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DETAILED PETROLOGICAL AND PETROCHEMICAL STUDIES OF ULTRAMAFIC ROCKS IN AND AROUND MALLANAYAKKANPALAIYAM AREA, METTUPALAIYAM ULTRAMAFIC COMPLEX (MUC), TAMIL NADU WITH SPECIAL SIGNIFICANCE TO PGE MINERALIZATION

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Abstract:

The area has been named with reference to the nearest village Mallanayakkanpalaiyam. Also this area is called as "M" area for report writing and convenience to presentation. The general trend of the block is N 70°E – S 70°W with 70° – 80° dipping towards south. In this block chromiferous meta-pyroxenite band has been traced for about 400m strike length with width 10-15m. Chromite is found as cryptic layering within meta-pyroxenite. Garnetiferous-gabbro and about one meter width of hornblende-ferrous amphibolite are inter-banded with ultramafic rocks in the northern side of Mallanayakkanpalaiyam block. A total number of 13 chip samples have been collected along 4 lkm traverse. In Mallanayakkanpalaiyam bands of ultramafic rocks have been traced 1) ultramafic band is southern side and co-banded with gabbro showing cumulus nature, hard and compact; 2) another in northern ultramafic band having 10-15m width with presence of actinolite-tremolite. The general trend is ENE 80°-85°WSW with 75°-85° dip towards northern direction. Hornblende biotite gneiss and banded magnetite quartzite have also been observed and sampled in these areas. Gabbroic rocks can be graded into anorthosites and pyroxenites with increasing amount of plagioclase and pyroxene respectively. Such gradations have been observed to take place respectively through leucogabbros and melanogabbros in field of Ayyampalaiyanm area, where mineral cumulation plays an important role to interpret the genesis. Garnet grains have been observed occurring as concentrated in the margins of gabbro / gabbroic bodies. Collected chip/groove samples for further studies. Metagabbros are medium to coarse grained and mesocratic, massive, hard and compact in hand specimen. The major rocks types exposed in this area are pyroxenite, amphibolites, meta-gabbro, and gabbroic anorthosite. The ultramafic rocks are inter-banded with meta-gabbro. The general trend of the rock is ENE –WSW with steep (75°-85°) dip towards south. The Meta pyroxenite bands are occurring as detached and discontinuous nature.

Key Words: Ultramafic Complex, Cauvery Suture Zone, Pegmatites & Pegmatoidal

Introduction:

Jayananda and Peucat (1996) suggest the generalised geological framework of southern India (Fig. 2.2), Tamil Nadu constitute various crustal areas like Nilgiri hills, Madras granulites and Maduraiarea, which are separated by shear zones. The Maduraiarea is the largest granulite areas of Southern India. They dominantly composed of high-grade metasedimentary and related rocks. The Maduraiarea has involved in a major Pan-African tectano thermal event. Based on geochronologic and isotope data the above authors inferred the contrasting thermal histories across the shear zone. The north of Palghat-Cauvery shear zone indicates an age of cooling around 2.1 Ga, while to the south in Madurai and Trivandrum areas much lower cooling ages of 480-420ma were recorded. North of Palghat-Cauvery shear zone crust formation and granulite metamorphism occurred during Archaean. The Proterozoic terrain in South India involved in Pan-African tectano thermal event similar to Sri Lanka, Madagascar and east Antarctica. The crustal growth had occurred along Palghat-Cauvery shear zone during 3-1.2 Ga and involved in granulite facies event close to 550 ma.

General Geology of Mettupalaiyam Ultramafic Complex Area Tamilnadu:

The MUC occurs within the 'Cauvery Suture Zone' (CSZ) (Gopalakrishnan et al, 1990) which is bound by two mega lineaments, the Moyar – Bhavani - Attur Lineament in the north and the Palaghat - Cauvery Lineament in the south. The Mettupalaiyam Ultramafic Complex (MUC) extends for about 60 km in a ENE-WSW direction from Tamil Nadu upto KeralaState boundary to the south of Bhavanisagar representing a dismembered sequence of dunite, pyroxenite ± chromite, garnet-pyroxene granulite, garnetiferous gabbro, gabbroic anothosite, anorthositic gabbro and anorthosite. The major rock unites are migmatite gneiss with subordinate charnockites and bear enclaves of high grade supracrustals of Sathyamangalam Group, equivalent to Sargur comprising amphibolite, fuchsite quartzite, garnet-biotite-kyanite ± sillimanite gneiss and older basic/ ultrabasic rocks. These litho units occur as tightly folded ENE-WSW to EW trending linear bodies within the amphibolite facies gneisses. The various litho units occurring in order of predominance are meta gabbro /

garnetiferous meta gabbro, gabbroic anorthosite / anorthositic gabbro, amphibolite, meta-pyroxenite ± chromite, talc-tremolite-actinolite schist, dunite and anorthosite. The mafic-ultramafic units representing a differentiated sequence presently occur as dismembered bands and lensoidal bodies within the gneissic complex, which are sheared and migmatised. All these rocks have undergone high degree of deformation and metamorphism.

Study Area:

The present work was aimed to carry out detailed petrological and petrochemical studies of the Mettupalaiyam Ultramafic Complex of Mallanayakkanpalaiyam area, Tamil Nadu. The study area falls in the Survey of India Toposheet No. 58 E/3) bounded between North Latitudes 11°15'00" to 11°30'00" and East Longitude 77°00'00" to 78°15'00". The traverse mapping of 16 line km has been carried out with collection of samples. A total number of 52 samples for REE and PGE analyses have been collected for petrographic study. Garnetiferous-gabbro and about one meter wide amphibolite are inter-banded with ultramafic rocks in the northern side of Mallanayakkanpalaiyam is shown in geological map.

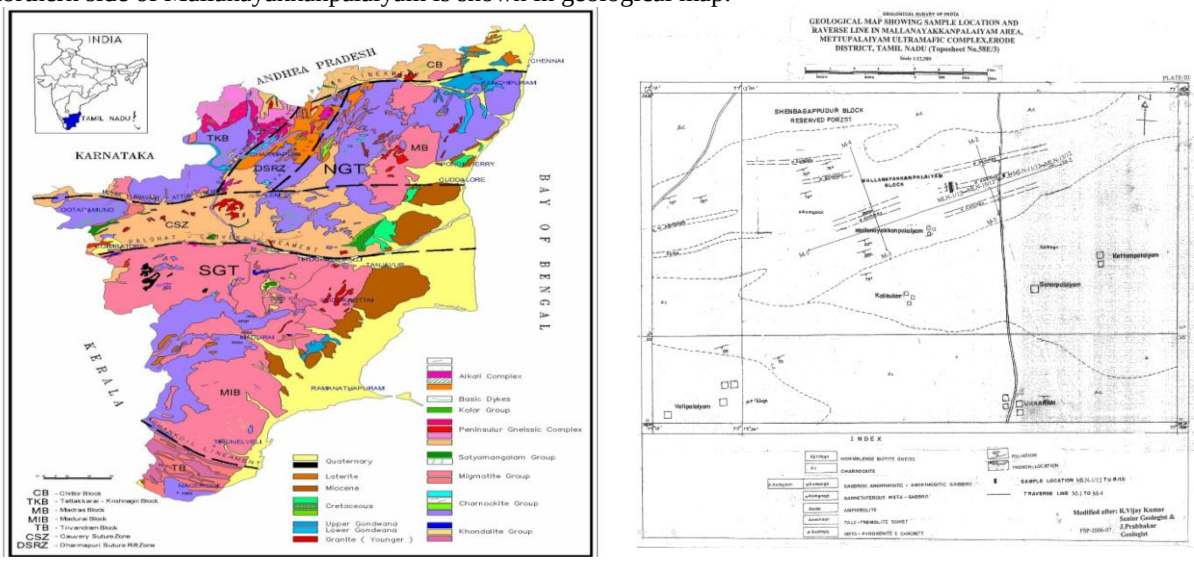

Figure 1: Study Area

Methodology:

Field Techniques and Sampling:

A systematic geological mapping was carried out on a scale 1: 50 000 with the survey of India Toposheet as the base. The geological mapping generally proceeded in five stages.

- ✓ Planning for field work
- ✓ Observations, mapping and collecting data by examining all geological features of the ground.
- ✓ Laboratory studies.
- ✓ Computing, Synthesis and subsequent interpretation of data through application of modern techniques.
- ✓ Finally the state of preparing geological map with report of the work.

A systematic representative samples of different rock types were collected. About 200 fresh and unaltered rock samples representing different rock types of the area from different locations were collected. The collected samples were numbered with location. Utmost care was given while taking measurement of attitudes and structural features and also in the collection of representative samples.

Field Photos

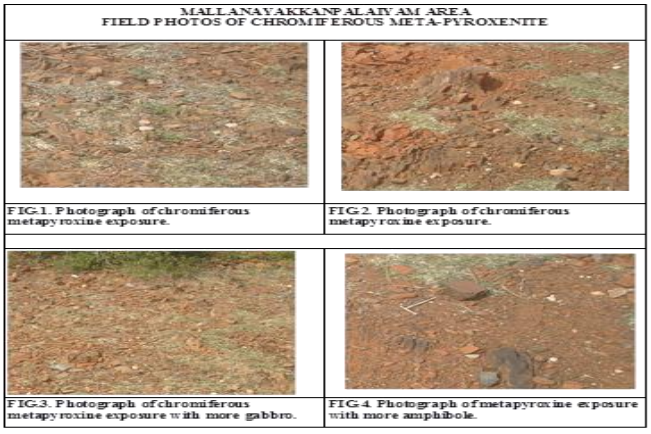

Fig. 2 Field Photos

Description of Rock Types

Fuchsite Quartzite:

This lithounit is generally considered to be characteristic of sargur/ Sathyamangalam Group. Fuchsite quartzite bands with or without kyanite and sillimanite are more frequently seen in Ayyampalaiyam Bloc. These bands are invariably associated with talc tremolite/ actinolite schist and ferruginous quartzite in several places and considered to be a part of Sathyamangalam Group.The quartzite band shows distinct compositional variation from arenaceous to more argillaceous towards east of Ayyampalaiyamarea. The quartzite is greenish white in colour with varying proportion of fuchsite mica concentrated mostly along the bedding planes. The massive quartzite exposed in the northern part at the top of the mound shows tight-upright fold on mesoscopic scale. The variation in the composition from arenaceous to more argillaceous is clearly discernible by alternating thin laminations of quartz rich and mica rich layers. This part of the band shows development of schistosity trending in NE-SW direction. This band is quite interesting as it contains less proportion of fuchsite/muscovite. The existence of fuchsite quartzite is very much restricted in Mallanayakkanpalaiyam area.

Talc Tremolite Actinolite Schist and Pegmatoidal Granite:

It occurs as small bands and lenses within the mafic-ultramafic suite. It is whitish to pink, greenish brown very soft and schistose in nature. It is essentially composed of acicular minerals such as talc, tremolite and actinolite. Talc tremolite - actinolite rock occurs as hydrothermal alteration product of ultramafics. This rock is highly deformed and sheared and isshown in geological map.Pink pegmatoidal granite forms the most dominant variety among granites. It is very coarse grained and composed of quartz, feldspar and biotite.

Pegmatites and Quartz Veins:

Pegmatites represent the last phase of igneous activity. The pegmatite veins occur in western spur of Pambukaradu hill, southeastern part of Talamalai, Anjalam, Kolakudi and Ichavari and are seen to transect the above mentioned rock units. In the western part of Pambukadu, low dipping pegmatite sheets are exposed at different levels. Similar low dipping sheets are exposed on the eastern slopes of the SE spur of Talamalai hill. Numerous pegmatites and quartz veins of unmappable dimensions are seen associated with the pink granite intrusives in the biotite gneiss in the southern sector. These may be related to pink granitic intrusives. The pegmatite sheets exposed at ground level are being quarried for quartz and feldspar. Pegmatites are mostly of the pink variety with large crystals of k-feldspar (10-15 cm) and quartz with few muscovites, biotite flakes.

Petrography in General:

Several processes have been proposed to explain to enrichment of PGE, and other nobles in cumulates of mafic and ultramafic rocks. Rocks formed by accumulation of precipitated crystals, the primocrysts in magma, is described as cumulated. 1) Some workers suggested that the PGE could crystallize from the magma as Platinum Group of Minerals (PGM) that accumulate on the top of crystal pile (e.g. Hiemstra, 1979). 2).Others have suggested that PGE are collected by a sulphide liquid that segregated from the magma and this sulphide liquid accumulated on the crystal pile (e.g. Campbell ed al,1983: Naldrett ed al, 1986). 3).Another process proposed in the collection of PGE by magmatic fluids enriched in Cl (Boundrean &McCallum, 1992) (Willmore et al,2000) in which percolated upwards through the cumulate pile and precipitated sulphide and PGE.

Metagabbroic Anorthosite:

These are fine to medium-grained rocks with less leucocratic nature than the anorthosites due to their higher ferromagnesium content in sample. These are generally found as a band in close association with anorthosites and gabbros. It shows primary banding with felsic and mafic layer. It consists occasional porphyroblastic garnet and mafic clots. Lineation due to parallel to sub parallel disposition of prismatic hornblende is characteristic in gabbroic anorthosite. It shows gradationally hanged into pure anorthosites and gabbros. It shows blotchy appearance due to clustering of the granular aggregates of hornblende in a matrix of plagioclases in some thin section and shows granoblastic texture. Plagioclases are altered to sericite. In thin sections these rocks preserve cumulative texture to a greater extent microphoto-V, Fig.9 &10. It is composed of plagioclase with hornblende and garnet as major minerals and diopsidicaugite, magnetite and apatite as minor accessory minerals. Based on thin section studies of metagabbroic anorthosite the following mineral assemblage is observed. Plagioclase + Hornblende $\pm$ Garnet $\pm$ Diopsidicaugite $\pm$ Biotite + Magnetite

Metagabbro:

Augite is almost colourless with zonal structure; weak pleochroism on shades of light green can be noted. Augite is prismatic with prismatic cleavage, having high relief. The gabbros are essentially composed of plagioclase, clinopyroxene, orthopyroxene and hornblende. The plagioclases are equigranular, subhedral in form with straight and curved interface contact with pyroxene and amphiboles; parallel to subparallel dimensional arrangements are common. The chief accessory minerals are hornblende, magnetite and biotite. Hornblende is mostly after pyroxene as paramorphic alteration product and as blotchy aggregate. Hornblende exhibits high relief, RI > CB green to greenish yellow pleochroism and prismatic cleavage. It gives higher order interference colour and inclined extinction. Biotite shows brown to straw yellow pleochroism, distinct basal cleavage, straight extinction and length slow character under crossed nicol; magnetite is high relief and euhedral in nature. The following mineral assemblage is observed based on thin section studies.

Plagioclase + Diopsidicaugite + Hypersthene + Biotite + Orthoclase + Hornblende + Magnetite

Meta-Pyroxenite / Garnetiferous Metapyroxenite:

These are coarse-grained melanocratic rocks with typical cumulate texture. These are equigranular, dense and compact. Mineralogically pyroxenite is completely composed of orthopyroxene and clinopyroxene with accessory magnetite in samples

Mallanayakkanpalaiyam Area:

Clinopyroxene grains are bending, breaking and forming amphibole, garnet with curved nature. In this section, clinopyroxene and garnets are more percentage and chromite & orthopyroxenite are less. Also noticed inclusion of clinopyroxene within the garnet are present. Therefore, this thin section rock is called as chromiferous metapyroxenite. In sample Reg no. MLN - 1/12 predominantly present of clinopyroxene and less orthopyroxene in the same band. This rock called pyroxenite. Based on thin section studies, in sample Reg. no. MLN – 3/12 predominantly presents of tremolite actinolite with euhedral-to-subhedral grainshown in microphoto-XIII Fig24. Profuse of very coarse-grained garnets are consisted. In sample Reg. no. MLN – 2/12 predominantly presents of euhedral-to-subhedral grains of tremolite actinolites.. Profuse very coarse garnets are consisted less amount of orthopyroxene are noticed. Garnet grains are coarse grained with breaking nature. Therefore, this rock is called garnetiferous tremolite actinolite schist. The dominant mafic mineral is augite. They occur as prismatic subhedral, to granular grains. Under crossed nicols, augite show higher birefringence and higher order interference colour of various shades. Augite grains show inclined extinction. It is optically negative. It shows alteration to hornblende.Hypersthene occurs as prismatic plates exhibiting straight extinction with second and third order interference colours. In some thin section, they show bending of hypersthene with minor fractures. The above properties indicate that the mineral is hypersthene. Magnetite occurs in insignificant amount as granules and dust either interstitial or included in other minerals. Based on thin section studies in pyroxenite the following mineral assemblage is observed.

Clinopyroxene (Di) + Orthopyroxene (Hy) + Augite + Hornblende + Magnetite $\pm$ Biotite

Talc Tremolite Actinolite Schist:

SampleS studied magascopically in hand specimen and microscopically. In hand specimen the tremolite actinolite altered to talc in field.In thin section studies, maximum pyroxene grains are changed to talc tremolite actinolite schist/ tremolite actinolite schist, colourless to pale green. The green varieties show faint pleochroism. Green ferriferous tremolite is known as actinolite. Tremolite-actinolite occurs in long prismatic crystals a columnar to fibrous aggregates. Two sets of cleavage 56 and 124° relief are fairly high. The maximum extinction angle is inclined and almost nearly parallel. The extinction angle and amphibole cross sections are characteristic. Wollastonite has the same general appearance as tremolite, but the trace of the optic axial plane is normal to the cleavage instead of parallel to it as in tremolite. Tremolite actinolite altered to talc in thin section.Under thin section, this rock shows short needless as well as long tabular tremolite / actinolite with rugged termination and often shows an interlaced arrangement.

Dunite:

In hand specimen heavy weight massive greyish yellow with cracks. In field, noticed secondary minerals of magnesite along irregular fractures. In thin section studies of samplesolivine fairly rich in iron. Olivine commonly shows altered to antigorite but in this section magnasite is present along irregular fractures . In hand specimen the rock is fine grained, highly weathered, dull earth coloured and compact with brownish yellow crust. It is ramified with reticulate veins of magnesite. Under thin section (SLT-M/1) this unit shows the presence of olivine and minor amount of relict pyroxenes.

Microphotos

Chromiferous metapyroxenite-MLN-6/12

Under Crossed Nicol | Under PPL

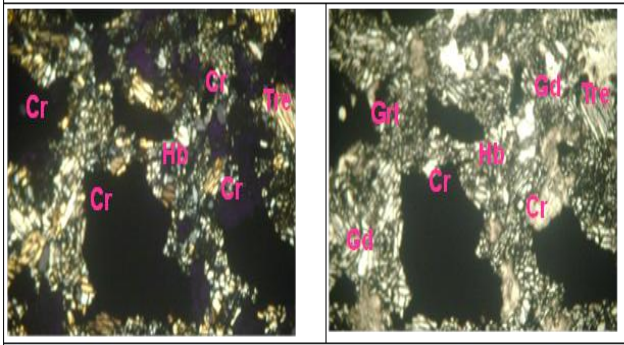

FIG : 20. Photo micrograph showing chromite, magnesio horblende, ferro gedrite & tremolite

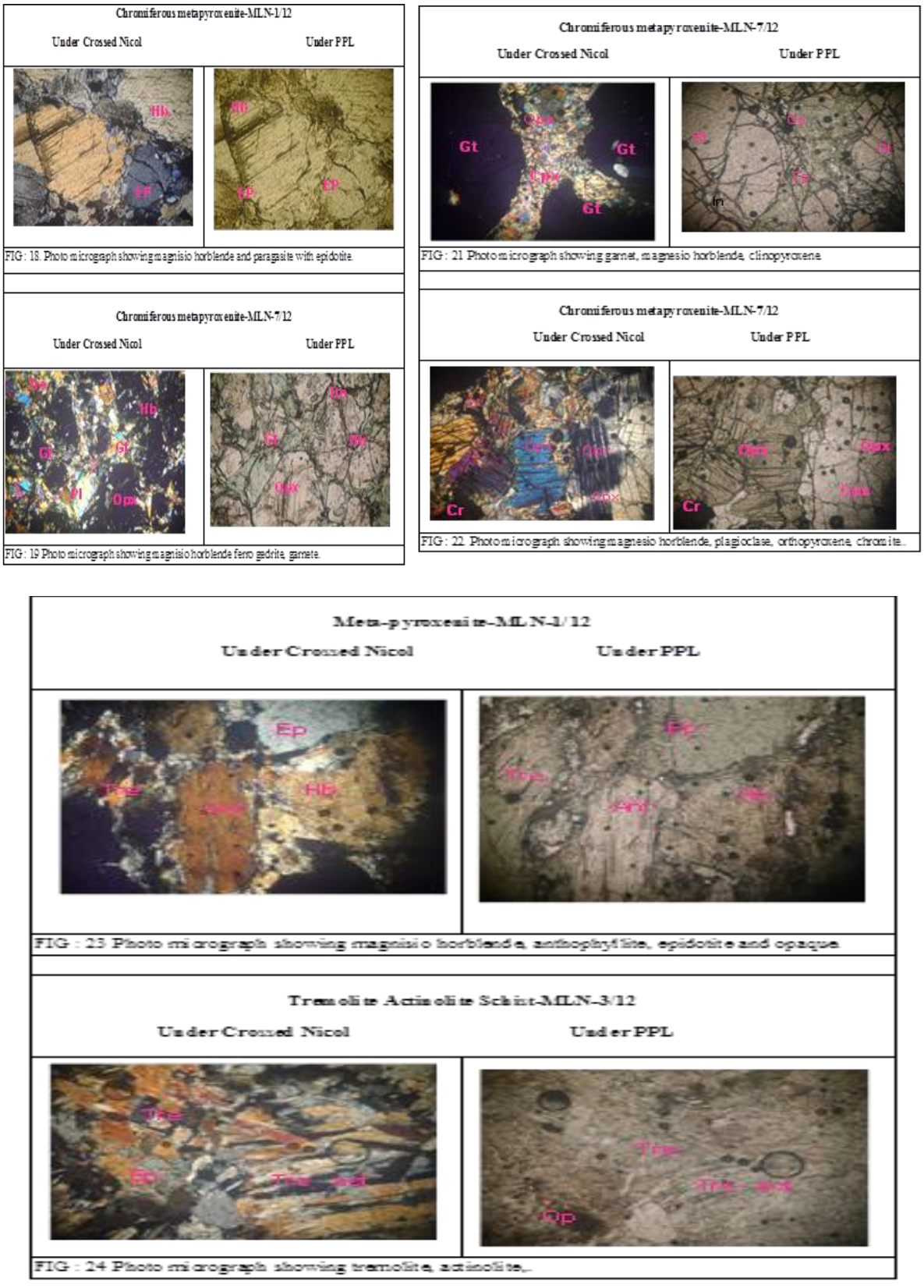

Figure 3: Microphotos

Major Elements Analysis of the Mafic-Ultramafic Rocks of Mallanayakkanpalaiyam Area (M –Area) in Mettupalaiyam Ultramafic Belt (MUB):

Table 1

Oxides.	Gt. Py	Meta-Py fine gr.	Py within Gt.	Cr.Meta.py.	Meta-py
Sample No.	MLN-4/12	MLN-5/12	MLN-6/12	MLN-7/12	MLN-8/12
SiO_2	45.49	47.48	46.41	43.64	44.49
TiO_2	0.59	0.46	0.54	0.29	0.16
Al_2O_3	14.04	11.52	12.12	17.77	16.09
Fe_2O_3	**15.51**	**13.12**	**15.03**	**16.69**	**12.87**
MnO	0.24	0.21	0.18	0.27	0.17
MgO	**13.11**	**17.32**	**15.56**	**12.90**	**15.99**
CaO	10.11	8.69	9.01	7.40	8.44
Na_2O	0.77	1.02	0.96	0.88	1.13
K_2O	0.10	0.15	0.17	0.12	0.13
P_2O_5	0.03	0.03	0.02	0.03	0.02
SUM	**99.99**	**100.00**	**100.00**	**99.99**	**99.99**
Sc (ppm)	30	31	19	31	12
V (ppm)	194	149	296	216	60
Cr (ppm)	400	**2607**	**20438**	**24823**	**1209**
Co (ppm)	99	80	95	116	103
Ni(ppm)	**666**	**742**	**921**	**834**	**1362**
Cu (ppm)	235	429	689	369	854
Zn (ppm)	122	108	307	482	170
Ga (ppm)	12	13	17	14	12
Rb (ppm)	7	5	6	6	5
Sr (ppm)	30	42	31	26	91
Y (ppm)	15	9	4	12	4
Zr (ppm)	37	23	27	27	17
Nb (ppm)	3	2	3	5	3
Ba(ppm)	42	44	58	58	31
Pb (ppm)	4	3	3	4	4
Th (ppm)	3	2	2	2	2
U (ppm)	1	1	1	1	1

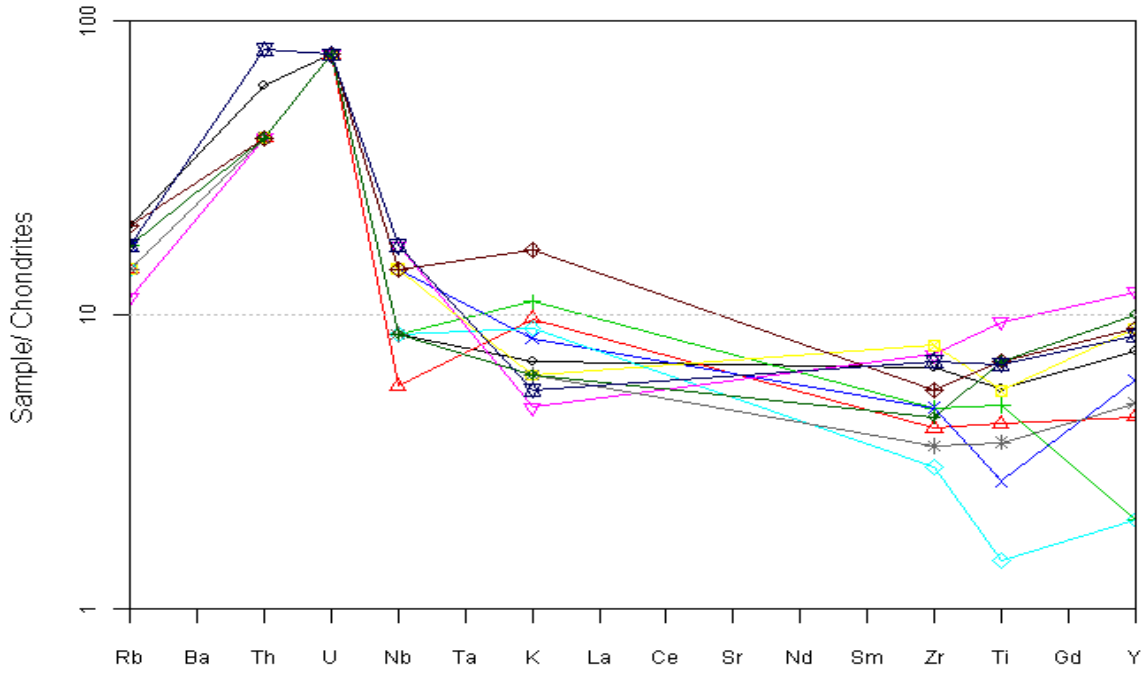

Figure 4: Values are normalized chondrites values based Sun et al (1980). In this diagram showing multi element variations.This diagram indicates high amount of Th and shows peak values in four samples in ppm level. Other REE elements are gradationally decreasing and showing antipathetic relationship each other.

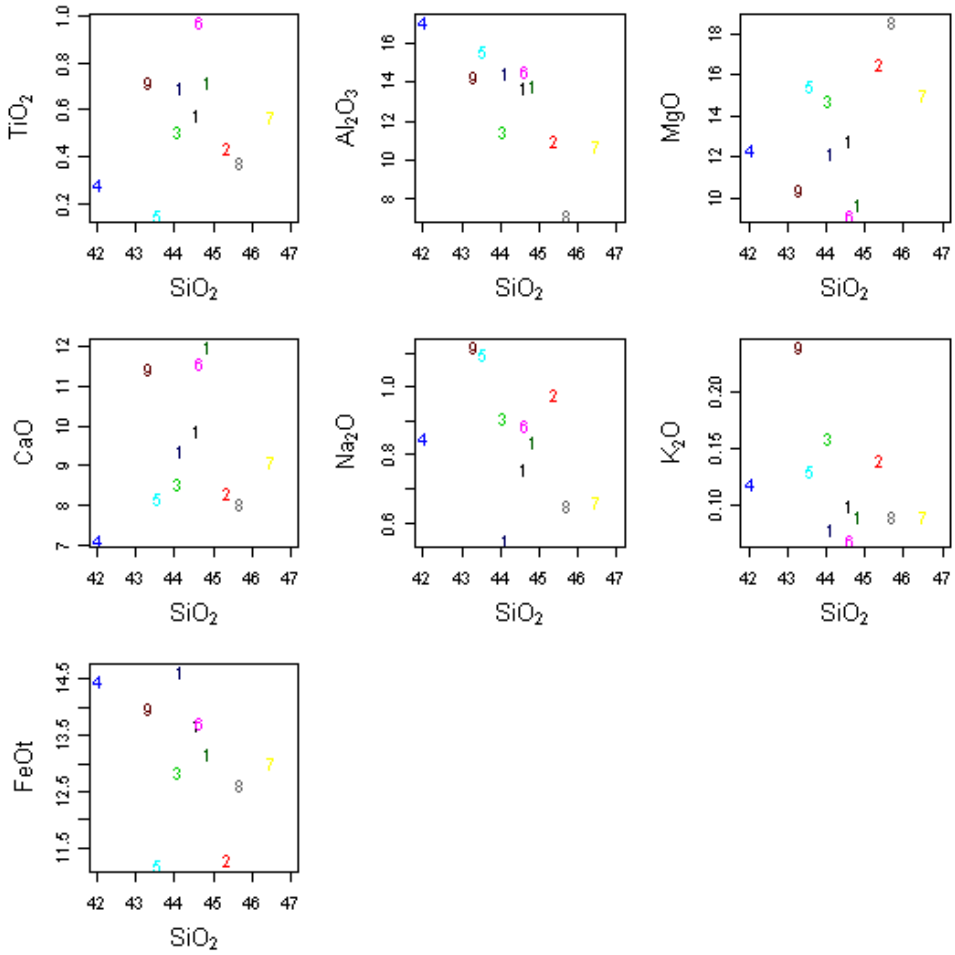

Figure 5: Binary variation diagrams are showing the plots of metapyroxenite/metagabbro suite of rocks a) SiO_2 Vs TiO_2, b) SiO_2 Vs A_2lO_3, c) SiO_2 Vs MgO, d) SiO_2 Vs CaO, e) SiO_2 Vs Na_2O, f) SiO_2 Vs K_2O, g) SiO_2 Vs P_2O_5 &g) SiO_2 Vs $FeO^{(t)}$.

Conclusion:

The area is mainly consisting of chromium bearing meta-pyroxenite. Chromium is dominantly present in the central part of the band. This band width is more than 15 m over a strike length is nearly 400 m. As per the petrographic study, predominantly presence of hornblende and less tremolite with garnet grains.

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