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# GUTTUR - AN IRON AGE INDUSTRIAL CENTRE IN DHARMAPURI DISTRICT

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A megalithic habitational cum burial site was discovered at Guttur in Dharmapuri district in the year 1982. The exploration also revealed the exposed portions of furnace along with blow pipes, tuyere, iron slags and potteries associated with megalithic period. The latter excavation brought to light a twin furnace datable to megalithic period. The entry of megalithic people into Dharmapuri district was derived on the basis of C-14 dating obtained at Togarapalli, a site situated 6 km south west of Guttur, On the basis of former dating the origin of megalithic culture at Guttur can be dated to c.500 B.C. The megalithic culture at Guttur had two phases extending over 700 years. The presence of structures datable to both the phases and the furnaces near the base of the hill indicated that the iron industry had flourished in both the period.

Iron artefacts collected from the site were analysed by chemical analysis, x - ray diffraction and metallographic studies. Metallographic studies revealed micro structures containing ledeburite and cementite indicating the manufacture of cast iron. In certain regions Martensite structure was also observed which was the result of quenching the metal during solidification. The slag analysis had confirmed that the ore smelted was of good quality and rich in $Fe_2O_3$

**Keywords** : Artefact, Black & Red ware, Cementite, Iron Age, Iron Slag, Ledeburite, Martensite, Megalithic period, Microhardness, Pearlite, Russet coated ware, Smelting

The district Dharmapuri has a glorious history about Iron industry. Situated on the north western side of Tamil Nadu, bordering Karnataka and Andhra Pradesh, the district Dharmapuri witnessed the diffusion of iron technology into Tamil Nadu from its northern border. Chronologically, the earliest megalithic type associated with people practising iron technology appeared in Tamil Nadu in the north western region around 500 B.C.[1] Located at a distance of 20 km in the north eastern direction from Krishnagiri, the industrial site Guttur lies ($12^0 25'$ N & $78^0$ $15'$ E) on the right bank of Guttur Channel and spread over a wide area covering the base of the Guttur hill.

Archaeologists under the direction of K.V. Raman, Professor of Ancient History & Archaeology, University of Madras surveyed the area in and around Guttur in the year

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1982. The exploration revealed the presence of a few disturbed megalithic burials besides large number of Black and Red Ware. Black Ware, Russet coated Painted Ware from the surface level. Iron slags, cinders blow pipes and tuyere in large numbers strewn over a wide area on the disturbed ashy white soil around the Guttur hill, indicating the industrial activity from early period. The sections of the cultivated land in the lower reaches of the mound showed fragments of bones, tiles, spindlewore etc.

## STRUCTURE

Based on the field work, four trenches were laid in the year 1983. Of these trenches GTR I, GTR III and GTR IV were laid on the foothills of the Guttur hill and GTR II some 100 meters east of the hill near the Viṣnu temple. The excavation brought to light structures in all the trenches.

The structure in GTR III was 0.18 m below the surface and is of recent origin. The triangle shaped stone structure in GTR II was found 0.87 m below the surface in layer 4 between the locus II and VII, projected out of the northern section to about 3.5 mts towards south and then runs towards south eastern direction about 6 mts. Thickness of the slabs are 0.05 m, width of the structure is 0.80 m. The inner and outer wall surfaces were kept in parallel line. The presence of post holes indicates that the structure was covered with thatched roof. The structure in GTR II can be assigned to the period I (c.500 to 100 BC) as was found in association with Black and Red Ware pottery.

The section scraping conducted at Togarapalli, a megalithic habitation site situated 6 km south west of Guttur by B. Narasimhaiah has provided a firm date for the Black and Red Ware level of the region. The Charcoal collected from layer 5, which overlies the 0.25 m thick layer 6, is dated by the C-14 method to 290 BC. Both the layers belong to the Black and Red Ware level. Based on this finding Narasimhaiah dated the beginning of Black and Red Ware culture[2] in this area to around 500 BC.

The structure in GTR I was set in a globularly elongated design between the locus III and IV and runs to a length of 3 m. The structure was found at a depth of 0.75 to 0.80 m below the surface in layer V. The thickness of the slab is 0.05 m. The slabs are interspersed with rubbles and mud plaster. The presence of post holes at this level reveal that the structure may be a covered one. The potteries found associated with the structural remains are Black and Red Ware, Black Ware, Russet coated Ware and Red slipped Ware. On the basis of the presence of potteries and other associated objects, the structure in GTR I can be dated to the transitional period from I to II c. 100 BC to 300 AD.

## FURNACE

The trench GTR IV revealed a twin elongated oval shaped iron furnace (fig. 1) measuring 2.02 m length, 0.63 m width and 0.45 m depth. The thickness of the wall portion measures 0.04 m on its northern side and 0.08 m on its southern side along with Black and Red Ware sherds and iron slags in stratified layers. The exposed portions of the furnace reveal three openings (fig. 2) with earthen pipes. The one at the bottom indicates the arrangements made for the retrieval of molten iron on its side. One of the other two openings near the top was for the bellows and for removing the slag from its front side. The author during the course of his recent exploration at Guttur has identified exposed portions of fourteen twin furnaces, some of them in straight line and others at right angle with provision for bellows in the middle near the base of the Guttur hill.

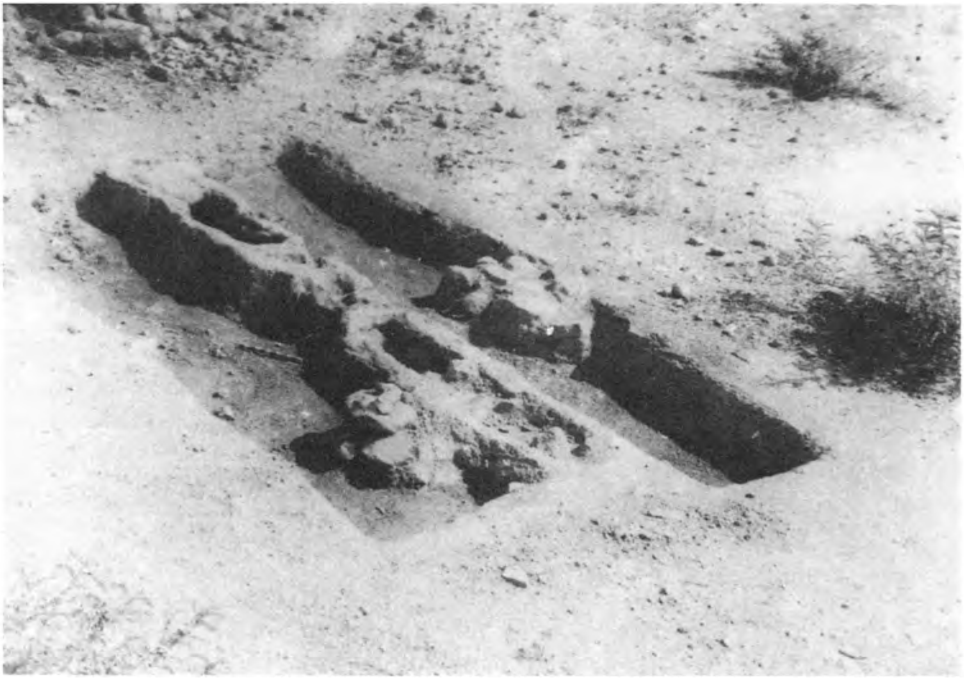

Fig. 1. G.T.R IV, exposed portion of twin elongated Oval Furnace.

The methods employed for smelting wrought iron and steel have been described by writers like Bruce Foote, Thomas Holland and others. According to Bruce Foote the method of smelting ore was simple, the apparatus used was very cheap and the iron produced was of excellent quality. The shape and construction of the furnaces varies slightly, but those generally used were nearly cylindrical, tapering into an irregular cone

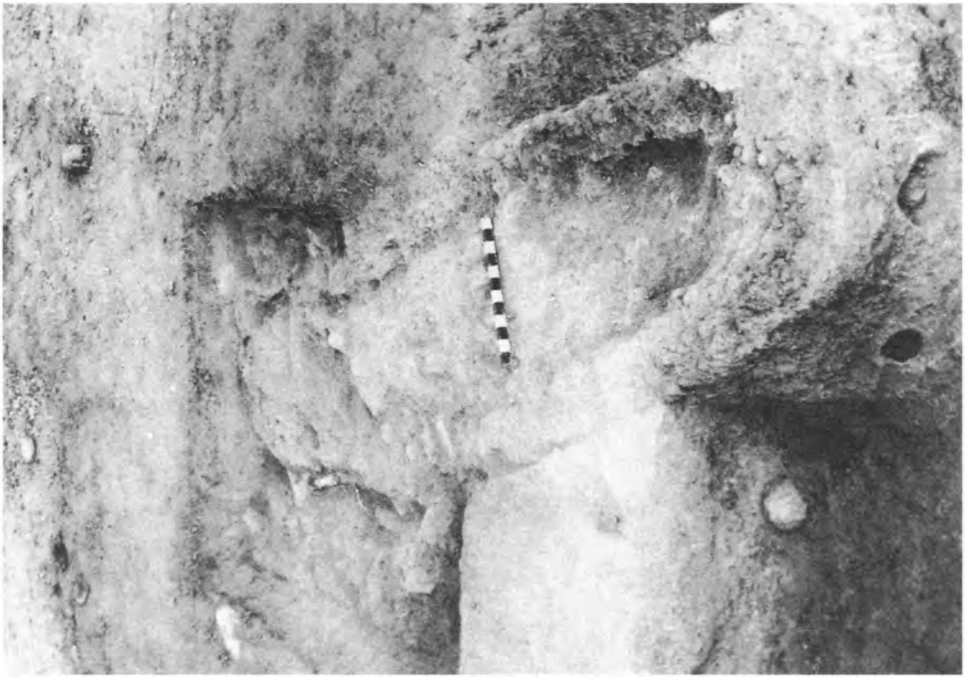

**Fig2.** Structure revealing three openings with earthen pipes.

at the top. The height of the furnace varied from 1 to 2 meters with a diameter of the interior of about 0.22 to 0.30 m, the furnace itself at the ground was about 60 m wide and tapered sometimes from the ground and sometimes from about one-third to one fourth of the height. The furnace that Bruce Foote described above resembled, very nearly, the one excavated at Guttur (fig. 3).

The furnaces were made of Red clay mixed with sand and they constantly required to have the inside renewed by fresh linings of clay which could not stand more than three or four days of working[4]. Bearing this in mind the iron smelters at Guttur constructed a twin furnace so that the production of iron could continue uninterruptedly in either furnace while one of them was under reconstruction. The furnace mentioned by the early scholars produced either wrought iron or were used to carburize wrought iron into steel with carbon content of 1 to 1.5%.

## Location of the Source of Ore

The site selected for smelting in the early period c.500 BC had to satisfy two important prerequisites viz., 1) proximity of the ore deposits and 2) availability of an

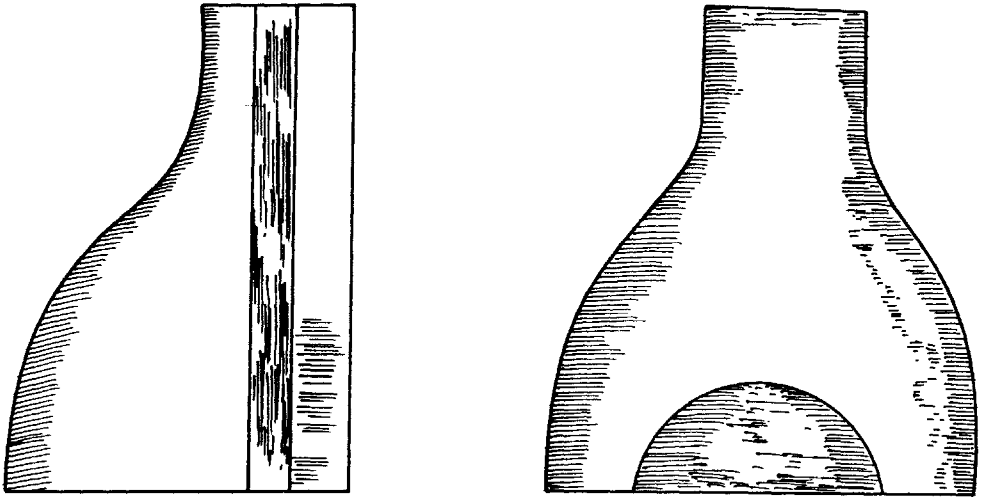

Fig 3. Line drawing showing section and elevation of native furnace. (Prospects of Iron and Steel Industry in Madras by Belliappa)

abundance of fuel, because the transportation of either of them over a long distance was beyond the resources of the early community[5]. This naturally restricted the location of iron smelting industry. The native practice of collecting the black iron sand from the rivulet after the rain was referred to by Buchanan in his travels[6]. The channel near Guttur hill probably was the source from which the early smelters collected the black sand washed down from the hill after the rain. The XRD analysis of the slag confirms this view as the ore smelted was of good quality and rich in $Fe_2O_3$.

## FUEL FOR SMELTING

The early smelters mostly used wood-charcoal as fuel for smelting. The ash in the wood - charcoal finds its way into the slag and most of its constituents lower the free running temperature of the slag[7]. Heath while reporting the native method of smelting iron in South India refers to the use of wood-charcoal as fuel throughout the different stages of making iron and steel[8]. The smelters of Guttur probably used wood - charcoal from *Acacia auriculata* which is still densely available in the Guttur hill.

Fig 4. Micro Structure consists ofcementite (white), fine pearlite (Black) and ledeburity, Micro hardness impressions can be observed. 280x

## METAL AND SLAG ANALYSIS

Iron artefacts and pieces of slag collected from the stratified layer were examined by chemical analysis, metallographic studies and x-ray analysis.

A specimen sectioned from an iron artefact was polished with fine alumina powder after grinding the surface with suitable grades of emery paper. The polished surface was etched with 2% Nital to reveal the microstructure. The microscopic examination across the cross section of the specimen revealed a widely varying structure. At one zone, the microstructure showed dark etching pearlite, white etching iron carbide called cementite and ledeburite. The microhardness measurements giving values of around 900 VPN in the white region of the structure confirms that the phase is cementite ($Fe_3C$) as shown fig.4). The ledeburite structure is a transformation product obtained at 1140°C upon cooling the molten metal from a higher temperature of about 1300°. The Carbon content in the metal would be in the range of 2.5 to 3.0% as estimated from the Iron - Carbon equilibrium diagram (fig.5)[9]. The microstructure examined at higher magnification gives a clear picture of ledeburite (fig. 6)·

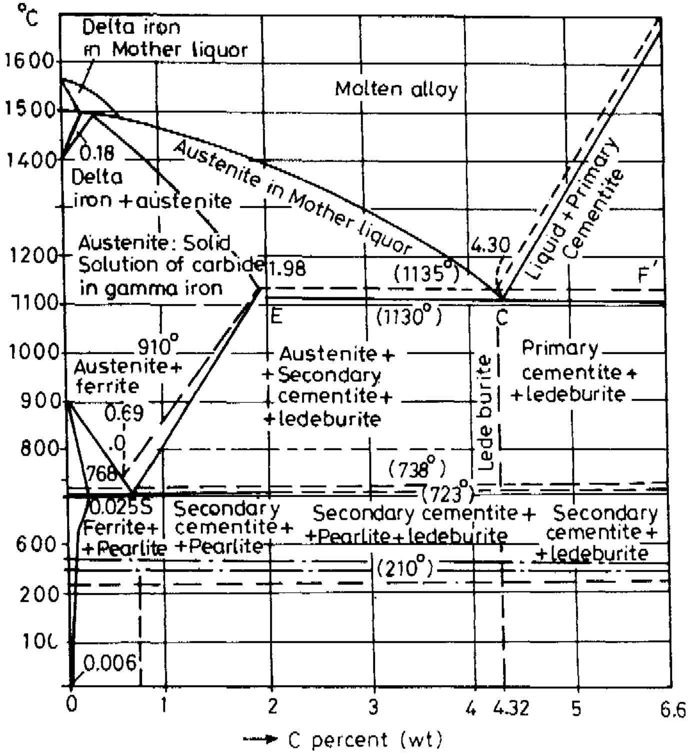


Fig 5. Iron - Carbon equilibrium diagram.

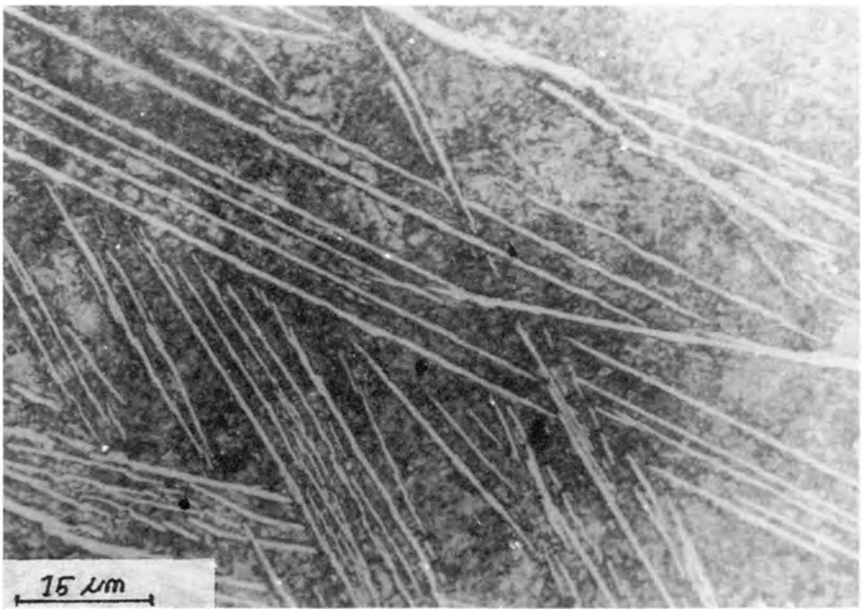


Fig 6. Micro structure showing ledeburite clearly, 700x

The microstructure in some zones consisted of primary cementite appearing as thin white platelet (fig. 7) and secondary cementite which look like channels along the prior austenitic grain boundaries. The matrix structure is fine pearlite. The presence of primary cementite (fig. 8) indicates that the carbon content in the metal would be higher than 4.3%.[10]

In certain zones, acicular structure typical of high carbon martensite was produced as a result of quenching the metal at high temperature (fig. 9). Average hardness value lying around 800 VPN supports this observation. Appearance of many cracks shows that the material has become brittle due to the hard phases like primary cementite and martensite (fig 10).

From the above studies, it appears that the iron artefact was made of cast iron which was splashed with water during solidification of the metal[11]. However, due to non-uniformity in the cooling rate across the section different structures have developed.

Another specimen cut from a completely corroded artefact was subjected to chemical analysis. It contained $Fe_2O_3$ (74.2%), Phosphorus (0.16%) and Sulphur (0.08%) with the

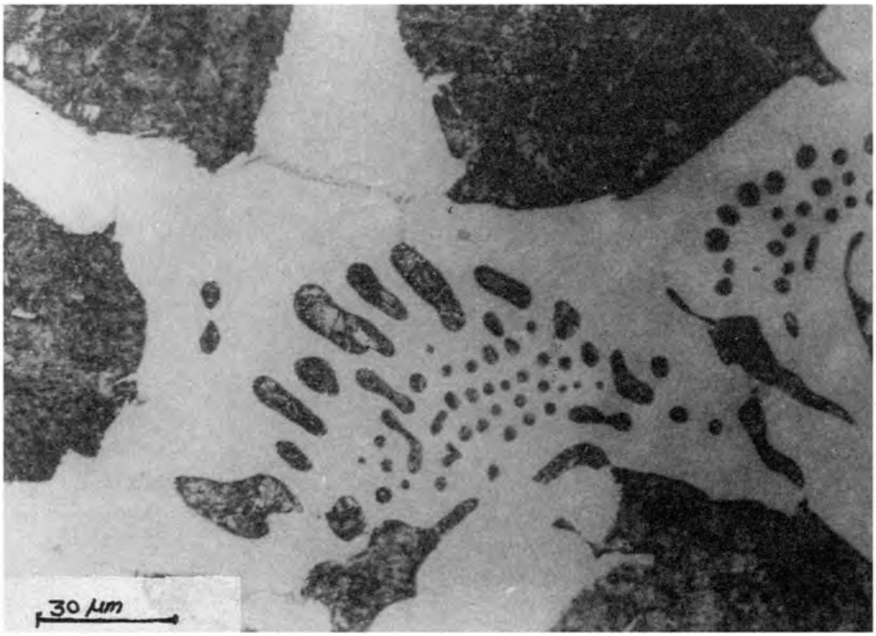


Fig 7. Micro Structure showing platelet of primary cementite and secondary cementite along grainboundary in the matrix of fine pearlite. 140x

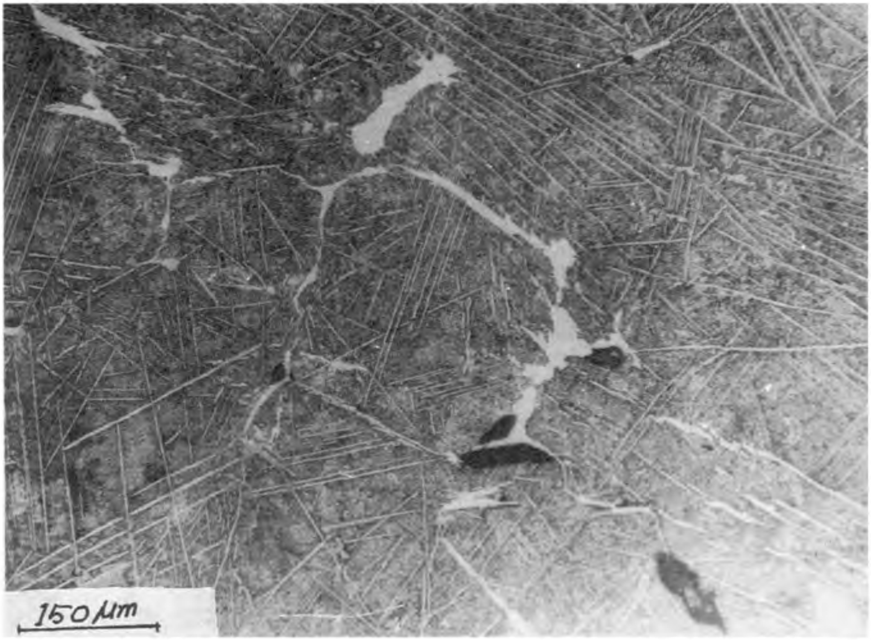


Fig 8. Primary cementite platelet, with the matrix being fine pearlite (black). 1400x

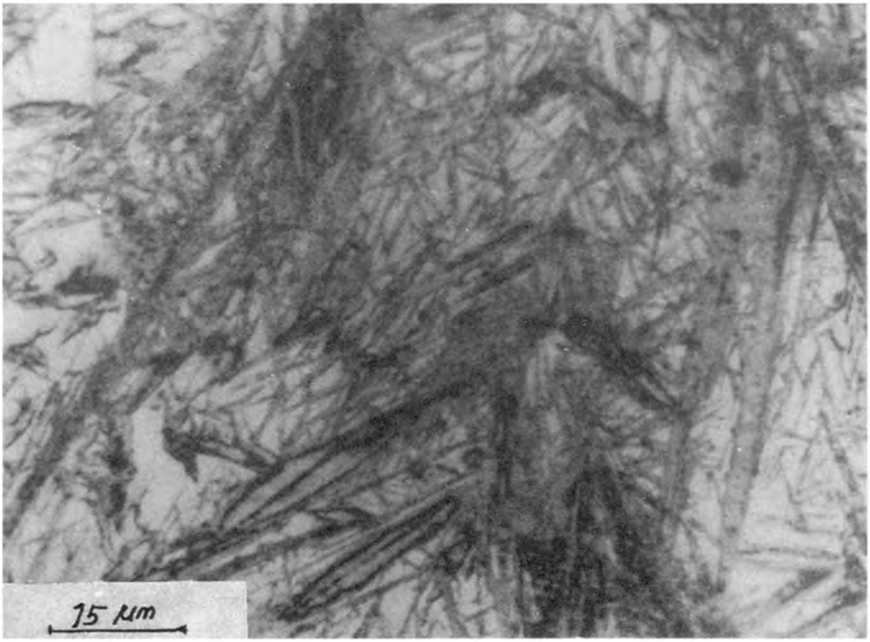


Fig 9. Structure reveals Acicular Martensite. 1400x

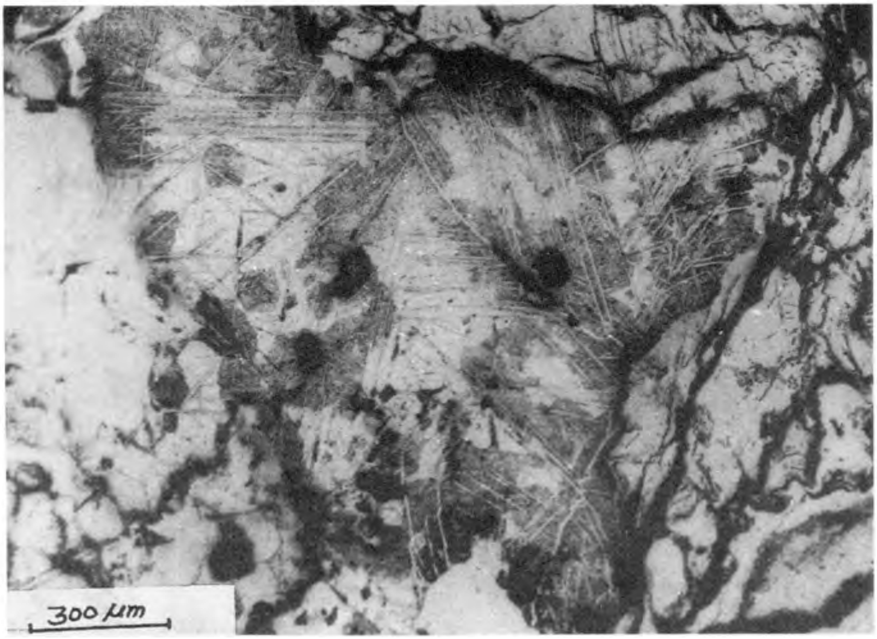


Fig 10. Structure showing cracks in the cementite and martensitic phases. 70x

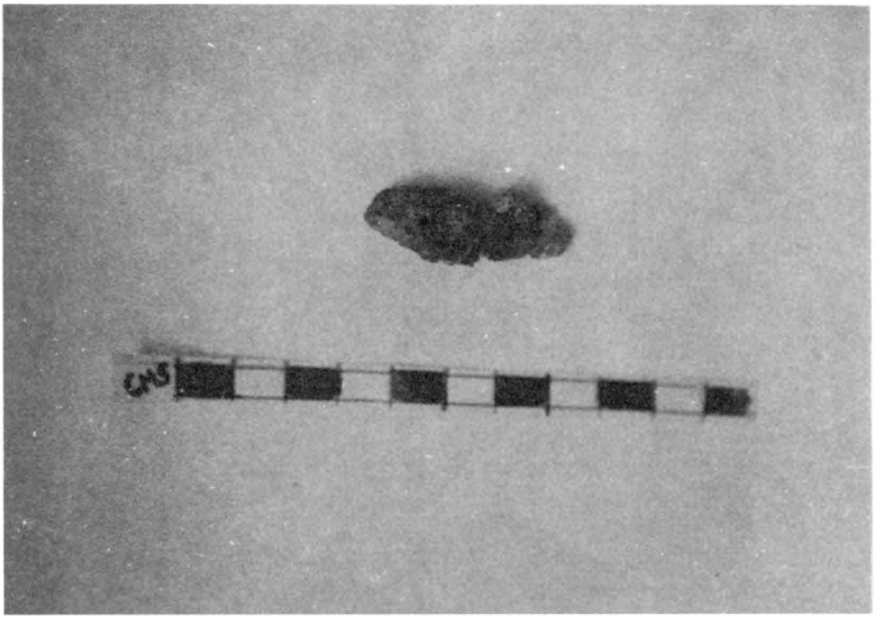


Fig 11. Iron Artefact - Guttur.

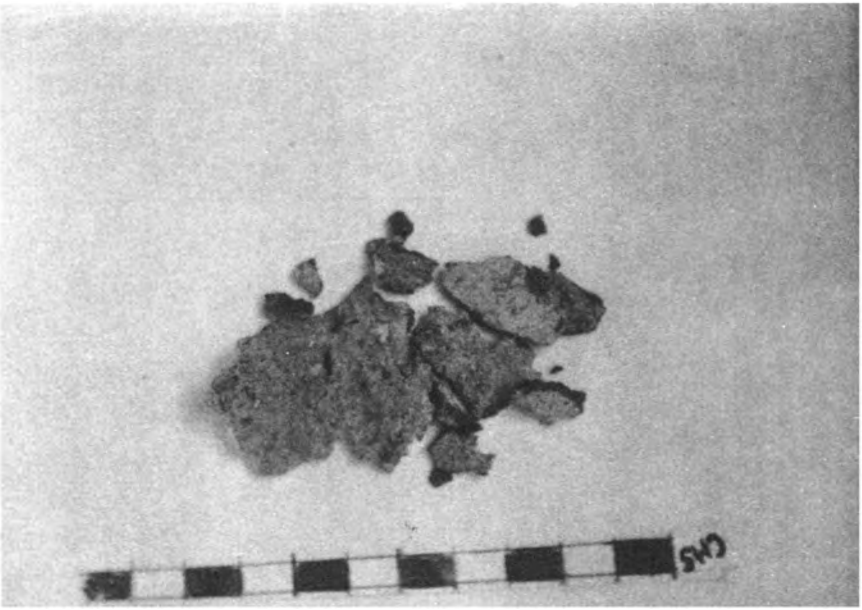


**Fig 12.** Iron Slag - Guttur.

balance being $Fe_3O_4$. The appearance of the specimen was reddish in the outer region and brownish black near the core, which strengthens the viewpoint that a ferrous object produced around third century BC, has corroded thoroughly over the last-several centuries. But since it was buried underneath the surface, there was no accessibility to oxygen of the core portion, which therefore got converted to the lower form of oxide, $Fe_3O_4$. The peripherals, however, were oxidized to $Fe_2O_3$.

A few twisted strips (fig 12) containing many pores, were also found near the furnace. These strips had greyish colour. The porous nature of the strips is apparently indicative of gas escaping from molten metal. X-ray diffraction analysis seems to indicate very good agreement with the Phase $Fe_2SiO_4$ (Fayalite). The chemical analysis indicates 0.24% phosphorous and 0.03% sulphur. Therefore the piece is likely to be a ferrous slag produced during melting. The absence of aluminate or other oxides in the slag analysis, carried out by x-ray diffraction and chemical analysis, leads to the conclusion that a good quality iron ore, rich in $Fe_2o_3$, was melted in a furnace using a silica lining.

## SUMMARY

Various grades of iron were known and recognized by their property in India from early times. The knowledge of iron metallurgy was much advanced in the last part of 1st millennium BC. The Sangam literature refer to the superiority of steel *ekku* over

***Table*** : 1 Chemical analysis of metals

| | P (wt%) | S (wt%) | C(wt%) | $Fe_3O_4$ | $Fe_2O_3$ (wt%) | $Fe_2SiO_4$ (wt%) | Total |
|---|---|---|---|---|---|---|---|
| Corroded artefact | 0.016 | 0.08 | 4.2 | 74.2 | 21.36 | - | 100 |
| Twisted metal strip | 0.24 | 0.03 | - | - | - | 99 | 100 |

iron - wrought and also objects made of cast iron. *Rasa tantra Samuccaya*, a thirteenth century literature mentions three kinds of iron *viz. munda* (cast iron), *tikshna* (steel) and *kānta* (wrought iron)[12].

The exploration at Guttur brought to light a habitation cum burial site near the base of the hill. The excavation though limited in scale revealed the existence of an iron smelting centre that continued over two cultural phases, covering a period of 400 years from the last quarter of the 1st millennium BC. Chemical analysis and metallographic study on the iron object showed that it was a cast iron with carbon content varying from 3 to 5%. Since there is evidence of solidification of metal from the molten condition it can be inferred that the smelters probably maintained high temperatures around $1300^0C$ for a long period using a high ratio of fuel to the ore and also by blowing air by a pair of efficient bellows. This resulted in the fusion of carbon with iron, producing an alloy of iron and carbon similar to the present day cast iron. The melting point of cast iron is lower than that of steel and therefore it would have been easier to produce cast iron. The Sangam anthology *Kurunthokai* refers to the manufacturer of cast iron bell by wax method, a process the early iron metallurgist inherited from bronze metal casting[13].

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