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Hyperspectral and Petro - Chemical Signatures Study on Corundum Bearing Litho-Units around Sringeri Area, Chikmagalur District, Karnataka, India

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ABSTRACT

Most extensively sought after gem stones are the varieties belonging to the mineral groups of corundum and beryl. Ruby and variously colored sapphires are next only to diamond in properties and beauty. In fact, many connoisseurs value ruby much higher than diamond, as large, flawless and intensely colored rubies are much rarer in nature than large diamond. Precambrian basement rocks of Karnataka composed of active and dynamic geological settings with economic mineral deposits and variety of gemstones. Sringeri area comes to Chikmagalur district, it has six kinds of litho units with economically viable minerals including gemstones varieties particularly in contact zones of ultramafics, Banded iron formation, amphibolite schist with gneiss and metabasalt & amphibolite - metagabbro. Random samples were collected such as amphibolite, gneiss and corundum within basement crystalline rocks 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 of the study area. Spectral radiometer instrument bring out diagnostic features on lithological contact for better discrimination of verity gemstones and altered minerals. The final results highlight the spectral characters of corundum in economic mineral industry and associated rocks for better mapping of Sringeri area of Chikmagalur district of Precambrian rocks and similar terrains of Karnataka State.

1. Introduction

Corundum is a very hard, tough, and stable mineral. Ruby is a transparent, lustrous, red gem variety of corundum. This is the most fascinating gem stones after diamond. It frequently shows variation in colour from deep to pigeon's blood red, in parallel or irregular bands (Basavarajappa and Maruthi, 2018). The colour is supposed to be due to traces of chromium. The minute, hexagonal or irregular, often elongated or angular cavities and irregularly occurring inclusions are distinguishing characters of natural ruby. It also has low dispersion and hence exhibit no 'fire'. There is an abnormal amount of fire, when parallel. Fibrous inclusions occur along the lines of crystallization (Basavarajappa et al., 2018) . Ruby, when cut in en-cabochon fashion (dome shaped, the base coinciding with the basal plane of the crystal) shows a white, six-rayed star on the surface when examined in light (Maruthi et al., 2018). The phenomenon is called as 'asterism'. Such star ruby is a valuable gem stone. Ruby occurs as disseminated crystals formed by (a) Magmatic segregation of basic igneous rocks. (b) Desilication of pegmatite dykes intruded into basic igneous rocks. (c) Metamorphism of highly aluminous rocks. And It also occurs as alluvial placers (Swaminath and Ramakrishnan, 1981). The study area Sringeri comes to Chikmagalur district. The district exposes mainly comprise rocks are equivalent to Sargur group, in Bababudan group of western ghats in southern India, Peninsular Gneissic Complex (PGC), contact zones of ultramafics, Banded iron formation, amphibolite schist with gneiss and metabasalt & Amphibolite - metagabbro and basic and younger intrusives of the precambrian era (Ramakrishnan and Vaidyanadhan., 2008). 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 $13^0$15.0' to $13^0$35.0' North latitude and $75^0$05.0' to $75^0$25.0' East longitude with an aerial extent of 54258 Hectares (Fig.1). The general area covering the soils of the Malnad parts of the Chikmagalur district are nearly poor acidic type. Along the south of Bababudan range, there is a rich tract of black cotton soil and also found in the neighborhood of Ajjampura together with red and gravelly soils and in different parts of Tarikere and Kadur taluks. The Western parts of Tarikere taluk contain sandy and gravelly soils. About 50% of the soils of the district are acidic

in nature and remaining areas are neutral with regard to soit reaction, A few patches of soils in Tarikere and Kadur talukg are alkaline in nature. The lateritic mils are found in parts of Koppa, Mudigere, and Sringeri taluks and are acidic in nature, with deficiency in Nitrogen, potash, Phosphorous and lime. Red sandy and red loamy soils, which are acidic to neutral, are found in and around Tarikere, NR Pura, and parts of Kadur Taluk.. The study area mainly comprises of red loamy & sandy soil. However, hilly area soil and mixed red & black soil are also found to occur in small areas in the central and northeastern part respectively, the red & block soils associated with metamorphosed granitic gneiss composition, ultramafics, Corundum bearing Amphibolite schist rocks. (CGWB., 2013).

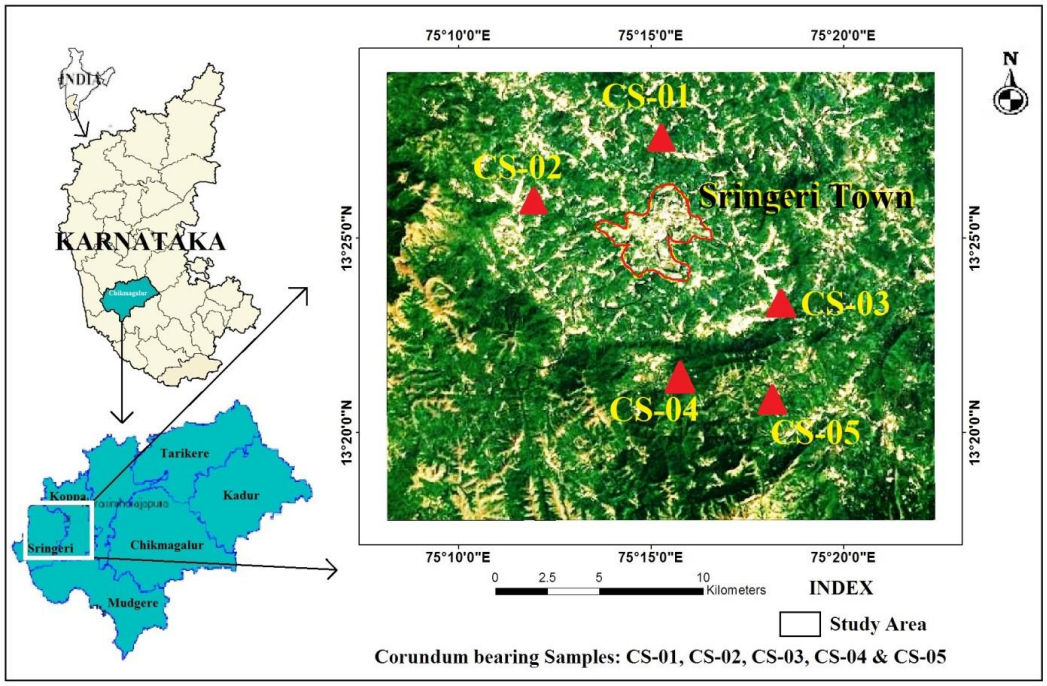


Fig.1. Google Earth image showing the location and samples collected in the study area

Table.1. Random Samples collected with GPS Locations

Sl No	Samples Name	Villages name	Latitude	Longitude
CS-01.	Corundum	Melukoppa	$13^0$27.310'	75^0 15.201'
CS-02	Corundum	Kogodu	$13^0$25.751'	75^0 11.931'
CS-03	Corundum	Kunchebylu	$13^0$23.135'	75^0 18.207'
CS-04	Corundum bearing amphibolites schist	Malanadu	$13^0$21.283'	75^0 15.719'
CS-05	Corundum bearing amphibolites schist	Heggaru	$13^0$20.798'	75^0 17.929'

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

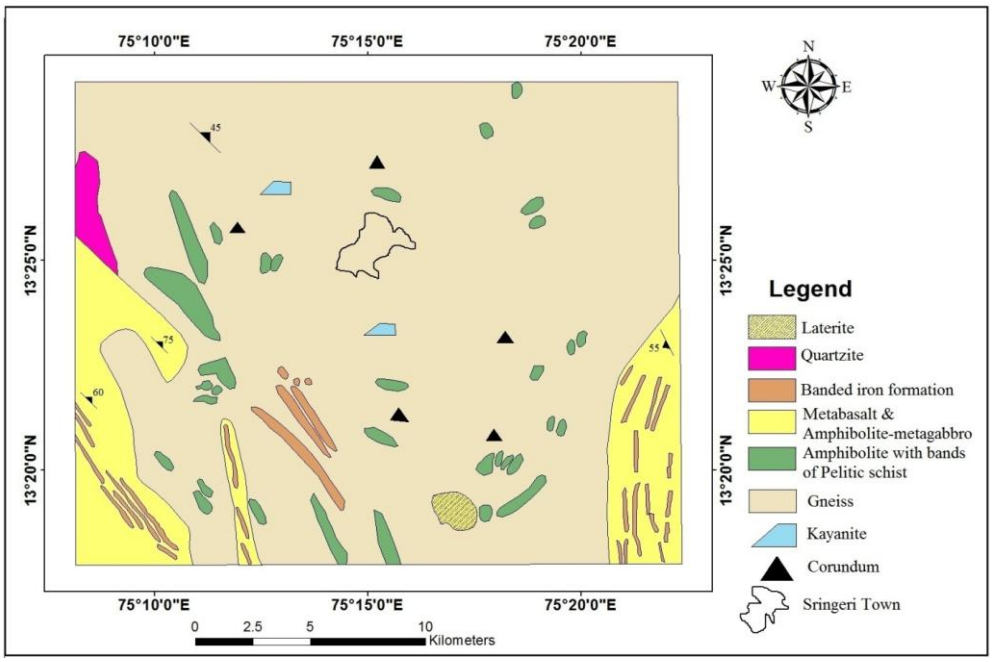


Fig.2. Geological map of the study area with sample Locations (after GSI 1966)

3. Geology

The study area Sringeri comes to Chikmagalur district. Geologically the study area made up of Archean Schists and basement Gneissic rocks. The Dharwar schists occupy 50% of the area of the district and occur as three distinct belts, The Kudremukh Gangamwla belt, the koppa belt and Baba budan belt (Manjunatha and Harry., 1994). The Kudremukh belt comprises hornblende schists, amphibolites, chlorite schist, mica schists and thick beds of magnetite quartzites. The magnetite quartzites forms a striking unit in the belt and is intricatlely folded. The Koppa belt extends from Kalasa for about 155 sq. Km passing through Shimoga district. The rock type consists of schists, chlorite schist, gritty argillites and magnetite quartzites (Naqvi and Rogers, 1983; Radhakrishna and Naqvi, 1986). The Baba budan belt is a crescent shaped hill range makeup of hornblende schists and traps, amphibolites quartizite, mica chlorite schists and capped by ferruginous quartzites. The granitic gneisses and granites which are grouped under Peninsular Gneissic Complex (PGC) covers rest of the area in Chikmagalur district (Radhakrishna, 1983). The district encompasses rich economic minerals such as iron ore, kaolin, kyanite, asbestos, bauxite, chromite, clay, copper, corundum, garnet, graphite, limestone, manganese, mica . Among these minerals, iron ore is being exploited on a large scale. Nearly 70% of the area in Sringeri taluk is covered by gneiss and rest of the area is occupied by schist formation. Weathered, fractured and jointed gneiss and schist rocks (Ramakrishnan and Vaidyanadhan., 2008). And further these rocks have a specks of Corundum bearing units.

4. Methodology

Field based samples were collected and carried carefully to the laboratory for Petrographic study using Petrological, Mineralogical research Microscope; while geochemical data was received through XRF 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 (48O) 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: 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 (Fig.3).

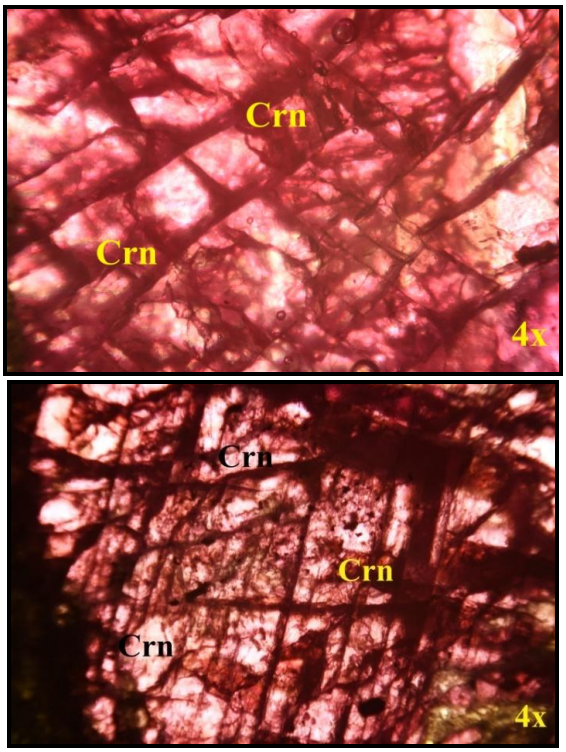
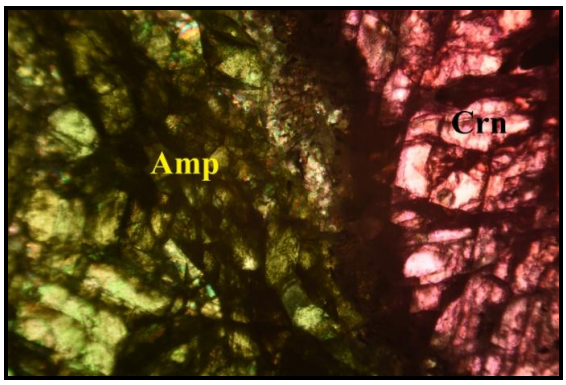


Fig.3. Corundum sample of Microphotographs.

5.2 Corundum bearing Amphibolite schist:

The central part is associated corundum which pink to blood-red colored; 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.4).



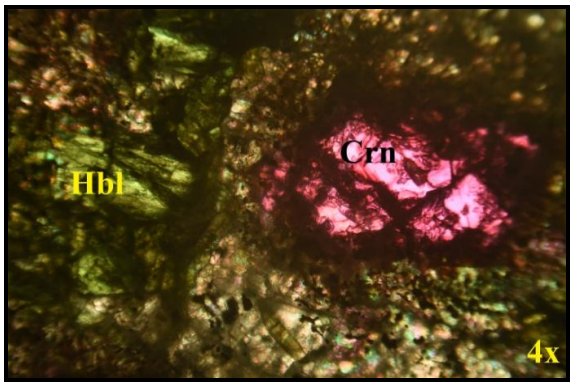


Fig.4. Corundum bearing Amphibolite schist samples of Microphotographs.

6. Hyperspectral Signatures

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 (Maruthi and Basavarajappa., 2018).

7. Result and Discussion

Major element composition of samples of corundum bearing rocks were determined at the chemical division and geochemistry its using XRF method. 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).

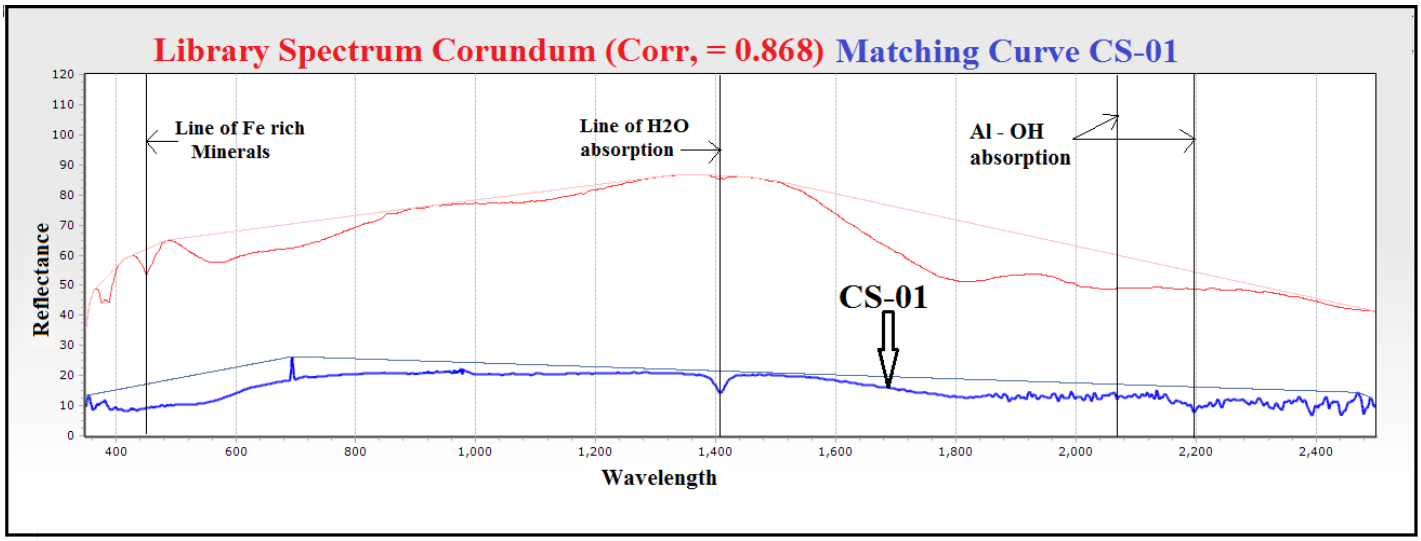


Fig.5. Lab Spectral signatures of Corundum, Sringeri area,

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 0.37% Cr. 1.40% Fe and 13.0% 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.5). 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 0.868 percent match the curve (Fig-5)

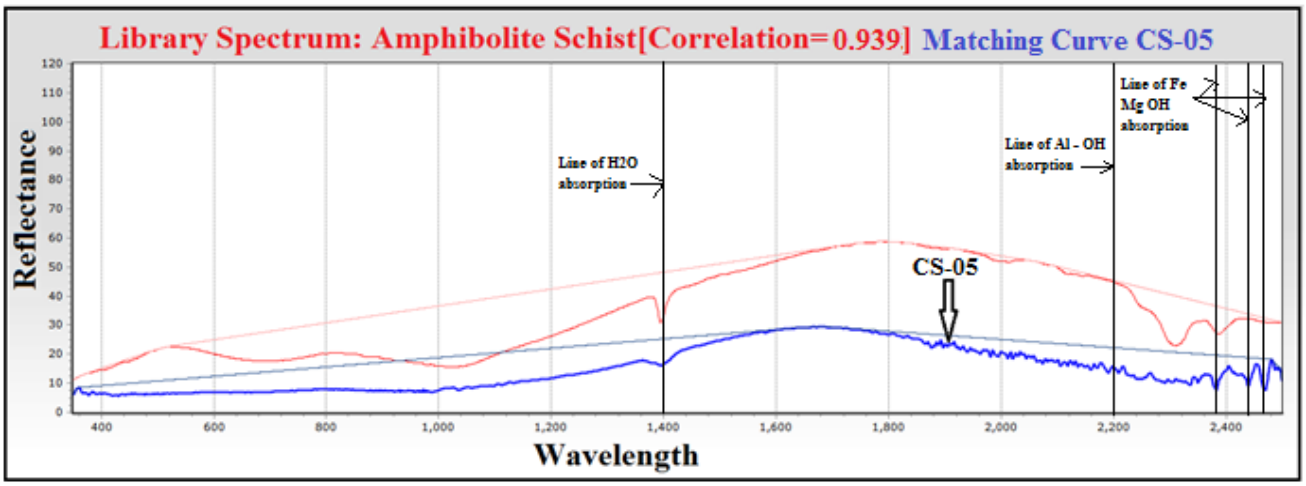


Fig.6. Lab Spectral signatures of Amphibolite Schist, Sringeri area.

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 31.0% and 35.00%; MgO content is fairly low and ranges from 9.56% to 10.78%; Al_2O_3 content high ranges from 28.75% to 30.96%; CaO content is 10.22% to 7.32%; K_2O content of ranges from 0.13% to 0.14%; TiO_2 content is fairly low and varies from 0.31% to 0.76% and P_2O_5 ranges from 0.32% to 0.56% (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.6). 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 0.939 percent match the curve (Fig-6). 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) (Fig-6).

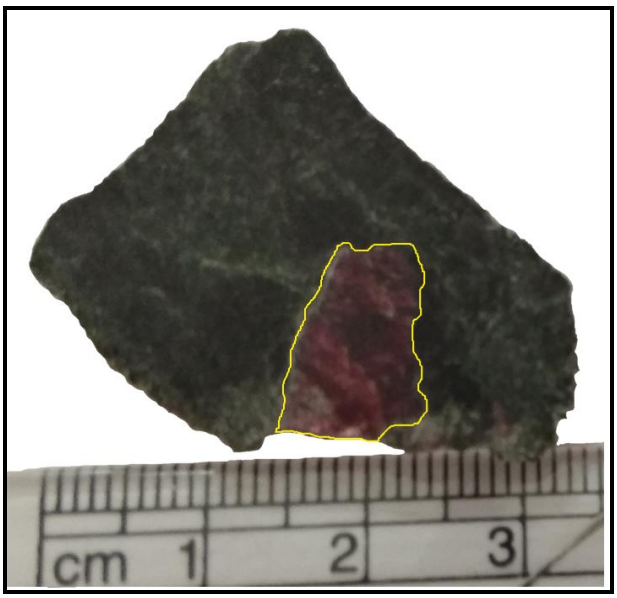


Fig.7. Hand specimen of Corundum bearing Amphibolite schist rock Collected samples Sringeri area of Chikmagalur district

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

Chemical Elements		Samples				
		CS-1	**CS-2**	**CS-3**	**CS-4**	**CS-5**
Elements (wt%)	SiO_2	13.00	14.29	15.00	31.00	35.00
	Al_2O_3	***81.20***	***79.35***	***78.95***	***28.75***	***30.96***
	Fe_2O_3	1.40	1.56	1.35	10.21	8.98
	MgO	N.D	N.D	N.D	9.56	10.78
	CaO	1.20	1.70	1.40	10.22	7.32
	K_2O	0.19	0.15	0.21	0.13	0.14
	TiO_2	1.50	1.18	1.35	0.31	0.76
	MnO	0.076	0.03	0.021	0.16	0.17
	P_2O_5	0.85	0.62	0.43	0.32	0.56
	Cr_2O_3	0.37	0.55	0.76	8.77	4.95
	NiO	0.001	0.004	0.003	0.14	0.23
	Total	**99.78**	**99.29**	**99.29**	**99.57**	**99.84**
Rock type		Corundum	Corundum	Corundum	Amphibolite Schist	Amphibolite Schist
Spectral Analysis						
Absorption spectra (µm)	Lab spectral signature	0.45, 0.7 2.100 2.200	0.45, 0.7 2.100 2.200	0.45, 0.7 2.100 2.200	0.700, 0.950, 1.400 1.910, 2.200, 2.310, 2.400	0.470, 1.400 1.910, 2.200, 2.250, 2.350
Best matches to	USGS	Corndum	corundum	corundum	Amphibole, Corundum	Amphibole, Corundum

8. Conclusion

Geological, Petrographic, Physical and Chemical characteristics are studied and discrimination shows purity of the mineral present in the Precambrian rock. Analyzed and Studies for the selected samples were carried out and identified mineral assemblage of corundum bearing rocks. The perfect tabular texture and pink 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. corundum purity amphibolite schist and corundum is best curve matches to compare the Spectral Evolution (SR-3500) instrument.

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