SYSTAMATIC MINERAL EXPLORATION STUDIES IN PARTS OF VELEGALLU SCHIST BELT, YSR DISTRICT, A.P., INDIA
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ABSTRACT
Systematic mineral exploration study involves conventional exploration techniques like identification of ore guides like stratigraphic, mineralogical, lithological, structural, geomorphological and geobotanical guides. Subsequently, establishment and characterization of spectral signatures displayed by various minerals in the study area using a geocoded satellite image will be done. In preliminary studies the image corresponding to the study area is georectified with the Survey of India Toposheet No. 57J08. In the present study, stratigraphic, mineralogical, lithological and geomorphological guides will be recognized and thematic maps were prepared by visual interpretation technique and the same is digitized by using GIS software. The thematic maps thus prepared are then compared with the ground truth. Then the spectral signatures were obtained by processing the image under material mapping and anomaly detection techniques for each mineral using USGS spectral library of ERDAS Imagine software. The spectral signatures of each mineral of USGS library obtained by the image processing are assigned to the location of the corresponding minerals in the study area by using GPS. Brecciated auriferous quartz reef associated with sulphide mineralization is identified along with wall rock alteration in the form of perceive biotization, silicification, sulphidisation and chloritisation in Velegallu Greenstone Belt. The study area shows old workings for extraction of gold and even shows pounding marks in flat rock beds around the villages in vicinity, which might have formed during process of winning gold from the host rock. The Geophysical, Geochemical data will be accumulated from other sources as done by the GSI and other organizations for the order of comparison with the present results.

Keywords: Mineral exploration, geobotanical guides, geomorphology.

1. Introduction
Velegallu schist belt of present study falls in the SOI Toposheet No. 57J/8 between latitudes 14°03′34.28″-14°02′40.81″ and longitudes 78°27′45.36″-78°27′16.00″ and located in south of Proterozoic Cuddapah basin (Figure 1). It lies on NNE of Kolar greenstone belt and form the eastern part of the Dharwar craton located in the southern part of Andhra Pradesh. It is one of the three Archaean greenstone belts i.e., Tsundupalle, Velagallu and Kadiri schist belts (GSI report 2010-12). The Velegallu schist belt is linear N-S trending belt extending from Kotakonda in the south to Bollagondicheruvu in the north where it is concealed by the rocks of the Cuddapah basin. It is dominated by greenstone, tonalite, granite gneisses ranging in age from 2.7 to 2.6 Ga (Swaminath and Ramakrishnan, 1981; Naqui and Rogers, 1987). Geophysical studies indicate the occurrence of pyrite and chalcopyrite, gold and silver mineralization in Banded Iron Formation (BIF) and petrological studies revealed the presence of silicification, biotitisation. The Velegallu schist belt is predominantly made up of a group of volcano-sedimentary rocks with sheared/faulted margins bounded by tonalitic-granodiorite-monzodiorite and granite-syenogranite suites of diapiric intrusions. Exploration...
studies done by GSI and other organizations identified gold anomalous zones in association with BIF, which is commonly contains visible sulphides, mostly pyrite and arsenopyrite in this belt (Plate-1 to 5). These organizations have enlisted number of zones with gold occurrences. Mallayakonda is gold bearing BIF zone with pyrite, arsenopyrite and gossan. Tsadukonda and Sivapuram are gold mineralized zones with disseminated pyrite, arsenopyrite and variegated gossan localized within BIF. In Tumukunta and Mulapalli areas reddish brown and yellowish green stains with faint sulphur smell were noticed by the GSI. In Gandimadugu area a quartz vein and metaproxenite body within quartz-muscovite-sericite schist containing Cu, Ag, and Au mineralization (GSI Special Publication by K.S.Rao 2001). Some old workings and pounding marks (Plate-6) are observed in the study area which might indicate the extraction and winning procedures of gold.

2. Stratigraphic guides

The Velligallu greenstone belt of eastern Dharwar Craton occurs within Peninsula Gneissic Complex (Joseph G.Meert et al., 2010). It is predominantly made up of a group of volcano-sedimentary rocks. The schist belt is sheared/faulted and bounded in both sides by tonalite-granodiorite-monsodiorite and granite-syenogranite suites of diapiric intrusions (GSI Report
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2010-12). The lithostratigraphic succession of Veligallu Schist belt (Srinivasan, 1992) is as follows.

**Table 1: Stratigraphic succession of Veligallu Schist Belt (Srinivasan, 1992)**

<table>
<thead>
<tr>
<th>Quartz reef/quartz vein</th>
<th>Dolerite dyke activity</th>
<th>Younger granite</th>
</tr>
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<tr>
<td>Mallayakonda formation:</td>
<td>Banded Iron formation</td>
<td></td>
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<tr>
<td>Shivapuram formation:</td>
<td>Bedded tuff, metaryholites, Veligallu Group</td>
<td></td>
</tr>
<tr>
<td>Tamballapalle Formation:</td>
<td>Metabasalt, metaultramafic bands</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Unconformity (?)</td>
<td></td>
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</tr>
</tbody>
</table>

2.1 Lithological guides

The major schist belt lithounit in the study area is quartz sericite schist with subordinate metabasalt, ultramafic rock, metabasalt rock exhibiting porphyritic nature (Plate-1). The ultramafic rocks identified in the area are talc-tremolite schist, pyroxenite and biotite schist occur as lenses. It constitutes metamorphosed basic and acid volcanic, and metasedimentary units comprising BIF (Plate-2) and quartz-muscovite-sericite±sillimanite schists. These are intruded by hornblende-biotite granodiorite/granite-migmatite/gneiss (Priyadarshi Sahoo et al., 2009). These rocks are evidently the host rocks for gold mineralization as observed in Kolar greenstone belt (T.S.Giritheran et al., 2001)

2.2 Mineralogical Guides

In greenstone belts of Dharwar craton gold mineralization is associated with green quartz (Plate-3), pyrite, arsenopirte, pyrophyllite, galena, sphalerite, chalcopire (Khan, 2001; Susmita Gupta et al., 2014). Similarly the mineralized zone in Veligallu schist belt is identified by wall rock alterations represented by retrogression of minerals and occurrence of potash in wall rock known as chloritisation and sericitisation. These zones are invariably associated with sulphide minerals like pyrite, pyrrhotite, chalcopyrite, galena and arsenopirte (Plate-4). Carbonatization is also observed. Occurrence of antimony, bismuth and tungsten is observed in the study which is also an indicative of Au mineralization (GSI report 1994).

2.3 Structural guides

In Veligallu greenstone belt the gold mineralization is evidently a shear controlled and fold closures and contacts of litho units sited adjacent to transition shear zones can be observed. The other control factors in particular are ductile/brittle (GSI report 1994). The schistose rocks trend along NW and SE and dip towards west. Schistocity related to first phase of deformation is more pronounced in all the schist belt rocks trending NNW-SSE to NW-SE with steep dips on either side. The second phase of deformation is recorded in quartz-chlorite-sericite schist trending ENE-WSW to E-W. Faults trending NE-SW are inferred Veligallu south Block (GSI report by K.Subba Rao, et al., 2010-12). The structural features observed in the study area favourably indicate the occurrence of gold.
2.4 Geomorphological guides

Papagni river forms the main drainage system which flows in N-S direction in northern part of Veligallu greenstone belt. The drainage pattern varies from sub-dendritic to trellis. The schist belt forms an undulating country rock with prominent linear ridges of BIF and quartz reef trending N-S to NNW-SSE. Tella Konda and Venkateswaruni Konda are foremost ridges in the northern part of Veligallu greenstone belt.

2.5 Geobotanical guides

Indicator plants develop capacity to grow in certain geological environments where other plants will not grow. High accumulation of a particular element in plants will act as defensive against the herbivours pathogens. Equisetum aryense and Equisetum confuse (horse tail) is an universal botanical indicator (R.R.Brooks, 1998) which is observed in the study area.

3. Methodology

The Veligallu greenstone belt host gold mineralization associated with sulphide bearing quartz vein running across the NE-SW trending shear zone. The surface indicators of gold mineralization are in the form of limonitisation, pyrite disseminations, malachite stains and silicification in quartz vein and metabasic rock (GSI report 2010-12). The following components are involved in the exploration programme.

3.1 Geophysical data

Geophysical data is obtained from the GSI report 2010-12. Based on these findings test boreholes drilled across the area. The geophysical anomaly indicate extension of sulphide mineralization at subsurface level in the SW continuity of the mineralized quartz vein.

3.2 Geochemical data

Prospecting stage Geochemical investigation report done by GSI shows feeble to moderate gold values with the weight average ranging from 0.11 g/t to 1.05 g/t has been noted.

3.3 Image processing and spectral studies

In the present study various image processing techniques like image sub-setting, histogram equalization were applied during the first stage of satellite image processing. Then the spectral analysis is done by applying Anomaly detection, Material mapping and Target detection techniques (Raghu Babu, 2012). The mineralized zones for selective minerals were identified based on their corresponding reflections while choosing from USGS spectral library. The map thus generated is then subjected to supervised classification to delineate the mineralized zones by FCC.

3.4 Anomaly detection

Anomaly detection is the process of searching an image to identify pixels that behave unusually than the surrounding pixels (Figure 2, 6, 10, 14, 18 and 22). For anomaly detection studies it is important to know the signatures of the material of interest or the
signatures of the surrounding environment. When the Anomaly detection process is complete the spectral analysis work station displays anomaly mask on top of the input image, with several small white areas. These white patches in black background in spectral analysis workstation represent anomaly of mineral of interest viz., Figure 2 – Galena, Figure6 – Hematite, Figure 10 – Magnetite, Figure14 – Pyrite, Figure18, Sulphur and Figure22 – Quartz.

3.5 Material Mapping

Material mapping is the process of searching an input image for the presence of a specific material based on an input spectrum (Figure 3, 7, 11, 15, 19 and 23). The material mapping process attempts to increase the responses of a selected mineral spectrum and suppresses the responses of the unknown materials. In the present the mineral signatures identified were shown in Figure 3 – Galena, Figure 7 – Hematite, Figure 11 – Magnetite, Figure 15 – Pyrite, Figure 19, Sulphur and Figure23 – Quartz respectively.

3.6 Target Detection

Target detection is the process of searching an input image for a specific material which is supposed to be present in very low concentrations in the study area (Figure 4, 8, 12, 16, 20 and 24). By comparing the results obtained for a mineral of interest should be compared with the true reflectance values of that mineral, the occurrence of that mineral should be confirmed and they were shown in Figure 4 – Galena, Figure8 – Hematite, Figure12 – Magnetite, Figure 16 – Pyrite, Figure20, Sulphur and Figure24 – Quartz.

4. Results and discussion

The Veligallu greestone belt fall in the southern portion of the SOI Toposheet No. 57j08 and the satellite image as well. Stratigraphically the Veligallu greenstone belt of Eastern Dharwar craton belongs to Peninsular Gneissic Complex. The study area composed of talc-tremolite schist, pyroxenite and biotite schist, metamorphosed basic and acidic volcanic, metasedimentary units with BIF and quartz-muscovite-sericite-sillimanite schists. The gold mineralized zone is shear controlled, first phase and second phase deformations are well noticed in schistose rocks. Geobotanical guides like Equisetum aryense and Equisetum confuse (horse tail tree) were evidently noticed in the study area. The satellite image of the study area is geo-referenced with the Toposheet 57j08 and the schist belt area subset is prepared. The Histogram equalization of the subset image is done in order to get equal distribution of the pixels throughout the image. The image subset is then subjected to Anomaly detection, Material mapping and Target detection spectral studies. The resultant images thus produced in each spectral study will give the anomalous reflection zones of minerals of interest. Spectral reflection curves are obtained from these zones were shown in Figure 5 – Galena, Figure 9 – Hematite, Fig,13 – Magnetite, Figure17 – Pyrite, Figure 21 – Sulphur, Figure 25 – Quartz and their characters were studied and attributed to their corresponding target minerals and standards for these minerals are generated. Spectral reflection curves generated based on the EMR reflections corresponding wave lengths of target minerals were given in Table -2. Later Supervised classification is applied to delineate the mineralized zones identified by performing the spectral analysis and maps have been prepared.
Table 2: Spectral Signatures recorded in the study area

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the Mineral</th>
<th>Wavelength µm</th>
<th>Reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Galena</td>
<td>0.5-1.3</td>
<td>0.77-0.90</td>
</tr>
<tr>
<td></td>
<td>Sample – 1</td>
<td>0.7-1.5</td>
<td>0.87-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Hematite</td>
<td>0.56-0.68</td>
<td>0.86-0.95</td>
</tr>
<tr>
<td></td>
<td>Sample – 1</td>
<td>0.57-0.70</td>
<td>0.90-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Magnetite</td>
<td>0.56-0.69</td>
<td>0.88-0.98</td>
</tr>
<tr>
<td></td>
<td>Sample – 1</td>
<td>0.57-0.70</td>
<td>0.91-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Pyrite</td>
<td>0.54-0.68</td>
<td>0.90-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 1</td>
<td>0.55-0.70</td>
<td>0.92-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Sulphides</td>
<td>0.55-0.70</td>
<td>0.92-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 1</td>
<td>0.56-0.70</td>
<td>0.93-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Quartz</td>
<td>0.54-0.70</td>
<td>0.91-1.00</td>
</tr>
<tr>
<td></td>
<td>Sample – 1</td>
<td>0.55-0.70</td>
<td>0.92-1.00</td>
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<td></td>
<td>Sample – 2</td>
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</tbody>
</table>

5. Conclusions

The Veligallu greenstone belt is an Archaean greenstone belt on the southern side of the Mesoproterozoic-Neoproterozoic Cuddapah basin. Regional mapping done by Geological Survey of India identified gold and polymetallic sulphide mineralization associated with several shear zones in Banded Iron Formation (BIF). The results of these studies reveal gold bearing zone with pyrite arsenopyrite and gossan localized within BIF. Old workings for gold extraction are also found here. A quartz vein and metapyroxenite body within quartz-muscovite-sericite schist containing copper, silver, gold mineralization is identified (K.S.Rao, 2001). Based on the above results present work has been taken up to perform spectral studies in satellite image to identified spectral signatures, to study their characteristics and assign standard spectral signatures to specific minerals of interest in the study area. The subset image of the present study area is analysed in various spectral analysis studies like Anomaly detection, Material mapping and Target detection and corresponding mineralized zone maps are prepared.

Plate 1: Banded Iron Formation with surface gossan
Plate 2: Dry river valley below dam view to north mafic volcanic (grey) to west

Plate 3: Minor copper staining

Plate 4: Ancient pounding marks presumably were ore was crushed to win gold
Plate 5: Green quartz in altered mafic host

Plate 6: Equisetum arvense indicator plant for gold

Figure 2: Satellite image subset of Veligallu Schist belt anomaly detection (Galena)

Figure 3: Satellite image subset of Veligallu Schist belt material mapping (Galena)
Figure 4: Spectral reflectance of Gelena in Veligallu Schist belt

Figure 5: Satellite image subset of Veligallu Schist belt area of target detection (Hematite)

Figure 6: Satellite image subset of Veligallu Schist belt area of Anomaly detection (Hematite)

Figure 7: Satellite image subset of Veligallu Schist belt material mapping (Hematite)
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Figure 8: Satellite image subset of Veligallu Schist belt area of target detection (Hematite)

Figure 9: Spectral reflectance of Hematite in Veligallu Schist belt

Figure 10: Satellite image subset of Veligallu Schist belt area of Anomaly detection (Magnatite)

Figure 11: Satellite image subset of Veligallu Schist belt material mapping (Magnatite)
**Figure 12:** Satellite image subset of Veligallu Schist belt area of target detection (Magnatite)

**Figure 13:** Spectral reflectance of Magnetite in Veligallu Schist belt

**Figure 14:** Satellite image subset of Veligallu Schist belt area of Anomaly detection (Pyrite)

**Figure 15:** Satellite image subset of Veligallu Schist belt material mapping (Pyrite)
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Figure 16: Satellite image subset of Veligallu Schist belt area of target detection (Pyrite)

Figure 17: Spectral reflectance of Pyrite in Veligallu Schist belt

Figure 18: Satellite image subset of Veligallu Schist belt area of Anomaly detection (Sulphur)

Figure 19: Satellite image subset of Veligallu Schist belt material mapping (Sulphur)
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Figure 20: Satellite image subset of Veligallu Schist belt area of target detection (Pyrite)

Figure 21: Spectral reflectance of Sulphur in Veligallu Schist belt

Figure 22: Satellite image subset of Veligallu Schist belt area of Anomaly detection (Quartz)

Figure 23: Satellite image subset of Veligallu Schist belt material mapping (Quartz)
These maps show reflections of various wave lengths emitted by minerals of interest in the form of spectral curves. Galena, at wavelengths between 0.5-1.5 µm showing minimum reflections of 0.77 and maximum of 1.00. Hematite showing significant reflections between 0.86-1.00 for wavelengths of 0.56-0.70 µm, whereas Magnetite showing reflections of 0.88-1.00 for wavelengths 0.56-0.70 µm. Pyrite showing reflections between 0.90-1.00 at wavelengths of 0.54-0.70 µm. Sulphides showing reflections at 0.92-1.0 for wavelengths of 0.55-0.70 µm. The spectral signature curves shown by Quartz are between 0.91-1.00 of wavelengths 0.54-0.70 µm.

6. References


