PETROCHEMICAL CHARACTERISTICS AND HYPERSPECTRAL SIGNATURES ON CORUNDUM BEARING PRECAMBRIAN LITHO-UNITS OF VARUNA AREA, MYSURU DISTRICT, KARNATAKA, INDIA

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ABSTRACT

Varuna area of Mysuru District, in Dharwar Craton is composed of precambrian dynamic geological settings is prospects of nearly four kinds of litho units with economically viable minerals including gemstones varieties particularly in contact zones of ultramafics, amphibolite schist with gneiss and granitoids. The study carried out by using advent high-tech tools of Spectro-Radiometer (Spectral Evolution SR-3500) instrument, DARWin SP.V.1.3.0 and GIS software's. Four types of random samples were collected such as gneiss, granitoids, ultramafics and corundum bearing amphibolite schist in the field along with quartzite ridge through GTC (Ground Truth Check). The spectral signatures of the collected samples were derived in a closed laboratory environment to achieve better accuracy. Hyperspectral (350-2500 nm) signatures were developed as the modern technology & works mainly on physico-chemical and optical properties of the litho units which help in mapping of precious gemstones at lithological contacts and mineralized zones. Spectro-radiometer instrument provides a high spectral resolution data of 10 nm to bring out diagnostic features on lithological contacts for better discrimination of gemstones bearing litho-units. The present study aims to apply the advent techniques of hyperspectral signature in mapping, exploration of corundum bearing litho units in Varuna area of Mysuru district in Precambrian basement rocks of Karnataka State.

Keywords: Petrochemical Hyperspectral Signature, Corundum, Precambrian rocks, Varuna, Mysuru.

1. INTRODUCTION

Corundum is a natural oxide of aluminium (Al_2O_3) with 52.9% aluminium and 47.1% oxygen. It has a hardness of 9 on Moh's scale making it the hardest substance after diamond. It has two varieties; viz precious (ruby and sapphire) and abrasive (common corundum). Emery is a natural mixture of opaque, granular corundum and magnetite with minor amount of haematite and other minerals. With a melting point of 2010^0C, corundum finds application in special refractory, crucibles, (Radhakrishnan, 1953) . In nature it occurs as a constituent of igneous rock as well as metamorphosed aluminous clay. In India workable deposits are found in Karnataka. Corundum is a crystalline mineral that occur in different colours, such as, white, grey, blue, green, red, yellow, or brown-based on impurities present (Chandrashekhar, H. and Nazeer Ahmed 1994). Pure ruby based corundum usually found in metamorphosed shales, limestones, metamorphosed igneous suits in the form of

veins, and in some igneous formations. It is used as an abrasive and as gemstone. As gems the red variety is called ruby and blue, sapphire. It is composed of aluminium oxide (Basavarajappa et al., 2004). Its crystal structure is hexagonal (Rhombohedral). The ruby and sapphire are mineralogically mere colored crystals of corundum, whose mineral composition on chemical analysis is shown to consist of earth alumina in crystallised state nearly in pure condition (Basavarajappa et al., 2017). These gems have almost invariably been discovered in the beds of rivers. In addition to its hardness of up to 9 on Mohs scale, corundum's density of 4.02 g/cm3 is unusually high for a transparent mineral composed of low atomic mass elements, such as, aluminium and oxygen corundum occurs as a mineral in mica schist, gneiss and some marbles in metamorphic terrain. It also occurs in low silica igneous syenite and nepheline syenite intrusives (Viswanatha, 1972). Other occurrences are as masses adjacent to ultramafic intrusives, associated with lamprophyre dykes and as large crystals in pegmatites. It commonly occurs as a detrital mineral in streams and beach sands because of its hardness and resistance to weathering. Translucent to opaque ruby, sometimes with asterism is known to be abundant at Mysuru and Subramanium in Karnataka (Jayashree Panjikar et al., 1984) The spectral signatures of the representative samples were compared with mineral spectra of USGS spectral library to record the spectral behavior (Basavarajappa *et al.,* 2015). The absorption and reflection features are studied as described by Hunt and Salisbury (1970), Hunt et al., (1971), Hunt and Ashley (1979) and Blom et al., (1980), the fresh or weathered surface of iron metallic elements causes strong absorptions in Visible and Near Infrared region.

2. STUDY AREA

The study area is located in between $12^0$25’ to $12^0$27’ North latitude and $76^0$72’ to $76^0$75’ East longitude with an aerial extent of 3,435 hectares (Fig.1). The general elevation is of 807 mts above MSL covering mainly red & block soils a flat lying gneisses, ultramafic, Corundum Bearing Pyroxene Granulate pelitics and amphibolite schist (CGWB., 2012).

Table.1. Sample Name and Location

Sl No	Sample Name	Location	Latitude	Longitude
CV-1.	Ruby	Varuna	$12^0$15.716’	76^0 44.163’
CV-2.	Amphibolites Schist	Varuna	$12^0$15.847’	$76^0$44.166’
CV-3.	Corundum bearing (Pilitic rock) Pyroxene Granulate	Varuna	$12^0$15.830’	76^0 44.165’
CV-4.	Corundum bearing Trimolite Actinolite Schist	Varuna	$12^0$16.026’	76^0 44.052’

Note: **CV**- **C**orundum at **V**aruna

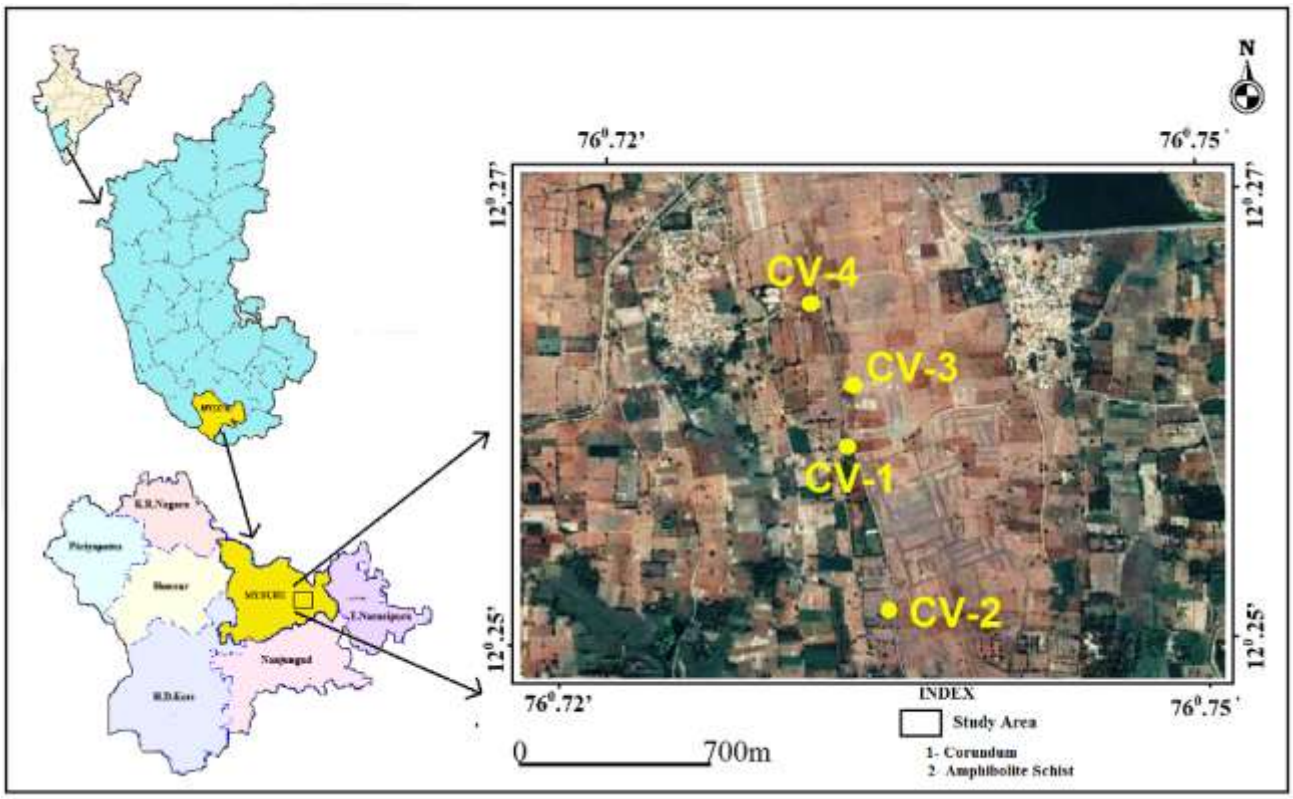

Fig.1. Google Earth image showing the location of the study area

3. GEOLOGY OF THE STUDY AREA

The study area belongs to Sargur group of rocks, between Chamundi hill and Varuna area is essentially a flat lying basement gneisses, ultramafic and amphibolite schist, These rocks are of great economic importance because of the presence of corundum and garnets. The district has a vast expanse of Magnetite gneisses. This high-grade schist is considered as oldest group of supracrustal rocks. These high-grade schists are noticed as rafts within the gneissic complex in the southern parts of the districts and form the type which belongs to Sargur group (Chandrashekhar, H. and Nazeer Ahmed, 1994). This belt starts from north-east of Sargur and it is the oldest group of Precambrian rocks formed about 3000 million years ago. This consists of mainly Kyanite, Silimanite, Graphite, corbonate minerals with Banded Iron Formations. These rocks are of great economic importance because of the presence of graphite, corundum and granets in them. They extend from Bilikere region up to the southern border of the district in the south, south west direction for nearly 50 km. Fine textured granitic rocks are found in Mysore Taluk and around Mysore City (Viswanatha, 1972). The Sargur schist extends from H.D.Kote taluk Mysore city for about 40kms. This belt was named as sargur series, it includes basic igneous rocks. The area between Bettadabeedu and Doddakanya is a flat lying gneissic terrain with numerous enclaves of meta Sediments.The schistose rocks are in the form of bands occurring north north-west of Nanjangud is about eight km in Varuna area and consist hornblende-granulite fuchsite quartzite and calsilicate rocks (Ramakrishnan and Vaidyanadhan.,2008). A complex of migamaties and gneisses occupies the area between the schist bands. Gneisses form gently undulating plains with very low relief. From South-East and North West charnockites are extended in this area. The youngest igneous rocks called Chamundi Granite (800 million Years) are found in the area. Several Dykes of felsites and porphyry associated with this area located in the north-west of the area (Ramakrishnan and Vaidyanadhan.,2008).

3.1 Physiography

Mysore district has Undulating table land with granitic rocks protruding at odd intervals located between Eastern and Western Ghats. The District is situated at an altitude of more than 600 meter above Mean Sea Level. The major hills of the district are Bettadapura hills (1339 meter) in the north-east and Chamundi hill (1074 meter) near Mysore. Towards South-West of H.D.Kote taluk, most of the area is under forest. The mountain ranges in the district originate from the Western Ghats along its southern borders and runs in a northwest and northeast direction. Except in the north, the district is almost entirely surrounded by the Western Ghats, which at places are an elevation of more than 1,200 metres above the mean sea level. (Ramakrishnan and Vaidyanadhan.,2008)

4. METHODOLOGY

All the Field based collected samples were carried carefully to the laboratory for Petrographic study using Petrological, Mineralogical research Microscope. Hyperspectral signatures analyses for all samples were carried out using Lab Spectro-radiometer instrument (Spectral Evolution SR-3500) at Department of Earth Science University of Mysore, Manasagangothri, Mysuru. (Basavarajappa et al., 2017). DARWin SP.V.1.3.0 software is well utilized in analyzing each spectral curves obtained from the collected samples (average of 4 spectral curves from each samples) and well correlated with the standard curves of USGS, JPL and JHU. Garmin-12 GPS is used to record the exact locations of each sample with an error of 9 mts during field visits (Basavarajappa et al., 2017).

5. PETROGRAPHY

5.1 Corundum: The corundum optical properties show Color: colorless, pink to blood-red colored (some time spotted in red – Ruby or blue-Sapphire) The red color is caused by the mineral chromium and shows brownish tone due to the presence of iron. Relief shows high to very high. Prismatic, tabular or skeletal crystals and Rhombohedral parting/ cleavages are common. pleochroism is very strong in ordinary light and shows deep red color when viewed in the direction of vertical axis and a much lighter color to nearly colorless in view at right angles to this axis. Birefringence weak, Uniaxial negative. but often up to low II order due to extra thickness of ultra-hard corundum. Parallel extinction. In hornfelses, high grade pelites and syenitic gneisses, environment contact and regionally metamorphosed rocks (Fig.2).

Sericite optical properties shows Color: colorless or turbid pale greyish, Monoclinic system, anisotropic, Pleochrosim – nill Relief weeak, Cleavage very good in one direction in basal sections have no cleavage, Biaxial high birefringence sericite also fills the micro fractures in plagioclase, but it does it in elongated crystals, unlike the rather equant hematite crystals. Sericite is a fine-grained variety of muscovite, with the same composition $KAl_2(AlSi_3O_{10})(OH)_2$. It usually forms by hydrothermal alteration of K-feldspars, which provide the necessary potassium. It grows in pre-existing microfractures where the fluids can penetrate, or in fractures created by the fluid pressure., sericite fills cracks around and across plagioclase crystals, sericite that probably has replaced feldspar (Fig.2).

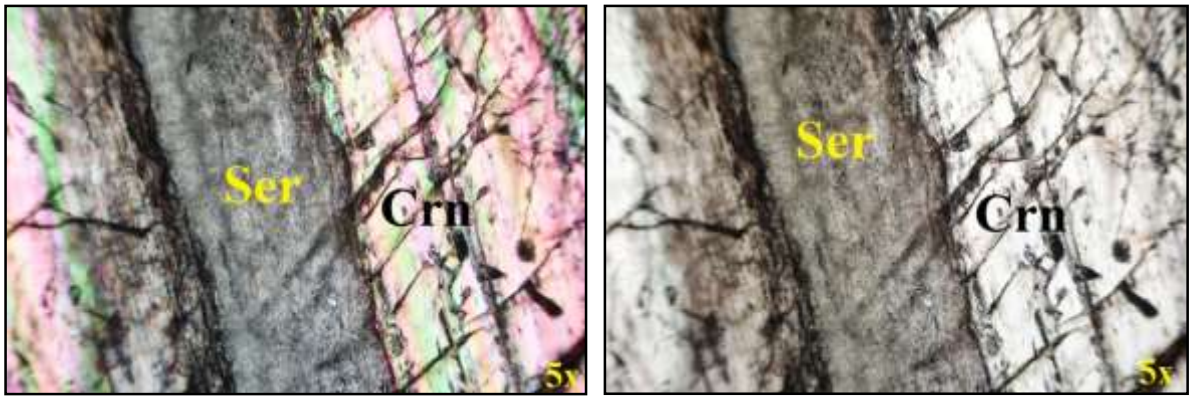

Fig.2. Bigger size Corundum under PPL and XPL

5.2 Amphibolite schist:.

The central part is associated corundum which shows pale blue color; uniaxial; low birefringence and surface relief is high. Amphibole is usually strongly green in coloure, yellow-blue, blue-green and brown. It shows strong pleochroic, moderate relief, high cleavage, birefringence biaxial and pleochroic appears in various shades of green and brown. In plane polarized light, the mineral colour of amphibole ranges from yellowish green to dark green in Colour (Fig.3). Iron rich Garnet shows rounded brown color shape, under microscope it's a silicate of various divalent metals (Aluminium,ferrous iron, and chromium) and trivalent metals (calcium, magnesium. Ferric iron and manganese) brown color with pitted appearance and inclusions of other minerals. Form as rounded polygonal section. Traversed by cracks. Cleavage nill. Very high relief and birefringence nill, istropic, its form very high relief and isotropism are characteristic. It is distinguished from olivine by its forms absence of alteration in to serpentine and isotropism (Fig.3).

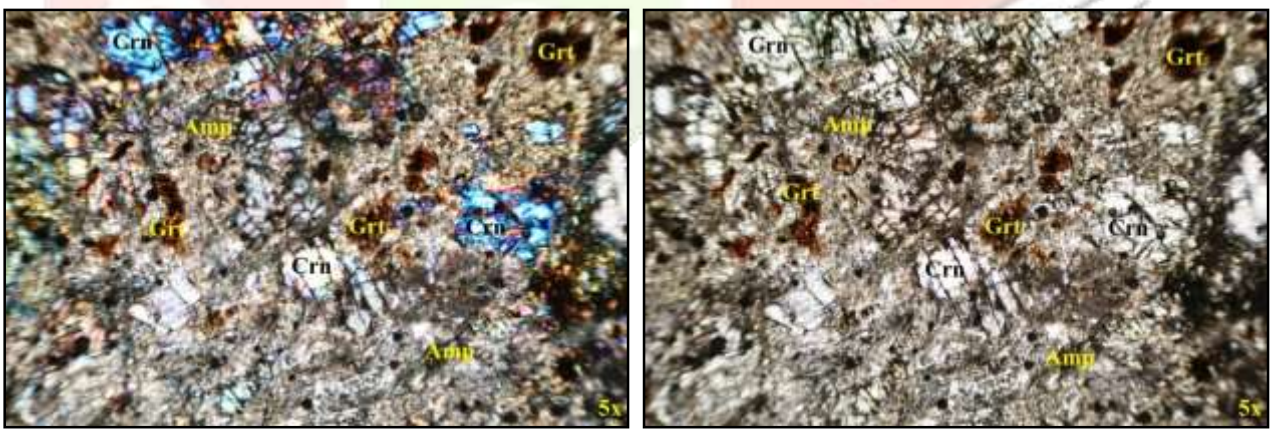

Fig.3. Amphibolite Schist under PPL and XPL

5.3 Corundum Bearing Pyroxene Granulate

Hypersthene is a iron magnesium silicate with more than 15% $FeSio_3$, (Mg, Fe) Sio_3 Color: body colour more marked than in enstatite, colorless to pale green or pale red. Form usually as prismatic grains the cross sections are nearly square. Well developed one set of cleavage traces in prismatic grains and two sets of cleavage traces at right angles to each other in (cross section) grains having nearly square shape. Relief high. Birefringence weak (slightly stronger than in enstatite) yellow to red of the I order interference colors positive elongation, biaxial negative. Extinction parallel in most sections.

Hornblende is the commonest amphibole found in igneous rocks and is most abundant in acid and intermediate rocks. It is less common in ultrabasic and basic rocks where other amphiboles are more commonly found. Most of the minerals show abundant in high grade regional metamorphic rocks such as schist, gneiss and granulite. It can also be found within immature sediments as clastic grains. Hornblende often alters to an intergrowth of tremolite and actinolite sometimes with epidote, giving a blue-green appearance in hand specimen. Central par Corundum shows red, pale blue and pale yellow colour; uniaxial; low bbirefringence, surface relief is high (fig-4).

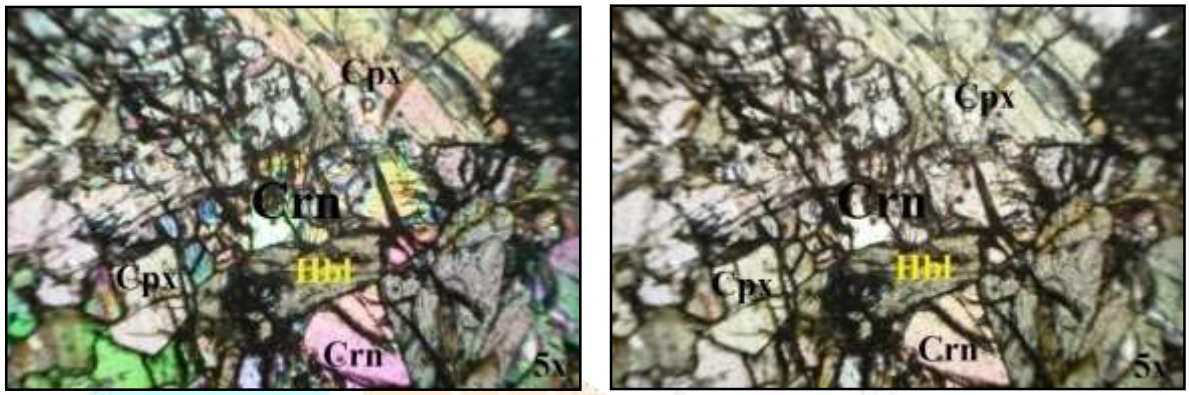

Fig.4. Corundum Bearing Pyroxene Granulate under PPL and XPL

5.4 Actinolite Trimolite Schist

Tremolite is a Hydrous silicate of calcium and magnesium and Monoclinic. Its form long prismatic bladed or needle-like sections and columnar to fibrous aggregates, Diamond shaped cross sections are also common Clevage shows longitudinal (prismatic) sections show one set of cleavage traces parallel to the length, Relief high positive, Birefringence moderate Blue, or green of II order interference colours positive elongation, biaxial negative. Inclined extinction. features Distinguished from actinolite and hornblende by its colourless (non-pleochroic) property, and from augite by its lower extinction angles and cross sections. Actinolite is a hydrous calcium, magnesium and iron silicate. Color shows pale green, pleochroic from green to greenish yellow. The rest of the properties regarding from, cleavage, birefringence, sigh of elongation and extinction are the same as in tremolite it has slightly higher relief than tremolite. Distinguishing features, low extinction angle pleochroism and the amphibole cross sections are characteristic. It is distinguished from hornblende by its lower extinction angles and from aegirine by its higher extinction angles and amphibole cross sections and from aegirine augite by its lower extinction angles and amphibole cross sections. Corundum shows colorless and pale blue colour; uniaxial; low birefringence, surface relief is high (fig-5).

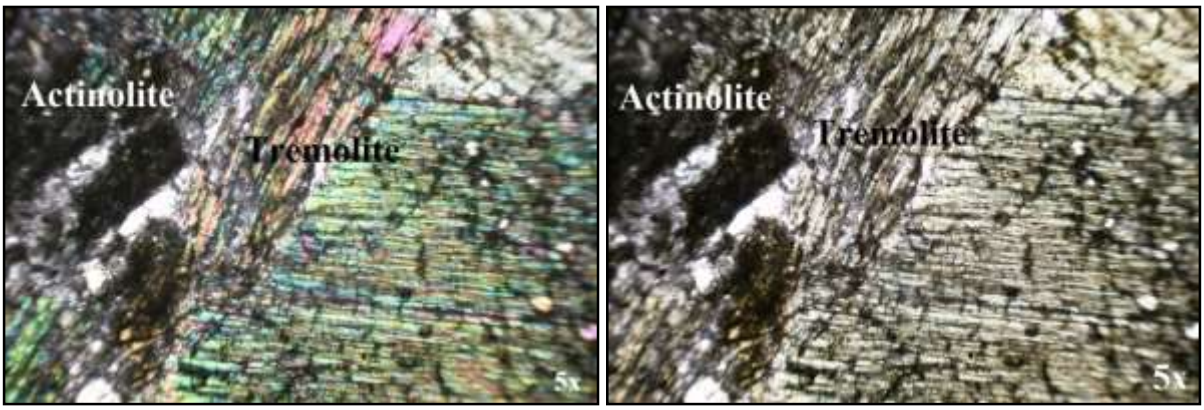

Fig.5. Actinolite Trimolite Schist under PPL and XPL

6. HYPERSPECTRAL SIGNATURS

Spectral signature measures all types of wavelengths that reflect, absorb, transmit and emit electromagnetic energy from the objects of the earth surface (Ali M. Qaid et al., 2009). Specral Evolution (SR-3500) Spectro-radiometer instrument has the ability to measure the spectral signatures of different rocks/ minerals. The SR-3500 operate in the wavelength range of 350–2500 nm with three detector elements: a 512-element Si PDA (Photodiode Array) covering the visible range and part of the near infrared (up to 1000nm) and two 256-element InGaAs arrays extending detection to 2500nm.The spectral signatures of the representative samples were compared with mineral spectra of USGS spectral library in DARWin SP.V.1.3.0 (Hunt et al., 1971). Absorption spectral values obtained from the DARWin software lab Spectra is the one character helps in the study of major and minor mineral constituents.

7. RESULT AND DISCUSSION

Major element composition of Four samples of corundum bearing rocks were determined at the using spectral signatures. The spectrometer component is a crossed Czerny-Turner configuration using ruled gratings as the dispersive elements. Energy enters the spectrometer and is collimated before being reflected off the gratings and refocused onto the PDA (Photodiode Array) detectors. There are three detectors. The first is a 512-element silicon array covering the spectral range from 350 to 1000 nm (280–1000nm). Two thermoelectrically cooled InGaAs (Indium Gallium Arsenide) arrays of 256 elements each extend the spectral range up to 1900nm and 2500nm respectively. The spectroradiometer and controlling electronics are contained in the housing. International standards for minerals such as USGS were compared along with the major elements for the field samples to check precision and accuracy of measurement. The certified and analyzed values of USGS are given in the figures along with major element abundances of samples to check the error limits of measurement (Hunt et al., 1971).

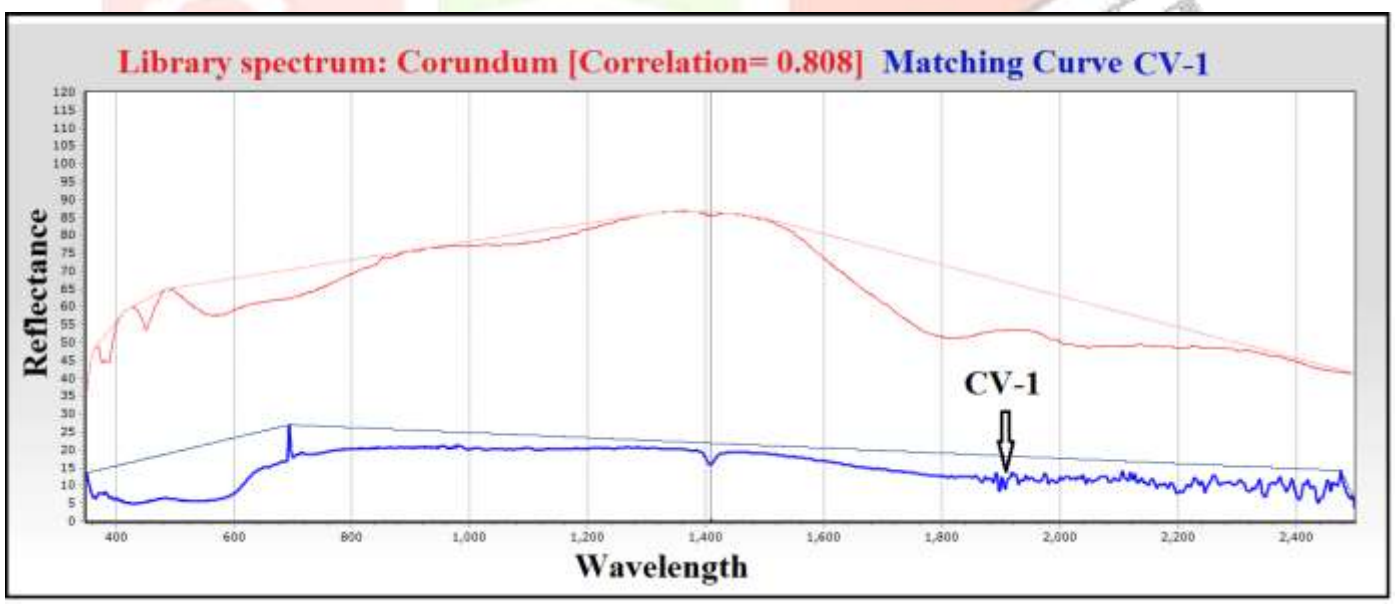

Fig.6. Lab Spectral signatures of Corundum, Varuna area, Mysuru

Corundum Al_2O_3 mineral type - Oxide (Hematite group) this sample prepared from crystals that were brownish near the surface. very sharp corundum reflections suggest excellent crystallinity and compostional homogenety. composition discussion analysis showed the sample to contain 0.01% Cr. 05% Fe and 0.2% Si with traces of Ti,

V, Mn, Mg, Ca and Cu the iron appears to be present on both ferrous (0.55. 0.45 and 1.1um absorption features) and ferric (0.7. 0.45 and near 0.4um) from the Cr^{3+} ion contributes to the 0.4. 0.55 and 0.7um (emission) features. spectral discussion Sample plots are correlated with standard USGS Spectral Library using absolute reflectance v/s wavelength which provide strong absorption range in 2.20 µm and 0.65 µm representing the mineral corundum shows intense absorption feature in 2.40 µm of the electromagnetic spectrum (Hunt et al., 1971). Absorption anomalies at wavelength regions of 0.55 µm and 0.9 µm of Fe3+ and Fe2+ ions are observed respectively with low reflectance in the VNIR region (Ali M. Qaid et al., 2009) (Fig.6). Major element content as Al_2O_3 content shows high range imparts a corundum character with that of high aluminum content. library spectrum corundum correlation score 0.808 percent match the curve (Fig-6)

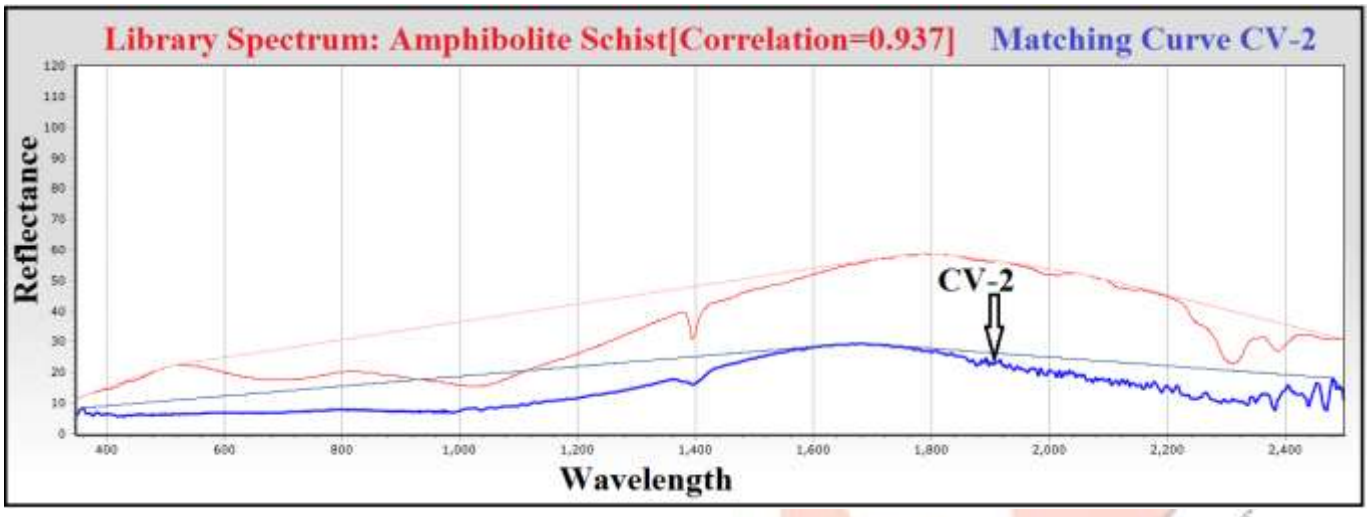

Fig.7. Lab Spectral signatures of Amphibolite Schist, Varuna area, Mysuru

Amphiboles are found principally in metamorphic and igneous rocks. They occur in many metamorphic rocks, especially those derived from mafic igneous rocks (those containing dark-coloured ferromagnesian minerals) and siliceous dolomites. Major and minor element content of amphibolite schist shows SiO_2 ranging between 41.64% and 42.01%; MgO content is fairly low and ranges from 9.66% to 8.28%; Al_2O_3 content high ranges from 24.76% to 26.57%; CaO content is 13.59% to 12.24%; K_2O content of ranges from 0.02% to 0.03%; TiO_2 content is fairly low and varies from 0.12% to 0.55% and P_2O_5 ranges from 0.01% to 0.04% (M. Qasim Jan 1988). Spectal discussion Sample plots provide strong absorption range from 2.0 – 2.25 µm representing the mineral corundum whereas amphibole shows intense absorption feature in 2.35 µm of the electromagnetic spectrum (Hunt et al., 1971). Absorption anomalies at wavelength regions 0.55 µm and 0.9 µm of Fe^{3+} and Fe^{2+} ions are observed respectively (Fig.7). Absorption range 1.4µm are noticed due to the presence of water and hydroxyl molecules in the present sample (Ali M.Qaid et al., 2009). library spectrum Amphibolite Schist correlation score 0.937 percent match the curve (Fig-7)

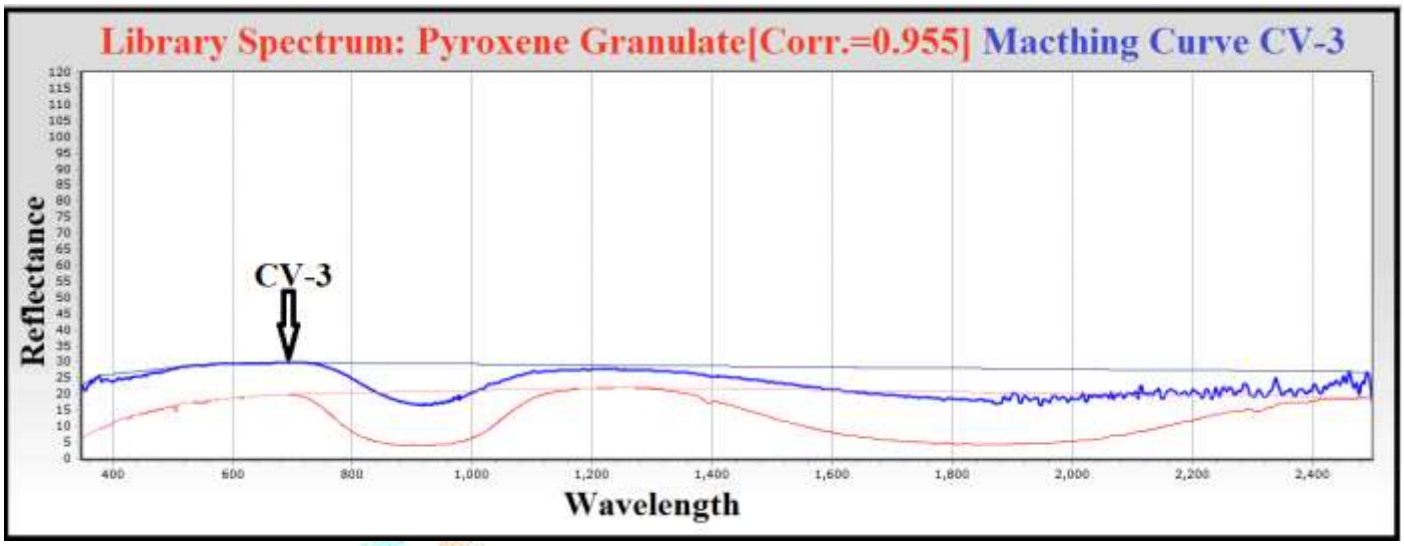

Fig.8. Lab Spectral signatures of Pyroxene Granulate, Varuna area, Mysuru

Hypersthene (Fe-rich enstatite, Pyroxene group) (Mg. Fe^{+2}) Si_2 O_6 mineral type Inosilicate. sample descripion intermediate member of the series enstatite orthoferrosilite. The original sample description and Vis-nir Spectrum was published by Singer R.B. 1981. Spectral discussion of Hypersthene shows spectra as strong range from 0.65m to 0.95m. The sample is pure Pyroxene except for a small (less than 2%) amount of tremolite. The tremolite shows in the spectra as weak (narrow) bands at 2,3m and 1.4m singer suspected the tremolite but it confirmed by higher resolution spectra in this library. The chemical composition XRF shows SiO_2 -55.30%, Al_2O_3 – 0.12%, TiO_2- 0.05%, Cr_2O_3- 0.02%, FeO- 9.38%, MnO- 0.15%, MgO- 32.80%, Na_2O- 0.00%, minor content as P2O5-0.01%. LoI-2.00%. the sample appears to be pure Pyroxene except for small amount of tremolite. Library spectrum Pyroxene Granulate correlation score 0.955 percent match the curve (Fig-8)

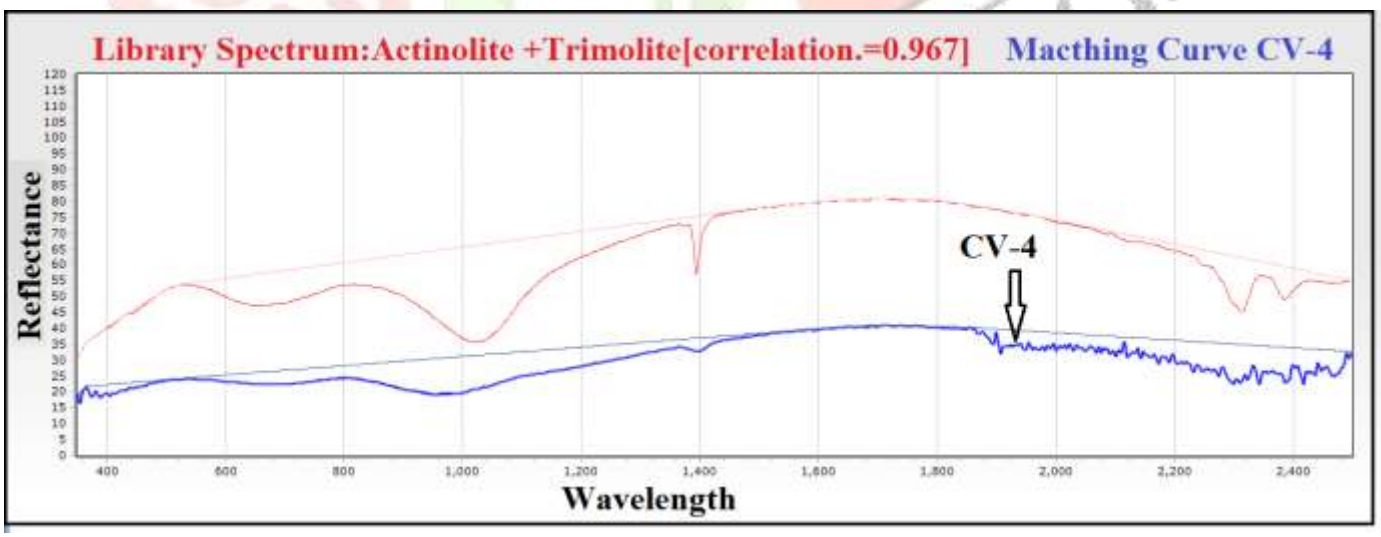

Fig.9. Lab Spectral signatures of Actinolite Tremolite Schist, Varuna area, Mysuru

Mixture Actinolite-Tremolite, Phlogopite and Chlorite Hornfels Rock (Amphibole group) Ca_2 (Mg, Fe^{+2})$_5$ Si_8 O_{22} $(OH)_2$ Actinolite, Tremolite bearing rock contact skarn quartz- monzonite wall rocks with the iron ore

deposit Spectral discussion generic broad Fe^{2+} one micron band an OH stretch at 1.4 microns and strong (Mg, Fe) OH combination bands at 2.32 and 2.38 microns.forms series with tremolite and Ferro-actinolite. Unusually large number of sharp reflections indicating excellent crystallinity and suggesting compositional homogeneity pattern is creel califomia and calculated tremolite pattern of Brog and Smith (1969). Chemical compostion XRF analysis of Actinolite - Tremolite Schist shows the distribution of major element content as SiO_2 -57.72%, Al_2O_3 – 1.38%, minor content as TiO_2- 0.01%, Cr_2O_3- 0.02%, FeO- 1.37%, MnO- 0.33%, MgO- 24.58%, CaO- 13.27%, Na_2O-0.37%, K_2O-0.09%. Library spectrum Actinolite Tremolite schist correlation score 0.967 percent match the curve (Fig-9)

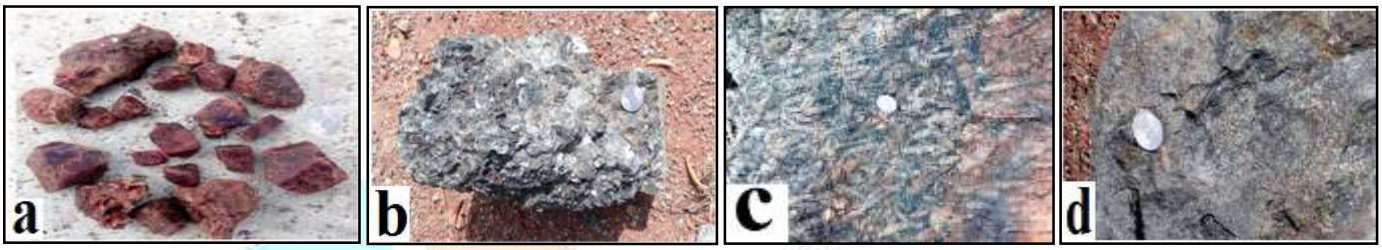

Fig.10. Hand specimen of (a)Corundum bearing Ruby (b)Actinolite Tremolite Schist (c)Pyroxene Granulate (d)Amphibolite Schist collected samples Varuna area of Mysuru.

8. CONCLUSION

Petrography and Geochemical signatures demarcating that Amphibolite is clearly showing corundum formation due to hydrothermal alterations during the metamorphic reactions and there is no clear such alterations in tremolite zone due to micro tectonic and deformational process. Lab spectra of corundum identified in the wavelength of 2.10 µm and 2.20 µm regions through the absorption curve matches the USGS standard. Petrographic studies for the selected samples were carried out and identified mineral assemblage of Corundum bearing rocks. The perfect tabular texture and colorless to red, pale blue pleochroic character reveal the presence of Corundum mineral in the collected samples. Hyperspectral signature data were analyzed for the same part of corundum bearing sample using Lab Spectro-radiometer which shows best match with that of USGS Spectral Library Standards. Compare the Amphibolite schist and Trimolite actinolite schist corundum purity is amphibolite schist best curve matches to compare the Spectral Evolution (SR-3500) instrument.

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