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An Investigation into the Iron Smelting Furnace Types on the Jos-Plateau, North-Central Nigeria: Results from Recent Survey

Dimas Solomon Gubam[1], Kimbers Y. Yoila Ph.D[2] and Prof. Kola T. Odofin[3]

[1]Department of Archaeology and Museum Studies,
Faculty of Arts, Federal University Lokoja, Lokoja, Kogi State, Nigeria,

[2,3]Department of Archaeology and Heritage Studies,
Faculty of Arts, Ahmadu Bello University, Zaria, Kaduna State, Nigeria

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Abstract

Communities on the Jos Plateau of North-Central Nigeria are known for their iron-smelting activities. Although colonial anthropologists and archaeologists have documented iron-smelting remains and associated cultural practices in the area, the furnace structures used across the region have received limited focused typological analysis. Existing studies have largely presented broad archaeological surveys or general descriptions of iron smelting, with less attention to the classification of furnace forms. This paper documents and examines iron-smelting furnace structures on the Jos Plateau using evidence from field surveys, previously reported archaeological sites, surface remains, and published ethnographic records. The study draws on the examination of furnace remains, including tuyere fragments and furnace-wall materials, alongside information from earlier archaeological and ethnographic accounts. It identifies variation in furnace form and arrangement and proposes a classification based on the available structural evidence. The findings provide a basis for understanding the range of furnace designs documented on the Jos Plateau and their significance for the study of indigenous iron-smelting technology. However, interpretations concerning chronological change, production scale, fuel availability, and social organisation require further evidence before firm conclusions can be drawn. The study contributes to the documentation of iron-smelting furnace structures in the region and provides a foundation for further comparative research into their technological and archaeological significance.

Keywords: Jos Plateau, iron smelting, furnace types, archaeological survey, African metallurgy

Introduction

Iron smelting was an important technological development in African history (Davidson, 1959). Knowledge of iron technology contributed to changes in production, migration and the development of societies, although its effects varied across different communities and historical contexts (Ndera, 2026). The Jos Plateau of North-Central Nigeria is an important area for studying this technology because of the widespread remains associated with iron production, including iron slag, furnace structures and tuyere fragments. Historical records, anthropological accounts and archaeological surveys have documented iron-smelting sites in different communities across the

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Plateau, indicating that iron production formed an important part of the region's technological history (Jemkur and Walu, 2002; Gubam, 2013; Maram, 2014; Fwatshak, 2014; NAK/SNP/1192/19/1941).

Ropp Rock Shelter is among the archaeological sites on the Jos Plateau discussed in relation to the region's early human occupation. Shaw (1978) reported archaeological evidence associated with occupation spanning the Late Stone Age and the Early Iron Age. Iron implements, slag and iron ore have also been reported from an excavation trench at the site. However, the presence of these materials does not, by itself, establish that iron smelting took place at the shelter or that the materials were associated with a particular smelting installation. Their significance depends on their archaeological context, the circumstances of their recovery and the dating evidence available. The provenance and chronological association of these finds therefore require careful consideration when using Ropp Rock Shelter to discuss the history of iron production on the Plateau.

Beyond Ropp Rock Shelter, the Jos Plateau contains numerous remains associated with iron smelting, including slag deposits, tuyere fragments, furnace-wall fragments and abandoned smelting installations. Historical and ethnographic records also document iron-smelting practices that continued in some communities until the twentieth century. Together, these sources demonstrate the importance of investigating the region's iron-production history. However, the distribution of smelting remains and the duration of the craft do not, on their own, establish how furnace designs developed or whether particular forms were associated with specific periods, production scales or communities.

Previous archaeological and anthropological studies have examined iron production on the Jos Plateau, including its social and cultural dimensions (Netting, 1968; Shaw, 1978). Earlier descriptions of furnace structures also provide a basis for examining the forms used in different parts of the region. The present study builds on this existing work by bringing together available descriptions, archaeological observations and documented accounts to examine furnace forms across the Plateau. Rather than assuming that no previous typological work exists, it assesses the available evidence to determine how far earlier studies have described and distinguished the furnace structures. This approach provides an opportunity to clarify the similarities and differences among the documented forms and identify areas where further field investigation is required.

Furnace structures are important sources of evidence for understanding the technological practices involved in iron smelting. Their shape, construction, dimensions and associated features can provide information about how smelting installations were built and used. Differences between furnaces may reflect technological choices, but explaining those differences requires evidence beyond morphology alone. Interpretations concerning production scale, fuel use, ore selection, labour organisation and cultural preferences must therefore be assessed against the archaeological context and any available ethnographic or historical information. Similarly, claims about changes in furnace design over time require reliable chronological evidence.

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This paper examines iron-smelting furnace structures on the Jos Plateau through the re-examination of previously reported archaeological sites, the analysis of surface remains and the review of historical and ethnographic accounts of iron smelting. It aims to document the furnace forms represented in the available evidence, establish a consistent classification and assess the significance of the observed variation. The study has three objectives:

1. To document and classify the main iron-smelting furnace forms reported on the Jos Plateau.
2. To examine variation in furnace design across documented sites and communities, while considering chronological differences where sufficient evidence is available.
3. To assess what the documented furnace forms and their archaeological contexts reveal about iron-smelting technology, resource use and social organisation on the Jos Plateau.

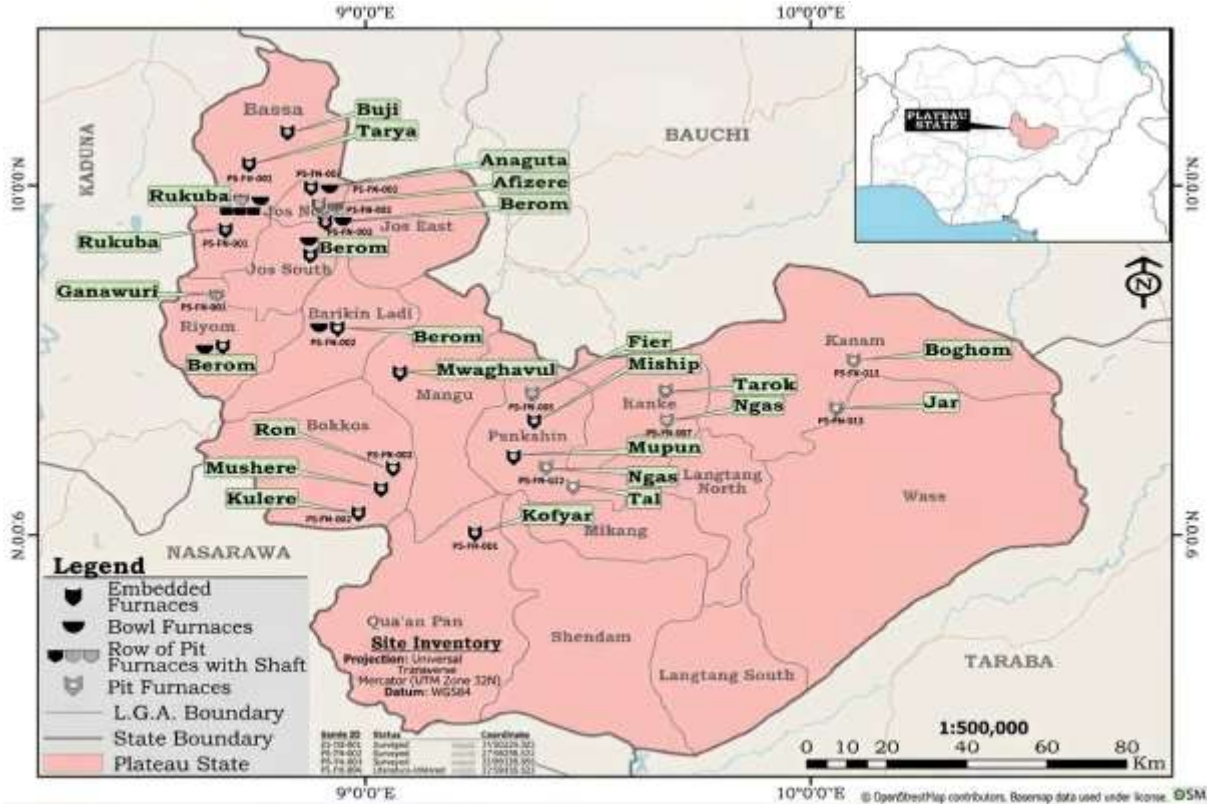

Figure 1: Distribution of Iron Smelting Furnaces Traditions across Various Ethnic Groups on the Jos-Plateau
Source: Modified from https://www.openstreetmap.org/#map=6/9.117/8.674

Methods of the Research

This study adopted a qualitative research approach that combined field surveys, a review of relevant literature and archival materials, and oral interviews. Field surveys were conducted on the Jos Plateau between 2018 and 2023. Sites were identified through previously published archaeological and historical reports (Fagg, 1958, 1969; Jemkur, 1989; Berthoud, 1969; Gunn,

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1953; Netting, 1969; Tambo, 1976; Temple, 1976; and Maram, 2014), as well as through engagement with local communities. The survey examined reported iron-smelting locations and visible remains, including furnace structures, furnace-wall fragments, tuyere fragments and slag deposits. Published ethnographic accounts and archival materials on communities of the Jos Plateau, together with relevant studies of iron smelting elsewhere in Nigeria, were also reviewed to provide historical and comparative context.

The research covered communities associated with the Buji, Tarya, Anaguta, Afizere, Berom, Rukuba, Ganawuri, Ron, Mwaghavul, Mushere, Kulere, Fier, Miship, Tarok, Ngas, Mupun, Tal and Kofyar peoples. The identification of sites drew on earlier reports and information supplied by community members. In some cases, hunters who had encountered archaeological remains in the bush identified their locations and explained what they knew about them. The researcher then visited these locations with the assistance of the hunters to examine the remains directly. This approach helped locate sites that might otherwise have been difficult to identify through published sources alone. The survey findings were considered alongside documentary and oral evidence. The field surveys discussed in this study took place between 2018 and 2023; the survey dates and provenance of individual photographs should be checked against the original field records to ensure that all captions accurately reflect when and by whom the images were obtained.

Oral interviews were conducted with 76 participants drawn from communities across the study area. The participants comprised six traditional rulers, ten academics, fifteen civil servants, twenty farmers, fifteen housewives and ten students. Participants were selected purposively because they were considered capable of providing relevant information about the history, location or technology of iron smelting. They included local blacksmiths, members of the last generation of iron smelters, community members with knowledge of the craft, traditional rulers familiar with community histories, hunters who had encountered smelting remains, and academics who had conducted research in the area. These participants did not necessarily possess the same type or level of knowledge. Former practitioners could provide information based on direct participation in ironworking, while other participants contributed observations, community histories, inherited accounts or research-based interpretations. Their accounts were therefore considered in relation to the source of their knowledge and, where possible, compared with the archaeological remains and documentary evidence.

The interviews used open-ended questions focusing on iron-smelting technology on the Jos Plateau, particularly the forms, construction and use of furnaces. Both group interviews and individual interviews were conducted. Group interviews allowed participants to discuss their knowledge and experiences, while individual interviews provided opportunities to obtain accounts from particular informants. Voice recordings were transcribed into written English, with translation undertaken where necessary. Field observations and relevant information were also recorded in written field notes. The interview material was examined alongside the field observations, published literature and archival records to identify descriptions of furnace structures and compare information from different sources. The available methodological record should specify how interview responses were organised and compared during analysis, including whether a formal coding procedure was used.

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Consent was sought from interview participants, and consent was granted. Participants were assured that their information would be treated confidentially. Community engagement formed part of the process of locating sites and obtaining information from people familiar with local iron-smelting histories. The research drew on archaeological field observations, oral accounts and existing documentary sources. However, any formal institutional ethical approval, community-level research permissions or archaeological survey and collection permits obtained for the work should be identified explicitly in the final manuscript. The paper should also clarify how consent for voice recording and translation was handled, and whether participants agreed to be identified by name when their statements or personal communications are cited. These details are important for transparency and for documenting the ethical basis of the research.

Iron-Smelting Furnaces, Tuyeres and Bellows: Technology and Operation

Iron-Smelting Furnaces and Their Importance

Iron smelting is the process of extracting metallic iron from iron ore through chemical reduction. It involves removing oxygen from iron oxides under controlled high-temperature conditions. In traditional bloomery iron smelting, the iron is produced mainly in a solid, spongy mass known as a bloom, while some of the impurities combine with other materials to form slag, which may become molten. The bloom is subsequently consolidated through hammering and forging to produce usable iron. Smelting should therefore be distinguished from melting, forging and blacksmithing, although these activities are related stages in iron production (Childs & Killick, 1993; Killick, 2015; Rehder, 2000).

The furnace is one of the principal structures used in this process. It provides an enclosed space in which heat, airflow and the chemical conditions required for the reduction of iron ore can be maintained. The structure also helps to regulate the movement of air and gases during smelting. Furnace construction is therefore an important part of iron-smelting technology because the shape, size, materials and arrangement of the furnace influence how the smelting process is conducted (Chirekure, 2015; Killick, 2015; Rehder, 2000).

The furnace structures documented on the Jos Plateau were constructed mainly from locally available clay. The clay was prepared by mixing it with water and working it into a suitable consistency before the furnace walls were built, often in layers. The choice of clay depended on the materials available to the smelters and their knowledge of suitable local resources. The internal surfaces of the furnaces were also formed from prepared clay to withstand the high temperatures generated during smelting. These construction practices demonstrate the importance of local knowledge in the selection and preparation of materials for iron production.

Ethnographic information from the Mwaghavul area refers to a plant known as *gagarang*, which was reportedly mixed with clay used for plastering the furnace. According to the account, the plant helped to strengthen the clay when exposed to heat. This information relates specifically to the reported Mwaghavul practice and should not be assumed to represent the construction methods of all iron-smelting communities on the Jos Plateau.

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The operation of the furnace required a suitable fuel supply and a means of introducing air into the combustion chamber. Charcoal was used as fuel, while bellows supplied air through clay pipes known as tuyeres. The interaction between charcoal, air and the furnace environment generated the heat and reducing gases needed to extract iron from the ore. The furnace therefore functioned not simply as a container for fire but as a structure that supported the chemical reactions involved in smelting.

Construction and Operation of Furnaces on the Jos Plateau

Ethnographic accounts describe several stages in the construction and operation of iron-smelting furnaces on the Jos Plateau. After the furnace had been constructed and prepared for use, charcoal was placed inside and ignited. Additional charcoal and iron ore were introduced during the operation. The bellows operators continuously supplied air through the tuyeres to maintain combustion and the required furnace conditions.

Vrengkat (personal communication, 2009) reported that the charge was added at intervals as the smelting process proceeded. According to this account, charcoal and ore were placed in layers over an initial bed of charcoal. The account provides information about the reported operating procedure, but it should be distinguished from direct observations made during the field surveys conducted between 2018 and 2023.

The charcoal served two related purposes. It provided heat through combustion and generated carbon monoxide, which acted as a reducing gas. Under suitable furnace conditions, carbon monoxide reacted with iron oxides and removed oxygen from them, allowing metallic iron to form. The reduced iron accumulated as a bloom, while impurities were incorporated into slag. The precise behaviour of the ore, gases and slag depended on the temperature, airflow, composition of the charge and other operating conditions.

The bellows were operated by hand, and the number of operators depended on the arrangement and size of the installation. Ethnographic information describes two or three men working the bellows during some smelting operations. A small wall was reportedly constructed between the furnace and the bellows operators to protect them from the heat. The account also describes a hole in the pot positioned at the top of some furnaces through which the smelters observed conditions inside the furnace.

According to the same account, the colour of the tuyere was used as an indication of the progress of the smelt. A red tuyere was interpreted as a sign of successful smelting, whereas a white tuyere was associated with an unsuccessful operation and could lead to ritual action to establish the cause. This information should be understood as a reported interpretation within the relevant smelting tradition rather than as a universal technical rule for determining the success of iron smelting.

The ethnographic accounts also describe the use of a pot at the mouth of some pit furnaces. The upper part of the pot was reportedly positioned to help regulate conditions around the furnace opening. Because furnace arrangements differed, this feature should be associated with the particular furnace form in which it was reported rather than presented as a characteristic of all furnaces on the Jos Plateau.

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Furnace Structure, Slag Removal and Reuse

The furnace remains documented on the Jos Plateau show differences in architectural arrangement and in the reported methods of removing smelting residues. These differences are important for classification, but the physical form of a furnace must be distinguished from the way it was operated. For example, a furnace may be built into an elevation or wall without this feature alone establishing whether slag was tapped during smelting.

In the accounts examined for this study, residues from some pit furnaces were reportedly removed through the upper opening, allowing the structure to be repaired and used again. Other accounts describe embedded furnaces in which the bloom and associated residues were removed through an opening near the base. These descriptions provide a basis for comparing the reported operating procedures. However, the presence of a lower opening for bloom extraction does not, by itself, demonstrate that the furnace was a slag-tapping furnace. Such a classification requires additional evidence, such as a channel through which slag flowed, identifiable slag-flow deposits, or other diagnostic features of slag tapping.

The distinction is important because the removal of slag and the removal of the bloom are not necessarily the same operation. In some bloomery furnaces, slag accumulated within the furnace or in a pit and was removed after or during the smelt. In other arrangements, slag could be allowed to flow out through a prepared opening. The classification of the Jos Plateau furnaces should therefore rely on the combination of architectural features, associated slag and other physical evidence rather than on the location of an opening alone.

Ethnographic accounts also indicate that some furnaces could be repaired and reused. When a furnace wall became damaged, the smelters reportedly prepared additional clay, sometimes mixing it with dried grass stalks, and applied it to the affected area. This practice reduced the need to reconstruct the entire furnace after every smelting operation. It demonstrates that furnace maintenance formed part of the technological process. However, evidence that a furnace could be repaired and reused does not establish the actual duration of use of any particular archaeological furnace. Such conclusions require evidence from the individual site.

The height of the furnaces, measured internally, ranged from 1.6 to 1.7 m. This measurement is retained as part of the study's recorded description of the furnace structures. It should be interpreted in relation to the particular furnaces measured and distinguished from the height of the portions that remain visible above the present ground surface. Some structures have suffered substantial deterioration through erosion, farming and other human activities. Consequently, the surviving height of a furnace may be much lower than its original height.

The construction and location of furnaces were also associated with cultural beliefs. Dadiyel (personal communication, 2020) reported that some furnaces were constructed outside settlements because of beliefs concerning ritual conditions and the possible effects of certain forms of contact on the smelting operation. In the account, menstruation and sexual activity were mentioned in connection with these restrictions. This information is presented as a belief reported by an informant within a particular cultural context, rather than as a universal practice among iron-smelting communities on the Jos Plateau. Such accounts are relevant to understanding how technical activities could be connected to ritual expectations and community values.

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Tuyeres and Bellows in Iron Smelting

Tuyeres and bellows were important components of the iron-smelting system, but they performed different functions. A tuyere is a heat-resistant conduit through which air enters the furnace, while a bellows is a device used to supply and force that air into the tuyere. The tuyere was generally made from clay capable of withstanding high temperatures. The bellows, by contrast, formed part of the air-supply apparatus and were not refractory materials.

Ethnographic information indicates that tuyere clay was sometimes collected from particular locations, including riverbanks. The choice of clay was based on the smelters' knowledge of materials considered suitable for producing tuyeres. Tylecote (1965) also discusses the use of different materials for air-delivery components in some iron-smelting contexts. Such comparisons are useful for understanding the range of materials employed in iron technology, although the practices reported elsewhere should not automatically be attributed to the Jos Plateau.

The manufacture of tuyeres was also examined through observations of blacksmithing activities in the area. In the observed process, prepared clay was mixed with water to produce a workable material and tempered with dried grass stalks. The clay was then moulded around a stick coated with ash. After the clay had taken shape, the stick could be removed, leaving a passage through which air could flow. Visual examination of some clay samples also revealed naturally occurring quartz grains, including grains approximately 1–2 mm in diameter.

These observations provide information about local clay preparation and the manufacture of clay air-delivery components. However, the equipment observed in blacksmith workshops should not be treated as identical to the equipment used in earlier iron-smelting furnaces without further evidence. The observations are relevant as an ethnographic comparison of techniques and materials, while the identification of archaeological tuyeres must be based on the characteristics and contexts of the recovered remains.

The bellows were described as being covered with animal skins, with goat skin reportedly preferred because of its strength. The bellows supplied air to the furnace through the tuyeres, helping to sustain combustion and maintain the conditions required for reduction. The number of bellows and operators could vary according to the furnace arrangement and the demands of the operation. The relationship between the bellows, tuyeres and furnace therefore formed an important part of the technical system.

The dimensions and geometry of the tuyeres require careful description. The ends must be identified consistently according to their function: the end connected to the bellows and the end exposed to the furnace interior. Any description of narrowing or flaring should be supported by measurements or a labelled drawing showing the internal and external diameters. This is particularly important when working with fragments, because a broken tuyere may not preserve enough of its original form to establish its orientation with certainty.

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Chemical Reduction and the Role of Carbon Monoxide

The reduction of iron ore during bloomery smelting involves chemical reactions between iron oxides and reducing gases generated by the fuel. Charcoal provides heat and participates in the production of carbon monoxide, which reacts with iron oxides and removes oxygen in the form of carbon dioxide. The reduction proceeds through different iron oxide phases, depending on the temperature and the chemical conditions within the furnace.

The simplified reactions can be represented as follows:

$$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2 \quad \text{(I)}$$
$$Fe_3O_4 + CO \rightarrow 3FeO + CO_2 \quad \text{(II)}$$
$$FeO + CO \rightarrow Fe + CO_2 \quad \text{(III)}$$

Source: David et al, 1989; Joosten, 2004

These equations illustrate the reduction of hematite to magnetite, magnetite to wüstite, and wüstite to metallic iron. They are simplified representations of the reduction stages rather than a complete description of all reactions that occur during smelting. The actual reaction pathways depend on temperature, gas composition, ore characteristics and other conditions inside the furnace.

The relationship between carbon monoxide and carbon dioxide is important because it helps describe the reducing conditions of the furnace. The CO/CO_2 ratio refers to the relative amounts of carbon monoxide and carbon dioxide in the gas mixture; it should not be confused with the percentage concentration of either gas. The verified CO/CO_2 information used in this study should be retained with its original supporting source and the precise meaning of the reported value clearly stated. Its interpretation should remain tied to the conditions and basis on which it was established rather than presented as a universal value for every iron-smelting furnace.

Air supply also affected the combustion process and the conditions required for reduction. The bellows forced air through the tuyeres, while the furnace walls helped contain heat and maintain an environment in which the reducing gases could react with the ore. The interaction of fuel, air, ore and furnace structure was therefore central to the production of metallic iron.

Archaeological Significance of Furnace Remains

Iron-smelting furnaces are important archaeological features because their construction and associated materials can provide evidence of past technological practices. Furnace walls, tuyere fragments, slag deposits and other remains can help researchers investigate how furnaces were built and operated. When these materials are considered together with site context, ethnographic accounts and published archaeological records, they provide a stronger basis for interpreting iron-smelting technology on the Jos Plateau.

Furnace morphology may also help identify differences in technological arrangements. However, the shape or size of a furnace does not independently establish the scale of production, the duration of a smelt, the amount of fuel used or the organisation of labour. These interpretations require supporting evidence, including the quantity and distribution of associated materials, the layout of the installations and reliable information about their use.

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The condition of the remains is an important consideration. Some furnaces survive only as low wall fragments or circular impressions, while other structures preserve more substantial architectural features. Where a furnace is heavily eroded, its original height and shape may be difficult to reconstruct. Classification should therefore identify the features actually observed and distinguish them from interpretations based on comparison with better-preserved structures or ethnographic descriptions.

The furnace remains on the Jos Plateau demonstrate the value of combining archaeological survey with ethnographic and historical evidence. At the same time, interpretations must account for differences in preservation, the limits of surface survey and the absence of secure dates for some structures. Furnace form can provide a useful basis for technological comparison, but chronological development and claims about changes in resource use or social organisation require additional evidence.

Taken together, the furnaces, tuyeres, bellows and associated residues provide evidence of the technical knowledge involved in iron production on the Jos Plateau. Their study helps document local approaches to furnace construction, air supply, fuel use and residue removal. A careful distinction between observed remains, reported practices and archaeological interpretation provides the most reliable foundation for comparing furnace traditions across the region.

The Jos Plateau Furnace Types

Furnace Forms Documented on the Jos Plateau

The field survey identified different furnace forms on the Jos Plateau. However, the remains are in varying states of preservation because of human activities, including farming, animal grazing and hunting, as well as natural processes such as erosion. In some locations, only low circular impressions or fragments of the original furnace walls remain visible above the ground. These conditions make it necessary to distinguish the original furnace structure from the features that can still be observed in the archaeological record.

One furnace form documented during the survey was the embedded furnace at Kisanchi in the Bassa area of Plateau State. Jemkur (2004) described this type of furnace as being constructed along stream banks or natural elevations. In this arrangement, the natural bank formed the rear of the furnace, sometimes after the surface had been excavated or shaped. A clay wall was then constructed at the front to complete the structure. The furnace observed at Kisanchi had an internal height of approximately 1.6–1.7 m. This measurement refers to the furnace described in the field observations and should not be confused with the height of the surviving remains of other, more heavily eroded furnaces.

The embedded furnace has also been discussed in earlier accounts of iron smelting in the region. Berthoud (1969) reported a furnace associated with the Ganawuri, while Jemkur (2004) used the term “embedded furnace” to describe a form constructed against a natural bank or elevation. These descriptions provide a basis for comparison with the Kisanchi example. Nevertheless, the terms should be used with attention to the actual construction features described in each source rather than assuming that every furnace built on an elevation belongs to the same category.

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For the present study, furnace classification distinguishes two broad architectural families: **shaft-type furnaces and bowl furnaces**. Within the shaft-type family, three construction or operational variants are distinguished in the available descriptions: short-shaft or pit furnaces associated with slag pits; free-standing cylindrical shaft furnaces; and embedded or bank-built shaft furnaces. The arrangement of furnaces as individual structures, clusters or rows is recorded separately because arrangement describes their spatial organisation rather than necessarily defining a different furnace form. Similarly, slag-pit use and slag removal are recorded as operational characteristics and are not treated as architectural forms on their own.

The classification is based on the structural features described in the field observations and the published accounts consulted for this study. Where a furnace is heavily eroded, its original form cannot always be established confidently. Such remains should therefore be classified as uncertain where the surviving evidence is insufficient to distinguish a short shaft from a bowl-shaped structure or another type of installation.



Figure 2. Short-shaft/pit furnaces with low walls on an elevation. Source: 2022

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Figure 3. Short-shaft/pit furnace. Source: field survey 2022



Figure 4. Remains of an embedded/bank-built furnace. Source: field survey; 2023.

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Figure 5. Bowl-furnace remains. Source: field survey; 2023.

Comparison with Furnace Types Reported Elsewhere in Nigeria

Previous studies have described several forms of iron-smelting furnaces in Nigeria. Williams (1975) and Anozie (1979), for example, discussed different furnace forms, including domed furnaces, shaft or cylindrical furnaces, and pit or bowl furnaces. These descriptions provide a national and regional comparative framework for examining the structures documented on the Jos Plateau. They should, however, be distinguished from the results of the present field survey.

Anozie (1979, p. 122) described the domed furnace as an improved form of shaft furnace, while Williams (1974) discussed slag tapping as a characteristic associated with the furnace form he described. These accounts indicate that furnace classification may involve both architectural construction and the way slag was managed during smelting. For this reason, a domed form should be identified by its architectural features, while slag tapping should be recorded separately as an operational characteristic supported by appropriate evidence.

The shaft or cylindrical furnace is another form described in the literature. Tylecote (1975) characterised the Taruga furnace as a thin-walled mud shaft constructed over shallow pits. Anozie (1979) also discussed the Taruga furnace in relation to shaft-furnace classification, although the distinctions made in the original sources should be checked carefully before treating these descriptions as identical or different categories. Anozie (1979) reported a height of approximately

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1 m for a small Taruga furnace. This figure provides a comparative measurement from the published literature and is not a measurement of the furnaces recorded at Kisanchi.

Sassoon (1964) and Tylecote (1965) also described shaft furnaces associated with the Ghizim of Potiskum. These accounts demonstrate that shaft construction was used in different Nigerian iron-smelting contexts. However, similarities in shape alone do not establish that the furnaces shared the same date, operational procedure or cultural origin.

Pit or bowl furnaces form another category in the literature. Anozie (1979) described these as shallow installations, with reported diameters of approximately 30–50 cm and depths of 30–40 cm, lined with a thin layer of clay. These dimensions are taken from the published description and should not be assumed to represent the dimensions of every bowl furnace on the Jos Plateau. For the present study, bowl furnaces are distinguished from shaft furnaces by their shallow construction and limited wall superstructure. Where erosion has removed much of a furnace wall, this distinction must be made cautiously and supported by additional structural evidence.

Earlier publications also mention furnaces constructed along stream banks or natural elevations. David et al. (1989), Sassoon (1964) and Tylecote (1965) are cited in the literature consulted for these arrangements. Such furnaces were constructed with the natural bank forming part of the structure, while an artificial wall completed the remaining side. The published descriptions also refer to the use of a clay nozzle for directing air into the furnace and a protective wall for the bellows operator. These accounts are useful for comparison with the embedded furnace documented at Kisanchi, but the similarity should not be taken as proof that all bank-built furnaces shared identical construction or operating procedures.

Earlier Studies of Iron Smelting on the Jos Plateau

Iron-smelting activities and furnace structures in Central Nigeria have been discussed by Nadel (1942), Fagg (1958, 1969), Jemkur (1989), Akinade (2003), Berthoud (1969), Gunn (1953), Netting (1968), Tambo (1976) and Temple (1963, 1976), among others. These studies provide historical and ethnographic information for examining the distribution of iron-smelting activities and the forms of furnaces used in the region. The published descriptions also indicate that free-standing shaft furnaces were widely reported in the Jos Plateau area.

Freund (1982) discussed the importance of iron smelting among communities of the Jos Plateau. Gunn's work on the Berom and Afizere also described shaft furnaces equipped with clay tuyeres and operated using bellows covered with goatskin (Gunn, 1953, 1956; the exact publication details and dates should be verified against the reference list). These descriptions can be compared with the furnace and air-supply arrangements documented in the present study. However, the distribution of a particular furnace form should be established from specific site records rather than inferred solely from the broad geographical coverage of an earlier publication.

Netting (1968) documented a compound furnace arrangement among the Kofyar in which multiple furnaces were constructed close together and associated with collective smelting organised by a lineage group. Other studies have also discussed multiple furnace installations in the region (Jemkur, 2004; Gubam, 1995). These records are important for understanding how individual furnace structures could form part of a larger production arrangement. Nevertheless, a group of

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adjacent furnaces should not automatically be assumed to have operated simultaneously or shared an air-supply system unless the structural or historical evidence supports that interpretation.

The available literature and the remains documented during the present survey indicate that iron smelting was an important technological activity in the Jos Plateau region. The condition of many surviving furnaces, however, limits the conclusions that can be drawn about their original dimensions and operating arrangements. Some structures survive only as circular impressions or low wall remnants, with visible portions reported to measure approximately 10–26 cm above the present ground level. These measurements describe the surviving remains, not the original height of the furnaces. They therefore do not contradict the 1.6–1.7 m internal height recorded for the embedded furnace at Kisanchi or the larger dimensions reported for other more complete shaft structures.

Classification of Furnace Forms Documented in the Study

The classification adopted here separates architectural form from spatial arrangement and operational characteristics. The shaft-type family includes short-shaft or pit furnaces, free-standing cylindrical shaft furnaces, and embedded or bank-built shaft furnaces. Bowl furnaces constitute the second broad architectural family. A row or cluster of furnaces is recorded as an arrangement, while evidence for slag pits or slag tapping is recorded as an operational feature.

This classification provides a consistent basis for comparing the remains documented on the Jos Plateau with the descriptions in earlier archaeological and ethnographic studies. It also recognises the limits of the evidence. Where only a small fragment or shallow surface impression survives, the classification remains provisional unless diagnostic features distinguish the furnace from other types.

The furnace remains at Kisanchi are particularly relevant because different furnace forms were reported in the same general area. Their presence shows that more than one furnace arrangement could occur within a local landscape. However, the coexistence of different forms at a site does not, by itself, establish that they were used at the same time or that they represent a chronological sequence. Secure dating and better-preserved contexts would be required to establish such relationships.

Results, Findings and Discussion

Results of the Survey and Classification of Furnace Remains

The research identified different forms of iron-smelting furnace remains on the Jos Plateau through field observations, examination of archaeological remains, and information obtained from community members and earlier studies. The classification considered furnace morphology, construction setting, associated materials, and ethnographic accounts from communities including Mwaghavul, Mupun, Ron, Ngas, Kofyar, Jar/Boghom, Berom, Anaguta, Afizere, Irigwe, Buji, and Rukuba. The evidence indicates two broad architectural forms: shaft furnaces and bowl furnaces. The shaft furnaces include short-shaft structures associated with pits, free-standing cylindrical structures, and structures built against natural banks or elevations. Clusters and rows of furnaces are treated as spatial arrangements rather than separate architectural types because the number and proximity of furnaces do not, by themselves, establish a different construction method or a shared operating system.

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Shaft-furnace remains were widely distributed across the surveyed areas of the Jos Plateau. The observed remains included fired-clay walls and lining fragments, tuyere fragments, and iron-smelting slag. The recorded dimensions varied according to the form and state of preservation of the remains. Some shaft-furnace remains were described as measuring approximately 1.5–1.7 m in height and 0.6–1.0 m in diameter. However, the individual measurements, number of furnaces measured, and preservation condition of each structure need to be presented in a site inventory before these ranges can be treated as representative of the surveyed furnace population. The measurements should also distinguish surviving wall height from reconstructed or estimated original height.

Slag deposits were found around some furnace remains, including deposits described as pits or concentrations of slag. These deposits provide evidence of iron-smelting activity in the areas concerned. However, the size or presence of a slag deposit does not independently establish the quantity of iron produced. The interpretation of these furnaces as high-output installations therefore remains provisional until the volume and character of the slag deposits, the number of smelting episodes, and other relevant evidence can be assessed. The current survey supports the presence and distribution of shaft-furnace remains, but it does not provide sufficient quantified evidence to calculate production output.

Bowl Furnaces

Bowl-shaped furnace remains were reported in the Kisanchi area of Rukuba land, where they occurred alongside shaft-furnace remains. The recorded dimensions were approximately 0.4–0.7 m in diameter, with limited wall superstructure. These dimensions describe the surviving features and should not automatically be treated as the original dimensions of complete furnaces. The survey also recorded slag associated with these remains, which was described as thin or sheet-like. Although slag morphology can contribute to furnace identification, sheet-like slag alone is not sufficient to distinguish a smelting furnace from a forge hearth, a collapsed furnace, or another feature associated with metalworking.

The identification of these remains as bowl furnaces should therefore be based on the combined evidence of their shape, surviving clay lining or wall structure, spatial relationship with other smelting remains, and associated materials. Where the remains are too eroded to establish these characteristics, they should be described as possible bowl-furnace features rather than securely identified examples. The distinction is important because the low profile of an eroded shaft furnace may resemble a shallow bowl-shaped installation after the upper walls have disappeared.

Earlier studies cited in this research, including Jemkur (2004), Franke (2016), and Adu (1985), provide a comparative context for considering furnace forms reported in the Jos Plateau and neighbouring areas. However, the chronology and geographical distribution described in those studies should not be transferred directly to the Kisanchi examples without confirming that the features are comparable in construction and archaeological context. The present survey identified bowl-shaped remains at Kisanchi, but no securely dated context has been established here to determine when these furnaces were used.

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An informant, Achikulli (personal communication, 2020), described bowl furnaces as installations used for supplementary or household-level iron production. This account provides a useful perspective on how such furnaces may have been understood or used locally. However, the survey did not independently establish the output, fuel consumption, operating temperature, or duration of smelting in these installations. Their small dimensions alone do not demonstrate that they were used by individual smiths, required less fuel, operated for shorter periods, or produced iron at lower temperatures. These interpretations should remain possibilities for further investigation rather than established results.

Multiple Shaft Furnaces and Furnace Arrangements

The survey documented groups or rows of shaft-furnace remains in the Rukuba area and in areas associated with Lai, within Bassa and Mangu Local Government Areas. Some of these structures were situated along natural walls, banks, or elevations. The arrangements are important because they show that furnace remains were not always isolated features. In some locations, several installations occurred within the same area, suggesting repeated or organised use of the landscape for iron smelting.

Field observations and oral accounts described some groups as containing approximately four to six shafts associated with a common clay platform. The accounts also referred to a shared air-supply arrangement and seasonal smelting organised through lineage groups during the dry season, following the harvest. These details require careful distinction between what was directly visible and what was reported by informants. The number of shafts and their proximity can be recorded as observable features where the remains are sufficiently clear. However, the existence of physical connections between the shafts, a common air-supply system, and simultaneous operation cannot be established from adjacency alone. Such interpretations require supporting plans, photographs showing the connections, identifiable air channels or tuyere arrangements, or other direct evidence.

Netting's (1968) account of compound furnace systems among the Kofyar provides a relevant comparison for examining the relationship between furnace arrangements and collective smelting. The comparison does not mean that the Kofyar and Rukuba installations were necessarily identical or that they belonged to the same period. The Kofyar evidence is a previously published account, whereas the Kisanchi observations belong to the present survey. Similarities in arrangement may indicate comparable ways of organising smelting activities, but they do not establish direct historical continuity.

Oral accounts relating smelting to lineage organisation and the agricultural calendar provide evidence of the social meanings attached to iron production in the communities concerned. They may also help explain how labour was organised when smelting took place. Nevertheless, the presence of several furnaces in one location does not by itself demonstrate centralised political authority, surplus production, or a production system extending beyond the household. These interpretations require additional evidence from the scale and organisation of production, the archaeological context, and the accounts of people with direct knowledge of the practices.

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Embedded or Bank-Built Shaft Furnaces

A further form recorded in the literature and discussed in the survey is the embedded or bank-built shaft furnace. Jemkur (2004) described this type at Kisanchi in the Bassa area of Plateau State and reported related forms in Southern Kaduna. In this construction, a natural bank or elevation forms part of the rear of the installation, while a built wall or clay structure forms the exposed front. In some cases, the natural surface may have been modified before the furnace was constructed. This form differs from a fully free-standing shaft because the surrounding landform contributes to its architectural setting.

The reported internal height of the Kisanchi embedded furnace is approximately 1.6–1.7 m. This measurement should be distinguished from the height of the surviving remains above the present ground surface. Erosion, collapse, farming, grazing, and other activities may have removed much of the original structure. The surviving height therefore cannot automatically be used to reconstruct the original height unless the basis for the reconstruction is documented.

Adangala (personal communication, 2020) described the operation of this type of furnace as communal and requiring substantial labour. The account also indicated that the furnace was operated from the top and that the iron bloom was removed through an opening at the bottom. These details are useful evidence of reported operating practice, but the distinction between an opening for bloom removal and a slag-tapping outlet must be maintained. An opening at the base does not, on its own, demonstrate that molten slag was tapped during smelting. A claim of slag tapping requires evidence such as a recognisable tapping channel, slag flow, or a deposit whose morphology and context support that interpretation. Unless such evidence is documented for the Kisanchi furnace, its operation should be described as reported bloom removal through a lower opening, while slag tapping remains unconfirmed.

The embedded furnace is therefore treated here as a construction variant of the shaft furnace rather than as a completely separate broad architectural family. Its defining characteristic is the use of a natural bank or elevation as part of the furnace setting. The operational practices reported for it are discussed separately because construction form alone cannot establish how slag was managed or how many people participated in each smelt.

Summary of the Observed Furnace Forms

The following classification summarises the forms discussed in this study. It distinguishes architectural characteristics from spatial arrangements and operational interpretations.

Category	Diagnostic characteristics	Survey location or evidence	Interpretive status
Short-shaft or pit-associated shaft furnace	Low surviving shaft or wall associated with a pit or slag deposit; original form may be difficult to determine where heavily eroded	Recorded in the surveyed areas; individual site IDs and counts remain to be tabulated	Classification should be confirmed from the combined morphology and context of each feature
Free-standing cylindrical shaft furnace	Upright, approximately cylindrical fired-clay wall or lining	Shaft-furnace remains reported across the Jos Plateau; some recorded dimensions are approximately 1.5–1.7 m in height and 0.6–1.0 m in diameter	Measurements are preliminary until individual records and sample counts are supplied

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Embedded or bank-built shaft furnace	Shaft built against a natural bank or elevation, with the landform forming part of the rear structure	Kisanchi, Rukuba area; internal height reported as approximately 1.6–1.7 m	Construction form described in earlier literature and discussed through survey and oral evidence; operational details require separate corroboration
Bowl-shaped furnace	Shallow bowl-like form with limited wall superstructure	Kisanchi, Rukuba area; reported diameter approximately 0.4–0.7 m	Identification should be based on morphology, lining, context, and associated materials, not sheet slag alone
Multiple furnaces arranged in a row or cluster	Several furnace remains in close proximity, sometimes along a bank or elevation	Rukuba/Kisanchi and areas associated with Lai; reported Kofyar comparison from Netting (1968)	Spatial arrangement rather than a separate furnace type; shared platforms, air supply, and simultaneous operation require direct evidence

This table provides a working classification rather than a complete quantitative inventory. Site identifiers, counts for each category, individual measurements, and the basis for classifying fragmentary remains should be added from the original field records. Where a feature cannot be assigned confidently, it should be recorded as uncertain rather than forced into one of the categories.

Discussion: Technology, Production and Social Organisation

The range of furnace forms documented in the survey suggests that iron-smelting remains on the Jos Plateau are not architecturally uniform. Differences in wall form, construction setting, surviving dimensions, and spatial arrangement provide a basis for investigating technological variation. The evidence also shows that more than one furnace form may occur within the same locality, as reported at Kisanchi. Such coexistence is important because it cautions against treating the Jos Plateau as a single, unchanging technological tradition.

However, the present evidence does not establish a chronological sequence linking shaft furnaces to the Nok period, bowl furnaces to a later household-production phase, or multiple furnaces along elevations to a later stage of lineage organisation. Surface morphology cannot independently date a furnace. The presence of similar forms in the Nok area and on the Jos Plateau may provide a basis for comparative research, but it does not establish a direct technological connection or contemporaneity. These questions require securely dated contexts and a more systematic comparison of construction features and associated archaeological materials. Until such evidence is available, the proposed relationships should be treated as hypotheses rather than demonstrated historical developments.

The *chaîne opératoire* approach associated with Lemonnier (1993) offers a framework for examining furnace construction and operation as a sequence of technical choices. From this perspective, furnace form can be considered alongside the selection of construction materials, the placement of tuyeres, the supply of air, the management of slag, and the organisation of labour. However, the survey does not establish that every architectural difference resulted from a deliberate response to fuel availability, labour requirements, or social organisation. Those explanations need to be tested against evidence for the operating conditions of each furnace type.

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The shaft furnaces and their associated slag deposits indicate iron-smelting activity, but the scale of production cannot be inferred from furnace size or slag-pit presence alone. Quantified slag deposits, evidence of repeated smelting, securely associated iron-production materials, and more detailed information about furnace operation would be needed to assess output. Likewise, although oral accounts describe some smelting activities as communal, the relationship between furnace arrangements and the organisation of labour requires further investigation. Gubam's (2013) interpretation of iron production on the Jos Plateau as organised beyond the household provides a point of comparison, but it should not be treated as direct proof of the organisation of every furnace recorded in this survey.

The bowl-shaped remains raise similar questions. Their relatively small surviving dimensions distinguish them morphologically from the larger shaft structures, but dimensions alone cannot establish their temperature, smelting duration, fuel demand, or production capacity. Nor do they demonstrate a historical shift from centralised production to household production. The account provided by Achikulli (personal communication, 2020) suggests that some bowl furnaces may have been associated with supplementary production, but this interpretation needs corroboration through further oral evidence and archaeological investigation. It is also possible that preservation has affected the dimensions and appearance of some remains, making it important to distinguish complete installations from eroded or collapsed structures.

The multiple furnace arrangements reported at Kisanchi and in the Kofyar area provide another avenue for investigation. Netting (1968) documented compound furnace systems among the Kofyar, and this published account allows comparison with the arrangements recorded during the present research. Nevertheless, the number of furnaces within a group does not automatically demonstrate simultaneous operation, a shared air supply, or centralised control. Those features should be established independently before the installations are interpreted as a coordinated production system. Oral accounts of seasonal and lineage-based smelting remain valuable evidence of local understandings of production, but they should be distinguished from the architectural evidence.

Overall, the survey contributes observations on furnace remains, their construction settings, associated slag and tuyere fragments, and their distribution in the areas investigated. Its principal contribution is the documentation and provisional classification of these remains, together with the identification of questions that require more detailed archaeological and technical investigation. The evidence supports technological diversity, while the chronology, production scale, and relationship between furnace form and social organisation remain open questions.

Limitations of the Study

The interpretation of the furnace remains is limited by their state of preservation, the coverage of the survey, the availability of individual site measurements, and the absence of securely dated contexts for the features discussed here. Farming, grazing, hunting, erosion, and other activities have affected many of the remains, making it difficult to distinguish original furnace architecture from later collapse and surface disturbance. The low height of some surviving features may therefore reflect erosion rather than the original design.

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The study also draws on different kinds of evidence, including direct field observations, oral accounts, and descriptions published by earlier researchers. These sources provide complementary information, but they are not interchangeable. Observed morphology can support a description of surviving structures; oral accounts can provide information about remembered or reported practices; and published studies can provide comparative examples. None should be used to establish chronology, production output, or technological connections beyond what the evidence supports.

The current classification is therefore provisional. A complete site inventory should provide a unique identifier for each feature, its location, measurements, preservation condition, associated materials, photographic record, and confidence level for its classification. Plans or measured drawings would be particularly important for assessing claims about interconnected shafts and shared air-supply systems. Secure dating and further analysis of slag, furnace lining, and associated materials would also help clarify the chronology and operation of the different forms.

Conclusion

The survey documents a range of iron-smelting furnace remains on the Jos Plateau. The evidence supports two broad architectural forms, shaft furnaces and bowl-shaped furnaces—with shaft furnaces represented by short-shaft or pit-associated forms, free-standing cylindrical forms, and embedded or bank-built forms. Multiple furnaces arranged in rows or clusters are treated as spatial arrangements rather than automatically as a separate architectural type. The findings indicate that different furnace forms and arrangements occur across the surveyed areas, and that more than one form may occur within the same locality. The study also records associated slag, tuyere fragments, and furnace lining, as well as oral accounts concerning furnace construction and the organisation of smelting activities. These observations provide a basis for further research into the technological and social history of iron production on the Jos Plateau.

The available evidence does not yet establish a chronological sequence among the furnace forms, a direct link between the surveyed remains and the Nok period, or a definite relationship between furnace dimensions and production scale. It also does not demonstrate that every group of adjacent furnaces shared an air-supply system or operated simultaneously. Such interpretations require further documentation, securely dated contexts, and more detailed technical analysis.

The study should therefore be understood as a contribution to the documentation and provisional classification of furnace remains on the Jos Plateau, rather than as a definitive or first typology. Its value lies in recording the observed diversity, distinguishing architectural form from spatial arrangement and operating practice, and identifying the evidence needed to investigate chronology, production, and social organisation more securely.

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