CHAPTER 1

INTRODUCTION

1.1 GENERAL

This thesis presents the observation, results and inference of certain field, laboratory and remote sensing based experiments carried out to look assess grades of magnesite and list two important industrial minerals, whose demand is growing by the hour.

The mineral deposits of economic value are neither distributed uniformly all over the surface of the globe nor were they formed all through the geological history of the earth. On the contrary, they are concentrated only in certain parts of some of the continents and were produced occasionally during a few distinct and well-defined periods of mineralization. Exploring these concentrated pockets is becoming increasingly difficult, especially in obtaining ground access to remote areas.

1.2 STATEMENT OF PROBLEM

Good quality of magnesite is a product always in demand this industrial is found to occur in dunites as a product of hydrothermal alteration parent rock namely dunite.

Conventional field mapping of the distribution of fresh and highly altered dunite is time consuming and requires detailed sampling and laboratory analysis. Remote sensing has the potential to provide detailed
information on mineralogy, chemistry and morphology of rock formations and minerals. This information is useful for mapping host rocks, alteration products and the characteristics of the minerals.

Figure 1.1 Reflectance curves of some common rock forming minerals
- Note the typical absorption spectra of limestone and alumina. Source: Gaffey S.J (1984)

In remote sensing studies, we rely on the spectral response of objects to recognize and map them. The unique spectral characteristic of Carbonate (limestone), Alumina(Clay) (figure 1.1) and the existence of dedicated remote sensing sensors such as ASTER, Yamaguhi (1998) and Hyperion (USGS) to map these minerals have encouraged me to use remote sensing as a mineral exploration tool.

A recent advance in remote sensing has led the way for the development of hyperspectral sensors. Hyperspectral imagery has proved successful in mapping of hydrothermal alteration minerals particularly since early 1980’s and it has represented a mature and established technology
Abundant information about many important earth-surface minerals is found within the spectral range of 0.4-2.5\(\mu\)m. In particular, the 2.0-2.5\(\mu\)m shortwave infrared (SWIR) spectral range covers spectral features of hydroxyl-bearing minerals, carbonates and sulphates, common to many geologic units and hydrothermal alteration assemblages (Goetz et al 1985).

For the past decades remote sensing has only been attempted in the multispectral mode (4-10 bands) for all applications including mineral exploration. However, it is a widely known fact that each mineral has its own spectral signature at given narrow wavelength bands. Such unique signature can be used for differentiating various minerals present in a remotely sensed image scene. It is also been well established that VNIR, SWIR, TIR expand wavelength region provide significant complementary data for geologic applications. It has been difficult to precisely identify most of the minerals using the currently available images data such as those from IRS LISS 3, TM and ETM due to their multispectral (broadband) characterization. In south India, especially in Tamil Nadu, many deposits of magnesite, crystalline and ferruginous limestone and base metals have been reported. The possibilities of new/additional deposits occurring adjacent areas or unexplored regions cannot be ruled out. The Salem region has been mapped and several mineralized zones have been demarcated and exploited. However, newer mineralized regions cannot be ruled out. Hence, there is strong need to look for these regions especially using hyperspectral remote sensing.

### 1.3 Remote Sensing as a Tool for Mineral Exploration

When light interacts with a mineral or rock, certain wavelengths are preferentially absorbed while at other wavelengths light is transmitted in the substance. Reflectance, defined as the ratio of the intensity of light reflected from a sample to the intensity of the light incident on it, measured by
reflection spectroradiometers which are composed of a light source and a prism to separate light into different wavelengths. The separated light beams interact with the sample and the intensity of reflected light of various wavelengths is measured by a detector relative to a reference standard of known reflectance. Thus, a continuous reflectance spectrum of the sample is obtained.

Reflectance spectra have been used for many years to obtain compositional information of the Earth’s surface. Similarly, it has been shown that spectral reflectance is visible and near-infrared offers a rapid and inexpensive technique for determining the mineralogy of samples and obtaining information on chemical composition. Electronic transition and charge transfer processes (e.g. changes in energy states of electrons bound to atoms or molecules) associated with ions of transitions metals such as Fe, Ti and Cr, largely determine the position of diagnostic absorption features in the spectra of minerals (Burns 1970, Adams 1974, 1975). In addition, vibrational processes in H₂O and OH⁻ (e.g. small displacements of the atoms about their resting positions) produce fundamental overtone absorptions (Hunt 1977, Hunt & Salisbury 1970). Electronic transitions produce broad absorption features that require higher energy levels than do vibrational processes, and therefore take place at shorter wavelengths (Hunt 1977, Goetz 1991). The position, shape, depth, width and asymmetry of these absorption features are controlled by the particular crystal structure and chemical composition of the absorbing mineral. Thus, variables characterizing absorption features can be directly related to the mineralogy of the sample.

Hydrothermal alteration is a complex process involving chemical replacement of original minerals in the rock by new minerals where a hydrothermal fluid delivers the chemical reactants and remove the aqueous reaction products (Reed, 1997). An understanding of hydrothermal alteration
is of great value because it provides insight into origin of ore fluids as well as chemical and physical attributes of ore formation.

The development of more sophisticated spectroscopy technology has created a possibility to characterize spectral features of minerals not only in the visible and shortwave infrared (SWIR). A typical example of hydrothermal altered area is found in Salem District, South India.

1.4 HYPERSPECTRAL REMOTE SENSING

Hyperspectral remote sensing, also known as imaging spectroscopy, is a relatively new technology that is currently being investigated by researchers and scientists with regard to the detection and identification of minerals, terrestrial vegetation, and man-made.

Hyperspectral imagers typically collect data in contiguous narrow bands (up to several hundred bands) in the electromagnetic spectrum. They produce vast quantities of data because of the number of bands simultaneously imaged. Hyperspectral data provide capabilities to discern physical and chemical properties of Earth surface features not possible using current broad-band multi-spectral satellites. High spectral resolution allows identification of materials in the scene, while high spatial resolution locates those materials (Gross and Schott, 1998).

Products derived from hyperspectral data include categorized images of different lithologies and maps detailing the distribution of specific minerals and their abundances. These maps provide geologists with an additional tool to decipher the overall lithologic and structural history of a region, and help to define potential exploration targets.
The minerals which have been successfully identified to date with imaging spectroscopy can be grouped as follows: OH⁻ bearing minerals, carbonates, sulfates, olivines, pyroxenes, iron oxides and hydroxides. The identification of minerals and the mapping of their distribution provide the necessary underpinnings for exploration purposes (precious and base metals, diamonds, etc.) and lithological (rock) mapping.

Hyperspectral products are relatively mature in arid (non-vegetated) environments. Basic research is still required to bring the product to maturity in vegetated terrains. Currently, mining companies are focusing mainly on sparsely vegetated regions, although research in vegetated sites is beginning.

Reflectance spectra of minerals measured by different spectroradiometers with different spectral libraries that are available in digital format (e.g. Grove et al. 1992, Clark et al. 1990a). Similar spectral libraries are available for vegetation (e.g. Elvidge 1990) and soils (e.g. Baumgardner et al. 1985, Condit 1970).

In the 1980s, mineral exploration was among the first operational applications of earth observation data in general, and the mineral industry is now a knowledgeable user.

Remote sensing of the surface of the Earth from aircraft and from spacecraft provides information not easily acquired by surface observations. Until recently, the main limitations of remote sensing were that no subsurface information could be obtained and that surface information lacked detail due to the broad bandwidth of scanners available. It has been shown that orbital imaging radar can provide subsurface data in arid regions (McCauley et al 1982), and work on high-spectral resolution radiometry has shown that earth surface mineralogy can be identified using spectral information from scanner
data (Goetz et al 1982). Conventional sensors (e.g. LANDSAT MSS and TM and SPOT) acquire information in a few separate spectral bands of various widths (typically in the order of 100 to 200 nm), thus smoothing to a large extent.

1.5 HYPERSPECTRAL SENSING AS A TOOL FOR MINERAL EXPLORATION

Hyperspectral spaceborne imaging spectrometers have been developed to measure the solar reflected upwelling radiance spectrum from 400 to 2500 nm resolution. The objectives of these imaging spectrometers are to use the molecular absorptions and constituent scattering characteristics expressed in the spectrum (Pantazis et al., 1998) to detect and identify the surface and atmospheric constituents present, assess and measure the expressed constituent concentrations, assign proportions to constituents in mixed spatial elements, delineate spatial distribution of the constituents, monitor changes in constituents through periodic data acquisitions and to validate, constrain and improve models.

Products derived from hyperspectral data include categorized images of bedrock distribution with geological labels, and maps detailing the distribution of specific minerals and their abundances. These maps provide geologists with an additional tool to decipher the overall lithologic and structural history of a region, and help to define potential exploration targets.

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1.6 HYPERSPECTRAL RADIOMETRY

Field spectroscopy is a technique of fundamental importance in remote sensing that deals with interactions between energy and objects in the natural environment. Studies of the reflectance properties of natural objects – such as minerals, rocks, water bodies, leaves and canopies – at higher spectral resolution permit a more detailed analysis of spectral features too narrow to be discriminated by coarse spectral resolution instruments.

In addition, they permit the application of more suitable interpretive techniques such as derivative analysis, a method that is receiving increasing attention in the field of remote sensing (e.g. Horler et al 1983, Card et al 1988, Penuelas et al 1993, Dungan et al 1996, Han and Rundquist 1997).

The field spec data are used as one of the inputs to correct the hyperspectral image for conditions in the atmosphere that intercept incoming solar radiation, thereby affecting the intensity or frequency of reflected energy signals. It is ideal to collect those data on the date of the collection of the image. Spectral measurements of surface reflectance of geological samples, an analytical spectral device.

The studies demonstrate that reflectance spectra generated by field spectroscopy can be used: (i) to select the appropriate regions of the electromagnetic spectrum for a given application of remote sensing, and (ii)
to determine the spectral parameters for assessing the properties of various cover types. With this background, the present study at the Salem magnesite, crystalline & ferruginous limestone area has been attempted.

1.7 EXPLORATION OF MAGNESITE, CRYSTALLINE & FERRUGINOUS LIMESTONE

This thesis is an attempt to determine quality of Magnesite, crystalline & ferruginous Limestone in Salem, Sankari and Ariyalur area Tamilnadu, respectively, using Remote Sensing techniques and geochemical analysis. This study focuses on the use of Hyperspectral remote Sensing techniques and geochemical analysis for the determination of grades of Magnesite, Crystalline & ferruginous limestone.

1.7.1 Magnesite

Magnesite, MgCO3 is a white solid that occurs in nature as a mineral. Several hydrated and base forms of magnesium carbonate also exist as minerals.

- Usually in dull white, sometimes spherical, microcrystalline masses developed in weathering. Small prismatic needles on serpentine; also in large transparent Iceland spar-type crystals and cleavages. Also coarsely granular, like a marble.

- Usually results from a hot-water (hydrothermal) alteration of serpentine, which creates solid white veins in the parent rock.

- Good crystals (mostly hexagonal, rhombohedra-terminated brownish prisms) have been found associated with strontianite and dolomite at Oberndorf, in Styria, Austria, in a magnesite quarry. Gabbs, Nevada, is the most commercial deposit in the U.S.A.
1.7.1.1 Uses

- Magnesite is also used in fertilizers and by food processing industry.

- Raw magnesite is dead-burnt for making basic refractory bricks, basic refractory mortars, ramming mass, tar/pitch impregnated magnesite magnesia-carbon bricks, slide-gate plates and other refractory.

- Caustic calcined magnesite is used for manufacturing sorel cement (magnesium oxide chloride), castable refractory and extraction of magnesium metal.

- It is also the source material for manufacture of magnesium compounds like magnesium sulphate (Epsom salt) and other salts used in paper and pharmaceutical industries

1.7.1.2 Future demand of magnesite

The apparent demand of magnesite is estimated to be 745000 tonnes by 2011-2012 as shown in figure 1.2. However, the production is estimated to be 659000 tonnes for the same year. There is gap in demand and domestic supply forecast which is expected to be met by important future. Presently also due to cheap imports domestic resources are not exploited optimally. There is need to explore and exploit magnesite for future demand.
1.7.2 Crystalline limestone

Limestone is usually described as rock made from calcium carbonate (CaCO₃), but in fact most limestone rock contains significant amounts of magnesium, silicates, manganese, iron, titanium, aluminium, sodium, potassium, sulphur (as sulphides or sulphates) and phosphorus.

1.7.2.1 Uses

Limestone is used for many industries, widely as construction material, mortar and cement, fertilizer, and flux for smelting of iron ores (Dietrich and Skinner, 1979; Hamilton et al, 1995).

1.7.2.2 Future demand of limestone

India has huge resources of limestone distributed over different parts of the country. The total limestone requirement in the XI th plan was estimated with the growth scenario of cement at 9% (2322.81 million tonnes), 10% (2376 m tonnes) for the GDP growth of 7%, 8% and 9 % respectively. (Figure 1.3).
1.7.3 Ferruginous limestone

It is one of the varieties of limestone it is composed of mainly ferruginous material present in the limestone. Ferruginous limestone, while the high grade deposits are directly utilised for the manufacturing of cement and lime, the other varieties are blended with the high grade deposits and made useable.

1.8 AIM & OBJECTIVES

- To assess the potential of the hyperspectral image data in the VNIR and SWIR regions of the EMR for limestone exploration and for locating Hydrothermally altered regions in the Salem region, South India.

- To study the hyperspectral characters of crystalline and ferruginous limestones.

- To identify the quality of limestone deposits from the hyperspectral signatures.
To identify alteration mineralogy from Dunite to Magnesite through hyperspectral radiometry.

1.9 OUTLINE OF THE THESIS

The thesis consists of nine chapters.

Chapter one emphasizes the statement of problem, the overall and specific objectives.

In chapter two, a review of the available literature including the theoretical aspect of topics crucial for this study will be assessed.

Chapter three will deal with information on geology and other information about the study area.

Chapter four concentrates on the methodology and instruments used in the study.

Chapter five with the hyperspectral studies of Magnesite and geochemical analysis of rocks were collected from the study area.

Chapter six deals focus on the hyperspectral studies of crystalline limestone geochemical analysis of rocks and minerals that were collected from the study area.

Chapter seven deals with ferruginous limestone geochemical analysis of rocks and minerals that were collected from the study area.

Chapter eight deals with results and discussions from the study.

The final chapter gives overall summary, conclusions on the results of the study, recommendations and limitations of the study.
1.10 CONCLUSION

Analysis of data related to availability, demand and consumption of magnesite and limestone clearly indicates that the resources of magnesite and limestone are depleting while there is an increasing demand for the same in India and across the globe.

A study of the geological set up and nature of mineralization indicates that the host rocks associated with magnesite and limestone in certain parts of Tamilnadu (Salem and Ariyalur districts) indicates the probability of occurrence of new/additional deposits of magnesite and limestone. Given the large extent of host rocks, it would become extremely difficult to map, identify and explore new/additional deposits of magnesite and limestone using conventional approaches of mineral mapping and exploration. Hence, it is opined that remote sensing could be ideal tool to identify and map zones of magnesite and limestone mineralization.

Further, given the characteristic spectral responses of magnesite, crystalline limestone and sedimentary limestone, hyperspectral remote sensing can be best suited tool for improved exploration of these mineralized zones.

The following chapters provide details of hyperspectral sensing approaches and the results of experiments carried out in Salem District, Tamil Nadu State, South India for Magnesite and limestone.