LATE ARCHAEAN - PALAEOPROTEROZOIC ALKALINE MAGMATISM IN THE DHARWAR CRATON OF PENINSULAR INDIA

P.Swamy Sharan[1], S. Ramesh[2],&K.David[3]
[1&3]Department of Geology, Kakatiya University, Warangal-506009, Telangana-INDIA.
[2] Geological Survey of India, Bhopal-462016-INDIA.

ABSTRACT

Alkaline magmatism did not carry out its activities on the planet Earth until the beginning of lateArchaean age although the manifestations of which are found in very few parts including India where the Dharwar Craton in Southern Peninsular India offered the platform to host a late Archaeansyenite body at Koppal in the state of Karnataka. The host DharwarCraton is predominantly represented by calc-alkaline granite with subordinate components of granodiorite, diorite and gabbro. The oblong syenite pluton, trending in the NE–SW direction, occupies an area of about 115 sq.kms. and it has a sharp contact with the surrounding granite gneisses. In the chondrite normalized REE plot, all the Koppalsyenites, without exception, show a contrasting pattern of LREE enrichment and HREE depletion. A sample of Koppalsyenites has given the SHRIMP Ur/Pb age Zircon age of 2528 ± 9 Ma (Chadwick et al, 2001).

The Dancherla alkali syenite body is located to the west of the PalaeoproterozoicCuddapah Basin in Anantapur district of Andhra Pradesh. The heart shaped Dancherlasyenite body occupies an area of 15 km^2 trending in the NNW-SSE direction. Rb-Sr whole rock isochron age of 2211 $\pm$ 110 Mawas indicated for the Dancherla alkali syenite body with low initial 87_{Sr} / 86_{Sr} ratio of 0.7004 $\pm$ 0.00046 (G.Suresh et al., 2010). The shonkinite magma, which was responsible for the derivation of syenites at Dancherla was itself derived from an REE enriched metasomatised source in the upper mantle. Plagioclase fractionation did not play any role in the evolution of these rocks as indicated by the absence of Eu anomaly.

Keywords: LateArchaean, Palaeoproterozoic, DharwarCraton, Syenite, Koppal, Dancherla,

INTRODUCTION

Globally alkaline rocks constitute a very minor group of all the variety of Igneous rocks. Alkaline magmatism started its course during the late-Archaean period but the activity of alkaline magmatism was far less during this and the succeeding period of Palaeoproterozoic time. If alkaline rocks are rare in general throughout the world, these rocks are even extremely rare during the late Archaean and Palaeoproterozoic period.

DISTRIBUTION

Fig.No.01: Distribution of late-Archaean alkaline rocks and carbonatites of the world

Table No.01.Distribution of late Archaean alkaline rocks and carbonatites of the world

Sl.No	Location - Area	Continent	Country	Age (in Ma)	Rock Types	References
01.	Itiuba Alkaline Syenite massif, Bahia State. $11^0 20'S$ $41^0 18'W$	South America	Brazil	2100	Alkali Syenites	Conceicao et al (1990, 1991)
02.	Guanambi-Urandi Batholith, GacaraSuja, South West Bahia State. $11^0 25'S$ $41^0 17'W$	South America	Brazil	2100	Alkali Feldspar Syenite, Monzonite	Paim et al (2002)
03.	Sakharjok West Keivy, Central Kola Craton alkaline massif. $61^0 34'N$ $105^0 15'E$	USSR	Russia	2105	NephelineSyenite, Alkali Syenite, Carbonatite	D.Zozulya et al (2009)
04.	TupertalicCarbonatite.					Larsen et al (1983),

	68^{0}94’N 50^{0}51’W	North America	Western Greenland	2105	Carbonatite	Larsen & Rex et al (1992)
05.	**KoppalSyenite, Eastern DharwarCraton,Karnataka.** **15^{0}20’N** **76^{0}15’E**	**Asia**	**India**	**2500-2400**	**Alkali Syenite**	**Chadwick et al (2001), Sadashivaiah&Ghosh Roy et al (1985),**
06.	The Slave Province, North West Canada. 55^{0}48’N 106^{0}03’W	North America	Canada	2606-2595	Syenite, Carbonatite	M.EVilleneuve et al (1998)
07.	SiilinjarviCarbonatite Massif, Westerm Karelia Craton. 61^{0}57’N 25^{0}44’E	Europe	Finland	2610	Carbonatite	Patchett et al (1981), Lukkarinen et al (2003), D.Zozulya et al (2009)
08.	Kola Peninsul Murmansk Domain. 68^{0}53’N 33^{0}02’E	USSR	Russia	2750-2610	Alkali granite, syenite, nephelinesyenites, carbonatites	M.N.Petrovsky et al (2009)
09.	Panozero pluton, Karelia. 63^{0}09’N 32^{0}59’E	USSR	Russia	2750-1900	Syenites, Xenoliths of kimberlites& alkaline rocks	S.B.Lobach-Zhuchenko et al (2010)
10.	Murdock Cree Pluton, Kirkland lake. 48^{0}09’N 80^{0}01’W	North America	Canada	2680	Melasyenite, melamonzodiorite, meladiorite, alkalifeldsparsyenite	Stephen M Browins et al (1993), Wyman &Kerrich (1988), Keiko et al (1996)
11.	Abitibi Greenstone belt. 48^{0}39’N 79^{0}48’W	North America	Canada	2680-2670	Alkali granite, Syenite, Nephelinesyenite	Sutcliffe et al (1990), Corfu et al (1991, 1989), Feng&Kenich et al (1992),
12.	Keivy Complex of the central Kola peninsula. 68^{0}52’N 33^{0}02’E	USSR	Russia	2682-2613	Alkali syenite, alkaline granite, syenogranite, nephelinesyenite	Mitrofanov et al (2000), Zozulya et al (2001,2009)
13.	Mikkelvik Alkaline Massif/Stock. 70^{0}03’N 19^{0}58’E	Europe	NorthernNorway	2695	NephelineSyenites, CancrinteSyenite dykes	D.Zozulya et al (2009), Boe (2000), Kulernel et al (2006)
14.	Mikkellvik alkaline stock, Westtroms basement complex. 70^{0}03’N 19^{0}58’E	Europe	Northern Norway	2695	NephelineSyenite, alkali (aegirine-augite) syenite	D.Zozulya et al (2009)
15.	Skjoldungen alkaline province, Eastern Main Craton. 66^{0}00’N 36^{0}58’W	North America	South Eastern Greenland	2698-2664	Syenite, NephelineSyenites, Carbonatites	Blichert-Toft et al (1995), D.Zozulya et al (2009)
16.	Cindar Lake (Gods lake domain), Knee lake area, Monitoba.	North	Canada	2705	Aegirine-NephelineSyenite,	A.R.Chakhmouradian

	$35^0 18'$N $111^0 31'$W	America			Biotite-VishneviteSyenite,	et al (2008)
17.	Poobah lake alkali rock complex, rainy river, Ontario. $40^0 26'$N $111^0 47'$W	North America	Canada	2706	Malignite (nepheline+pyroxene+K-Feldspar)	R.P.Sage (1988) Mitchel (1976)
18.	Eastern Gold Fields, Australia, YilgarnCraton. $31^0 14'$S $119^0 20'$E	Australia	WesternAustralia	2715-2630	Alkaline granite, Syenite, Monzonite	Stephen wyche et al, Smithies, Champion et al (1999)
19.	Sanukotoid pluton, Baltic Shield, Central Karelia. $61^0 31'$N $105^0 18'$E	USSR	Russia	2740	Monzonite, Lamprophyres	S.B.Lobach et al (2008), Blichert-Tort et al (1996)
20.	Pilbara Craton, Wstern Australia. $35^0 59'$S $146^0 16'$E	Australia	Western Australia	2940-2930	K-rich syano granite,	R.H.Smithies et al (2000), Nelson et al (19981&999)

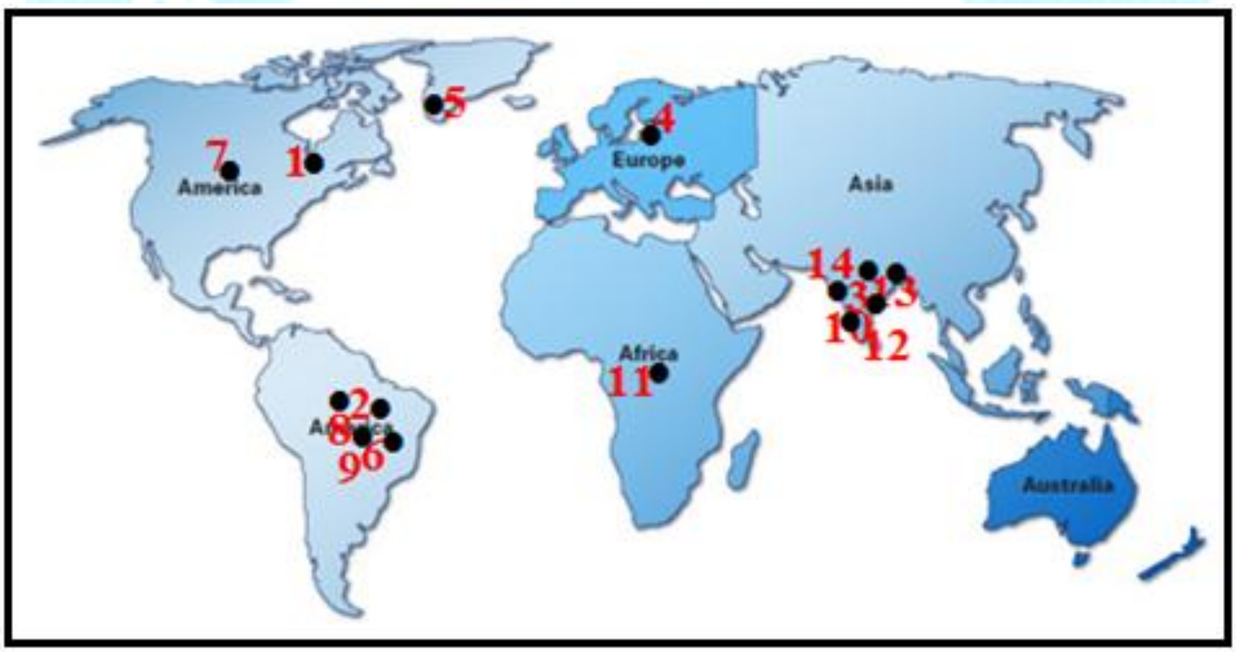


Fig.No.02:Distribution of Palaeoproterozoic alkaline rocks and carbonatites of the world

Table.02.Distribution of Palaeoproterozoic alkaline rocks and carbonatites of the world

Sl.No	Location - Area	Continent	Country	Age (in Ma)	Rock Types	References
1.	Kirkland lake $48^0 09'$N $80^0 01'$W	North America	Canada	1505	Trachyte/ Syenite	Woolley et al (1987)
2.	Campalegreo de lourdes alkaline province $10^0 54'$N $51^0 54'$E	South America	North Eastern Brazil	1507	Alkali Syenite	Wernick et al (1981) Pla'Cid et al (2001)

3.	Pulikonda Alkaline Province, Eastern DharwarCraton, Cuddapah. 13^{0}56'N 78^{0}51'E	Asia	India	1500	Aegirinie – augite, Alkali Syenite	G.Suresh et al (2010)
4.	Koillismaa layered igneous complex 63^{0}23'N 33^{0}17'E	Europe	Finland	1615	Quartz alkali feldspar syenite	Lauras et al (2004)
5.	RapakiviKetilidianorogen 65^{0}58'E 37^{0}08'N	Greenland	South Greenland	1790	Rapakivi Granite, Syenite	Grocott et al (2000)
6.	Angico dos Dias, North Bahia State. 14^{0}30'S 51^{0}48'W	South America	Northern Brazil	1800	Carbonatite, Syenite, Alkali Lamprophyre	Silva et al (1988)
7.	Wollastone Domain lake area, Saskatchewan. 52^{0}05'N 106^{0}31'W	North America	Canada	1812	Monzodiorite	Harper et al (2006)
8.	Serro do Meio Suite, Riocho do pontal fold belt. 12^{0}45'S 38^{0}44'W	South America	Northern Brazil	2010	Carbonatite	J.Pla'Cid et al (2001)
9.	Morro do AfonsoSyenite intrusion/pluton 12^{0}40'S 39^{0}45'W	South America	Brazil	2098-2081	Alkali feldspar syenite	J.Pla'Cid et al (2006) Conceica et al (1995)
10.	**DancherlaSyenite, Eastern DharwarCraton, Anantapur. 15^{0}07'N 79^{0}32'E**	**Asia**	**India**	**2200**	**Alkali syenite**	**G.Suresh et al (2010)**
11.	Congo Craton (Ntem complex), South Cameroon. 0^{0}04'S 15^{0}48'E	Africa	Congo	2321	Syenite	R.Jahamari et al.
12.	**PikkiliNephelineSyenite, Tamil Nadu. 12^{0}15'N 78^{0}03'E**	**Asia**	**India**	**2340**	**Nepheline Syenite**	**Kumar et al (1998), Navaneethakrishnan&Chandrasekaran et al (1994).**
13.	**Hogenekal, TamilNadu. 12^{0}07'N 77^{0}46'E**	**Asia**	**India**	**2436**	**Carbonatite**	**Anil Kumar et al (1998),**
14.	**Newania, Rajasthan. 25^{0}32'N 74^{0}42'E**	**Asia**	**India**	**2436**	**Carbonatote**	**Schleicher et al (1997).**

The intensity of alkaline magmatism during the primitive stages in the late Archaean and the Palaeoproterozoic to the present indicates a gradual increase especially during the Phenerozoic. In contrast the sub-alkaline magmatism during the same period of evolution shows no such trend.

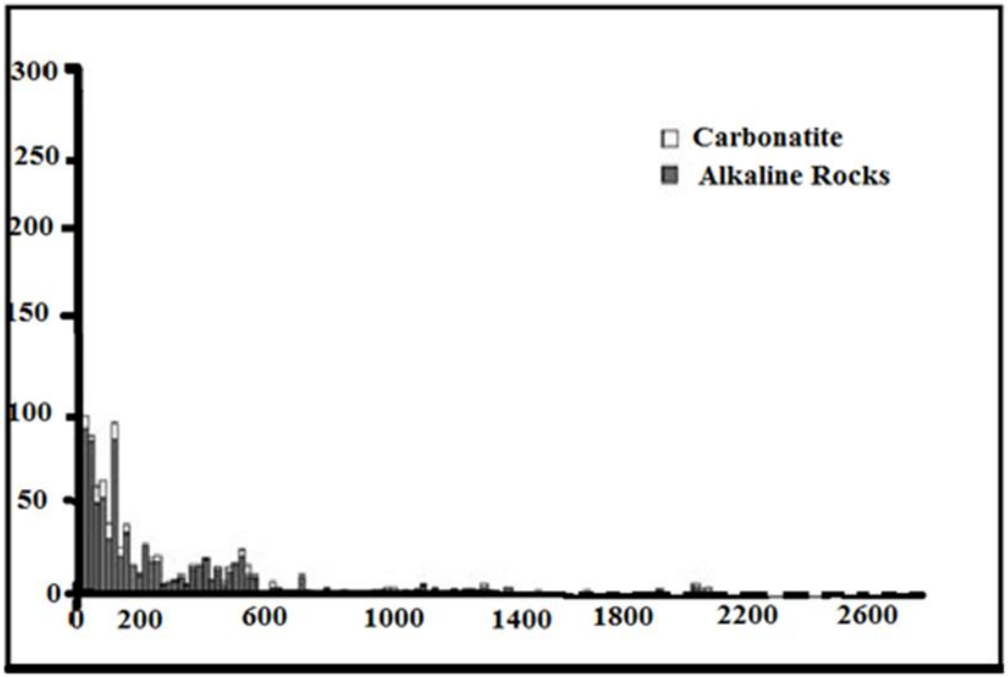


Fig.3. Distribution of intensity of continental alkaline magmatism with time (after Kogarko, 2006)

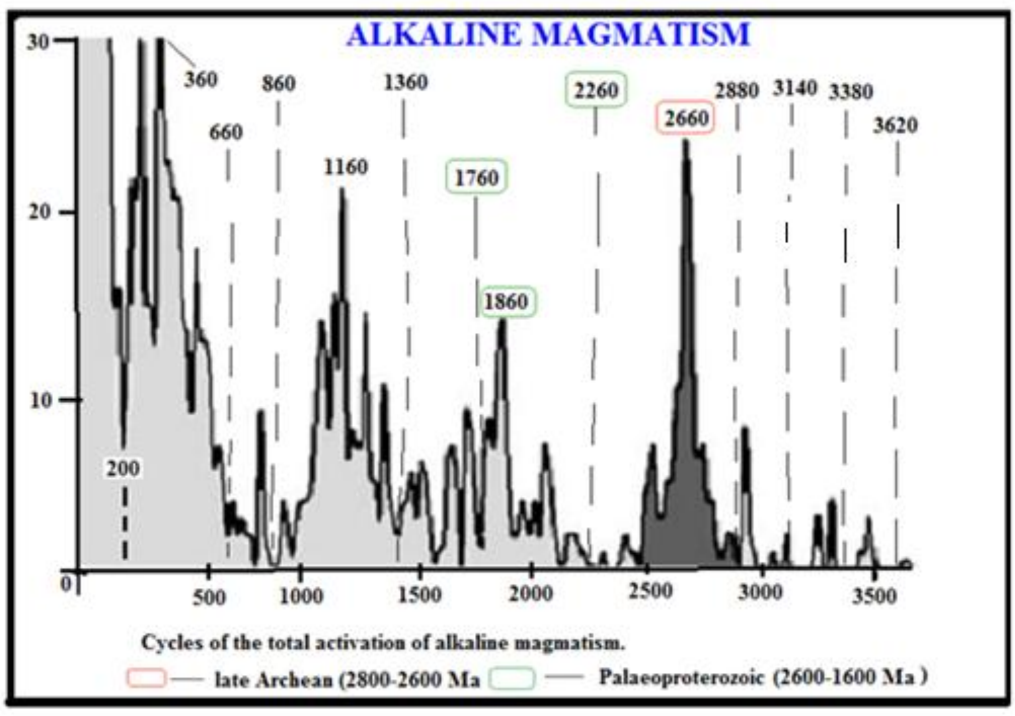


Fig.4. Cycles of the total activation of subalkaline and alkaline magmatism, whose boundaries were constrained based on sharp decrease in magmatic activity (after Balashov & Glaznev, 2006)

As reflected elsewhere, late Archaean and Palaeoproterozoic alkaline rocks are extremely rare occurrence in India also.

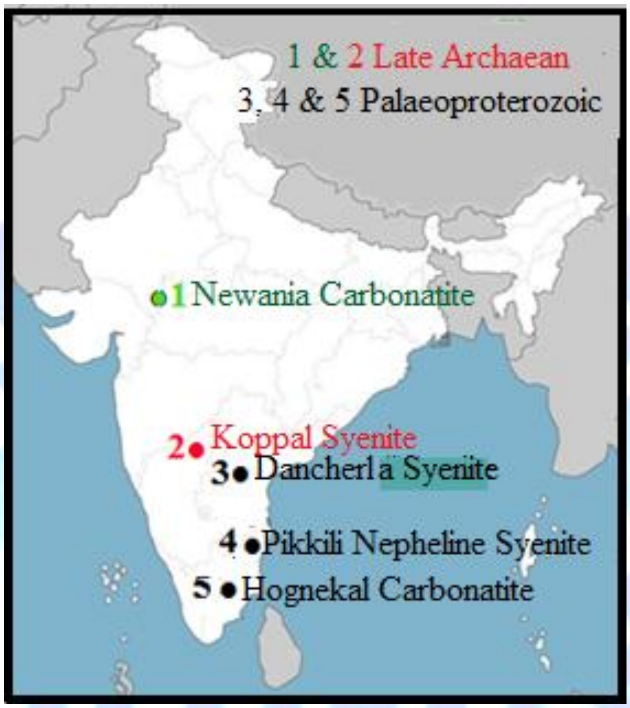


Figure No.05: Distribution of late ArchaeanAlkaline Rocks and Carbonatites of India

In order to understand the background of alkaline magmatism and alkaline magmatic activity in the Indian sub-continent, it becomes necessary to know how alkaline rocks are distributed in the sub-continent.

To cut the long story short, about six alkaline provinces have been identified in India which is as follows...

I. Southern Indian Peninsular Province,
II. Cuddapah Intrusive Province,
III. Bastar Province,
IV. Deccan Province,
V. Vindhyan Province and
VI. Shillong Province.

REGIONAL GEOLOGY

Out of the six alkaline provinces, in India three belong to the Midproterozoic age and one, two Neoproterozoic followed by Cretaceous to Triassic. These younger provinces are located one on the western side in the Deccan Volcanic Province (DAP) and another on the North Eastern Province. It is interesting to note that in India almost all the late Archaean and Palaeoproterozoic alkaline rocks occur in Peninsular India including the Southern Indian Peninsular Province. Only one occurrence of Palaeoproterozoiccarbonatite can be found outside the peninsular India and it occurs at Nawania in Rajasthan which is situated in the northern part of India. The occurrence of late Archaean and Neoproterozoic alkaline rocks in the DharwarCraton has been taken up for a detailed study and the same has been presented here. The late ArchaeanKoppalsyenite pluton occurs 15°20' N; 26°15' E in the neighbouring southern state of Karnataka, it spreads over an area of about 100 sq.kms. The syenite has intruded the country rocks represented by metatexites and older gneisses with local swarms of late pegmatoids.

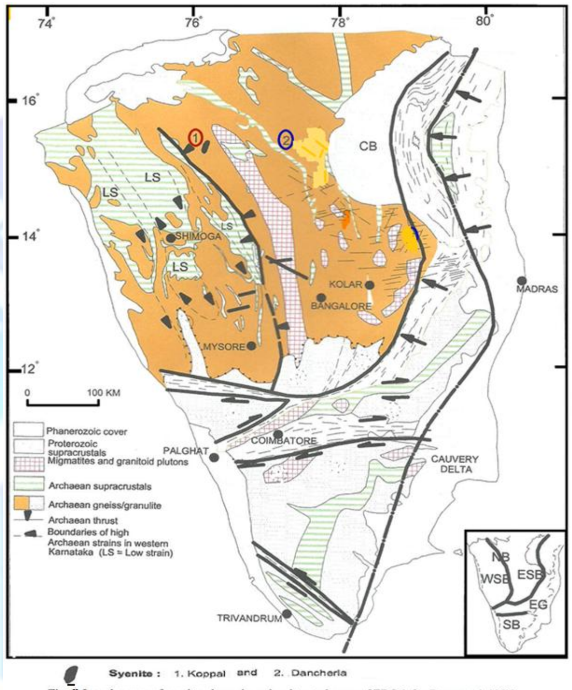


Fig. 5 Location map of syenites shown in regional tectonic map of EDC (*after* Drury et al. 1984).

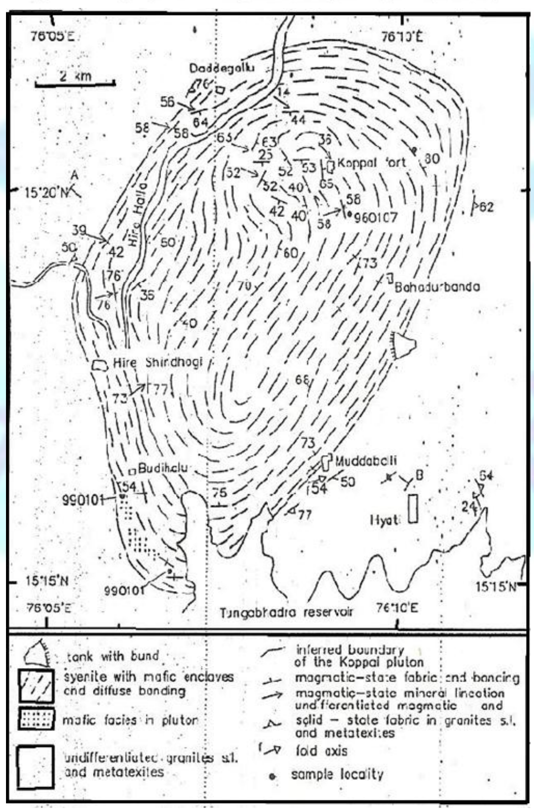
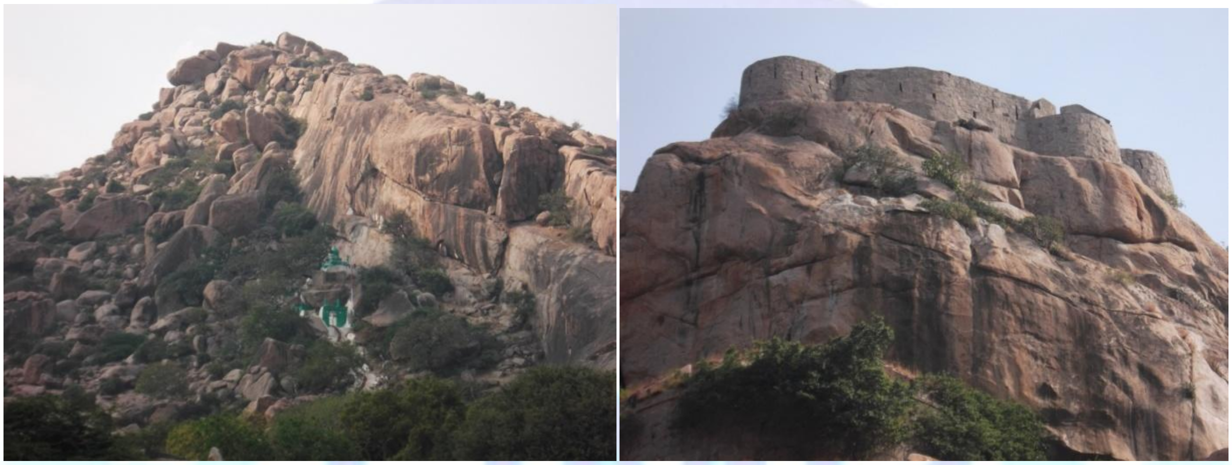


Figure No.07: Map of the exposed area of the Koppal pluton and its granites. The NE and SW closures of the pluton are not exposed but the inferred boundary in these areas is in accord with observations by Appanagoudar (1973) (after Chadwick et al., 2001).

Field photographs of late ArchaeanKoppal alkali syenite pluton



Few occurrences of Late Archaean to palaeoproterozoicsyenites and alkali syenites (aegirine – riebeckite) have been found recently in the northwestern and northcentral part of the Eastern DharwasrCraton. These rocks are mostly confined to major regional scale deep seated strike slip fault zones which were identified west and south of the Cuddapah Basin in EDC (e.g., Dancharla alkaline complex, Anantapur district, Andhra Pradesh, South India), and this alkaline magmatism took place prior to the emplacement of mafic dyke swarms (MDS).

Therefore, these these episodes (Koppal and Dhancharla) have been accounted as primary alkaline magmatic event in the Eastern DharwarCraton as well as the Indian sub-continent during the period of 2.52 Ga to 2.21 Ga.Mesoproterozoic to Neoproterozoic(1400 to 600) alkaline magmatism of the Prakasham Alkaline Province (PAP) have been taken place where the contact zone between Eastern DharwarCraton (EDC) and Eastern Ghat Mobile Belt (EGMB) represents intra-plate alkaline magmatic environment, considered as second event in the Eastern DharwarCraton. Thus, there is a huge gap identified between primary (late Archaean to Palaeoproterozoic) and secondary event (Mesoproterozoic to Neoproterozoic). In this gap there are no such alkaline magmatic occurrences found in the Eastern DharwarCraton (EDC).

Palaeoproterozoic alkali syenite pluton is found at Dancherla of Anantapur district. The Dancherla alkali syenite pluton occupying an area of about 15 sqkms and is located to the west of the PalaeoproterozoicCuddapah Basin. The heart shaped Dancherlasyenite body trends in the NNW-SSE direction. As in the case of Dancherlasyenites are also emplaced within the Archaean gneisses.

These syenites are mostly or completely felsic rich rocks composed of non-perthitic micro clean with subordinate plagioclase. Amphibole can be seen getting replaced by biotite. TheDancherla alkali syenite is a coarse grain variety mostly composed of non-perthitic microcline with sub ordinate plagioclase. The maficsconstituting roughly 30 to 35% are mainly represented by greenish amphibole which shows frequent alteration to chestnut brown biotite. This is the mesocratic variety of syenite.

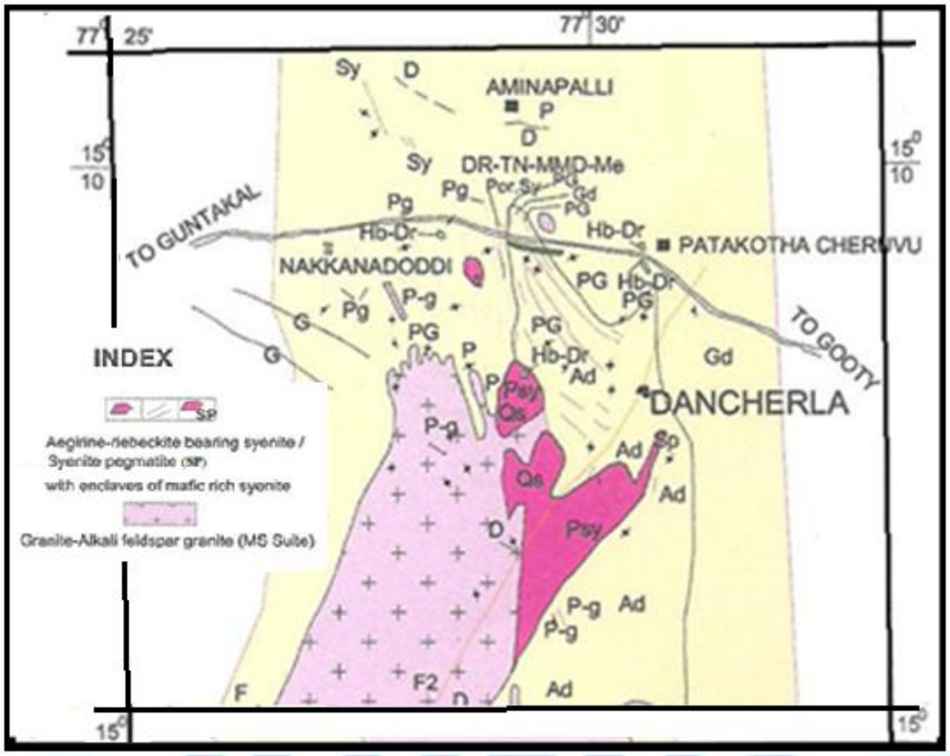


Figure No.08: Geological map of PalaeoproterozoicDancherla alkali syenite

Field photographs of PalaeoproterozoicDancherlaalkali syenite pluton

CONCLUSION

The late Archaean alkaline magmatic activity in the Koppal alkaline pluton first started with ultramafic and mafic magmatism which resulted small lensoidalpyroxenites and dykes of gabbros at limited places; this was followed by gabbros, both are derived from the subalkaline garnet free spinel peridotite mantle source. Further residual magma underwent with low degree partial melting and slightly metasomatised by the plume or slab melt. The resultant magma rich in alkalis and have been enriched in the upper mantle level. On the basis of geochemical studies (enriched LREE, slab pattern of

HFSE and absence of Eu anomaly) the Koppalsyenite has been emplaced into the hotter gneisses during the late Archaean period (accretion of Dharwar batholith) in the modern subductional arc settings in which the alkali rich magma derived from the source of phlogopite bearing garnet-peridotite enriched mantle.

According to Balashov andGlaznev, the distribution of five groups of sub alkaline and alkaline rocks in the late Archaean - Phenerozoic period are strictly controlled by mantle cycles. The relevance of mantle and its subsequent metasomatism for the generation of alkaline magma have to be understood for dealing with the petrogenetic aspects of crustal rocks in the generation of alkaline magmas i.e. in the magmatic processes during the generation of mantle magmas and their consolidation in the crust increases with the increasing age. According to the cycles of alkaline magmatism has proposed by Balashov and Glaznev, the Dancherla rocks come under sub alkaline category and it is interestingly to note that sub alkaline magmatism played dominating role in the late Archaean and Palaeoproterozoic periods. The source magma or the parental magma for the Dancherla has undoubtedly been generated in the mantle which must have undergone metasomatism before the generation of magma. Thus, as elsewhere, sub alkaline and alkaline magmatism have made their signatures somewhat prominently in the Indian sub-continent also.

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