Non-ferrous Extractive Metallurgy

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Lecture-02

Brief History of Non-ferrous Metal (Contd.)

Friends, I will continue with the history of non-ferrous metals.

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Now, in the last lecture, I had shown a slide which said that up to about 5000 B.C, we had Paleolithic or Old Stone Age, then there was the New Stone Age, where settlements began to appear and then around 3500 B.C we had a beginning of ancient civilizations in Egypt, Mesopotamia, Indus valley and China.

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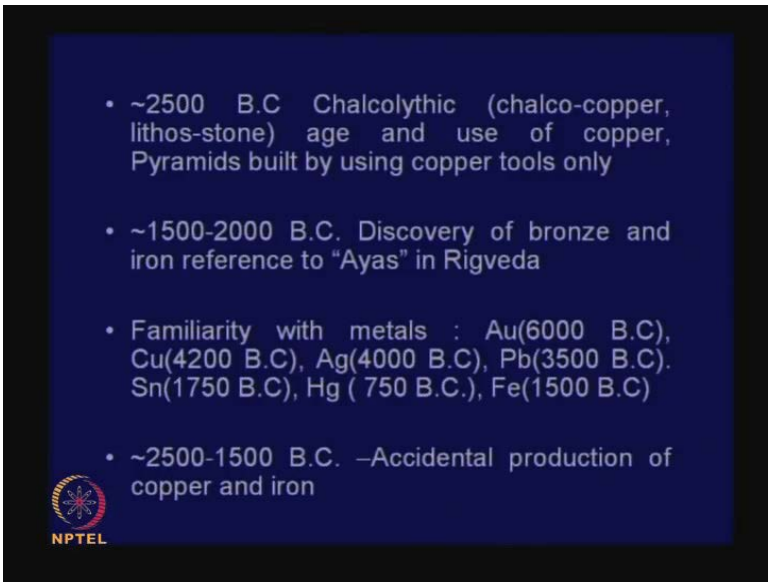

Now, I also mentioned last time that copper seems to have been discovered rather accidently, when the malachite, that something that which is CuCO3Cu(OH)2, which the Egyptians used for eye shadows, thinking it has miraculous properties, and they were not very wrong, actually it is beneficial to the skin also.

If some malachite falls into fire, where this carbon, then copper will be produced, because copper oxides will be reduced. So, they must have found this accidently, and then they learnt by trial and error how to make large quantities of copper.

Now, if copper contains some tin ores, then tin will get oxidized along with copper and you will produce bronze. So, they started producing bronze also. In the ancient times very often, they could not tell exactly what was in an alloy. So, they sometimes would have called it superior copper or soft copper or hard copper, but definitely they learnt to make bronze. So, we had Stone Age, Copper Age, and then Bronze Age.

Now, the familiarity with metals, started with gold, because gold is found in native state with copper, whereas, copper is also found in native state, and also it came out of this over accidently, as I mentioned. Silver which actually occurs with gold and then lead, tin, they must have also come from accidental reduction of oxides by carbon.

Mercury came bit later, because an ore of mercury- HgS, if it is heated, it decomposes, produces mercury. So, somebody must have accidently produced mercury. Iron came in

the same scene around 1500 B.C, and there is a very interesting story, about how iron may have been found.

In India, there are stories amongst many tribal's, that what happened actually, is that in the deep in the woods, some hunters

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-chased a small animal, which could have been a rat or rabbit or something, and that animal jumped into an anthill. Anthills are common in forest areas, it is about 5 to 6 or 8 feet high, which happened at a hole on top and many of them, have a hole on top. So, it jumped into the anthill, and now to catch it they put a stone on top of the anthill and covered all the cracks, etcetera with bushes. They put a log through a hole and set a fire. They put some holes here and there for the smoke to come out, so they thought either the animal will come out and they will catch it or it will get roasted alive inside.

Now, their story is that there was a wind blowing at that time, so the fire… the wind helped the fire, and there was a draft that came, and the fire went on and on, and there was a surprise for them, when after a few hours they did not know what to do. They left it there; they thought the animal was completely roasted and ruined anyway.

So, they left it, and the next morning, they found there was a metallic mass inside, which was very hard. What was this metallic mass? What might have happened is that anthill was in an area, where there was iron ore, and those lots of carbonaceous metal inside,

and when they set that in fire there was a reduction. The carbonaceous material reduced iron ore to a spongy mass, a kind of sponge ore.

This story, it sounds very possible, because even until eighteen century the tribal's were making this kind of iron in small blast furnaces, which were not very much, taller than anthills, may be 5 to 6 feet height only, almost the similar shape. And the idea was the same that you have iron ore and you have charcoal and you put some fluxes so the slag's come out and iron is not totally molten, but it is semi solid.

So, we get what we call this a spongy mass, which have to be beaten for the slag's to be separated and the metallic mass to be consolidated. So, this is the story that the tribal say. And the traditional iron producing furnaces which continued in India till the eighteenth century uses were only one meter height.

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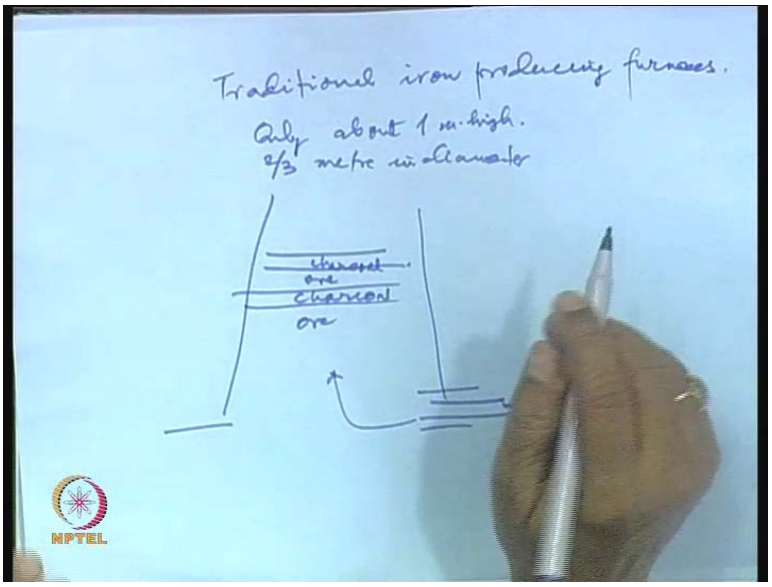

Traditional iron producing furnaces, about which I have given you some data little earlier, are only about a meter high and two-thirds of a meter in diameter. They would be filled with this iron ore, charcoal in a number of layers. This is what they would do: ore charcoal, ore-charcoal and they had a bellow here, that human somebody will jump up and down and put the bellow, so that the air would be forced in and they would get temperatures about say 1000 degrees, 1100 degrees, 1200 degrees; not enough to melt

iron, mind you, but they will get a semi-solid mass from which, I mentioned earlier, you have to beat, squeeze the slag out and we call that iron wrought iron.

Now, in ancient India, iron making centers developed in center lined India: Bihar, Bengal, Assam, U.P, Rajasthan, Karnataka and many are there. They were in forest areas where lot of charcoal was available and the tribesmen, when the tribal's became very good at it, and many of them are called Lohariyas, and actually some of these tribes became so good in making high quality wrought iron that the special names, were attached to this kind of wrought irons.

Like in Bihar and Bengal there is a Munda tribe, even now. So, in ancient times the iron they produced was known as Munda Loha. So, that Munda Loha, was a famous kind of a sponge iron they produce. Now, this course is about non-ferrous metals, so I would not talk about iron steel anymore.

What about non-ferrous metals? As I mentioned in only 7 metals, I have listed. I did not mention zinc, because zinc came into the scene much later. The only reason is very simple that it is not very difficult to produce zinc by reduction of zinc oxide. You can take zinc sulphide mineral in ore, if we heat it, make zinc oxide and you can reduce it by carbon produces zinc, but the zinc comes out as a vapour, and it will escape. So, one has to learn how to condense the zinc.

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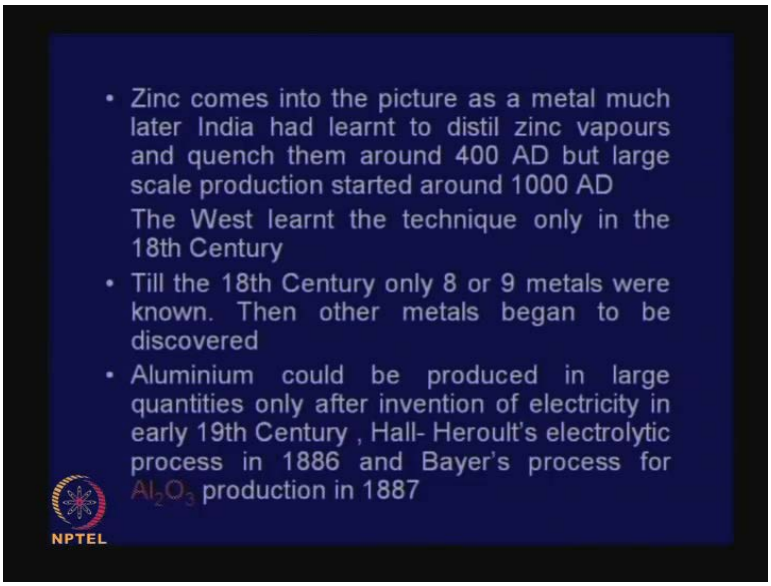

Now, Indians apparently learnt them around 400 A.D, how to condense a zinc and they kept very quiet about it. The rest of the world did not know about it and around 1000 A.D, large scale productions are started in Rajasthan of zinc, and they learnt to alloy produce not only zinc but brass by along with copper.

But please remember, first brass may have been produced not by adding zinc to copper but by a process of cementation. Means, if one takes ores of zinc and copper together and heat, you may end up with a brass, but that will not be very high quality brass. And to get high quality brass with high quantities of zinc, zinc has to be produced separately.

Now, until about, as I said the tenth century, only 7 metals were known. India only knew about zinc, which others did not know about, and that is how that what it remained. It is only in the eighteenth century, till eighteenth century, we had these 8 metals or 9 metals and aluminum could be produced in large qualities quantities only after the invention of electricity in the nineteenth century.

And that is how, we came to Hall-Heroult's process, and that was helped by the Bayer's process for Al2O3 production, which went into the Hall-Heroult's process electrolytic cell.

And from nineteenth century then, many others metals were beginning to be discovered. Like, in the eighteenth century, when other metals began to be discovered well like cobalt, platinum, nickel, bismuth, manganese, molybdenum, tungsten, zirconium titanium. They came much later only in eighteenth, nineteenth centuries.

Nineteenth centuries many more metals were added. Now, let us come back to the history of metal production, non-ferrous metal production in India. There are two kinds of historical evidence about the non-ferrous metal production in ancient India; one we call is literary evidence,

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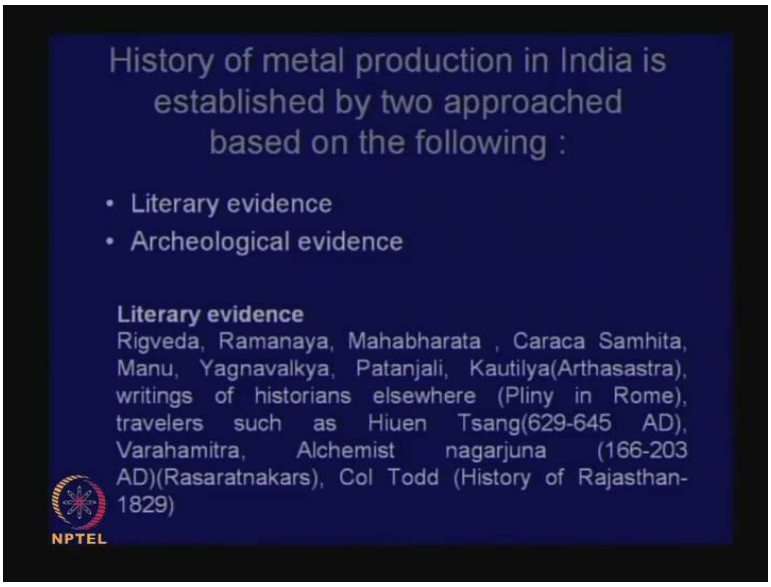

-and the other is archeological evidence. Literary evidence obviously, means the literature we have where there is mentioned of non-ferrous metals and there is plenty of that.

There are numerous texts starting with a Rig-Veda, Ramayana, Mahabharata, Caraca Samhita, Manu, Yagnavalkya, Patanjali, Kautilya; Kautilya's Arthashastra. They all mentioned different kinds of metals and there is of course, also many visitors who came to India in ancient times like we had Hiuen Tsang, a famous Chinese historian. We had Alberuni who came later, and then we also have a Britisher called Colonel Todd who wrote history of Rajasthan in the nineteenth century.

So, these are some of the sources from which you get a lot of information. Now, as I had mentioned earlier in Rig-Veda the word Ayas comes very frequently. Many people think it means iron, but there are other people who say not only iron it also refers to metals as such because they talk about "Red Ayas" and "Black Ayas". "Red Ayas", means copper and black means iron.

Ramayana contains a shorter list of minerals and metals, but Mahabharata has a many references to many metals, including iron, because by that time India had come into Iron Age and it mentions iron extensively everywhere.

There is description of many brass statues in the writings of Chinese traveler, Hiuen Tsang, who visited India between 629 and 645 A.D. He has written extensively about use, production and use of brass in India.

There is a special reason why brass became so important in India. Indians have always been crazy about gold. Now, brass was thought to be a kind of gold or a substitute of gold. So, brass had a strong attraction for Indians, as a matter of fact, there are stories that when some kings ran out of gold, for whatever application they had in mind, like cladding of the buildings or making of statues, they asked for a substitute and that was a brass and there are people who could make that.

There is a extensive reference to bronze and brass in the 4th century B.C writings of Kautilya's Arthashastra and a Kautilya was said to be the mentor of Chandragupta Maurya, and after Chandragupta became the emperor, he went in to his the other career where he wrote extensively and Arthashastra is one of the books he wrote.

There is early 6th century B.C writing of a very well known author called Varahamitra, and then most extensive descriptions of metals alloys are found in writings of one man

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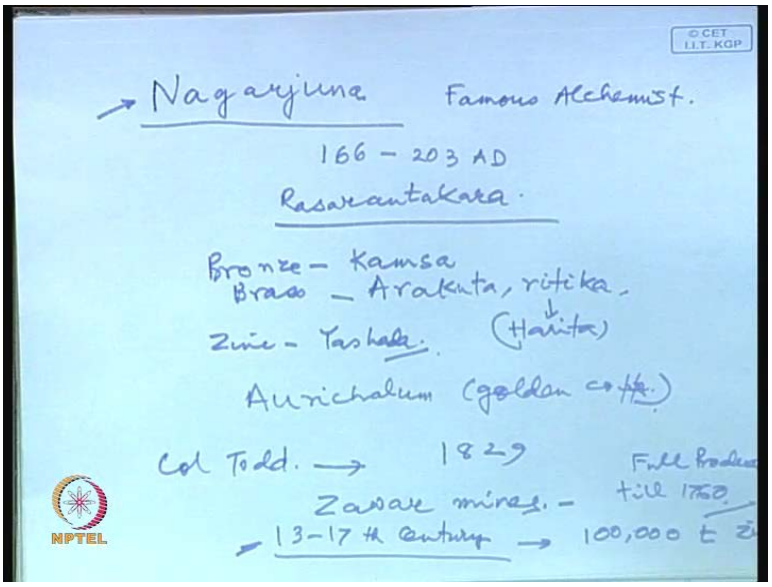

-called Nagarjuna. This name you should know. You should remember. He was one of the most famous alchemists of ancient India who lived from 166 to 203 A.D. He wrote a

famous book, a text called Rasaratnakara, where he has described different metals and processes for making them.

And he also is mentioned by many kings, who actually invited him to come and produce the gold for them, because they thought, he was producing gold even when he was making zinc.

There is there are mentioned some metals in writings of Charaka; Charaka Samhita, 3rd century B.C writings of Manu, Yajnavalkya, Patanjali, all of them, before the Christian era.

At that time, the word for bronze was Kamsa (Refer Slide Time: 18:10), from which we today in Hindi, we say kansa, and you know, there was also the other words for brass which was Aratika, Arakuta, ritika. Actually ritika is derived from Harita; Harita means yellow, so because it is yellow it is called ritika, some have written it mentioned it also Arakuta and of course, you know that this zinc was called yashada.

There are many Roman traders, and at the time there was trade between India and Roman. Some Roman traders have written about use of metals in India. Some historians of Rome like “Pliny”, he mentions something called Aurichalum (Refer Slide Time: 19:28), means gold and copper, which actually referred to zinc.

Colonel Todd, an English man, who wrote famous history of Rajasthan in 1829. Actually have written very extensively about the metallurgical activities in Zawar mines and a lot of credit goes to him for telling us, initiating the Indian historians, to look back into the history of production of copper, zinc and lead in the Rajasthan area.

And during the 13th to 17th century, there are records that Zawar mines, were in full production till full production till 1760 and there were finally, abundant because at that time Marathas were regularly attacking Rajasthan, and also the area got flooded. So, until then Zawar mines are producing copper, zinc and brass etcetera, and during the 13th to 17th century, then an estimate says that 100,000 tons of zinc were produced, and they are very basis of this estimates.

So, we have the thriving industry in zinc and you know that zinc was produced; it went into making brass also. Now, I mentioned about Nagarjuna, the alchemists in the second century.

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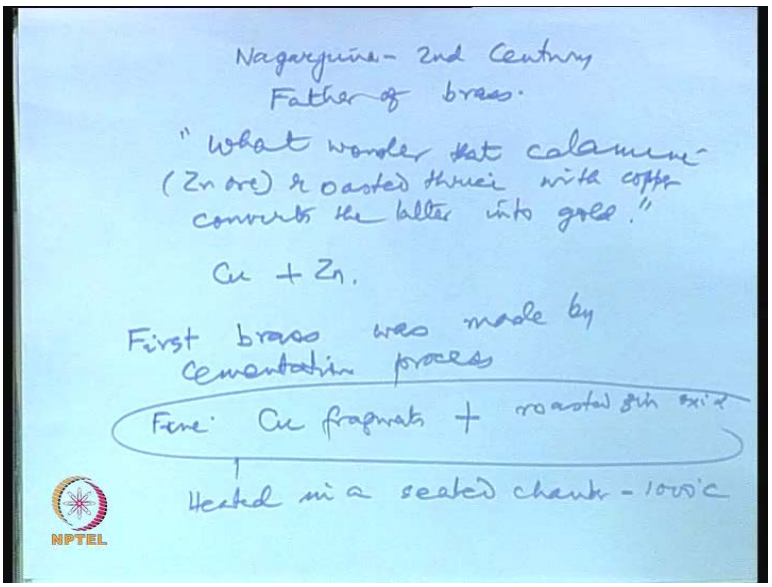

Nagarjuna started it all. He is known as the father of brass; he wrote in his text Rasaratnakara that I have mentioned that, “what wonder is that Calamine, that is zinc ore roasted thrice with copper converts the latter into gold”. So, this is the kind of process, he was doing that.

Now, you can make brass by adding copper and zinc but this is not how the first brass was made. The first brass was made by “cementation process”, and in this, the process is copper fragments; fine copper fragments mixed with roasted zinc as Nagarjuna says, heated in a sealed chamber 1000 degree centigrade will produce zinc, because copper will replace zinc from the zinc ore and that excess copper will dissolves zinc.

But it so happens that by this process one cannot produce a brass which contains good amount of zinc. It will be 9-10 percent; is a poor quality brass in many ways.

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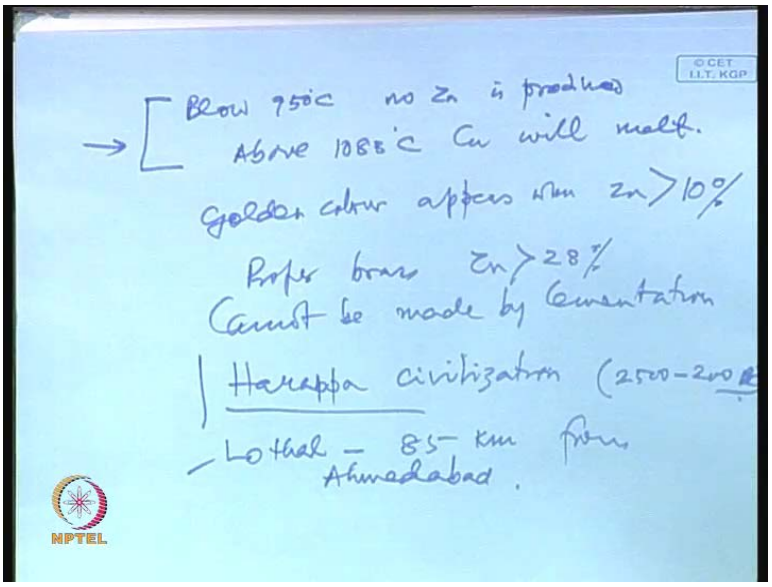

Besides, below 950 C, no zinc is produced, even if all traces of oxygen is there. Above 1083 degrees, copper will melt, and if copper melts then the dissolution, the cementation reaction, will not be so effect. So, the temperature has to be controlled in between these two and our ancient, the metal workers of Rajasthan, are learnt to do that. They could control, so that the cementation reaction could proceed, and they were producing poor quality. Now, the golden color appears when zinc exceeds 10 percent.

So, before that if people were making zinc, brass elsewhere, it was not so attractive, as what when Indians started doing that. Proper brass will need zinc in excess of 28 percent, proper brass. This cannot be made by cementation; means cannot be made by heating copper fragments with roasted zinc ore. You have to prepare zinc separately and then make an alloy, which the Indians learnt to do around 400 A.D.

This had become quite common actually by 6th century onwards, and then it by 10th century, it became a thriving industry in India. There is evidence and this evidence come from Hiuen Tsang that in Taxila, there were huge structures made of brass, and today there are statues from brass vases from that era, which contains more than 34 percent zinc.

The Harappa civilization (Refer Slide Time: 26:37), which tribed in North West India, that was 200 B.C, the wide area. They here using all kinds of metal artifacts and they had a famous port called Lothal, which is only 85 kilometers from Ahmadabad.

Now, excavation sub is made in Lothal, and huge numbers of artifacts have been found. These have tools, weapons, personal ornaments, objects of domestic use, figurines etcetera and then we have found these things from all over India also, the excavations reveal that lot of evidence of metallurgical activities, in ancient India, but Harappa is famous as a civilization for industrial and trading activities. They had connections through sea route, through land route and they were producing all kinds of things.

Some objects contain lead, pure copper ingots where they were 99.8 percent that has also been found. What is difficult to say is that what was produced by ores collected locally or ores in concentrates imported through land route or through sea from elsewhere.

Now, some people believe that you can tell, whether the metal used in an object found at a place has been produced from a local ore or mineral by looking at the impurity contents. The idea is this; that suppose you find certain impurities in a figurine that you have found at one place, and if the same kinds of impurities are there also in locally available ores and minerals, you may be tempted to think that the metal has been produced from that ore, or an mineral, but people have questioned this; there are many reasons to believe that this may not be true.

What is true though, that many objects of brass or bronze that were made in India, certainly the metal and alloy must have been produced in India, there is no doubt about that. And much of these activities took place in the Aravalli hill region of Rajasthan, and there are many archeological excavations have found some wonderful examples of metallurgical activities, and how they were produced, because the ancient furnaces rows and rows of them, they are all available. They are all been found and there are pictures now and some of them have become very famous ports; very famous sites.

Now, you see this is

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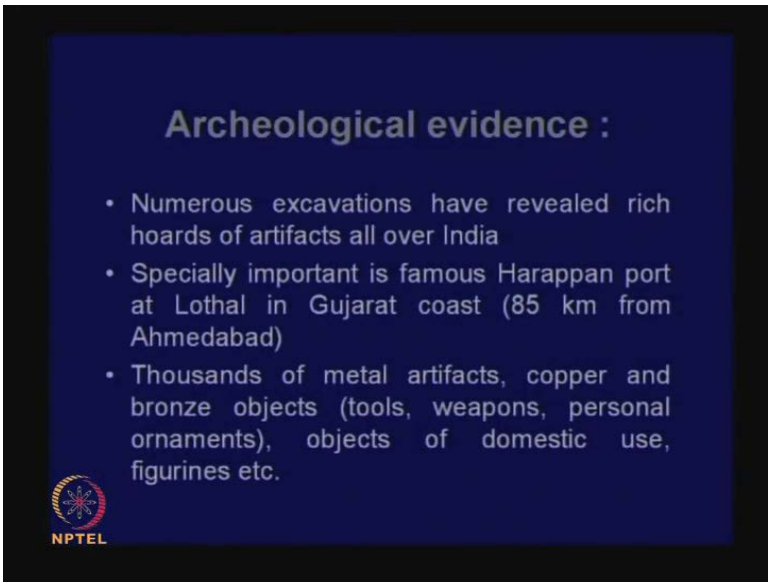

when I was talking about earlier, I talked

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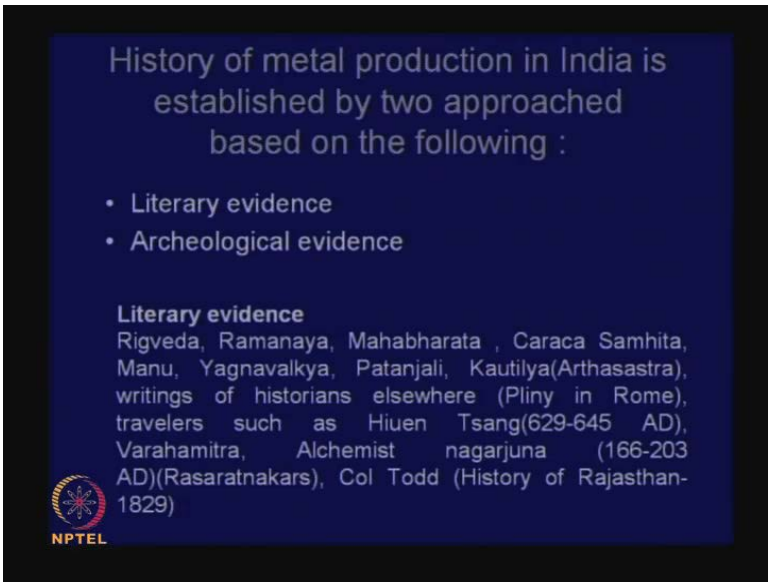

about literary evidence. Now, we are talking about archeological evidence. We have numerous excavations which have revealed rich hoards of artifacts all over India.

The specially important, as I mentioned is Harappa port at Lothal, Gujarat coast. The thousands of metal artifacts copper and bronze objects selling from all over India in

many places, because it spread from the North West to the rest of India, and on the basis of that today, we know what all things were happening in India.

Like, I would show you the picture of the copper furnaces.

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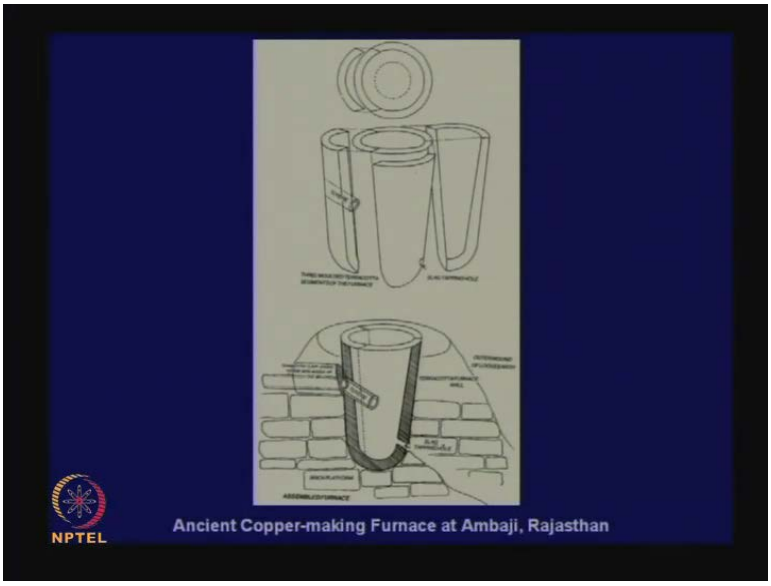

This is the kind of furnaces, which it just may be a foot or too high. The fragments of these ancient copper furnaces have been found in many sites in the Rajasthan region and from the basis of that, the drawing has been made.

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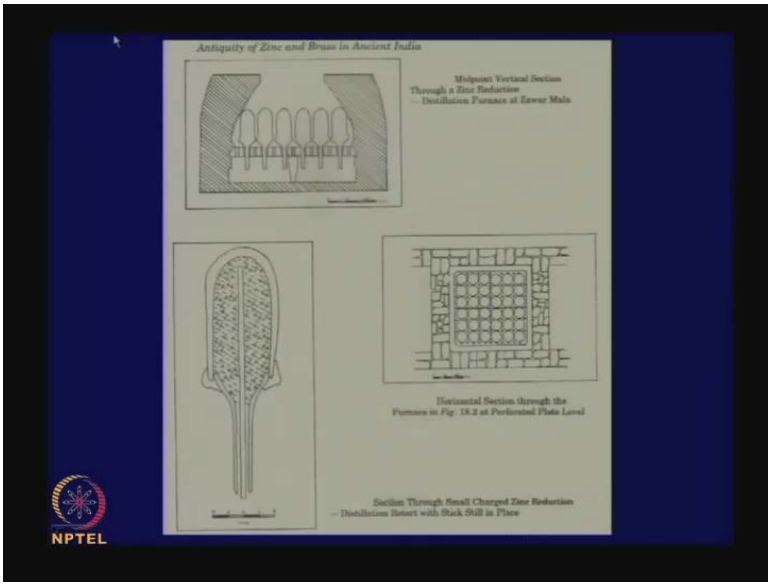

These are the drawings actually made from furnaces of ancient sites, as to how zinc was distilled in India. You have these retorts, and in this retorts, this is where the charge was there. The zinc ore roasted with carbon, and zinc vapors came and condensed here. So, they were also sometimes called brinjals because they are look like brinjals.

So, you see there is an escape route for the gas, because the CO gas has to go out, but the zinc from the charge came and condensed all around here, all around the center tube. Now they always used huge number of retorts in groups, often in groups of 36, in a chamber, and they were of two kinds. They were vertical retorts and they were also horizontal retorts.

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This is an actual site on a hill side, you see the retorts embedded are still there, and these have not became archeological sites of great importance. This is a retorts wall of Zawar mines.

So, this was very special technology of India, which was not available and Indians somehow are managed to keep it very secretly. They would not tell anybody and till 18th century, nobody knew what was there going on.

Now, the details of exactly how things were done, in… for making copper or zinc, they are available now. They are available in the text, especially in people like Nagarjuna has very clearly written the steps to be taken, how to make what. Like you know the copper

alloys are produced in small furnaces, using crushed quartz about equally in weight of the ore, and nearly twice as much charcoal had to be added. The slag mainly fayalite, FeSiO2, which melts at about 1170 degrees could be removed.

Only, if the whole charge was taken to about 1200 degree that is what I am saying, the copper melting point is 1083 degree, but we have to run the process at about 1200 degrees to make sure that fayalite slag part is removed and the ancient Indians were doing that.

For producing zinc, fayalite sphalerite that is zinc ore was (ZnS) mixed with impure dolomite crushed quartz, and roasted first to make oxides, which were rolled into one centimeter pellets, with some salt and carbonaceous matter, and they were heated in small retorts, each containing 1.5 kg like kg in clay retorts, with the pictures I showed.

With funnels like condensed tubes, heating was external, temperature at 1250 degrees. Often, cow dung cake was used, for quick heating of the entire furnace. And after 6 hours, 200 to 500 kg…, 500 grams of zinc, could be produced in each retort. So, each retort produced maximum of half kg of a zinc metal.

How do we know all these details? Again, there are extensive discretional details in many ancient texts. Secondly, there are excavations today, which have revealed all the retorts, some with charges intact. So, people have taken out the retorts; analyze what is there in the charge. Some with zinc, some before they were fired; they are all there, because as I mentioned, in 18th century they were all flooded, and they were abandoned, so they have stayed as it is.

Now, what finally… what happened actually to all of that? Now, the decline was because of two reasons; firstly from 400 A.D to about 11th century, the Zawar mine area was very active. Then you know Mahmud Ghazni, when he attacked India, he was devastating.

And Alberuli, a traveler who had come from Persia at that time, has mentioned that by that attack, he almost killed the sciences of the areas that he conquered and people fled, but what happened is many people became very secretive and some continued their work, but would not let others know. For example, that zinc production continued but

even Mughals, did not know much about that until 17th -18th century, nobody knew about them.

But then many people, skilled people also moved southwards, which were then there was no Muslim rule there. They were relative peace. The south of India acquired a very special (( )) area of bronze and brass, and that continued, and that continues even now. There are people who are still making beautiful bronze castings, beautiful brass statues', using the lost wax process and that has continued for centuries.

So, the statements by the Persian traveler Alberuni was Mahmud Ghazni utterly ruined the prosperity of the country. Hindu sciences have retired far away from the parts of the country conquered by us, and it happened, they all fled south.

And many artisans moved to southern states, but the art of brass making did continue in secrecy, as I mentioned. Even Mughals, were not quite aware of it, and Abul Fazal mentions in Ein-I-Akbari more about Hindu Asthadhathu, which supposedly contains copper, tin, zinc, lead then gold, silver and sometimes mercury added as an amalgam, but he did not does not write about zinc as such.

By Asthadhathu, some others meant that it had copper, bronze, brass. Very often bronze and brass they were thought to be metals. Lead, iron, gold, silver and arsenic, but clearly zinc was not identified by Abul Fazal.

Anyway, now I will end by giving you some pictures of the… from ancient India of some artifacts.

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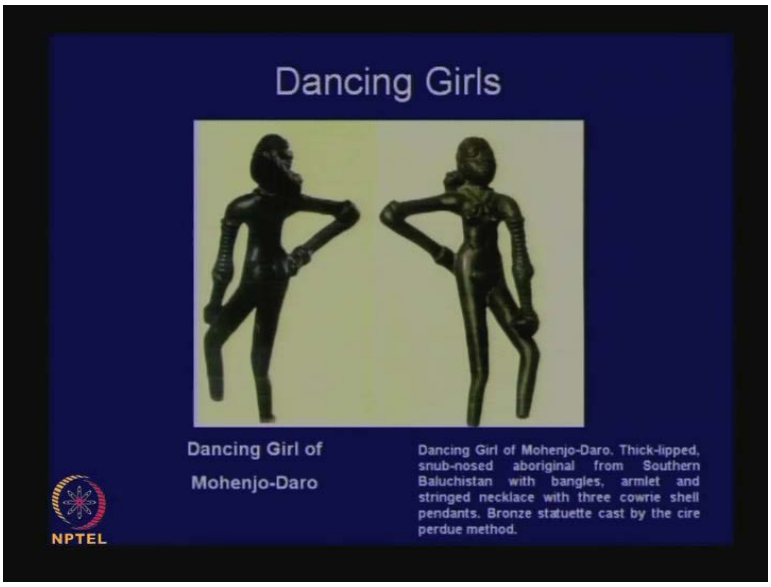

This is one of the oldest figurines made of a non-ferrous alloy and very famous dancing girl of Mohenjo-Daro, Mohenjo -Daro is now in Pakistan, but this is almost a symbol of India. The thick-lipped, snub -nosed original from Southern Baluchistan with bangles, armlet and stringed necklace with three cowrie shell pendants. Bronze statuette cast by some method, I do not know what that method means.

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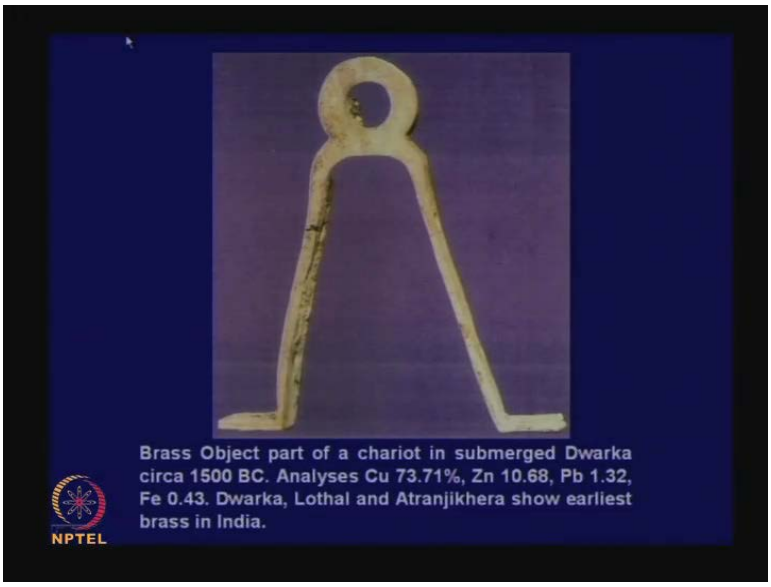

Here is a brass object that was part of a chariot in submerged Dwarka dated 1500 B.C, in of the coast of Gujarat. They have found now in the sea, submerged walls, obviously

they say that was the city of Dwarka, which got flooded and this now under sea. Lots of things have coming out. This has come from that submerged Dwarka.

Now, these analyses, copper, zinc as 10 percent, lead one percent, though this must have come, the zinc must have come by cementation process, means copper filings added to roast a zinc ore and heated to get this brass.

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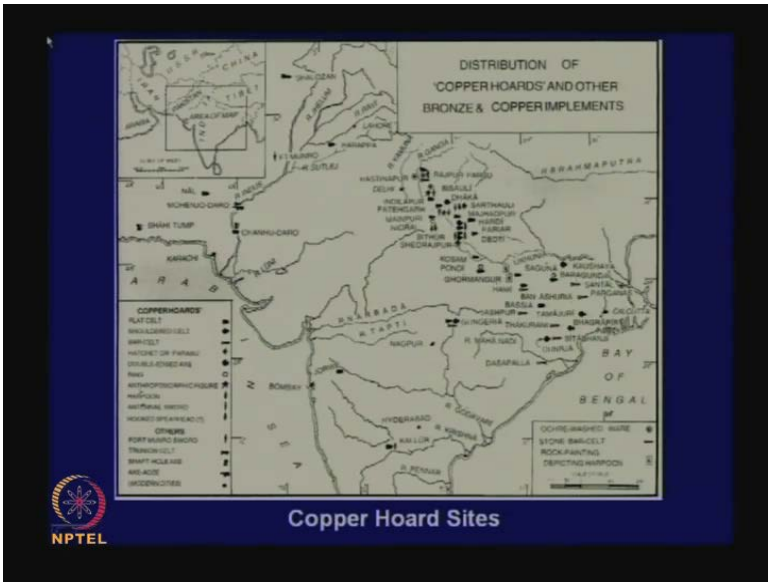

This is a picture of just after the Harappa period and later period, the copper hoard sites; ancient copper artifacts, they think 100, 1000 B.C, 2000 B.C, have been found from all over these places, huge, which means that it spread from the Rajasthan area, all across Northern India and towards the south also in later periods. This I have shown in ancient copper. These are the ancient zinc retorts.

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Now, let me end by showing some beautiful pictures, which speaks so highly of not only our expertise in our metal production, boasts also in craftsmanship.

This is the apart this is from the Gupta period, means middle of the first millennium is called the Gupta period. This have copper 73 percent, tin 5 percent, zinc 3 percent, which means at that time again that zinc was come in, because it happened to be in the ore, and metallographic showed later the green boundary. The attractive image has triple folded neck. You can see the neck, the broad shoulders, the armlet and the headed band, etcetera. Now, the beauty is not only that somebody produced a metal like that, but they had a method to cast a statuette figure in of this quality.

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Here is one which is a 7th century A.D, analyses 73 percent copper, tin 2 percent, zinc 10 percent. So, it is tin, zinc, lead, iron; is a strange kind of an alloy, almost became like an Ashtadhatu, but you cannot call it a bronze. It is more of a brass with little bit of tin that what for us gives this color. But look at the look at the beauty of this sculpture.

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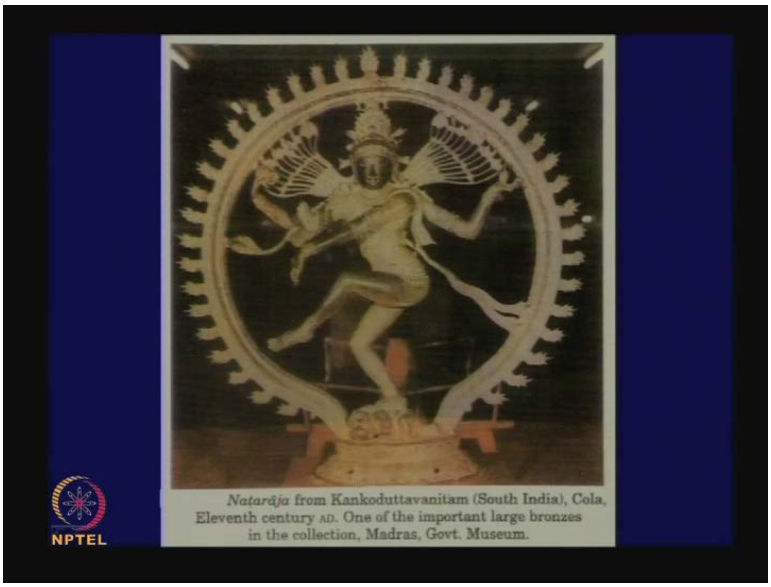

Now this of course, this is one of the many Natarajas that remain, is considered by the experts, to be one of the most artistics things ever created in world... in world art. Then, the lot of interpretations of this, but I would not like to go into the aesthetic aspects. I just

want to you to tell you, it is from south India, the Chola dynasty, 11th century A.D, and one of the important large bronzes in collection of Madras government museum. It is made of bronze, copper, tin.

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This is again early Chola period, another thing, Shiva Nataraja, rather 950 AD.

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This is an Ardhanarishvara, half-woman, half-men. It is Chola period, 11th century. It is a close up profile.

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This is another thing from ten thousand 1070 to 1125 (( )), from here we can say it looks more like bronze to me.

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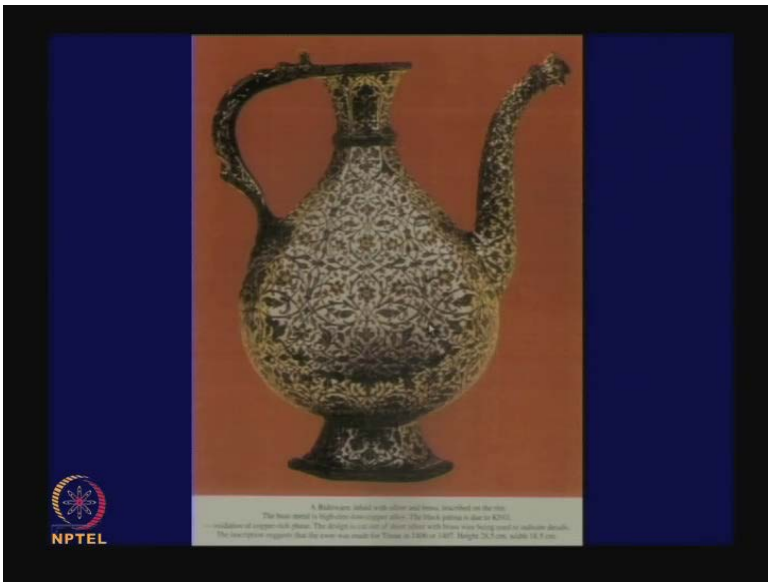

Now, here is another very interesting kind of alloy, which seems to very peculiar to India. Maybe, it was… it is there in the Middle East. Also, this kind of thing is called bidriware, bidri. And a bidriware is in led with silver and brass. You tried in the rim; the base metal is high zinc, low copper alloy.

So, it is a different kind of brass. Very high zinc, low copper alloy and on that they have in led of silver and brass. The thick patina is due to they treat it with some chemicals by KNO, to give you some black marks, some oxidation of copper rich face, a beautiful design. This is a bidriware.

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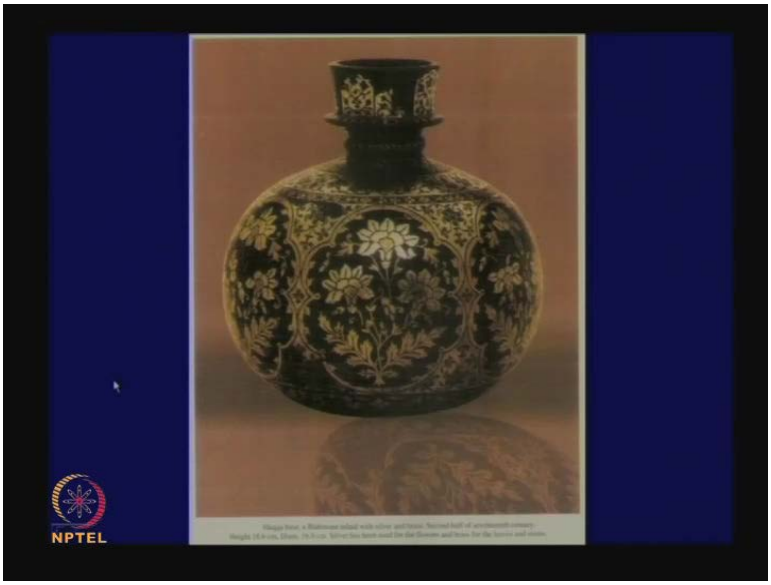

This is also an Indian, a bidriware. Now, I am giving you a random sample of some beautiful objects of art, made of non ferrous metals. If you go to Indian museums, especially if you go to south India, to Madras, Bangalore, see the museums. You will be amazed at the kind of expertise; we had in casting these figurines out of non-ferrous metals bronze and brass.

Now, first of all Indians made those alloys, and secondly found those alloys they made those beautiful things of art. So, India had achieved excellence not only in non-ferrous metal production, but also in using those alloys to make beautiful things. Apart, from other things for different kinds of uses, which you have find in Lothal.

So, I think I will conclude this lecture now by saying that we have very briefly gone through the history of metal production in the world, and we have seen that from Stone Age, we moves into Chalcolithic period, where copper was used with stone like in Egypt and many other places, copper have been being produced accidently, perhaps.

And then if there were tin ores along with copper, we produce bronze. People learnt that here is something, which is very superior to copper in terms of hardness, and initially they did not understand, as to what it was, but they found that this kind of ore, produces this kind of copper, which is better than the other kind of copper, and only slowly they began to learn that there was a another metal in it. So, people identify tin also.

Brass came as later. Brass of the kind what we you know later. Initially the brass was made by cementation process, which contained only small quantities of zinc. You take copper filings, heat with zinc ores, and you some zinc will get reduced, and you will get a copper zinc alloy, but you never get an alloy which is more than 9 or 10 percent zinc. So, it is not a very good quality brass.

Very good quality brass was first produced in India, starting from about 400 A.D, because India had learnt the process of distillation of zinc. They knew how to quench the zinc vapors in a retort.

Now, a retort is a very special kind of device. It cannot be completely sealed, because when the roasted zinc ore is been reduced by carbon, then carbon monoxide is been produced. So, it has to escape. So, you have to find a way of allowing CO to escape, but not zinc vapor to escape, which means, there has to be some outlet where as the temperature drops, it must be in open air, and as the temperature drops zinc vapors must quench to give you the metal, whereas, this CO goes out. So, they had by trial and error, they have perfected with the technique. They are producing zinc from 400 A.D.

So, India did have a very rich heritage in non-ferrous metal extraction. Unfortunately, when I talk about rich heritage in non-ferrous metal extraction, it is only the common non-ferrous metals: copper, lead, zinc, tin. Not so much of mercury also, all the mercury they did produce, mercury was extensively used in alchemy in Ayurvedic medicines.

But perhaps in China, they produce many tons of mercury, because there was an emperor whose tomb has been excavated now, he actually created for him a paradise, in which he was buried, and all that has now been excavated. Apparently, they were underground; his tomb surrounded by rivers of mercury, and that was the legend. That it is not a bit of, there were actually rivers of mercury. Now, people thought it was a legend, but now they

are found that the soil there is really is very rich in mercury. So, they are producing because they had whole lot of HgS.

But India of course, was always crazy about gold and India was always importing gold through sea route, through land route. Some are from Tibet, a lot of gold was coming, because Indians were crazy about holding gold, and because they were crazy about gold, Indians are also crazy about zinc because you look like gold. And that is the reason why people like Nagarjuna, spent the entire life time, trying to produce zinc in large quantities.

Well, I guess that should be enough about the history of metals in India and a world, and now I will go into the subject proper in my next lecture.

Thank you.