THE DELHI IRON PILLAR: CULMINATION OF INDIGENOUS IRON METALLURGY OF INDIA

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NMD – ATM, IIT BHU Varanasi – 12th Nov. 2013

Two iron master pieces –handiworks of Ancient Indian 'engineers'!

A. An Old Picture of 7 ton Delhi Iron Pillar -4th-5th A.D.

B. Iron beams of Sun Temple (Konark) 9th-10th A.D.

SPECIFICITIES OF INDIGENOUS IRON

- These specimens manifest mastery in:

  A- Production of corrosion resistant iron

  B- A seamless forge-welding technique

  C- Capacity to produce homogenous quality iron and steel in large quantities that too in small furnaces

- **The questions that may be asked here are:**
- Were these qualities achieved through contacts with outside agencies?

- Alternatively, were these results of long experience and experimentations?

- We need to look into history of iron working in India to answer these questions.

QUESTIONS THAT NEED TO BE ADDRESSED HERE

- Advent of iron in India – when and where?
- How did iron metallurgy develop over the centuries.
- Are there identifiable stages of development of iron metallurgy?
- Is it possible to reconstruct metallurgical developments purely on the basis of archaeological evidence?

Does literary evidence offer some insights?

- Are there ethnological models for reconstructing the ancient iron working?
- Did the ancient metallurgical skill vanish altogether or it left a legacy behind?

PROBLEM ADDRESSED

- We first propose to highlight contexts of early occurrences of iron in India.
- The chronological framework of different iron production centres may be briefly examined with a view to date the advent of iron in India.
- Examination of precise chrono-cultural contexts and stages of metallurgical development.
- A close look at results of analysis of iron objects at different cultural stages is inevitable to assess the state of metallurgy during the antiquity.
- Ethnological evidence on iron working needs to be examined closely for getting a clearer perspective on metallurgical processes as they might have existed in the ancient times.

- The ancient Indians, excelled in metallurgy being exponents of zinc distillation (2nd-3rd BC) that is the earliest in the world.
- So it seems the case with iron as indicated by radiocarbon dates from recent excavations.
- Saliency of Indian iron noted by foreigners-

- 1- In 5th BCE Herodotus, the Greek Historian observed that in the battle of Thermopylae the Indian solders fought with iron - tipped arrowheads.
- 2- Ktesias, the Greek ambassador to Persian court was gifted with Indian made swords by the king and the Queen Mother in 5th BCE.
- 3- Alexander received 30 talents of iron ingots along with bags of gold dust as tribute by the vanquished rulers of North West India in 326 BCE.
- The colonial attitude however, refused to accept it

The British Archaeologists of 20th century believed that iron was introduced by the Greeks and Bactrians around circa 6th- 5th century BCE.

- Also that iron in Taxila or Megalithic burials in south India dated to 6th-5th BCE brought in by the immigrating Aryans or Greeks/Bactrians etc.
- Today these assumptions do not stand the scrutiny.

- It is now proven that iron is a by-product of copper technology; (Wertime *et.al*. 1980).
- Whether Aryans came from the west and brought knowledge of iron technology with them- is now contested.
- Whether there was a diffusion of iron or it had an indigenous origin?
- We propose to take a quick look at the issue

I. DIFFUSIONISTIC THEORY OF IRON IN INDIA

- Iron was believed to be a complex metal to be produced independently.
- The earliest users were the Hittites and Mitannis of West Asia who kept the knowledge a secret.
- Dispersal of iron with migrations of Hittites to different regions.
- The region was inhabited by the Aryans worshipping Vedic deities.
- They migrated to India with iron weapons-as the theory propagated.
- Hence the association of iron with Aryans.
- This gives credence to theory of diffusion.

Tbilisi
Aral Sea
Lake Balkhash
Caspian Sea
Qizilqum Desert
Yerevan
Baku
Garabogazköl Basin
Bishkek
Uzbekistan
Tashkent
Kyrgyzstan
Turkmenistan
Ashgabat
Dushanbe
Tajikistan
Tehran
Baghdad
Iraq
Iran
Kabul
Afghanistan
Islamabad
Kuwait City
Persian Gulf
Manama
Riyadh
Pakistan
Saudi Arabia
Doha
Abu Dhabi
United Arab Emirates
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US Dept of State Geographer
1281 km

A QUICK LOOK AT RELATED FACTS

- The word *ayas* used in Rigveda, the earliest Aryan text perhaps did not mean iron.
- Rather it stood to denote metal in general.
- Only later, in Vājsanayi Sa□hitā of Yajurveda (with advent of iron?) we come across – two distinct terms, viz. Krishnāyas and Lohitāyas - Black and Red metal.
- More importantly, ^{14}C dates from Northwestern borderland of India are younger than those reported from the mainland.
- The early ^{14}C dates from heartland of the sub-continent show an earlier beginning of iron there.

I. Comparative dating of occurrence of iron in India and the neighborhood.

Swat-Gandhar- Baluchistan :12/1100-1000 B.C.E.

Afghanistan : 11/1000 B.C.E.

China : 900-800 B.C.E. or even later

II. Recent ^{14}C dates from the heartland of India:

1800 B.C.E. Dadupur (Lucknow)

1600-1500 B.C.E. Malhar (Chandauli, near Varanasi)

1400-1300 B.C.E. Raja-Nal-Ka-Tila (Mirzapur)

Recent Position – comparatively earlier dates in India

Deduction?- Indigenous origin of iron? Possibly more than one centre of early occurrence of iron.

Nepal
Kathm
New Delhi
Uttar Pradesh
Dadupur
Lahuradewa
Masondih
Anai
Malhar
Agiabir
Nal Ka Tila
Raipura
Rajasthan
Madhya Pradesh
Chhattisgarh
of Kutch
Gujarat
India
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488 km

Table I.1 : Radiocarbon Dates from Iron Age level (Raja Nal- Ka –Tila)

Sl. No.	Laboratory Number	Layer/ Depth	Radiocarbon dates in years BP/BCE 5568±110 BP	Calibrated dates based on half life 5530±40 Years	Calibrated
1.	BS-1378 1996-97 Trench No. U-19	(6) 1.95-2.00#m With iron	2550±110 BP 600±l10 BCE	2626±110 BP 676± 110 BCE	822 (773) 486 BCE
2.	PRL-2047 1996-97 Trench No. U-20	(6) 2.08-2.10#m With iron	2890±90 BP 940±90 BCE	2980±90 BP 1030± 90 BCE	1196 BC-1188 BCE 1164 BC-1143 BCE 1132 BC-976 BCE 970 BC-930 BCE
3.	BS –1299 1995-96 Trench No. A-l	Pit sealed by layer No. (6) With iron	2830±100 BP 880± 100 BCE	2914±100 BP 960± 100 BCE	1118 (963) 859 BCE
4.	BS –1300 1995-96 Trench No. A-l	(6) 2.00#m With Iron	3060±110 BP 1110± 110 BCE	3150±110 BP 1200± 110 BCE	1423(1307) 1144 BCE
5.	PRL-2049 1996-97 Trench No. T-19	(6) 2.00#m With Iron	3050±90 BP 1100± 90 BCE	3150±90 BP 1200± 90 BCE	1406 BC -1198 BCE 1186 BC-1164 BCE 1143 BC-1132 BCE

Table I.2 : Radiocarbon Dates from iron age level (Malhar) ,Chandauli

Sl. No.	Laboratory Number	Radiocarbon dates in BP/BCE on the basis of half life 5568±30 years 5730±40 years		Cal BCE Stuiver *et. al.* one sigma
1.	BS - 1623, MLR II Trench No. XAl, Layer No. (3) Depth 0.55 cm	3450±90 BP 1500± 90 BCE	3550± 90 BP 1600± 90 BCE	1882 (1743) 1639 BCE
2.	BS - 1614, MLR II Trench No. Al, Layer No. (3) Depth 61-63cm	6380±110 BP 4330± 110 BCE	6570± 110 BP 4620± 110 BCE	5475 (5358, 5351, 5340, 5329, 5323) 5262 BCE
3.	BS - 1593, MLR II Trench No. Al, Layer No. (3) Depth 90-100cm	3540±90 BP 1590± 90 BCE	3650± 90 BP 1700± 90 BCE	2012 (1882,1836,34) 1742 BCE
4.	BS - 1590, MLR II Trench No. XAl, Layer No. (4) Depth 80cm	3740±80 BP 1790± 80 BCE	3850± 80 BP 1900± 80 BCE	2283 (2141) 1984 BCE

Table I.3 : Radiocarbon Dates from iron age level (Jhunsi, Allahabad)

Sl. No.		Trench details	Radiocarbon yrs BP	5568±30	5730±40	Date in BCE/AD	Calibrated dates in BCE/AD
AU/JHS/ 9	2075	C-15 (46) 1210	Pre NBP with iron	2650±90	2730±90	780±90 BCE	897 (806) 789 BCE
AU/JHS/ 12	2077	C-15 (49) 1240	Pre NBP with iron	2820±90	2900±90	950±90 BCE	1107 (973, 956, 941) 844 BCE
AU/JHS/ 16	2081	C-15 (53) 1325	Pre iron (Chalcolithic)	2700±90	2780±90	830±90 BCE	966 (830) 799 BCE
AU/JHS/ 18	2083	C-15 (62) 1520	Pre iron (Chalcolithic)	3200±90	3290±90	1340±90 BCE	1597 (1490, 480, 1450) 1400 BCE

^{14}C DATES FROM RAIPURA, SONBHADRA

Laboratory Number	Layer/ Depth	Calibrated Age with 1 sigma	Calibrated Age with 2 sigma
BS#3384 Charcoal Less Carbon*	Tr. YI-11, Depth 60 cm, Floor 1 of Lr. (2) NBPW	340 Cal BCE (± 50) with 1 sigma	400 Cal BCE (± 200) with 2 sigma
BS#3386 Charcoal	Tr. YH-11, Depth 130- 135 cm, Pit 3 sealed by Lr. (2) NBPW	430 Cal BCE (± 80) with 1 sigma	460 Cal BCE (± 100) with 2 sigma
BS#3536 Charcoal	Tr. YI-11 90 cm, Pit sealed by Lr. (4) With Iron	**1720 ± 220 cal BC** **with 1 sigma**	
BS#3545 Charcoal	Tr. YH-11, Depth 85 cm, Pit sealed by Lr. (3) Without iron	2410 ± 140 cal BC with 1 sigma	
BS#3544 Charcoal	Tr. YH-11, Depth 100-105 cm, Pit sealed by Lr. (4) Without iron	2510 ± 180 Cal. BC with 1 sigma	
BS#3537 Charcoal	Tr. YH-11, Depth 150-155 cm, Pit sealed by Lr. (4) Without iron	2710 ± 90 cal BC with 1 sigma	
BS# 3387 Charcoal	Tr. ZB-10, Depth 140-145 cm, Pit 4 sealed by Lr.(5) Without iron	2720 Cal BCE (± 80) with 1 sigma	2690 Cal BCE (± 230) with 2 sigma
BS# 3385 Charcoal	Tr. ZB-10, Depth 170-175 cm, Pit 5 sealed by Lr.(5) Without iron	2770 Cal BCE (± 80) with 1 sigma	2790 Cal BCE (± 310) with 2 sigma
BS#3542 Charcoal	Tr. ZH-10, Depth 195-200cm, Pit sealed by Lr. (7) Without Iron	2790 ± 60 Cal. BC with 1 sigma	
BS#3383 charcoal	Tr. ZH-10, Depth 170- 175 cm, Pit 7 sealed by Lr. (8) Without iron	3270 Cal BCE (± 130) with 1 sigma	3240 Cal BCE (± 290) with 2 sigma

* For the Sample No. BS#3384, small amount of carbon implied loss of precision.

II. INNOVATIONS IN IRON METALLURGY

Archaeological investigation reveals an evolution of iron technology over the centuries definable at three stages :

- The age of commencement (18/1700-9/800 B.C.).
- The age of consolidation (9/800-4/300 B.C.).
- The age of culmination (4/300-5/600 A.D.).

Iron Objects at different cultural stages

TOOL TYPE	NAME OF TOOL	EARLY STAGE	MIDDILE STAGE	LATE STAGE
Hunting Tool	Spear heads	★	★	★
	Arrow heads	★	★	★
	Points	★	●	●
	Socketed tangs	★	●	●
	Blades	★	★	●
	Spear lances	●	★	●
	Dagger	●	★	★
	Sword	●	★	★
	Elephant goad	●	★	★
	Lances	⊗	⊗	★
	Armour	⊗	⊗	★
	Helmet	⊗	⊗	★
	Horse bits	⊗	⊗	★
	Caltrop	●	●	★
Agricultural Tools	Axes	★	★	★
	Sickles	★	★	★
	Spade	⊗	★	●
	Ploughshare	⊗	★	●
	Hoe	⊗	★	★
	Pick	●	●	★
Household objects	Knives	★	★	★
	Tongs	★	●	●
	Discs	⊗	★	●
	Rings	⊗	★	●
	Spoons	⊗	★	★
	Sieve	⊗	⊗	★
	Cauldron	⊗	⊗	★
	Bowls	⊗	⊗	★
	Dishes	⊗	⊗	★
Structural and craft tools	Rods	★	●	●
	Pins	★	●	●
	Nails	★	★	★
	Clamps	★	★	★
	Chisel	⊗	★	★
	Pipes	⊗	★	●
	Sockets	⊗	★	●
	Plump bob	⊗	★	●
	Chains	⊗	★	★
	Door hooks	⊗	★	★
	Door handle	⊗	⊗	★
	Hinges	⊗	⊗	★
	Spikes	⊗	⊗	★
	Tweezers	⊗	⊗	★
	Anvils	⊗	⊗	★
	Hammers	⊗	⊗	★
	Scissors	⊗	⊗	★
	Saw	⊗	⊗	★

Index :

Definite existence ★

Confirmed data N.A. ●

Non-existence ⊗

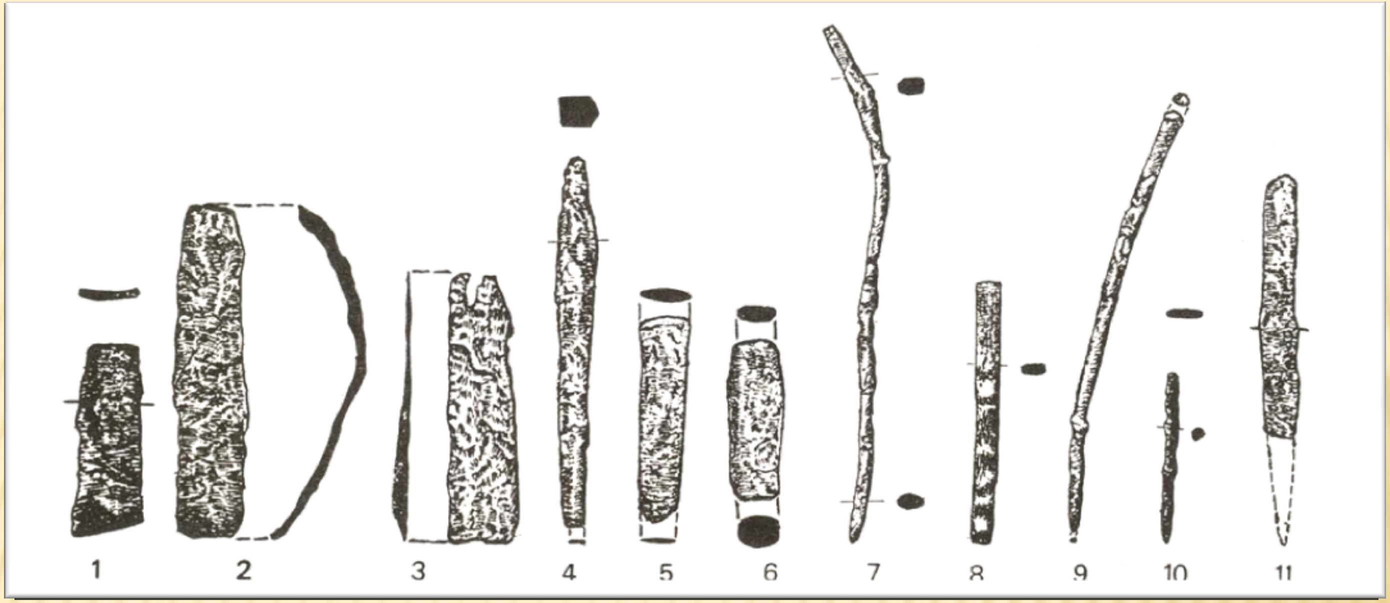
IRON METALLURGY AT THREE STAGES OF DEVLOPMENT

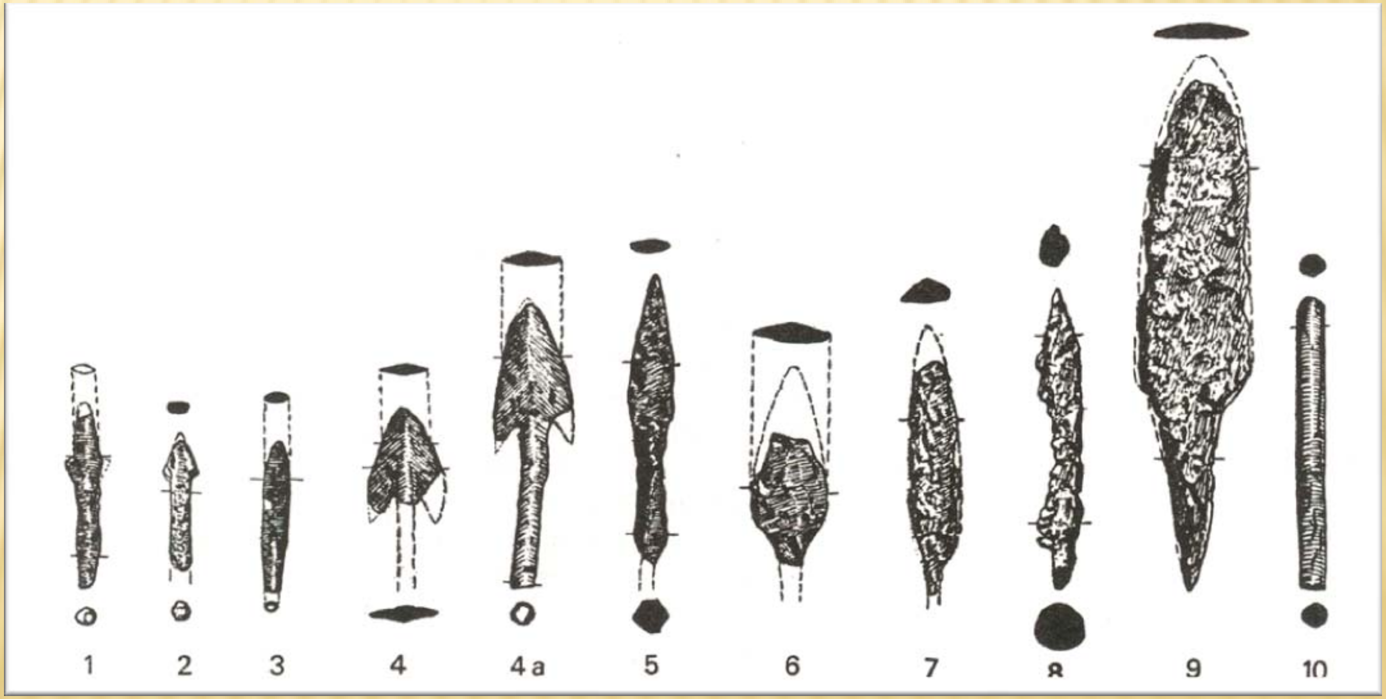
A. EARLY IRON AGE: THE AGE OF COMMENCEMENT

- Elementary tool-typology starting with incidental occurrence of bits of iron-Noh.
- Wrought iron with plenty of slag inclusion
- Number and quality of iron objects gradually improves within this period of 600 years

Table III. Distribution of Iron Objects at PGW level (Atranjikhera)

Sl. No.	Objects	Lower	Middle	Upper	Total
1.	Arrow-head	-	7	14	21
2.	Spear-head	-	3	5	8
3.	Shaft	2	5	3	10
4.	Tongs	-	-	1	1
5.	Clamp	-	10	11	21
6.	Nail	2	4	14	20
7.	Bar\rod	-	2	5	7
8.	Hook	-	2	5	7
9.	Borer	1	2	3	6
10.	Chisel	-	4	2	6
11.	Needle	-	-	1	1
12.	Axe	-	-	1	1
13.	Knife	-	1	2	3
14.	Bangle	-	1	1	2
15	Indeterminate	2	3	9	14
	Grand Total	7	44	77	128

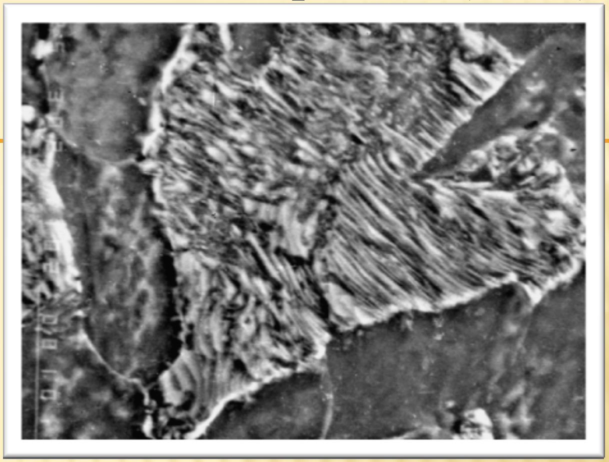




Iron Objects of PGW (Stage I, Atranjikhera)

Photomicrograph, iron implement showing Widmanstaaten pattern (500X)

A. Photomicrograph, iron implement showing carburization Widmanstaaten pattern, Hatigra (500X) (1000 BCE)



B. Electron Photomicrograph, iron implement, Hatigra (3000X) , (1000 BCE)

C. Electron micrograph of a sickle, 1000X, 15KV revealing tempered martensitic structure, Pandurajardhibi, (900/800 BCE)

Metallographs of Iron Objects

IRON AND STEEL IN MEGALITHIC BURIALS

- From Mahurjhari (Vidharbh) steely iron comes from 900 BCE from a Megalith (Deshpande *et al.2010*).
- Sample of 900 BCE shows quenching and tempering.
- Bloomery Iron was initially produced at Megalithic iron working centres like Mahurjhari.
- Carburization, quenching and tempering were in vogue as early as 1000/900 BCE.
- Possibly this led to further innovations visible in crucible steel making.

Fig. 1. Structure of core of the sample from Mahurjhari at × 100. (900 BCE)

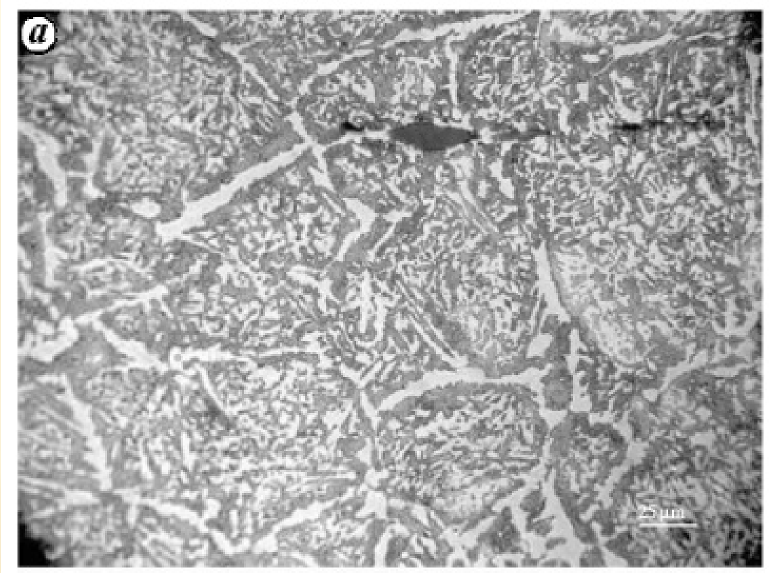


Fig. 2. Part of Figure 4 at × 400 (*a*) (900 BCE).

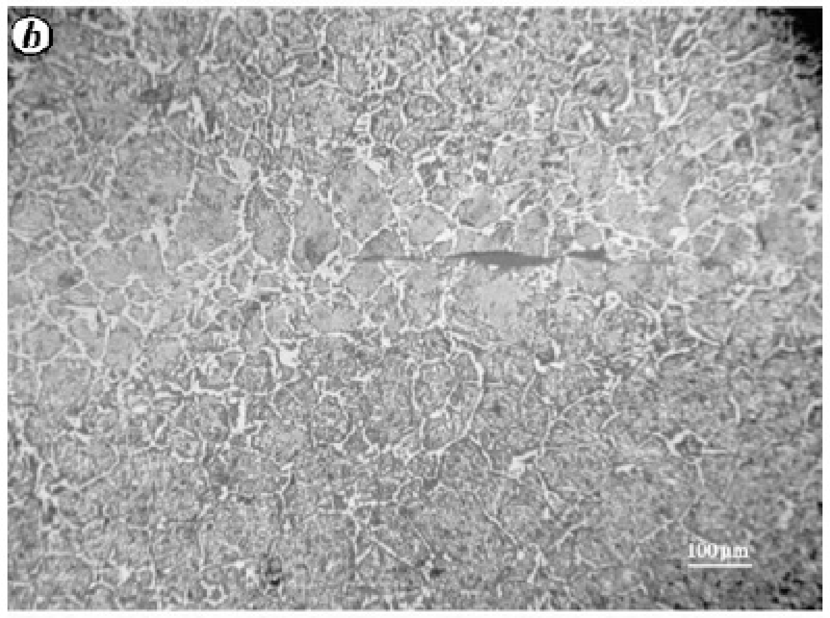


Fig. 3. Part of Figure 4 at × *100 (b)* (900 BCE)*.*

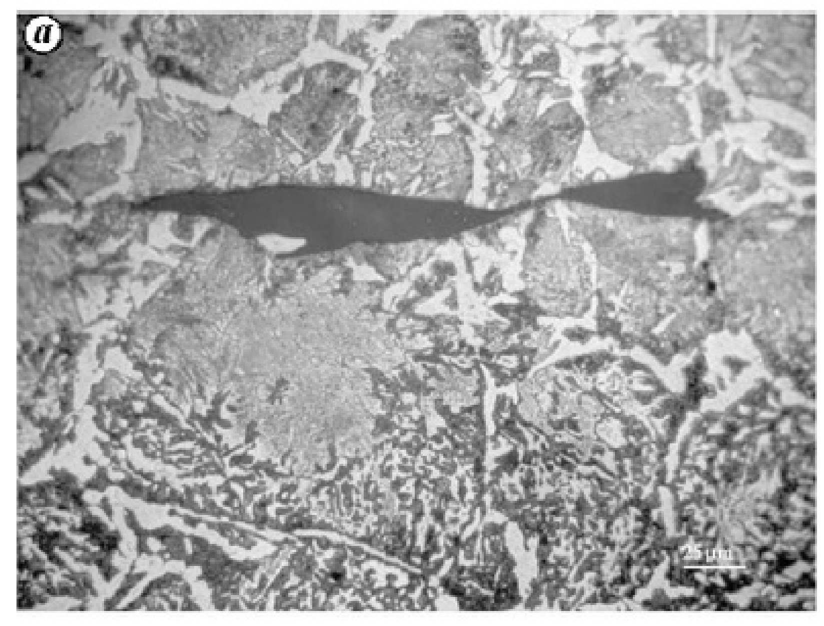


Fig. 4. *a, Part of Figure 5 b at × 400. ,* (900 BCE)

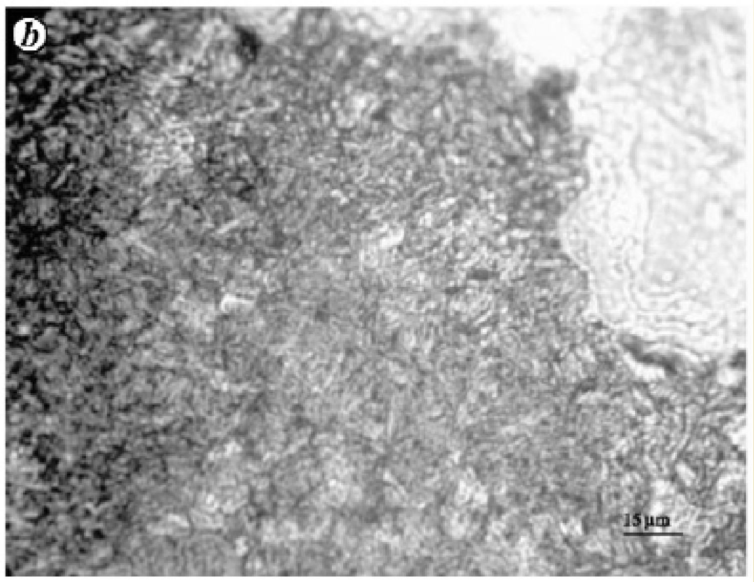
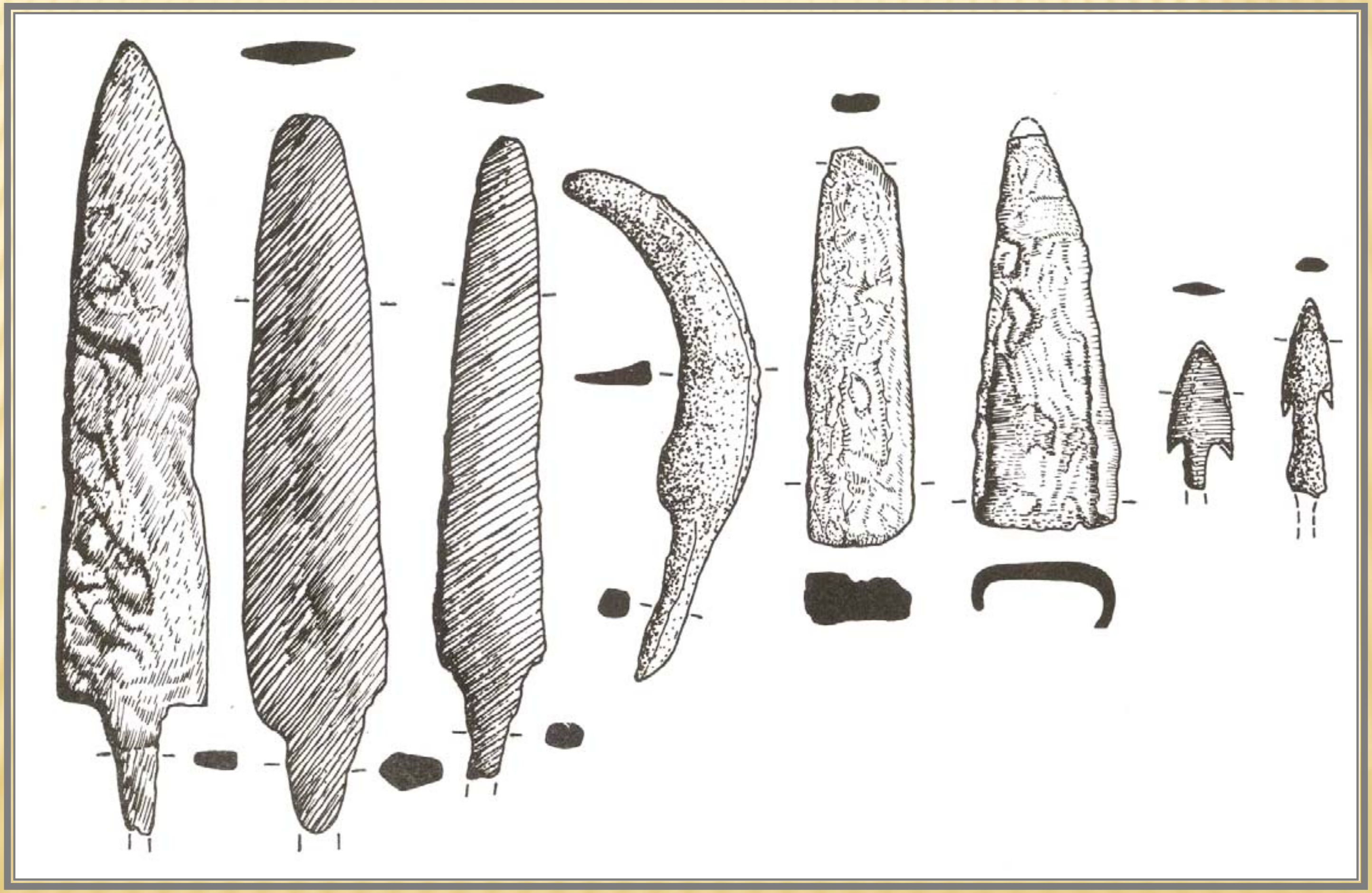


Fig. 5. *b, Darker etching area from Figure 6 a at × 650 showing tempered martensite and oxidized surface (top* right corner)., **(900 BCE)**

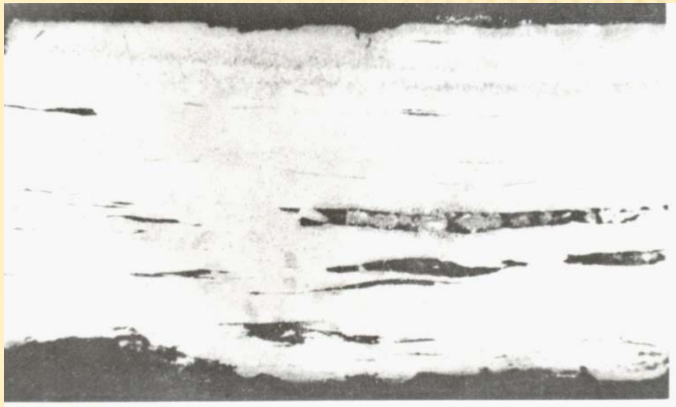
B. MIDDLE IRON AGE : CONSOLIDATION OF TECHNOLOGY

- A relative improvement in tool typology (NBP Period)
- Use of agricultural implements and more complex types in hunting/war
- Introduction of carburization, quenching

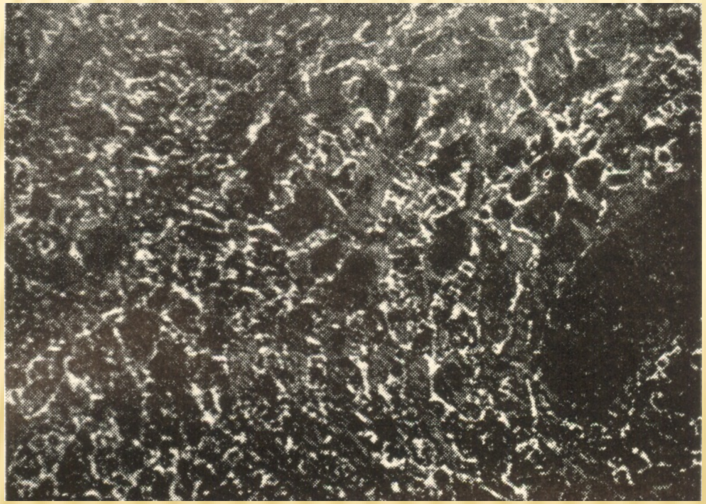


Iron objects NBPW (Stage II, Atranjikhera)

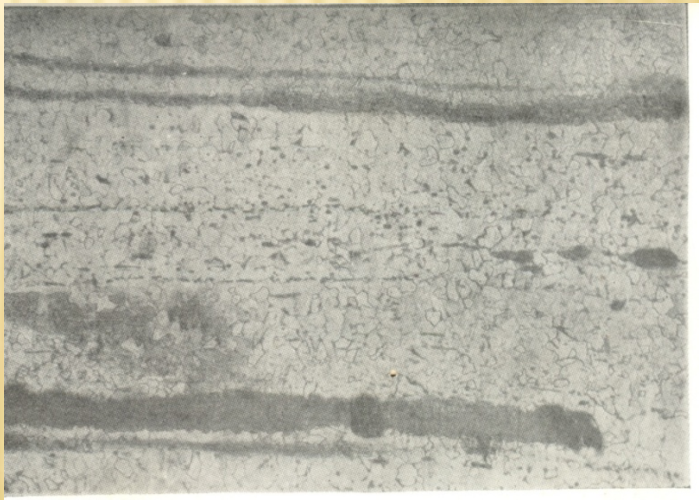
A. Hoe from Dhatwa (500-300 BCE)



B. Microstructure of Hoe, Dhatwa showing Laminated structure



C. Metallograph, arrowhead –Rajghat, (600 BCE)



D. Metallograph –Prakash (600 BCE)

C. LATE IRON AGE : THE ERA OF CULMINATION

- **A more evolved tool typology: diversification and proliferation of iron objects**

- **Crucible steel of South India is a culmination of steel technology.**

- **The Wootz steel industry flourished till pre-modern times.**

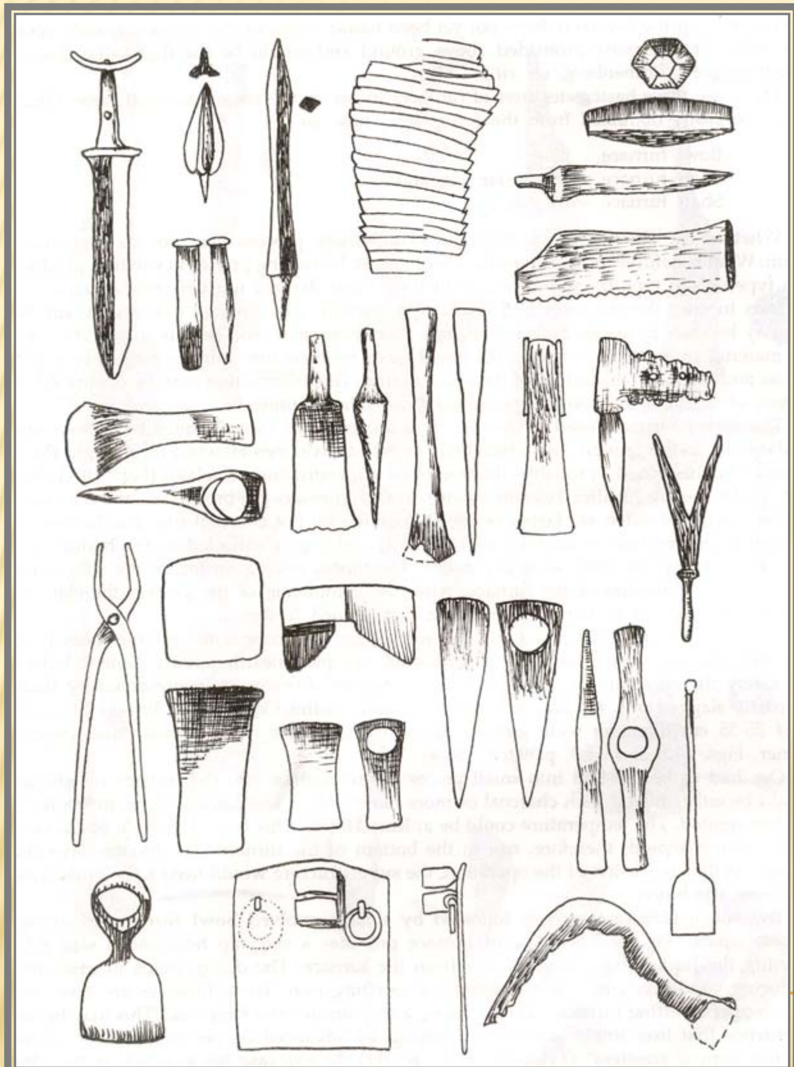
- **Manufacture of colossal marvels like Delhi Iron Pillar.**

- **Iron pillar at Dhar, the longest pillar of its kind in the world.**

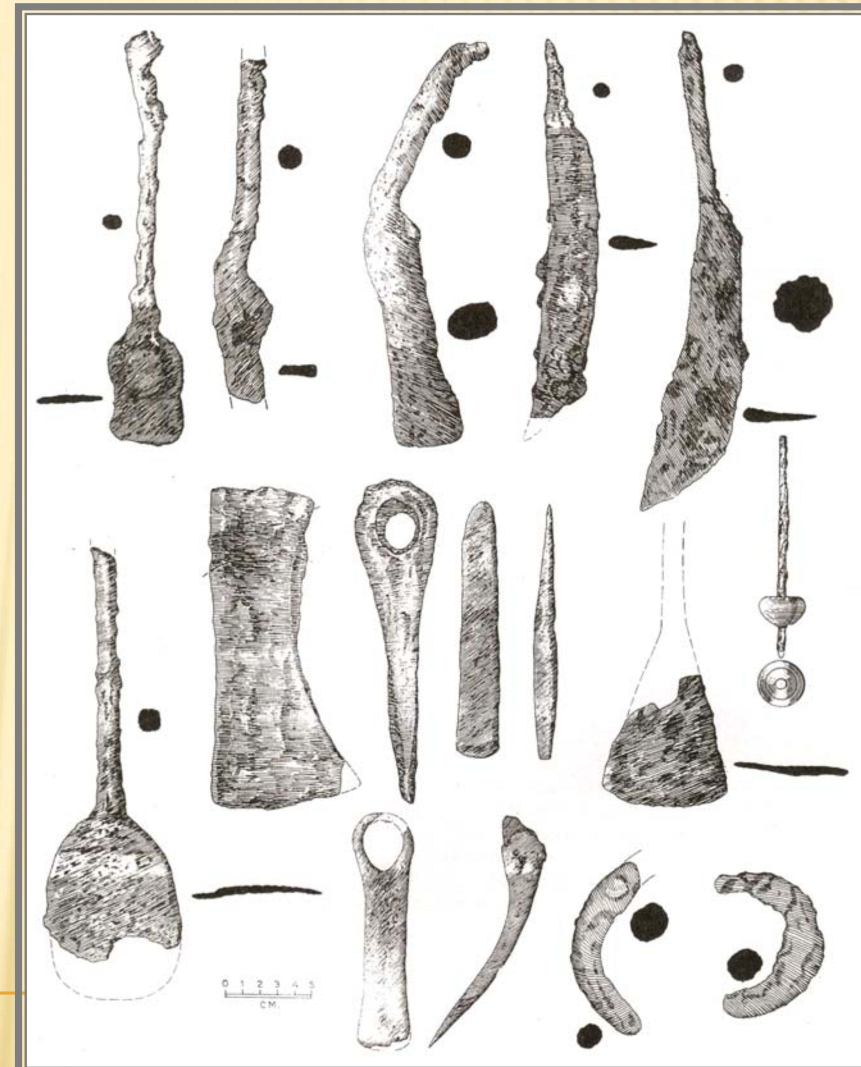
- **This proves that ancient Indians excelled in forging technique**

- **Production of corrosion-resistant (phosphoric) iron**

- **Metallurgical techniques like quenching, tempering, lamination etc. become commonplace and used appropriately.**

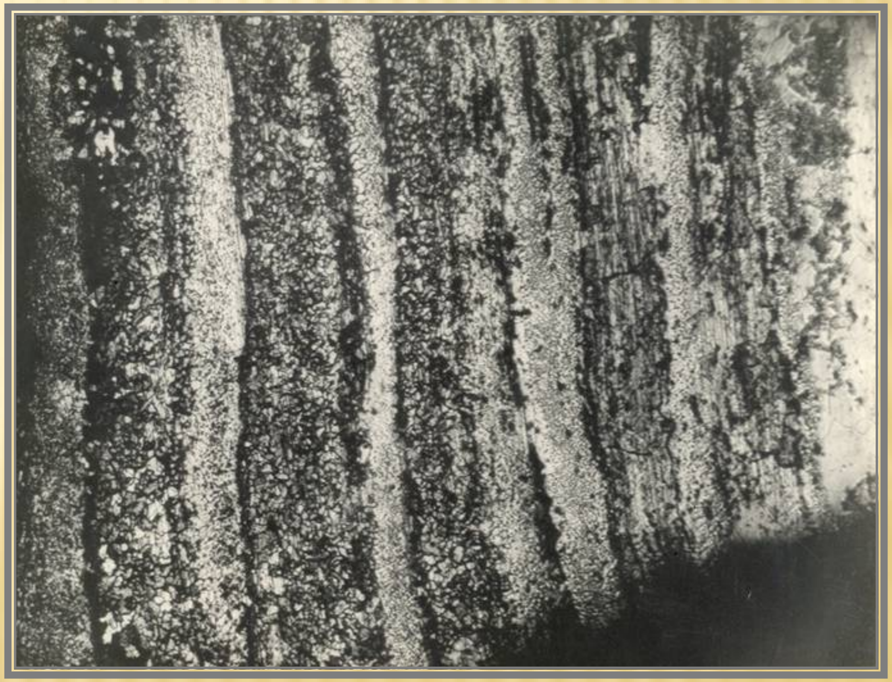


A. Iron objects (Stage III, Taxila (200-400 CE.)



B. Iron objects (Stage III, Khairadih, UP., (100 CE.)

A. Microstructure of a kitchen spoon, Sringverpur (200-300 CE.)



B. Lamination Technique (knife) , Sringverpur (200-300 CE.)

RECONSTRUCTING IRON TECHNOLOGY-ARCHAEOLOGICAL EVIDENCE

Ancient furnace remains - mere pits with ash, slag, refractory material

A. PGW level

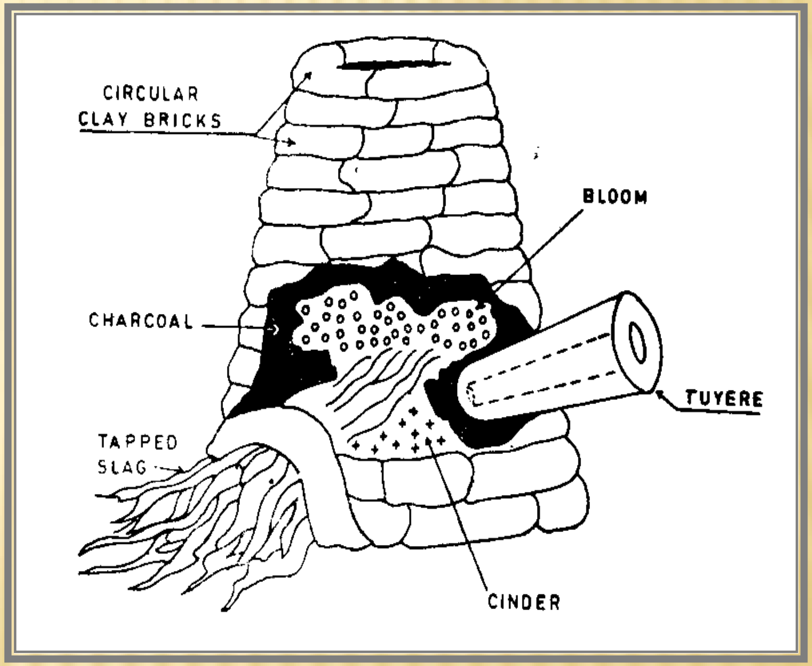
- Noh and Jodhpura
- Atranjikhera
- Jakhera

B. Black and Red ware

- Pits at Pandu Rajar Dhibi, Mangalkot etc.
- Malhar (Lohsan) - remain of cylindrical furnace

C. Megalithic Culture

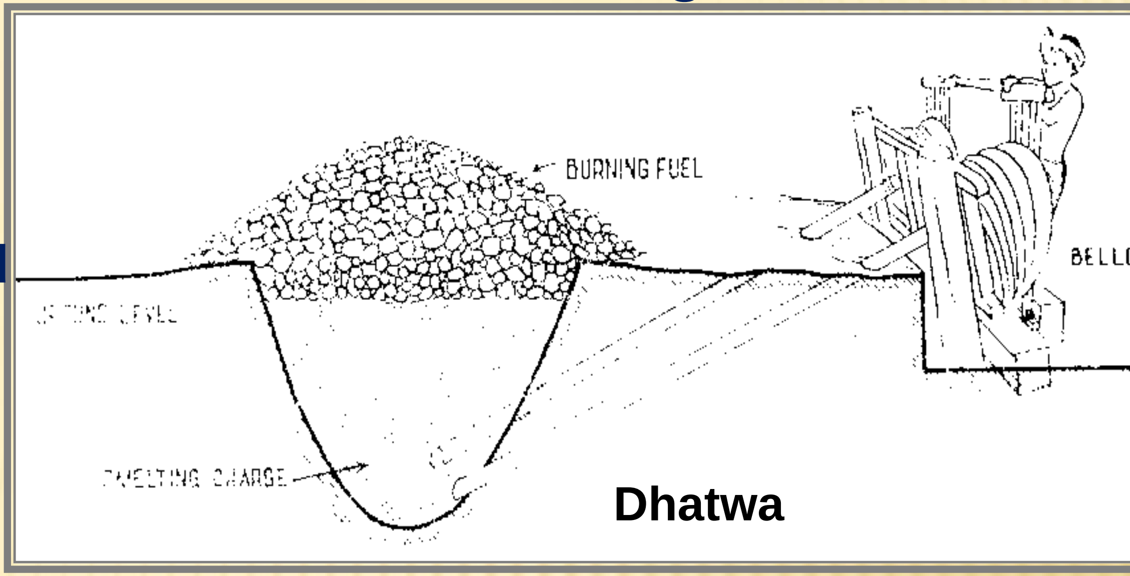
- Naikund - Vidarbh

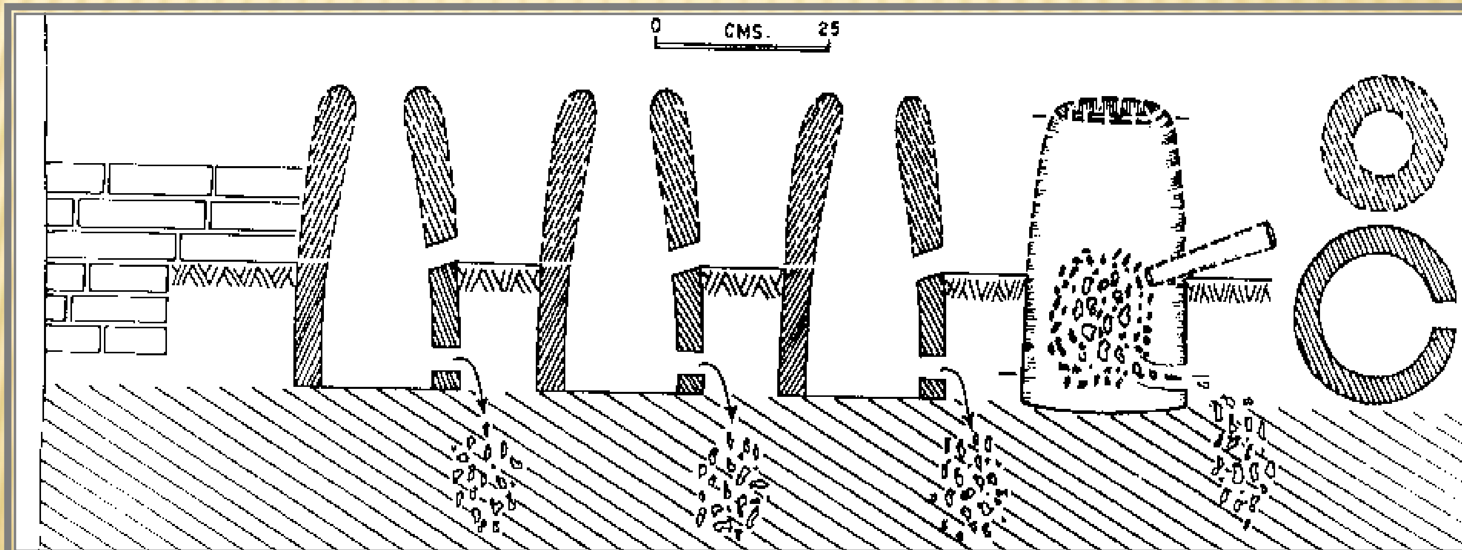


Megalithic Naikund

Reconstruction of ancient iron smelting furnaces

Reconstructed Bowl shaped furnace at Dhatwa, NBP Period





Series of furnaces at Khairadih,UP. (Kushan Period 100-200 CE.)

A. Short handled pestles from a furnace complex, Khairadih

B. Legged querns, Khairadih

C. Quern, Chalcolithic, Senuwar

Ore Crushing Implements

A: Ancient Furnace and forge (Raipura, District Sonbhadra, U.P. ,2010-11

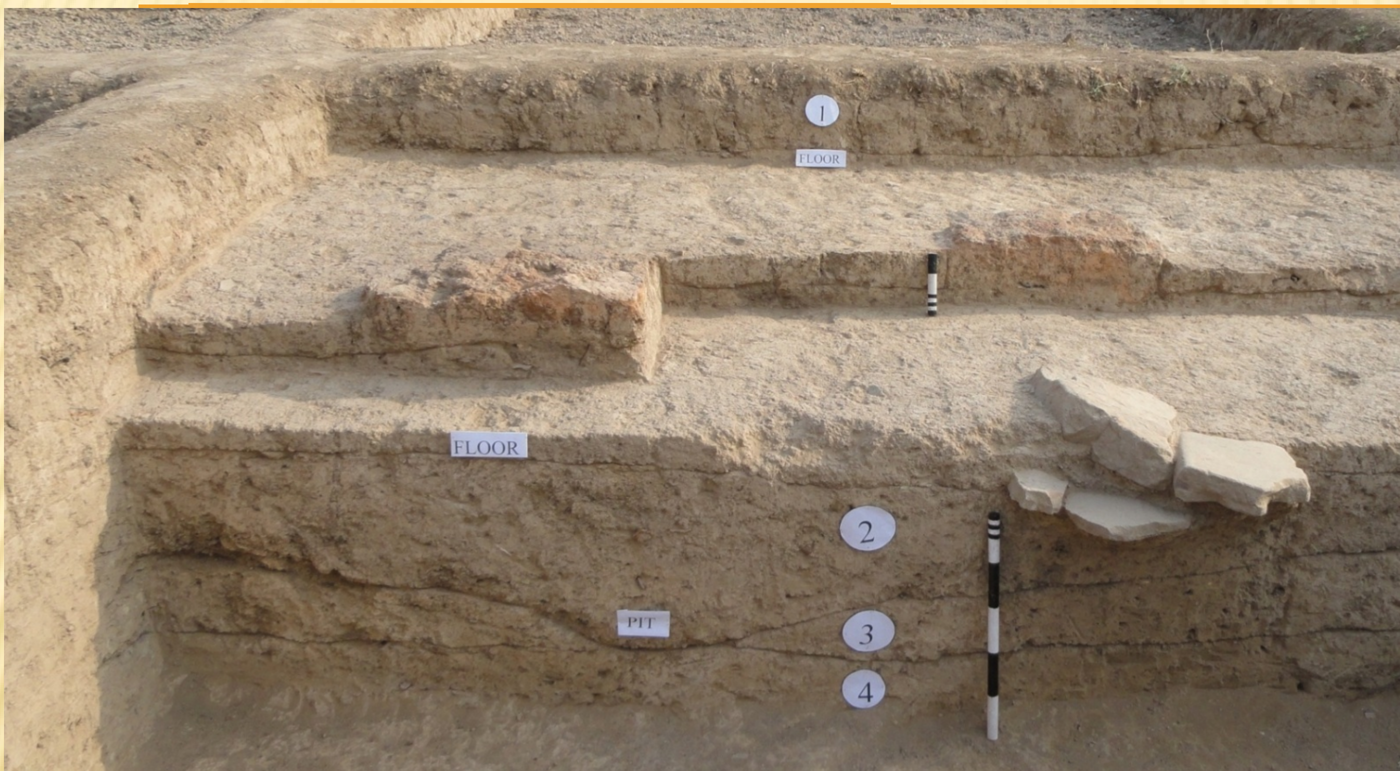
B : Ancient Furnace and forge (Raipura, District Sonbhadra, U.P., 2010-11)

C: Ancient Furnace at Lohsan Malhar Pd II

D: Ancient Furnace at Lohsan, Malhar Pd II

E: Agaria, Furnace, Ranchi

FURNACE AND FORGE WITH STONES TO WEIGH DOWN BELLOWS (RAIPURA, PD.III)

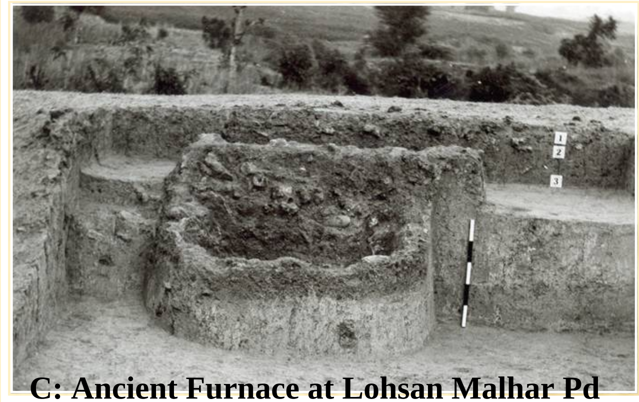


Iron Ingot recovered from the trench at Raipura

- Even after the decline of iron industry which had become famous all over the pre-modern world, the traditional iron workers continued to smelt and forge iron in remote areas of the country.
- We have located the Agaria tribe residing in remote forested parts of India who can still smelt iron with some persuation.
- They use small clay furnaces, charcoal and iron nodules scattered in iron rich M.P.-U.P border areas
- Interestingly there is similarity in furnace design of pre-industrial and ancient ones seen in excavations

A: Ancient Furnace and forge (Raipura, District Sonbhadra, U.P. ,2010-11

B : Ancient Furnace and forge (Raipura, District Sonbhadra, U.P., 2010-11)



C: Ancient Furnace at Lohsan Malhar Pd II

D: Ancient Furnace at Lohsan, Malhar Pd II

E: Agaria, Furnace, Ranchi

- Thus iron metallurgy evolved and attained great level of excellence over the millennia.

- Centres came up for production and distribution of iron across the country right from ancient times as is well documented.

- When the Europeans came to India they were struck by the quality of iron in India and extensively documented the flourishing indigenous iron industry up to 19th century.

- It may be interesting to refer a few observations made by British geologists and engineers here:

- Capt. Presgrave of Sagar (MP) mint analysed the iron produced by the Agarias, an iron working community at Tendukhera (near Hoshangabad). His assessment is being reproduced here. He commented, “----bar iron…of most excellent quality, possessing all the desirable properties of malleability, ductility at different temperatures and of tenacity for all of which I think it cannot be surpassed by the best Swedish iron; ... the Agaria piece when brought to the bend it showed itself possessed of the power of elongating and stood the bend better than the general run of English iron purchased in the Bazar"

In 1875, all sharp edged weapons of Malabar region in southern India were confiscated to be destroyed by the British rulers of India. The difficulties faced in the process were recorded,

"the blades of these knives were about 4 inches (101.6mm) wide and 1/16 inch (1.5875mm) in the thick part, and 16 inches (406.4mm) to 18 inches (457.2mm) long, and the handles were of about 8 inches (203.2mm) long. These knives were all made of the native iron from the Indian blast furnaces, and wonderful material they were. To break them was impossible, so A pair of strong hand-shears was made to cut them up. But the remarkable point was this, that if put into the shears with the thin cutting edge first, they could not be cut at all, but notched the shear blades immediately,"

Likewise, la Touche (1918) observed about the quality of iron made in India and its demand in the outside world saying, "...Its (iron's) superiority is so marked, that at the time when the Britannia tubular bridge across the Menai straits was under construction preference was given to use of iron produced in India".

"Indian steel was celebrated from the earliest antiquity and the blades of Damascus which maintain their pre-eminence even after the blades of Toledo became celebrated, were in fact made of Indian iron.....The *Ondanique* of Marco Polo's travels refers originally, as Col. Yule has shown, to Indian steel, the word being a corruption of the Persian *Hindwany* i.e. Indian steel. The same word found its way into Spanish in the shapes of *Alhinde* and *Alfinde* first with the meaning of steel and then of a steel mirror, and finally of the metal foil of a glass mirror. The *ondanique* of Kirman, which Marco Polo mentions, was so called from its comparative excellence, and the swords of Kirman were eagerly sought after in the 15th and 16th countries A.D. by the Turks who gave great prices for them. Arrian mentions Indian steel '*Sideros indicos*' was imported into Abyssinian ports" (Sir George Braidwood ,1878)

WHY DID THE INDIGENOUS IRON INDUSTRY DECLINE AND WHY ?

- Inherent weakness of indigenous ironworking?
- Colonial design?
- I quote mineralogical Surveyor of India in Kumaon in1887
- "as the working of these metals (iron and copper) might injuriously affect important articles of British import, attention should be paid to finish off the local production capability."
- Indifferent policy in independent India?
- The tribals dispossessed from forests for (a)resource conservation?
- (b)Environment protection?
- Is it truly So?- they tap resources not rated economically viable and are wasted any way.

SURVIVAL OF IRON WORKING

- In some remote pockets we find ironworkers
- There is continuity in furnace design from ancient to the pre-industrial times.
- The ethnic communities like Agarias and Asurs can produced iron with some effort.
- It was documented by us under INSA project.



Iron working in progress (Pipra, Sidhi,M.P.)

Furnace being charged

Smelting in progress-I

Smelting in progress-II

Retrieval of bloom

Forging of the bloom

OBSERVATIONS

•Summing up the discussion, we observe that India has a long history of iron working lasting over 4000 years.

•A strong spirit of innovation pervades among iron workers who attained mastery over the craft through experiments and experience.

•The consequence is nearly 7 ton victory pillar, standing tall for nearly 2000 years –the ‘rustless wonder’ of the world!

•The iron produced in India, right from 4^{th} BCE adorned the foreign courts as noted by Ktesias.

•The traditional iron working survived till recently in remote areas as a legacy of the once flourishing indigenous iron industry, a metallurgical heritage of India

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SHOULD WE DO SOMETHING TO SAVE THE LEGACY OF INDIGENOUS IRON INDUSTRY?

- We need to preserve this heritage of technology

- Do proper documentation

- If possible, give new in-puts, innovate and improvise the traditional iron technology which is dying due to our indifference and negligence

- A critical study of archaeological specimens can provide insights into the properties of ancient metallurgy to be replicated.

- Prof. R. Balasubramaniam made sincere efforts to critically study and analyse Iron Pillar and ancient iron for which India was famous all over the world.

- It provided insights for producing a better quality steel than the modern one.

- India’s heritage in metallurgy has much to offer to the world but is still waiting real attention.

- The field of archaeo-metallurgy will remain indebted to Prof. R. Balasubramaniam for his contributions.

- I take this opportunity to pay homage to

Profs. R. Balasubramaniam and B. Prakash.

Thank you for your attention