Petrology and associated alterations of younger granitoids of Peninsular Gneissic Complex of Mall area, Eastern Dharwar Craton, Southern India

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Abstract- The Eastern Dharwar Craton is a Late Archean calc-alkaline complex of juvenile and anatectic granites, granodiorite, monzonites and diorites. The northern part of the EDC comprises of Peninsular Gneissic Complex –II (PGC-II) of Archean to Paleoproterozoic ages. It comprises of hybrid granite gneiss, grey hornblende biotite granite, grey porphyritic granite, grey biotite granite, grey hornblende granite, alkali feldspar granite and pink granite which were later categorized as Tonalite-Granodiorite- Monzogranite (TGM) suite and Monzogranite-Syenogranite (MS) suite. These litho-types are intruded by pegmatites, quartz veins and basic dykes of dolerite, gabbro and pyroxenite. The supracrustals belonging to Dharwar Supergroup are represented by amphibolite and meta basalt which occur as rafts/enclaves within the Peninsular Gneissic Complex-II. Alteration zones, most important features of terrain which are imprints of later phase activities including deformation, hydrothermal and mineral fluids. Study of these alteration zones may help in understanding the deformational and associated late phase hydrothermal events. The present study is about bringing out the alterations within the granitoids of Peninsular Gneissic Complex- II (PGC-II) which is one of the characteristic features of granitoids of Mall area of Nalgonda District, Telangana. These alterations are mainly associated with shear zones and joint planes within the granitoids. The granitoids are part of younger granitoids of PGC-II of Eastern Dharwar Craton covering parts of Toposheet 56L/09 & L/13 in Nalgonda and Ranga Reddy districts of Telangana, South India. The shear planes within the granitoids area are probable sources of carrying out the potassic and chloritic material into the surrounding rocks through joint/fracture planes. The alteration is present in both pervasive and channel flow. These alteration zones are usually associated with fluoride, hematite, pyrite, molybdenum and REE phases. Petrographic studies including SEM reveals that these alterations helped in enrichment of REE phases and a few sulphide phases within the host rock. Chemical analysis reveals that the host rock i.e., Porphyritic alkali feldspar granite contain Molybdenum upto 5.5 % and upto 2000 ppm of TREE with enrichment of LREE (La, Ce, Nd and Sm). Progressive approach towards these alteration zones might help in establishing probable mineralized zones of sulphide and other minerals.

Keywords: Eastern Dharwar Craton, granitoids, Alteration, shear plane, Molybdenum, REE, Mall, Peninsular Gneissic Complex.

INTRODUCTION

Geology of the area is brought out by many workers. Foote R.B. (1885) was first to describe the granitoids of the area. Eventually, Mukherjee (1947) grouped granitoids of Peninsular Gneissic Complex (PGC) and established few younger dykes and quartz reefs in the area. Ganesan and Khan (1990) characterized granitoids of PGC into two types i.e., banded, schlieren layered granite/ adamellite/ granodiorite gneisses, with or without migmatitic structures, and very coarse grained/ porphyroblastic alkali feldspar granite. All these litho-units are traversed by different sets of basic dykes mostly confined to the tensional fracture zones. They have also identified the shear zones in the area which are mainly occupied by pegmatites, aplites and quartz veins. Four phases of deformation were also identified which have developed numerous distinct faults and fractures and reactivated some of the fractures, filled with basic intrusives. Subsequently, Maharaja Singh et al. (1990), classified the granitoids into three types viz. very coarse-grained porphyritic granite (grey to pink),

medium to coarse grained granite (grey to pink) and fine-grained homophonous granite (grey to pink). Different episodes of dyke activity in the area confined mainly in N-S, NW-SE and E-W to ESE-WNW directions, which further cut across by numerous N-S trending younger quartz reef. On the basis of mutual relationship between dyke and quartz reef they opined multiple pulses of acid and basic magmatic activities in the area. They have also reported numerous pegmatite and epidote activity throughout the area but more pronounce in the shear zones.

Present study discusses the petrology and characteristic features i.e., alteration zones within the granitoids of PGC-II and associated mineralization in the country rocks.

GEOLOGY OF THE AREA

Regionally, the study area occupies towards north-west end of the Peddavura schist belt in the Eastern Dharwar Craton; where vast area predominantly covered by PGC-II rocks (Fig.2). The rock types in area includes granite gneiss which act as basement for intrusion of Tonalite – Granodiorite - Monzogranite Suite (TGM) and Monzogranite - Syenogranite (MS) suites Nibedita Sahoo et al. (2016); they further intruded by alkali-feldspar granite; All of these granitic suites broadly belong to PGC-II. Mafic-ultramafic dykes, pegmatites, quartz veins and carbonate veins form younger intrusives. Major part of study area is occupied by porphyritic alkali feldspar-granite (PAKF granite) spread mainly in the northern part of the block as linear ridges found in NW-SE direction which is well coinciding with major lithological trend observed during aerial reconnaissance study (ASTER, LISS-II and Toposheet) (Fig.2). A medium- coarse grained non-porphyritic alkali feldspar granite is intruding the porphyritic variety at many places in the NW direction. Another major litho-unit of the area is monzogranite occupying the southeastern part of the area forming isolated mounds with syenogranite in the core with gradational contact representing zoned intrusive nature. Granite gneiss is the oldest mappable litho-unit found in the study area which is exposed as isolated hills in the central part and eastern part of the area. Gneiss has well defined gneissosity trending NW-SE with steep dip towards NE. Migmatite gneiss and amphibolite are found as older enclaves within granitoids of the area. The study area has numerous pegmatites, epidote veins, fluoride veins, quartz reefs and basic dykes. Basic dykes including dolerites and pyroxenites are seen intruding the granitoids of the area. Occurrence of epidote veins and fluoride veins along with potassic and chloritic alteration along the joint planes is the extensively seen in the study area.

There are two distinctive shear zones have been mapped in the area i) NW-SE passing through the rocks of central part of the block with dextral sense of shear mainly affecting PAKF granite with intensive mylonitization. ii) NNW-SSE mainly seen in the northern half of the block as discontinues shear bands with dextral sense of shear. Intensive potassic & chlorite material intrusion is noticed along the shear planes resulting in alteration of country rock i.e., PAKF granite (Fig.3). Both the shear planes are seemed to have intersected each other at many places resulted in dragging of the earlier shear fabric (NW-SE) towards the later plane (NNW-SSE). These alteration zones are usually associated with clusters of fluoride crystals (Fig. 4) and molybdenum.

Lithology	Supergroup	Age
Gabbro, Dolerite, Pyroxenite, Porphyritic dolerite	Basic intrusive	Mesoproterozoic
Quartz veins	Peninsular Gneissic Complex II	Archaean to Paleoproterozoic
Pegmatite, aplite veins		
Alkali feldspar granite		
Pink granite		
Porphyritic grey granite		
Grey hornblende-biotite granite		
Grey biotite granite		
Grey Hornblende granite		
Hybrid granite gneiss	Dharwar Supergroup	Archaean
Meta basalt		

Table 1: Regional stratigraphy of the area. (References: H.J. Maharaja Singh & K. Nagarajan, F.S.1988-89; V. Ganeshan & I.K. Khan, F.S. 1988-89; A.A. Bhaskar, F.S. 1987-88).

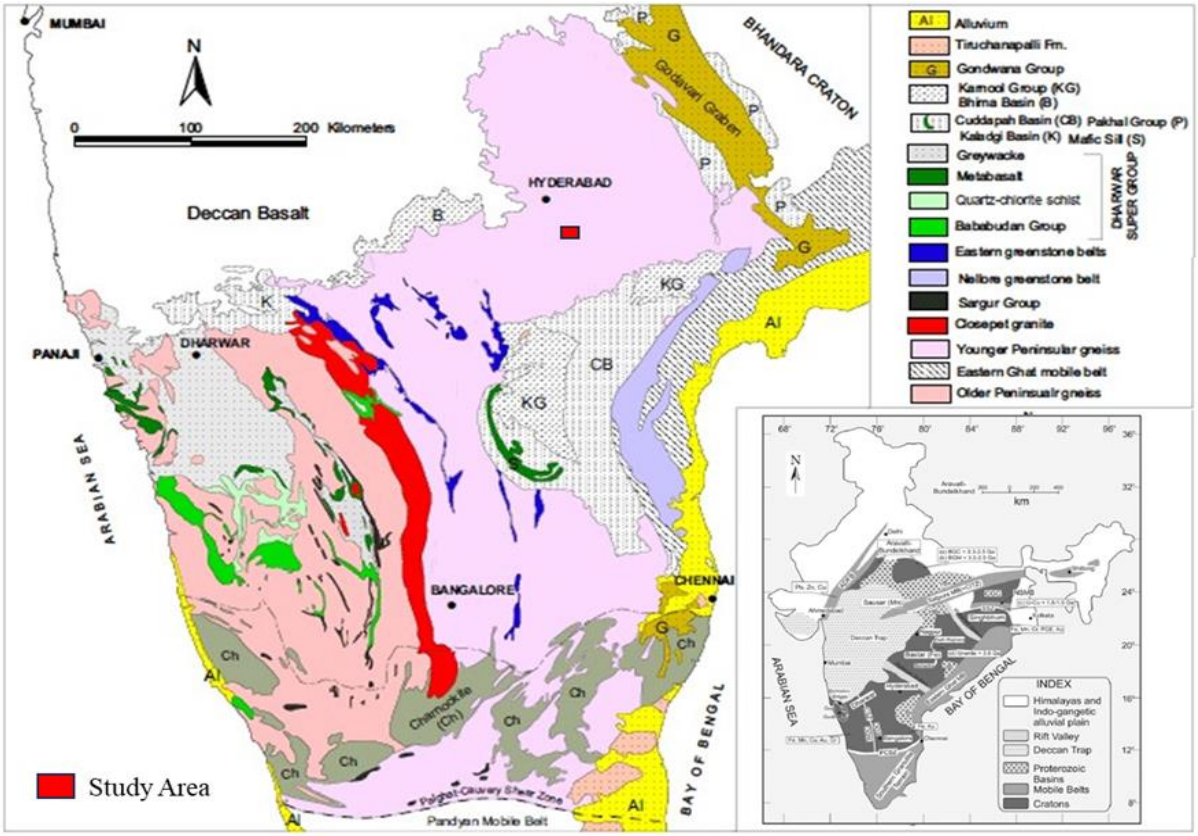

Figure 1. Regional geological map of the Dharwar Craton after Ramakrishnan and Vaidyanathan (2008).

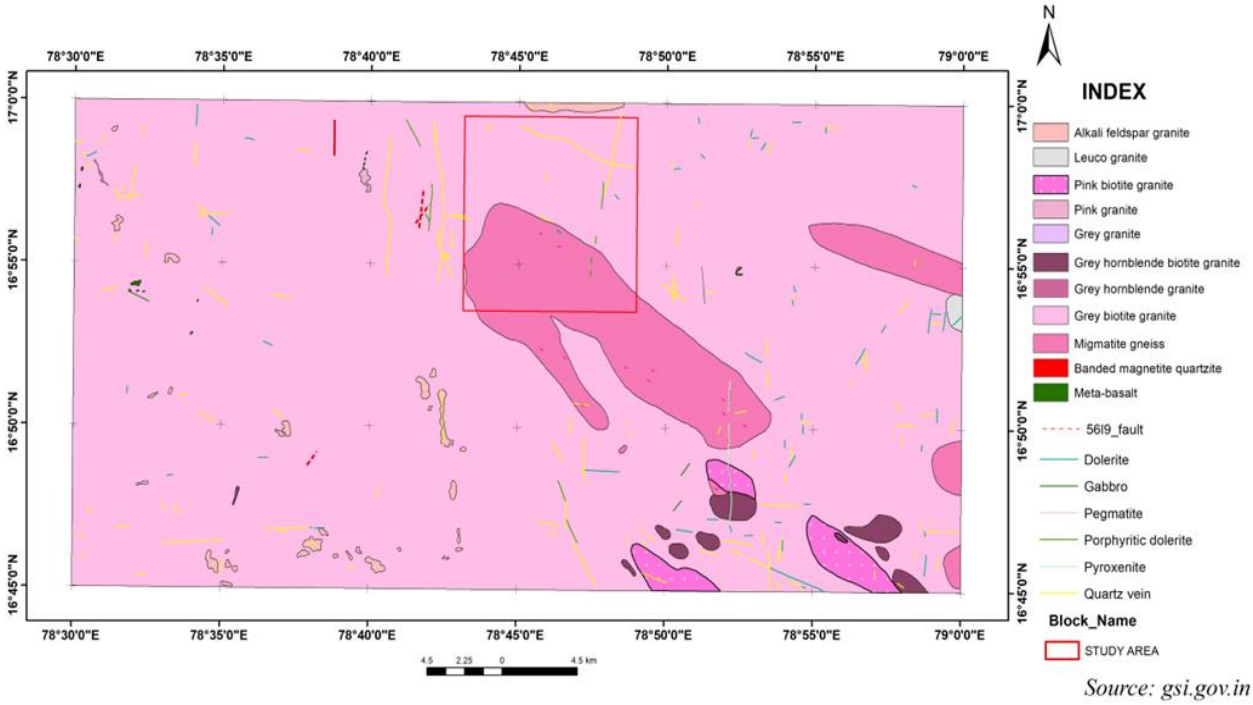

Fig. 2: Geological Map of Toposheet 56L/09 & L/13 covering parts of Nalgonda and Rangareddy districts of Telangana.

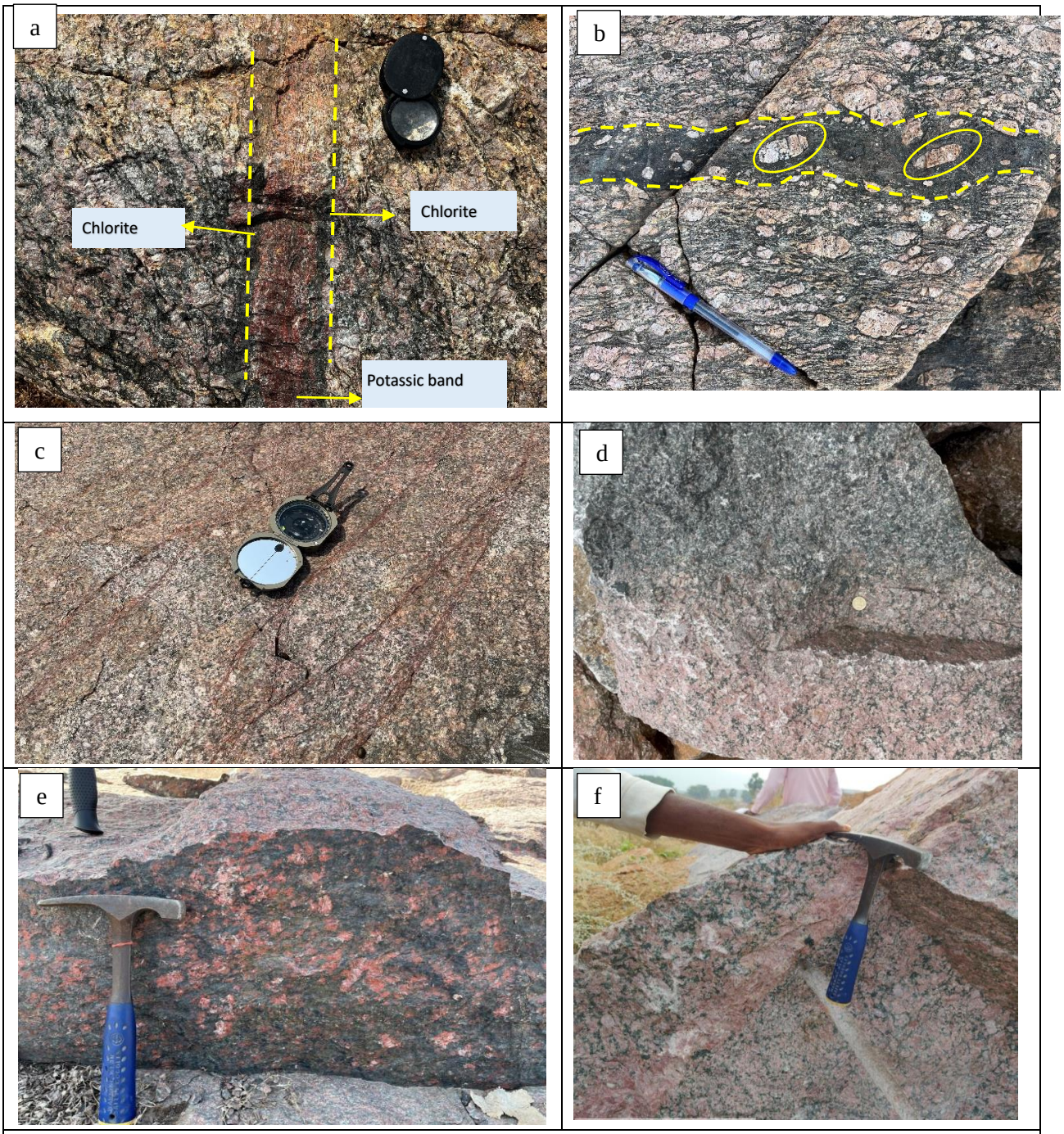

Fig 3. Photographs showing the characteristic features of PAKF granite with influx of potassic and chloritic material along shear planes and joint planes and the gradual alteration of original grey-colored feldspars to pink-colored feldspars (a) & (b) Intrusion of potassic & chloritic material along shear planes.
(c) & (d) Alteration in both channel flow and pervasive flow within PAKF granite
(e) & (f) Altered PAKF granite showing flesh red colored/pink-colored feldspars.

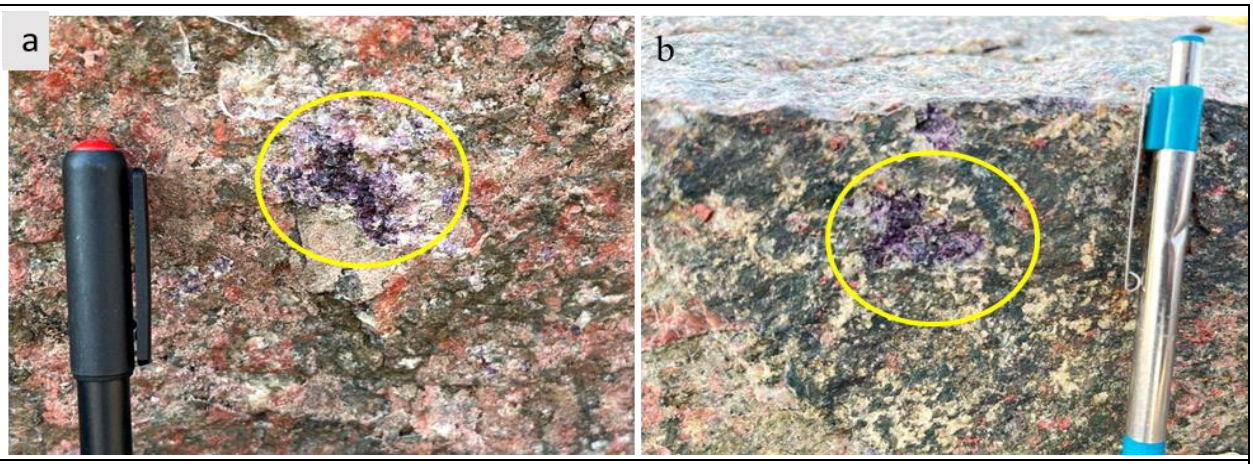

Fig 4. Potassic alteration along joint planes (a), alteration associated with fluorite (a&b) within PAKF granite along shear/joint planes observed near Madanapuram village.

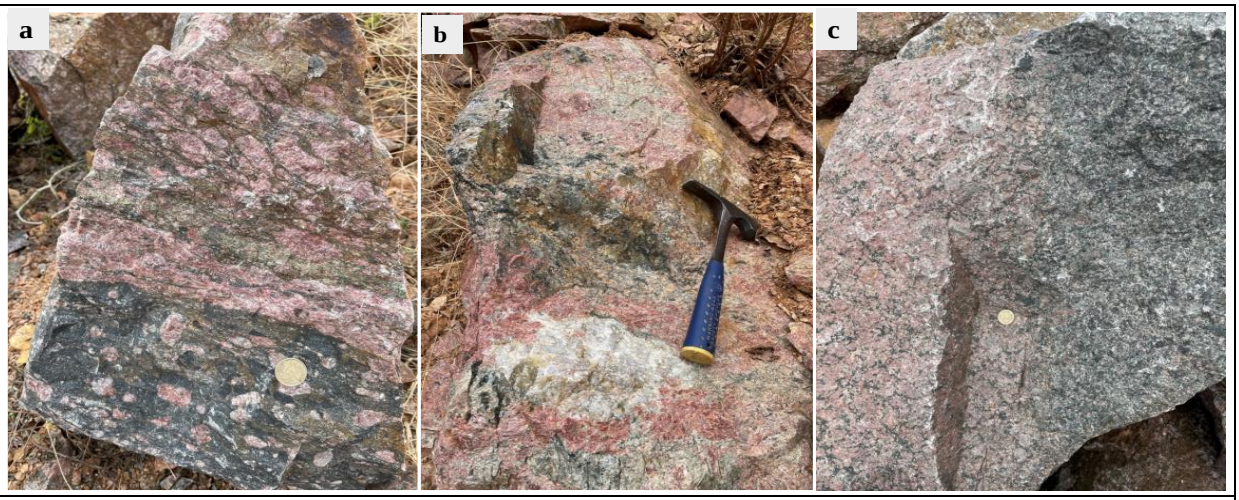

Fig 5. Alteration (potassic and chloritic) observed along shear planes (NNW-SSE) within PAKF granite where the original grey-colored feldspars are gradually converting into deep pink/flesh colored feldspar phenocrysts.

METHODOLOGY

The area has been mapped on 1:12,500 scale and sampling has been carried out at favorable locations in order to study the mineralogical and chemical characters of the rock sample falling within the vicinity of alteration zones. Geochemical analysis of all the samples were carried out at Chemical Division, Geological Survey of India, Southern Region, Hyderabad.

10 nos. of Bed Rock samples were collected from porphyritic alkali-feldspar granite with potassic and chloritic alterations along the joint planes and shear planes are common in the area (Fig.3). Two major alteration zones were identified where extensive alterations are observed. These alteration zones could be the target zones for mineralization in granitoids of the area. The alteration was prominent at 3 different places as discontinuous patches/outcrops and they were demarcated as zones of alteration. Firstly, these zones were divided into small grids and from each grid samples were collected systematically (Chip method) along the joint/shear planes where the alteration is prominent. All the samples were processed and powdered to -120 size and analyzed to assess the potentiality of REE along with U, Th, Nb, Ta, Hf, Cs, Li and F content. However, the rock samples carrying specks of sulphides have also been analyzed for Pb, Zn, Cu, Ag, Au and as content.

Also, a total of 20 nos. of petrographic samples were

collected covering the major parts of the alteration zones of the study area. The rock samples were collected from in-situ outcrops devoid of any weathering and contamination. Thin sections were studied under petrological microscope/SEM in order to identify the mineralogy, textures, micro-structure, alteration and mineralization. Petrographic studies were carried out on *Nikon Eclipse LV-100 POL Polarizing Microscope* to determine the petrological aspects. For Whole-rock major-oxides, trace-elements and REE were determined by XRF as well as ICP-MS methods respectively at Chemical Division, Geological Survey of India, Southern Region, Hyderabad. Whole-rock powder samples were used for the geochemical analysis are prepared fresh representative rock samples from the Insitu outcrops by hammering; Mortar pestle powdering method with -120µ mesh sieve used to get the final powdered sample. It was then thoroughly mixed by quarter-conning to increase the homogeneity. Then it was transferred into clean polythene pack, where it was mixed well to homogenous. Such same sample was used for both XRF and ICPMS analysis by making press pellets and solutions by acid-digestion respectively. LOI was determined by Fire Ash methods. Geochemical results are presented and discussed as follows.

PETROGRAPHY

Major Rock types of the study area are Granite Gneiss, Monzogranite, Syenogranite, Porphyritic Alkali feldspar granite and mafic enclaves. Megascopically the litho units of the area undergone shearing, mylonitization and various alterations viz. potassic, sericite, chlorite, epidote, carbonate etc.

Granite gneiss of the area holocrystalline, inequigranular, medium to coarse grained essentially consists of almost K-feldspar (55-60%), Quartz (20-25%) plagioclase feldspars (5-10%) biotite (5-7%) (based on V.E). Minor minerals include hornblende (~2%), epidote and chlorite (Fig. 5.39 a). The accessory phases include of sphene, apatite, zircon and opaques include magnetite.

Monzogranite of the area is coarse grained, holocrystalline having distinct mineral assemblage showing hypidiomorphic texture. (Based on VE) the primary minerals of monzogranite in the area consists of almost plagioclase (Approx.50-60%) K-feldspar (Approx.20-25%) and quartz (Approx.15-20%). Minor minerals include hornblende and biotite. Accessory phases are epidote, chlorite, apatite, zircon, allanite, sphene and opaques. The secondary alteration products are kaolinite, sericite and chlorite formed due to diuretic alteration of K-feldspar, plagioclase feldspar and biotite vice versa.

Syenogranite of study area medium to coarse grained, holocrystalline showing hypidiomorphic texture, inequigranular seriate textures. The essential minerals of syenogranite consists of almost K-feldspar (60-70%), Quartz-(10-15%) Plagioclase feldspar (<10%). Minor minerals include hornblende and biotite. Accessory phases are epidote, chlorite, apatite, zircon, allanite, sphene and opaques. The secondary alteration products are kaolinite, sericite and chlorite.

Porphyritic Alkali feldspar granites are coarse to very course in grain size, inequigranular, holocrystalline. majorly consists of phenocrysts/Megracryst of alkali feldspar (microcline and orthoclase)-80%, quartz-10% and plagioclase <5%. Accessory minerals are mainly represented by biotite, chlorite, allanite, epidote, fluorite, sphene, apatite, zircon, carbonate, hornblende and opaques include magnetite, sulphides are molybdenite, pyrite, chalcopyrite, covellite.

Alteration of plagioclase to sericite (sericitization), kaolinization along the fractures and grain boundaries is noticed. Allanites are associated with biotite which are found within the interstitial space of quartz and feldspar, these produce radiating haloes into the surrounding grains (Fig.7d). Apatites are found as cluster of inclusions within the orthoclase and plagioclase interstitially, these are well as associated with altered biotite and chlorite where allanites in green mafics may resemble ophitic texture (Fig. 7c). Cluster of sphene showing reddish brown to brown strong pleochroism, associated with sericitization and chloritization in alkali feldspar granite. Rutile having dark reddish-brown colour is subhedral, corroded by the k-feldspar. Fluorite veins are present along the fracture planes and weak cleavages associated with hydrothermal alteration (Fig.7a). Chloritization, saussuritization is noticed mostly along the fracture planes and crack where biotite and plagioclase undergone deuteric alteration (Fig. 9). Shearing in porphyritic alkali feldspar shows mylonite formation along which re-orientation of K-feldspar, elongated quartz ribbons rimmed by biotite with deuteric alteration forming saussuritization and chloritization.

Molybdenite deposited as fracture fills exhibiting branching texture associated with corroded allanite (Fig.8). Irregular formation of very tiny of molybdenite veins within the allanite grain and cluster of molybdenite mineralization within K-feldspar are observed.

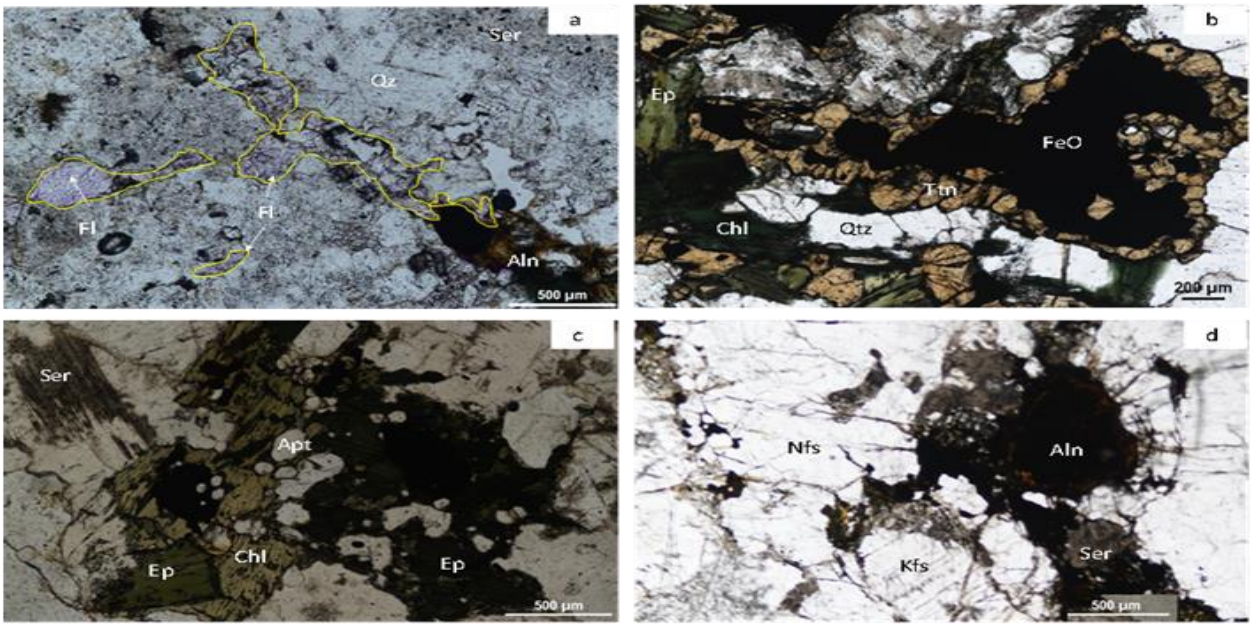

Fig. 7: a) Photomicrograph (cross polarized light) showing grains of allanite, fluorite, apatite association within altered alkali feldspar granite. b) Photomicrograph (plain polarized light) showing epidote, chlorite, sericite formed due to alteration, liberation of a FeO in sphene within syenogranite (PAKFG).C) Alteration within alkali feldspar granite with apatite inclusions within interstitial of Chlorite under ppl. d) Photomicrograph (plain polarized light) showing grains of allanite with radial cracks and sericitized grain of Plagioclase within Allanite bearing alkali feldspar granite at South of

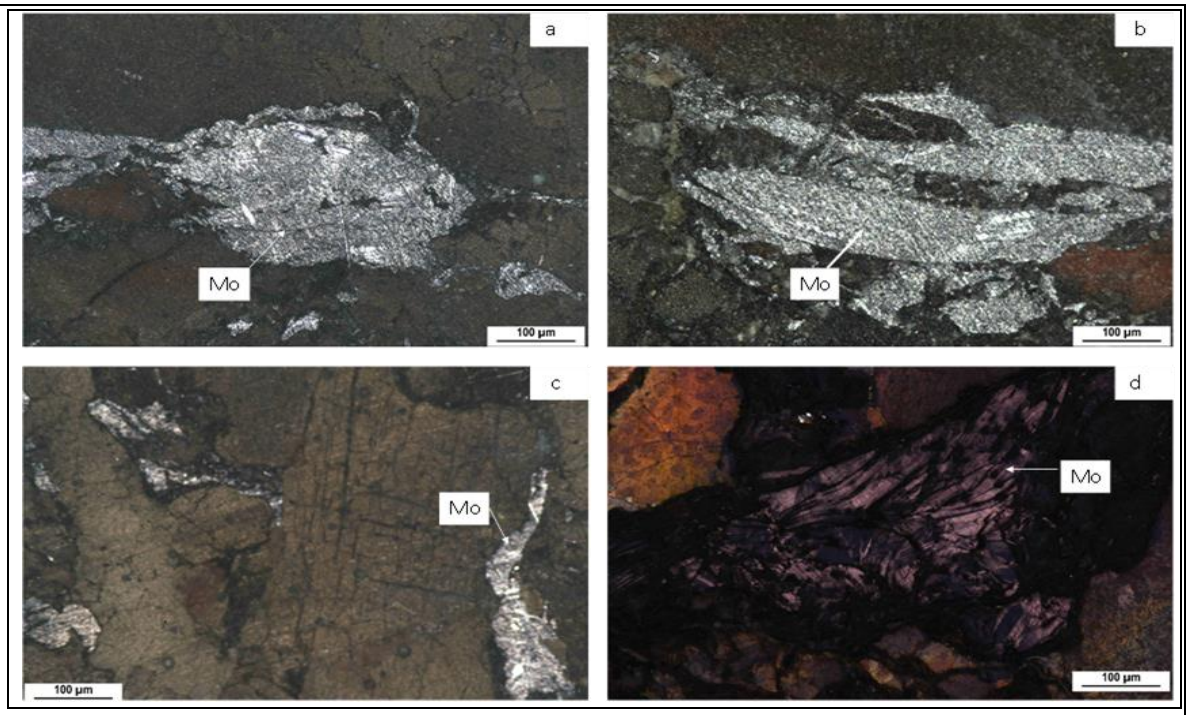

Fig. 8: a, b, c & d) Occurrence of molybdenite mineral as a fracture fill on various scales hosted by porphyritic alkali feldspar granite at the contact of pegmatite to east of Tammadapally village

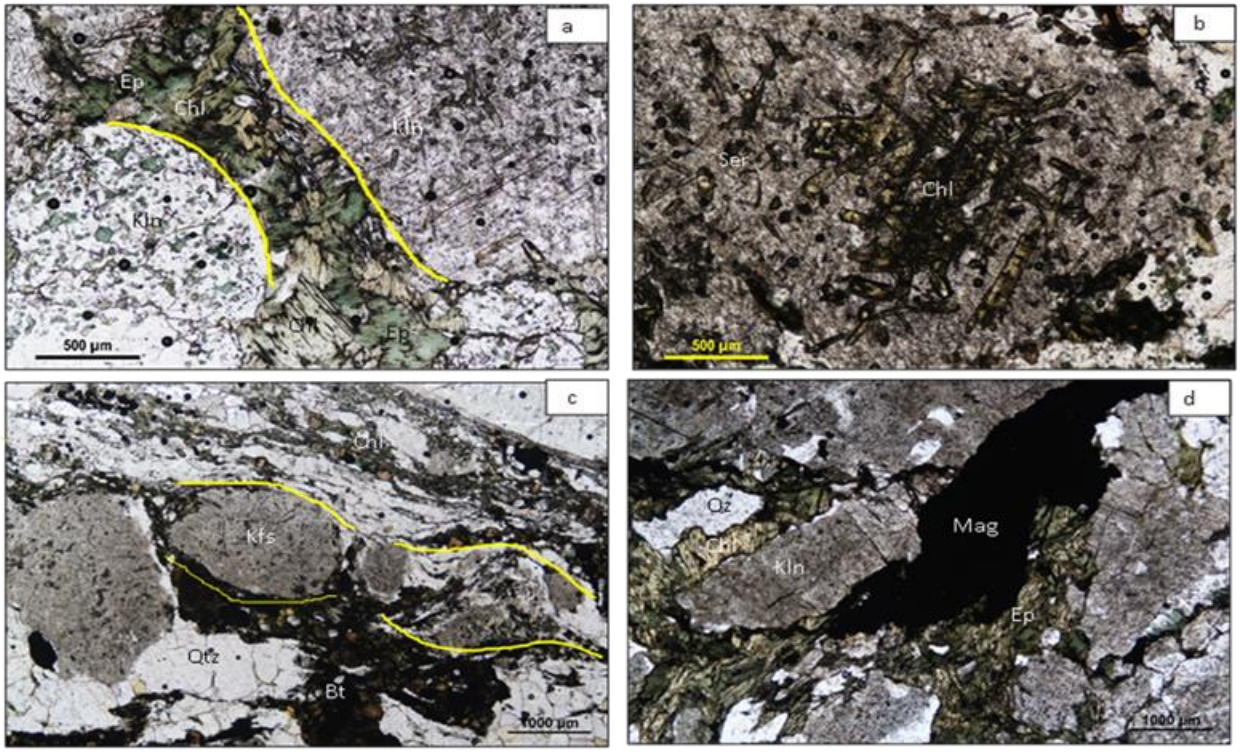

Fig. 9: a) Photomicrograph (PPL) showing the chlorite- epidote alteration along the fracture plane. b) Deuteric alteration forming the cluster of chlorite grains and sericitization in feldspar c) Chlorite-epidote-sericite alteration associated along shearing within the granite d) Opaques (Magnetite) occupied the interstitials of feldspar in altered granite.

GEOCHEMISTRY

The geochemical analytical data of granitoids of the study area reveals that the most of the rocks are metaluminous to peraluminous in nature belonging to calc-alkaline series of rocks and forming in the late orogenic settings. The detailed geochemical characters of each rock are as follows.

Granite gneiss: contains high SiO2 (68.2wt% -73.2 wt.%) and Al2O3 (13.3 wt%- 15.5 wt.%); with moderate to low Fe2O3 (1.52-4.430 wt.%), CaO (1.30-3.05 wt.%) and low in MgO (<0.95 wt.%) and TiO2 (0.17-0.63 wt%.). In TAS diagram, rock is classified as granodiorite to granite range (Fig 5.69 a), They are metaluminous to peraluminous.

Monzogranite: contains high SiO_2 (68.14 -73.62 wt.%) and Al_2O_3 (12.01 - 15.75 wt.%); with low to moderate Fe_2O_3 (1.09-3.30 wt.%), CaO (1.51-3.19 wt.%) and low in MgO (<1.3 wt.%) and TiO_2 (0.09-0.55 wt%.). the rock is classified as granite (Fig 5.69 a), They are mostly meta-aluminous.

Syenogranite: contains high SiO_2 (70.18-71.87 wt%) and Al_2O_3 (13.78 - 15.32 wt.%); with moderate to low Fe_2O_3 (0.82-1.46 wt.%), CaO (0.73-1.31 wt.%) and low in MgO (<0.32 wt.%) and TiO_2 (0.04-0.16 wt%.). rock is classified falls under granite field (Fig 5.69 a), They are metaluminous.

Porphyritic Alkali-feldspar granite: contains high SiO_2 (61.82-69.73 wt%) and Al_2O_3 (12.39 wt%- 14.96 wt.%); with moderate to low Fe_2O_3 (2.14-5.33 wt.%), CaO (1.14-4.26 wt.%) and low in MgO (<1.5 wt.%) and TiO_2 (< 1.1 wt%.), rock is classified as quartz monzonite to granite fields (Fig 5.69 a), They are meta-aluminous.

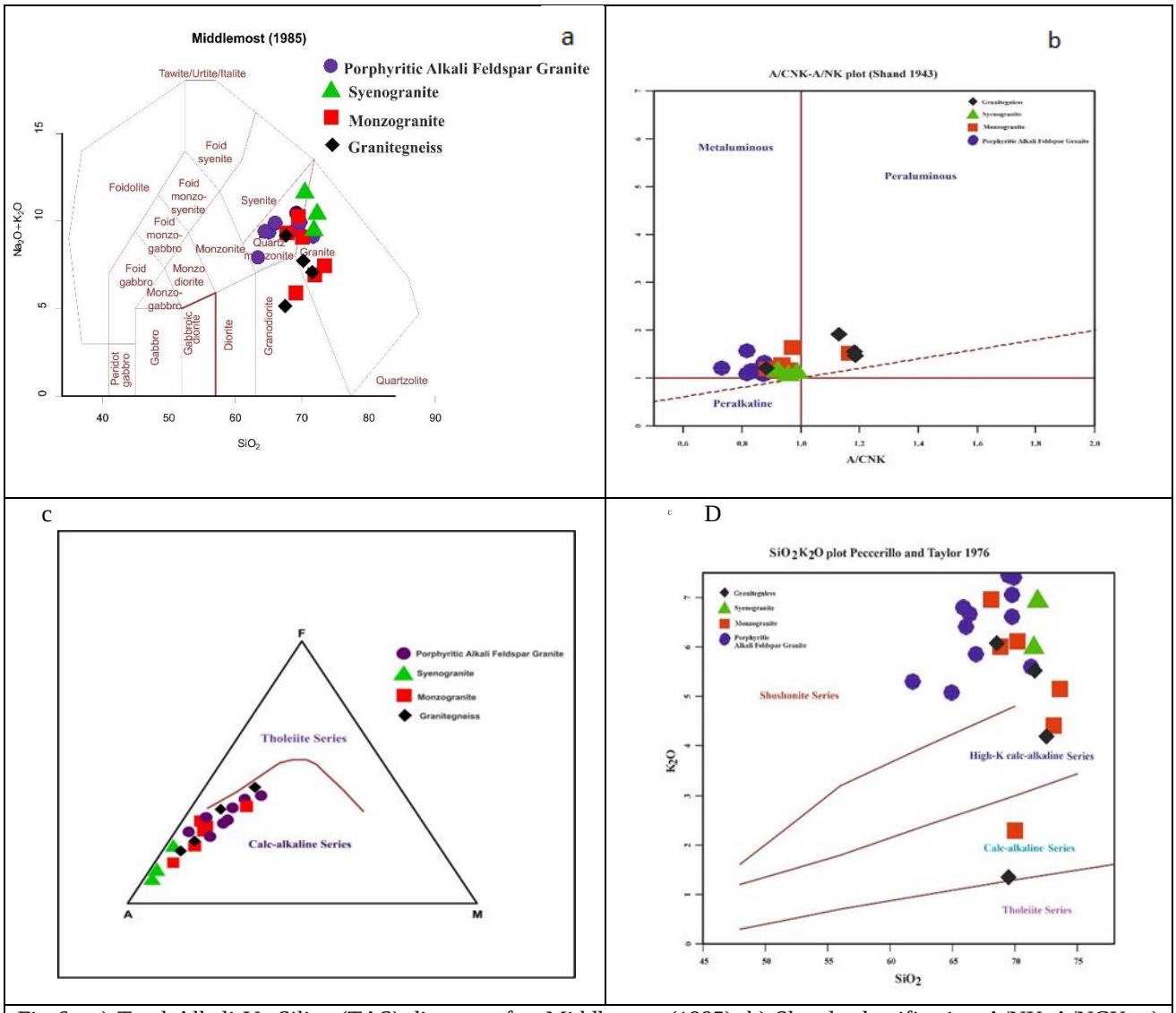

Fig 6. a) Total Alkali Vs Silica (TAS) diagram after Middlemost (1985); b) Shands classification A/NK-A/NCK; c) AFM diagram and d) SiO_2vs.K_2O (Perccerillo and Taylor 1976) diagrams for the rock types from the LSM area.

DISCUSSION

The area has evidences of intensive shearing in NW-SE direction and NNW-SE direction with dextral sense of shearing. It is observed that along these shear planes (NNW-SSE) and joint planes there is potassic and chloritic material emplacement which resulted in alteration of country rock to more potassic and more pinkish/flesh red in appearance. From the field observations it is assumed that the potassic/chloritic material is intruded along the shear planes (NNW-SSE) and carried into the adjacent joint planes. Increased density of joint planes helped in accommodating more fluid resulting in intensifying the alteration. Along with potassic and chloritic material, mineral phases like fluorite, apatite, tourmaline, epidote etc. were also seen along these planes. Although the fluids seem to have intruded along shear planes, the joint planes are playing major role in accommodating the later solutions and alteration of country rock. This phenomenon is very well exposed especially in the norther half of the block in and around Mall, Godkondla, Nallavelli and south of Narsimhapuram villages.

Joint planes are seen in whole litho-package cut across in various orientations and with different density. The general trend of these joint planes are NE-SW, NW-SE, NE and EW having vertical to steep dips on either side. In terms of joint planes, the area can be divided into two different parts i.e., northern part covered by PAKF granite and southern part mostly covered by monzogranite. Usually, the alteration is restricted to few cms on either side of the joint planes but at some places depending upon the density of joints the alteration is spread all over the rock. Along with potassic and chloritic material, mineral phases like fluorite, apatite, malachite etc. were also seen along the joint planes. Apart from joint planes, shear planes of outcrop scale also seem to have carried the potassic material into the rock and intensifying. As they are accommodating various fluid phases, they are targeted for sampling to find out the potentiality of REE and other mineral phases of the rocks of study area. At places these joints are forming the surface manifestation of ductile shear zones beneath the surface.

CONCLUSION

The study area is mainly represented by Porpgyritic alkali feldspar granite (PAKF granite), monzogranite, syenogranite, granite gneiss of PGC-II, along with older enclaves of migmatite gneiss and amphibolite. Amongst the granitoids PAKF granite is the most dominant litho-unit followed by monzogranite. Monzogranite and syenogranite shows zoned nature with monzogranite in the margins and syenogranite in the core. These granitoids are further intruded by numerous pegmatites, basic dykes, epidote veins, fluoride veins, carbonate veins and ultramafic bodies. The intrusive activity took place is mainly in NW-SE direction and is more frequent in monzogranite as compare to other granitoids of the area. Intensive potassic & chloritic alteration is noticed along the NNW-SSE shear planes and joint planes of various trends resulting in alteration of country rock. This phenomenon is mainly observed within PAKF granite covering northern part of the block. From the field observation it is assumed that the potassic and chloritic material is intruded along the shear planes (NNW-SSE) and carried to adjacent joint planes accommodating the fluids and subsequently altering the country rock.

Petrographic studies reveal that the granites of the study area indicative of sub-solvus type formed below solvus (about 400°C) temperature having both feldspars that shows perthitic and myrmekitic intergrowths formed under hydrous conditions. Replacement reaction mechanism Na-K exchange at low to moderate stress conditions during rapid cooling may cause for flame perthite.

Interpretation of Geochemical characters of the granitoids of the studied area shows that the majority of the rocks are metaluminous of calc-alkaline series. The Tectonic discrimination diagram shows that the rocks of the area are mostly formed within late-orogenic to syn-collision settings. Mineralisation point of view the alteration zones might have played a major role in enrichment of mineral phases like molybdenum, fluorite and other sulphides. progressive approach towards the alteration zones and shear zones may lead to establish probable mineralised zones in the area.

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