Petrological studies of Angadimogar quartz-syenite intrusive, Kasaragod District, Kerala, India

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***Abstract*—Neo-Proterozoic aged Syenite and alkali granite intrusions with strong alkaline characteristics sporadically penetrate the granulitic terrain of SW India. These intrusions, found in the Precambrian terrain, remain unaltered by metamorphism or deformation, displaying a distinct alkalic signature. They are closely associated with taphrogenic faults and regional lineaments. Among them, the Angadimogar intrusive (AM) [12º38'N - 75º00'E] in the Kasaragod district of Kerala is one of 18 bodies that have punctured the Peninsular shield of India, preserving evidence of significant felsic magmatic activity. The AM pluton is positioned near the continental margin, along a fault lineament trending NW-SE.**

The AM pluton consists of 3 types of rocks that are quartz syenite, quartz monzonite and syeno granite, they show medium to coarse grained texture, and are predominantly composed of K-feldspar ranging from 35 to 63%, with subordinate amounts of quartz 5-18%, plagioclase 1-27%, and ferromagnesian minerals such as amphibole biotite ranging from 5 to 30%. Accessories like magnetite, sphene, apatite, and zircon are also present.

***Index Terms*— quartz syenite, syeno granite, Angadimogar Pluton, Kasaragod, Kerala.**

I. INTRODUCTION

The Kerala region in the southern part of the Indian peninsula is primarily characterized by high-grade rocks such as charnockites, granulite-facies metasediments, and migmatitic gneisses. Throughout this terrain, there are numerous intrusions of alkali-granitic and syenitic bodies (Santosh and Drury, 1988). Geochronological data obtained from these bodies suggest Late-Proterozoic to early Paleozoic ages.

In the Kasaragod district of Kerala, specifically in the Angadimogar area, a sizable syenite pluton has been identified, appearing as hillocks predominantly covered by laterite. One such syenitic body, composed of quartz syenite, is found in an abandoned quarry within the Angadimogar village. This paper focuses on the field setting and petrographic characteristics of the quartz syenite body located approximately 1 kilometer south of the banks of the Shiriya River in the Kasaragod district of Kerala.

II. GEOLOGY AND FIELD SETTING

The granulite terrain of Southern Peninsular India is intruded by a suite of alkaline plutons. In this study, attention is drawn to a syenitic formation situated within Kerala state, bounded to the north by the Mercara Shear Zone (MRSZ) and to the south by the western extension of the Moyar Shear Zone (MOSZ) (Fig. 1). The Angadimogar intrusive is situated northeast of the Kasaragod district and southeast of Angadimogar village. This area lies near the continental margin, with the Shiriya River flowing west to east, dividing at Angadimogar village into two branches, one continuing north as the Shiriya River and the other south as the Chandragiri River. The exposed portion of the Angadimogar intrusive lies between these two rivers, covering an area of approximately 30 to 50 square kilometers. The exposed rocks of the intrusive are sporadic, appearing as hillocks and quarries.

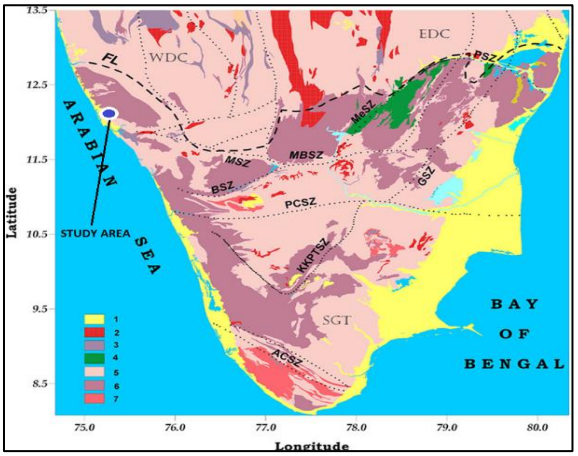

Figure 1: A generalised geological map of the Southern Peninsular India showing study area location.

The syenitic body displays an intrusive relationship with the surrounding metamorphic country rock, mainly hornblende-biotite gneiss, biotite-hornblende gneiss and charnockites. Due to extensive lateritization and the accumulation of soil, sharp contacts between the syenitic body and the country rocks are not discernible, especially in high altitude areas. 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 (Fig. 2).

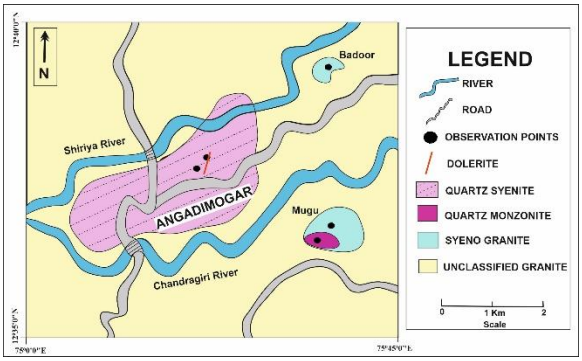

Figure 2: A generalised geological map of the Angadimogar Pluton (map modified after Santosh et al. 2015).

Large bodies of pink quartz syenites are found near Angadimogar Government School and along the riverbanks of the Shiriya River. They are also present in road cuttings near Puttinge Bridge and as boulders in the Badoor area near construction sites. The 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. Syeno granites are observed along the riverbanks of the Chandragiri River, exhibiting considerable weathering, and are also found in the Mugu area. Quartz monzonite is another rock type prevalent in the Mugu area alongside syeno granites, with a transition from pink quartz monzonite to grey granite is evident in exposures. Charnockites are seen at few places where they occur as patches within syeno granites in the Mugu and Badoor areas, characterized by a medium to coarse-grained granoblastic texture. Localized intrusions of large mafic dykes intersect the syenites and syeno granites in certain areas (Fig. 3).

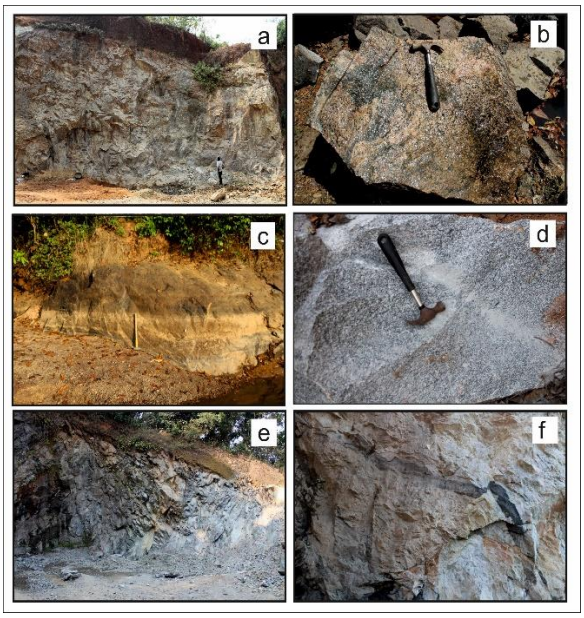

Figure 3: Representative photographs of Angadimogar syenite pluton. (a) Overview of the freshly exposed quartz syenite quarry in Angadimogar area. (b) Photograph illustrating huge pink quartz syenite boulder from the puttinge bridge road cutting. (c) Weathered quartz syenite exposed at the Shiriya river bed. (d) Freshly exposed syeno granites Badoor area. (e) Photograph shows mixing and mingling of 2 rock types i.e., syeno granites and quartz monzonite at Mugu area. (f) Photograph depicting dolerite dykelet cutting through the quartz syenite body at Angadimogar quarry.

III. PETROGRAPHY

Field observations yielded samples of three distinct rock types, which underwent petrographic analysis to determine their compositions. The modal composition of 12 representative samples from the Angadimogar pluton is detailed in Table I. The samples pertaining to the 3 rock types exhibit quartz contents ranging from 5 to 18 vol%, alkali feldspar contents ranging from 35 to 63 vol%, and plagioclase contents ranging from 1 to 27 vol%. Based on the modal Q-A-P proportions (Streckeisen, 1976), rock samples AGM-F4, RC-5, RC-3, and BDR-4 are classified as quartz syenites, while MG-10 and MG-12 are categorized as quartz monzonites, and samples RC-8, MG-16, and BDR-F9 are designated as syeno granites (Fig. 4). These rock types, namely quartz syenites, quartz monzonite, and syeno granite, constitute the primary lithologies of the Angadimogar Pluton, prominently exposed in active

quarries, river and road cuttings. Fresh samples of these three rock types were collected for the present study. All three rock types exhibit a leucocratic colour.

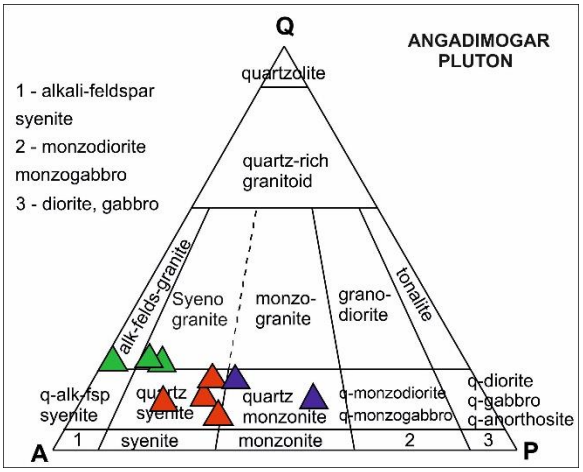

Figure 4: Q-A-P plot of modal composition (vol%) of Angadimogar quart syenites (red triangle), syeno granites (green triangle) and quartz monzonites (blue triangle) (Streckeisen, 1976).

Megascopic observations show that quartz syenites is pinkish in colour, medium grain size, and is characterized by a porphyritic texture (Fig. 5a). Upon microscopic examination, two varieties of quartz syenites have been identified: one displaying a coarse-grained texture and the other exhibiting variation from medium to fine grained texture. The rock exhibits porphyritic to granular texture. These syenites primarily consist of K-feldspar 40-60 vol%, comprising mostly orthoclase and microcline minerals, followed by plagioclase 15-20 vol%, quartz 5-10 vol%, and mafic minerals such as pyroxenes, amphibole, and biotite 5-8 vol%. Additionally, accessory minerals such as sphene, garnet, opaque minerals, apatite, zircon, along with secondary calcite and occasional muscovite are present. Subhedral to anhedral grains of K-Feldspar constitutes the dominant phase in these rocks, Orthoclase shows cloudy first order grey colour and exhibits Carlsbad twinning in few sections. Microcline present in these rocks exhibit cross hatched twinning with 1st order colours of grey and blue. Resorbed plagioclase in microcline crystals are found in few sections. Plagioclase occurs as subhedral to anhedral laths, mostly of albitic composition (Fig. 5b). It exhibits regular lamellar twin with closely spaced lamellae. Anhedral and undeformed quartz grains occur as larger grains as well as in interstitial spaces of plagioclase and K-feldspar. Amphibole, pyroxene and biotite constitute the ferromagnesium minerals of the rock.

Megascopic examinations reveal that the syeno granite exhibits a light greyish colour, medium grain size, and equigranular texture (Fig. 5c), while the quartz-monzonite displays a pinkish coloration, medium to coarse grain size, equigranular texture, and a massive appearance. Petrographic observations of the syeno granite indicate an allotriomorphic texture dominated by K-feldspar, primarily orthoclase, comprising around 50-55% of the volume, accompanied by smaller amounts of microcline. Plagioclase of albitic composition constitutes approximately 15-18% of the volume, followed by quartz at 18-20%, and various mafic minerals such as amphibole and biotite at 5-6%. The plagioclase grains exhibit sericitization, while microcline displays cross-hatched twinning. Quartz grains show undulose extinction and are often associated with feldspar grains. Amphiboles and biotite are present as anhedral to subhedral crystals with distinctive pleochroism and interference colours (Fig. 5d). Accessory minerals include epidote, zircon, apatite, opaques, and sphene.

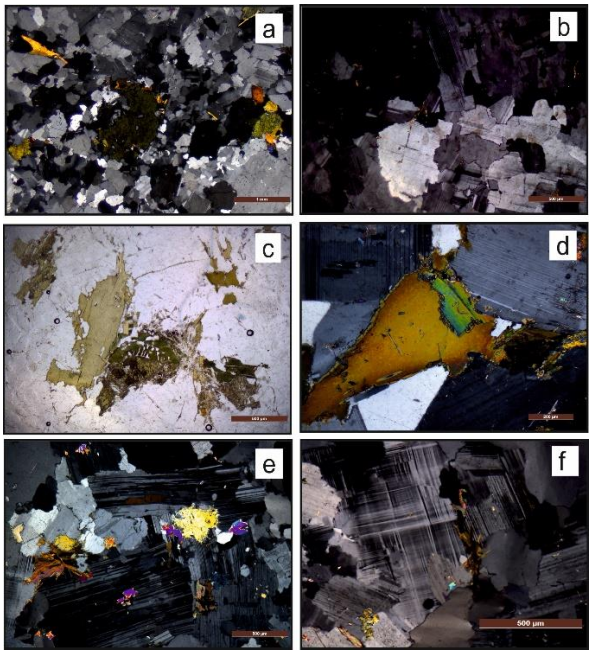

Figure 5: Photomicrographs of representative samples from Angadimogar pluton (a) porphyritic amphibole surrounded by fine-grained K-feldspar + plagioclase + microcline +quartz from quartz syenite. (b) Photomicrograph showing large plagioclase laths from quartz syenite sample (c) Porphyritic pyroxene

and amphibole under PPL from syeno granite sample. (d) syeno granite constituting plagioclase, K-feldspar and pyroxene with accessory mineral zircon embedded within. (e) Bladed biotite surrounded by plagioclase laths is seen on the quartz monzonite sample. (e) Photomicrograph showcasing large microcline grains from quartz syenite samples of Angadimogar.

Under a microscope, the quartz-monzonite rock exhibits a porphyritic texture. Its composition predominantly consists of K-feldspar (30–35 vol%), primarily orthoclase, followed by plagioclase (18–25 vol%) and quartz (10-12 vol%), alongside ferromagnesian minerals such as amphibole and biotite (25–30 vol%). Coarse-grained porphyritic plagioclase often forms intergrowths with K-feldspar (Fig. 5e). The plagioclase laths, mostly albitic in composition, appear as subhedral grains exhibiting extreme sericitization and zoning in certain samples. Microcline, a dominant phase, displays distinct cross-hatched twinning (Fig. 5f). Quartz is observed as anhedral grains, showing undulose extinction and predominantly filling interstitial spaces. Amphiboles manifest as medium to large grained anhedral to subhedral crystals, uniformly distributed throughout the rock. Biotite occurs as subhedral to anhedral grains, occasionally appearing in a bladed form with bright yellow to brown pleochroic colours. Epidote crystals, acicular in shape, are found closely associated with amphiboles, displaying high interference colours. Accessory minerals such as zircon, epidote, and sphene are also present in this rock type.

IV. DISCUSSION

The quartz syenite of AM pluton is an ovoid shape body of ~50 sq km intruding the Peninsular Gneisses such as gneisses and charnockites. The alkaline formation of Angadimogar pluton is situated in proximity to the continental margin and aligns with a fault lineament trending NW-SE. 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 quartz syenites of Angadimogar 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 AM 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 (45-79 vol %), with orthoclase being more dominant than microcline minerals, followed by plagioclase (16-39 vol %) and quartz (8-26 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 crystallisation close to the solvus and abundance of sphene and primary garnet in the rock therefore suggests high titanium content of the parent magma.

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

Table 1: Modal Compositions of samples from Angadimogar Pluton of Kasaragod district, Kerala.

	AGM F4 1	RC 5 6	RC 3 7	BDR 4 11	MG 10 4	MG 12 10	RC 8 5	MG 16 8	BDR F9 9
Quartz	10.08	11.31	10.33	5.73	11.54	11.58	16.33	15.58	18.60
Plagioclase	19.00	22.73	14.72	21.80	27.32	19.83	1.19	1.83	1.36
K-Feldspar	36.68	52.77	63.10	41.53	35.65	35.90	62.63	59.92	63.84
Amphibole	12.56	0.54	0.00	3.33	0	0.67	0.04	0.67	0.84
Pyroxene	8.76	2.35	1.20	16.93	19	25.03	6.41	8.08	5.72
Biotite	4.56	3.50	2.10	3.47	1.86	0.08	6.63	5.78	2.36
Sphene	1.68	0.62	3.06	4.47	1.29	0.00	0.56	0.83	0.64
Garnet	2.88	1.38	1.70	1.13	1.36	2.00	0.67	1.2	0.96
Zircon	1.08	0.08	0.00	0.40	0.5	1.00	0.19	0.25	0.52
Opaques	2.96	4.73	3.87	1.27	1.3	4.20	5.37	5.67	4.88
Recalculated QAP									
Q	15.33	13.03	11.72	8.30	15.48	17.20	20.37	20.14	22.19
P	28.89	26.18	16.70	31.57	36.66	29.46	1.48	2.36	1.62
A	55.78	60.79	71.58	60.14	47.84	53.34	78.14	77.48	76.18