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Elemental Mapping , Hyperspectral Signatures And Petro-Geochemical Study Of Thorium Bearing Titanite In Pegmatites Of Kommenahalli Village, Krishnarajpet, Mandya District, Karnataka

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ABSTRACT
Geological, Petro-Geochemical and Hyperspectral Signatures for titanite (sphene) mineral was carried out which are fully crystallized around Kommenahalli village. They form part of the early Archean Greenstone Belt of Krishnarajpet Schist Belt, Dharwar Craton. During the course of field investigation it was observed crystals of titanite which are dark brown to black, faceted with considerable sizes were embedded in the pegmatite rock. Titanite (sphene) with chemical formula $CaTiSiO_5$ has commercial value as a source of titanium, used in pigments. In titanite sometimes where calcium may be partly replaced by thorium. Fresh samples of titanite (Sphene) in Pegmatites were randomly collected in the field through GTC (Ground Truth Check). Rock samples were studied under Transmitted light microscope, SEM-EDX and Spectro-Radiometer. The final results highlight the spectral signatures of Titanite derived in laboratory and compared with USGS Spectral library. Also by EDX studies got to know the presence of thorium in Titanite. The occurrence of titanite (sphene) around Kommanahalli area adds academic economic importance not only by the presence of thorium in it but also the wedge or diamond shape of this grain which in many rocks it is not in common.

KEYWORDS: *Thorium bearing Titanite, Pegmatite, Hyperspectral signatures, SEM-EDX, Kommenahalli village, Karnataka*

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I. INTRODUCTION

Titanite (Sphene) having chemical formula $CaTiSiO_5$. First recognized in 1787 by Marc August Pictet, it was described in 1795 by Martin Klaproth, who gave it the name 'titanite' Sphene is named from the greek word "sphenos" for wedge, because of its typical wedge shaped crystal habit. It is also alternatively called titanite for its titanium content. Titanium is one of the steel hardening metals, which is gaining importance from day to day. Titanite is used primarily as a metal and pigment. Titanium metal is well known as a material with a superior strength to weight ratio and corrosion resistence. These charecteristics have made titanium the most important metallic component in aeronautical and aerospace applications. In titanite trace impurities of iron and aluminium are typically present. Also commonly present are rare earth metals including Cerium and Yttrium, Calcium may be partly replaced by thorium(Gromet and Silver 1983; Ward et al 1992; Bea 1996) (Green and Pearson 1986). Titanite has commercial value as a source of titanium, but deposits with enough titanite are rare (Klein and philpotts, 2013). Titanite is coloured yellow to green to brown and even black, possibly reflecting its content of iron and occurs in wedge-shaped crystals belongs to monoclinic crystal system. An attempt to study the Geological, Petro-chemical and Hyperspectral Signatures for titanite (sphene) mineral within the pegmatites of precambrian terrain was carried out which are fully crystallized around Kommenahalli village, Krishnarajpet.

II. STUDY AREA

The study area falls in toposheet number 57D/6 located in between $12^0$36'30'' to $12^0$37'30'' North latitude and $76^0$27'30'' to $76^0$28'30'' East longitude (Fig.1).

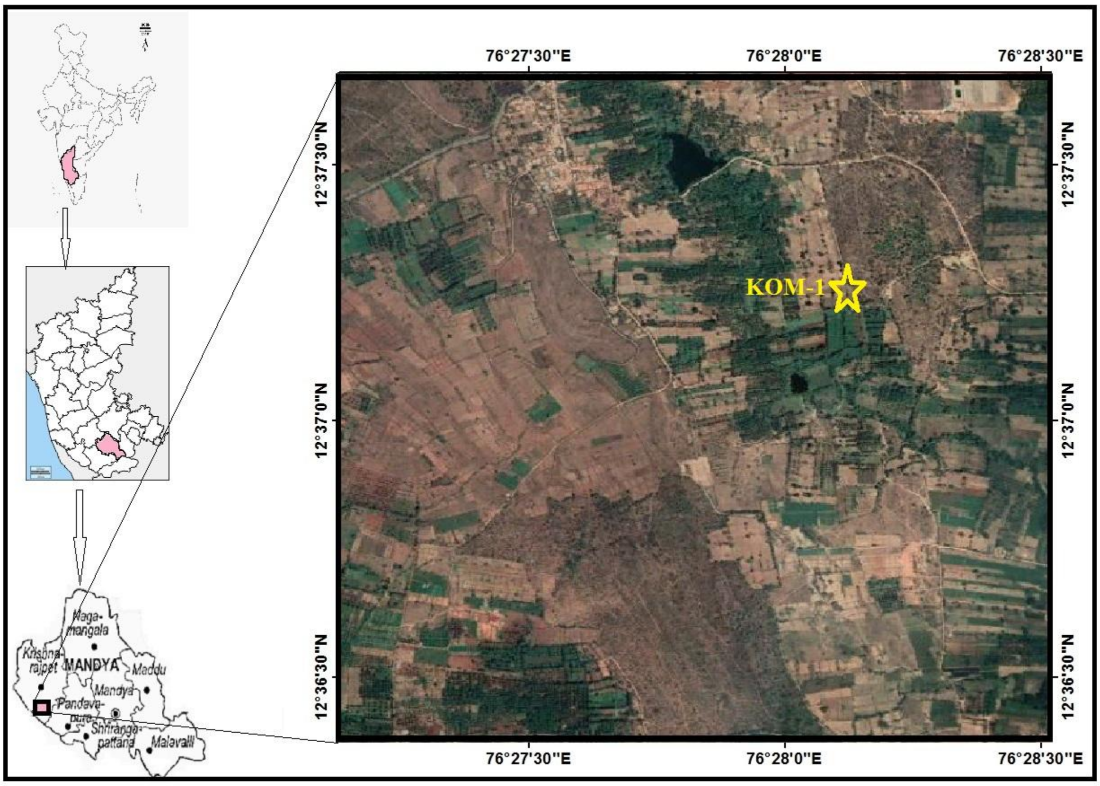

Fig.1. Google Earth image showing the sample location of the study area

Table.1. Sample Name and Location

Sl No	Sample Name	Location	Latitude	Longitude
KOM-1	TITANITE	KOMMENAHALLI	12^{0}37'19'' N	76^{0} 28'4'' E

Note: KOM-KOMMENAHALLI

III. GEOLOGY

In Mandya district many rock types have been exposed from Archean to Proterozoic. It hosts many economically valuable deposits like gold, iron, magnesite, titaniferous magnetite, corundum, asbestos, Steatite etc. Krishnarajpet schist belt which is designated as Attikoppa belt is one of the well-developed early Archean greenstone belts of Karnataka. Bellibetta range exposes a thick pile of tremolite-actinolite- talc schist which constitutes the lithological assemblage. Talc tremolite actinolite schist makes a preponderant ultramafic unit. The peninsular gneissic complex (PGC) is represented by migmatite and granodiorite –tonalite gneiss of pink to gray color varieties. Pegmatite which occurs close to Bellibetta, intrudes into the meta-mafic and ultramafic rocks. Books of muscovite mica sheets are well developed throughout the body and have an irregular contact with the country rock. Another pegmatitic body exposed northwest of Bellibetta peak has given rise corundum crystals. Also crystals of titanite which are black, faceted with considerable sizes were embedded in the pegmatite is recognized in the field (Fig.2) .

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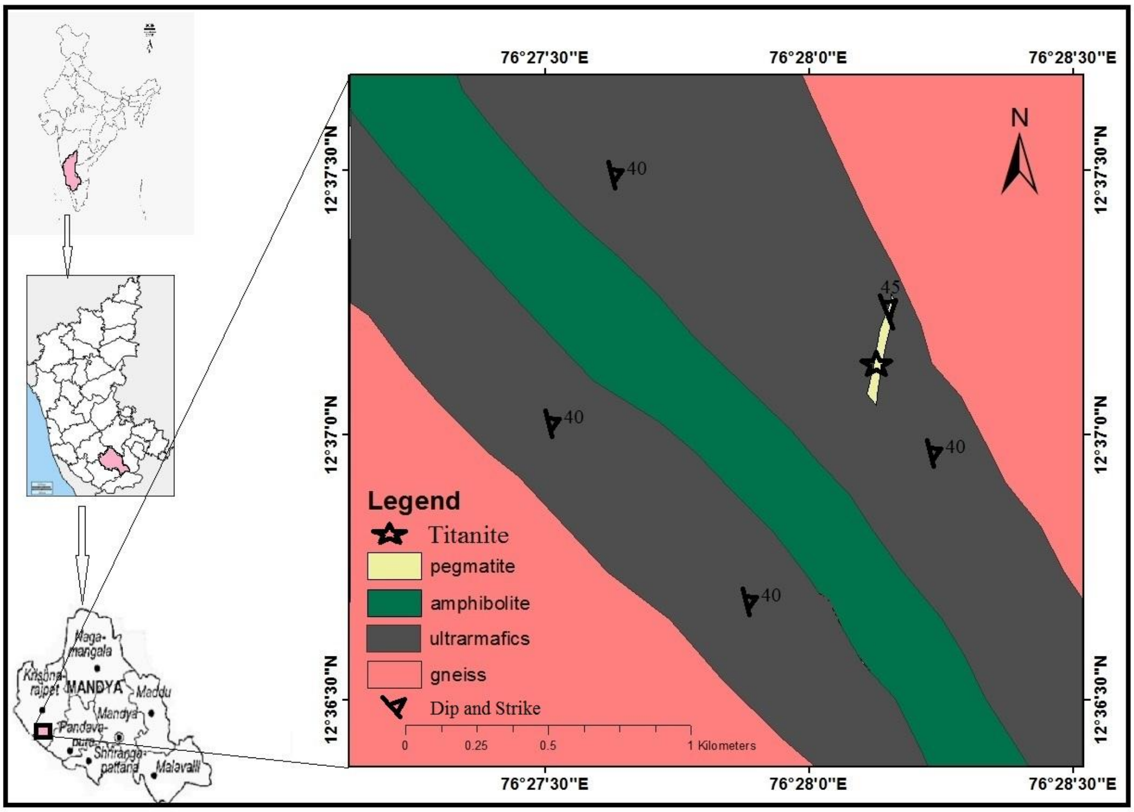
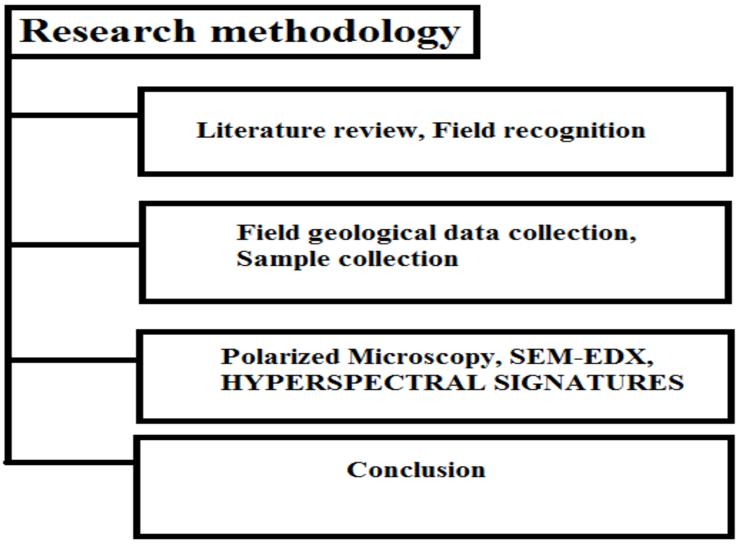


Fig.2. Geological map of the study area (after GSI 1965)

IV. METHODOLOGY

Field samples were collected and carried carefully to the laboratory for Petrographic study. Rock and thin section samples were studied under transmitted light microscope, Scanning electron Microscope with Eectron Dispersive Spectroscopy (SEM-EDS) at Central instrumentation and research facility Vijnana Bhavan University of Mysore; Hyperspectral Signature Analysis (HSA) were carried out using Lab Spectro-Radiometer instrument (Spectral Evolution SR-3500) at Department of Earth Science, University of Mysore, Manasagangothri, Mysuru. 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 were correlated with the standard curves of USGS, JPL and JHU. Survey of India (GSI) topo map and geological quadrangle map 1:250,000 scale is used during the field investigation (Basavarajappa et al., 2019). Garmin72 GPS is used to record the exact locations of each sample.



V. PETROGRAPHY

Representative pegmatite containing thorium bearing titanite thin section were used for a detailed petrographic investigation. Titanite is a common accessory in many igneous and metamorphic rocks. In this sample the titanite mineral shows brown to red color in plane and crossed polars. Mineral grain shows very high relief with extreme birefringence and shape of mineral grain shows euhedral which shows monoclinic crystal system. It shows habit/form Euhedral to subhedral grains with a wedge- or diamond-shaped cross section. Margin of it shows alterations. Along its other sides it is surrounded by quartz mineral. From above observations observed the mineral is identified as titanite (sphene)(Fig.3).

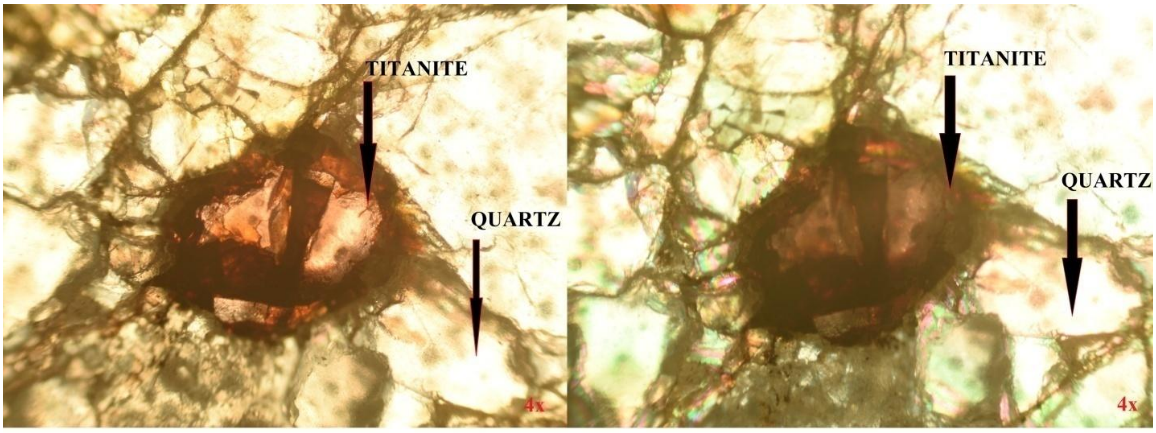


Fig.3. Photomicrographs of Titanite under PPL and XPL

VI. SEM AND EDS/EDX ANALYSIS

The Scanning Electron Microscope (SEM) is used to study sample surface and its morphology. It is an important tool for imaging material surface as well as for identifying chemical signatures. Scanning Electron Microscopy (SEM) magnifies a specific sample region using a high energy focused beam of electrons. The sample is under vacuum to ensure the electron beam stays focused and does not interact with particles in the air. When the beam of electrons hits the sample, it causes secondary electrons to be released from the sample which are detected to provide an image based on the topography of the surface. The two detectors most commonly used include the Secondary Electron Detector (SED) and the Backscattered Electron (BSE) Detector. The electrons interact with the detector to create an image. The most reliable way to identify minerals through the SEM is to compare their characteristic morphologies with the elemental compositions determined by the EDX. The sample region evaluated with SEM Analysis can also be analyzed to determine the specific elements that comprise the sample region by utilizing Energy Dispersion Spectroscopy (EDS). Xrays are also released from the surface of the sample that carries a unique energy signature that is specific to elements found in the sample. These X-rays are detected with the EDS detector to give elemental information about the sample. EDS provides data about the chemical composition of the sample and provides additional data about the features that are observed in the SEM microphotographs. (Basavaraappa et al 2020)(Abrar Ahmed et al 2020). This combined technique is referred to as SEM-EDS or SEM-EDX Analysis (PinakiSengupta et al., 2008). The SEM-EDX analysis is as shown in (Fig.4 and Fig.5).

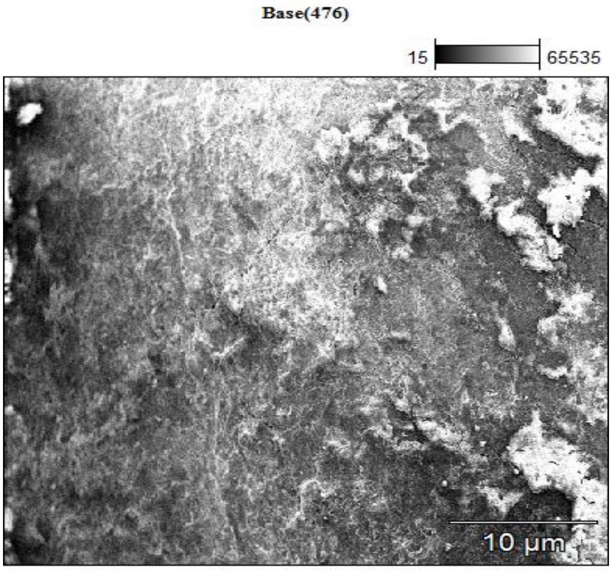


Fig.4 SEM image of Titanite mineral in 10 microns.

Elemental analysis of a sample is obtained by collecting the characteristic X-rays generated as the electron beam scans the sample. In general, the EDX is used to obtain rapid analysis of elements.
The EDX results are as follows in figure 5.

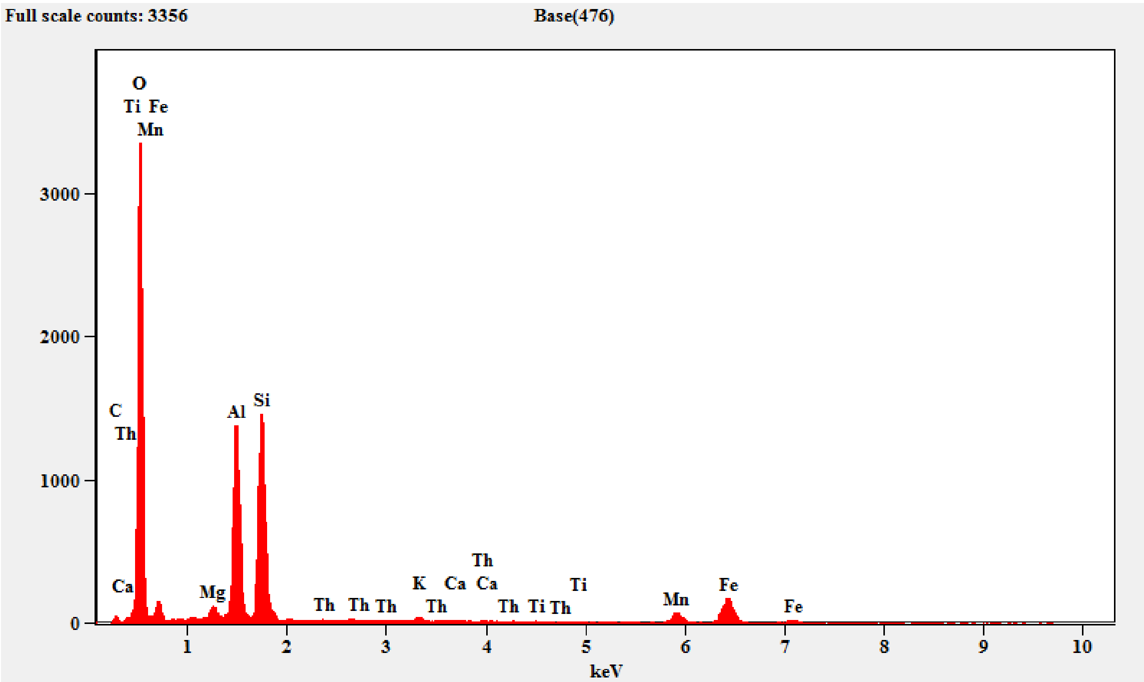


Fig.5 Typical EDX spectrum of Titanite: y-axis depicts the number of counts and x-axis the energy of the X-rays.

The position of the peaks leads to the identification of the elements and the peak height helps in the quantification of each element's concentration in the sample which is as shown in Table-2.

Table -2: Quantitative Results

Element Line	Weight %	Weight % Error	Atom %
C K	32.53	± 1.53	57.34
O K	0.15S	---	0.20
Mg K	0.97	± 0.10	0.84
Al K	17.68	± 0.32	13.87
Si K	24.24	± 0.38	18.27
Si L	---	---	---
K K	0.82	± 0.09	0.44
K L	---	---	---
Ca K	0.42	± 0.09	0.22
Ca L	---	---	---
Ti K	0.22	± 0.11	0.10
Ti L	---	---	---
Mn K	5.55	± 0.52	2.14
Mn L	---	---	---
Fe K	17.36	± 0.74	6.58
Fe L	---	---	---
Th L	---	---	---
Th M	0.06	± 0.35	0.01
Total	100.00		100.00

From the above observations atomic percents of Mg, Al, Si, Ca, Ti, Mn, Fe and Th were determined. The elemental analysis photographs of individual elements of titanite are as shown below (Fig.6).

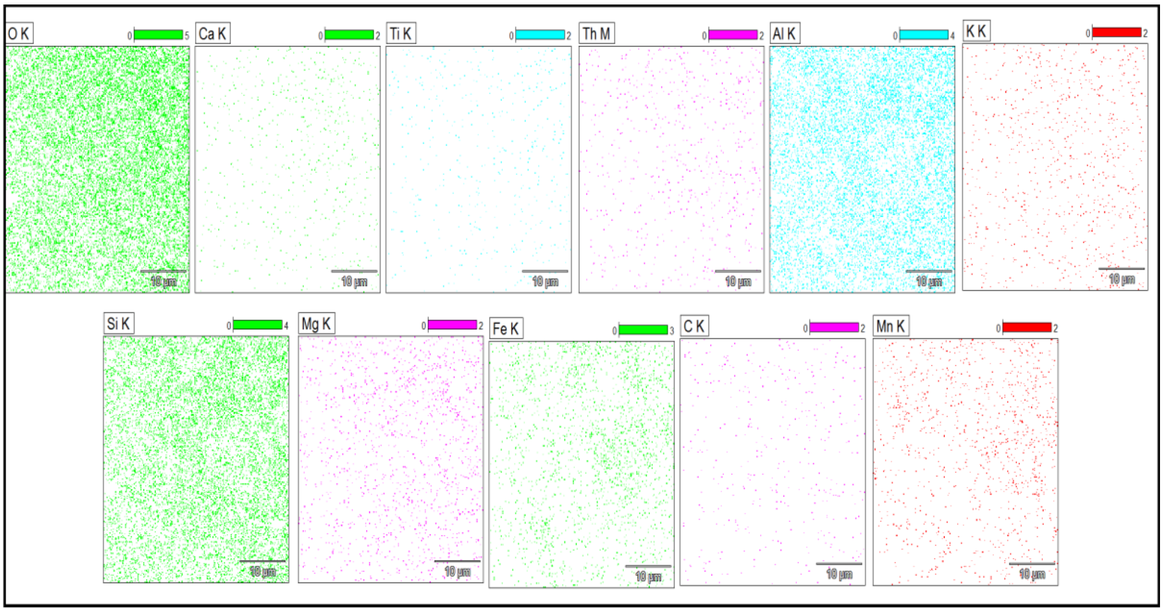


Fig.6. Photographs of individual elements of Titanite

VII. 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) (Basavarajappa et al., 2018,2019,2020). Spectral signatures discriminate individual minerals based on their absorption features. Spectral range from 0.4 to 1.0 μm range is important for mapping iron oxides (hematite, goethite, limonite, jarosite). Spectral range from 2.0 to 2.5 μm is useful for mapping of hydroxyl-bearing minerals, sulfates and carbonates, common to many geologic units and hydrothermal alteration assemblages. 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 (Photo Diode Array) covering the visible range and part of the near infrared (up to 1000nm) and two 256-element In GaAs 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 et al., 2019, Abrar Ahmed et al., 2019).

The Spectral Signature curves of Titanite derived are as shown below:

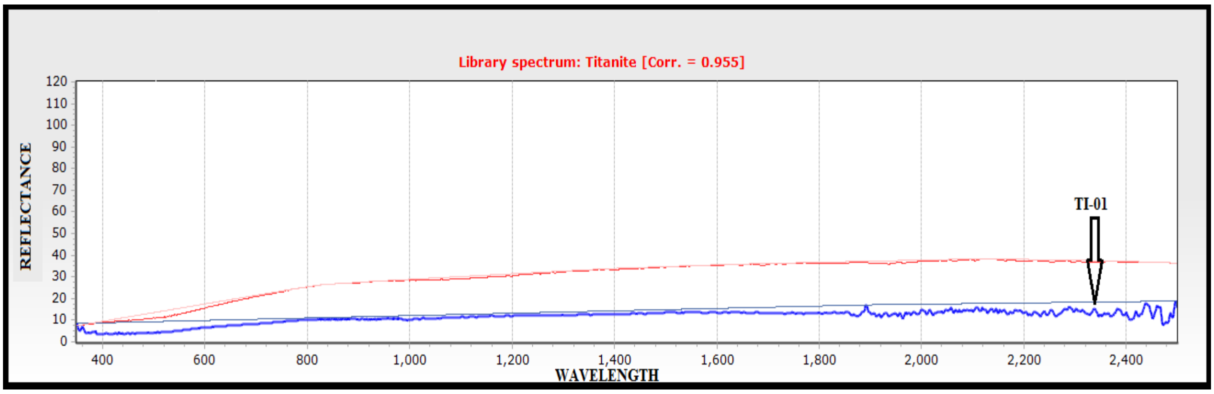


Fig.7. Lab Spectral signature of Titanite, Kommanahalli village

Sphene is a widespread accessory mineral in igneous and metamorphic rocks. The spectrum is quite typical of titanite (sphene) with chemical formula $CaTiSiO_5$. Calcium may be replaced partially by strontium and barium, or by the rare earths and thorium. This particular sample is a dark reddish brown, apparently due primarily to both the ferric iron and titanium. The presence of about 5 percent opaque magnetite lowers the overall reflectivity of this sample.

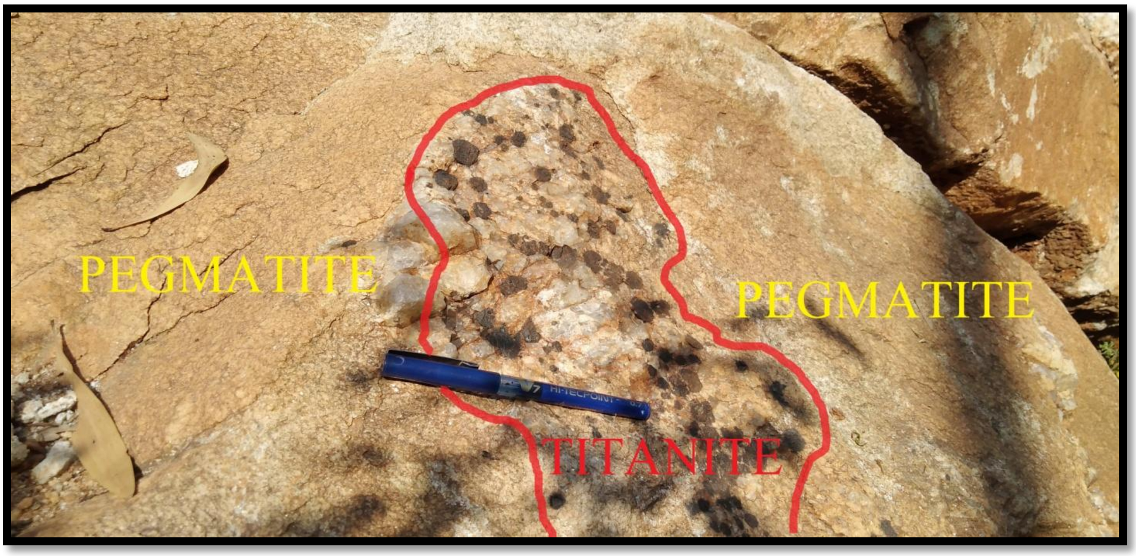


Fig.8. Field photograph of Titanite bearing pegmatite (Kommanahalli village).

Fig.9. Photograph of Titanite crystals, Kommanahalli village.

VIII. CONCLUSION

Geological, Petro-chemical and Hyperspectral Signatures for titanite (sphene) mineral was carried out which are fully crystallized in pegmatites around Kommenahalli village, Krishnarajpet. SEM-EDX studies revealed percentage of Th content in the collected sample of Titanite(sphene) along with presence of other elements like Mg, Al, Si, Ca, Ti, Mn, Fe. Also elemental mapping of individual minerals gives the percentage of elements which are present in the given mineral. The measurement of spectral signature of titanite mineral using Spectro-Radiometer was produced and also correlated with USGS spectral library. It gave correlation score of about 95%. From the above analysis done it may be said that Mandya district hosts economically valuable deposits like thorium bearing titanites along with other minerals and there is a need for their exploration in future for fuel energy which is very important as said by Charles Stevens CEO of Laser Power Systems, just one gram of thorium produces more energy than 28,000 liters of petrol.

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