URANIFEROUS CALCRETE MAPPING USING HYPERSPECTRAL REMOTE SENSING

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ABSTRACT

Calcrete, the calcium carbonate duricrust generally occurs in arid/ semiarid region. Globally, it has been used as a non-traditional constructional material. The recent discovery of calcrete hosted secondary uranium deposits in Australia and Namibia has kindled interest in exploration of calcretes in many parts of the world. In this study, palaeochannel related calcretes of the Thar desert, India is explored as a possible source for uranium mineralization. The adopted exploration strategy includes mapping of calcretes using hyperspectral satellite data, in-situ radiometric survey, analyses of field collected samples for mineralogy and geochemistry. Calcretes along palaeochannels were mapped using Hyperion data, field spectra and Spectral Angle Mapper (SAM) technique. It was found that the adopted technique could also differentiate high-, and low-Mg calcretes with 72% accuracy. Mineralogy of calcrete includes calcite (40-60%), quartz (30-45%) and feldspar (10-15%) with minor amount of clay minerals (montmorillonite, kaolinite, illite, goethite). In in-situ radiometric survey, the range of uranium, thorium and potassium in the calcretes varies from 2.4-11ppm, 5-28.2ppm, and 0.8-4.2% respectively.

Index Terms— Spectral Analysis, Spectral Angle Mapper, Hyperspectral Remote Sensing, Calcrete

1. INTRODUCTION

The largest near-surface secondary Uranium (Carnotite) mineralization commonly found in calcrete and gypcrete [1]. Carnotite usually form in arid to semi-arid climate where deeply weathered, uranium-rich granites occur such as the deposits of Australia [1], Namibia and India [2]. Factors which play major role in calcrete-carnotite precipitation are source rocks, arid to semi-arid climate, geochemical transporting agents, evaporation, geochemical barriers, and suitable physical-chemical conditions for precipitation [1]. The selected area has the potential for such kind of mineralization because of the conducive conditions in terms of source rocks (Malani granites), palaeoclimate (wet Neogene period) and present day climate regime (warm-arid) conditions.

Analysis of reflectance spectra is a quick, non-destructive and inexpensive technique for estimating mineralogy, chemical composition and semi-quantitative abundances [3]. The spectral absorption position and shape are directly related to the mineralogy and chemistry of the sample [3,4] within the field of view. Due to CO_3^{2-} ion, carbonate exhibits two distinct vibrational absorption bands at 2.50µm to 2.55µm and 2.30µm to 2.35µm, with three other weaker absorption between 2.12µm to 2.16µm, 1.97µm to 2µm, and 1.85µm to 1.87µm [4].

The advent of lab/field spectroradiometer opened a new perspective in mineral exploration which has been used for up-scaling the ground knowledge to satellite scale [3]. To validate the spectroscopy results, conventional geochemical analysis techniques such as X-ray Diffraction (XRD), X-ray Fluorescence (XRF), Inductively

Coupled Plasma (ICP), and petrography are used [3,4]. Spectral signatures acquired from different platforms (laboratory, field, airborne and spaceborne) have been used in many geological applications such as mineral exploration [3,4] and lithological discrimination [3,5]. The objective of this paper is to study and use the VNIR and SWIR spectra to map the calcretes.

2. STUDY AREA

The study area is bounded by northern latitudes 27°24' to 27°54' and eastern longitudes 74°17' to 74°30' covering the north part of Nagaur (Dujar and Ladnun) and south of Churu (Taal Chhapar) district of Rajasthan, India. The Aeolian sands intermixed with silt, clay, gypsite and calcrete constitute a dominant surficial cover in this area.

3. HYPERION DATA AND PROCESSING

The Hyperion sensor on board the EO-1 satellite measures the reflected energies between 0.35 to 2.57μm wavelength range in 242 contiguous spectral bands with 30m spatial resolution [5,6]. Out of 242 bands, 158 were subjected to atmospheric correction [6] module (FLAASH- Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes) of ENVI. The parameters chosen for atmospheric correction are given in Table-1.

Parameters used in FLAASH module	
Ground Elevation	350m
Atmospheric Model	Tropical
Water Absorption Feature	1135nm
Aerosol Retrieval	2-Band (K-T)
Aerosol Model	Rural
Wavelength Recalibration	Yes
MODTRAN Multiscatter Model	DISORT
MODTRAN Resolution	1cm^{-1}

Table-1: Parameters for atmospheric correction

Since, spectral absorption feature analysis is the key of hyperspectral remote sensing; an accurate wavelength calibration is critical and most important for atmospherically corrected hyperspectral data. Shift in the wavelength can introduce significant errors in classification and target detection. In this study, O_2 (762.6nm) and CO_2 (2052.45nm) absorption positions were used for wavelength recalibration. To isolate the noises and determine the inherent data dimensionality, Minimum Noise Fraction (MNF) was applied on VNIR and SWIR bands separately.

4. LAB AND FIELD DATA MEASUREMENTS

Fieldspec®3 portable field spectroradiometer have been used to measure the reflectance spectra of samples. Standard calibration and spectral acquisition procedures were followed [3]. Due to atmospheric water vapor and gases, measured spectra contain noises which can introduce errors while image classification and abundance estimation [3,5]. In this study, the spectral noises caused by water vapor were manually removed and subsequently resampled equivalent to Hyperion wavelength range. The samples collected from the field were analysed using XRD (PANAlytical-X'Pert PRO), XRF (PANAlytical- PW2404) and spectroscopic techniques [3,5]. The overall methodology followed in this study is shown in Fig.1.
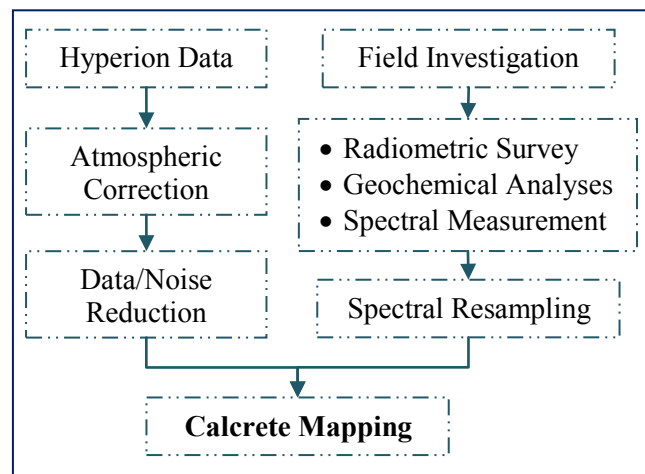

Fig.1: Adopted methodology

5. RESULTS AND DISCUSSION

It is evident from XRD analysis that Calcrete is predominantly composed of calcite (40-60%), quartz (30-45%) and feldspar (10-15%) with pyroxene and clays minerals (montmorillonite, kaolinite, illite, goethite) in minor proportions. The major oxide geochemistry of studied calcretes include CaO (52-55%), SiO_2 (10-46%), Fe_2O_3 (1-2%), MgO (0.3-3%) and Al_2O_3 (1-2%). Gamma-ray spectrometer (RS-230) is used in field for radiometric survey. The area showing anomalous values of uranium (2.4-11ppm), potassium (0.8-4.2%) and thorium (5-28.2ppm) were identified through this instrument.

Referring to United States of Geological Survey (USGS) reflectance library spectra and published literatures [4], the absorption positions of the calcrete spectra were resolved into minerals. Representative lab measured calcrete spectrum is shown in the Fig.2. Carbonates have very strong vibrational absorption bands in thermal infrared wavelength region whereas, combination and overtone bands occurs in SWIR. Compare to other combination and overtone bands, 2.50-2.55μm and 2.30-2.35μm are prominent. Apart from these, weak absorption feature are seen between 2.12μm to 2.16μm, 1.97μm to 2μm, and 1.85μm to 1.87μm [4].
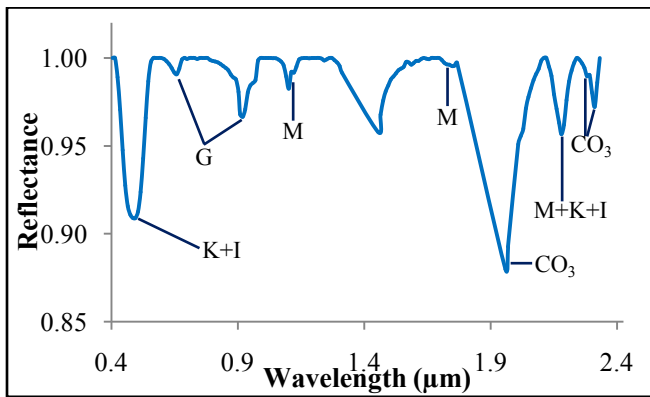
▪ M-Montmorillonite; K-Kaolinite; I-Illite; G-Goethite

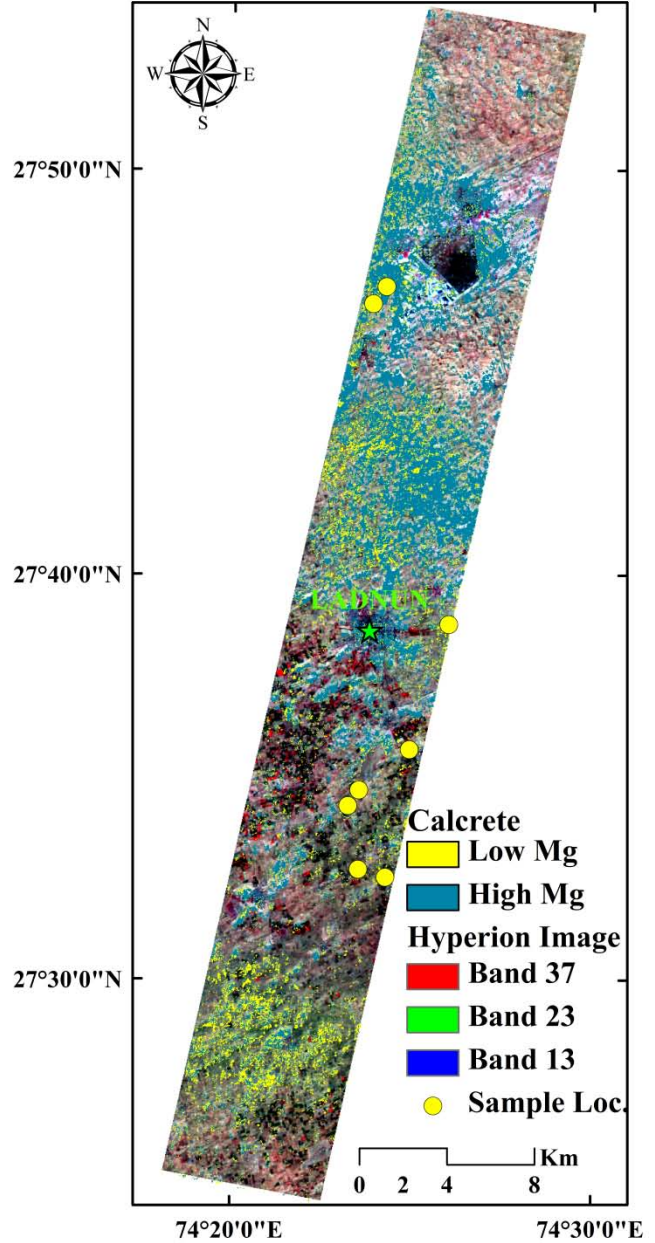**Fig.2: Continuum removed calcrete lab-spectrum**

Fig.3: Classified Hyperion image

In the ground/satellite measured spectra these weak absorption features may or may not be present, depending upon the carbonate content in sample and level of a desired signal to the level of background noise (SNR). In addition to that, because of atmospheric water vapor, 1.85-1.87μm absorption feature of CO_3 gets masked out. In this study, we identified two representative spectra of calcretes with high (2.4%) and low (0.3%) Mg content. It is

evident from the lab spectra, as the composition changes (Mg content) from Calcrete to Dolomite, 2.35μm absorption positions get shifted towards shorter wavelength (2.30μm) [4]. Selected representative lab spectra were used to classify the processed hyperion image, (Fig.3) using Spectral Angle Mapper (SAM) technique [3,5,6]. Fig.3 shows the classified result overlaid on hyperion Image representing the spatial distribution of calcretes in the study area. To evaluate the accuracy of classified result, sample locations were used as the reference [7]. It is evident from the confusion matrix, classification through SAM using lab measured spectra produces 72.15% overall accuracy.

6. CONCLUSION

The adopted spectroscopic procedure is efficient in calcrete mapping. It has capability to identify the minor variation in chemical composition with good classification accuracy (72.15%). Regardless of atmospheric water vapor noises, hyperion data and lab measured reflectance spectra have great potential in calcrete (with high and low Mg content) exploration. The spectroscopy and geochemical analyses give acceptable results which is comparable with published data [8]. In-situ Gamma-ray spectrometry and geochemical analyses confirm the presence of secondary Uranium mineralization in the study area. Misra et al. (2011) have reported significantly higher concentration of Uranium in calcretes of Nagaur district of Rajasthan, India. Uranium ranging from 6 to 195ppm with an average value of 90.66ppm [2]. For further investigation, a detailed study is required.

ACKNOWLEDGEMENT

7. REFERENCES

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