Petrological studies of Kunduluru syenite intrusive, of Andra Pradesh, India

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***Abstract*—The Kunduluru syenite body [81°21'15"N-17°41'45"E], located within the Eastern Ghat Mobile Belt (EGMB) in Andhra Pradesh, India, is an important geological feature associated with alkaline intrusions. The body is primarily composed of leucocratic syenite with a porphyritic to granular texture, and exhibits significant feldspar content, particularly K-feldspar (orthoclase and microcline perthite), along with plagioclase and minor quartz. Mafic minerals such as amphibole, pyroxene, and biotite are present in subordinate amounts, contributing to the rock's mineral diversity. Accessory minerals like zircon, sphene, and apatite are found in trace quantities, while secondary alterations, such as calcite and muscovite, occur in certain sections. The syenites exhibit a high silica content, with a clear dominance of salic minerals, indicating the oversaturated nature of the magma. The intrusive body, with a sharp contact to the surrounding granulitic rocks (gneisses and charnockites), stretches approximately 1 km in length and is situated near a fault lineament trending NE-SW. These syenites reflect the petrogenesis of alkaline magmatic processes in the region and contribute valuable insights into the tectonic history of the area. Field and petrographic studies highlight the role of tectonic forces and crustal processes in the formation of this alkaline intrusion, offering a glimpse into the geological evolution of the Eastern Ghat region.**

***Index Terms*—EGMB, syenite, perthite, Kunduluru alkaline body, Andra Pradesh, India.**

I. INTRODUCTION

The Eastern Ghat Mobile Belt (EGMB) is a northeast trending ~1000 km long discontinuous array of different litho tectonic units, subdivided into four major zones, namely the khondalite zone (KZ), migmatite zone (MZ), western charnockite zone (WCZ), and the transition zone (TZ) (Ramakrishnan et al., 1998; Dasgupta et al., 2017). The WCZ comprises two granulite terranes: Rengali and Jeypore Provinces. The

(deformed) ARCs are located near the boundary of Leelanandam (1990) observed that almost all DARC occurrences of EGMB lie close to the Fermor's line (Fermor, 1936), which bounded the associated with any alkaline silicate host rocks.

The Kunduluru alkaline belt is located in the Bhadrachalam agency area near chinturu in Alluri Sita Ramaraju district, Andhra Pradesh. The Kunduluru alkaline outcrop is located at a distance of 20 km NE of the Kunavaram alkaline body, which has also been mapped and studied in the present study.

II. GEOLOGY AND FIELD SETTING

The Eastern Ghat Mobile Belt map shown (Fig.1) is an important geological region located in India, primarily running parallel to the eastern coastline. It is a part of the larger Peninsular Ghat System, which is known for its significant geological formations. The Eastern Ghat Mobile Belt is predominantly composed of a variety of metamorphic rocks, formed under different pressures and temperatures over geological time. Granulites, gneisses, schists, quartzites, and amphibolites: These metamorphic rocks reflect the complex geological processes that have shaped the Eastern Ghat Mobile Belt, with varying grades of metamorphism and tectonic conditions. The region has undergone multiple phases of metamorphism, ranging from low-grade to high-grade conditions, the tectonics have identified several phases of crustal deformation.

The areas of Kunduluru are mainly covered by khondalites and charnockites of the Eastern Ghat mobile belt. Thus, from an overall picture, the Kunduluru and Kunavaram alkaline belts are

emplaced within the Eastern Ghat granulites close to its western boundary where the Eastern Ghat mobile belt and the Bastar craton are placed side by side.

Detailed field investigations in and around the Kunduluru alkaline belt (Fig. 2) by the candidate spread over for three field seasons, were undertaken to map the alkaline rock belt and as well as the surrounding granulite country rocks. In this context it should be mentioned that the two earlier workers namely Chakravarthi (1972) and Rajesham (1980) have mentioned the occurrence of two parallelly disposed alkaline belts at Kunduluru. The alkaline rocks stretch continuously for nearly 1 km length, from in the Gollagudem NE to Jallivarigudem in the SW, with a width ranging from 200 - 300 m. This belt forms the main alkaline body of Kunduluru and apart from there a small isolated exposure of 100 m length and 50 m width is found 2 km NE of Kunduluru village, the rocks of this exposure are of porphyritic nature unlike the gneissic appearance of the main belt. The contact of this alkaline belt with the adjoining country rocks is observed to be very sharp. Few large xenolithic masses of country rocks are found within the alkaline belt at two or three locations; the contacts between such xenoliths and the enclosing alkaline rocks are again distinctly sharp. The foliation trends in the alkaline belt and in the adjoining country rocks are one and the same (NE-SW). This alkaline belt on its eastern side is in contact with khondalitic rocks and along this contact there flows the Peddavagu which ultimately joins the Godavari River towards the northern side of the belt. The Kunavaram alkaline belt is abruptly terminated towards the southern part by the NE-SW trending Godavari graben.

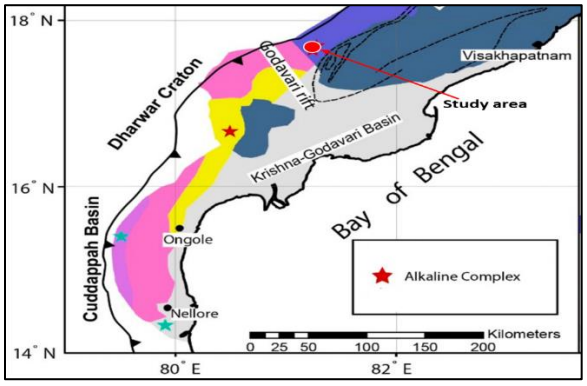

Figure 1: A geological map of the Eastern Ghat Mobile Belt showing study area location (after Dobmeier and Raith (2003); Chetty (2014).

Kunduluru syenitic body displays an intrusive relationship with the hornblende nepheline syenite and biotite nepheline syenite. The associated metamorphic country rock is Amphibolite, granite gneiss and charnockites. Field observations reveal three types of rocks are found in the study area: two pink-coloured rocks and one grey coloured rock. The syenitic body is further intruded by dolerite dykes and sills and further intruded by feldspar veins.

Figure 2: The google earth map of the Kunduluru area.

The pink syenites boulders are found near Gollagudem area (Fig. 3 a & b). Syenitic body exhibits significant grain size variations, with coarse-grained varieties containing abundant pink feldspar and large mafic grains, while medium-grained varieties are richer in grey feldspar, with finer mafics and minor quartz content.

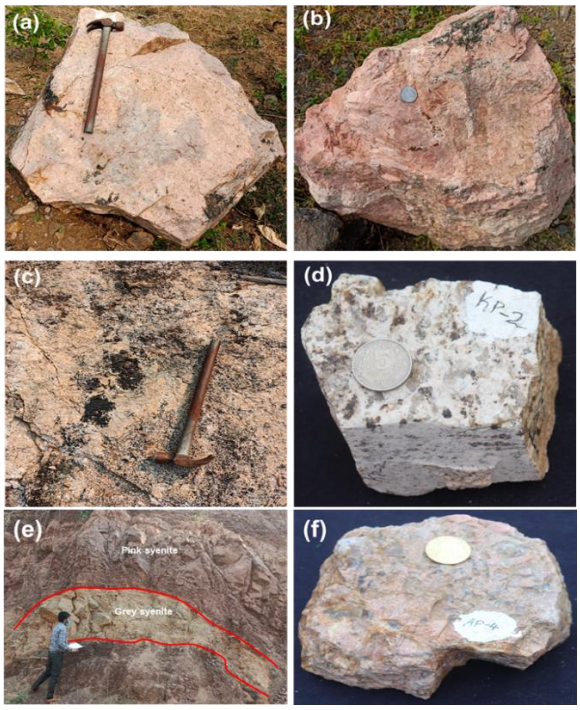

Figure 3: Representative photographs of Kunduluru syenite pluton. (a) & (b) Photograph illustrating

huge pink syenite boulder from the Gollagudem area. (c) Weathered syenite exposed at the Jallivarigudem. (d) Megascopic sample of syenite bodduraigudem area. (e) Overview of the road cutting cross section of pink and grey syenites exposed at Kunduluru. (f) megascopic sample of syenite at Mulkanapally.

III. PETROGRAPHY

The Kunduluru alkaline body consists of several distinct rock types, among which syenite is the primary rock type observed in the field. Petrographic analysis of representative syenite samples from the area reveals detailed information regarding mineralogical composition, texture, and the relationships between various rock-forming minerals. The syenites from Kunduluru exhibit a leucocratic color, and they are characterized by a porphyritic to granular texture. Based on modal compositions, syenite from Kunduluru exhibit a mineralogical composition dominated by alkali feldspar (48-64 vol%) and plagioclase (8-20 vol%), with quartz making up a minor proportion (1-4 vol%). The mafic minerals, including pyroxenes, amphibole, and biotite, contribute to about 5-8 vol%, while accessory minerals like sphene, opaque minerals, apatite, and zircon are present in trace amounts. Secondary minerals, such as calcite and occasional muscovite, are also observed, particularly in altered sections. Based on the modal Q-A-P (table.1) proportions (Streckeisen, 1976), rock samples KL-1-3, MK-3, MK-5, GG6-7, and JG 8-9 are classified as syenites, while all the samples are designated as fall in the syenite (Fig. 4).

The dominant feldspar species in these syenites are orthoclase and microcline. The K-feldspar minerals appear as subhedral to anhedral grains, which are the primary phase of the rock. Orthoclase shows a characteristic cloudy, first-order grey color under polarized light and exhibits carlsbad twinning in some sections. Microcline, the most abundant feldspar, is noted for its distinct cross-hatched twinning pattern, with first-order grey and blue interference colors. Resorbed plagioclase inclusions are sometimes found within microcline crystals, indicating a textural relationship between the two feldspar types (fig. 5f).

Plagioclase in these syenites primarily occurs as subhedral to anhedral laths of albitic composition. These crystals exhibit regular lamellar twinning with closely spaced lamellae, a feature typical of albite. Some plagioclase laths show zoning, often accompanied by sericitization, suggesting alteration in certain sections. Coarse-grained plagioclase sometimes forms intergrowths with K-feldspar, highlighting the close spatial relationship between these two feldspar minerals (fig. 5e).

Quartz in the syenites is present as anhedral grains, varying in size from larger individual crystals to smaller grains filling interstitial spaces between feldspar minerals. The quartz grains commonly show undulose extinction, a sign of crystallographic strain, and appear predominantly within the interstices of feldspar, further indicating the late-stage crystallization of quartz in the syenitic rock (fig. 5c &d).

The mafic mineral suite in Kunduluru syenites consists mainly of amphibole, pyroxene, and biotite. Amphiboles occur as medium to large anhedral to subhedral crystals, evenly distributed throughout the rock. These minerals often exhibit high interference colors, with some crystals showing an acicular habit. Pyroxenes, while less abundant, are also present in anhedral to subhedral forms. Biotite is observed as subhedral to anhedral grains, occasionally displaying a bladed form with bright yellow to brown pleochroic colors. The mafic minerals contribute to the overall ferromagnesian mineral content, although they remain subordinate in the rock (fig. 5a & b).

Various accessory minerals, including sphene, garnet, zircon, and apatite, are observed in trace amounts throughout the syenite. Sphene is typically present as small, anhedral to subhedral crystals that show high interference colors under polarized light. Garnet and zircon are also present in minor quantities, generally occurring as euhedral crystals. Secondary minerals such as calcite are commonly found in altered sections, along with occasional muscovite, which appears as fine-grained aggregates within the rock.

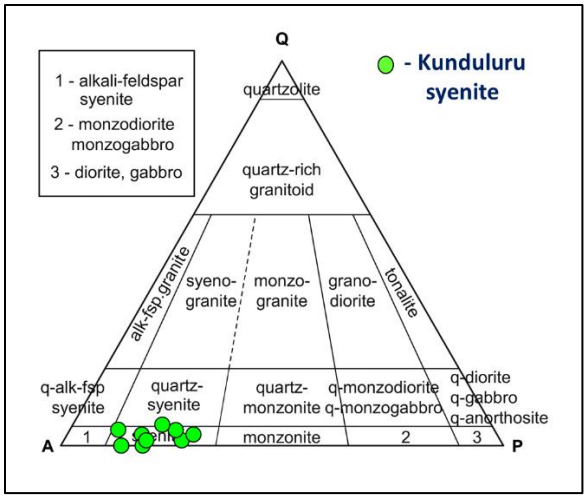

Figure 4: Q-A-P plot of modal composition (vol%) of Kunduluru syenites (green circles), (Streckeisen, 1976).

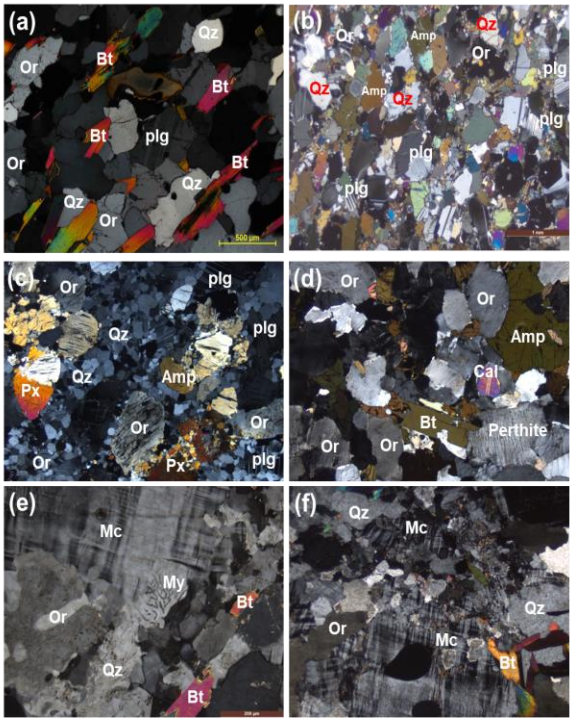

Figure 5: Photomicrographs of representative samples from Kunduluru alkaline body (a) Bladed biotite surrounded by plagioclase laths (b) Amphibole, quartz and plagioclase laths from syenite sample (c) Porphyritic pyroxene, amphibole and orthoclase under XPL from syenite sample. (d) Syenite constituting plagioclase, K-feldspar, amphibole and calcite minerals. (e) Myrmekite texture shows quartz and plagioclase. (f)Iron oxide mineral is surrounded by bigger microcline crystals from syenite samples of Kunduluru.

IV. DISCUSSION

The syenite of KL alkaline body is an ovoid shape body of ~20 sq km intruding the alkaline belt in Eastern Ghat Mobile Belt such as gneisses and charnockites. The alkaline formation of Kunduluru alkaline body is situated in proximity to the continental margin and aligns with a fault lineament trending NE-SW. The leucocratic to melanocratic nature of these rocks show case a diverse range of colors, which include different shades of grey, pink, flesh-tones and greyish-pink. The high proportion of K-feldspars and plagioclase feldspar with relatively low contents of mafic minerals which include amphibole, ±pyroxene, magnetite etc., in the syenites of Kunduluru ensures the colour index barely crosses the 20%, and hence accounts for an overall improvement in the silica content and projects a silica oversaturation character that is well supported by the overwhelming abundances of salic minerals. The KL rocks typically showcase granoblastic texture and range from medium to very coarse-grained, are less deformed and lack any foliation. However, the plagioclase laths in these rocks under the exposure of small stress and strain exhibit bending and stretching of lamellae due to deformation the rocks are primarily comprised of K-feldspar (68-85 vol %), with orthoclase being more dominant than microcline minerals, followed by plagioclase (10-28 vol %) and quartz (1-5 vol %). Mafic minerals such as amphibole dominant over pyroxenes and biotite, and accessory minerals like sphene, opaques (magnetite > ilmenite), apatite, zircon, along with secondary calcite and rare muscovite occur in these rocks. The co-existence of microcline perthite with independent microcline possibly indicates crystallization close to the solvus and abundance of sphene and primary garnet in the rock therefore suggests high titanium content of the parent magma.

V. CONCLUSION

The Kunduluru syenites are leucocratic, feldspar-dominated rocks with a porphyritic to granular texture. The primary minerals include K-feldspar (orthoclase and microcline), plagioclase, and quartz, with secondary mafic minerals such as amphibole,

pyroxene, and biotite. The overall mineralogy is typical of syenitic rocks, with feldspar showing significant variation in size and texture. Accessory minerals like zircon and sphene, along with minor secondary alteration products such as calcite and muscovite, contribute to the complexity of the syenitic composition. These syenites reflect the geologic processes that led to the crystallization of an alkaline magma, offering insights into the petrogenesis of the Kunduluru alkaline body.

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Q: Quartz; A: Alkali Feldspar; and P: Plagioclase

Table 1: Modal Compositions of samples from Kunduluru alkaline body of Andra Pradesh, India.									
	KL	KL	KL	MK	MK	GG	GG	JG	JG
	1	2	3	4	5	6	7	8	9
	3	2	2	3	2	2	1	3	2
K-Feldspar	62	54	57	64	63	48	59	54	55
Plagioclase	8	18	12	15	10	20	14	18	15
Quartz	3	2	2	1	1	2	1	3	4
Pyroxene	8	6	8	6	8	8	8	10	8
Amphibole	10	12	16	8	8	10	12	8	9
Biotite	2	0.5	0.5	2	1	2	2	2	1
Magnetite	2	3	0.5	1	3	1	2	2	1
Sphene	1	2	1	2	-	1	-	1	1
Apatite	1.2	0.6	0.4	-	1	-	-	-	3
Zircon	-	-	0.3	1	1	-	1	-	-
Recalculate QAP									
Q	4.11	2.70	2.82	1.25	1.35	2.86	1.35	4.00	5.41
A	84.93	72.97	80.28	80.00	85.14	68.57	79.73	72.00	74.32
P	10.96	24.32	16.90	18.75	13.51	28.57	18.92	24.00	20.27