Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture – 27
Hydrothermal Processes and Resultant Deposits (Contd.)

Welcome to Today's lecture, we shall discuss briefly on certain other important types of hydrothermal systems and the resulting hydrothermal deposit, we will be looking at the sediment hosted massive sulfide deposits or which are every waited as this SMS as the sediment hosted massive sulfide deposit in kind of a analogous to what we say is the volcano genic massive sulfide is VMS. So, these deposits we call as the sediment hosted massive sulfide deposits or the SMS.

They have been variously named; they were they were for some time they were the deposits which we know this zx type of deposit. So, this synsedimentary exhalative type of deposits meaning that the process is not purely a sedimentary deposit, mineralization is not because of the process of sedimentation in addition to the sedimentation in the sedimentary basin some something else or some other component is required to form the minerals the sulfide minerals.

We they can be we prefer to call them as the SMS the way we have been naming the hydrothermal systems.

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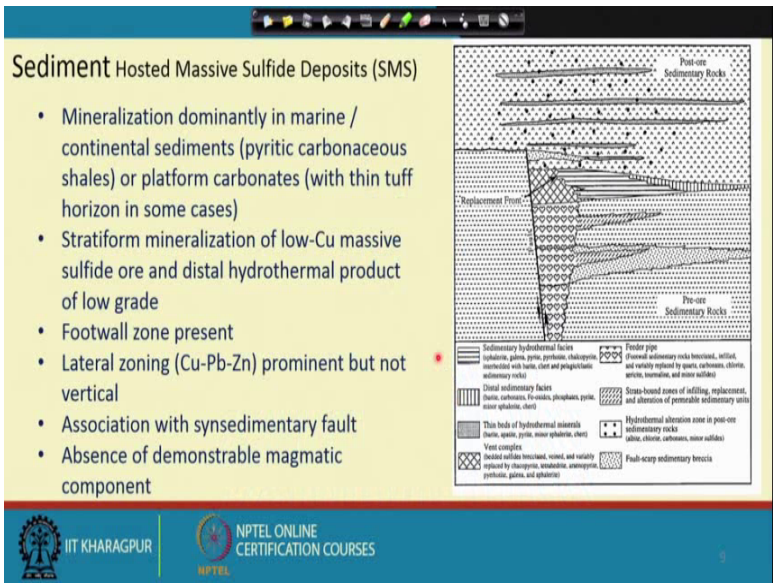

So, let us have a look as to what their characteristics are. So, the sediment hosted massive sulfide deposit are a very important class of deposit contributing majority of the lead and zinc resources of the world.

The famous deposits are the very well known deposit there. In fact, distributed in all almost all the continents and their quite rich in terms of their quantity in tonnage contributing most of lead and zinc, the Sullivan deposit in Canada is one of the one which is worth mentioning. Mount izar mineralizing system in Queensland in Australia and also the Macarthur river basin in Australia, Rommel's burg in Germany, the Irish deposits and some important occurrence in India where there is still some debates, but there could be also included under this the Zawar Rajpura Dariba in the northwestern India the Arabella full belt these deposits like Zawar Rajpura Dariba lead and zinc deposit. They also are included in this part this category and they are a very important class of deposits.

So, the mineralization is dominantly in marine or continental sediments pyrite carbonaceous shale or platform carbonates, with sometimes the presence of a to fascias horizon is also there. They are essentially Stratiform in nature as could be seen from this diagram and this is a typical idealized morphology like the one which we showed for VMS this is an idealized morphology for an SMS, where we can we see that there are in since sedimentary Basinal fault which is invariably present and there is a brick shaded zone which is also present and there are proximal sulfide mineralization in the form of the sedimentary hydrothermal phases, Where Sphalerite, galena, pyrite, Pyrrhotite chalcopyrite mineralization associated here and also a Distanfaci sedimentary facies bright carbonate and these are in terms of the grade they are rather lean type of mineralization or low grade whereas, the proximal one is the rich mineralization and there are some post or sedimentary rocks.

So, what exactly is observed is that the sulfide body is pretty conformable, is pretty much conformable with a sedimentary strata, this is like what we get in the VMS one deposits, this is the pre ore sedimentary rocks and constituting of the different facies this is the feeder pipe and this is the vent complex. This one which is shown as a crosshatch here is the vent complex and this is how is the general morphology of the SMS deposit they can be called stratiform, mineralization and although the ore minerals are not exactly deposited is plastics on the basin and they do have a have their limitation. The lateral

zoning is prominent, but not the vertical one and they are always associated with synsedimentary fault and one of the important point of distinction here is that just about sometimes a little bit of a thin presence of thin tuff horizon they are not associated with any significant a prominent magnetic member or magnetic component.

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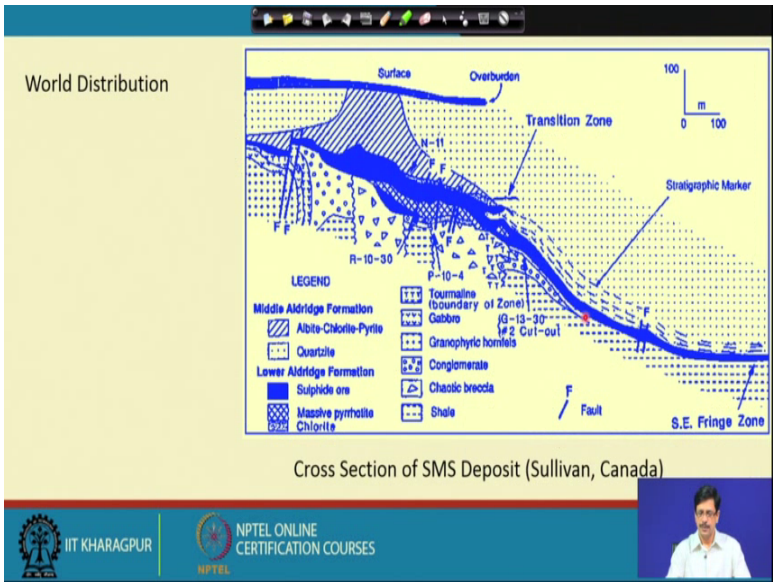

The morphology of the ore body a could be very well seen here, this section is from the Sullivan deposit in Canada, where you could see the sulfide ore very well conformable to the sedimentary strata. So, different horizons are present and it has a very prominent zone which is a a brecciated zone here, which is shown by this is the chaotic breccias zone which we just saw in a generalized morphology and a conglomerate horizon here and sometimes there are some basement mafic member as gabbro which is present in the Sullivan deposited as you see, as you can see here. This is kind of a generalized conforming to the generalize morphology is one of the important deposits SMS deposit in Canada.

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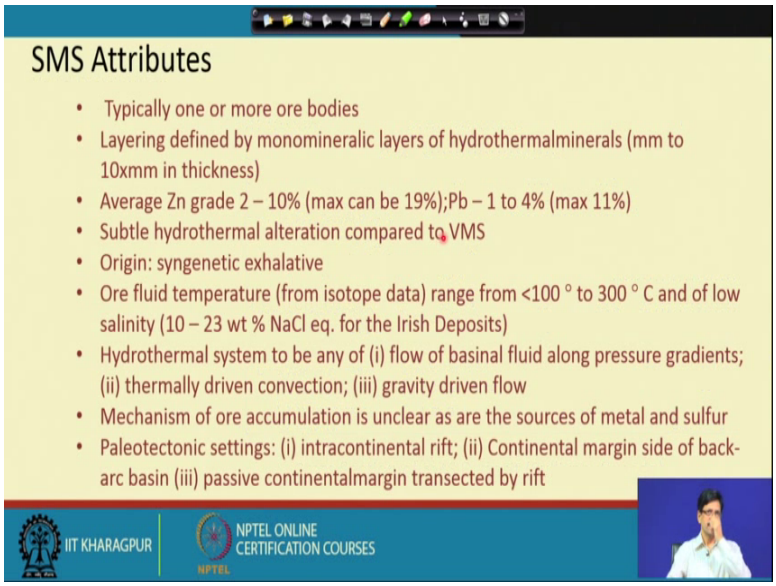

So, the attributes are the typically one or more ore bodies ore bodies can be multiple the layering defined by monomeric layers of hydrothermal minerals millimeter to tens of millimeter in thickness and the averaging grade can be height can go up to in 10 percent or sometimes can go up to even 19 percent lead going to 1 to 4 percent maximum 11 percent. And in contrast or in contrast to the VMS deposits there the hydrothermal alteration which we see is very prominent in the feeder pipe is rather very subtle in these SMS type of deposits.

So, the origin is syngenetic exhalative because we need to have some component because these sediment, sedimentary facies that we are showing the sedimentary horizons. They may not be may not be actual contributor of the metal and we need to have the metal source coming from somewhere these deposits unlike the VMS deposits where we see or we can do fluid inclusion work and this these type of deposits do not provide much of scope to do fluid inclusion work because there is no much of accompanying gangue mineral like quarge which is present, which where the fluid inclusion work could be done.

So, the ore fluid temperature constraint from may most mostly from the isotope data range from about 100 to 300 c degree Celsius and this itself tells that a 3 up temperature up to 300 degree Celsius can only be achieved if there is some input of heat from the

subsurface and the salinity of the fluid is rather low to moderate 10 to 23 weight percent nacl that is coming from the Irish deposits.

So, the hydrothermal system to be could be visualized to be anything of a flow of basinal fluid along a pressure gradient or could be thermally driven convection or could be gravity driven flow. So, in this case of a flow of basinal fluid, here the temperature of the fluid is definitely is expected to be not that very high, but only that there must be some kind of situation where the sedimentary strata have been compressed and the basinal fluid must have been squeezed out in a pressure gradient and those fluid by virtue of their higher salinity could have dissolved as appreciable amount of the metal and to have deposited in the local says its own.

So, mechanism of ore accumulation is rather unclear as are the source of metal and sulfur paleotectonic settings in this they are likely to be in the intercontinental rift continental margin side of the back arc or the passive continental margins with transacted by rift, where exactly we can explain the situation of the squeezing of this basinal fluid if it happens to be a passive continental margin transected by a rift and.

So, sometimes the metal when we get such kind of tofacias even though thin tofacias horizon they could also their source of the metal or the metal could have been source from somewhere deeper or more efficient if this the situation where we visualize the system to be a thermally driven convection there it becomes more explainable. But, situation remains a little bit less clear when the ore fluid temperature is low although we know that a cornet fluid can always be a met career of metal and the deposition or the metals can take place and we see the temperature range going down to as low as 100 degree centigrade is explainable and fits to the model.

So, that is all about the information that you could give about the SMS deposits.

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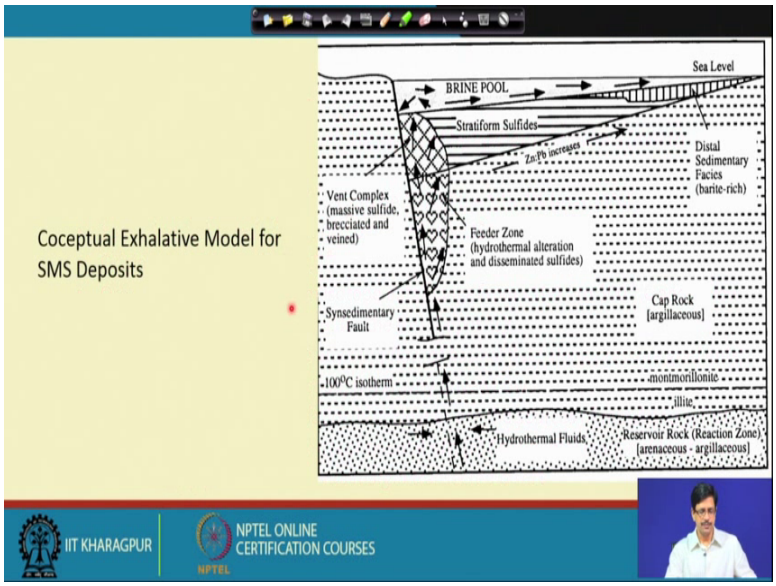

So, this is a conceptual model for the exhalative conceptual model for SMS deposit, where the hydrothermal fluid could be squeezed from the reserve where rock which is the reaction zone could be are arenaceous argillaceous rock. This is the hydrothermal fluid and this hydrothermal fluid will rise and which is shown in this is a feeder zone have to thermal alteration will be mop will be very moderate or subtle here and this is the vent complex of the massive sulfide brecciated veined and this is the distal this is the proximal stratiform sulfide and the distal which we saw in the typical morphology of the this one of the one such model.

But one can always imagine analogous to a situation what is happens in case of a volcanogenic massive sulfide that there could be some magnetic activity some, volcanic activity which could be there in the subsurface providing the heat and because this fluid has to the buoyant and has to be compressed and move through this and also it must occur.

So, it also depends on the volume of the rock that is involved it would require if it, if the metal has to be only be derived from this sedimentary pile then it definitely would require a far greater amount of the rock to be involved and the fluid to be squeezed out from this sedimentary horizon and to be channelized to such kind of system as it as shown here.

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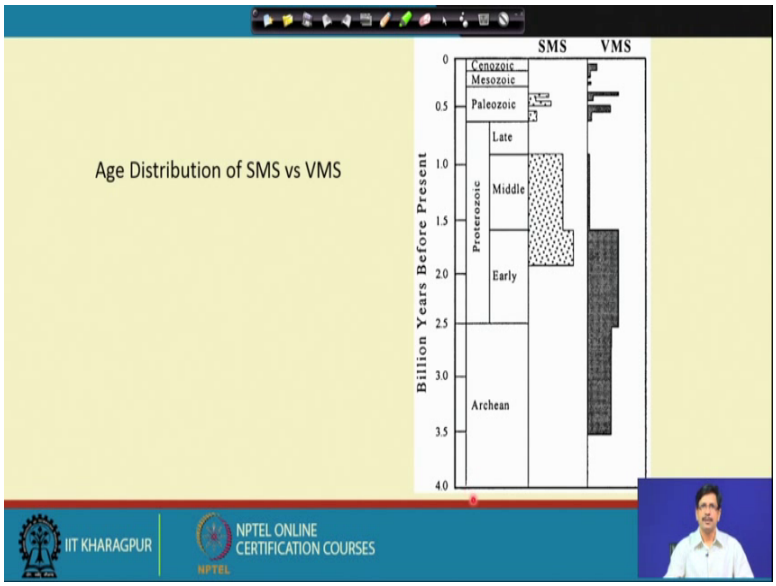

Here is a brief comparison of the temporal spectrum of these deposits, they even though they range from early proterozoic to end of the paleozoic. So, they are the density of occurrence the frequency of occurrence is far more within the within the proterozoic as compared to, unlike the volcanogenic massive sulfide deposits which range in age from archean to Cenozoic. These deposits are not found to occur in rocks which are younger than Paleozoic, the Mesozoic and Cenozoic sedimentary basins seem to be devoid of these deposits which is the reason is not very well known, why is it so, but there is an observational fact ok.

From now we begin.

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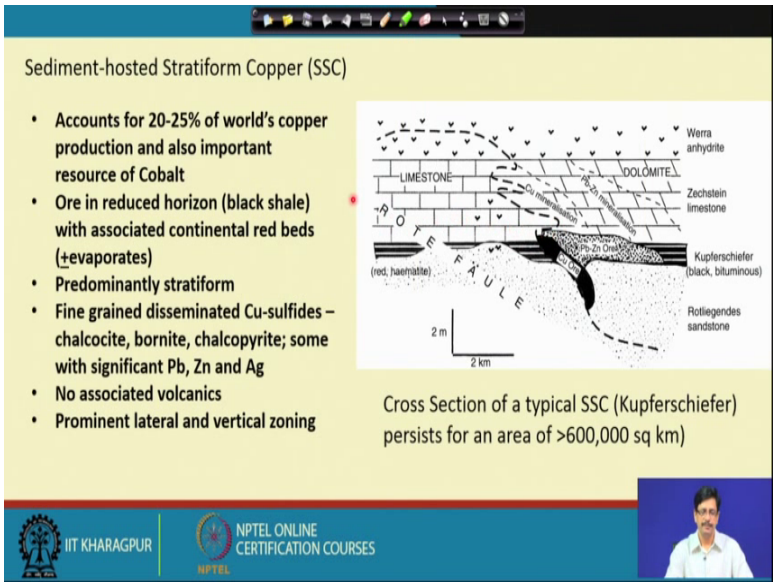

Now, we switch over to another very important class of hydrothermal deposit which are the sediment hosted stratiform copper deposit the, or the SSC deposit, these deposits are a major contributor of copper. They possibly next to the power free copper deposits accounting for 20 to 25 percent of the worlds copper production and we more important they are also a resource of cobalt and the occurrences, 2 important occurrences can be quoted as far as this important deposit type is concerned.

The one is the Zambian copper belt in Africa which is a huge copper bearing essentially their copper bearing black shales they are reduced horizon zone of, reduced conditions where metal sulfides have formed or deposited and the other one which is shown here is known as the kupferschiefer which is essentially a black shale copper bearing, black shale horizon.

And it is a very unusual situation where this particular horizon has a total area of coverage about more than 600000 square kilometer distributed over about 7 countries in central Europe, Germany, Poland even going to the to UK and this is a it is not of course, this be a this prominent horizon which is a copper bearing black shale is not being worked or workable mines are not there. They are definitely some very selected areas especially the where it is exposed in Poland and some other areas where they are being very actively recovered exploited for the metal copper and cobalt.

The ore is in reduced horizon black shale with associated continental red beds and evaporates the association with continental red bed is very a very prominent and very critical to the situation of the SSC deposits as well as evaporates because the evaporates bear a little bit of significance as far as the hydrothermal system in general are concerned, most of our ideas coming from the situation which prevails in the red sea where the fluid is essentially a very concentrated briny fluid much more in salinity than average seawater.

Because these fluids are supposed to be derived by resolution of these evaporate beds which are the beds of the salt which result because of the evaporation of seawater in landlocked basins and they are for predominantly stratiform even far more stratiform characteristics than the SMS and much larger lateral extent. They are fine grained disseminated copper sulfides, chalcocite, bornite chalcopyrite some amount of significant lead zinc and silver.

These mineralogy is very characteristic in this sense that the minerals like chalcocite or this diginite and copper rich type of minerals which are generally observed in low temperature environments or in this super gene sulfide enrichment kind of zone in existing deposits. These are the kind of mineralogy which dominates the stratiform sedimentary, sedimentary strati from copper deposits like what we see in the kupferschiefer or the Zambian copper belt and there is no associated volcanic and there is prominent lateral and vertical zoning that is also observed in the source.

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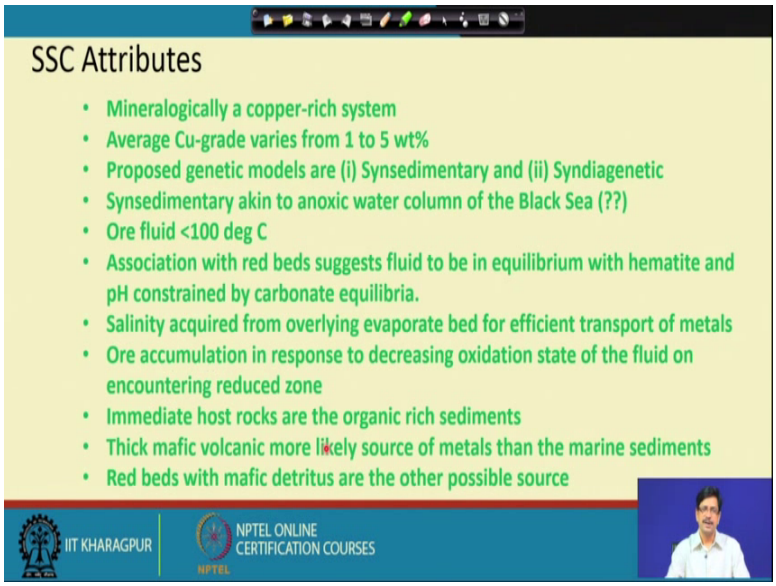

So, mineralogically it is a copper rich system average copper grade varying from 1 to 5 percent, the proposed genetic model are this is synsedimentary or syndiagenetic because the synsedimentary process which we just have just seen in case of the SMS deposit is a very efficient mechanism that during the process of sedimentation there is some extra input in terms of fluid or the metal from another source which can make the minerals deposit along with the sedimentary strata. And the other one is syndiagenetic in the sense that the deposit formation is as follows the stage of compaction and very low temperature situation in which the mineral start to reconstitute are. So, the very very low grade metamorphic low grade mineral start to form.

So, the synsedimentary is akin to a anoxic water column that is prevailing in the black sea because, the situation could be compared to a stratified black sea where we see that the lower most part is very very reducing and using kind of environment in which the sulfide, the metal sulfides can precipitate and as layers. So, it could be a situation like that, the synsedimentary where even no extra it will only be coming out because of the very high dissolving power of such kind of water some such kind of very low and low pH and reducing fluid which can accommodate or can dissolve a lot of metals which we see in the present situation in black sea.

So, the ore fluid is always a low temperature fluid less than 100 degree celsius, but still we can put them in the category of hydrothermal there the association is red bed is

important because the fluid must have been at some point of time in equilibrium with hematite must have been oxidizing and the appropriate ph, that is constant by carbonate equilibrium pH need to be a little high at least stability filter by carbonate or carbonate.

So, that such kind of an oxidize oxidizing fluid will be able to dissolve and transport appreciable amount of the metals. Salinity as I just mentioned as the overlying evaporate bed have contributed to the high salinity of this hydrothermal fluid and for the efficient transport of metals the ore accumulation is in response to decreasing oxidation state of the fluid on encountering the reduced zone which is the black shales which on or and is with carbonaceous particles and they created reducing zone where the sulfides could favorably be deposited.

And sometimes these how this sedimentary strata are also associated or overly thick mafic volcanic more like the source of and which could possibly provide the metals then the marine sediments, red beds with mafic detritus and other are the other possible source we see even though we do not see a very prominent magnetic component here, but they we see the mafic members as they treat us within the sedimentary horizon and they could possibly contribute because we know that copper can come from a basaltic kind of a source much more than it can come from any sedimentary horizon like a shale or a sandstone. So, this put also so the red beds and the, are the tritle mafic components are also potential metal contributors in this, but in this kind system which give rise to the statiform sedimentary copper deposits.

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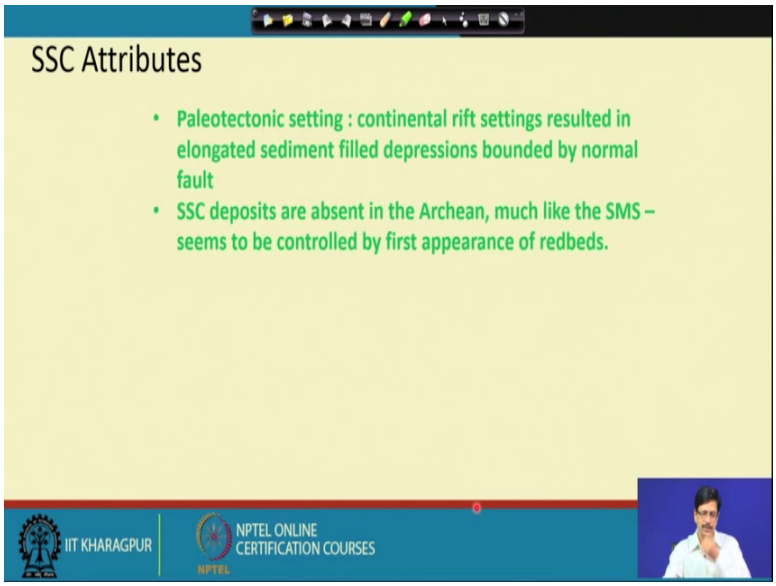

And the paleotectonic setting they are very much expected to be in continental rift settings, that resulted in the elongated sediment filled depressions bounded by normal fault and the sed this SSC deposits are absent in archaean much like the SMS seems to be controlled by the first appearance of red beds. That is one of the very significant aspect of these deposits that they never form in the Archaean in the where we know that the condition or the because of the very low partial pressure of oxygen. The conditions were much more reducing and which might not have been able to create a system where you need in oxidizing condition for the efficient transport of the metals and then deposition in reduced zones.

So, that is how they are lacking in the Archaean and the first appearance of the red beds seems to be an important, important controlling factor information of these deposits.

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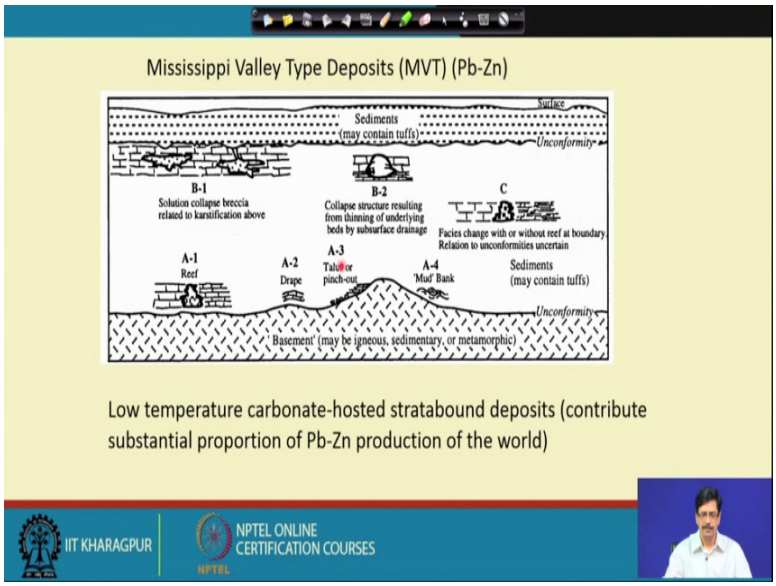

So, this in this particular series of the hydrothermal systems which are associated with sedimentary rocks, the another important class is the Mississippi valley type of deposits which are also the major contributor of lead and zinc in the world and this cut, this diagram is a composite diagram which shows all the possible conditions in which we can see this MVT type of force forming. Situation 1, it could be a solution collapse breccia related to karstification; that means, they these are essentially the cavities in the limestone which we call them as cast and there could be deposition of these sulfides metal sulfates of lead and zinc.

The situation 2 could be it is a collapse structure resulting from thinning of underlying beds and sub surface drainage and here it could be a facies change with without reef at boundary relation to unconformities. Here I mean it is not exactly known whether they are related to unconformities, but there is a facies change in the sedimentary horizon and they seem to have been controlled by this process, they could be on a basement high which on this here is it shown here the mud bank or the talus or pinch out kind of structure grape kind of structure and the reef in the limestone.

So, essentially this Mississippi valley type deposit the MVT type deposits are characteristically hosted in carbonate rocks and there could be many different possible locals in which the ores could be localized or the deposition of the ores could be controlled.

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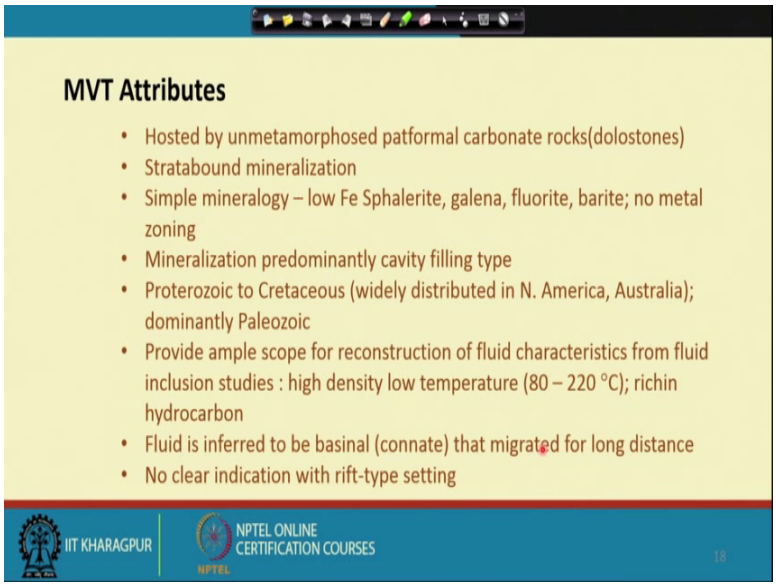

So, main attributes of the Mississippi valley type deposits is they are hosted by unmetamorphosed platformal carbonate this sequence is just not they do not show any indication of bit getting metamorphosed and the most preferred horizon is basically the dolostones, the carbonate rocks they startabound. So, startabound generally indicates that need not have to be seen sedimentary or they need not have to be seen genetic, they rather more likely to be epigenetic; that means, the mineralization being temporally away temporarily different or younger to the formation of the host carbonate rocks.

Mineralogy simple low irons sphalerite galena fluoride barite. In fact, these are the deposits from which the most of the fluid inclusion data on these sphalerites are come because the low irons sphalerite are far more amenable to fluid inclusion studies because of their transparent characteristics and they provide important inputs to the fluid characteristics. The mineralization is prominently cavity filling type as we have seen whether it is a cast or it is a facie change or the situation to be created for the deposition of the sulfides the at the engine they range in age from proterozoic cretaceous widely distributed in north America, but dominantly Paleozoic there are some Australian occurrences as well.

And this as I just said that there are ample scope for reconstruction of the fluid characteristic from fluid inclusion studies and the fluid inclusion studies indicate a very high density, but low temperature fluid of 80 to 220 degrees centigrade and this deposits,

the ore fluid is very very characteristic in the sense that they do have a precible hydrocarbon concentration. They dominate the generally the fluid inclusions when we see we see a very significant component of methane there and there are also heavier hydrocarbons are detected and they almost look like almost oilfield brines and the temperature is low from 80 to 200 degree cent 220 the fluid is inferred to be basinal that migrated for long distance and no clear indication with rift type.

So, here corresponding to the penultimate point it is very interesting. In fact, these are the deposits from which the concept of the long distance migration of connate fluid was proposed because of the fact that the fluid characteristics did not quite match with any fluid that could possibly be generated from the host carbonate rocks and the carbonate rocks.

So, good degree of replacement in during the mineralization and then there are many ideas that were proposed, like whether the metal and the sulfur were carried together or the metal and the sulfur were derived from different types of fluid and those detailed discussion is out of score for this discussion, but they are a very interesting case and this hypothesis is still being held at the Mississippi valley type deposits a result of.

So, this would actually mean that there must have been some kind of tectonic activity could have driven the fluid out of the sedimentary horizons from one particular local and then migration of the fluid either a through a gravity type of flow or because compaction driven flow. But, since they are basinal connate fluid there will be the salinity will be high and they could be they are very potent potential metal contributor they lots of metal like zinc and lead could be complex in such kind of chloride rich fluid and these deposits also, the possibility of metals getting complex in organic complexes like some organic ligands being more prominent in the fluid for the dip for the transportation of lead is also being proposed ok.

So, with this we conclude the discussion with this put, this range of hydrothermal deposits the volcanogenic massive sulfide deposit, the sediment hosted massive sulfide deposit, the sedimentary strata from copper deposit and the Mississippi valley type deposits. They exhibit many different types of situations, but somehow they do have some features which can be compared like for example, a distal type VMS and an SMS deposit could possibly be having the similar type of morphology and attributes and. So,

that is how they make a good case of comparing them in terms of the ore fluid involvement of connate fluid for the mineral for transportation and deposition of the sulfides. So, they these 4 they constitute a very interesting and important class of deposits which have generated enough of academic interest in addition to the fact that they have been major contributor of metals base metals like copper lead and zinc.

Thank you.