Determination of Spectral Characteristics on Archaean Komatiites in Ghattihosahalli Schist Belt (Gsb) of Kumminagatta, Chitradurga District, Karnataka, India

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Abstract: Komatiites contain economic important nickel, chromium, titanium and copper deposits and their spectral absorption characters are highly important in the remote sensing technique to map and explore such deposits bearing rocks. This study integrates hyperspectral signatures; petrological and geochemical characters of serpentinite bearing ultramafic komatiite rock noticed at the Ghattihosahalli Schist Belt (GSB), near Kumminagatta village, in the Chitradurga district of Karnataka, India and demonstrate specific spectral absorptions of the rock. The measurement of spectral signatures of the rock using spectroradiometer produced significant absorptions near 700, 900 to 1100, 1400, 2300, 2380 and 2470 nm in the 350-2500 nm wavelength. The spectral absorptions depend mainly on the optical and physico-chemical characters of the rock and are studied with the spectra of mineral library of USGS and JPL and characterized. This study can be used in the remote sensing technique to map similar rocks and bearing mineralization of the remote areas.

Keywords: Geochemical data; GSB, Komatiite; Kumminagatta; Spectral signatures

1. Introduction

Komatiite is an economic minerals bearing rock and study of this rock is also significant to understand the evolution of the Earth’s crust and mantle. The rock contains valuable deposits of nickel, chromium, titanium and copper which are of economic interests (Arndt et al., 2008). Komatiite magma erupted on the Earth’s surface through partial melting in the mantle at depths far greater than those that yield the modern basaltic magmas (Arndt et al., 2008). Similar studies provide important evidences to thermal and chemical evolution of the planet, and nature of the Precambrian mantle (Arndt et al., 2008). The spinifex texture of Komatiite (STK) is characterized by presence of parallel and radiate arrangements (spiky, randomly oriented leaves or needles) of elongate olivines and pyroxenes implying the rapid crystallization from an ultramafic liquid (Nesbitt, 1971; Arndt et al., 2008). In India, the Komatiites occurrence of Ghattihosahalli Schist Bet (GSB) is spinifex textured and contains high Mg content (ultramafic composition, Vishwanatha et al., 1977). It is volcanic/sub-volcanic origin (Jayananda et al., 2008) formed around 3384 M.Y (Prabhakar and Namratha, 2014). Detailed field studies have been carried out by Ramakrishnan et al., (2012), Jayananda et al., (2013), and Prabhakar and Namratha (2014). The trace element analyses of the Komatiite rock shows 2625 ppm, 1588 ppm, 2360 ppm of nickel, chromium, and titanium respectively (Arndt et al., 2008; Jayananda et al., 2008). This study
characterizes the hyperspectral signatures of such economic important Komatiite rock and correlates petrographic and major elements chemistry in interest of mapping the rock.

1.1. Study Area

Ghattihosahalli Schist Belt (GSB) of Karnataka, India consists of volcano-sedimentary sequence includes the ultramafic Komatitites, steatite, amphibolites with interlayered fuchsite quartzite and barite beds (Vishwanatha et al., 1977; Radhakrishna and Sreenivasaiah, 1974). It is correlated with the Sargur Group, which is older than the greenstone sequences of the Dharwar Supergroup in Karnataka (Vishwanatha and Ramakrishnan, 1975; Chadwick et al., 1981; Paranthaman, 2005). The GSB is about 15 km long and 300 m wide, represents a linear en echelon array of enclaves of the high-grade supracrustal rocks occurred very close to western margin of the Chitradurga Schist Belt (CSB) in the Western Dharwar Craton (Narayana and Naqvi, 1980; Jayananda et al., 2008; Ramakrishnan et al., 2012). The study area, Kumminagatta village in the Chitradurga district of Karnataka lies in between 13°56’ to 14º00’ the north latitude and 76°14’ to 76°19’ the east longitude at elevation ranges from 813 to 848m above Mean Sea Level (Figure 1). Here, the occurrences of serpentinite bearing Komatiites in the GSB are mapped by Vishwanatha et al. (1977). In the field, the rocks occurred as circular exposure and showed undoubted spinifex texture, deformed nodular structure stacked randomly and accentuated by thin stringers of magnetite in hand specimen (Vishwanatha et al., 1977).

![Map of Ghattihosahalli Schist Belt (GSB) after Jayananda et al., 2008](image)

**Figure 1:** Google Earth image shows the sample locations (STK-1; STK-2; STK-3 & STK-4) of the Archaean Komatiite in the Ghattihosahalli Schist Belt

2. Methodology

In this study, four representative rock samples of spinifex textured Komatitites (STK-1; STK-2; STK-3 & STK-4) have been collected during field visits for laboratory study. Hyperspectral measurements of field samples are carried out using a spectroradiometer instrument, FieldSpec-3 (Laboratory Analytical
Spectral Device), in the wavelength of 350-2500nm at the Geological Survey of India (GSI), Bengaluru. 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 ENVI v4.2 (Basavarajappa et al., 2015; Rajendran et al., 2014). The samples are studied for petrographic characters using a microscope by preparation of microscopic thin sections and were analyzed for major chemical elements. Survey of India (SoI) toposmap (57C/5 [grid: B-1]) of 1:50,000 scale is used during the field work to study the Komatiite rocks and the samples are collected using a handheld GPS (Garmin-12) instrument.

2.1. Field Study

At southern part of Kumminagatta village, a prominent circular hill (Figure 1) shows exposure of komatiite rocks associated with talc-actinolite-tremolite schist and hard meta-peridotite. In the field, the rocks showed a well developed coarse spinifex textures consist of randomly oriented plates and bundles of altered olivines in fine grained matrix ranging from 1 to 8 cm in length and 0.5 to 5 mm in width (Figure 2a, b, c). Here, the Komatiites are interlayered and well exposed on the top of the hill; while the massive exposures are found at the lower levels of the hill (Jayananda et al., 2008). During the field work, four rock samples of massive, dark reddish brown and showed spinifex grass texture are collected. Lensoidal and bladed crystals of olivine and randomly stacked and accentuated by thin stringers of magnetite are observed in fresh samples (Ramakrishnan et al., 2012). The olivines of the rocks are showed alteration of serpentine by weathering process (Ramakrishnan and Swami Nath, 1981). At few places, the Komatiite is associated with quartzite signify that its occurrence is ultramafic subaqueous volcanism and chemical precipitation of eruption (Jayananda et al., 2008).

![Figure 2: Field photographs (a, b, & c) show the spinifex textures in the outcrop of Komatiites at south of Kumminagatta village of Ghattihosahalli Schist Belt](image)

2.2. Petrography and Geochemistry

The Komatiites are mainly made up of olivine and altered serpentine minerals with streaks of magnetites which are observed under petrological microscope (Ramakrishnan et al., 2012). The Komatiite exhibited bundles of long & short olivine’s, sub-parallel and cross cutting serpentines (olivine altered product) with small isolated patches of fibrous asbestos (Figure 3a & b). The major element analysis of the rock samples showed high concentrations of SiO$_2$ (40.37 %), MgO (32.42 %) and Fe$_2$O$_3$+FeO (10.17 %) and low amounts of K$_2$O (0.10 %), CaO (2.37 %) and Na$_2$O (0.25 %) (Table 1: Narayana and Naqvi, 1980).
Figure 3: Microphotographs show a. spinifex texture of the Komatite and b. the parallel and randomly oriented olivine blades of serpentine with minor carbonate and fine grained opaque minerals (PPL, 4x)

Figure 4: Laboratory spectral plots of Archaean Komatiites of the Kumminagatta village, Karnataka

2.3. Interpretation of Hyperspectral Signatures

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. Mapping of rock types based on absorption signatures in the spectral wavelength and spectral bands of satellite data are carried by several geologists. In remote sensing technique, an extensive range of minerals are mapped, including the MgO-rich serpentines (Rajendran et al., 2012, 2013, 2014), based on their absorption characters in the spectral wavelength (Rowan et al., 2006; Ali Mohammad, et al., 2009). Laboratory spectroradiometer instrument has their own light source for illumination of the specimen and has very high spectral resolution and measuring reflectance percentages of samples.
from 400 to 2500 nm (Lipton, 1997). 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). The study of minerals of phyllosilicates showed narrow spectral absorption features near 2.2 μm wavelength region due to mainly presence of Al-OH contents in the minerals. The octahedral sites in the phyllosilicates are occupied by magnesium instead of aluminum, the combination OH stretch produces (Mg-OH bending) strong absorption features in the vicinity of 2.30 to 2.35 μm (Hunt, 1977, 1979; Abrams et al., 1988; Mars and Rowan, 2010; Rajendran et al., 2012, 2014; Rajendran and Nasir, 2014).

In this study, the Mg-rich altered serpentine minerals are a key element to recognize Komatiite (King and Clark, 1989). As well as, spectral absorptions of the OH and H2O contents of the rocks and bearing minerals that are representing the metamorphic reaction (by water within Archaean Komatiites, Shrivastava et al., 2009) can be interpreted in the near 1.39 to 1.90 μm respectively (Ali Ali Mohammad et al., 2009). The spectra of the Komatiite samples are given in Figure 4. It shows well identified absorption features near 700, 900 to1100, 1400, 2300, 2380 and 2470 nm. In the spectra, the shallow absorptions near 700 nm and the broad deep absorptions from 900 to 1100 are due to presence of ferrous iron content present on the surface of the samples. The sharp and deep absorption at 1400 nm is due to presence of OH and H2O contents present in the altered minerals of the samples. The significant absorption at 2300 is due to presence of the Mg-OH and the shallow absorptions near 2380 and 2470 are influenced by the FeMg-OH contents in the samples.

Table 1: Integration of hyperspectral & geochemical signatures on Archaean Komatiites

| S. No. | Elements   | STK-1  | STK-2  | STK-3  | STK-4  | Average | Lab spectra (µm) | Best matches                  |
|-------|------------|--------|--------|--------|--------|---------|------------------|-------------------------------|
| 1.    | SiO²⁺      | 39.43  | 42.18  | 40.08  | 39.81  | 40.37   |                  |                               |
| 2.    | TiO₂       | 0.23   | 0.19   | 0.19   | 0.27   | 0.22    |                  |                               |
| 3.    | Al₂O₃      | 2.09   | 3.21   | 3.54   | 4.13   | 3.24    |                  |                               |
| 4.    | Total FeO  | 8.73   | 9.22   | 11.61  | 11.13  | 10.17   | 0.7, 0.94 & 2.47 | Fe rich minerals              |
| 5.    | MnO        | 0.14   | 0.11   | 0.15   | 0.16   | 0.14    |                  |                               |
| 6.    | MgO        | 32.87  | 31.12  | 31.31  | 34.39  | 32.42   | 2.311 to 3.19    | Serpentinite & Mg(OH) rich type of minerals |
| 7.    | CaO        | 3.01   | 2.56   | 2.69   | 1.24   | 2.37    |                  |                               |
| 8.    | Na₂O       | 0.21   | 0.27   | 0.23   | 0.30   | 0.25    |                  |                               |
| 9.    | K₂O        | 0.15   | 0.08   | 0.09   | 0.10   | 0.10    |                  |                               |
| 10.   | P₂O₅       | 0.09   | 0.15   | 0.12   | 0.16   | 0.13    |                  |                               |
| 11.   | H₂O⁺       | 7.61   | 9.60   | 9.81   | 7.89   | 8.72    | 1.39 & 1.90      | OH & H₂O type of minerals     |
| Total |            | 94.56  | 98.69  | 99.82  | 99.58  |         |                  |                               |

3. Results and Discussion

Understanding of spectral absorptions features of the Komatiite rocks based on their optical and physico-chemical characters is significant in remote sensing technique to map the rock and explore the economic important minerals of the rock. Here, the study of petrological characters and chemical analyses of the four rock samples showed that these are composed of olivine and altered serpentine minerals and have high SiO₂ (40.37%), MgO (32.42%), FeO (10.17%) and H₂O (8.72%) contents in average of analyses. The measurement of hyperspectral signatures of the rock in the 350-2500 nm
wavelength showed absorption features near 700, 900 to1100, 1400, 2300, 2380 and 2470 nm. Table 2 shows the specific absorption values in the wavelengths. The features of absorptions are mainly depends the surface minerals of the rock samples. The weathered olivine minerals of the rock developed the ferrous iron rich rock surface which produced broad Fe-OH absorption at the wavelength of 900-1100 nm evidently in the spectral plot. As well as, the occurrence of serpentine minerals in the rock, due to hydrothermal alteration of olivine, produced Mg-OH and FeMg-OH absorptions at 2300, 2380 and 2470 nm significantly. The chemical analyses of the samples showed presence of the 8.72% of H2O contents in the samples which may be due to presence of water during metamorphic reaction. The H2O contents and the OH contents present in the altered minerals developed together the absorption at 1400 nm clearly. The comparative study of minerals spectra of mainly the olivine and serpentine minerals from the spectral libraries namely USGS and JPL correlated well and more confirmed such interpretations of the spectral absorption features to the specific wavelengths. Thus, the petrological study showed the minerals of the rock and chemical analyses produced the concentration of chemical elements of the rock which are characterized the spectral absorption features. This study clearly demonstrated and documented the spectral absorption features of the Komatiite rock which depend the optical and physico-chemical characters of the rock.

Table 2: Spectral absorption values of the Archaean Komatiite rocks

| Wavelengths in nm | Sample No. | STK-1 | STK-2 | STK-3 | STK-4 |
|-------------------|------------|-------|-------|-------|-------|
| 700               |            | 665   | 704.4 | 707   | 725.4 |
| 900-1100          |            | 948.5 | 977.4 | 972.2 | 924.9 |
| 1400              |            | 1392.2| 1392.6| 1392.2| 1392.6|
| 2300              |            | 2314.6| 2314.6| 2314.6| 2312.8|
| 2380              |            | 2384.5| 2384.5| 2386.3| 2389.8|
| 2470              |            | 2461.5| 2473.8| 2466.8| 2465  |

4. Conclusion

Characterizing of Archaean Komatiite's by hyperspectral signature using a portable field instrument can save time and great expense to map the rock and bearing economic mineral for exploration. In this study, the hyperspectral signatures of the Komatiite rock samples of Kumminagatta village in the Chitradurga district of Karnataka state, India are measured and the specific absorptions features of the rock are recorded and interpreted with their field, petrological and chemical analyses results. Spectral curves of the Komatiite samples showed the absorption features which are depends mainly the major mineral constituents and elements concentrations. The features are unique and recommended to use to map Komatiite. The study clearly demonstrated the spectral absorption features are characterized by the optical and physicochemical characters of the rock. The study on the spectral absorption characters of the Komatiites allows the user to choose the specific spectral bands in the hyperspectral bands to map Komatiite and explore economic minerals of the rock elsewhere.

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