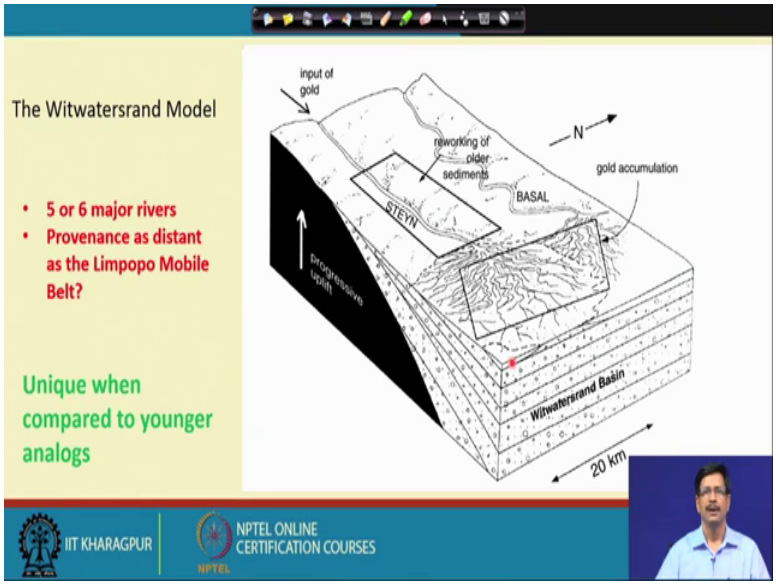
Mineral Resources: Geology, Exploration, Economics and Environment

Prof. M. K. Panigrahi
Department of Geology and Geophysics
Indian Institute of Technology, Kharagpur

Lecture – 13
Sedimentary Processes and Resultant Deposits (Contd.)

Welcome to today's lecture, we will pick it up exactly the point where we left the discussion in the last class. We were discussing the classic Witwatersrand value a placer deposit of gold, and uranium in the south of in South Africa. Is a case of a classic place a deposit being depth by which was developed by 5 to 6 major rivers, and the provenance was a gold bearing quartz load deposits in the nearby cationic area.

(Refer Slide Time: 01:01)



And it is also unique in the sense that it is also a major resource of uranium, where there is significant enrichment of uranium. In the form of they try to will uraninite along with the along with gold, and there are zones where was the southern part uranium dominates over gold, and in the northern part gold dominates, and uranium, and it is a deposit which is arcanine is gold deposit.

So, is it happens with all the gold deposits the ideas about the origin of these deposits will always be debated there are features, which will be indicating origin in a mechanism which would otherwise look different from the well accepted placer modern mechanic mechanical concentration model. The situation is there be gold grains here they retain

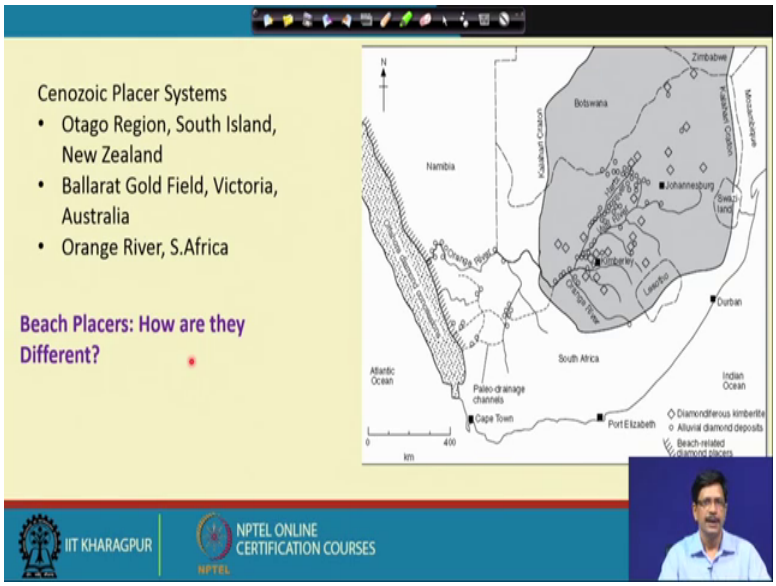
their detrital characteristics, along with the indicating transportation long a distance transportation, along with the detrital quartz grains constituting the conglomerate bed, and the localization of mineralized enriched mineralization at the contacts when whenever there is a holder on unconformity erosion on surface.

And the evidence of the glacier model also comes from the fact that gold has been transported is dominantly detrital, when rather than being dissolved in some fluid and getting enriched in the deposit, because of they believed reducing condition of the archaean atmosphere, where gold was are not soluble, in the crystal fluid I take was an oxidizing fluid points transport in a fluid medium. And so, is uranium uraniumnite which also cannot get transported in the fluid in a soluble plastics form and that is how we believe the detrital model, and there is little indications of this deposit being better more force to any hand grain rather than simple every low grade insist with metamorphism, and which possibly would not be efficient enough to mobilize other fluid.

Although we have not, so the alternate model which have been proposed by many workers, which is the hydrothermal model for this origin of the deposit we will defer the discussion till the time that, we discuss about the nature of hydrothermal fluid, and what hydrothermal fluid are, but for the time being we finish off the discussion of this particular deposit with the fact, but there has been alternate model of hydrothermal origin for mineralization of gold, and uranium in this deposit.

So, with this let us move over to the situations where, we could see some of the very recent placed deposits which are of mechanical concentration origin.

(Refer Slide Time: 04:28)



So, here there is the Cenozoic placer systems, one is the Otago region in South Island New Zealand, which is the area where with the sediments that we derived from the Otago is build, where there are some a gold deposits. And this Otago region in South Island New Zealand is one of the recent example examples are very a young placer deposits are gold, and the Ballarat gold field Victoria Australia, it is also a gold only deposit of mechanical concentration origin it is also placer. Here on this right side we what is shown here is the Orange River system in South Africa. And this is the Namibia, this is the Botswana, where if is also very well known for it is diamond potential and this area, which is the area is drained by the Orange River.

All those which is shown with diamond symbol are generally the areas which having diamond deposits in the form of the Kimber lighted diamond, Kimber light pipes. And we could see that this is an ideal situation where, this Orange River which is formed as an offshore diamond concentration here, as a very recent example of a failure perfect laser system of diamond.

This is also essentially flueal although the deposition has taken like, in case of or rather unlike in the case of Witwatersrand where the deposition has been moved on the if you deltaic part of the system, here some of the deposition has also has been taken place in the near shore offshore region where it is also driven by the eddy currents. And this is

one example where we can see a mechanical concentration process, which is been operating in giving rise to diamond deposits a placer origin.

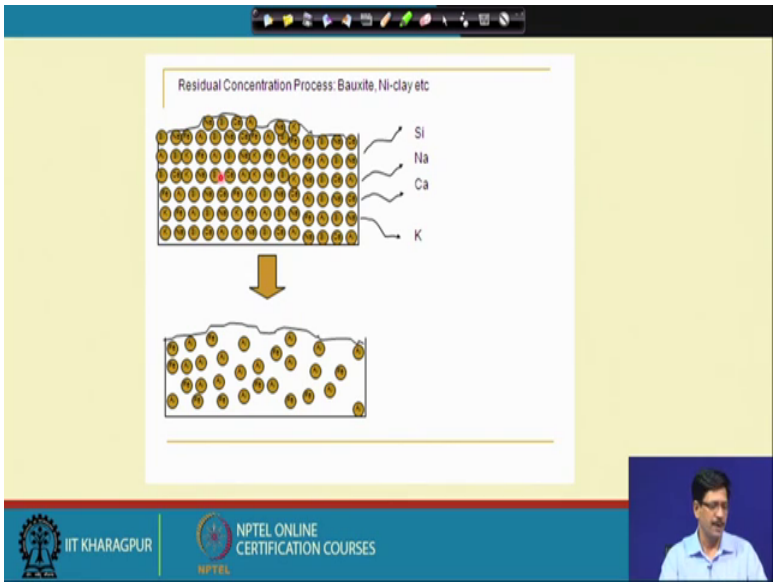
As we know that placer deposits could also originated by the waves, by the tides waves, that we see in the littoral region, in the of the beach region of the Scheldt region in the seas world ocean. They only situation is that, whether the beach places would be different from the way we have dealt with the for the flueal places or not, mechanism wise it is difficult that the beach places should be having any kind of a settling type of sorting here, because of the very narrow and a very turbulent, very energetic conditions prevailing there, and the Schwarz region.

Enplanement also looks to be a unlikely, but all depends on the local conditions of the tide and it is energy, where in some of the beaches it is it is believed that it there is some amount of entrainment mechanism which also works. Then with this kind of situation we mostly would be explaining, the concentration of the sorting, of this parting, of the enrichment, of this high density material in the form of pleasure by shear, and by transportation sorting kind of mechanism, which I will not be discussing in much in details here.

Examples of beach placers, we get a huge accumulation of a minerals like monazite, which is a essentially primary source of the metal thorium, which is very essential for generation of nuclear energy, and the example is the eastern coast of India, where we get lots of such occurrences enrichment of which, we call them as the beach places summarizite bearing sand deposits all along the different selected area in the east coast. And it of course, will very much depend on the availability of such kind of provenance or such kind of rocks, which will have the concentration of these heavier minerals, and that is how it is subjected to a situation that if we have the appropriate provenance.

It is all about the flueal of the system, the flueal placer of palcer of the alluvial placer, and the beach placers. We will not be discussing any very there are not many areas where you get distinct places of Aeolian origin. So, we will not be discussing that here. Now we will be switching over to another important process which is also an exogenous process driven the energy being provided by sun.

(Refer Slide Time: 10:03)



And this process is essentially the process of enrichment, we call this processes as residual concentration process. Essentially it is a process which is arising out of the differential of constituent from the rocks leaving behind a constituent, which will be useful rocks.

So, for example, this is a pattern which shows it is an original rock, let us say it is of a granitic composition, which contains silica alumina, sodium, calcium, potassium magnesium, and other major oxides. And this particular rock is subjected to a weathering condition in the on the surface, and the physicochemical conditions will be such that other than aluminum and a little bit of iron, most other constituents silicon, silica the alkaline will be leached out on the rock. So, that we are left with a residue which is enriched with respect to aluminium.

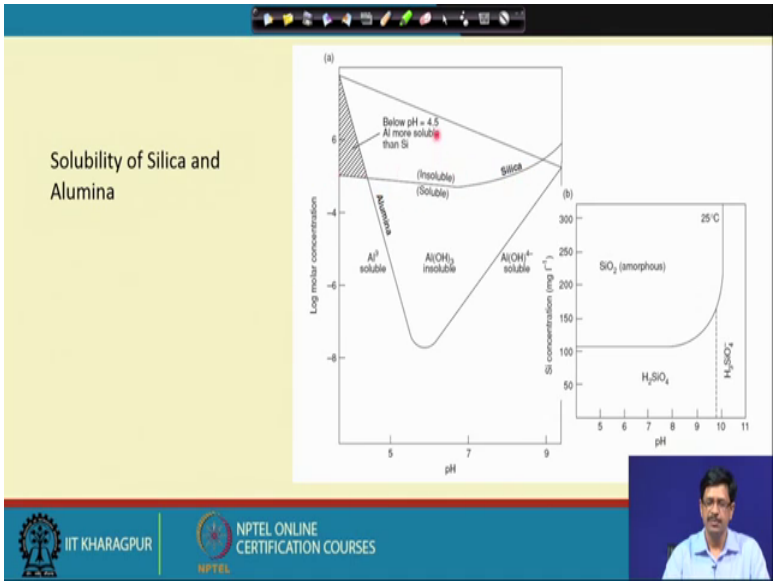
So, such kind of residual concentration process have been in operation, and they are all the recent phenomena cordinary deposits, which are being worked out in many different parts of the world there is a lot of very good examples Indian examples which will be discussing details, that is the east coast bauxite, or then on the eastern coast of India.

So, the prime is so, the free conditions that, we have is that the rock should be aluminum rich in alumina. And also the concentrations of silicon silica should be low. And the situation fable is favored by proper topographic, and climatic parameters. Generally we observe that this kind of weathering processes are more facilitated trade N humid tropical

kind of climate, where this of this weathering and the dissolution of many of the elemental oxide species is favored, and is efficiently done by the fluid, which essentially is the meteoric fluid, which precipitates on surface. And then interacts with the rock, and is and you be obvious here, such kind of residual concentration process will be very much dependent on the nature of the surface of the rock. If it is should have enough of surface area available for the interaction of the fluid with the rock.

So; that means, the if a rock if a good fracture density, in the surficial region which will allow efficient population of the meteoric fluid, will always be a better host to give rise to such deposit, then a rock which is un fractured or having not providing any porosity permeability for the meteoric fluid to work on it.

(Refer Slide Time: 13:18)



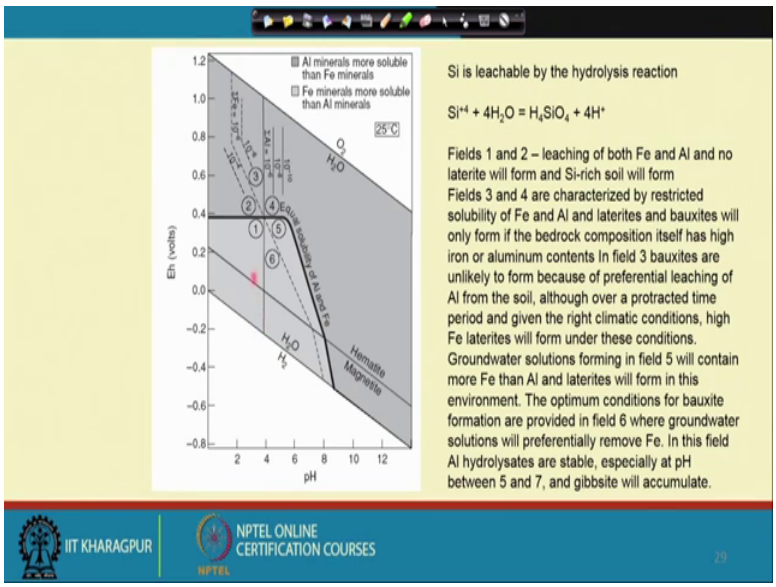
Now, if you want to understand the process, then we have to get into a little bit of fundamentals a little bit about the behavior of elemental oxide like silica, and alumina, here we are considering silica and alumina, because the constituent the silica is the one which we essentially would like to be removed from the rock. So, that the rock becomes richer and alumina, and it is this kind of deposit, this kind of process this which is we call them as the residual concentration process. Generally gives rise to deposits of aluminum and most of the world production of aluminum comes from such kind of deposits, which at the residual concentration deposit. And similar to a very familiar process that we see in many parts which has the laterites, is essentially is lateralization

process by which a rock is get gets converted into a rock rich richer in aluminum, and iron, giving it a very typical or texture, which is we generally we see as laterite we call them as a pisolitic texture. And as and when the conditions are conducive with them are favorable when there is substantial enrichment alumina, and then they give rise to the bauxite, and either we call them as lateritic bauxite.

So, here we see the antibiotic relationship between the two important species like, silica, and alumina. Alumina is as we all know it is approtec in it is characteristic a solubility increases both in the alkaline and the acidic conditions, and passes through minima at around a that is of just about 6 near about 6 wherein passes through the minima. So, it would indicate that anywhere, we get it such kind of a fluid where the alumina will be insoluble, and silica will be soluble, and that will be a situation where will be that will be the most favorable condition for getting a rock entries to the spectra lamina.

And one more important thing is that the topographic factor is also an important one, because since we since we need the components like the alkali, I alkali magnesium silicon, all to be dissolved in the meteoric water, and to be out of the system or to leave the system, not to be reprecipated is in many form so; that means, we need to have a good favorable topography for this process to operate efficiently.

(Refer Slide Time: 16:11)



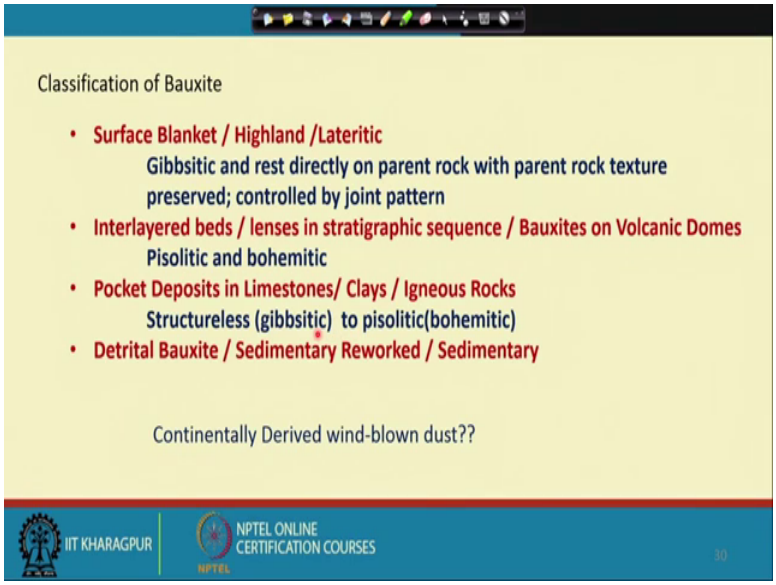
And so, let us look at this diagram which is in Eh that is diagram, which we discussed in the context of iron deposits in the previous class, is also the edit shown in the lower and

upper limit of that is and Eh in natural aqueous environment, and also holds good for the surface. And in this diagram without getting the further much of the complicated details this is an EHP is diagram on which, this thick line thick curve is the curve for ISO or equal solubility of both aluminum, and iron.

So, the condition on anywhere on the surface is near to this thick line, then will we are unlikely to get any rock we enriched with respect to aluminum, it will only be giving rise to a rock which where the alumina and iron will be of equal proportion, and that will not be a material which will be calling it the over a bauxite.

The area which is in lighter gray is essentially the area in which aluminum is more insoluble, and as we just have seen that is at around about 6, where the aluminum is most insoluble, and we can get the bauxite permission on corresponding to this kind of Eh and pH that is especially the field which is marked as 6 in this diagram, in a contrast to that if we look at any other field for example, in this particular region anywhere we will get aluminum as more soluble. So, the aluminum will dissolve, and will be out of the system, and we would not be able to have any bauxite deposit form there.

(Refer Slide Time: 18:02)



So, there is outcome of for this process of residual concentration is the formation of the bauxite ore. In fact, the bauxite are the lateritization is a process, it is same that any question, any surface, any rock which is exposed on the surface, can be can be lateritized. It just needs the meets the appropriate combination of the physical, and the

chemical environment, even in a rock like basalt which want these contents very less amount of silica compared to rocks which (Refer Time: 18:14) rock, where the silica is more can also be lateritized as there are examples, Indian examples where the salty crocks were, enriched by this process to give bauxite deposits from central Indian example.

So, they I will discuss them, and any dock which is aluminum bridge for example, we have the fast track of the cinema night bearing quadruple silver night, and garnet bearing quadruple (Refer Time: 19:08), in the eastern hearts wealth which are known in the condalites. They have been the important major source rock from which the massive east coast rocks I deposits formed.

So, these bauxites definitely would be could possibly be classified or could be distinguished on the basis of the kind of source rock from where they are derived, and also the exhibit different type of structure, and texture. Most situations where we get this bauxite is at the surface blanket where or we can call them in the highland literate, or highland or the lateritic bauxite, which forms from common rocks here the mineral is gibbsitic.

So, what we actually call it bauxite is essentially miner logically is a is a combination or as a mixture of hydroxides of aluminium, if it is Al OH 3 it is gibbsite al alpha or gamma form of Al Ol OH or LOL. This is basically the diaspore bohevaik. So, if the one which we call as the bauxite whole is combination of these aluminium hydrated oxides of aluminium. And one thing with respect to this diagram also you should remember, that it is virtually not quite possible to get a rock or epoxy bauxite which will be absolutely or free of iron, we should containing a concentration of iron to 0, immediately the bauxite will have some amount of iron in it.

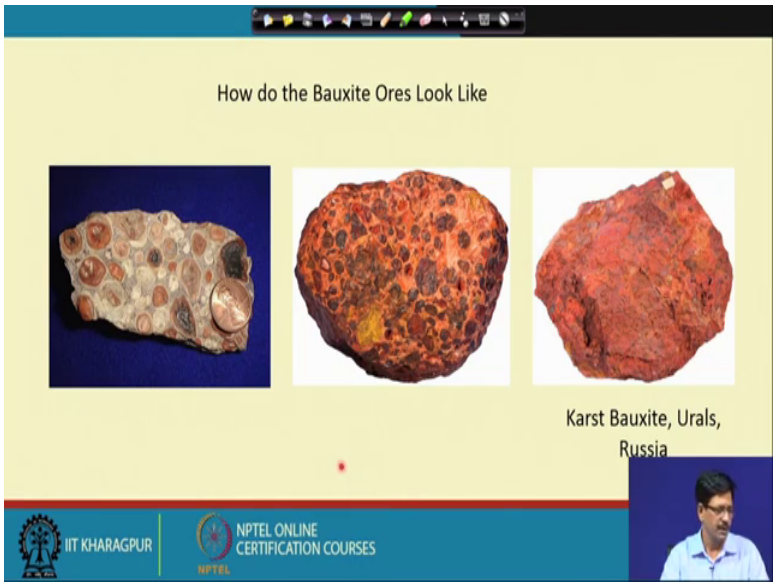
So, the hydrated oxide (Refer Time: 20:48) iron which is a limonite kind of material are also, there in the bauxite to go. So, the surface blanket we find it is more gibbsitic rest directly on the parent rock, with a parent rock texture preserve, and it is controlled by the joint pattern in the rock. We can get also you get bauxite in internally at beds, lenses, and starting graphic sequence, bauxites, and volcanic domes, where the bauxite is pisolitic behind mineralogical is a bohemitic.

There are pocket deposits in limestone they essentially the karst type of bauxite, which form in the cavity solution cavities that are formed in the limestone, because of desolation phenomena. And they even later on deposited by clay material alumina series material, and where we also get bauxite formed in that pockets of deposited limestones clay, or igneous rocks there is a structureless, more gibbsitic to pisolitic.

We also sometimes get the trital bauxite bauxite which have been transported from the previous enriched part, enriched bauxite eco which are basically sedimentary of the reworked, and essentially we understand these processes to be a residual concentration process, through the interaction of surface fluid, with rock under favorable physical, and chemical parameters.

But there are also possibilities people believe that in many of the areas where there are each box I deposits. They actually result from the continentally derived wind-blown dust which get converted to bauxite, we cannot discuss much on their exact mechanism because it is not known, but we at least can understand who the this process by using simple Eh that is diagram, and mutual solubility of the species like silica alumina, and iron.

(Refer Slide Time: 22:51)

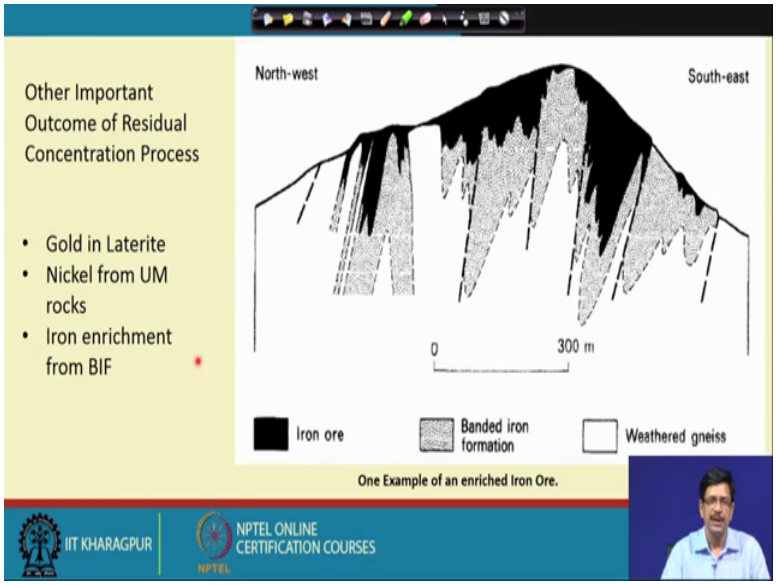


Here are some of the pictures this is the typical look of a bauxite, as to what we call is the a small hemispherical as a misspherical mass it is here are the pisolites, and they range inside and few millimeters to centimeters something larger. So, this is a typical

Luke of the bauxite a cone, which is derived for a is a highland bauxite with pisolitic texture.

This is another example of a bauxite ore or where, we can see it is more iron bearing, this is a typical bauxite sample or the karst bauxite in Ural in Russia. And this is also contents mostly beherit as the aluminum mineral, and it has some of the iron minerals is limoniteen this is a typical loop of the bauxite a course. Even the sometimes you almost like a which I call the bauxite duric crusts sometimes form as a almost like a layer weak like, weak looking kind of layer on the host rock,, and which one of the examples in the east coast bauxite, for which they were not been able to be identified for a good amount of time.

(Refer Slide Time: 24:21)



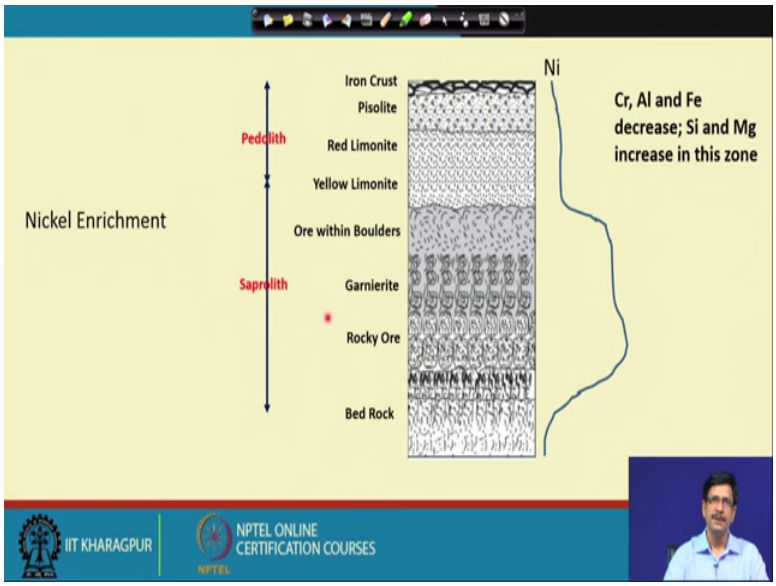
Well so, this process that we are essentially considering are the processes which are processes of essentially enrichment means from an existing, I will rock like a aluminous rock like a granite or a condalite, this material being converted to bauxite. And we also as we discussed when we were dealing with the iron deposits of sedimentary origin, we discussed that what we see is the primary ores in the form of the layered rendered hematite jasper, or rendered hematite corezite, there the actually the concentration or the content in terms of iron, will be always fall short of what can be called as in high grade ore going to up to 55 or 68 percent of iron oxide.

Here this is a good example is taken from one of the iron mine, it is what we see is these are the banded iron formation. And it is formed the enriched iron enriched part almost similar to what we get in case of residual concentration. So, iron deposits also can get enriched to high grade from the from the low grade parent material, and in this process where we have to have a situation where, there will be enhanced solubility of the silica which is present in the paper crystalline a form called a del form and jasper, they have to be selectively leached out of the material giving rise to the high grade ore.

This lateritization process is also is an important process after it was observed that some of the terrains, where there are some primary gold mineralization in some proximity, close proximity, or in some distance. The lateritization process also enriches of the literates also contain some gold in few parts per million, in some areas of the world they are also being walked out for gold, they have after that the economic importance of this laterite also went up.

The other important metal which also is enriched in the process of residual concentration is nickel, and the source rock of the ultramafic rocks. In fact, these resources of nickel in the is a residual concentration is even higher than what are available in the form of the nickel for us sulfide deposits in the ultramafic rocks. So, essentially the minerals in the ultramafic rocks the aliven mean mainly the aliven in the paraxine a content nickel in their structure, and when they are exposed these are acted upon by the surface processes, and get converted to sub this the fermentation minerals like, all if an get is serpentinezed. And this serpentine after a further process of enrichment gives rise to horizons, where the nickel is trapped.

(Refer Slide Time: 27:49)



This a typical profile of nickel; nickel for us nickel say, the nickel for us literite rezone which will be having a iron crust, followed by a pesiolotic lateritic kind of zone, then will be followed by a red limonite, and yellow limonite. And then will have the ore within boulders, and this is the zone which is labeled as garnierite; garnierite is essentially a name, which is a generic name given to the nickel for us clay minerals, which are derived through the process of alteration and hydration of the pheramic origin the primary ferromagnetism minerals like olivine, and the finally even they in the deeper part where the fresh rock is the exposed or you get the fresh rock. And if you take the nickel concentration, then the nickel concentration here, will be low within this top part which will be defined by the pedolith plus.

So, essentially pedolith the term is he denotes the soil top soil layer, and the saprolith is the layers which actually indicates, the more rock like characteristics, where is this saprolith zone which is the one which is more enriched, and the zone in which you get the concentration of nickel wrapped in the nickel for us clay minerals, which are the garnierite. And if you look at this profile a nickel concentration has a high in these zones where, we have the ore within the boulders (Refer Time: 29:45), and the rocky or and again falls back to normal background value, when it is the basement rock or the host rock.

And in this situation we see that chromium aluminum and iron will always decrease, in this particular region they will have the minimum value, because this region is the ore or the nickel can be extracted where difficult can attain concentration with of the order of even 1 to 2 percent, and a silicon, and magnesium will also be increasing in this zone, because they are leached out from the surface and deposited here, within this region and so, where we get the clay which are essentially alumina silicates. And clay I mean hydrated aluminum silicate.

So, that is how we get the zone here. So, these are the examples of a surface operated process, an exhaustions process, which gives rise to reach ore deposits of a important metals like aluminium, and sometimes with a nickel, and gold. And also if we consider that enrichment of the primary iron ore to give rise to the high grade ores by selective leaching of silica that also, can be included in this process, although these do not come under the strict process of sediment sedimentary process, but their surface operated process. So, will continued discussion about this.

Thank you.