TECHNOLOGY OF IRON AND STEEL IN KODUMANAL – AN ANCIENT INDUSTRIAL CENTRE IN TAMILNADU

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The iron and steel from India especially wootz steel was famous from earlier times and most sought after in the western world. The early Roman literature refers to the import of steel from the Chera country in south India. The excavation of an iron and wootz steel industrial site at Kodumanal and reference to wootz steel in Tamil literature of classical age (*Sangam*) indicate that the Roman Egypt imported finest steel from Tamil country.

The sword bit and a dagger piece were put to metallographic test. The study revealed that the sword bit contained spheroidal graphite phase and forge welding of high carbon cutting edge on low carbon dagger bit. A thin layer was found coated on the cutting edge and probably used to protect it from rust.

Key words: Classical literature, Ferrite, Pearlite, Spheroidal graphite, Urukku, Wootz.

HISTORICAL STUDY

The early part of Christian era witnessed the growth of Indo-Roman trade in Peninsular India and in this the maritime trade played an important role in the economic life of the Indian subcontinent from c.100 AD to 300 AD Periplus mentions the kingdom of the Cheras, their port Muziri as the chief port and an active shipping centre on the western coast (Schoff: 1915: 236). The encyclopedia of the Roman Empire, compiled by the elder Pliny under the title, *Historia Naturalis*, refers to the iron from the Seres. (Schoff: 1915: 224). The Roman knowledge of the Peninsular kingdoms especially that of the Cheras seems to have originated from Sri Lanka as it refers the Cheras as Seres (in Sinhalese language, the Tamil Chera became Seri). The Peninsular Indian trade with the

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Romans can be classified into those goods that were offered directly to the Romans by the local traders and others through south Arabian merchants. While the merchants of Roman Egypt bought some eastern products from the Malabar coast certain other products of large demand in the Mediterranean, like steel and cinnamon were not offered to them directly by the local traders and were handled by the south Arabian merchants. Roman traders bought these articles from the red sea ports. Periplus refers to the "Ferrum Indicum" among the list of imports into Abyssinia (Schoff: 1915:230).

The "Wootz", Roman Egypt imported from east, was really of good grade charcoal steel produced by native process jealously held secret and unknown to the Romans. Periplus, mentions Ferrum-Indicum among the list of articles, subject to duty at Alexandria. The paucity of archaeological material, to corroborate the early Roman literature, led the scholar to think that the source of finest steel, "the Romans imported", was from central India (Schoff: 1915:237). But two important archaeological discoveries: 1. the discovery of inscribed potsherd in Tamil Brahmi script, near the Red sea (Comb: 1991:34:6) and 2. the excavation of an industrial and trade centre at Kodumanal (Rajan: 1997:75) near Karur, the capital of the Cheras, confirmed the reference in the ealy Roman literature that the Romans imported the finest steel from India and the possible source of its origin might be the kingdom of the Cheras and not central India as postulated by Schoff (Schoff: 1915: 235).

ARCHAEOLOGICAL STUDY

Kodumanal (11°6′ 42″ N, 77° 30′ 51″ E,) lies in the semi-arid zone on the northern bank of Noyyal, a tributary of river Kaveri and the village is actually situated on the ancient trade route connecting Karur, the capital of the Cheras of the classical age (300 BC to 300 AD) with the western coast through the Palghat pass. Pattirrupattu the classical literature (v:67,74), refer to the thriving commercial and industrial activity at Kodumanal in the ancient period (c. first century AD).

Habitation-cum-burial complex is situated 20 km west of Chennimalai, a place noted for its rich magnetite ore and one and a half-km south of Kodumanal village. Mining & Smelting of magnetite iron in the Chennimalai region was reported till about the middle of the nineteenth century A.D, in the memoirs of Francis Buchanan (Buchanan: 1988:285) and in the reports of Heath (Heath: 1837:185-92) and Campbell (Campbell: 1842; 217-8).

The industrial site at Kodumanal was discovered by S.Raju (Rajan: 1994:57) in the year 1961 and the excavations at Kodumanal over five seasons by the department of archaeology, Tamil university and the state department of Archaeology brought to light the vestiges of cultural artifact revealing the presence of iron, steel and gem industries at Kodumanal from the beginning of cultural life around c.300 BC (Rajan: 1997:77-9).

The excavation exposed an iron and steel industrial centre in two groups of trenches 300 meters apart from each other and situated respectively on the southern and northern part of the habitation mound (Rajan: 1994:65).

The trench laid on the southern edge of the habitation mound yielded a circular base of a bowl furnace 115 cm in diameter at a depth of 65 cm. right on the natual soil (Fig 1). The shape of furnace area was distinguished by the white colour, caused perhaps, due to high temperature. Iron slags burnt clay embedded with slag, tuyere pieces with vitrified mouth and a granite slab were collected near the furnace area. Some of the iron slag stuck to the wall portion of the furnace had a smooth surface. Presence of tuyere 15 cm in length, 6 cm in thickness and a hole of 1.5-cm diameter suggest that the bellows were used quite nearer to the furnace.

Crucible Furnace (Line Drawing)

Diameter: North-South-112 cm, East-West-100 cm, Wall thickness-20 cm

Small Furnace: Diameter Top: 9 cm, Base: 0.9 cm

Fig 1. Crucible furnace (Line drawing with small furnaces)

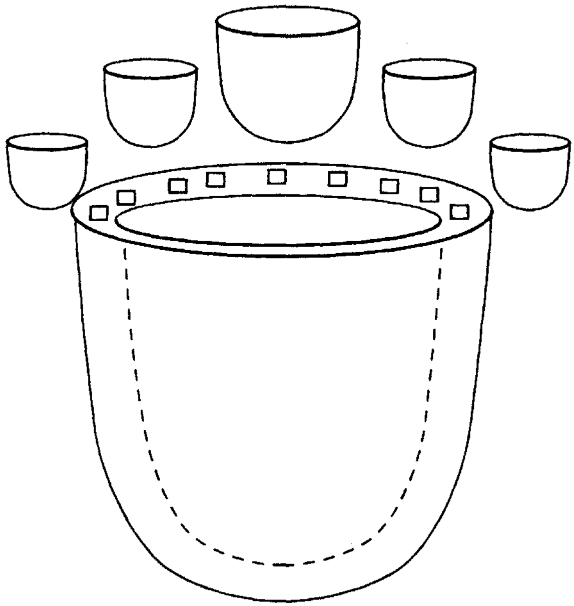


Fig 2. Model of bowl furnace at Perungallur (1st Century AD)

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 is still in semi solid condition as sponge or raw bloom from which the slag partially drains away, rest of the slag and gong material is removed by hammering while the slag is still in fluid state (Tylcote : 1962: 183-4).

The absence of potholes, floor level and the mere occurrence of potsherds devoid of other cultural artifact in the smelting area suggest that the iron smelting was done on the periphery of the habitation. Pre-industrial Indian steel "wootz" became popular for its cutting qualities. Purananuru (v: 14), mentions the famed Indian steel as "URUKKU" meaning steel or fused metal (Burrow: 1961:569). The excavations at Kodumanal yielded important evidence regarding the manufacture of wootz steel by crucible process in the Chera country. Kodumanal was one of the earliest wootz steel producing centre in south India and probably exported steel to the Roman Egypt, as reported by the elder Pliny in his *Historia Naturalis*, as the iron from the Seri. Three hundred meters north of the iron-smelting furnace, a large oval shaped furnace surrounded by 12 small furnaces was exposed at a depth of 125 cms. The small furnaces were used as low temperature zone, where the crucibles collected from the main furnace were kept, to cool down slowly in the low temperature zone (Fig. 2). The absence of tuyere in the crucible furnace suggests the use of natural drought of air for blast (Rajan: 1994:66). The wootz steel at Kodumanal was manufactured by the carburization of iron in a crucible furnace where a batch of close crucibles with low carbon iron charge were stocked and fired on a 2½-4 hours cycle at high temperature. The steel inside the crucibles when opened was found with a metallic surface with a tendency to crystallization, which showed that the metal had undergone complete fusion (Tylcote: 1962:294).

Metallurgical Study

A sword bit (Fig. 3) and a piece of dagger (Fig. 4) are the artifacts metallographically examined, and the study revealed the technology that went into the making of the artifacts. The polished and etched surface of the sword bit revealed a microstructure of ductile iron with graphite nodules (spheroidite) in an envelope of free ferrite. Most of the

Fig 3. Sword bits from Kodumanal habitation area

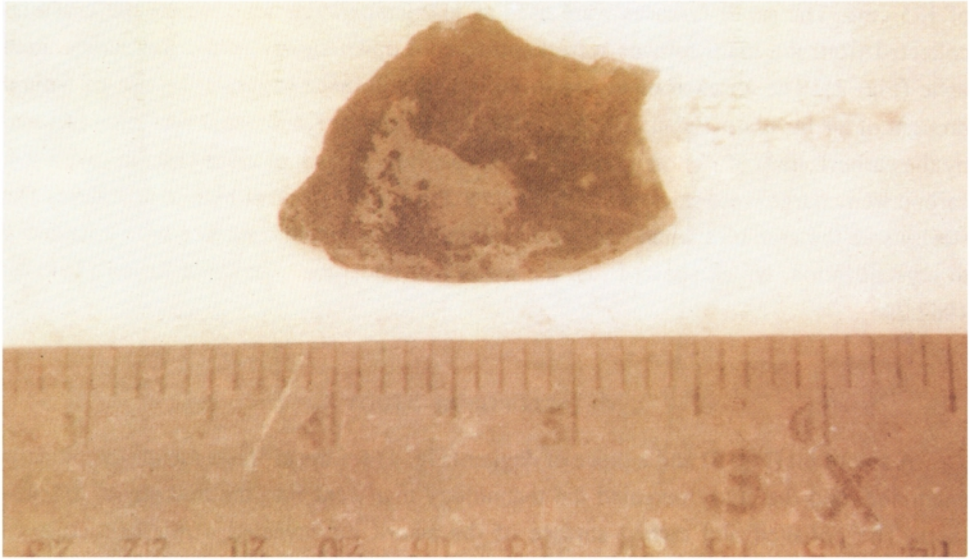
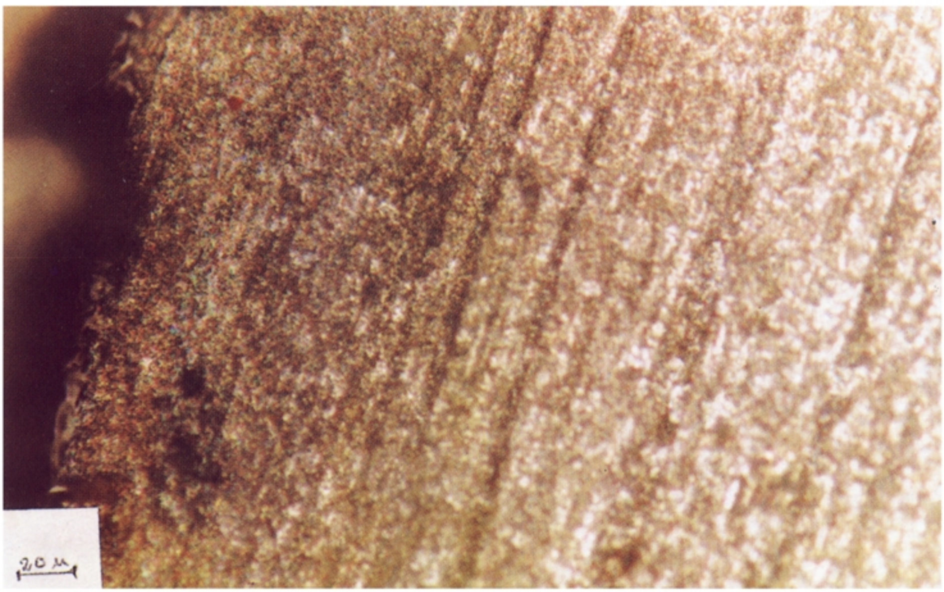


Fig 4. A dagger piece from Kodumanal habitation area

original pearlite has decomposed resulting in a matrix of free ferrite and 5% pearlite (black irregular). The addition of magnesium (or cerium, a modern process unknown in ancient times) spheroidial the graphite, which appears. globular in the microstructure (Fig.5). It has to be ascertained by further analysis of iron artefact from Kodumanal that the spheroidal graphite iron obtained was accidental or deliberately made by the artisans of earlier days. Some of the seaweeds contain higher magnesium content(4%) and the artisans probably used these weeds instead of green leaves (*Acacia auriculata*) normally used in the crucibles thus resulting in the formation of S.G. iron instead of wootz steel. M.D.Kajale (Kajale: 1994:vol. 4, no.35, 32-33) in his report on plant remains from Kodumanal excavation, referred to the presence of weeds like Euphorbiaceae type (single seed weed) and indeterminate grass weed, but it is not known about the level of magnesium in these weeds. The cutting edge of the dagger has a thickness of 1.0 mm and appears to be forge welded to the centre piece. The carbon content of the cutting edge is around 0.8% (Fig.6). The microstructure of the centrepiece contained mostly ferritic grains with a few patches of pearlite (Fig. 7), whereas the cutting edge shows mostly pearlitic grains with globular carbides (Fig 8). The hardness studies confirm that the centre piece is softer with about 100 vhn and the cutting edge being hard with around 240 vhn. Micro structural studies showed that the cutting édge is coated with a thin white layer (Fig 9). It is interesting to note that the cutting edge is not corroded even though it was made


20 µ

2000 years back. However, the region where the edge is chipped off was corroded (Fig.10). Purananuru (v.95)refers to the painting of iron artifact with ochre and ghee to protect it from rust. The white layer in the cutting edge probably indicates the oxide coating mentioned in the early literature.

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