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Petrography and Mineral chemistry of Calc-silicate rocks from Bandihalli area, Tumkur District, Karnataka

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Abstract— In this paper an attempt has been made to present petrography and chemistry data for the principle minerals (Garnet, Clinopyroxene and Plagioclase) of the Calc-silicate rocks from Bandihalli area to understand the petrogenetic significance and to quantity the pressure-temperature conditions of metamorphism by using different garnet-pyroxene thermometers.

Keywords— Calc-silicate rocks, Petrography, Garnet-pyroxene thermometer, Bandihalli, Metamorphism.

I. INTRODUCTION

The Bandihalli area is located in Koratagere taluk of Tumkur district. It is named after a village, which is about 6 kms SSW of Huliyurdurga town. Bandihalli rock series occurs as a linear belt stretching between Bandihalli and Raghavana Hosur (Fig. 1). The main lithologies of the area are comprising of supracrustal rocks (metapelite, quartzite, calc-silicate rock and iron formations), amphibolite, actinolite schist, gneisses and dolerite dykes. Calc-silicate rocks occur as bouldary exposures and rarely as bands, are well exposed around Bandihalli village. Jayaram (1926) has named them as Bandites after the village Bandihalli. The calc-silicate rocks are mesocratic and green in colour (Fig. 2). One of the main features of these calc-silicate rocks is presence of green garnet. These rocks extend from Bairanayakanahalli upto Nidsale for about 10 kms in E-W direction. They are closely associated with amphibolites, actinolite schists and gneisses. While they have conformable relationship with actinolite schists and amphibolites, their relationship with gneisses on the other hand is not clear. However, they are traversed by quartzo-feldspathic veins which might have been related to adjoining Closepet granite. In this paper we were focussed mainly on petrographic and mineral chemistry studies of Calc-silicate rocks to estimate pressure-temperature conditions of metamorphism.

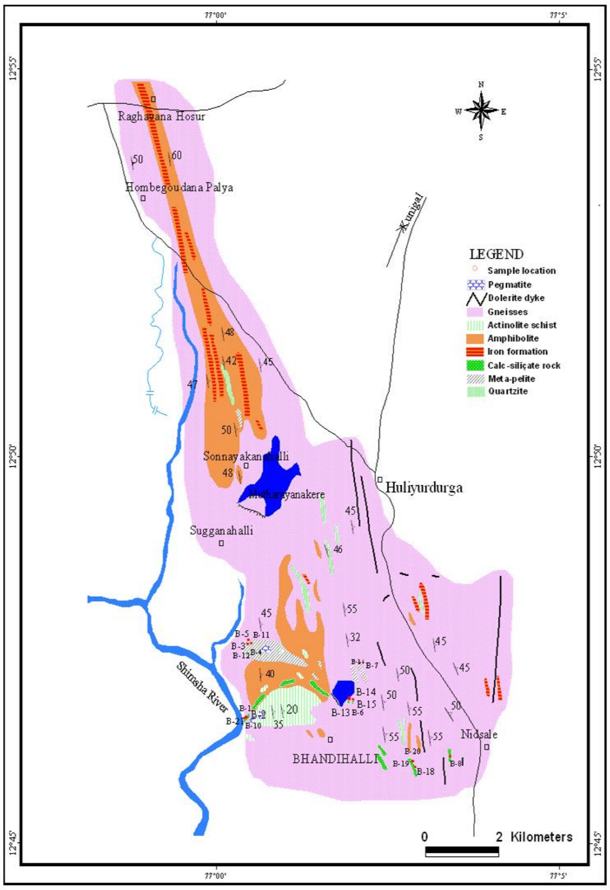

Fig. 1. Geological sketch map of Bandihalli area (modified after Mahabaleswar et al 1989).

Fig. 2. The mesoleucocratic and green coloured calc-silicate rocks showing foliation (about 0.5 'E' of Guddada Rangaswamy Temple).

II. PETROGRAPHY

We have studied nearly 10 samples of Calc-silicate rock and photomicrographs were taken by using Leica DMRXP petrological microscope at Geological Survey of India, Bangalore. The detailed petrographic descriptions were described below;
Based on mineral paragenesis two major groups of Calc-silicate rocks were recognized namely garnetiferous and non-garnetiferous which in turn can be further divided into the following subgroups.

Garnetiferous variety:

1. Garnet + clinopyroxene + clinozoisite + zoisite + plagioclase + calcite + quartz + scapolite + chondrodite.

In thin section the rock shows granulitic texture. Garnet is green in colour and occurs as porphyroblasts and is isotropic (Fig. 3). Clinopyroxenes occurs as anhedral grains, showing well developed pyroxenic cleavages and occurs as inclusions in clinozoisite. Plagioclase occurs as laths and is breaking down to zoisite and calcite. Scapolite occurs as columnar grains, with lot of inclusions. Chondrodite shows pleochroism from yellow to colourless. Sphene is wedge shaped showing honey yellow colour (Fig. 3). Quartz grains are highly crushed.

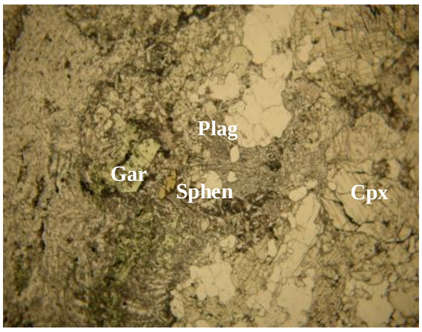

Fig. 3. Calc-silicate rock showing granulitic texture with green garnet pophyroblast and wedge shaped sphene.

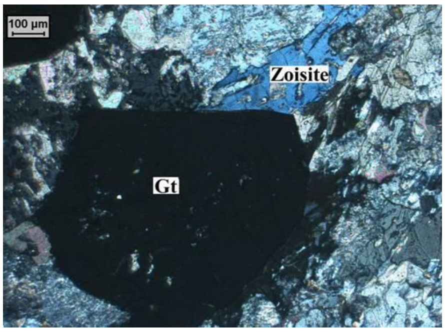

Fig. 4. Calc-silicate rock showing garnet porphyroblast and anhedral zoisite with blue interference color.

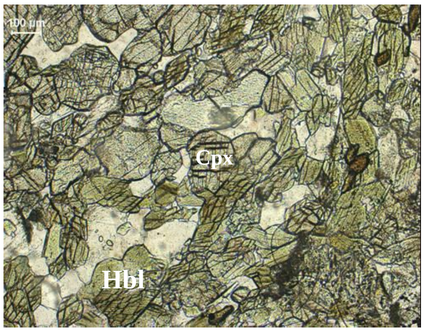

Fig. 5. Calc-silicate rock showing granoblastic texture with Cpx + hornblende grains.

2. Garnet + scapolite + clinozoisite + zoisite + hornblende + clinopyroxene + chondrodite + sphene + quartz.

In thin section the rock shows granulitic texture. Garnet occurs as porphyroblasts, showing green colour and is isotropic. Clinopyroxenes is present in very minor quantities and shows well developed pyroxenic cleavages and is colourless, shows inclined extinction. Clinozoisite occur as prismatic blades, colourless, has one set of cleavage and shows inclined extinction. Zoisite occurs as anhedral plates and show blue interference colour (Fig. 4) and has straight extinction. Hornblende occurs as prismatic crystals showing amphibolic cleavages. It is pleochroic from green to pale green. It is in minor quantities. Scapolite occurs as anhedral plates containing number of inclusions and show grey interference colour. Sphene is wedge shaped showing honey yellow colour.

Non-garnetiferous variety:

1. Cpx + hornblende + plagioclase + quartz + scapolite.

In thin section the rock shows granoblastic texture (Fig. 5). Cpx + hornblende + quartz + plagioclase and Scapolite occur as equilibrium assemblages, with lobate contacts and triple junctions. Scapolite is colourless and shows first order grey interference colour and is full of inclusions and is altering to calcite. Cpx occurs as anhedral grains, with green colour showing pyroxenic cleavages. Hornblende occurs as prismatic crystals showing amphibolic cleavages (Fig.5).

2. Cpx + chondrodite + scapolite + plagioclase + quartz.

The rock shows granoblastic texture and consists of Cpx + chondrodite + scapolite + plagioclase + quartz. All these minerals represent equilibrium assemblages. Cpx occurs as anhedral grains, with green colour. Chondrodite is colourless and occurs as subhedral grains. Scapolite is colourless and shows high order interference colour. Plagioclase occurs as laths and shows well developed twinning. Quartz occurs as anhedral grains.

III. MINERAL CHEMISTRY

Chemical compositions of the various minerals were determined by using a JEOL-JXA-8600 electron microprobe at Yamaguchi University, Japan and with a CAMECA SX-50 Electron Probe Microanalyzer (EPMA) at the Petrological Laboratory of Geological Survey of India, Kolkata. The chemical data of the principal minerals of the studied Calc-silicate rocks were presented in the following paragraph.

Green Garnet: The chemistry of green garnets is presented in Table I. The cations are calculated on the basis of 24 (O) atoms. These green garnets have high CaO and variable Cr_2O_3 to call it as true "Uvarovite". It can be thus termed as "Chrome grossular". This is conformity with the conclusions of the earlier workers (Somashekar and Naganna, 1966; Viswanathaiah et al 1979) with regard to the composition of these garnets. CaO content of the studied green garnets varies from 30.43-31.82 wt% and Cr_2O_3 content varies from 8.43-11.72 wt%. Apart from the high Cr_2O_3 content, these green garnets contain appreciable amount of MnO (3.51-4.43 wt %).

Table. I. Chemical analysis of Green Garnets.

Sample No.	B-1						
Oxides	1	2	3	15	18	19	20
SiO_2	37.19	37.19	36.88	37.22	37.76	37.10	37.97
TiO_2	0.30	0.25	0.27	0.21	0.28	0.25	0.26
Al_2O_3	12.43	11.31	12.29	13.11	13.69	12.75	14.17
Cr_2O_3	10.29	11.72	11.02	9.06	8.63	9.86	8.43
FeO	5.29	4.76	4.97	5.48	5.73	5.08	5.63
MnO	3.55	3.52	3.51	4.25	4.43	3.62	4.39
MgO	0.27	0.21	0.22	0.27	0.31	0.32	0.31
CaO	31.01	31.82	31.60	30.53	30.59	31.52	30.43
Na_2O	0.02	0.03	0.00	0.00	0.01	0.00	0.00
K2O	0.00	0.01	0.01	0.00	0.02	0.03	0.01
F	0.00	0.00	0.20	0.02	0.00	0.11	0.00
Total	100.36	100.83	100.97	100.14	101.45	100.64	101.60
Cation Numbers based on (O) 24							
Si	5.95	5.95	5.89	5.96	5.95	5.92	5.96
Ti	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Al	2.34	2.13	2.31	2.47	2.55	2.40	2.62
Cr	1.30	1.48	1.39	1.15	1.08	1.24	1.05
Fe	0.71	0.64	0.66	0.73	0.76	0.68	0.74
Mn	0.48	0.48	0.48	0.58	0.59	0.49	0.58
Mg	0.06	0.05	0.05	0.06	0.07	0.08	0.07
Ca	5.31	5.45	5.41	5.23	5.17	5.39	5.12
Na	0.01	0.01	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.01	0.00
F	0.00	0.00	0.10	0.01	0.00	0.06	0.00
Total	16.20	16.22	16.33	16.22	16.20	16.29	16.18
X_{Fe}	0.11	0.10	0.10	0.11	0.11	0.10	0.11
X_{Mn}	0.07	0.07	0.07	0.09	0.09	0.07	0.09
X_{Mg}	0.01	0.01	0.01	0.01	0.01	0.01	0.01
X_{Ca}	0.81	0.82	0.82	0.79	0.78	0.81	0.79

Clinopyroxene: The chemical analyses of clinopyroxenes are presented in Table II along with the structural formula based on 6 (O) atoms. The sum of cations is nearly equal to 4.00 indicating low Fe^{+3} in cpx. The chemistry of clinopyroxene corresponds to the composition of salite end member (see Fig. 6). CaO content varies from 25.77-26.22 wt%, MgO content varies from 12.00-13.02 wt% and FeO content varies from 7.07-7.74 wt%. These clinopyroxene also have some appreciable amount of Cr_2O_3.

Table. II. Chemical analysis of Cpx.

Sample No.	B-1			
Oxides	5	6	7	14
SiO_2	51.73	53.04	52.41	51.32
TiO_2	0.01	0.03	0.05	0.03
Al_2O_3	0.83	0.63	0.69	2.90
Cr_2O_3	0.65	0.35	0.39	0.79
FeO	7.54	7.56	7.74	7.07
MnO	0.98	1.04	1.05	1.00
MgO	12.68	13.02	12.69	12.00
CaO	25.77	26.22	26.18	25.98
Na_2O	0.26	0.14	0.32	0.25
K2O	0.00	0.00	0.04	0.00
Total	100.45	102.02	101.57	101.34
Cation Numbers based on (O) 6				
Si	1.94	1.96	1.95	1.91
Ti	0.00	0.00	0.00	0.00
Al	0.04	0.03	0.03	0.13

Cr	0.02	0.01	0.01	0.02
Fe	0.24	0.23	0.24	0.22
Mn	0.03	0.03	0.03	0.03
Mg	0.71	0.72	0.70	0.66
Ca	1.04	1.04	1.04	1.03
Na	0.02	0.01	0.02	0.02
K	0.00	0.00	0.00	0.00
Total	4.04	4.03	4.04	4.03
X_{Mg}	0.75	0.75	0.75	0.75
X_{Fe}	0.25	0.25	0.25	0.25

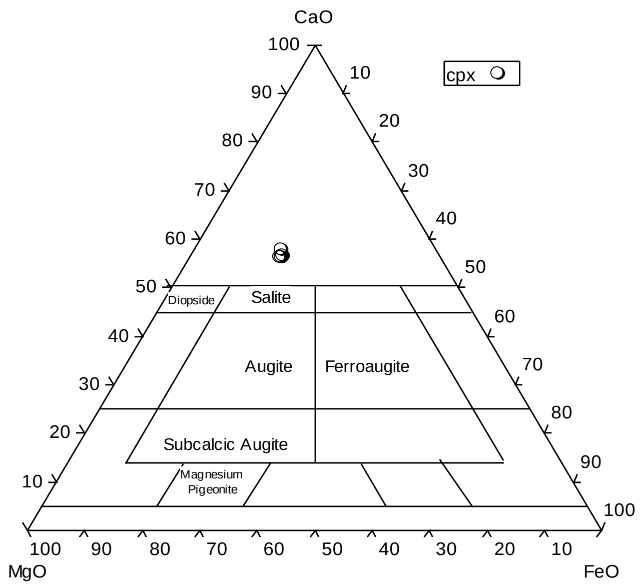

Fig. 6. Nomenclature of Clinopyroxene.

Plagioclase: The chemical analyses of Plagioclase are given in Table III along with the structural formula based on 32 (O) atoms. The An content of Plagioclase is about 99.78 to 99.98% which corresponds to anorthite. Plagioclase compositions are plotted on the feldspar triangle (Fig. 7).

Table. III. Chemical analysis of Plagioclase.

Sample No.	B-1					
Oxides	8.00	4.00	12.00	13.00	16.00	17.00
SiO_2	39.04	38.36	39.29	39.85	39.70	40.18
TiO_2	0.00	0.05	0.00	0.00	0.02	0.00
Al_2O_3	31.64	31.23	31.43	32.95	32.46	32.76
Cr_2O_3	0.01	0.64	0.03	0.00	0.02	0.72
FeO	1.80	1.49	1.03	0.90	0.62	0.59
MnO	0.03	0.22	0.04	0.03	0.03	0.03
MgO	0.03	0.01	0.01	0.02	0.02	0.00
CaO	26.52	26.15	26.54	26.53	26.19	26.95
Na_2O	0.00	0.00	0.01	0.00	0.02	0.03
K2O	0.01	0.01	0.00	0.02	0.01	0.00
F	0.00	0.00	0.01	0.08	0.03	0.00
Total	99.08	98.15	98.38	100.37	99.13	101.25
Cation Numbers based on (O) 32						
Si	1.90	1.89	1.92	1.90	1.92	1.91
Ti	0.00	0.00	0.00	0.00	0.00	0.00
Al	1.82	1.82	1.81	1.86	1.85	1.83
Cr	0.00	0.02	0.00	0.00	0.00	0.03
Fe	0.07	0.06	0.04	0.04	0.02	0.02

Mn	0.00	0.01	0.00	0.00	0.00	0.00
Mg	0.00	0.00	0.00	0.00	0.00	0.00
Ca	1.39	1.38	1.39	1.36	1.36	1.37
Na	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.01	0.00	0.00
Total	5.19	5.19	5.17	5.17	5.16	5.16
%Ab	0.00	0.00	0.07	0.00	0.15	0.19
%An	99.98	99.95	99.93	99.91	99.78	99.79
%Or	0.02	0.05	0.00	0.09	0.06	0.02

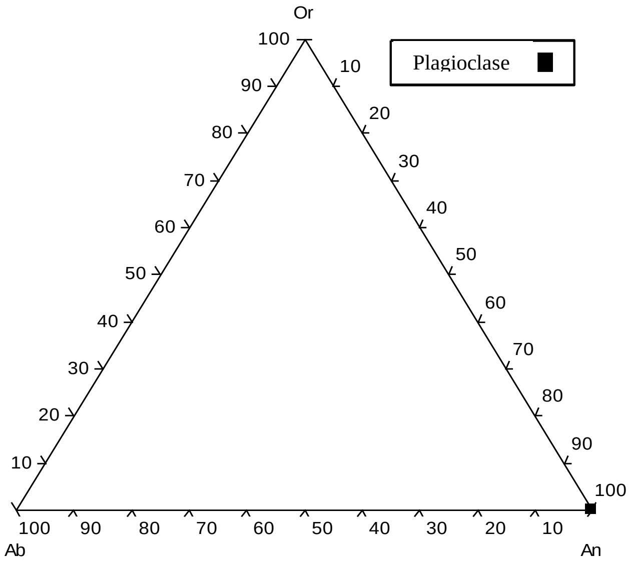

Fig. 7. Feldspar triangle.

Garnet-clinopyroxene thermometer:
The temperature dependence of Mg-Fe exchange between garnet and clinopyroxene has long been recognized as a potential geothermometer. The geothermometric relation has been investigated by Ellis and Green (1979), Ganguly (1979) and Dhal (1980). The calibration of Ellis and Green (1979) is based on compositions of coexisting garnet and clinopyroxene that crystallized from glasses of basaltic composition in the system CaO-FeO-MgO-Al_2O_3-SiO_2. Ganguly (1979) developed two geothermometric expressions, one applicable above 1060^{0}C and the other below 1060^{0}C, to account for a possible change of slope of lnK_D vs. 1/T relation owing to heat capacity effect. Ganguly (1979) and Dhal (1980) have examined the effect of Mn in addition to other variables, Fe/Mg, Ca and pressure. Dhal thermometer has been empirically derived from a granulite terrane in southwest Montana (Dhal 1979). Geothermometric equations developed by Ellis and Green (1979), Ganguly (1979) and Dhal (1980) are used in the present study and the results are listed in the Table IV.

Table IV. Calculated temperatures based on Garnet-Cpx pairs for the studied Calc-silicate rock at 5kb of pressure.

Sample No.	Garnet-Cpx Thermometry	T in ^{0}C
B-1	Ellis and Green (1979)	1047
	Ganguly (1979)	962
	Dhal (1980)	728

IV. DISCUSSION AND CONCLUSION

To evaluate the temperature of metamorphism of calc-silicates rock only models based on ion-exchange reaction (continuous) between two co-existing solid solutions are used as they are more consistent than models based on discontinuous reactions. Accordingly the temperature obtained using Ellis and Green (1979) model gives 1047^0 C, and that of Ganguly (1979) and Dhal (1980) gives lower temperatures i.e. 962^0 C and 728^0 C respectively at an assumed pressure of 5kbars. The higher temperature may be due to the Cr rich nature of the garnets of the calc-silicate. Since most of the thermometric models used do not take into account the effect of mixing property of Cr and Ca, as adequate mixing property data to solve for the effect of Cr in garnet is still lacking.

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