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Forging networks and mixing ores: Rethinking the social landscapes of iron metallurgy

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ABSTRACT

This research explores the networks of technological knowledge that influenced changes in the iron production practices of western Uganda in the second half of the second millennium AD. Temporal and spatial variability in technological processes were observed within the research area, in terms of the style and construction of the furnaces, the use of a manganese-rich flux, and the configuration of tuyères. These shifts were considered in relation to the social dimensions of iron production, specifically the protection of technical knowledge. Informed by ethnographic data from the study area, variations were noted in the participation in, or exclusion from, iron production activity on the basis of gender and clan affiliation. This stands in contrast to ethno-historic accounts that speak of a strongly regulated production environment.

This paper considers that an uncritical emphasis on conservatism provides an inadequate framework for addressing long-term change in iron production technologies. It suggests that constellations of knowledge in western Uganda fostered the potential for innovation and experimentation, resulting in dynamic technological practice. This paper urges a more nuanced discussion of how complex metallurgical technologies transform and move within cultural and physical landscapes, with ramifications for how we conceptualize the emergence and adoption of early technologies.

1. Introduction: Variability and change in iron metallurgy

Archaeometallurgical research in Africa continues to illustrate the extensive technological diversity that dominated the pre-industrial iron smelting landscapes of the African continent (many examples to be found in Cline, 1937; Childs, 1991; Killick, 2016). This variation is far in excess of that documented in Europe, despite the much greater volume of European research that has been carried out (Killick, 2015), and yet it appears to stand in opposition to the recurring narrative in ethnographies of the rigidity and invariability of African iron production technologies. The conservatism and protectionism of technological knowledge implied in the ethnographic and ethnohistoric literature cannot satisfactorily address questions of how and why broad technological variation in the smelting record ultimately developed. Thus, this paper sets out to explore potential social influences on processes of variation and change in iron production practices, using the pre-colonial archaeometallurgy of western Uganda as a case study.

Technology can be construed as the application of knowledge (Jordan, 2015) – knowledge that is discernible within the products it creates, and the waste associated with those products. Technological change, therefore, is the process of transformations in knowledge: "a continuous, cumulative, and, largely, an irreversible process" (Parayil, 1991: 299). Seeming in contrast to this, ethnohistoric examples of African iron smelting present technologies that are tightly bound by strict behavioural and technological rules and rituals. This has often been interpreted to indicate unchanging, unchangeable technologies, especially in accounts of the early 20th century, which presented African iron smelting as "hidebound by taboo and ritual, inherently conservative with no tendency to innovate" and saw the iron workers themselves as "automaton[s] reproducing technical steps with the aid of ritual mnemonics" (Fowler, 1990: 37). Such generalisations, drawn from early ethnographic studies of African metallurgy (e.g. Cline, 1937; Wyckaert, 1914) and summarised in widely influential books (e.g. Eliade, 1956; Herbert, 1993), have permeated into more recent interpretations of the organisation of African iron production (e.g. Brown, 1995: 91[1]), and of the organisation of metallurgy in general (e.g. Giles, 2007; Roberts, 2008). However, historical analyses of pre- and post-colonial African societies illustrate their capacity for significant socio-cultural transformations in the recent and more distant past (e.g. Connah, 1998; Doyle, 2006a), which suggests that caution is required when applying the ethnographic record to archaeological data (Iles and Childs, 2014; Cunningham and MacEachern, 2016). Although

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[1] "the beliefs associated with ironworking itself make it a particularly conservative craft".

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resistance to change may be observed in individual workshops, an assumption of persistent conservatism omits the possibility of change that can occur within lifetimes, over generations or on even longer timescales. As Schmidt (1996: 4) warns, "technological histories that hold important stories of innovation and invention have been erased and replaced by representations that focus on ritual practice and beliefs surrounding iron production".

It is possible to place the preoccupation with the continuities and constants that constitute smelting 'traditions' as a tendency to overlook the dynamic nature of African society and technological capability in general (see Killick, 2015). European travellers to sub-Saharan Africa in the late nineteenth and early twentieth centuries were fascinated by ritual aspects of African life, drawn to exotic, repetitious and choreographed performance. This has arguably influenced modern anthropological and archaeological interpretations of iron production activity,[2] and it is feasible that more elaborate technological behaviours were given prominence in early accounts, overshadowing smelting activity that did not involve explicit ceremonies and rituals, and entrenching a perception of rigid and inflexible gestures and routines (see Iles, 2013a). Many iron production technologies of the nineteenth and twentieth centuries were certainly steeped in ritual, prohibitions and symbolism (see examples in Childs and Killick, 1993; Schmidt and Mapunda, 1997). However, this paper questions to what extent these elements are universal within African iron production technologies, how dynamic they were in themselves, and what time-depth can be attributed to them (see also Herbert, 1993; Chirikure, 2007; Iles, 2013a; Stahl, 2015; Mtetwa et al., 2017).

It is worth acknowledging at this point that bloomery iron smelting[3] is undoubtedly a high-risk investment activity; once a furnace is fired and a smelt is underway there is a lot at stake. Days or weeks of resource procurement and preparation culminate in a firing that could potentially fail if various requirements have not been met: too much variation from a known and accepted 'recipe' may result in economic loss for participants, or a loss of status or reputation. Access to the usual resources (including charcoal, ores and clays), furnace construction, weather conditions, the experience and energy of the head smelter and bellowers are all factors that are liable to vary from smelt to smelt, that might affect the temperature, furnace atmosphere or progress of a smelt, and which will have an impact on the outcome. Together, these considerations might indeed result in technological conservatism, especially in comparison to technologies with a lower investment of time and materials.

What role can concepts such as experimentation and creativity play within these constraints? Was there scope for individuals to experiment with these processes, stimulating invention and innovation, but also, inescapably, risking failure? Or were unintentional or unavoidable modifications the primary way by which these complex technologies changed through time[4]? The American blacksmith and anthropologist Charles Keller talks of the satisfaction gained from novelty and new ideas as a smith, but also of the satisfaction of continuity with the past – a tangible link with those who worked iron before him (Keller and Keller, 1996: 41). It may be important to note that Keller's experience is of twentieth century artist-blacksmithing communities of North America rather than African industrial metalworkers of the nineteenth century, but similar sentiments are apparent in Schoenbrun's analysis of changing engagements with shrines and spirit mediums around Lake Victoria on the cusp of the second millennium AD. Schoenbrun (2016: 216-7) asks how a community reconciles political transformation alongside maintaining fidelity to their ancestors. In both circumstances the question asks, how does traditionalism accommodate change? Where does the balance between these competing forces lie in different societies, past and present?

With these questions in mind, this paper considers the temporal changes apparent in the iron production technologies of western Uganda in the second millennium AD, in relation to different smelting communities and the 'networks of knowledge' (Kodesh, 2008, 2010) that may have linked them and influenced their technological trajectories. The research set out to explore the cultural landscape of iron smelting in western Uganda by combining archaeological, archaeometallurgical and ethnographic approaches. It identified shifts in smelting technology over time, which in turn inspired a discussion of the identity, relationships and behaviour of those who made and worked with iron. In this way, a greater understanding of how past iron production was organised in this part of the Great Lakes region can be formed, and the mechanisms of socio-economic activity that result in spatial and temporal variability in technological practice can be examined.

2. Precolonial iron production in western Uganda

This research explores these ideas of transformations in technological knowledge using an analysis of data derived from the excavation of several iron production sites in western Uganda, dating to the second half of the 2nd millennium AD. A combination of archaeometallurgical and ethnoarchaeological evidence was used to reconstruct some of the precolonial iron technologies undertaken in Mwenge – a region of western Uganda renowned historically for iron production (Fig. 1. Iles, 2011, 2013b).

This area provides a particularly interesting case study by which to discuss the movement of iron production knowledge in the wider Great Lakes region. There is little current evidence for very early iron production either in Mwenge specifically or in western Uganda more generally. This diverges from the evidence for iron smelting prior to 1000 CE in the southwest corner of the Great Lakes region (including Rwanda, Burundi, the DRC and north-west Tanzania), where evidence for early iron production stretches back to at least the mid-first-millennium BC (van Grunderbeek et al., 2001). In contrast, the earliest evidence so far for smelting in western Uganda is the furnace at the site of Munsa, dating to the fourteenth century AD and situated roughly 50 km to the west of Mwenge (Fig. 1. Robertshaw, 1997; Iles et al., 2014). It is possible that the lack of iron production remains is linked to a low population density in western Uganda prior to the second-millennium AD, with an accompanying low demand for iron (Schoenbrun, 1998; Robertshaw, 1999; Iles, 2013b), although there is scope for more archaeological research in the region to explore this further. Nevertheless, by the mid-second-millennium AD, western Uganda (and Mwenge in particular) had developed into a thriving centre for iron production, with a wide-reaching reputation for the manufacture of high quality iron: an industry that continued well into the twentieth century.

Considering western Uganda as an 'internal frontier' (Kopytoff, 1987) into which communities may have expanded through the second millennium AD provides a useful framework for thinking about how iron production might have become established in the landscape and within the social structures of the region at this time. Different groups of people would have moved into the area bringing with them different packages of craft knowledge, as well as an increasing demand for iron to clear land, hunt and farm. It is also in this later period that individual wealth – potentially augmented by producing iron – began to play an increasing role in the formation of hierarchies of power, which previously had been tied to lineage and heredity (Schoenbrun, 1998;

[2] Echoed in Sarkozy's supposition that "the African peasant only knew … the endless repetition of the same gestures and the same words" (speech given by Nicolas Sarkozy in 2007 at the University of Dakar, Senegal, quoted in Stahl, 2014).

[3] Bloomery (or direct) smelting describes the separation of iron oxides from a host ore, and their transformation to iron. A carbon-saturated, reducing atmosphere within a furnace reduces the iron oxides to iron metal. The heat within the furnace is high enough to melt the gangue (rock) minerals (which form the main part of the waste product of the process, slag), but not high enough to melt the iron: the iron remains mostly solid throughout (a bloom).

[4] Doolittle's "incremental changes" (1984) or Merton's "unintended consequences" (1936).

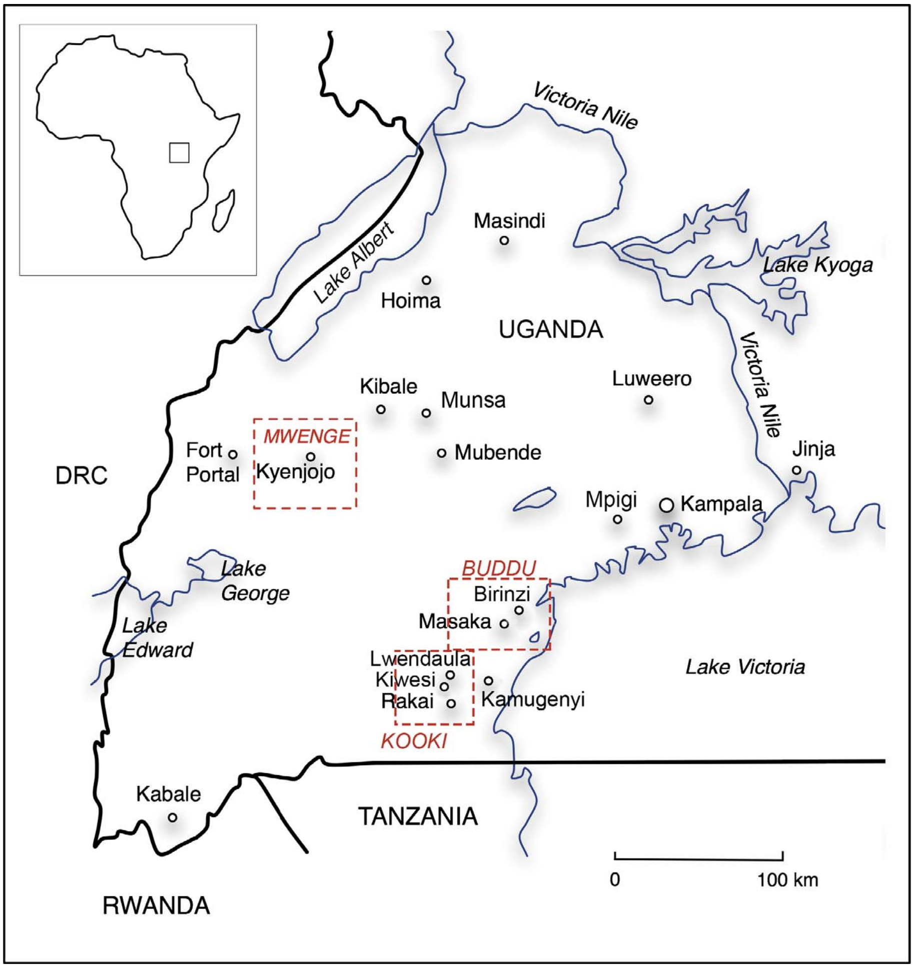

Fig. 1. Map of western Uganda showing location of Mwenge in relation to modern population centres and other sites mentioned in the text.

Ashley, 2010; Robertshaw, 2010). Iron is likely to have played a role in this socio-economic shift, augmenting the wealth and thus power of those who took part in its production. Did this melting-pot of knowledge in-flows on one hand and increasing demand on the other inspire technological innovation? Through an amalgamation of the existing ethnohistorical, ethnoarchaeological and archaeological data, in conjunction with the archaeometallurgical and ethnoarchaeological data presented here – it became clear that there was indeed significant temporal variation in past iron production practice within Mwenge over the past 600 or so years.

2.1. Archaeometallurgical evidence

During fieldwork in Mwenge in 2007, six smelting sites were excavated, and samples of slag[5] and technical ceramic (tuyères[6], furnace lining) were taken from each site for further analysis. Previous papers saw the publication of the results of the archaeological and archaeometallurgical analyses (Iles, 2011, 2013b, 2014), but a summary of key points is provided here.

Smelting remains were excavated at the sites of Kyakaturi, Mirongo, Rugombe, Kirongo, Kisamura and Rukomero (Fig. 2), and slag and tuyère remains collected from these sites were analysed using a combination of optical microscopy, scanning electron microscopy and polarizing energy dispersive X-ray fluorescence with energy dispersive spectroscopy to explore the bulk chemistry and mineralogical composition of each studied sample (Iles, 2014). Radiocarbon dates generated from charcoal excavated from the lower fills of excavated furnaces at each site clustered in two ranges: fourteenth-fifteenth centuries AD (Kyakaturi, Mirongo, Rugombe) and seventeenth-twentieth centuries AD (Kirongo, Kisamura and Rukomero) (Table 1). The furnaces themselves were all found to be pit furnaces, ranging between 50 and 100 cm in diameter, and extending between 30 and 60 cm in depth, but there were some distinct differences in the technologies undertaken, summarised below in brief descriptions of the smelting sites presented in chronological order. Further detail on the technological reconstructions is available in Iles, 2011, 2014.

At some point in the late thirteenth / fourteenth century, smelters at the site of Kyakaturi were making iron from a very rich iron ore with significant levels of phosphate (c. 1.4 wt%), and using tuyères made from highly refractory clay. Using this ore had several implications for the ironworkers: the high iron content meant that it would have been necessary for them to add crushed quartz to the smelt to enable a slag to form, and the phosphoric nature of the ore would have resulted in iron with a phosphorous content of up to 0.35 wt% – a potentially brittle metal, but tough (Iles, 2014).

During roughly the same period, smelters at Mirongo, approximately 20 km to the southwest of Kyakaturi, had no need to add quartz: the ore they used had sufficient gangue to allow a slag to form, particularly in conjunction with the less refractory clay they crafted their technical ceramics from. These differences are not unexpected, and could feasibly relate to the particular raw materials available at each location. However, a variant in evidence at Mirongo attributable to a conscious choice made by the smelters, was that the furnace was operated with only one tuyère: a design element seen also in the furnace at

[5] The waste product of smelting, primarily composed of rock minerals from the ore that have been melted away from the iron oxides in the ore during the course of a smelt.

[6] The ceramic pipes that are used to introduce air into the body of a furnace.

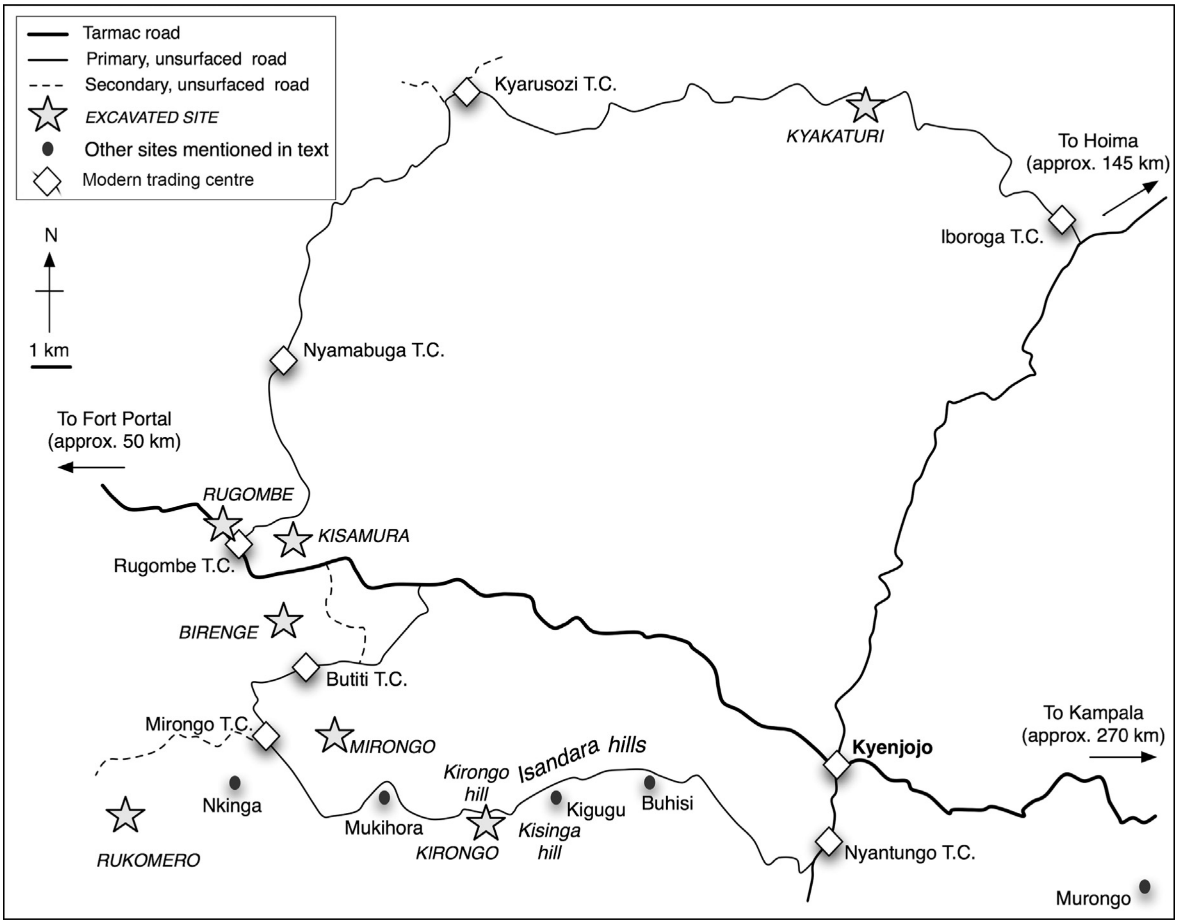

Fig. 2. Sites in Mwenge.

Table 1
Radiocarbon dates of excavated furnaces in western Uganda, calibrated using OxCal 4.3 and IntCal13 to 2-sigma (https://c14.arch.ox.ac.uk/oxcal/OxCal.html) (Iles et al., 2014).

Site	Lab Code	date bp	Cal. ad
Munsa	AA-19334	615 ± 50	1285–1411
Kyakaturi	OxA-20936	625 ± 50	1290–1399
Mirongo	OxA-20933	553 ± 27	1314–1430
Rugombe	OxA-20931	479 ± 26	1410–1450
Kirongo	OxA-20938	148 ± 25	1667–1949
Kisamura	OxA-20932	102 ± 25	1685–1928
Rukomero 1	OxA-20934	148 ± 25	1667–1949
Rukomero 2	OxA-20935	170 ± 28	1661–1954

the fourteenth century site of Munsa (Iles et al., 2014). The use of a single tuyère certainly had implications for the formation of the slag block and the growth of the bloom within the furnace, but it would also have meant that a smaller number of bellowers were needed to power the bellows.

Slightly later in time, in the first half of the fifteenth century, smelters working at the site of Rugombe (Fig. 3) – also nearby – were beginning to experiment with a new technology: the addition of a manganese-rich flux. This addition would have enhanced the operating parameters of the smelt as well as increasing the potential yield of iron from the ore (Iles, 2014), and was demonstrated by elevated levels of manganese oxide (c. 3–7 wt% as compared to c. 1 wt%) in some of the slag blocks at that site.

By the time the three later sites were in operation – sometime between the seventeenth and twentieth centuries – the addition of a manganese-rich flux had become more prevalent, and more pronounced. Slag blocks from the site of Kisamura and Kirongo contained

Fig. 3. Excavated furnace at Rugombe.

particularly high levels of manganese oxide, not infrequently ranging up to 12 wt%. These two sites – as well as a cluster of slag blocks from Mirongo (Mirongo Group 2) – showed particularly strong technological similarities. Combining evidence from furnace excavation and slag morphology suggests that furnaces with a single-tuyère were being used at Kisamura and Kirongo (Fig. 4), and there is evidence for the use of

Fig. 4. Excavated furnace at Kirongo, looking south, with slag block in-situ. The morphology of this slag block is suggestive of the use of one tuyere.

banana plants in the furnace pits at Kisamura and Mirongo Group 2 (Iles, 2009). This might correlate with the comparatively late arrival of banana plants in western Uganda. Though there was a "banana revolution" around the shores of Lake Victoria between the twelfth and fifteenth centuries, when banana cultivation increased in scale and importance (Schoenbrun, 1998: 167), it is likely that these plants would have arrived in the drier areas of western Uganda – with its stronger emphasis on pastoralism – slightly later in time (see also Hamilton et al., 2016).

The outlying smelting site during this later time-period, both technologically and geographically, is Rukomero. Set further apart from the other Mwenge sites, the smelters at Rukomero were not adding a discernible flux of any kind to their smelts, and they were smelting in larger, deeper furnaces, which resulted in more inconsistent furnace atmospheres during firing (Fig. 5). Given the broad calibration range associated with the radiocarbon dates from Kirongo, Kisamura and Rukomero (Table 1), it is currently not possible to say whether these sites were contemporaneous or otherwise.

2.2. Mixing ores in Mwenge

In addition to this archaeological evidence, Mwenge enjoys an unusually rich documentary history of iron production. Some of the iron working technologies of the Bunyoro Kingdom (under whose jurisdiction Mwenge found itself in the later centuries of the second millennium AD) were recorded and photographed by the missionary and ethnographer John Roscoe in the early twentieth century (Roscoe, 1915, 1923). Roscoe witnessed Nyoro smelting at a craft exhibition organised for the king in the vicinity of Hoima (Fig. 1; Deane, 2007). Descriptions of early-twentieth century smelting also appear within the clan traditions recorded by the historian Carol Buchanan (1974, 1979). Ethnoarchaeological interviews undertaken by Terry Childs in the 1990s (1998, 1999, 2000) provide useful technical detail derived from the memories of a smith from Nkinga (Fig. 2). Furthermore, archaeological survey in 2007 led by the author also came across those who remembered smelting. In order to locate and record metallurgical sites, the 2007 survey combined interviews with targeted informants who were already known to have had links to past iron production, alongside daily walking survey. The walking survey presented valuable opportunities to speak to a wide spectrum of local community members, many of whom had memories or stories of past iron smelting (for a more detailed discussion of the survey and interviews, see Iles, 2013a). This approach ensured that a broader and more inclusive range of memories was accessed in the community, rather than just those who were prominent locally for their connections to past iron production activity. This is important if a wide range of voices and experiences is to be considered in our construction of knowledge regarding iron production technology (Iles, 2015; see also Chirikure, 2016; Mtetwa et al., 2017).

The accounts of Childs, Buchanan and Roscoe – although they describe different furnace designs and tuyère configurations[7] – are linked by their descriptions of the use of two ores, mixed together prior to a smelt. Childs' (1998: 130) account refers to one ore that is black and glittery, and one that is red and dense. These two ores were combined as they dried before use, giving them the opportunity to 'befriend' or 'embrace': possibly an indirect reference to a genderisation of these ores, as also noted in Roscoe's account:

> "There were two kinds of stone in use and in common parlance they were referred to as the male and the female. The male was regarded as better in quality, but it had the disadvantage of being hard to break and prepare for smelting. It was black in colour and was found in the hill Nyaituma, usually on the surface of the ground. The female, or soft, iron was found in Galimuzika Busanga; it was red and lay in layers running into the hillside."
>
> (Roscoe, 1923: 217-8)

There are a handful of other examples in the ethnographic literature of African iron smelting where two ores are combined. The Jur, in what is now South Sudan, smelted male and female ores together – 'Obau' and 'Okina' – "it is the general belief that both of these substances must be present before iron can be produced" (Crawhall, 1933: 41). In Cameroon, Babungo smelters used limonite and haematite ores of different colours, again classified as male and female, their combination necessary for successful iron production (Fowler, 1990: 203). Also in Cameroon, We/Isu smelters mixed a male ore (a ferrous gravel) with a female 'ore' (a clay) (Rowlands and Warnier, 1993: 524). Marakwet and Atharaka smelters of western Kenya, interviewed by Brown (1995: 45), referred to different ores as male and female or husband and wife, while Somali smelters in eastern Kenya considered iron ore to be female and iron metal male (ibid.). Todd (1985: 93) also recorded the use of a mixture of limonite and magnetite to smelt in south-west Ethiopia, though whether they were associated with genders was not noted.

Closer to Mwenge, there are several further examples of dual-ore smelting in present day Uganda. Roscoe's (1911: 379) account of Baganda smelters, probably witnessed close to Mpigi (Fig. 1; A. Reid pers. comm. 2010) also refers to a hard 'male' ore and a soft 'female' ore being combined, which Cline (1937: 47-8) again suggests would have been a magnetite 'male' ore and a haematite 'female' ore. These smelters were of the Bushbuck clan, who obtained their ore from the border of Kooki and western Buddu (Fig. 1). An informant in the village of Kamugenyi, also in Buddu (Fig. 1) – a smith and former smelter, born in 1910 – spoke of the use of two ores, and although he could not be more specific about their nature, MacLean recorded the occurrence of yellowish-brown limonite and black goethite within the landscape (MacLean, 1996: 29). Of particular interest is the long distance MacLean's informant recalled travelling to collect iron ore from Lwendaula – over 30 km and two days journey to the west of the smelting site at Kamugenyi (Fig. 1; MacLean, 1996: 29), but very close to the source of the iron ore in Roscoe's 1911 account, and also to the smelting site of Kiwesi, which was also excavated during the 2007 research (Fig. 1; see Iles, 2013d).

[7] Childs describes a furnace pit one meter in diameter and one meter deep, lined with ash but with no walls or superstructure and with a protective shelter built over it. One pair of bellows was placed at the side of the furnace, with a tuyère set into the pit (Childs, 1999: 31-2). Buchanan's account describes the construction of small pit furnaces with six or seven bellows, surrounded by stones, all within a thatched enclosure approximately two metres in diameter (Buchanan, 1974: 103). Roscoe's account of the royal smelters of Bunyoro describes unusual furnaces, comprising round pits, approximately 50 cm deep and 50 cm in diameter, with a baked clay cover. A hole in the cover was used as a chimney (Roscoe, 1923: 220-1).

Fig. 5. Smelting furnaces excavated at Rukomero.

Fig. 6. Screen-grab from KTN News Kenya broadcast (28 July 2013) with a feature on the "despised and isolated" Il-Kunono blacksmithing clan. Reproduced with kind permission from The Standard Group PLC.

Identifying the mineralogy of the ores used in the Mwenge smelting presented an opportunity to link the ethnographic record of Nyoro smelting with archaeological data. The description of the red, soft ore is feasibly a description of haematite. Cline (1937: 117) interprets the 'male' ore to be a colluvial or alluvial magnetite. This is an understandable assumption based on Roscoe's description, but importantly one that was made with no first-hand knowledge of the area. Instead, the black, sparkling ore described in the ethnographic literature is likely to be a manganiferous mineral added to the smelts, evident in the elevated manganese oxide levels present in many of the archaeological slag samples. The addition of this material would have acted as a flux, reducing the viscosity of the resulting slag, facilitating the separation of the slag from the bloom, and improving the yield of iron from the iron ore. Recent analysis of a sample of the 'male' ore, collected from a mine near Kirongo, confirmed this hypothesis (a full discussion of the technical analyses and the implications of a manganese-rich flux is presented in Iles, 2014).

3. Shifting technological knowledge in western Uganda

The evidence presented above suggests a collage of technological knowledge in western Uganda from the fourteenth century AD to within modern memory. Later technologies (including inferences from twentieth-century ethnographic examples) show increasing evidence for the use of a manganese-rich flux. However, this is not the only technological change through time – later sites tended to use furnaces with a single tuyère rather than multiple tuyères, and the slag blocks from these sites were more likely to have impressions of banana plants in addition to reeds and grasses (Iles, 2009, 2011, 2013c, 2014). What might have prompted these shifts in smelting practices? As Gosselain (2008a: 152) states regarding pottery, but which is just as applicable to all crafts, "we cannot hope to understand the spatial and temporal evolution of pottery traditions without paying attention to the specific social and historical contexts to which they belong." The ethnographic and historic accounts of the region were thus re-examined in order to consider the different communities of practice in the region, and the possible means of knowledge flow that may have encouraged technological change; salient points are discussed below.

3.1. Networks of clans as networks of knowledge

In many accounts of sub-Saharan African crafts, participation and the behaviour of participants – the contexts that frame potential knowledge transmission activities – are tightly bound with identity. Identity, particularly gender and clan, has regularly been seen as shaping whether and to what extent technical, social and esoteric knowledge of iron production was focused within particular groups, and whether and to what extent it was spatially and socially restricted (see Herbert, 1993; Sterner and David, 1991; Tamari, 1991).

Clans or castes associated with metal working are common throughout eastern Africa, such as the smelters of the nineteenth-century kingdom of Karagwe (Reid and MacLean, 1995), the blacksmiths and potters of Darfur (Haaland, 1985), and the blacksmithing clans associated with pastoralist groups of east Africa (Cline, 1937). Some of these smithing and metal working clans are physically and socially isolated from the rest of the community, even now (e.g. Fig. 6). This behaviour has been associated with a restriction on the participation of outsiders, thus ensuring that knowledge, and therefore power, is monopolised within a particular clan or lineage (e.g. Haaland, 1985; see also Crown, 2016). Limiting economic competition has also been linked to the embedding of technology within complex ritual and esoteric knowledge (Childs, 1991: 346). Smelts undertaken under the leadership of a master smelter who alone held ultimate ritual and technical knowledge were unrepeatable by those without access to that knowledge. In some cases, master smelters required apprentices to prove their loyalty and their dedication to the craft before they were initiated to the full secrets of smelting and given the "essential technical and ritual knowledge" needed to smelt (Childs and Killick, 1993: 329).

These models, which link the concealment of knowledge to the maintenance of power and authority, presume a particular perspective on the role, history and operation of clans in the region. The clan structure of the Great Lakes is typically seen as an exclusory, patrilineal system, with membership as "exclusive as any medieval guild system" (Ingham, 1975: 16). However, this idea originated with very earliest ethnographic accounts of the region, accounts written at a time at which "the disorder and demographic collapse of colonial rule" had already transformed the social organisation of knowledge (Guyer and Eno Belinga, 1995: 118; Kodesh, 2010[8]). Instead, the dynamic and variable nature of clan organisation is increasingly being emphasised, with implications for how the organisation of craft production is perceived (Tamari, 1991; Wallaert-Pêtre, 2001; Stahl, 2016). Of particular relevance in this case, recent historical assessments of clans in Uganda (e.g. Kodesh, 2008, 2010; Willis, 1997) present a nuanced view of clan histories and functions: that of 'networks of knowledge' (Kodesh, 2008, 2010), a mobilisation of a collective, compositional knowledge that is improvised, socially responsive and constantly changing (Guyer and Eno Belinga, 1995).

The clan-landscape of the Great Lakes transcends both modern-day political borders and the configuration of the second millennium kingdoms, and is thought to have been a vital feature of economic life in western Uganda, playing a pivotal role in social change (Willis, 1997; Schoenbrun, 2016: 230). It operated as an extensive system of "contacts, exchanges, and movements" as well as maintaining "ancestral vocations" associated with specific clans, including certain production industries as well as other social and economic roles (Chrétien, 2003: 90-4). The Basita clan, for example, is associated with ironworking in Bunyoro (Buchanan, 1974: 102-4), but also has counterparts in other kingdom territories in Uganda, Tanzania and Rwanda (Buchanan, 1979: 102; Chrétien, 2003: 89, 90). These units established and maintained networks across distant and geographically unconnected clan lands, drawing together dispersed communities "whose leaders possessed a variety of skills, thus forging a powerful connection between clanship … and the composition of knowledge" (Kodesh, 2008: 200; 2010). The establishment – around 500 years ago – of these networks of knowledge resulted in the formation of more "efficacious social and productive networks" facilitated by the "language and practices of clanship" to enable larger and larger groups to remain connected as interlocking communities (Kodesh, 2010: 182).

An overriding theme drawn from the collected histories of the origins of Bunyoro is the wide-ranging, inclusive, multi-ethnic nature of the kingdom (Buchanan, 1974): populations are frequently said to arrive in the region to be encompassed into the social landscape. Doyle (2006b) highlights this as an unusually positive feature. Stories regarding the convergence of many different peoples over many different time periods have stressed the value of inclusion and cooperation, culminating in what Kopytoff (1987: 51) describes as "anomalous communities". The iron smelting practices recorded in western Uganda are products of this dynamic and interconnected social landscape, with clans acting as networks of contacts, exchanges and movements, crossing kingdom boundaries and linking extended families and different communities of practice. Migration histories of clans associated with iron production provide some estimation of the complexity of the gradual movements of small groups and the density of social interactions during this period (see Fig. 7; Buchanan, 1974, 1979). The diverse backgrounds of those living in Mwenge – a heterogenous population constituted from waves of immigrants – might shed light on the development of varied iron production styles around the region. Considering iron production within the framework of the clan networks that gradually colonised this 'frontier zone' during the second millennium emphasises a viewpoint of social connections and networks, craftspeople moving between communities and bringing with them their way of doing things (Huntley et al., 2012: 16).

There is certainly a strong indication of the ties between the smelting industries of the neighbouring – and often hostile – kingdoms of Bunyoro and Buganda, born of a vigorous relationship of cooperative trade as well as competition. Bunyoro supplied all the iron to "the countries to the south and the east and for many years the Nyoro smiths were superior to the others" (Roscoe, 1923: 141-2), Grant (1864: 293) observed that the spears the Banyoro used were the worst in the region, as all high quality spearheads were sold to Buganda. In the early eighteenth century, during a period of territorial expansion, Buganda took the iron-producing district of Buddu from Bunyoro as well as the Kingdom of Kooki, gaining access to significant iron resources and local populations who were known to be skilled ironworkers (Reid, 2002; Humphris et al., 2009; Schoenbrun, 1998). Some of those who live in Kooki today continue to associate themselves with the Bunyoro Kingdom (Iles, 2011).

It is relevant to note that although all published accounts of Nyoro and Ganda smelts mention the use of two ores, elevated levels of manganese oxide have not been detected in archaeological smelting slag from either Buddu or Kooki. Archaeometallurgical research carried out at a smelting site in Buddu – Birinzi, dated to the 18th–19th centuries AD (Fig. 1; Humphris et al., 2009) – found levels of manganese oxide of under 0.1 wt%, a similar amount to that detected in analyses of slag from Kiwesi in Kooki, which also provided a post-18th century date (Iles, 2013d). These data indicate that the furnace charge in these smelting episodes did not contain a manganese-rich mineral in significant quantities, though it does not preclude the use of a mix of two iron ores. As such, although these technologies might be following a similar recipe – to mix one hard black ore with one soft red ore – the implications of using a black ore in Buddu may be different from using a black ore in Mwenge, if those ores happen to be an iron oxide (magnetite or goethite) and a manganese oxide (e.g. psilomelane/romanèchite) respectively.[9] It is feasible that this represents different technical outcomes for similar technological behaviours in Mwenge and Buddu providing a knowledge link between different iron production practices. Further analyses of slag from Buganda could provide an insight into this tantalising proposition.

3.2. Interactions and the movement of knowledge

If it has been useful to shift the emphasis away from clans as exclusive and exclusionary units and to consider the social landscape of Mwenge more as a cooperative network, it is also relevant to reflect on the interactions and experiences of smelting groups and explore how exposure to different smelting practices may have occurred in the past. An emphasis on iron smelting's conformity to ritualised procedures naturally lends itself to an association with "closed" contexts of knowledge transmission, which is itself associated with limited innovation and integration of influences from outside groups (as discussed by Wallaert-Pêtre (2001) in relation to ceramic apprenticeships). Although specific learning environments are difficult to infer from the

[8] See also discussion of the European construction of African ethnic identities in Richards and MacDonald (2015).

[9] see Radivojević and Rehren (2016) for a discussion of the selection of metallurgical raw materials on the basis of macroscopic appearance in Vinca culture copper smelting in Serbia and Bosnia and Herzegovina. In that case, the importance of colour over mineral type drove the selection of copper ore mixes (combining a green and black ore).

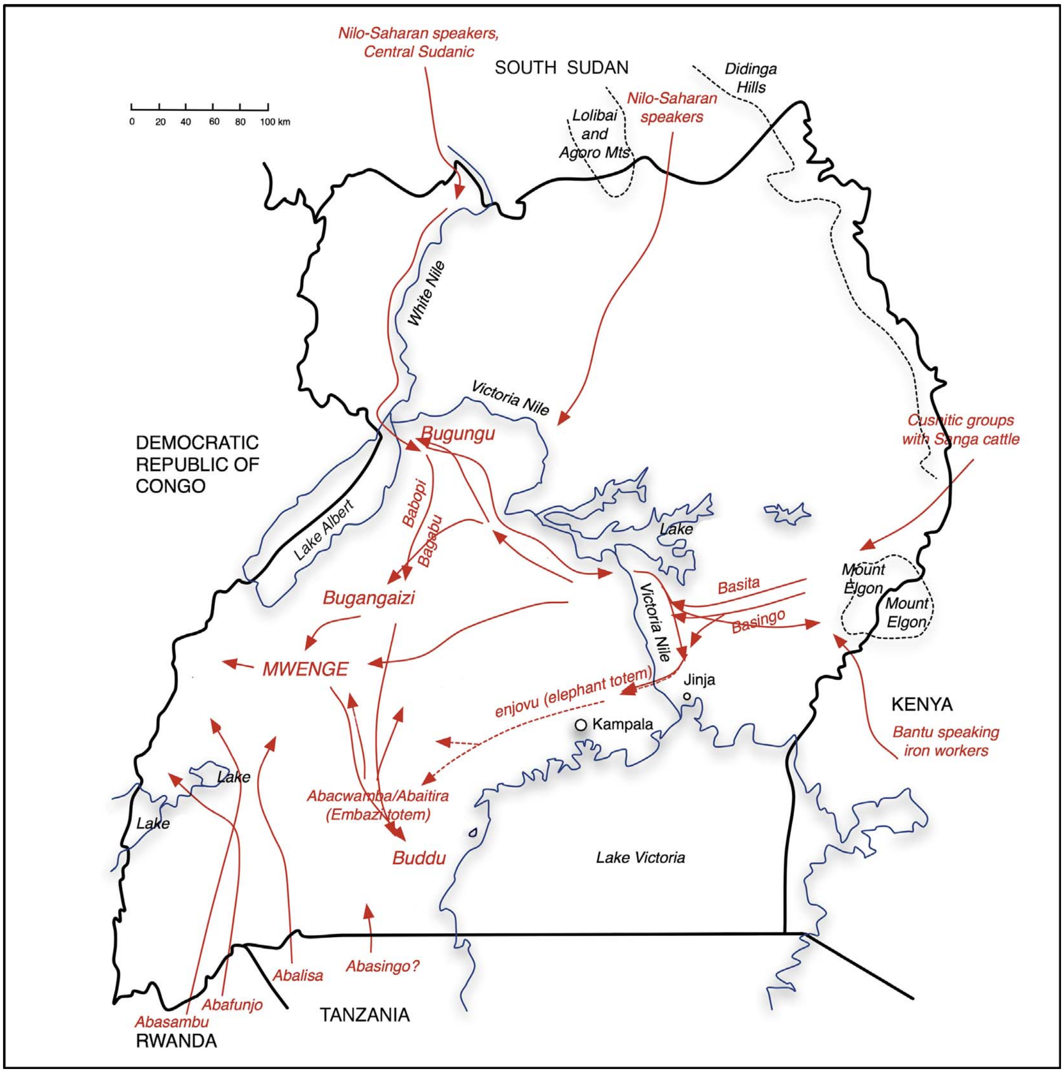

Fig. 7. Migration histories of clans associated with iron production in western Uganda, constructed from oral histories and place name analysis (Buchanan, 1974, 1979).

archaeological record (Crown, 2001), there are suggestions in Mwenge that some knowledge moved through inter-clan friendships (Iles, 2011: 518) or inter-clan marriages, with parallels in the transmission of style documented in groups of potters (e.g. Herbich, 1987):

> "There is a story which says that the Abahinda clan who are Bahuma from Ankole, did not know how to work in iron. They intermarried with the Basita, and the children stayed with the clan of their mothers and learned how to work in iron."
>
> (Buchanan, 1974: 102)

> "part of the Banywagi clan say they accompanied Rukidi south into Kitara [Bunyoro]. They ultimately settled around Ruhoko in Mwenge saza, where they were "blacksmiths and worked with the Basita."
>
> (Buchanan, 1974: 214)

However, there may have been further social features that facilitated the movement of knowledge between smelting groups, one of which is variability in the participation of women. There are numerous examples of smelting or smithing groups which exclude women, and which forbid women to be in the vicinity of smelting activity (e.g. Roscoe, 1911; Brock, 1965; Reid and MacLean, 1995). Many accounts from across the continent describe furnaces becoming the fertile wives of the smelters, transformed through the rituals, symbolism, decoration, dance and music of matrimony and childbirth to ultimately 'give birth' to a bloom of iron (see Cline, 1937; Herbert, 1993; Schmidt, 2009). In many such accounts, smelters were expected to be faithful to their new 'wives' and eschew their human ones, if only temporarily, abstaining from conjugal relations for the course of the smelt, and sometimes avoiding all contact with women (e.g. Fowler, 1990; Herbert, 1993; Roscoe, 1911). In these examples, women of childbearing age were excluded from smelting sites, not only to enable isolation for the smelters so as not to tempt them to infidelity, which would cause the furnace to 'abort' and fail, but also so as to not induce sterility in the women themselves (Herbert, 1993). In order to facilitate this, such smelts were sometimes located far from habitation sites (e.g. Childs, 1991) or shielded from view by vegetation (e.g. Reid and MacLean, 1995) in order to ensure that contact with those not directly involved in the smelt is avoided (although see Calabrese, 2000; Childs and Killick, 1993).

Some consider that this relationship between women and iron smelting in sub-Saharan Africa may in part be a functional device, restricting the identity of those involved in, or even observing, metallurgical activity (Reid and MacLean, 1995).[10] The exclusion of women (especially those of childbearing age, and therefore also of marriageable age) is said to have prevented women from acquiring

[10] Although other cultural factors are also certainly at play. See Herbert, 1993 for an in-depth analysis of the relationship between iron production and gender in Africa.

knowledge of iron smelting, either through their participation, through witnessing a smelt, or being privy to smelting secrets shared in the marital bed. If marriage was a means by which new sources of knowledge were tapped (Guyer and Eno Belinga, 1995: 115), by excluding women, this power was restricted to the male factions of a community, which may have served – particularly in exogamous clans – to ensure that technological knowledge was not transferred to rival groups through matrimony (Reid and MacLean, 1995).

However, the exclusion of women is not universal, as a handful of historical and ethnoarchaeological accounts show. Informants in Mwenge were divided on whether women were permitted to be actively involved in smelting activities or were forbidden from even approaching a smelting area (discussed in detail in Iles, 2013a, 2015). Other examples of women taking part in iron smelting activity have been documented in the late-nineteenth and early-twentieth centuries among the Pare of northern Tanzania (Baumann, 1891; Kotz, 1922), the Njanja of Zimbabwe (Chirikure, 2007), the *mana* (iron workers) of Oska Dencha in Ethiopia (Haaland, 2004a), and the Maasai (Cline, 1937: 115). These examples – though rare – do illustrate the possibility of changing or divergent gender roles in iron smelting 'traditions', and suggest that there is scope for fair consideration as to whether past iron technologies were always strictly gendered (see also Budd and Taylor, 1995; Stahl, 2016).

Associated with the exclusion of women is the notion that iron smelting was undertaken in locations away from the general public, and away from chance encounters with (potentially smelt-endangering) women. However, several of the Mwenge informants also emphasised the public nature of smelting. One informant stated that smelters (as well as smiths[11]) generally located furnaces close to roads in order to advertise their trade and their wares (Iles, 2011: 519), another that anybody could come and help with the bellowing, with the smelt publicised by the loud sounds of the bellows (Iles, 2011: 514). An informant of Robertshaw's stated, "ore was taken to other areas or smelted close to communication routes (paths)" (Robertshaw, 1991). Indeed, archaeological survey often finds furnace bases in or near road surfaces (Connah, 1996; Iles, 2011; see Fig. 8). This tends to be thought of as sampling bias (e.g. Humphris, 2010: 300), as roads are some of the few open ground surfaces with minimal vegetation cover that makes survey by sight possible. However, it is worth considering that furnaces may well have originally been located beside major routeways, and the roads of today may be remnants of much older pathways that have been etched into the landscape over time (see Roscoe, 1915: 19), allowing for interactions between smelters, smiths and others, and associated exchanges of information – social, and potentially technical. This does not preclude the possibility that smelts and smelters were separated from passers-by with fencing, as witnessed in Karagwe (Reid and MacLean, 1995). Some (though not all) Mwenge smelters screened off their smelting areas using a plant called *orusororo*, whose name means "to separate" (Childs, 1999: 32), and some informants during the 2007 survey did emphasise the secret nature of smelting.

This builds a picture of smelting practices in Mwenge whereby participation in iron smelting could sometimes be broadly inclusive and whereby technological practice can sometimes be publicly visible. Together these factors hint of a reflexive system that has a greater tendency towards change and innovation than previously presumed. This is in keeping with considerations of cultural behaviour that steer away from assuming stability: "current practices and beliefs that appear to represent unbroken continuity with the past should continually be tested against archaeological evidence" (Brumfiel and Robin, 2008: 4). The boundaries of male/female domains are subject to continual renegotiation (Herbert, 1993), and other examples also suggest that ethnographic models of gendered practice and secrecy may not have prevailed in the past (Chirikure, 2007). Access to knowledge is likely to have fluctuated in relation to various socio-economic factors, such as technological stability, changes in social diversity, and shifts in the value of the finished product (Crown, 2016). A new consideration of both gender and secrecy in iron production presents opportunities to expand understandings of the social realm of iron production and implications for the transfer of technical knowledge between different groups.

[11] Travellers through the region in the late nineteenth century remarked on the gossip that could be heard at blacksmith's shops – these were important social hubs (Grant, 1864; Schweinfurth et al., 1888).

Fig. 8. Furnace 1 at Mirongo (foreground), exposed in road surface prior to excavation. A second furnace is located approximately 2 m further along the road, but is only indistinctly visible in this phoograph.

4. Concluding thoughts

This paper argues that new technological elements moved through western Uganda during the mid-second millennium AD due to the interactions of different communities of practice in a period of substantial reorganisation of the socio-cultural landscape. An increased demand for iron and a mix of people with different technological backgrounds may have provided the impetus for externally driven change. By the mid-second millennium AD, when the kingdoms in this part of Uganda were becoming established, iron was already forming a major part of local economies and regional trade networks, with significant social kudos attached to its production. A range of different populations were moving into and through the area throughout this time period, bringing with them different bodies of technological knowledge that had developed in response to different social, economic and environmental needs. The great distances travelled by some groups to obtain ore – such as those documented by MacLean in Buddu (MacLean, 1996) – present a mechanism whereby different smelting groups may have come into contact with others from distant locations. Furthermore, networks of clans across the region may have linked smelters from different knowledge lineages, and shifting emphases on prohibitions and restrictions associated with iron technologies may have fostered interactions and innovations at different times.

The use of a second ore provides a particularly tantalising link between different communities of practice in the Buddu/Kooki and Mwenge areas, though it is currently not possible to suggest the direction of this knowledge flow. The use of an additional manganiferous material, seen initially in the fifteenth century site of Rugombe, might be a feature of a technology integrated with existing Mwenge smelting practices. The exploitation of a manganese-rich flux would have increased the yield of iron from an ore, and may also have improved the qualities of the resulting metal itself, as was purported in various regions of Europe famed for the production of hard, strong and workable iron and steel (Iles, 2014). It is not possible to determine whether these materials were deliberately selected to produce a superior iron, or because they were easier to smelt, or because they fitted with a 'recipe', or for another reason entirely. However, this development nevertheless contributed to the establishment of Bunyoro as a key regional centre for iron production.

Dynamic social contexts may have facilitated the spread of technical knowledge. In particular, this research questions the extent to which iron production knowledge was universally protected within certain groups through esotericism and the exclusion of women and non-clan members, keeping recipes and methods secret from competitors. Although it is often the control of secret knowledge that leads to the acquisition and maintenance of prestige, authority and influence, there may also be benefit in the timely sharing of knowledge, through the development of trust, indebtedness and personal relationships, where cooperation is beneficial to all (Antonelli, 2000; Crown, 2016). In a setting of rapidly increasing demand for metal products, it is plausible that a hunger for production was stronger than the "metal monopoly" proposed by Haaland (2004b: 2).

Certainly, the ethnographic data hints at a scenario of varying degrees of participation and inclusion, whereby information was sometimes shared – although not necessarily freely, and not necessarily all the time – demonstrating the intricacy and complexity of knowledge exchange, and the very personal qualities of trust and suspicion that shape interactions between craftspeople as individuals (e.g. Papousek, 1989). The personalities and individual agencies of those involved are certainly influential, prioritising improvisation, ambition, risk or determination to varying degrees (see Dobres, 2000; Gosselain, 2008b; Harris, 2016). The heated discussions between the master smelter and his assistants as relayed through several smelting reconstructions conducted in Barongo, Tanzania (Schmidt, 1997) are testament to the complex and personal influences that might be at play at each and every smelt, and what might happen when those discussions and compromises go wrong. A master smelter not only has to negotiate the physical aspects of a smelt, he also is tasked with managing the personalities of each of his workers. Issues of ownership, status, craft specialisation, centralisation, conflict and competition, knowledge of other pyrotechnologies, and a group's tolerance of technological change and innovation will impact upon how a technology shifts and develops in each individual case, determining what elements of a technology remain the same through time and what will be transformed (Hjärthner-Holder and Risberg, 2003: 84-5):

> "the acceptance or rejection of an invention, or the extent to which its implications are realized if it is accepted, depends quite as much upon the condition of a society, and upon the imagination of its leaders, as upon the nature of the technological item itself."
>
> (White, 1962: 28)

More rigorous dating, in particular, holds the key to more robust analysis of patterns of change in the iron technologies of western Uganda, allowing for future research to develop methodologies that can test and examine some of the proposed pathways through which knowledge of these technologies were acquired, adapted and optimised to suit new local needs and increasing demand. There is much scope to refine our understanding of the archaeology of iron production in western Uganda. Exploring iron production in conjunction with other linked fields of practice, such as the use of manganese or haematite slips on local pottery, would be highly relevant.

In contrast to the "wealth and maturity" of understandings of past iron production processes and iron working methods, "our understanding of the nature of the relationships between the people and societies that contextualised its use" are underdeveloped (Juleff, 2013: 137). While there is great success at identifying and characterising variation in metallurgy, there is less success at detecting and characterising the processes of change that shaped that variation (though there are exceptions of course, e.g. Charlton et al., 2010). This is particularly striking in comparison with studies of pottery manufacture, which sits at "the leading edge of archaeological engagement with the concept of communities of practice" (Joyce, 2012: 154).

The availability of relevant data must have much to do with this distinction: ceramicists have multiple strands of evidence to work from to infer technological behaviour – temper use, clay acquisition, forming techniques, surface decoration, shape and so on. Unlike metallurgists, they have been able to observe different modern potting groups working concurrently, including their interactions and relationships, and their propensity to innovation and improvisation (e.g. Gosselain, 2016). Incorporating formal theories of learning into their work has enabled an explicit emphasis on the social contexts of knowledge transmission, such as the boundaries between different traditions, the impact of 'mediators' or 'brokers' in forging links across these boundaries, and the implications of different forms of knowledge acquisition and apprenticeships on innovation and the organisation of production (Lyons and Clark, 2012: 28; e.g. Minar and Crown, 2001 (eds.); Cordell and Habicht-Mauche, 2012 (eds.); Roddick and Stahl, 2016 (eds.)). As archaeometallurgists, engaging with these concepts has the potential to reveal more about the individuals, groups and societies carrying out past metal technologies, as well as the networks, affiliations and relationships that shaped their technological behaviour. Unfortunately, with local memories of iron production waning fast, they are becoming increasingly difficult – if not impossible – to explore ethnographically.

Whilst variation within technique and style is widely recognised, more can be done to scrutinise the possible range of localised responses to the changeable social and economic contexts within which technology is embedded. Ethnographic information derived from African examples is used to provide context and colour to many archaeological remains of metalworking sites throughout the globe, both explicitly and implicitly, often with only limited understanding of the original ethnographic research that it is based on. Certain narratives are oft repeated: smiths and smelters worked in secret, women were excluded, information was protected. We must be careful that the narratives we build are based on a firm footing, and that the caveats of ethnographic research are loudly proclaimed. In most smelting reconstructions (or interview series), an ethnographic account focuses on only one master smelter's method for iron production. This research suggests that what is likely to be a high level of local technological variation is unable to be expressed within just one reconstruction; there is a need to be wary of drawing on a limited set of primary observations that are repeatedly cited. As Schmidt (1998: 141) asserts:

> "It is the anomaly, the piece of evidence that does not fit the model or analog, that begs to be explained and therefore holds the key to understanding change and reveals deeper systems of meaning."

It is through an exploration of these nuances that a more sensitive and revealing picture can be built of how past smelters operated and interacted within the boundaries of their political, social, environmental and personal surroundings.

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References

Antonelli, C., 2000. Collective knowledge communication and innovation: the evidence of technological districts. Reg. Stud. 34, 535–547.
Ashley, C., 2010. Towards a socialised archaeology of ceramics in Great Lakes Africa. Afr. Archaeol. Rev. 27, 135–163.
Baumann, O., 1891. Usambara Und Seine Nachbargebeite. Dietrich Reimer, Berlin.
Brock, B., 1965. Iron working amongst the Nyiha of southwestern Tanganyika. South Afr. Archaeol. Bull. 20, 97–100.
Brown, J., 1995. Traditional Metal Working in Kenya. Oxbow, Oxford.
Brumfiel, E., Robin, C., 2008. Gender, households, and society: an introduction. Archaeol. Papers Am. Anthropol. Assoc. 18, 1–16.
Buchanan, C., 1974. The Kitara complex: the historical tradition of Western Uganda to the 16th century. [Unpublished PhD thesis]. Indiana University, Bloomington.
Buchanan, C., 1979. Courts, clans and chronology in the Kitara complex. In: Webster, J. (Ed.), Chronology, Migration and Drought in Interlacustrine Africa. Longman Press, London, pp. 87–124.
Budd, P., Taylor, T., 1995. The faerie smith meets the bronze industry: magic versus science in the interpretation of prehistoric metal-making. World Archaeol. 27, 133–143.
Calabrese, J., 2000. Metals, ideology and power: the manufacture and control of materialised ideaology in the area of the Limpopo-Shashe confluence, c. AD 900–1300. South Afr. Archaeol. Soc. Goodwin Series 8, 100–111.
Charlton, M., Crew, P., Rehren, Th., Shennan, S., 2010. Explaining the evolution of ironmaking recipes – an example from northwest Wales. J. Anthropol. Archaeol. 29, 352–367.
Childs, S.T., 1991. Style, technology and iron-smelting furnaces in Bantu-speaking Africa. J. Anthropol. Archaeol. 10, 332–359.
Childs, S.T., 1998. 'Find the ekijunjumira': iron mine discovery, ownership and power among the Toro of Uganda. In: Knapp, A., Pigott, V., Herbert, E. (Eds.), Social Approaches to an Industrial Past: The Archaeology and Anthropology of Mining. Routledge, London, pp. 123–137.
Childs, S.T., 1999. 'After all, a hoe bought a wife': the social dimensions of ironworking among the Toro of East Africa. In: Dobres, M., Hoffman, C. (Eds.), The Social Dynamics of Technology: Practice, Politics and World Views. Smithsonian Institution Press, London, pp. 23–45.
Childs, S.T., 2000. Traditional iron working: a narrated ethnoarchaeological example. In: Bisson, M., Childs, S.T., de Barros, P., Holl, A. (Eds.), Ancient African Metallurgy: The Socio-Cultural Context. Altamira, Walnut Creek, pp. 199–253.
Childs, S.T., Killick, D., 1993. Indigenous African metallurgy: nature and culture. Annu. Rev. Anthropol. 22, 317–337.
Chirikure, S., 2007. Metals in society: iron production and its position in iron age communities of Southern Africa. J. Social Archaeol. 7, 72–100.
Chirikure, S., 2016. 'Ethno' plus 'archaeology': what's in there for Africa(ns)? World Archaeol. 48, 693–699.
Chrétien, J.-P., 2003. The Great Lakes of Africa: A Thousand Years of History. Urzone, New York.
Cline, W., 1937. Mining and Metallurgy in Negro Africa. George Banta, Wisconsin.
Connah, G., 1996. Kibiro: The Salt of Bunyoro, Past and Present. BIEA, London.
Connah, G. (Ed.), 1998. Transformations in Africa: Essays on Africa's Later Past. Leicester University Press, London.
Cordell, C., Habicht-Mauche, J. (Eds.), 2012. Potters and Communities of Practice: Glaze Paint and Polychrome Pottery in the American Southwest, A.D. 1250–1700. University of Arizona Press, Tucson.
Crawhall, T., 1933. Iron working in the Sudan. Man 33, 41–43.
Crown, P., 2001. Learning to make pottery in the prehispanic American Southwest. J. Anthropol. Res. 57, 451–469.
Crown, P., 2016. Secrecy, production rights, and practice within communities of potters in the prehispanic American Southwest. In: Roddick, A., Stahl, A. (Eds.), Knowledge in Motion: Constellations of Learning Across Time and Place. University of Arizona Press, Tucson, pp. 67–96.
Cunningham, J., MacEachern, S., 2016. Ethnoarchaeology as slow science. World Archaeol. 48, 628–641.
Deane, E., 2007. Visualising History: The Mackie Ethnological Expedition (1919–1920) to Eastern Africa as seen through the photographs of the Reverend John Roscoe. [Unpublished MA dissertation]. University of East Anglia, Norwich.
Dobres, M.-A., 2000. Technology and Social Agency: Outlining a Practice Framework for Archaeology. Blackwell, Oxford.
Doolittle, W., 1984. Agricultural change as an incremental process. Ann. Assoc. Am. Geogr. 74, 124–137.
Doyle, S., 2006a. Crisis and Decline in Bunyoro: Population and Environment in Western Uganda 1860–1955. James Currey, Oxford.
Doyle, S., 2006b. From Kitara to the Lost Counties: genealogy, land and legitimacy in the Kingdom of Bunyoro, western Uganda. Social Identities 12, 457–470.
Eliade, M., 1956. Forgerons Et Alchimistes. Flammarion, Paris.
Fowler, I., 1990. Babungo: A Study of Iron Production, Trade and Power in Nineteenth Century Ndop Plain Chiefdom (Cameroon). [Unpublished PhD thesis]. UCL, London.
Giles, M., 2007. Making metal and forging relations: ironworking in the British Iron Age. Oxford J. Archaeol. 26, 395–413.
Gosselain, O., 2008a. Mother Bella was not a Bella: inherited and transformed traditions in southwestern Niger. In: Stark, M., Bowser, B., Horne, L. (Eds.), Cultural Transmission and Material Culture: Breaking Down Boundaries. University of Arizona Press, Tucson, pp. 150–177.
Gosselain, O., 2008b. Thoughts and adjustments in the potter's backyard. In: Berg, I. (Ed.), Breaking the Mould: Challenging the Past Through Pottery. BAR International Series 1861. Archaeopress, Oxford, pp. 67–79.
Gosselain, O., 2016. The world is like a beanstalk: historicizing potting practice and social relations in the Niger River area. In: Roddick, A., Stahl, A. (Eds.), Knowledge in Motion: Constellations of Learning Across Time and Place. University of Arizona Press, Tucson, pp. 36–66.
Grant, J., 1864. A Walk Across Africa: Or Domestic Scenes From My Nile Journal. William Blackwood and Sons, London.
Grunderbeek, M.-C., Roche, E., Doutrelepont, H., 2001. Un type de fourneau de fonte de fer associe a la culture Urewe (age du fer ancient) au Rwanda et au Burundi. Mediterr. Archaeol. 14, 271–297.
Guyer, J., Eno Belinga, S., 1995. Wealth in people as wealth in knowledge: accumulation and composition in Equatorial Africa. J. Afr. History 36, 91–120.
Haaland, R., 1985. Iron production, its socio-cultural context and ecological implications. In: Haaland, R., Shinnie, P. (Eds.), African Iron Working: Ancient and Traditional. University Publishers, Oslo, pp. 50–72.
Haaland, R., 2004a. Iron smelting – a vanishing tradition: ethnographic study of this craft in sout-west Ethiopia. J. Afr. Archaeol. 2, 65–79.
Haaland, R., 2004b. Technology, transformation and symbolism: ethnographic perspectives on European iron working. Norwegian Archaeol. Rev. 37, 1–19.
Hamilton, A., Karamura, D., Kakudidi, E., 2016. History and conservation of wild and cultivated plant diversity in Uganda: forest species and banana varieties as case studies. Plant Diversity 38, 23–44.
Harris, M., 2016. Finding connections along the river in the lower Amazon, Brazil. In: Roddick, A., Stahl, A. (Eds.), Knowledge in Motion: Constellations of Learning Across Time and Place. University of Arizona Press, Tucson, pp. 155–178.
Herbert, E., 1993. Iron, Gender and Power: Rituals of Transformation in African Societies. Indiana University Press, Indianapolis.
Herbich, I., 1987. Learning patterns, potter interaction and ceramic style among the Luo of Kenya. Afr. Archaeol. Rev. 5, 193–204.
Hjärthner-Holder, E., Risberg, C., 2003. The introduction of iron in Sweden and Greece. In: Nørbach, L. (Ed.), Prehistoric and Medieval Direct Iron Smelting in Scandinavia and Europe: Aspects of Technology and Science. Aarhus University Press, Aarhus, pp. 83–86.
Humphris, J., 2010. An Archaeometallurgical Investigation of Iron Smelting Traditions in Southern Rwanda. Unpublished PhD thesis. UCL, London.
Humphris, J., Martinón-Torres, M., Rehren, Th., Reid, A., 2009. Variability in single smelting episodes – a pilot study using iron slag from Uganda. J. Archaeol. Sci. 36, 359–369.
Huntley, D., Fenn, T., Habicht-Mauche, J., Mills, B., 2012. Embedded Networks? Pigments and long-distance procurement strategies in the late prehispanic Southwest. In: Cordell, L., Habicht-Mauche, J. (Eds.), Potters and Communities of Practice: Glaze Paint and Polychrome Pottery in the American Southwest, A.D. 1250–1700. University of Arizona Press, Tucson, pp. 8–18.
Iles, L., 2009. Impressions of banana pseudostem in iron slag from eastern Africa. Ethnobotany Res. Appl. 7, 283–291.
Iles, L., 2011. Reconstructing the Iron Production Technologies of Western Uganda: Reconciling Archaeometallurgical and Ethnoarchaeological Approaches. UCL, London accessible online: http://discovery.ucl.ac.uk/1306719/.
Iles, L., 2013a. Applying ethnographic presents to archaeological pasts: preliminary thoughts on memories of iron production from western Uganda. In: Humphris, J., Rehren, Th. (Eds.), The World of Iron. Archetype, London, pp. 281–287.
Iles, L., 2013b. The development of iron technology in precolonial western Uganda. Azania 48, 65–90.
Iles, L., 2013c. The use of plants in iron production: insights from smelting remains from Buganda. In: Stevens, C., Nixon, S., Murray, M., Fuller, D. (Eds.), The Archaeology of African Plant Use. Left Coast Press, San Francisco, pp. 267–274.
Iles, L., 2013d. Analysis of iron working remains from Kooki and Masindi, western Uganda. Nyame Akuma 80, 43–58.
Iles, L., 2014. The exploitation of manganese-rich 'ore' to smelt iron in Mwenge, western Uganda, from the mid-second millennium AD. J. Archaeol. Sci. 49, 423–441.
Iles, L., 2015. Iron production in Uganda: memories of a near-forgotten industry. In: Orange, H. (Ed.), Reanimating Industrial Spaces: Conducting Memory Work in Post-Industrial Societies. Left Coast Press, Walnut Creek, pp. 158–175.
Iles, L., Childs, S.T., 2014. Ethnoarchaeological and historical methods. In: Roberts, B., Thornton, C. (Eds.), Archaeometallurgy in Global Perspective: Methods and Syntheses. Springer, New York, pp. 193–215.
Iles, L., Robertshaw, P., Young, R., 2014. A furnace and associated ironworking remains at Munsa, Uganda. Azania 49, 45–63.
Ingham, K., 1975. The Kingdom of Toro in Uganda. Methuen, London.
Jordan, P., 2015. Technology as Human Social Tradition: Cultural Transmission Among Hunter-Gatherers. University of California Press, Oakland.
Joyce, R., 2012. Thinking about pottery production as community practice. In: Cordell, L., Habicht-Mauche, J. (Eds.), Potters and Communities of Practice: Glaze Paint and Polychrome Pottery in the American Southwest, A.D. 1250–1700. University of Arizona Press, Tucson, pp. 149–154.
Juleff, G., 2013. Invention, innovation and inspiration: optimisation and resolving

technological change in the Sri Lankan archaeological record. In: Humphris, J., Rehren, Th. (Eds.), The World of Iron. Archetype, London, pp. 137–145.
Keller, C., Keller, J., 1996. Cognition and Tool Use: The Blacksmith at Work. Cambridge University Press, Cambridge.
Killick, D., 2015. Invention and innovation in African iron-smelting technologies. Cambridge Archaeol. J. 25, 307–319.
Killick, D., 2016. A global perspective on the pyrotechnologies of sub-Saharan Africa. Azania 51, 62–87.
Kodesh, N., 2008. Networks of Knowledge: clanship and collective well-being in Buganda. J. Afr. History 49, 197–216.
Kodesh, N., 2010. Beyond the Royal Gaze: Clanship and Public Healing in Buganda. University of Virginia Press, London.
Kopytoff, I., 1987. The African Frontier: The Reproduction of Traditional African Systems. Indiana University Press, Bloomington.
Kotz, E., 1922. Im Banne Der Furcht: Sitten Und Gebräuche Der Wapare in Ostafrika. Advent-Verlag, Hamburg.
Lyons, P., Clark, J., 2012. A community of practice in diaspora: the rise and demise of Roosevelt Red Ware. In: Cordell, L., Habicht-Mauche, J. (Eds.), Potters and Communities of Practice: Glaze Paint and Polychrome Pottery in the American Southwest, A.D. 1250–1700. University of Arizona Press, Tucson, pp. 19–33.
MacLean, R., 1996. The Social Impact of the Beginnings of Iron Technology in the Western Lake Victoria Basin: a district case study. [Unpublished PhD thesis]. University of Cambridge.
Merton, R., 1936. The unanticipated consequences of purposive social action. Am. Sociol. Rev. 6, 894–904.
Minar, C., Crown, P. (Eds.), 2001. Learning and craft production. J. Anthropol. Res. 57 (4).
Mtetwa, E., Maposa, Y., Manyanga, M., Chirikure, S., 2017. When the smith is a woman: innovation, improvisation and ambiguity in the organisation of African iron metallurgy. In: Manyanga, M., Chirikure, S. (Eds.), Archives, Objects, Places and Landscapes: Multidisciplinary Approaches to Decolonised Zimbabwean Pasts. Langaa RPCIG, Bamenda, pp. 295–318.
Papousek, D., 1989. Technological change as social rebellion. In: van der Leeuw, S., Torrence, R. (Eds.), What's New? A Closer Look at the Process of Innovation. Unwin Hyman, London, pp. 140–166.
Parayil, G., 1991. Technological knowledge and technological change. Technol. Soc. 13, 289–304.
Radivojević, M., Rehren, Th., 2016. Paint it black: the rise of metallurgy in the Balkans. J. Archaeol. Method Theory 23, 200–237.
Reid, R., 2002. Political Power in Pre-Colonial Buganda: Economy, Society and Welfare in the Nineteenth Century. James Currey, London.
Reid, D.A.M., MacLean, R., 1995. Symbolism and the social context of iron production in Karagwe. World Archaeol. 27, 144–161.
Richards, F., MacDonald, K., 2015. From invention to ambiguity: the persistence of ethnicity in Africa. In: Richards, F., MacDonald, K. (Eds.), Ethnic Ambiguity and the African Past: Materiality, History, and the Shaping of Cultural Identities. Left Coast Press, Walnut Creek, pp. 17–54.
Roberts, B., 2008. Creating traditions and shaping technologies: understanding the earliest metal objects and metal production in western Europe. World Archaeol. 40, 354–372.
Robertshaw, P. 1991. Unpublished fieldwork notes.
Robertshaw, P., 1997. Munsa earthworks. Azania 32, 1–20.
Robertshaw, P., 1999. Seeking and keeping power in Bunyoro-Kitara, Uganda. In: McIntosh, S. (Ed.), Beyond Chiefdoms: Pathways to Complexity in Africa. Cambridge University Press, Cambridge, pp. 136–150.
Robertshaw, P., 2010. Beyond the Segmentary State: creative and instrumental power in western Uganda. J. World Prehistory 23, 255–269.
Roddick, A., Stahl, A. (Eds.), 2016. Knowledge in Motion: Constellations of Learning Across Time and Place. University of Arizona Press, Tucson.
Roscoe, J., 1911. The Baganda. Macmillan and Co, London.
Roscoe, J., 1915. The Northern Bantu: An Account of Some Central African Tribes of the Uganda Protectorate. Cambridge University Press, Cambridge.
Roscoe, J., 1923. The Bakitara or Banyoro. Cambridge University Press, Cambridge.
Rowlands, M., Warnier, J.-P., 1993. The magical production of iron in the Cameroon Grassfields. In: Shaw, T., Sinclair, P., Andah, B., Okpoko, A. (Eds.), The Archaeology of Africa: Foods, Metals and Towns. Routledge, London, pp. 512–550.
Schmidt, P., 1996. Reconfiguring the Barongo: reproductive symbolism and reproduction among a work association of iron smelters. In: Schmidt, P. (Ed.), The Culture and Technology of African Iron Production. University of Florida Press, Gainesville, pp. 74–127.
Schmidt, P., 1997. Iron Technology in East Africa: Symbolism, Science and Archaeology. James Currey, Indiana.
Schmidt, P., 1998. Reading gender in the ancient iron technology of Africa. In: Kent, S. (Ed.), Gender in African Prehistory. Altamira, Walnut Creek, pp. 139–162.
Schmidt, P., 2009. Tropes, materiality, and ritual embodiment of african iron smelting furnaces as human figures. J. Archaeol. Method Theory 16, 262–282.
Schmidt, P., Mapunda, B., 1997. Ideology and the Archaeological Record in Africa: Interpreting Symbolism in Iron Smelting Technology. J. Anthropol. Archaeol. 16, 73–102.
Schoenbrun, D., 1998. A Green Place, A Good Place: Agrarian Change, Gender, and Social Identity in the Great Lakes Region to the Fifteenth Century. James Currey, Oxford.
Schoenbrun, D., 2016. Pythons worked: constellating communities of practice with conceptual metaphor in northern Lake Victoria, ca. AD 800 to 1200. In: Roddick, A., Stahl, A. (Eds.), Knowledge in Motion: Constellations of Learning Across Time and Place. University of Arizona Press, Tucson, pp. 216–246.
Schweinfurth, G., Ratzel, F., Felkin, R., Hartlaub, G. (Eds.), 1888. [trans. R. W. Felkin] Emin Pasha in Central Africa: being a collection of his letters and journals. George Philip and Son, London.
Stahl, A., 2014. Africa in the World: (re)centering African history through archaeology. J. Anthropol. Res. 70, 5–33.
Stahl, A., 2015. Metalworking and ritualization: negotiating change through improvisational practice in Banda, Ghana. Archaeol. Papers Am. Anthropol. Assoc. 26, 53–71.
Stahl, A., 2016. Complementary crafts: the dynamics of multicraft production in Banda, Ghana. In: Kelly, S., Ardren, T. (Eds.), Gendered Labor in Specialized Economies: Archaeological Perspectives on Female and Male Work. University Press of Colorado, Boulder, pp. 159–190.
Sterner, J., David, N., 1991. Gender and caste in the Mandara Highlands: northeastern Nigeria and northern Cameroon. Ethnology 30, 355–369.
Tamari, T., 1991. The development of caste systems in West Africa. J. Afr. History 32, 221–250.
Todd, J., 1985. Iron production by the Dimi of Ethiopia. In: Haaland, R., Shinnie, P. (Eds.), African Iron Working: Ancient and Traditional. University Publishers, Oslo, pp. 88–101.
Wallaert-Pêtre, H., 2001. Learning how to make the right pots: apprenticeship strategies and material culture, a case study in handmade pottery in Cameroon. J. Anthropol. Res. 57, 471–493.
White, L., 1962. Medieval Technology and Social Change. Oxford University Press, Oxford.
Willis, J., 1997. Clan and history in western Uganda: a new perspective on the origins of pastoral dominance. Int. J. Afr. Historical Stud. 30, 583–600.
Wyckaert, R., 1914. Forgerons païens forgerons chrétiens au Tanganika. Anthropos 9, 371–380.
KTN News Kenya "Meet the Il-Kunono clan that is despised and isolated in Samburu county", broadcast 28 July 2013. Last accessed on 24 August 2017 at www.youtube.com/watch?v=x_Ri1yH-c1A&t=5s.