CHAPTER - 5

CONCLUSION
**CONCLUSIONS**

The Kollegal Shear Zone is located in the Northern Granulite Terrain (NGT) and western part of the Biligirirangan hill ranges trending N 15°E about 65 Km length and 25 Km wide in range. The northern tip of the Kollegal Shear Zone is connected to the Major Chitradurga Mylonite Fault Zone and in the south dextrally controlled joining to the Moyar Shear Zone in Southern Granulite Terrain (SGT).

Majority of the major shear zones are running EW direction in the Southern India where as this Kollegal Shear Zone is running NS direction and connected to Dharwar Craton (Fig 5.1).

This shear zone mainly composed of gneissic exposures with granulites, within this gneissic terrain migmatisation, retrogression and prograde type of processes are well noticed. The main rock types are gneisses, pink gneisses, Migmatitic gneiss, biotite gneiss, banded gneisses, Charnockites, dolerites, pegmatites, gabbros, amphibolites, fuchsite quartzites, carbonates, Ultramafic rocks, pelites and auriferous quartz veins are presented in the study area.

Amphibolite facies gneissic rocks are predominantly exposed towards western part of the study area. Within the gneissic terrane parallel to the regional foliation, the amphibolites occur as enclaves vary in size, gneisses are medium to coarse grained bearing rocks feldspatic amphibolites and exhibit banding with leucocratic. These coarse grained gray granodioritic granitoid gneisses are the most abundant lithology in the North South and East West of Kollegal Shear Zone. Where they show relict
Fig. 5.1. Simplified and improved geological map of southern granulite terrain (after Drury and Holt, 1980, GSI, 1989, 1995, Chetty et al., 2003) showing the study corridor and Kollegal Shear Zone (KSZ) major shear zones connecting the major Cauvery Shear Zone (CSZ) include: Moyar (Mo), Bhavani (Bh), Salem-Attur (S-A), Palghat-Cauvery (P-Ca referred to as the Chennimalai-Noyil shear zone, CNSZ in this study). Mettur (MSZ) and Kodaikanal - Oddanchattram - Karur (KOKSZ), WDC and EDC: Western and eastern parts of the Dharwar craton: TZ transition zone.
magmatic fabric defined by alignment of feldspars, biotite and amphibole in low strain areas in the shear zone.

Field Relations

Field relations are characterised by the major and minor structural data like Amphibolite facies gneisses trending N 15 to N 20°E and dipping 65 to 75°W. In the western part of the study area, fissile and migmatized highly deformed gneisses migmatitic gneisses and younger granitoids are the predominant rock types are noticed in the middle part of the shear zone. This zone is having charnockite-gneiss mixed zone of all the three types like massive charnockites, retrogressed charnockites with many enclaves of other granulites and later dolerite dykes, and intrusions of fracture filling younger auriferous quartz veins. Here the late dolerite dykes are across all the lithologies in the study area.

Structural Interpritations

The Kollegal Shear Zone rocks have undergone multiple deformational processes, like pervasive planar structures is represented by general foliation, and the regional foliation is markedly uniform trending NNE-SSW direction with moderate to steep dip on either sides of the exposures. The foliation shows swerves to close to the fold closure and warpings are observed in the area.

Migmatitic gneisses comprise several facies that include tonalite, granodiorite, granite and pegmatite that cut across all the facies. Coarse grained grey granodioritic migmatised gneisses are the most abundant lithology in the South East and South West of Kollegal Shear Zone.
Basic granulites show relict gabbroic texture, porphyroblastic garnet is noticed in few gabbroic rocks. Hornblendites another variant of the gabbroic rocks occur in minor amounts, they exhibit granoblastic texture, medium to coarse grained olivine bearing hornblende pyroxenites occur as enclaves within the Kollegal Shear Zone. Dolerites have emplaced subsequent to high grade metamorphism as they show no signs of deformation and metamorphism.

Stratigraphically the rock types of Kollegal Shear Zone have been classified and arranged below.

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<th>Late Proterozoic</th>
<th>Early Proterozoic</th>
<th>Late Archaean</th>
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<td></td>
<td></td>
<td>Kollegal sheared gneisses</td>
<td>Charnockites</td>
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<td></td>
<td>Auriferous quartz veins</td>
<td>Mylonites</td>
<td>Meta pyroxenites</td>
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<td></td>
<td>Pegmatites</td>
<td>Epidote hornblende gneisses</td>
<td>Basic granulites</td>
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<td>Incipient charnockitization</td>
<td>Pink migmatitic gneisses</td>
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<td>Granites and granitoids</td>
<td>Quartzofeldspathic gneisses</td>
<td>Granulites</td>
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<td>Amphibolite Facies Gneisses</td>
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<th>Archean (basement)</th>
<th>Peninsular gneiss</th>
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The regional foliation surfaces is mostly parallel to the lithological contacts suggesting isoclinal nature of folds. There are mainly 3 types of folds have been recognized in the study area F₁-tight to isoclinal, recumbent to reclined with axial trace in NNE-SSW, axis plunge low towards SSE associated with regional metamorphism of granulite facies with respect to the M₁ and deformation type 1 is D₁. F₂ - open fold NE-SW axial trace, low southerly plunging with respect to the D₂-deformation 2 with respect to the metamorphism 2, M₂. F₃ - open fold WNW – ESE axial traces in the field respect to the D₃ and metamorphism 3, M₃ is retrogressed shear controlled once in the area.

The last structurally controlled metamorphic stage is M₄ at this stage tectonically there is a over lap of the granulite terrain on Dharwar Craton (Fig.5.2) at that stage crustal collision and emplacement of younger Pan African type of migmatitic granitoids with enormous leucosomes have been formed, these later leucosomes are undisturbed by the metamorphism of 3 type in the study area. At this stage their was an new orthopyroxene grow and a patchy undisturbed charnockites are very well noticed in the migmatitic leucosomed granitoid portions of the eastern part of the Kollegal Shear Zone all along the foot hills of the Biligirirangan hill ranges in parts of Kollegal to Talavadi area.

The mean peak metamorphism (M₁) temperatures and pressures obtained based on the chemistry of the co-existing mineral assemblages in gneisses in the Kollegal Shear Zone yield a mean temperature of 750 to 860°C and pressures of 4 to 6 K bars for the older gneisses. The paleo – pressures data indicate depth of burial of these rocks of about 26 kms during gneissic facies earlier metamorphism around 3.32
by ago (Archaean basement). After this their was a second type of metamorphism i.e. M2 temperature and pressure estimates and fluid activity in the Kollegal Shear Zone gives evidences that the high grade granulites of the area have been formed under a temperature about 850 to 950°C and pressure about 7.5 to 8.5 Kb and with high density fluid activity is involved in this stage with absence of water and saline inclusions in this stage (late Archaean). The third type of metamorphic event in the area i.e. M3, after and at the time of retrogression which was controlled by shearing of the rocks in the terrain bleaching activity of the massive charnockite giving rise to retrograde gneisses includes the CO₂+H₂O+NaCl inclusions in the metamorphism 3 stage (Early Proterozoic), (Fig. 5.3). Finally in the Kollegal Shear Zone after metamorphic stage of Amphibolite facies gneiss with medium to moderately low temperature and pressure there is a transition zone has been developed by neotectonic collision of Dharwar Craton and Granulite terrain (Fig. 5.2). This transition zone was identified has Kollegal Shear Zone and the last stage of metamorphism called M₄, metamorphic stage 4, at that time the younger rocks of Pan African type have been formed (Proterozoic).

Fluid Inclusion studies in the gneisses of the Kollegal Shear Zone indicate the presence of high density CO₂ rich fluids in minerals like garnet (1.01 gm/cc) and quartz (1.00 to 1.04 gm/cc). Textures and chronology of fluid entrapment studies points to syn-metamorphic nature of these carbonic inclusions. Presence of few empty inclusions as well as necking features suggest intensity of deformation, the rocks have suffered. Based on the presence of high density CO₂ inclusions (1.09 g/cc) in quartz grains in the matrix combined with mineral P-T data a near initial isobaric cooling of
Fig. 5.2. Tectonically modified zone of Kollegal Shear Zone. (model concept, taken from Chetty et.al., 2003)

Fig. 5.3. Schematic representation of CO₂ activity and source of heat raisers for critical granulite metamorphism and anatexis metasomatism. (model taken from Janardhan et.al., 1982)
the gneiss have been recorded. This is in contrast to isothermal uplift observed in Kerala-Khondalite belt (Santosh 1988).

Major elemental data of the Kollegal Shear Zone of gneiss exhibit igneous parentage and are tonalitic to trondhjemetic in composition. This is in contrast to tonalitic to granodioritic composition of the Nilgiri granulites (Srikantappa et al., 1988). Major elemental data of gneiss, basic granulites and pyroxenites of the Kollegal Shear Zone indicate that they are not cogenetic are derived from different magmatic sources. Basic granulites of the Kollegal Shear Zone are iron rich tholeiitic to high alumina basalts and exhibit low K-tholeiite geochemistry.

CHARNOCKITES

Medium to coarse grained, dark greenish grey coloured massive to well banded Charnockites are the predominant rock types in the Kollegal Shear Zones. Non garnetiferous Charnockites are more common when compared to garnetiferous Charnockites of Nilgiris and Moyar Shear Zone in the southern part of shear zones of the study area. The general greasy appearance of Charnockite and their altered weathered brownish skin on exposure, hinders the study area of minor sinistral shears structures present in them. Charnockites shows the presence of lath shaped yellowish brown orthopyroxene crystals.

CHARNOCKITE-GNEISS MIXED ZONE

The Charnockite gneiss mixed zone traced between the banded Charnockite zone of the Kollegal Shear Zone and amphibolite facies gneiss towards western
margin is significant because of the occurrence of both incipient Charnockite locality as well as features of retrogression.

Incipient Charnockitization is seen along ductile shear planes which cross cut the earlier regional foliation in the area. This phenomenon is attributed to have taken place at a later stage during $M_2$ metamorphism in the area when compared to the main granulite facies metamorphism ($M_1$) during which banded Charnockites are produced. P-T conditions of incipient Charnockitization is difficult to as certain in the P-T space because of lack appropriate mineral assemblages. This process appears to have been taken place during upliftment of the terrane probably at pressures of 3.5 to 4 K bars in Kollegal Shear Zone as estimated from the very low density data of CO$_2$ inclusions (0.89 to 0.90 g/cm) in the incipient charnockites at temperatures around 500 to 700°C. Migmatization and recrystallization of matrix quartz grains appears to have taken place during this P-T conditions under CO$_2$ fluid regime. The process of retrogression noticed in the Charnockite gneiss mixed zone is a early to incipient charnockite formation phenomena related, mainly to brittle type of deformation in the area. Development of bleached zones is seen along these brittle shear planes. The mineral assemblages developed in the retrogressed zones indicate middle to lower amphibolite grade of metamorphi. High density CO$_2$ rich fluids show progressive decrease in density and in intensely sheared zone there is almost complete removal of CO$_2$ inclusions. There is addition of low (3 wt% Nacl equivalent) to high salinity (upto 35 wt%Nacl equivalent ) aqueous inclusions during shearing and retrogression. Thus the fluid regime changed from the early high density (1.07gm/cc) CO$_2$ rich to low density (0.98g/cc) CO$_2$ inclusions and aqueous inclusions during the process of
retrogression. Based on the mineral assemblages as well as fluid inclusion data, pressures of 4 K bars and temperature of 55°C is estimated for the process of retrogression.

The Proterozoic crustal shortening and crustal thickening of the two crustal blocks along the transition zone must have initiated the significant crustal uplift of around 2.5 km encompassing the Palghat gap (Fig. 5.2). The brittle crustal rocks along the axis of uplift got ruptured by tensile stress resulting from upwarping; and the ruptured rocks of comparatively soft hornblende and biotite gneisses were eroded away easily by fluviatile action (Radhakrishna, 1969). At the same time, it is but natural that the compressed continental crust 4 to 5 km thicker than that of the Dharwar Craton in the north (Srinagesh and Rai, 1996), would buckle and break up along the zone of the sudden change in crustal thickness. Beneath thick crust, gabbro-eclogite transition may further enhance the negative buoyancy within the lower crust, which may ultimately lead to delamination (Kay and Kay, 1993). After detachment, extensional crustal thinning controlling exhumation occurs leading to exposure by erosion of the rocks of the lower crustal levels. The rising hot asthenospheric material to fill the gap created by foundering of the lower crust may uplift and intrude deep into the upper crustal column (Pili et al., 1997). The crustal thickness of the Kollegal Shear Zone is to be compared and estimated to the adjacent gneisses and closepet granites about 26 km (Srinivasan 1985; Fig. 5.4).
The older tonalites represented by pebbles evolved in a thinner crust, while the majority of the members of the peninsular gneisses evolved when the crust had been thickened to more than 25 Km. Closepet granite was emplaced in a much more thickened crust.

1 = Bangalore gneiss 39.4 Km
2 = Closepet granite 65.9 Km
3 = Tarikere valley gneiss 39 Km
4 = Hassan gneiss 30 Km
5 = Kaldurga pebble granitoids 12 Km
6 = Biligirirangan granulite gneiss 26 Km
7 = Bababudan gneisses 20.5 Km
8 = Kollegal Shear Zone gneisses 25 Km
CONCLUDING REMARKS

Field and petrographic study of the rock types around Kollegal Shear Zones has shown that there is a broad lithological and structural continuity from Amphibolite facies gneiss to granulite facies rocks in the area.

High grade metamorphic rocks of Kollegal Shear Zone comprise older peninsular gneisses, chamockites, basic granulites and metapyroxenites, epidote hornblende biotite gneiss, quartz feldspathic to pink magmatitic gneisses and late granitoid leucosomes with incipient chamockite zones.

The chemical signatures of Kollegal Shear Zone granulitic rocks are in tonalitic to trondhimitic in composition showing magmatic origin and mineral chemistry suggests that the basic granulites are in metamorphic origin and chamockites of the area are in transition zone.

A set of remarkable dolerite dykes are traversed across all the lithounits in the study area. Later fracture filling quartz veins, some of them are auriferous, quartz veins are seen in the study area with high density of CO₂ fluids.

This Kollegal Shear Zone is deformed and disturbed by metamorphisms of mainly 4 type (M₁, M₂, M₃ & M₄, Fig. 4.18, Chapt. 4). The younger granitoids are formed at the time of M₄ by crustal collision Fig. With very low temperature and pressure i.e. 4 to 5 k.b. and 550 to 650°C with formation of pan African type of chamockitization is a significant investigation by the author in this study. A tectonic region of early collision followed by a late stage extensional tectonics is envisaged based on P-T-t path in the study area.
Reworking of early crust along shear zone, the migmatisation, magmatism and intrusion of younger rocks took place during the extensional tectonic regime, during Neo-Proterozoic to Pan African types., (M₄).

The earliest syn-metamorphic fluids are preserved in quartz and garnet and in matrix of plagioclase is granulites and gneisses of the Kollegal Shear Zone. The CO₂ monophase inclusion of high density appear to have been derived from mantle sources. Occurrence of high-density CO₂ inclusions indicates extensive magmatic underplating below the crust.

Fluid inclusions suggest that most of the CO₂ inclusions to be post-peak metamorphic with reference to M₂ and their CO₂ density data pass mineral P-T box for M₂ indicating fluids are synmetamorphic with earlier lower density of M₁, P-T box of gneisses with lower density of hydrous inclusions.

Fluids in retrogression represents M₃ and finally very low density fluids fall on M₄ i.e. Pan African type.