Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture – 37
Mineral Exploration (Contd.)

Welcome to today's lecture. We will continue our discussion on the principles of remote sensing trying to get a little bit of overview, not getting into the very detailed of the digital image processing or much detail about the procedures. Only we will be focusing on the utility as far as the mineral exploration is concerned.

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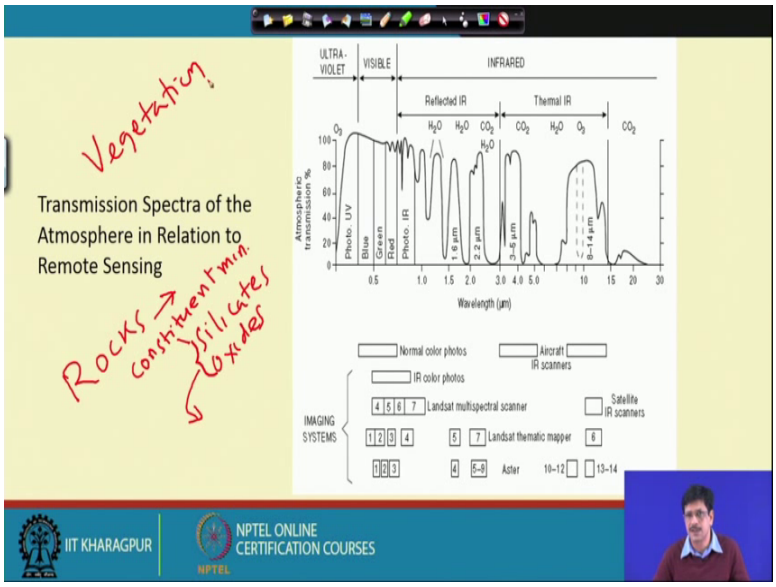

So, continuing with the previous discussion. Let us have a look at the interaction of the suns electromagnetic energy with the atmosphere and that will give us a broad guideline. Here as you could see the entire spectrum up to 30 micrometer is shown and we generally confined ourselves to about 3.5 micrometer or.

So, if you look at the ranges within this, then we have seen. We will be not be considering the ranges over here. So, you could see our lands at multispectral scanner. The band 4 corresponding to about starting from 0.5 band 4, 0.5 band 6 and band 7. Here is the multispectral scanner. We could see the thematic mapper. Here is the band 5 and here is band 7 corresponding to longer and in the reflected infrared wavelength range and what we are seeing on this electromagnetic spectrum of the Atmospheric Transmission

Spectra is that we get certain lows. All which are basically the troughs. Which is shown here in this range 1 and this range here is 2 and 3, 4 like that.

So, they all result because of the absorption of the electromagnetic energy by the moisture and carbon dioxide in the atmosphere. So, this part of the electromagnetic spectrum cannot reach to the spectrometer which is installed in the satellite at a remote height. Keeping. These are the guiding factors for designing of a particular spectrometer or the interpretation of spectra and in what wavelength range we are looking at them and what interpretation we can make from them.

And. So, this is the aster band and this is from up to this band is thermal IR band. It goes which is far better utility and. With this if we. Now, what remains at our, what would be the principles that will be guiding the remote sensing technique? Fundamentally we understand the interaction of the earth objects with the electromagnetic energy of sun and they will be reflected and emitted in different wavelength ranges and part of it will be absorbed by the atmosphere.

And they are even without the major absorption peaks what we get for water and carbon dioxide. There will be some amount of attenuation will always be done by the atmosphere and the what the satellite will receive will have to make some necessary corrections for all these atmospheric corrections and then the final that the data that will be received by it could be utilized will be analyzed in terms of the presence of the earth objects.

So, what remains at the back of it is that we can only understand this if we do have certain guidelines coming from the laboratory study of different earth objects. So, our earth objects have been placed at different rocks, soils or vegetation. The earth objects will be the visible rocks means their constituent minerals, I we could study the spectral characteristics of the constituent minerals of such rock. These constituent minerals are mostly the silicates and sometimes there are some specific type of the silicates or oxides which could be possibly well characterized in the laboratory so that they could be better understood in the digital images that are produced from the electromagnetic spectrum.

That is received by the satellite camera. Sometimes these oxides and silicates are very much associated with ore formations like we have studied during our hydrothermal processes the one of the very important characteristics of hydrothermal deposits are the

presence of the hydrothermal alteration zones. Such hydrothermal alteration zones are characterized by hydrothermal alteration minerals. Which are generally the oxides in the hydrous silicates, which are the different types of clay minerals. Which we saw them forming through some specific reactions in environments like porphyry copper deposits or a scorned or in low type gold deposits and. In fact, every hydrothermal deposit has it is own characteristic alteration zone alteration characteristics.

And then their interaction with vegetation is also another very important factor. Because in most part of the earth which is covered by the vegetation what we essentially the electromagnetic spectrum that we get is of for the vegetation. So, if we can interpret them in terms of a characteristics that is manifest in by because of the presence of a mineral deposits and imparting certain geochemical stresses on them. Then they can also be very effectively utilized for mineral exploration.

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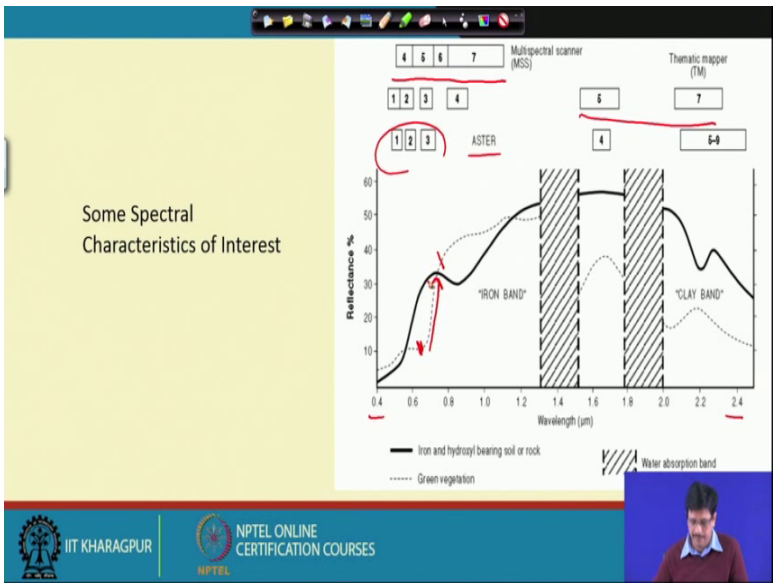

Here is an example. Here the spectra is again shown from 0.4 to 2.4 micrometer wavelength and these band at 1.4 and near about 1.8 is essentially the water absorption band here. And we have studied this reflectance spectra of these typical materials. Let us say for example, this thick line is for the iron and hydroxyl bearing soil or rock and the dotted line is for the vegetation.

So, this kind of spectra are going to give us the idea and here for our are quick reference which we have also given the spectral ranges of a multispectral scanner, the thematic

mapper and aster ranges or aster rib lengths. So, as it looks like that any particular material like an iron and hydroxyl bearing soil or rock has it is own characteristic spectra. Which will also be the same when this object is actually reflecting the earth's electromagnetic energy and the reflected wave is being received by a satellite spectrometer.

So, similar kind of spectra would be obtained from them and we have to just design or we have to just identify such spectral characteristics. So that we can say that this particular area and of course, they have to be present within the pixel size the ground resolution that is there inherent in the design of the camera and if supposing that we have enable to keep a get improved and more and more improved round resolution, then it will be possible to detect the presence of such material.

And then another interesting feature over here for the vegetation spectra can be seen that the vegetation reflectance spectra. We see just about the edge of the visible range about 0. 6, 0.7. Within this there is a sudden increase in the reflectance from the vegetation. So, this will see in very interesting and an important indicator as far as pendulous rotation is concerned.

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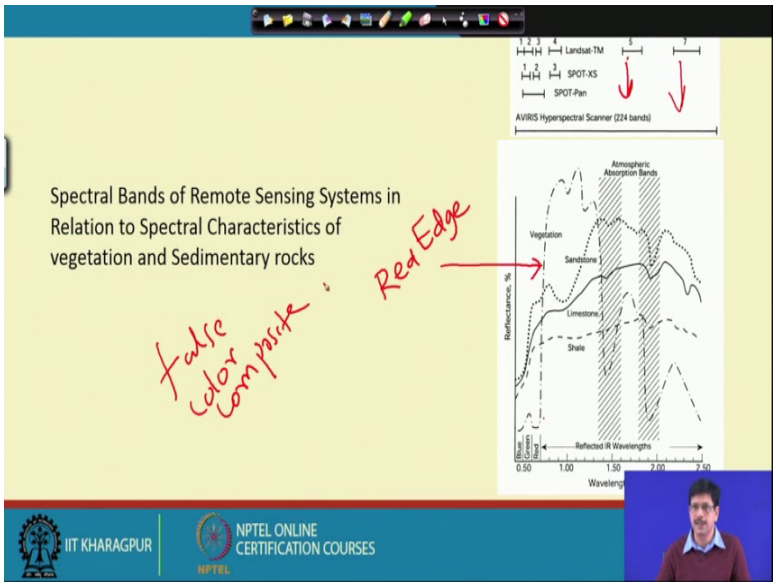

And here this some of the spectral bands of some characteristic mineral. Here is as we saw before, this is the spectral band for vegetation reflectance spectra which is just on

edge of the visible range of the electromagnetic spectrum. That is why it is called as the red edge.

And other than that these are our some of these chosen rock types, sandstone, a limestone and a shale which are their spectral characteristics are shown here and with the atmospheric absorption band shown and also the spectral bands of the satellites like landsat TM are also shown here say for example, if we just correspond this is the band 5 of a thematic mapper and this corresponds to a spectral characteristic of a vegetation over here or for a limestone or for a sandstone shale here.

So, we could see that they could be very well discriminated and even if individually if they are not able to be discriminated sometimes when we combine. So, this is the 7th band of I have the thematic mapper and this is the 5th band of thematic mapper and this is the 3rd band.

So, who are generally will also it will be relevant to just make a mention that all these spectral data which are recorded in a satellite camera, which is a spectrometer are the data stored in different bands and in the images could be prepared in these different bands come individually or sometimes they could be color coded and they could be superimposed on each other and all the bands could be mixed up and then color coded and what we get is a college false color composite type of composite images.

We assign certain combination of the blue, green and the fundamental colors. So, more important than that is the analyzing the spectral data in such kind of discrete bands and see whether how they could be useful for us.

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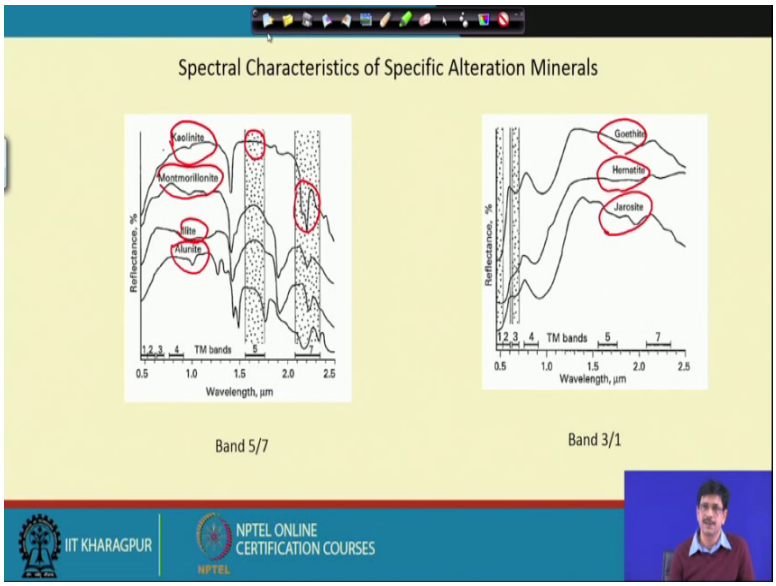

So, here we could see very clearly some of the interesting features. For example, keolinite is a very common mineral in a argellic alteration zone in many of the hydrothermal mineralizations. For example, porphyry copper, montmorillonite is a clay which is present in many of the alteration zones illite. This kind of alteration zones are present sometimes in the VMS deposit and kaolinite and alunite as you have seen is a potassium aluminum. A potassium aluminum sulfate is very characteristic of the advanced argillic alteration in a porphyry copper deposit.

And here these 2 bands which are characteristically shown here is the band 5 and band 7 of thematic mapper. So, we saw before the band 5 and band 7 are both in the reflected infrared range and if we could just see them individually. For example, if we prepare an image out of the band 5 of the spectra that you have received from anywhere from the surface, then it will possibly not be very easy to discriminate these clay minerals. For example, take the case of kaolinite. In kaolinite, in band 5 we get a reflection high somewhere in this region corresponding to band 5, but a low corresponding to the band 7.

So, now the thing is that if we could somehow make a combination of these 2 bands. For example, take a ratio of band 7 by band 5, a band 5 by band 7 either the 2. This numerical value for that will be much more magnified compared to the image which is taken on an independent a single band like a band 5 or band 7. Similarly these are the

iron oxide minerals, goethite, hematite these are essentially the ones which are associated with the gossans on the supergene oxidation of sulfide ore bodies which we saw before and jarosite which is also a very important sulfide mineral. Which forms in very acidic environment in acid mine drainage areas or sometimes by oxidation of pyrite also an important indicator mineral of a very acidic and advanced arsenic type of a situation.

So, keeping this at the back of our mind if we look at this, this gives us some principles without getting much into the mathematical details of their processing of the intricacies of the acquisition of the data and how the data stored and all these which constitute the subject of remote sensing when they are studied systematically as a subject.

So, these things are taught, but here we will only be concerned about how we are utilizing it for mineral exploration. In the context of hydrothermal mineralization that such kind of mineralization can be very well characterized by the more sensing is clear from these series of diagrams that we have seen.

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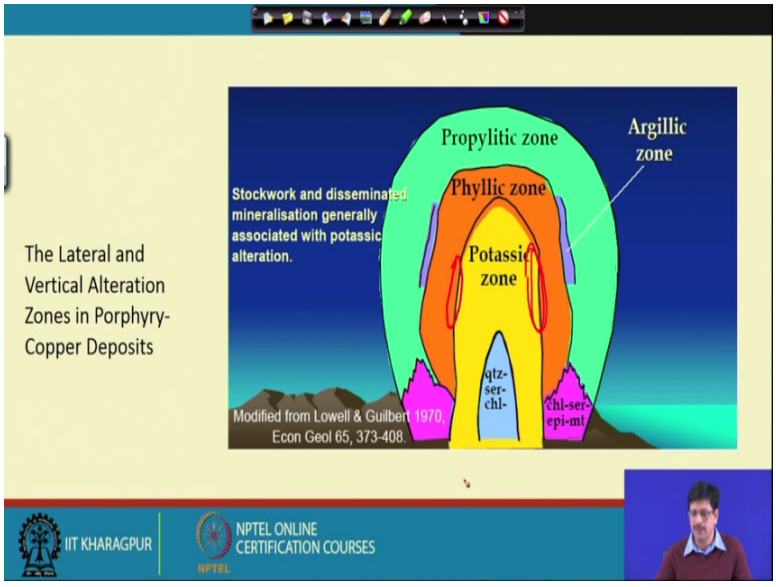

Now, we could possibly recall and identify this is a schematic or a proposed model of the alteration zones around porphyry copper deposits. It is a very generalized idea taking the porphyry copper deposits that occur all over the world and we know that the alterations are arranged in a journal pattern which could be in terms of a vertical or lateral, because, if we move from the core to away, we also encounter the potassic, phyllic and propylitic

zone and the argillic zone and also if we move vertically also. They basically called as the lateral and the vertical alteration zone and zones around porphyry copper deposit.

So, if there is such porphyry copper deposit and the ore is actually on the boundary between the potassic and the phyllic zone. This is the richest part of the ore and it might not have been exposed to the surface in many of the cases or there could be many such distortion of changes to this very idealized alteration pattern. As we discussed before sometimes a particular alteration zone could be over printed by later alteration and many complications could be there, but looking at the generalized picture.

So if this particular deposit is whether or it is exposed to the surface just the alteration zone like.

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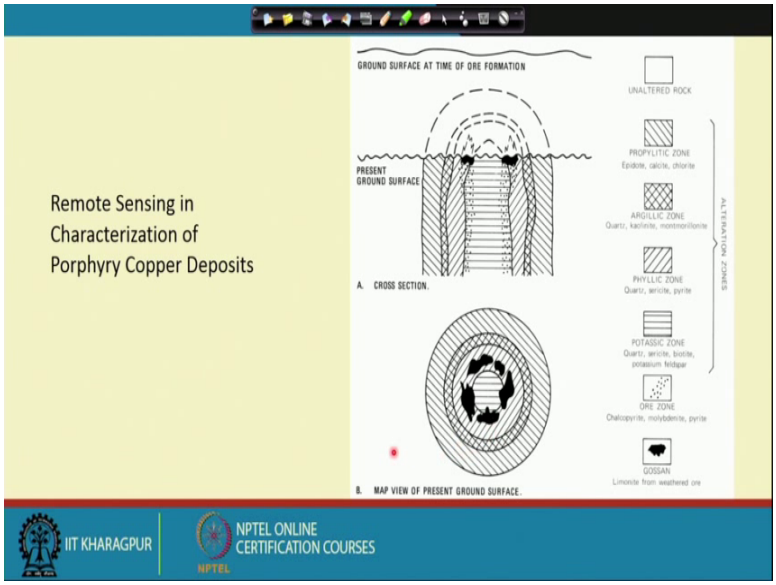

Like this is schematic diagram of that. There is a porphyry copper deposit and suppose it is altered now and this is the present surface exposed. This is the ground surface. The time of the ore formation, this is the present ground surface and now this kind of. So, this is the propylitic zone, this is the argillic zone, this is the phyllic and the core zone which is if we look at it at a plant view then it would look as if they could be identified and we know that their characteristic minerals like mica sedicite of the kaolinite, which is on the argillic zone or advanced argillic zone illuminate.

So, here the symbol is shows here is the propylitic zone. Which is the outermost zone. This is the argillic zone and this is the phyllic zone and this is the potassic zone and this even we can when the ore body is exposed to the surface, what is shown here? We could get some of the supergene oxidation taking place and the ore body getting sufficiently oxidized and the presence of gossan could be there and that is how it is depicted on this diagram which is a plan view of that.

So, correlating with the previous spectra that you have seen of alteration minerals, it looks very possible that if they happen to be and such kind of alteration zones happen in scales of tens of meters and if we have the Missouri obtained or acquired with such kind of a ground resolution, then it will be very possible to discriminate the different or to first of all to identify that such alteration zones exists and also to discriminate the different alteration zone and this gives us the idea that what exactly we are looking for.

We are looking for indications of an ore body ore deposit. That is hidden below and also to some extent. We also know what kind of deposit it is likely to be.

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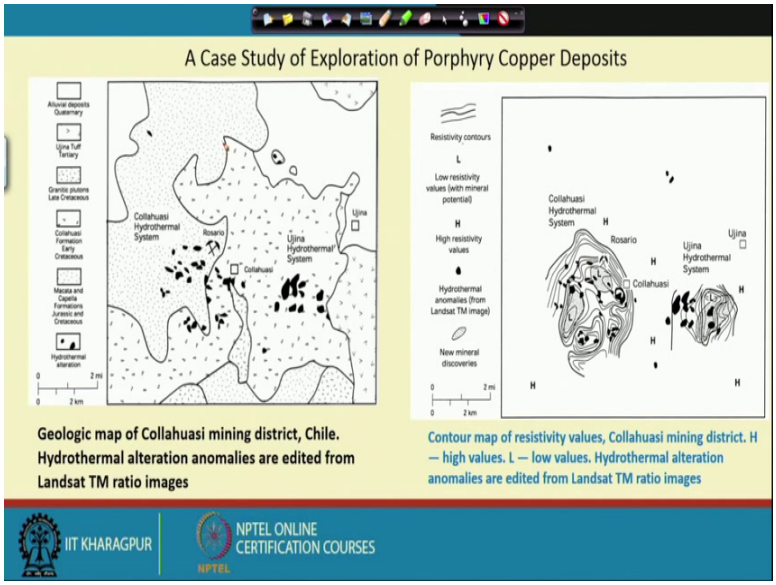

So, this is a case study that has been taken from one of the publications. This case study. We all know that the Andean region, the Chilean Andes has a highest frequency of occurrence of such porphyry copper deposits and the area where the famous chuquicamata the (Refer Time 18:47) and the LTM kind of deposit the major porphyry copper deposits.

So, this area or this map which depicts which has been given here on the left hand side is the map of an area where there is one deposit, known deposit which was there previously in worked as the Rosario deposit and the rest of the areas were not known to be containing any other porphyry copper deposit. So, even one thing we have to keep in mind that even the porphyry copper despites the frequency of occurrence is quite high in such kind of region, but their surface expressions. They are presence.

So, they are not necessarily all the time exposed to the surface. There soil covered and they need to be explored. This is the example. Now, here on this according to the thing that we are seen here, this is the major granitic pluton and this is the later a Jurassic formation which is overlying it and these black ones are the hydrothermal alteration zones. So, it is actually the collahussi mining district in Chile where the hydrothermal alteration anomalies are edited. Now, this particular area these alteration zones which are shown here this black alteration zones are actually inferred from the thematic mapper imagery by taking such kind of the band ratio images and were plotted.

So, such kind of hydrothermal alteration features would always indicate that there is a height this hydrothermal system which was active. 2 such hydrothermal systems were identified here. This is the Rosario hydrothermal system. This is the area with the collahussi mining district is and this is the area which was not previously known to be containing any porphyry copper deposit. As state as we have introducing the subject before that any particular discovery is does not result from just every only single technique methodology. That is gives us a most definitely vindication and based on which we infer the presence of any mineral deposits.

So, on the right this area was subjected to the electrical resistivity survey. We know that when the area any zone condense is hydrothermal alteration minerals, the clay minerals. There the electrical resistivity is definitely is likely to be decrease compared to the dry rocks which are in the surrounding. In most of the cases even we will be also seeing such case studies. Again electrical resistivity, electrical method also comes out to be a very efficient tool to indicate presence of hydrothermal alteration zones.

So, what we are seeing here these 2 areas the Rosario area and the Eugenia area and the Chilean Andes could very well be their presence of such kind of alteration zone is also supported. These contours are the resistivity contours, where the l stands for the lowest.

So, the values are going lower and lower and such kind of zones very low resistivity zones where what they marketed, which are very much coinciding with the alteration zones which are delineated or though which are identified by using the Landsat TM imagery by the taking the ratio of the bandses, band 1 or band 5 and 7.

So, this is an area where. As it happens. After it was confirmed from 2 independent methodologies, 1 is using the satellite image data and the resistivity survey. The presence of such hydrothermal alteration zone were confirmed and the later on follow up drilling operations discovered hues porphyry copper systems within the areas which it was not known to be existing and it can be cited as one of the success stories utilizing remote sensing technique for discovery of mineral deposit.

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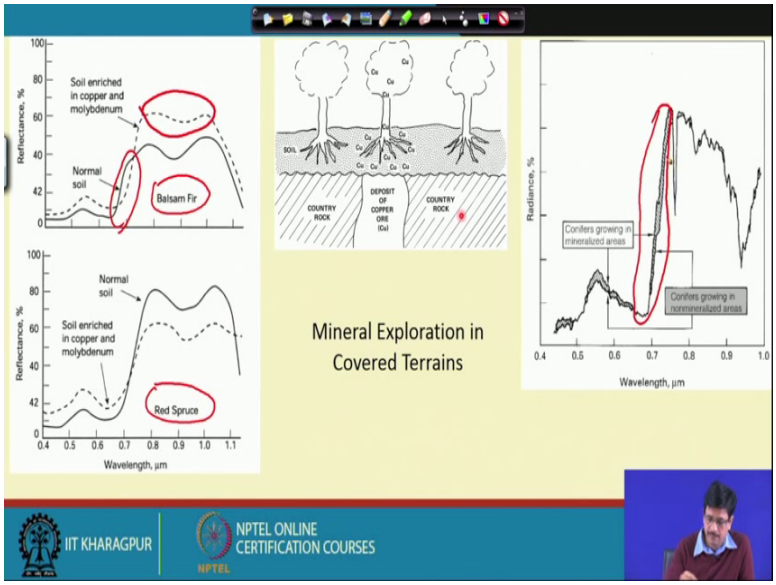

So, this is also again very interesting. Here we are talking about the same situation that what exactly how remote sensing can come to, can help us in exploring for regions which are under cover and at the beginning, we reminded ourselves of the very fact that most of our exploration efforts today are actually targeted towards detecting ore bodies which are under cover. Because most ore deposits which were exposed in the surface have mostly been or the large such deposits which are exposed in the surfaces all been discovered.

So, we would also have all the time to look for indications for deposits which are subsurface. These are some of the examples here. In the reflectance spectra of vegetation

we discussed about the red edge which is here. This is the red edge. So, this red edge is a very characteristic or if we take the total vegetation as a whole together, then we see that this is an example of this thick line representing the spectral characteristic of vegetation which are growing on a normal soil and the dotted curve is showing the vegetation. The vegetation which is growing on a soil which is having copper and molybdenum mineralization

We could clearly see that their spectral characteristics are different. Where the reflectance of that vegetation coming from the soil which grows on copper and ridge soil is higher than that of the vegetation which grows in a soil which is not enriched with Copper River situation is also observed here depending on. Is they depending on this. So, here it is a plant species which is balsam fir and here it is the plant species which is red spruce.

We do not have much of such Indian example at this moment to show so, but in principle we can always see them as what underlies the utility of remote sensing is a technique for mineral exploration. So, here exactly the opposite is happening. Here it is normal vegetation the reflectance spectra of vegetation coming from a normal soil and the soil which is enriched in copper and molybdenum.

Only thing is that the plant species are different here. So, this reminds us of the fact that such kind of signatures are actually not unique. The signatures will be very much dependent on the type of a plant species that are going and they constitute a major component of what we label as a biogeochemical survey by geophysical survey. Where the individual plant species characteristics also is important. Which is the cartoon is shown here, which shows that the vegetation characteristic for a soil which is just above a deposit of copper.

So, this soil here is likely to be enriched in copper and. The tree the plant which is growing here is also likely to have a greater uptake of the metal and is concentrated in it is different parts. For example, the chlorophyll of the plant which is exposed and from which we get the ready of the electromagnetic signature compared to the plants which will be growing on soil, which does not have that any mineralization which is below.

This is also an interesting situation. Here we were discussing about the red edge. This is the red edge. The increase in the reflectance of the vegetation just at the edge of the

visible part of the electromagnetic spectrum and what we essentially get sometimes is this red edge.

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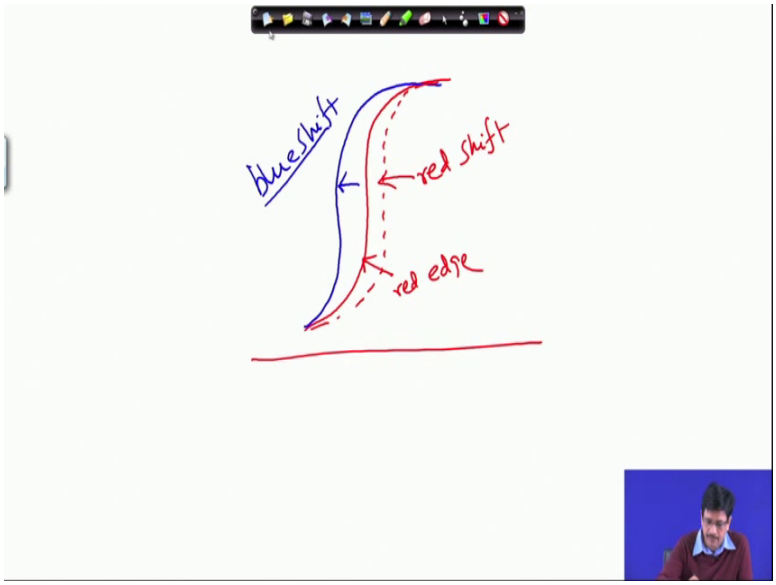

This red edge which we are seeing here like this can be shifted to a shorter wavelength and in that we call this red edge as undergoing the blue shift and at times it can shift to a longer wavelength in which we can call it as a red shift.

So, this red edge characteristics of the vegetation, they in the reflect inspector of the red edge is a very interesting feature which also is of a great utility for mineral exploration and because sometimes it is observed that this red edge also changes it is position during the phonological cycle of the plants in the deciduous forests. Which grow in the subtropical or monsoon kind of climatic zones such as in India.

And the one which is shown here is the red edge. As we could see that this a particular type of plant the conifers which grow in mineralized area undergoes a blue shift and then compared to the normal red edge in conifers which are growing a normal area. So, even such kind of very minute changes in the position of the red edge.

It could be detectable and then detectable by very involved and sophisticated analysis of the spectral data that we acquired from the satellite imageries and. They can be a very good use for mineral exploration. We will continue our discussion on such case studies

and usefulness of such or these use of such kind of methods in exploration of different types of deposits in the next class.

Thank you.