P-T Estimates of Pelitic schists and Gneisses around Mangpu, Darjeeling district, West Bengal, India

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Abstract
The Mangpu area represents a portion of the green-schist to upper amphibolite facies terrain of the lesser Himalaya. The metamorphic conditions estimated through the different models of geothermometry and geobarometry equilibria suggest pressures between 4.6-5.0 kbar and temperature ranges between 480°C-540 °C for Garnet-chlorite-white mica zone (zone B), 5.0-5.5 kbar pressure and temperature 550 – 600 °C for Staurolite-biotite-chlorite zone (zone C), 6.0-6.4 kbar pressure and temperature 660 -690 °C for Kyanite-biotite-staurolite zone (zone D) and 6.5-7.0 kbar pressure and temperature 690 -710 °C for Sillimanite-biotite-staurolite zone (zone E).

Keywords: Mangpu, Schists, Gneisses, Geothermobarometry, Lesser Himalaya

Introduction
The investigated area forms a part of the inner belt of the Lesser Himalaya and consists of various lithostratigraphic units of low to high metamorphic grade (Figure 1). Mangpu is situated 35 km away from Ghoom in the Darjeeling district of West Bengal. The main problems in lithostratigraphic classification of rock formations of the Darjeeling-Sikkim Himalaya is due to the inaccessibility of the terrain and general unfossiliferous nature of the rock types and their polyphase deformation. The geological set-up and stratigraphic position of the rock units of the Darjeeling-Sikkim Himalaya are debatable because of tectonic complexity, polyphase metamorphism and unfossiliferous nature of most of the lithounits.

Fig 1. Generalized tectonic division of Himalayas (modified after Prakash and Tewari, 2013). The location of Mangpu is indicated in the box.

The geological formations from south to north of the Darjeeling-Sikkim Himalaya are disposed in reverse tectonic order (i.e., the older rocks overlying the younger rocks and this is incidental). A dominant pervasive planer structure in the rock types dips to the north and the whole north-dipping pile of metasediments and metamorphites represents a Reversed Stratigraphic Sequence (RSS) younging up-dip towards south. Various workers (Ray, 1976; Acharyya and Ray, 1977) introduced classification of Daling Group and Darjeeling Group based on thrust tectonics. However, in the present classification, the Darjeeling Group comprises high grade schists and gneisses exposed typically in Darjeeling hills as well where the Daling Group comprises phyllites and low grade schists. According to...
the presence isograd and critical mineral assemblages the area has been divided into five metamorphic zones i.e. Zone A (chlorite-white mica- biotite zone); Zone B (Garnet-chlorite-white mica zone); Zone C (Staurolite-biotite-chlorite zone); Zone D (Kyanite-biotite- staurolite zone); Zone E (Sillimanite- biotite- staurolite zone). The main objective of this paper to extricate pressure temperature condition of different metamorphic zones during prograde regional metamorphism.

Field occurrences
The different rock types encountered at successive lower to higher structural levels are i. feldspathic chlorite-sericite phyllite with chlorite-sericite phyllite and gneisses (greywacke schist of Ray, 1947 and diaphoretic gneiss of Jangpangi, 1972). The gneisses correspond to the Litngse Gneiss of Acharyya (1975, 1978) which are considered to be an earlier intrusive into the Daling Formation according to him. ii. chlorite-sericite (±garnet) phyllite/schist with interbedded quartzite (golden and silvery mica schists of Ray, 1947), iii. mica schists (± kyanite ± staurolite ± garnet) and inter-bedded quartzite (ganetiferous mica schist of Ray, 1947), and iv. mica gneisses (± garnet ± staurolite ± sillimanite ± kyanite). Besides these, lenses of amphibolites, calc-schists and streaks of graphite schists are also found as concordant bodies within the first three rock types.

i. **Feldspathic chlorite-sericite phyllites:** Phyllites are medium to fine grained rock with distinct schistosity defined by the arrangement of biotite and muscovite flakes and characterized by the presence of feldspar quite often in the shape of small augens. At some places phyllites interlayered with quartzite.

ii. **Chlorite-sericite phyllite/schists (± garnet):** These are shiny, fine to medium grained rocks with well-developed thin foliation planes. In the northern part of the area the rock is schistose in character with dazzling silvery white or golden yellow surface. The chlorite schist is green in colour and is punctuated by the occurrence of quartz veins and lenses.

iii. **Mica schists (±kyanite ±staurolite ±garnet ±chlorite):** The Mica-schists are characterized by different types of folded structures (Figure 2a). These schists are stubbed by garnet, kyanite and staurolite. Garnet is most conspicuous mineral present in these schists, its diameter being upto more than 6 mm. and megascopically visible. This rock also bears signature of shearing. Kyanite, when megascopically recognisable, is present in the form of small blue blades more distinct in weathered schists. Staurolite has not been recognised megascopically.

iv. **Mica gneisses (±garnet ±staurolite ±sillimanite ±kyanite):** Highly sheared biotite rich Lingtse gneiss shows augen and subaugen structure. Darjeeling gneisses are characterised by coarse-gneissic texture and white-grey colour. Though in many cases it is sillimanite-bearing, the mineral is not seen in most hand specimens. Alternate leucocratic bands of quartz and feldspar and melanocratic bands of micas are conspicuous in the gneisses. Gneiss shows different types of folding. The second deformation (D2) associated with the Himalayan orogeny is responsible for the generation of appressed, isocinal, recumbent/reclined flattened flexure slip fold (F2) on all scales with occasional axial planar crenulation cleavages and pervasive schistosity. These folds apparently represent a stage of superimposed fields of strain during progressive deformation. Extreme cases of mobilization of gneisses result in the formation of locally granitized zones, leading to biotite granite gneisses. At some places the asymmetric (Z-shaped, S-shaped) folding (Figure 2b).

![Fig 2 a. Crenulated mica schist.](image1.png) ![Fig 2 b. Exposure of sillimanite gneiss with well developed gneissic banding forming asymmetric folding.](image2.png)

**P-T condition**
In the following account only a summary of the various equations used to derive the P-T conditions of metamorphism are given. The models of the mineral equilibria for the garnet-biotite thermometer and garnet-muscovite-biotite-plagioclase-quartz barometers are applicable to the rocks of the area.

**Garnet-Biotite Thermometer**
The models have been applied to schist and gneiss from the Zones B to E. Eight pairs has been chosen for garnet-biotite Fe-Mg thermometry. Temperature has been calculated for rim and core compositions. The core and rim temperatures obtained from the
The core and rim temperatures obtained from the garnet-staurolite-mica schist of Zone C are 572°C and 617°C (Thompson, 1976); 557°C and 596°C (Holdaway and Lee, 1977); 546°C and 603°C (Ferry and Spear, 1978); 581°C and 613°C (Lavrent’eva and Perchuk, 1981); 566°C and 613°C (Hodges and Spear, 1982); 628°C and 645°C (Picage and Greenwood, 1982); 566°C and 613°C (Perchuk and Lavrent’eva, 1983); 572°C and 587°C (Ganguly and Saxena, 1984); 587°C and 606°C (Perchuk et. al., 1985); 550°C and 558°C (Indares and Martingnole, 1985); 635°C and 658°C (Williams and Grambling, 1990); 516°C and 543°C (Dasgupta et. al., 1991); 530°C and 573°C (Bhattacharya et. al., 1992); 510°C and 544°C (Kenoko and Miyano, 2004). All the models were plotted in histogram shown in Figure 3. The core and rim temperatures obtained from the garnet-kyanite-mica schist of Zone D are 744°C and 754°C (Thompson, 1976); 620°C and 628°C (Goldman and Albee, 1977); 702°C and 711°C (Holdaway and Lee, 1977); 672°C and 687°C (Ferry and Spear, 1978); 699°C and 706°C (Lavrent’eva and Perchuk, 1981); 696°C and 711°C (Hodges and Spear, 1982); 644°C and 660°C (Picage and Greenwood, 1982); 680°C and 687°C (Perchuk and Lavrent’eva, 1983); 587°C and 694°C (Ganguly and Saxena, 1984); 712°C and 719°C (Perchuk et. al., 1985); 640°C and 651°C (Indares and Martingnole, 1985); 656°C and 674°C (Williams and Grambling, 1990); 659°C and 646°C (Dasgupta et. al., 1991); 609°C and 617°C (Bhattacharya et. al., 1992); 612°C and 634°C (Kenoko and Miyano, 2004). All the models were plotted in histogram shown in Figure 3. The core and rim temperatures obtained from the garnet-sillimanite gneiss of Zone E are 713°C and 754°C (Thompson, 1976); 596°C and 625°C (Goldman and Albee, 1977); 675°C and 709°C (Holdaway and Lee, 1977); 726°C and 783°C (Ferry and Spear, 1978); 677°C and 704°C (Lavrent’eva and Perchuk, 1981); 741°C and 816°C (Hodges and Spear, 1982); 804°C and 877°C (Picage and Greenwood, 1982); 655°C and 681°C (Perchuk and Lavrent’eva, 1983); 709°C and 746°C (Ganguly and Saxena, 1984); 682°C and 733°C (Perchuk et. al., 1985); 654°C and 660°C (Indares and Martingnole, 1985); 818°C and 895°C (Williams and Grambling, 1990); 654°C and 660°C (Dasgupta et. al., 1991); 634°C and 664°C (Bhattacharya et. al., 1992); 650°C and 667°C (Kenoko and Miyano, 2004). All the models were plotted in histogram shown Figure 3. An average core and rim temperature for all these models are 383±47°C and 421±43°C for Zone B; 558±43°C and 589±41°C for Zone C; 668±36°C and 677±37°C for Zone D; 675±64°C and 725±79°C for Zone E. The average temperature has been plotted against core and rim temperatures of different zones shown in Figure 5.

Fig 3. Coexisting Garnet-Biotite pairs and derived temperature for the Zone B, C, D and E

Garnet-plagioclase-biotite-muscovite-quartz barometer
The garnet-plagioclase-muscovite-biotite-quartz barometers were applied to schist and gneiss. The core and rim pressure for Zone B obtained from different models are 4.3 kbar and 5.1 kbar (Ghent and Stout, 1981); 3.3 kbar and 4.0 kbar (Hodges and Crowley, 1985);
3.9 kbar and 5.1 kbar (Hoisch, 1990). The core and rim pressure for Zone C obtained from different models are 5.7 kbar and 5.8 kbar (Ghent and Stout, 1981); 4.8 kbar and 5.6 kbar (Hodges and Crowley, 1985); 4.7 kbar and 5.5 kbar (Hoisch, 1990).

The core and rim pressure for Zone D obtained from different models are 6.4 kbar and 6.5 kbar; Hodges and Crowley (1985) 5.3 kbar and 5.6 kbar; Hoisch (1990) 5.9 kbar and 6.2 kbar. The core and rim pressure for Zone E obtained from different models are Ghent and Stout (1981) 7.0 kbar and 7.1 kbar; Hodges and Crowley (1985) 5.6 kbar and 6.0 kbar; Hoisch (1990) 6.3 kbar and 6.4 kbar. The average pressure for core and rim calculated through garnet-plagioclase-biotite-quartz barometers are 4.2±0.8 kbar and 4.9±0.6 kbar for Zone B; 5.0±0.5 kbar and 5.6±0.12 kbar for Zone C; 5.8±0.4 kbar and 6.0±0.45 kbar for Zone D; 6.5±0.8 kbar and 6.7±0.7 kbar for Zone E. The average pressure has been plotted against core and rim temperatures of different zones shown in Figure 5.

**Fig 4.** Coexisting Garnet-plagioclase-muscovite-biotite-quartz assemblage and derived pressure for the Zone B, C, D and E.

**Fig 5.** Average value of pressure and temperature has been plotted against different metamorphic zones.

**Conclusion**

Metamorphic conditions have been estimated through the use of conventional geothermobarometry suggest the following temperatures (± 50°C) and pressures (± 0.5 Kbar): > 480°C-540°C temperature and 4.5-5.0 kbar pressure for Zone B, 550 - 600°C temperature and 5.0-5.5 kbar pressure for Zone C, 660 -690°C temperature and 6.0-6.4 kbar pressure for Zone D and 690 -710°C temperature and 6.5-7.0 kbar pressure for Zone E.

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References