BSc (IV) semester: Lecture Notes

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Contd....from previous Lecture notes

Concept of Index Minerals, Isograds and Metamorphic Facies

G. M. Barrow (1893, 1912), while studying in the Scottish Highlands, was the first to show that there could be a systematic variation in the mineralogy of metamorphic rocks, which is related to the changing metamorphic conditions (temperature in particular) to which the rock had been subjected to during metamorphism.

Barrow found that that the pelitic rocks (metamorphosed argillaceous sedimentary rocks, e.g., shale metamorphosed to slate to schist)) rich in Al-rich minerals like micas could be divided into a series of metamorphic zones, each characterised by appearance of a new metamorphic mineral with the increasing intensity of metamorphism (metamorphic grade). He also noticed that mineralogical changes were accompanied by coarsening of the grain size in the rock from fine grained slaty rocks to coarser grained schists; slates are least metamorphosed from original pelitic sediemnatry rock (low grade) and schists are more metamorphosed (higher grade).

Successive metamorphic zones in an area are characterised by appearance of new minerals, not encountered in lower grade rocks. The sequence of apperaence of minerals is as follows:

Chlorite zone: chlorite + muscovite + quartz + albite

Biotite zone: biotite+ chlorite + muscovite + quartz + albite

Garnet zone: garnet + biotite ± chlorite + muscovite + quartz + albite (and/or oligoclase)

Saurolite zone: staurolite + garnet + biotite + muscovite+ quartz+ albite (or other sodic plagioclase)

Kyanite zone: kyanite + quartz+ plagioclase+ muscovite+ garnet

Sillimanite zone: sillimanite + biotite + muscovite +quartz + plagioclase + garnet ± staurolite ± kyanite

This metamorphic zoning reported first from Scotish Highland is also known as Barrovian zoning, and has subsequently been reported from many parts of the world.

Please note that the minerals that characterize each zone (e.g., chlorite, biotite, garnet etc..) marked in yellow above are termed Index Minerals. However, each index mineral may persist to higher grades than the zone it characterises.

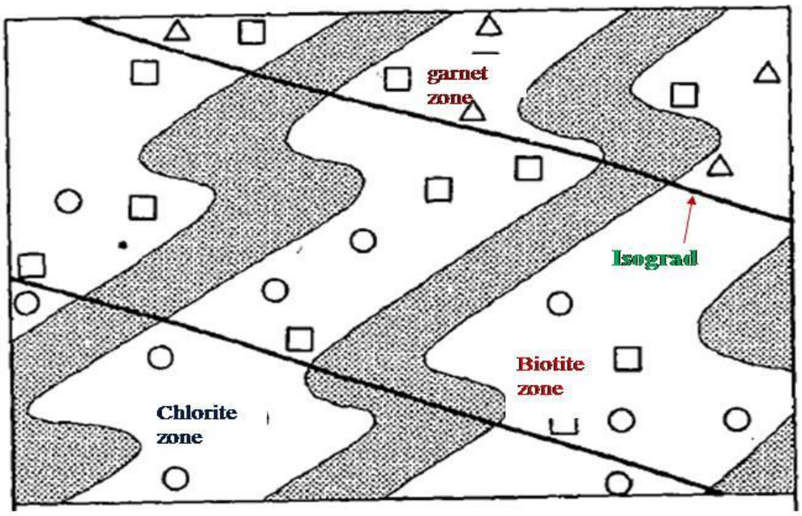

Fig. 3. Schematic diagram showing different metamorphic zone and isograd (modified after Yardley, 1990). Stippled areas represent non-pelitic lithologies.

By plotting the location of different index minerals (i.e. appearance of a particular index mineral) on a map (Fig. 3), lines can be drawn through the first appearance of each index mineral with increasing grade of metamorphism. Tiley termed the zone boundaries **isograds**

(Fig. 3), meaning lines of constant metamorphic grade. This pattern of progressive increase in metamorphic grade in an area is what is known as Progressive Metamorphism

Table 1: showing corresponding common metamorphic rock type that form from the original rocks (yaken from Yardley, 1990)

Original material	*Metamorphic rock type* (noun/adjective)*
Argillaceous or clay-rich sediment	Pelite/pelitic
Arenaceous or sandy sediment	Psammite/psammitic or quartzofeldspathic (if appropriate)
Clay–sand mixture	Semi-pelite
Quartz sand	Quartzite
Marl	Calc-silicate/calcareous
Limestone	Marble
Basalt	Metabasite/mafic
Ironstone	Meta-ironstone/ferruginous

Metamorphic Facies

The concept of metamorphic zoning and Index minerals hold good if bulk rock composition (i.e. whole rock composition) in an given area remains same. However, in most the cases, different rock types with varying bulk compositions do exist. Therefore metamorphic condition (P-T) is estimated by using mineral assemblage in the rock, instead of a single index mineral.

To overcome this difficulties, Eskola (1915) and subsequent studies devised a scheme of metamorphic facies, which defines broader Pressure-Temperature conditions rather than most specific zones in individual rock types. In metamorphic facies concept, it is postulated that once it is known that some metamorphic mineral assemblages were stable together at some pressure-temperature conditions (equilibrium assemblage), these mineral assemblages can be used to draw certain reasonable conclusions about pressure-temperature conditions that prevailed during metamorphism.

A metamorphic facies thus can be defined as a range of temperature-pressure conditions over which a particular common mineral assemblage or range of mineral assemblages are stable. Different metamorphic facies as suggested by Eskola as shown in a Pressure-Temeprature space in Fig. 4. However, Eskola recognized these facies principally on the basis of characteristic mineral assemblages in the mafic rocks. He also correctly deduced relative pressure-temperature condition represented by different facies on the fact that rocks formed at higher pressure likely to contain denser minerals than the rocks of same composition metamorphosed at lower pressure.

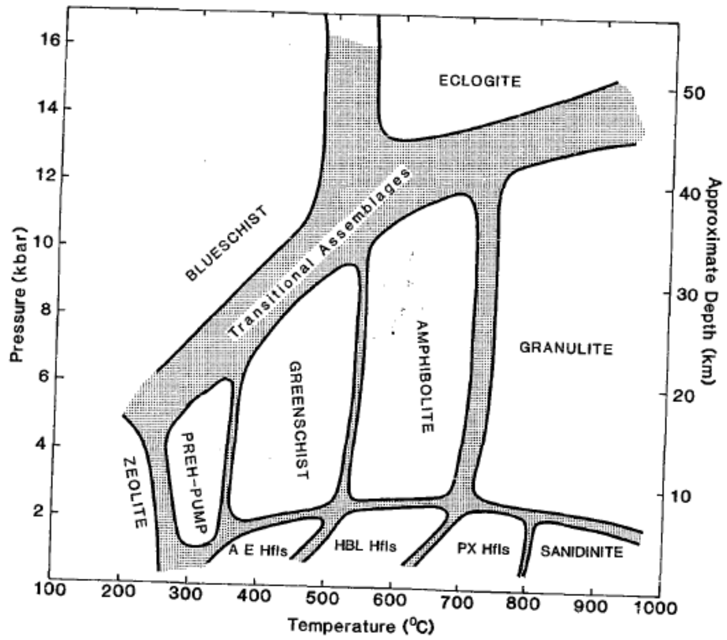

Fig. 4. Pressure-Temperature-depth diagram showing different metamorphic facies (taken from Yardley, 1990)

1. Facies of moderate pressure and moderate to high temperature: The greenschist, amphibolite, and granulite facies account for bulk of the metamorphic rocks. Granulite facies rocks form at a higher grade that that of both greenschist facies and amphibolites facies rocks.

2. Facies of low grades: two types- the zeoloite facies and the prehnite-pumpellite facies

3. Facies of contact metamorphism: at low pressure and high temperature of metamorphic aureoles (see also earlier lecture note), gradation between assemblages of the albite-epidite hornfels facies, hornblende hornfels facies and pyroxene hornfels facies may take place.

4. Facies of high pressure: The blueschist and the eclogite facies conditions. In blueschist facies metamorphosed mafic rocks characteristic ‘blue colour (more commonly lilac-grey in hand sample) imparts by presence of alkali amphibole glaucophane rather than more common green calcic amphiboles. The eclogite facies is characterized by the occurrence of Na-rich clinopyroxene (omphacite) instead of calcic clinopyroxene.

To be continued....