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Characterization of Granitoids Adjoining Southern Part of Kadiri Schist Belt, Eastern Dharwar Craton, South India: Their Tectonic Implications.

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Abstract: *The southern part of Kadiri Schist Belt is in juxtaposition with granitoids on either side which include TTG, TGM, and MS suites. The schist belt rocks and granitoids exhibit three phases of deformation. The granitoids are mainly medium to coarse grained and exhibit hypidiomorphic texture. Geochemical signatures suggest that the granitoids are magmatic, metaluminous, calc-alkaline and grouped under mixed origin. The field, mineralogical and chemical observations discriminate them as I-type. Petrogenetic studies indicate that polyphase polymigmatised TTG gneisses show the existence of older simatic crust which later gave rise to varied sialic crust in marginal basin environment. The calc-alkaline TGM suite points to magma mingling and mixing and fractional crystallization differentiation. The MS suite has evolved due to crustal anatexis and mantle derived melts.*

Keywords *: Granitoids, Kadiri Schist Belt, Magma mingling and mixing, Petrology.*

I. Introduction

Kadiri schist belt which lies in the eastern tectonic block includes bimodal, mafic-felsic, volcanic association like many Archaean Greestone Belts (Barker and Peterman, 1974[1]; Condie, 1981[2]; Ayres et al., 1985[3]; Peate et al., 1997[4]). Bimodal volcanic rocks have been reported from various schist belts in the Eastern Dharwar Craton such as Sandur (Hanuma Prasad et al., 1997[5]). Hutti (Anantha Iyer and Vasudev, 1980[6]; Giritharan and Rajamani, 1998[7]) and Ramagiri (Meenal Mishra and Rajamani, 1999[8]). The granite-greenstone terrane in Andhra Pradesh is made up of vast stretches of granites and gneisses that enclose thin linear schist belts. Kadiri Schist Belt is one such belt located to the south west of Cuddapah Basin having larger area occupied by meta-acid volcanics compared to basic volcanics and hence represents the higher stratigraphic level in the greenstone model of Anhaeusser et al., (1969)[9].

II. Geological Setting

The study area is confined to the granitoids adjoining the southern part of Kadiri Greenstone Belt covering parts of Anantapur and Chittoor districts. It is situated between Kadiri in the North and Kandukuru in the South. The width of the belt varies from one kilometer to 4.8 kilometers and it lies between North Latitudes $13^{0}45'$ and $14^{0}07'$ and East Longitudes $78^{0}02'$ and $78^{0}15'$ covered in the Government of India Toposheet Numbers 57J/3, 57J/4, 57K/1 and 57K/2 and is geologically mapped on 1:50,000 scale (Fig. 1).

The central portion of the study area constitutes the schist belt, which runs roughly in the NNW-SSE direction and comprises predominantly acid volcanic rocks with minor amounts of basic volcanics. It is in juxtaposition with granitoids on either side which include Tonalite- Trondhjemite -Granodiorite Suite(TTG), Tonalite-Granodiorite-Monzogranite Suite(TGM) and Monzogranite-Syenogranite Suite(MS). Acid volcanics are represented by rhyolite, quartz porphyry and quartz feldspar porphyry. Metabasalt, meta-andesite and basic tuffs constitute the basic volcanics. Impersistent bands of BIF within acid volcanics occur as minor intercalations. A conglomerate horizon is traced in the southern part of schist belt near Kandukuru The above litho-units are intruded by younger granitoids, dolerite and gabbro dykes, pegmatite and quartz veins.

The schist belt components occur as enclaves in the adjoining granitoids; among them metabasalt is the most predominant enclave (Fig. 2); the presence of these relict and undigested metabasalt enclaves apparently suggest that the original width of the schist belt was perhaps much more than what we see now (Chetty, 1989)[10].

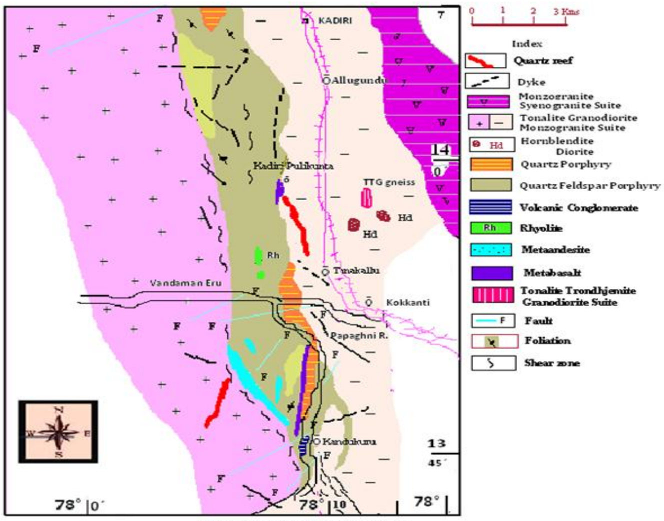

Fig. 1 Geological map of the study area.

The schist belt litho-units and adjoining granitoids were subjected to three phases of deformation namely D1, D2, D3. Leucocratic and melanocratic bands in TT Gneisses, intrafolial band warps (East-West) and progressive migmatisation suggest the formation of intricately folded and banded tonalite-trondhjemite gneiss (Fig.3). The Tonalite–Granodiorite-Monzogranite group is a syntectonic intrusive emplaced during the second deformation. It displays primary magmatic flow structures which are parallel to and continuous with the S2 fabric in the greenstone belt and TT gneiss. Late D2 ductile shearing resulted in the development of the regional shear zones. The MS Suite also exhibits primary magmatic flow related fabric modified partly due to this deformation. The last phase of deformation, the regional D3 event is represented by broad warps with axial traces trending ENE-WSW to ESE-WNW through E-W direction. Near vertical axial planar fractures are developed due to deformation. Some of the D3 related fractures further developed into regional fault zones occupied by quartz reefs. They extend upto the Cuddapah basin and offset its margin as observed in the satellite imageries.

Fig.2 : METABASALT ENCLAVES IN GRANITOIDS

Fig.3 : INTRICATELY FOLDED TTG GNEISS

III. Petrology

As per the IUGS – Streckeisen classification (Pitcher, 1997)[11], the plots of the granitoids of the study area lie in the fields of tonalite, granodiorite, monzo-granite and syenogranite fields. Plagioclase feldspar and quartz are the dominant phases constituting TTG group. The rocks are medium grained and exhibit equigranular to inequigranular seriate xenoblastic texture. The gneissosity is defined in two ways namely, (1) plagioclase feldspar rich bands alternating with mafic +quartz+ plagioclase bands and (2) plagioclase +quartz+ rich bands alternating with relatively mafic rich bands. The modal composition of TT gneiss is presented in Table.1 and the QAP plot is given in Fig. 4.

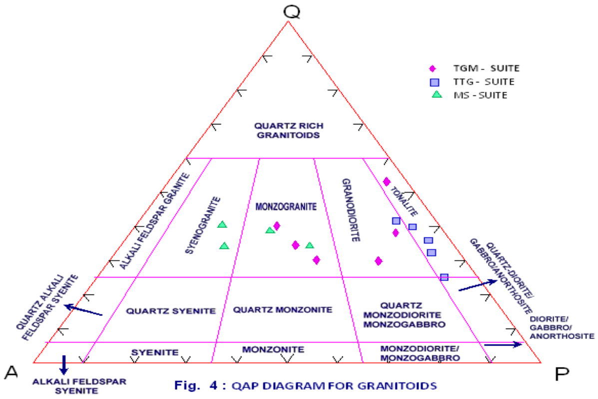

Fig. 4 : QAP DIAGRAM FOR GRANITOIDS

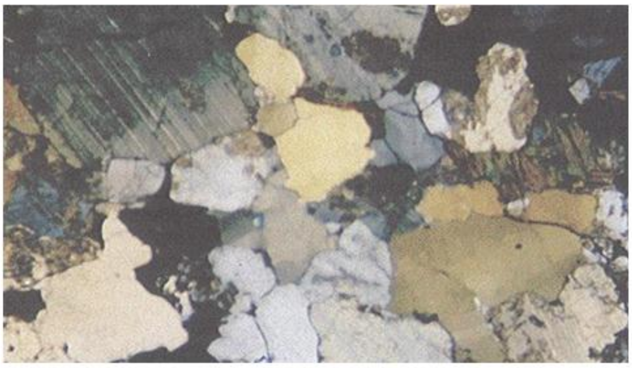

Fig.5 : TONALITE DEPICTING HYPIDIOMORPHIC GRANULAR TEXTURE IN TGM SUITE

The granitoids of TGM group are characterized by the predominance of igneous microstructures and textures, and a wide range in the modal content of the different mineral constituents. They are chiefly made up of plagioclase feldspar. K-feldspar, quartz, homblende and biotite in different proportions. The accessory phases include sphene, opaques, apatite and zircon in the decreasing order of abundance. As per the IUGS – Streckeisen Classification (Pitcher, 1997[11]), they fall in the categories of tonalite, granodiorite and monzogranite with successive decrease in the plagioclase/potash feldspar ratios (Table.1 & Fig.4). All the components of the group are medium to coarse grained, equigranular and exhibit hypidiomorphic texture (Fig. 5).

Potash feldspar, plagioclase feldspar and quartz constitute the essential minerals in the all phases of MS group. The modal analysis data of representative samples is presented in table1. As per the IUGS-Streckeisen classification, majority of the MS group of rocks fall in the monzogranite and syenogranite (combined granite) fields (Fig. 4).

TABLE – 1 :

Rock No.	Quartz	K-Feldspar	Plagioclase	Mafics
PSV 92	34	4	57	5
PSV 105	30	5	58	7
PSV 108	31	4	55	10
PSV 114	33	3	62	2
PSV 118	23	6	63	9

MODAL COMPOSITION of TTG

Rock No.	Quartz	K-Feldspar	Plagioclase	Mafics
PSV 125	39	31	27	3
PSV 130	31	33	34	2
PSV 139	32	28	38	2
PSV 152	24	21	48	7
PSV 159	28	30	36	6
PSV 162	33	25	34	8

MODAL COMPOSITION of TGM

Rock No.	Quartz	K-Feldspar	Plagioclase	Mafics
PSV 176	33	40	21	6
PSV 178	28	33	33	6
PSV 182	31	26	34	9
PSV 190	34	40	21	5

MODAL COMPOSITION of MS

IV. Geochemistry

The geochemistry of granitoids adjoining the southern part of kadiri schist belt has been attempted using major oxide and trace element determinations. Five samples from tonalite-trondhjemite-granodiorite (TTG) suite, fifteen samples from tonalite-granodiorite -monzogranite (TGM) suite and twelve samples from monzogranite-syenogranite (MS) suite are chemically analysed and their analysis together with their C.I.P.W. norm and Niggli values are given in the tables 2,3 and 4 respectively. proportions. The accessory phases include sphene, opaques, apatite and zircon in the decreasing order of abundance. As per the IUGS – Streckeisen Classification (Pitcher, 1997[11]), they fall in the categories of tonalite, granodiorite and monzogranite with successive decrease in the plagioclase/potash feldspar ratios (Table.1 & Fig.4). All the components of the group are medium to coarse grained, equigranular and exhibit hypidiomorphic texture (Fig. 5).

CHEMICAL ANALYSIS OF T.T.G.

Constituents	1	2	3	4	5	Average
Sample No. / Major(Wt.%)	SV16	SV17	SV18	SV19	SV20	
SiO_2	69.12	68.50	67.60	64.50	60.2	65.98
TiO_2	0.45	0.47	0.40	0.45	0.88	0.53
Al_2O_3	15.08	15.06	16.27	13.64	14.41	14.89
Fe_2O_3	2.82	3.37	1.50	2.48	3.05	2.64
FeO	2.30	1.80	1.82	4.50	4.14	2.91
MnO	0.04	0.03	0.03	0.17	0.11	0.07
MgO	0.62	1.08	1.55	0.06	4.86	1.63
CaO	3.73	3.78	3.85	2.23	3.68	3.45
Na_2O	3.74	4.16	4.47	5.77	2.94	4.21
K_2O	1.08	1.13	1.48	4.06	3.48	2.24
P_2O_5	0.31	0.33	0.18	0.06	0.38	0.25
LOI	0.65	0.95	0.82	0.86	0.68	0.79
Total	99.94	99.53	99.97	98.78	98.81	99.40
Trace (ppm)						
Co	30.25	29.98	29.08	26.92	22.50	27.74
Ni	27.21	27.01	26.99	24.50	20.92	25.32
Cr	120.53	121.00	122.50	110.35	98.98	114.67
Cu	10	<10	<20	10	<10	12.00
Pb	<10	<10	10	20	10	12.00
Zn	35	40	25	28	60	37.6
Ba	110.53	109.50	111.60	100.00	90.65	104.45
Rb	149.62	150.45	148.98	145.50	130.00	144.95
Sr	243.98	244.02	200.45	189.90	180.45	211.76
Zr	38.8	38.48	37.99	32.48	30.95	35.74
A/CNK	1.07	1.01	1.02	0.98	0.88	0.99
C.I.P.W(Norm)						
Quartz	34.87	31.25	25.51	10.53	8.99	22.23
Orthoclase	6.42	6.69	8.80	23.99	20.54	13.28
Albite	31.90	35.26	38.08	47.56	50.04	40.56
Anorthite	16.62	16.62	8.12	13.02	14.85	13.84
Corundum	1.72	0.91	0.72	0.84	0.92	1.02
Diopside	8.99	8.54	9.02	9.48	9.76	9.14
Hypersthene	2.72	2.69	5.01	1.20	3.06	2.92
Magnetite	4.16	4.22	2.22	3.04	3.09	3.34
Haematite	0.68	0.51	0.80	0.85	0.74	0.71
Ilmenite	0.86	0.89	0.76	0.82	0.89	0.84
Pyrite	0.38	0.17	0.24	0.35	0.41	0.31
Apatite	0.74	0.78	0.43	0.14	0.52	0.52
Niggli Values						
Si	249.50	248.67	235.17	239.40	245.65	243.67
Al	39.40	38.31	39.31	47.00	41.50	39.70
Fm	20.36	16.92	19.74	18.74	20.35	19.22
C	23.39	21.08	21.71	20.90	24.12	22.24
Alk	19.53	20.40	20.45	19.53	21.25	20.23
Mg	0.51	0.35	0.38	0.43	0.50	0.43
K	0.25	0.17	0.20	0.21	0.26	0.21

CHEMICAL ANALYSIS OF TONALITE-GRANODIORITE-MONZOGRANITE-SUITE, C.I.P.W. NORM AND NIGGLI VALUES

Constituents	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Sample No. / Major(Wt.%)	SV1	SV2	SV3	SV4	SV5	SV6	SV7	SV8	SV9	SV10	SV11	SV12	SV13	SV14	SV15	
SiO_2	66.8	67.70	61.60	63.54	67.00	62.06	63.11	68.28	69.18	64.24	69.86	71.44	71.14	70.83	70.14	67.12
TiO_2	1.26	1.33	0.65	0.42	0.42	1.02	0.98	1.04	1.02	1.13	0.57	0.35	0.50	0.41	0.50	0.77
Al_2O_3	14.3	13.47	16.95	18.05	16.30	15.34	14.27	14.54	15.49	14.81	14.66	14.25	14.72	14.16	14.84	15.27
Fe_2O_3	0.99	1.20	2.13	1.80	1.65	0.11	0.54	0.52	0.04	0.04	1.45	1.60	1.26	1.40	0.55	1.01
FeO	2.50	2.30	3.25	2.10	2.23	5.60	4.91	3.00	1.71	5.00	1.21	1.01	0.95	1.24	2.74	2.65
MnO	0.04	0.04	0.09	0.06	0.06	0.09	0.10	0.04	0.01	0.08	0.01	0.03	0.06	0.05	0.06	0.05
MgO	3.49	2.99	2.50	1.25	1.05	4.85	4.76	2.88	2.43	3.70	0.54	0.46	0.35	0.94	0.34	2.16
CaO	1.86	1.50	5.72	5.38	4.80	3.45	3.33	1.36	0.62	2.35	2.97	2.59	2.70	2.41	2.50	2.90
Na_2O	3.96	3.62	4.45	4.25	4.20	3.48	3.40	3.65	4.79	3.67	3.36	3.54	3.60	3.64	4.80	3.89
K_2O	3.42	3.87	1.15	1.38	1.45	2.94	2.79	3.39	3.32	2.99	3.76	3.75	3.88	3.96	2.96	3.00
P_2O_5	0	0.00	0.25	0.17	0.16	0.00	0.00	0.00	0.00	0.00	0.05	0.07	0.09	0.12	0.05	0.12
LOI	0.95	1.09	0.95	0.82	0.60	0.82	0.90	0.80	0.5	1.35	0.81	0.68	0.55	0.75	0.44	0.80
Total	99.57	99.11	99.69	99.42	99.92	99.76	99.09	99.50	99.15	99.36	99.23	99.78	99.80	99.91	99.93	99.54
Trace (ppm)																
Co	20	30	10	20	15	30	25	20	20	20	15	20	20	10	35	17.66
Ni	55	75	40	50	45	100	70	40	40	80	40	40	40	60	85	57.33
Cr	50	75	50	50	55	100	100	50	50	100	50	50	50	55	100	65.66
Cu	20	10	20	10	<10	20	20	10	10	30	20	10	10	10	30	16.00
Pb	<10	<10	10	<10	20	<10	<10	<10	<10	<10	<10	26	20	<10	<10	12.4
Zn	40	40	60	28	35	60	50	30	30	50	30	30	35	40	60	41.2
Ba	200	300	140	168	150	200	200	200	200	180	545	416	595	512	158	277.6
Rb	300	300	80	100	110	80	90	100	110	90	276	315	249	195	80	165
Sr	120	100	175	152	160	200	200	200	300	200	145	144	145	150	163	170.26
Zr	90	100	110	200	162	100	110	120	140	120	150	282	266	175	100	148.33
A/CNK	1.0	0.90	0.76	0.99	0.94	0.80	0.80	0.90	1.0	0.90	0.97	0.97	0.97	0.96	0.94	0.92
C.I.P.W(Norm)																
Quartz	21.25	24.41	15.37	20.19	24.95	12.62	16.37	24.85	22.37	17.71	29.04	30.56	29.31	28.15	23.76	22.72
Orthoclase	20.49	23.33	6.80	7.56	8.57	17.56	16.79	20.30	19.96	18.03	22.16	22.10	22.99	23.34	17.43	17.82
Albite	33.98	31.25	37.65	35.96	35.54	29.76	29.21	31.29	41.11	31.68	28.43	30.04	30.46	30.89	40.70	33.19
Anorthite	11.29	9.25	22.88	25.58	21.34	17.74	15.74	13.48	11.05	15.39	13.82	11.90	12.54	10.56	10.22	14.85
Diopside	4.40	3.58	3.13	0.30	1.17	11.52	10.72	3.95	1.96	9.00	0.42	0.38	0.26	0.45	1.62	3.52
Hypersthene	4.70	3.81	8.01	4.90	4.`19	8.68	8.47	3.41	1.57	5.97	1.27	0.97	0.77	2.71	3.94	4.22
Magnetite	1.46	1.78	3.09	2.61	2.39	0.16	0.80	0.75	0.04	0.06	2.10	2.32	1.81	2.03	0.78	1.47
Ilmenite	2.42	2.58	1.23	0.80	0.80	1.96	1.90	1.99	1.95	2.17	1.06	0.66	0.93	0.76	0.93	1.47
Apatite			0.58	0.39	0.37						0.12	0.16	0.19	0.28	0.09	0.27
Niggli Values																
Si	280.35	304.86	235.17	239.40	247.69	211.02	223.83	305.09	332.28	247.92	343.52	362.78	365.74	301.94	331.50	288.87
Al	35.26	35.68	38.06	40.00	39.31	30.61	29.79	38.34	43.08	33.57	42.35	42.55	44.54	35.47	41.27	37.99
Fm	23.93	23.24	30.75	18.74	11.01	33.88	34.04	22.25	11.53	30.00	14.31	13.79	11.58	14.98	15.22	20.61
C	15.62	14.32	23.39	21.71	21.08	17.76	18.09	13.94	12.39	15.28	15.58	14.08	13.20	10.95	12.60	15.99
Alk	25.19	26.76	19.24	19.53	20.45	17.76	18.00	25.47	32.28	21.09	27.74	24.55	30.67	25.79	13.89	23.23
Mg	0.49	0.44	0.51	0.43	0.38	0.52	0.53	0.41	0.40	0.45	0.38	0.31	0.28	0.47	0.17	0.41
K	0.36	0.41	0.15	0.21	0.18	0.36	0.35	0.38	0.31	0.35	0.42	0.41	0.41	0.42	0.28	0.33

The chemical analyses indicate that majority of samples have more than 66% SiO_2 and hence classified as ‘acidic suite’(Charmichael et al.,1974[12]. The mean Al_2O_3 concentration in the granitoids of study area is 15.02% classifying them as Low -Al gneisses (Monrad,1983)[13]. The K_2O in granites has a wider spread, indicating K-influx during the formation of granitoids. The development of K-Feldspar megacrysts and marginal variation of K_2O / Na_2O in all the suites (majority of the samples) suggest that K_2O and Na_2O were enriched simultaneously and this is mineralogically reflected in the local replacement of plagioclase by K-feldspar. The Al_2O_3 / (Na_2O + K_2O) ratios in granitoids are less than 3.4 pointing to their sub-alkaline nature (Bose, 1989)[14]. In the AFM diagram (Fig 6) (Barkar & Arth,1976)[15], the granitoids of the Kadiri area conform with calc-alkaline trend. The Na_2O/CaO ratio for granitoids is more than 2, indicating that the plagioclase feldspar in granitoids may be oligoclase. The SiO_2/MgO ratios broadly show two trends. Some of the samples show below 100 and the other above 100. This chemical behaviour suggests crustal contamination of magma during its ascent or emplacement (Hyndman, 1972)[16]. All the samples have higher SiO_2 and lower FeO, MgO and CaO weight percentages approximating to the mantle derived magmas. All the granitoids can be classified as metaluminous (A/CNK >1.0 and A/NK<1.0) using Shand’s index. The metaluminous and calc-alkaline behavior further suggest contamination of mantle derived magma with crustal material.

CHEMICAL ANALYSIS OF MONZOGRANITE-SYENOGRANITE SUITE- C.I.P.W. NORM AND NIGGLI VALUES

Sample No. / Major(Wt.%)	SV1	SV2	SV3	SV4	SV5	SV6	SV7	SV8	SV9	SV10	SV11	SV12	
SiO_2	73.26	73.50	72.04	73.29	72.00	72.50	73.17	73.54	72.55	71.64	71.81	71.51	72.56
TiO_2	0.19	0.22	0.31	0.31	0.29	0.26	0.36	0.43	0.25	0.39	0.36	0.44	0.31
Al_2O_3	13.93	13.60	13.44	13.43	13.46	14.93	13.30	13.04	13.26	13.21	13.64	13.14	13.61
Fe_2O_3	0.26	0.68	0,50	0.94	0.37	0.22	0.25	0.31	1.27	1.25	1.16	1.31	0.7
FeO	1.20	0.90	1.80	0.80	0.66	1.40	1.35	1.26	0.75	0.89	0.84	0.97	1.06
MnO	0.02	0.03	0.07	0.03	0.08	0.03	0.04	0.08	0.06	0.05	0.05	0.05	0.04
MgO	0.54	0.36	0.45	0.31	0.57	0.43	0.58	0.59	0.49	0.61	0.50	0.54	0.49
CaO	1.27	1.02	1.74	0.86	0.57	1.48	1.64	1.68	1.57	1.86	1.72	1.76	1.43
Na_2O	2.84	2.27	3.70	0.38	3.51	2.75	3.54	3.48	2.85	2.68	2.62	2.72	2.77
K_2O	5.92	6.52	5.25	6.31	5.30	4.15	5.10	5.13	5.93	5.55	5.67	5.76	5.54

P_2O_5	0.07	0.07	0.09	0.04	0.10	0.13	0.04	0.11	0.09	0.09	0.04	1.11	0.16
LOI	0.56	0.16	0.50	0.48	0.95	0.59	0.60	0.45	0.65	1.30	0.80	1.25	0.69
Total			99.89		99.86		99.97	100.08	99.71	99.51	99.21	99.55	99.04
Trace (ppm)													
Co	20	10	20	20	20	20	10	20	20	20	20	10	17.5
Ni	40	50	50	40	50	40	50	40	60	60	50	40	47.5
Cr	55	70	50	50	55	30	55	50	55	75	50	100	57.91
Cu	10	15	10	20	10	<10	15	10	10	25	15	20	14.16
Pb	28	25	31	20	25	<10	20	20	28	<10	<10	25	21
Zn	40	35	30	40	35	35	40	30	30	50	50	40	37.91
Ba	180	420	330	210	416	330	375	436	160	180	200	175	284.33
Rb	175	257	277	265	337	100	257	265	210	140	175	190	220.66
Sr	125	135	111	130	111	120	124	132	110	100	132	124	121.66
Zr	230	280	288	290	308	200	352	282	220	225	135	140	245.83
A/CNK	1.04	0.98	0.90	0.94	0.93	0.95	0.92	0.90	0.94	0.95	1.00	0.94	0.94
C.I.P.W(Norm)													
Quartz	30.00	32.70	25.92	33.40	26.68	36.90	28.55	29.39	29.78	30.29	30.52	29.60	30.31
Orthoclase	35.10	38.80	31.02	37.80	31.32	24.80	30.08	30.37	35.04	32.86	33.57	33.98	32.89
Albite	24.10	19.30	31.22	20.40	29.70	23.70	30.04	29.45	24.03	22.76	22.09	23.10	24.99
Anorthite	6.00	4.80	4.63	4.10	5.29	6.60	5.32	4.81	5.89	7.52	8.32	6.64	5.82
Diopside			2.90		1.51		2.17	2.38	1.06	0.89	0.16	1.08	1.51
Hypersthene	3.06	4.59	2.21	1.08	3.05	2.98	2.08	1.77	0.74	1.17	1.30	0.92	2.07
Magnetite	3.09	1.10	0.71	1.28	0.55	0.34	0.38	0.43	1.86	1.81	1.67	1.88	1.25
Ilmenite	0.36	0.42	0.57	0.60	0.57	0.50	0.66	0.80	0.46	0.72	0.70	0.85	0.60
Apatite	0.17	0.17	0.21	0.10	0.23	0.31	0.09	0.23	0.21	0.19	0.09	0.23	0.18
Niggli Values													
Si	370.85	395.92	379.37	395.4	38.11	387.41	396.84	370.90	395.98	387.47	391.88	385.68	357.98
Al	42.10	42.64	41.65	41.92	41.88	42.38	42.42	42.14	42.53	41.99	43.82	41.72	42.26
Fm	11.70	12.48	12.25	11.94	13.38	11.71	11.74	11.72	12.57	13.70	12.48	14.11	12.48
C	9.83	9.88	9.81	9.22	8.84	8.99	9.58	9.88	9.23	10.71	10.11	10.11	9.68
Alk	36.60	35.85	36.27	36.20	35.88	35.98	36.24	36.50	36.65	33.26	33.57	34.03	35.58
Mg	0.39	0.32	0.28	0.32	0.30	0.40	0.37	0.41	0.38	0.42	0.34	0.38	0.35
K	0.50	0.48	2.47	0.56	0.50	0.54	0.48	0.49	0.57	0.57	0.59	0.58	0.69

Based on chemical studies, the kinematic classification was given for granitic rocks by Marmo (1955)[17], 1971[18]); the synkinematic granite is characterized by alk: c = 3, f_m is variable but usually between 15 and 30; 6<alk>11; K_2O: Na_2O =<1, whereas in the late kinematic granite, silica, alumina, and alkalies are more than those of synkinematic granite. This kinematic classification is applied to the granitoids of the study area. The average values for granitoids show alk: c = 3.2; f_m = 19.54; alk = 30.53; K_2O: Na_2O = 1.18; these values correspond to syn-kinematic granite.

The trace element content of the TTG/TGM granitoids is more or less consistent with the distribution pattern of the major elements except in the barium values. The K/Rb ratio is similar in all the samples analysed indicating their consanguineous relationship. The MS suite has chemistry distinct from the other two suites of granitoids. It is high silica, K/Rb enriched and high potash rich suite.

In order to establish the chemical classification of granitoids of the study area, all the analysed samples are plotted on K_2O versus Na_2O diagram (Fig.7) (Harpun, 1963)[19]. All the granitoids fall in granite, adamellite, granodiorite and tonalite fields. When the ionic weight percentage of Ca-Na-K are plotted in trilinear diagram (Fig.8) (Dhana Raju and Krishna Rao 1972)[20] most of the granitoids of the study area plot in the field delineated for magmatic rocks. A-B diagram (Fig.9) of Debon and Le Fort (1982)[21] and Debon et al., (1986)[22] is used in distinguishing peraluminous and metaluminous character of granitic rocks. The granitoids of Kadiri area, when plotted on this diagram, show metaluminous character. The metaluminous granites are often calc-alkaline.The classical calc-alkaline trend is clearly brought out on the AFM diagram (Fig.6) (Barkar & Arth,1976[15]). Thus, the granitoids of the study area are magmatic, metaluminous and calc-alkaline, and are grouped under mixed (crust and mantle) origin (Queree, 1985[23]; Jahn et. al., 1988[24]; Stern and Hanson,

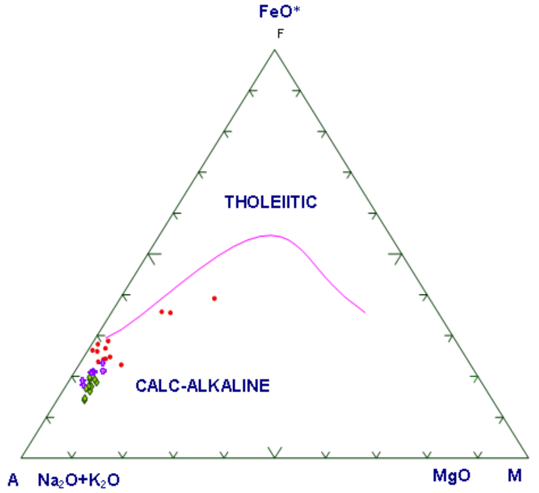

FIG. 6: A-F-M DIAGRAM FOR GRANITOIDS

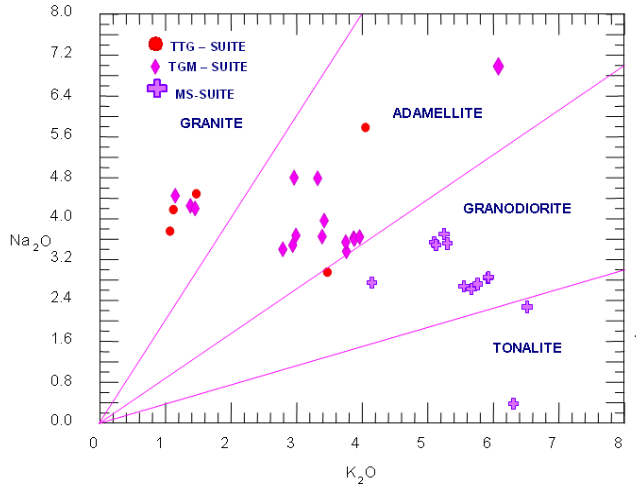

FIG. 7: K_2O Vs Na_2O DIAGRAM

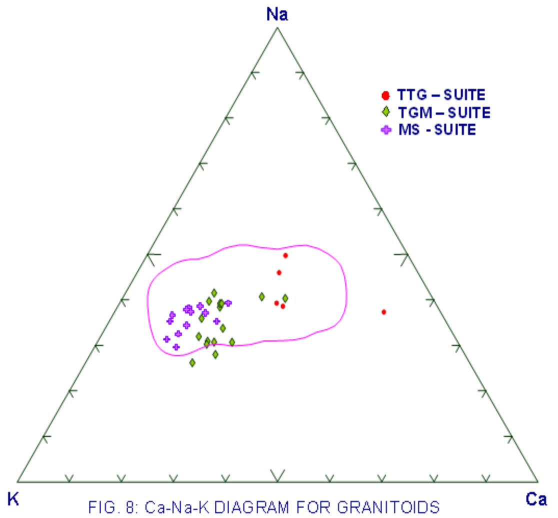

FIG. 8: Ca-Na-K DIAGRAM FOR GRANITOIDS

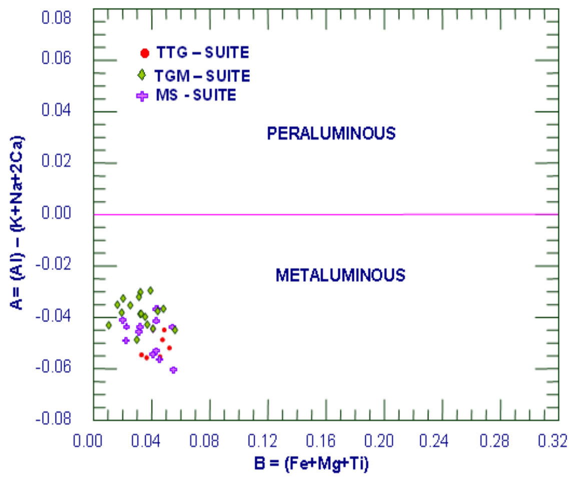

FIG. 9: A – B DIAGRAM FOR GRANITOIDS

1991[25]; Jayananda et. al., 1995[26]).

The metaluminous granites can originate by melting of metabsalt or basic lithologies (Condie, 1981[2]; Ellis and Thomson[27], 1986; Martin, 1987[28]; Tait and Harley, 1988[29]; Silver and Chappell, 1988[30]; Chappell and Stephens, 1988[31]; Sarvothaman and Leelanandam, 1992[32]; Galer, 1994[33]; Hanumanthu and Babaiah, 1996[34]; Hanumanthu and Padmasree, 2003[35]). Most of the petrologists agree that the granites originate at the crust – mantle interface and involve crust and mantle – derived components (Brown, 1977[36]; Leake et al., 1980[37]; Deppaolo, 1981[38]; Didier et al., 1982[39]; Pitcher, 1983[40]). The high TiO2, MgO and Sr values in the granitoids may be inherited from an enriched mantle or lower crust with mafic constituents (Chappell and Stephens, 1988[29]).

1.1. I AND S TYPES: Classification of granites according to their magmatic origin results in the formation of two contrasting groups, S-types and I-types. S-types result from the partial melting of metasedimentary source rocks, a process called anatexis or ultrametamorphism. I-types are derived from source rocks of igneous form composition that have not gone through the surface weathering process, or crystal fractionation of magmas. In the Na2O Vs K2O diagram (Fig.10) Smit, 1982[41], majority of the granitoids of the study area plot in the field of I-type, but some samples of TGM and MS suites are plotting near the margin of the S-type field; this may be due to the crustal contamination. The evolution of MS suite is due to melts derived from crustal anatexis and also partly from mantle derived melts. They show marginally I-type and S-type. The other evidences which support the I –type are Alumina Saturation Index (ASI) (<1) and normative diopside. Thus, the field, mineralogical chemical observations are consistent in discriminating the granitoids of study area under I-type.

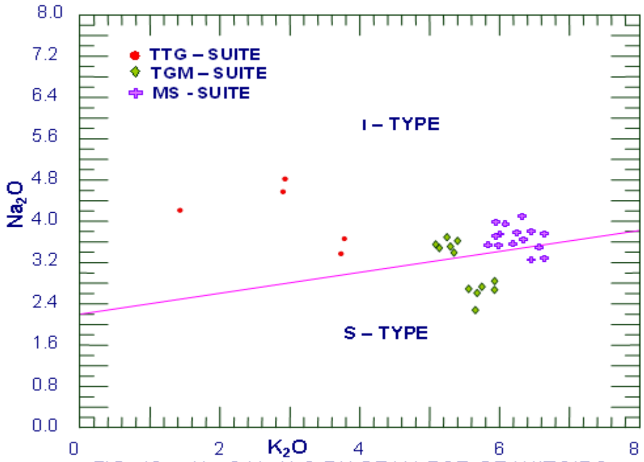

FIG. 10: Na_2O Vs K_2O DIAGRAM FOR GRANITOIDS

V. Petrogenetic Models for Kadiri Granitoids

Some of the late Archaean granitoids in the eastern Dharwar craton have already been studied by several workers who proposed petrogenetic models (Friend, 1983[42]; Condie et al., 1985[43]; Allen et al., 1986[44]; Balakrishnan and Rajamani, 1987[45]; Newton, 1990[46]; Jayananda, M. and Mahabaleswar. B., 1991[47]; Krogstad et al., 1995[48]). The data presented in the preceding topics is qualitatively used to focus on the petrogenetic mechanism and source of granitoids adjoining Kadiri greenstone belt.

5.1. TTG Suite

The TT gneiss forms a unique suite of rocks geochemically similar to the trondhjemitic rocks of the TTG suites occurring in different Archaean terrains. Its high Na_2O/K_2O ratio and high alumina content makes it comparable to the Saganaga tonalite from Minnesota (Arth and Hanson, 1975[49]), Kaap Valley pluton, Barberton Mountain land (Condie and Hunter, 1976[50]), trondhjemite of the TTG suites from Finland (Arth et al., 1978[51]; Martin, 1987[28]) trondhjemitic rocks from the eastern Greenland (Tarney et al., 1979[52]), and the marginal gneiss of the western Dharwar craton (Monrad, 1983[13]). Majority of these Archaean trondhjemites as also some of the later trondhjemites form part of the 'fractionated' gabbro-tonalite-trondhjemite-granodiorite suites. A review of the geochemistry of the Archaean to modern trondhjemitic rocks is given by Drummond and Defant (1990)[53]. Based on trace element composition, it is possible to propose a petrogenetic hypothesis for TT magma, which is to have generated by the partial melting of basic volcanics or reworking of older tonalitic rocks. This can be interpreted in terms of a major input of crustal components in their genesis. After its formation, the protolith of TT gneiss is subjected to deformation and metamorphism together with the greenstone belt. The igneous textures have been totally obliterated and the gneissosity is developed due to deformation (Myers. 1978[54]).

5.2. TGM Suite

The TGM suite is similar to the classic Mesozoic-Cenozoic subduction related calc-alkaline plutonic suites (Roddick, 1983[55]; Anderson, 1990[56]; Pitcher, 1997[11]) in the western part of the two American continents, but more specifically to the Sierra Nevada batholiths (Bateman, 1988[57]) and the Coastal Batholith of Peru (Pitcher, 1985[58]). Gopal Reddy and co-workers (1991[59], 1992[60], 1993[61], 1994[62], 1998[63]), (Gopalan, C.V and Suresh. G., 2004[64]) have reported widespread occurrence of compositionally diverse calc-alkaline granitoids which form a regionally coherent granitoid suite over large tracts of the low grade kadiri granite-greenstone terrain. Field, petrographic and geochemical criteria suggest multifactorial processes (Pichter,1997[11]) responsible for the formation of the expanded suite of TGM. The dominantly metaluminous character of the TGM suite supports the partial melting of meta igneous source.

The compositional variation within the TGM suite as in other calc-alkaline and expanded suites may be due to different petrogenetic processes such as progressive partial melting, partial melting of heterogeneous source, fractional crystalisation of parental granitic magma of relevant composition and magma mixing and mingling by mechanical and chemical interaction of the co-existing mafic and felsic magmas. The recognition of field and pertrographic evidences indicative of the coexistence of mafic and felsic magmas are important for considering the role of magma mixing in the evolution of granites (Reid et. al., 1983[65]; Marshall and Sparks, 1984[66]; Bacon 1986[67]; Didier and Barbarin, 1991[68]).In the study area, ubiquitous presence of mafic microgranular magmatic enclaves (MME) with cuspate and lobate margins within the granitoids with higher mafic content (Fig.11), occurrence of synplutonic microgranitoid mafic dykes (MMD) with lobate margins, back-veining structures and local disruption of the dykes (Fig.12), association of hornblendite-diorite series of rocks(HDS) are some of the evidences which suggest interaction, mixing and mingling of co-magmatic mafic felsic melts within the TGM suite.

The linear inter-elemental variation (SiO2 vs other oxides) and the wide spectrum of compositions (from Fe-Mg poor to Fe-Mg rich and low silica to high silica) support the field and petrographic evidence of magma mixing. Hence, it is inferred that magma mixing has played an important role together with differentiation by crystal fractionation during the evolution of the TGM rocks.

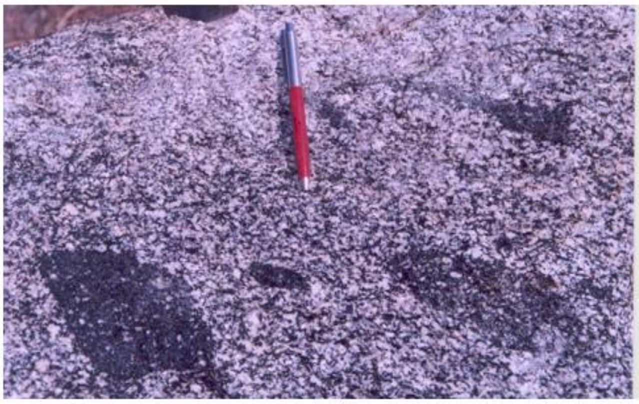

Fig. 11 Micro mafic enclaves in TGM Suite

Fig. 12 Disrupted MMD in Granitoids

5.3. MS suite

The MS suite is similar in composition to the closepet granite which is an extensively studied granite batholith of the Dharwar craton. The early workers suggested metasomatic transformation of the surrounding rocks of Peninsular Gneiss and Schistose rocks (Radha Krishna, 1956[69]; Divakar Rao et al 1972[70]) for the origin of closepet granite, based on the prevailing theories on the origin of granites. But the later workers on the grounds of field relations, petrography, geochemistry and isotopic studies have advocated partial melting of the Peninsular Gneiss (Friend, 1983[42]; Friend and Nutman, 1991[71]; Newton, 1990[46]; Jayananda & Mahabaleswar, 1991[47]; Jayananda et al., 1995[26]). Condie et al (1985[43]) emphasized the significance of fractional crystallization after partial melting. Partial melting of the pre-existing crustal rocks is the only plausible model for the generation of the MS suite. It has restricted chemical composition, close to the "granite minimum melt" which is characteristic of granites derived by crustal anatexis (Winkler 1979[72]). The high Rb and low Sr indicate crustal derivation by partial melting for the origin of the MS suite.

VI. Discussion & Conclusions

Based on intensive field and petrographic studies it can be said that the polyphase polymigmatised TTG banded gneisses indicate existence of older simatic crust which upon migmatisation and intrusion of differentiated mafic melts gave rise to varied sialic crust in the marginal basin environment. The migmatisation at different periods gave rise to different generations of trondhjemites. The compositionally expanded calc alkaline TGM suite is metaluminous with synplutonic microgranitoid dykelets and enclaves indicating magma mingling & mixing and fractional crystallization differentiation. The geochemistry points to mantle derived melts as source for these rocks and continental magmatic arc tectonic environment. During emplacement of TGM, the pre existing subduction TTG crust was migmatised and yielded trondhjemite melts.

The homophanous to leucocratic variants of MS suite of granitoids show intrusive character and range in composition from monzogranite-syenogranite. The main characteristic feature of this suite is absence of microgranitoid dykelets and enclaves. The evolution of this suite is due to the melts due to crustal anatexis and also partly from mantle derived melts. Thus, the field, petrographic and geochemical data is qualitatively used to focus on the processes involved in the magma generation and its evolution that resulted in the manifestation of the three suites of granitoids of the study area.

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