CHAPTER 8

SUMMARY AND CONCLUSIONS
The study is a multifaceted investigation on charnockites and associated rocks (especially the gneisses) of the MGB to bring out the different aspects of their petrogenesis. The thermobarometric study is extended to the adjacent ACS, to make a regional appraisal of PT evolution of the terrains. The occurrence of graphite in the MGB and its inscrutable relation with the rocks of the terrain also form a matter of analysis in this study. The role of CO₂ in the genetic history of the charnockites as well as the graphite mineralization is also taken into account by analyzing the fluid inclusions in graphite bearing charnockites. EPMA-based monazite dating technique has been employed to date some of the gneisses from the MGB.

The MGB, a high-grade granulite facies terrain is characterized mostly by charnockites and different gneisses. The MGB is subdivided into a western block in Kerala - MBK and an eastern block in Tamil Nadu-MBTN, the two having some lithological differences that are noticed in this study also. The MBK is characterized by foliated charnockites and hornblende-biotite gneisses and MBTN characterized by massive charnockites and enderbites. The other rock types present in the MGB are mafic granulites, calc-silicate series of rocks, quartzites, many types of gneiss like biotite gneiss, garnet-biotite gneiss, garnet cordierite-sillimanite gneiss, migmatitic gneiss etc. Many granitoid intrusives and mafic dykes are also present. The block has experienced three major structural evolutionary events as evidenced from the mesoscopic field structures. Detailed field relationships of the different rock types are made out from the fieldwork and are confirmed by petrographic studies. This includes a variety
of prograde and retrograde reactions reflecting the polymetamorphosed nature of the area.

Detailed interpretation of reaction textures, mineral chemistry and estimation of pressure – temperature conditions of selected samples from the MGB and the ACS were done. The samples include mafic granulite, charnockite, garnet-biotite gneiss and garnet-cordierite gneiss. While most of the rocks show retrogressive textures, the mafic granulites exhibit some prograde reaction textures leading to the formation of pyroxenes preserved in them. The gneisses from the ACS give some typical mineral assemblages representing fluid as well as melt involved reactions.

Mineral chemistry of the major minerals in comparison with the minerals from similar rock types of adjacent blocks was also done. Pressure-temperature estimates of these rocks have been calculated using different models. Garnet–biotite thermometers are mostly used to estimate the temperature of the terrain since these minerals are common in almost all samples studied. Garnets show slight increase of FM towards the rim while they are in contact with biotites. This Fe-Mg exchange reaction can be elucidated as the cause of decrease in temperature from core to rim of garnets.

Compared to the ACS, the MGB shows a lower but a more or less constant pressure (4-5 kb). The cordierite bearing assemblages recorded highest pressures (8.2kb), owing to their proximity to major shear. Rim to core variation of pressure is also noted in both groups of samples, but only at a minor level.
The reaction textures and mineral chemistry of the samples from the MGB and the ACS reveal that both the domains exhibit contrasting P-T paths. The MGB samples express evidences for isobaric cooling whereas the ACS has experienced an isothermal decompression path. Peak-metamorphic temperatures are 1167 °C for the MGB and 910 °C for the ACS.

The occurrence, genesis and mineralogical characterization of graphite from the study area were another part of investigation. An attempt has also been made to bring out the temperature conditions of graphite formation in the terrain. Using different techniques like XRD and Raman spectroscopy the crystallite size and degree of crystallization of graphites were calculated. From X-ray diffractograms, concentrating in the (002) peak reflection of graphites the 2θ, d values and full width of the peak at half-maximum are estimated and from which the metamorphic temperature was calculated. The crystallite size (Lc) along stacking direction is then calculated from Scherrer's equation. The Raman spectrum for a highly ordered, totally crystalline, pure carbon material that is properly called graphite gives a single first order Raman peak or ordered peak (O) at approximately 1580 cm⁻¹ and disordered peak or secondary peak (S) at about 2725 cm⁻¹. In the present samples it shows an ordered peak at 1584 cm⁻¹ and disordered peak at 2732 cm⁻¹.

The X-ray diffraction studies and the Raman spectroscopy suggest that the graphite occurring in the MGB is well ordered. The graphite crystallization is found to be an irreversible progressive reconstruction process even to the highest grades of metamorphism. The temperature of
formation of the graphite is found to be at $700 \pm 100^\circ C$. Preliminary carbon isotope results points to two different sources of carbon, i.e., the biogenic precursor and the carbonic fluid from the deeper crust for graphite mineralization in the MGB.

The fluid inclusion studies were pertained to a detailed investigation on the influence of $CO_2$ influx in charnockitization as well as the graphite mineralization. It also aimed to find the temperature of entrapment of the $CO_2$ inclusions in the graphite bearing rocks to reconfirm the temperature of graphite genesis.

Chronologically the fluid inclusions are found to be of three major generations. 1) Monophase carbonic inclusions with well-developed negative crystal shape seen isolated or in isolated groups in the samples. 2) Monophase carbonic inclusions of pseudosecondary type (occurring in arrays mostly along healed fractures). 3) Secondary type (occurring along fractures) biphase ($CO_2 + H_2O$) as well as polyphase ($CO_2$ liquid + $CO_2$ gas+ $H_2O$+ NaCl) inclusions that can be considered to be the last generation fluid inclusions. From microthermometric investigations it is found that the monophase $CO_2$ inclusions are considerably pure, sometimes with negligible amount of $CH_4$. The calculated density of the inclusions falls in a nominal range of 0.77-0.87 g/cc and show that the isochores does not satisfy the conditions of synmetamorphic entrapment. This type of situation is reported in many studies on $CO_2$ rich fluid inclusions in high-grade terrains with considerable explanations. Here, the decrease in fluid inclusion density is due to the precipitation of graphite and consequently the isochores extrapolated from the densities do not pass through the pressure
temperature conditions at which the inclusion was trapped with pressure underestimates up to 2kb (Cesare, 1995). The interpretation of the evolution of the pseudosecondary inclusions described in this study pertains to the oxidation of graphite, from biotite bearing rocks during high temperature metamorphism. In the present study, even though the mineral equilibria gives a peak metamorphic temperature around 800°C the most visible inclusions shows much lower temperature pointing a condition of re-equilibration of the inclusions which in turn makes the density changes of the fluid within the inclusions due to leaking or the change in volume of the inclusions. The re-equilibration effect in the inclusions is confirmed from its peculiar morphology.

The presence of some melt-inclusions noticed in the samples points to the role of certain magmatic activity in the evolution of the host rock. From the fluid inclusion petrography it is evident that the melt inclusions are pre-genetic to the fluid inclusions. The very low densities (0.58 -0.75 g/cc) of the CO$_2$ present in the youngest generation of biphase/polyphase inclusion identified in the samples indicate a low temperature origin. The presence of saline brine within these inclusions and its high salinity indicates retrograde dehydration reactions. The coexistence of CO$_2$ inclusions and NaCl-CaCl$_2$-H$_2$O high salinity inclusions also indicates that the graphites present in the samples have reacted to the formation of those low-density carbonic inclusions.

Thus the fluid inclusion studies reveal the presence of three sets of fluid inclusions representing three important stages in the evolution of the terrain. The first generation is the monophase CO$_2$ inclusions.
Petrographically they are considered as primary fluid inclusions but they owe comparatively lower density than the synmetamorphic inclusions recorded elsewhere from the granulite-facies rocks from the SGT. So they do not represent a peak metamorphic entrapment. The decrease in the density is interpreted to be due to the graphite precipitation from the fluids. Pseudosecondary biphase/monophase inclusions formed by the re-equilibration or modification of the first generation fluids are considered to be the second generation. The youngest generation fluids are the secondary inclusions within which high saline brine is incorporated. This fluid is considered as the causative for the retrogression and the release of secondary CO₂ when interacted with graphite.

Monazite dating carried out on samples from seven different locations from the MGB gives an apparent heterogeneity in Th-U-Pb composition and the age distribution forms three different clusters. The results give three ages for the entire samples from which two of them can only be considered as well defined. That is at 469Ma (Ordovician) and 546Ma (Cambrian). The third cluster at 710Ma (Upper Proterozoic) is neglected since the data is scarce. The two ages around 500 ± 50 Ma corresponds with the Pan-African orogeny time. These ages confirms that a pronounced PanAfrican metamorphic event has occurred in the MGB as in many other parts of the SGT.