PETRO – CHEMICAL AND SPECTRAL SIGNATURES ON CORUNDUM BEARING PRECAMBRIAN AMPHIBOLITES IN SULLIA AREA, DAKSHINA KANNADA DISTRICT, KARNATAKA, INDIA.

Basavarajappa H.T and Maruthi N.E
Department of Studies in Earth Science, Centre for Advanced Studies in Precambrian Geology,
University of Mysore, Manasagangothri, Mysuru – 570 006, Karnataka, India

ABSTRACT

Corundum deposits and occurrences are typically associated with Amphibolite schist in Sullia area. Precambrian basement rocks of Karnataka composed of active and dynamic geological settings with economic mineral deposits and variety of gemstones. These gemstones were noticed all along the lithological contacts of Green stone & Schist Belts, younger granites and granitoids of Dharwar Craton. Corundum is a rock-forming mineral occurs in igneous, metamorphic and sedimentary rocks which represent rich amount of Aluminium oxides (Al_2O_3) in hexagonal crystal structure. The extreme hardness of corundum makes an excellent abrasive for industrial uses. The study area Sullia comes to Dakshina Kannada District. The district exposes mainly rock types belonging to the Precambrian Peninsular Gneissic Complex (PPGC), schistose rocks of Sargur group and Dharwar super group. Random samples were collected such as gneiss, granitoids, and corundum bearing amphibolite schist through GTC (Ground Truth Check). The study carried out by geological, petrochemical and Hyperspectral signature using advent high-tech tools of Spectro- Radiometer (Spectral Evolution SR-3500) instrument, DARWin SP.V.1.3.0 and GIS software's. The spectral signatures of the collected samples were derived in laboratory environment to achieve better accuracy. Hyperspectral (350-2500nm) were developed as 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. The present study aims to charactrize the spectral behavior of Corundum and associated rocks. Spectral radiometer instrument bring out diagnostic features on lithological contact for better discrimination of gemstones and altered minerals. The final results highlight the spectral characters of corundum and associated rocks for better mapping in similar terrains of Sullia area of Dakshina Kannada district in Precambrian basement rocks of Karnataka State.

Keywords: Hyperspectral Signatures, Geochemistry, Corundum, Amphibolite schist, Sullia.

1. INTRODUCTION

Ruby is commonly known as Manak or Lal in Hindi and Manikya in Kannada. It is the transparent red-colored variety of corundum mineral. The word corundum is derived from the Sanskrit word kuruvinda and in Sanskrit ruby stands for Ratnaraj which means something like king of the gemstones. Ruby is distinguished for its bright red colour, being the most famed and fabled red gemstone. Besides, its bright colour, it is a most desirable gem due to its magnificent colour, excellent hardness and outstanding brilliance, durability, luster and rarity. Transparent rubies of large sizes are even rarer than diamonds and ruby is found in hexagonal prisms and blades forms (Basavarajappa et al., 2018). The ruby, which sprays out red rays in the sunlight and glow in darkness, is considered a superior quality gemstone. Ruby when rubbed on a stone and the stone shows signs of rubbing and also the ruby does not lose its weight, it is considered to be of a superior quality. The chemical formula for ruby is, Al_2O_3, sp. gr., 3.9-4.1 and its

hardness is 9 (Basavarajappa and Maruthi, 2018). The study area Sullia comes to Dakshina Kannada District. The district exposes mainly rock types belonging to the Precambrian Peninsular Gneissic Complex (PPGC), migmatites and granodioritic to tonalitic Gneiss, schistose rocks of Sargur group and Dharwar super group, older Northern granulites of Karnataka (Basavarajappa et al., 2018) younger granite, Kyanite sillimanite schist of Khondalite group (Awasthi and Krishnamurthy, 1979). The PGC occupy two-thirds of the area and is represented by migmatite, gneiss and other granitoids, the high grade schists equelent to Sargur group occur as continuous bands, small enclaves within the PGC and comprise amphibolites, and ultramafics (Ravindra and Janardhan, 1981). The spectral signatures of the field samples were compared with mineral spectra of USGS spectral library to record the spectral behavior (Basavarajappa and Maruthi, 2018). The absorption and reflection features are studied as described by Hunt and Salisbury (1970), Hunt et al., (1971), Hunt and Ashley (1979) and (Graham Hunt 1977), the fresh or weathered surface of iron metallic elements causes strong absorptions in Visible and Near Infrared region of electromagnetic wavelength.

2. STUDY AREA

The study area is located in between $12^0$31' to $12^0$36' North latitude and $75^0$21′ to $75^0$28' East longitude with an aerial extent of 4,279 hectares (Fig.1). The general area covering mainly red & block soils associated with metamorphosed tonalite-trondhjemite-granodiorite gneiss composition, ultramafics, Corundum and Amphibolite rocks (CGWB, 2009).

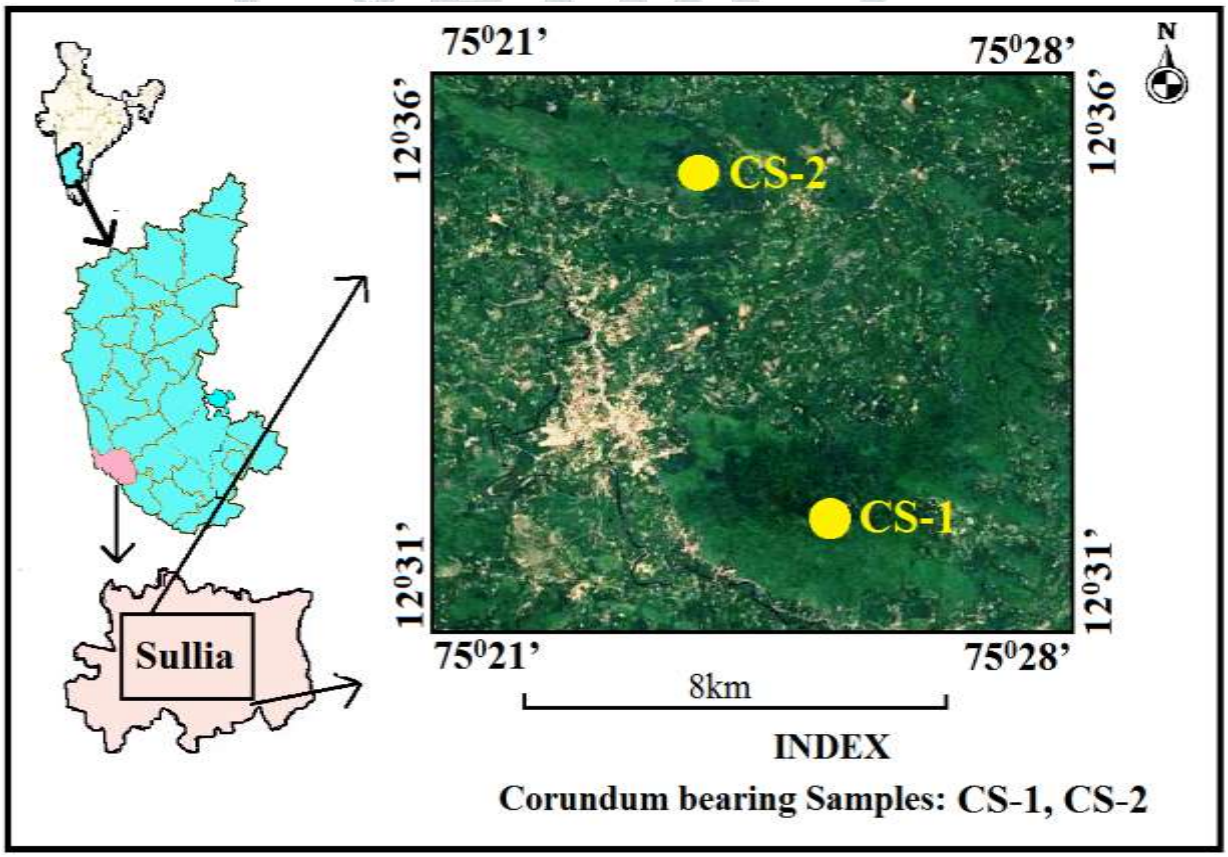

Fig.1. Google Earth image showing the location of the study area

Table.1. Samples collected and it's Location

Sl No	Samples Name	Villages name	Latitude	Longitude
CS-1.	Corundum (Ruby)	Sullia	$12^0$32.536'	75^0 25.423'
CS-2.	Amphibolite Schist	Sullia	$12^0$36.071'	$75^0$23.684'

Note: **CS- C**orundum at **S**ullia

3. GEOLOGY SETTINGS

Study area Sullia comes to Dakshina Kannada District. The district exposes mainly rock types migmatites and granodioritic to tonalitic Gneiss, schistose rocks, younger granite, Kyanite sillimanite schist. The coastal stretch and the adjacent Western Ghats are composed of Precambrian (Archeaen) rocks and the Phanerozoic formations. Sargur group is composed of high grade metamorphic rocks of upper amphibolitic to lower granulitic facies, occurring within gneisses and granites (Swaminath and Ramakrishnan, 1981). Awasthi and Krishnamurthy, (1979) and Ravindra and Janardhan, (1981), in their study reported the presence of rock type equivalent to Sargur group in the southern most part of coastal Karnataka such as Puttur, Sullia and Dharmasthala. The main rock types in the area are pyroxene granulites, garnetiferous biotite gneisses. As mentioned earlier, the Peninsular Gneisses covers major part of the southwest coast consisting of migmatitic grey gneisses which fall within tonalite-trondhjemite-granodiorite composition (Naqvi and Rogers, 1983; Radhakrishna and Naqvi, 1986). The charnockite rock formations are diminishing towards northern part of the coastal region, suggesting an increase in the metamorphic grade from North to South (Radhakrishna, 1983). Dharwar supergroup rocks such as metavolcanics, banded magnetite quartzites, and porphyritic lavas, tuffs and chlorite schists rests unconformably over the peninsular gneiss basement. The unconformity is marked by an oliogomictic conglomerate belonging to early Proterozoic age (Swaminath and Ramakrishnan, 1981). Phanerozoic Formations Laterites form extensive cover along the coastal tract as well as foot hills of Western Ghats, which occurs as plateaus and cappings over basement rocks. These laterites are formed during the Tertiary period (Vishwanathaih et al., 1974). Poorly developed Quaternary formations can be seen along the coast of Karnataka and they are represented by boulder-pebble beds deposited on the paleo-river channels of Nethravati and Gurupur (Subrahmanya et al., 1991). The greater part of the Sullia taluk is laterite covered. Beneath this cover, major rock types encountered are gneisses and granulites containing enclaves of kyanite-sillimanite ± corundum schist; kyanite-sillimanite-garnet-graphite schist; quartz-chlorite-biotite schist; quartzite; chlorite-tale-actinolite schist and amphibolite. The mineralogy of these assemblages are strongly reminiscent of Sargur supracrustals, though they could equally well be correlated wjth the khondalites(Ravindra and Janardhan, 1981). Younger augen granites are seen. These rocks show a general EW trend and dip steeply towards north. Towards the north, NNW trends prevail. The EW trends appear to be late and are superimposed (Ravindra and Janardhan, 1981)

4. METHODOLOGY

Field based collected samples were carried carefully to the laboratory for Petrographic study using Petrological, Mineralogical research Microscope; while geochemical data was received through XRF and ICP-MS (Inductively Coupled Plasma Mass Spectroscopy) Minerals, Materials Science & Technology Division NIIST Thiruvananthapuram, Kerala. 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 and Maruthi., 2018). 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. Survey of India (GSI) topo map and Geological quadrangle map (48P) of 1:2.50.000 scale is used during the field work to study corundum bearing litho units. 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 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 and regionally metamorphosed rocks (Maruthi et al., 2018) (Fig.2).

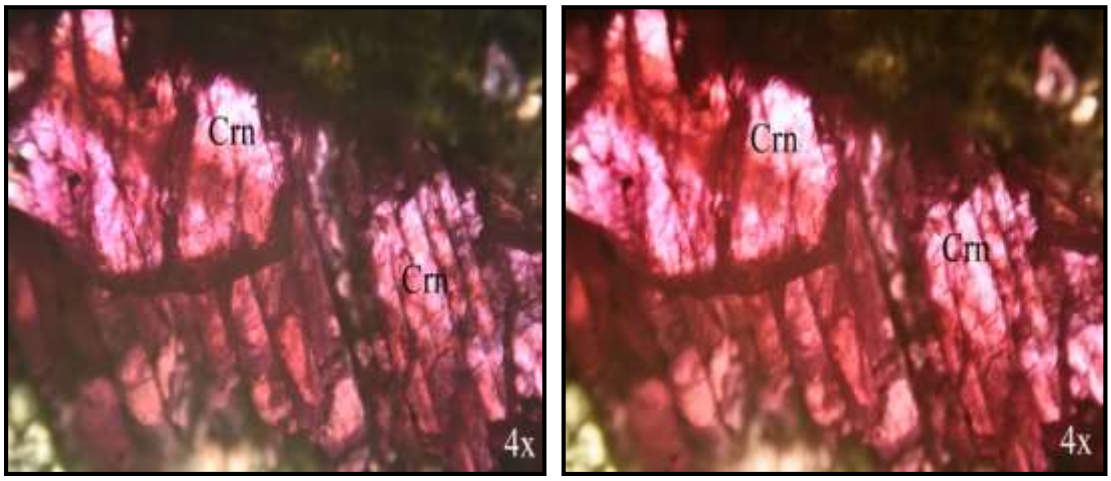

Fig.2. Corundum under PPL and XPL

5.2 Amphibolite schist:

Amphibole is usually strongly green in coloure, yellow-blue, blue-green, dark greenish 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. The corner part is associated corundum which shows pinkish red color; uniaxial; low birefringence and surface relief is high (Fig.3).

Amphibolite hosted Corundum shows various shades of yellowish green and reddish brown to dark brown are observed in hornblende showing Slender prismatic to bladed crystals, with 4 or 6 sided cross section which exhibit amphibole cleavage also has anhedral irregular grains which shows moderate to high positive relief. Hornblende cleavages on intersection at fragment shape is controlled by cleavage; birefringence; interference colors usually has higher first or lower second order. The mineral shows simple and lamellar twinning; biaxial and shows alteration to biotite & chlorite or other Fe-Mg silicates. Corundum shows pale yellow colour; uniaxial; low birefringence, surface relief is high (Fig.3).

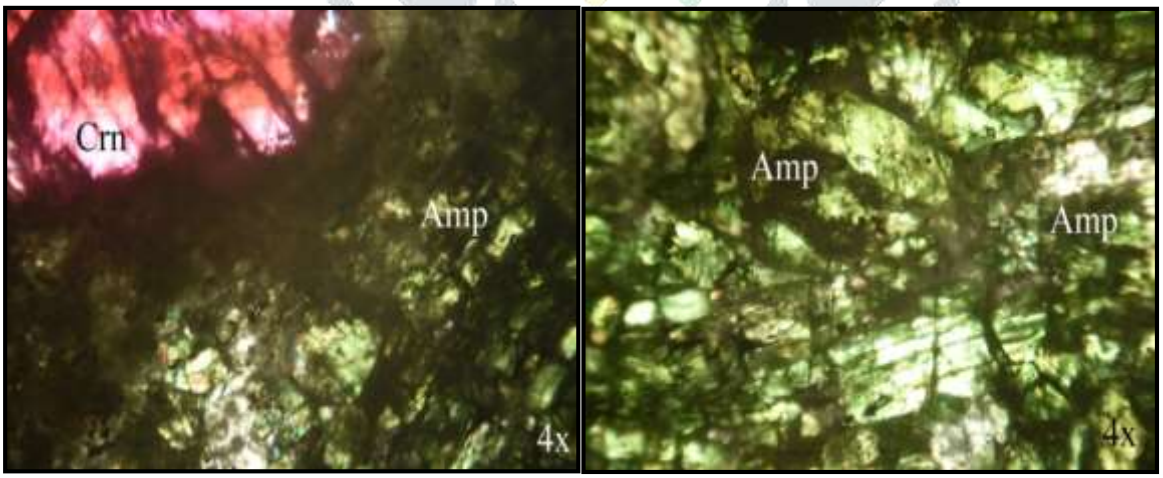

Fig .3. Corundum bearing Amphibolite Schist under microphotographs.

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 samples of corundum bearing rocks were determined at the chemical division and geochemistry its using XRF and ICP-MS methods. 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).

Corundum Al_2O_3 mineral type - Oxide this sample prepared from crystals that were brownish near the surface and bluish – green near in the interior. Very sharp corundum reflections suggest excellent crystallinity and compostional homogeneity (Maruthi et al., 2018). 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.4). 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 0.919 percent match the curve (Fig-4)

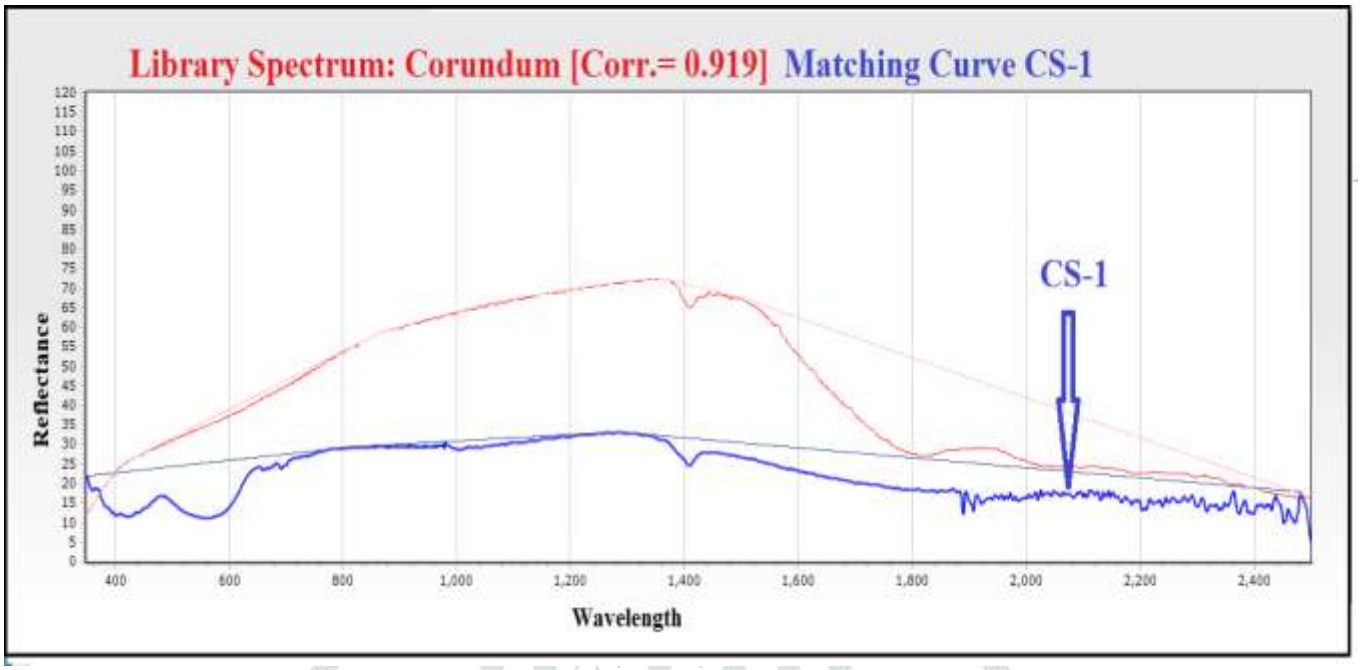

Fig.4. Lab Spectral signatures of Corundum, Sullia area,

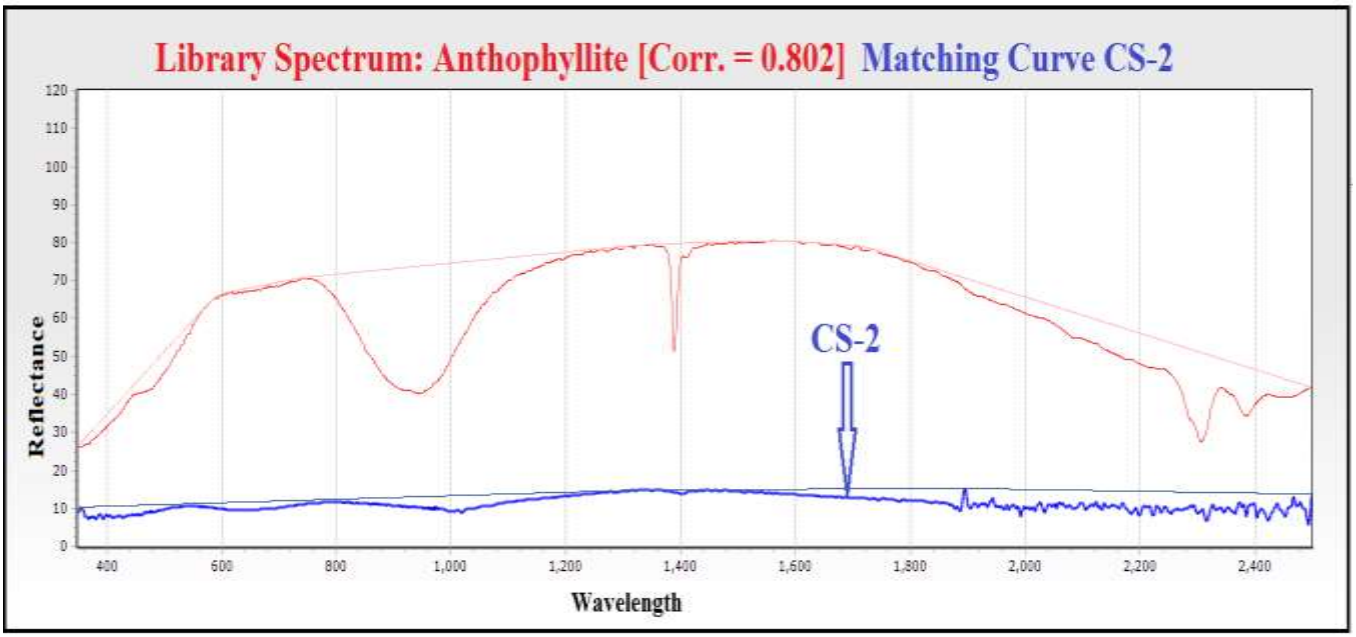

Fig.5. Lab Spectral signatures of Anthophyllite, Sullia area,

Anthophyllite (Amphibole group) mineral type Inosilicate (Mg Fe^{+2})$_7$ Si_8 O_{22} $(OH)_2$. Forms series with Magnesio-Anthophyllite and ferro-anthophyllite. The dominant feature in its spectrum is the very well defined band at 0.95um due to Fe^{+2} in the octahedral site and this is accompanied by bands at 0.375. 0.475 and 0.65um the very weak 0.65um band indicates the presence of a very little ferric iron which enters the mineral when aluminum substitutes for silicon bands at 1.4, 2.34 and 2.4um are all due to the OH vibrations and there is a complete absence of evidence for molecular H_2O (Hunt et al., 1973). 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 (Maruthi et al., 2018). 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.5). Absorption range 1.4µm is 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 0.802 percent match the curve (Fig-5). Lab spectra of

corundum strong absorption range identified in the wavelength of 2.10 µm and 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).

Table.2. Major Elements and Spectral analysis data of the samples of the study area

Chemical Elements		Samples	
		CS-1	**CS-2**
Elements (wt%)	SiO_2	18.14	30.7
	Al_2O_3	***73.68***	***26.2***
	Fe_2O_3	0.63	10.54
	MgO	0.12	23.52
	CaO	5.42	5.57
	NiO	0.28	0.54
	K_2O	0.28	0.85
	TiO_2	0.15	0.62
	MnO	0.36	0.13
	P_2O_5	0.23	0.71
	Cr_2O_3	0.14	0.24
	Ba O	0.38	0.001
	ZnO	0.12	0.13
	Total	**99.93**	**99.751**
Rock type		Corundum	Amphibolite Schist
Spectral Analysis			
Absorption spectra (µm)	Lab spectral signature	2.10, 2.20, 2.40 0.65	0.657, 0.880, 1.400, 1.800, 2.250, 2.350, 2.400
Best matches to	USGS	Corundum	Amphibole, Anthophyllite corundum

Fig.6. Hand specimen of Corundum bearing Amphibolite Schist (a) & Ruby(b) (Corundum) collected samples Sullia area of Dakshina Kannada district.

8. CONCLUSION

Geological, Petrographic, Physical and Chemical characteristics are studied and discrimination shows purity of the mineral present in the Precambrian rock. 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 present in the collected samples. 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 shows the purity of mineral present in the rock. 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. Ruby is basically aluminium oxide and is used Madicinal mineral to treat anaemia or shortage of blood. It is also useful in treatment of low blood pressure and mental diseases. It strengthens nervous system and help fighting paralysis. It is also utilized for indigestion and gastric troubles.

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