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Identification of a slag-draining bloomery furnace in the Mandara Mountains (Cameroon)

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ABSTRACT: In 1953 René Gardi photographed, sketched and briefly described the functioning of bloomery furnaces of the Teleki, a small ethno-linguistic group in the Mandara mountains in North Cameroon. Internal evidence and new data on smelting practices in this region suggest that Gardi's sketch and description are inaccurate. Using Gardi's diary, it is argued here that the circumstances of his visit precluded a well-grounded assessment of bloomery techniques, and that Teleki furnaces could not have worked in the way he suggests. Comparative data is presented, gathered among the Bana, who live 20km from the Teleki. These indicate that a previously unrecognized slag-releasing type of furnace was common to both groups. Of the three known montagnard furnace types the Teleki-Banan is the most sophisticated—both specialized in the production and export of iron.

René Gardi's account of Teleki furnaces

In the Mandara Mountains there are many different ethno-linguistic groups (see Fig 1) and several of them are known as iron smelters, each with their own particular design of furnace. In 1953 René Gardi visited and recorded iron smelting among both the Mafa and the Teleki. This paper presents a re-appraisal of the Teleki furnaces, and compares them with those used by the Bana as well as with the rather different furnaces used by the Mafa and the Sukur people.

René Gardi (1909–2000) pioneered the study of iron production in the Mandara mountains of northern Cameroon, a geographic and cultural region that extends westwards into north-eastern Nigeria (Fig 1). A decade after his death, his observations are still contributing to new discoveries. I recently obtained a copy of his rare and precious *Schwarze Hephästus* (Gardi 1954) and, after studying the superb photographs and accounts of smelting among the Mafa recorded in February and March 1953, turned to the pages on the Teleki, a group he had visited later in March and whom he calls the 'Tschédé'.[1] The Teleki are a montagnard population numbering only 1665, according to the 1987 census. They now live in five 'quarters' up to 15km apart, of which one of the largest, Teleki-Feng/Ndibishi, was probably the one visited (Brye 2001). Gardi took several pictures of their voluptuous furnaces in use (Fig 2) besides many others. These contrast with tall furnaces of the type known only amongst the Mafa (Fig 3) which, in the course of a smelt sometimes taking over 24 hours, produce a heterogeneous bloom mass; this consists of wrought iron, steel and cast-iron pellets mixed with slag and charcoal (David *et al* 1989). I first read Teleki furnaces as large versions of the smaller type that, in the course of a day's smelting, produces a batch of relatively homogeneous iron blooms. Variant forms of these constitute the only other type known thus far in the Mandara mountains. I filmed one in action in 1989 among the Plata (David 1995) (Fig 4). Sukur furnace masters state that their furnaces produced batches of from seven to eleven blooms a day, with nine as the median value (David and Sterner 1996, 16). These two types of furnace were first described by Gardi (1953) and Sassoon (1964) respectively. I shall refer to them as 'Mafan' and 'Sukurian'.

Mafan furnaces are characterized by a tall shaft, measuring about 160cm in height from base of furnace to tuyère

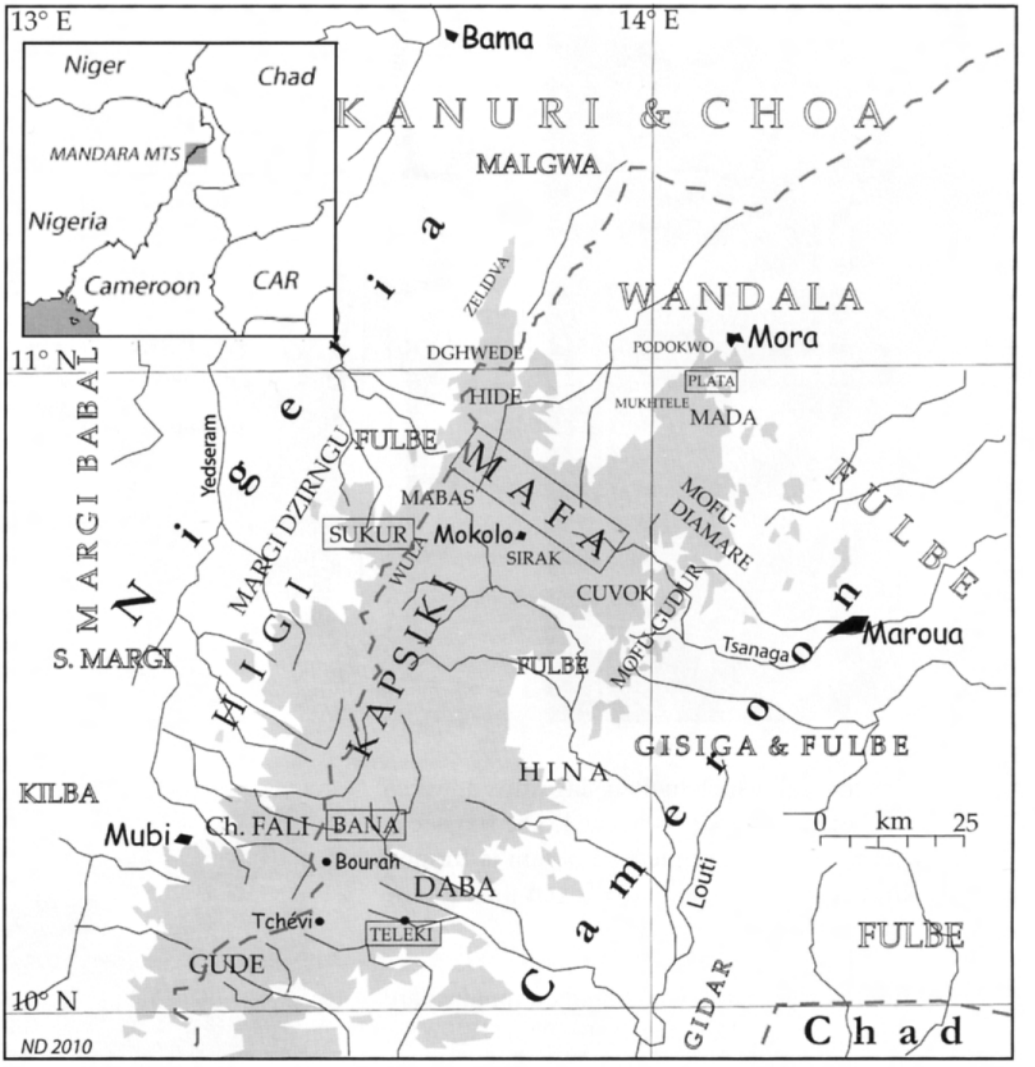
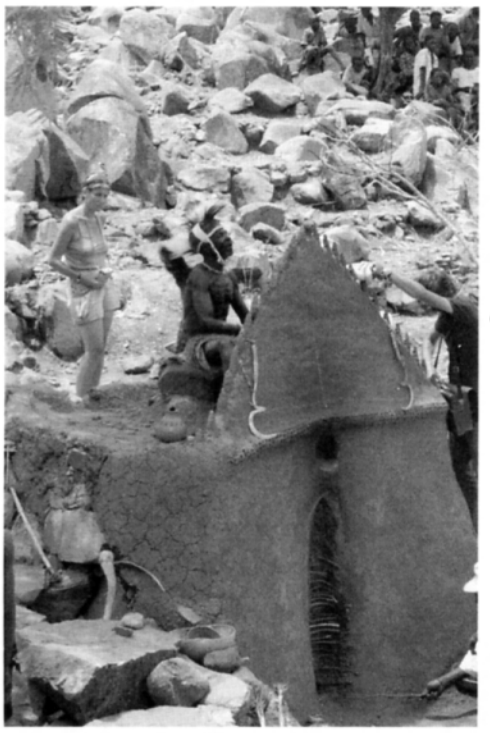


Figure 1: The Mandara mountains (defined by 2000' contour) of north-eastern Nigeria and northern Cameroon showing selected towns, villages, rivers, montagnard (solid text) and plains (unfilled text) ethno-linguistic groups. Boxes indicate groups of special interest in the context of this paper.

Figure 2 (below): Teleki furnaces, estimated height c2m. According to Gardi the men are singing and pumping the bellows, but it is far from clear that a smelt is in progress (Gardi 1953, Plate 54). Photo René Gardi 1953/77/12 by kind permission of Bernhard Gardi.

port inlet in the case of the relatively small example illustrated (Fig 3) to about 2m, well over the height of a man, in that of the Soulédé furnace recorded by Gardi in March 1953 and illustrated in *Schwarze Hephästus, Momente des Alltags* (B Gardi 1995, 106–7) and elsewhere. Sukurian shafts can be as short as 75cm (the Plata example) but are more often nearer a metre. In relation to men standing by the Teleki furnaces, I estimate their total height at just over 2m and furnace shaft height at about 155cm. These estimates are to be preferred over the larger figures calculated from Gardi's (1954, 120) problematic cross-sectional sketch of a Teleki furnace (Fig 5). Size apart, Teleki furnace shafts are sharply differentiated from those of the other types, the sketch showing a narrowing a little more than half way down the furnace shaft with a grating integral with the furnace across it. Gardi (1954, 120) describes its role as follows:

> 'In this kind of furnace the lower door is not walled off, rather, where the smith with his wooden tool frees the way for the slag (see sketch), there is a floor pierced



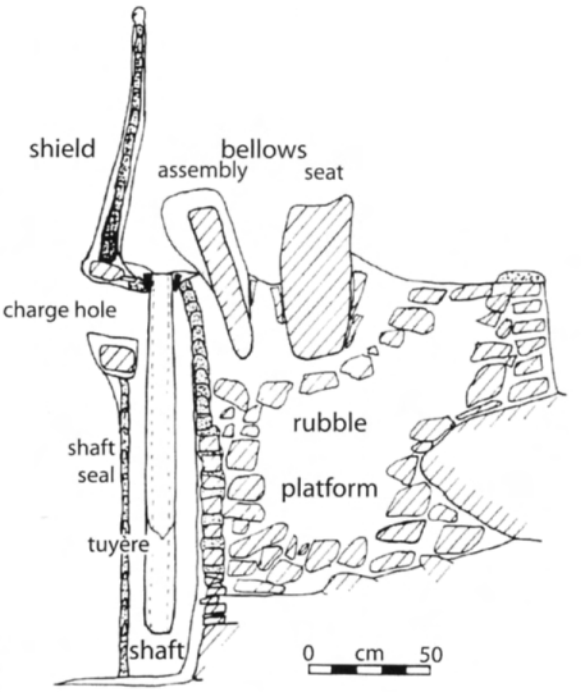


Figure 3: A Mafa furnace in operation in 1986, with Judy Sterner and Yves Le Bléis (centre left and right) recording the music of a harpist as Dokwaza sings and pumps the bellows, and its cross section (David et al 1989).

with holes through which molten slag drips down so long as the openings are not blocked. The furnace is charged only until such time as a bloom is formed. This can then be comfortably removed through the upper opening' (my translation).

In the light of what we know of Mandara montagnard smelting (see especially David *et al* 1989) this is, for the following four reasons, a most surprising statement.

1. The proportions and described use of the upper and lower parts of the shaft, accessed by the charge hole and the lower shaft opening respectively, make no sense in terms of Mandara montagnard smelting practices. The lower half of the shaft as shown in the sketch is far larger than would be needed to receive slag drips from a bloomery process notable for the exceptionally small amounts of slag produced. This suggests that the grating—difficult to examine while work was in progress—might actually have been located lower down in the furnace.

2. In other montagnard furnaces the lower shaft opening is either sealed during the smelt with a thin wall of daub or is blocked off with some combination of daub, tuyères, rocks and sherds. This is necessary to conserve heat, allowing the zone below the tip of the tuyère to achieve the high temperatures of 1200° to 1300°C required for reduction of magnetite ore. Where the opening is sealed, a small vent is pierced through the seal to allow passage and observation of gases and removal of slag; other forms of closure allow for passage

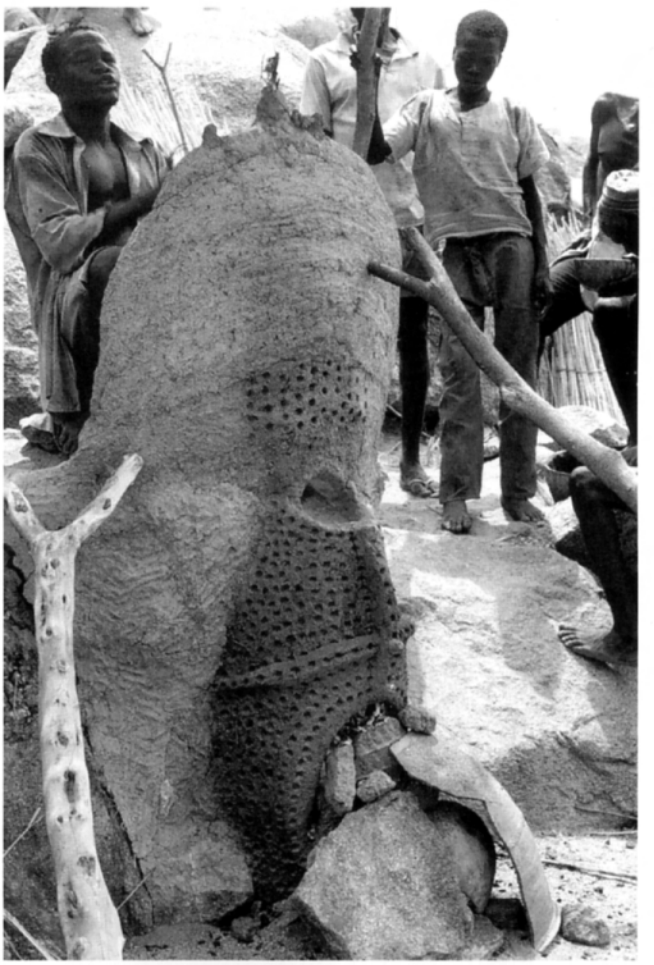


Figure 4: Plata furnace during a re-enactment arranged for the MAP team by Scott MacEachern in 1989 (David 1995). The shaft opening is poorly blocked, resulting in considerable heat loss. Photo David Killick.

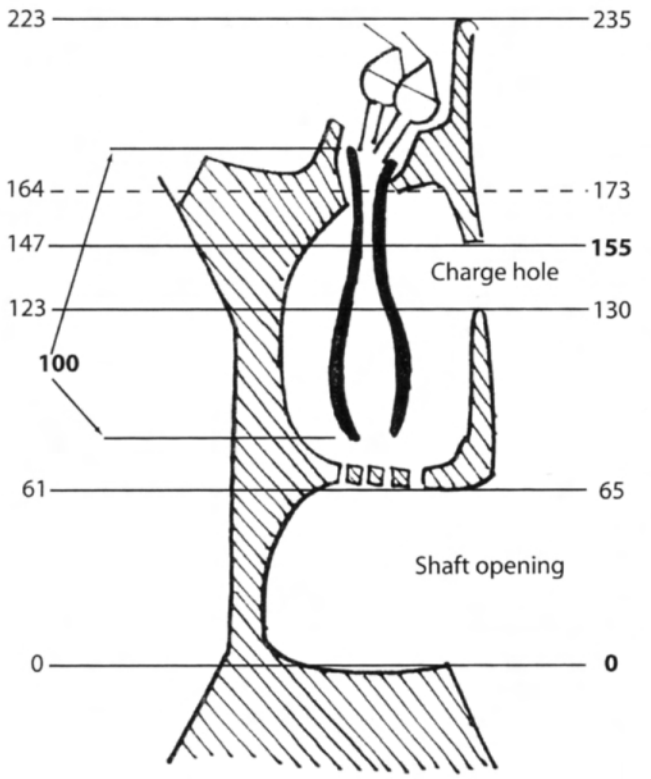


Figure 5: René Gardi's (1954, 120) sketch of the cross section of a Teleki furnace overlain with my estimates of dimensions (in centimetres). Those on the left side are based upon my estimates of tuyère length; those on the right upon my estimate of the height of the top of the charge hole. Overall height is exaggerated in both estimates (see text).

of gases. If the lower opening of the Teleki furnace was indeed not closed, monitoring of the smelt would have required observation of the exhaust gases as they passed through the grate—and this would have been extremely inconvenient, if not impossible.

3. Teleki tuyères illustrated by Gardi are built up of daub over a tubular ceramic armature with an everted upper rim on which the tuyère hangs supported by the tuyère port at the top of the furnace shaft. The much thicker lower part of the tuyère serves both to deliver air from the bellows and to assist in slag formation, slag having the temporary function of inhibiting reoxidization of metallic iron. The lower ends of these tuyères are eroded and vitrified, indicating that, in the course of smelting, the daub has been subject to melting from the bottom upwards, reducing the length to about a metre.[2] They are in fact discarded stubs, original length unknown. In all Mafan and Sukurian furnaces the configuration at the start of a smelt is that the tuyère reaches down to within 10cm of the base of the furnace. This maximizes the potential height of the bloom mass in Mafan furnaces and, in Sukurian ones, the number of blooms that can be produced from a

Table 1: Percentage of furnace height of the furnace in Gardi's sketch (Fig 5) and his photograph (Fig 2).

	Percentage of total height	
Furnace parts contributing to height	Sketch	Photographs
Shield	34.0	24.2 – 22.9
Charge hole (upper opening)	10.6	17.9 – 19.4
Base of charge hole to top of shaft opening	27.7	29.5 – 29.1
Shaft (lower) opening	27.7	28.4 – 28.6

single tuyère. Gardi's sketch—whether drawn at the time or later, from inspection or verbal description—would indicate that the Teleki were either unaware of or chose to ignore this very simple relationship.

4. Even if Teleki smelters made use of locally-made iron forge tongs and other tools, no bloom could have been easily, if at all, extracted from its bed of red-hot coals through the charge hole, unless the furnace was left to cool overnight. Nowhere in the Mandara mountains does this occur. As soon as reduction is judged complete, the bellows fall silent, the wall or materials blocking the lower opening are torn down and the bloom mass or bloom is extracted in a fiery deluge of charcoal and slag. It seems improbable that if the Teleki furnace was indeed designed for the batch process only one bloom would have been made at a time. Removal of the bloom through the charge hole also raises metaphorical difficulties. Throughout the Mandara mountains furnaces are to some extent equated with women, and babies are not delivered *per mundum* (see David 2001).

The reliability of both the sketch and of Gardi's account of the process is therefore in question. The sketch itself is impressionistic and raises four difficulties.

First, whereas Gardi's photographs show that the base of the lower shaft opening is at ground level, the sketch shows it raised up on what one might infer to be a daub base. Second, the proportions of the sketch vary substantially from those of the two very similar working furnaces shown in the photographs (Table 1). Third, the part of the furnace wall shown projecting downward from the shield is problematic since it serves no purpose and would make it unnecessarily difficult to charge charcoal and ore through the charge hole. If it did not exist and the charge hole extended to the top of the shaft, the proportions of the furnace in the sketch would be closer to those estimated from the photographs, and the total height of the furnace estimated from the sketch would be reduced to 211cm, closer to the 2m estimated from the photograph shown as Figure 2. Finally, the tuyère in the sketch appears modeled on discarded stubs leaving no room for an unworn, longer example which, so far as we know,

Gardi never saw. This raises another problem: David Killick (pers comm 4 March 2010) is of the opinion that the tuyère tip in the sketch is so close to the grate, presumably made of the same daub as the rest of the furnace, that the grate itself would melt during a smelt.

In short, there are multiple reasons why Teleki smelting would not and could not have been practised in furnaces designed and used in the manner described. What then is one to make of Gardi's interpretation? Like all good travel writers, he was an astute and thoughtful observer with a demonstrated capacity for precise documentation. He worked efficiently and effectively and with a highly developed aesthetic sense, as is evident in the photographs and in the accounts of cultural life and descriptive passages that appear in his many books. He clearly had good rapport with the montagnards, admired them, and was not romantic about them even if in the fashion of the day he sometimes presented them to his western readers in a Rousseau-esque light. At the time of their visit to the Teleki, he and his colleague and travelling companion, the anthropologist Paul Hinderling only had, it is true, experience of Mafan furnaces. Of these they had in the previous weeks observed and recorded two smelts by Mafa furnace masters. Their detailed and timed accounts and photographic and film records (Gardi 1953, 85–114; 1954; 1955a; 1959; Hinderling 1953, 1955) are unparalleled at that date, and they were both evidently willing to observe without (intentionally) influencing the process.

Circumstances of Gardi's visit to Teleki

If therefore Gardi misunderstood how Teleki furnaces were used it was not because he was unready or unwilling to document smelting. To understand what it was that he saw, we must consider the context of observation. Bernhard Gardi, René's son, has made this possible by providing me with copies of his father's diary entry on his visit to Teleki and of the eight rolls of photographs taken during the visit.

The trip was arranged by a French administrator, M Touteau. He had met Gardi through the Mokolo expatriate network, learned of his desire to study brass casting and invited him and Hinderling to Bourah, where he was stationed with his wife, with the promise of a visit to a brass smith. They travelled down from Mokolo in a truck loaded with Touteau's considerable retinue on Thursday 18 March, and spent part of that day helping to collect taxes at Tchévi, centre of the small Sharwa ethnic group. The events of Friday 19 March 1953, are best told in Gardi's own words. It helps to know that as the crow flies Bourah is 9.2km north of Tchévi and 16.5km west-northwest of Teleki (10° 10' 1" N; 13 ° 38' 19" E), which is in turn 14.1km east of Tchévi (Fig 1).

> So Touteau promised [on Thursday] that the next day we would drive together in the truck [to Teleki]. The chief [of Bourah] was informed as was the chief of the Tchide [sic] in Teleki about our coming in order that, goddammit, everything would be readied for the next day, for the brass casting and lost-wax demonstration. All very well, but when at eight the next morning we ready to drive off, the good man learned that there was no road! We'd have to go on foot! There is no way that in this land without maps we could have known, but he, the administrator, should have. And so against their will a dozen fellows were drummed up to carry our gear. Once again we couldn't set off without table and chairs, without the whole 'popote' [cooking equipment, tableware, cutlery, indeed everything required for civilized dining and often packed into a case], and for lunch Madame had over our protests ordered hors d'oeuvres, chicken, potatoes, salad and dessert coffee, the cooks sweated and laboured, and of the four of us not one eat more than seven forkfuls, it was far too hot; we were just thirsty after the morning's march...
>
> They act stupidly and make it so fearfully complicated; when it's just the two of us we just have a light picnic at lunch time and a proper meal around eight o'clock in the evening.
>
> Item, we got there, Madame was wearing very light sandals and her feet were soon ruined, so she climbed up on the horse and rode herself sore as she wore no breeches but just a light summer frock, and the tired old nag was sweating as one might expect. And we arrived, a very pretty brook under huge ancient shade trees, and then at the abso-bloody-lutely best time for photography when everything is bathed in glistening light, we went into the village, and it worked, the furnace, no, two furnaces were fired up, the bellows sang and drummed, but there was no brass casting to be seen, instead they were smelting iron ore. Now that was just fine by me, once more iron. A new type of furnace, small differences, much better finished than those of the Matakam [Mafa]. Nothing to describe; the photos tell it all.
>
> But we were after the lost-wax technique, and again a great storm blew up, charged with misunderstandings, until the chief had caught on, the Big Chief [of Bourah, presumably], who had to go along with it. Touteau had simply forced him to tag along with us. Thereupon

Table 2. Inferred sequence of photographs taken by René Gardi at Teleki and approximate times estimated by shadow angles. Photos published in Schwarze Hephästus (1954), Mandara (1953) and Kirdi (1955b) are noted.

Photo sheet	Photo number and content		Estimated time (photos primarily used in estimates)
121	1–6	Smith in forge (#5 1955, 123)	
	7	Mme and M Touteau and Teleki man	
	8–9	Teleki mother and children huddled in shade of Euphorbia cf. kamerunica	12:00 (7–9, 12)
	10–11	Teleki man with and without robe	
	12	Smith's forge (1954, 95)	
77	1–12	Furnaces in use (#6 1954,121; 1955b, Abb. 60; #9 1955b, Abb. 59; #12 1953, Abb 45; 1954, 115; 1955b, Abb. 71)	12:00 (5–12)
10	1–3	Furnaces in use (#1 1954, 117)	
	4	Tuyères (1954, 119)	12:00–12:30 (2)
	5–6	Furnaces in use (from further away)	
	7	Man, upper body (taken near furnaces)	
	8–9	Woman standing	12:30–13:00 (8–9, 11)
	10–11	Woman potter wedging clay	
	12	Woman potter with pots drying in room	
131	1–3	Houses on rocky hillside with large rock and baobab (#2 1953, Abb. 7)	14:00–14:30 (1)
	4–7	Details of room (with daub granaries and other features) under construction (#5 1953, Abb. 8, note caption)	14:00–14:30 (5, 6)
	8–9	Pot finial	
	10	House under construction	
	11	Village scene	
	12	Decaying furnace	
81	1–2	Rooms under construction, one with pillars, etc.	14.30 (2)
	3	Daub granaries over rooms	
	4–7	Teleki women	
	8	Teleki woman's brass leg ornaments and toe rings (1954, 127))	
	9	Houses on rocky hillside (retake of 131/1)	
	10	Man standing by base of very large baobab	
	11–12	Houses on rocky hillside	
62	1–12	Brass smith modeling wax using board and investing mould in clay (#4 1954, 125; 1957, Abb. 72; #7 1957, Abb. 61)	15:00–15:30 (1–2,11–12)
34	1–6	Brass artifacts, moulds and byproducts of brass casting	
	7–9	Portrait heads of young man	
	10	Two Teleki men	
	–	11 and 12 not present	
135	1–7	Male portraits (#7 of Teleki chief, 1954,113; 1955b. Abb. 74)	
	8–10	Flute players	15:30–16:00 (8)
	11–12	Madame Touteau repairs her makeup	

we saw quite a bit of the lost-wax process but not all. Basics: wax model; clay around it; let it dry; melt out the wax; melting of the metal, pouring brass-bronze in [to the mould]. The wax can be 'carved', decorated, so that amazing forms are produced.

The 'farewell concert' of the flute players whose ear-splitting din accompanied us for three quarters of an hour, see the photos, then the chief claimed that Bourah was closer than Tchevi, it was in fact an hour further away, and at seven in the evening we got back to the truck, and to Mokolo by eleven. A fine example of French organizational genius. Nevertheless a very fine day. (from René Gardi's unpublished diary, pp. 91–92, my translation).

It is clear from the above that Gardi was not in control of the planning or length of the visit. Neither had the mess-

age sent by M Touteau to the Teleki chief been acted upon, if indeed it was correctly transmitted and understood. However, the time spent at Teleki in observing various activities must have been at least to some extent under Gardi's control. Thus the timing of the visit and the photographs taken give an indication both of his priorities and of the possibilities for observation and recording.

Reconstruction and reinterpretation of the visit

In conjunction with the diary, the time of day Gardi took his pictures can be crudely estimated by study of the photo sheets, each of which represents the negatives from a roll of film printed at actual size one by one on barite paper and glued down in four rows of three pictures each. Film rolls appear to have been numbered in advance and selected for use without reference to sequence. Information on the sun's altitude at different times of the day on the 19 March 1953, obtained by use of *Cartes du Ciel* (ver 3.1), allows shadows in certain of the photos to be read in the manner of a sun dial (Table 2). The diary helps to establish overall duration. Gardi states on page 91 that it took them 2¼ hours to walk from Bourah to Teleki, but this must be an underestimate for a straight line distance of 16.5km even if, as may have happened, they drove 4km or so down the Bourah-Tchévi road before striking off on foot with about 14km before them. On the next diary page Gardi mentions six hours of hiking in the day, or three hours each way, which still seems fast, especially since they did not get away until some time after 8:00. It is hardly possible that they reached the outskirts of Teleki before 11:30, a time confirmed by Gardi's ironic comment about the light.

Upon arrival they rested, nibbling at the lunch provided by Mme Touteau, while the Teleki chief was notified. Then began a whirlwind of activity with a visit to a forge and immediately afterwards to the furnaces, the pictures of which were all taken around noon over a period less than an hour. The forge and the furnaces seem to have been located near the edge of the village. Nearby they visited a potter. At about 14:00 they reached a more densely settled area on the lower slopes of a hill where Gardi took two rolls of photographs of architectural and other subjects including one shot of a disused and decaying furnace. It may have been around this time that there was the palaver over the visit to the brass smith, at whose work area they seem to have arrived at around 15:00, staying perhaps for an hour during which time the smith demonstrated modelling and mould making but not casting. Then, after taking pictures of notables and entertainment by flute players, they would have left Teleki no later than 16:30 in order to arrive back at the truck by 19:00. It was indeed a long and strenuous day, even without the jarring ride home, a lot of it over bedrock, to Mokolo.

The brevity of his visit to the furnaces and Gardi's succinct statement about them are strong indications that he regarded his encounter with the iron workers more as a photo opportunity than as an invitation to metallurgical inquiry. Indeed this was his approach to the whole visit, a partial exception being made for the brass casting. In the short time spent with the iron workers neither he nor Hinderling could have made serious inquiries about Teleki smelting practices. It should also be remembered that questions and responses would have had to be filtered through French 'Teleki' translation perhaps with intercalated Fulfulde. Under such circumstances, accurate recording of a complex technical process was impossible.

This would be especially the case if what Gardi was shown was not smelting at all. Touteau's message of the previous day does not appear to have been understood and I suggest that, as the messenger was quite likely aware of the visitors' interest in iron metallurgy, it had been distorted in transmission to something nearer to: 'The Frenchman orders you to make iron for his white guests tomorrow.' But, the reduction of magnetite ore, specified as such by Gardi (1955b, Abb. 59 caption), to metallic iron is not something that can be done at the drop of a hat. The smelting season was approaching, which accounts for the pristine state of the furnaces seen in use, and there was charcoal and ore to hand, but smelting also requires the organization of production teams usually on a greater than familial scale, local beer which takes several days to brew, and, vitally, the collection of a substantial number of mainly plant 'medicines' which in part constitute a set of coded instructions to the furnace telling it how to produce the desired bloom (David 2001). With the best will in the world, unless it had by chance coincided with their own plans, the Teleki could not have put on a smelt on 19 March. The photographs suggest they did something rather different.

In the 18 pictures relating to iron working, two furnaces are shown in operation and the largest number of people seen together is seven. The same two men, both highly conscious of the camera, are at the bellows throughout the first roll of film, one being replaced at the further furnace by another in one shot on the second film. Each furnace is also served by a different man seen either standing in front of the charge hole (though not actually charging either ore or charcoal) or busying himself with a pole in the lower part of the furnace. The others are not working and could be spectators, Teleki guides or members of the visiting party. The

Mandara mountains smelts of which I have knowledge all required several workers, often including a harpist-singer, and attracted a considerable audience, no doubt augmented by the presence of whites and through time as smelting ceased as an economic practice and took on aspects of heritage celebration. The near absence of spectators, and especially of children, around the Teleki furnaces is remarkable.

The furnaces are associated with wooden structures of the kind often raised to protect the furnace crew from the sun. However, both are dilapidated and neither is thatched. Very little charcoal, about a basketful for each furnace, is visible and there are no obvious ore containers, though some might have been brought in the small pottery bowls seen in Figure 2, or perhaps in the jar placed next to the near furnace. Although the pictures are probably not posed, there is none of the energetic involvement in a demanding technological process evident in Gardi's pictures of Mafa smelts at Ldamsay and Soulédé. It all adds up to a lot less than a smelt and more of a performance, one believed by the actors to have been commanded by the French administrator. '*Nicht zu beschreiben, siehe photos*.' Gardi's few lines of description of the Teleki smelting process published in *Schwarze Hephästus* and quoted above do not constitute a claim to have observed a Teleki smelt any more than his remark in the diary that 'they were smelting iron ore'. He had, however, in his sketch of a furnace cross-section, noted an element new to montagnard metallurgy, the pierced floor or grate between the upper and lower parts of the furnace shaft. What was its function?

Evidence from the Bana

In 1990 Judy Sterner and I enjoyed a six-week field season based in Mokolo. We were invited by a retired schoolmaster, M. Job Naï Tomassa, a Bana, to visit Guili, the Bana centre, 11km north of Boura. He told us that he had assisted in smelting as a small boy, somewhere in the 1940–55 period, and that whereas Bana smiths and their wives the potters were casted, any man could smelt. He described the furnace as vertical and, my notes read, 'as if it opened from the bottom rather than from the front—possibly some kind of slag tapping?'. However, since in his boyhood magnetite was hard to come by, a litre being the product of a day's gathering and panning, and charcoal was also difficult to obtain, not a great deal of smelting was going on.

We left Mokolo for Guili in the early morning of 11 May and stayed overnight. The first afternoon was devoted to ceramics and visiting forges. On 12 May, during the morning and early afternoon, accompanied by Epafras Zira David, son of a smith who had formerly smelted, we walked from Guili marketplace some two kilometres along a track running north and slightly west beneath Guili mountain. On either side of a low pass separating Guili proper from Mazavə we saw furnaces in various states of decay, three on the Guili side and five on the other. The northernmost and best-preserved of each group (Guili 1 and Mazavə 1) was recorded, others being in various states of repair down to barely recognizable daub basal remains. There were in addition several spreads of slag that represent furnace emplacements. These last were not counted in our total of eight furnaces, a minimal estimate of the numbers operating in the latest stages of smelting which we were told lasted until 1958, just before independence. Had we searched other areas or further along and on both sides of the track and on higher slopes we would certainly have found more. Orientation of all examples found was, as at Teleki and elsewhere, with the shaft openings down slope.

Although there could well have been differences in exterior form and finish, the similarity of the Bana furnaces (Figs 6 and 7) to the unpublished Gardi picture (1953/131/12), of an abandoned example in process of decay, verges on the identical. The bellows assembly shown in other of Gardi's pictures, a daub mass built up against the back of the shield into which twin pot bellows are embedded, is also indistinguishable from the Bana pattern. In addition, the Bana furnaces throw light on the internal characteristics of shafts: where sheltered from exposure to weather, these remained smoothed and even polished, facilitating the descent of charcoal and ore to the blast zone below the tip of the tuyère. An apparent difference is the presence, *c*30cm above the base of the shaft, of a daub ledge, barely identifiable in some cases, reasonably preserved in others, running round the interior of the shaft (Figs 8 and 9). Because it is lower than the top of the shaft opening it is necessarily of horseshoe shape. According to the 70-year-old brother of Kwoyni, builder of the Guili 1 furnace, who met us on site and remembered smelting very well, this ledge served to support the fire and bloom while allowing liquid slag to drip down into the base of the shaft and form prills. In other words it performed the function of Gardi's grate, but was placed much lower in the furnace than shown in his sketch (Fig 5). The lower shaft opening was walled up during the smelt and a small vent cut through it at the bottom to allow for the evacuation of gases and perhaps, though this would seem unnecessary, some removal of slag. This seal was broken down once a bloom had formed above the bloom support, and the bloom was removed through the shaft opening—not

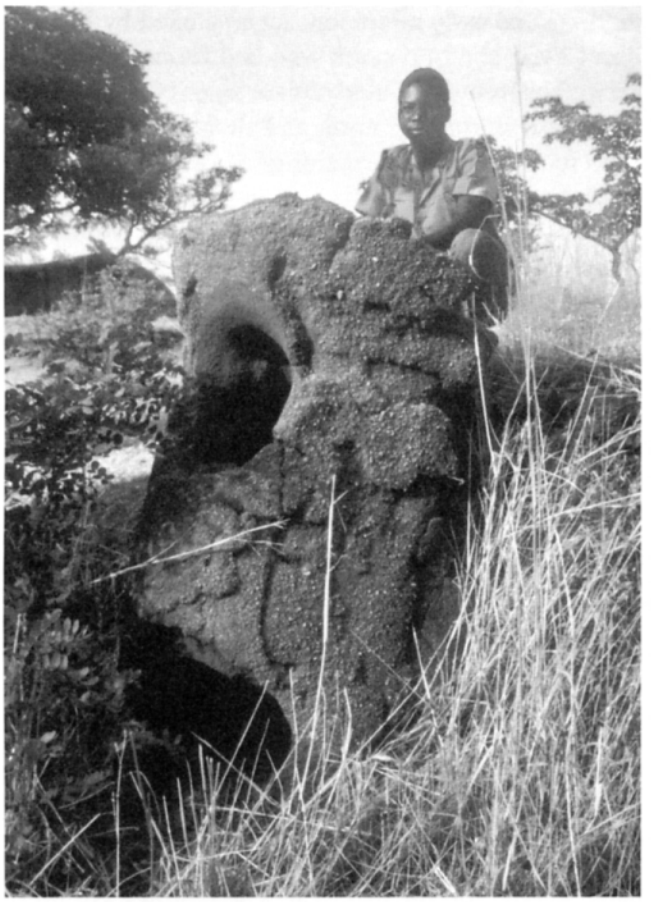


Figure 6: The Guili 1 furnace, half profile view.

Figure 7: The Mazavə 1 furnace, frontal view.

through the charge hole. Although some iron formed in separate fragments or broke off the bloom during its removal, blooms were generally coherent and of ring shape, often with a hole in the middle. Four were typically produced in a day. We saw no blooms at Guili, but quantities of slag prills of various forms around old furnaces support the description of the process offered.

The similarity of form of the Bana and Teleki furnaces is, as noted above, very evident to the eye. Direct comparison of Teleki to Bana furnace proportions is difficult since, firstly, furnace proportions change differentially in the course of decay and not only by preferential loss of the shield: it is clear from Gardi's photographs of Teleki furnaces in use that their charge holes had been recently reduced in diameter by the addition of daub that would be subject to erosion in the rains. And, secondly, in the case of abandoned and decaying furnaces, it is not possible to establish the base of the shaft opening without excavation.

My estimates of the relative proportions of the furnace near Teleki seen in Figure 2, the decayed Teleki furnace, and comparably decayed Bana examples, are given in Table 3. While there is variation within and between the Teleki and Bana samples, it is not suggestive of different ethnic types. Further, M Tomassa told us that Bana had replaced Daba at Guili, some coming from Teleki,

Table 3: Comparison of Teleki and Bana furnace height proportions.

	Teleki and Bana furnace height proportions—percentage of height (less shield)			
Preserved furnace parts contributing to height	**Furnace near Teleki: Fig 2**	**Teleki decayed furnace Gardi 1953/131/12**	**Bana Guili 1: Figs 6 & 9**	**Bana Mazavə 1: Fig 7**
Charge hole (upper opening)	22.4	28.2	29.0	30.2
Base of charge hole to top of shaft opening	37.3	41.0	33.6	34.1
Shaft (lower) opening	40.4	30.8	37.4	35.7
Actual height to top of charge hole	155cm (est)	?	135cm	154cm

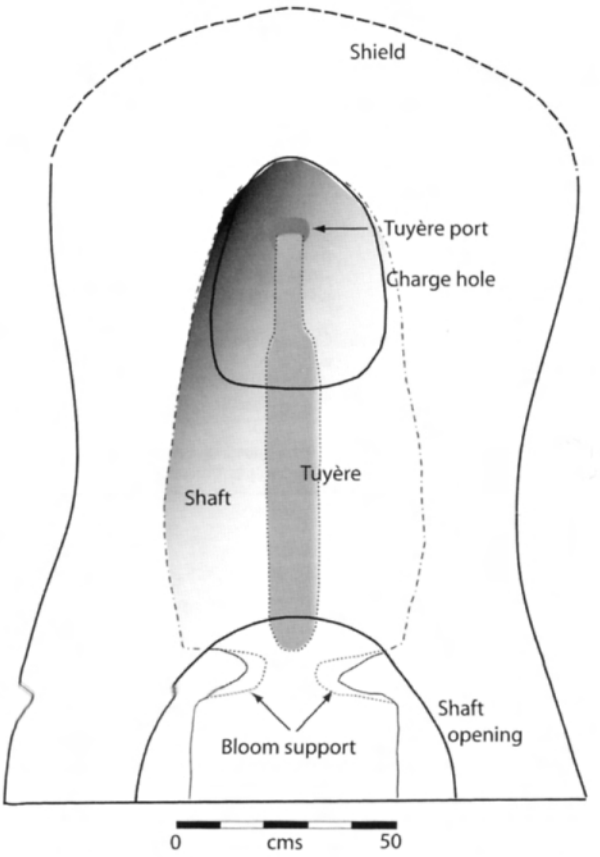


Figure 8: Diagrammatic frontal reconstruction of the Mazavə 1 furnace, drawn from photographs and field measurements. The daub bloom support is horseshoe-shaped and open to the front. Tuyère length is estimated at 103cm.

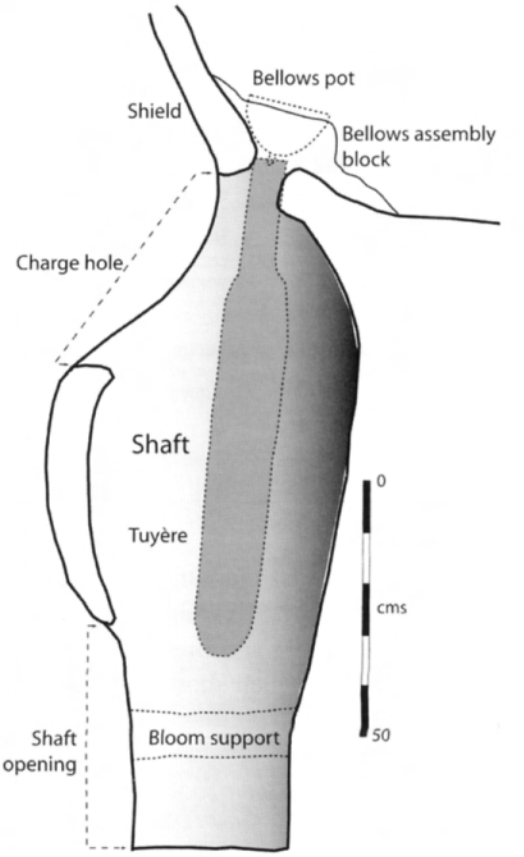


Figure 9. Diagrammatic cross-sectional reconstruction of the Guili 1 furnace, drawn from photographs and field measurements. The partially-reconstructed lines of the daub bloom support are indicated. Tuyère length is estimated at 98cm.

only 20.5km to the SSE, and others from Sukur, much further north. While such stories cannot be accepted at face value, the claimed connection with Teleki should not be ignored.

The Teleki-Banan slag-draining furnace

The data presented above support the view that Teleki and Bana furnaces were so similar that they cannot be differentiated, at least in their basic structure and functioning. I have shown that the evidence against this view—Gardi's brief account in *Schwarze Hephästus* of the use of Teleki furnaces and his cross-sectional sketch—carries little weight. Neither the statement nor the drawing is viable in terms of metallurgical process, while the length and nature of Gardi's visit rendered the gathering of quality information impossible. To be explicit, I am arguing by analogy from the numerous documented similarities between Teleki and Bana furnaces that other features were also similar, and most significantly that the grate, the 'floor pierced with holes' noted by Gardi, was in function and form comparable to the bloom supports identified in Bana furnaces. Unfortunately, this cannot be checked by reference to Gardi's photographs since, where visible, the interior of the lower shaft opening is always too dark for features to be clearly observed. In the photograph on *Schwarze Hephästus* page 121, showing a man squatting on charcoal while using a pole in the interior of the lower furnace shaft, a lighter area is visible within the shaft below the point of his tool but more than 30cm above the base of the furnace. This could represent a ledge somewhat higher than in the Bana furnaces recorded, or an extension of the fresh plastering seen in the charge hole, the lower edge of which might, before a real smelt, have coincided with the top of a ledge. In the absence of new fieldwork the question remains moot.

It remains to characterize these furnaces in the context of other Mandara montagnard types. The Teleki and Bana furnaces are differentiated from the Mafan and Sukurian types in the ways described below.

1. Unlike in Sukurian furnaces, the shaft opening is temporarily walled up with daub instead of being blocked off during each bloom-making episode with some combination of daub, tuyère fragments, rocks and sherds.

Table 4. Characteristics of tuyères used in selected Mandara montagnard furnaces. Dimensions have been variously measured or estimated

Ethnic Group	Furnace type	Tuyère form	Approximate tuyère dimensions before use	Tuyère use
Mafa	Mafan	Heavy and long. Proximal end formed over ceramic armature and built up by the addition of cylinders from junction with armature.	Length 144 to *c*200cm; max. diameter 13+cm; bore at tip 6.5cm but less above, weight 20kg and up.	Ceramic armature required to support weight of tuyère throughout a long continuous smelt. Armature unlikely reused.
Teleki	Teleki-Banan	Heavy. Proximal end formed over ceramic armature. Building technique unknown.	Length *c*100cm or longer; max. diameter 15–18cm; bore 4.5–6cm, weight 13–16kg.	Ceramic armature required to support weight of tuyère throughout a day's smelting of about four ring-shaped blooms. Armature unlikely reused.
Sukur	Sukurian	Intermediate. Proximal end formed over ceramic armature. Building technique unknown.	Length *c*100cm; diameter 12–14cm; bore 4.5cm; weight perhaps 12kg.	Ceramic armature required to support weight of tuyère throughout a day's smelting of *c*9 blooms of about 1.4 to 2kg. Armature typically reused.
Plata	Sukurian	Light. Formed over a wooden pole.	Length 80cm; max. shaft diameter 7cm; bore 4cm; weight *c*5kg.	Several used in a day's smelting, probably one per bloom.

2. Amongst Mandara montagnard tuyère forms, ranging from light Plata Sukurian examples to long, heavy Mafan pipes, Teleki and Bana specimens fall near the heavy end, despite their shorter length, and would have sufficed for a day's smelting (Table 4).
3. Unlike in Mafan furnaces, because blooms are supported above the furnace base and removed at relatively short intervals—probably 2 to 3 hours—the vent pierced in the daub wall across the shaft opening does not have to be raised in the course of the smelt to follow the upwards retreat of the tuyère.
4. Again unlike in Mafan furnaces, since slag can drip and flow down through the bloom support, there is no need to remove slag from below the active reduction zone. This slag-draining feature justifies distinction of a third montagnard furnace type, the Teleki-Banan.
5. Given slag-draining, it seems likely that considerably larger blooms could form than in the case of Sukurian furnaces, where the accumulation of slag beneath and around the bloom quickly degrades the efficiency of reduction to the point that it becomes necessary to remove the bloom and slag and to start again. Though fewer blooms were extracted in a day than from Sukurian furnaces, the quantity of metal produced may have been similar.
6. In both Mafan and Sukurian furnaces the wall or blocking material must be cleared from the shaft opening in order to remove the bloom mass or bloom. Removal was also necessary here, but extraction of a ring-shaped bloom resting on the bloom support through the space between the support and the top of the shaft opening without serious damage to either must have required a skill comparable to turning a breech presentation in the womb to achieve a favourable birthing position. I suspect that the similarity was not lost on their master smelters, and that the relatively large shaft space beneath the bloom support was designed to facilitate manipulation of pokers, hooks, hardwood poles and perhaps tongs in bloom removal.

Of the three montagnard furnace types, the Teleki-Banan is the most sophisticated in concept and, while we have no way of measuring its productivity against others, this must have been at least comparable. Elsewhere in the Mandara, notably at Sukur, a smith-potter caste monopolized smithing and potting, but any household head could smelt, a situation associated with specialization in iron production and a considerable export trade. Iron production was organized in this manner among the Bana (and by analogy also the Teleki). Bloomery iron, besides being forged and consumed locally, was exported by the Bana either as tools or blooms, although apparently not in the form of the 'currency' bars made elsewhere in the region. The Kapsiki immediately to their north were their main clients, as perhaps also the Jimi around Bourah and the Daba.

In conclusion, some six decades after René Gardi visited Teleki and recorded new and critical, if somewhat misunderstood, information about their furnaces, and 20 years after Judy Sterner and I visited Guili for a stay of little over 24 hours, our data have been combined and mined to reveal new dimensions of the Mandara mountains' unique metallurgical tradition. Many questions about Mandara iron production, technology and culture remain. Some pertaining to social science are answered in *Metals in Mandara Mountains' society and culture*, a book edited by the author of this paper and submitted for publication. But what technical considerations lie behind the variation in furnace types? Complex balances between ore, water, fuel and labour availability and requirements are no doubt in play within and between differing cultural traditions. Such matters are beyond the scope of the present paper and will most profitably be tackled after publication by David Killick and colleagues of the metallurgical evidence gathered thus far by the Mandara Archaeological Project and other teams.

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Notes

1 Gardi also refers to the Teleki as Gude, an ethnic group numbering about 96,000 in 1987, of whom 68,000 were living in Nigeria. In fact the Teleki, who have also been called Cede and linked to the Gude (*eg*, Seignobos 2000), are not as closely related linguistically to the Gude as they are to the Sharwa of Tchévi, though they, together with the closely nterrelated Bana, Kapsiki and Higi, are all members of the Chadic Biu-Mandara A8 linguistic grouping (Brye 2001, and Ethnologue [Lewis (ed.) 2009 and see http://www.ethnologue.com/show_family.asp?subid=602-16 consulted 2010/03/01]). With the exception of the Kapsiki (van Beek 1987 and numerous other publications) none of the A8 groups have ever been the subject of a full scale ethnography. This accounts in part for the confusion over their names, language names and cultural relationships in the very limited literature.

2 No scale is given in Gardi's photograph. However, the diameter of the ceramic armature is likely to be fairly similar across furnaces that use them. In 1989 the Mafa master smelter Dokwaza Kawa made an armature for the re-enactment of a smelt in the same furnace used by him in 1986 (David *et al* 1989). Its mid-shaft diameter measured 87mm. This figure was applied to estimate the length of the nearest tuyère stub in the picture, giving a length estimate of 92cm, and a maximum tuyère diameter of 18.5cm. As it is unlikely that a smaller furnace would use a substantially fatter tuyère than a Mafa one, I propose minimum estimates for Teleki tuyères as follows: armature diameter 71mm ; tuyère length after use 75cm; maximum diameter 15cm. This allows for a bore of 40-50mm.

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