Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture - 43
Mineral Exploration (Contd.)

Welcome to today's lecture we just saw the way the mineral deposits discovered and in the last 2 case studies, it was quite clear that data generated from various techniques need to be synthesised need to be studied together for any successful exploration program.

Today we will discuss something which will be only in that line and this topic which is essentially goes by the name as mineral potential mapping.

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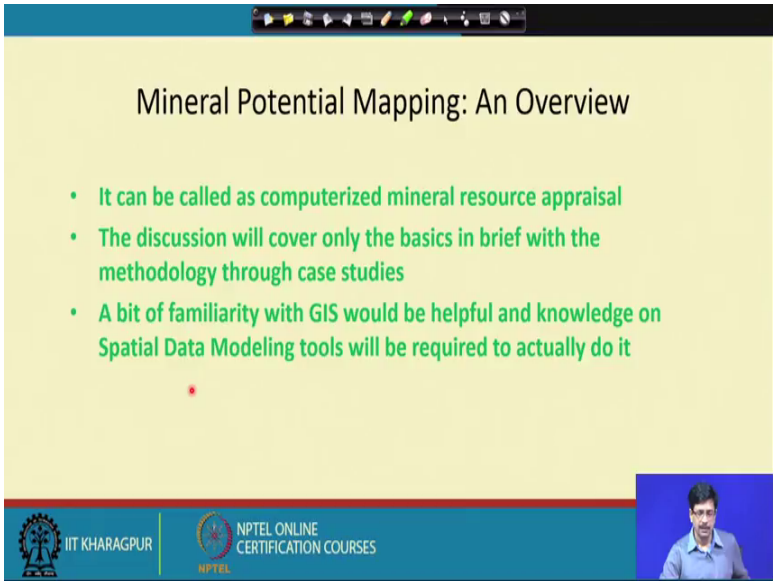

The intension here is that this some introduction to this concept should be given without getting into the much details of the, much into the procedural details or the implementation through software, but it since the mineral exploration today is very much dependent on analysis of use information gathered from all possible sources geology, geophysics and geochemistry and there is the demand or there is a need for better and better methodologies for synthesis of the data. And essentially what one would like to have is a geologist, we always deal with maps there are different types of maps like a litho logical map, the structural map of the kind of aeromagnetic anomaly map, gravity

anomaly map all this things we have already seen and they all they are all in reference to a specific area a space.

So, they are essentially data in space and what essentially we would like to have also a map which would indicate areas where there would be, there where we could possibly indicate or we could demarcate or through any of our coding that those areas should are indicated to be highest probable or the most potential areas and that is why the concept this known as a mineral potential mapping.

Means at the end product of it one would always like to see a map where areas with the highest probability of occurrence of ore deposit could be identified and such kind of such areas which in the in the actual case studies where you saw some data acquired by some specific methods, we actually target for that we always try to in the process of exclusion select out areas which would be more potential and. So, that more intense ground exploration work would be carried out.

So, the intense here is also the same. So, it can be called as a computerised mineral resource appraisal and we will restricting to only the very basic idea about this concept, although it requires familiarity with geographic information system, but this discussion would be made in a way that there is that to be no need get into the fundamentals. But, geographic information system has a tool has is essentially very very important very essential in any kind of work which involves mapping analysis of data, which are essentially acquired with respect to space.

Because, whenever we talk about geochemical anomaly we do talk about sampling points, whenever we talk of any of aeromagnetic maps it is with respect to a particular area bound by the latitude and longitude and every point of sampling is known that at what interval the data is taken, there essentially data in space.

So, what generally we think about of the process that we should be doing with them is essentially the spatial data, to model the spatial data this is this example is intentionally taken, because.

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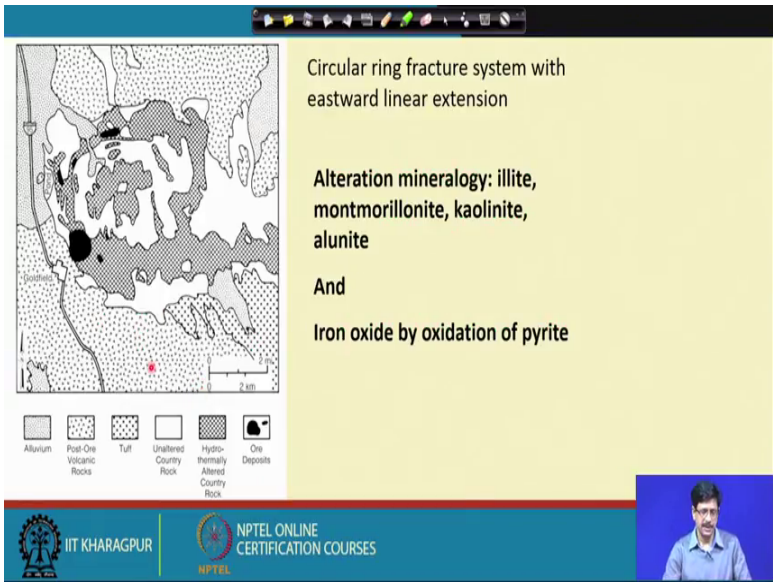

Say for this is a this is an area which is mineralised area and this blackbody shown as the ore deposit and the ore deposit is surrounded by hydrothermally altered country rock and there are different types of lithology, there are there are some tools there are post ore volcanic rocks and their covered with alluvium. Say this is an this is an area which is, which shows mineralization and associated feature then it should be how we can suppose this area is studied by remote sensing.

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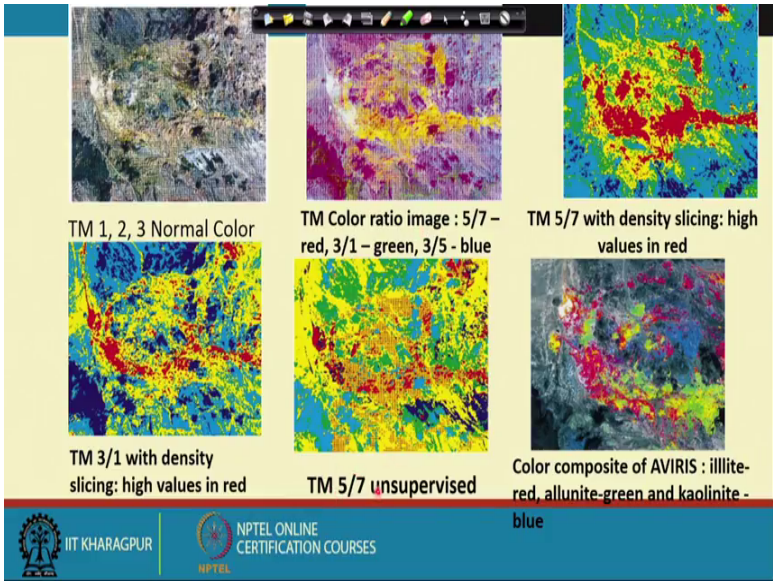

By taking the digital image data in different bands that we discussed and suppose we are considering the thematic mapper which has got 7 bands which we discussed before and this coloured pictures are the end products of analysis of the digital data using various techniques.

We discussed about the taking a ratio of the band 3 to band 1 to bring out the iron oxides species or band 5 to band 7 to bring out the altered the clay mineral species 5 by, 5 by 7 and there are some methodologies typically digital image analysis methodology which even can suppose for example, this is 5 by 7 ratio image and this is an image where a little bit more of improvement technique has been used.

So, what you could see here that the area that mineralised area is which is also this it is definitely bound by definite space spatial coordinates spatial limits and every point within this is also specially known, it is specially referenced in terms of we might say in terms of pixel and referring to a particular coordinate in terms of latitude and longitude.

So, this is also since we have got some idea about digital image and representing a ground resolution in terms of the pixel, pixel could be of depending on what is the satellite as we saw in case of ATM or the thematic mapper the pixel could be 30 meter to 30 meter resolution. So, within that which we are basically acquiring the data. So, this also is can be thought of as the data which is a special data referring to the smallest ground resolution unit and then is compiled in a map. So, this also is a map.

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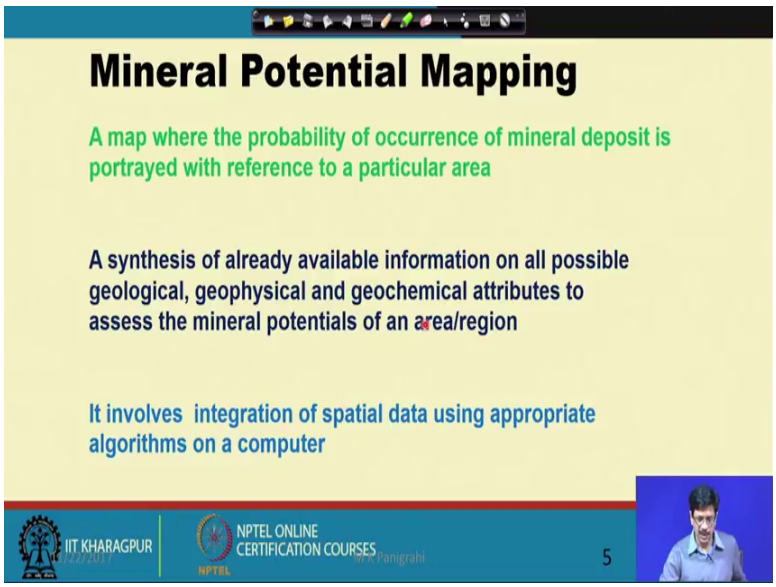

So, a mineral potential map is a map where the probability of occurrence of mineral deposit is portrayed with reference to a particular area, we all understand probability. So, means which is a parameter a probability can take a value from 0 to 1.

If we say probability 0 means we can say that this deposit is never to be found there. Which is theoretically generally a value of 0 is not given and a probability of 1 means deposit has to is certain to be there and when we see in terms of the mineral exploration and synthesising of information in finally, producing in form of a mineral potential map we can see the value of the probability how what kind of value does it take.

So, it is a synthesis of all already available information on all possible geological, geophysical and geochemical attributes to assess the mineral potentials of an area or region. So, here it would not be very difficult to understand that we know that geological data, subjective data because in geological data we plot the geological map or we indicate the structural patterns in terms of the presence of defoliation the data of defoliation or the fold axis of the axial planner features or fracture, fracture density. So, many things we can present on a geological map.

So, from the previous example that I gave about a satellite image data being produced at a map where every pixel has got some value, known value in terms of number. Similarly, a geological map if I could be converted also into an object where also within a confine of a definite spatial coordinate every point could be represented with some numerical value geophysical anomaly values are in any case got coming as numbers. There they could be used geochemical attributes are also in terms of geochemical anomaly, in terms of concentration p p m or p p b of any of the metal of interest which are also has numerical data.

They can be assess and we need to have a methodology where all these types of data corresponding to a to the same space, same bound, same space bound by the geographical coordinate could be synthesised and essentially one thing is also important to mention here that this mineral potential mapping exercise is essentially it could come very much under the Brownfield exploration category where, we need to have some information about the area where there is a mineral deposit or an ore body is existing. So, that we could associate the existence of that particular that ore body with all other attributes such a geological, geophysical or geochemical and this would be something

like it will be independent of any genetic hypothesis being known for that particular deposited known because the out of the available geological elements all of them may not be a part of the mineral on the origin or the genetic model that we have built up for the origin and evolution of that particular deposit.

So, it involves integration of spatial data using appropriate algorithm and it needs a computer.

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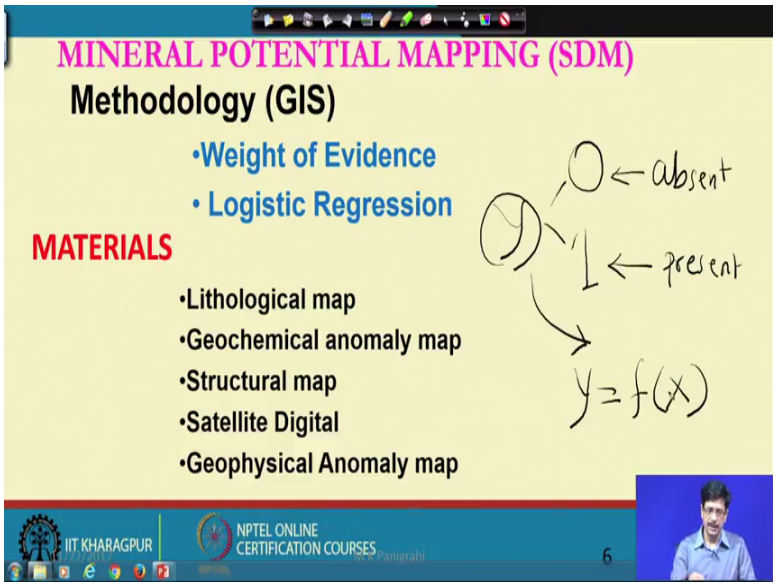

There are many methods I will not be going into all of them one of, one of the there are some simple methods like a weight of evidence means it is the self explanatory that we will be taking something as evidence in favour of occurrence of a mineral deposit, that is an event which is. So, that evidence could be all the geological geophysical and geochemical data that we are talking about and here it will only be this method of this method is that we take some evidence and then come out with some inference in terms of probability.

The other one is logistic regression, where we its if we know what the normal regression is in the normal regression a dependent variable like y is fit to be an to be a function of an independent variable x, 1 independent variable x and more than one independent variable x 1, x 2, up to x m where in a normal regression we take the dependent variable as obtain as attaining any numerical value, but in case of the logistic regression our the value that the dependent variable can take is either 0 or 1. Means 0 would correspond to

the situation where the deposit or the feature that we are looking for in our cases and ore body is absent, of the situation could be that ore body is present. And this if this is about y then this y is being visualised or can be can be fit to be a function this y to be a function of x where, this x could be representing the all the attributes all the geological elements of whatever data will be there which could be which we could quantify and I would not go in to any of the details of this methodology.

This can be later on learn and this provide us with bit of interest to go and see what is happening in mineral exploration, just other than confining ourselves to just see the purpose being at we also have some of the things in the agenda to learn them and know what exactly it is

So, the materials are a lithological map or geochemical anomaly map a structural map satellite digital image with also. So, processing come out with the alteration map or presence of alteration zones and so on a geophysical anomaly map.

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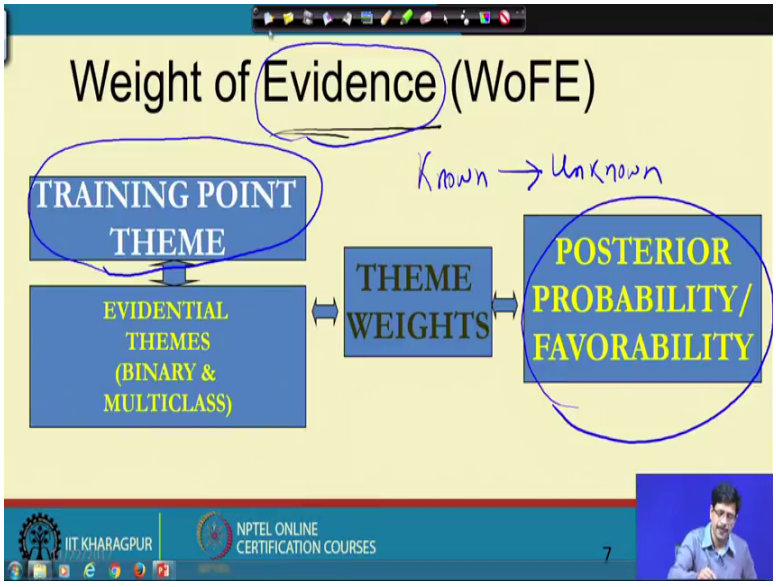

So, it is a situation where I will come to this training point theme what it is. So, we propose in this particular methodology which is the weight of evidence means we will take some evidence, as providing the evidence for the presence of what we are looking for as a mineral deposit.

So, whatever we will be preparing in terms of the information will be called as the evidential theme and here the evidential theme also could be presented in terms of present or absent; that means, the value could be 0 or o1ne even if we do not get into that now where evidence. So, for example, a structural map could be 1, 1 theme of information or 1 layer of information or a geological, lithological map the presence of that particular lithology and particular selected areas.

And then this training point theme will be essentially the points in space where we know that the deposit is occurring and that is why we say that it is from known to unknown, this is from known to unknown. Means we know that the particular deposit particular will be getting at the discussion it will be clear we know that the deposit or know body is present in a point in space, on the surface, on the earth surface or subsurface then deposit is present and that deposit that particular point is having all other attributes in terms of the geological geophysical and geochemical.

And now, we are going to associate this feature being present with all the other attributes that are observable there and we will be analysing them with this methodology that and then produce something which is called a map where the probabilities will be indicated it will call it as a post area probability this example gives suppose this is the rectangular part which is shown here is the, is the region and out of which this part is the study area.

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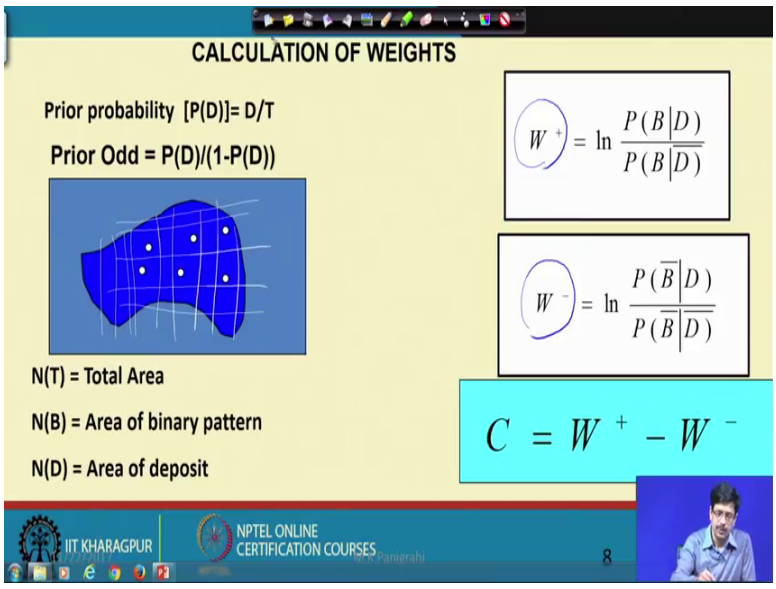

And in this study area suppose this white dots 1, 2, 3, 4, 5, 6 the 6 dots are the points where the ore deposit is known to be present.

And now since we have an idea of the ground resolution and pixel or resolution element pixel or so we know that we can divide this whole area of interest into innumerable number of such divisions each representing like its division is 1 element and that division of that element could always be characterised whether this particular deposit which is present in that I can possibly give a bit of an idea here.

Suppose I will just draw lines like this. So, out of which I can say that is white dot is present in this pixel, this pixel, this pixel, this pixel, this pixel and this pixel and rest of the other pixels are where deposit is not present so; that means, I can think of that this a parameter which is called a prior probability by dividing the probability occurrence of a deposit is the number of points on which the deposit is occurring divided the total number of such.

Suppose there are 1000 squares here out of the 1000 squares 6 squares has this mineral deposit; that means, the probability can be expressed a 6 by 1000. So, which will be something like 0.0015 or something like that and. So, this gives gives me an idea that what is the probability if I take this area of interest, what is the probability that any point would contain an ore body. Which is now, so there situations will come that this these all these pixels are also having the geological geophysical and geochemical attributes.

Now, think of that this particular point where the deposit is occurring other situations will be that the deposit is non occurring, whether the features should be occurring or there are situations where the deposit would be occurring, but the features would be not be occurring and the other 4 situation is that the deposit is not occurring or the feature of interest any geological or geophysical geochemical is also not occurring.

So, it will give rise to concepts of some positive weights or some positive weights here or some negative weights, means positive weights means all these cases where deposit is occurring and all these cases where the deposit is not occurring and it will give me some numerical value that I could assign by combining this positive or the negative weights and each would be each would be with respect to that particular same particular element or the smallest area that I am dividing it into and considering that to be a point.

So, here this positions of the coordinates of this points which are occurring here are the can be considered as making up an information layer or an information where these coordinates are identified as the deposit or the feature being present. And that will be that we will consider or that is being called or being termed as the training point takes and then what we generally do.

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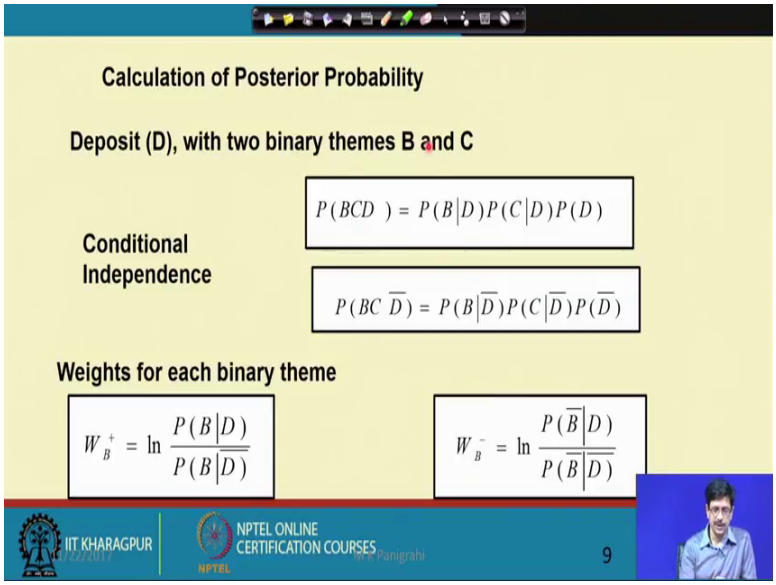

So, these are the weights and not getting into the mathematical details by simple methods of conditional probability and calculation of post area probability.

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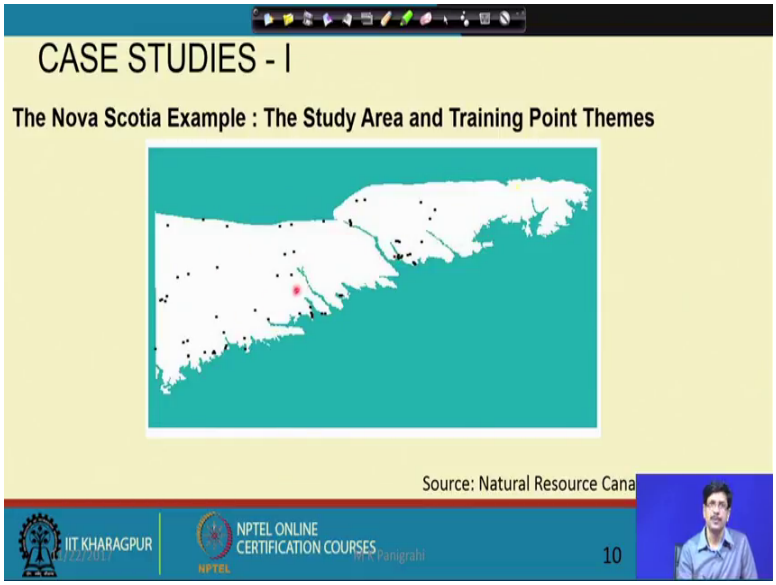

We calculate, what is the probability of occurrence of a particular; what is the probability of occurrence of an ore body at any point of interest in the whole area. So, that we could also join them in terms of contour or we can put them into some categories and produce something called a post area probability map.

So, this example has been taken from the published data of natural resource Canada, this is the example of a study area and the black dots are representing the locations or the points where gold deposits are occurring, let us see.

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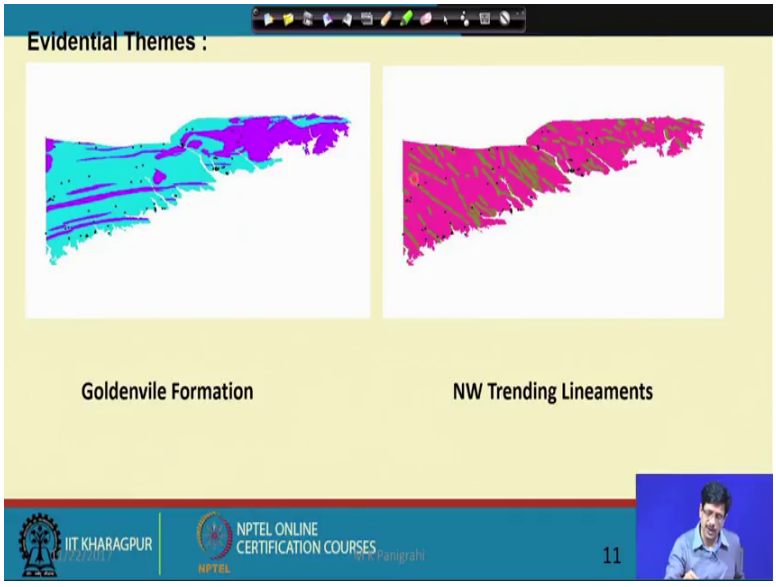

So, what you mean by such evidential themes or what are the evidence that we are actually taking. So, this is in this particular study area what is demarcated in purple colour corresponds to the formation of, corresponds to the presence of a particular rock type. Let us say it is green vile formation, golden vile formation, it could be it could be anywhere in any geological training where such situations could be existing. So, suppose one particular information, here we could see the situation we are talking about, presence of this particular ore body particular geological unit and presence of ore body. So, situations are there that the ore body is occurring where the rock is present, the ore body is occurring where the rock is not present, the ore body is not occurring where the feature is present or the ore body is not occurring where the feature is also not presence, those for probable possibilities coming out very clearly when we are seen such a study area

where the locations of the deposit are shown and in addition to the preparations of a particular rock type.

Similarly, if we have done the structural analysis of the area then these are the regions in which we could trace out the lineaments and what is shown is thick lines is a concept which we use as a proximity means for example, if there is a this is this is the linear feature whether a mineral ore body is lying either very close to it or very far of it.

So, we can think in terms of an influence of the particular element, which is a structural element in relation to its spatial association with the occurrence of the ore body, which we call as a buffer. I may not it just for your knowledge, but it does not require to have to be understood right now it could only understood in terms of what spatial distance away or within from that particular geological feature the ore body is occurring.

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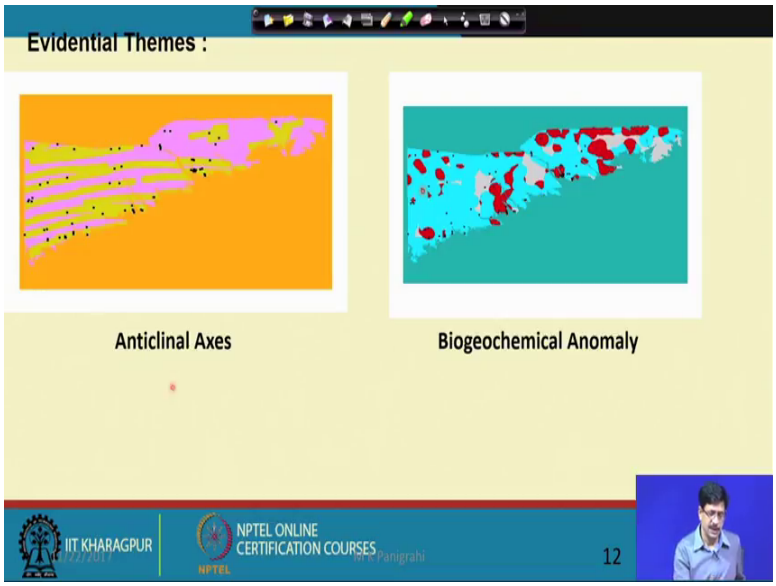

Similarly, this is the plot of the anticlinal axis that is studied here and with respect to that also be how the ore deposits ore bodies are, the ore body points are fixed only we are showing the other geological features.

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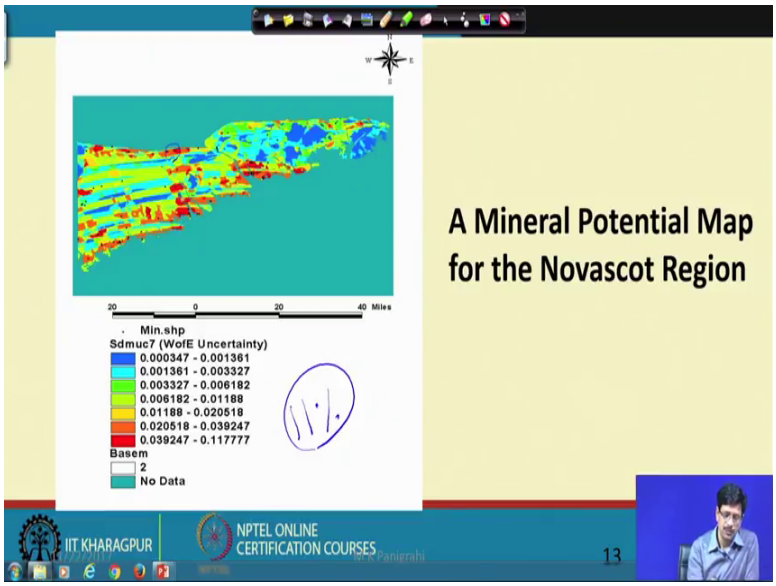

This is a biogeochemical anomaly map and combining all these together what is produced here is a map which looks like, this is the mineral potential map of the region where the probabilities are scaled from very low value sorry, very very low values are 0.000347 to come into 0.03, 0.03 to 0.1

So, 0.1 necessarily means that it is about 0.11 so; that means, just about 11 percent in terms of the probability and as we discussed before a mineral exploration is essentially a very high risk economic activity and here the success rate is actually very low and the what basically is coming out from here even such kind of a loop values what is shown as probability, but still.

So, what we are seeing in this map here that all those areas which are shown as very high probability of going up to 11 percent are already also containing the deposits. Like situations here we could see that it is containing the deposit at many other situations where the high probability areas already showing the deposit to the present. So, that gives us a kind of a validation of our procedure even though it could still be having some errors here and there which could be further be rectified.

For example, even deposit occurring in an area which is within a lower probability and then what is more interesting is that there are areas which are demarcated to be areas of high probability, but they do not have an ore body now. So, this possibly the areas which can be selected for further intense ground exploration work as we have seen in the case

studies which we discussed before whether it is a thing we are doing by a potential mineral potential mapping and then coming out to the to selecting a high probable area this situation as the same that in this synthesis what we have done here that we have used more varied type of information.

Geological as we saw from the occurrence of a particular rock type structural. geochemical and also geophysical by integration of all these data, but and then associating that with the presence or absence of an ore body in that particular region gives us regions which look to be further potential in terms of occurrence of the ore body and those areas could be taken of a further exercise.

So, this exercise which is a mineral potential mapping is basically done as a pre exploration exercise and would minimise or would definitely optimise a lot of the cost of factor an actually making many such unsuccessful intense ground exploration prospecting work.

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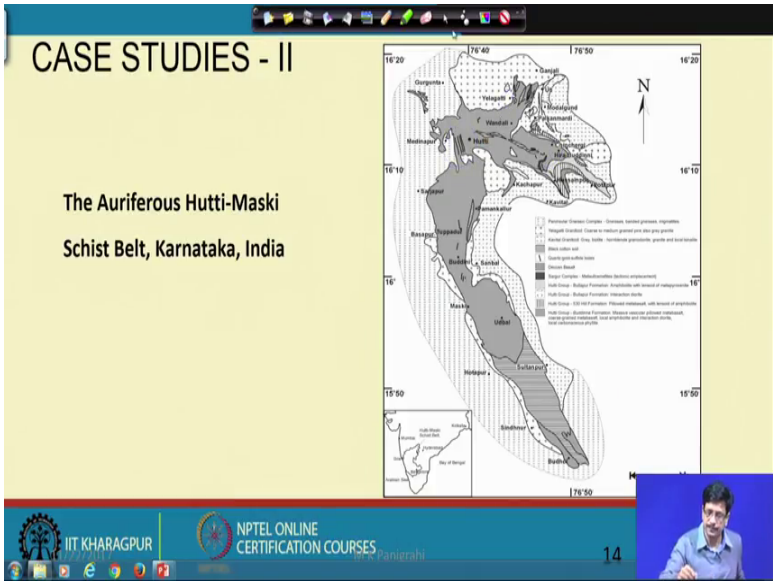

I just complete the I will just finish the discussion in with the example of bit of a of course, even though it is not a very successful as it tuff successful exploration effort are just could be looked at from academic point of view this map Hutti-Maski schist belt was earlier shown and where the presently active this these are the presently productive areas like Hutti, Hirabuddini and Ooty and the other ones like with this small bodies over here. Stiller the prospects and this is the entire Hutti-Maski schist belt which is one of the

schist belts occurring in the Dharwad Ketan like or very other auriferous schist belt. Situation is that in this entire schist belt only there are a very few working mine represents of the ore body is known so far.

So, let us see what we could yeah.

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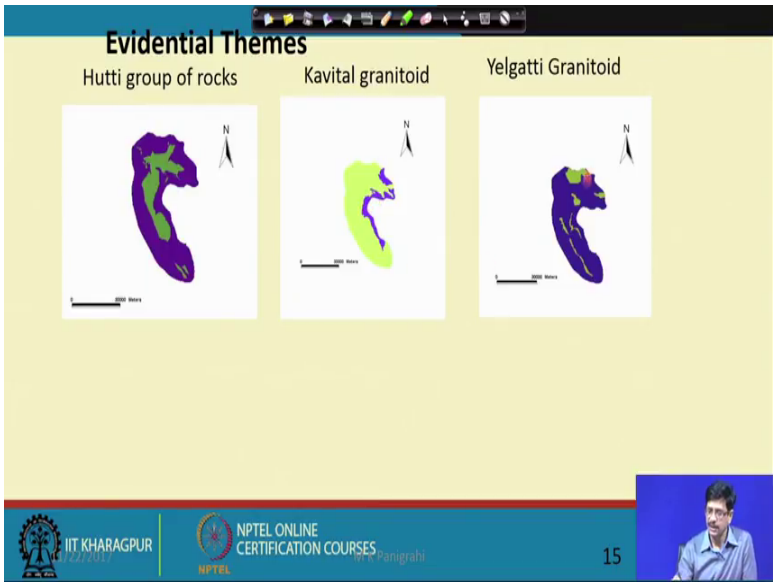

So, this is the example that the Hutti group of rock could be shown here and here it works as a binary theme in the sense that whatever area is shown in green represents of the Hutti group of rock will be considered as the feature being present or the value being 1 and the rest the value being 0 and similarly the occurrence of the one of the pages of granite the capital granite is shown here this is for the other face of granite.

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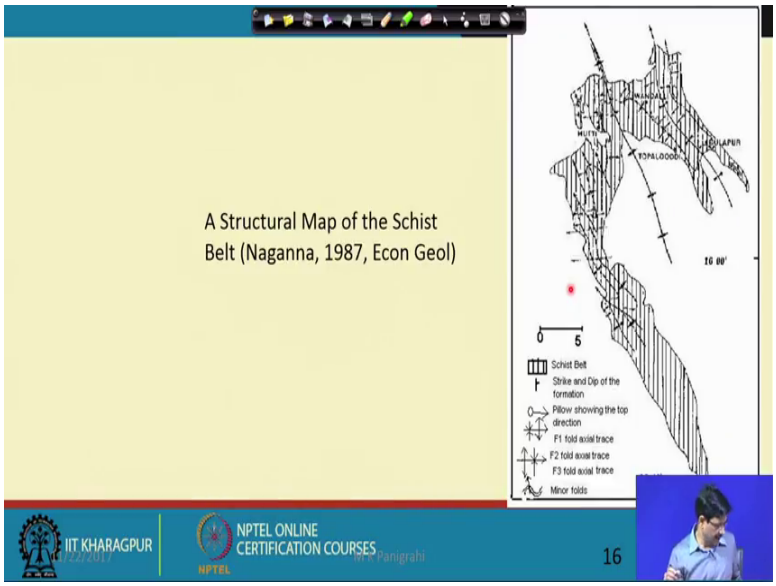

And this is a example structural map which was produced long back, the structural map has got the f 1 fold traces f 2 fold trace the fault and the various structural elements which are present here.

Now, this particular qualitative map could be converted into quantitative one by the process same process that was discussed by dividing the area into as many number of small cells is present and see whether a particular feature is present or absent in terms of and f 1 fold axis or f 2 fold axis.

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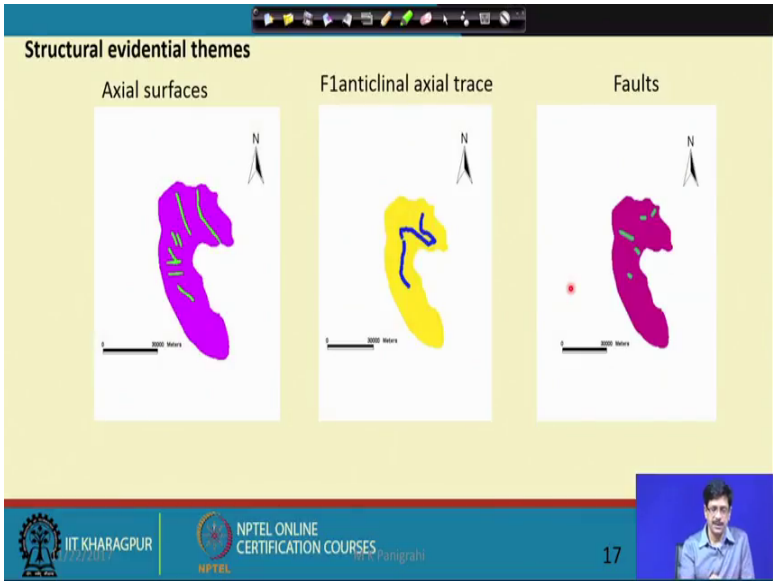

And this is the example in which such kind of structural elements have been picked up and are presented in the form of evidence, in exactly the same way that whatever has been shown by this green thick lines at the points on which this feature is existing and the rest of the area the feature is not existing.

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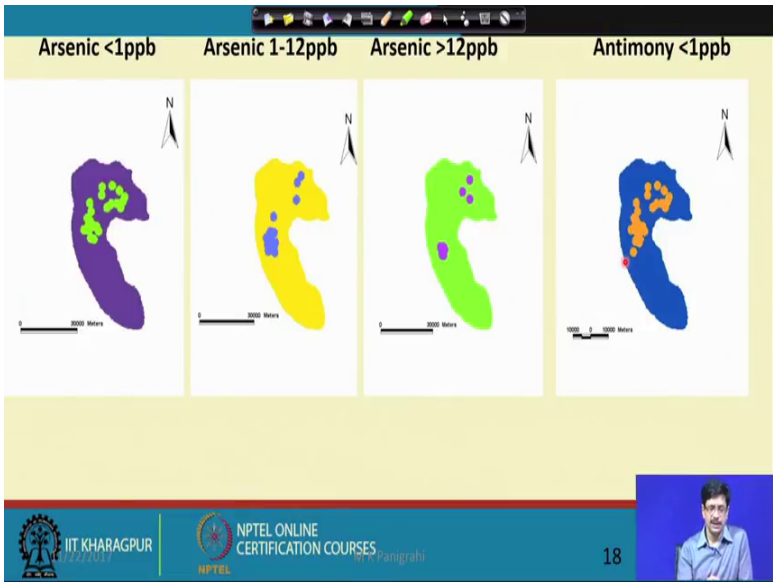

Similarly, this will be f 1 anticlinal axis these are the traces of the faults and suppose this work this area was subjected to a was some geochemical studies, geochemical anomaly geochemical dispersion pattern and arsenic and antimony were measured in the soils of the entire area and then this is could be a choice that let us see what are the areas where the arsenic is less than 1 parts per billion or the areas which are between 1 to 12 parts per billion or more than 12 parts per billion.

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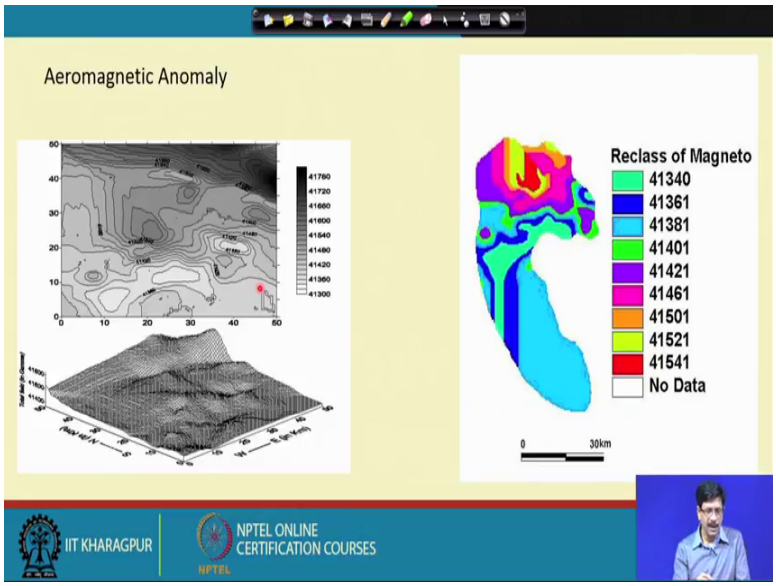

It could be one could choose could have a basis of this and can also have similar pattern generated and a part of the area where the aeromagnetic anomaly map was available. So, that an magnetic geomagnetic and the airborne magnetic anomaly map was the data was reduced and the surface it was projected to surface and this kind of a surface geochemical anomaly map could produce for this area which is true for only the upper half of the area that also since these are also numerical values. We can also be we could also discretise that and could divide them into regions in terms of the several limits of the several ranges of geomagnetic aeromagnetic anomaly map and could also integrated is one of the layers.

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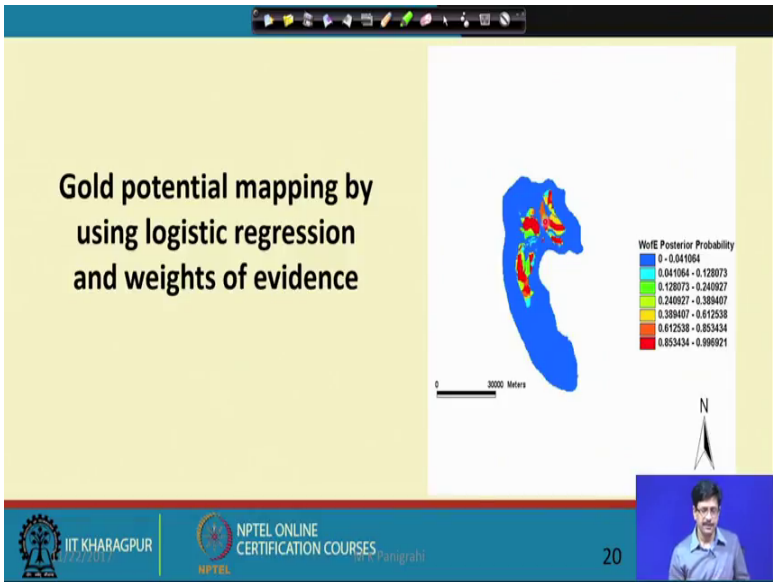

And then we integrate them all and find out something which is gold potential map by using the calculation of the posterior probability by using the weight of evidence or and also similarly the same thing could be done by using a logistic regression. Where our as we just introduced that is a situation in which the dependent variable is representing 2 states were present or absent not getting into much details of the analysis and this kind of a mineral potential map could be produced.

Here the values of course, pretty high 0.85 to 0.99 may be the weight has been scale and this also can be validated by the showing of the areas in dark red or dark orange when the highest potential and then seeing actually whether the working mines are falling on them, that gives us some amount of confidence and then these areas could be the areas where the probability of occurrence of this gold deposit are now presented to be high and that could possibly be could be examined with respect to other features.

Because, such kind of a map also could be prepared by taking the digital image ah images that are prepared by analysing the digital image data in various ways, production of hydrothermal alteration zone or the lithology and many other structural features like in the case studies we discussed before and further areas could be pinpointed for more intense ground exploration work.

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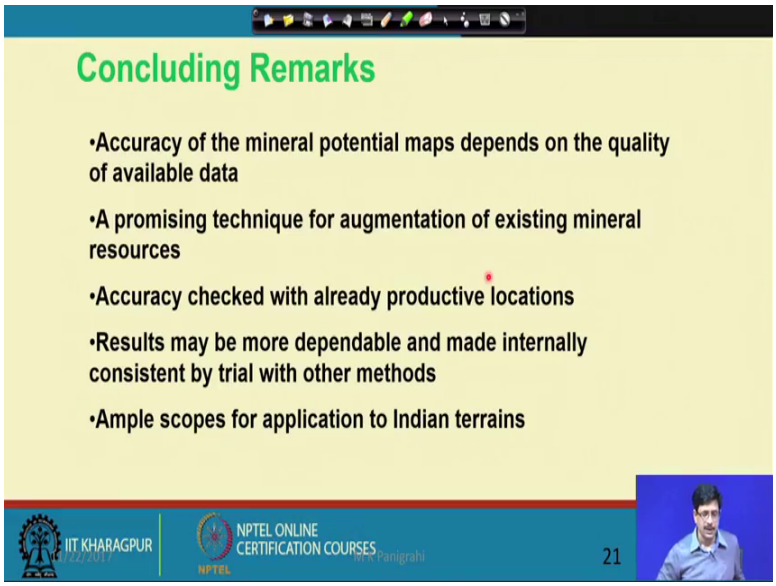

So, the in such kind of exercise which is just given as an example is not as successful exploration history. So, such kind of exercise depends on the accuracy of the input data that that is being taken, in the satellite image data or the other kind of data of course, and the geophysical anomaly data is they have been interpreted and the depending on the method that has been applied.

But then since they are being taken as input data the accuracy of the data is very essential this techniques are promising and the accuracy are checked by the already productive locations and. So, these are the this methods are they have got a ample potentials to be applied in the Indian situation and they are being very routinely applied in many parts of the world to conclude that the discussion on the mineral exploration and the case histories, it can only be told that there are many more the present day.

There are many new developed techniques which are come up and the mineral exploration. Now, being told in terms of prospectivity of favourability analysis and using all and all the techniques of spatial data modelling which can which one can learn and they had stages.

Thank you very much.