Mineral Resources: Geology, Exploration, Economics and Environment
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Lecture – 40
Mineral Exploration (Contd.)

Welcome to today's lecture. So, we just concluded our discussion on the genetic models and their user utilization in formulation of exploration criteria for taking the example of the volcanogenic massive sulphide deposits and such kind of genetic models in many other important genetic types such as the low type gold deposits or the sediment hosted massive sulphide deposits, volume pick, the IOC type of deposits all these genetic models whatever state they are in terms of their formulation can be translated into formulation or exploration criteria when we understand the critical processes which operate in a much larger scale. Then coming down to the district scale and deposit scale processes. Which actually the vital in giving raise to the deposit in it is form, that we see in it is enriched form.

Today we will be briefly discussing about a method, this geochemical method of prospecting. We will just have a brief idea about the method and see how much we could discuss about it, how much you can learn about this method and getting into the fundamental principles, because, most of the; some amount of discussion which we had before as regards to the geochemical prospecting or exploration. Their present state in which we use them, they have come of age.

Because of availability of very high precision analytical equipment by which we have been able to analyze to very low concentrations in the part of parts for billion, parts for trillion and we target to generate geochemical anomaly maps on local as well as the general scale and in this exercise actually what we intend to generate either geochemical anomaly map and we will see how it could be in different scales, but before we actually go on to pick up a sample from anywhere on the earth crust in our search.

For an ore deposit, we need to have the basic background information about the deposit characteristics in terms of some preliminary idea. It is a disposition in the crustal rocks and at least in the way we talk us sometimes undercover to some geological information.

Which is obtained during in the percolation and the detailed survey stages, some idea has to be there with us.

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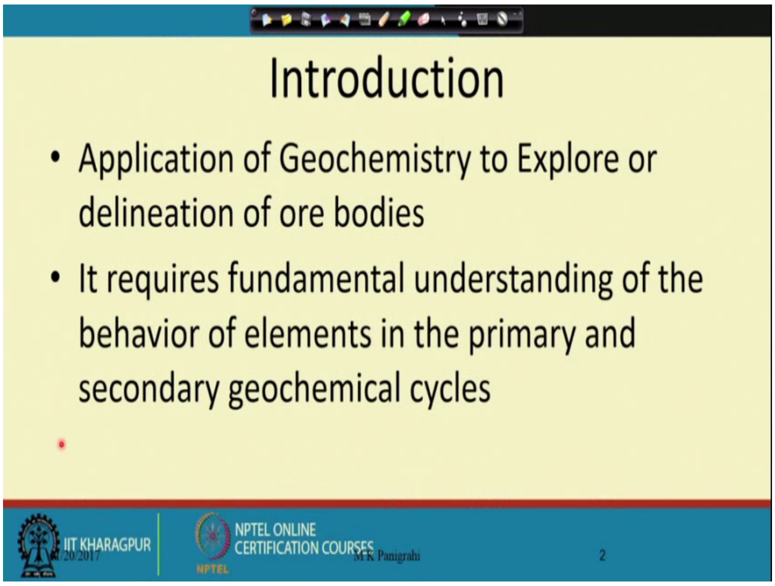

So, here; this is as we discussed before that is application of geochemistry to explore for delineation of hidden ore body which are underlying undercover and it requires fundamental understanding of the behavior of elements in the primary and secondary geochemical cycles. The primary geochemical cycles are the first stage formation of the ore bodies from an by the process of either a magnetic fascination or a hydrothermal deposit, but once the deposit is formed the petals that are enriched in the deposit will always tend to migrate under concentration gradient to different media like within the rock itself, within the rock matrix or within the covered soil pore spaces are filled up with water and they enhance the mobility of these metals and they get dispersed in the soil horizon which are ever in the plants in the water bodies and so on.

And we divided them into different geochemical exploration. The geochemical constructing types such as litho geochemical pedo geochemical or soil geochemical hydrogen chemical and biochemical; so, today the discussion will be mostly focusing on the soil geochemical exploration because, it needs some fundamental understanding about soil because soil is the media from which will be sampling and the.

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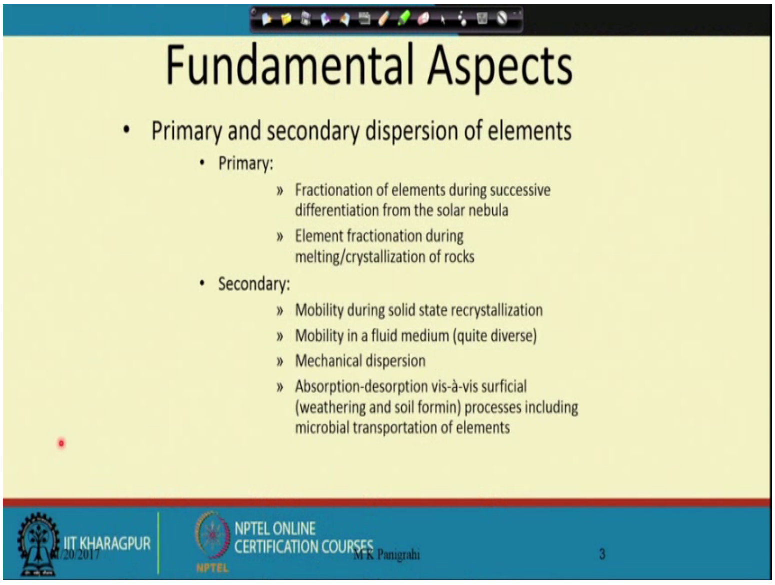

So, here the fractionation of elements during the successive differentiation from solar nebula we discussed before and that was the preliminary stage first stage of dispersion and element fractionation and during the melting of crystallized on the rocks. This goes in the primary process.

And secondary the mobility during solid state recrystallization, mobility in the fluid medium which is the main focus as well as the exploration is concerned. Because mobility during solid state crystallization can always take place during the metamorphism of an existing ore body or there are some ideas that are coming up that evens the already formed sulfide ore body could possibly undergo go some amount of melting.

But the process how efficient it is to redistribute or enhance. So, further enrichment of the ore bodies in terms of rich ore is not very well constant edge of now and the mechanical dispersion that takes place by the mechanical disintegration of the ore bodies and the absorption desorption by a vis a vis surficial processes including microbial transportation even though we do not have much of scope into the details of the microbial process, but the adsorption desorption process play vital role in the secondary mobility of the metals.

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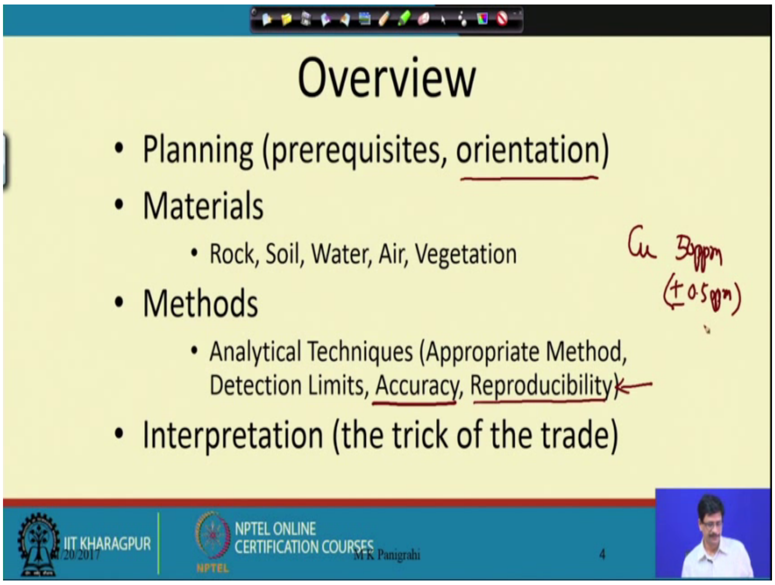

Any geochemical prospecting program it requires a detailed planning, the requisites and orientation or basically what we understand by this orientation will discussing a little bit of details. The materials that we are trying to analyze the Rock, Soil, Water, Air or Vegetation; the methods the analytical techniques, appropriate method, detection limits, accuracy and reproducibility, interpretation and that is what is a trick of the trade.

There could be textbook knowledge will always or they any standard information about the geochemical prospecting will always be referring to these parameters such as accuracy and reproducibility or precision and accuracy these are the 2 terms which very widely referred to any analytical any literature dealing with analysis of geological materials accuracy. We understand that whether we use a method. The results that is coming up from the particular equipment by whatever analytical protocol that we are establishing whether this analysis should be accurate or not.

So, this accuracy can only be checked by many cross or analyzing in many different instruments, many different methods and many of the analytical protocols are very well established. Like X-Ray, fluorescence, spectrometry or atomic absorption spectrophotometry or inductively coupled plasma mass spectrometer. So, these are the equipment where by use of reference standards and this kind of analysis are produced to fair degree of (Refer Time 08:10). It is goes without saying that without checking of the accuracy any data that has been generated is not usable and for any meaningful interpretation, for the geochemical prospecting program.

And reproducibility is the thing a factor by which we machine step the analytical procedures, analytical protocol stability and the range by which a particular and the result is reproducible when replicate measurements are taken by that machine and that is one of the important parameters. That we report for example, we report a certain metal in this in the form of ppm say in a rock we analyzed for copper and we report that copper is present in 50 ppm and we have to give you the give the figure as 2 plus minus of what? It is a plus minus 0.5 ppm. Possibly would make it a very good analysis or can also put in terms of 5 percentage and 5 percent, 2 percent or 1 percent. This is all determined by regular routine analytical protocols and interpretation of the chemical data when they are translated into the form of geochemical anomaly is actually the trick of the trade.

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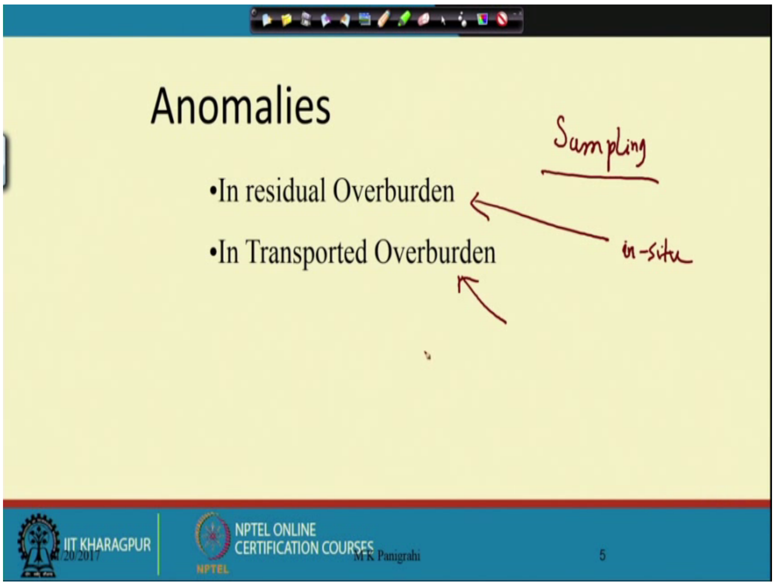

Whenever we talk about a geochemical prospecting programs geochemical by using analytical technique and what remains there is the most fundamental aspect with the sampling. This is one of the most important aspect of the geotechnical prospecting program because it is not only that the sampling has to be representative any biasness in the collection of samples will lead to erroneous result and in addition to that there must be some amount of sampling strategy, which also should be adopted to see to it that what we have sampled is actually will be telling us they giving us the right information. I will just discuss in a little bit while now.

Whenever we talk about a soil and that we are taking a sample of soil which is an overburden and several feet, sometimes several tens of meters in thickness. Which are the product of the rock weathering and perform the overburden. So, these soils generally can be of 2 types. 1 is the residual overburden. What is called residual overburden? Residual overburden essentially means that the soil has formed in C2 means wherever we are finding the soil is actually the product of degradation of the rocks which is just lying beneath the soil horizon and in that case the soil will inherit the characteristics of the rock from which it is derived.

Although, the details of the soil forming process is beyond the scope of the discussion here, but at least we must understand what the soil type is in a particular area or the soil profile and the other type of the soil that we see that we might see in any particular area could be transported overburden and this actually is a tricky affair whenever we are analyzing soil sample from an area for interpretation in terms of a geochemical anomaly to detect hidden ore body. It definitely depends on whether we have sampled the residual overburden or the transporter overburden.

Transporter overburden essentially means that the soil which is observed on any particular area lying over the rock is actually not the product of the degradation of the rock which is lying below, but they are transported from the soil formed in some place and they have been transported by the action of gravity or by some transporting agent and deposited on the area where you are seeing them.

So, in principle the transported overburden will not be reflecting any of the characteristics of the terrain where in terms of the hidden ore body, but then it is not a very easy job to distinguish between the overburden residual for the transported. We can just have a brief idea from this.

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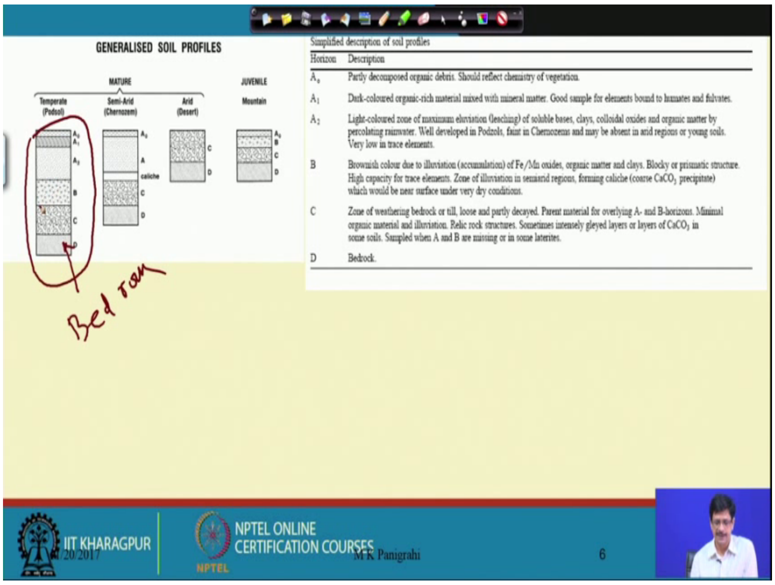

So, this shows a generalized soil profile and as we all know that the soil profile is going to be different from different geographical domains and for example, the first column over here is the soil profile which develops in a temperate humid climate is the person and it has the soil horizons A0, A1, A2, B, C and D. Normally the D refers to the bed rock. Which is and this of course, corresponds to the residual soil. It is for our classification scheme and the immediately layer which lies above which is the C zone. Which is the zone of weathering of the bed rock or till and their loose and partly decayed and they do preserve the texture of the rock to some extent.

The parent material for the overlying A and B, they are the parent material because if this D is essentially unweathered or undegraded material. Then it is essentially B and the M horizons are essentially derived from the C horizon. Where it mimics the rock structure sometimes there the some of the registered oxides. They possibly stay back in this particular region and then the B layer is the brownish color due to elevation this accumulation of iron and manganese oxide and organic matter in clays and the blocky or prismatic in structure, a high capacity for trace elements most of the trace elements get (Refer Time 14:25) in this zone.

The zone of elevation in semi arid regions forming caulis or this calcium carbonate you could just be a comparison. So, here the situation is such that the A0 zone actually is mostly humus reach and partly decomposed organic debri and it only reflects the it does not reflect much about what is the subsurface condition is and this A1 also it is dark colored organic rich material next with mineral matter.

And then this A2 layer which is light colored zone of maximum elevation where; that means, maximum leaching has been taking place in this zone and this content the reach plays colored a lock sides and then the organic matter were filtering rain water. These well developed in ore zones in the humid climate and so, the soil profile which is shown in a temperate kind of a climate will be different from the soil profile which is occurring in a semi arid region. In which will not have a B layer and in place of that will have a calcium carbonate rich Calais. This is an arid desert region is where we will not be having any of this A0, A1 or A2 zones and this is a juvenile formation of just below among the foothill region. Where these zones will be developed, but their thickness will be different, they have less. Even though these are not to scale in a normal temperate climate we could expect this kind of a zonation of the soil profile and also the thickness by which will be present.

So, the importance of the soil profile is that whenever we are planning a geotechnical exploration program geochemical prospecting program we must be very sure exactly what we should be sampling. Normally the A0 or the A1 type of zones depending on they will be bearing and from place to place from different geographical domain. So, samples have to be a necessarily be taken from the A2 or the B horizons. If we want to analyze or if we say that this soil characteristics will be actually reflecting on the subsurface hidden ore body of any particular enrichment of any particular metal.

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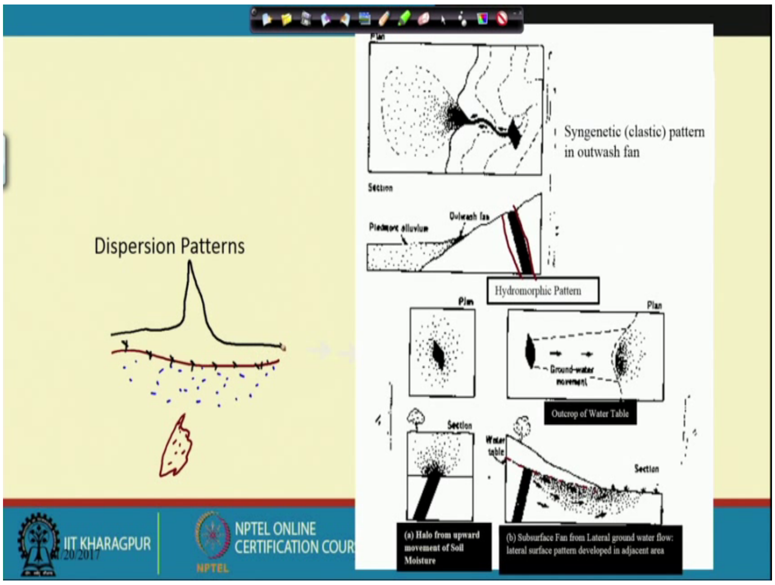

These are some of the some ideas can be obtained from looking at these figures which are pretty old, but then still very informative regarding what exactly happens and how do we distinguish between transported and residual overburden. So, this particular figure where one is shown on a plan view and the one on a section, this black body is representing the hidden ore body and is on a sloping surface and this dotted curves at the contour lines and it shows a normal weathering process by which the ore body is getting weather and it is forming a fan shaped dispersal pattern below the foothill and in which case the element of interest will be present only in a very larger area, but in a much more diffused manner without keeping any sharp anomaly in anywhere in the area and so, these are the different types of hydrographic patterns.

One can expect this is a situation in who is the region ore body at the section is shown here and this is a situation which will be happening if there is a ore body and the metals have migrated or have diffused through in the concentration gradient and will be dispersed in this and if we take the soil sample from here, we are likely to get some signal from there and here it shows the pattern in the with respect to the water table.

And the cross section is more informative here and this dotted line here is the water table and since and this is the surface and water table has water table. The ground water generally flows in a hydrostatic gradient as has been shown by the arrow and this particular groundwater will curve over will dissolve the ore body that is constituents of the ore body and will disperse in down the gradient in the soils which are over here and in these cases all these cases which is shown in a plan give here will be always be getting the concentration of this particular element of interest in a far more diffused manner. Then what could be possibly a very sharp value that we expect sometimes that if there is an ore body somewhere here and.

These are the soil and if we measure the concentration of any metal, then if we are going to take the samples from different points and there will be plot, then it is going to give us some sharp anomaly for any particular metal that we are interested in.

So, this is an example in which it would give a some clue as to identify with the particular area. The soil could be transported soil or could be residual soil.

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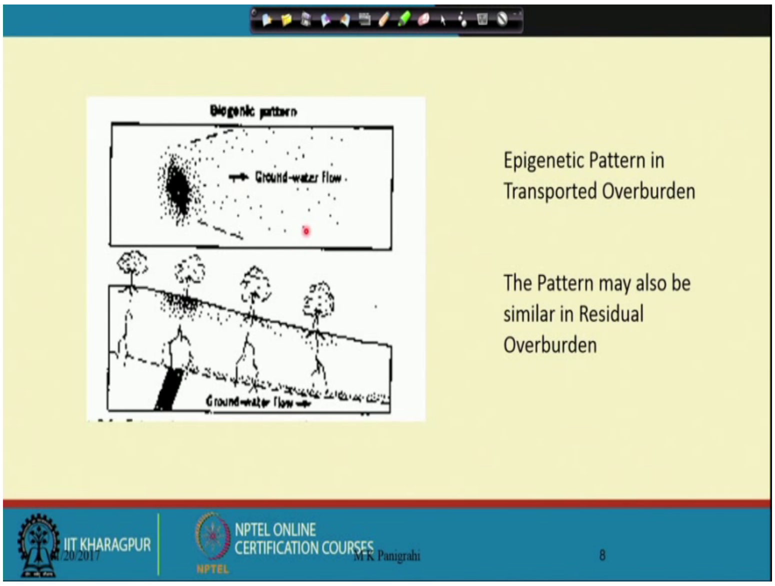

This is an epigenetic pattern in transported overburden. Similarly the plan view over here is at the soil which is there on a slope and the groundwater sloping and the actual anomaly will be distributed all over these areas and following the flow of the groundwater and sometimes better may also be similar in residual overburden.

So, there are certain situations in which the identification of the residual and the transported may not be that very shale.

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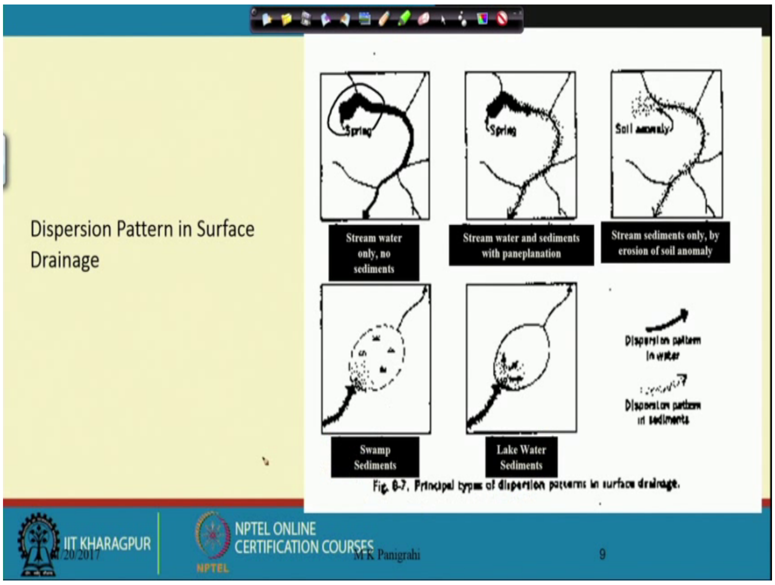

And these are some interesting pattern on in terms of the dispersion. These are the dispersion pattern in surface drainage. If we have an ore body here and it has to be a radial kind of a then it is pattern. Then the metal of interest will be getting dispersed in the stream water only, but only in the stream water, but no sediments here in the stream water and sediments with manipulation depending on the slope and the topography of the area and here in this stream sediments only by erosion of soil anomaly and in this case it is a swamp sediment and this creates a lake water sediments and these are the principle type of dispersal pattern in subsurface drainage. Which we might expect and can plan the sampling program for a geochemical survey.

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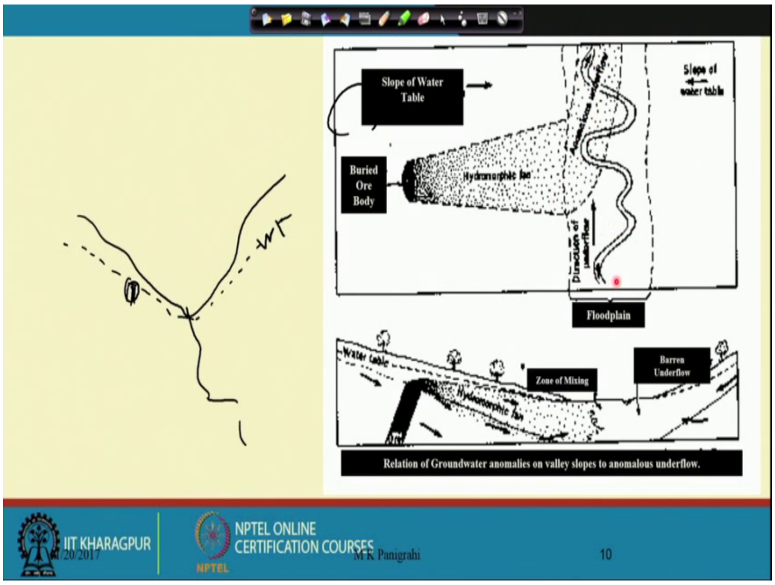

And this is also an interesting situation where this is the river and here is the hidden ore body the buried ore body and this is the slope of the water table in this direction and this water table will always follow and will get exposed on the stream which will be something like where the river is flowing. So, the water table will always follow a pattern like this and whatever any ore body which will be lying here somewhere as shown in this diagram will always carry the metals in solution and will get discharged on the river bed and that is how we could always get a concentration.

For example, if this happens to the water body in the area, then and this happens to be the regional slope. Then the concentration of the elements as the metal of interest will always be higher in the downstream direction compared to the somewhere region here.

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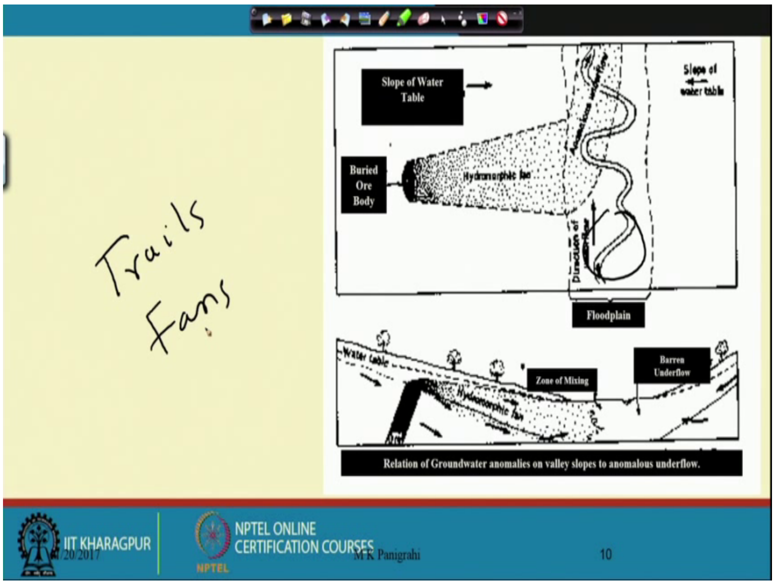

So, these gives some of the ideas at how this metal of interest or the element of interest can get dispersed. This is the section view of that. That is what is shown here. This is the floodplain. This is the barren under flow and this is the ore body which is getting dispersed by the hydromorphic and forming a hydromorphic fan pattern.

What basically what is being shown here essentially they call is the trails and fans. In most of the cases these can be termed as the trails or some of the cases as you have seen in forming the alluvial plain; the alluvial region getting mechanically degraded from the preparent ore body. They form some patterns which can be called as fans like the situations which we were showing here.

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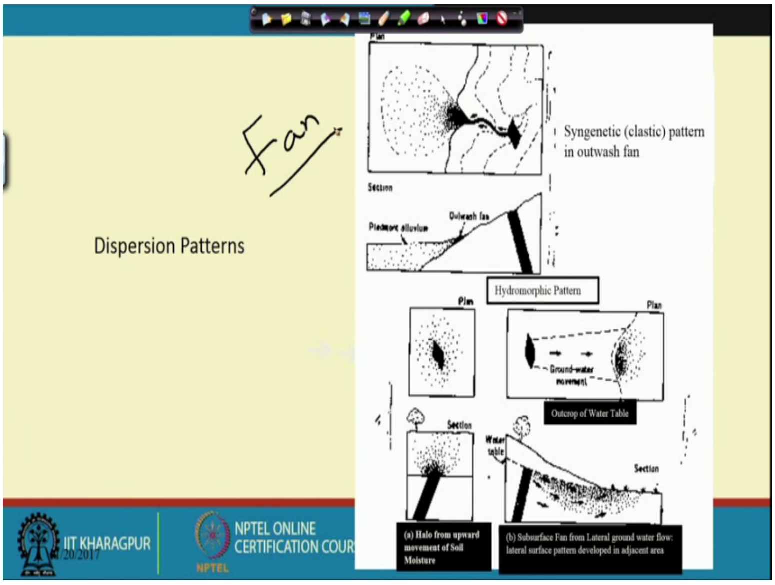

When this kind of a situation can be called as forming as the dispersion pattern, which can be called as fan; just making a shape which can be very well familiar termed as a fan and as compared to situations which could be just to the trails.

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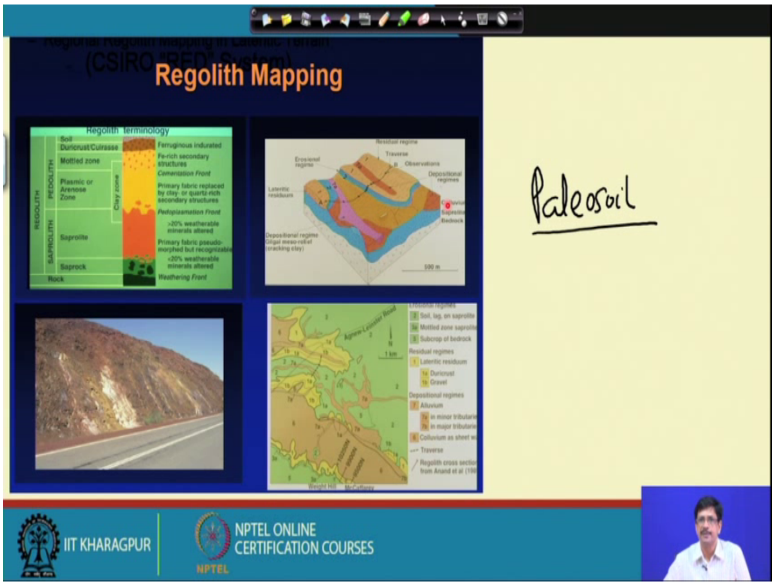

Now, many of these situations, many countries, many geographical regions including what we have in the Indian subcontinent, we have the formation of these soils for very long geological time and these soils they do form something which is generally called as a regolith and it is regolith is essentially can be called as failure soil and depending on the time during which they have formed, they saw some well defined patterns. The way exactly we saw a soil profile, we could also have this kind of regolith profile and in many of the countries like in Australia and this regulates a very well studied and because most of the country like Australia are actually covered by thick regulate layers and it is a similar situation in many parts of our country; where the study of regolith have been very important with the recent past 1 or 2 decades, and if we could see here all of the regolith profile so that regolith is broadly divided into a saprolith and pedolith. Pedolith essentially is the soil part of it.

In saprolith is actually the altered rock part of it and like the soil profile we see at the base of it is the rock which is the unwhethered part of the rock and just above the rock in the saprolith layer and the saprolith zone we get the sap rock. Which is essentially containing the fragment of the bed rock and will be 20 percent about whether able minerals is alter followed by this saprolite. Which will be a layer, where it is primary fabric pseudomorph, but recognizable of the parent rock and this is a kind of, you can call is a pseudo plasmation front. Arm information of the, this is the front which actually goes over to formation of the fresh soils.

And there is a clay zone. Which is the primary fabric replaced by clay or quads these secondary structures and then it come to cementation front and the top is essentially the soil followed by a duricrust means a compacted layer. Which consist the ferruginous material iron oxide material. That is already shown by the pegiolitic kind of structure and it is basically are divided by a plasmic or the arenose zone, the mortal zone, the duricrust and the soil.

So, this soil it is shown on a cross section here and. This regolith profile needs to be studied well and in areas if there is a plan of getting out the geochemical prospecting, then the regolith profile is something which is very has to be understood very properly. And here this it can be seen on a section that these layers which are the erosion regime and with the lowest part of this plasmic aronous zone is it is exposed and on the top part you could see the saprolitic bed rock and this is colluviums and so, they have different reflections and this soil and the regolith geochemistry is then now being very actively studied for as a tool for mineral exploration in many different parts of the world including the one as we have said.

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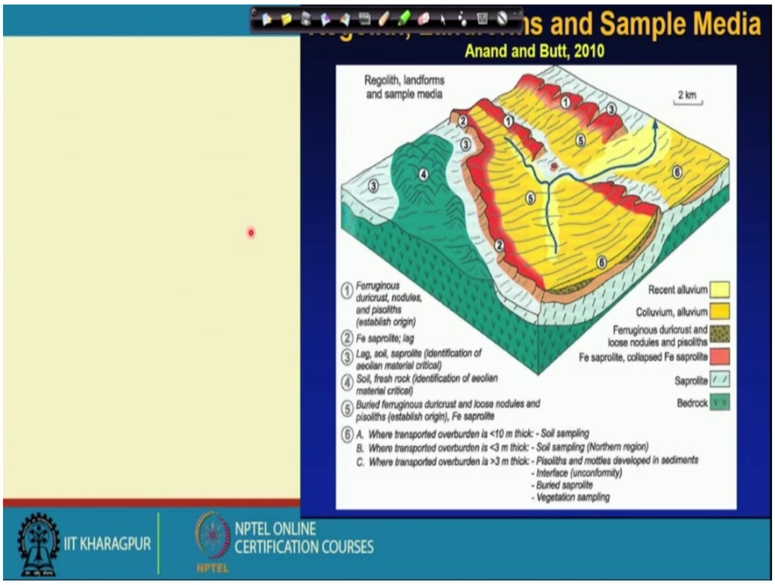

So, this is taken from anand and butt 2010. They are different layers which are shown here. The ferruginous duricrust which is the top layer is shown here and it is been dissected by the normal erosion process and then the sap rock part is exposed. This is the deepest part, which is the soil. The fresh rock identified iolian materialists. Sometimes there could be also iolian origin where the iolian contribution has to be identified in this very critical and.

So, here the bed rock is saprolited. Which was shown before they are in saprolite, the original duricrust alluvium and the recent alluvium which is this part is or the recent alluvium here just along the river channels; this also requires a very detailed study as to during geochemical prospecting program which part of the regolith. How the regolith has to be sampled? So, that it could give us meaningful indications results and analysis for our interpretation for geographical anomaly.

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So, what exactly is proceeded before analytical work or before exactly a soil sample is taken. Essentially it is known as an orientation survey. The pilot investigation to establish the optimum routine field analytical and interpretative procedures it actually is preceded by something which is a orientation survey.

So, this orientation survey before we take up any particular sample for analysis. This theory should clear understanding of the target that this type. So, knowledge of subsurface environment, the sample types available. The sample collection procedure means when we are talking about the soil profile normal soil in any particular geographical region, there we must know that how deep we should collect the sample. That we represent the exact zone which will be reflective of exactly subsurface condition sample interval orientation and density the sample interval is a very important decision to be taken, because, it depends on the dimension of the targeted ore body, and in case for example, if there is a situation depending on how the ore.

So, suppose there is an area where.

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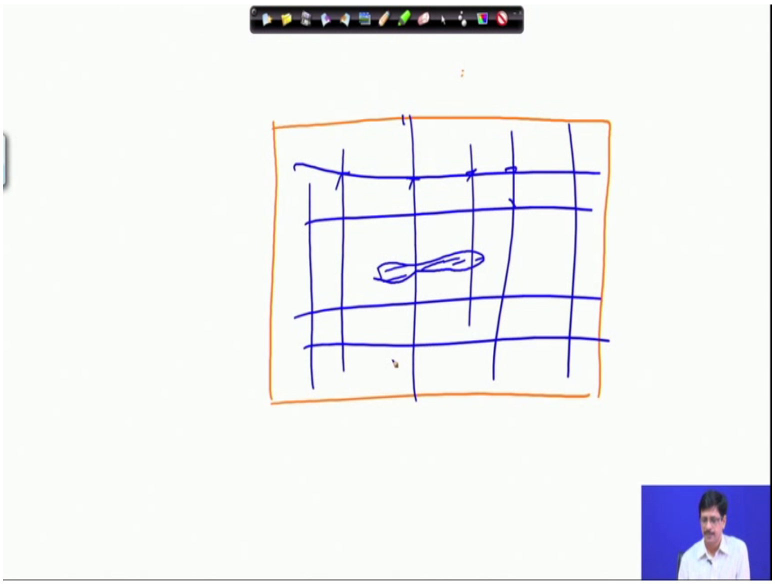

And we expect that there should be an ore body somewhere here. Somewhere it is just the surface out of which I am just representing and if plan sampling interval that sampling that I am taking for the soil and depending on the grid that I am following for the sampling.

How closely spaced or how widely spaced the sampling. If this is the grid on which we are taking the sample presuming, then we are taking on a regular interval and it might so happen that depending on this size and shape or orientation of the particular hidden ore body. We might even miss the signature of the ore body, if the sampling interval is not exactly proper.

So, there are many exploration programs which fail because of improper anywhere any of the deficiency where if this book sampling or the sampling density, sampling pattern is somewhat not appropriate. Then the field observation requires sample size requirements and which fraction of the samples will to be analyzed. So that fraction will actually be reflecting or the death fraction will only be, because the metals of interest may not always be present in all the fractions of the soil, which is mixture of all different size fractions.

Sometimes it may be the very small fractions less than 2 millimeters. Even the clay of these play particles, they are in the metal of interest. Maybe more because of adsorption and the coarser particle may not have the metals and then depend which the death decision has to be made very initially, very firmly that which fraction has to be analyzed and the analytical method that is going to be selected and the geochemical suit and the data format and then these types of orientation survey will be based on the public data. That is reviewed on the case histories and experts opinion consultants are they just some of the examples here.

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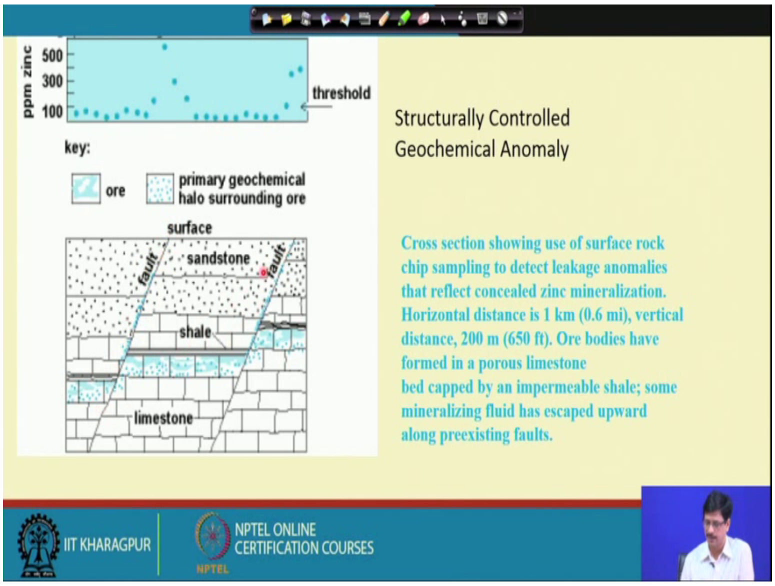

So, this is a schematic section of ore body which is there below shale and there has been caught by. This is the layer which is mineralized and discard by fault and if there are sampling which is done on this particular surface and then we might get some kind of anomaly here. So, these are the structural control geochemical anomaly. This cross section shows use of the surface rock chip sampling to detect leakage anomalies. These are the anomaly. The elements will definitely have a higher mobility on this kind of faults and fractures and the anomaly this will become clearer.

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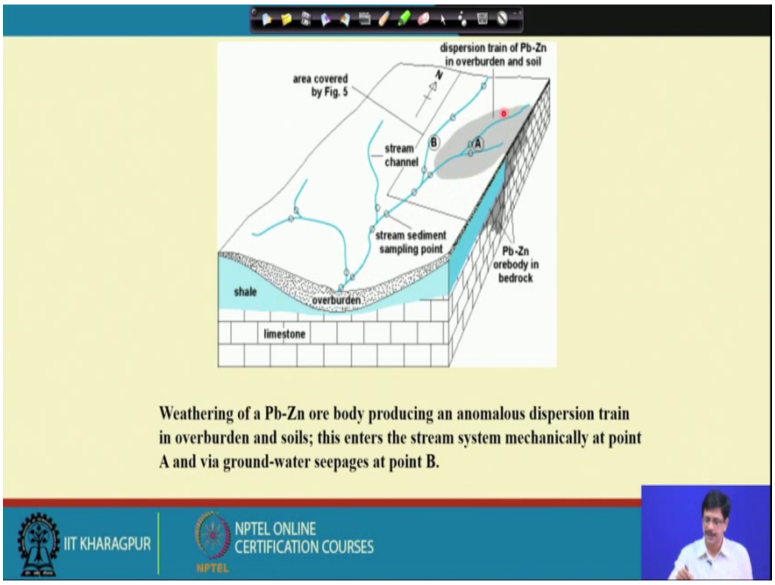

And this is also an example. How if there is a hidden ore body somewhere here it is shown by the lead and zinc ore body bed rock and it has been dissected by the streams. So, in stream channels if we analyze the stream channel for example, the weathering of the lead ranging or body this producing the anomalous dispersion train. Here will be essentially be sampling the train. Which is found by this river and we can trace back called it.

Because for example, if we look into the sediments of this particular order stream. You would not get anything and only you will be getting in this and that is how it will make us target or reach at the target that we are looking for.

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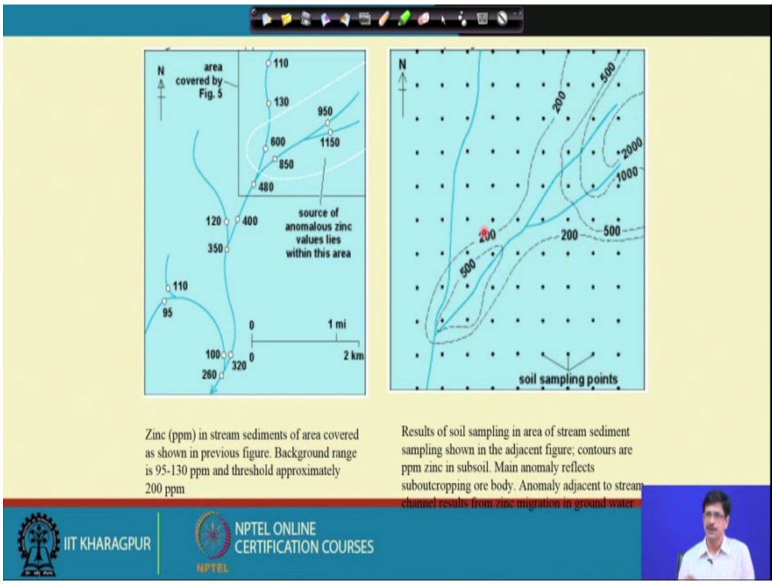

So, these are some of the patterns that form. This gives an idea about the pattern the results of soil sampling in an area of stream sediments. This is how the stream sediments are analyzed and that grid is made for the soil survey. These are the contours and after we do the analysis, the analytical result can be represented in the form of a geochemical anomaly map and joining the points are equal values to form such kind of contours and this you can see very clearly here that if the ore body reaches lying in this particular region that the contours are increasing 200, 500, 1000 and 2000. And that is how instead of. There are several such profiles which are compiled together.

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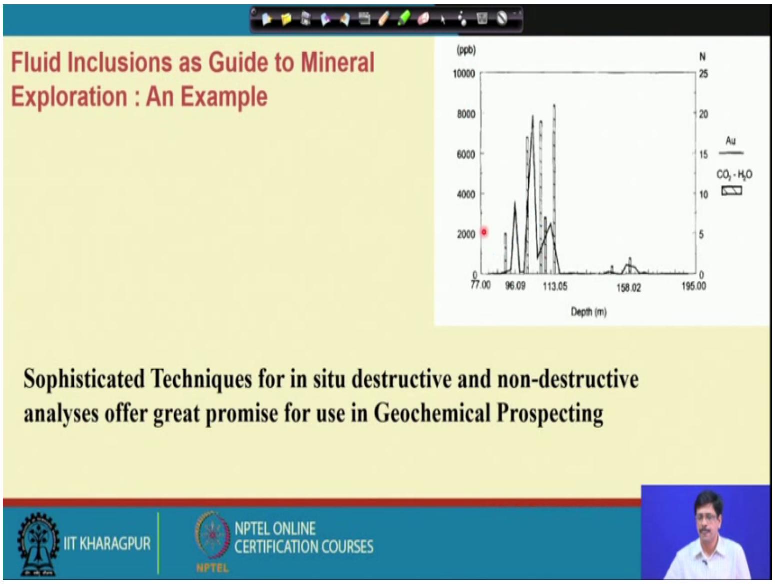

And so, we will continue our discussion on the geochemical methods of prospecting.

Thank you.