

In the footsteps of Ananda Coomaraswamy: Veralugasmankada and the archaeology and oral history of traditional iron smelting in Sri Lanka

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ABSTRACT: Two well-preserved, bellows-driven, shaft furnaces are representative of a traditional, village-based iron-smelting technology that survived into the early 20th century. The excavation data is one component of the record of this technology, which is supplemented by the illustrated eye-witness account by Ananda Coomaraswamy, and also by more recent interviews with the last local inhabitants with first-hand experience and memory of the process itself and the craftsmen involved. These strands of evidence are brought together to give a near-complete description of a bloomery process that has parallels on several continents and the potential to inform the interpretation of many less-complete records.

Introduction

It is not often in archaeometallurgy that the convergence of documentary, ethnographic and archaeological records allows the near-complete description of an obsolete technology. This is, however, the case for the traditional village iron-smelting technology of Sri Lanka. The soundness of the account is underpinned by the knowledge that all three records derive from the same geographical location. While the data presented is strongly location-specific, the process being described—iron smelting in a small, bellows-driven shaft furnace—is ubiquitous on several continents and therefore has the potential to inform the interpretation of many other less complete records.

This paper focuses on the archaeological excavation of two village smelting furnaces but draws extensively on ethnographic and documentary data to ‘flesh out’ the account with real characters and give it a human context. The individuals featured here are among the last people in the world to smelt iron by traditional methods.

Ananda Coomaraswamy and the iron-workers of Balangoda District

Anyone with an interest in the ethnography of iron outside of Africa is likely to have read the eye-witness accounts of traditional iron smelting and crucible steel manufacturing in Sri Lanka, recorded in the early 20th century by Ananda Coomaraswamy (1956). The detail, clarity and insight of the accounts, enhanced by drawings and several photographs (Figs 3–5), could only be the work of someone aware of the significance of the then near-moribund processes in the context of contemporary European interest in Asian technology, crafts and resources. This vision is characteristic of the polymath Coomaraswamy, who became the first keeper of Indian Arts at the Museum of Fine Arts, Boston and was one of South Asia’s best-known philosopher-art historians. The accounts derive from the period 1902–1906 when Coomaraswamy was Chief Mineralogist of the Ceylon Mineralogical Survey. In this role his fieldwork took him to Balangoda on the southern flanks of the central highlands (Fig 1). Coomaraswamy knew that traditional iron smelting and steel-making were still active in the area and appears to have sought out the places where

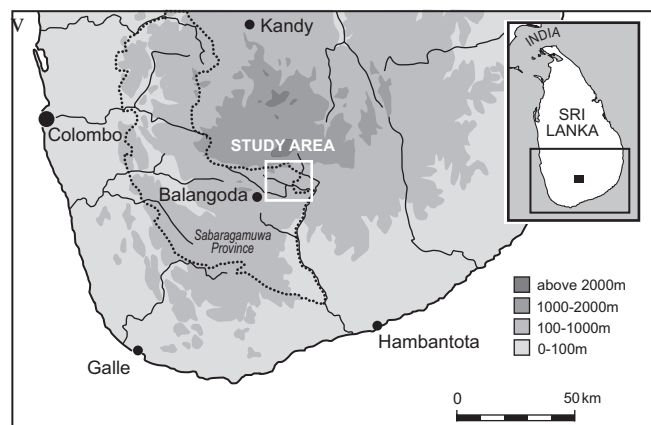


Figure 1: Map of Sri Lanka with Sabaragamuwa province and Samanawewa project area outlined.

steel was produced, mentioned in an earlier and equally significant account by Ondaatje (1854).

Setting aside the account of crucible steel making (Wayman and Juleff 1999), what Coomaraswamy witnessed in the village of Hatarabage (Fig 2) was traditional iron smelting using a small bellows-driven shaft furnace. The demonstration staged for him was carried out by an old man called Kiri Ukkuva and his sons, who were members of the *yamannu* (smelters) caste. Coomaraswamy's description of the furnace structure and the process is reproduced here as Appendix A. The accounts first appeared in 1903 and 1904 and were to some extent re-worked in later publications (Coomaraswamy 1907; 1961), the best known being the second edition of

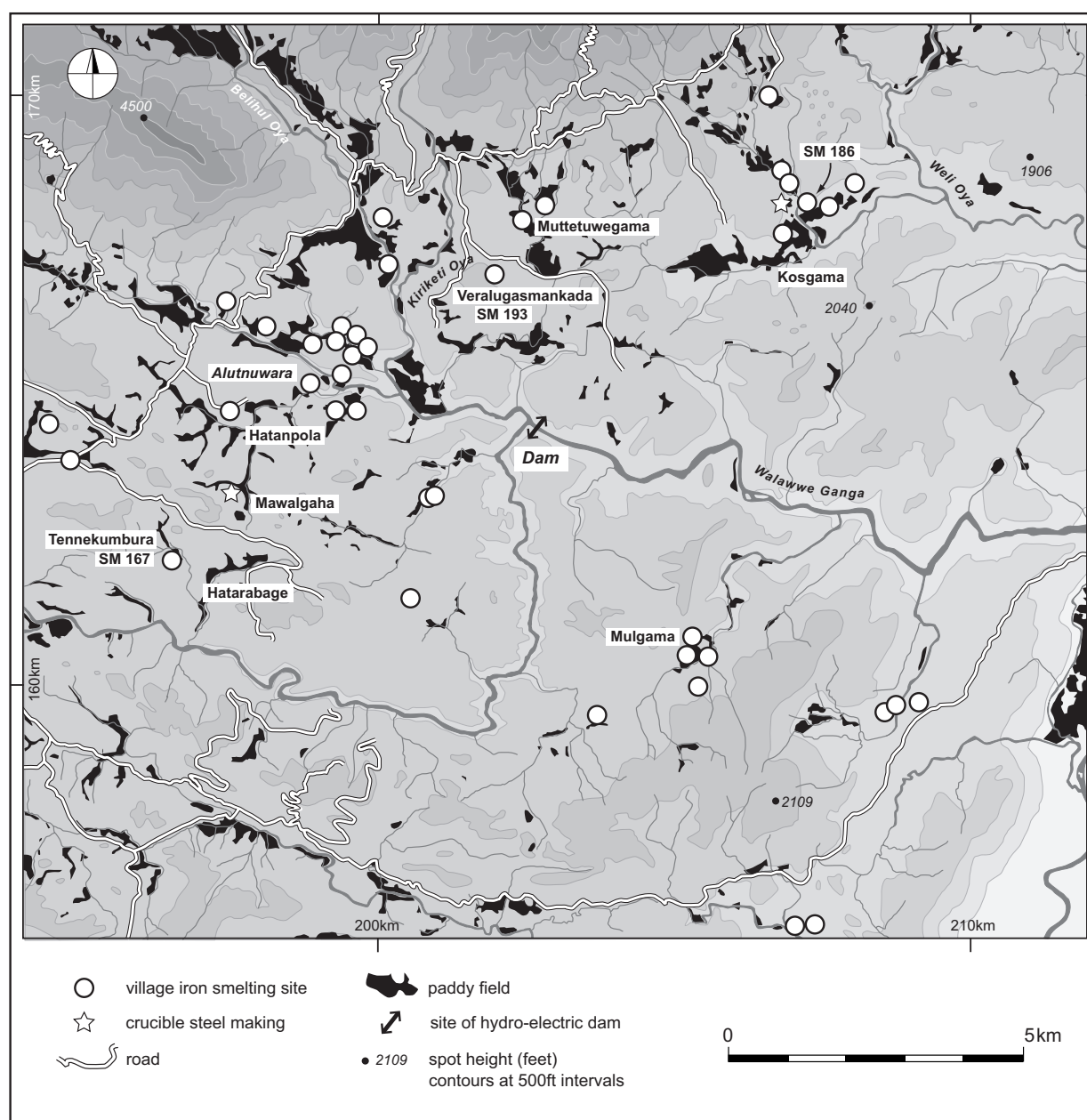


Figure 2: Map of the Samanawewa project area showing places mentioned in text and all village smelting sites recorded.



A

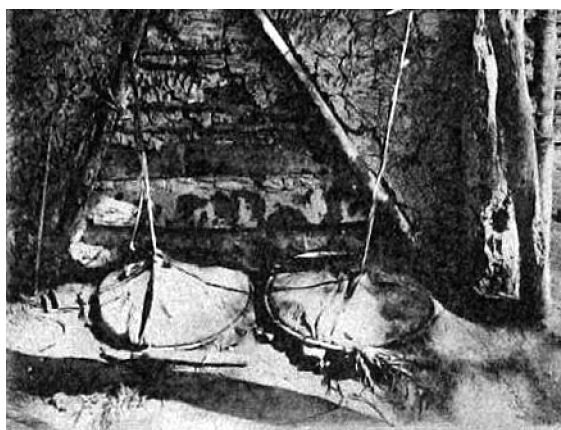


B

Figure 3: Iron smelting demonstration at Hatarabage held for Ananda Coomaraswamy. A: the workshop with two furnaces and the bellows operator visible behind the wattle and daub wall separating the bellows from the furnace. B: detail of the smelter, possibly with his foot on a stepping stone at base of structure. The two large shoulder stones appear to be plastered into the structure.

Medieval Sinhalese Art (Coomaraswamy 1956). Copies of the photographs taken during the smelting demonstration, reproduced in *Medieval Sinhalese Art*, have been on display for many years in the Kandy Museum in Sri Lanka. It appears that Coomaraswamy's English wife, Ethel, a woman who made her own significant contribution to textiles and weaving in the arts and crafts movement (Jayawardena 1995, 169), travelled with her husband as the photographs taken at the time (Figs 3–4) are attributed to her (P Sivaprakaspillai, pers comm).

It is important to note that Coomaraswamy's section and plan of the furnace (Fig 5) are likely to have been simplified. Certainly, the furnace chamber he depicted has nothing of the subtle changes in profile found on the contemporary excavated examples described in this



A



B

Figure 4: A: the foot bellows used in the Coomaraswamy smelting demonstration, showing their construction. B: the operation of similar bellows at Mawalgaha where Coomaraswamy recorded a demonstration of crucible steel making.

report. In fairness, he would have had little opportunity to appreciate the complexity of the chamber unless he too had excavated one of the furnaces. This suggests other smelting furnaces illustrated in ethnographic accounts of the 19th and early 20th century may also be lacking in significant detail.

The Samanalawewa Archaeological Survey

It was Coomaraswamy's accounts that provided the initial impetus for the Samanalawewa Archaeological Survey. Revisiting the villages he mentioned seemed the obvious first step in identifying field evidence for iron production and correlating it with documentary accounts. The opportunity and imperative for the survey were then provided by the eponymous hydro-electric scheme that threatened to inundate a large portion of the low-lying land of the area (Fig 2).

The first core area survey took place in 1988. In 1990 a

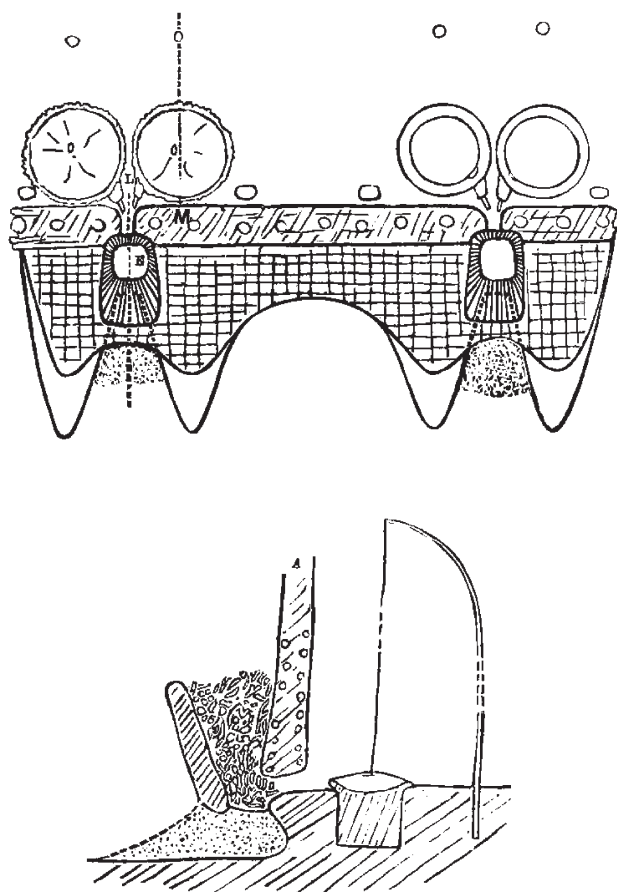


Figure 5: Plan and section of the iron smelting furnace at Hatarabage (after Coomaraswamy 1956, plate 53).

second field campaign surveyed outlying areas specifically for archaeometallurgical evidence, resulting in a total area of about 78km² being examined. While the survey was not comprehensive, the sampling level was estimated to be as high as 75% of the archaeological record (Juleff 1998, 45). A total of 140 sites relating to iron-working were identified, of which 42 presented features that were consistent with elements of Coomaraswamy's descriptions. Ironically, despite being the original focus of the survey, these 'village' smelting sites, so called because of their location within village settlements, were eclipsed from the outset by the 'west-facing' group of late 1st millennium wind-powered iron-smelting sites (Juleff 1996) and only now receive deserved recognition.

Ethnographic survey

At the time of the first field survey at Samanalawewa, Coomaraswamy's eye-witness account was only 84 years old, sufficiently recent for the iron-smelting industry to perhaps still be within living memory. Although Coomaraswamy (1904) reported that the technology was on the brink of extinction, his own annual production

figures of 200 blooms for three families implies a reasonably healthy output (though 200 may be a misprint for 20, based on local *devale* (temple) records requiring six blooms a year from one household (Juleff 1998, 356)). A further demonstration of iron smelting took place at an exhibition in 1922, suggesting that while the technique may have been largely moribund by then it was not entirely forgotten (Nell 1922).

Thus, at the same time as the field surveys were being carried out, the Samanalawewa project also collected ethnographic data on the metallurgical traditions of the area. This was done through chance encounters during field reconnaissance, casual conversations and arranged interviews with residents of the village settlements. The initial aim was to identify the locations where the iron smelting and steel-making processes that Coomaraswamy witnessed actually took place. This objective developed into a more comprehensive recording of the experiences, knowledge and memories of the descendants of the last smelters and smiths of the area. The primary data comprised a series of 14 interview transcripts which have been synthesised and discussed alongside other sources, such as temple records of feudal duties and dues (Juleff 1998, 343). Three of the interviews, with K G Augustina, K G Giragi and D K Ranhavadiya (Figs 8, 21 and 22), are directly relevant to site SM193 described below, and these transcripts are reproduced in Appendix B.

Augustina, the last person alive to have actively participated in iron smelting, lived in the village where Coomaraswamy watched iron being smelted; she may indeed be one of the smallest children in Figure 3. Giragi is Augustina's cousin and married into the smelting family that lived at Veralugasmarkanda and operated the furnace reported on here. While she remembered iron being smelted she was never particularly involved. Her son, Ranhavadiya, on the other hand, despite never having seen the process, was deeply interested and listened intently to the recollections of his father and uncles. He had also written down the words of two traditional working songs that his family sang (Juleff 1998, 122); the translation of one of them is given in Appendix C.

Location and setting

The area known as Samanalawewa comprises the upper reaches of the Walawwe Ganga (river) and its tributaries, and lies to the east of the regional market town of Balangoda in the province of Sabaragamuwa (Figs 1 and 2). Sabaragamuwa is rich in natural resources with an agricultural subsistence economy based on scattered vil-



Figure 6: Site SM193 (ringed), with paddy fields in the foreground and scrub-covered hillslopes beyond.

lage settlements, each with its own irrigated paddy (rice) lands. Traditional land tenureship and social structure is feudal and based on large temple (*devale*) and manorial holdings. In this area the local *devale* is at Alutnuwara (Fig 2). Most villages comprise an extended tract of low-lying paddy land encircled by scattered hamlets, each occupied by a family-clan group, generally with a shared caste-craft specialisation, *eg* potters, basket-makers, farmers, smiths or smelters (for an explanation of the Sri Lankan caste system see Ryan 1953). The location of SM193 (below) was typical of the 42 village smelting sites. In a few cases possible furnace structures did survive but in the majority the evidence was restricted to deposits of slag.

SM193: Veralugasmanakada

The smelting site in the hamlet of Veralugasmanakada, recorded as site SM193 by Juleff (1998), lies next to the paddy fields that form the focus of the hamlet at the southern end of the larger village of Muttetuwegama (Fig 2). Veralugasmanakada formed a satellite community of iron smelters primarily serving the larger village. The site was first located in December 1990 through contact with Ranhavadiya and Giragi. Ranhavadiya knew the



Figure 7: Site SM186 on a scrub-covered slope overlooking Kosgama paddy fields.

whereabouts of slag deposits and furnace remains in the area and was able to guide the project team to the site.

The furnace site lies in a valley bottom on the NW edge of the paddy fields which serve the hamlet (Fig 6). Immediately to the north and west are steep hillsides now covered with high grass indicative of *chena* (swidden) cultivation. The re-growth of scrub on the site largely



Figure 8: Furnace SM193 from the NW showing partially excavated vertical stone slabs with the hole cut for bellows access visible in the central stone; D K Ranhavadiya is looking on.

obscured the upstanding remnants of the furnace and associated scatter of slag, and without Ranhavadiya the site would not have been identified.

SM186: Kosgama

The first site identified by the survey with visible furnace remains was situated on scrubland adjoining a large tract of paddy land in the village of Kosgama, c.5km to the east of SM193 (Fig 2). The remains of a pair of village smelting furnaces protruded through the ground surface (Fig 7). The site was investigated on the day of its discovery because it was remote from the core area of the project and was unlikely to be revisited. The results of this investigation are included in this report for comparison with SM193 and because the subsequent ethnographic survey established a family connection between this and other sites in the main Samanalawewa survey area.

Excavation at Veralugasmankada (SM193)

The furnace survived as an upstanding feature visible amongst the vegetation that had started to reclaim the levelled terrace on which it was constructed (Fig 6). In spite of the vegetation, initial assessment suggested little damage had occurred to the furnace; its internal cavity was filled with soft earth. Much of the very top rim of the shaft was eroded but sufficient remained to indicate its position, and one of the pair of large supporting stones on either side of the slag-tapping arch at the front of the furnace had been removed. Otherwise, the hard-fired clay lining of the furnace was undamaged. While some of the stony soil banked around the furnace for support had also eroded, the majority remained and comparison with Coomaraswamy's photographs (Fig 3), indicated an exceptional level of preservation.

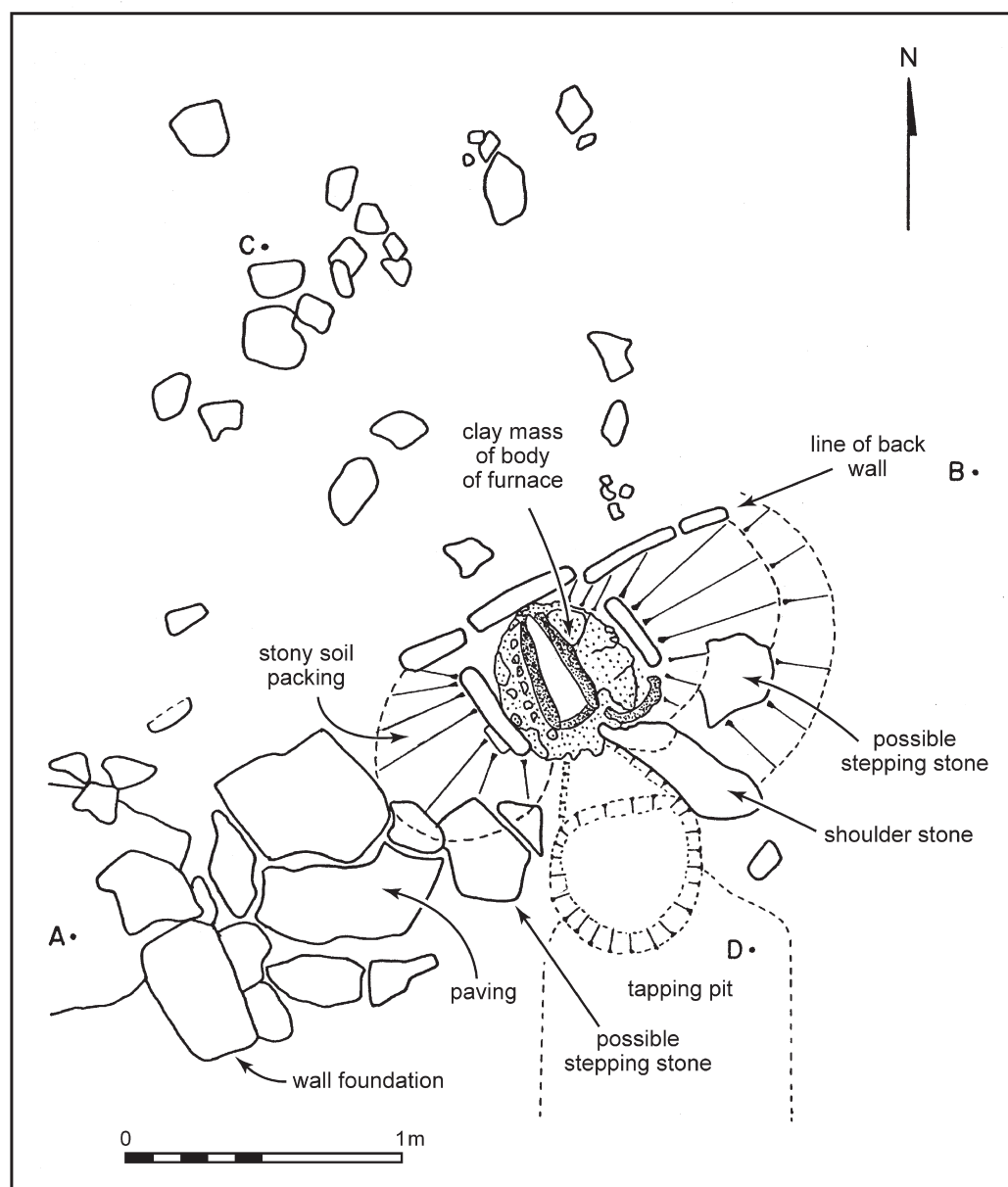


Figure 9: SM193 excavation plan.



Figure 10: Detail of furnace SM193 after the stone lintel of the tapping arch and the clay furnace wall above it have been cut through. The blowing hole is visible protruding through the smooth inner lining. Scale bar 10mm divisions.

Excavation methodology

The primary aim of the excavation was to recover a complete and coherent record of the furnace. Preliminary clearing of vegetation and loose soil over an area of 5x4m revealed so much of the external fabric of the structure and the spatial arrangement of the working area that both were readily planned and photographed (Figs 8–9) (Malim *et al* 1995).

To investigate the construction, design and interior of the furnace, hand excavation removed half of the furnace. First its SW quadrant was excavated (Fig 10) followed by the NW quadrant (Fig 11). This allowed sections of the furnace to be recorded (Fig 12). For ease of orientation, the term ‘front’ is used here to describe the southern side of the furnace with the slag-tapping arch and large supporting stones. The ‘back’ refers to the northern side of the site where the bellows would have been located.

The hard, fired-clay body of the furnace was cut using hacksaw blades which gave a clean surface for the



Figure 11: Section of furnace SM193 from the W (cf Fig 12, C-D). The shape of the interior is visible as well as the cavity (to the left) between the stone slab with a hole and the furnace wall. The thinness of the front wall is also evident.

main red clay of the furnace walls but proved less successful where the clay was heavily vitrified. At the front, the furnace wall above the slag-tapping arch was thin and crumbled when cut. Samples of the main body of the furnace and of the inner relining were collected for analysis, and charcoal from a well-sealed context within the furnace was sent for species identification of the fuel used (see below). Samples of slag were also collected from the waste discarded around the site and were analysed, along with the refractories.

Summary of results

The layout of the site and the principal elements of the furnace are shown in Figures 8–14, and described below.

The platform on which the furnace stood was only superficially levelled and gradual hillslope erosion since abandonment of the site had removed, or possibly obscured, any evidence of a made or trampled floor. Evidence for the shelter covering the furnace is seen

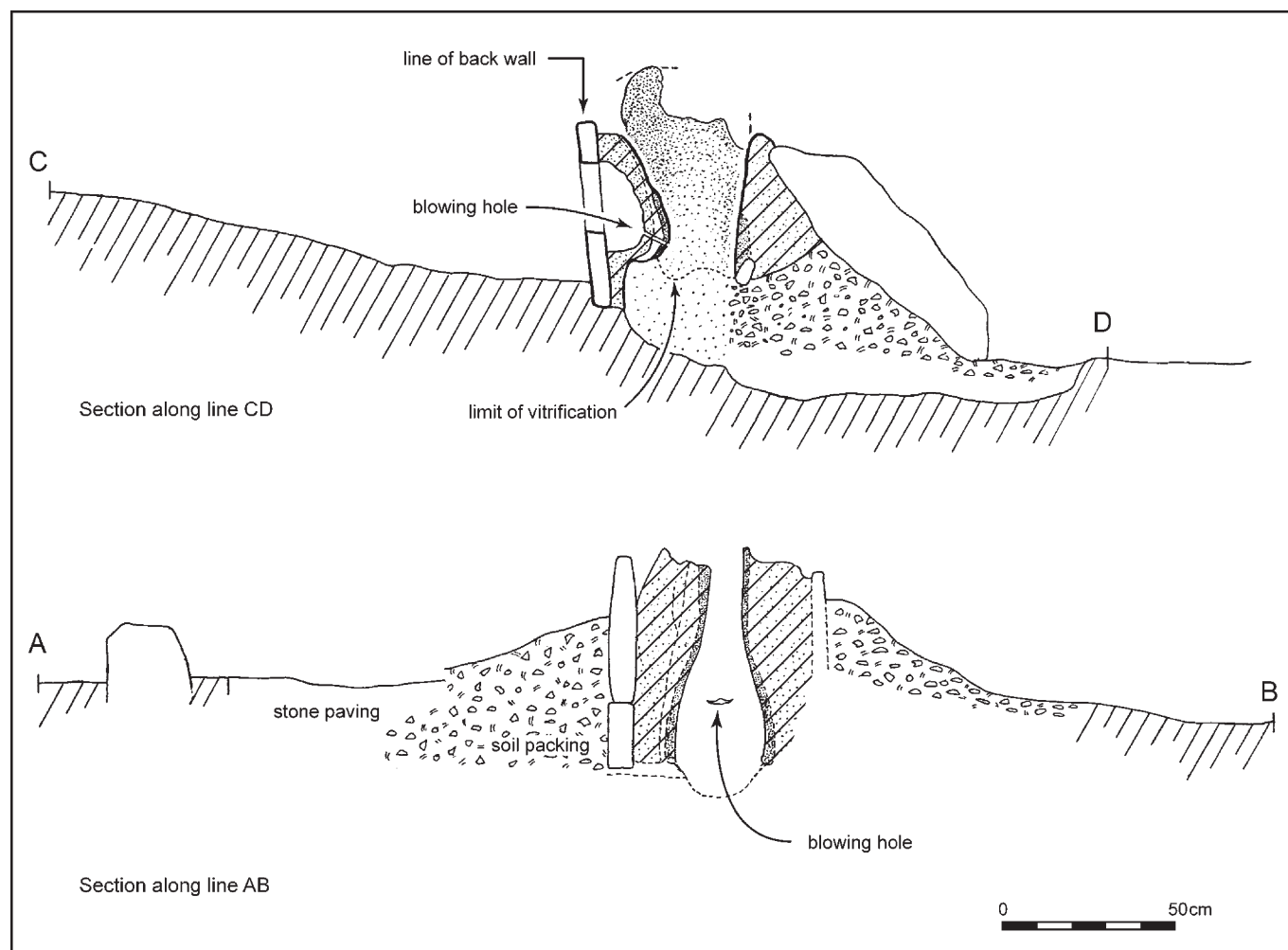


Figure 12: Sections through furnace SM193. Points A-B and C-D are shown on Figure 9. The blowing hole but not the back wall of the furnace is shown in section A-B.

in the line of tumbled stones extending for 1.9m across the back of the site 1.5m from the back of the furnace, and in the two larger stones, set upright in the ground and defining the base of a wall to the west of the furnace (Fig 9). No post or stake-holes to support the roof of the shelter were identified in the loose soil. On the basis of the evidence for an open-sided shelter shown in Coomaraswamy's photograph (Fig 3), the support for the roof would have been provided by a number of large posts to which smaller horizontal timbers were tied.

Also shown in Figure 3 is a wattle and daub wall separating the bellows from the furnace. At Veralugasmarkada this position is marked by a line of four stone slabs, set vertically in the ground, separating the furnace from the area where the foot bellows would have been located (Figs 8–9). If the line of these slabs is extrapolated to the west it follows the edge of a small area of paving and the wall foundation described above. A step in the level of the subsoil along the line of vertical slabs and the edge of the paving (Fig 12, C–D), with the paving on the

lower level, provides further evidence that the vertical slabs formed the base of a barrier. This separated the front of the furnace from the bellows, and also provided support for the roof.

Slag and smelting debris lay scattered to the south, just below the furnace terrace. The focus of the excavation was the furnace structure itself so no measurements were made of the extent or quantity of slag, especially as it was not confined to a discrete deposit. The amount of slag was not substantial and this, combined with the apparent single-phase use of the platform, suggests that smelting at this site had not been long-lived, although the furnace itself had been re-fettled (see below).

The furnace was constructed within a shallow pit cut into the lower level of the platform. The same shallow pit also functioned as the slag-tapping pit, extending south from the front of the furnace (Figs 9 and 12). The slag pit was defined by hard edges near the furnace but became increasingly less distinct further away.



Figure 13: Top of furnace SM193 from N showing triangular plan of the upper shaft, the line of stone slabs defining the back wall at the bottom, the remaining shoulder stone of the front arch in position, top left, and near it a curving fragment of furnace wall protruding from the clay furnace body. Scale bar 100mm divisions.

The superstructure of the furnace was formed within a box of large stone slabs. The back of the box was the line of vertically set slabs already described. Cut into the centre of the largest slab was a rectangular aperture, 120x150mm, aligned with the blowing hole (Figs 8 and 12). The E and W sides of the box were also formed by large, vertically-set stone slabs. That to the W was shown by excavation to be two vertical slabs set one on top of the other (Figs 10 and 13). The fourth side is the front of the furnace, which accommodates the slag-tapping arch, and is formed by two much larger sub-rectangular blocks of stone set in the ground to form an inverted V. That on the western side had been removed but its imprint remained visible so its original existence could be recorded (Fig 14).

To provide further support for the box, external mounds of stony soil were banked up against the vertical stone slabs on both the west and east sides, filling the areas between the vertical slabs of the back wall and the



Figure 14: Furnace SM193 from the S after removal of some soil packing between the paving and the vertical stones of the box to the left of the furnace chamber. The tapping arch and crumbling front wall are exposed. The horizontal stone slab behind the in situ shoulder stone is possibly a stepping stone. Scale bar 100mm divisions.

large stones forming the shoulders of the tapping arch. Immediately behind the shoulder stone on the eastern side, a large curved fragment of used furnace lining had been incorporated into the stony packing, probably as a repair or reinforcement (Figs 13–14). The overall result was a mound, extending for almost 2m from E to W, containing the stone slab box (Fig 12, A–B). It is probable that erosion lowered the mound, leaving the top of the furnace exposed and the stone slab box visible. There was no evidence for corresponding paving or a wall foundation on the east side of the mound. However, after cleaning away the loose soil from the mound, two large flat-topped stones were revealed, set into the bottom edge of the mound material, immediately adjacent to the positions of the shoulder stones forming the tapping arch. These appeared to have no structural function but could have been stepping stones, allowing closer observation of the top of the furnace (Fig 9).

Table 1: SEM-EDX analyses of slags and refractories from SM193 (normalised wt%)

BRML No		SiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	TiO ₂
43921T	Furnace lining matrix	52.9	40.3	2.8	<0.3	0.8	0.3	<0.3	1.6	<0.3	0.7
43920V	Furnace lining matrix	56.8	32.6	2.8	<0.3	0.5	0.4	0.4	4.9	<0.3	1.2
43919S	Low-fired furnace wall matrix	55.8	36.5	3.6	<0.3	0.5	0.3	<0.3	1.7	<0.3	1.0
43933W	Slag, bulk	26.1	6.7	56.0	0.7	1.6	3.2	0.7	1.6	0.8	0.5
43933W	Slag, wustite phase	0.8	0.9	96.5	<0.3	<0.2	0.4	<0.3	<0.3	<0.3	1.4
43933W	Slag, fayalite phase	28.7	0.4	64.3	1.0	4.3	0.6	<0.4	<0.3	<0.3	<0.3
43933W	Slag, glass phase	36.3	15.5	26.7	0.5	<0.2	11.8	1.1	4.6	2.7	1.0

Notes: Analyses were carried out using a Link Systems spectrometer attached to a JEOL JSM840 SEM, operated at 15keV and 2nA. Relative precision is better than 5% for elements in excess of 10% absolute, and better than 10% for elements in excess of 1% absolute. However, as many of the results represent the analysis of polycrystalline, multiphase samples, the accuracy of the results cannot be precisely evaluated. For details of this approach see Freestone and Tite 1986. The analyses of the ceramic matrices are each means of three analyses of areas of clay with no grains greater than 10µm. The analyses of the slag phases are of typical grains/areas. The bulk slag analysis was obtained by scanning over an area of approximately 80mm².

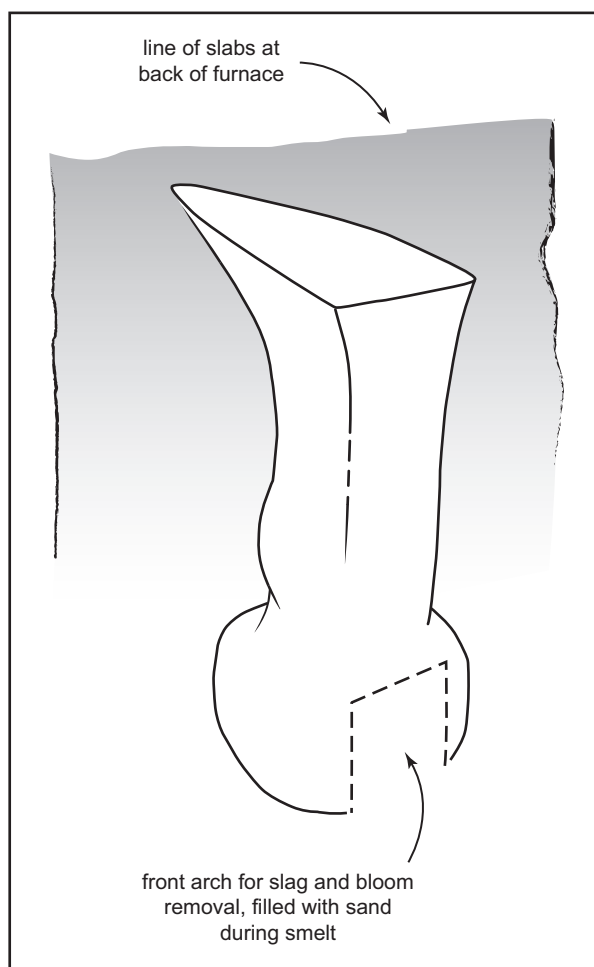


Figure 15: SM193: reconstruction drawing of the internal shape of the furnace chamber.

The furnace chamber was formed within the box structure using coarse red clay containing abundant quartz fragments. Thin-section and SEM-EDX analysis by Ian Freestone (then at the British Museum) showed that the furnace linings and furnace wall have essentially the same composition and represent the same clay which was carefully prepared by the admixture of abundant angular quartz (Table 1). This quartz or quartz-rich rock temper was probably deliberately crushed; its addition would have reduced the tendency of the furnace walls and lining to fail in use. The clays themselves are relatively refractory; however, weathering under tropical conditions tends to increase the alumina content of clay and reduces the alkali and alkali-earth oxide contents, so this clay need not have been especially sought out but may simply be a local deposit.

The sequence of construction and the complex shape of the chamber was only revealed with the removal of the SW quadrant of the furnace (Fig 10) and then of the NW quadrant to give a complete section (Fig 11). Although

the clay body and the inner lining of the chamber appear as different-coloured layers, the same coarse clay was used throughout and the colour variation is due to changing oxidation conditions. It was clear from the half-section that the chamber had been relined on more than one occasion (Fig 12). The fired red clay did not uniformly fill the box-like cavity created by the stone slabs. It appeared on excavation as a roughly cylindrical mass, c. 0.50m in diameter, leaving the corners filled with looser soil through which the fine roots of the covering vegetation had penetrated (Figs 9 and 13). It is possible that the cylindrical clay mass is the result of hard firing through heat transfer during smelting, leaving unfired and poorly-fired clay in the extreme corners which then eroded out after the furnace was abandoned. The alternative interpretation is that the furnace was formed as a cylindrical mass, with the box and packing mound added subsequently. The available evidence does not resolve whether the stone box was a permanent structure within which the furnace could be built, and presumably rebuilt, or whether it was constructed to support a pre-existing clay furnace.

Only with the sectioning of the furnace (along line C–D, Fig 12) did the complex and subtle shape of the furnace chamber become fully apparent. The shape changes throughout its height and is not a simple cylindrical shaft. At the base was a bulbous, sub-spherical slag-bloom chamber, circular in plan. Above this was a smaller combustion zone, sub-rectangular in plan, at the level where the blowing hole pierced the back of the furnace lining. Above this, the shaft narrowed further along its E–W axis, before flaring outwards to form a funnel-shape that appeared as an elongated triangle at the upper rim of the furnace (Figs 15, and 11–14). The internal dimensions were 0.27m diameter for the slag-bloom chamber, 0.20m N–S and 0.21m E–W for the sub-rectangular combustion zone and 0.40m N–S and 0.15m E–W at the open top of the shaft. The thickness of the clay forming the furnace was 0.16m in the bulbous part of the slag chamber and 0.21m towards the top of the furnace. The short remaining section of the rim of the furnace demonstrated a final outward flaring of the upper part of the shaft and showed the full internal height of the furnace was 0.85m.

The furnace was lined with fine grey clay (the colour being due to the reducing conditions within the furnace) which covered the walls from about 0.10m below the out-flaring of the rim down to the bottom, but not across the floor. Near the bottom finger marks were well preserved as the lining was fired but not vitrified at this level. Vitrification of the furnace lining began just below the

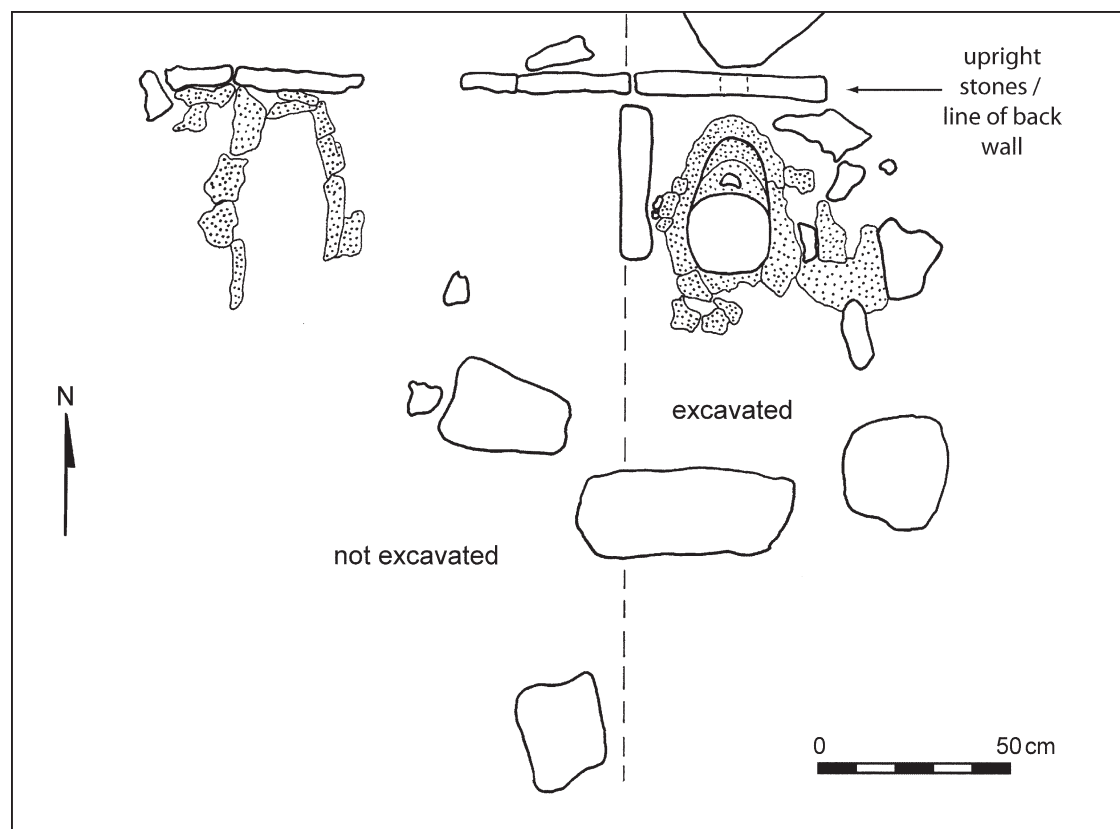


Figure 16: Plan of SM186 showing the pair of furnaces connected by single back wall.

blowing hole at the back of the furnace and extended upwards with decreasing intensity.

The arch at the front of the furnace, through which the slag was tapped and the bloom of iron extracted, was set well back between the two large shoulder stones. It was formed of small stone slabs set in clay, with a horizontal stone forming a lintel. The opening was 0.27m wide and about 0.16m tall. The sides of the arch were clearly vulnerable to damage during removal of the bloom and showed evidence of having been repaired. The clay of the furnace wall immediately above the arch was considerably thinner than that on the east and west sides, with the result that it was cracked and crumbling, and fell away on excavation.

The constriction in the cross-section of the furnace in the combustion zone is caused in the main by the inward swelling of the back wall of the furnace. This is best observed in the excavated half-section (Fig 11). The blowing hole itself is no more than a small hole, c. 40mm diameter, pierced through the clay and modelled to protrude slightly into the furnace chamber (Fig 10). Heavy vitrification occurs both above and below the blowing hole with the greatest thickness being immediately above. The inclination of the blowing hole was 27° to the horizontal, which is quite typical in early furnaces (Tylecote 1981). The half-section also revealed a large cavity between the perforated vertical stone slab and the

curving back wall of the furnace (Figs 11–12). This part of the surviving fired and vitrified furnace wall is a little over 0.10m in thickness and the cavity has a maximum horizontal dimension of about 0.14m. The only access to this cavity is via the hole cut in the vertical slab or via the blowing hole itself. It is not certain whether it is an intentional feature or the result of slumping during use or post-abandonment erosion and disturbance; see below for further discussion.

Despite careful excavation, no evidence for the settings of foot bellows, as described by Coomaraswamy and the ethnographic record, could be detected in the area immediately behind the furnace. The lack of an obvious compacted floor level, possibly removed by subsequent hillslope erosion, and the loose soil of the platform compounded the problem of identifying any cut features.

Investigations at Kosgama (SM186)

Because no further survey in the Kosgama area was envisaged when the site was first identified in 1989 (Fig 7), the general nature of the structure was resolved in a brief exploratory excavation. A measured plan of the visible surface features was made and the internal fill and deposits immediately to the front and back of the right-hand furnace were removed (Figs 16–18). The two furnaces lay 0.3m apart and were defined as a single installation by a line of vertically set stone slabs



Figure 17: Furnace SM186 from the S showing the tapping arch with stone lintel, and the large shoulder stone out of position in the foreground.

extending behind the structures. The similarity between these and furnace SM193 is evident from the plans (cf Figs 16 and 9). A full description of the furnace is given by Juleff (1998, 83).

While generally less well-preserved than SM193, the tapping arch was intact, measuring 0.25m high and 0.30m wide. On the left-hand side the arch was constructed of clay as part of the furnace lining while the right-hand side had been damaged and repaired by inserting an upright stone slab. The sides support a stone lintel encased in the clay of the furnace wall. Again, the clay furnace wall is thinnest and most damaged above the tapping arch; clearly this is an area of weakness. The large shoulder stones that define the tapping arch and retain the banks of packing soil on either side are missing, although one large stone that may have served this purpose lay discarded to the front of the furnace (Figs 16–17).

The same stone slab box structure, with the clay furnace constructed inside, is seen at this site although only two of the three vertical sides are visible. The vertical slab immediately behind the furnace was broken but preserved the base of a sub-rectangular hole, 70x150mm, piercing the stone to allow bellows access (Fig 18). Again, no evidence for bellows could be identified. A



Figure 18: Furnace SM186 from the N showing broken stone slab with part of hole for bellows access. The arch of the blowing hole in the inner furnace wall is also just visible.

large stone slab lying horizontally behind the vertical slab containing the bellows hole (Fig 16) may have served as support for a pipe connecting the bellows and the furnace but equally may not be *in situ*.

Internally, the clay furnace lining is modelled as a rounded base surmounted by a funnel-like shaft with an oval plan that flares outwards towards the top. No upper rim of the furnace survived and the full height of the structure could not be recorded but was over 0.54m. The internal surface of the lower part of the furnace was damaged and partially lost but where it survived it extended down to bedrock but did not line the base of the furnace. Above the slag-bloom chamber the surface of the wall was heavily vitrified at the level of the blowing hole but became less so towards the top of the furnace. Like SM193, the clay wall protrudes into the furnace at the blowing hole, which in this case was recorded as a horizontally-aligned oval of *c.* 100mm, the aperture having been enlarged by damage to the inner vitrified wall of the furnace, possibly caused during excavation (Figs 17 and 18).

Discussion

Field remains and the problems of interpretation

The village iron-smelting furnaces exemplify small-scale iron production by the bloomery process the world over. The unique feature is their excellent preservation which, coupled with the local memory of their operation and the surviving iron blooms, creates an opportunity for the study of the bloomery process generally.

To reinforce the value of this record it may be useful to reflect on the more usual remains of early smelting. Early furnaces were often transient structures with lives measured as often in months as in years (Craddock 1989).

Normally no more than the truncated base of the furnace survives and from this, and odd surviving fragments of refractory in associated slag deposits, the whole of the superstructure has to be reconstructed. As with SM193 and SM186, furnace bases are usually circular, typically 0.2–0.4m internal diameter, surrounded by a thick ring of clay. From this evidence two kinds of furnace have traditionally been postulated: either a shaft furnace of uniform cylindrical shape, possibly tapering a little towards the top, or a bowl furnace, still of circular plan but with the furnace walls coming in sharply to create a dome or partial dome. The choice depends partly on cultural context, and to a lesser degree on the surviving remains; it is increasingly recognized that both reconstructions are over-simplistic.

Percy (1864) defined these two basic categories of furnace, based on his study of the then-known examples which were principally from India. He noted primitive metal production seemed to be carried out in bowl furnaces but more sophisticated processes used the shaft furnace and thus the idea was born that there was a progression from bowl to shaft furnaces. In Britain for example, while the remains of Iron Age smelting would have been assumed to belong to a bowl furnace, the same remains from a Roman context would be reconstructed as a shaft furnace. Clough (1985) has shown that shaft furnaces were almost certainly used throughout. This conclusion is now increasingly borne out by fieldwork.

What interests us here is the difficulty of furnace reconstruction where everything above the base is missing. If the Veralugasmarkada furnace had been in the usual state of preservation then nothing would have survived except a slightly-burned bowl-shaped depression, possibly with some of the basal stones of the superstructure also surviving. This would have been interpreted as the base of a shaft furnace. If, however, preservation had been deemed good and the first 100 or 200mm of the sharply inclining clay-lined sides of the chamber had survived, then the structure would have been interpreted with confidence as a small bowl furnace. At this postulated level of preservation it would be almost impossible to predict the true shape of the main body of the furnace. Fragments of the clay lining from the spoil heap might well show odd curves and changes of profile, but these are notoriously difficult to orientate into a coherent reconstruction, and are anyway often the result of heat deformation. The intact furnace from Veralugasmarkada thus presented an opportunity to accurately record the true shape of a small bloomery, typical of the process used around the world, although with many variations.

The furnace

Against this background we can now look more critically at some features of the furnaces described here, and include reference to points of debate raised in discussions with Peter Crew (pers comm). Most accounts of traditional smelting illustrate and record the external appearance of a furnace which is often a simple cylinder and this is then extrapolated to describe its interior. Perhaps the most striking aspect of the Veralugasmarkada furnace is the complexity of its internal modelling (Fig 15); there are no parallels recorded for this shape.

Crew suggests that the inward swelling of the furnace wall in the region around and below the blowing hole was to anticipate and accommodate the erosion of the lining at that point during the smelt. His experimental furnaces started as cylindrical but developed a similar swelling during use, but predominantly just above the blowing hole rather than below (eg Crew 1991, fig 1). In Crew's experiments the blowing hole was extended out into the furnace shaft to form a tuyere but normally, by the end of the smelt, this had eroded back to the furnace wall. The blowing hole of the Veralugasmarkada furnace may have been treated in a similar manner and even though highly vitrified it still projected outwards at the end of the smelt.

It could be argued that the undulating profile of the back wall, including the protruding blowing hole, may be in part accentuated by heat distortion and sagging during a succession of smelts. While some distortion would have occurred it does not fully explain this profile as there is little or no evidence for remodelling of the furnace between smelts or smelting campaigns and the same profile with very similar dimensions was also recorded for furnace SM186, although not seen in the clarity of a fully excavated half-section. Thus, the evidence suggests that this profile was largely the intended design of the furnace interior.

The damage and weakness of the furnace wall on the front (non-blowing) side in both SM193 and SM186 probably reflects the intensity of the blast from the blowing hole. By restricting the shaft at the level of the blowing hole it is likely that the combustion zone occupied the whole width of the furnace. This restriction would ensure that no material descending from the shaft above could pass through the combustion zone unreacted. The upper funnel-like shaft would have accommodated a greater volume of material than the combustion zone. However, as charcoal was consumed by combustion the packing of the charcoal-ore bed would loosen, increasing the rate of descent in



Figure 19: Two axe-cut blooms from the Samanalawewa project area. Scale bar 150mm.

the lower shaft. Narrowing the diameter of the shaft would counteract this and thus help to maintain or even increase residence time, allowing ore to achieve and respond to reaction temperatures.

The steep undercutting below the protruding blowing hole may have helped to minimize damage caused by the attachment of the bloom to the furnace wall. The shape of the furnace suggests that as the bloom of iron grew below the blowing hole it could sit largely free of the furnace walls. Certainly none of the unprocessed blooms seen in Sri Lanka show evidence of attachment to a furnace wall (eg Fig 19).

Coomaraswamy (1956) states that the bottom of the furnace was filled with sand before each smelt and illustrates this with a deep bed of sand in the base of the furnace (Fig 5). The volume of the basal slag-bloom chamber in both the excavated furnaces was large compared with the upper part of the structure. Sand by itself would make a poor base for retaining liquid slag and Crew (pers comm) has suggested that the sand would have been further lined with charcoal fines. The importance of the sand filling was reiterated by Augustina in her interview and by Ranhavadiya (Appx B), and also in the words of the smelter's song (Appx C), which refers to tapping slag through the sand. It is possible that some sand remained in place in the base of the furnace and could be augmented with new sand as required while temporary material such as charcoal fines would be added from the top of the furnace before each smelt. However, we should be cautious of assuming evidence where we have none, especially when the physical record is otherwise so comprehensive.

The red clay of the furnace body is fired hard upwards from about the level of the tuyere but towards the base the degree of firing is lower and indeed the softest, partially or un-fired material in the extreme corners of the stone box had been invaded by termites. Thus it would seem the clay was not deliberately fired as part of the

construction process and only those parts adjacent to the strongest heat became fired during use.

Significantly, the clay was also missing from between the pierced stone slab, which could be designated the bellows protector, and the clay of the furnace wall, resulting in a sub-spherical cavity in both excavated furnaces (eg Fig 11). During excavations at SM193, it was assumed this cavity was the result of termite activity in the softer poorly-fired clay. However, the possibility was raised that this might be an intentionally constructed cavity. If the wattle and daub wall that enclosed the pierced stone bellows protector provided a permanent, semi-airtight seal around the bellows nozzles, it could be postulated that the cavity might act as a pressure chamber, allowing the blast from the blowing hole to be continuous, rather like the action of a bagpipes. Figure 4 shows evidence which might support this interpretation: the logs forming the base of the foot bellows are permanently embedded in the ground up to the rim, leaving only the skins visible. Thus the pipe leading from bellows to furnace must also be buried.

Coomaraswamy's description of this pipe is very brief, in contrast to his detailed descriptions of visible parts of the bellows and furnace, reinforcing the conclusion that it was out of sight. This suggests that the junction between the bellows pipe and the blowing hole was beyond reach and could not be adjusted or maintained, and separating the two with an internal pressure chamber could help ensure an uninterrupted airflow. However, such a pressure chamber could not be entirely beyond reach as access would be needed to free the nozzle of the blowing hole when it became blocked with vitrified furnace wall or slag, as it inevitably would at some point. In counter argument, it is difficult to explain these cavities as an intentional part of furnace construction as they would weaken the structure where it needed to be strongest, *ie* around the blowing hole. A further explanation might be that if the furnace wall was softened during smelting the blast from the sealed bellows would tend to create a void as air pressure pushed the wall forwards towards the furnace. Whether the cavity behind the blowing hole was an intentional construction or the consequence of blowing under pressure, or of post-abandonment deterioration can not be resolved without excavation of another furnace and/or experimentation to test the concept of a pressure chamber.

None of the local interviewees could add detail to this question although the construction and operation of the bellows frequently featured in their descriptions, probably because of the high visibility of the apparatus and the tradition that it was the duty of the younger members of the community to operate the bellows, thus

leaving a vivid memory in the minds of informants. Coomaraswamy's illustration shows separate pipes and nozzles from each bellows meeting but not joining at the opening through the wall between bellows and furnace (Fig 5). Despite the detail of the bellows operation, only one informant mentioned a Y-shaped bamboo to connect and direct the blast from two foot bellows into a single blast and this was not reported with great certainty (Juleff 1998, 345), probably because the bellows pipes were not visible. Equally, the pierced stone bellows protector is not referred to by any of the informants or by Coomaraswamy. Clearly it must have been obscured by the wattle and daub wall, otherwise such a distinctive artefact would have been commented on.

No trace of the wooden 'pots' buried in the ground behind the wattle and daub wall could be found in either excavation. Neither was there any trace of the stake holes that would have held the framework for the backstrap supporting the bellows operator, or the poles used to pull up the hide skin of the bellows between each footstep. The construction and operation of the foot bellows are well illustrated and described by Coomaraswamy (Fig 4 and Appx A).

The stone slab box within which the clay furnace is constructed would have provided mechanical stability and thermal insulation, given that there would be a thermal gradient of around 1000°C through the furnace wall. The packing material outside the stone box would have offered further stability. It is likely that with the removal of the two large shoulder stones, major repairs could be carried out, or even a complete new furnace built within the box, without disrupting the overall structure, including the wattle and daub wall and the bellows setting. Fig 3 suggests that the furnace has a coating of mud plaster obscuring much of the construction detail. This is a common practice used on houses, hearths and many stone and mud-built structures in the area.

The stone slab box would also have helped to keep the furnace structure dry and insulated from any dampness within the external soil packing. In combination, the line of stones and the wattle and daub wall rising from them provided support for the packing soil. The neatly-paved area to the left-hand side of the furnace would have provided dry storage for both ore and charcoal so charging the furnace could be undertaken efficiently. Although speculative, the large stones of the paved area might be the remnants of a second furnace that was dismantled and reused. The reasons for suggesting this are that both SM186 and Coomaraswamy's example are

double furnaces and Giragi remembers two furnaces side by side, although she did not say she was particularly describing Veralugasmarkada (Appx B).

This discussion of the excavation data has allowed us to add significant detail and precision to the schematic furnace drawings left us by Coomaraswamy (Fig 5). With the help of Ethel Coomaraswamy's photographs (Figs 3–4) we now have a substantial record of the visible elements of the furnace, although uncertainty remains over parts that were hidden from view.

The process

The mechanism of iron production by the bloomery process has been frequently described and intensively studied since at least the time of Percy, and his *Metallurgy of Iron and Steel* (1864) remains one of the most important sources for descriptions of early processes. Among the many more recent studies, those of Tylecote (1976; 1987) are the most comprehensive but Killick and Gordon (1988) give a succinct account of the principles of the process. Rostoker and Bronson (1990) include many relevant processes from the Far East and SE Asia, and experimental studies over the past 30 years such as those of Wynne and Tylecote (1958), Tylecote *et al* (1971) and Crew (1991) have also proved of great value in reconstructing the process.

In progressing from the physical evidence of the structures themselves to consider the smelting process that operated in them it is important to remain focused on known data relating to this technology and, while noting analogies and parallels, not to impose detail from other processes. The process used in the excavated furnaces would have been that described by Coomaraswamy (Appx A).

Coomaraswamy's record, the interviews and the archaeological record all provide information about the ore and the fuel. SW Sri Lanka has abundant small surface deposits of lateritic iron ores formed by tropical weathering. Being surface deposits they are readily accessible and there is little or no evidence for deep mining. Six deposits were identified at Samanawewa during the survey, although undoubtedly more exist in the area, and two of these are known to have been exploited in living memory (Juleff 1998, 104). Augustina (Appx B) recalls her family collecting ore from a nearby hill and hammering it to the size of road metal, and in a brief field experiment material gathered from the same deposit was sorted by Augustina who selected the most suitable material for smelting. Interestingly, her selection was precise and critical and from several kilos of what appeared to less experienced eyes to be all good quality

ore, only the most dense, homogeneous, non-vesicular brown haematite was chosen (Appx B). Ranhavadiya reported that his family collected ore from a nearby hill called Katagalhinna (Appx B). This deposit was visited and recorded as SM55(O) (Juleff 1998, 246) and it is this deposit which would have provided the ore smelted in the Veralugasmanakada furnace. Analyses of ores from four Samanalawewa sites have Fe_2O_3 contents of 67–90%, with most at the higher end of this range (Juleff 1998, 30 and 211). Coomaraswamy gives an ore analysis from the area which includes 72% Fe_2O_3 , with SiO_2 and Al_2O_3 as minor components (Appx A). This suggests that careful selection could give a furnace charge of very high-grade ore, although equally a mixture from within the range would ensure a viable self-fluxing charge. One further observation on the acquisition of ore concerns the line in the smelter's song (Appx C) that says, 'Yamana goes to the hills' which is repeated as 'You are asked to go to the hills'. The song progresses through the main actions of the smelt and these lines appear to be describing collecting ore from the hills. What is pertinent is that going to the hills for ore seems to take place contiguously with smelting, suggesting that ore is not collected in advanced and stockpiled but is used 'fresh' for each smelt or smelting campaign. Using materials that are 'fresh', new or pure has strong cultural resonance in Sri Lanka.

Beyond hammering the ore to the desired 'road metal' size, no further ore preparation seems to have been required. The question of whether the ore was roasted is unclear. There are no roasting hearths in the vicinity of the furnaces or obviously roasted ore within the debris assemblages of the numerous village smelting sites to suggest that it was. When the local iron workers were consulted, the idea of burning the ore before it was put into the furnace was a mystery. Augustina, our most reliable informant, had no recollection of ore roasting. The lines of the smelter's song, 'You small children who tread the bellows—go carefully around the unburnt rock [ore]', also perhaps implies that the ore was not roasted. The image conjured by this line is of the master smelter instructing a group of boisterous youths responsible for keeping the foot bellows going throughout the smelt not to climb over or scatter the pile of ore waiting to be charged into the furnace. Perhaps the practice was to pile ore in predetermined quantities and the youngsters were in danger of upsetting a well-established routine.

On the other hand, Coomaraswamy does say that the ore was roasted (Appx A). But it is worth reflecting more cautiously on Coomaraswamy's account in this instance. His mention of ore roasting is brief and cursory and is not underpinned by the same level of observational detail that

he brings to other aspects of the process. From his general background and writing on the subject of traditional iron smelting it is obvious that he was quite familiar with other accounts of the process (Coomaraswamy 1956) and it is possible that he has assumed there should be an ore-roasting stage. This is not the only instance where doubt might be placed on the consistency of the eye-witness element of his account. However, the experience of the first author here, using ores from two of the Samanalawewa deposits in smelting experiments, has been that roasting the ores for about 45 minutes over an open fire before charging into the furnace, in this case the earlier wind-powered furnaces, significantly improved the iron yield from the smelt (Juleff 1996; 1998, 196). One further possibility exists. The hills of the Samanalawewa area are prone to bush fires during dry seasons. Fires may be set deliberately to encourage growth of new grass for pasture or may be accidental; either way they can be ferocious and reach temperatures sufficient to roast the top surface of *in situ* ore. Removing this 'naturally roasted' material for smelting would then expose a new surface for next season's bush fires. On the present data it remains uncertain whether or not the ore was roasted but further research could resolve this question.

Turning to the charcoal fuel, the ethnographic record holds a wealth of information. The tree species used for charcoal and the methods of its production have been studied (Juleff 1998, 105). Despite the abundant local flora, the consistent use of a limited range of species was striking. The dominant charcoal species used for smelting and smithing all belong to the genus *Syzygium* (Myrtaceae family) with local names *maran*, *path-beriya* and *damba*. These names recur throughout the ethnographic record and were also identified in the archaeological record. Charcoal samples from SM193 were identified by Caroline Cartwright (British Museum) as *Syzygium spathulatum* (*path-beriya*), *Syzygium zeylanicum* (*maran*) and *Syzygium gardneri* (*damba*). Coomaraswamy makes no mention of the type of charcoal used in the smelting demonstration he witnessed. Perhaps charcoal was still then a commonplace material and did not arouse interest in the way it might now. The methods of producing large quantities of charcoal using either a pit or a surface clamp are described in the ethnographic record and the pit method was re-enacted by local blacksmiths to prepare 1000kg of *Syzygium* sp. charcoal for wind-powered smelting experiments (Juleff 1996; 1998, 178).

There is contradictory information about preheating and charging the furnace. While it is an accepted norm that any furnace would need to be slowly brought up to temperature before smelting began, to avoid damage

through thermal stress and shock, there is little evidence that the village furnaces were intentionally preheated. Modern smelting experiments suggest it would have taken between two and three hours to bring a furnace of this size up to heat (around 1000°C at the furnace wall in the vicinity of the blowing hole) before charging the first ore, and well in excess of 1300°C in the centre of the reaction zone itself (Merkel 1990; Crew 1991). In contrast, both Coomaraswamy and Augustina say that the furnace is charged from the outset with alternating layers of ore and charcoal and, while Coomaraswamy says that more ore and charcoal would be added as the smelt proceeds, Augustina implied that while charcoal would be added no further ore was charged. It is not clear if Augustina means during the smelt or towards the end of the operation; the position of this comment in her interview transcript could imply either (Appx B). Her estimate that each smelt consumed one or two sacks of charcoal is plausible. A sack in Sri Lanka will hold in the region of 25kg of charcoal and a consumption rate per smelt of 25–50kg is reasonable, especially if no extended preheat took place.

There is no mention of the addition of a separate flux, and the composition of the ore given by Coomaraswamy (Appx A) would have been self fluxing, with the silica and alumina reacting with some of the iron oxide to form the necessary slag. Microstructural and compositional analysis of the slags from SM193 confirms they are typical bloomery slag comprising predominantly fayalite (Fe_2SiO_4) with some wustite (FeO) in a glassy matrix, with compositions well within normal ranges (Table 1).

The charging ratios, the relative quantities of fuel and ore, are not known directly. Coomaraswamy does not give figures but says the furnace is filled with alternating layers of ore and charcoal while Augustina claims the alternating layers were at a 1:1 ratio by volume, that is by shallow basket-loads. As charcoal is much less dense than iron ore this would imply that a much greater weight of iron ore than fuel was charged, which seems improbable; Crew (pers comm) suggests a ratio of about 2:1 fuel to ore by weight for bog ores and about 3:1 for haematite. The 1994 experiments at Samanawewa in the wind-powered furnaces found a 1:1 weight ratio for ore to charcoal gave the best results, excluding additional charcoal used to preheat the furnace for an hour and charcoal added at the end of the smelt to maintain the bed level within the furnace (Juleff 1996; 1998, 211).

Both Coomaraswamy and Augustina agree the duration of a smelt was in the order of three to three and a half hours and Augustina adds that the bellows were operated

throughout the three hours. Giragi, Augustina's cousin who lives at Veralugasmarkada, thought that the furnace ran all night and the bloom was extracted in the morning but she claims not to remember the process well. Perhaps the most valuable information on smelt duration again comes from Augustina, who said that once a bloom was extracted the furnace could be quickly cleaned and immediately reused (Appx B).

Other useful insights into the duration of a smelt and the production sequence come from Capt Campbell, who was the Assistant Surveyor of the Madras Establishment in the mid 19th century. He studied the commercial viability of traditional Indian smelting and noted that using the local bloomeries, four men, comprising one master and three labourers, made three lumps (blooms) of iron per 12-hour day (Percy 1864). This would suggest that Coomaraswamy's and Augustina's figures are about right and Giragi's all-night smelt is wide of the mark. However, a possible explanation has been suggested by Crew (pers comm) which reconciles all the accounts. He suggests that the overnight smelts described in the interviews were in fact short campaigns in which several blooms were produced. Very approximate timings might be a preheat of about one hour followed by three or perhaps four, three-hour smelts making twelve to fourteen hours in total—a good night's work. Of course, the great advantage of working through the night would be the visibility of the flame burning off carbon monoxide at the top of the furnace. By day this flame would be barely visible but by night it would show clearly as the blue flame of reducing conditions.

This record of the production of the blooms in batches with one smelt following directly after another in the still-hot furnace is of some importance as too often now it seems to be assumed that a bloomery furnace produced just one bloom in a campaign, and the overall efficiency of the process is calculated on the basis of this assumption. Given the great expenditure of time and fuel to prepare and heat the furnace, it was clearly sensible to carry on smelting while the furnace was still hot. Neither Coomaraswamy nor most other outside observers record this, but they were describing the bloomery process at the end of its life when demand for the product had dropped away and smelting was just carried out as a demonstration for observers.

The vital part played by the bellows features strongly throughout the interviews with all local informants (Juleff 1998, 106). Unfortunately, no video recording facilities were available to record the hand actions and the facial expressions that animated their memories

of this obviously arduous but enjoyable communal task. The bellows are well described and illustrated by Coomaraswamy (Fig 4) and there is little to add, except perhaps to draw attention to the cadence and rhythm of the smelter's song which surely times the footfall on the bellows (Appx C).

Within the furnace, if all was going well, as the ore particles descended through the burning charcoal bed, reactions would begin to reduce the metal oxides to metallic iron while the remaining material combined to form the all important slag. Once in the hottest part of the furnace, in front of the blowing hole, the small plates of freshly-formed iron would coalesce to form the bloom while the fluid slag sank through and around the iron.

The slag would sink to the sand filling the base of the chamber below the growing bloom. Coomaraswamy noted that the slag was tapped as necessary during the smelt. This is confirmed both by the morphology of the slag discarded on the sites as well as by the ethnographic record. Our local informants were unanimous in describing the technique of periodically driving a stick through the sand blocking the tapping arch and allowing the slag to run out, with the last of the slag solidifying and filling the hole. This operation, like the treading of the foot bellows, would have been one of the more visible aspects of the process and would have left a lasting image in the minds of onlookers.

The smelter's song (Appx C), describes bringing the pointed boring-stick to the sand and repeats the line translated as 'You were asked to cry'. The Sinhala verb used here, *andanawa*, means to cry — which made little sense in the context of smelting until observing slag flowing out of the experimental wind-powered furnaces as molten red rivulets, demonstrated the inspired visual simile between slag tapping and hot running tears. As the tapping action was repeated several times during the smelt the appearance of the last slag tapped is typically of a bundle of slag 'sticks', with a hollow-centred slag cake at one end representing the last of the slag to remain in the furnace. Slag fragments with this morphology are

common amongst the discarded waste at many of the village smelting sites.

When the smelt had reached its end and the smelter judged that a bloom had formed, the sand filling the arch at the front of the furnace was raked away and the red-hot bloom extracted. Undoubtedly this was an awkward manoeuvre requiring skill and experience. We can deduce that it regularly caused damage as repairs were identified on the tapping arches of both the excavated furnaces. However, it is worth noting that it is generally accepted for most bloomery processes that the bloom will become attached to the furnace wall in the vicinity of the blowing hole while it is forming, and that removal of the bloom will require detaching it from the wall. While we may assume this also to be the case for the village smelting process, the furnace lining of SM193 showed little evidence of damage and it is not clear if the damaged furnace lining of SM186 was caused during excavation. Both furnaces clearly had been abandoned after their last use with no evidence of repairs intended for a further smelt that never took place. From this we must conclude there was minimal damage to the internal walls and that this, as suggested above, is in part due to the careful modelling of the internal furnace profile.

The red-hot bloom, once removed from the furnace, was immediately hammered with wooden poles to consolidate it and then tested by cutting halfway through with an axe and prising the cut open to reveal the, hopefully, fully homogeneous interior (Fig 19). Note that, with the exception of the axe used to cut the bloom, wooden tools were used throughout, as described by Coomaraswamy and explained by local informants. Wooden poles were bound together to form tongs to extract and manipulate the bloom, wooden sticks were used to consolidate the bloom and a pole was used to prise open the axe cut, which is made on a wooden anvil. It was explained by blacksmiths not of the smelters caste that smelters were not traditionally entitled to use iron tools in their craft, a mark of their social status. The axe was an exception to this and, although not verified, they undoubtedly would have used iron agricultural tools to cultivate their

Table 2: Blooms collected during the Samanawewa Archaeological Survey

Site code	Site name	Reg no	Wt (kg)	Condition	Notes
SM 83	Mulgama	1129	4.25	complete	analysed (Wayman and Juleff 1999, bloom 1) (Fig 19)
SM 83	Mulgama	252	4.00	complete	used in forging experiment (Juleff 1998, 355)
SM 167	Tennekumbura	1130	3.75	complete	analysed (Wayman and Juleff 1999, bloom 3)
SM 187	Mawalgaha	1178	6.20	complete	crucible steel-making site
SM 187	Mawalgaha	1131	4.00	half bloom	
SM 187	Mawalgaha	1132	4.05	half bloom	analysed (Wayman and Juleff 1999, bloom 2)

lands—the restriction was therefore relevant only to their caste/craft practice (Juleff 1998, 109).

The product

While no blooms were recovered from either Veralugasmankada or Kosgama, nine blooms were collected during the Samanalawewa surveys, six from known sites (Table 2) and these provide an invaluable source of information. They were donated by local informants who had had them in their houses or gardens for many years, suggesting that they could reasonably be provenanced to the particular sites and villages.

All the blooms listed and others observed in the survey area and also in other parts of southern Sri Lanka are axe-cut as described above. Interestingly, those which are only half of a cut bloom were collected from the crucible steel making site at Mawalgaha, within the blacksmithing village of Hatanpola, and we can assume that they had been cut in two at the site in readiness to be forged. As a re-enactment of this process, a complete bloom (No 252) was taken to be forged by the Hatanpola blacksmiths, and the first task of the smith was to split the cut bloom into two before one half was forged into a knife (Juleff 1998, 355).

The practice of cutting or splitting the red-hot bloom straight from the furnace to demonstrate its quality is not restricted to Sri Lanka. It has been recorded in India by Buchanan (1807), Yule (1842) and McWilliam (1920), and numerous archaeological examples of split blooms, dating from the Iron Age to medieval times, from western Asia to Spain and Scandinavia have been reported by Pleiner (2000). What is significant here is that the ethnographic record says that splitting the bloom is the last action of the smelter. In the words of one informant, ‘out of the furnace, cut, into the mud-pool, no more’ (Juleff 1998, 353).

Coomaraswamy reports the bloom weight to be about 6lb (2.7kg) which is less than those recorded in Table 2. It is possible that his bloom was smaller as it was produced as a demonstration rather than representing normal practice. The average weight of the four complete blooms in Table 2 is 4.5kg and if the weights of the two half-blooms are doubled and added to the total, the average rises to 5.7kg. In Pleiner’s survey of split blooms in Europe, he recorded a wide range of bloom weights, from 0.4 to 50kg, with significant numbers clustering in the 2.5–5kg range (Pleiner 2000).

If the amount of iron produced and its homogeneity is of importance to the smelter, the first question asked

by the blacksmith contemplating forging the metal would concern the quality of the metal, in particular its hardness. Fortunately, as part of a wider programme of metallographic analysis of artefacts and material from the Samanalawewa project, three of the blooms in Table 2 were sampled and analysed by Mike Wayman (Juleff 1998, 387; Wayman and Juleff 1999). The published discussion can be summarized as follows:

The blooms contain metallic iron, slag inclusions and porosity, and show considerable variation in the degree of consolidation. A wide range of microstructures were observed as the metal comprises iron with highly variable carbon and phosphorus contents. Slag inclusions were wustite dendrites in a glassy matrix which in some cases also contains fayalite. Manganese is present in trace amounts in the slag inclusions but is not present in the metal of any of the blooms.

One of the blooms in Table 2 (Reg No 1130), along with three others of the six analysed by Wayman (Wayman and Juleff 1999) showed evidence, in the form of interdendritic phosphorus segregation revealed by Stead’s reagent, for melting in regions with highest carbon contents as a result of the lower melting temperature of higher-carbon alloys. Melting is not normally associated with bloomery iron, which forms well below the melting point of iron. However, melting is known to occur in processes such as the Japanese *tatara* furnace and some West African bloomery furnaces (David *et al* 1989), and most significantly in the wind-powered furnaces of Samanalawewa itself (Juleff 1996; 1998, 197). Higher carbon content and thus potential for localized melting is also being increasingly recognized as possible in European bloomery processes.

The evidence points to an efficient and highly-evolved process and considerable technological accomplishment. Thus, from a western, functional perspective, it seems counter-intuitive that this does not then equate with thriving economic activity. Without being drawn into an elaborate quantification exercise, it is difficult to account for the annual production of 200 blooms that Coomaraswamy reports in his administration reports to the Mineralogical Survey of Ceylon of 1904 as the output from two or three families (though note the query on this number given above). Production of this order is not reflected in the local temple records (Juleff 1998, 110) and we can assume that there would have been declining dependency on locally-produced iron long before Coomaraswamy visited the area. The maximum required of a smelter family to satisfy temple landlords was six blooms per year which could be the output of two smelting campaigns, and in more recent

times this could be commuted to a cash payment (Juleff 1998, 356). This is by no means an arduous requirement and would leave the smelter with the security of his land-holding and both time and resources to put to his own purposes. Yet there is no record of any smelter becoming wealthy or influential on the basis of his technical expertise. The ethnographic record tells us that blooms were made to order and usually in exchange for food, as expressed in the smelter's song (Appx C). Blooms were neither sold directly to the blacksmith nor did the blacksmith order iron from the smelter. If a farmer needed a new tool he would approach the smelter to first make the iron which he would then take himself to the smith for manufacture. In this way it was the farmer who dictated the nature of supply and demand on a day-to-day level and not the smelter or the smith.

A measure of the *laissez faire* atmosphere that prevailed can be gauged by the numbers of good-quality blooms still in existence in the area. In addition to the nine blooms mentioned above, the first author here observed at least a further 10–15 blooms in village houses and the manor houses of local landowners, across the region, invariably used as doorstops. These are blooms in excess of individual requirements but which have not been transformed into a saleable commodity. In contrast, Pleiner (2000) records only 300 blooms for all of Europe from the prehistoric to the medieval periods, which is the level of survival we might expect for a material too valuable to be left in its raw state.

A testament to the quality of the blooms and their ease of forging, as well as the skill level of local blacksmiths, is given by the forging of the Mulgama bloom by the Hatanpola blacksmiths (Juleff 1998, 355). In the space of just 2 hours and 20 minutes bloom No 252 was forged into a finished knife. The work included cutting the split bloom into two halves; forging one half to a bar; separately forging a small fragment of steel (scrap lorry spring) to a strip; cutting a V-shaped groove in the bar; inserting the steel strip and forge-welding the two together; forging the knife with integral tang; piercing two rivet holes in the tang; quenching the back of the knife; filing the blade; heating and quenching first the blade and then the whole knife; a final heating in an open flame and quenching again; attaching two wooden blanks to the handle with rivets; shaping the handle and finally sharpening the blade by filing. The opinion of the three brothers who carried out the work was that the bloom iron was hard to forge and it was not as good as the scrap metal they were accustomed to but they knew it was the metal their fathers used. Although precise weights were not recorded there was little loss of metal/slag during the process and the finished piece was a substantial *malu*



Figure 20: Blacksmith's forge and family of H A Seelappu in Hatanpola after the forging of the Mulgama bloom in 1988. The three brothers who carried out the forging are fifth, sixth and seventh from the left. The fourth and youngest family member (brother or cousin) is holding the finished knife.

pīhiya (fish knife) 300mm long (Fig 20). This result contrasts significantly with the losses reported by Crew (1991) in forging 2kg blooms down to billets and then bars of around 500g. Capt Campbell reported similar forging losses in southern India in the mid-19th century (Percy 1864). However, forging experiments by David Sim (Sim 1998, 37–50; Sim and Ridge 2002, 65–8) have reported losses in the region of 12%, significantly also only forging a portion of the bloom at a time rather than attempting to forge the whole mass.

The producers

In discussing the products of the village smelting technology it becomes evident that there was little economic imperative driving production. The explanation for this lies in the feudal, caste-based society in which the technology operated. A detailed discussion of caste/craft specialisation is beyond the scope of this paper which, in many ways, leaves us by-passing the one defining factor determining the socio-economic dynamics of the village smelting process. However, in brief, the agricultural caste is the highest and largest of Sri Lanka. Below this are the 'other' or service castes in which the *navandanno* rank highest. This comprises all artisans including non-ferrous metalworkers and blacksmiths who are called the *achari*. The smelters, or *yamannu*, on the other hand, are an occupational sub-group of the *padu*, a large, low-status caste (Ryan 1953, 127). Why such a technologically important and specific group as the smelters are incorporated into this disparate caste is not known. It is however possible that the smelters are traditionally aligned with the *Pulindas*, the native vedda (aboriginal) people of Sabaragamuwa, although this was not discussed during conversations with local informants. Another explanation might be that the *yamannu* were demoted from



Figure 21: K G Augustina at her home in Tennekumbura in 1989.

a higher status when large groups of artisans emigrated from Kerala, in southern India, to Sri Lanka under royal patronage in the 15th and 16th centuries (Codrington 1909; Pieris 1956). If the caste status of the smelters is regarded as suppression or social isolation it may reflect a mechanism, conscious or not, for dissipating the potential power base of the smiths and smelters combined.

The consequence of this caste division is that there is little or no contact or technological continuum between smelters and smiths. The exchange of blooms is via either the temple or manorial landowner, or the village farmer. No matter how much iron a smelter was able to produce he would only ever exchange it for goods because he lived within a largely subsistence economy, and, because caste was immutable, no matter how much material wealth he might accumulate through exchange, his position in society could not be advanced. In reality, no social system ever functions as rigidly as this, and there are interesting nuances in the evidence from Samanalawewa that suggest there was a point of contact between smelters and crucible steel makers. This and the possibility that the geographic distribution of smelters' and smiths' sites and settlements in relation to the central temple settlement also reflects hierarchical relative caste positions has been explored (Juleff 1998, 115).

How then do we reconcile the high level of technologi-

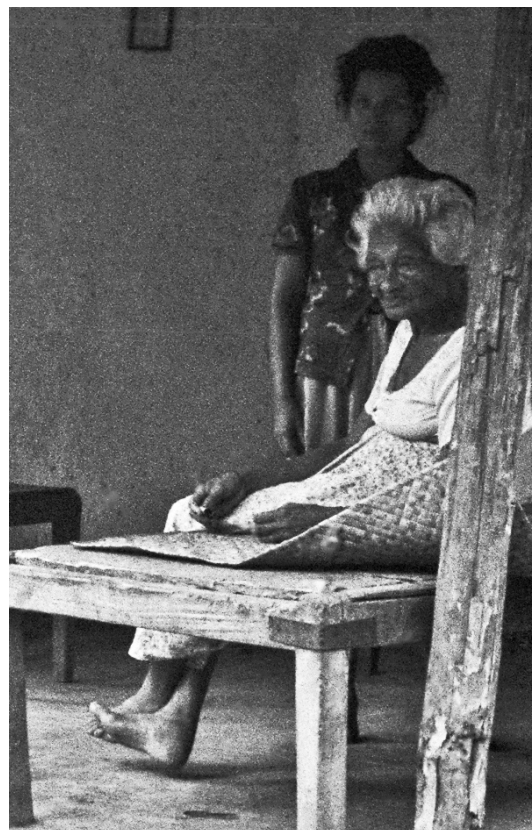


Figure 22: K G Giragi sitting at her home in Veralugasmarkada in 1990.

cal evolution of this smelting process with the lack of economic imperative? The smelter was secure in his landholding and could produce the metal required of him with relative ease, so addressing this question requires us to look beyond functional explanations. Perhaps ease and convenience are motivating factors as strong as meeting demand, expanding production and market dominance.

The final section of this report must be reserved for the real people whose words, memories, homes and families have woven the thread connecting us, them and Ananda Coomaraswamy with the past. There were many encounters with older members of the community who recalled memories of the old ways of making iron which were anchored in familiar places and people. Of these, the three people who provided the most direct link to the past were Augustina, Giragi and Ranhavadiya. Only Ranhavadiya is still alive, frail but proud to have passed on his memories and especially the songs he had collected from his father.

To focus on each individually, K G (Kudu Galelage) Augustina (Fig 21) lived most of her life at Tennekumbura (SM167, Fig 2) within the larger village of Hatarabage. She is the last person to have actively participated in iron smelting, helping her husband and family. The initials prefixing her name refer to her *ge* (family or clan).

As it was her extended family that were the smelters of Hatarabage it is highly likely that it was her father or grandfather who demonstrated iron smelting for Coomaraswamy. In meeting and talking to Augustina it was quickly apparent that a shared knowledge and interest in iron and smelting can transcend language and class/caste barriers. Her enthusiasm to describe the process, recreating the furnace in her hand actions, could only come from long-buried first-hand experience.

K G (Kudu Galelage) Giragi is Augustina's cousin (Fig 22) and also originally came from Tennekumbura; the family likeness between them is apparent. She moved to Veralugasmanakada when she married D K (Dehigastalawe Kaluwalage) Rankira. Iron was then still being smelted at Veralugasmanakada but she had no role in it and has few first-hand recollections.

Her son, D K (Dehigastalawe Kaluwalage) Ranhavadiya (Fig 8), lives at the family home in Veralugasmanakada and knows where the remains of the furnaces are. He always took an interest in his father's and uncles' stories of the past and regrets that no one is interested any longer in iron smelting. He and his mother have a relation who lives at Medawala Kosgama (SM209 in the site gazetteer; Juleff 1998) called K H (Kiri Hewayalage) Rankira. Another project informant, Dingiri Nainde (Juleff 1998, 351) is also a relation of theirs. His real name is Kiri Hatana but by changing his name to Nainde, a traditional blacksmith's name, he had disassociated himself from the lower status smelters. However, in the course of his interview (Juleff 1998, 344) it became clear that he had had a close involvement with smelting. He recalled visiting a smelting family (probably his relations) to the east, beyond Kosgama, at a place called We-eliya, a walk of some 20km from his home. There was a famous smelter at We-eliya called Rankina (not to be confused with K H Rankira above as the names were recorded with care during the interviews although it is possible the informants are referring to the same person). And so the network of relations and families spreads, and with it the distribution of sites we see in the archaeological record.

Chronology and the historical record

One final issue is the chronology and earliest appearance of the village smelting technology. What is included here is a brief synthesis of data published elsewhere. This technology is not confined to Samanalawewa but was widespread across much of Sri Lanka. It occurs in English documentary sources from the 17th century when it was described by Knox (1681) in his account of life in the Kingdom of Kandy. Numerous other colonial accounts from the 16th–19th centuries, including those

by Davy (1821), Baker (1885) and Tennent (1859), describe elements of the process. In addition to evidence of the technology in Sri Lanka, there are a number parallels between the village smelting furnaces and furnaces recorded from eastern, central and southern India (eg Yule 1842, Percy 1864, McWilliam 1920 and Cammiade 1931). The technological features shared between Indian and Sri Lankan processes suggests the process witnessed in Samanalawewa derives from India (Juleff 1988, 89). Given the predominance of wind-powered smelting at Samanalawewa until the 11th century, it is likely that the introduction of a new, bellows-driven technology from India post-dates this time. There are two documented occasions when South Indian craftsmen settled in Sri Lanka. The first was reputedly in the 9th century, when the *kammalan* (smiths) of Kerala emigrated 'in a body' to Sri Lanka and had to be forcibly returned under armed guard (Juleff 1998, 89). The second and more probable source of the village technology was in the 15th and 16th centuries when craftsmen of the Pandyan Kingdom of Tamil Nadu were induced to settle in Sri Lanka by royal endowment of land and social privileges (Codrington 1909; Coomaraswamy 1956). While these accounts generally refer to smiths rather than smelters, it is possible to argue that newly arriving smiths would bring with them all the 'tools' of their craft, including skilled smelters.

Conclusions

This study started with the description of iron smelting in *Medieval Sinhalese Art* and has truly walked in the footsteps of Ananda Coomaraswamy. Along the way it has pieced together the archaeological sites of past smelting with the landscape and communities in which it operated, and the iron that was made with the people who made it. While there must be some notes of caution and uncertainty, what we have presented here is a near-complete record of this technology that will serve as a powerful analogy for less complete records of traditional iron smelting in bellows-blown furnaces the world over.

The excavation and study of the small furnace at Veralugasmanakada shows that its operating parameters are comparable to those of other traditional bloomeries, either experimental or ethnographically recorded. The excellent archaeological survival of the structure has enabled recording and interpretation of the sophisticated internal shape of the furnace which is more complex than that of any previous reconstructions based on surviving remains. This suggests that there may be a whole range of sophisticated procedures and structures standing at the head of long traditions of local developments in many parts of the world.

Acknowledgements

This paper is dedicated to the memory of P B Karunaratne (Karu), who played a central role in gathering the evidence on which it is based, and to the memory of K G Augustina, who shared her enthusiasm for her traditional craft with all who met her.

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Appendix A: Coomaraswamy's (1956) eye-witness account

The methods of the few remaining smelters are unchanged. Iron is still smelted at Hatarabage, near Balangoda, by men of low caste (*yamannu*). The photographs reproduced [Figs 3–4], show the workshop of an old man named Kiri Ukkuva, and his sons. The furnace is beneath the thatched roof of a shed open on all sides; it is quite close to the house occupied by the smelter and his family; for it is generally more convenient to collect and bring the ore to the furnace, than to establish the furnace near the ore. But smelters used also to erect the furnace near the ore, as in the case of those who used to visit Nuvara Eliya to work the iron ores there found. The ore is generally the nodular hematite or limonite which arises as a decomposition product of the country rocks, and is widely distributed in small quantities. Before smelting, the ore is broken into

small pieces, and roasted to drive off water. In some districts it appears that the ore used has been magnetite. The analysis of a typical hematite is as follows:

SiO₂ 9.14%, Al₂O₃ 9.85%, Fe₂O₃ 72.30%, FeO 0.22%, H₂O 8.40%, S nil, P₂O₅ 0.05% and P 0.022%.

The essential parts of the furnace are the well or furnace proper; a wall of wattle and daub protecting the bellows blower from the heat of the fire; and the bellows behind this wall. The well has two openings, one in front, from which the slag runs out, and through which the bloom of iron is ultimately extracted; and a smaller opening behind, through which a blast of air from bellows is forced into the well. The bottom of the furnace is covered with sand, which also fills up the front opening. A charcoal fire is started at the bottom of the well and covered with layers of ore and charcoal until the well is filled, a continuous blast of air from the bellows keeping up the fire meanwhile. Additional ore and charcoal are added as the work proceeds, the stoking with charcoal, together with the occasional letting out of slag, being sufficient occupation for one man.

The bellows, from which a continuous blast is kept for three hours or more, are worked by two other men, who share the work by turns; they are of a primitive but ingenious type. Behind the furnace are embedded vertically in the ground two logs of wood, about 17 inches in diameter, and hollowed out above to a depth of three or four inches; over each of these a piece of deer skin is tied, having a small hole near its centre, and at the centre a piece of cord attached, which latter is fastened six or seven feet above to a springy stick, the lower end of which is embedded in the ground. From each of these two sections of the bellows a small pipe conducts the blast into the hole leading to the well of the furnace. The bellows blower stands with his feet, one on each of the deer skins, facing the wall and lifting and putting down his feet in turn, drives a continuous blast of air into the furnace; for as he puts down his foot to press out the air from one skin, he covers the hole in it with the sole of his foot; and meanwhile the other skin is filled with air through the hole, which is uncovered when he lifts his foot, the skin being pulled up by the tension of the bent stick upon the string. On either side of the blower is a stake which he grips hold of, and to which a strap is fastened that passes round behind him and supports his back.

After three hours or more, when the iron is found to be ready, the sand is cleared away and the bloom pushed out through the opening, and then follows the process of 'cutting the iron'. The bloom of iron is taken up in long tongs made of greenwood sticks tied together near one end, and it is then beaten a little into shape with thick sticks; then while it is held down on a log with two of the wooden tongs a third man takes a ketta and cuts the lump of iron nearly half through; the gash so made is widened by the insertion of a green log, which is beaten in so as to force the edges further apart; this is done that the quality of the iron may be examined, for the outside is spongy, and the whole texture far from homogeneous. The bloom is then thrown into water and afterwards taken out and left to finish cooling.

The bloom thus made is soft and malleable, and weighs about 6 lb; it is sold to the blacksmiths for 50 cents.

Appendix B: Extracts from interview transcripts published by Juleff (1998)

Notes in [] brackets are additions made when the transcripts were first compiled and those in () are later clarifications.

K G (Kudu Galelage) Augustina (age 97) and **K G (Kudu Galelage) Piriasanga** (age 55–60) [were interviewed in 1989 at their home in Tennekumbura in the presence of a large crowd of villagers. Augustina has a very clear memory of smelting iron with her husband and his family but it was difficult talking to her as she is deaf and the onlookers were more concerned that we talk to her son. Piriasanga had seen smelting being done when he was a small boy, and had obviously helped to operate the bellows, but his memory is not as clear as his mother's.]

They are the only *yamannu* family in the village. It is not an iron-smelting village. Augustina's husband and his family were the last to smelt iron in the area. Of the family it was Piriasanga's father [Augustina's husband] and his uncle who did the smelting. When Piriasanga was only six his father fell ill and stopped smelting. Piriasanga and his two brothers were too young to learn the process from their father.

The smelting was done close to their present house, just above the paddy fields in what is now a coconut garden (SM167). The *yapas*, which they call *yakadagal* [lit. iron-stone], was collected by the family from a nearby hill called Katawalahela or Maran Mandiya* (SM176(O)). Up to ten or fifteen family members were needed to collect the *yakadaga* which was collected from the surface and hammered into small pieces about the size of road metal. The furnace, called *usna*, was charged only with *yakadagal* and charcoal. The prepared ore and charcoal were covered to keep them dry and stored next to the furnace. The first layer was charcoal and then iron ore, then charcoal again. If there was space left in the furnace, further alternating layers of ore and charcoal were added until the furnace was full to the top. The usual charge was approximately 1:1 ore to charcoal and was measured in *katakuda* [baskets]. Normally the charge was approximately three basketfuls of each but precise amounts were not measured. To operate one furnace for one smelt about one or two sacks of charcoal were used.

Only *maran* charcoal was used. Extra charcoal was added during smelting through the top of the furnace, which remained open. Smelting took approximately three hours and the bellows were operated throughout the three hours. The bellows used were the *thalimana* type. The two bowls of the bellows were made from the bases of *kitul* palms covered with sambhur hide. The *thalimana* was positioned behind a high wall directly in front of which the furnace was situated. The *thalimana* was usually operated by a younger member of the family. The sambhur skin was raised and lowered with the help of two vertical strings, and a single hole in each skin acted as a valve which was opened and closed by the operator's foot. There was a back strap which the operator could lean against for support. Occasionally the furnace was stirred with a stick during smelting before extra charcoal was added. No more ore would be added.

The furnace was about three feet high [0.9m] and three feet [0.9m] square. The furnace surround was made from *kudugala*

[locally the term is used to describe the most commonly available local stone which is weathered garnetiferous granulite] and the furnace itself was lined with clay. The base of the furnace was loose sand. The tuyere entered the furnace about six inches [0.15m] from the furnace base. There was only one tuyere and one set of bellows per furnace, although there may be two furnaces side by side, and two tuyeres per one set of bellows. [This last phrase is confused.]

During firing the slag was allowed to flow out through the sand. A stick was pushed through the sand filling the front [arched] opening into the furnace and as the stick was pulled out again the molten slag flowed out after it. At the end of smelt the loose sand at the front of the furnace was raked away, any excess charcoal in the furnace was raked out, and the red-hot bloom was pulled out [through the front arch of the furnace]. The bloom was immediately placed on a log and was cut. The furnace could then be cleaned and re-used immediately. Often there was slag left at the bottom of the furnace.

The family made their own charcoal out in the jungle. The branches were stacked in a trench and then covered with leaves and earth to stop the smoke escaping. The fire is called an *anguru-mela*.

Their ancestors had an order from the king to make iron for the *devale*. In return they were granted the use, and harvest, of six *palas* [extent of land] of local paddy fields. The paddy fields were shared between three or four 'parties' according to a system of *tattumaruru* [alternating share]. They were obliged to provide the *devale* [at Alutnuwara] with five blooms per year. At a later stage the *devale* asked for 25 rupees per year instead of raw iron.

The remaining iron was sold to anyone who wanted tools made by the blacksmith. There was very little direct selling to the blacksmith. They say many of their blooms went to Mawalgaha. The iron given to the *devale* was worked at Hatanpola. Iron did not pass directly from the smelters to the Hatanpola blacksmiths. They did not make iron continuously, only when it was ordered.

* [A number of loose ore lumps were collected from the hill immediately behind Augustina's house. These varied from light-weight, red/black vesicular material to small pieces of less common, dense yellow/brown rock. Augustina was asked to select the most suitable material for smelting. All the vesicular material was discarded immediately. Only a few of the densest lumps were suitable in her opinion and even these should be broken up to remove the lightest material (in colour). Her selection was made first on the basis of weight/density and then colour.] She said that they never dug more than a 'few feet' for ore and the collected rock had only to be broken into small lumps (about 40x40mm) to prepare it for the furnace. (It is important that Augustina had no knowledge of ore-roasting, even when specifically asked.)

K G (Kudu Galelage) Giragi (age 90) comes from Iriyawinna, Tennekumbura. Augustina is her cousin. As a small child she remembers iron smelting being done by her family at Tennekumbura but she was not particularly interested in it and therefore does not recall how it was done. Augustina is older and may remember. Tennekumbura was the last place where iron was smelted. She married DK Rankira and moved to his

home here in Veralugasmarkada. By the time she came to Veralugasmarkada no one was smelting here anymore. She has relations at Medawala Kosgama. Dingiri Nainde, whose name is really Kiri Hatana, is also her relation.

[Charcoal] There are a lot of slag heaps in the village but she cannot remember where the furnaces were. Both *milla* [*Vitex pinnata*] and *maran* were used for charcoal. The smelters made their own charcoal. They also made charcoal for the blacksmiths when they wanted it.

[Giragi then sang for us a portion of the songs which were sung while the iron was being smelted.] The verses were sung on the first day of using a new furnace. After the first bloom from a new furnace had been cut they would celebrate by eating *kiri-bath* [milk-rice]. She remembers a pair of furnaces side-by-side being operated by two pairs of [foot] bellows. Work would start in the early evening and would go on all night. The bellows were operated continuously throughout the night and the bellows operators would take turns. The bloom was removed in the morning. The furnaces were never worked during the daytime. The furnaces were worked in family groups.

There was a special medicine used for furnace burns. Slag is referred to as *bora* only, not *yabora*.

D K (Dehigastalawe Kaluwalage) Ranhavadiya (age 52) is the son of Giragi. His father, D K Rankira, and all his family have always lived at Veralugasmarkada. His mother comes from Iriyawinna, Tennekumbura [where Augustina now lives]. Augustina originally came from Kosgahawela, which is also near Hatarabage. He has never seen iron being smelted but heard about it from his father and his relations.

Without digging a pit, a base of large logs is made. On top of this small branches are piled up in the form of a 'tent'. The pile can be up to 30 feet [10m] long. The pile is covered with green leaves and tightly-packed earth. The charcoal is made from green wood, with a little dry wood to start the fire. The pile is set on fire at one end and it is left to burn through. As the burnt wood collapses in they add more earth and trample the pile to dampen the flame. Using this method rather than the pit method it is possible to make an unlimited amount of charcoal. *Maran* and *path-beriya* are used. This technique is no longer used. Now charcoal is made in a bonfire and the fire is put out with water. For smelting you need a lot of charcoal. Large areas of jungle have been cut for charcoal. He does not know how much charcoal is needed for smelting but it is a large amount.

There were six or seven furnaces working in Veralugasmarkada. At the front of the furnace there were two stones set at angles with a hole between and below them. This opening is called the *usnakata* and was filled with sand and during smelting a green *kappetiya* stick was used to poke through the sand into the furnace. The slag then flowed out through the hole.

Yapas was collected from Katagalhinna (SM55(O)) nearby and brought to the furnace in pingos [a pole loaded at both ends and carried over the shoulder] before smelting. If seven blooms were made in the seven furnaces the first bloom removed was given to the *devala*.

Appendix C: The smelter's song

Treading the bellows is one of two songs collected from Ranhavadiya, who had heard his father sing them and had written them down in the 1950s. They were everyday working songs rather than songs for special occasions. Where the original is ambiguous or Ranhavadiya gave additional explanations; alternative translations are given in brackets.

Yamana treads the bellows—and down goes Yamana
Yamana pierces the slag,—Yamana brings out the slag
Big pot-bellied Yamana—Yamana goes to the hills
To the Yamana who tread the bellows—from where do they get
their food today

With cooked yams and cooked jak—tonight their meal is here
The pointed boring-stick—bring it here to the sand
You small children who tread the bellows—go carefully around
the unburnt rock [ore]

You are asked to go to the hills
You are asked to hammer the iron [ore]
You were asked to cry [break out the slag]
You are asked to go to the hills
You are asked to hammer the iron [ore]
You were asked to cry [break out the slag]
I was asked to rest [sleep]
You were asked to bring chillies
You were asked to give water to drink
You were asked to bring jaggery
You were asked to bring treacle
You were asked to cry [break out the slag]
You were asked to bring chillies
You were asked to bring salt
You were asked to cry [break out the slag]
I was asked to rest

Notes: Many smelters and their descendants are very pot-bellied. Breaking out the slag allows it to flow, as if the furnace were crying. Jak is a starchy fruit akin to breadfruit and jaggery is palm sugar. The balance between work and the food that had been brought to pay for the work is evident, as is the cycle of bellows pumping and rest.

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