Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture – 15
Morphology of Ore Deposits

Welcome to today's lecture. In the previous classes, we had a brief overview of mineral deposits formed by magmatic and sedimentary processes. Before we move over to the other processes of mineral deposit formation, it would be worthwhile to have a discussion on one of the very fundamental aspects of mineral deposits which is not only important from fundamental point of view, but also it is important from a practical point and utilitarian point or economic point of view as well.

So, that is essentially is basically the morphology of the ore bodies morphology means we mean precisely; what is morphology is the way in which an ore body is disposed in 3 dimension in association with crustal rocks in any segment in Earth's crust and in the course of a discussion on the magnetic deposits, we have had a look on the magnetic deposits like the comite deposits, nickel sulphide deposits occurring in ultramafic complexes and also with intermediate rock composition and the occur in a stratiform manner.

Almost mimicking the sedimentary strata and then we have seen that the result of crystallization differentiation of apparent basaltic magma and such kind of ore bodies generally, if they are not that very not very deformed, they do preserve their pristine characteristics; their characteristics as we have seen in case of the Boswell complex.

And the other example that we saw in that of the kimberlite pipes which occur typically in the carrot shaped form as dry themes and the dikes that are exposed on the earth surface with permanent features and there it is a very characteristic and also it tells gives a very fundamental idea about the process in which the body has formed and the come into existence.

Morphology of the ore body gives very preliminar very fundamental idea about the process as we have seen in. Please do examples that we discussed and then morphology has got a very important role to play in all other deposit times that subsequently, we will be discussing some of the important classes as the hydrothermal deposits. So, before we go to look at the process in details, it would be worthwhile to discuss a little bit about the various ways in which such kind of deposits conform in the earth's crust it can be present in the earth's crust

The morphology we study. So, there will be 2 main important aspects; it is very fundamental.

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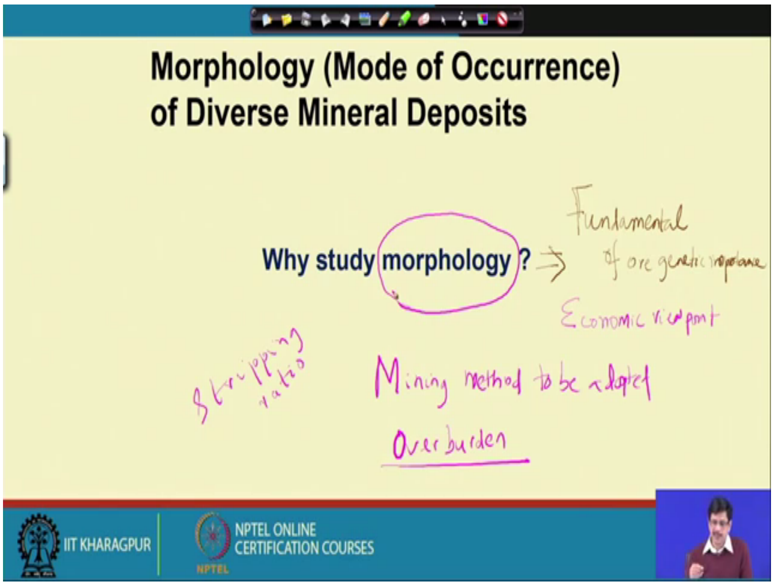

It is one of the very fundamental attribute is the one of the very fundamental attribute of ore genetic importance and number 2 is that a the morphology of the ore body needs to be a certain, it is a must for any mineral deposit which is discovered and is going to be economically worked out. So, this particular deposits, it is very important that its morphology worked out for economic viewpoint because essentially the morphology decides the very way the very method by which the ore deposit will be mined, will be recovered, will be exploited in any particular mineral deposit where this ore body has been discovered.

So, the initial stages of the look the searching for this ore deposit and after the presence of a ore body is conformed which we will be discussing in our later part of this lecture series, one we discuss detailed about the exploration methods.

So, once the ored; ore body has been identified, it is known to be existing, it is very important to work out the 3 dimensional disposition pattern in the crustal rocks. So, that decides it is a very important aspect which decides the method of mining the mining method that is to be to be adopted because there are certain parameters that comes to consideration is that in order to exploit a particular ore body in any situation existing in the crust.

It is very important to estimate that how much of the rock which I; which are not economically important to us, but our occurring as what we call them is overburden what you call is overburden is there; any amount of material either weathered rock mass or any later deposition of sediments or soil or any other unit any other entity that are associated which are generally known by the by the term overburden has to be removed in order to exploit the ore the unit any amount of ore from the ore body.

So, that ratio the amount of ore to the amount of rock or amount of overburden to be removed to get a unit mass of the ore which is known as the stripping ratio, it is an important economic parameter which comes into existence. So, understanding the morphology of the ore body is of paramount importance in economic geology and study of the ore deposits and also related economic activities.

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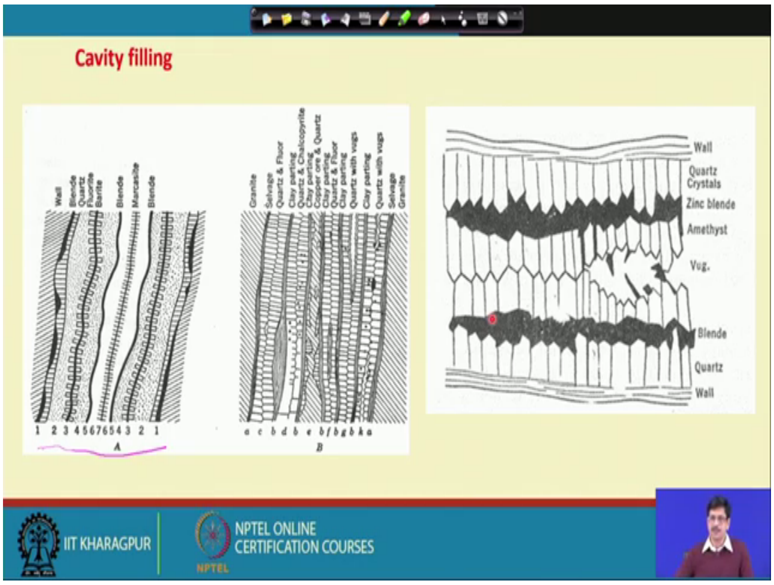

Let us so as far as the hydrothermal deposits are concerned the details of which we will be seeing in terms of the process, in the coming lectures can be generally be divided or can we can be classified into main disturb and into the 2 types as cavity filling or as replacements. So, cavity filling the term is very self explanatory. So, wherever there is a cavity that is made in the rocks by natural process

So, that cavity is basically open for fluid infiltration and fluid circulation. So, wherever there is a fluid that is occupying in a open space the fluid will deposit its minerals depending on the; on account encountering the appropriate physicochemical conditions and it invariably we have seen that in the crustal rocks wherever there are fracture spaces there has been deposition of minerals by that factor fluid which circulates in the fracture and this gives a very good ideas to the clear cut symmetry as to can be very well observed here.

We see that from this is the core or this is the center of the vein that we are that we see here; this is the center of the vein and the deposition of materials on the on the either side of the center has taken place very symmetrically. So, we are seeing here that blende standing for zinc blende; it is fluoride, then barite fluorite quartz and again blende and again wail. So, likewise we see that there is a symmetry that exists on either side of this centrally; centrally placed deposit.

So, this generally happens with gradual opening of the fracture and deposition of minerals is in this in this particular sequence here, it is an example in which same thing which we call them as the comb structure or cocaine kind of structure which mimics that of a comb which you can be seen very clearly here as this; this is the fracture space where the crystals have basically deposited on the fracture wall and the project with their projecting faces and very much look like a comb and this is a normally a comb structure.

And this is a magnified view of that we could see that there are many different generations of quartz plus ore mineral again quartz plus ore mineral which happens in a typical cavity filling situation. So, it is called as cavity filling; it is just because its filling up the cavity and filling up the cavity with by the deposition of the minerals.

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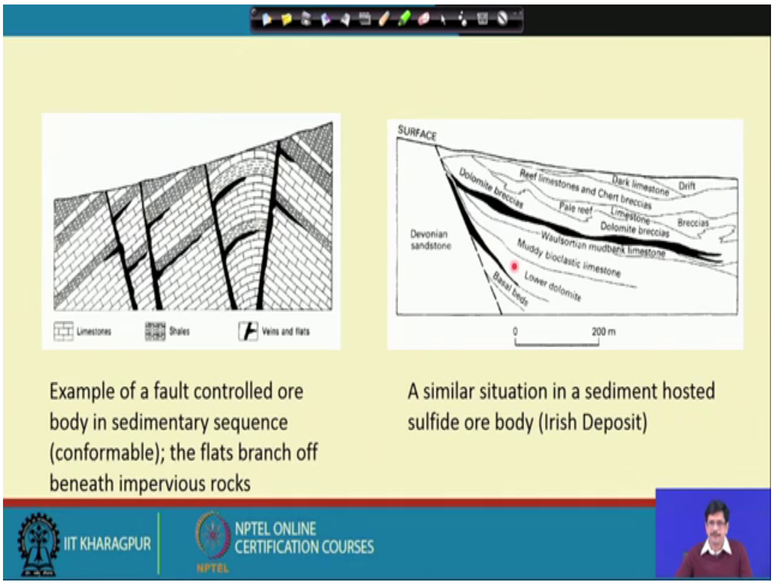

And these are typically this is a typical of the situation where we could see that this is a sequence of sedimentary strata and there are faults. So, this would be fluid which have gone into the fault have deposited the ore minerals and have just followed the bidding plane in forming the flag branches of whenever there is an impervious rock for example, there is a calcareous rock which is served as a rock through which we could move and whereas, the shales; more rebellious than the limestone and the deposition of the ore minerals in this form has only happened whatever they are; it is got a the fluid has been got a favorable channel way and although the main channel has been the for default.

So, this is an example of a fault control ore body this is an example of a this is situation similar when a sediment hosted sulfide ore body which will be studying in some amount of detail in the coming classes. So, there we could see that the where very much conformable to the sedimentary strata which you can see here.

So, these kind of ore bodies will be simpler to as an as a till the time till then they are occurring in undeformed conditioner in the class where I have suffered a very little of deformation. So, such kind of original pristine characteristics are very much preserved.

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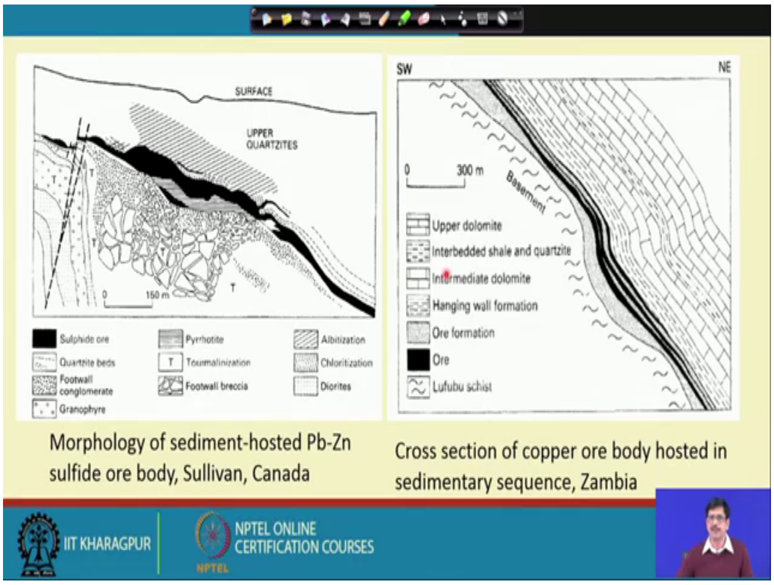

And this is an example where again a conformable ore body is present along with the sedimentary strata in a sediment hosted sulfide deposit this is the example of a copper to copper mineralization and in strata of sandstone typically are the kind of sandstone hosted copper deposit strata from copper, it is an example from the Zambian copper belt.

So, these kind of situations here the kind of mining method that that is to be able to be adopted will very much be decided by a proper worker working out of the geometry of the ore body in the subsurface the depth dimension which generally is not a not easy to be estimated on the surface where they need to be they need a lot of methods to be adopted for certainty of their 3 dimensional structure which will be topic of discuss in some of our subsequent lectures.

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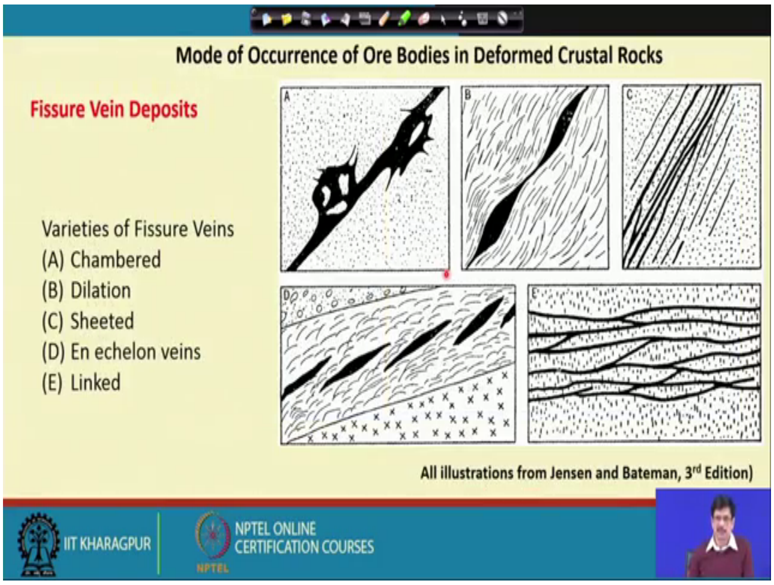

These class of mode of occurrence which we work in state in that way the different modes of occurrence is a basically been is known by a print class which are called fissure vein deposits.

So, the fissure vein deposits fissure is any weak plane that is created within the earth's crust because of stress that is applied on the rock because of many different conditions for deformation or could also be occurring because of solution dissolution of the rock because of fluid and here there are some diverse situations which have depicted the in first case.

It is a chambered type of fissure vein fissure is a plane of weakness wherever the so, they will always have a geometry that derive the one of the dimensions will be will have higher than the other 2 like this one here this is the case where there have been some dilation in the country systoles country rocks and they fluid only could be occupying the zones where there has been dilation and this is the situation which is depicting several-several such fissures which are just disposed parallely and which you could be called as a sheeted kind of fissures.

In this kind of case its known as the initial ore kind of pattern where there are independent lengths; lengths ore bodies or fissures which maybe might have opened because of those at the dilational zone like what we see here, but here they are not connected to each other and this kind of a pattern is very well known as an initial ore pattern and this is a situation in which the different from what was shown in this case as its features are interlinked and all these are marked by this thick line is actually representing the deposition of ore minerals from the fluid on these fissures.

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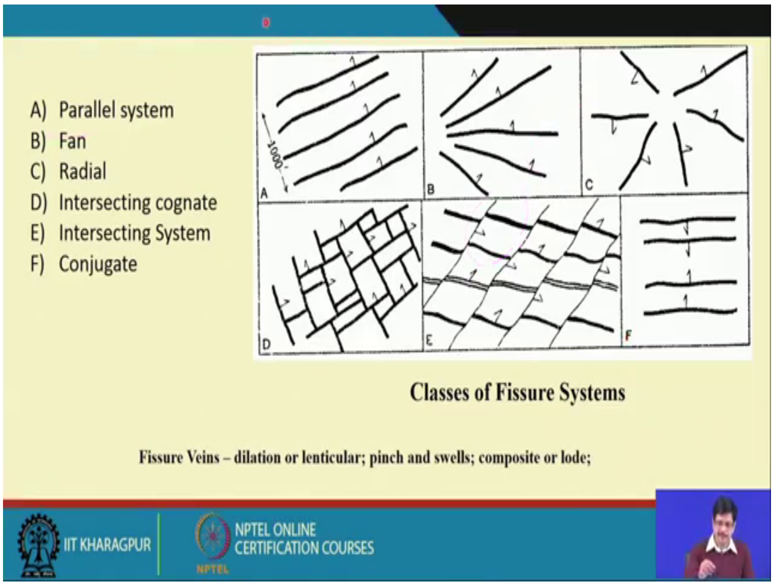

Here, we are saying that these fissures could develop either parallel manner the sheeted ones which you saw, it could be making a radial pattern, it could be occurring as in case of C, this is a radial pattern. In this case, it is kind of a fan and in case of second figure is kind of a fan; in this case, they are intersecting each other, but they are cognate in the sense that they formed at the same time the this one represents a intersecting system where they are conjugates fractures means when the stress is applied the fractures that are developing in different geometry abiding by the laws of fracturing and in this case it is again a parallel sheeted kind of fissure system.

So, all these situations are observed in the brittle deformation zone of the crust mostly in the hydrothermal deposits these are interesting situations.

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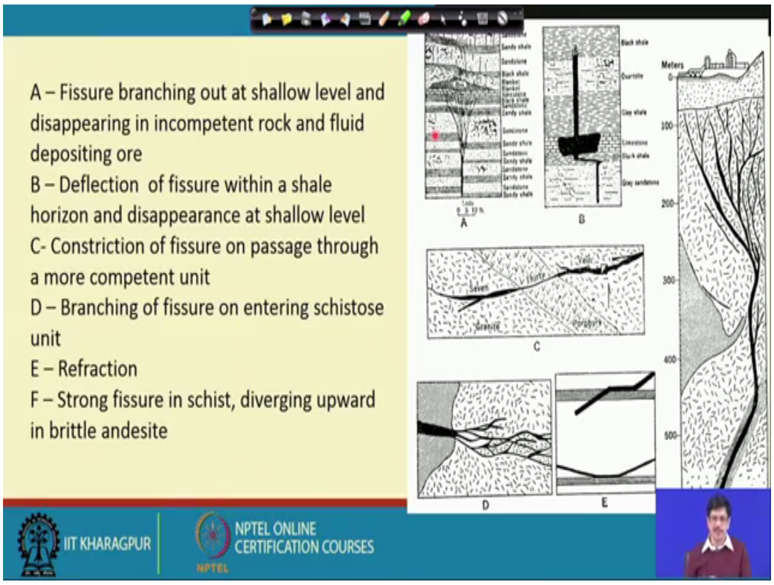

So, if we have different rock types sequences or different rock types and also with depth when a fissure is developing as a strong fissure and a thick on feature fissure over here and as A is a when we transmits, it will always get branched out and also will be very much dependent on whether it encounters more competent or incompetent rocks if the; if it encounters more incompetent rock, then the fracture either died out or basically they form a network or branched out and whenever it comes with a more impervious rock there the ore is deposited.

This is also a situation where there is a shell in which we see that the fracture is thicker, but is it again when it enters a more competent rock like a like a porphyry it gets almost like form a reticulate kind of pattern here, it is the case where the fracture gets thin down when it moves through different rock types here, it is the case of fracture deflection here it is the case of the branching of the fissures when the main fissure from the schistose rocks the entering a more brittle or competent rock here.

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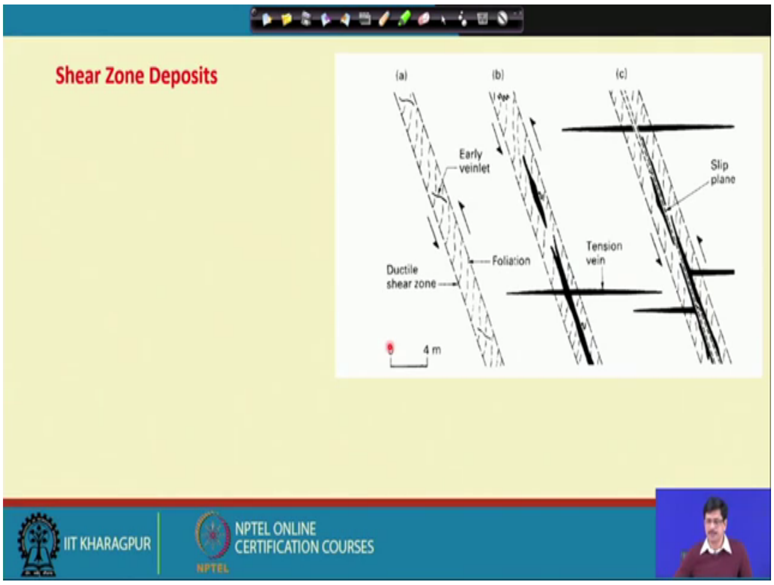

So, these are one of the very important types of morphologies which we get to see in mineralization that occurs in shear zones. So, before that we can just have a very preliminary brief idea about the development of this kind of shear zone here as I shown by the arrow mark here.

So, there are movement of this box in this has given by this arrow and because of this there are some the dotted line actually has marketing the marketing the fabric that is developed in rock and when the movement occurs in this away there are some dilational zones which are created within the rock and they become the locus, they become the lousy of deposition of early set of veinlets because of population of fluid within this because it is a shear zone there is brittle or ductile shearing of the rock and there is reduction of volume of the rock and that allows the crustal fluids to be channelized through this and they occupy the dilational locals where there are early from veins.

And the progressives shear these early from veins they themselves also get flattened out and they are also deformed and if the shearing is progressive or this shearing is again subsequently there is another generation another phase of shearing and with progressive shearing then it also forms such kind of horizontal tension veins and by the time the shearing is has moved has progressed to a very later stages there we see the early formed a quartz since they themselves get sheared and these are very very common features which we observe in mineralization associated with shear zone some of the examples which we will see later on in case of the copper deposits and some in the Singhbhum shear zone or the gold bearing load deposits in India where there are very much shear control.

So, shear zones are very important locales or very important elements of study as far as mineralization is concern and they do represent a crystal scale deformation they are very sometimes they are very much deeply seated and they make prominent crustal features such as lineaments which can be observed on the map or from smaller scale synoptic maps.

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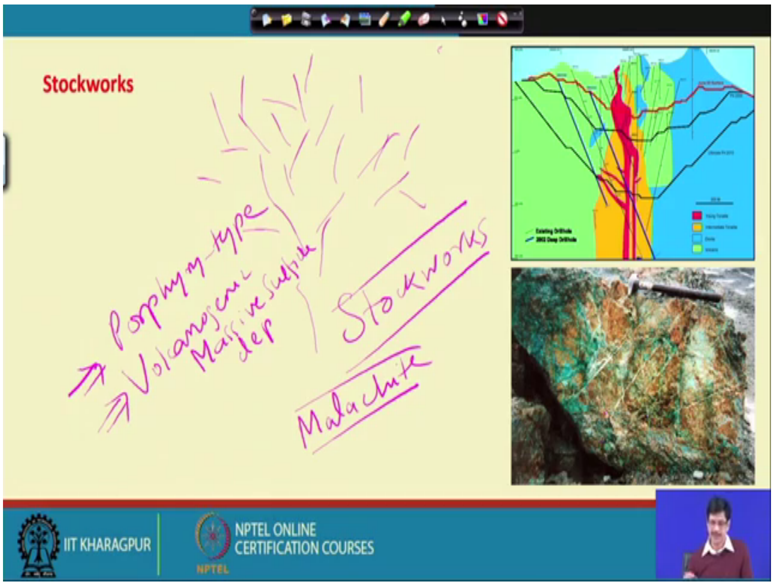

There is an example like this we will be taking ups some time later, but before that this is a typically deposit paprika type copper deposit and in this kind of situation we find that the mineralization take takes place in a more of a more volume of the granite and it is associated with lots of dense fracturing because of by mechanism of hydro fracturing the pressure that is exerted by the fluid which accumulates and they exceeds the yield strength of the rock and in which case it kind of reticulate kind of fracture pattern is develops which is generally known by term or stockworks.

Such kind of stockworks are very very common in many types of mineral deposits especially the porphyry type porphyry type copper deposits sometimes in volcanogenic massive sulfide deposits and also some brittle information zone in the cross wherever there has been evidence of fracturing due to fluid or hydro fracturing we generally see such kind of stock works generated .

This is a picture taken from one sample where you could the scale could be observed and what I have drawn here in this sketch representing a stock work which is just a dense network of fracture that is generated in the rock because of fluid pressure and this particular material is a raw is an ore in which it has this kind of a stock work related mineralization of copper and this copper mineralization has been later been oxidized giving rise to this kind of.

This would be pattern that is made or that is formed by the later oxidation product of the copper minerals here which are malachite which you know are the copper carbonate minerals which form because of the oxidation of copper sulfide primary copper sulfide it gives a very good idea about what the fracture; the stock works are or what the stock work mineralization generally looks like.

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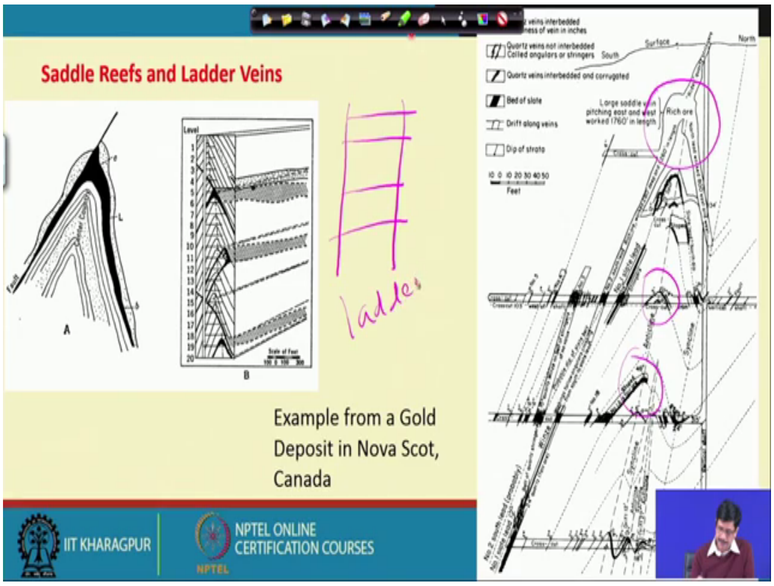

And they just some of the very typical features in the formed terrines this is the very this feature which is called the saddle reef which almost mimics the back the saddle which is put on the back of the horse people who ride the horse. So, here it is a sketch that how this generality the a hinge part of the fold where the there is maximum accumulation of the ore here and such kind of features are observable and this is the this is a case of a gold deposited in nova scot in Canada where we could see that this rich; this zones where the rich mineralization takes place in most of the areas are which are the a hinge zone hinge part of this fold and this many of the layers are folded.

So, this is the feature which is named which is named this saddle reefs and there are situations which are also they look like the fractures which is just like a ladder I mean they have been filled up by fluid and there is the mineralization. So, they are known as the ladder veins.

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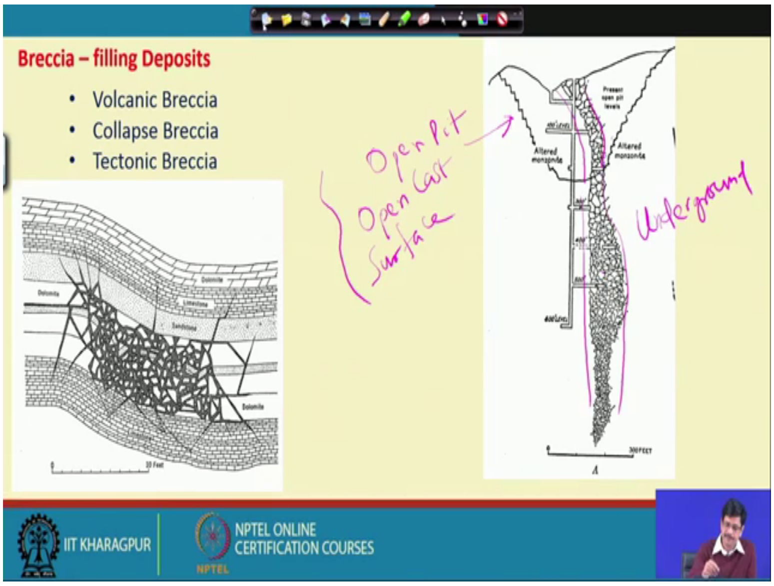

And these are sometimes there could be features which you could which you could in terms of the morphology in terms of mode of occurrence we could clearly see that the mineralization is mineralization taken place in the Breccia and such kind of occurrences are observed in many different types of deposits, it will be seeing them in the subsequent discussions,

So, these are different types they could be either a volcanic Breccia or a collapse Breccia or a tectonic Breccia, it is in here is an example of a Tectonic Breccia which is formed within the dolomite and the mineralization has taken place in this within the spaces created by the Brecu; Breccia, they becomes a Joel which is porous and allows the fluid infiltration and deposition of ore minerals

This is also represents a very interesting situation which is a Breccia pipe type of situation where this outline indicates that this has been this particular deposit has been worked out by a method of mining which is basically this from this what is basically shown here is the kind of open pit or open cast or against a surface mining type of method in which the ores that is occurring within the Breccia pipe has been being mined and from here also, we can make some idea as to what we were talking about the amount of the country rock to be removed to excess or to exploit the quantity of the ore which is present here that gives us a very good idea.

So, here we could be clearly see that the volume of ore which is here and that the needed the material from all these which is shown by this tape which is the outline of the peak to be taken out in order to get the ore and that ore body has been later on I have been taken out by doing by going underground and adapting to a different type of mining practice which is the underground mining.

So, this clearly demonstrates clearly justified to what we initially started the topic is the importance of understanding the morphology or working out the morphology of the ore body which not only just gives idea about the process by which the ore; ore body is originated, but also important clues and important guidelines by which the exploitation of the ore body could be taken up.

And this is a very interesting feature of a Breccia pipe what we what we see here and this is almost up to six hundred eight hundred or even thousand foot and is deeply seated and because of some process of Brecciation which could also be because of very explosive fluid activity which it shows.

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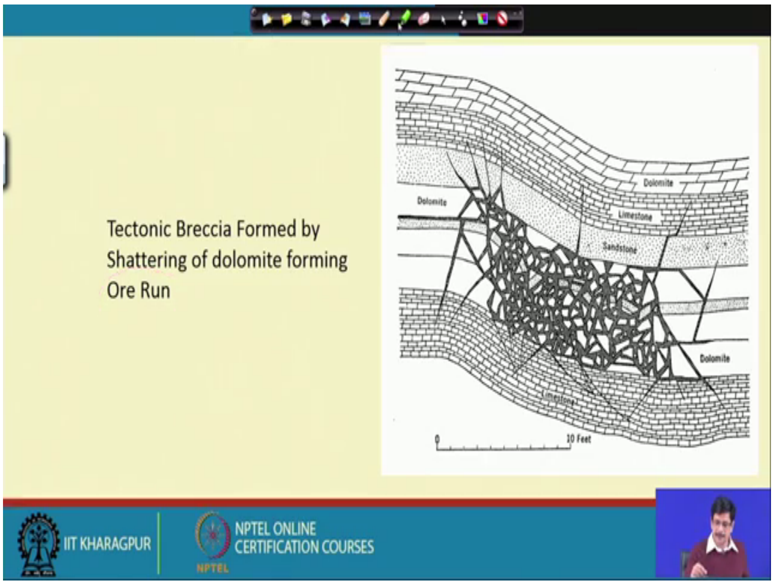

There is tectonic Breccia formed by shattering of dolomite forming; what is essentially in the mining geological term is known as ore run.

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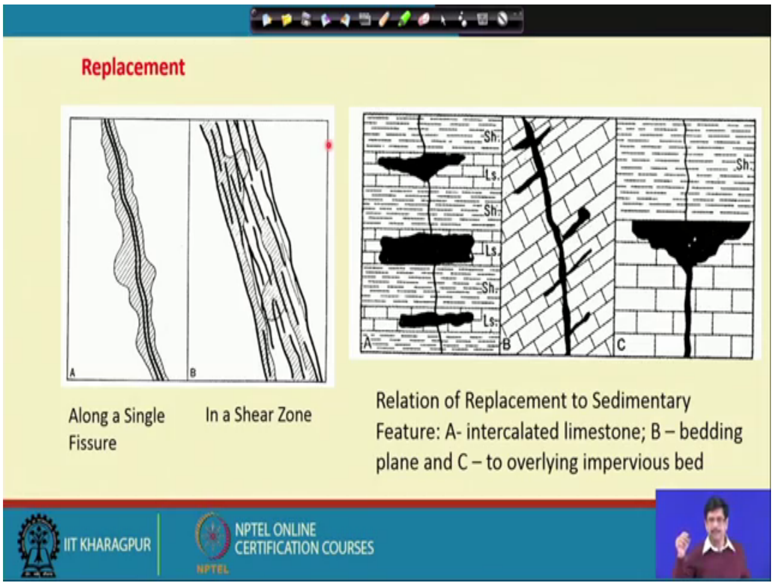

And the deposits and we first told that they could be either of the cavity filling type or the other one is essentially the replacement type where you could see that this is the main feature on which the mineralization took place, but the deposition which is formed in the form of there has been taking place in terms of the deposition of the minerals on either side of the fracture is not symmetrical which indicates that there has been some amount a replacement of the country rock through these kind of fissures. This also shows the same situation and in this; in these cases wherever it has got a suitable country rock the deposition of the sulfide minerals as taken place which is also because of replacement these are all examples in which the fluid has actually deposited the ore materials ore minerals by replacing the country rock selectively by either dissolving the components of the country rock and then depositing the metals in them

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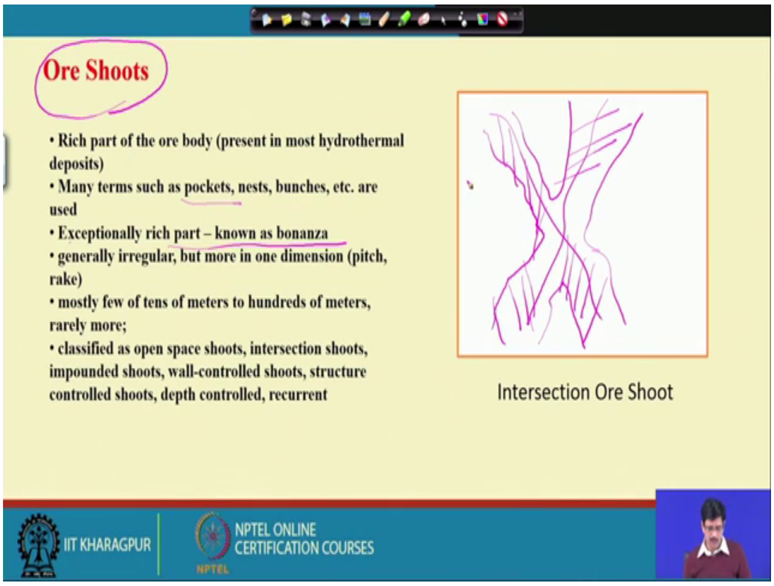

And this is a very very commonly used term in mining geology literature which is called the ore shoots. So, ore shoots essentially is the enriched part or the rich part of the ore body which is present in an hydrothermal deposit there are many term such as pockets nests bunches etcetera which are used in the context of this kind of ore shoots.

They are exceptionally rich parts sometimes forming as the bonanza and which are the zones which are mostly look for during the mining and they are generally irregular, but more in one dimension the intersection of the abiding with the a fringy fracture where there is a fissure is been created there because of the solution activity ore one ore body would be forming which will be more in one dimension mostly few tensors. For example, if we have some kind an intersection type of fissures then the ore shoots will be forming something like.

So, there will be an example of an intersection ore shoot, there could be either; I mean they could be of different types and they are open space shoots, they are intersection shoot like the ore which is shown here and the previous example where open space shoot well controlled and there are structurally controlled shoots. So, we come to close of this discussion on the morphology of the ore body and we saw that it is essentially very important from 2 aspects from the origin of the ore body as well as from the economic exploitation of the ore bodies. So, we will continue in the next week ok.

Thank you.