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PETROLOGY OF THE ALKALINE PLUTONS FROM THE SOUTHERN PENINSULAR AT KOPPAL, KARNATAKA STATAE

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ABSTRACT

Alkaline rocks are the principal source of diversified mantle material, which is widely used for the modeling of mantle petrology. This note reports new occurrences of syenite bodies around Koppal area from the Karnataka state. Petrological and geochemical studies suggest that the syenites have a pronounced A-type affinity, metaluminous characteristics with high concentrations of alkalies, Rb, Sr, Zr, and high K_2O/Na_2O ratio. Miaskitic nature (agpaitic index<1) of syenite suggest involvement of CO_2 related phase in their genesis. The petrological characteristics signify crystallization of the rock at shallow levels within the crust. Geochemistry favours mantle origin of the magma and enrichment of Ba and Sr are indicative of involvement of carbonatite melt in the source region. Evidence of alkaline magmatism can be founded as far back as the Late Archaean period.

Key words: Alkaline plutons, Geochemistry, Syenite,Koppal area.

Introduction

The Alkaline rocks are more diverse group of continental rocks which are having mostly alkaline compositions, these rocks occurs in the interior regions of continents and they are far from the orogenic belts of convergent plate boundaries, although some are associated with continental rifting. Alkaline igneous rocks which have higher concentrations of alkalis accommodated in feldspar alone, the excess appearing as feldspathoids, sodic pyroxenes, sodic amphibolies and other alkali rich phases. These rocks are low in SiO_2 and/or alumina with respect to alkalis and will have nepheline and/or acmite in their norm but carbonatites are silica deficient and are rarely alkali rich. Volumetrically, alkaline rocks account for less than one percent of all igneous rocks. Despite this, their remarkable mineralogical diversity has brought them repeatedly to the attention of scientists with the result that alkaline rocks account for about half of all igneous names. This diversity brings largely from an abundance of alkalis and deficiency in silica which together generates a large number of mineral species not stable in more silica-rich, alkali-poor magmas. However, a large part of the attention given to alkaline rocks is due to their characteristic high concentrations of incompatible or large ion litho file (LILE) elements.These are often of more than academic interest as most of the world's resources of Nb, Ta and rare earth elements (REE) are found in or around alkaline igneous rock bodies. The economic importance of alkaline igneous rocks is further enhanced by their association with economic deposits of apatite and with diamonds.

Evidence of alkaline magmatism can be founded as far back as the Late Archaean period. For instance, biotites from the Poobah lake syenite in north-western Ontario have been dated at around 2.7 Ga (Mitchell, 1976) and similar age reported by Larsen et al., 1983 for the Tupertalikcarbonatite in Western Greenland.

Objective

Alkaline rocks are the principal source of diversified mantle material, which is widely used for the modeling of mantle petrology. For this reason the alkaline rocks always give more attention to petrologists and academic researchers. Many alkaline rocks are reported in the world from different tectonic settings, but their occurrence is vey less during the late Archaean period and unique phenomenon in the Indian sub-continent. This late Archaean period is the initial age to their evolution and alkaline magmatic activity was not recorded greater than 2.70 Ga. During the Late Archaean (2.52Ga) period the only occurrence of syenite in Koppal pluton was found in the EDC of South India and comprises mafic (pyroxenite) and felsic intrusions (syenite). The overall objective of this study is therefore to examine and document in detail the field studies, petrography, mineral chemistry and geochemistry of alkaline magmatic activity in the Koppal pluton.

Research methodology

To fulfill the above objective the systematic methodology has been followed and made description here. After concerned detailed literature, the study area covers under Survey of India toposheet no. 57 A/3 (1: 50,000 scale) and detailed field surveys were carried to understand the relationship of the different lithology of the Koppal pluton. During the field surveys various features such as mafic enclaves in different shape and size, synplutonic dykes and schlieren bands have been identified with in the syenite body and the major lithounits have been marked using the Geological map of Koppal alkaline pluton after Chadwick et al., (2001).

Location

In the past Koppal was referred to as 'KopanaNagara' covers few areas of Koppal District. Koppal is newly formed district of Karnataka state on 01-04-1998 and is separated from Raichur District. **The Study area** is situated in and south of the Koppal town lies between 15^{0} 16' 00" to 15^{0} 22' 00" North Latitude and 76^{0} 06' 00" to 76^{0} 10' 00" East Longitude and it falls under Survey of India toposheet no. 57 A/3. Koppal district is bounded by Raichur district in the east, Gadag district in the West, Bagalkot district in the north, Bellary district in the south (Figure.1.1).

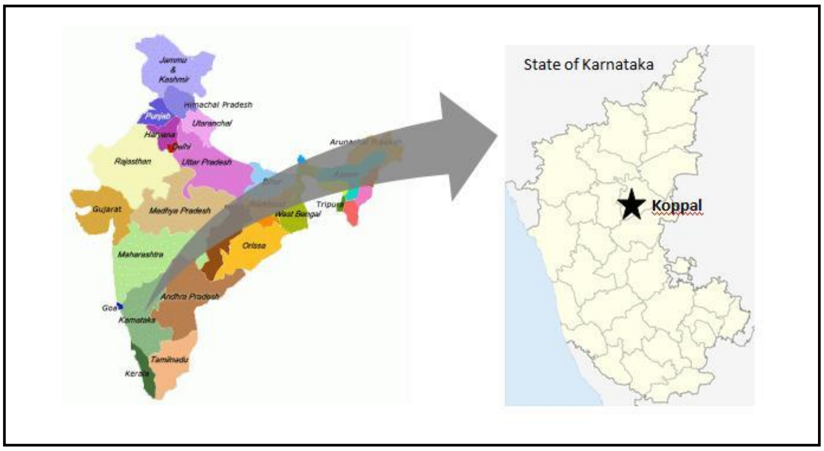


Figure. 1.1 Map showing location of the study area

Definition

The term ‘Syenite’ coined from Latin as "Lapis Syenitis" (lapis = stone; Syene = an ancient city of southern Egypt) (Plinius, Werner, 1788), is a coarse-grained intrusive igneous rock of the same general composition as granite but with the quartz either absent or present in relatively small amounts (<5%). The feldspar component of syenite is predominantly alkaline in character (usually orthoclase). Plagioclase feldspars may be present in small quantities, less than 10%. Syenites are usually either peralkaline with high proportions of alkali elements relative to aluminum, or peraluminous with a higher concentration of aluminum relative to alkali elements (K, Na, and Ca).

Syenites usually occur as relatively small independent intrusions or more commons as satellite bodies, related to larger intrusions with different overall compositions. In many areas Syenites are comagmatic with granitic intrusions. As these Syenites tend to form marginal igneous facies to more bigger granitic bodies, the former are often interpreted as having evolved from the latter. This poses problems, because if a Syenite is to evolve from granite, significant amounts of SiO2 have to removed; and significant amounts of MgO, total Fe, MnO and TiO_2 and also CaO and Na_2O have to be added.Most of the authors agreed that the rock contains any of the property given below than the rock will qualify the term 'Alkaline' (Sorensen, 1974 and references there in).

1. Igneous rocks of Atlantic or alkaline series
2. Igneous rocks with alkali feldspars as predominantfeldspar, i.e. with more alkalies thanaverage for their clans
3. Igneous rocks with feldspathoids
4. Igneous rocks with alkali-lime index less than 51%
5. Igneous rocks with feldspathoids and /soda-pyroxenes and/or amphiboles.

Review of Literature

The Koppalsyenite was first reported by **Sadashivaiah** and **Appanagoudar (1971)** at Koppal area. Based on mineralogy and limited chemical composition,**Appanagoudar (1973)** concluded that the syenite represents an "uncontaminated magmatic residuum", with possible contamination by the host granites at marginal zones. Also, compared the mafic inclusions in syente with amphibolites in the host granites and gneisses and drew attention on pyroxenites in the SW of the pluton.

Brian Chadwick et al (2001) was first recorded a SHRIMP U/ Pb zircon age of the syenitic pluton at Koppal, which reveals that it was emplaced late in the accretion of Dharwar batholith and also discussed about magmatic characteristics, structure and mode of emplacement.

Alkaline rocks in the Continental region

Tectonic settings in the continental areas are much allowed to occurrence of the alkaline rocks then in oceanic settings. Mostly rift systems and subductional arc settings favor to evolve the alkaline rocks.

Alkaline rocks are rare in the Archaean period, but their sporadic occurrences world-wide (Canada, Australia, Greenland and Russia) in late Archaean terrains represented by: *(a)* felsic alkaline intrusive complexes in eroded continental crust (mostly syenites, nephelinesyenites and carbonatites) (e.g., Cavell, et al., 1992; Blichert-Toft, et al., 1995; Zozulya et al.,2005); *(b)* high silica mafic potassic alkaline lavas (e.g., Brooks et al., 1982; Lafleche et al., 1991); and *(c)* the calc-alkaline lamprophyre dikes (e.g., Currie & Williams, 1993) attest to the fact that most of them have been emplaced between 2.7-2.65 Ga. To date, no alkaline rocks have been found in terrains older than 2.7Ga. This apparent paucity of alkaline magmas in the Archean may be due to the existence of a different crust-mantle system i.e., the thermal and tectonic regimes differed substantially from that of the present (such as the well known greater heat production and vigorous mantle convection during Archaean) and which prevented the production of alkaline magmas or merely reflects the lack of preservation.

The late Proterozoic period has witnessed global scale alkaline magmatism between 650-500Ma along the Pan-Gondwana fold belt (Veevers et al., 2007). The alkaline rocks and carbonatites (ARCs), in particular A-type granite, nephelinesyenite, and carbonatites of this age are common in Africa, South America, India, Antarctica and Australia implying that they were generated in an extensional regime of trans-current motions driven by post-collisional oblique stresses related to Pan-Gondwana tectonics. According to Veevers (2007), the ARCs filled openings at releasing bends along trans-current fractures during reversal of the sense of motion as well as during relaxation of stress after collision.

Table. 1 Distribution of Late Archaean alkaline rocks in the World

Sl.No	Location - Area	Geological province	Country
1	Otto stock	Abitibi granite-green stone belt, Lake	Canada
2	Murdock Cree Pluton, Kirkland lake.		Canada

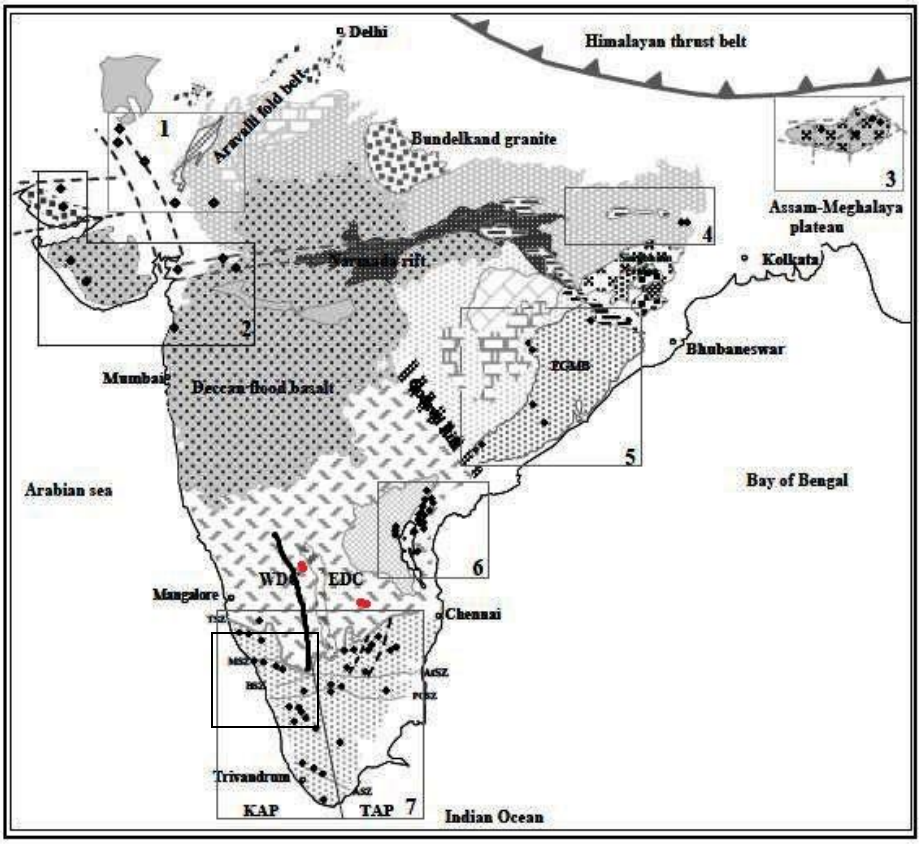
3	Cindar Lake (Gods lake domain), Knee lake area, Monitoba	Superior Province (2700 Ma.)	Canada
4	Poobah lake complex, Quetico provincial park.		NW-Ontario(Canada)
5	Wapikopa Lake		Ontario(Canada)
6	Winnie Lake stock		Canada
7	Garrison stock		Canada
8	Mc Elroy stock		Canada
9	Label stock		Canada
10	Mikkellvik alkaline stock	West Troms Basement Complex	Northern Norway
11	Iokangskii Intrusive complex	Kola Peninsula (2613 Ma)	Russia
12	Murmansk Domain, Kola Peninsula		Russia
13	Keivy and Ingozero Complex		Russia
14	Sanukotoid pluton, Baltic Shield, Lake panezoro pluton, Central Karelia		Russia
15	Mount Monger, Emu, Claypan and Ninnis suites	Eastern Goldfields, YilgornCraton (2650 Ma)	Western Australia
16	Pilbara Craton		Western Australia
17	Skjoldungen alkaline province, Eastern Main Craton	Eastern Nain Craton (2700 Ma)	S E Greenland
18	Koppal alkaline pluton (present study area)	Eastern DharwarCraton (2528 Ma.)	India

(Table compiled from Blichert-Toft et al., 1996; Zozulya et al., 2002, 2008 and references there in)

Alkaline Rocks in the Indian Sub-Continent: An Overview

Alkaline rocks widely distributed in Indian sub-continent from silica over saturated to under saturated varieties with or without ultramafic – corbonatite associations during the time span between 2528 to 40 Ma. Most of thesilica undersaturated types (nepheline bearing felsic and mafic rocks) are confined to the coastal granulite terrain. In accordance with their spatial distribution manifested seven broad alkaline provinces have been documented as follows (Santhosh& Drury, 1988; Santhosh et al., 1989; Ratnakar&Leelanandam, 1989; Rajesh &Santhosh, 1996; Chadwick et al., 2001; Mahadevan, 2002; Leelanandam et al., 2006; Suresh et al., 2010)

These (syenitic) rocks were early reported in the Cuddapah basin of Andhra Pradesh by Willam King (1872), Sivamalai of Coimbatore district, Tamil Nadu by Holland (1901), Koraput of Orissa by Walker (1908), Kishangarh of Rajasthan by Heron-(1924), and Kunavarm-Vinayakapuram of Khammam district, Andhra Pradesh by Hamza Ali (1945-46).



General geological map of India showing major geological terrains and intrusive alkaline complexes of peninsular India. The rectangle demarcates the provinces of alkaline plutonic complexes. 1= Aravalli province; 2= Deccan province; 3=Assam-Meghalaya province; 4= Granulite terrain of West Bengal province; 5=Eastern Ghat province; 6=Eastern Dharwar and Prakasam alkaline province; 7= Southern granulite terrain province which is subdivided into two sub-provinces such as KAP (Kerala alkaline province) and TAP (TamilNadu alkaline province), WDC=Western Dharwarcraton; EDC=Eastern Dharwarcraton. *(Map is compiled from the references mentioned in the subsequent paragraphs)*

Based on their broad spatial distribution, the India alkaline rocks are found in seven different provices (Figure. 2.2), namely,

i. Aravalli belt
ii. Deccan volcanic provice
iii. Eastern Ghat mobile belt
iv. Granulite terrain of West Bengal
v. Assam-Meghalaya plateau

vi. Eastern Dharwar and Prakasham alkaline province

vii. Southern Granulite terrain

Geological Setting of Koppal Alkaline Pluton

The alkaline pluton have emplaced into different geological settings in the world as elliptical, oval, rounded and spherical shaped batholiths, plutons, stocks, plugs and dyke like bodies with or without mixing magmatic characters (mafic enclaves and syn-plutonic dykes). The Late ArchaeanKoppal alkaline pluton (2528 Ma) (Chadwick et al., 2001) is an elliptical body and emplaced into the Peninsualr gneisses in CentalDharwar Province of the Eastern DharwarCraton (EDC), Southern Peninsular India, in and around Koppal town covering at about 60 sq km area and extended towards southerly with its long axis NE – SW direction. As per Appanagoudar, 1973 the host rocks of the Koppal pluton are various granites and gneisses but Chadwick et al., 2001 identified diffusely banded schlieric granites and metatexites derived from older ortho gneisses and it was emplaced late in the accretion of the Dharwar batholith (Chadwick et al., 1997, 2000, 2001). Also he has shown evidences of incompletely melted sheets of gneisses (xenoliths) within the diffusely banded schlieric granites and metatexites which are found immediately adjacent to the Koppal pluton. Intermingling of older grey granitoids and younger pink granites gave rise to diffusely banded granites which were later affected by solid-state flattening and folding (Chadwick et al., 2001). Appanagoudar, 1973 stated that no sharp contact has been identified between syenites and their host rocks i.e peninsular gneisses but Chadwick et al., 2001 concluded that Koppal pluton is an intrusive and not an in situ derivative of host granites. Appanagoudar (1973) mentioned that the boundary of the pluton appears broadly concordant with planar fabrics of host rocks.

Diffused magmatic banding and magmatic foliation represented by mafic minerals are the two principal characters of the KoppalSyenite which are controlled by different variations in proportions of pyroxene, amphibole and feldspars. Magmatic banding persists such a long distance along the strike and break down into schlieric wisps. Magmatic banding and magmatic flow folds are well exposed at Koppal fort. Magmatic state planar fabric parallel to banding defined by pyroxene and amphibole minerals.

The generalized geological sequence which was observed in the field which was corroborated with previous workers and the distinct magmatic events of the area are given in Table. 1

Table.2 Geological sequence of different rock types in the Koppal alkaline pluton

Age	Cratin& sub-craton	Province	Emplaced pluton	Lithology
Proterozoic	Eastern DharwarCraton* (DharwarCraton)	Central Dharwar Province*	Koppal Alkaline Pluton*	Dolerite dykes
Late-Archaean				Quartzo-feldspathic veins
				Pegmatites
				Quartz veins &aplites
				Granite
				Syenite
				Gabbro
				Pyroxenite
Archaean			Peninsular Gneissic Complex	Tonalite- Trondhjemite-Granodiorite gneisses(TTG suite)

(*references mentioned in the text)

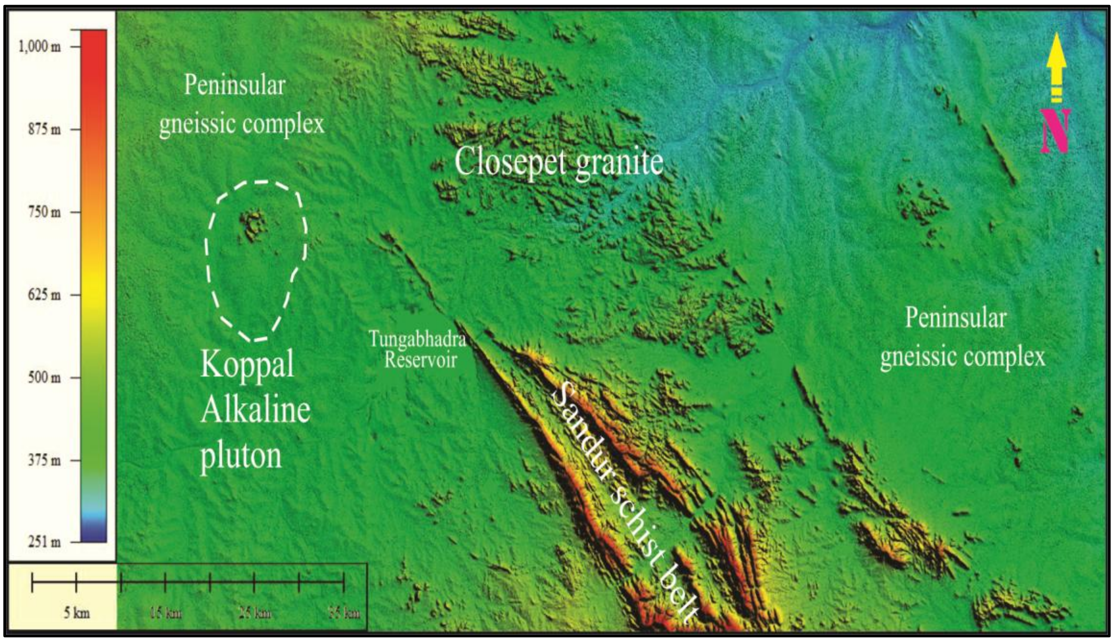


Figure. 3.3 Various lithounitsrevocked from Eastern Dharwarcraton, Southern Peninsular India by DEM HSV shedder map. The present study area- Koppal alkaline pluton marked by dashed circle. *(Source: Bhuvan, NRSA ISRO)*

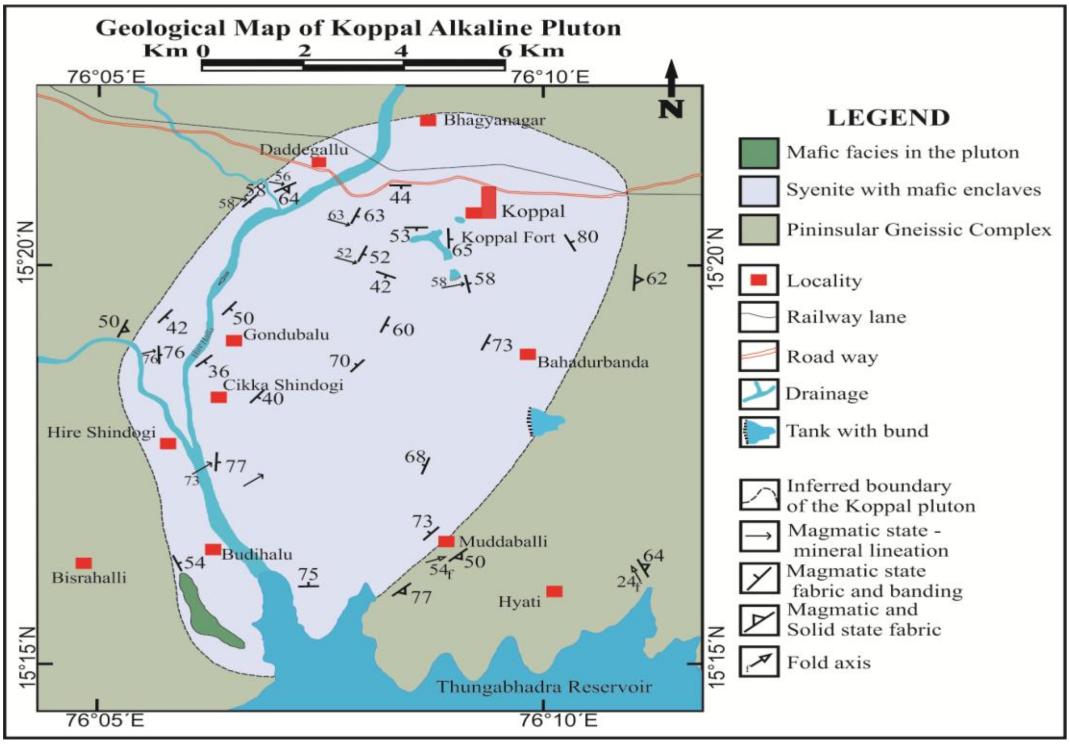


Figure. 3.4 Geological map of the Koppal Alkaline Pluton, Koppal, Karnataka State, India *modified* after Chadwick et al., 2001.

The plutonic regime around Koppal exposes emplacement of a suite of syenites ranging from alkali feldspar syenite, syenite to monzonite into the Peninsular Gneiss. The later intrusives include gabbro and pyroxenite of mafic-ultramafic affinity, small dolerite dykes, pegmatite, aplite and quartz veins of discordant nature.

Each rock type is characterized by some prominent petrographic signatures reflecting their respective chemical composition and crystallization history. Choosing of the rock samples for petrographic studies are necessary to obtain an authentic petrogenetic model, detailed mineralogy, textures and microstructures. The modal mineralogy and detailed textures of the rocks reveal the nature and composition of the rocks and to great extent, the process involved during their magmatic crystallization.

Table.3 Petrographic classification of syenites, mafic and ultramafic rocks of the Koppal alkaline pluton

Location	Nature of the rock	Sample	Colour and grain size
Koppal alkaline Pluton	Mafic-rich Syenite	**L3-K3**	Mesocratic, equigranular
		L6-K3	Mesocratic, equigranular

<table>
<tr><td rowspan="20"></td><td colspan="2" rowspan="2"></td><td>L9-K4</td><td>Mesocratic, equigranular</td></tr>
<tr><td>L11-K1</td><td>Mesocratic, equigranular</td></tr>
<tr><td rowspan="18">Syenites</td><td rowspan="13">Foliated</td><td>L1-K5</td><td>Leucocratic</td></tr>
<tr><td>L2-K2</td><td>Leucocratic</td></tr>
<tr><td>L3-K2</td><td>Leucocratic</td></tr>
<tr><td>L4-K1</td><td>Leucocratic</td></tr>
<tr><td>L5-K1</td><td>Leucocratic</td></tr>
<tr><td>L5-K2</td><td>Leucocratic</td></tr>
<tr><td>L6-K4</td><td>Leucocratic</td></tr>
<tr><td>L7-K1</td><td>Leucocratic</td></tr>
<tr><td>L12-K1</td><td>Leucocratic</td></tr>
<tr><td>L13-K1</td><td>Leucocratic</td></tr>
<tr><td rowspan="5">Unfoliated</td><td>L1-K4</td><td>Leucocratic</td></tr>
<tr><td>L1-K13</td><td>Leucocratic</td></tr>
<tr><td>L8-K1</td><td>Leucocratic</td></tr>
<tr><td>L9-K3</td><td>Leucocratic</td></tr>
<tr><td>L9-K7</td><td>Leucocratic</td></tr>
<tr><td rowspan="2">Intrusives</td><td rowspan="2">Mafic and Ultramafic Intrusive bodies</td><td colspan="2">L1-K2</td><td>GABBRO</td></tr>
<tr><td colspan="2">L1K-10</td><td>Pyroxenite</td></tr>
</table>

The whole rock geochemical studies have been carried out with an objective to mainly decipher the classification of the alkaline rocks and to understand the petrogenetic history. This chapter is dealing with major oxides and trace elemental analysis which are giving here in two different parts. The geochemical characteristics and behavior of alkaline rocks thrust into the most significant part of the igneous rocks due to their fascinating chemistry.

Analytical Methods

The major oxides analyses carried out in the National Geophysical Research Institute (NGRI), CSIR, Hyderabad, India and the trace elements analysis were conducted in Geological Survey of India (GSI), Southern Region, Hyderabad.

Sample Preparation and Processing

Out of 21 samples, 14 samples were selected including 3 mafic intrusive rocks for geochemical studies after thorough scrutiny of megascopic and microscopic observations. They were broken and reduced into small chips by using hammer and hard stainless mortar followed by coarse powder using laboratory type jaw crusher and fine powder was made (-

300 mesh size) by using agate mortar for maintaining homogeneity and true representativeness of the sample. The sample powder was obtained by coning and quartering and followed by storage of the samples in dry plastic containers. Further 1g sample powder is transferred to sample dies and is pelletized with boric acid at a pressure of 25000 kg/cm^2 in a hydraulic press to obtain pellets of 41mm diameter.

The major oxide analysis was carried out by using Phillips Magix PRO model PW 2440 wave length dispersive X-ray fluorescence spectrometer coupled with automatic sample changer PW 2540 and it is a sequential instrument with single goniometer based measuring channel which is covering the complete elemental range from F to U in the concentration range of a few ppm to percentage level. This instrument fully controlled by microprocessor with end window X-ray tube in Rh mode and using maximum voltage/power up to 60 kv/125mA at a maximum power level of 4 KW. The instrument is measured precision between 1% and 2%.

Whole rock geochemistry of the Koppal Alkaline Pluton

The analyzed oxides, trace and rare earth elementals concentrations and along with their corresponding CIPW norm values and coordinates of petrogeny's residua system of investigated syenite, pyroxenite, gabbro and later intruded dolerite dyke from the Late ArchaeanKoppal alkaline pluton have been furnished in Table. 5.7 to Table. 5.8. Geochemical elucidations of the Koppal alkaline rocks including their mafic intrusive were brought out critical characteristics of source of the magma, occurrence and behavior.

During the course of petrographic studies, it is observed that the Koppal alkaline rocks were exhibiting mineralogical consistency but However for the purpose of better understanding we divided into 3 types on the basis of color index (modal abundance of mafic minerals) and textures. Here, in the part of geochemical studies, we adopted same as above which we have shown in the petrography. We kept withstanding on the above, conveniently, described whole rock geochemistry of mafic intrusives and syenites in the subsequent paragraphs.

Major oxide chemistry of ultramafic and mafic rocks

Three samples, pyroxenite, Gabbro and dolerite, are selected for geochemical studies to better understand their geochemical aspects and relationship with syenite. The determined chemical composition of pyroxenite has been furnished in Table 1 and 2. The major oxide data of pyroxenite is showing steep depletion values SiO_2 (43.56), TiO_2 (0.73), Al_2O_3 (7.48), MnO (0.14), Na_2O (1.13), K_2O (0.34), and P_2O_5 (0.11) and highly enrichment of MgO (25.04), CaO (11.87) and FeO (7.18) which indicates the magma is highly differentiated from the source. Expectedly, the pyroxenite consists high magnesium number (Mg# = 100MgO/MgO + FeO_t (85.28), solidification index (71.56) (Kuno, 1968) and low differentiation index (37.16) (Torntan and Tuttle, 1960) and low iron number or Fe- number (0.25). Fe- number has calculated as: ($Fe^v = Fe^{2+}/Fe^{2+} + Mg^{2+}$)

The representative major oxide and their norm values of gabbro and dolerite has furnished in Table 1 and Table 2 respectively. The oxide values in weight percentage of SiO_2 (46.55 & 45.08), MnO (0.18 & 0.18), K_2O (0.62 & 1.26), P_2O_5 (0.17 & 0.09) are lesser content whereas Fe_2O_3 (3.66 & 5.25), FeO (8.33 & 6.61), MgO (11.57 & 13.4) and CaO (10.21 & 10.36) are enriched of both gabbro and dolerite respectively. In fact, depletion of SiO_2, MnO, K_2O and P_2O_5, slightly enrichment of Fe_2O_3 and Na_2O and strong enrichment of MgO, CaO and FeO indicate calc-alkaline character and differentiated source of the magma.

Here the determined chemical analyses are presenting through different variation diagrams to chemically classify the rocks and determine the course of magmatic crystallization. The investigated pyroxenite and gabrro both are showing sub-alkaline nature whereas later intruded dolerite is exhibiting alkaline affinity (Figure.5.1a) (Irvine and Baragar, 1971). When plotted total alkalis against silica (Figure.5.1) (Cox et al., 1979; Middlemost, 1985), pyroxenite is exhibiting sub-alkaline ultrabasic peridotitic affinity whereas gabbro is showing sub-alkaline basic gabbroic affinity and dolerite is alkaline basic gabbroic affinity. In accordance this data manifested that subalklaineperidotitic magma formed clinopyroxenite and gabbro by fractional crystallization, and residual magma has become alkaline in nature.

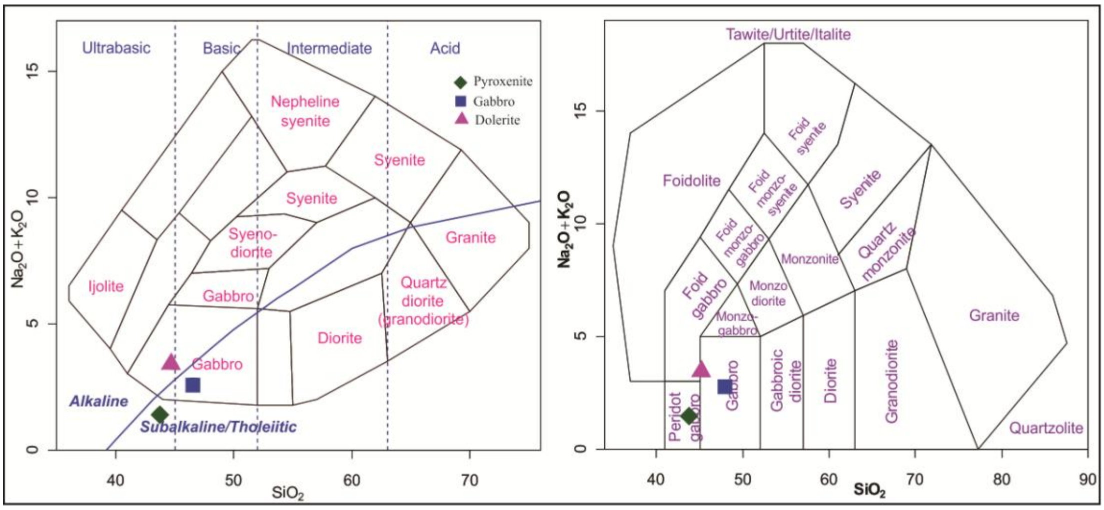


Figure.plot of total alkalis vs silica diagram after Cox et al., 1979 and middle most, 1985. Thick blue line separated between sub-alkaline and alkaline (Irvine and Baragar, 1971)

Conclusions

Undeformed and unmetamorphosedKoppal alkaline pluton constitutes major lithology of ultramafic pyroxenite, mafic gabbro, syenites (alkaline felsic rock), and potassic granites.Early formed pyroxenite and gabbro both are subalkaline rocks whereas syenites are alkaline felsic rocks which reflect an emplacement of the Koppal alkaline magmatism started with subalkaline and ends with alkaline character.The main emphasis and predominant lithounit of the Koppalsyenites are intermediate to basic in composition.

Koppalsyenites are alkaline (low silica and high alkali content) and undersaturated which were corroborated with their normative acmite, nepheline and olivine.These are coming under ultrapotassic/shoshonitic series of rocks.Orthoclase, albite, ferroandiopside to sub-calcic magnesianaugite and edenite (Mg-Hornblende) are the important mineral constituents of the syenites and zircon, apatite, allanite, epidote, titanite and magnetite are the considerable amount of accessory phases.

Alteration of primary minerals affected by the magma's own late stage solutions. These syenits are magnesian, miaskitic (agpaitic index less than 1.2) and metaluminous rocks. Mela, foliated and massive syenites were derived by the process of low degree partial melting as well as progressive fractional crystallization of mafic parental magma This parental magma has been formed by melting of LILE enriched mantle which was composed of phlogopite bearing garnet peridotite.The melt was intruded into the overlying TTG gneissic suite of continental crust through deep seated trans-lithospheric fault and/or shear zones, and induced partial melting. Simultaneously the parental mafic magma underwent a limited amount of fractional crystallization.The differentiated mafic magma and weak assimilation of basement anatexis mixed and produced melasyenite to potassic granites as an end member in the pluton.The enrichment of the mantle might have been metasomatised from hybridized slab melts at subductional environment and emplaced the syenites at the age of 2528 Ma. This phenomenon is to similar and may have coincided occurrence of the Late Archaeanpotassic granites (Closepet granite; 2515 Ma) which were emplaced into the TTG crust of Eastern DharwarCraton.

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