Hyperspectral Signatures and Field Petrography of Corundum Bearing Litho-Units in Arsikere Band of Haranahalli, Hassan District, Karnataka, India

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ABSTRACT

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 present study aims to characterize the spectral behavior of Corundum and associated rocks using Spectro-radiometer instrument calibrating in between 400-2500 nm wavelength. Spectro-radiometer instrument records 10 nm resolution data to bring out diagnostic features on lithological contacts for better discrimination of gemstones and altered minerals. The final results highlight the spectral characters of corundum and associated rocks for better mapping and exploration in similar terrains of Karnataka State.

Keywords: Hyperspectral Signatures, Corundum, Arsikere band of Haranahalli, Hassan.

1. INTRODUCTION

Corundum occurs in a large number of localities in Dharwar Craton of all the schist belts in Karnataka State. Corundum-bearing rocks in the study area are associated with metamorphosed leucocratic pelitic gneiss. Corundum constituent of high grade pelitic schists belonging to Sargur Group occurs as enclaves within Peninsular Gneissic Complex (PGC) (Viswanatha, 1972). Corundum-bearing rocks are associated with metamorphosed mafic rocks of meta sedimentary rocks including gneiss, schist, amphibolite and minor iron formation (Radhakrishnan and Vaidhyanadhan., 2011). Un-oriented corundum crystals surrounded by alkali feldspar hallow formed by replacement of the gneiss with the addition of aluminium and potassium in Granulite facies metamorphism of aluminous sediment produced biotite-syenite gneiss (Basavarajappa *et al.*, 2004). Corundum bearing cordierite-sillimanite schist/ gneiss occur on either side of Closepet granite as enclaves in Peninsular Gneisses; contact of ultramafics pegmatite's; aplite veins disseminated grains in anorthosite kyanite/ staurolite schist; high grade pelitic schist gravel beds and stream sediments as a placer (Radhakrishnan, 1953). The bulk sample of corundum collected as abrasive (industrial) quality of gem quality popularly known as ruby and sapphire (Sampath Iyengar., 1922). 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 $13^0$12’30” to $13^0$15’0” North latitude and $76^0$13’0”to $76^0$16’30” 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 associated with metamorphosed leucocratic pelitic gneiss (CGWB, 2007).

Table.1. Samples collected and its Location

Sl No	Samples Name	Villages name	Latitude	Longitude	Trending directions
CH-1.	Corundum	S-Maknalli	$13^0$13.868’	76^0 14.762’	NNW
CH-2.	Amphibolite Schist	Kodimata	$13^0$13.747’	$76^0$14.873’	N20^0W
CH-3.	Hornblende Gneiss	Harnalli	$13^0$13.945’	76^0 14.239’	N50^0E
CH-4.	Chlorite Schist	Guttigehalli	$13^0$14.301’	76^0 14.512’	N24^0W

Note: **CH**- **C**orundum at **H**aranahalli

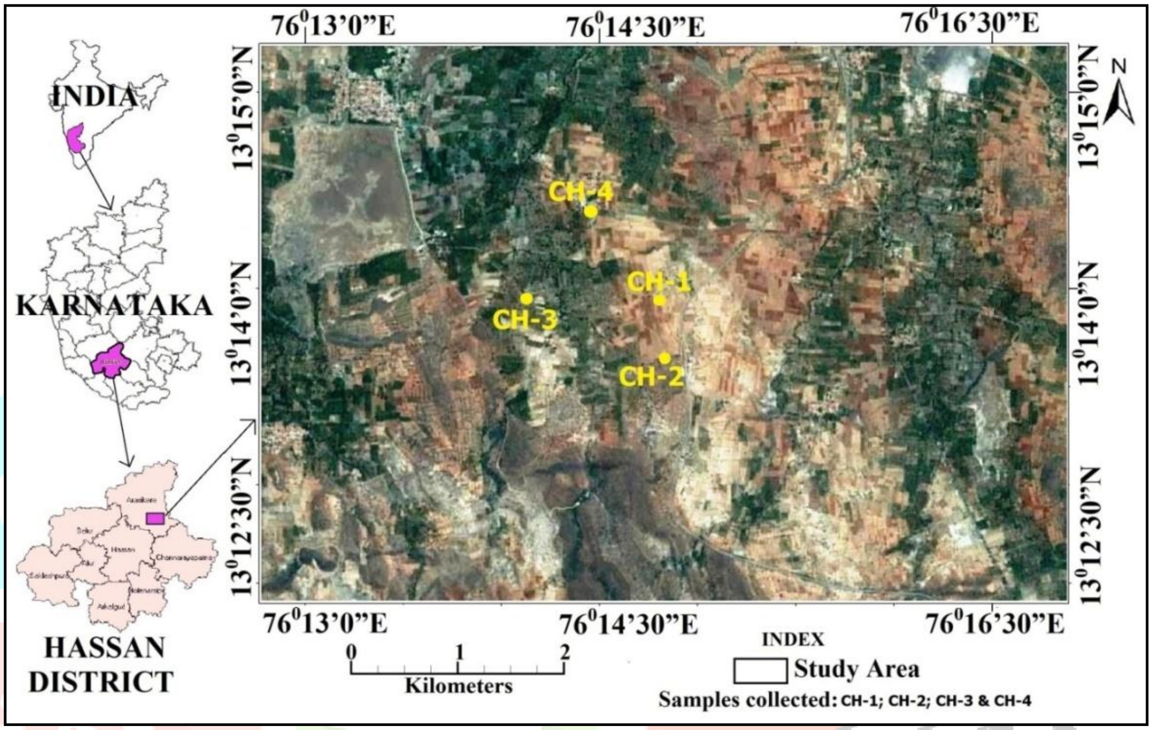

Fig.1. Google Earth image showing the location of the study area

3. GEOLOGY SETTINGS

Geological, the study area belongs to Sargur group of rocks which comprises corundum bearing rocks were principally made up of interspersed by lands tremolite schist, hornblende gneiss, amphibolites schist along with intrusive dykes of dolerite and reefs of quartzite (Ramakrishnan and Vaidhyanadhan., 2008). The study area consists of tremolite schists, hornblende gneisses which were defined by the mafic/ ultramafic suites along with younger gabbro/ dolerite (traversed by Arsikere granite) and pegmatite veins (Radhakrishnan and Vaidhyanadhan., 2011). The schistose and their associated rocks constitute the major Dharwar Craton of Archaean system and are designated as the Holenarasipura and Nuggihalli schist belts.

Amphibolite are predominantly exposed and are closely associated with ultra basics, trending North 30°W with a dip of 30°-80° towards E and NE direction. Amphibolite shows high schistocity and exhibits foliation with greenish grey color and semi-hard in nature (Ramakrishnan and Vaidyanadhan.,2008) Granitic Gneisses exposed predominantly and has in contact with Schist Belt in the Western part of the study area, trending North 20° E direction (Ramakrishnan and Vaidyanadhan.,2008) The gneisses are banded in nature with gray to white gray in color.

4. METHODOLOGY

All the 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). Hyperspectral signatures analyses for all samples were carried out using Lab Spectro-radiometer instrument at Geological Survey of India, Bengaluru (Basavarajappa et al., 2015). ENVI v4.2 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 shows similar color appearance in both plane and crossed polarized lights. Corundum is depicted by pink to blood-red colored and can vary within each gem variety of the mineral Corundum. The red color is caused by the mineral chromium and shows brownish tone due to the presence of iron. It shows uniaxial, birefringence & 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 (Fig.2)

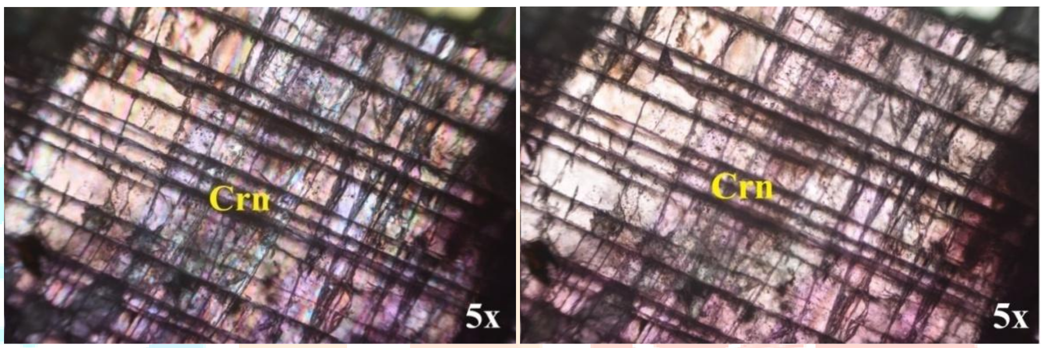

Fig.2. Corundum under PPL and XPL

5.2 Chlorite Schist: The mineral chlorite is a hydrous silicate of aluminium, iron and magnesium optical properties shows colourless or pale green to deep green faintly to moderately pleochroic in shades of green and yellow. Prominent cleavage traces parallel to the length; birefringence is weak; extinction parallel to the cleavage trace are observed in most of the chlorite minerals and crystal system is monoclinic. Tremolite is a mineral that is typically associated with secondary alteration processes in igneous rocks as well as in metamorphic rocks in the form of typical mineral facies of green schists. It occurs as a result of alteration of micas, although it is commonly found as alteration of amphiboles and pyroxenes. The pleochroic property shows light green to colorless; while medium relief interference color shows berlin blue color. The second order interference color is depicted by the mineral mica. The central part is associated corundum which shows pale blue color; uniaxial; low birefringence and surface relief is high (Fig.3)

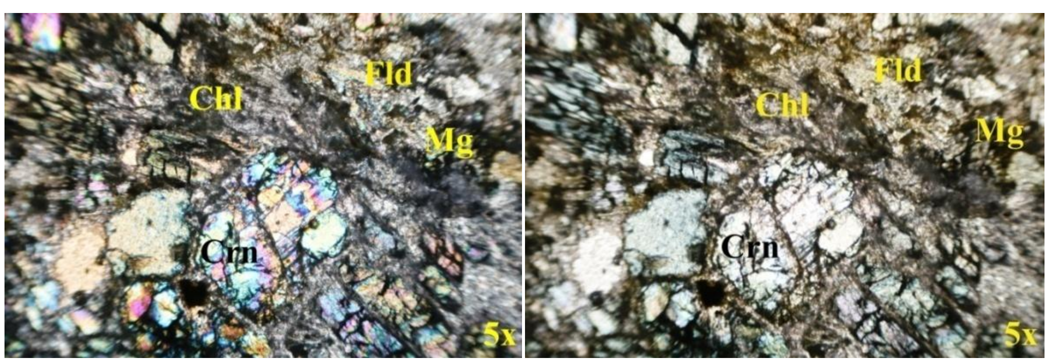

Fig.3. Chlorite schist with Corundum under PPL and XPL

5.3 Hornblende gneiss: Various shades of yellowish green and reddish brown to dark brown are observed in hornblende gneiss 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.4).

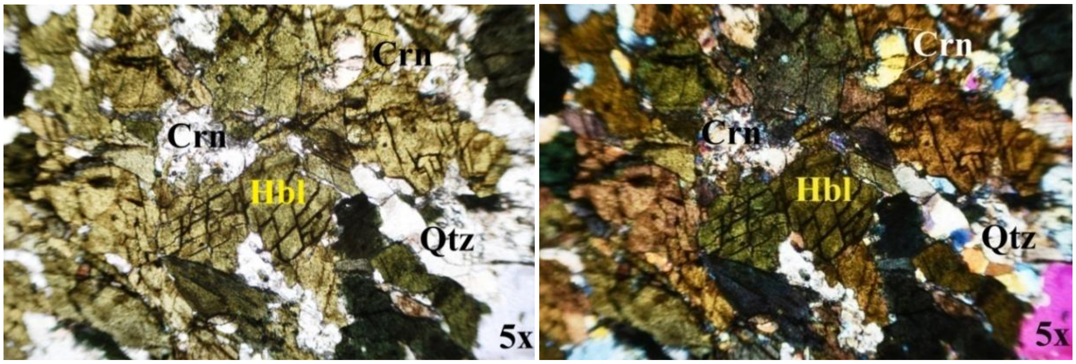

Fig.4. Hornblende gneiss under PPL and XPL

5.4 Amphibolite schist: 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.

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.5).

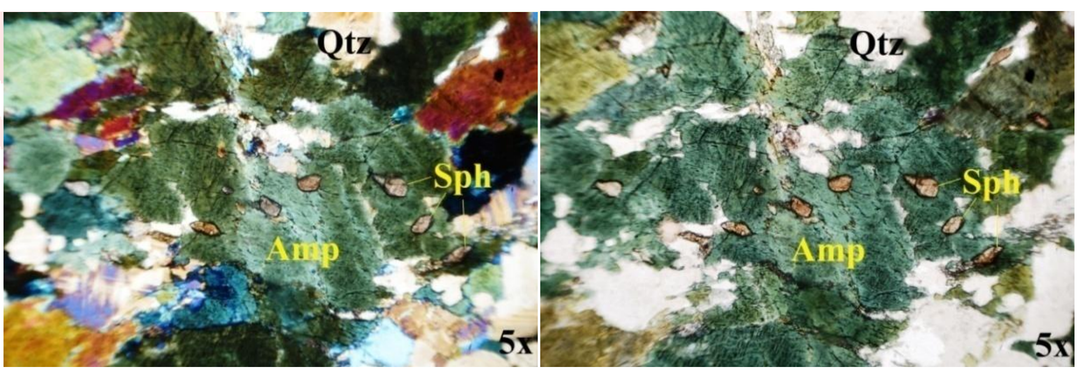

Fig.5. Amphibolite Schist under PPL and XPL

Sphene mineral appears as slightly brownish color with extremely high relief and high interference colors. Euhedral forms having acute rhombic (elongated diamond-shaped) cross sections. Birefringence very strong high order white interference colours but are usually masked by the strong body colour or destroyed by total reflection, biaxial positive. Rhombic sections have symmetrical extinction. It does not extinguish completely on rotation of stage does not show complete darkness in extinction positions due to strong dispersion. It shows acute rhombic cross sections with extremely high relief (Fig.5).

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). Fieldspec^{3} Spectro-radiometer instrument has the ability to measure the spectral signatures of different rocks/ minerals in between the range of 350-2500 nm wavelength. The spectral signatures of the representative samples were compared with mineral spectra of USGS spectral library in ENVI v4.6 (Basavarajappa et al., 2015). Absorption spectral values obtained from the ASD (Analytical Spectral Device) lab Spectra is the one character helps in the study of major and minor mineral constituents.

7. RESULT AND DISCUSSION

Major and minor element composition of Four samples of Corundum bearing rocks were determined at the chemical division and geochemistry is recorded to earlier literature its using XRF and ICP-MS. 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 tables (Table.1) along with major and trace element abundances of samples to check the error limits of measurement (Aditi Mandal et al., 2012).

CH-1 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 Fe^{3+} and Fe^{2+} ions are observed respectively with low reflectance in the VNIR region (Ali M. Qaid et al., 2009) (Fig.6). The chemical analysis of corundum shows the distribution of major element content as Al_2O_3 content shows high range from 87.68% to 90.27%; and minor content as SiO_2 ranging between 2.82% and 6.14%; MgO content is fairly low and ranges from 0.18% to 1.28%; CaO content ranges from 0.29% to 0.66%; K_2O content ranges from 0.04% to 0.16%; TiO_2 content is fairly low and varies from 0.44% to 0.1%; P_2O_5 ranges from 0.02% to 0.01%. High Al_2O_3 (>80%), SiO_2 (>6%) and low TiO_2 (0.44%) content imparts a corundum character with that of high aluminum content.

CH-2 Sample plots are correlated with standard USGS Spectral Library using absolute reflectance v/s wavelength which provide strong absorption range from 2.25 – 2.35 µm and 0.65 µm representing the mineral corundum; whereas tremolite shows intense absorption feature at 2.40 µm of the electromagnetic spectrum (Hunt et al., 1971). Fe^{3+} and Fe^{2+} ions were observed in 0.55 µm and 0.9 µm respectively with low reflectance in the VNIR region (Ali M. Qaid et al., 2009) (Fig.6). The major element content of tremolite schist shows SiO_2 ranging between 39.59% and 43.70%; Al_2O_3 content high ranges from 29.60% to 32.11%; CaO content is low 4.43% to 4.57%; MgO content is fairly moderate and ranges from 8.52% to 8.80%. On the other hand, TiO_2 content is fairly low and varies from 0.74% to 0.87% and P_2O_5 ranges from 0.02% to 0.7%.

CH-3 Sample plots provide strong absorption range from 2.25 – 2.35 µm and 0.66 µm representing the mineral corundum; whereas hornblende shows intense absorption feature in 2.40 µm of the electromagnetic spectrum (Hunt et al., 1971). Absorption anomalies at 0.55 µm and 0.9 µm are observed due to the presence of Fe^{3+} and Fe^{2+} ions respectively (Fig.7). The element content of hornblende gneiss shows SiO_2 ranging between 47.71% and 48.48%; MgO content is fairly moderate and ranges from 8.87% to 9.77%' Al_2O_3 content high ranges from 18.99% to 19.29%; CaO content is 10.09% to 12.09%; TiO_2 content is fairly low and varies from 1.23% to 1.3%; P_2O_5 ranges from 0.05% to 0.06% and K_2O content of 1.95% to 1.68%.

CH-4 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.8). Absorption range from 1.4 – 1.9 µm are noticed due to the presence of water and hydroxyl molecules in the present sample (Ali M.Qaid et al., 2009). 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).

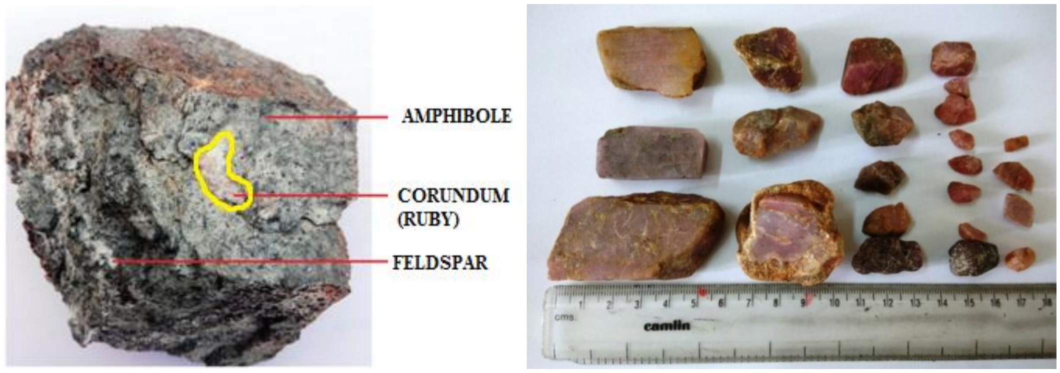

Fig.7. Hand specimen of Corundum bearing Amphibolite Schist & Ruby (Corundum) collected samples Arsikere band of Haranahalli, Hassan.

Fig.6. Lab Spectral signatures of Arsikere band, Hassan

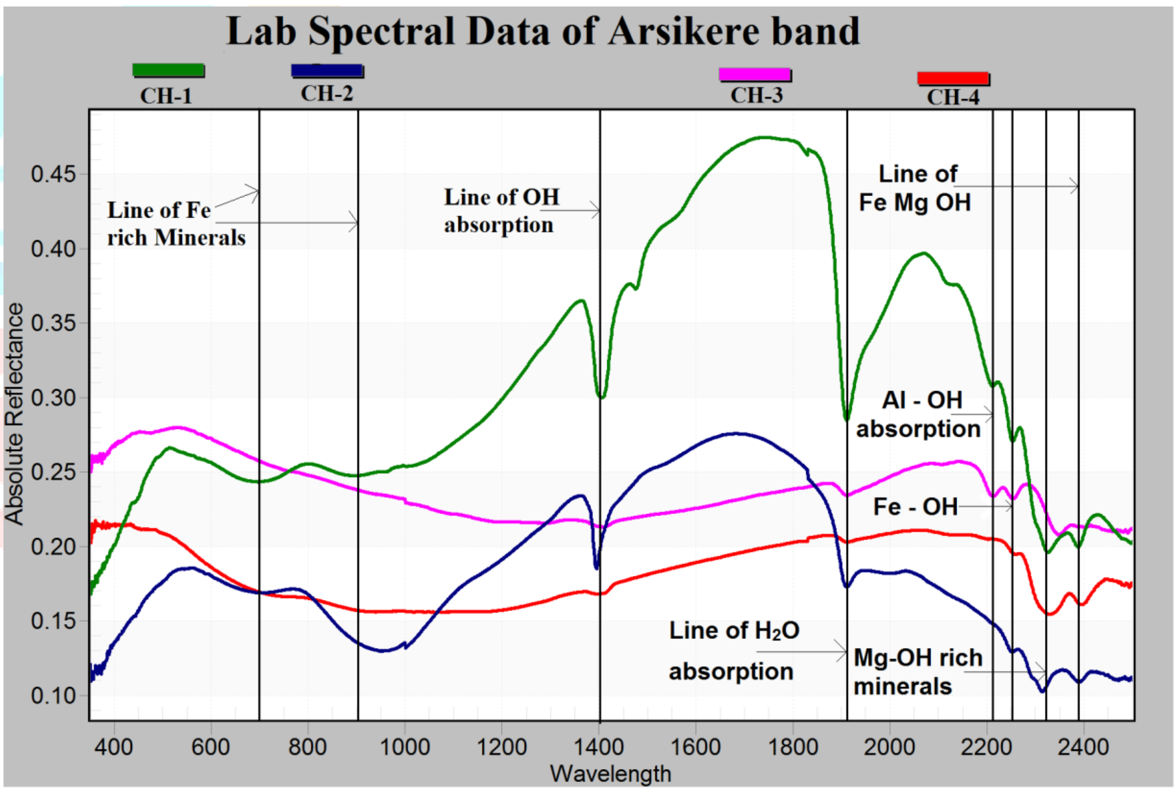

Table.1. Major Elements and Spectral analysis data of the samples of the study area

Chemical Elements		**Samples**			
		CH-1	**CH-2**	**CH-3**	**CH-4**
Elements (wt%)	SiO_2	6.14	43.7	47.71	42.01
	Al_2O_3	***87.68***	***29.6***	***18.99***	***26.57***
	Fe_2O_3	1.02	8.59	6.68	4.61
	MgO	1.28	8.52	9.77	8.28
	CaO	0.66	4.57	12.09	12.24
	Na_2O	n.d	1.58	n.d	2.57
	K_2O	0.04	n.d	1.95	0.02
	TiO_2	0.44	0.74	1.23	0.55

	MnO	0.005	0.06	0.09	0.17
	P_2O_5	0.02	0.02	0.05	0.04
	Cr_2O_3	0.16	0.03	0.01	0.34
	Ba O	0.003	0.001	0.08	0.1
	LoI	1.57	1.6	0.47	0.14
	Total	**99.018**	**99.011**	**99.12**	**97.64**
Rock type		Corundum	Tremolite Schist	Hornblende Gneiss	Amphibolite Schist
Spectral Analysis					
Absorption spectra (µm)	Lab spectral signature	2.200	0.657, 0.880, 1.400, 1.800, 2.250, 2.350, 2.400	0.700, 0.950, 1.400 1.910, 2.250, 2.310, 2.400	0.470, 1.400 1.910, 2.200, 2.250, 2.350
Best matches to	USGS	Corundum	Tremolite, corundum	Hornblende, Corundum	Amphibole, Corundum

8. CONCLUSION

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. 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.

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