# AN ARCHAEOLOGICAL INVESTIGATION OF IRON SMELTING SITES AT TSAUNI, GIWA LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

**BY**

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## DEDICATION

This thesis is dedicated to my dear wife, Mrs Titi Odofin for her encouragement and support.

## CERTIFICATION

This thesis titled, An Archaeological Investigation of Iron Smelting Sites at Tsauni, Giwa L Government Area, Kaduna State, Nigeria, by Odofin Akolade Tinuoye meets the regulati governing the award of the degree of Doctor of Philosophy of Archaeology of Ahmadu B University, Zaria and is approved for its contribution to knowledge and literary presentation.

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## DECLARATION

I hereby declare that this thesis is the product of my own research and written by me. It has not been presented for higher degree in any other University. All sources of information have been duely acknowledged to the best of my Knowledge.

**ODOFIN, AKOLADE TINUOYE**

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**ABSTRACT**

The recent archaeological research conducted at Tsauni iron smelting sites, Giwa Local Government Area, Kaduna state, Nigeria, was essentially a study of the iron smelting at Tsauni which involved archaeological surveying, excavation, metallurgical analyses and radio carbon dating. Archaeological surveying of Tsauni in this research project indicates considerable disparity in the physiographic and material evidence of the north and the south of the area. The spatial configuration of the material evidence at Tsauni suggests that the location of smelting sites was predicated on two factors: proximity to source of ore (as indicated in the closeness of sites to the lateritic outcrops commonly found in the area) and the source of water reflected in location near streams or gullies. Archaeological excavations conducted in the area also indicate close affinities between the furnaces used at Tsauni north and south which were draught induced type and the tuyeres which area also morphologically similar. From the metallurgical analyses of iron smelting residues, we discovered that mineralogical phases in the slag samples from Tsauni are essentially similar and are also closely related to samples from some sites in the Zaria region. Based on technical analyses therefore, we posit, that there were no marked differences in the pattern of iron smelting within Tsauni and other sites in the Zaria region. The C14 dates from Tsauni north and south, which fall within the first and fourth centuries AD further corroborate our view that smelting operations in the two areas were very similar, which goes to suggest that what have been construed as different sites may actually be the same. The dates appear to be strongly indicative of the existence of pre-Hausa iron smelters at Tsauni and the possibility that iron smelting spread to other parts of Zaria area from there.

## PREFACE

This dissertation is structured into seven chapters. The first chapter, which is the introduction, focuses on the research problem, justification, aim and objectives, scope of study, theoretical framework and methodology. This sets the foundation for the work by discussing the motivation for the study, nature of the research, what it seeks to achieve and how it intends to do so.

Chapter two provides the physical and socio-cultural background of the area of study. The aim being to provide spatial and socio- cultural contexts that will aid a proper articulation of the material evidence, its diversity, configuration and antiquity.

The third chapter is a literature review of the past studies on iron working in some parts of the Africa, West Africa, Nigeria and the Zaria region. The purpose is to understand the continental and regional trends in the archaeological investigations of iron smelting and particularly the state of research at Tsauni and Zaria region at large.

Chapters four, five and six are more focused by dealing with the evidence of iron smelting in the area of study. In chapters four and five the results of archaeological survey and excavations conducted at Tsauni are presented, while chapter six reports on the technical analyses of samples and age determination.

The seventh chapter, which is the last, provides a summary of the research based on the aim and objectives and takes a retrospective look at issues and questions raised in the previous chapters. It provides clarifications and draws conclusions on some issues like archaeological potentials, the nature, variations, impact and antiquity of the iron smelting technology in the area of study and then suggests areas for future investigations based on the extent to which the goal of the research have been achieved.

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# CHAPTER ONE

# INTRODUCTION

## Introduction

The state of archaeological research in the Zaria area can still be described as incipient. It's largely exploratory nature can be seen in terms of limited reconnaissance, surveying and excavation of sites, little application of analytical scientific techniques of archaeological investigations and patchy and unrepresentative dating of material evidence.

In terms of frequency of studies of archaeological sites in the Zaria area between 1970 and 1980, the iron smelting site of Samaru West appears to have attracted more attention by pioneering researchers (Obayemi and Sutton) more than others (Effah-Gyamfi1981a). The close proximity of Samaru West site to the main campus of the Ahmadu Bello University Zaria, Nigeria seemed to have been responsible for this. Samaru West site was first excavated by Obayemi and dated to the $7^{th}$ century AD (Sutton 1976) and subsequently by Sutton (1976) who also excavated the site and obtained 8 Radio Carbon dates within the range of $7^{th}$ and $8^{th}$ centuries AD, which seems to lay credence to Obayemi's earlier date. A follow-up investigation conducted by Effah-Gyamfi (1981a) did not however involve any dating. A subsequent archaeological study of the same site conducted by Dilli (1986) was essentially reconnaissance in nature and merely aimed at documenting the material evidence of iron smelting which was then under serious threats of erosion.

The Tsauni North iron smelting site was located in 1975 by Sutton through Dr J.H Polhemus (Sutton 1985). Material evidence of iron smelting was discovered at Tsauni

north in association with terracotta figurines (Sutton 1985). The figurines at Tsauni North are made of coarse textured clay, characteristically small and with distinct artistic features which Sutton considered not to belong to the Nok style (Sutton 1985).

Sutton's archaeological research on iron smelting Samaru West and Tsauni was essentially a study of the technical basis of iron smelting there. Specifically, the study of the typology of iron smelting furnaces and tuyeres appeared to have mostly engaged his attention. In the study, Sutton observed that Tsauni north furnaces which he categorized as Taruga style are associated with 'standard' tuyeres (Effah-Gyamfi 1981c; Sutton 1985), while Tsauni south furnaces which belong to the Samaru West type are associated with 'massive' tuyeres (Sutton 1985). He further considered the Tsauni north furnaces to be contemporaneous with Taruga and the Nok culture (Sutton 1985), while the Tsauni south and Samaru West ones are dated to the second half of the first millennium AD (Sutton 1985) about a thousand years later than the Taruga style. We observe that the dates given by Sutton for the furnace of Tsauni north and south were essentially speculative as they were based on the extrapolation of information from the C14 dates from Taruga and Samaru West and Dalla Hills rather than any scientific dating.

Massive types of tuyeres have also been reported at Kubani river valley in the Zaria area which are tapering and grass tempered with the narrower end of hole-5cm and up to 12cm at the broader with an external diameter of about 30cm. Sutton has also reported smaller tuyeres at Tsauni north and Ungwa Makera (Sutton 1976; Abubakar 1987), the bores of which range from 3cm-5cm with external width of up to 10cm.

**Research Problem and Justification**

Compared to Samaru west, Tsauni iron smelting sites, located just about 8km south east (as the crow flies) have not been similarly investigated by researchers in the area. Despite the studies conducted at Tsauni by Sutton (1976, 1985) and Effah-Gyamfi (1981a), no single chronometric date has been obtained. This has made it very difficult to satisfactorily relate Samaru west to the Tsauni sites. This observable lapse has made it impossible to proffer answers to some questions which are pertinent to any meaningful understanding of the relationship between these two geographically contiguous areas of iron smelting. Such questions include: are the two iron smelting areas temporally different or the same? Are they in the same or different industrial complexes? Were the two areas occupied by diverse groups of iron smelters at different periods or by homogeneous groups contemporaneously?

Although Effah- Gyamfi (1981c) had attempted to date the site of Tsauni south, it was not based on any scientific method of age determination. In realization of the loopholes inherent in his speculative dating based on typological comparison of pottery samples from Tsauni south, Samaru West and Pantaki, Effah- Gyamfi agreed that the actual acceptable date will have to await scientific age determination. In the same vein the typological study of iron smelting furnaces at Tsauni north and south was not associated with any scientific date. The Taruga and Nok culture dates suggested for Tsauni North furnaces and the corresponding 'standard' tuyeres (Sutton 1985) and the second half of the first millennium AD for the Tsauni south furnaces with their 'massive' tuyeres are speculative as there is no scientific date for any of them. Until the

commencement of this research project, there were no archaeologically obtained dates for the sites of Tsauni north and south.

Apart from the above lacunae in the past studies of Tsauni iron smelting sites, the issue of delineating the north from the south has also been a contentious one. The pioneer investigators did not seem to have clearly shown the relationship between the two Tsaunis. While Sutton (1976) sees Tsauni north and south as distinct and temporally different sites in line with his typological categorization of iron smelting furnaces, Effah-Gyamfi (1981c) argues that the two are essentially the same, based on the observed typological similarities in pottery samples. The need to empirically show the relationship between the two Tsaunis or otherwise, is partly a justification for this current research.In addition, it is noteworthy that little is known about the techniques of iron smelting in the Zaria area from the pioneering studies. In line with the current trends in the studies of early iron metallurgy in Africa, the potentials of using residues to determine the nature of iron smelting operations is also a motivation for this investigation. These trends are exemplified by the adoption of replicative experiments by several researchers namely, Friede and Steel(1977, 1988 in Okafor 1993), Schmidt (1977) among the Haya of North West Tanzania, Todd (1985), Pole (1974, 1975, 1985) in Northern Ghana and Van Noten(1985) in Zaire, Rwanda and Burundi.

**Aim and Objectives of Research**

Our interest to conduct an archaeological investigation into iron smelting in the Zaria area began in the early 80s. Following a number of visits to the sites of Samaru west, (latitude $11^0$ 09' N longitude $7^0$ 37'E) Turunku (latitude $10^0$ 48.87'N and longitude

$7^0$ 41.45'E), Kufena (latitude11$^0$ 04.98"N and longitude $7^0$ 39.41" E), Kargi (latitude $11^0$ 04' 30"N and longitude $8^0$ 18' 45"E) and Tsauni (fig5), We became acquainted with the impressive archaeological evidence of iron smelting in the area. This research interest was further enhanced by the challenges posed by the pioneering archaeological investigations in the area, particularly the works of Leggett(1969), Obayemi(1976), Sutton (1976, 1977, 1985), Bala (1977), Effah-Gyamfi (1981a, 1981c) and Boachie-Ansah (1983, 2000) which have significantly helped to draw attention to the rich archaeological potentials of the Zaria area.

The purpose of this research is therefore to conduct an archaeological investigation into early iron smelting in the Zaria area with particular emphasis on Tsauni. The study is essentially directed at a better understanding of the nature of the technology of iron smelting at Tsauni as a way of drawing useful clues about early iron extractive industries in the Zaria area as a whole. We believe that the study of iron smelting at Tsauni presents an opportunity of providing a concrete platform for a better articulation of the over all picture of iron working in the Zaria area and its impact. It has always been our view that conducting a research in a place where some studies had taken place helps to better illuminate the object of such investigation, since knowledge is expected to be cumulative. This research should therefore be seen from the perspective of the need for an enhanced understanding of some fundamental issues concerning iron smelting in the Zaria area.

Our aim in this research would be achieved through the following objectives:

(1)To identify and document the material evidence in the area of study which is currently being destroyed by gully erosion and human activities as a way of salvaging it.

(2) To investigate the spatial configuration and diversities of the material evidence of iron smelting at Tsauni as a way of understanding the nature of iron technology in the area.

(3) To date the iron smelting sequence at Tsauni for a better grasp of the antiquity of early iron working in the Zaria area.

(4) To suggest possible impact of iron smelting on the environment and the people of Tsauni area in the past.

**The Scope of Research**

The field research upon which this dissertation is based involved archaeological reconnaissance, excavation, technical analyses and scientific age determination. Archaeological reconnaissance was carried out to locate material evidence and understand its spatial distribution as it relates to iron smelting at Tsauni. The sites located during the survey were examined for their potential relevance to the goals of the project as earlier articulated, while excavations were conducted to expose and recover subsurface material evidence with a view to understanding their depositional sequence, cultural and geological stratigraphy and to obtain materials for technical analyses and radio carbon age determination.

The research was conducted at Tsauni in the Zaria area (fig4).The selection of the Tsauni sites for investigation was predicated upon the impressive archaeological remains found in the area. The corpus of material evidence at Tsauni found within an area of about 4km by 2km is a strong indication that it was indeed an important centre of iron working in the Zaria area. Tsauni area which is the main focus of this study is located on latitude $7^0$ 36" N and longitude $11^0$ 6" E. It lies about 12km North West of the ancient

city of Zaria, along the old Zaria- Birni Gwari road in Giwa Local Government Area of Kaduna State, Nigeria.

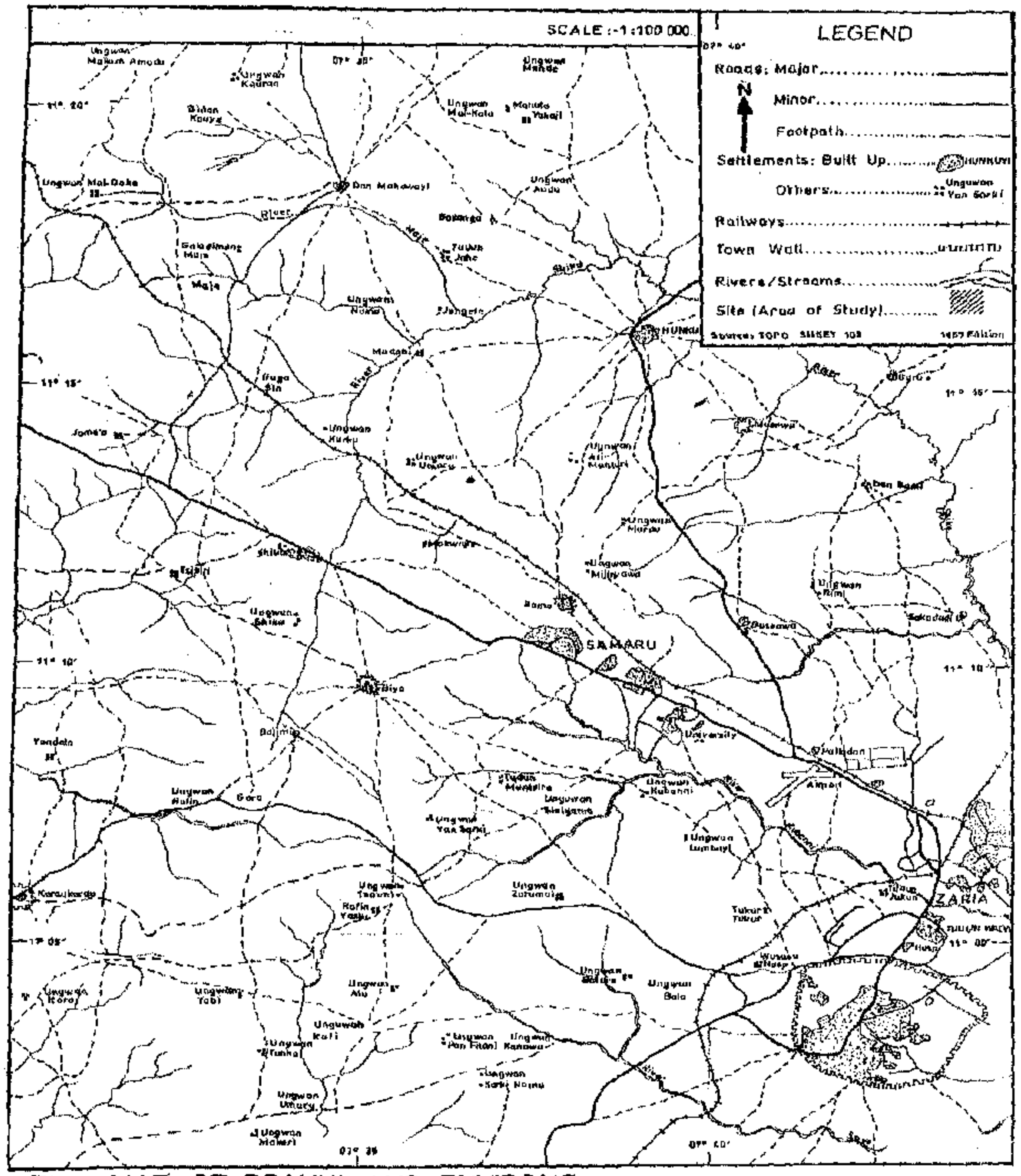



Fig 4: MAP OF TSAUNI AND ENVIRONS

The field research was carried out in two parts of Tsauni earlier defined as Tsauni north and south by Sutton (1976) and Effah-Gyamfi (1981c). In addition preliminary contacts and assessment of Tsauni showed that these two parts are distinct in terms of physiography and surface archaeological materia. A closer observation indicates that the part of Tsauni which lies south of the Zaria-Birni Gwari road is associated with longer stretch of lateritic ridge and several erosion gullies while on the other hand, the part that is located north of the road is plainer with shorter lateritic ridge and fewer erosion channels, with the two areas contrasting significantly in surface archaeological material as will be seen in the results of archaeological surveying in chapter four.

Ecologically, the Tsauni sites exhibit the same physical characteristics with other places in the Zaria area in terms of physiography, drainage, geology, climate, vegetation and fauna as could be seen in the discussion of the physical environment of the area in chapter two.

For adequate coverage and objective evaluation of the surface archaeological material at the two sites, four test pits each were excavated at Tsauni north and south. Details of the criteria for the selection of the locations for excavations are discussed in chapter four.

In addition to the sites of Tsauni, samples of iron smelting residues were also collected from Samaru west, Kufena, Kargi, and Turunku sites for metallurgical analysis as a way of having a general perspective of the nature of iron smelting in the Zaria area. Surface slag and laterite samples were collected in 2008 from Samaru West site by this author, surface slag from Kufena in 1982 by Effah-Gyamfi, surface slag from Kargi in

1980 by Effah-Gyamfi and surface slag from Turunku in 2006 by M.K Aliyu of the Department of Archaeology, Ahmadu Bello University, Zaria.

This research focuses only on the period associated with the working and using of iron at Tsauni as distinct from the preceding phase of human occupation of the area. The study isolates iron smelting in particular for investigation, though we are aware that iron working involves smelting and smithing and that the two are closely related. This was deemed fit in consideration of our research interest.

**Theoretical Framework**

In due consideration of the goals of this investigation earlier enunciated in this chapter, we adopt a theoretical framework that takes cognissance of the recovered archaeological material and the technology of iron smelting. The study which focuses on contextualizing the spatial and temporal dimensions of the archaeological material of iron smelting as well as the nature and impact of iron smelting technology considers the synergy of culture historical, systemic models of culture and cultural ecological approaches as an appropriate theoretical framework. The adoption of more than one theoretical approach in an archaeological research has been advocated due to the complexity of culture and the problems of dealing with the archaeological record (Sharer and Ashmore 2003). This theoretical framework is thus a three-dimensional approach to the study of iron smelting sites at Tsauni.

From the pioneering works of Sutton (1976) and Effah-Gyamfi (1981c), we observed that the archaeological material of iron smelting at Tsauni needs to be properly put in its spatial and chronological contexts as earlier indicated in the justification for

research. This is what this research project seeks to achieve through the use of culture historical approach. In this regard, the past is reconstructed from the viewpoint of normative model of culture, which holds that within a particular society, behavioural patterns are consequent upon adherence to a set of norms which are thus transferred from one generation to the next (Sharer and Ashmore 2003). The archaeologist then uses the normative perception of culture to reconstruct or describe the nature and sequence of past human behavior. This view of a culture is based on the assumption that the material evidence that is retrieved by an archaeologist is representative and reflective of the past behavioural patterns. Based on this assumption in the normative model, archaeologists view culture as patterned, largely predictable and can therefore draw conclusions about past cultural norms from the material evidence of the culture under investigation. The patterns and differences in the material evidence therefore enable the archaeologists to reconstruct changes in behavioural norms in time and space. As observed by Sharer and Ashmore (2003), the most suitable approach to the understanding of the temporal, spatial and functional dimensions of a culture is the culture historical framework which is typically based on inductive reasoning. The temporal and spatial dimensions of the culture historical approach provide the pivot for interpretation of the culture under study.

Since the study of iron smelting sites at Tsuani seeks to document the spatial configuration and provide chronological framework of the material evidence, we consider the basic goals of this research to be in conformity with the tenets of culure historical approach. In culture historical approach, interpretation is derived from synthesizing the spatial and temporal dimensions of the archaeological data and fashioned by the scope of the synthesis. This approach, which accommodates differences in the scope of research

from an interpretation of data from a single site to a combination of sites, is considered appropriate to specifically study the iron smelting sites at Tsauni and shed lights on adjoining ones in the Zaria area.

Culture is defined as non biological means by which people adapt to the natural and social environment (Sharer and Ashmore 2003). Technology, which is an integral part of a culture, is considered as the part of a culture most closely linked with the natural environment (Sharer and Ashmore 2003). Technology has also been seen as a link between the natural environment and human interaction which implies that the methods and equipment used for specific function over time and space are dependent on the past accumulation of technological knowledge which also depend on the nature of the environment and the available raw materials in an area (Sharer and Ashmore 2003). Three categories of technology have been identified: the human-embodied type which comprises skills, knowledge and experience, the capital-embodied, such as machines, equipments and tools and the disembodied one comprising blue prints, products and product specifications (Fadahunsi 1986 in Okpoko 1999). The significance of the study of technology in archaeology, which this research project partly entails, has been underscored. It reveals the steady progress in man's skills, the notion based on the fact that most of the stages of prehistory have been defined based on technology (Hole and Heizer 1973). The three-age-system of stone, bronze and iron postulated by Thomsen (Hole and Heizer 1973) was used to describe man's cultural evolution. Childe (1944b in Hole and Heizer 1973) observed that the three-age-system is indicative of considerable level of technological advancement that enhanced man's capability to do more things than what had been possible (Hole and Heizer 1973). The study of technology can assist

in drawing inferences about man's relations with other people and also reveal location and techniques of making objects (Hole and Heizer 1973).

Cultural ecology is one of the time tested theoretical frameworks in anthropology (Sharer and Ashmore 2003). It is a subfield in anthropology that seeks to understand the operations of culture systems in ecologic terms (Hole and Heizer 1973). The total network of relationships between the subsystems is refered to as the ecologic system or ecosystem which comprises three subsystems-culture, biota and the physical environment (Hole and Heizer 1973). The importance of cultural ecological model in archaeological study can also not be overemphasized because it enables archaeologists to identify several components of human interactive systems and the parts of technology adapted to each (Sharer and Ashmore 2003). Cultural ecological model which is based on the adaptive aspects of culture sees culture, and in particular technology as the primary means by which human societies adapt to their environment (Sharer and Ashmore 2003; Renfrew and Bahn 1997; Hole and Heizer 1973). According to Sharer and Ashmore (2003), there is a distinction between environmental determinism and cultural ecology, the implication being that environmental changes can even be brought about by cultural changes, which is contrary to the deterministic view that cultures must necessarily adapt to the natural environments in which they are found. Cultural changes have the capacity to alter the landscape, which implies that every society exploits and changes its natural environment in some ways (Sharer and Ashmore 2003). The nature of a particular technology determines the part of the natural environment to be exploited, which implies that each technology exploits different resources from the natural environment where it is

operated (Sharer and Ashmore 2003). In a broad sense, people living in similar environments solve the problem of adaptation in similar ways (Hole and Heizer 1973).

The use of systems models of culture is also considered very important to this study. As rightly observed (Hole and Heizer 1973), the concept of system is central to scientific and historical studies. The system's models of culture are based on the general systems theory (Sharer and Ashmore 2003). In systems theory, a system is defined as a set of parts and the relationships among the parts (Hole and Heizer 1973; Sharer and Ashmore 2003). In anthropology, culture is seen as a system composed of various highly interrelated parts such as the subsistence, social, technological and religious subsystems which operate together consistently to ensure stability and a measure of predictability (Hole and Heizer 1973; Thompson and Longacre (1966 in Hole and Heizer 1973). In anthropology, culture is seen as systemic. The systemic model of culture considers all material remains in an archaeological site as highly patterned due to how the extinct society was organized (Hole and Heizer 1973).

In the archaeological investigation of iron smelting sites at Tsauni, we consider the material evidence at the sites as reflective of the organization of the society responsible for it and the technology of iron smelting which is central to this study as a subsystem of the cultural system.

In the context of our investigation of iron smelting sites at Tsauni, we observe that the need to study the material evidence in spatial and temporal contexts makes the choice of cultural- historical approach relevant as a theoretical framework. The study of the technology of iron smelting, as a means by which people adapted to their natural environment and a way of determining the parts of the environment exploited in the past

has also made cultural ecology model a suitable theoretical framework in this study, while the systemic model of culture provides a wholistic basis for our investigation since it sees the archaeological evidence of iron smelting at Tsauni as highly patterned and the technology associated with it as a subsystem of an extinct cultural system.

**Research Methodology**

This section describes and explains the various methods used in this field research and shows the preference of certain techniques over others.

Field investigations took place between 2006 and 2009. Taking cognissance of the theoretical framework of the research, which is a three-dimensional approach comprising culture historical, culture ecology and systemic models, we realized the imperative of developing a methodology that would incorporate relevant oral data, archaeological methods of investigation and laboratory analysis as shown in our subsequent discussions.

**(1) Oral Sources**

We recognize the imperative of the use of different categories of oral sources as identified by Vansina (1965) in this research. This was done in order to ensure the reliability of the information collected. The potentials of oral tradition in locating sites and interpreting archaeological data as enunciated by Schmidt (1975, 1978), Shaw (1970), Willett (1973) have been recognised and significantly tapped in this research.

Collection of oral tradition spanned through significant period of this research. This was done to ensure the reliability of the information collected. Investigations have

indicated that informants often tend to be skeptical and even reluctant to give information or tell the truth until they know the genuineness and intensions of the enquiries (Schmidt 1978a). Collection of oral tradition was conducted in the communities that are closely located to the iron smelting sites at Tsauni. These are Rafin Yashi, Ungwan Tsauni, Yan Sarki, Ungwan makera and as far as Zaria (fig 4). The object of the collection of oral tradition was to extrapolate information that could shed some lights on the nature and significance of iron smelting in the Tsauni area.

In the course of this research, a total number of twenty-five informants were interviewed (AppendixV). The main criteria used for the selection of informants were age and acquaintance with the subject matter of the research. Interviews were conducted in Hausa language since our informants could express themselves only in Hausa language. In the course of conducting the interviews, questionnaires were used though not given to informants to complete. Since one was not well grounded in Hausa language, the assistance of some staff and students of the department of Archaeology, Ahmadu Bello University with sufficient proficiency in Hausa language was sought to translate the interviews without any difficulties or distortions. In addition to being well grounded in Hausa language, they are also well acquainted with the subject matter of the research which is iron smelting. This was necessary in order to forestall haphazard translation and the tendency to quote researcher and informants out of context. Group interviews conducted in this research were structured and controlled in order to ensure that informants gave only information considered relevant to the research, though information not directly related to the questions asked but considered important was also documented. Interviews were recorded only in notebook and took place (in most cases) in the

residence of each traditional head of the community. We avoided the use of tape recorder in the collection of oral information since there is the tendency for informants not to be as forthcoming as possible especially when they realise that their voices are being recorded. At the end of the interview in each community, group photograph of informants and researcher was taken for documentation of the exercise (plates 197-200).

**(i) Archaeological Reconnaissance**

Archaeological reconnaissance which involves a systematic attempt aimed at identifying archaeological sites implies the discovery and location of sites (Sharer and Ashmore 2003) was accorded high priority in this field research. This is in realization of its importance as an archaeological method that yields data about the range in form in terms of size and arrangement of archaeological sites, their total number and spatial distribution in an area (Ashmore and Sharer 2003). The data obtained from the distribution of sites in an archaeological reconnaisance may reveal inter sites locational patterns and relationship with the environmental variables (Sharer and Ashmore 2003). The study took cognissance of important attributes of archaeological remains, namely abundance and clustering of archaeological materials (Renfrew and Bahn 1997) Abundance, which is an attribute often expressed as the density of site or artifact was used to indicate the frequency of material evidence in the area of study, while clustering, which is the degree of spatial aggregation of archaeological data (Renfrew and Bahn 1997), was used to assess the variations in different material remains at the sites.

As earlier indicated, the archaeological reconnaissance carried out in these field investigations was aimed at locating the occurrences of arghaeological evidence of iron

smelting and studying its spatial configuration at Tsauni. The sites located during the reconnaissance were scrutinized for their potential contribution to the goals of this research project. To ensure thoroughness, the site reconnaisance was conducted in three seasons from May 2006 to April 2009 usually during the dry season when vegetation cover was burnt and ground visibility became very clear. The technique adopted involved traverses and transects. We were guided by Global Positioning System (GPS) and Magnetic Compasses as we walked along parallel transect paying attention to site indicators such as artifact scatters and concentrations and contrasts in vegetation. Erosion gullies were closely examined for material remains. The use of GPS particularly has proved to be easier and more accurate method of site planning by calculating the user's location by triangulation via satellite (Sharer and Ashmore 2003). The hand held GPS sets used were also more portable than the conventional surveying equipments in addition to being more accurate. The technique was therefore considered as more accurate than the conventional methods of surveying such as compass traversing and chain surveying. In addition to this, personal observation shows that GPS has the capacity to determine the height above sea level, location and bearing simultaneously. Generally, the limitations of the GPS include: fluctuations in readings due to its connection to the satellite, margin of errors and variation in it which depend on the type of GPS used (Professor Garba 2009 pers. Comm.). The GARMIN 12 GPS used for the reconnaissance has about 10m precision. Sites were recorded in notebooks, photographed and mapped to show their locations and the distribution of archaeological materials. Ubiquitous archaeological finds and features such as slag, tuyeres, furnaces and mounds were studied, photographed and left at their positions (see Chapter 4). Some furnaces were measured to determine their

height, diameter and wall thickness. Random collections of surface archaeological remains such as slag and tuyere samples were carried out. These were labeled and bagged for subsequent technical analyses.

**(ii)Excavation**

This was an indispensable archaeological method used in this field research to retrieve sub-surface material evidence from the sites. The choice of sites to excavate was predicated on the principle of clustering of artifacts as earlier indicated. Iron smelting, which is the focus of this research project guided our choice of sites for excavation during which a total number of eight test pits were excavated, four each from Tsauni north and south.

Test pit excavations were conducted basically with picks, shovels, trowels and head pans. Arbitrary level method was adopted in the excavations, since it was not initially possible to discern the natural stratigraphy. Excavation procedures and finds were adequately recorded in field notes, while photographs were taken with digital cameras to complement the recording of the exercise. Contour maps of excavated areas and the profiles of test pits (where applicable) were drawn. Details of excavations carried out in this research are reported in Chapter five.

**(iii) Cataloguing and quantitative analyses.**

Samples that were collected from the reconnaissance and excavation were kept in cloth and plastic bags and conveyed to the store room of the Department of Archaeology, Ahmadu Bello University, Zaria, Nigeria for cleaning and cataloguing. Charcoal, slag

and tuyere samples were not washed in water but left to dry and later brushed. Charcoal samples collected for radio carbon dating were wrapped in aluminum foil and kept in plastic bags. Basic quantitative analyses of material samples collected including cataloguing, counting and dimension measurements were conducted both in the field and at the Department of Archaeology, Ahmadu Bello University, Zaria, Nigeria.

In the course of our field research, we observed a conspicuous absence of pottery in the excavated areas in Tsauni north and south. Although pottery occur elsewhere in the Tsauni sites, the fact that an impressive typological analysis of the pottery (Effah-Gyamfi 1981a) and technical analysis (Oladipo *et al* 1992) had earlier been carried out in the area suggested to us that there may be no need to dwell on that aspect which seemed to have been fairly addressed.

**(iv)Morphological Examination:** Physical examination of samples was carried out before the commencement of the laboratory analyses. The purpose was to provide useful information for some aspects of the metallographic analyses that followed. Okafor (1992) stressed the importance of morphological examination of iron smelting residues. This involved observation of colour and magnetism. Determination of the magnetic property of slag samples was carried out by using a strong magnet with the results shown in table2.

**(v)Technical analyses**

The technical analyses of samples of material evidence of iron smelting collected in the course of our field investigations were carried out at the Major Analytical

Instrumentation Centre (MAIC), Department of Materials Science and Engineering, University of Florida, Gainesville, USA between April and September 2008.

There are several techniques of analysing iron smelting residues such as: Scanning Electron Microscopy,( SEM ), Energy Dispersal Spectroscopy(EDS), X-ray Diffraction (XRD), X- ray Fluorescence ( XRF), Induced Coupled Plasma Spectroscopy (ICPS), Atomic Absorption Spectroscopy(AAS) and Wave Length Dispersal Spectroscopy (WDS). The types of material and the objectives of the analyses were taken into consideration in our choice of SEM, EDS and XRD techniques. This was also based on the advice that in order to ensure more reliable results, more than one technique should be used to analyze the same material (Killick 1990; Mapunda (1995). Details of the techniques used, their application and results are discussed in Chapter six.

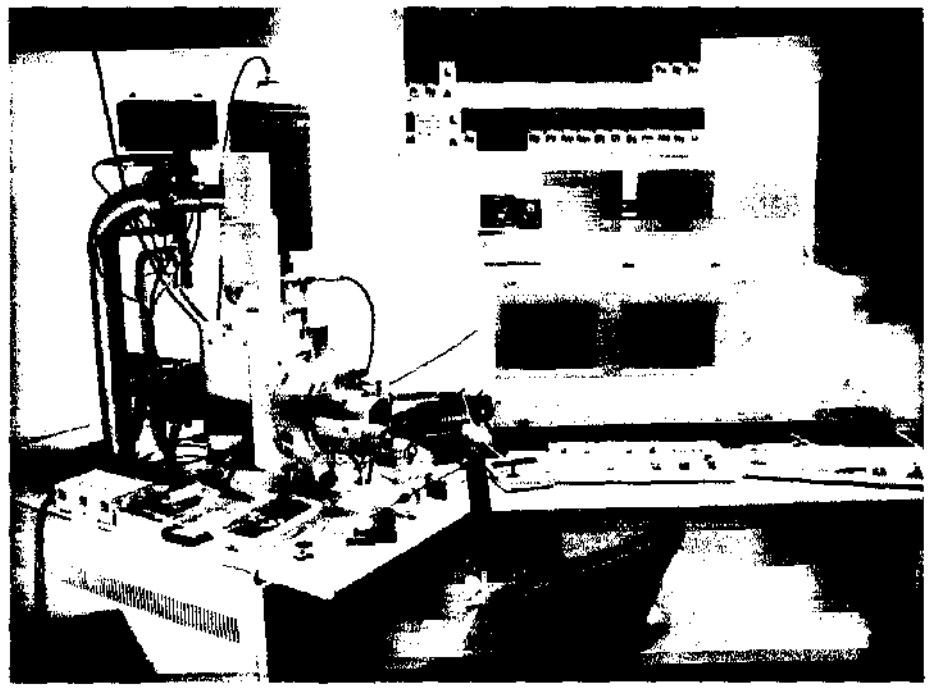


**Plate 1:The Scanning Electron Microscope(left) and Energy Dispersal Spectroscope.**

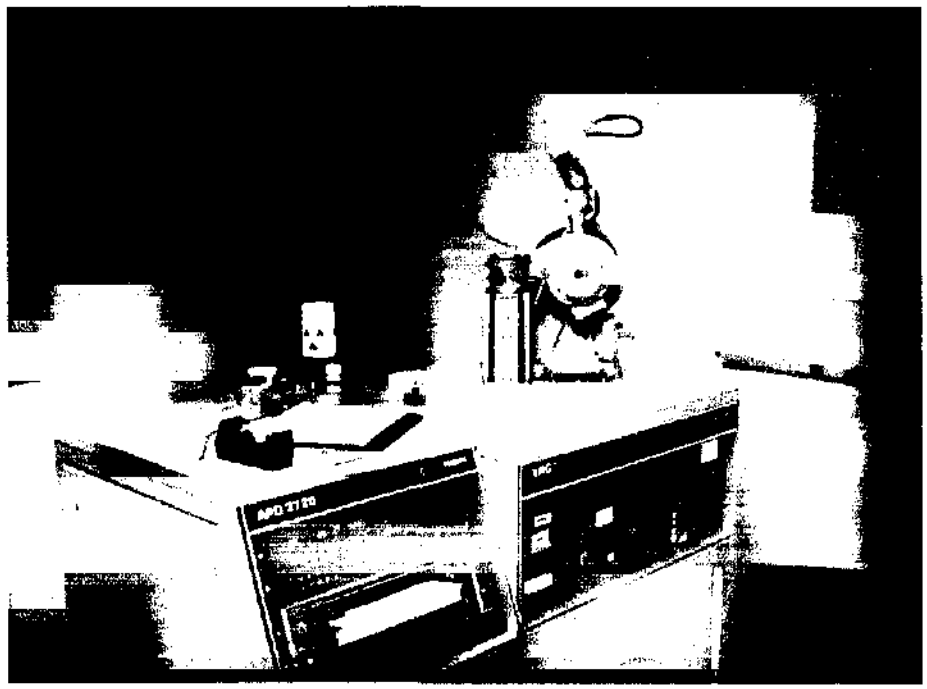


**Plate 2: The X-Ray Diffractometer.**

**Sampling:** The total number of samples of slag, tuyere and laterite are shown in table I (AppendixI). Samples were collected for physical and technical analyses. A total number of 20 samples analyzed were collected from Tsauni north, Tsauni south, Samaru west, Kargi, Turunku and Kufena sites. The samples from the Tsauni sites comprised excavated and surface finds while those from other sites are surface collections. The collectors of the samples had earlier been acknowledged in this chapter. The selection of the samples for technical analyses was based on the objectives of research, representativeness in terms of geographic spread, availability and financial capacity.

**Preparation of Samples:** The procedures adopted in the preparation of samples for the technical analyses were in accordance with the basic principles designed for the preparation of standard metallographic samples (Voort 2004). Two types of sample preparation were carried out in the technical analyses. One involved the use of solid

specimens while the other utilized powder samples. Scanning Electron Microscopy (SEM) and Electron Dispersive Spectroscopy (EDS) analyses were conducted with solid specimens while X-Ray Diffraction (XRD) was with powder specimens. The SEM/EDS analysis was conducted by Dr Bradt Willenberg and Mr Danny McIntyre, while the XRD analysis was undertaken by Dr Gerald Bourne and also Mr Danny McIntyre at the Major Analytical Instrumentation Centre (MAIC) of the Department of Materials science and Engineering, University of Florida, Gainesville, USA. This author was also involved in the preparation of specimens for the SEM/EDS and the XRD analyses (plates 4, 8 and 9).

**Sectioning:** The first step in sample preparation was sectioning. This involved the removal of a conveniently sized and representative specimen from a larger piece. This is usually the first major operation in the preparation of metallographic samples. This step is very important when preparing specimens for metallographic analysis. The dominant principle in sectioning is to prevent damage and reduce changes in the specimen condition due to heat or deformation of microstructures emanating from sectioning process (Voort 2004). This makes the use of a suitable cutting medium imperative. This principle was taken into consideration while sectioning the samples.

The method adopted for the cutting of samples was mechanical sectioning. The machine used was BUHLER ISOMET Low Speed Saw. The diamond saw fitted to it ensured accurate cutting of specimen thereby producing regular, smooth and shining surface. Its low speed and the use of methyl alcohol lubricating fluid were meant to minimize the distortion of sample microstructures as well as prevent adverse effects of the heat generated during cutting as a result of friction (Dr Gerald Bourne 2008 personal

communication).This technique was preferred to other available methods such as the use of Hand saw, Band saw and Electrical Cutting Machine.

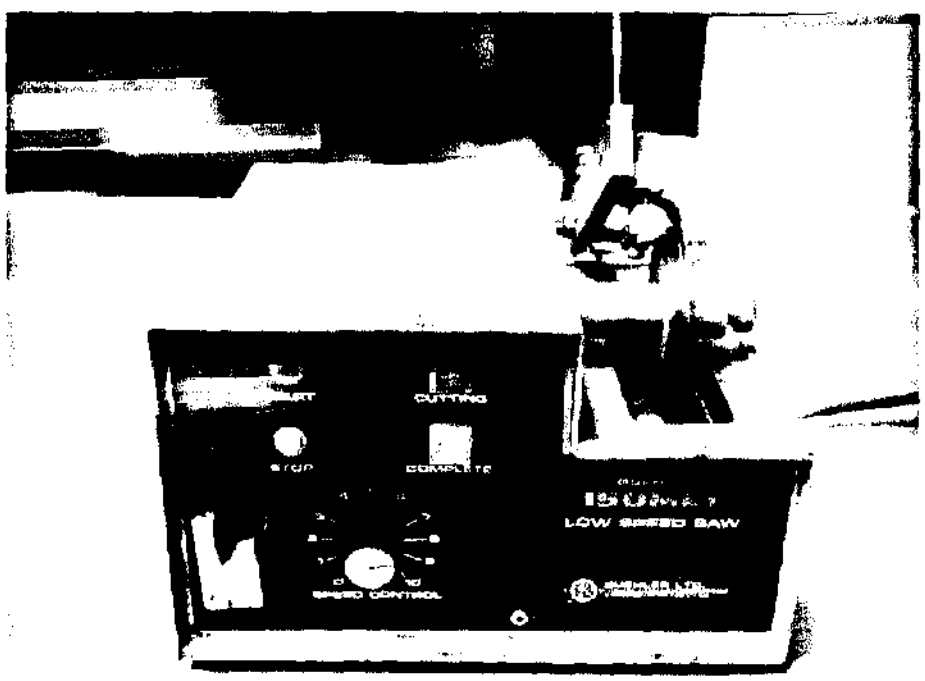



**Plate 3: The BUHLER ISOMET low speed saw.**

Samples that were small enough to be mounted on the machine without any need of breaking were sectioned directly while those that were bigger had smaller pieces cut from them for sectioning with the machine. This was done by using an instrument known as the Vise to hold such samples while a screw driver and hammer were used to carefully remove a small piece. An average of about 0.5cm specimen was sectioned from each sample.



**Plate 4: The vise instrument**

**Mounting:** This was the next stage in the preparation of metallographic samples. It was specifically carried out for SEM and EDS analyses. Mounting is the encapsulation of a sectioned specimen in a mold (Voort 2004). After cutting a specimen to an appropriate size, mounting is often desirable or necessary for subsequent handling and polishing. The type of mounting adopted for this purpose was cast mounting. The process involved the mixture of resins that are cast able at room temperature. A cylindrical open end polyester mold was cleaned and sprayed with Halogenated hydrocarbon ether mold release agent in order to reclaim the mold from the adhering effects of resins and hardener. The sectioned specimen was then placed inside the mold and a mixture of 10ml of Epoxyl resin and 2ml of hardener poured into it and left to solidify or "cure" overnight at room temperature. This is other wise known as "cold" mounting because it does not require any external heating. The preference for cast mounting in this analysis was due to its merits over the compression method which include relative ease of mixing resin and hardener, no

requirement for mounting pressure and the possibility of producing several mounts at a time (Voort 2004 ).

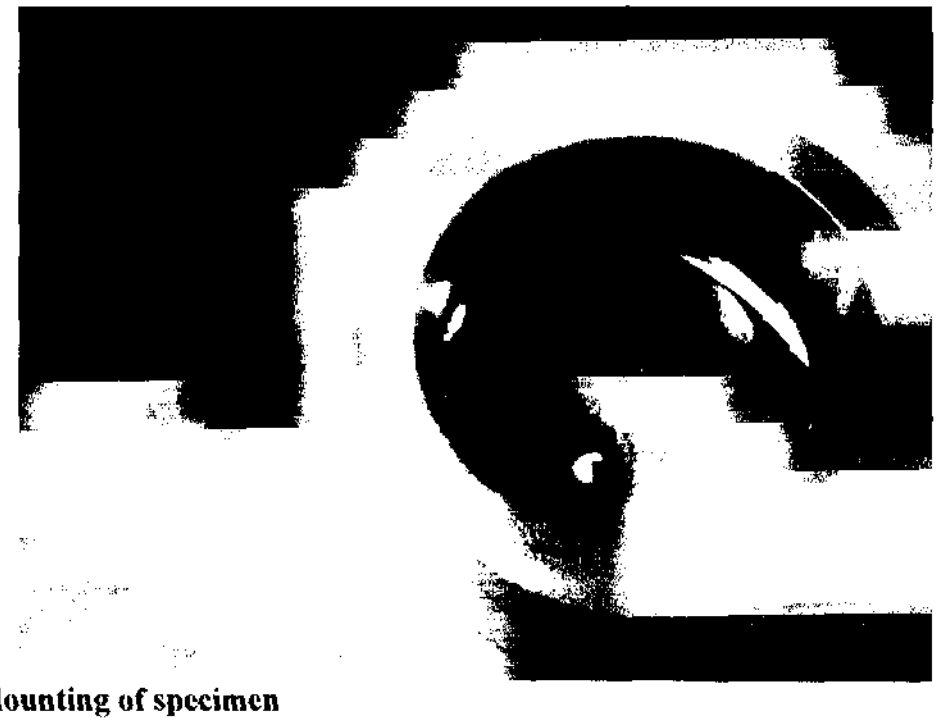


**Plate 5: Mounting of specimen**

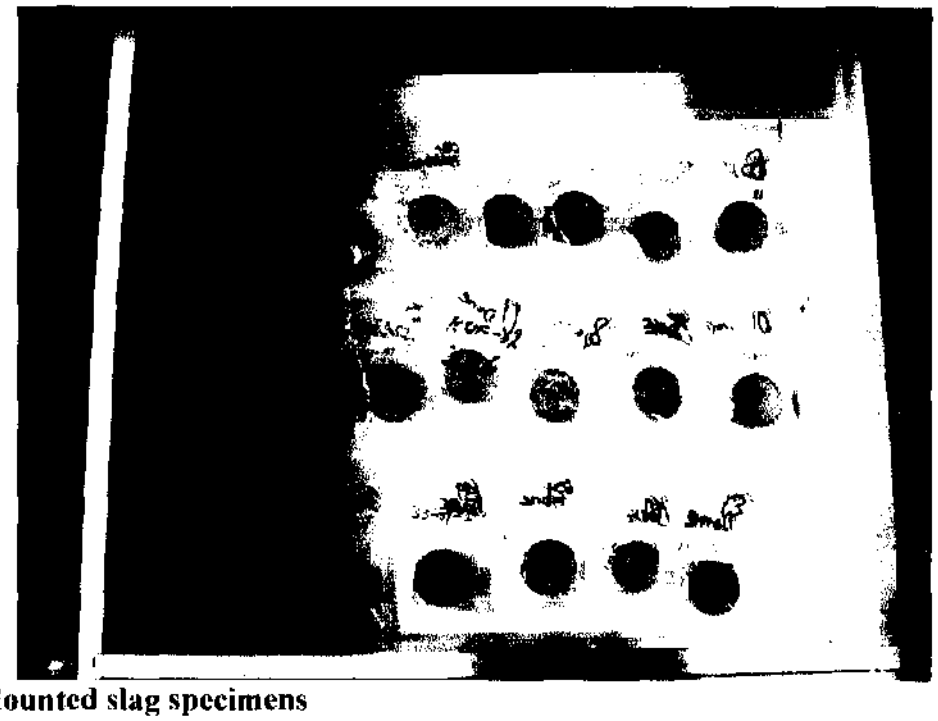


**Plate 6: Mounted slag specimens**

**Mount Marking:** After mounting, the specimens were marked for clear identification of samples. This was done with indelible ink which is permanently visible and protected with the specimen.

**Polishing:** It is is a method of preparing metallographic samples involving the use of abrasive particles in liquid suspension among the fibres of a cloth. The objective being to produce a bright mirror like or highly reflecting surface commonly referred to as a polished surface for easy identification of microstructures of metallographic samples during analysis (Voort 2004).Polishing was carried out with Grinding Wheel Machine set at 250 rotations per minute. This method is known as vibrating polishing. The polishing exercise took cognissance of the need to produce scratch-free, highly reflecting surfaces and prevention of distortion of microstructures of samples. To achieve these, polishing was carried out in two stages. The first involved grinding with five Silicon Carbide polishing papers of different grits: 120, 240, 320, 400 and 600. This stage of polishing began with the 120 (the roughest) and terminated at the 600 grit paper (the smoothest). During polishing each paper was soaked in water in order to ensure that the abrasion of the sample surface did not result to friction that can generate heat which is capable of deforming the microstructures of the specimen being polished.

The second stage which was the final was aimed at ensuring fine polishing of the specimens. It involved the use of polishing clothes of different microns: 15, 5, 1. 0, 0.3 and 0.05. Polishing commenced with the 15 micron cloth (the roughest and progressed to the 0.05 micron (the smoothest). The same Grinding Wheel Machine set at the same speed was used at this stage of polishing. Each polishing cloth was soaked with water and sprinkled with an abrasive chemical, Alumina Slurry. As the polishing progressed, each

cloth was soaked with Alumina Slurry of corresponding microns. For instance, 15 micron cloth was used with 15 microns Allumina Slurry, 5 micron cloth with 5 microns Allumina Slurry and so on.



**Plate7: The grinding/polishing machine**

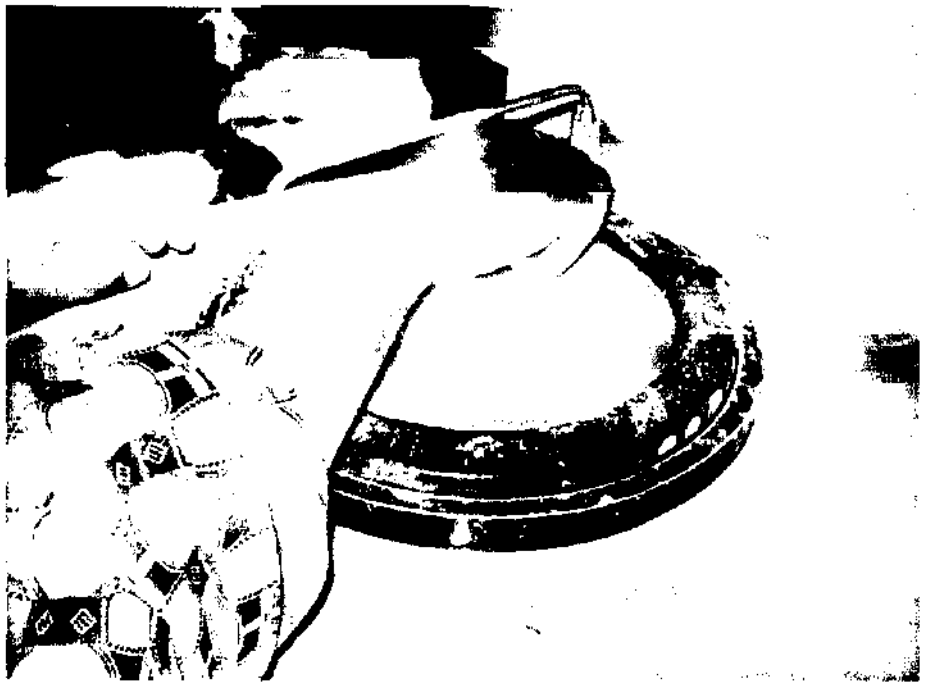


**Plate 8: Grinding/ polishing of specimen in progress**

Quality time was devoted to the polishing of each sample. From my personal observation it was done as long as necessary to produce scratch-free and reflecting surface of specimen without destroying it. The quality of polishing was frequently assessed in Optical microscope. After polishing, specimens were thoroughly washed in Ultra sonicator to remove contaminants, rinsed with isopropyl alcohol and then dried by blowing in Air Compressor. They were then kept in Petri dishes and stored in the desiccator to prevent contamination and /or oxidation.

**Etching:** Five highly magnetic samples were selected for etching. This was intended to separate the grain boundaries of the phases mainly by developing relief between them (Samuels 1980). A phase is defined as "a material having the same composition, structure and properties everywhere under equilibrium conditions" (Askeland 1989:274). The polishing that preceded this stage which produced specimens with scrach-free surfaces, without surface deformations, flowed materials (smears) and pull out was a necessary preparation for etching (Voort 2004). Chemical etching, which was used for this sample preparation is one of the most popular in producing contrasting images of phases. For this etching, the samples were immersed into 3% nital (solution of 3ml nitric acid and ethyl alcohol for 5 seconds, rinsed in water and dried in Air compressor.

**Coating:** This involved the coating of the specimens with carbon using Evaporative Carbon Coater. This stage was the last in sample preparation for SEM and EDS analyses. The purpose of carbon coating was to produce conductive specimens, reduce the absorption of X-rays by samples, remove surface charging from specimens and minimize

heating which can cause deformation of the microstructures (Voort 2004; Dr Willenberg 2008 pers. Comm).

**Pounding:** For the Powder XRD analysis, specimen of about 10mg each was taken from the same samples that were prepared for SEM and EDS. This was to ensure a uniform basis for comparing the results from all techniques used. The specimens removed were then ground to fine powder using a ceramic mortal and pestle, preparatory to forming on slides.

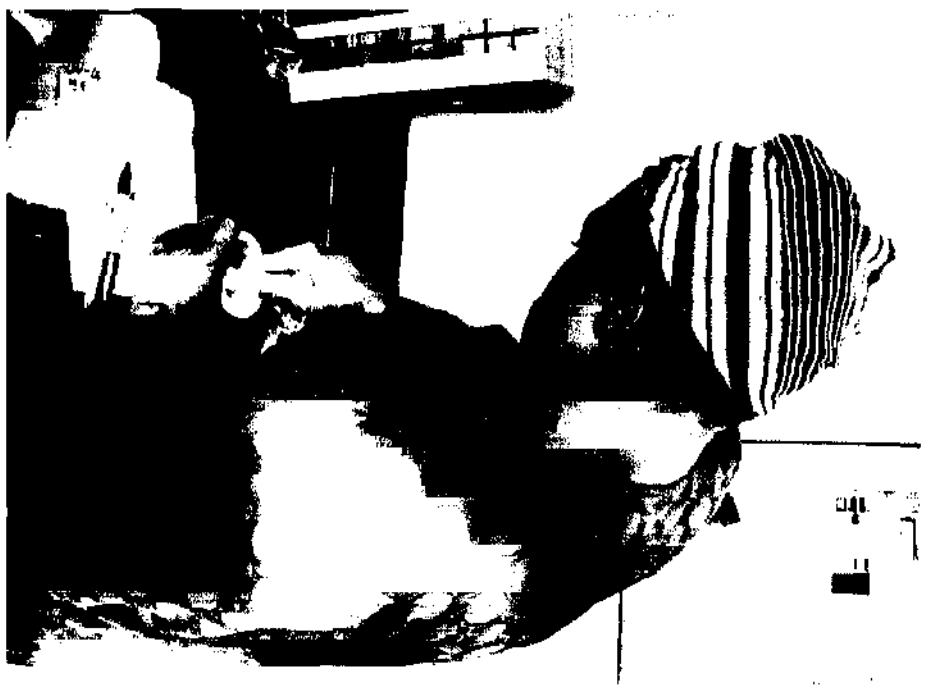


**Plate 9: Pounding of specimen for powder XRD in progress.**

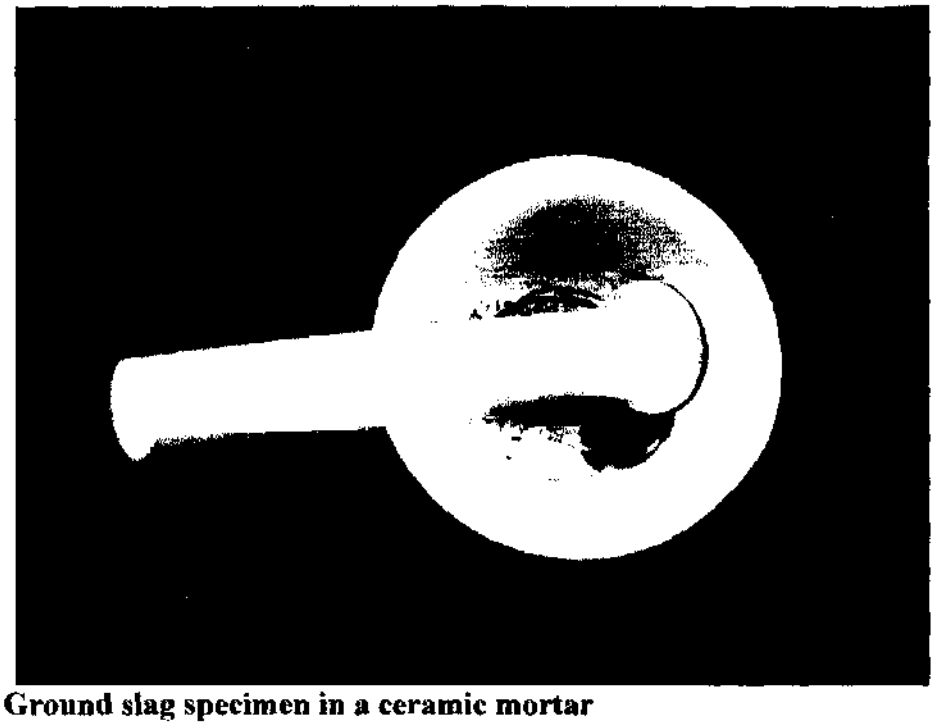


**Plate10: Ground slag specimen in a ceramic mortar**

**Forming on Slide** The powdery specimens produced were subsequently transferred to the slide and mixed with amyl acetate which is non reactive glue. The glue was meant to stick the powder specimens to the slide before being mounted on the axis of the cylindrical X-ray camera.

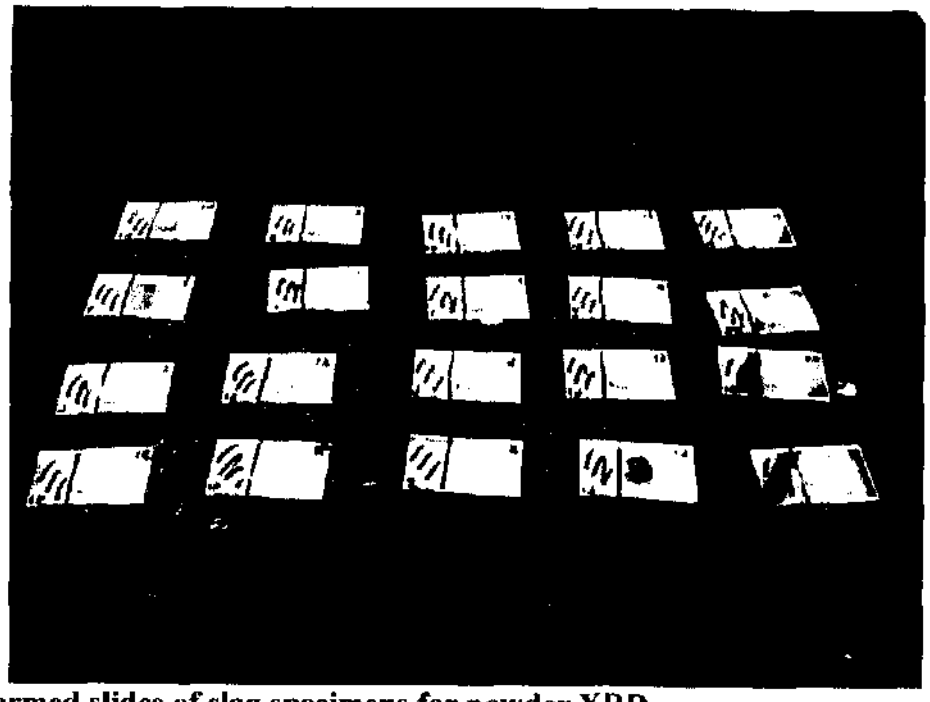


**Plate11: Formed slides of slag specimens for powder XRD**

# CHAPTER TWO

# PHYSICAL AND SOCIO-CULTURAL BACKGROUND OF ZARIA AREA

## Introduction

This chapter presents an overview of the environment and socio-cultural background of the research area. This is aimed at providing the contexts necessary for a clear articulation of the material evidence discussed in subsequent chapters.

## THE PHYSICAL ENVIRONMENT

### Geographical Location

The Zaria area in this research project lies between latitudes $9^0$-12" N and longitudes $7^0$ – 9" E. It covers Zaria and its immediate environs. It is located within the old Zaria province (Fig 3). The area is in the North western state of Kaduna, Nigeria. The archeological map (Fig 5) of Zaria area shows the location of the sites investigated by the pioneering researchers

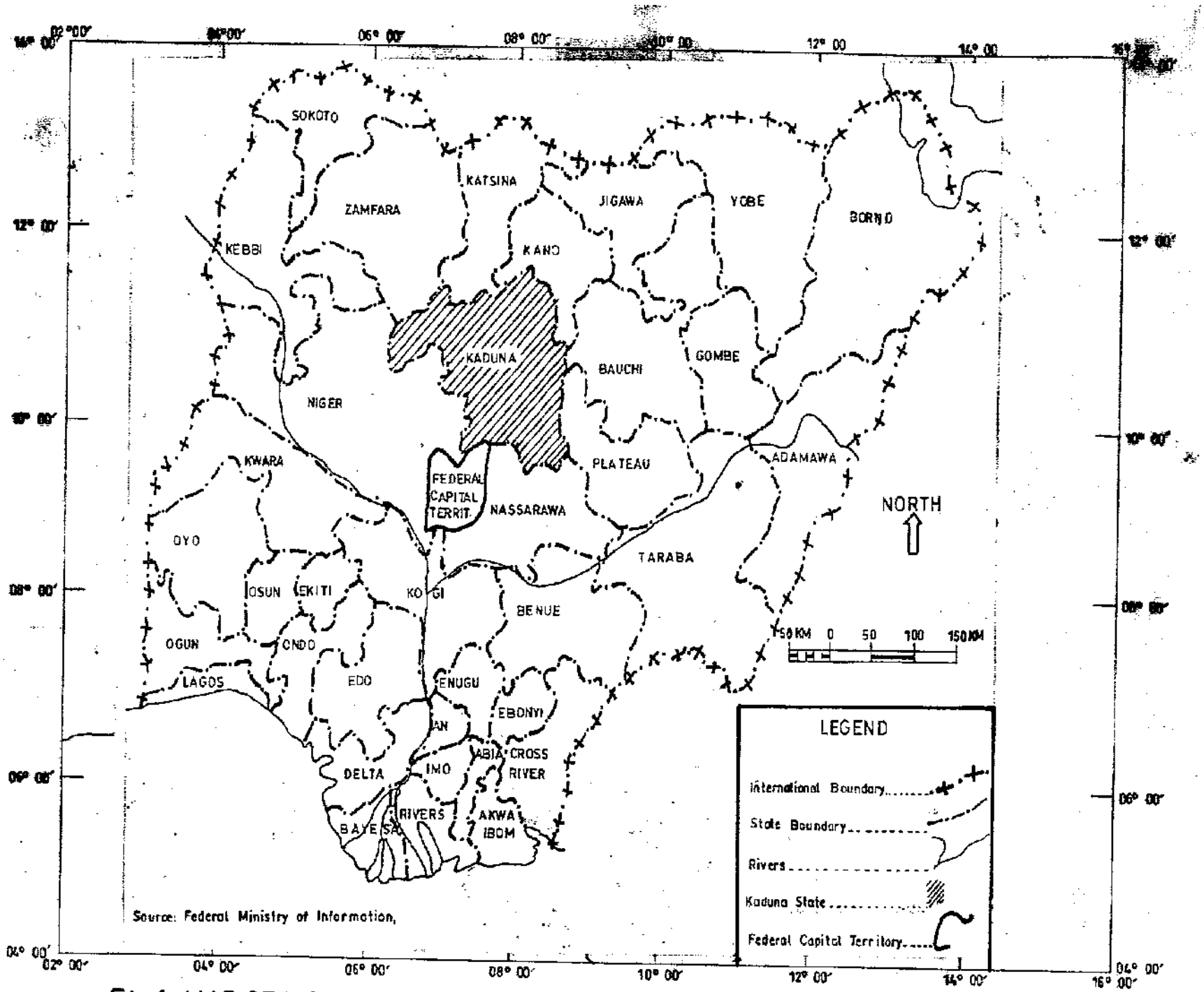



Fig 1: MAP OF NIGERIA SHOWING KADUNA STATE

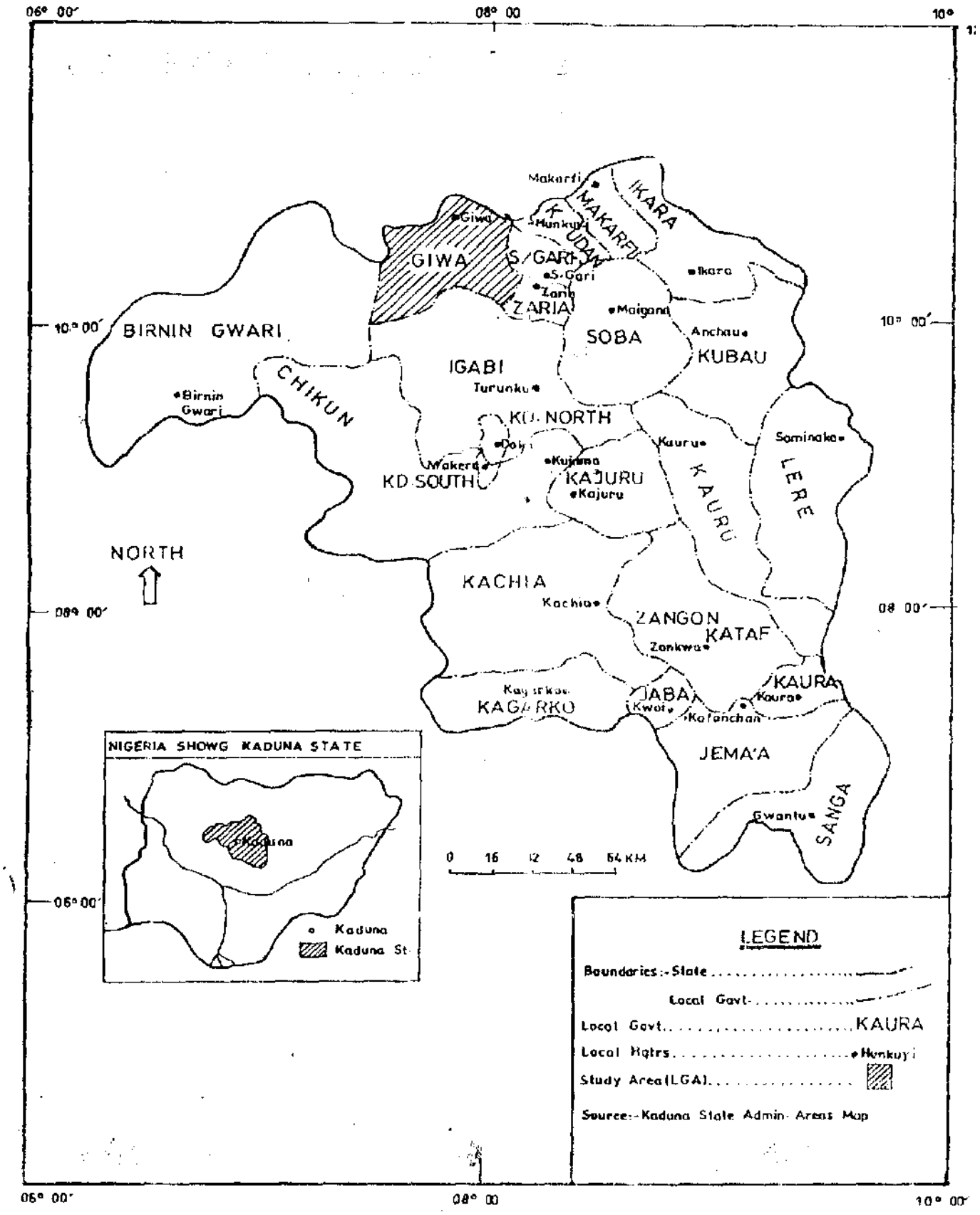



Fig 2: MAP OF KADUNA STATE SHOWING GIWA L. G. A.

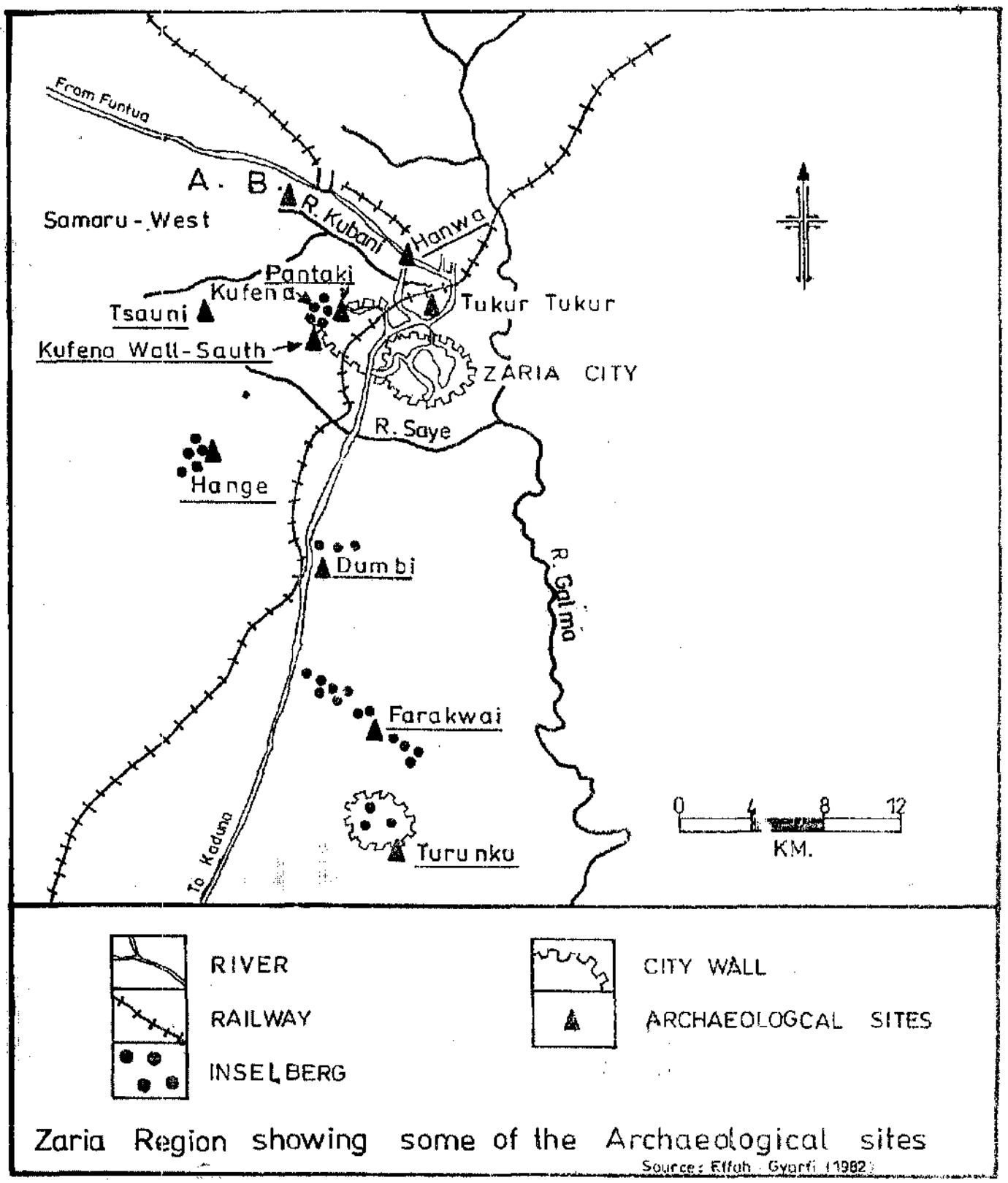



Fig 5: MAP SHOWING SOME ARCHAEOLOGICAL SITES IN THE ZARIA AREA

**Relief and Drainage**

The Zaria area is found within the Zaria-Kano plains which is an extensive pene-plain characterized by crystalline metamorphic rocks of the Nigerian Basement Complex (Wright and McCurry 1970). It generally lies about 2000ft (600m) above sea level (Thorp 1970; Smith 1966; Kirk-Greene 1966). The area is associated with a number of granite inselbergs such as Kufena, (latitude $11^0$ 04. 980' N, longitude $7^0$ 39 .416' E); Hanwa,(latitude $11^0$ 07.211' N, longitude $7^0$ 42.659' E); Dumbi(latitude $10^0$ 57.7 N, longitude $7^0$ 39.3' E) and Wusasa (latitude $11^0$ 04.597 N, longitude $7^0$ 40.475' E) which are made of crystalline igneous rocks and similar to others in the Guinea Savanna Zone of Northern Nigeria (Adebote *et al* 2008).

The mesas are another category of landforms found in the Zaria region. They are tabular hills between 4.5 and 15m (Thorp 1970), rising from the gentle slopes of the surrounding plain by a concave slope that steepens to a cliff of 0.3-1.8m, which is coincident with the hard layer of lateritic iron stone on top of these hills.The Mesas are characterized by decomposed rock made of kaolinitic clay interspersed with original quartz grains and different types of mixed aluminum and iron oxides. They are residuals of formerly extensive sheets of decomposed rock in which iron oxides are deposited in distant upper horizon, examples of which are found at the Azaru Forest Reserve along the Zaria-Kaduna road and at Samaru in the Junior Staff Quarters of the Ahmadu Bello University, Zaria, Nigeria (Thorp 1970).

The ruwares are low whale back features with longer length than width and height which are sometimes surrounded by round boulders or core stones. Several examples are found around Kufena, Hange and Dumbi inselbergs (Thorp 1970).

The micro landforms associated with the inselbergs and ruwares of the Zaria region are weather pits, lapies, perched boulders, exfoliation sheets and scales. Weather pits are depressions of different sizes and shapes hollowed out of fresh sand rock with steep sides, abrupt edges and bowl shaped floors. Their sizes range from 0.3-1.8m long, 0.9m deep and 1.2-1.8m wide. They are products of chemical weathering by water which persisted in one place for a longer period after rain than an adjacent rock (Thorp 1970).This landform is different from elliptical rock hollows which were apparently initiated from non geomorphic process but later used by humans for grinding (Thorp 1970; Glaeser 1981)

Perched boulders are remnants of an exfoliation sheet while core stones are the undecomposed cores of joint blocks surrounded by gritty clays of weathered granite, commonly found on the Hange inselbergs, while the lapies are channels and grooves formed on granite rocks (Thorp 1970), which can be attributed to a new phase of inselberg weathering which mostly occur on the Tukur-Tukur inselbergs.

The plains are very distinct and impressive landforms which have been associated with several types of human activities such as settlement, farming, herding and a wide range of industrial activities. The Zaria plains and the high plains of Hausa land in general have been associated with warping at different periods the latest of which occurred in the pleistocene period (Thorp 1970). The Zaria plains have been attributed to the occurrence of deeply weathered proto plains characterized by the iron stone mesas and the residual inselbergs. The interplay of complex geomorphological factors has constantly changed the outlook of Zaria plains since its formation believed to date to the Tertiary era. The presence of primary lateritic iron on these plains which is similar to

others in West Africa may indicate a common period of intense and prolonged chemical weathering during the Oligocene-Miocene period associated with the decomposition of basalts of the Jos Plateau (Thorp 1970). Zaria plains exhibit almost flat profiles reflecting the low river gradient and making the landscape uniquely horizontal. The remarkable flatness of these plains poses a problem of run-off and erosion in the area. Several distinct landforms are associated with the Zaria plains within about 10 miles (16km) radius of Zaria. These include partially eroded lateritic stones, widely spaced streams and banks virtually without gullies characterized by gentle slopes, swampy and aluviated floor. The south west is associated with eroded iron stones with characteristic very gentle slopes. Gullies are a common phenomenon in the area and are found mostly along the valleys of the Kubani and Saye rivers (Thorp 1970).

Zaria region is also associated with a very impressive drainage system of which the Galma is the major river. Located on the basement complex of the Northern Nigerian Shield (Garba and Schoeneich 2003), it is a main tributary of the river Kaduna which takes its source from the Ganawari hills, in old Bauchi province, enters the Zaria province at the South east and flows North west, then South west towards the Niger province (Kirk-Greene 1976). The name"Galma" is derived from its resemblance to the large Zaria hoe which is so called. It is a perennial river unlike many of its tributaries which are seasonal. The main tributary of the Galma is Kubani. Other rivers in the area include the Saye, Awai, Marmara, Tubo, Mariga, Likarbu, Kuban and Kinkiba (Thorp 1970).The Kubani, with an incised channel cutting into the gravels and alluvium along its course and into the decomposed rock is seasonal river (Thorp 1970; Garba and Schoneich 2003). Streams that flow for some time into the dry season are mostly fed by ground water

(Garba and Schoneich 2003). Two types of aquifer have been identified in the Zaria region: the regolith (soft overburden) type which is the main aquifer and the fractured bedrock aquifer. The water table of the area varies according to the season but generally lies at a depth of less than between 5m to 15m (Garba and Schoneich 2003).

The Kubani River exhibits interesting land forms such as complex arrangement of old Meander loops, Ox bow lakes, Cut-offs, Swamps, and Levees. The Galma flood plain is composed of silts and clays with a strong mixture of organic matter, a degraded bluff and a low terrace (Thorp 1970).

The well drained nature of the Zaria region has undoubtedly proved very beneficial to the past inhabitants of the area in several ways such as agriculture, iron smelting and pottery making. In modern times, the rivers are still very valuable in terms of their use for irrigation to support dry season farming (Mangut 1983), fishing, rearing of livestock and domestic purposes.

**Geology**

Zaria lies within the northwestern Nigeria which forms part of the extensive Pan-African mobile belt separating the West Africa and Congo Cratons (Garba 2008). The north western Nigeria Basement Complex comprises gneisses migmatites (Wright and Mc Curry 1970; Garba 2008), metasediments of Precambrian age intruded by series of granitic rocks of Late Precambrian to Early Paleozoic age which are in some areas cut and displaced by Late Pan-African faults (Garba 2008).

From the various studies of the geology of the Zaria area (Mc Curry 1970, 1973; Webb 1972; Olatunji 1968 1970, 1979 and Ike 1974, 1989 in Garba 2008), the following

rock types have been identified: the gneissic complex (Dahomeyan Basement) with remnants of an ancient metasedimentary sequence (the Older Metasediments); metasediments (Schist belts) of middle to Late proterozoic age, and intrusive granitic rocks of late proterozoic to Cambrian age (Older granites), (Garba 2008)

Large parts of Zaria area are underlain by poorly exposed weathered gneiss with subordinate migamatite. The gneisses, which vary in composition and texture range from biotite and horn blend-bearing with textures ranging from banded to auger (Wright and Mc Curry 1970; Garba 2008). The metasediments exhibit north-south trends with apparent comformable relationship to the gneiss complex. These are found to the east and west of Zaria known as the Zaria and Karaukarau schist belts respectively and are mostly quartzites, phyllites, semi-peltic and peltic schists with minor carbonaceous schists (Garba 2008). Due to the friable nature of the schists which form the greater part of the metsedimentary belts, there is differential erosion in the river valleys (Garba 2008). The varieties of schist found in the Zaria area include: muscovite-quartz, biotite-muscovite, feldspathic, carbonaceous and anthophyllite-conderite (Garba 2008).

The older granites found in the area are intrusions into both the gneissic complex and the metasedimentary belts with widespread quartz veins and tourmaline rocks (Garba 2008). The exposure of granites is generally good in Zaria but elsewhere they are buried under a thick superficial cover except where it forms outcrops of isolated hills known as inselbergs, low whalebacks granite pavement. Webb (1922 in Garba 2008) suggested the term Zaria Batholith for the Older Granite which extends in a North-South direction across the area of at least 90km and up to 22km wide traceable from around Zaria Southwards to the vicinity of Kaduna.

More than 100 dykes, 250 pegmatites and 150 quartz veins showing spatial affinities with the granite area have been identified in at least 21 localities in Zaria (Olatunji 1970, 1979 in Garba 2008). These minor bodies comprise Aplite/microgranite dykes, pegmatites and quartz veins. The aplite/microgranite dykes are the most abundant of the minor rock formations varying considerably in length and width of outcrops 50-100m and 0.5 – 5m respectively (Garba 2008). Modal analyses show that the microgranite is made up of 38-40% k-feldspar, 26-27% plagioclase, 28.5-31.5% quartz and 4-6% biotite (Garba 2008). Next in abundance are the pegmatites which are both concordant and discordart to regional structure. The pegmatites generally exhibit length of 5-20m and 10cm – 1m width with dip angles ranging from 45-90$^0$ (Garba 2008). Typical pegmatites localities are west of Zaria, GRA quarters, BZ Staff Housing Area of the Ahmadu Bello University Zaria Main Campus and the Kinkiba-Richiffa area to the east and north east of Zaria with the Kinkiba-Richifa pegmatites notable for their germstones such as beryl, tourmaline and aquamarine and some metal occurrence (Garba 2003, in Garba 2008). The quartz veins are the smallest group of the minor rock formations in the Zaria area comprising generally the glassy variety with varying shades of smoky, amethystine and milky colouration.

The area is also characterised by diverse superficial deposits (Wright and Mc Curry 1970) which can be broadly classified into two: laterites and alluvium deposits. Laterites which may form "insitu" by the decomposition of the basement rocks, pegmatites or quartz veins or may have been transported and deposited along river valleys can develop on gently undulating surfaces that may be as thick as 6m (Wright and

McCurry 1970 in Garba 2008) made a distinction between "older" and "younger" laterites in the Zaria area.

The Alluvial deposits of the Zaria area have also been categorized into "older" and "younger." The "older" alluvial deposits which are broadly contemporary with the "younger" ones overlie most of the Zaria area and are made of accumulations of fine grey-brown sands, clays, red sands and gravels varying from 5-13m in thickness (Garba 2008; Mc Curry 1970), while the younger alluvium is the product of the most recent erosion cycle, comprising grey-brown sands, silts and clays over 10m thick in several places (Olowu 1967 in Garba 2008).

A number of minerals of economic significance are known to occur in the Zaria area Wright and Mc Curry 1970; Garba 2008). These include amethyst which occurs in quartzveins and found at about four major localities, the most important of which is at Dala, about 5km West of Kofan Kwiambana of Zaria City (Garba 2008). It is used locally for a variety of decorative purposes including jewellery.The distribution of amethyst is found in Dala near Wusasa on latitude $11^0$ 04' N and longitude $7^0$39' E, Panmadina area on latitude $11^0$ 01'N and longitude $7^0$ 39'E, Hange Hill area on latitude $11^0$ 07'N and longitude $7^0$ 37'E and the Nigerian College of Aviation Technology, Zaria on latitude $11^0$ 08'N and longitude $7^0$ 41'E (Garba 2008). Other minerals found in the Zaria area include: anthophyllite – asbestos in an area South East of Karaukarau, though not in economic significance beryl crystals in varying sizes, commonly found in pegmatites of the Kinkiba-Richifa area, east of Zaria, bisonuth columbite – tantalite found south west of Richifa, feldspar in southwest of Karaukarau, though its extent is neither known nor tested (Garba 2008). Lepidolite is associated with the Richifa area,

though the extent is not yet known, tourmaline crystals (green and pink varieties) which may be of gem quality are found in Kinkiba-Richifa pegmatite belt and quartz is found northwest of the Zaria area (Garba 2008). Occurrence of Manganese has also been identified northwest of Danja, graphite in small quantities northwest of Karaukarau with low carbon content to be of economic significance (McCurry 1973 in Garba 2008), clays and laterites in most parts of the Zaria area and used locally for pottery while laterites used as building material and for road surfacing were also extensively smelted locally for iron as evident in the abundant slag collections and smelting furnaces commonly found in the Zaria area (Hore 1970; Garba 2008). Stones used for construction purposes are abundant in the numerous outcrops of the Zaria Batholith where they are quarried and crushed and due to its beautiful and gneissic texture, the Zaria granite has potential of an ornamental building stone as could be seen in the present commercial quarrying of granite blocks for export near the Nigeria College of Aviation Technology, Zaria (Garba 2008).

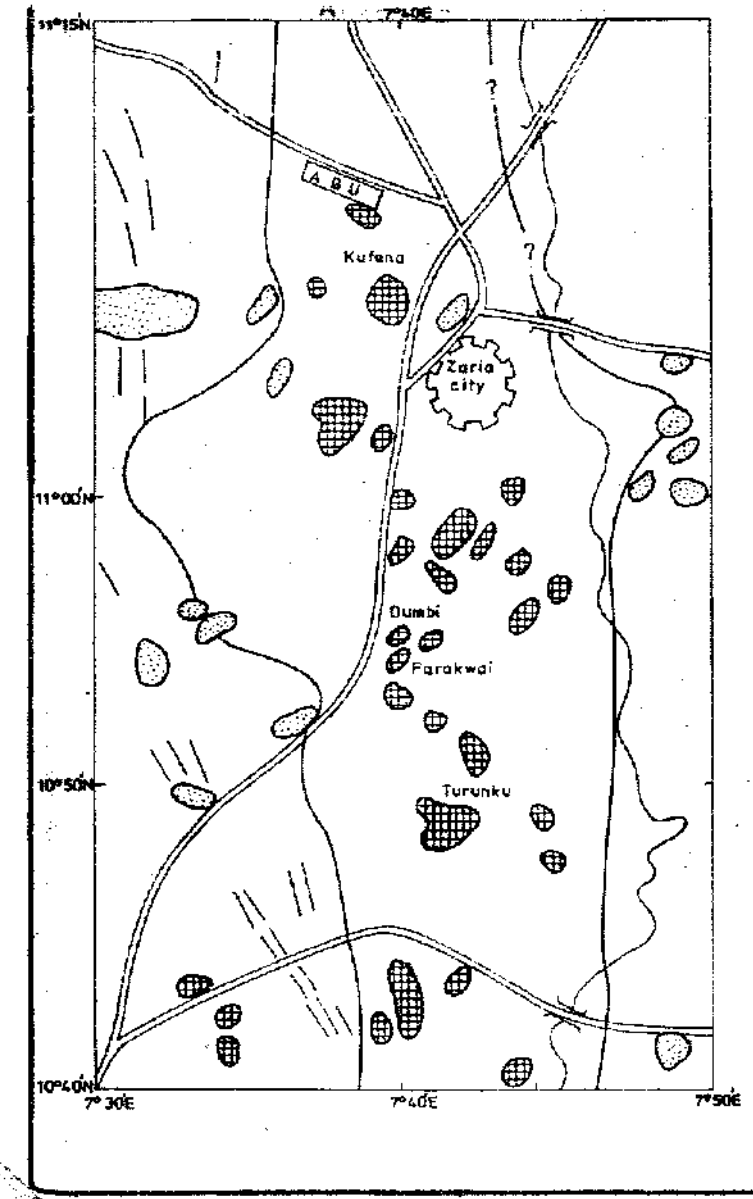



Fig 6: GEOLOPICAL MAP OF ZARIA AREA

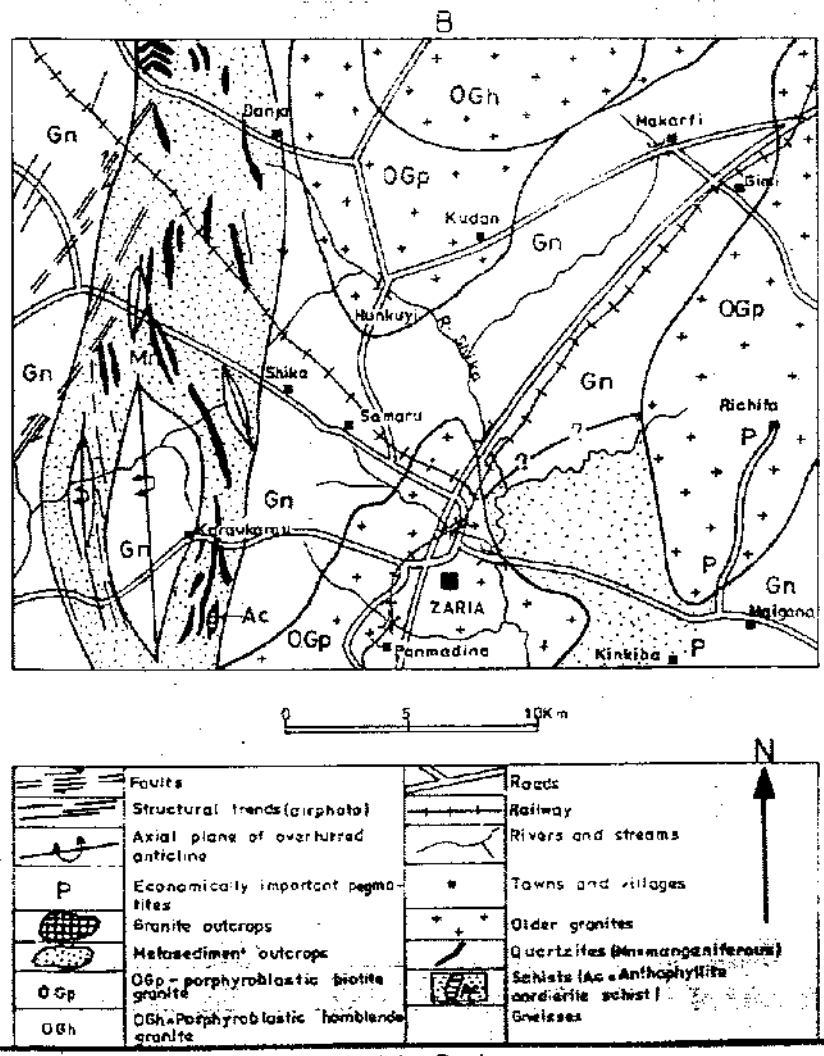



Fig.2. The Geology of Zaria and its Region.
Modified after Webb (1972) and McCurry (1973)

**Climate**

Zaria, located in the Centre of Northern Nigeria on latitude $11^0$, 3'N, longitude $7^0$ 42'E at a height of about 66lm A.S.L. and more than 600 km from the sea lies within the Sudan Savanna bio-climatic zone characterised with distinct wet and dry season, with the wet season occuring between late May and early October, while the dry season which occurs between late October and early May practically records no rain (Ati and Sawa 2008).

Zaria climatic conditions are controlled by two air masses – the tropical continental (cTs) and the Tropical Maritime (mE). The tropical continental winds are of northern origin, very dry, hot in the day and cool at night due to the long track of Sahara desert (Ati and Sawa 2008). The cTs winds are dust laden and of low humidity while on the other hand the Tropical Maritime is of southern origin. Characteristically it is moisture laden due to its long sea track (Ati and Sawa 2008).

There are two distinct seasons in Zaria area - the dry and rainy seasons (Hore 1970; Ati and Sawa 2008). The dry season normally spans between late October and early May and dominated by the Tropical continental air mass and its characteristic weather conditions. The onset of the dry season in Zaria area marks an end of the sticky heat that occurs between September and October (Ati and Sawa 2008). The dry season in Zaria area has been divided into early, middle and late with each of these parts marked by distinct weather conditions (Ati and Sawa 2008). The early dry season is marked by a sharp drop in the humidity of the surface air and a change in the direction of the surface winds. The relative humidity drops sharply from 60-65% in October (average 10am) to about 25 – 30% in November. The early dry seasons is also characterized by more

prevalence of the north-easterly winds, sharp fall in daily maximum temperature with consequent rapid increase in the diurnal range of temperature (Ati and Sawa 2008). In November, daily maximum temperatures may rise as high as $32^0$C while the minimum may fall as low as $11^0$C (Ati and Sawa 2008).This period is characterized mostly by clear sky which allows longer hours of sunshine with the daily average length of sunshine between 10.6 to 9.2 hours (Ati and Sawa 2008). The soil at this period is still moist and can supply sufficient moisture to the surface air by evaporation and transpiration which could be further strengthened by the sudden surge of south-westerly wind (Ati and Sawa 2008).These conditions and local heating can result into formation of a few cumulus clouds strong in the afternoon that disappear at night (Ati and Sawa 2008). Generally, the mornings and nights are cooler and more pleasant than the period between September and October due to low humidity with the occurrence of dusty winds starting to appear and increasing in frequency (Ati and Sawa 2008).

The mid-dry season occurs between December and January. This period is characterized by drier air with relative humidity of 15-20% in December and 10 – 15% in January. At this period, the dry north-easterly continental winds become steady leading to a weather condition locally known as harmattan (Hore 1970; Ati and Sawa 2008) associated with the production of surface turbulence of a suspension of fine dust particles in the air with maximum intensity between December and January.The thickness of the hazy and dust layer of the harmattan rarely exceeds a height of 1,515m. This is further characterized by very poor visibility, drastically reduced insolation with consequent reduction in the daily maximum temperatures (Ati and Sawa 2008). The basic characteristics of harmattan include: north easternly direction of the winds with different

speed, low humidity, large daily range of temperature and absence of convective type of cloud (Ati and Sawa 2008). The intensity of harmattan wind varies from one year to another. In its severest form it can be very hazy and dusty with drastic reduction in visibility. In some years, extreme harmattan conditions could be recorded in the Zaria area such as those of 1987, 1992 and 2005 (Ati and Sawa 2008).

The late dry season occurs between February and early April. At this period, there is a struggle between the maritime mT air from the south and the continental cT air from the north to take control of Zaria (Ati and Sawa 2008). This can be explained by the unstable pattern of winds in the Zaria area which can sometimes be south westerly or north easterly between March and early April (Ati and Sawa 2008). The late dry season is generally characterized by rise in relative humidity from 15 – 20% in March to 50 – 60% in April, sharp rise in diurnal maximum and minimum temperatures and occurrence of very hot 'sticky' weather synonymous to that of the coastal area of Nigeria ( Hore 1970; Ati and Sawa 2008). Another feature of this period is the unstable lapse rates leading to the formation of cumulus clouds in the afternoon some of which may transform to cumulonimbus clouds (Hore 1970; Ati and Sawa 2008). The transformation of cumulus clouds to cumulonimbus is normally accompanied by thunder, lightening and heavy showers which hardly exceed 25-30 minutes. These are also accompanied by strong gusty winds which sometimes wreak havoc by blowing off house roofs, falling electric poles and trees (Hore 1970; Ati and Sawa 2008). The thunderstorms however normally bring with it a refreshing weather condition evident in the sudden fall in air temperature (Hore 1970; Ati and Sawa 2008)

Generally in tropical continental climatic zone, the onset of wet season is usually the hottest (Minns 1984). At this period, all the rains fall with little or none in the dry season. The amount of rainfall recorded in any part of this climatic zone normally depends on the nearness to the equator. The effect of proximity to the sea on climate is also felt in this zone, as the closer a place is to the sea, the higher will likely be its level of rainfall (Minns 1984).

The rainy season in Zaria area occurs between late May and early October. In May, the thickness of the moist air is about 606m which increases with the progress of the rainy season (Ati and Sawa 2008). The rainy season in Zaria area is characterized by highest frequency of occurrence of squall winds which are normally formed under strong lines of instability in the upper layers of the atmosphere and humidity and traceable to the Maritime winds usually occur after a day or two of high temperatures and very still air (Hore 1970; Ati and Sawa 2008). The initial rains are usually preceded by heavy clouds, accompanied by lightening and thunderstorms. The duration of such rain may be an hour or two (Hore 1970; Ati and Sawa 2008). Generally during the rainy season in the area, the daily maximum temperature drops and the diurnal range of temperature falls than in the preceeding season while relative humidity rises to between 65-67$^{0}$C with increase in cloud formation and shorter duration of sunshine (Hore 1970; Ati and Sawa 2008). The first rain of the year normally falls in Zaria and its environs as showers in late March or Mid April the effective onset of the rainy season being between May 20$^{th}$ and 30$^{th}$ (Ati and Sawa 2008). Once the rains start, the monthly rainfall continues to increase in each successive month till August when the highest rainfall is recorded (Ati and Sawa 2008). After the peak of rainfall in August, the month of September records a fall. Few scattered

showers associated with thunderstones can occur in the area before the rainy season finally ends in early or mid October (Ati and Sawa 2008).

The mean monthly rainfall distribution for Zaria and its environs is 33 mm in April, 150 mm in May, 143mm- June, 213mm – July, 272mm – August 201mm – September and 38mm- October with mean Annual of 1000 mm (Ati and Sawa 2008). It is noteworthy that the temporal variability of rainfall in the Zaria area has shown a decline in the mean Annual Rainfall from 1969/70, a period that marked the beginning of the 1969/70 sudano-sahelian drought which came to its peak in 1972/73 (Ati and Sawa 2008).

The effect of evapotranspiration, which is the combined loss of water from all surfaces including plants (Ati and Sawa 2008), is also considerable in Zaria and its environs. It is interesting to note that the 66 – 85% of precipitation is returned to the atmosphere through evapotranspiration which is greater than the annual rainfall recorded in the area (Ati and Sawa 2008). The seasonal patterns of evapotranspiration in Zaria area have led to two distinct periods of maximum evapotranspiration which occur before and after the rains and two minima in August and December/January (Ati and Sawa 2008).

On the whole, it can be observed that the seasonal diversity of the climate of Zaria area has considerable impact on human activities such as farming and rearing of animals, which normally vary in scope with the weather.

**Soils**

The study of soils of the Zaria area has not been accorded much attention as evident in the fact that the only soil survey carried out in the area by the land Resources Development Centre (LRD) of the British Ministry of Overseas Development was essentially reconnaissance in nature (Jaiyeoba 2008). In an attempt to address this apparent lapse, Jaiyeoba (2008) attempts to corroborate the Klinkenberg (1970) discussion on the Zaria soils with other isolated published and unpublished works, the LRD survey and about two decades of his field experiences in the Zaria area.

The soils of the Zaria area represent an interface between intensive chemical weathering of rocks and an active surface and sub-surface denudation system intensified by rainfall and rapid run off (Jaiyeoba 2008). Characteristically, the properties of the soils in the Zaria area represent a complex interplay of intensity of weathering and rate of lateral and vertical eluviations of materials which are related to environmental features such as lithology, topography, climate vegetation and so on (Jaiyeoba 2008). The soils of the Zaria area developed from within parent materials formed through several cycles of alternating wet and dry conditions over a gently undulating terrain, under savannah environmental condition and increasing modification by man (Jaiyeoba 2008).

The parent materials of the soils are derived from crystalline metamorphic rocks of the Basement Complex and Quaternary deposits with emergence of two distinct groups (granitic rocks and Schists (Jaiyeoba 2008). Generally soils formed from granitic rocks in the area are more sandy, lower in nutrients and more acid, while on the other hand, the Schists weathered into clay-rich regolith with sand fraction varying in quartz content of

the rocks. Soils formed from the regolith tend to be less sandy and higher in nutrient content (Leow and Smith 1981 in Jaiyeoba 2008).

Alternate periods of biochemical and physical weathering associated with the strong seasonal climatic conditions in the Zaria area result in the production of laterites in several places while the gently sloping topography causes rainfall run-offs that lead to selective removal of fine materials thereby leaving a concentration of sand and coarse materials near the surface (Jaiyeoba 2008). The biotic factor which has to do with the role of vegetation and fauna, particularly the role of man is also crucial in explaining soil degradation in the Zaria area (Jaiyeoba 2008). The nature of soils of the Zaria area is also determined by a major factor which is the Aeolian addition of materials (Jaiyeoba 2008). The soils of the area fall mostly in the zone which agriculturists have described and mapped as the Loess Plain Unit Soils (Lawes 1962; Higgins 1963 in Jaiyeoba 2008). The texture of the loess deposit characteristically described as exhibiting high proportion of fine sand (Lawes 1962; Kowal 1972 in Jaiyeoba 2008) is recognizable as homogeneous deposits separated by an erosion boundary from underlying weathered rock with variable depth that can be up to 1m (Smith and Whalley 1980 in Jaiyeoba 2008). When uncultivated, under the impact of intensive rainfall, the soil is prone to capping, which promotes surface run-offs (Kowal 1972; Lawes 1962 in Jaiyeoba 2008; Klinkeneberg 1970). When dry, it has a tendency to break down under cultivation into loose powder that can easily be eroded by the wind (Jaiyeoba 2008).

Most soils in the Zaria area are developed on the deeply weathered metamorphic rocks of the Basement Complex which according to CCTA legend (D' Hoore 1963 in Jaiyeoba 2008) belong to the leached ferrugmous tropical soils (FAO: Ferric Luvisols, in

Jaiyeoba 2008; Klinkeneberg 1970) A few found in valley bottom positions (Fadama in Hausa language) are hydromorphic (FAO: Gleysols), while those around the base of inselbergs and other residual hills are weakly developed known as lithosols (Jaiyeoba 2008).The leached ferruginous tropical soils of the area are characterized by a range of colours from dark brown in the topsoil to yellowish red or yellowish brown in the subsoil (Jaiyeoba 2008) Chemically the soils are moderately acidic with $P^H$ level of between 5.3 and 6.5 (Jaiyeoba 2008). The organic content of these soils is highly variable but generally low, often less than 1.5% at the surface and 0.5% at the subsurface with the clay mineralogy dominated by Kaolinite (Jaiyeoba 2008).

The Fadama soils are found in the flood plains of the major rivers in the Zaria area, characterized by dark grey colour at the surface horizon and dark grey down the profile, variations in their texture are attributable to differences in their parent materials (Jaiyeoba 2008). During the dry season, the surface layer of these soils often exhibits weak polygonal cracking (Jaiyeoba 2008). The Fadama soils generally exhibit poor to very poor drainage characteristic but where a stream has cut into the valley it tend to be better drained (Jaiyeoba 2008).

The occurrence of the weakly developed soils (lithosols) is commonly associated with the base of inselbergs and crests of ridges but could also be found close to rock outcrops (Jaiyeoba 2008). They are generally characterized by poor horizon development and are mainly less than 50cm deep with colour ranging from pale brown to light yellowish brown in the surface layer to yellowish red at the lower (Jaiyeoba 2008). The texture of these soils may vary from sandy loam in the top layer to sandy clay loam at the

lower with angular quartz, feldspar grains and few stone contents and moderate acid $P^H$ level of less than 6.0 (Jaiyeoba 2008).

Although the leached tropical ferruginous soils possess good moisture retention capacity, adequate aeration with brief waterlogging (if it occurs at all) and sufficient rooting depths for most crops they are nonetheless associated with management problem which arises from the heavy weathering of the parent materials, leaching of exchangeable bases with low organic matter (Jaiyeoba 2008). The soils are therefore inherently poor and cannot sustain intensive agriculture for a long period without addition of manure or fertilizers (Jaiyeoba 2008). Other management problems of these soils include: formation of pan due to poor aggregation (Jaiyeoba 2008), rapid sealing of the surface following rainfall and crusting with subsequent drying cycles (Jones 1971: Kowal 1972; Jaiyeoba and Ologe 1986 in Jaiyeoba 2008). These conditions can create problem of sharp decrease in water penetration and storage at critical periods in the growth of crops, while the occurrence of surface crust could also result to anaerobic conditions that can aid the growth of weeds. Another problem of the soils is water erosion which can be aggravated when the vegetation cover is removed and cultivation takes place (Jaiyeoba 2008). In addition, the leached tropical ferruginous soils of the Zaria area is also associated with the presence of laterite in their profiles (Young 1979, in Jaiyeoba 2008) which if found in a massive and continuous manner can limit the root development and susceptibility of crops to even moderate drought (Jaiyeoba 2008).

The Fadama soils are associated with deep gully erosion, poor drainage that may adversely affect rooting in the soils and susceptibility to contamination especially of heavily metals with the use of sewage water for irrigation (Okofu 1999 in Jaiyeoba

2008), while the major problems associated with the weakly developed soils at the base of inselbergs are limitation of agricultural use due to shallow depths and severe erosion on steep slopes (Jaiyeoba 2008).

Traditionally, the management of soils in the Zaria area was carried out by fallowing or land rotation and cultivation of crops like sorghum, pearl, millet, maize, groundnut, cotton, cowpea and yam in mixed farms or as intercrops (Jaiyeoba 2008). However due to rapid growth in population and the expansion of market for agricultural produce recently, there has been increasing soil degradation and low yield due to cultivation of lands that are considered or marginal or fragile as demonstrated under experimental conditions at the Institute for Agricultural Research at Samaru (Jones 1971, Dunham and Aremu 1979 in Jaiycoba 2008) and under small holder conditions at Guga (Jaiyeoba 1995, 2003 in Jaiyeoba 2008).

**Vegetation**

The vegetation of Zaria area falls within the Northern Guinea Savanna vegetation zone (Jackson 1970; Jaiyeoba 2008). This vegetation is dominated by the following tree species: *Isoberlinia doka* (Hausa name:Doka), *I. tomentosa* (Hausa name:Fari-doka), *Uapaca togoensis* (Hausa name:Kafago), *Terminalia avicennioides* (Hausa name:Baushe) *Combretum brinderlanum* (Hausa name:Taraminiya), *Piliostigma thonningii* (Hausa name:Kargo), *Bridelia ferruginea* (Hausa name:Kirni), *Vitellaria paradoxum* (Hausa name:Kade), *Vitex donianna* (Hausa name:Dinya), *Parkia biglobosa* (Hausa name:Doruwa), *Parinapi curatellifolia* (Hausa name:Rura), *Ximenia americana* (Hausa name:Tsada) *Stereospermum kunthianum* (Hausa name:Sansami), *Nauclea latifolius*

(Hausa name:Tafashiya), *Annona senegalensis* (Hausa name:Gwanda-daji) *and Dichrostachys cinerea* (Hausa name:Dundu), *Tamarindus* (Hausa name:Tsamiya), *Ceiba pentandra* (Hausa name:Rimi) and *Adansonia digitata* (Hausa name:Kuka) (Jackson 1970; Jaiyeoba 2008) The grasses are tufted and of low cover. These include: several species of *Andropogoneae* like *Hyparrhenia spp, Andropogon spp* (Gamba grass), *Schizachyrium semiberbe and Monocymbium ceresiiforme.* The non natural category comprises of *Andasonia digitata, Ceiba pertandra, Magnifera indica and Tamarindus* (Jackson 1970).

According to Dhiliwayo (1987), specifically the Zaria urban centre is characterized by four concentric zones of vegetation which are a product of a long history of human activities. The first zone is characterized by lack of natural vegetation, while a few species like the tamarind, *Vitellaria paradoxum* and the mango (*Magnifera indica*) are preserved for economic purposes. The second vegetation zone is that of periodic cultivation characterized by scrubby regrowth savannah vegetation (Dhiliwayo 1987), the third is an open irregular savannah where firewood is cut while the last is mature climax savannah woodland (Dhiliwayo 1987).

The current outlook of the vegetation of the Zaria area is a product of modification that resulted from a long period of occupation (Jackson 1970; Jaiyeoba 2008). The vegetation of the area has been grouped into tree savanna parkland/shrub savanna/savanna woodland, fadama grassland, riparian forest, inselberg vegetation, iron pan vegetation, afforested vegetation and garden (Jaiyeoba 2008). The savanna parkland/shrub savanna/savanna woodland exhibit little difference in nature which is only reflected in the relative proportion of woody and herbaceous components (Jaiyeoba

2008). This group of vegetation evolved from bush fallowing system forming a distinctive pattern in the Zaria area. The tree savanna or parkland is a peculiar artificial vegetation type which characterizes many settlements in northern Nigeria (Jaiyeoba 2008). This vegetation community consists of immature trees of economic value. The trees are mostly indigenous and represent eithern the few surviving species of once tree savanna woodland or trees deliberately planted (Jaiyeoba 2008). Prominent among the trees in this vegetation community are; *Ceiba pentandra, Tamarindus, Adansonia digitata, Mangifera indica, Vitex doniana, Vitellaria paradoxum, Borassus aethiopum, Afzelia africana, Acacia albida, Khaya senegalensis, Parkia biglobosa, Daniella Oliveri, Ficus Sycomorus and Pterocarpus erinaceus.* The shrubland zone merges with the tree savanna or savanna woodland vegetation (Jaiyeoba 2008). This vegetation is made up of tree species modified by recurrent annual fires, fuel wood collection and bush fallowing (Jaiyeoba 2008).

The fadama or floodplain grassland is found in floodplains or fadama (Hausa), Marshy Oxbow lakes, river banks and shallow backwaters (Jaiyeoba 2008). The vegetation community is characterized by grasses whose morphology varies with water depth associated with several species such as: *Echinochloa pyramidalis, phragmites mauritanus, Saccharum spontaneum, Oryza barthii and Vetiveria nigritana* (Jaiyeoba 2008). The tree species include; *Mitragyna inermis, Syzigium guineense and Terminalia glaucescens* (Jaiyeoba 2008).

Riparian forest vegetation is found in river levees, stream banks and seasonally dry watercourses (Jaiyeoba 2008). A typical riparian vegetation comprised trees such as: *Raphia sapium ellipticum, phoenix reclimata and Albizia zygia including shrubs* and

*climbers like landolphia spp, Nupoleona imperialis, Olax spp, paullinia pinnata, Similax kraussiana* and *Culcasia scandens* (Jaiyeoba 2008).

The inselberg vegetation is the remnant of a dry forest often found at the base of inselbergs where the runoff from the exposed rock creates soil conditions favourable for continuing growth of vegetation during dry season and weathered granite rocks supply mineral nutrients to the soil (Jaiyeoba 2008). The soils are often intensively cultivated with remnant of vegetation comprising such trees such as *Albizia coriaria, A. zygia* and *Milletia thonningii* and climbers *like Acacia ataxacantha, Saba florida* and *Discorea spp* and forest undergrowth mostly *Anchomanes diffonis* (Jaiyeoba 2008).

Iron pan vegetation is associated with layer of laterite found in the profiles of gullies, caping to small hills and as small escarpments. Several plant species mostly shrubs are associated with the occurrence of such laterite formation. These include: *Manotex kerstingii, Uapaca togoensis, Afronnosia laxifora, Parinari curatellifolia, pterocarpus erinaceus, Ficus spp, Diosyros mespilliformis, Detarium microcarpum, Combretum binderianium* etc (Jaiyeoba 2008)

Afforested vegetation in the Zaria is largely due to the deliberate planting of trees by government departments and private individuals (Jaiyeoba 2008). This vegetation is characterized by exotic tree species considered to be of better value than the indigenous ones either economically or interms of growth (Jaiyeoba 2008). Such trees include: *Daniellia Oliveri, Khaya senegalensis, Mangifera indica* and *Dalbergia sissoo* (Jaiyeoba 2008).

**Fauna**

There are several types of fauna in the Zaria area. These can broadly be classified into mammals, birds, insects and worms. About 370 species of birds have been identified in the area, of which 225 are residents including 145 migrant birds (Lewis 1970). The Zaria area is characterized by several habitat types such as freshwater lakes, rivers, seasonal streams, ponds, cultivated parklands, mature and degraded savannas, seasonally flooded wetlands locally known as *fadama*, gallery forests, inselbergs, reedbeds, urban semi urban and rural settlements which account for its rich faunal diversity (Ezealor 2008).

The study of the faunal diversity of the Zaria area has attracted considerable interests among scholars in the area as could be seen in the works of (Fry 1965, 1966, 1967; Skinner 1966; Skinner and Pettet 1970; Dyer 1977, and Ezealor 1984 in Ezealor 2008) which involved extensive survey and publication of checklists of the avifauna. Reed *et.al* (1967 in Ezeaor 2008) also listed fishes from Zaria while Umar (1989 in Ezealor 2008) made a check list of fishes probably caught around the Zaria area and sold in the Zaria Central Market. Others include: Elgood *et al*'s (1994 in Ezealor 2008) check list of the birds of Nigeria and Hapold's (1987) Mammals of Nigeria (in Ezealor 2008) in which birds and mammals of the Zaria area were mentioned.

A wide range of diversity of invertebrate has been identified in the Zaria area. These include some which are associated with human crops and livestock diseases such as agrotid moths (*sesamia calamistis)* and *S. Pinephaga* that destroy cereals, the bruchid beetle (*callosobruchus maculates*) that destroys cowpea (Booker 1967 in Ezealor 2008) and Tsetse flies (*Glossina spp*), the vector for *Trypanosomca spp* that cause sleeping

sickness in humans and nagana in ungulates (Ezealor 2008). Others are: Milestones (*Loranthacere*) (Bako 2001 in Ezealor 2008), the Tailor Ant (*Oecophylla longinoda*) (Booker 1961 in Ezealor 2008), the chironomid fly (Hinton 1966 in Ezealor 2008), *Culex Cladocera, Ostracoda copepoda*, grasshopper (*Zonocerus variegates*), crypsis, invertebrate parasites of economic importance such as twelve species of nematodes - *Haemonchrus contortus, H. placei, Trichostrogylus colubriformis, T. Capricola, Coopenia Cuticei, Galgeria pachycelis, Oesophagostomum coumbiamum, Trogyloides, Papillosus Trichurix ovis, T. globulosa, skrochinema ovis and Gongylonema verrucosum.*

Studies of aquatic ecosystems have also revealed abundant and diverse aquatic invertebrates which include the presence of *psychoda* and *pericoma* Culex species, *Chrironomus* and *Bulinus* in a polluted stream (Smith 1975 in Ezealor 2008), freshwater snails (Smith 1975 in Ezealor 2008), and 78 aquatic invertebrate species with a high number of Blackfly (*Simultum spp*) larvae which causes river blindness in river Galma (Mbah 1987 in Ezealor 2008).

The activities of the growing human population in the Zaria area have continued to pose serious threats to vertebrate animals (Ezealor 2008). These include: rodents (Ezealor 1984 in Ezealor 2008), Anaplectes weaver (*Anaplectes rubriceps*), Wahlberg's Eagle (*Aquila Wahlbergi*), Pied Crows (*Carvus albus*), Crawshay's Hare (*Lepus Crawshayi*) and Red-throated Bee eaters (*Merops bullocks*) breeding in the River Kubani Valley (Dyer 1979 in Ezealor 2008). Vertebrates such as Hares *(Lepus Crawshayi*), Squacco Herons (*Ardeola ralloides*), a common water bird of the area, three chameleon species, toads particularly (*Bufo spp*) and pigmy Blind Snake (*Leptotyphlops spp*) are also formed in the Zaria area (Ezealor 2008). The area is also associated with some

seasonal intra-continental migratory birds such as Abdim stock (*Ciconia abdimii*) and Grey Hornbill (*Tocus nasutus*) revered to throughout northern Nigeria as the "rain bird" (Ezealor 2008).

The presence of certain types of bird recently, in the Zaria area have led some environmentalists like Fry (1973 in Ezealor 2008) to suggest increasing aridity. These include: Black-headed plover (*Vanellus tectus*), Red-bellied Starling (*Lamprotornis pulcher*) cut-throat (*Amadina fasciata*), Melba-Flinch (*Phtilia melba*), White-billed Buffalo weaver (*Bubalornis albirostris*), Blue-napped mousebird (*Colius macrourus*) and European Turtle Dove (*Streptopelia tutur*) (Ezealor 2008). The occurrence of these birds is normally linked with the more northerly arid Sudan and Sahel savanna environments (Walker 1965, in Ezealor 2008).

**Environmental Depletion of the Zaria Area**

Historically, human modification of the natural environment of the Zaria area has been traced to the colonial and post colonial agrarian expansion policies aimed at increasing cultivation in order to increase revenue from agriculture (Jaiyeoba 2007). Consequently, the percentage of the land use of Zaria area in terms of crop production and animal grazing almost doubled between mid 70s and mid 90s (Jaiyeoba 2007). The discernible changes in the period were: increase in urban area, severe decline in savannah wood land, steady increase in the extent of flood plain agriculture, transition of previously forested areas into agricultural lands, prevalence of erosion/ bare soil in the 1980s, intensification of agricultural land use, application of chemical fertilizers and/or pesticides and introduction of new species into the area (Jaiyeoba 2007).

The modification of environment of the Zaria area has been attributed mainly to rapidly growing population and attendant higher demand for agricultural land, livestock production, fuel wood collection and poverty (Jaiyeoba 2007).

The exploitation of the natural environment has been considered as the most important means of sustenance of livelihood in the Zaria area which has resulted in environmental degradation that is visible in terms of deforestation, depletion of biological diversity, flooding and erosion, pollution, drought, urban decay and municipal waste disposal (Jaiyeoba 2007).

The most important factor for deforestation in the Zaria area has been identified as the high proportion of population dependent on farming and/or forest resources for livelihood (Jaiyeoba 2007). Presently, fuel wood is the main source of energy for cooking by over 80% of the population of the Zaria area (Jaiyeoba 2007). Other factors include: intensive grazing, persistent bush burning and reduction in or absence of fallow periods.

The depletion of the biodiversity of the Zaria area is caused by factors such as: indiscriminate felling of trees, bush burning and increased pressure from hunters resulting in the increased number of endangered species of plant and animals (Jaiyeoba 2007).

Flooding and erosion have been identified as a common phenomenon in the Zaria area resulting from high intensity rainfall and poor forest management (Jaiyeoba 2007). Pollution and urban decay and municipal waste are also important causes of environmental degradation in the Zaria area. Different types of pollution have been identified in the area. These are air and water pollution (Jaiyeoba 2007). The causes of air pollution include: dust, smoke and emission of toxic substances, while water pollution

is caused by metal fabrication, food processing and discharge of waste waters into streams and open drainages (Jaiyeoba 2007).

Industrial waste pollution is also increasingly becoming a major problem in the major population centres of the Zaria area (Jaiyeoba 2007) as evident in the flow of industrial waste into public drains and rivers. This environmental problem is created basically by defective waste disposal management in two main ways which are: incomplete collection of waste and improper handling of same whereby household and industrial wastes are handled together resulting in pollution of soil and ground water (UNEP 2000 in Jaiyeoba 2007).

Environmental degradation of the Zaria area is also caused by climatic variability and drought as could be seen in the annual variability in rainfall of between 15 and 20mm, which is quite common in the Zaria area (Jaiyeoba 2007). The area is also to some extent affected by the recurrent and sometimes intense and persistent drought conditions characteristic of the Sudan-Sahel zone (Jaiyeoba 2007).

## SOCIO-CULTURAL BACKGROUND

### Historical Background

Most historical works on the pre-colonial and colonial Zazzau kingdom feature issues relating to origin, chronicle of rulers, political system and administration, economic activities and relationship with other Hausa states.

Imporatant cities such as Birni Kano, Birni Katsina, Birni Zaria and Birni Sokoto were capitals of states which grew by the political and economic domination of smaller towns and settlements in the hinterland (Dhiliwayo 1986). One of the ways in which this

was achieved was by absorbtion and subjugation. In the case of Zaria, Kufena and Tukur-Tukur were the suburbs which were absorbed and subjugated (Dhiliwayo 1986). The crucial factor in the growth of precolonial cities in Hausaland was the development of crafts, commerce and trade which was better manifested in these capitals than the hinterland (Dhiliwayo 1986). The most important crafts were cloth making, leather working, smithing and pottery which were also well reflected in *Birni Zaria.* The growth of Birni Zaria has also been attributed to the presence of rich agricultural land with adequate rainfall for the production of crops such as cotton, groundnut, guineacorn and yam among others and man's ability to utilize his natural resources for the satisfaction of his needs as indicated by the developments of important crafts such as iron working and cloth making(Dhiliwayo 1986) The cities were important centres of commerce where the development of production of goods later led to the emergence of a distinct group of traders. Precolonial cities in Hausaland had contacts with one another and long distance markets (Dhiliwayo 1986).

Zazzau is the ancient name for Zaria, one of the seven Hausa Bakwai (true Hausa) states. Other names used were Zak Zak and Zeg Zeg (Smith 1960; Hogben and Kirk-Greene 1966; Kirk-Greene 1966). The people of Zaria are still called Zage-Zagi or Zazzagawa in Hausa language. Zaria chronicle identified sixty rulers of Habe Zazzau before the Fulani conquest of 1804. According to tradition, before their settlement in present day Zaria, the Hausa first settled at Kawar, Rikochi, Wuciciri and Turunku, (Smith 1960; Hogben and Kirk-Greene 1966; Kirk-Greene 1966; Smith 1976; Dhiliwayo 1986). The ruler of Turunku known as Bakwa Turunku later moved to Kufena. Several reasons are contained in different versions of oral tradition to explain the movement from

Turunku to Kufena. These include; the threat posed by Kargi and the need to secure a more defensible position, the necessity for settlement expansion and the quest for sustainable water supply to the people of Turunku (Dhiliwayo 1986). The archaeological investigation conducted by Sutton (1976d) seems to lay some credence to the temporal relationship between Turunku and Kufena. In it Sutton tentatively asserts that the ruins of Turunku are older than those at Kufena foothills (Dhiliwayo 1986). The Galma River was identified as the boundary between Turunku and Kargi (Hogben and Kirk-Greene 1966; Dhiliwayo 1986). Oral traditions also identified Bakwa, the 22nd ruler in the Zaria chronicle as a great ruler acclaimed to have liberated his people from the terrors of the kororofa (Jukun) invasions (Kirk-Greene 1966; Dhiliwayo 1986:)

The strong relationship that existed between Zaria and Turunku was evident from two perspectives. One, Zaria was named after the second daughter of Bakwa (Hogben and Kirk- Greene 1966; Kirk-Greene 1966 :) and two the local name *Gidan Bakwa* (the house of Bakwa) for the palace of the Emir of Zaria (Dhiliwayo 1986).

Several versions of oral traditions have tried to explain the location of Zaria in its present location. One was the claim of discovery of a suitable location for chief's compound by a hunter known as Bono and subsequent leading of people to a place between Madarkaci and Kufena (Dhiliwayo 1986). Another talked of the existence of a kingdom of Zegzeg formerly known as Kwangoma which existed in the 13th century, the economy of which was based on the exploitation of the alluvial gold. In the 16th century the centre of the kingdom was said to have shifted to Turunku. The same tradition noted that foreign merchants were resident in Zaria with Zaria ceasing to be an autonomous

merchant community in the 17th century due to domination by a local dynasty that was militarily strong yet closely linked to the new Hausa urban culture.

According to the king lists of Zaria, seventeen kings reigned before the mid 15th century with their seat of government probably at Kufena (Smith 1976). The eldest daughter, Amina said to have become the ruler of the Zazzau kingdom later in the 16th century, enlarged her domain by several conquests including those of the Nupe and the Jukun kingdoms and even made the powerful states of Kano and Katsina to pay tributes and was said to have built walled camps wherever she halted (Kirk-Greene 1966). There was however a decline in the fortune of Zazzau kingdom by the end of the 16th century, when it was again subjected to the control of the Bornu kingdom in the North east. The list of sixty rulers of Zazzau ended in 1804 when the last (Makau) was driven and a Fulani dynasty established in 1835 (Kirk-Greene 1966, Hogben and Kirk-Greene 1966).

**Economic Activities**

Historically, Zaria was an important commercial centre which functioned as a distribution centre. Apart from its own products such as shoes, slippers, long riding boats, saddles, skin, seats and other textile items (Dhiliwayo 1986), Zaria also handled distribution of products like kolanuts from Gwanja, glass and beads from Nupe area, gold dust from the south, tin products from Europe such as swords and silks (Dhiliwayo 1986). Notably, Zaria market was located where the caravans made their "tongas" or camps and also a duty collection centre (Dhiliwayo 1986).

Presently, Zaria is still an outstanding commercial centre associated with complex and highly diversified economic activities. One of these economic activities in the Zaria

area is farming. This involves the cultivation of a wide range of food and commercial crops. There are two main types of farm land in the Zaria area, upland fields known as "gona" and lowland fields known as "fadama" (Norman 1970). During the wet season when most farming activities take place, crops such as yam (*Discorea spp)*, cassava (*Manihot esculenta*), maize (*Zea mays*), beans (*Vigna unguiculata*), sorghum(*Sorghum bicolos*), groundnut(Aranchis hypogaea), tomato(*Lycopersicon esculentum*), pepper(*Capsicum annuum*), garden egg (*selanum incanum*), etc are cultivated. During dry season, farming is normally restricted to cultivation of sugar cane (*Saccharum officinarum*) pepper, tomato, spinach (*Amaranthes spinosis*), onion (*Alium cepa*) etc. Dry season farming is normally carried out in the Zaria area by means of irrigation along the banks of some Rivers. For instance, Mangut (1983) reports the practice of shadouf irrigation system along the bank of river Galma for dry season farming.

As earlier observed in our discussion of soils in the Zaria area in this chapter, the land fallow system is no longer prevalent in the Zaria area due to the pressure on the available farmlands as a result of growing population. Presently farmers in the area now depend more on application of manures and chemical fertilizers to enhance soil fertility. Hoes and cutlasses still remain the predominant agricultural tools used in the area, although the adoption of animal ploughing to augment the old system of cultivation is fastly gaining currency. In addition to the traditional farmers who form the majority, there are also pockets of large scale farmers who engage in mechanized farming. It can be observed that Zaria is a very big production centre of several agricultural produce and a major distribution centre to every part of Nigeria.

Rearing of animals is another important aspect of the economy of Zaria and its environs. Striking diversity in forms of animal husbandry and the people associated with it have been observed in the Zaria area (van Raay 1970). Stock owners in the Zaria area are broadly categorized into three- the nomadic stock owners (Bororo), semi-settled stock owners and settled stock owners (van Raay 1970). The Bororo nomadic stockowners speak Fulfude language and still adhere to their traditions and values (van Raay 1970). This group which lives in a state of perpetual wandering exhibits a division of labour in which men engage in herding while women undertake milking of cattle and preparation of food (van Raay 1970). The semi nomadic stockowners group is distinguished from the nomadic one by the location of a permanent homestead where the rest of the group normally joins them at the onset of rainy season (van Raay 1970). They exhibit similar characteristics with the nomadic stockowners. The semi-settled stockowners belong to a group that engages both in farming and livestock rearing with fixed habitats where they stay through out the year (van Raay 1970). This group exhibits several distinct characteristics from those earlier discussed in terms of speaking Hausa language and not taking part in the traditions of others (van Raay 1970). The movements of this group out of their localities southwards normally take place around January and February with return before the start of rainy season (van Raay 1970). The settled stock owners are those who maintain a permanent contact with their homesteads (van Raay 1970). These are in two categories: One category are farmers who often group the livestock in a few herds and taking them out daily for grazing (van Raay 1970), while the second belongs to stockowners who hire others to take care of their stock for them (Van Raay 1970). These are the rich people who have the tendency to convert wealth to livestock especially cattle

(van Raay 1970). The herdsmen employed under this arrangement are normally paid either in cash or kind (Van Raay 1970). The importance of livestock keeping in the ecoomy of the Zaria area is multi dimensional. These include: provision of wealth for stockowners, supply of products like milk, meat, hides and skins and enhancing soil fertility for farming, etc. In addition to cattle rearing, several livestock are also reared in the Zaria area such as goats, sheep, pigs, camels, asses, donkeys, domestic and guinea fowls, ducks, pigeons, turkeys etc.

Zaria being an important centre for traditional arts and crafts such as weaving, blacksmithing, dyeing, tanning and pottery is associated with a wide range of products which are also contributory to the economy of the Zaria area. Apart from these, trades like metal welding, carpentry, masonry, plumbing, electrical works, auto electrical works, etc are also important contributors to the economy of the Zaria area.

A number of companies are located in Zaria. They engage in the production of items such as cigarettes, cosmetics, water packaging, agro allied and pharmaceuticals.

The location of Zaria on the major north-south road and rail line has been an important factor in its growth as a major commercial centre (Davies 1970). However, presently, train services are virtually non-existent in the Zaria area- a situation which is similar to what happen in other parts of Nigeria.

The relationship between Zaria and its surrounding communities is that between the urban area and rural markets (Davies 1970). The dominance of the Zaria markets is indisputable with a complex relationship existing between the Zaria markets and those of the rural areas. The urban markets are normally the first to visist for all requirements by

the rural populations and the ultimate when the rural ones cannot supply them (Davies 1970).

White collar jobs are also an important aspect of the economy of Zaria and its environs. As earlier indicted, Zaria is a major educational centre with several educational institutions. In addition to these are non-educational establishments such as the Nigeria Railway Corporation, Power Holding Company of Nigeria, British American Tobacco Company, Zaria Pharmaceutical Company, Sun Seed Company, Private Health Centres and a number of banks as earlier mentioned. The earnings of workers in these establishments are very significant to the quantum of income of the people in the Zaria area in terms of its multiplier effects.

**Social Amenities**

Medical and health services in the Zaria area are provided by Federal, State, Local Governments and Private Organizations (Mamman and Laah 2008), while the area has also witnessed a growing patronage of traditional medical practitioners due to scarcity of orthodox health institutions and facilities and inefficiency of the available ones (Silas 2000 in Mamman and Laah 2008). Emphasis of Health care delivery in the area is more on preventive as indicated in community health care, environmental and personal hygiene, and immunization of children against childhood killer diseases such as polio myelithis, tuberculosis, whooping cough, measles, cerebro-spinal meningitis and yellow fever (Mamman and Laah 2008). The largest and most important Hospital is the Ahmadu Bello University Teaching Hospital Shika, located about 20km west of Zaria. The influence of this hospital extends to virtually every part of Nigeria as patients from

different parts of the country seek for medcial treatment there. The establishment of the Zaria pharmaceutical Company is also noteworthy in the health care delivery in Zaria area.

Zaria is one of the Nigerian cities with largest concentrations of educational institutions. The importance of Zaria in the field of education is most obvious (van Raay 1970). The educational institutions in the Zaria area are owned by Federal, state, and private concerns. The Ahmadu Belo University, Zaria is the largest in the area. Others include: Nigeria College of Aviation Technology, National Institute for Transport Technology, National Research Institute for Chemical Technology, Leather Research Institute, Federal College of Education, Nuhu Bamali Polytechnic and several primary and secondary schools. Zaria has been described as the educational giant of Northern Nigeria (van Raay 1970). This appellation derives from a set of favourable conditions resulting from Zaria's long history as political, religious and educational centre (van Raay 1970). The position of Zaria as a provincial capital with the advent of colonial administration, its central location in northern Nigeria and ready accessibility from all directions, pleasant temperature regime and the serenity of the surrounding country side (van Raay 1970) are some of the factors that have made Zaria an educational nerve centre of Northern Nigeria.

The provision of electricity is mainly by the Power Holding Company of Nigeria, majorly owned by the Federal Government of Nigeria. The epileptic services of this company in the area have resulted in many people making private arrangements for power supply by using power generating sets. The supply of pipe-borne water to the Zaria area is carried out by the Kaduna State Water Corporation. The services of this

government owned company however appear to be confined to the Zaria metropolis, while some arrangements in form of provision of wells and bore holes may be put in place for the surrounding communities.

In terms of transportation, as earlier indicated, Zaria has fairly impressive road networks linking it to all parts of Nigeria. The rail lines also connect Zaria to the far North, South east and west, though this transportation system has become moribund for some time now.

The commercial needs of Zaria and its environs are attended to by a number of banks located within the metropolis. Notable among these are the First Bank of Nigeria Plc., Union Bank of Nigeria Plc., United Bank for Africa Plc. Intercontinental Bank Plc, Oceanic Bank Plc, Zenith Bank Plc., Bank PHB, Diamond Bank Plc, Afribank Plc, United Bank Plc, and Guarantee Trust Bank Plc. We observe that recently there seems to be a noticeable increase in the presence of Banks in Zaria apparently apparently to cope with the increasing commercial activities in the area.

The maintenance of law and order and provision of security are taken care of by the presence of two Army formations; the Nigeria School of Military Police, Bassawa, located in the North West suburb of Zaria and the Nigerian Army Depot in Sabon-Gari, Zaria. Several Police Stations are also sited in the area in addition to para-military commands such as the Nigeria Civil Defence Corps, Federal Road Safety Corps, Nigeria Immigration Service, Nigeria Prison Service, State Security Service, Nigeria Customs and National Drug Law Enforcement Agency. There are also several courts located in the Zaria area to adjudicate in disputes. The highest courts in the area are High Courts owned by the Kaduna State Government. There are also magistrate customary and Sharia

courts. Customary and Sharia courts were established to adjudicate in disputes involving Christian and Muslim litigants respectively.

As an important political, commercial and educational centre in northern Nigeria, Zaria is also associated with a number of telecommunication service providers. These are: MTN Nigeria, GLOBACOM Nigeria, VISAFONE Nigeria, ZAIN Nigeria, STARCOMMS Nigeria, MULTILINKS Nigeria, INTERCELLULAR Nigeria and ETISALAT Nigeria. The upsurge in the provision of telecommunication services in Zaria has undoubtedly enhanced commercial activities and social interactions among the people in the area.

**Population, Ethnic Groups and Beliefs**

Based on the 1991 Nigeria National Population Census, the Zaria area has a population of 1,364,942, comprising 708, 456 males (51.90%) and 656, 486 females (48.10%) (NPC1998 in Mamman and Laah 2008). The breakdown of the population figures in the six local Government Areas in existence in the Zaria area in 1991 is as follows: Giwa-171,061(12.5%), Igabi-308,239(22.6%), Makarfi-203,040(14.9%), Sabon-Gari-224,067(16.4%), Soba-174,217(12.8%) and Zaria-284,318(20.8%). with the largest land area has 22.6% of the total population of the Zaria area, Zaria (20.8%), Sabon-Gari (16.4%), Makarfi (14.9%), Soba (12.8%), Giwa (12.5%) of the total population of the Zaria area.

The age structure of the population of Zaria area is similar to any other part of Nigeria (Mamman and Laah 2008). It is characterized by high proportion of the young with about 44% 14 years and below, those between the ages of 14 and 64 years are about

53% with 65 years and above constituting about 3% of the total population (Mamman and Laah 2008). In terms of total figures, males are higher in number than females in the Zaria area as earlier seen, a phenomenon attributed to factors such as high maternal mortality and sex-selective nature of migration specifically in Sabon-Gari local Government Area (Mamman and Laah 2008).

The average population density of the Zaria area in 1991 was 153 persons per square kilometer which however varies from one local Government Area to another (Mamman and Laah 2008). The population density of the Zaria area exhibits three patterns: sparsely populated areas with less than 100 persons per $km^2$, moderately populated areas with densities of between 100-500 persons per $km^2$ and densely populated areas with densely populated areas with densities of over 500 persons per $km^2$ (MOEFED 1996 in Mamman and Laah 2008). The densely populated areas are Zaria and Sabon-Gari which is attributable to historical, cultural, administrative, religious and economic factors while the sparse populations identified in Soba, Giwa and Igabi Local Government Areas have been attributed to their rural nature and absence of economic activities that can attract people (Mamman and Laah 2008).

The 2006 census shows that the population of Zaria area is 1,859,232 (NPC 2009; Federal republic of Nigeria Official Gazette, Vol.96, No2 2009). This figure comprises 941,470 males and 917,762 females which constitute 50.64% and 49.36% respectively. The breakdown of the total population according to the six Local Government Areas (as earlier indicated) is as follows: Giwa-292,384 (15.74%), Igabi-430,753 (23.17%), Makarfi-146,574 (7.89%), Sabon-Gari-291,358 (15.67%), Soba-291,173 (15.66%) and

Zaria-406,990 (21.89%). The 2006 population figure of Zaria area shows an increase of 494,290 which is (36.21%) over that of 1991.

Although details of the structures of the 2006 population figures are yet to be released, it appears the trends may not be significantly different from those observed in 1991. This is because the Zaria area has not experienced any major occurrences such as mass migration from rural to urban or urban to rural area, mass deaths as a result of natural disasters and/or wars that are capable of radically changing the demographic structures recorded in the 1991 census (Dr Laah 2009, pers.com). An observation of the current population figure of the Zaria area, though devoid of information on aspects like age structures, population densities etc, still exhibits a pattern that is akin to that of 1991. For instance it could be seen that the population of males is still higher than that of females-a pattern that is similar to that of 1991.

Zaria and its environs are pluralistic in terms of ethnic composition with the Hausa as the dominant ethnic group (Mamman and Laah 2008). Other major ethnic groups include: the Fulani, Beri Beri, Yoruba, Igbo and Northern minority groups like the Kataf, Ninzan, Koro, Kagoro, Kagoma, Jaba, Kanikon, Kadara, Ikulu, Kaje, Tiv, Jukun, Nupe, Birom, Gwari etc. and southern minorities such as Ibibio, Efik, Ijaw, Itsekiri, Bini etc. (Mamman and Laah 2008). The main medium of communication in the area is Hausa language, while English is used as medium of communication among the elites. Though Arabic is taught in koranic schools, it is not a medium of communication in the Zaria area (Mamman and Laah 2008).

Islam and Christianity are the main religious in the Zaria area and the Hausa, are predominantly Muslims mostly found in the old walled settlement known as Zaria City

with spill over in Tundun Wada which is located at the north east outskirt of Zaria city. More than 50% of the population of Zaria and its environs are Muslims (Mamman and Laah 2008). We observe that Christianity is the dominant religion among the non-Hausa ethnic groups in the area as indicated by the presence of several churches in Sabon-Gari, Samaru and the suburbs of Zaria. There are also practitioners of traditional religion (Mamman and Laah 2008).

The adherents of the two main religions normally celebrate their festivals at stipulated periods. The Christian religious festivals are Christmas, New Year and Easter which are observed on 25th December, 1st January and between March and April respectively. The Muslim festivals are Fitri, Kabir and Mauloud.

The people of Zaria and its environs are well known for their traditional 'durbar" normally organized by the Zaria Emirate to celebrate religious festivals and commemorate turbaning of traditional title holders and visits of dignitaries from within and outside the country. The Durbar is normally associated with spectacular display of regalia and horsemanship to add colour, pomp and pageantry to the celebration in question (Mamman and Laah 2008). The Durbar also provides opportunity for traditional title holders and political leaders to discuss important matters relating to the progress of the area (Mamman and Laah 2008)

In addition, personal observation also shows that Zaria is popular for its wide range of traditional arts and crafts such as leather works, blacksmithing, cloth weaving, dyeing, pottery, traditional barbing, circumcision and architecture though most of these are presently in state of decline due to modernization.

# CHAPTER THREE

# LITERATURE REVIEW

## Introduction

This chapter undertakes a review of some studies on early iron technology by focusing on the continental, regional and local perspectives of such investigations. The first part focuses on the various views regarding the origin of iron technology which have continued to influence archaeological investigations of iron working on the continent and how these have directed the courses of various researches on the subject over time, while the second part addresses the process of iron smelting while the third looks at the types of material evidence of iron smelting and its significance in the study of early iron smelting technology.

## Early Ideas about Iron

The earliest source of iron used by man to fashion his implements was from meteorites (Trigger 1969; Tylecote 1980; Okafor 1992; Mapunda 1995. The Quran even alludes to the first use of meteoric iron by humans when it states that "and we sent down iron in which has incredible strength and many benefits for mankind" (Hummel 2003)

The use of meteoric iron was however limited before the beginning of iron smelting. The first sign of this was in ancient Egypt and Summer in 4000BC when small objects like; tips of spears and ornaments were produced from meteorite iron. The use of meteorites at the period appeared to be ceremonial as iron from this source was more expensive than gold as indicated by the Hittites' trading of iron for silver by barter with Assyria at the rate of forty times the weight of iron (Hummel 2003).

Despite the use of meteoric iron, the Iron Age was believed not to have commenced until man developed the capacity to produce iron from ores due to lack of occurrence of meteorites in sufficient quantity and the difficulty of forging the pieces into desired implements (Tylecote 1986; Okafor 1992).

**The Schools of Thought on the Origin of Iron Metallurgy**

Perhaps the most controversial of the issues in the studies of iron technology is that of origin which has continued to engage the attention of scholars and to a large extent determined the pattern and results of their investigations. Traditionally, the "home" of iron metallurgy has been traced to the Near East. Archeological research into early iron metallurgy has shown that the oldest iron artifacts came from the Near East. Excavations at the site of Samarra in Northern Iraq produced "a four-sided instrument" about 4.3cm in length from a grave and dated to about 5000B.C while the site of Tepe Sialk in Northern Iran has yielded three small almost spherical balls form a habitation level and dated to between 4600 and 4100BC (Waldbaun 1980; Mapunda 1995). The nickel content analyses of some of these iron objects aimed at determining whether they were produced from smelted or meteoritic iron indicated that the object from the site of Samarra was smelted and that from Tepe Sialk was from meteoritic iron (Waldbaun 1980).

While Iron smelting is thought to have begun about seven millennia ago in the Near East, the Iron Age however did not start there until about four millennia afterwards when iron was no longer considered as a luxury but became accepted as the predominant material for fashioning tools and weapons. The Iron Age first flourished in the Near East at about the $10^{th}$ century BC in a vast region from Greece to the Levantine coast, around the $7^{th}$ century, later in Europe and area farther to the east (Waldbaun 1980)

On the other hand, archaeological investigations on the Iron Age of Africa indicates that the earliest iron objects discovered in the continent are meteoritic from the sites of El Gerzeh and Armant in Egypt where nine beads and a ring have been discovered respectively and dated to between 3500 and 3100BC (Waldbaun1980). Earliest evidence of iron smelting in Africa has also been traced to Egypt where finds from the sites of Giza and Abydos have been dated to the Fourth Dynasty (ca2565-2440B.C) and the Sixth Dynasty (ca2345-2181B.C) respectively (Waldbaun 1980). However, Snodgrass (1980) observes that iron production was irregular in Egypt until the seventh century B.C. apparently because the earliest source of iron there before that time was meteoritic.

**The Diffusionist School of Thought**

The earliest phase of archaeological investigations into iron metallurgy in Africa was dominated by the issue of origin. In an attempt to unravel the origin of iron technology in Africa, external source was most often postulated. This diffusion school of thought was predicated on the notion that since iron working involved a highly complex technical process; it could not have originated from more than a single centre from where it eventually diffused to other parts of the world.

The belief of the diffusion school is hinged on the claim that in order for iron metallurgy (which was a complex technology) to develop, it must be preceded by a less complex, lower temperature pyrotechnology such as those of the production of copper, lead, tin, glass, cement and/or kiln-fired pottery and terracotta (Wertime 1980; Kense 1985; Kense and Okoro 1993). The scholars in this school further argued that iron technology would have emerged from the use of iron ores as fluxes as in the smelting of

copper and lead which could have made the smelters acquainted with kilns, bellows and fluxes used for iron smelting. According to this school of thought, Sub- Saharan Africa could not have developed iron technology independently because it has no conclusive evidence for non- ferrous pyrotechnologies predating iron metallurgy (Kense 1985; Phillipson 1985).

The diffusionist school was basically predicated on two theories: the Carthagenian and the Meroetic theories. The Carthagenian theory was propounded by a French Africanist, Raymond Mauny who came up with a view that iron metallurgy was possibly transmitted to western Africa south of the Sahara desert (Alpern 2005). His view was basically rested on the claim that by 1100 BCE, the Phoenians had acquired common knowledge of iron working, while about the same time they had started exploring and colonizing the western mediterianean (Alpern 2005). Raymond Mauny (1952 in Alpern 2005) also posits that although it is a possibility that the Phoenicians had brought their knowledge of iron metallurgy, iron was not discovered in Carthagenian tombs before the sixth century BCE (Alpern 2005). Mauny's (1952 in Alpern 2005) theory was further based on the speculation that Carthage which was founded in 814 BCE passed its knowledge of iron metallurgy to the Berber natives of the area around the sixth century BCE who in turn transmitted it to their fellow Berbers in the sahara who would have been eager to acquire such weapons since they were warriors (Alpern 2005). According to Mauny (1952 in Alpern 2005), the intermediaries for the transmission of the iron working were likely to be the black slaves who the southern Berbers used to carry out the laborious task. Further Raymond Mauny (1952 in Alpern 2005) argued that the iron technology could then have been transmitted south to savanna zone possibly by either

fleeing slaves or by deliberate diffusion to the lands of black farmers where there was abundance of iron ore especially laterite and word fuel in iron smelting (Alpen 2005). This supposed transmission of iron knowledge has been dated to 300 BCE (Mauny 1952 in Alpern 2005).

Some of the proponents of the Carthagenian theory (Sasson 1963; Phillipson 1985) also believed that the route from Carthage across the Sahara to West Africa was the most probable for the transmission of iron technology. They posited that knowledge of iron metallurgy was brought to the Mediterranean by the Phoenicians around 1000 B.C and that by the sixth century B .C, the Berbers of North Africa who must have learnt the technology from the Carthaginians were establishing themselves south of the Sahara at that period and iron smelting would have reached the southern part of the Sahara during the first few centuries (Sasson 1963).

Linguistic evidence has also been put forward by Raymond Mauny (1952 in Alpen 2005) to strengthen his thesis that iron diffused to West Africa from Carthage. He argued that words used for iron that are similar to the Phoenician word for iron "barzel" occur in Berber vocabularies throughout the Sahara and also in the Teda language of Tibesti and Fezzan (Mauny 1952 in Alpern 2005). Mauny further observed some similarities in the terms used for iron among many black peoples living in the savannah such as Bariba, Jukun and Kanuri (Mauny 1952 in Alpern 2005).

One of the main critics of Mauny's (1952) Carthagenian theory was Henri Lhote (1952 in Alpern 2005) who criticized Mauny on the basic issues that the theory was predicated. He had argued that the Saharan Berbers are not metallurgists and were therefore not capable of the blacks iron working (Lhote 1982 in Alpern 2005). In

addition the words for iron derived from the punic root "bizl" generally stop before the areas occupied by blacks (Lhote 1952 in Alpern 2005). Also the characteristically high smelting furnaces found in West Africa do not exist north of the linguistic/racial extent, while the goatskin bellows of northern Africa do not generally occur in the south of the linguistic/racial divide (Lhote 1952 in Alpern 2005). The occurrence of different local words for iron among the sub-saharan blacks suggests that their knowledge of iron working must have come from different sources rather than thorough the Berbers or the Egyptians (Lhote 1952, in Alpern 2005). The array of evidence available such as ethnographic, archaeological, linguistic and historical, Lhote (1952) argued are indicative of the 'African' character of the iron industry in the black world. An attempt to 'salvage' the carthagerian theory led Raymond Mauny (1953 in Alpern 2005) to advance some counter-arguments against Lhote's (1952) critique. These are: that the lack of evidence for iron smelting in the sahara was not unexpected, both iron ore and wood for charcoal fuel are scarce except below the southern limit of the desert about $16^0$N (Mauny 1953 in Alpern 2005) and whatever available timber must have been quickly exhausted with few traces of iron working left. As nomads, the Saharan Berbers would require much less iron than settled black farmers occupying the south (Mauny 1953 in Alpern 2005), Linguistically, Mauny (1953) further argued that the prevalence of several words for iron in West Africa reflects the conducive environment for iron in terms of abundance of ores, fuel and markets. Mauny further argued that one of the most efficient methods possibly adopted by the ancestors of the Berber Tuareg was to transmit iron working from neighbour to neighbour and from the Mediterranean shores to the edge of the black world (Mauny 1953 in Alpern 2005).

Despite the emergence of evidence for Punic iron working at Carthage in the late 1970s, Mauny's theory hardly attracted much attention among Africanists (Alpern 2005). In 1975, an archaeological investigation aimed at searching for evidence of metal working at Punic Carthage on the slopes of Brysa Hill, started with a team of French archaeologists headed by Serge Lancel (1977 in Alpern 2005). The discovery of evidence of iron working by the team in form of slag, charcoal, tuyere fragments and furnace parts was dated by Serge Lancel *et al* (1977 in Alpern 2005) to the third century BCE. Follow up excavations by the French team led to the discovery of several similar workshops which Lancel (1982) has suggested to be indicative of a iron smelting (Lancel 1982 in Alpern 2005). Further evidence of iron working has been found by the 1980s by some German archaeologists who discovered much older proof of iron working in a location between Byrsa Hill and the nearby coast of the Mediterranean. A spectacular discovery of a complete "artisanal quarter" dated to the eight century BCE was made which included large quantity of iron slage, furnaces tuyeres and buried earth (Rakob 1988 in Alpern 2005).

Though the various archaeological discoveries made at Carthage seemed to lay some credence to Raymond Mauny's (1952) Carthagenian theory, the report on the analysis of slag samples by a German geochemist, Ingo Keesmann in 2002 dealt another blow to it. He had reported that all analysed slag samples showed iron smithing not smelting (Keesmann 2002 in Alpern 2005). In assessing the available evidence concerning iron diffusion across the Sahara in the first millennium BCE, Holl (2000 in Alpern 2005) argued that there was no concrete proof.

The discovery of what has been known as the "chariot roads" in the Saharan rock art is also important in the evaluation of the Carthagenian theory the occurrence of several paintings and engravings of horse-drawn chariots, oxcarts and wagons have been discovered in the Saharan rock art was used by Raymond Mauny, Henri Lhote and others to argue for the existence of prehistoric trans-saharan routes (Alpern 2005). According to Mauny (1978 in Alpern 2005), the rock art indicating the chariot routes was not indiscriminately distributed, with a few exceptions it is grouped into two relatively narrow bands across the Sahara. One of which was from the Fezzan in Libya toward Gao on the Niger river while the older one ran from Morocco toward the Timbuku area farther up the Niger. The designs of the horse-drawn chariots and men figures that accompany them have been seen as very significant in any attempt to understand metallurgical origins in the sub-saharan Africa because the chariots likely contained metal parts and because of the representation of possible metal heads on Javelins, lances and daggers (Alpern 2005). The Rock art of the Sahara also showed the North Africans known as Libyco-Berbers. These are men shown as warriors with Javelins or lances and sometimes with a dagger attached to the left arm together with a shield usually round or rectangular (Alpern 2005). The discovery of evidence linking the Libyco-Berbers and their horses and chariots with the use of metal within a specific period was made by two French researchers (Alpern 2005). Jean-Pierre Roset discovered a site located along a Wadi called Iwelen north of Air nearly 200 miles (320 km) north of Agadez, while he and a colleague, Francois Paris visited Iwelen several times (Alpern 2005). The Iwelen evidence shows remains of two small settlements associated with hundreds of rock engravings and about sixty burial mounds (Cornevin 1993 in Alpern 2005). Many of the

engravings show variation of Libyco-Berber warrior always brandishing along spear or lance usually with a leaf-shaped head and sometimes with a shield (Cornevin 1993 in Alpern 2005) what looked like a horse-drawn chariots also found at Iwelen (Cornevin 1973 in Alpern 2005). Charcoal from heartus in the settlement areas of the site of Iwelen was radio carbon dated to 910-790 BCE (Roset 1990 in Alpern 2005). Based on the evidence discovered at Iwelen it has been suggested that iron technology may have been eventually transmitted from the Agadez area in the north (Alpern 2005).

An important archaeological evidence of occurrence of iron with copper dated to the second half of the first millennium CE was discovered at the site of Marandet, south west of Agadez at the foot of the Tigidit Cliff. The discovery at this site is unique because of the presence of several small ancient metallurgical crucibles numbering close to 2000,000 (Grebenart 1985 in Alpern 2005).

In 1972, an archaeological discovery at the site of Do Dimmi revealed some bases of small shaft furnaces and charcoal with an uncalibrated radio carbon date of 678 ± 120 BCE. The date was then the earliest in sub-saharan Africa. The subsequent calibrated date of the evidence was placed between 1126-606 BCE at two stigma level. The date was however accepted with the suggestion that the wood might have already been old when used for charcoal (Posnansky and McIntosh 1976 in Alpern 2005). The calibrated range of the date was later corrected to between 1030 – 580 BCE considered as too early (Quechon and Roset 1974 in Alpern 2005). Subsequently, the site of Do Dimmi yielded a dozen more radio cabon dates for the occurrence of copper and iron at the site which fall to a period before 1350 BCE. This site was said to have indicated evidence of mastery of iron technology between 3500 and 3000 Bp (Quechon 1996 in Alpern 2005).

The site of Do Dimmi further produced five dates in 1989 which indicate that iron ore was smelter there between 1000 and 500 BCE which was later reduced to 800 BCE (Alpern 2005).

Six calibrated dates of potsherds and metal objects ranging from 1673-1421 to 1257-901 BCE (Alpern 2005) have been produced from Termit sites. Based on the datings of the potsherds and charcoal from five Termit sites, it was concluded that the early dates from Termit exclude a Mediterranean or Meroitic origin of iron working in sub-saharan Africa with possibility of independent invention (Alpern 2005).

From the above harvests of dates obtained from some archaeological sites in north Africa, the supposed route of iron transmission from Carthage to West Africa, we observe that in most cases, the dates are either older than or contemporaneous with the 814 BCE date which Raymond Mauny (1952 in Alpern 2005) gave for the establishment of Carthage. The implication of this is that Carthage was not likely the source of iron working transmission to West Africa through North Africa as posited by Raymond Mauny. The evidence from the sites of Do Dimmi, Termit and Iwelen especially are strongly indicative of multi-foci sources of iron working knowledge or pockets of areas of independent development.

The importance of Meroe as an iron working centre was first recognized by Sayce (1912 in Shinnie 1985). However his report which was largely based on the occurrence of several mounds of iron slag at Meroe was considered inaccurate (Shinnie 1983). Subsequent visit by Arkell in 1940 yielded more information which was published by Wainwright (Shinnie 1985).

The view that Meroe was the source of diffusion of iron working to other parts of Africa was however first expressed in detail by Wainwright (1945 in Shinnie 1971). Based on the notion that since Meroe was working iron on a large scale at the period when its use was apparently unknown further south or west, there is a possibility that the knowledge was transmitted from there (Shinnie 1971). Several iron smelting centres have been known in the Sudan of which Meroe is the most important (Shinnie 1971) Meroe which was apparently occupied by the ruling house of Napata at about sixth century BC appeared to have been inhabited from 750 BC to as late as te fourth century AD and possibly later (Shinnie 1971). The occurrence of large number of iron slag mounds at Meroe has attracted the attention of visitors which has led to the view that it was the centre from where the techniques of iron working spread to other parts of Africa (Shinnie 1971). Sayce's (1912) description of Meroe as "the Birmingham of ancient Africa", which was obviously predicated on the mounds of iron slag was also important as one of the views used to portray the significance of Meroe in the dissemination of knowledge of iron working to Africa. In addition, the meroetic view was supported by the supposition that Meroe was not only a centre of diffusion of iron working, but also a source of some less tangible influences such as state formation and divine kingship (Shinnie 1967 in Shinnie 1971). Arkell (1961 in Shinnie 1971), one of the proponents of the meroetic theory also reported that the occurrence of pottery that exhibit meroetic characteristics on the surface of some mounds located south of the White Nile which he investigated (Shinnie 1971).

The criticisms of the supposed role of Meroe in the diffusion of iron working to the rest of Africa have come from different sources. For instance Shinnie (1971) has

observed that there is no archaeological evidence supportive of that claim on the grounds that with the exception of the Island of Meroe, no objects or monuments of the meroetic culture have been found up to the Blue Nile at least as far as Sennar. He further contended that there is no proven archaeological evidence either from Meroe or pharaoh Egypt to suggest wide scale diffusion of techniques, concepts or material that could lay credence to the meroetic view (Shinnie 1971). One very important criticism of the Meroetic view was advanced by Tylecote (1970). Based on his metallurgical analysis of iron slag from meroe, he contended that the numerous mounds of iron slag found at Meroe were not truly reflective of the scale of iron working there and that the technique of iron smelting at Meroe was inefficient, which was responsible for the extraction of a small percentage of iron from the smelted ore while the rest was lost as iron slag.

**The Independent School of Thought**

The independent school of thought later emerged as a natural reaction to the claim of external origin by the diffusionists. Its protagonists believed that iron metallurgy must have developed independently in Sub- Saharan Africa, based on some reasons. One of these arguments is that there is no evidence whatsoever to trace the origin of iron working in Sub- Saharan Africa to an external source. Lhote (1952) for instance observes a total lack of evidence for early iron working among the Saharan Berbers and on that basis argues that iron technology was independently developed in Sub- Saharan Africa. Diop (1968) and Keteku (1987) also hold that iron metallurgy was independently developed in Africa. Based on the consideration of the early dates of 350 B.C from the iron working sites at Nok, Diop (1968) concludes that there was no reason why the Negroes should not have discovered how to work iron by themselves. In the same vein,

Rustard (1980) also supports the independent school of thought by arguing that "the emergence of iron technology in the Nok culture cannot be explained by diffusion from Meroe. Further it is highly unlikely that Carthage was a source of knowledge about iron for the participants in the Nok culture. Therefore in the absence of evidence to the contrary, iron technology may be considered an autochthonous development in the Nok area or culture".

Another ground for debunking the external origin model is the lack of affinity between the iron metallurgies of Sub- Saharan Africa and Eastern Mediterranean. As argued by Andah (1979), the most informative criterion to determine the diffusion of iron technology in space would be similarities between the 'donor' and the 'recipient' technologies and since this is absent, there is no basis for tracing the origin of iron technology in Sub- Saharan Africa to external source. Schmidt (1983) shares the same view who, based on iron smelting technologies at Kagera region of North west Tanzania and Taruga in Nigeria argues that iron metallurgies at the two sites are so distinct from what is known from Europe or the Middle East and that the most reasonable hypothesis to explain the origins of the preheated smelting technology is an independent invention in Africa.

The view of the autochthonous school of thought has been further buttressed by the impressive and highly diversified nature of iron technology in Sub- Saharan Africa which have led the adherents (Schmidt 1981, 1983; Schmidt and Avery 1978; Okpoko 1987; David *et al* 1989) to believe that the African iron workers were not mere copyists of a foreign technology but authors of theirs. Based on the evidence of iron smelting at the site of Mafa in North Cameroon, Nicholas David and his associates observed that

because there is no record of such techniques in use anywhere else, local invention is implied (David *et al* 1989).

The discovery of some archaeological evidence for early copper working have posed a serious challenge to one of the arguments of the diffusion school of thought which has been based on the absence of a preceding non-ferrous technological tradition in Sub- Saharan Africa. With the date of 1000 B.C being the reexamined date for early copper smelting, it can still be argued that copper working preceded iron metallurgy for three to four centuries when the sixth century B.C dates from Taruga and Nsukka Division are taken into cognizance (Tylecote 1975; Okafor and Phillips 1992; Okafor 1992). The dates of between 1950AD and 8$^{th}$ century B.C obtained by Okafor (1992) from Nsukka Division of South Eastern Nigeria is particularly significant as it has compelled a rethinking of the antiquity of early iron smelting technology in the Nigeria area. Dates of between 1715±35 and 4005±40 recently obtained from the site of Lejja in Nsukka Division of South East Nigeria (Eze-Uzomaka 2009) which seem to indicate that the antiquity of iron smelting is over 2000 years in the Nigerian area however appear to be associated with some skepticism.

In addition, the Independent School of thought holds that the universal application of the pyrotechnologies hypothesis is untenable as an explanation for the origin of iron technology in Africa south of the Sahara. According to Diop (1974 in Alpern 2005)) and Andah (1979), the application of this model in Sub- Saharan Africa is tantamount to the importation of western models which do not work because their cultural and ecological background are different from that of Sub-Saharan Africa. On the grounds that iron ores are more abundant in Sub- Saharan Africa, and more recognizable than copper and tin,

Andah (1979) argues that "iron metallurgy could have begun without passing through copper and bronze working or even preceded copper and bronze working. Moreover in different parts of this region, the beginning of the Iron Age may have been characterized by the working of different forms of iron ore by different methods (such as experimenting with meteoric iron)"

Andah (1981) has further challenged the external origin model by considering it as another version of the 'Hamitic myth' which was aimed at demonstrating the superiority of the white race over the blacks. He observes that it is incorrect to always ascribe ideas and peoples usually from the north across the Sahara as having stimulated or generated important prehistoric developments like food production, iron technology and copper working in West Africa.

**The Cautious School of Thought**

The third view known as the cautious school of thought on the origin of iron working in Africa is currently gaining currency among Africanist Scholars. It is a reflection of the view of scholars who believe that our current knowledge of iron working in Africa is still not sufficient for a precise position to be adopted on whether it diffused or was independently invented. Essentially this school of thought represents a mid-way approach between the two extreme views that have dominated thinking on the origin of iron technology in Africa: the diffusionist and the autochthonous invention. Interestingly, the main proponents of these two schools such as Andah (1979) and Phillipson (1985) who though to some extent had supported the independent school have also expressed their belief that more studies are required before a firm position can be adopted on the issue. As Andah (1979) opines, not enough is yet known about when, with whom and

how iron technology began in West Africa for any one to assert that it diffused from outside. In similar vein, Phillipson (1985) also posits that the knowledge can no longer be assumed to have been transmitted to West Africa from the North, the most probable explanation are either that it was a local invention based on earlier copper smelting technology or that the relevant technology was transmitted from North Africa, the confirmation of which will have to await the recovery of detaild evidence of the smelting techniques practised in the two areas. Africanist scholars namely Okafor (1993), Mapunda (1995), Woodhouse (1998 in Alpern 2005), Killick (2004 in Alpern 2005) and Herbert (2005 in Alpern 2005) can rightly be categorized as belonging to the cautious school of thought.

A close observation of the views of some Africanists in the cautious school of thought suggests two slightly different views. These are what we may term as "cautious skepticism" and "cautious optimism". The cautious skeptics are those Africanists who believe that the level of research on the issue of origin of iron technology in Africa is outrightly of no value to warrant any reasonable deductions to be made. One of those who hold this view is David Killick (2004 in Alpern 2005:93)) who opined that the quality of evidence assembled up to now is "so poor that we cannot yet establish when iron began in sub-saharan Africa, statistical manipulation of the current corpus of radio carbon dates of the earliest metallurgy is absolutely useless...". In the same vein, Herbert (2005 in Alpern 2005:93), also argued that it may "never be posslbe to write a history of African metallurgy that truly satisfies the historians inordinate greed for both generalization and specificity". The views of the "cautious optimists" are exemplified by Okafor's (1993:434) opinion that "the dates associated with iron-working activities are

not at present sufficiently precise or reliable to settle the question of origins" and Woodhouse's (1998 in Alpern 2005:93) assertion that "before a clear picture can be developed much more research needs to be undertaken both on the existing data and in the field with excavation".

The need to intensify archaeological research by paying particular attention to cultural and ecological factors which possibly played important roles in the indigenous development of iron metallurgy in various parts of Africa can not be over stressed as Okpoko (1987:224) aptly asserts "The production of steel in Sub- Saharan Africa in prehistoric times and the significance of metals and smiths in the socio-political and economic lives of the African Peoples from ancient times call for a critical reassessment of the diffusionist theories of the beginnings of iron technology in parts of Africa... It indeed makes no sense to depend so much on dates in attempts at tracing the so called 'routes' through which the knowledge of iron smelting spread to parts of Africa. There is now need to look at the cultural environment within each society which made possible the take-off of such technology (that is the natural demands for the iron produced; sources of the raw materials; people with skill necessary for the exploitation and refinement of the raw materials; and the type of metal working processes which occurred in each society)".

**Investigations of Iron Working In Northern Nigeria**

In terms of archaeological investigations of iron, Northern Nigeria can no longer be described as a virgin land. The studies have been based on two main sources of evidence-archaeological and ethnological (Abubakar 1987). From archaeological studies, the chronological framework of early iron working in Northern Nigeria has been fairly addressed. One of the archaeological sites with well known antiquity is Taruga in Nok zone of central Nigeria which has produced a number of radiocarbon and thermoluminiscence dates that range between the sixth century BC and early first millennium AD (Fagg 1959, 1965, 1969) while evidence of iron working at Dalla in Kano has also been dated to between the 6$^{th}$ and 7$^{th}$ centuries AD (Sutton 1985). The site of Daima in the Lake Chad area of Nigeria has also yielded dates of between the 5$^{th}$ and 6$^{th}$ centuries AD (Connah 1966, 1967). Evidence of iron smelting was dated to between 7$^{th}$ and 8$^{th}$ centuries AD (Sutton 1976; Effah-Gyamfi 1981) at the site of Samaru West in the Zaria area. From the various studies conducted in Northern Nigeria, lack of knowledge of the socio-economic and cultural contexts of early iron technology and the people responsible for it has been the bane of such investigations. As aptly observed by Effah- Gyamfi (1981), these two issues have been elusive to researchers in the area. For instance, attempt to ascribe complex social organization to the technological advancement implied in iron metallurgy at Nok has been seen as speculative (Abubakar 1987). Generally, archaeological investigations in Northern Nigeria have shown that the knowledge of technical aspects of iron metallurgy is inadequate for the understanding of the stage of the technology (Abubakar 1987).

Ethnological studies have also proved invaluable to our understanding of iron metallurgy in Northern Nigeria in the area of mining of iron ore. Studies have shown that one important attribute of a smelter is his ability to distinguish between the ore and the surrounding area. In his investigation of iron metallurgy in the Kingdom of Zamfara in the 19th and 20th centuries, Abubakar (1987) observed that the smelter's ability to understand the criteria of appearance, texture and density was very vital in the identification of quality ore for use in iron smelting. He however observed that the present knowledge on identification of ore is inadequate to determine the evolution of the technology. Studies have indicated that the need to source for high quality iron ore has led to smelters travelling long distances from home to areas where rich ores were found. Such practices have been reported at Sukur in North Eastern Nigeria by Sasson (1972), Katsina (Usman 1974). Preference for high quality ore has also been identifiedas reason for high concentrations in certain areas and subsequent abandonement after exhaustion (Abubakar 1987). The use of slag for resmelting appeared to have added another dimension to iron smelting in Northern Nigeria. The Birom, Bikom and Oku have been known to have smelted iron from a mixture of ore and slag (Abubakar 1987). Three types of iron ore mining have been identified. These are; surface, quarry and pit types. The surface mining type has been identified at Sukur where magnetite was sourced for from the sand beds (Sasson 1964). Based on archaeological investigations at Samaru West where smelting furnaces have been found in close proximity to lateritic outcrops (Sutton 1976a), quarry type of mining has been suggested in the Zaria area (Abubakar 1987). Similar case has also been reported at Katsina (Usman 1974) and Lankan district of Jos Plateau (Daze 1981). The pit type of mining was reported in several parts of Zamfara

kingdom in the 19th and 20th centuries (Abubakar 1987). In the area, mining of ore was carried out collectively and smelters operated from mining camps known as *Zango*. Before the Jihad, there was no need to seek permission from the village head before going to the mining camps, but this soon changed after the Jihad due to political, economic and security reasons (Abubakar 1987). In smelting operation in which the site is located very close to the source of ore, there was no problem of transportation. However in cases where the sources of ore and fuel were not close to smelting sites transportation problem was usually evident as seen at Zamfara where donkeys were used(Abubakar 1987) and Lankan district of Jos plateau (Daze 1981).

Several types of smelttig furnaces have been found in different parts of Northern Nigeria. Generally in Hausaland and Central Nigeria, Iron smelting furnaces are referred to as large pots (Cline 1937; Sutton 1985). One type is the hearth furnace, which is defined as that with height equal or less than the diameter. This was reported to be in use among the Oku and Bikom on the Jos Plateau (Daze 1981). The furnace is characterized by the production of pure iron at a temperature of not exceeding $750^0$C. The shaft furnace which is a cylindrical mud structure over a shallow pit has been reported at Lankan district (Daze 1981). Characteristically this furnace tapers as the height increases. Its use has been widely reported in several parts of Northern Nigeria especially at Kano, Katsina and Zamfara. According to Kense (1983) this is the most developed and efficient of all traditional smelting furnaces. The Calatan furnace, associated with an open reduction chamber below the ground with a single tuyere through which the draught is forced using bellows was reported among the Nupe (Nadel 1942). In this furnace, smelting of iron is carried out between 5 and 6 hours. The Sukur type furnace, named after the hill top

village of Sukur in North Eastern Nigeria, has also been identified. This type is believed to be common in the hill areas of Northern Nigeria. Smelting of iron is believed to be take place in the Sukur furnace within just an hour. Sasson (1972) sees this as need for fuel economy which suggests an adaptation to a deforested environment caused by large scale iron smelting in the area.

Tuyeres of different types have also been reported in the area. According to Sasson (1972), the simplest were used in some shaft furnaces with natural draught and those that utilized bellows. There were also huge ones used singly as in the cases of Catalan and Sukur furnaces. In the simple type, a single stick or two could be used for its construction, Masive tuyere types have been reported at Kubani river valley in the Zaria area. It is tapering and grass tempered with the narrower end of hole-5cm and up to 12cm at the broader. Its external diameter is about 30cm. Sutton has also reported smaller tuyeres at Tsauni north and Ungwa Makera (Sutton 1976a; Abubakar 1987).The bores of these tuyeres range from 3-5cm and external width of up to 10cm.

**Studies in the Zaria Area**

The impressive archaeological evidence in the Zaria area has attracted the attention of archaeologists and amateurs (such as geologists and geographers) since the 70s. This was not unconnected with the proximity of the Ahmadu Bello University Zaria to the Iron Smelting sites of Samaru West, Tsauni, Pantaki, Kufena, Turunku, and Kubani river valley. In addition to the rich evidence of iron smelting; the area is also associated with stone tools (Obayemi 1976, Sutton 1976a), abandoned settlements on inselbergs

(Legett 1969; Sutton 1977; Bala 1977) defensive walls (Obayemi 1976; Sutton 1977; Effah- Gyamfi 1979a) and ceramics (Sutton 1976a; Effah- Gyamfi 1981c).

A close look at the various archaeological studies in the area indicates that the evidence of iron smelting appear to have engaged research interests most. This is due to the quantum of material evidence of iron smelting such as iron slag, remains of smelting furnaces and tuyeres found in most sites in the Zaria area.

The first archeological investigation of iron smelting in Zaria are was carried out by Ade Obayemi in 1972 (see Sutton 1976b) in which he reported the excavation of an iron smelting site at Samaru west and a radio carbon date that falls within the $7^{th}$ century A.D.

Effah-Gyamfi(1981) reported that subsequent study of the same site was conducted by Sutton (the aim being to further investigate the methods of iron smelting and typologies of furnaces at the site), from which eight more radio carbon dates that fall within the range of $7^{th}$ and $8^{th}$ centuries A.D were obtained.

A follow up investigation was also carried out at Samaru west by Effah-Gyamfi, (1981) aimed at understanding the socio- economic and cultural contexts of ironworking at the site and the possible relationship of the smelters with the former inhabitants of Kufena, Turunku and Zaria. In the study, an occupational site (latitude $11^0$ 09' 12" N and longitude $7^0$ 37'E) was excavated. The material remains recovered from the site were; a polished stone axe, grinding stones, pottery, daub fragments, tuyeres and a knife blade. Unlike the preceding studies, Effah-Gyamfi did not date the material evidence for iron smelting at Samaru west. He however paid particular attention to the analysis of pottery which formed the bulk of the objects recovered at the site. In order to understand the

socio- cultural context of iron smelting in Samaru west, Effah-Gyamfi conducted a comparative study of its pottery with those from Tsauni south and Pantaki sites. Based on the analysis, he observed that pottery from Samaru west was remarkably similar to those of Pantaki in terms of texture, vessel forms, techniques of production and decorative motifs and concluded that there is evidence of cultural affinities between the two sites.

Also taken into account the typological analysis of pottery from Samaru west, Tsauni south and Pantaki and the nine radio carbon dates obtained from Samaru west by Obayemi and Sutton, Effah-Gyamfi suggested that Samaru west could probably be older than Pantaki and Tsauni south and that Pantaki may be earlier than Tsauni south. He further argued that Kufena south sites and Tsauni south could be placed within the same chronological frame. In Effah-Gyamfi's (1981) opinion, the site of Pantaki may have been abandoned by the time the Kufena wall was constructed which implies that the settlers of Pantaki were those who relocated to the plains that were walled. Based on "intuition", Gyamfi suggested dates of Ca 900-1100 AD and Ca 1100- 1300 AD for Pantaki and Tsauni South respectively (Effah-Gyamfi 1981).

Oladipo *et al* (1992) also investigated the relationship between the sites of Samaru west, Pantaki and Tsauni. The results of the study of samples of potsherds from the three sites by using Instrumental Neutron Activation Analysis (INAN) indicates that the pottery from Samaru west and Pantaki are related while those of Tsauni are not. This pioneering analytical technique seems to confirm Effah-Gyamfi's (1981) findings which show that pottery from Samaru west and Pantaki are more related than those of Tsauni south, suggesting the same pattern of relationship among the iron smelters of the three sites.

In line with the typological study of iron smelting furnaces at Tsauni north and south by Sutton (see Effah- Gyamfi 1981); the two sites which are about a kilometer from each other are considered to be temporally different. A contrary view by Effah-Gyamfi however did not consider the two sites to be chronologically different but that the observed typological disparities in the smelting furnaces of both sites were either due to the application of different techniques of smelting by the same group of smelters operating at the same period or culturally similar group operating simultaneously at the two sites. Effah-Gyamfi (1981) further suggests that Tsauni south was probably the source of iron used by the early occupants of Kufena when it was the centre of cultural, political and economic activities in the Zaria area, view which was ostensibly informed by the massive quantity of material evidence at the site of Tsauni south.

Boachie- Ansah (1983, 2000) reports an archaeological investigations conducted at the site of *Tsofon Kargi* (old Kargi), located on latitude $11^0$ 04'30"N and longitude $8^0$ 18' 45" E, about 110 kilometres north east of Zaria. According to oral tradition and the Kargi Manuscript, the site of old Kargi is considered to be one of the earliest in the Zaria area (Boachie- Ansah 1983, 2000). The material evidence associated with the site include; iron slag, remains of defensive walls, grinding stones, cowries, daub fragments, barbed arrow heads, and pieces of bones. Attempt at dating the site through the Electron Spin Resonance Spectroscopy technique by using cowries was considered unsuccessful (Boachie-Ansah 2000) as the range of four dates between 1,000 and 69,000 years was seen as too early. However, based on cross cultural dating with fragments of local tobacco smoking pipe, Boachie-Ansah suggested a date of about 1600 AD for Tsofon Kargi.

**Iron Smelting**

This section provides a background to the technology of iron smelting discusses the basic procedures adopted in iron smelting operation with emphasis on the sourcing of ores, construction of smelting apparatus and the smelting process itself and identifies the types of material evidence associated with iron smelting and their usefulness in the study of early iron technology.

Iron is the third most abundant mineral in the earth crust, constituting about 5% of the earth crust (Hummel 2003). Iron does not occur naturally in pure state but is always found in combined forms with some elements to form different kinds of compounds known as ores which vary in the percentages of their iron content. The commonest iron ores include; Haematite ($Fe_2O_3$), Limonite ($Fe_2O_3.H_2O$), Magnetite ($Fe_3O_4$) and Siderite ($FeCO_3$) (Hodges 1964; Okafor 1992).

Various types of iron ore were believed to have been used in antiquity for iron smelting in different parts of Africa. These include haematite -the commonest (Okafor 1992), limonite, magnetite (Sasson 1964, Okafor 1992), siderite (Schmidt 1997) and laterite (Effah-Gyamfi 1981; Sutton 1985; Tylecote 1965; Okafor 1992; Sasson 1964).

Archaeological investigations in parts of Africa have shown that different grades of ores have been used for smelting of iron. For instance, ores that were as low in iron content as 21% are known to have been used in parts of South Africa (Friede 1980; Okafor 1992). According to (Sasson 1964; Tylecote 1965; Okafor 1992) such ores were treated in order to reduce the siliceous matter in them. Studies have shown that smelters had developed certain criteria to identify and differentiate various grades of ores. For instance the Haya iron smelters in Northern Tanzania distinguished between the ores in

their environment by using colour and density (Schmidt 1997), while smelters in old Zamfara kingdom in the 19th and 20th centuries also adopted appearance, texture and density citeria to select high grade iron ores for smelting (Abubakar 1987). After the identification of ore, the next stage is its mining. Three types of ore mining have been identified- surface, quarry and pit mining (Abubakar 1987).

The sourcing and preparation of ores and fuel are very fundamental to any smelting operation. This should be seen against the back drop of the fact that ore is the raw material from which iron can be extracted and fuel is the source of energy without which there can not be the reduction process that is necessary for iron smelting. Early iron smelters have sourced the ores used for smelting operations in different ways. For example, in most parts of West Africa, ores were collected from outcrops on the surface, valley sides or by open cast mining while in other areas, ores were collected from alluvial deposits and weathered rocks along river courses (Tylecote 1965; Anozie 1979; Sasson 1964). Among the Haya of north western Tanzania, iron ores were mined from considerable depth under the earth surface (Schmidt 1997) while the early smelters in Nsukka Division of south eastern, Nigeria collected the ores (Haematite) used for their smelting operations from foot hills (Okafor 1992). In antiquity, smelters were known to have smelted iron from different grades of ores available in their areas, contrary to the notion that haematite and limonite were preferred to other types of orc. For example in the site of Sukur, there is evidence that magnetic sand (black iron oxides) was used to smelt iron (Sasson 1964). In Mafa, Northern Cameroon, magnetite was successfully smelted with a yield of 61% of iron from the quantity of ore put in the furnace (David *et al* 1989). From the various examples in different parts of Africa, it is evident that the

choice of ores was largely a function of availability rather than preference. The availability of ores has been found to be a primary factor in iron smelting and due to its heaviness; smelting sites are normally located close to this very important raw material while its exhaustion can lead to the end of smelting in a particular area as observed in Nsukka Division, Nigeria (Okafor 1992).

The next step in iron smelting operation is the preparation of ore, which also took different forms in various iron smelting communities in Africa. In some places, ores were collected as nodules and then broken into pieces to allow easier reduction. In other places, this is followed by roasting (Schmidt 1996, 1997). Chemically, the roasting of ore has been found to have some desirable effects such as; discharging of the carbon oxide, water and sulphur that may be in the ore, making it more friable thus becoming readily breakable to desired pieces, increasing the porosity and allowing better penetration of reducing gas during smelting (Okafor 1992)

Fuel is another important requirement in iron smelting. In antiquity, different types of fuel were used in various parts of Africa. The predominant type used was charcoal normally derived from the burning of sap wood, while in some cases there was direct use of wood as observed in Orba Nsukka in south eastern Nigeria (Okafor 1992). Andah (1979) also observed the use of wood and charcoal by early iron smelters. Most iron smelters of antiquity seemed to have had preference for the use of hard wood that can burn slowly, producing little ash as seen in Nsukka Division, Nigeria (Okafor 1992) and in central and southern Africa (Van der Merwe 1980). Our research indicates that *Prosopis africana*, known as *Kir'ya* in Hausa was the most preferred for iron smelting and blacksmithing in the area of study. The choice of such wood was undoubtedly aimed

at ensuring adequate fuel economy for the iron smelting operations. Trees such as Locust bean (*Parkia biglobosa*) and Acacia (*Acioa barteri*) were used in Orba Nsukka in Nigeria (Okafor 1984), while in Toumra in the Sudan, *Acacia nilotica* and *Tamarindus indica* were preferred (Haaland 1985). The impact of exploitation of trees for fuel in iron smelting was undoubtedly environmental degradation in terms of deforestation.

Next in the process of iron smelting is the construction of furnace, tuyeres and bellows. A furnace can be described as the 'house' where smelting of iron is carried out. It can also be seen as the reducing chamber (Okafor 1992) which is an enclosure that allows restricted supply of oxygen. Different types of furnaces were used for iron smelting in antiquity. These have been broadly grouped into bowl or pit, dome and shaft furnaces (Tylecote 1965; Pole 1975; Sutton 1985; Van der Merwe 1980). Based on their techniques of operation and forms, smelting furnaces can also be classified into two main categories; slag tapping and non-slag tapping. The construction of furnaces took different forms among the various iron working communities in Africa. In Nsukka division for instance, furnaces were constructed with internal wooden frames with walls constructed with wattle and daub (Okafor 1992). The Haya of Tanzania made use of a wide range of materials such as mud, stones and slag (Schmidt 1997). To ensure a successful operation, smelters were always conscious of the need to construct strong furnaces capable of withstanding the high temperature normally required for smelting of iron. This was normally achieved by constructing furnaces with refractory clay tempered with materials like stones, grasses and slag. As was earlier observed in this work, there is no empirical evidence to show that the antiquity and efficiency of a furnace have any relationship with its structure, which implies that the various types of furnaces used in Africa were

essentially an adaptation to the prevailing environmental conditions and different technological experiences of the iron smelters. Therefore the categorization of smelting furnaces according to their levels of sophistication has no basis in the current state of early iron smelting.

Construction of tuyere and bellows is also crucial in bloomery iron smelting process. Tuyeres are the channels that convey air into the furnace for combustion to take place during smelting. On the other hand, bellows are devices designed to force draught into the tuyere and subsequently to the furnace. The construction of bellows is only relevant to smelting operations in which forced draught furnaces are used. In antiquity, most tuyeres were constructed with refractory clay (Okafor 1992) which made it possible for them to withstand the intense heat of smelting. The hardening effects of such exposure to heat also toughen (vitrify) the tuyeres and make them resistant to adverse weather conditions. Bellows are normally the least resistant to weather conditions due to the use of perishable objects such as wood and animal skin for their construction. This accounts for why they are not found in smelting sites (Okafor 1992) as they are highly biodegradable

**The Process of Iron Smelting**

Iron smelting was an intricate metallurgical process. It was also a laborious as well as a capital intensive operation (Okafor 1992). The ultimate desires of iron smelters was to see that the smelting exercise is successful as anything that is contrary can be construed beyond financial loss as even a disaster to the community due to the close link with women fertility (Okafor 1992). In some iron smelting communities, sexual symbolism was associated with smelting. Smelting of iron was likened to human

reproductive process in which the furnace was seen as a pregnant woman carrying a foetus (the bloom). The success of the smelting was synonymous with the successful delivery of a baby by the woman, while the contrary implies a miscarriage which must be avoided at all costs. For instance, such belief was reported by Schmidt (1997) among the Haya smelters in Tanzania which necessitated precautionary measures like sacrificing to some gods in order to ensure the success of the smelting operation.

Irrespective of the societies involved, certain basic requirements were necessary for the success of any iron smelting operation. One of such is the capability to generate a temperature range of 1100-1200$^0$C which is required to separate slag from the bloom (Okafor 1992). In smelting operation, iron is reduced from its ore at a temperature that is below its melting point of 1535$^0$C and above the melting point of slag which is 1200$^0$C-1300$^0$C (Tylecote 1986). It has been observed that the smelting of iron that is attempted at any temperature below the above range of temperature will not be successful (Andah 1979; Okafor 1992). As observed by Schmidt (1997), two of the important conditions that ensured success in African iron smelting process were the maintenance of high temperatures and the presence of sufficient quantity of carbon monoxide to ensure effective reduction process (Schmidt 1997). It has however been discovered that the attainment of temperatures as high as indicated above may not be necessary if fluxes were used in smelting operation (Tylecote 1962). Fluxes are materials that can lower the melting point of an oxide or slag as well as render materials more easily removed from the furnace (Tylecote 1962). Examples of materials probably used in smelting processes in antiquity were lumps of clay (Okafor 1984), clay and quartz (Craddock *et al* 2007)

Smelting of iron in bloomery furnace involves a chemical reaction known as oxidation- reduction process. First, the oxidation process takes place when the carbon fuel reacts with oxygen which results in the simultaneous formation of carbon monoxide (CO) and carbon dioxide ($CO_2$). With a sufficient quantity of carbon monoxide (which is a reducing agent) in the furnace, a reduction process is set in motion on the ore. The reaction of carbon monoxide with the ore produces iron, impurities (slag) and carbon dioxide as illustrated below.

$C + O_2 \rightarrow CO_2$

$2C + O_2 \rightarrow 2CO$

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (Okafor 1992)

It therefore implies that the complex nature of iron smelting as highlighted above demands that smelters must be highly versatile in order to be able to cope with the demands of this metallurgy. Such versatility is reflected in their ability to source the ore, understand its chemical properties, know the attributes of the wood to use for fuel, know and possess the capacity to generate adequate temperature and the ability to effectively coordinate all facets of the smelting operation.

**Material Evidence of Iron Smelting**

The material remains of iron smelting are often referred to as residues, four categories of which have been identified- smelting slag, cinder, fuel ash slag and refractory materials (Tylecote 1987; Okafor 1992; Mapunda 1995). Out of all the material evidence of iron smelting, the most commonly found in archaeological sites are slag due to its virtual indestructibility (Okafor 1992). In addition, slag is the most reliable

in terms of physical and chemical analyses (Friede 1977). The merits of slag (as pointed out above) over other iron smelting archaeological material are the basis for its choice for technical analyses in this research. While cinder, fuel ash slag and refractory materials are often found in different quantities at smelting sites over a period of time due to their varying resistance to natural and human factors, smelting slag are the most indestructible of the residues and more reliable in physical and chemical analyses than others (Friede 1977; Okafor 1992). It was the consideration of its relative reliability in terms of usefulness for physical and chemical analyses that partly informed our choice of iron slag for technical analysis in this research.

# CHAPTER FOUR

# ARCHAEOLOGICAL RECONNAISSANCE

## Introduction

Archaeological reconnaissance was carried out at Tsauni north and south iron smelting sites between May 2006 and April 2009. The exercise took place during dry season in the area, when most of the vegetation cover had been burnt. This enabled us to achieve good visibility on ground, which made it possible to identify the material evidence and their configuration at the sites.

The objectives of the reconnaissance were:

(a) To make an inventory of the surface material evidence

(b)To assess the cultural viability of the sites and

(c) To select areas to excavate.

The methods and instruments adopted in the traverse survey had already been discussed in the section on methodology in chapter one.

The name Tsauni in Hausa means hill or outcrop. This is commonly found in the area in form of laterite outcrops. A prominent laterite outcrop is located about 15m south of the main road from Zaria to Birni-Gwari on which the MTN mast has been erected. It was this outcrop that we used as the demarcation between Tsauni north and south. In the demarcation, the iron smelting site located south of the laterite outcrop on which the MTN mast is erected was referred to as Tsauni South site, while the one located north was referred to as Tsauni North site.

Our preliminary investigations showed that apart from the laterite outcrop and the main road which served as the demarcation, Tsauni north and Tsauni south also differ in physiographic form.

Tsauni north is more of a stretch of plain land dotted with laterite outcrops and a few erosion channels. We observed that the Tsauni north site that we investigated is under intensive cultivation which is now posing a serious threat to it. On the other hand, Tsauni south exhibits a somewhat different physiography. It is a valley bounded to the north, northeast and west by lateritic ridges. Tsauni south is crisscrossed by gully erosion channels that currently pose even more serious threat to the site than in Tsauni north (plates 14 and 15). Tsauni south is not as intensively cultivated as Tsauni north apparently due to its unsuitable agricultural use.

Based on Andah and Okpoko's (1994) view, of an archaeological site as a spatial clustering of artifacts, features and/or ecofacts, we initially considered the clusters of material evidence at Tsauni north and south as constituting two sites. The clusters comprise mostly of slag scatters, relics of furnaces and tuyeres. For the purpose of convenience, the sites of Tsauni north and south were broken into units which in most cases exhibit similar material evidence. A unit may comprise one or more smelting area. For this reconnaissance, we define a smelting area as a location where there is occurrence of at least one of the evidence of iron smelting in form of furnace, tuyere or slag pieces. One site each was investigated from the north and south of Tsauni in this research. Greater part of pioneering archaeological reports on Tsauni iron smelting have centred on Tsauni south (Sutton 1976, Effah-Gyamfi 1981). This apparent lopsidedness of the

pioneering investigations in the area, informed our decision to study at least a site in Tsauni north.



**Plate 12: Central view of Tsauni north**

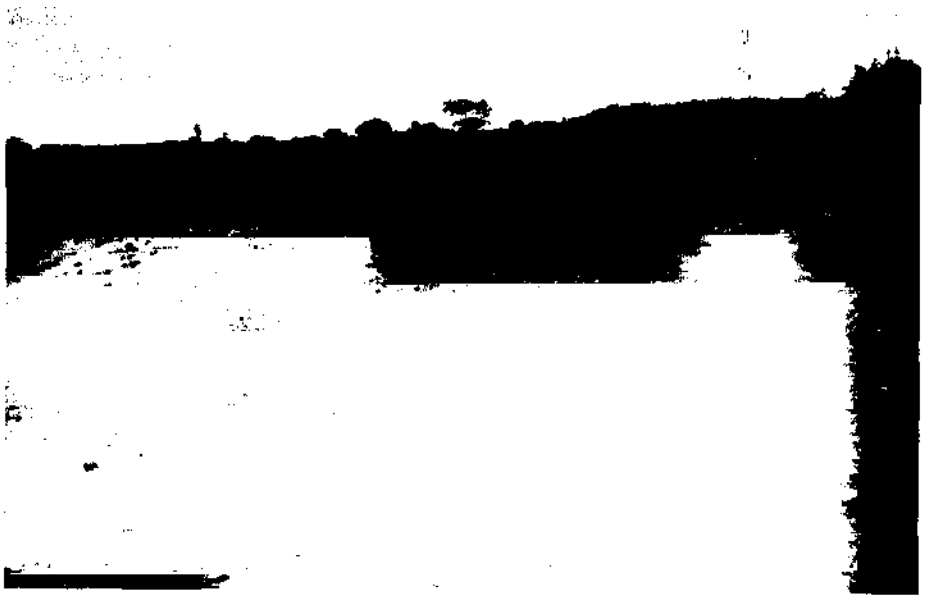


**Plate 13: Western view of Tsuni North**

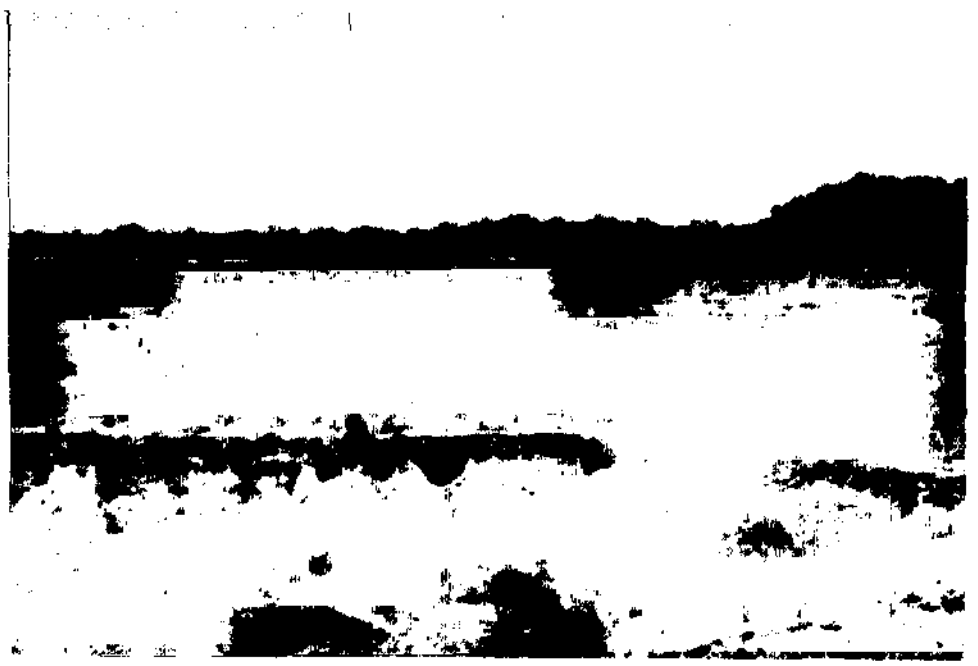


**Plate 14: North-western view of Tsauni South showing severe gully erosion**

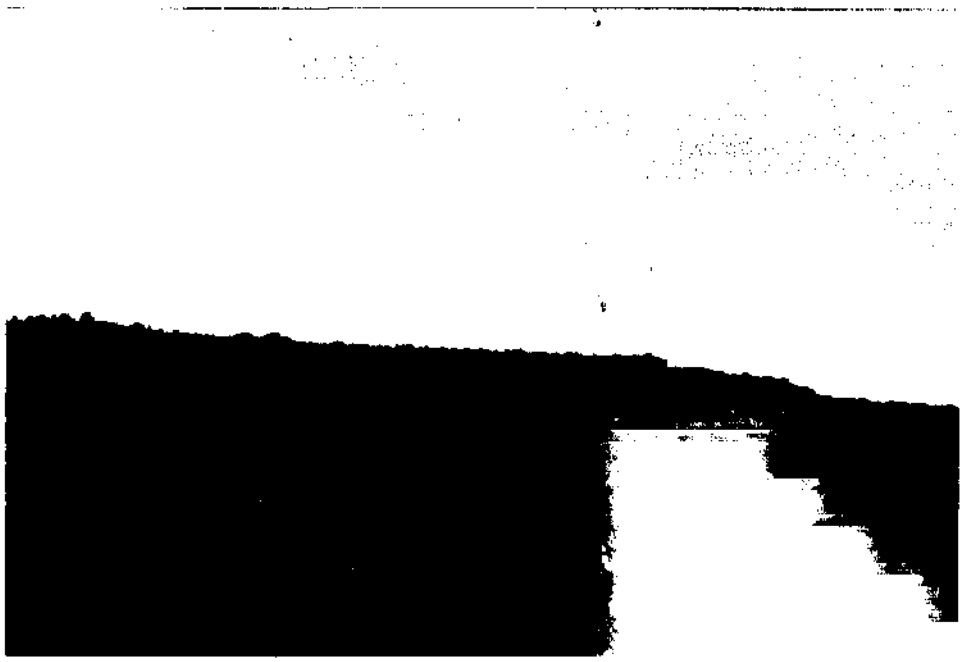
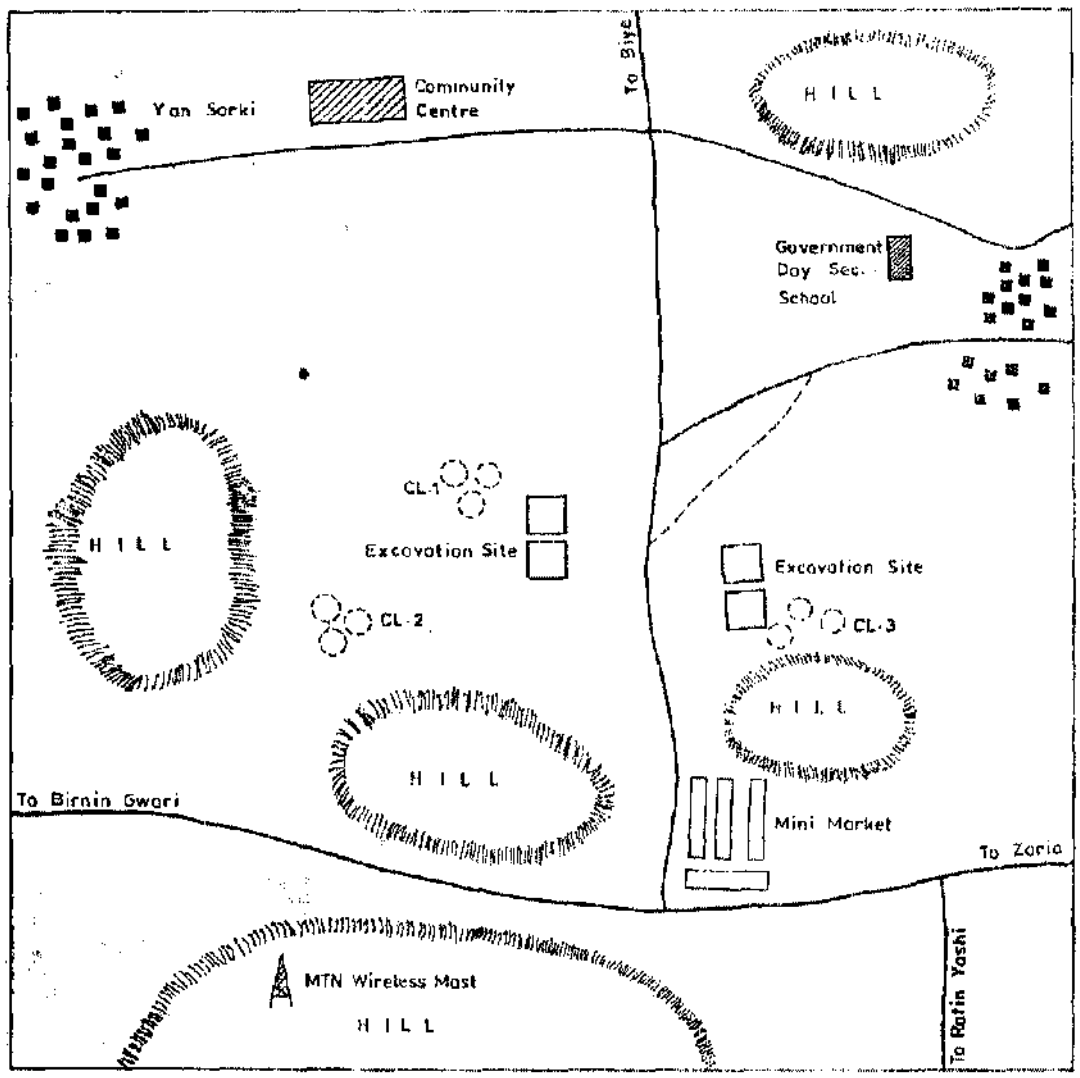


**Plate 15: Central view of Tsauni South showing devastating gully erosion**

**THE TSAUNI NORTH SITE**

The traverse survey of Tsauni north was conducted for the purpose of identification of areas to be excavated. The site is located at about a kilometre north of the main road to Birni Gwari and beside a road running north south to Yan Sarki village. The GPS position of the site is latitude $11^0$ 06' 54" N and longitude $7^0$ 35'39.5" E on an altitude of 720m above sea level.

The site investigated has two sections. The road to Yan Sarki was used to delineate the site into Eastern and Western sections. Eastern section is located right of the road while the western one lies at the left (fig7, plate 16). The western section comprises two units of slag scatters and outline of smelting furnaces (while the eastern one has one unit. Unit N1, western section is located about 150m north east of 2 and about 100m west of unit N3 in the eastern section




Roads: Major .....

Minor .....

Footpath .....

Cluster of Iron Slag ..... CL

Settlement .....

N

Fig 7: SKETCH MAP OF TSAUNI NORTH SITE

**The Western Section**

***Unit N1***

UnitN1, western section is located on latitude $11^0$ 54' N, longitude $7^0$ 35' 40" E. It is characterized by a wide slag scatter starting about 7m from the road leading to Yan Sarki village and covering an area of about 35 by 35m to the foot of a lateritic outcrop which is part of a lateritic ridge located west of Tsauni north ( plate 16). In this unit, the slag pieces are generally small in size, with a few exceeding 10cm in size and associated with furnace outlines and pieces of broken furnace and tuyeres. Two groups of foundations of smelting furnaces are found towards the centre of the slag scatter. They are small and barely 1m in diameter with average wall thickness of 8cm (plate17). One group had 3 furnace bases while the other was associated with two.

Unit N1, western section lies on a slope with visible signs of sheet erosion. Our observation shows that erosion activities have washed some of the surface finds such as pieces of slag and fragments of furnace and tuyeres from their original positions. We observed with particular interest the location of the material evidence of iron smelting at the foot of the lateritic outcrop which could possibly have been the source of ore for the smelting operations in the area as Sutton (1976, 1985) and Effah-Gyamfi (1981a) had earlier observed. Our prelimnary assessment of the material evidence in this unit showed that proximity to the source of raw material was probably the overriding factor in the choice of the area for iron smelting. We also observed a virtual absence of potsherds in this cluster. Based on the use of occurrence or absence of pottery by Effah-Gyamfi 1981a) to differentiate between a factory site and an occupational one at Samaru West, We suggest that this unit was probably an industrial one.

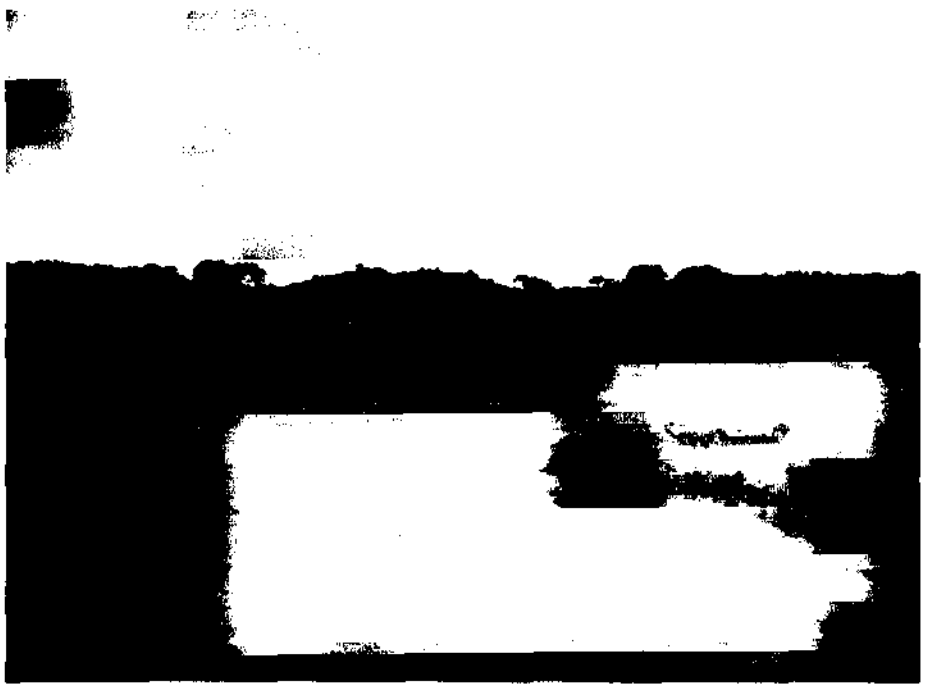


**Plate 16: General view of Tsauni North site. At the top right hand corner of the photograph is Unit N1, western section, located at the top left hand corner is Unit N2 while at the camera position is unit N3 in the eastern section**

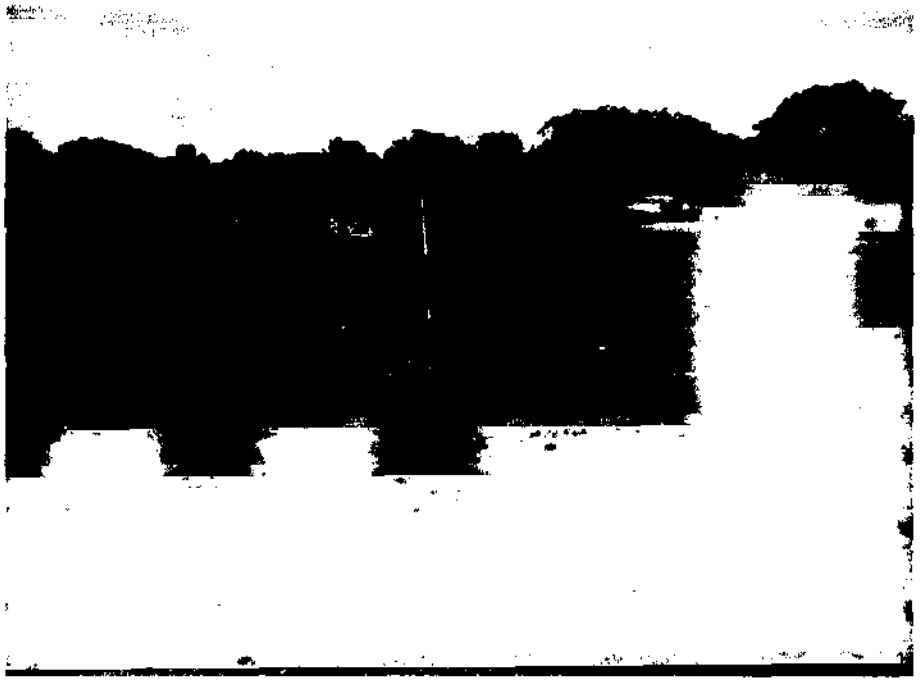


**Plate 17: North-eastern view of Unit N1, western section of Tsauni North**



**Plate18: A close-up of Unit N1, western section, Tsauni north showing remnants of a furnace**



**Plate19: A close-up of a broken tuyere in Unit N1, western section, Tsauni north.**

*Unit N2*

Unit N2 is located on latitude $11^0$ 06' 42.8"N, longitude $7^0$ 35' 35.5"E and altitude 726m above sea level.The unit is located southwest of unit N1 of the western section covering an area of about 60m East-West and 45m N/S. There are 5 smelting areas in the unit. Smelting area1 covers an area of about 5m in diameter. To the east is an unusually large outline of a furnace measuring 1.5m in diameter (plate 10). Smelting area 2 is located about 5m east of point 1 and characterized by a slag scatter covering an area of 6m in diameter. No furnace outline was identified with this slag scatter. Smelting area 3 lies about 6m east of point 2 and associated with a slag scatter within an area of about 5.5m in diameter. Smelting area 4 is located about 10m north west of point3. It has a slag scatter of about 5m in diameter and associated with a few pieces of tuyeres while Smelting area 5 is found 7m east of point 4 and about 20m from the road to Yan Sarki road, covering an area about 5m in diameter. No outline of a furnace or tuyere pieces was found in this smelting point.

Unit N2 shows some similarities to N1. One of these is the absence of potsherds. It was also observed that it is located at the foot of the lateritic outcrop which may imply the strong influence of the source of raw material on the citing of the smelting areas. However in contrast, unit 2 occupies a larger land area than unit N1 and is associated with more smelting areas. While unit N1 is associated with one Smelting area, five were identified in unit N2.

**Eastern Section**

***Unit N3***

Unit N3 (plate 11) is located on latitude $11^0$ 06' 44" N, longitude $007^0$ 35' 43.1" and altitude of 726m above sea level. It is located 10m east of Yan Sarki road. Unit 3 lies at the south east of the Tsauni north site at about 100m east of unit N2. At about 10m south of Unit N3 is part of the southern outcrop of laterite which is not as high and wide as the northern ridge. It has dimensions of 20m E/W and 10m N/S. In terms of land area, Unit N3 is the smallest in dimensions.

Though there is only one smelting point in this unit, the slag pieces are larger than those of other units in Tsauni north. When viewed from the north, the slag scatter looks like a heap of slag about half a meter high (plate 22). However from the other sides, it could be seen as a thin layer on a natural mound. Pieces of what could have been a large tuyere are also visible in the unit (plate23).

The location of this unit close to an outcrop of laterite is also similar to those of Units N1 and N2 with probably the same implications in terms of sourcing of ore for smelting.

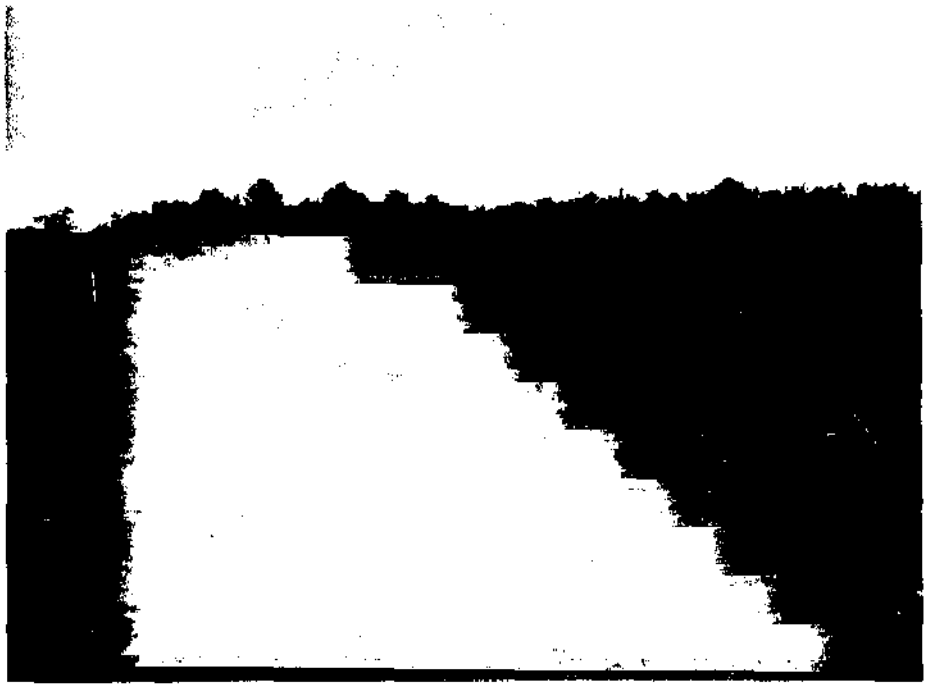


**Plate 20: Northern view of Unit N2, western section of Tsauni North**

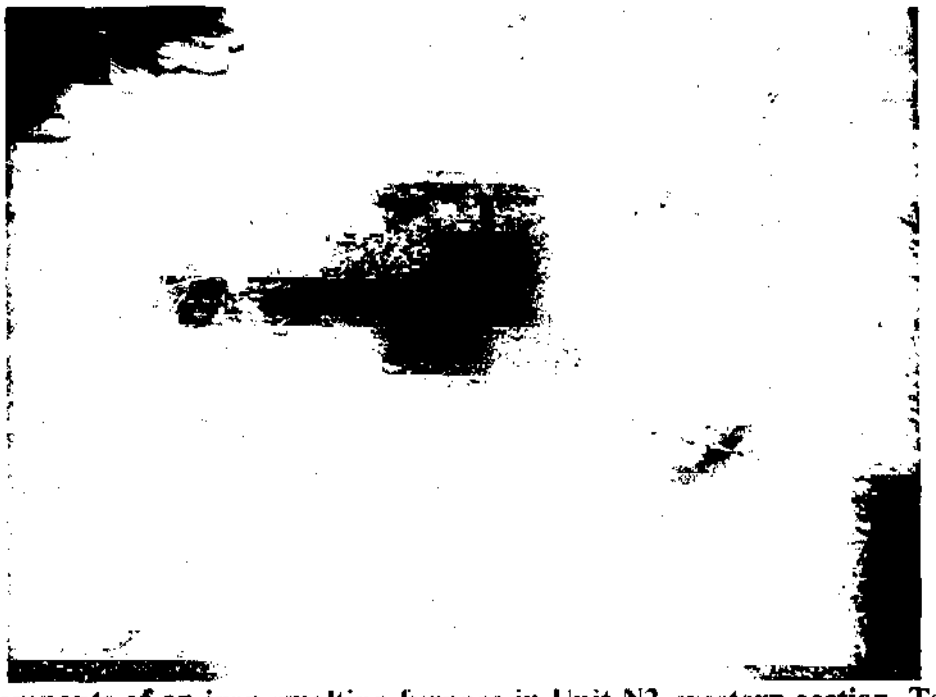


**Plate 21: Remnants of an iron smelting furnace in Unit N2, western section, Tsauni North**

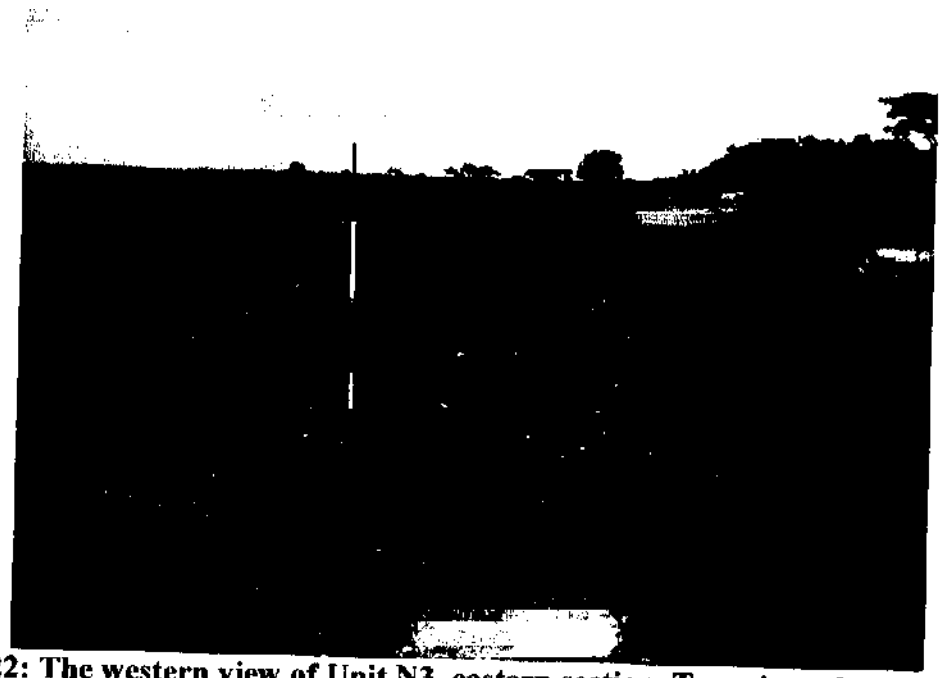


**Plate 22: The western view of Unit N3, eastern section, Tsauni north. At the horizo is the Kufena Hill.**



**Plate 23: A close-up view of pieces of a broken tuyere in Unit N1, western section, Tsauni north**

## TSAUNI SOUTH SITE

For the purpose of our reconnaissance at Tsauni South we identified five sections. The gullies created as a result of severe erosion in the site appear to have naturally delineated the site into five, hence the need to conduct its reconnaissance accordingly. The identified sections are: Eastern, North eastern, Central, North western and South Western. Due the vastness of the site, three datum points were chosen for the reconnaissance as discussed later in this chapter. For the Eastern section, a granite outcrop was used, the MTN mast was the datum point for the North eastern, Central and North Western sections while the datum point for the South Western section was a sheet laterite outcrop located at the end of the western lateritic ridge.

### The Eastern Section

The granite outcrop used as the datum point (plate24) is located about 550m west of Rafin Yashi Primary School, covering an area of about 20 by 15m. The GPS readings of the datum point are latitude N $11^0$ 05' 27.3" and longitude E $7^0$.34' 41.3" with altitude of 992m above sea level.

#### *Unit S1*

This is located on latitude $11^0$ 05' 29.6"N, longitude $7^0$ 34' 41.5"E and altitude 695m above sea level. Unit S1 (plate 24) is about 25m north of the datum point covering an area of about 35m North/East and 20m East/West. Four smelting areas are identified in this unit.

The first smelting area (plate25) is at the southern end of Unit S1, covering an area of about 15m in diameter. At the centre of it is part of a furnace. The slag heap in

this smelting area has been eroded, leaving the slag scatter as patches. The second smelting area (plate26) is found 10m east of the first. It is about 10m in diameter also with remnant of a furnace at the centre. Only a few patches of slag scatter are identifiable there. Smelting area 3 is (plate27) is about 15m north of smelting area 2. It covers an area of 6m in diameter. There is an outline of a furnace in the middle with a few slag scatter. Smelting area 4 (plate28) is about 12m west of smelting area 3. It has a diameter of about 6m with remnants of a furnace at the southern part. Most of the slag scatter has been eroded into the gully.



**Plate 24: The granite outcrop at the southern end of Tsauni South used as datum point for the Eastern Section**



**Plate 25: A close-up of Smelting area 1 in Unit S1, eastern section, Tsauni south viewed from the south**

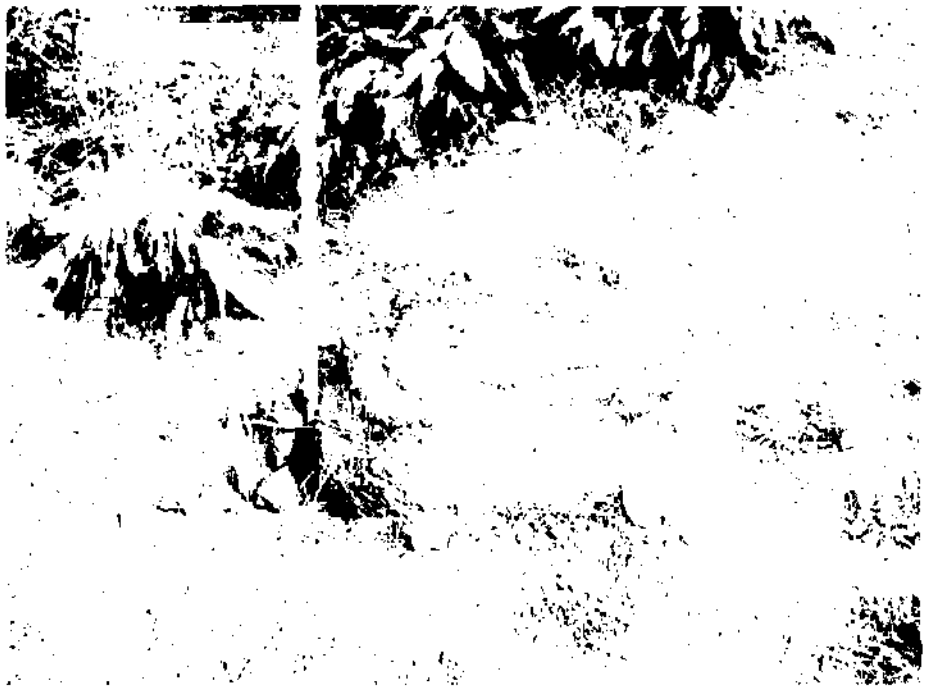


**Plate 26: Smelting area 2 in Unit S1, eastern section, Tsauni south**

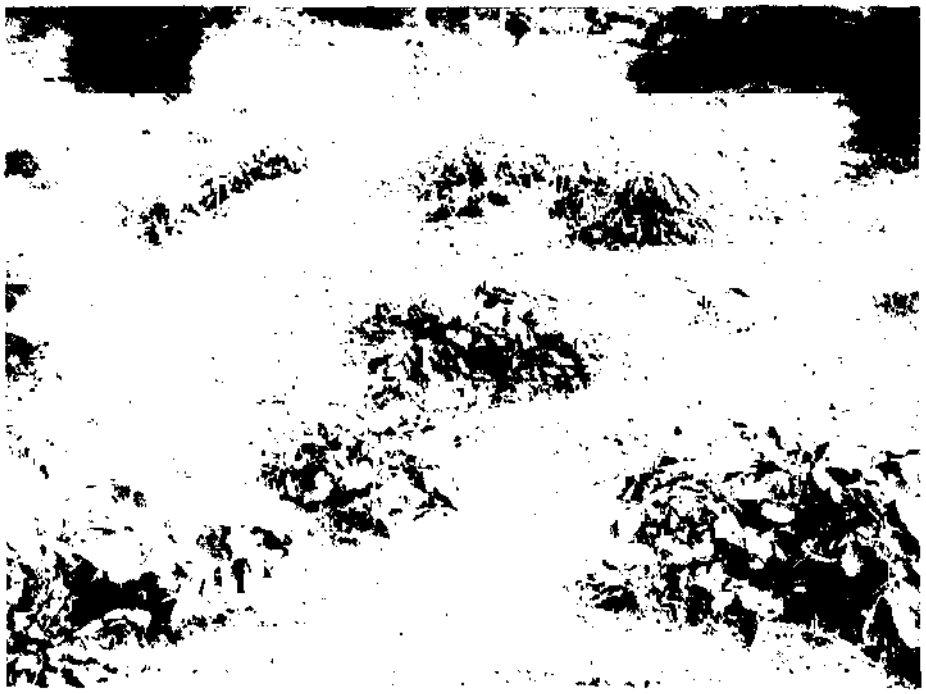


**Plate 27: Smelting area 3, eastern section, Tsauni south viewed from the South. Note that it is at the edge of a stream**

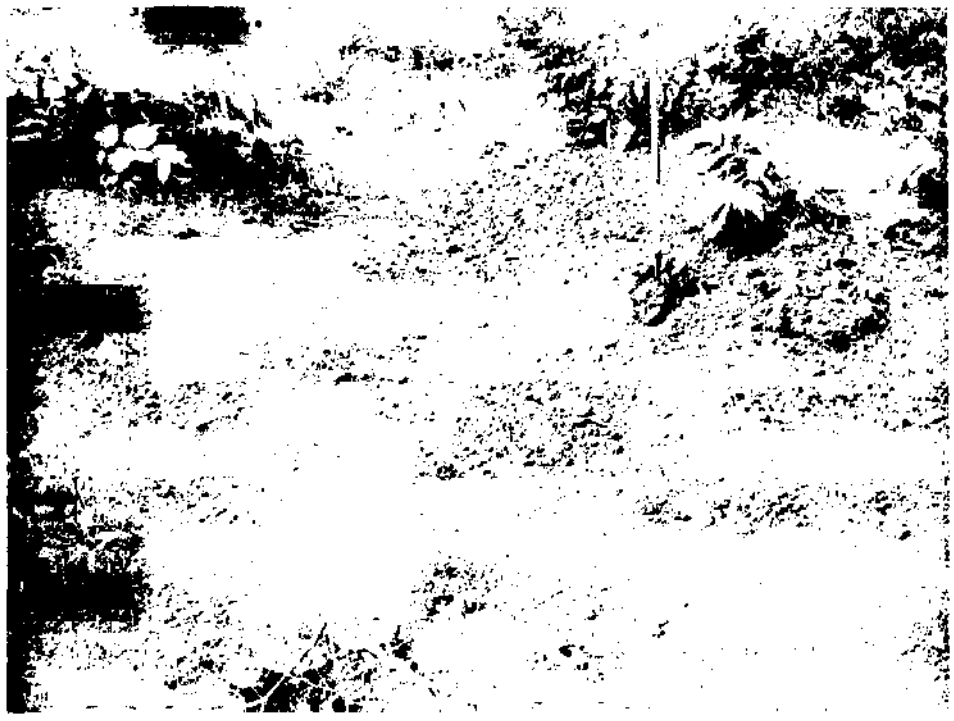


**Plate 28: Smelting area 4 in Unit S1, eastern section, Tsauni south viewed from the east**

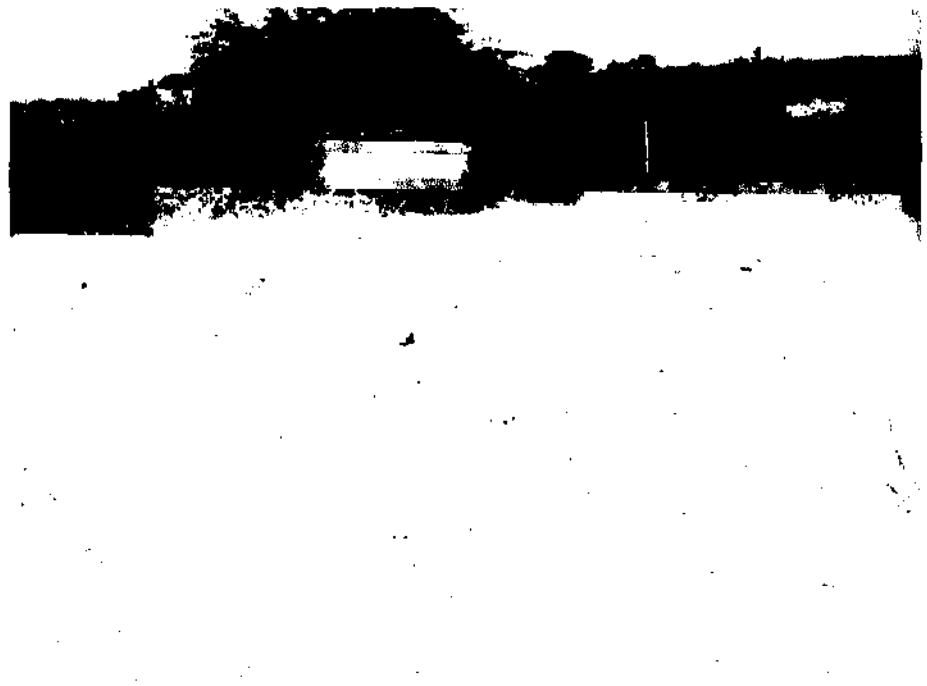


**Plate 29: Unit S2, eastern section, Tsauni south viewed from the east. The only smelting area seen here is almost completely destroyed by cultivation.**

***Unit S2***

This unit lies on latitude $11^0$ 05' 33.2"N, longitude $7^0$ 34' 49.0"E and altitude 701m above sea level. Unit S2 (plate29) is located about about 50m away from the gully. It covers an area of about 25m N/S and 15m E/W. It is found in an area with well developed soil which probably has attracted cultivation in the area. There is only one smelting area identifiable in this unit which is a collection of slag and stones covering an area of 5m in diameter.

***Unit S3***

It is located on latitude N.$11^0$ 05' 35.4" longitude E.$7^0$ 35' 00.8" and altitude 705m above sea level. The unit is about 250m northeast of unit 2. It is on the western part of a lateritic outcrop. It is located about 600m west of Ungwan Tsauni. The unit covers an area of 60m N/E and 25m N-S and is associated with three smelting areas.

The first (plate31) is to the south, about 8m in diameter. It has large broken parts of a furnace and a slag heap to the south. Smelting area 2 (plate32) is about 15m to the north and about 10m in diameter. At the center of it is a group of three furnances built very close together. The slag heap, half of which has been eroded into the gully is about30cm high and characterized by large pieces of tuyeres. The third smelting area (plate33) is beside the lateritic outcrop about 15m away from 2, to the east. It is about 20m W-E and 15m N-S. It has a single furnace to the south while at about 5m to the east are two furnaces closely built together.

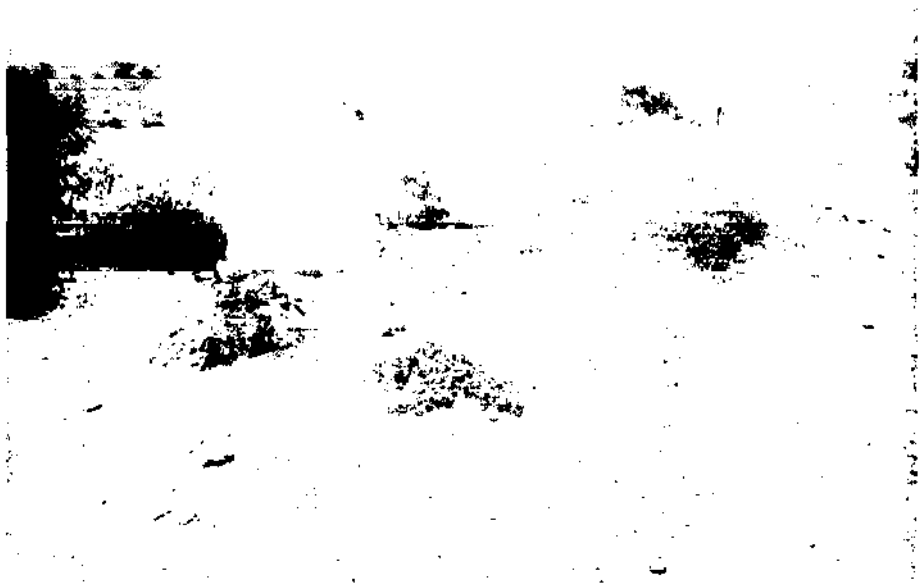


**Plate 30: A general view of Unit S3, eastern section, Tsauni south. The ranging pole is on smelting area 1.**

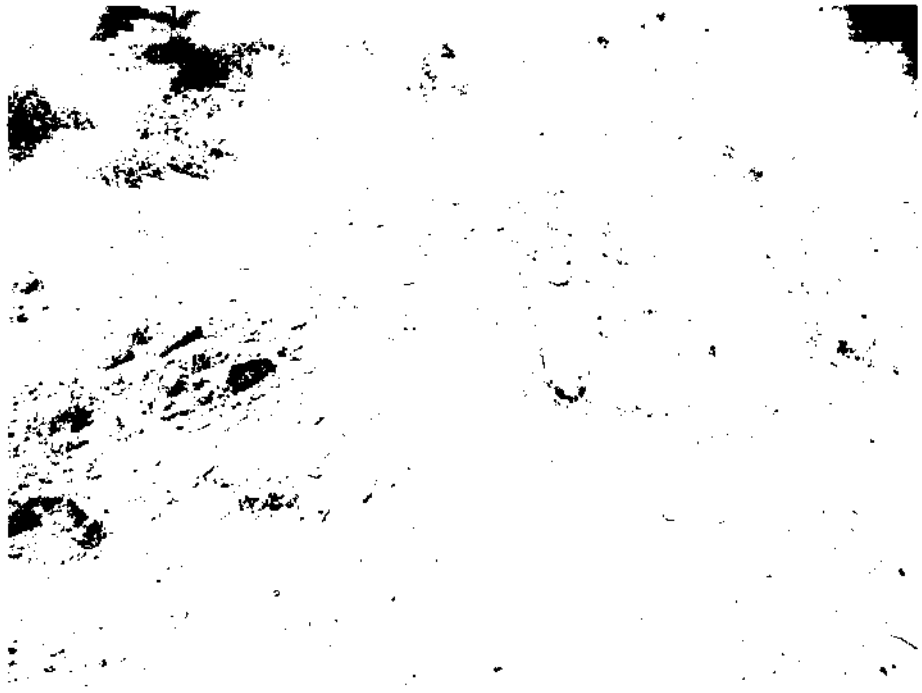


**Plate 31: A close-up of smelting area 1 in Unit S3, eastern section, Tsauni south**



**Plate 32: Slag scatter of smelting area 2 in Unit S3, eastern section, Tsauni south**



**Plate 33: A close-up of a furnace in smelting area 3, Unit S3, eastern section, Tsauni south**

***Unit S4***

It lies on latitude $11^0$ 05' 40.9"N, longitude $7^0$ 35' 08.9"E and altitude 709m above sea level. Unit 4 (plate34) is found about 200m away from Unit S3, at the northwestern side of the lateritic outcrop on which Ungwan Tsauni is found. As a result of gully erosion only a narrow strip measuring about 12m (W-E) and 8m (N-S) is left of this Unit.

Two smelting areas are found in this Unit. Smelting area 1 (plate35) is found on the footpath that runs from Ungwan Tsauni across the gully to the other side of Tsauni South. It has an area of 5m in diameter with the remnant of a furnace on the footpath. Smelting area 2 (plate36) is about 5m to the northeast of point 1. It measures 4m in diameter with a furnace to the eastern part of it.

*Unit S5*

Unit S5 is located on latitude $11^0$ 05' 49.2"N, longitude $7^0$ 35' 13.9"E and altitude 715m above sea level. The Unit (plate37) is found about 300m to the north of Unit S4 along a stream. It is on a plain area with developed soil where cultivation has been taking place. The Unit is about 15m (W-E) and 20m (N-S). Slag pieces are seen scattered all over the Unit but only one smelting area is identifiable, which is about 5 m in diameter. No remnants of a furnace are seen except a collection of slag and stones.



**Plate 34: A general view of Unit S4, eastern section, Tsauni south**



**Plate 35: A close-up of the furnace in smelting area 1, Unit S4, eastern section, Tsauni south Note that the footpath passes directly on the furnace.**



**Plate 36: A close-up furnace in smelting area 2 of Unit S4, eastern section, Tsauni south**

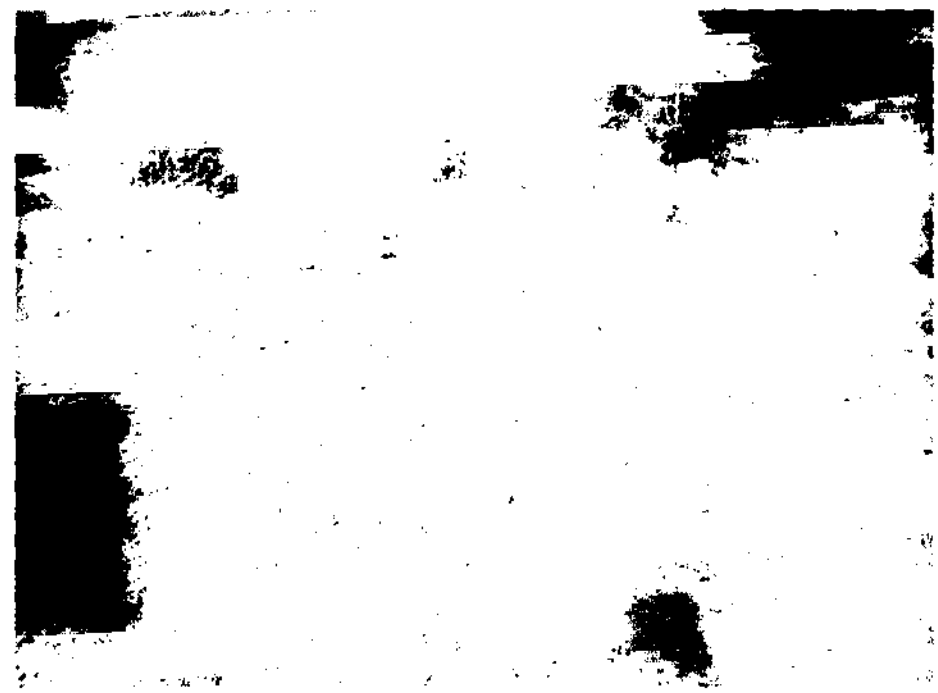


**Plate 37: A general view of Unit S5, eastern section, Tsauni south viewed from the east with the ranging pole indicating the location of the only smelting area.**

**The North-Eastern Section**

On latitude $11^0$ 06'08.7"N, longitude $7^0$35'12.8"E lies a scatter of potsherds in association with about 4 pieces of what appear like fragments of furnace. It is located 400m south of the MTN Mast and associated with occurrence of slag found within an area of 10m diameter. We identified 3 Units in the North- eastern section of Tsauni south.

**Unit S6**

Unit S6 is found 60m east of this feature. The Unit was the one excavated in 2007. Smelting area 1 is a slag scatter on a mound of 16m diameter (Plate38). It is located on latitude $11^0$ 06'08"N, longitude $7^0$ 35'15"E and latitude 718m above sea level. Smelting area 1 is associated with large quantity of slag, furnaces and fragments of

tuyeres. Smelting area 2 is located 27m north east of smelting area 1. This smelting area is characterized by collection of slag on a mound and a furnace outline (plate39). It is deeply eroded in the east by a deep gully. The smelting area 2 occupies an area 8m diameter.



**Plate 38: Slag mound of smelting area 1, Unit S6, north eastern section, Tsauni south excavated in 2007.**

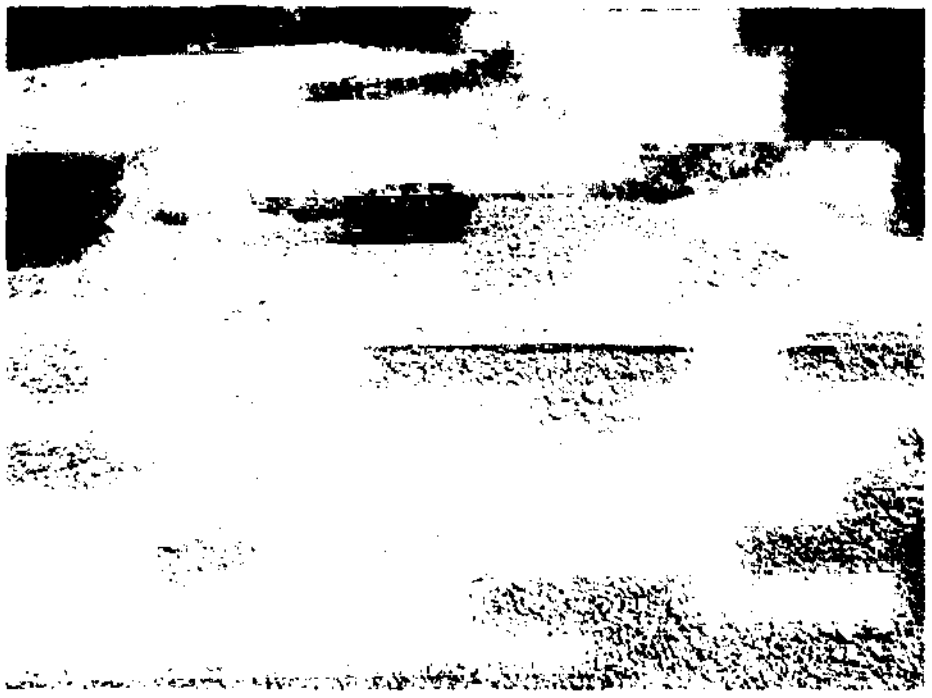


**Plate 39: Smelting area 2 in Unit S6. North eastern section, Tsauni south Note the deep gully that has cut off what was originally part of this Unit.**

***Unit S7***

This Unit lies on latitude $11^0$ 06'10.2"N and longitude $7^0$ 35'15.7"E and altitude 719m above sea level. It is found 50m north of Unit S6 and associated with pottery and slag scatter (plate40). We identified two smelting areas in this Unit. The Unit occupies an area 26m (N/ S) and 24m (W/ E). Smelting area 1 is associated with slag and pottery scatter of 12m in diameter while smelting area 2 is also identified with slag and pottery scatter of about 6m located 10m North West of area 1.

***Unit S8***

Unit S8 marks the limit of the North eastern section of Tsauni South. It is located on latitude $11^0$ 06'12.3"N, longitude $7^0$ 35'14.5"E and altitude 723m above sea level. This Unit is found 28m North west of Unit S7. Its dimensions are 58m (N-S) and 34m (W – E). Three smelting areas were identified in this Unit. Smelting area 1 is a collection

of slag 2m in diameter (plate41), while smelting area 2, located 25m west of 1 is identified with scatter of slag and pottery within a diameter of 6m (plate31). Smelting area 3 lies 36m, north east of area 2 and is associated with slag scatter and a tuyere partly buried in the ground. It has an area 1m in diameter (plate42).



**Plate 40: A general view of Unit S7, north eastern section, Tsauni south showing smelting area 2 (see ranging pole).**



**Plate 41: A general view of Unit S8, north eastern section, Tsauni south showing smelting area 1 (ranging pole).**



**Plate 42: A close-up of smelting area 2 in Unit S8, north eastern section, Tsauni south**



**Plate 43: A close-up of smelting area 3 in Unit S8, north eastern section, Tsauni south**

**Central Gully Section**

The central gully is the eroded middle portion of Tsauni South site (plates 14, 15, 50, 51) that stretches southwards. In this part of the Central gully, there are 4 Units, with 1 and 2 located at the southern end of the gully while 3 and 4 are towards the north.

At latitude $11^0$ 05' 41.1"N, longitude $7^0$ 34' 33.9"E and altitude 698 m above sea level, there are three collections of laterite beside Unit S9, to the south. The three collections are separated by about 2m of space (see plate44). The laterite collections appeared to have been deliberately gathered there for certain purpose. A closer observation also indicated that the collections were not from the immediate surrounding, as the area is composed of quartz and granite stones. It is also interesting to note that one

of the collections appeared to have been broken into smaller pieces (see plate45), which seems to suggest preparation for certain use



**Plate 44: The three collections of laterite, Central gully section, Tsauni south viewed from the North-East.**



**Plate 45: Close-up of one of the laterite collections, Central gully section, Tsauni south Note that the laterite appeared to have been broken into smaller pieces.**

***Unit S9***

Unit S9 (plate46) is located on latitude $11^0$ 05' 41.1"N, longitude $7^0$ 34' 33.9"E and altitude 698m. It occupies an area of about 100m east to west and about 80m north to south. Two smelting areas are found in this Unit. Smelting area 1 (plate46) is to the southwest of the Unit. It is about 3m in diameter with a few broken parts of a furnace. On the other hand, Smelting area 2 (plate47) is larger, stretching for about 15m east to west and about 10m north to south.

***Unit S10***

Unit S10 is located on latitude $11^0$ 05' 43.6"N, longitude $7^0$ 34' 35.6"E, altitude of 702m and about 60m northeast of Unit S9. It covers an area of about 40m east to west and about 25m north to south. At the western part is a smelting area, the only one

identified in this Unit. The smelting area measures about 15m east to west and about 10m north to south.



**Plate 46: A general view of Unit S9, Central gully section, Tsauni south from the east showing Smelting area 1 (ranging pole position).**

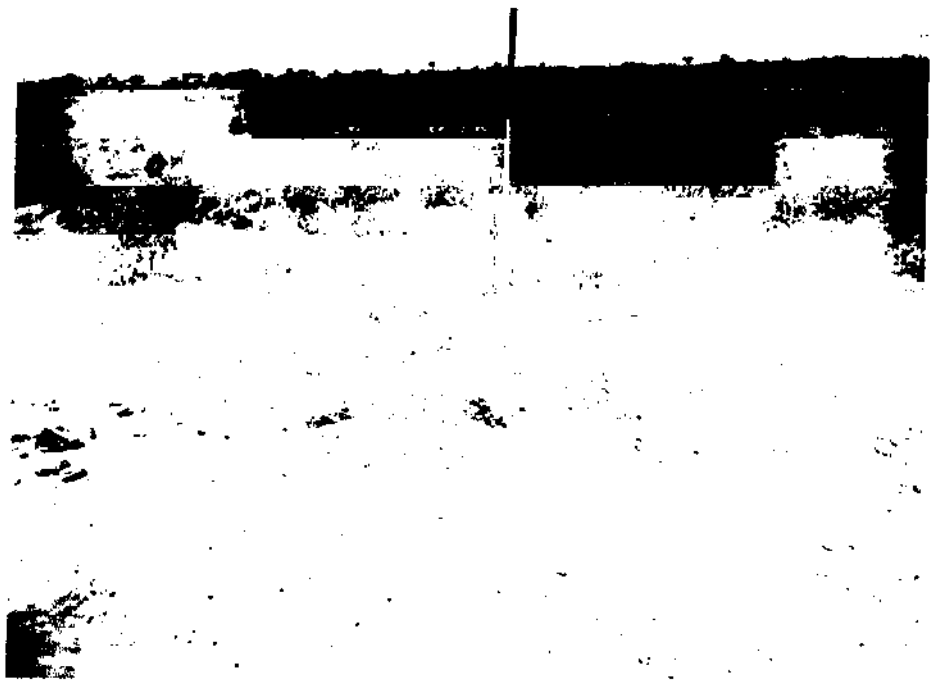


**Plate 47: A close-up of smelting area 2 in Unit S9, Central gully section, Tsauni south**



**Plate 48: A general view of Unit S9, Central gully section, Tsauni south**



**Plate 49: A close-up of the smelting area in Unit S9, Central gully section, Tsauni south**

***Unit S10***

This Unit is located on latitude $11^0$ 05' 44.3"N, longitude $7^0$ 35'02.7" E and altitude 705m. It has almost been completely washed away. From what is left, it could have been a very large mound but presently, only a patch of about 2m to the northwest is intact. The eroded portion could be seen running into the gully (plate 50).

***Unit S11***

It is located on latitude $11^0$ 05' 48.6"N, longitude $7^0$ 35' 03.9"E and on altitude 709m above sea level. The Unit is by far larger than 1 in the area. Although erosion has washed away large portion of it, the smelting areas are still visible. Unit S11 measures about 60m (N-E/S.W and 50m (N-W/S-E) and is associated with 3 smelting points.

Smelting area 1 is located at the south-western portion of this Unit (plate52). It is about 8m in diameter with large pieces of furnace and tuyeres while Smelting area 2 is to the southeast, about 30m from 1 most of which has been eroded leaving only about 5m. Smelting area 3 is about 20m northwest of the second smelting area. It is about 7m in diameter with large pieces of furnace and tuyeres (plate53).

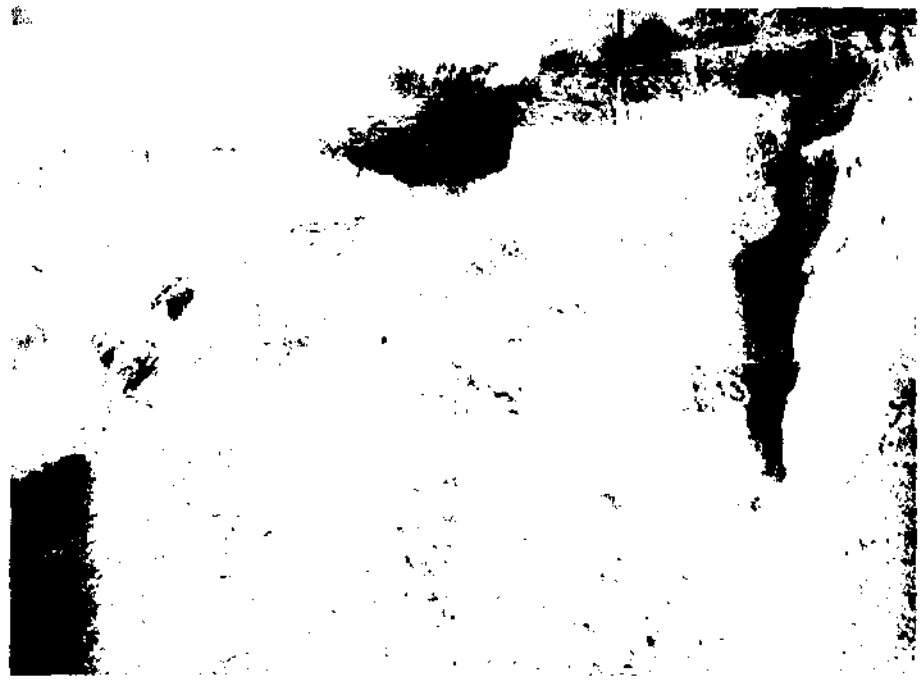


**Plate 50: Remnants of the only smelting area in Unit S10, Central gully section, Tsauni south Note how erosion is cutting and washing a large mound of iron smelting debris into a deep gully.**



**Plate 51: The central gully, Tsauni south showing the devastation of some of the sites. Towards the far end in the photograph is smelting area in Unit S10 while the camera position is smelting area 3. Note how erosion is destroying the site.**

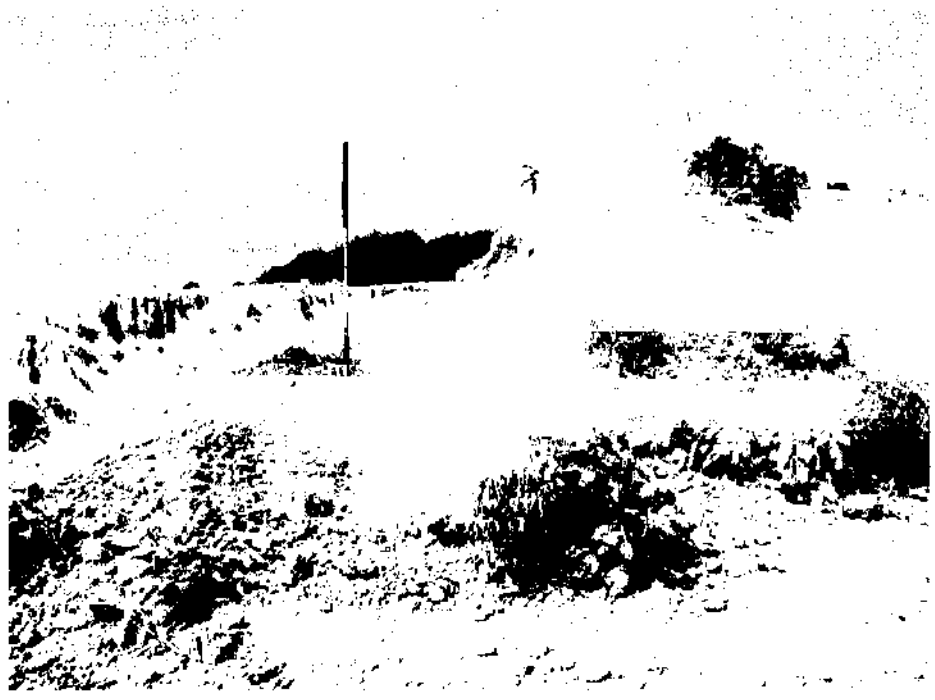


**Plate 52: A close-up of smelting area 1 in Unit S11, Central gully section, Tsauni south**



**Plate 53: Smelting area 2 in Unit S11, Central gully section, Tsauni south viewed from smelting area 3 to the South.**

**North Western Section**

***Unit S12***

Unit S12 is located on latitude $11^0$ 06' 04.5"N, longitude $7^0$ 35' 05.9"E and altitude 719m above sea level. It is 12m (N –S) and 72m (W - E). This Unit has one smelting area and is associated with one furnace outline with huge furnace wall, the diameter of which is 80cm. A slag heap of 1m in diameter (plate55) was found 3m north east of the furnace outline. This Unit is characterized by sheet erosion which is washing away the slag collection in the smelting area (plate 54)

***Unit S13***

The location of Unit S13 is latitude $11^0$ 06' 06"N, longitude $7^0$ 35' 06"E and altitude 723m above sea level. Its North-South and West-West dimensions are 22m and

12m respectively (plates 56 and 57). This Unit is identified with only one smelting area associated with slag collection of 4m diameter.



**Plate 54: A general view of Unit S12, north western section, Tsauni south, from the southeast.**



**Plate 55: A close-up of the smelting area in Unit S12, north western section, Tsauni south**



**Plate 56: A general view Unit S13, north western section, Tsauni south from the southeast.**



**Plate 57: A close-up of the smelting area in Unit S13 north western section, Tsauni south**

***Unit S14 (Plate 58)***

It is located on latitude $11^0$ 06' 06.8"N, longitude $7^0$ 34'57.2"E and attitude 724m above sea level. Its north-south dimension is 48m, while it is 56m West-East. This Unit lies 60m west of 2 and is generally characterized with slag scatter. Three smelting areas were identified in Unit S14. Smelting area 1 lies 10m from southern limit of Unit S15 and is characterized with slag scatter. Its dimensions are 10m (N – S) and 14m (W – E). Smelting area 2 is located 8m north of smelting area 1 with dimensions of 6m (N - S) and 6m (W – E). It is also associated with slag scatter. Smelting area 3 is located 12m north west of area 2 and associated with scatter of tiny pieces of iron slag (plate59). This smelting area is 12m (N – S) and 12m (W – E).

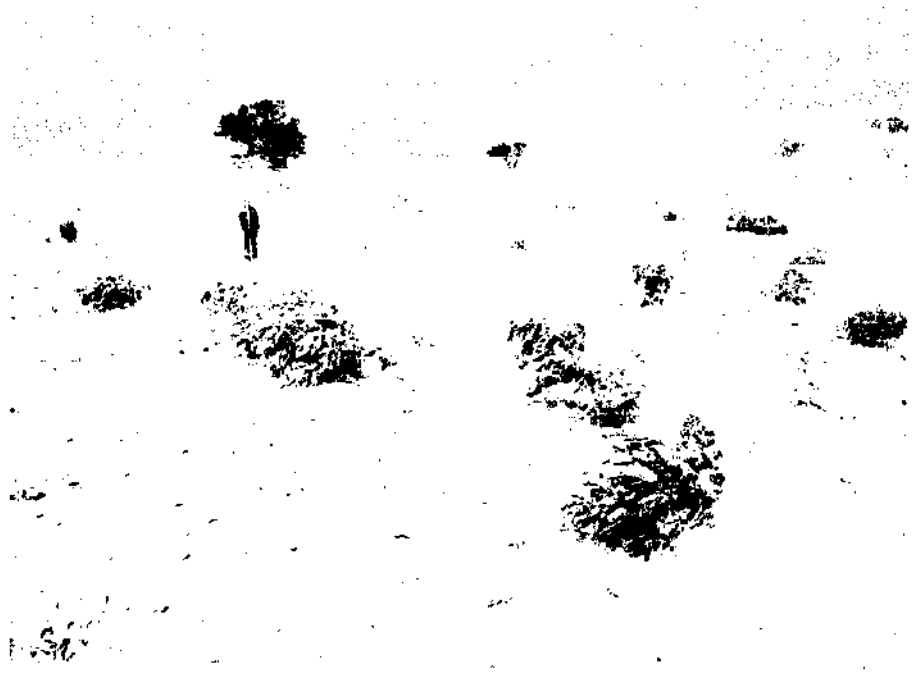


**Plate 58: A general view of Unit S14, north western section, Tsauni south from the east**



**Plate 59: A close-up of smelting area 3 in Unit S14, north western section, Tsauni south**

***Unit S15***

It is found 18m, north east of Unit S15 and located on latitude $11^0$ 06' 07.6"N, longitude $7^0$ 34'58.5"E and altitude 726m above sea level. Its dimensions are 32m (N – S) and 24m (W – E). Two smelting areas were identified in this Unit. Smelting area 1 (plate 60) marks the southern limit of Unit 4 which has a circular slag scatter of 6m diameter. Smelting area 2 (plate61) lies 16m north east of 1 and is associated with slag litter covering an area 10m (N –S) and 10m (W – E).

***Unit S16***

This Unit lies on latitude $11^0$ 06' 09.3"N, longitude 7 35'02.5"E and altitude 725m above sea level. It is found 40m north east of Unit S15 with dimensions of 47.5m (N – S) and 64m (W – E) (plate 62).

We identified three smelting areas in this Unit. Smelting area 1 is associated with slag and pottery litter, with higher quantity of pottery than slag. No tuyere or furnace fragment was found. It occupies an area of 8m in diameter and marks the western limit of Unit 5. Smelting area 2 lies 10m north east of point 1. It is characterized by slag fragments of furnace and pottery scatter within an area of 6m diameter while Smelting area 3 is located 16m east of 2 and is associated with scatter of slag and pottery with slag more in quantity. Its north-south and west-east dimensions are 7.5m and 15m respectively. A special feature (plate 63), which is a mound littered with potsherds and bone fragments was found. It has a diameter of 5m.



**Plate 60: Unit S15, north western section, Tsauni south showing Smelting area 1.**



**Plate 61: Smelting area 2 in Unit S15, north western section, Tsauni south**



**Plate 62: Unit S16, north western section, Tsauni south viewed from the Southeast.**



**Plate 63: Special feature of a mound littered with fragments of bone and potsherds in Unit S16**

***Unit S17***

This Unit is found 90m North West of 5. It is located on latitude $11^0$ 06'13.6", longitude $7^0$ 35' 03.3"E and altitude 722m above sea level. Six smelting areas were identified in Unit S18 which occupies an area of 44m (N – S) and 50m (W – E). Smelting area 1 is 8m in diameter, marking the south eastern limit of Unit S18 and is associated with slag and pottery scatter with slag more in quantity. Smelting area 2 lies 4m west of 1. It is identified with scatter of slag and pottery within an area of 8m diameter. We observed that slag scatter is more in quantity than pottery there. Smelting area 3 is located 8m north of 2 and is also associated with slag and pottery scatter with more slag than pottery. It occupies an area of 15m diameter. Smelting area 4 is found 10m North West of 3. It is associated with slag and pottery scatter within an area of 12m diameter. We observed also that slag pieces are more than potsherds in this smelting point. Smelting area 5 is located 6m north of 4 and characterized by slag scatter of 6m diameter while smelting area 6 is found 5m north of 5 and identified with large pieces of slag occupying within an area 6m in diameter. We observed that the slag pieces in this smelting area are bigger than those found in any of the smelting point in Unit S17 (Plate64)

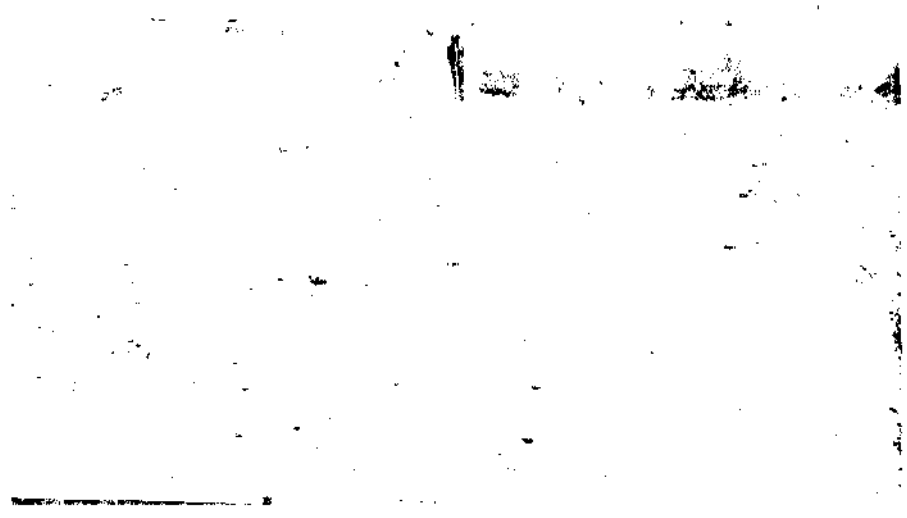


**Plate 64: *General view of Unit S17, north western section, Tsauni south from the South***



**Plate 65: Large pieces of slag in smelting area 5, Unit S17, north western section, Tsauni south**

***Unit S18***

Unit S19 is located on latitude $11^0$ 06'16.2"N, longitude $7^0$ 35'02.1"E and altitude 727m above sea level. It lies 48m north west of Cluster 6. The only Smelting area identified in this Unit is 24m (N – S) and 16m (W – E) in dimension and associated with slag scatter (plate66).

***Unit S19***

Unit 8 marks the northern end of Tsauni South. It is located 78m north west of Unit S19 on latitude $11^0$ 06'11.2"N, longitude $7^0$35'01.8"E and altitude 744m above sea level. One smelting point was identified in this Unit. It is a slag litter on a mound of diameter 17.5m (Plate 68). Unit S19 is located 30m south of Birni Gwari road.

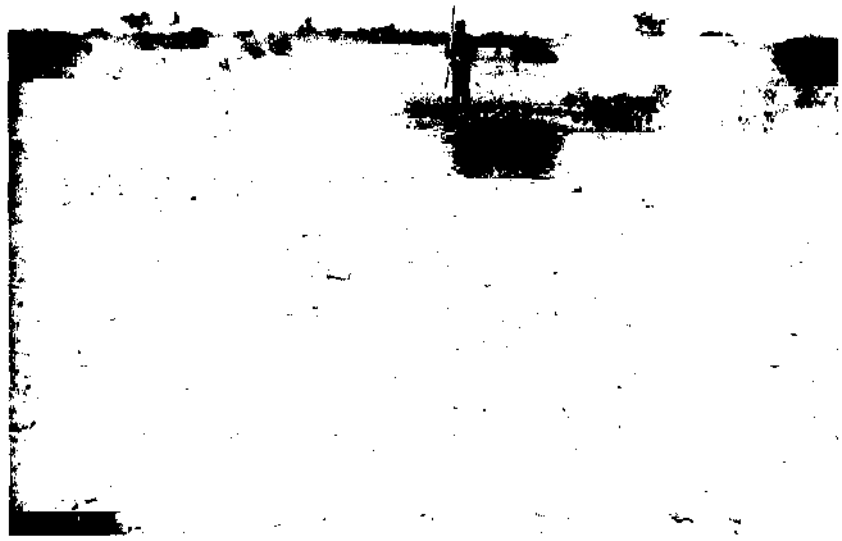


**Plate 66: Unit S18, north western section, Tsauni south viewed from the south showing the only Smelting area.**



**Plate 67: Unit S19, north western section, Tsauni south viewed from the south showing the only smelting area identified in the Unit. The Zaria Birnin- Gwari road is 30m north.**

**The South-Western Section**

The reconnaissance of the South Western section of Tsauni south started from the laterite outcrop which marks the south western end of the laterite ridge (plate68).The outcrop (latitude $11^0$ 05'53.4"N longitude $7^0$ 34'21.9"E and 708m above sea level measuring 45m (North-South), 50m (West-East) was adopted as our reference point.

***Unit S20***

From this position, Unit S20 (latitude $11^0$ 05' 47'8" N, longitude $7^0$ 34' 26.9"E and altitude of 699m above sea level) was located. It is characterised by pottery and slag scatter (plate71). The slag scatter is smaller in quantity than that of pottery measuring 50m (north-south) and 70m (east-west).

***Unit S21***

Unit S21 (plate 72) is located 11m east of Unit S20 on latitude $11^0$ 05' 46.3", longitude $7^0$ 34' 27.4" E and 698m above sea level). It is a circular area associated with a collection of laterite boulders (plate73) which may have been part of the raw material (ore) used in smelting operation in the area. Close observation showed that the laterite boulders were deliberately gathered presumably to be used as ore for smelting as seen in the Central gully section.



**Plate68: The lateritic outcrop used as the datum point for the South-western section, Tsauni south**

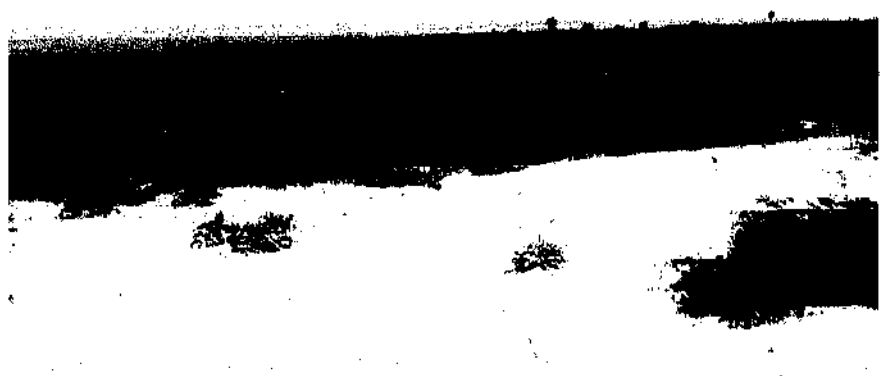


**Plate 69: The South-western lateritic outcrop (at the horizon) viewed from the south east of Tsauni South.**

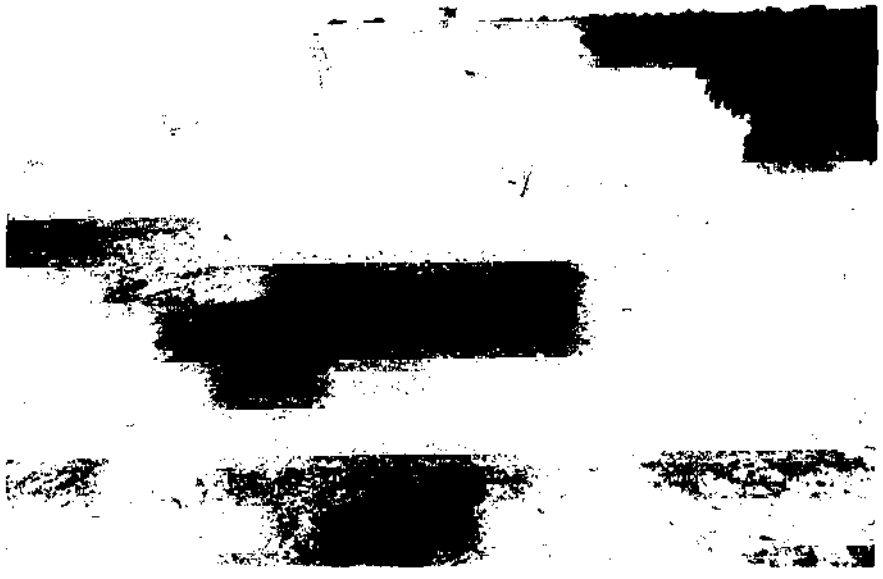


**Plate70: Unit S20, South western section, Tsauni south viewed from the South.**



**Plate 71: A close-up of a collection of laterite, potsherds and slag pieces, Unit S20, South western section, Tsauni south**



**Plate72: A general view of Unit S21, south western section, Tsauni south**

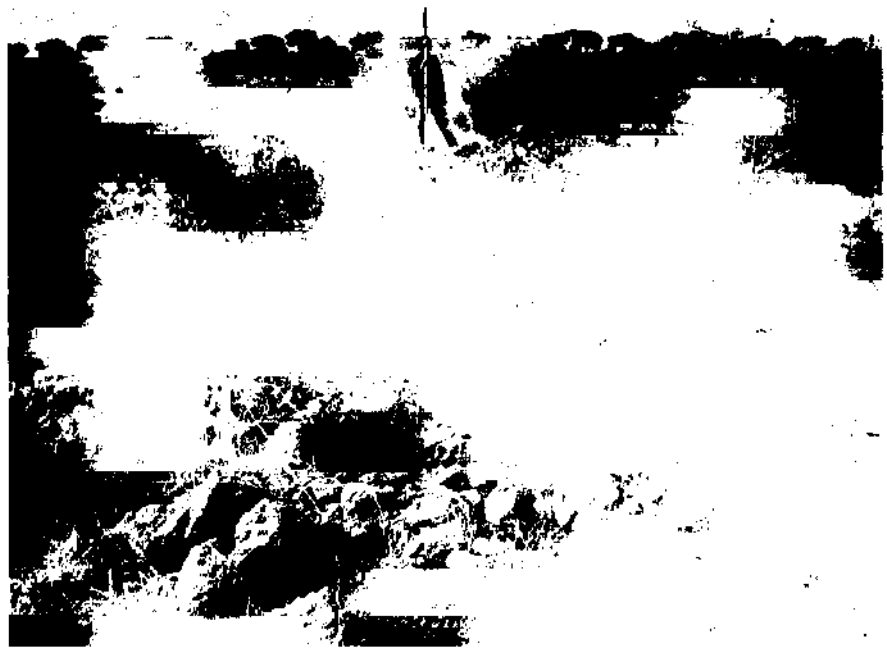


**Plate 73: A collection of laterite associated with Unit S21, south western section, Tsauni south**

***Unit S22***

Unit S22 lies on latitude $11^0$ 05' 48.5"N, longitude $7^0$ 34.30"E and 701m above sea level and located 80m north east of Unit S21. Visibly, it is a smelting area, measuring 100m (north-south) and 20m (west-east) with three smelting areas identified (plate74). Smelting area 1 is a slag scatter on a natural mound (plate75) of 10m diameter. It marks the southern limit of Unit S22, while smelting area 2 located 20m north of 1 is associated with slag scatter and huge broken furnace walls (plate 76) covering a circular area of 10m diameter. Smelting area 3 (plate77) is located 11m north of 2 and is associated with litter of iron slag and broken of furnace walls that are not as large as those found in 1. While the fragments of furnace walls cover an area of 1.5m in diameter, that of the slag scatter is 4m in diameter. Smelting area 4 is associated with a furnace base, fragments of

furnace, tuyeres and thick potsherds. It is located 22m northwest of 3 and covers an area of 26m diameter. This marked the northern limit of smelting area 3.

***Unit S23***

Unit S23 lies 200m north of 3 on latitude $11^0$ 05' 52.4" N, longitude $7^0$ 34' 32.6"E on an attitude of 702m above sea level. We identified two smelting areas in this Unit. Smelting area 1 is characterized by huge fragments of furnace walls, tuyeres and slag scatter which cover an area 7m in diameter (plate78). Smelting area 2 is located 6m north of 1 and associated with huge pieces of broken furnace walls, tuyeres and slag litter covering an area of 2m diameter (plate79).



**Plate 74: Unit S22, south western section, Tsauni south viewed from the South.**



**Plate75: Smelting area 1, Unit S22, south western section, Tsauni south viewed from the East.**



**Plate76: Smelting area 2, Unit S22, south western section, Tsauni south viewed from the East.**



**Plate 77: Smelting area 3 in Unit S22, south western section, Tsauni south viewed from the South.**



**Plate78: A view of Unit S23, south western section, Tsauni south from the south-east (smelting area 1).**



**Plate79: Smelting area 2 in Unit S23, south western section, Tsauni south viewed from the South-East.**

***Unit S24***

On latitude $11^0$ 05'54"N, longitude $7^0$ 34' 29.9"E and altitude 709m above sea level, Unit 7 is located 10m northwest of Unit S23. Visibly, this Unit does not look like a smelting area (plate80). The slag litter here is by far smaller in quantity than the pottery. However what makes this Unit distinct is the presence of what looks like potsherd pavements. Four areas of these were observed, with the largest (3m diameter located at the central part of Unit S24 (plate81).

***Unit S25***

It is located 50m north west of Unit S25 on latitude $11^0$ 05'54"N, longitude $7^0$ 34'28'0"E and 708m above sea level. It covers an area 60m (north-south) and 43m (west-east). We observed that this Unit has three smelting areas and is generally characterized by slag litter, broken furnace walls, tuyeres and furnace foundations (plate82). Smelting area 1 is

located south east of Unit S25, marking its southern limit. It is associated with litter of fragments of furnace, tuyeres and iron slag covering an area 12m in diameter. On the other hand, Smelting area 2, located 20m north east of 1 is associated with a furnace stocked with solidified chunk of slag (plate83) with no evidence of slag litter, broken furnace walls or tuyeres. Smelting area 3 lies 32m west of 2 and is also associated with a furnace stocked with a chunk of solidified slag though with slag scatter but no fragments of furnace walls and tuyeres.

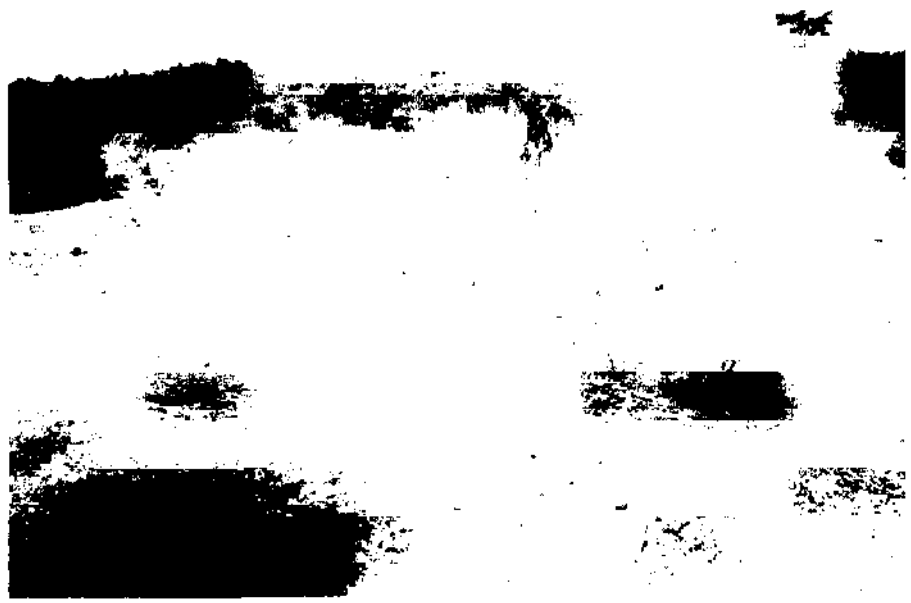


**Plate 80: A general view of Unit S24, south western section, Tsauni south from the East**

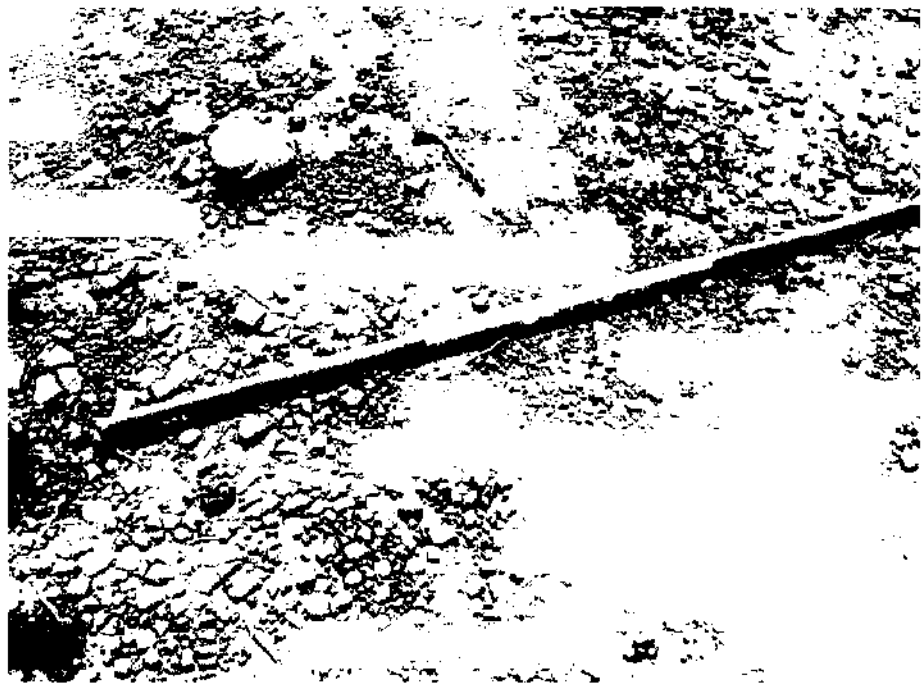


**Plate 81: Close up view of what looked like a potsherd pavement in Unit S24, south western section, Tsauni south**

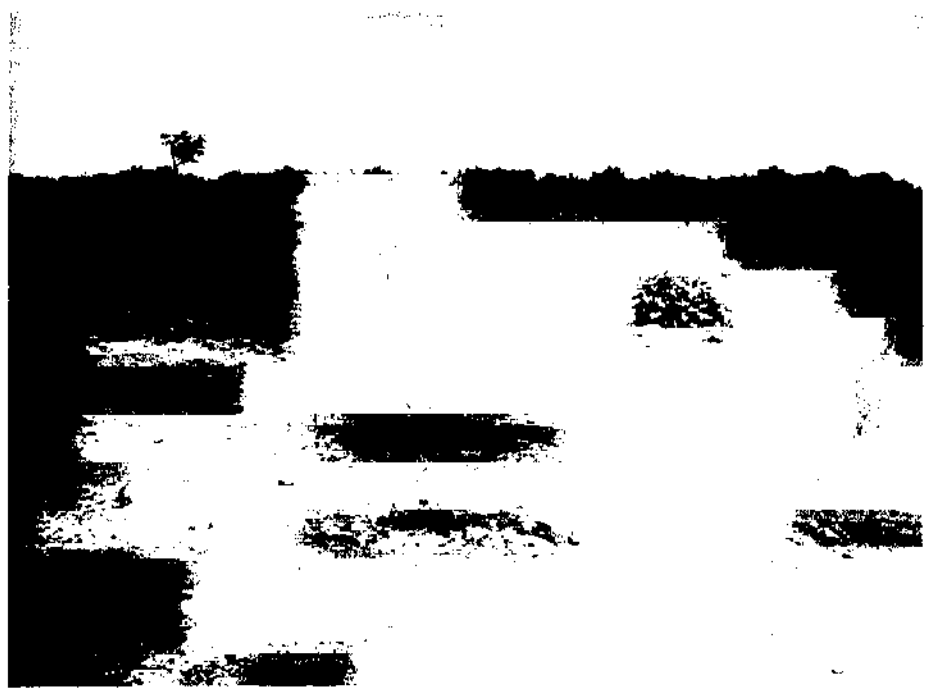


**Plate 82: Unit S25, south western section, Tsauni south viewed from the South-east.**



**Plate 83: Close up of Smelting area 2 in Unit S25, south western section, Tsauni south showing a furnace base with solidified chunk of slag.**

***Unit S26***

At 40m North West of Unit S25, we identified Unit S27 (plate84) on latitude $11^0$ 05' 55.3'N, longitude $7^0$ 34' 30.4 E and altitude 710m above sea level. Three smelting areas were identified in this Unit. Smelting area 1 comprises broken furnace walls and slag litter covering an area 4m in diameter, while 2 is located 9.5m south west of 1 and associated with a furnace base stocked with solidified chunk of slag (plate85). Smelting area 3 lies 18m North West of 3 and associated with one furnace base measuring 0.75m in diameter and fragments of tuyere and slag scatter.

***Unit S27***

Unit S27 lies on latitude $11^0$ 05' 55".4N, longitude $7^0$ 34' 37.5" and altitude of 705m above sea level. It is located 130m north east of Unit S26. This Unit is associated

with large quantities of broken furnace walls, tuyeres and slag litter (plate86). We identified six smelting areas in Unit S27. Smelting area 1, which marks the southern limit of this Unit, is associated with slag litter on a mound of 18m diameter with huge broken furnace (plate87) and tuyeres. Smelting area 2 is situated 3m north east of 1. It is characterized by a circular thin layer of slag scatter on a natural mound of 1m diameter, while 3 is located 3m north east of 2. This smelting area is also associated with slag litter on a natural mound with large broken furnace walls and tuyeres (plate88). Smelting area 4 is found 3m north east of 3 and is also characterized by slag scatter on a mound which is 9m in diameter. Smelting area 5 is 13m north east of 4. It is associated with a natural mound (plate88). A twin furnace was found at the north western part of this smelting area, the diameter of the bigger is 1m while that of the smaller is 0.75m. Midway in smelting area 5 at the east is a broken furnace, 0.75m in diameter with pieces of iron slag. This smelting area has a diameter of 2.3m (west-east), while 6 is located 3m north of 5 and characterized by litter of broken furnace walls and iron slag covering an area of 18m in diameter (west-east).

***Unit S28***

At 300m east of 8, Unit S28 (latitude $11^0$ 05' 51" N, longitude $7^0$ 31' 46.8"E on attitude of 708m above sea level) was located. The dimensions of this Unit are 74m (north-south) and 38m (west-east). Three smelting areas were identified in Unit S28 (plate 90). Smelting area 1 is associated with litter of tiny pieces of iron slag marking the southern limit of the Unit covering an area 12m in diameter. Smelting area 2 is located 46m north east of 1, associated with the base of a furnace, 80cm in diameter with an unusually thin wall without slag (plate 91). Smelting area 3 on the other hand is

associated with slag scatter but with no fragments of furnace or tuyeres. It is located 7m north west of smelting area 2 and covers an area of 4m in diameter.

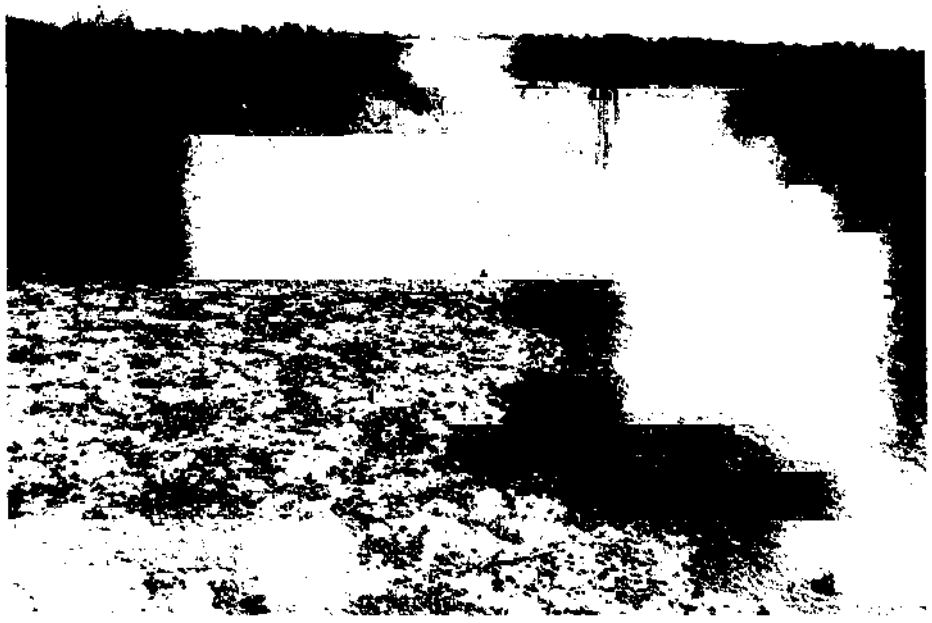


**Plate 84: Unit S26, south western section, Tsauni south viewed from the West.**



**Plate 85: A solidified chunk of slag inside a furnace in Unit S26, south western section, Tsauni south**

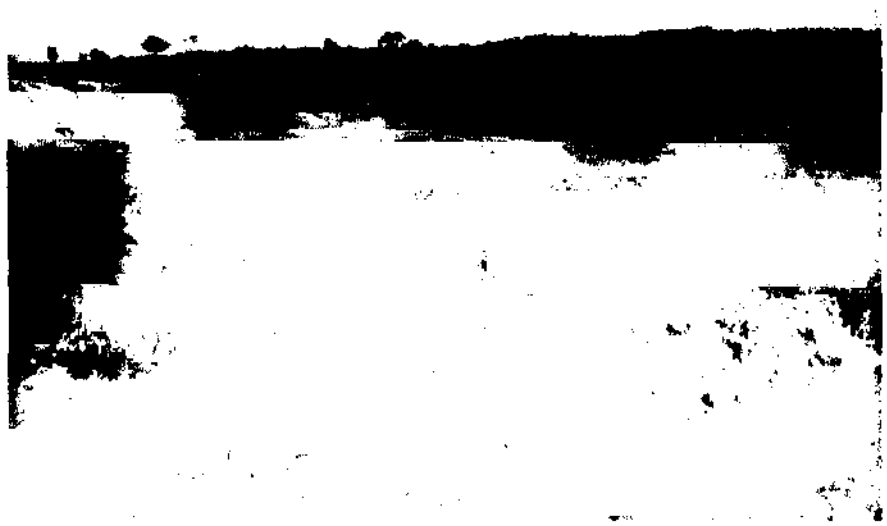


**Plate 86: Unit S27, south western section, Tsauni south viewed from the south showing the central slag mound.**



**Plate 87: Unit S27, south western section, Tsauni south viewed from the north showing the Southernmost Smelting area 1**



**Plate 88: Smelting area 3 in Unit S27, south western section, Tsauni south viewed from the southwest showing remains of a furnace.**



**Plate 89: Smelting area 5 in Unit S27, south western section, Tsauni south viewed from the southwest showing remains of a furnace**



**Plate 90: Unit S28, south western section, Tsauni south viewed from the Northwest.**

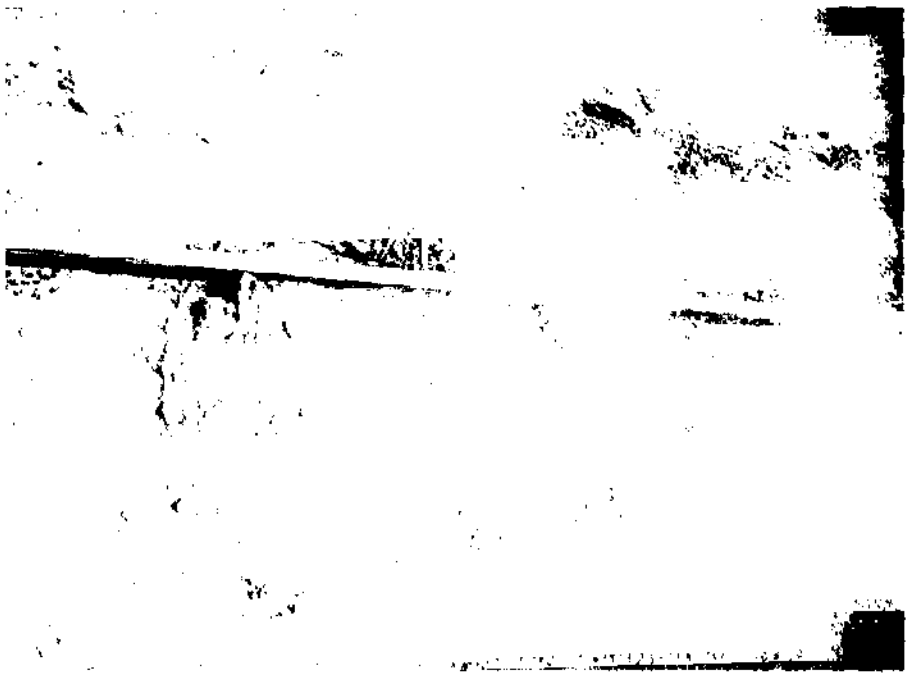


**Plate 91: An outline of a furnace in Unit S28 south western section, Tsauni south. Note that the wall is unusually thin**

***Unit S29***

Unit S29 (latitude $11^0$ 05', longitude $7^0$ 34'48.3" E, and altitude 703m above sea level) is located 28m east of 9 (plate92). It covers an area of 46m (north-south) and 42m (west-east). Two smelting areas were observed in this Unit. Smelting area 1 (plate 93) which marks the southern end of Unit S29 is associated with litter of slag and potsherds covering an area 8m in diameter. Smelting area 2 found 8m north east of 1 is a natural mound, 6m in diameter, associated with scatter of potsherd and pieces of iron slag. We observed that potsherds were more in quantity than iron slag there.

***Unit S30***

Unit 11 lies on latitude $11^0$ 05'45.4" N, longitude $7^0$ 34'98.9" and altitude 704m above sea level). It is located 120m south east of cluster 10 and generally characterized by big fragments of furnace walls and tuyeres in association with slag pieces (plate94).

Two smelting areas were identified in the Unit. Smelting area 1(6m diameter), which marks the southern limit of the Unit is associated with a furnace base, 40cm in diameter (plate95). Smelting area 2 is located 6m north west of 1. A broken furnace with thick wall was found there. This smelting area is about 1.5m in diameter.

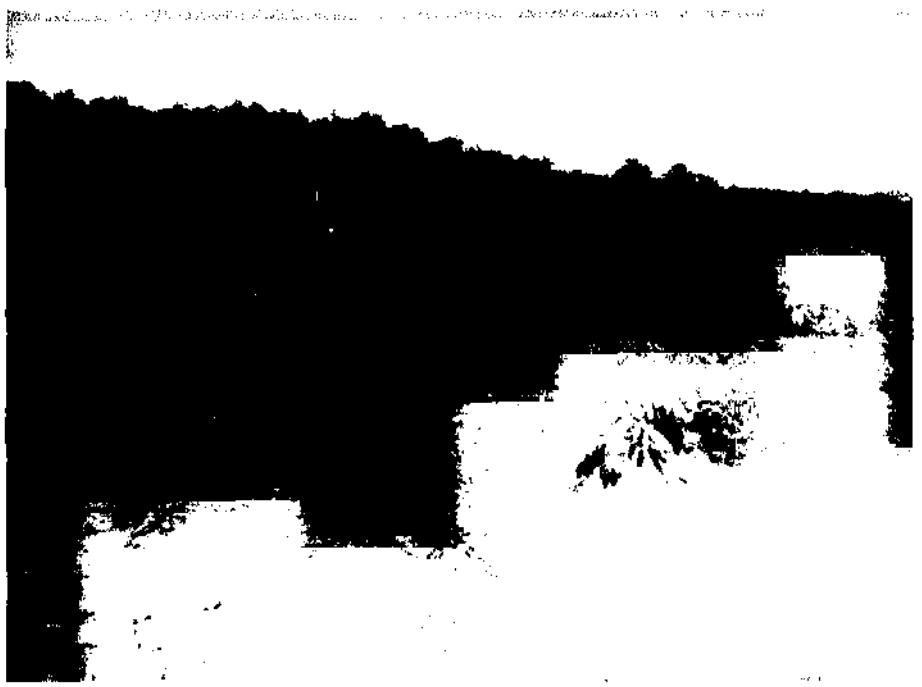


**Plate 92: Unit S29, south western section, Tsauni south viewed from the South.**

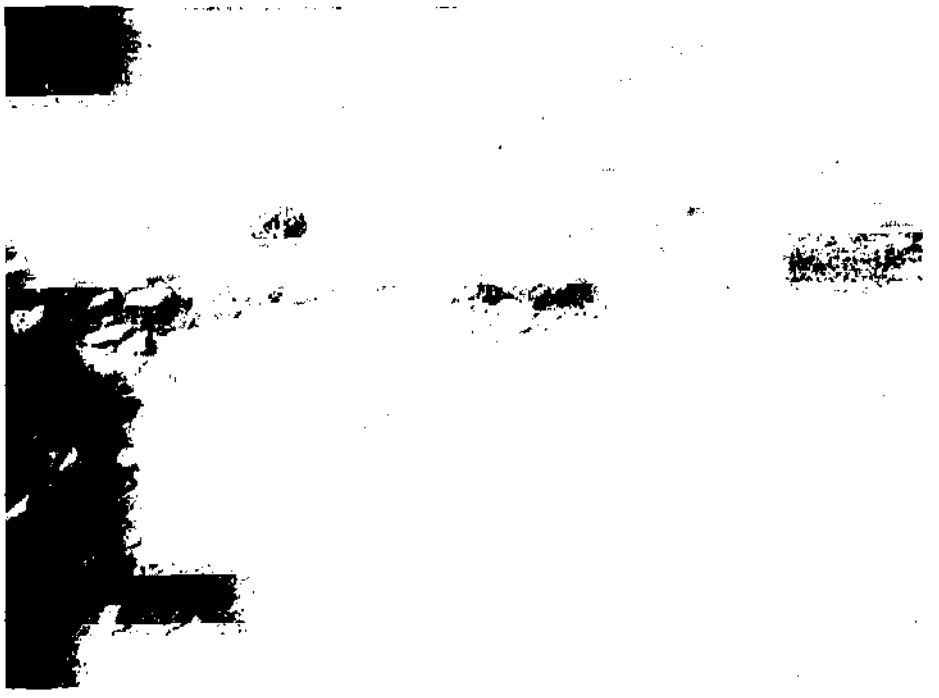


**Plate93: Smelting area 1 in Unit S29, south western section, Tsauni south viewed from the west.**

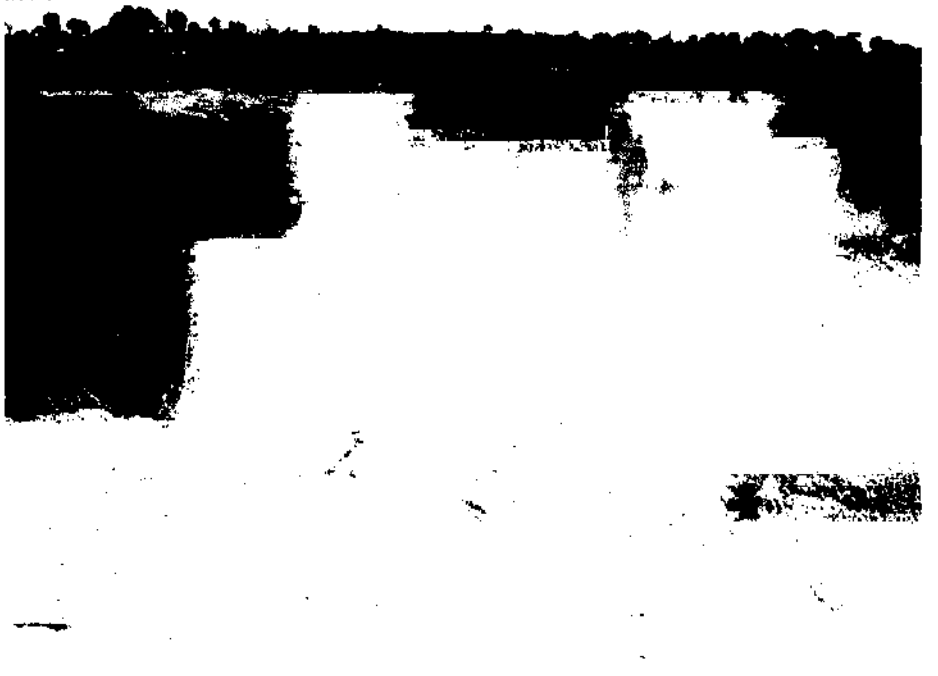


**Plate 94: Unit S30, south western section, Tsauni south viewed from the Northwest.**



**Plate 95: Remains of a furnace marking the Southern end of Unit S30, south western section, Tsauni South**

**GENERAL OBSERVATIONS**

The following general observations were made in the course of the archaeological reconnaissance of Tsauni north and south sites. At Tsauni north, the area associated with material evidence of smelting activities is smaller in size compared to Tsauni south. This may not be unconnected with the nature of the area which makes cultivation more possible than the south. The prevalence of farming activities in Tsauni north could have been responsible for the destruction of iron smelting evidence which tends to account for its relative paucity than in the south. In addition, Tsauni north generally portrays an occurrence of smaller pieces of smelting slag associated with smaller furnaces and tuyeres compared to those associated with Tsauni south which are bigger. It is also observable that smelting sites are normally located close to lateritic outcrops, a

phenomenon that tends to lay credence to the possibility that the raw mareials (ore) were sourced from these outcrops. Compared to Tsauni south, we observed that erosion activities are not as pronounced in Tsauni north and the proximity of smelting sites to streams as sources of water for iron smelting is not a very strong factor. Due to its more plain nature, the occurrence of material evidence does not follow any diverse physiographic characteristics.

The heaviest concentrations of material evidence in form of slag, huge furnace walls, and tuyeres are observable in the South Western section than in any other. Here, two types of slag accumulation were identified. These are accumulation on natural mounds and on plain land. The North Western section also has evidence of slag accumulation on natural mound but not as pronounced as in the South western section. The Eastern, North Western and Central gully sections lack heavy accumulation of slag and other debris on natural mound like the South Western section.

The choice of Tsauni south for iron smelting and the concentration of smelting activities in the area appeared to have been due to the fact that large parts of the area are not cultivable. This is in sharp contrast to the situation in Tsauni north where the land is more plain and therefore more cultivable.

In addition we observed that all smelting activities as indicated by the material remains were conducted in the valley of Tsauni south. No material evidence was found outside the valley. This seems to lay some credence to our view that the lateritic ridges that surround Tsauni south were probably sources of raw material (ore) used for smelting operations (Sutton 1976a, 1985; Effah-Gyamfi 1981)

It is also instructive to note that natural agent (gully erosion) is more responsible for the destruction of material evidence of iron smelting in Tsauni south than humans. However, despite this, the area still exhibits more debris of iron smelting than Tsauni north.

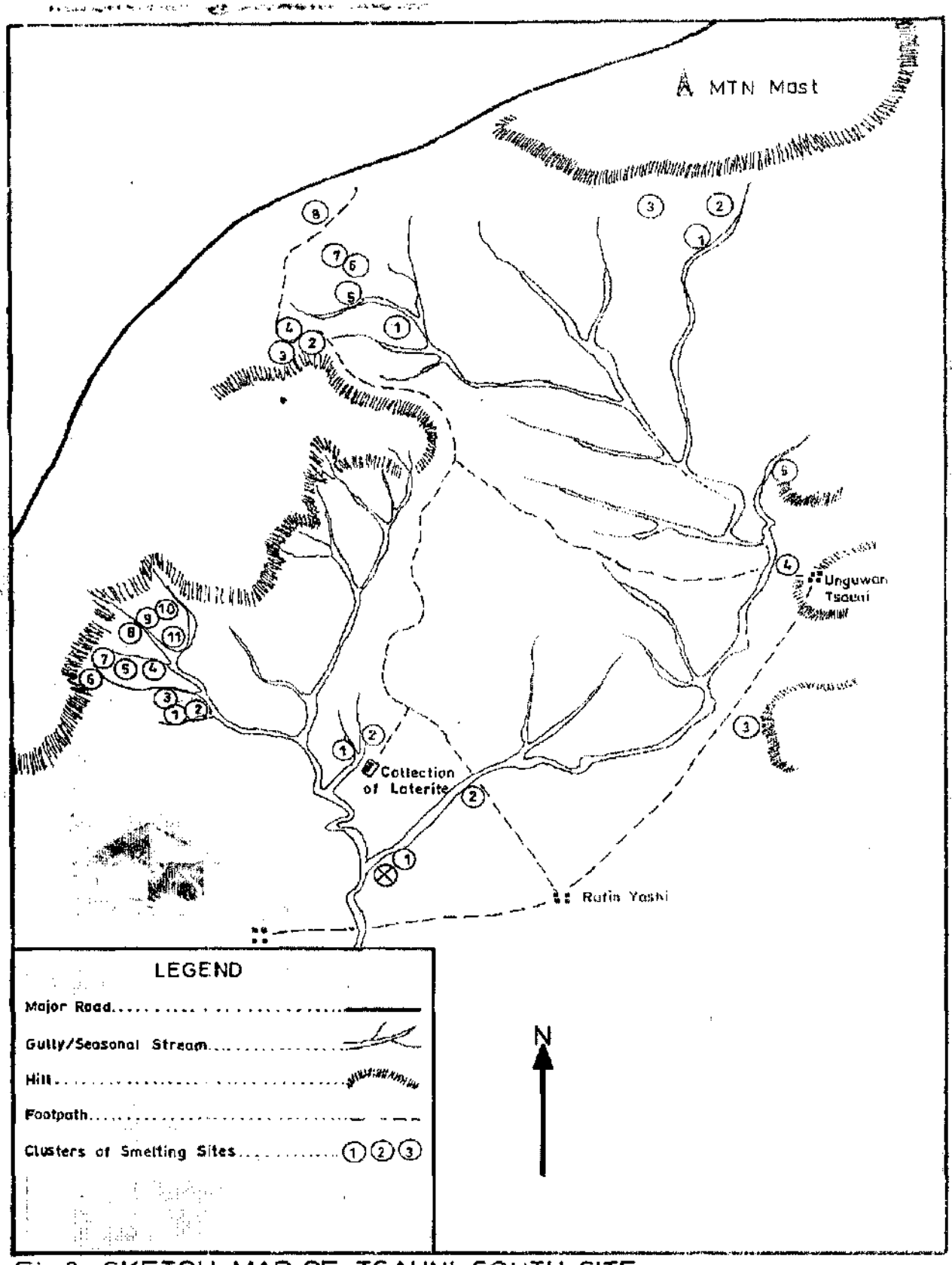



Fig 8: SKETCH MAP OF TSAUNI SOUTH SITE

# CHAPTER FIVE

# EXCAVATIONS

## Introduction

In this chapter, we present the results of the excavations conducted at Tsauni between May 2006 and June 2007. The objectives of the excavations were:

(i) To recover material evidence for study.

(ii) To retrieve material remains for metallurgical analyses and scientific age determination to shed light on the nature of iron smelting and its antiquity in the area of study.

(iii) To assess cultural viability of the sites.

(iv) To understand the stratigraphy of the excavated areas.

For a balanced geographical spread of our investigation, four test pits were sunk each at Tsauni north and Tsauni south. Our determination of soil colours in these excavations was based solely on visual impression.

## TSAUNI NORTH EXCAVATIONS

The area excavated in Tsauni north lies about 1km from the Zaria-Birni Gwari road and located right of a road running north/south to the village of Yan Sarki. The area excavated is on latitude $11^0$ 06.536' N, longitude $7^0$ 35.437' E. and altitude 717m above sea level.

Two test pits were excavated at Tsauni north between May and June 2006, each measuring 3m by 3m. The areas excavated were in Unit1, western section of Tsauni north (plate 6), characterized by the presence of litter of iron slag, pieces of broken furnace

walls and tuyeres. The slag pieces are small, only a few of which exceed 10cm in length. Unit N1 lies at the foot of the lateritic outcrop (north of the Zaria-Birni Gwari road) running north/south of the Zaria- Birni Gwari road.

In selecting the areas to excavate, we observed the outlines of 2 groups of smelting furnaces at the centre of Unit N1 which were about 4m to each other. One group was associated with 3 furnace bases while the other revealed two. The occurrence of these furnaces almost joined together, raised the issue of how they could have been used simultaneously during a smelting operation. We then decided that the excavation of the two groups of furnaces will help in shedding some lights on the type of furnaces in the area and possibly how they were used for smelting operations.

An area of 50m by 50m was gridded because we believed this was necessary to ensure a proper understanding of the topography of excavated areas in relation to that of the entire Unit N1 (Fig 13). Excavation was conducted using the spit level method. For that purpose, a spit level of 20cm was adopted. The distance of point C (the South East corner) of pit I to point B (the North East Corner) of pit II was 9.88m, while that of point D (South West Corner) of pit I to point A (North West Corner) of pit II was 9.81m.

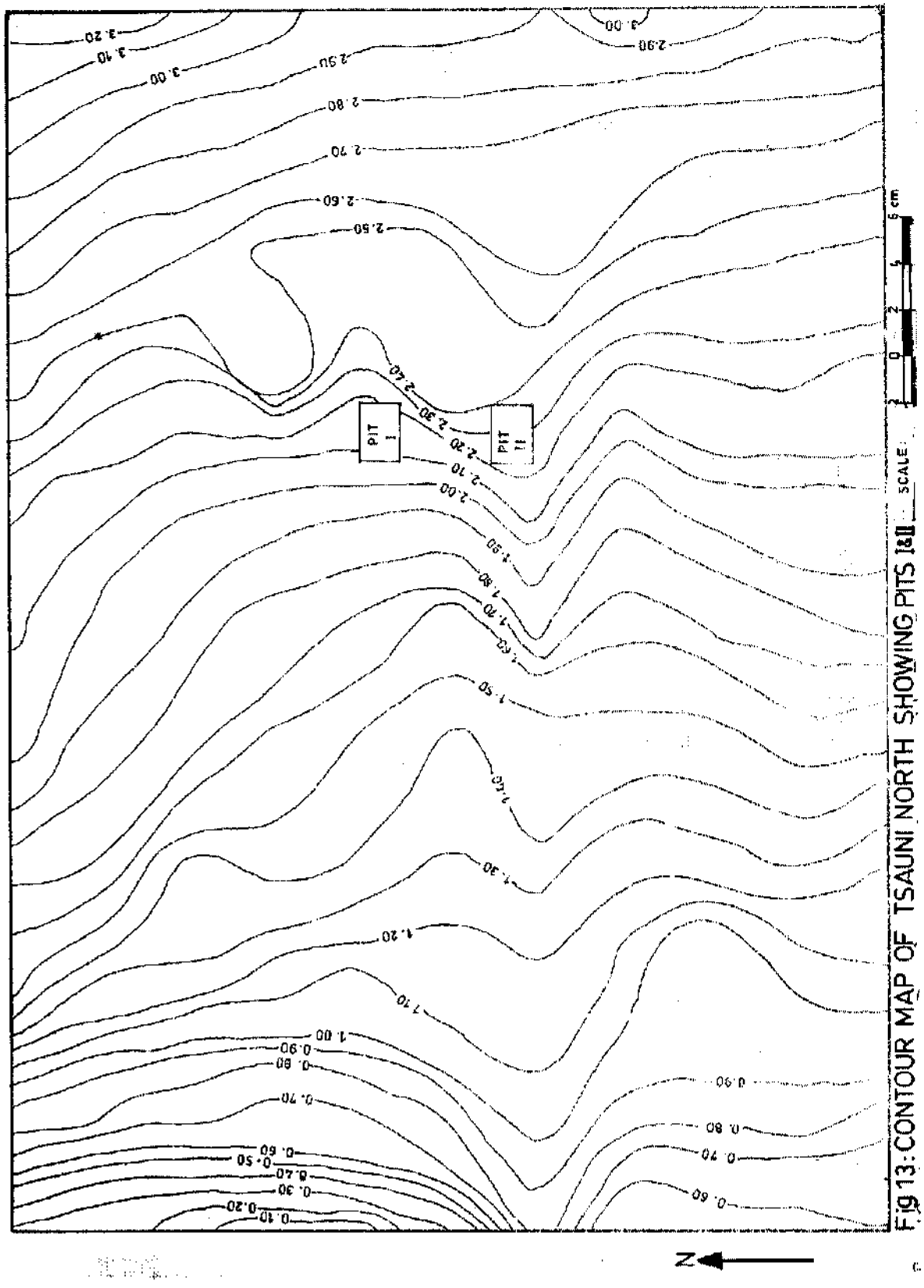



Fig 13: CONTOUR MAP OF TSAUNI NORTH SHOWING PITS I&II

**TEST PIT I**

Test Pit I (TSN-06-I) is located on latitude $11^0$ 06.534"N, longitude $7^0$ 35.440E and 715m above sea level. Prior to the commencement of excavation, we noted that the surface soil of the area was reddish brown and lateritic in nature. We also observed a wide scatter of iron slag, pieces of broken furnace wall and tuyere fragments on the surface. As earlier indicated, the most curious aspect of the area to be excavated was the presence of three furnaces on the surface that were very close to one another (plate96). We therefore saw the need to excavate these furnaces as a way of understanding how they could have been used during smelting operations.

***Spit Level 1*(0-20cm)**

At the first spit level, we observed the presence of compact, brownish top soil. Occurrence of iron slag in association with broken furnace walls and tuyeres were also noted at the north western corner of Test pit I at about 10cm below surface. The eastern corner was characterized by loose soil, while the soil became drier and more compact towards the western corner of the Test pit. The three furnaces identified in pit one were named as A, B and C respectively. Furnace 'A' was located towards the south western wall, furnace B at the middle of furnaces A and C, while furnace 'C' was located towards the northern wall (plate99, fig9). Occurrence of slag was observed in furnace A while C was also associated with iron slag and pieces of broken furnace.

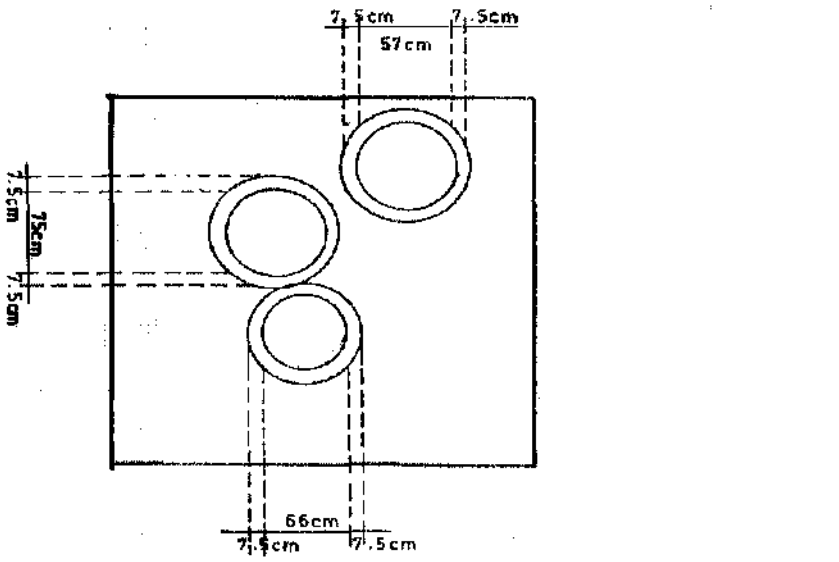



Fig 9: POSITION OF FURNACES IN PIT I, TSAUNI NORTH SITE



**Plate 96: Setting pit 1 excavation in Tsauni North.**



**Plate 97: Pit 1 of Tsauni North after the topsoil had been removed.**

*Spit level 2 (20-40cm)*

At the second spit level; the northern wall exhibited compact and dry soil with few iron slag while the southern wall was more damp, brownish and loose. At this level, we observed the occurrence of a tuyere, 24cm from the northern wall, while the second tuyere was located north of furnace B. The length of the first tuyere was 1.4cm, outer diameter – 7 cm, inner diameter – 3 cm and thickness 2cm. The second tuyere measured 1m in length, with outer diameter of 11cm, inner diameter 7cm and thickness of 2cm. At the end of the second spit level, three furnaces were clearly identified and their dimensions measured. Furnace A was found separate, while B and C were joined together. The dimensions of the furnaces were as follows; outer diameter of furnace A-81cm inner diameter – 60cm and thickness 10.5cm, outer diameter of furnace B was 81cm, inner diameter – 57cm and thickness 12cm, while furnace C had outer diameter of 81cm, inner diameter – 51cm and thickness of 15cm. Furnace C was the thickest of the three, while B was irregular in shape. Furnaces A and C were bowl like. This suggested to us that furnace B may have been a broken part of C since it was joined to it. The biggest of the three was furnace B. We further observed that furnace B did not contain slag as A and C which goes further to suggest that it was just a fragment of a furnace and not a separate one as earlier thought. The distance of furnace A to C was 76cm, while B to C was 17cm. The average outer diameter of the furnaces in Test pit I, Tsauni north is 81cm while their average thickness is about 13cm.

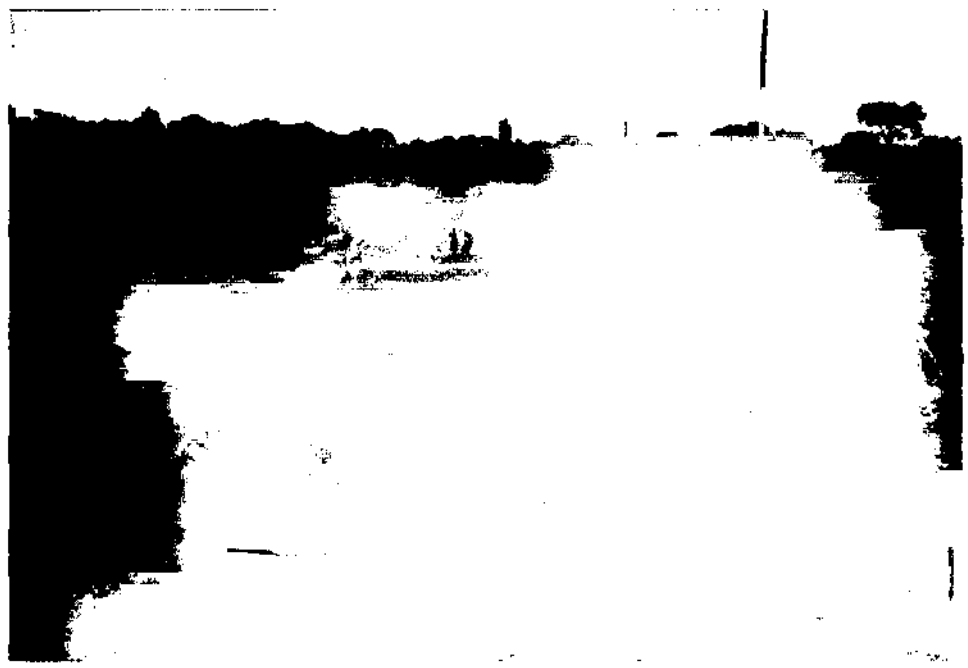


**Plate 98: Level 1 of Pits 1(camera point) and 2 (ahead), of Tsauni North excavations, viewed from the East**

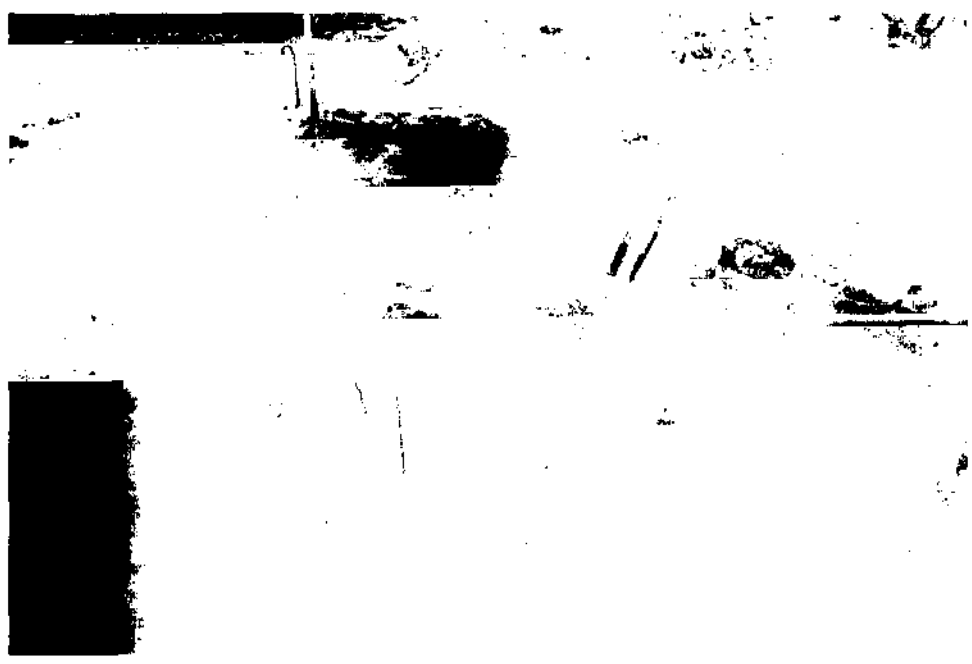


**Plate 99: Pit 1 in Tsauni North showing the three furnaces as seen in Level 2.**

***Spit level 3 (40-60cm)***

At spit level three, an occurrence of a group of tuyeres "in situ" was noticed at 25m from the southern wall and 24cm from the western wall. This was identified as the southern group of tuyeres, 24cm from furnace 'A' (plate100). The northern group of tuyeres was found close to furnace 'C', just 8cm away (plate 101). At the end of this spit level, furnace 'A' was broken and its round base exposed.

***Spit level 4 (60-80cm)***

At level four, occurrence of reddish brown soil was still noticeable. The western wall exhibited reddish brown and compact soil, while that of the eastern wall was greyish brown and clayey. A group of fragments of tuyeres were found embedded in the western wall (plate 103), while iron slag were found in the eastern wall. At this level, charcoal pieces were found in furnaces A and C and collected for C14 age determination as earlier indicated in chapter one.

***Spit level 5 (80-100cm)***

Spit level 5 began with the occurrence of reddish brown compact soil and concentration of iron slag at the south western corner of Test pit I. At this level, a group of eight broken tuyeres were found. They were all apparently discarded after successive use. No regular pattern of arrangement could be identified with them as they face different directions in the pit. We considered these as special features and took their dimensions accordingly. Their average length was 22cm, outer diameter – 9cm and 5cm – inner diameter, with thikness of 2cm.We also observed the presence of accumulated iron slag beneath the group of eight tuyeres.

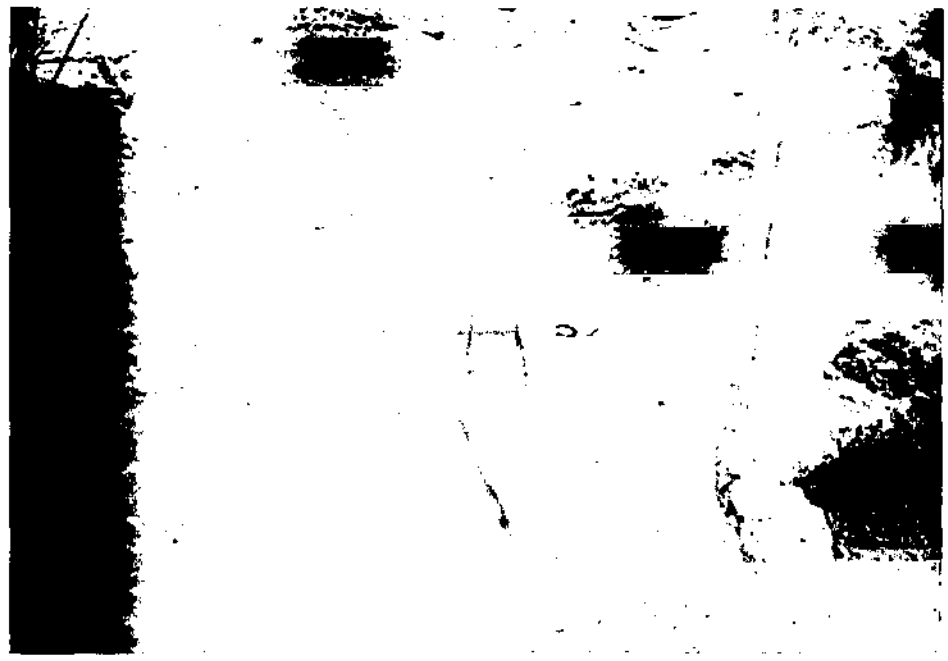


**Plate 100: Tuyeres found embedded in the southern wall at Level 3 of pit 1, Tsauni North.**

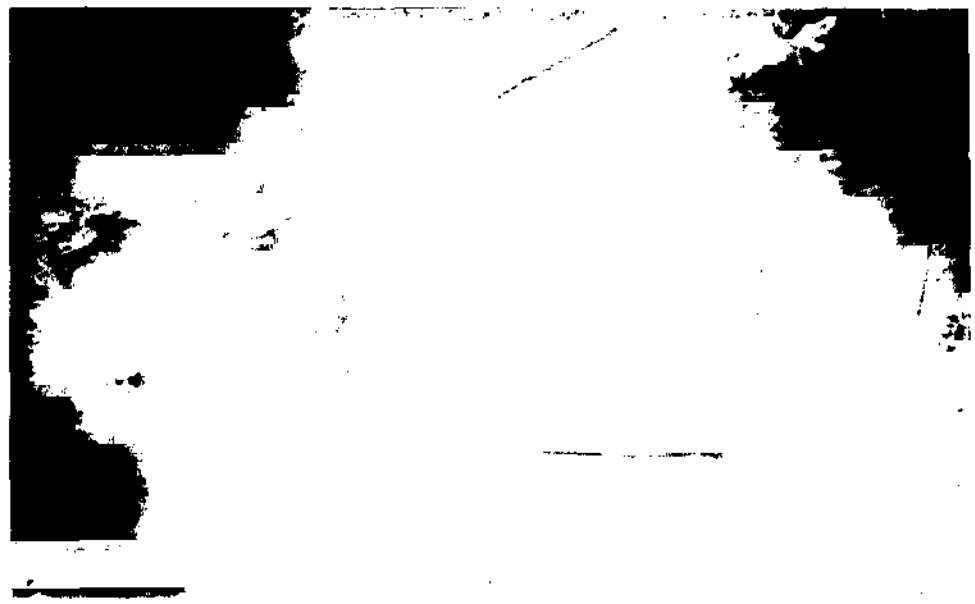


**Plate 101: A collection of tuyeres around furnaces in pit 1 of Tsauni North**

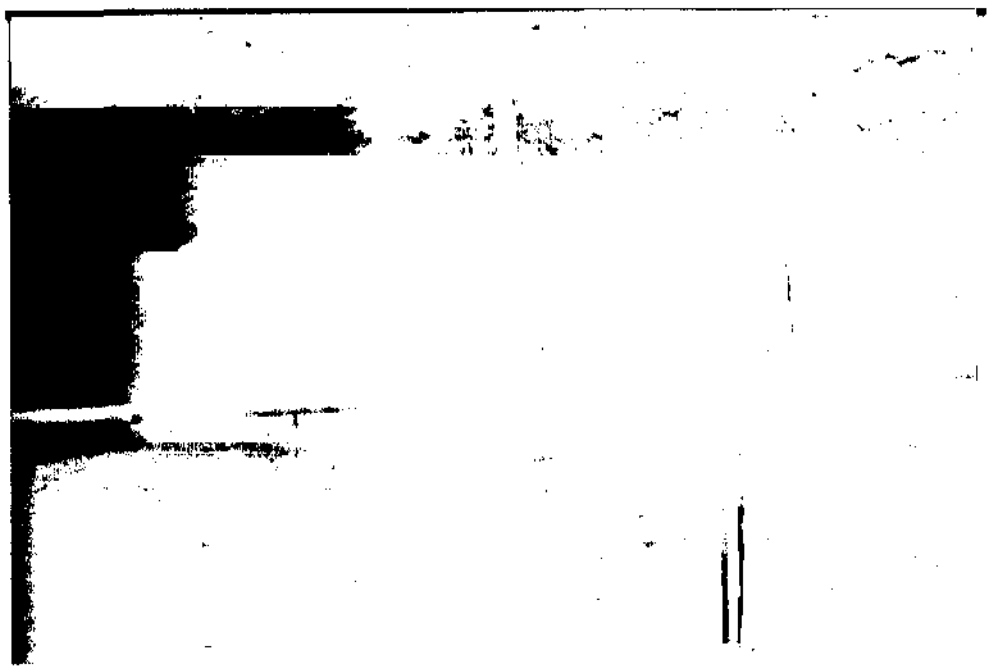


**Plate 102: A collection tuyeres towards the northern wall of level 3 in pit 1of Tsauni North.**

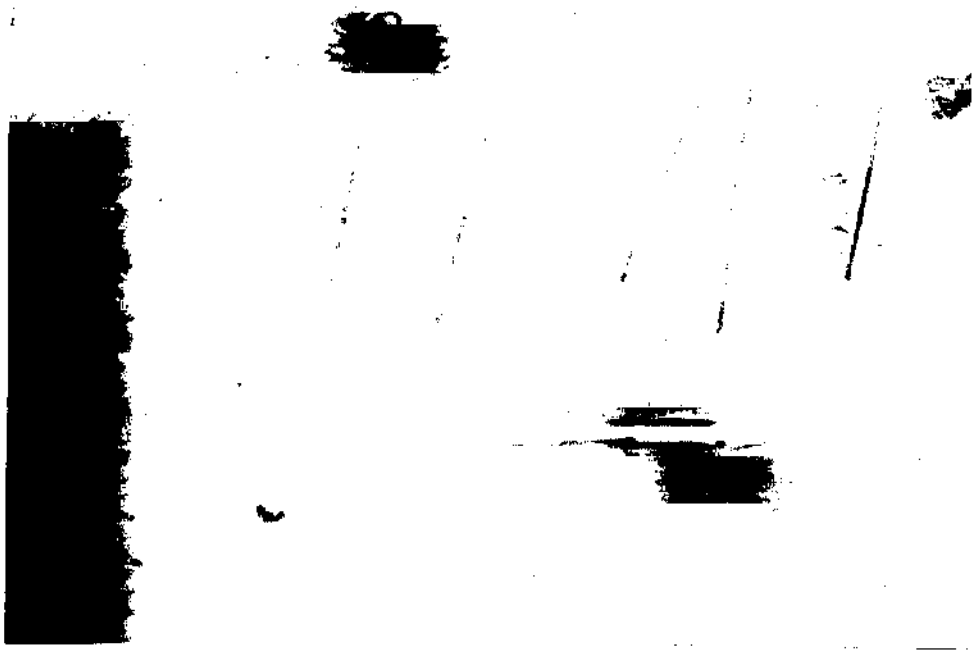


**Plate 103: Level 4 of pit 1, Tsauni north indicating tuyeres embedded in the western wall.**

***Spit level 6 (100-120cm)***

Spit level six exhibited lateritic and very hard soil under where the eight tuyeres were dug out. We observed the occurrence of large quantities of slag at this level. Two tuyeres were found at the western wall. Tuyeres were found in the south from point A towards D at 120cm and associated with iron slag and laterites. At the southern wall, one potsherd was found, the first since the commencement of the excavation. A sample of iron slag was taken from the south western corner of the pit for analysis. The occurrence of grey brownish lateritic soil was further observed at this level but without cultural remains.

**Spit *level 7(120-140cm)***

The spit level seven featured reddish brown lateritic soil without cultural material. Visibly, this was the sterile layer which signified the end of the excavation of pit I of Tsauni north.

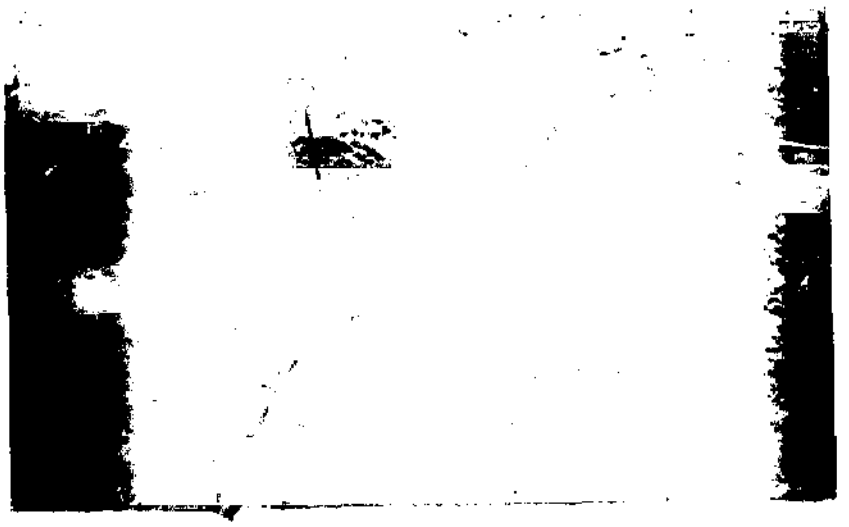


**Plate 104: A tuyere found in the southern wall of pit 1 at level 5, Tsauni north**

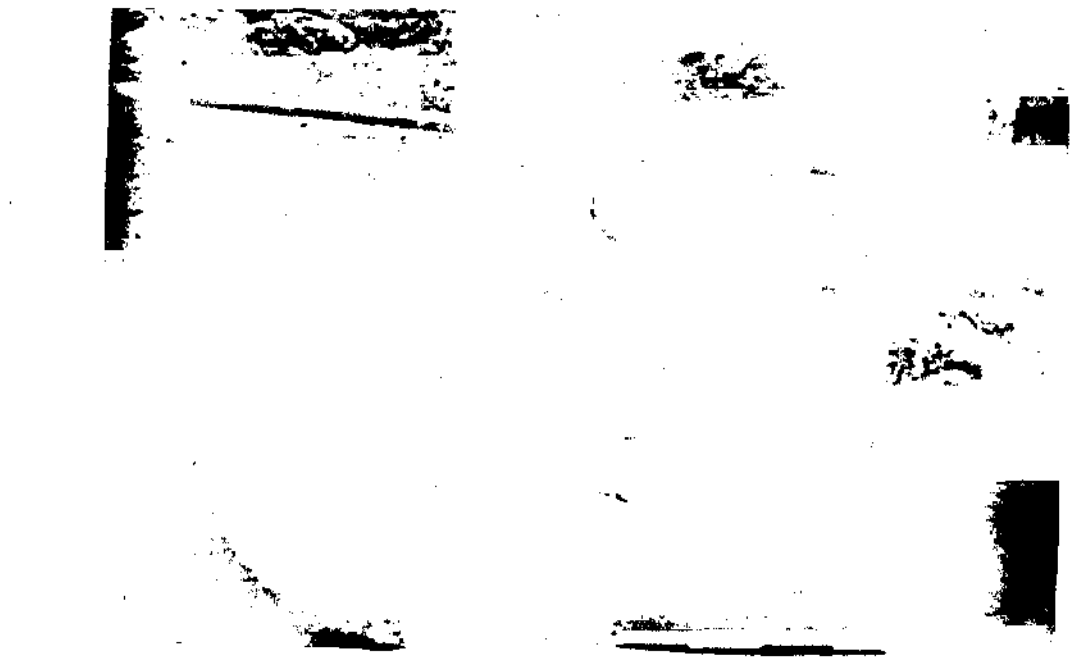


**Plate 105: The bottom of the furnaces in Level 6 of pit 1 in Tsauni north.The survey pins indicate the location of group of tuyeres. Note also what we initially termed as furnace B (located in the middle of A and C) looking like a fragment of a furnace**

Our general observations in the excavation of pit I were as follows: that the occurrence of iron slag and tuyere fragments at each spit level signifies that the site must have been a major industrial one, which was used for smelting operations several times, that successive smelting operations may have been characterized by renovation of furnaces for successive smelting activities, and construction of new tuyeres and the discard of old ones as evident in the group of eight tuyeres found scattered in the pit. The almost complete absence of potsherds further laid credence to our assertion that pit one was an industrial site. At the end of excavation, it was apparent that the furnaces B and C were not separate furnaces as we had earlier thought rather we concluded that B was a fragment of C. From the dimensions of furnaces A&B, we discovered that the two are the same in outer diameters (81cm), which implies same size. In addition, the tuyeres found in this pit also exhibited similar morphological characteristics. In terms of thickness, we

observed that they have an average dimension of 2cm and all indicate evidence of grass tempering.

**TEST PIT II**

Test pit II was also located on latitude $11^0$ 06.540'N, longitude $7^0$ 35.442'E and altitude 710m above sea level. The same contouring as in pit covered Pit II, due to the closeness of the two pits (Fig 13). Like pit I, the surface soil of pit II was reddish brown with litter of iron slag, broken furnace walls and fragments of tuyeres. It was also associated with outlines of two furnaces that were very close to each other. The curiosity generated by the occurrence of these very close furnace bases was partly responsible for the choice of the area for excavation.

***Spit level 1(0-20cm)***

At the first spit level, we observed that the top soil was loose; similar to the western corner of Test pit I. Pieces of iron slag were found at this spit level, about 5cm below the surface.

***Spit level 2(20-40cm)***

At spit level 2, the western wall exhibited reddish soil with occurrence of iron slag at about25cm below surface, broken tuyeres and fragments of furnace wall.

***Spit level 3(40-60cm)***

At the third level, the southern wall was harder, more compact and stony with the presence of iron slag. We also found pieces of charcoal at the base of one of the two furnaces (the eastern one) which was the smaller of the two. Furnace A was located west of the pit, while furnace B was in the south. At this level, we observed that what we earlier saw as a separate furnace A was actually a collapsed wall of a furnace. This

assertion was informed by the fact that it was not associated with any foundation. It was however associated with pieces of charcoal which were sampled for radio carbon age determination. The western part of the pit was reddish brown and compact while the eastern side was greyish brown and clayey. Tuyeres were found *in situ* in the western portion, with none in the eastern portion. The group of tuyeres found "in situ" was located close to furnace A in the south western portion from point D towards A at 1.25m.They have an average outer diameter of 8cm and inner diameter of 4cm, with an average thickness of 2cm. The dimensions of this group of tuyeres in Pit II of Tsauni north portray similarity to those of Pit I as earler indicated. Evidence of grass tempering was also noticeable in the morphology of the tuyeres.

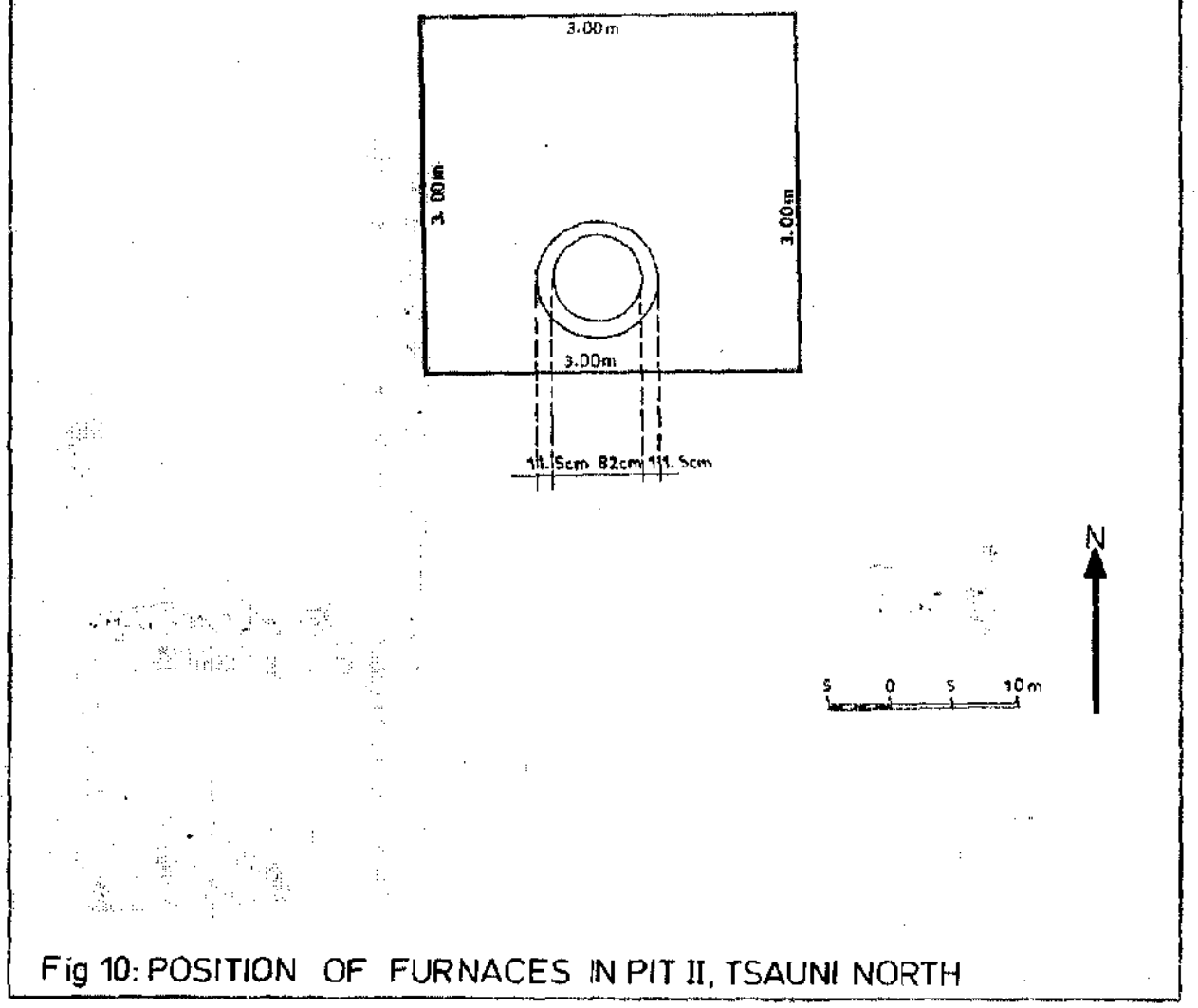



Fig 10: POSITION OF FURNACES IN PIT II, TSAUNI NORTH

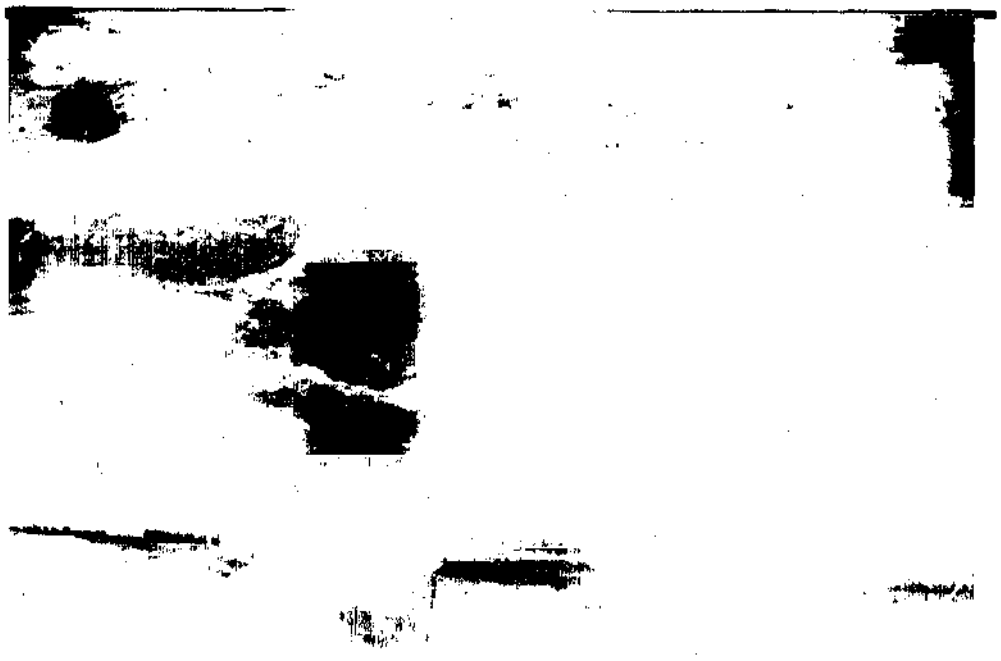


**Plate 106: Level 2 of Pit 2, Tsauni North showing Furnace B.Note also the fragment of furnace initially seen as a separate furnace.**

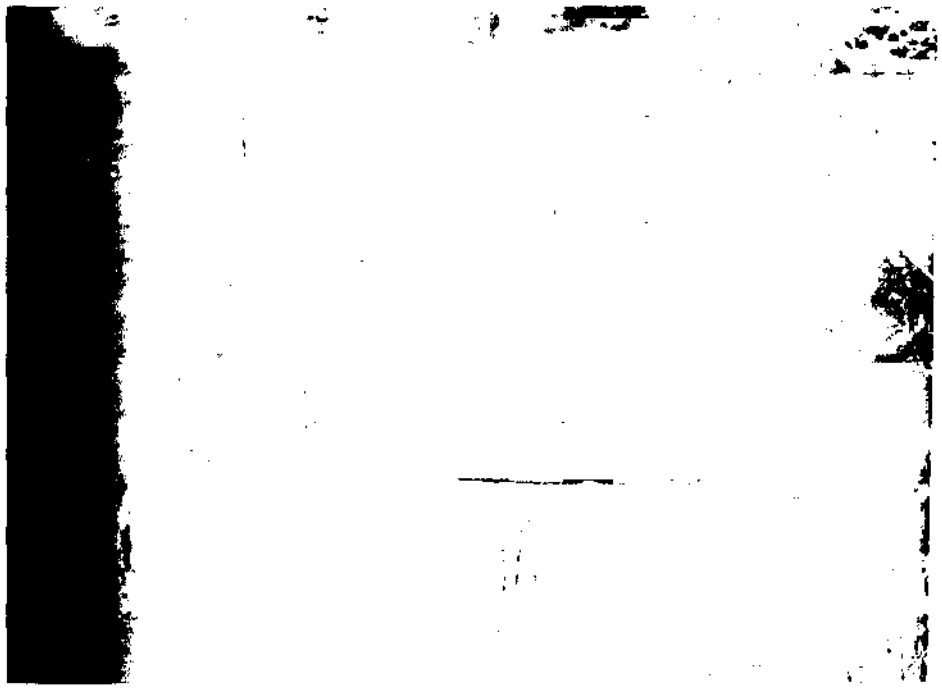


**Plate 107: Level 3 of Pit II, Tsauni North.**

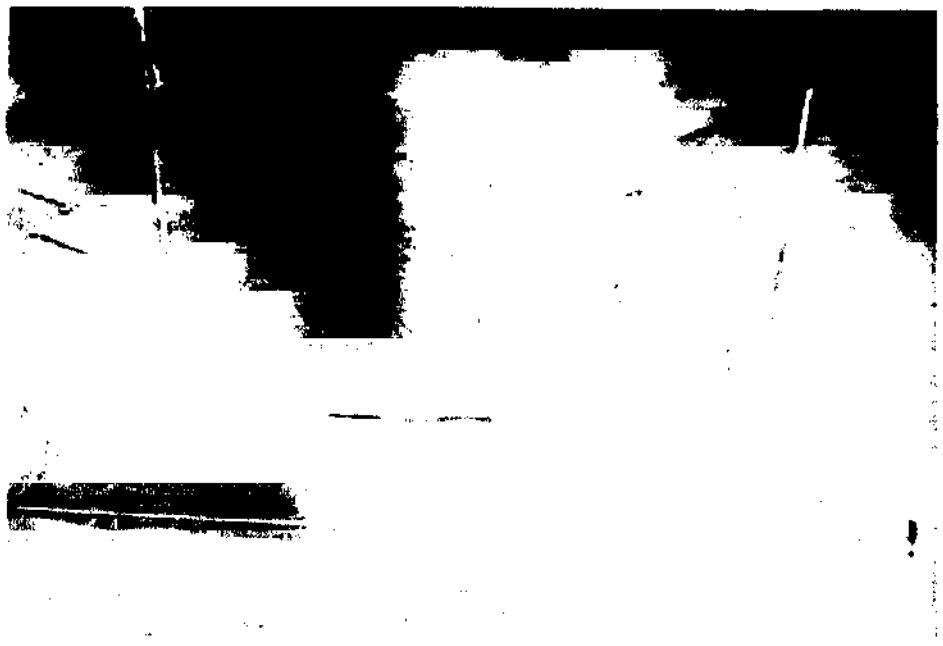


**Plate 108: The bottom of Pit 1, Tsauni North.**



**Plate 109: The bottom of Test Pit II, Tsauni North**

***Spit level 4 (60-80cm)***

The fourth level was characterized by the presence of iron slag, broken tuyeres and lateritic soil as in the previous levels.

***Spit level 5 (80-100cm)***

At spit level 5, we continued to observe reddish lateritic soil but with rare occurrence of cultural materials.

***Spit level 6 (100-120cm)***

Spit level 6 also portrayed reddish lateritic soil with complete absence of material evidence which indicated sterile layer.

We observed striking similaritics between pits I and II in terms of the nature of soils and cultural materials such as iron slag, fragments of furnace and tuyeres with conspicuous absence of pottery.

**Profiles of Test Pits I And II**

**Test Pit I**

The identification of the stratigraphy of Test pit I was also based on our visual impression. The northern wall exhibited three natural strata; reddish brown, reddish brown lateritic and sterile layers. The most prominent of these layers is the reddish brown. On the other hand, the southern, eastern and western walls exhibited four soil strata; the dark brown, reddish brown, reddish brown lateritic and sterile layers (fig11). Essentially, the soil strata of Test pit I did not show any sharp contrasts which suggest that the area was probably utilised once by a group of smelters

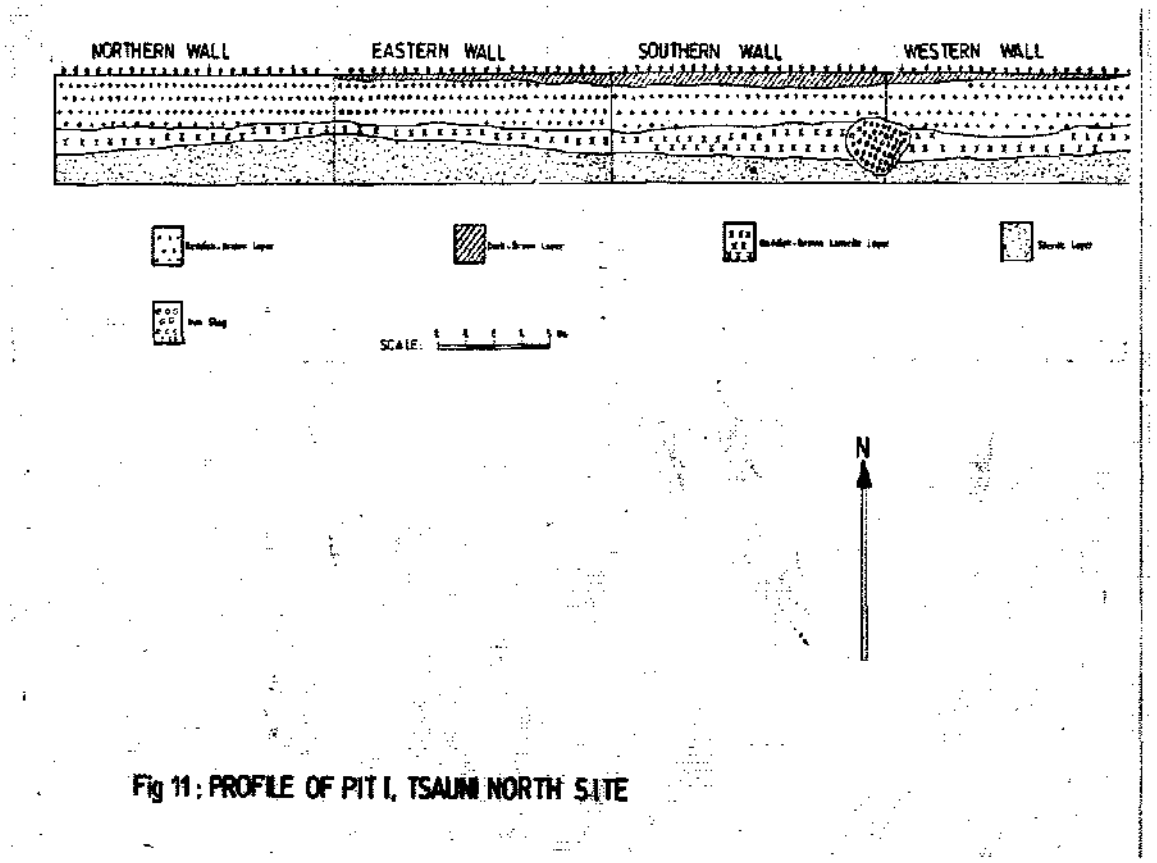



Fig 11 : PROFILE OF PIT I, TSAUNI NORTH SITE

**Test Pit II**

The profile of Test pit II (Fig 12) was also based on visual impression. It shows that the topsoil of northern wall was brownish grey, underlain by lateritic reddish layer and sterile layer. The southern wall was associated with three players; the topsoil which was a thin lateritic layer associated with slag, was underlain by lateritic reddish brown layer. The second layer was compact, lateritic and reddish brown. A burrow, 15cm wide was found at the south eastern corner. The origin was unknown. The third layer cuts across almost the entire southern wall while the western wall of layer one was lateritic soil associated with iron slag and a disturbed portion. Generally, the western wall was characterized by reddish brown lateritic soil. The eastern wall on the other hand showed loamy top soil, reddish brown second layer, reddish brown and lateritic third layer.

On the whole, we noticed that there were no sharp differences in the natural stratigraphy of Test pit II which also suggests that it was an industrial site associated with a single phase of use presumably by a group of smelters.

The excavation of Test pits III and IV in Unit N3 of Tsauni north was aimed at comparing the material evidence with those of Pits I and II in Unit N1. Specifically, we considered it appropriate to further study the nature of the furnaces that characterized iron smelting at Tsauni north with a view to comparing them with those of Tsauni south. At the time of surveying, we drew some similarities with the natural mounds found at Tsauni south and the one in Unit N3 of Tsauni north. It was therefore imperative to have a general pattern of furnaces associated with the mounds as one of the parameters to compare iron smelting in the two sites. An area 30m by 30m was gridded in this unit for

proper expression of the general topography of the area in relation to the excavated portion (Fig 14)

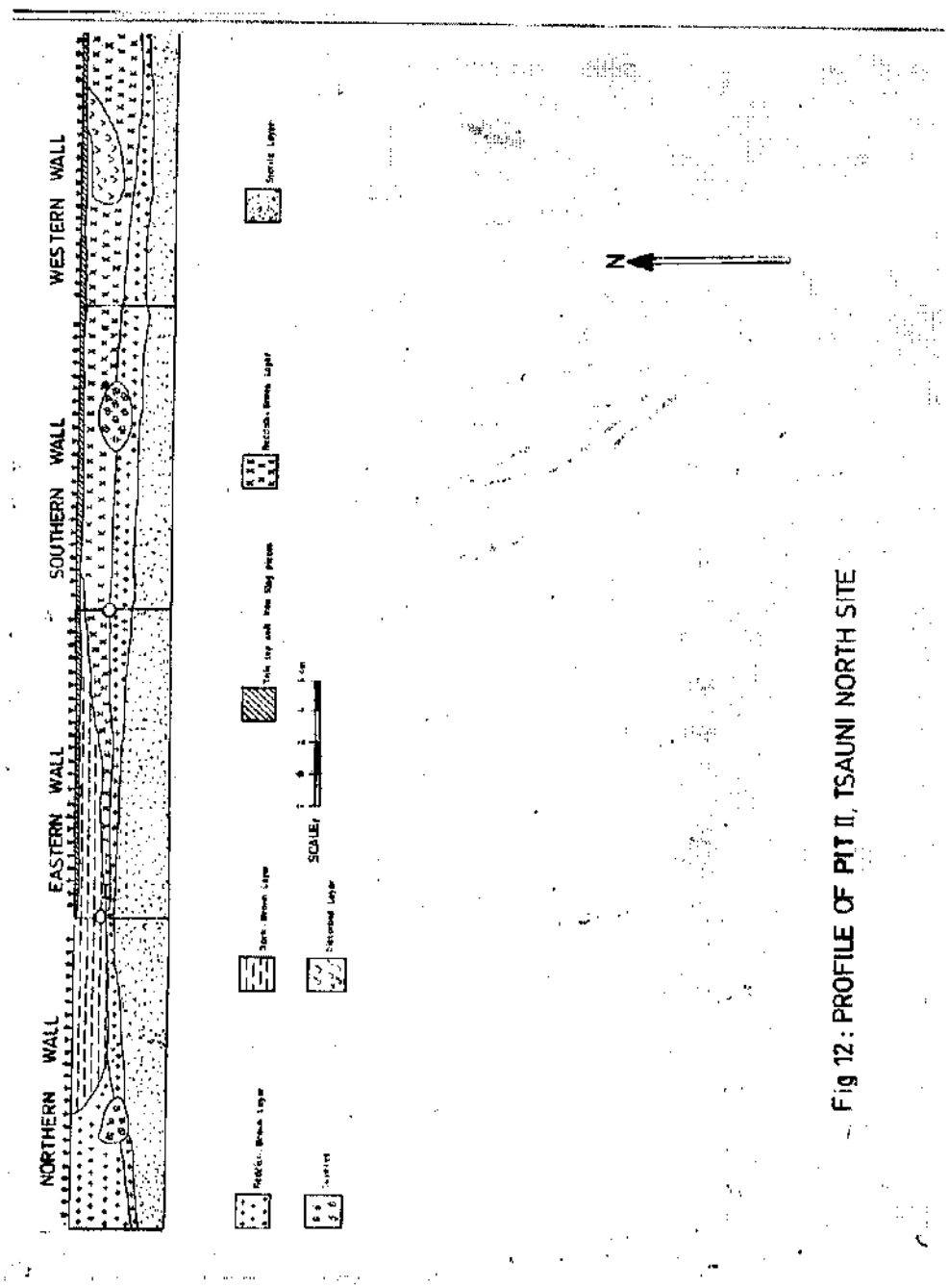



Fig 12 : PROFILE OF PIT II, TSAUNI NORTH SITE

**TEST PIT III**

Test Pit III is located on latitude $11^0$ 06.433"N, longitude $7^0$ 35.477'E and altitude 717m above sea level. The pit was in Unit N3 of Tsauni north located on a mound littered with pieces of iron slag measuring 3m by 4m. The top soil of the excavated area was light brownish associated with large quantity of iron slag pieces. Like other pits, pit III was also excavated using the spit level of 20cm.

***Spit level 1(0-20cm)***

At the first spit level, we observed that the northern wall exhibited reddish lateritic soil with high concentration of iron slag (about 15 cm below the surface). Conversely, the southern wall was compact, brownish without iron slag. Although the northern wall generally had high concentration of iron slag pieces, it was observed that the north eastern part had higher concentration than the north western part which was characterized by loose and coarse soil texture. The eastern wall was greyish brown and compact, while the western wall was associated with pieces of iron slag

***Spit level 2(20-40cm)***

The second level showed the south western corner of the pit exhibiting compact and brownish soil, while the south eastern part was loose and brownish. Pieces of iron slag and a broken tuyere were found at the north western wall. At this level, the furnace– like feature observed in the western part of the pit was seen to be a big fragment of furnace wall.At this level, although most part of the pit indicated that the sterile layer was reached, we observed an occurrence of iron slag pieces and rootlets at the northern wall. Consequently, a 1 by 4m section was cut for further digging. This later led us to the

sterile layer at the depth of 60cm at the northern wall. No stratigraphy of pit III was taken because none was discernible.



**Plate 110: The spot on which Pit III, Tsauni North was set for excavation.**

**TEST PIT IV**

Test Pit IV is also located on latitude $11^0$ 06.436'N, longitude $7^0$ 35.479'E and altitude 716m above sea level. It falls within Unit N3 and located to the immediate north of Pit III. It was a 3 by 3m pit excavated by adopting an arbitrary level of 20cm. Before excavation, the surface was associated with large quantities of iron slag, laterites and fragments of furnace without pottery (plate 111).

***Spit level 1(0-20cm)***

At the first level of pit 4, sandy and clayish soils with brownish lumps of lateritic soils were found in association with roots. Pieces of iron slag (about 19cm below

surface) occurred at the southern wall of the Test pit. At point D, (south east) of the pit, a feature that was initially thought to be a tuyere was later discovered to be a lump of laterite.

***Spit level 2 (20-40cm)***

At the second spit level, roots continued, while the colour and texture of the soil remained the same.

***Spit level 3 (40-60cm)***

At the third spit level, potsherds, pieces of iron slag and laterite modules were identified. At the southern wall of the pit, we observed that the soil was clayish with no cultural object. After digging about 3cm at the third spit level, we were convinced that the sterile layer had already been reached (plate 112).

The stratigraphy of Test Pit IV, Tsauni north was not taken, due to non availability of distinguishable soil strata.

**General Observations**

Our general observations in the excavations of Test Pits III and IV of Tsauni north were as follows; one, no single furnace was found associated with this natural mound which portrayed a sharp difference with the excavated pits in Tsauni south. Two, there was a conspicuous absence of charcoal in the area which also differed from pits 1 and 2 of Tsauni north and the pits excavated in Tsauni south. These two Test pits were associated with bigger pieces of slag than what we earlier observed from the pits I and II previously excavated in the area. Since we could not identify any furnace structures with pits III and IV, it was not possible to compare the material evidence there with the pits I and II beyond our observation that the slag pieces at the former were larger than the later.

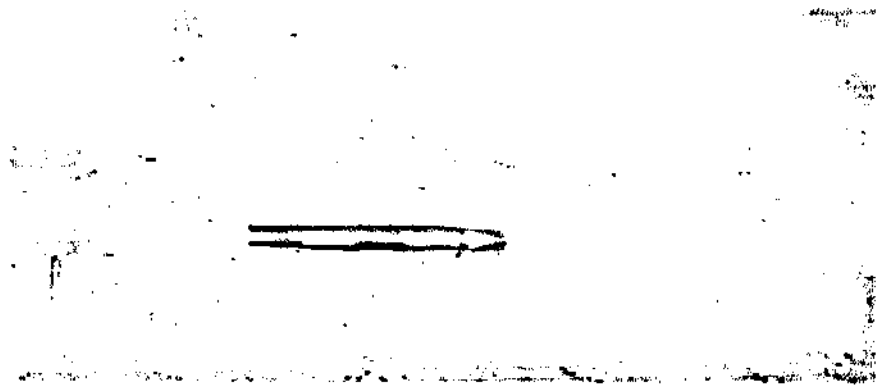


**Plate 111: Setting of Pit IV in Tsauni North**

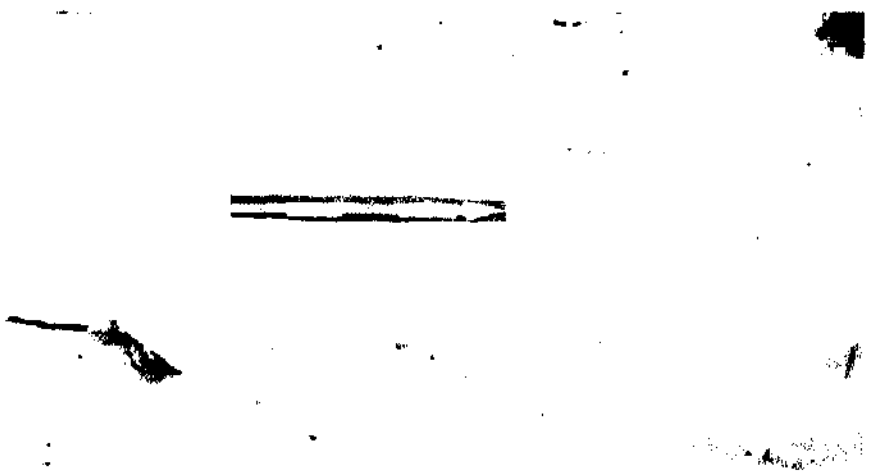


**Plate 112: Approaching the sterile layer in Pit IV, Tsauni North.**

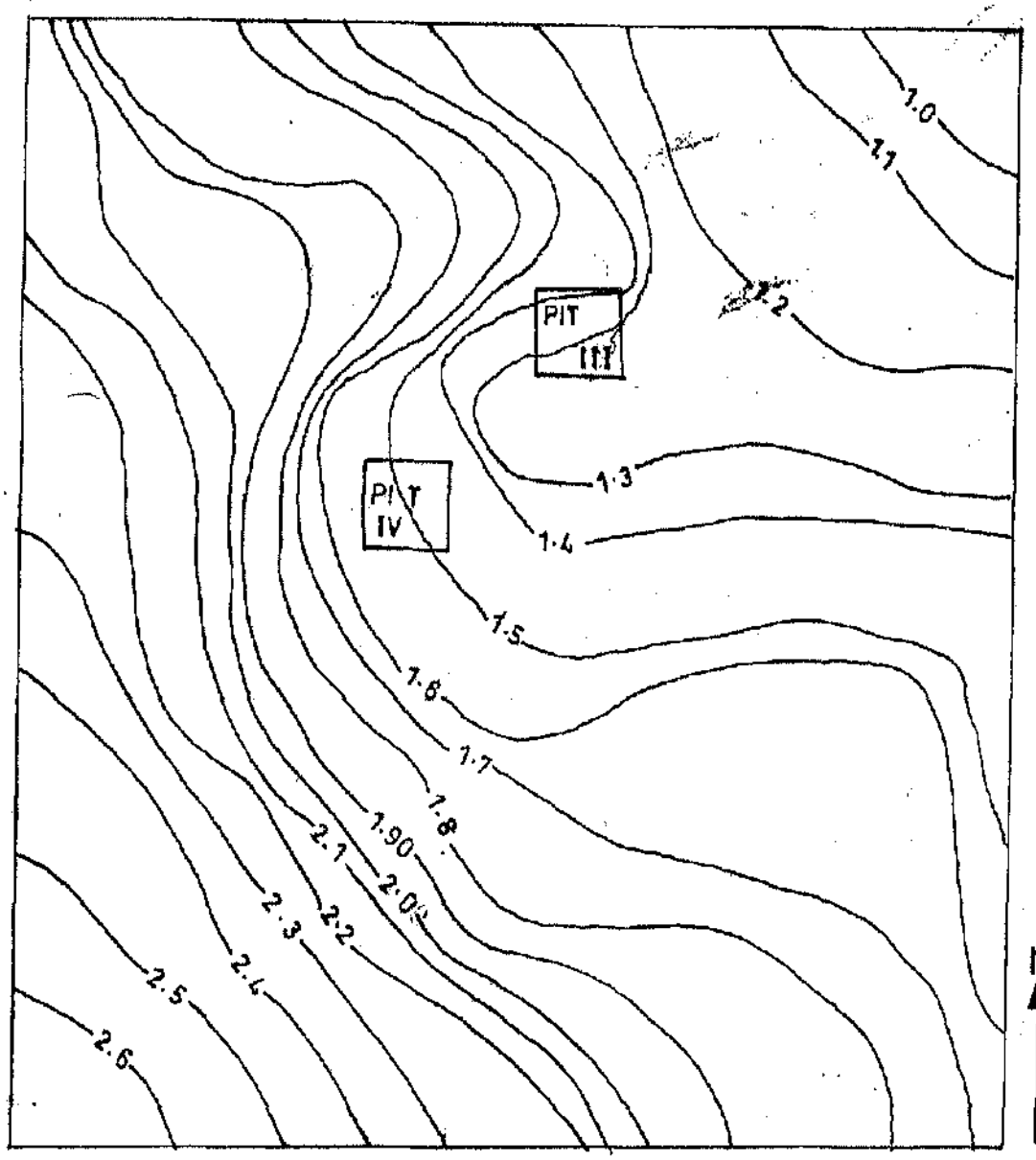



Fig 14: CONTOUR MAP OF TSAUNI NORTH SHOWING PITS III&IV

## TSAUNI SOUTH EXCAVATIONS

A mound with litters of pieces of iron slag and fragments of furnace and tuyeres located in Unit1 in the north eastern section of Tsauni south was earmarked for excavation. The occurrence of bases of furnace there partly formed the basis for the selection of the area for excavation. We had thought that the excavations we help us to compare the smelting furnaces at Tsauni south with those of the north.

An area of 50 by 35m was consequently gridded in the area and a contouring map produced (fig15). The gridded area was considered adequate to vividly show the nature of topography of the area marked for excavation. The gridded portion was however not a square as in Tsauni north. The presence of a gully in the west of the area informed our decision to reduce the width of the gridded area to 35m. Four test pits were also excavated in the area like Tsauni north. While three pits were sunk on the mound, the fourth was essentially a salvage excavation intended to rescue a furnace that was almost completely eroded into a deep gully. A spit level of 20cm was also adopted for the excavations since it was initially impossible to discern the natural strata.

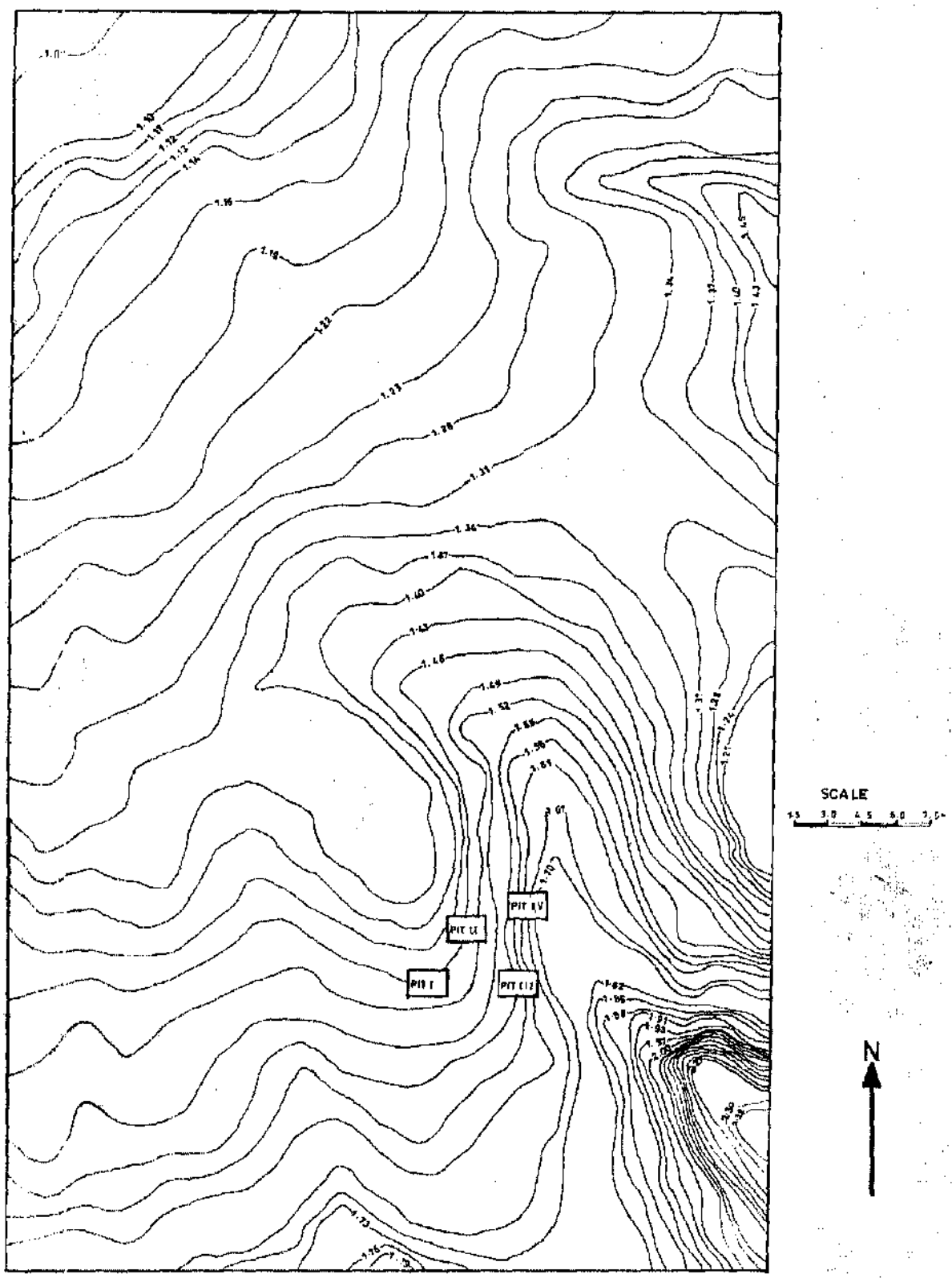



Fig 15: CONTOUR MAP OF TSAUNI SOUTH SITE SHOWING PITS I, II, III & IV

**TEST Pit I**

It is located on latitude $11^0$ 06.131"N, longitude $7^0$ 35.248" and altitude 705m above sea level. The 3m by 3m test pit was located south west of the mound (plate 113).

Before excavation, large quantity of pieces of iron slag and fragments of furnace and tuyeres were observable on the surface of the area demarcated for pit1 excavation. Two fragmented furnaces were seen with a shrub in one of them (plate 113). The two were arranged perpendicularly to each other and labeled furnaces A and B. Furnace A (in north eastern corner of the pit) lied 40 cm to B. Furnace B is located at the centre of the pit. Pit 1 is located west of the mound. Furnace A was 40 cm to the western wall of pit II. It is 90cm in outer diameter and 64cm-inner diameter with thickness of 13cm. The distance between the two furnaces is 28 cm. Furnace B is 89 cm to the eastern wall. It is 80 cm in outer diameter and 50 cm- inner diameter with a thickness of 15 cm.

After clearing the surface, we observed discrepancies in the soils at different parts of the surface. While the north western part was dark brown, the south western and the eastern parts were reddish brown. Generally, the topsoil was loose with the presence of pieces of iron slag, broken furnace and tuyeres. As digging commenced, Pieces of charcoal and broken tuyeres were found at the western side, while concentration of iron slag was noticed at the southern part.

***Spit level 1(0-20cm)***

At spit level one, a broken tuyere was found at the south western wall, 60 cm towards point D. At about 10cm below the surface, we observed concentration of iron slag around the western wall with pieces of charcoal. The south western part showed more compact soil than other parts of the pit. At this level, we noticed that the base of the

two furnaces showed more reddish soil than other parts of the pit which seems to indicate the effects of intense of heat on the soil during smelting operations. At the end of this spit level, a feature was found protruding from the south western wall of the pit. The feature was found 30 cm from point D, stretching about 21cm into the pit, and extending 22cm into the wall. It was assumed to be either a lump of iron slag or a tuyere.

***Spit level 2 (20-40cm)***

At spit level 2, the two furnaces A & B were excavated. At about 30cm below the surface, we noticed occurrence of dark soil in association with pieces of iron slag, charcoal and roots inside furnace B, while at its base, we observed a big broken tuyere which appeared to have been deposited inside the furnace because it was not found in central position (plate 116). The dimensions of the tuyere were length-48 cm, outer diameter-20cm and inner diameter of 10cm with thickness of 5cm.



**Plate 113 : Setting of Pit 1 in Tsauni South for excavation.**

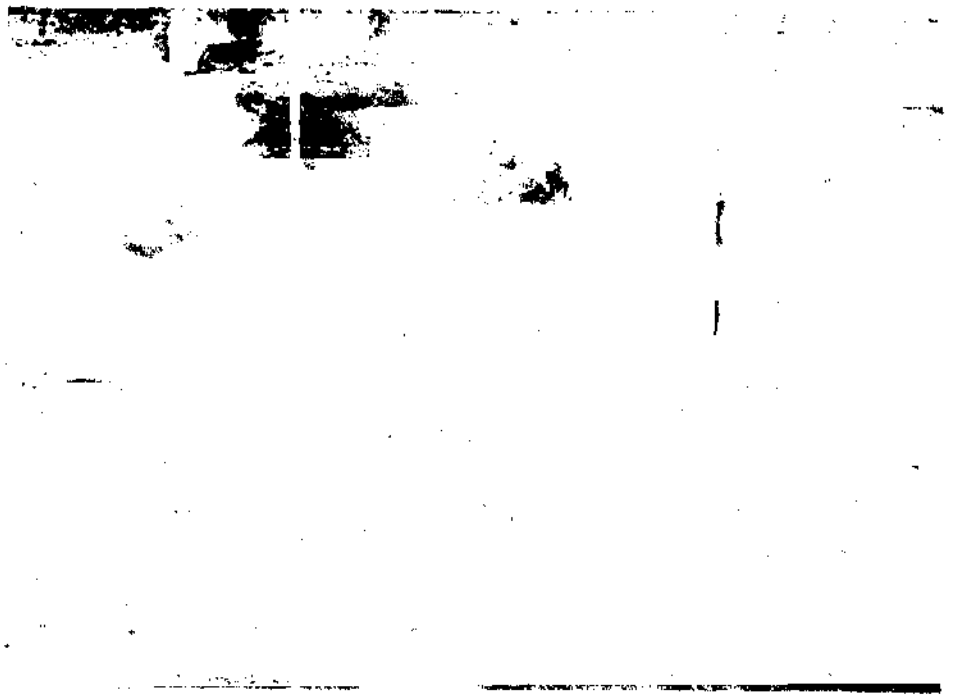


**Plate 114: Level 1 of Pit 1, Tsauni South showing the furnaces excavated.**

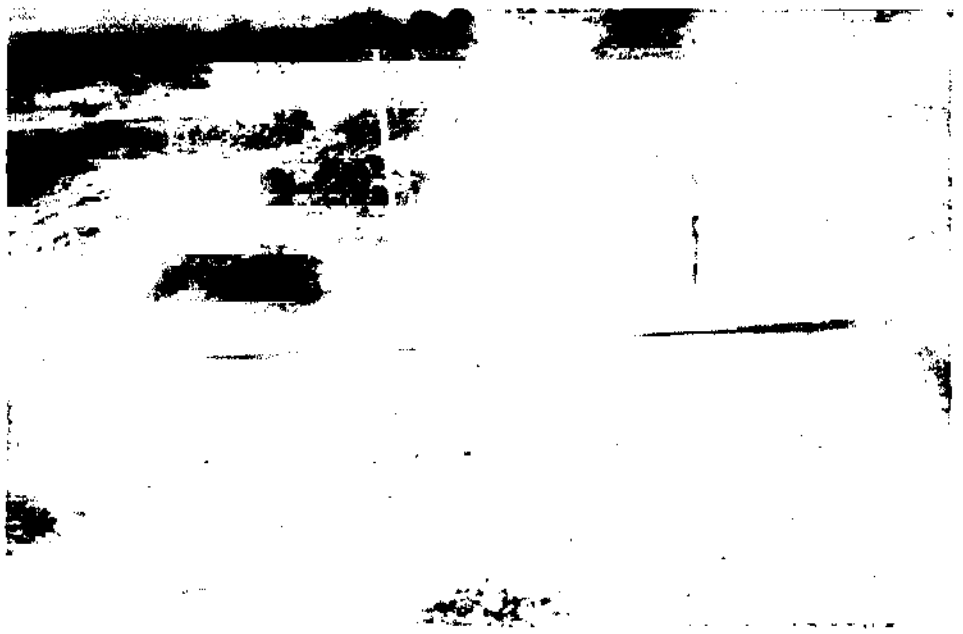


**Plate 115 : Level 2 of Pit 1, Tsauni South.**

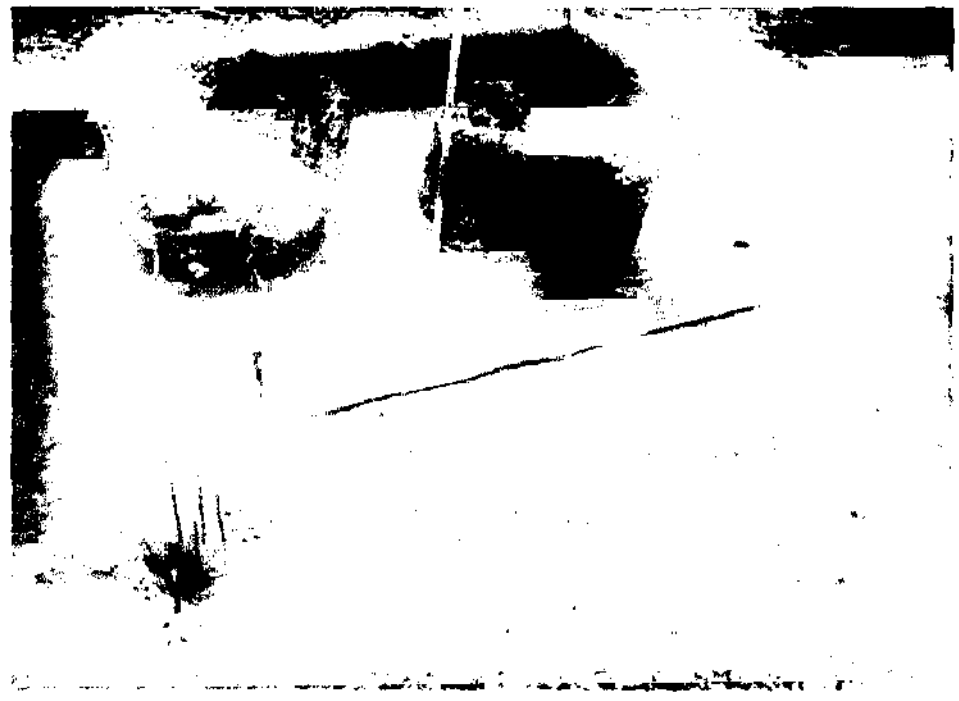


**Plate 116: Level 3 of Pit 1 Tsauni South.**

***Spit level 3 (40-60cm)***

At spit level 3, the features of the two furnaces became more diagnostic as we observed that they looked like shaft furnaces with well defined and built up walls. Furnace A had been greatly adversely affected by roots and a shrub that grew in it, thus it was not considered as important to our study as furnace B which seemed to be relatively undisturbed. The soil at this spit level, was characteristically lateritic and full of pieces of iron slag. At the base of furnace B we also observed found pieces of iron slag. We particularly noted that the pieces of laterites at the base of this furnace were either not well burnt or practically smelted. This was an important clue to us as it seemed to confirm our earlier view that the laterites found in the area were the ores used for the smelting operations.

***Spit level 4 (60-80cm)***

At the beginning of spit level 4, it was clear that the northern portion of the pit was already sterile, and then the western section was marked for further excavation. This was aimed at understanding how the slag was tapped. For this purpose, the section of the pit, 1.70m from point D towards C, 1.30m from B towards A and 1.25m from western wall to the furnace and 1m from southern wall to the furnace was marked for further digging. Level 5 (plates 118 and 119).

The excavation terminated at the fifth spit level at the south western section, while the sterile layer was already recorded at the fourth spit level of the pit at the northern section due tu absence of cultural materials. Pieces of charcoal were collected at the base of furnace B close to the discarded tuyere for radio carbon age determination.



**Plate 117: A tuyere found inside furnace 2 in level 4, Tsauni South.**



**Plate 118 : A close-up of the tuyere inside the furnace of Pit 1, Tsauni South.**



**Plate 119: Level 5 of Pit 1, Tsauni South.**



**Plate 120: The bottom of Pit1Tsauni South showing stratigraphy**

**Profile of Test Pit I, Tsauni South**

Due to the occurrence of discernible natural soil strata, the profle of pit 1, Tsauni south was taken. The northern wall was associated with three strata. The first stratum was light grey soil with laterites and pieces of iron slag. The second layer exhibited light reddish brown with roots, while the third potrayed light reddish brown soil with patches of grey. The identification of the natural strata was however based on visual impression.

The eastern wall was also identified with three soil strata the first stratum was lateritic light grey soil with occurrence of pieces of iron slag, while the second and the third exhibited light reddish brown soil with roots and light reddish brown with patches of grey soil respectively.

As earlier observed, the southern wall was dug to the fourth spit level. The South eastern wall exhibited the same soil strata as the northern and eastern walls. On the other hand, the south western wall exhibited two strata; the lower layer was brownish red with pieces of iron slag while the upper stratum was light grey.

The western wall was associated with two segments; the south west and the north western sections. The south western wall as earlier observed was dug up to the fourth spit level. It exhibited four soil strata (see fig16) while the north western segment had two strata.

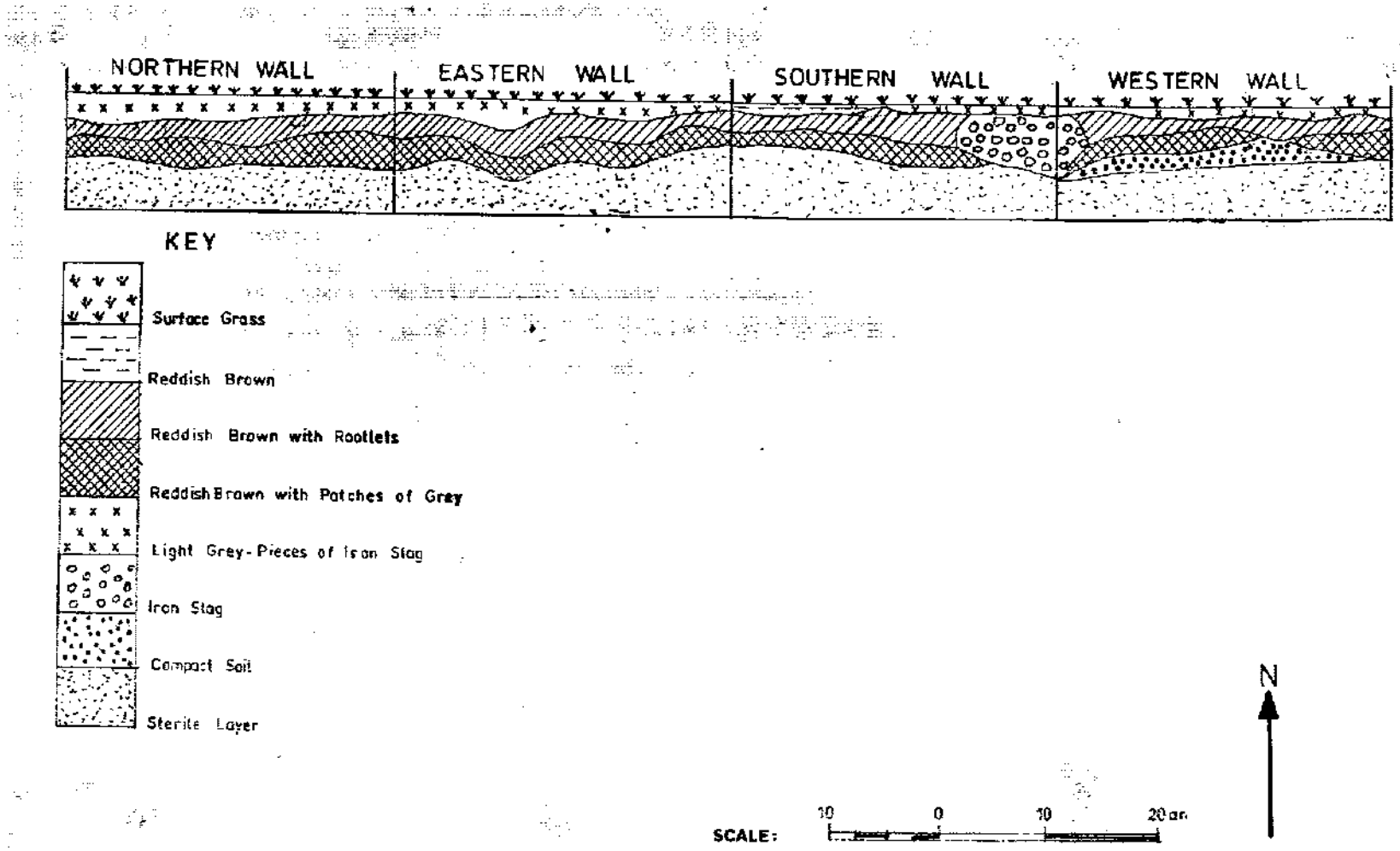



Fig 16: PROFILE OF PIT I, TSAUNI SOUTH

**TEST PIT II**

Test Pit II of Tsauni south is located on latitude $11^0$ 06.134" N longitude $7^0$ 35.252'E and altitude 707m above sea level. It is located on the northern side of the same mound where pit 1 was excavated. The main purpose of this excavation was to compare what initially looked like two furnaces in the north of the mound (pit II) with those identified in the south west (pit I). Prior to the commencement of excavation of this test pit, the surface was covered by pieces of iron slag and fragments of furnace walls, a similar feature with the portion where pit I was excavated.

Digging was also carried out by adopting spit level method, because the natural strata of the pit were not initially discernible. Pit II was however 4m by 3m in order to cover the area associated with what we considered as furnace bases. The spit level of 10cm was adopted for the excavation.

At the top soil level (0 – 10cm), the soil colour was reddish brown, hard and associated with rootlets. The finds observed were pieces of iron slag, tuyere and furnace fragments.

***Spit level 1 (0-10cm)***

The first spit level showed reddish brown soil with rootlets, pieces of iron slag and tuyere fragments.

***Spit level 2 (10-20cm)***

The second level was characterized by brownish soil with pieces of charcoal, tuyeres and iron slag.

***Spit level 3 (20-30cm)***

At this level, the soil became grey in colour with gritty texture. Charcoal, iron slag and fragments of furnace were also noticeable at this level.

***Spit level 4 (30-40cm)***

The fourth spit level exhibited dark soil mixed with charcoal and ash in association with fragments of tuyere and slag pieces. Charcoal sample was collected at this arbitrary level for radiocarbon age determination.

***Spit level 5 (40-50cm)***

At the fifth spit level the soils were clayish with no cultural materials visible which suggested that we were getting close to the sterile layer. Consequently, the excavation was terminated at 60cm below the ground level having come to the sterile layer (Plate 121).

***Spit level 6 (50-60cm)***

With persistence of the features observed at spit level 5, the excavation of this test pit was terminated at about 60cm below surface having come to the sterile layer (Plate 121).

Apart from charcoal, and pieces of slag, furnace and tuyere, no furnace outline was identified in pit II. What we earlier thought were two furnaces later turned to be fragments of furnace. In the absence of any furnace structure, the collection of charcoal sample for age determination was considered important to help our understanding of the antiquity of iron smelting in the area.



**Plate 121: Bottom of Pit II Tsauni South.**

**Profile of Test Pit II**

Since, the western wall of pit II was the only one with discernible strata; its profile was drawn accordingly (fig17). Two strata were identified on the western wall of the pit with no stratigraphic differences noticeable on the northern, southern and eastern walls.

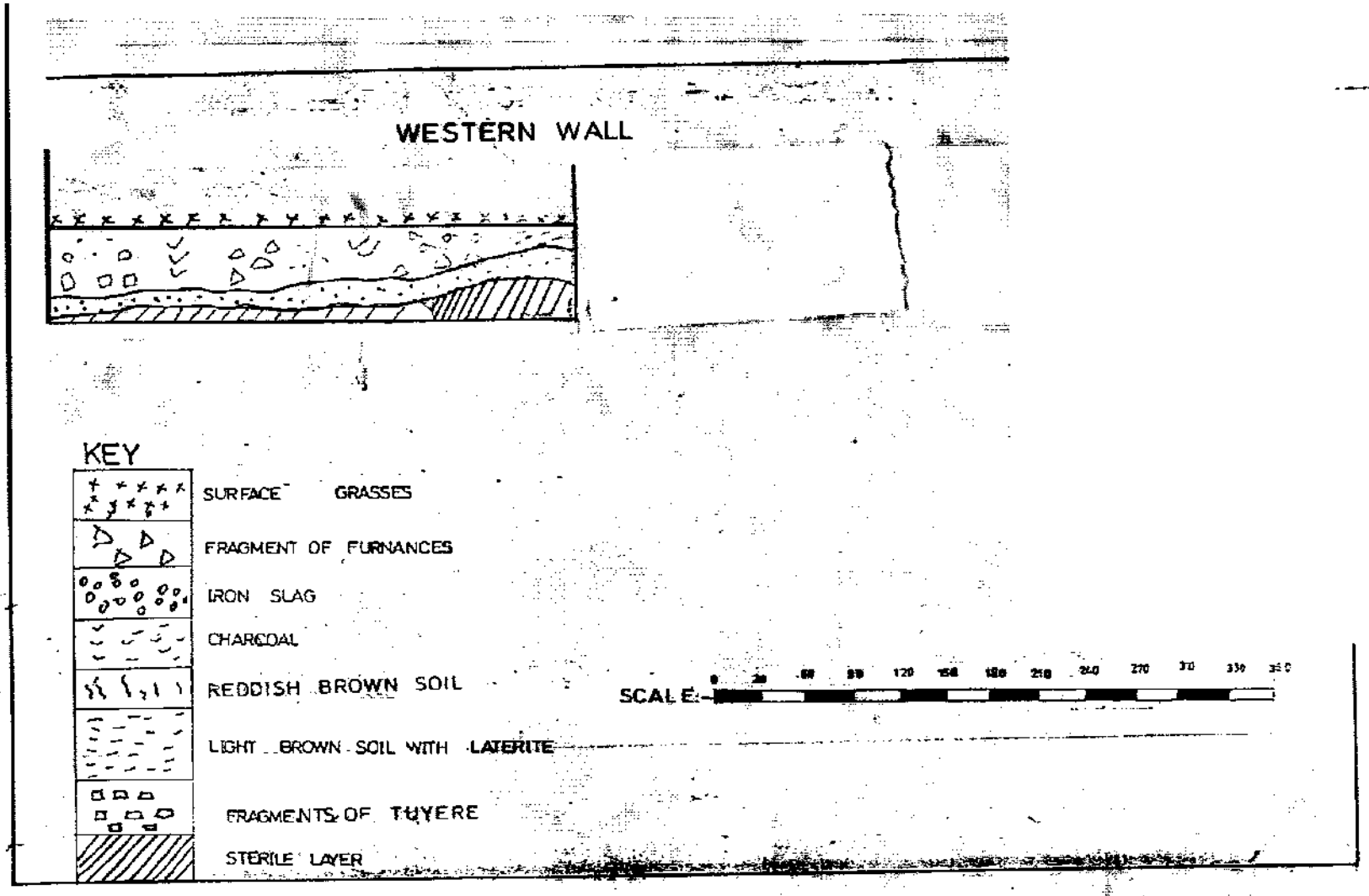



Fig 17: PROFILE OF PIT II, TSAUNI SOUTH

**TEST PIT III**

Pit III is located on latitude N $11^0$ 06' 54" and longitude E $7^0$ 35' 40". The pit was excavated south east of the same mound as pits I and II. It was a 3 by 3m pit, excavated by adopting an arbitrary level of 20 cm. It was initially thought that the excavation of the pit will further shed lights on the type of furnaces associated with the slag littered mound and also help in the assessment of the cultural viability of the mound. The surface was associated with fragments of furnace, pieces of iron slag and shrubs (Plate 122)

***Spit level 1(0-20cm)***

At spit level one, the soil was light brown and slightly clayish with pieces of charcoal, iron slag and fragments of furnace observed.

***Spit level 2 (20-40ccm)***

Spit level 2 showed few pieces of iron slag with stones mixed with clayey soil. At this level, a burrow was identified at the western wall extending to the northern wall of pit III (fig17).

***Spit level 3 (40-60cm)***

At level spit level 3, a section of the pit 1.5 by 3m was marked for further digging. Since no cultural material was visible, digging was ended accordingly having reached the sterile layer

**Profile of Test Pit III, Tsauni South.**

The strata identified in pit III were mainly three. These were grey, brownish and reddish lateritic (fig18). Occurrence of charcoal pieces was also important though not collected for age determination having done so in pits I and II.

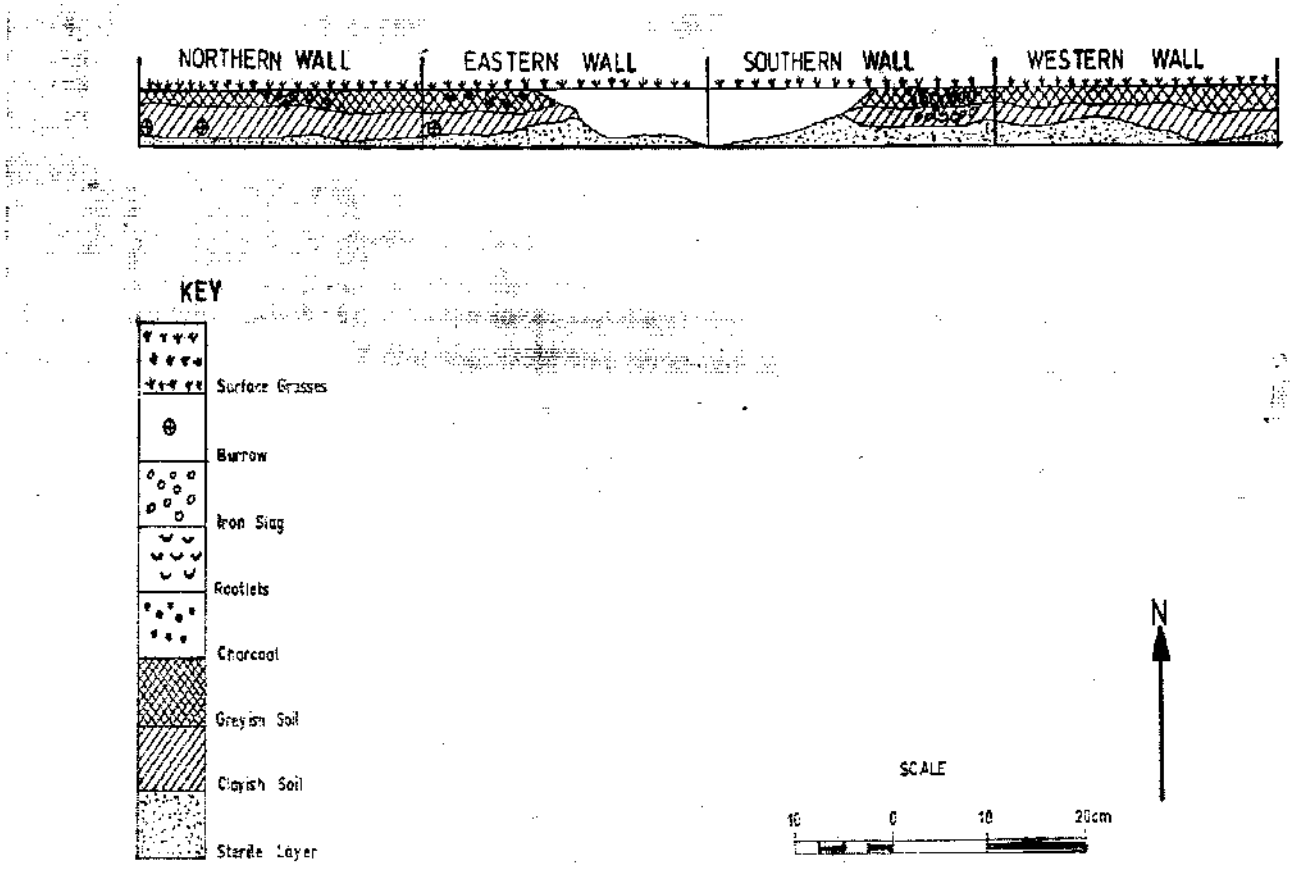



Fig 18: PROFILE OF PIT III TSAUNI SOUTH



**Plate 122: Setting of Pit III, Tsauni South for excavation**



**Plate 123: Level 1 of Pit III, Tsauni South.**

**TEST PIT IV**

Test Pit IV was located on latitude $11^0$ 06.141'N and longitude $7^0$ 35.265'E. The excavation of the pit was essentially rescue in nature as earlier indicated in this section. Due to the discovery of a furnace base, that was seriously threatened by erosion (plate 124), we considered it appropriate to conduct a salvage excavation.

The surface of the area was associated with a furnace outline with scanty shrub laterite outcrop and pieces of iron slag. The furnace associated with pit IV measured 65 cm. in diameter, with thickness of 20cm. A spit level of 10cm was adopted for the excavation.

***Spit level 1 (0-10cm)***

At spit level one, the soil was lateritic in nature, while the digging of the first spit level was in progress; it was observed that the sterile layer was already visible. Efforts were then concentrated on rescuing the furnace, with a view to comparing it with those of pits I and II, Tsauni south.

***Spit level 2 (10-20cm)***

The digging of the second arbitrary level was then commenced. At this level, it was observed that the soil began to change from reddish brown to bright orange colour and then to whitish brown. At this level, the soil was more clayish unlike the lateritic type of the first spit level.

***Spit level 3 (20-30cm)***

At the third level, excavation was conducted with extra care in order to ensure careful removal of the furnace. The pit was demarcated into two sections. The soil at the fourth level was observed so be clayish, a bit damp, compact, grey and reddish brown. Pieces of

iron slag were seen in western side of the furnace which slopes sharply into the gully (plate 127), suggesting that the furnace was also designed to tap slag as furnace 2 in pit 1. In the absence of material evidence, it was observed at this stage that the sterile layer had been reached and with the furnace dug out, the excavation was stopped.

**Profile of Test Pit IV**

The profiles of three walls of Test pit IV were taken-the northern, southern and eastern walls. Three strata; lateritic reddish brown, compact whitish and reddish brown were identified. The western wall showed a single stratum, which was lateritic (fig 19)



**Plate 124: Setting Pit IV, Tsauni South for excavation. Note how erosion is threatening the furnace.**



**Plate 125: Level 2 of Pit IV, Tsauni South.**



**Plate 126: Level 3 of Pit IV, Tsauni South.**

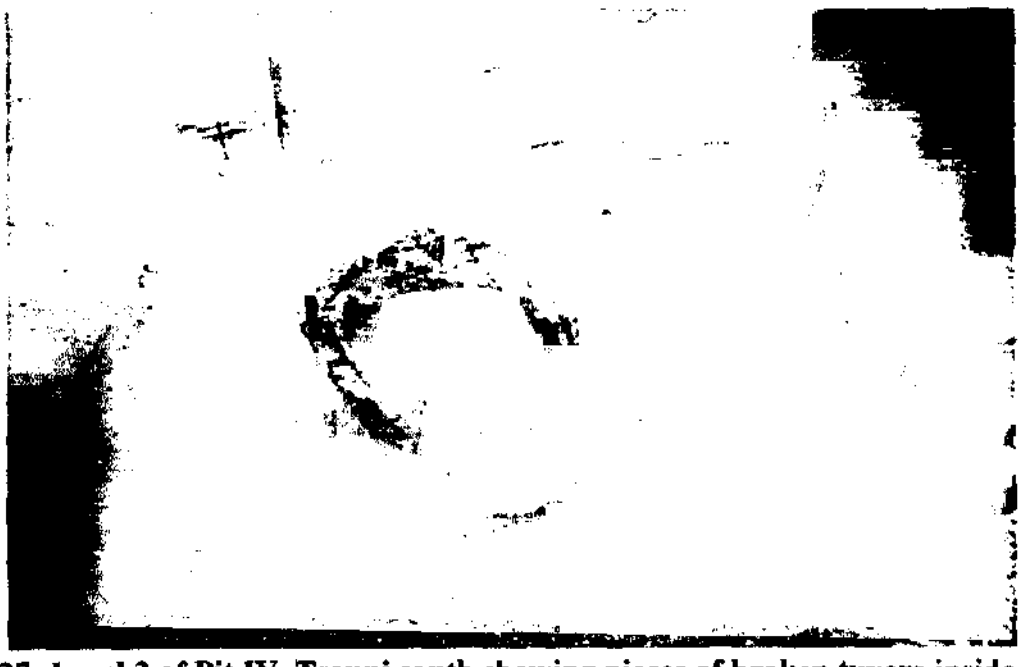
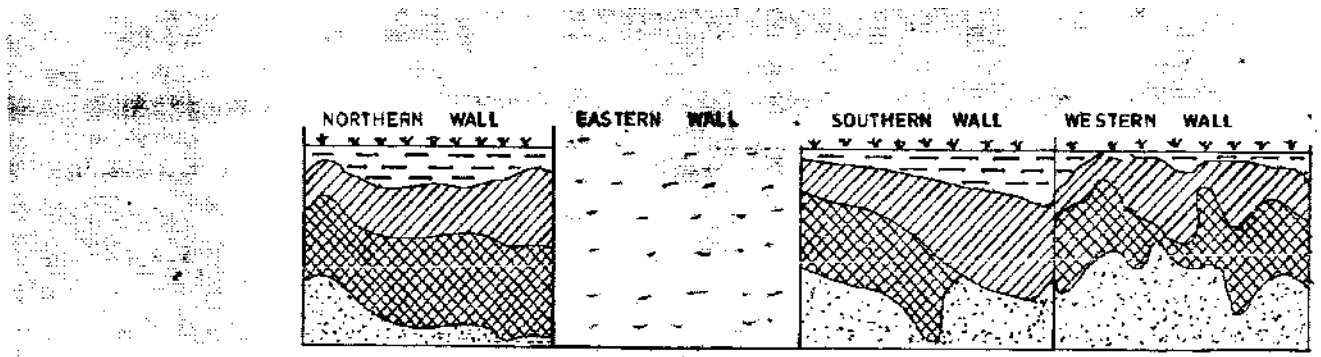


**Plate 127: Level 3 of Pit IV, Tsauni south showing pieces of broken tuyere inside the furnace.**



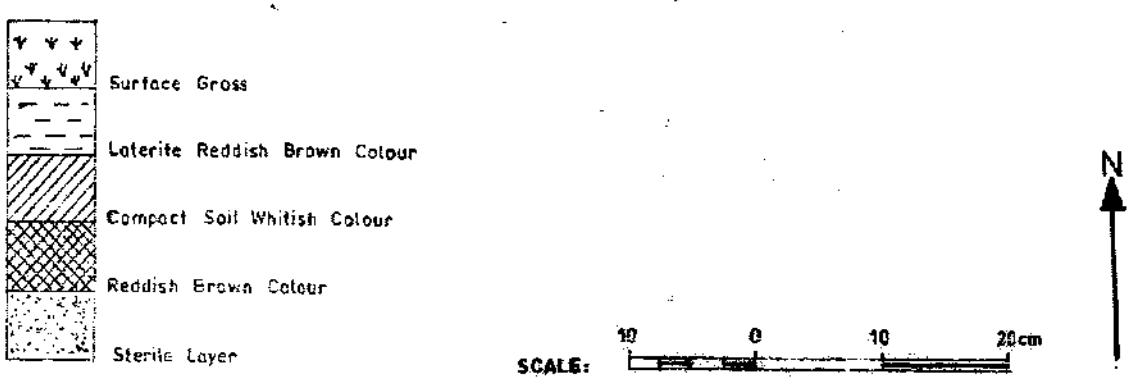




Fig 19: PROFILE OF PIT IV, TSAUNI SOUTH

**General observations on the excavations at Tsauni north and Tsauni South**

A close look at the excavations conducted at Tsauni north and Tsauni south has led to certain observations which are imperative in an attempt to compare evidence of iron smelting in the two areas. In terms of outer diameters of the furnaces in Tsauni north, we recorded an average of 81cm, while that of Tsauni south was 90cm. The average thicknesses of the furnaces excavated at Tsauni north and Tsauni south are 13cm and 14cm respectively. The tuyeres from the two sites are also comparable in some respects. In Tsauni north, the average thickness of excavated tuyeres was 3cm while it was 5cm in Tsauni south. In addition, we observed that tuyeres from the two sites portray evidence of grass tempering. From these we surmise that the structures used in iron smelting at the two sites exhibit close affinity to the extent that one can see a close relationship between the two. This seems to suggest a close relationship between the iron smelting processes in the two areas.

# CHAPTER SIX

## LABORATORY ANALYSES AND AGE DETERMINATION

### Introduction

This chapter presents the results of the technical analyses of samples of slag, tuyere and laterite (Tables1-125 and Figs 2-154 and Plates 128-196) and the C14 age determination (Table 126) of charcoal samples collected during the field research. It attempts to discuss the rationale for the preference of the analytical techniques used over others, the goals of the analyses, evidence from the technical study and the report on age determination.

As discussed in chapter one, three methods of laboratory analyses of iron smelting debris were adopted in this technical study. These included; Scanning Electron Microscopy (SEM), Electron Dispersive Spectroscopy (EDS) and X-Ray Diffraction (XRD). These analytical techniques were aimed at achieving two objectives: (1) to determine the type and source(s) of raw material (ore) and (2) to determine how efficient the smelting operations were.

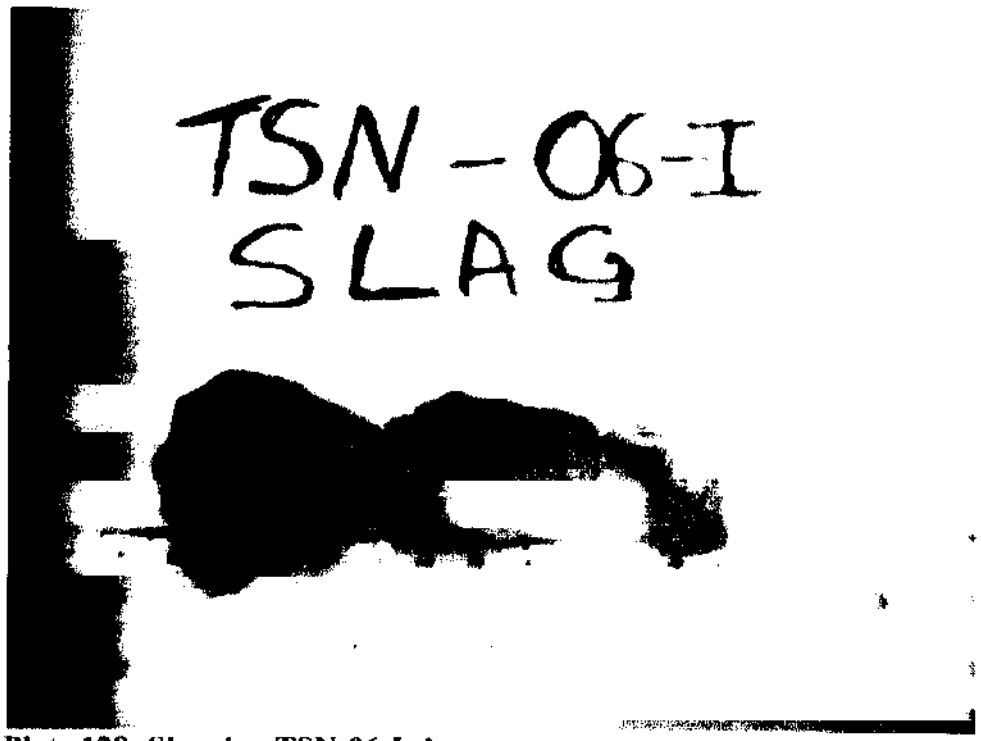



**Plate 128: Showing TSN-06-I slag**

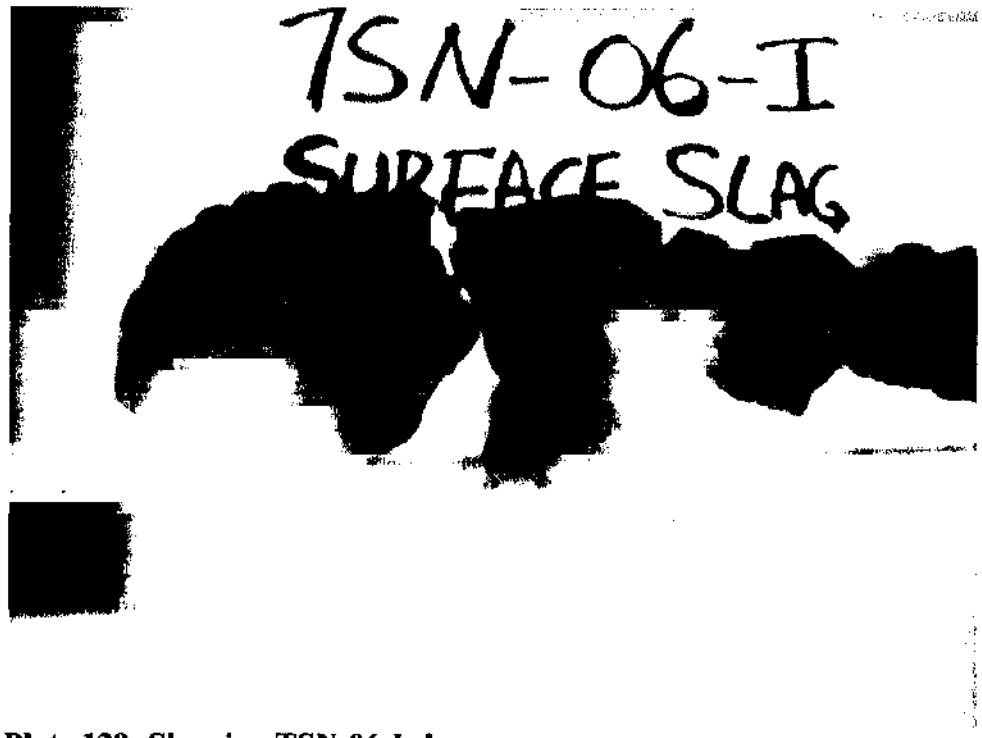



**Plate 129: Showing TSN-06-I slag.**

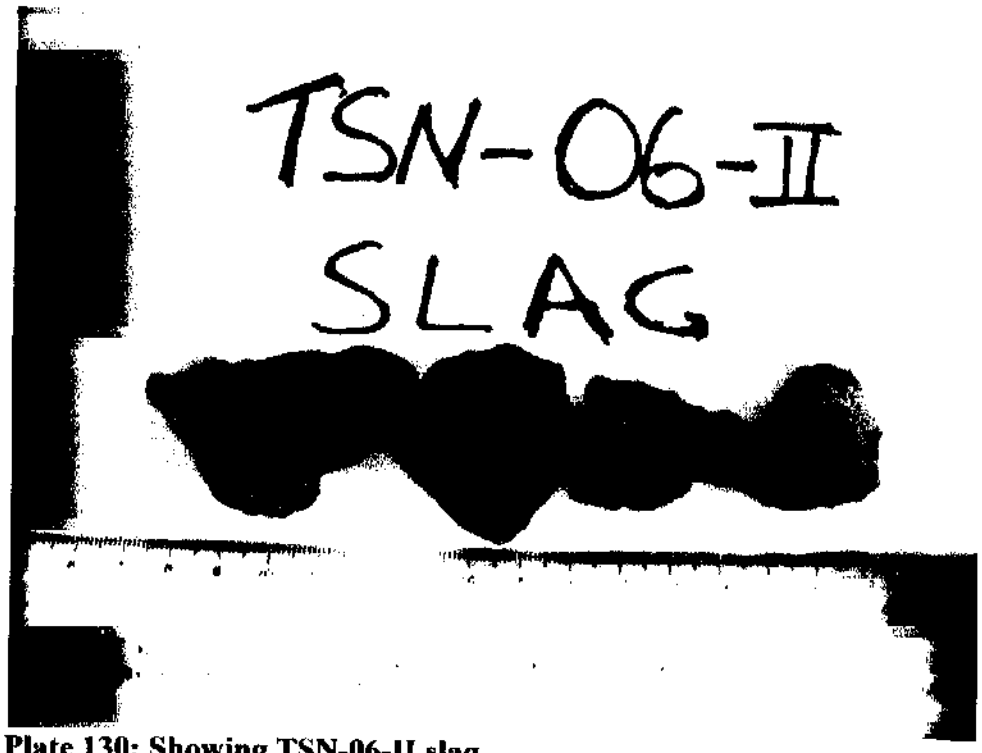



**Plate 130: Showing TSN-06-II slag**

T.N (x. 11

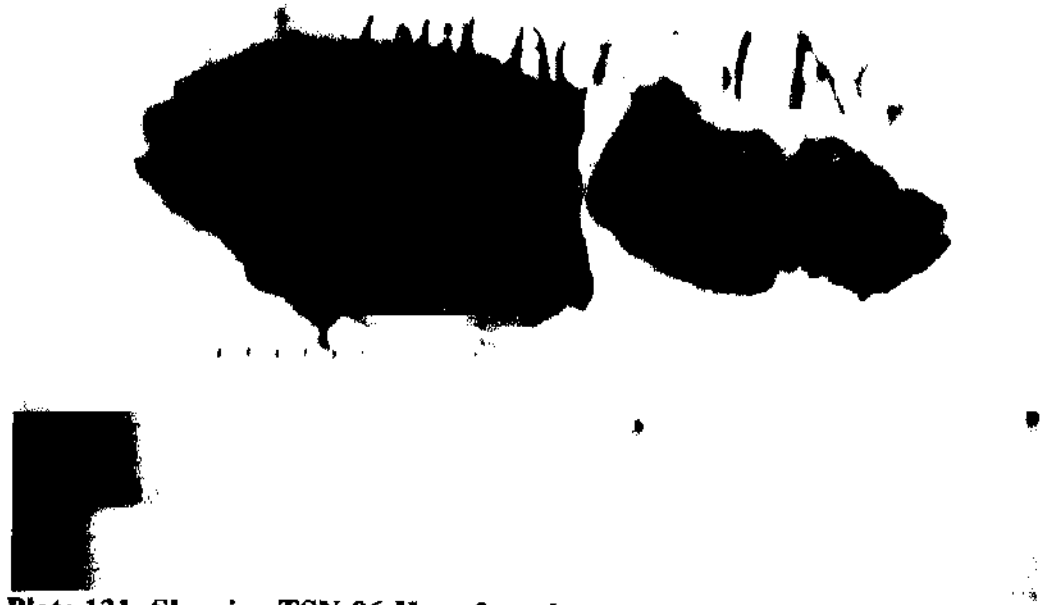


**Plate 131: Showing TSN-06-II surface slag**




**Plate132: showing TSN-06-II Tuyere fragment**

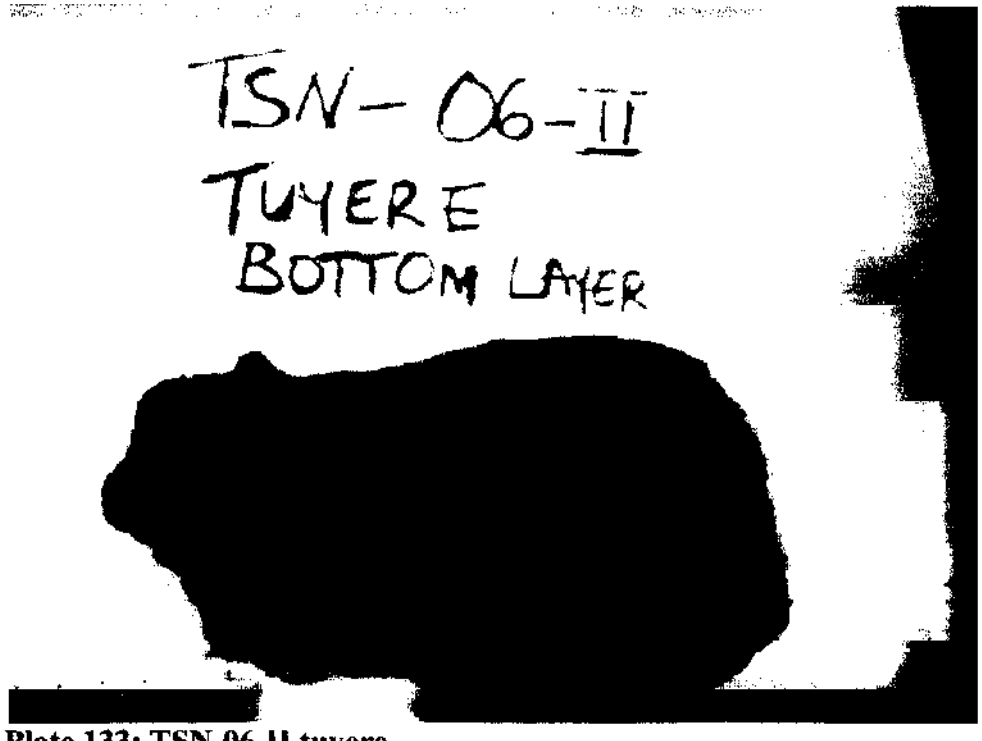



**Plate 133: TSN-06-II tuyere**




**Plate 134: Showing TSN-07-I slag.**

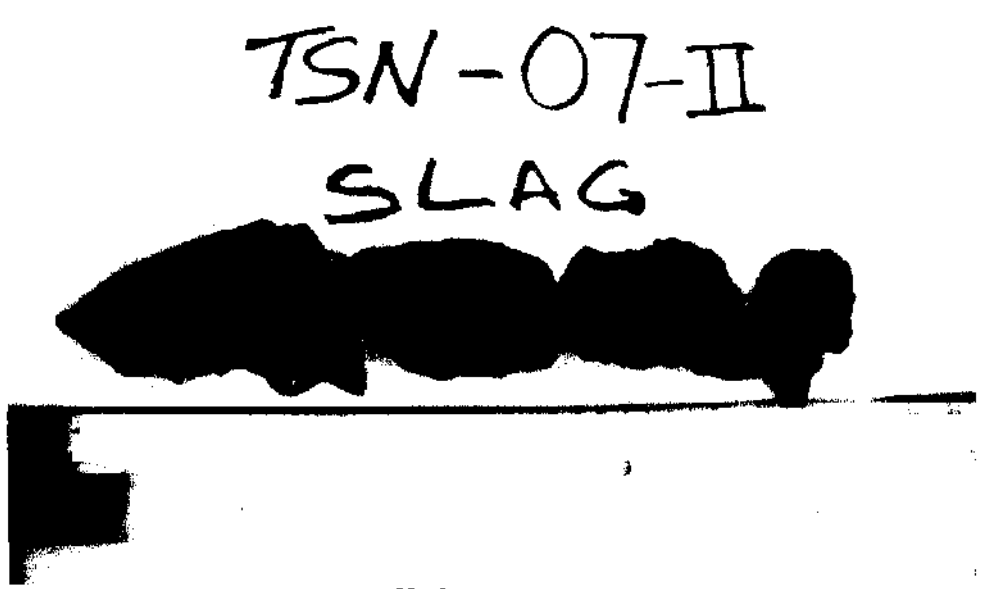



**Plate 135: Showing TSN-07-II slag**

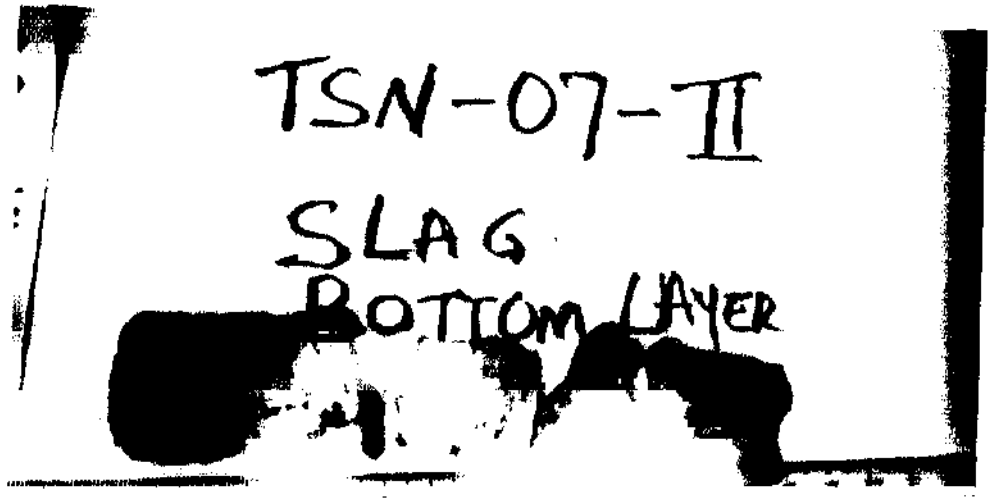



**Plate 136: Showing TSN-07-II slag**

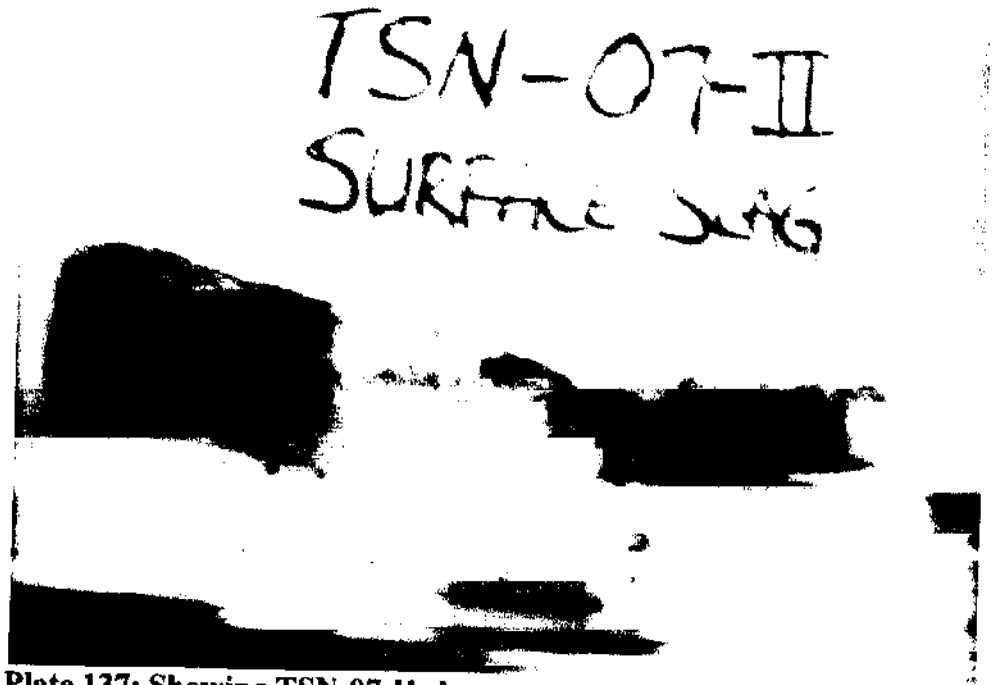



**Plate 137: Showing TSN-07-II slag**

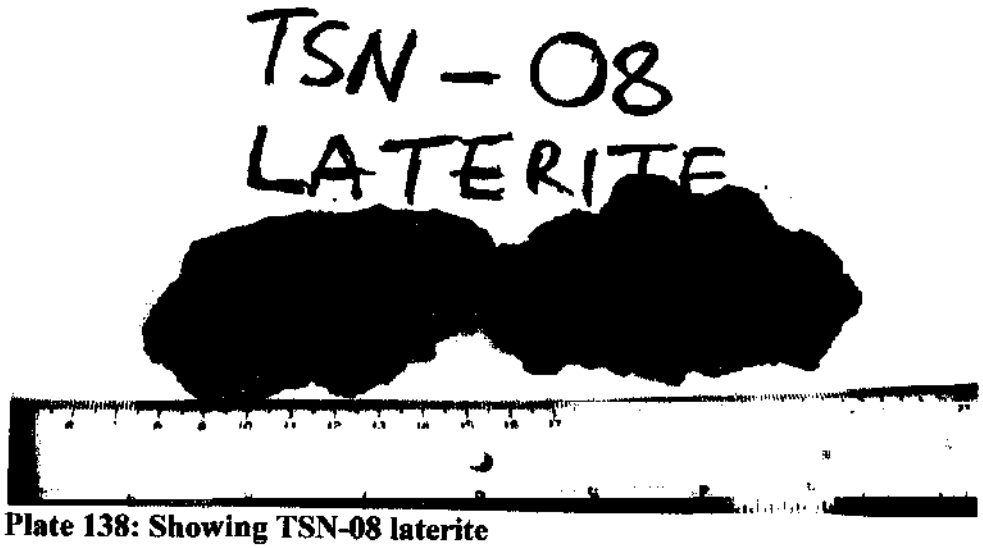



**Plate 138: Showing TSN-08 laterite**

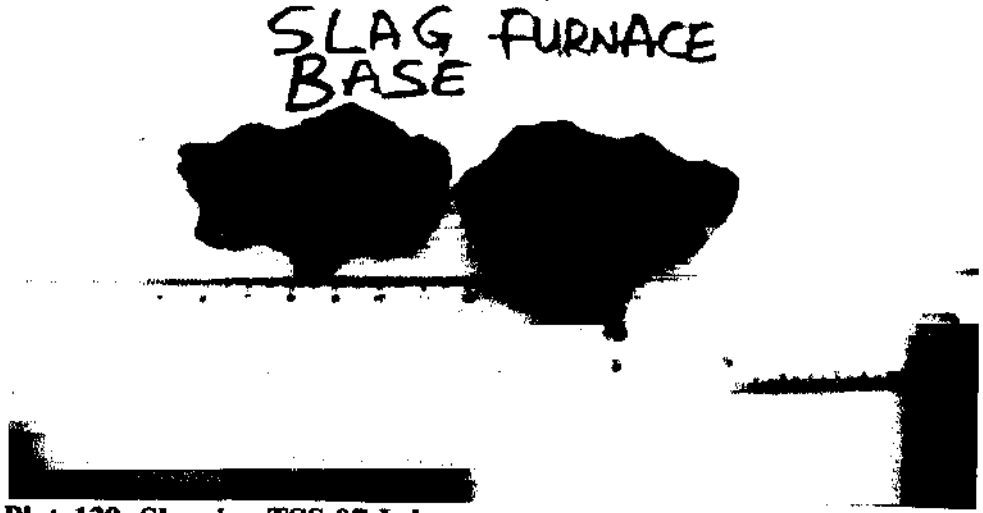



**Plate139: Showing TSS-07-I slag**

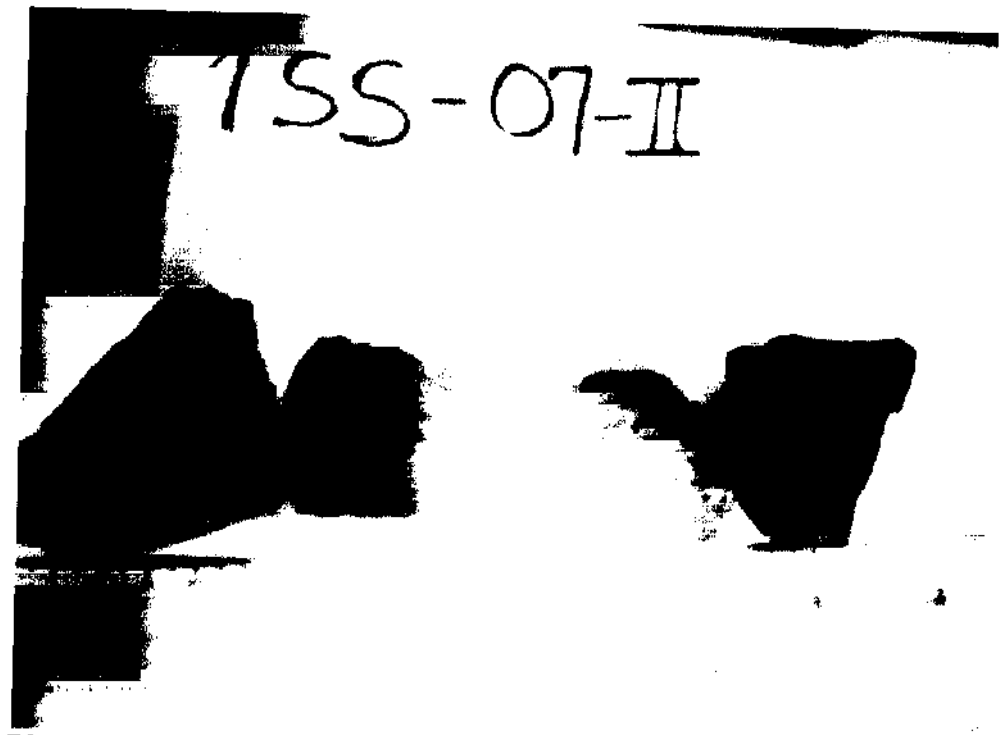



**Plate140: Showing TSS-07-II slag**

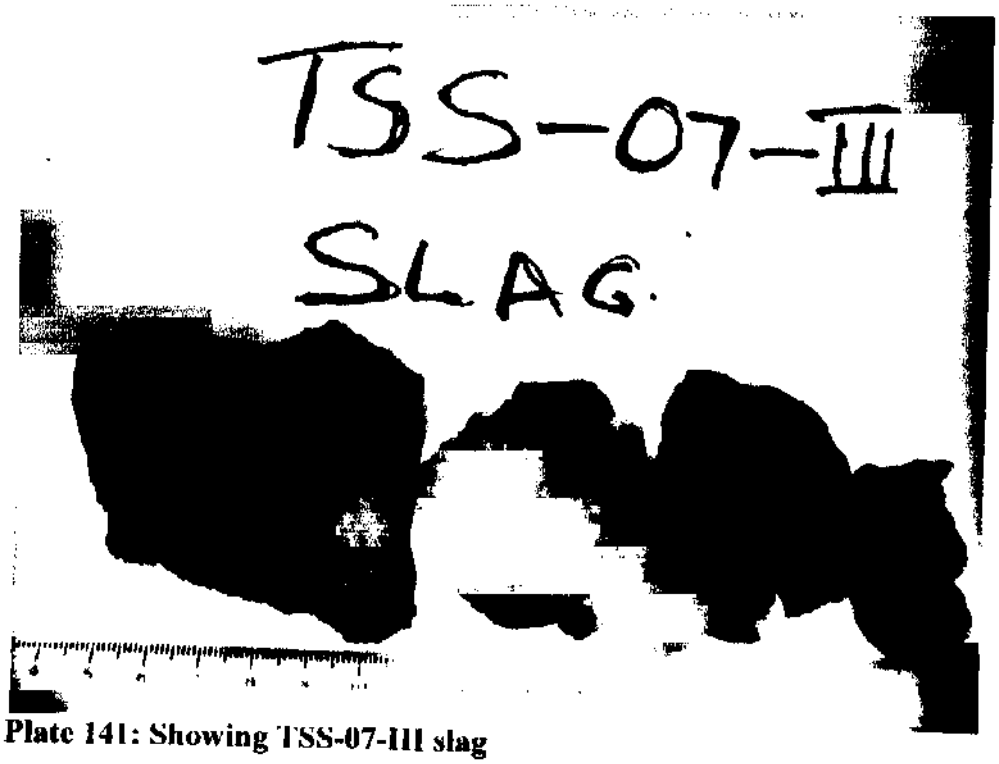



**Plate 141: Showing TSS-07-III slag**

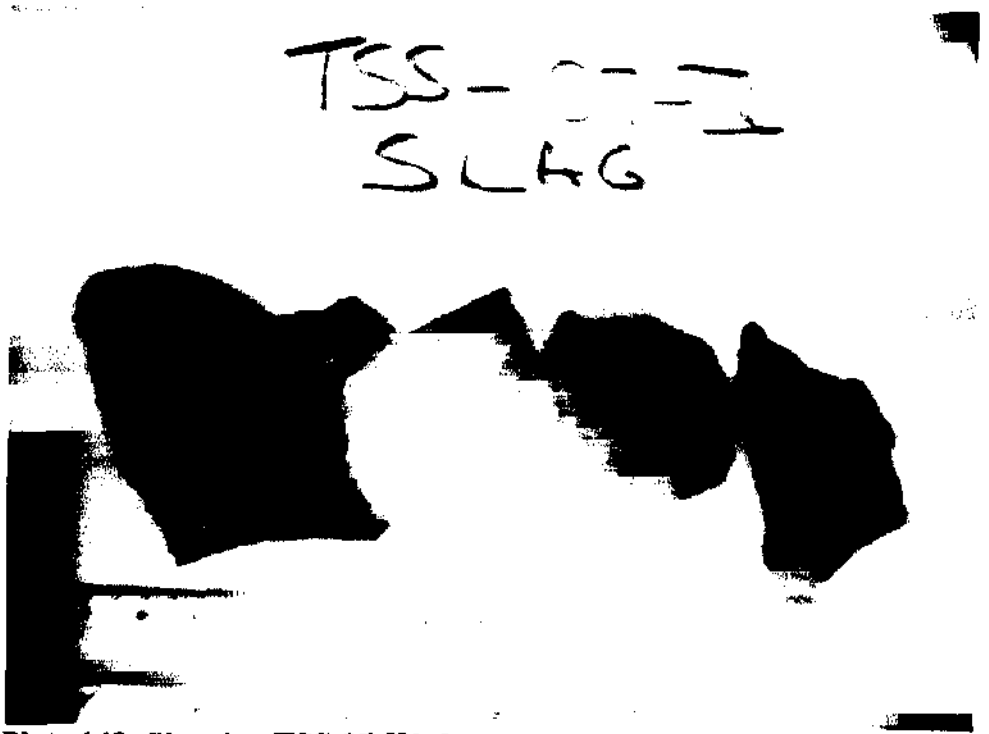



**Plate 142: Showing TSS-07-IV slag**




**Plate 143: Showing KRG-80 slag**

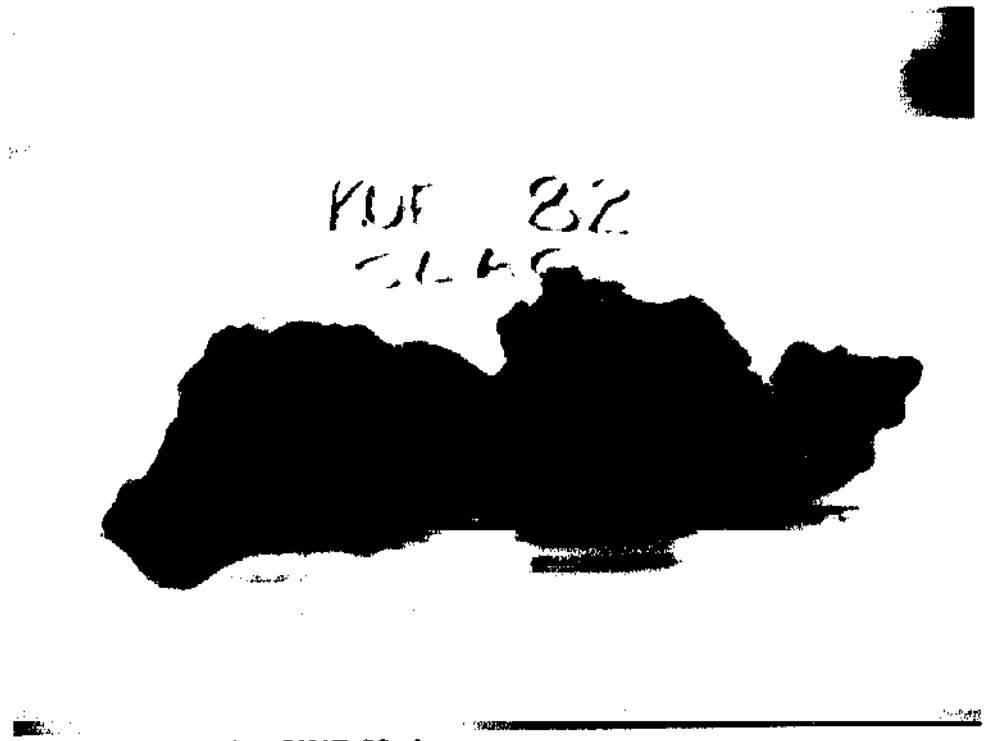


**Plate 144: Showing KUF-82 slag**

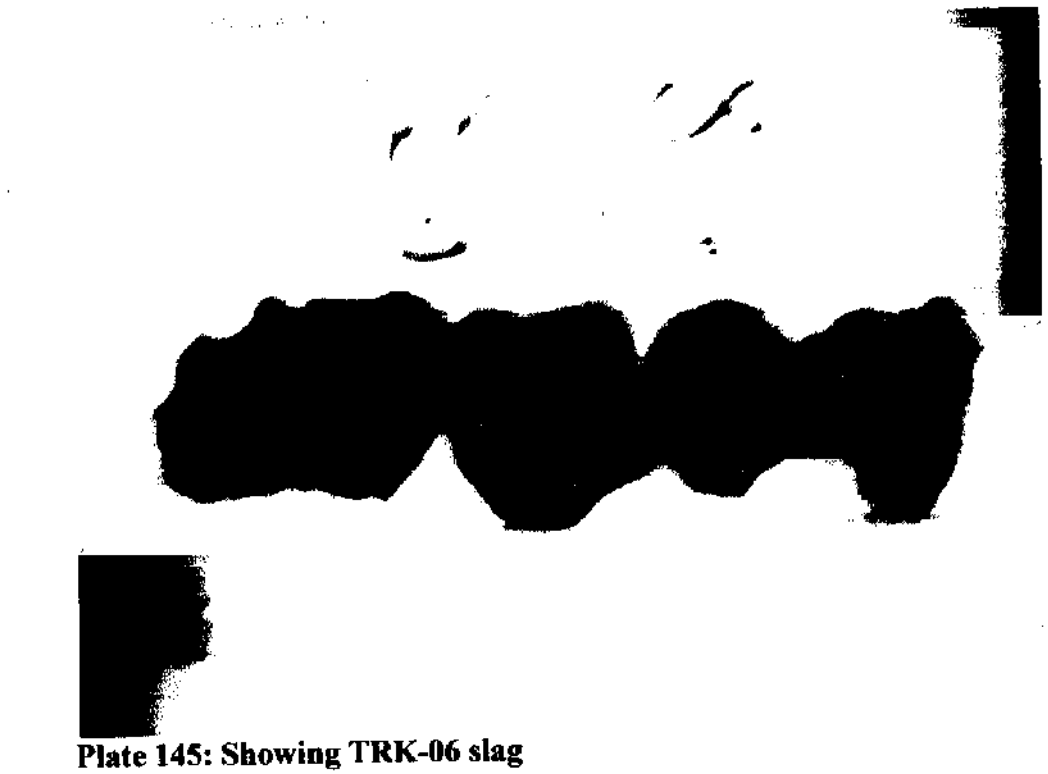


**Plate 145: Showing TRK-06 slag**

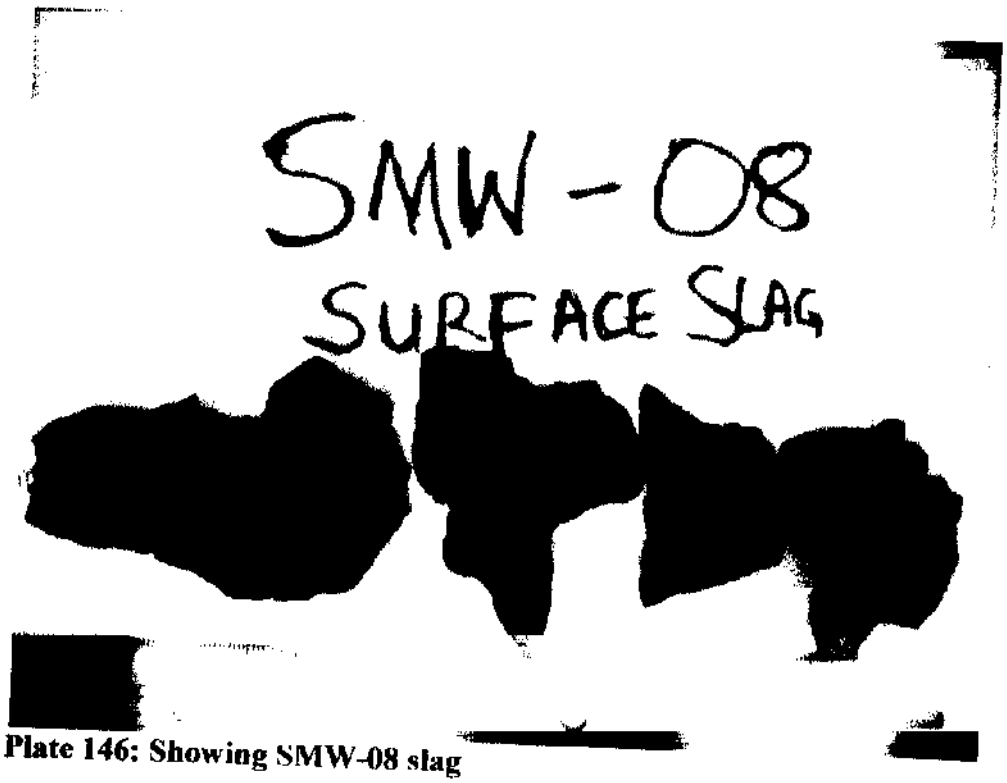



**Plate 146: Showing SMW-08 slag**

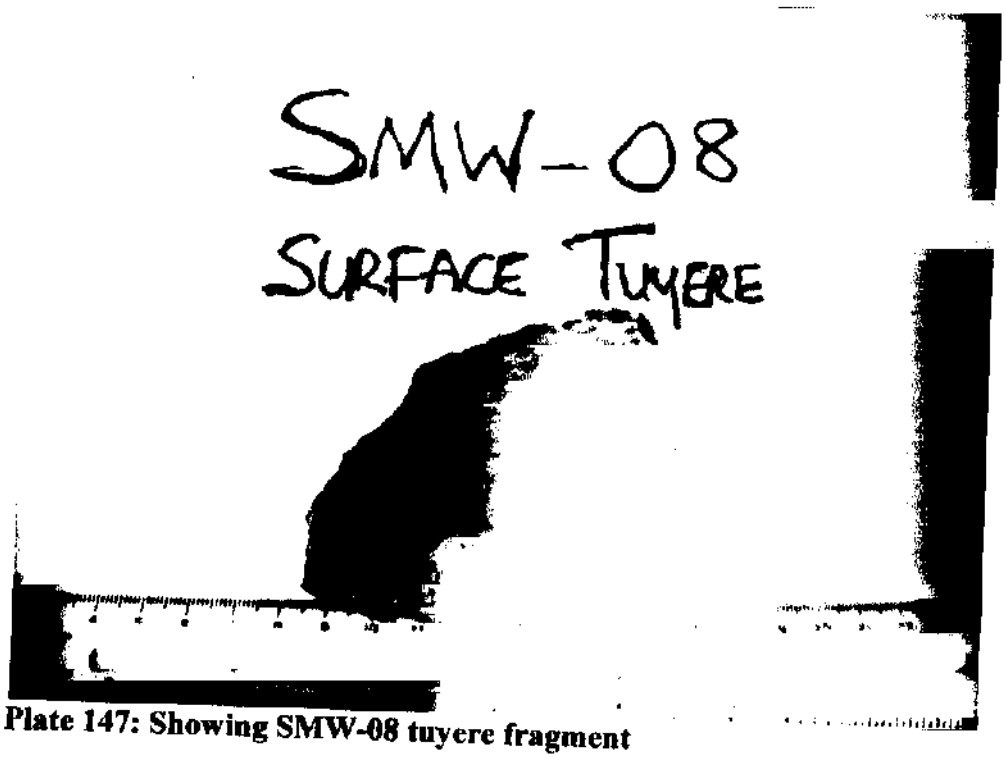



**Plate 147: Showing SMW-08 tuyere fragment**

**The Scanning Electron Microscopy and Electron Dispersal Spectroscopy Results**

This is a two-in-one technique of analysis because the Scanning Electron Microscope is routinely attached to Electron Dispersal Spectroscope. The Scanning Electron Microscopy is one of the two types of Electron Microscopy the other being Transmission Electron Microscopy. Compared to Optical Microscopy, generally, Electron Microscopy techniques can be used to study the surface and internal structure of a wide range of materials and can provide more detailed information (Tite, 1972:242).

The SEM is based on the principle of passage of a high energy electron beam through a series of magnetic lenses which demagnify the diameter of the beam. The fixing of two sets of magnetic scanning coils in the final lens is to ensure the deflection of the beam over the specimen surface in a raster-like pattern (Tite, 1972:242). Two types of electrons are involved in the Scanning Electron Microscope; primary and secondary electrons. Primary ones are otherwise called backscattered electrons. These are the electrons that are deflected out of the specimen due to their interaction with the electric charge carried by the nuclei of the atoms at the specimen surface. On the other hand, secondary electrons are those that are ejected from the atoms of the specimen as a result of inelastic collision between the primary electrons and these atoms (Tite, 1972). The backscattered electrons and primary electrons are comparable in terms of having energies of up to 100 KeV, while the secondary ones emitted from the surface have energies of up to 50 KeV. The backscattered and secondary electrons are detected with a scintillation or semi conductor counter. Only the high energy backscattered electrons that are scattered in to the solid angle of the counter are detectable while the low energy secondary ones emitted from the surface of specimen are electrically attracted to the counter with a

positively charged wire mesh (Tite, 1972). The electrical signal from the counter controls the brightness of the spot on the screen of a cathode ray tube while the spot scans both the cathode ray tube screen and the specimen surface. This results in the display of an enlarged picture of about x50, 000 of the distribution of the backscattered electron current over the specimen surface on the screen.

In practice, the secondary electron emission is normally used to examine the surface micro topography, while the backscattered (primary) ones are studied to obtain information on the chemical composition of the specimen at the surface (Tite, 1972).

The merits of the SEM which is always attached to EDS over some instruments like transmission and optical microscopes include the following; versatility in the investigation of the microstructures of materials, ability to detect major and minor elements in samples, non- destructibility of specimens, relative ease of handling, high resolution power, time saving, greater field than for example optical microscope due to the small size of its final lens aperture and the small working distance and the possibilities of image formation that are usually easy to interprete (ASM International, 2004; Tite, 1972; Goldstein et al, 1992; Reimer, 1998). In addition, the verity of this technique in archaeological investigations has been proved by several scholars such as Fells (1983), Goucher (1983), Todd (1976), McDonnell (1986), Okafor (1993), Mapunda (1995) who have used it to obtain quality results from the analyses of iron smelting debris.

The Energy Dispersive Spectrometer (EDS) otherwise known as X-ray detector (Williams and Goldstein, 1986: 123) operates by energy distribution of the radiation that is emitted by the sample which is analyzed by a solid state detector. In it, the X-ray photo

electrons generated by inner shell ionizations in the specimen enter the detector, where they create electron-hole pairs in the lithium-drifted silicon crystal. A charge pulse created is proportional to the energy of the incoming X-ray. The charge is then amplified and discriminated according to its energy. A signal corresponding to the energy is processed into the appropriate channel of a multi- channel analyzer (MCA). There is a detector which is enclosed in a high- vacuum tube and protected from the atmosphere and environment by a thin beryllium sheet known as window. The whole system is then cooled to liquid nitrogen temperature in a Dewar normally attached to the EDS to reduce electronic noise (Williams and Goldstein, 1986:124).

The advantages of EDS over the traditional Wave length Dispersive Spectrometer (WDS) include: relatively small size, speed in collecting and simultaneously displaying X-ray data from a wide energy range and relatively large collection angle. However, its limitations which include poor energy resolution (~150eV) and inability to detect X-rays from elements below Na (Z=11) in the periodic table are not considered as major practical handicaps in most analyses (Williams and Goldstein, 1986:124).

All samples were analyzed by Dr Brad Willenberger of the Major Analytical Instrumentation Centre (MAIC) of Department of Materials Science Engineering, University of Florida, Gainesville, USA, using a JEOL JSM-6400 SEM (JEOL USA, Peabody, MA) equipped with an Oxford energy dispersive spectroscopy (EDS)

Each sample had an x20 SEI image taken of it, as well as an x20 BEI. Two regions were then selected from the x20 BEI, based on the degree of contamination and the level at which that spot represented the sample as a whole. From the regions chosen system and a LINK ISIS software package version 3.35 (Oxford Instruments USA, Concord

MA). All samples were analyzed at 15 KeV accelerating voltage to maintain consistency with the standardless digital library. This accelerating voltage is more than sufficient to observe all X-ray peaks of interest with EDS. Image processing was performed utilizing features available in the LINK ISIS software package. Each sample was set to a 16mm distance from the lens. A count rate of approximately 1.35 (kcps – kilo counts per second) and a dead time of 20% were kept as the standard for all samples. From these specifications, the EDS scan took about 100 seconds. The images were 8-bit 512x384 ultrafine resolutions. The scan rate was set to slow with a 200μs dwell time. The calibration for the EDS was taken with Cu tape and the numbers for zero, energy and counts were kept to around 9.62, 19.99 and 19000, respectively. Each sample was carbon coated and also had carbon paint touching the actual slag so as to not build charge from the SEM. The mounted specimens were then carbon coated (Ion Equipment Corp., Santa Clara, CA) and stored in petri dishes. An x500 SEI and BEI were taken. Using the x500 BEI, spots were chosen on different compositional areas found in the BEI. Distinctive compositional areas appear as differing grey scales. One spot was placed on each unique grey scale and an EDS taken from it to determine its elemental composition. The results of the SEM/EDS analyses are as follows:

The x20 BEI of sample 1 (TSN-06-I slag) shows dark grey fayalite containing light grey wustite and glass matrix (plate148), while the x500 BEI of ROI No.1 exhibits massive grey fayalite containing dark grey angular hercynite and glass matrix (plate149). The BEI ROI No 2 of the sample also shows massive grey fayalite containing dark grey angular hercynite, white wustite and glass matrix (plate150)

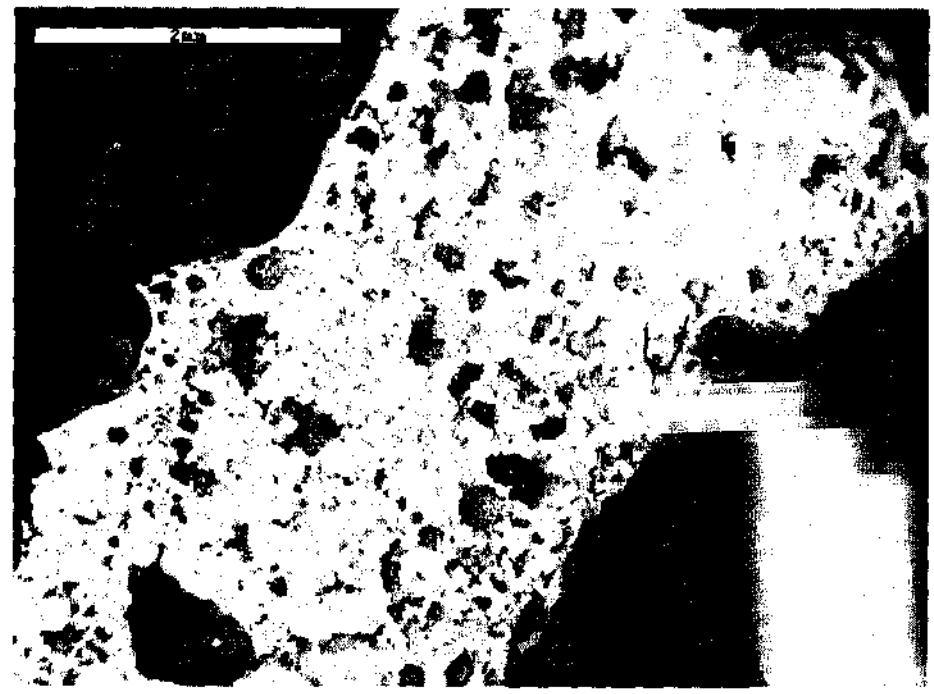


**Plate 148: Sample1 (TSN-06-I slag) x20 BEI showing grey fayalite containing light grey wustite and glass matrix.**

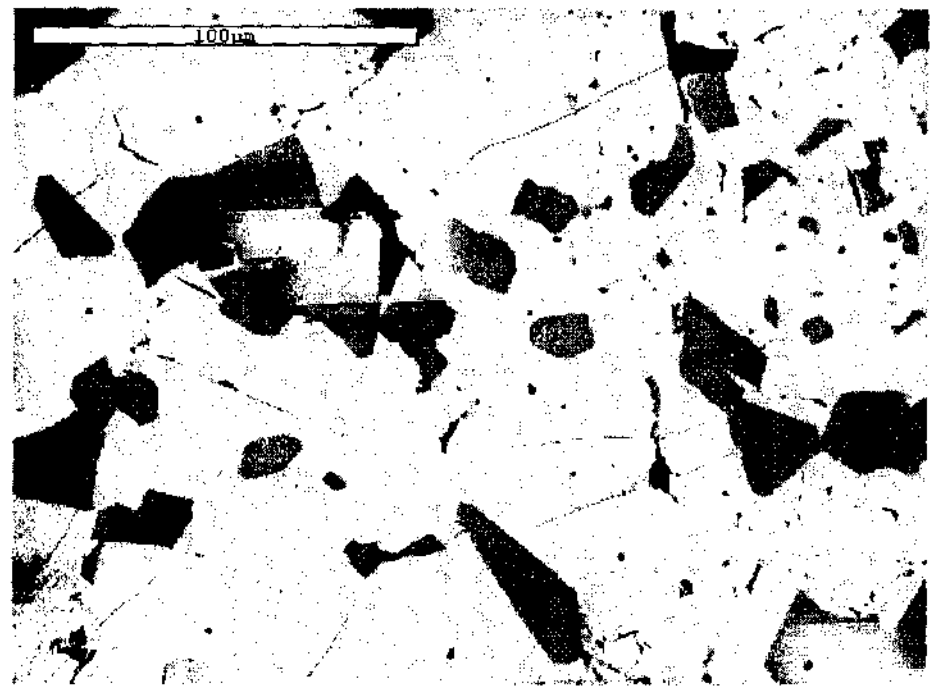



**Plate 149: Sample 1(TSN-06-I slag) x500 BEI ROI No.1 showing massive grey fayalite containing dark grey angular hercynite and glass matrix.**




**Plate 150: Sample1 (TSN-06-I slag) x500 BEI ROI No.2 showing grey fayalite containing dark grey angular hercynite and white wustite with glass matrix.**

The x 20 BEI of sample 2 (TSN-06-I slag) is associated with massive light grey fayalite, dark grey hercynite and glass matrix (plate151). The x500 BEI of ROI No 1 exhibits parallel and sub parallel fayalite and matrix of glass (plate152). The micrograph of x 500 BEI ROI No 2 of same sample is damaged and therefore can not be shown (see the elemental composition below.

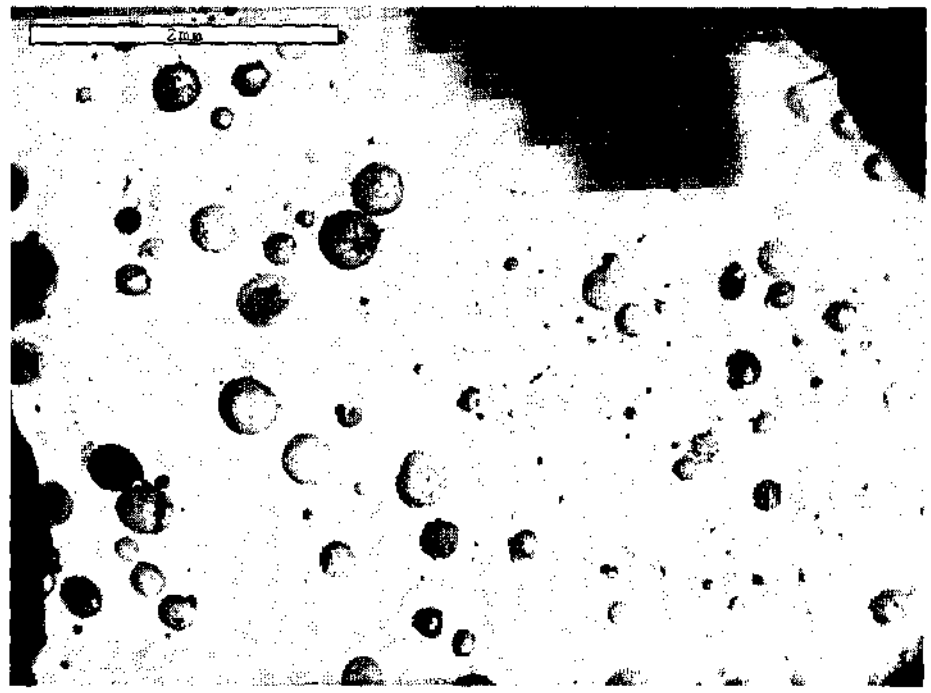


**Plate 151: Sample2 (TSN- 06-I slag) x20 BEI showing massive fayalite containing dark grey hercynite and glass matrix.**



**Plate152: Sample 2 (TSN-06-I slag) x500 BEI ROI No.1 showing parallel and sub-parallel fayalite and pool of glass.**

In sample 3 (slag sample from TSN – 06-II), the x20 BEI shows light grey fayalite containing dark grey hercynite and glass matrix (plate153). The x500 BEI ROI No1 of the sample exhibits massive light grey fayalite, dark grey hercynite and glass matrix (plate154) while, the x500 BEI ROI No.2 of the same sample exhibits parallel light grey fayalite, hercynite, wustite, leucite and glass matrix (plate155).

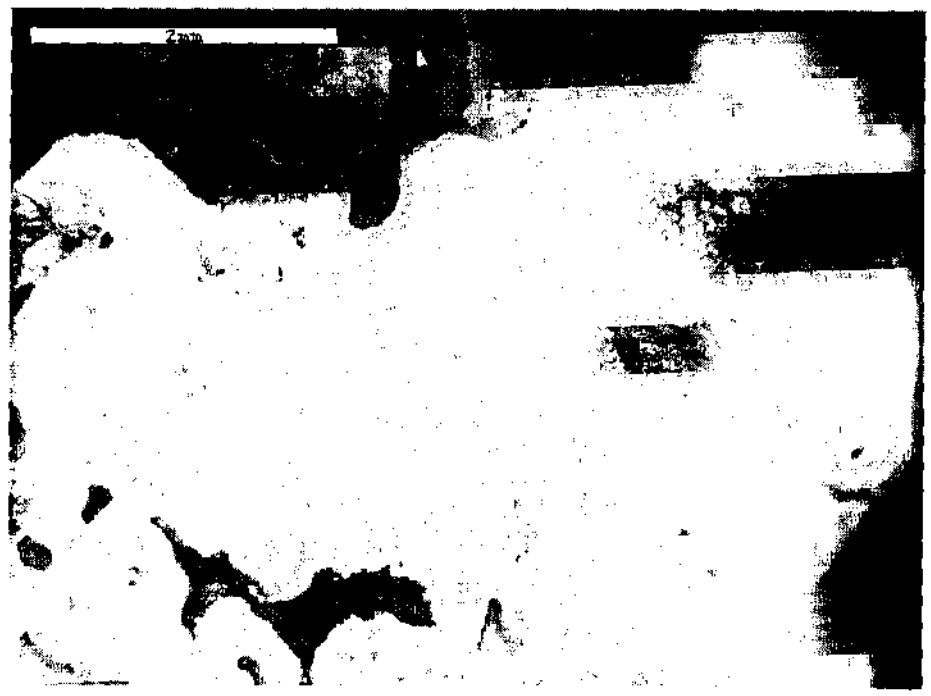


**Plate 153: Sample3 (TSN-06-II slag) x20 BEI**



**Plate154: Sample 3(TSN-06-II slag) x500 BEI ROI No.1 showing light grey fayalite and light grey fayalite containing dark grey hercynite and glass matrix.**




**Plate155:Sample3 (TSN-06-II slag) x500 BEI ROI No. 2 showing parallel fayalite, hercynite, wustite, leucite and glass matrix**

The x20 BEI of sample 4 (TSN-06-II slag) reveals massive light grey fayalite containing dark grey hercynite and glass matrix (plate156), while the x500 BEI ROI No1 and x500 BEI ROI No 2 are damaged (see their elemental compositions in tables 22&23)

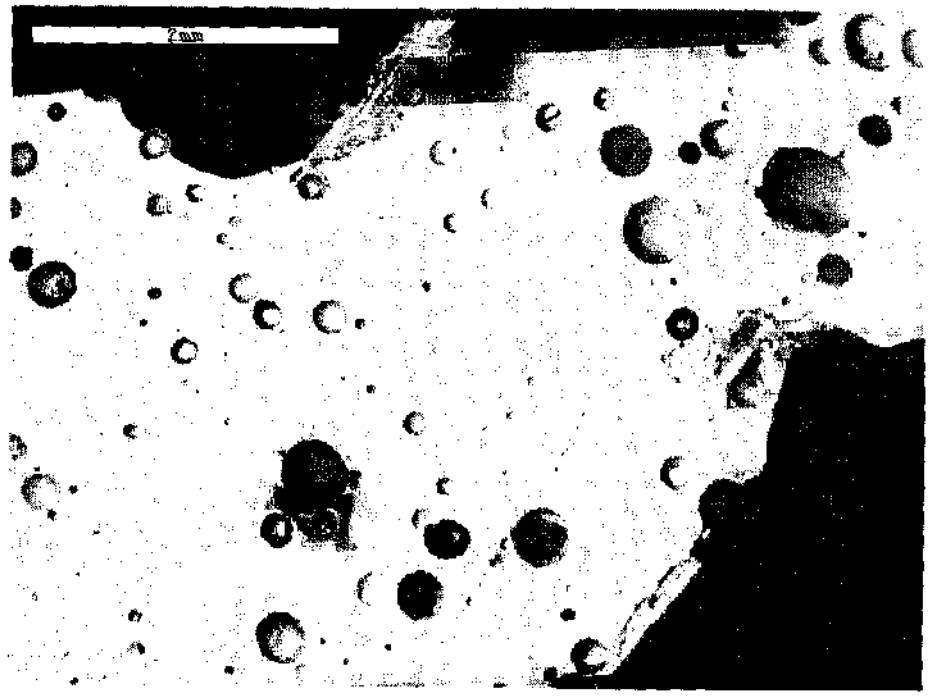


**Plate156: Sample 4 (TSN-06-II slag) x20 BEI showing massive light grey fayalite containing dark grey hercynite and glass matrix**

The micrographs of sample 5 (TSN-06-II tuyere) are not available due to the damage of the sample during preparation. The elemental compositions of the spots are however shown in tables 24-26.

The x20 BEI of sample 6(TSN-06-II tuyere) exhibits massive fayalite, hercynite and glass matrix (plate157). The sample was removed from the slagged edge of the tuyere, little wonder that it shows close affinity to the mineralogical phases typical of bloomery slag samples.The BEI ROI Nos.1 and 2 were damaged (see tables..for elemental composition of the spots).




**Plate 157: Sample6 (TSN-06-II tuyere) x20 BEI showing fayalite, hercynite and glass matrix.**

The x20 BEI of sample 7 (TSN-07-I slag) exhibits massive fayalite, hercynite and glasss matrix (plate158)). Note a line running longitudinally across the sample indicating cracking during sample preparation. The x500 BEI ROI No.1shows Parallel and sub-parallel fayalite containing grey hercynite, dendrites wustite and glass(plate 159) while x500 BEI ROI No.2 also exhibits parallel and sub-parallel light grey fayalite containing dark grey hercynite, dendrites wustite and pools of glass (160).

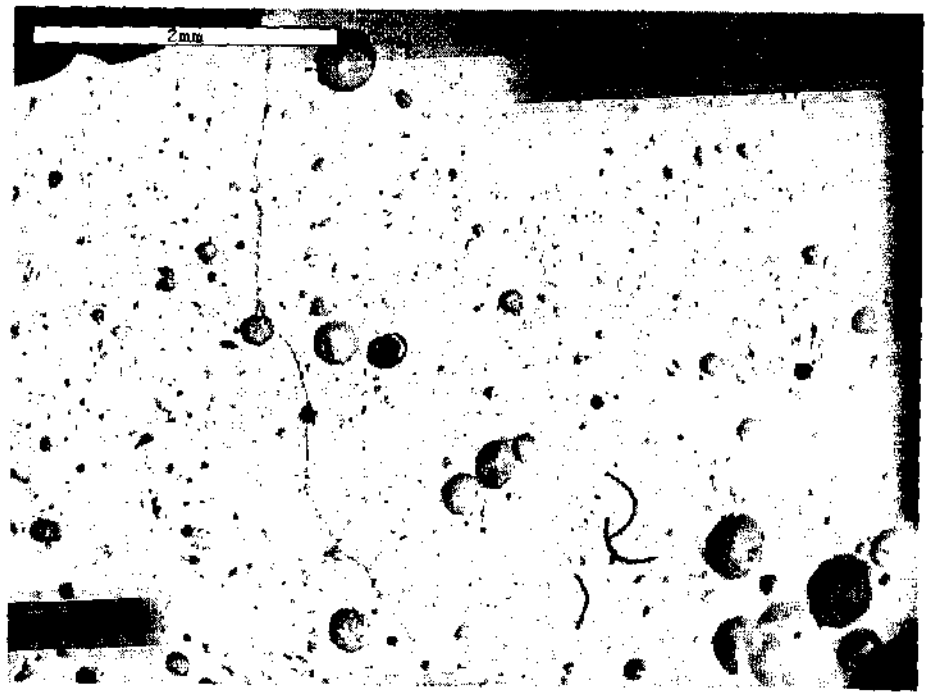



**Plate 158: Sample7 (TSN-07-I slag) x20 BEI showing massive fayalite, hercynite and glasss matrix.**

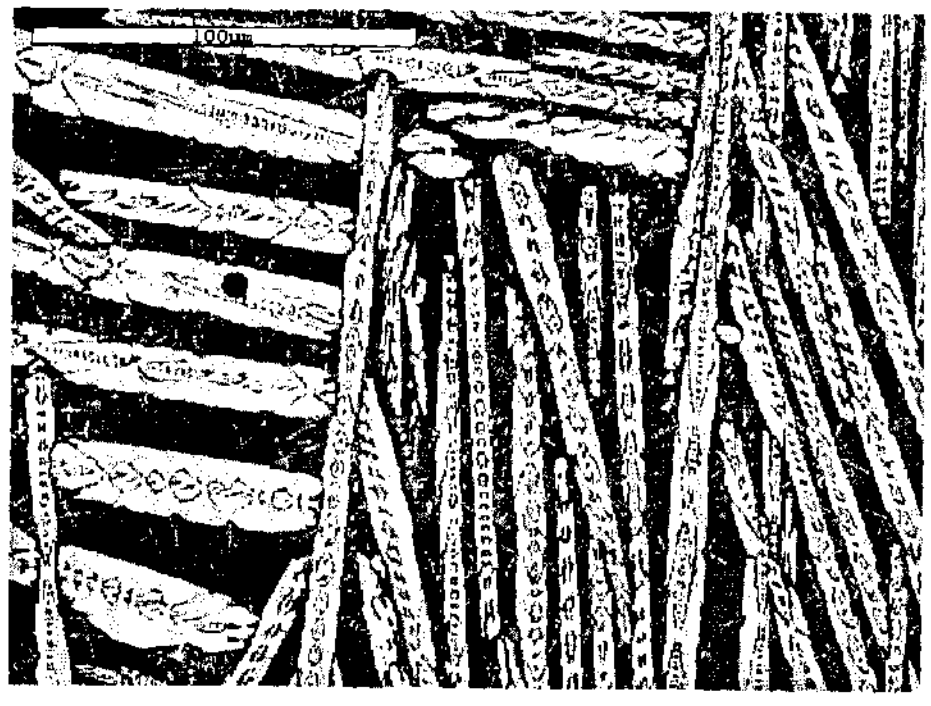



**Plate 159: Parallel fayalite with grey hercynite, dendritic wustite and pool of glass.**




**Plate 160: Sample7(TSN-07-I slag) x500 BEI ROI No 2 showing parallel and sub-parallel light grey fayalite containing dark grey hercynite, dendrites wustite and pools of glass**

Sample 8 (TSN 07-II slag) x20 BEI displays massive light grey fayalite, containing dark grey hercynite and pools of glass (plate161), while x500 BEI of ROI No 1 of same sample exhibits parallel and sub-parallel light grey fayalite containing dark grey hercynite and glass pools (plate 162).The x500 BEI ROI No.2 shows parallel light grey fayalite containing dark grey hercynite and pool of glass.(plate 163).

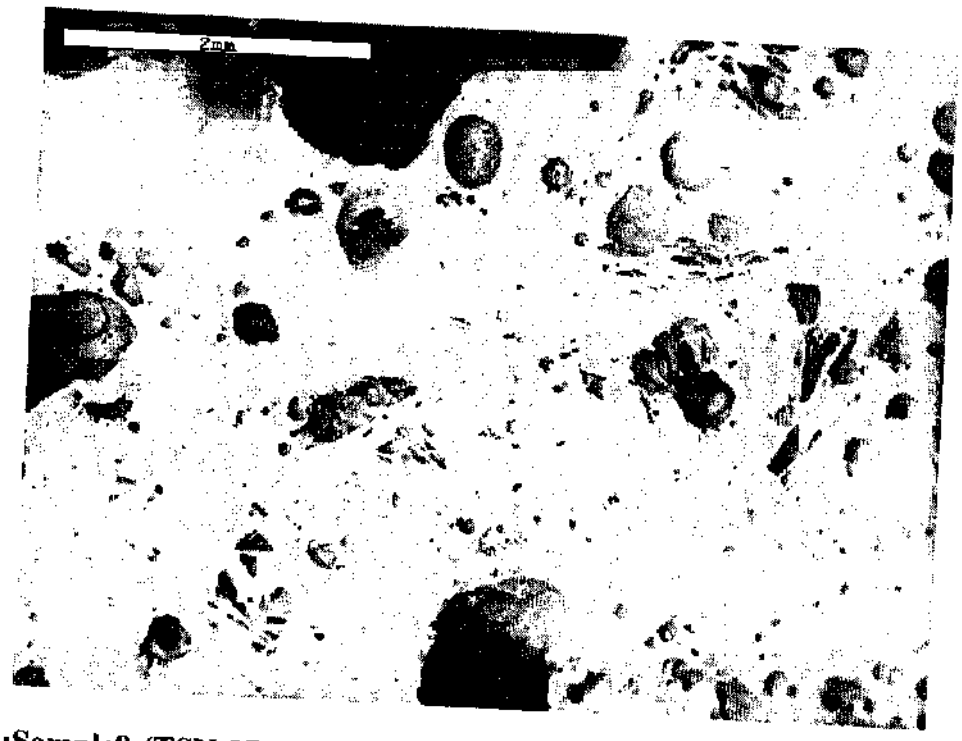



**Plate161:Sample8 (TSN-07-II slag) x20 BEI showing light grey fayalite, containing dark grey hercynite, and pools of glass**

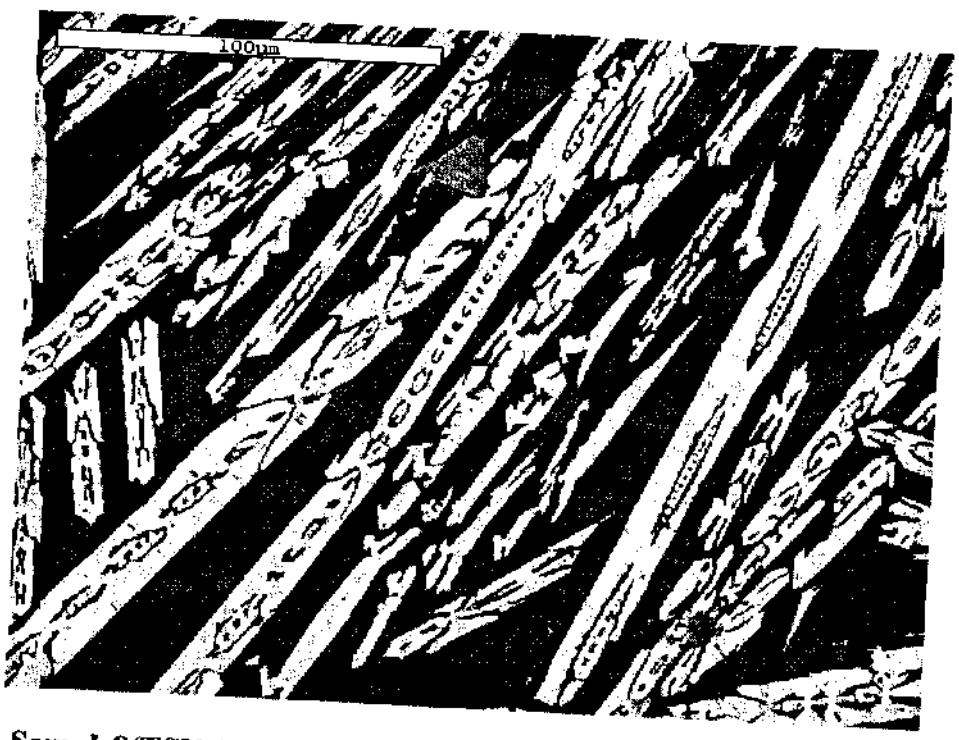



**Plate162: Sample8(TSN-07-II slag) x500 BEI ROI No.1 showing parallel and sub-parallel light grey fayalite containing dark grey hercynite and pools of glass.**

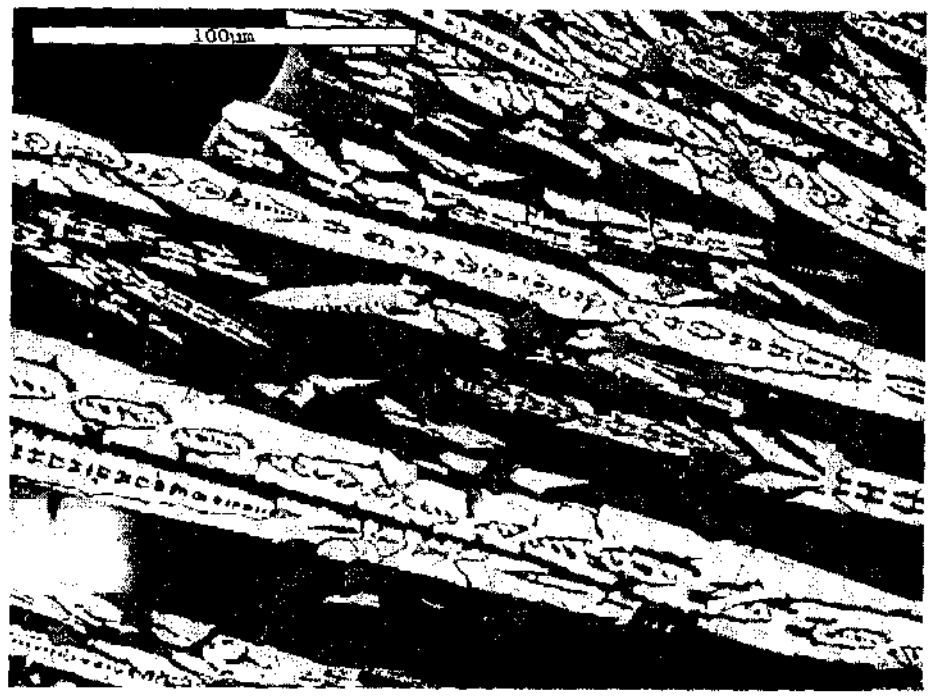



**Plate163:Sample8(TSN-07-II slag) x500 BEI ROI No.2 showing parallel light grey fayalite containing dark grey hercynite with pools of glass.**

The x20 BEI of sample 9 (TSN-07-II slag) is deformed. Its x500 BEI ROI No1 however shows massive light grey fayalite containing white crystals of wustite and pools of glass (plate164). The x500 BEI ROI No.2 also displays massive light grey fayalite containing white wustite and and glass pools (plate 165)

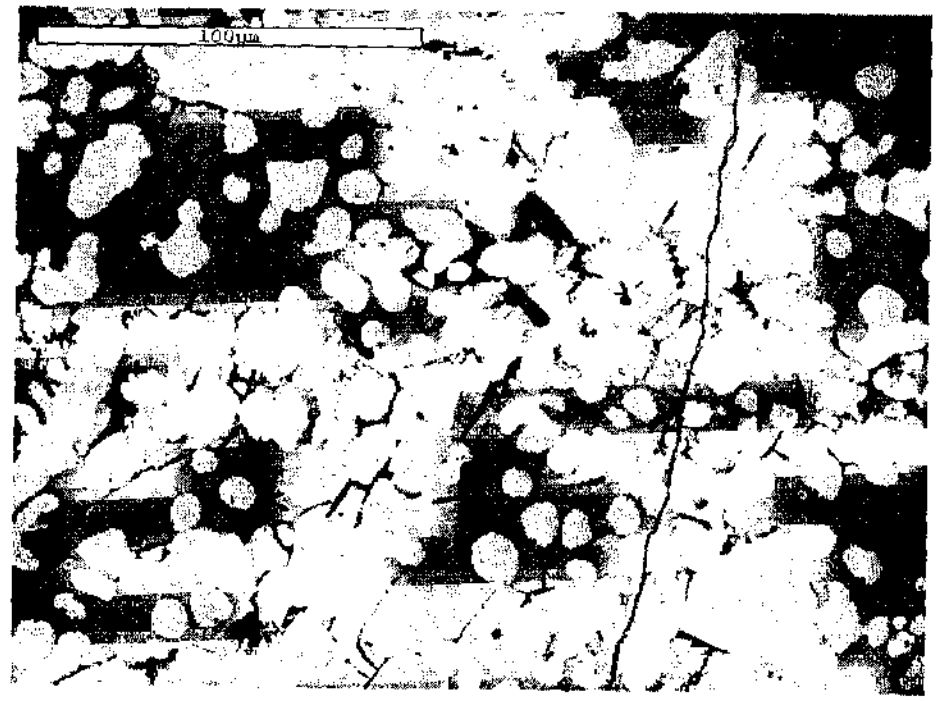



**Plate164: Sample 9(TSN-07-II slag) x500 BEI ROI No.1.showing light grey fayalite containing white crystals of wustite and pools of glass**

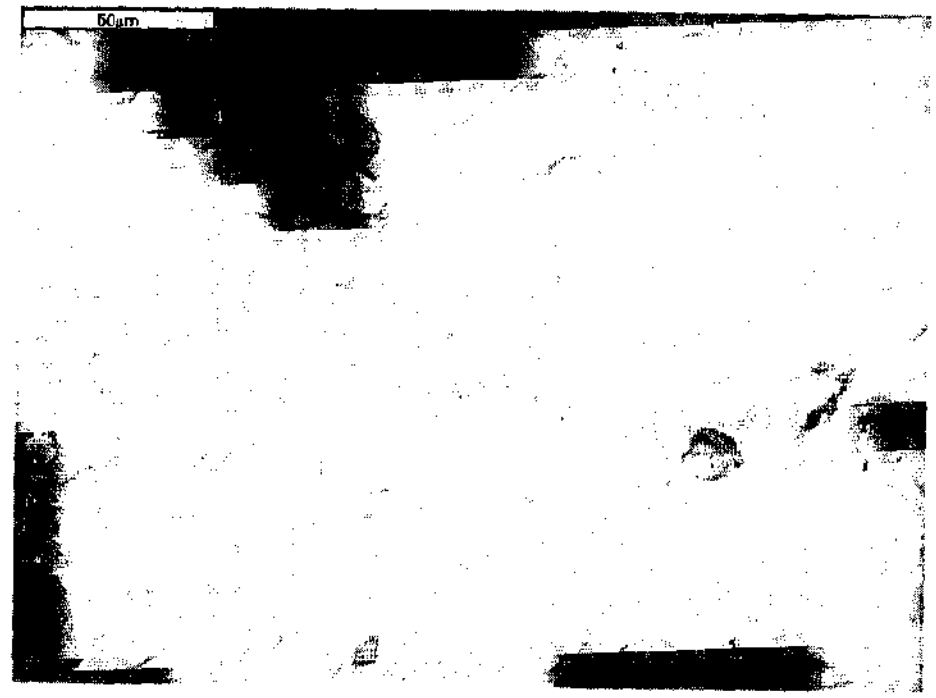



**Plate165: Sample 9 (TSN-07-II slag) x500 BEI ROI No 2 showing light grey fayalite containing white wustite and and glass pools.**

Sample10 (TSN-07-II slag) x20 BEI exhibits masive light grey fayalite and dark grey hercynite with pools of glass (plate166). The x500 BEI ROI No 1 of the sample also shows massive fayalite containing dark grey hercynite leucite and pool of glass(167) while the ROI No 2 of sample 10 is displays massive fayalite containing sub-angular hercynite and pools of glass (plate 168).

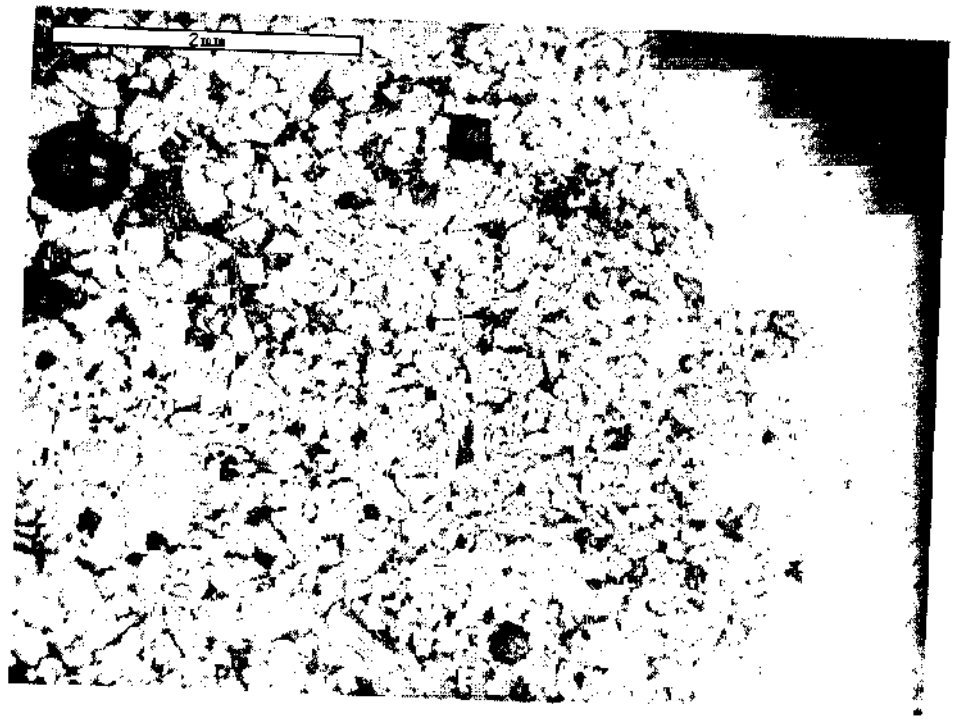


**Plate 166: Sample10 (TSN-07-II slag) x20 BEI showing light grey fayalite and dark grey hercynite with pools of glass.**

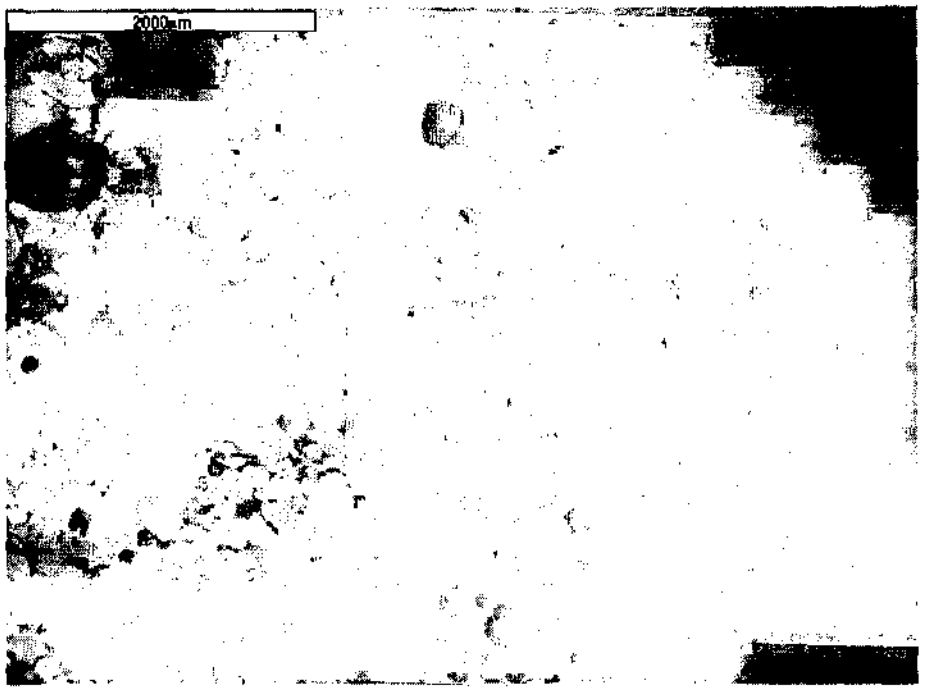



**Plate167:Sample10 (TSN-07-II slag) x500 BEI ROI No.1 showing massive fayalite containing dark grey hercynite, leucite and pool of glass.**

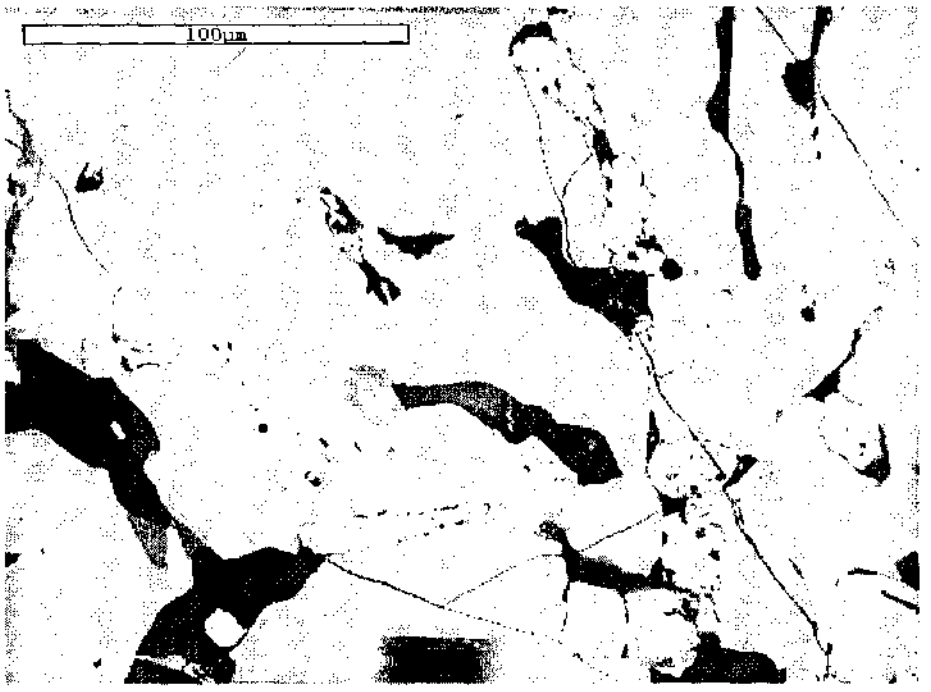



**Plate168:Sample10 (TSN-07-II slag) x500 BEI.ROI No.2 showing fayalite containing sub-angular hercynite and pools of glass**

Sample 11 (TSN – 08, laterite) x20 BEI is characterized by massive light grey fayalite containing dark grey hercynite, leucite and pools of glass (plate169). The x500 BEI ROI No.1 of same sample shows grey fayalite containing wustite, leucite and hercynite with glass matrix (plate170). The x500 BEI ROI No 2 exhibits grey fayalite containing wustite, leucite, hercynite and glass matrix (plate 171).

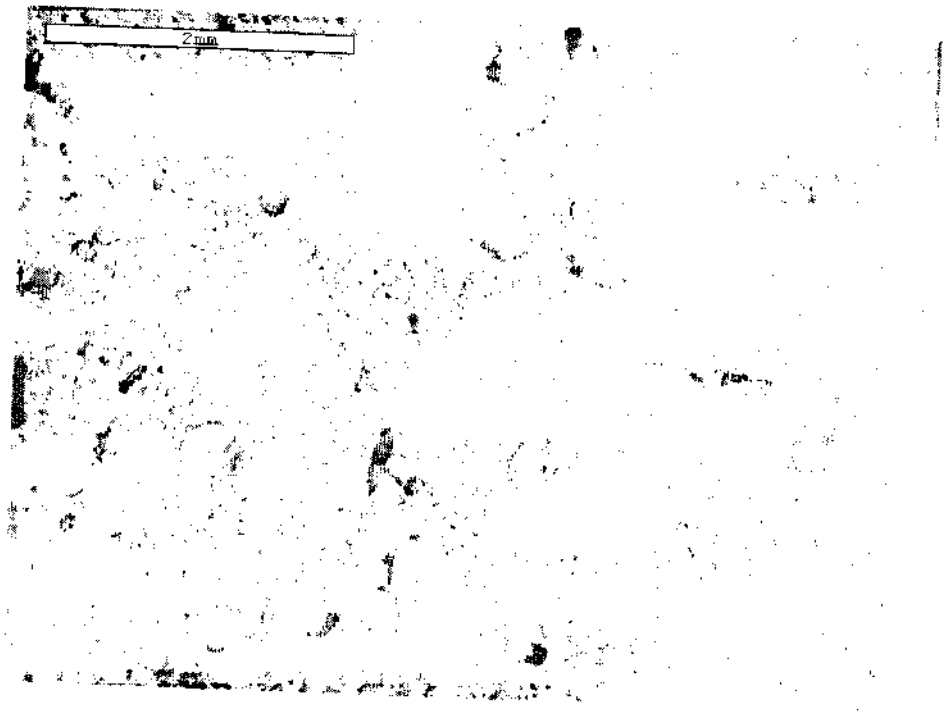



**Plate169: Sample11 (TSN-08 laterite) x20 BEI showing light grey fayalite containing dark grey hercynite, leucite and pools of glass**



**Plate170:Sample11 (TSN-08 laterite) x500 BEI ROI.No.1 showing grey fayalite containing wustite, leucite and hercynite with glass matrix**

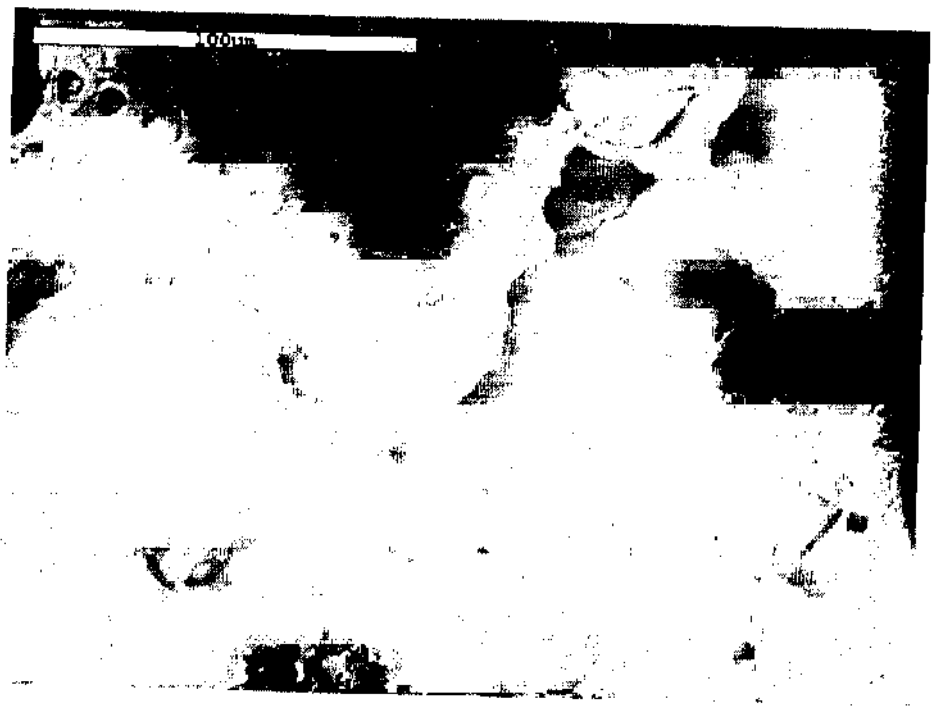


**Plate171:Sample11 (TSN-08 laterite) x500 BEI ROI No.2 showing grey fayalite containing wustite, leucite, hercynite and glass matrix.**

The x20 BEI of sample 12 (TSS-07- I slag) exhibits light grey fayalite containing some hercynite, leucite and glass matrix (plate172). The x500 BEI ROI No.1 displays massive fayalite containing white metal iron, white dendrites wustite and pools of glass (plate173). The x500 BEI ROI No2 shows massive grey fayalite containing white specks of dendrites wustite and pools of glass (plate174). Note that the sample shows some marks resulting from bad handling probably during polishing.

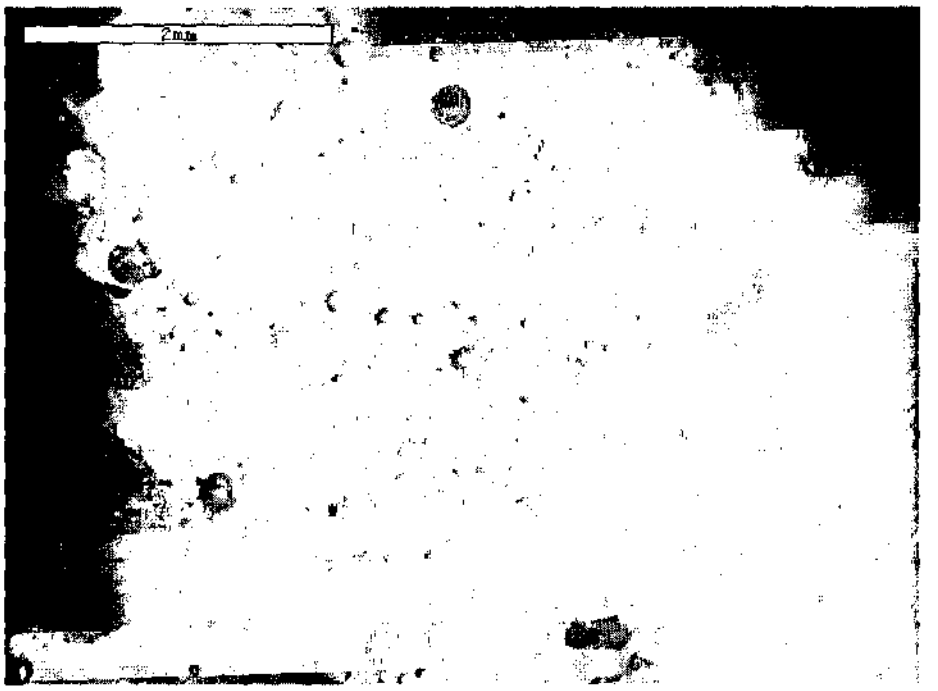


**Plate172: Sample12 (TSS-07-I slag) x20 BEI showing light grey fayalite containing some hercynite, leucite and glass matrix**




**Plate173:Sample12 (TSS-07-I slag) x500 BEI ROI No.1 showing fayalite containing white metal iron, white dendrites wustite and pools of glass.**

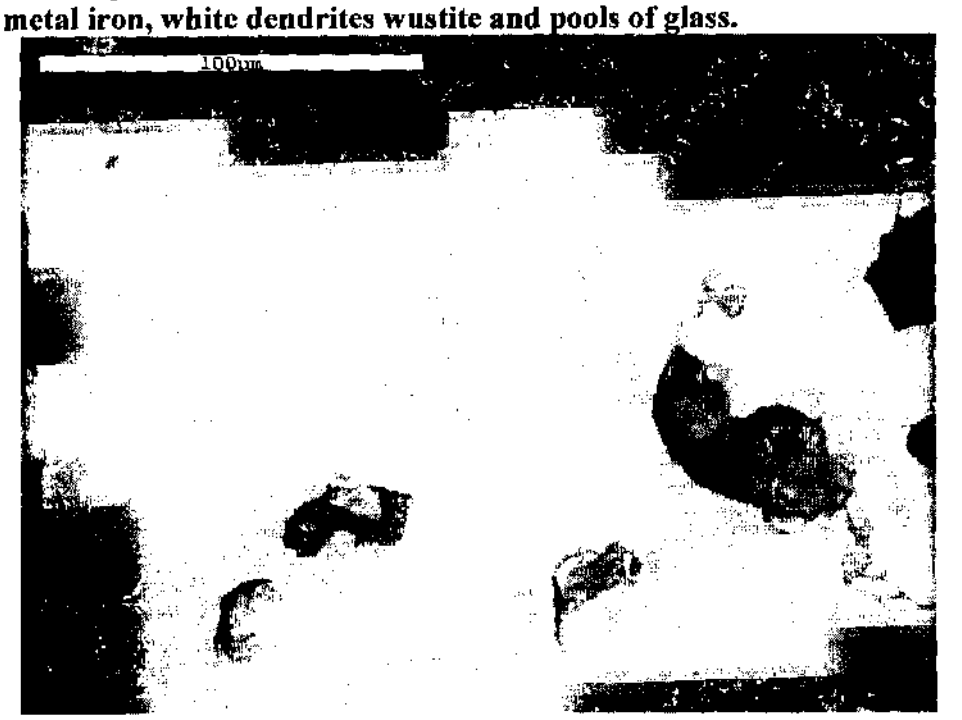



**Plate174:Sample12 (TSS-07-I slag) x500 BEI ROI No.2 showing massive grey fayalite containing white dendrites wustite and pools of glass.**

Sample 13 (TSS-07-II slag) at x20 BEI shows massive grey fayalite containing dark grey hercynite and glass matrix (plate175). The x500 BEI of ROI No1 shows

parallel and sub-parallel light grey fayalite containing some wustite, dark grey hercynite and glass (plate176). The x500 BEI ROI No.2 exhibits parallel and sub-parallel fayalite containing massive hercynite and pools of glass (plate 177).




**Plate 175:Sample13 (TSS-07-II slag) x20 BEI.showing grey fayalite containing dark grey hercynite and glass matrix**




**Plate176: Sample 13(TSS-07-II slag) x500 BEI ROI No.1 showing parallel and sub-parallel light grey fayalite containing some dendrites wustite, dark grey hercynite and glass matrix.**




**Plate177:Sample13 (TSS-07-II slag) x500 BEI ROI No.2 showing sub-parallel light grey fayalite containing some wustite, dark grey hercynite and glass**

From Sample 14 (TSS-07-III slag) the x20 BEI exhibits massive dark grey fayalite containing whitish dendrites wustite and pools of glass (plate 178). The x500 BEI of ROI No. 1 of the sample shows parallel light grey fayalite containing dark grey hercynite and glass matrix (plate179). The x500 BEI ROI No 2 of the sample also exhibits parallel and sub-parallel light grey fayalite containing dark grey hercynite small white dendrites wustite and glass (plate180). The micrograph shows a crack that resulted due to problem of preparation.

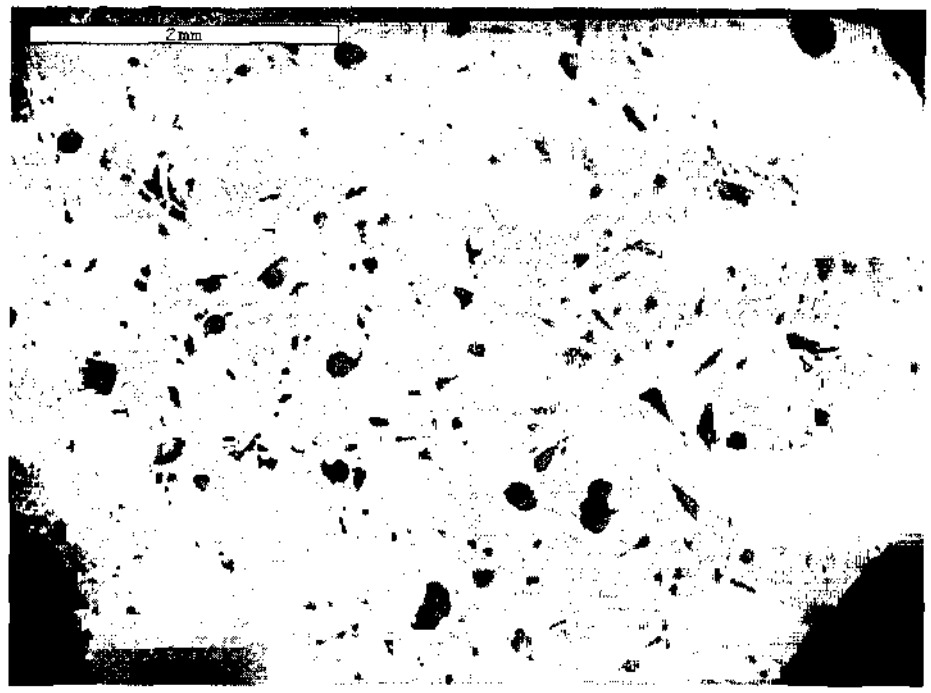



**Plate178: Sample14 (TSS-07-III slag) x20 BEI showing massive dark grey fayalite containing grey hercynite whitish dendrites wustite and pools of glass**

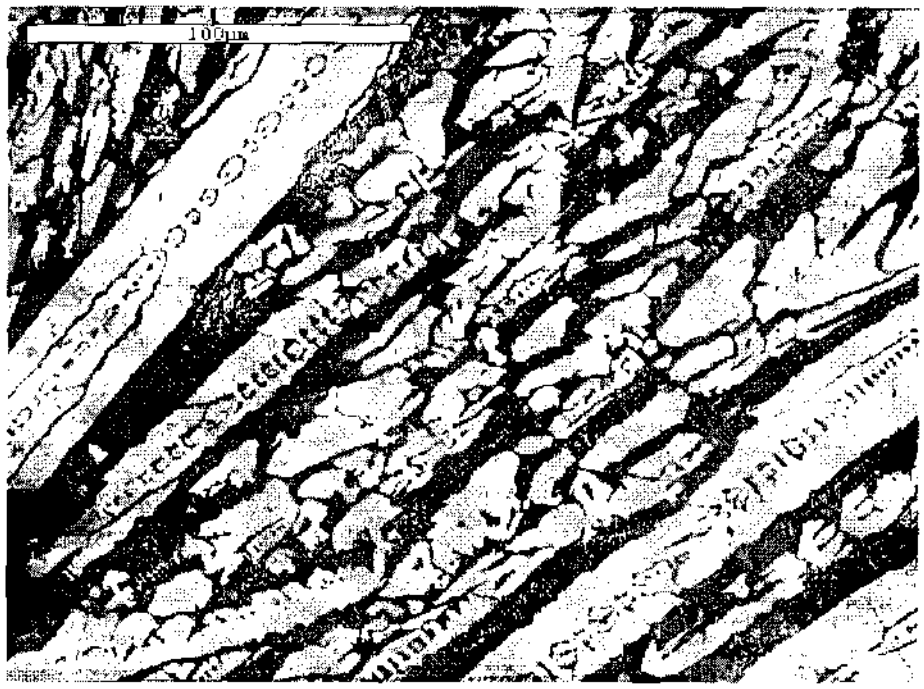



**Plate 179: Sample 14(TSS-07-III) x500 BEI ROI No.1 showing parallel light grey fayalite containing dark grey hercynite and glass matrix**




**Plate180:Sample14 (TSS-07-III slag) x500 BEI ROI No.2 showing parallel and sub-parallel light grey fayalite containing dark grey hercynite small white dendrites wustite and glass. Note that a crack developed during sample preparation.**

The x20 BEI of sample 15 (TSS-07-IV slag) shows dark grey fayalite containing massive wustite, bubbles of hercynite and pools of glass (plate 181). The x500 BEI ROI No.1 exhibits parallel and sub-parallel light grey fayalite containing dark grey hercynite with glass(plate182), while the x500 BEI ROI No.2 shows also shows parallel and sub-parallel light grey fayalite containing dark grey hercynite with dendrites wustite and glass (plate 183).




**Plate181: Sample 15(TSS-07-IV slag) x20 BEI showing dark grey fayalite containing massive wustite, bubbles of hercynite and pools of glass**

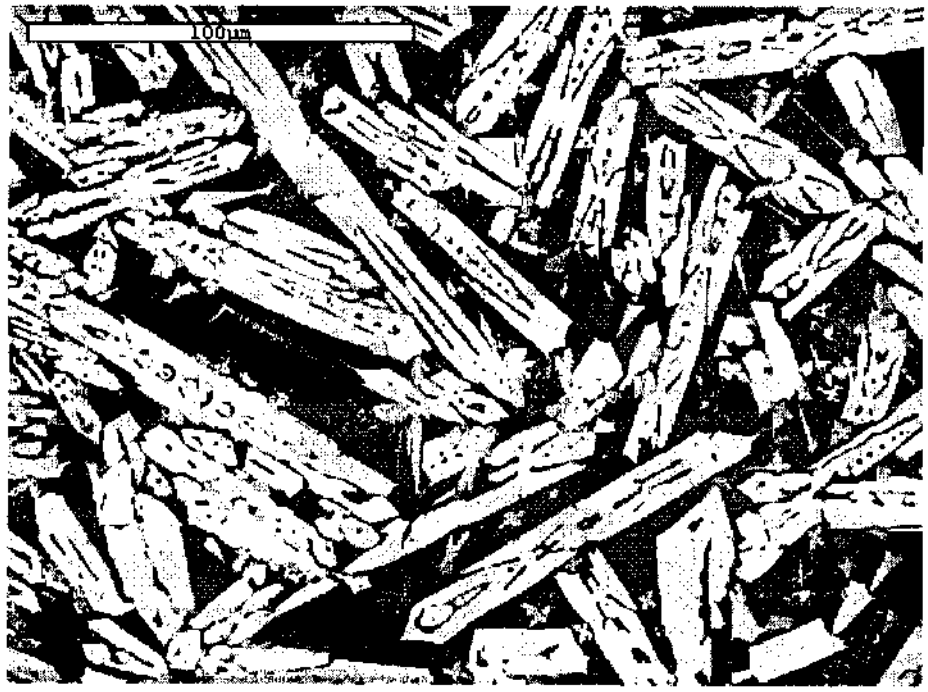



**Plate182:Sample15(TSS-07-IV slag) x500 BEI ROI No.1 showing parallel and sub-parallel light grey fayalite containing dark grey hercynite with glass.**




**Plate183:Sample15 (TSS-07-IV slag) x500 BEI ROI No.2 showing parallel and sub-parallel light grey fayalite containing dark grey hercynite with dendrites wustite and glass.**

Sample 15 (KRG 80 slag) x20 BEI shows massive light grey fayalite containing dendritic wustite, bubbles of hercynite and pools of glass (plate184). The x500 BEI of ROI No1 displays massive grey fayalite containing dendritic wustite with bubbles of hercynite and pools of glass(plate185) while the BEI ROI No.2 shows parallel and sub-parallel light grey fayalite containing hercynite and glass (plate186).

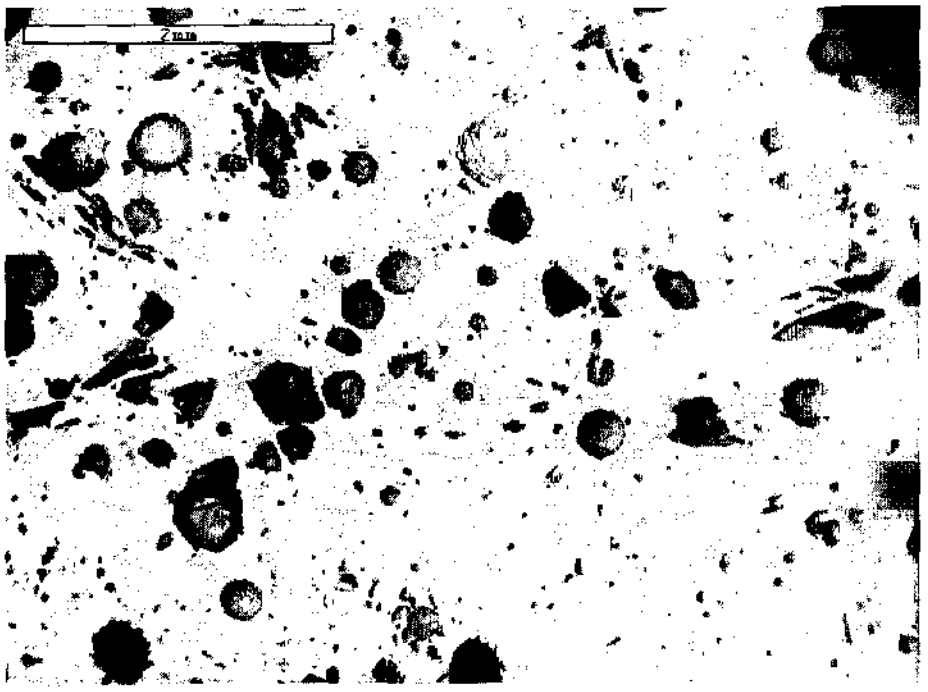


**Plate184:Sample16 (KRG-80 slag) x20 BEI showing light grey fayalite containing dendritic wustite, bubbles of hercynite and pools of glass.**

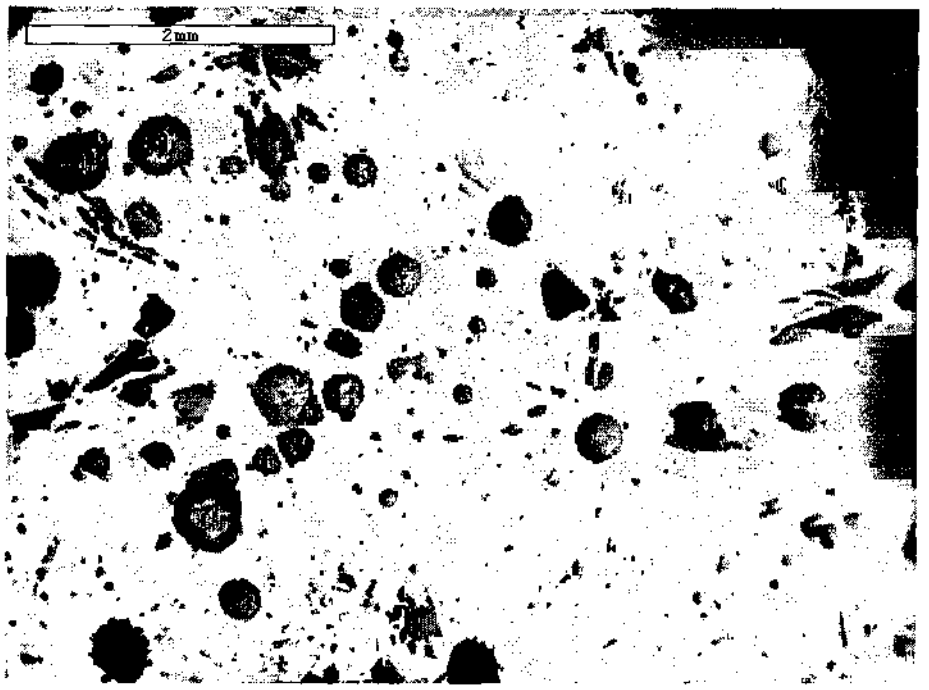



**Plate185:Sample16 (KRG-80 slag) x500 BEI ROI No.1 showing light grey fayalite containing dendritic wustite with bubbles of hercynite and pools of glass.**

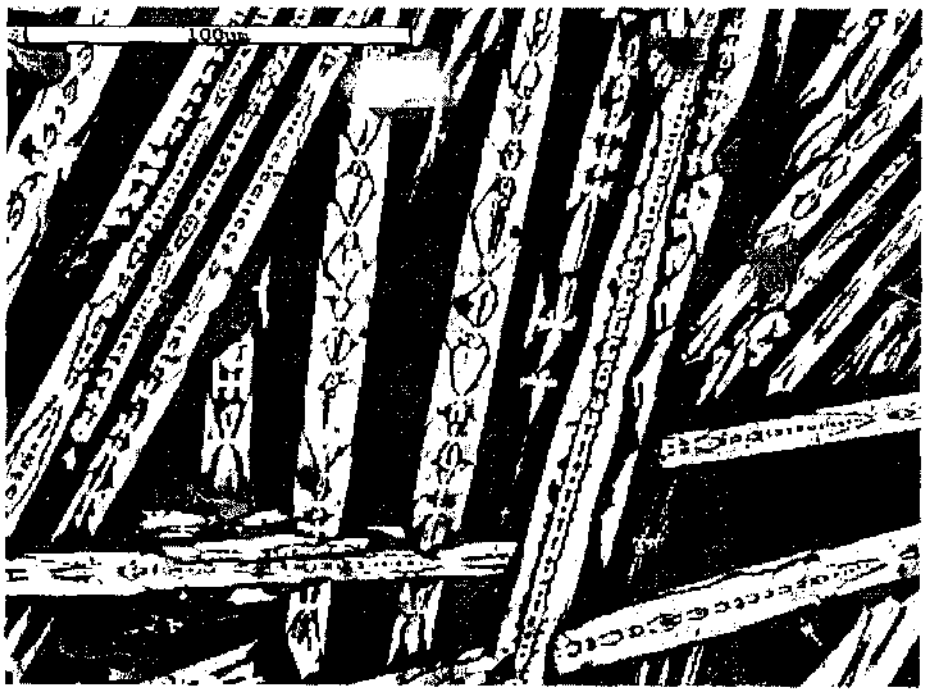



**Plate186: Sample16 (KRG-80 slag) x500 BEI ROI No 2 showing parallel and sub-parallel light grey fayalite containing hercynite and glass.**

From Sample 17 (KUF- 82 slag), the x20 BEI shows light grey fayalite containing hercynite and dark glass (plate187). The x500 BEI ROI No.1 exhibits massive grey fayalite containing free wustite, grey angular hercynite and dark glass(plate188) while the x500 BEI ROI No. 2 shows massive grey fayalite containing angular dark grey hercynite, free wustite and glass(plate 189).




**Plate187: Sample17 (KUF-82 slag) x20 BEI showing light grey fayalite containing hercynite and dark glass matrix.**



**Plate188: Sample 17(KUF 82 slag) x500 BEI ROI No.1 showing massive grey fayalite containing free wustite, angular grey hercynite and dark glass.**

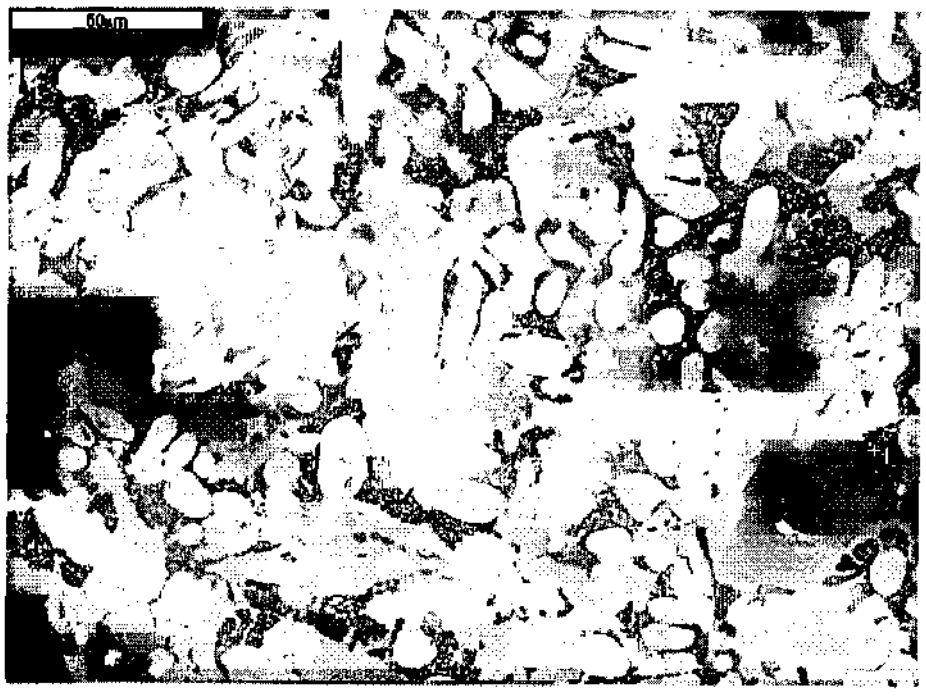


**Plate 189: Sample 17(KUF 82 slag) x500 BEI ROI No.2 showing massive grey fayalite containing angular dark grey hercynite, free wustite and glass.**

Sample 18 (TRK – 06 slag) x 20 BEI exhibits massive light grey fayalite containing dark grey hercynite, leucite and pools of glass (plate 190). The x500 BEI ROI No.1 shows massive light grey fayalite containing dendrites wustite, dark grey angular hercynite and black glass matrix (plate191) while the x500 BEI of ROI No 2 of shows parallel and sub-parallel containing dark grey hercynite and glass matrix (plate192).

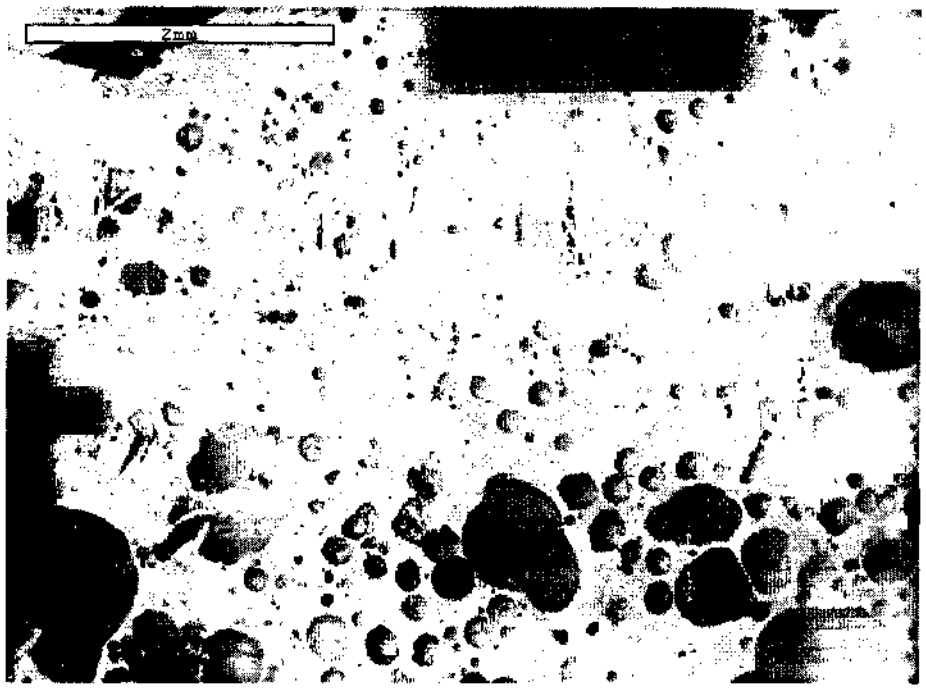



**Plate190:Sample18 (TRK-06 slag) x20 BEI showing light grey fayalite containing dark grey hercynite, leucite and pools of glass.**

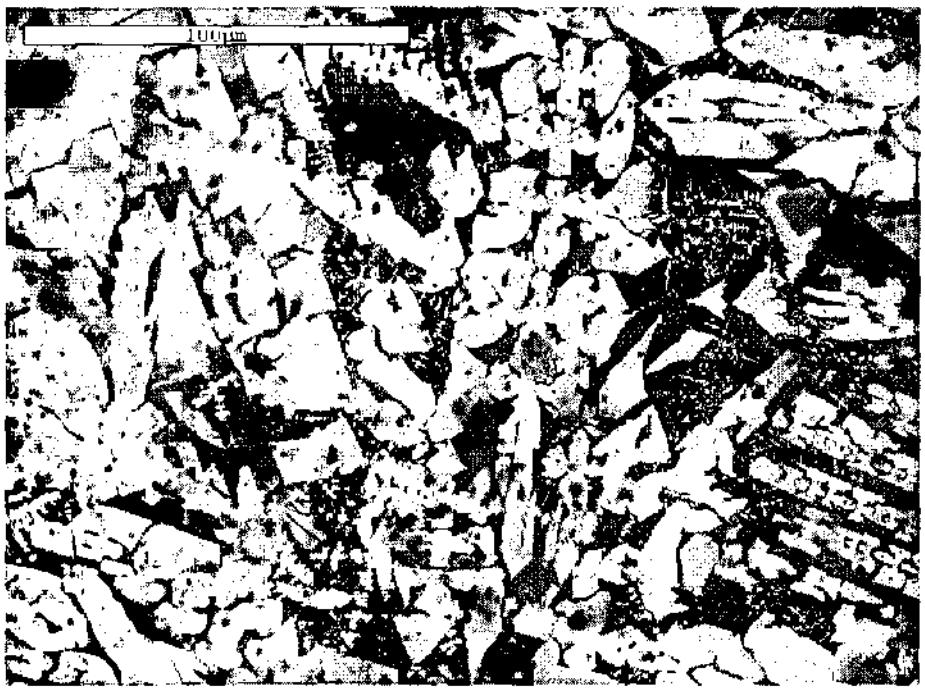



**Plate191:Sample18 (TRK-06 slag) x500 BEI ROI No.1 showing light grey fayalite containing dendrites wustite, dark grey angular hercynite and black glass matrix**

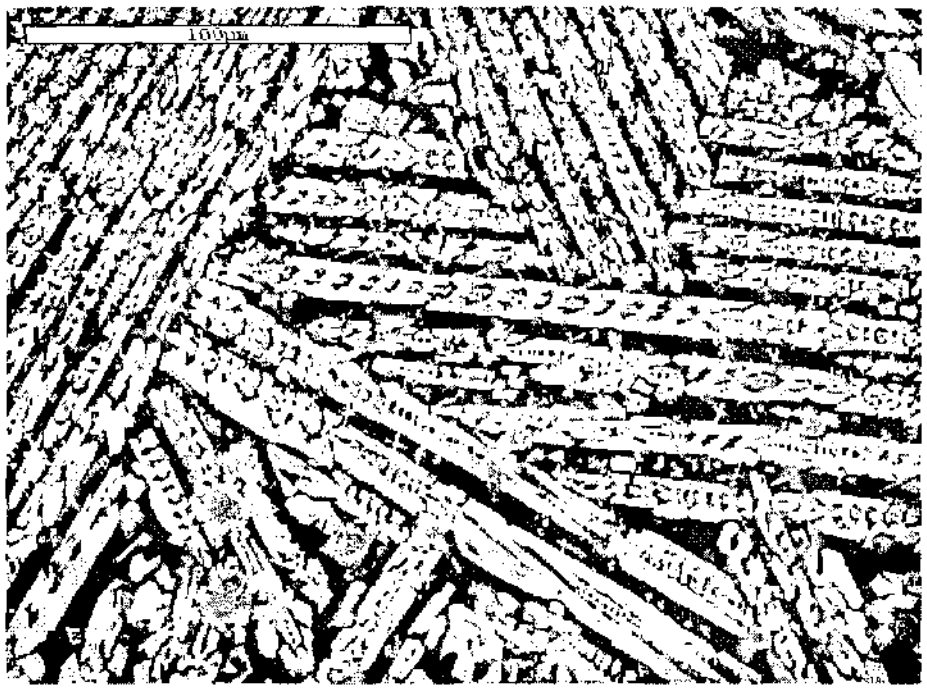



**Plate192:Sample18 x500 BEI ROI No.2 showing parallel and sub-parallel light grey fayalite containing dark grey hercynite and glass matrix**



**Plate193: Sample 19 (SMW-08 slag) x500 BEI ROI No.2 showing parallel and sub-parallel light grey fayalite containing dark grey hercynite, dendrites wustite and glass.**

The x20 BEI of sample 20 (SMW O8 tuyere) exhibits light grey fayalite containing grey hercynite, wustite and glass matrix (194). Its x500 BEI at ROI No 1 shows massive dark grey fayalite containing white dendrites wustite and tiny patches of glass (plate195) while the x 500 BEI ROI No 2 shows massive dark grey fayalite, white metal iron and dendrites wustite. Note the concentration of globules of white angular iron at the centre of the sample which indicates that a substantial quantity of iron was lost to the slag during smelting operation (plate196)

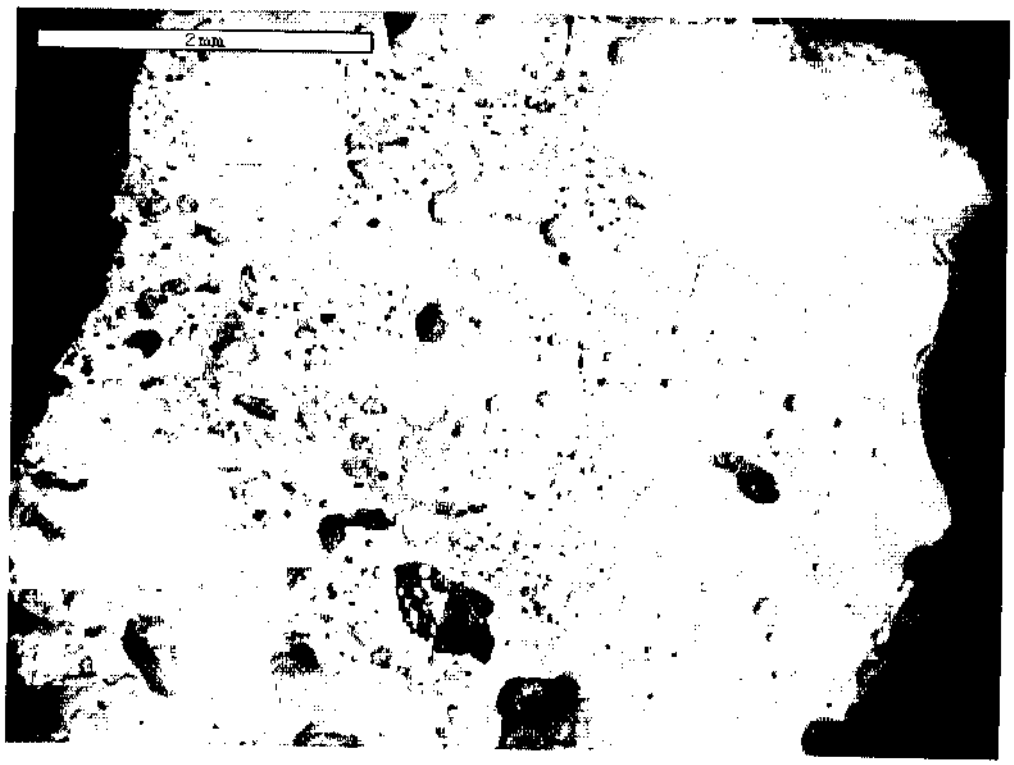



**Plate194:Sample20 (SMW-08 tuyere) x20 BEI showing light grey fayalite containing grey hercynite, wustite and glass matrix.**

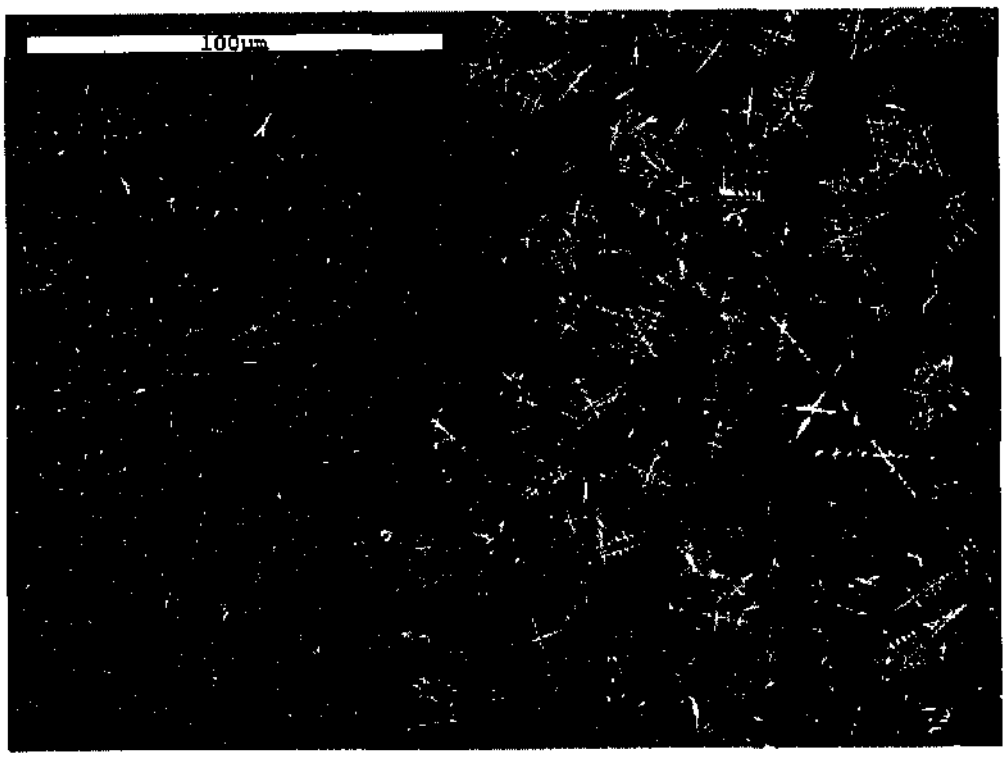



**Plate195: Sample20 (SMW-08 tuyere) x500 BEI ROI No.1 showing dark grey fayalite containing white dendrites wustite and tiny patches of glass.**

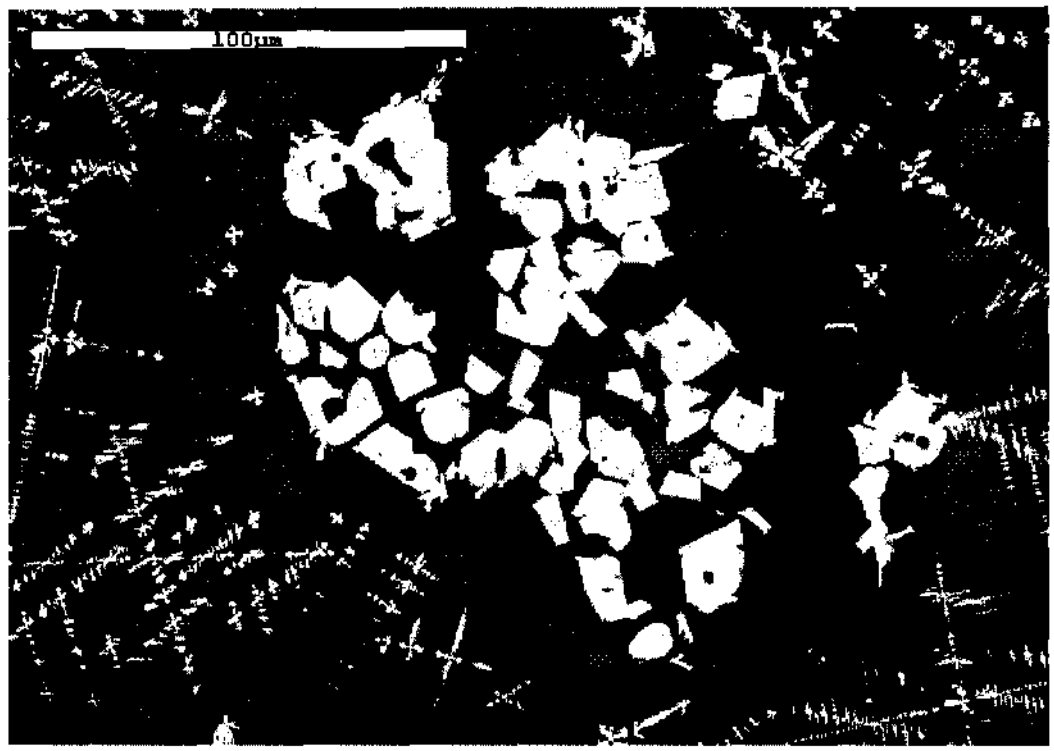



**Plate 196: Sample 20 (SMW-08 tuyere x500 BEI ROI No. 2 showing massive dark grey fayalite, white metal iron and dendrites wustite.**

The results of the SEM/EDS analysis showed that the dominant mineralogical phases in the residue samples are fayalite, wustite, hercynite and glass as indicated above.

**The X- Ray Diffraction Results**

In contrast to the SEM/EDS used to determine the chemical composition that is the concentration of constituent elements, X-ray diffraction technique is used to identify the mineralogical phases and chemical compounds in samples in addition to extracting information relating to the mechanical and thermal treatments of metal artifacts during fabrication (Tite 1972). The remarkable ability of X-rays to penetrate opaque objects and to non-destructively reveal its microstructures makes this technique very useful in the analysis of iron smelting residues.

Generally, the principle underlying this technique has to do with the bombardment of the specimen with a beam of monochromatic X-rays (that is X-rays with a sharply defined wave length). In this technique, the reflection of X-rays when they strike a specimen is similar to the reflection from a mirror (Tite 1972). The difference between the XRD and other techniques is that in XRD, the X-rays penetrate below the surface of the crystal and are reflected from the successive atomic layers. Therefore the maximum intensity of the reflected X-rays occurs at the angles at which the contributions from successive planes are in phase. This is expressed in Bragg's relationship which states that for a maximum reflected intensity, the path difference for successive reflections must equal a whole number of wave lengths (Tite 1972). A crystalline specimen that is struck by the X-rays will then produce a series of X- ray intensity maxima referred to as the diffraction pattern the study of which can lead to the identification of the mineral constituents of the specimen.

Specifically, the Powder X-ray Diffraction used in these analyses involves the production of a beam of monochromatic radiation from X-rays emanating from a high – voltage X-ray tube which is then directed to the sample crystal lattice planes. In a powder rotating sample, since these lattice planes exist at all orientations, the cone of X-rays strikes the film in a pair of spots. The reflections from the planes with other spacings then produce more spots leading to a series of dark spots referred to as the diffraction pattern which is formed on the processed photographic film (Tite 1972). Modern X-ray diffraction patterns are often generated by electronic recording (Krawitz 1986). The crystal structures of the phases are contained in a data base known as Powder Diffraction File (PDF) comprising of books, CD-ROMS, magnetic tape and microfiche. The file is

then used to identify the mineral phase displayed by a specific diffraction pattern. X-ray Powder Diffraction has been found very useful in qualitative and quantitative analyses of materials.

This Powder X-ray analysis like the Scanning Electron Microscopy (SEM)/Electron Dispersal Spectroscopy (EDS) was carried out at The Major Analytical Instrumentation Centre (MAIC), Department of Matrials Science Engineering, University of Florida, Gainesville, USA to identify the mineralogical phases in the samples which the SEM/EDS technique could not achieve. The analysis was conducted by Dr Gerrald Bourne of the same Centre.

For the XRD analysis of samples, a computer-controlled diffractometer used automatic progammes to measure, record and interprete the different diffratograms. The computer programme used for this purpose was *Phillips PW 1877 Automated Powder Diffraction Version 3.6g (951214)* while Phillips and PW 1876 PC Version 1 of 15$^{th}$ September 1995 was used to identify the mineralogical phases which are shown in table3

From the identified mineralogical phases, fayalite is virtually reflected in all the samples. The occurrence of this mineralogical phase is typical of bloomery slag (Craddock *et.al* 2007; Okafor 1992; Mapunda 1995). Fayalite occurred in samples 2-6, 13, 14, and 17-20 which constitute 90% of the total number analysed (table3).

**Mineralogical Composition**

A total of 12 mineralogical phases were identified from the 16 slag samples analysed. These are Fayalite ($Fe_2SiO_4$), Wustite (Fe0), Magnetile ($Fe_3O_4$, Haematite ($Fe_2O_3$), Hercynite ($FeAl_2O_4$), Corundum ($Al_2O_3$), Quartz ($SiO_2$), Cristobalite ($SiO_2$, same chemical formular with Quartz but formed from high temperature silica), Mullerite ($Fe_2Si_3O_9.2H_2O$), Leucite ($KAlSi_2O6$), Sillimanite ($Al_2SiO_5$), Zirkelite (Ca,Fe) Zr,Ti $Th)_2,O_5$ and Calcium oxide (CaO). Out of these mineralogical phases, fayalite is the major phase in all the slag samples. It is found in 15 out of the 16 slag samples analysed. Its occurrence as a mineralogical phase in the analysed samples constitutes approximately 93.8%. The preponderance of fayalite ($Fe_2SiO_4$) over other mineralogical phases in the analysed slag samples conforms to the general characteristic of bloomery slag which is normally fayalitic in nature (Okafor 1992; Craddock *et al* 2007). Corundum ($Al_2O_3$) is next commonly found mineralogical phase in the slag samples analysed. It occured in 13 of the total 16 slag samples, which constitute 81.25% of the total. Mullerite ($Fe_2Si_3O_9.2H_2O$) is found in 8 of the 16 slag samples which account for 50%. Magnetite ($Fe_3O_4$) occur in 7 of all the samples, that is 43.8%, while haematile, ($Fe_2O_3$) is found in 6 of the 16 slag samples, constituting 37.5%, cristobalite (Si02) and Quartz (si02) both occur in 5 each of all the slag samples (31.3% each), wustite is found in 4 (25%), while Hercynite ($FeAl_2O_4$), leucite ($KAlSi_2O_6$), sillimanite ($Al_2SiO_5$) and calcium oxide (CaO) are found one each in 16 of the slag samples constituting 6.3% each.

The occurrence of each of the mineralogical phases in the analysed samples may suggest the smelting technology adopted in the area of study. The occurrence of

corundum ($Al_2O_3$) which is an oxide of aluminum may be strongly indicative of the effect of the clay used in the construction of the furnace walls and tuyeres. The frequent occurrence of corundum, is also typical of several bloomery slag (Craddock et.al. 2007:11) though it also occurs in certain medieval bloomery slag from Britain produced by smelting ores with a clay-rich gangue material (Morton and Wingrove 1972). High contents of alumina ($Al_2O_3$) have been associated with African bloomery slag as seen in the Nsukka region of south eastern Nigeria where slag from smelting sites spanning two millennia consistently contained similar quantities of $Al_2O_3$. The Nsukka iron ores used for smelting contained aluminum which have been identified as the source of the $Al_2O_3$ in the slag (Okafor 1992, Whiteman and Okafor 2003). The slag produced by the Dimi traditional iron smelters in south west Ethiopia, regularly contains substantial quantities of aluminum which also originates from the ore used (Todd 1985). In the analyses of iron smelting residues from some Early Iron Age sites in Rwanda and Burundi, East Africa, Craddock *et al* (2007:11) observed based on phase diagram, that there are two possible ways by which clay could have come into the slag. These include, deliberate use as a flux in form of raw clay or used furnace fragments or alternatively, it could have resulted from the reaction between clay-free charge on the one hand and the tuyeres and furnace walls. The presence of alumina in the slag samples is most likely to have resulted from the reaction of the non-clay material with the tuyeres and furnace walls and possibly the ore that was used for the smelting operations. The analysed laterite sample from Tsauni north smelting site, which is possibly part of the ore used for the smelting operation (Oladipo *et al* 1992; Effah-Gyamfi 1982 Pers.Comm), indicates the occurrence of corundum($Al_2O_3$) which is common to tuyere samples from Tsauni north and Samaru

west smelting sites ( samples 6 and 20 in table123). These observations suggest that the presence of corundum ($Al_2O_3$), cristobalite ($SiO_2$, an oxide of silica formed at very high temperature) and quantz ($SiO_2$) actually originated from two sources (the ore and the tuyeres and furnace walls). The occurrence of other mineralogical phases like hercynite, mullerite, leucite and sillimanite suggests that they were products of chemical reactions of the non-clay material with the tuyeres and furnace walls during the iron smelting operations since they contain aluminium and silicon oxides in some forms.

Interestingly, the slag samples from Tsauni north and south smelting sites exhibit a common occurrence of mineralogical phases such as fayalite, magnetite, wustite, haematite quartz, corundum, cristobalite, mullerite, which also tends to suggest uniformity in the smelting technology in the area of study.

The limitation of this view, which is based on the results of the XRD analyses of the slag samples is obvious. One of these is that the XRD diffractograms had too much background to allow for 100% identification of some mineralogical phases. Also some XRD patterns showed amorphous regions which implies that there is a portion of the volume that can not be accounted for by using XRD. Nonetheless, the mineralogical phases identified should be taken as the major ones that were identifiable in the XRD analyses which have significantly helped to shed light on the elemental compositions of the samples and the micrographs derived from the SEM/EDS analyses.

A look at the results of the SEM/EDS and the XRD analyses as earlier presented to a large extent showed the occurrence of similar dominant mineralogical phases in the residues that were analysed. These are fayalite, wustite, haematite, magnetite and

hercynite. This to a large extent justifies our earlier decision to use the two techniques corroboratively.

**Efficiency of Smelting Operations**

One of the objectives of the research is to determine the efficiency of the iron smelting operations at Tsauni. We wish to indicate however that the determination of technological efficiency in this context is relative. In other words, our analyses have not been directed at quantifying the percentages of efficiency of iron smelting.

Fundamentally, the determination of efficiency of a bloomery smelting operation is often carried out by assessing the quantity of metallic iron and free iron oxides (wustite and magnetite) found in the slag (Morton and Wingrove 1972; Rostoker and Bronson 1990; Killick 1990; Craddock *et al* 2007).

Although a slag with high iron content can be physically identified by using criteria such as density, magnetism and colour (showing oxidation marks of reddish and yellowish colouration on the surface), however, technical analysis is more proven in determining the efficiency of the smelting operations that produced such slag. This is because it reveals the mineralogical phases that are present and their relative quantities.

**Metallographic Indication**

Fundamentally, the presence of metallic iron and a high percentage of free iron oxides especially wustite (FeO) and magnetite ($Fe_3O_4$) (Morton and Wingrove 1972; Killick 1990; Rostoker and Broston 1990) in the slag are indicative of inefficient smelting technique. On the other hand, slag with little quantity of the iron oxide phases indicates an efficient reduction technique. However while this can be taken as a general

rule in assessing the efficiency of smelting processes it should be known that slag is a heterogeneous material and a single smelt is capable of producing a wide variety of slag. Even in a single slag (Okafor 1993), there are often found, different mineralogical compositions.

A total of 16 smelting slag from five sites were analysed to attempt to answer the question of efficiency of smelting processes. The results are presented in table 2 in which the dominant phases are shown but not quantified in percentages. The results indicate that wustite, fayalite, haematite, magnetite, hercynite and quartz phases are the dominant in the slag from Tsauni north and south sites. From the results, of the XRD, we observed that the break down of the occurrence of mineralogical phases indicates that the ratio of proportions of free iron oxides to the iron free oxides is 3:2 (table124). According to (Morton and Wingrove (1972), Roster and Bronson (1990), Killick (1990) and Craddock *et al* (2007) we therefore posit that since the proportions of free iron oxides are higher than those of iron free oxides, the slag samples are indicative of inefficient smelting operations.

**Determination of the Melting Temperatures of Slag**

Another criterion used to infer the efficiency of smelting operations was the determination of the the melting temperatures. Though the estimation of smelting temperatures from slag is usually problematic, Craddock *et al* (2007) have however argued that fundamentally, the maximum temperature needed to smelt a particular metal is indicated by the temperature that is required to melt its slag. This implies that the melting temperature of the slag shows to a considerable extent the smelting temperature

of the metal that produced it. This principle formed the basis of our adoption of the direct technique of determining the melting temperatures of the slag samples.

Although there are different techniques used for the determination of melting temperatures of metal slags (Okafor 1993; Mapunda 1995; Rhines and Hill 1959), we adopted the direct observation technique in these technical analyses. This involves heating or cooling of a sample and watching for melting or solidification (Rhines and Hill 1956).

The technique involved heating of a tiny specimen of slag in a crucible with hydrogen touch till it melts. The temperature at which the melting was observed was quickly recorded by inserting a thermocouple into the melted slag. The melting temperature recorded by the thermocouple was subsequently transferred to the computer and the graph plotted using the Excel graphing tool of the Microsoft word. The results are shown in Appendices…

Personal observation of this technique showed that it has some merits over the indirect technique which involves the use of phase diagrams. This direct technique is by far simpler than the indirect one since it involves direct measurement of temperatures of melted slag. In addition, it is reversible, which implies that the process can be repeated as often as necessary to ensure accuracy of the final data obtained.

The technique used led to the result shown in table125. From the results obtained, slag samples from Tsauni north exhibit melting temperatures of between1041$^0$C and 1286$^0$C (table 125) with mean melting temperature of 1173$^0$C. On the other hand, the melting temperatures of slag samples from Tsauni south are within the range of 1137$^0$C to 1294$^0$C (table 125) and a mean melting temperature of 1215$^0$ C.We also observed that

the temperatures of slag samples from Samaru west, Kargi, Kufena and Turunku fall within the range of 1158$^0$C to 1292$^0$C (table125), with the mean temperature of 1248$^0$ C.

Comparatively, the smelting temperatures of slag from Tsauni north and those of Tsauni south on the one hand are within the same range and are also similar to those of Samaru west, Kargi, Kufena and Turunku sites (see table125).

The results further indicate that the melting temperatures of the slag samples fall roughly within a range of the free flowing temperatures of iron slag, 1160-1190$^0$c (Bachman 1983), 1200$^0$C (Craddock *et al* (2007:12), 1200-1250$^0$C (Freestone and Tite 1986) and 1400$^0$C (Todd 1976; Todd and Charles 1978), the slight variations noticeable being indicative of some margin of experimental errors associated with the direct technique (Dr Bourne 2008 pers. Com.).

However, from the results of this direct technique, it appears that the iron smelting operations that produced the anlysed slag were relatively inefficient. Though the attainment of the flowing temperatures as indicated above was evident, the smelting of iron does not necessarily require a temperature as high as those recorded. According to Sasson (1972), the process of reduction of iron ore to metallic ore starts at a relatively low temperature of about 450$^0$C and it may therefore not be necessary to attain a furnace temperature that is more than 850$^0$C for iron smelting to take place once other essential factors such as excess of charcoal and control of air are in place.

An observation of the melting temperatures of the slag samples indicates that the iron smeltings were conducted at somewhat higher temperatures than necessary, given the mean temperatures of 1210$^0$C, 1164$^0$C, and1230$^0$C of slag samples from Tsauni north, Tsauni south and Samaru West, Kufena, Kargi and Turunku sites respectively.

Since the attainment of smelting at minimum temperature possible is an important indication of an efficient process of iron smelting, it therefore implies that extraction of iron at relatively high temperatures as those recorded from the slag samples from Zaria area portrays adoption of an inefficient technique. From the investigation of iron smelting in the Nsukka division of Eastern Nigeria, slag identified with higher temperatures were considered as being associated with earlier phases of iron smelting characterized by the use of relatively cruder and somewhat inefficient technique of smelting (Okafor 1992; Okafor 2009, pers. Com). Given the limited number of slag analyesd in this research project, we may not be able to draw such far reaching conclusions on the phases of development of iron smelting in the Zaria area as the case in the Nsukka Division.

**Past Investigations of Pottery at Tsauni**

At early stage of this research, two types of analysis of finds were contemplated in line with the aim and objectives of the study. These were typological and technical analyses. However as the investigation progresses, we observed an unusual dearth of pottery, which normally constitutes the bulk of material evidence in Iron Age sites (Effah-Gyamfi 1981). In the course of excavation of sites at Tsauni north and south, there was conspicuous absence of pottery which makes its typological study impossible. Due to this problem and in realization of the fact that pottery is a convenient base for the study of cultural and chronological linkages of Iron Age communities (Effah- Gyamfi 1981), recourse to the extrapolation of information from the impressive comparative analysis of pottery from Tsauni, Samaru west and Pantaki conducted by Effah- Gyamfi (1981) became inevitable. The close proximity of the tree sites (located within a radius of about 7km particularly makes the result of his investigation very relevant to our research.

In the comparative analysis of pottery samples from Samaru west (latitude $11^0$ 09.5'N, longitude $7^0$ 37'E), Tsauni south ( latitude $11^0$ 06'N, longitude $7^0$ 35' E) and Pantaki (latitude $11^0$ 05.5' N, longitude $7^0$ 39.5 E), based on visual inspection of potsherds and using the criteria of size, paste, thickness, shape of vessel and decoration Effah- Gyamfi (1981) concludes that the pottery samples from Samaru west and Pantaki exhibited a level of similarities to suggest that the settlers/smelters in the two sites appear to have greater cultural linkages with one another than those at Tsauni south. He observed that the linkages between Samaru west and Pantaki pottery could be seen in techniques, forms, texture and to a large extent in decoration patterns. Effah-Gyamfi

further observed that the pottery from Tsauni north and south do not exhibit any temporal differences.

A Neutron Activation Analysis was subsequently conducted by Oladipo *et al* (1992) with a view to investigating the relationships between the pottery samples from the three sites. The study examined the similarities in the elemental concentrations and based on cluster analysis concludes that Tsauni is unique and that the samples from Samaru west and Tsauni south do not portray significant similarities despite the distance of just 7km between the two sites (Oladipo *et al* 1992). This scientific analysis of pottery from the three iron smelting sites seems to confirm the typological study earlier carried out by Effah-Gyamfi (1981)

Based on the typolgical and scientific analyses of the pottery samples, the following deductions can be made; (1) that the pottery from Tsauni north and south are similar (2) that the pottery from Tsauni and Samaru west do not exhibit similarities to enable any suggestion of cultural affinity which implies that(1) that there seemed not to have been any cultural or chronological difference between the smelters that occupied the north and south of Tsauni and (2) that the smelting sites of Tsauni are culturally and temporally different from that of Samaru west.

Interestingly the above inferences appear to have been confirmed by the similarity in the C14 dates obtained from Tsauni north and south in this research, which contrast sharply with those from Samaru west.

**Age Determination**

For the purpose of radiocarbon dating of iron smelting at Tsauni, we considered charcoal samples (Tite 1972) that are closely associated with iron smelting debris as invaluable datable materials. At Tsauni north, charcoal samples were recovered from two pits excavated in 2006. These are TSN-06-I (pit I) and TSN-06-II (pit II). The sample collected from TSN-06-I came from the base of furnace A (one of the three furnaces in pit I), located south of the excavated pit, while the one from TSN-06-II was also retrieved from the base of a broken furnace wall located east of the excavated pit. The charcoal sample from Tsauni south TSS-07-I(pit I) was collected from the base of furnace B associated with a broken tuyere while that for TSS -O7 –II (pit II) was recovered from slag pieces at the second spit level (about 30cm) below the surface. The collection of samples of charcoal was based on the need to adequately reflect those that are directly indicative of iron smelting which when dated will show the antiquity of the smelting operations associated. It was with this understanding that we considered the charcoal specimens associated with smelting furnaces (where available) as appropriate for the determination of the antiquity of iron smelting at Tsauni.

The charcoal samples collected from the excavated pits at Tsauni north and south were dated at the Radiocarbon Dating Laboratory, Illinois State Geological Survey, University of Illinois, at Urbana-Champaign, U.S.A. The age determination of the samples was by conventional radiocarbon dating method. The choice of this dating method was preferred to the AMS technique due to its cheaper cost, though it required the use of more quantities of charcoal samples than the AMS. The percentage of

precision of the dating was less than 0.5% with 5568years adopted as half life for the age calculation.The results are presented below (see Appendix..)

From the sites of Tsauni north, the two excavated pits TSN-06-I and TSN-06-II yielded radiocarbon dates of 1560 ±70BP and 1750 ±70 BP respectively. On the other hand, the Tsauni south pits TSS-07-I and TSS -07-II produced dates of 1560 ± 70BP and 1790±80 BP respectively. The calibration of the dates was carried out using the Radiocarbon Calibration Program of Stuiver and Reimer (1986-2005) and Stuiver et al (1993). Calibration of the dates was in 2sigma for high level of precision. The calibrated dates for TSN – 06 – I and TSN -06 – II are 349 – 368 AD and 87 – 104 AD respectively while those for TSS –07-I and TSS-07-II are 349-368 and 79-397 AD respectively.

An observation of the calibrated dates of TSN –06-I indicates that it falls within the 4$^{th}$ century AD, while that of TSN –06-II is in the range of 1$^{st}$ to 4th C. AD. The TSS-07-I calibrated date lies within the 4$^{th}$ C.AD with that of TSS –07-II within the 1$^{st}$ and 4$^{th}$ Centuries AD. From the calibrated dates, we observe that the two excavated pits at Tsauni north lie between the 1$^{st}$ and 4$^{th}$ centuries AD while those of Tsauni south are also within the range of 1$^{st}$ and 4$^{th}$ centuries AD. This implies that the dates of both excavated sites all are within the 1$^{st}$ and 4$^{th}$ centuries AD.

# CHAPTER SEVEN

# IMPACT OF IRON SMELTING, SUMMARY, CONCLUSION AND RECOMMENDATION

## Introduction

This Chapter addresses the impact of iron smelting at Tsauni, summarizes the research, draws out the limitations of the work, attempts an assessment of the extent to which the basic goals of the research have been archieved and makes suggestions for furher investigations.

## The Significance of Iron Working in Africa

The significance of iron working (smelting and smithing) has been extensively investigated among the early societies in Africa. The place of this metallurgy was very crucial that it is still visible in several facets of the present day societies in various parts of the continent and still generates a lot of interests among scholars. The nature of significance of this technology is multidimensional as can be seen in subsequent discussions.

Iron technology is believed to have greatly enhanced farming, hunting, fishing and palm wine tapping activities, wood carving and medicines in early African societies (Okpoko 1987) due to the significant improvements it represented over the use of wood, stone and bone implements. Further to this is the economic significance of iron metallurgy in the use of iron to pay bride prices in Bameda (Cameroon) (Okpoko 1987).

The significance of iron technology has also been seen in terms of changes in the settlement patterns and increase in population density with subsequent social changes and more pronounced division of labour (Okpoko 1987). Iron metallurgy has conferred on

several people who possessed its high social-status in their various societies. This has been traced to a number of factors, such as; the economic significance of the technology, the role of the practitioners in the security of their respective communities and the magic powers normally associated with them. Among the Yoruba for instance, the blacksmiths in the past were appointed as political aids, war leaders and local heads, while some are revered to this day as great medicine men that possess divine powers (Okpoko 1987). It is however evident that the important social status accorded to iron workers is generally more relevant to blacksmiths rather than the smelters. This can be seen among the Nupe, in Central Nigeria, and among the Amube blacksmiths in Orba Nsukka division of south eastern Nigeria (Okafor 1984; Okpoko 1987). It is also clear from various studies that the social status of iron workers (especially the blacksmiths) is not always positive. Among some people in Yoruba land for instance, blacksmiths are seen in negative light as people who are responsible for spilling of human blood because they are the producers of weapons used in wars (Odofin 1986). Similar view also obtains among the Dogon of Mali in which the blacksmith creates fear in people due to the belief that he possesses the powers to change to any type of animal at will. In addition, the Dogon hold the belief that the smith's veins contain mixed blood partially made up of sacrificial blood and that the implements used by the smiths are symbols of the organs and limbs of victim of ritual sacrifice (Dieterien 1973, Okpoko 1987). This negative social status associated with the Dogon blacksmiths has led to the formation of a blacksmith caste that cannot intermarry with other members of the society.

The evolution of certain ritual practices in some parts of Africa is also attributable to iron metallurgy. For example, among the Yoruba, blacksmithing is strongly associated

with Ogun (the god of iron). Blacksmiths are regarded as Ogun's children in Yoruba society. They normally perform rituals in Ogun's shrine. The central role of ogun in Yoruba society as seen in the past and even at present is reflected in diverse sayings among the people. One of such common praise phrase is "*Ogun baba irin*" which translates to "Ogun the father of iron". *Ogun de 'le aro o joba nile aro* which translates "Ogun came to the forge and became king there". Some proverbs in Yoruba language also allude to the significance of Ogun in the Yoruba society. For example *Orisa to ni t 'o gun kosi, yi o fenu re fo isu je* which interprets, "Any deity that disrespects ogun will use his mouth to peel yam", shows that Ogun is highly revered even among other Yoruba deities.

Mutually beneficial relationships exists between blackmsihts and the people benefiting from their services like farmers, fishermen, hunters, wood carvers etc. in different parts of West Africa in which the smiths produce the implements used by their patrons in exchange for money.

The Environmental dimension has also been introduced to the significance of iron metallurgy in African societies. As observed by (Okpoko 1987), the capacity of iron implements to manipulate the environment was evident in terms of digging of wells and cisterns which could have made all year round habitation of otherwise hostile environments possible. It has been established by various researchers (Stohl 1986; Shaw and Daniels 1984; Oyelaran 1991) that the transition from lithic to metal using culture in West Africa marked an important innovation and advancement in technology which might have allowed greater manipulation of the environment

Hoverver, a negative dimension of environmental impact of iron smelting was inferred by Sasson (1972) at Sukur in North east Nigeria where he observed that fuel efficient furnaces were constructed as a reponse to large scale deforestation due to massive felling of trees for iron smelting.

In different parts of Africa archaeological studies have associated certain symbolism and ritual practices to iron smelting and blacksmithing. Investigations of the ritual and symbolic practices among some African societies have shed considerable light on the nature, contents and socio-cultural contexts of iron working. As Schmidt (1997:231) observes, "archaeology of ideology is no longer an idea that elicits scorn or derision". Schmidt sees a powerful intersection of material and ideational worlds in African iron smelting which has significant implications for the study of long term cultural change and continuities at cross-cultural level. He attributes this to widespread belief systems entrenched in iron working in Africa. Schmidt (1997) observes that because the ideology of iron smelting especially in the Bantu speaking African has a material component, it should be possible to infer ideology in the archaeological record with a view to gaining a better understanding of how it is expressed over time. Schmidt (1997) further identifies two basic but closely related ideas that transform iron smelting from a technology into social activities. These are ideas of fertility and protection from evil forces. In the domain of fertility, a fertile furnace will produce large quantity of iron thereby contribute to the reproduction of the society. The malevolent forces (whether ancestral spirits or witchcraft) are also essential for the production of iron during smelting to ensure optimum yields during smelting operations when most African iron smelting cultures practice fertility rituals and those aimed at appeasing the malevolent forces.

Ritual offerings are common phenomena in African iron smelting in different parts of Africa (Schmidt 1997). Such ritual offerings in most cases are either placed under the foundation of the furnace as exemplified by the Fipa of south western Tanzania or by digging a special pit at the base of the smelting furnace to keep the ritual objects. These are known in the practices of the Barongo of Tanzania (Schmidt, 1996) and the Babungo of Cameroon (Fowler 1990). Schmidt (1997) identifies the ritual pot of the Pangwa of Tanzania in which a concortion of magical objects is prepared as meant to ensure the fertility of the furnace. Iron smelting ritual practices have also been identified among the Tabwa of eastern Zaire, the Fipa in Tanzania, the Chulu and Phoka in Malawi (Schmidt 1997)

Closely related to the ritual pratices identified in most iron smelting cultures from different parts of Africa is the issue of taboos normally associated with iron smelting process. One of the most important taboos that surround iron smelting is the prohibition of sexual intercourse between the iron smelters and women during the process of iron smelting (Schmidt 1997). Failure of smelting operations is in most cases attributed to sexual intercourse. This taboo is well entrenched among the Haya and the Fipa of Tanzainia. Among these smelters, the smelting furnace is likened to a woman while the bloom is a foetus. Violation of the taboo is normally associated with miscarriage as adultery is seen to cause miscarriage in humans (Schmidt 1997). Another important taboo identified among many African iron smelters is that which forbids women from coming close to the smelting area, particularly not to come into contact with the furnace or its parts (Schmidt 1997). This is however not a general rule as there were some smelting communities like the Kwanyama of southern Angola where women operate the

bellows. Menstruating women are also restricted from any part of a smelting operation. Contact with a menstruating woman is believed to be capable of causing failure of a smelting operation. This is vividly seen in the smelting operations by the Barongo smelters of Tanzania.

**Impact of iron smelting on Tsauni**

We underscore the impact of iron smelting at Tsauni here by drawing inferences from related studies conducted in different parts of Africa as seen above. From our interactions with the inhabitants of the nearby communities of Ungwa Tsauni, Rafin Yashi and Yan Sarki, it appears that the people of these areas have no knowledge of those responsible for the iron smelting at Tsauni, which tends to suggest that they may not be related to the iron smelters. It does not appear that any of these communities is earlier than the 16$^{th}$ century AD, which is the date for the movement of the people from Turunku to Kufena (Hogben and Kirk-Greene 1966). Infact our observation would seem to suggest that the communities are much more recent than 16$^{th}$ centuryAD.

Although there is lack of credible information from the people in the adjoining communities on who the iron smelters at Tsauni sites were, we considered this not a justification to ignore the very crucial issue of the impact of iron smelting on the area of study. Therefore, in order to draw some useful clues on the subject, oral traditions were nonetheless collected from the nearby communities on iron technology and its impact. These were Ungwan Rafin Yashi, Ungwan Tsauni, Ungwan Yan Sarki and Ungwan Makera.

The purpose of this was to have a basis for extrapolation of information on the impact of iron metallurgy in the area in antiquity. Although we are not unware of the pitfalls in such information, collected from people who we have no concrete prove of being the direct descendants of those responsible for the Tsauni iron smelting or even related to them we are however aware that impact of iron metallurgy generally appeared not to be significantly different among the various societies in Africa in the past. If this view holds as could be seen in the various investigations in parts of Africa as discussed above, it implies that the oral traditions from adjacent communities could shed some lights on the issue under consideration.

In the domain of the environment, we suggest that the impact of the iron smelting at Tsauni is traceable to two sources; the mining of ore and the production of fuel. Since these two are vital requirements for iron smelting and constitute an integral part of the natural environment, their exploitation will undoubtedly impact negatively on the environment. In chapter four of this work, based on the comparison of the corpus of material evidence for iron smelting, we observaed that the scale of iron smelting was larger at Tsauni south than in the north and that erosion is more severe in the former than the latter. In terms of the environmental impact of iron smelting on the two sites, we surmise that there is a relationship between the degree of environmental depletion as indicated by soil erosion and the scale of smelting at Tsauni.

Three types of iron ore mining have been identified in antiquity (Abubakar 1987). These are surface, quarry and pit minings. The surface type has been associated with the hill top village of Sukur in North Eastern Nigeria where iron smelting was practised up to 1962 (Sasson 1964). The quarry type has been identified at Katsina (Usman 1974),

Lankan district of Jos Plateau (Daze 1981) and inferred from the closeness of iron smelting furnaces to the lateritic outcrops in the Zaria area (Abubakar 1987). The pit type involved the digging of holes which could vary in depths depending on where the iron ore is located. This type of mining was identified with the iron smelting of the kingdom of Zamfara in the 19th and 20th centuries (Abubakar 1987) and in the Lankan district of Jos Plateau (Daze 1981). Irrespective of the type of ore mining involved, since the practice was extractive in nature, environmental deterioration is implied. We therefore see the extensive mining of iron ore at Tsauni as contributory to the current scale of soil erosion in the Tsauni area.

Production of fuel for iron smelting may have also contributed to the scale of soil erosion which could have resulted from deforestation. According to oral traditions, the most commonly used tree for the production of charcoal for smelting and smithing in the area was *Prosopis africana*, known as *kir'ya* (in Hausa language), which is a savanna tree associated with very hard, tough and reddish brown wood (plates 201&202) (Keay *et al* 1964; Mann *et al* 2003). The quality of the *kiriya* wood in terms of its ability to burn consistently and produce a lot of heat is a common knowledge among our informants. A saying in Hausa language, *Parpatsi kamar wutar kir'ya* (Abdullahi Wakili 2009, pers. Com), which translates "talking like the fire of *kir'ya*", normally used to describe a talkative is indicative of the recognition of the quality of the wood or charcoal from *kir'ya*. Similar observation has also been made on the value of the wood from this tree for blacksmithing among the Maguzawa of Northern Nigeria (Akodu 2001). At Tsauni and environs, we observed a rare occurrence of *kir'ya* due to its demand for domestic use. The exploitation of trees for iron smelting, which we believe must have been on a large

scale at Tsauni given the scope of smelting operations as indicated by the quantum of material evidence in the area suggests considerable depletion of the vegetation. As one of our informants has observed, the current sparse vegetation cover of Tasuni is not unconnected with the massive felling of trees used for fuel for iron smelting in the area in the past (Isiaka Alhaji Musa 2009, pers.com). Personal observation in the area of study shows that big *kirya* trees are rarely found in the smelting sites while it is even difficult to find the tree at all in some places in the area. The large scale exploitation of vegetation due to iron smelting has also been observed elsewhere. For example, at Sukur, in North Eastern Nigeria, where iron smelting continued till 1962, the quest for suitable trees for charcoal had led smelters to travel up to 32km. These were then transported to the villages where smelting took place. According to Sasson (1972), the development of the fuel efficient furnace seemed to be an attempt to tackle the problem of fuel supply to cope with the scale of iron smelting at Sukur. We also see a connection between the level of tree felling and the current massive scale of soil erosion at Tsauni. There is a direct relationship between the scale of tree felling in the area and massive erosion which is attributable to deforestation.

From our investigations, the economic impact of iron smelting was also considerable. Though the assessment of this is not as visible as we had suggested in the area of its environmental impact, we nonetheless surmise that iron smelting also appeared to have created an economic base for the smelters in relation to other sectors of the society, given the indispensability of their technology. According to Isiaka Alhaji Musa (2009, pers. com), the sale of bloom within the area of production or even as far as Kano was an important means of livelihood for the smelters.

In the area of social impact, oral traditions indicate that iron smelters and blacksmiths were held in very high esteem. In most societies however, the smelters were more revered than smiths partly because they were considered to be more ingenous to have the capacity to produce iron from stones. The greater honour and respect accorded smelters compared to blacksmiths in the area of study partly stemmed from the society's belief that a man who can "bring out iron from the ground is greater than the one who merely fashions it into impliments" (Isiaka Alhaji Musa 2009 pers.com). Though both were called Makera (Blacksmiths in Hausa language), the smelters were referred to as the bigger of the two. Among the privileges that the socities accorded the smelters in the past were the titles of Sarkin Makera (Head of the Blacksmiths) for the head of their lineages, closeness to the village head and opportunities to marry women of their choice. These privileges were all in recognition and appreciation of the production of tools, impliments and weapons by smelters and smiths for their respective communities (Yahaya Abdulmumini 2009, pers com).

**Summary, Conclusion and Recommendations**

In the first chapter, which is introductory, the research problem and justification showed the largely exploratory nature of pioneering archaeological investigations characterized by incomprehensive identification, surveying and excavation of sites, inadequate scientific analysis of finds and lopsided dating of sites in the Zaria area. A detailed archaeological surveying and mapping of iron smelting sites at Tsauni north and south have to a large extent addressed these observed lapses in the pioneering archaeological study of the area. In chapter two, we attempted to put the subject of our investigation (that is the evidence of iron smelting at Tsauni in physical and socio-cultural contexts and infers that the environment of the area of study was an ideal one fpo iron smelting as indicative of the nature of its geology, drainage vegetation among others. From chapter three in which we undertook a review of the relevant literature dealing with past archaeological investigations of iron working in different parts of the world, we noted the extent of works by the pioneering researchers in the area of study and made case for a better understanding of the nature of iron smelting in the area of study in line with the current trend which utilizes scientific methods of analysis to extract information from material evidence of smelting. From the archaeological surveying conducted at Tsauni and reported in chapter four, it is evident that there is a sharp contrast between the corpus of material evidence associated with Tsauni north and south. Tsauni south exhibits more quantities of relics of iron smelting than Tsauni north.This observation suggests that smelting activities were more prevalent in the former than in the latter, a phenomenon not unconnected with the terrain of Tsauni south that is largely more rugged than Tsauni north. The iron smelters evidently found larger area of Tsauni south more useful for

industrial activities while the more arable land of Tsauni north was largely devoted to farming.

Our surveying of Tsauni north and Tsauni south also indicates that iron smelting activities were restricted to the valleys and in most cases close to the laterite outcrops due to the heaviness of the laterite ore which necessitated the location of smelting sites close to the sources of raw material. The proximity of smelting sites to lateritic outcrops seems to lay credence to our view that these outcrops were apparently the sources of ore used for smelting operations in the area. This view appeared to have been confirmed to a large extent by the results of our X-Ray diffraction ( XRD) analyses which showed close affinities between the mineralogical phases of laterite samples from Tsauni north and the slag samples from Tsauni south on the one hand and the slag samples from Tsauni north and south on the other.

The configuration of relics of iron smelting at Tsauni also reveals unique intra and inter site patterns. In Tsauni north, the general pattern of layout of material evidence showed the prevalence of smaller furnaces and tuyeres. In this patterning, we observed a direct relationship between smaller furnaces and tuyeres, which contrasts sharply with that of Tsauni south where bigger furnaces are most often associated with bigger tuyeres.

The inter site contrasts in the configuration of material evidence of iron smelting is that while bigger furnaces associated with thicker walls are generally associated with Tsauni south,the opposite is true of Tsauni north. In terms of occurrence of iron slag also, we observed differences in the nature of slag found in the two areas. While most iron slag in Tsauni north are tiny pieces, those found in the south are bigger. Based on our

archaeological surveying at Tsauni, we therefore draw a strong relationship between the size of furnace, tuyere and the slag produced from smelting operations.

The excavation of eight test pits in Tsauni north and south partly formed the basis of our inferences on iron smelting activities in the area which showed certain similarities in the smelting operations in the two sites. From the excavations of pits I and II in Tsauni north, we observed that the tuyeres used for smelting operations were generally smaller than pit I of Tsauni south. The discovery of several tuyeres in pits I and II of Tsauni north also indicates that the smelting site was in use for a considerable period of time during which successive smelting operations were carried out. Another area of similarity in the smelting of iron in the two sites is that the smelters made use of slag-tapping furnaces. While we observed what looked like flow channels for molten slag in pits I and IV of Tsauni north, the discovery of concentration of slag very close to the bottom of the furnaces in pits I and II also suggests that a slag tapping method may also have been adopted in the area. Our view of the use of slag tapping method of iron smelting is further strengthened by the observation that most smelting sites in Tsauni north and south are located on sloppy areas which naturally enables the molten slag to flow out of the furnace with relative ease.

In chapter six, the technical analyses also shed some lights on the inefficiency of iron smelting in the area. First, the SEM/EDS and XRD analyses which revealed the dominance of free iron oxides mineralogical phases, we suggest that the smelting processes indicative of the slags analysed were inefficient. Given the similarities observable in the mineralogical compositions of these slags we posit that the iron smelting operations in the Zaria area were essentially similar in terms of the sources of

raw material (ore) and the fuel used. Second, from the determination of smelting temperatures, that these generally fall within 1100-1200$^0$C considered as the required furnace temperature, we however observe that since iron ore can be reduced at as low temperature as 450$^0$C and smelting archieved at about 850$^0$C (Sasson 1972), it implies that the attainment of temperatures as high as those indicated above is practically unnecessary and therefore indicates waste of fuel which tantamounts to inefficient smelting processes. This view formed the basis for the categorization of iron smelting at Nsukka Division of souh east Nigeria into phases in which slags associated with higher smelting temperatures were considered to belong to earlier periods of practice of iron smelting in the area (Okafor 1992; Okafor 2009 pers. Com). In addition, we argue that the smelting processes in the sites within the Zaria area are similar as could be seen in the uniformity of the smelting temperatures of the analysed slags which is suggestive of probable use of similar furnace types and fuel.

The radiocarbon dates from the excavated pits at Tsauni north and south are very intriguing in several respects. In one aspect, the dates are the first archaeologically obtained from Tsauni since the start of research in the area. It should therefore be regarded as foundational and indeed fundamental to our understanding of the antiquity of iron smelting at Tsauni in particular and the Zaria area in general. In essence these C14 dates have broadened archaeologists' view about the antiquity of iron smelting in the Zaria area. It also noteworthy that the radiocarbon dates from the two supposedly different smelting sites are very similar as indicated. The fact that they both fall within the 1$^{st}$ and 4$^{th}$ Centuries AD is very curious. The possible interpretation of this finding is that the two areas of iron smelting which had hitherto been construed to be two different

smelting sites are actually the same. This cautious position which is predicated on the four radiocarbon dates obtained presently can however not be ignored. We therefore posit that as foundational as these radiocarbon dates are, they are nonetheless very important to the rethinking of the lingering issue of delineation of Tsauni iron smelting sites. In the light of the C14 dates obtained in this research, we argue therefore that Tsauni north and south previously thought to be temporally different are the same, the position which is in consonance with the view expressed by Effah-Gyamfi (1981c).

Interestingly, the dates for Tsauni are older than those earlier obtained from the site of Samaru West. With the evidence at our disposal it can cautiously be argued that Tsauni iron smelting is older than Samaru west by a margin of between four and six centuries. Based on this finding, it is evident that Tsauni and Samaru west smelting sites are temporally different which implies the probability of different groups of smelters having occupied the two areas, given the wide chronological gap evident in their radiocarbon dates. The earlier speculative date of 1100-1300 AD for Tsauni south by Effah-Gyamfi (1981) can no longer hold in the light of the current C14 dates as they clearly show that iron smelting at Tsauni predate that of Samaru west.

The C14 dates obtained from Tsauni have vividly shown that iron smelting in the Zaria area is of considerable antiquity than earlier reported. The recent research has clearly pushed the date for iron metallurgy in the area far backward from the 7$^{th}$ C.AD to the 1$^{st}$ century AD which calls for an overall rethinking of the antiquity of iron extractive industries in Zaria area.

**Limitations of Research**

In the course of this work, certain problems were encountered which we believe should be kept in mind before any objective assessment of the success of the research is made. Language to some extent constituted a limitation to this research when it is realized that the researcher is not a fluent speaker of Hausa language, which is the predominant language in the area of study. One was constrained to make use of interpreters, who though assisted in the collection of oral tradition were obviously no perfect substitute for a direct communication between informants and the researcher.

Although some excavations were carried out in this work, we owned up to the fact that the number of pits is limited compared to the size of the area surveyed while the technical analyses that followed the excavations were also constrained from certain perspectives. In one aspect, limited number of slag was analysed while in another the quantification of the percentages of mineralogical phases in the SEM and XRD analyses of slag could not be carried out mainly due to time constraint. This has not allowed for a more precise assessment of the efficiency of iron smelting from the analysed slag samples.

We also observe some constraints in the aspect of dating in this research. While it should be recognized that the current dates from Tsauni are fundational, it is equally important to emphasis the fact that they are limited in number. As earlier reported in chapter six, four C14 dates were obtained due to financial constraint. This has constituted a restraint to drawing far reaching conclusions especially about the issue of cultural and temporal relationships between iron smelters at Tsauni and Samaru West on the one hand and other sites in the Zaria area on the other.

Another problematic of this study is that there appears to be no concrete and convincing evidence that the present inhabitants of the communities that are adjacent to Tsauni smelting sites are related to those who smelted iron there. From our investigations, there is obviously a temporal disconnect between the two as evident in several contradictions in oral traditions. The seriousness of this as a limitation to this research can best be appreciated when it is realized that our attempt to reconstruct the possible sobio-cultural and economic impact of iron smelting was hinged on information from people who appear not to be the descendants of the Tsauni iron smelters. This implies that the oral data collected results from such exercise may not be a true reflection of the issue that was investigated.

However, notwithstanding the constraints in this investigation, we nonetheless observe that the set goals earlier set for this research as highlighted in the introductory chapter have to a considerable extent been achieved. For example, the material evidence of iron smelting at Tsauni has been articulated and its spatial configuration documented. The study has also shed considerable lights on the hitherto non- existent chronological framework for Tsauni sites. Technical analyses have illuminated our understanding of the nature of iron smelting at Tsauni in terms of the sources of raw material (ore). These pioneering technical analyses of iron slag in the area of study seemed to have corroborated the results of archaeological surveying to suggest that the lateritic outcrops may be the sources of older laterites used for iron smelting.

The contentious issue of whether there were separate sites of Tsauni north and south also appears to have been considerably addressed in this work. From the results of archaeological surveying, excavation and chronological age determination, it seems that

the two parts of Tsauni previously construed as two culturally and temporally distinct sites are the same. The relationship of Tsauni and Samaru West also appears to have been substantially addressed in this study. Based on the radio carbon dates obtained from Tsauni, we seem to have some level of leavage to posit that Tsauni iron smelters were temporally different from those of Samaru West. The C14 dates from Tsauni seem to have complemented the results of the earlier typological study of pottery sample from Tsauni, Samaru West and Pantaki by Effah- Gyamfi (1981) and the subsequent Nuclear Activation Ananlysis by Oladipo *et al* (1992) which point to the possibility that smelters from Tsauni and Samaru West were not only culturally distinct but temporally not similar.

In assessing the efficiency of iron smelting processes at Tsauni and some sites in the Zaria area, the results obtained from the Scanning Electron Microscsopy(SEM), which showed the dominance of free iron oxides mineralogical phases over the iron free ones, those of the X-ray Diffraction(XRD) which also showed higher ratio of proportions of occurrence of free iron oxides to the iron free oxides and the determination of smelting temperatures by direct technique which indicate that iron smeltings were carried out at very high temperatures than was actually required, generally seem to suggest the use of inefficient iron extraction techniques in the Zaria area as possible indication that the technology was at its incipient stage.

Based on this study, we also suggest that iron smelting may have had considerable impact on Tsauni area especially in the aspect of environment as may be inferred from the current massive gully erosion which may not be unconnected with the extensive exploitation of raw material and production of fuel for smelting operations. We have also

extrapolated information from the studies carried out elsewhere in Africa and the collections of oral traditions from the adjoining communities to suggest that iron smelting at Tsauni could have had similar impact on the society that was responsible for it.

Generallly, this research represents a substantial contribution to the knowledge of iron smelting not only at Tsauni sites but Zaria area at large. By this arhaeological investigation, the outlook of archaeological research in the area of study has undoutedly been significantly enhanced.

**Suggestions for Further Investigations**

Consequent upon the limitations of this research earlier identified, we recommend future investigation that will involve more reconnaissance of sites especially in the north of Tsauni and more excavation of sites in the north and south especially in places that are currently being seriously threatened by severe gully erosion with a view to salvaging the material evidence.

There will also be need for more dating of material evidence in future research as a way of providing a stronger basis for comparison of the iron smelting at Tsauni with those of other sites in the Zaria area. This is in realization of the fact that the more the dates obtained the more may tend to be the level of objectivity in comparing two or more archaeological sites.We further suggest that the future chronological age determination in the area of study should be diversified with consideration given to the thermoluminescent dating of vitrified smelting residues such as furnace linings and tuyeres to corroborate radio carbon dates.

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**Appendix I: Showing samples of iron smelting material remains from Zaria Area, magnetic properties, dominant mineralogical phases, ratio of proportions of free iron oxides to iron free oxides and melting temperatures of iron slag**

| Sample | Description | Site | Provenance | Quantity |
|---|---|---|---|---|
| 1 | Slag | TSN-06-I | 15cm below surface | 3 |
| 2 | Slag | TSN-06-I | Surface | 4 |
| 3 | Slag | TSN-06-I | 25cm below surface | 3 |
| 4 | Slag | TSN-06-I | Surface | 3 |
| 5 | Tuyere | TSN-06-I | 15cm below surface | 1 |
| 6 | Tuyere | TSN-06-I | 25cm below surface | 1 |
| 7 | Slag | TSN-07-I | 15cm below surface | 2 |
| 8 | Slag | TSN-07-II | 10cm below surface | 4 |
| 9 | Slag | TSN-07-II | 42cm below surface | 4 |
| 10 | Slag | TSN-07-II | Surface | 4 |
| 11 | Laterite | TSN-08 | Surface | 2 |
| 12 | Slag | TSS-07-I | 40cm furnace base | 2 |
| 13 | Slag | TSS-07-II | 15cm below surface | 4 |
| 14 | Slag | TSS-07-III | 15cm below surface | 4 |
| 15 | Slag | TSS-07-IV | 5cm below surface | 4 |
| 16 | Slag | KRG- 80 | Surface | 2 |
| 17 | Slag | KUF – 82 | Surface | 3 |
| 18 | Slag | TRK – 06 | Surface | 4 |
| 19 | Slag | SMW – 08 | Surface | 2 |
| 20 | Tuyere | SMW – 08 | Surface | 1 |
| | | | | |

**Table1: Showing iron smelting residues from some sites in Zaria area.**

| Sample | Site | Provenance | Magnetisation |
|---|---|---|---|
| 1 | TSN-06-I | 10cm below surface | Slightly Magnetic |
| 2 | TSN-06-1 | Surface | Slightly Magnetic |
| 3 | TSN-06-II | 25cm below surface | Strongly Magnetic |
| 4 | TSN-06-II | Surface | Not Magnetic |
| 7 | TSN-07-I | 15cm below surface | Not Magnetic |
| 8 | TSN-07-II | 10cm below surface | Not Magnetic |
| 9 | TSN-07-II | 42cm below surface | Strongly Magnetic |
| 10 | TSN-07-II | Surface | Strongly Magnetic |
| 12 | TSS-07-I | 10cm below surface | Slightly Magnetic |
| 13 | TSS-07-II | 15cm below surface | Slightly Magnetic |
| 14 | TSS-07-III | 15cm below surface | Slightly Magnetic |
| 15 | TSS-07-IV | 25cm below surface | Strongly Magnetic |
| 16 | KRG-80 | Surface | Slightly Magnetic |
| 17 | KUF – 82 | Surface | Strongly Magnetic |
| 18 | TRK – 06 | Surface | Slightly Magnetic |
| 19 | SMW - 08 | Surface | Slightly Magnetic |

**Table2: Showing Physical Examination of Slag Samples: Magnetisation**

| | | | |
|---|---|---|---|
| 1 | TSN-06-I | Slag | Fayalite, haematite corundum, mullerite |
| 2 | TSN-06-I | Slag | Fayalite, haematite, magnetite, corundum, mullerite |
| 3 | TSN-06-II | Slag | Fayalite, magnetite, quartz, corundum. |
| 4 | TSN-06-II | Slag | Fayalite wustite, magnetite, cristobalite |
| 5 | TSN-06-II | Tuyere | Fayalite, haematite, quartz |
| 6 | TSN-06-II | Tuyere | Fayalite, haematite, corundum, mullerite, quartz |
| 7 | TSN-07-I | Slag | Fayalite, wustite, magnetite, corundum |
| 8 | TSN-07-II | Slag | Fayalite, corundum |
| 9 | TSN-07-II | Slag | Fayalite, haematite, corundum, mullerite |
| 10 | TSN-07-III | Slag | Fayalite, wustite, cristobalite, mullerite, corundum. |
| 11 | TSN-07 | Laterite | Haematite, quartz, alumina |
| 12 | TSS-07-I | Slag | Haematite, quantz, mullerite, corundum, zirkelite |
| 13 | TSS-07-II | Slag | Fayalite, hercynite, quartz, corundum, mullerite |
| 14 | TSS-07-III | Slag | Fayalite, magnetite, corundum, cristobalite |
| 15 | TSS-07-IV | Slag | Fayalite, haematite, sillimanite, mullerite, calcium oxide |
| 16 | KRG-80 | Slag | Fayalite, mullerite, leuncite |
| 17 | KUF-82 | Slag | Fayalite wustite, quartz, mullerite, corundum |
| 18 | TRK-06 | Slag | Fayalite, haematite, magnetite, corundum, christobalite |
| 19 | SMW-08 | Slag | Fayalite, magnetite, quartz, corundum. |
| 20 | SMW-08 | Tuyere | Fayalite, haematite magnetite, mullerite, cristobalite, corundum. |

**Table3: Showing the Dominant Mineralogical Phases in Smelting Residues from some Sites in the Zaria**

| Sample No. | Frequency of occurrence of free iron oxide phases. | Occurrence of iron free oxide phases. | Ratio of proportion of occurrence of free iron oxides to iron free oxides. |
|---|---|---|---|
| 1.TSN-06-I | 3 | 1 | 3 : 1 |
| 2. TSN-06-I | 4 | 2 | 2 : 1 |
| 3.TSN-06-II | 2 | 2 | 1 : 1 |
| 4.TSN-06-II | 3 | 1 | 3 : 1 |
| 7. TSN-07-I | 3 | 1 | 3 : 1 |
| .8 TSN-07-II | 1 | 1 | 1 : 1 |
| 9 TSN-07-II | 3 | 1 | 3 : 1 |
| 10 TSN-07-II | 3 | 2 | 3 : 2 |
| 12 TSS-07-I | 3 | 2 | 3 : 2 |
| 13TSS-07-II | 3 | 2 | 3 : 2 |
| 14 TSS-07-III | 2 | 2 | 1 : 1 |
| 15 TSS-07-IV | 3 | 2 | 3 : 2 |
| 16 KRG-80 | 2 | 1 | 2 : 1 |
| 17 KUF-82 | 3 | 2 | 3 : 2 |
| 18 TRK-06 | 3 | 2 | 3 : 2 |
| 19 SMW-08 | 2 | 2 | I : 1 |
| Total | 43 | 26 | 3 : 2 |

**Table 4: Showing the ratio of proportions of free iron oxides to iron free oxides in the slag samples from Zaria area.**

| Sample | Site | Melting Temperature $^{O}C$ |
|---|---|---|
| 1 | TSN-06-I | 1236 |
| 2 | TSN-06-I | 1268 |
| 3 | TSN-06-II | 1159 |
| 4 | TSN-06-II | 1117.2 |
| 7 | TSN-07-I | 1117.4 |
| 8 | TSN-07-II | 1041 |
| 9 | TSN-07-II | 1165.4 |
| 10 | TSN-07-II | 1286 |
| 12 | TSS-07-I | 1294.1 |
| 13 | TSS-07-II | 1137.2 |
| 14 | TSS-07-III | 1272.4 |
| 15 | TSS-07-IV | 1158 |
| 16 | KRG-80 | 1158 |
| 17 | KUF-82 | 1272.2 |
| 18 | TRK-06 | 1270 |
| 19 | SMW-08 | 1292.2 |

**Table5: Showing the Melting Temperatures of Slag Samples from some Sites in the Zaria area**

**Appendix II: Elemental Compositions and EDS Spectra of slag samples from some sites in Zaria Area.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O K | 35.10 | 56.74 |
| Na K | 0.21 | 0.23 |
| Mg K | 0.13 | 0.14 |
| Al K | 25.90 | 24.83 |
| Si K | 0.27 | 0.25 |
| Ti K | 0.56 | 0.30 |
| Fe K | 37.30 | 17.28 |
| Ni K | 0.54 | 0.24 |
| Total | 100.00 | 100.00 |

**Table6: Elemental composition of Sample 1, ROI No.1 spot 1**

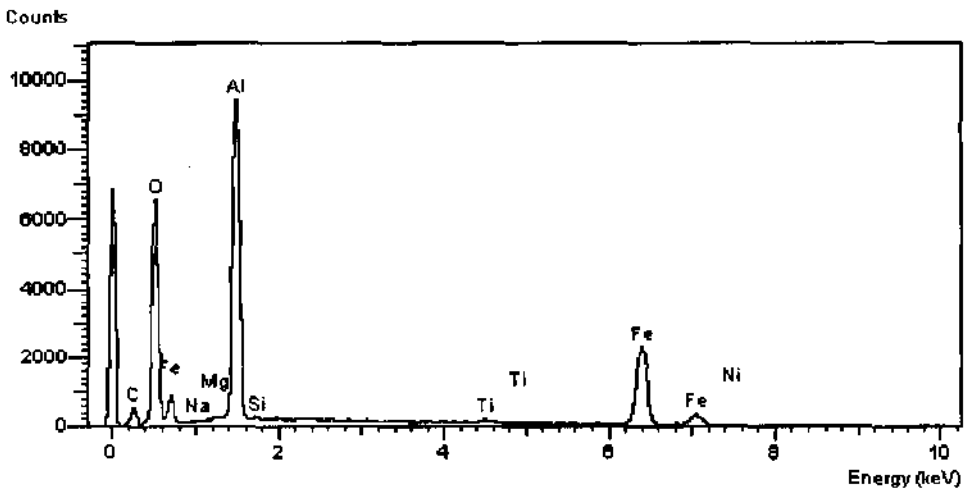



**Fig20: Spectra of Sample1 ROI No.1 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.95 | 58.49 |
| Mg | 0.19 | 0.23 |
| Al | 0.15 | 0.16 |
| Si | 14.15 | 14.31 |
| Ca | 0.45 | 0.32 |
| Fe | 52.11 | 26.50 |
| Total | 100.00 | 100.00 |

**Table 7: Elemental composition of Sample 1, ROI No.1 Spot 2**

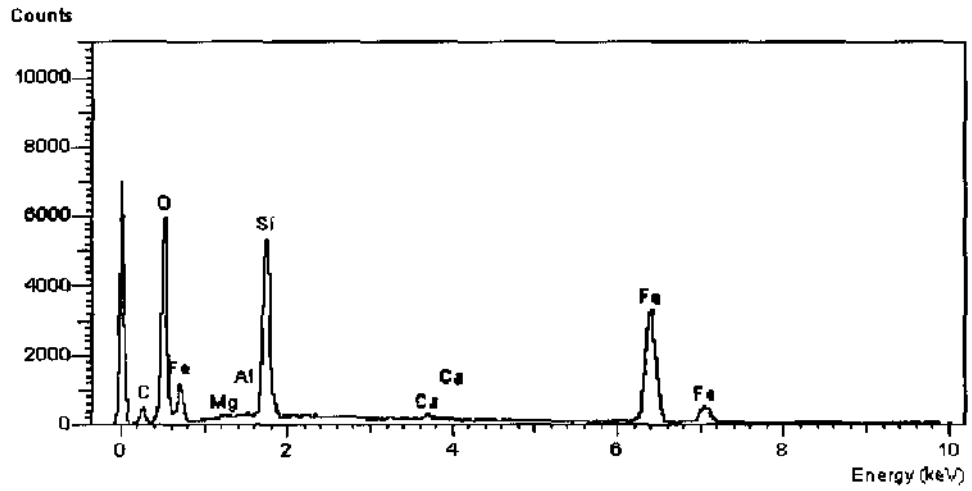



**Fig21: Spectra of Sample1 ROI No.1 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 43.68 | 59.66 |
| Na | 0.21 | 0.20 |
| Al | 12.41 | 10.05 |
| Si | 26.57 | 20.67 |
| K | 16.20 | 9.05 |
| Fe | 0.93 | 0.36 |
| Total | 100.00 | 100.00 |

**Table8: Elemental composition of Sample 1, ROI No.2 Spot 1**

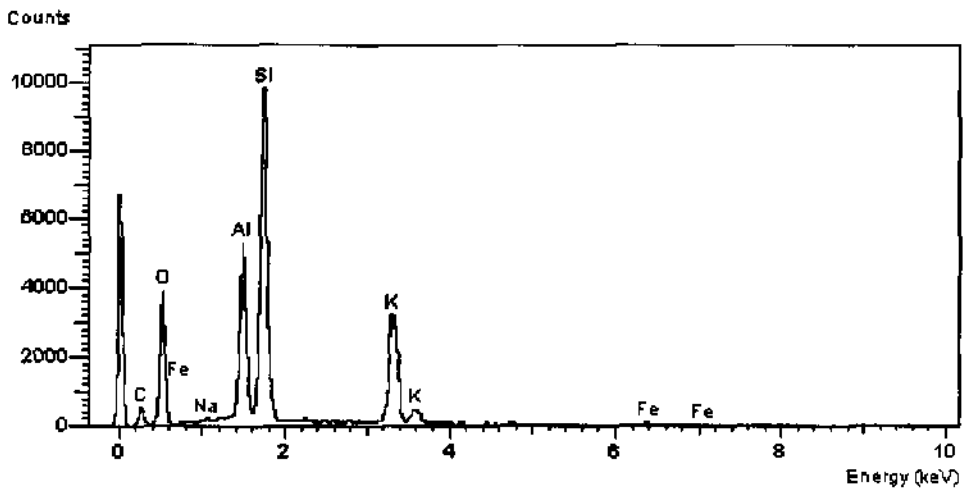



**Fig22: Spectra of Sample 1: ROI NO. 2 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.16 | 56.88 |
| Na | 0.12 | 0.13 |
| Mg | 0.14 | 0.15 |
| Al | 25.66 | 24.61 |
| Si | 0.23 | 0.22 |
| P | 0.09 | 0.08 |
| Ti | 0.63 | 0.34 |
| Fe | 37.98 | 17.60 |
| Total | 100.00 | 100.00 |

**Table 9: Elemental composition of Sample 1, ROI No.2 Spot 2**

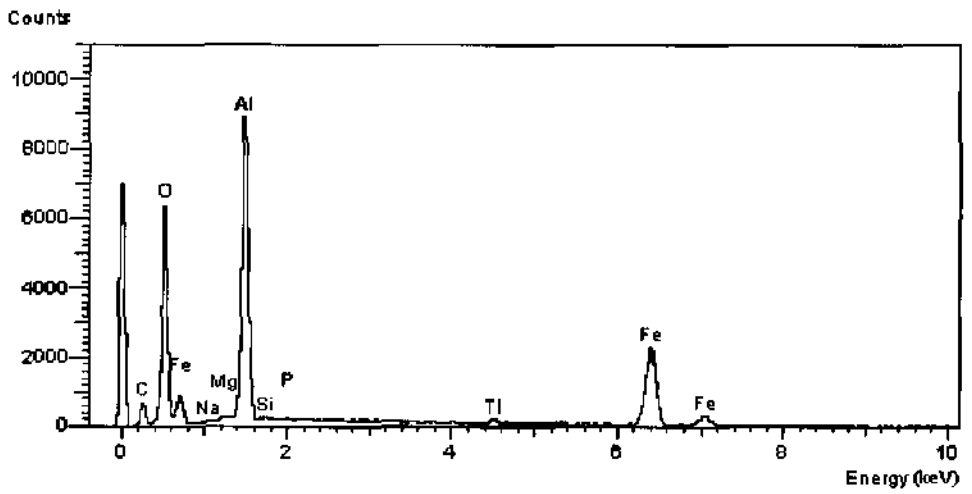



**Fig23: Spectra of Sample 1 ROI No.2 Spot 2 EDS**

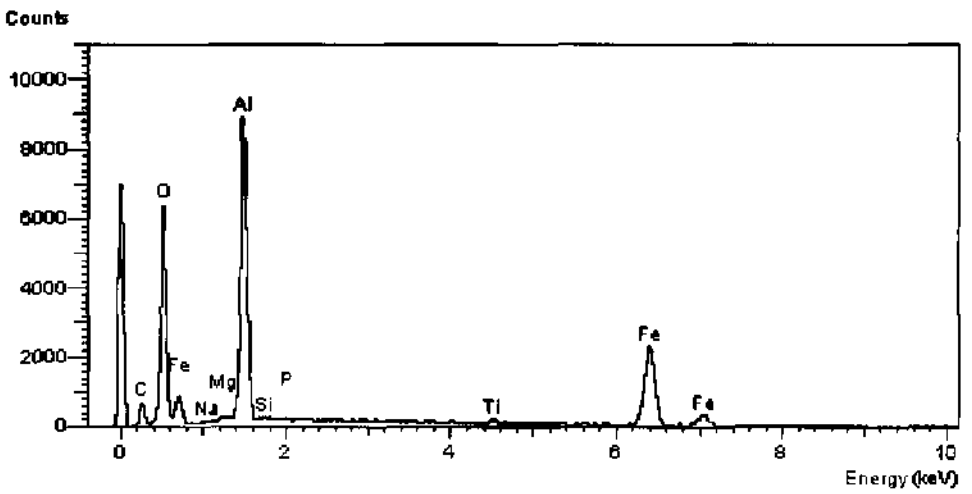



**Fig23: Spectra of Sample 1 ROI No.2 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.93 | 60.30 |
| Mg | 0.34 | 0.39 |
| Al | 0.61 | 0.63 |
| Si | 14.14 | 13.90 |
| Ca | 0.34 | 0.23 |
| Fe | 49.64 | 24.55 |
| Total | 100.00 | 100.00 |

**Table 10: Elemental composition of Sample 1, ROI No.2 Spot3**

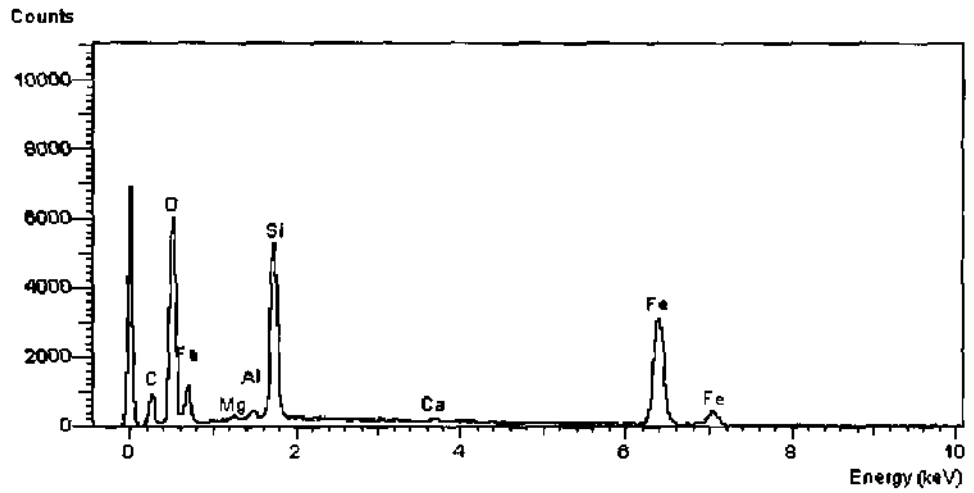



**Fig 24: Spectra of Sample 1: ROI No. 2 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 26.86 | 55.95 |
| Al | 0.30 | 0.36 |
| Si | 0.29 | 0.35 |
| Ti | 0.57 | 0.40 |
| Fe | 71.98 | 42.94 |
| Total | 100.00 | 100.00 |

**Table11: Elemental composition of Sample 1, ROI No.2 Spot 4.**

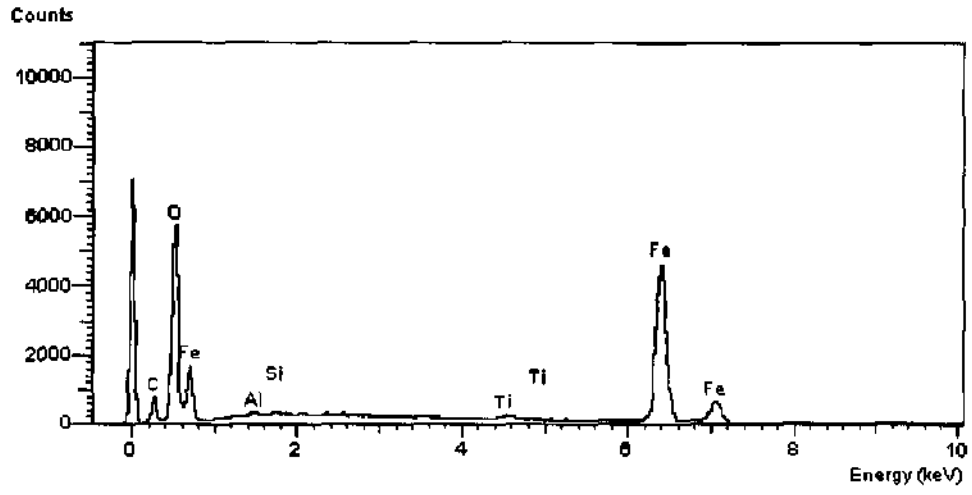



**Fig25: Spectra of Sample1: ROI No. 2 Spot 4 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O K | 40.17 | 60.26 |
| Al K | 10.31 | 9.17 |
| Si K | 20.33 | 17.37 |
| K K | 0.90 | 0.55 |
| Ca K | 2.70 | 1.61 |
| Ti K | 0.50 | 0.25 |
| Fe K | 25.09 | 10.78 |
| Total | 100.00 | 100.00 |

**Table 12: Elemental composition of Sample 2, ROI No.1 Spot 1**

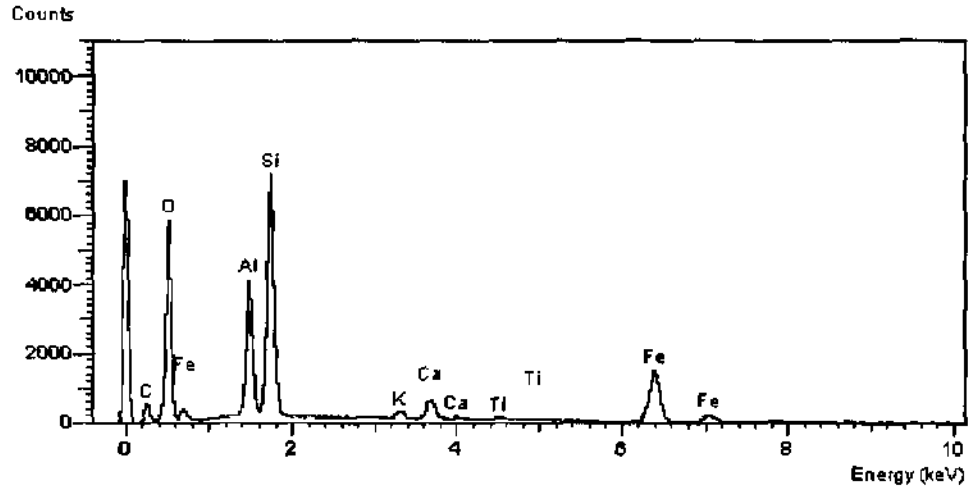



**Fig26: Spectra of Sample 2: ROI No. 1 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.15 | 57.67 |
| Mg | 0.13 | 0.15 |
| Al | 0.35 | 0.38 |
| Si | 14.06 | 14.37 |
| Ca | 0.24 | 0.17 |
| Fe | 53.07 | 27.27 |
| Total | 100.00 | 100.00 |

**Table 13: Elemental composition of Sample 2, ROI No. 1 Spot2**

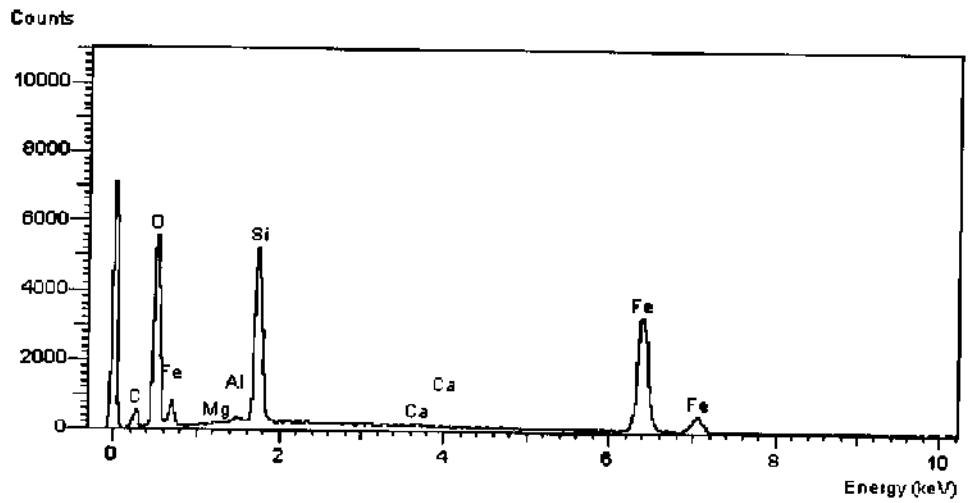



**Fig27: Spectra of Sample 2: ROI No. 1 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.87 | 57.78 |
| Al | 5.43 | 5.34 |
| Si | 17.42 | 16.44 |
| K | 0.45 | 0.31 |
| Ca | 1.41 | 0.93 |
| Ti | 0.27 | 0.15 |
| Fe | 40.15 | 19.06 |
| Total | 100.00 | 100.00 |

**Table14: Elemental composition of Sample 2, ROI No.2 Spot1**

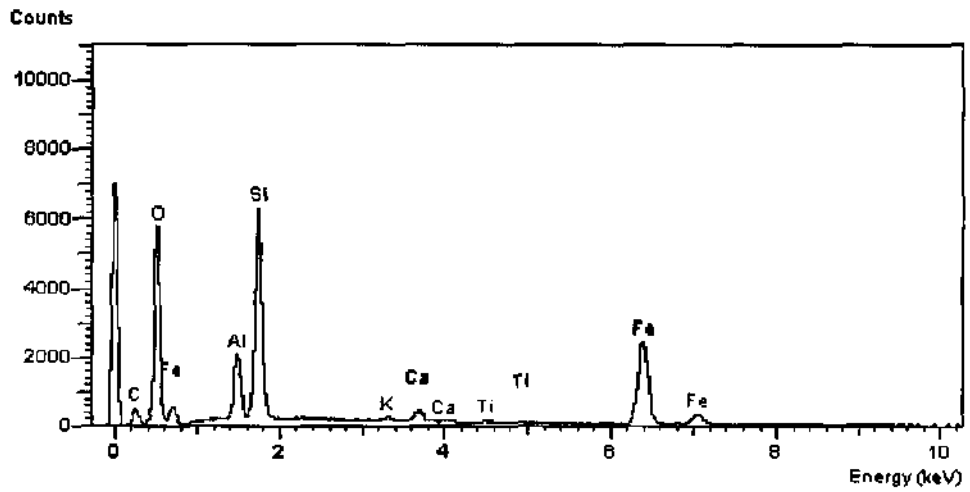



**Fig28: Spectra of Sample 2: ROI No. 2 Spot 1 EDS**

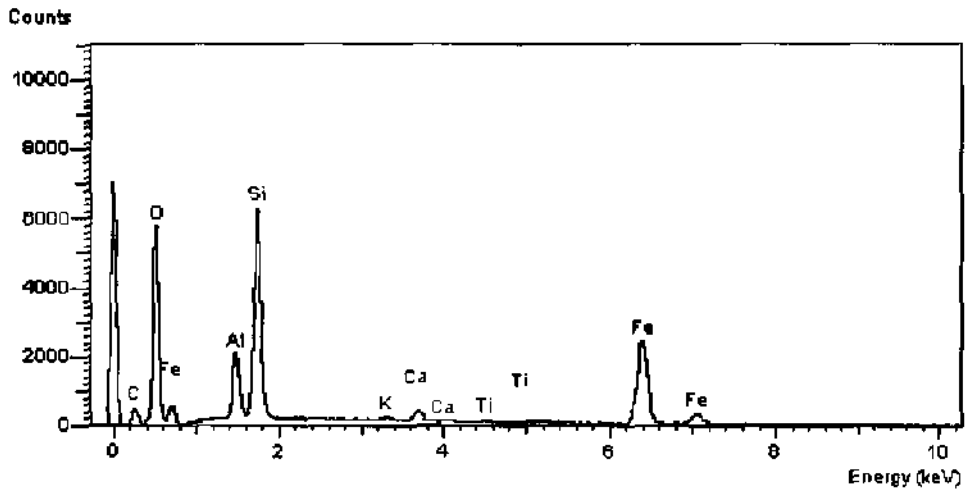




**Fig28: Spectra of Sample 2: ROI No. 2 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 43.53 | 61.44 |
| Na | 0.36 | 0.35 |
| Mg | 0.01 | 0.01 |
| Al | 7.92 | 6.63 |
| Si | 27.16 | 21.84 |
| P | 1.22 | 0.89 |
| K | 3.97 | 2.29 |
| Ca | 0.62 | 0.35 |
| Ti | 0.62 | 0.29 |
| Fe | 14.59 | 5.91 |
| Total | 100.00 | 100.00 |

**Table15: Elemental composition of Sample 3, ROI No.1 Spot 1**

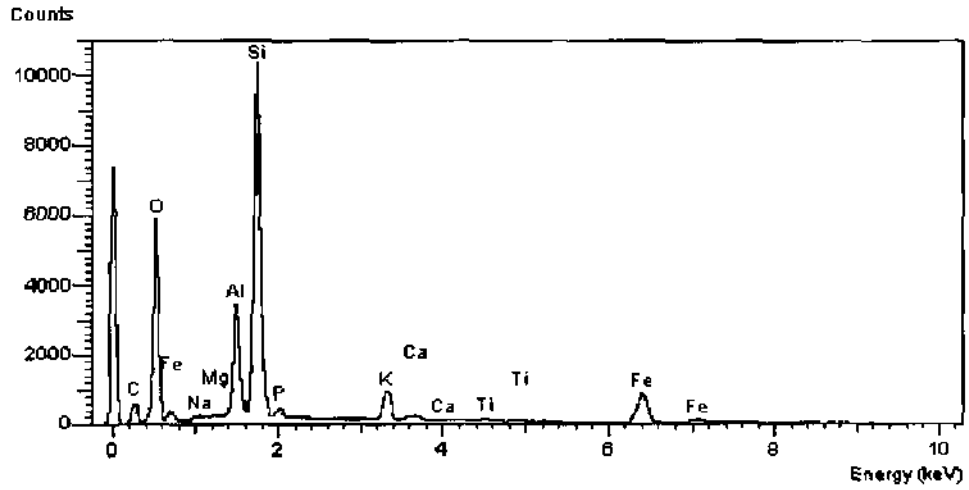



**Fig29: Spectra of Sample 3: ROI No. 1 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 42.29 | 60.68 |
| Na | 0.32 | 0.32 |
| Al | 11.11 | 9.45 |
| Si | 23.57 | 19.26 |
| P | 0.85 | 0.63 |
| K | 3.14 | 1.84 |
| Ca | 0.53 | 0.31 |

| | | |
|---|---|---|
| **Ti** | 0.47 | 0.23 |
| **Fe** | 17.72 | 7.28 |
| Total | 100.00 | 100.00 |

**Table16: Elemental Composition of Sample 3, ROI No.1 Spot 2**

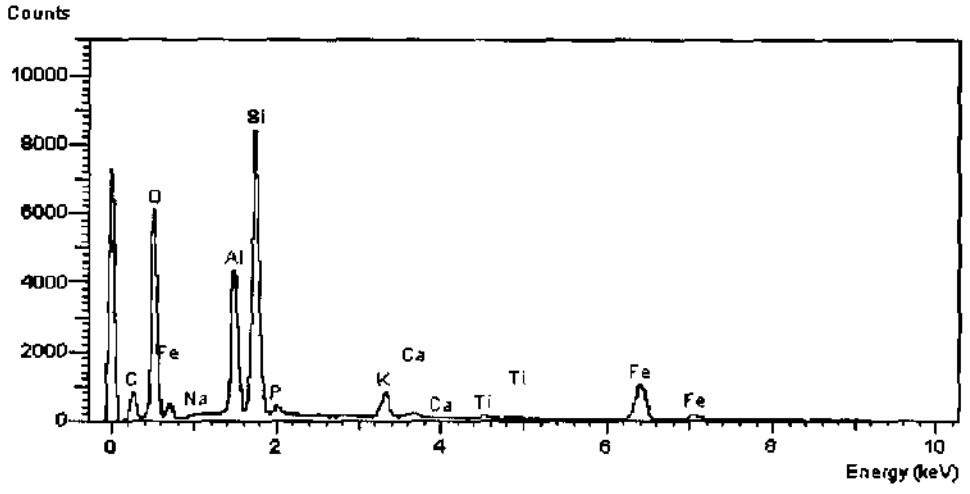



**Fig30: Spectra of Sample 3: ROI No. 1 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 36.83 | 57.45 |
| Na | 0.13 | 0.14 |
| Al | 28.59 | 26.44 |
| Si | 1.00 | 0.89 |
| P | 0.04 | 0.03 |
| K | 0.23 | 0.15 |
| Ti | 1.00 | 0.52 |
| Fe | 32.18 | 14.38 |
| Total | 100.00 | 100.00 |

**Table17: Elemental composition of Sample 3, ROI No.1 Spot 3**

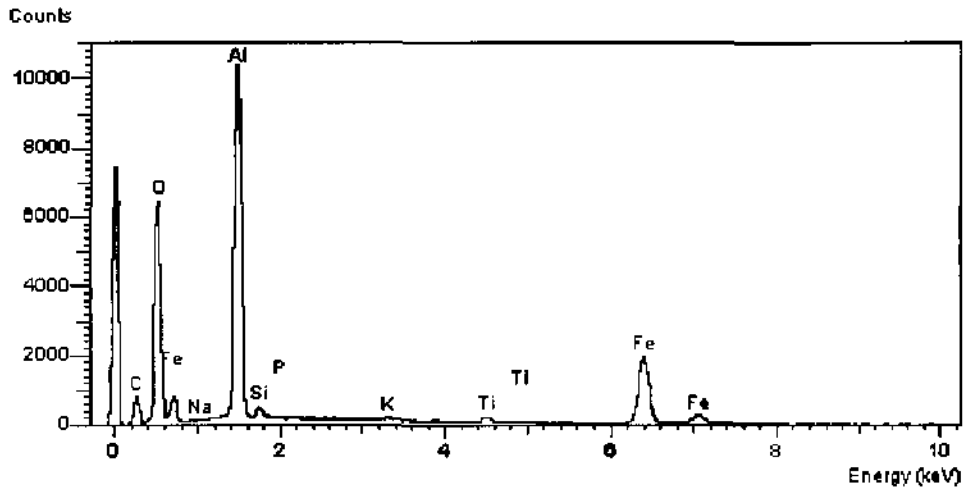



**Fig31: Spectra of Sample 3: ROI No. 1 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.15 | 59.80 |
| Mg | 0.22 | 0.26 |
| Al | 0.04 | 0.04 |
| Si | 14.12 | 14.07 |
| Fe | 51.47 | 25.83 |
| Total | 100.00 | 100.00 |

**Table18: Elemental composition of Sample 3, ROI No.1 Spot 4**

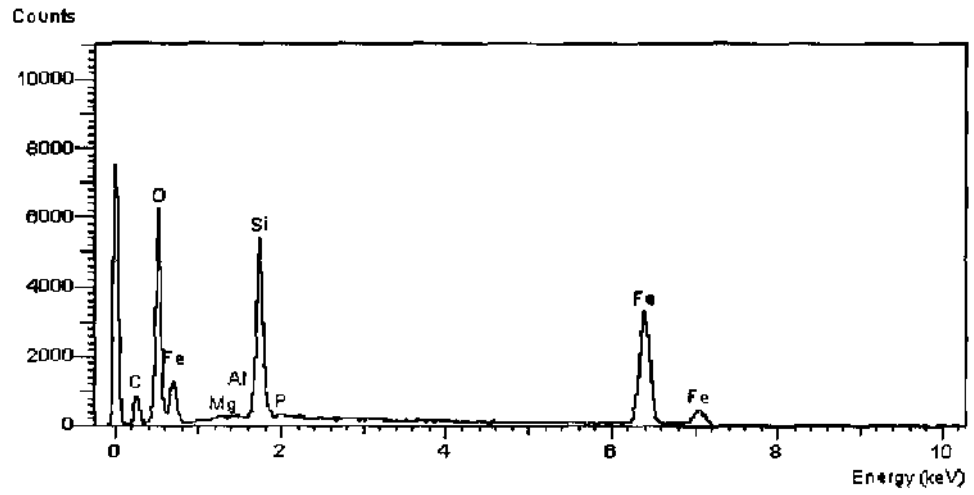



**Fig32: Spectra of Sample 3: ROI No. 1 Spot 4 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 29.97 | 59.90 |
| Fe | 70.03 | 40.10 |
| Total | 100.00 | 100.00 |

**Table19: Elemental composition of Sample 3, ROI No.1 Spot 5**

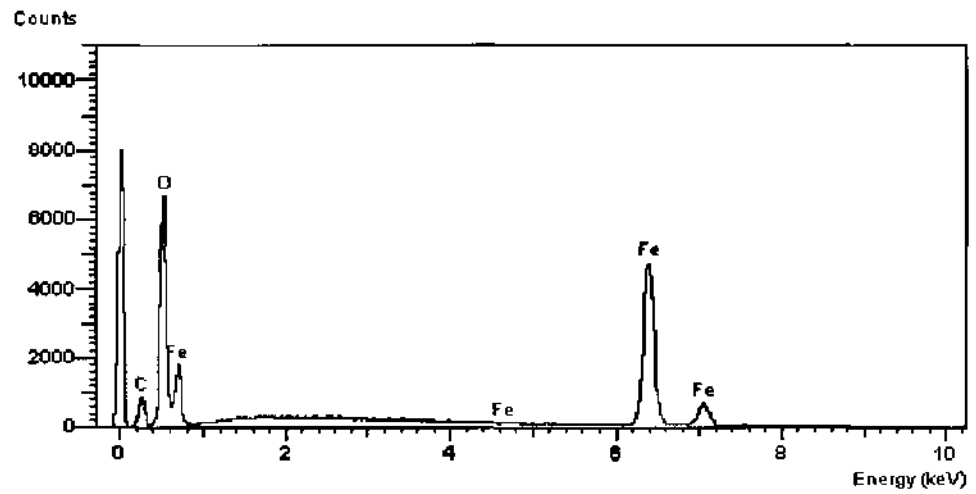



**Fig 33: Spectra of Sample 3: ROI No. 1 Spot 5 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 53.04 | 66.61 |
| Si | 46.36 | 33.17 |
| Fe | 0.60 | 0.22 |
| Total | 100.00 | 100.00 |

**Table20: Elemental composition of Sample 3, ROI No.2 Spot 1**

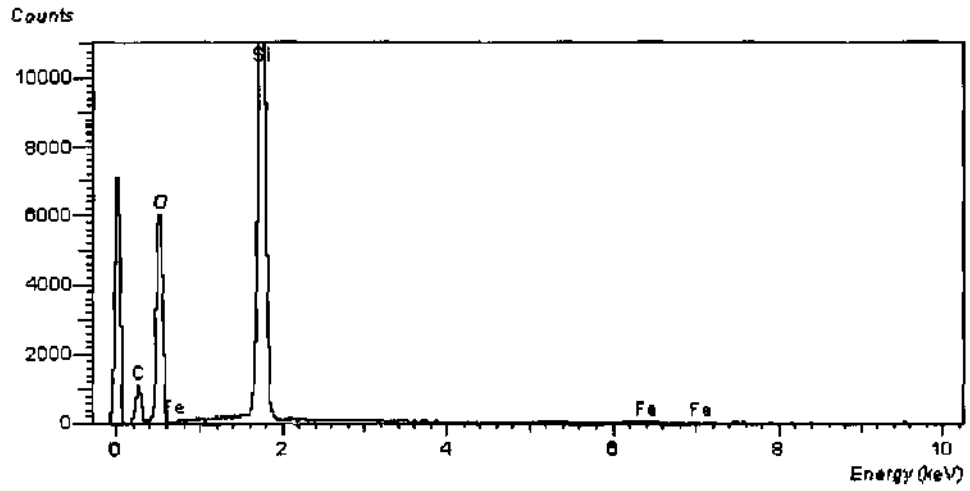



**Fig34: Spectra of Sample 3: ROI No. 2 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 42.62 | 60.44 |
| Na | 0.40 | 0.40 |
| Mg | 0.07 | 0.07 |
| Al | 10.06 | 8.46 |
| Si | 26.00 | 21.00 |
| P | 1.12 | 0.81 |
| K | 4.39 | 2.55 |
| Ti | 0.57 | 0.27 |
| Fe | 14.77 | 6.00 |
| Total | 100.00 | 100.00 |

**Table21: Elemental composition of Sample 3, ROI No.2 Spot2**

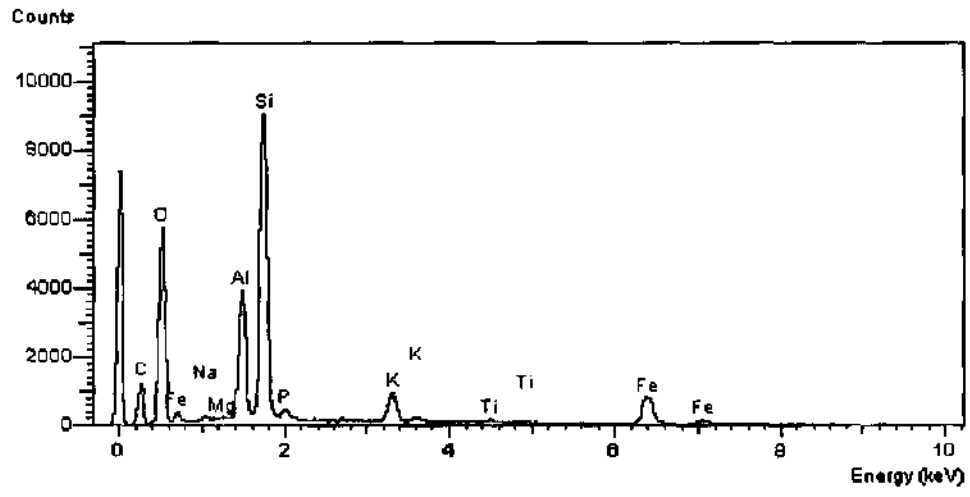



**Fig35: Spectra of Sample 3: ROI No. 2 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 33.96 | 59.49 |
| Mg | 0.15 | 0.18 |
| Al | 0.14 | 0.14 |
| Si | 14.26 | 14.23 |
| P | 0.29 | 0.26 |
| Fe | 51.20 | 25.70 |
| Total | 100.00 | 100.00 |

**Table22: Elemental composition of Sample 3, ROI No.2 Spot3**

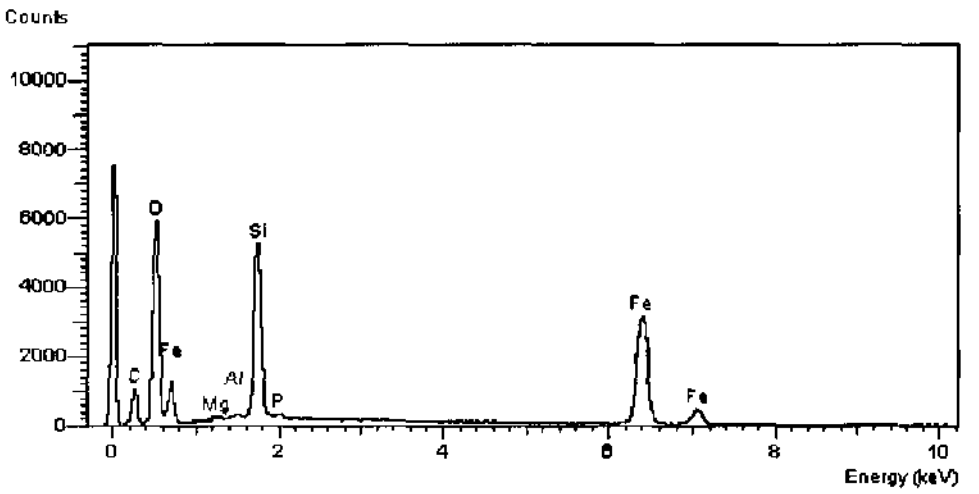



**Fig 36: Spectra of Sample 3: ROI No. 2 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 45.93 | 74.70 |
| Al | 0.15 | 0.15 |
| Si | 0.08 | 0.07 |
| Fe | 53.84 | 25.08 |
| Total | 100.00 | 100.00 |

**Table23: Elemental composition of Sample 3, ROI No.2 Spot4**

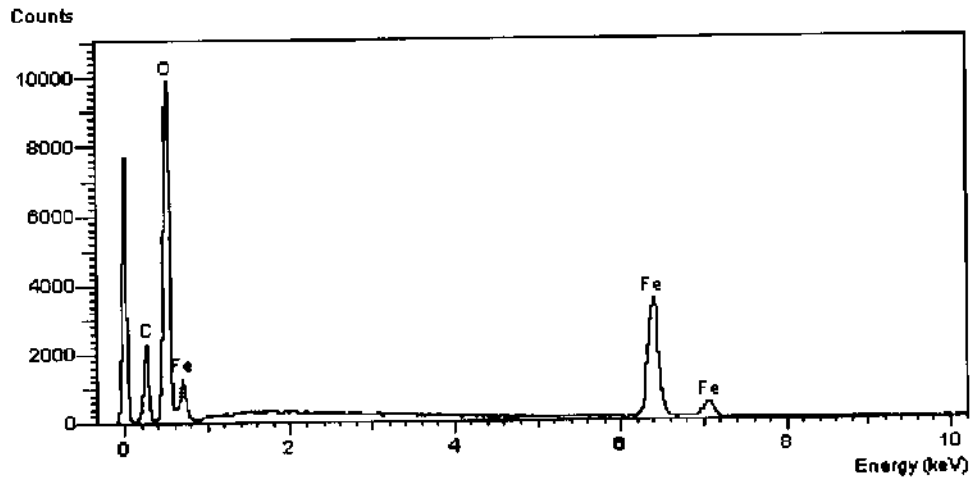



**Fig37: Spectra of Sample 3: ROI No. 2 Spot 4 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 29.63 | 59.44 |
| Si | 0.19 | 0.22 |
| Fe | 70.18 | 40.34 |
| Total | 100.00 | 100.00 |

**Table24: Elemental composition of Sample 3, ROI No.2 Spot 5**

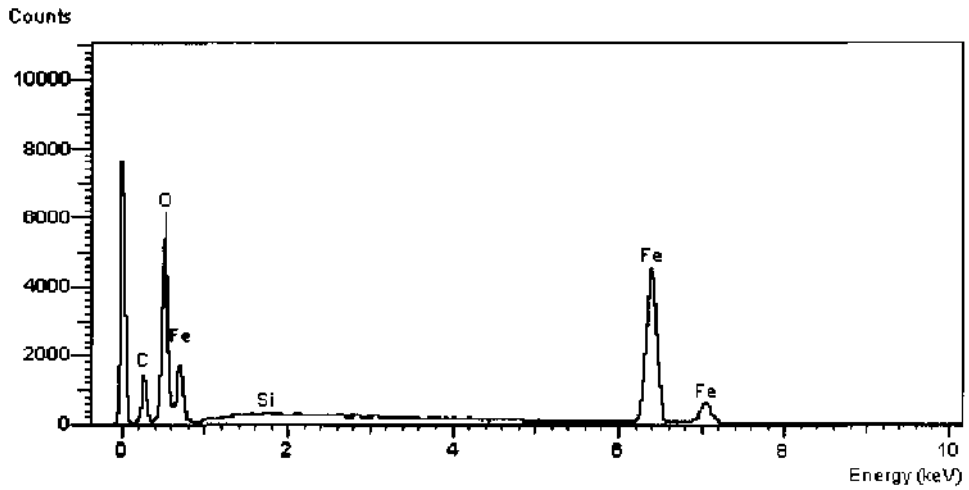



**Fig38: Spectra of Sample 3: ROI No. 2 Spot 5 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 2.64 | 8.64 |
| Fe | 97.36 | 91.36 |
| Total | 100.00 | 100.00 |

**Table25: Elemental composition of Sample 3, ROI No.2 Spot 6**

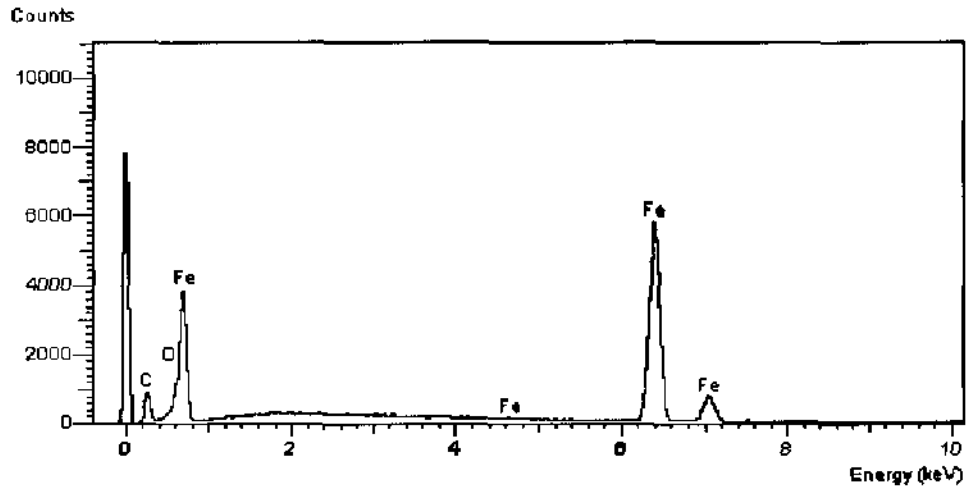



**Fig39: Spectra of Sample 3: ROI NO. 2 Spot 6 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.57 | 57.66 |
| Mg | 0.16 | 0.17 |
| Al | 5.38 | 5.17 |
| Si | 19.88 | 18.36 |
| K | 0.85 | 0.57 |
| Ca | 1.78 | 1.15 |
| Ti | 0.33 | 0.18 |
| Fe | 36.05 | 16.74 |
| Total | 100.00 | 100.00 |

**Table26: Elemental composition of Sample 4, ROI No.1 Spot 1**

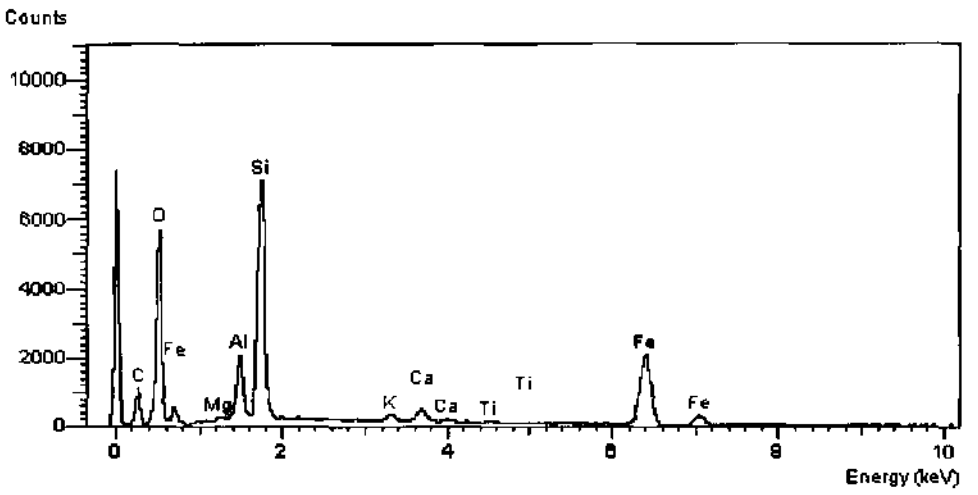



**Fig40: Spectra of Sample 4: ROI NO.1 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.30 | 57.19 |
| Na | 0.22 | 0.24 |
| Mg | 0.29 | 0.30 |
| Al | 5.56 | 5.34 |
| Si | 20.05 | 18.50 |
| K | 0.78 | 0.52 |
| Ca | 1.93 | 1.25 |
| Ti | 0.24 | 0.13 |
| Fe | 35.63 | 16.53 |
| Total | 100.00 | 100.00 |

**Table27: Elemental composition of Sample 4, ROI No.2 Spot 1**

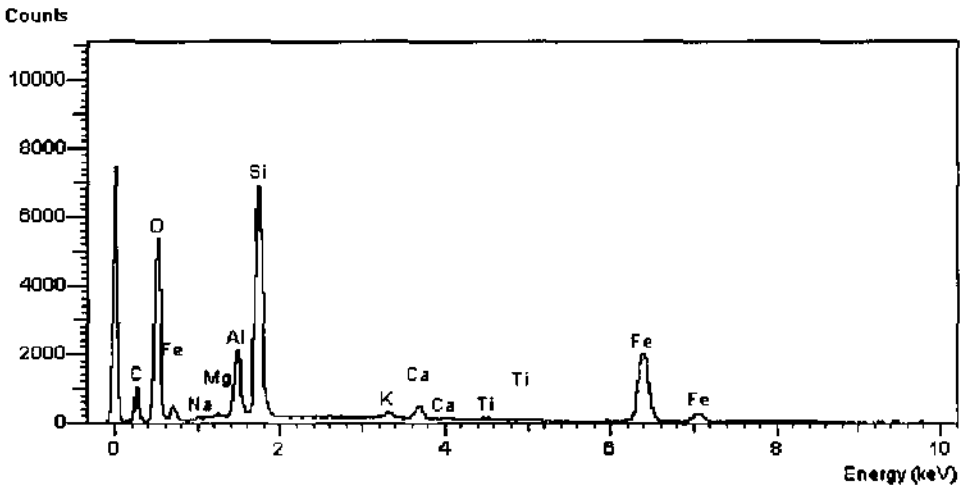



**Fig41: Spectra of Sample 4: ROI No. 2 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 46.33 | 62.52 |
| Mg | 2.15 | 1.91 |
| Al | 7.90 | 6.32 |
| Si | 30.22 | 23.23 |
| P | 0.44 | 0.31 |
| K | 1.59 | 0.88 |
| Ca | 2.57 | 1.39 |
| Ti | 0.48 | 0.22 |
| Fe | 8.32 | 3.22 |
| Total | 100.00 | 100.00 |

**Table28: Elemental composition of Sample 5, ROI No.1 Spot1**

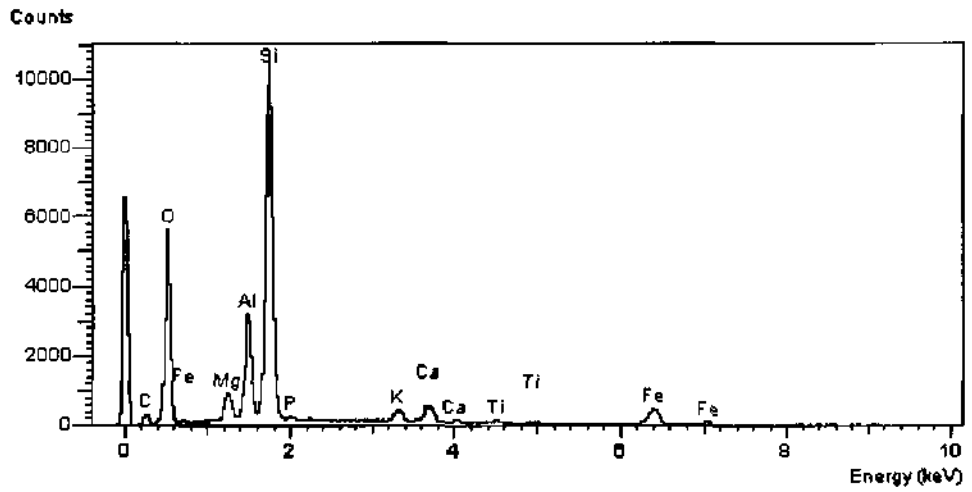



**Fig 42: Spectra of Sample 5: ROI No. 1 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 52.38 | 65.88 |
| Si | 47.62 | 34.12 |
| Total | 100.00 | 100.00 |

**Table29: Elemental composition of sample 5, ROI No.1 Spot 2**

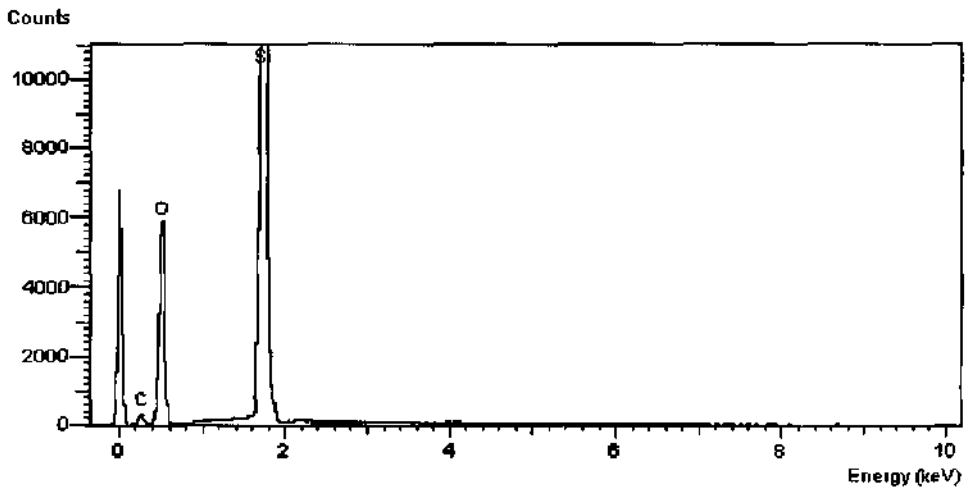



**Fig43: Spectra of Sample 5: ROI No. 1 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 52.57 | 66.05 |
| Si | 47.43 | 33.95 |
| Total | 100.00 | 100.00 |

**Table30: Elemental composition of Sample 5, ROI No.2 Spot1**

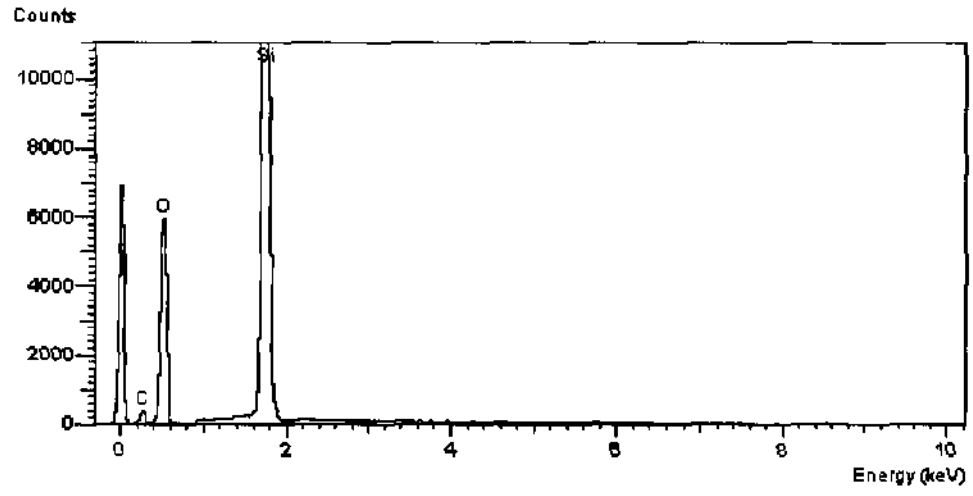



**Fig44: Spectra of Sample 5: ROI No. 2 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 44.52 | 59.06 |
| Na | 0.11 | 0.10 |
| Mg | 0.12 | 0.10 |
| Al | 14.44 | 11.36 |
| Si | 35.72 | 27.00 |
| K | 2.43 | 1.32 |
| Ca | 0.16 | 0.09 |
| Ti | 0.35 | 0.15 |
| Fe | 2.15 | 0.82 |
| Total | 100.00 | 100.00 |

**Table31: Elemental composition of Sample 6, ROI No.1 Spot1**

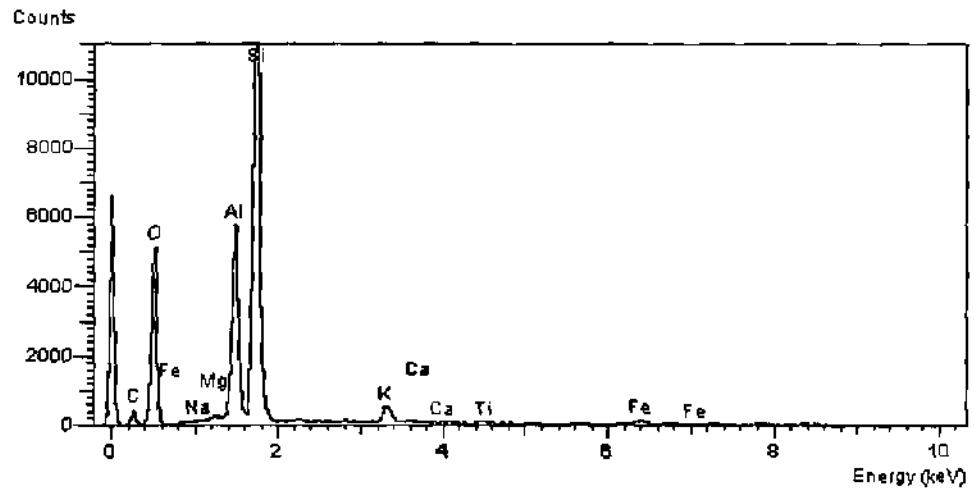



**Fig45: Spectra of Sample 6: ROI NO. 1 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 52.32 | 65.80 |
| Al | 1.14 | 0.85 |
| Si | 46.54 | 33.35 |
| Total | 100.00 | 100.00 |

**Table32: Elemental composition of Sample 6, ROI No.1 Spot2**

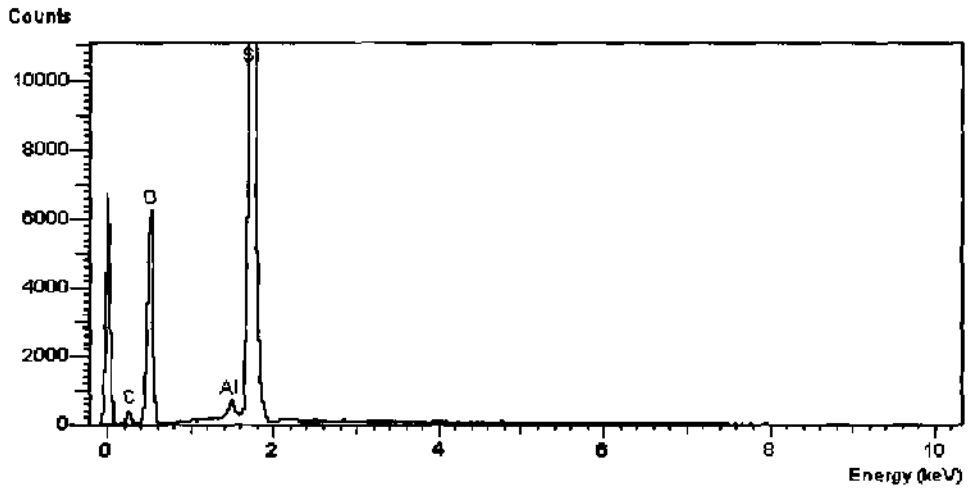



**Fig 46: Spectra of Sample 6: ROI NO. 1 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.37 | 64.82 |
| Si | 14.48 | 16.51 |
| Zr | 53.15 | 18.67 |
| Total | 100.00 | 100.00 |

**Table33: Elemental composition of Sample 6, ROI No.1 Spot 3**

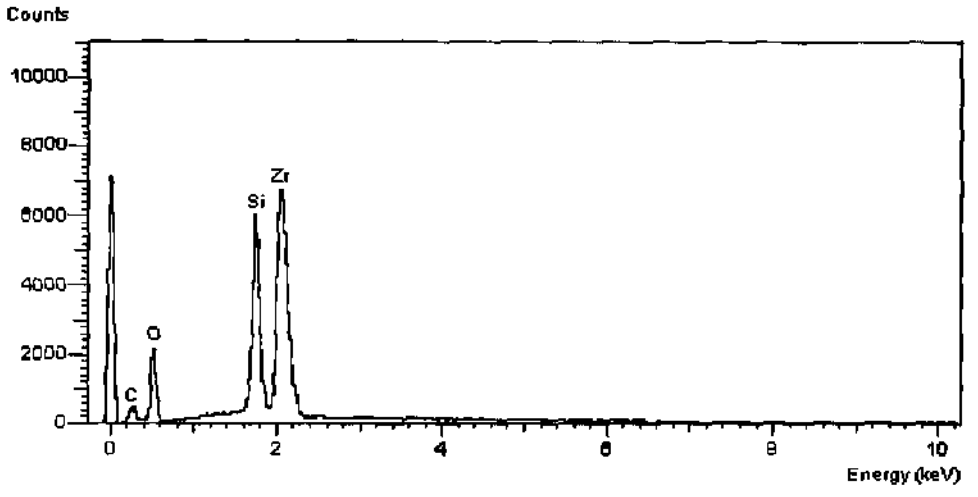



**Fig 47: Spectra of Sample 6: ROI NO. 1 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 46.28 | 62.11 |
| Na | 0.19 | 0.18 |
| Mg | 0.61 | 0.53 |
| Al | 8.85 | 7.01 |
| Si | 33.16 | 25.36 |
| K | 2.53 | 1.39 |
| Ca | 0.71 | 0.38 |
| Ti | 0.55 | 0.23 |
| Fe | 7.12 | 2.74 |
| Total | 100.00 | 100.00 |

**Table34: Elemental composition of Sample 6, ROI No.2 Spot1**

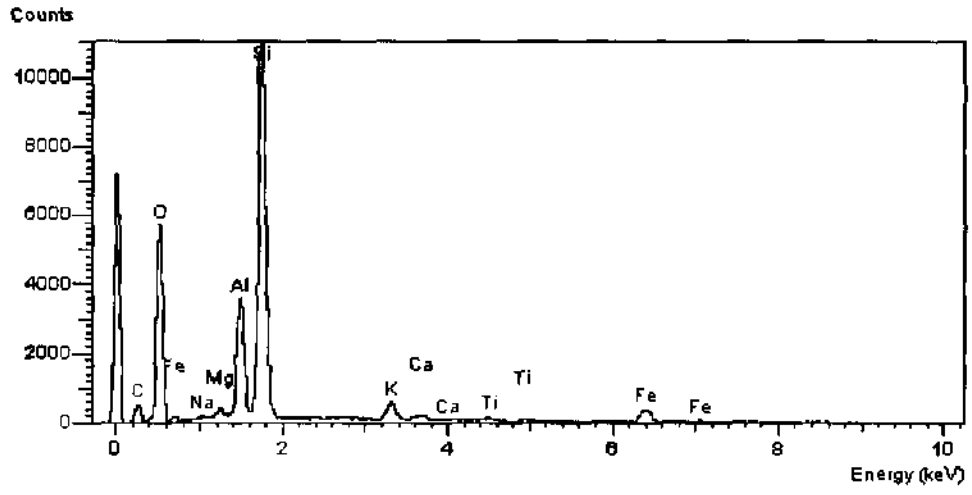



**Fig48: Spectra of Sample 6: ROI No. 2 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 48.01 | 62.59 |
| Mg | 0.14 | 0.12 |
| Al | 18.81 | 14.54 |
| Si | 27.48 | 20.40 |
| K | 1.36 | 0.73 |
| Ca | 0.19 | 0.10 |
| Ti | 0.44 | 0.19 |
| Fe | 3.57 | 1.33 |
| Total | 100.00 | 100.00 |

**Table 35: Elemental composition of Sample 6, ROI No.2 Spot2**

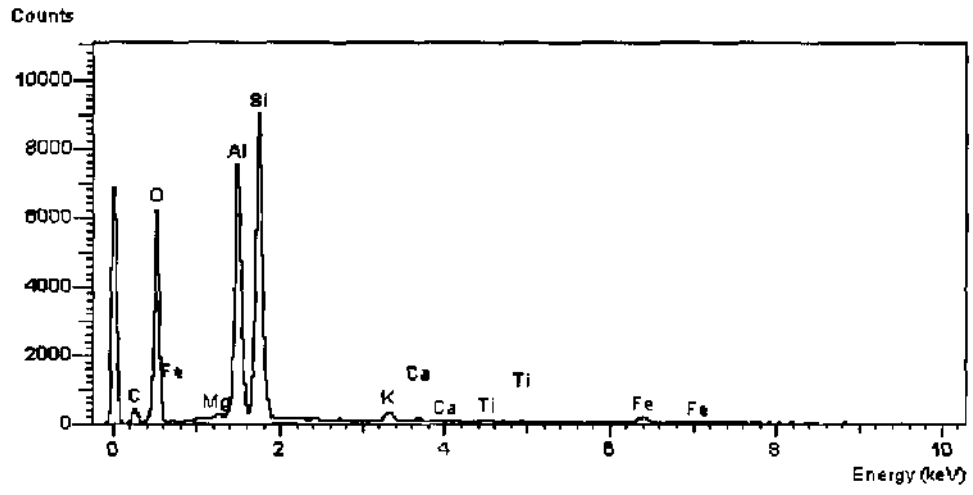



**Fig 49: Spectra of Sample 6: ROI NO. 2 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 39.33 | 59.56 |
| Al | 11.61 | 10.43 |
| Si | 17.42 | 15.03 |
| K | 1.31 | 0.81 |
| Ca | 5.65 | 3.42 |
| Ti | 0.57 | 0.29 |
| Fe | 24.11 | 10.46 |
| Total | 100.00 | 100.00 |

**Table 36: Elemental composition of Sample 7, ROI No.1 Spot1**

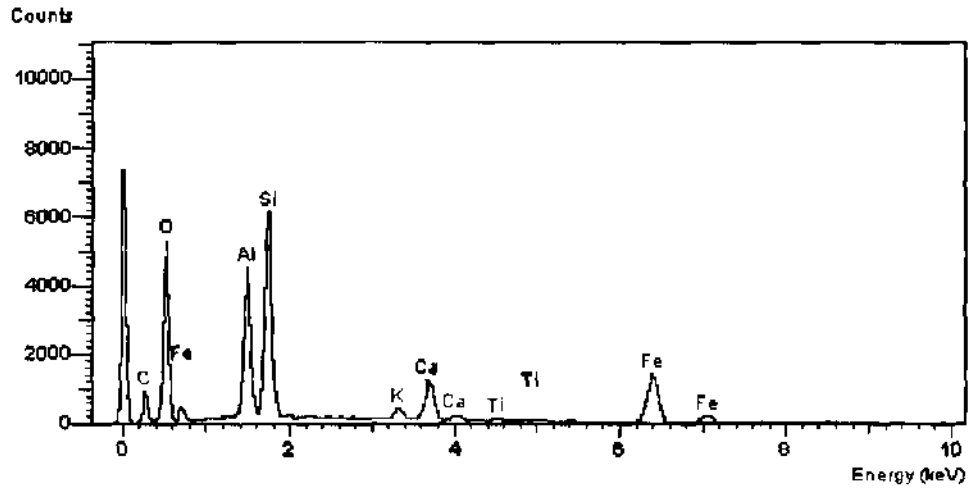



**Fig 50: Spectra of Sample 7: ROI No 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 33.84 | 59.35 |
| Mg | 0.53 | 0.61 |
| Al | 0.40 | 0.42 |
| Si | 13.70 | 13.68 |
| Ca | 0.31 | 0.21 |
| Fe | 51.22 | 25.73 |
| Total | 100.00 | 100.00 |

**Table 37: Elemental composition of Sample 7, ROI No.1 Spot2**

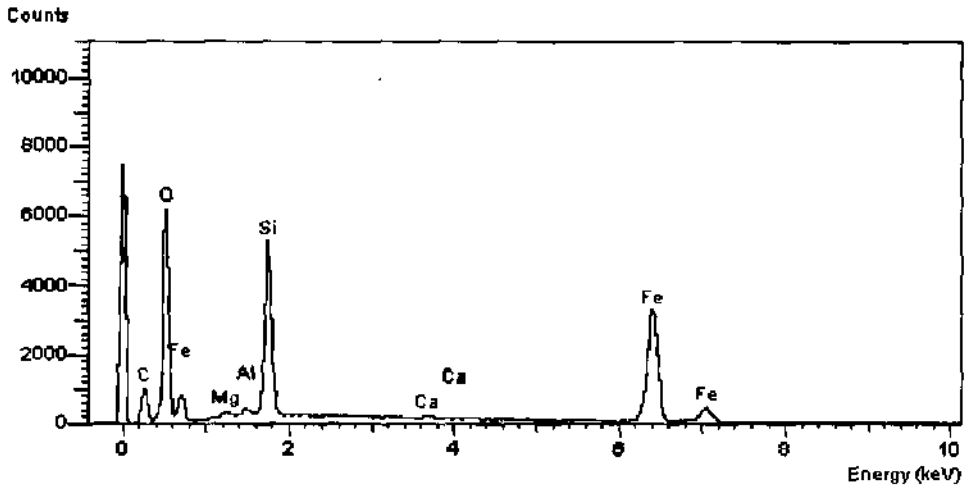



**Fig 51: Spectra of Sample 7: ROI No 1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 38.42 | 58.37 |
| Al | 12.28 | 11.06 |
| Si | 18.03 | 15.62 |
| K | 1.49 | 0.92 |
| Ca | 6.00 | 3.64 |
| Ti | 0.54 | 0.27 |
| Fe | 23.25 | 10.12 |
| Total | 100.00 | 100.00 |

**Table38: Elemental composition of Sample 7, ROI No.2 Spot1**

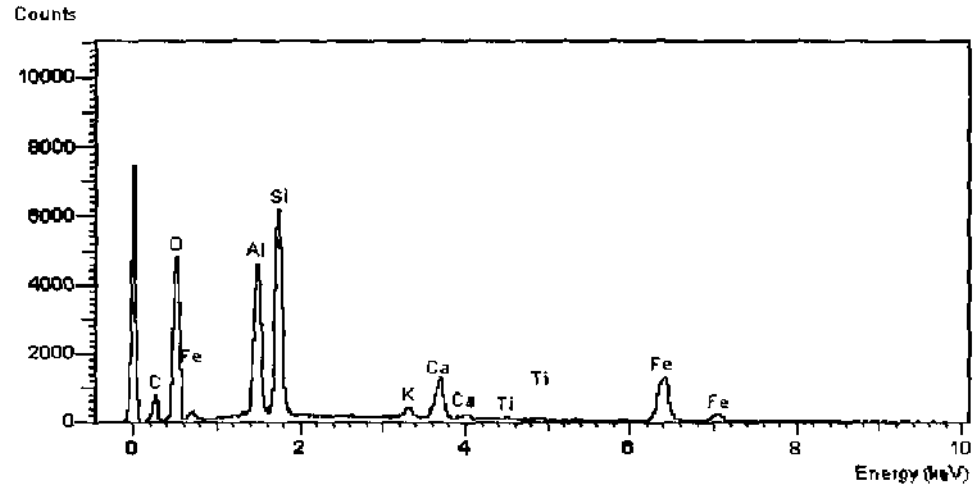



**Fig 52: Spectra of Sample 7: ROI No 2 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.37 | 57.70 |
| Mg | 0.45 | 0.53 |
| Al | 0.47 | 0.50 |
| Si | 14.12 | 14.34 |
| Ca | 0.37 | 0.26 |
| Fe | 52.22 | 26.67 |
| Total | 100.00 | 100.00 |

**Table 39: Elemental composition of Sample 7, ROI No.2 Spot2**

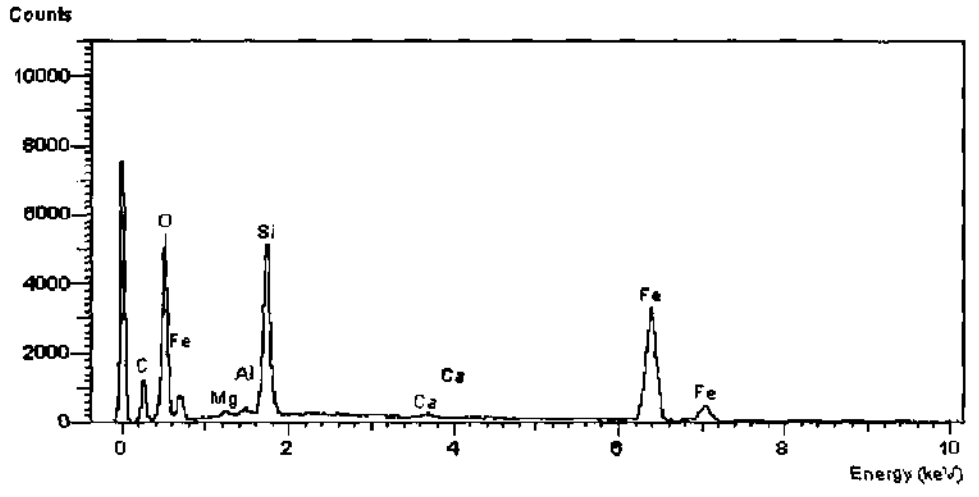



**Fig 53: Spectra of Sample 7: ROI No 2 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 43.05 | 61.67 |
| Na | 0.14 | 0.14 |
| Al | 13.09 | 11.11 |
| Si | 21.83 | 17.81 |
| K | 0.24 | 0.15 |
| Ca | 0.98 | 0.56 |
| Ti | 1.17 | 0.56 |
| Fe | 19.50 | 8.00 |
| Total | 100.00 | 100.00 |

**Table 40: Elemental composition of Sample 8, ROI No.1 Spot1**

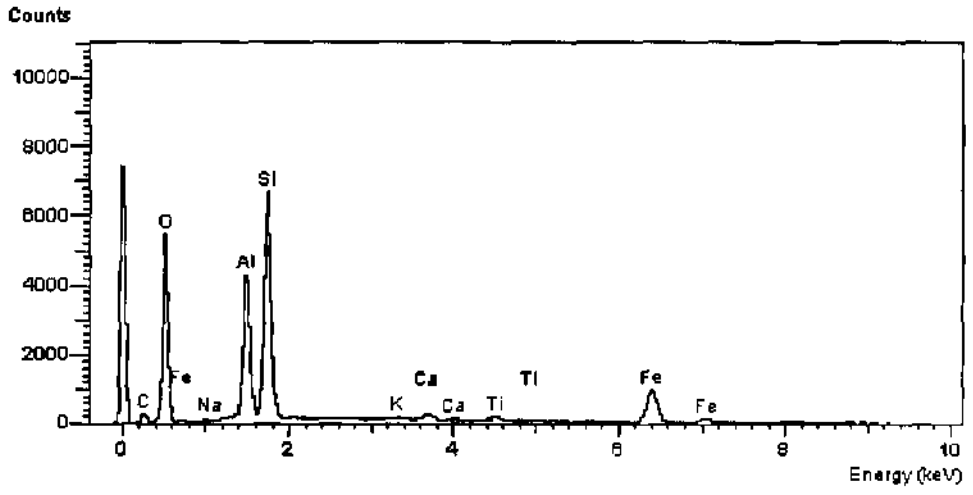



**Fig 54: Spectra of Sample 8 ROI No.1 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 40.74 | 60.73 |
| Al | 10.85 | 9.59 |
| Si | 20.08 | 17.05 |
| K | 1.15 | 0.70 |
| Ca | 1.68 | 1.00 |
| Ti | 0.59 | 0.29 |
| Fe | 24.91 | 10.64 |
| Total | 100.00 | 100.00 |

**Table 41: Elemental composition of Sample 8, ROI No. 1 Spot 2**

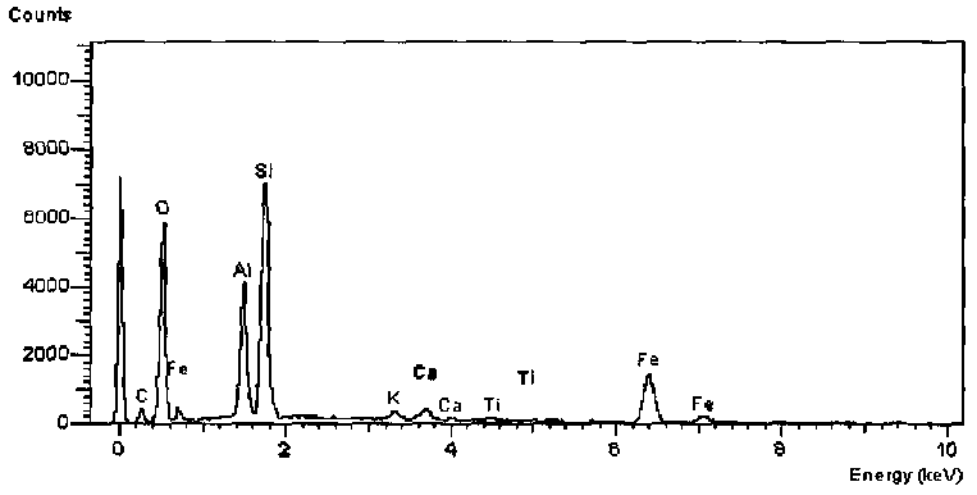



**Fig55: Spectra of Sample 8 ROI No.1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 38.78 | 60.28 |
| Al | 25.93 | 23.90 |
| Ti | 0.33 | 0.17 |
| V | 0.75 | 0.37 |
| Cr | 1.38 | 0.66 |
| Fe | 32.83 | 14.62 |
| Total | 100.00 | 100.00 |

**Table 42: Elemental composition of Sample 8, ROI No.1 Spot3**

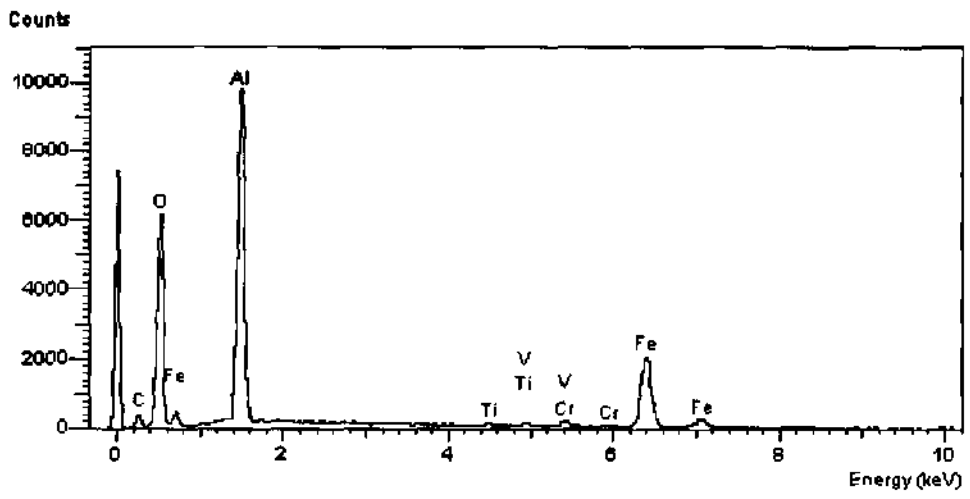



**Fig56: Spectra of Sample 8 ROI No.1 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.24 | 57.85 |
| Mg | 0.19 | 0.23 |
| Al | 0.15 | 0.16 |
| Si | 13.99 | 14.30 |
| Fe | 53.43 | 27.46 |
| Total | 100.00 | 100.00 |

**Table 43: Elemental composition of Sample 8, ROI No.1 Spot 4**

.

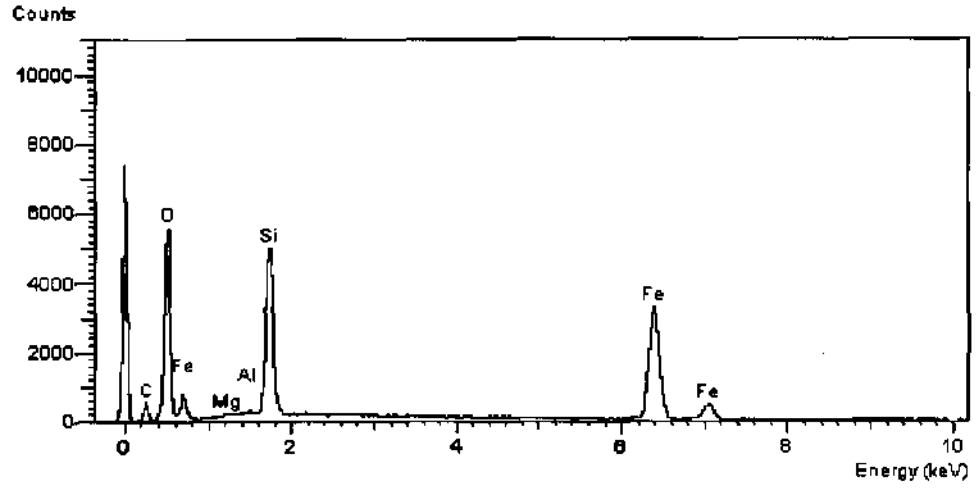



**Fig57: Spectra of Sample 8 ROI No.1 Spot 4 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 41.25 | 61.17 |
| Al | 10.75 | 9.45 |
| Si | 20.15 | 17.02 |
| K | 1.18 | 0.72 |
| Ca | 1.63 | 0.96 |
| Ti | 0.56 | 0.28 |
| Fe | 24.48 | 10.40 |
| Total | 100.00 | 100.00 |

**Table 44: Elemental composition of Sample 8, ROI No.2 Spot1**

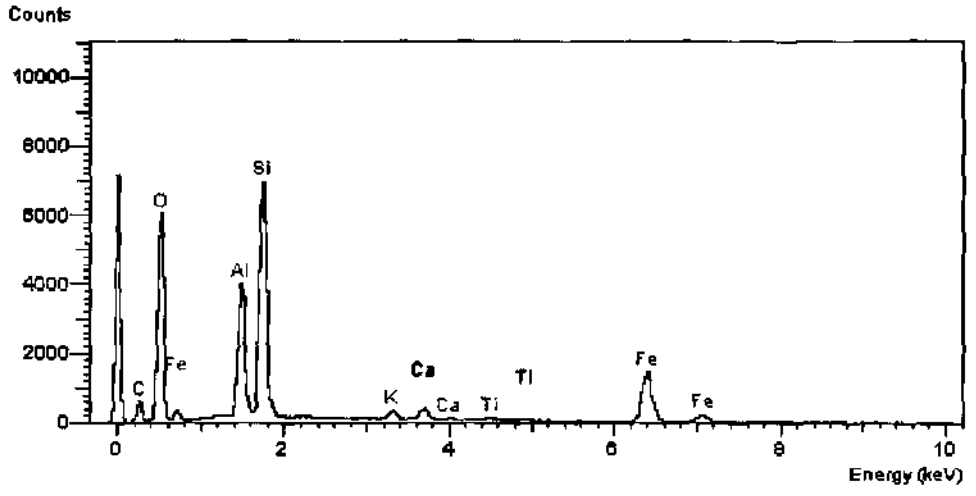



**Fig58: Spectra of Sample 8 ROI No.2 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 38.59 | 60.24 |
| Al | 25.53 | 23.63 |
| Ti | 0.39 | 0.20 |
| V | 0.60 | 0.30 |
| Cr | 0.96 | 0.46 |
| Fe | 33.93 | 15.17 |
| Total | 100.00 | 100.00 |

**Table45: Elemental composition of Sample 8, ROI No.2 Spot2**

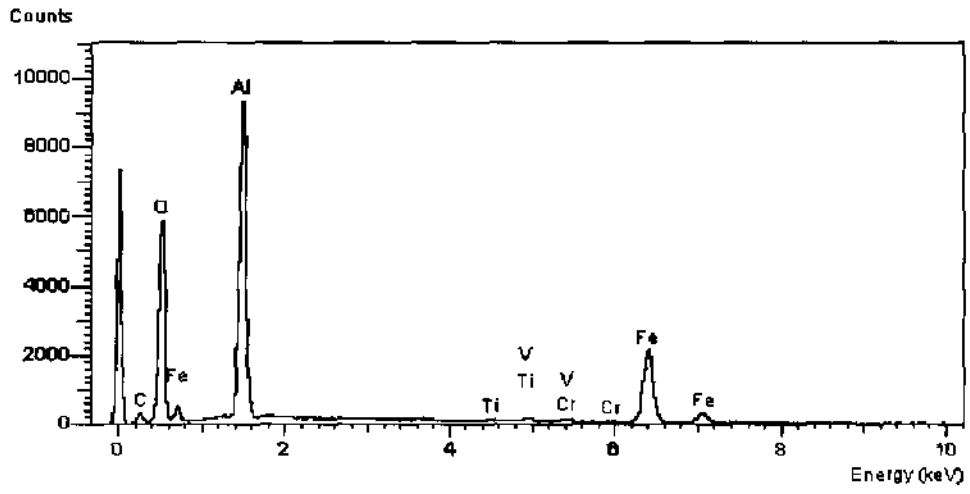



**Fig59: Spectra of Sample 8 ROI No.2 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.96 | 58.64 |
| Mg | 0.11 | 0.13 |
| Al | 0.16 | 0.17 |
| Si | 13.97 | 14.15 |
| Fe | 52.80 | 26.91 |
| Total | 100.00 | 100.00 |

**Table 46: Elemental composition of Sample 8, ROI No.2 Spot3**

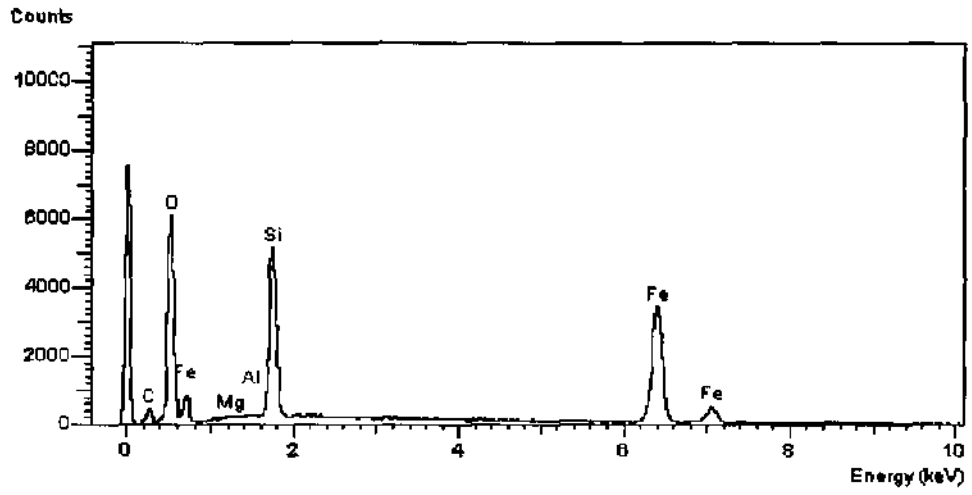



**Fig 60: Spectra of Sample 8 ROI No.2 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.01 | 59.45 |
| Mg | 0.37 | 0.43 |
| Al | 0.43 | 0.45 |
| Si | 14.14 | 14.08 |
| Ca | 0.19 | 0.13 |
| Fe | 50.86 | 25.46 |
| Total | 100.00 | 100.00 |

**Table 47: Elemental composition of Sample 9, ROI No.1 Spot1**

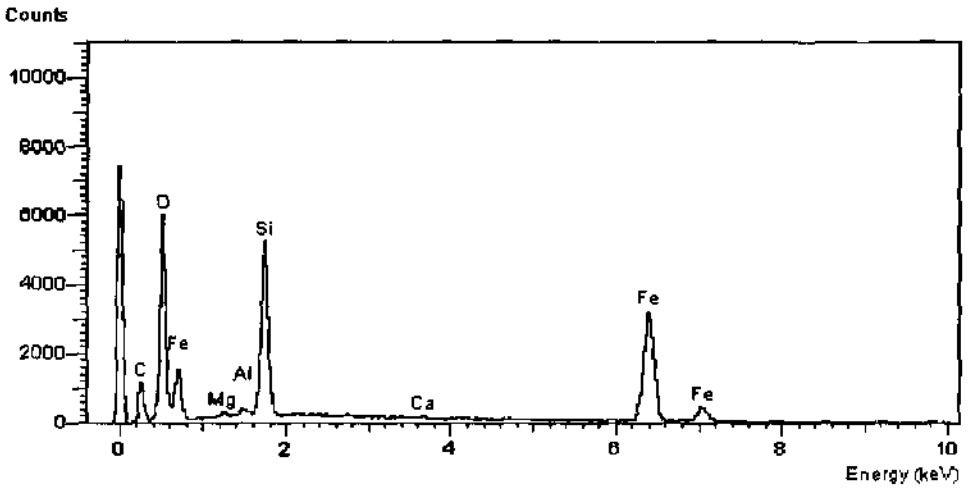



**Fig 61: Spectra of Sample 9 ROI No. 1 Spot 1 EDS.**

| Elmt | Element Atomic |
|---|---|
| | % % |
| O | 23.51 51.32 |
| Al | 0.94 1.22 |
| Si | 0.31 0.38 |
| Ti | 0.25 0.18 |
| Fe | 74.99 46.90 |
| Total | 100.00 100.00 |

**Table 48: Elemental composition of Sample 9, ROI No.1 Spot 2**

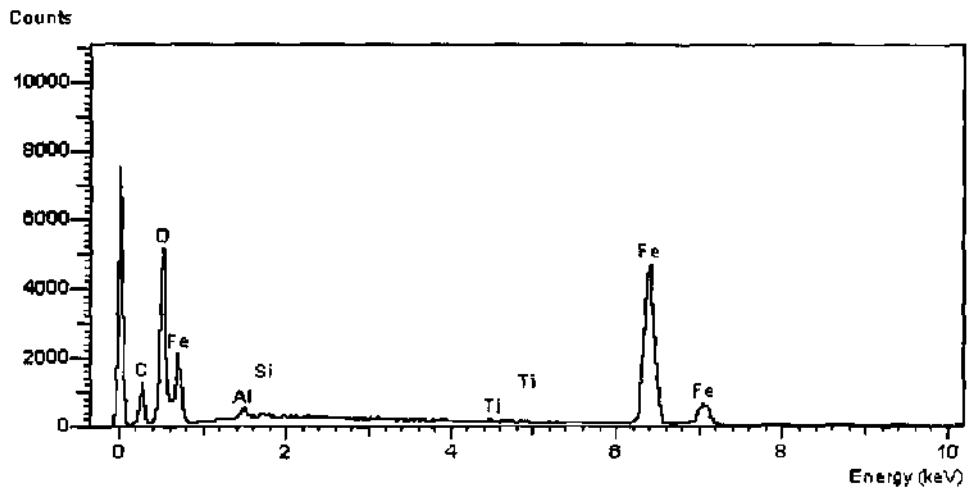



**Fig 62: Spectra of Sample 9: ROI No.1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 33.20 | 58.61 |
| Mg | 0.11 | 0.13 |
| Al | 1.73 | 1.81 |
| Si | 13.11 | 13.18 |
| Ca | 0.15 | 0.11 |
| Fe | 51.70 | 26.16 |
| Total | 100.00 | 100.00 |

**Table 49: Elemental composition of Sample 9, ROI No.1 Spot 3**

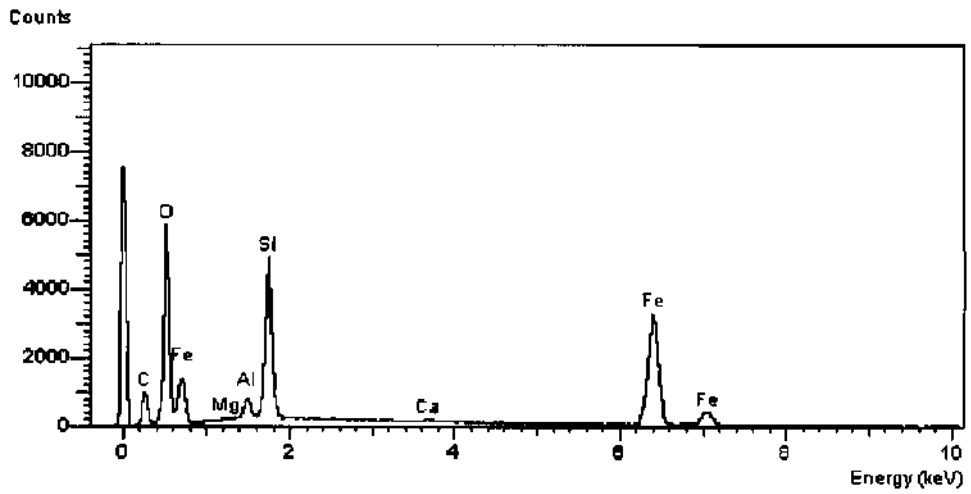



**Fig63: Spectra of Sample 9 ROI No.1 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| **O** | 42.37 | 55.85 |
| **Al** | 55.19 | 43.14 |
| **P** | 0.10 | 0.07 |
| **Ti** | 0.93 | 0.40 |
| Fe | 1.41 | 0.54 |
| Total | 100.00 | 100.00 |

**Table 50: Elemental composition of Sample 9, ROI No.2 Spot1**

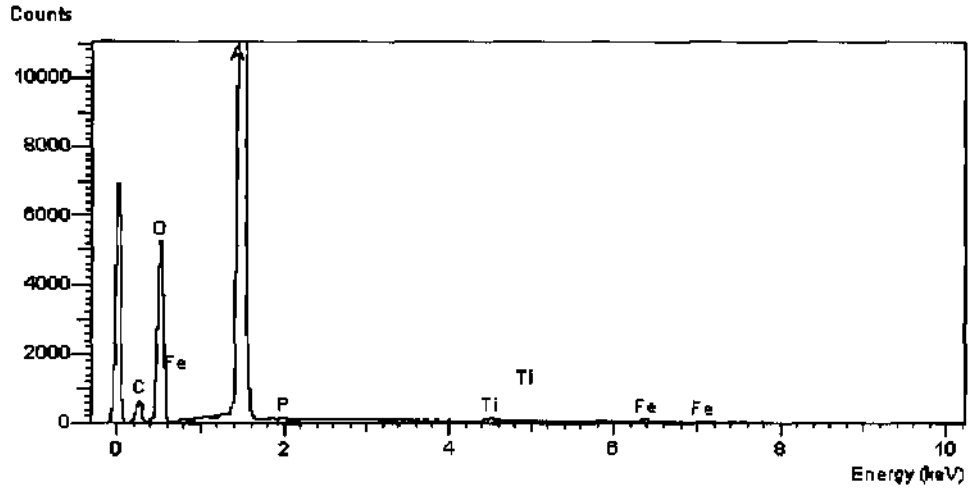



**Fig64: Spectra of Sample 9 ROI No. 2 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 42.96 | 61.86 |
| Na | 0.27 | 0.27 |
| Al | 9.56 | 8.17 |
| Si | 19.01 | 15.59 |
| P | 0.90 | 0.67 |
| S | 0.13 | 0.08 |
| K | 6.97 | 4.11 |
| Ca | 5.60 | 3.22 |
| Fe | 14.60 | 6.03 |
| Total | 100.00 | 100.00 |

**Table 51: Elemental composition of Sample 9, ROI No.2 Spot2**

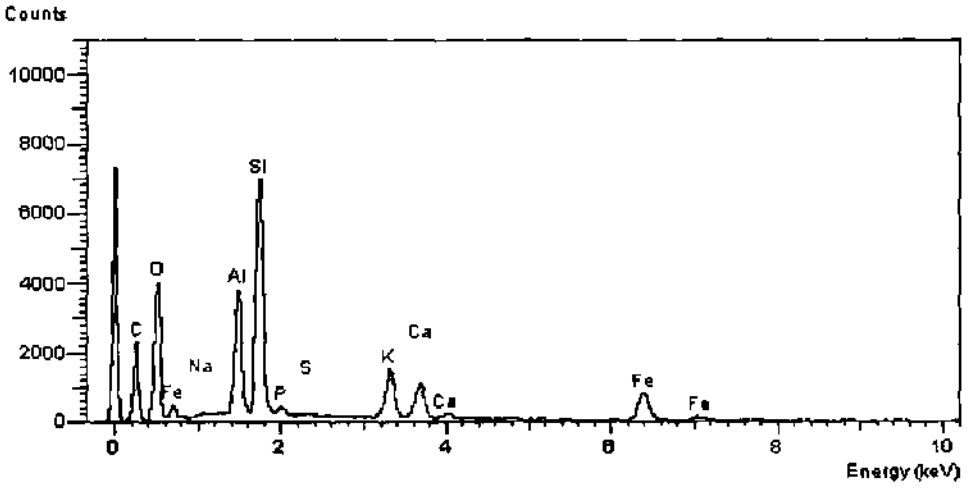



**Fig65: Spectra of Sample 9 ROI No.2 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 43.10 | 61.93 |
| Na | 0.24 | 0.24 |
| Al | 9.75 | 8.31 |
| Si | 19.16 | 15.68 |
| P | 0.90 | 0.67 |
| S | 0.20 | 0.14 |
| K | 6.73 | 3.95 |
| Ca | 5.46 | 3.13 |
| Fe | 14.46 | 5.95 |
| Total | 100.00 | 100.00 |

**Table 52: Elemental composition of Sample 9, ROI No. 2 Spot3**

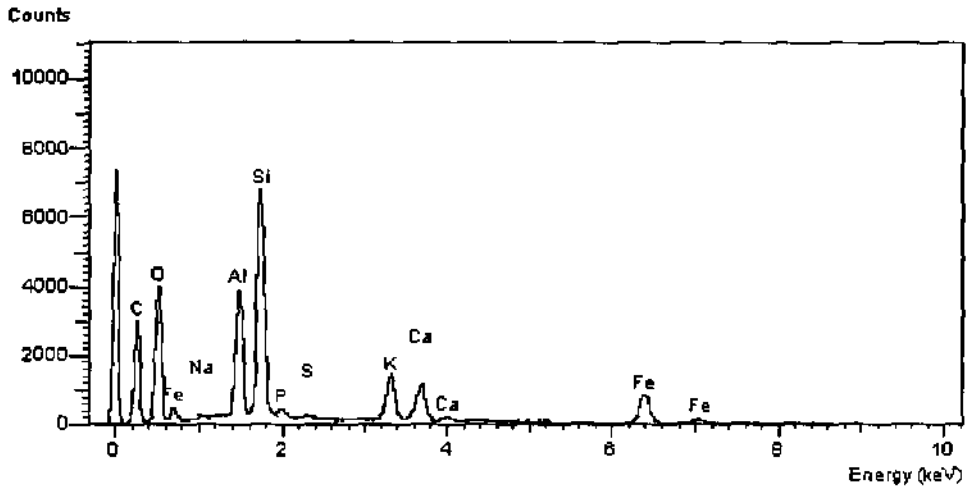



**Fig66: Spectra of Sample 9 ROI No.2 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.82 | 55.54 |
| Al | 21.98 | 22.06 |
| Si | 0.93 | 0.90 |
| Ti | 0.47 | 0.26 |
| Fe | 43.80 | 21.24 |
| Total | 100.00 | 100.00 |

**Table 53: Elemental composition of Sample 9, ROI No.2 Spot4**

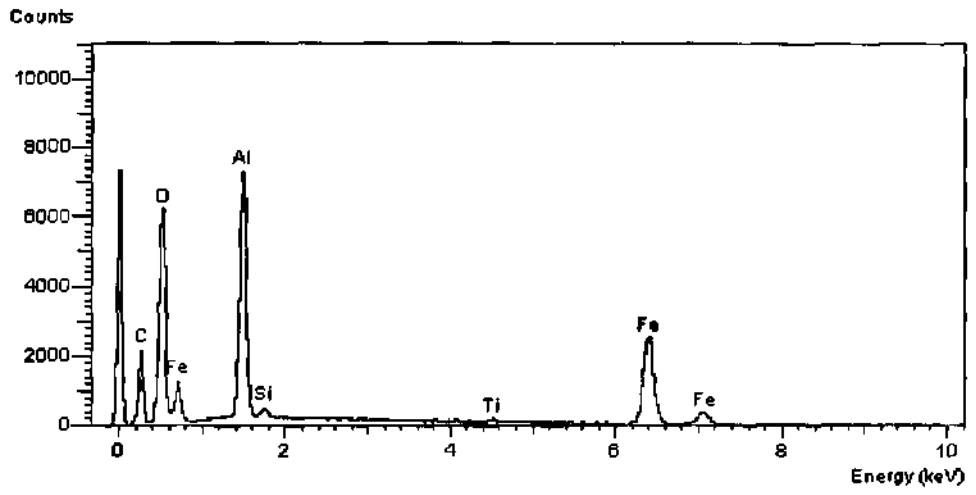



**Fig 67: Spectra of Sample 9 ROI No.2 Spot 4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 45.58 | 61.61 |
| Na | 0.25 | 0.23 |
| Al | 16.33 | 13.09 |
| Si | 22.11 | 17.02 |
| K | 0.97 | 0.54 |
| Ca | 11.84 | 6.39 |
| Fe | 2.92 | 1.13 |
| Total | 100.00 | 100.00 |

**Table 54: Elemental composition of Sample 10, ROI No.1 Spot1**

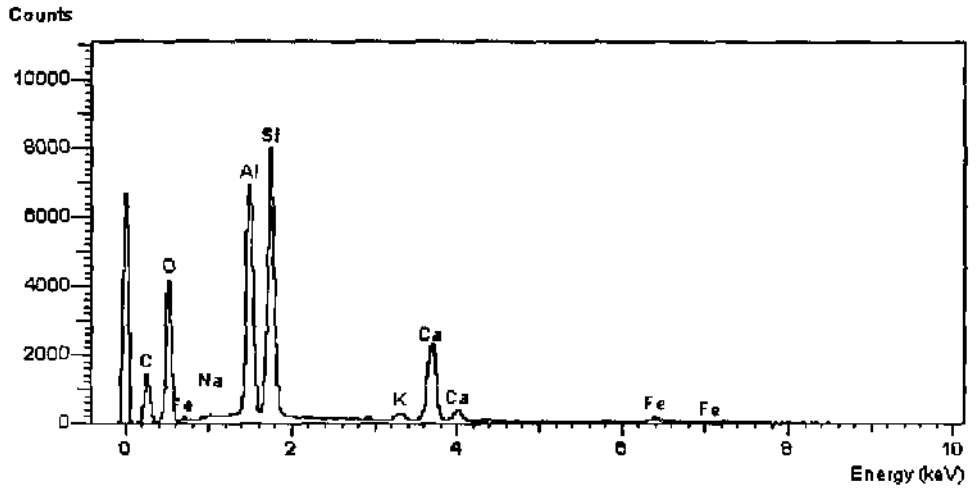



**Fig68: Spectra of Sample 10: ROI No.1 Spot 1.EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.64 | 56.61 |
| Al | 2.15 | 2.03 |
| Si | 22.43 | 20.30 |
| P | 0.58 | 0.48 |
| Ca | 14.70 | 9.33 |
| Ti | 1.32 | 0.70 |
| Fe | 23.18 | 10.55 |
| Total | 100.00 | 100.00 |

**Table 55: Elemental composition of Sample 10, ROI No.1 Spot2**

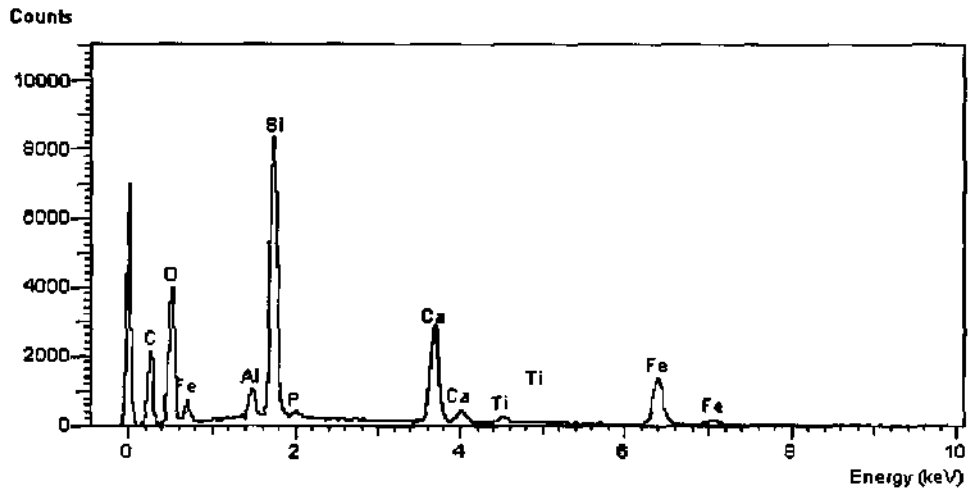



**Fig 69: Spectra of Sample10 ROI No.1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.44 | 59.82 |
| Si | 14.86 | 14.70 |
| Ca | 1.33 | 0.92 |
| Fe | 49.37 | 24.56 |
| Total | 100.00 | 100.00 |

**Table 56: Elemental composition of Sample 10, ROI No.1 Spot 3**

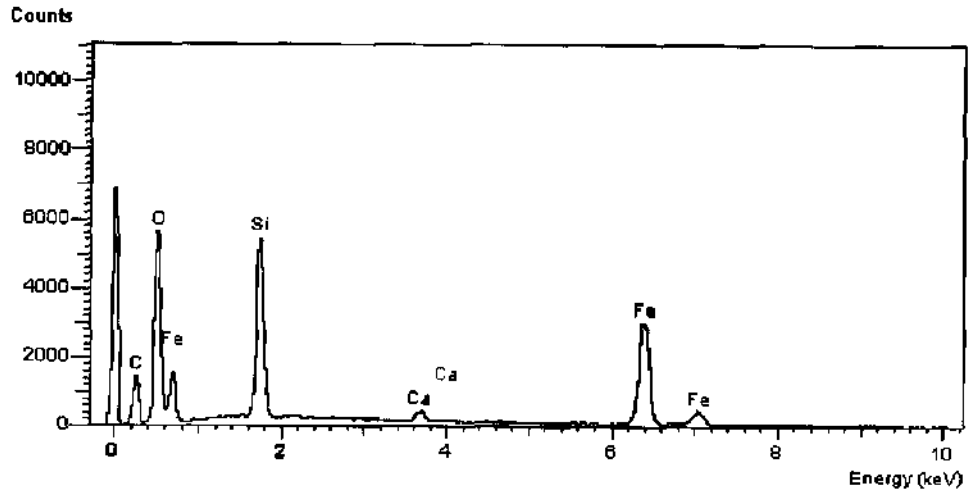



**Fig70: Spectra of Sample10: ROI No.1 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 41.17 | 61.58 |
| Al | 0.13 | 0.12 |
| Si | 2.82 | 2.40 |
| P | 16.77 | 12.96 |
| Ca | 36.62 | 21.87 |
| Fe | 2.49 | 1.07 |
| Total | 100.00 | 100.00 |

**Table 57: Elemental composition of Sample 10, ROI No.1 Spot4**

.

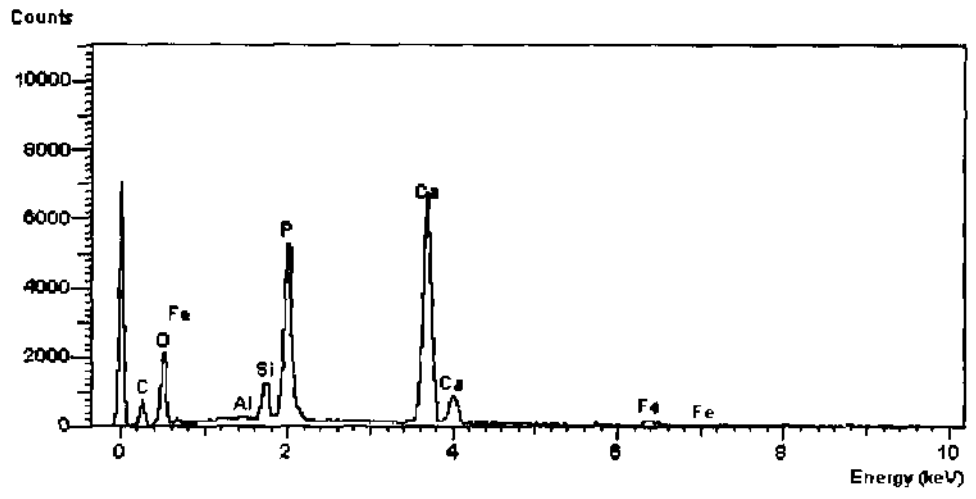



**Fig71: Spectra of Sample10 ROI No.1 Spot 4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 43.72 | 59.69 |
| Al | 12.15 | 9.83 |
| Si | 27.11 | 21.08 |
| K | 16.32 | 9.12 |
| Fe | 0.70 | 0.28 |
| Total | 100.00 | 100.00 |

**Table 58: Elemental composition of Sample 10, ROI No.2 Spot1**

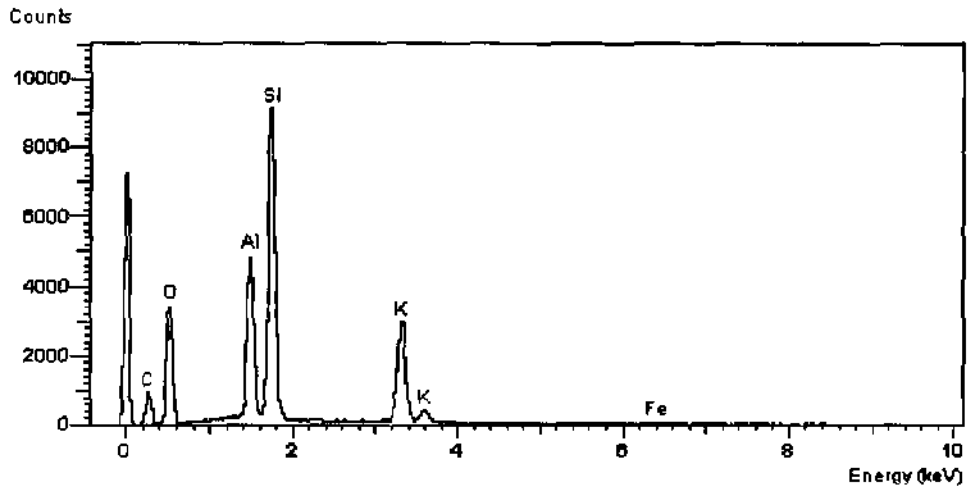



**Fig72: Spectra of Sample 10: ROI No.2 Spot 1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 41.65 | 61.98 |
| Si | 4.01 | 3.41 |
| P | 16.07 | 12.35 |
| Ca | 35.42 | 21.04 |
| Fe | 2.85 | 1.22 |
| Total | 100.00 | 100.00 |

**Table59: Elemental composition of Sample 10, ROI No.2 Spot2**

.

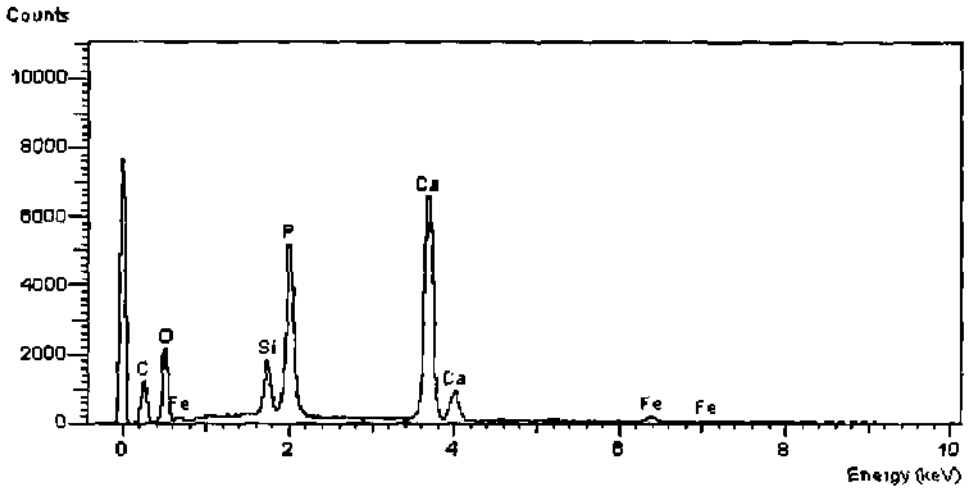



**Fig73: Spectra of Sample 10: ROI No.2 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.61 | 58.30 |
| Mg | 0.13 | 0.14 |
| Al | 7.54 | 7.32 |
| Si | 12.66 | 11.81 |
| P | 0.18 | 0.16 |
| Ca | 9.07 | 5.92 |
| Ti | 0.39 | 0.22 |
| Fe | 34.42 | 16.13 |
| Total | 100.00 | 100.00 |

**Table 60: Elemental composition of Sample 10, ROI No.2 Spot 3**

.

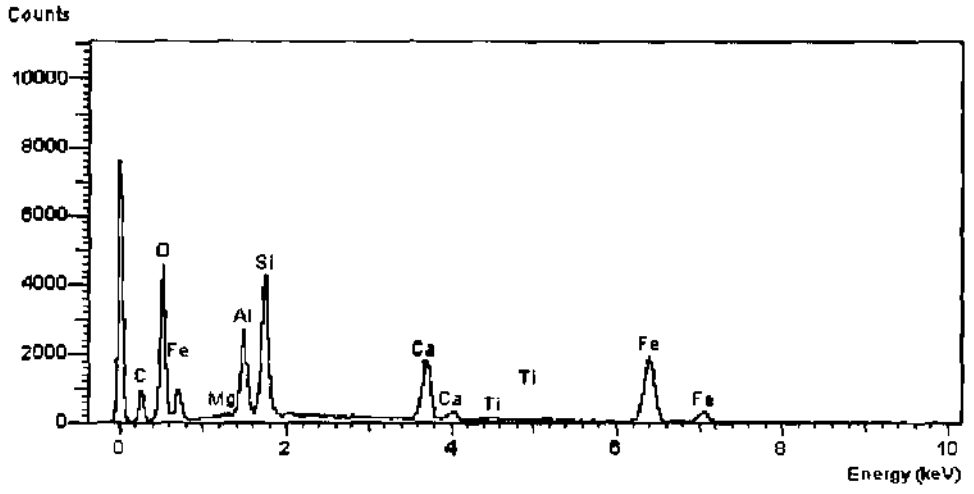



**Fig74: Spectra of Sample 10: ROI No.2 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.19 | 59.50 |
| Mg | 0.82 | 0.94 |
| Si | 14.40 | 14.27 |
| Ca | 0.36 | 0.25 |
| Fe | 50.23 | 25.04 |
| Total | 100.00 | 100.00 |

**Table 61: Elemental composition of Sample 10, ROI No 2 Spot 4**

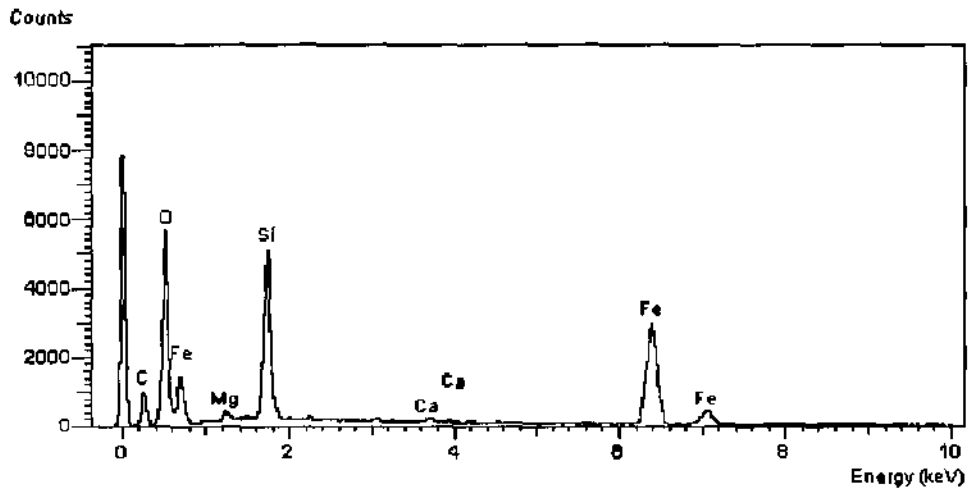



**Fig75: Spectra of Sample 10: ROI No.2 Spot 4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 26.44 | 54.20 |
| Al | 3.51 | 4.27 |
| Si | 0.51 | 0.59 |
| Ti | 0.90 | 0.62 |
| Fe | 68.64 | 40.32 |
| Total | 100.00 | 100.00 |

**Table 62: Elemental composition of Sample 10, ROI No 2 Spot 5**

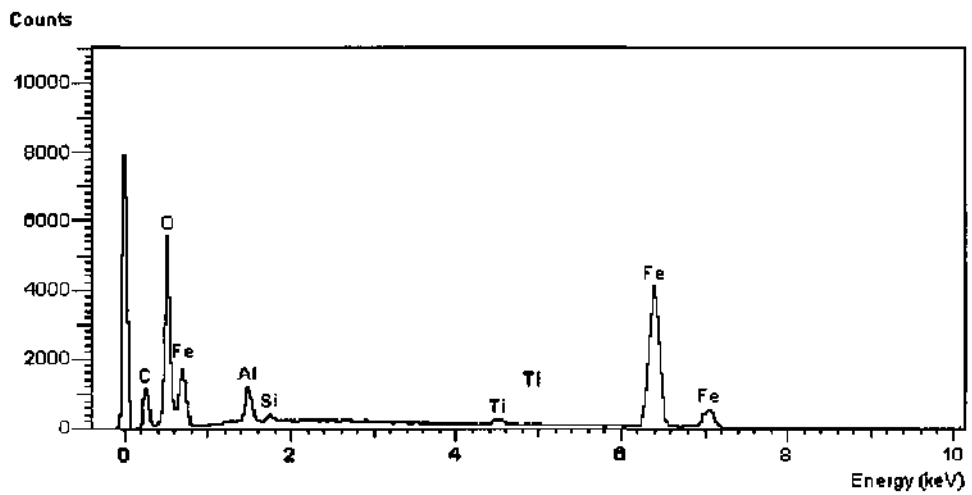



**Fig76: Spectra of Sample 10: ROI No. 2 Spot 5 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 50.22 | 67.42 |
| **Al** | 4.61 | 3.67 |
| Si | 0.52 | 0.40 |
| S | 35.45 | 23.76 |
| Cl | 5.17 | 3.14 |
| **Ca** | 0.39 | 0.21 |
| **Fe** | 3.64 | 1.40 |
| Total | 100.00 | 100.00 |

**Table63: Elemental composition of Sample 11, ROI No.1 Spot 1**

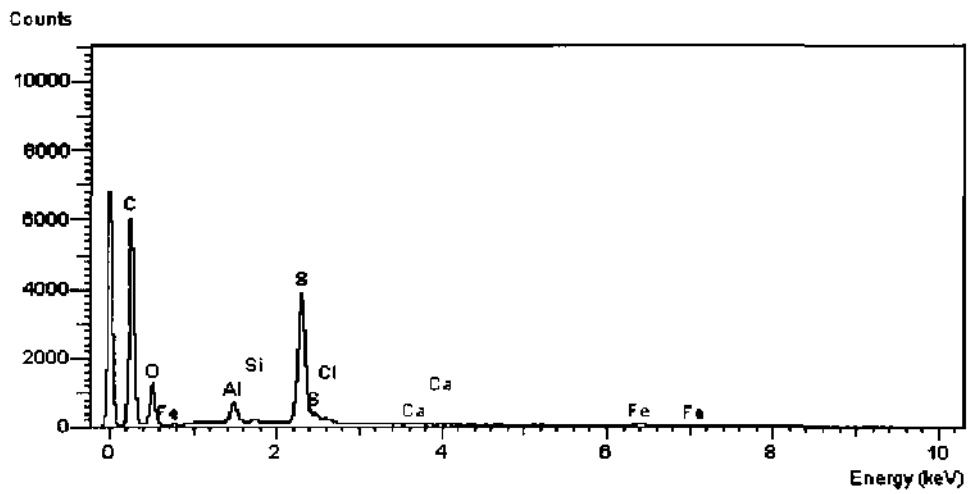



**Fig77: Spectra of Sample 11: ROI No.1 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 51.50 | 65.16 |
| Al | 0.23 | 0.17 |
| Si | 47.91 | 34.54 |
| Fe | 0.36 | 0.13 |
| Total | 100.00 | 100.00 |

**Table 64: Elemental composition of Sample 11, ROI No.1 Spot 2**

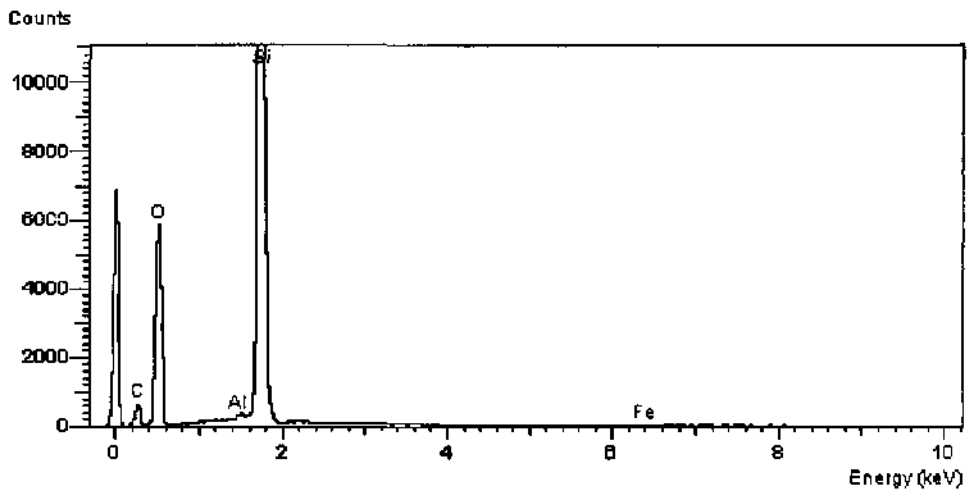



**Fig78: Spectra of Sample 11: ROI No.1 Spot 2.EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 40.36 | 63.05 |
| Na | 0.16 | 0.18 |
| Al | 10.75 | 9.95 |
| Si | 11.04 | 9.82 |
| Ti | 1.68 | 0.87 |
| Fe | 36.01 | 16.13 |
| Total | 100.00 | 100.00 |

**Table 65: Elemental composition of Sample 11, ROI No.1 Spot3**

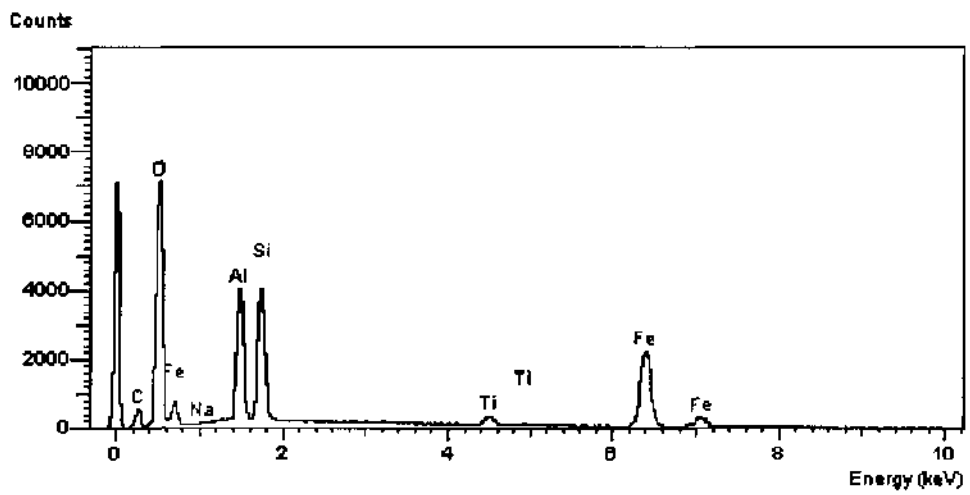



**Fig79: Spectra of Sample11: ROI No.1 Spot3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 53.53 | 68.00 |
| Al | 19.50 | 14.69 |
| Si | 20.84 | 15.08 |
| Fe | 6.13 | 2.23 |
| Total | 100.00 | 100.00 |

**Table 66: Elemental composition of Sample 11, ROI No.1 Spot 4**

.

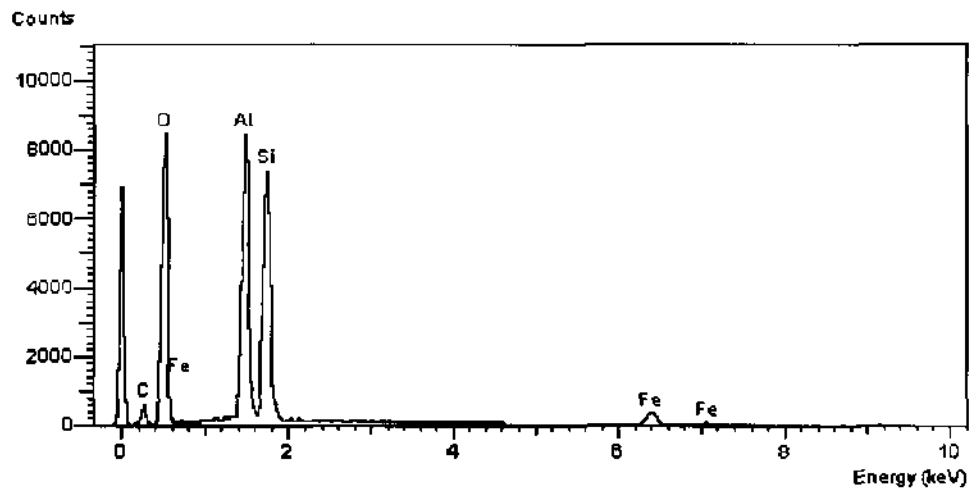



**Fig80: Spectra of Sample11: ROI No.1 Spot 4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 55.08 | 68.38 |
| Na | 0.10 | 0.08 |
| Mg | 0.07 | 0.06 |
| Al | 0.10 | 0.08 |
| Si | 44.17 | 31.23 |
| Fe | 0.48 | 0.17 |
| Total | 100.00 | 100.00 |

**Table 67: Elemental composition of Sample 11, ROI No.2 Spot 1**

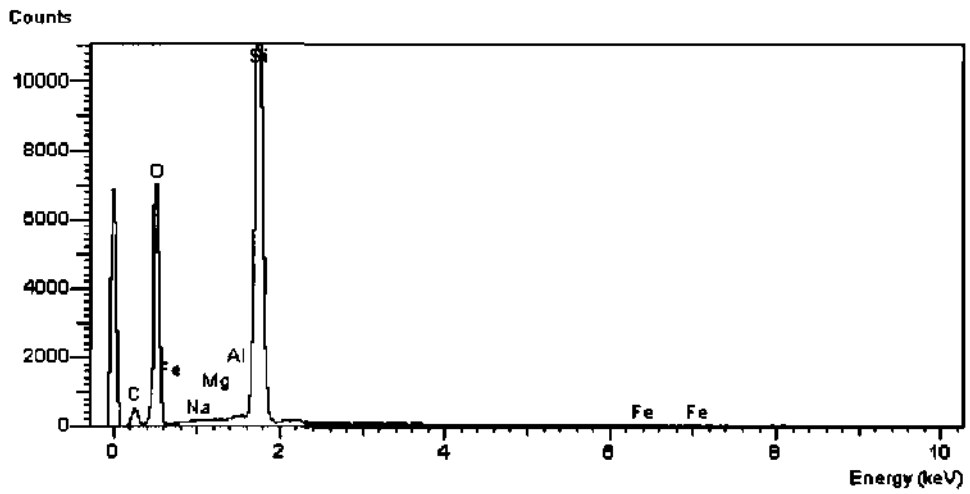



**Fig81: Spectra of Sample11: ROI No.2 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 44.61 | 62.95 |
| Na | 0.11 | 0.11 |
| Al | 18.55 | 15.52 |
| Si | 16.18 | 13.01 |
| K | 0.47 | 0.27 |
| Ti | 0.45 | 0.21 |
| Fe | 19.63 | 7.93 |
| Total | 100.00 | 100.00 |

**Table 68: Elemental composition of Sample 11, ROI No. 2 Spot 2**

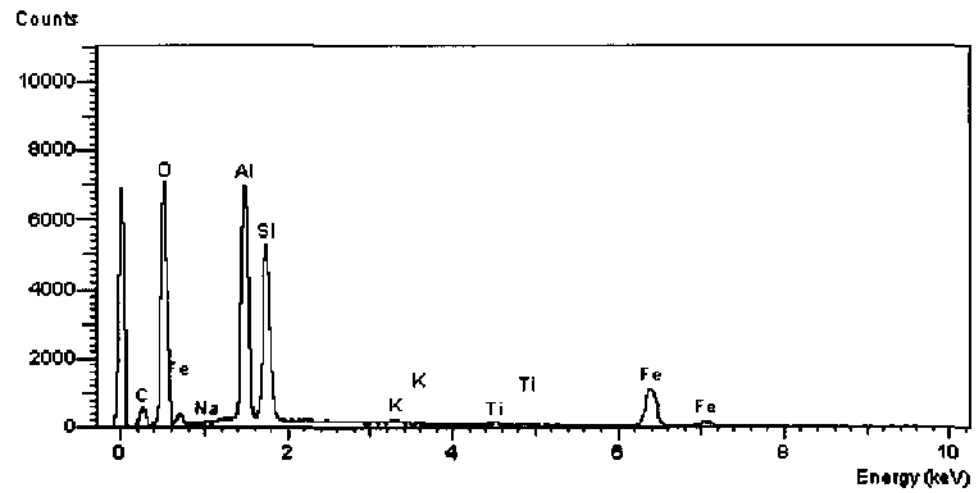



**Fig 82: Spectra of Sample 11: ROI No.2 Spot 2 EDS**

| Elmt | Atomic % | Element % |
|---|---|---|
| O | 41.77 | 63.22 |
| Mg | 0.11 | 0.11 |
| Al | 13.24 | 11.88 |
| Si | 12.43 | 10.72 |
| Fe | 32.45 | 14.07 |
| Total | 100.00 | 100.00 |

**Table 69: Elemental composition of Sample 11, ROI No. 2 Spot 3**

.

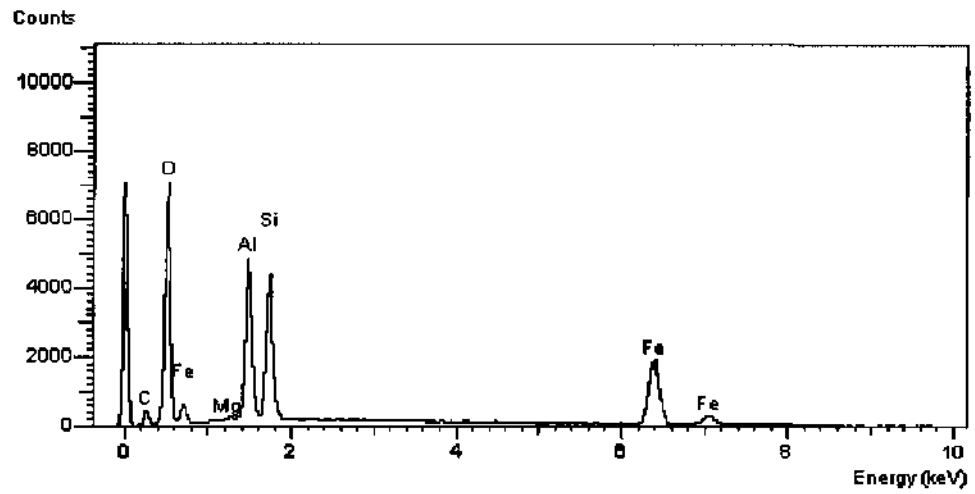



**Fig 83: Spectra of Sample 11: ROI No.2 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.13 | 60.69 |
| Al | 9.29 | 9.52 |
| Si | 4.67 | 4.59 |
| Fe | 50.91 | 25.20 |
| Total | 100.00 | 100.00 |

**Table70: Elemental composition of Sample 11, ROI No.2 Spot 4**

.

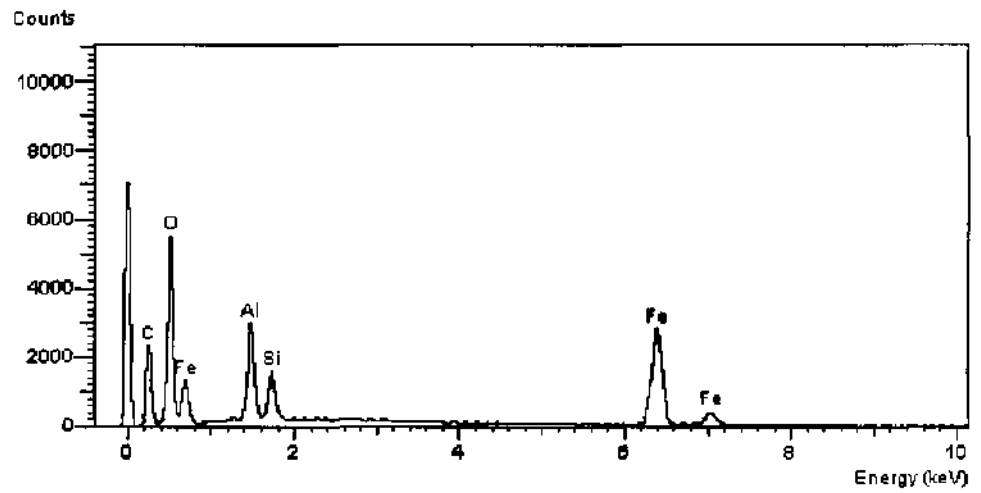



**Fig 84: Spectra of Sample 11: ROI No.2 Spot 4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 51.81 | 65.59 |
| Na | 0.12 | 0.10 |
| Al | 0.24 | 0.18 |
| Si | 46.80 | 33.75 |
| Fe | 1.03 | 0.38 |
| Total | 100.00 | 100.00 |

**Table71: Elemental composition of Sample 12, ROI No.1 Spot 1**

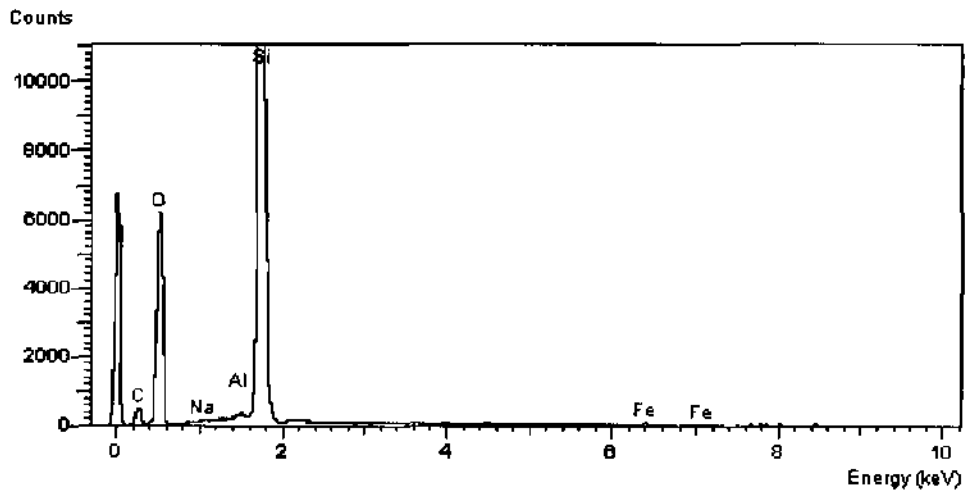



**Fig 85: Spectra of Sample12: ROI No.1 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 46.21 | 62.50 |
| Na | 0.22 | 0.21 |
| Mg | 0.08 | 0.07 |
| Al | 8.42 | 6.75 |
| Si | 32.30 | 24.88 |
| K | 3.08 | 1.70 |
| Ca | 0.67 | 0.36 |
| Ti | 0.46 | 0.21 |
| Fe | 8.56 | 3.32 |
| Total | 100.00 | 100.00 |

**Table 72: Elemental composition of Sample 12, ROI No. 1 Spot 2**

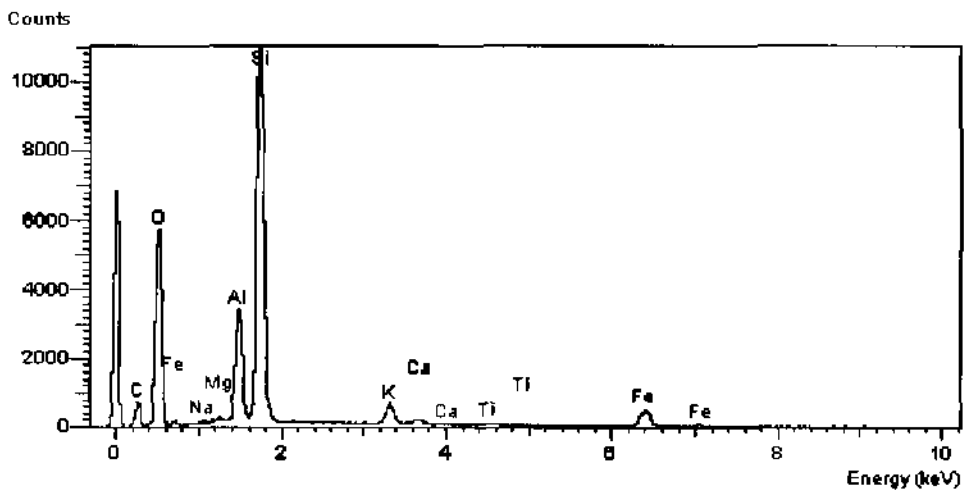



**Fig 86: Spectra of Sample 12: ROI No.1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 30.26 | 57.19 |
| Al | 8.66 | 9.70 |
| Ti | 0.40 | 0.26 |
| Fe | 60.68 | 32.85 |
| Total | 100.00 | 100.00 |

**Table 73: Elemental composition of Sample 12, ROI No.1 Spot 3**

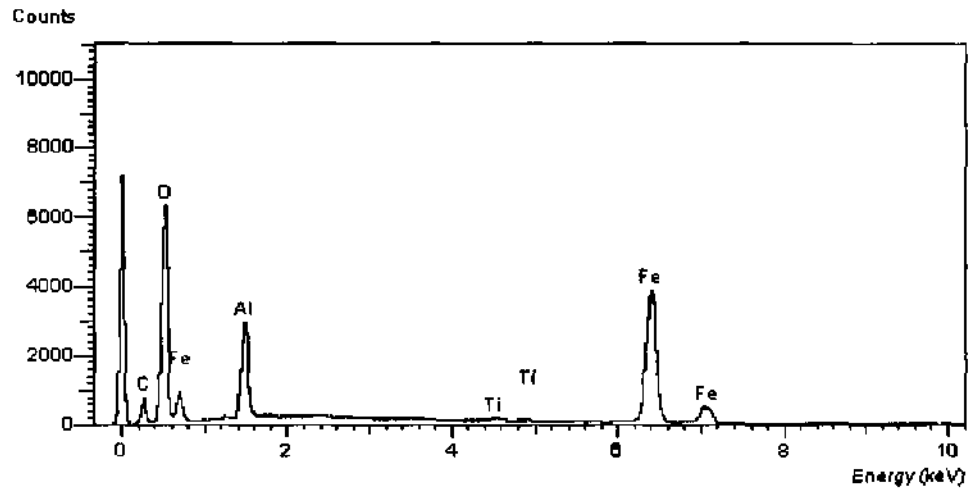



**Fig 87: Spectra of Sample 12: ROI No.1 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 51.55 | 65.13 |
| Si | 48.45 | 34.87 |
| Total | 100.00 | 100.00 |

**Table74: Elemental composition of Sample 12, ROI No.2 Spot 1**

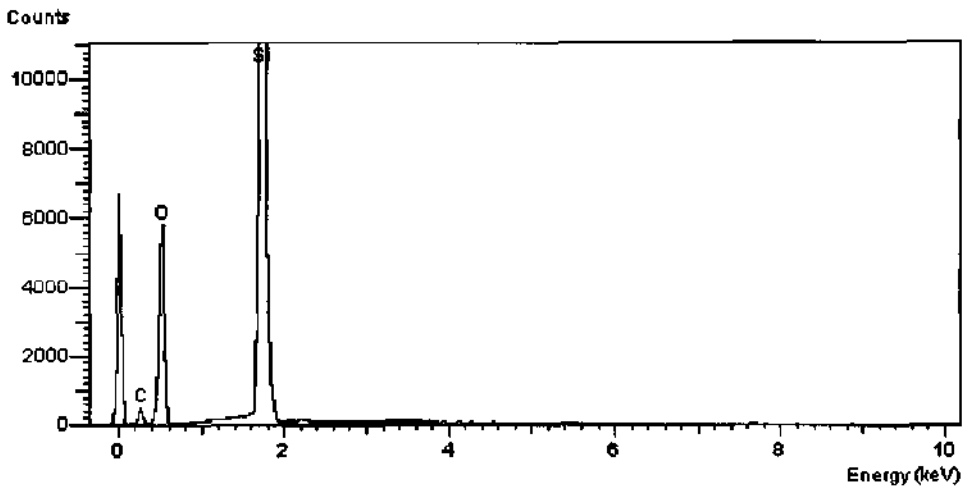



**Fig 88: Spectra of Sample12: ROI No.2 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 45.65 | 61.27 |
| Al | 6.80 | 5.40 |
| Si | 37.57 | 28.72 |
| K | 4.05 | 2.22 |
| Ca | 0.39 | 0.21 |
| Ti | 0.59 | 0.27 |
| Fe | 4.95 | 1.91 |
| Total | 100.00 | 100.00 |

**Table75: Elemental composition of Sample 12, ROI No.2 Spot 2**

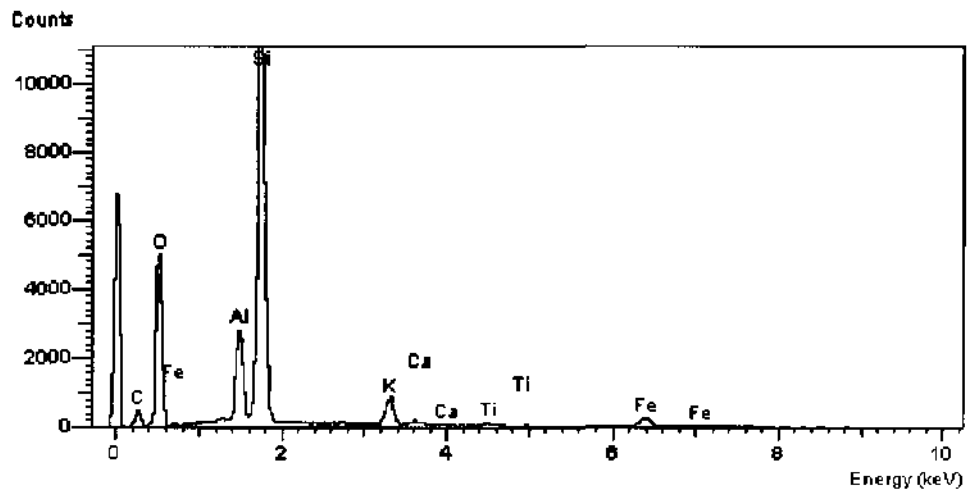



**Fig 89: Spectra of Sample 12: ROI No.2 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 33.85 | 66.18 |
| Si | 14.34 | 15.97 |
| Fe | 0.37 | 0.21 |
| Zr | 51.44 | 17.64 |
| Total | 100.00 | 100.00 |

**Table76: Elemental composition of Sample 12, ROI No.2 Spot 3**

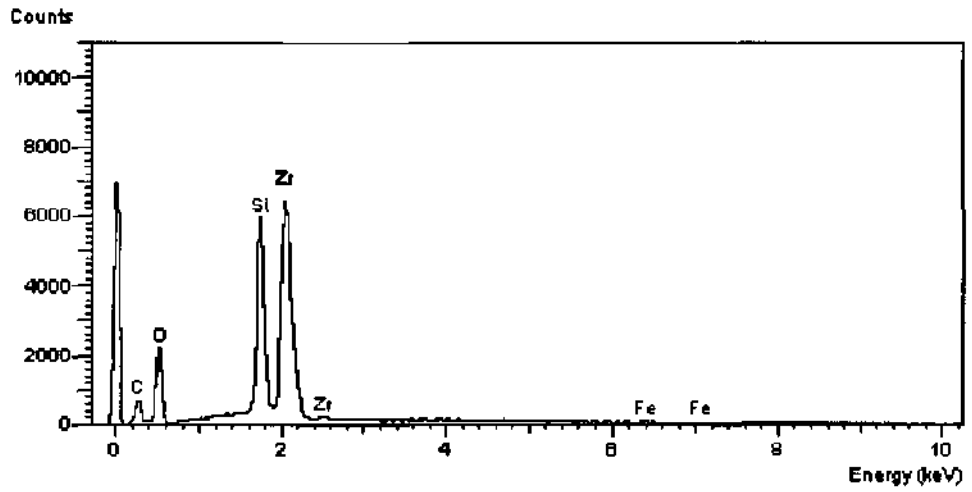



**Fig 90: Spectra of Sample 12: ROI No2 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 38.37 | 58.98 |
| Na | 0.21 | 0.23 |
| Al | 7.01 | 6.39 |
| Si | 22.84 | 20.00 |
| K | 0.46 | 0.29 |
| Ca | 2.11 | 1.29 |
| Ti | 0.77 | 0.39 |
| Fe | 28.23 | 12.43 |
| Total | 100.00 | 100.00 |

**Table77: Elemental composition of Sample 13, ROI No.1 Spot 1**

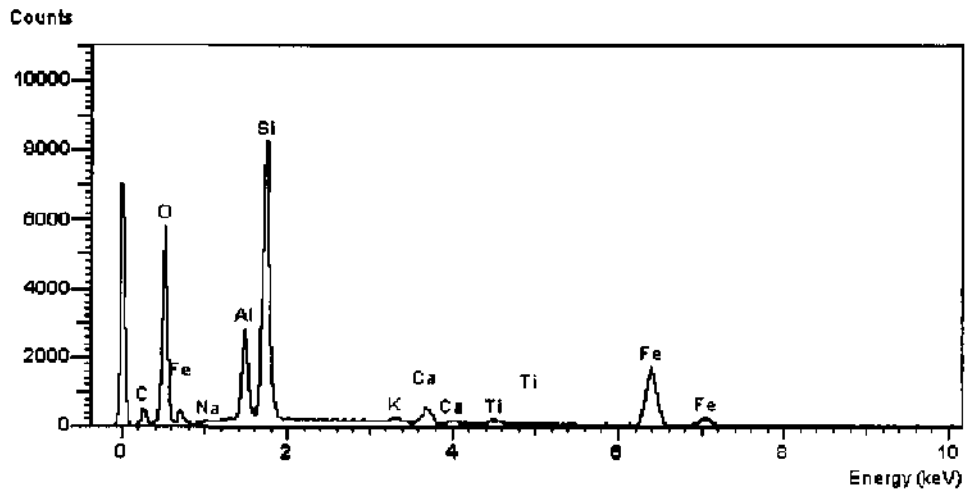



**Fig91: Spectra of Sample13: ROI No.1 Spot 1.EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.67 | 56.96 |
| Al | 27.25 | 25.80 |
| **Si** | 0.50 | 0.45 |
| **Ti** | 0.53 | 0.28 |
| **V** | 0.37 | 0.19 |
| Fe | 35.68 | 16.32 |
| Total | 100.00 | 100.00 |

**Table78: Elemental composition of Sample 13, ROI No.1 Spot 2**

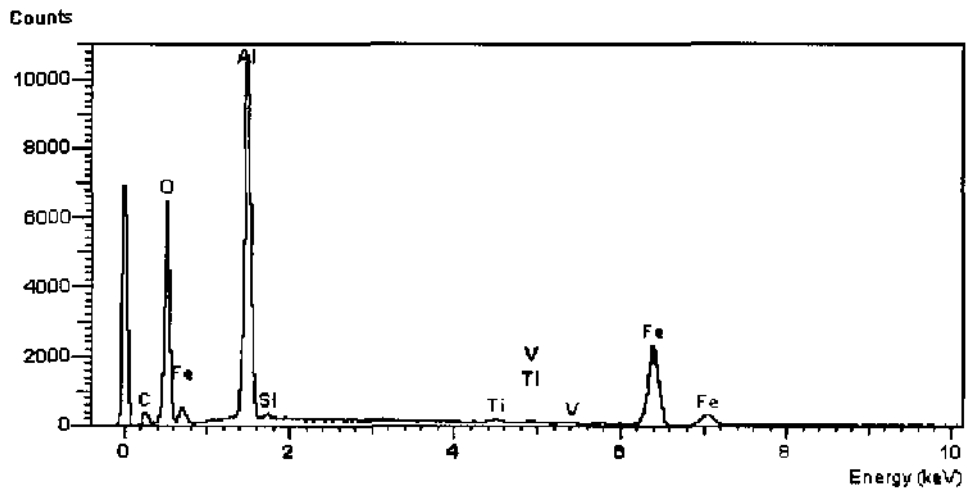



**Fig 92: Spectra of Sample 13: ROI No.1 Spot2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 30.48 | 55.87 |
| Mg | 0.30 | 0.36 |
| Al | 0.27 | 0.29 |
| Si | 14.01 | 14.63 |
| Fe | 54.94 | 28.85 |
| Total | 100.00 | 100.00 |

**Table 79: Elemental composition of Sample 13, RO1 No.1 Spot 3**

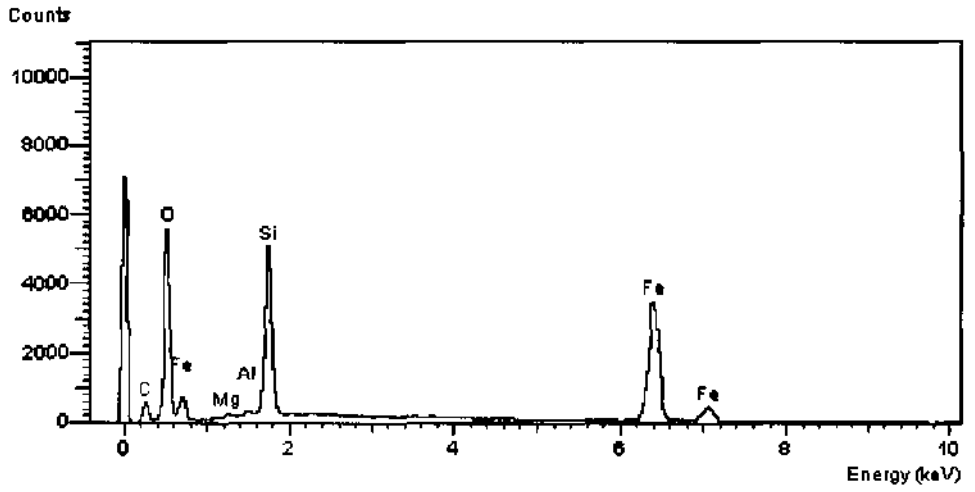



**Fig 93: Spectra of Sample13: ROI No 1 Spot3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 39.47 | 59.05 |
| Al | 9.66 | 8.57 |
| Si | 23.22 | 19.79 |
| K | 0.46 | 0.28 |
| Ca | 3.43 | 2.05 |
| Ti | 0.96 | 0.48 |
| Fe | 22.80 | 9.78 |
| Total | 100.00 | 100.00 |

**Table80: Elemental composition of Sample 13, ROI No.2 Spot 1**

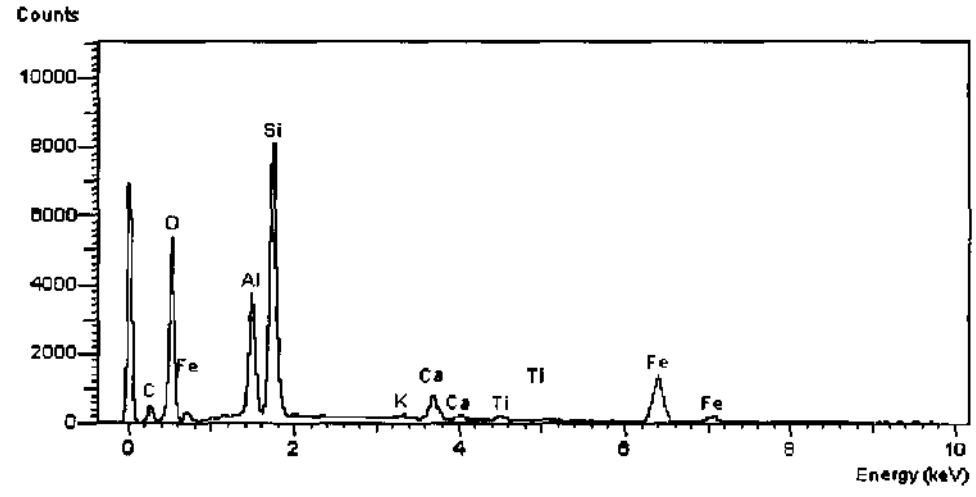



**Fig 94: Spectra of Sample 13: ROI No2 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 35.97 | 57.94 |
| Al | 24.78 | 23.67 |
| Si | 0.28 | 0.25 |
| Ti | 0.84 | 0.45 |
| V | 0.94 | 0.48 |
| Cr | 1.38 | 0.68 |
| Fe | 35.81 | 16.53 |
| Total | 100.00 | 100.00 |

**Table 81: Elemental composition of Sample 13, ROI No.2 Spot 2**

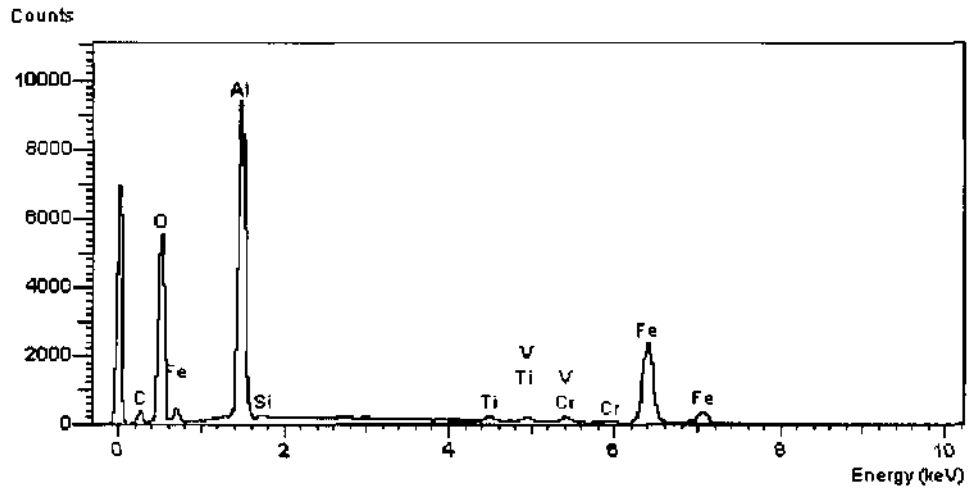



**Fig 95: Spectra of Sample13: ROI No2 Spot2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 31.22 | 56.82 |
| Mg | 0.24 | 0.29 |
| Si | 13.91 | 14.41 |
| Fe | 54.63 | 28.48 |
| Total | 100.00 | 100.00 |

**Table 82: Elemental composition of Sample 13, ROI No.2 Spot 3**

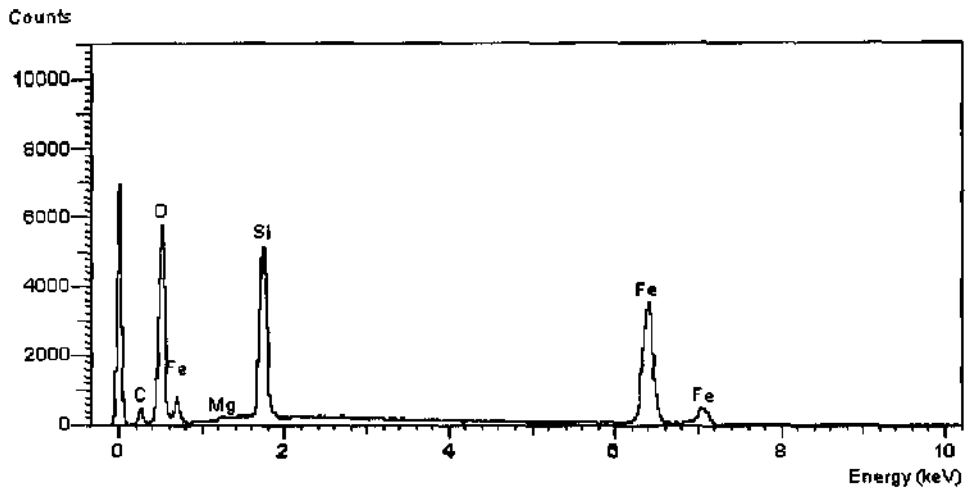



**Fig 96: Spectra of Sample 13: ROI No.2 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 38.58 | 58.60 |
| Al | 12.37 | 11.14 |
| Si | 19.58 | 16.94 |
| K | 0.73 | 0.45 |
| Ca | 1.87 | 1.13 |
| Ti | 0.58 | 0.29 |
| Fe | 26.29 | 11.44 |
| Total | 100.00 | 100.00 |

**Table 83: Elemental composition of Sample 14, ROI No. 1 Spot 1**

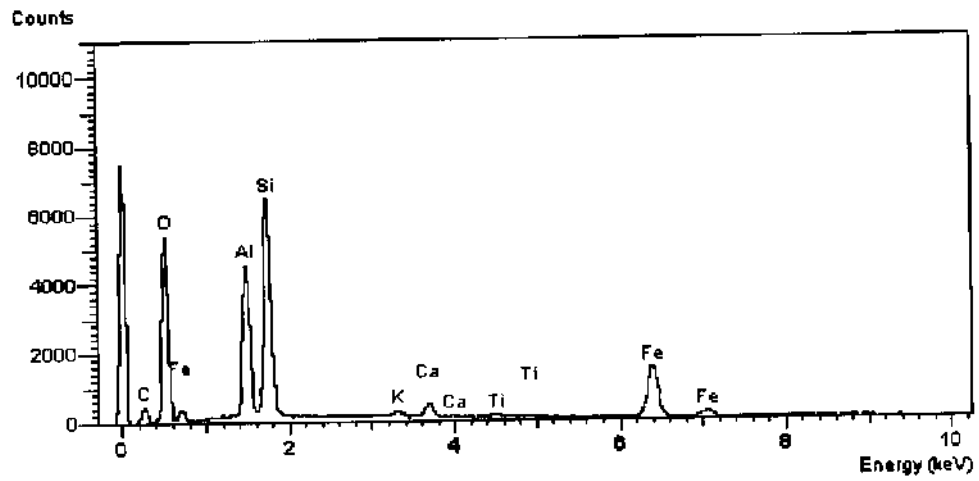



**Fig 97: Spectra of Sample 14: ROI No.1 Spot 1.EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 36.89 | 58.18 |
| Na | 0.22 | 0.25 |
| Al | 15.36 | 14.37 |
| Si | 12.08 | 10.85 |
| K | 1.04 | 0.67 |
| Ca | 0.33 | 0.21 |
| Ti | 0.85 | 0.45 |
| V | 0.18 | 0.09 |
| Fe | 33.05 | 14.93 |
| Total | 100.00 | 100.00 |

**Table 84: Elemental composition of Sample 14, ROI No. 1 Spot 2**

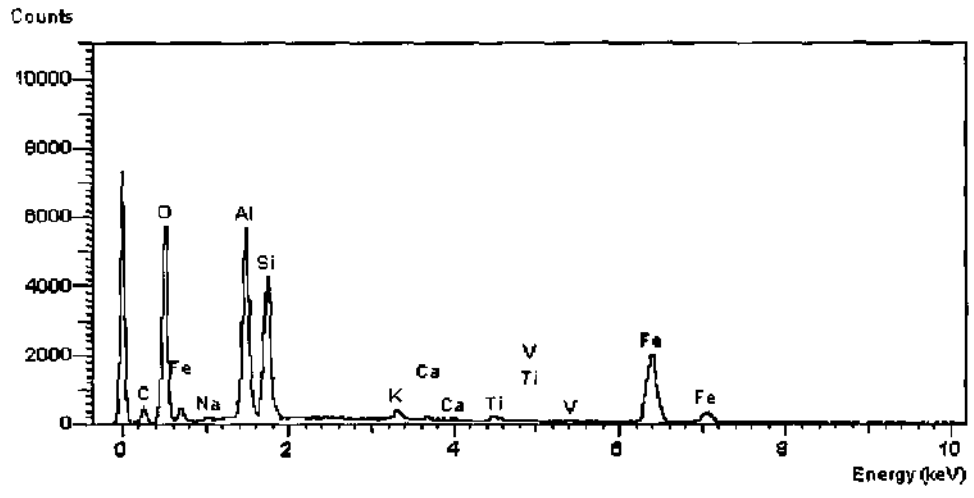



**Fig 98: Spectra of Sample 14: ROI No1 Spot 2.EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 30.79 | 56.31 |
| Mg | 0.11 | 0.13 |
| Al | 0.19 | 0.22 |
| Si | 13.99 | 14.57 |
| Fe | 54.92 | 28.77 |
| Total | 100.00 | 100.00 |

**Table 85: Elemental composition of Sample 14, ROI No.1 Spot 3**

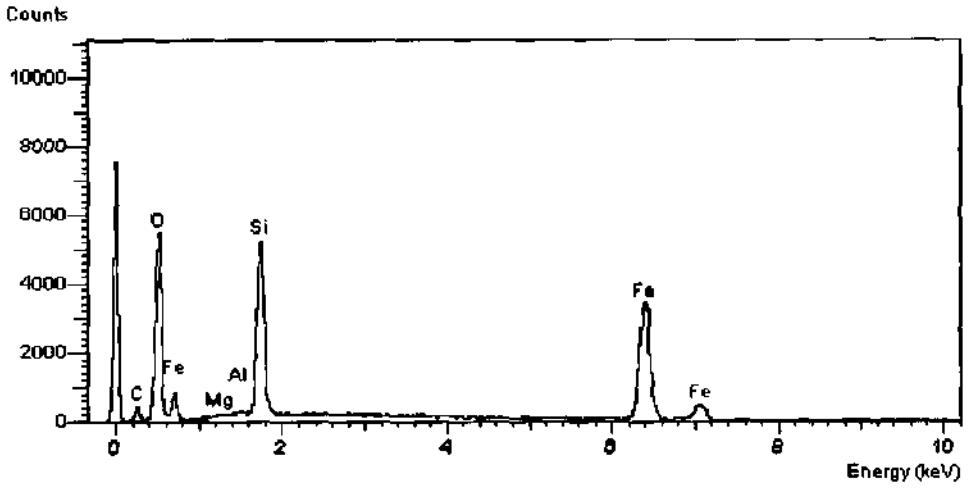



**Fig 99: Spectra of Sample14: ROI No 1 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 38.72 | 58.56 |
| Na | 0.22 | 0.23 |
| Al | 11.10 | 9.96 |
| Si | 20.82 | 17.93 |
| P | 0.14 | 0.10 |
| K | 1.04 | 0.64 |
| Ca | 2.43 | 1.47 |
| Ti | 0.66 | 0.33 |
| Fe | 24.87 | 10.78 |
| Total | 100.00 | 100.00 |

**Table86: Elemental composition of Sample 14, ROI No.2 Spot1**

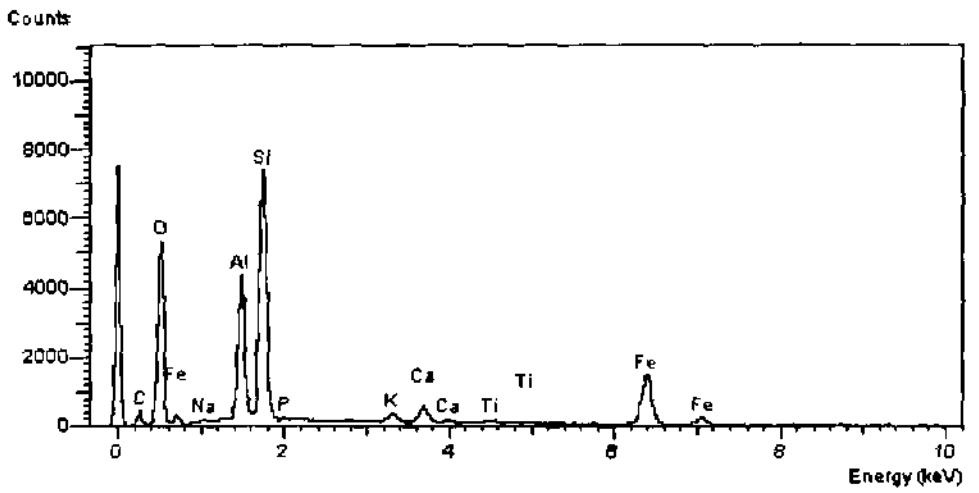



**Fig 100: Spectra of Sample14: ROI No2 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.44 | 56.33 |
| Al | 21.73 | 21.07 |
| Si | 3.98 | 3.70 |
| K | 0.40 | 0.27 |
| Ca | 0.20 | 0.13 |
| Ti | 1.10 | 0.60 |
| V | 0.42 | 0.22 |
| Fe | 37.73 | 17.68 |
| Total | 100.00 | 100.00 |

**Table87: Elemental composition of Sample 14, ROI No.2 Spot 2**

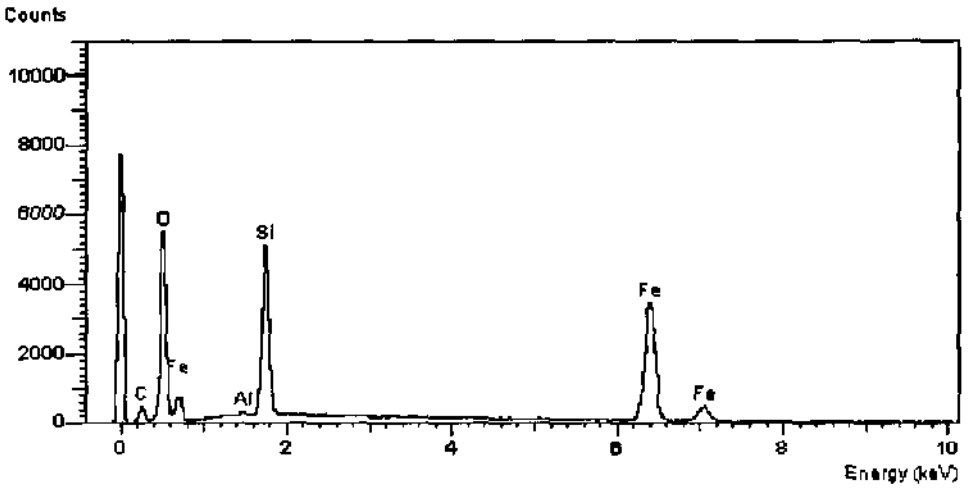



**Fig 102: Spectra of Sample14: ROI No2 Spot3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 39.17 | 59.01 |
| Al | 9.51 | 8.49 |
| Si | 20.56 | 17.65 |
| P | 0.15 | 0.12 |
| S | 0.07 | 0.05 |
| K | 1.36 | 0.84 |
| Ca | 7.18 | 4.32 |
| Ti | 0.42 | 0.20 |
| Fe | 21.58 | 9.32 |
| Total | 100.00 | 100.00 |

**Table89: Elemental composition of Sample 15, ROI No.1 Spot1**

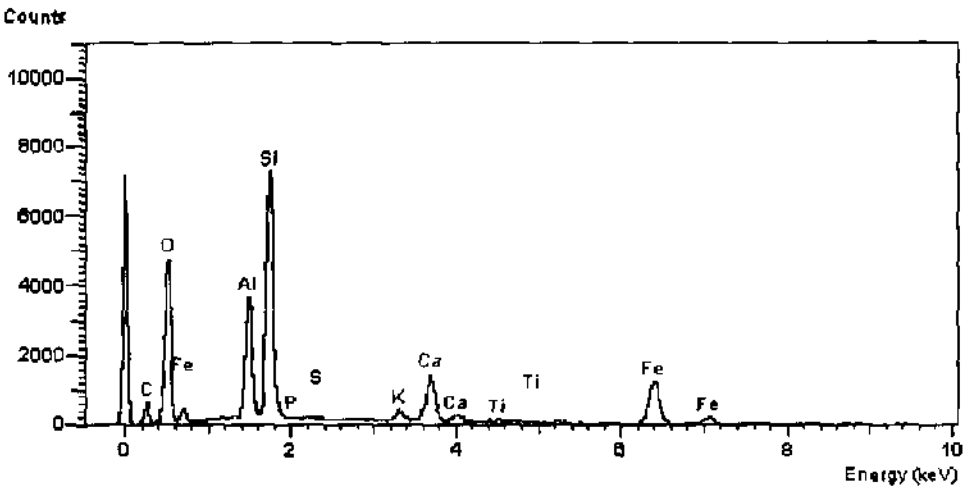



**Fig 103: Spectra of Sample15: ROI No.1 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.40 | 56.16 |
| Al | 18.26 | 18.77 |
| Si | 0.79 | 0.78 |
| Ti | 1.85 | 1.07 |
| V | 0.56 | 0.31 |
| Fe | 46.12 | 22.90 |
| Total | 100.00 | 100.00 |

**Table90: Elemental composition of Sample 15, ROI No.1 Spot2**

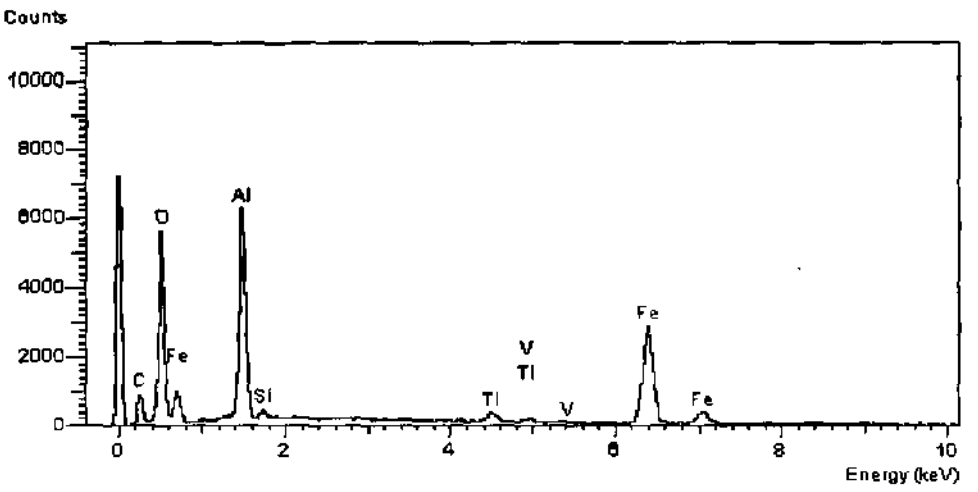



**Fig 104: Spectra of Sample 15: ROI No1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.41 | 56.16 |
| Al | 18.26 | 18.77 |
| Si | 0.79 | 0.78 |
| Ti | 1.85 | 1.07 |
| V | 0.56 | 0.31 |
| Fe | 46.13 | 22.91 |
| Total | 100.00 | 100.00 |

**Table91: Elemental composition of Sample 15, ROI No.1 Spot 3**

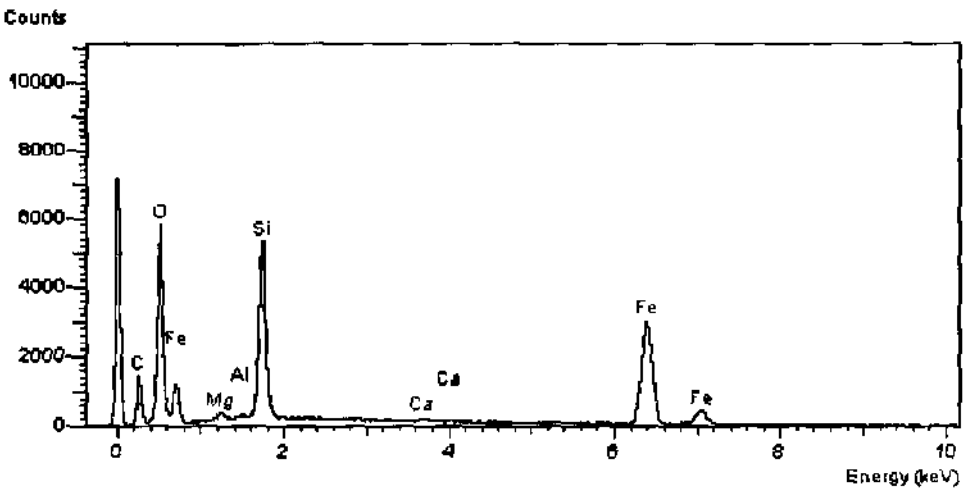



**Fig 105: Spectra of Sample15: ROI No1 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 39.91 | 59.42 |
| Al | 11.64 | 10.28 |
| Si | 19.22 | 16.30 |
| K | 1.17 | 0.71 |
| Ca | 7 .58 | 4.50 |
| Ti | 0.69 | 0.35 |
| Fe | 19.78 | 8.44 |
| Total | 100.00 | 100.00 |

**Table92: Elemental composition of Sample 15, ROI No.2 Spot 1**

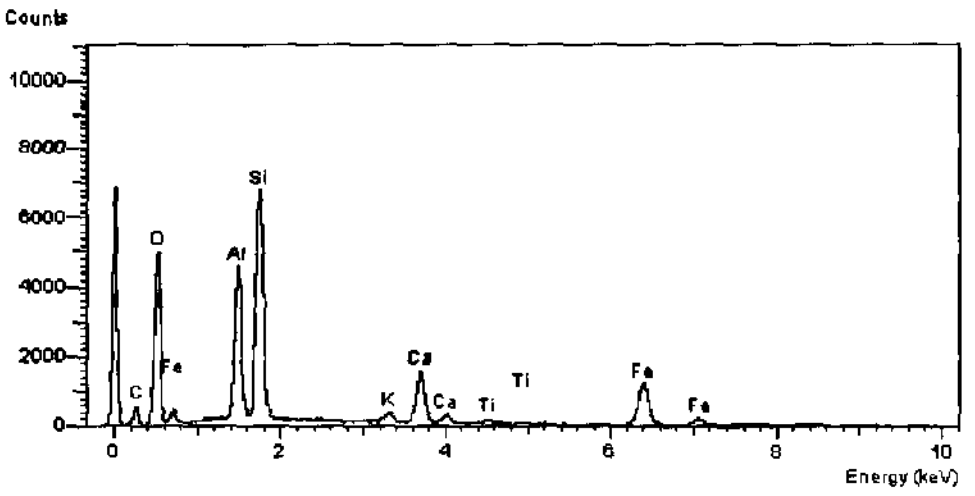



**Fig 106: Spectra of Sample 15: ROI No2 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 33.21 | 58.62 |
| Mg | 0.54 | 0.62 |
| Al | 0.17 | 0.18 |
| Si | 14.16 | 14.24 |
| K | 0.02 | 0.02 |
| Ca | 0.38 | 0.27 |
| Fe | 51.52 | 26.05 |
| Total | 100.00 | 100.00 |

**Table93: Elemental composition of Sample 15, ROI No.2 Spot 2**

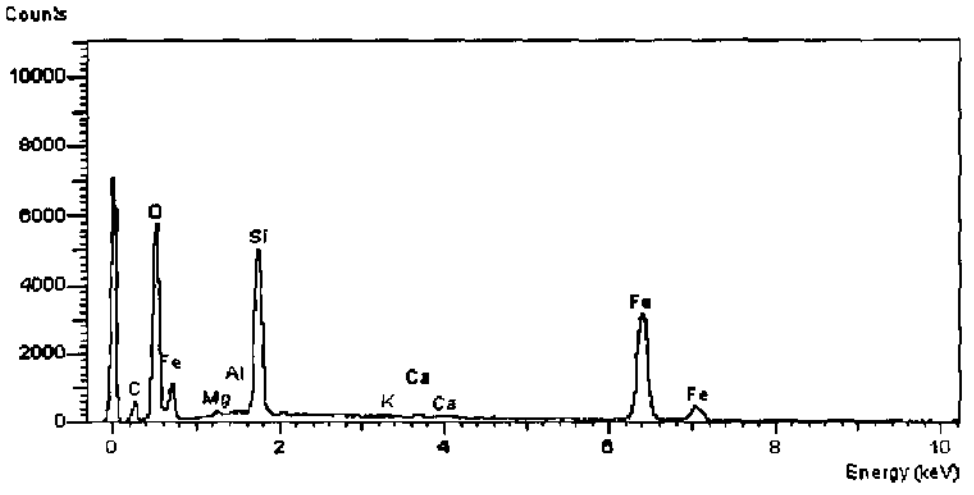



**Fig 107: Spectra of Sample15: ROI No2 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 37.16 | 58.33 |
| Al | 10.56 | 9.83 |
| Si | 15.25 | 13.63 |
| K | 0.50 | 0.32 |
| Ca | 7.67 | 4.82 |
| Ti | 1.30 | 0.68 |
| Fe | 27.56 | 12.39 |
| Total | 100.00 | 100.00 |

**Table94: Elemental composition of Sample 15, ROI No.2 Spot 3**

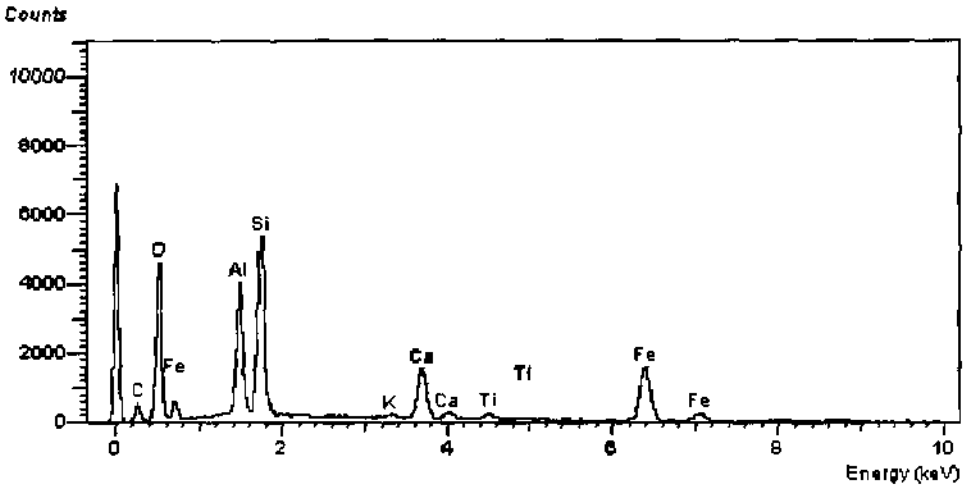



**Fig 108: Spectra of Sample15: ROI No 2 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 39.94 | 60.27 |
| Al | 10.52 | 9.41 |
| Si | 19.69 | 16.92 |
| K | 0.84 | 0.52 |
| Ca | 1.76 | 1.06 |
| Ti | 0.56 | 0.28 |
| Fe | 26.69 | 11.54 |
| Total | 100.00 | 100.00 |

**Table95: Elemental composition of Sample 16, ROI No.1 Spot 1**

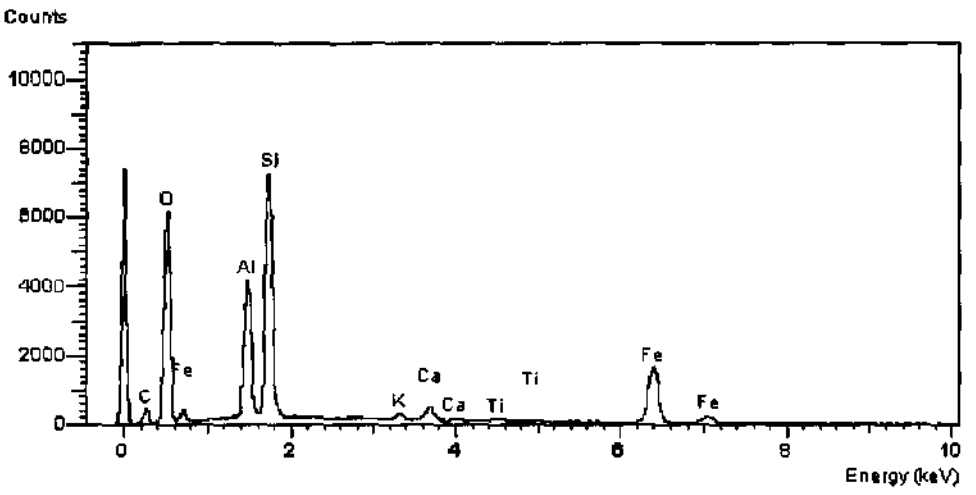



**Fig 109: Spectra of Sample 16: ROI No1 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 37.35 | 57.76 |
| Al | 11.34 | 10.40 |
| Si | 19.41 | 17.10 |
| K | 1.20 | 0.76 |
| Ca | 1.80 | 1.12 |
| Ti | 0.90 | 0.46 |
| Fe | 28.00 | 12.40 |
| Total | 100.00 | 100.00 |

**Table96: Elemental composition of Sample 16, ROI No.1 Spot2**

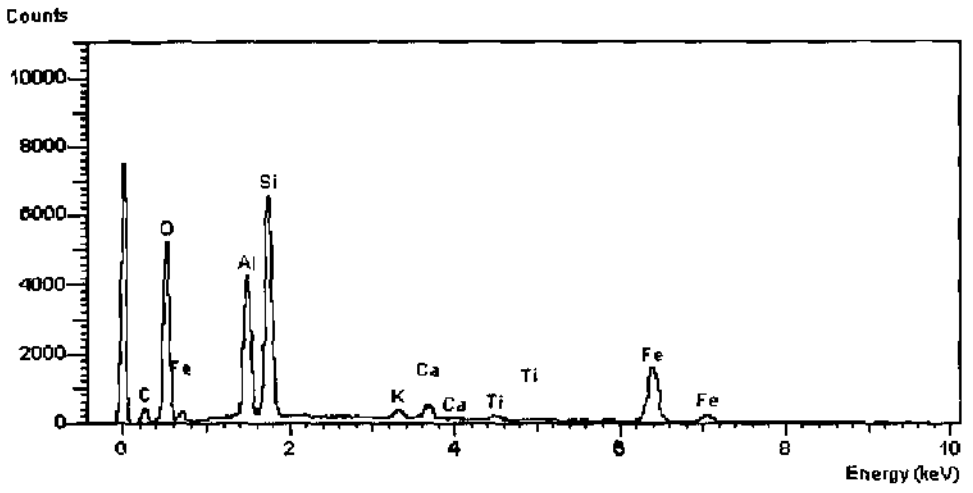



**Fig 110: Spectra of Sample 16: ROI No1 Spot2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.47 | 58.01 |
| Mg | 0.21 | 0.25 |
| Al | 0.27 | 0.29 |
| Si | 14.09 | 14.34 |
| Fe | 52.96 | 27.11 |
| Total | 100.00 | 100.00 |

**Table97: Elemental composition of Sample 16, ROI No.1 Spot 3**

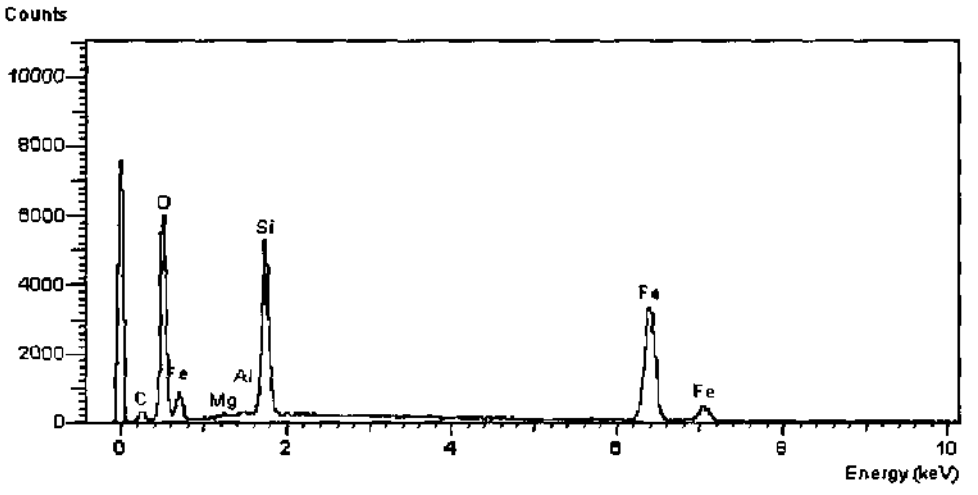



**Fig 111: Spectra of Sample 16: ROI No1 Spot 3 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 37.73 | 58.91 |
| Al | 9.11 | 8.43 |
| Si | 19.09 | 16.98 |
| K | 0.88 | 0.56 |
| Ca | 1.34 | 0.84 |
| Ti | 0.54 | 0.28 |
| Fe | 31.31 | 14.00 |
| Total | 100.00 | 100.00 |

**Table98: Elemental composition of Sample 16, ROI No.2 Spot1**

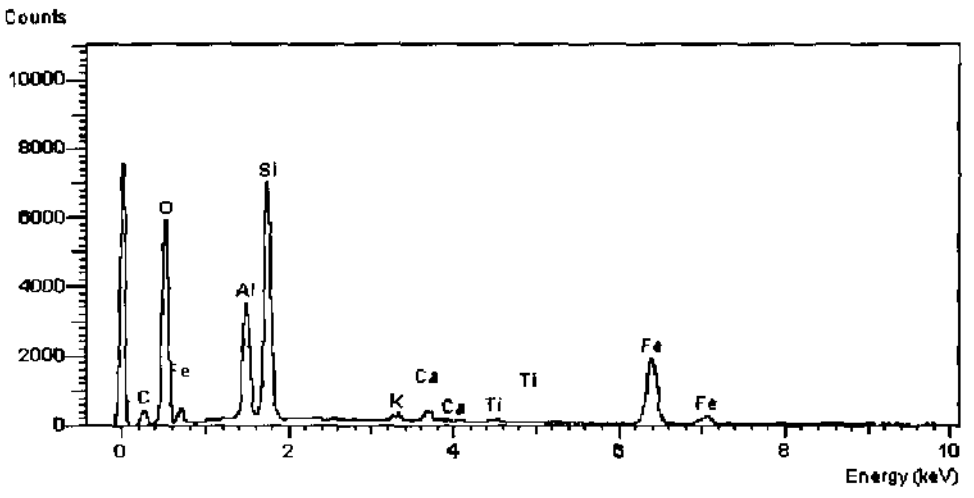



**Fig 112: Spectra of Sample16: ROI No.2 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 37.04 | 58.61 |
| Mg | 0.08 | 0.08 |
| Al | 25.99 | 24.38 |
| Si | 0.17 | 0.15 |
| P | 0.08 | 0.07 |
| Ti | 0.53 | 0.28 |
| V | 0.66 | 0.33 |
| Cr | 0.90 | 0.44 |
| Fe | 34.55 | 15.66 |
| Total | 100.00 | 100.00 |

**Table99: Elemental *composition of* Sample 16, ROI No.2 Spot 2**

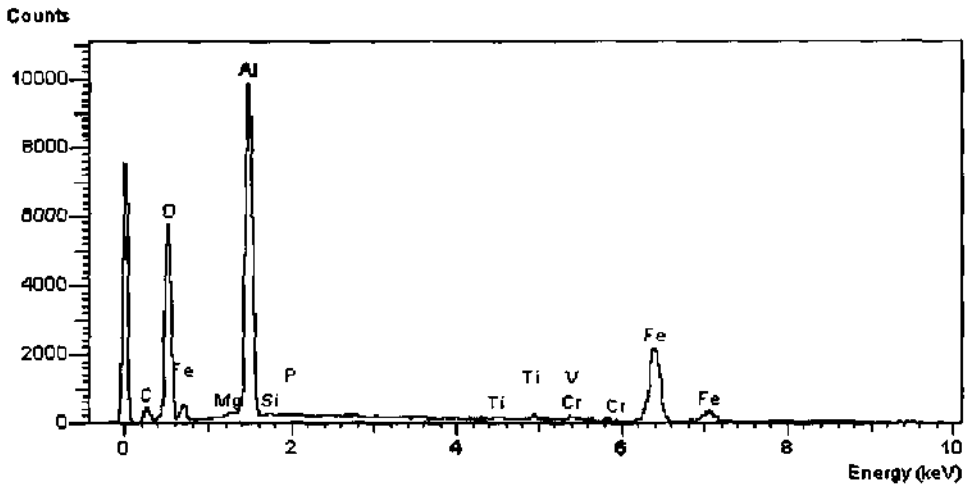



**Fig 113: Spectra of Sample 16: ROI No.2 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 31.57 | 57.05 |
| Mg | 0.25 | 0.30 |
| Al | 0.17 | 0.18 |
| Si | 14.17 | 14.59 |
| Fe | 53.84 | 27.88 |
| Total | 100.00 | 100.00 |

**Table100: Elemental compostion of Sample 16, ROI No.2 Spot 3**

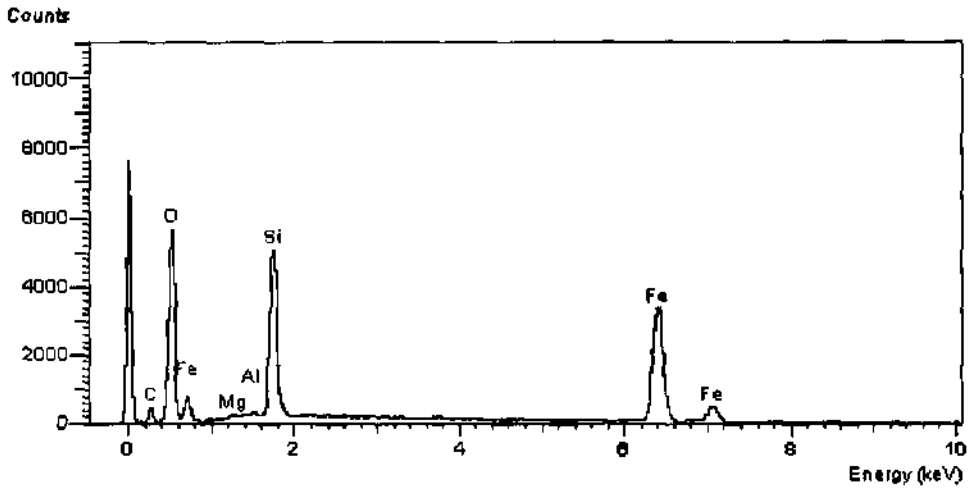



**Fig 114: Spectra of Sample 16 ROI No 2 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| **O** | 39.48 | 56.08 |
| **Al** | 12.94 | 10.90 |
| **Si** | 26.83 | 21.72 |
| **K** | 16.33 | 9.49 |
| **Ti** | 0.22 | 0.10 |
| Fe | 4.20 | 1.71 |
| Total | 100.00 | 100.00 |

**Table101: Elemental composition of Sample 17, ROI No.1 Spot1**

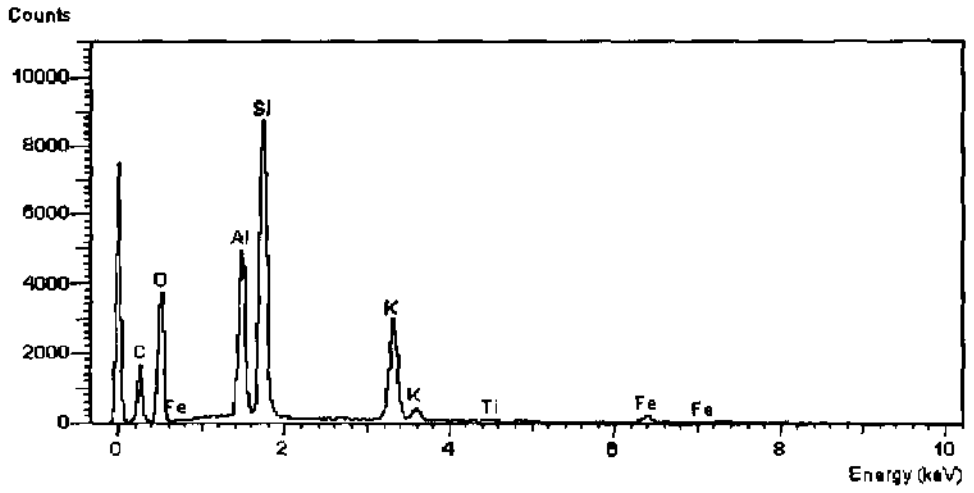



**Fig 115: Spectra of Sample 17: ROI No1 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 39.48 | 56.08 |
| Al | 12.94 | 10.90 |
| Si | 26.83 | 21.72 |
| K | 16.33 | 9.49 |
| Ti | 0.22 | 0.10 |
| Fe | 4.20 | 1.71 |
| Total | 100.00 | 100.00 |

**Table102: Elemental composition of Sample 17, ROI No.1 Spot2**

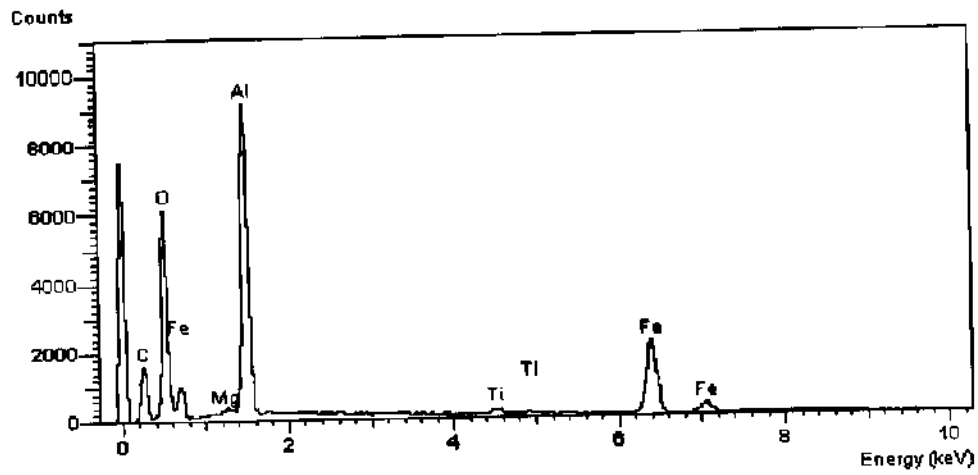



**Fig 116: Spectra of Sample17: ROI No.1 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 33.77 | 55.09 |
| Mg | 0.26 | 0.28 |
| Al | 27.44 | 26.54 |
| Ti | 1.07 | 0.58 |
| Fe | 37.46 | 17.51 |
| Total | 100.00 | 100.00 |

**Table103: Elemental composition of Sample 17, ROI No.1 Spot 3**

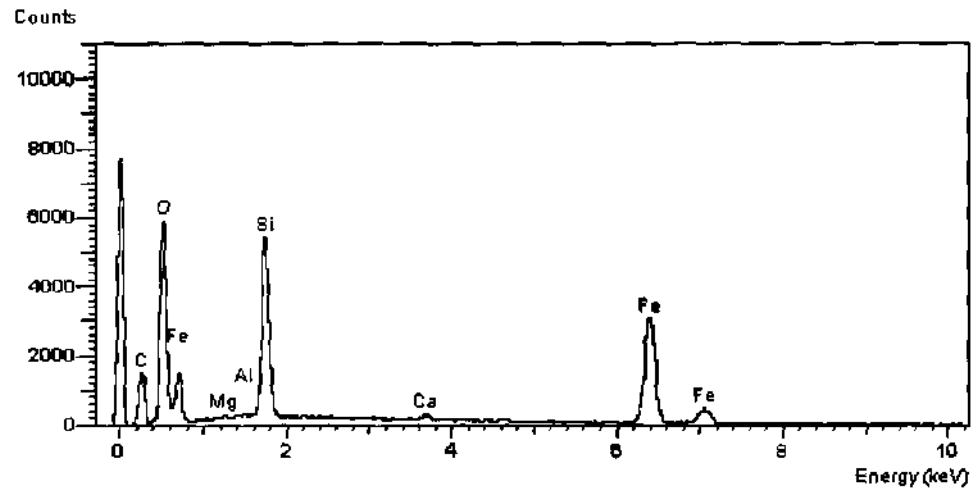



**Fig 117: Spectra of Sample 17: ROI No.1 Spot 3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 22.50 | 50.19 |
| Al | 0.17 | 0.22 |
| Si | 0.25 | 0.32 |
| Ti | 0.26 | 0.19 |
| Fe | 76.82 | 49.08 |
| Total | 100.00 | 100.00 |

**Table104: Elemental composition of Sample 17, ROI No.1 Spot 4**

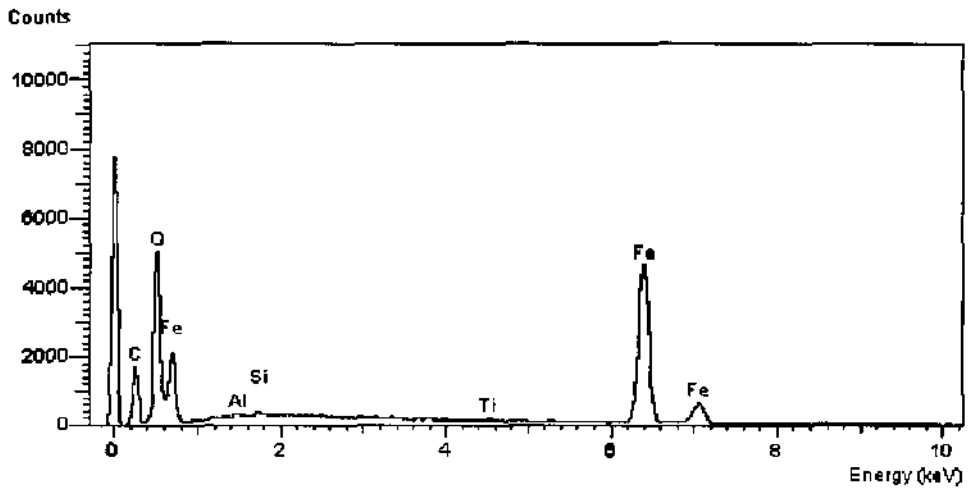



**Fig118: Spectra of Sample 17: ROI No.1 Spot4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 44.41 | 60.66 |
| Al | 12.11 | 9.81 |
| Si | 25.28 | 19.67 |
| K | 16.32 | 9.12 |
| Fe | 1.88 | 0.74 |
| Total | 100.00 | 100.00 |

**Table105: Elemental composition of Sample 17, ROI No. 2 Spot 1**

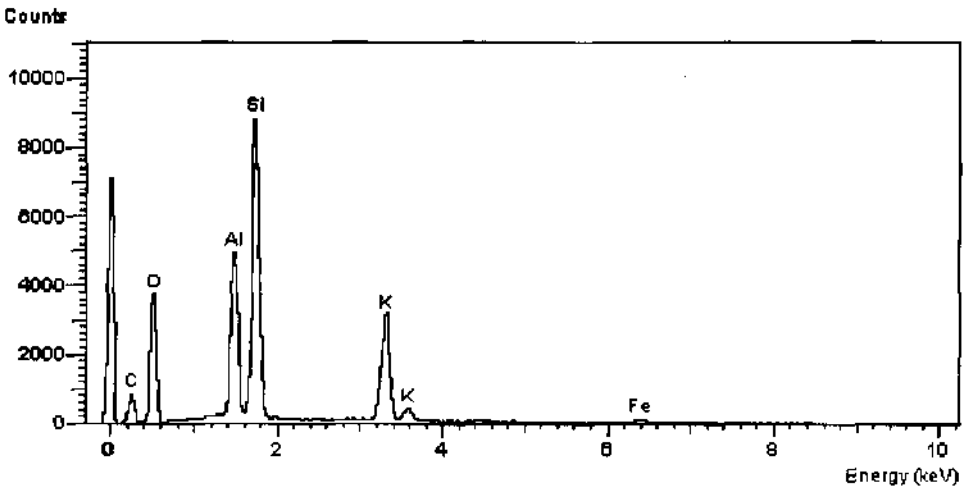



**Fig 119: Spectra of Sample 17: ROI No.2 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.22 | 55.73 |
| Na | 0.20 | 0.22 |
| Mg | 0.28 | 0.30 |
| Al | 26.42 | 25.51 |
| Ti | 1.27 | 0.69 |
| Fe | 37.61 | 17.55 |
| Total | 100.00 | 100.00 |

**Table106: Elemental composition of Sample 17, ROI No.2 Spot 2**

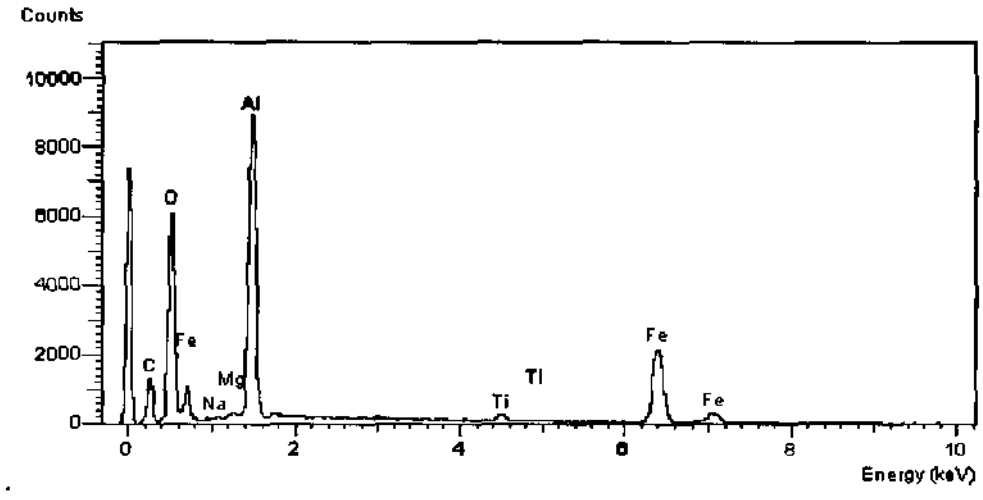



**Fig 120: Spectra of Sample 17: ROI No.2 Spot2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.67 | 60.14 |
| Mg | 0.35 | 0.40 |
| Al | 0.10 | 0.10 |
| Si | 14.29 | 14.12 |
| Ca | 0.54 | 0.37 |
| Fe | 50.05 | 24.87 |
| Total | 100.00 | 100.00 |

**Table107: Elemental composition of Sample 17, ROI No.2 Spot 3**

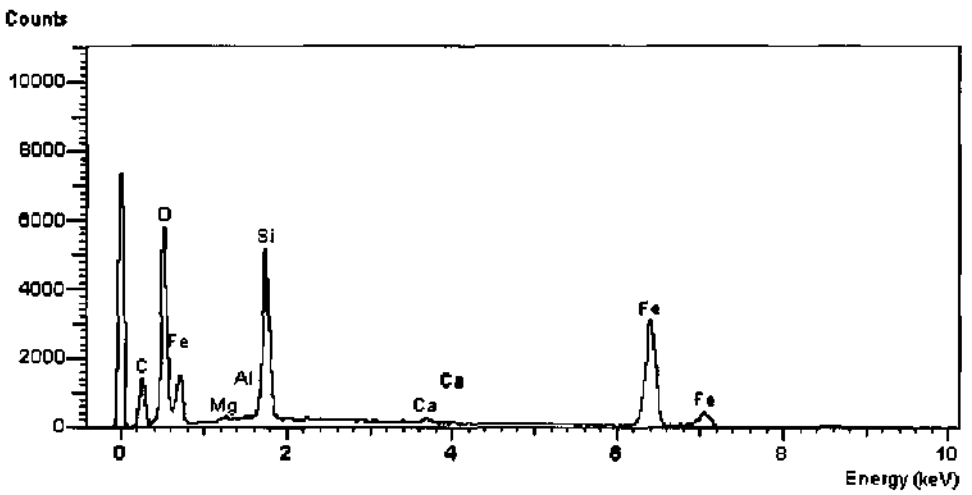



**Fig 121: Spectra of Sample 17: ROI No2 Spot3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 23.43 | 51.44 |
| Al | 0.23 | 0.31 |
| Si | 0.33 | 0.41 |
| Ti | 0.46 | 0.34 |
| Fe | 75.55 | 47.50 |
| Total | 100.00 | 100.00 |

**Table108: Elemental composition of Sample 17, ROI No.2 Spot 4**

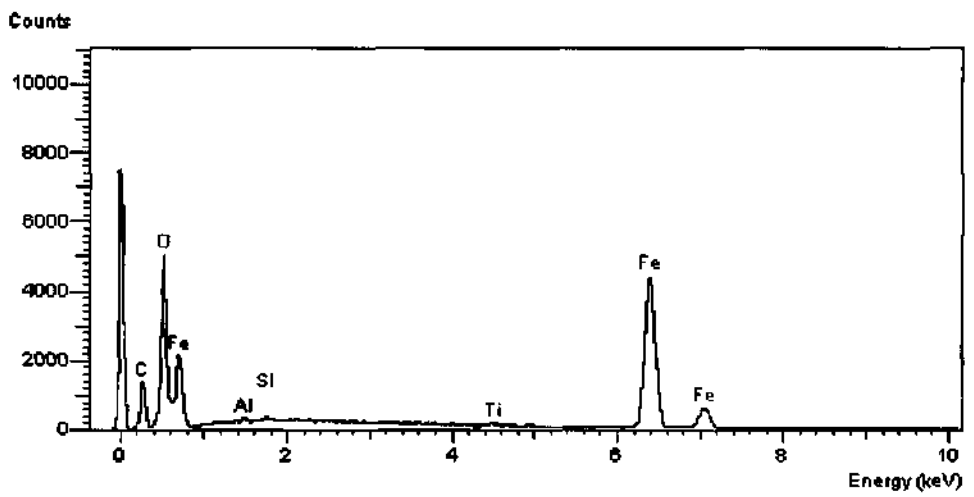



**Fig 122: Spectra of Sample17: ROI No2 Spot 4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.35 | 57.55 |
| Mg | 0.23 | 0.26 |
| Al | 1.66 | 1.75 |
| Si | 13.42 | 13.60 |
| P | 0.36 | 0.33 |
| Mn | 1.51 | 0.78 |
| Fe | 50.49 | 25.73 |
| Total | 100.00 | 100.00 |

**Table 109: Elemental composition of Sample 18, ROI No.1 Spot 1**

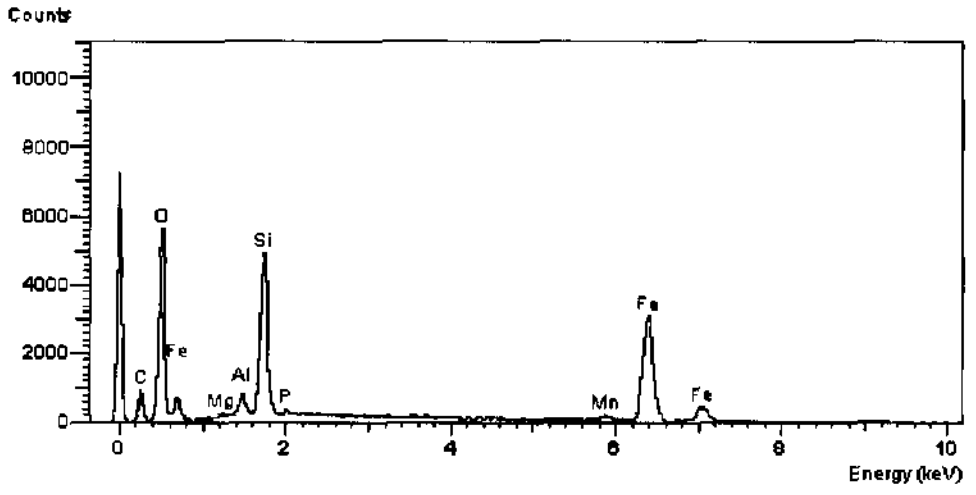



**Fig 123: Spectra of Sample 18: ROI No.1 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 31.42 | 56.89 |
| Mg | 0.23 | 0.28 |
| Al | 0.27 | 0.29 |
| Si | 13.17 | 13.59 |
| P | 0.96 | 0.90 |
| Ca | 0.22 | 0.15 |
| Mn | 1.65 | 0.87 |
| Fe | 52.08 | 27.03 |
| Total | 100.00 | 100.00 |

**Table110: Elemental composition of Sample 18, ROI No.1 Spot 2**

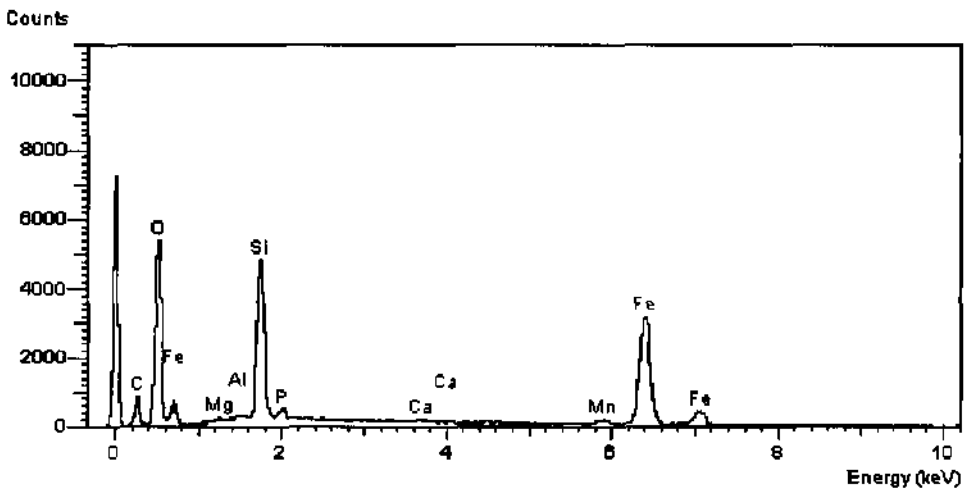



**Fig 124: Spectra of Sample18: ROI No1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 42.15 | 61.12 |
| Al | 23.40 | 20.12 |
| Si | 8.78 | 7.25 |
| P | 0.96 | 0.72 |
| K | 0.85 | 0.50 |
| Ca | 1.51 | 0.88 |
| Ti | 1.75 | 0.85 |
| Mn | 0.48 | 0.20 |
| Fe | 20.12 | 8.36 |
| Total | 100.00 | 100.00 |

**Table111: Elemental composition of Sample 18, ROI No.1 Spot 3**

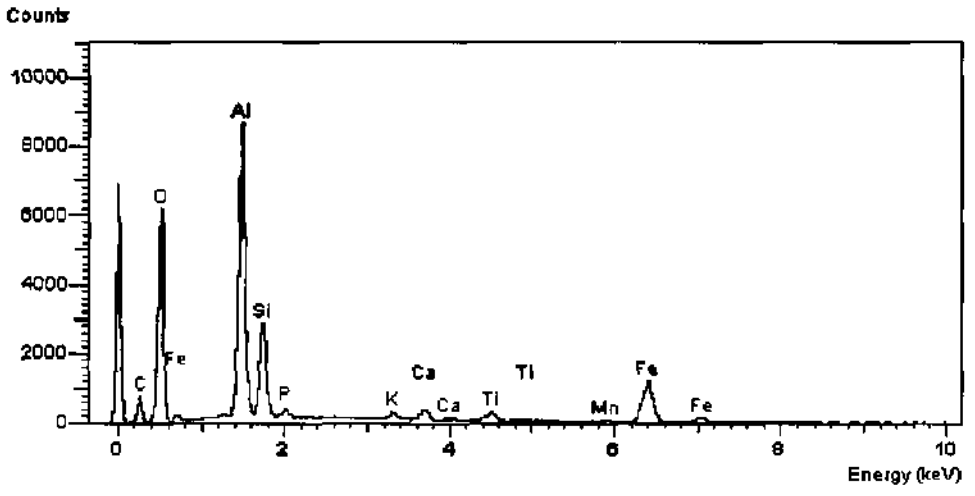



**Fig 125: Spectra of Sample 18: ROI No.1 Spot3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 27.89 | 52.50 |
| Mg | 0.37 | 0.45 |
| Al | 1.06 | 1.18 |
| Si | 14.36 | 15.40 |
| Ca | 0.20 | 0.15 |
| Ti | 0.15 | 0.11 |
| Mn | 1.85 | 1.02 |
| Fe | 54.12 | 29.19 |
| Total | 100.00 | 100.00 |

**Table112: Elemental composition of Sample 18, ROI No.1 Spot 4**

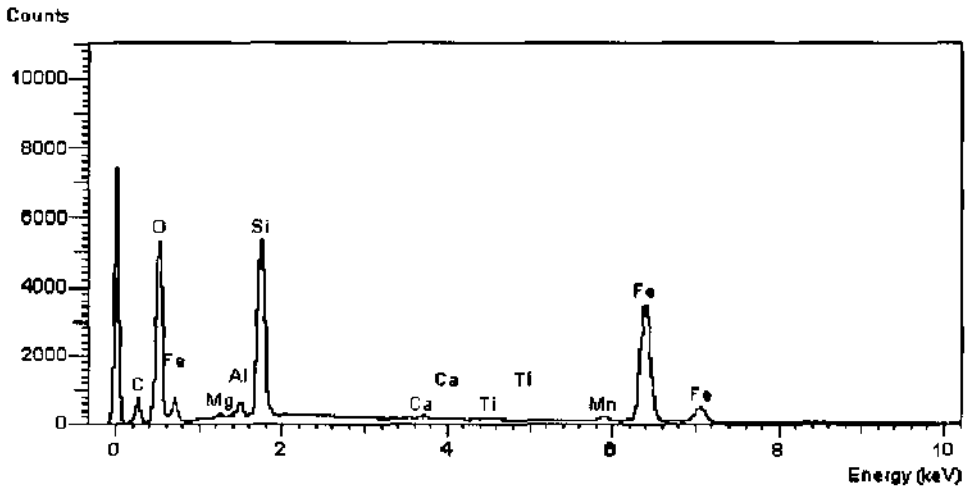



**Fig 126: Spectra of Sample18: ROI No 1 Spot 4 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 39.64 | 59.43 |
| Al | 7.71 | 6.85 |
| Si | 21.46 | 18.33 |
| P | 2.05 | 1.58 |
| K | 1.44 | 0.88 |
| Ca | 5.57 | 3.33 |
| Ti | 1.11 | 0.56 |
| Mn | 0.64 | 0.28 |
| Fe | 20.38 | 8.76 |
| Total | 100.00 | 100.00 |

**Table113: Elemental composition of Sample 18, ROI No. 2 Spot1**

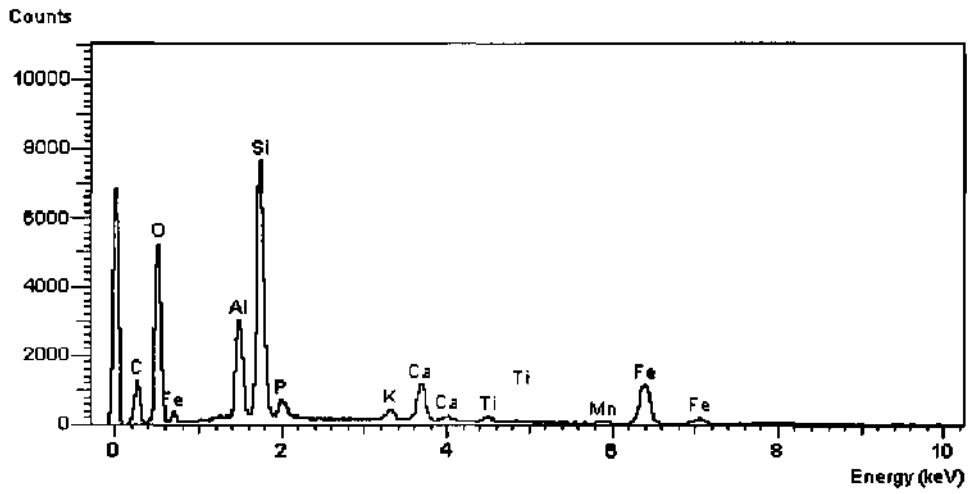



**Fig 127: Spectra of Sample18: ROI No.2 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.38 | 55.49 |
| Al | 20.53 | 20.86 |
| Si | 0.29 | 0.28 |
| Ti | 4.45 | 2.55 |
| V | 0.65 | 0.35 |
| Mn | 0.70 | 0.35 |
| Fe | 41.00 | 20.12 |
| Total | 100.00 | 100.00 |

**Table114: Elemental composition of Sample 18, ROI No.2 Spot 2**

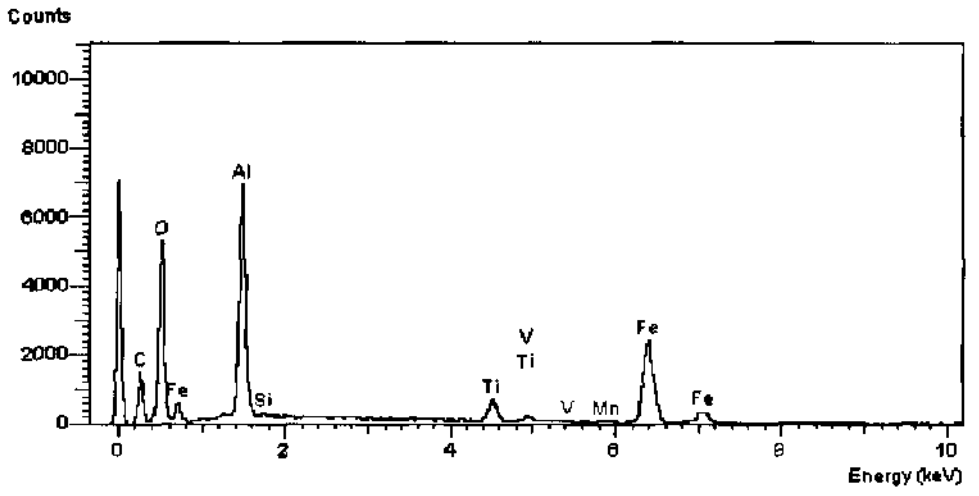



**Fig 128: Spectra of Sample 18: ROI No 2 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.08 | 54.81 |
| Al | 18.66 | 18.90 |
| Si | 3.10 | 3.02 |
| P | 0.25 | 0.22 |
| K | 0.46 | 0.32 |
| Ca | 0.51 | 0.35 |
| Ti | 4.72 | 2.70 |
| Mn | 0.56 | 0.28 |
| Fe | 39.66 | 19.40 |
| Total | 100.00 | 100.00 |

**Table115: Elemental composition of Sample 18, ROI No.2 Spot 3**

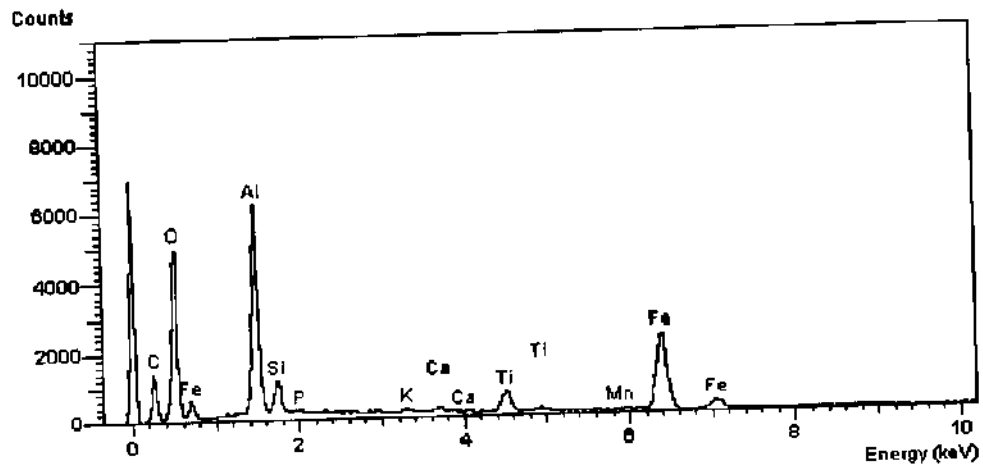



**Fig 129: Spectra of Sample18: ROI No2 Spot3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 28.40 | 53.08 |
| Mg | 0.43 | 0.53 |
| Al | 0.40 | 0.44 |
| Si | 14.70 | 15.65 |
| P | 0.40 | 0.39 |
| Ca | 0.23 | 0.17 |
| Ti | 0.33 | 0.22 |
| Mn | 1.94 | 1.05 |
| Fe | 53.17 | 28.47 |
| Total | 100.00 | 100.00 |

**Table116: Elemental composition of Sample 18, ROI NO.2 Spot 4**

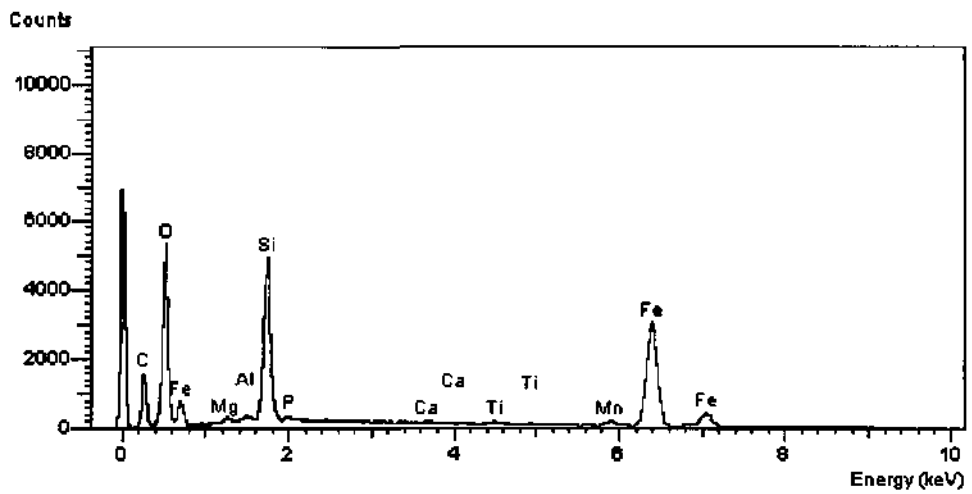



**Fig 130: Spectra of Sample18: ROI No 2 Spot 4 EDS**

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| Elmt | Element % | Atomic % |
|---|---|---|
| O | 37.34 | 58.79 |
| Mg | 0.21 | 0.22 |
| Al | 5.96 | 5.56 |
| Si | 20.53 | 18.42 |
| K | 1.27 | 0.82 |
| Ca | 2.85 | 1.79 |
| Ti | 0.47 | 0.25 |
| Fe | 31.37 | 14.15 |
| Total | 100.00 | 100.00 |

**Table117: Elemental composition of Sample 19, ROI No.1 Spot 1**

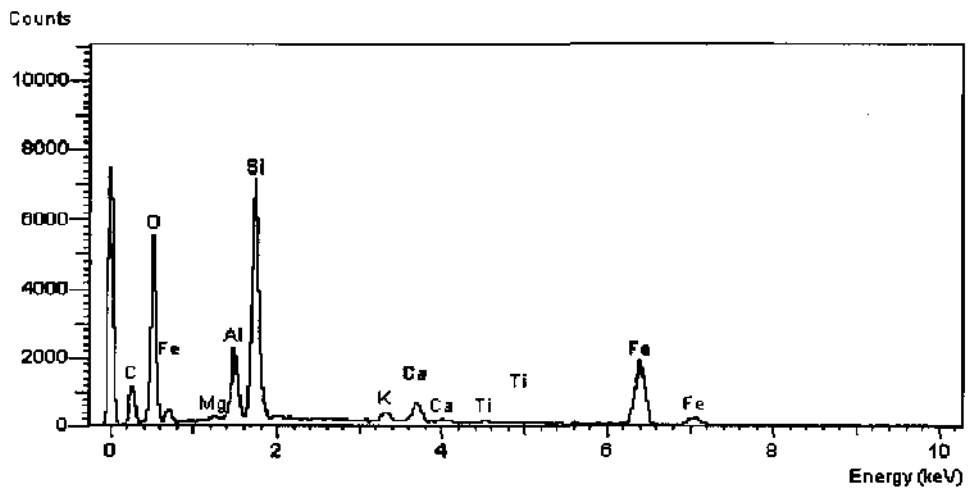



**Fig 131: Spectra of Sample 19 ROI No.1 Spot1 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 33.60 | 56.23 |
| Mg | 0.18 | 0.20 |
| Al | 5.25 | 5.20 |
| Si | 18.03 | 17.19 |
| K | 0.75 | 0.51 |
| Ca | 2.12 | 1.42 |
| Ti | 0.48 | 0.27 |
| Fe | 39.59 | 18.98 |
| Total | 100.00 | 100.00 |

**Table118: Elemental composition of Sample 19, ROI No.1 Spot 2**

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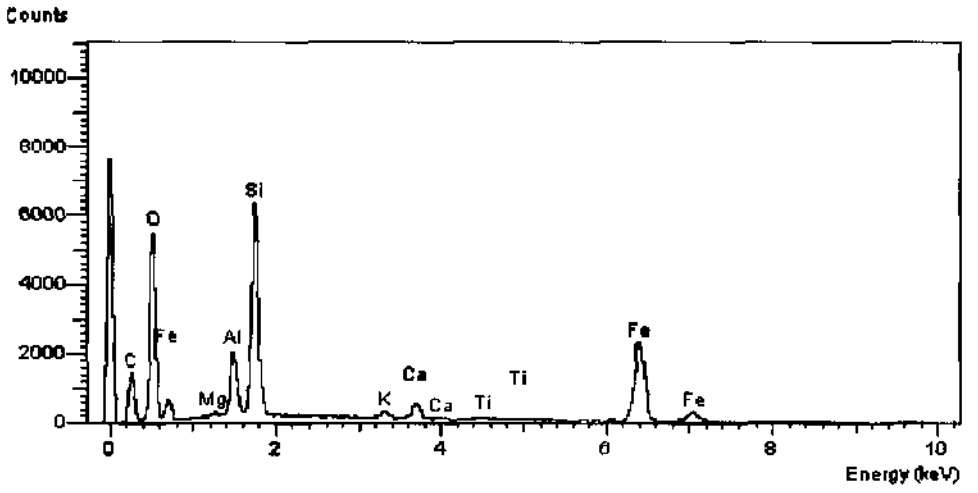



**Fig132: Spectra of Sample 19 ROI No.1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 38.62 | 58.98 |
| Al | 8.97 | 8.12 |
| Si | 20.47 | 17.81 |
| K | 1.18 | 0.74 |
| Ca | 4.83 | 2.94 |
| Ti | 0.89 | 0.46 |
| Fe | 25.05 | 10.96 |
| Total | 100.00 | 100.00 |

**Table119: Elemental composition of Sample 19, ROI No.2 Spot 1**

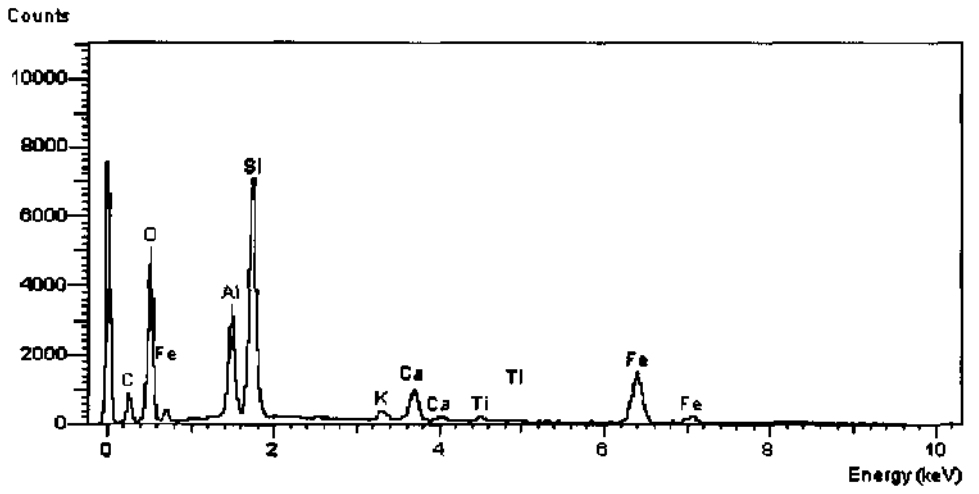



**Fig133: Spectra of Sample 19 ROI No.2 Spot1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 32.33 | 57.70 |
| Mg | 0.62 | 0.72 |
| Al | 0.20 | 0.21 |
| **Si** | 14.10 | 14.34 |
| Ca | 0.32 | 0.23 |
| Fe | 52.43 | 26.80 |
| Total | 100.00 | 100.00 |

**Table120: Elemental composition of Sample 19, ROI No.2 Spot 2**

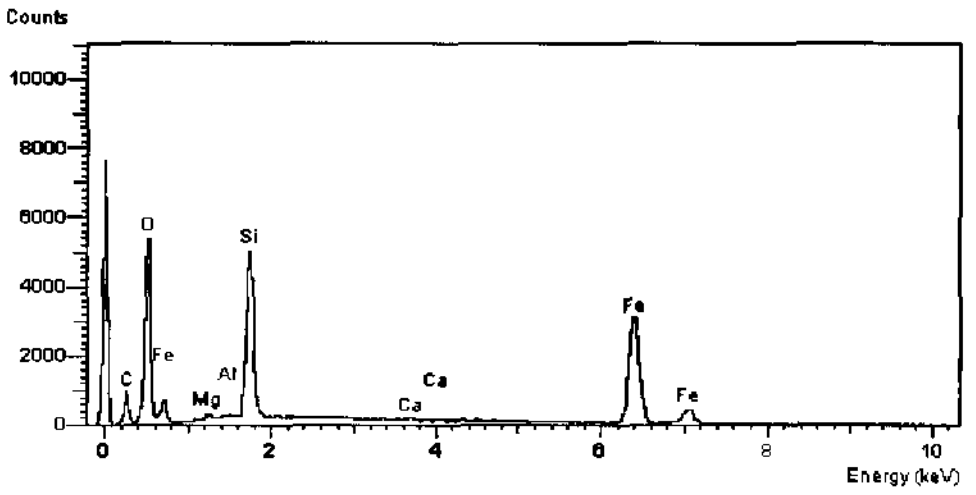



**Fig134: Spectra of Sample 19 ROI No.2 Spot 2 EDS**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 44.84 | 61.37 |
| Na | 0.20 | 0.20 |
| Mg | 0.65 | 0.59 |
| Al | 9.48 | 7.69 |
| Si | 29.85 | 23.27 |
| K | 3.21 | 1.80 |
| Ca | 2.86 | 1.56 |
| Ti | 0.48 | 0.22 |
| Fe | 8.43 | 3.30 |
| Total | 100.00 | 100.00 |

**Table121: Elemental composition of Sample 20, ROI No.1 Spot 1**

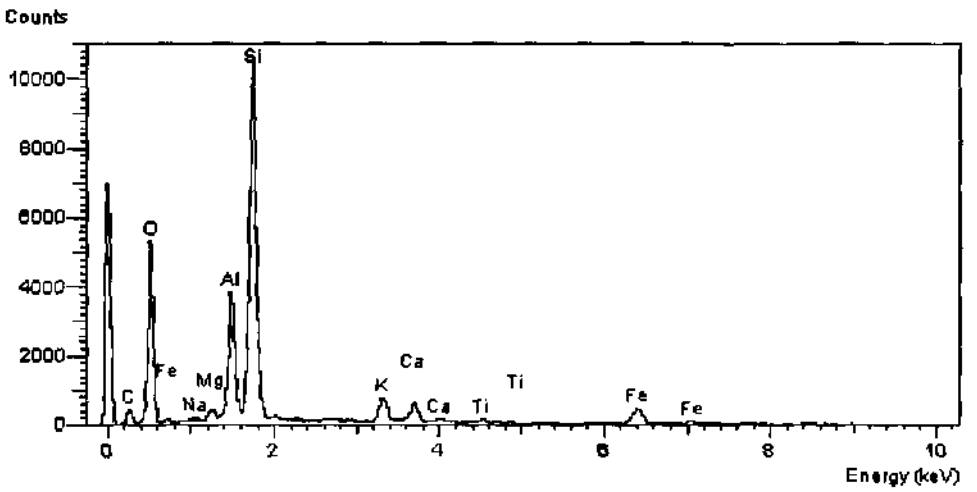



**Fig 135: Spectra of Sample 20: ROI No1 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 34.15 | 61.08 |
| Mg | 0.14 | 0.17 |
| Al | 5.86 | 6.22 |
| Si | 3.19 | 3.25 |
| K | 0.25 | 0.18 |
| Ca | 0.15 | 0.11 |
| Ti | 2.05 | 1.22 |
| Fe | 54.21 | 27.78 |
| Total | 100.00 | 100.00 |

**Table122: Elemental composition of Sample 20, ROI No.1 Spot 2**

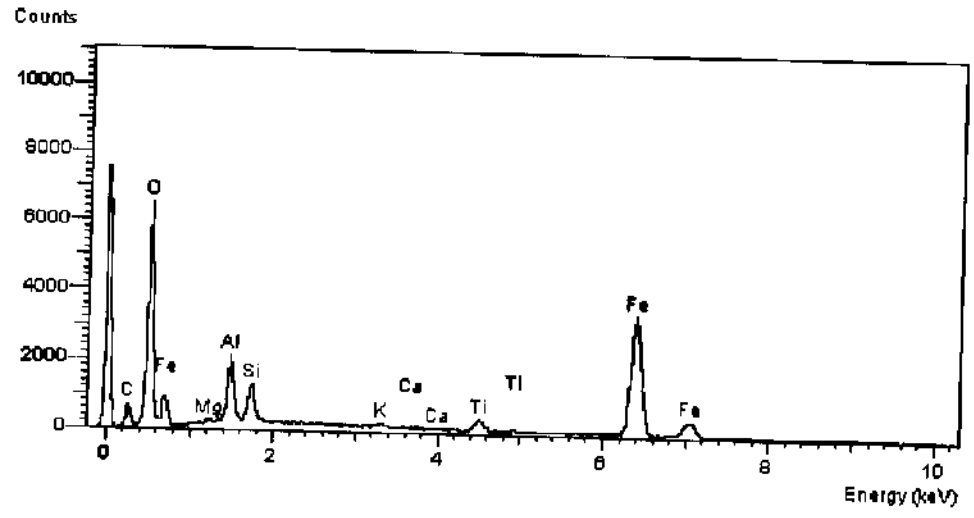



**Fig 136: Spectra of Sample 20: ROI No1 Spot 2 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 46.43 | 62.23 |
| Mg | 0.24 | 0.21 |
| Al | 12.92 | 10.27 |
| Si | 29.31 | 22.38 |
| K | 2.87 | 1.57 |
| Ca | 1.08 | 0.58 |
| Ti | 0.41 | 0.18 |
| Fe | 6.74 | 2.59 |
| Total | 100.00 | 100.00 |

**Table123: Elemental composition of Sample 20, ROI No.1 Spot 3**

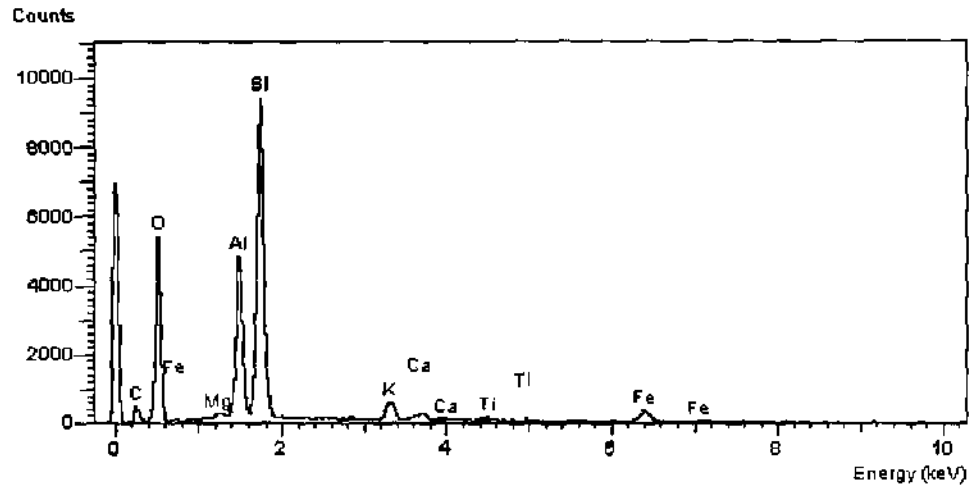



**Fig 137: Spectra of Sample 20: ROI No1 Spot3 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 44.69 | 61.29 |
| Na | 0.21 | 0.20 |
| Mg | 0.60 | 0.54 |
| Al | 9.57 | 7.78 |
| Si | 28.37 | 22.17 |
| P | 0.38 | 0.27 |
| K | 3.34 | 1.87 |
| Ca | 5.36 | 2.94 |
| Ti | 0.76 | 0.35 |
| Fe | 6.43 | 2.53 |
| Zr | 0.30 | 0.07 |
| Total | 100.00 | 100.00 |

**Table124: Elemental composition of Sample 20, ROI No.2 Spot1**

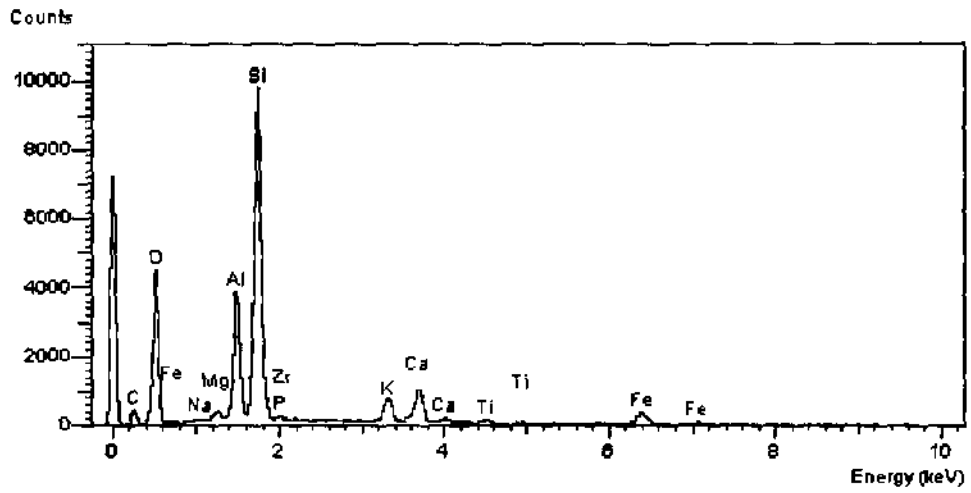



**Fig138: Spectra of Sample 20 ROI No.2 Spot 1 EDS.**

| Elmt | Element % | Atomic % |
|---|---|---|
| O | 29.43 | 57.10 |
| Mg | 1.37 | 1.75 |
| Al | 4.45 | 5.12 |
| Ti | 0.38 | 0.24 |
| Fe | 64.38 | 35.79 |
| Total | 100.00 | 100.00 |

**Table125: Elemental composition of Sample 20, ROI No.2 Spot 2**

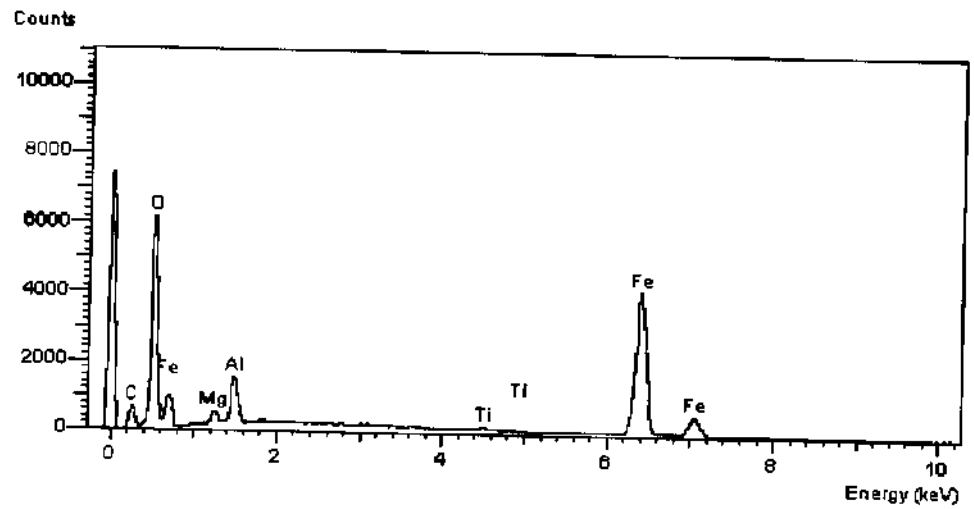



**Fig139: Spectra of Sample 20 ROI No. 2 Spot 2 EDS.**

## Appendix III: Graphs showing melting temperatures of iron slag samples.

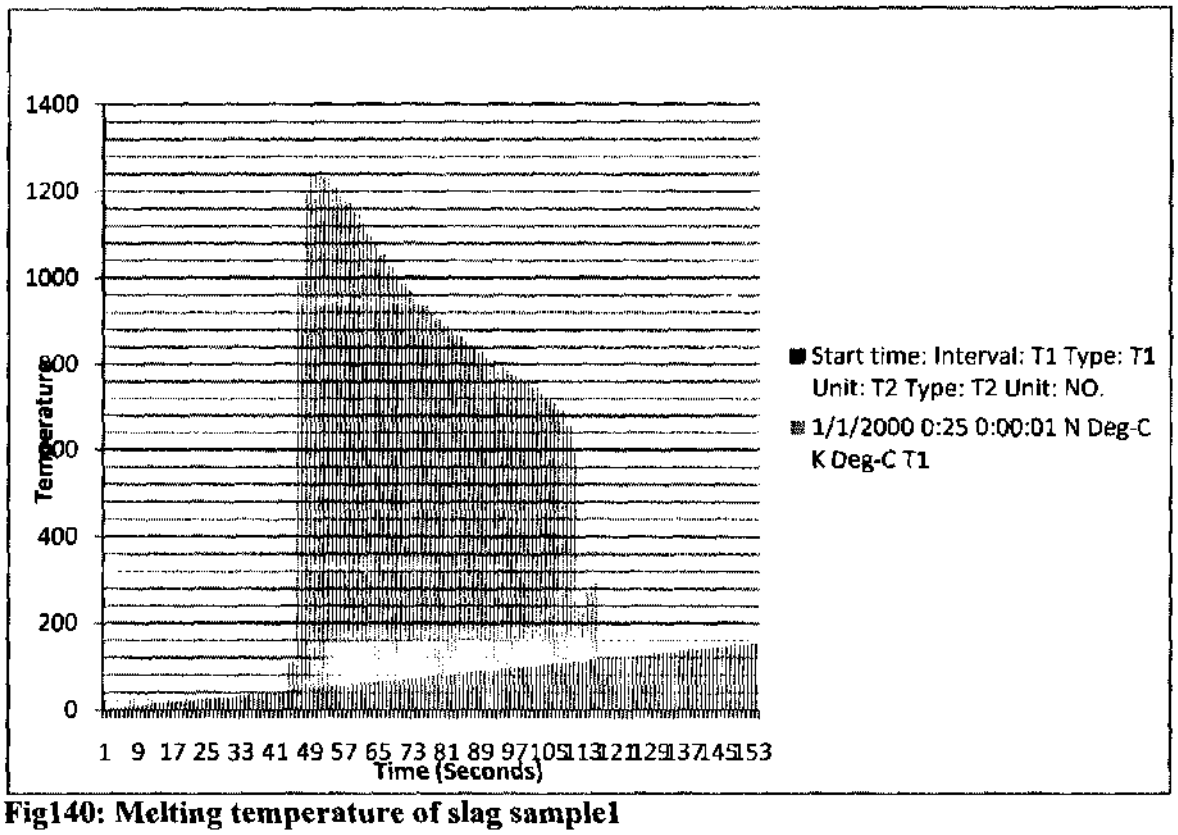



**Fig140: Melting temperature of slag sample1**

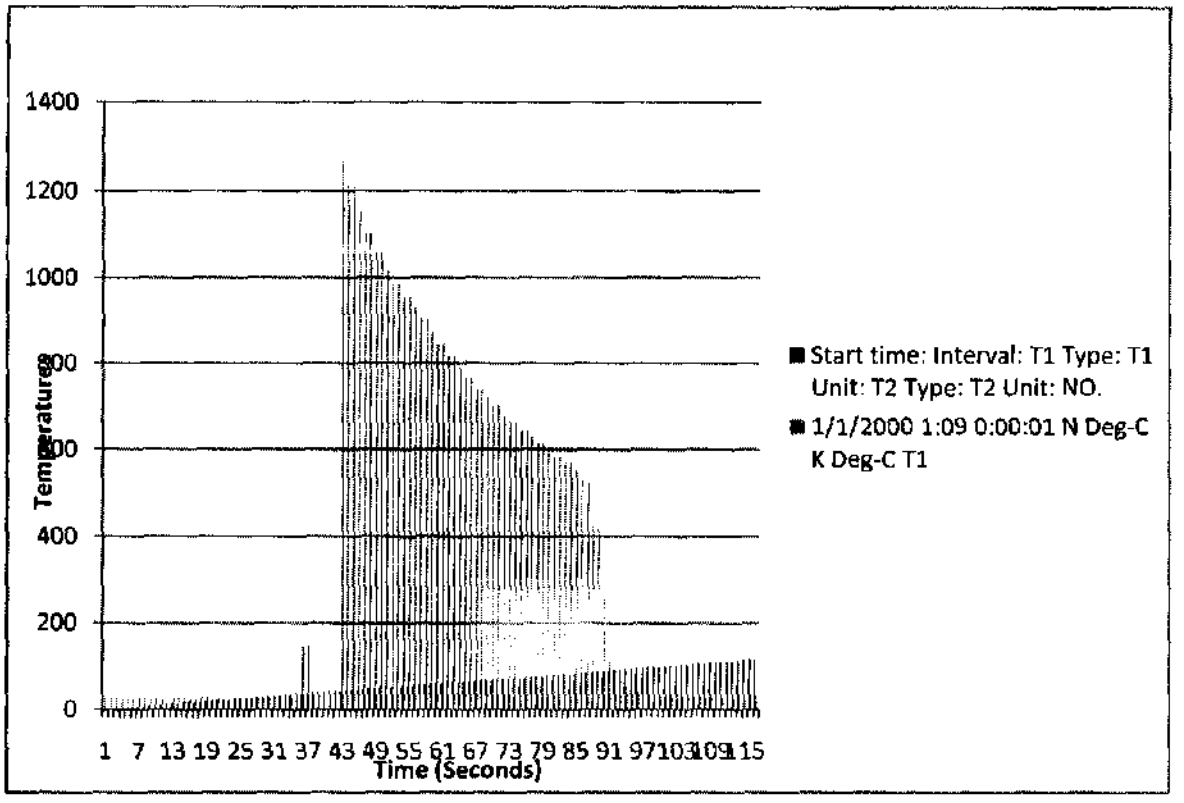



**Fig 141: Melting temperature of slag sample 2**

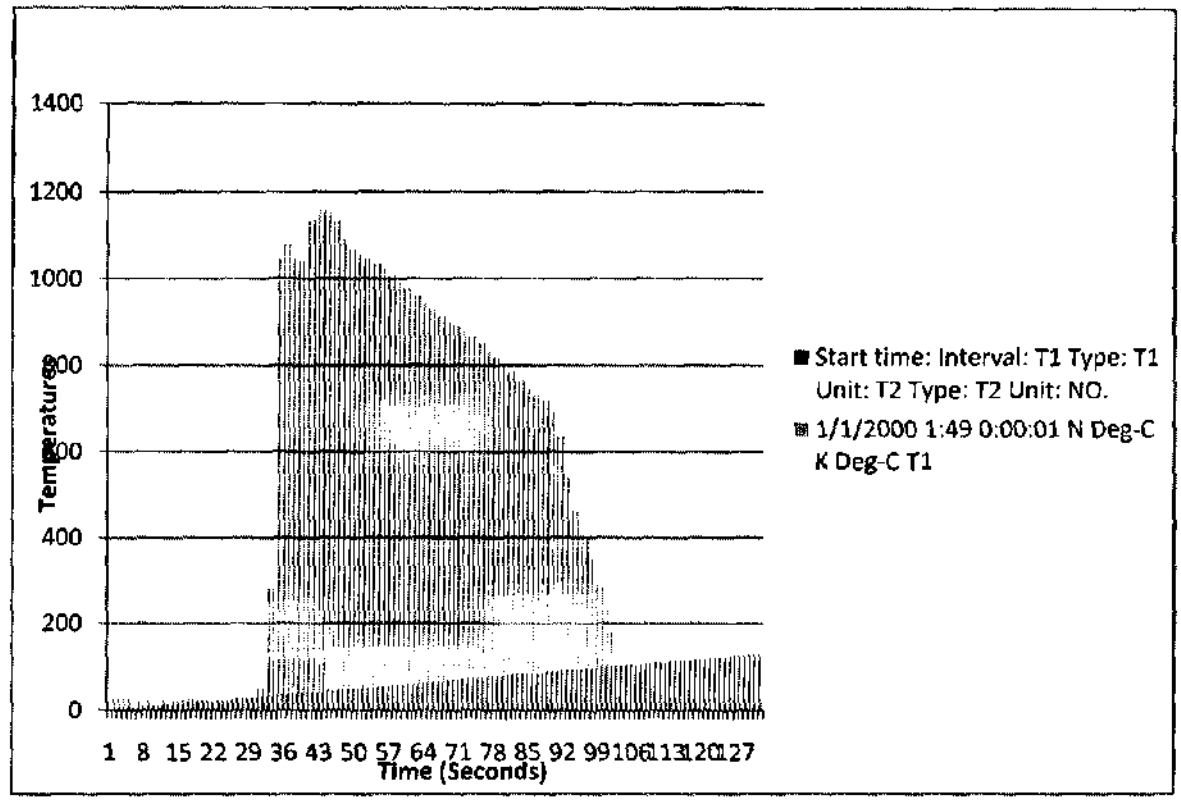



**Fig 142: Melting temperature of slag sample 3.**

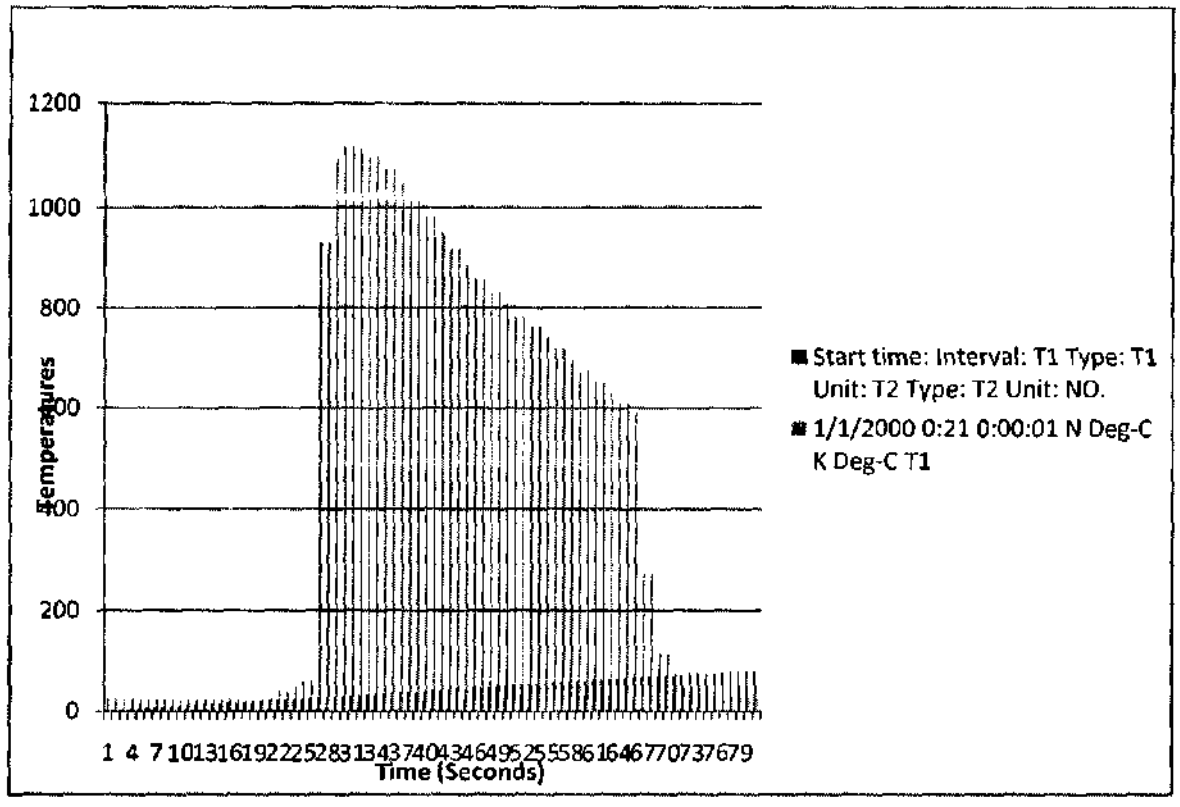



**Fig143: Melting temperature of slag sample 4.**

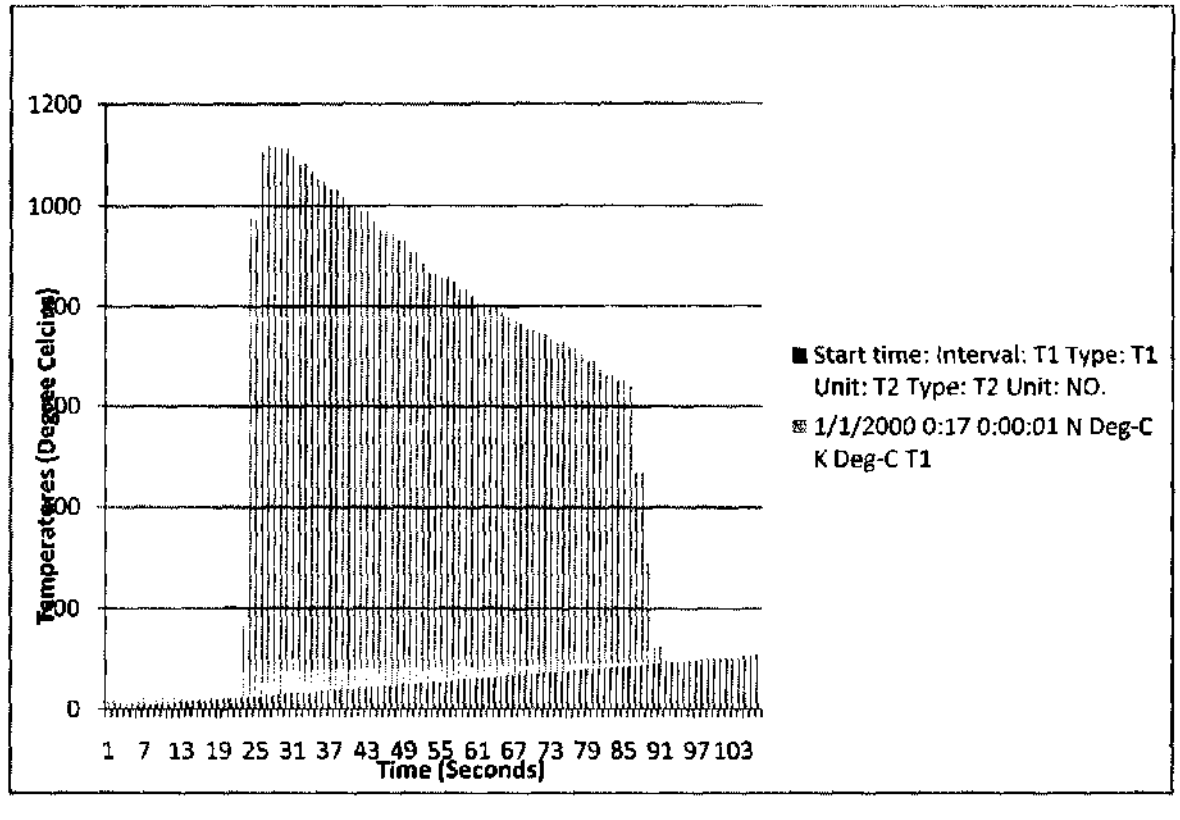



**Fig144: Melting temperature of slag sample 7.**

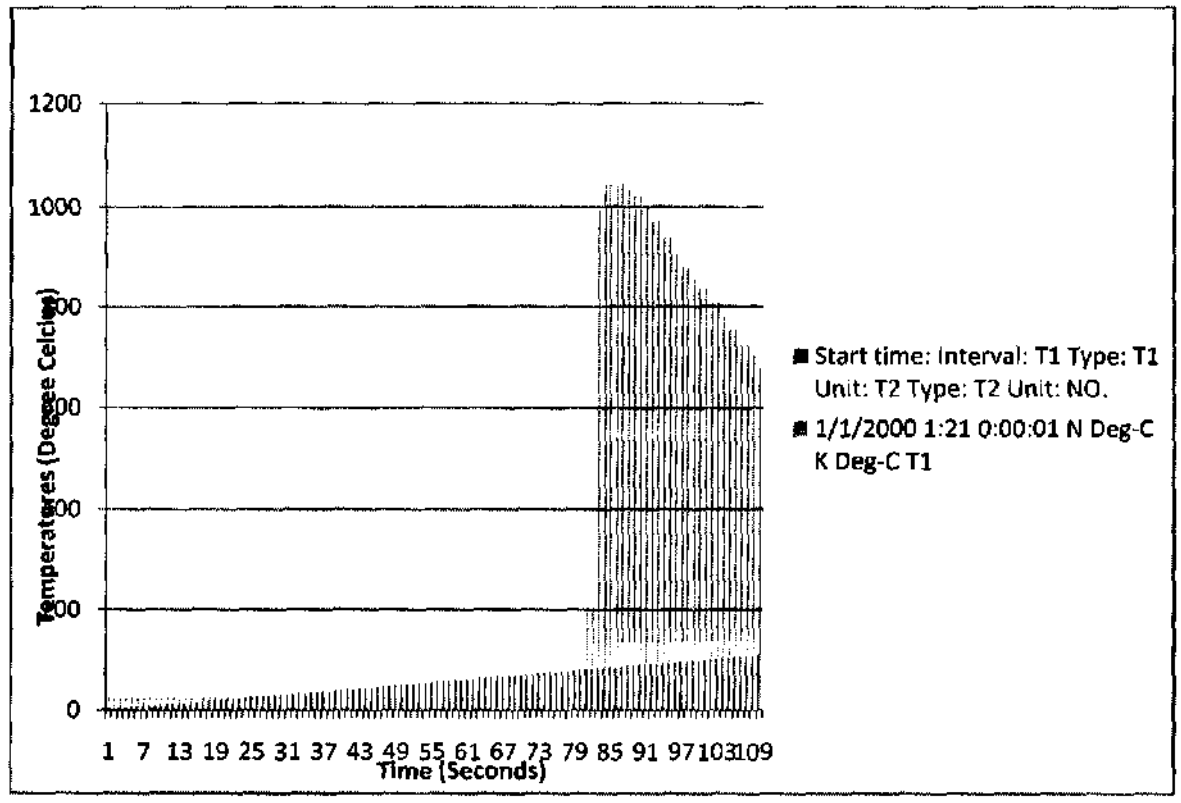



**Fig145: Melting temperature of slag sample 8.**

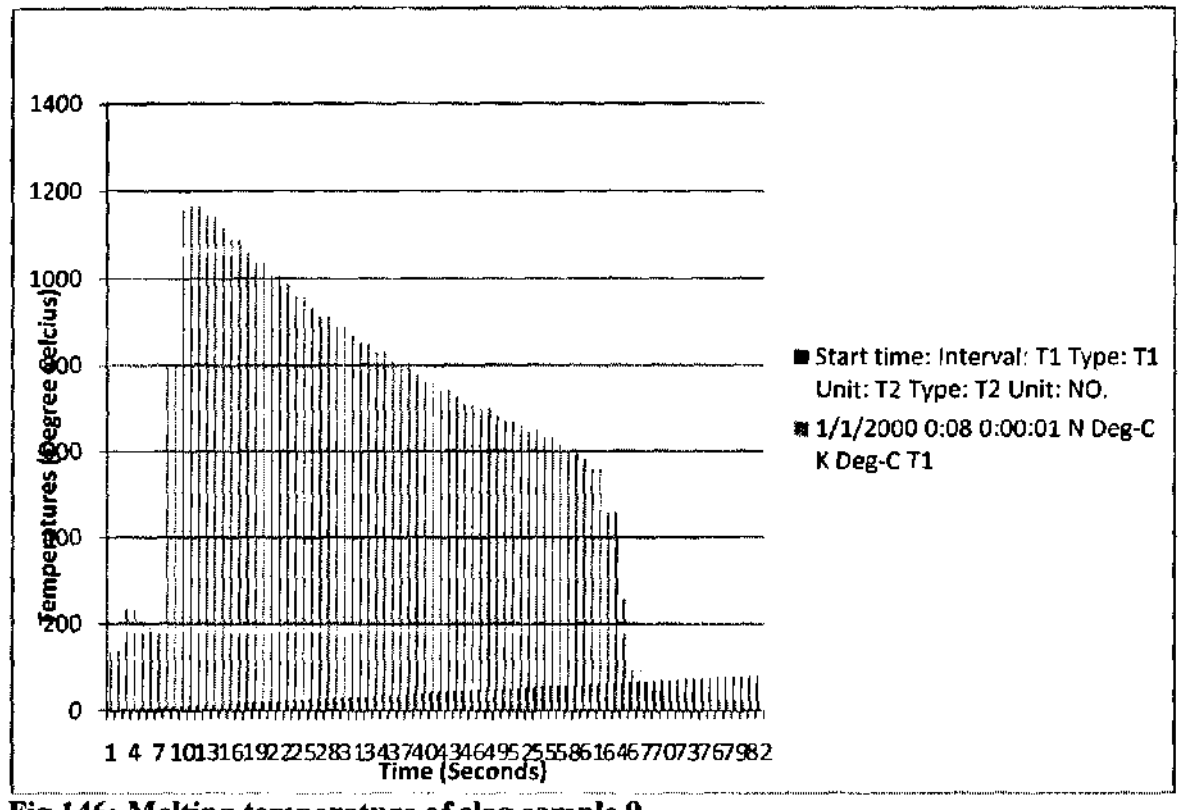



**Fig 146: Melting temperature of slag sample 9.**

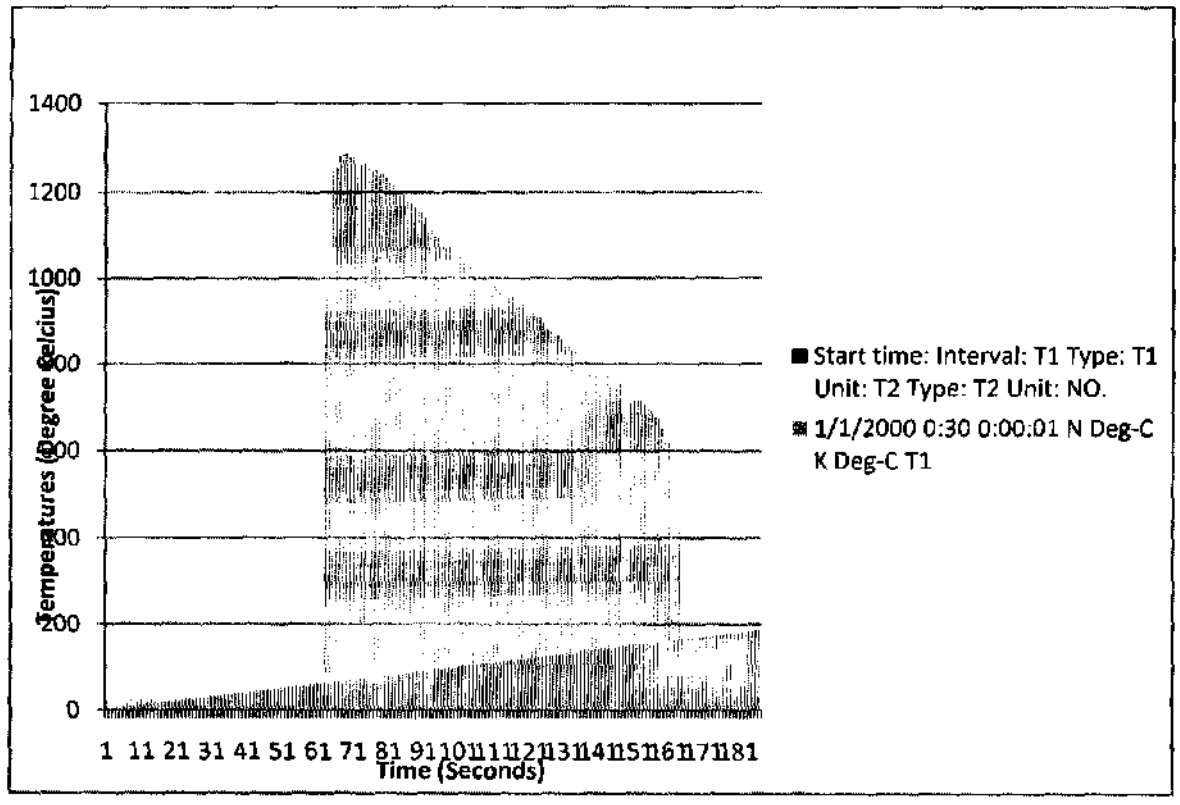



**Fig147: Melting temperature of slag sample 10.**

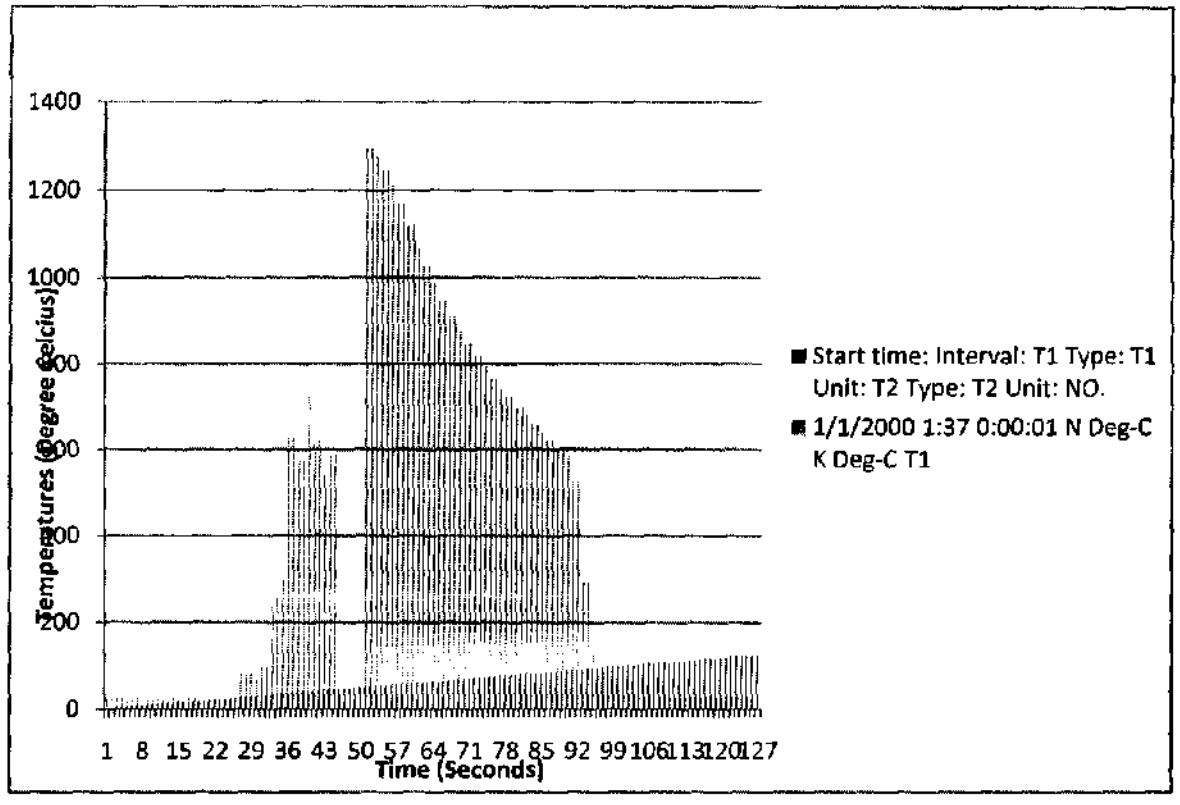



**Fig 148: Melting temperature of slag sample12**

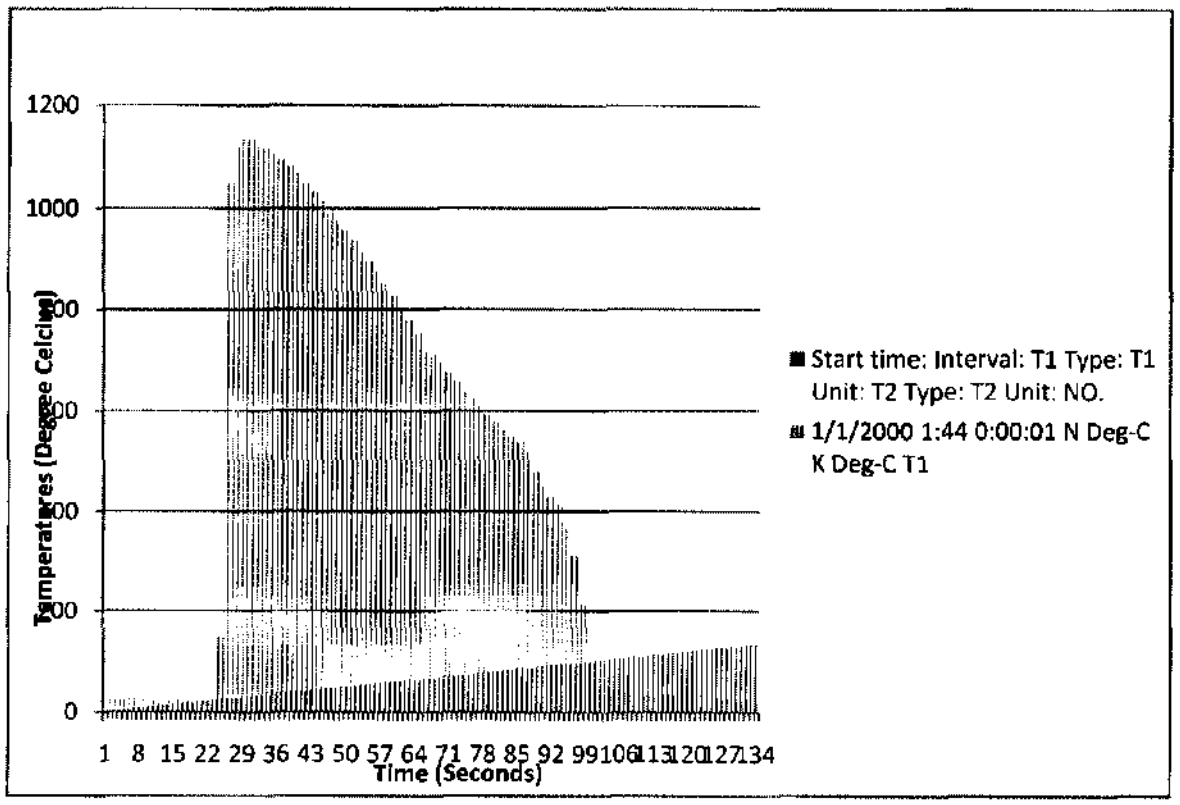



**Fig149: Melting temperature of slag sample13**

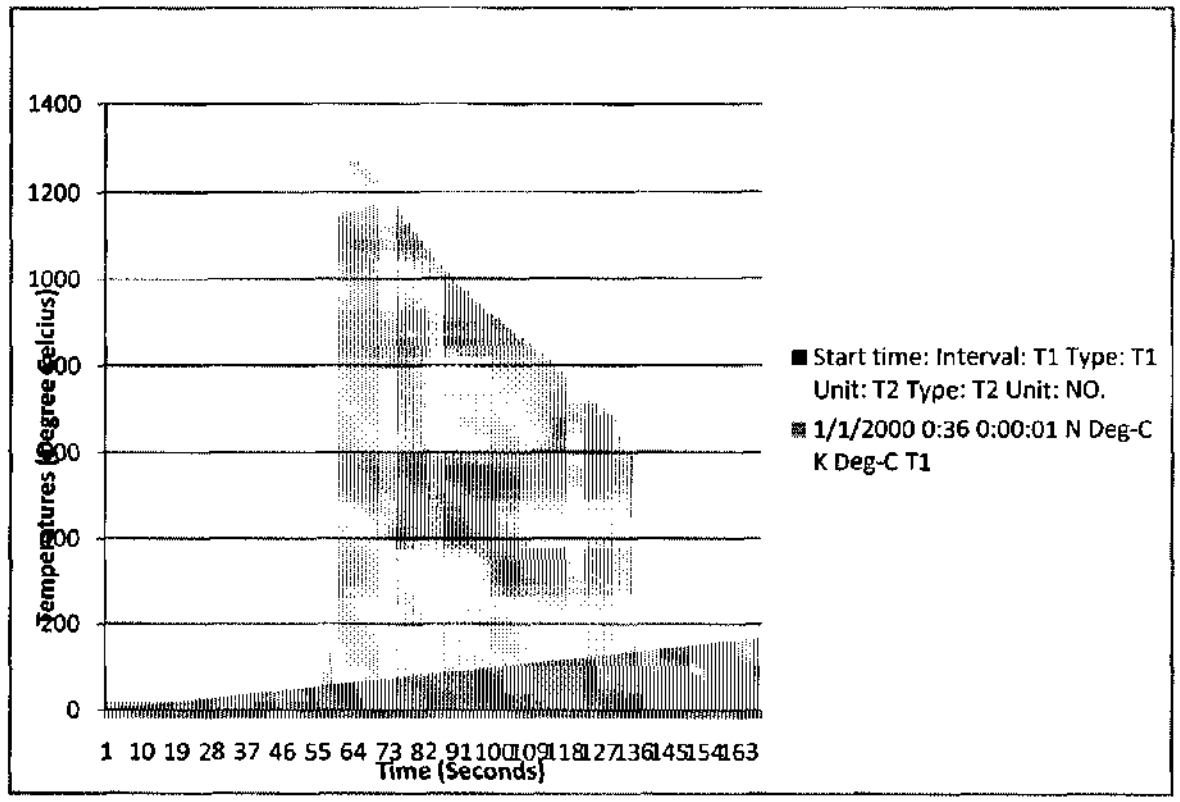



**Fig 150: Melting temperature of slag sample14**

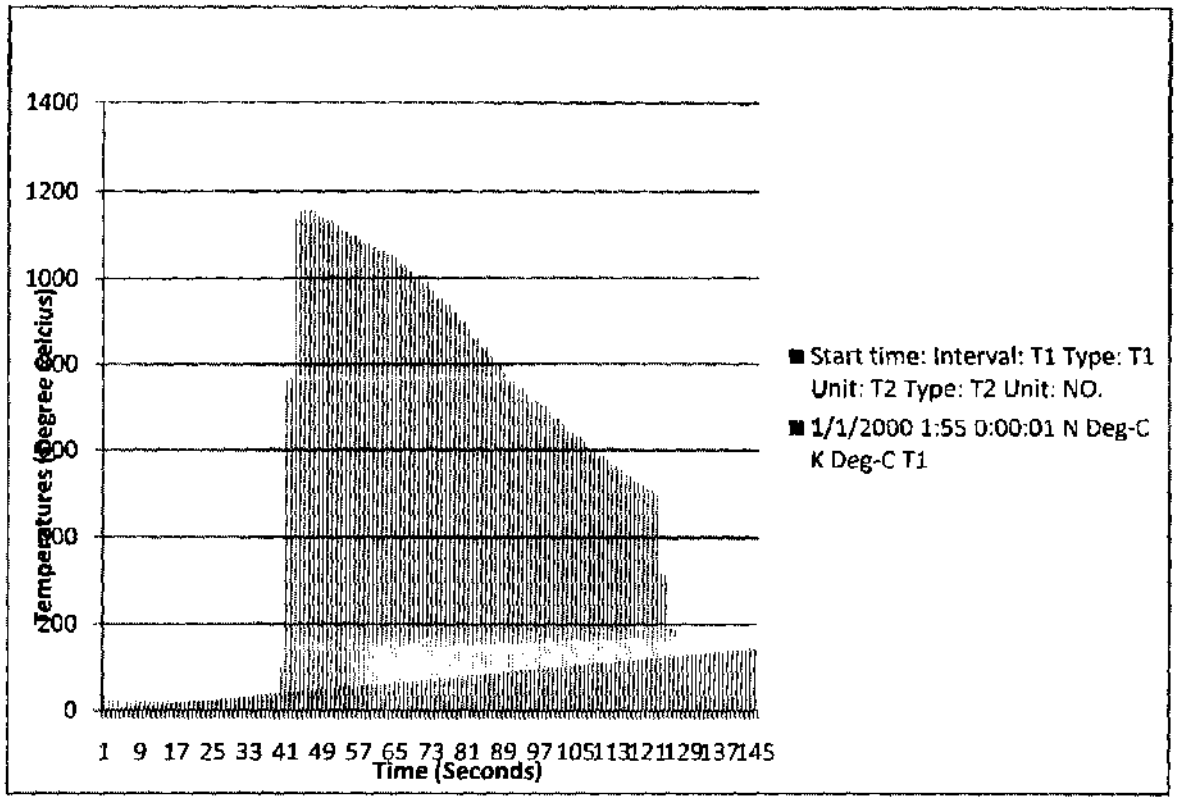



**Fig151: Melting temperature of slag sample15**

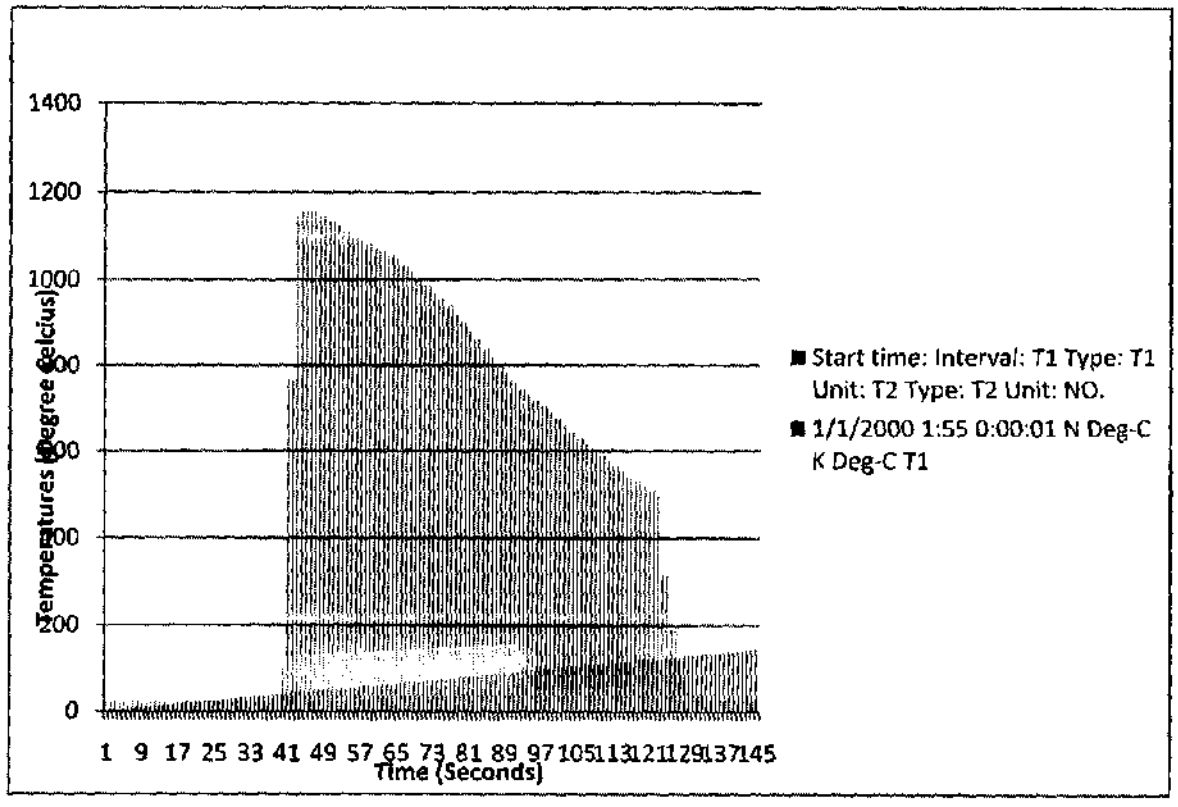



**Fig152: Melting temperature of slag sample16**

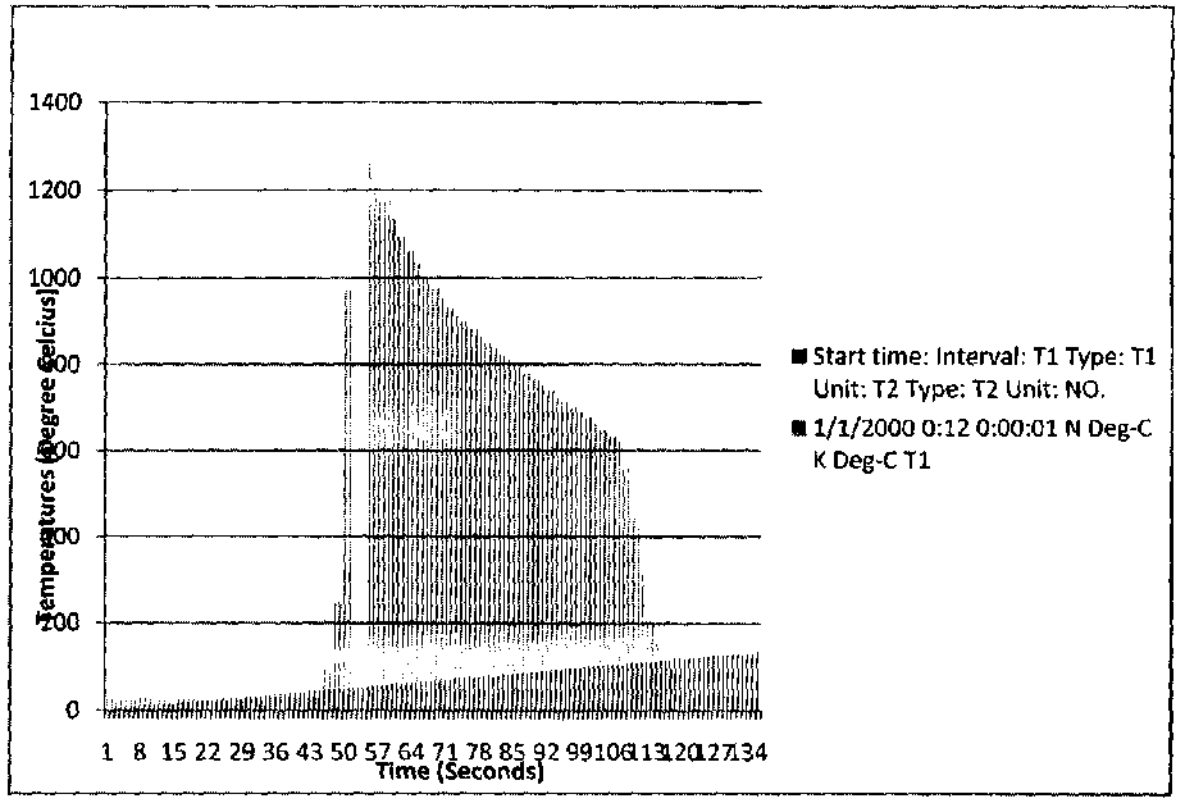



**Fig153: Melting temperature of slag sample17**

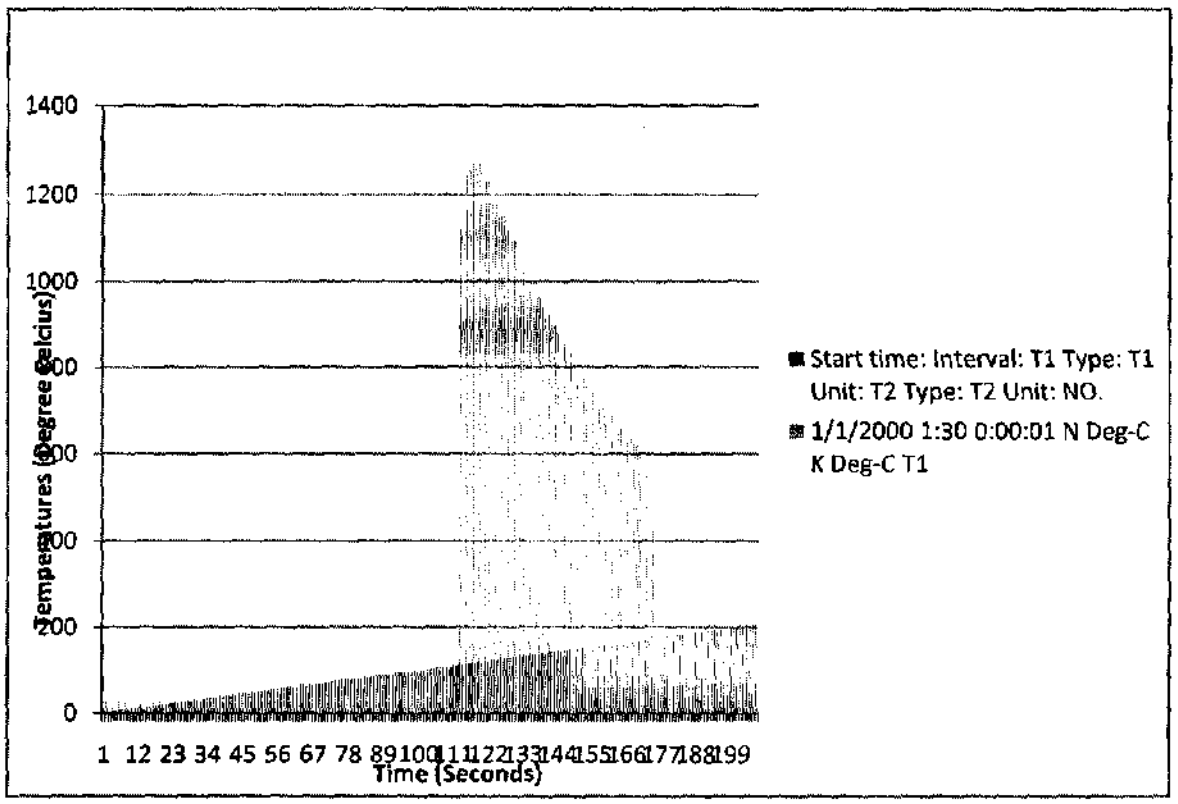



**Fig154: Melting temperature of slag sample18**

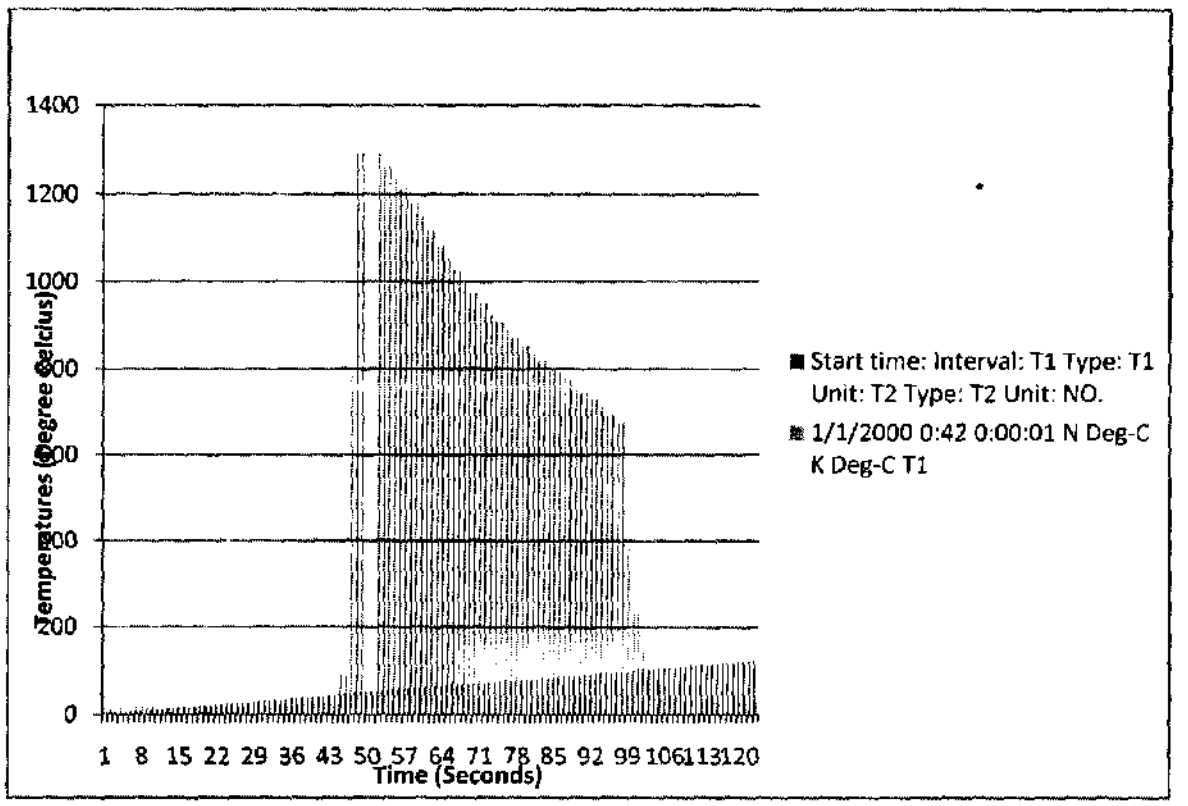



**Fig155: Melting temperature of slag sample19**

**Appendix IV: Showing the result of C14 age determination**

| S/No | Sample ID | Lab No. | Sample Description/Weight | C13 | C14 age Bp | Cal. AD age range | % area enclosed |
|---|---|---|---|---|---|---|---|
| 1. | TSS-07-I | ISGS 6297 | 80 Chars Max | -24.9 | 1560 ± 70 | 349 – 368 | 95.4 (2 sigma) |
| 2. | TSS-07-II | ISGS 6298 | 80 Chars Max | -25.1 | 1750 ± 70 | 87 – 328 | 95.4 (2 sigma) |
| 3. | TSN-06-I | ISGS 6299 | 80 Chars Max | -25.2 | 1560 ± 70 | 349 – 368 | 95.4 (2 sigma) |
| 4. | TSN-06-II | ISGS 6300 | 80 Chars Max | -24.9 | 1790 ± 80 | 79 – 397 | 95.4 (2 sigma) |

**Table 126: Result of Age Determination**

**Appendix V: List of informants.**

| Name | Age | Occupation | Place |
|---|---|---|---|
| 1. Mallam Yahaya Abdulmumini Zazzau | $80^{+}$ | Blacksmithing/Sarkin Makera | Unguwan Kaura, Zaria City |
| 2. Alhaji Akilu Hussaini | 47 | Sarki Yan Sarki (Village head of Yan Sarki) | Yan Sarki Village |
| 3. Alhaji Shehu Umoru | 67 | Farming and Rearing | Yan Sarki Village |
| 4. Alhaji Abdullahi Mukhailu | 58 | Farming and rearing | Yan Sarki village |
| 5. Mallam Abdullahi Wakili Umoru | 45 | Farming and rearing | Yan Sarki village |
| 6. Alhaji Tukur Umoru | 55 | Farming and rearing | Yan Sarki Village |
| 7. Alhaji Nasiru Abdullahi | 50 | Farming and rearing | Yan Sarki village |
| 8. Mallam Audu Shehu | $70^{+}$ | Blacksmithing and farming | Unguwan Makera village |
| 9. Mallam Danladi Isa | $60^{+}$ | Blacksmithing and farming | Unguwan Makera village |
| 10. Mallam Abdullahi Mustapha | 45 | Blacksmithing and farming | Unguwan Makera village |
| 11. Mallam Bala Ahmadu | 42 | Blacksmithing and farming | Unguwan Makera |
| 12. Mallam Umoru Abdullahi | 45 | Blacksmithing and farming | Unguwan Makera |
| 13. Mallam Abubakar Audu | 40 | Blacksmithing and farming | Unguwan Makera |
| 14. Mallam Isiaka Abdullhi | 40 | Blacksmithing and farming | Unguwan Makera |
| 15. Alhaji Idris Mukhailu | 55 | Sarki Rafin Yashi (village head) | Unguwan Rafi Yashin |
| 16. Mallam Muhamadu Sani | About 100 | Farming | Unguwan Rafin Yashi |
| 17. Alhaji Alhassan Yunusa | 48 | Farming | Unguwan Rafin Yashi |
| 18. Mallam Abdulsalami Yau | 55 | Farming | Unguwan Rafin Yashi |
| 19.Mallam Muhammadu Lawal | 80 | Farming | Unguwan Rafin Yashi |
| 20.Mallam Isiaka Alhaji Musa | 60 | Farming | Unguwan Rafin Yashi |
| 21.Mallam Abdulhamidu Shuaibu | 85 | Farming | Ungwan Rafin Yashi |
| 22. Alhaji Yahaya | 60 | Farming | Unguwan Tsauni |

| | | | |
|---|---|---|---|
| Yakubu | | | |
| 23. Alhaji Gambo Ahmadu | 80 | Farming | Ungwan Tsauni |
| 24. Mallam Abdulsalam Umar | 65 | Farming and rearing | Ungwan Tsauni |
| 25.Mallam Abdulmumin Bello | 40 | Faming and rearing | Unguwan Tsauni |

**AppendixVI: Questions for interviews.**

**I. Personal Data**

(a) Name

(b) Age

(c) Place of Birth

(d) Occupation

(e) Marital Status

(f) Position in the community

**II. Iron Smelting**

1. How did the people source their iron in the past?
2. What is the indigenous name for it?
3. Do you still practice it presently?
4. Have you ever participated in iron smelting in the past?
5. If yes where and when did you participate?
6. Describe how it was carried out?
7. What sex, male or female was responsible for iron smelting?
8. Did smelting take place within the settlement or outside it?
9. Give reasons for your answer.
10. How will you identify a location where iron smelting took place in the past?
11. What is the local name for the waste products of the smelting operation?

**The mining and processing of iron ore.**

1. From what type of materials was iron produced in the past?
2. How were the areas that contained iron ores located?
3. Were there different types of iron ores in your area in the past?
4. If yes, mention them. How were they distinguished?
5. What criteria did they use to identify and select high quality ore?

6. How was the ore mined? Mention whether from the surface or beneath and the tools used.

1. Were there groups that specialized on mining of ore or were miners the same as smelters?
2. Any beliefs or rituals associated with mining of ores?
3. Was mining conducted by individuals or groups?
4. Can you still identify the location where mining of ore took place in the past?
1. How can such mining sites be identified?
2. Were smelting sites located close to the mining areas? Give reasons.
3. If no, how was the ore conveyed to the smelting site?
4. Was there any preparation before the ore was smelted? If yes, describe it.
5. Did the preparation of ore have any effect on the success or failure of smelting operation?
6. What happened whenever the available ore in an area became exhausted?

**Construction of apparatus for iron smelting**

1. What is the local name for iron smelting?
2. What were the types of furnaces used for smelting?
3. What importance did a smelter attach to a furnace?
4. How were furnaces constructed? Mention raw materials, methods and beliefs attached to the construction works.
5. Who owned a furnace?
6. What was the life span of a furnace?

7. Any special groups associated with the construction of furnaces?
8. Was there any apparatus used for conveying air into the furnace during smelting operation?
9. If yes, describe it.
10. How was it constructed? Mention raw materials and the techniques of construction.
11. Was any apparatus used to force air through the pipe into the furnace?
12. If yes describe it.
13. How was it constructed? Describe the raw materials used and the methods of construction.

**Fuel Production**

1. What type of fuel was used for smelting operation? Mention whether wood or charcoal.
2. Mention the name(s) of the tree(s) used as fuel.
3. Give reasons for the preference of wood from such trees to others.
4. Is there any adage to capture the significance of such tree(s) in smelting operation?
5. How important was fuel to a smelter?
6. Did the source of fuel determine the location of a smelting site?
7. How was the fuel processed?
8. Any substitutes for the use of the tree(s) that you mentioned in iron smelting?
9. Any alternatives to the type of fuel that was commonly used?

**Iron smelting and products**

1. At what season was iron smelting conducted? Give reasons.
2. Describe the process of iron smelting with particular reference to the extraction of bloom and tapping of slag.
3. Were there any beliefs and rituals attached to iron smelting?
4. What were the things that a smelter must put in place to ensure the success of a smelting operation?
5. Any specific role for women and children in a smelting operation?
6. How did a smelter see a failed smelting operation?
7. How long could a smelting operation last?
8. Were there different grades of bloom? What criteria were used to identify the high quality ones?
9. Any difference between smelters and blacksmiths?
10. If yes, how were blacksmiths procuring their bloom, from open markets or direct sale to individual smiths?
11. Do you have any implement manufactured from smelted bloom?
12. What are the main differences between the impliments produced from traditionally smelted iron and those from scrap metals?

**Apprenticeship, guild System and socio-economic significance**

1. Was iron smelting exclusively for specific lineages or opened to the entire community?
2. How did smelters operate, as guilds or individuals?
3. How did smelters organize themselves?

4. Did they have heads to regulate their activities?
5. What was the relationship between the smelters and other artisans and craftsmen in the community?
6. How did smelters see their role in the community?
7. What significance did the community attach to the work of the smelter?
8. Who was considered more important by the community between smelters and smiths?
9. Werehere special privileges for iron smelters in the community? Mention them.
10. What relationship existed between smelters and the traditional ruler of their community?

**Impact on the Environment**

1. Did iron smelting have any effect on the physical environment?
2. If yes, how can this be evaluated?
3. What effect did it have on the soil?
4. What effect did it have on the vegetation cover particularly the trees exploited for fuel production?

**Appendix VII: Photographs showing informants in the area of study.**



**Plate 197: Informants and author at Ungwan Yan Sarki**



**Plate 198: Informants and author at Ungwan Makera**



**Plate 199: Informants and author at Ungwan Rafin Yashi**



**Plate 200: Informants and author at Ungwan Tsauni**

**AppendixVIII: Showing *Kirya* wood at Ungwan Makera.**

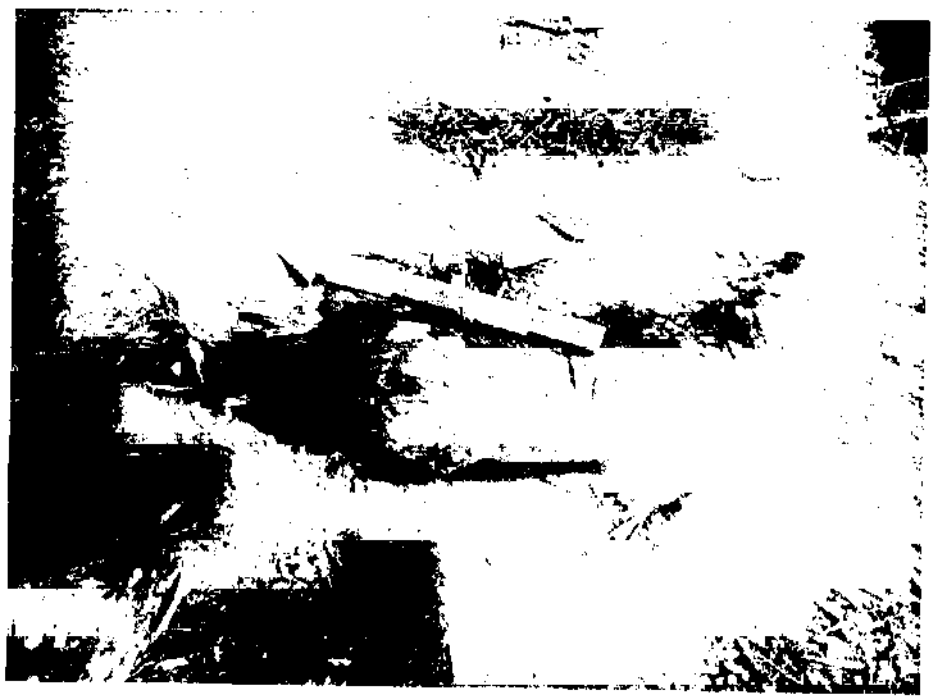


**Plate 201: A piece of *Kirya* wood at Ungwan Makera**

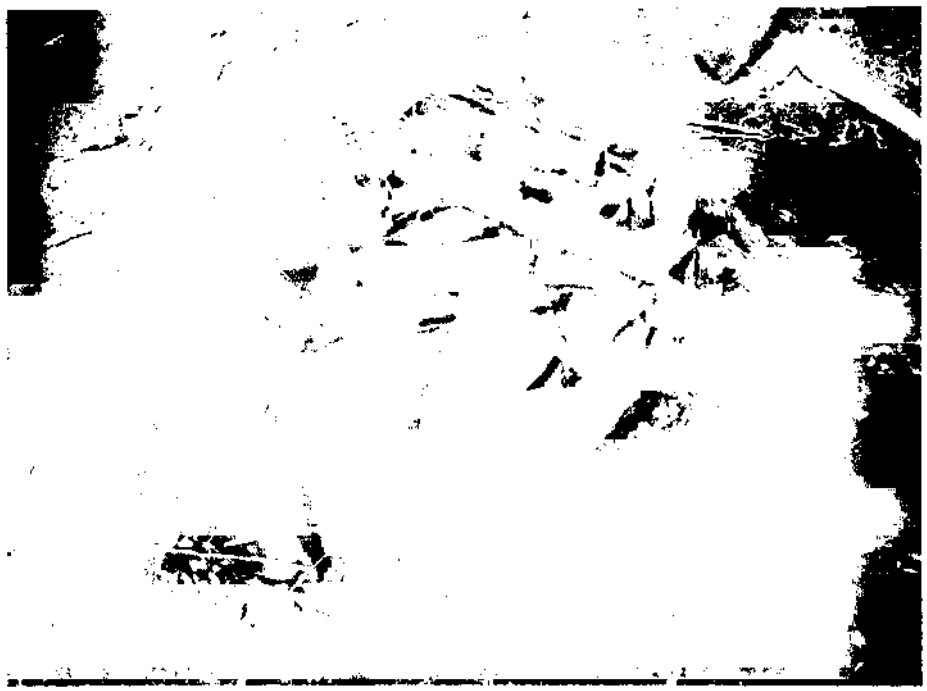


**Plate 202: Split *kirya* wood for cooking at Ungwan Makera**