CHAPTER VI

CONCLUSIONS

In this Chapter, salient observations made in understanding the various tectonothermal events, including U-Pb in-situ monazite geochronology of Sargur schists and granulites exposed around Kollegal in southern part of Dharwar craton is presented.

The Archaean terrain in the Dharwar craton, South India is one of the few well exposed regional terrain in which one can trace the lithological sequences from the granite-greenstone belts in the north to granulite facies terrane in the south. The Dharwar craton is sub-divided into Western and Eastern Dharwar Craton (WDC and EDC), separated by a major Chitradurga Shear Zone (CSZ). The WDC consist mainly of Tonalite-Trondhjhemite-Granodiorite (TTG) suite of gneisses, termed as the Peninsular Gneiss which have been formed during a major orogeny around 3,000 m.y. ago, with earlier events around 3,300 to 3,400 m.y. Metasedimentary rocks consisting of quartzites, BIF, meta-pelites and carbonates are intruded by layered ultramafic-mafic igneous complexes belonging to Sargur Group well exposed in WDC. The protolith age of Sargur Group of rocks vary from 3,100 to 3,300 m.y. Both the gneissic complex and the Sargur Group of rocks are overlain with a profound unconformity by Dharwar supergroup. The Dharwar supergroup is composed of QPC (quartz-pebble-conglomerate) at the base, followed by quartzite-basalt-BIF; polymict conglomerate-wacke-pelite-quartzite-carbonate-manganese formation; pillowed basalt- chert-BIF formations. They have been variously deformed and metamorphosed to greenschist to amphibolite facies conditions. The age of the Dharwar supergroup is about 2,600 to 2,800 m.y. Isolated younger granites of 2,600 m.y. age termed as the Chitradurga granite intrude the schistose rocks as well as the Peninsular Gneiss.

The EDC, consist essentially of greenstone belts with pillowed basalts, BIF, pyroclastics and QPC associated with quartzites, marble, pelite and manganese formation. The greenstone belts in the EDC are well known for their gold occurrence with age of schist belts ranging from 2,600 to 2,700 m.y. There are no basement-cover
unconformities like in the WDC. The younger granitoids termed as Closepet granite have intruded into schist belt around 2,500 to 2,600 m.y.

**GRANULITES**

The Dharwar craton show a regional metamorphic overprint from greenschist facies in the north to granulite facies rocks, generally termed as charnockites in the south. The metamorphic isograde run from E-W, which is orthogonal to the general N-S regional structural fabric of the various schist belts in the craton. Development of a broad metamorphic zonation from amphibolite to granulite facies exist from north to south in the Dharwar craton. Along the transitions zone, near the OPX-in isograde, transformation of ortho-gneiss to incipient charnockite or arrested charnockite formation is recorded. South of the OPX-isograde, massive charnockitic granulites which have been variously designated as the Biligirirangan granulites (BRG) and Male Mahadeswara granulites (MMG). Granulites, generally termed as charnockites in the Dharwar craton represent an exhumed part of the deeply buried continental crust. Studies on granulites will gives light on lower crustal processes and their nature responsible for the growth and evolution of the continental crust.

**GEOLOGICAL SETTING**

**Sargur Schist Belt (SSB)**

Field and petrological studies of rocks exposed in the Sargur Schist Belt (SSB) around Sargur area show occurrence of fuchsite quartzite, para-gneisses (with kya+sill+corun) rare cordierite-sill+opx gneiss, garnet-biotite schists, marbles and calc-silicates, and cherts and BIF (Banded Iron Formation). These rocks represent a series of sedimentary rocks deposited in a shallow-water intra-crustal environment. The sediments were intruded by ultramafic-mafic complexes. The various metasediments were suffered two periods of deformation with the early tight fold overprinted by the late more open fold. Subsequently, the rocks were suffered high grade regional metamorphism. The various mineral assemblages developed in pelites, carbonates, mafic and basic granulites suggest indicate upper-amphibolite facies metamorphism. The last stage of igneous activity is represented by intrusion of pink granites and dolerite dykes. Minor effects of retrogression are also documented in meta gabbro.
The formation of garnet coronas in basic granulites in SSB is related to the following metamorphic reactions:

\[
\text{opx + plag} \rightarrow \text{grt}^2 + \text{qtz}
\]

\[
\text{opx + cpx \pm ilm \pm magt} \rightarrow \text{grt}^2 + \text{qtz}
\]

**Granulites**

The granulite facies rocks exposed around Biligirirangan and Male Mahadeswara hills in southern part of Dharwar craton is predominantly composed of massive to banded charnockitic granulites associated with numerous basic granulites. Apart from these various types of metasedimentary units like metapelites, quartzites, carbonates and banded iron formations occur. All these rock units show a regional N-S trending metamorphic fabric. The charnockites as well as the basic granulites of BRG/MMG show micro-textural features typical of granulite grade metamorphism. Medium to coarse grained charnockites, basic granulites and cordierite-bearing gneisses are the common rock types exposed in the M.M.Hills. These rocks are interbanded with iron formations, calc-silicates, quartzites and metabasic rocks. They show a regional foliation trending N-S with dips varying from 50-80° west. The strongly migmatised pelites show effect of partial melting with garnet development in the leucosome.

The granulites show at least three deformational events based on structural investigations. The charnockitic granulites of the BRG/MMG show evidence of ductile to ductile-brittle deformation. Retrograde metamorphic alteration is reported for basic granulites.

Garnet and cordierite in metapelites, normally contain inclusions of biotite, sillimanite and quartz and suggest the following prograde metamorphic reactions:

\[
\text{Bt+Sil+Qtz} \rightarrow \text{Crd+Kfs+V}
\]

\[
\text{Bt+Sil+Qtz} \rightarrow \text{Grt+Kfs+V}
\]

\[
\text{Bt (+Ti,F)+Sil+Qtz\pm plag} \rightarrow \text{Grt+Cord+Fe-Ti oxide\pm Kfs+V}
\]

The formation of garnet coronas in basic granulite is related to the following metamorphic reactions:
CONDITIONS OF METAMORPHISM AND P-T-t PATH

The P-T conditions of metamorphism are well constrained using different critical mineral assemblages like garnet-biotite; garnet-orthopyroxene-plagioclase; garnet-clinopyroxene-plagioclase; orthopyroxene-clinopyroxene; garnet-cordierite and hornblende - plagioclase and by applying various recent thermodynamic models available.

The geological, petrographic and micro-textural studies show that the various rock types in the study area have undergone a regional granulite facies metamorphism and suggest a distinct near Isothermal Decompression (ITD) path. From the P-T diagram it is inferred that the rocks in both SSB and BRG/MMG have undergone two similar tectono-thermal events viz., M I and M II. There is a considerable decrease in paleo-pressures during MII metamorphism (upto 3 kbar), indicating nearly Isothermal decompressional (ITD) path for both the tectonic blocks.

The stable mineral assemblage of orthopyroxene, clinopyroxene and plagioclase define the peak MII metamorphism in basic granulites. P-T conditions of M I metamorphism cannot be estimated due to lack of mineral assemblages related to early phase of metamorphism.

MII metamorphism in basic granulites is characterized by the stable mineral assemblages of garnet, orthopyroxene, clinopyroxene and plagioclase. The temperature of MII metamorphism is estimated from garnet-orthopyroxene, garnet-clinopyroxene and two-pyroxene pairs which yield 570°-720°C, 500-680°C and 690-890°C respectively for SSB. Whereas temperature estimates of 650-750°C, 600-700°C and 538-835°C respectively is estimated for the similar mineral assemblages from the BRG/MMG.

The retrograde cooling path of metamorphism is characterized by the extensive formation of coronitic garnet, developed between orthopyroxene/clinopyroxene and plagioclase is well preserved, particularly in basic granulites. The P-T condition estimated for the coronitic garnet assemblage is below the near-peak granulite facies.
metamorphic conditions. These assemblages give paleo-pressure data ranging from 5.2-5.9 kbar with a temperature range of 465-617°C for the SSB. The lower pressure estimates of 3-4.8 kbar and moderately higher temperatures of 520-660°C is estimated for the granulites from the BRG/MMG.

Both the SSB and BRG terrain exhibit similar P-T-t paths (clock-wise, ITD path) with prograde and retrograde reactions. This type of ITD P-T-t path is related to collision type of tectonic events in the area.

The summary of the metamorphic history of the study area is as follows;

<table>
<thead>
<tr>
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<th>Sargur Schist Belt (SSB)</th>
<th>Granulites(BRG/MMG)</th>
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<td>MI metamorphism</td>
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<td>3,100</td>
<td>2,900-3,100</td>
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<td>MII metamorphism</td>
<td>572-720</td>
<td>640-777</td>
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<td>T</td>
<td>7.5-8.5</td>
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<td>2,400</td>
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<tr>
<td>MIII metamorphism</td>
<td>465-620</td>
<td>550-674</td>
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<tr>
<td>T</td>
<td>5.2-5.9</td>
<td>3.5-4.8</td>
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The Granulites (BRG/MMG) show wide spread paleo-pressure data related to MII metamorphic event, ranging from 9.3 to 5.9 kbar with temperature of 640 to 777°C. In contrast, the paleo-pressure data for MII metamorphic event in SSB exhibit a narrow pressure ranging from 8.5 to 7.5 kbar and temperature of 572 to 720°C. During MIII metamorphic event, which is interpreted to be mainly related to uplift of the two crustal blocks, the paleo-pressure data in BRG/MMG is lower up to about 3.5 kbar when compared to relatively higher paleo-pressure of up to 5.2 kbar during MIII in SSB. This difference in paleo-pressure data between the two adjacent crustal blocks indicate the exposure of relatively deeply buried granulite facies rocks in the eastern part of the area to high crustal level when compared to the Sargur Schist Belt.

**GEOCHEMISTRY**

The present geochemical data for rocks from SSB and BRG/MMG show that the basic granulites from both the terrane exhibit tholeiitic to Fe-rich tholeiitic trend and sub alkaline nature in different discrimination diagrams. They fall in the calc-alkaline basalt field and are magnesian nature with low potassium. The charnockitic granulites (BRG/MMG) show igneous protolith characteristic and are trondhjemite in composition which are comparable with the Peninsular gneiss which form the basement for the Sargur Schist Belt.
The rocks do not show any komatiite geochemistry suggesting that they are mainly plutonic igneous bodies.

**MONAZITE GEOCHRONOLOGY**

The monazite U-Pb in-situ age dating indicates at least two periods of metamorphic events and deformation in the area. The present data indicate that the Sargur Schist Belts and Granulites (BRG/MMG) underwent at least one previously unrecognised amphibolite to granulite facies metamorphism around 3,100 m.y. Many early workers had suggested that the SSB had undergone an early episode of metamorphic event, before the regional 2,600 m.y. event in the Dharwar craton. The present study has brought into light the early episode of MI metamorphic event around 3,100 m.y in the Sargur Group of rocks. However, there is a lack of textural evidence for the development of penetrative fabrics during this earliest M1 metamorphism in the area probably due to dynamic recrystallization of minerals during MII metamorphism.

The second metamorphic event (MII), is associated with the regional granulite facies metamorphism about 2,500 m.y which took place in the southern part of Dharwar craton during Late-Archaean. Growth of monazite within the cordierite, K-feldspar and quartz matrix during the later phases of regional granulite facies dynamothermal event corresponds to the inferred M (II) events.

This study is the first of its kind to detect contrastingly older and younger ages from a single monazite grain from the southern part of the Dharwar craton.

**SALIENT OBSERVATIONS:**

The rocks types present in both the Sargur Schist Belt (SSB) and in the Biligirirangan and MM Hill granulites are similar with the exception of charnockites, suggesting lithological similarities between the two tectonically separated blocks in the area. The basic granulites as well as cordierite bearing gneisses show well preserved metamorphic mineral assemblages in both the areas. Based on micro-textural studies, porphyroblastic garnet with clinopyroxene plagioclase and cordierite with plagioclase represent mineral assemblages developed during MII metamorphic event in the area. The coronitic garnet preserved in basic granulites from
both the tectonic blocks with clinopyroxene and plagioclase represent mineral assemblages developed during MIII retrograde metamorphic event.

The Granulites (BRG/MMG) show wide spread paleo-pressure data related to MII metamorphic event, ranging from 9.3 to 5.9 kbar (crustal thickness of 32 to 20 km) with temperature of 640 to 777°C. In contrast, the paleo-pressure data for MII metamorphic event in SSB exhibit a narrow pressure ranging from 8.5 to 7.5 kbar (crustal thickness of 29 to 26 km) and temperature of 572 to 720°C. During MIII metamorphic event, which is interpreted to be mainly related to uplift of the two crustal blocks, the paleo-pressure in BRG/MMG is comparatively lower, up to about 3.5 kbar (about 12 km thick crust) when compared to relatively higher paleo-pressures of up to 5.2 kbar during MIII event in SSB. This difference in paleo-pressure data between the two adjacent crustal blocks indicate the exposure of relatively deeply buried granulite facies rocks in the eastern part of the area to higher crustal level when compared to the Sargur Schist Belt. The upliftment of the granulites has taken place mainly along the major N-S trending, steeply dipping (eastward dipping) Kollegal Shear Zone (KSZ), which is a major shear zones separating the Sargur Schist Belt and Granulites in the area. Structural analyses in the KSZ indicate a sinistral sense of displacement of the two tectonic blocks, indicating that the granulite terrane represent the uplifted blocks against the SSB.

U-Pb in-situ monazite age data reported for the first time in the present study suggest that the Sargur Schist Belts and Granulites (BRG/MMG) underwent at least one previously unrecognised amphibolite to granulite facies metamorphic event around 3,100 m.y. The second metamorphic event (MII), is associated with the regional granulite facies metamorphism about 2,500 m.y which took place in the southern part of Dharwar craton during Late-Archaean. Growth of monazite within the cordierite, K-feldspar and quartz matrix during the later phases of regional granulite facies dynamothermal event corresponds to the inferred M (II) events around 2,500 m.y.