International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org

Geochemistry of Amphibolite – Granulite facies gneisses of Sakaleshpur-Somvarpet Area, Western Dharwar Craton

Jayaram G.N[1]., Anantha Murthy K.S[1]., Lingadevaru .M[2]and Govindaraju[1]
[1]Dept. of Applied Geology, Kuvempu University, Jnanasahyadri, Shankaraghatta - 577 451, Shimoga District, Karnataka
[2]Dept. of Geology, School of Earth Sciences, Central University of Karnataka, Gulbarga-585 106, Karnataka
Email: jayaramhonnavar@gmail.com; ks.amurthy@yahoo.com; ml_devaru@yahoo.com; drgov@yahoo.com

ABSTRACT

The Sakaleshpur-Somvarpet area, which falls on 'Former's orthopyroxene isograde line, forms a western part of the Amphibolite – Granulite facies transition zone of Southern Dharwar Craton and represents the northern tip of Mercara granulites. All the litho units, except mafic dykes, show a prominent NW-SE fabrics, which appear to have been produced during late Archaean shear deformation. The incipient charnockite, which, occur as greasy brown patches along the shear planes of gneisses, over prints the gneissic fabric, both along and across. On Harker's variation diagrams, the gneisses and incipient charnockite define igneous exhibit calc-alkaline fractionation trend. In contrast to the gneisses, incipient charnockites are depleted in LIL elements, the characteristic feature of granulite facies rocks. Depletion of LIL elements like Rb, Cs, Th, Ba and U in incipient charnockite suggests the passage of a fluid phase which extracted these elements. High K/Rb (2-2.5) and low Rb/Sr (0.01-0.09) ratios from gneisses to incipient charnockite follows distinct depleted granulite trend (DGT). Both gneisses and incipient charnockite display slightly variable and fractionated REE patterns. Among the REE, HREE like; La, Pr and Ce are slightly depleted in incipient charnockite. However, overall concentrations of the other REE are similar in both gneisses and incipient charnockite. Fractionated REE patterns suggest the magmatic history of gneisses and incipient charnockite, similar to the classical Archaean tonalitic to trondjhemitic suites.

Keywords:
Gneiss; incipient Charnockites; Sakaleshpur,-Somvarpet; Western Dharwar craton

Introduction:

Regional metamorphic gradation from amphibolite to granulite terrains exist in many parts of the world. Southern Peninsular India exposes one of the largest granulite terrains of the world, wherein, continuous unbroken amphibolite to granulite facies transition zone exists. The report of incipient charnockite formation, which grades on to a massive charnockite upland belt further south at Kabbal in southern part of Dharwar Craton, Karnataka, by Pichamuthu (1960), has opened up new vistas and kindled new interest in the study of charnockites in Southern Peninsular India. Bhattacharya and Sen (2000) have opined that the study of Kabbal type charnockites provides an important constrains on the mechanisms of transformations. Several workers have suggested that the amphibole bearing gneisses with basic enclaves are transformed to charnockite by the breakdown of amphiboles to orthopyroxene at relatively low H_2O fugacites (Janardhan et.al, 1979, 1982, 1994, Friend 1981; Condie et al. 1982; Hansen et al 1984; Mahabaleswar et al.

1995; Raase et al, 1986; Srikantappa et al 1987 and Peucat et al. 1993,1989;). Many of these contributions mainly discuss physical conditions of metamorphism, element mobility during granulite metamorphism, role and source of fluids. Therefore, the granulite terrain has received much attention in recent years in view of the gneiss – charnockite relationship (Hansen et al 1987; Raase et al 1986; Bhattacharya and Sen, 2000; Rajesh and Santhose 2004; Sharma and Prakash 2007; Rajesh, 2012). Sakaleshpur-Somvarpet area forms a part of amphibolites to granulite facies transition zone in the western Dharwar Craton (Anatha Murthy et al, 2013: Jayaram Et al, 2012, 2014). Although this area falls in the Fermers orthopyroxene isograde not much work has been done because of thick vegetation and paucity of outcrops. Few quarries opened up very recently provided ample opportunity to study gneiss – charnockite relationships in this area. This paper presents data on the petrology and geochemistry of amphibolite facies gneiss and incipient charnockites of Somvarpet and Sakaleshpur area. and this has bearing on understanding the process of charnockitization.

Geology of the area

The Sakaleshpur – Somvarpet area which forms a part of Amphibolite – granulite facies transition zone of western Dharwar Craton is located between $75^0 45^' - 75^0 55^'$ longitude and $12^0 35^' - 12^0 56^'$ latitude. The area forms a part of the Western Ghats and is characterised by undulated and rugged terrain covered with thick vegetation. Consequently, the out crops for observation and sampling are limited to quarries and road cuttings. The major lithologies of the area include amphibolite facies gneisses with patches of incipient charnockites, Metabasics (pyroxene granulites & amphibolites) and mafic dykes (Fig.1).

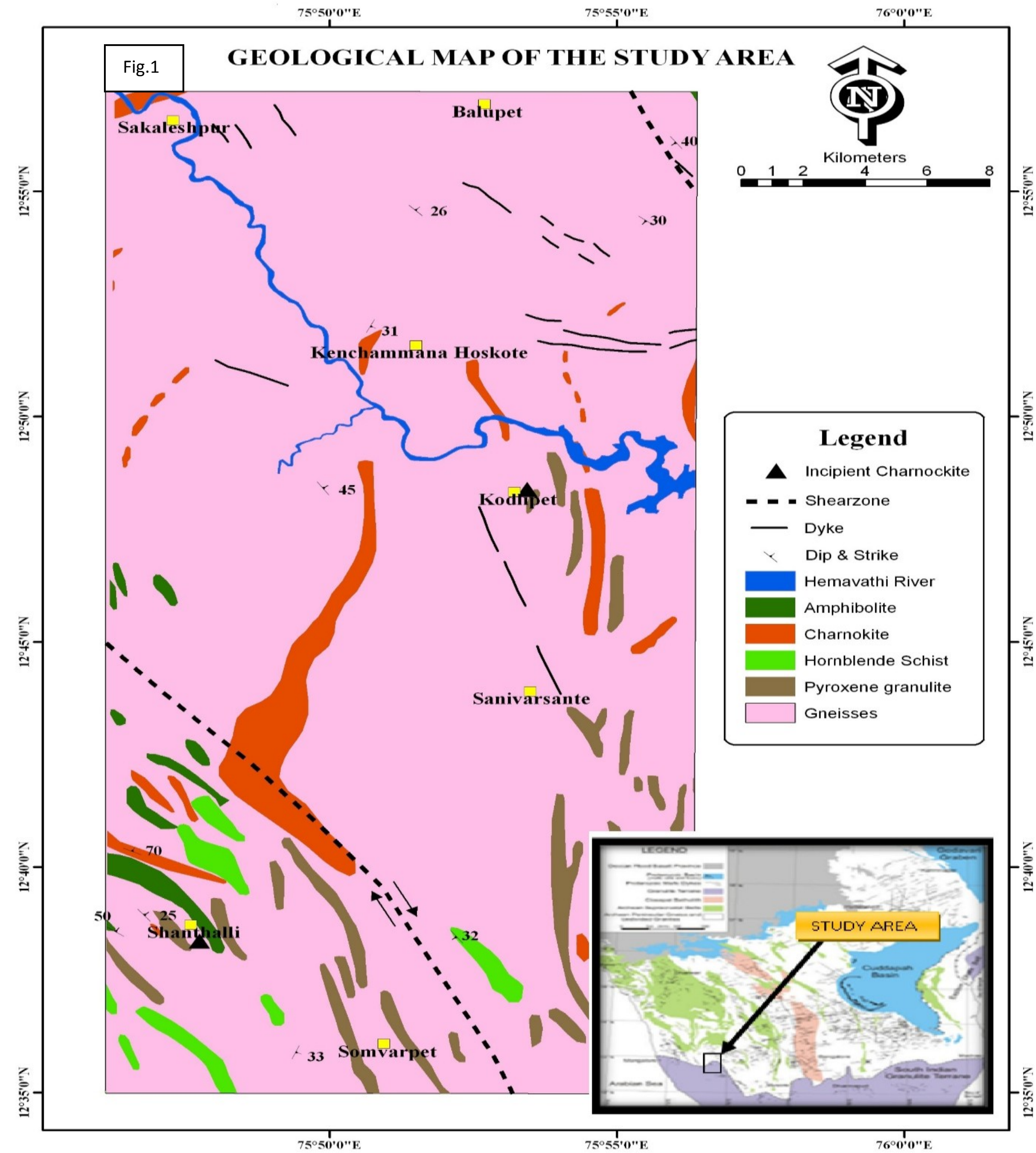
The gneisses are the most dominant litho units of the area, however, it well exposed in Kodlipet and Shanthalli and Jakkanahalli quarries for observations. The gneisses are grey to pink in colour, medium to coarse grained and exhibit typical gneissic fabric and migmatised to varying degrees and often over printed by greasy brown patches incipient charnockite along and across the gneissic fabric (Plate.1).

The incipient charnockite occurs as discrete patches within the gneisses. These patches generally vary in size from 2 to 5cm (Plate.2 & 3). It is distinctly coarse grained xenoblastic nature. The gneissic foliation quite often is bent or swerved at the borders of the charnockite patches (Plate.1). The close observation reveals the development of orthopyroxene along conjugate shears, trending $N30^0W$ to $N15^0E$ along and across the foliation very well observed in Kodlipet, Shanthalli, Jakkanahalli quarries.

Metabasics represented by pyroxene granulites and amphibolites occur predominantly in the southern part study area. They occur as large continuous bands within the gneisses, and some of the bands are traceable for more than a kilometre along the strike. Metabasics are coarse to medium grained and exhibit granulitic to schistose texture.

Petrography

Gneisses: gneisses exhibit typical gneissose texture (Plate - 4) and often banding with alternate layers of felsic bands consists of quartz and feldspars and mafic layers with biotite and/or hornblende. Mineralogically, it consists of quartz + K-feldspar + Plagioclase + Biotite $\pm$ hornblende $\pm$ garnet in the order abundance. K-feldspars represented by both microcline and orthoclase and are often show perthitic texture (Plate.5). Laths of plagioclase feldspar exhibits multiple twining and often exhibit antiperthetic texture, and bent lamellae is not uncommon. Both quartz and feldspars show marginal granulation. evidencing the rock has subjected to deformation.



International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org


Plate.1

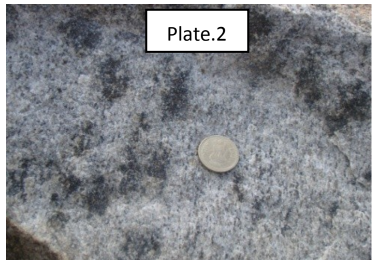


Plate.2


Plate.3

Plate 1&2 Field photograph showing development of Orthopyroxene along and across the foliation of gneiss at Jakkanhalli quarry, about 10 Km west of Somvarpet.

.

Plate. 3 Field photograph showing orthopyroxene developed in pegmatitics phase at across the gneissic foliation at Kodlipet quarry.

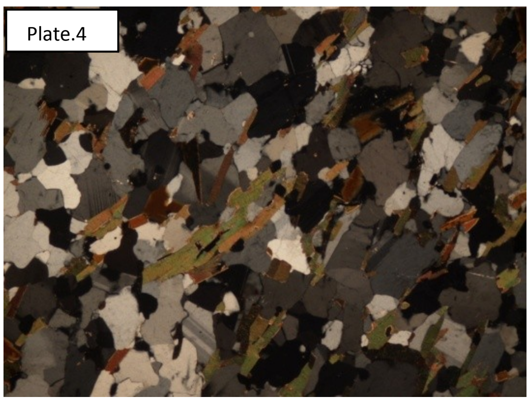


Plate.4

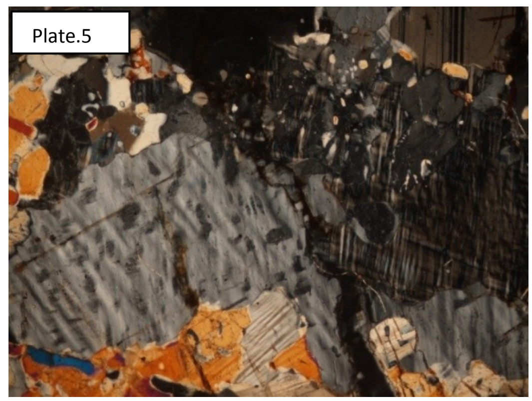


Plate.5

Plate - 4 Microphotograph of gneiss. Note the gneissose fabric. Plate - 5 Microphotograph of gneiss. Note the antiperthitic nature of plagioclase.

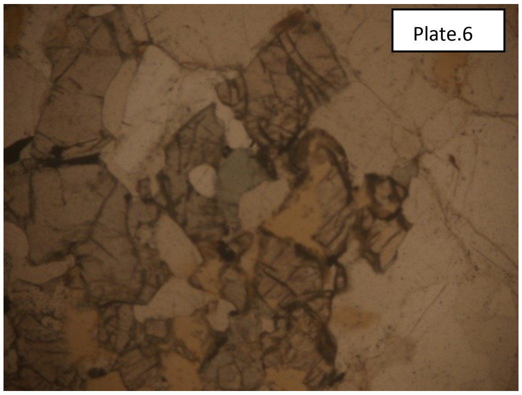
Incipient charnockite: The incipient charnockite is coarse grained and exhibits xenoblastic texture (Plate - 6). Mineralogically, the incipient charnockite comprises of; Quartz, Plagioclase and K-feldspars, Biotite, Hornblende and Hypersthene.

Plagioclase is the most abundant mineral of incipient charnockite and it occurs as stretched and deformed subhedral grains, and often shows antiperthetic texture. Euhedral to subhedral grains of K-feldspar

show cross hatched twinning. Unhedral grains of quartz with marginal granulation exhibits typical undulose extinction. Large plates of hypersthene show greenish brown to dark brown pleochroic colours and occur along the fractures and grain boundaries of biotite and/or hornblende (Plate - 7) which indicate, the large plates of hypersthene have formed by the following reaction as envisaged by Janardhan et al 1979; Friend 1981; Hansen et al 1984. Petrographic study reveals the development hypersthene along fracture and grain boundaries of biotite and/or hornblende

Biotite+Quartz$\pm$Hornblende $\longrightarrow$ Hypersthene + K-feldspar.

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org



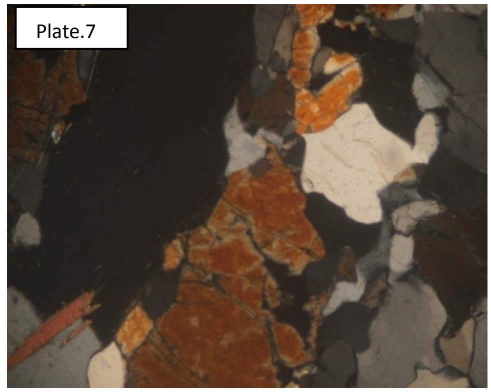


Plate.6 Microphotograph of incipient charnockite note the xenomorphic texture of incipient charnockite.
Plate.7 The formation of hypersthene by the breakdown of Biotite in presence of quartz at Kodlipet.

Geochemistry:

Major, Trace and REE geochemical data presented in Table 1 and CIPW norms in Table 2 represents three samples of gneisses and three samples of Incipient charnockite samples collected from quarries near Shanthalli, Kodlipete and Jakkanahalli. The samples were analyzed by using ICP-MS at activation laboratory Canada.

Table 1. Major oxides in %

Wt %		Shanthalli		Kodlipete		Jakkanhalli		Kabbaldurga		Archean peninsular Gneiss (Gorur)
		Gn-Ch		Gn-Ch		Gn-Ch				
ICP-MS accuracy and detection limit		J.11.19C	J.11.19B	J.11.11	J.11.10	J.11.41	J.11.40	Gneiss	Incipient charnockite	
SiO_2	0.1	71.47	71.05	66.79	68.2	70.52	72.02	68.4	71.4	76.31
TiO_2	0.1	0.395	0.37	0.756	0.57	0.483	0.281	0.62	0.49	0.59
Al_2O_3	0.1	15.93	15.26	15.73	13.69	14.68	15.43	13.6	13.7	12.10
Fe_2O_3	0.1	0.79	0.66	1.39	2.05	0.72	0.70	3.98	3.13	3.23
FeO	0.1	1.99	1.75	3.54	5.49	1.89	1.75	2.5	1.6	
Mno	0.1	0.022	0.029	0.057	0.041	0.027	0.052	0.06	0.06	0.04
MgO	0.1	0.94	0.41	1.68	0.52	0.58	0.69	0.77	0.79	0.39
CaO	0.1	2.94	2.97	3.95	2.54	1.81	2.6	2.44	1.95	1.41
Na_2O	0.1	4.58	4.33	3.56	4.21	4	4.89	3.65	3.76	3.63
K_2O	0.1	1.42	2.02	1.86	1.19	3.78	1.88	3.31	3.67	1.02
P_2O_5	0.1	0.04	0.09	0.38	0.09	0.16	0.09	0.17	0.12	0.02
LOI		0.4	0.23	0.57	0.4	0.79	0.29			
Total		100.9	99.18	100.3	98.99	99.45	100.7			
Trace Elements in PPM										

Rb	2	34	18	73	20	74	28	56.6	44	45
Sr	2	466	399	987	440	397	462	401.8	234.5	73
Ba	3	232	454	617	213	837	415	419.8	312.5	71
Zn	30	60	< 30	90	130	50	50	67.4	62.7	112
Zr	4	169	145	227	222	323	149	326.1	271.9	235
Hf	0.1	4.4	3.3	5.3	5.5	6.9	3.5	7.6	6.5	6
Nb	1	12	4	11	4	8	14	7.5	21.5	16.5
Y	2	13	4	24	15	14	9	86.6	26.5	83
Th	0.1	23.3	20.3	32	28.6	27.4	7.7	11.1	6.1	3.8
U	0.1	1.3	0.2	3.1	0.9	1.1	0.7	0.9	1.3	3.4
Cu	10	20	<10	70	<10	20	10	14.5	31.8	
Pb	5	15	8	13	12	19	14			
Ga	1	19	15	19	23	17	17			20.5
Sc	1	04	02	08	03	03	04			8.5
V	5	42	53	91	93	32	28	50.3	109.1	7
Co	1	24	32	26	35	31	26	35.7	71.8	49
Gd	1	5.9	01	7.7	7.6	5.6	2.2	9.5	8.7	
Ta	0.1	0.5	0.5	1	0.5	0.8	0.8	0.1	0.7	1
W	10	225	337	218	340	316	263			
Ni	2	5.6	5.01	6.2	4.5	7.2	6.9	9.5	8.7	4.5
Cr	2	4.2	4.0	2.8	2.6	5.0	4.9	6.4	5.8	18.5
REE in PPM										
La	0.1	62.2	18.2	90.2	111	101	37.5	61.8	44.3	23.3
Ce	0.1	130	28	174	213	183	72.9	132.4	81.5	52.5
Pr	0.1	13.4	2.59	18.8	21.9	17.7	6.3	16.8	8.7	5.9
Nd	0.1	47.5	8.9	69.9	76.9	58	21.3	62.8	30.1	27.5
Sm	0.1	8.2	1.3	11.5	1.2	8.1	2.9	13.9	5.5	8.15
Eu	0.1	1.51	1.14	2.77	1.64	1.33	1.04	1.6	1.2	3.65
Gd	0.1	5.9	01	7.7	7.6	5.6	2.2	14.4	5.7	8.3
Tb	0.1	0.7	0.1	1	0.8	0.6	0.3	2.3	0.8	1.3
Dy	0.1	3	0.7	4.7	3.7	3.1	1.5	24.7	7.5	8.05

International Journal of Research
International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org

Ho	0.1	0.5	0.1	0.9	0.6	0.5	0.3	3.2	1	
Er	0.1	1.1	0.3	2.3	1.4	1.3	0.9			2.35
Tm	0.1	0.13	<0.05	0.33	0.14	0.16	0.13			0.65
Yb	0.1	0.7	0.3	2	0.7	0.9	0.8	8.1	2	2.8
Lu	0.1	0.11	0.05	0.3	0.09	0.12	0.14	12.4	4	0.75

Table 2. CIPW NORMS

	Gn-Ch		Gn-Ch		Gn-Ch	
Minerals	J.11.19C	J.11.19B	J.11.11	J.11.10	J.11.41	J.11.40
Quartz	30.62	30.35	26.95	29.67	27.38	28.89
Orthoclase	8.39	11.94	10.99	7.03	22.34	11.11
Albite	38.75	36.64	30.12	35.62	33.85	41.38
Anorthite	14.52	14.37	17.55	12.2	8.23	12.54
Diopside	0	0	0	0	0	0
Hypersthene	3.99	8.39	7.13	8.73	3.57	8.82
Ilmenite	0.75	0.7	1.44	1.08	0.92	0.53
Apatite	0.09	0.21	0.9	0.21	0.38	0.21
Zircon	0.03	0.03	0.05	0.04	0.06	0.03

Gneisses:

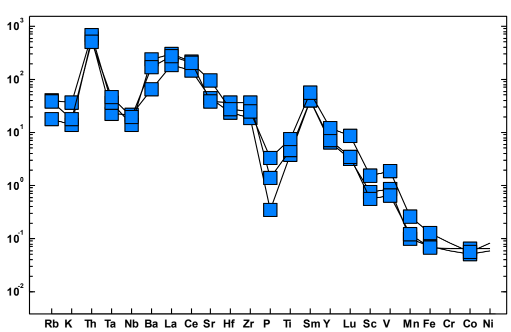
Geochemical data of gneisses of around Sakaleshpur-Somvarpet area presented in table.1 Gneisses indicates not much variable SiO_2 content 66.79 to 71.47%. On the Harker's variation diagram (Fig.2a-j) the plots of Al_2O_3, Fe_2O_3, MgO, CaO, TiO_2 and P_2O_5 exhibits negative correlation where as Na_2O and K_2O do not show any definite trend with SiO_2. When compare with Gorur gneiss (Bhaskar Rao et al., 1991) around Sakaleshpur-Somvarpet gneiss do not show much variation in bulk chemistry of major oxides, except slightly increased Al_2O_3, MgO and slightly decreased SiO_2 concentration. On A-F-M diagram (fig.3) gneisses of the present study show calc-alkaline trend and is substantiated on the Qtz-Ab-Or CIPW normative and K-Na-Ca daigram (Barker and Arth, 1976) follow trondjamitic trend (fig.4&5). Trondjemitic nature is further substantiated in the An-Ab-Or normative daigram (fig.6, after O'Conner,1965). The average Al_2O_3 content of gneisses is 15% and hence belong to high Al-TTG (Barker and Arth, 1976).

The trace element concentrations around Sakaleshpur-Somvarpet gneisses are slightly variable (Rb,Sr, Ba, Zr, Hf, Nb, Y, Th, U and Pb), the abundance of incompatible elements are presented in the daigram (fig.9, normalised after Wood et al.,1979). In this diagram gneiss show strong negative peaks at Ti-P-Sc. LIL element viz., Rb (34-74ppm), Sr (397-987ppm), Ba (232-837ppm), Th (23.3-32ppm) and U (1.1-3.1ppm) show moderate to high concentration, these unsystematic variation and enrichment could be due to their

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org

instability during granite melting or presence of monazite and when compared average value of LILE with Gorur gneiss Sr, Ba, Th and U are slightly higher concentration and almost similar to the Kabbaldurga and B.R.Hills (P.Allen et al. 1984 and K.C.Condie et al. 1984). The gneisses show very low content of Y and Ti compared to the average content for Archean grey gneisses (Condie, 1993; Martin, 1994). The HFS elements (Nb and Hf,) do not show much variation except Zr, which show large variation (169 to 323ppm). The transition elements such as Ni and Cr are slightly variable, and ranges from 5.6-7.2ppm and 2.8-5ppm respectively. However, the average composition of the HFS elements and transition elements are exhibits similar concentration except Cr, which shows lower concentration when compared to Gorur gneiss and Kabbaldurga (Bhaskar Rao et al., 1991, Battacharya et al., 1991). To evaluate the tectonic setting of gneiss the analysis are plotted on different discriminate diagram on variable K/Rb (100-500, Fig.7) and low Rb/Sr ratios (0.04-0.1, Fig.8). The Rb/Sr ratios are even higher than the upper mantle value (0.03; Sun. 1982).

The REE data around Sakaleshpur-Somvarpet gneiss presented in table 1. Chondrite normalised REE patterns of gneisses are displayed in fig. 10 and normalised values are after Masuade et al (1973). The REE plot shows slightly fractionated pattern with $(La/Yb)_{N.}$ The slightly fractionated REE pattern is mainly due to LREE enrichment rather than the HREE depletion. Gneisses of the study area are characterised by the LREE enriched and Low HREE pattern observed here are quite similar to the REE patterns of Gorur gneiss and Kabbal (Bhaskar Rao et al., 1991; Bhattacharya et al., 1991).



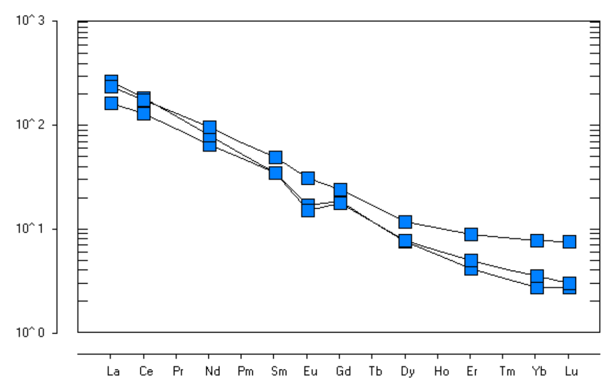


Fig.9. Normalized trace element abundance pattern of gneiss, Chondrite – Wood et al (1979b)
Fig.10. Normalized REE pattern of Gneiss, Cond-Masuda.et. al (1973)

Incipient Charnockite

Geochemical data of gneisses of around Sakaleshpur-Somvarpet area presented in table.1. The major oxides such as MgO, FeO, CaO, P_2O_5 and TiO_2 in incipient charnockite exhibit positive correlation with SiO_2 (Harker's variation diagram, Fig.2a-j), whereas, K_2O, Na_2O and Al_2O_3 do not define any definite trend. The range of K_2O (1.19 to 2.02%) content of

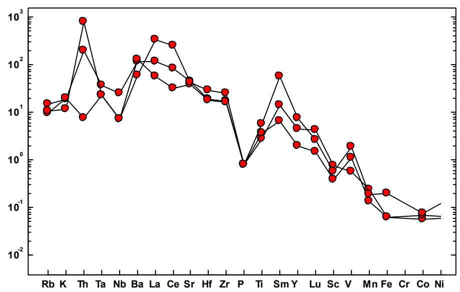
International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org

incipient charnockite is compared with the reported values of K_2O (0.5 to 1.5%) for incipient charnockite of B.R.Hills (Janardhan et al, 1982) and Kabbaldurga area (Stahle et al, 1987) shows higher concentration. On the AFM diagram (fig.3) the incipient charnockite of Sakaleshpur – Somvarpet area display well defined calc-alkaline trend. These calc-alkaline nature incipient charnockite substantiated on An-Ab-Or (Fig.6), Ab-Qtz-Or and Na-K-Ca (fig.4&5) CIPW normative trilinear diagrams the rock follows trondjametic trend.

The trace element concentrations around Sakaleshpur-Somvarpet incipient charnockite are exhibits slightly variable Rb (18-28ppm), Sr (399-462ppm), Zr (145-222ppm), Hf (3.3-5.5ppm), Nb (4-14ppm), Y (4-15ppm), Th (7.7-28.1ppm), U (0.2-0.9ppm) and Pb (8-14), the abundance of incompatible elements are presented in the daigram (fig.11, Condrite – Wood et al 1979b). These HFS elements and LILE concentration are depleted when compared with gneisses and average values are compared to the values reported for Kabbal charnockites (Janardhan et al., 1982; Stahle et al., 1987) shows slightly increased (Sr and Th) and decreased (Zr, Hf, Nb, Y, Rb and U). The transition elements such as Ni, Co, Zn and Cr among these, Ni and Cr elements are slightly variable, and ranges from 4.5-6.9ppm and 2.6-4.9ppm respectively and the remaining element such as Zn & Co doesn't show much variation from gneiss to incipient charnockite, except Jakkanhalli quarry Co concentration increases from gneiss to incipient charnockite (26-31ppm). However, the average composition of the transition elements are exhibits similar concentration except Cr, which shows lower concentration when compared to Kabbaldurga charnockite (Battacharya et al., 1991). To evaluate the tectonic setting of incipient charnockite the analysis are plotted on different discriminate diagram with variable K/Rb (800-1200, Fig.7) and low Rb/Sr ratios (0.03-0.04, Fig.8). The Rb/Sr ratios are even higher than the upper mantle value (0.03; Sun. 1982) and K/Rb ratios exhibit depletion towards granulite trend. This would be due to preferential depletion of Rb relative to K and Sr during granulite grade of metamorphism. The incompatible trace element abundance patterns (spider diagram fig.11) also indicate the depletion LILE and values of these elements are highly dependent on metamorphic grade (Wood et al, 1979). In spider diagram the incipient charnockites show prominent Nb-Ti anomalies P negative anomaly is also common and it could be due to apatite fractionation.

The REE data of Sakaleshpur-Somvarpet incipient charnockites presented in table 1. The normalized values are after Cond-Masuda.et. al (1973) (Fig.12). The REE plot shows slightly fractionated pattern with $(La/Yb)_N$ ratios. The La, Pr, Nd and Ce concentrations are slightly depleted in charnockites relative to gneisses except Kodlipete quarry, here these elemental concentration is increased. The slightly fractionated REE pattern is mainly due to LREE enrichment rather than the HREE depletion. The LREE enriched pattern observed here are quite similar to the REE patterns of Kabbaldurga charnockite (Bhattacharya et al., 1991; Friend and Numan, 1992).

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org



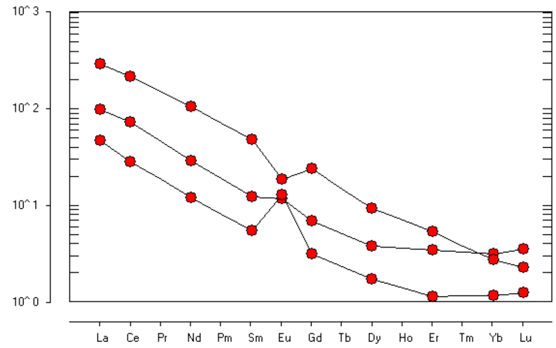


Fig.11 Normalized trace element abundance pattern of incipient charnockite, Condrite – Wood et al (1979b). Fig.12 Cond-Masuda.et. al (1973) normalized REE pattern of incipient charnockite.

Discussion and conclusion

The mechanisms of transformation from gneiss to charnockite in southern peninsular India has been demonstrated by Pichmuthu, 1960; Ramaingar et al, 1978; Janardhan et al, 1979, 1982; Srikantappa and Ravindra kumar, 1985; Friend 1981 and Raith et al 1983;Yoshida et al., 1991; Bhattacharya and Sen, 2000, Newton et., 2014. Field and petrographic relations of the rock types around Sakaleshpur-Somvarpet area suggest that the biotite and/or Hornblende bearing gneisses have been transformed to charnockite during granulite facies metamorphism. Textural evidence indicated that the formation of hypersthene by metamorphic reaction of biotite/Hornblende in the presence of quartz following the reaction (Winkler, 1976).

Biotite + Quartz $\pm$ Hornblende = Hypersthene + K-feldspar

Despite petrographic differences, the amphibolite facies gneisses and charnockite are broadly similar in terms of the major element chemistry. On Harker's diagram both gneiss and incipient charnockite define fractionation trend. Na_2O, K_2O and P_2O_5 slightly decrease in a linear fashion with increasing SiO_2 exhibiting, calc-alkaline fractionation and is substantiated on CIPW normative value exhibits trondjametic in nature. Low and relatively constant K_2O values appear on incipient charnockites to reflect K depletion by fluid phase during a granulite facies metamorphism.

The LIL elements concentrations in Sakaleshpur – Somvarpet in incipient charnockites are depleted when compared to the associated amphibolite facies gneisses and the data is comparable with the Kabbaldurga and other granulite terranes of South India (Limbert and Heier, 1968; Sighinolfi, 1971; Tarney and Windley, 1977; Newton et al, 1980). The depletion of LIL elements like Rb, Cs, Th, Ba and U from gneiss to charnockite has successfully been explained in terms of the passage of a fluid phase by Janardhan et al (1979 and 1982), Weaver and Tarney, (1981) and Condie et al (1982). However, these fluid inclusions are not totally devoid of water even in high pressure incipient charnockites (Allen et al 1984). Granulite facies rocks generally exhibit high K/Rb ratios (2-2.5) and follows distinct depleted granulite trend (DGT). Charnockites of the present study show high K/Rb ratios (fig.7) and low to very low Rb/Sr ratios (fig.8). Transition

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 3, March 2015
Available at http://internationaljournalofresearch.org

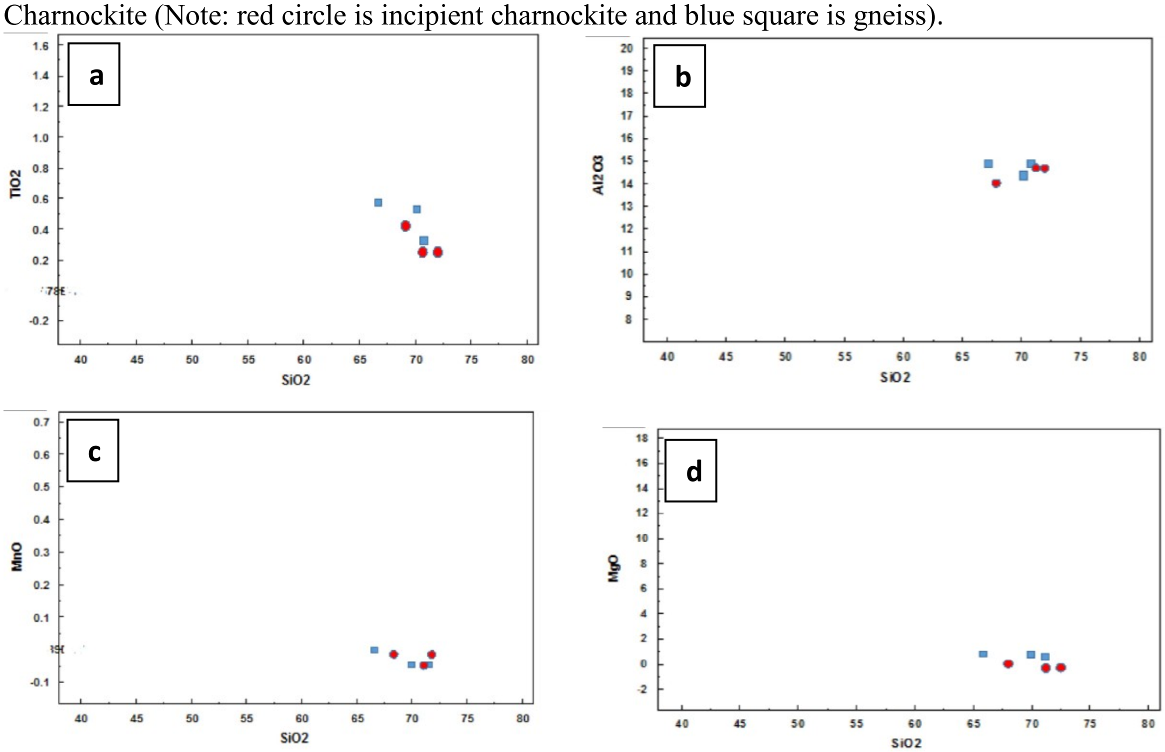
elements (Ni, Cr, Co, V and Sc) are similar in both gneiss and incipient charnockite. The high field strength (HFS) elements (Nb is 8-15ppm, Y is 13-30ppm, Zr is 323-94ppm, Hf is 4.4-2.2ppm and Ta is 0.5-1.4ppm) shows slightly variation from gneiss to charnockite, when compared to gneisses, the incipient charnockites show higher Nb and Y contents. This may be due to a prominent role of Amphibole and/or garnet fractination. The negative anomaly of P could be due to fractionation of Apatite.

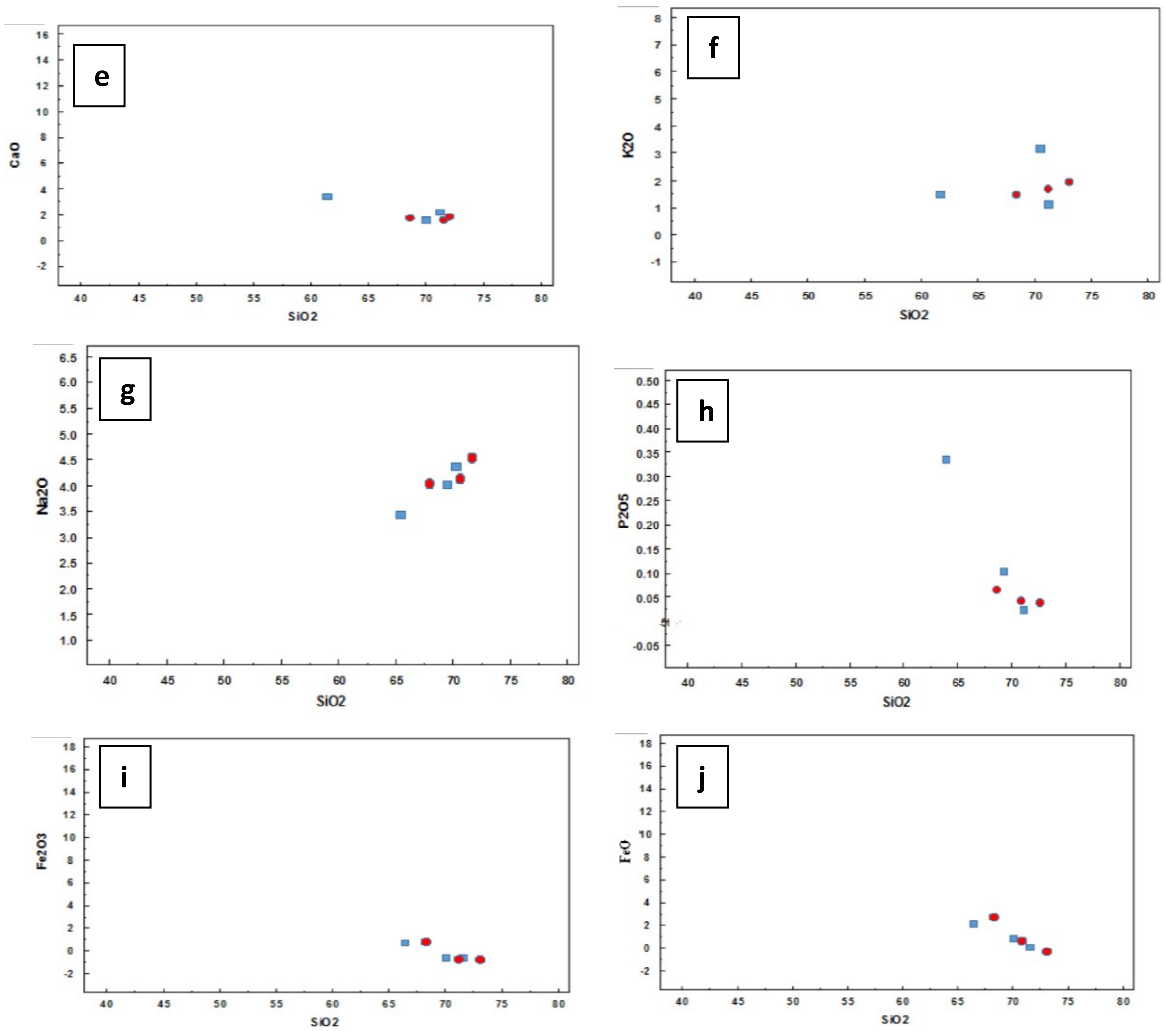
The La, Pr and Ce concentrations are slightly depleted in Sakaleshpur – Somvarpet charnockites relative to gneisses and the values of these elements can be comparable to Kabbal charnockites reported by (Friend and Numan, 1992). Both amphibolite facies gneiss and incipient charnockite display fractionated REE pattern. Strongly fractionated REE is due to enrichment of LREE. It is also observed progressive decrease of HREE and increase of LREE during CO_2- induced incipient charnockite formation (Basavarajappa, 1992). This implies that the observed REE pattern significantly remobilized during fluid phase metamorphism. Strongly fractionated REE patterns with HREE depletion suggest that magmatic history of the gneisses and incipient charnockites are similar to the classical Archean tonalitic to trondjametic suites.

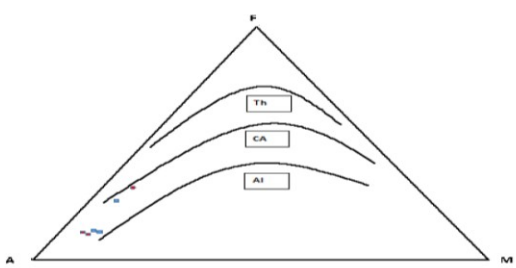
Acknowledgments:

We thank UGC, New Delhi for financial support uder UGC major research project (F.No. 37-257/2009 (SR). We express our sincere thanks to the Co-ordinator, UGC-SAP (DRS-II) and FIST programme and the Chairman, PG studies and Research, Dept. of Applied Geology, Kuvempu University for extending the laboratory facilities.

Fig.2(a-j) Harker's variation diagram of major element plotted against $SiO_2$for gneiss, Incipient Charnockite (Note: red circle is incipient charnockite and blue square is gneiss).







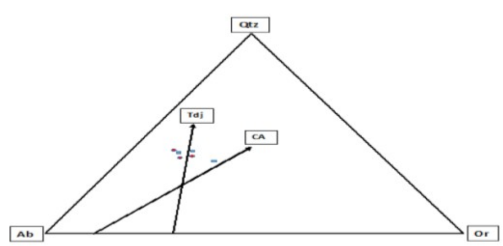
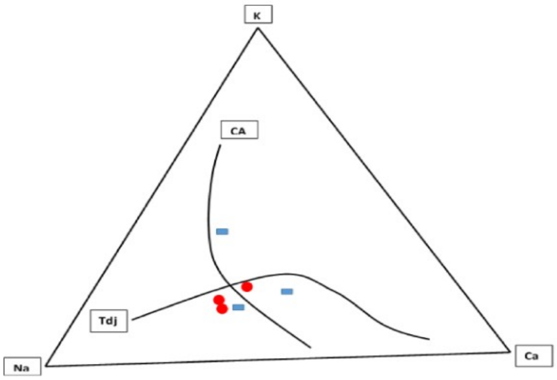


Fig.3 A-F-M diagram (Kuno. 1978) for gneisses, incipient charnockite. The plots fall in the Calc-alkaline field. **Fig.4** Qtz-Ab- Or normative daigram (Barker and Arth, 1976) for gneisses, Incipint charnockite. The plots fall in the fields of trondjamitic trend. (Note: red circle is incipient charnockite and blue square is gneiss).



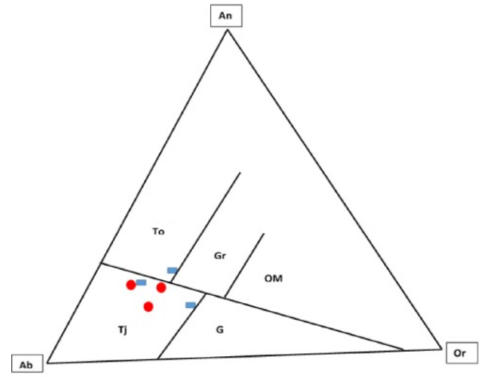
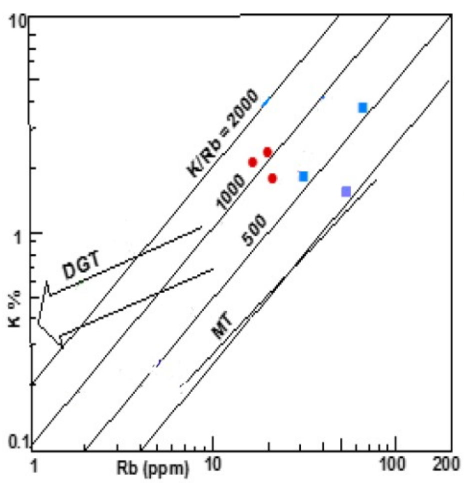


Fig.5 K-Na-Ca daigram (Barker and Arth, 1976) for gneisses, Incipint. The plots fall in the fields of trondjamitic trend. **Fig. 6** An-Ab-Or normative daigram (after O'Conner,1965) for gneisses, Incipint charnockite. The plots fall in the fields of tonalite and trondjamite. (Note: red circle is incipient charnockite and blue square is gneiss).



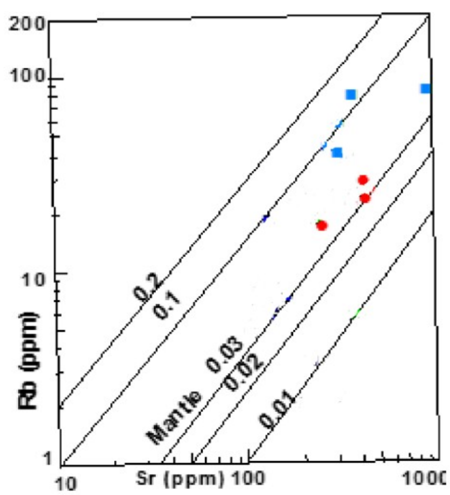


Fig.7 K-Rb distribution in gneisses, Incipint charnockite. MT(main trend for continrntal crust defines by Shaw, 1968). DGT (Depleted granulited trend). The mejority of samples plots follows in the fields of depleted granulite trend. **Fig.8** Rb-Sr distribution in gneisses, Incipint charnockite. The samples plots follows in the fields of mantle to lower crust trend. (Note: red circle is incipient charnockite and blue square is gneiss).

Reference:

[1.] Anatntha Murthy. K. S., Jayaram. G. N., Lingadevaru. M and Govindaraju (2013) Petrlogy and geochemistry of pyroxene granulite of Somvarpet, South Western Dharwar Craton, Karnataka, India. *Extended Abstract, Goldshmidt 2013 conference, Italy 25th- 30th August 2013, pp 590.*

[2.] Bhattacharya and sen.1986 . Granulit metamorphism, fluid buffering and dehydration melting in Madras charnockites and metapelites. *Jour. Petrol. 27:1119-1141.*

[3.] Bhattacharya. S and Sen. S. K (2000) New insights into the origin of Kabbaldurga charnockites, Karnataka, South India. *Gondwana Research, v. 3 (4), pp. 489-506.*

[4.] Barker and Arth, (1976). Generation of trondjamite-tonalite-liquids and archean bimodal trondjamite-basalt suits. *Geology, 4:219-240.*

[5.] Chetty. T.R.K. Mohanty. D. P and Yellappa. T (2012). Mapping of shear zones in the Western Ghats, Southwestern part of Dharwar craton. *Jour. Geol.Soc.India. 79:151-154*.

[6.] Condie et al (1982). Geochemistry of the low to high grade transition zone, Southern India. *Contrib Mineral Petrol 81; 157-167.*

[7.] Drury. (1973), The geochemistry of Precambrian granulite facies rocks from the Lewisian complex of Tiree, Inner Hebrides, Scotland. *Chem. Geol 11: 167-188*.

[8.] Friend (1981), Charnockite and granite formation and influx of CO_2 at Kabbaldurga; *Nature (London) 294, pp550-552.*

[9.] Harley.S.L, (1989). The origin of granulites: a metamorphic perspective. *Geol. Mag. 126: 215-247.*

[10.] Hansen et al (1984), Pressure, temperature and metamorphic fluids across an unbroken amphibolite facies transition in southern karnataka, India; (eds) Akroen, AM Goodwin and G N Hanson, *Arch. Geochem. (Berlin: Springer-Verlag) 161-181.*

[11.] Holt and Wightman (1983), The role of fluids in the development of granulite facies terrane of south India; *J.Geol.Soc. London, 140 651-656*.

[12.] Hansen et al (1986), Charnockites in the making in south India and sri lankha; *contrib. Mineral. Petro, v2, pp 258-281.*

[13.] Hansen et al (1987), Charnockite in the making in southern India and Sri Lankha. *Contrib Mineral Petrol 96; 225-244.*

[14.] Janardhan et al, (1979), Ancient crustal metamorphism at low PH2O. Charnockites formation at Kabbaldurga, South India; *Nature London, 278, 511-514*.

[15.] Janardhan et al. (1994). Formation and tectonic evolution of granulites from Biligirirangan and Niligiri Hills south India: Geochemical and isotopic constraints. *Jour. Geol. Soc.India. 44:27-40*.

[16.] Janardhan et al (1982), The transformation of amphibolite facies gneiss to charnockite in southern karnataka and northern Tamil Nadu, India. *Contri Mineral Petrol 79; 130-149.*

[17.] Jayaram. G. N., Lingadevaru. M., Anatntha Murthy. K. S and Govindaraju (2012) Petrology of Amphibolite to Granulite facies transition zone around Sakaleshpur - Somvarpet area, Western Dharwar craton. '*Frontiers of Earth Science Research' pp 30-34, Professional book Publisher, ISBN: 978-81-909728-40.*

[18.] Jayaram. G. N., Lingadevaru. M., Anatntha Murthy. K. S and Govindaraju (2014) geochemistry of pyroxene granulite around Somvarpet, South Western Dharwar Craton, Karnataka, India. *The Indian Mineralogist. V.48 (1), pp. 108-123.*

[19.] Newton et al (1981), Ancient granulite terrains – "eightkbar metamorphism". *Eos 62: 420*.

[20.] Newton et al, (1980). Carbonic metamorphism, granulites and crustal growth. *Nature, 288:45*.

[21.] P.Allen et al. (1984). Origin of Archean charnockites from Southern India. In A.Kroner, G.N.Hansen and A.M.Goodwin (Eds), Archean Geochemistry. *Springer verlag Berlin. 182-203*

[22.] Pride and Mc-(1980), REE element geochemistry of the Scourian complex NW Scotland – evidence for the granite link. *Contrib Mineral Petrol 73: 403-412.*

[23.] Peucat et al. (1989). Sr, Nd and Pb isotopic systematic in the Archean low to high grade transition zone of Southern India: sun-accretion Vs post accretion granulite. *Jour. Geol. 97:537-550.*

[24.] Peucat et al. (1993). Age of younger tonalitic magmatism and granulite metamorphism in the south Indian transition zone (Krishnagiri area): comparision with older

Peninsular gneiss from Hassan-Gorur area. *Jour. Meta. Geol. 11:879-888.*

[25.] Raase et al (1986), Progressive metamorphism of mafic rocks from greenschist to granulite facies in the Dharwar craton of South India. *J. Geol. 94: 261-282*.

[26.] Ramaingar et al (1978), Charnockite – gneiss complex relationship in Southern Karnataka; *Jour. Geol. Sic. India 19 411-419.*

[27.] Rajesh. H. M and Santose. M (2004), Charnockite magmatism in Southern India. *Jour. Earth planet. Sc. Vol-04, pp. 565-585.*

[28.] Rajesh. H. M (2012) A geochemical perspective on charnockites magmatism in Peninsular India. *Geoscience Frontiers. V. 3(6), pp. 773-788*.

[29.] Raith et al (1983), Regional geothermobarometry in the granulite facies terrain of South India; *Trans. R. Soc. Edinburgh (Earth. Sci.) 73 221- 244*.

[30.] Sharma and Prakash (2007). Reaction texture and P-T conditions of opx-crd gneisses from Karimnagar, Andhra pradesh, India. *Jour. Mineral and petrol, Vol.90, pp.175-195*.

[31.] Sighinolfi, 1971; Stahle et al (1987), Element mobility during incipient charnockite formation at kabbaldurga, Southern India. *J. Petrol., Vol. 28, pp. 803-834*.

[32.] Srikantappa,1992. Syn-metamorphic carbonic inclusions in the Satanuru-Halagur granulites, Karnataka, India. *Jour. Geol. Soc. India. 39:502-508.*

[33.] Stahle et al, (1987). Element mobility during granulite formation at Kabbaldurga, Southern India. *Jour. Petrol. 32:201-238*.

[34.] Srikantappa et al (1985), progressive charnockitization of a Leptynite - Kondalite suitein Southern kerala, India- evidence for formation of charnockite,througha dcrease in fluid pressure. *J. geol. Soc. Ind., Vol. 26, pp.849-872.*

[35.] Tarney and Windley (1977), Chemistry thermal gradient and evolution of the lower crust. *J. geol Soc Lond 134: 153-172.*

[36.] Devaraju.T.C and Sadashivaiah.M.S. (1969). The charnockites of Satanuru-Halgurarea, Mysore state. *Indian Mineralogist. 10:67-88*.

[37.] Yoshida. M, Santosh. M and Shirahata. H (1991) Geochemistry of gneiss-granulite transformation in the incipient charnockite zones of Southern India. *Mineralogy and Petrology, v. 45, pp 69-83.*