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Iron Ironworks of West Africa

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I. Introduction

The study of ancient iron smelting in Africa has been, in recent decades, the center of interest of many researchers in archaeology, history, anthropology, and so on. The stake and the interest of this study is the knowledge of the history of techniques in West Africa in which the approach of ancient metallurgy of iron is inscribed. At the very beginning of these investigations, the origins of technology were most often discussed. At the current state of research, the scientific debate is no longer at the level of the origins of this metallurgy especially as it has sparked publications that have finally confirmed the autochthony and the age of this industry in Africa, which probably did not know that a single center of origin and diffusion: 1000 BC in Niger, site of Termit; 800 BC in Nigeria, Jos region; 1000 BC in Central Republic of Africa; and 1200 BC near the Victoria Lakes (Bocoum 2002: 61; Robion-Brunner 2018b).

Scientific research carried out in recent decades on the ancient iron metallurgy has often emphasized technical, human, and sociocultural aspects. These revealed knowledge at the level of science, knowledge and know-how, technologies, myths, cosmogony, etc. which show a wealth and an undeniable material and intangible heritage.

The ancient metallurgy of iron, as practiced in Africa until the middle of the twentieth century, is a set of technical processes for obtaining iron from ore, by smelting of oxides. These processes are part of the operating chain. The latter consists of several stages that range from prospecting, the collection or extraction of iron ore, the preparation, and the smelting of iron ore in the furnaces to the transformation of the magnifying glass into finished products in the forge. This operating chain is rich in the technological specificities of each metallurgy, which leads to a diversity and an exceptional wealth of practices. However, contact with the West, colonization and the introduction of iron bars, and iron recovery in West African societies will lead to real changes in the production of iron, especially in the region. Forge, where technical and cultic practices continue today in our societies south of the Sahara.

In this approach we present the technical and cultural richness of this iron technology known largely thanks to the ethnographic investigations, to the vestiges and sites of this industry discovered all over West Africa, and to the adaptation of the techniques of the blacksmiths the demands of the modern world, which is driving a real technological change.

II. The Ancient Metallurgy of Iron in West Africa: A Wealth of Innovative Processes

Apart from archaeological research, much of the knowledge of the technical and sociocultural aspects of the operating chain of early iron production is known through ethnographic and experimental investigations. Indeed, these deliver results that complete the data of archaeology,

thus allowing the understanding of the metallurgical activity, abandoned more than half a century ago. Traditional iron metallurgy has several stages.

At each of them, ritual and forbidden techniques are omnipresent and mark the inseparable character between material technical aspects and immaterial ritual aspects.

From the Mine to the Smelting of Iron Ore

All operations to obtain the bloom include prospecting, collecting where ore extraction, iron ore preparation, furnace construction and reduction of ore in furnaces.

Ore Prospecting or Prospecting

In Africa, prospecting methods are varied and very diverse depending on the time, space, and prospecting period. The operation of prospecting or finding the ore is most often the responsibility of the most experienced men with a ritual knowledge to complete the stage. During the prospection, divination practices often precede the operation. In particular, Gulmanceba metallurgists in Burkina Faso practiced geomancy to determine if the output would be successful by determining the directions to be taken for prospecting, the favorable moments, and the sacrifices to be made before the prospection campaign (Thiombiano-Ilboudo 2010: 249).

In addition, several indices based on very old knowledge can locate the iron ore. In fact, the knowledge of nature and the observation of certain plants are determining factors that make it possible to locate the iron ore during the prospection. The presence of certain plants such as wiliwiga (*Guiera senegalensis*), wɛdga (*Saba senegalensis*), and kubrsak (*Cassia sieberiana*) reveals the existence of iron ore under certain formations of ferruginous cuirass (Kiénon-Kaboré 1998: 87). In the Moosé of central, north-ern, and northern central Burkina Faso, the observation of the smoke emanations released from the ground after the rain or in the evening after falling temperatures was a sign of the existence of the ore. The prospecting techniques are indeed diverse and denote the wealth of these metal- lurgies of iron in West Africa which are not exhaustive in this study.

Obtaining Iron Ore

The techniques of obtaining the ore are various, and most often it is about collection of surface, open excavations, trenches, and wells (of circular or rectangular form some of which with galleries). In Africa in general, extraction by circular or rectangular well is one of the most common extraction methods.

At this stage of the operating chain, rituals are still ubiquitous. Minors must abide by certain rules, such as not having sex the day before the operation or with the same women before the start of the extraction. The exploitation of iron is surrounded by a large number of rites and taboos, so as not to offend the living spirit of the iron on which depends the smooth running of operations (Kiénon-Kaboré 2003). Prohibitions related to the extraction of ore are a means to secure the pro- duction of iron by establishing a climate of peace and social harmony between blacksmiths to avoid any social tear that could be fatal to the duties assigned to them (Kienon-Kaboré 2017).

The work in mining operations is very difficult and therefore requires a large workforce. To extract iron ore, miners use several types of equipment such as picks with extremely rigid blades, daba, traditional flashlights to illuminate the interior of wells, baskets and ropes to raise the ore, etc. The work was done at the chain. The persons in charge of the extraction and the transport are generally men; however in some societies as among the Gulmanceba, the women took part in the works. The extraction periods were those of the dry season, between January and April, so as not to be hampered by rainwater. This period allowed the blacksmiths to take

advantage of the season free of field work to make the material and not lose an annual campaign of culture, for those who were metalworkers and farmers. The search for the ore was a decisive step, but the preparation of the latter before its introduction into the furnace conditioned the success of the operation.

Ore Preparation

Regarding ore processing, metallurgists used several processes. These include crushing, sizing, washing, drying, and roasting. All these treatment techniques can be grouped into two types, namely, physical and thermal treatments. Physical treatments include sight sorting, crushing, sizing, and washing (Robion-Brunner 2008: 205). They make it possible to reject the iron-poor parts and to improve the behavior of the ore during the smelting process.

In the Moosé and Gulmanceba of Burkina Faso, and the metallurgists of Benin, the ore was either simply crushed and calibrated in small pieces the size of a chicken egg by experienced people, or it underwent other treatments that allowed to modify the nature of the ore to facilitate smelting (Kienon-Kaboré 2003: 102). On the other hand, at the Senufo of Koni, in the north of Côte d'Ivoire, at the extraction of the ore, they obtained a powder that had first to be moistened, shaped into small balls the size of an egg hen, which was then allowed to dry before loading into the furnace (Kiethéga 1996: 311). Some ores were washed to rid them of clay loam that could hinder the smelting of iron ore and reduced to powder and then to an egg-sized ball (Essomba 1983).

Heat treatments – roasting, for example – are the firing of an ore in an oxidizing atmosphere and at temperatures well below the melting point (800–900°). This operation allows dehydration (disappearance of water molecules), decarbonation (transformation of carbonates into oxides by release of CO₂), or desulfurization (release of sulfur contained in sulfides) of the ore (Robion-Brunner 2008: 205). It is noted that all these treatment techniques serve a specific purpose, facilitating smelting while achieving good yields.

Furnace Construction

Before the smelting, the furnace construction is of paramount importance. However, it is important to note that given the diversity of furnaces in West Africa, it would be imperative to take them all up with the stages of their construction. We will discuss the construction of a simple and well-known furnace type that encompasses the wealth of knowledge in the field. The furnace and accessory construction techniques are diverse and result from the multitude of techniques employed in African societies. There are furnaces with natural draft or forced draft or furnaces underground, semiunderground, open-pit, pit, etc. In this approach we present the example of the forced air draft furnace which also shows the technical richness of these metallurgists. Water, clay, and straw are the essential materials. The termite mound soil is also used for the construction of the furnace because of its better soil quality which, according to the metallurgists, withstands the high temperatures of smelting. The clay is kneaded with straw which is allowed to rest for several hours. Meanwhile, a bundle of millet stems made and cut to the size of the future furnace is attached in three places to have the frustoconical shape of the future furnace. Then, the metallurgist clears the ground and digs a circular pit (about 20 cm deep) to the shape of the base of the furnace (about 1 m in diameter), in the center of which it makes a hole. He arranges for the pit to have an inclined slope on the west side. After that, the bundle of millet stalk is transferred there and serves as a mold for the construction of the furnace. The kneaded clay is placed all around it and plastered with a corncob, fingers, and other suitable equipment. Three days later, the bundle of millet stalk is removed or burned inside the furnace that has taken shape. This last operation has a double advantage. The heat helps to harden the furnace, and the resulting ash, which remains in the crucible, allows the magnifying glass not to weld to the ground.

The construction of the furnace is followed immediately by the realization of the accessories. The manufacture of pots and secondary nozzles obeys the same principles as the furnace, with the difference that the latter two do not use the same molds. For pots of the blower, a terrine of about 30 cm in diameter is essential. The mold of the secondary nozzles is a cylindrical wood 1 m long and about 14 cm in diameter. The main nozzle has the shape of a funnel and serves as the junction point of the two secondary nozzles, at the opening of the furnace, where it fits first. It plays the role of air duct here; otherwise the air could disperse at the junction of the two secondary nozzles. A forked wood is used to keep the furnace tilted. With the furnace construction completed, the blacksmith prepares for the smelting stage. The basic elements are the ore, the fuel, and the oxidizer (air) essential for the rest of the operation.

Combustible

A variety of fuel was used for the smelting of the ore, and each had specific qualities that acted on the good smelting of the ore. The most sought-after species were those with a high calorific value and also exhibited crush resistance in order to descend without crumbling or settling, a condition for the regularity of good combustion.

The choice of species is determined by the qualities specific to the species. Metallurgists have most often used green charcoal because it has a higher heating value than dry wood. In Burkina Faso, in the province of Bulkiemdé, metallurgists most often use *Khaya senegalensis*, *Guiera senegalensis*, *Detarium microcarpum*, *Burkea africana*, *Cassia sieberiana*, *Terminalia macroptera*, and *Butyrospermum parkii*. *Burkea africana*, *Detarium microcarpum*, and *Terminalia macroptera* are much more commonly used in blacksmithing. One mentioned has the reputation of making the iron easy to handle the purification and gives a very good quality to the metal. *Khaya senegalensis*, *Guiera senegalensis*, *Burkea africana*, and *Cassia sieberiana* are used for both smelting and forging. In the majority of blacksmiths, *Cassia sieberiana*, the roots of *Guiera senegalensis*, and the *Khaya senegalensis* carbonized together facilitate the smelting of iron ore. The *Burkea africana*, considered as the best in forge and the furnace, is the species most sought after by all blacksmiths of Bulkiemdé (Kiénon-Kaboré 2003).

The Smelting of Iron Ore

This stage also begins with sacrifices and rituals that differ from one society to another. The mode of loading depends on the blacksmith and the type of furnace. Sometimes ore and charcoal are alternately laden, as is the case in some Moosé, Gulmanceba, Bwa, and Dagara populations of Burkina Faso, Bassars of Togo, Niger, and Ivory Coast. Some metallurgists dispose of the charcoal in the middle of the furnace after making a crucible, and then the ore is put all around it.

The forced air draft furnace by the use of bellows works most often in the morning (5 am–18 pm). This type of operation allows metallurgists to have control over the intensity of the air. They may decide to stop, increase, or slow down the supply of air depending on the progress of the operation.

On the other hand, most natural air draft furnaces work at night. These are the case of the furnaces of Yatenga and some of Niger. The smelting takes place every night between 6 pm and 5 am; the smelting operation takes into account the wind conditions. Indeed, the absence or excess of air can affect the operation of the furnace by smothering or very rapid combustion of coal. This reason may have guided the blacksmiths to run the natural air draft furnaces at night, where the winds are moderated in some parts of Africa, to avoid malfunctioning.

The magnifying glass obtained after the smelting can be used directly in the forge for the manufacture of finished products or undergo purification at the smelting sites to facilitate refining at the forge.

The knowledge of the operational chain of the old iron metallurgy through ethnographic data shows the wealth of this traditional industry which includes geological, technical, mineral, chemical, meteorological, etc. They contain values of all kinds that disappear over time and the modernization of different African societies.

The work of the forge is also an important step which also includes technical and cultural knowledge and know-how.

Forging the Object

This phase is the transformation of the metal into a finite object. The blacksmith has a wide range of gestures and technical processes determined according to his raw material, his skills, his knowledge, the complexity of the object to be manufactured, and economic constraints (Robion-Brunner 2008: 216).

The Workshop of Forge

In the forge workshops, the magnifying glass obtained by the metallurgists was intended for the manufacture of tools for field work, weapons of war, and domestic, cultural, and religious objects. The workshop had a variable layout, workshop tools were diverse, and staff depended on the origin of blacksmith. The blacksmith's workshop at Bulkiemdé in Burkina Faso has a small forge of reduced size. It consists of a conical thatched roof shed. Circular in shape, it measures approximately 3 m in diameter and is composed of bellows, which are always two in number, with a fireplace and an anvil. Bellows are constructed in the same way as those of furnaces, with the only difference being that forges are small (Kiénon- Kaboré 2003). The same type of development is found in the Gulmanceba blacksmiths of Fada N'Gourma in eastern Burkina Faso where the roof is covered with a roof of millet stalks (Ilboudo-Thiombiano 1991). The spatial organization of the forge respects a certain number of prohibitions and mystical facts. The forge workshop can be family or community and most often located outside the family yard, in the center of the village.

Forging Equipment

The blacksmith uses specific tools for making finished products in the forge. These elements are most often common to African forges. The forge material is composite. We have iron anvils fixed on a tree trunk, chisels (for cutting), limes (for sharpening), pliers (to seize the red iron), hammers (for pinging), buckets, and cans. The anvil is the central element of the forge given its technical and cult role. It is a frustoconical mass of variable size, embedded in a tree trunk or inserted directly on the ground. Some companies use a mass of stone. At the level of the blacksmiths of Bulkiemdé, when the blacksmith decides to stop his trade, it remains the only element of the forge implanted to serve for ritual ceremonies of care or protection. Aside from the anvil, master piece of the forge, there are other types of tools each having a specific function. The pincer is the most used among these secondary tools. It is used to introduce, remove the heated object from the fireplace, and soak the iron in water. The chisel often has two different dimensions (a smaller one to cut small pieces of iron and the largest to cut larger blocks) serves, using the pincers and the hammer, to cut the supports of objects to make up. The needle is used to drill holes in tools that require them. To polish the sharp parts of knives, blades, and lances, the blacksmith uses a kind of scraper. The blacksmith uses fabrication techniques that start with hammering, dipping, welding, and other techniques of recoiling and chemical surface treatment for some delicate objects such as blades, lighters, knives, etc. (Kiénon-Kaboré 2003).

The Products of the Forge

With this forging material, the blacksmith manufactures tools, the majority of which consists of instruments for domestic use such as ladles and spatulas. The tooling for field work, such as the axe, the ermine, and the la, is the most requested and most made by the blacksmith. Apart

from these indispensable items for farmers, the artisan blacksmith also manufactures small domestic materials such as large needles used to make holes on the damaged parts of the wooden gourds in order to repair them. The tools of decoration of the leather, the iron for spinning cotton, and the making of mats are also the fact of blacksmiths. Other objects such as rings, amulets, and bracelets that serve to protect themselves from diseases and evil spirits are also the work of blacksmiths. Artisans use techniques of making objects that denote technical know-how and wealth. Each object has its own approach specificity that highlights a certain subtlety.

The forge in African societies has extensive functions. It is used not only to make the necessary tools for society but also plays an important cultural and worship role.

The remains of all this inheritance are most often remnants of iron metallurgy and are composed of extraction wells, heaps of slag, furnaces of smelting, etc.

III. Sites of the Ancient Metallurgy of Iron: A Technological Diversity in West Africa

The witnesses to this technical heritage, which show the former importance of iron metallurgy in these societies in the south of the Sahara, are most often found in rural areas. The remains and sites at the level of urban areas are most often destroyed by rampant urbanization. A large part of the whole of this technical heritage is currently in ruins for natural and anthropogenic reasons. These are diversity of sites and archaeological remains reminiscent of a recent past very active in the production and marketing of iron metal. In this article, we have chosen to present only few examples of metallurgical sites in West Africa in order to show the technical and heritage wealth of this industry. Each country of this part of Africa has benefited from more or less extensive research that has revealed many iron production sites, but we will only present those in Benin, Burkina Faso, Côte d'Ivoire, Mali, and Togo. The research presented for each country mentioned above is not exhaustive.

Benin

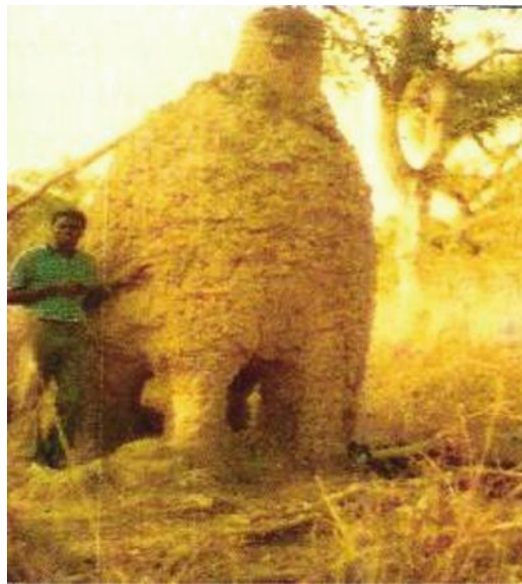
Research on ancient iron metallurgy in this country has made it possible to chronologically date the beginning of iron metallurgy during the first millennium BC in the Mono region (Randsbord and Merkyte 2009). During the first millennium AD, the iron production is becoming more wide-spread. Iron is produced in the Atakora from the fifth century AD (Ndah 2009: 435), in the Dendi Region from the fifth century AD (Robion- Brunner 2018a), and in the northeast of Benin, in Boo country, from the twelfth century (Banni- Guénné 2012).

In the Atakora region, metallurgical sites of ancient iron have been identified in the Tanguiéta region, Boukombé, Koukouabirigou, Koutacoingou, and Tèkouantè, and in the Natitingou region, Perma, Bouyagnidi, and south of Tayakou at the edge of the waterway called Ouankou. At Kèténkè, a site was located 10 km east of the village. It is composed of a large furnace of the Boonga type of central and northern Burkina Faso. It can reach a height of 3,75 m with a circumference of nearly 4, 30 m.

In northeastern Benin, research has highlighted several iron metallurgical sites (Banni-Guénné 2013). On the smelting sites of Ségbana, Kaiama, and Bensékou, Oumarou Banni Guene identifies two types of processes which he calls process Munga and Fufuna which are, respectively, the fact of sedentary and itinerant blacksmiths in the Borgou in Boo country. The Fufuna furnaces are smaller compared to those of the larger Munga process (Photo 1).

In the Dendi country, five smelting traditions divided into three groups have been distinguished: that of the reusable furnace with tapped slag (tradition 1), that of the non-reusable furnace with internal slag (tradition 2), and finally those of the reusable furnace with internal slag (traditions

3–5; Fig. 1; Robion-Brunner 2018a). The localization of iron traditions shows that the northwest is more diverse than the southeast. All the traditions are present around the village of Pekinga. This area seems to have welcomed blacksmiths belonging to diverse geographical origins. The craftsmen expressed their identity through their skills. We still do not know whether their settlement was contemporary, but what is certain is that Pekinga was a crossing zone. A series of 12 radiocarbon dates and oral traditions confirm that iron production started at least at the end of the first millennium AD and progressively decreased since the beginning of the twentieth century. Data are currently insufficient to assess the beginnings and fluctuations in iron production over this long period and to conclude whether the different traditions were contemporary or consecutive. Nevertheless, the variability of the metallurgical remains probably reflects significant modifications in population settlements. Moreover, some of these variations are very close to other West African remains. At least four traditions have the same spatial organization, the same type of furnace, and the same type of slag as those observed at Korsimoro by Serneels (Serneels et al. 2012, 2014) and near Niamey by Guillon (Guillon et al. 2016).



Furnace Munga. (Photo Banni-Guéne 2013)

More than 30 iron smelting sites have been located on the Abomey-Bohicon plateau and around the cities of Dogbo and Kétou (Fig. 2). Their activity began timidly during the first millennium BC and expanded from the second half of the first millennium AD east of Sodohomé. At its peak around the fifteenth century, it stopped abruptly at the beginning of the sixteenth century before the establishment of the kingdom of Dahomey. However, during this reign (1650–1900), iron objects were manufactured locally, but from iron imported either from neighboring regions or from European countries (Burton 1864). One of the possible reasons given for the end of iron production in the Mono is the arrival in the middle of the sixteenth century of an episode of drought in this region already subject to the effects of Dahomey Gap. This climatic factor in a dry sub-humid environment makes biomass regeneration problematic and thus the availability of wood and therefore coal, an essential fuel for operating reduction furnaces and forging furnaces (Randsborg and Merkyte 2009). The study of archaeological remains and iron production volume showed the existence of three periods corresponding to different production levels and techniques (Randsborg and Merkyte 2009; Fig. 2):

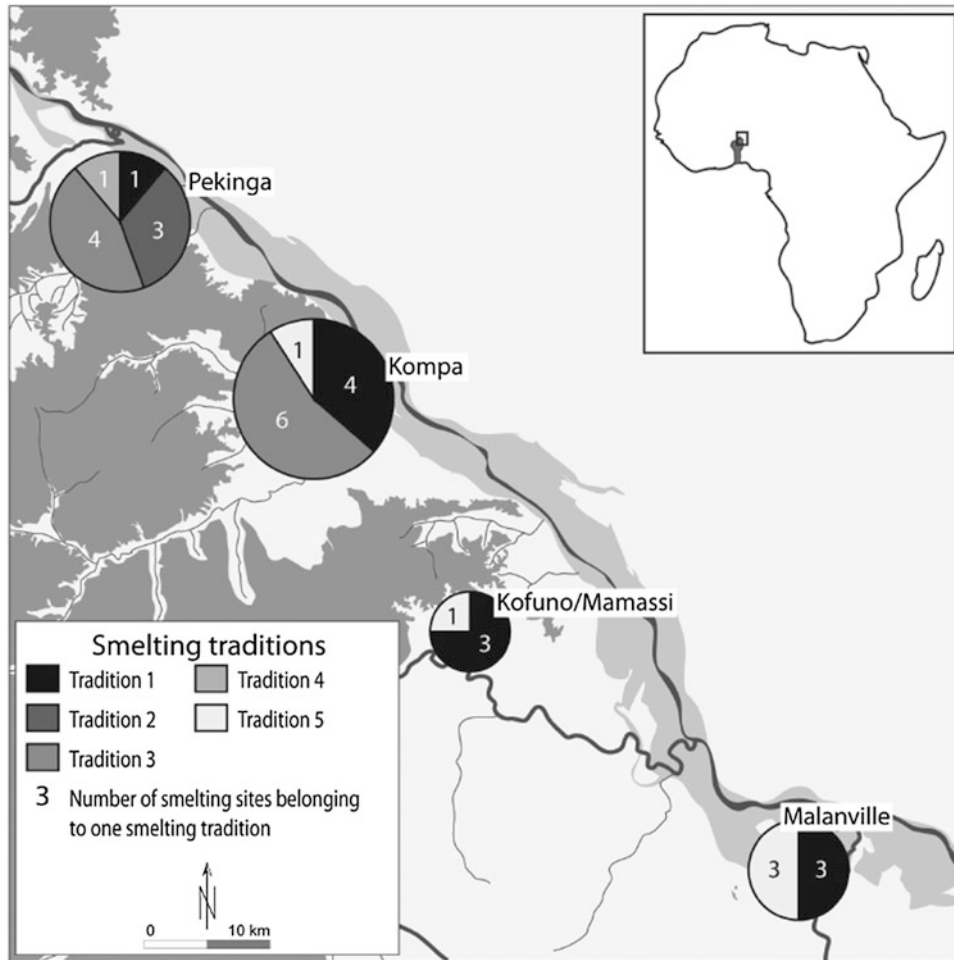
1. Between the eleventh and twelfth centuries AD, iron was produced between Tado and Sodohomé in small bellows furnaces.

2. Between the thirteenth and fourteenth centuries, the furnaces operated with natural ventilation distributed in the tank by several small tuyères, the smelting workshops established outside the housing areas multiplied and occupied a wider region ranging from Cheito in the west to Kétou in the northeast and Pobé in the southeast, and their production met a wider regional demand, probably including long- distance trade.

3. Between the fifteenth and sixteenth centuries, the furnaces, still naturally ventilated, were now equipped with several large tuyères. Real pre-industrial districts are being set up, but refocused on the southwestern part of the area. Their production, in excess, is then turned toward an export extra-regional. Through topographical surveys and cubages, it is established that the latter have produced more than 60,000 tons of slag over six centuries (Randsborg and Merkyte 2009).

As this estimate does not take into account all reduction workshops (calculations are based on data from 12 smelting sites out of the 30 identified), iron production was expected to be even higher, placing the Mono region on the list of the most important iron centers in West Africa.

The dimensions of the tuyères and their number are directly related to the morphology of the smelting structure. Sometimes markers of the ethnic origin of metallurgists, these elements often materialize population movements in a region. Crossed with ethnohistorical data, the analysis of archaeological remains makes it possible to trace the history of the iron industry and blacksmiths (Randsborg and Merkyte 2009). Thus, the large tuyère furnaces set up in the fifteenth century are associated with the arrival of Gbe-speaking peoples in the Mono. Gradually driving the Yoruba people to the East, who used to use small nozzles, these new populations bring a technique that seems more efficient, allowing the increase in iron production.



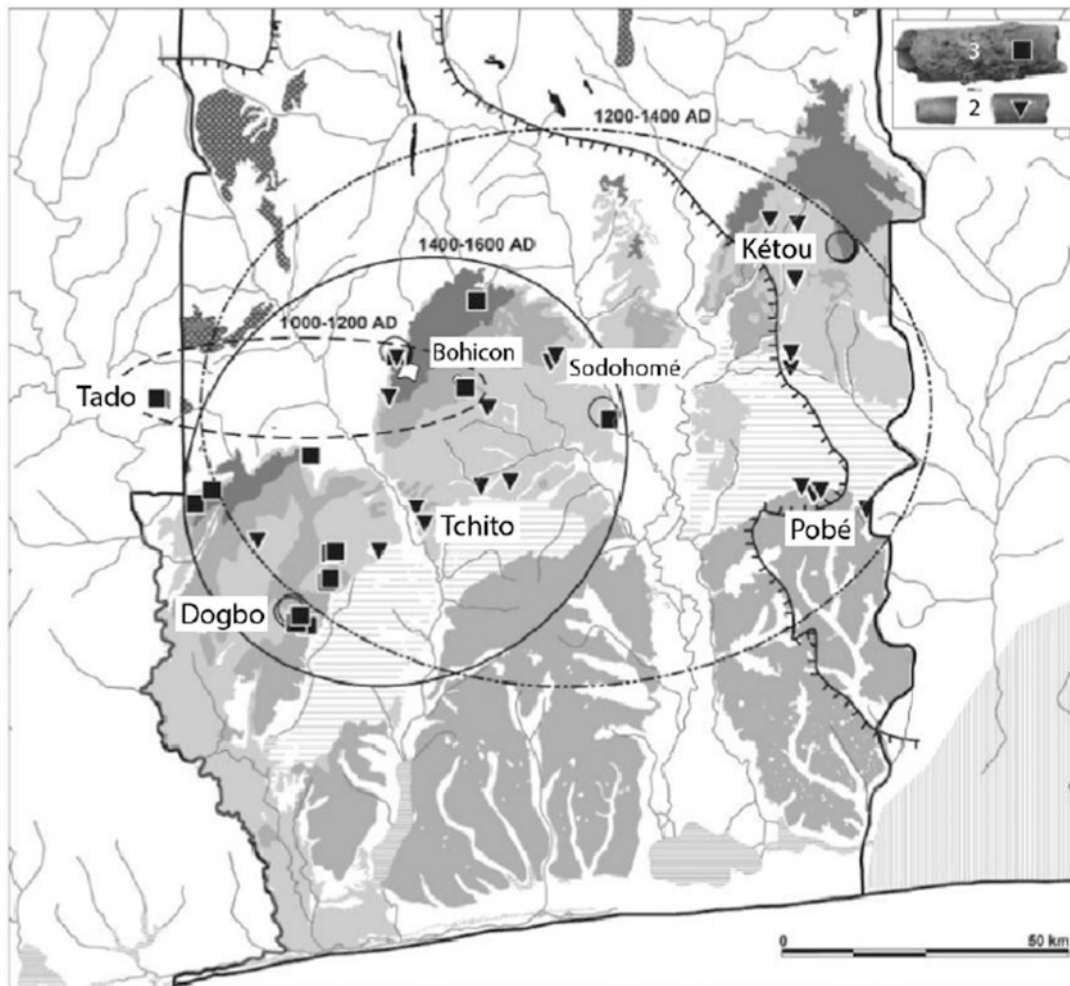
Localization of the five smelting traditions in the Dendi country

Burkina Faso

Burkina Faso, like other sub-Saharan African countries, has been a major iron-producing area over the past centuries. The importance of this industry is perceptible through the sites and vestiges discovered throughout the territory. Some metallurgical sites have brought decisive data to the understanding of the history of ancient iron metallurgy in Burkina Faso. We can cite those of Ronguin, Tiwêga, Kindbo, Yamané, Korsimoro, Wolgteng-gooden, Tougaré, Beli in the Markoye region, etc.

Research in recent years has made it possible to advance a little more in the understanding of iron metallurgy in Burkina Faso. Among these investigations, those of Yamané-Nimpoui and Korsimoro have made it possible to renew the knowledge of ancient iron metallurgy in Burkina Faso.

The site of Yamané-Nimpoui is located 70 Km north of Ouagadougou. It houses numerous remnants of iron metallurgy composed of iron slag, nozzles, furnace walls, and well-preserved furnaces. The excavations made it possible to identify a first type of furnace which measures about 3, 5 m high and a second type whose bases are very eroded. One of the main characteristics of the first type of furnace is the presence of a cylindrical block in the center of the furnace during the smelting that works with a natural draft. The coal collected during the excavations made it possible to date one of the structures by 14c dating in the fourteenth century AD (Serneels et al. 2015: 4).



*The iron smelting sites of the Mono region with different chronological periods and different types of nozzles.
(According to Randsborg 2009: 211)*

Another important site was identified and excavated at 70 km northeast of Ouagadougou. It is the metallurgical site of the iron of Korsimoro. In this region there are several technical traditions, the first identified of which present certain peculiarities (Serneels et al. 2011: 23–54). The first is the set of large, single-use slag furnaces. These are circular furnaces aligned on a straight line that worked with battery (Photo 2). The dates obtained are between the seventh and tenth centuries AD. The second type is characterized by large reusable, trapped slag furnaces that provide dates between the eleventh and thirteenth centuries AD. The furnaces are massive buildings scattered with natural draft of air. They have four openings, and the cylindrical and massive nozzles (diameter 12–15 Cm) are reused. Technical tradition 3 consists of large, reusable, cast slag furnaces dated between the fourteenth and sixteenth centuries with a single furnace placed in the center of an elliptical work area. The releases form a ring with a slag mound placed in the west. The nozzles are relatively small, 3–4 cm in internal diameter and 7–9 cm in outer diameter, and the slags found are blocks of cast slag. The furnace sometimes has five openings. As for technical tradition 4, it is represented by small, single-use, trapped slag furnaces dating from the seventeenth century. The furnace bases are of very low diameter which contains a massive cylindrical slag. They are presented by battery of 10–50 units. The diameter varies between 15 and 25 cm, and the depth is 30–40 cm and reaches exceptionally 80 cm. The use of bellows is most likely for its operation (Photo 3).



Technical tradition KRS1 (Photo Serneels et al. 2011)

The diversity of archaeological data and technical traditions on ancient iron metallurgy in Burkina Faso shows the dynamism of this industry over the past centuries. Burkina Faso, in view of these research results, constitutes an important center of production which the ethnographic data also confirms.

Ivory Coast

In Ivory Coast, the results of excavations in the Folon region of Kaniasso in the northwest of the country have provided important scientific knowledge on the production of ancient iron metallurgy. Metallurgical technical traditions are identified, and the first absolute chronology on this theme is obtained for the first time in Côte d'Ivoire. Different technical traditions are identified from the earliest investigations in the village of Siola, KAN 1 (eleventh to fifteenth centuries AD), KAN 2 (fifteenth to twelfth centuries AD), and KAN 3 (seventeenth to nineteenth centuries) (Serneel vincent et al. 2013).

The first technical tradition KAN 1 (eleventh to fifteenth centuries AD) located in area 2000 of Siola and Doumbala-Kokoroni K-301 is the set of furnaces constructed of sunken slag nozzles. It is characterized by the presence of small elliptical or subcircular mounds consisting of small fragments of slag cast in cords. The nozzles associated with the KAN 1 tradition are cylindrical and small gauge. They are reused for the construction of the furnaces (Photos 4 and 5). The furnaces are built on pillars formed by blocks of irregularly shaped laterites above; a wall constructed using cylindrical sections of used nozzles is mounted. Initially, the furnaces are installed above a low elliptical depression in the bedrock. The furnaces probably work with a natural draft fed by nozzles, and the flow of slag through the door during the operation is the rule. In spite of everything, some internal slag also forms (Serneels et al. 2013).



Technical tradition KRS4 (Serneels et al. 2013)



Furnace tradition KAN1 in Siola (Serneels et al. 2013)

The second technical tradition KAN 2 (fifteenth to seventeenth centuries AD), characterized by trapped slag furnaces, is composed of broken blocks of internal slag. This KAN 2 tradition has been identified at Siola 1200–1300 and Doumbala-Kokoroni K-201. The furnaces are subcircular constructions of 1.3 m in diameter. The material is a clay mixed with some gravel. These structures are reinforced by sections of used nozzles, arranged horizontally and which are then encompassed in the Earth mass (Photos 6 and 7). These pillars are 30 cm wide and 50 cm high. Then a clay wreath connects the pillars. The furnaces have been used repeatedly, and the air supply is probably based on a natural draft, with at least six large nozzles. The slag accumulated at the bottom of the furnace is evacuated after cooling the furnace.

The third technical tradition KAN 3 (seventeenth to nineteenth centuries AD), consisting of very large furnaces with trapped slag, is characterized by large annular clusters consisting of large blocks of internal slag surrounding a structured work area. At the center is a very large furnace with an external diameter at the base of more than 2 m. The furnaces are very powerful constructions (Photo 8). They have a door and four or five doorways. They are built to serve a lot of times. The furnaces probably work with a natural draft. The remains of the KAN 3 tradition are impressive. In half of the cases, the accumulation of slag is 2.5 m high or higher.

A fourth tradition is highlighted in Siola in area 4000 and dated from the eleventh to the thirteenth century (Serneels Vincent et al. 2015: 93). In fact, surveys have made it possible to update furnace bases after a depth of 50–80 cm. The furnaces are clearly distinguished from the structures belonging to the other technical traditions of the Kaniasso District. These are pits dug into the lateritic bedrock. They have an elliptical shape (Photo 9) and have a well-marked door, about 60 cm wide, placed at one end of the large axis of the ellipse. This area of Siola 4000 contains remnants of nozzles specific to their shape. These are large massive nozzles longer than 40 cm, weakly tapered with a subcircular to elliptical section. The peculiarity of these

nozzles is the existence, in addition to the normal nozzle, of three perpendicular openings of rectangular or circular section according to the models (Photo 10). The activity was intense, with at least 200 furnaces in operation. However the complexity of the structures does not allow at this stage the work to clearly characterize this technical tradition.



Furnace tradition KAN 1 in Doumbala (Serneels et al. 2015)



Tradition KAN 2 in Siola (Serneels et al. 2013)



Furnace tradition KAN 2 in Doumbala (Serneels et al. 2015)



Tradition KAN 3, site of Siola (Serneels et al. 2013)



Furnace tradition KAN 4, site Siola 4000 (Serneels et al. 2016)



Nozzle with lateral opening, Siola 4000 (Serneels et al. 2013)

Mali

In Mali, many vestiges testify to the production of iron. The study of those established on the Dogon plateau revealed the existence of different techniques present in a relatively small territory and operating at the same time. The work has resulted in dates extending from the sixth to the twentieth centuries AD (Robion-Brunner 2008: 237–347). In total, six (6) technical steel traditions have been clearly identified based on the spatial organization of production sites, furnace types, and associated waste assembly.

In the Fiko tradition, furnaces are often organized in drums of two, occupying a more or less circular work area. The slag is rejected on the periphery of the smelting area and forms a frustoconical cluster whose center has a crater with almost vertical walls and reinforced by slag walls.

There are double clusters due to the junction of two clusters. The furnaces are imposing structures of elliptical plan (2.5×1.5 m) with a basin shaped lower part. At mid-height, the wall of the furnaces is pierced by a series of embrasures intended for the installation of massive nozzles. The vaulted superstructure is 2.5 m above the bottom. The majority of the slags are poured, but slabs in the form of slabs are encountered. The beginning of production on the site of Fiko remains unknown, but it is clearly attested from the year 1100 AD and continues until around 1900 (Robion-Brunner 2008).

In the Ouin tradition, a single furnace occupies the center of a cluster of annular slags. The workshops consist of one or more rings. The furnaces have a circular section of one (1) m in diameter. They have a lower pit about 50 cm deep, a door, and 5–8 embrasures with a chimney up to 1.5 m above the traffic floor. On the side, a sandstone block staircase gives access to the upper opening. The slag is poured and the tuyères massive. The lower part of the chimney was built using lozenge-shaped raw bricks. These furnaces share similarities with furnaces from Yatenga (Burkina Faso) and attributed to Kibsi metallurgists, who were present before the conquest of the country by the Nakombsé in the fifteenth century AD (Kiéthéga 2009).

In the Ama tradition, site organization and furnaces have similarities to that of the Ouin tradition. The furnaces excavated at Amabalaginna are rather small (diameter 80 cm), of circular section, with a pit dug in the substrate, a door, and only five embrasures for the nozzles at the ground level of circulation and a slightly frustoconical chimney. The slag is shaped like a thick, curved plate. The solidified slag therefore has a central vacuum of the cooling mode. A large majority of nozzles is clogged with slag.

In the Tinntam tradition, the furnace construction technique is the cladding on the outside by a cladding of sandstone blocks surrounding a slag-bound construction using clay mixed with straw. On the inner walls a layer of nozzle fragments is applied, which is then covered by a thin clay film. The furnaces include a buried pit, a door, and nine narrow embrasures at the ground level of external circulation surmounted by a massive chimney high of about 2 m. The nozzles are thin and cylindrical and the slags are small cast fragments. They are frequently contiguous two by two. The spatial organization of the sites is not always the same. The other sites of the tradition are much more modest and are characterized by furnaces arranged randomly and each surrounded by a rejection of more or less annular slags.

The Aridinyi tradition is characterized by massive furnaces built of banco-bound slag. The lower part is a shallow bowl. And the globally frustoconical chimney rises about 2 m above it. The inner tank, wide at the base, closes in dome and is extended by a much narrower duct. A door and five embrasures are made at ground level of circulation. An external staircase provides access to the upper opening. These furnaces produce mainly internal slags in the form of roughly hemispherical large blocks up to 80 cm in diameter and 40 cm thick for a weight exceeding 100 kg. The nozzles are massive. The furnaces are arranged either randomly or in parallel rows. The spaces between the furnaces serve to reject the slag blocks. The accumulation of waste forms retaining walls. This is the case where on the large site of Aridinyi, the cluster of slag forms a single massive thick more than 2 m by 100 m long traveled by narrow streets lined with high slag walls connecting places occupied by furnaces.

The sites of the Enndé tradition are most often the juxtaposition of small, low mounds or even simple debris spreading. The excavation carried out by S. Perret uncovered a buried furnace base, with an access pit and a door as well as five embrasures for the nozzles at ground level of

circulation. The construction is made of banco and slag. The diameter of the tank reaches about 1 m. The slag in these furnaces has irregular block shapes with flow structures and many traces of sediment adhering to the surfaces. These are bottom slag.

This research helps to understand the development of iron production in Dogon countries in the Bandiagara region.

Togo

In Togo, several researches have identified sites of ancient iron metallurgy in the regions of Bassar, Dapaong, and Tado, allowing some to situate this activity in a chronological context and to know the operative chain of this industry.

In the Bassar region, iron production began as early as the fifth century BC and ceased in the middle of the twentieth century AD. After a chronological hiatus, this activity took off at the end of the first millennium AD (De Barros 1986). The workshops are established along two discontinuous mountain ranges rich in iron seams. The study of the volume of iron production taking into account the chronology makes it possible to divide the history of the Bassar iron industry into five periods (from Barros 1985, 1986, 2013):

1. Between the middle of the fifth century BC and the first century AD, iron was produced and transformed into an object around the Dekpassanware site.
2. Between the end of the first millennium AD and the middle of the fourteenth century, steel sites multiplied in the region, and their production was small and supplied local needs.
3. Between the middle of the fourteenth century and the end of the sixteenth century, steel activity increased and became important.
4. Between the seventeenth century and the beginning of the nineteenth century, it reached a surplus production turned toward extra-regional exports.
5. During the nineteenth century, it continued to expand, but some intersocietal relations disrupted trade and production; the latter ceased at the beginning of the twentieth century in the eastern part (Kabu/Bassar), while around the city of Bandjéli, it was not until the 1950s that local iron was permanently replaced by European imports.

Thanks to topographical surveys and cubages, production can be estimated at more than 200,000 tons of slag over the last six centuries (Robion-Brunner et al. in preparation). This estimate makes the Bassar district one of the most important iron centers in West Africa.

As elsewhere on this continent, the direct method of obtaining iron was used. Macroscopic analysis of the slags shows that external slags are in the majority in the Bassar region but that they are accompanied by other types of internal slag. In total, seven types of slags divided into five iron assemblies are characterized on the Bassar sites. This diversity of techniques corresponds to both different time periods and different geographical locations. Apart from an iron tradition present at all times and throughout the region, it seems that there was a technical change around the sixteenth century and that the processes differ on either side of the Katcha River. In the eastern sector, two technical traditions appeared at the beginning of the thirteenth century, and then a third one appeared in the middle of the fifteenth century in the northern part. In the western sector, the southern and northern parts are not contemporary. In the south, metallurgy seems to begin at the end of the thirteenth century and end at the beginning of the fifteenth century. Two techniques are used together but not on the same sites. In the northern part, the iron industry began in the sixteenth century. On these sites, two technical traditions are used in parallel, but not with the same intensity.

The surveys and excavations conducted at Tado by the team of Dr. Aguigah Dola have identified many metallurgical sites (Aguigah 2015). After analysis of the data, it has been established that it is a natural-run, semiunderground, flared- base furnace with a conical upper part.

This diversity of remnants and iron metallurgical sites is evidence of the importance of this industry at the technical, economic, military, and sociocultural level.

IV. Ancient Metallurgy of Iron and Society

The History of techniques cannot, however, be done outside of society, culture and thoughts that constitute a whole with the technique strictly speaking. Indeed, the technique which is the peculiarity that man has to invent the tools and the processes to act on his environment in a sustainable and reproducible way is most often the reflection of culture, society, and thought, in a word of the Homo technicus in Its environment (Garçon et al. 2010: 11).

The Ancient Metallurgy of Iron in Society

The introduction of ancient iron metallurgy has profoundly affected African societies. Indeed, this industry has been at the base of the formation of strong, powerful, and structured states in Africa. Its role in the structuring of societies has been decisive in many socioeconomic and political upheavals. Its military and political consequences have been an important lever in the establishment of many kingdoms and empires during the African Middle Ages. Indeed, during the time of the African Middle Ages, the control of the iron mines and the control of iron gave a certain economic and military power to the different kingdoms and empires which succeeded one another: the empire of Ghana (VIIe in XIe century), Mali (from the thirteenth to the fourteenth century), and Songhai (middle of the fifteenth to the sixteenth century). Their political, military, economic, and social history illustrates the importance and role of iron in the organization and structuring of these societies. In addition, iron, tenacious, ductile, and malleable, which has improved weapons, will also play an important role in agricultural yields, as the increase in iron production has fueled trade.

Indeed, iron has been the basis of an important agricultural revolution and dynamic trade in West Africa. Metalworking allowed blacksmiths to make various tools used in agriculture. This unavoidable material in agriculture has therefore played an important role in agricultural production. The consequence is the multiplication and increase of agricultural resources. For the African continent, trans-Saharan trade has been an exchange network where iron played an important role after that of gold. Other commercial networks have existed and participated in this dynamic trade.

During the production of iron in furnaces and forging, man has developed over the years innovations of several kinds. The techniques developed have evolved over time but also in space. They improve, transform, and evolve to the rhythm of human thought and adapt to the context of the moment. What are the innovations in iron metallurgy?

Technical Changes and Societies

At the level of the operating chain, the technical changes are especially noticeable today at the level of the work at the forge. Experiments have also revealed the use of new equipment. In the same way the raw materials and the products have changed according to the context and the new needs of the society. Blacksmiths continue to use traditional technical gestures when necessary. Their role in society has also changed over time. At the level of the smelting of iron ore, for experimental reasons, the resumption of this activity for educational and research purposes allowed the use of new materials to facilitate the work, most often because of the absence of the iron ore old material that is difficult to reproduce, inappropriate, or low yielding.

As an example, the 2005 experiments in Park W, part of Burkina Faso, for the construction of the bellows furnace, the nozzles connected to the blower jars, usually made of earth, have been replaced by modern iron pipes. However, of all these changes, changes in the forge are related to the current needs of companies in sub-Saharan Africa. These mutations are visible in many African societies. In this chapter, we discuss the case of mutations in Burkina Faso where important studies have been conducted.

Mutations Related to the Equipment or Operation of the Forge

As the techniques are evolving, many blacksmiths have released their creative genius to adapt traditional techniques to the reality of the moment, modernity, and the environmental context.

The workshop itself has changed. Forging workshops vary from one region to another but also according to blacksmiths and production techniques.

Zakaria Lingani writes that “the traditional workshop is a set of places in the house. It is a shed built outside the concession with a straw roof placed on some posts” (Lingani 1988: 66).

But, nowadays, it is not uncommon to see iron poles supporting the forge shop as found in Gourcy in north and west central Burkina Faso.

In the same way the sheet is introduced in the construction of the workshop like roof, which did not exist formerly. Also, the use of a plastic tar- paulin above the roof is an introduction to modernity in the workshop. All these innovations in the forging workshop are the fact of the popularization of iron material and the availability of these different raw materials, more accessible nowadays.

In terms of technical changes and innovations, the equipment of the forge workshop has also changed. In the device for manufacturing objects, the use of an electric coil is used instead of traditional wind tunnels. This electric coil is a recovery equipment of old cars originally used to cool the engine of vehicles. It plays an important role in the energy production system and in the operation of production. This original duct system for the fire- place blower is used by Adama Traoré, a smelter in the village of Kolonkani-Ba (Burkina Faso). Many blacksmiths use this system.

The innovation also lies in the use of a battery in blacksmith shops for the operation of the forge (in Kolonkani-Ba, Sabou, and Ouagadougou). It is a battery, usually 12 volts, intended to supply the electrical circuit of cars. Similarly, solar panels are used to power the home. For example, the modernization of Adama Kindo forging has two wind tunnel systems, one manual and the other solar. The manual system is used in case of solar energy failure.

Also, the frames of mussels formerly made of earth are also made of wood precisely boards used in the process of production.

In Sabou, a town located 100 km west of Ouagadougou, many forges are semi-modern. The forge shop is characterized by a shed under which are found, as a working device, a fireplace built of clay bricks, a ventilation system materialized by a bicycle or motorcycle man, and a darned air brewer from a motorcycle chain cover.

The raw material is obtained from recovery equipment such as rims of motorcycles and vehicles, motorcycle coils, old cooking pots or old aluminum dishes, old empty cans of drinks cans, plates, and all other object containing aluminum. Formerly intended to produce blades of hoes, arrows, and objects of adornment, the productions are today very varied. A diverse range of tools is manufactured in its semi-modern workshops. These include groundnut shellers, single plows, multipurpose plows such as plowers, seeders, plotters, weeders, and scrapers.

In order to participate in the Tougan agricultural and craft fair in 1989, the Souabo and Toungaré family produced iron from which they pulled a plow. Iron and plow were presented at the fair.

From the technical point of view, faced with the invasion of the industrial metal and the profusion of the artisan welders, the blacksmiths had to learn to adapt. The smelting gradually disappeared at the beginning of the twentieth century, and production has also changed. Some objects remain unavoidable and unequaled, among which tools for working wood and earth are still produced by craftsmen. Some blacksmiths have made a radical change in their production (Léonce 2009: 67).

Technical progress evolves in time and space, and man uses his creativity to evolve his techniques according to his environment. The mechanism created by Adama Traoré in the village of Kolonkani-Ba shows how modern elements can be used to lighten work and obtain better returns. It also denotes the inventive spirit and continual changes in techniques.

The Metallurgists-Smiths from Yesterday to Today

In the majority of blacksmith companies, the vision of iron in African societies has also marked the various roles played by the blacksmith, an important and unavoidable figure.

The place of the blacksmith in these societies is closely linked to the image of iron, its conception in these societies where the metallurgical industry is related to ritual aspects. Indeed, techniques and rites are complementary and inseparable. In Burkina Faso, in some blacksmith societies, apart from its technical contribution through the production of iron, the blacksmith is the very one who is at the center of cultural life. The blacksmith plays distinct roles according to the societies to which he belongs. Being a blacksmith is a vocation, one is often born blacksmith, one works iron, and one carries out also important missions in the company, like that to calm the conflicts. The blacksmith, a central figure in society, is at the beginning and end of life. He heals the body and the spirit, protects, and advises. The blacksmith is also asked for his mediating role in conflicts. The blacksmith within these companies becomes a key figure.

These roles have continued in the villages because the blacksmith is still feared and respected in the majority of societies.

In the past, the production of iron and the work at the forge were an activity most often exclusive according to the blacksmith companies. In fact, iron metallurgy was the main activity, but not permanent, because trade or barter was able to cover the needs of the blacksmith. During the drought period, he was looking for his ore, reducing it to have a good reserve of magnifying glass. In the rainy season, during which the demand for finished products increases, he devotes himself to forging, trade, and/or trade. But with the gradual cessation of iron production and the introduction of salvage iron, metallurgists and blacksmiths intensified field work. Nowadays, blacksmiths are also farmers, and the work at the forge has become a complementary activity. Their ancestors were metallurgists. They worked on natural draft or bellows furnaces. But the present generation did not participate in the different operations. They remain today blacksmiths, farmers, and healers.

V. Conclusion

The approach highlights the complexity and diversity of the old iron metallurgy in West Africa. The process of developing the metal from the search for ore to the transformation of the magnifying glass into finished products reveals a wealth and diversity of operations. The variety of furnace shapes, ore processing, smelting, and refining operations is a fundamental feature of iron metallurgy in West Africa. Thanks to the ethnographic approach, we know how the metallurgists produced the iron magnifier. The ethnographic aspects shed light on the

archaeological data and show indeed a certain technical richness which includes knowledge, botanical, mineralogical, meteorological, and other related fields. The protection of these technical knowledge and archaeological sites related to iron metallurgy is more than an emergency. Archaeological remains that have been abandoned for some time may disappear without proper study or development. The protection of this technical heritage makes it possible to safeguard a wealth that contains technical, educational, moral, and symbolic values for West Africa. Research on the ancient metallurgy of iron must emphasize the technical, sociocultural approaches of each society and deepen local studies because the data of current investigations have shown technological and sociocultural wealth that differ from a society to another at reduced scales.

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