Introduction to Ancient Indian Technology.
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Lecture-35.

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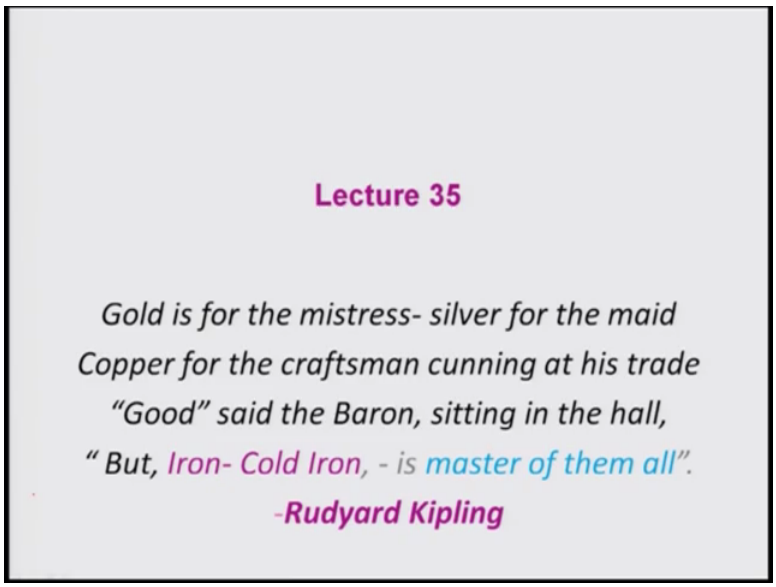

Let us start this lecture with the thought process from Rudyard Kipling who says 'Gold is for mistress - Silver for the maid Copper for the craftsman cunning at his trade. "Good" said the Baron, sitting in the hall, "But, Iron- Cold iron, - is master of them all".' So this is a beautiful poem written by Rudyard Kipling who has talked about iron and which is the master of all the metals that we have discussed till now.

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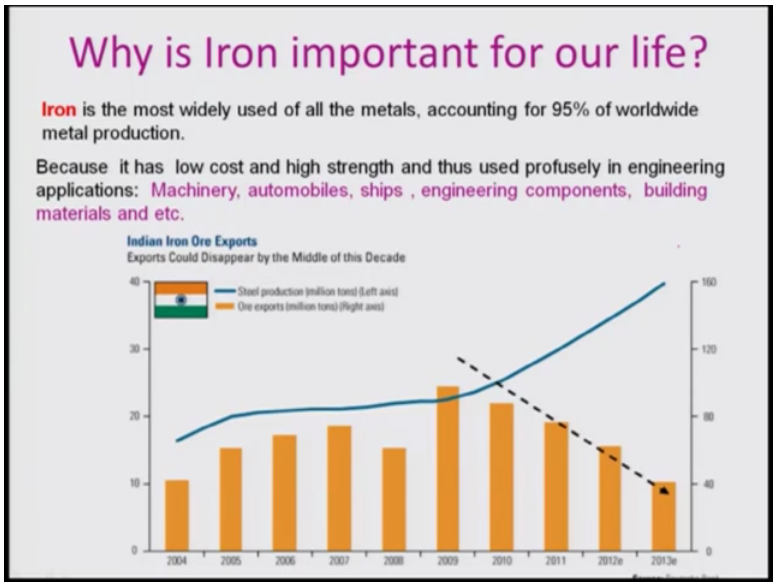

We have discussed lot of you know metals in ancient India which are being used and today we will be discussing about iron making in ancient India. So a question might be coming to your mind why is iron important for our life. If you look at iron is one of the most widely used metals accounting for around 95 percent worldwide of metal production at this moment. And why it is being used very profusely because of fact that it is having very low cost with high strength. Therefore it is being used profusely in engineering applications even in our day to day life like if you look at Al pin, safety pin, you know nail, hammer lot of other places we do use in our day to day life apart from the engineering application.

But engineering applications some of the examples I am just giving you not all that is machinery, automobiles, ships, engineering components, building materials and several of them. So therefore that is very important and if you look at in India we are having iron production which is increasing you know, this is the blue lines. It is in million tons of course 2013 people are you know escalating it to higher you know level in the sense people are thinking of something around maybe two seventy million tons per year they want to produce and earlier days of course iron ores were being exported but once we started enhancing our production and also utilization in the local markets and then naturally the oil exports over exports, iron over exports have been decreasing and that is a good thing.

Instead of selling this iron ores in a very lower value you can have a product, add the value to this iron and then you can sell it. That is the better way then what I remember when I was a kid I am in Orissa like we were selling this iron to japan, iron ores to Japan not iron at a throw away price. So it is good that we are doing and it is not that currently you know iron being used profusely but irons also were used in ancient times.

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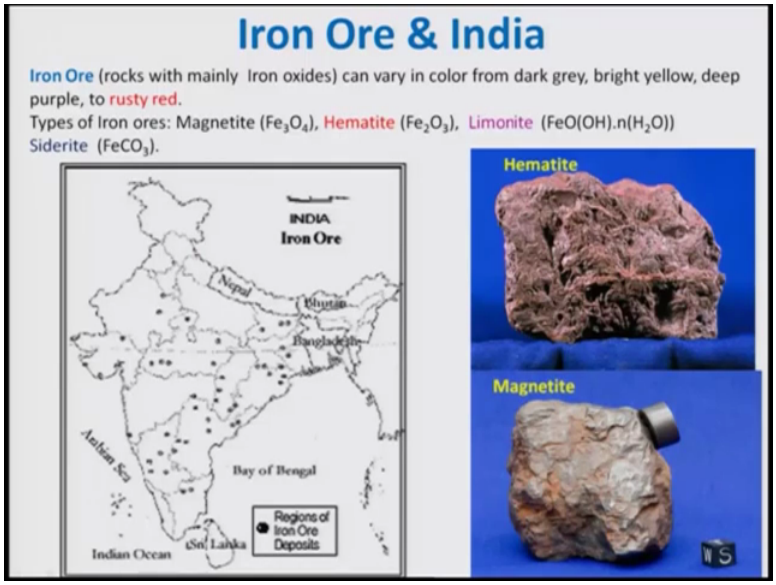

Let us look at the iron ore which is basically a mixture of rocks and iron oxide predominantly but some other metal impurities might be there. it can have different colors like dark grey, bright yellow or deep purple to rusty red and of course from this color one can identify the iron ores different kinds.

some of the iron ores which are available in India are Magnetite, Hematite, Limonite and Siderites. But hematite is being predominantly you know available in our country which is color is shown in this diagram you know and which corresponding to basically rusty red kind of things and of course the Magnetite is little different than that it is having more shining. And Magnetite is the ore which is the which can attract the iron because it is having magnetic properties.

So if you look at iron ore deposits you can find various parts starting from the south sides to all regions in the eastern side, even in the middle of India MP, and even Maharashtra and Gujarat and then even West Bengal, Jharkhand and several area. Most of the parts of India except few places like Gangetic plains and then Himalayan region you know like India is having a large deposits which are scattered around across the country.

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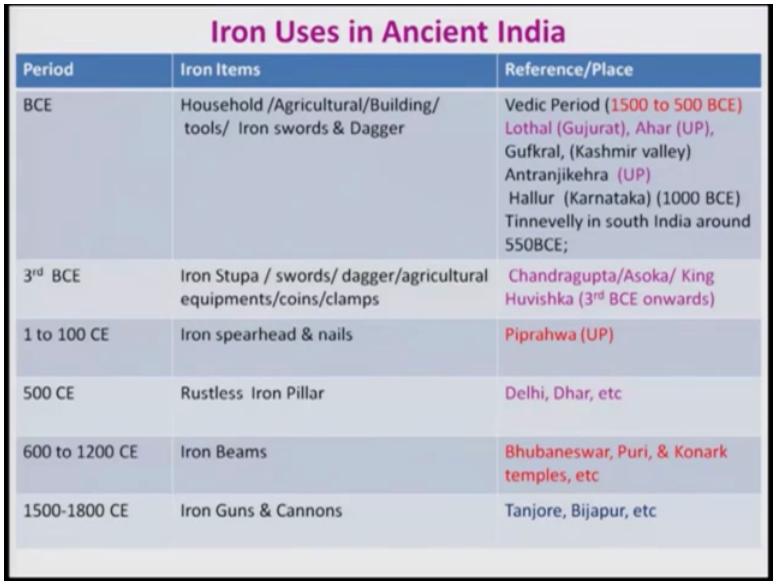

Iron Uses in Ancient India

Period	Iron Items	Reference/Place
BCE	Household /Agricultural/Building/ tools/ Iron swords & Dagger	Vedic Period (1500 to 500 BCE) Lothal (Gujurat), Ahar (UP), Gufkral, (Kashmir valley) Antranjikehra (UP) Hallur (Karnataka) (1000 BCE) Tinnevelly in south India around 550BCE;
3rd BCE	Iron Stupa / swords/ dagger/agricultural equipments/coins/clamps	Chandragupta/Asoka/ King Huvishka (3rd BCE onwards)
1 to 100 CE	Iron spearhead & nails	Piprahwa (UP)
500 CE	Rustless Iron Pillar	Delhi, Dhar, etc
600 to 1200 CE	Iron Beams	Bhubaneswar, Puri, & Konark temples, etc
1500-1800 CE	Iron Guns & Cannons	Tanjore, Bijapur, etc

So let us look at now the how the iron were being used in ancient India. If you go to Harappan period people could not find much use of iron. However during Vedic periods which span around something 1500 to 500 BC and people were using iron for household agriculture, tools, buildings and even tools, and iron and sword and daggers all those things were basically made of iron at that time.

And lot of evidence are being found out that is the Lothal you might be remembering Lothal which is located in Gujarat which is a part of Harappan civilization, Ahar in UP and Gufkral in the Kashmir valley, Antranjikehra in UP, Hallur In Karnataka. Of course Hallur in Karnataka around something 1000 BC people have found out that iron being used and Tinnevelly in south India around 550 BC.

Besides this you can find during this Mauryan kingdom and after that Kanishka kind of things. Like Chandra Gupta, Asoka and King Huvishka, that periods people were using the iron made you know swords, daggers, agriculture tools, coins, clamps and several other things they were using. And during 1 to 100 CE iron spear heads, nails of course apart from the other things what has been described earlier like swords, daggers and coins and clamps. Their evidence is being found out and Piprahwa in UP region. And of course you people will be very much aware about rust less iron pillar which is located now in New Delhi, earlier it was there that belongs to something 500 CE.

And 600, 1200 CE lot of iron being used in various places but most remarkable is the iron beams which were used in temples of Konark, Puri and Bhubaneshwar you will find and of

course after 1200 till 1800s apart from other day to day you know equipments and tools and then and other items, the iron were profusely used for making iron guns and cannons in a big way. Those evidence has been found in Tanjore, Bijapur, Muzaffar Nagar and several other places which I will be discussing about them some of them.

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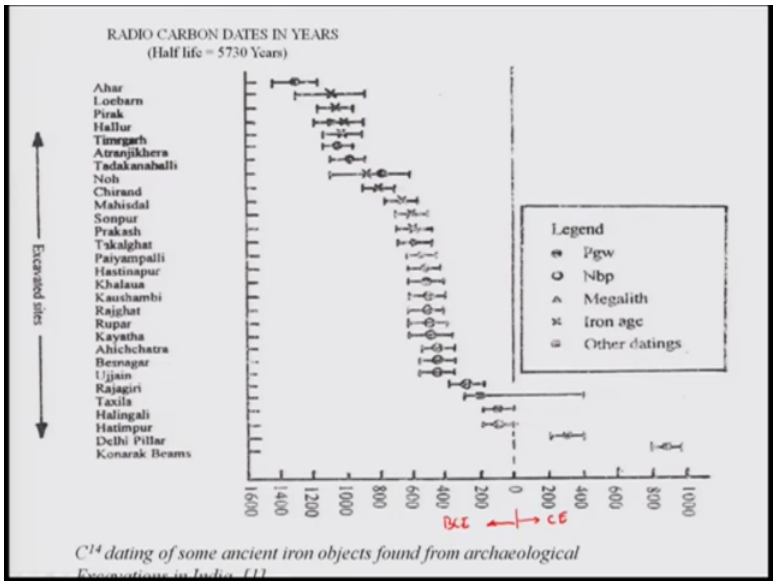

C^{14} dating of some ancient iron objects found from archaeological

Let us look at where people found these irons and they in the left hand side it is shown the various places and here it is the years and this side is basically if you look at this is CE and this side is BCE, before common era and after common era. So if you look at they got the iron in this as I told Ahar, Loebarn and other places and even Atranjikhera and Noh in Sonpur, there are several places some of them I am just mentioning so that you can keep in mind. Hastinapur which is a mythological city that is nearby New Delhi and Kaushambi, Rajghat, Rupar and Ujjain, Raj, Rajagiri, Taxila and of course the Delhi pillar and Konark beams like you can see.

That means people started using around something maybe you know 1300 BC or little bit more, because this is the era bar which is shown that this can you know be from this for example if I take about this thing then this will be basically from 1400 to 1200 that range, it cannot be that exact.

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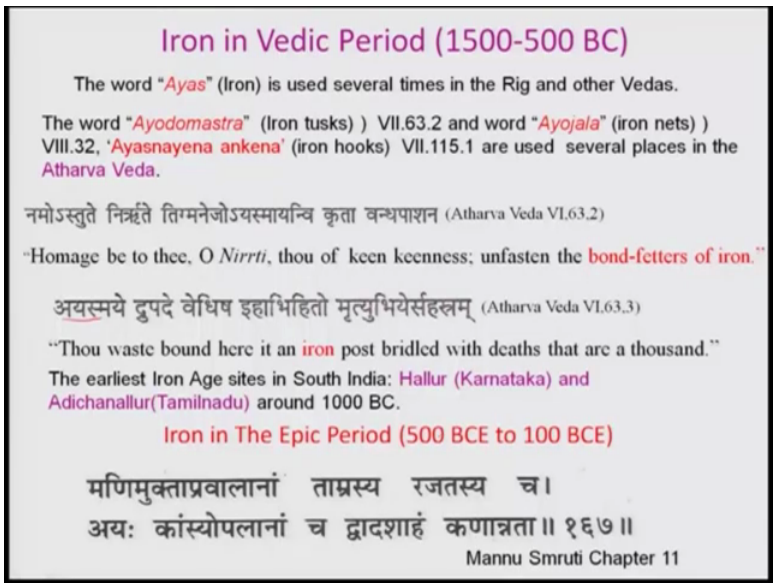

So that people have found out and there is a clear evidence that Indians were using irons profusely staring from something around 1300 BC onwards. And during Vedic period you can look at the evidence in the Vedas like Rig vedas and Atharva vedas and other things like the word "Ayas" which is known as iron basically is used in several times you know in Rig Veda and other Vedas and the word "Ayodomastra" is basically the iron tusk and "Ayojala" is iron nets.

If you look at if this is the true then you know like question here is how they are making that iron nets and "Ayasnayena ankena" that is iron hooks were used in several places in Atharva Veda and only we will consider two shlokas just to look at how this iron word is being used in this shloka from Atharva Veda that is homage "Homage be to thee, O Nirrti, thou of keen keenness; unfasten the bond-fetters of iron".

So if you look at that means they were using this iron therefore they will be knowing the strong ness of the iron and if you look at this is the Ayasnayena this is the word which is corresponding to the iron "Thou waste bound here it an iron post bridled with deaths that are a thousand" and this is, this shloka is basically from Atharva Veda also.

And if you look at the earliest Iron Age sites in south India is located in Hallur in Karnataka and Adichanallur in Tamilnadu which dates back to around 1000 BC. And iron in the epic periods if you look at which is you know around something 500 BCE to 100 BCE. I have taken a shloka from Mannu Smruti and again this is Aya and Aya basically means the iron and which says "Mani mukta pravalana thamrasya rajatasya cha ayan kanstyopalana cha

dwadasan kana natha". So you can see that even again iron even being used here of course for this you know like people have found out evidence by the from the excavated items.

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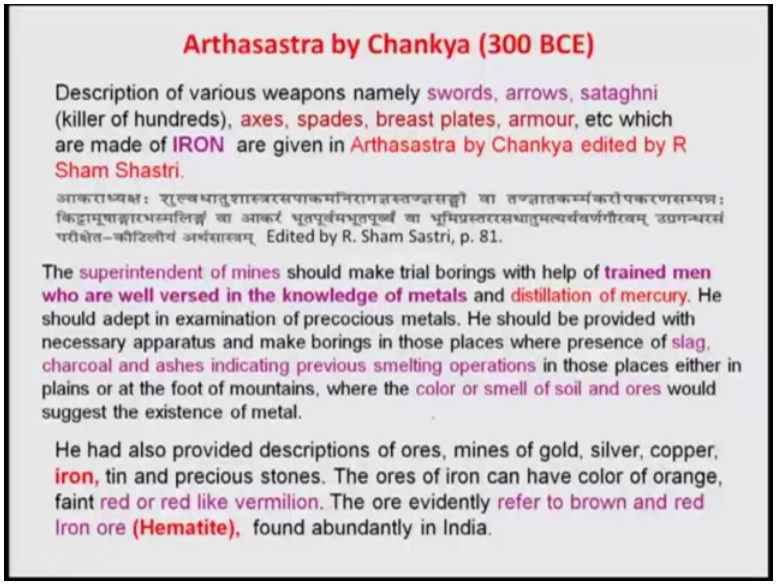

And let us look at evidence of the iron uses in ancient India from Arthasastra by Chanakya which is around 300 BCE. And he has described various weapons namely swords, arrows, sataghni, sataghni means killer of hundreds. I do not know how they were doing that and that is one has to find out and axes, plates, breast plates, armors, etc. which these items you know he has mentioned in his text and which are made of iron and this is being taken basically Arthasastra by Chanakya edited by R Sham Shastri.

This text not only talks about the uses of irons, also talked about how one can really you know mine it and what has to be done and there is a very clear cut that there is a system of making you know training the people, how to mine and also the manage the mining process and other things.

For example what the shloka I have taken from R Sham Shastri from here. This shloka indicates like if you look at "Akara dakshya" means superintendent of mines should make trial borings with the help of trained men who are well versed in the knowledge of metals. That means there was also training trained people at the time who must be used for making a trial boring before mining and there is also a superintendent of mines that what he has talked about. And he should be adept in the examination of the precious metals.

That means the superintendent of the mines would have the knowledge about the you know precious metals whether it is the right or wrong and he should be provided with necessary

apparatus, make borings in those places where presence of slag, charcoal, ashes and others indicating previous smelting operations in those places either in the plains or at the foot of mountains.

And they were also can identify the place of mining by the you know color or the smell of soils or ores so that you now you can find out you know which metal is there. That means that there were procedures of course in terms of very what you call way of color and smells they could identify where the mine is located and they could you know bore those things and find out whether it is viable or not to have digging the mines.

And in this text the description about ores, mines of gold, silver, copper, iron, tin and precious stones are being mentioned and as I told earlier that the ores of iron can have color of orange, faint red or red like vermilion and this was very predominant because this is refers to the brown and red iron ore that is Hematite found abundantly in our country.

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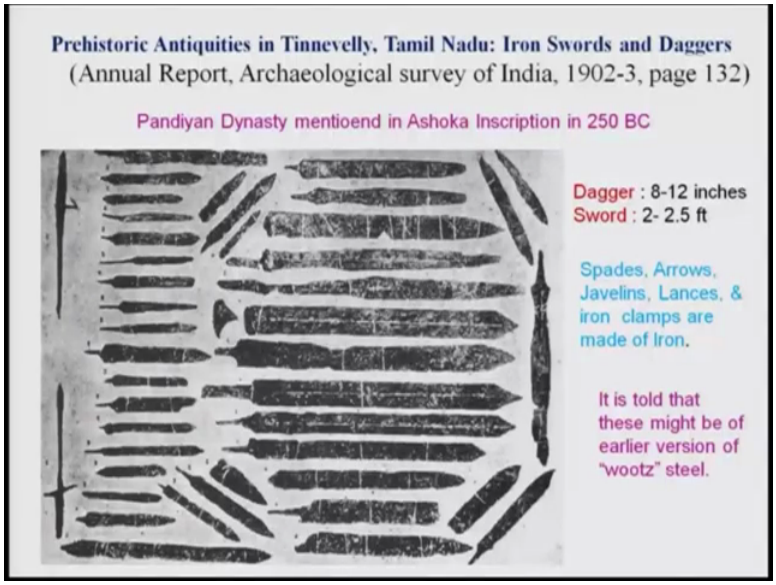

So let us look at some of this prehistoric antiquity in Tinnevelly, Tamilnadu which I have shown here the iron swords like these are the big swords and daggers this is smaller daggers. This evidence one can find about the Pandiyan dynasty mentioned in Asoka inscription in around 250 BC. And these daggers what people found out from this excavation is that something eight to twelve inches and sword is around two to two point five feet. Not only the sword and daggers but also the arrows, javelins, lances, iron clamps are made of iron were found during the excavations.

And it is being claimed by various researchers that these might be the earlier version of "Wootz" steel. Question might be coming to your mind what is Wootz steel. We will be discussing little bit about it. A Wootz steel is a very advanced steel as of now and it is having super plasticity properties and we will be discussing little bit about it later on.

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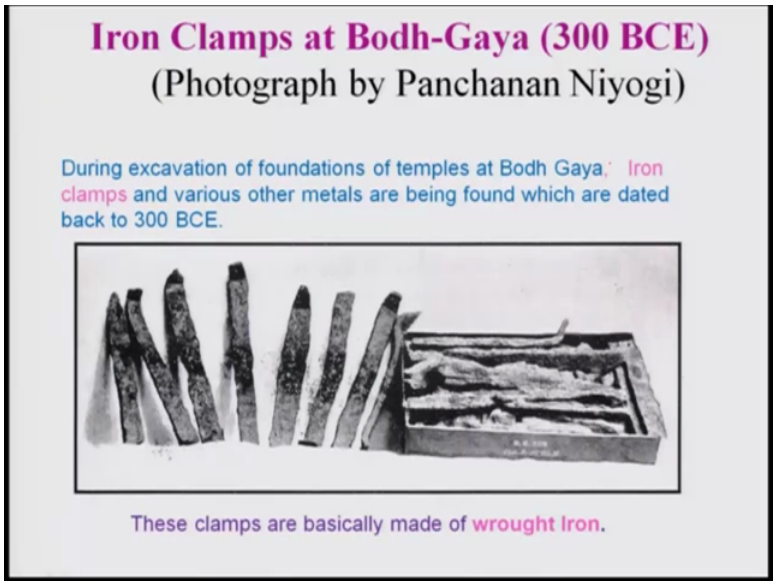

And iron clamps were found at Bodh Gaya at around which are dated back to the 300 BCE and these are the iron clams I have shown here which they got from during excavation of foundation of temples at Bodh Gaya and these clamps are basically made of wrought iron. And we know that Ayurveda was flourishing in our country and so also the surgery and the surgery book is Sushruta Samhita.

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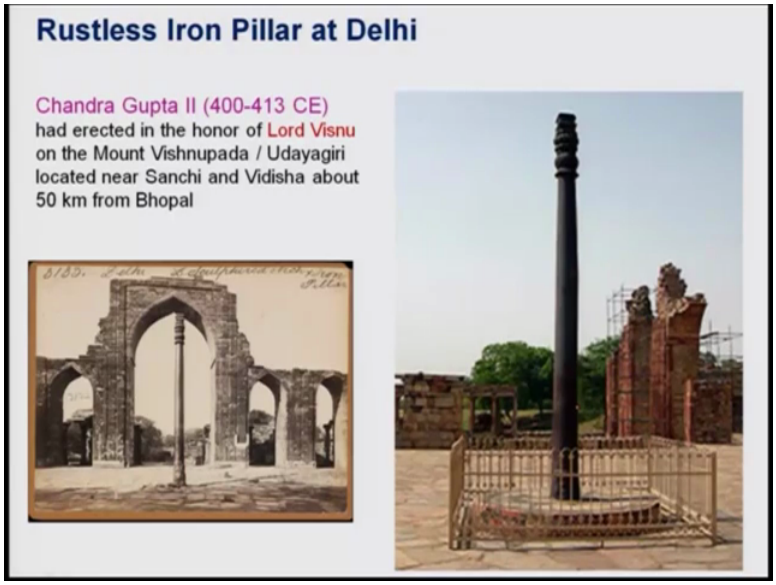

And surgery was conducted in ancient India which and we had discussed little bit and hundred twenty five surgical instruments made of iron were being mentioned in the Sushruta Samhita. Some of the you know pictures I have shown here are quite complex. How they are making so minute tools which can be used for surgery. That is the one question really bothering me and even today it is difficult to manufacture them. So those manufacturing techniques of course are not available as of now. But one need to find it out how they were doing at that time.

And all of us we know about the rust less iron pillar at Delhi New Delhi and which is located in the Qutab Minar of New Delhi and this is the picture what you will get here and which is located. But it was not established there, it is basically from other places and the earlier view of this pillar is shown here which is having a gate and now it is not there. This pillar was basically made by Chandra Gupta II around 400 to 413 CE in the honor of Lord Vishnu on the Mount Vishnupada or nowadays it is known as Udayagiri located near the Sanchi and Vidisha about fifty kilometer from Bhopal.

And of course there is a lot of historical things there are people who conquered this is place during what you call medieval time, they would have bought this to iron pillar to the Qutab Minar and erected it.

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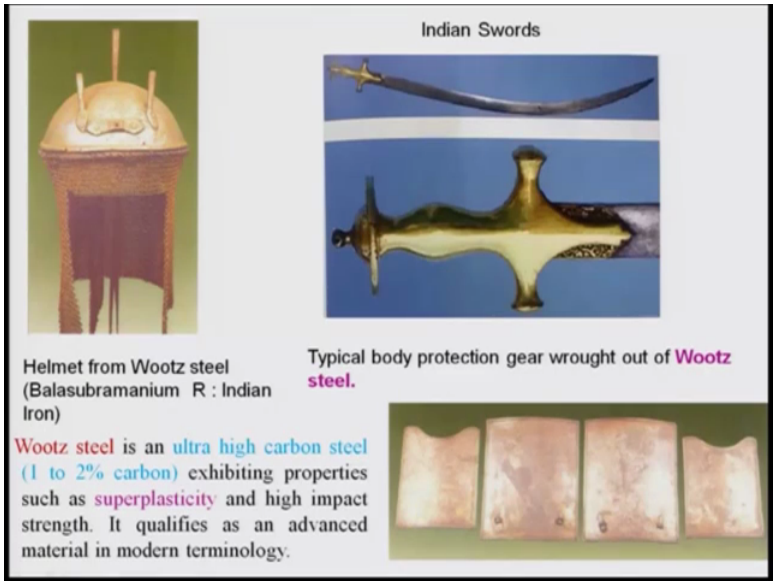

So beside this you will find there are several other items that I have shown here and this is a very interesting one Helmet from the Wootz steel. I have taken this from a book known as the Indian iron by Balasubramanium R and these are the Indian swords which are very famous

now also because of its you know because of its you know ductility and also with strength well known and it is also known as the Damasoda sword.

This Wootz steel is being used to protect the body like these are the body protection gears which were being used earlier days during the war by the warriors. Nowadays of course you are we are getting the bullet proof jackets like if you look at these are the ancient bullet proof jackets and these are made of basically Wootz steel. Wootz steel is an ultra-high carbon steel exhibiting properties such as super plasticity and high impact strength and it qualifies as an advanced material even in modern terminology. So for this Wootz steel you know if you look at European struggled a lot to find out how the Indians were making, even during British period, but they were successful later on of making this kind of materials Woodtz steel.

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And iron beams temples at Konark being used and not only in Konark but also Puri and Bhubaneshwar Odhisa around 640 to 1174 CE and this is the temple of course which is there in this door nearby this place this iron beams are being used. And it has been claimed that in the entire world the Indians were the first to use the beam you know for taking the structural load and which was a very unique experiment and they had done it successfully because the load due to the stone is very very high and that could be taken by this iron beams. It is not only the Konark temple they have used, in the garden temple at Puri number of iron beams at the lintels of doors is something ninety five people found out.

In the same temple the number of iron beams below the pillar plates is around 239. So it is a large you know number of beams were being used. People were very much found of using

beams at that time it looks to me, made of iron. How they were making, what will be the dimension, how they will decide it, what will be the cross-section, what will be the length all those questions comes to mind our mind and but unfortunately not much is data is available as of now. However one can explore it to find out what are the methodology by which they were designing this.

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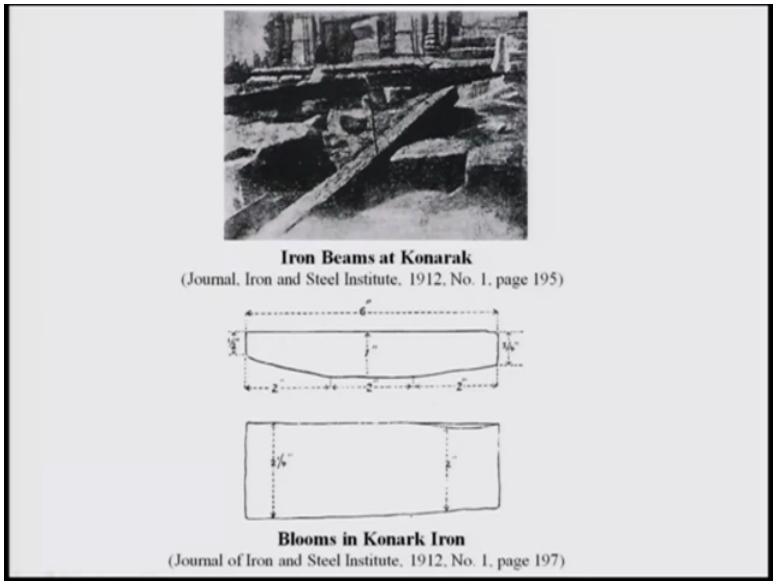

And of course these are the some of the iron beams that I have shown which are being autographed during something 1912 and which were lying you know and similarly the beams in Konark irons are being shown here and iron were being used profusely at the time for temple construction and other things.

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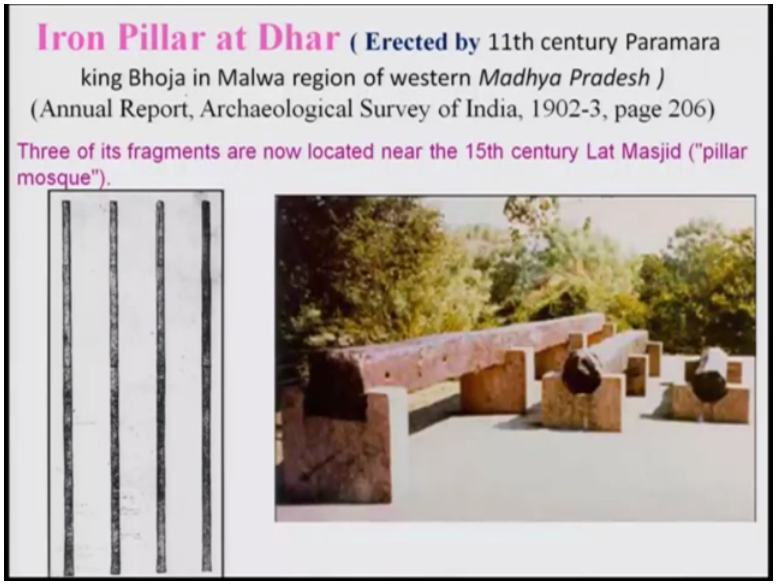

Let us look at iron pillar at Dhar which was erected by eleven century former king Bhoja in Malwa region of western Madhya Pradesh. Although there is a controversy, people say that before that the iron pillar was there at Dhar but now people are accepting that this might be the eleventh century. And 3 of its fragments are located near fifteenth century at Lat Masjid. Lat meaning in Hindi basically pillar mosque right, pillar and of course Masjid is a mosque. These are the pillars that are still laying means before this Masjid being made that you know that place lot of iron pillars might be there.

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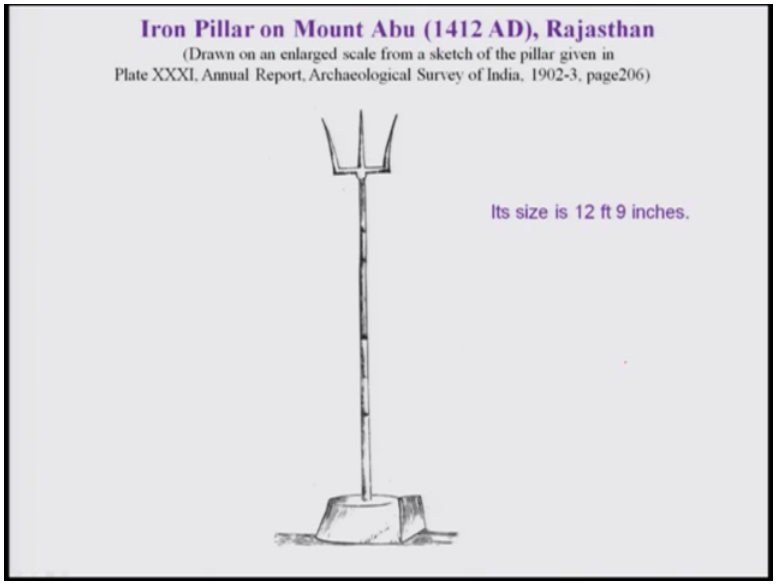

So let us look at another you know another item of iron pillar on Mount Abu in Rajasthan which was erected around 1412 AD and its size is twelve feet and nine inches. Of course whether it has been made in a single piece and how they have made this trident all those things one has to look at from manufacturing point of view. It is a very remarkable thing that they have made and there may be several others iron items which were being lost because it gets corroded right.

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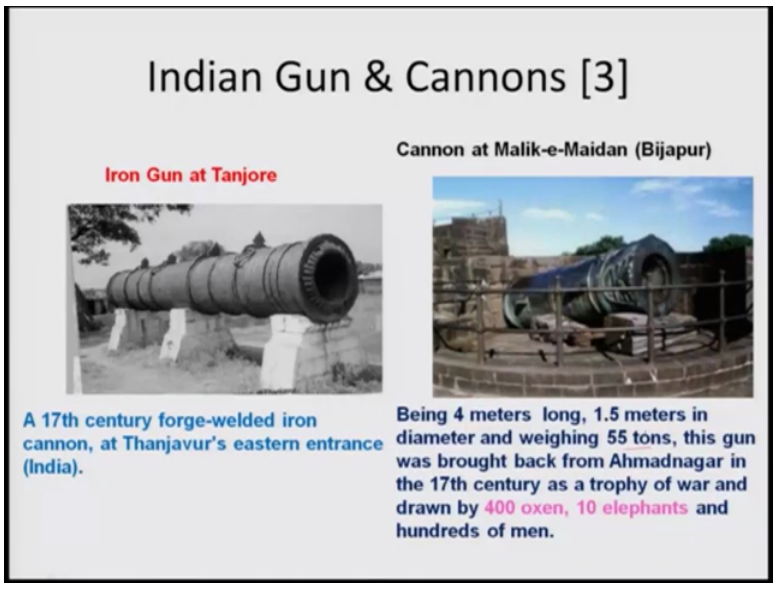

And if you look at like this during medieval times lot of guns and cannons were made out of iron. I will just show you some of them. Iron gun at Tanjore which is a seventeenth century forge-welded iron cannon at Tanjavur eastern entrance and this is a very heavy one and diameter you know like quite huge and so also the length. And cannon at Malik-e-Maidan in Bijapur which is four meter long and one point five meter in diameter weighing around fifty tons and this gun was brought back from Ahmadanagar in the seventeenth century as a trophy of war because they won the war and therefore they will take that gun out and which was drawn by something four hundred oxen and ten elephants and hundreds of men.

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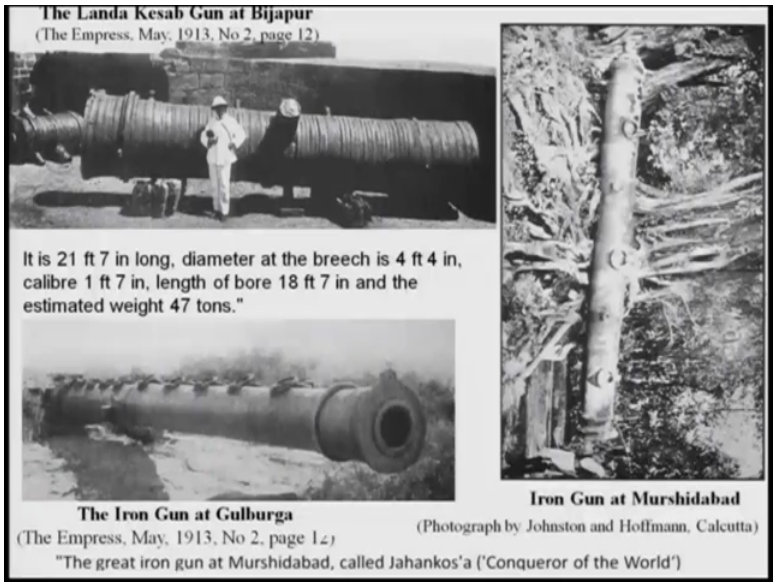

To transport basically cannon is not that easy. Even during the war time you know people left their cannon because they cannot really transport it, it is very heavy. So there is a another gun I am just discussing the Landa Kesab gun in Bijapur and it was basically quite huge and around twenty one feet seven inches long and diameter at the breech is around four feet four inch, that means diameter of this gun is outer diameter is around that, whereas the caliber that is the what you call inner diameter through which the cannon will be passing is one feet seven inch. And the length of the bore is eighteen feet seven inch and estimated weight around forty seven tons.

So if you look at how they were deciding what will be the length, what will be the caliber and what will be the breech and then why they were giving a lot of thickness and what pressure will be developed by that motion because of firing. See whether they were they might be doing it by some thumb rule but one has to look at it. Some studies they has to be done and lot of science can be unraveled by that.

There is a iron gun at the Gulbarga and which is being taken this figure in 1913 and there is a iron at the Murshidabad. There are several of them in Murshidabad of what you call West Bengal and this is known as the great iron gun at what is called the conqueror of the world called Jahankos they named it and each gun was having their own name.

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Table : Chemical composition of iron produced by ancient Indian furnaces [1]

Source	C%	Si%	Mn%	P%	S%	Others
Delhi Iron Pillar	0.23	0.066		0.18	Traces	N_2 = 0.0065%
Bhubaneswar Iron Beams	0.27 to 0.45	0.05 to 0.11	Trace to 0.04	0.015 to 0.018	0.006 to 0.015	Cr – 0.9% Ni – 1.6%
Bastar Iron Axe (100 years old)	0.25 to 0.45					Other elements in traces
Smelting iron from Jabalpur (recent)	0.59	110 ppm	40 ppm			Cu – 340 ppm Ni – 353 ppm Others in traces
Smelted iron Bishunpur (recent)	0.016 to 0.043		0.057	0.02 to 0.2	0.007 to 0.013	

And let me talk about the chemical composition of iron produced by ancient Indian furnaces like if you look at Delhi iron pillar is around point two three carbon of course silicon is very very rare and phosphorus zero point one eight. And Bhubaneswar iron beams are also in the

similar range but little bit in the higher side point four five carbon and others are trace materials and there is also Chromium and Nickel little bit is there in Bhuvneshwar iron.

I think they may not be adding this thing maybe part of their ore which they could not have removed it and which may be acting as a better one you know like on the rusting point of view. The Bastar iron axe which is something zero point two five to zero point four five carbon. Question is how they were controlling carbon, whether they were controlling or not all those questions comes into mind because the carbon content will be deciding the strength of the iron.

The smelting iron from Jabalpur 0.59 this is the recent one they have conducted some experiment using the ancient procedure and smelted iron which also they have used the ancient procedure but demonstrated recently. The carbon is 0.016 to 0.043. So if you look at of course lot of research has been done by you know in recent time looking at ancient way of making iron in India. So I will be just now I will be discussing about the classification of iron and its properties in ancient India.

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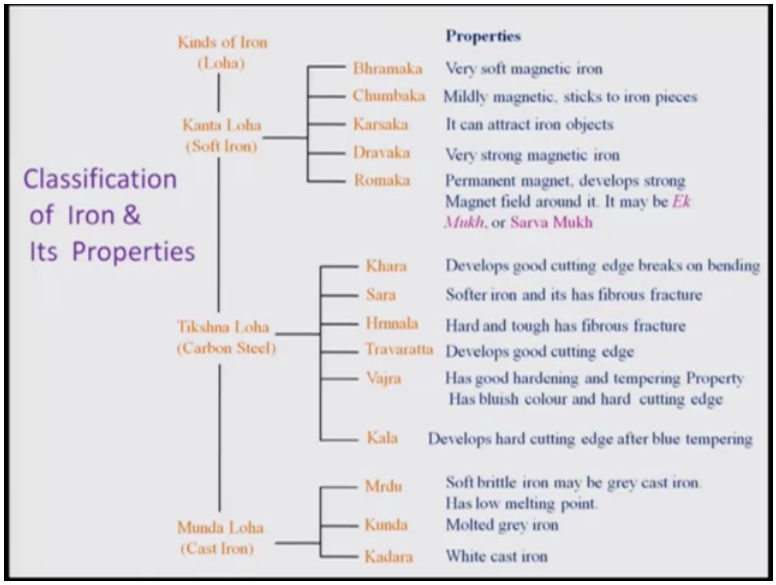

The ancient India the irons are divided with basically Kanta iron, Tikshna Loha, and Munda Loha and the soft iron which is basically Kanta iron Loha is can again classified as Bhramaka means very soft magnetic iron, Chumbaka mildly magnetic or sticks to iron pieces, and Karsaka it can attract the iron objects, Dravaka very strong magnetic iron and Romaka which is permanenet magnet, develops strong magnet field around it. It may be Ek Mukha or Sarva Mukha.

So that means you know they have classified several kinds of magnetic irons and you know which is known as soft iron and Tikshna iron is Khara develops good cutting edge which breaks on bending, and Sara the softer iron and it has the fibrous fracture, Hranala the hard and tough has fibrous fractures, Travaratta develops good cutting edge, Vajra which has been used in mythological several time which has good hardening and tempering property. It has bluish color and hard cutting edge and Kala develops hard cutting edge after blue tempering.

And the Munda Loha which is basically cast iron and this is Mrudu soft brittle iron may be grey cast iron, it has low melting point. Kunda is molted grey iron, Kadara is white cast iron. If you look at the ancient people were having a very sound knowledge about the types of iron and its properties. So therefore it is very clear that people were having a good knowledge about iron and iron making, how to use it and other things. With this I will stop over. In the next lecture we will be discussing about how iron was being processed from the iron ores in the ancient time. Thank you very much.