Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture - 24
Hydrothermal Systems

Welcome to today's lecture. We will continue discussing on the topic of metalofesitic hydrothermal system and the most studied, and the most important one are the deposits, which are associated with granite greenstone terrains occurring as low type gold deposits in almost all the old cratonic blocks, like the Yilgarn Cratonic in Australia, the Bobottown mountain range in Africa, the Narrower Cationic in India, Superior Province in Canada, in the Abitibi Greenstone Belt.

And in this context we are discussing about the model, that was proposed for these type of deposits, to explain the formation of such kind of load gold deposits, in diverse type of lithologies the most important ones and the most common ones, being the quartz rich loads. In which gold occurs as either free gold or is inclusions in some sulphide minerals, either pure gold quartz loads or associated with sulphides of copper iron and sometimes very rarely, arsenic antimony mercury type of metals.

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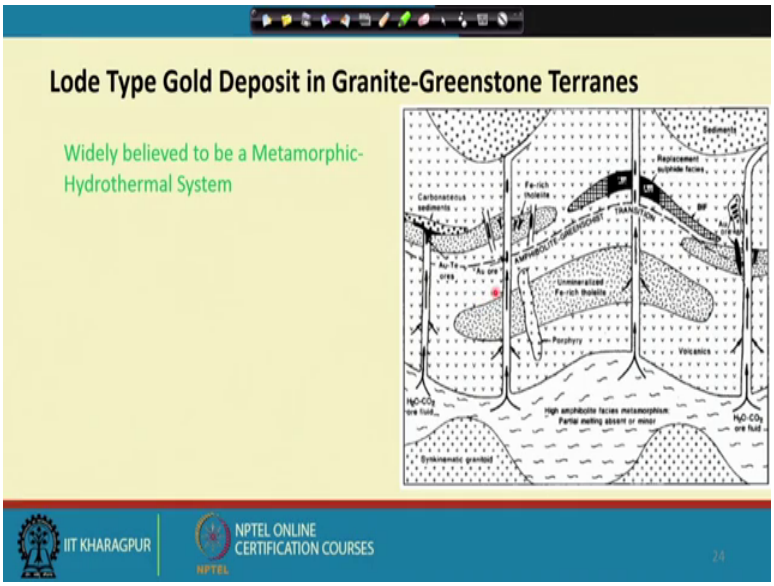

So, we would like to have a look the about discussing about the model. So, this model explains the diverse lithologies, in respect of occurrence of gold in these terrains.

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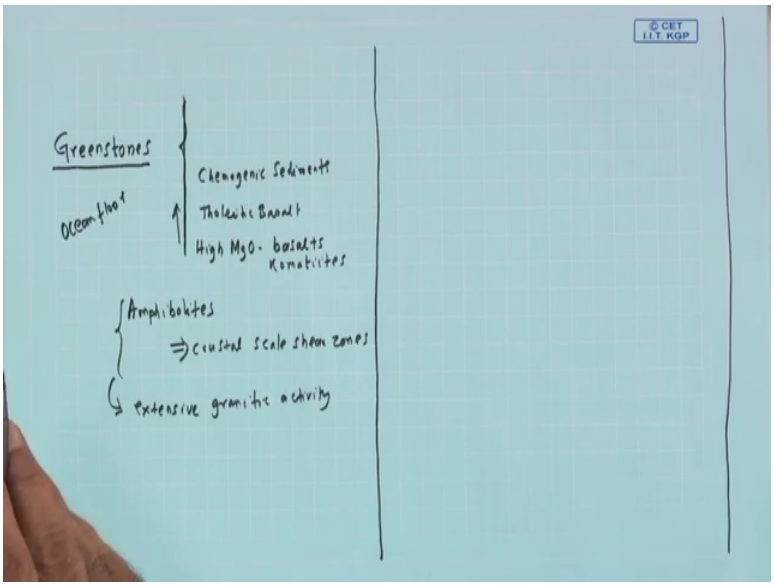

So, the translation of this model, to the occurrence of gold in these terrains can be observed in terms of their occurrence in, what we know is the greenstone belts gold greenstone belts, which are mostly measured in your key is; and they are mostly a metamorphosed, volcano sedimentary, sequence the old volcano sedimentary sequence which are known as the greenstones. These greenstones specifically the green stones, the ones which start from very high Mgo bearing basalt, which are the T comma Ts and give rise to sequence of Tholeitic basalt and the sequence evolves with bimodal volcanism Chemerigic sediments such as the Bifs, plastics and Felsic volcanic units.

And these greenstone sequences, which are essentially ocean floor volcanism and giving rise to the volcano sedimentary sequence, they get after the closure of the basins they get, they are subjected to deformation and metamorphism, of high grade high temperature low pressure kind of metamorphism and what we observed them in the greenstone belts? They are mostly as the amphibolites, and they occur is curvilinear or belts, extending for several kilometers in strike length and extending deep, for even a few kilometers.

And these are associated with customs and shear zones, which are the which are the locals, on which we see the quartz the gold bearing quartz loads and these terrains, are understood to have evolved through a series of deformation episodes, almost 4 to 5 such deformation episodes.

And these terrains have one thing is common that that is extensive, granitic activity and they do overlapping time with this period of metamorphism and the mineralization. And so, that is how they are the done at greenstone terrain. And so, these folder occurrences are confined to such kind of greenstone belts, in most of the cationic blocks and they give rise to huge quantity in terms of even some of the deposits which are called as joint gold deposits, like the one in the Abitibi province in Canada, and in other parts also they do have substantial quantity of gold present in the form of these loads.

And a variable grade in terms of the grams per ton, going in the surface in the surficial part of the shallower part the grades usually are, very high and they generally diode to values as low as even 2 or one gram per ton in better depth.

So, this model is a as a as a working model, which explains the formation of the gold deposits and the basic mechanism is that, the transportation of the metal in appreciable quantity, in a fluid which is essentially derived by metamorphism of this volcano sedimentary sequences, especially the units, like this the basal unit which is a Chomatide basalt. Which is supposed to have a higher concentration of gold, compared to the other litho units gold being a compatible metal.

But the model of course, proposes that it need the there is no litho units, which needs to be having a higher concentration of gold, because the capability of this fluid, which is which liberty which is liberated during the process of metamorphic depolarization is efficient enough to carry gold, in substantial concentration and popularly held belief is that, the maximum amount of gold is deposited, after the emperor greens is sees transition and it is how the deposits are mostly the rich deposits are observed with the shallower, but although mineralization saw with a continuum up to higher and low (Refer Slide Time: 07:33), is also observed in some of the deposits.

So, this is one of the examples, where the mineralization can be ascribed to a fluid, which is which has it is origin in the metamorphism. Although there are many hypotheses involved or many opposing views, which are proposed which I will not be discussing in details. Other deposits, which are there will always lack a very, because very unequivocal evidence of metamorphic fluid, or as we in the in the beginning when we are discussing about the sources of fluid and the hydrothermal mineralization process. We often see that, mineralization process results from mixing of fluids of diverse

sources. So, there are other deposits which possibly have or owe their origin to metamorphism, but then the mineralization process sometimes is dominated by other fluids and those cannot be exclusively called as the metamorphogenic model, metamorphogenetic deposits and then. So, this all about the basic idea, that you could have without getting into any of the opposing hypothesis of the controversies.

Because these deposits are one of the most extensively studied most widely studied, vectors continents and the amount of information generated all these deposits is quite voluminous, with the fluid characteristics with the deformation with the genesis of sub state deposits.

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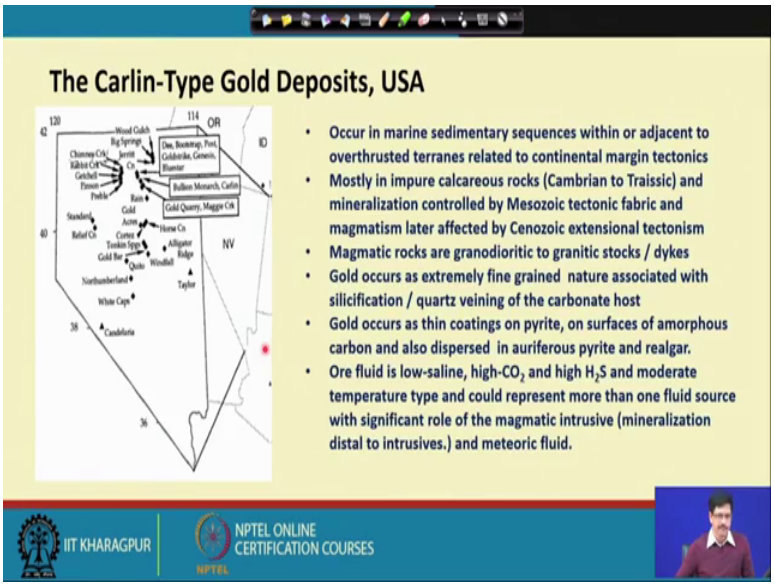

So now I will switch over to a new class of deposit, which are the they are also a very important source of gold, these are the karlin type gold deposit and here there is a map of the Western United States of the state of Nevada, which has been are magnified here.

So, these deposits we could see is a, very is a classic gold belt in the Western American Cordillera and these deposits are essentially associated with, sedimentary with a sedimentary sequence. Although the fluid that cause in the mineralization, is not necessarily a sedimentary or a Cornett fluid, but it is a it is one of the most complicated most intricate it most of one of the most complicated deposit types ah, but they are very they are the rich gold occurrences, which are very much sought after the reactive exploration goes on in this region for discovery of new deposits. Some of the localities

like the Karlin and all these areas, we never the discussed which would the major occurrences of karlin type of gold deposits.

So, they occur in marine sedimentary sequences, this marine sedimentary sequences are pelagic sequences, formed in accretionary zone and during the paleozoic and post they are all then after the deposition of this paleozic sedimentary sequences, they subjected to compressive region and they were intricately tralssic, during the mesozoic tectonic techtronism and they acquired a very intricate mesozoic tectonic fabric.

And essentially the sequence is variants elementary sequence, consisting of argillaceous and calcareous rocks and then in the post Mesozoic the this terrain experienced magnetic activity, in the form of are intrusion of some of felsic rocks in form of stocks, as well as dykes broadly granitic in composition and here in this facility of these deposits of the gold occurs extremely fine grained nature, associated is with solicitation and quartz meaning.

The mineralization essentially is by replacement, of this calcareous rocks by silica which is termed as gesporoid in this particular types of deposits, and gold occurs is thin coatings on pyrite on surface of a memphis carbon and also dispersed in auriferous pyrite and realgar, here the ore fluid is essentially, a low saline carbon dioxide containing and s fluids containing fluid which resembles sometimes to, some of the epithermal mineral deposits. But they are being classed as a as their individual type, which are named after in the most of these deposits were studied and their distinctiveness were brought out, they clearly there is a role played by the late granitic intrusive.

So, the mineralization is either proximal or distal to this interest intrusive and the fluid inclusion evidence, clearly indicates the involvement of meteoric fluid, have and be with the magnetic component also, present these 2 diagrams depict sequence, the model the hypothesis on the origin of the karlin type gold deposits.

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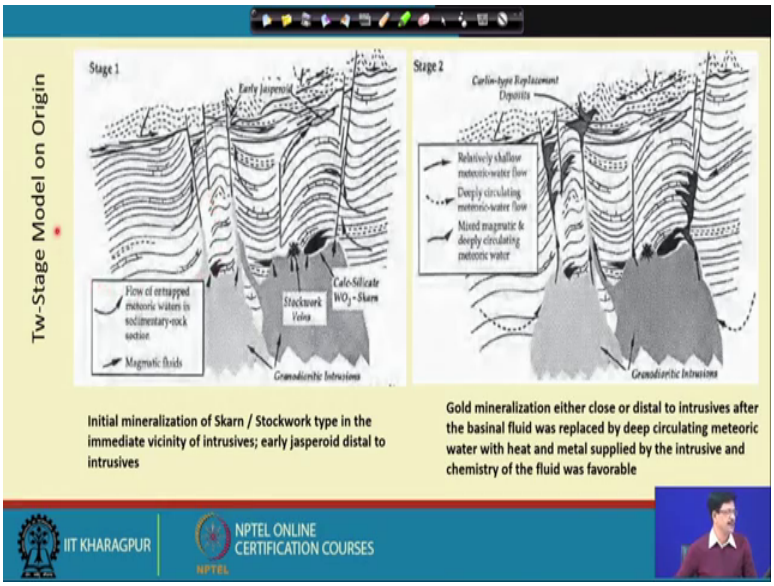

So, as you could see here it is almost resembles it is a very intricately deformed sedimentary basin, where there has been very high angle aj faults are high angle normal folds and these are the these are the domains. In which the early replacement of the carbonaceous rocks by silica and just better, replacements took place and there were inclusion of the felsic ah, magma filled magnetic body grano diuretic inclusion in forms of stocks, and immediate vicinity of these stocks there were stock work type of veinings and formation of the calsilic rate, type skawn and there were these intrusives essentially made, driven or the these intrusive also contributed the magnetic fluid at the initial stages.

So, the initial minerals mineralization was more of a skawn stock work type and immediate vicinity of the intrusives and with later progress into the later stages, the distal karlin type replacement deposits started to form in these regions which guided, very much structurally controlled and these are close to a distal to the intrusive, after the basinal fluid was replaced by deep circulating meteoric water. So, these with the heat provided by these fills again 2 sips it set up the convective circulation convective flow of the meteoric fluid and it is believed that gold is.

Gold and the fluid in terms of sulfur and the complexing species, were contributed by these felsic magma and these mineralization resulted and this is tentatively or this is a very simplistic way, of presenting the origin of this kind of very important class for

deposits, they are not only confined to the karlin in the in the in the movement they are not mostly confined to, these Western United States, there are similar type of deposits which are also reported elsewhere.

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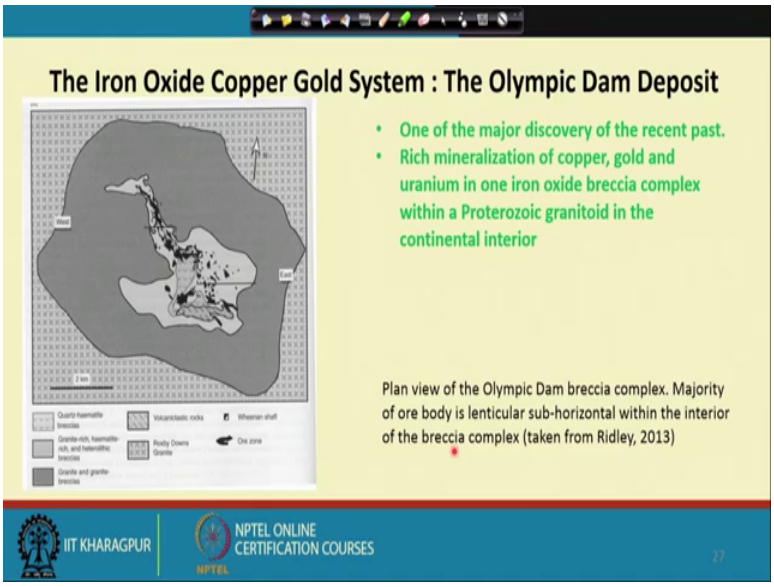

So, with the discussion on the Karin type deposit, which one of the very special type of deposits, or very special type of hydrothermal system; we would now go over to discuss, another very special type of hydrothermal system which is the iron oxide copper gold system, and it is actually this particular class of this particular group of deposits, where named or started to be started to be investigated in more details. After the discovery of this olympic dam deposit, which can be told is one of the major discoveries of the recent past, in mineral in the history of mineral exploration, where a huge concentration of copper gold and uranium was found a in a body of a granite, which is essentially within the zone of which is brecciate in this zone kind of a breccias complex.

Almost going to the order of gigaton, quantity of the metals copper gold going to point 5 grams per ton grade copper and massive uranium inhalation was observed. In one of the associated with this breccia complex within devolar within the rocks (Refer Slide Time: 17:04) the granitite in a in the in the garbler coition in South Australia. So, this kind is a very important discovery in the recent past and it gave rise to a new concept of ore deposits, which were named is the iron oxide copper gold or Io Cg class of deposits,

because the occurrence of such kind of mineralization in a in a granitite in a continental interior was not known till that time and.

So, they you could there is the plan of this deposits plan is shown here, this granite is this granite is shown as the roxby downs granite, within which there is a breccia complex, occurring almost to 4 kilometers to 6 kilometers kind of area, and is essentially covered by later sediments, and the majority of the ore body is a lenticular suffer a gentle within the interior of the breccia complex, and we will just see, how this deposit how the how the mineralization is disposed to the subsurface from the subsurface section of this deposit.

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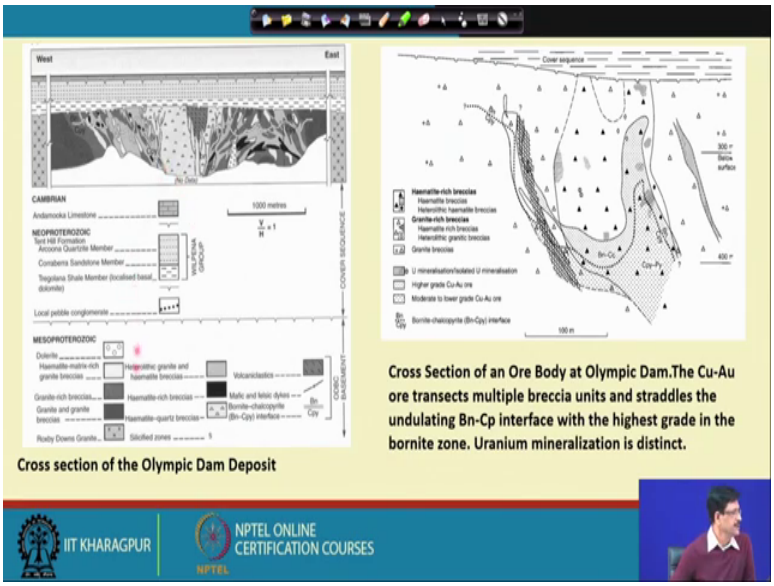

As you can see here, this is a cross section of the olympic dam deposit, where the breccia complex and the mineralization is shown. And this is this is the mid proterozoic sequence, of the of the granite and the rafic and felsic dykes and this is the dixia zone, which contains the mineralization and if we look at the one of the one of the ore body in it is subsurface section, if we had a clearer idea as to what the mineralization is like.

There is clearly a the mineralization a reach and mineralization of copper in form of bornite, of it straddles the lower grade or the chalco pyrite zone, and they make the uranium mineralization is pretty distinct, and is not it is a it occurs I saw it is occur separately, as a ore body in the upper part.

And. So, the this cross section. So, this deposit led to a lot of speculation about, what could be the origin of this deposit. So, the fluid characteristics does not indicate a very clear cut direction magnetic source, but there is the from the temperature and salinity value of this fluid, that gave rise to this olympic dam deposit, do does indicate that there has been involvement of more than one type of fluid in giving rise to this mineralization. The popularly held view is that it evolved by mixing of 2 fluids one, which is an oxidized fluid with sulphate essentially the.

This occurrence of this hematite rich breccia this breccia is essentially is a hematite rich breccia in which the mineralization occurs, the copper mineralization occurs within the breccia breccia complex. Essentially constitutes of contains hematite along with fragments of the granite and. So, this in itself is a distinct type which is different from the porphyry type deposits or any of this skawn type of mineralization, in the in the most simply term possibly, it could be thought of is some kind of an epithermal system, but it does not have any such kind of alteration zones as we see in the periphery copper deposit.

And this the discovery of this deposit relate to a elaborate program of exploration search, and many a they were discovered in many other areas in the world and they go by this individual classes IoCg type of deposits and exemplify and identified by this olympic dam deposit, which is almost unique in it is mode of occurrence and most of it is characteristics ok.

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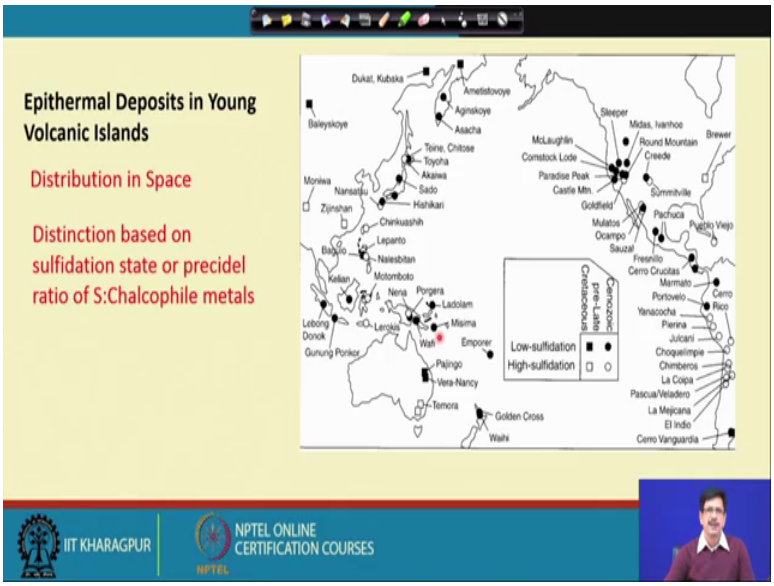

So, that brings us to as discussion, to a close of a discussion where we were mostly dealing with hydrothermal systems, which were associated with directly or indirectly with felsic intrusives and deeper sources as a metamorphic fluid and we saw the characteristics of such kind of deposits briefly, without getting into much of the details of the genesis of such deposits.

Now, we would like to go over to a very interesting class of deposits, which are essentially which are known as epithermal deposits, in young volcanic islands. We have been seeing through such kind of maps that, this is the pacific ring of fire and the deposits which are which are which we are going to discuss now, are distributed all around is of the specific plate or what is basically known as the specific ring of fire. The important ones we could see here, just about in the near the papua new guinea island there is one small island which is lihir island which holds a very rich important gold deposit, there is the ladolam deposit all across all along.

If we see the Japanese island arc here, there are some deposits like this in the Kyushu province this is the Hishikari deposit one of the very rich gold deposit, and in the in the Western Margin of this South American continent and the Western American Cordillera. We get series of such deposits, which are which also are associated with where essentially. So, their epithermal essentially mean that, they are confined to the top 5 kilometer in there within the earth crust means the active ore forming process is within

that kind of a depth range as compared to many of the hydrothermal systems, which we have discussed so far are depleted.

So, these are the a near surface operating hydrothermal systems. So, here as you can expect that, the young volcanic islands are definitely responsible for formation of such kind of deposits. So, as far as this particular this particular class which are the epithermal deposits, in the young volcanic islands are concerned. These deposits are broadly classified into 2 types, the one with a low sulfidation type and the high sulfidation type.

On this diagram the ones which are with open circles or open square are the high sulfidation ones, on the closed circles into closed squares as the low sulfudation ones and ones as you could see here, that these low sulfidation or this high sulfidation ones, which is which are occurring in the Andean Chilean Andes in the South in the Western Margin of South American continent is very closely, specially associated with porphyry copper deposits.

So; that means, they must be having something some common parentage as far as the mineralization process is concerned, and in most of most deposits it is observed that they do have a very close time relationship, they are mostly synchronous or at the same time as formation of this porphyry copper deposits, which themselves are very young; deposits such as laddolam, which is almost about 400000 years over this 0.4 million years old.

So, these deposits and the processes, they give us ample scope to understand the hydrothermal ore farming process, we can call them almost as present the ore forming systems. So, the distinction based on the classification is the low sulfudation and high sulfudation is essentially based on the oxidation state of sulfur the sulfur is mostly in the plastic state here, and actually the classification based on the ratio of sulfur to chalcophile metals, it is not exactly that they do contain a lot of sulfur, but the deposits they are essentially they have a high sulfur versus chalcoohile metals and the sulphonation state is higher means, as expected the high sulfidational deposits are likely to be dominated.

By mineralogy which are pyrite or bornite mineralogy and whereas, the low sulfudation ones will be pyrrhotite arcsino pyrite dominated mineralogy and they do have also characteristically the high sulfidation deposits, essentially of very low going to the low

pH and their alteration characteristics are accordingly reflected in the in the alteration zones compared to the low sulfidation deposits, high sulfidation deposits are as dominantly of base metals like copper, and the low sulfudation deposits dominantly are for the precious metals like gold and silver, although they will have some trace of the each in the other.

And what is more interesting is that, the low sulfidation in as a similar geological terrain like, a Japanese island arc, can have as you can see from the from the belligerents here, both can have the low sulfidation and high sulfidation deposits. So, it would be it should be expected that, occurrence of the low sulfidation or high sulfidation has some local controls, although the broad broadly the kind of volcanism of the composition of the host rocks, would look to be more or less similar.

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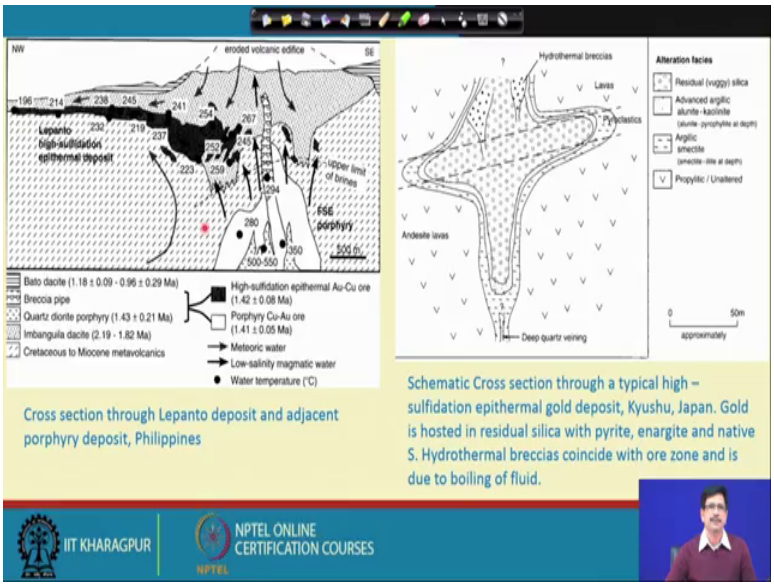

Here is a cross section of. So, you will just briefly look into the characteristics of these high sulfidation and the low sulfidation deposits, to the left is a cross section of a high self-reduction deposit. Where it is observed that the deposits are, they occur to very close to the volcanic center. This is an example of one high sufidation deposit in philippines where the porphyry deposit in the close vicinity is also shown, and the way the migration path of the fluid and the temperature decreasing tend of the temperature is shown. So, there less than about a kilometre within the volcanic center, and their depth range is

about within 1.5 to 2 kilometers from the surface, this is a classic example and they are sometimes associated with breccias, and interestingly.

If it say these ore bodies do have an inverted teardrop type of shape, and the they are essentially associated with something which is a very interesting feature, which a residual and foggy silica, which indicates that before the mineralization episode they fluid which interacted with the with this within this particular zones, where was extremely acidic in it is nature and it almost dissolved out the rest of the component just leaving behind the foggy silica zone.

And this later on the metals were deposited is metal sulphide in this acid in this foggy silica zone, that this basically is the mineralized zone and they are they are surrounded by the alteration, which is advanced argilic alteration which is illuminate bearing at work alunite and calarite bearing advanced angelic alteration and with peripheral argelic and prophylactic kind of unaltered situation also is observed.

So, they do they are they are very much typified by very low pH conditions, giving rise to alunite in the alters in zone of the advanced argelic alteration, the hydrothermal brecccia is coincide with the ore zone and here, this kind of brecciation within the mineralized zone does indicate there must have been some boiling of the fluid, which caused the hydro fracturing and formation of the breccia and this is kind of a thing which you can is a model for the origin of the high sulfidation deposits, setting of an acid alteration and high sulfidation ore formation and ore forms with.

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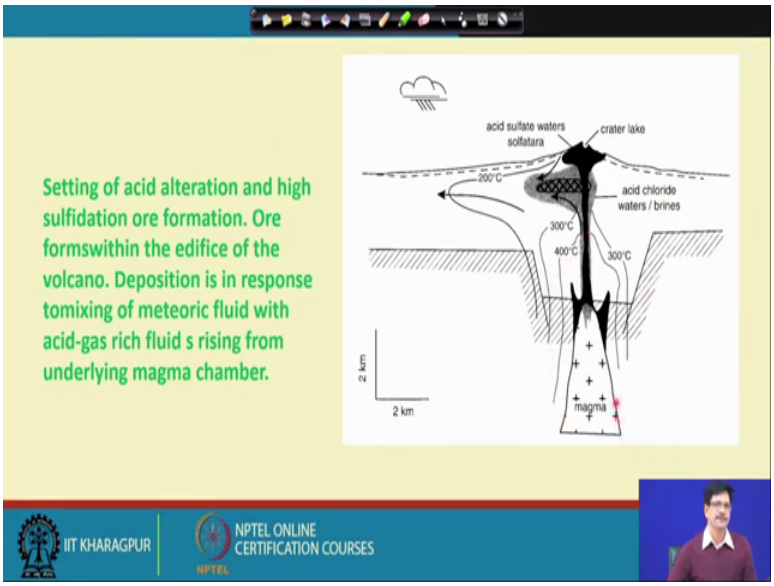

So, here this zone is the formation of the ore and this is the crater lag and the temperature contours are shown, and as you could see here the ore fluid generally is of a high saline, below this there is a zone which defines the fluid characteristics to be of higher concentration brines, compared to the ones which is causing the mineralization by effectively by dilation of meteoric water during the process of mineralization.

So, this deposition is response to mixing of meteoric fluid with acid gas rich fluid, rising from underlying magma chamber, the magma chamber is responsible in providing the very acidic sulfurous of vapour, that condenses into the metallic fluid and becomes very acidic in it is nature, sulfate rich and cause the alteration value right type of alteration and they are very typical of the high sulfidation deposit.

So, we will continue discussing about the epithermal deposit in young volcanic islands.

Thank you.