

## **Introduction to Ancient Indian Technology.**

**Professor D. P. Mishra.**

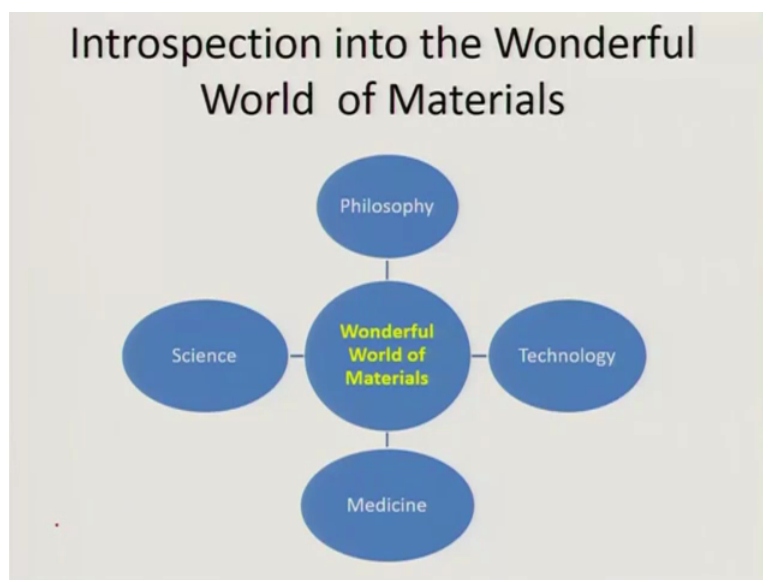
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**Lecture-32.**

### **Material technology: Metals and Metallurgy in Ancient India.**

Let us start this lecture about the Material Technology and we will be discussing basically about Metals and Metallurgy in ancient India. If you recall that in the last 31 lectures we have basically discussed about glimpses of ancient Indian science and technology, later on we moved to the agriculture and then subsequently to the housing and textile and of course towards end we were discussing about water management system in ancient India.

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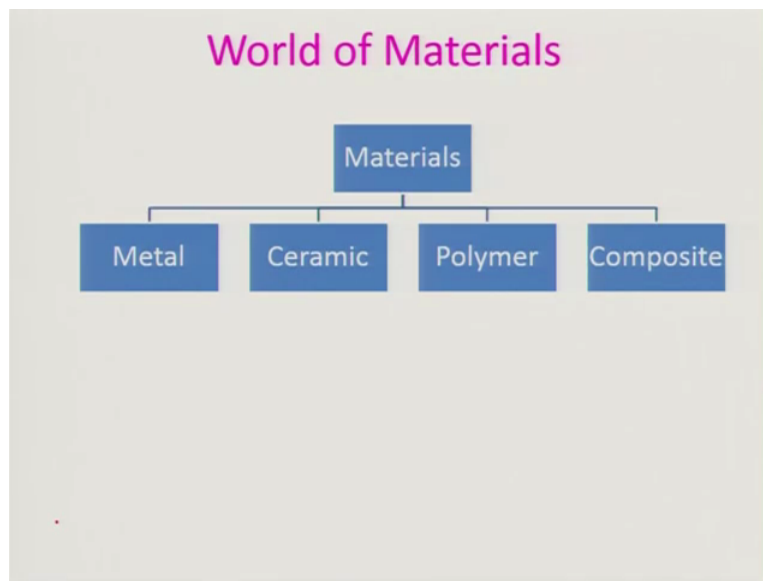
And today we will be discussing about metal and about materials and let us look at basically wonderful world of materials. And when you talk about materials that plays a very important role in not only in ancient India and also in the present time, because we are now having the materialism which is very predominant in our life. But if you look at the Indian Philosophy, they are always for the materials but not that blatant materialism that is going on.

So, I will be trying to draw your attention to the philosophy of Sankhya which was a very much talking about what you call Prakruthi and Purusha. When you talk about Prakruthi it is basically material. And if you look at like our way of life what is being talked about in the Indian philosophy is basically the Dharma, Artha, Kama, Moksha. If you want to realize the Artha and Kama then you need to play with the materials and material plays an important role. When you talk about materials basically we need to understand what is the basic science

in it and also how to utilize, the understanding for developing certain technology which will be achieving the you know desire and also the Artha the material kind of things such that are the needs such that you can achieve your the ultimate goal that is the Moksha.

So, when you talk about this Prakruthi, we are a part of the nature, the mother nature and keeping mind that mother nature is a great designer of all the materials what we see and also the you know various products. And modern science and technology try to what you call mimic them not in a very nice way but at least attempted to you know copy it and and also spoiling certain process and when you talk about this also we need this medicine and materials are important so far preparation of medicine which is required for a health of not only the human beings also the other living and nonliving beings around the world. So, therefore we need to take care of the mother nature as a whole as we are s part of it. So, we need to look at the you know metal and metallurgy in that part.

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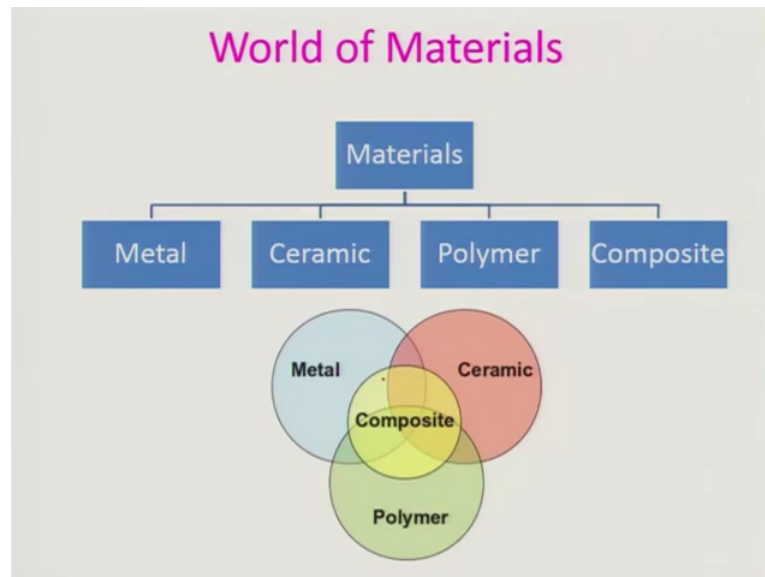


Let us look at the world of materials. And in ancient times the materials being used can be classified into 4 categories. One is Metal; the other is Ceramic, Polymer and Composite. If you look at Metal, the various kinds of metals are being were being used in ancient India, of course we are always being fond of Gold and Silver apart from Copper and also the Iron and beside this there are alloys, various kinds of alloys kind of thing like your Bronze and then Brass and several other things.

Ceramic of course, was being used earlier days in various forms like your if you look at we talk about the potteries and then glass and several other things we use. So, ceramic comes

into polymer were being used earlier but most of them are derived from the what you call biology or the polymers were basically from the natural polymers or polymer was a natural nature unlike in modern time where we use unnatural polymers. Now-a-days people are talking about bio degradable polymer that is why.

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But you combine all these kind of things together you get may get another material which is basically composite, that means will be you know various combination one can think of like metal and ceramic, you can think of composites also metallic ceramic and polymer various permutation and combination you can. In ancient India you may get some of the examples of composite material. For example like brick making, in the brick itself we use the ceramic like clay and besides this we will be using some kind of a saw dust and other things. Even I was told that people were having the bow made of composite materials earlier times which was a very light in weight and also accurate in their flexibilities for this thing. And beside this for walls and for mortars and other kind of ingredients you know composites are being used.

So, if you look at although the today materials have you know improved a lot and then it varieties are there but earlier time most of the things were natural in nature or they were making themselves although they are processing but they were not designing them you know what you call the way it has been done in modern time.

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Does India have a Strong Metallurgical Background?			
Period	Cultural History of India		Introduction of Metals & Technology
	Year	North	
1 M to 4000 BCE	Pre-Harappan Period	Neolithic and Chalcolithic	Native Metal gold (Au), Copper(Cu), Possibly Meteoric Iron
3500 BCE	Indus Valley Civilization	Neolithic and Chalcolithic	Silver (Ag), Lead (Pb), Arsenic (As) & Copper (Cu) Alloys, Foundry Technology (casting)
1500-2000 BCE	Vedic Period	-----	Iron age culture, steel & Metal working, Distillation
600 BCE	Rise of Magadha	-----	Amalgamation, Soldering, Brass Gilding, etc.

So, now a question might be coming to your mind that does India have a strong metallurgical background in ancient time? Certainly yes, we will look at the background of it. Look at historic chronological or how it was developed if you look at 100 million to 4000 BC, there is a basically Pre-Harappan period where people were using the Gold, Copper, possibly may be meteoric Iron kind of things. And of course, the 3500 BC onwards like you know Indus Valley Civilization where people were using you know Silver, Lead, Arsenic, Copper and also of course you know other may be but also there alloys being used for their day to day affairs.

Of course Indus Valley Civilization was agricultural mostly but apart from that they have also used some of these metals. And it was also been talked about they were knowing the Foundry you know technology. Because of if you recall that I had shown you earlier a dancing girl statue which was basically casting and more research has been going on today also to find out how they were doing means I was told that the last was cast method which is also known as investment casting was also there in the during the Indus Valley Civilization.

And if you come to the Vedic Period which is around 1500 – 2000 BCE apart from the Silver, Gold and other Coppers and other alloys they were started using Iron profusely and also the Steel and metal works were developed, and beside this they were also using the Distillation process. And of course, later on the 600 BCE onwards that is there is a Rise of Magadha. There is a various amalgamation of the metals were being done and they also had developed some soldering technique and Brass gildings because they have started using also Brass in number of ways.

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Period	Cultural History of India		Introduction of Metals & Technology	
	Year	North		South
500 BCE		Buddhist period	-----	May be Wootz steel (Matter & Atomic Theory)
321-184 BCE		Mauryan Dynasty	-----	Cupellation & other refining technology
319-606 CE		Gupta Dynasty	Pallavas	Commercial scale Zn, Brass, cire perdue (Lost wax) Process of Casting

**Cupellation** is a process of separating the precious metals, like gold and silver, from base metals in which ores/alloyed metals are oxidized to very high temperature and base metals are separated by absorption into the walls of a cupel.

So, if you go to the Buddhist Period something around 500 BCE onwards and it was being mentioned that Wootz Steel was developed at that time, Matter and Atomic Theory was also developed during that time. If you go to the Mauryan Dynasty particularly from Chandra Gupta, Ashoka and other things 321 – 184 BCE, there is a method of you know Cupellation, they had found out and beside this, they had other refining technology. Cupellation is a basically refinery process of separating the precious metal like Gold, Silver from the base metal in which you know like ores or alloyed metals are oxidized to a high temperature and a base metals are separated by absorption into the walls of cupel. We will be discussing a little bit more about cupel, cupellation later on.

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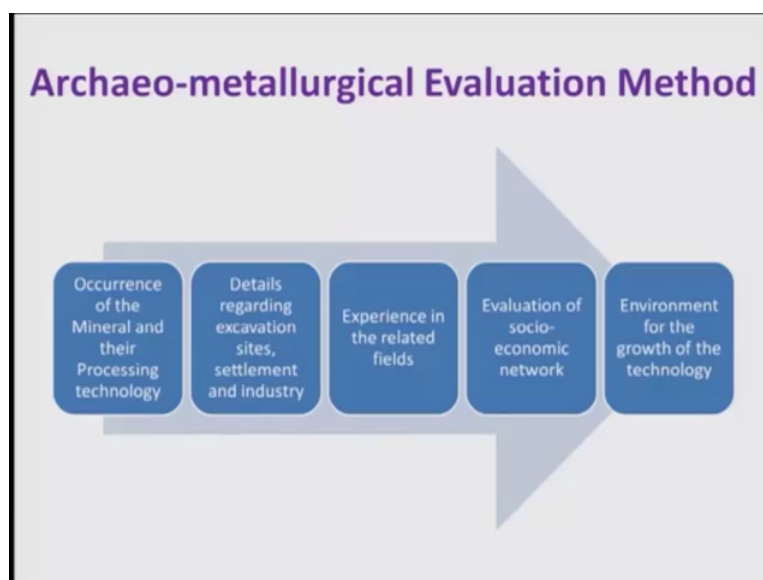
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Period	Cultural History of India		Introduction of Metals & Technology	
	Year	North		South
600-710 CE.	Invasion of Huns	Chalukyas & Chola Empire	-----	Extensive use of Iron, Steel, Hg, Zn etc.
1000 CE	Afgan's Raid	-----	-----do-----	
1100 CE	-----	Hoysala	-----	Brass & Bronze Casting
1300-1572 CE	Mughal Sultanate	Vijayanagar	-----	Bronze guns & Metal crafts
1498 to 1707 CE	----Do----	Industrialization of Iron, Steel, Brass & Bronze	-----	
1605-1761 CE	British Empire	French in India, War between British & Tipusultan	-----	Modern Metal Technology, Iron Guns

And 600 – 700 CE you will find a of course, the northern portion was invaded by Huns and of course in southern portion Chalukyas and Chola empire was existing. There is extensive use of Iron, Steel even Mercury, Zinc apart from your Copper, Gold, Silvers and other things. Of course 1000 CE, the northern was subjected to Afgan’s raid and lot of things lost in the process, of course southern side was not affected and lot of metal works were going on in the southern side of the country.

And 1100 CE, Hoysala is a very big empire and then you know like Brass and Bronze casting was profusely used in the southern part of the India apart from the other usual metal work. And of course during 1300 – 1572 CE Mughal Sultanate was there in the northern India and while the Vijaynagar empire was in the southern part and both were using the metals and metal crafts for preparing for the war, making guns and apart from your jewellery and other day to day materials.

So, of course later on 1498 – 1707 CE like there was a industrialization of Iron, Steel, Brass and Bronze and I think the British also enter into this pictures along with the French people and there is of course a war in-between the British and also the Tippu Sultan during 1605 to 1761 CE and this is of course the British Empire time and where modern metal technology were used for making the rockets and also the iron guns were been developed.

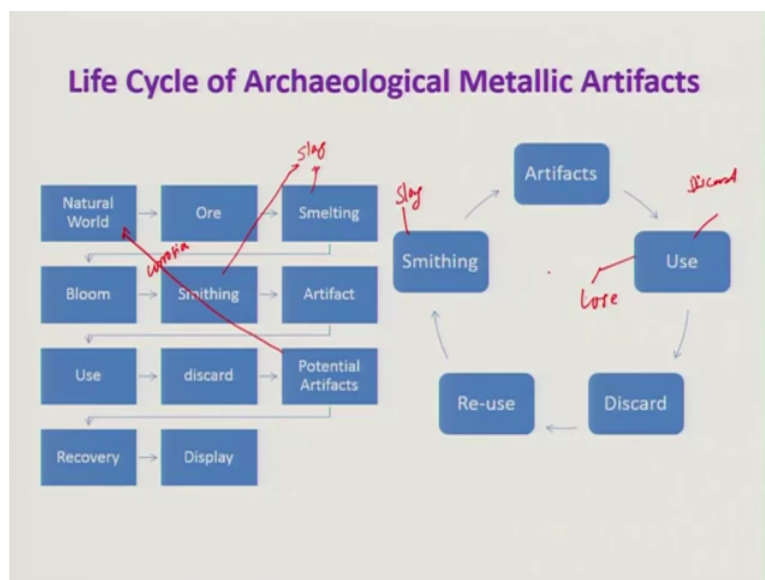
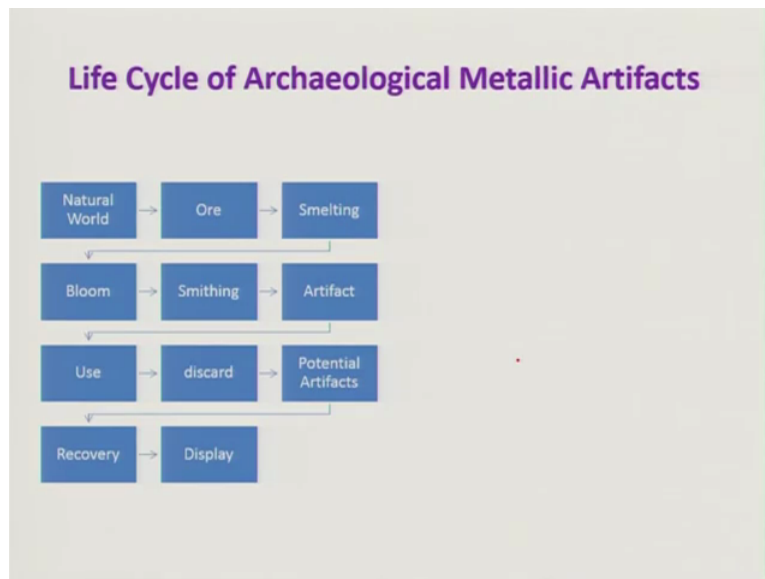
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So, if you look at the metal and metallurgy basically was a part and parcel of Indian life in ancient time. So, if you look at Archaeo-metallurgical Evaluation method at this moment if you want to do then we will have to follow certain principles that is occurrence of minerals

and their processing technology, one has to identify, not only that also details regarding excavation sites, settlement and industries one has to also look at. One should have some experience in the related fields so that you can identify what are the things going on and evaluation of socio-economic networks what was prevailing at that time and also we need to look at what was the environment at that time which was instrumental for the growth of the technology, what it was prevailing in ancient time.

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So, when you look at the study you will have to look at in a totality not in an isolated manner, so that is the important message we need to learn and it is not only for the metallurgy but for other things, other technologies as well. If you look at Life Cycle of Archaeological Metallic Artifacts, what we can get and identify and then try to find out that when it was, how it was

being fabricated and how it is evolved. Then of course the natural world that provides the basically ore and once we get the ore we will have to smelt it and when we smelt there will be also the slag which will be produced right.

And out of this smelting we can get the bloom and then when we smith also we get the slag. See if you look at the slag again will be coming out of the smithing and we can produce some artifacts and artifacts when you use like you can use and then you can discard also but you can also preserve it right and you may lose it. And when you do that like it can be you know all these three things can be again coming to the potential artifacts. And when we talk about potential artifacts it may corrode or there might be some corrosion. If there is a corrosion it may go back to the natural world right, it may go back to the natural world due to corrosion right. And of course these potential artifacts, you can recover, you can analyze it right, you can display it. After recovering this potential artifacts you can display it, you can analyze it to find out what are the components?


I have put that thing in a little you know cycled manner not that the way it is linearly it is been shown in this. So, if you look at when you talk about these artifacts basically it will be used and it can be also what you call, when you use, you can discard also right? You can discard it and when you discard you may also lose it and when you there might be a some loss and then we will go to the potential artifacts and then we can re-use it also that is another way. And once you do it re-use because then discard it will be re-used then you can get to the smithing and smithing when you talk about that there might be a slag right, the whole cycle it goes on. So, by that way one can look at this you know archaeological metallic artifacts to find out how good or how bad and then for your analysis.



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### A brief History of Indian Metallurgy

- **Vedic period** :As per **R. S. Sharma(1988)** several metals were being used for making various tools for agriculture, defence and transport by land, sea. (Rgveda Sruti 1.1.,1.3.1,1.3.2 and in Yajurveda 1.4 and 4.33)
- **Prakash S (1965)** mentioned the importance of fire discovery for processing of metals. **Rishi Angiras is considered to be discoverer of fire.**
- Native metals like **Gold, Silver, Copper and Iron** have been the first to be discovered as early as 6000 to 1 million years BCE in India.
- The **Arthashastra**, the earliest Indian text has mentioned about the mineralogical characteristics of metallic ores and other mineral-aggregate rocks.
- It recognizes **ores in the earth, in rocks, or in liquid form, with excessive colour, heaviness and often-strong smell and taste.** A gold-bearing ore is also described in this text.



Ref: R S Sharma, 1988, Historical Archeology of India; given in History of Technology in India, vol 1 edited by A K Bag, INSA, New Delhi

Now, let us look at a brief history of the Indian Metallurgy, and of course there was metallurgy in the Indus Valley Civilization what we are calling now Indus-Saraswathi Civilization or Jindime kehte hain Sindhughati sabhyatha right. And as per the R.S.Sharma in 1988 has written an article on historical archaeology of India, of course I have taken that from the History of technology in India, Vol-1, edited by A.K.Bag, INSA, New Delhi.

According to R.S.Sharma, several metals were being used for making various tool, tools for agriculture, defense and transport by land and sea. And he has given lot of examples Rig Veda Sruti and Yajur Veda. That is another author also Prakash mentioned the importance of fire discovery for processing of metals. And the Rishi Angirasa is considered to be the discoverer of fire. Because fire is the prime mover of the all the civilization, what we can think of. So, therefore also he has mentioned that the Yagnakundas or the fire places like was a open laboratory where lot of experimentation might have been done.

And they might have learnt a lot about the metal and metal processings. But unfortunately they did not write down in a very systematic manner except in a cryptic way they are mentioned in the Vedas. There might be the reason is that like people were transferring the knowledge from one generation to another but in their own clan or in their own family, but they were not giving to others, that might be one of the reasons why you know they did not write it down on a very elaborate way.

And even that kind of mind set is prevailing today because why I am saying with confidence one of my student who is from Trivandrum, like his family was having a what you call

technology of making the idols using the lost works method. And I asked them to make a video for this course and then so that we can show but he told it cannot be done because it is a secret. So, therefore even today it is happening so it might be the one reason what Prakash has mentioned.

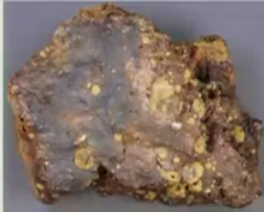
And beside this if you look at native metals like Gold, Silver, Copper, Iron have been the first to be discovered as early as 6000 to 1 million year BCE in India, that he has claimed. And of course, you will get a lot of information about the metal and metallurgy in the Arthashastra. Although if you look at earlier days people were using arrow kind of things here right, and arrow and the bow and some people says that the bow will be little flexible in nature but arrow will have this is a metal. So, which were being very much you know being used in ancient India if you go to our mythological stories and other things you will find that our warriors were carrying the bow and arrows.

If you look at the Arthashastra, which is the one of the earliest Indian text, has mentioned about mineralogical characteristics of metallic ores, other mineral aggregate rocks and I will be discussing some of them and of course they have not described the way the modern people are familiar with. But however from their description one can find out that those are the these materials.


It recognizes also the ores in the earth, in the rocks or in the liquid form with excessive colour, heaviness and often strong smell and taste. These are the things they were using for characterizing the ores and materials, like a colour, heaviness or a smell, taste. So, and he has mentioned a gold bearing ore in that text.

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- Similarly, the silver ore described in the *Arthashastra* seems to be a complex sulphide ore containing silver (colour of a conch-shell), camphor, *vimalaka* (pyrite).
- The *Arthashastra* describes the sources and the qualities of good grade gold and silver ores.
- Gold smelting was known as *suvarnapaka*.
- Copper ores were stated to be 'heavy, greasy, tawny (chalcopryite left exposed to air tarnishes), green (color of malachite), dark blue with yellowish tint (azurite), pale red (native copper).



Gold Ore




Copper Ore

In the similar manner silver ore was described in Arthashastra which seems to be a complex Sulphide ore containing Silver and they are mentioned that you know this ore will be having colour of conch-shell. And they have also talked about the camphor and vimalaka or pyrites. The Arthashastra describes the sources and the qualities of good grade Gold and Silver ores. Gold melting was known as a suvarnapaka. You know like pakam means basically cooking and they are talking about cooking of the you know Gold that is the suvarnapaka.

As I told that you know this is the Gold ore which you know looks like the whatever the description they have given in the text of the Arthashastra. So, this is about copper ore and you know the colour wise you can see and from this one can identify. And according to the Arthashastra by Kautilya, the Copper ores were stated to be 'heavy, greasy and tawny' and this if it is of course kind of this thing then it is a one can identify that colour has to be chalcopryite left exposed to air and then gets tarnished. And there might be some other varieties of Copper ore that is a green colour of malachite and there is a dark blue with yellowish tint azurites and pale red native copper. There are various kinds of Copper ores are being mentioned in the Arthashastra text.

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- Lead ores were stated to be **greyish black, like kakamecaka** (colour of galena), yellow like pigeon bile, marked with white lines (quartz or calcite gangue minerals) and smelling like raw flesh (odour of sulphur).
- Iron ore was known to be greasy stone of pale red colour, or of the colour of the *sinduvara* flower (Hematite).
- The *Arthashastra* also describes a system of coinage based on **silver and copper**. The *masaka*, *half masaka*, *quarter masaka* known as the *kakani*, and *half kakani*, copper coins (progressively lower weights) had the same composition, viz., one-quarter hardening alloy and the rest copper.



Galena:Lead ore

Hematite

Coins of Ashoka

Lead ores were stated to be a greyish black like kakamecaka means colour of galena. If you look at the galena you know it looks like that the lead ore. And you know this kakamecaka the colour of galena was the black, the greyish black looks to be the similar one that of the galena right. And there are some other things like yellow like pigeon bile marked with white lines [quartz or calcite gangue minerals] and smelling like a raw flesh [odour of Sulphur]. You know they have having these characteristics to identify the ore which happens to be the you know Lead.

So, Iron ore was known to be greasy stone of pale red colour or the colour of a sinduvara flower or Hematite. Of course there are various kinds of you know iron ores are mentioned in some other text which I will be discussing later on when we will be talking about iron and its uses. So, Arthashastra also describes a system coinage based on Silver, Copper. They are having a very standard units of measuring the weight of these materials in a Silver and Copper coin. They use masaka, half masaka, quarter masaka known as kakani and half kakani.

Also like if you look at they were having using for Gold different kind of masakas and then for Silver different kind, both are not same weight kind of things. And Copper coins progressively lower weights you know as compared to the Silver had the same composition like one quarter hardening alloy and the rest Copper. So, you know copper they might have used you know alloy as the coin and let me show you a coins of Ashoka. This is a basically a Silver coins which were made during the time of Ashoka.

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Metal	Process of Extraction
Gold	Gravity Separation
Silver and Lead	Roasting and reduction smelting
Copper	Carbothermic reduction of cuprite
Iron and steel	Smelting of Iron ore

And when you talk about metallurgy of pure metals in India, then we will talk about various processes. For Gold there is a gravity separation which we will be discussing. And Silver and Lead – Roasting and reduction smelting, Copper – Carbothermic reduction of cuprites and Iron and Steel – Smelting of Iron ore. So, we will be discussing all these processes how Indians were making in ancient time.

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**GOLD**

- Gold is very ductile metal that 1 g can be drawn into more than 1.24 km long wire without any intermediate annealing. But it can not be used for any war weapon due to its softness. It has higher corrosion and oxidation resistance.



Kolar Gold mine

So, if you look at Gold, Gold is a very very ductile metal and it has a higher corrosion and oxidation resistance. One gram of Gold can be drawn into more than 1.24 km long wire without any intermediate annealing. So, that is why it has been used very easily for jewellerys, very nice jewellery you can find even today although it was being done earlier

days by hand now it is machine is making. And I always emphasize that you know a hand is you know should be kept or the what you call this art of making the jewelry must be kept so that mind will be developed. But as Gold is a soft material then it cannot be really used for any war weapons or any other places where the hardness is called for.

If you look at, according to researcher, Neolithic men around 4500-2000 BCE would have first become acquainted with native Gold in India. In India not many Gold artifacts dating to the Pre-Harappa period have been reported. That is a very contradictive statement but however we could not get much. But in Vedic literature Gold has been mentioned several times as Hiranya. So, therefore it might be you know Vedic period Gold you know having a prominence. .

And recurrence of this metal in Copper age particularly 5<sup>th</sup> millennium is more common and many artifacts have been reported from South India. And even today also the in South India Gold is considered to be the very important and they are having lot of Gold ornaments and also they hoard a lot of Golds.

So, India has the distinction that the deepest ancient mines in the world for the Gold come from the Maski region of Karnataka with Carbon dates from the mid one 1<sup>st</sup> millennium BC. So, this is you know one of the oldest Gold mines in the entire world, India is having and that I have shown here. This is still you know it is people are using it and they have done open cast kind of things they were using you know very road and different ways. Kolar and Hatti Gold mines were being worked even in prehistoric times.

And it has been proved beyond doubt that the South Indians had learnt the technology of mining Gold, established the smelting technology on a commercial scale and metal was being traded through the Lothal by sea route to the Harappa, Mohenjo-Daro and even Egypt, Greece, Rome and Africa and other countries. With this we will stop over here.