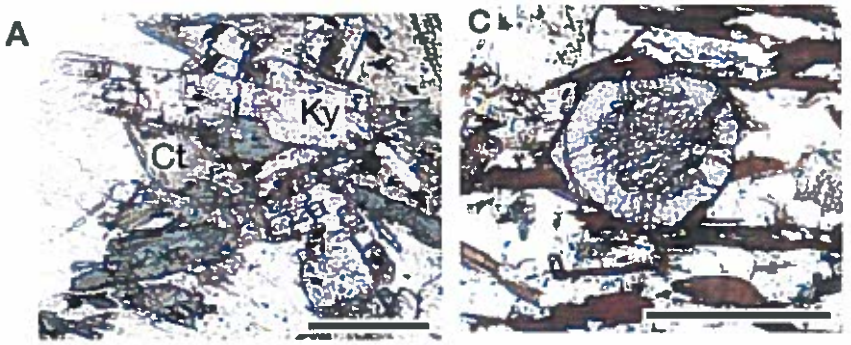
9. The figure below shows AFM diagrams for metamorphic zones from NE Scotland.



a) Why are the minerals plotted as a band of compositions?
b) Make a list of the all the divariant mineral assemblages in the staurolite zone. (note there are three significant chemical components in this system).
c) The images shown below show the microstructures of two rocks with trivarant assemblages from the same outcrop. Rock A has chloritoid (Ct in image, Cld on AFM diagram) and kyanite, rock C has garnet and biotite. What metamorphic zone does this outcrop come from?



d) In the garnet metamorphic zone, rock composition X has an assemblage of grt, chl, and biotite. List the mineral assemblages that will occur in rock X in the chlorite zone, the biotite zone, the staurolite zone and the sillimanite zone.
e) Draw an AFM diagram for the kyanite zone, which is between the straurolite and the sillimanite zones.

10 Some metamorphosed sandstones and mudstones in a regional mountain belt occur in four metamorphic zones which contain the following mineral assemblages.

zone I: sandstone layers: quartz, K-feldspar, muscovite, water
mudstone layers: pyrophyllite, muscovite, quartz, water

zone II: sandstone layers: quartz, K-feldspar, muscovite, water
mudstone layers: kyanite, muscovite, quartz, water

zone III: sandstone layers: quartz, K-feldspar, kyanite, water
mudstone layers: kyanite, muscovite, K-feldspar, water

zone IV: : sandstone layers: quartz, K-feldspar, sillimanite, water
mudstone layers: sillimanite, muscovite, K-feldspar, water

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7. Give short answers to the following questions;

a) What is the definition of metamorphism and what grain-scale processes are involved?
b) What is a polymorph?
c) What is the pressure at the base of the continental crust at a depth of 30 km and the base of oceanic crust at a depth of 6 km. Note that the density of granitic rocks is 2650 kg/m^3, the density of basaltic rocks = 2800 kg/m^3, g =9.8 m/s^2, SI units of pressure are Pa and 1 kilobar (kb) = 100 MPa.
d) What are the main heat sources that control the geotherm in stable crust?
e) What is the difference between local metamorphism and regional metamorphism?

8. Give short answers to the following questions;

a. Draw a pressure (P) -temperature (T) diagram showing the conditions of the main metamorphic facies.

b. The figure shows a map of the regional paired metamorphic belts in Japan

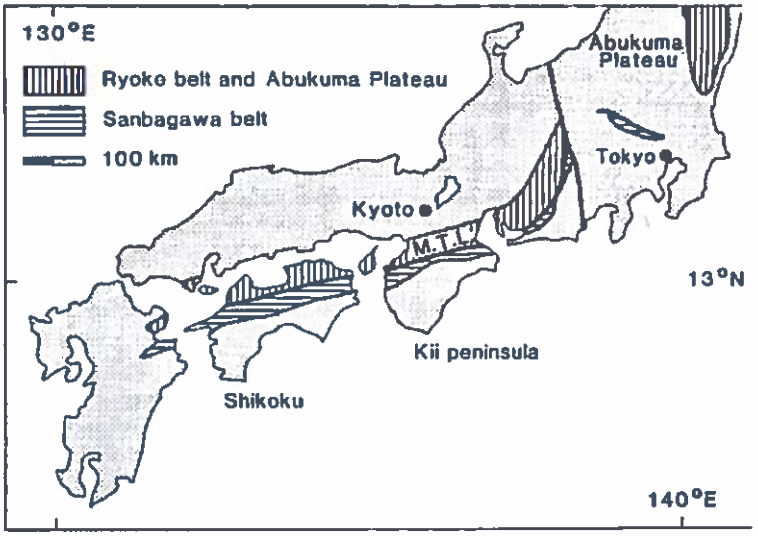

Fig. 7.1 Map of south-western Japan, showing Ryoke and Sanbagawa belts separated by the Median Tectonic Line (M.T.L.), and the Abukuma Plateau.

Both metamorphic belts were formed during the Jurassic to Cretaceous. The Sanbagawa belt has glaucophane and eclogite metamorphic zones. The Ryoke belt has biotite, andalusite and sillimanite metamorphic zones.

Draw a PT diagram showing the stability fields of the Al_2SiO_5 polymorphs minerals, the amphibole glauophane and the pyroxene omphacite and draw the metamorphic field gradients for the Ryoke and Sanbagawa belts.

c. In what tectonic environment were the Ryoke and Sanbagawa metamorphic belts formed?