Non-ferrous Extractive Metallurgy

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Module No. # 01

Lecture No. # 03

Sources of Non-ferrous Metal

Now, friends we are now coming to module 2 for this course.

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Now in module 1 I delivered 2 lectures essentially dealing with very briefly, the history of non-ferrous metal production in India.

In the second module, we are now coming to the subject proper and we will briefly discuss the following things: sources of non-ferrous metals - land and sea, principle of exploration of mineral deposits, principles of ore beneficiation and when we discuss the sources of non-ferrous metals, we will definitely talk a bit about non-ferrous metal wealth of India.

Now, you should first know very clearly the distinction between ore and mineral, do not confuse these two words. And ore is a mixture of many minerals, ores contain minerals, but the word mineral means, it is a naturally occurring inorganic compound containing one or more metals in association with non metals such as, oxygen, sulphur and halogens in more or

less in a fixed composition like, when you say hematite is a mineral of iron, hematite composition is F e 2 o 3.

When we said, some other mineral like, Galena it is p b s it is a mineral of lead, but in nature very rarely you find a mineral as such. There would be many minerals mixed together and along with them. There will be other minerals which we normally do not associate as a source of metal like sand, like aluminum silicates, it is a part of sand these we often call as gang or things that simply dilute the metallic value, but they are also minerals.

So, a mineral is a naturally occurring inorganic compound and it will be a combination with a metal and a non- metal like oxygen or sulphur or halogens. Like, you will find some exports sea benches, some chloride deposits, which actually have come from the sea, after the sea water has vaporized from that shallow beach you are left with some salts which are chlorides.

Even our salt mine which has sodium chloride, it is a source or sodium, but very rarely it is only sodium chloride, it should have other chlorides in it. And ore therefore may be defined as a naturally occurring aggregate or a combination of minerals, from which one or more metals can be recovered.

So, when we say here, we have an ore which means, we can get from that ore 1, 2, 3 may be more metals and their approaches as available for that, but just may have something it does not become an ore. For example, you go somewhere, where there is a whole lot of sand, there, in theory it has S i o 2 and theory you can get silicon out of that, but we do not call it an ore of silicon.

Obviously, something that is not considered an ore today, may become so tomorrow when technology advances, like the sand would become a ore of silicon if there is a technology which can economically or efficiently get synchronize out of that or or when you have clay, all kinds of clay which has alumina in them, we can consider someday it can become an ore of aluminum, but today it is not an ore of aluminum.

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Now, where do we find this minerals, this many the there are ores and minerals on land and we say that, they are found in earth's crust. Now, it cannot dig into the earth because people know that, the core of earth is very rich in heavy metals like nickel, iron etcetera. But, we cannot get there, our explorations for metals are generally confined to a few kilometers of the earth's surface and you can call it a crust, may be 10 kilometer thickness of the earth, of the earth that includes the sea, mind you that that is called a crusts, so the land area in that crust is a source of ores and minerals.

And there is also the sea which is the largest part of the crust, the sea also is a source of metals. Because, there are many minerals have deposited in them, we find that for various geochemical processes, not all elements are found everywhere, means elements that make this earth is not uniformly distributed at least in the crust.

There are reasons why there are pockets of some available here, pockets of some other metals are available elsewhere, normally in flat grounds, you will find deposits of alumina, alumina silicates in hilly region, especially hills that have been weathered the way like the Aravalli region of Rajasthan you find sulphides, there are various reasons why you get sulphides in this kind of region in oxides in flat ground, I would not go into that, but the point is that not all metals elements are uniformly distributed.

Now, suppose you find there is an ore and I mention something which is not an ore today may become an ore tomorrow. But, what really makes an ore and ore that govern that is

governed by technology and economy and here are the points. First of all the percentage of metal values has to be reasonably high, if suppose there is there is an ore where the metal value is very very small, then we would not like to call it an ore.

In India for example, we have iron ores which are very rich in iron. There are also ores, which are so pure in iron that we do not consider to be iron ore in India. But, for some other country it could be an iron ore, because they do not have ores even containing that much of iron. So, percentage of metal values in an ore is a parameter, nature of the occurrence that is form of occurrence. It may be high in in a metal, but it may be so fixed with the other non metals or a gangue material, that is very difficult to get it out of that ore.

So, again we would not call it an ore unless the metal value is recoverable, that is related to percentage of impurities and their association, physical conditioning of the ore. There are in some areas, iron ore which is very pure, but it it may be found in a fine form, it is very difficult to process as an ore; we may not call it an ore.

Then there is also location and magnitude of deposits. If it is located in a very hard place, which is very hard to for transport or the deposit is very small, it may not be attractive from economical point of view, proximity to transport facilities and other services. Suppose, in the Himalayan range you find some ore bodies, well it may be good from theoretical point of view, but practical point of view, we cannot we cannot exploit them so they we would not consider the ore.

Market value of metals, even ore has metals may be high values, but metal value is negligible. Then it is not much of an ore, then the economy of extraction, which we are discussing would also relate to two other things: value of land, cost of rehabilitation. If it becomes very difficult to acquire land in a place or whatever reasons, if there are people being displaced the cost of rehabilitation is very high, then the factors that govern economy of extraction would be negative.

That would rather should rather not go for put it up an industry for extraction. Similarly, there other issues like environmental and social concerns, if we have a process that would cost too much of pollution in an area whether people all around and their lives will be affected, then we will not have a good practical reasons for going for extraction. So, as I said that a whole lot of factors governed the economy of extractions and they have to be getting in time.

Now, how do we find such ocean minerals? Now, in ancient times it was easy, because many minerals were easily spotted on earth's crust. Even now, you go to many areas you find a red earth you know, it is iron ore rich; you may even get big boulders of iron iron ore hematite lying around.

Similarly, many other minerals are easily spotted and people had, people had done this to that what metals were contain in them, because the physical characteristics made it very apparent as to what kind of metals were to be found in them, but then as we as, the extraction processes became more sophisticated and then demands for very large ore deposits were there, because you wanted to set up industries, modern methods have to come for exploration and identification of ore bodies; many of which were hidden under the earth and many of them were not apparent on the surface.

Because in ancient times, they were all on the ground, so our ancients are taken them out from the surface I have already processed and the millen have passed and everything is full of soil hidden under the soil are the ores. How do you find, what are they?

Now, for that we go for, we apply geophysical methods, we try to understand the properties of the layers of earth in that area. Now, of course, over if we suspect that there is something in certain area we have to make some measurements, there are geophysical measurements, and a service had done on the surface to understand how the electrical property is changing, how electrical resistivity is changing.

If these things change, there we know there is something under the surface. Suppose, there are radioactive minerals, then radioactivity will change, as you as you go by. So, we have to depend on geophysical measurements for exploration.

So, that is the first step, after you have suspected through geophysical explorations, the occurrence of some ore bodies, then we have to for actual drilling, by drilling and taking out samples. Now, this sort of things outside the scope of this course, but I just want to give you a hint of the way things perhaps are done. Now, here is an example of trying to locate some magnetic ores.

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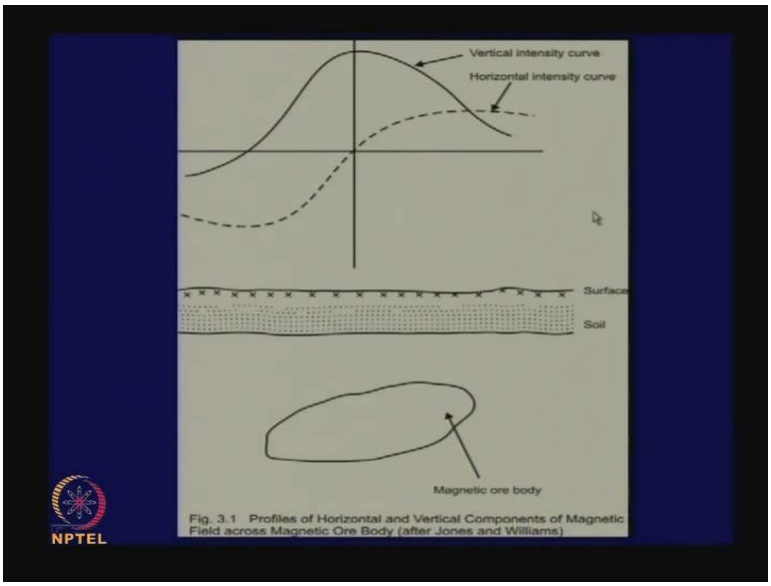

You know there were many ores which are magnetic, which are magnetic properties like for example, some ores of iron ore (( )) magnetic, the others and as we go by we will see some of them. So, suppose this is the layer surface and this is a soil here and hidden inside is a magnetic ore body. Now on that, if say service done and magnetic measurements are made in in two directions, this way and that way, from that we can draw a map of something that is hidden below the surface, which is giving anomalies in measurements, magnetic measurements.

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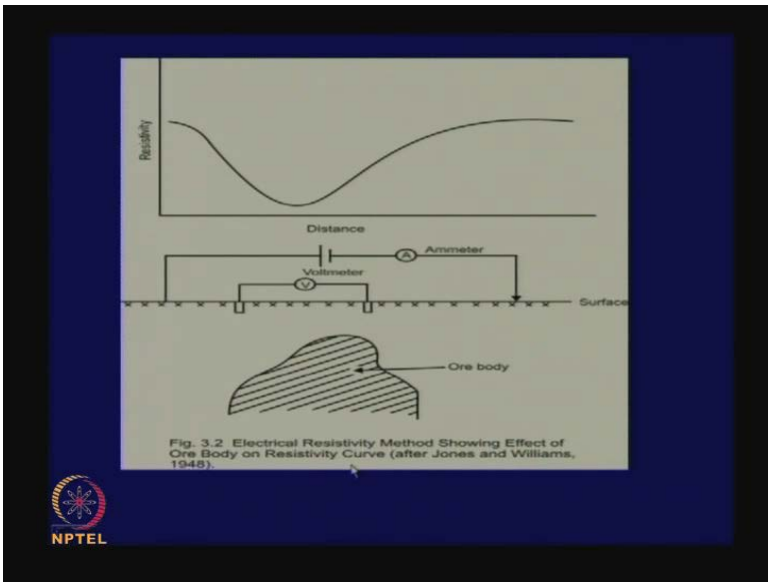

Similarly, if one applies a voltage at different locations and measures the current flowing and defined that, there is some place where resistivity's suddenly dropping, it means you find, here you go on measuring the current flowing and take the whole thing from one place to another and you find there is a place where suddenly the there is a hint of dropping resistivity. It means the whole thing is seems to be a very conducting, there is something under the surface, then you suspect, there is hidden inside an ore body which is electrically conducting.

So, then you have to start drilling here, find out whether your suspicious are true. Similarly, there were electrical flow lines, survey can be done in different directions, define the current lines, defined it many potential lines and from them, they can actually guess the kind of ore body, shape and size of the ore body, that is under the layer of soil.

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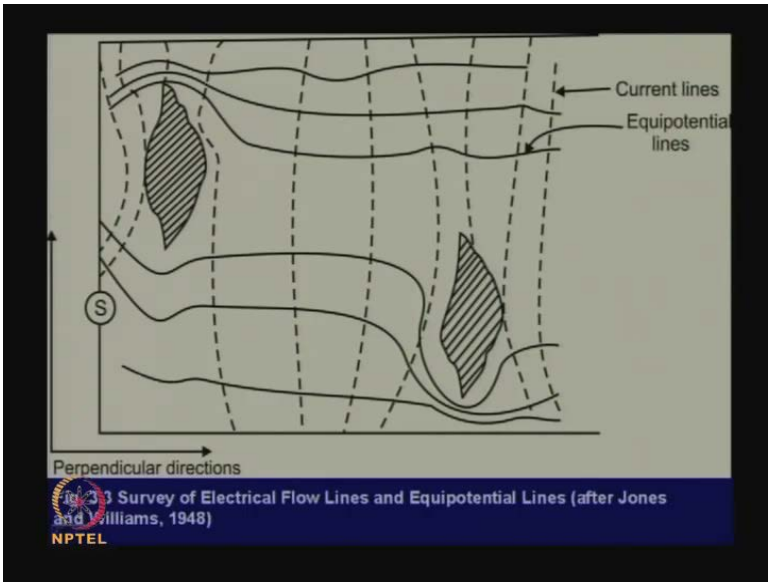

Now, these days the measurements have become sophisticated, that they need not go and do the survey on ground, it can be done by from aircrafts. So, the aircrafts fly on the ground in a grid, for me in this direction first with certain intervals and the plane will fly in certain direction, in other directions and they will maps will be drawn of electrical, magnetical and all kinds of properties from which they can guess that where this is, what kind of ore body may be there.

Now, I will not discuss anything beyond this, I would now go into the subject by starting with sources of metals. For more details of this, you can refer to as my book to which I I made a mention earlier Extraction of Non-ferrous Metals by Ray, Sridhar and Abraham. And is

published by Affiliated East-West Private Limited, first published in 1984, but then it is being repeated many times.

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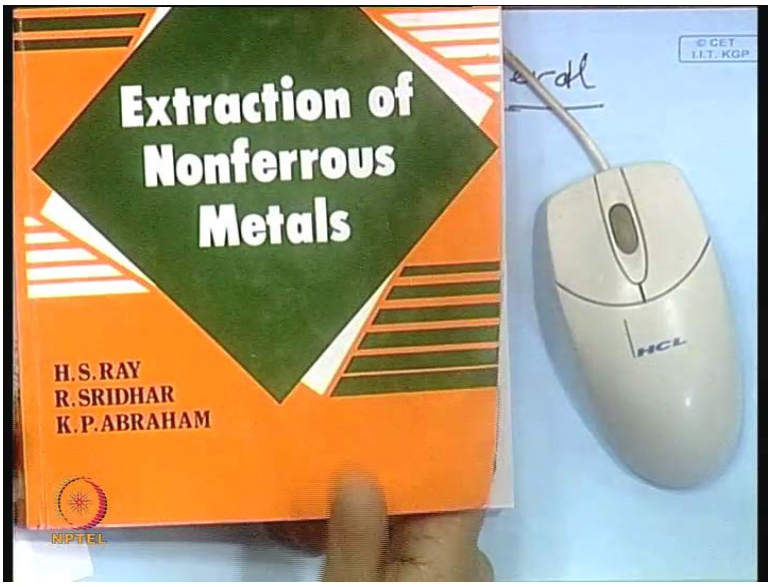

Now, many figures and tables that I would show will have a reference for which the details have given in this book. So, I I have not given details of all the references in the diagrams etcetera, that are shown, for that you have to back to that that book.

Now, as I mentioned earlier, there are ore deposits all over the earth's crust, all over the globe, but there are certain pockets which happen to be very rich; it is to also country wise. Like in India, there are certain pockets it is in the south of Bihar Jharkhand area or Salem in Tamilnadu, they are seem to extremely rich in certain element.

Similarly, in the coastal areas, there are certain areas where, very very rich in certain things, I would not go why this has happen, but this is the fact; that there are pockets where they are they are rich in certain metals, what about the earth, over all?

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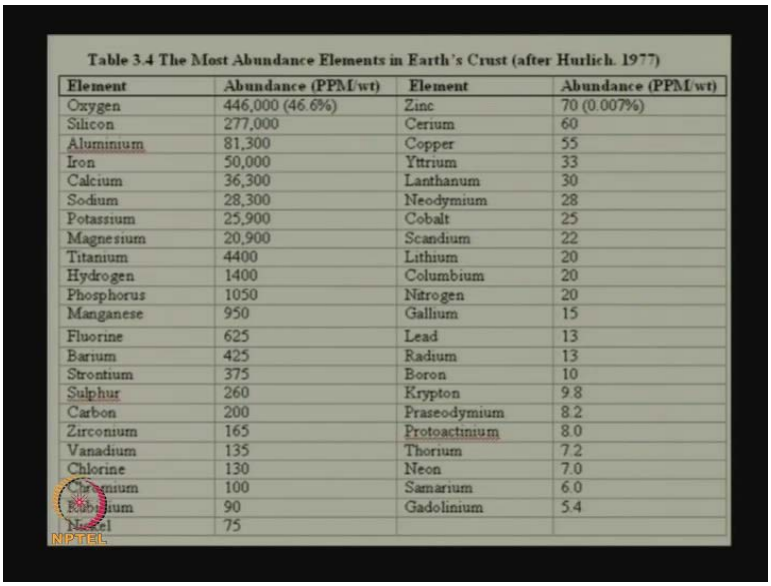

Table 3.4 The Most Abundance Elements in Earth's Crust (after Hurlich. 1977)

Element	Abundance (PPM/wt)	Element	Abundance (PPM/wt)
Oxygen	446,000 (46.6%)	Zinc	70 (0.007%)
Silicon	277,000	Cerium	60
Aluminium	81,300	Copper	55
Iron	50,000	Yttrium	33
Calcium	36,300	Lanthanum	30
Sodium	28,300	Neodymium	28
Potassium	25,900	Cobalt	25
Magnesium	20,900	Scandium	22
Titanium	4400	Lithium	20
Hydrogen	1400	Columbium	20
Phosphorus	1050	Nitrogen	20
Manganese	950	Gallium	15
Fluorine	625	Lead	13
Barium	425	Radium	13
Strontium	375	Boron	10
Sulphur	260	Krypton	9.8
Carbon	200	Praseodymium	8.2
Zirconium	165	Protoactinium	8.0
Vanadium	135	Thorium	7.2
Chlorine	130	Neon	7.0
Chromium	100	Samarium	6.0
Rubidium	90	Gadolinium	5.4
Nickel	75		

Here is a table that shows the relative abundance of various elements in earth's crust. Mind you again, I am talking about the top layer of the globe about 10 kilometer layer. We are not talking the entire cross section; I am not saying the earth is made up of this; no, talking about the crust. It is you will find that, most abundant is oxygen, the oxygen of course is there in air, but oxygen tremendous amounts in all this silicates, silica, alumina they are all made up of oxides.

Then the element which is the most abundant is silicon, then comes alumina, then comes iron and you will find ores is an iron age. So, you would think that iron is most abundant metal which is not true, aluminum is more abundant than iron, but why is iron more popular? It is, because of its properties, because it is easier to extract, iron has been extracted long ago because, iron oxide can be reduced by carbon either charcoal or coke; alumina cannot be produced that way. For aluminum to be produced one have to wait till the 18 th century and invention of electricity without that it was just not possible to produce aluminum in large scale.

As a matter of fact, even in the 18 th century and rather 19 th century towards the middle or little later, when alumina will just begin in to come, it was so expensive that, many kings served fellow kings food on aluminum vessels, on aluminum plates, with aluminum cutlery because, it was much more expensive than gold and silver, but you find that aluminum in spite of its abundance is not as common as iron. Now, if we take the first eight metals in the

list, the first eight metals made 90 percent means from oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium up to here that is 98 percent of the earth's crust.

And of this, 75 percent is accounted for by only silicon and aluminum; the rest are all in very small quantities. So, again the use of a metal in everyday is not related to the relative abundances in earth crust because, there are many factors which governed, why a metal should become popular? Economy of extraction, its properties and based on that only iron has become so important, aluminum is also become an important.

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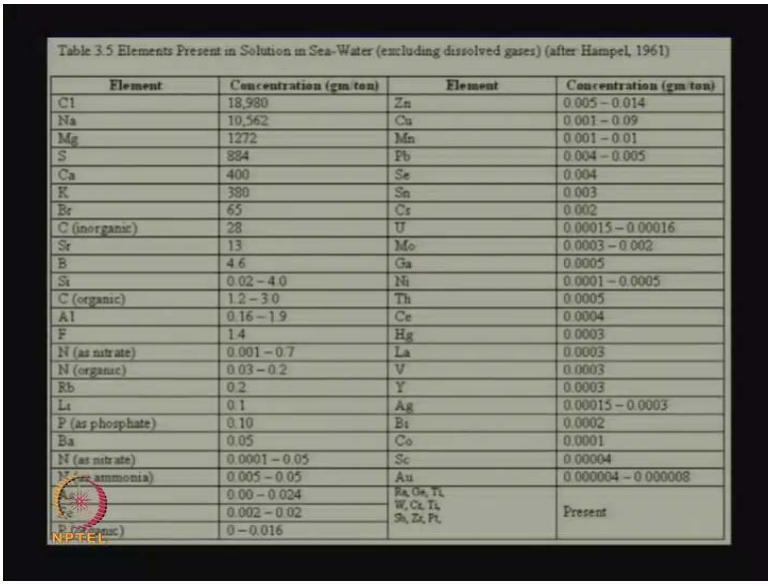
Table 3.5 Elements Present in Solution in Sea-Water (excluding dissolved gases) (after Hampel, 1961)

Element	Concentration (gm/ton)	Element	Concentration (gm/ton)
Cl	18,980	Zn	0.005 – 0.014
Na	10,562	Cu	0.001 – 0.09
Mg	1272	Mn	0.001 – 0.01
S	884	Pb	0.004 – 0.005
Ca	400	Se	0.004
K	380	Sn	0.003
Br	65	Cs	0.002
C (inorganic)	28	U	0.00015 – 0.00016
Sr	13	Mo	0.0003 – 0.002
B	4.6	Ga	0.0005
Si	0.02 – 4.0	Ni	0.0001 – 0.0005
C (organic)	1.2 – 3.0	Th	0.0005
Al	0.16 – 1.9	Ce	0.0004
F	1.4	Hg	0.0003
N (as nitrate)	0.001 – 0.7	La	0.0003
N (organic)	0.03 – 0.2	V	0.0003
Rb	0.2	Y	0.0003
Li	0.1	Ag	0.00015 – 0.0003
P (as phosphate)	0.10	Bi	0.0002
Ba	0.05	Co	0.0001
N (as nitrate)	0.0001 – 0.05	Sc	0.00004
N (as ammonia)	0.005 – 0.05	Au	0.000004 – 0.000008
	0.00 – 0.024	Ra, Os, Tl, W, Cr, Tl, Sb, Zr, Pt,	Present
	0.002 – 0.02		
P (organic)	0 – 0.016		

Now, apart from the earth's crust, the land mass, the other source of non-ferrous metals is the seas; the seven seas as we say they cover the globe. Now, since water flows everywhere, you may think that the composition of sea water should be uniform. This is largely true, largely true, but there may be reasons why there could be certain locations where the sea water composition is bit different from sea water composition elsewhere, you must try to understand, what has given this metal in the sea?

Now, one theory is that, over the millennia, the rivers that are flowing over land, that are coming from the hills, they have dissolved through dissolution, they have brought in many elements and which have gone into the sea or they have caused erosion of many minerals which have gone into the sea and through some reactions of dissolve in the sea.

But, if we have to find something in the sea, obviously it is something which is in the soluble state. We will see later on in the sea, there are also me insolvable matter which are sources of matters, but this theory does not account for all the dissolved elements in the sea, it is now known that the elements in the sea are not only coming because of the rivers flowing into the sea or the rain water, washing material from land mass into the sea.

But, some are coming from the bottom of the sea, because of their many sea bottoms have big cracks which run from kilometers and hundreds of kilometers. There are under sea volcanoes and from there, there are eruptions, there are continuous inflows of various things which contain different kinds of metals. So, that is under sea input of elements as well as, the input from rivers etcetera that account from the elements that we find in the sea. Now, in the sea everything, every element you can think of it is present.

Now, interestingly of course, the most abundant is chlorine and sodium. Because, sodium chloride dissolves in water and you would not find sodium chloride and land if they had been it is all been most term. So, these two I have maximum, then comes magnesium, magnesium chloride is there, then there all other things are there; in fact you will be surprised to know there is also gold and silver in sea water, you will see there is gold also, now you might think this gold in 0.000004, 0.000008 means nothing but, that is not true.

We are giving them here in gram per ton, now if you find out 1 cubic kilometer of sea water, find out how many tons that means of sea water; and if you multiply by this gram per ton, you will find, that will mean huge amounts of gold. So, if it could get hold of 1 kilometer cube of sea water we can extract lot of gold from that.

And in fact attempts were made it to extract gold from sea water at one time, I think some are in France in sea beach, but they had to abundant that because it was feasible technologically possible. But, not economically attractive means, you have to process huge amounts of sea water to get that gold which is not worth all that expenses. So, what I am saying is sea water has all these things, whole lot of things in sea water they are in solution in some salt form. Now apart from that, we know that all this account dissolved solids account from 3.5 percent of dissolved solids, that sea water context more sea water has 3.5 percent dissolve solids.

And in that 3.5 percent all this elements are there, notice one important thing, the relative abundances of elements in sea water are very different from the relative abundances figures in the land mass, it should be it should be very clear to you why it is because, here it depends

on solubility; what is more soluble in water will be present in greater amounts and also what is coming more from the bottom of the sea will be in greater amount.

So, sea water has one kind of distribution of elements and the land mass has another kind of distribution. Now, as I said they are the localized changes because of injection from the bottom of the sea and there is also another very interesting, this in why there are certain regions, pockets, where the elemental concentration can be different. And this comes from sea organisms observing certain elements in preference to others it is known that some sea organisms like algae, they accumulate it is a kind of sea width they accumulate high concentrations of iodine.

In fact, iodine as an element was first found from analysis of algae, so if there is a region of sea water where there is lot of algae, you will find lot of iodine in that part of the sea; algae is not found everywhere in equal amounts, so iodine will be concentrated. There there could be other such organisms or even some animals, which actually, selectively accumulate certain elements.

So, apart from the sea water as a body, we also consider the sea organisms as a source of elements. So, the sea is giving us two sources: the sea water and a sea organisms, there is a third source in sea which is very interesting they are called Polymetallic Nodules or Manganese Nodules. In the floats of many seas and that fortunately includes also Bay of Bengal, people have found rounded solid nodules from say, half a centimeter to couple of centimeters, 10 centimeters, 12 centimeter they cover sea beds huge huge areas.

And people have analyzed to find that, these nodules are very rich in some elements, some metals that are, why they are called a polymetallic nodules? And this is an estimate of reserves of polymetallic nodules or I am writing reserves of metals in Pacific Ocean nodules and I am comparing them, compared to land reserves and nodule reserves.

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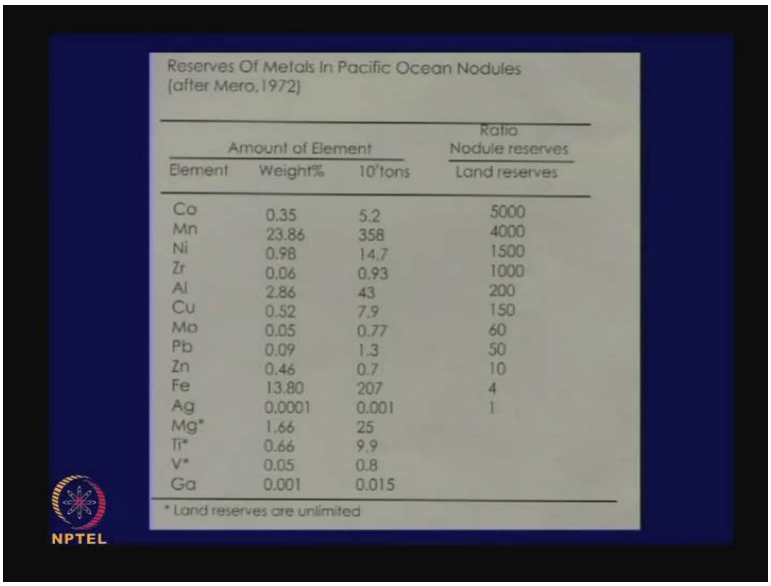

Now it is surprising that, there are the nodule reserves apparently contain 5000 times cobalt than is available in land reserves. In the case of manganese, 4000 times than that of that in the land reserves, nickel 1500 times and etcetera etcetera. Now, a lot of interest now has grown in this area and you know there are all kinds of international treaties regarding sea coast line, sea floor and essentially, if you want to be in the game, you have to spend money, you must understand why India sends an expedition to Antarctica every year, because we have a permanent station in Antarctica.

We claim a part of Antarctica, similarly in sea water, in in the sea floor countries which invest money in explorations are given rights of an extraction of nodules. So, India is amongst a few countries which have invested heavily in survey of sea floor to see how much of nodule is available where, and then finally, India has settle for certain areas and said they are not interested in other areas, so have they have let go their rights to the other areas.

But, in the Bay of Bengal and some other places, India has spent money and they have rights or excavations of sea nodules from that area; there is a problem because its sea nodules are in the ocean floor to get them out of that ocean floor in large quantities is difficult. But in future, we may have a technology of pumping them out or some undersea vessels going there and mining them and bringing them out there are also, some shallow seas like not far off from the shore in Bay of Bengal, where sea nodules are found that may not be so difficult. In Pacific Ocean you have to go 5 kilometer down below to the sea floor, we have to get the sea

nodules. Anyway coming back to the subject the pacific ocean nodules, figures are only for pacific ocean, it does not mean other oceans do not have it they also have that.

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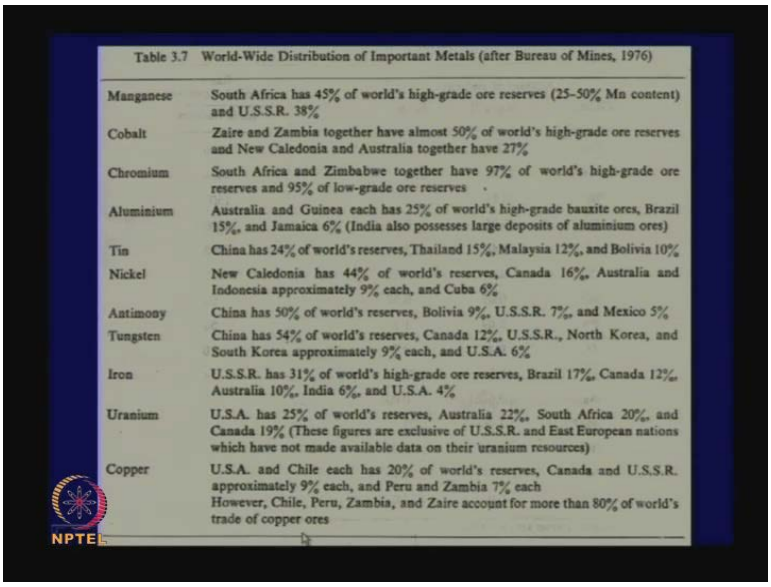

Now we will, we have talked about four sources: the land reserves, the sea and the sea means; in the sea, we have the sea water, we have the sea organisms, organisms like the weeds, we also have the ocean floor nodules. There are two other kinds of sources and to that I would come later. Let me first mention one or two things about the land reserves; in our book, we have given a lot of data about what minerals are found everywhere, which countries rich in which ore and which mineral. But, it is not necessary for you to know this, if you get some time some time or if the occasion demands you can go through.

But I wish to point out the World-Wide Distribution of some important metals to indicate where does India figure, because there are a few places where India as as a is very important country. Manganese you will find, there are some countries like South Africa or US s or most of the manganese found there.

But manganese is found in India also large quantity that is enough for now. Cobalt you will find Zambia, Zaire have almost fifty percent of worlds high grade ore reserves, South Africa, Zimbabwe has ninety seven percent of the high grade ores of chromium, aluminum is where you find mention of India?

India has large deposits of aluminum ores, may be not as much as some other countries like Brazil or Jamaica or Canada, but it is very large tin, China has 24 percent of world's reserves, India has nothing very little tin; only some tin has been found in Madhya Pradesh (( )) district unfortunately antimony we are not we do not figure anywhere, tungsten we do not figure in the list of countries which are rich iron ore, India comes there we have only 6 percent of iron ore, but we have high quality iron ore.

Uranium we do not have and that is the big problem with India and all the nuclear tricky etcetera is to look for this uranium from Canada or USA or Australia or South Africa who have uranium ores. Copper we have some, but we are no where amongst the countries which are rich, same with Molybdenum, Columbium. India has figures very strongly in titanium; we have titanium 4 percent, I should not say very strongly, but fairly strongly 4 percent and something that is not mentioned, India is very rich is in thorium; I will come to that later on. So, to summarize actually India's we can say that, about the mineral wealth of India we have adequate to abundant-ores Aluminum, Beryllium, Chromium, Manganese, Magnesium, Titanium, Zirconium, Thorium and the rare earths.

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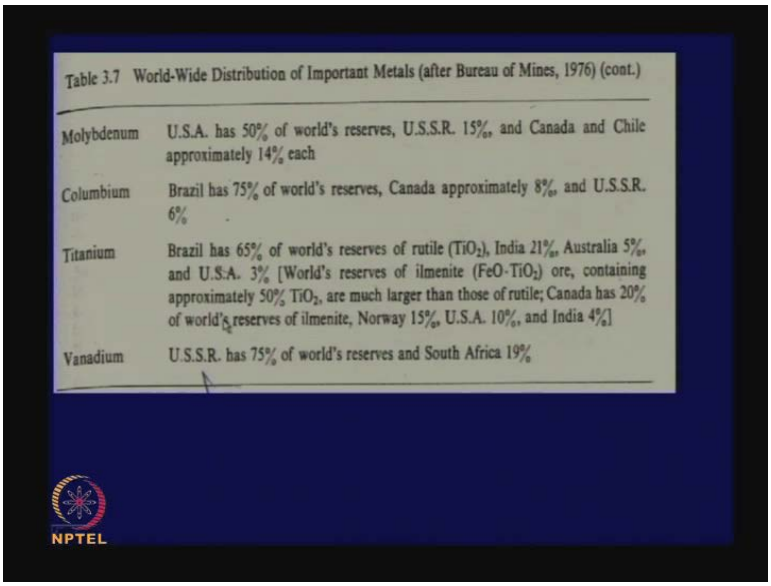

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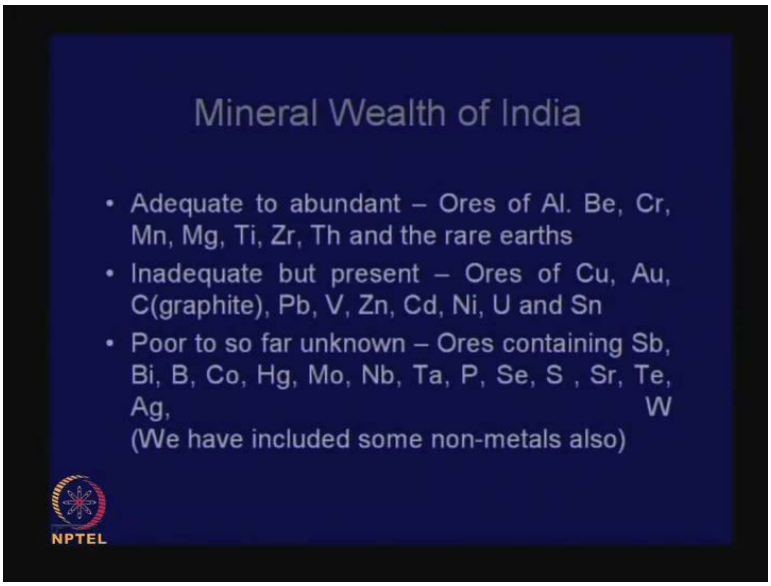

In adequate, but present ores of Copper, Gold graphite it is not a non metal, but I have include it here led Vanadium, Zinc, Cadmium, Nickel, Uranium, tin, poor to not so far unknown as ores of Antimony, Bismuth, Boron, Cobalt, Mercury, Molybdenum Niobium, Tantalum etcetera, etcetera. Here we have included some non-ferrous, non metals also, now the, so position of India is, India is not very rich in terms of non-ferrous metals excepting thorium, we do have adequate quantities of Titanium, Manganese, Zirconium etcetera.

But, what we have is our expertise this is not necessary always to have your own ores and minerals. If we have the intelligence, we can import process and have your metals and minerals; look at Japan they have no minerals, they have no ores, but they have the knowledge, they have the technology and they have the right policies and they thrive. So, we need not always say that, we cannot be rich in this area of technology, because you do not have the ores and minerals are not necessary.

But certainly, ores and minerals give you in the mineral wealth, from that India is not as well place the south Africa or Australia or America or Canada, but not very poorly of also they should know that, at one time India was the only country which produced diamonds in south India Golconda, all the diamonds came out of Golconda until the south African mines were discovered in the last century, now they are leaders.

Nobody knows, it is quite possible that, there are some are hidden here and there some mineral wealth still have not found and we will find them it is possible, so the exploration is

very important for India. So far what I have discussed is that, what are the sources of metals and I had pointed out that, the important sources of land mass, sea water and in sea water in sea, these are sea water, sea organisms and nodules. That is one more source of metals that you should not forget and that is scrap metal.

And metals that are recovered from metal scrap or wastes are known as secondary metals like, supposing we are producing aluminum and you are sending it out into the market in the form of vessels or containers etcetera etcetera, which after sometime are discarded, that becomes the source of the metal, that has to be recycled like iron and steel in the advanced countries, some 40 percent of iron comes from a recycled iron and many of them come from car bodies.

Lead can be easily recycled, aluminum, zinc, copper everything can be recycled and when you recycle the metal, there is an advantage that it needs much more energy to extract the metal from ore, it requires less energy to extract it from scrap or some metallurgical waste which is not a metal scrap, but may be its there in the slag you recover it from there, it will require less energy and there it will less expensive.

Actually you can think of a day, where the world will not need ores and minerals; the world will produce all the metals, it needs by recycling the scrap, because after all it cannot go on producing more and more and more and metals for all kinds of uses, there will be a saturation point that you do not need more than this much of metal at a time. And you have a steady state, the scrap that goes comes back and it produce the fresh metal.

It is beginning to happen as I said in western countries, in the in the for iron and steel about 30 40 percent is beginning cycle. So, scrap metal is also a very important source of metal; and there is also something called metallurgical wastes, in many metallurgical processes we may produce a slag which contains a valuable metal.

And perhaps, the slag is a better source of the metal than some ore in on the surface of the earth on the land mass. There are, we will see examples that in many cases, it is from the slag we recover that metal. So, metal slag is a metallurgical waste, there can be other kinds of wastes, so metallurgical waste and scrap metal is another source of metal.

Now, I just want to end this by mentioning one more thing that we talked about manganese nodules, and I said that there is much more manganese in them, much more of something

than we have in this in this sea. And I said, there is a problem that to get them out of the sea floor is a problem, there is another problem say this a whole lot of manganese in the manganese nodules which are actually polymetallic nodules, but there is manganese available in earth's crust also as manganese ores and easier to get manganese out of that.

It is something that gives a negative picture to that nodule, that we need not extract nodules from manganese, but we have to extract them for the other metals like nickel, cobalt etcetera. But, then we have to end up extracting manganese also, so it is a question of economics, you cannot take out just one or two metals from a nodule, that you have taken so much effort to bring it out of the sea floor.

But then, if you take out all the metals that including manganese, it is also not very advisable because, there is lot of manganese on earth's crust which is very easily extracted; so lot of conflicting things are there, but on the whole, manganese nodules can be called a future source of some strategic metals.

And interesting things about in this nodules, which average size as I said from this to that about 4 centimeter, is that they are being produced all the time by some some processes in the sea floor. And it is said that, everywhere some processes occur when may be some sea organisms also take place and they have said that in the Pacific Ocean alone they estimate is every year 10 million tons of this manganese nodules have produced.

Now in a land mass, if there is an ore body it's fixed, it is not renewable, but manganese nodules appear to be renewable, you can take them out again fresh amounts of nodule will be found. Actually people have done experiments to find this out, they have taken out some manganese nodules from somewhere else and have seen the fresh generation of manganese polymetallic nodules.

So, we have an in exhaustive source of Nickel, Cobalt, Copper and Manganese and some other materials also, if only we could get them out of the sea floor, we would have no problem. And I mentioned that, India may not be very rich, but then we are not very poor either. I like to end by mentioning one particular, I do not have a slide, I will show you this particular table, not this table sorry.

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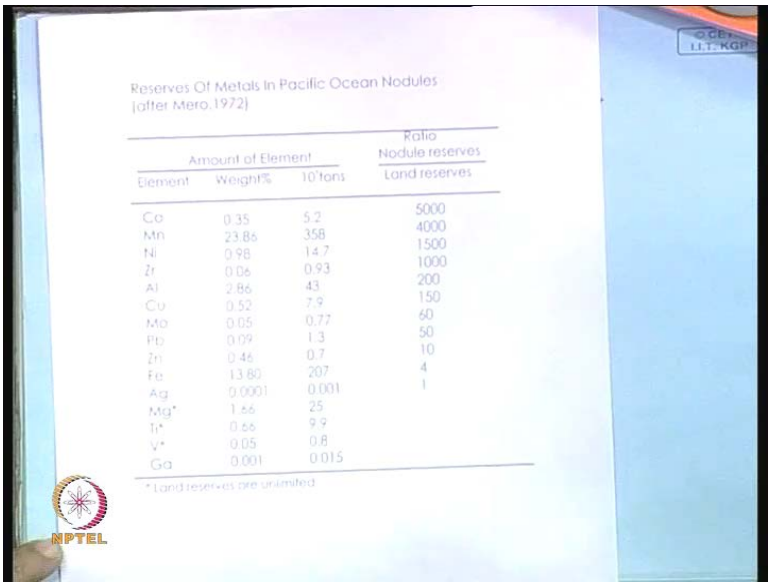

May be, I will cover that in the next, I will like to talk about in the next lecture, I have a very particular resource that is very important for India and that is this the all along the sea beaches, we have special kind of sand in certain pockets. This contained many minerals not only titanium, but rare earths and that is a very very rich raw material we have and I will discuss in the next lecture.

So, let me wind up by saying that, we have discussed briefly from where do we get metals, what is the difference between an ore and a mineral; we cannot call any source which has a metal and ore because, there are some economical factors that tell us whether we can extract metal out of that body.

There are also technological factors that, unless we have a process to extract the metal out of an ore body, we cannot call it an ore like, the question can be are manganese nodules ores of nickel and cobalt, we do not use the word ores for manganese nodules, yet so very easily we say there are sources of several metals, there sources they would become ores when we will have an economical method of extracting of taking them out of the sea floor and extracting metals.

Incidentally many CSR laboratories have worked on this polymetallic nodules from sea floor, I happen to be the director of regional research laboratory Bhubaneswar, where we have a project which is going for about 20 years on extraction of this values from manganese nodules or polymetallic nodules from the sea floor. Our job is to extract the metallic values

from the nodules given to us, some other agencies job was to collect them from the sea floor. Now, we have a process not only us there is an another laboratory which has also worked on the process.

We believe that, we are technologically successful, we can get all the metals out by a process which some day can be skilled up and there can be a plant operating, which will produce these metals starting with this polymetallic nodules from the sea floor. The question of economics is mostly tied up with extraction, with collection from the sea floor; if that can be solved, we will have a process and if if that could be done India will have all the Cobalt and Nickel it wants, and also me other metals some people have argued that, we have to take out manganese also, may be we will take out manganese as well. So, thank you very much.

Now, in the next class, I will talk especially about the beach sands of India. One of the most important resources we have that Contain, Titanium, Sodium rare earths and these valuable things it is very important from a point of view of a nuclear and geo program because it has to be based on thorium. So, our next lecture will be on beach sands, particularly how do we treat them, how do we beneficiate them and how we extract things from them. Thank you very much.