Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture – 42
Mineral Exploration (Contd.)

Welcome to today's lecture. In the previous lecture, we had a brief overview of the geophysical methods, the magnetic gravity and electrical methods. Although, there are methods like seismic method and radiometric methods which are also used for exploration of mineral deposits, although the seismic method is not that very regularly used because of the fact that the differences in the geological properties of common rock rocks in the crust and any ore body in terms of propagation of the elastic waves is not that very distinct as in the case of any oil pool in a sedimentary strata.

So, with the brief idea about the basic knowledge about the electrical gravity and magnetic methods and also the geochemical prospecting methods known let us have a look on the exploration the discovery history or the exploration history of couple of interesting mineral deposits of course, there not Indian examples.

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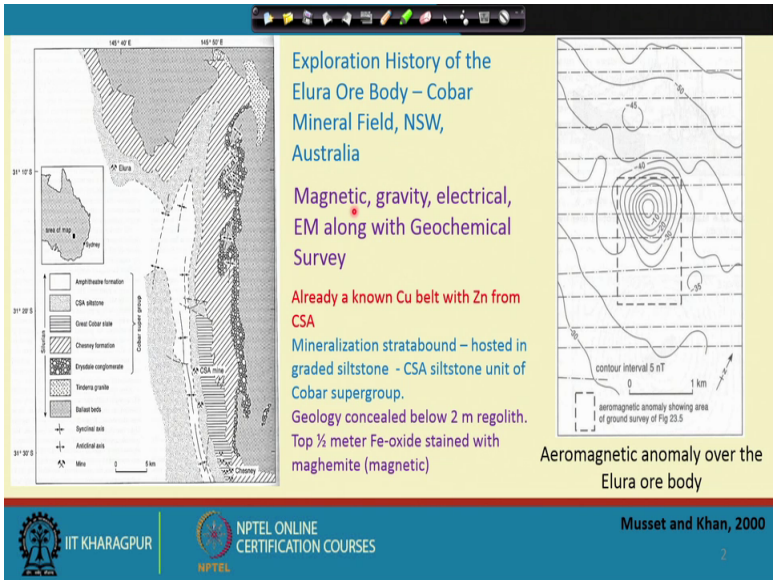

But, they are taken from that these examples come from mainly from the southern Australia where there are records of systematic investigation till the point that a mineral deposit is confirmed the discovered by the application of this methods in series and then

combining the results and interpretation and finally, intersecting the ore body by a drill hole.

So, coming to the area where this has been documented this is the Cobar mineral belt of southern Australia here is it shown in the graph. So, this is essentially is a folded sedimentary basin and there are still stones and shales and there has been one working mine here in the CSA mine which is essentially zinc mine and from the general geology of the area and the strata bound nature of occurrences of the ore bodies, an exploration program was conceptualised and since, they are strata bound and they are deposits the metals like copper zinc sulphide the essentially sulphide deposits.

So, it was initially the airborne geomagnetic anomaly maps we were studied in the reconnaissance stage and the exploration, it was quite natural that it would the exploration efforts would be focused on areas southern north because here we can see this and this inclinal axis this anticlinal and these are the CSA still stone and the shale in which actually host the sulphide bodies.

So, after a series of after a study of the airborne geomagnetic anomaly maps some few areas were selected and one area which is shown here as Elura was selected was focused or selected for further investigation based on geomagnetic anomaly maps and the interesting facts about this area is that this area is covered by almost 2 meters of regolith and more importantly there is a half a meter thickness of ferruginized materials consisting of mostly maghemite which also gives a magnetic signals.

So, it was definitely a quite close and tricky affair to choose as choose an area and this area was chosen for further ground and further investigations and so, after this area were chosen there are magnetic ground magnetic and gravity electrical methods were carried out here. So, this diagram on the right it shows the results of aeromagnetic anomaly map of the area and the dotted the lines are the line showing the flight path and as you could be clearly seen here that in this area we could see the magnetic anomaly in terms of the this contour intervals are 5 nanotesla and at the centre almost like a bulls eye there is about a 50 nanotesla anomaly, 40 nanotesla anomaly was observed and which is bound by this area and then it was followed up so.

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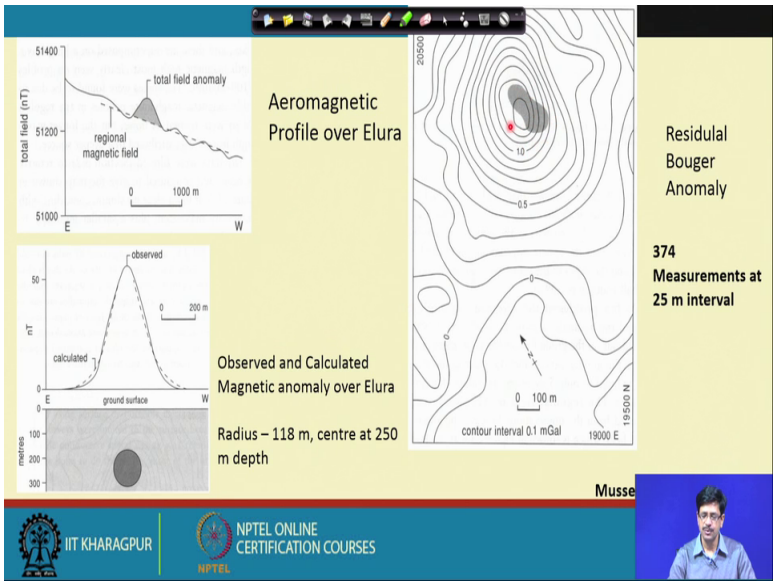

As we know that any of the geophysical methods it requires a lot of careful and systematic connections to the raw data that is obtained and here could see the since this is a regional magnetic anomaly slope and when the data were plotted and corrected. So, one anomaly of about 40 nanotesla, 55 nanotesla positive anomaly was obtained corresponding to what was shown as the bulls eye in the previous diagram and this magnetic anomaly was interpreted in terms of a ticking the model of a spherical in the body and this anomaly was interpreted and on the basis of this spherical body and previously what we discussed about the calculation of depth of occurrence of this magnetic body it was calculated that this body could be about 118 meter in radius and the centre to be lying from the surface at about 250 meter. So, this was the preliminary results from the magnetic survey.

And, then since we also know that this metal sulphide ore bodies or by virtue of their higher density would also be reflected or also be manifest in the gravity anomaly. So, this diagram over here shows the results of gravity survey which was conducted almost about 374 measurements at 25 meter interval and contoured in terms of the gravity anomaly in milligals.

So, this is the after all and it is a lot of connections as we know after all the connections were applied. So, this is the final gravity anomaly map where we can see that this area

which was a magnetic high also is coinciding with a gravity anomaly contour or the centre with the highest gravity anomaly.

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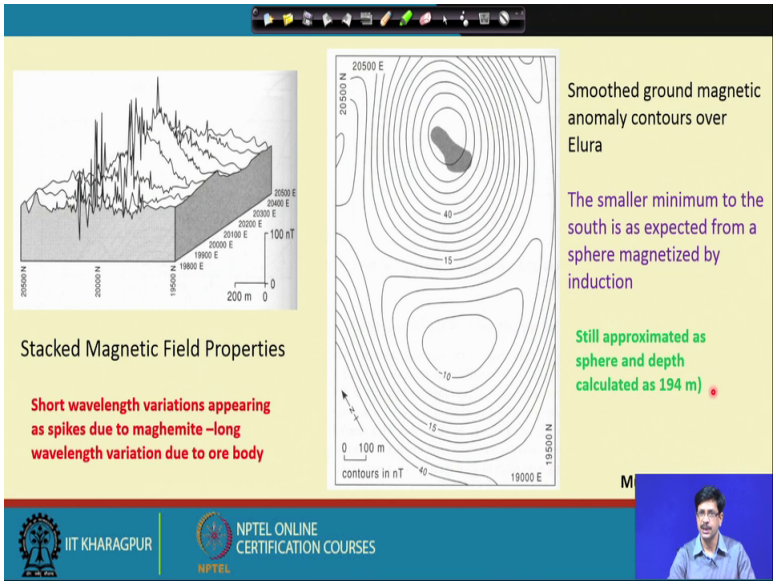

And, this magnetic data further studied and the magnetic profiles were done on this area and it was represented on stack magnetic field map here in which you could see there are some minor short wave length variations and those variations were ascribed to the presence of maghemite on the surface, but there are long wavelength variations like what we could see from in the bound of the 20,100 east to 20,300 east where it is very clearly the magnetic anomaly is observed and here this is the smoothed ground magnetic anomaly map ground magnetic anomaly work which was done on the area and this is the final result. This is smoothed ground magnetic anomaly contour where Elura and there is a smaller minimum to the south which is expected from a sphere that is magnetized by induction.

So, this is still was modelled as a spherical body and from the study it was calculation of the depth it was refined depth value was refined to be a data 194 meter as same almost near to the depth that was calculated from the gravity survey.

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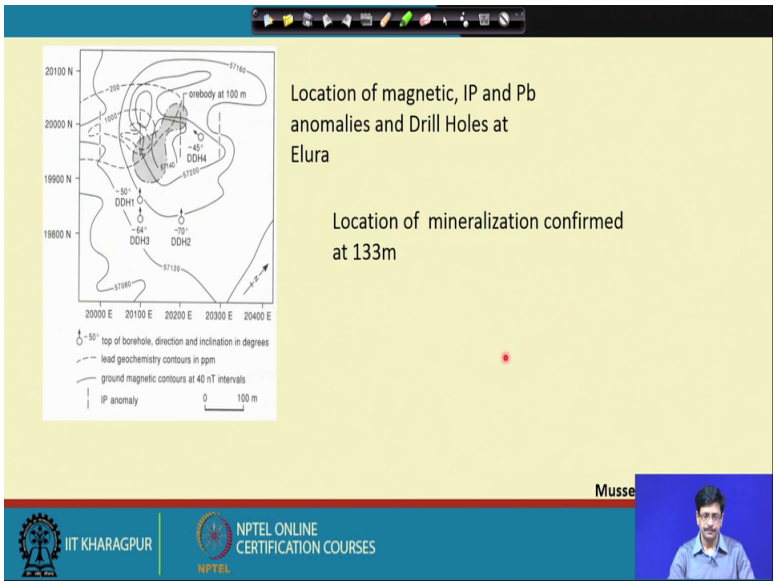

And, then once this area was 0 and further investigations were carried out as you could see. So, we have seen that this particular area, in order for the exploration work to progress towards this converse so that a discovery of the deposit is indicated. So, then it was further studied more intensely with a ground with a geochemical survey and you could see the lead concentration anomaly over here which has shown by this dotted line here is 200, 1000.

So, this area comes out to be the area most anomalous with respect to lead and the ground magnetic anomaly contours at forty nanotesla are also shown here which also is indicating a magnetic high here and also this area was subjected to induced polarisation because that is one of the methods which is encouraging and is used for sulphide ore bodies and the IP anomalies are also shown through this vertical lines.

And, the final effort for physical for confirming the physical presence of an ore body is through the drill holes and these are the locations of the drill holes. So, this first drill hole was sunk was drill through and it resulted in location of a mineralisation which was confirmed later on 133 meters below the surface. So, it could be very well seen that right from the beginning from the very choice of the area if the choice of the area would not have been proper the possibly this exploration program could have been abandoned at any point of time.

And, what this exploration story tells us is that it is the not a single method will actually give us the right idea about the existence of an ore body the as we have seen here through series of work as magnetic and gravity work and so, afterwards it was the situation is that before the deposit could be really as declared as discovered and it is quality quantity parameters also needs to be established and also more importantly the shape or the 3 dimensional disposition pattern disposition of the ore body was also to be ascertained.

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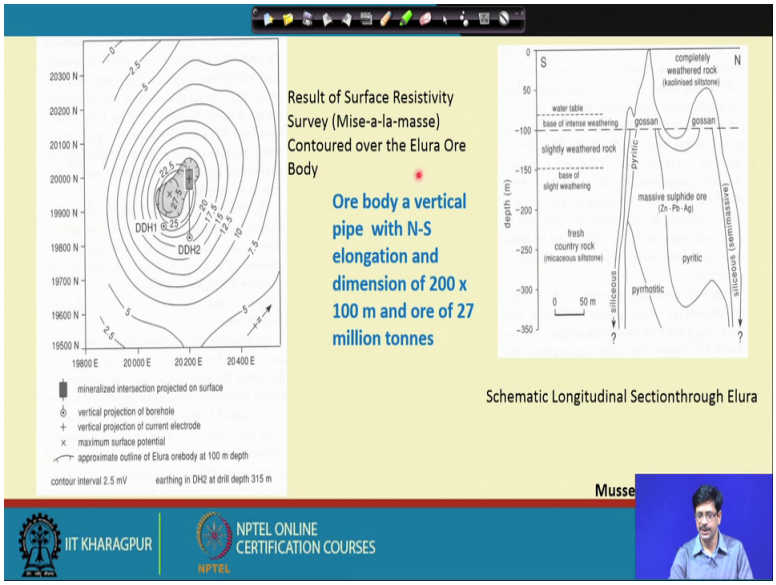

Before during the discussion with the resistivity method we saw that one of the ways to understand the ore body geometry in the subsurface could be the Mise-a-la-masse type of resistivity survey which is conducted in the area and in which one of the electrodes one of the current electrode is put on the surface exactly above the ore body which is approximated from the maximum of the geochemical anomaly and the magnetic anomaly.

So, one of the electrodes was one of the current electrode was fixed on that and in a Mise-a-la-masse method the other electrodes are generally to be put through the boreholes, but since the area was not favourable for that the other electrode array in different profiles were also placed on the surface only and from that the shape of the ore body was ascertain. So, this diagram shows the shape of the ore body here and with all this is the approximate outline of the ore body.

And, then after the series of drill holes and through the use of this as was shown in a 3 dimensional diagram before, from the Mise-a-la-masse method the actual shape of the ore body was ascertained which was about in dimension about 200 to 110 meters and the from the density that is calculated from the gravity method and from the drill core also the further data were obtained on the density of the ore body and the final ore body shape was ascertained which turned out to be a body which is a vertical pipe like body here and with the north south elongation and the dimension about 200 into 100 meter and the total amount of metal the ores was found out to be about 27 million tonnes.

So, this discovery is irrespective of whether such a where this deposit is discovered. This discovery history gives us a lot of insight to what exactly happens and it is almost period, it of course, varies from different deposit to deposit and this deposit at least could be presented as a case as a whole period from the very beginning of a choice of an area and then the series of this geophysical and the geochemical methods and back and supported by the observed geological methods the it takes about anything between 10 to 12 years for till the time that the ore body is finally, ascertained, the quality quantity parameters are determined and then the deposit is actually ready to be exploited.

So, in a way what we discussed about the mineral exploration can be divided into two broad categories as brown field and green field. We could possibly label this particular exploration under a brown field and so, that is the region possibly the time required or time period for the exploration processes to take would be little less then what generally would happen in a green field exploration where things start from scratches.

So, this is one of the interesting cases (Refer Time: 15:46) mineral exploration that will provide us a lot of insight and we try to understand subject this subject a little deeper. So, I will go through browse through another interesting case history of mineral exploration.

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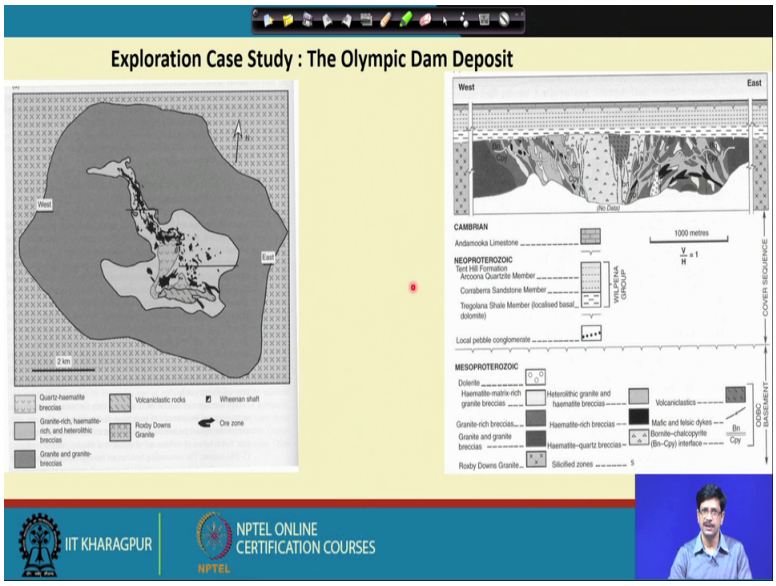

In fact, this exploration came as a breakthrough or is a very major discoveries in the recent past of course, it was all during the late 70's, early 80's of the last century, but this mine which is the Olympic dam deposit is known to be one of the richest deposit and as we discussed during our discussion about the type of this deposit. After the discovery of this deposit this deposit class broadly named as the iron oxide copper gold IOCG deposit came into existence in the literature.

And as we knew that this is the Roxby Downs granite and within the granite we have a brecciated zone granite breccias and within that we have the ore which is concentrated in the form of the iron rich iron oxide rich breccia with some amount of sericitic kind of alteration and the here is the cross section which we also saw and the interesting fact about this deposit is like the earlier case study it is also covered by younger sediments and thick soil.

Let us first look at the exploration history of this deposit.

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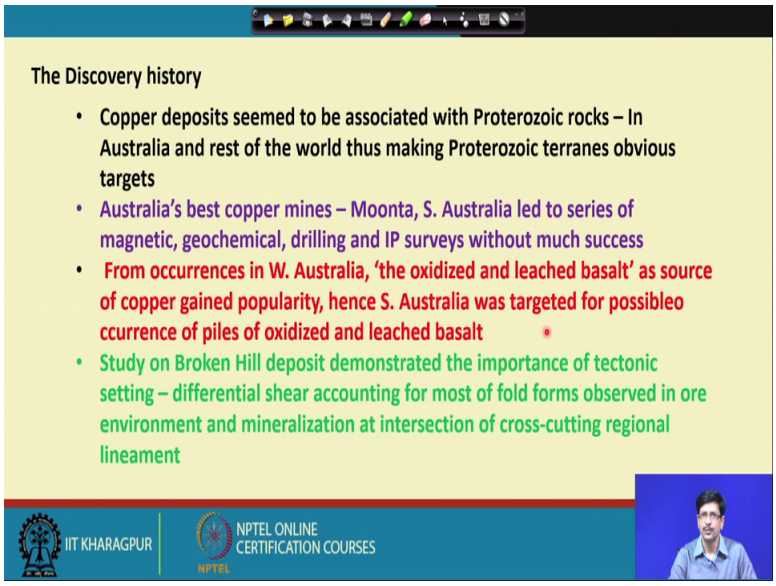

So, it started like this that there was a concept that copper is usually fine of the proterozoic rocks in Australia or in other parts of the world that it was a notion that cooper deposits will be occurring or a associated proterozoic rocks. So, then proterozoic rocks where, obviously, the targets will become the targets for exploration and also that the best copper deposit so far in Australia the Moonta Copper mine in South Australia which is which has a history of production of copper and was also occurring in the nearby areas and so that south Australia region it was able to study to series of magnetic geochemical and the drilling and in this polarization kind of survey, but without much success.

And, right about it that time the concept of the hypothesis that copper is actually leached from basalt and is mineralised along with the nearby sediments or whatever could be the situation lead leading to the hydrothermal generalization. So, this concept of copper in this the oxidised and leached basalt as the source of copper were also coming up and was quite popular and hence south Australia was targeted for the possible occurrence of this. So, people are more interested in getting piles of oxidised and leached basalt. So, if there are oxidised and leached basalt they will possibly be reflected in the magnetic properties magnetic and because of their higher density they could possibly be limited by some such kind of exercise.

And, there was another so far basically, will be seen through in this exploration history is that generally through the systematic study of ore deposits we come up with ideas on ore genesis of the origin of the ore deposit. Those ideas could be utilised or could be of the any exploration program could basically be based on these ideas that are developed on the origin of this deposits. So, leached basalt was one idea.

The other idea was that from the study of the Broken Hill deposit that tectonic setting the deformation feature in the series of for the deformation episodes like differential shear accounting for most of the fold forms that is observed in the ore environment is also important. So, that means, intersection of cross cutting regional lineament also was supposed to be one of the important features and should be look for or should be targeted for mineral exploration.

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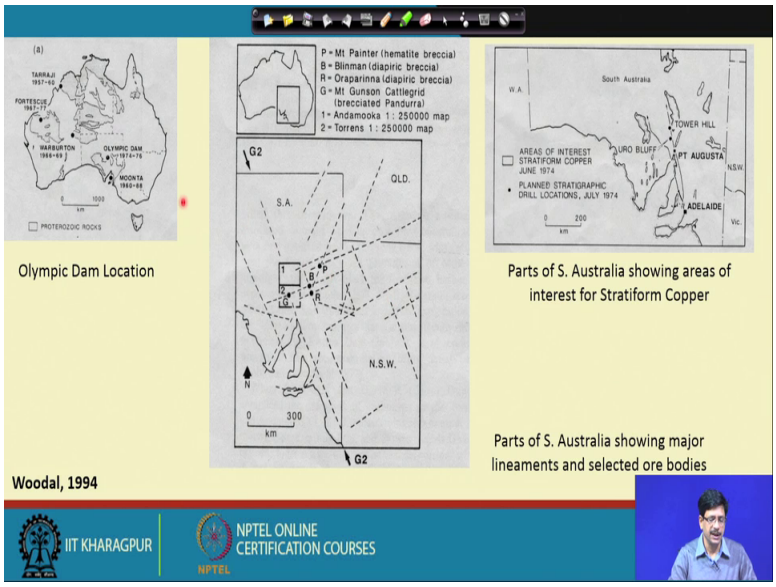

Here is the map of Australia. This is the area which has shown with this pattern is basically Proterozoic rock occurrence of proterozoic rocks. This is Western Australia here is here was Moonta. So, this is the area of South Australia which was the focus area and this trying to apply the idea of leached basalt or the intersection of structural elements. So, this area was subjected to systematic study through. So, there could be two ways. So, if we if we are focusing on the lineament then we have to study a series of satellite imagery because satellite imagery are ones which give us the very clear idea about the lineament pattern in a regional scale and here is the area which is shown here.

So, this area bound by this one which is the Andamooka area it is about this area was 1 is to 250000 scale aerial photographs were studied satellite imageries and this area and here is the locations this is the Mount Painter, this is Blinman diapiric breccia and this is the Oraparinna, this is diapiric breccia and so this is the setting and these are shown the lineament patterns are shown on the dashed line here.

And, so, this is the part of Southern Australia, here is readily is the part of Southern Australia which the showing the areas of interest for study from copper and so, this provided the basic framework for further exploration of the areas and taking this particular part into consideration.

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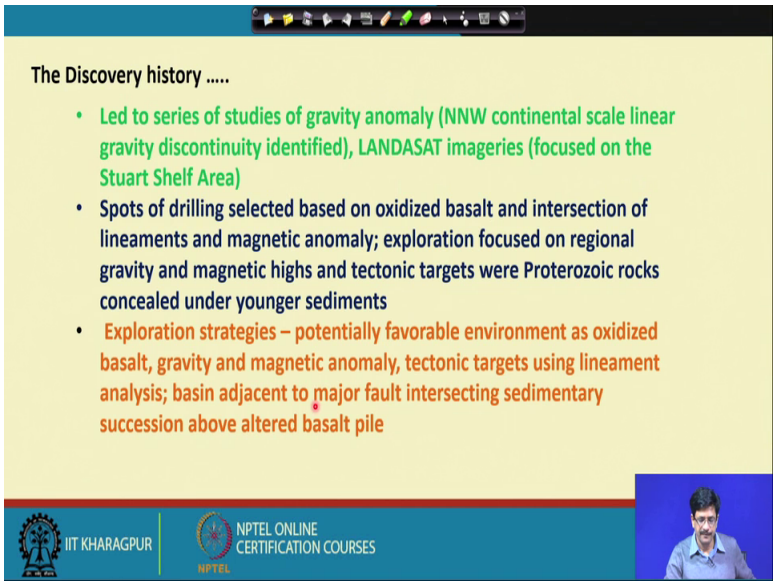

So, that then the series of gravity anomaly this led to the as shown in the previous map load to the north west continental scale linear gravity discontinuity and the LANDASAT imageries they were they all focused on the area which was shown through the boundaries here this is this is known as these Stuart Shelf Area in South Australia.

And, then so, the idea was that the areas which would indicate presence of basalt oxidized basalt and also the areas who would have indications of intersection of the lineaments should be chosen as the areas for drilling or sportswear more intense ground exploration ore could be carried out. So, the exploration focused on the regional gravity and magnetic highs and tectonic targets were proterozoic rocks concealed under younger

sediments and that is that is been the situation here as this one in the map these are all under copper.

So, the exploration strategy was potentially favourable environment as oxidised basalt gravity and magnetic anomaly, tectonic targets using lineament analysis and the basin adjacent to major fault intersecting sedimentary successions above the altered basalt pile because there are the chances of occurrence of an ore body would be maximised.

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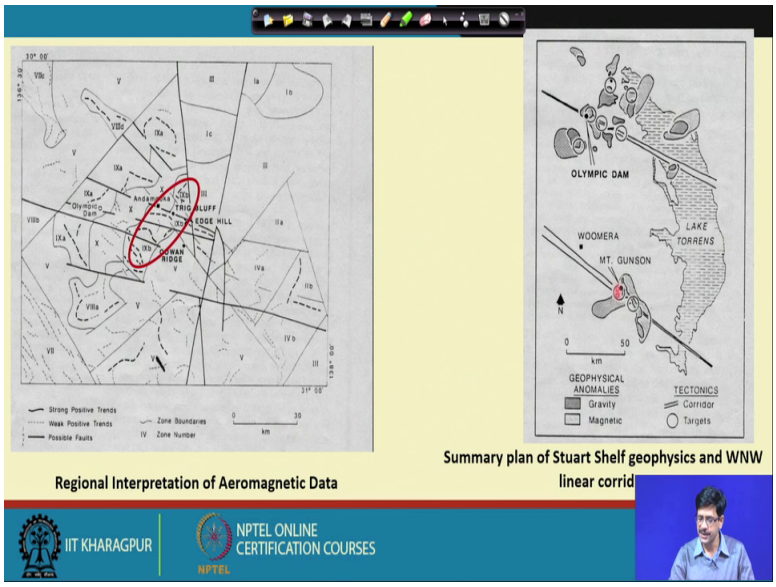

So, this is the map this is the regional interpretation of the aeromagnetic data and these are the aeromagnetic contours which are plotted here and this is the area from the, this was the kind of an area which was chosen based on the aeromagnetic and the intersection of lineaments. So, this area was focused for further exploration work. And the, this is the summary plan for the Stuart Shelf geophysics and the West North West linear corridor and these are the area this is the mount concerned area where there are some mineralization of unknown and this is the area which is the Olympic dam area.

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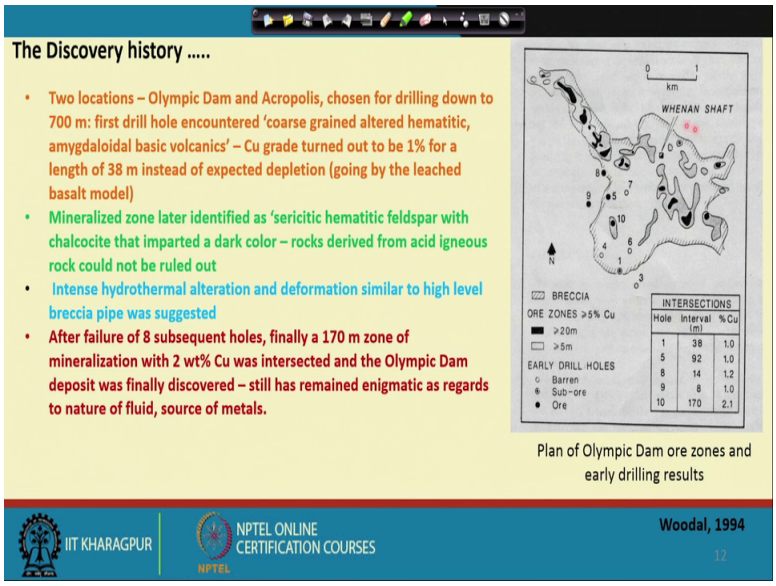

So, based on these studies the two locations were selected one of the Olympic dam and the other one is the acropolis there are chosen for drilling down to a depth of 700 meter. So, the first drill core now here this exploration took a very interesting turn that the first drill hole that was dealt within the near the Olympic dam area it intersected a material which was labelled as coarse grained altered hematitic amygdaloidal basalt basic volcanics.

The material which was recovered from the drill hole looking like the dark the Milano critic material and what was at the back of the mind was that it would be an area where there would be altered basalt leached basalt and so, the material which was obtained from there it gave a coarse grained nature with altered hematitic and what was interpreted is amygdaloidal basic volcanics will be coming to that.

So, now if that is the, if that was the leached basalt then the concentration of copper is expected to have decreased there or this particular patch; would have been depleted with copper, but what was observed by just the reverse. The copper grade was actually the within a drill core length of ore 38 meters, it showed a higher concentration of copper of the order of 1 percent.

So, then it will definitely, but in any case when the copper concentration was 1 percent, whether it was a basic whether it was leached basalt or any other kind of lithology then exploration work continued and later on this mineralised zone was identified as a

sericitic hematitic feldspar with chalcocite actually this dark colour of the material was imported by fine chalcocite which generally forms in the supergene oxidation zone, but here this ore was quite rich in chalcocite and from the hematitic material and the feldspar and kind of alteration which is coming out of feldspar the idea that it could also have been derived from felsic igneous rock who also could not ruled out and this intense hydrothermal alteration and deformation.

So, this intense hydrothermal alteration and deformation was more similar to high level breccia pipe the kind of morphology which we have seen before and they are this kind of breccia pipe which also do occur in many of the porphyry copper deposits occurring in the Chilean Andes, but the geology was definitely not that very similar. So, after the after the detection or after the first drill hole went through and recovered about 38 meter of mineralized zone there were 8 subsequent drill holes which failed and finally, the first drill hole was somewhere here and later on the many of this drill holes we could see here. They failed until the point that the point number 10 this drill hole was this spot was drilled and then it gave about 170 meter zone of mineralised mineralisation with 2 weight percent of copper.

And, then so that was the vital part of the exploration history the exploration work and that definitely confirmed the presence of rich mineralisation of copper and now, deposit was finally, discovered and as shown in this diagram one can easily see that these are the part which actual the rich mineralisation part, which was a actually North East of this drill hole and which was subsequently discovered as you could see here areas where there are more than 20 meter and areas where less than equal to 5 meter and the values are also given in terms of the zones which are there. So, that gave the that it came with a record of about more than near about a 2 decades of exploration of this area and the final discovery of a deposit which came as a breakthrough in the history of mineral exploration and coming out to be the one of the rich sources of copper; not only copper, but also uranium in this.

Now, the situation is that then these genetic hypothesis the whole story the moral of this exploration story is, that this exploration work would have been abandoned at any point of time not getting altered basalt and the more interesting is the readiness to accept or to accommodate with whatever changes or whatever or making a little bit of a change in the

idea that is that was actually is at the back of the success of this exploration of this Olympic dam deposit.

And, as we can see even today the genetic the origin of this deposit is still very enigmatic in terms of the source of metal and the source of fluid and still the occurrence of some of the basic volcanic nearby does not rule out that the copper is derived from the altered graphic rock or it could or the occurrence of the extensive proterozoic granite which is also could be another equivalent or an or more as identical potential for contributing the metal and the fluid, but we know that the fluid here does not give a clear cut signature of a magnetic direct magnetic derivation.

So, the whole idea this paper which has been this idea has been taken of the thing which is been presented. It was titled as whether it is conceptualism or empiricism which one is more important as far as mineral exploration is concerned. So, the basic conclusion is that it is both it conceptualism as well as empiricism; empiricism means whatever coming out from observational fact or whatever ideas could be initially formulated from the knowledge of origin of this deposit they both play an important role in a successful discovery of mineral then ore deposits.

So, that these two case histories will definitely solve as also would generate quite a bit of interest and would give an idea as to what mineral exploration is and how it is a result of multidisciplinary approach and synthesis of data of various types.

Thank you. So, we will continue with our discussion.