Chapter 9

Conclusions and Contribution

9.1 INTRODUCTION

The present study was carried out in the GSB of the state of Karnataka, to delineate the altered minerals and alteration zones through multispectral and hyperspectral remote sensing techniques for mineral exploration. This chapter also highlights the major outcomes and contributions of this research work. The findings of each of the objectives and major outcomes of this research work are summarized below.

9.1.1 IDENTIFICATION OF ALTERATION ZONES USING MULTISPECTRAL IMAGERY

LANDSAT ETM+ data were processed to delineate the altered minerals and alteration zones in the study area. Various image processing techniques such as FCC of band combinations 7-4-1 and band 7-5-1 (in RGB); band ratios techniques viz., 5/7, 3/1, 3/5 and 5/4 were applied to ETM+ data for the delineation of clay, iron oxide and ferric mineral distribution. Band ratio map of (5/7) shows the distribution of clay minerals, which mainly occurs over the GSB and in patches towards northern and southern part of the image. Iron oxide alteration map (3/1) and ferrous mineral map (5/4) shows the distribution of iron in the area (Figure 3.2, 3.3 & 3.4). Band ratios: (5/7)–(4/3) and (4/5)–(4/3) were used to delineate alteration zones. Band ratio (4/5)–(4/3) shows the distribution of hydroxyl minerals and to reduce the effect of vegetation subtraction of band ratio (4/3) was carried out. Mineral composite / FCC images indicate the combined distribution of iron and hydrothermal altered minerals in the study area. Similarly, the PCA and Crosta techniques were also applied to the ETM+ image to identify H and F-band for hydroxyl and iron minerals, based on their statistical analysis of PC image. The H and F bands were used to generate H+F bands for further analysis. The H, F and H+F bands were used to generate Crosta image to delineate the alteration zones in the area. Alteration zones were delineated in white, light blue and blue colour from the Crosta image of the study area (Figure 3.9).
9.1.2 MAPPING OF ALTERED MINERALS AND ALTERATION ZONES USING HYPERSPECTRAL IMAGERY

Hyperspectral remote sensing techniques were applied to delineate the altered minerals as well as alteration zones in the study area. Hyperion data was processed to identify endmembers which are extremely pure pixels. Three classification techniques viz. SAM, SFF and BE were applied to decipher the mineralogical composition of endmembers generated from Hyperion image. Total 11 altered minerals and one soil were identified in the study area and these altered minerals are: goethite, hematite, smectite, chlorite, calcite, antigorite, nontronite, kaolinite, muscovite, prochlorite, microcline and greyish brown loam. These identified altered minerals were supplied as input for the SAM classification of Hyperion data to delineate the spatial distribution of each altered mineral in the study area. The result of the SAM classified image was also analysed and it showed the maximum spatial distribution of nontronite (6.6 %) which is followed by microcline (5.3 %), antigorite (5.1 %), muscovite (5.0 %), chlorite (4.2 %) and kaolinite (3.7 %). Goethite, hematite, smectite, calcite and prochlorite shows their distribution between 0.17 and 1.5 %. Greyish brown loam covers 8.87 % part of the area (Figure 4.9).

The alteration zones identified from the processing of ETM+ data were also compared with the results of Hyperion image and it was found that the zones delineated from both data show similarity. Hyperion image is able to decipher the mineral composition, whereas ETM+ is unable to do so.

9.1.3 DELINEATION OF ALTERATION ZONES IDENTIFIED FROM MULTISPECTRAL, HYPERSPECTRAL DATA OVER GEOLOGY FOR SAMPLE COLLECTION

The identified alteration zones and altered minerals from different processing techniques, applied over ETM+ and Hyperion data was integrated in a GIS platform with the geology and topography of the study area to delineate the alteration zones for sampling. Field verification was carried out in order to validate the results of the ETM+ and Hyperion data. During the field checks, it was observed that the area is mainly occupied by the argillite of variegated nature and metabasaltic rocks. Oxidation in argillite is frequent and due to the effect of oxidation, argillite shows
orange to yellow colour in the area. Sericitization and kaolinization processes were also recorded in the field (Figure 5.4a-f, g-l, m-o). The alteration zones delineated from ETM+ and Hyperion images were verified and the altered minerals delineated from the Hyperion image showed good match with field data. 20 samples of representative rocks were collected from alteration zones of the schist belt for the spectroscopic, petrographic study and the generation of spectral library.

9.1.4 COLLECTION OF SPECTRAL SIGNATURE OF SAMPLES USING SPECTRORADIOMETER FOR SPECTROSCOPIC STUDY

Further, the ASD Spectroradiometer instrument was used for the generation of spectral signature of different rocks and soil sample collected from the field on the basis of textural, compositional and colour variations. The Spectroradiometer covers same wavelength range as Hyperion image. The spectral signatures of 20 samples were generated. There are two processes (electronic and vibrational) which are responsible for the absorption of light in a mineral and this absorption playing an important role for identification of mineral composition. The spectral signature of 20 samples were processed and compared with each other. Based on the similarity in the absorption features which were caused due to electronic and vibrational processes in the minerals, they were grouped into 12 different groups. The mineral composition of these 12 spectral signatures was delineated through SAM, SFF and BE classification techniques. The identified minerals and soils are: clinochlore, margarite, anorthite, montmorillonite, chlorite, kaolinite, hematite, hornblende, muscovite, dolomite, lepidocrosite/goethite and greyish brown loam (Figure 6.3a, b; 6.4a, b; 6.5a, b; 6.6a, b; 6.7a, b; 6.8a, b).

9.1.5 ANALYSIS OF SPECTRAL SIGNATURE OF ALTERED MINERALS, PETROGRAPHIC STUDY AND BUILDING UP SPECTRAL LIBRARY

Detailed analysis of each spectral signature of mineral and soil were carried out along with petrographic study of selected samples to validate the results of remote sensing study. During analysis of spectral signature it was found that the spectroscopic study of the samples collected from the field gave much better and accurate information regarding the mineral composition of the samples compared to
conventional methods like petrographic study, especially in the case of highly altered and fine grained minerals. The petrographic study could not provide exact mineralogy of the samples, whereas hyperspectral study gives more accurate information on mineral composition.

During field visits, it was observed that there are effects of oxidation on the rock surface and due to those effects, the rock surface became red or orangish red and oxide minerals were developed. To identify the oxide minerals in a sample, normally ore petrography study is performed. But in the spectroscopic study, the effect of oxidation is well reflected and minerals were easily delineated. Carbonate veinations and replacement of primary minerals by secondary carbonate is also frequent in the area. This was reflected very well in the spectral signatures. Other than obtaining information on mineralogy, the compositions of the soils were also accurately derived. Petrographic study of hornblende collected from an alteration zone shows that this rock hosts gold mineralization (Figure 7.5a, b, c). Gold mineralization is reported by earlier researchers, hosted by BIF, metabasalt and meta-volcanic rocks near the study area.

Based on the above study and certain mineral occurrences, following alteration zones were delineated in the area: propylitic (chlorite, clinochlore), phyllic (muscovite), argillic (montmorillonite), advanced argillic (kaolinite), dolomitization (dolomite) and oxidation (goethite, hematite).

9.1.6 RE-CLASSIFICATION SPATIAL DISTRIBUTION OF ALTERED MINERALS

The spectral signatures of the above mentioned 12 altered minerals were used for the re-classification of the Hyperion image in order to delineate their spatial distribution in the area. The spatial distribution of each altered mineral was calculated in terms of percentage. The results show the maximum spatial distribution of montmorillonite (8.9 %) which is followed by hematite (3.2 %). Other minerals such as kaolinite, muscovite, dolomite, anorthite and hornblende show spatial distribution of < 1 %. Few altered minerals could not be delineated in the Hyperion image after re-classification and the reason is probably their small areal extent which is less than 30 m x 30 m. The greyish brown loam shows 32.85 % distribution in the area (Figure
8.1, table 8.1). The major part of the study area, especially the northern and southern part of the schist belt is occupied by black cotton soil.

Results of SAM classification of Hyperion image performed before and after field validation were also compared and it shows that out of 12 minerals (minerals and soil) 7 are well matched and these are: goethite, hematite, chlorite, kaolinite, muscovite, calcite/dolomite and greyish brown loam.

The spectral library for all the 12 altered minerals incorporating petrographic details were generated which can be used for the delineation of similar kind of altered minerals in other parts of the country.

The result of Hyperion data processing gives detailed information on the altered minerals and alteration zones whereas the multispectral data only provide broad information about altered zones. Therefore, Hyperspectral remote sensing technique helps to locate those alteration zones that can be associated with certain mineralization of significance with better accuracy and in a time saving manner.

9.1.7 A NOTE ON THE IMPLICATIONS OF THE PRESENT STUDY TO DISASTER MANAGEMENT AND MITIGATION

It is noteworthy that the thesis presents a detailed account of geology, tectonics and the mineral wealth of the Gadag Schist Belt of Western Dharwar Craton, Karnataka. The study builds on the limitations of the conventional methods of geological, geophysical and geochemical exploration and exploitation and looks beyond into the application of field based and remotely sensed information through their meaningful integration in the GIS platform. Through this study, we could clearly identify altered minerals in the area and their spatial distribution. Most of these minerals are indicators of alteration zones, which can further be used as indicators of economically important mineral deposits. However, the altered (mostly clay) minerals have certain properties that are important in terms of absorption and movement of water. They can easily act as barriers to flowing water due to their low porosity and permeability. The clays have a tendency to absorb water and swell and later shrink as they lose water, thereby exerting enormous pressure (force) on rocks causing them to fracture. Regular shrinking and swelling of clays in this semi arid terrain can easily dislodge large boulders and also facilitate rock movements that can pose serious threat to life and property. While wet, these clays can exert an outward buoyant force propelling rock to fall.
Most importantly the altered minerals, which cover most of the surface area can become wet in case of rains. They swell, coagulate and can easily form a thin layer on the surface. Again due to their low porosity and permeability they would not allow any percolation of water. In case of heavy rain, this can eventually lead to flooding and non-replenishment of underground water causing a serious situation. Prior knowledge of their spatial distribution can help in proper planning and development so as to better manage and mitigate any unforeseen disaster. In such a situation hyperspectral remote sensing is a powerful tool to identify and delineate the spatial distribution of those clay minerals responsible for the rock movement or landslides.

9.2 MAJOR CONTRIBUTIONS OF THIS RESEARCH

- Hyperspectral data are explored and altered minerals were demarcated in the study area. Based on the occurrences of certain specific minerals, following alteration zones were identified: propylitic, phyllic, argillic, advanced argillic, dolomitization and oxidation.

- Delineated alteration zones can be extended to the unknown/virgin mineral provinces.

- An inventory record of spectral signature of 11 altered minerals and one soil were created which can be useful in other parts of the country for the delineation of similar kind of minerals.

- Potential and limitations of multispectral and hyperspectral imageries were compared and results indicate that, alteration zones can be delineated from multispectral data only, whereas hyperspectral data is capable of precise identification of the composition of altered minerals as well as alteration zones for mineral exploration.

- Identification of specific spectral channel for discriminating various mineralized zones.
Upgradation of existing geological maps based on hyperspectral data.

Hyperspectral remote sensing study can be very useful to prevent the natural hazards such as landslide because of its capability to delineate the clay minerals accurately.