Remote Sensing and GIS
Prof. Rishikesh Bharti
Department of Civil Engineering
Indian Institute of Technology – Guwahati

Lecture – 20
Hyperspectral Remote Sensing – V

In my previous lecture, I have covered the field spectroscopy different available spectral library spectral analysis and how do we use this technology in different application. So, I started with planetary exploration, I gave you some of the example the published work. Now, let us continue that before that just to refresh your memory I just want to highlight.

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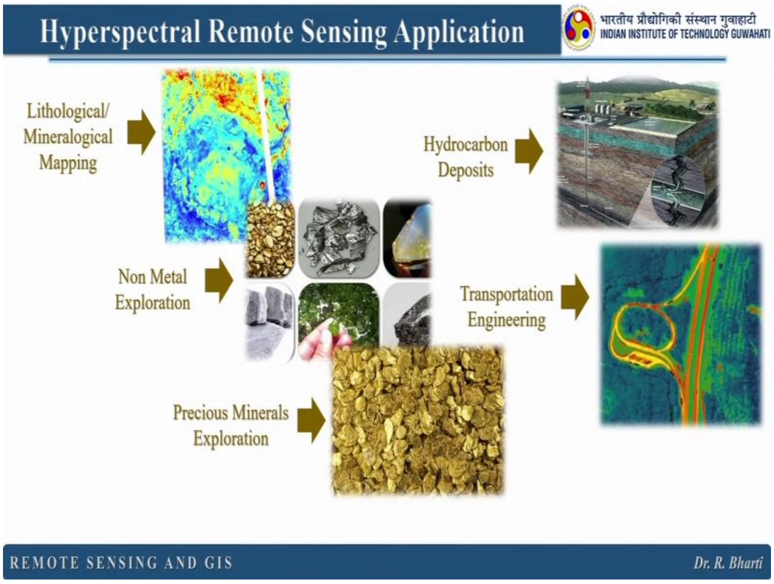

What are the different application of remote sensing which I have already covered in the previous lecture? So, this is first application where we use this hyper spectral remote sensing technique or the spectroscopy technique for lithological mapping and mineralogical mapping. The next application is non metal exploration. Third one is precious mineral exploration, then hydrocarbon deposits or in other words you can say how to detect the micro seepages using this space based data right. The next example in Transportation Engineering.

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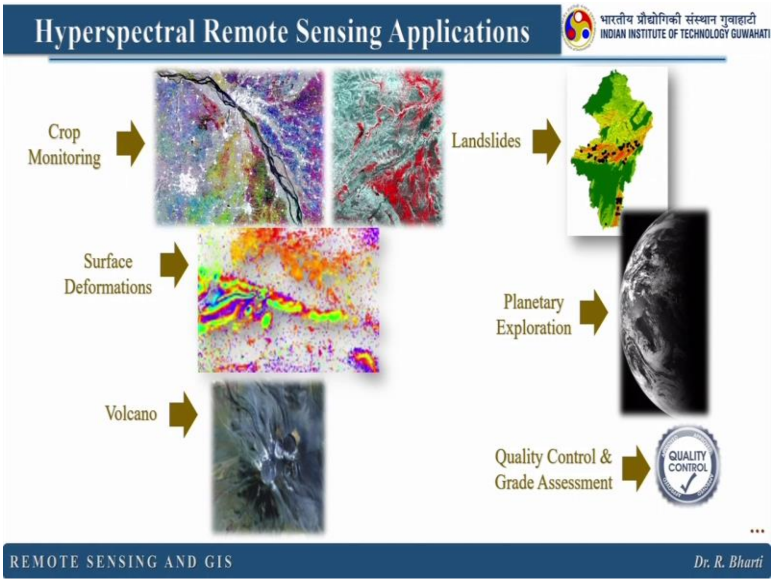

Then Crop Monitoring, Surface Deformation, Volcanic studies , Landslides, Planetary Exploration, and Quality Control and Grade Assessment. So, this is related to industry where we produce the material and we want to take the quality. So quality of the food grains. Let us continue with the planetary exploration.

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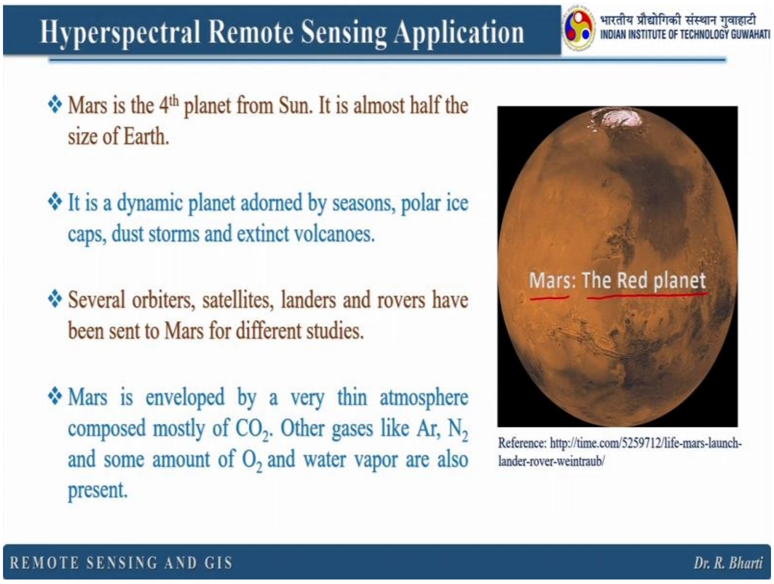

So here, this study is for the Mars which is also known as the red planet. So here, I will just give you the brief introduction about the Mars why it is important and why do we study this particular planet when we are living on Earth. So Mars is the fourth planet from Sun. It is almost half the size of Earth. It is a dynamic planet adorned by season polar ice caps, the strong and extinct volcanoes, right. Several orbiters, satellites landed and rovers have been sent to study the Martian surface.

Mars is enveloped by a very thin atmosphere composed mostly of carbon dioxide and other gases like argon, nitrogen and some amount of oxygen and water vapour are also present on Mars right.

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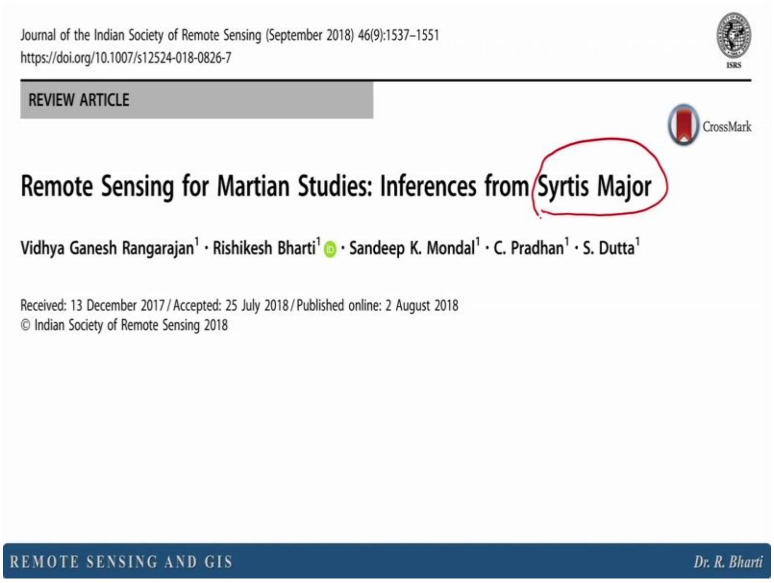

So, this is the background of the Mars why it is important and since this is one of the planet in our solar system, so it is very important to study this particular planet to study the evolution of this solar system as well as the evolution of this Earth, right. So right now, I am going to explain this particular work where we have used this remote sensing in particular hyper spectral remote sensing for Martian studies.

And here basically, we have considered this as our study area, Syrtis Major. So for certain studies, what are the different types of sensors which are giving us the data? So, let us understand what are the different types of sensor available? And what is their potential application.

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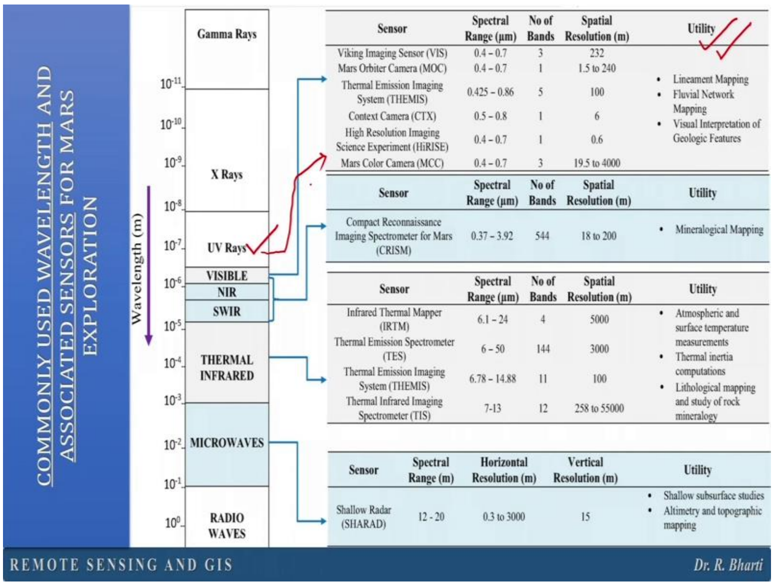

So, here you can see the commonly used wavelength in different studies and associated sensors. That means, the sensors available in this space which can give you the data of Martian surface in what wavelength they are working and what is the major utility of that data right. So, if you see this is the wavelength of our electromagnetic wavelength. So, here we have Gamma rays, X rays, UV, Visible NIR, SWIR, Thermal, Microwave and Radio waves.

So, if you see this particular section is connected with this visible, so, this is used for lineament mapping, fluvial network mapping and visual interpretation of geological features. Whereas, this visible NIR and SWIR if they are used together, they can be used for mineralogical mapping. So, here I am not talking about the method like if it is multispectral Panchromatic or hyperspectral here I am talking about the wavelengths which can be used for different application right.

So, if you see this thermal infrared, this is basically used for atmospheric and surface temperature measurement, thermal inertia computation, and then lithological mapping and study of rock mineralogy. The microwave wavelength is used for shallow sub surfaces studies, altimetry and topographic mapping, you can go through this table and understand what wavelength you want to use and corresponding which data is available and what is your application.

So, we always start with our application, then we look for the wavelength in which wavelength we want to work and which wavelength is beneficial for us to solve our application or purpose and then we look for which are the data sets available for our studies right. So, this is how we have to try or we have to use or we have to decide the data for our application that was related to all the data sets available for Martian studies.

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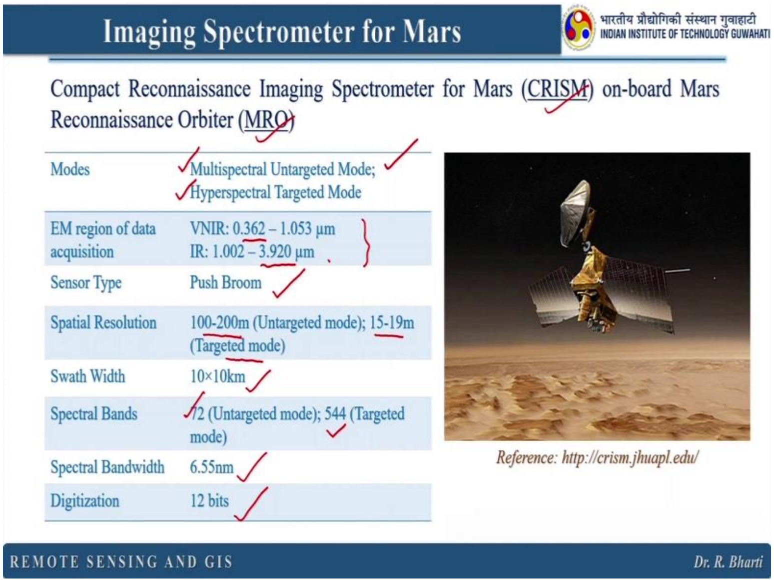

Now, let us see what data we have used in this particular study. So, that was CRISM, which on board this MRO. So MRO is a career and CRISM is a sensor. So, CRISM is a hyper spectral sensor and its technical specifications are given here. So, it can measure the images in two different modes. First one is multispectrum. Next one is hyperspectrum. So, it can capture both types of data, then it works between 0.362 to 3.920 micrometres.

So, this is very important to see whether this wavelength is useful or not, then the sensor type is push broom. I hope you remember the basics, spatial resolution for multi spectral data it is 100 to 200 meters that is why it is known as untargeted mode. Whereas, in hyperspectral, which is considered as targeted mode, the spatial resolution is very good 15 to 19 meter, swath width is 10 by 10 kilometre that means, one scene will be of 10 by 10 kilometre.

Spectral band 72 for multispectral and 544 for hyperspectral and the spectral bandwidth is 6.55 nanometer and the digitization or in other words, it is radiometric resolution of this CRISM data is of 12 bits, so, that 12 bit gives you the flexibility to dissolve the incoming radiation in many segments right.

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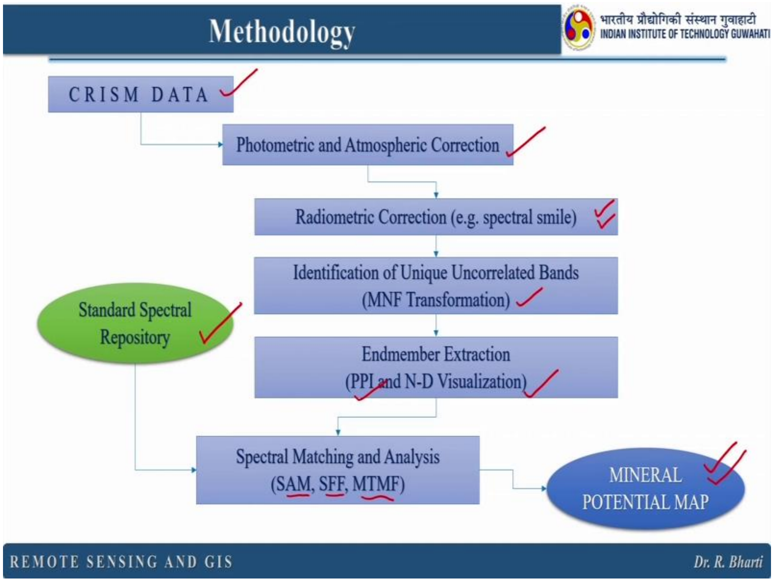

So, what method we have used to solve our purpose here. So, first we started with CRISM data. So, CRISM is a hyperspectral data. So, it needs to be corrected for photometric and atmospheric effects. And then once you do that, then you have to do the radiometric calibration. And once your data is corrected for the photometric, atmospheric and radiometric errors, then you can use this data to derive the end members. I hope you remember the basics of hyperspectral.

So we have to derive the end members from the image then only we can resolve that image derived end member with respect to library to derive the composition right once we get this MNF or PCA output, then we can use this n-D visualizer it and we can plot the data in n dimension and we can derive the or we can extract the end members by using this PPI, right and once we get the end member, then we do the spectral classification or the soft classification using SAM, SFF, MTMF and other methods.

Here, once you do that, anyway you will get the output you will get a classified image. But is it meaningful information? No unless until we do not resolve our end members extracted from the image with respect to spectral library, this classified image has no meaning. So, that is why I have put here standard spectral library and then we will do the spectral analysis and we derive our composition right.

So, for a given pixel, what is the composition that is derived by analysing this image end members with respect to the spectral library, right.

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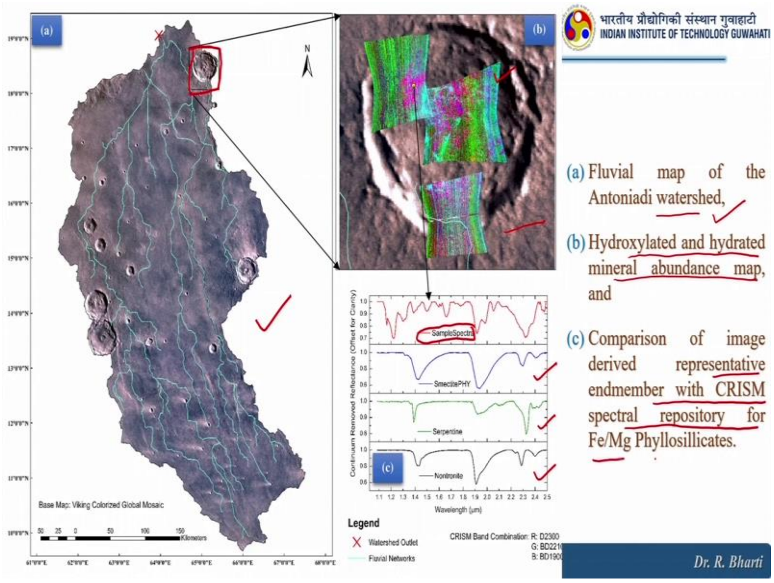

Following this method, we have derived the hydroxylated and hydrated minerals on Mars. So, here, this particular section that is part of this image that is a, which is here, it says fluvial map of the Antoniadi watershed, so this I will cover in the future lectures. The next part of this map says hydroxylated and hydrated mineral abundance map. So this is basically the coverage of your CRISM data, because CRISM data coverage is 10 by 10 kilometre.

And this is a huge crater. So this is basically zoomed part of this right. So, you can see here this is a crater. Now, on top of this crater, we have got only three scenes of CRISM which were good. So, that we have used and then we have done the spectral analysis. And then we found that this is the spectra of your image. And these are the spectra of your library, right. So these were analysed and the comparison was done.

So comparison of image derived representative endmembers with CRISM Spectra repository for Fe/Mg phyllosilicates. So here, this is how we say or how we prove that on Mars, this kind of mineral or rock is present, right.

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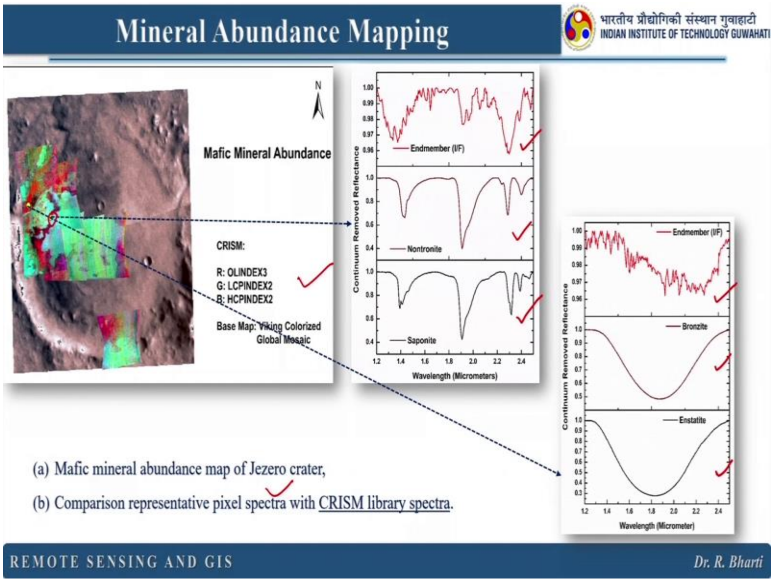

In this slide, you can see some more detail about this world where this particular map says Mafic mineral abundance map of Jezero created this is from Jezero crater, now, here you can see for this particular pixel can you see this yellow colour? So, basically for that particular pixel, we have got this end member and these are the spectra from CRISM library right.

And we have compared these two for the presence of mafic minerals and for the next pixel, you can see here these are the spectras. So, here I just want to give you the flavour how we do this spectroscopy for Martian studies or maybe for our exploration right. So, this you can think of utilizing in your application. Here I have put some references which are very important.

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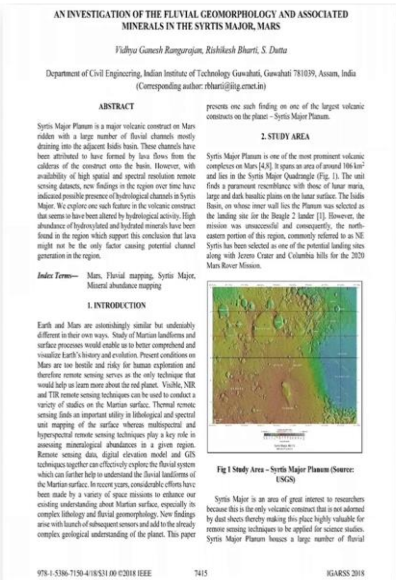

AN INVESTIGATION OF THE FLUVIAL GEOMORPHOLOGY AND ASSOCIATED MINERALS IN THE SYRTIS MAJOR, MARS

Vidhya Ganesh Rangarajan, Rishikesh Bharti, S. Dutta

Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781039, Assam, India
(Corresponding author: rbharti@iitg.ernet.in)

ABSTRACT

Syrtis Major Planum is a major volcanic construct on Mars ridden with a large number of fluvial channels mostly draining into the adjacent Isidis basin. These channels have been attributed to have formed by lava flows from the calderas of the construct onto the basin. However, with availability of high spatial and spectral resolution remote sensing datasets, new findings in the region over time have indicated possible presence of hydrological channels in Syrtis Major. We explore one such feature in the volcanic construct that seems to have been altered by hydrological activity. High abundance of hydroxylated and hydrated minerals have been found in the region which support this conclusion that lava might not be the only factor causing potential channel generation in the region.

Index Terms— Mars, Fluvial mapping, Syrtis Major, Mineral abundance mapping

1. INTRODUCTION

Earth and Mars are astonishingly similar but undeniably different in their own ways. Study of Martian landforms and surface processes would enable us to better comprehend and visualize Earth's history and evolution. Present conditions on Mars are too hostile and risky for human exploration and therefore remote sensing serves as the only technique that would help us learn more about the red planet. Visible, NIR and TIR remote sensing techniques can be used to conduct a variety of studies on the Martian surface. Thermal remote sensing finds an important utility in lithological and spectral unit mapping of the surface whereas multispectral and hyperspectral remote sensing techniques play a key role in assessing mineralogical abundances in a given region. Remote sensing data, digital elevation model and GIS techniques together can effectively explore the fluvial system which can further help to understand the fluvial landforms of the Martian surface. In recent years, considerable efforts have been made by a variety of space missions to enhance our existing understanding about Martian surface, especially its complex lithology and fluvial geomorphology. New findings arise with launch of subsequent sensors and add to the already complex geological understanding of the planet. This paper presents one such finding on one of the largest volcanic constructs on the planet – Syrtis Major Planum.

2. STUDY AREA

Syrtis Major Planum is one of the most prominent volcanic complexes on Mars [4,8]. It spans an area of around 106 km^2 and lies in the Syrtis Major Quadrangle (Fig. 1). The unit finds a paramount resemblance with those of lunar maria, large and dark basaltic plains on the lunar surface. The Isidis Basin, on whose inner wall lies the Planum was selected as the landing site for the Beagle 2 lander [1]. However, the mission was unsuccessful and consequently, the north-eastern portion of this region, commonly referred to as NE Syrtis has been selected as one of the potential landing sites along with Jezero Crater and Columbia hills for the 2020 Mars Rover Mission.

Fig 1 Study Area – Syrtis Major Planum (Source: USGS)

Syrtis Major is an area of great interest to researchers because this is the only volcanic construct that is not adorned by dust sheets thereby making this place highly valuable for remote sensing techniques to be applied for science studies. Syrtis Major Planum houses a large number of fluvial

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And to understand this Martian studies using hyperspectral remote sensing technique, this paper can help you to increase your knowledge or improve your knowledge in this domain.

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Now, let us see some of the examples for Earth right. So, how do we use this hyperspectral remote sensing for Earth exploration or in different application right now, we are shifting from other planets to Earth right.

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So, here is some of the papers which I want to highlight here you can refer them if you are interested in this particular research area. So, this paper says hyperspectral remote sensing and geological application. Here, this paper is for uranium in this zone mapping. Then, we have marine geology paper that says the suspended sediment concentration can be identified using this hyperspectral remote sensing.

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URANIFEROUS CALCRETE MAPPING USING HYPERSPECTRAL REMOTE SENSING

*Rishikesh Bharti and D. Ramakrishnan**

Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai-400076, India
*Corresponding Author: ramakrish@iitb.ac.in

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

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A field technique for rapid lithological discrimination and ore mineral identification: Results from Mamandur Polymetal Deposit, India

D Ramakrishnan*, M Nithya, K D Singh and Rishikesh Bharti

Department of Earth Sciences, Indian Institute of Technology Bombay, Mumbai 400 076, India.
Corresponding author. e-mail: ramakrish@iitb.ac.in

This work illustrates the efficiency of field spectroscopy for rapid identification of minerals in ore body, alteration zone and host rocks. The adopted procedure involves collection of field spectra, their processing for noise, spectral matching and spectral un-mixing with selected library end-members. Average weighted spectral similarity and effective peak matching techniques were used to draw end-members from library. Constrained linear mixture modelling technique was used to convolve end-member spectra. Linear mixture model was optimized based on root mean square error between field- and modelled-spectra. Estimated minerals and their abundances were subsequently compared with conventional procedures such as petrography, X-ray diffraction and X-ray fluorescence for accuracy assessment. The mineralized zone is found to contain azurite, galena, chalcopyrite, bornite, molybdenite, marcasite, gahnite, hematite, goethite, anglesite and malachite. The alteration zone contains chlorite, kaolinite, actinolite and mica. These mineral assemblages correlate well with the petrographic measurements ($R^2 = 0.89$). Subsequently, the bulk chemistry of field samples was compared with spectroscopically derived cumulative weighted mineral chemistry and found to correlate well ($R^2 = 0.91$–0.98) at excellent statistical significance levels (90–99%). From this study, it is evident that field spectroscopy can be effectively used for rapid mineral identification and abundance estimation.

1. Introduction

Reflectance and emission spectra are extensively used to derive information on chemistry and atomic structure of various inorganic and organic compounds. Diagnostic absorption features in visible- and near-infrared (350–1000 nm) regions of spectra of minerals are mainly governed by electronic processes such as crystal field, charge transfer, conduction bands and colour centres (Adams 1974, 1975; Hunt 1977; Hunt and Ashley 1979; Clark et al. 1990a; Burns 1993). In longer wavelength regions (2000–16,000 nm), vibration processes involving stretching, rotation and bending of molecules are responsible for producing absorption features corresponding to fundamental, overtone and combination modes (Farmer 1974; Hunt 1982; Gaffey et al. 1993; Clark 1999). The position, shape, depth and width of these absorption features are governed by chemical composition and atomic structure of materials under investigation (van der Meer and De Jong 2006). In geological applications, such absorption features at characteristic wavelengths can be directly related to mineralogy (Hunt and Salisbury 1970; Clark 1999). Further, magnitude of spectral absorption at any specific wavelength can be related to abundance of constituent minerals (Clark et al. 1990b; Hapke 1993; Ramsey

Keywords. Field spectroscopy; linear mixture modeling; cumulative weighted mineral chemistry; mineral exploration.

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In another paper again the uraniferous calcrete were mapped using this hyperspectral remote sensing. This paper highlight the advantages of hyper spectral remote sensing or in particular spectroscopy in field for mapping the lithology or the ore mineral identification, now, let us start with lithological discrimination and ore mineral identification. So, this is from the previously listed work right.

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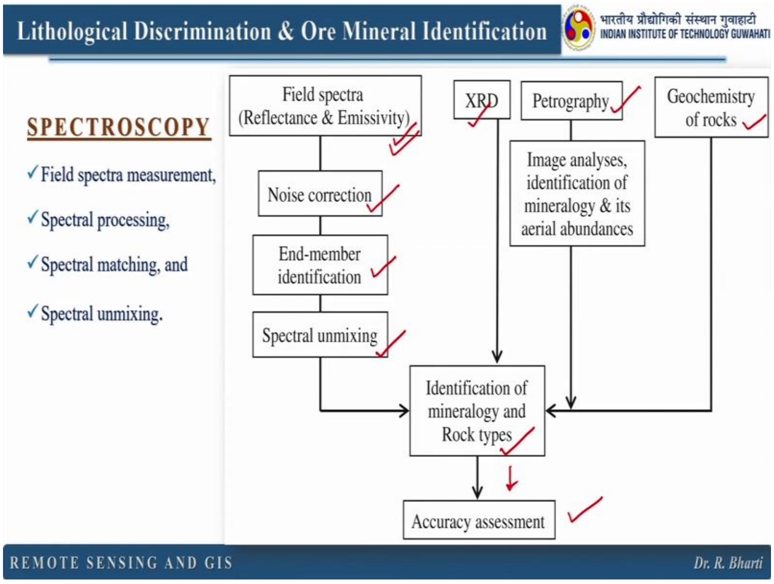

So, here, what are the advantages of spectroscopy and what are the steps you have to follow to solve a particular problem that you need to understand. So, when we are using the spectroscopy for the lithological discrimination and ore mineral identification, the first step in this method will be measurement of field spectra. Then processing of the measured field is spectral lab spectra.

Then spectral matching with the library spectra and then the spectral unmixing and then you will derive at certain composition. So, here this is how this work was done. So, the field is spectra, which is basically reflectance and emissivity both that were collected in the field. Then noises were removed from this particular spectrum and end members were selected. So, representative samples were selected to be part of this particular analysis.

Then spectral unmixing was done. At the same time, the field samples were analysed with XRD and then mineralogy and rock types were identified. Similarly, using this spectrography and geochemistry of rocks. So, that were used to verify the results because here we need to establish a method which can be used for the direct identification of ore minerals or lithological decision.

So that is why all these conventional techniques were used to prove that this field spectroscopy results are good. So, after combining everything, then we analysed all the data sets and then we have also produced the accuracy, right. So this is from a published paper, which is listed in the previous slides. Now, after this, the most important part of this work is Spectral Unmixing.

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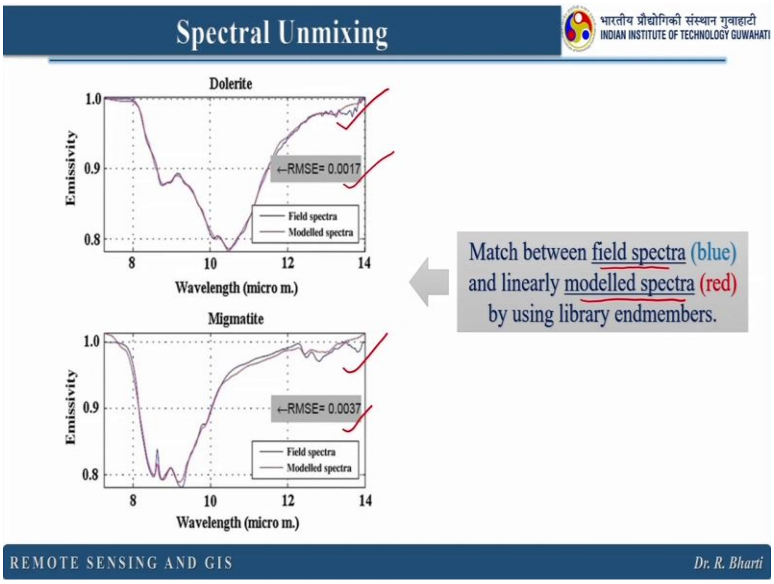

So, here you can see the match between field spectra and the modelled spectra. So, you can just see how well they are matching with each other, all the major troughs were matched. So, that is why the RMSE is in order of 0.0017 and here it is 0.0037 it says that the modelled spectra is matching well with your field spectra or lab spectra right.

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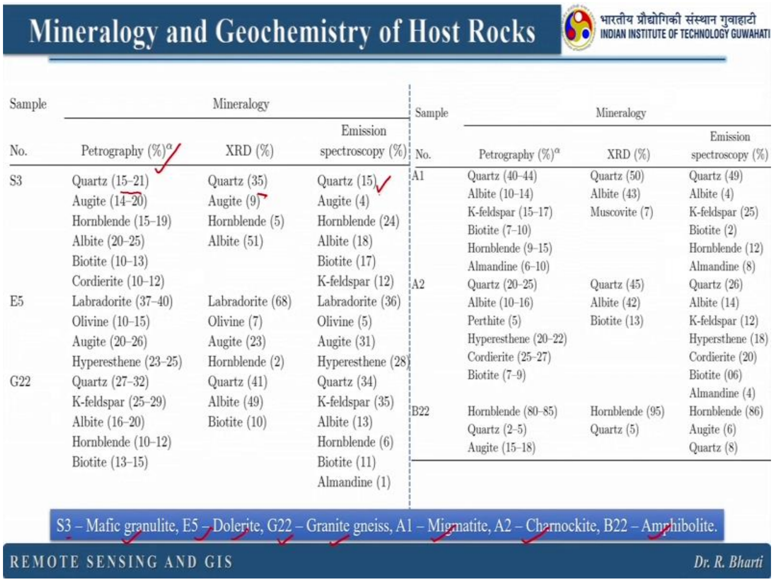

Sample No.	Mineralogy: Petrography (%)[α]	XRD (%)	Emission spectroscopy (%)
S3	Quartz (15–21)	Quartz (35)	Quartz (15)
	Augite (14–20)	Augite (9)	Augite (4)
	Hornblende (15–19)	Hornblende (5)	Hornblende (24)
	Albite (20–25)	Albite (51)	Albite (18)
	Biotite (10–13)		Biotite (17)
	Cordierite (10–12)		K-feldspar (12)
E5	Labradorite (37–40)	Labradorite (68)	Labradorite (36)
	Olivine (10–15)	Olivine (7)	Olivine (5)
	Augite (20–26)	Augite (23)	Augite (31)
	Hyperesthene (23–25)	Hornblende (2)	Hyperesthene (28)
G22	Quartz (27–32)	Quartz (41)	Quartz (34)
	K-feldspar (25–29)	Albite (49)	K-feldspar (35)
	Albite (16–20)	Biotite (10)	Albite (13)
	Hornblende (10–12)		Hornblende (6)
	Biotite (13–15)		Biotite (11)
			Almandine (1)

Sample No.	Mineralogy: Petrography (%)[α]	XRD (%)	Emission spectroscopy (%)
A1	Quartz (40–44)	Quartz (50)	Quartz (49)
	Albite (10–14)	Albite (43)	Albite (4)
	K-feldspar (15–17)	Muscovite (7)	K-feldspar (25)
	Biotite (7–10)		Biotite (2)
	Hornblende (9–15)		Hornblende (12)
	Almandine (6–10)		Almandine (8)
A2	Quartz (20–25)	Quartz (45)	Quartz (26)
	Albite (10–16)	Albite (42)	Albite (14)
	Perthite (5)	Biotite (13)	K-feldspar (12)
	Hyperesthene (20–22)		Hypersthene (18)
	Cordierite (25–27)		Cordierite (20)
	Biotite (7–9)		Biotite (06)
			Almandine (4)
B22	Hornblende (80–85)	Hornblende (95)	Hornblende (86)
	Quartz (2–5)	Quartz (5)	Augite (6)
	Augite (15–18)		Quartz (8)

So, once you have this kind of confidence on your spectral unmixing then you can produce this kind of tabular data where you can compare the results derived from spectral unmixing and XRD petrography and other conventional techniques. So, here you can see from petrography, the quartz is 15 to 21 this is the range of percentage whereas in XRD it is 35 with emission spectroscopy it is 15% so, in this case it is matching will with Petrographic result.

Similarly, Petrography XRD and emission spectroscopy results were compared in this particular table where this S3 is for mafic granulite E5 is dolerite G22 is basically Granite, A1 is Migmatite A2, is Charnokite B22 is Amphibolite So, this was a very good work towards proving the spectral unmixing can give you a good result which can match well with your conventional instrument results right.

Let us see the example of uraneferrous calcrete mapping in this particular section where we have used this spectroscopy or hyper spectral remote sensing.

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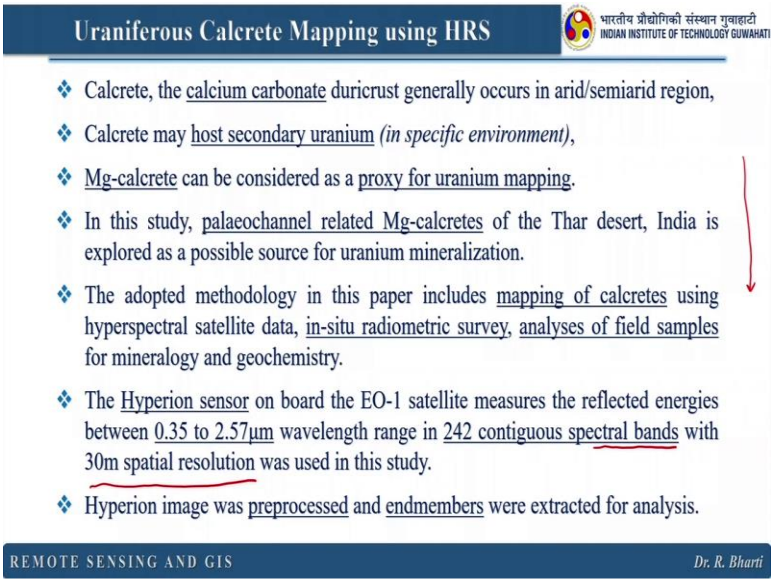

So, just to give you the background why this is important, I am going to explain some background story of this particular work. So, calcrete the calcium carbonate duricrust generally occurs in arid to semi-arid region right. Calcrete may host secondary uranium in a specific environment.

It is not like always you will get uranium but in a specific environment, it can host secondary uranium right. Mg-calcrete can be considered as proxy for uranium mapping. Once we know that calcrete may host secondary uranium or if you can confirm with the conventional technique that this particular calculate is having uranium concentration in more percentage then you can do the further studies.

And that is how we have written Mg-calcrete the magnesium rich calcrete can be considered as proxy for uranium mapping, because the concentration of uranium is very, very less in water or in soil samples so it cannot be identified directly from the space. So, that is why this MG calcrete will be used as a proxy. So, in this study palaeochannel related MG calcrete of the Thar Desert, India is explored as possible source of uranium mineralization.

The adopted methodology in this paper includes mapping of calcretes using hyper spectral satellite data, insitu radiometric survey, analysis of field samples for mineralogy and geochemistry, the Hyperion sensor onboard Earth observation-1 satellite measures the reflected energies between 0.35 to 2.57 micrometer wavelength range in 242 contiguous spectral bands with 30 meter of spatial resolution.

So, in this study, we have used Hyperion sensor and which is a hyperspectral sensors and the spatial resolution was 30 meters and we got 242 bands from this particular sensor. In this section, I will explain how we have used this hyperspectral remote sensing for mapping the uranium by using the proxy which is basically Mg-calcrete. For that, Hyperion image was pre-processed and end members were extracted for the analysis.

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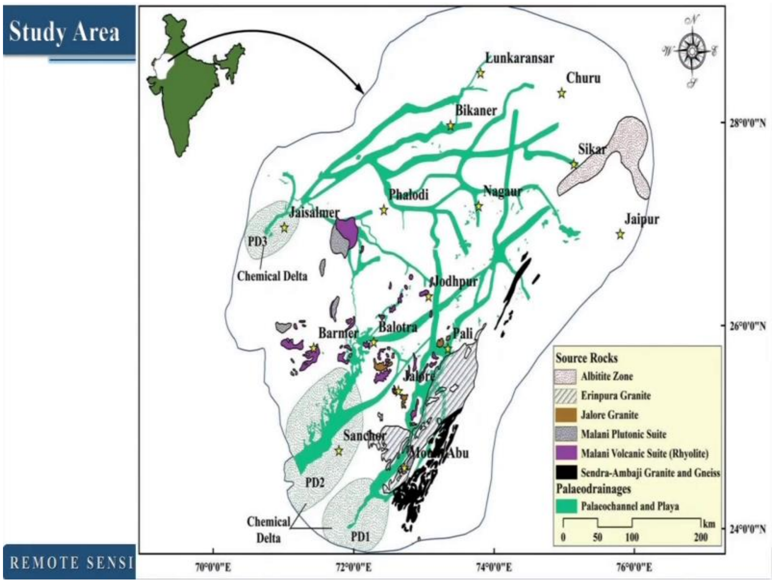

You can see the study area here. This is actually the Rajasthan. I hope you remember how we derive the end members from the image. First we pre-process the data for different errors. Then, we extract the end members by following a procedure First we will identify the unique uncorrelated bands using MNF PCA or CCA. Then we use PPI and n-D visualizer to extract the end members. Once you have that end member, then you can do the spectral analysis.

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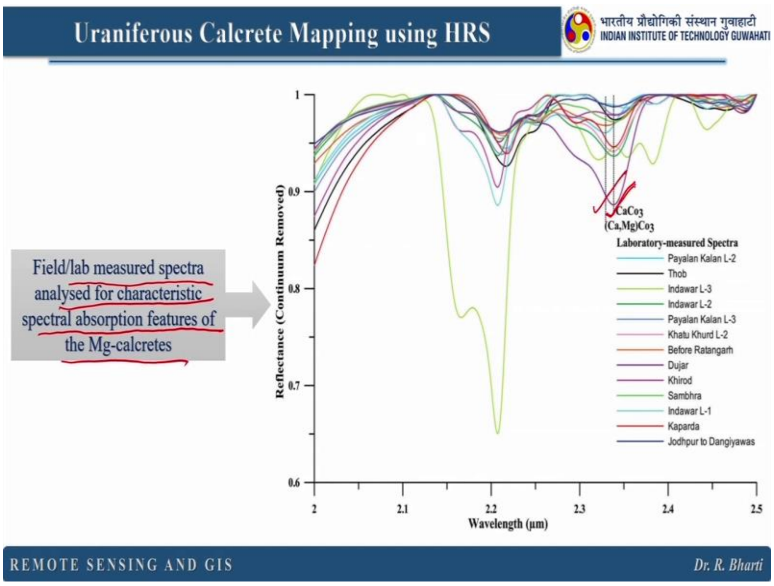

Based on our understanding of the absorption feature of calcium carbonate and when it is rich in magnesium, where it will occur, you can pinpoint the absorption features which are related to set mineral composition right. So, here the field lab measured spectra analysed for characteristic spectral absorption feature of the Mg-calcerete. So, here we can see the distinct or characteristic absorption feature reduced by Mg-calcrete right.

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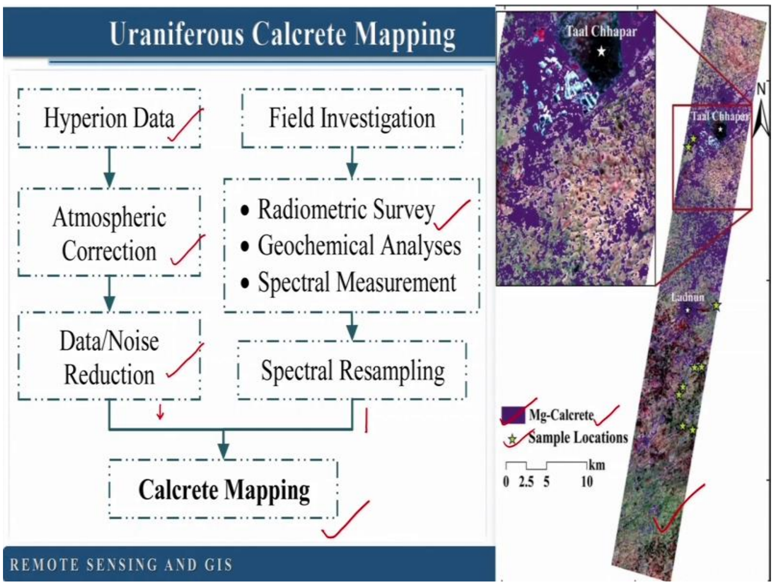

So, this is the methodology which we have followed in this particular work. So, the Hyperion data was used and the atmospheric correction was done. After that data was corrected for the noise and the unique bands were identified. Same time the field investigation was conducted and the radiomatric survey was done.

And the samples were corrected for the lab analysis and then geochemical analysis and spectral measurements were performed right. And once you do that, then spectral re sampling was done because the data which is available from this Hyperion, they have different bandwidth and the number of bands are different. And here the data which we have got from the spectroradiometer has different bands and the bandwidth right.

Two sampling rates are very different from each other. So, you need to maintain the uniformity so, that you can perform a comparison right and once you do that, then after the analysis you will get the calcrete map and specifically Mg-calcrete. So, you can see here that this is a Hyperion image. And here this purple colour is basically representing the Mg-calcrete and these were the sample location which were analysed in this sample.

So, here I just want to highlight, if you can identify the presence of very low concentration uranium in soil, then this technique can be used for any other application, all the methods have their own limitation. So, here because of that we could not directly identify the uranium, but the proxy were used to identify the uranium concentration right. In the next work Hyper spectral remote sensing was used to estimate the suspended sediment concentration. So, you can see here.

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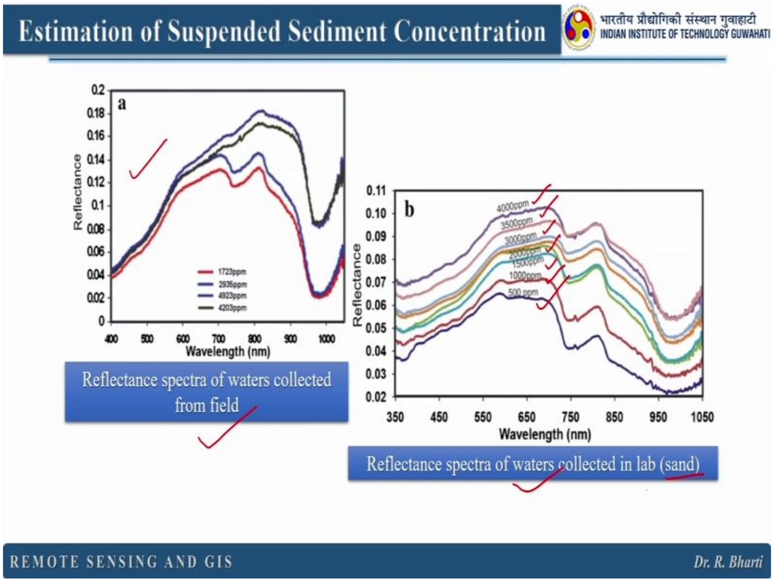

Reflectance spectra of water collected from field is shown here. And reflectance spectra of waters collected in lab with sand is used here. So, different concentration were used to generate such spectral response and once you have you can perform the spectral analysis and you can see not all the wavelengths are sensitive to change in the concentration. But some of the wavelengths are very sensitive and which can be used to identify the concentration of suspended sediment in water.

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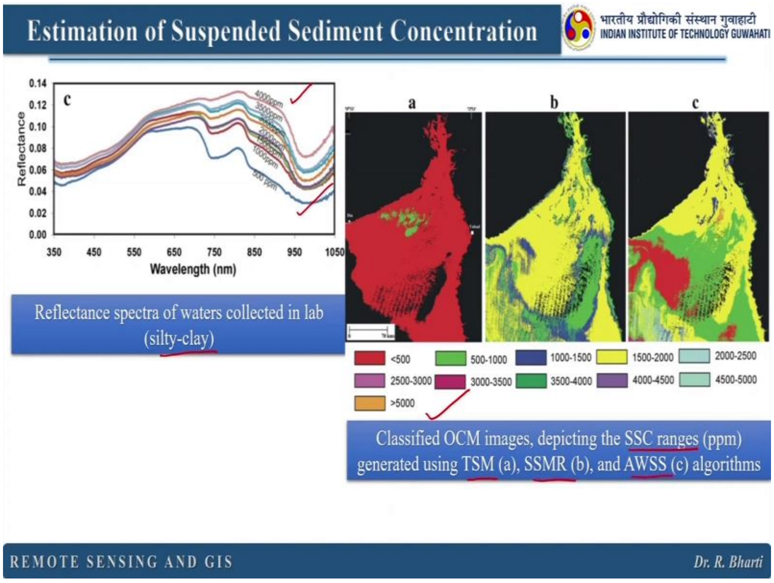

Here you can see another example and this is for silty clay. So, the reflectance Spectra's are shown here. Similarly, by adding the silty clay more and more we have reached to this 4000 ppm and then for individual concentration this spectra was measured. And once you have that, then you can easily identify what are the wavelengths which are sensitive for this change in suspended sediment.

Once you identify those wavelengths and, if you can find the satellite images in those particular wavelength regions, then you can use that particular value to detect the suspended sediment concentration. That is how this OCM image was used to identify this suspended sediment range in this particular study area.

So, here for this classification, you have this TSM, SSMR, AWSS is different methods. So, you can refer this particular work and you can learn more about this application.

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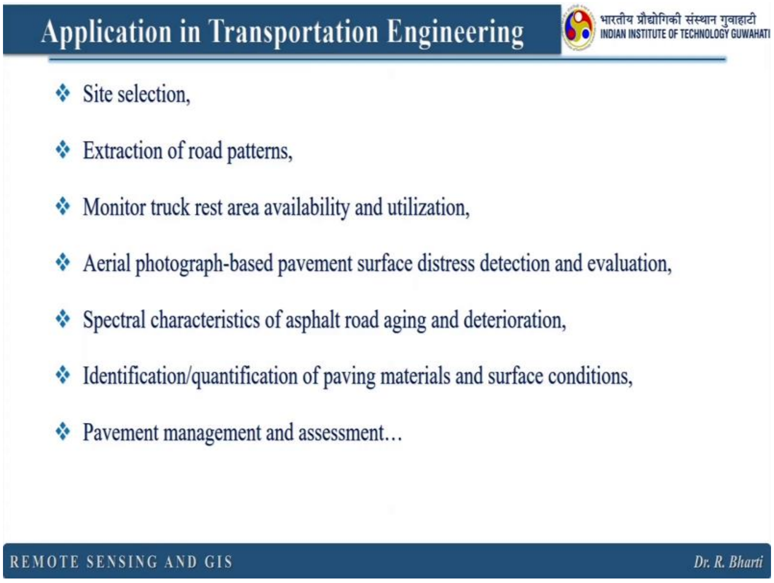

Let us see some example or how we perform this spectroscopy, when we are talking about the Transportation Engineering, so, site selection you can perform extraction of road patterns you can derive monitoring of truck risk area availability and utilization that also you can plan or you can monitor aerial photograph based pavement surface distress detection and evaluation.

The spectral characteristic of asphalt road ageing and deterioration, then identification and quantification of paving materials and surface condition. So, all these can be done using remote sensing or in particular hyperspectral remote sensing right. I will show you some of the example, where people have already used this particular technique.

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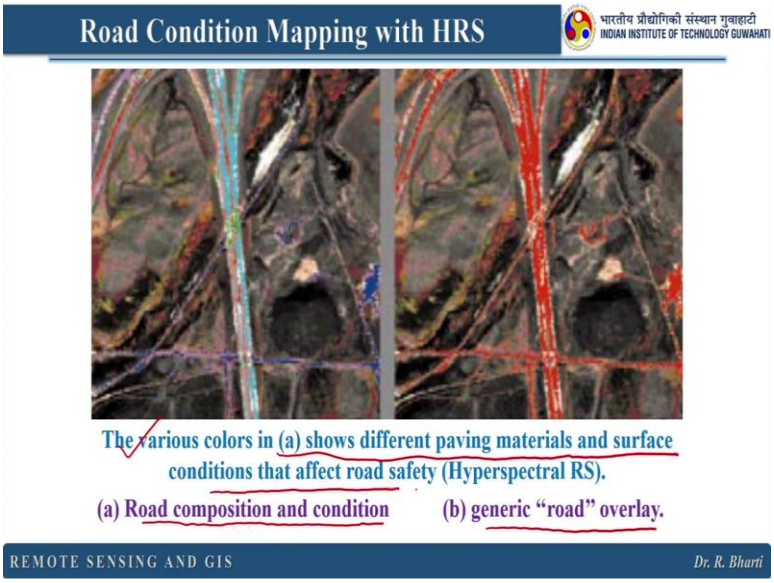

And proved this method can be used in this application. So, here you can see the (a) which is this one. So, it says road composition and condition (b) is generic road overlay right. So, the various colour in (a) shows different paving materials and surface condition that affects road safety. So, this is from hyperspectral remote sensing.

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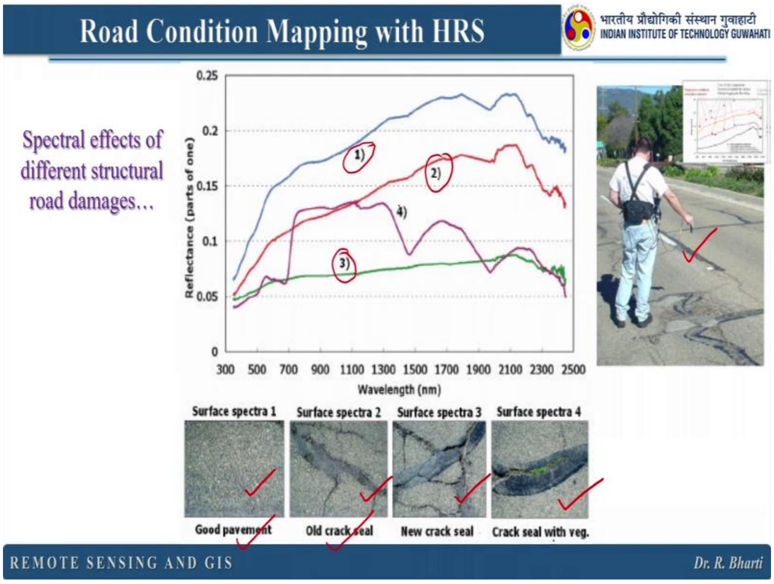

Right now, let us understand how sensitive these spectral responses are right. So, you can see here, this gentleman is capturing the spectral behaviour of this particular area or this particular road. So, you can see, he has used good pavement, old crack seal, new crack seal with vegetation, right. And for all of them, he has reduced this spectrum. So, the first one belongs to good payment (2) belongs to old crack seal.

(3) belongs to new crack seal, which is this one and forth belongs to crack seal with vegetation which is this one. So, when this vegetation is coming into the picture vegetation spectral feature is also coming here, right. So, it is very easy to identify the condition of the road using this hyper spectral remote sensing in another example.

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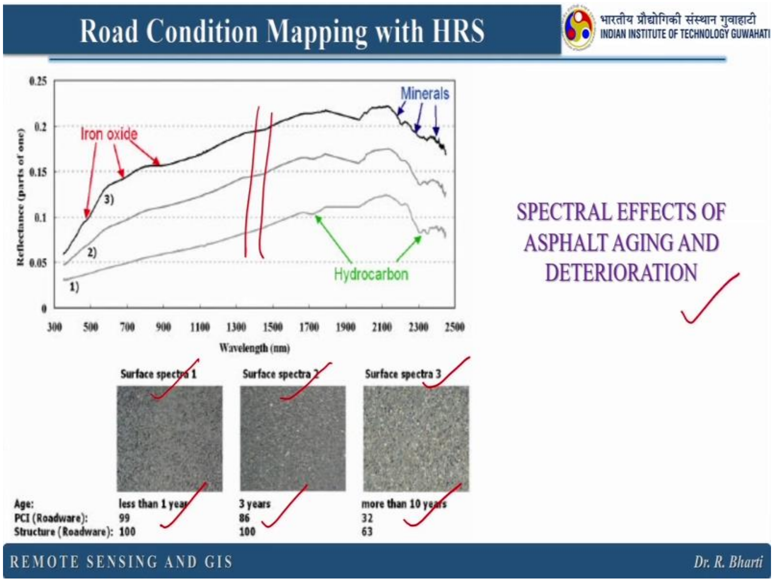

You can see surface a spectra (1), (2) and (3) were collected and this is for less than one year, this is three years and this is 10 years. How these spectras are changing and how they are different from each other. So, this can be analysed and you can easily find out what is the condition of the road using this particular technology. So, here it is to highlight spectral effect of asphalt ageing and deterioration right.

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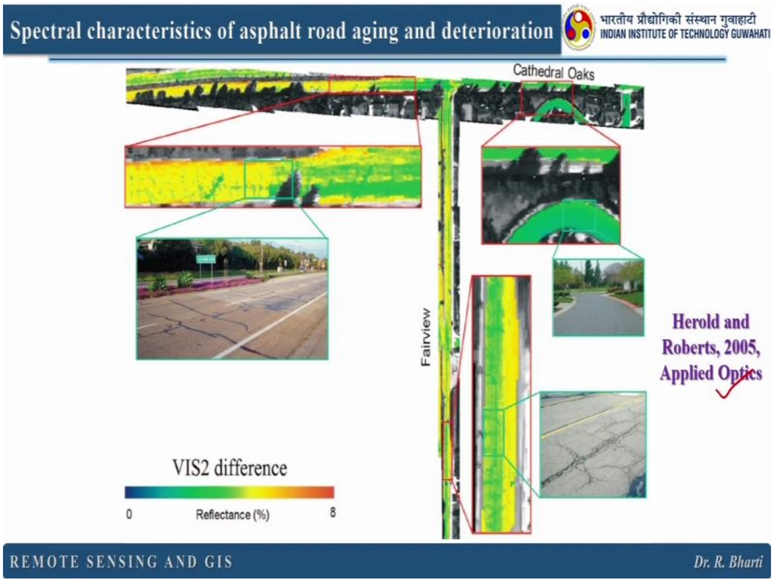

This is a very interesting work if you are specifically interested in Transportation Engineering, you can just read this particular paper explained beautifully, how well this hyper spectral technique is used in this particular problem, right.

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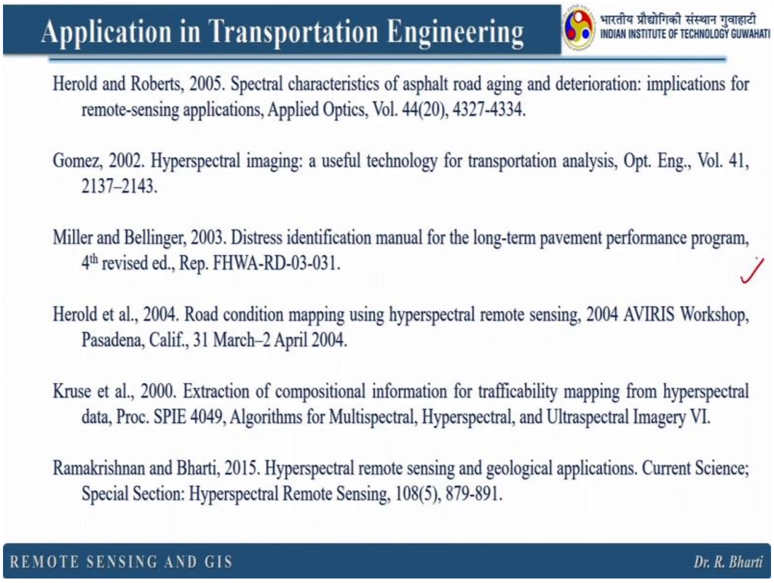

These are the references if you are interested in using this hyper spectral technique in Transportation Engineering. You can just go through them and you can find now, the next application is hydrocarbon exploration.

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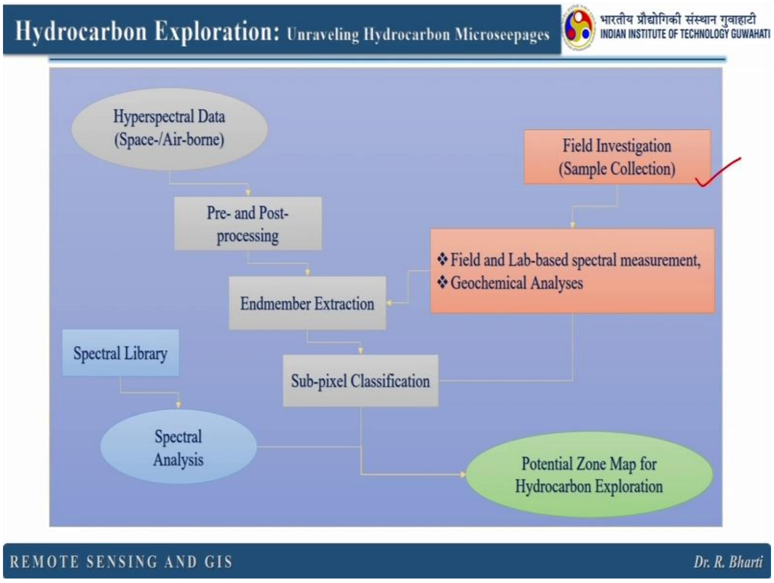

Where I have given the methodology in this particular methodology. You can see, it starts with hyper spectral data, which can be captured from space or maybe from airborne platform, then these datasets need to be pre-processed and corrected for all the errors. Once you are confident that all the errors have been removed, you can perform the end member extraction and once you do that, then you can perform the classification.

And that will give you the classified image with respect to that end members right. Same time you have to perform field investigation and the field spectra will be measured and the collected samples will be analysed for the presence of hydrocarbon. Once you have all this results, then you can use this spectral library and you can merge all these information together to analyse or to identify what is the potential areas or what are the potential areas for this hydrocarbon exploration.

Here one thing which I have not mentioned that hyper spectral remote sensing can be used to identify this hydrocarbons indirectly, because whenever there is a micro seepeges because of the emission of the gases and the leakage of this oil on this surface, you may have some signature in terms of vegetation distress or maybe the clay mineral formation right. So, if you are not able to detect them directly.

You can track these proxies to identify whether this area is having any kind of micro seepages right. So if you can do that, then you can justify using this field investigation this area and then you can conclude that these are the hotspots which are potential for the hydrocarbon exploration right.

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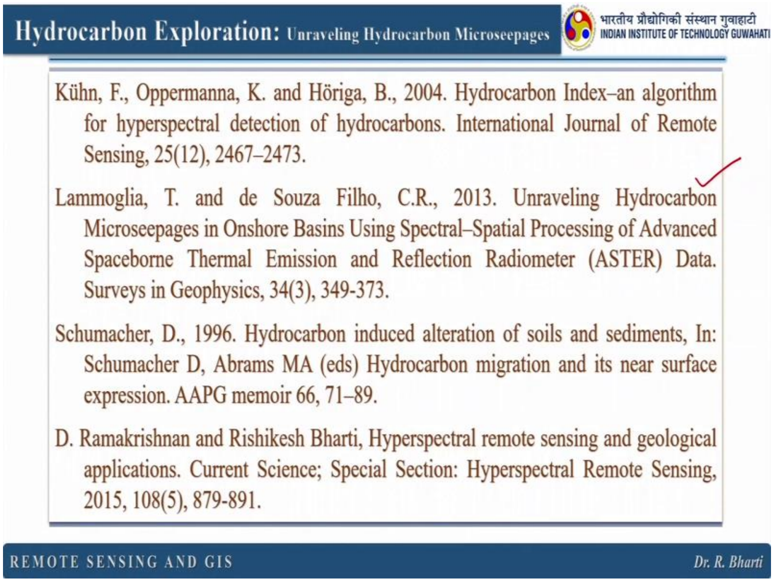

Here I have listed some of the papers from this particular application. So, if you are interested, you can just go through them. So, that is all for today will start next topic in my next lecture Thank you.