HYPERSPECTRAL SIGNATURES, ELEMENTAL MAPPING AND PETRO-CHEMICAL CHARECTERISTICS OF STEATITE DEPOSIT AROUND PANDITANAHALLI VILLAGE, DHARWAR CRATON, KARNATAKA, INDIA

Abrar Ahmed[1], Manjunatha M.C[2], Maruthi N.E[3], Siddaraju M.S[1] and Basavarajappa H.T[1]

[1]Department of Studies in Earth Science, Centre for Advanced Studies in Precambrian Geology, University of Mysore, Manasagangotri, Mysuru, India

[3]Department of Geology, Yuvaraja's College, University of Mysore, Mysuru, India

[2]Department of Civil Engineering, Maharaja Institute of Technology, Thandavapura, Mysuru, India

Abstract

Dharwar Craton is structurally controlled and highly deformed terrain which is rich in varied mineral deposits. It is known for mineral deposits like iron, gold, copper, manganese, chromium, uranium, asbestos, corundum, garnet and talc. Occurrences and good workable deposit of steatite around Panditanahalli village of Hassan district have been identified and demarcated. At present there is no mining activity but it was believed that the first attempt of steatite mining at Panditanahalli was done by Cholas dynasty. Steatite is a talcose rich compact metamorphic rock. They are well known for their heat resistant and other physical properties so it's been used in fireplace liners, cookware, electronic insulator, ovens, masonry heaters, and carvings etc. Fresh samples of steatite, hornblendite, gabbro and pegmatite gneiss were randomly collected in the field through GTC (Ground Truth Check). Rock samples were studied under Transmitted light microscope, Reflected light microscope, SEM-EDX and Spectro-Radiometer. Petrography helped to know the minerals which are associated with steatite, SEM-EDX studies helped to know the high Mg elemental percentage present in the given steatite sample. Spectral signatures of rock sample were studied by Spectro-Radiometer (Spectral Evolution SR-3500) instrument. The spectral signatures of the collected samples were derived in laboratory environment to achieve better accuracy. The present work is aimed for studying the petrological, geochemical and hyperspectral signatures of steatite and their associated litho units. *The final results highlight the minerals present in steatite and spectral characters of steatite for mapping and demarcating the deposit in the study area and also for better mapping in similar areas around Precambrian terrains, Dharwar Cratonic Group(DCG) of Karnataka State.*

Keywords: *Steatite, Petrography, Hyperspectral Signatures, SEM-EDX studies, Panditanahalli village, Dharwar Craton.*

1. INTRODUCTION

Steatite is a talcose rich compact metamorphic rock. The other name for steatite is soapstone. This rock is well known for their heat resistant and other physical properties. They have a wide range of applications. They are been used in fireplace liners, cookware, electronic insulator, ovens, masonry heaters, and carvings etc. In India for centuries as a medium for carving this rock has been used. Famous Chennakeshava temple in bellur is built with this soft rock. Occurrence of steatite deposit around Panditanahalli village have been identified and demarcated. At present there is no mining activity but it was believed that the first attempt of steatite mining at Panditanahalli was done by Cholas dynasty. Swami Nath and Ramakrishnan1981 who worked in those areas said the presence of ultramafic schist (soapstone). Srinivas and Srinivasan,1974, Rama Rao., 1975) and also have

been investigated for copper at Kalasapura (Narasimhan and Viswanatha., 1970).(Rajendran and Aravazhi.,2011) briefly explained about the ancient canal and stone quarries near Halebidu. (Basavarajappa and Maruthi, 2018), (Basavarajappa et al., 2018).Derivedhyperspectral signatures of corundum near Haranahalli of Arsikere band.(Maruthi et al., 2018)(Maruthi et al., 2019) has done alteration zone mapping using Aster data of Limestone Deposits of Parts of Chikkanayakanahalli, Southern Part of Chitradurga Schist Belt,**(**Abrar Ahmed.,et al 2019)**(**Abrar Ahmed., et al 2020) have studied and demarcating the steatite deposits near Andale and Vadrahalli village. A brief account of Geological, Petrological, SEM-EDX, Hyperspectral Signatures studies of steatite deposit around Panditanahalli village is been discussed.

2. STUDY AREA

The study area is located in between 13°10'0" to 13°112'0" North latitude and 75◦59'0" to 76◦0'30" East longitude. The area falls in the toposheet number 48O/16 and 57 C/4 in the Hassan district of Karnataka.

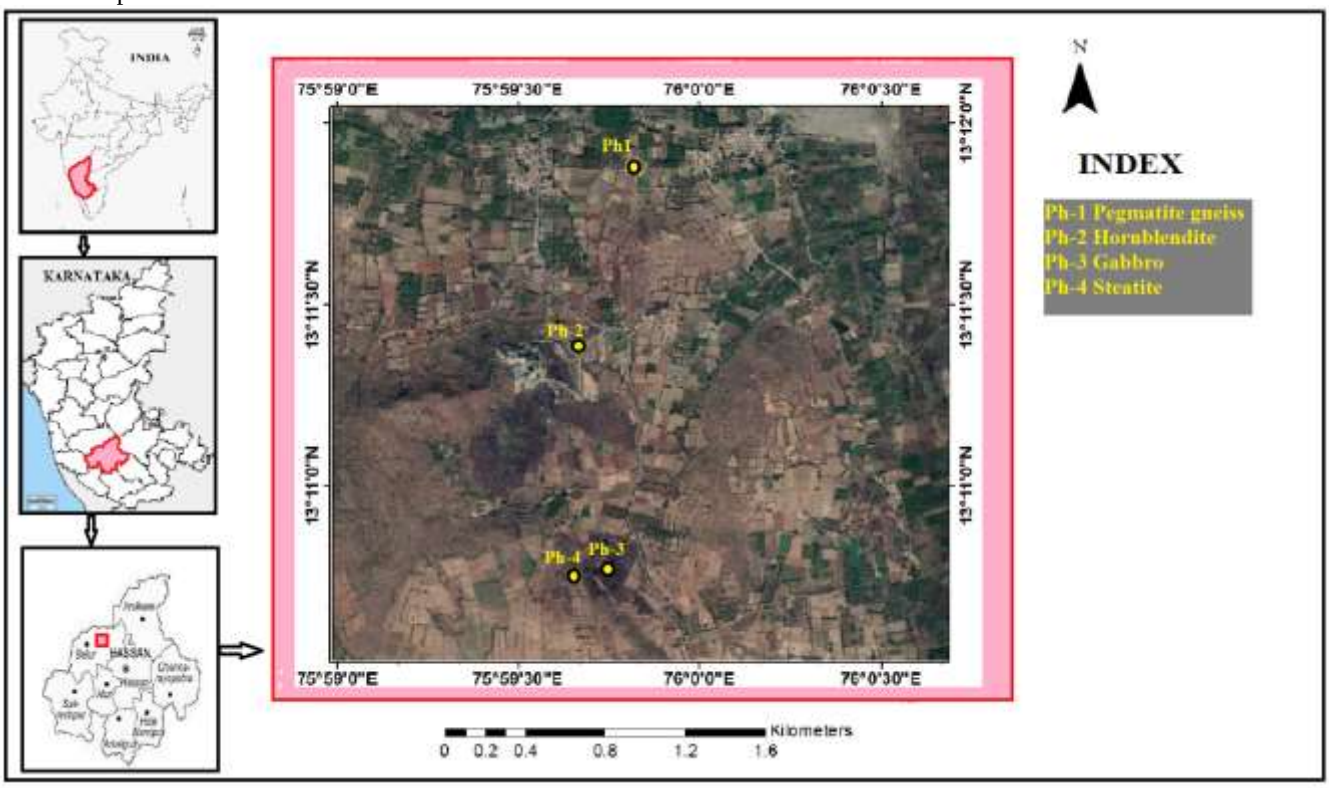

Fig.1. Google Earth image showing the sample location of the study area

Sample number	Sample Name	Location	Latitude	Longitude
Ph1	**Pegmatite gneiss**	**Panditanahalli**	**13°11'21''**	**75°59'39''**
Ph2	**Hornblendite**	**Panditanahalli**	**13°8'0.429''**	**75°59'49''**
Ph3	**Gabbro**	**Panditanahalli**	**13°10'46''**	**75°59'43''**
Ph4	**Steatite**	**Panditanahalli**	**13°11'51''**	**75°59'37''**

3. GEOLOGY

Hassan district geologically consists of older Precambrian rocks which are rich in varied mineral deposits. Several economically valuable deposits are found to occur in rocks ranging from Archean to Proterozoic like gold, uranium, chromite, corundum, garnet, copper, asbestos, vermiculite and also steatite(Ramakrishnan and Vaidyanadhan., 2008). The study area falls near Sigegudda schist belt south of Pushpagiribetta. The strike foliation of the rock types are in general NNW-SSE direction. The occupied by rocks like Penensular gneiss, basic dykes, ultramafics and ambhibolites. The Penensular gneiss occurs as a major rock unit, Ultramafics they occur as linear bands or lenticular patches within the gneissic complex. Amphibolite dykes contains lot of hornblende and basic dykes are seen intruding in this area(Radhakrishna, 1983).

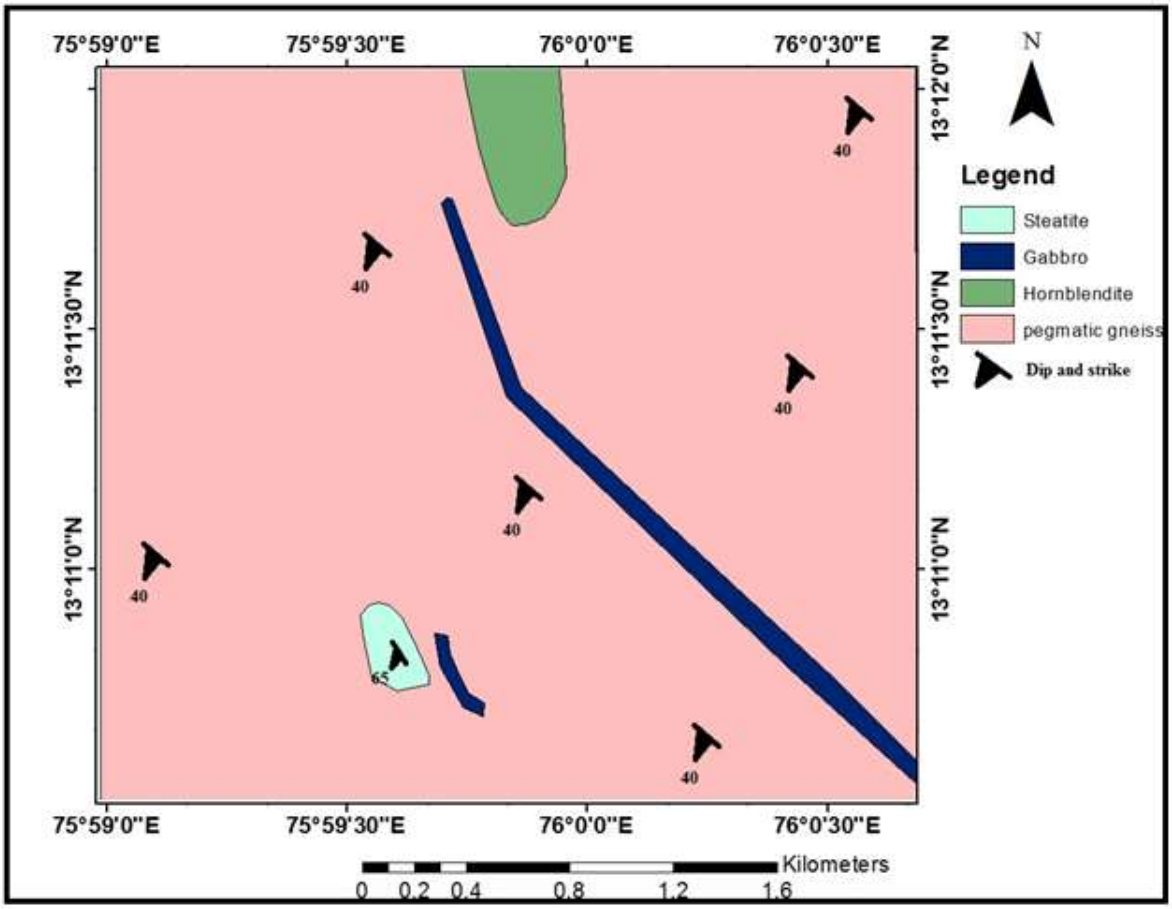

Fig. 2. Geological map of the study area (after GSI 1971)

4. METHODOLOGY

Rock samples were collected in the field and carried carefully to the laboratory for petrographic study. Rock 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 Signatures analysis for rock sample 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 (48o) of 1:250,000 scales are used during the field investigation to study the steatite deposits occurring in that area. Garmin-72 GPS is used to record the exact locations of each sample with an error of 9 mts during field visits.

5. PETROGRAPHY

Petrography is the study of rocks in thin section by means of a petrographic microscope. From the 19th century onwards the study of the optical properties of minerals gives much information of mineral content and the textural relationships within the rock. Many things can be studied with the help of optical microscope also the mineral phases (Basavarajappa et al., 2018).

5.1. Steatite:

Steatite contains majority magnesium rich mineral 'talc' showing massive in texture. Serpentinization process is clearly seen, where in some regions serpentine is commonly found pseudomorphed after olivine which is its one of the characteristic feature. Olivine is seen replacing as serpentine and later gets talcified which may be from hydrothermal alteration of magnesium rich minerals. It clearly shows the alterations of serpentinization and talcification (steatization) in mafic minerals. There is also presence of magnetite mineral showing eudral crystals, in which some are getting oxidized. With all the above observations seen the rock is identified as Steatite (Fig.3).

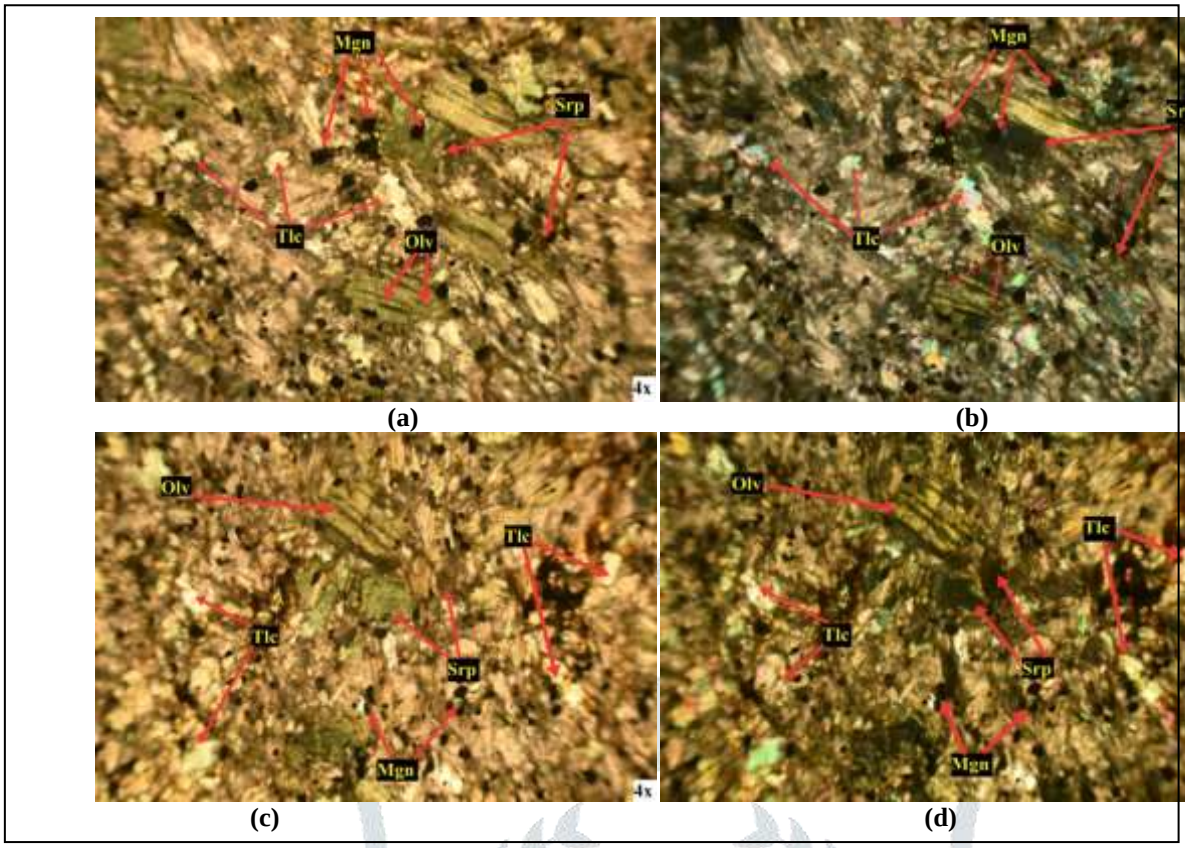

Fig. 3.Photomicrographs ofSteatite under PPL and XPL

5.2. Hornblendite:

The hornblendite mainly consisting of the amphibole hornblende. In a plane polarized light a thin section of hornblende mineral ranges from green to brown in colour. It shows two directions of excellent cleavage that intersect at 120° and 60°. Comparatively hornblende crystals are larger in size. There is also presence of quartz which is an assecory mineral. With all the above observations seen the rock is identified as Hornblendite (Fig.4).

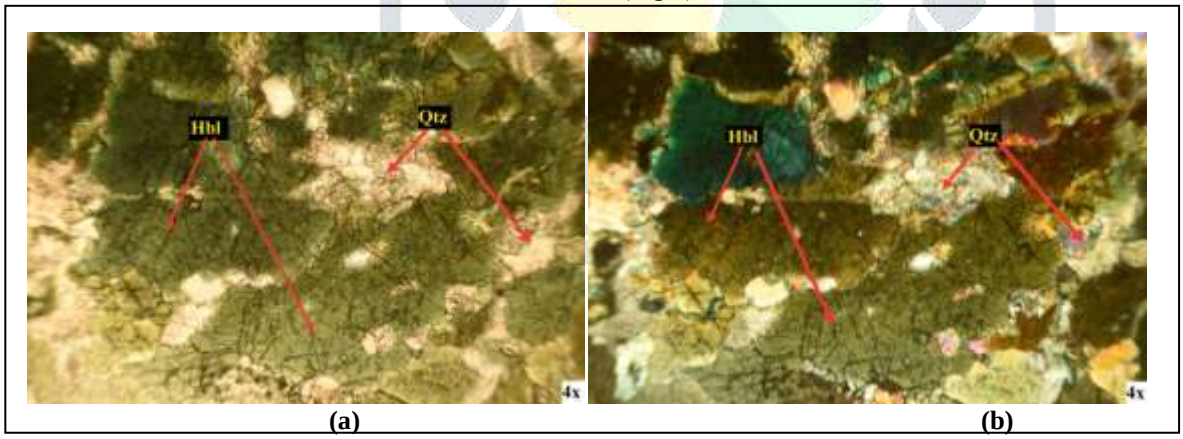

Figure.4.Photomicrographs of Hornblendite under PPL and XPL

5.3. Gabbro:

The gabbro consisting abundant of plagioclase feldspar and then pyroxenes with very little quartz. It shows phaneritic texture (medium to coarse grained). Plagioclase feldspar can be easily identified by their twining under crossed nicols and pyroxene by two directions of cleavage intersecting at nearly right angles. With all the above observations seen the rock is identified as Gabbro (Fig.4).

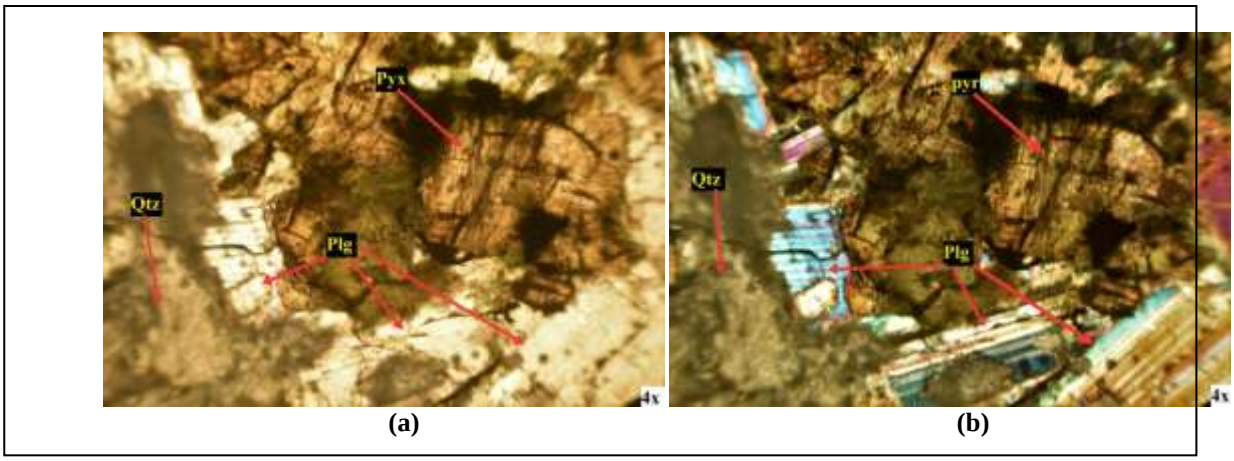

Figure.5.Photomicrographs of Gabbro under PPL and XPL

54.1. Pegmatitic Gneiss:

The pegmatitic gneiss mainly consisting of large plagioclase feldspar with quartz mineral.The mineral under plane polarized light shows colourless, non-pleochroic with low refractive index. In crossed nicolsplagioclase feldspar shows deformed twinning. Therefore the rock has been identified as pegmatitic gneiss (Fig.4).

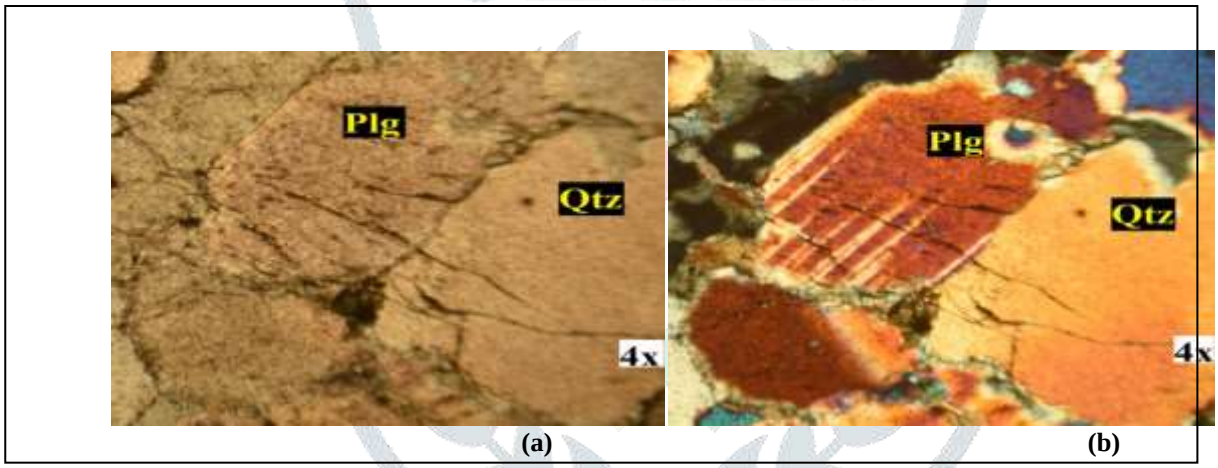

Figure.6.Photomicrographs of Pegmatitic Gneiss under PPL and XPL

6. SEM AND EDS/EDX

The Scanning Electron Microscope (SEM) it is an important tool for imaging material surface as well as for identifying chemical signatures. It 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. This instrument has variable pressure capability, allowing imaging and analysis of non-conductive surfaces 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. SEM analysis is more powerful than Optical Microscopy not only because of the much increased magnification power but also because of the increase in depth of field. The sample region evaluated with SEM analysis can also be determining the specific elements that comprise the sample region by utilizing Energy DispersionSpectroscopy (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. EDS provides data about the chemical composition of the sample and provides 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 (PinakiSengupta et al., 2008). The SEM-EDX analysis is as shown in (Fig.8, 9 and Table1)**(**Abrar Ahmed., et al 2019).

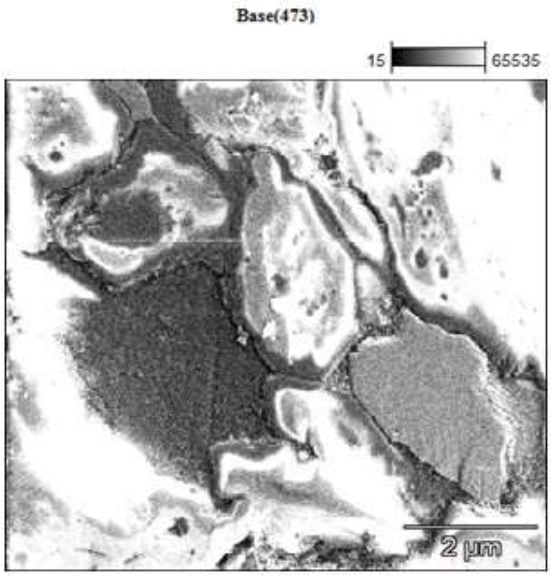

Fig.7. SEM image data of steatite

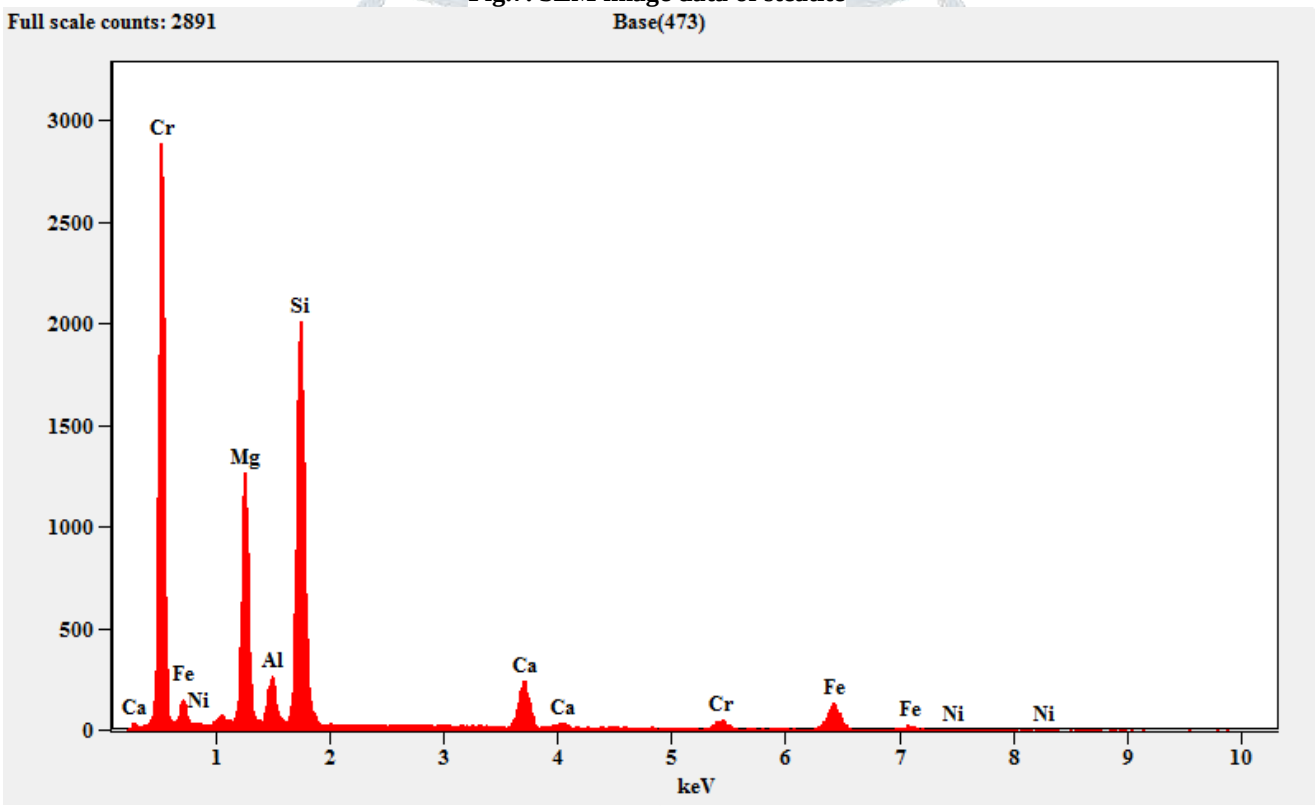

Fig.8. Typical EDX spectrum: y-axis depicts the number of counts and x-axis the energy of the X-rays. The position of the peaks leads to the identification of the elements and the peak height helps in the quantification of each element's concentration in the sample.

Table-1: Showing elemental analysis of Steatite

Element Line	Weight %	Weight % Error	Atom %
Mg K	20.68	± 0.37	26.68
Al K	3.64	± 0.54	4.23
Si K	43.63	± 0.52	48.71
Si L	---	---	---
Ca K	9.98	± 0.35	7.81
Ca L	---	---	---
Cr K	4.38	± 0.23	2.64
Cr L	---	---	---
Fe K	17.24	± 0.81	9.68
Fe L	---	---	---
Ni K	0.46	± 0.34	0.25
Ni L	---	---	---
Total	100.00		100.00

Energy Dispersive X-ray Spectroscopy (EDS) as an analysis method the steatite rock contains the presence of elements like Mg, Al, Si, Ca, Cr, Fe and Ni were determined. Here mainly concentrate of Mg presence is in 20.68%. The elemental analysis photographs of individual elements of steatite rock are as shown below (Fig.9).

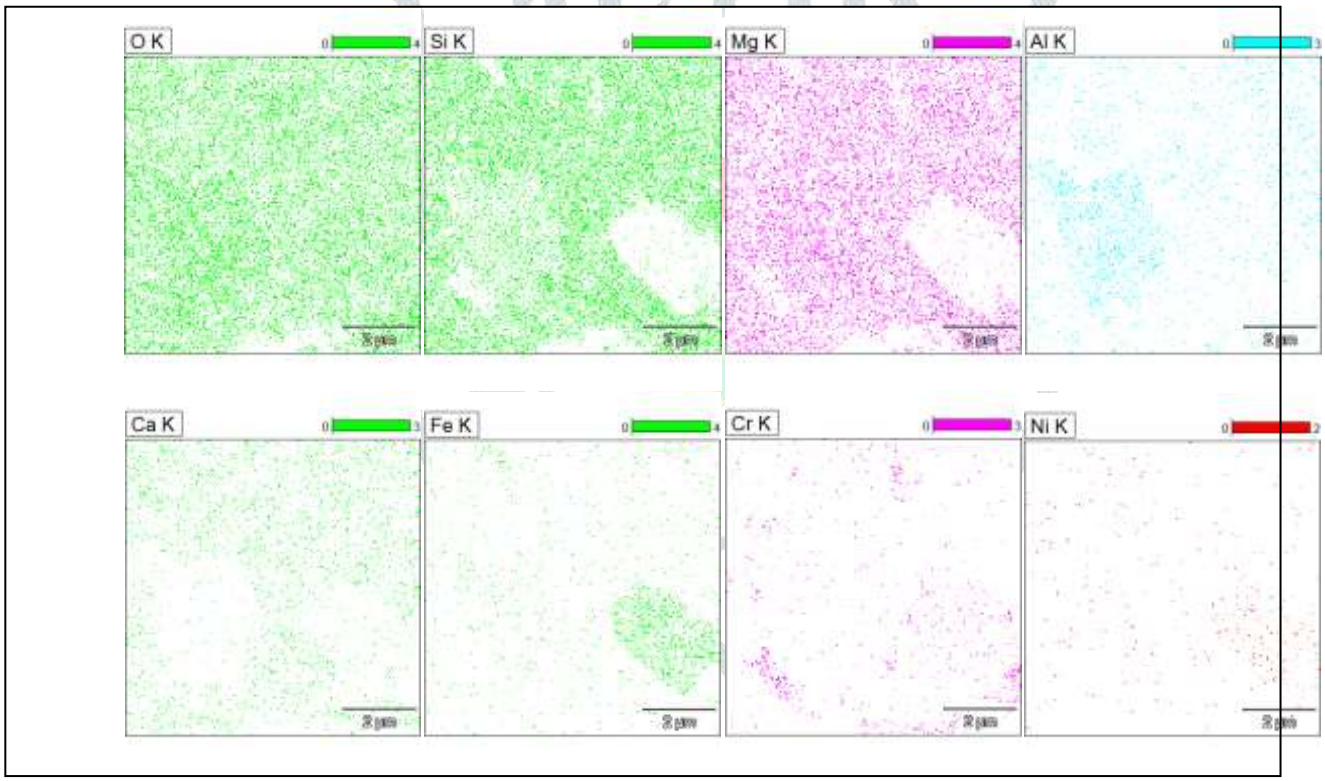

Figure.9. EDX image analysis of individual elements in Steatite

SEM-EDX studies helped to know the high Mg elemental percentage present in the given steatite sample. Presence of iron particularly at one region cleary shows the presence of euhedral crystal. Also presence of chromium and nickel suggests that the steatite have been formed from ultramafic rock which is erupted and formed from deep seated magma occurring around Panditanahalli village (Abrar Ahmed et al., 2019)(Abrar Ahmed et al., 2020).

7. HYPERSPECTRAL SIGNATURES

Spectral signature is the variation of reflectance or emittance of a material with respect to wavelengths (i.e., reflectance/emittance as a function of wavelength). Spectral signature measures all types of wavelengths that reflect, absorb, transmit and emit electromagnetic energy from theobjects of the earth surface (Ali M. Qaid et al., 2009) (Basavarajappa et al., 2017, 2018, 2019 and 2020). Specral Evolution (SR-3500) Spectro-radiometer instrument has the ability to measure the

spectral signatures of different rocks/ minerals. The SE-3500 is a portable spectroradiometer which is ideal for lab or field use. 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 InGaAs arrays extending detection to 2500nm(Maruthi et al., 2019). 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 DARWinsoftware lab Spectra is the one character helps in the study of major and minor mineral constituents ((Hunt et al., 1971, (Basavarajappa and Maruthi, 2018) (Maruthi and Basavarajappa, 2018)(Maruthi et al., 2018)(Abrar Ahmed et al., 2019).

8. RESULT AND DISCUSSION

The Spectral signature curves of Steatite rock were derived are as shown below with description:

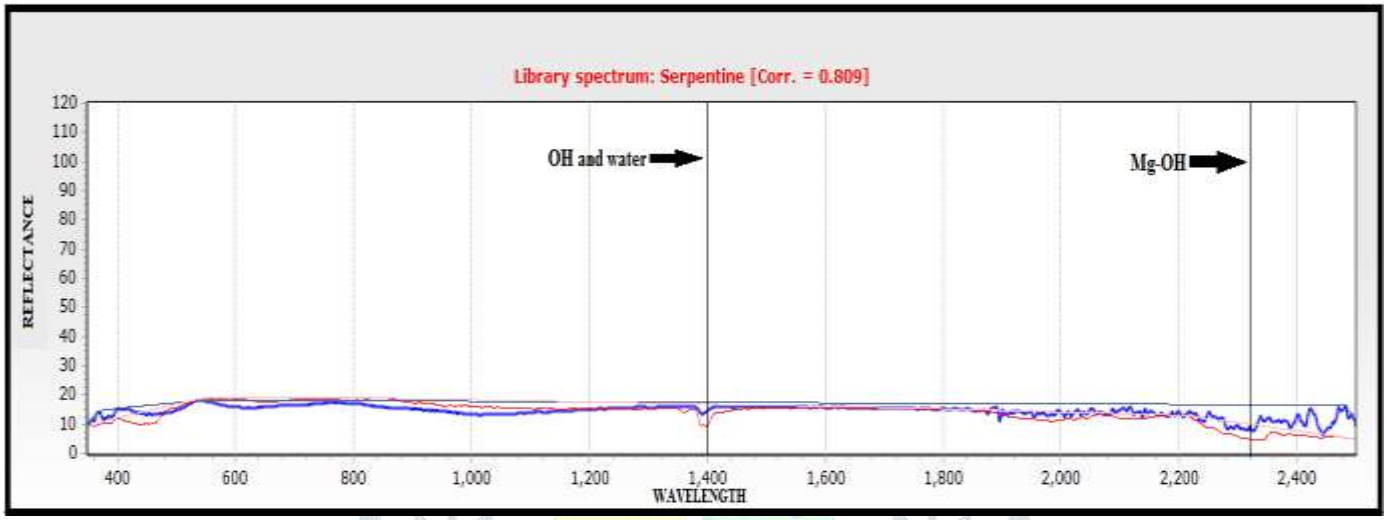

Fig.10. Lab Spectral signatures of serpentine (Panditanahalli area).

The spectrum is of serpentine. Serpentine is a hydrous secondary mineral, typically an alteration product of olivine, pyroxene, or amphibole. Weak ferric and ferrous ion bands are displayed by this sample near 0.7 and 1.0µ respectively, which may be original, or due to the presence of a small amount of unaltered amphibole. The bands near 1.4µ are hydroxyl bands.

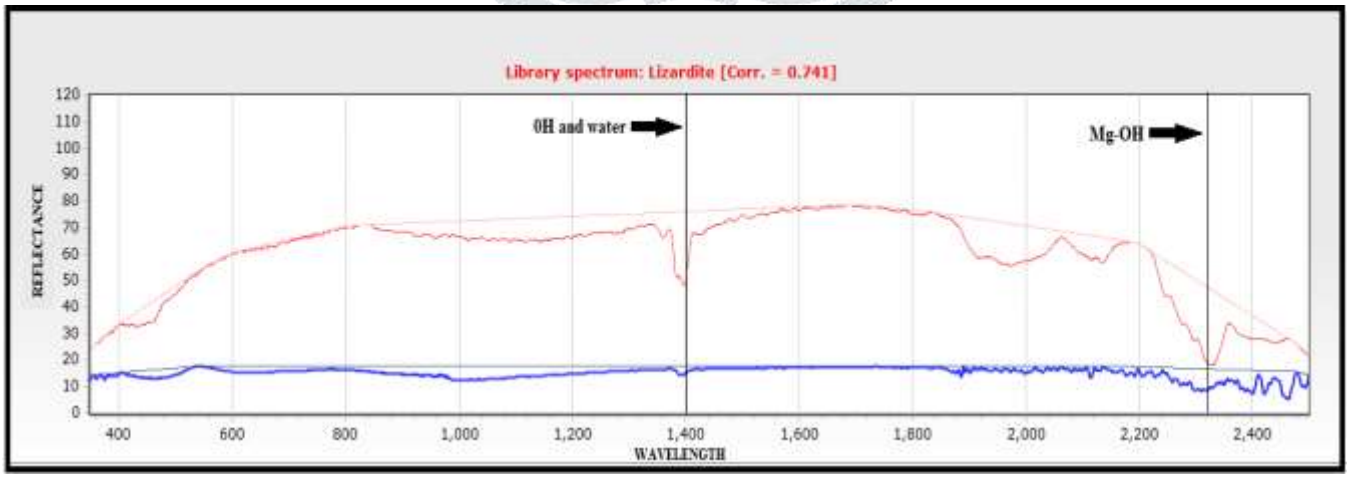

Fig.11. Lab Spectral signatures of serpentine (Panditanahalli area).

The spectrum is of Lizardite (Kaolinite-Serpentine group)which is an Mg-rich serpentine. The spectrum has characteristic features at 2.3 microns with high Magnesium percentage. Lizardite mineral is probably the most common serpentine mineral which usually replaces olivine or other minerals in ultramafic igneous rocks.

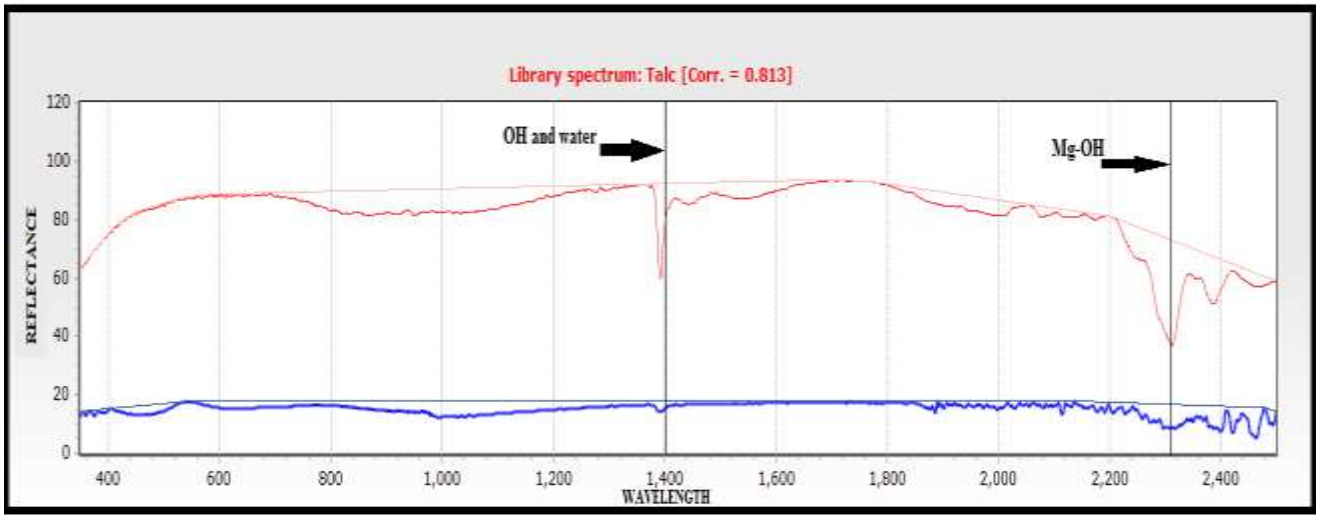

Fig.12. Lab Spectral signatures of Talc (Panditanahalli area).

Talc is a hydrous magnesium silicate, essentially $Mg_3Si_4O_{10}(OH)_2$, of secondary origin. It may be found in altered ignneous rocks, but is more typical of metamorphic varieties. It is formed by alteration of magnesian silicates such as olivine, pyroxenes and amphiboles. Talc may bear a little iron, aluminum or nickel, and ferrous ion in this talc probably accounts for the iron bands on either side of 1µ. Hydroxyl bands are particularly strong and sharp in this sample, which displays them near 1.4µ.

Table-2: XRD-ANALYSIS

Oxide	Amount %
SiO_2	60.47
TiO_2	0.04
Al_2O_3	0.12
Fe_2O_3	0.87
FeO	0.10
MnO	0.01
MgO	**30.29**
ZnO	0.00
BaO	0.01
CaO	0.05
Na_2O	0.04
K_2O	0.00
P_2O_5	0.27
Cl	0.01
F	0.51
LOI	5.31
Total:	Total 92.31

Fig.13.Field photograph of steatite(Panditanahalli village).

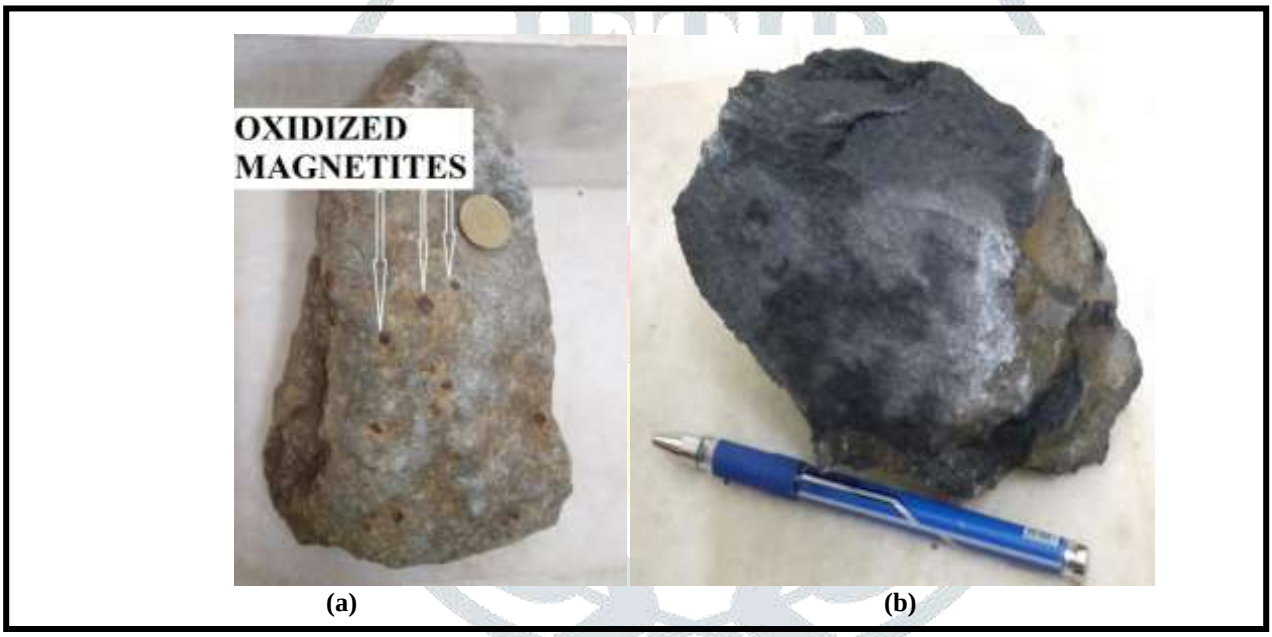

Fig.15. (a) Photograph of steatite showing oxidized magnetites in it (Panditanahalli village).
Fig.15. (b) Photograph of steatite showing talc.

10. CONCLUSION

Deposit of steatite around Panditanahalli village of Hassan district have been identified and demarcated. Geological, Hyperspecral signatures, SEM-EDS analysis with elemental mapping, and Petrographic studies help to find out Physical and Chemical characteristics. Geological studies helped to understand the field setup of the steatite deposit with their associated lithounits. Petrography helped to know the minerals like serpentine, olivine, magnetite and talc are associated with steatite, Petrography also helped to know the olivine is seen replacing as serpentine and later gets talcified by hydrothermal process that clearly shows the alterations of serpentinization and talcification (steatization). SEM-EDX studies helped to know the high Mg and Cr elemental percentage present in the given steatite sample with minor Ni. Presence of Lab spectra in steatite rock with minerals like serpentine, lizardite, talc were identified and absorption curve matches the USGS standard shows the purity of mineral present in the rock. From the above analysis done it may be said that the steatite deposit of panditanahalli of high Mg percentage have been formed from Hydrothermal fluids. Which interact with the other minerals like serpentine to form talc by hydroyhermal alteration as massive in texture which are from ultramafic in origin coming from deep seated magma.

Acknowledgment

The authors are indepthly acknowledged Prof. P. Madesh, Chairman, DoS in Earth Science, Centre for Advanced Studies in Precambrian Geology (CAS), Manasagangothri, University of Mysore, Mysuru. I would like to express my special thank of gratitude to Institute of Excellence, VijnanaBhavan, Manasagangotri, Mysore and Geological Survey of India.

REFFERENCE

1. Abrar Ahmed, Basavarajappa H.T, Maruthi N.E, Siddaraju M.S (2019) Physico-Chemical charecteristics and Hyperspectral Signatures on Steatite deposit around Andale village, DharwarCraton, Karnataka, India. JETIR June 2019, Volume 6, Issue 6. Pp.473-480
2. Abrar Ahmed, Maruthi N.E, Basavarajappa H.T (2019) Comprehensive study of Hyperspectral Signatures, Petrography and Edx analysis on Gold bearing litho units of Nuggihalli Schist Belt, DharwarCraton, Karnataka, India. International Journal of Computer Engineering and Technology (IJCET) Volume 10, Issue 03, May-June 2019, pp. 45-59
3. Ali M. Qaid, Basavarajappa H.T and Rajendran S.(2009). Integration oof VNIR and Spectral Reflectance for Mapping Mineral Resources; A case study, NorthEast of Haah, Yeman, J. Indian.So. Remote Sens, Vol.37, pp. 305-315.
4. AnanthaIyer, G.V. and Vasudev, V.N. (1979) Geochemistry of the Archeanmetavolcanic rocks of Kolar and Hutti gold field, Karnataka, India. J. Geol. Soc. India, 20: 419-432.
5. Azaroff L V and Pease D m 1974 X-ray spectroscopy (New York: McGraw Hill), pp. 288.
6. Basavaraappa H.T, Dinakar S, Satish M.V, Nagesh D and Manjunatha M.C, (2013). 'Applications of Remote Sensing and GIS in Morphometric Analysis on Precambrian Rocks, Kollegalshearzone, Chamarajanagar District, South India' International Journal of Earth Sciences and Engineering, ISSN 0974-5904, vol. 07, no.1, pp. 230-241.
7. Basavarajappa H.T and Maruthi N.E (2018). Hyperspectral And Petro - Chemical Signatures Study On Shear Zone Controlled Corundum Bearing Pelitic Rocks Of Budipadaga Area, Chamarajanagara District, Karnataka, India. International Journal of Research and analytical Reviews (IJRAR) Volume 5, Issue 3, pp. 906-913.
8. Basavarajappa H.T and Maruthi N.E (2018). Hyperspectral and Petro - Chemical Signatures study on Corundum Bearing Litho-Units around Sringeri Area, Chikmagalur District, Karnataka, India. RESEARCH REVIEW International Journal of Multidisciplinary Volume 3, Issue10, pp. 899-904.
9. Basavarajappa H.T and Maruthi N.E (2018).Petro – Chemical and Spectral Signatures On Corundum Bearing Precambrian Amphibolites In Sullia Area, Dakshina Kannada District, Karnataka, India. Journal of Emerging Technologies and Innovative Research (JETIR) Volume 5, Issue 7, pp. 75-83.
10. Basavarajappa H.T and Maruthi N.E (2018). Petrochemical characteristics and Hyperspectral signatures on Corundum bearing Precambrian litho-units of Varuna area, Mysuru district, Karnataka, India. International Journal of Creative Research Thoughts, Volume6, Issue1, Pp.998-109.
11. BasavarajappaH.T, and Maruthi N.E (2018). Hyperspectral Signature Study Finds Corundum Alters To DiasporeInflueance Of Climate Change Of DharwarCratonArsikere Band Of Haranahalli, Hassan District, Karnataka, India. Journal of Environmental Science, Computer Science and Engineering and Technology (JECET) Volume 7, Issue 2, Pp.238-246.
12. Basavarajappa H.T, Maruthi N.E (2018),Petrochemical characteristics and Hyperspectral signatures on corundum bearing Precambrian lithounits of Varuna area, Mysuru district, Karnataka, India ,International Journal of Creative Research Thoughts, ISSN:2320-2882, Volume6, Issue1
13. Basavarajappa H.T, Maruthi N.E and Manjunatha M.C (2017). Hyperspectral Signatures and Field Petrography of Corundum bearing litho-units in Arsikere band of Haranahalli, Hassan District, Karnataka, India. International Journal of Creative Research Thoughts, Volume5, Issue4, Pp.3791-3798.
14. Basavarajappa H.T, Maruthi N.E and Manjunatha M.C, (2017) " Hyperspectral Signatures and Field Petrography of Corundum bearing litho-units in Arsikere band of Haranahalli, Hassan District, Karnataka, India"International Journal of Creative Research, ISSN:2320-2882, Volume5, Issue4.
15. Basavarajappa H.T, Maruthi N.E, Jeevan L and ManjunathaM.C (2018). PhysicoChemicalcharecteristics and hyperspectral signature study using geomaticsongem variety of Corundum bearing Precambrian litho-units of Mavinahalli area, Mysuru district, Karnataka, India. International journal of Computer Engineering and Technology (IJCET) Volume 9, Issue 1, pp. 102-112.
16. Beckinsale, R.D., Drury, S.A. and Holt, R.W. (1980) 3,360 my old Gneisses from the South Indian Craton. Nature, 283: pp. 469-470.
17. Chadwick, Ramakrishnan, Vishwanatha M.N., and Srinivasa Murthy V.(1978). Structural studies in the ArchaeanSargur and Dharwarsupracrustal rocks of the Karnataka Craton, Jou. Geol. Soc. Ind., 19, pp. 531-549.
18. Chesterman, C.W; Lowe, K.E. (2008). Field guide to North American rocks and minerals. Toronto; Random House of Canada. ISBN 0-394-50269-8.
19. Chibber, V.N (1953) Steatite deposits of Bheraghat, Jabalpur district, M.P., India. Eco.Geol, v. pp. 53-57.
20. D.G.A. Whitten, J.R.V. Brooks (1979), The Penguin Dictionary of Geology, pp.426.
21. Dana, James D; revised by Cornelius S. Hulbert JR. (1959). Dana's Manual of Mineralogy, 17th edition. New York: wiley.
22. Deer, W.A., Howier, R.A., Jussman.J. (1985) An introduction to the rock forming minerals. pp. 515-517.

23. Drury, S. A., Hharris, N.B.W., Holt, R.W., Reeves-Smith, G.J. and Wightman, R.T. (1984) Precambrian tectonic and crustal evolution in south India. J. Geol., 92:pp. 3-20
24. Dyar, M.D; Gunter, M.E. (2008). Mineralogy and Optical Mineralogy. Chantilly, Virginia: Mineralogical Society of America. ISBN 978-0-939950-81-2.
25. EVA.S.Schandl and Wiicks.F.J. (1993) Carbonate and Associated alteration of Ultramafic and Rhyolitic Rocks at the Hemingway property, Kidd Creek Volcanic Complex, Timmins, Ontario, v.8 pp. 1615-1635
26. Godkee, S.S. (1971) Steatite-Talc deposits in South Rathnagiri District. Indian minerals. V.25 (2) pp. 119-125.
27. Maruthi N.E and Basavarajappa H.T (2018). Hyperspectral and Petro - Chemical Signatures study on Corundum Bearing Amphibolite Schist of Magadi Area, Ramanagara District, Karnataka, India. RESEARCH REVIEW International Journal of Multidisciplinary Volume 9, Issue 3, pp. 773-779.
28. Maruthi N.E and Basavarajappa H.T (2018).HyperspectralAnd Petro - Chemical Signatures Study On Corundum Bearing Litho-Units Of Precambrian Basement Rocks Around Closepect Granite Madhugiri Area, Karnataka, India. Journal of Emerging Technologies and Innovative Research (JETIR) Volume 5, Issue 12, pp. 619 - 628.
29. Maruthi N.E and Basavarajappa H.T (2018).Hyperspectral Signatures and Petro - Chemical Charectistics Study on Corundum Bearing Litho-Units of Sargur Area, Mysuru District, Karnataka, India. International Journal of Research and analytical Reviews (IJRAR) Volume 5, Issue 4, pp. 65-74.
30. Maruthi N.E, BasavarajappaH.T, Reza Ravanshadand HabibulRahmanMasoumi. (2019).Hyperspectral And Petro-Chemical Signatures Study On Corundum Bearing Litho-Units Of Precambrian Rocks Around Bangarpet Area, Kolar District, Karnataka, India. International Journal of Research and Analytical Reviews (IJRAR), Volume.6, Issue 2, Page No pp.795-804, May 2019.
31. Maruthi N.E, Basavarajappa H.T, and Siddaraju M.S (2019). HyperspectralAnd Petro-Chemical Signatures Study On Corundum Bearing Litho-Units Of Precambrian Basement Rocks Around Chitradurga Area, Karnataka, India. International Journal of Research and Analytical Reviews (IJRAR), Volume.6, Issue 2, Page No pp.242-250, June 2019.
32. Maruthi N.E, Basavarajappa H.T, Jeevan .L and Siddaraju M.S (2018).Hyperspectral Signatures On Corundum Bearing Litho-Units Of Precambrian Basement Rocks Around Closepet Granite Pavagada Area, Karnataka. International Journal of Computer Engineering and Technology (IJCET) Volume 9, Issue 3, pp. 86-94.
33. Maruthi N.E, Basavarajappa H.T, Manjunatha M.C, and Harshavardhana A.S. (2019). Hyperspectral Study And Integration Of Petro-Chemical Signatures On Corundum Bearing Litho-Units Around Maddur, Mandya District, Karnataka, India. International Journal of Research and Analytical Reviews (IJRAR), Volume.6, Issue 1, Page No pp.897-903, January -March 2019.
34. Moine, B., Fortune J.P., Moreau, P. And Viguier. F. (1989) Comparative mineralogy, geochemistry and conditions of formation of two metasomatic talc and chlorite deposits: Trimounds (Pyrenees, France) and Rabenwald (Eastern Alps, Austria). Economic geology, 84. pp. 1398-1416.
35. Mukhopadyay, D. (1986) Structural pattern in the DharwarCraton. J. Geol. X. V. 94. Pp. 167-186.
36. Naha, K., Srinivasan, R., Gopalan, K., Pantulu, G.V., SubbaRao, M. V., Vrevsky, A.B. and Bogomolv, YE. S. (1993) The nature of the basement in the ArcheanDharwarCraton of Southern India and the age of the Peninsular Gneiss. Proc. Indian. Acad. Sci. (Earth and Planet. Sci.), 102: pp. 547-565.
37. Prochaska, W. (1989) Geochemistry and Genesis of Austrian talc deposits. Applied Geochemistry, v.4. pp. 511-525.
38. Radhakrishna BP (1983). Archean granite-greenstone terrain of the South Indian Shield. In: Naqvi S W and Rogers J J W (eds.), Precambrian of South India. Geological Society of India Memorandum, 4, 1-46.
39. Radhakrishnan, B.P. and Naqvi, S.M. (1986) Precambrian continental crust of India and its evolution.j. Geol. V. 94, pp. 145-166.
40. Rajamani, v. (1990) petrogenesis of metabasites from the schist belts of the Dharwarcraton: Implications to Archean mafic magmatism. Jour. Geol. Soc. India. V. 36. pp.565-587.
41. Rama Rao (1962) A handbook of the geology of the Mysore State, Southern India. Banglore printing and publishing Co., pp. 264.
42. Rama Rao, B.V. (1974) Discovery of Uraniferousprecabrian conglomerates at chikmangalur, Karnataka State. Curr. Sci 44 pp. 174-175.
43. Ramakrishnan M. and R. Vaidyanadhan. (2008). Geology of India, Volume-1, Pp: 108-120.
44. Ramakrishnan, M and Viswanatha, M.N (191) Siggeguda belt in early precambriansupracrustals of Karnataka Memoir. Geol.Surv. India, Vol. 112. pp. 143-146.
45. Rowan L.C, Mars J.C, 2003. Lithological mapping in the Mountain Pass, California area using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data. Remote Sensing of Environment 84 (3), pp. 350-366.
46. S. P. VenkataDasu and AljazAkhtar (195) Report of thereconnaitory surveys of gold in the Siggeguda area, Karnataka state. GSI, pp 1-20.
47. Sabin S F, 1997. Remote Sensing principles and interpretation, third ed , pp. 494.

48. Saine Petit. Francois Martin., AndrzeWiewiora., Philippe DE Parseval and Alain Decarreau. (2004) Crystal-Chemistry of talc: A near infrared (NIR) spectroscopy study. AM. Min, v. 89, pp. 319-326.
49. Shear zone controlled Corundum bearing Pelitic rocks of Budipadaga Area,Chamarajanagara district, Karnataka, India. International Journal of Research and analytical review (IRAR) Volume 5, Issue 3, pp-906-913.
50. Taruck, Edward J, and Lutgens, Frederick K. (1999). Earth: An Introduction to Physical Geology, 6th edition, upper Saddle River, NJ: Prentice Hall.
51. Thiagarajan. (1958) Talc-Magnesite rock near Bhitar Dari, Dhalbhum sub-division, Singhbhum district, Bihar, Indian Minerals. Vol.12 (3), pp. 208-211.
52. Venkatesh, v. (1951) A note on the testing of some steatite specimens from Rajasthan and Madhya Pradesh. Indian minerals. Vol. 5(3), pp. 128-135.