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METALLURGY AND METAL INDUSTRY IN ANCIENT TAMILNADU – AN ARCHAEOLOGICAL STUDY

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The archaeological study carried out in the twentieth century showed the existence of iron smelting industrial sites datable to the second half of the first millennium BC in India and especially in Tamilnadu. The iron and steel furnaces found at Guttur and Kodumanal in Dharmapuri and Erode districts of Tamilnadu and the iron artefacts produced in these centres revealed the technical advancement made by the iron smelters around c.500 BC.

Key words : Kammala, Martensite, Purananuru, Urkku, Widmanstatten, wootz steel .

Archaeological exploration and excavations carried out since the last quarter of the 19th century in India has given us a large volume of antiquities in the form of metal artefacts and exposed portions of smelting furnaces. The study of ancient metals in India by the archaeologists (Banerjee) and on ancient metallurgy by other scholars (Neogi, P. & Hegde, K.T.N.) clearly showed the beginning of metallurgy and metallurgical knowledge in India.

The research on ancient metallurgy in India made its beginning when Hadfield studied the material from Besnagar (India) and Taxila (Pakistan) with chemical analysis and micro structural study (Chakrabarti: 1992, p.13). Panchanan Neogi did chemical and metallurgical analysis, tensile strength, forging and corrosion resistance of early iron pillars and beams from the Archaeological finds such as Delhi Iron Pillar and beams from Konark (Chakrabarti: 1992, p.15). He also made an integrated approach to the

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study of evolution of metals in India by supplementing literary and archaeological evidence to the metallurgical studies. The analysis made by Prakash, Hegde and others on iron artefacts from other archaeological sites has revealed a broad picture on ancient metallurgy in India.

The middle of the first millennium BC witnessed the arrival of people using metal in their daily life into Tamilnadu from Karnataka and Andhra Pradesh. The districts in Tamilnadu bordering these states viz. Coimbatore, Salem, Dharmapuri and North Arcot formed the nuclear zone of iron age culture and from there it further diffused towards the other regions of Tamilnadu. The excavations conducted at Guttur (*IAR*: 1982 p.68) and Mallappadi (*IAR*: 1977-78, p.50) in Dharmapuri, Paiyampalli (*IAR*: 1964-65, p.40;1967-68, p.31) and Appukkallu (*IAR*: 1976-77, p.69) in North Arcot and Perur (*IAR*: 1963-64, p.40) in Coimbatore and stratigraphical section scrapping conducted at Togarapalli and Mullikkadu in Dharmapuri (Narasimhaiah: 1980, p.182) revealed the presence of a community highly specialised in agro pastoral economy. The profuse occurrence of iron artefacts especially agricultural tools in these sites indicate the presence of skilled artisan workforce in their midst. A heavy concentration of iron age settlers in some of the mineral rich region shows their reliance on these resources. The settlement pattern of the early iron age people in Tamilnadu indicate that they were reverain in nature and they diffused towards the interior of Tamilnadu through the valleys of major rivers or through their tributaries (Udayaravi.Moorti: 1994, p.44). The iron age habitation in the districts of Dharmapuri and North Arcot reveal their concentration along the course of the river Pennaiyar or its tributaries. The migration of the iron age people from the point of their entry in Tamilnadu to the interior region shows their progress from simple village folk depending mainly on pastoral economy to the establishment of large towns where trade, commerce and industry flourished. The development also led to the transition from pre-historic to early historic culture in Tamilnadu.

The discovery of iron and steel furnaces at Guttur (Dharmapuri, 1983), Kodumanal (Erode, 1986-96) Bahur (Chingleput, 2001) and other places brought to light the existence of a class of artisan community with profes-

sional skill and expertise within the megalithic community. The early Tamil literature while making reference to the role of blacksmith in ancient Tamil society mentions that the manufacture of weapons and other artefacts of daily needs were the duty of the blacksmith :

(*Purananuru*: v.170: ...*pakaivarku kir ppyan paṭkkṅ karṅkaik kollan visaitter kūdamodu porum ulaikkal lanna* (i.e. *pittan korran* is like blacksmith's anvil against strong hammer) *Purananuru:* v.180: *tannurk karuñ kaik kollanai yirakkkum trttilai neḍuvel vadittchinenavē* (i.e. soldier Iranturkilan Toyan Maran had begged his blacksmith to manufacture long darts so that he will win victories over his enemies) *Purananuru:* v. 312 vēl *vaḍittuk koṭukkal kollṛkku kaḍne,* (i.e. it is the duty of the blacksmith to manufacture vel or dart for the gallant soldier).

The large quantity of iron artefacts recovered from the burial and habitation sites datable to the iron age period indicate that the artisan community were in constant demand for the supply of these artefacts. The furnaces exposed and the artefacts present also point to the advanced state of technical knowledge in iron smelting and indicate that the early migrants were not incipient in their knowledge of iron smelting and this they might have acquired somewhere outside Tamilnadu, on their way, before their entry into Tamilnadu.

Copper was smelted in India in the Ganeswar-Khetri region around c.2700 BC and it made its entry into the Deccan around c.1800 BC (Bharadwaj: 1973, p.140). However the absence of copper in the Neolithic levels at Paiyampalli, T.Narasipur and Nagarjunakonda and its appearance along with iron in the megalithic habitation level clearly indicate their late arrival in the South. Copper ore has been found in Tamilnadu in the districts of South Arcot, Coimbatore and Tirunelveli. Inspite of the fact that copper can be reduced to metallic form at a temperature much lower than that of iron, there is hardly any evidence of copper smelting in these districts. The available archaeological data suggests that either the copper belt is not viable for commercial smelting in the ancient period or the technological skill attained in iron smelting and large scale production of iron artefacts probably dampened the urge of the iron age folk to smelt

copper from the ore (Rajan: 1994, p.99). The bronze articles like strainer, sieve cups and the ornamental lids with flower or animal motifs from the archaeological sites of Kodumanal and Adichchanallur show similarities with those recovered at Mahurjari in Deccan. The bronzes exhibit a high degree of skill in workmanship. The comparative rarity of bronze objects and their use for personal ornament show that this metal must have been scarce and highly valued and used only by the higher-class people. The identical nature of these objects found in places situated far away from one another stipulates a common origin. Whether the Iron Age people in Tamilnadu imported these copper objects from other parts of India as finished goods or imported copper sheets or ingots and manufactured objects locally with artisans settled from other parts is to be ascertained (Rajan: 1994, p.98). The excavations at Kodumanal brought to light more than 100 potsherds bearing Brāhmi letters and some of them having Sanskritised names clearly indicating the close links the southern region had with the other parts of India in the ancient period (Rajan: 1994, p.82).

Iron smelting operation datable to sixth century BC was found in Tamilnadu in the form of slags at Paiyampalli (*IAR*: 1967-78, p.31) and Appukkallu (*IAR*: 1976-77, p.69) in North Arcot district. Iron smelting industrial sites datable to iron age (c.600 to 200 BC) was discovered at Guttur (c.500 BC) in Dharmapuri district (*IAR*: 1982-83, p.67) and at Kodumanal (c.300 BC) in Erode district. Recent excavations at Bahur near Chingleput by the department of Archaeology, University of Madras, in the year 2001 brought to light two iron smelting furnaces datable to c.100 BC. Other than these three excavated sites iron and steel smelting furnaces datable to megalithic period (c.600 BC –300 AD) were found at Mel-Siruvallur (South Arcot), Kattankulathur (Chingleput), Pakkam (South Arcot), and Perungalur, Ponparakkottai, and Tiruvarankulam (Pudukkottai). A Pandya inscription from the temple at Tiruvarankulam town (10° 56' N 78° 22' E) dated in the 4th year of Jatavarman Virapandya III (1299 AD) speaks of iron smelting industry in this town and the black smiths colony on the western side of the temple .The inscription also mentions the tax levied on the furnace in operation at Tiruvarankulam (*Manual of Pudukkottai*: Vol. I: 1938, p.196). Though the present generation does not know much about

the iron smelting carried on in earlier times, the author discovered two round furnaces about 1 km north-west of the present *Kammala* (Blacksmith) colony .The furnaces were found embedded on the banks of a tank formed by the excavation of soil around the place for brick industry.

GUTTUR

The excavations in the year 1982-83 at Guttur (12° 25' N 78° 15' E) near Krishnagiri brought to light for the first time in Tamilnadu an industrial centre where iron artefacts were produced by casting around c.500 BC. The surface around the foot of the hill contain large amount of iron slags, cinder, blow pipes with vitrified mouth and ashy white soil. The above finds clearly indicate the flourishing industrial activity at Guttur from the time of its occupation by the iron age artisan community. The excavation revealed a twin elongated oval furnace measuring 2.02 m length, 0.63 m width and 0.45 m depth. Brick structure was found on either side of the furnace and in between the twin furnace. The one at the middle was probably used for the bellows and the other on its sides was used for filling of the furnace with fuel and ore while the smelting was in progress. The measurement of the furnace showed that it could have been the largest furnace in operation at that time in India. Prakash quoting Buchanan states that the twin hearth furnace of Malabar was the largest furnace with a production capacity of 250 kg per heat. According to Prakash the twin hearth furnace of Malabar came into operation only in the 18th or 19th century AD (Prakash: *Puratattva*: 1989, No.20, p.119). However, the excavation at Gutttur revealed the existence of a twin furnace, similar in measurement and typology, producing cast iron in Tamilnadu around c.500BC.

Balfour in his account on the furnace from Malabar states that the furnace differs widely from the still more primitive forges of Salem and Coimbatore. According to him, "the egg shaped furnace was four times bigger than the circular furnaces used in Salem and Coimbatore regions. The height of the furnace from the ground measures 3 m. Native steel for edging ordinary tools was prepared direct from the crude, loupe or mass as it drawn from the furnace. The lump was never uniform in quality, but

presents various degrees of carbonisation. Portions may always be selected more peculiarly adapted to the production of steel, which indeed approximate so nearly to steel itself, that may require only to beaten out and tempered to form that metal in its primitive state. The manufacture of cast steel as in the case of Salem was not in practice in the Malabar region" (Balfour: 1855, pp.106-7). The chemical analysis of the artefact showed that it was a cast iron with carbon content varying from 3 to 5per cent. The microscopic examination across the cross section of the specimen revealed a widely varying structure viz. dark etching pearlite, white etching iron carbide called cementite, ledeburite and martensite. The ledeburite structure is a transformation product obtained at 1140°C upon cooling the molten metal from a higher temperature of about 1300°C (Raghunatha Rao et.al: 1997, pp.352-4). Archaeological excavations from other sites in Coimbatore district viz. Kannarappalayam near Mettuppalayam (Walhouse: 1875, pp.17-34) and Nattukkalpalayam (Sandford: 1901, pp.461-71) brought to light hollow terracotta rings, datable to megalithic period (c.3rd century BC), each measuring 30cm in diameter and provided with a spout. The terracotta ring mould with spout was probably used to make cast iron rings or strings as it was found along with iron slag and other furnace material in these sites. The molten iron was poured inside the ring through the spout. The metal inside was either slow cooled by leaving it for some time or fast cooled by water quenching as was made at Guttur. On cooling down the iron would get the shape of the terracotta ring and the cast iron was recovered by breaking-open the mould. The discovery of twin furnaces at Guttur and the terracotta ring moulds in the excavations at Nattukkalpalayam and Kannarappalayam indicate the existence of cast iron foundry in ancient Tamilnadu, where the ancient artisans produced artefacts such as iron rings, iron bells etc by casting as manufactured in an iron foundry in modern times.

KODUMANAL

The excavations at Kodumanal (11° 6' 42" N 77° 30' 51"E) from 1985 to 1996 has yielded material evidence to the presence of metal and bead

making industries. The industrial centre also formed the hub of trade activities from where itinerant and maritime trade were carried out with other regions in India and west Asia from 300 BC to 200 AD. The furnaces exposed include bowl furnaces and crucible furnace with smaller furnaces around. The shape of the bowl furnace was distinguished by the presence of burnt clay having smooth surface and circular in form. The white colour in furnace area clearly indicates that it was caused by high temperature produced during the smelting operation. Since the furnace was in broken condition the height of the furnace could not be ascertained. However, the base of the furnace measuring 115 centimetres in diameter indicates that it was bigger than the bowl furnace in use at Salem and Coimbatore regions in the 18th and 19th centuries AD. The height of the furnace should correspondingly higher than the 19th century furnaces in this region and could be around 4 feet. Two other bowl furnaces in broken condition were found in the trenches near the one exposed and they indicate the active smelting operation in this ancient industrial site. The wrought iron piece and the granite slabs found near the broken furnace show the nature of smelting. The bowl furnace at Kodumanal probably attained a temperature of 1300° C well above the minimum temperature at which iron oxide can be reduced to iron but substantially below the melting point of the metal. The iron thus produced would be still in semi - solid condition as sponge iron with other impurities embedded in it. The iron required further heating and forging before it could be made malleable and soft for further use. The granite slabs found near the furnace suggests their use as an anvil for forging.

Tamil classical works *Purananuru* v.13. *(kolkalirrāl kāppudaiya veḷummurkkip ponniyar punaitoṭṭiyān, i.e.* the ferrules covering the tusks of elephants were made of steel) refer to the artefact made of *Urrukku* i.e., fused metal or steel (Burrow: 1961, p.569). The excavations at Kodumanal yielded important evidence regarding the manufacture of steel by crucible process as early as c.300 BC. The crucible furnaces exposed of which one was in unused condition were found at a depth of 125 cm below the ground, right on the natural soil. The crucible furnace was oval in shape and was

surrounded by twelve small furnaces. The oval shaped furnace-measured 112 cm north - south and 100 cm east - west. The furnace had a depth of 40 cm and the furnace wall had a thickness of 20 cm. The small circular furnaces had a diameter of 30 cm at the mouth with a small hole or depression at the centre. The main furnace had rectangular holes made in an acute angle near the mouth and the small furnaces were connected to the main furnace through burnt clay pipes. The small furnaces were used as low temperature zone, where the crucibles collected from the main furnace were kept to cool down by air. The presence of Widmanstatten structure in the artefact from Kodumanal confirms that the metal was fast cooled in air. The Widmanstatten structure occurs in steels, which have been rapidly cooled from a high temperature (~1000° C) but not quenched with water. The Widmanstatten structure is formed by the ejection of ferrite or cementite along certain crystal planes forming a mesh like arrangement (Tylcote: 1964, p.316). The absence of martensite and the presence of Widmanstatten structure in the artefact from Kodumanal showed that it was a fast cooled one but not quenched with water. The accounts of Buchanan, Heath and others clearly describe the use of bellows and tuyere in the manufacture of wootz steel as against natural drought used by the ancient makers of steel in the Salem region. The presence of post-holes around the crucible furnace area indicates that there was a superstructure over the industrial site. The location of the steel making industrial site in the midst of the occupation area unlike the iron smelting furnace site and the relatively better living condition of the steel producing artisans than their iron smelting counterparts points to the flourishing market for the value added product from Kodumanal. The iron and steel industries at Kodumanal played an important role in the trans-regional trade in ancient Tamilnadu. This is clearly revealed by the occurrence of Roman wares, potsherds bearing Sanskritized inscriptions in Brāhmi script and punched marked coins contemporaneous to the industries discovered (Rajan: 1994, p.97).

MEL - SIRUVALUR

The manual of South Arcot district (Garstin: 1878, pp.441-451) states that iron is found in abundance in parts of Tiruvannamalai taluk, on the slopes of the Kalrayan hill and in Sankarapuram taluk. Three iron producing industrial centres datable to megalithic period (c.200 BC to 300 AD) were found at Pakkam, Puthianpettai, and Ravatnallur besides Mel-Siruvalur identified by Sarada Srinivasan. Hero stone inscriptions in *Vatteluttu* character and dated in the 24th and 29th regnal year of the Pallava king Simhavishnu (c.550 to 580 AD) were discovered by the author along with SriRajavelu (A.S.I.Epigraphy branch) in the course of the field exploration on the western outskirts of the villages Mel-Siruvallur and Pakkam. Mel-Siruvallur is situated 8 km South of Moongilthuraipatu on the Sankarapuram Road in SankarapuramTaluk in South Arcot district. The megalithic (c.200 BC to 300 AD) cairn circles found on the western side of the road in disturbed condition indicate the occupation of the site in antiquity. Sarada Srinivasan of the Institute of Archaeology, London, identified evidence of metallurgical activity from a mound on the southern periphery of the village in the year 1991. According to her, the villagers had no memory of any metallurgical activity in recent times in this village. The functioning of the steel industry in early times was revealed by the presence of debris of the furnace material, vitrified slag and broken crucibles from the mound (Sarada Srinivasan: 1994, p.52). Numerous crucible fragments and a bowl shaped vitrified crucible in broken condition together with glassy slag were collected by the author in a field on the southern side of the habitation. The broken crucibles and slag material were analysed by Sarada Srinivasan. The main constituents of slag consisted of iron and silica suggested that these were of fayalite type. This suggests that the initial smelting of ore was carried out in a bloomer furnace as was done at Kodumanal. The iron bloom thus produced may have formed part of the charge to produce wootz steel by crucible process. Her investigation of crucibles also revealed that the fabric of the Mel-Siruvalur crucible consists of a porous glassy matrix with distinctive cooked rice hull relics dispersed in the matrix along with sand or quartz grains, a distinctive feature of the manufacture of Deccani Wootz Crucibles (Sarada Srinivasan: 1994, p.56).

KATTANKULATHUR

An early iron smelting industrial site is found at Kattankulathur, about 35 km South of Madras and 5 km North of Chingleput town on the national high way. The site is located 1 km southeast of Kattankulathur Railway station. The industrial site measures an area of 10 acres with two mounds in the middle. The mound measures 500 square meters of which one is partially exposed revealing the base of a furnace, tuyere, blowpipes and slags. Black and red ware pottery pieces were picked while clearing the vegetation around the furnace area. Two round pits each measuring 45cm in diameter were found scooped out of the natural bedrock near the mound. The pits, basing on its location near the smelting site, were probably used by the smelters to pound the ore into small granules. The account of Balfour in the year 1855 refers to the presence of iron bearing rocks on the hill near Venpakkam, 5 km south of Chingleput town and the ore from this region might be a source for the early smelters of Kattankulathur. Wet chemical analysis was done on the iron sample collected from Kattankulathur in Chingleput district. Most of the iron present in the artefact was transformed into mineral form (Fe_3O_4) elemental iron was found in the order of 38.16%. The other elements found in the sample include carbon 2.10%, Manganese 0.58%, Phosphorous 0.038%, Sulphur 0.019%, and Silicon 6.48%.

PERUNGALUR

Perungalur is located (10° 56′ N 78° 29′ E) 30 km from Tanjavur towards Pudukkottai. The statistical account of the then Pudukkottai state for the year 1813 refers to the rich iron bearing laterite deposits and iron smelting operation at Perungalur. The antiquity of the town is seen by the presence of megalithic burials which can be dated to 1st century BC to 3rd century AD on the basis of megalithic incursion into Pudukkottai region from lower Kaveri region around 2nd –1st century BC. A bowl shaped furnace along with slags, tuyere and Black and Red ware pottery were found by the author in a farmers field. On enquiry, the furnace was found unearthed along with the other materials three feet below the ground in the

midst of the field where the farmer was digging for a well. The site where the furnace was discovered lies on the outskirts of the Perungalur town towards Tanjavur. The furnace measures 65 cm in width and 55 cm in breadth. Molten iron slag piece was taken from the furnace rim portion and analysed. The study revealed that the major constituent was silicon- dioxide and its presence on the outer surface was 45.49% and 24.93% on the inner surface. The other elements present in the slag were Manganese dioxide (MnO_2) 2.88% on the outer surface and 1.90% on the inner region and Carbon (C) 2.30% . The presence of Iron oxide (Fe_2O_3) on the two regions was 51.63% and 73.13%.

VEPPANGUDI

An iron-smelting site is found near the village Veppangudi about 3 km east of Tiruvarankulam town. Iron furnace, blowpipes and tuyeres are found embedded with slag forming into a huge mound covering an area of one acre. A megalithic habitation site (1st century BC to 3rd century AD) is situated 2km from the industrial site. Wet chemical analysis was done on the iron sample collected from the industrial site on the outskirts of the Village Veppangudi in Pudukkottai district. Most of the iron present in the artefact was transformed into mineral form (Fe_3O_4) elemental iron was found in the order of 36.18%. The other elements found in the sample were Carbon 2.26%, Manganese 0.52%, Phosphorous 0.041%, Sulphur 0.016%, and Silicon 7.10%.

SUMMARY

Archaeological studies in Tamilnadu revealed the entry of iron using people around c.500 BC and with their arrival there was a great leap forward from stone age to iron age. The early entrant was not only well versed in smelting the ore into iron but also had considerable knowledge in making the famous Indian Wootz steel. The twin oval shaped furnace excavated from Guttur was one of the biggest furnace so for unearthed in India. The artefact analysed from the furnace area indicate that it was a white cast

iron. The reference in the early Tamil classical literature *(Kurunthokai,* v.155*)* and the terracotta ring mould from the excavated industrial site near Coimbatore indicate that the early iron-mongers produced white cast iron not by accident but with deliberate knowledge. The cast iron artefact and the twin furnaces from Guttur indicate the existence of iron foundry as early as c.500 BC in Tamilnadu. The bowl furnace and the crucible furnace from Kodumanal showed that the early smelters reduced iron in a spongy form in the bowl furnace and later converted it into steel in the crucible furnace. The migration of iron age people from their point of entry into the interior regions of Tamilnadu also witnessed their progress from simple village-based economy to the establishment of large towns where trade, commerce, and industry flourished. The presence of metal artefacts especially of iron, besides furnace materials and enormous quantity of iron slag in the lowest stratum of the iron age settlement indicates that a substantial section of the community were artisans by profession.

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