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Archaeological Investigation on Iron Metallurgy in Damba Iron Smelting of the Nok Culture Area, Central Nigeria

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Abstract: This research presents the findings of an archaeological investigation into iron metallurgy at the Damba iron smelting site, located in the Nok cultural area of central Nigeria. The study addresses significant gaps in our understanding of indigenous iron production technologies, specifically focusing on technological innovation and industrial organization within the Nok culture during the first millennium BCE. While previous archaeological investigations on African/Nigerian Iron Age were predominantly based on ethnographic studies and speculation due to limited scientific analysis of metallurgical remains, this research employs systematic archaeological methods combined with scientific analyses to examine iron smelting technology at Damba. The Damba iron smelting site, situated in a valley close to Janajala in Kagarko Local Government Area, Kaduna State, exhibits characteristics of a well-organized iron production workshop. The site's environmental setting, including proximity to River Damba (a perennial water source) and the presence of a mountain with documented rock hollows possibly used for ore processing, suggests strategic selection for smelting activities. Excavation of a 5m × 3.20m area revealed four furnaces labeled A, B, C, and D, with diameters ranging from 60-65 centimeters. The systematic excavation employed spits of 0-20 centimeters for the workshop area and 0-10 centimeters for individual furnaces, reaching sterile layers to ensure complete recovery of archaeological materials. The research methodology integrated comprehensive survey techniques including systematic field walking, GPS mapping, and detailed documentation of surface features. Ground reconnaissance identified the stream serving as water source at N09.550880 E007.674800 (614m NW), and a rock hollow with diameter 26cm and depth 9cm at N09.551700 E007.6741300 (625m). Excavation recovered significant cultural materials including iron slag, pot sherds, iron implements, stone implements (including a round stone hammer), charcoal samples, soil samples, and burnt clay. Notably, Furnace B yielded two large iron slags at 50cm depth, while Furnace D produced two large burnt clay pieces at the same depth, possibly indicating foundation preparations for fire management. Soil samples collected from the workshop floor and individual furnaces were subjected to laboratory analysis at the Soil Science Department, Nasarawa State University. Atomic Absorption Spectrophotometer analysis revealed iron content ranging from 9.458 mg/L to 9.759 mg/L across samples, providing preliminary evidence of the intensity and scale of smelting operations. The presence of a complete pottery vessel in Furnace D and significant pot sherds in other furnaces, except Furnace A, indicates the integration of ceramic production with metallurgical activities. The research aims to: (1) survey, excavate, and document the characteristics of Damba iron smelting site; (2) examine operational functions through comparative analysis of four excavated furnaces focusing on slag morphology and chemistry, soil micro-stratigraphy, ore characterization, and stone hammer analysis; (3) compare Damba evidence with data from Taruga and other Nok sites; (4) reconstruct the chaîne opératoire of iron smelting at Damba; and (5) study pottery decoration and form attributes as chronological indicators. This investigation addresses critical questions in Nok iron metallurgy, including whether furnace diameter correlates with chronological age and whether sites with limited slag deposition represent older traditions. The research contributes to broader understanding of technological choices, knowledge systems, and cultural traditions in early African iron production, providing crucial evidence for the organization and expertise of iron smelters in the Nok culture area.

Keywords: *Iron Metallurgy, Nok Culture, Indigenous Technology, Archaeometallurgy, Iron Smelting, Central Nigeria, Technological Innovation, Furnace Analysis.*

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I. INTRODUCTION

Archaeological investigations on African/Nigeria Iron Age were mostly based on ethnographic studies. Some scholars have agreed that there is need to concentrate on how and why Iron metallurgy spread and subsequently developed, instead of focusing on when and where Iron first appeared. On the basis of the foregoing arguments, it could be inferred that the divergent views of most scholars on African/Nigeria Iron Age were based on assumptions and speculation, as a result of the few archaeological investigations conducted in the area then, because most metallurgical material remains were not subjected to scientific analysis whereby appropriate scientific results could be derived from such studies.

The remains of Iron smelting material in Nigeria such as slags, tuyeres, furnaces, potsherds are distinctive and have regional variations. The factors that were responsible for the variability include the various types of ore, suitable furnace types, demand for the different quantities of Iron products for the different agricultural tools and weapons required by the people.

Metallurgy is both the art and science of working metals through the processes of separation of the metal from the parent ores, forging the end product in order to produce tools, implements, weapons, ornaments and sculptures. It also embraces the mining of metallic ores, the professional studies of the chemical and physical properties of metal artefacts or works of art.

Since 2005, the Nok research project has been studying many aspects of the archaeological record in central Nigeria dating in the first millennium BCE. Important Topics are the art historical as well as chemical investigation of Nok terracotta figurines (Beck 2014; Breunig & Mannel 2016 ;), the establishment of relative and absolute chronology (Franke 2016), reflections on settlement structures (Breunig & Rupp2016), as well as archaeobotanical investigations on subsistence and vegetation (Hohn ¨et al. 2016). Over 300 sites have been documented through survey, 80 of them were excavated. In most cases Nok sites are composed of a shallow layer of scattered finds. With the exception of furnace sites, features are only discernible as find concentrations within the soil.

The joint project in the Nok culture area between 2006 and 2017 that the project unceremoniously ended, we were able to excavate 26 furnaces in the Nok culture area, most of these sites were located in open plain land, and in most cases not located close to source of water, hill among others.

- *Joh Mari*

In March 2006, during their stay in the town of Joh Mari close to Nok, Breunig and Rupp were informed of an unexcavated iron smelting furnace right in the center of the town. Arriving at the site, the mentioned furnace was already partially destroyed and missed one half of its furnace wall and infilling. However, next to the halfway destroyed furnace, the upper eroded walls of a second furnace reached to the occupation layer. The second furnace was excavated by Breunig and Rupp with a small trench (1x 1.5 m) dissecting the furnace in its middle axis to produce a profile section of the Furnace feature.

- *Intini*

Some parts of the Intini area were heavily disturbed by looters searching for Nok figurine finds. In their spoil heaps, ceramic sherds, single pieces of figurine fragments, and big grinding stones were identified**.** The excavation revealed further furnace walls with signs of heat exposure, charcoal, iron slag, and ceramic finds.

- *Pulu*

Two round structures were found in the middle of an unpaved road while driving on it. Iron slag was already found on the surface. Due to the diameter and mutual spatial relation of the two round furnace features found at Pulu, the Intini furnaces served as a fitting comparison and conceptual departure.

In close proximity to the furnaces, three additional furnaces were documented during excavation. However, excavations were limited to the furnaces on the road. Both furnaces were cut in half with two separate trenches. The southern furnace was cut with a 2 x 1 m trench, whereas the northern furnace was cut with a trench measuring 1 x 2 m). The profile sections at Pulu exhibit two separate filling layers: one layer filling the furnace pit and one layer on top of the pit filling the space between the furnace walls. Like at Intini, the lower layer in both furnaces contained more charcoal leading to its darker color and looser sediment.

Furnace 1 (south) has an external diameter of 126 cm, with walls 5–18 cm thick and 20 cm deep. With a total depth of 40 cm for the whole feature this leads on to a pit depth of only 20 cm. Furnace 2 (north) has a very similar structure with varying measures of ±5 cm. Furnace walls from both furnaces are not erect but slightly convex.

Pulu furnace structure and size resembles the one at Intini. Only the number of finds diverges with Intini having considerably more finds of any type. Solely undecorated potsherds have been found at Pulu. Within the upper layer of furnace 1, tuyere pieces were documented. From both furnaces only 20 pieces `of slag were excavated. Both furnaces contained enough charcoal for the extraction of archaeobotanical samples. The archaeobotanical sample from furnace 2 (north) provided a radiocarbon date derived from charcoal.

- *Sabon Janruwa*

Sabon Janruwa 1 is a furnace site which was discovered close to the Janruwa C site and lies in flat and fallow terrain during dry season. Due to its good accessibility the site was picked in February 2011 for geomagnetic prospection coupled with excavation and soil sampling for X-ray fluorescence analysis (XRF) in Frankfurt. Around the site, several looting holes from 2003 were still visible. However, no severe damage to the area was documented. First test excavations showed rich cultural layers close to the occupation layer.

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➢ *Daji Gwana Furnace Site*

Daji Gwana furnace site was found 100 m away from the site of Daji Gwana k. Daji Gwana lies at a slight terrain slope in an area covered with looting holes. Daji Gwana provided finds like Grinding stones, charcoal, an almost complete pottery vessel, iron slag, and terracotta.

Figurine parts probably from one feature. Daji Gwana provides radiocarbon dates from pennisetum: 2530 ±30 bp (Beta 382620): 797–731 cal BCE (35.8 %); 691–660 cal BCE (13.9 %); 651–543 cal BCE (45.7 %) and one from charcoal: 2490 ±30 bp (Beta 383578): 781–511 cal BCE (95.4 %). All calibrations were made with OxCal 4.2.4, IntCal 13. The Daji Gwana furnace site was already discovered during the excavation of Daji Gwana, but was only excavated in 2013. One iron smelting furnace was already seen on the surface. After cleaning the area two additional furnace features were found.

➢ *Kolin Kuchimi*

Kolin Kuchimi was found in a plain next to the base of a monolith. KOL is divided in two trenches. KOL 1 contains three furnaces whereas KOL 2 only contains one bigger furnace Whereas furnaces A, B, and C at KOL 1 exhibit typical Nok iron smelting furnaces, like at Intini or Baidesuru, KOL 2 shows very uncharacteristic features. The KOL 2 furnace has a double-walled or lined furnace wall and had slag pieces with up to 20 cm of size in its infilling.

➢ *Ruga Fulani*

Ruga Fulani was found on the open road. Two furnaces with distinct Nok measurements were seen already on the roads surface. In advance of the excavation, according to the excavation documentation, both furnaces were immediately compared with Intini and Pulu. Like Baidesuru, Daji Gwana furnace site, Janjala furnace site and Kolin Kuchimi, Earlier excavation as mentioned above had look at smaller trenches with limited number of furnaces This research will look at the indigenous technology used in the site through a comparative analysis of the four furnaces excavated to determine the expertise used at the respective furnaces Damba Iron smelting site, this site is located in the valley.

II. DAMBA IRON SMELTING SITE

N 09.55084 E 007.67501
Activity: 29/9/2025- 2ND October.04.2025)
Excavation: YES

➢ *Site Information*:

This iron smelting site, is located in a valley, where activities of smelting is suitable, there is a stream know as river Damba by the people that live in Janajala, the closest community to our site , this stream does not dry all through the year as confirmed by oral source, also on the top of the mountain to the North of our site , we survey a pond , also at the top of the mountain we survey a rock hollow that might had been as a result of hammering at the site. Damba Iron smelting site we survey four furnaces. A, B, C and D The excavation of the site was done with a spit of 0-20 centimetres and we got to the sterile layer where we concluded the base of the respective furnaces. The furnaces we divided in section to excavate them while we used a spit of 0-10 centimetres, artefacts collected from the respective furnaces are : pot sherds, iron slag, iron implements, stone implements, charcoal sample soil sample, in furnace B at 50 centimetres two big iron slag were found and at furnace D two burnt clay were found in same position.

➢ *Aim and Objective of the Research*

To examine the indigenous technology through the comparative analysis of the four furnaces excavated at Damba iron smelting site to determine the expertise of the smelters of the respective furnaces.

- To survey, excavate and document the characteristics of Damba iron smelting site.
- To examine the operational function of Damba iron smelting site through a comparative analysis of four excavated furnaces, focusing on four categories of material evidence: Slag: The morphology, chemistry, and distribution of smelting waste products, Soil samples: Micro stratigraphic analysis of furnace floors and surrounding areas, Ore: Characterization of raw materials and evidence for ore selection and processing, Stone hammers: Analysis of ore-crushing tools and their spatial distribution
- To compare the Damba iron smelting evidence with data from Taruga and other Nok sites, assessing regional variation and commonalities in Nok metallurgical traditions.
- To reconstruct the chaîne opératoire of iron smelting at Damba, identifying technological choices and their implications for understanding skill, knowledge systems, and cultural traditions
- To study the pottery which concentrates on decoration and form attributes, as these have proven to be the most important chronological indicators. As well as useful information for distinguishing between Nok and other pottery traditions.

III. METHODOLOGY OF THE RESEARCH

Damba Iron smelting site is located in the valley close to Janajala, Kagarko Local Government Area Kaduna state, the site is located in a suitable environment for the ease of smelting iron, among such evidences are: a stream that serves as a source of water, a mountain where we documented a rock hollow that might had been a result of the smelters that once worked in the site. The furnaces located at the site are four in number, that we labeled A, B, C and D.

The ear marked area was 5 metres by 3.20 metres and four furnaces with their diametres ranges from 65 centimetres for furnace A the largest furnace in the sites while the two other furnace have 60 centimetres diametres and are close to one another, furnace D that is the smallest and is also separated from furnace B and C There is an hypothesis we hope to proffer answer to at the end of this research from our Investigation in the NOK Culture area. We discovered that furnaces that have a diameter above 50 centimtres are older Iron Smelting site. Also, Site where little amount of iron slag

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are found are older when dated, some of these questions shall be answered at the end of our research at Damba Iron smelting site

The systematic identification and recording of archaeological finds and features are generally referred to as archaeological reconnaissance survey. Reconnaissance survey is the meticulous observation of the landscape using a broad range of techniques by the archaeologist in location of archaeological sites (Renfrew and Bahn, 1996). Archaeological reconnaissance survey can be achieved by driving, riding or walking on foot in the archaeological sites. Airplanes and drones were and are sometime used for extensive reconnaissance. Other new technologies in archaeology such as electrical resistivity and proton magnetometer have recently helped in detecting sub-surface ditch, earthworks and buried materials.

Ground reconnaissance method was used at Damba Iron smelting site at the following were survey and mapped at the site, The stream that serve as source of water known as rafin Damba N09.550880 E007.674800 ,614metres NW, the rock hollow with a diameter 0f 26cm and depth of 9cm, the mountain is located on N09.551700 E 007.6741300 625m. Our reconnaissance at Damba involved systematic field walking and traversing the sites identified with the use of a Global Positioning System (Garmin GPS76 with a margin error of 6m), tapes and a camera. The goal of this approach was for easy identification and documentation of finds and features that relates to Iron smelting in the area, as well as to determine the extent of the sites.

➢ *Excavation*

The excavation of the site was done with a spit of 0-20 centimetres and we got to the sterile layer where we concluded the base of the respective furnaces. The furnaces we divided in section to excavate them while we used a spit of 0-10 centimetres, artefacts collected from the respective furnaces are : pot sherds, iron slag, iron implements, stone implements, charcoal sample soil sample, in furnace B at 50 centimetres two big iron slag were found and at furnace D two burnt clay were found in same position.

Excavation is a very important aspect of archaeological research which involves a careful and systematic digging of material remains beneath the ground. Excavation is the fundamental process by which the archaeologist recovers under reliable circumstance material remains of past human activities (Chard, 1969). At the site to be excavated, the first thing to be done involves explaining and discussing the proposed archaeological investigation and any inconvenience that may be caused particularly to the members of the communities (landowner) and discussing what is to be done. This is because some crops may be destroyed in the process or there could be places where visitors including the research team will not be allowed to go within the communities. The researcher will also discuss with the members of the communities how the excavations will be conducted throughout the period of the work.

The primary goal at the site to be excavated will be accurate recording of field observations as well as the representative sampling of the evidence of Iron smelting and associated features. A site map of the site will be provided, including each furnace or mound of slag and other features to be investigated, along with locations of the test pits. At Damba iron smelting site a 5metres by 3.20metres pit was sunk with the intent of getting the required sample of the residues in context. Different photographs were taken at all stages for proper documentation. During the course of the excavation the following strategy namely: excavation of test pits, excavation of furnaces or special features, and collection and recording of slag and samples were used. The excavation we adopted a spit of 20 cm for the workshop and 10cm for the respective furnaces

The excavation of the smelting workshop we collected a round stone hammer, fragment of iron slag and unburnished pot sherd.The diameters of the furnaces and the distance between one furnace and the other are as follows:-Furnace A has a diameter of 65cm and the distance between furnace A to Furnace 70cm , Furnace B has a diameter of 60cm ,furnace B to furnace C are close compare to the distance between furnace A and B as well as the distance between furnace C and D , furnace C has a diameter of 60cm and its 100cm away from furnace D that is also 60cm in diameter.

At the spit 0-40cm in the excavation of the workshop the dark colour was observed in the soil of the floor of the excavated workshop, the soil sample was collected for further laboratory analysis.

- *The Respective Furnaces Had the Following Cultural Materials*

✓ *Furnace A*

- 0-10cm,
- 10cm-20cm,
- 20cm-30cm, no iron slag,
- 30cm-40cm charcoal,
- 40cm-50cm, charcoal, iron slag
- 50cm-60cm.charcoal

✓ *Furnace B*

- 0-10cm,
- 10cm-20cm, ,
- 20cm-30cm, charcoal
- 30cm-40cm Iron ore
- 40cm-50cm, Pot sherds, iron slag
- At 50cm. 2 big Iron slag probably used to set the foundation for fire
- 50cm-60cm, pot sherds,

✓ *Furnace C*

- 0-10cm,
- 10cm-20cm,
- 20cm-30cm, charcoal
- 30cm-40cm soil sample,

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- 40cm-50cm, Pot sherds, iron slag
- 40cm-50cm
- At 60cm. Rim of pot sherd

✓ *Furnace D*

- 0-10cm, Pot sherds
- 10cm-20cm,
- 20cm-30cm, Pot sherds
- 30cm-40cm Pot sherds
- 40cm-50cm, Soil sample, charcoal.
- At 50cm. 2 big burnt clay probably used to set the foundation for fire
- 50cm-60cm Pot sherds, stone tool

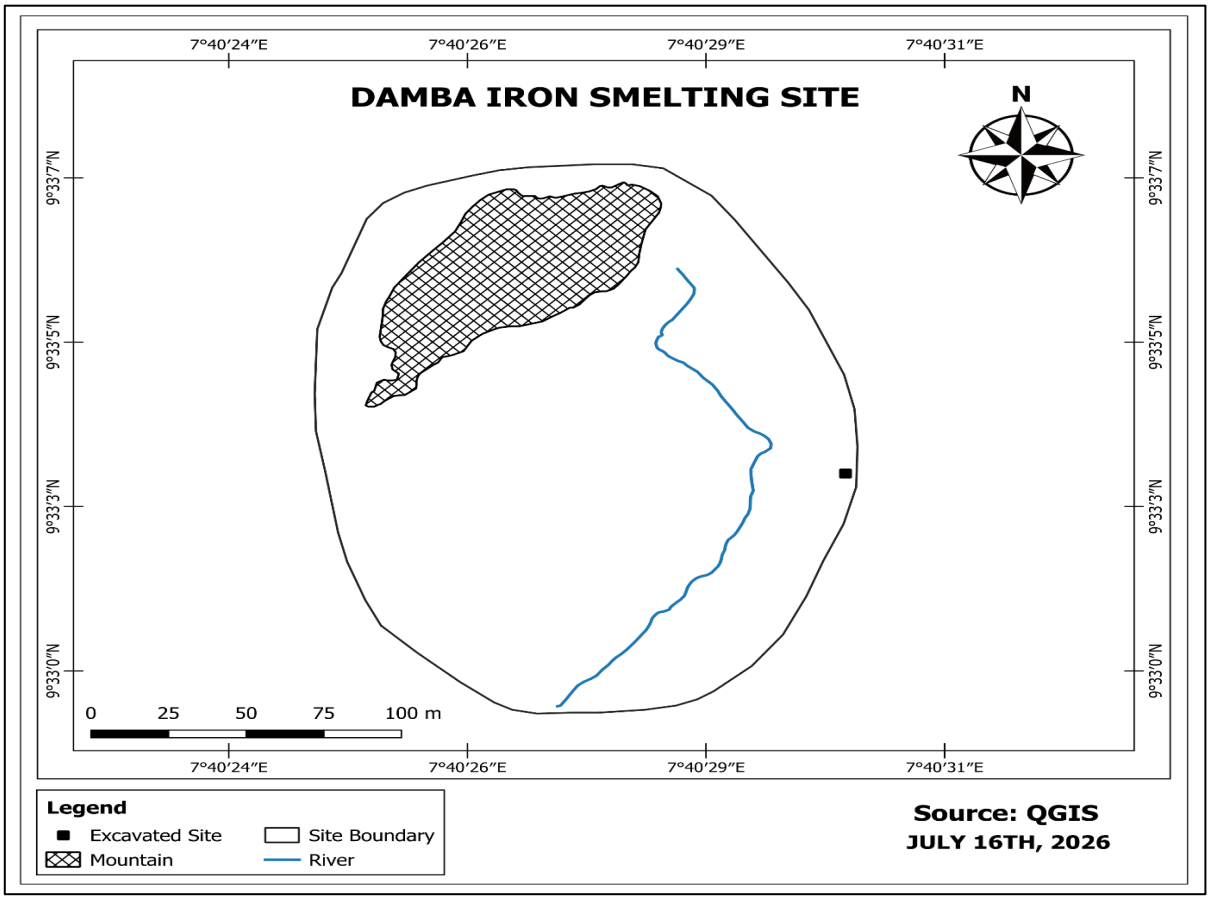

Fig 1 Map of Damba Site

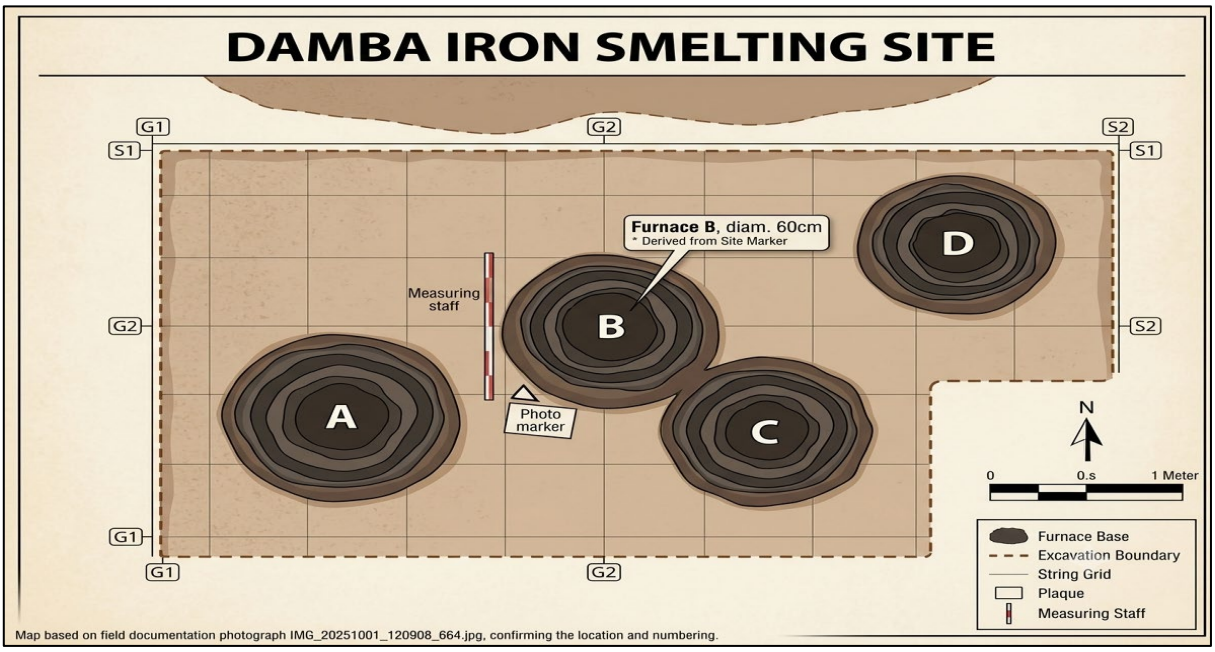

Fig 2 Diagram of the Excavated Furances

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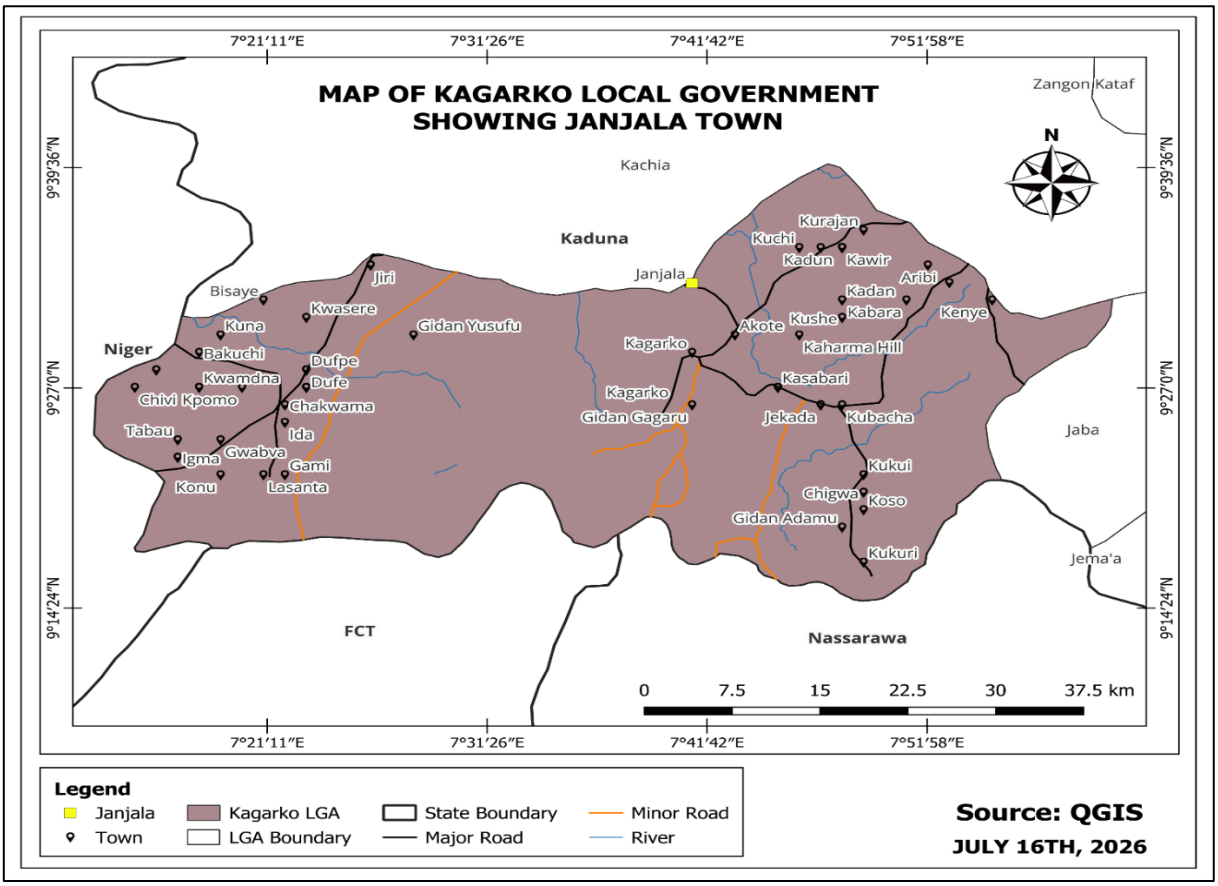

Fig 3 Map of Kagarko Local Government

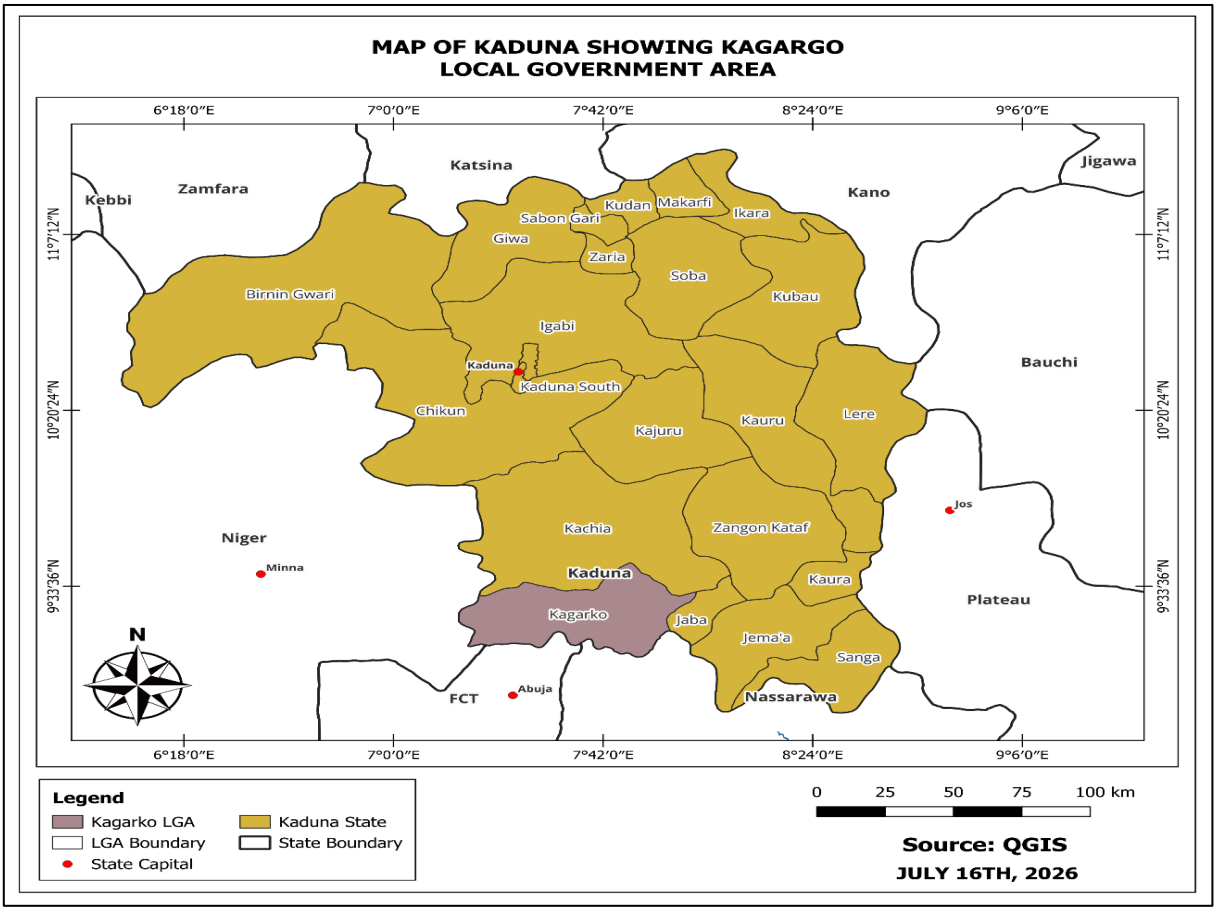

Fig 4 Map of Janjala and Surrounding Towns

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Plate 1 Furnace Remains

Plate 2 Furnace Remains

IV. FINDING FROM THE SURVEY AND EXCAVATION

➢ *Furnace Remains*

In archaeology, the furnace is the central feature in the study of ancient iron technology. It is the Structure in which iron ore was transformed into usable metal, and its remains provide direct Evidence of early metallurgical knowledge, technological development, and cultural practices, at Our excavated workshop in Damba we excavated four furnaces labelled A, B, C and D.

Plate 3 Furnace Remains

➢ *Stone Ball*

Stone balls are important material remains associated with pre-smelting and smelting activities, Particularly in early iron-producing societies. Their presence at iron-smelting sites helps Archaeologists reconstruct the technological processes, organization of labour, and cultural Practices involved in ancient metallurgy. They serve the following purposes in iron smelting Activity at our workshop in Damba we collected a stone ball from our excavation.

Plate 4 Stone Ball

➢ *Soil Sample*

In the course of excavation, we collected several soil samples from the workshop and the Respective furnaces that are of interest to help to answer some of our research question, these soil Samples were taken to the Soil Science Department, where the content of the soil has helped to Provide more information on the landscape of the workshop as it relate to smelting activity Carried out at Damba Iron smelting workshop.

➢ *Rock Hollow on Damba Mountain*

In archaeological studies of iron smelting, rock hollows are significant because they provide Direct evidence of ore preparation, fuel processing, slag handling, cooling, and ritual practices.

Their association with furnaces and slag deposits helps archaeologists reconstruct the full Operational sequence of ancient iron production.

One of the most important functions of rock hollows in iron smelting is their use as ore Preparation tools. Iron ore had to be crushed or ground before smelting to improve reduction Efficiency, Rock hollows served as natural mortars, where ore was pounded using stone balls.

Archaeologists identify this function through: Smoothened or polished hollow surfaces, Residues Of iron ore (reddish stains). Rock hollows were used in processing charcoal: Charcoal was crushed into smaller particles to Regulate furnace combustion. Rock hollows provided stable surfaces for this activity. This Practice helped achieve uniform fuel size, improving smelting temperature control.

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Slag Collection and Cooling In some smelting sites, rock hollows were used to: Collect molten Slag drained from slag-tapping furnaces. Allow slag to cool and solidify safely. Prevent molten Waste from spreading across working areas.

➢ *River Damba*

Water and rivers were not incidental but fundamental to iron smelting activities in ancient Societies. Archaeologically, their significance lies in their role in cooling, clay preparation, and ore Washing, site selection, ritual practice, and environmental sustainability. The close association Between iron-smelting sites and water sources helps archaeologists reconstruct ancient Metallurgical landscapes and understand the integrated relationship between technologies, Environment, and belief systems... at our workshop in Damba there is a river that is about 200 Meters away from the excavation area were we excavated the four furnaces.

One of the most direct technological uses of water in iron smelting is quenching. Hot iron blooms and forged tools were rapidly cooled in water to: Harden the metal, prevent Cracking and Make iron workable for forging. Rivers provided a constant and reliable water Supply for this process.

Clay Preparation for Furnaces and Tuyères.Water was essential in preparing clay materials used In iron smelting. Clay mixed with water was used to: Build furnaces, Make tuyères (air pipes) And Repair furnace walls. Riverbanks were ideal sources of both water and suitable clay.

➢ *Iron Slag*

Damba iron smelting site like other Nok smelting site heaps of iron slag is not a common evidence seen at the smelting sites in the Nok culture area, slags are mainly collected in the excavated furnaces and in some cases around the site, all the excavated four furnace remains in our excavation we collected iron slag in all furnaces.

➢ *Charcoal Samples*

The charcoal samples collected in the course of the excavation were collected at the fourth spit and more, to avoid collecting charcoal samples from recent man activities that might had taken place at the site.

➢ *Pot Sherds,*

A complete pot when restored was found in furnace D, other furnaces except furnace a yielded significant pot sherds.

➢ *Iron Objects*

A Small iron implement was found at the floor of the workshop.

➢ *Burnt Clay*

Were also collected from the excavation.

V. TENTATIVE CONCLUSION

The cultural materials, slag, soil, ore collected from the four excavated furnace shall be subjected to scientific analysis to understand the smelting technology used in the respective furnace, our earlier research in the Nok Iron smelting sites gave us a clue that some of the sites where more than one furnaces are located provide evidence of different technology of smelting process.

In the course of excavation, we collected several soil samples from the workshop and the respective furnaces that are of interest to help to answer some of our research question, these soil samples were taken to the Soil Science Department, where the content of the iron in soil was provided. The result below Furnace A is G/No 1, Furnace B is G/No 2

Apparatus and Material used for the Analysis of the soil sample are:- Analytical balance, horizontal shaker, 50ml Polyethylene centrifuge tube, Centrifuge(3500rpm), Volumetric flask and dispenser.

Preparation of Extraction solution (O.W HCL) is as follows:-

Wash clean your 1 liter volumetric flask and 100ml measuring cylinder, add about 500ml of distilled water into the volumetric flask, measure out 3.75ml of cone HCL to the volumetric flask and shake, make to volume with distilled water and finally shake.

Sample Extraction for Micronutrients Determination on Atomic Absorption Spectrophonmeter.

Weigh out 2.00g of soil (air-dry, passed 2mm polyethylene sieves) into a polyethylene centrifuge tube, add 20ml of O.W HCL, close the centrifuge tube do not use rubber stoppers, shake for 30 minutes on a horizontal shaker, centrifuge the content for 10 to 15 minutes at 3500rpm until a clear suspension is obtained, Decant the clear suspension into a polyethylene vial and store for micronutrients

Table 1 Soil Samples Results

G/No	Fe (mg/L)
1	9.458
2	9.510
3	9.747
4	9.759
5	9.669

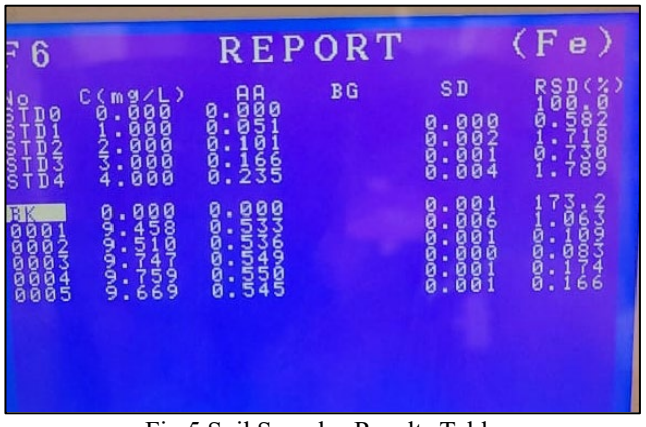

Fig 5 Soil Samples Results Table

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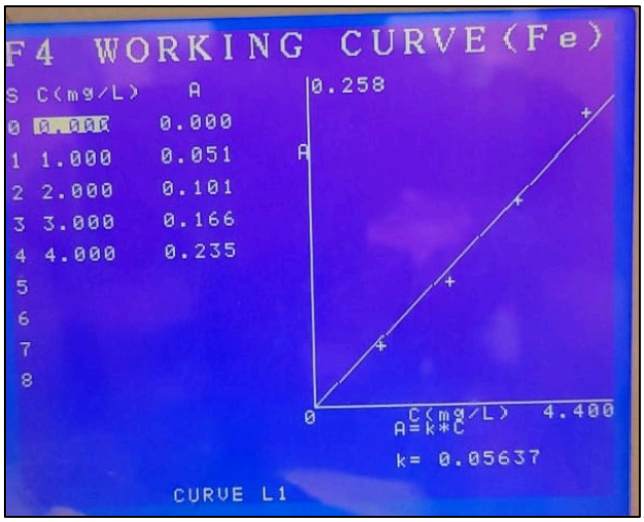

Fig 6 Soil Samples Results Curve

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