Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture - 02
Mineral Deposits in Space and Time

Welcome to the second lecture on the series on Mineral Resources. In the first lecture, we got in introductory overview of mineral resources is to what they are, control of certain fundamental parameters on the availability of this mineral resources in terms of the quantity that they are available. And the occurrence of various mineral resources in the earth's crust; we saw that this term resource is a qualitative term used to represent a total quantity of the mineral resources of different metals and minerals..

So, the resource actually comprised of the individual mineral deposits of those metals or minerals, and they do occur in the earth's crust; either exposed on the surface or at different depths going down to even up to 5 kilometers. Now, in this lecture let us try to get an overview of the distribution of these mineral deposits in space and time. Because essentially space means we again consider the repository of these mineral deposits, there is the crust or more precisely the upper continental crust; in this the mineral resources of different metals and minerals may occur..

So, we give a brief recapitulation that we discussed about the certain fundamental aspects. And now let us move onto the distribution of mineral deposits in space and time.

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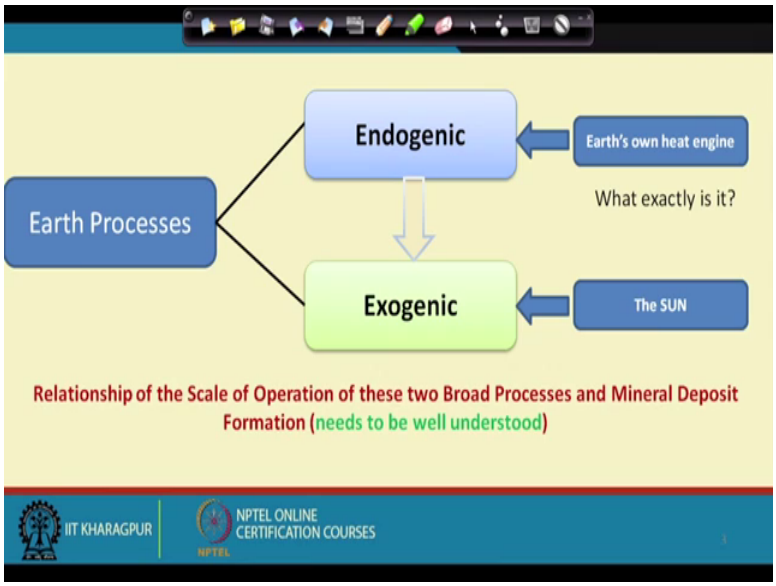

Now, before we highlight or before we start discussing on the distribution of these mineral deposits in space, space means it is again we can recall that is the earth's continental crust. So, it is the earth; so, before we go to the distribution of these mineral deposits in space, let us first consider the earth because the domains in which these mineral resources are enriched to give us the mineral deposits are a result of the earth processes operating at different scales.

And those are processes we fundamentally can classify in the context of mineral deposit formation, of course, it is generally applicable to the formation of different types of rocks and since mineral deposits are an integral part and they occur in association with the common crustal rocks. So, they are also results of the broad processes operating inside the earth.

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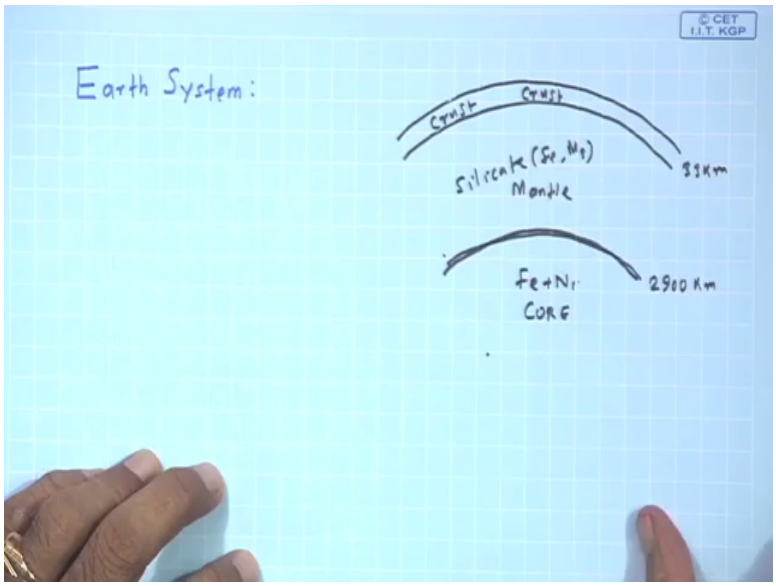

So, we generally that is how we describe. So, when you come to the earth, so the earth is like a big machine or we call it as the earth system where the different components of the system they operate in a well orchestrated manner driven by the energy. The energy has to come from somewhere. So, we have decided we have divided the processes into two broad categories that is the endogenic and the exogenic..

So, the endogenic, so before coming to understand the endogenic process, let us first let us recall that there are different components of this earth system. This is represented as the crust which I am represents in a very simplified manner and this is the mantle and the core.

So, the Everest crustal depth is about 33 kilometers and so this is the core, the mantle. So, we will have to see that when we say that the endogenous process are essentially driven by the earth's on heat engine, so where from this heat will come. If we begin with a originally homogeneous molten earth then it has evolved, and is still evolving in the process of loss of heat. And we know this core is essentially the metallic iron plus nickel. I am putting things in much simpler form the mentally silicate mainly of iron. And magnesium and this is the crust constituted of the upper and the lower crust and sometimes.

So, essentially the because of the difference in the thermal conductivity between the core and the mantle, so additional heat energy always keeps accumulating on the cross mental

boundary and that periodically is given off in the form of form of plumes which are basically essentially pockets of heat energy which rises through the mantle. And then melts the crust different domains in continental as well as oceanic domain.

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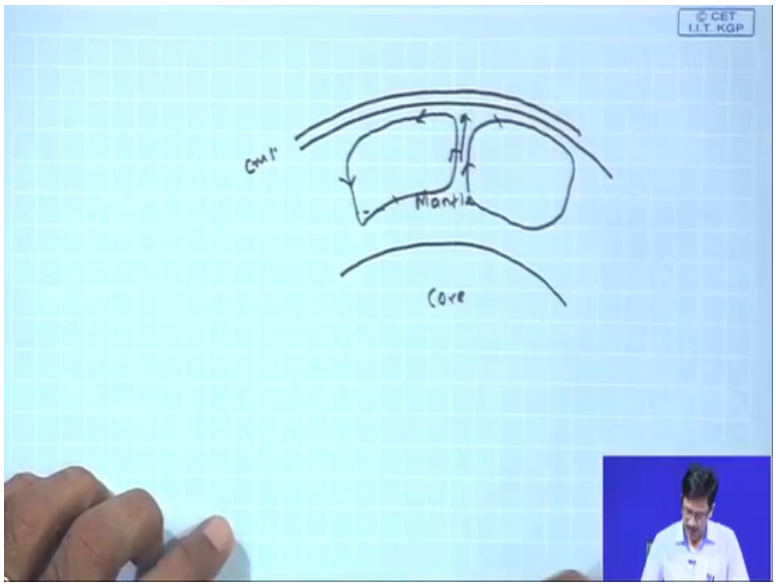

And if we look at the diagram in a little more process oriented manner then we know that because of this mantle the lower mantle is the (Refer Time: 08:00) mantle which is in a theological state which is more liquid and solid. And there is convection going on continuously these being the regions where the convection cell up well.

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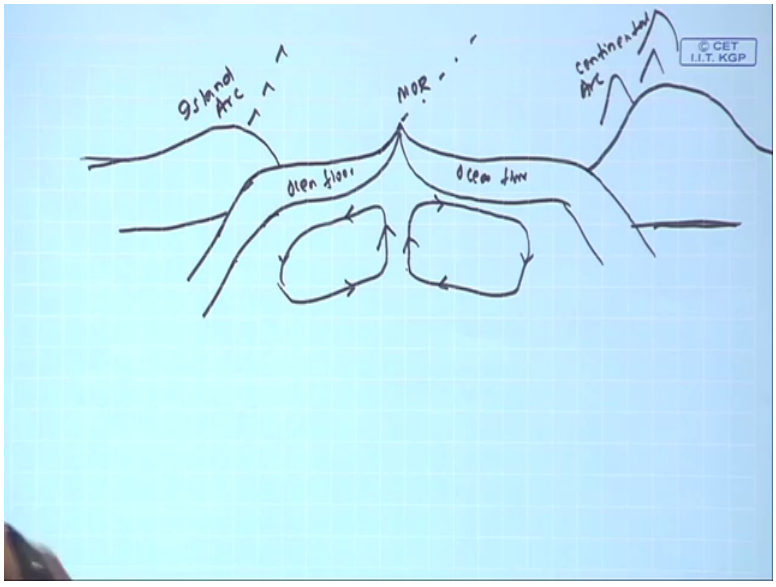

And where they up well they give rise to situations like this. So, these are essentially the zones of esterospheric upwelling and where their generation of the celtic melt by melting of this esterospheric mantle and generation of the ocean for basalt. And these are the domains of the island arc, where oceanic and oceanic plate subducts against an oceanic plate these domain is a continental arc where an oceanic plate subducts against the continental lithospheric plate and this is the mid oceanic ridge. So, this is a broad framework of the tectonic of the activity which we can explain in terms of the earth's heat engine the work the earth heat engine at work mainly driven by the convection cells in the asthenosphere.

So, we will try to see or we will try to correlate the distributional the distribution of this mineral resources in space. And in addition to that we as we have already stated that there are situations in which the thermal plumes rise from the core mantle boundary and also cause melting a different domains in the continental. And oceanic crust giving rise to volcanic oceanic islands as well as the mid continental magnetic activity which will see them in greater details later.

But in the other process, so that is the process which is responsible mainly in distribution of the mineral deposits because they do form rocks and mineral deposits are associated with the are integral part of the crust forming process and are associated with the common rocks in the continental crust. So, they are also a result of this broad activity which is driven by the earth's on heat engine. Only thing that that whether this scale at which we are trying to understand this process whether these scale is the generation of the mineral deposits also happen in that scale or there are some local scale processes which are needed in addition to that we will be looking at them in due course of this lecture.

So, the second category of process, which is the exogenic process. So, this endogenic process is essentially responsible for formation of rocks the magnetic rocks igneous rocks. And also the rocks which are formed by the process of metamorphism in areas where active deformation is going on with input of heat coming from different sources are. The other broad earth process is the exogenic process the exogenic process for which the energy is essentially provided by the sun..

Now, as you could see in the diagram the exogenic process means essentially means the weathering process, erosion, transportation, and deposition in sedimentary basins normal weathering process or evaporation these kind of processes are they do operate on the surface of the earth and the energy is provided by the sun.

But as you could see in the diagram that the endogenic process and the exogenic process could possibly be correlated could some relationship could be established between them because the weathering and erosion processes, denudation processes will also be depending on the rate at which the any part of the continental mass is rising. For example, so the relationship so the scale of the operation of the two broad processes have to be understood if we want to explain the distributional peculiarities or the distributional characteristics of these ore deposits. As I told that there are some local scale manifestation of these broad r processes which operate in a much larger scale.

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So, if we want to understand mineral deposits ore deposit formation, it is very essential for us to have; this space means essentially we mean that the earth; that the continents the surface of the earth as we see and then we could just look at the distribution. So, here we have the globe the physical map of the earth with the present day distribution of the land and sea, we all know that the earth is covered 70 percent by water by the oceans and about 30 percent are available as continental mass for us.

So, let us try to first look at the distributional peculiarities of metals just to bring out the fact that the distribution of different mineral resources are not just very uniform all across; the continents all across the surface of the earth that is all exposed to us. So, just I have taken the example a few example of one of the metals iron which is available in abundant quantity and is one of the important metally resources for steel and the infrastructure industry.

So, let us look at this. This is the superior province in North America, this is the Labrador trough, this is in Brazil what the (Refer Time: 15:48) This is the Damara belt in Namibia. This is the Barberton mountain range in South Africa. This is there the two areas that are shown two or three areas the lower one is Dharwar Craton in India; the middle one is the Central Indian sedimentary basin (Refer Time: 16:10) where we get iron. This is the Singhbhum Craton in India. And this is the Hamersley basin in Australia.

So, this the purpose of showing this is that what we get the iron ores at present to us in billions of tons in quantity, they are distributed in only a few localities on the in the continents. They are not just this is a (Refer Time: 16:40) iron in Russia. And these are the ones which give the maximum major bulk of the production of iron in the world and sometimes giving the quantity in very huge quantity which we call them a super large deposit.

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Similarly, let us look at the a distributional peculiarities of metals like copper, lead and zinc, this distribution is definitely not very exhaustive I have only selected few of them. This is the Chilean; this is the Andean mountain range in Chile. And we get the maximum distribution of maximum frequency of occurrence of copper deposits here. This is in the state of cubic in Canada where we get the famous Noranda deposit which is copper. Here is the Zambian copper belt in Africa. Here this is the Cyprus (Refer Time: 17:48) belt in the middle in part of the Alpha in Himalayan Chain. Here this is the Malanjkhand copper mine in India, k 3 copper mine in India and this and so on.

The lead and zinc deposit which are marked is black, this is the famous Sullivan deposit in Canada. This is the Mississippi region, the famous Mississippi valley type deposit occurring in the state of Kentucky, Missouri here in North America. This is the Zavar Rajpura Deriba the northwestern India which have produced major quantity of lead and zinc in the Indian subcontinent.

And this is the Japanese island arc which also gives very rich lead and zinc deposit. There are many more deposits these are the significant ones in the world which produce the maximum amount of the metals. So, here the intention is very clear just to show that the distribution of these deposits is so very non uniform on the across the continents in the world.

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Gold, so this is the Nevada state of Nevada in United States which is currently on the very actively producing gold of the world. This is the Abitibi Greenstone Belt in Canada having very super large deposits of gold. And this is the Witwatersrand. This is the Ghana in Africa. This is the Barberton mountain range gold deposits. And this is the one of the major gold producing areas in the world is the Yilgarn craton in Australia, the famous Carl gulley gold deposits. And here also the Dharwar craton deposits like Colar and Hatti..

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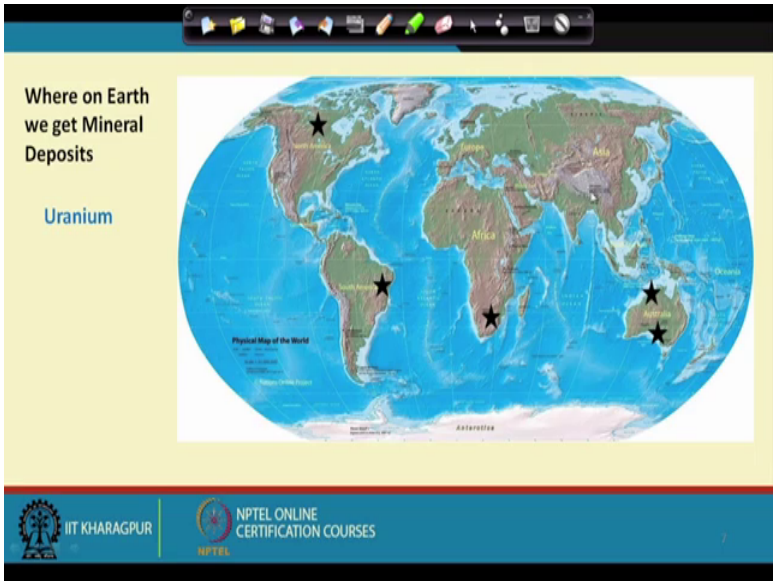

So, if we can always look at and visualize the distributional peculiarities of metals, this is the this is uranium this is the famous Athabasca basin in Canada. This is (Refer Time: 20:00) in Brazil. This is the Witwatersrand basin also producing the uranium. This is the Olympic dam deposit in Australia and this is the alligator river deposit the famous (Refer Time: 20:13) deposit uranium deposit in Australia. So, these constitute the major sources, major resources of the metals where they produce bulk of the uranium of the world.

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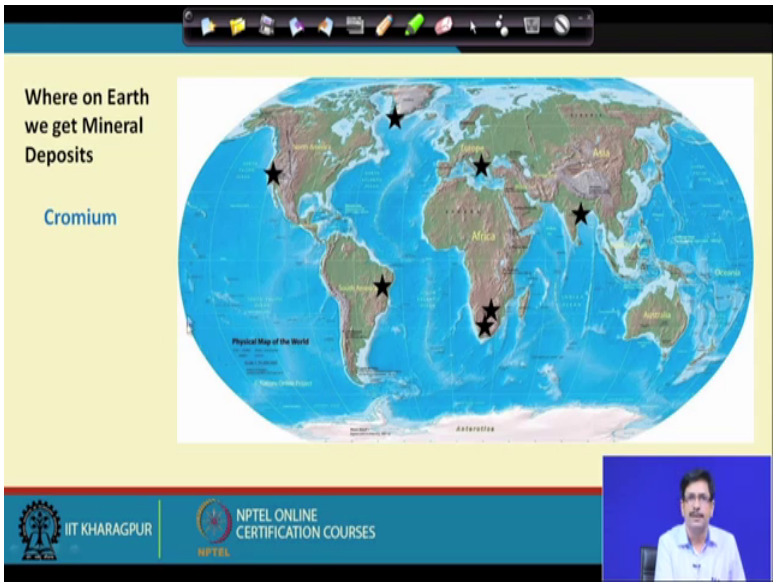

And similarly we can see the chromium, this is the steel water complex, this is the scale gird complex in Greenland. This is the Booze belt complex and the great dike of Zimbabwe and the Booze belt complex. And here the chromite deposits of India. We will be looking at the mineral resources in a greater details when we come to the individual deposit types.

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So, what we actually we are observing here this diagram is just one such example. So, the percentage of gold total in ounce by region; this is Asia, this is whole of Africa is just

this is the North America, South America, Australia. So, what we observe here is that the Australia the looking at the area of Australia, it contributes about 12 percent. Let us say take gold for example, we can take we can look at such example or many more of such metals which are on great demand or are very useful for our industry and economic very high economic value.

So, at tiny Australian Manland is contributing about 12 percent of the total gold of the world, whereas the whole of Asia is only about 17 percent, Africa is 17 percent and the whole of Europe is contributing only 2 percent. America taken the North America is 34 percent then the South America is 17 percent. So, thing think which is pretty observable here is that the mineral deposits do have a very gross non uniformity in their occurrences across the continents. And we will have to see we what exactly how they can be rationalized, how they can be understood in the in the context of the broader earth process as we have defined as a exogenic and the endogenic processes.

Look at this diagram which is again one which was plotted where the total number of the mineral commodities that is produced in any of the country against their area, area of the geographical area of the country. And this is a broad band which is defined with it would look like the total mineral endowment is somewhat in proportion to the total geographical area of that country some of the countries which will be this diagram has been taken from the book of Stephen Kessler. Some of the countries would look as if their mineral endowment is far less than what would be expected from the geographical area. And some of the mineral deposits some of the countries will be producing lot more number of mineral commodities then what would be what would be expected from the total geographical area.

See here the situation is that it is just not the geographical area, it is definitely something more fundamental that is to be so the mineral resource endowment the number of deposits and the total quantity is not in proportion to area of any continent. And as we will also see gradually that the identical geology of a region or terrain does not guarantee equal mineral endowment. And in the present day context, mineral deposit occurrences seem to be controlled by global tectonic processes and diverse tectonic domain which would be seeing.

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So, now, let us try to rationalize the occurrences distributional peculiarities of the mineral resources in relation to because the broad the arc processes in the broadest sense could be visualized through the present day global tectonics process. Here the different plates are shown I will be very brief as I showed this is the Chilean Andes, where most of the where with the highest frequency of occurrence of the copper deposit also the western part of North America which is the North American cordillera. And regions like this, this is the Papua New Guinea, and some of the areas Philippines and so on.

So, there is at least we could see a very clear cut co reliability that the mineral deposit are controlled by the global tectonic process when we see the process it is just not only. So, this is a subduction zone, where a continent where a oceanic plate is subducting against a continental lithosphere where this is the context continental arc. These kind of domains called tectonic domain are more akin to island arcs where like the deposits which is what exact type of deposits we will be discussing then in due course in the lecture.

It is not only just this so we can make a broad correlation with the endogenous process which basically is manifested in the global tectonics and magnetic activity within the continents or magnetic activity on continental margins. We do also have some can draw some idea about the exogenous process the exogenous process which are where we have the major river system like where we have the in Africa or in South America where the major river systems are there and weathering erosion processes are taking place in.

Say for example, if we look at this diagram then the areas where the weathering and erosion processes is expected to be far greater in extent or far faster, these are the areas where we have represent a mountain chains. And we all know take the example of the Himalayan mountain chain, and we have the erosion of the Himalayan mountain chain by the river system and deposition of the sediments in huge quantity in this Bengal in the form of Bengal (Refer Time: 26:56) And there are many other such areas where we can correlate the exogenous process also.

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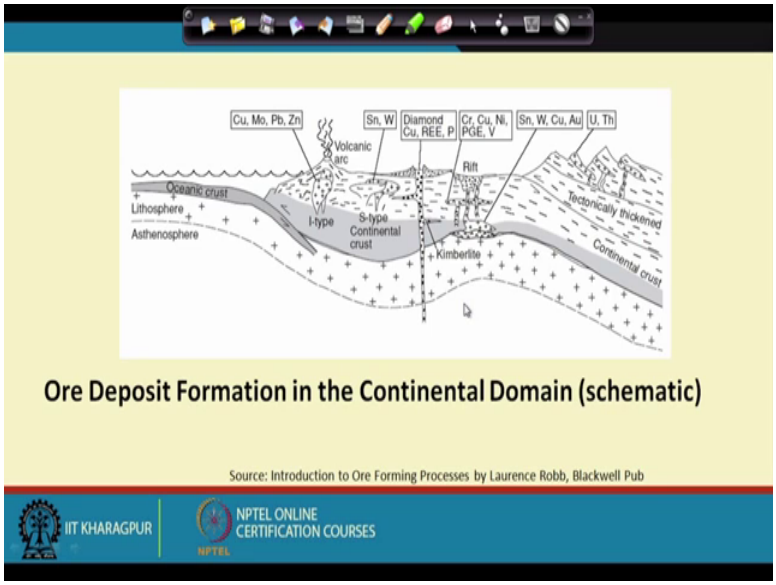

And then interesting and another interesting, so here is a very schematic diagram of what happens in respect to the process that you have just seen. This is a continental arc akin to the Chilean Andes margin, where we get deposits of copper and molybdenum. This is the continental interior where we can have magmatism in the form of ultramafic bodies giving rise to diamond deposit..

We can have ultramafic magmatism giving rise to chromium nickel deposit. And here this is something which is very similar to what is happening in the alpine himalayan mountain chain there are intense tectonic activity lots of extra heat being generated through the frictional through the thrusting processes of the rock masses and small quantities of felsic mails being generated. And there are chances of getting some uranium or thorium type of deposit which we saw there the lithofyle elements which generally get

enriched in crustal rocks. And also in the midcontinent, we have tin tungsten kind of deposits.

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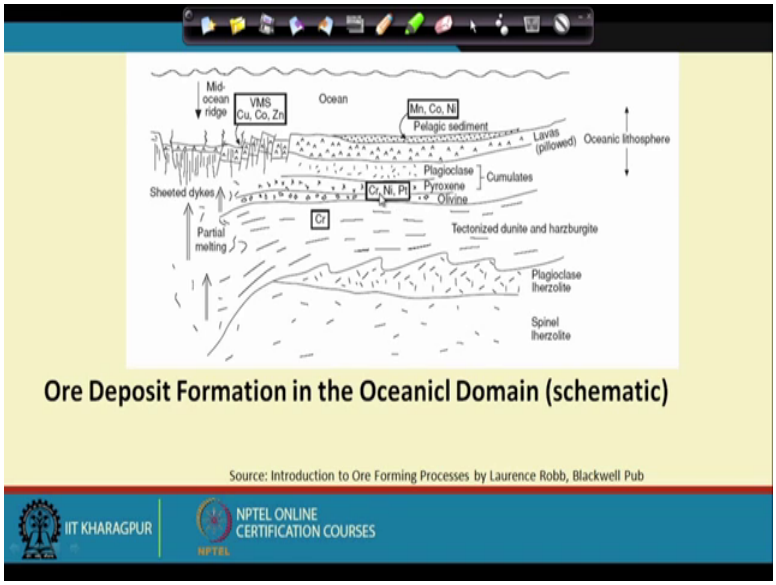

So, and this is a situation which is corresponding to the mid oceanic ridges where the structure is pretty much complicated with faulted and fracture giving rise to a fracture network and circulation of the seawater and giving rise to deposits of copper, lead, zinc. We will see what exactly they are what genetic category they belong to in due course of the lecture. And the mafic bodies which are in placed at greater depths are also giving rise to chromium nickel and platinum group of metals.

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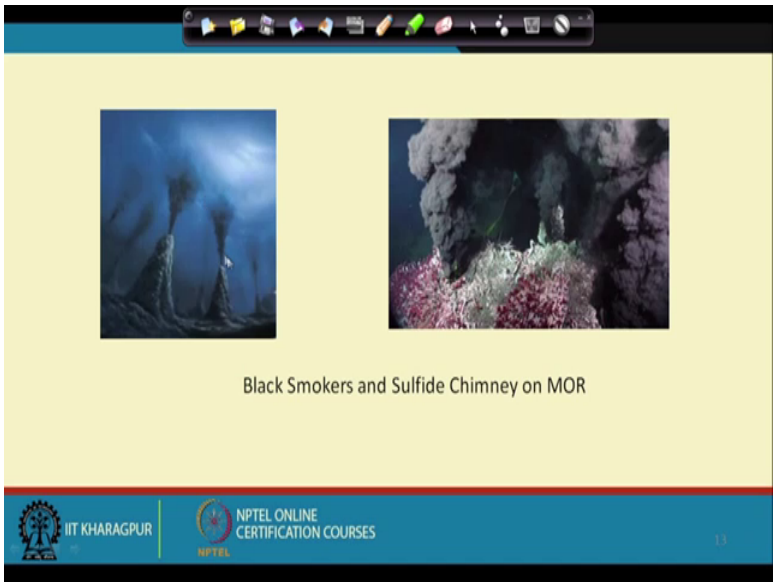

So, these are the present day. So, we asked the question that whether mineral deposits are being are formed in the present day or not. So, these are some of the pictures which are taken from the mid oceanic ridges like the mid atlantic ridge or the piece pacific rise where we see that mineral deposit formation is taking place at right this point of time. These are features which are called in the sulfide chimney which are essentially deposition of the metal sulfides..

And these are the features which are very popularly known as the black smokers consisting of very fine particles of sulfides which rise to the water column in the sea. What seas the bottom of the sea seas sea floor, and this is a process of present day mineralization which is and the deposits that we that we discussed about in occurring in the Chilean Andes region are just about a few million years old.

So, to sum up we do have a distributional peculiarity of these resources of minerals of different metals and minerals and that distributional peculiarities could be very well explained based on the endogenic and exogenic processes that are operating in the interior of the earth as well as the surface of the earth. So, this much for today, we will continue in the next class.

Thank you.