Mineral Chemistry and Petrography of the Bronzite Bearing Galaxy Granite, Chimakurti Mining Area, Prakasam District, Andhra Pradesh

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ABSTRACT
The gabbro and norite which is a part of the Chimakurti layered Complex, in the Prakasam District, Andhra Pradesh, is exported to other country as *galaxy granite*. The bronzite present within gives a metallic lustre when polished, making it an attractive dimensional stone. Present study gives a detailed chemistry of the pyroxene along with petrography.

Keyword: Galaxy granite, Chimakurti, Bronzite

INTRODUCTION

Chimakurti (Fig:1A), near Ongole, Prakasam district, Andhra Pradesh exposes lithounits of a layered mafic-ultramafic complex composed of clinopyroxenite, anorthosite and gabbroic norite/ noritic gabbro representing the deeply eroded precursors of massive anorthosite (Thomas,1990). The Chimakurti Complex is an oval shaped body emplaced along the contact zone of Eastern Ghat Supergroup of rocks to the east and Sargurs/Dharwarian rocks to the west, extending over 100 sq.km area, with NE-SW elongation. The core of the complex, is occupied by an olivine-pyroxenite, surrounded by gabbro-norite and two arcuate bands of anorthosite in the northern part and a minor fayalite bearing quartz monzonite in the southwestern part, suggesting different stages of differentiation during emplacement. These have been traversed by dolerite dykes, along NE-SW to E-W, NW-SE and N-S related to three sets of major fracture systems/shears. Gabbronorite owing to the presence of bronzite in it, has gained much demand as dimensional stone under the trade name "*Galaxy Granite*" being exported to a number of other countries, having more than 20 mines present in the area.

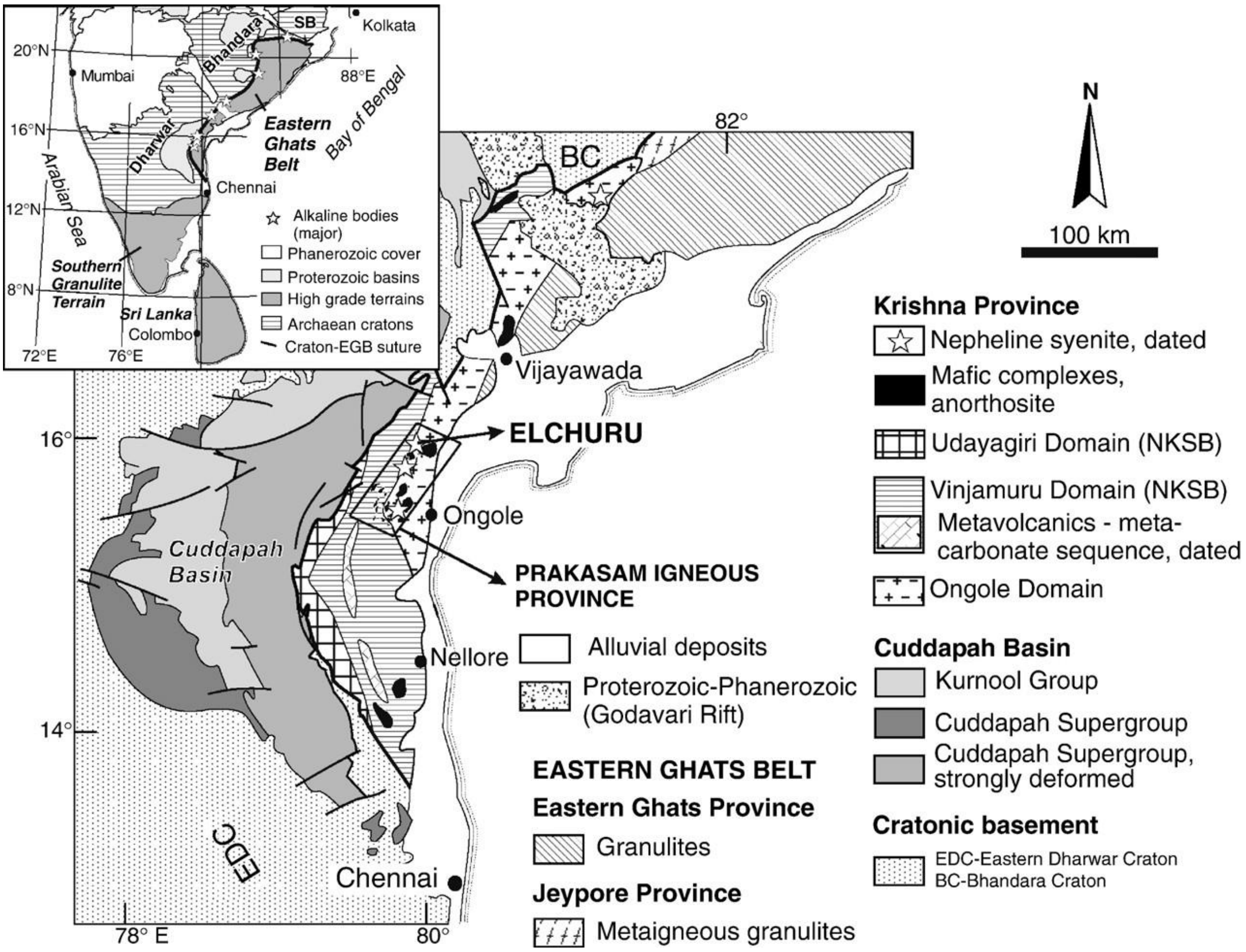


Fig:1A : Geology of the Krishna Province of the Eastern Ghats Belt (EGMB) and surrounding regions showing the location of the Prakasam igneous province and the Chimakurti, Elchuru alkaline complex (NKSB=Nellore Khammam Schist Belt). The inset shows a map of peninsular India with the locations of the major alkaline bodies along the craton–EGMB contact zone (after Dobmeier and Raith, 2003 and Upadhyay et. al. 2006)

Geological set up of Chimakurti area

Rocks of the Chimakurti Pluton is exposed on undulating hills, where they have been extensively quarried. The Chimakurti Pluton intruded country rocks in the transition zone between granulite facies and amphibolite facies rocks. The Chimakurti Pluton is an elliptical body occupying an area of approximately 100 sq.km, having a ring structure, with a sequence from core to margin olivine clinopyroxenite; anorthosite; olivine bearing gabbronorite; gabbronorite. At the contact with the Chimakurti Pluton, metapelitic rocks record imprints of ultra high temperature contact metamorphism (~6-7kb) (Babu, 1996 ; Dasgupta et.al., 1997). Two pyroxene thermometry records temperatures of ~1100°C at the centre of the Chimakurti Pluton (Rao, et.al., 1998).

The clinopyroxenite, anorthosite and gabbro portions of the Chimakurti Pluton show gradational relationships in terms of colour index and grain size in the field. Clinopyroxenite and anorthosite are coarse-grained (grain size upto 4 cm). There is a gradual decrease in the grain size from core to the periphery of the pluton (3-4 cm to <1mm). Along the periphery gabbro and norite occurs, especially in the south western margin, with well developed magmatic layering with inwards dips of moderate to steep angles (72° to 78°, Babu, 1996). Some of the marginal gabbro and norite are very fine grained (<1mm) and may represent chilled margin. Locally, some of the marginal rocks show effects of strain including banding of plagioclase. In the present paper, only the gabbronorite rock type or "***Galaxy Granite***", have been emphasized.

The Galaxy Granite:

This litho unit forms the major component of the Chimakurti Complex. It surrounds the pyroxenite which is in the core and forms high hills.x. It shows variation in composition from gabbro-olivine-norite to norite.. Olivine content increases from periphery to the core of the intrusive body. Towards the periphery gabbro-norite shows crude layering. The felsic mineral in this unit is plagioclase feldspar (gem variety labrodorite) and quartz occurs as accessory mineral. The mafic minerals in this unit are olivine, bronzite and augite. Biotite, apatite and opaques occur as accessory phases. Pyroxene to amphibole alteration is observed. The Chimakurti complex is emplaced along the axial trace of a regional NE-SW fold. It is massive in character and emplaced in concentric configuration since the rocks in it do not show well developed foliation or there is no clear cut fold pattern within the complex except the flow foliation which is rather evident in gabbro norite, in the form of banding (of mafic and felsic rich layers) at places and partial preferred orientation of constituent minerals. Its concentric configuration suggests that it is a partial "ring complex", and also a conical shape "funnel shape" as reflected from its centrally dipping foliation trend within the gabbro norite.

PETROGRAPHY

Analytical techniques:

Mineral chemistry of various phases of galaxy granite have been analysed by CAMECA SX100 Electron Probe Micro Analyzer (EPMA) housed at GSI,Hyderabad. An acceleration voltage of 15 kV, beam current of 20 nA, beam diameter of 1 µm and a counting time of 10 s were used. The microprobe was calibrated using (Na, Al) on Albite, (Mn) on Rhodonite (Ca, Mg) on Diopside (Ti) on TiO_2, (K,Si) on Orthoclase (Cr) on Chromium (Fe) on Almandine. Analyses of the selected and representative mineral phases are given in Table:1.

The rock is medium grained and greenish in colour. It varies in composition from gabbro-olivine-norite to norite. But the average overall composition is olivine-gabbro-norite. Olivine content increases from periphery to the core of the intrusive body. Toward the periphery gabbro-norite shows crude layering.

Under thin section it is found to contain augite, bronzite and plagioclase with biotite, quartz as accessory phases. Pyroxene to amphibole alteration is seen (Fig:2A,2B,2C,2D,2E &2F). It displays subophitic to ophitic texture. Plagioclase displays bent twinned lamellae indicating the evidences of deformation. Bronzite displays iron oxides along cleavage planes. Biotite is seen to develop along the margin of the clinopyroxene and bronzite crystals probably resulted as a result of alteration (Fig:3A,3B,3C,3D,3E &3F). The biotites are titanium rich with TiO2 ranging from 3.9 to 5.3%. The bronzites have FeO in the range 23 to 25%(Table-1). The plagioclase has Xab .42 and Xan .52 while the cpx are augite (Fig:4A & 4B).

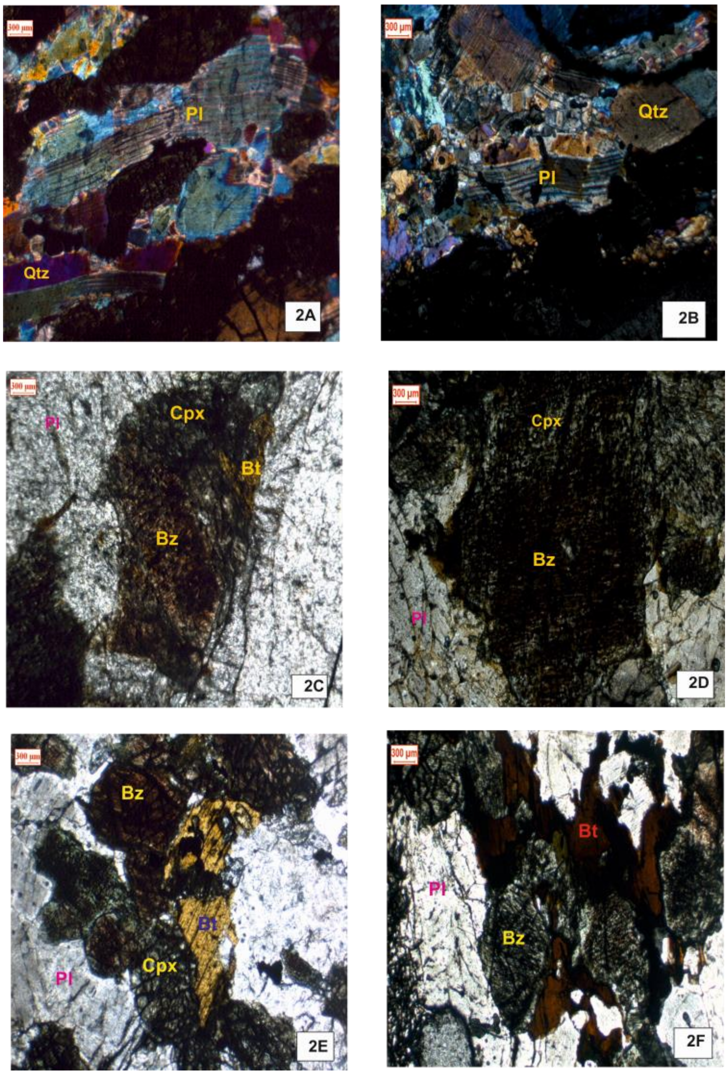


Fig 2A:Plagioclase,quartz are the felsic minerals in the gabbro-norite rock.
Fig 2B: Bending of plagioclase lamella indicating the deformation of the rock.
Fig 2C:Formation of bronzite(Bz) from the Orthopyroxene.
Fig 2D:Plagioclase,clinopyroxene & bronzite assemblage in gabbro-norite rock.
Fig 2E:Formation of biotite in the margin of the clinopyroxene and bronzite grains.
Fig 2F: Plagioclase,clinopyroxene , bronzite & biotite assemblage in gabbro-norite rock.

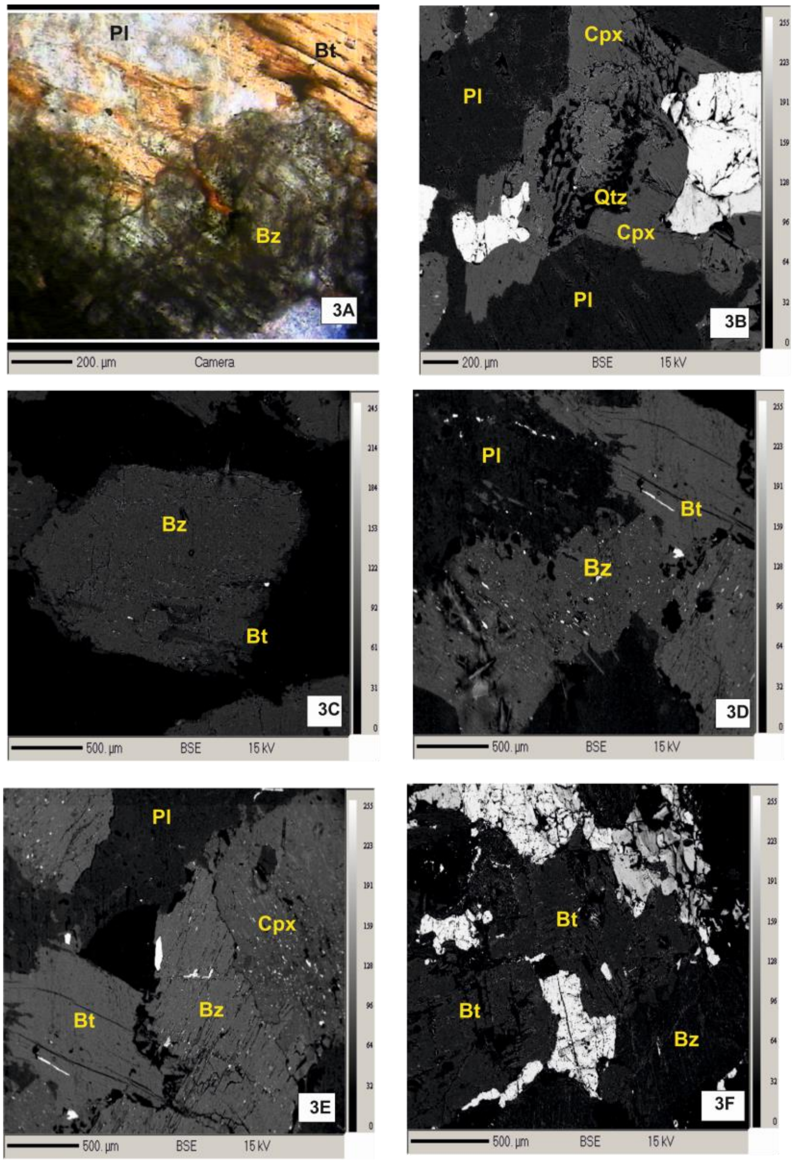
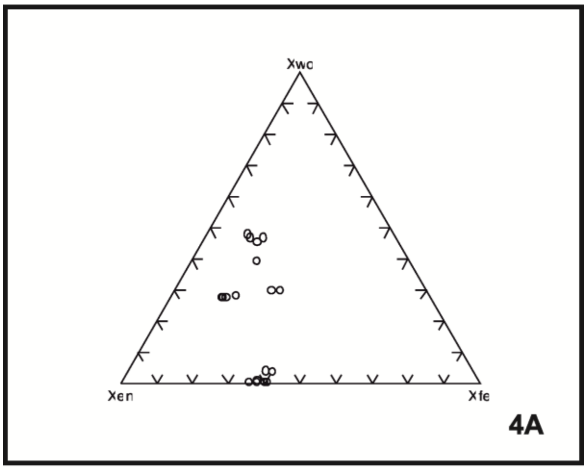


Fig 3A:Tripal point junction of plagioclase,biotite & bronzite.
Fig 3B:Quartz inclusion within the bronzite & clinopyroxene grain.
Fig 3C:Biotite form in the margin of bronzite.
Fig 3D:Bronzite,biotite,plagioclase assemblage in gabbro norite rock.
Fig 3E:Another view of Bronzite,biotite,plagioclase assemblage in gabbro norite rock.
Fig 3F:Microfolding in biotite grain.



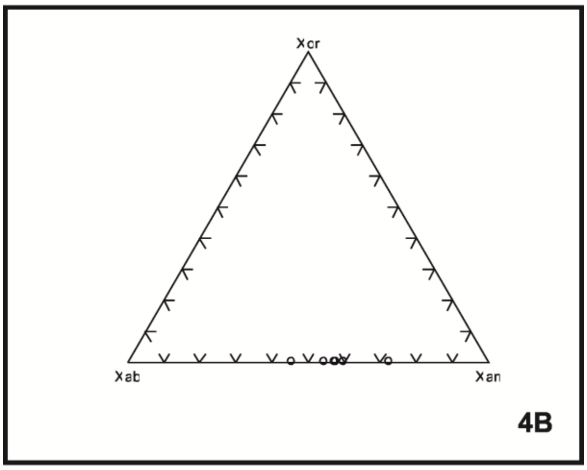


Fig 4A: Composition diagram of Clinopyroxene.
Fig 4B: Composition diagram of Plagioclase feldspar.

TABLE 1: EPMA analysis data of different mineral phases of *Galaxy Granite*

SLIDE NO	White	White	White	White	White	White	White	PIT-6	PIT-7	BLACK	BLACK
MINERAL	Bronzite	Bronzite	CPX IN RIM	Bronzite	CPX RIM	CPX CORE	Bronzite	Bronzite	CPX	CPX	CPX
Data Set/Point	1 / 1 .	3 / 1 .	4 / 1 .	6 / 1 .	7 / 1 .	8 / 1 .	9 / 1 .	16 / 1 .	17 / 1 .	20 / 1 .	21 / 1 .
SiO2	53.018	53.011	44.887	51.616	45.151	52.183	53.665	54.198	53.125	55.061	56.087
TiO2	0.111	0.059	0.845	0.543	1.409	0.35	0.042	0.054	0.259	0.265	0.229

Al2O3	1.387	1.148	10.228	1.145	7.622	2.368	0.814	1.184	1.838	2.906	2.257
Cr2O3	0.011	0.014	0.004	-0.032	0.06	0.032	0.011	0.048	0.058	0.027	-0.005
Fe2O3	0	0	0	0	0	0	0	0	0	0	0
V2O3	0	0	0	0	0	0	0	0	0	0	0
MgO	20.016	20.426	12.265	19.735	11.211	12.603	21.279	22.627	13.884	18.209	18.672
FeO	23.693	24.783	13.554	25.032	14.142	9.515	24.88	21.929	7.547	8.781	8.172
CaO	2.06	0.469	11.988	2.004	11.422	22.406	0.41	0.344	22.596	12.367	12.447
MnO	0.511	0.544	0.123	0.502	0.187	0.276	0.486	0.44	0.173	0.167	0.101
CoO	0	0	0	0	0	0	0	0	0	0	0
NiO	0	0	0	0	0	0	0	0	0	0	0
ZnO	0.032	0.076	0.018	0.034	0.082	0.052	0.014	0.052	0.004	0.03	-0.014
Na2O	0.037	-0.002	0.999	0.036	0.932	0.482	0.003	0.011	0.374	0.319	0.206
K2O	0.015	-0.008	1.273	-0.004	1.015	0.012	0.006	0.003	0.011	0.118	0.115
Total	100.891	100.52	96.184	100.611	93.233	100.279	101.604	100.786	99.869	98.25	98.267

SLIDE NO	White	White	White	White	White	White	White	PIT-6	PIT-7	BLACK	BLACK
MINERAL	Bronzite	Bronzite	CPX IN RIM	Bronzite	CPX RIM	CPX CORE	Bronzite	Bronzite	CPX	CPX	CPX
DataSet/ Point	1 / 1 .	3 / 1 .	4 / 1 .	6 / 1 .	7 / 1 .	8 / 1 .	9 / 1 .	16 / 1 .	17 / 1 .	20 / 1 .	21 / 1 .
oxygen basis	6	6	6	6	6	6	6	6	6	6	6
f1	2.24	2.25	2.35	2.27	2.43	2.24	2.22	2.21	2.23	2.20	2.19
# Si	1.98	1.98	1.75	1.95	1.82	1.95	1.98	1.99	1.97	2.01	2.04
# Ti	0.00	0.00	0.02	0.02	0.04	0.01	0.00	0.00	0.01	0.01	0.01
# Al	0.06	0.05	0.47	0.05	0.36	0.10	0.04	0.05	0.08	0.13	0.10
# Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
# Fe3+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
# V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
# Mg	1.11	1.14	0.71	1.11	0.68	0.70	1.17	1.24	0.77	0.99	1.01
#total Fe	0.74	0.78	0.44	0.79	0.48	0.30	0.77	0.67	0.23	0.27	0.25

# Ca	0.08	0.02	0.50	0.08	0.49	0.90	0.02	0.01	0.90	0.48	0.49
# Mn	0.02	0.02	0.00	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00
# Co	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
# Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
# Zn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
# Na	0.00	0.00	0.08	0.00	0.07	0.03	0.00	0.00	0.03	0.02	0.01
#K	0.00	0.00	0.06	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.01
Cation	3.99	3.99	4.05	4.01	4.01	4.01	4.00	3.98	3.99	3.93	3.91
Xfe	0.38	0.40	0.27	0.40	0.29	0.16	0.39	0.35	0.12	0.15	0.14
Xen	0.58	0.59	0.43	0.56	0.41	0.37	0.60	0.64	0.40	0.57	0.58
Xwo	0.04	0.01	0.30	0.04	0.30	0.47	0.01	0.01	0.47	0.28	0.28

SLIDE NO	White	White	White	PIT-8	BLACK	PIT-1
MINERAL	Plag	Plag	Plag	Plag	Plag	Plag
DataSet/Point	5 / 1 .	14 / 1 .	15 / 1 .	18 / 1 .	22 / 1 .	30 / 1 .
SiO2	53.998	55.001	57.97	53.486	50.944	54.119
TiO2	-0.013	-0.026	-0.031	-0.007	0.006	0.002
Al2O3	26.71	27.161	25.748	27.798	30.131	26.768
Cr2O3	0.02	-0.03	0.002	-0.01	0.015	0.011
Fe2O3	0	0	0	0	0	0
V2O3	0	0	0	0	0	0
MgO	0.001	-0.005	-0.004	-0.001	0.001	0.008
FeO	0.095	0.068	0.161	0.099	0.41	0.061
CaO	11.602	11.002	9.203	11.764	14.678	11.394
MnO	0.015	-0.04	0.02	0.012	-0.018	0.023
CoO	0	0	0	0	0	0
NiO	0	0	0	0	0	0
ZnO	0.074	0.041	0.049	0.051	-0.018	-0.028
Na2O	4.751	5.173	6.217	4.454	3.104	4.778
K2O	0.201	0.124	0.26	0.173	0.061	0.18
Total	97.454	98.469	99.595	97.819	99.314	97.316

SLIDE NO	White	White	White	PIT-8	BLACK	PIT-1
MINERAL	Plag	Plag	Plag	Plag	Plag	Plag
DataSet/Point	5 / 1 .	14 / 1 .	15 / 1 .	18 / 1 .	22 / 1 .	30 / 1 .
oxygen basis	8	8	8	8	8	8
f1	2.786	2.749	2.706	2.774	2.758	2.785
# Si	2.504	2.516	2.610	2.469	2.338	2.508
# Ti	0.000	-0.001	-0.001	0.000	0.000	0.000
# Al	1.460	1.465	1.367	1.513	1.630	1.463
# Cr	0.001	-0.001	0.000	0.000	0.001	0.000
# Fe3+	0.000	0.000	0.000	0.000	0.000	0.000

# V	0.000	0.000	0.000	0.000	0.000	0.000
# Mg	0.000	0.000	0.000	0.000	0.000	0.001
#total Fe	0.004	0.003	0.006	0.004	0.016	0.002
# Ca	0.576	0.539	0.444	0.582	0.722	0.566
# Mn	0.001	-0.002	0.001	0.000	-0.001	0.001
# Co	0.000	0.000	0.000	0.000	0.000	0.000
# Ni	0.000	0.000	0.000	0.000	0.000	0.000
# Zn	0.003	0.001	0.002	0.002	-0.001	-0.001
# Na	0.427	0.459	0.543	0.399	0.276	0.429
#K	0.012	0.007	0.015	0.010	0.004	0.011
Cation	4.986	4.986	4.986	4.979	4.986	4.980
Xab	0.421	0.456	0.542	0.402	0.276	0.427
Xan	0.568	0.536	0.443	0.587	0.721	0.563

SLIDE NO	White	BLACK	BLACK	BLACK
MINERAL	BIOTITE	BIOTITE	BIOTITE	BIOTITE
DATA SET POINT	2 / 1 .	19 / 1 .	25 / 1 .	27 / 1 .
SiO2	37.096	38.009	37.108	36.764
TiO2	3.968	4.911	5.244	5.259
Al2O3	12.441	13.744	13.581	13.885
Cr2O3	0.031	0.003	0.127	0.089
Fe2O3	0	0	0	0
V2O3	0	0	0	0
MgO	13.367	14.244	13.623	14.182
FeO	15.796	13.049	14.731	14.778
CaO	0.124	0.8	0.008	0.048
MnO	0.051	0.034	0.047	0.088
CoO	0	0	0	0
NiO	0	0	0	0
ZnO	0.063	0.02	0.089	0.018
Na2O	0.094	0.067	0.068	0.119
K2O	9.058	9.578	9.532	9.379
Total	92.089	94.459	94.158	94.609

SLIDE NO	White	BLACK	BLACK	BLACK
MINERAL	BIOTITE	BIOTITE	BIOTITE	BIOTITE
DATA SET POINT	2 / 1 .	19 / 1 .	25 / 1 .	27 / 1 .
oxygen basis	11	11	11	11
f1	4.67	4.50	4.55	4.53
# Si	2.89	2.85	2.81	2.77
# Ti	0.23	0.28	0.30	0.30
# Al	1.14	1.21	1.21	1.23

# Cr	0.00	0.00	0.01	0.01
# Fe3+	0.00	0.00	0.00	0.00
# V	0.00	0.00	0.00	0.00
# Mg	1.55	1.59	1.54	1.59
#total Fe	1.03	0.82	0.93	0.93
# Ca	0.01	0.06	0.00	0.00
# Mn	0.00	0.00	0.00	0.01
# Co	0.00	0.00	0.00	0.00
# Ni	0.00	0.00	0.00	0.00
# Zn	0.00	0.00	0.00	0.00
# Na	0.01	0.01	0.01	0.02
#K	0.90	0.91	0.92	0.90
Cation	7.77	7.73	7.74	7.77
X Fe	0.40	0.34	0.38	0.37
X Mg	0.60	0.66	0.62	0.63

CONCLUSION:

The gabbro-norite body, occurring within the Chimakurti Complex are being extensively mined and exported as galaxy granite because of the presence of bronzite. It has augite, bronzite and plagioclase as the main mineral constituents. Alteration of pyroxene to amphibole and biotite is noticed. Mineral chemistry of bronzite indicate that these have 25% FeO indicating a very high content of iron and reflecting its suitability as a main constituent for the galaxy granite. The bronzite has released iron oxide along the cleavage planes which is responsible for the metallic luster.

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