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Hyperspectral and Geochemical Signatures Study of Indutrial Steatite Deposit Around Bhahaddurghatta-Hosahatty Village of Chitradurga Taluk, Karnataka, India

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Abstract:-- **Steatite with wide diversified applications and varied compositions is one of the most important industrial materials. In 2013, India ranked 2nd position in terms of quantum production of Steatite and talc mineral. Each steatite deposit being unique needs to be characterized in terms of its genesis and more so in respect of ultramafic-derived steatite deposits which although minor account for the best in terms of quality and application. Steatite is a massive variety of talc (hydrothermally altered ultramafic rock) occurs associated with ultramafic rocks of the Sargur Group and Bababudan Group. Steatite is a soft talcose rock that is easily carved even with stone, bone or metal tools. In the Bronze Age, steatite vessels seemed to become more common. The present study demonstrates the geochemical and hyperspectral characterization of steatite deposits in Bhahaddurghatta-Hosahatty village. This deposit occurs to be linear shaped with almost NNW-SSE direction. Transmitted light microscope, SEM-EDX and Spectro-Radiometer instruments were actively utilized as methodology on economic deposits of steatite in the study area. The spectral signatures of the collected samples were derived in laboratory environment to achieve better accuracy based on their physico-chemical and optical properties. The lab spectral absorptions were studied with the spectra of USGS and JPL mineral library. The final results highlight the characterization of industrial steatite deposits for its effective mapping and utilization.**

Index Terms:- Steatite, Geochemistry, Hyperspectral signatures, Bhahadurghatta-Hosahatty Village.

1. INTRODUCTION

Steatite (Soapstone) is one of the substantial resources of Karnataka along with talc (GSI, 2006). Steatite or soapstone is a general term used to describe metamorphic rocks that are composed primarily of talc, hydrous magnesium silicate, but which may contain varying quantities of other minerals of carbonate, amphibole, magnetite and chlorite (Ervan Garrison, 2016). Steatite deposits form as a result of regional or contact metamorphism due to the metasomatic alteration of an original parent body (Ervan Garrison, 2016). These parent bodies are normally ultrabasics, such as serpentinites, peridotites, dunites and pyroxenites, or in some rarer cases the original deposit may be a carbonate sedimentary rock (Ervan Garrison, 2016). The ease of carving and its thermal properties probably made it a material that was much sought after by using steatite (Ian Stephen Johnson, 1994). Steatite is an industrial natural material specially used in ceramics, paints, papers, plastics and roofing (Ervin Brown, 1973). Smaller quantities go into textiles, rubber, lubricants, cosmetics and other uses. These physical properties have resulted in steatite being used as a raw material for the production of many domestic and decorative items throughout the world (Ian Stephen Johnson, 1994). However, the geological formation process has only occurred in a limited number of locations (Ervin Brown, 1973). Steatite and talc in India occur in the states of Andhra Pradesh, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and Uttar Pradesh (Indian Minerals, 2019). The best deposits in terms of quality and reserves are confined to Peninsular India, of which Rajasthan account for nearly 97% of the total known reserves of India and present a wide and interesting spectrum of association with various types of rocks belonging to different age groups (Prasanna Kumar, 2005). Precambrian rocks of Karnataka with their wide range of mineral composition endowed with a variety of economical valuable mineral deposits (GSI, 2006). In

Karnataka state, steatite deposits of economic importance are reported from the districts of Hassan, Tumkur and Mysore districts, all of which are hosted in the ultramafic-mafic rocks (GSI, 2006). As an initial material for steatisation process, talc-carbonate rocks may be formed from any ultrabasic rock type (Hess, 1933). Chemical changes connected with the process of steatisation involve a number of possible reactions, depending on the mineralogy of the initial precursor and the composition of the fluids introduced (Ian Stephen Johnson, 1994). The process starts from forsterite, anthophyllite or serpentinite and introducing only water, and/or silica reactions (Ian Stephen Johnson, 1994). This study characterizes the hyperspectral signatures of such economic important steatite deposits and correlates its petrographic and major elements chemistry in interest of mapping the rock (Basavarajappa et al., 2017).

2. GEOLOGICAL SETTINGS

It is located in between 14024' to 14029' N latitude and 76006' to 76010' E longitude with an arial extent of 78 km2 (Fig.1).The area falls under the Survey of India (SoI) toposheet number 57B/3 of 1:50,000 scale with an average elevation of 700m above MSL. The study area lies in a part of 2 district boundaries namely Chitradurga-Davangere. Chitradurga district exposes a variety of rock types ranging in age from Archean to Proterozoic (GSI, 2006). They include high grade schists of the Sargur Group, Gneisses, Migmatites and Granites of Peninsular Gneissic Complex and the Greenstone belt of Dharwar Super Group. The Dharwar Super Group consists of Bababudan and Chitradurga Group of rocks, occupies the central part of the district as a linear belt trending NNW-SSE, where as the Sargur Group and Peninsular Gneissic Complex occupy the eastern and western parts (GSI, 2006). The Chitradurga schist belt shows enormous lithologic variations within the short distance due to frequent facies changes and lateral impersistence of Formation (GSI, 2006).

b

3. Field Study: Occurrence of Steatite deposit in Bhahaddurghatta-Hosahatty village have been identified and demarcated in the lithological map of the study area (Fig.1). General geomorphology, major structural trends, drainage pattern, land use and soil cover were noticed and recorded during the field visits (Maruthi et al, 2019). An ultramafic body has been altered to steatite along its contact with the other rock types in Hosahatty village. Random samples of gneiss, quartzite, steatite, metabasalt, limestone and dolerite porphyry had collected around Bhahadurghatta-Hosahatty village. Contact zone of steatite occurs with quartzite towards east and metabasalt towards west. Graded & cross bedding quartzite was noticed with pinkish color due to iron content. Few quartz veins were also observed intruding during field survey which shows specks of chalcopyrite stains. Steatites are massive, dark grey colored shows poorly developed schistosity trending NW-SE direction. Quite often it exhibits a pitted appearance due to dissolution of carbonate and oxidation of sulfides in it.

Table.1. Sample Name and Location

Sl No	Sample Number	Sample Name	Latitude	Longitude
1.	HS-1	Gneiss	$14^0$26'09'' N	$76^0$09'45'' E
2.	**HS-2**	**STEATITE**	**$14^0$25'26'' N**	**$76^0$08'30''E**
3.	HS-3	Metabasalt	$14^0$25'39.197'' N	$76^0$8'4.403''E
4.	HS-4	Limestone	$14^0$25'41.672'' N	$76^0$7'52.384''E
5.	HS-5	Dolerite Porphyry	$14^0$25'13.039'' N	$76^0$8'0.337''E
6.	HS-6	Quartzite	$14^0$25'22'' N	$76^0$8'24''E

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3. METHODOLOGY

Fresh samples of steatite with quartzite, dolerite porphyry, limestone, metabasalt and pegmatite gneiss were randomly collected in the field through GTC (Ground Truth Check) and analyzed in the laboratory. Survey of India (GSI) topomap and geological quadrangle map (57B) of 1:250,000 scale was acquired for proper field investigation of steatite deposits and associated lithologies in the study area (Basavarajappa et al., 2018). Garmin e-Trex GPS was used to record the exact locations of each sample with an error of 3 mts during field visits (Basavarajappa et al, 2017). In this study, four representative rock samples of steatite [HS (Hosahatty Sample)-1; HS-2; HS-3 & HS-4] have been collected during field visits for laboratory study. Rock samples were studied under Transmitted Light Microscope, Stereo Zoom Microscope and Scanning Electron Microscope with Electron Dispersive Spectroscopy (SEM-EDS) at Central Instrumentation and Research Facility, Vijnana Bhavan, University of Mysore (Abrar Ahmed et al, 2020). Hyperspectral Signature analyses were carried out using Lab Spectro-Radiometer instrument (Spectral Evolution SR-3500) at Department of Studies in Earth Science, University of Mysore, Manasagangothri, Mysuru (Abrar Ahmed et al, 2019). The instrument has the spectral resolution of 3 nm (at 700 nm) and 10 nm (at 1400/2100 nm). The obtained spectral curves are further interpreted and compared with the spectra of the standard spectral libraries (USGS and JLP) using DARWin SP.V.1.3.0 software (Basavarajappa et al., 2015).

4. PETROGRAPHY AND GEOCHEMISTRY:

The steatite is mainly made up of talc minerals which are fine grained and massive in nature, replacing the pre-existing minerals in almost all directions. The talc is bright colored (1st to 2nd order of interference colors) and variation of color in plain-polarized light verses cross-polarized light is observed. It contains magnetite which is opaque in nature which appears to be black (Fig.3). The major element analysis of the rock samples showed high concentrations of SiO_2 (58.38 %), MgO (31.90 %) and Fe_2O_3 (0.22 %) and low amounts of K_2O (0.01 %), CaO (0.65 %) and Na_2O (0.17 %).

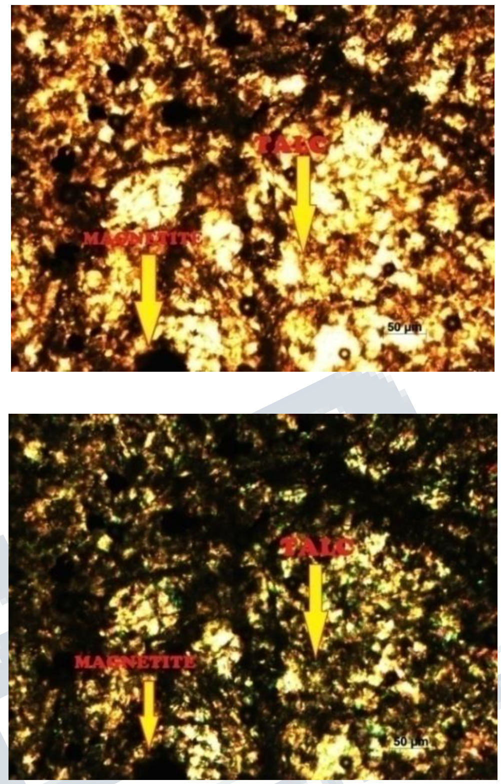

Fig.2. Photomicrographs of Steatite sample under PPL and XPL

5. STEREO-ZOOM MICROSCOPY:

Polished sections of Steatite samples were studied under stereo-zoom microscope to analyze the metallic minerals. The sample shows the presence of pyrite and hematite. Pyrite crystals are cubic in shape and sulfide group of oxidation process is clearly notices on its margins (Abrar Ahmed et al, 2020). Magnetite occurs as opaque minerals and even observed within the crystals of pyrite mineral.

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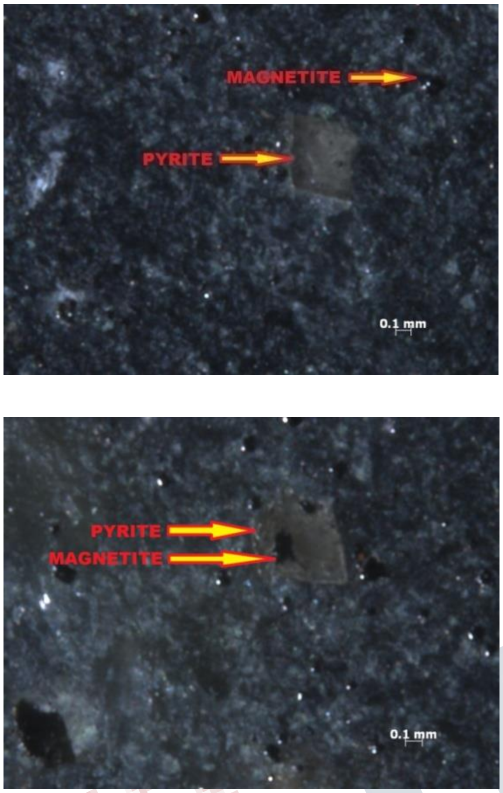

Fig.3. Photomicrographs of polished samples of steatite

6. SEM AND EDS/ EDX ANALYSIS: SEM Analysis is more powerful than optical microscopy not only due to increased magnification power but also due to increase in depth of field (Siddaraju et al., 2019). 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). X-rays 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 (Abrar Ahmed et al., 2020). EDS provides data about the chemical composition of the sample and additional data about the features that are observed in the SEM microphotographs. This combined technique is referred to as SEM-EDS or SEM-EDX Analysis (Pinaki Sengupta et al., 2008). The resulting surface morphology was observed using a Hitachi S-3400N scanning electron microscope with energy of 5.00 kV model EVO LS15. Results reveal high Mg elemental percentage (16.95 %) present in steatite sample along with other elemental percentage such as O, Si, Fe, Al, Cr, Cu and Ca. The occurrence of Cr in steatite rock sample clearly says its parental material is of mafic to ultramafic in origin. This highlights that the steatite samples of Bhahaddurghatta-Hosahatty village formed from Mafic-Ultramafic rock formed from deep seated magma.

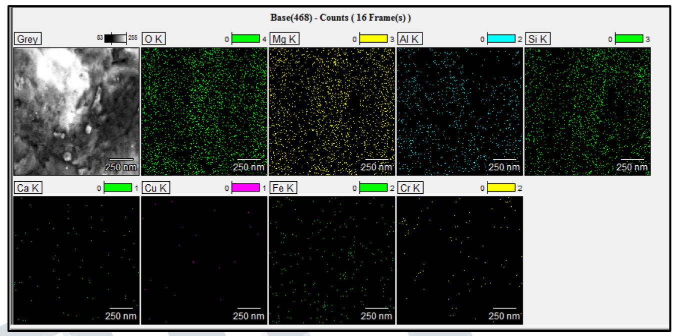

Fig.4. SEM image of Steatite sample with EDX image analysis of individual elements

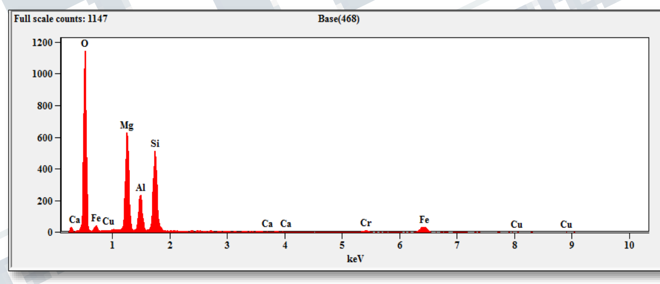

Fig.5. Typical EDX spectrum: y-axis depicts the number of counts and x-axis the energy of the X-rays. The position of the peaks leads to the identification of the elements and the peak height helps in the quantification of each element's concentration in steatite sample

Table.2. EDX analysis of Steatite sample of Bhaddurghatta-Hosahatty village

Sl No	Element Line	Weight %	Weight % Error	Atom %
1	*O –K*	47.32	± 6.01	61.93
2	*Mg –K*	16.95	± 0.42	14.60
3	*Al –K*	3.94	± 0.26	3.06

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4	*Si –K*	22.78	± 0.46	16.98
5	*Si –L*	---	---	---
6	*Ca –K*	0.16	± 0.11	0.08
7	*Ca –L*	---	---	---
8	*Cr –K*	2.08	± 0.24	0.84
9	*Cr –L*	---	---	---
10	*Fe –K*	6.08	± 0.81	2.28
11	*Fe –L*	---	---	---
12	*Cu –K*	0.68	± 0.44	0.22
13	*Cu –L*	---	---	---
	Total	***100.00***		***100.00***

7. INTERPRETATION OF HYPERSPECTRAL SIGNATURES:

Spectral Evolution (SR-3500) Spectro-radiometer instrument operate in the wavelength range of 350–2500 nm with three detector elements (Lipton, 1997). Study of hyperspectral signature of minerals using "laboratory grade" spectroscopic principles (Clark et al., 1990) is more significant for identification and mapping of surface mineralogy and rock types. In remote sensing technique, an extensive range of minerals are mapped, including the MgO-rich minerals (Rajendran et al., 2013), based on their absorption characters in the spectral wavelength (Ali Mohammad, et al., 2009). The troughs in the obtained spectra are the absorption features representing the diagnostic characters of a unique mineral can be interpreted by studying the width and depth of the spectra (Lipton, 1997).

7.1 Spectral Characteristics of Steatite:

The explanation with Spectral signature curves of Steatite rock derived is as shown below:

7.1a Hornblende Mineral Spectral Signature: The spectrum is quite typical of hornblende spectra, which is as shown in the Fig.12. It display a rapid fall off in intensity from 200nm to the blue due to broad Fe^{2+} and Fe^{3+} absorption near 700 nm and 1000 nm. The hydroxyl band at 1.4 μm is also reduced in intensity or missing, leaving only OH features at 2330 nm and 2400 nm.

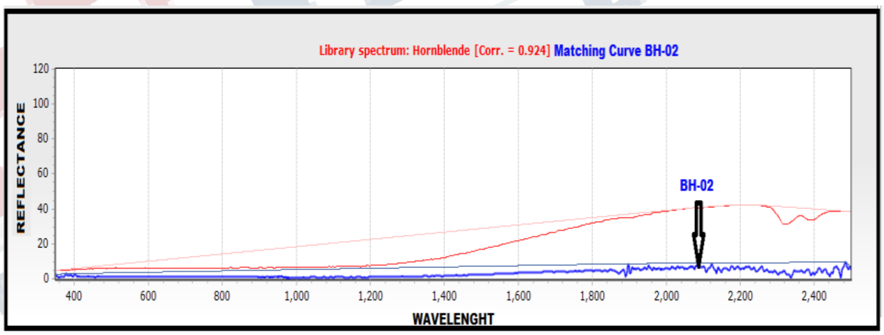

Fig.6. Lab Spectral signature of Hornblende, Bhahaddurghatta-Hosahatty village

7.1b Magnetite Mineral Spectral Signature: Magnetite is well crystallized and peak compositions are consistent with Fe_3O_4 composition. It is unusual in that it also exhibits a very weak band near 1000 nm due to the ferrous ion which is as shown in Fig.13. Magnetite is sometimes found in veins of large masses as a product of magmatic segregation, and as beds or lenses in metamorphic rocks.

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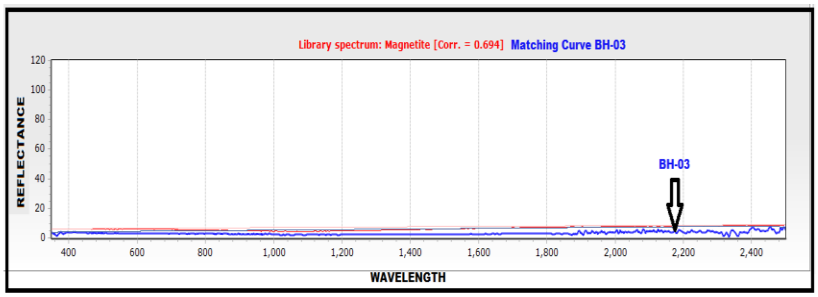

Fig.7. Lab Spectral signature of Magnetite, Bhahaddurghatta-Hosahatty village

7.1c Talc Mineral Spectral Signature: Talc mineral in collected Steatite sample belongs to hydrous magnesium silicate formed by the alteration of pyroxene, hornblende and amphiboles. Mg-rich altered minerals are a key element to recognize talc mineral / steatite rock (King and Clark, 1989). The spectrum of talc mineral has Mg-OH characteristic feature at 2340 nm. Spectral absorption H2O contents of steatite are representing the metamorphic reaction by water within (Shrivastava et al., 2009) can be interpreted in the near 1910 nm (Ali Mohammad et al., 2009). Strong Fe-related absorptions in the visible create a reflectance peak at about 486 nm. 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). Lab spectrum of talc curve shows 0.521 % correlation score with that of USGS Standard library. The shallow absorptions from 990 to 1010 nm and 2290 nm are due to presence of ferrous iron content present on the surface of the sample (Basavarajappa et al, 2017). The shallow absorptions near 2456 nm are influenced by the FeMg-OH contents in the sample.

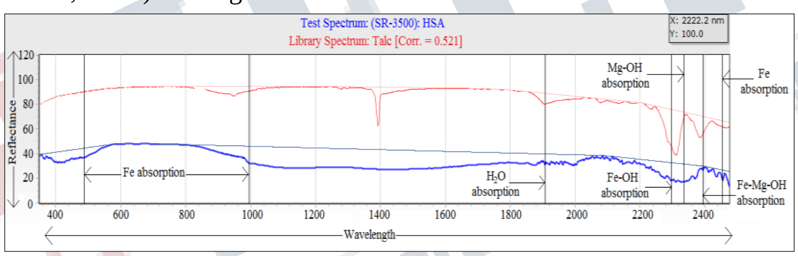

Fig.8. Lab Spectral signature of Talc (HS: Hosahatty-Steatite)

Table 1: Integration of Hyperspectral & Geochemical Signatures on Hosahatty Steatite samples

Sl. No	Major Elements	HS-2a	HS-2b	HS-2c	HS-2d	HSA*	Lab Spectra	Best matches
1.	SiO_2	62.52	53.22	58.68	59.13	***58.38***		
2.	TiO_2	0.02	0.05	0.01	0.04	***0.03***		
3.	Al_2O_3	0.21	0.16	0.11	0.24	***0.18***		
4.	Fe_2O_3	0.23	0.21	0.18	0.26	***0.22***	486, 990 to 1010, 2290	Fe rich minerals
5.	MnO	0.48	0.59	0.57	0.60	***0.56***		

6.	MgO	27.59	34.19	33.78	32.04	***31.90***	2340 nm	Mg(OH) rich type of minerals
7.	CaO	0.63	0.59	0.67	0.71	***0.65***		
8.	Na_2O	0.15	0.19	0.20	0.14	***0.17***		
9.	K_2O	0.02	0.00	0.01	0.01	***0.01***		
10.	P_2O_5	---	---	---	---	---		
	Total	***91.85***	***89.20***	***94.21***	***93.17***	***92.10***		

Note: HAS= Hosahatty Samples Average

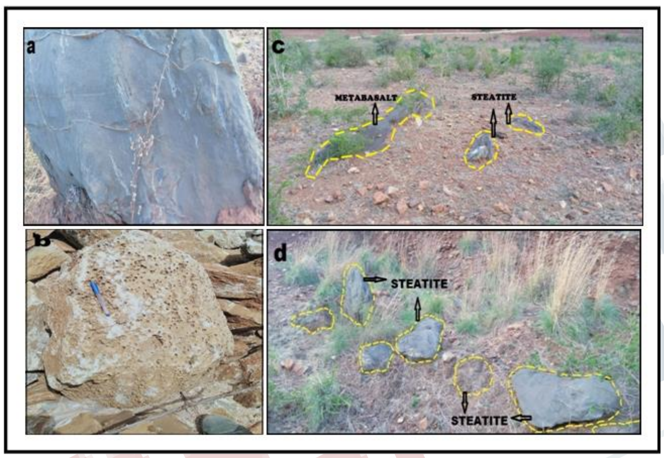

Fig.9. Field photographs of (a) Steatite (b) Steatite exhibiting pitted appearance (c) Contact between Steatite and Metabasalt (d) Steatite outcrop and most of it is under soilcover

8. CONCLUSION:

SEM-EDX studies revealed high percentage of Mg content in the collected sample of steatite along with presence of lesser chromium (Cr) element. The measurement of spectral signatures of the rock using spectro-radiometer produced significant absorptions near 990, 1010, 2290, 2340 and 2456 nm in the 350-2500 nm wavelength. Steatite rock characterization by hyperspectral signatures using a portable field instrument can save time and great expense to map such economic mineral for exploration. There is a wide range of variation in the SiO2, MgO and Fe2O3 contents in the steatites, which may be attributed to the variation in the parent minerals forming talc/ steatite. From the above analysis done it may be said that the steatite deposit have been formed from Mafic to ultramafic magma and this is one of the good industrial material occurring around Bhahaddurghatta-Hosahatty village. Integration of geochemical & spectral signature studies became potential technique in mapping and exploration of economically valuable deposits of the country.

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