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Preliminary Results – Hyperspectral Image Analysis for Dolomite Identification in Tarbela Dam Region of Pakistan

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Abstract*—The blessings of hyperspectral remote sensing are manifold and it has enabled researchers to locate, map and identify different materials on the surface of Earth. Hyperspectral remote sensing play a key role in mineral mapping activities and it can be a much powerful and cost effective tool for mineral development activities in a developing country like Pakistan where there are rich mineral resources but lack of means of extraction is still a constraint in their efficient usage for betterment of country's economy. In this paper we investigate the adequacy of the hyperspectral remote sensing data acquired by Earth Observing -1 (EO-1) hyperspectral sensor, over an area of Tarbela Dam region (Lat. 32^0 05'N, Long. 72^0 41' E), which is a rich mineral resource of Pakistan. Many notable minerals have been found in this region among which analysis of identification of dolomite through hyperspectral imagery of Tarbela Dam region is the major aspiration of this research article. The results presented in this paper may refer to the preliminary steps that can be taken for minerals identification using hyperspectral imaging in Pakistan. The analysis of spectral signature of the dolomite which is a sedimentary carbonate rock and a mineral both composed of calcium magnesium carbonate is described through software Erdas IMAGINE®. However large noise ratio showed to represent a constraint for dolomite identification as it is likely to conceal spectral information due to rocks and vegetation cover. In the end, we suggest some techniques to help improve these analyses.

***Index Terms*— Hyperspectral remote sensing, Tarbela Dam, spectral information, noise ratio, mineral mapping**

I. INTRODUCTION

Hyperspectral remote sensing has been used for increasing knowledge and perception of the earth's surface [1]. Recent advances in sensor technology and the increasing demand by user's community for the higher resolution data have led to the swift development of hyperspectral remote sensing [2]. A number of airborne as well as space-based (satellite) sensors have been launched for the better visualization and exploration of land assets such as minerals exploration and identification, vegetation cover and crops assessment to name a few. Specially, the launch of spaceborne sensors has opened a door of globalization in the field of remote sensing and it has made possible an easy access for the geographically restricted areas of the worlds. High resolution satellite data has been easily made available to researchers by organizations such as National Aeronautics and Space Agency (NASA) and United States Geological Survey (USGS) which has enabled them to perform more accurate analysis of remotely sensed data.

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Hyperspectral remote sensors concurrently collect image data in dozens or hundreds slight or neighbouring spectral bands over wavelength that can range from the ultraviolet to the thermal infra-red resolution of fine 10nm [1]. This unique spectral resolution has opened the door to a series of civilian and military applications among which some of them are land use, agriculture assessment, ecological and environmental monitoring, ground cover classification, mineral exploration, change detection, man made materials identification and detection, target activities and surveillance and the basic concept underlying all these applications is that all substances depending on their molecular composition scatter electromagnetic energy at specific wavelengths in distinctive patterns [1]. Hyperspectral remote sensing data were acquired for the first time in Southern America in 1995, over some areas of Brazil, using NASA's Advanced Visible and Near-Infrared Image Spectrometer (AVIRIS) and the study was part of SCAR-B (Smoke, Reasoning and Radiation-Brazil), a combined scientific mission between NASA, the Brazil Area Agency (AEB) and the Brazil Nationwide Institution for Area Research (INPE) and the unique dataset gathered by this mission over Brazil symbolizes the first hyperspectral data ever obtained over a tropical region [2]. Among the various applications of hyperspectral remote sensing, locating minerals on the surface of earth using hyperspectral imagery is now well developed. Hyperspectral imagery has been used to detect and map a wide variety of minerals having characteristics reflectance spectra [3]. Minerals and rocks display certain analytic spectral characteristics throughout the electromagnetic spectrum that allow their chemical composition and relative abundance to be mapped [2]. Minerals are one of the key natural resources of any country and their proper use play a major role in the country's economy and development. Although, Pakistan has a rich mineral wealth but due to lack of extraction means and their proper use, minerals do not make the major part of country's economy. Pakistan Mineral Development Corporation (PMDC) is an autonomous corporation responsible for expanding and helping mineral development activities in the country [4]. In Pakistan, available assessments of high spectral resolution data are mostly based on NASA's Hyperion (EO-1) hyperspectral sensor. Using hyperspectral remote sensing technique for mineral exploration in Pakistan can improve and enhance the mineral development activities in the country. In this paper, we analyse the identification of dolomite using spaceborne hyperspectral imagery (Hyperion EO-1 data) of Tarbela region located in Khyber Pakhtunkhwa (KP) province of Pakistan, and the preliminary results are shown here considering the restraints of vegetation, weathering and soil etc.

We performed the digital image processing using software Erdas IMAGINE® from Intergraph (formerly ERDAS Inc.), and analysed the identification of dolomite using target identification technique. The image processing shown here refers to the preliminary steps that can be used for the extraction of minerals in Pakistan using hyperspectral imagery.

II. PHYSIOGRAPHY AND GEOLOGY OF TARBELA DAM

Tarbela Dam on the Indus River in Pakistan is located in Haripur District, Hazara Division, Khyber Pakhtunkhwa, about 50 kilometres northwest of Islamabad. Because the source of the Indus River is glacial melt-water from the Himalayas, the river carries huge amounts of sediments. However, sedimentation has been much lower than predicted, and it is estimated that the useful lifespan of the dam will be 85 years [5]. The notable minerals in Haripur district are sandstone, limestone and dolomite [6]. Hazara district Hills comprise crystalline and metamorphic rocks with non-fossiliferrous sedimentary deposits and gabbroic intrusions, ranging in range from Precambrian to Permian and the present geologic structure is the result of extensive folding, shearing and faulting associated with regional crustal deformation originating form the northward subduction (under thrusting) of the Indian Sub Continental Plate below the Eurasian Plate [6]. In earlier works, there have been many studies describing the geology of this region among which a geologic survey of Southern Himalaya in Hazara, Pakistan conducted by United States Geological Survey (USGS) and Geological Survey of Pakistan in 1975 described that the dolomite unit of Tarbela area consists of dark-weathering interlayered brown and grey micro-crystalline dolomite. USGS survey (1975) also revealed that the dolomite unit is thin to thick bedded and commonly cherty, and in places rounded sand sized quartz grains are scattered throughout the rock [7]. Dolomite is the name of a sedimentary carbonate rock and a mineral, both composed of calcium magnesium carbonate $CaMg(CO_3)_2$ found in crystals. Dolomite rock (also dolostone) is composed predominantly of the mineral dolomite. Limestone that is partially replaced by dolomite is referred to as dolomitic limestone, or in old U.S. geologic literature as *magnesian limestone*. Dolomite was first described in 1791 as the rock by the French naturalist and geologist, Déodat Gratet de Dolomieu (1750–1801) for exposures in the Dolomite Alps of northern Italy.

Figure 1 - Left: Red box showing Area of Interest (Image Source: USGS Earth explorer); Right: Satellite Image of the Tarbela Dam on the Indus River of Pakistan (Source: NASA Astronaut Photography Database)

III. EO-1 HYPERION

The launch of NASA's Earth Observing -1 (EO-1) satellite Hyperion sensor in November 2000 marked the establishment of spaceborne hyperspectral mapping capabilities [8, 9]. Hyperion is a satellite sensor covering the 0.4 to 2.5 micrometers spectral range with 242 spectral bands at approximately 10nm spectral resolution and 30m spatial resolution from a 705km orbit [8, 11]. Hyperion is a pushbroom instrument, capturing spectrum of a line 30m long over a 7.5 Km-wide swath perpendicular to the satellite motion [12]. The system has two grating spectrometers; one visible/near infrared (VNIR) spectrometer approximately 0.4 – 1.0 µm and one short-wave infrared (SWIR) spectrometer approximately 0.9 – 2.5 µm [8]. Data are calibrated to radiance using both pre-mission and on-orbit measurements [13]. There are three instruments on board the EO-1 spacecraft named as Advanced Land Imager (ALI) which provides image data from ten spectral bands (band designation), Hyperion which collects 220 unique spectral channels ranging form 0.357 to 2.576 micrometers with a 10nm bandwidth and Linear Etalon Imaging Spectrometer Array (LEISA) Atmospheric Corrector (LAC) which provided the first space-based test of an on-board Atmospheric Corrector (AC) for increasing the frequency of surface reflectance estimates [9]. Table 1 summarizes the overview of EO-1 satellite sensors.

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Table 1: EO-1 Satellite Sensors Overview (Source: Satellite Imaging Corporation, US)

Parameters	EO-1		
	ALI	HYPERION	AC
Spectral Range	0.4 - 2.4 µm	0.4 - 2.4 µm	0.9 - 1.6 µm
Spatial Resolution	30 m	30 m	250 m
Swath Width	36 Km	7.6 Km	185 Km
Spectral Resolution	Variable	10 nm	6 nm
Spectral Coverage	Discrete	Continuous	Continuous
Pan Band Resolution	10 m	N/A	N/A
Total Number of Bands	10	220	256

Table showing the different parameters for Satellite Sensors i.e., ALI (Advanced Land Imager), Hyperion & AC (Linear Etalon Imaging Spectrometer Array Atmospheric Corrector)

EO-1/Hyperion provides the highest available spectral resolution in the field of satellite-borne remote sensing systems [14]. Detailed classification of land assets through the Hyperion will enable more accurate mineral exploration, better predictions of crop yield and better containment mapping [15].

IV. HYPERSPECTRAL DATA PROCESSING

Hyperspectral imaging is concerned with capacity, examination and analysis of the spectra acquired form a given sensor in a short, medium or long distance by an airborne or satellite [1, 16]. NASA's Jet Propulsion Laboratory (JPL) began a revolt in the field of remote sensing introducing new instruments like airborne imaging spectrometer [1]. This concept of hyperspectral imagery was beginning in the 1980's by A.F.H. Goetz and his colleagues at NASA's [1, 16]. This system used more than 200 spectral bands and was able to cover the wavelength region from 0.4 to 2.5µm at a nominal spectral resolution of 10m [1, 17, 18]. Although hyperspectral data can also be analyzed using multispectral image analysis techniques but classical multispectral image analysis methods do not take full advantage of the spectral dimensionality of these datasets [8]. Thus hyperspectral imaging takes more in-depth analysis of imagery than multispectral image analysis.

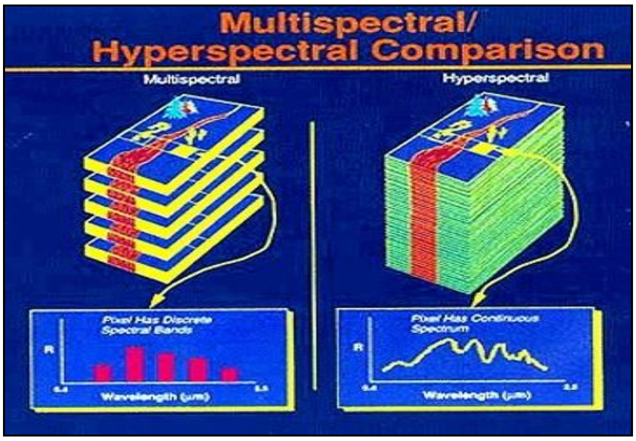

Figure 2: Comparison of multispectral data with hyperspectral data (Source: NASA)

Processing hyperspectral data requires different approaches in comparison to multispectral data and the main idea behind hyperspectral data is to identify the composition of superficial materials based on their spectral signature in 0.400 to 2.500µm wavelength range [2]. Hyperspectral images such as Hyperion are widely used for mineral mapping and lithological discrimination of the geological units [19, 20, 21, 22, 23, 24]. Fusion of short wave infrared (SWIR) and long wave infrared (LWIR) spectral imaging is standard for the detection of minerals in the feldspar, silica, calcite, garnet and olivine groups as these minerals have their most distinctive and strongest spectral signature in the LWIR regions [25]. The atmospheric gases, aerosols (airborne particulate matter), clouds scatter and absorb solar radiation can modulate the reflected radiation from Earth and this attenuation can affect the intensity and spectral composition of the radiation [26, 27]. Even though, images have number of spectral channels, spectral images never depict the true radiance of the surface due to the sensors and atmospheres [24, 28]. If the image is atmospherically not corrected, none of the process results would be accurate, so, in order to avoid these kinds of problem, atmospheric correction or radiometric calibration should be performed before starting the classification processes [24]. Atmospheric correction attempts to minimize the atmospheric effects [3]. So, the first step in hyperspectral data processing is the atmospheric correction. Our study area is the long narrow strip of Hyperion image of Tarbela dam located on the Indus River of Pakistan having scattered vegetation cover. Nowadays, there are many different techniques and many ready-to-use professional tools in form of software packages are available for researchers to help them perform the atmospheric correction of hyperspectral data. We performed the de-hazing of the Tarbela hyperspectral imagery using the haze reduction function of Erdas IMAGINE® software (Intergraph Corporation). The de-hazing algorithm can turn a hazy data set into a crisp and neat image [29]. The second step in hyperspectral image processing is the measurement of signal-to-noise ratio (SNR). SNR is a measure that compares the level of a desired signal to the level of background noise and it is defined as the ratio of signal power to the noise power. In order to measure the SNR of haze-reduced hyperspectral image of the Tarbela dam, we used the Signal-to-Noise function of Erdas IMAGINE® software. Figure 3 (below) shows the hyperspectral imagery of Tarbela dam, the reduced haze image and SNR computed image.

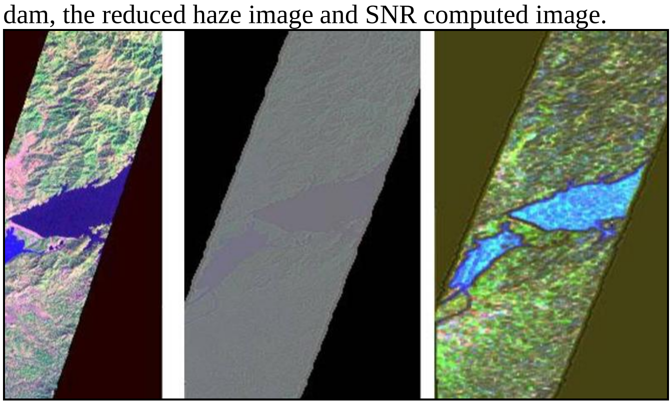

Figure 3: Left: Long narrow strip of EO-1 showing hyperspectral imagery of Tarbela Dam region of Pakistan, Center: Haze reduced image of the hyperspectral imagery, Right: In this image S/N ratio model has been applied using Erdas IMAGINE®

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Spectral libraries are collections of reflectance spectra measured from materials of known composition, usually in the field or laboratory and spectra from libraries can guide spectral classification or define targets to use in spectral image analysis [3]. So, the next step involves the spectral profile analysis of hyperspectral Tarbela imagery with the spectral signature of dolomite. Erdas IMAGINE® software contain spectral libraries developed by JPL (Jet Propulsion Laboratory), USGS and Erdas which contain spectral signature for a wide variety of materials ranging from minerals, vegetation etc. These spectral libraries play a vital role in hyperspectral image analysis. For identification analysis of dolomite, we adopted the approach of spectral signatures classification and identification that involves some sort of comparison between pixel spectral signature (unknown) and spectral signature of reference materials in order to establish the relation that how similar both spectral signatures are. We identified some specific points in the imagery and generated their spectral profile using Erdas IMAGINE® software. Then, this spectral profile was compared with the reference spectral signature of dolomite available in JPL library of Erdas IMAGINE® software.

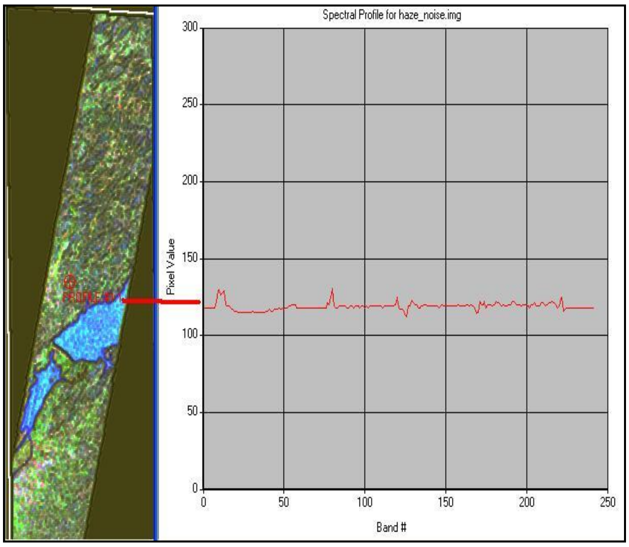

Figure 4: Spectral profile of a selected point in the processed image

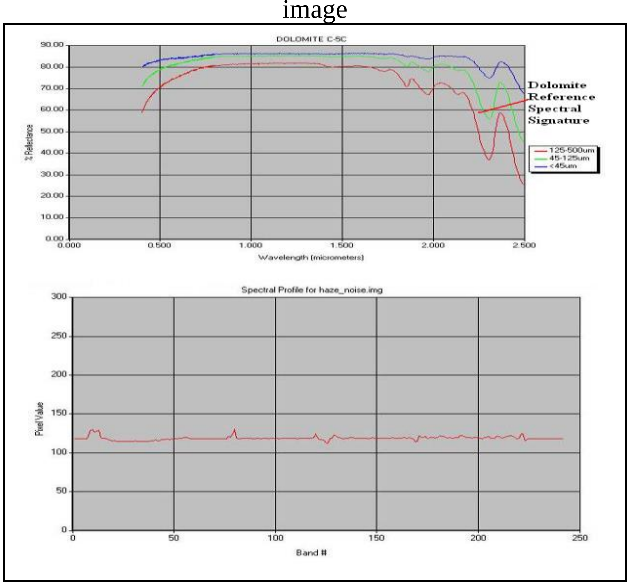

Figure 5: Image showing comparison of spectral profile of a selected point in the processed image with the spectral signature of dolomite

V. UNCERTAINTIES

Since vegetation cover on the banks of Tarbela dam concealed most of our image and also due to noises present in the imagery, dolomite identification cannot be analyzed reliably from our hyperspectral image and we could not make a perfect match between the spectral signatures. The results and analysis can be much improved in the absence of vegetation and noises.

VI. CONCLUSION AND DISCUSSION

Hyperspectral image analysis can be a very powerful tool for cost effective identification and analysis of minerals in a country like Pakistan where there are still lack of reliable and efficient resources for the extraction of rich minerals wealth. Efficient and cost effective extraction of minerals and their proper usage can greatly help in improving the economy of the country. Although, there was some uncertainty in the image processing due to the presence of vegetation cover and noises, but the steps shown here can be referred to as the preliminary steps for the identification analysis of minerals. We suggest some statistical tools such as statistical filtering and using bi-variety regression analysis that can remove the noises present in the imagery. Many statistical packages are available to the researchers nowadays where these techniques can be applied to help improve the analysis.

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