The Origins of Iron Metallurgy in Africa

New light on its antiquity

West and Central Africa

Edited by
Hamady Bocoum

UNESCO PUBLISHING
MEMORY OF PEOPLES

The Origins of Iron Metallurgy in Africa

New light on its antiquity: West and Central Africa

In the same collection:

The Abolitions of Slavery
L'affirmation de l'identité culturelle et la formation de la conscience nationale dans l'Afrique contemporaine (in French and Spanish)
L'Afrique entre l'Europe et l'Amérique (in French only)
Atlas of the World's Languages in Danger of Disappearing
The Christianization of Ancient Russia
Contact de civilisations en Martinique et Guadeloupe (in French only)
Destins croisés: cinq siècles de rencontres avec les Amérindiens (in French only)
Distinctive Characteristics and Common Features of African Cultural Areas South of the Sahara
Eternal Afghanistan
From Chains to Bonds: The Slave Trade Revisited
Handbook for the Collection of Traditional Music and Musical Instruments
Lacquerware in Asia, Today and Yesterday
Laos and Ethnic Minority Cultures: Promoting Heritage
The Silk Roads: Highways of Culture and Commerce
Specificity and Dynamics of African Negro Cultures
Viet Nam's Cultural Diversity: Approaches to Preservation

The Origins of Iron Metallurgy in Africa

New light on its antiquity: West and Central Africa

Edited by Hamady Bocoum

Memory of Peoples

UNESCO Publishing

The authors are responsible for the choice and presentation of the facts contained in this book and for the opinions expressed therein, which are not necessarily those of UNESCO and do not commit the Organization.

The designations employed and the presentation of material throughout this publication do not imply the expression of any opinion whatsoever on the part of UNESCO concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Published in 2004 by the United Nations Educational,
Scientific and Cultural Organization
7, place de Fontenoy, 75732 Paris 07 SP

Typeset by Desk, F-53940 Saint-Berthevin
Printed by Sagrafic, Barcelona
Cover photograph: © J. Meniaud, Paris, E. Larose, 1912

ISBN 92-3-103807-9

Printed in Spain

Foreword

The interest aroused among very many specialists and the general public on the appearance of the French edition of 'The Origins of Iron Metallurgy in Africa: West and Central Africa' in 2002 meant that it could only be a matter of time before an edition was brought out for the benefit of the English-speaking public.

This publication attempts to face the major intellectual challenges that have come in the wake of globalization with its attendant dangers of stratification and reduction, not to mention denial, of immemorial heritages. Having striven constantly to meet such obstacles, UNESCO went on to adopt the Universal Declaration on Cultural Diversity in November 2001. The present work shows not only that sub-Saharan Africa witnessed the *in situ* genesis of an ironmaking industry, thereby contributing to the technological heritage of humanity, but that it also used that know-how to hand down a broad spectrum of expertise that can stand comparison with that of the whole continent, not to speak of the rest of the world. Such diversity is confirmed by Edwin Eme Okafor in regard to the size and use of furnaces and the treatment and production of fuel. This is also brought out by Pierre de Maret who writes not only of technical diversity, but also of the importance of the cultural and symbolic diversity of African iron metallurgy. Bruno Martinelli reaches the same conclusion when he affirms that the range of this technology is at the heart of today's interrogation that seeks to grasp, above and beyond such techniques, the knowledge systems of the societies, states and civilizations of this part of the world.

The publication of an English-language version of this work is therefore a timely event. It is to be hoped that it will contribute to the considerable volume of thought and action now being brought to bear to reassess the input of the tangible and intangible heritage which, however poorly understood at present, yet is destined to contribute so much to the building of the African continent in time to come.

Katerina Stenou
Director
Division of Cultural Policies
and Intercultural Dialogue
UNESCO

Contents

Table of illustrations

Figures

Plates and photographs

Tables

List of contributors

David A. Aremu
University of Ibadan
Department of Archaeology and Anthropology
Ibadan, Oyo State, Nigeria

Isaac Adeagbo Akinjogbin
Obafemi Awolowo University, Ile-Ife
Ile Road, Ile-Ife, Osun State, Nigeria

Hamady Bocoum
Director of the Heritage, Republic of Senegal
Ministry of Culture, Avenue Léopold Sédar Senghor, Dakar
Cheikh Anta Diop University, BP 206, Dakar, Senegal

Joseph-Marie Essomba
University of Yaoundé I
Department of History, Art and Archaeology
BP 755, Yaoundé, Cameroon

Philippe Fluzin
Director of UMR 5060, CNRS (French National Centre for Scientific Research)
Metallurgy and Cultures Laboratory
Belfort-Montbéliard University of Technology,
90010 Belfort Cedex, France

Joseph Fazing Jemkur
Centre for Nigerian Cultural Studies
Ahmadou Bello University
Zaria, Kaduna State, Nigeria

Louise-Marie Maes-Diop
Geographer and historian, Paris
'Khepera' Association
BP 11
91192 Gif-sur-Yvette, France

Pierre de Maret
Rector, Free University of Brussels
44, avenue Jeanne, 1050 Brussels, Belgium
Léopold Sédar Senghor University of Alexandria
1, Ahmed Orabi El Mancheya Square
P.O. Box 21111
415 Alexandria, Egypt

Bruno Martinelli
Maison Méditerranéenne des Sciences de l'Homme
5, rue du Château de l'Horloge
13024 Aix-en-Provence, France

Edwin Eme Okafor
Department of Archaeology
University of Nigeria
University Road, Nsukka, Enugu, Nigeria

Alain Person
Laboratory of Research on Africa
Maison René-Ginouvès, CNRS-UMR 7041
Allée de l'Université
92023 Nanterre Cedex, France
Université Pierre et Marie Curie
Laboratories of Geology of Sedimentary Basins
75252 Paris Cedex 05, France

Gérard Quéchon
Laboratory of Research on Africa
Maison René-Ginouvès, CNRS-UMR 7041
Allée de l'Université
92023 Nanterre Cedex, France

Preface

Dialogue between cultures and civilizations as a foundation of lasting peace is one of the most fertile intuitions of the founders of the United Nations Educational, Scientific and Cultural Organization (UNESCO). And, in the words of the UNESCO Constitution, 'it is central to constructing the defences of peace in the minds of men'.

UNESCO should promote such dialogue among cultures and civilizations as a matter of urgency, in particular in response to Samuel Huntington's theory of the clash of civilizations. Thus, the time has come for a critical, positive reflection on the concept of civilization, which has too often been the target of intellectual and historical manipulation seeking to legitimize all manner of political domination and discrimination. It is this context that gives the Iron Roads in Africa project its profound significance and scope. The ultimate aim is to adopt a rigorous, interdisciplinary and international scientific approach to restore to Africa that profound marker of civilization thus far denied to it: iron. Scientific knowledge, science, skills, know-how, technology, society, myth and cosmogony: all of these 'fields' – in Pierre Bourdieu's sense of the word – are structured and endowed with significance by iron. For Africa, there are some essential issues at stake: historical truth, recognition of its heritage and the possibility of revitalization through its endogenous mastery and knowledge of iron.

In the *General History of Africa* – a major contribution by UNESCO to an objective rereading of the continent's long memory – the chapters relating to African iron metallurgy examined new sites and provided new datings which have substantially modified our knowledge of the age, diversity and extreme longevity of the African iron industry. At its first meeting (held in 1995 at Abuja in Nigeria) the International Scientific Committee of the Iron Roads in Africa Project recommended to the Director-General of UNESCO the publication of a work on African iron metallurgy, which included the paper presented by Nigeria at the meeting ('Twenty-five Centuries of Ironworking in Nigeria').

In order to reflect subsequent research developments the present volume contains, in addition to the Abuja documents, further contributions that are consistent with the continuing commitment by UNESCO to update knowledge in this field. The papers presented by Hamady Bocoum, Pierre de Maret, David Aremu, Gérard Quéchon and Bruno Martinelli at the scientific meeting on iron

metallurgy in Africa (held at UNESCO Headquarters on 12 November 1999 during the thirtieth session of the UNESCO General Conference) have considerably broadened the scope of this volume, taking it beyond the borders of Nigeria to report research developments in Niger and, to some extent, Central and even southern Africa.

In addition to this series of UNESCO documents, and for the sake of a balanced perspective, it was considered useful to add two further articles. While this publication was intended to cover both West and Central Africa, for various reasons the majority of the articles selected for inclusion concern West Africa, with the notable exception of Pierre de Maret's excellent survey covering both Central and southern Africa. The article by Joseph-Marie Essomba, although confined to Cameroon, partially redresses this imbalance and reflects UNESCO's commitment to reviewing the entire Iron Roads in Africa network.

This book also contains an article by Philippe Fluzin, Director of Research at the Centre National de la Recherche Scientifique (CNRS), who has contributed an expert analysis of the process chain in iron and steelmaking, illustrated with examples from Africa. Fluzin's work enables us to grasp both the universal nature of the physico-chemical processes associated with the development of iron and steelmaking and the specificity, albeit relative, of the findings in Africa. From this standpoint, UNESCO's interest in the study of iron metallurgy in Africa, apart from the chronological aspect that is so much in need of re-examination, is also intended to restore to its rightful place the contribution of African metallurgists to the technological heritage of humanity.

We are quite aware that this book does not tell the whole story. However, the pressing need to refute theories that continue to describe sub-Saharan Africa as a mere recipient of a technology as important as that of iron has spurred us into action. It is intended to supplement this work later on with further contributions about other regions of the African continent. The vast field of research opened up by the Iron Roads in Africa project cannot fail to bolster UNESCO's strategic option in favour of intercultural dialogue through a proper estimation of the contribution of each people to the universal heritage of humanity.

Doudou Diène
Former Director
Division of Intercultural Dialogue
UNESCO

Introduction

Hamady Bocoum

The first consultative meeting of specialists to launch the Iron Roads in Africa project was held in Maputo from 10 to 13 December 1991 on the initiative of the Mozambique National Commission for UNESCO. The aim was to review the knowledge acquired in this field since the publication of the *General History of Africa* and to propose moves to reflect the priorities laid down by the project's International Scientific Committee (a body that is made up of persons from all over the world).

The publication of this work therefore required a considerable amount of coordination for which we are indebted to Suzanne Diop, head of the programme, who, under Doudou Diène, former Director of the then Division of Intercultural Dialogue at UNESCO, served as a 'bridge' linking a wide variety of specialists.[1] She understood the concerns of the researchers, negotiated copyright agreements with publishers and supervised the transcription of the papers presented at the meeting on iron metallurgy in Africa (held at UNESCO Headquarters on 12 November 1999).[2] She was also responsible for coordinating the work of collecting the documents that initiated the project and which have been included here at the behest of the chief editor.

These precautions were essential since the articles which follow are the product of collective and at times solitary efforts, yet they always aspire to the same goal: a better understanding of African iron metallurgy in all its dimensions.

1. Between 1991 and 1997 Ana Elisa Santana Afonso, currently a UNESCO staff member, followed by Sedate Jobe, a member of the Gambian Government, was responsible for implementing the project, with the assistance of Marie-Florette Lengue. We also wish to express our gratitude to Sara Cortès, Binta Moussa and Carine Nsoudou for their assistance with the publication of this book.
2. That meeting and the present publication received the intellectual and financial support of UNESCO's Cultural Heritage Division.

Since the start of the project the aim has always been to disseminate technical data. Nevertheless, it soon became clear that what counted most was not simply discovering the origin of Africa's iron metallurgy: the ultimate and perhaps most fundamental value lay in unearthing the technical characteristics of what may rightly be called a 'guild' which modern science can still observe *in vivo* like a time machine moving back through several millennia of technical history. The goal was also to understand the social, economic and cultural implications of such an impressive technical innovation. More than any other analogy, it echoes, not surprisingly, the outcome of the unequal combat between earthenware and ironware, given the profound changes that occurred in societies that opted for or otherwise came to use iron.

In certain respects the articles in this book endeavour to provide a response to one or other of the questions raised. These responses, which are necessarily provisional owing to the sustained pace at which discoveries are being made and facts called into question, must therefore be regarded as stages that are meaningful solely in the light of their original contexts, some reaching far back into the past. In the last ten years much has been written about iron in Africa and in the world, and many diffusionist theories have crumbled under the weight of the evidence. The publications that have emerged since the start of the project clearly reflect this recent fascination with African metallurgy and the fireworking trades in general – around which a good part of the archaeological and anthropological literature is being polarized – and point to the many upheavals under way.[3] Among the various approaches in use, some are particularly worthy of attention because they will no doubt do much to influence research in years to come. In that connection, mention may be made of chronology, the technical history of ironmaking and the renewal of the anthropological discourse that has been much harmed by a questionable brand of comparativism.

Of all these lines of research it is surely in the field of chronology that the findings of archaeology are invoked almost invariably with misgiving. In this field there is clearly reluctance to consider or acknowledge that diffusionist hypotheses may well be open to question; paradoxically, although proposed more than half a century ago, they have never been in any way confirmed. Furthermore, there is, perhaps, cultural resistance to accepting the evidence, whereas the opposite – a new reading of the anthropological data – is giving rise to less passionate debate (for example, Herbert, 1993; McNaughton, 1988; Tamari, 1997). Hence the chronology of iron in Africa continues to drag the dead weight of diffusionism, which historically stands out as a means of negating

3. In addition to the UNESCO bibliographies (Bocoum, 1995a, 1995b; Killick, 1995; Miller and Maggs, 1998), many recent publications complement the articles published in this book and reflect the dynamism of research on African iron metallurgy.

the cultures encountered by a conquering Europe. Those cultures therefore were almost everywhere too young, too rustic or too unrefined to bear the comparison.

The dark continent, classified in the good old evolutionist traditions as a dead end, owed everything – it went without saying – to the rest of the world even though not a single credible argument or piece of evidence could be found to support that thesis. Most early researchers in African archaeology encountered that obstacle without their position being explicitly ideological or objectively conscious. That was the case with Arkell (1966), Huard (1960, 1964, 1969), Mauny (1952, 1953, 1971), and even Shinnie (1971). Even today, despite the weight of evidence, doubts about the origin of iron in Africa are still being raised in certain publications.

This is the perspective from which we should view the articles contained in this book. The first part of the book is devoted almost entirely to Nigeria, which, following the international consultative meeting of specialists organized by Mozambique, hosted the first meeting of the International Scientific Committee of the Iron Roads in Africa project, at which a review of research findings in Nigeria was presented by the Nigerian delegation. That was before a number of important publications enlarged on questions that had never been satisfactorily answered. However, the right questions were being asked. Jemkur's study on 'The Beginnings of Iron Metallurgy in West Africa', appearing at a time when the latest research findings in Central Africa and in neighbouring Niger were still not widely known, clearly indicated the objective limits of the diffusionist hypotheses as a whole, whether North African or Meroitic. The same author also made the point – and this deserves attention – that the technological affiliation between bronze and iron was not necessarily of relevance to developments in Africa.

More technical in its aims, Okafor's overview 'Twenty-five Centuries of Bloomery Iron Smelting in Nigeria' is a review of the various processes developed over more than two millennia by ironworkers in the regions studied. The author has made a remarkable contribution to the technical history of Nigerian iron metallurgy. The Nsukka region would appear to be a particularly appropriate laboratory for studying the evolution of technical processes since it has been active over a time span of more than two and a half millennia from 760 B.C. to A.D. 1950. Following a minutely detailed analysis of post-reduction products, Okafor pertinently identifies three stages in the evolution of the ironmaking processes developed by ironworkers in the Nsukka region, which are in reality technical advances. He notes that a high proportion of wustite in the free state is found in the slag during the first stage, while it is practically absent in the middle stage, suggesting greater technical mastery and a better yield. Technical mastery was to improve even further with the use of fluxes and improvements in bellows, yielding high-quality reductions at the lowest possible temperatures – between 1150 °C and 1280 °C – and producing considerable savings in labour since the

furnaces were at that point functioning by natural induction. These observations afford a view of the state of mind of the ironworkers: far from being simple imitators, they were aiming resolutely for improvement, which requires the capacity for observation, comparison, deduction and anticipation – the hallmarks of a scientific mind. Listening to the story told by post-reduction materials can sometimes lead to surprising discoveries that call into question a good number of assumptions.

It is tempting to deviate from the order in which the contributions are presented in this volume to introduce at this point the article by Fluzin on 'The Process Chain in Iron and Steelmaking: Archaeological Materials and Procedures – The Contribution of Metallographical Studies', a natural complement to Okafor's research. In his article Fluzin approaches iron and steelmaking, in the direct form in particular, from an entirely new angle. Fluzin the engineer has been inspired by the cultural and ethnographic aspects of direct iron and steelmaking to fine-tune his approach, calling for collaboration between archaeologists and engineers to deal with the complexity of the questions raised by ancient ironmaking.

Iron smelting, refining and forging are seen, therefore, as three technical stages each leaving its mark on the final product, be it slag, artefact or mere scale. The archaeometrical study of ironmaking residues, which has led to the development and use of methodological tools vital to this type of research, is a rapidly expanding field enabling researchers to make increasingly fine discriminations between the indicators of reduction, refining and forging. In addition, it has already contributed to a better functional interpretation, not only of technological spaces, but also of the effectiveness of the processes used by artisans, taking into consideration the quality and quantity of the raw materials available, in addition to the socio-political environment. The articles by Okafor and Martinelli demonstrate how fruitful an approach this is, making Fluzin's contribution a veritable 'discourse on method'.

Following the articles dealing with chronological and technological aspects, the work of Akinjogbin on 'The Impact of Iron in Yorubaland' finally lends consistency to the Nigerian contribution, which encompasses all aspects of ironmaking even though, for obvious reasons of resources and time, the entire country could not be investigated. There can be no doubt that the unification of the Yoruba under the rule of the partisans of Oduduwa can be largely explained by military superiority based on the use of iron. The forge itself was to become, through the presence of 'Ogun Laadin' (Laadin's blacksmith shop) in the palace of the Ooni, a symbol of royalty. Ogun, the god of iron, was also the patron god of the Yoruba royal family, which says a great deal for the role of ironmaking in that society where, even now, all those in iron-related jobs or, more broadly, in the mechanical trades, regard Ogun as their patron saint. Moreover, as in many African societies, Ogun and the forge, and in particular the anvil, are invoked in the course of trials undergone to elicit the truth.

The second part of the book presents the papers prepared for the Meeting on African Iron Metallurgy organized by UNESCO in 1999, at which experts reviewed the chronological findings and the technological and sociological literature that had emerged from the previous ten years of research on iron in Africa.[4]

In his paper on 'Iron Metallurgy Datings from Termit (Niger): Their Reliability and Significance', which focuses on the region of West Africa, and Niger in particular, Quéchon reviews the research carried out at both Termit and Egaro and rightly notes the high recurrence of dates, which dispels any doubt as to the cultural contexts associated with the earliest iron objects in those regions. Copper and iron objects first appeared in 1500 B.C. in this region, where technical installations (forges) have been dated to 800 B.C.

The paper by Person and Quéchon on 'Chronometric and Chronological Data on Metallurgy at Termit' is particularly instructive in its chronological approach. The main feature is a graph of date clusters for the earliest Iron Age sites, complementing and enlarging on Quéchon's conclusions. The authors convincingly demonstrate the homogeneity of the Termit series, for which there is a high degree of consistency in the dates – spanning the period 3300 B.P. to 1400 B.P.[5] – accompanied by a remarkable cultural continuity. In respect of other chronological evidence, the dates available for the region of Central Africa (Clist, 1995; de Maret, 1996; Woodhouse, 1998) are as ancient as those obtained in West Africa, while Gabon and Cameroon also yield very early dates. This leads to the logical conclusion that there neither North Africa nor Meroe provided entry points for iron into Africa, because the continent itself, in view of chronological and cultural consistencies noted, provides sufficient evidence to support the hypothesis of independent invention.

Also working with chronological data, Maes-Diop, who had already explored the possibility of the independence of African ironmaking in a study backed by rigorous methodology (Maes-Diop, 1968), draws the logical conclusion from an accumulation of facts that can no longer be attributed to chance. Eastern Niger alone has yielded nearly half the dates prior to 1500 B.C., while the rest are distributed between Anatolia, Egypt and Mesopotamia. Following chronologically after Niger is the region of Lake Victoria-Nyanza (Van Grunderbeek, 1982) which has been dated to between 1400 B.C. and 1200 B.C., making it nearly contemporary with eastern Niger and thus lending support to the probability of an independent origin. Then come Cameroon, Central Africa and

4. The following authors participated in the 1999 meeting at UNESCO Headquarters: David Aremu, Hamady Bocoum, Pierre de Maret, Bruno Martinelli, Alain Person and Gérard Quéchon. To these should be added the names of those who were unable to present their work at the meeting but who kindly transmitted a copy of the same to UNESCO: Louise-Marie Maes-Diop, Joseph-Marie Essomba and Philippe Fluzin.
5. B.P. = 'before present'. Year 0 is, by convention, 1950. – Ed.

Gabon, well before Meroe and the Carthaginian world. Drawing every possible conclusion from this distribution and relying on the authenticity of accounts of ancient trade between the Nile Valley and the rest of Africa (for example, the expeditions by Herkouf *c.* 2400 B.C.), Maes-Diop does not rule out the possibility of the early introduction of iron into Egypt from western and central Sudan across the Ennedi plateau. For the author, viewing the situation from the opposite perspective compels us to reconsider dates that have been dismissed too cursorily as contrary to expectations, and to disseminate the results of new research. The present work goes some way to meeting that requirement.

In 'Iron Metallurgy in Africa: A Heritage and a Resource for Development', Bocoum reviews the diffusionist conceptions of iron in Africa from a dual viewpoint – cultural and technological – and concludes that not a single argument disputing the independent origin of ironmaking in Africa is based on reliable scientific evidence. Any doubts about the reliability of some of the data are isolated cases that can be satisfactorily explained. On the opposing side are convergent sets of dates and contexts for West Africa, Central Africa and the Great Lakes region. Nowhere in the world is there a comparable set of data of such antiquity. The case for the independent origin of ironmaking in Africa appears to have been won, even though considerable effort is still needed to study its technical aspects, the latter-day heritage and the implements that contributed to the development of Africa.

The article by de Maret on 'Central Africa: Knowing Iron' adopts an interdisciplinary approach, having technical as well as cultural dimensions. The author highlights a series of particularly striking symbolic parallels found along the iron routes around the world, which simply reflect the universal categories of the human mind. This is a lesson in humility for those who would interpret convergences exclusively as an indicator of the initiator-disciple dyad. With regard to technology, de Maret also demonstrates (using the example of the Luba) that the ironworkers of this tribe knew how to produce and refine cast iron. This revelation is an important contribution to the study of African iron metallurgy since it was assumed until recently that ironworkers did not know how to smelt iron but only how to reduce iron ore. It is becoming clear that African iron metallurgy still has surprises in store. But we must act now before it is too late.

As if in answer to this appeal, Essomba in his chapter on archaeology of the Iron Age in southern Cameroon reviews the research carried out there as part of a systematic programme of inventories, excavations, analyses, formations and reconstructions. After ten years of research, the findings speak for themselves: evidence of an Iron Age dating back to the first millennium B.C. and signs of sedentarization and food production, all present within a culture at the crossroads of Bantu migrations. Nevertheless, despite these findings, the author rightly notes that much remains to be done before we can claim an adequate understanding of the Iron Age populations and cultures in central and southern Cameroon.

Produced a few years later, the article by Aremu entitled 'Iron Roads in Africa: A Contribution from Nigeria' is an update that confirms the relevance of the 1995 data. Nigeria turns out to be a region of metallurgical activity dating back to ancient times (eighth century B.C.) and demonstrating a remarkable continuity: today, ironworkers still play an active role in the country's economic, social and cultural life. The sites, some of which have been the subject of intensive research, are spread across every region of the country. The work by Aremu thus confirms, as has already been shown by previous studies, that the Yoruba region is an ideal window through which to view metallurgical cultures and the social, cultural, economic and political ramifications of ironworking.

'On the Threshold of Intensive Metallurgy: The Choice of Slow Combustion in the Niger River Bend (Burkina Faso and Mali)' by Martinelli is as much an illustration of the great scientific potential of African ironmaking as a lesson in methodology. The author demonstrates how an overly stereotyped myth of the blacksmith has hindered the study of the far more complex universe of African metallurgy, which, as far back as our knowledge goes, has always been, and remains, a world of innovation and progress. In this area, Africa provides an unparalleled laboratory. The choice of slow combustion is a perfect illustration of this: the Yatenga ironworkers, like their counterparts in Nigeria (see Okafor in this volume), in choosing slow combustion and natural induction, opted for efficiency and labour saving, thereby using fewer workers than would have been necessary with mechanical blowers. Martinelli's perspective is interesting too in view of his hypothesis that slow combustion is the result of social transformations and a reflection of the technological, cultural and political issues associated with them.

From this introduction, the reader will, it is hoped, have realized the considerable distance we have come and the extent to which our perspective has been transformed in the process. We can no longer continue to maintain that Africans were mere consumers of iron metallurgy because, clearly, there were innovations. These were numerous and affected all aspects of the process chain (slow combustion, natural induction, the great variety of architectural designs and material facilities, and so forth). In fact no other continent displays as much variability in the use of the process chain of direct reduction as Africa, where artisans have even been so ingenious as to produce iron in hearths made from banana-tree trunks (Celis, 1991b).

Therefore, while the early literature on the origins of iron metallurgy clearly demonstrates that researchers at that time were unable to avoid the convenient solution of a diachronic projection to support the assumption that the Negroes, slaves of the Berbers, could not have been initiators, recent publications show that the upheavals now under way are the result of a radical change in perspective.[6]

6. In reality, such attitudes were part of the cultural ambience of an era in which colonized peoples, guided by others, could only be perceived in general as consumers (Mauny, 1953; McIntosh, 1994).

Like their colleagues worldwide, African archaeologists are increasingly free of the oppressive weight of ideology, while a greater harmonization of working methods is leading to a new and rigorous context for research of all kinds in the field of early ironworking. Extremely strong convergent trends, based on greater command of data, provide support for the hypothesis of the existence of one or more independent centres for the origin of iron metallurgy in West Africa, Central Africa and the Great Lakes region.

By enlarging this perspective to embrace iron and steelmaking worldwide, we can see that the history of technical progress, where human ingenuity stands above all other considerations, differs fundamentally from biological history where contingencies determine and frame the passage from one stage to another. Viewed in this light, diffusionism, as the sole explanation for the spread of technical progress, is clearly inadequate in that the assumption that iron metallurgy had a single origin – and the further, even more functionalist assumption that the more complex process of iron metallurgy can only have developed from copper metallurgy – are in fact based entirely on unverifiable hypotheses or fabrications that are purportedly logical and inescapable. Breaking away from this kind of scientism was no doubt the first taboo to overcome, and this is precisely what appears to be happening. In retrospect, the principal lesson of the history of iron metallurgy is that worldwide, in very different settings, human communities have been able to respond effectively to the challenges raised by the technical development of their societies.

In conclusion, we can only express the hope that UNESCO, working hand in hand with the scientific community, will maintain and reinforce the Iron Roads project, because the present and future lessons to be learned from African iron metallurgy will, we are convinced, be a major contribution to enhancing the scientific heritage of humanity. The small window opened by this volume is but a timid beginning.

Part One

Twenty-five Centuries of Ironworking in Nigeria

Nigerian Contribution to the First Session of the International Scientific Committee on the 'Iron Roads in Africa' Project (Abuja, 23–27 February 1995)

Introductory Note

Part One consists of three chapters spanning a period of about 3,000 years of bloomery iron smelting in Nigeria.

Chapter 1 summarizes the beginnings of ironworking in Africa with particular reference to the Nigerian setting. It recapitulates the theories propounded by the two existing schools of thought as regards the origin of African ironworking, the 'diffusionist' school and the 'indigenous development' school. There follows a summary of reported information coming from the Nok culture and collected in Nigeria. Examples of later metallurgical activities carried out in other parts of northern Nigeria (Daima and Samaru West) are also given. These include current ethnographic data.

Chapter 2 is a detailed study of bloomery iron-smelting technology in Nigeria with specific reference to the Nsukka area where numerous vestiges survive. These techniques have been studied in the region as part of archaeological and ethnographic research. The results of macro- and micro-analyses conducted on smelting residues reveal that iron was smelted in the region 760 cal. (calibrated) B.C. to about A.D. 1950 cal., that is, for more than twenty-five centuries. This makes the region one of the earliest centres of bloomery iron smelting in Africa. These results further reveal the mineral constituents, basicity and viscosity of the slags as well as the working temperatures of the furnaces. Finally, they reveal the proportion of iron extracted from these ancient iron ore residues.

Chapter 3 deals with the socio-political impact of iron technology in Nigeria, this time taking the Yorubaland as an example. It is evident, we hope, that this socio-political impact, highlighted here with particular regard to the Yoruba area, pertains *mutatis mutandis* to all other parts of Nigeria.

The Beginnings of Iron Metallurgy in West Africa

Joseph Fazing Jemkur

Origins and spread

The region of West Africa has incontestably been the subject of much richer ethnographic and archaeological research by both Europeans and Africans, from the days of Mungo Park (1813) to the ethnographic present, than have other parts of Africa. Abundant data have been gathered about West African metallurgical technology (Jemkur, 1989; Okafor, 1975a, 1975b; Tylecote 1975a). The region has long been recognized by researchers as being particularly suited to iron technology (Lhote, 1952, p. 270). However, although some antique origins had been surmised for iron production in West Africa, little archaeological information, from which to construct any type of chronological framework for the industry, existed until recognition of the Nok culture in central Nigeria.

The terracotta figurines that have been recovered from the Nok Valley were found mixed, in the same alluvial deposits, with items such as polished stone axes and iron fragments (Fagg, 1969). Subsequent radiocarbon data determinations obtained for these deposits put this material between 500 B.C. and A.D. 200 (Barendson et al., 1965). The archaeological context of these finds was, of course, unclear, for it was not considered safe to regard them as belonging to the same period until such an association was established *in situ*. This happened in 1960 with the excavations at Taruga and the finding of iron, Nok terracottas and domestic debris in good association, dated to the late first millennium B.C. (Fagg, 1969).

It is clear that this region (Fagg, 1969; Tylecote, 1975) was producing its own iron by at least the fourth century B.C., with the following determining critical stages: 400 B.C. ± 140, 300 B.C. ± 100, 280 B.C. ± 120, and 210 B.C. ± 95.

These early dates undoubtedly make the Taruga iron-smelting furnaces the earliest ones known in West Africa (until the Opi figures were produced: Okafor,

1990–91). Some specialists on this subject have seen them as evidence of an independent invention of iron metallurgy in West Africa (Davies, 1966; Maes-Diop, 1968; Andah, 1979) but others, who have studied the technical aspects of the question, have argued that this is unlikely since, except in Mauritania, West Africa had no Bronze Age. Everywhere else in Africa south of the Sahara, the use of iron succeeds the use of stone for implements and weapons. Without any intermediate copper and bronze metallurgy, it is difficult to see how late Stone Age people could have discovered the use of iron by themselves and mastered it so quickly without any outside influence (Coghlan, 1942; Shinnie, 1967, 1971; Tylecote, 1975b). It has nevertheless been maintained that this might have happened as a result of the temperatures obtained in firing pottery and the accidental inclusion of iron ore in the fire. But such an eventuality would certainly not have produced a bloom, since pottery firing temperatures only amount to 600 to 800 °C, and no charcoal, kiln or air draught are used for their attainment (Coghlan, 1942).

Among archaeologists working in the Nigerian region, emphasis has now shifted from the 'diffusionist' theory to the examination of the actual level of metallurgical sophistication attained by a particular group. The study of the methods of production of various iron-producing societies can result in the clarification of certain patterns of cultural similarities and contacts across the African continent. However, for the purposes of this paper, we reproduce below the arguments for and against the diffusion of iron technology in West Africa and, in general, in sub-Saharan Africa (Jemkur, 1992).

The Meroitic connection

The discovery of iron and steel is said to have taken place among the Calybes of Armenia, subjects of the Hittite Empire, at about the end of the first half of the second millennium B.C., and the knowledge of ironworking in all of Europe and Western Asia is ultimately traced to this source. By 100 B.C. the knowledge had become fairly general throughout South-West Asia (Hawkes and Woolley, 1963, p. 564). However, it took it considerably longer to diffuse to Egypt. 'Prior to the seventh century B.C., iron appears to have been rare in Egypt and was used mainly for magical and ornamental purposes' (Trigger, 1969, p. 34). It was only during the Saite period (665–525 B.C.) that iron smelting became evident in Egypt. Iron came into general use in Egypt later, that is, by the fifth century B.C. (Trigger, 1969, p. 36).

In the Nilotic Sudan, ironworking seems to have begun under the reign of Harsiyotef, who ruled during the period 416–398 B.C. (Arkell, 1966, p. 452; Trigger, 1969, p. 43). From 450 B.C. to the fourth century A.D., there is a complete archaeological sequence for Meroe, based mostly on excavations of royal

cemeteries. The iron objects that are dated *c.* 750 B.C. to *c.* 400 B.C. tend to be small and infrequent. Of 1,550 graves predating 400 B.C. at Napata, only eighteen contain iron objects (Arkell, 1966, p. 452). Trigger (1969, p. 42) considers that the presence of iron objects at this time is evidence of trade, since there is no positive evidence of iron production. It was not until the end of Meroitic power in A.D. 350 that the nature of iron objects changed. Iron jewellery became scarce. Numerous heavy objects appear for the first time, while the types of utilitarian object increase in number. The tool kit includes knives, swords, horse bits, axes, hoes and hammers. Many of the objects have socketed attachments, unlike the tangled tools of the Meroitic period. It would seem that only after the fall of Meroe did iron technology turn to tool manufacture and large-scale production, thereby increasing productivity (Trigger, 1969, p. 49). Trigger voices several reservations about this interpretation. The excavations are almost entirely of graves, and not of habitation sites. The representativeness of the grave goods has yet to be determined as they may reflect the normal tool kit.

Phillipson published (1970, p. 5) a date of 514 B.C. ± 73 for a piece of charcoal, found associated with fragments of iron, iron slag and pottery at the very bottom of the largest slag heap – 'Birmingham 97'. He feels that it was at this time that the Meroites first started to produce iron. Tylecote (1975b, p. 5) states that the early Iron Age phase at Meroe is represented by small brown furnaces found at a level immediately above one dated at 280 B.C. ± 120. These furnaces are not at all similar to Taruga shaft furnaces. Trigger's conclusions about the sequence of iron technology at Meroe, the dates for ironworking at Taruga and for Birmingham 97, as well as the dissimilarity of Taruga and early Meroitic iron-smelting furnaces, make it improbable that Meroe was a centre of iron technology diffusion to West Africa. In fact, Shinnie (1967, p. 14; 1971, p. 99) considered the Meroitic culture to have been exclusively oriented towards the Nile River on the basis of the fact that no Meroitic material has been found further west than the banks of the Nile. Furthermore, according to Trigger (1969, p. 26), the earliest evidence of contact between the Nilotic and Darfur cultures dates to A.D. 550.

Finally, Daima is one of the few fairly well documented archaeological sites in Nigeria. It lies near the corridor formed by Lake Chad and the Mandara Mountains. Through this corridor, east–west contact in the Sudan area is likely to have occurred. So far, Daima is the only known Nigerian site spanning the transition from a stone, and bone, technology to an iron one. The layers associated with the latter have yielded the following dates: A.D. 980 ± 650, and 450 B.C. ± 95 (Connah, 1981; Fagan, 1967, p. 518; Shaw, 1969). The abundant polished stone assemblages in the layers are indicative of a neolithic pattern. Within this sequence, the earliest iron was found at a depth of 6.5 metres, suggesting a date in the fifth century A.D. Three more dates were later published: A.D. 1060 ± 90, A.D. 630 ± 190 and 570 B.C. ± 100 (Connah, 1981; Fagan,

1969, p. 153). On the basis of the penultimate date, Connah revised his estimate of the introduction of iron objects from the first to the fifth century A.D. Daniels later examined statistically the entire sequence of dates related to the site and concluded that a fifth to sixth century A.D. date is most probable with regard to the introduction of iron (Willett, 197l, pp. 355–6). If indeed iron-working techniques reached West Africa from Meroe, they must have passed through Daima. If this were so, one would expect to find evidence of use of iron at Daima at a date much earlier than the dates attributed to the Nok culture site of Taruga, situated almost 1,000 kilometres to the south-west. Present evidence does not support this. In fact, it rather suggests that iron was being smelted at Taruga some 600–800 years before it reached Daima. This element and the fact that the iron industry at Meroe employed Roman-type slag-tapping (Tylecote, 1975) would indicate that neither iron objects nor iron technology diffused from Meroe to the Nok, contrary to what has often been proposed (Clark, 1969).

The Carthaginian connection

Another route by which ironworking techniques are considered to have reached West Africa is across the Sahara from Carthage (see for example, Mauny, 1952, 1971, 1978; Shaw, 1969, 1978, 1981). Carthage was founded at about the end of the ninth century B.C. by the Phoenicians who had already established settlements on the Mediterranean coast of Africa as early as about 1100 B.C. They came from an area where iron was widely used earlier than in Egypt (Mauny, 1978). Iron objects started appearing in their tombs from the sixth century B.C., and by the third century B.C. Carthage had become an important ironworking and trading centre. Carthaginian influence became strong on the North African coast along the Gulf of Gabes, inland of which was the powerful tribe of the Garamantes. The Carthaginians also undertook explorations along the African coast west of the Gibraltar Strait. It has been thought that it was through these contacts with the Carthaginians that ironworking techniques gradually spread across the Sahara to centres in West Africa (Mauny, 1952; Shaw, 1969).

Two possible routes have been cited along which knowledge of iron smelting could have crossed the Sahara to West Africa. One route extends from the Gulf of Syrtis to the bend of the Niger at Gao, and could have been the route by which a knowledge of iron reached Nigeria along the River Niger from the area of Carthaginian influence, with chariot-using Garamantes as intermediaries. The second route extends from southern Morocco, through Mauritania, along the Oualata and Tichitt Cliff to the Middle Niger. There are rock paintings along these routes indicating that horse-drawn chariots traversed them before 1000 B.C. (Mauny, 1971).

It has been deduced from the above that the Berber-speaking peoples of the desert, having learned metallurgy from the Carthaginians, were themselves responsible for passing it on to the peoples to the south, via the aforementioned routes (Mauny, 1971, pp. 66–87). Recent archaeological research in West Africa on the appearance of metalworking has shown that the above explanation is much too simplistic. It is already known from Lambert's work in the south-west Sahara that copper was being mined and worked around Akjoujt in Mauritania by the middle of the first millennium B.C., or even earlier (Lambert, 1971, pp. 9–12). Evidence is now coming up from other parts of West Africa, especially Niger, pointing to the appearance of copper before iron. Radiocarbon dates for copper working in the first millennium B.C. and even earlier have been reported from the Sekkiret and Azelik areas in Niger (Calvocoressi, 1971). These dates suggest that, as in the Akjoujt region of Mauritania, copper ores were also being exploited in Niger as far back as the early first millennium B.C. It is therefore possible that the metallurgical techniques practised in the Azelik region may also have served as preparation for the more complex processes of smelting iron.

Evidence for the existence of an early Iron Age in Nigeria has also been reported. Three radiocarbon dates late in the first millennium B.C. have been set for early use of iron in the Termit Massif area of south-east Niger (Posnansky and MacIntosh, 1979, p. 184). Three further radiocarbon dates, falling in the last three centuries B.C., have also been reported from the same areas of Niger for iron metallurgy at Teguef n'Agar. These seem to support the view that iron technology reached West Africa from the north.

Finally, radiocarbon dates for an early Iron Age have also been set for the savanna belt, especially Jenne-Jeno in the inland Niger Delta in Mali. This site was excavated in 1977 (McIntosh and McIntosh, 1981, pp. 1–22). It produced evidence that iron-using and manufacturing peoples were occupying the site in the third century B.C. Iron and slag were present in the oldest levels, together with a large amount of household debris. Six radiocarbon dates have been obtained from the site. Two – 210 B.C. ± 50 – stemmed from the basal levels, which contained iron and slag. Since the site is situated on an alluvial plain lacking stone or iron, the presence of slags led the excavators to conclude that the ore must have been imported into the area. Iron could have been transported to the site via the west Saharan route, which would point to early interregional exchanges among the areas concerned.

Thus, present available evidence suggests that, during the first millennium B.C., there were at least two important centres of copper working in the southern Sahara, Mauritania and Niger. It is possible that the Mauritanian centre developed through technology imported from the Mediterranean by Libyan Berbers, as a result of Phoenician and Carthaginian initiatives in prospecting for new mines in southern Morocco (Mauny, 1978). It is also possible that the same process may have occurred in the central Sahara, directed from Carthage towards

the Niger bend near Gao and giving rise to a later, but still 'early', ironworking activity in Mali and Nigeria. On the other hand, the centre of copper metallurgy in the Azelik area in Niger may well have facilitated the spread of iron to Nigeria, thereby suggesting a second possible diffusion route. The dates of ironworking for Taruga together with the recent dates from Niger and elsewhere in the Sahara makes the trans-Saharan route probably, though not necessarily, more acceptable than the route through Meroe. How ironworking actually arose south of the Sahara remains unclear. The new evidence for copper working preceding iron metallurgy in Niger may turn out to be important, but we are still far from understanding the social and economic context that precipitated this important technological transformation.

The local connection

It is now becoming increasingly apparent that the diffusionist theory, as summarized above, tends to be simplistic and mostly lacks hard evidence to support it. In the light of recent archaeological work on the subject in Africa south of the Sahara, there is an emerging school of thought that argues for possible independent beginnings of ironworking technology for West Africa (and indeed in other centres of Africa south of the Sahara). The proponents of this view (Andah, 1979, 1981; Lhote, 1966; Maes-Diop, 1968; Rustad, 1980; Schmidt and Avery, 1978; Trigger, 1969) have pointed to many gaps in the diffusionist thesis. For example, some of these scholars (Andah, 1979; Maes-Diop, 1968) agree that iron ore smelting does not require very high temperatures (1100 °C to 1300 °C), and that therefore iron technology may have developed directly from pottery firing techniques (Okafor, 1992a and b). The fact that there is no evidence of metallurgical know-how prior to knowledge of iron metallurgy in the Nok culture and Opi areas cannot be used as an argument against a local development of iron technology. It has also been observed that ferruginous laterite is widespread in West Africa in the form of both surface outcrops and underground deposits, and may have been known and exploited long ago (Okafor, 1992a). It is therefore possible for an Iron Age to have developed without passing through copper and bronze metallurgy. Available field information would suggest that ironworking is widespread in many parts of Africa. The few dates available for ironworking in some parts of Africa south of the Sahara are as early as, if not earlier than, those obtained for the 'donor' areas. For example, apart from the Nok culture area where ironworking is known to have been established at least by the fourth or fifth century B.C., other early dates, of about the fifth century B.C., have come from Ethiopia at Matara, while radiocarbon dates point to the existence of ironworking in the Bahaya area of Lake Victoria by 500 B.C. (Schmidt and Avery, 1978).

It has also been observed that the argument for diffusion from North Africa relies solely on the dates relating to the Phoenician and Carthaginian cultures in North Africa. No materials from Carthage and Utica, and in fact no site with Phoenician material, have been found to be earlier than the eighth century B.C. (Warmington, 1969). Although Carthaginians were producing armour on a mass scale by the third century B.C., Mauny (1971) holds that: 'It is only from the sixth century B.C. that iron appears in their tombs; from the third century it definitely replaces bronze as a material of ordinary use.' The 100- to 200-year interval between the presence of iron technology at Carthage and its appearance in the Nok culture area make diffusion possible, but the interval's shortness renders diffusion improbable (Diop, 1973; Andah, 1979).

The fact that there is at present a lack of concrete dating evidence for the 'beginnings' of iron metallurgy for most parts of sub-Saharan Africa, coupled with the realization that not much is yet known about when and how ironworking began in sub-Saharan Africa, makes it difficult for us to hold rigidly to the view that the knowledge of ironworking was introduced from outside.

Early ironworking in Nigeria

The remains of furnaces found in Taruga belonged to non-slag-tapping shaft furnaces (Tylecote, 1975a and b). They all had thin-walled mud shafts over shallow pits. Tylecote estimated the overall height of the larger furnaces to fall between 1 m and 2 m or more. They are considered as free standing and the presence of several tuyères near the base has been noticed (Tylecote, 1975b, p. 5). These tuyères had a bore diameter of 20 to 30 cm, but were shorter than the ones of the Meroitic furnaces. Tylecote distinguished between the pit-type shaft furnaces of Taruga and the slag-tapping type furnaces. Since he had earlier implied that tapping the slag was a technological advancement (Tylecote, 1965, p. 193), the Taruga furnaces can be taken as representing a more primitive stage of West African ironworking development. They are considered to belong to type 'B'. The third to fifth century B.C. dating of Taruga furnaces renders them contemporaneous with the Meroitic finds. There was clear evidence, Tylecote concluded, that Nigeria did not derive its iron technology from Sudan but from elsewhere (Tylecote, 1975b, p. 4).

Until recently, even the dates established for the Nok area seemed questionable in relation to the remaining archaeological evidence that has been collected, with an apparent long hiatus between the Nok iron tradition and later manifestations in the Nigerian area (late first millennium or after). However, as already noted above, the Daima mound from north-eastern Nigeria has yielded an early ironworking date of A.D. 630 ± 190 (Connah, 1971, p. 71). Also, excavation of iron furnace remains from Dala Hill in Kano City has yielded a date of A.D. 635 ± 95

(Willett, 1971, p. 368). This date would seem to agree closely with the ones from Daima and Zaria in the Kubanni Valley. This latter area yielded the remains of several furnaces at Samaru West, which were dated at A.D. 685 ± 80, A.D. 750 ± 155, A.D. 930 ± 95 and A.D. 940 ± 75 (Sutton, 1976, p. 18). These remains were associated with slag heaps, tuyère fragments and what seem to be slag-tapping pits. One furnace was fully excavated before removal for display, and turned out to be of barrel-like cylindrical shaft, about 1 m high and less than 1 m in diameter (Sutton, 1976, p. 4). One other feature of these furnaces was a cylindrical pipe-hole that extended about 20 cm on the exterior of the wall at the base. This pipe-hole had a bore of about 35 cm high and 25 cm broad and sloped downward towards a slag pit. Sutton suggested that this hole may have served as an inlet for the tuyère openings in the rest of the furnace.

Sutton identified two types of tuyères from the area: the one at Samaru West was a massive, tapering type, with a bore measuring from 5 cm, at one end, to 12 cm at the other, and had an external diameter of up to 30 cm. This contrasted with the smaller tuyères from Tsauni North and Makera (Sutton, 1976, p. 5), which had a bore of 3 to 5 cm and an external width of up to only 10 cm. Since the Samaru furnaces were about 1 m high, they may well have been of the 'C' type and, therefore, association with the massive-type tuyères would be expected. If, nevertheless, the distinction between the two tuyère types represents a change both in the times and in technology, then the evidence from Samaru and Taruga would substantiate the evolutionary development of 'B' to 'C' type furnaces in West Africa.

Recent ethnographic and historical surveys of ironworking techniques in the present Kaduna and Plateau states have tended to lend support to the above. Here, the presence of furnaces with massive tuyères is very noticeable (Jemkur, 1989). The furnaces are very similar to the ones described, for example, in the case of Samaru West. This type of furnace (free-standing) is widespread in southern Kaduna state, where there are hundreds of such remains. Judging from the number of furnaces and the large concentrations of the waste, it is evident that large-scale iron-smelting activity occurred in the area in the recent past. The free-standing furnaces here are invariably found in a poor state of preservation, mostly in the open, in plains and valleys close to some river. They are today barely visible at ground level, as circles, most of which rarely exceed 10 to 40 cm high. In some places they cover a very large expanse, usually in clusters, each of which consists of some six to eight furnaces. This picture is common in many parts of northern Nigeria, especially in Bauchi, Plateau, Kano, Katsina and Sokoto states.

The second type of furnace in the area consists of embedded furnaces. These were found to be better preserved. In fact, most of them are still intact. This type of furnace was built along stream banks, the back of the furnace being formed by the natural bank, sometimes scooped out a bit, and then bellied with a wall built

to form the front. The reason for their near-complete preservation was the absence of animal and human activities (other than rodent). They were only subject to erosion. They are generally about 1 m in height, each having two openings (holes). With few differences in the detail, the smelting processes and apparatuses collected in the field seem to be identical in most parts of the Nigerian savanna. The following is a description of the processes, as remembered by elders from the Kurmin Mazuga, Nok and Ashafa areas (all in southern Kaduna state). The Ikulu (Bakulu) people inhabit Kurmin Mazuga and Ashafa, while Nok is inhabited by the Jaba (Ham) people. These ethnic groups are said to be expert in iron smelting, so that most of the other ethnic groups in the area purchase their wrought iron from them.

Generally, iron was produced from the ground by the process of smelting. Essentially, the ore was obtained from mines that were shallow in some cases, while in others they exceeded 10 m in depth. Iron-rich ore was located by observation of the type of sand left by run-off water along pathways, farms, streams and so forth. The iron ore, usually in the form of relatively soft rock, was broken into pieces by hand using stone tools. The crushed ore was then mixed with charcoal that supplied the heat necessary for smelting the ore. The charcoal was usually made from hardwood such as acacia or bishiya (among the Hausa), commonly found in the area. The mixture of ore and charcoal was then poured into the smelting furnaces. The mixture was lit and air supplied to the furnace from below. Once the furnace attained a high temperature, the melt trickled down to the mould in the ground through a hole in the furnace wall. The mould is a hole dug in the ground below the furnace. The molten iron was then allowed to solidify in the form of an ingot (wrought iron). This ingot was then used to produce various articles, such as farm implements and tools. The tools used for the working of the ingots into tools were all of strong granite stone, until the coming of Europeans who introduced more sophisticated tools. Among the Ikulu and Jaba people, smelting involves a great deal of ritual at the different stages. We were told that smelting involves preparations connected with beliefs that certain people could affect the process spiritually. Furnaces are preferably built in stream banks. In the words of one of the elders: 'our people carried out smelting near streams, and obtained different metal from that of the Hausa. The Hausa built their furnaces like brick ovens and not on stream banks.'

Our investigation has shown that, in the savanna region of northern Nigeria and indeed most parts of Nigeria and West Africa in general, iron technology has been widespread and abundant for over twenty-five centuries, in other words since before the coming of the Europeans, contrary to some of the early European literature to the effect that West Africans had no knowledge of iron until the arrival of the white man (McPhee, 1926). The laterites of most parts of West Africa lent themselves to exploitation for iron, as is evident from the visible remains of smelting. Iron was of great economic importance in these areas and

was traded far and wide. For example, interviews conducted in Daura (Katsina state) indicated that smelting was carried out in the area until the 1940s, when it was halted by force. Before then, sales of iron from Daura were considerable in the French Territories.

The establishment of British rule in Nigeria put an end to this once prosperous local industry. Everywhere the inhabitants were forced to abandon the traditional art of iron smelting in favour of the cheaper iron imported from Europe. The arrival of the British did in fact destroy the industrial base much needed for Africa's technological and cultural development; for the level of technological development greatly affects a people's culture, and hence one aspect of the cultural progress of a people is contingent upon the state of its technology.

Twenty-five Centuries of Bloomery Iron Smelting in Nigeria

Edwin Eme Okafor

The first part of this exposition establishes clearly that people in the African continent began to produce iron tools from their own smelted iron ore twenty-five centuries ago.[1] This development was not fortuitous, since iron ore, the third most abundant mineral after silica and alumina in the continent, is ubiquitous there (Andah, 1979). Iron ore exists in the form of oxides: haematite, siderite, goethite and magnetite (Tylecote, 1987). Each one of these oxides was exploited and smelted wherever it was found in Africa (Okafor, 1984a, b, c). Refractory clay, the other necessary ingredient for ironworking, used for the making of tuyère, furnace and hearth, is very common in the continent (Childs, 1984). Fuel, mostly timber and/or charcoal, was readily available especially during the early and middle period of bloomery ironworking. Finally, labour was not scarce, especially in the period before the transatlantic slave trade (Okafor, 1992a).

With the means to satisfy every requirement of this industry readily available in the continent, the great diversity of production techniques and apparatuses employed in Africa is not surprising (Schmidt, 1977). In no other continent has such a broad variety of furnace types and functions been recorded (Kense, 1983; Pole, 1985; Sutton, 1985). Diversity has also been manifest in fuel treatment and production. Signally, it is only in Africa that production of high carbon steel from bloomery furnaces has been observed (Bellamy and Harbord, 1904; Schmidt and Avery, 1978).

Hardly any part of Nigeria had no remains of bloomery ironworking. Such remains have been mapped and studied, for example, in Argungu, Daura, Katsina, Zaria, Maïdi, Chawai, Ashafa, Kurmin Mazuga, Zagomida, Nok, Taruga, Birom and Combe in the north (Jemkur, 1989). In the west, such remains have been reported in Oyo, Ola Igbi (Bellamy and Harbord, 1904), Igbira, Ogbo-

1. On the occasion of the first meeting of the Scientific Committee of the Iron Roads in Africa project, the Steering Committee organized a remarkable exhibition on iron in Nigeria, from the origins of the industry to the present.

moso and Esie (Aremu, 1990); and they have been studied and mapped at Awka (Okafor, 1976), Ukehe (Ekechukwu, 1989), Aku (Njoku, 1986), Opi, Abakaliki, Orba, Umundu, Owerre-Elu, Lejja, Abiriba, Awgu and Okigwe (Okafor, 1984b, 1992a).

Although ironworking remains have been found in other parts of Nigeria outside Nsukka division (Bellamy and Harbord, 1904; Effah-Gyamfi, 1981; Fagg, 1969; Nicklin, 1981; Okafor, 1983; Sassoon, 1964; Sutton, 1976; Tylecote, 1975b), none can be compared with those in Nsukka, either in volume or in variety of techniques employed. In Nsukka division mounds, aggregate and cylindrical blocks of slags of early ironworking have been discovered at Owerre Elu, Opi, Orba, Umundu, Lejja, Aku and Ukehe. Ethnographic, ethnoarchaeological and archaeological investigations by Njoku (1986), Okafor (1984a) and Onyeke (1986) show that many different systems of iron-smelting were implemented, with use of different apparatuses and techniques within the same ethnic group. Unfortunately, harsh climatic conditions had caused most of the remains of this industry to disintegrate: thus elements that survived are mainly tuyère, furnace fragments and slags, which are almost indestructible (Okafor, 1992b; Tylecote, 1987). Fortunately, Okafor (1992a) recently applied very modern scientific techniques to study the Nsukka bloomery ironworking. The results of that study form the basis of this discussion of bloomery ironworking techniques employed in Nigeria and other parts of Africa.

Iron-smelting process in Nigeria

Eleven carbon-14 (C-14) dates obtained by the Accelerator Mass Spectrometry Laboratory of the University of Oxford show that from 760 cal. B.C. to A.D. 1950 cal. (cal. = probable dates) there has been continuous iron smelting in Nsukka division (Okafor, 1992a, b; Okafor and Phillips, 1992). The dates concerning Nsukka iron-smelting sites span all accepted published radiocarbon dates for early iron-smelting sites in other parts of Nigeria (Anozie, 1979; Calvocoressi and David, 1979; Connah, 1968, 1981; Fagg, 1969; Shaw, 1969, 1978, 1981; Sutton, 1976). During this long period the industry experienced, in the area, some changes in technique, perfecting production and increasing efficiency. The earliest period was more labour intensive and less efficient in iron extraction than later ones. Based on data from the present research, Nsukka iron smelting falls into three chronological phases, each corresponding to a chronological sequence and characterized by particular forms of the smelting residues.

EARLY PHASE OF NSUKKA IRON SMELTING

The early phase of Nsukka iron smelting is represented by sites at Opi, Lejja and Aku. Three AMS radiocarbon ages, 2305 B.P. ± 90, 2170 B.P. ± 80 and 2080 B.P. ± 90 (Okafor and Philips, 1992), based on secure contexts and obtained by accelerator mass spectrometry, are available for this phase. Calibrated on the 1986 Stuiver and Pearson rating curve, using the 1989 calibration programme of Van der Plicht and Mook, these dates fall between 765 B.C. cal. and A.D. 75 cal., with a 98 per cent probability. This is the oldest iron-smelting period in Nsukka. Iron smelting during this phase was done in forced draught shaft furnaces, connected through channels with slag pits. Furnaces measured 0.85 m to 1.25 m in diameter, and had thin walls about 40 mm thick. Slags from these furnaces were tapped intermittently into the slag pits through the connecting channels. The slags solidified in the pits, forming cylindrical blocks.

These blocks weigh from 43 to 47 kg, and have an average density of 3.89 gm/cm^3. Their colour varies from dark brown (MC 7.5 YR 4/4) to strong brown (MC 7.5 YR 5/8).[2] They are rustless and some of them are slightly magnetic on fresh surfaces. They bear no inclusions. Samples analysis of these blocks has shown a very low basicity, with a mean value of 0.03 (0.01 standard deviation). Their melting temperatures range between 1155 °C and 1450 °C.

SEM (scanning electron microscope) and EDS (energy dispersive X-ray micro-analyser) analyses of slags from the early phase of the Nsukka iron-smelting sites reveal a mainly fayalithic composition. Apart from fayalite, other major phases are hercynite and wustite. Leucite and glasses are minor phases in the slags of this period. These phases exist in different structural forms and textures.

Opi slags contain more hercynite mineral (22.47 per cent) than any other slag from Nsukka. Hercynite has a high melting temperature (1780 °C). Consequently, all Opi slags with a high silica content (Al_2O_3) and hercynite content display melting points ranging between 1350 °C and 1450 °C. The iron smelters at Opi, it seems, attempting to liquefy the high Al_2O_3 gangue, produced slags featuring high melting temperatures.

This was an incidental occurrence in the early phase of iron smelting in Nsukka. The technique of slag liquefaction at high temperatures improved in the late phase of Nsukka iron smelting through use of silica as flux to lower the melting point of the gangue and extract more iron from the ore. The silica formed iron silicate with some oxide, thereby freeing reduced iron. This produced wustite-free slags, characteristic of the late phase of Nsukka iron smelting, discussed below.

Wustite, free iron oxides, was found in all but three slag samples from the early Nsukka iron-smelting phase. In Nsukka slags, free iron oxides or wustite

2. According to Munsell's colour code.

exhibit dendritic structures of varying sizes. Since wustite is the penultimate stage in the reduction of iron ore to metal iron (Morton and Wingrove, 1969, p. 1557), the level of wustite in slags is thought to indicate the efficiency level of a given bloomery operation. The higher the free iron oxide content of a slag, the less efficient the smelting operation (McDonnel, 1986, p. 86); that is, the wustite content of bloomery slags will vary as a function of the operator's skill in running the furnace in a way that leaves minimum wustite in the slags. Improvements in techniques would account for increasing efficiency and decreasing wustite slag content (Morton and Wingrove, 1972, p. 480). It would thus seem that, in the Nsukka division, iron smelters in the early phase sites were less efficient in extracting iron than smelters of the middle and late phases. Although wustite is only 6.2 per cent of the mineral content of Opi slags, this percentage is higher than in slags from all other phases.

THE MIDDLE PHASE OF NSUKKA IRON SMELTING

Two high-precision dates, 1060 B.P. ± 60 and 570 B.P. ± 60, have been obtained by AMS for the middle phase of Nsukka iron smelting. Calibration of the two dates for two standard deviations gives a range of A.D. 810 to 1435 cal. This suggests that the middle phase of Nsukka iron smelting probably fell between A.D. 810 and 1435 cal. (Okafor, 1992a and b). Iron-smelting sites belonging to this phase lie in the Owerre-Elu-Nru-Isiakpu-Edeoballa axis. During this phase, iron was still smelted in forced-draught shaft furnaces. Slags were still tapped but not into pits: they were allowed to run out of the furnace and spread on the ground around it, thereby taking flat, smooth, ropy surfaced forms.

These typical tap slags survive in flat cake forms weighing 1.5 to 4.2 kg. They are very dense, 4.2 gm/cm^3 on the average. Some are weakly magnetic on fresh surfaces. They have no rust or inclusions. They display mixed colours of dark brown (MC 7.5 YR 3/4) and black over their entire surface (MC 7.5 YR 2/10). Their sections are bluish grey and are coarsely vesicular near the surface. Samples analysis of these slags shows a very low basicity (mean: 0.02; S.D.: 0.01).

Most slags from this phase contain no free wustite. This suggests improved efficiency and mastery over reduced iron extraction techniques. Improvement is also witnessed by the low melting points estimated for most of the slags of this period: 75 per cent of total analysed slags from this phase feature melting points below 1200 °C. Then again, SEM and EDS analyses of these slags show them to consist of fayalite, hercynite and a few patches of glass localized in the vasicles. Some also contain white dendrites of wustite. The most abundant mineral in these slags is iron silicate or fayalite (Fe_2SiO_4) amounting to 76.42 per cent of their mineral content based on volumetric calculations.

Of the twelve Owerre-Eru slag samples studied, only five contained wustite. Wustite, in dendritic form, constitutes 3.92 per cent of the mineral content of the middle phase slags analysed in this research.

The plot of Owerre-Elu slags in the $FeOAl_2O_3SiO_2$ ternary phase diagram manifests evident variations of composition. Seven of these slags contain no wustite and have lower melting points of 1150 °C, as opposed to the five with wustite-containing samples, whose melting points range between 1150 °C and 1325 °C. The information provided by these slags may be understood better by analysing the radiometric dates obtained from charcoal associated with the slags at the site. Based on C-14 dates, Owerre-Elu belongs to the middle phase of Nsukka iron smelting. This phase lasted probably from about A.D. 800 to 1430 cal. The late phase of Nsukka iron smelting (represented by Orba and Umundu sites discussed below) extended from A.D. 1430 to 1950 cal.

On this evidence, one may suggest that Owerre-Elu slags with no wustite and low melting points (very similar in this respect to Orba and Umundu slags) belong to the latter period of the middle phase, while the remaining slags, containing wustite samples with higher melting points (similar in this respect to Opi slags), belong to the early period of that phase.

THE LATE PHASE OF NSUKKA IRON SMELTING

The late phase of Nsukka iron smelting covers the period from about A.D. 1430 to about 1950 cal. This is based on six high-precision AMS dates, 200 B.P. ± 80, 205 B.P. ± 80, 300 B.P. ± 90, 215 B.P. ± 100 and 295 B.P. ± 85, derived from secure contexts (Okafor and Phillips, 1992). The iron-smelting sites of the Orba-Umundu-Eha-Ndi-Agu area belong to this phase.

The furnace in use during this phase, though still of the shaft type, was self-induced. These furnaces were not tapped during smelting. The entire furnace load was raked out after smelting and blooms were sorted from residues (Okafor, 1984a, b, c). The reduction of labour needed by this technique was achieved at the expense of production duration. Self-draught shaft furnaces require a longer smelting time. This was advantageous, for it allowed smelters to charge the furnace as many times as they wished, thereby producing bigger blooms in one smelting round.

Iron slags from the late Nsukka iron-smelting phase survive at the smelting sites in aggregate form. As a result of their extraction from the furnace by raking and their sorting from the bloom, they survive as amorphous irregular aggregates. They are highly vesicular and have a relatively low density. The average density of slag samples from Orba and Umundu is 3.98 gm/cm^3 and 3.6 gm/cm^3 respectively. Their colour varies from dark brown (MC 7.5 YR 3/4) to black over their entire surface (MC 7.5 YR 2/10). A few of these slags have some quartz inclusions, but without any rust. None of the slag samples from these sites is

magnetic. As with Opi and Owerre-Elu slags, Orba and Umundu slags have a low basicity. The mean basicity of Orba and Umundu slags is 0.01 and 0.02 respectively. Their melting temperatures range from 1150 °C to 1280 °C.

SEM and EDS analyses of slags from late-phase Nsukka iron-smelting sites show that the slags consist of fayalite, hercynite and glass. Umundu and Orba slags contain high siliceous glass owing to excess silica in the slags.[3] Free iron oxides and wustite are totally absent from late-phase slags. This demonstrates the high level of iron extraction efficiency attained by late-phase Nsukka iron smelters. As observed above, the level of free iron oxide in slags indicates an iron master's ability to run the furnace so as to minimize the iron left in the slag (Morton and Wingrove, 1969; 1972, p. 478).

Ethnographic data from the area show that sand was loaded into the furnace as smelting progressed, perhaps to flux the smelt (Okafor, 1984a, b; c, pp. 24–5). Tylecote (1987, p. 108) observed that high-grade ores, rich in iron oxide, require sand flux for a better yield of iron. The practice of fluxing bloomery smelts with sand has been documented in many early metalworking sites (Fells, 1983, p. 132). During his research on the early ironworking sites at Nebersdorf in Austria, Sperl (1980, pp. 61–74) discovered excess quartz in the slags, which may have been used as flux. In South Africa, iron smelters at the site near Phalaborwa fluxed their smelts with silica (Van der Merwe and Killick, 1979, p. 89). The sand used produced the excess silica that gave rise to a high glass content in the Umundu and Orba slags. Glass constitutes 27.33 per cent and 27.25 per cent, respectively, of the mineral constituents of these slags.

Most Orba and Umundu slags fall within the fayalite-hercynite-iron cordierite triangle (some fall within the fayalite-hercynite-wustite triangle). This bears out the findings of microanalyses of these slags, which failed to detect wustite in slags from Orba and Umundu.

The estimated melting temperatures of Orba and Umundu slags range between 1150 °C and 1280 °C and fall within the minimum temperature requirement for bloomery iron smelting (Van der Merwe, 1969, p. 17; Tylecote, 1987, p. 296). The production of these wustite-free slags at low melting points was assisted by the silica that Orba and Umundu iron smelters used in fluxing their smelts. The silica reduced the melting points of the gangue and combined with some iron oxide to free reduced iron.

The late phase of Nsukka iron smelting marks the final stage and the end of iron smelting in that region, in terms of iron extraction efficiency and minimal labour demand. None of the slags from this phase contains wustite, and this suggests a total extraction of available iron from the smelt. The phase also featured the use of sand as flux to lower the melting point of the gangue in the smelt. Thereby, the sand-formed iron silicate, with iron oxide, freed reduced

3. This is the phenomenon of vitrification. – Ed.

iron. Slags of this phase had the minimum melting temperatures necessary for any bloomery smelting.

Discussion

The developments in Nsukka bloomery technology discussed above suggest continuous progress towards labour conservation. After the early phase, slag pits were abandoned, and in the middle phase, slags were tapped straight on to the ground surface. In the late phase, the introduction of self-draught furnaces rendered bellows unnecessary. Labour was also saved by the disappearance of the need to tap slags as smelting progressed. Instead, the furnace was off-loaded at the end of the smelt. It is evident that there were continuous changes in Nsukka, each aiming at perfecting techniques and reducing labour requirements.

Morphological and physical analyses of smelting residues from Nsukka show clearly that they fall into three definite groups, corresponding to the three phases, without any possibility of a fourth phase. The differentiation of the group by distinct technological and ethnoarchaeological characteristics indicates that concrete variations occurred in iron-smelting techniques in the area of the Nsukka division. Such variations also existed in the three phases identified above. This raises the matter of how Nsukka iron smelting was organized. The questions that arise from the data obtained lead to the following questions:

- Were there individual iron-producing communities in the Nsukka area, practising this activity and producing their iron independently of the other groups?
- Why does each phase represent a different technological phase of the industry?
- Why are the three observed phases not represented in any one site?

The question of whether the various communities producing iron in Nsukka did so independently implies that each produced its iron only within one of the three phases observed, and did not engage in any production either before or after that phase. It is unlikely that this was the situation in Nsukka, since the available dating evidence and the results of the residue analyses suggest a continuous development.

With regard to the second question, two points would explain why each phase of Nsukka iron smelting was technologically different from the others. Late-phase smelting operations were clearly better and more efficient than earlier ones. Technological changes that differentiate the Nsukka iron-smelting phases can be explained, in part, as resulting from several decades of experience. This is quite probable since C-14 dates from the four sites studied demonstrate clear progress from about 760 B.C. to A.D. 1950, as borne out by the results of the residue analyses.

Second, the furnace operations associated with each of the phases show a steady shift towards labour reduction. Two factors, economic and political, identified by other researchers (Afigbo, 1973a; Oguagha, 1982; Shaw, 1970), operated in northern Igboland between the middle and the late phase of Nsukka iron smelting and may have led to labour shortage in the area of the division. Shaw (1970, p. 285) observed that the trade goods that the Ibo exported in the ninth century A.D. to their northern neighbours included slaves. Afigbo (1973a, pp. 79–80) also noted that, in the nineteenth century, slave trading was one of Nsukka's most established commercial activities. He mentions Nkwo-Ike, Ozalla (in Nsukka division), as a renowned slave market. The fear of slave raids and the actual fall in population due to the export of able-bodied young men must have limited the labour essential to the iron-smelting industry.

Other threats to the labour available in this period in the Nsukka area were raids and wars by the Igala against the Nsukka. The Nsukka-Igala war dates span the eighteenth and nineteenth centuries A.D. (Oguagha, 1982, p. 58). They were prolonged wars, and at their peak, left most of Nsukka under Igala influence. It is likely that the technological changes differentiating the Nsukka iron-smelting phases were concrete responses of the iron masters to labour shortage.

This is evident with respect to the middle phase of Nsukka iron smelting, when slag pits were abandoned and slags were tapped straight on the ground surface. Improvement and experience over several years, plus increasing labour shortages, led to abandonment of forced draught furnaces, and to the non-tapping of slags as smelting progressed. (The furnace was off-loaded once at the end of the smelt.)

Probably as a result of scarcity of labour and insecurity stemming from slave raiding and the Nsukka-Igala wars, some iron smelters used wood directly in their smelting, without taking time to burn it in order to produce charcoal. Ethnographic data from Ama-Orba suggest that the Ama-Orba iron smelters used this technique during the late phase of Nsukka iron smelting (Okafor, 1984a, b; c, p. 23). It reduced required labour and produced a change in the prevalent technology.

Differences in iron-smelting techniques observed in each of the three phases of Nsukka iron smelting thus reflect the state of society during each phase. The early phase of Nsukka iron smelting appears to have been peaceful, and therefore the industry could afford to be very elaborate and complex. Iron smelters had enough labour and time to build and use forced-draught shaft furnaces, dig slag pits, line them with clay and provide connecting channels to the pits.

The severe threat to available labour by both the Atlantic and the internal slave trades, and the insecurity induced by the Nsukka-Igala wars, imposed certain technological changes. This is evident in the late phase of Nsukka iron smelting. As a result of the labour scarcity and insecurity, the forced-draught shaft furnace technique was abandoned in favour of the self-draught furnace technique, thus eliminating the roles of bellowers. Red-hot slags ceased to be

tapped as the smelting progressed, and instead, the entire load of the furnace was off-loaded once at the end of the smelt. At times, when severely pressed by the above constraints, late-phase iron smelters adjusted further their technology by smelting directly with wood instead of charcoal, thus saving the time and labour of charcoal production.

To understand why the three phases are not present at any one site, it is vital to know the course of events in northern Igboland (which includes Nsukka division) during the early Iron Age. Glottochronology studies show that Igbo began emerging from the Kwa linguistic sub-family as a separate ethnic group about 6,000 years ago (Afigbo, 1973b, p. 8; Armstrong, 1962, p. 284; 1964, pp. 22–3). This view is supported by archaeological materials from northern Igboland sites, particularly from Nsukka, excavated by Hartle, suggesting that the area was occupied before the third millennium B.C. The study of pottery from these sites shows close similarities in colour, form and decoration between the excavated sherds and those that are still in use in the area today (Hartle, 1967, pp. 134–43).

Historical and ethnographic data from Igboland show that when the Igbo emerged as an ethnic group, they first settled in northern Igboland. Their culture developed from there and they expanded to the other areas they now inhabit. It is relevant that even now many Igbo groups claim that their ancestors lived originally on the northern Igbo plateau, before moving out in search of unoccupied land (Afigbo, 1973b, p. 9).

A number of factors attracted the ancestors of the Igbo to the northern Igbo plateau. The area, although originally in the forest zone, is at the fringe of the savanna belt. This, according to Uzoezie (1972), made land exploitation and farming feasible with the limited tools at their disposal. Also, this area, particularly in the later period, was on the major trade routes that connected the Igbo with the Igala and the Idoma in the north, and with the Ijaw and Cross River areas in the south.

Finally, it is on this northern Igbo plateau, mainly on the Nsukka-Udi Cuesta, that the most abundant deposits of iron ore are located. The ore caps the residual hills in the area, and most of it contains up to 50 per cent iron (Umeji, 1980). It is probable that, during the long occupation of this plateau, some group of Igbo people learnt how to smelt iron ore. Afigbo observed that:

> The northern Igbo plateau and its extension to Bende is rich in iron ore deposits. And it is here that smelting and ironworking were most highly developed in Igboland. The iron tools and implements that were produced on the plateau were in great demand over the rest of Igboland and beyond.
>
> (Afigbo, 1973b, p. 16)

From C-14 evidence, it would appear that this iron-producing group, possibly as early as the eighth century B.C., first settled the woods and exploited the ores at the early-phase sites (Opi, Lejja and Aku sites). On the evidence from slag

analyses, the loss of iron to slags prevalent at the sites of this period suggests that the producers were still trying to improve their mastery over ore exploitation techniques. This phase may have ended around the first century A.D., according to C-14 dates. It is probable that exhaustion of resources, ores and fuel at early-phase sites and the need for iron tools led to a search for new sources of raw materials. This prompted the group, or its descendants, to move into the middle-phase area (Owerre-Elu-Nru-Isiakpu) where rich iron ore capping the Nru-Isiakpu ridge and abundant hard wood for fuel were to be found. Available C-14 dates show that these sites were exploited probably between A.D. 800 and A.D. 1450.

Probably by around A.D. 1430, the resources necessary for iron smelting were diminishing at the middle-phase sites and the need for iron tools led to exploitation of resources in the late-phase areas (Umundu-Orba-Eha-Ndi-Agu). As discussed above, this was the last phase of iron smelting in the Nsukka division. Six C-14 dates show that iron was smelted in this area between A.D. 1430 and A.D. 1950.

From the foregoing evidence, we conclude that in the Nsukka area bloomery iron smelting was conducted by a specialized group of craftspeople who moved from one location to another as available raw materials were exhausted at each site. Bellamy and Harbord (1904) observed that Ola Igbi iron smelters near Oyo in Yorubaland similarly relocated their industry whenever they exhausted available resources at a given site. Archaeological evidence discussed above demonstrates cultural continuity in the area, from the third millennium B.C. to the present (Hartle, 1967). Hence, ancestors of the present Nsukka communities have always lived in the area. Ethnoarchaeological evidence from the *Eguru* (blacksmiths) shows that ironworking had been a craft for segregated groups that were not open to everybody. It had been a craft for a closed caste that jealously guarded its privileges and duties and shunned admission of non-members (Okafor, 1984a, b; c, pp. 69–76).

Evidence obtained in linguistic studies on the Nsukka division seems to support this conclusion. All the communities in the area have common words for the key items related to iron production. For example, furnace is generally known as *itoro* or *utu*, bloom is known as *aga*, slags are known as *afuru* or *nsi igwe* and iron ore is known as *nne igwe* or *nne ukwume*. Uniform vocabulary for all key elements of iron production is a strong indication of ‘a group practice’ as opposed to an activity by multiple distinct practitioners.

This conclusion is also supported by the fact that the Nsukka people, although they all know these key elements of iron smelting by name, do not know how it all came about. For example, most people who live within the early- and the middle-phase areas do not know how the smelting debris around them originated. Even the oldest man in Opi, Onyishi Abonyi Nnamani, from the Idi Opi clan of Umugedu village, informed the writer that the cylindrical blocks of

slag in Opi are 'small hills germinating from the ground'. He believes that humans did not make them. A similar story was told at Owerre-Elu where Onyishi Ozioko Ugwu described the flat tap slags as *nsi igwe*, given to Owerre-Elu people by God to defeat their Edeoballa enemies. This, I learnt, referred to an occurrence whereby the Owerre-Elu people inflicted heavy casualties on their enemy by throwing slags on them.

Finally, a tradition recorded by C. Onyeke (1986, p. 14) from the Idi Opi clan claims that the Opi people never smelted iron themselves, but that iron smelting at Opi was carried out by outsiders who came, lived with them, and left at the end of their work. Bloomery iron smelting is a highly specialized trade. In many artisan communities such as Igboland, the presence of iron smelters would be very valuable for the production of raw materials to make most of the tools needed by the community. Otherwise, the clan would object to smelters camping and doing their smelting wherever they found raw materials. The tradition of locating smelting sites close to iron ore sources would explain why the smelting group moved to fresh ore sites when they exhausted the ore available in the various locations. In northern Igboland, Njoku (1986) recorded that, when choosing smelting site locations, more consideration was given to the distance from available ore than from wood. However, where conditions were favourable, both were taken into account.

Observations

Based on the discoveries made, the following conclusions have been reached about Nsukka bloomery iron smelting:

- Nsukka bloomery iron smelting took place from about 765 B.C. cal. to about A.D. 1950 cal. During this long period, the industry went through three phases. Each successive phase represented a technological change in the industry.
- On the whole, Nsukka bloomery technology was very efficient in terms of iron extraction. Very little free iron oxide was left in the slags. In this regard, the earliest period of this industry was least efficient, while the latter period was most efficient, achieving almost maximum iron extraction from the ore and reducing labour requirements.
- Nsukka bloomery iron smelting was conducted in shaft furnaces of various forms. In the Nsukka area, forced-draught shaft furnaces were used from the inception of the industry till about A.D. 1430. The slags of these furnaces were not tapped as smelting progressed.
- No pit or bowl furnace was found in the Nsukka division. What some thought to be bowl furnaces (Anozie, 1979) turned out to constitute slag pits into which slags were tapped as smelting progressed.

- Nsukka bloomery iron smelters smelted local goethite and haematite. Nsukka iron ores were rich in alumina (Al_2O_3), with significant levels of silica ($Si0_2$). Initially, the high presence of alumina in the iron ore led to use of high smelting temperatures. Later, the temperature was lowered by use of sand flux. Major mineral phases in Nsukka slags are fayalite, hercynite and wustite. Minor phases present in some of these slags are glass, leucite and magnetite.
- Nsukka slags have very low basicity. Nsukka bloomery iron smelters did not use any lime or any lime-rich flux in their smelting.
- The presence of iron ore determined the location of the smelting sites. The sites were relocated when the ore was exhausted. In the Nsukka area, bloomery iron smelting was conducted by a specialized group of craftspeople who moved from one location to another as they exhausted available raw materials at each location.
- Nsukka bloomery iron smelters limited themselves to the production of blooms. They never refined or forged the blooms they produced. The blooms were sold to blacksmiths who refined and forged them into tools.
- The economic and political conditions prevalent in the region determined the development of the various technological phases of the industry. The restriction of labour supply to the industry in the middle and late phases of its development was overcome through the adoption of straight smelting techniques, which were less labour-intensive.

The Impact of Iron in Yorubaland

Isaac Adeagbo Akinjogbin

Impact of iron metallurgy on the socio-political system

The time lag between the first knowledge of iron in Yoruba society, and its full impact on it, is not known. It is unlikely that such an impact would affect all aspects of Yoruba life at the same time. It would appear however that the first major impact of iron on the Yoruba socio-political system occurred between the ninth and the tenth centuries A.D. Before then the socio-political system in Yorubaland centred on small villages, while clusters of villages formed the highest political organization (Akinjogbin, 1981; Obayemi, 1977, pp. 255–322). The role of overall head of the cluster, called *Oba* (king), rotated among the heads of the component villages in an agreed order. The *Oba* was both the ritual and political head, and a principal part of his duties was propitiating the land.

Toward the end of the ninth and the beginning of the tenth centuries, Chief Oduduwa started a revolutionary movement in Ile-Ife that resulted in the transformation of the village clusters into one big composite city. The thirteen village clusters in Ife became one single city with Oduduwa as the only *Ooni* (king) (Adediran, 1981), who donned a beaded crown (*ade ileke*) and lived in a large palace (*aafin*) in the middle of the city. All the former villages in the cluster were forcibly brought together and their former heads became religious chiefs (*isoro*) propitiating the land for the well-being of the *Ooni.* Although some of them retained the prefix *Oba*, which they attached to their titles, they lost political and economic powers and were subjected to the political authority of the *Ooni* who thenceforth ruled their former territories as integral parts of his kingdom.[1]

1. Such as Obalesun in Ife and Ado Ekiti, Obaluru and Obalara in Ife. The title ‘Ooni’ has been variously translated, but it may have developed from the word ‘oghene’, which meant ‘very big’.

Once the experiment succeeded and became settled in lle-Ife, many of the sons and war captains of Oduduwa went all over Yorubaland, repeating the same processes and establishing kingdoms, based on Oduduwa's model at lle-Ife (Akinjogbin, 1981, Chapter 12). Thus most of Yorubaland, hitherto organized in village clusters, was transformed into large kingdoms, governed by the sons and associates of Oduduwa and their descendants. Some traditions relate that there were seven such kingdoms, while others affirm that there were sixteen; but an actual count in the early years of the twentieth century revealed more than twenty such kingdoms (Anon, 1903).[2]

In what processes did this revolution occur and what, apart from leadership, was the key factor in its success? Although the traditions have tried to downplay the fact, the transformation process from village clusters to kingdoms occurred through military conquest. In Ile-Ife and everywhere else in Yorubaland, the Oduduwa group usually started as the smaller party, which overcame a larger and apparently stronger one; and the decisive factor in favour of the Oduduwa group was the use of iron. Usually, because of a desire to de-emphasize force, this factor is not highlighted explicitly in the traditions, but a number of indices betray the decisive role of the use of iron in this whole revolution.

First, Ogun, the god of iron, was the patron god of Oduduwa, leader of the revolution, and of all his sons and followers who later became *Obas*. Still today, an Ogun festival, called by various names in different parts of Yorubaland, takes place every year. It is the one occasion when the *Oba*, normally living secluded, appears in public, wearing the sacred crown (*are*). Wherever Yoruba royalty was established, Ogun became the patron god. It is a telling detail that the Ewuare Empire actually bore the name of Ogun.

A second indication that iron played a decisive role in the Oduduwa revolution was the establishment of a blacksmith's shop right inside the *Ooni*'s palace. This workshop was called the 'Ogun Laadin' (Laadin's blacksmith's shop) and is reserved today as a tourist attraction in the way it is thought to have been at the time of Oduduwa.

A third indication is that a short cutlass, called *ogbo*, or its enhanced form *ida* (sword), became the symbol of authority and justice. Every new Alaafin ritually receives the *ida oranyan* ('Oranyan's sword') at the beginning of his reign. Most *Obas* in Yorubaland still have either the *ogbo* (short cutlass) or the *ida* carried in front of them on formal public occasions.

That iron was regarded as a priceless metal was indicated when Oduduwa gave an iron chain (*epe*) to his first grandson who became the Olowu (King of Owu). One line in the *oriki* of the Olowu is *Omo ajifepe sire* ('the child of one who plays with an iron chain'). The importance of iron to the Oduduwa revolution was probably not only because it provided the decisive war implements,

2. See discussions of this issue in Biodun Adediran (1984).

but also because it revolutionized agriculture and increased the food supply. Testimony to this is supplied in the tradition that, soon after Oduduwa's revolution, the population of Ife grew rapidly and indeed outgrew the food supply, necessitating organized emigration.[3]

Given the importance of iron, employed simultaneously as an instrument of defence, attack, justice and agriculture, it is hardly surprising that under the Oduduwa dynasty every kingdom, indeed every urban centre within each kingdom, possessed as many iron-smelting factories and blacksmith's shops as were considered necessary to make it self-sufficient.

By the beginning of the fifteenth century, all the iron used in Yorubaland was smelted locally in furnaces constructed by the Yoruba, with ironstones and heating agents entirely procured from their locality. In seventeenth- and eighteenth-century Africa, at the height of the transatlantic slave trade, the Yoruba continued to prefer their own smelted iron and regarded imported iron as ritually impure and 'deaf'. Most Yoruba urban centres had their own ironstone quarrying sites, called *Oko ota* or *Oko eta* (ironstone farms), and at least one small furnace (*Ile Iponrin* or *Ile Isunrin*) in the district. Johnson records that certain areas, such as Okemesi in Ekiti and Ilorin in Yorubaland, were famous for their ironstones (Johnson, 1921, p. 119). It is presumed that such places supplied areas less well endowed. Large urban centres were served by many furnaces and exported their surpluses. In spite of the civil wars that engulfed Yorubaland from 1793 to 1893, and the massive social, demographic and economic dislocations, visitors to Laagbe near Oyo in 1904 still saw eleven iron-smelting furnaces (Williams, 1973) working at full capacity and employing about 100 workers. Indeed, an educated Yoruba man living in Lagos felt compelled to report his astonishing discovery of these factories to his fellow inhabitants of Lagos who, he suspected, had perhaps forgotten, like himself, that such knowledge ever existed among their peoples.

The loss of political and economic initiative by Africans, as well as a policy of discouraging the growth of local industrial ventures in order to protect imports, undoubtedly contributed to the demise of iron smelting in Yorubaland. This activity persisted until about 1936 when iron was last smelted at Isundunrin (near Ejigbo), a town seemingly named after its smelting industry.

Design of a Yoruba furnace

The Isundunrin furnace had not completely collapsed by 1956 when the then Government of Western Nigeria established the Yoruba Historical Research Scheme under the directorship of Dr S. O. Biobaku. One of the research assistants

3. This is preserved in the Odu Ofunsa.

in that organization was the late Pa David Adeniji. He had been trained as an iron smelter as a boy and probably worked at the Isundunrin furnace before he went to school. In 1977, a few years before his death, Pa Adeniji published a detailed description of the design of a typical iron-smelting furnace in Yorubaland. The following description is taken entirely from his work (Adeniji, 1977).

According to Pa Adeniji, a typical iron furnace must be situated in a grove, away from human habitation but within hearing distance. It was usually located on a site of an area of about 200 sq ft (70 sq m) on a hard, level, properly drained ground that had been cleared of all roots and bushes. The factory house was installed at the centre of this plot. The furnace building was constructed either in a circular form (pre-nineteenth-century style) or in a rectangular form. The building had two entrances, one facing east to bring in fresh air and the other facing west to let out excess heat. It had six or eight windows for the benefit of the workers, who had to remain inside continuously, sometimes for seventy-two hours or more. The roof of the building was much higher than in a normal house in order to prevent the thatch from catching fire. A platform was raised at the centre of the building and the actual furnace was built on this platform. A small shallow trench was dug, facing the eastern entrance and ending up at the base of the platform supporting the furnace. A bigger trench (9 ft x 9 ft x 9 ft, or 3 m x 3 m x 3 m) was dug facing the west entrance. The two trenches were separated by 6 ft (2 m) of solid earth, on top of which rested the platform that carried the furnace. A 2-inch (5 cm) hole was bored to connect the large trench and the floor of the furnace. Through this narrow hole, hot air escaped and slag dropped from the furnace into the large pit.

Around the furnace, which stood on a platform, were six openings, each large enough for a man's hand and connected with the east-facing trench. A tuyère was inserted into each opening to regulate the inflow of air. Seven smaller platforms were also raised around the base that carried the furnace, for the convenience of those who stoked the fire and poured in raw ironstone; this was inserted through the top of the furnace.

The smelting process

Once the furnace was in place, the smelting process could start. There were three types of iron-bearing stones.

1. The *Sagodo* (large type), containing the highest percentage of iron content.
2. The *Afuye* ('light stone') or *Oko* (after the name of the town where it was first discovered): as its name implies, it was lighter and possessed a smaller percentage of iron than the Sagodo.
3. The *Agunwinni* ('iron sand').

All three were mined either vertically or horizontally, depending on the direction of the underground deposits. Some mines were deep enough to necessitate ladders, and miners sometimes slept underground for days.

Men did the mining and the actual smelting at the furnace. Women washed the stones absolutely clean, pounded them into smaller bits and carried them to the furnace building. But it was strictly forbidden for them to go near the furnace during the actual smelting.

To provide the necessary heat, three types of hardwood were burnt into charcoal and used in the smelting. The woods were *Erun* (*tali),* also called *Obo* (*Erythrophleum guineense*), *Orupa dudu*, also called *Ako orupa*, and *Ponhan*. The botanical names of the latter two are still unknown. For the tinder, charcoal and animal dung were mixed together, dried and ground into powder. When everything was ready, the tinder was poured into the oven, a short proprietary ceremony was held in honour of Ogun, and the fire was lit. Both the coal and the ironstone were poured into the furnace in agreed proportions. The fire was kept up at full blast for three days (seventy-two hours) during which a heat of over 1050 °C could be produced. Then two days (forty-eight hours) were allowed for cooling down, before the iron was fetched out of the furnace. To produce steel, the iron was further heated in the blacksmith's shop where all the impurities (called *pepe irin*) were removed and carbon was introduced. The steel thus produced was used largely to manufacture heavy tools.

Attention should perhaps be drawn to a number of features in the iron-smelting industry in Yorubaland. First, all the materials used in the entire process were fully produced locally and were available practically throughout Yorubaland, although some areas were better endowed than others. No importation was needed, nor was any carried out. Second, although the technology was simple, it was effective and satisfied the entire Yoruba demand for iron and iron goods. It probably left some excess for export to neighbouring areas. Thus, complicated designs are not always synonymous with effectiveness. Third, and this may not be obvious from the description so far, the whole process was not regarded simply as 'technical' or 'technological', but also had some religious value attached to it. At every stage of the production process certain codes of behaviour had to be followed by the smelters, and Ogun, who was revered as the *Oniporin akoko* (first iron smelter), was propitiated. Before igniting the tinder, the very essence of fire was invoked so that the greatest heat could be produced. The iron thus made was in turn regarded as 'pure' and capable of 'hearing' when the appropriate language was spoken to it. It was not 'impure' and 'deaf' like the European iron.

The manufacture of iron implements

According to Johnson (1921), 'before the period of intercourse with Europeans, all articles made of iron and steel, from weapons of war to pins and needles', were manufactured by the Yoruba from the iron and steel produced in their furnaces. Adeniji has attempted, unsuccessfully in our view, to list all the items manufactured in a Yoruba blacksmith's shop (Adeniji, 1977). Indeed, Yoruba blacksmiths prided themselves on being able to manufacture just about anything, as long as it could be described clearly.[4] And they could not have been far wrong, for soon after the introduction of guns into Yorubaland in the nineteenth century they quickly mastered their manufacture, and the making of iron shot in place of the lead shot brought by the Europeans.

The blacksmith's shop that produced all these implements was even simpler than the furnace.[5] It was an open rectangular shed of some 2 m by 4 m. The most important fixture in it was the *Ogun*, which served both as the guardian spirit and the implement on which heavy pounding was carried out. Another fixture was the *Akamo* (fixed in the ground), on which other smaller poundings were done. The instruments consisted of the *Emu* (grip), the *Omo owu* (small iron club), the *Iya owu* (big iron club), the *Motaake* (iron hammer), the *Ilu* (awl) and an *Obe* (knife). All of them could be packed in containers and carried from place to place. In fact they were carried to war fronts. There were two types of bellows (*ewiri*), that is, vertical and horizontal. Palm kernel shells (*eesan*) provided the material for heating the iron to the required temperature. Each Yoruba town might have as many blacksmiths' shops as were necessary for satisfying its requirements in agriculture and defence. A small town might have five shops, while a large city like Ibadan could have hundreds.

Unlike the iron-smelting furnaces, blacksmithing has not entirely disappeared in Yorubaland. Indeed, it has shown a remarkable ability to adapt to the changing technological culture, in spite of official neglect and occasional discouragement. Today, Yoruba blacksmiths are manufacturing bolts and nuts for imported machines, spare parts for cars and engines, and sometimes simple machines, such as block-makers and grinders. They could do a great deal more with the benefit of training and official encouragement.

4. As summarized in the Uprina Sauomg, 'Apejuwe ni alagbede ro' ('Blacksmith manufactures anything that is described').
5. The description that follows stems from my own field observations.

Iron technology and Yoruba culture

We have already pointed out that iron smelting and iron manufacturing were not regarded as mere technology (which undoubtedly they were). Since they concerned the very survival of the Yoruba, with respect to both food supplies and security, they became an integral part of their spiritual well-being. We have already noted that *Ogun oniporin akoko* (the first iron smelter and first blacksmith) is the royal deity in Yorubaland. Wherever there was Yoruba political influence, Ogun was introduced as the royal *Orisa*. We have also noted that Ogun was the patron deity of all ironworkers, whether iron smelters or blacksmiths. Today motor vehicle drivers, tailors, welders and anyone who uses iron in his/her daily profession or calling, consciously or unconsciously acknowledges Ogun as a patron deity.

As in most other professions in ancient Yorubaland, iron smelters and blacksmiths belonged to particular lineages (*ebi*). They had special facial marks called *Gombo*, and Ogun was prefixed to their names.[6] Their favourite colours were white and black. Red was particularly forbidden. Their favourite drink was palm wine. They were expected to be morally upright, because their patron god, Ogun, was credited with a mercurial temper and would mete out instant justice to deviants. With respect to miners, it was believed that any wrongdoing might cause the pit to collapse on their heads.

Ogun's role as an agent meting out instant justice has continued to be exploited. Today, whenever an *Oba* (king) sits to hear a case, an iron implement, symbolizing Ogun, is placed in front of him. Litigants kneel by the symbol and, having sworn by Ogun, can be relied upon not to speak blatant falsehood. Even in modern law courts, it is believed that a litigant who swears by Ogun will speak the truth, because he believes that Ogun will give him justice, even if the law courts deny him it.

6. Examples include Ogunbayo and Ogunfansi.

Part Two

Meeting on African Iron Metallurgy

UNESCO, Paris,
12 November 1999

The Process Chain in Iron and Steelmaking: Archaeological Materials and Procedures

The Contribution of Metallographical Studies

Philippe Fluzin

The process chain in iron and steelmaking

The transformation of ore, a natural substance, into functional iron objects entails passing through a series of technical stages during which the material undergoes chemical and physical transformations. The purpose of archaeometrical studies of metallurgical products and waste is to reconstitute this process chain (Figure 1).

The first phase in the art of metalmaking involves separating the metal in the ore from the other elements with which it is combined. Among the most important of these is oxygen. Iron has three oxides: ferric oxide (haematite, Fe_20_3, which may be hydrated; goethite, limonite and so on), magnetic oxide (magnetite, Fe_30_4) and ferrous oxide (wustite, FeO). Oxygen must be eliminated with the help of another chemical compound (such as the carbon in charcoal). Thus metal is obtained by means of a successive reduction of these oxides. The other elements contained in the ore (gangue) are expelled to varying degrees in the form of slag.

It should be noted that, in contact with the environment, metals that have been reduced tend (with the exception of gold) to revert to the state of oxides: this is known as 'oxidization' (corrosion). In fact metals 'come alive' in an environment containing the very element (oxygen) from which they have been separated in the production process.

Regardless of the time period, place or process in question, three indissociable elements play a part in the reduction process (Figure 1):

- *Ore*: iron is the fourth most abundant element in the earth's crust, but occurs in a wide range of mineralogical combinations in the form of ore. The value

of an ore and the use to which it is put obviously depend on its iron oxide content but also, first and foremost, on the nature and concentration of the elements with which it is combined. Ore is seldom used in the state in which it is extracted from the mine. It must be prepared through various forms of preliminary processing (such as washing, crushing, sorting, sizing, roasting and calcination).

- *Fuel* (such as charcoal, peat, coke): the carbon that it contains is a triple agent; it produces heat, reduces the ore and combines with the iron to produce steel and cast iron (Plate VIII, see page 94). The distinction between iron, steel and cast iron is fundamental in this regard. It has always been possible to tell them apart by the way they look and behave, but it was not until the work carried out by Roozeboom in 1889 and Osmond in 1898 (see Chezeau and Fluzin, 1997) that breakdown charts were produced, making it possible to define theoretically the distinctive parameters of iron, steel and cast iron. (Pure iron contains less than 0.02 per cent carbon, steel 0.02 to 1.7 per cent and cast iron 1.7 to 6.67 per cent.)
- *Oxidizing agent* (oxygen in the air): this is the main factor determining the temperature level attained in the furnaces. In an attempt to raise it, natural draught was abandoned for forced-air processes, first manual (bellows), and later hydraulic (twelfth century) and mechanical.

As indicated in Figure 1, it is essential to view the iron and steelmaking process in terms of a number of stages: preparation, reduction, refining, forging, shaping and so forth. Some of these stages are outlined below.

Metal production processes and the main associated archaeological residues

There is probably no one single centre of origin and dissemination of iron-making: one can mention 1300 B.C. in Anatolia or 2000 B.C. in Niger, at the Termit site, noting that our recent work in the Central African Republic indicates the existence of a number of very old original sites in Africa. Not wishing to enter the somewhat controversial debate about the origins of these processes (Pleiner, 2000), we shall confine ourselves to summarizing the main stages in the evolution of iron and steelmaking methods (Figure 1).

These are very diverse, but they can nevertheless be summed up by taking as our main criterion the temperature reached in the hearths or furnaces, which governs the physical state of the materials processed. Let us take T as the temperature attainable through a given process, and Tf as the temperature at which the metal melts. Then:

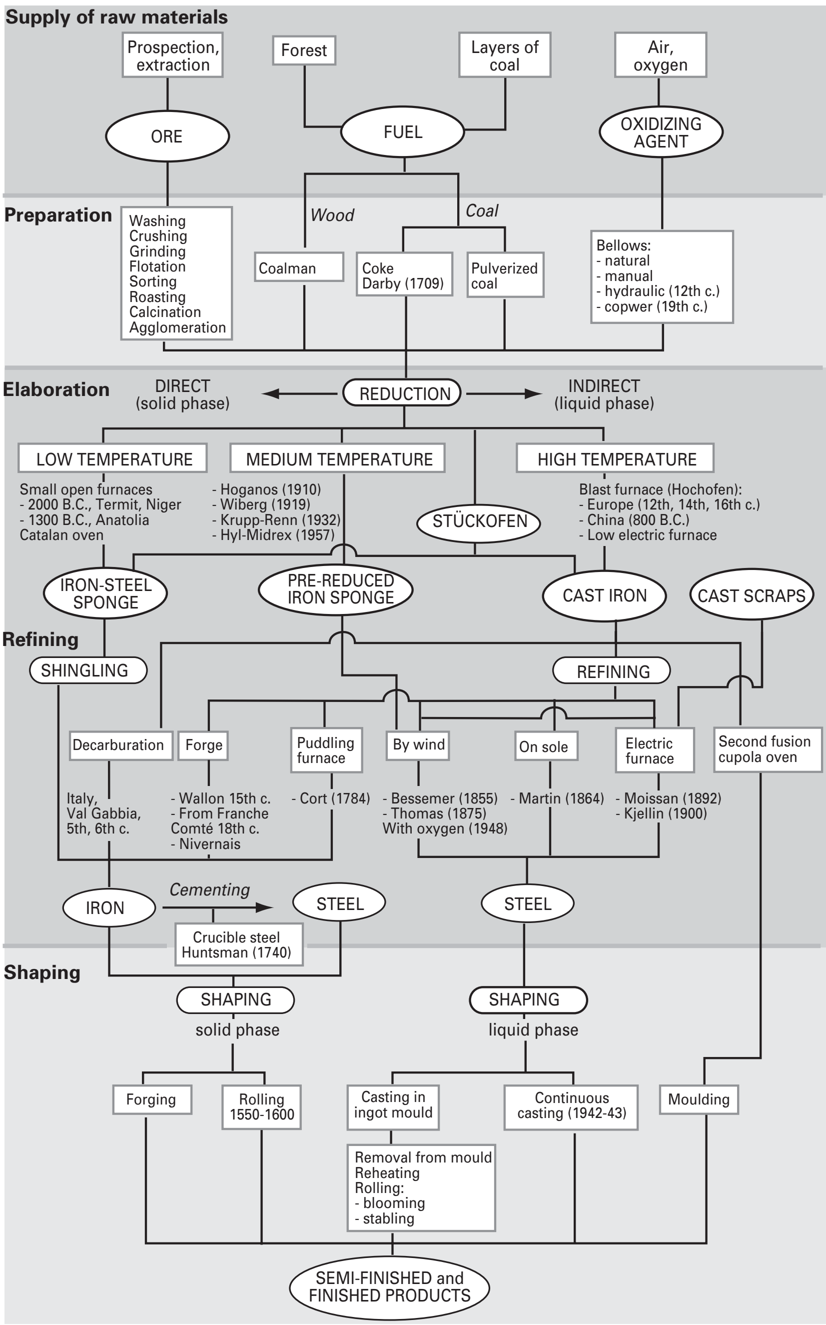


Figure 1. The iron and steel process and its historical evolution (© P. Fluzin, 2000. In collaboration with V. Serneels, Institute of Mineralogy, University of Fribourg, Pérolles, 1700 Fribourg, Switzerland).

- If T is lower than Tf, we are dealing with the so-called 'direct method' (turning ore directly into iron and/or steel). The metal produced by this form of reduction remains solid (albeit dough-like), but the slag may flow from the furnace.
- If T is higher than Tf, then we are dealing with the 'indirect method'. The products resulting from the reduction process are liquid: cast iron and slag. Although cast iron may be moulded, it cannot be forged as it is too brittle, and must be decarbonized to obtain steel by one of two kinds of refinement: with or without melting . This extra stage of refining accounts for the term 'indirect'. In this chapter, we shall be looking mainly at different aspects of direct iron and steelmaking. (For the indirect process, see Fluzin, 1999, 2000a and b; Petrequin et al., 2000).

THE PROCESS CHAIN IN DIRECT IRON AND STEELMAKING

In direct iron and steelmaking, we may distinguish three main stages (reduction, refining and forging/smithing), which may or may not take place at the same site (Plate I).

Each stage involves a specific operation and results in a product and a more or less specific type of waste. We shall summarize these stages briefly without entering into a detailed description of the physical and chemical processes involved.

Plate I. Direct reduction and its products

Photo 1. Ethnoarchaeological mission: contemporary small open furnace in Burkina Faso, Toungaré site, Bulkiemdé province, 1994 (© P. Fluzin).
Photo 2. Experimental reconstitution: type-2 model small open furnace, Clérimois (Yonne), Archéodrome de Beaune, 1996 – C. Dunikowski, S. Cabboï, P. Fluzin and A. Ploquin (© P. Fluzin).
Photo 3. Ethnoarchaeological reconstitution: Agorregi forge, Basque Country (Spain), 1999 – M. Urteaga, P. and S. Crew, P. Fluzin, R. Herbach, V. Serneels and P. Dillmann (© P. Fluzin).
Photo 4. Dense slag flow plaques (superimposed ribbons). Experiment with Aulnay-Truchet type low hearth (Sarthe), 1997 – C. Dunikowski, S. Cabboï, P. Fluzin and A. Ploquin (© P. Fluzin).
Photo 5. Internal slag flows. Danawel archaeological site (Senegal), 1995 – H. Bocoum and P. Fluzin (© P. Fluzin).
Photo 6. Furnace bottom: excavation A 28. Aulnay-Truchet site (Sarthe), 1997 – S. Cabboï (© P. Fluzin).
Photo 7. Contemporary bloom. Ethnoarchaeological mission, Toungaré site (Burkina Faso), 1994. Weight: 60 kg (© P. Fluzin).
Photos 8 and 9. Ethnoarchaeological reconstitution: Agorregi forge, Basque Country (Spain), 1999, bloom No. 8, 21 kg – M. Urteaga, P. and S. Crew, P. Fluzin, R. Herbach, V. Serneels and P. Dillmann (© P. Fluzin).


1


2


3


4


5


6


7


8


9

Reduction

The first stage consists in transforming (by reduction) the iron ore into crude metal in a low furnace or hearth (Plate I, Photos 1 and 2). This operation, combining ore, charcoal and atmospheric oxygen, takes place at a temperature lower than the metal's melting point. The iron and steel produced remain dough-like, while the ore gangue turns into liquid or semi-liquid slag (depending on the composition of the ore or the use of additives, the fluxes). This slag either runs off or gathers inside or outside the furnace (Plate I, Photos 4, 5 and 6). A detailed morphological examination of these products yields information about the functioning and architecture of the furnace (GSAF, 1997; Leroy, 1997; Serneels, 1993). Slag flows outside the furnace are found mostly either in the form of plaques or of single or superimposed ribbons (Plate I, Photo 4). They may line a hollow or channel dug in front of the furnace to contain them (Biélenin et al., 1998). Slag remaining inside the furnace takes the form of more or less compact blocks, moulded to the shape of the base of the hearth or blended with the mass of charcoal (Plate I, Photos 5 and 6). Direct reduction tends to produce dense slag, a blend of silicates and iron oxides, along with varying amounts of vitreous matter. In some cases its porosity becomes far greater (spongy, lightweight slag) after cooling. This slag often forms sizeable accumulations, frequently detectable on the ground during site prospecting.

It is impossible to offer a detailed typology of low hearths, as they exist in such variety. However, they can be grouped, for example, into three families according to whether the slag separates fairly easily from the metal, runs off inside or flows away outside the hearth (Biélenin et al., 1998; Pelet, 1982; Pleiner, 1998; Serneels, 2000).

Regardless of the type of low hearth, charcoal and ore (or blends of ores and possibly flux) are fed alternately into the upper part of the chamber. Combustion takes place through natural and/or artificial ventilation (by means of bellows in the latter case).

The number of parameters in the reduction operation is very great, and know-how alone allows mastery of the process. Since know-how unfortunately leaves no archaeological trace, it is essential to carry out numerous experiments in order to grasp the processes involved, and, where possible, observe *in situ* and *in vivo* the rare African ethnic groups still in possession of that know-how (while avoiding any wholesale transposition of the findings (Celis, 1991a; Fluzin et al., 1995; Fluzin, Serneels et al., forthcoming; Petrequin et al., 2000). Following the reduction process (which, according to our experiments, can last from four to twenty-four hours depending on the type of furnace and the ventilation conditions), a fairly heterogeneous, spongy mass is extracted from the hearth (through an opening or by destroying the furnace): this is the sponge iron (or bloom; Plate I, Photos 7, 8 and 9). It may weigh (depending on the size of the

furnace and the quantity of ore used) anything from a few hundred grams to 90 kg in the case of some African examples known to us. This bloom is an agglomerate of metal of varying degrees of compactness (iron or steel; Plate I, Photo 9), slag and charcoal. The quality of the bloom is closely linked to the ironworker's mastery of the reduction process: hence, the sponge iron is seldom sufficiently dense and pure not to require refining, which is probably vital in virtually every case.

Refining

Refining consists in hammering the bloom while it is hot ('nobbling' or 'shingling') in order to expel the impurities and make the metal more dense (Plate II). Depending on the quality (homogeneity or compactness) of the bloom, we can distinguish at least two main types of refining (Figure 2):

- Working the mass directly after it is removed from the furnace or after heating it in a special hearth or furnace (Plate II, Photo 10).
- Breaking the bloom into pieces of varying size, to be sorted if necessary (separating the barren materials, but also the iron and steel, as notably practised by certain Japanese artisans) and assembled in the forge (Plate II, Photo 11).

It may be useful to carry out an initial refining ('roughing') of the bloom as soon as it emerges from the reduction furnace. Taking advantage of thermal inertia, this favours the agglomeration of the metal and makes for greater compactness while expelling a number of barren elements. Nonetheless, further refining in the forge, often essential, is carried out preferably in a special hearth or furnace (Plate II, Photos 12 and 13). It is worth mentioning cases where the bloom is introduced as it is (or in large fragments, depending on its bulk) into such furnaces in order to liquefy the accompanying slag as far as possible (especially in the cases of so-called 'dirty' bloom). Some ethnological and archaeological examples testify to this practice (Martinelli et al., 2000). The sponge iron (bloom) is 'dried' to varying degrees and divested of its external (and internal) slag, leaving a particular type of residue: 'channel'-type slag flow (Biélenin et al., 1998).

In this case, depending on how reductive the refining has been, the carbon content of the sponge may be increased by means of cementation. It is not impossible in this way to produce highly carburized steels, and even cast iron (Fluzin, 1999), by heating the bloom several times in the same furnace. (Even the low hearth may be reused for this type of operation.)

The waste produced by the refining operation – which may entail several stages: primary and secondary roughing (cf. Mangin et al., 2000b) – may be extremely varied: slag flow fragments, shapeless slag masses with varying metal content, slag-saturated metal shreds, and so forth. The latter type of waste is

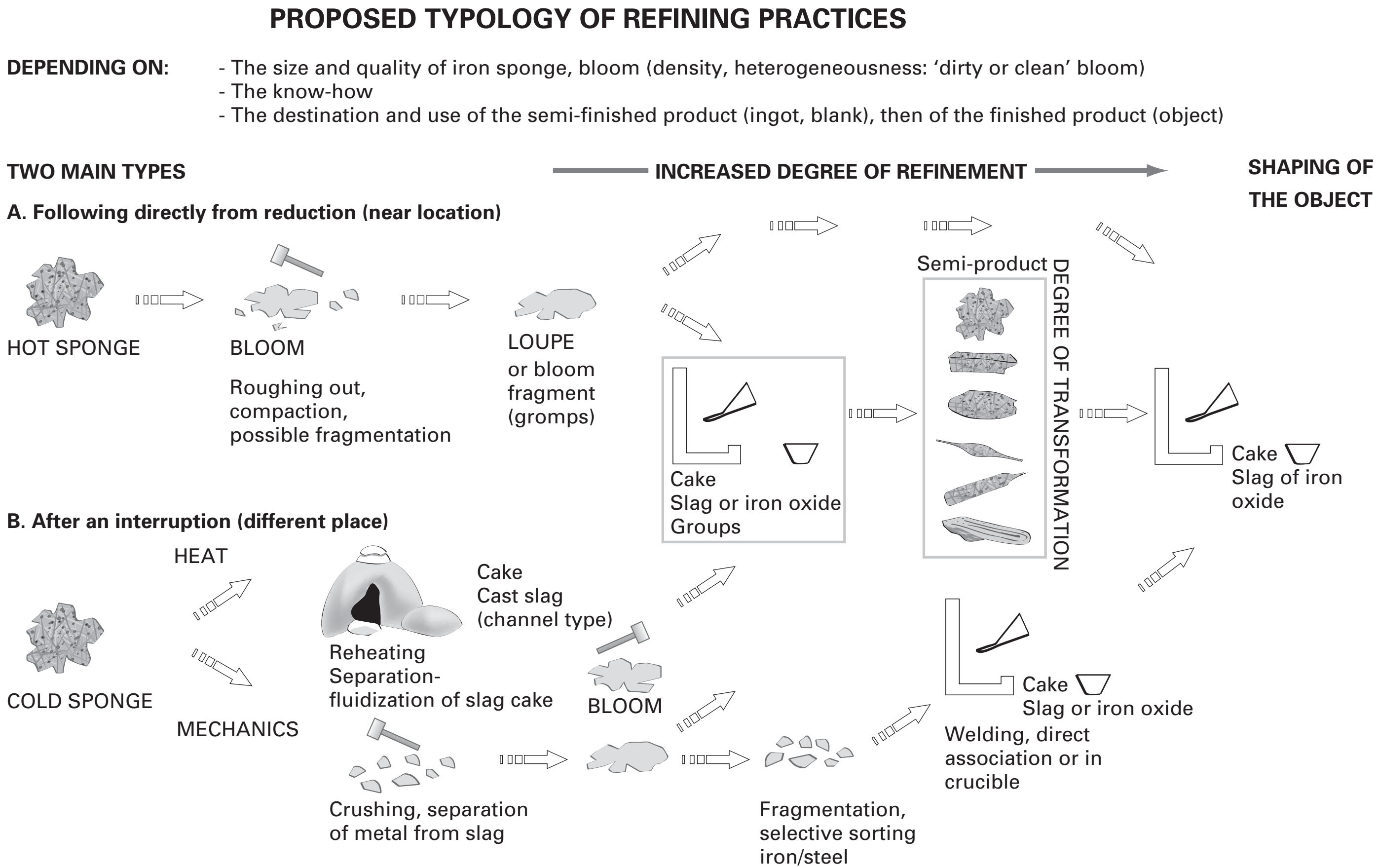


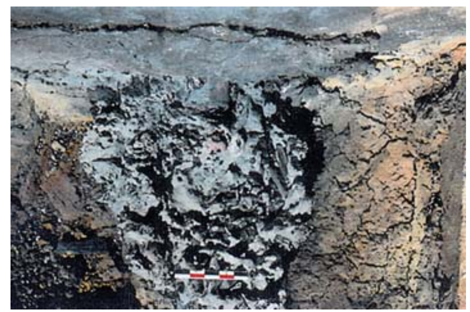
Figure 2. The process chain in ironmaking: refining (© P. Fluzin, 1999)


10


11


12


13


14


15


16


17


18

Plate II. Refining, practices and waste

Photo 10. Ethnoarchaeological reconstitution: Agorregi forge, Basque Country (Spain), 1999 – M. Urteaga, P. and S. Crew, P. Fluzin, R. Herbach, V. Serneels and P. Dillmann (© P. Fluzin).
Photo 11. Traditional Japanese processes. Reduction and refining by fragmentation of the bloom, blade forging, polishing. Nancy, Jarville 1989 – O. Masami, W. Ryosui, P. Merluzzo, C. Forrières, A. Thouvenin and A. Ploquin (© P. Fluzin).
Photo 12. Contemporary refining forge hearth. Ethnoarchaeological mission, Toungaré site, Burkina Faso, 1994 (© P. Fluzin).
Photo 13. Refining forge hearth and object shaping. Nancy experiment, 1997 – D. Leclère, P. Fluzin, M. Leroy and P. Merluzzo (© P. Fluzin).
Photo 14. Slag cake (1.5 kg) after refining of a 4.7 kg bloom. Nancy experiment, 1997 – D. Leclère, P. Fluzin, M. Leroy and P. Merluzzo (© P. Fluzin).
Photo 15. Gromps. Macrograph before and after cut (sample F104/06: 109 g). Ancient agglomeration of Blessey-Salmaise (Côte d'Or), 2000 – M. Mangin and P. Fluzin (© P. Fluzin).
Photo 16. Slag cake (409 g), Cricket site (Alexandria, Egypt), Hellenistic period – V. Pichot and P. Fluzin (© P. Fluzin).
Photo 17. Section of archaeological cake. Ponte di Val Gabbia site, Bienno (Italy), 5th and 6th centuries A.D. Weight: 2.5 kg, 1998 – C. Cuccini Tizzoni, M. Tizzoni and P. Fluzin (© P. Fluzin).
Photo 18. Left to right: metal fragment, slags, slag billets recovered from the bottom of a refining hearth. Belfort experiment, 1995 – D. Leclère and P. Fluzin (© P. Fluzin).

known as 'gromps' (Nosek, 1994; Plate II, Photo 15). Gromps are an integral part of the activity of 'compacting' the bloom, and their proportion varies considerably from one bloom to another, depending on its quality (density of the metal, lack of pollutant inclusions, porosity and so on). Various melted materials gather at the rounded base of the refining hearth (Plate II, Photo 14) and form a vaguely hemispherical mass or slag cake (Plate II, Photos 16 and 17).

These slag cakes come in many shapes and sizes but tend to be large and heterogeneous, with numerous inclusions of metallic fragments, suggesting short-lived thermomechanical activity (Mangin et al., 2000b; Plate II, Photo 17). However, the morphological aspect (mass) of these residues is not a sufficiently distinctive criterion, as our work on the Blessey forges has shown (Mangin et al., 2000a). Their size is related essentially to the quantity of matter being worked (with or without additives).

The archaeometrical study of a slag cake can yield very important general information about the forging activity carried out in the hearth that produced it. This information can be many-faceted. Metal scraps (fragments, blanks, rejects, recycled objects and so on) may provide selective information about the technical object of a kind very different from that which derives from slag waste and

concerns the quality of metal worked or the metalworker's skill (welding, heating processes, type of tool used and so on). Given the complementarity of these specific facets, it is important to be aware of them and to carry out the widest possible cross-studies when selecting samples.

The amount of slag associated with the task of refining a 'clean' bloom or of secondary refining may be quite small. Obviously the same is not true of a bloom still containing large amounts of non-metallic elements ('dirty bloom') and when additives, deoxidants or fluxes (sand, clay and so on) are used.

Our experiments and ethnoarchaeological finds suggest that the refining of a bloom regarded as 'dirty' involves the loss of around 80 per cent of its original weight in order to obtain an ingot (Crew, 1991; Dillmann et al., 1998; Fluzin, 1999; Leroy, 2000). Half this weight loss is accounted for by material consisting largely of slag-coated metal shreds, which may be assimilated to 'gromps', 10 per cent consists of scale and 20 per cent is made up of slag and billets. A clean bloom sheds only half its original weight, the bulk of it at the beginning of the operation. The weight of slag cake obtained, without taking into account any additives, is around half the initial bloom weight. These figures not only help in arriving at a conservative estimate of the quantities produced (metal and waste), but also demonstrate the high loss of metallic fragments, some of which end up in the slag cakes or shapeless residues (gromps).

The use of a solid metal anvil (steel) turns out to be inappropriate at the beginning of the refining operation, especially in the case of heterogeneous blooms (insufficient compactness, presence of iron and steel, raising the problem of weldability levels and so on). The propagation of shock waves may reduce the solidity of the metal during agglomeration and generate major losses. In our experiments we therefore invariably begin refining on a wooden block (Plate IV, Photo 28) and finish on a metal anvil. The use of a wooden mallet is also useful at this stage.

During excavations of a forge site, it should not therefore be forgotten that anvils are not necessarily made of metal. Besides cost considerations, wood and stone (Plate IV, Photos 29 and 30) may be better suited to much of the work done in a forge, given the intrinsic characteristics of these materials. (Again, the contribution of ethnoarchaeology is considerable.) They dampen shock waves and hence are particularly suitable for welding operations (refining, recycling and so on). Wood is not always preserved but it is important to observe *in situ* the surfaces of stone remains so as to detect surfaces possibly used for hammering or showing traces of surface oxidization (Plate IV, Photo 30). The dimensions of the anvil must also be taken into consideration. Depending on the type of work carried out, a heavy anvil is not always a necessity. Stake anvils are a case in point (Plate IV, Photo 31). In the absence of any material remains of an anvil, its position in relation to the forge hearth may be located by taking into account functional requirements and differences in ground colour due to the presence of

metal scale. The Blessey F 104 workshop illustrates the point perfectly (Mangin et al., 2000a).

In principle, the product resulting from refining is a semi-finished product (ingot) of varying quality, as certain archaeological and reconstitution examples demonstrate (Plate III). Given the efforts involved, the quality of fabrication of the ingot is likely to reflect the particular specialization of a workshop or its 'commercial' purpose (as in the case of bipyramidal ingots, Plate III, Photos 24 and 27, or currency bars, Plate III, Photo 21). Examples from Africa show that people tend not to bother to produce especially elaborate shapes for local use (Fluzin, 1994; Plate III, Photo 19).

It is interesting to note that in rural Gaul the semi-finished products in circulation were not of a very high standard of refinement but came closer to roughly refined bloom fragments (Mangin et al., 2000b).

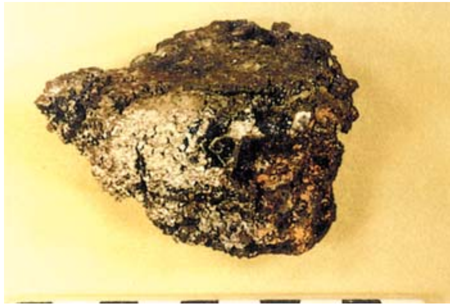
Such ingots may therefore take the form of roughly refined blooms (Plate III, Photo 9), bars (Plate III, Photo 20), folded-over leaves, salmon-type blocks (Plate III, Photos 22, 23, 25 and 26), elongated bipyramids (Plate III, Photos 24 and 27), blanks or currency bars (Plate III, Photo 21). Their size varies according to the initial blooms, the degree of refining, the nature of the metal (iron/steel) and the purpose of the product.

Forging of objects

This third phase in the process chain involves the shaping of artefacts on the anvil by the blacksmith (Plate IV, Photo 32). The term 'forging' (or 'smithing') should be reserved for the thermomechanical processes of shaping metal and the thermochemical processes that alter the structure and composition of the metal.

Plate III. Semi-finished products and ingots

Photo 19. Refined bloom, possibly an ingot (contemporary, weight: 420 g). Ethnoarchaeological mission, Toungaré site (Burkina Faso), 1994 (© P. Fluzin).
Photo 20. Gallo-Roman ingot in shape of irregular bar: Touffreville site (Calvados), 1995. Weight: 2.410 kg; 21 cm long; max. width: 5.5 cm; trapezoidal section: 5.5 x 5.4 x 4 cm – N. Coulthard and P. Fluzin (© P. Fluzin).
Photo 21. Blank of currency bar type: Aulnat site (Auvergne), 250–200 B.C., 737g – L. Orengo and P. Fluzin (© P. Fluzin).
Photos 22 and 25. Ingot, probably Gallo-Roman, from Coulmier-le-Sec site (Côte d'Or), weight: 4.7 kg; 16.3 cm long; median section: 7.5 x 7.2 cm – J. Dumont (© P. Fluzin).
Photos 23 and 26. Ingot from Carthage (4th–3rd centuries B.C.). Weight: 1.77 kg; 20 cm long; 6.5 cm wide; 4 cm thick – F. Essaadi and P. Fluzin (© P. Fluzin).
Photo 24. Bipyramidal ingot (dredged from the Oise). Weight: 4.3 kg; 55 cm long; median section: 6.3 x 5.3 cm (© P. Fluzin).
Photo 27. Quarter section of bipyramidal ingot. Total weight: 4.3 kg – M. Leroy, P. Merluzzo and P. Fluzin (© P. Fluzin).



19

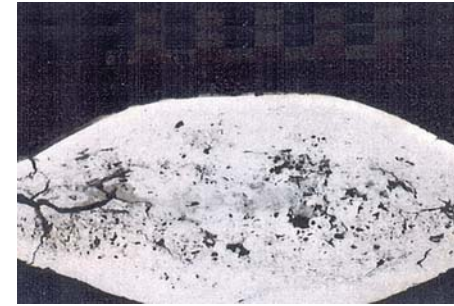
20

21

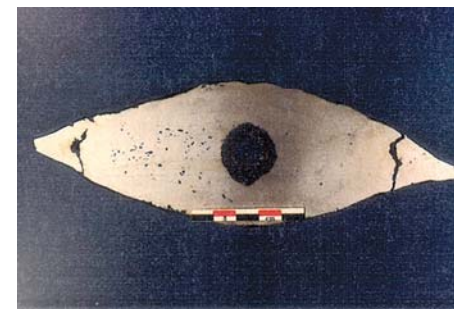
22

23

24



25



26

27

The starting material may be an ingot or a piece of metal in the form of a blank of the object to be produced or a billet produced by recycling various metal fragments. The most characteristic waste at this stage consists of scale, small flakes of iron oxides that come away from the surface of the metal during hammering (Plate IV, Photo 34). Naturally they are most plentiful near the anvil itself. As we noted earlier, this may provide evidence for the existence of the anvil even when it is physically no longer there. Scale is in fact the result of the oxidization of the metal after it has been in the forge hearth and hammered. For a given object, the amount of scale produced is indirectly linked to the number of times that the object has been into the hot hearth. The hammering itself depends on the smith's skills and the complexity of the object to be forged.

Our forge experiments show that fire losses during the production of an object (miner's pick or sword) come to around 10 per cent of the initial weight of the base metal (ingot). It should be emphasized in this instance that the basic material was perfectly refined and that the size of the scale depends on the metal being worked; the production of a small object (a hobnail, for example) generates small scale, whereas this is naturally not the case with a sword. That being said, scale is thin and extremely fragile and so tends to fragment. The use of an additive (to facilitate welding) also alters the morphology and nature of scale.

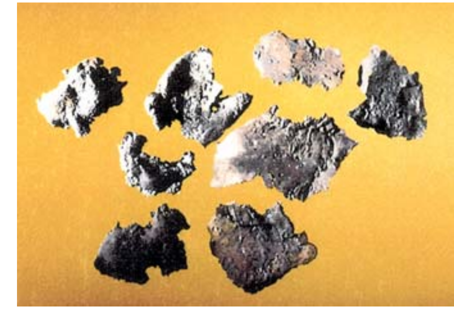
When excavating a forge, it can be interesting to make a rough estimate of the quantity of metal worked by sampling and sifting the scales, as we did at the Blessey forges (Mangin et al., 2000a). At the base of the hearth various melted materials may accumulate and form a hemispherical slag (Plate IV, Photo 33). Deoxidants (sand, clay and so on) are often instrumental in the formation of slag

Plate IV. Forging: practice, tools and waste

Photo 28. Refining of bloom on wooden anvil. Belfort experiment, 1995 – D. Leclère and P. Fluzin (© P. Fluzin).
Photo 29. Refining on stone, Yelwani (Niger), 1991 (from G. Célis).
Photo 30. Stone anvil 0.33 m x 0.20 m; 0.17 m high; 18 kg. Ancient agglomeration of Blessey-Salmaise (Côte d'Or) – A. Faivre, M. Mangin and P. Fluzin (© P. Fluzin).
Photo 31. Ethnological anvil, Naudjèla, Bulkiemdé province (Burkina Faso). 145 mm long; 69 mm wide; weight: 1.6 kg – H.T. Kienon and P. Fluzin (© P. Fluzin).
Photo 32. Final refining of bloom on anvil. Nancy experiment, 1997 – D. Leclère, P. Fluzin, M. Leroy and P. Merluzzo (© P. Fluzin).
Photo 33. Gallo-Roman forging slag cake (Saverne). Weight: 205 g, viewed from above – A.M. Adam and P. Fluzin (© P. Fluzin).
Photo 34. Iron oxide scale produced during forging – D. Leclère and P. Fluzin (© P. Fluzin).
Photo 35. Forge scrap, Aigueperse site (Auvergne), late 2nd century B.C. – L. Orengo and P. Fluzin (© P. Fluzin).
Photo 36. Metal scrap with imprint of hot slice (30 mm x 22 mm; weight: 24 g). Ancient agglomeration of Blessey-Salmaise (Côte d'Or) – M. Mangin and P. Fluzin (© P. Fluzin).


28

31

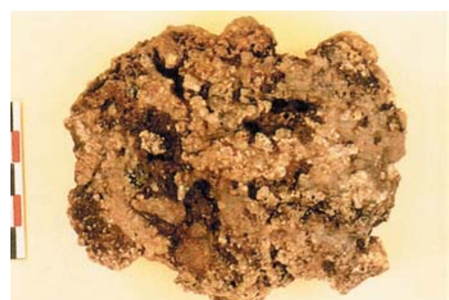

34

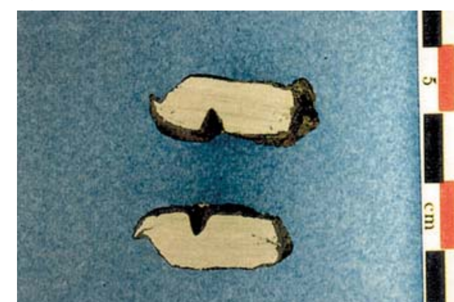

29


32


35


30


33



36

cakes. One also finds shapeless slag masses with variable metal content, often highly oxidized. In principle, smith forging does not produce slag flows; where it does, quantities are small. The other characteristic waste is scrap material (Plate IV, Photos 35 and 36), depending on how much the metal has been worked.

It will be seen that whereas waste produced by reduction and by the ensuing operations (refining and shaping) may easily be distinguished, identifying the waste coming from one or other of the two subsequent stages is more difficult. Both stages may take place in the same workshop, using the same hearths or similar hearths alongside one another, and they may be combined in a single operation. The sponge iron with the slag removed is purified by shingling, and immediately or soon afterwards transformed into a semi-finished product (bars or ingots). After that, it may be shaped into an object in the same place, using the same structures and the same tools. It should also be said in this connection that the quantity of waste (slag), the proportions of which depend on the operation, decreases as one moves from reduction to forging operations (including refining and smithing), always bearing in mind that the number of operations carried out and the volume of products forged obviously affect the quantity of waste.

ARCHAEOMETRY OF IRON AND STEELMAKING VESTIGES

Methodology

Laboratory research on archaeological materials can contribute very significantly to an understanding of metallurgical residues. There are numerous possibilities of analysis, and results of such analysis complement one another (Mangin et al., 2000b; Ploquin, 1994; Serneels, 1994). Research in this field is making constant progress.

However, the results of these investigations, which are relatively time-consuming and costly, depend very much on the quality of sampling and other data deriving from archaeological finds on the ground. When workshops are being excavated, the spatial distribution of certain waste materials (unreduced ore in furnace-charging areas, scale around the anvil and so on) makes it possible to identify the specialized working areas.

In addition to studying the structures and stratigraphic relationships, it is essential to take into account all the metallurgical waste (with respect to its distribution, macroscopic classification, sorting and quantification). This is a sine qua non of a truly representative sampling. It should not be forgotten that there may be ‘exotic’ types of waste along with the more traditional ones, attesting to failures, tests, mixing of ores and so on. Laboratory study of samples is compli-

cated by the heterogeneity of the physical chemistry of the materials resulting from solid-phase iron metallurgy. The kinetics of the processes set in train is generally very far removed from the theoretical conditions of equilibrium (temperature and pressure gradient in the furnaces, irregularities in the gas flows, and so on). Whatever the research methods used, observations must be carried out on samples that are large enough to be representative. In many cases, the whole sample must be studied, especially if the method involves microscopic examination ('micro-examination of the macro-ensemble').

Hypotheses based on observations of archaeological material may be tested by comparing the latter with waste and products from experimental reconstructions (Fluzin et al., 2001) and from traditional processes that may still be observed in some parts of the world. Ethnoarchaeology thus yields very valuable data about the social and economic aspects of iron and steelmaking: manual techniques, know-how transmission, work organization, interactions with other activities, and so forth (Fluzin et al., 1999).

The different approaches

In order to arrive at a pluridisciplinary interpretation, the archaeometer should attempt to weigh all the physicochemical facts observed in an honest and humble manner. Experience, greater numbers of samples, cross-checking against data obtained by different methods and transdisciplinary cooperation (as close as possible with field archaeology in particular), all serve to reduce the errors of interpretation. However, such errors are never eliminated completely. The problem of the representativeness of the sample studied remains central to any approach of this kind.

For the purposes of this chapter, we shall discuss only archaeometrical approaches designed to interpret metallurgical waste as evidence of a given technical stage: but other approaches, such as dating slag by means of thermoluminescence or archaeomagnetism, are also possible. Further, the contribution of the natural sciences to the study of ancient metallurgy should not be overlooked (for example, identification of carbons and other fuels).

Laboratory study of metallurgical waste is essentially concerned with the identification of constituents (chemistry and mineralogy) and the observation of microscopic textures that demonstrate how these materials were formed. Several techniques are brought into play, from the largest to the smallest scale of observation. (The specialists concerned, metallurgists, geologists and physicists, may sometimes have certain differences of approach and interpretation.)

Metallography (Fluzin, 1999, 2000a, 2000b) makes a major contribution to the identification of metallic phases and to observations relating to the aspect of grains, oxides, inclusions in relation to their environment, and macroscopic textures (matrix).

Generally, the sample is cut and the resulting surface is finely polished (up to 1 micrometre). The study is then carried out under the microscope, enabling the arrangement and form of the metal grains to be observed with the help of the strong reflective power of these materials (reflected light). The use of various reagents facilitates observation. The hardness of the material may be measured by spot indentation. In this way, polished sections of considerable size (over 100 cm^2) may be observed.

Complementary results may be obtained using more sophisticated methods. This is true in particular of spot analyses of chemical elements (scanning electron microprobe). For this type of study, laminae or small polished sections are generally used. To resolve specific questions, high-tech methods (synchrotron radiation) may be necessary, for example, in the case of microanalysis (micro-diffraction and X microfluorescence) of non-metallic inclusions in the material (Dillmann et al., 1998; see below).

Illustration of some findings

DISTINCTIVE METALLURGICAL INDICATORS (PLATES V TO VIII)

The aim is to identify a number of distinctive indicators of the process chain with a view to determining from a metallographical standpoint what occurs between reduction (bloom) and the shaping of an object. It should be made clear that, while the presence of an indicator may point to a given operation, its absence is also a very interesting piece of information. The lack of a typical profile may also be regarded as significant in as much as it permits reasoning by elimination. Furthermore, because of their specific characteristics, some indicators may 'survive' (forming indeed a legacy) several operations (for example, folds and concentric globules in the reduction process and the first phase of refining) but may be 'incompatible' with other operations: such is the case, for instance, of hardening structures in reduction slag.

At any rate the most reliable basis for arriving at a hypothesis is a coherence analysis of the presence or absence of the various indicators. Mastery of the reduction process determines the quality of the final product (dirty or clean bloom depending on the density of the metal, the proportion of slag and charcoal, the quantity of porosities and so on) and, consequently, the quantity and type of post-reduction waste (slag, gromps and cakes of different shapes and sizes).

REDUCTION INDICATORS (PLATE V)

Below are given some examples of metallographical indicators found in slag flows, which are generally the most plentiful, as well as in certain gromps and slag cakes.

As pointed out elsewhere (Fluzin, 1994), species with a relatively low level of oxidization should be dominant in view of the reducing atmosphere (the wustite/magnetite/haematite relationship), but marginal reoxidizations (superficial or localized) cannot be ruled out. What we are concerned with here is indeed the relative importance of the different oxides, since the isolated example of wustite (FeO) may not be significant given its relatively widespread incidence. A post-operation oxidization (generalized corrosion) cannot make this oxide appear, to the extent that there has been no subsequent reheating (to over 570 °C). The presence of iron hydroxide is in this case the paramount indicator.

The metal (iron or steel) may assume different appearances, while tending to maintain 'intimate contact' with the matrix (fayalite and so on), without major peripheral oxidization of the metallic element and without any evidence of thermomechanical deformation. It may take the form of globules, often monocrystalline, distributed in filaments and/or strings near the reduction vectors (charcoal, diffusion shaft or air bubble; Fluzin, 1994). This configuration (Plate V, Photos 37–40) may even correspond to the original ore grains as illustrated by the most visible case of oolithic ore from Lorraine (Leroy, 1997), (Plate V, Photo 37). The degree of agglomeration of these metallic globules will depend on the elimination of interstitial slag (that is, on the process of 'drying the sponge iron', Plate V, Photos 39–41).

The metal may take on the appearance of a polycrystal with a centripetal agglomeration of small globules, possibly near a porosity (Fluzin et al., 1995; Plate V, Photo 45).

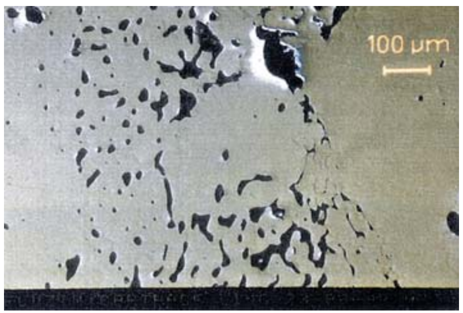
It may also develop within the wustite (partial or total reduction in the globules), even when the latter has a dendritic aspect (Fluzin, 1995). The structure of dendritic solidification, which requires locally a temperature higher than melting point, is also an indicator of the thermodynamic conditions of the environment. Thus, the shape and size of the dendrites tell us about the contextual thermic conditions (temperature level, kinetics and direction of cooling). The presence of large dendrites of wustite indicates prolonged maintenance of high temperatures and slow cooling.

The morphology of grains (metallic elements) is usually not very angular and presents no particular hardening in the case of polycrystals.

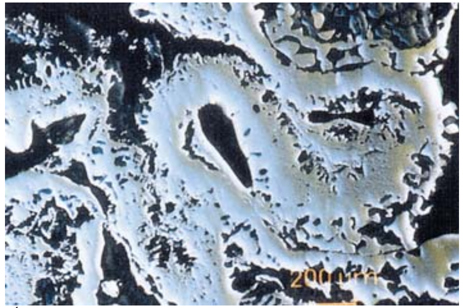
It is possible to observe (quite rare at the reduction stage) the presence of apparently spherical globules in the plane of the cut (but they may in fact be more cylindrical and have the form of filaments). This morphology is likeliest when the carbon content increases as a result of the lowering of the melting point of the iron-carbon alloy. It may be associated with high temperature levels

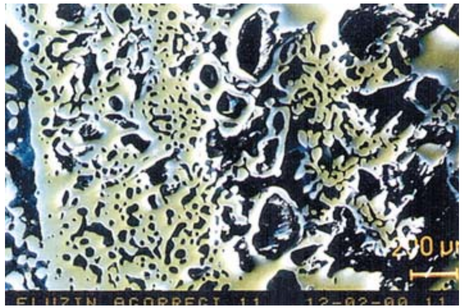

37

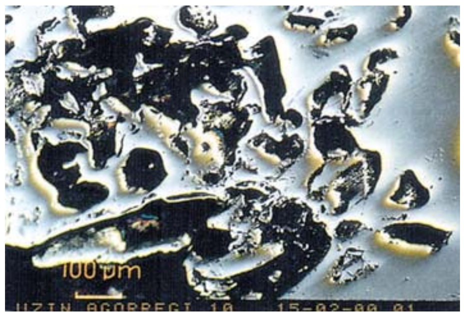
38



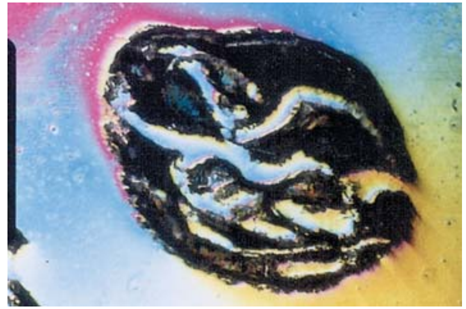
39


40

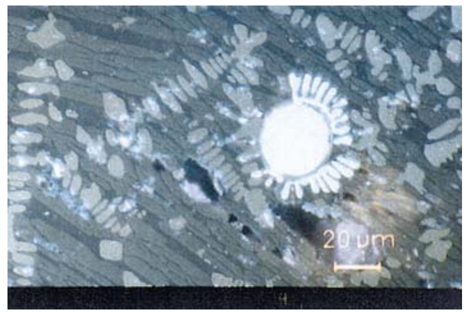

41



42


43

44



45

Plate V. Metallographical indicators: reduction

Photo 37. Oolithic ore from Lorraine. During reduction, the metal emerges retaining the shape of the oolith. Reduction and refining experiment, Nancy-Belfort, 1995 – D. Leclère, P. Fluzin, M. Leroy and P. Merluzzo (© P. Fluzin).
Photos 38 and 39. Concentric agglomeration and densification in the middle of ingot from Carthage – cf. Plate III, Photos 23 and 26 (© P. Fluzin).
Photos 40, 41 and 42. Filament- and string-shaped agglomerations with evacuation of slag. Beginning of fold formation. Experimental blooms from Agorregi (Spain) – cf. Plate I, Photos 8 and 9 (© P. Fluzin).
Photo 43. Metallic folds formed during the refining of a bloom. Belfort experiment, 1995 – D. Leclère and P. Fluzin (© P. Fluzin).
Photo 44. Slightly deformed folds. Experimental bloom from Agorregi (Spain) – cf. Plate I, Photos 8 and 9 (© P. Fluzin).
Photo 45. Centripetal agglomeration. Slag flow, Ponte di Val Gabbia site (Italy) – cf. Plate II, Photo 17 (© P. Fluzin).

(tuyère). Ferrite may however also take on this appearance when the temperatures reached are high enough to make it 'dough-like' but without going beyond the liquidus (1536 °C). If it does go above this temperature, depending on the cooling conditions, this may imply the existence of solidification structures (dendrites). The decarburization of the steel might also account for these features. Although these configurations may be observed in the reduction process, they tend nonetheless to be more frequent in forging operations.

Porosities (very often with a characteristic morphology) are found to varying degrees depending on the extent of elimination of barren material (resulting from the melting of the ore gangue, fayalite and so on). Along with some of these porosities (in particular those with the greatest number of voids), folds in the process of formation may be observed, varying in size and formative stage (Plate V, Photos 42–44). They are the result of the gradual coalescence and agglomeration of metals, which become denser as the silicon-coated matrix 'dries out'. As the liquid slag flows away, the various metallic globules and filaments tend to join together, leading – depending on the context – to the formation of folds. These are relatively large and misshapen at the beginning of the process, and disappear gradually as thermomechanical treatment is applied (refining and forging). These folds are therefore frequently observed in the metal blooms as well as in the various types of waste associated with the different phases of refinement (for example, gromps and slag cakes).

It should be noted that certain folds also seem to appear in some cases of artefact smithing (especially during the recycling of small metal fragments). A very high working temperature (partial melting) could trigger a dissociation of the metal as a function of dependence on the initial shaping (residual texture effect).

INDICATORS OF REFINEMENT FORGING (CRUDE METAL WORKING): PLATE VI

These are undoubtedly the most difficult indicators to highlight (especially in slag cakes) because of the possible continued presence of reduction indicators and the fact that they may be associated with smithing indicators.

The preponderance of an oxidizing atmosphere should be discernible, as we have already mentioned, through the existence of degrees of oxidization of the more oxidized metal species.

One needs to take into account that the forging operation is governed by a series of thermomechanical cycles that may be reflected, regardless of the number of items processed, by a certain stratification of the waste (slag cakes). The degree of stratification varies with the duration and temperature level of each heating cycle, and may be evidenced in various ways (distribution and morphology of porosities, patterning of the matrix, nature and distribution of metal fragments, and so on). Where the metal is concerned, the intensity of the thermomechanical deformations is perceptible (depending on the temperatures reached) through the structural deformations that subsist (work-hardening, alignments of impurities, and so forth).

The metal 'lost' during the refining operation is not negligible, as is shown by our experimental reconstructions (Leroy et al., 2000). The number and size of the fragments are greater at the beginning of the operation. This should, for example, be reflected in the distribution of the metal within the slag cakes. The thermomechanical characteristics of this operation are such that the metallic fragments found in the slag cakes may take on different features, together and/or separately:

- A random distribution of fragments with relatively jagged outlines (sharp angles), not continuously linked to the matrix (Plate VI, Photo 46).
- A more sizeable and compact lump of metal, corresponding to the loss of large pieces (at the start of the operation). It is of interest to characterize the nature of the metal worked (concerning iron/steel and the percentage of carbon): doing so offers clues as to the homogeneity of the basic metal and the possible intended use of metals of different kinds.
- Internal reoxidization of the metal (near gas diffusion shafts; Plate VI, Photo 50) or peripheral reoxidization, characteristic of the preponderance of an oxidizing atmosphere in the forging process (Plate VI, Photo 49). In the case of steel, this reoxidization may be accompanied by superficial decarburization (Plate VI, Photo 50). It should be remembered that the inverse operation of carburization calls for very long run times (ten hours or more) (Fluzin, 1994) and a reducing atmosphere.
- Presence of small, distorted metallic folds imperfectly welded inside the piece of metal, indicating inadequate forging (Plate VI, Photos 52–54).

- Local presence of hammer-hardened metal with an irregular outline (Plate VI, Photo 47). In the metal, alignments of inclusions indicate the direction and intensity of hammering. Inclusions are deformed to a greater or lesser extent depending on their composition and the working temperature.
- Possible presence of scale, or traces thereof (Plate VI, Photos 48 and 49), in slag cakes, although this is mostly found near the hammering area.
- Presence of metal pellets (cylinders) or beads of metal (iron/steel), partially reoxidized or not at all. The non-reoxidization of these metallic elements, despite their being in an oxidizing forge atmosphere, may be explained by local conditions limiting the diffusion of oxygen (the metal is located inside a relatively protective fayalite environment). Our experimental reconstructions have shown that these pellets tend to be situated near a high heat source (tuyères).

The quality of the refining work, which may be carried out in several stages (roughing out/compaction in phase one, and preparation of semi-finished product in phase two), may therefore be evaluated within the metal from several concomitant characteristics:

- freedom from inclusions (porosity and inclusion rate)
- morphology of the porosities and inclusions (deformation)
- number and morphology of folds
- homogeneity of the iron/steel distribution and so on.

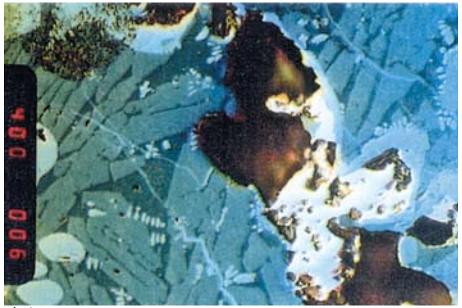
INDICATORS OF THE FORGING OF OBJECTS (WORKING WITH REFINED METAL): PLATE VII

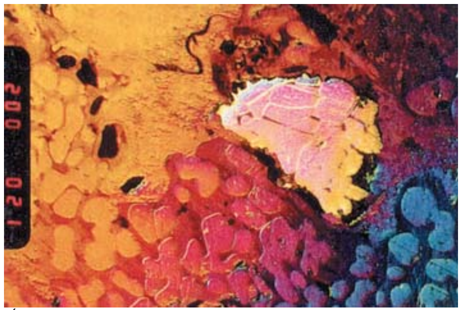
In cases where the forging of artefacts is dissociated from metal-refining operations, our experiments and observations call for the following remarks.

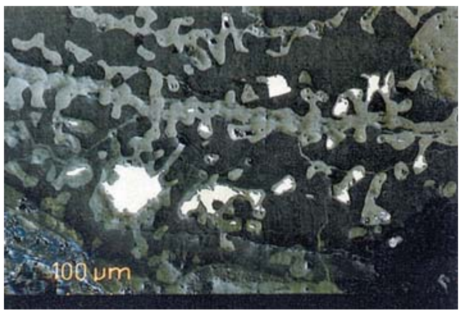
When blacksmiths want to make good quality objects, it is in their interest to work with the cleanest possible hearth so as to control the work properly (visual estimation of temperature, and avoidance of various kinds of pollution) and to concentrate the fire by adapting the hearth to the type of object to be worked. There is thus an incentive for the hearth to be kept clean. The amount of waste, already relatively small (in charcoal-burning forges), will consequently be smaller, unless additives are used.

The frequency of heating cycles is higher (according to the type of manufacture). They are of relatively short duration. (The metal should not be allowed to burn, in the case of steel, and fire losses should be limited.) This results in greater homogeneity of waste (slag, slag cakes and reduced stratification). Moreover, burned metal gives rise to fairly characteristic metallographical features.

Mention should however be made of the special case of welding (Guillot et al., 1987), which presents a number of specific technical characteristics, depending

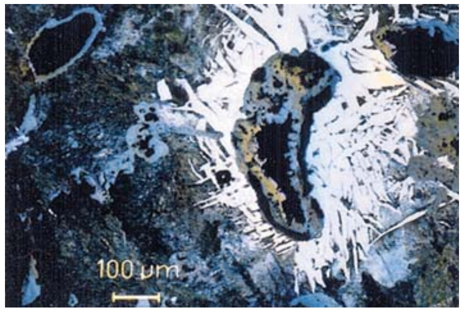

46


47

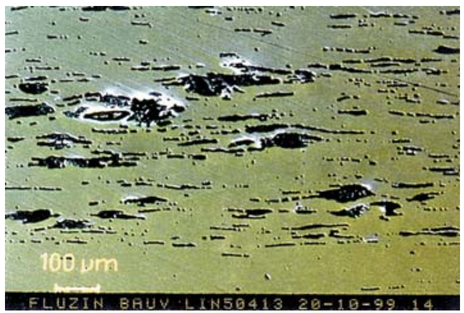


48

49



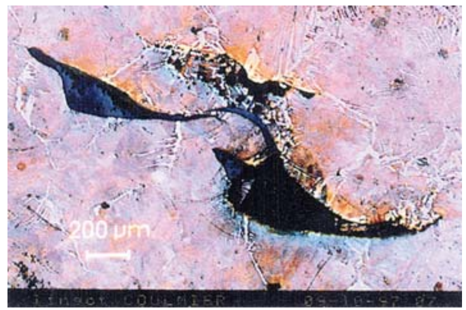
50



51

52


53



54

Plate VI. Metallographical indicators: refining

Photo 46. Fragment of jagged iron embedded in a porosity. Gallo-Roman archaeological cake. Touffreville site (Calvados), 1995 – N. Coulthard and P. Fluzin (© P. Fluzin).
Photo 47. Idem. The metal has been slightly hardened (© P. Fluzin).
Photo 48. Heat reoxidization of iron filaments and globules (ferrite). Slag cake: 125 g. Oppidum of Condé sur Suippe (Aisne), 2nd–1st centuries B.C. – S. Bauvais, P. Pion and P. Fluzin (© P. Fluzin).
Photo 49. Heat reoxidization. Slag cake: 139 g. Ancient agglomeration of Blessey-Salmaise (Côte d'Or) – M. Mangin and P. Fluzin (© P. Fluzin).
Photo 50. Decarburization by oxidization around a porosity. Slag, Aigueperse site (Auvergne), end of 2nd century B.C. – L. Orengo and P. Fluzin (© P. Fluzin).
Photo 51. Thermomechanical crushing. Bar fragment (currency bar type): 132 g. Oppidum of Condé sur Suippe (Aisne), 2nd–1st centuries B.C. – S. Bauvais, P. Pion and P. Fluzin (© P. Fluzin).
Photo 52. Metal folds almost completely welded, experimental blooms from Agorregi (Spain) – cf. Plate I, Photos 8 and 9 (© P. Fluzin).
Photo 53. Folds in the process of being crushed. Archaeological slag, site of Blessey-Salmaise, Forge F104, sample 104/15 – M. Mangin and P. Fluzin (© P. Fluzin).
Photo 54. Folds in the process of being crushed with partial flint infilling. Middle of an archaeological ingot (cf. Plate III, Photos 22 and 25), Coulmier-le-Sec site (Côte d'Or) – J. Dumont, M. Mangin and P. Fluzin (© P. Fluzin).

in particular on the carbon content of the alloy. Successful iron and steel welding calls for a welding heat of 1300 to 1500 °C for iron and 1100 to 1300 °C for steel. The period of time for which weld is likely to be successful in normal conditions is called the 'weldability level'. That level is wider for iron than for steel. Welding steel on to iron is more difficult, since both metals must be brought simultaneously up to their weldability levels, calling for a wide temperature range. Moreover, the build-up of oxides on the surfaces to be welded prevents contact between the metals. During the heating process the surfaces to be joined must therefore be sprinkled with sand or a 'pickling' agent (such as powder ore) to limit oxidization and cause the layer of oxide to flake off. The sand then combines with the iron oxide to form a silicate that is fluid at high temperatures, and is evacuated by hammering in the form of scale and slag, resulting in the alignment of inclusions in the welding (Plate VII, Photos 59 and 62). Moreover, thermochemical processing (carburizing, nitriding, selective quenching and so on) calls for the use of appropriate substances (organic matter, clays and so on), some of which may be found in the slag cakes.

The proportion of metal lost (in the slag cakes) is markedly less than in the refining operation, and when it exists it often presents, depending on the heating (temperature level reached) and cooling conditions, considerable hardening in close connection with the matrix (Plate VII, Photo 55). In some cases, considerable hardening is found in association with microdamaskeening (Mangin et al.,

2000a, sample F 104/08 and 09). This takes the form of an iron/steel micro-composite (0.02 to 0.4 per cent carbon) with a perfectly homogeneous texture (Plate VII, Photo 63). This micro-structural configuration (at grain level) is rather exceptional and should lend remarkable mechanical characteristics to the metal.

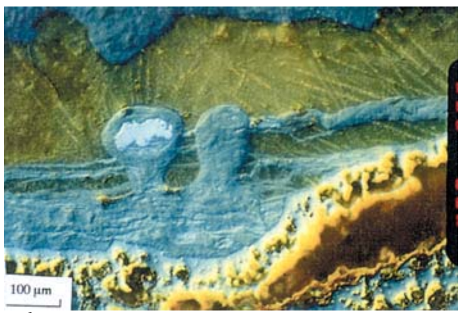
Similar observations have been made (albeit on a smaller scale) in the case of contemporary nanomaterials produced by mechanosynthesis (association of nanocrystals by mechanical shocks). One possible theoretical explanation implies a phenomenon of aggregation (when a sponge fragment or bloom is involved) following the thermal dissipation of the shock energy (hammering a small volume) linked to the level of the forging temperature. That would then lead (accidentally or intentionally, given a sample number of three) to damaskeening based on 'microcrystallization'. This structural phenomenon is remarkable, since it resembles materials of the future currently also being produced in our laboratory (Fluzin and Gaffet, 1997). At the same time, we should bear in mind as well the exception of 'recycling' forging, featuring numerous welding of elements of different sizes and types (percentage of carbon), which may entail considerable losses of metal in the forge hearth. It is not uncommon to encounter decarburization at the edges of the metallic elements richest in carbon.

The forge environment (apart from the slag cakes and scale) may also yield varying amounts of materials in the form of fragments of mostly oxidized metal. These may include scraps, blanks, tool tongs and fragments or pieces of metal intended for reuse (Plate IV, Photos 35 and 36). Morphological and metallographic studies of these materials may help to identify the type of activity, as has been particularly well demonstrated by our recent work on the Alesia countryside

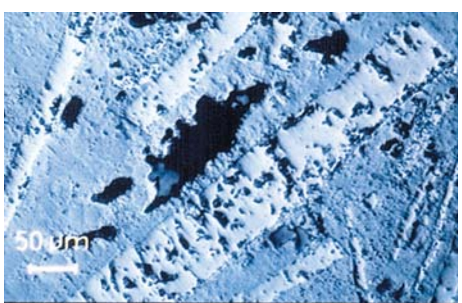
Plate VII. Metallographical indicators: forging (of objects)

Photo 55. Fragment of hammer-hardened iron in a Gallo-Roman archaeological cake. Touffreville site (Calvados), 1995 – N. Coulthard and P. Fluzin (© P. Fluzin).
Photo 56. Filament of almost completely reoxidized iron. Archaeological slag. Juude-Jaabe site (Senegal), 1995 – H. Bocoum and P. Fluzin (© P. Fluzin).
Photo 57. Lamellar scale vestige. Slag cake, oppidum of Condé sur Suippe (Aisne), 2nd–1st centuries B.C. – S. Bauvais, P. Pion and P. Fluzin (© P. Fluzin).
Photo 58. Globular scale vestige. Slag cake – same as Photo 57 (© P. Fluzin).
Photo 59. Primary inclusions deformed in the direction of hammering. Ingot from Alésia (F-XXIV–408), 1996 – M. Mangin, P. Fluzin and P. Dillmann (© P. Fluzin).
Photo 60. Inclusions in an object during forging. Nancy experiment, 1997 – D. Leclère, P. Fluzin, M. Leroy and P. Merluzzo (© P. Fluzin).
Photo 61. Inclusions in a bar fragment (68 g). Ancient agglomeration of Blessey-Salmaise (Côte d'Or) – M. Mangin and P. Fluzin (© P. Fluzin).
Photo 62. Welding. Imperfect metal joints. Scrap. Aigueperse site (Auvergne), end of 2nd century B.C. – L. Orengo and P. Fluzin (© P. Fluzin).
Photo 63. Microdamask. Scrap. Ancient agglomeration of Blessey-Salmaise (Côte d'Or) – M. Mangin and P. Fluzin (© P. Fluzin).

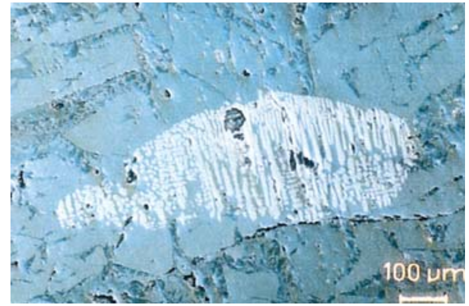

55



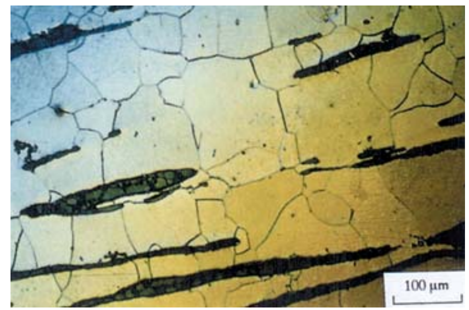
56



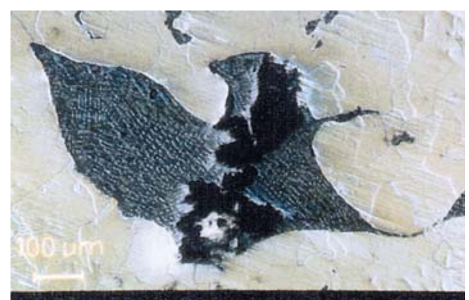
57



58

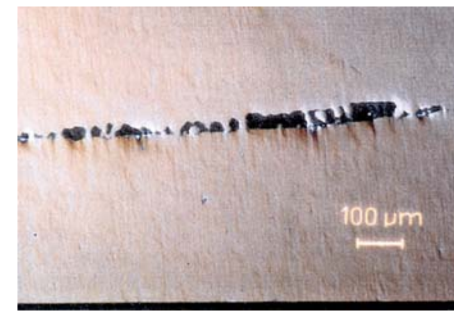


59

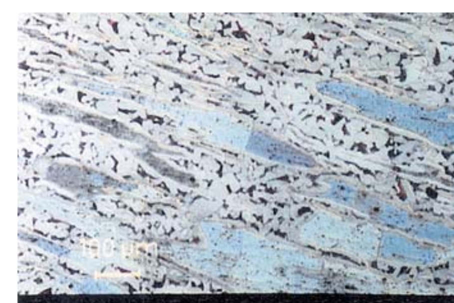


60

61



62


63

and the Blessey site (Mangin et al., 2000a). A small scrap of metal (Plate IV, Photo 36) may offer vital information about the work carried out in the hearth. We may observe a tool mark (slice made in hot metal), showing that the smith tried to offcut a small piece of metal 30 mm long and 6 by 7 mm in section, and it is possible, given its size, that it was intended for producing a nail (a hobnail in this case). Thanks to this sample, we also have some information about the tools used. The chisel, whose imprint is complete, was of the same size (16 mm wide). The tongs used to grip it had closed jaws and must have been quite small. The object must have been difficult to grip tightly enough and was dropped. Losses when forging these kinds of metal element must for this reason have been quite commonplace. We can also evaluate the metalworker's skill (heat treatment and so on). For example, producing simple metal sheets (for armour, sword sheaths and so on) called for greater skill (and higher quality metal) than making bulky objects. Producing sheets is harder, the thinner the metal and the greater the surface to be covered.

Scale is found, as in the case of the refining operations, mainly near the hammering areas although some may also be found in the slag cakes (Plate VII, Photos 57 and 58). It tends to be more abundant than other kinds of waste. The size of the pieces depends on the surface of metal worked: turning out a small item produces small scale, while working larger surfaces, for example making swords, results in larger scale, as was demonstrated by the reconstitution we carried out on the swords of Gournay-sur-Aronde (Oise). When additives are used, scale may have a 'bubbly' morphology (Dunikowski et al., 1996). Quantitative evaluation of scale by means of sampling and sifting gives an idea of the extent, and sometimes the type, of activity (Mangin et al., 2000a).

The workshop tends to be organized according to a quite precise pattern (depending on the type of activity). This should be apparent from the archaeological residues, normally clustered in the vicinity of the hearth. Since objects must be forged before they cool down too much, and must be placed with greater or lesser frequency in the hearth, it is possible to situate the location of the forging operation (position of anvil) at about 1 m or 2 m from the hearth. This is usually apparent from a blackening of the ground as a result of the presence of scale.

We cannot here provide a more detailed account of the results obtained through this method (metallography). This method, although limited to a 'reading of the metal' in its environment (artefact, cake or slag), enables us to work on large samples at a reduced cost, and not only yields indicators as to the nature of the metal-making activity but also gives us insights into how the item was manufactured, and into the quality of the workmanship.

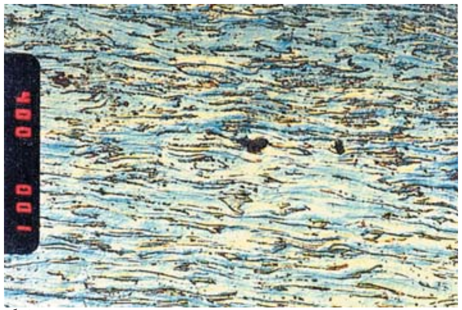
Comprehensive chemical analyses (which we shall not explain in detail) invariably concern a limited volume of materials (tens of grams) and are not strictly speaking representative. Furthermore, there is no universally applicable

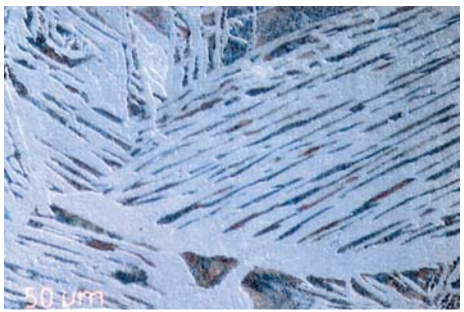
method of analysis encompassing all the wishes of archaeologists. Each method of analysis has its own special characteristics, and above all its limitations and potential sources of error, which need to be understood if wrong interpretations are to be avoided. There is no point in compiling data if its (intrinsic or extrinsic) accuracy cannot be guaranteed (Fluzin, 1983). Indeed a present-day physical chemist or metallurgist will not always be able to understand or even interpret the special chemistry of archaeological samples, if she/he does not venture out of the laboratory. From a chemical and mineralogical viewpoint, ancient slag is quite unlike natural rocks and thus may confuse the geologist. It is also quite distinct from the residues of modern metallurgy, so that metallurgists are often puzzled by the numerous 'anomalies' that they may come across. Some of these anomalies are of interest in many ways, when it comes to improving fundamental knowledge of present-day or future materials (past-present-future link: through the study of ageing of materials and the development of new ones, and so on).

ANALYSIS BY MICRODIFFRACTION OF SYNCHROTRON RADIATION

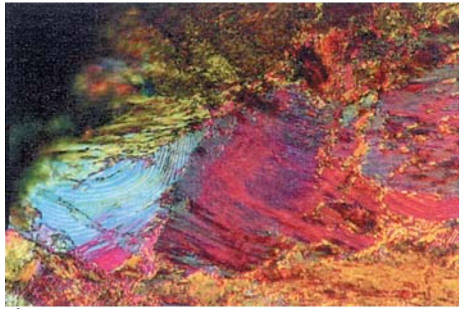
This type of analysis is an example of recent discoveries (Dillmann et al., 1998). One of the main lines of research into the history of iron and steelmaking concerns the appearance in Europe of the indirect (blast furnace) process which gradually replaced the direct (low hearth) process. Metallographic techniques provide a wealth of information about the thermomechanical and thermochemical processing that metal undergoes in the course of production. However, they do not enable us to establish with sufficient accuracy the process used in ore reduction. Hence, there is a need to characterize the nature and crystalline structure of the inclusions found in the metal matrix, inclusions that may result either from reduction or from refining. Understanding the thermodynamics of the formation of these inclusions gives us a better grasp of the reduction processes. It is for this reason that a study has been undertaken, in partnership with the Laboratoire de Recherche des Monuments Historiques (Champs-sur-Marne, France) and the Laboratoire pour l'Utilisation du Rayonnement Électronique (Orsay, France), to determine the composition and structure of inclusions in objects representative of the evolution of the iron and steelmaking techniques under review. For that purpose, we assembled a corpus (over 100 references) containing objects ranging from the Gallo-Roman period to the nineteenth century. They were collected on the basis of strict criteria allowing a reconstitution of the historical and technological contexts of their manufacture. This corpus was augmented by a number of samples from experiments conducted with two particular types of ore in reconstituted low hearths. Comparing the types of inclusions identified, relative to the processes whereby the different items in the

64


65

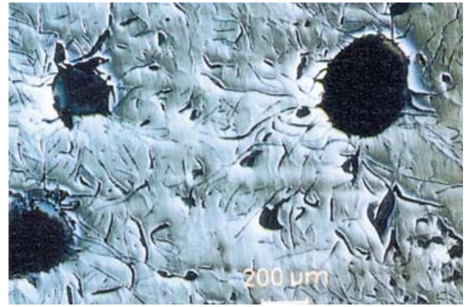


66

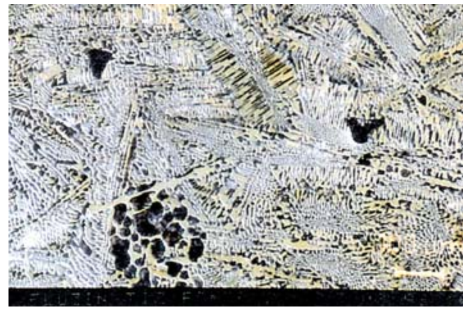

67

68

69



70


71

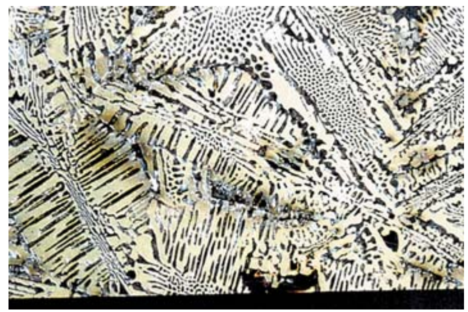

72

Plate VIII. The metal structure: iron, steel and cast iron, based on a metallographical study of archaeological samples

Photo 64. Pure iron, ferrite (© P. Fluzin).
Photo 65. Pure iron, hammer-hardened ferrite (© P. Fluzin).
Photo 66. Steel with 0.3% carbon, structure of needle-shaped 'Widmanstätten' ferrite (© P. Fluzin).
Photo 67. Steel with 0.8% carbon, generalized lamellar perlite (© P. Fluzin).
Photo 68. Tempered steel, nodular bainite, troostite (© P. Fluzin).
Photo 69. Tempered steel, martensite (© P. Fluzin).
Photo 70. Grey cast iron with graphite nodule (© P. Fluzin).
Photos 71 and 72. White cast iron, ledeburite (© P. Fluzin).

corpus were produced, lent added value to the analytical data. The inclusions were systematically analysed with the help of microdiffraction and X microfluorescences under synchrotron rays. Manipulations were carried out on the D15 line of the Laboratoire pour l'Utilisation du Rayonnement Électronique. The analytical data obtained enabled us to determine four distinguishing factors linking the structure and composition of inclusions to one another of the iron ore reduction processes (direct or indirect):

- An inclusion type with a high silicon and low iron content was identified only among inclusions deriving from items produced by direct reduction. These inclusions were always found close to highly carburized areas.
- Spinel-type aluminized phases were identified only in inclusions deriving from the direct method.
- Phosphates seem to occur only in inclusions formed during refining (indirect process). In particular, the presence of calcium phosphates can only be due to the voluntary addition of lime during this stage. This configuration might however also exist in certain ores subject to direct reduction (Lorraine).
- Differences in chrome, vanadium and titanium contents were found. The maximum contents observed in inclusions of objects produced by the indirect process were 10 to 100 times higher than those in inclusions resulting from the direct process. This difference may be due to the concentration of the elements in question, in the form of carbides during smelting and their oxidization during refining.

Thus, local analysis techniques based on synchrotron radiation have enabled us to ascertain the structure and composition of non-metallic inclusions present in ancient iron objects. The resulting data throw fresh light on the history of the basic techniques, highlighting in particular the appearance of the indirect iron-ore reduction process. Examination of the inclusions enables us to situate the

analysed archaeological object in its historical and technical context. It does not, however, amount to a new dating method.

Conclusion

It is quite difficult to describe, in the space of a few pages, the relatively vast field of archaeometrical research that makes possible the reconstitution of the different stages of the process chain in iron and steel production on the basis of archaeological residues.

The selected examples presented illustrate the relevance of the results obtained over the past few years, and the need for genuine interdisciplinary cooperation (between the social, natural and material sciences). Each method and each discipline has its limits, and only scientific cross-checking can help us make archaeological residues 'speak' while minimizing possible sources of error. In return, this work enriches each of the scientific fields concerned. Understanding iron and steelmaking residues contributes to the history of technology in general, and also opens up perspectives on the economic and social dimensions of the industry, and thereby on history more generally. Beyond their technical aspects, these studies seek to throw light on the people behind the techniques. The contribution of ethnoarchaeology is fundamental from this standpoint and cannot be over-emphasized. Moreover, slag and ancient metals offer engineers very real analogies that help understand the phenomena of the ageing of materials. Such knowledge is applicable to the fields of civil engineering, heritage conservation and even modern waste management. The structural anomalies observed in ancient metals offer clues for new materials, such as those produced by means of mechanosynthesis (Fluzin and Gaffet, 1997).

Yet, despite all our efforts and success, we must remain modest, in recognition of the fact that 'technical objects, the physical translation of an intellectual system, are never completely known' (Simondon, 1969).

Iron Metallurgy in Africa: A Heritage and a Resource for Development

Hamady Bocoum

The history of sub-Saharan African metallurgy, written too summarily in the early years of the last century on the basis of a few fragmentary texts and all too brief archaeological soundings (in many cases designed to confirm what was assumed to be known in an all-prevailing diffusionist climate) has already been, and will undoubtedly continue to be, subject to much revision.[1] As increasingly consistent data are gathered pointing to the autonomy of African ironworking, the latter might indeed proceed from several independent centres. However, the interest of African metallurgy does not derive solely from this chronological dimension. It also stems from the technological continuum that today still allows us to observe *in vivo* pyrotechnic traditions affording exceptional opportunities for studying one of humanity's most decisive technical achievements: the mastery of iron. It lies too in the remarkable adaptability of iron craftspeople who, faced with shortages of all kinds, still manage to keep the flame of ingenuity burning in Africa.

1. In 1971 Mauny, one of the founders of West African archaeology, published a rather pessimistic work entitled *Les siècles obscurs de l'Afrique Noire* (Black Africa's dark centuries), in which he expressed the researcher's bewilderment at the scarcity of sources in certain fields. Two decades later, in 1988, McIntosh and McIntosh partly responded, in 'From siècles obscurs to revolutionary centuries on the Middle Niger', to the concerns voiced in that pioneering work by highlighting all that archaeological research had been able to contribute to knowledge of the societies of the Middle Niger. In point of fact, archaeology is constantly providing new revelations in every field of research: revelations whose importance, given the enormity of work to be done, is unlikely to fade in the foreseeable future.

Iron in Africa: a 4,000-year-old heritage

The vexed issue of the origin of iron metallurgy in Africa has for many decades fuelled an open debate that continues to divide the scientific community. The nature of the information available and the extremely wide range of possible interpretations do not always serve to settle a debate that in many respects remains more wide open than ever. In point of fact, although more and more datings suggest that iron production in Africa originated in the middle of the second millennium B.C., if not earlier, which would make it one of the oldest metallurgical 'industries' in the world (hence the hypothesis of an autonomous locus for its invention), various observations and comments concerning the reliability of certain measurements give rise to suspicions, some of them legitimate, that need to be taken into account.

Written sources being of no avail for most if not all of Africa south of the Sahara in respect of facts whose antiquity is to be counted in millennia, archaeology alone can provide decisive answers to the questions raised. Therefore it will be necessary in each case to base our approach on facts that have been soundly established by archaeological research in order to assess the arguments that underpin the competing hypotheses.

Hypotheses and facts

Analysis of the arguments put forward by the proponents and opponents of the notion of the autonomous origin of African ironworking reveals that these are prompted by conflicting methodological considerations. In broad outline, those who contend that borrowing is involved favour the hypothesis of a single locus or centre of invention, and are concerned with bringing to light relevant transitional sites or moments, while those who argue the case for autonomous invention base their arguments far more on archaeological evidence, to which they seek to ascribe a chronological, technological and cultural coherence. All the same, by placing the two approaches in perspective and by relating them to research-generated facts, it is possible to identify the permanent factors around which the controversy revolves (Holl, 2000, p.8).

HYPOTHESES REGARDING AN EXOGENOUS ORIGIN

The exogenous origin of iron metallurgy may be regarded as a recurrent issue of African archaeology, so intimately is it bound up with the discipline's entire history on the continent. Prior to the large-scale advent of absolute chronological data, this view was based on two guiding concepts.

Starting from the assumption of a single locus for the invention of metallurgy, the main concern of those holding this view was to identify transmission routes (for instance, Huard, 1960; Leclant, 1956; Mauny, 1952; Phillipson, 1985; Tylecote, 1975). However, it was indisputably Mauny (1952) who propounded this hypothesis most systematically: in that author's view, it was the Hittites who discovered the techniques of ore reduction during the second millennium B.C. Those techniques, he argued, subsequently spread throughout the Mediterranean, gaining a foothold in Egypt through direct contact. The Amarna letters, dating from 1300 B.C. and addressed to Ramses II, did in fact record the delay in delivery of a consignment of iron ingots to the Pharaoh. Despite that early contact, initiation into iron-processing technology proper did not occur, Mauny claimed, until around the seventh century B.C., following the invasion by Assourbanipal.

In the case of West Africa, Mauny rules out all possibility of transmission through Egypt, opting rather for an indirect form of introduction through the Phoenicians. The contact, he suggests, took place in North Africa: it was the Berbers who allegedly introduced the techniques into West Africa, gradually, some time after the sixth century B.C.

Those who contest the thesis of an autonomous African origin for ironworking also draw upon a technological argument, namely that iron production presupposes the pyrotechnic knowledge required to master high temperatures. This argument establishes a de facto causal relationship between the knowledge of copper metallurgy and the acquisition of a technical capacity that could lead to the altogether more complex invention of ironworking. Alongside these two main lines of reasoning there exists a third, and because it relies on recent data, novel argument (Killick et al., 1988), which is based on challenging the reliability of certain carbon-14 (C-14) measurements obtained in Niger by Grébénart (1983b, 1985, 1988).[2] In connection with this problem, there is a notable tendency to contest C-14 dates in arid zones where the potential presence of old charcoal may give rise to a considerable chronological discrepancy.

Nevertheless, in their archaeological constructions, that is, in the formulation of their hypotheses, these authors do not deviate greatly from the hypotheses already referred to (Mauny, 1952). For even though they rule out the idea of such techniques being introduced into West Africa from the Nile Valley, they uphold the notion of trans-Saharan transmission. However, it is worth noting that there is no longer any fixation on the Punic city of Carthage, for both Morocco and Libya (the Gulf of Sidra) are also seen as possible transmission routes.

2. Clearly this author was mistaken when he formally identified certain ecofacts (rubefied halos corresponding to charred tree trunks) as furnaces used for iron production.

HYPOTHESES REGARDING AN ENDOGENOUS ORIGIN

Contrary to what might be thought, the idea that iron metallurgy in Africa is of endogenous origin is a very old one. Authors such as de Mortillet (1903), Von Luschan (1909), Reinach (1913) and De Pedrals (1950) all mooted the possibility at the end of the nineteenth century or in the first half of the twentieth century. Such studies, based on very limited data, focused for the most part on the originality of the reduction processes used by the Africans (Von Luschan, 1909).

It was probably Lhote (1952) and Diop (1973, 1976) who first attempted to rethink the question in a debate in which they took issue with Mauny (1952), who drew his inspiration essentially from the positions adopted by Leclant (1956). In his first publication, focused on ancient Egypt, Diop (1973, p. 532) put forward the hypothesis that iron metallurgy was an African invention dating back to the Ancient Empire. In support of his thesis he cites several discoveries made *in situ*, in particular that of a piece of iron, produced by reduction, close to the air vent of the Great Pyramid built around 2700 B.C. Pursuing his investigations, Diop (1976) opened up new vistas thanks to the datings which he carried out at the Termit site in Niger (Dak. 145: 678 B.C. ± 120 and Dak. 147: 974 B.C. ± 120). Those datings made the hypothesis that iron metallurgy had spread down from North Africa, including Egypt, all but unworkable. That revelation, which was greeted somewhat coolly, marks in retrospect a veritable turning point in research on iron metallurgy in Africa, in the sense that it called cogently into question what had hitherto been the prevailing assumptions. A considerable accumulation of further datings was to follow.

Recent archaeological data and their significance

With the intensification of archaeological operations in Niger, Nigeria and the Great Lakes region (Rwanda, Burundi), a relatively substantial body of radiocarbon measurements has now become available. The research carried out by Grébénart (1983a, 1983b, 1985, 1988), though it gave rise to disputes, and sometimes to objective challenge (Killick et al., 1988), has now been validated by independent work (Paris et al., 1992; Quéchon, 1995). Their findings have indeed made it possible to establish a consistent array of absolute chronological datings that invalidate all diffusionist theories, which have been stripped of their chronological bases – a somewhat damning indictment (Grébénart, 1983a, 1983b, 1985, 1988; Holl, 1988, 1993, 1997, 2000; Okafor, 1992a, 1992b, 1993; Paris et al., 1992; Quéchon, 1995; Van Grunderbeek, 1992; Vignati-Pagis, 1995; Wiesmuller, 1996, 1997).

In this connection, it should be noted that the evidence gathered at Termit is confirmed by the series of findings at Do Dimmi, which yielded five dates between 1010 B.C. and A.D. 35. In order to validate the choice of the earlier date, it may be recalled that Termit's West 9 station also yielded two measurements between 1395 and 820 B.C. in adjusted figures (Paris et al., 1992, p. 58). In the same area, specifically at Egaro, two measurements carried out on pottery gathered in a context in which iron artefacts are found yielded dates lying between 2520 and 1675 B.C. in adjusted figures (Paris et al., 1992, p. 58). One measurement even yielded 4000 B.P. + 110, that is, between 2900 and 2300 B.C.[3]

In Niger, in the region of Azawagh, the In Tékébrin site, which has yielded copper artefacts, has been dated to between 2531 and 1675 B.C., dates obtained using three different types of material (charred bones, charcoal and ceramics), located all very close to one another, a fact that substantially strengthens the hypothesis of the homogeneity of the grouping studied. According to Paris et al.:

> The first metal artefacts (iron and copper) appeared earlier than 1350 B.C. in a still broadly Tenerean context (i.e. Ténéré-derived), since they were found on a site occupied by craftsmen specializing in the production of small scrapers.
>
> (Paris et al., 1992, p. 59)

Thus the dates obtained in West Africa, Central Africa (Essomba, 1992a, 1992b; Holl, 1988, 1991, 1997; Zangato, 1993, 1999) and East Africa today form a body of evidence sufficiently consistent for all authors to agree that the Meroitic hypothesis – that is, of a borrowing from Meroe – has definitely collapsed. If this is so, contestation of the autonomous origin of African ironworking becomes totally refocused on the credibility of the North African route, which itself is based on no more coherent data (Holl, 2000). Indeed, all the currently available archaeological evidence points against the hypotheses of a North African route, as these are reflected in the work published by Miller and Van der Merwe (1994, pp. 8–9). These authors have proposed two possible transmission routes, the Gulf of Sidra (present-day Libya) via Gao to Niger, or from Morocco to Timbuktu – proposals supported by no recent discoveries. In point of fact, they differ little from those put forward by Mauny (1952), who, faced with the absence of decisive evidence, was reduced to making the point in connection with the Punic world that, although no workshops had been discovered for the reduction of iron ore, finished artefacts were to be found in tombs dating from the sixth century B.C.

Half a century later the situation has not fundamentally altered since, for the period concerned, no coherent ironworking complex of comparable antiquity to that situated in Niger has been brought to light in North Africa. From this it

3. See Stuiver and Pearson (1986).

could be inferred that, in the present state of our knowledge, and failing any decisive evidence to substantiate the claims concerning the transmission routes posited to date, the debate is closed.[4]

Divergences and hypotheses

Despite the substantial contribution made by archaeological research to establishing a coherent chronological framework, not all the issues relating to early ironworking in Africa have been settled once and for all. Indeed, some remain extremely debatable. These issues concern in particular pyrotechnic culture (that is, the existence of a culture involving fire-based technology), the reliability of certain C-14 measurements obtained in Niger, and the problem of the transitional sites capable of strengthening the hypothesis of an endogenous invention of ironworking. Accordingly, we should like to discuss such hypotheses briefly in order to indicate in what respect, even if they cannot be wholly discounted, they still do not in their current state of formulation constitute reservations such as to justify any substantial misgivings about the plausibility of the arguments for the indigenous origin of African ironworking.

PYROTECHNIC CULTURE

Whatever the issue considered, the question of the autonomous origin of African ironworking can be reduced to a single line of inquiry. Since oxide-reducing processes are governed by strict, universal principles geared to mastery of high temperatures, did African ironworkers possess the necessary technical proficiency?

Some substance may be given to this question by drawing upon the aspects already highlighted in this work (in the chapter by Fluzin), which indicate that of all the parameters involved in the reduction of iron oxides, temperature remains the most important. For it is temperature that determines the physical condition of the metal, and makes it possible, at the functional level, to distinguish between direct and indirect processes according to whether the temperature reached is above or below melting point.

In the light of these considerations, and in connection with the specific case of Niger, it does not seem to us appropriate to support the thesis of the need for a lengthy apprenticeship in order to move from copper metallurgy to the more

4. In point of fact the issue is not so simple, since the reservations posited need to be taken into account in order to consolidate the analytical basis of forthcoming research, which should cover the different aspects of the cultural and technological environment of these early Iron Age civilizations. Only by these means will we gradually attain an adequate understanding of the transformations that have taken place.

complex process of iron metallurgy. Access to high temperatures was in fact intrinsic to the logic of the technical operative chain of copper production, as is borne out by the experimental studies conducted on slag associated with copper production in Afunfun. Those studies suggest, according to Killick et al. (1988), that temperatures of between 1350 °C and 1450 °C may have been reached. Such temperatures being amply sufficient for producing iron through a process of direct solid-phase reduction, we may infer that the chronological proximity of iron and copper production is a decisive argument for the existence of a technological environment conducive to ferrous oxide reduction, and hence to the production – that is, invention – of iron.

CONCERNING FOSSIL COAL AND CHRONOLOGY

The possible use of fossil coal in Niger (in the Afunfun 175 metallurgical station) was mooted by Killick et al. (1988, pp. 390–1) in order to explain the uniqueness of furnace 8 (1710 B.C. + 50, 2450–1750 B.C.). For that reason, Killick rightly suggested that the charcoal gathered in that installation should not necessarily be regarded as synchronous with the operation of the putative furnace. Since then, however, new data have been amassed (Paris et al., 1992; Quéchon, 1995) indicating that, in the distribution of the metallurgical sites in question, the Afunfun site is no longer an isolated case. As already pointed out, there are today several sites that have yielded comparable dates.

Accordingly, were we to confine ourselves to the (rate of) recurrence of the facts (which is the basis of the statistical approach in the construction of any archaeological hypothesis), any generalization, if it is not to be improper, should accept the second millennium B.C. as marking the beginning of metallurgy in that region. The metalworkers of the Agadez region would in that case have acquired, through their own observations, an understanding of the technical principles of reduction. This transitional assessment, altogether more soundly argued than all rival hypotheses, nevertheless does not rule out the continuation of research, in particular through the collation of C-14 measurements with thermoluminescence-based datings, or again by recourse to archaeomagnetism dating. To this requirement should also be added the need for a more contextual approach to the dates obtained.[5]

5. Despite the evidence already accumulated in the definition of the cultural context within which the first appearances of iron in Niger occurred, only a dating of the artefacts associated with iron production (coal or charcoal inclusions in the slag, furnaces, objects) will provide irrefutable arguments. UNESCO should encourage the setting up of a team of experts to settle this matter.

THE ISSUE OF TRANSITIONAL CULTURES

The issue of transitional cultures is a hardy perennial in archaeology. Attempts to pinpoint the appearance of an innovation in a given community, and its archaeological visibility, depending on whether the innovation is abrupt or gradual, frequently lead to the formulation of two hypotheses. Hence, cases in which the new technique or technology gains a foothold in a particular society that adopts and frequently perfects it are commonly interpreted as the markers of a gradual evolution, one that may possibly account for an invention. On the other hand, the rapid emergence of an already full-blown technology is frequently seen as an instance of borrowing. Thus this variant of 'technological' evolutionism, even though solidly rooted in historiographic traditions, is an unfortunate development to which we have learned to adjust: it does not, however, provide evidence with which to contest the antiquity of the appearance of metallurgy in Niger. For, despite the difficulties inherent in interpreting surface sites, there is convincing evidence of transitional cultures existing in Niger between the end of the Neolithic and the beginning of the Iron Age. In the region of Termit, the earliest metallurgical evidence is associated with an as yet not fully defined lithic industry that Quéchon (1995, p. 309) calls, with all due prudence, the 'Tenerean' (or Ténéré-derived) industry of Termit. That industry, which developed between 3300 and 1500 B.C., is characterized by the predominance in stone-based production of disks, bifacial triangles, foliated items, scrapers, planes, saws and such. As regards pottery, this is of the Sudanese-Sahelian type, at least in its initial stages, for:

> Towards the end of the period (2000–1500 B.C.) there appear new forms and new decorations (curved-necked bowls, the curve being enhanced by a pivoting impression, and bowls having a thickened rim and partially decorated with geometric compositions), which gradually become predominant, until they come to characterize the later period.
>
> (Quéchon, 1995, p. 309)

Seen in this light, the reservation concerning cultural transition should also, in our view, be ruled out, particularly since metallurgical techniques first appeared in Niger in a 'Neolithic setting'.

Naturally one can expatiate at still greater length about the question of invention in pre-industrial societies prior to the gradual development of modern science. The issue is in our view implicit, waiting to arise in regard to any observation carried out in an environment containing the seeds of a qualitative leap. Thus many instances of accidental reduction of certain ores are pointed to by Routhier (1963) who reports that in New Caledonia bush fires sometimes cause small schist blisters or plaques to melt and vitrify at the foot of trees. This type of accident, for example, is entirely plausible for Niger, especially in connection with the case of certain so-called elongated 'furnaces', the configuration and

modus operandi of which appear to obey no logic. Thus, even if they must as a result continue to be seen essentially as ecofacts, there is nothing to indicate that they might not have inspired the metalworkers of the time. One might just as well wonder why the apple fell on Newton's head while he was lost in thought: was it chance or necessity?

Iron in Africa: its exceptional longevity and remarkable adaptability

If iron is of such antiquity in Africa, it is also in Africa that iron production has been, in its technical principles, the most conservative. Having taken part only as consumers in the formidable renewal of ironworking,[6] African metallurgists nevertheless managed to save a major heritage from total destruction.[7] For that reason also, Africa is today the only place in the world where it is still possible to observe, *in vivo*, a traditional iron-producing furnace being operated by the so-called 'direct reduction' method. Thus neither the Atlantic slave trade, with the arrival of the iron ingot, which brought about here the meeting or intersection of the iron roads and the slave route, nor the progress of the market economy, succeeded in wiping out African know-how in matters of iron production. This remarkable capacity to resist constitutes a magisterial contribution – far transcending its anecdotal interest – made by the continent's metalworkers to the technological heritage of humanity. They have the immense merit of safeguarding that heritage as a living witness for history.

Closer to us, the success of recycling, especially in the artistic field, tends to eclipse the dynamism of the traditional forge, so that the latter appears to the uninformed observer to be rising from the ashes. But it should be pointed out that nothing could be more mistaken, for the forge never ceased its activity. Thus in the fifteenth century, with the establishment of regular trading relations with Europe, blacksmiths were the first craftsmen whose know-how was recognized and even sought after, not least for purposes of maintenance of small craft. The

6. Routhier (1963), *Les gisements métallifères, géologie et principes de recherches*, Paris, Masson.
7. Thanks to the technical capacity to smelt iron, the transition from direct to indirect reduction made possible numerous applications that were to exert a multiplier effect on all other industrial sectors. Concurrently, the continuous-flow operation of blast furnaces would usher in the low-cost mass production of which Africa was one of the recipients, in particular in the context of the Atlantic slave trade. The iron ingot inexorably gained ground on the continent, concomitantly triggering the decline of local production. Indeed, it is no exaggeration to say that it was from that period that the continent began to lag behind in technological terms (Bocoum, 2000).

navigator Francisco de Coelho Lemos, who spoke from personal experience, notes with assurance that 'if it was necessary to make a few metal fittings for the rudder or tiller, as happened to me, very skilled native Negro blacksmiths were to be found here'.

Likewise, the crisis of the early 1980s and the various adjustment plans, which led both to the collapse of price and credit control policies and to the brutal halting of efforts to build up infrastructures in most African countries, had a particularly stimulating impact on the ironworking trades. For not only the peasants, but an increasing number of city dwellers turned to local handicrafts in order to meet their most urgent needs in matters of equipment (Fall, 1985, 1995, 1997). This trend is extremely marked in many sectors today, notably in agriculture, in the arts and handicrafts (including crafts using salvaged materials), and in the industrial sector. The long-heralded end of the small craftworker, doomed by the mass influx of industrial products, has just not happened.[8]

In point of fact, the salvage and reprocessing industry is itself far older than is thought, for in order to fully understand its history in Africa one must go back several centuries. Metallographic analyses conducted on African archaeological objects quite clearly establish that blacksmiths were in the habit of assembling metal fragments of different origin and composition in order to create new artefacts not necessarily intended for the same purpose as the original items (Bocoum, 1988, 2000). It was in line with this tradition that African craftworkers began to transform metal packaging into objects for use, play or decoration. In the same vein, they have sometimes also excelled in reproducing the firearms introduced by Europeans, and even undertook, at the instigation of their sovereigns, a veritable campaign of industrial espionage, as was instanced by the adventure of the blacksmith Siakha Kuruma, a native of Samory, who spent some time in the Saint-Louis arsenal in order to study how repeater rifles worked. Indeed, tradition has it that Siakha's outstanding success earned him the nickname 'the ten-shooter rifle man' (Person, 1970).

Finally, in the field of manufacturing, once the problems relating to welding and soldering have been mastered, ironworkers throughout Africa are today

8. Even though they scarcely ever reactivate their installations any longer, except on the occasion of specific ceremonies (reconstitutions, rites and so on), they have at least managed to maintain in operation a technological heritage that is over 4,000 years old. In point of fact, with the introduction of harness- and yoke-based cultivation techniques, African craftspeople were to succeed very rapidly in copying the proposed models, and frequently managed to improve them by adapting them to the different types of soil, to the morphology of the populations for whom the implements were intended and to the traction power of their animals. There is no doubt that the success of ass- and horse-drawn tillage owes a great deal to the ironworkers. It is they too who ensure the maintenance, and indeed renewal, of the existing stock of equipment.

achieving applications which, if encouraged, should in the near future lead to a relatively advanced degree of autonomy in the provision of equipment and infrastructures. This activity, quasi-industrial in scope – so successfully has its modus operandi been adapted to modern production conditions – embraces a whole range of fields, from metal fittings to the production of agricultural machinery, grain mills, oil presses, water pumps and so forth. It is doubtless in this area that Africa's ironworkers are in the process of achieving their greatest revolution, taking an unexpected revenge upon those who, no doubt too summarily, had consigned them to the scrap heap of history. Their ability to respond efficaciously, today as in the past, to a wide range of opportunities and promptings has in reality transformed them into powerful economic agents whose participation in the development effort may prove substantial indeed, if they are provided with a suitable framework.

Conclusion

In any study of technical facts and cultural features, particularly when these date as far back as those relating to the appearance of iron in Africa, the search for chronological coherence on the basis of the archaeological evidence is an unavoidable exercise. The available documentation considerably strengthens the credibility of an autonomous centre for the invention of iron metallurgy in Africa, one whose existence might well result from a phenomenon of convergence. That theoretical possibility – namely, convergence – fails, curiously often, to feature among the concerns of researchers, who are inclined rather to develop centrifugal models. Fortunately, history is beginning to fill up with examples to the contrary. Such is the case, in particular, regarding the recent discoveries relating to indirect iron reduction, which establish that European ironworkers had independently succeeded in mastering this process, contrary to the diffusionist theories that situated its origins in China (Fluzin et al., 1998).

The Iron Roads in Africa Project also opens up a vast area of research in a range of fields, prominent among these being the study of the economic, social and political consequences of metallurgy and those relating to urban development. All such research should contribute to the renewal of studies on the history of technology in Africa, a history which hitherto has been a prisoner to comparativism and analogy, traits that – to say the least – are not very rewarding.

Iron Metallurgy Datings from Termit (Niger): Their Reliability and Significance

Gérard Quéchon

This chapter is intended to clarify the chronology of the origins of iron at Termit and show the coherence of that chronology, through a methodology closely linked to the specific area and based on the reasoning derived from the evidence. This chapter offers no overview of ancient African metallurgy as a whole.

Scientific findings, particularly in relation to social sciences, depend directly on the methodology used in surveying and even on the material conditions under which it is carried out. However obvious this remark may appear, it is none the less essential in so far as the fact is not always borne in mind in archaeological reporting.

Since the researcher's function is to try to fill gaps in knowledge, it is not surprising that many cannot bear the thought of not being able to obtain an answer to a question. From there to camouflaging ignorance by filling in the blank areas on the map with monsters, as was the fashion in the sixteenth century, is a simple step that is sometimes taken, all the more readily in that archaeology is a frustrating field which yields only a jumble of fragments of incomplete puzzle boards.

The question of the beginnings of metallurgy in Black Africa provides a good example of this attitude: often, the arguments on the subject defended by an archaeologist may appear perfectly consistent and even convincing, but in reality serve to cover a lack of verified evidence, most of the regions regarded in such cases as possible routes for the diffusion of metallurgy being unknown territory at the time of enunciation of the arguments. 'Scientific' conclusions reached in such a manner are inclined to resemble a pure exercise in style.

Similarly, many archaeological maps indicate ancient migratory routes where population densities, based on the density of sites, manifest (at times comically) the activities of prehistorians rather than the presence of prehistoric peoples.

When a region is left blank on the map, the first question to ask is whether it contains little archaeological evidence or is relatively unexplored. We must not jump to the conclusion that there are not enough facts, when what is missing is merely information.

For example, the zone immediately south of Termit has never been prospected, and further south, the Zinder region has been the subject only of a preliminary study by J.-P. Maître, carried out just before his sudden death and consequently unpublished. From conversations in the past with this colleague and friend, I know that the region is difficult to interpret and that any possible discrepancies with the prehistory of Ténéré are probably due in large measure to their different climates and palaeoenvironments. There is, in any event, nothing that could justify the conclusion by McIntosh (1994) that 'the lands west of Lake Chad lying between Termit and Taruga did not begin to use iron for nearly a millennium after [these two areas] did'. In the field of prehistory too, we must once and for all stop confusing the absence of proof with the proof of absence.

Also, to produce results closer to truth, the outcomes of fruitless explorations should be published as well. However, this practice is indeed rare, given the notion of 'economic efficiency' that prevails in the present context.

Such considerations – which may appear to have little to do with 'science' – are nevertheless essential because they determine the reliability of the results. But they are rarely taken into account in publications.

Last, one must stress the gap between the desirable and the possible. The right procedure at Termit would have been to deploy in the field the broadest possible multidisciplinary team, including a palaeometallurgist. Regretfully, the financial constraints encumbering research nowadays forbade this. It must therefore be stressed that the results presented here have been obtained on a strictly generalist basis.

Geography, climate and archaeology of the region

Lying close to 16º N, Termit was during the Holocene period in a region particularly sensitive to climate change and possibilities of settlement. This small tabular massif is structured around a north-south fault generating a series of endoreic basins that were periodically filled with water.

The archaeological sequence has constantly to be assessed in the light of these environmental variations, bearing in mind that the relation between favourable climate and population density is far from being systematic. On closer inspection, this relation turns out to be extremely complex, and should at the very least be the subject of a macro-regional study (Person and Quéchon, 1997; Quéchon and Person, 1997).

The oldest evidence comes from an Acheulean bifacial industry, which was succeeded by a Middle Palaeolithic flake industry. The sites, to be found all over the massif but especially in the northern part, are mainly piedmont deposits yielding an abundant array of tools which, however, with rare exceptions have been considerably displaced. So far no way has been found to obtain absolute

dates, and it is important to note the absence of any Aterian traces in the region despite the tight grid layout used for the exploration.

The Holocene sequence, to which we shall now turn, yielded the best and most numerous results. One finds first, approximately 9,000 years before our era, an early Neolithic period with heavy tools including picks, bifacial tools and hoes – evidence of very early agricultural activity, albeit probably of a temporary nature. Next come the stone and pottery industries, not very abundant but from the same family and more or less related to what used to be called the Neolithic of Sudanese tradition (gouges and so forth). Most of the archaeological artefacts of these ancient periods show signs of a hydromorphic patina, evidence that their location is older than the highest levels of the local lakes and marshes.

The recent Neolithic that follows is characterized by a local variant of the Tenerean Neolithic, known as the 'Gossololom facies', with an impressive range of highly characteristic tools including foliated bifacial objects, discs, rectangles, saws, unifacial oval blades and other items. However, the main interest of this period lies in the fact that the great majority of the deposits relating to it have remained *in situ*, although on the surface. It is very easy to identify the different zones: excavation, blank production, work areas, storage and others. These deposits yield a great deal of unusual information on the organization of space and on the economic and social organization of the occupants of these sites. We see, for example, that artisans were using, as it were, production-line techniques to make certain types of tools for the purpose of exchange, as their production clearly exceeded their own needs.

This lithic tradition continues – in a slightly modified form – until the moment when, in a context where artisans continued to specialize in stone tools, the first pieces of metal (iron and copper) appear at the sites.

We then gradually enter into an intermediate phase (a siderolithic one) where stone tools continue to play a major role despite the production of iron in low forges. Soon afterwards the region was abandoned, most probably because of a worsening climate.

Dating

The cultural sequence outlined above does not in principle give rise to any particular problems. It is logical, forms part of a schema of growing complexity, and is to some extent internally coherent. However, when the first dates were obtained, their – at that time – unexpected age was surprising with regard to both its beginning, with the early appearance of Neolithic signs (which is not the subject of this article), and its end, with the presence, much earlier than expected, of metal at the sites and then of metalworking furnaces.

To review the facts, in 1972 the first dates of 2630 B.P. ± 120 for a hearth bed at Do Dimmi, and 2925 B.P. ± 120 for a site with iron and copper tools caught our attention; however, since they were, at the time, isolated datings, caution was called for. One of the principal objectives when field operations were resumed in 1982 was to confirm or invalidate this early chronology. The first results showing that the large settlement at Do-Dimmi was contemporaneous with the neighbouring low forges seemed to represent a confirmation.

Nevertheless, the difficulty of obtaining dates from charcoal and the relative uncertainty of such dates – because the sites were in the open air – led to an attempt to obtain dates from organic ceramic tempers which, if successful, would have the advantage of yielding a precise chronology linked to the cultural context itself, since the dated objects are a part of it. This project, carried out jointly by Saliège, Person, Paris and myself, yielded extremely positive results, in particular with respect to Termit. The blind-study measurements carried out by Saliège on potsherds from various periods turned out to be astonishingly consistent and concordant with the archaeological evidence (Table 1). In addition, the comparison whenever possible of ceramic and charcoal dating from the same site yielded very convincing results (Table 2). With the exception of two sites out of a total of some thirty measurements (rather a good sign since overly perfect results in the area of absolute chronology might be suspicious), the result is a set of dates delimiting a firm chronology.

The significance of these datings for ancient metallurgy in Africa will be discussed in greater detail in the following chapter. It can be summarized here in two essential dates, confirmed several times: iron and copper objects appeared in Termit in approximately 1500 B.C., and the first known smelting furnaces date from approximately 800 B.C. (Photo 73).

Saliège obtained the datings in the table in a blind study. Those followed by an asterisk indicate the presence of metal objects at the site. With the exception of the two sites in brackets, the results are consistent with archaeological evidence.

In this regard we must be entirely clear: the gap between these two dates does not at all imply that there were two successive cultural phases in Termit, a first one in which the population was familiar with metal but not with ore reduction, and a second one in which the complete process of metallurgy was understood. This scenario, in our view, appears to be highly unlikely. Simply put, we must stick rigorously to the observed facts: for the time being, there is a big gap between the first objects found and evidence of the first reduction processes. This gap is, moreover, not surprising: the remains of hearths are as rare as they are inconspicuous and only two of them have been discovered, even for the period when metal tools were becoming more common. It therefore makes sense that hearths from the beginning of the period have not been found.

As often as possible, multiple datings were obtained from the same site, either with a new carbon sample or by dating the organic temper of potsherds. The goal was to check the consistency of the chronology first within and then between sites.

Similarly, the fact that the dates of low forges span several centuries should not be ascribed to imprecise methodology: when the discovery was made, it was obvious that a number of reduction operations had been carried out at the same

Table 1. Datings based on organic ceramic tempers

The datings below were obtained in a blind study by Saliège. Those followed by an asterisk indicate the presence of metal objects at the site. With the exception of the two sites in brackets, the results are consistent with archaeological evidence.

Sites	Datings
Ancient pottery	
West Termit (southern dune)	7160 ± 300
Cheguelenga 84	6760 ± 100
West Termit 130	6085 ± 290
West Termit 131	5275 ± 180
West Termit (northern dune)	5240 ± 100
Bezi Yasko 134	5000 ± 120
'Tenerean' pottery	
Gara Tchia Bo 200	4420 ± 200
Gara Tchia Bo 20	3625 ± 90
Gossololom Bo 151	3600 ± 100
Gara Tchia Bo 176	3510 ± 100
Gossololom Bo 152	3235 ± 120
Bézi Atchwa	3225 ± 90
[Gara Tchia Bo 75	1960 ± 150]
'Post-neo Phase 1' pottery	
Tchiré Ouma 147	3300 ± 120
Gara Tchia Bo 48 west	3265 ± 100*
Gara Tchia Bo 48 east	3260 ± 100*
Tchiré Ouma 146	3230 ± 170*
West Termit 95-b	3100 ± 100*
Tchi Guiribé 127-b	2950 ± 100*
West Termit 8 b	2880 ± 120*
[Gara Tchia Bo 48 B	2430 ± 110*]
'Post-neo Phase 2' pottery	
Do Dimmi 16	2270 ± 90*
Chegulenga 123	2095 ± 200*

site and that the large neighbouring settlement had been occupied for a long time. Later datings confirmed the accuracy of this observation by verifying that these two sites were contemporaneous over a long period of time, at least during the last eight centuries B.C.

The earliness of these dates obviously rules out a Mediterranean or Meroitic origin for iron metallurgy in the sub-Saharan regions, a hypothesis that has also been called into serious question over the past twenty years by the increasing number of African iron sites dating from the last millennium before Christ.

Table 2. Multiple datings

As often as possible, mutiple datings were obtained from the same site, either with a new carbon sample or by dating the organic temper of potsherds. The goal was to check the consistency of the chronology first within, and then between, the sites.

Satisfactory results			
Site	Charcoal 1972	Charcoal 1982-1985	Organic tempers
Do Dimmi 15 (open furnaces)	2630 ± 120 2065 ± 60	2500 ± 70	
Do Dimmi 16 (settlement)	1745 ± 110	2590 ± 120	2270 ± 90
West Termit 8B (site with metal objects)	2925 ± 120	2880 ± 120	
Gara Tchia Bo 176 (late Tenerean)	3535 ± 200	3510 ± 100	
Gara Tchia Bo 20 (late Tenerean)	4100 ± 90	3695 ± 80	3625 ± 90
West Termit (Middle Neolithic) : – organic fossil soil – higher-level pottery	6340 ± 100	5240 ± 100	
Inconsistent results			
	Expected age	Obtained age	
		Charcoal	Organic tempers
Gara Tchia Bo 75	± 3500/3000	445 ± 80	1960 ± 150
Gara Tchia Bo 172	± 3700/3200		2530? (without error bar)

Given our current state of knowledge, we accept the existence of an endogenous African development of iron metallurgy. Did it arise at Termit? Perhaps, but this does not rule out the possibility that the next series of investigations may lead to revision. Particularly noteworthy are the even earlier dates obtained at Egaro, 70 km west of Termit, but without the critical apparatus to make the information absolutely certain (Paris et al., 1992). What is important is that we now have a reliable chronological framework for the beginnings of metallurgy in the region.

This framework, although based, as we have just seen, on numerous and consistent measurements, is nevertheless in dispute, perhaps because of a reluctance to accept new perspectives, even though we sometimes accept without a murmur data whose reliability is far from proven simply because it agrees with the conventional wisdom.

McIntosh (1994), in particular, believes that the Termit dates should be approached with considerable scepticism. Her conclusion is based on two considerations:

- The first early datings for metallurgy in Niger – the copper 1 dates proposed by Grébénart for the Agadès region – are no longer accepted (Killick et al., 1988).
- There is a danger of finding fossil carbon at the surface sites in Niger, and perhaps at many other sites, as well as in the reduction furnaces.

With regard to the second point, it suffices to point out that, if such were the case, the set of Termit dates could not possibly be consistent because the relationship between samples dated and human activity of the period would have been purely a matter of chance. On the contrary, it is clear that all the dates – whether they relate to charcoal from hearths or to ceramic tempers – are internally consistent to a remarkable degree and corroborate in all aspects the purely archaeological evidence.

It was this very awareness of the difficulties of dating surface sites that led us to delay publishing the data until we had obtained and cross-checked a larger number of results from the same site using different elements, and until the maximum number of possible measurements taken at different sites had been added. It turned out that all the data obtained were relevant and mutually consistent. For the chronology to be false, it would therefore be necessary for all the measurements, regardless of their origin, to be affected by the same error, which is statistically improbable.

It is interesting to note that the pottery datings prove *a contrario* that the hearth-floor charcoal and the dune charcoal found at the sites themselves are neither fossil nor exogenous charcoal fragments unrelated to human activity, since if they were, no cross-checking of dates would have been possible.

The first point, addressed to archaeologists who were among the first to point out that the way in which the question of the copper 1 at Agadez had been

Photo 73. Datings of the metallurgy of iron at Termit

raised was far from satisfactory, cannot be upheld. Calling into question the metallurgy dates at Termit on the pretext that other metallurgy dates, proposed by someone else involved in another project in another region, have turned out to be debatable seems to be a specious argument to say the least. By such criteria, the small world of prehistorians would rapidly have been immersed in a new, unexpected and interminable dispute.

With regard to surface sites, one major objection remains: are the metal fragments and the rest of the archaeological material contemporaneous? This is a crucial point: in presenting the sequence, we strongly emphasized the fact that the documents proved the absence of any visible mixing in terminal Neolithic sites at Termit. It was in this context, then, in conjunction with other remains in a logical arrangement that is remarkable and recurrent, that the first metal objects appeared. If some mischievous palaeo-Toubou had scattered them at

some earlier time where we found them, he must also have been a remarkable prehistorian because, each time, he managed to leave the metal objects behind in the same ceramic and stone culture at sites dating from the same period (approximately 2800 to 3300 B.P.) and never at more ancient sites. The argument is even stronger if one attempts to imagine the occupation of the region by a historical population familiar with metallurgy: in that case, it would have left no other traces of its existence than these repeated metal 'offerings' left on certain carefully selected sites belonging to their predecessors.

Nothing more needs to be said about a series of observations that we believe to be well founded. Nevertheless, not all the problems of this ancient metalworking industry have been resolved. While the chronology has been established, we know practically nothing about the technology, the processes of creativity and the extent of the industry – to mention only some of the questions yet unanswered.

Conclusion

Given our current state of knowledge, we are unquestionably bound to accept the hypothesis of an endogenous origin, first for chronological reasons, and second, because the metallurgy industry in question made its appearance within complex and highly 'technical' cultures, and thus in a setting conducive to innovation.

I should like nevertheless to stress the fact that this is not a final position: the cradles of humanity, of agriculture, of cattle breeding, of metallurgy and so forth are unquestionably cradles on wheels, and some of the infants in them can expect a rocky future. Hardly tempted as I am by the obstinate pursuit of an archaeological scoop or some spectacular find, I would like to remind myself, and the reader, that it is in itself unimportant whether African metallurgy is the most recent or the most ancient, or whether it is endogenous or exogenous. If it turns out that more ancient dates found elsewhere indicate that iron was diffused from some other source, Africa will be neither the better nor the worse for it: having roots does not mean claiming that they are deeper than those of others.

Yet, while all well-founded scientific positions are respectable, ideological ones are sometimes less so. Undeniably, scientific opinions, like all human judgements, are influenced by the philosophical and political context in which they are formulated. Thus the question of the origin of African metallurgy has often been examined (and unfortunately still is from time to time) in the light of reasonings embodying power relations between North and South, colonizers and colonized.

Chronometric and Chronological Data on Metallurgy at Termit: Graphs for the Study of the Ancient Iron Ages[1]

Alain Person, Gérard Quéchon

As this is a follow-up to the previous chapter, we will not repeat the archaeological arguments developed there but will endeavour to follow a chronological approach to iron metallurgy through the use of graphs, while raising some questions with regard to the problems of C-14 dating.

In the previous chapter, for reasons of clarity and practicality, all the chronological data were expressed in non-calibrated form. Since the principal objective was to verify the relevance of different types of measurements obtained from the same site, or of the same types of measurements obtained from different sites, it seemed more appropriate to use the simplest formulation. In so doing we were well aware that the data were not expressed in real chronological time but in terms of radiometric dating, whose relationship with historical time is very close but nevertheless complex. The first phase was therefore chronometric – testing the archaeological validity of the measured age of a sample without necessarily including it in a general temporal frame of reference. Comparisons are made between samples (Figure 3) or groups of samples (Figure 4). In the second phase, we designed a chronological approach to Termit: the measures were calibrated (Table 3) in order to fit them into a chronological calendar (Figure 5) so that the historical data relating to the beginnings of metallurgy at Termit could be compared with all other archaeological events.

Before we embark on a scientific assessment of C-14 dating, two points must be addressed:

- *The problem of the archaeological representativeness of the measurement.* This problem can be debated in the context of the work at Termit for which all the data are available. The method used was the application of C-14 dating to the anthropic materials themselves: vegetable tempers included in pottery objects (Durand et al., 1999; Saliège and Person, 1991), charcoal fragments

1. The authors wish to thank Vincent Balter for his valuable and willing assistance in preparing Figure 5, and Jean Polet for his advice and final reading.

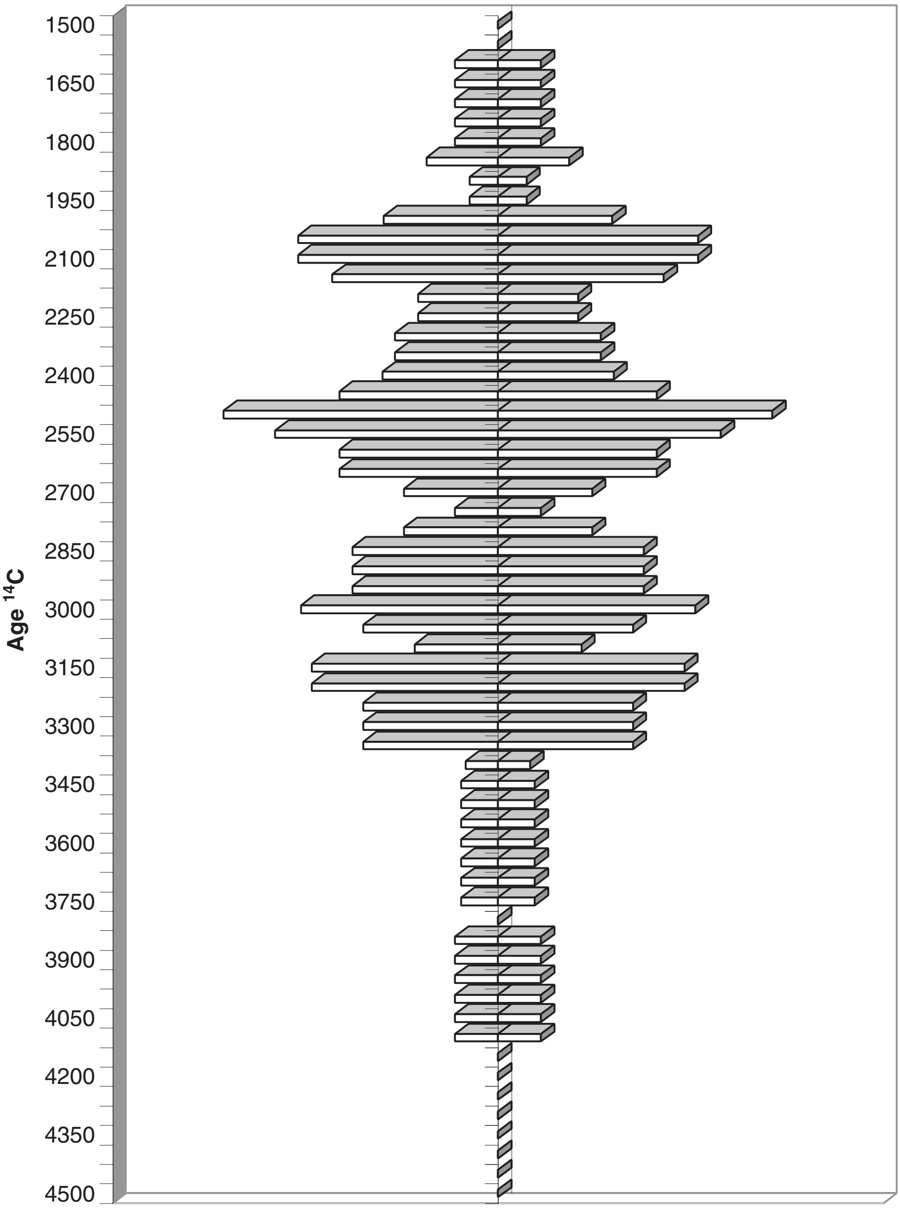


Figure 3. Diagram of carbon-14 B.P. measurements at Termit-Egaro. Histogram in fifty-year classes of radiocarbon dates B.P. not gauged according to the confidence interval of measurements.

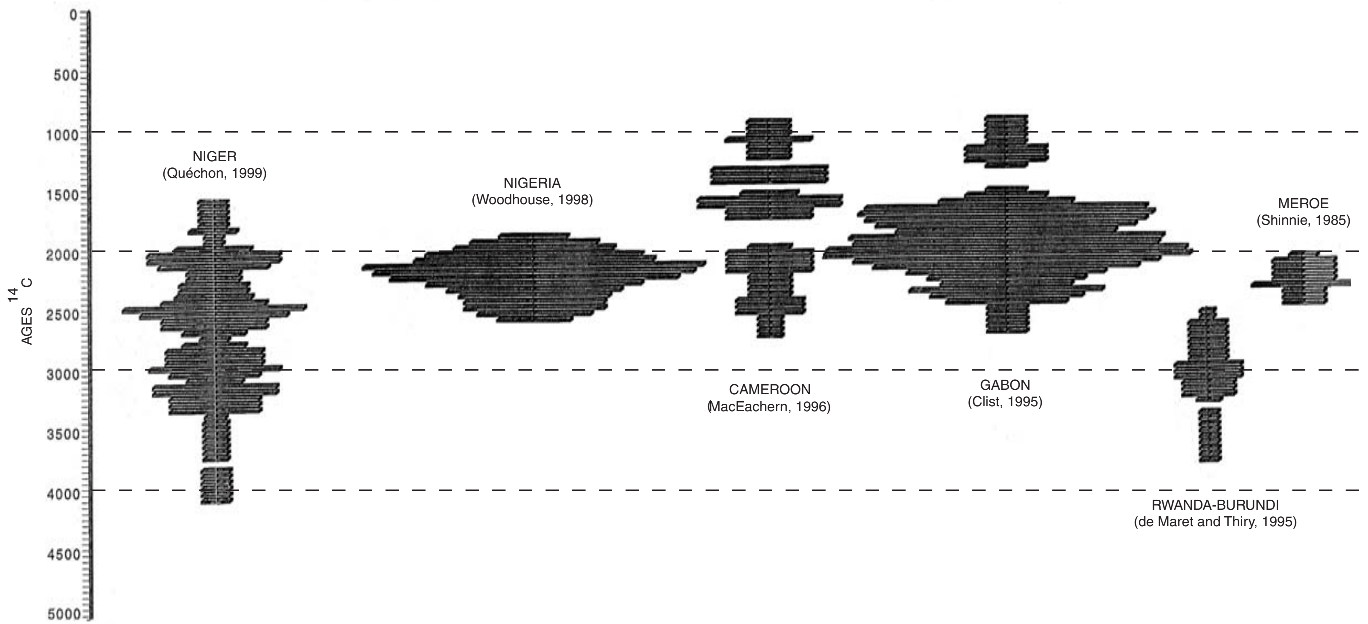


Figure 4. Comparative histogram of carbon-14 ages

Table 3. Dating of organic vegetable tempers of ceramics

Sites (samples) calibration	Lab code	Material	C-14 B.P. age	Calibrated B.P. age	Calibrated B.C./A.D.	Age B.C./A.D.
Gara Tchia Bo 200	Pa 547	Vegetable temper	4420 ± 200	– 4985	3036 B.C.	3364-2789 B.C.
Gara Tchia Bo 20 a	UPS	Charcoal	4100 ± 90	– 4564	2615 B.C.	2871-2493 B.C.
Gara Tchia Bo 20 b	UPS	Charcoal	3695 ± 80	– 4036	2087 B.C.	2192-1947 B.C.
Gara Tchia Bo 20 c	Pa 505	Vegetable temper	3625 ± 90	– 3919	1970 B.C.	2131-1828 B.C.
Gossololom Bo 151	Pa 539	Vegetable temper	3600 ± 100	– 3885	1936 B.C.	2120-1776 B.C.
Gara Tchia Bo 176 a	UPS	Charcoal	3535 ± 200	– 3780	1831 B.C.	2136-1616 B.C.
Gara Tchia Bo 176 b	Pa 484	Vegetable temper	3510 ± 100	– 3760	1811 B.C.	1944-1686 B.C.
Gossololom Bo 152	Pa 540	Vegetable temper	3235 ± 120	– 3461	1512 B.C.	1629-1398 B.C.
Bézi Atchoua	Pa 511	Vegetable temper	3225 ± 90	– 3421	1472 B.C.	1602-1407 B.C.
Gara Tchia Bo 75	Pa 643	Vegetable temper	1960 ± 150	– 1884	66 A.D.	114 B.C.-235 A.D.
Tchiré Ouma 147	Pa 320	Vegetable temper	3300 ± 120	– 3476	1527 B.C.	1734-1429 B.C.
Gara Tchia Bo 48 W M	Pa 811	Vegetable temper	3265 ± 100	– 3468	1519 B.C.	1673-1421 B.C.
Gara Tchia Bo 48 E M	Pa 810	Vegetable temper	3260 ± 100	– 3467	1518 B.C.	1671-1419 B.C.
Tchir Ouma 146 M	Pa 510	Vegetable temper	3230 ± 170	– 3460	1511 B.C.	1683-1312 B.C.
Termit west 96 b M	Pa 481	Vegetable temper	3100 ± 100	– 3281	1332 B.C.	1443-1219 B.C.
Tchi Guiribé 127 b M	Pa 669	Vegetable temper	2950 ± 100	– 3098	1149 B.C.	1307-999 B.C.
Termit W 8 a M	IFAN	Charcoal	2924 ± 120	– 3067	1118 B.C.	1300-924 B.C.
Termit W 8 b M	Pa 688	Vegetable temper	2880 ± 120	– 2971	1022 B.C.	1257-901 B.C.
Do Dimmi 15 a F	IFAN	Charcoal	2630 ± 120	– 2752	803 B.C.	898-601 B.C.
Do Dimmi 16 a M	UPS	Charcoal	2590 ± 120	– 2744	795 B.C.	832-533 B.C.
Do Dimmi 16 b M	Pa 296	Charcoal	2580 ± 80	– 2742	793 B.C.	810-559 B.C.
Do Dimmi 15 b F	Pa 288	Charcoal	2500 ± 70	– 2581	632 B.C.	791-420 B.C.
Gara Tchia Bo 48 B1 M	Pa 519	Vegetable temper	2430 ± 110	– 2399	450 B.C.	772-391 B.C.
Do Dimmi 16 c M	Pa 504	Vegetable temper	2270 ± 90	– 2321	372 B.C.	399-195 B.C.
Gara Tchia Bo 181 F	Pa 351	Charcoal	2120 ± 60	– 2086	137 B.C.	196-45 B.C.
Cheguelenga 123 M	Pa 662	Vegetable temper	2095 ± 200	– 2045	96 B.C.	383 B.C.-122 A.D.
Do Dimmi 15 c F	UPS	Charcoal	2065 ± 60	– 1996	47 B.C.	162 B.C.-9 A.D.
Do Dimmi 16 d M	IFAN	Charcoal	1745 ± 110	– 1665	285 A.D.	143-422 A.D.

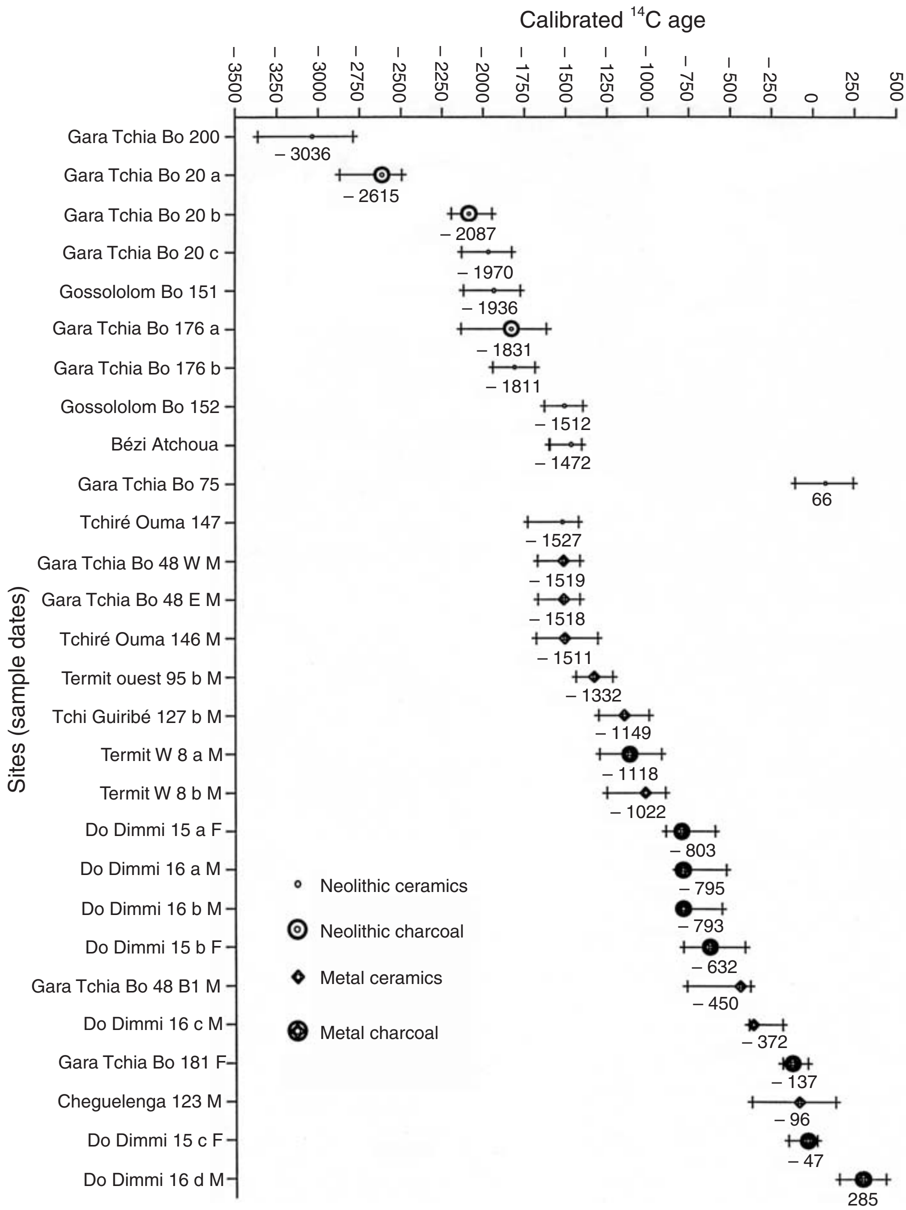


Figure 5. Chronology of the end of the Neolithic era and the early stages of metallurgy at Termit.

from archaeological sites (cross-checked against the results of pottery datings) and the bases of reduction structures (Photo 73).

- *The reliability of the measurements that, for example, depended on the amount of usable charcoal.* The reliability can be determined here in two ways: by data provided by the dating laboratories – the narrowness of the confidence interval furnished by the laboratories provides the basis for assigning weights to the time intervals used in the graphs; and by the consistency of the dating with a group of datings obtained from the same archaeological context.

It was considered helpful to express in graphic form (Gasco, 1985; Voruz, 1995) all of the twenty-eight measurements made by the laboratories throughout the programme (Table 3) in order to obtain a preliminary picture of the beginnings of iron metallurgy in the Termit massif (Figure 3).[2] The result is a weighted cumulative histogram in which each datum is assigned the same surface area so that the most precise data, those with a narrow confidence interval, would not have a less important share than the others in the frequency bars but would, on the contrary, figure prominently in them. To make it more readable the histogram is 'pear-shaped' (Evin and Oberlin, 1998; Gasco, 1985) whereby the abscissa representing the chronological axis is drawn vertically and the histogram and its mirror image are presented on either side of the axis.

The homogeneity of the graph comes out clearly. There is continuity in the dating, which already provides support for the existence of ancient metallurgy between 3300 B.P. and 1400 B.P. The period between 3300 B.P. and 2000 B.P., for which there are twenty-six datings, covers the greater part of the metallurgic activity at the archaeological sites. To reflect all the C-14 datings obtained in the region, we have also included the two dates obtained at the Egaro sites: 4000 B.P. ± 110 for Pa 629 and 3645 B.P. ± 150 for Pa 661 (Paris et al., 1992). These dates were obtained under good field and laboratory conditions. However, since only one mission was carried out, caution is advisable especially with regard to surface sites. It is easy to read graphically the impact of these two dates between 4100 and 3300 B.P. (Figure 3). To make a visual comparison of these data with the available bibliographic data on iron metallurgy in Africa, we established, in the same way, cumulative histograms of datings for each major region where there exists a series of datings for the period before 1000 B.P. (Clist, 1995; de Maret and Thiry, 1996; MacEachern, 1996; Okafor, 1993; Woodhouse, 1998). We have also included the small amount of existing chronological data on Meroe (Shinnie, 1985) because of the 'mythical' reference role played by that site in the literature (Figure 4). Needless to say, with regard to the data published by

2. Laboratory of Dating of the Institut Fondamental d'Afrique Noire (Dakar), Laboratory of Isotopic Geochemistry of Paris Sud University (Orsay), and Laboratory of Dynamic Oceanography and Climatology of Pierre et Marie Curie University (Paris).

various authors at different periods of time, it was not possible to develop a critical mechanism comparable to the one established for the Termit sites, because not all the scientific information needed was available. What we have then is simply a compilation of the results, expressed in C-14 dates B.P., designed to give a succinct overview – albeit as comprehensive as possible – of the published data.

Such a graph nevertheless confirms, in an initial analysis, the antiquity of iron metallurgy in Africa. All the histograms, including those from the most distant regions, clearly demonstrate a good chronological consistency. Once again, the hypothesis of a diffusion from Meroe is visually invalidated. On the contrary, it seems that the dates proposed for Central Africa are as old as those for Niger. Finally, there exists an impressive series of concordant measurements for Gabon, Nigeria and Cameroon.

After this, albeit schematic, overview of the beginnings of iron metallurgy in sub-Saharan Africa, it is interesting – for the Termit region, where the requisite information is available – to try out a more finely tuned approach to absolute chronology by transforming all the datings from the period under study into calendar dates and then regrouping them (Figure 5). It was not possible to present the results in the same graphic form as that used for the uncorrected data: the probability that a calendar date will be located at a particular point within its confidence interval is governed by a complex formula related, among other things, to the number of interceptions between the uncorrected measurement and the calibration curve. The type of graph used thus far was therefore inapplicable.

Furthermore, even if it had been possible, it would not have been desirable to use the same kind of graph, because the aim was now to define an accurate chronology and it was preferable to make a clear distinction between the two procedures. We therefore adopted a more traditional presentation in which the results were organized in a stepwise series of cultural groups, corresponding to a temporal scale expressed in historical years. The margin of error was deliberately limited to 1s because the large number of convergent dates justified the minimization of statistical uncertainty and also because the test we made with a margin of 2s yielded a more cumbersome and complex graph without adding any new information.

The number to the right of each date represents the highest value at the top of the calendar probability curve and consequently almost never falls in the middle of the confidence interval. These numbers are for information purposes and provide a more visually effective, if not more precise, picture of the sequence of events.

The conclusions are obvious: the cultural continuity in which the first iron objects make their appearance is as clear on the graphs as it is on the ground: there is no break in the period spanning the recent Neolithic to the end of the prehistoric human occupation of the massif, but simply evolutions.

One should note in passing, but without overstating its significance, the repetition of certain values, both for the dates indicating the earliest presence of iron at the sites (1519, 1518, 1512) and for the dates of the first low forges (803, 795, 793). Even though such a degree of precision must be regarded as anecdotal, it confirms the validity of the chronological framework. This is especially true because all the datings are clustered even more closely than on first inspection, if the three most extreme datings presented – the oldest and the two most recent ones – are examined separately. The dating obtained at site 200, 3036 B.C. (3364–2789 B.C.) corresponds to a group which seemed to us to be the oldest in the Tenerean series: the full array of customary lithic objects is not yet present and there are ceramic forms which disappear later on. The fact that this dating is several centuries earlier than the others makes sense because, even if it is a forerunner, it is not properly speaking part of the cultural context in which the first metal objects made their appearance.

The two most recent dates give rise to a different problem. The first, A.D. 66 (114 B.C.–A.D. 235) for site 75, cannot be from the Tenerean period. Here it is most probably a more recent allochthonous charcoal, derived from a pedogenic carbonate deposited in the pore spaces of the pottery following a temporary period of immersion, for example; pre-treatment in the laboratory was not enough to eliminate it. The second case is more complex: it concerns the Do Dimmi site, which includes both a settlement and low forges and is known to have been an important site that continued in use for several centuries. The six dates ranging from 800 B.C. to 50 B.C. are not therefore surprising. However, the last date – A.D. 285 – seems, in the context of Termit, somewhat late. Obviously, the date cannot be rejected for that reason alone and we have therefore kept it in the display. We must, however, share our doubts especially about a site located on what is today the main camel route and thus more likely than others to contain more recent elements.

Having concluded this graphic analysis of a series of dates which are validated by the local archaeological context, by their internal consistency and by their correspondence to the available bibliographic data, it seems difficult to challenge, at least in good faith, the antiquity of the beginnings of African metallurgy.

Central Africa: Knowing Iron

Pierre de Maret

Some people no doubt wonder why UNESCO decided several years ago to launch an intercultural project on the 'Iron Roads in Africa', and above all what it has to do with UNESCO's Department of Intercultural Dialogue and Pluralism for a Culture of Peace.

This UNESCO initiative was in response to persistent demands by numerous African scholars, diplomats, government leaders and intellectuals. But, we may ask, did this not stem from a backward-looking interest in a technique symbolizing an Africa that is now a thing of the past? How could such an initiative foster intercultural dialogue, let alone promote peace?

Africa is the continent in which ironworking was the most widespread, with:

- a number of basic common characteristics that give African metalworking its specificity and originality;
- great technical, cultural and symbolic diversity, which are all variations on this common basis;
- a remarkable continuity spanning several millennia, which suggests that the origins of this fundamental technique may actually lie in the African continent.

In the intercontinental dialogue, African ironfounders and ironsmiths bear witness to African skills and knowledge of iron – a field that has also played a fundamental role in many other civilizations throughout the world. It is no accident that so many Anglo-Saxons are called Mr or Mrs Smith. In France, a book by Robert Griffon, *Le dernier forgeron* (1999), is a nostalgic evocation of the former importance of that trade. The author, who wrote his thesis at the Sorbonne on the ironsmiths of the Cher region, shows to what extent the smithy was a prime focus of village conviviality. This ties in fully with my African experience: everywhere the smithy plays a vital role in dialogue. Furthermore, it was often a place from which all violence was strictly banned. Smiths have often

played a role in peacemaking between individuals and peoples; set apart from the community, but endowed with extraordinary powers, they have often interceded between enemies and acted as emissaries in cases of conflict between families or ethnic groups.

More generally, with regard to intercultural dialogue, what has long fascinated me about ironworking are the extraordinary symbolic parallels between different civilizations, whether in Africa, Asia or Europe. This takes us back to the universal categories of the human mind as expressed by Lévi-Strauss, an ideal anchorage point for both intercultural dialogue and scientific research. From this point of view, Africa offers scholars an extraordinary setting for observation and analysis, one in which technology, archaeology and anthropology may engage in dialogue, providing examples and interpretative models whose importance goes far beyond a strictly African framework.

I should like to look chiefly at two sets of issues, taking as a basis my own experience in Central Africa, where I have been working for some thirty years. Since much has been said about the antiquity of metallurgy in Africa, not least by my colleagues Hamady Bocoum and Gérard Quéchon, I should like to begin by touching on this aspect, and then examine briefly several technological matters before going on to consider the relationship between metallurgy and systems of thought among the Bantu.

How old is metallurgy in Central Africa?

Over a century ago, a geologist and amateur archaeologist (Stainier, 1897) had an intuition, based on the extent and sophistication of metallurgy in Central Africa, that –contrary to the racist conceptions of the time – there must have been a very old tradition of metalworking there. For a long time it was assumed, somewhat mechanically, that metallurgy was linked to Bantu expansion and that they were in some way mutually explanatory.

How did the Bantu spread across Central Africa? Thanks to their agricultural superiority, their knowledge of metallurgy enabling them to clear the great forests, and their military superiority, rooted in their possession of iron weapons. Since the area in which the Bantu languages originated was close to that of the Nok culture, to which the earliest iron-smelting furnaces are dated, archaeology seemed to confirm that hypothesis, which was borne out by what the linguist Guthrie (1970) believed was evidence of the proto-Bantu's mastery of metallurgy before their migrations began.

Following on from Guthrie's work, François Nsuka (1980) and I were able to show that Guthrie's proto-Bantu reconstructions do not prove that metallurgy was born at that time. The probability is that such terms as 'axe', 'hoe' and even 'forge' and 'ore' originally had meanings that were not related to metal.

This led scholars gradually to dissociate the origin of ironworking from the Bantu in Central Africa, especially since more ample research has yielded dates in various localities that are as early as, if not earlier than, that of Taruga in the Nok area of Nigeria. The dating of the beginning of ironworking in Central Africa has been pushed progressively back from the beginning of the Common Era to the fourth, fifth and even seventh century B.C.[1]

There is a fairly general consensus that over the Nok area in Nigeria (Okafor, 1993), Cameroon, Gabon (Clist and Lanfranchi, 1989; Lanfranchi et al, 1991), the Central African Republic (Essomba, 1992b; Zangato, 1993, 1999) and Rwanda (Van Grunderbeek, 1992), ironworking was present from the end of the ninth century B.C. There is a set of dates in the same region that are even earlier, going back as far as the fifteenth century B.C., but in view of their great age, various scholars have been inclined to consider these samples to be contaminated and hence to reject them.[2]

In any case, with the rejection of very early dates, there has been a tendency, which I have denounced in a recent paper (de Maret and Thiry, 1996), to suppose that ironworking could not be older in Africa than in other continents. Any dates before 1500 B.C. were therefore rejected. However, the results found in Niger (Paris et al., 1992; Quéchon, 1995) tend to prove the contrary.

There is another indication that the use of iron goes back a very long time in Central Africa, perhaps as long as in Niger. We have a series of deep pits dating from about 3000 B.P., 3500 B.P., or even 4000 B.P. (in other words around 2100 or even 3000 B.C.), whose primary function remains a matter of controversy (tuber storage?), but which were later used as refuse dumps. Now these pits contain practically no stone chips or stone tools. While the stone industry was still very much in evidence until around 3500 B.P., it was suddenly interrupted in sites of open-air settlement. This sudden disappearance, which is attested from the Congo to Cameroon and as far away as Ghana, is difficult to explain. What could have replaced stone? It is tempting to think that it might have been iron. Unfortunately, no trace of it has yet been found from such a remote period. However, that may be explained by the fact that iron artefacts were rare and precious, and were therefore systematically salvaged and reworked, and that the rest rusted away. The absence thus far of furnaces, tuyères and slag has prompted

1. Given the fluctuations in carbon-14 content in the atmosphere in those periods, the calibration of the dates places them in a period spanning the eighth to the fifth centuries B.C. (2520–2160 B.P.). This time span is too broad for a fine-tuned chronology that might make it possible to determine the precise area in which metallurgy originated and the manner in which it was spread.
2. In a case familiar to me from Yaoundé, Cameroon, a date from this period for a pit containing slag was not confirmed by other dates for the same pit, or for that matter for a series of other pits with about forty dates in ten or so other sites in the region.

Lavachery (1997–98) to conjecture that these populations used iron but did not produce any.

Two of our scholars, de Maret and Thiry (1996) have re-examined the linguistic data and reached very interesting conclusions that may corroborate the hypothesis that iron artefacts had long been known and used, even though metallurgy was not practised. The term for 'iron' does indeed appear to be of proto-Bantu origin, whereas the term for 'iron ore' is probably of more recent origin and spread from east to west from the region of the Great Lakes towards Angola and Namibia.

All this seems increasingly to indicate a very early acquaintance with ironworking, and hence its probable discovery on the African continent, with, in some regions of the continent, a kind of mobile frontier, rather like the conquest of the American West. There would thus have been vast areas where there was no mastery of techniques for the reduction of iron ore, but where iron tools were to be found in some places long before all the stages of ironworking were mastered.

Technical aspects of iron metallurgy in Central Africa

While furnaces and reduction techniques have claimed much of the attention of anthropologists, archaeologists and technology experts, the work of ironsmiths has been neglected. Metallographic analyses carried out by my colleague Terry Childs (1991b), at the time he was at MIT in Boston, of iron axes and knives from Zimbabwe, in particular from the ruins of Great Zimbabwe, and of other archaeological artefacts – dating from the eighth to the fourteenth centuries – from the Luba homeland bear witness to the extraordinary technical mastery of Bantu ironsmiths. By soldering and welding, ironsmiths often managed to produce a steel blade with a low carbon content on to which they soldered a layer of steel that gave a sharp edge. The centre of the blade, which was softer, helped to absorb the shock of blows against hard objects.

The Luba often recycled used artefacts: hoes were re-forged into hatchets, hatchets into knives, knives into razors, and finally razors into scalpels.

My excavations in this region have helped to clarify the archaeological sequence of the Iron Age in this area from the seventh century to the modern Luba. This is the longest sequence currently known, and has made it possible to follow the development not only of ironworking, but also of copper working (de Maret, 1979 and 1980; de Maret and Thiry, 1996). The Luba ironsmiths also practised wire drawing from both of these metals for decorative purposes. In general, very little is known about their wire-drawing techniques and unfortunately they have practically disappeared.

However, the greatest surprise of Childs's metallographic analysis of Luba archaeological artefacts is the presence of cast iron (inclusion of carbide) in

bracelets in increasing proportions as time went on. Production of cast iron is confirmed by the early testimony of a missionary, who spoke of cast iron being poured into a mould to make hoes, and by surviving oral traditions (Childs, 1991b).

The presence of real cast iron is quite extraordinary because it implies a degree of technical skill and systematic achievement of very high temperatures that were said to be impossible with African techniques. This explains the insistence of Jean Devisse and other specialists in France that we should be speaking about iron ore reduction rather than smelting. But now we must recognize that the Luba knew how to cast iron, and had been able to do so for over 1,000 years.

The second major surprise is that, because cast iron is too brittle to be forged, a stage of decarbonization was required to enable its forging, and this is clearly what the Luba ironsmiths were doing, because the bracelets under study are essentially made of steel encasing cast-iron layers. As stressed by Childs (1991b), Luba techniques for working iron and copper evolved in tandem, and the techniques developed for one metal were adapted to the needs of the other. For example, the Luba also developed a technique for separating the ore contained in the sand of riverbeds by means of what in modern metallurgy is called the 'Hancock jig', in other words a process of differential sedimentation in running water.

In short, if we only take the trouble to study closely the various aspects of forging, and not just reduction and smelting/casting techniques, we can see the great sophistication of numerous aspects of the Luba's ironworking, which ought to be studied before they disappear once and for all.

Symbolic aspects of ironworking in Central Africa

After looking at historical and technological aspects, let us now examine the symbolic aspects of ironworking.

Sexual symbolism is predominant in iron ore reduction and iron smelting, and the symbolic aspect of the operation is fundamental, as has been demonstrated by Echard (1983a, 1983b). It involves establishing as close a correlation as possible between the production of metal and that of human beings. These two crucial operations are both part of a broad sphere encompassing procreation, generation, regeneration, transformation, fertility, fecundity and success – a special and subtle mixture of force, knowledge, skill and luck which, as in many other cultures, is inherent in the highly polysemic concept of power or might.

In Bantu Central Africa, iron smelting is identified clearly, and more or less simultaneously, with coitus and childbirth. The furnace is decorated with breasts and scarifications symbolizing women; it is occasionally girded with a waistband,

for example among the Shona of Zimbabwe, and the vocabulary used to designate its various parts refers to the female body. We may note in passing the parallel with pottery, which is also made of clay and whose parts are designated, as in many of the world's languages, by parts of the body: belly, lip, bottom, shoulder and so forth. Such is the power of the universal categories of human thought.

The bellows, with its two chambers, is frequently identified with the penis and testicles, and the rhythm with that of the sexual act.

Over a wide area of Central Africa, charms are placed inside the furnace, often buried in the centre, occasionally in a small pot.[3] The latter practice is ancient and widely attested from the Congo to Rwanda, as demonstrated by archaeology.

With humans too, sexual relations generate heat, as can be seen, for example, in the beliefs of the Zulus or the Thonga. According to the Manyika of Zimbabwe, the joining together of a man and a woman is particularly dangerous, being burning hot. It not only melts down the frontiers between two individuals but also between the sexes, and between top and bottom. For them, the sexual act is clearly an act, literally, of fusion.

Similarly with regard to pregnancy, there are numerous links between metallurgy, pottery and human beings.

Built away from the village, the furnace is often screened in West Africa by an awning. As with pottery, iron smelting is surrounded by taboos of an essentially sexual nature, such as abstinence and a ban on the presence of women, especially pregnant or menstruating women.

For the Thonga – who were well described by Junod (1910) – 'a child is the result of a successful firing, and is regarded as a pot which has been fired and did not crack during the firing'. In English, too, you can be a little 'cracked'. As my teacher, Luc de Heusch (1982), used to say, the Thonga believe that care must be taken to ensure that the firing of the child is controlled and to avoid any sudden overheating. Pregnant women, for example, must avoid eating food that is too hot or spicy.

As with smelting, the firing of pottery is subject to taboo. Pregnant or menstruating women are banned from participating in it. Often, only women past the menopause may be in charge of the firing: it is thought to make younger women barren.

With regard to childbirth, the cast iron is more or less explicitly the child of the woman/furnace, and the slag is the placenta. Among such peoples as the Minyanka, Lovedu or Sotho, after birth the child must be cooled down, smoked or sprinkled with water like a piece of forged metal. New life is created when

3. In December 1997, this practice was observed once again in the framework of a reenactment exercise carried out by north Cameroon ironsmiths during the international workshop on African fire skills (METAF) that I organized in Yaoundé.

water cools fire, just as an ironsmith uses water to cool a shapeless piece of metal to create a new shape.

Nobody waits for fired pottery to cool down. On the contrary, the pots are taken out of the kiln while they are still hot and are sprinkled with water, a decoction of bark, or ash. It is striking that, in the region where this is done, newly born children are treated in almost exactly the same way, so much so that we may well ask whether it is pots that are treated like children or the other way round, and whether, when a newly born child is smoked or sprinkled with water, the intention is not to treat it like a pot.

Many more examples might be cited. Clearly gestation, smelting and the firing of pottery are all parts of the firing process; birth is assimilated to the extraction of cast iron or of pots from a kiln. However, there is a paradox. Although ritual practices are much more developed for the success of the smelting/reduction operations than for forging, casting – the quintessential metallurgical operation – does not figure among the rituals. On the contrary, the act of forging is one of the key aspects of the symbolic system, whereas ritual acts do not occupy such a central place. Among the Bantu, the ironsmith frequently occupies a central position among rites and myths, often intervening metonymically, represented by his nyundo, 'hammer and anvil'. The parallel between smelting and childbirth may explain this paradox. Both women and smelters go into hiding in order to 'give birth'. On the other hand, the forge is a very public and convivial place in the centre of the village where people like to come to chat and watch the ironsmith at work. Smelting and forging both transform matter, even though they represent very different operations from both a technical and a symbolic point of view. While smelting is a kind of birth, the opposite is not true. A furnace is like a woman giving birth, but a woman giving birth is not like a furnace. The metaphor is not reversible.

Another theme found from one end of Central Africa to the other, in places where royal lineages developed, is that an ironsmith king is the source both of the dynasty and of knowledge of metallurgy. In this area, stretching from Angola to Uganda, it is not unusual to find in enthronement rituals a moment when two hammers are hit together, which refers probably as much to the king/ironsmith as to the transformation of an individual into a consecrated king by means of a process that is assimilated to ironworking and aimed at toughening the king and giving him strength.

To conclude very tentatively this brief excursion into the Bantu symbolic universe, the ironsmith's anvil, with its patently phallic shape, is often a subject of special treatment, especially since it also evokes, among the Luba for instance, another object that is also linked to fertility and is of phallic shape – the dolls handled by small girls or, occasionally, barren women.

These anvils are associated with royalty, and are often found among the most sacred regalia, for instance at the Mwami court in Rwanda and Burundi.

Interestingly, in the course of my excavations in the Upemba depression in the heart of the great Luba kingdom, one such anvil was also found in what was clearly the grave of an important figure.

To return to this vast symbolic field encompassing fertility/infertility, good luck/bad luck, hot/cold, life/death, dry/wet, hard/soft, open/closed and male/female, the study of metallurgy also provides references to the relations between the sexes, in all senses of the word.

It would be rather reductionist and ethnocentric to view the prohibitions that may be observed as a way of separating the male and female spheres. In fact, at particular moments and stages, there may even be cooperation, for instance with a view to treating sexual problems among individuals of the other sex (in Rwanda, for instance, cases of female frigidity). The male and female powers are complementary and necessary in order to balance each other, to control heat, to define limits, and to help to go beyond these limits.

Transformation processes are central to relations between the sexes and to the perpetuation of the social, natural and symbolic order. Through their technical, physiological and symbolic complementarities, they remind us, as they remind the Bantu, of the constant interdependence of men and women.

This, too, is one of the foundations of intercultural dialogue.

Conclusion

In Africa, particularly Central Africa – torn by countless atrocious conflicts, falling prey to the manipulations of history and identity which we witness – the time has come to demonstrate to its peoples, and to the individual men and women who constitute them, that many more things unite them than separate them and that their similarities are much more important than their differences.

A comparative analysis of the techniques, vocabulary, rites and myths associated with metallurgy illustrates the point clearly. When one is aware of the crucial role played by iron and iron metallurgy in African civilizations from the economic, political and symbolic points of view, one understands better the interest shown by African researchers and decision makers in this topic.

Moreover, the very ancient history of this pyrotechnology and the ingenuity, creativity and excellence that continue to be shown by many African artisans are a source of legitimate pride. If we wish to promote intercultural dialogue and pluralism in the era of globalization, a measure of cultural reciprocity among peoples is essential. Nothing is more pernicious in this connection than the absence of exchange and the unilateral imposition of a dominant model. In fact, cultural reciprocity is, in part, defending the 'cultural exception'.

Status of Iron Age Archaeology in Southern Cameroon[1]

Joseph-Marie Essomba

In March 1983, following the recommendations of the Garoua meeting, we drew up an archaeological research programme in central and southern Cameroon, focused mainly on the Iron Age. The programme was one in a series of projects carried out under the auspices of the former Ministry of Higher Education, Informatics and Scientific Research (MESIRES), the Anthropological Research and Studies Centre of the former Human Sciences Institute (ISH) and the University of Yaoundé. The programme, which began in 1989, was carried out in partnership with the French Institut de Recherche pour le Développement (IRD: overseas scientific and technical research institute, formerly ORSTOM) over a period of three years.

Subject and aims of the programme

The history of pre-colonial Cameroon, in particular the southern part of the country, remains obscure. As part of the research effort needed to reconstruct that past, the archaeology of the Iron Age should contribute to the study of the peopling of the relevant area and of the development of societies. Moreover, Iron Age archaeology is highly relevant to the early history of a large part of the Central African forest region, in particular with regard to the spread of the Bantu people, taking us back 4,000 years. It should be noted that since research on their cultural identity began, the probable cradle of the Bantu-speaking peoples

1. This text, which is reproduced with the previous publisher's permission, is a revised version of a paper that originally appeared in M. Delneuf, A. Froment and J.-M. Essomba, *Paléo-anthropologie en Afrique Central: Un bilan de l'archéologie au Cameroun*, Paris, L'Harmattan, 1999.

has been located on the border between Nigeria and Cameroon, from where they are thought to have spread out across Central Africa during the Iron Age. Archaeological work has demonstrated the significance of the migration and expansion routes taken by these peoples – the natural pathways provided by the savannas of the Atlantic coast, the watercourses of the equatorial forest, the northern forest/savanna interface and the savannas of Central Africa, as suggested by the work of Van Noten (1982).

The centre and south of Cameroon are undoubtedly one of the transit and settlement zones of the earliest Bantu speakers, whose economic, social and technological history can be recovered by archaeological research and the study of their oral traditions and material cultures. This reconstruction can only be accomplished by establishing a chronological framework and by studying the environment in which these peoples and their civilizations developed in Central Africa. The programme therefore focuses on:

- identification and cartography of Iron Age sites in southern Cameroon;
- excavation of the sites identified and scientific study of the archaeological evidence;
- establishment of a chronological framework for the early history of the region;
- study of the environment: its impact on the evolution of societies in the forest zone, and hence the importance of the future contribution of the ECOFIT (intertropical forest ecosystems) programme;
- reconstruction of the historic aspects of technological history (iron metallurgy and ceramics, with particular attention to their operational sequences) and economic history;
- the scale of Bantu migrations in southern Cameroon (through a series of studies ranging from archaeology to population biology).

Another branch of the programme focuses on culture. It involves:

- collecting material of historic and archaeological interest for the National Museum;
- training young Cameroonian researchers in archaeology;
- organizing scientific and cultural events in the form of seminars, lectures, symposia, publications and exhibitions.

Methodology

With regard to methodology, we apply to the study of iron the pattern of existing scholarly approaches to the past of southern Cameroon societies. We view ironworking as a technological process, as an economic factor and as a societal phenomenon. The study of iron and the Iron Age therefore requires an inter-

disciplinary approach involving the earth sciences, the natural sciences, and laboratory analyses (using archaeological and chronological data as the source material).

Oral sources are a particularly effective means of gaining greater understanding of many questions in this field. Surveys have opened up new horizons for the study of technological processes, and of the economic and social role of iron. This choice of methodology is developed at length in *Civilisation du fer et sociétés en Afrique centrale* ('Iron civilization and societies in Central Africa', Essomba, 1992b).

Review and results of research work

REVIEW OF WORK CARRIED OUT (1983–8)

Since 1983 we have conducted research in the departments of Lékié, Nyong and Kellé, Sanaga Maritime and Mfoundi; this led to the identification and excavation of the sites of Nkometou and Pan-Pan. A preliminary survey of this work in 1988 (Essomba, 1988) highlighted the importance of Iron Age archaeology for the early history of the region (Figure 6).

Three of the site areas studied – Nkometou and Pongsolo (Lékié) and Pan-Pan (Nyong and Kellé) – yielded valuable and previously unknown data. Mention should also be made of the Obobogo site studied by de Maret (1992), the Okolo site studied by Atangana (1988) and the Ndindan site studied by Mbida (1992). From these sites it was estimated that the Iron Age in the region began somewhere in the fourth century B.C.

The Nkometou site

Nkometou, about 20 km north of Yaoundé, where excavations began in 1983, is an important site because of the number of pit structures identified and the evidence found in some of them. Generally speaking, the data from the Nkometou excavations reveal two stages of civilization: a Neolithic stage with a food economy based on palm nuts and the use of millstones, grinders and pottery utensils; and a second stage – the Iron Age – with metallurgical remains (slag) dating from the fifth century B.C. (Essomba, 1992a).

The Pongsolo sites

Situated in Lékié, these deposits have yielded useful evidence concerning the question of iron production in the region. In addition to the oral information gathered on iron production and the traditional technique of reduction, radiocarbon dating was carried out on the Pongsolo I and Pongsolo II sites, placing

them between the fifteenth and sixteenth centuries A.D. (Essomba, 1998,1992a, 1992b). This chronology is corroborated by certain oral traditions relating to the occupation of the region by the ancient Beti, who may therefore be regarded as the occupants of these sites.

The Pan-Pan sites

These sites have produced valuable data on recent populating of the region and the study of iron reduction techniques. They have been dated to the fourteenth

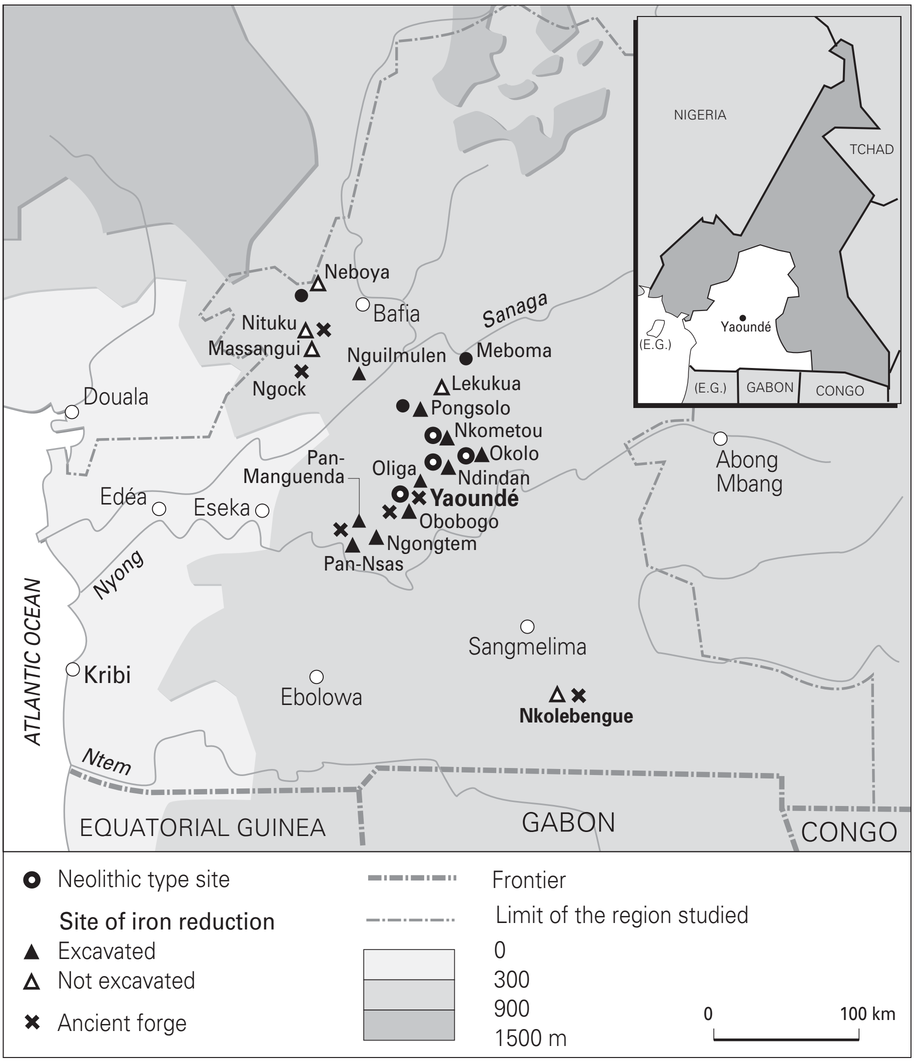


Figure 6. Principal sites studied by the author in the region

and fifteenth centuries A.D. The Pan-Pan reduction furnaces are impressive, being built in a distinctive architectural style featuring small terracotta bricks. They are exceptional in the Central African forest zone and are dated to the period when the ancient Bassa occupied the region (Essomba, 1985, 1988, 1989, 1992b).

This research necessitated exploring new directions, in particular looking into new areas with intensified use of archaeometry.

NEW DATA (1989–91)

From 1989 to 1991, we pursued our research on Iron Age archaeology in partnership with ORSTOM, in the context of the problem area and objectives defined above. During this period, work was carried out at the Oliga site in Yaoundé and at the Saka site in Awae and in the Zoétélé district.

The Oliga site

Situated in the northern sector of Yaoundé, Oliga was excavated between 1989 and 1990. It contains the first buried reduction furnace to be excavated in southern Cameroon. This site, which dates from the first millennium B.C., yielded unexpected data on the Iron Age in southern Cameroon and in the Central African forest zone (Essomba, 1989, 1992b).

Several samples of charcoal were taken from different stratigraphic levels of the structure. Twelve of them were dated by the radiocarbon method: four were analysed by Evin at the Radiocarbon Laboratory of Claude Bernard University (Lyon I), and eight by the Beta Analytic Laboratory, Miami, Florida (United States). The results of these chronological analyses are presented in Tables 4 and 5.

What conclusions can be drawn from this range of dates? A critical analysis of the data must be based on the stratigraphic position of the samples within the archaeological layers and how far back in time they go, in relation to what is already known about the region.

Generally speaking, according to the dates obtained by the two laboratories, the structure dates from between the end of the second and the beginning of the first millennium B.C. Moreover, from a stratigraphic standpoint, the dates are fairly consistent with the layers from which the samples were taken.

Thus, the furnace is dated to the first millennium according to three of the dates obtained by the Lyon laboratory: Ly-4976; Ly-4977; and Ly-4978 (Table 5). These dates may be regarded as concordant with the dates obtained by the Beta Analytic Laboratory: Beta 32 264, Beta 31 410, Beta 32 228, Beta 31 411 and Beta 31 534 (Table 4). The date Ly-4979, 1945 B.P. ± 250, or 831 B.C. to A.D. 567, at archaeological level 4, seems to be flawed by a significant margin of error and should be viewed with great caution, without however being totally rejected. In that connection, it should be noted that at level 6, which is not very

far from level 4, we obtained the date Beta 31 411: 2710 ± B.P. 130, or 1256 to 500 B.C., which is close to the date at layer 7 (Beta 31 410: 2820 B.P. ± 100).

An examination of these results shows that, of the twelve dates obtained, three place the furnace at the end of the second millennium and the beginning of the first millennium B.C. For the time being they may seem excessive and should be viewed with caution. Seven dates place the furnace within the first millennium B.C. and only one date puts it at the beginning of the first millennium A.D.

Nevertheless, and as we have already pointed out, while dates falling within the fourteenth, thirteenth and twelfth centuries B.C. may today appear to be too early for the beginnings of iron metallurgy in the Central African forest zone,

Table 4. Radiocarbon dating of the Oliga site (Beta Analytic Laboratory, Miami, Florida)

Sample number	Laboratory number	B.P. dates	Calibrated dates	Square and archaeological level (in cm)
1	Beta 31 411	2710 ± 130 B.P.	1256–500 B.C.	A2 (–90) NA7
2	Beta 31 412	1860 ± 70 B.P.	0–334 B.C.	A1–B1 (–50) NA1–2
3	Beta 31 413	1960 ± 80 B.P.	± 70 B.C. 70 A.D.	B2 (–60) NA3
4	Beta 31 414	2820 ± 70 B.P.	1300–800 B.C.	A2 (–50) NA2
5	Beta 31 410	2810 ± 100 B.P.	1300–800 B.C.	A2 (–90) NA7 (–100)
6	Beta 31 534	2110 ± 60 B.P.	367 B.C. 10 A.D.	A2 (–90) NA7
7	Beta 32 228	2150 ± 80 B.P.	400 B.C. 22 A.D.	A2 (–100) NA7
8	Beta 32 264	2200 ± 60 B.P.	400 B.C. 90 A.D.	A2 (–110) NA10 (–120)

Table 5. Radiocarbon dating of the Oliga site (Laboratoire de Radiocarbone, Claude Bernard University, Lyon I)

Sample number	Laboratory number	B.P. dates	Calibrated dates	Square and archaeological level (in cm)
9	Ly-4976	2150 ± 60 B.P.	365–68 B.C.	A2 NA11 (–130)
10	Ly-4977	2185 ± 110 B.P.	539 B.C. 26 A.D.	B2 NA10 (–120)
11	Ly-4978	2380 ± 110 B.P.	± 773–212 B.C.	B2 NA11 (–130)
12	Ly-4979	1945 ± 250 B.P.	831 B.C. 567 A.D.	B2 NA4 (–70)

this is not the case for dates between the ninth and eighth centuries B.C., which are fully consistent with current thinking about the chronology of the Iron Age in East, West and Central Africa (Essomba, 1992b).

These dates, ranging from the end of the second millennium B.C. to the beginning of the first millennium A.D., pose a problem, that is, of knowing how long the furnace was in use. Unfortunately, there is no concrete evidence that might provide an answer. All that can be said is that the dates push back the beginning of the Iron Age in the region during this period. This is especially significant because the dates were obtained in two different laboratories from samples taken from a genuine reduction structure.

Even more important, with regard both to these dates and the site in general, is that the above dates make the Oliga furnace the oldest iron reduction structure known today in the Central African forest zone. It is interesting to note that known dates in Gabon now place the early iron reduction sites between 450 and 600 B.C. (Clist, 1989). Recent archaeological research carried out in Gabon has brought to light many samples of iron palaeometallurgy with dates comparable to those recorded for southern Cameroon at Obobogo, Ndindan, Nkometou and Oliga (Clist et al., 1986).

New research is planned at the Oliga site to add to our knowledge of the successive occupations of the site and possible environmental changes. The Oliga site is therefore of vital interest to present-day investigation of the Iron Age in Central Africa.

The Saaka site

In March 1990, exploration in the Awae district of the department of Mefou enabled researchers to identify the site of Saaka located among the Mvele people. A trial excavation turned up characteristic evidence of an iron reduction workshop: slag, blast pipe fragments and pottery shards. Initial radiocarbon datings for the workshop place it between the sixteenth and seventeenth centuries A.D., which corresponds to the period when the Beti peoples settled in the region. Study of this site is to be continued.

ARCHAEOLOGICAL RECONNAISSANCE IN THE ZOÉTÉLÉ DISTRICT

From July to August 1990 we carried out an archaeological reconnaissance mission in the Zoétélé district, in the department of Dja and Lobo, in the forest zone of southern Cameroon, about 100 km south-east of Yaoundé. Members of the mission included R. Asombang, archaeologist (Institute of Human Sciences) and J. P. Ossah Mvondo (École Normale Supérieure, Yaoundé). The purpose of the mission was to identify and locate potential archaeological deposits in the Zoétélé district, particularly from the Iron Age.

Despite the efforts made to carry out archaeological research in southern Cameroon, the southern province, and in particular the department of Dja and Lobo, remain practically unexplored. The archaeological information at present available is inadequate. These circumstances justify the exploration carried out at Zoétélé, the first stage in a long process of research that needs to be conducted in the department as a whole, as well as in the southern province. The reconnaissance mission brought us to villages such as Nkooveng, Nkolmebong, Fibot, Nkoumadzap, Otetek Etoto, Zoétélé Brousse and Zoétélé Village (Figure 7).

Our research method was based on a study of the 1:200,000 map of the region, on which we identified certain villages by toponymic means. Elderly individuals and traditional authorities were then interviewed and asked to fill out a questionnaire on ancient villages and old iron production workshops. We also systematically explored the fields and existing dwellings in an attempt to identify and locate the remains of former activities. Two types of deposit were identified, relating to prehistoric and Iron Age sites.

PREHISTORIC SITES

Rock shelters of Akok-Oveng (NK1)

This site is in fact located at the edge of the Zoétélé district and the department of Nyong and Mfoumou, but remains of importance to our work because it borders on our area of study. It is 1 km from the Edjom road and 12 km from the village of Fibot, at 3°28’02" N. and 11°57’06" E. The façade of the shelter is 140 m long and its depth at the centre is approximately 21 m. The height, measured from the central axis, is nearly 50 m and the floor slopes from left to right, producing a difference in level of nearly 4 m. The site has been adapted for worship: it contains a statue of the Virgin Mary, an altar and benches. According to our sources, the Catholic mission often holds masses there.

No remains were found on the surface, owing perhaps to the development of the site, which may have resulted in their disappearance. Because of the shelter’s religious functions, we thought it unseemly to do any digging. Other rock shelters have been reported in the region and will be explored and studied during future missions.

Nkolmebong (NKM1)

This site is situated at 3°26’03" N. and 11°05’ NW. of Fibot. It is 3.4 km from the centre of Fibot, on the Eboman road, and is located in Yemfok, in the village of Nkolmebong at an altitude of 690 m. Our interest had been sparked by a legend that talks of knee-prints in the rock. We found fourteen circular and six oval hollows. In general, these hollows are between 10 and 15 cm in diameter and between 3 and 12 cm deep. The length of the oval hollows varies from 32 to

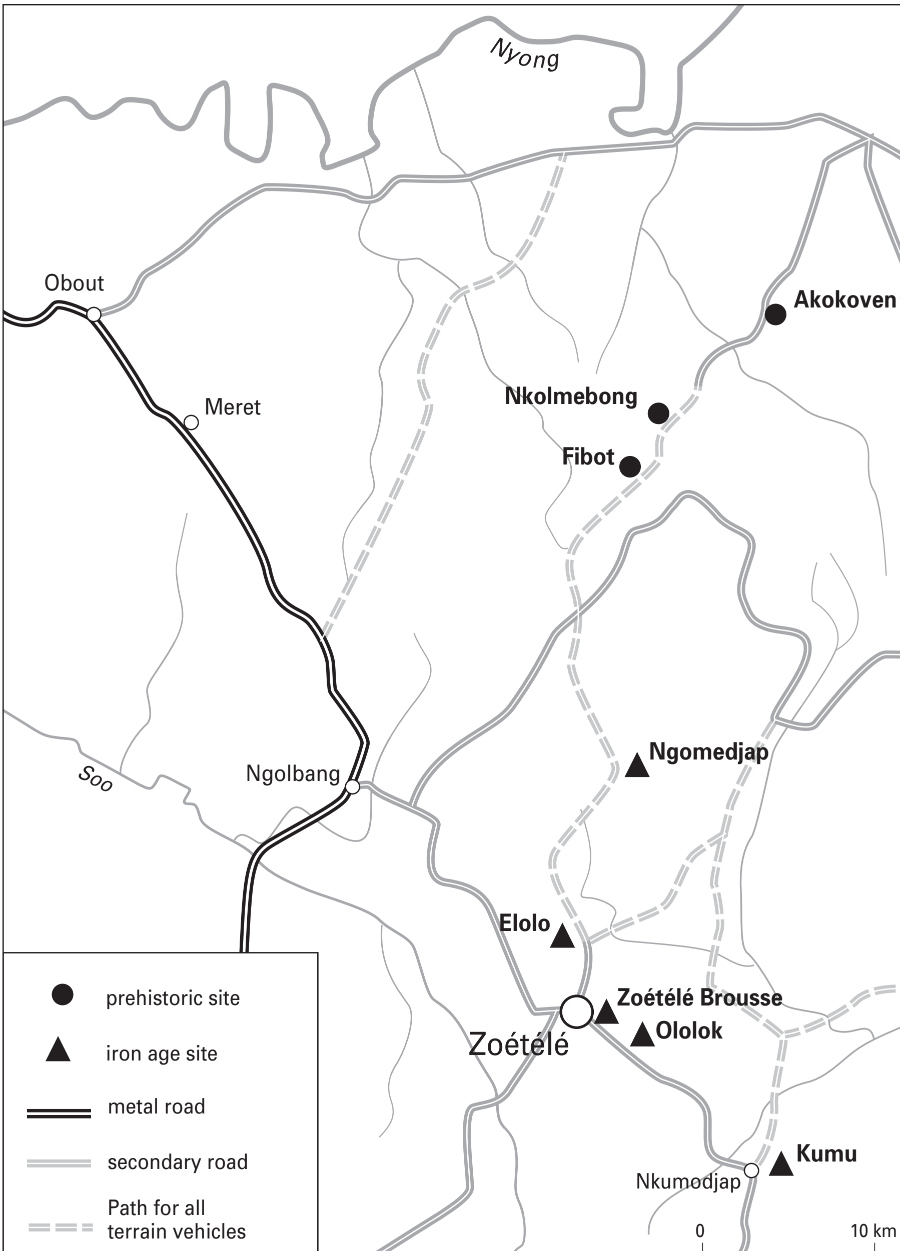


Figure 7. Archaeological prospection in Zoétélé district: principal sites identified by the author (July–August 1990).

90 cm and the width from 12 to 25 cm. Broadly speaking, the elements are arranged in a circle. While the grouping clearly indicates human activity, at the present stage in our research we cannot provide a valid explanation of these features. Their interpretation remains an open question (Figure 7, Nkolmebong site).

The three rock shelters of Akok-Oveng

Separate from the rock shelters of Akok-Oveng (NK1), this site lies to the northeast of Nkolmebong. We are unable to give the coordinates because of the special difficulties we encountered in finding our way through the bush while prospecting. It took us fifty minutes to walk from the main road to the shelter. This rock shelter takes its name from the Oveng tree growing in front of the opening. The site consists of three cavities forming a semi-polygon (Figure 7, Akok-Oveng site). The first cavity, on the left, is the shallowest, measuring no more than 2.62 m at its deepest point, and 9.5 m in length. The floor is flat and covered with vegetation. The second cavity, in the middle, seems likely to contain artefacts. The occupation zone is also the area into which the upper cave has eroded, leaving deposits 15 cm thick. An undecorated shard, found on the surface beside a gully, shows signs of wear and has a quartz temper. Two other shards, also undecorated, were found at a depth of approximately 10 cm. At its deepest point, the second cavity measures 6.20 m. The slope rises uniformly from front to back, the height is 8 m and the opening is 19.70 m wide.

The third cavity, on the right, has an opening 13.40 m long and measures 7.45 m at its deepest point. The floor slopes from right to left and is covered with rocks, making excavation impossible. The rocks appear to have fallen from the roof of the cave. It should be noted that this rock shelter is in constant use by the present population.

All of these sites call for further research. Because none of them has been dated, it is still difficult to determine whether they were occupied during the Iron Age.

IRON AGE SITES

The Zoétélé sites

Zoétélé Village and Zoétélé Brousse are two distinct sites. In an attempt to determine their origin, interviews were held with Thomas Ngane Oyono (born around 1916) and Célestin Oyono (born around 1933). From what they said, it appears that the name Zoétélé was given to Lucien Oyono Eyamo (*c.* 1888–1933), a member of the Fang group, by his parents because of his great wealth, skills and prowess in battle, and his many other accomplishments. All these exploits caused him to be compared to an elephant. In him his parents had

found their elephant. The site of Zoétélé or 'standing elephant' was named after him.

Before the arrival of the Germans in Cameroon, the parents of Oyono Eyamo, known as Zoétélé, first lived in the place now called Zoétélé Brousse. This site is located 10° NE. of Zoétélé town and 1,500 m from the village of Eteto, which is 11.8 km from Zoétélé town. Oyono Eyamo left Zoétélé Brousse to found Zoétélé Village. According to our informants, iron was produced here in ancient times. As a result of our explorations we identified and located archaeological sites in both places.

Zoétélé Brousse (ZB1)

The site was identified from slag found on the surface 500 m from the spot indicated by our informant. This discovery led us to explore the surrounding area, resulting in the discovery of site ZB1-Locus A (excavation point A) or ZB1-LA.

Zoétélé Brousse (Locus A) or ZB1-L.A.

The site, to the west of ZB1, consists of a circular mound, 52 cm high and 4.3 m in diameter, lying 12° NW. of Zoétélé town on the cocoa-tree plantation of Ebene Mengue. The entrance to the site is at Otetek on the Meba road, in the village of Chief Jacques Oyono. It is 1 km from the road.

A trial trench of 1 m^2 was dug on the site, using surface traces of burnt clay and charcoal to choose the spot. The burnt clay looked like fragments of brick. We had to go down to a depth of 90 cm before we could determine the nature of the structure, which turned out to be an iron-production workshop. In the course of the excavation, we observed minor damage to the structure caused by palm-rat holes in its upper and lower parts and by ants' nests. We regularly turned up large pieces of charcoal during the digging, concentrated mainly on the western side. Tests made on four samples yielded dates between the sixteenth and seventeenth centuries A.D. A blast pipe fragment 5 cm long was recovered, confirming the hypothesis of an iron-reduction workshop, despite the fact that no slag deposits have as yet been found. Further research is needed.

Zoétélé Village

This site is 1 km from the sub-prefecture of Zoétélé town, on the right-hand side of the road leading to Meba, in the courtyard of Joseph Aba Bilunga, who died in 1958, and who was the brother of Oyono Eyamo of Zoétélé town. We observed, on the surface only, small pieces of slag spread over a 6 m^2 area. The proximity of the road and various houses may indicate that the site has been disturbed and could once have been a forge. No trial trench was dug.

The Otetek site (OT1)

This site, at 3°14'06" N. and 11°54'05" E., is 3 km south-east of Zoétélé town on the Nkoumadzap road. The metallurgical site is located exactly 52° SE. of Zoétélé town, about 100 m from the Minkoumou-Nkoumadzap intersection, in the courtyard of the Christian Evangelical Mission.

A toponymic study brought us to the Otetek site. During our surveys, an informant, the Reverend Josué Mezang Mezang (aged 68), reported that this locality had originally been called Velemekon and its first inhabitants had been the 'Yetchang', who settled there before the Fong. They had named the locality Auxerre, which means 'softly' in the Beti language.

Our informants reported that their grandparents had produced iron. However, they were unable to tell us where the old workings were situated. Explorations in the village enabled us to identify an iron-production site in the courtyard of the Christian Mission. Slag was found over a 100 m^2 area, together with charcoal. Scattered pottery fragments and small pieces of slag appear to indicate that that site was used as a forge. Excavation was postponed to another mission.

Koumou (KM1)

The site of Koumou is in the village of Nkoumadzap, 10 km from the sub-prefecture of Zoétélé. It is near the Lobo River, 475 m from the Koumou Falls, on a plantation that is today run by Thomas Akoa Jean, a 27-year-old peasant, who served as our guide. According to our informants, the ancestors of the Nkoumadzap peoples inhabited the site in ancient times. The site was bulldozed during the construction of the road. A 1 m^2 trial trench was dug to a depth of 1 m, yielding fragments of bricks, slag and pieces of blast pipe and charcoal. We await radiocarbon dates for this site.

All in all, the archaeological reconnaissance mission to the Zoétélé district produced valuable results. Eight sites were identified, three of them prehistoric and five from the Iron Age. The mission focused on the north and south-east areas of the district. This choice was based on the practice of ethnoarchaeology, which led to the identification of ancient sites in these areas. The remains are remote from present-day settlements, which explains the difficulties of wide-ranging exploration in a forest zone and the reason for resorting to the ethnoarchaeological approach.

The mission highlighted once again the rich archaeological heritage of southern Cameroon in both prehistoric and Iron Age sites. Investigation of the inventoried sites is becoming a matter of urgency. A study of them will undoubtedly yield data casting greater light on the ancient history of Cameroon. There is also an urgent need to intensify oral surveys, which are of the greatest assistance for the cartography of these sites, while informants are still living.

Conclusions and prospects

The research carried out over the last ten years under the programme on the Iron Age and iron metallurgy in central and southern Cameroon has produced important historical results from both the chronological and the technological points of view. Our findings were of special interest to the 1986 symposium and were the subject of public lectures at the University of Yaoundé in March 1990, the University of Bangui in April 1990, the French Cultural Centre in Yaoundé and Akwa Palace in Douala in April 1991 (Essomba, 1992b).

Today it can be said that in central and southern Cameroon the beginnings of the Iron Age go back to the first millennium B.C. That period was marked by sedentarization, food production, the clustering of populations in villages and the peopling of the region by Bantu speakers. The latest research shows that the dates obtained for the iron-production workshops are consistent with the oral traditions concerning the occupation of the region by the ancient Beti peoples between the sixteenth and seventeenth centuries (Nkometou, Saaka and Zoétélé Brousse sites). This research also enables us to establish beyond doubt that from the first millennium B.C. southern Cameroon was at the crossroads of the migration routes of the ancient Bantu-speaking peoples. A very important fact in the history of the early peopling of Central Africa has thus been brought to light.

While the results of the research programme seem positive on the whole, much remains to be done. The work needs to be extended to all the departments of southern Cameroon. In addition, we have yet to address environmental questions, relating to the early economy, the occupation of space, plant cover and its evolution. These questions need to be studied with the help of palynology, anthropology and palaeoclimatology. Such research should enable us to establish a reliable chronological framework for the Iron Age in southern Cameroon, linked to research work carried out in Woleu-Ntem in Gabon and to planned research in Adamaoua and on the Atlantic Coast. The basic findings should be analysed as part of the wide-ranging project for the study of human and environmental evolution in the Bantu-speaking area of Central Africa. Once again, palynology, anthropology and palaeoclimatology should be involved in the work. The result will be a better understanding of the early history of Central Africa during the period of the Iron Age.

Iron Roads in Africa: A Contribution from Nigeria

David A. Aremu

Early evidence of ironworking in Nigeria

HISTORICAL EVIDENCE

One of the earliest indications of ironworking in West Africa, dated to around 2500 B.P., comes from Taruga. The dates in question concern actual iron-smelting furnaces that have been excavated. There are earlier dates, but the association of dated charcoal with archaeological artefacts is not certain, since the findings come from alluvial deposits (that is, they were washed into a river, and since they stayed in the old river bed, one cannot be sure that they belong to the same era).

If, however, the dates associated with this figurine complex (Nok culture) are used as a marker, then ironworking in Nigeria could date as far back as 3000 B.P., even 3500 B.P. Even if consideration is restricted to the most recent date (500 B.C.), such dating is still too close to dates concerning iron at Meroe and Carthage for the idea of propagation from either of these areas to be plausible.

If the development of iron in the Plateau state or the Nok area received any outside stimulus, this stimulus, probably partial, may have just as well come from the Mauritanian region in the west, and only indirectly, if at all, from the north-west. Such stimulus may have had some relation to the earlier development of copper mining in Mauritania. In this regard, it is significant that:

- mines and implements in the Akjoujt region of Mauritania date back to 3500 B.P.;
- the tradition of metalworking in this region was more or less a continuous one, expanding when circumstances were propitious, and going back to dates as early as 400 or 500 B.C., or 2400 or 2500 B.P. (Andah, personal information).

In the Kastina Ala area, Andah has investigated a number of rock shelters along a rocky escarpment, and an open living area on an adjacent slope. One rock shelter, Tse Dura, has been researched and evidence so far suggests two main occupation phases. The earlier one was by people using ground and polished stone tools and pottery but no iron, while the later phase was by people who used, and perhaps worked, iron. Eight radiocarbon dates for this phase suggest that iron metallurgy had reached this region by the fourth century B.C. (Calvocoressi and David, 1979).

Iron may have appeared at Daima (Figure 8) in the fifth or sixth century A.D. (one thousand years later than at Nok). More recently, dates from ironworking sites have been reported from Dalla Hill, Kano (A.D. 635 ± 95) and Samaru West site 1, Zaria (A.D. 685 ± 80), (Calvocoressi and David, 1979; Posnansky and McIntosh, 1979; Sutton 1976). There are other similar sites for a distance of 1 km along the Kubanni River, dating to the same period, namely fourth to eleventh centuries A.D. These dates show clearly that there was intensive ironworking in the area during the second half of the first millennium A.D.

Shaw (1976) investigated a number of mounds between Bida and Zungeru. Funeral jars, surfacing by erosion of these mounds, have been known for many years. Test excavations conducted in various parts of the Rafiu Ndoko mound produced a series of Iron Age occupation levels. Composite charcoal samples from three areas at the centre of the mound indicate an occupation spanning the third to seventh centuries A.D. Samples from a trial trench near the edge of the site produced rather late dates (eighth to tenth centuries). At Uffe Ijumu – where Ade Obayemi excavated the Ado furnace site – iron smelting is dated to the period between the ninth and fourteenth centuries A.D. (Aremu, 1990).

Anozie (1979) excavated sites at Umundu near Nsukka and at Umukete Aguleri in the Anambra Valley. Three dates from Umundu relate to a much later period in the eighteenth and nineteenth centuries. In the Afikpo locality, Chikwendu excavated an abandoned dwelling site at Ugwuagu (site 2). The finds, including a good deal of pottery, as well as iron, animal bones and human sepulchres, are of an age and character quite different from those of Ugwuagu site 1. Three dates (from trench A) fall in the fifteenth and sixteenth centuries A.D., and two (from trench B) in the thirteenth and ninth centuries (Calvocoressi and David, 1979).

There are other iron-smelting sites with abundant smelting evidence, but without any relevant excavations or dates. Such is the case with the Yankari National Park smelting sites at Ampara, Delimiri and Shaushau, with over sixty iron-smelting furnaces, furnace bases and heaps of iron slags (Photos 74 to 83). The Igede iron industrial complex (Figure 8), located at Ibila-Alukpo, Oju L.G.A., Benue state, covers a wide area of about 2 km^2 to the east of the local government headquarters on the Ibila-Ilache road. It numbered over thirty ovens, including thirteen shaft furnaces that were in good condition, the others having collapsed to the base level.

There are five iron-smelting furnaces and heaps of slags at Ijaye, near Moniya, Oyo state, where the Archaeology and Anthropology Department of Ibadan University is carrying out field research. These and other sites have to be studied before any meaningful conclusion is reached about the beginning of ironworking in Nigeria, in relation to the rest of Africa.

IRON-SMELTING SITES IN NIGERIA

The report that follows is based on the author's fieldwork and on written accounts of iron-smelting sites in Nigeria (Figure 8 and Table 6). Evidence of iron smelting occurs in most states of Nigeria, but is more concentrated in

Figure 8. Localities of the principal iron-smelting sites in the states of Nigeria

Table 6. Iron-smelting sites in Nigeria

States (Fig. 8)	Sites	Remarks
Abia		
Adamawa	Sukur	Great slag heaps and debris of tuyères and furnace walls
Anambra	Akwa	
	Igbo Ukwu	10th century A.D.
	Umukete Aguleri	
Akwa Ibom		
Bauchi	Yankari National Park	More than 60 furnace walls and
	Ampara	slag heaps not yet excavated
	Delimiri, Shaushau, Panguru	
	Others	
	Schiri, Fagam, Fele, Fali, Baura, Muta, Kagalam, Mia Bin, Kirifi, Kantara, Kariya Wuro	
Bayelsa		
Benue	Tse Dura	Dated to the 4th century B.C.
	Ibila Alukpo, Otukpo	17 bases and 13 furnaces
	Utonkon	5 shaft furnaces
	Edumoga	
Borno	Daima	5th century A.D.
Cross River	Mbak Itam	Furnace walls, tuyère and slags
	Ikom	Slag heaps about 3 m high
	Eyanga	
Delta		
Ebonyi	Amagu Ugwu	150–50 B.C.
	Afikpo	Discovery of a small quantity of iron at Ukpa rockshelter
Edo	Benin	1180 A.D. ± 105
	Aladja	Iron and steel complex
Ekiti	Okemesi	Iron slags
Enugu	Lejja	Tuyères, pit furnaces and slags
	Aku (near Lejja)	2nd century A.D.
	Umundu	1625-1775 A.D.
	Opi	5th century B.C.
F.C.T.	Abuja	
	Taruga	440 B.C. ± 140
Gombe	Panguru	
Imo	Abiriba	
Jigawa		
Kaduna	Samaru West	*C.* 685 A.D. ± 8th century A.D.
	Madakiya	
	Kagarko	Slag heaps
Kano	Dalla hill	635 ± 95 A.D.
Katsina		
Kogi	Odo Ere-Akata	A furnace and iron slags
	Ijomu	Iron slags and tuyères
	Uffe Ijumu	9th–14th centuries A.D. with a furnace and slag heap
	Ajaokuta	Slags and furnace remains; iron and steel industry

States (Fig. 8)	Sites	Remarks
	Itakpe	Iron slags
		Iron and steel industry
Kebbi		
Kwara	Ilorin	Meaning: 'Where we sharpen iron'
	Iponrin	Meaning: 'Sharpening iron'
	Idofin-Ojokolo Mt.	Iron slags, tuyères and furnace bases
	Idofin-Igbo Aawo	Heap of slags
	Olla	Destroyed iron-smelting site opposite the police station of the town
	Obo Ayegunle	Iron slags
	Owa Kajola	Heaps of slags and tuyère
	Owa Onire	Iron slags, tuyère and furnaces
	Oba	1310 A.D. ± 140 and 1585 A.D. ± 80
Lagos	Agege	
Nassarawa	Yelwa	100 A.D.–700 A.D.
Niger	Bida	
	Makera Takunpata	
	Kongo Makeri	Makera in Hausa means 'iron'
	Zungeru	
	Rafiu Ndoko	
Ogun	Otta, Ilaro, Ilobi; Oke Odan, Ijebu Ode	
Ondo	Ondo	
Osun	Isundunrin	Meaning: 'Where we smelt to become iron'. Domed furnace, iron slags
	Ile-Ife at Woye Asiri	1135 A.D.
	Olaigbi, Ogunro, Ogbomoso	
Oyo	Oyo (town)	Many destroyed iron-smelting sites in the town, e.g. at Isokun, Fatunke
	Old Oyo National Park	
	Agunrin	'Where they pound iron'
	Iseyin	
	Igunrin	'Pounding of iron'
	Ogunremi	
	Iponrin	'Sharpening iron'
	Ijaye	5 furnaces and heaps of iron slags
	Moniya	Destroyed site in town, opposite Allied Bank
Plateau	Dusten Kongba	Iron objects occurred in a level dated to 2780 ± 100 B.C.
	Jos	
	Nok	3500 B.C. (Y-142–3)
	Samun Dukya	1520 ± 115 B.C.
Rivers	Ke	1335 ± 85 A.D.
	Onyoma	
Sokoto	Yawuri	
	Ilela	220 A.D.
Taraba		
Yobe		10 furnaces and slag heaps
	Gujba L.G.A. at Ligdir	
Zamfara	Zamfara	

some. Road construction, building, mining, farming, infrastructure development and treasure hunting have destroyed many of these cultural heritage sites. For a better picture of 'iron roads' in Nigeria, in relation to the rest of Africa, to emerge, holistic studies of all identified sites are necessary. In Nigeria, evidence and tradition of iron smelting is visible in various forms. For example, iron slags, tuyères, furnace bases and walls, as well as iron objects are common in the areas where they have been discovered. The language (personal names and praise names, names of towns and localities, proverbs and popular songs) reveals practice of iron skills in the past. The list of Nigerian sites in Table 6 is not exhaustive but includes only sites known to the author at this time.[1]

It is noteworthy that pre-colonial iron-smelting evidence exists in Ajaokuta, Aladja and Itakpe where iron and steel complexes operate at present. This last fact may suggest that evidence of iron smelting in other parts of Nigeria and of Africa could indicate the existence of iron ore quantitatively and qualitatively adequate to support modern industrial iron and steel production.

Iron smelting in Nigeria

IRON PRODUCTION

To understand iron-smelting techniques, archaeologists have asked questions about the following in particular: the manner in which smelting furnaces were used; their construction and shape; the way of smelting ore in furnaces; site layout; traditional rites, taboos and social aspects connected with ore smelting; and the dates when smelting first began and came to an end in each region identified.

In dealing with a particular continent or region, such as Africa or West Africa, one should, among other things, be aware of which ethnic groups there specialized in the various types of iron metallurgy, and what similarities or differences in construction, smelting process and other aspects are evident in different parts of each sub-region.

The processes of iron smelting consist of the preparation of the furnace, tuyères and charcoal. They also include prospecting for iron ore, mining, ore preparation, and of course, smelting per se.

1. If our readers are aware of any iron-smelting or archaeological sites not listed here, we request them to contact the author, any department of archaeology or the National Commission for Museums and Monuments of Nigeria. As observed above, many of the sites have been destroyed. There is a need to enforce cultural heritage preservation laws in Nigeria and to excavate untapped sites, an effort that calls for funding by competent branches of government and by UNESCO.

74

76

75

77

78

79

80

81

83

82

Photo 74. 5-cm hole to verify reduction of iron ore in furnace (© Aremu).
Photo 75. Tuyères in respective holes (© Aremu).
Photo 76. Door of furnace (© Aremu).
Photo 77. Iron-smelting site, Yankari National Park, Bauchi state (© Aremu).
Photo 78. Slag heaps on Ampara iron-smelting site (© Aremu).
Photo 79. Scaled external coating of a tank furnace (© Aremu).
Photo 80. Side view of a shaft furnace (© Aremu).
Photos 81, 82 and 83. Various stages of destruction of shaft furnaces (© Aremu)

In prospecting for iron, the smelters are accompanied by a young person (a virgin boy or girl). Searching for iron ore with a virgin, beyond the fact that smelters who are old need a young fellow with sharper eyes, has a spiritual meaning.

Insects bringing soil out of the ground provide a lead. Smelters look for such traces, and when these contain ferrous materials, they know that iron ore could be found at such a place. They also depend on visual observation and on their experience, the best means of locating iron ore.

Before mining starts, they prepare food for the duration of their stay at the site and sacrifice to propitiate the god Ogun. The mining equipment needed includes cutlasses for clearing the bush, pickaxes for digging, heavy picks for excavation, and hoes for gathering and removing the earth. To the same purpose, they also use baskets and small, light calabashes. They employ ladders to descend into and climb out of the pit or ore tunnel, as well as lamps if the pit is deep and dark (Aremu, 1990).

In mining iron ore, the ground is dug both vertically and horizontally. Miners fear the latter method very much, for it has cost many lives. While digging iron ore, they observe taboos: they must not bear ill will towards anybody, not have sex with another man's wife, and not steal. It is believed that if the miners break any of these taboos, the ceiling of the tunnel they are digging may cave in and kill them. This is why people say: 'whoever will do the work of iron-smelting must do no evil....Whoever smelts iron must not accept evil charms to harm others' (Adeniji, 1977 p. 12; Aremu, 1999, pp. 187–8).

When mining iron ore, ironworkers operate as a team, and this teamwork extends to other stages of the ironworking process as well.

In ore preparation, once on the surface, the iron ore is sorted and crushed to gravel size. Once it has been crushed, it is carried to a stream for washing, or water is fetched in order to wash it. After washing, the ore is poured on a coarse mat spread on the ground and left in the sun until it is bone-dry, and then ground into powdery form.

Fuel preparation involves preparing charcoal for the fire to smelt the iron. The following varieties of wood are used:

- *Sasswood (Obo), Erythrophleum quineense*
- *Aformosia laxifora (Shedun)* or *Pericolpsis laxiflora*
- *Lophira lanceolata (Ponhan).*

These are all varieties of hardwood and are prepared through particular techniques (Aremu, 1990, pp. 190–1). Round furnace construction provides an enclosure that generates heat for smelting. The walls are built of clay. Various furnace types are used in Nigeria: domed, shaft and bellows furnaces. Tuyère holes are provided at the base of the furnace for air intake during smelting, by natural draught or by bellows.

In smelting, once the iron ore is dry, a small charcoal fire is kindled in the furnace and a mixed charge, made up of ore and fuel alternately, is placed on it.

The furnace temperature is raised by natural draught or bellows, and the air supply is controlled in the later stages by watching the colour of the flame coming from the charge. Smelting in domed and shaft furnaces, as witnessed at both Isundunrin and Yankari (Bauchi), lasts at least eighteen to twenty hours. After smelting, the furnace is allowed to cool, and the spongy mass of metallic iron, the bloom, is removed. The bloom has to be reheated and hammered into a compact mass, an operation repeated several times to drive out all the slags.

Some people still practise iron smelting in Nigeria. They bear witness to the past, and this is one reason for video recording their smelting processes in order to preserve the knowledge before it is lost.[2]

IRON FORGING TECHNIQUES

Forging technology involves shaping by hammering and heating, tempering and welding. All three activities usually take place in a blacksmith's shop. The workshop is part of the forge, with fire and anvil, where metals are heated and shaped. Once the iron is obtained the ironsmith puts it in the fire and, when it is red-hot, flattens it by hammering and cuts it to the desired shapes.

Tempering helps toughen iron by heating and hammering, to repeatedly drive out the slags. Welding involves joining together two or more iron pieces. This too is achieved by heating iron to a red-hot stage and hammering the pieces together to the desired shape. All three activities are repeated several times in the furnace and on the anvil.

In the past, blacksmiths depended on locally smelted iron. Today, they obtain the necessary metal from old automobile parts and other scrap iron. Other materials used by ironsmiths include charcoal and palm-kernel shells for fuel in the furnace.

Ironsmiths' tools include huge stone blocks used as anvils, smaller smooth stones employed as whetstones, bellows made with hollow wooden pipes, goatskin or sheepskin and bamboo sticks, and stone hammers whose size varies depending on the work at hand.

A lighter long hammer and an iron billet are used for tapping edges into shape, and protruding bits of red-hot metal are trimmed off with an adze. A cold chisel and hammer are used to cold-cut bits of iron. A concave surface rock is sometimes used for shaping hoe blades. A hollow-surfaced rock, containing

2. Five video films have been made under the direction of the author, including two on iron-smelting processes: *Demonstration of iron smelting at Isundunrin* (Pal, 80 mins.); *Iron smelting in Wikki, Yankari National Park, Bauchi* (Pal, 60 mins.); *Brass casting in Obo Aiyegunle* (NTSC, 100 mins.); *Bauchi iron-smelting sites in Ampara, Yankari National Park* (Pal, 40 mins.); and *Building of a shaft furnace in Wikki, Yankari National Park, Bauchi* (Pal, 60 mins.).

water into which hot iron is dipped during the forging process, is part of the equipment. Iron pincers or tongs are used to hold the hot metal.

In times past, ironsmiths made every kind of iron tool and instrument, such as hoes, cutlasses, axe heads, knives, chisels, razors, rods, chains, armlets, hairpins, adzes, horse bits and stirrups, among many others.

Blacksmithing holds an important place among the traditional industries of Nigeria. This is reflected in the wide distribution of the trade, which is found in every settlement, from village level upwards. While the practice of iron smelting has ceased in almost all Nigerian communities, blacksmithing is still carried on in every town and village.

Iron in everyday life in Nigeria

Iron has many advantages over copper, bronze and brass. It is a harder metal and can be sharper than the others, which are more suitable for utilitarian and ornamental purposes, whereas iron lends itself to the fashioning of various types of tools and weapons. Iron is therefore superior in efficiency to stone, copper and bronze. Iron tools and weapons lend themselves to forest clearing, woodworking, agriculture, animal slaughter and killing of enemies effectively and effortlessly. This potential helped to accelerate the spread of iron technology in Africa.

Many African societies earned considerable prestige from their knowledge and ownership of iron. Ironworking and usage contributed to the creation and expansion of states. To mention but a single famous example, it was iron that ensured Assyrian victory over the Kushites in about 660 B.C.

Ironworking in Nigeria developed from the sudden discovery of smelting techniques and, more recently, from the spread of modern industrial techniques of iron and steel production at Ajaokuta, Aladja and Itakpe. The range of products made by the earliest craftspeople has now expanded in scope to meet the many demands of everyday life.

Tables 7 to 13 indicate some of the fields – economic, domestic, religious, political and military – in which iron is in daily use in Nigeria.

Beliefs linked to iron

Ethnographic studies in Yorubaland show that ironworkers and users believe in and worship Ogun, the god of iron. Such beliefs and customs may predate the available archaeological evidence in Nigeria. Ogun is the divinity to which iron and steel, and any implements and tools made from them, are thought to belong. Ogun's principal symbols are iron, the anvil, the dog, mariwo (young palm fronds) and certain trees (Aremu, 1990). Thus iron symbolizes Ogun, and vice versa.

Table 7. Tools for productive activities

Categories	Objects	Remarks
Blacksmith's tools	Scrappers	Used for making scale models
	Cutters	
	Knives	
	Files	
	Punches	
	Tongs	
	Iron anvils	Stone anvils are also used
	Hammers	
	Spatulas	
Bronze and brass caster's tools	Similar to above	
Woodcarving tools	Cutlasses	
	Aboro (Yoruba)	Big and small
	Axes	
	Knives	
	Saws	
Farm implements	Hoes	Big and small
	Cutlasses	
	Yam knives	
	Guinea corn knives	
Hunting tools	Traps with arrows	Big and small
	Traps without arrows	Big and small
	Rat-traps	
	Arrows	
	Gun parts	
	Clubs	
Fishing materials	Fish-hooks	
Palm-wine tapping tools	Cutlasses	
	Palm-tree axes	
	Palm-tree knives	Aha: Yoruba
Weaving implements	Rod for ginning cotton	Omo Obibo: Yoruba

Table 8. Household utensils and appliances

Objects	Remarks
Okra knives	
Axes	
Braziers	Ifonna: Yoruba
Meat driers	Ayanra: Yoruba
Metal plates	
Chains	

Table 9. Religion and cult purposes

Categories	Objects	Remarks
Religion	Symbols of Ogun	
	Symbols of Sango	
	Symbols of Osanyin	
	Symbols of Egungun	
	Symbols of Obalufon	Obalufon was the first artist in metal (bronze or brass)
Cult	Ogboni cult	Mainly in bronze/brass
	Iya, infinite mother	
	Ogboni Edan staff	

Table 10. Ceremonial objects for marriage

Objects
Marriage ceremonial staff
Brass wedding plates

Table 11. Political and military purposes

Categories	Objects	Remarks
Political	Royal swords	
	Royal plates	
	Royal seat	
	Royal sceptre	Brass or bronze
Military	Daggers	
	Iron swords	
	Aba	Lock for protection against enemies
	Poison arrows	
	Cutlasses	

Table 12. Human and animal motifs

Objects	Remarks
Human and animal motifs	
Bronze or brass heads	For example, those from Ife and Benin
Bronze or brass animals, snakes and birds	For example, the Igbo Ukwu bronze snake

Table 13. Various: panels, locks, etc.

Objects
Volkswagen uprights and chassis
Casting of keys, locks, etc.

Ogun's outstanding feature is his link with iron and other material elements of technology. Ogun is almost universally associated with potentially dangerous technology (weapons, motor vehicles, trains and electricity) and perilous, male professions: ironmaking, hunting and warfare in the past, transportation, construction, mechanics and engineering at present (Sandra, 1980, pp. 6–7). Both the harmful and the beneficial aspects of these associations are included in the Ogun corpus of beliefs.

The Yorubas believe that it is Ogun (iron) who, as master artist, puts the finishing touch to the creative work of men. He is responsible for overseeing the acts of circumcision, face-marking, tattooing or surgery that are necessary for people's good health. For it is believed that all iron and steel tools belong to Ogun and that all who use them do so under his authority (Alabede, 1993, personal information; Idowu, 1975, p. 88).

In Yorubaland, therefore, any reference to Ogun symbolizes iron. Accordingly, he is regarded as the god of war and of warriors, hunters and the hunt, ironsmiths, engineers, mechanics, engine drivers, machine operators, and, all who handle anything made of iron or steel. All are considered as being under obligation to worship or propitiate him, especially before undertaking any new work such as opening a smithy, going on a hunting expedition, purchasing a new vehicle or giving thanks after escaping from such a disaster as a motor or gun accident.

The Yoruba often recall the proverb: *Bi Omode bada'le, ki o ma da Ogun oro Ogun* kewo (If one breaks a covenant at all, it must not be with Ogun: the matter is strictly taboo where Ogun is concerned). Non-Christians still swear by an iron implement rather than the Bible when in court (although Jesus Christ enjoined Christians not to swear at all, but to say simply 'yes or no' – Matthew 2, v. 34–7).

Ogun used to be worshipped before and after every war (Ojo, 1971, pp. 169–70). This is now done during the first yam harvests between June and September. Dogs have replaced humans as the principal sacrificial victims. In Idofin and Obo Avegunle, it is in August that the consumption of new yam is marked ceremoniously. Formerly worshipped countrywide, Ogun is now adored by a mere handful of devotees and blacksmiths in Yorubaland. Ire in Ekiti state is still the centre of such worship. Ikole, Ondo, Ado-Ekiti and Otun celebrate the annual festival elaborately, although Christianity in particular and Islam have generally reduced the number of Ogun worshippers in Yorubaland.

Ogun's male-oriented nature is apparent in the fact that women, contrary to most other Yoruba religions, cannot serve as priestesses (although they now may participate in ceremonies). Sacrifices and prayers aim at appeasing Ogun's destructive side in order to avert danger, and especially accidents. Worshippers pray less frequently for individual goals, such as aspirations linked to wealth, power, fertility and so on.

It is interesting, in the light of the foregoing, to observe how iron has significantly influenced beliefs and spiritual life in various parts of Nigeria, and in Africa in general. That may not be unrelated to the belief that ironworking came from the soul, and accordingly took root very readily in their beliefs and systems of worship. A survey of iron roads in Africa would not be complete without reference to popular beliefs and customs relating to Ogun. In any smelting and smithing work, Ogun is propitiated and is seen as the overall source of success.

A great deal of research work remains to be done if the contribution of different Nigerian societies to the iron roads in Africa is to be appreciated fully. Such research should be properly planned, programmed and funded, besides covering archaeology, ethnography and other related disciplines.

On the Threshold of Intensive Metallurgy: The Choice of Slow Combustion in the Niger River Bend (Burkina Faso and Mali)[1]

Bruno Martinelli

The pre-industrial production of iron has a long history in West Africa, going back more than 2,500 years. Whether from an archaeological, historical or anthropological standpoint, sub-Saharan Africa clearly possesses a heritage that has general value in the history of metallurgy. The direct reduction of iron ore lasted for a very long time in the region, and the diversification of methods resulted in a range of technologies unparalleled in other parts of the world. This diversity represents one of the most important contemporary questions when it comes to defining, understanding and comparing all these different technologies, bearing in mind that such complex technologies, developed in a quest for efficiency, are first and foremost systems of knowledge. For all human sciences concerned with the technical and social dimensions of metallurgy (including archaeology, history and anthropology), Africa is unmatched as a comparative research laboratory. Contemporary research on ironworking in Africa is changing the way we look at the past of the societies, states and civilizations in that part of the world.

Until the beginning of the twentieth century, artisans supplied metal instruments far and wide, thereby helping to shape the political and economic structure of the regions. Between the fifteenth and nineteenth centuries, ironworking contributed to the emergence of the Malinke, Soninke, Songhay and Mossi (*Moose*) states or kingdoms in the Sudanese-Sahelian regions of the Niger Bend. In addition to supplying weapons for military activities, iron production in these regions allowed greater areas of land to be cleared for cultivation and fostered the technological development of the farming of grain crops (millet and sorghum).

1. With the agreement of the editor, this text is a revised version of an article published in 2000 in P. Pétrequin, P. Fluzin, J. Thiriot and P. Benoît (eds.), 'Arts du feu et production artisanales', *Twentieth Antibes International Meeting on Archaeology and History*, Antibes, Editions APDCA.

While we have long been aware of the impact of metal products on trade and markets, we are only just beginning to measure their effect on ecosystems and crop development. Metal production was a significant factor in regional differentiation and social change. Many of the West African pre-colonial states sought to attract, administer and protect metalworkers of different status without necessarily restricting their independence or their mobility. That was the case in the Senegal Valley, on the Jos and Taruga plateaux in Nigeria, in several parts of the interior delta of the Niger, in the Mandingue mountains in Mali, Fouta Djalon in Upper Guinea, Kenedougou, the Songhay region and the Agadez region in Niger. The Yatenga country, situated in the north of Burkina Faso, was one of these centres of intensive production with a large-scale impact (Figure 9).

This kingdom, founded at the end of the sixteenth century, reached its height in the eighteenth and nineteenth centuries with a period of exceptional growth in metal production and trading activity. Although the traditional activities of ore mining and reduction ceased altogether during the 1950s to 1960s, ironworking is still actively practised in the region and, with the use of recycled metals, meets the diverse needs of rural and urban populations alike. The Yatenga is rich in traditions, attesting to the place this industry has occupied in the historical and material culture of the region's populations.

In this chapter we develop two lines of thought concerning iron metallurgy in Yatenga, structured around the concepts of technological and social change. On the basis of our observations in the field, we postulate a close relationship between a major technological change, comprehensible in a theoretically reconstructed ethnographic context, and a process of social and political stratification that evolved from the end of the eighteenth century to the beginning of the twentieth century. One of the most important issues in this process was the definition of the status of the blacksmith as master of production operations and organizer of the commercialization of the iron produced in exchange for acceptance of the social constraints of rules of enclosure. The studies carried out in Yatenga demonstrate that, contrary to a preconceived pattern of transcultural consistency all too often regarded as evidence, the status of the metalworker has evolved through successive phases. In this region, it is the result of an overall social transformation whose technological, economic and political impact can be traced. The 'choice of slow combustion' relates to these three issues.

Two technological and social systems

Metallurgy is an indicator of the complexity of African societies and of the material and human exchanges that took place within them. The differentiated status of specialized craftspeople depends on social configurations, which are different, even when they have been in contact both spatially and historically, as was the

Figure 9. Yatenga and the extent of Mossi metallurgy

case in the Niger Bend region in recent centuries. The very notion of 'blacksmith' (which – as we tend to forget – is first of all the result of debatable translations) expresses this remarkable variety. Ethnological literature has presented a stereotyped image of the blacksmith, apprehending it only through the prism of myths and ritual functions while remaining blind to metallurgy itself. M. Griaule's work entitled *Dieu d'eau* (1948), which places the civilization-shaping blacksmith at the centre of the Dogon cosmogony (Mali), is a typical example of this approach. It is worth noting that, although a major mining and iron production site, Wol (Woru), was located only a few kilometres from Sanga where Griaule and his team carried out their fieldwork for over thirty years, not a single researcher ever mentioned its existence. Of course the metalworkers operating there at that time were not blacksmiths as such but rather simple farmers, incompatible with the image of the mythical blacksmith presented as the model common to all the Dogon peoples. Could this be the reason for that curious silence?

For both technical and social reasons there are very broad variations in the status of the blacksmith in West Africa. It is a status determined by the entire set of relations that existed between the artisans and the suppliers or possessors of the raw material, as well as the intended beneficiaries of the iron produced – all the function and power categories that defined society as a whole. For these various reasons, iron metallurgy offers a key to a comparative study of West African societies in terms of the development of both their social structures and their technological systems and ecosystems. Several blacksmith categories often coexisted in the same region, proof that each population had its own particular set of differentiating criteria. By extension, the notion of artisanship, in particular where the 'fire arts' are concerned, should be made to conform to different definitions and local circumstances.

Ore processing presupposes the mastery of fire in a furnace, of which there are many known types, structures and operating systems (with and without ventilation). Those who operate the furnace do not always enjoy artisan status within their society. In regions where metalworking has been carried out on a scale large enough to have warranted study (the northern part of the Niger Bend – Burkina Faso, Mali, the northern regions of Togo and Benin, northern Cameroon and Niger), certain farmers mastered and monopolized furnace technology, supplying the metal to blacksmiths who were mere manufacturers. The German ethnologist Renate Wente-Lucas (1977) clearly demonstrated the existence of this dual system in the Matakam, Sukur and Kirdi societies of northern Cameroon. The question of a distinction between the categories of metalworker and blacksmith was also raised by Echard (1965) in the light of data collected on the Hausa of Niger, and again by Dupré (1981–2) with reference to Central Africa. In other societies, blacksmiths were in charge of the entire range of operations from the extraction of the ore to the manufacture of objects. Thus, farmer-

metalworkers can only be regarded as 'artisans' in the context of a concept imported from outside, the definition of which is in part theoretical.

In all these societies, the artisans recognized as such in vernacular terminology are the blacksmiths. Known as 'bellows-workers' or 'anvil-workers', they are identified by their activity of manufacturing their products and delivering them to local consumers. In these contexts the distinction is never simply technical and economic, but also ritual, symbolic and social. The systematic association of metalworking with the blacksmith class by earlier and contemporary authors hinders our understanding of ancient African societies. The difficulty arises also from the absence of specific local terms for farmer-metalworkers, even though there is always one for blacksmiths. Archive documents should therefore be subjected systematically to critical verification through field studies.

Segmentary societies, states and metallurgy

As a simplification, and without overlooking the existence of intermediate systems, it is possible to distinguish between two technological, social and political systems. In many societies there was a two-tiered model in which the primary processing activities (ore extraction and reduction) were carried out by farmers, who then supplied the metal, under various kinds of contractual arrangements, to the blacksmiths for manufacturing. In other societies, the metalworking model was such that blacksmiths alone handled the entire operation, from the mine to the forge.

The first model is characteristic of segmentary societies, which did not develop centralized political power until the beginning of the twentieth century. Their social system was based on lineage with legal and territorial authority vested in the senior members or representatives of the lineage. Lineage represents a unit that is economic, religious and political. My own research has focused on lineage societies of farmer-metalworkers in the western Bassar region (northern Togo) and in the Dogon region (Mali). The second model appears to have come to its fullest expression in the context of state formations during the pre-colonial era. The model is built on two linked systems: a system of technological specialization and a hierarchical system of identity and status. Blacksmiths were at the centre of a system of occupational categories (shoemakers, weavers, dyers, woodworkers, boatmen, griots and so forth) under which they were required to be endogamous in return for the exclusive right to a technical-economic specialization and social and religious powers. The ancient West African Malinke, Peul and Songhay kingdoms provide remarkable examples of this type of system (McNaughton, 1988; Olivier de Sardan, 1982). My research on this second type of metal production was carried out in Yatenga, in the north of Burkina Faso (Figures 9 and 10).

The technological transformations in iron metallurgy in this part of Africa are inextricably linked to the formation of complex societies with underlying hierarchies. Segmentary societies did not escape this trend. They were by no means closed as has sometimes been thought, because they were involved in trading circuits (iron, gold, salt, kola and textiles) and witnessed population movements. They borrowed certain social categories from neighbouring state-based societies (as did, for example, the Dogon in relation to the Bambara). The social situations that can be observed in the field have remained diverse, because they arose from specific circumstances and reflect the complexity of the stages through which these societies have passed. The region where I am pursuing my research provides a remarkable illustration of this, with regard to both the Mossi (*Moose*) in Burkina Faso and the Dogon in Mali. By examining the relationship between iron metallurgy, overall political development, agriculture and trade, it is possible to determine the social and political conditions that led to the emergence of the specific status of 'blacksmiths' as recognized artisans of fire and iron. This status is a product of social history and has varied widely from one African society to another. For each variation, it is important to determine how and when that status came into being and what form it took, starting from a set of social conditions where the distinction between artisan and non-artisan was less marked.

This evolution sometimes took place in a climate of constraint, with warrior-chieftainships subjugating small groups of blacksmiths and then controlling the production of weapons. That was the case in Yatenga under the rule of Naaba Wumtanângo (sixteenth century). This type of recruitment could not be carried out on a broad scale, or for extended periods of time. While seeking to attract large numbers of blacksmiths to help produce weapons, the political authorities were obliged to respect the blacksmiths' sense of independence and their refusal to submit to restrictions. There are many examples to demonstrate that the blacksmiths had at their disposal a graded scale of responses to conflicts with the authorities: strikes, curses and emigration. Artisanship evolved more generally through adaptation to internal stratification and to the increasing complexity of agricultural and urban societies in favourable contexts of human settlement, formation of political structures, exchanges of goods and mobility of people and ideas.

The coexistence of reduction metallurgies carried out by farmers and blacksmiths, artisans and non-artisans (as defined by local criteria) was reflected in different forms of technical complementarity, contacts and exchanges, as a result of which each group, depending on its resources, was seen as specializing in a particular domain in relation to its neighbours. That was true of the direct production by blacksmiths of the kinds of steel – generally called 'hard irons' – used to make the blades of axes or sabres. Up to the twentieth century, some of the Yatenga blacksmiths – large-scale producers of metal – procured their supplies of

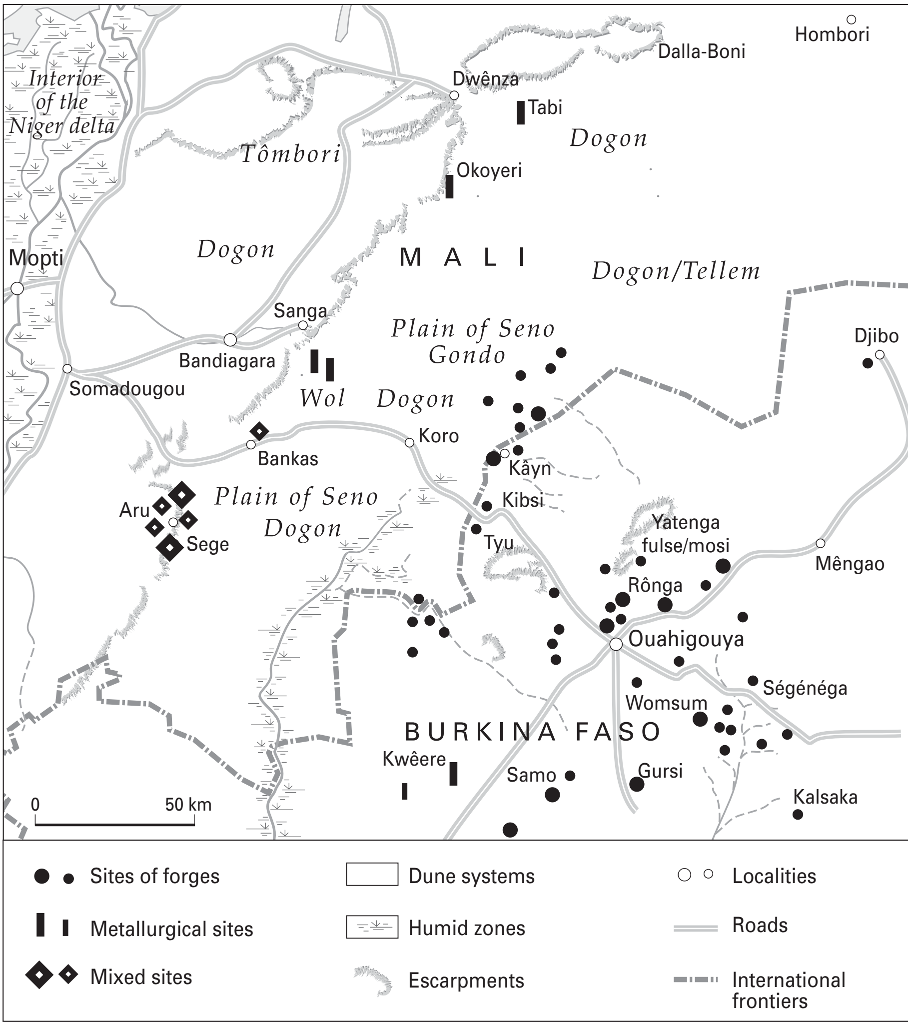


Figure 10. Farmer-metalworkers and blacksmiths in Yatenga and the Seno plain

'hard iron' or steel from farmer-metalworkers in the northern part of the Samo region or even further afield in the Dogon region. The farmer-metalworkers kept their monopoly over what was a strategic product, as these metals were used for axe and sabre blades until they were replaced by steels imported from Europe.

Anteriority and complexity

These data raise various kinds of questions: historical, technological and social. Is one system older than the other? Although African metallurgy can be organized chronologically on the basis of datings, we have almost no knowledge of the corresponding social structures. The two systems continued to coexist until the twentieth century. In the absence of facts, an explanatory model transferred from the Mediterranean Neolithic age to sub-Saharan Africa enables the systems to be placed in a historical hierarchy. This model posits metalworking as an important clue to the 'emancipation of the technician' and the transition from 'multi-skilled' societies to complex societies (Leroi-Gourhan, 1964, p. 238). It suggests that dualist systems are older or more archaic than unitary systems. To judge whether there was actually a transition from proto-artisanship to artisanship in the strict sense, it may be asked whether the debate might not be moved into the field of technology. The typological criterion is not the deciding factor, at least with regard to the Niger Bend region as a whole. An attempt to classify induced draft furnaces in more than 100 reduction sites in this region (Martinelli, 1993a, 1993b) has not enabled us to establish an unequivocal correlation between the technology used and the social identity of the producers (Figure 11).

Technologies similar to the induced draft furnace were used by blacksmiths in some cases and by farmer-metalworkers in others, both in neighbouring areas and in areas remote from one another (Photos 84 and 85). There is no reason not to assume that two-way borrowing went on between these groups. The Dogon metallurgies, running from the north to the south of the cliffs, provide a most remarkable example of technical convergence and sociological divergence (Martinelli, 1995b). While it cannot be ruled out a priori, the criterion of technological complexity would require a theoretical analysis of processes which, given the present state of knowledge, cannot be carried out with the necessary rigour.

Complexities are not always found where one expects them. Certain farmer-metalworkers were so widely recognized by neighbouring blacksmiths as producing metals of superior quality that this may have led the latter to stop producing metal. That was true in Yatenga at the end of the nineteenth century and at the beginning of the colonial period. Is the scale of production criterion any less debatable? In his work on the Hausa blacksmiths and Touareg blacksmiths, Echard (1965 and 1992) rightly gave strong emphasis to the impact of African metallurgies on social space, with regard to both the functioning of production units in territorialized regions and the transfers of materials, exchanges of finished products, mobility of populations and trading cycles.

Scale of production and control over product distribution and human mobility depend on overall political and social factors. The comparisons (still very few) that we are able to make between dualist systems show that, while

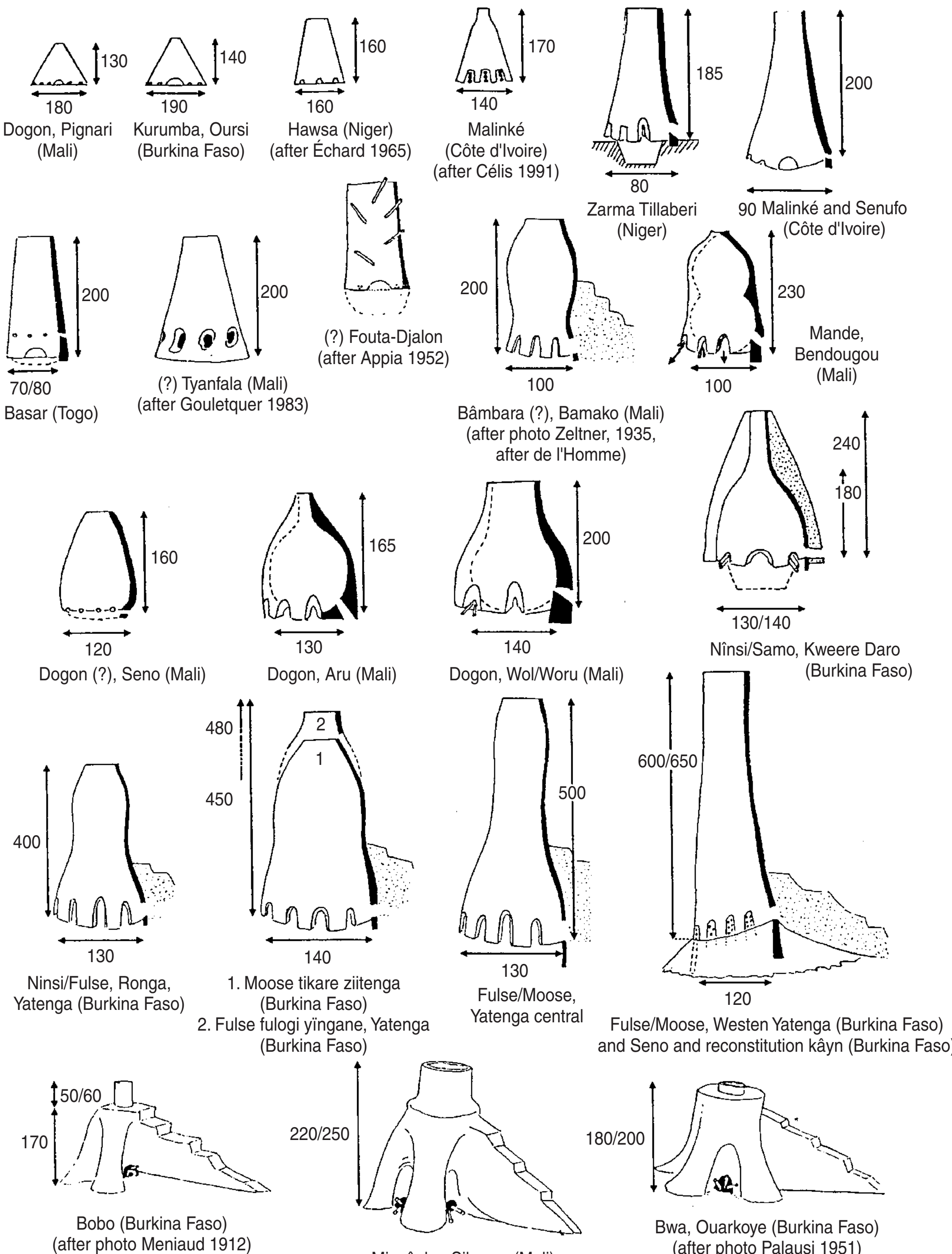


Figure 11. Principal types of induction furnaces in the Niger Bend

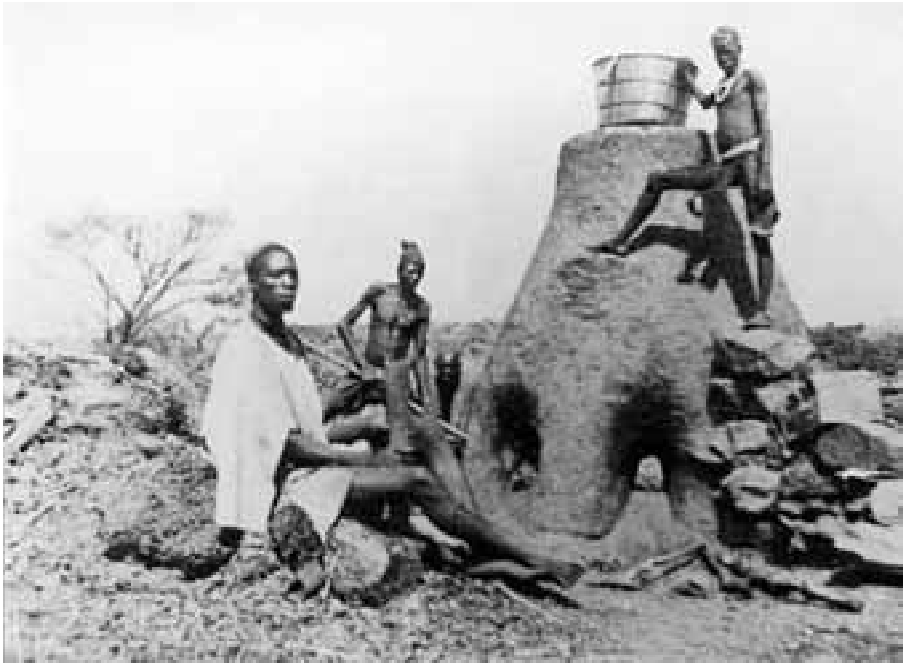


Photo 84. Furnaces of Dogon metallurgists in Wol and Sege (© C. Desplagnes, 1906)

many operated on a micro-regional scale (Dogon region), some were producing enough for large-scale export. This was the case in the Bassar region, in northern Togo, where hoe blades were produced for export by caravan to the Dagomba kingdom to the west and to the Guinea coast.

In conclusion, the questions raised by the plurality of metal-production systems remain largely unanswered. We know that structural correspondences existed between metal-production systems and social and political systems. The societies in which the mining and reduction activities were carried out by farmers, who did not have artisan status, were in general segmentary societies, whereas metallurgic activities entirely controlled by blacksmiths developed in stratified societies with a state structure. It would be necessary to determine with which underlying socio-political structure these 'trends' were linked in order to evaluate their scope and their impact on the comparative history of West African societies.

Photo 85. Old furnaces (*bôn-daagha*) in Yatenga (© B. Martinelli)

Technological change in Yatenga

A specific study of the social processes that developed in conjunction with metallurgy in Yatenga provides answers to some of these questions. The subject is interesting for two reasons. This mining and metalworking region of major importance was for more than three centuries under the control of endogamous blacksmiths coexisting at the technical level with farmer-metalworkers in the neighbouring regions. The latter provided the steel for objects deemed to be of value – sabres and the sharpest cutting instruments (axes and adzes). Within the Mossi (*Moose*) political sphere of influence, Yatenga was the only region that underwent a social transformation, as a result of which metal producers had to choose between the metalworking trade – by becoming full-fledged 'blacksmiths' – and agriculture, giving up all metallurgic activity.

This transition, which is probably not very exceptional in West Africa, gives rise in particular to the question of the technical, social and symbolic limits defining the status of a blacksmith in certain societies. Such limits are all the more precisely and consciously defined as they juxtapose complementary groups whose former relationships were not erased from lineal memory. For a metalworker

to become a blacksmith meant crossing a threshold as significant as the one crossed by a farmer or warrior becoming a blacksmith. The change in status from metalworker to blacksmith took place in a climate of social disruption and even breakdown, because the fundamental principle involved was endogamous marriage and the set of prohibitions accompanying it. Oral history has many illustrations of this point, all of them convergent, and enables us to determine the principal phases of a transition that began in the sixteenth century in the reign of Naaba Wumtanângo and was completed in that of Naaba Kângo (1757–87), (Izard, 1980, 1983, 1985). The latter ruler played a decisive role in the building of the kingdom and the codification of the status of the blacksmiths. His reign was marked by the constitution of a centralized state and a stratified society, with safer trade routes and increased exchanges with neighbouring countries, and the expansion of settled agriculture – all of these conditions being conducive to the growth of metal production.

During the second half of the eighteenth century, and parallel to this social process, metalworking technology underwent an important change, of which there are archaeo-technological traces. Early furnaces were cellular structures with continuous ventilation and pits. Using a technology similar to that used until recently in northern Samo, these furnaces yielded a limited quantity of metal but with a high proportion of steel. They were known as *bôn-daase* (singular: *bôn-daagha*), which means 'male furnaces'. At the end of the eighteenth century, a new method of direct reduction was developed in conjunction with the invention of a new type of furnace. The sequence leading to the innovation, which has been reconstructed on the basis of several pieces of archaeological evidence, has been ascribed to a group of blacksmiths in a circumscribed zone in the central Yatenga region. By virtue of its role in the social and technological history of the region, this group had ascendancy over all Yatenga blacksmiths, with a special right to set up foundries. The new furnaces were in the shape of tall conical or cylindrical columns (Photo 87). The slag was evacuated laterally from the structures. A comparative study of these furnaces shows that most were very large in size, which makes sense in a context of large-scale production. The furnace known as *bônga* (plural: *bômse*) was considered to be a 'female furnace' with all the associated parturition symbolism. It was designed to process large quantities of ore (approximately one ton) and produced about 150 kg of iron blooms per operation. The *bômse* furnaces were 5 m high on average, although many were as tall as 6.5 m.

The reduction system of the Mossi (*Moose*) blacksmiths of Yatenga included not only this large furnace but also two other furnaces equipped with bellows. The smaller was the *fôn-doogho*, used to refine – purify and carburize – small quantities of the iron produced in the *bônga*, for specific forging operations. The larger bellows-equipped furnace was the *bwaagha*, a multifunctional furnace of inclined tubular form used in Yatenga for the special purpose of producing steel

Photo 86. Contemporary furnaces (*bônga*) at Yatenga (© B. Martinelli)

from iron-manganese ore (*sidgha*) extracted from a single site near Ouahigouya, the capital of the province. This type of furnace was common to all the populations in the centre and the south, from Burkina Faso (Bisa, Lobi, Dagara and Kasena) to northern Ghana.

This multiphase reduction system with several furnaces was used because it yielded a massive initial production, after which the product was refined and then underwent different transformation processes depending on the requirements of the forge and the market, as well as on whether it could be sold locally, regionally or beyond. Blooms produced in the *bônga* were heterogeneous compounds in which carbon had been absorbed in variable proportions depending on the length of time and the combustion zone in the furnace. Blacksmiths made a distinction between ordinary, soft or 'fresh' iron (*kutu masgha*), and very soft or 'acid' iron (*kutu misgu*) for low-carbon content material at maximum temperatures of 900 °C to 1000 °C. This heterogeneity of the product meant that the sorting had to be done mechanically, and be followed by an additional reduction process for refining the iron. Some of the iron produced was directly forged into agricultural implements or domestic utensils. This kind of iron oxidized relatively easily and was therefore adequate for frequently renewed tools, but not for weapons or for tools used for striking against a hard and resistant surface.

The lowest-quality iron – known as 'acid' iron (*kutu misgu*) because it oxidizes rapidly owing to its low carbon content – was also produced. Some blacksmiths engaged in the unscrupulous commercial practice of selling this type of iron in distant markets during trading trips. They were familiar with the art of forgery. The entire blade of an axe or adze could be fashioned out of hard metal produced in a *bwaagha* furnace, but it proved to be more profitable to weld an edge of hard iron on to a core made out of ordinary iron.

Although technically able to produce it, blacksmiths stopped producing hard iron (*kutu kyênga* or *kyeghênga*) once they were able to procure it from Samo metalworkers (*nînsi*) in the southern Yatenga region. Although production had decreased substantially by the beginning of the twentieth century, a few of these furnaces were still operating at the end of the 1950s in the outlying northern and western areas of Yatenga. It was in one of these regions, near the border with Mali (Figure 9), that I carried out several reconstructions. According to observations dating from the early twentieth century (found in the archives of colonial administrators prior to 1914), there were 1,000 to 1,500 furnaces in operation at that time. At a rate of two to three reductions for each production season (February–April), these furnaces must have supplied in the early twentieth century – a period of regression – enough metal to forge more than 1,000 tons of iron annually.

SLOW-COMBUSTION REDUCTION PROCESS

In comparison with other regions of West Africa, the reduction process was remarkably long. Depending on the size of the furnace and the number of openings (nine or eleven), the process lasted from three to seven days. Seven-day

Photo 87. Mossi blacksmiths' iron furnaces in Yatenga, with soldier indicating scale (© J. Meniaud, Paris, É. Larose, 1912)

reductions have been attested by investigations carried out in several parts of Yatenga, remote from one another to ensure reliability of the data. In 1988, in the locality of Kâyn on the border with Mali, I carried out two reduction operations: one lasting three days (70 hours) and the other four and one-half days (100 hours). Some of the blooms obtained at the end of these operations were recovered, refined and then forged by several blacksmiths.

With regard to the duration of reduction, it should be specified that the master blacksmiths involved had carried out their last reduction with the *bônga* in 1962, almost thirty years before. They had planned to construct a furnace with eleven openings and to carry out a seven-day reduction, explaining the procedure to me in the course of numerous interviews. In piercing the openings in the reconstructed furnace, the blacksmiths realized that the furnace had the necessary height but that its diameter at the base was not sufficient. They accordingly built a larger than average furnace with nine openings. The duration of the reduction process was then determined by the quantity of the ore and the combustible material. This error of calculation had the advantage of enabling us to compare and analyse the results of two operations. It demonstrated that there is a margin of freedom in the decisions involved in the smelting operation, starting with the design of the furnace. The experience points to the need, generally

speaking, to take a relative view of results obtained from reconstructions; however, it also yields valuable additional data, provided they form part of a technological analysis. While the reconstructions carried out by experienced technicians are in no way artificial, they bring into play the random variables of memory, which must be taken into account when interpreting the data.

Regardless of the length of the operation, the *bônga* furnace is filled just once, before the fire is lit. There is no addition of ore or charcoal (the only fuel derived from *Prosopis africana* or, in its absence, *Boscia angustifolia*, *Pterocarpus lucens* or *Anogeissus leiocarpus*). The openings are closed off before the fire is lit and remain so until the morning of the day on which the materials are removed. The slag is first evacuated through a hole, from which it is 'urinated' (*dûnleere*) towards the outside of the furnace, for a period of six to eight hours. The blooms are positioned behind each opening, through which they are extracted. They have the appearance of metallic sponges, weighing 10 to 30 kg depending on the size of the opening. Under the right technical conditions, nine or eleven blooms will yield 150 to 200 kg of heterogeneous metal. The final usable product, comprising the three qualities of iron mentioned above, represents only 30 to 60 per cent of the matter recovered. This considerable variability in content reflects a wide variation in competence among the blacksmiths. At the bush camp where the reduction operations were carried out, this competence was exhibited immediately through mechanical verification of the quality of the metal, which was subject to collective assessment. Considering the height of certain furnaces (Photo 87), the technique chosen reflected a trend towards 'gigantism', highlighting a tendency to explore technical limits at the expense of technological performance. It points to the unfinished nature of the innovation process which, if colonialism had not arrived to hamper it, could have continued into the twentieth century.

Taken together, these technical indices demonstrate the singular nature of metallurgy in Yatenga compared with neighbouring and even more distant regions in Africa. It is characterized by the choice of a slow-combustion reduction process resulting from the blocking of the furnace openings for 90 per cent of the operation. Rather than the size, form or structure of their furnaces, it is this 'slow-combustion' process that blacksmiths regard as the hallmark of their technical identity. They are relatively aware that such a criterion of identity places the emphasis on the mastery of temperature and on the progress represented by the ability to contain increasingly high temperatures over a prolonged period of time in a restricted combustion area.

We may well wonder as to the reasons and significance of this technical 'choice'. In what sense can we speak of a choice when the whole complex of technical determinants is considered particularly constraining? Slowness or rapidity have no significance in themselves. The criteria of technical awareness have been based on both oral investigations of familiarity with other technologies, acquired

during apprenticeship journeys (Martinelli, 1995a, 1996, 1998), and on reconstructions during which records are kept of the temperatures, materials and processes used. They highlight concepts of thresholds, safety margins and technical decisions. The heterogeneity of the zones and phases of combustion in the furnace may be observed and interpreted in terms of the management and representation – both perceptual and cognitive – of the relations between matter and fire.

THE THERMAL PROCESS

This system of reduction by induction has the peculiarity of not requiring any human intervention during 90 per cent of the process, from ignition, with all the openings blocked, to the evacuation of the slag, which begins half a day before the total opening up of the furnace. To understand what happens inside this kind of furnace, of which the blacksmiths speak metaphorically (in terms of gestation, birth, and so on) while demonstrating a practical mastery of its phases, hypothetico-deductive reasoning must be backed by measurement. This involves weighing and sampling the materials before and after the operation as well as recording the temperature in various parts of the furnace during the reduction process. These records were kept in order to compare the results of reduction processes of varying lengths.

The temperature curves were established by using platinum-rhodium temperature probes with an effective range of 400 °C to 1400 °C. One of the probes was placed on the floor of the furnace, above the opening for the evacuation of slag, and the others were placed at 1.5 m, 2.5 m and 3. 5 m (Figure 12). This arrangement enabled us to record the twin phenomena of heating and combustion, which are the keys to the roasting process.

The diffusion of carbon monoxide for sixty hours at a temperature exceeding 600 °C in the upper part of the furnace, before the ore descends into the combustion zone, is essential to the smelting process. This pre-reduces the ferrous oxide at a fairly high temperature, and softens and breaks down the ore. The fissures found in pieces of 'non-transformed' ore recovered at the end of the process seem to confirm this. The aim is also to regulate the propagation of gases so as to avoid any uncontrolled collapse of the charge. These conclusions appear to match the observations of Leroy (Leroy et al., 2000, pp. 37–51) based on an experimental study of furnaces and reduction processes used with ore from the Lorraine region.

The temperatures registered in the central combustion zone (between the furnace floor and 1.5 m) show that a prolonged reduction of iron oxides takes place there, at a temperature stabilized between 800 °C and 950 °C, after approximately twenty hours of combustion. This phase lasts from fifty to seventy hours (with all the openings blocked). A comparison between operations demonstrates an apparent gain of approximately 100 °C, on average, when the

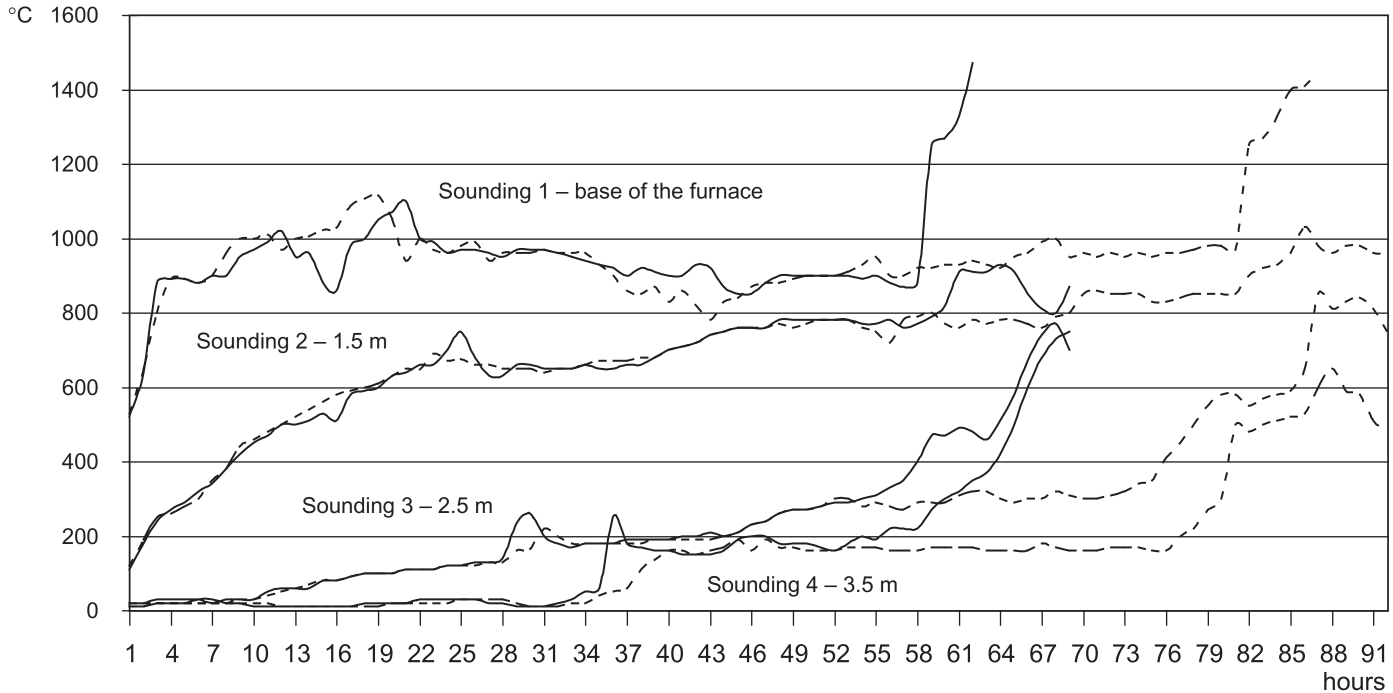


Figure 12. Yatenga, Kâyn: reduction compared 70/100h. Temperature curves

reduction time is prolonged by 30 per cent. This observation corresponds to those made in other regions on induction furnaces of a different design, for example the observations of Goucher (1984) and de Barros (1985) in the Bassar region of Togo. By analysing the temperature curves, the reduction process can be broken down into three phases:

- A rapid rise in temperature for a period of twenty hours in the lower part of the furnace, with an initial peak affecting all parts of the furnace: this peak is an objective indicator of the end of the initial roasting phase and the shifting of the combustion zones. It marks the threshold at which the temperature stabilizes in each zone.
- A slow upward rise in the average temperature in the different parts of the furnace, which produces heating (600 °C to 800 °C) in a carbonaceous atmosphere: the layers of ore descend slowly, subject to controlled combustion and a constant temperature (of 800 °C and 1000 °C), over more than fifty hours.
- An abrupt increase in temperature during the last ten hours, beginning with the evacuation of the slag through a small lower opening called the *dûnleere* (the place through which the furnace 'urinates'). In the lower part of the furnace the average temperature rises immediately to more than 1250 °C. During one of the reconstitutions the lower probe had to be removed subsequent to being damaged at a temperature of 1450 °C, five hours after the slag evacuation had begun. The pipes are unblocked intermittently to observe the combustion colour. The blacksmiths insert sticks through the pipes for several hours to activate the flow of slag. The temperature then stabilizes at over 1200 °C in the central zone during the six final hours, until the extraction of the blooms.

COMPARATIVE STUDY OF MATERIALS

After a preliminary reduction process of seventy hours, nearly 40 per cent of the crushed ore loaded into the furnace was recovered in a non-reduced state. Considering this result in relation to the size of the furnace (which, as mentioned above, was a compromise between a furnace with nine openings and a furnace with eleven openings), it was decided to carry out a second reduction, relying once more on the knowledge of the blacksmiths as regards the length of the operation. This lasted 100 hours.

A comparative study of the materials reveals several facts (Table 14). Prolonging the reduction time by thirty hours produced a 6.17 per cent gain in output, amounting to a yield of 22 per cent of metal relative to the weight of ore initially loaded, excluding non-reduced ore. Moreover, the amount of non-transformed ore was reduced by half, from 328 kg to 158 kg. Equally important was the significant increase in bonded slag (*nwâre*) evacuated from the furnace.

Superposing the curves shows that the relevant difference was not the increase in temperatures but rather the prolongation of the second phase of the process, during which heating and combustion produced their effect. A comparison between these two operations highlights the relevance of the empirical and vernacular concept of slow combustion. Prolonging the duration of the reduction probably coincided (at least in part) with a crucial phase of a process whose conclusion constitutes the blacksmiths' main concern.

Table 14. Yatenga: reconstitutions carried out at Kâyn. Comparative list of materials

	Values		**+/–**
Total duration (days)	3.5	4.5	
Total days			
Combustion duration (hrs)	70	100	
Materials			
Charcoal:			
– Total kg	910	925	15
– No. baskets	91	93	2
– Layer 1 (kg)	420	412	– 8
– Layer 2 (kg)	170	192	22
– Layer 3 (kg)	160	170	10
– Layer 4 (kg)	160	180	20
– Remaining at end of reduction process (kg)	176	36	– 140
– Consumed (kg)	734	889	155
Ore:			
– Raw (kg)	958.50	973	14.5
– 1st crushing (kg)	910	903	– 7
– 2nd crushing (kg)	837	846	9
– No. baskets	131	133	2
– Layer 1 (kg)	422.1	412	– 10.1
– Layer 2 (kg)	100.8	125	24.2
– Layer 3 (kg)	314.1	309	– 5.1
– Total charge (kg)	837	846	9
Straw not packed (m^3)	3	3	
Results of the reduction			
Ore:			
– Untransformed (kg)	328	158	– 170
Bloom (non-refined iron):			
– Opening 1 (kg)	23.2	27.2	4
– Opening 2 (kg)	8.2	21.3	13.1
– Opening 3 (kg)	6.1	13.5	7.4
– Opening 4 (kg)	6.1	12.1	6
– Opening 5 (kg)	3.1	9.6	6.5

	Values		+/–
– Opening 6 (kg)	6.8	18.3	11.5
– Opening 7 (kg)	7.3	18.6	11.3
– Opening 8 (kg)	18.5	29.1	10.6
– Opening 9 (kg)	0.8	1	0.2
– Total kg	80.1	150.7	70.6
Slags:			
– Vitrified slag, nwâre (kg)	90	175	85
– Bloc slag, rângo (kg)	70.9	92	21.1
– Slag at furnace bottom (kg)	34	65	31
– Total kg	194.9	332	137.1
Summary and quotients*			
Ore (O) total charge (kg)	837	846	9
NTO untransformed ore (kg)	328	158	– 170
Ore O2 > O-NTO transformed (kg)	509	688	179
Charcoal C consumed (kg)	734	889	155
Slag S total (kg)	194.9	332	137.1
Blooms B total (kg)	80.1	150.7	70.6
Residues (ashes, gases, etc.) calculated by deduction			
O2-B-S total (kg)	234	205.30	– 28.70
O2-B-S (%)	27.96	24.27	– 3.69
Ratios	**Reduction**		**+/–**
	70 hrs	**100 hrs**	**30 hrs**
O/C	1.14	0.99	– 0.19
O2/C	0.69	0.77	0.08
O/S	4.29	2.55	– 1.75
O2/S	2.61	2.07	– 0.54
C/S	3.77	2.68	– 1.09
O/B	10.45	5.61	– 4.84
O2/B	6.35	0.18	0.08
B/O	0.10	0.18	0.08

* O: ore; NTO: untransformed ore; O2: ore 2nd crushing; C: charcoal; S: slag; B: bloom.

I had entertained the hypothesis that a prolonged and intensive reduction of the iron oxides, conducive to the diffusion of carbon within the iron, owing to the furnace's blocked openings, would enable steel to be produced directly. This hypothesis was not borne out by the results obtained during the reconstructions (Table 11.1). That does not mean, however, that the hypothesis is not consistent with the use of this type of technique, as reported by certain blacksmiths. A small amount of steel (hard iron – *kutu kyênga*) did remain at the centre of the largest blocks, although its proportion was not significant. Slow combustion apparently

has other objectives. If we put the question to the blacksmiths, their reply is that slow combustion is necessary for several reasons. These include:

- The quantities of ore to be reduced and fuel to be burned.
- The resistance of the structure: furnace walls are not designed to resist prolonged exposure to temperatures in excess of 1000 °C . The blacksmiths declare that the openings are closed off for 85 per cent of the reduction time so that the furnace 'will not split open'. Many stories are told of inexperienced blacksmiths (Martinelli, 1996) whose furnaces cracked. It does not seem to occur to the blacksmiths to modify the construction technique, for example by reinforcing the walls with blocks of slag and clay supports, as in the case of some Dogon and Samo furnaces with which they are familiar.
- Controlling the interaction of the materials and gases during the reduction process. Increases in the temperature of the roast change the manner in which the materials are dispersed in the furnace. The charge may collapse and create gaps in the ore and charcoal, allowing the carbon to escape directly instead of diffusing slowly. Slow combustion makes for a steady descent of the fuel charge and greater evenness in the action of the carbon on the iron oxide.
- Temperature control: for the blacksmiths. Technical progress is measured in terms of the capacity to control temperature rises and contain the highest temperatures in a focal area of the furnace. One purpose of this technique is to limit heterogeneousness in the zones and phases of combustion, and consequently in the metals finally produced.
- Increasing the proportions of 'hard iron' (*kutu kyênga*) and ordinary or 'fresh' iron (*kutu masgha*), directly usable in the forge, as compared to 'acid' iron (*kutu misgu*). The blacksmiths believe that the three qualities of iron correspond to variable reduction times at the base of the furnace – hard iron being associated with the longest, and acidic iron with the shortest reduction spans during the final phase of the opening of the furnace.

Transmission and mastery of ironworking

The blacksmiths' representations of the slow-combustion process are precise and varied. They point to common standards in the management of safety margins, which must be maintained every time the process reaches a new stage, identifiable by perception (hearing, sight or smell) or reasoning. To understand and control the technique of these induction furnaces, mere observation is not enough. The furnace is a closed and opaque environment: understanding its structure means understanding how it functions. This technology calls for a thorough understanding of the physico-chemical process underlying the transformation of the ores, and a capacity to anticipate irreversible processes. The

possibility of corrective intervention is very limited, which is why the blacksmiths say that once the furnace is loaded, 'everything depends on God Wênde'.

Acquiring full knowledge of the chain of steps of the process leading to ore reduction is a lengthy affair. In Yatenga, apprentices had to learn to forge before being initiated in the reduction process, considered as the final stage in the transmission of the skills of the trade (Martinelli, 1996). In this way, a system of compartmentalized knowledge came into being. Learning how to work with the *bônga* furnace extended over a large part of the smith's professional life. The elders in this lineage kept information secret at strategic points in the operation. The norms governing mutual help among members of the same lineage and community, and the necessary assistance of the elders, combined to determine the transmission of knowledge. In multi-generational lineage groups, blacksmiths aged thirty or forty years could be confined to the subordinate tasks of extracting ore and making wood charcoal. They were admitted only as observers or labourers to the key operations involved in ore reduction. Certain knowledge (both technical and symbolic) relating to the slow-combustion process was transmitted exclusively through an initiation process among the elders. Young blacksmiths were thus conditioned to regarding the initial elaboration of iron as a highly complex process, requiring the observance of particularly strict rules and standards.

An economic and technical choice

The technical system of the Yatenga blacksmiths is characterized by the desire to produce surpluses for exportation to other areas in the Mossi (*Moose*) region and to neighbouring countries as far as the border with Ghana. Starting with the phase of innovative research and throughout the nineteenth century, the choice of slow combustion by the Yatenga smiths tended to parallel an economic option: preference for a quantitative leap in production enabling ironworking to become part of long-distance trade and exchanges. Most blacksmith families were organized so that, at the close of the dry season when the farmwork was starting to the east and south-east, groups of young men could set off in donkey and ox-drawn caravans to sell blades adapted to the needs of customers in those regions (Ouagadougou, Pwitenga, Tenkodogo and the southern Mossi-Gurûnsi region). Some of the young men returned immediately to Yatenga with supplies of cowry shells or food and manufactured goods; but many others continued with their donkeys in the direction of Ghana, participating in the Mossi trade cycles, and networks and returning several months later with kola. Some went on to sell kola in Mopti and Timbuktu and only then returned to Yatenga, their caravans loaded with dried and smoked fish. The products of the forge provided, for those involved in long-distance trading, the initial capital for a trade cycle.

In Yatenga, the monopoly exercised by the blacksmiths over iron operations was closely bound up with the stratification and external dynamics of Mossi (*Moose*) society. Having removed themselves from the arenas and functions of power, at the cost of a restrictive system of endogamy, the Yatenga blacksmiths turned towards large-scale production and commercialization. They increasingly found themselves travelling alongside merchants on the caravan routes linking the north of the Niger Bend with the countries of the Guinea coast. They enjoyed a certain prosperity up to the beginning of the twentieth century, all the while continuing to distinguish between trade with local farmers for food, governed by a code of mutual give and take, and long-distance trade governed by mercantilism.

The choice of slow combustion was inextricably linked to a change of identity whereby these early versatile producers – farmers and metalworkers – became 'blacksmiths', according to criteria imposed on them by the Yatenga rulers. The technological change was the consecration and embodiment of this status of full-fledged 'artisan'. In return for their submission to authority and acceptance of a system of social enclosure, the ironworkers enjoyed an increasing monopoly of the production of iron in a context favourable to demographic, spatial and social expansion. In contrast, the farmer-metalworkers of the neighbouring regions of Samo and Dogon continued to engage in essentially sedentary and local activities. Buyers (blacksmiths and farmers) continued to come to them for supplies of hard iron. The territory and the world of the blacksmiths were quite different. Their existence and their activity were, from apprenticeship onward, marked by great economic and migratory mobility. This enabled them, in a sense, to regain their freedom. The dynamism of this ironworking tradition, characterized by the invention of furnaces of a capacity exceptional for sub-Saharan Africa, was based on intensive flows of knowledge, individuals and products. This mobility required open and safe communication routes. That was the basis of the compromise between the Yatenga rulers and the ironworkers. The social causes of this transformation are therefore numerous and interrelated: the general development of agriculture, the reinforcement of political power at the centre and periphery of the administered territories, the establishment of safe routes and markets, and the prevailing social dynamics at both local and regional levels.

Assessment of the Dating of Ancient Relics of Ironworking in Africa: Main Lessons

Louise-Marie Maes-Diop

Contrary to the 'Carthaginian theory', in 1968 we ended an article entitled 'Traditional metallurgy and the iron age in Africa' with the following words:

> While it now seems proven that traditional iron metallurgy in Africa was very old, widespread and indigenous, it still remains, on the other hand, to be determined where the earliest ironworking centres were, together with their precise dates and hypothetic iron roads across the continent.
>
> (Maes-Diop, 1968)

Over the last thirty years or so, several very important dates have been established which make it possible to pinpoint the antiquity of iron metallurgy in Black Africa. If we adopt the type of table prepared by Jean-Pierre Mohen, our current knowledge of the beginning of the Iron Age in Africa and the world may be summarized as in Table 15.

Table 15. Chronological order and location of the most ancient relics of reduced iron ore in the world

Dates B.C.	Location	Type of samples
2900–2300	Eastern Niger	Various artefacts
2565–2440	Egypt	Terrestrial reduced iron (hoe)
2520–1675	Eastern Niger	Various artefacts
2450–2100	Mesopotamia and Anatolia	Dagger blades and fragments
2345–2181	Egypt	Block of iron ore (reduced)
1991–1786	Lower Egyptian Nubia (Middle Kingdom)	Spearhead
1870–1130	Eastern Niger	Various artefacts
1810–1375		
1800–1750	Cyprus	Coarse pearl
1400–1200	Lake Victoria – Nyanza region	
1300–800	Cameroon	
Around 1100	China	

Dates B.C.	Location	Type of samples
Around 950	Greece, Nigeria (perhaps much earlier)	
903–796	Central Africa	
713	Napata (Nubia)	
Seventh century	Gabon, Carthaginian world, India	
Sixth century	Meroe	

J. P. Mohen (1990, 2001) also draws attention to an iron tool (containing no nickel) found in a grave dated 5000 B.C. at Samarra in Iraq, about which there are questions. In addition, the blade of the Tell Asmar dagger (in Mesopotamia) had disappeared as a result of oxidation. What was analysed were a few scraps that were stuck to the handle, that is, particles of oxide deriving from the decomposition of the blade. In this case, the apparent absence of nickel is hardly conclusive. On the basis of the dates obtained at Egaro, some of the terrestrial iron samples found in Egypt dating back to the Old Kingdom (2565–2181 B.C.) may be thought to be West African in origin, all the more since in Mesopotamia and in Anatolia the dates range between 2450 and 2100 B.C., except if that of Samarra was to be confirmed. It should be noted that the iron relics are usually rusty.

After the crucial dates of Eastern Niger (Quéchon et al., 1992) and those of the regions near the western and southern shores of Lake Victoria Nyanza (Van Grunderbeek, 1982), significant dates were obtained in 1998–9: in Cameroon for the Oliga site (north of Yaoundé) a series of dates spanning the period from 1300 B.C. to A.D. 567 (Essomba, 1998). In the Central African Republic, in the megalithic region of Bouar at the Gbabiri site (site 77), the rectified dates are around 800 B.C. (Zangato, 1995, 1999). Accordingly the antiquity and endogenous nature of African palaeo-ironworking are now unquestionable and undisputed. The schematic map (Figure 13) summarizes the location of iron sites prior to the sixth century B.C.

The civilization of Nok-Taruga (Nigeria, to the north of Basse Bénoué) is characterized above all by its terracotta figurines, which are associated with an iron industry; the carbon-14 dates span from 3500 B.C. to A.D. 200. In fact, only a few dates exist for the Nok region due to a lack of sufficiently numerous and systematic excavations. For forty years, the two oldest dates, 3500 B.C. and 2000 B.C., have been deemed unacceptable without valid reason. At the present time the dates generally admitted for the Nok civilization do not go back beyond the ninth or tenth centuries B.C. In view of the antiquity of iron in the Termit Massif, which may date from before 2500 B.C., this question should be reconsidered. Furthermore, in his chapter, Aremu mentions a number of iron objects found at Dusten Kongba (Plateau state, to the north of Bénoué) in a layer dated

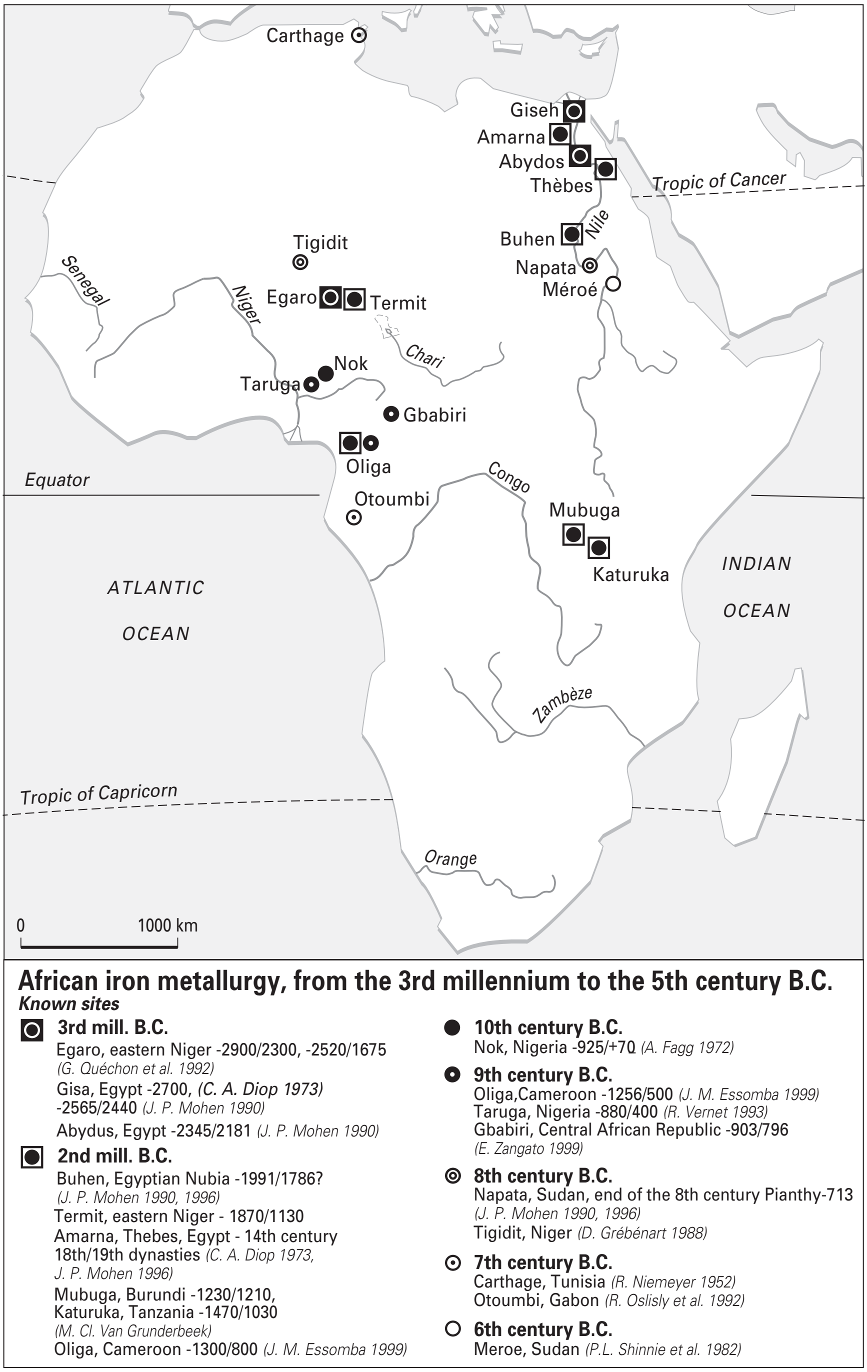


Figure 13. African iron metallurgy from the third millennium to the fifth century B.C.: known sites (© L.-M. Maes-Diop, after J.-L. Tamissier).

2780 B.C. ± 100. One cannot over-emphasize the priority that should be accorded to this region as a location for thorough excavations, all the more since in eastern Niger, iron artefacts are older than remains of furnaces (see Chapter 5 by Bocoum).

In Zambia iron is present from at least the beginning of the Christian era. In South Africa (southern bank of the Limpopo), there is evidence of iron metallurgy in the third century A.D.

The very presence of the iron industry that arose in sub-Saharan Africa, in conjunction with that of stone and other metals (copper, gold, tin, bronze and so on), implies a relatively high population. Trade already existed in Black Africa in that early period: 'A certain number of objects which have been excavated show that extensive trade networks existed in the early Iron Age' (Van Noten, 1981). This author points out that that trade must have been 'chiefly confined' to areas near the great rivers, since sites far from the main river arteries or lake regions have produced very few imported objects.

Such extensive trade networks existed in the third millennium B.C. (in this connection, let us recall the four expeditions conducted by the Egyptian Herkuf in the twenty-fourth century B.C.): hence the possibility of iron trade between the various regions of Africa. The word for iron is similar in ancient Egyptian and in the Bantu and Sudanese languages.[1] Iron may have reached Egypt from western and central Sudan via Ennedi, where ancient evidence of spears was noted by Huard (1964).

Further excavations and dating are needed to increase our knowledge, although the speed with which iron disappears in hot and humid climates is likely to make it difficult to ascertain the true situation in many cases.

In conclusion, it would appear that the reduction technique for iron ore was invented in Black Africa towards the middle of the third millennium B.C., that is at the same time or perhaps even earlier than in western Asia. Those two centres of invention were not connected, apparently. However, this is not absolutely certain. It is worth noting that neither Egypt nor Mesopotamia had iron ore in their own territories. But given that they already knew how to smelt other metals, reduced iron ore may have been imported. However, the findings of excavations and dating suggest that ironworking, in the history of humanity, sprang from western Africa on the one hand and on the other hand from Anatolia. This said, none the less, other regions might have surprises in store.

Systematic prospecting should be carried out, not only in the Nok region, the areas between Nok and the Termit Massif and in Chad (at Korotoro and in the Ennedi region), as well as in the oases that link Chad to Egypt (Nukheila/Merga, Bir Abu Husein, Selima, Kharga, Dakhla, Farafra), around Lake Victoria

1. Whereas, on the contrary, the common root of the word for 'iron' in the Semitic languages is quite different (Lhote, 1952).

Nyanza, and between Nok and Sine-Saloum (Senegal). Furthermore, the mines in Télénugar in Chad have yet to be dated, not to mention the iron that has appeared in layers post-2000 B.C. in the Nachikufien sites (Zambia).

Cultural foundations and institutions should play an active role in promoting excavations and dating, as well as the incorporation into school and university textbooks of this new information, which considerably modifies the erroneous vision that still prevails both of Africa's past and of the continent's contribution to the technical and cultural development of humanity.

General Bibliography

ADEDIRAN, B. 1981. The early beginnings of the Ife state. In: I. A. Akinjogbin (ed.), *A History of Ife*. Ife, Université Obafemi Awolowo.

——. 1984. Ife-Western Yoruba dynastic links re-examined. *Africa Zamani*, Nos. 14–15, pp. 82–5.

ADENIJI, D. 1977. *Iron Mining and Smelting. No. 31.* Ibadan, Institute of African Studies, University of Ibadan. (Occasional publication originally written in Yoruba, and translated into English by Professor R.G. Armstrong.)

AFIGBO, A.E. 1973a. Trade and trade routes in nineteenth-century Nsukka. *Journal of Historical Society of Nigeria*, Vol. 7, No. 1, pp. 77–90.

——. 1973b. Prolegomena to *The Study of the Cultural History of the Igbo-Speaking Peoples of Nigeria, West Africa.* (Presented to the IXth International Congress of Anthropological and Ethnological Sciences in Chicago, USA, 28 August–8 September 1973.) London, Oxford University Press, pp. 16–17.

AKINJOGBIN, I.A. 1981a. *Yoruba before Oduduwa.* Ife, O.A.U. (Seminar series, Department of History.)

——. 1981b. *A History of Ife*. Ife, Université Obafemi-Awolowo.

ANDAH, B.W. 1979. Iron-age beginnings in West Africa: reflections and suggestions. *West African Journal of Archaeology*, Vol. 9, pp. 135–50.

——. 1981. Prehistoric reconnaissance of parts of North Central Upper Volta: its bearing on agricultural beginnings. Dakar, *Bulletin de l'I.F.A.N.*, Vol. 4, No. 2, pp. 219–50.

ANON. 1903. Native crowns. *Journal of the African Society*, Vol. 2, No. 7 (April), pp. 312–15.

ANOZIE, F.N. 1979. Early iron technology in Igboland (Lejja and Umundu): perspectives on West Africa's past. *West African Journal of Archaeology*, Vol. 9, pp. 119–34.

AREMU, D.A. 1990. *Archaeology of Northeast Yorubaland, Kwara State, Nigeria, with Emphasis on Early Techniques of Metalworking.* Ph.D. thesis, Ibadan, University of Ibadan, Department of Archaeology and Anthropology.

——. 1999. Preservation of Ampara and Delimiri ironworking sites: toward the promotion of Nigeria's cultural heritage. *African Archaeological Review* (London), Vol. 16, No. 14, pp. 199–210.

ARKELL, J. 1966. The Iron Age of Sudan. *Current Anthropology*, Chicago, University of Chicago Press, Vol. 7, No. 4, pp. 451–2.

ARMSTRONG, R.G. 1962. Glottochronology and West African linguistics. *Journal of African History*, Vol. 2, pp. 284.

——. 1964. *The Study of West African Linguistics.* Ibadan, Ibadan University Press, pp. 22–3.

ATANGANA, C. 1988. *Archéologie du Cameroun méridional: étude du site d'Okoli* [Archaeology of Southern Cameroon: Study of the Okoli Site]. Doctoral thesis in Archaeology. Paris, University of Paris I (Panthéon-Sorbonne).

AVERY, D.H.; NICHOLAS, S.; VAN DER MERWE, J.; SAITOWITZ, S. 1988. The metallurgy of the iron bloomery in Africa. In: R. Maddin (ed.), *The Beginning of the Use of Metals and Alloys*, Cambridge, MA, MIT Press, pp. 261–82.

AVERY, D.H. and SCHMIDT, P. 1986. The use of preheated air in ancient and recent African iron-smelting furnaces: a reply to Rehder. *Journal of Field Archaeology*, No. 13, pp. 354–7.

BARENDSON, G.W.; DEEVEY, E.S.; GRALENSKY, L.J. 1965. Yale natural radiocarbon measurements, III. *Science*, No. 126.

BARROS, P. (de). 1985. *The Bassar: Large-Scale Iron Producers of the West African Savanna.* Ph.D. thesis, Ann Arbor, University Microfilms International.

BELLAMY, C.V. and HARBORD, F.W. 1904. West African smelting house. *Journal of the Iron and Steel Institute,* Vol. 66, No. 2, pp. 99–126.

BIÉLENIN, K.; MANGIN, M.; ORZECHOWSKI, S. (with contribution by P. FLUZIN and A. PLOQUIN). 1998. La sidérurgie ancienne et l'exploitation minière dans les montagnes Sainte-Croix (Petite Pologne). III. Archéométrie et histoire: les montagnes Sainte-Croix et les régions productives européennes (fin de l'âge de fer – début du Moyen Age) [Ancient ironworking and mining in the Sainte-Croix Mountains and the productive regions of Europe (end of Iron Age to start of Middle Ages)]. *Dialogues d'histoire ancienne*, No. 24/1, pp. 139–93.

BOCOUM, H. 1988. Métallurgie et couvert végétal dans la moyenne vallée du Sénégal et dans les régions voisines [Metallurgy and plant cover in the lower valley and adjoining regions of Senegal]. *Notes de biogéographie,* No. 3, Dakar, Université Cheikh Anta Diop, Centre régional inter-africain d'archéologie, pp. 67–78.

——. 1990a. *La métallurgie du fer au Sénégal des origines au XXe siècle: esquisse d'une évolution des techniques de production. Symposium international du Comité de la métallurgie ancienne* [Iron metallurgy in Senegal from the origins to the twentieth century: evolution of production techniques at a glance. International symposium of the committee on ancient metallurgy]. Paris/Belfort, Editions Belfort Sevenans.

——. 1990b. Contribution à la connaissance des origines du Takrur [Contribution to knowledge of the origins of the Takrur]. *Annales de la Faculté des Lettres et Sciences Humaines* (Dakar), No. 20, pp. 159–78.

——. 1995a. Les routes du fer en Afrique, grandeur et décadence des forgerons [The Iron Roads in Africa: glory and decadence of blacksmiths]. *Sources* (Paris, UNESCO) No. 70, p. 4.

——. 1995b. *Bibliographie du fer en Afrique de l'Ouest* [Bibliography of iron in West Africa]. Paris, UNESCO. (Document.)

——. 2000. *L'âge du fer au Sénégal* [The Iron Age in Senegal]. Dakar, Institut fondamental d'Afrique noire, Université Cheikh Anta Diop.

BOCOUM, H.; GUILLOT, I.; FLUZIN, P. 1988. Apport de la métallographie structurale à l'interprétation fonctionnelle de trois objets en fer du Sénégal [Contribution of structural metallography to the functional interpretation of three iron objects in Senegal]. *Revue d'archéométrie,* No. 12, pp. 57–69.

CALVOCORESSI, D. and DAVID, N. 1979. A new survey of radiocarbon and thermoluminescence dates for West Africa. *Journal of African History,* Vol. 20, No. 1, pp. 1–29.

CELIS, G. 1991a. *Eisenhütten in Afrika* [Ironmaking in Africa]. Frankfurt am Main, Museum für Völkerkunde.

——. 1991b. *Les fonderies africaines du fer, un grand métier disparu* [African iron foundries: a great art lost]. Frankfurt am Main, Museum für Völkerkunde.

CHEZEAU, N. and FLUZIN, P. 1997. Historique des aciers spéciaux. In: G. Beranger, G. Henry, P. Soulignac (eds.), *Les aciers spéciaux* [History of special steels], Paris, Lavoisier (Collection 'Techniques et documentation'), pp. 3–20.

CHILDS, S.T. 1968. Clay to artifacts: resource selection in African early-iron-age ironmaking technologies. In: G. Bronitsky (ed.), *Pottery Technology Ideas and Approaches,* London, Westview Press.

——. 1984. *Clay to Artifacts: Resource Selection in African Early-Iron-Age Iron-making Technologies.* Denver, paper from American Anthropologists Association, 83rd Annual Meeting.

——. 1986. *Style in Technology: A View of African Early-Iron Age Smelting through its Refractory Ceramics.* Unpublished Ph.D. thesis. Boston, Boston University.

——. 1989. *Copper and Iron: Bearers of Powers and Status in Zaïre and Zimbabwe.* Final Report to the Getty Foundation (for the period of February to August 1989).

——. 1991a. Transformation: iron and copper production in Central Africa. In: P. Glumac (ed.), *Recent Advances in Archaeometallurgical Research.* Philadelphia, MASCA/University of Pennsylvania Museum, pp. 33–46.

——. 1991b. Style, technology and iron furnace in Bantu-speaking Africa. *Journal of Anthropological Archaeology,* Vol. 10, pp. 332–59.

CHILDS, S.T.; DEWEY, W.; KAMWANGA, M.; de MARET, P. 1990. Iron Age and Stone Age research in the Shaba Region, Zaïre: an interdisciplinary and international effort. *Nyame Akuma,* No. 323, pp. 54–9.

CLARK, J.D. 1969. *The Prehistory of Africa.* London, Thames and Hudson.

CLINE, W.B. 1937. *Mining and Metallurgy in Negro-Africa.* Menasha, George Banta. (General Series in Anthropology, No. 5.)

——. 1936. *The Sources of Metal and Techniques of Metal Working in Negro-Africa.* Cambridge, Harvard University Press.

CLIST, B. 1988. La fin de l'âge de la pierre et les débuts de la métallurgie du fer au Gabon: résultats préliminaires des recherches de terrain de 1986 à 1987 [The end of the Stone Age and the beginning of iron metallurgy in Gabon: preliminary results of field research from 1986 to 1987]. *Nsi* (Libreville), No. 2, pp. 24–8.

——. 1989. Vestiges archéologiques de fonte du fer dans la Province du Woleu Ntem au Gabon [Archaeological remains of iron smelting in the province of Woleu Ntem in Gabon]. *Nsi* (Libreville), No. 6, pp. 79–96.

CLIST, B. and LANFRANCHI, R. 1989. Vestiges archéologiques de fonte du fer dans la Province du Woleu Ntem au Gabon [Archaeological remains of iron smelting in the province of Woleu Ntem in Gabon]. *Nsi* (Libreville), No. 6, pp. 139–50.

——. 1995. *Gabon, 100,000 ans d'histoire* [Gabon: 100,000 years of history]. Saint-Maur, Sépia.

CLIST, B.; LANFRANCHI, R; OSLISLY, R.; PEYROT, B. 1986. Métallurgie ancienne du fer au Gabon: premiers éléments de synthèse [Ancient iron metallurgy in

Gabon: a preliminary survey]. *Muntu, revue scientifique et culturelle du CICIBA* (Libreville), No. 5, pp. 47–55.

COELHO LEMOS, F. (de). 1953. *Duas Descriçoes Seiscentistas da Guiné. Citada a paginaçao, seguida da folha dos.* Lisbon, D. Peres. (Manuscript.)

COGHLAN, H.H. 1942. Some fresh aspects of the prehistoric metallurgy of copper. *Antiquity,* No. 22, pp. 22–38.

CONNAH, G. 1968. Radiocarbon dates for Benin City and further dates for Daima, N.E. Nigeria. *Journal of Historical Society of Nigeria,* Vol. 4, No. 2, pp. 317–20.

——. 1971. Recent Contributions to Bornu Chronology. Ibadan, *West African Journal of Archaeology,* Vol. 11.

——. 1981. *Three Thousand Years in Africa: Man and His Environment in the Lake Chad Region of Nigeria.* Cambridge, Cambridge University Press.

CREW, P. 1991. The experimental production of prehistoric bar iron. *Historical Metallurgy,* Vol. 25, No. 12, pp. 21–36.

DAVIES, O. 1966. Comment on iron in Sub-Saharan Africa (Comments on the Iron Age of Southern Rhodesia by Summers). *Current Anthropology* (Chicago), Vol. 7, No. 4, pp. 470–71.

DELNEUF, M.; FROMENT, A.; ESSOMBA, J.-M. 1999. *Paléo-anthropologie en Afrique centrale* [Palaeo-anthropology in Central Africa]. Paris, L'Harmattan.

DE PEDRALS, D. 1950. *Archéologie de l'Afrique noire* [Archaeology of Black Africa]. Paris, Payot.

DILLMAN, P.; FLUZIN, P.; BENOÎT, P. 1998. Du fer à la fonte. Nouvelles approches archéométriques [From iron to cast iron: new archaeometrical approaches]. In: *L'innovation technique au Moyen-Age. Actes du VI[e] Congrès international de la Société d'archéologie médiévale* [Records of the Sixth International Congress of the Society of Medieval Archaeology], (Dijon, October 1996.) Paris, Errance, pp. 160–8.

DIOP, C.A. 1973. La métallurgie du fer sous l'ancien Empire égyptien [Ironworking in the ancient Egyptian Empire]. *Bulletin de l'IFAN,* Série B, No. 3, pp. 533–47.

——. 1976. L'usage du fer en Afrique [The use of iron in Africa] *Notes africaines,* Dakar, IFAN, No. 152, pp. 94–5.

DUNIKOWSKI, C.; LEROY M.; MERLUZZO, P.; PLOQUIN, A. 1996. L'atelier de forge gallo-romain de Nailly-Les Bordes (Yonne): contribution à la caractérisation des déchets de production [The Gallo-Roman iron workshop at Nailly-les-Bordes (Yonne): contribution to identification of production remains]. *Revue Archéologique de l'Est,* Vol. 47, pp. 97–121.

DUPRÉ, M.C. 1981–2. Pour une histoire des productions: la métallurgie du fer chez les Teke (Congo) [Towards a history of manufacturing: ironworking among the Teke (Congo)]. *Cahiers de l'ORSTOM,* Série Sciences humaines, Vol. 18, No. 2, pp. 195–223.

DURAND, A.; PARIS, F.; SALIEGE, J.-F. 1999. Peuplements et environnements holocènes du bassin oriental de l'Azawagh (Niger) [Holocene population and environments of the eastern basin of the Azawagh (Niger)]. In: F. Paris (ed.), *Études nigériennes,* Saint-Maur, Sépia, No. 57, pp. 33–70.

ÉCHARD, N. 1965. Note sur les forgerons de l'Ader (pays Hausa, Niger) [Note on the blacksmiths of Ader (Hausa country, Niger)]. *Journal de la Société des Africanistes*, Paris, Vol. 35, pp. 353–72.

——. 1983a. (ed.). *Métallurgies africaines. Nouvelles contributions* [African metallurgy: new contributions]. Paris, Société des Africanistes.

——. 1983b. Scories et symboles. Remarques sur la métallurgie hausa du fer au Niger [Slag and symbol: comments on Hausa ironmaking in Niger]. In: N. Echard (ed.), *Métallurgies africaines. Nouvelles contributions.* Paris, Société des Africanistes.

——. 1992. À propos de la métallurgie: système technique, organisation sociale et histoire [Metalworking: technical system, social organization and history]. In: E. Bernus and N. Échard (eds.), La région d'In Gall-Tegidda-n-Tesemt (Niger). *Etudes Nigériennes,* (Paris, Karthala), No. 52, Paris, Karthala.

EFFAH-GYAMFI, K. 1981. Excavation of an early Iron-Age occupation site at Samaru-West, Zaria. *Zaria Archaeological Paper,* No. 3, pp. 6–54.

EKECHUKWU, L.C. 1989. A new furnace type from the north of Igboland. *Nyame Akuma,* No. 32, pp. 20–21.

ESSOMBA, J.-M. 1979. *Introduction à l'étude du fer dans l'histoire des sociétés traditionnelles du Sud Cameroun* [Introduction to the study of iron in the history of traditional societies in southern Cameroon]. CERELTRA liaison (ONAREST). Final report of the first meeting, held in Garoua, of archaeologists working in Cameroon. Yaoundé. (Duplicated.)

——. 1985. Archéologie et histoire au sud du Cameroun: découverte et hauts-fourneaux en pays bassa [Archaeology and history in southern Cameroon: discovery of blast furnaces in the Bassa region]. *Nyame Akuma,* No. 26, pp. 2–4.

——. 1986a. Quelques analyses de métallurgie ancienne du fer à Pan Pan en pays bassa (Sud Cameroun) [Analyses of ancient iron metallurgy at Pan Pan in the Bassa region (southern region)]. *Nsi* (Libreville), pp. 15–19.

——. 1986b. Recherche sur l'identité ethnique des Fali du Cameroun. Contribution de l'archéologie [Research on the ethnic identity of the Fali of Cameroon:

the contribution of archaeology]. *Archéologie africaine et sciences de la nature appliquées à l'archéologie* (Bordeaux, 1983). Paris, Organisation internationale de la francophonie (ACCT)/Centre national de la recherche scientifique (CNRS)/Centre régional inter-africain d'archéologie (CRIAA), pp. 519–34.

——. 1986c. Le fer dans le passé des sociétés traditionnelles du Sud-Cameroun [Iron in the past of traditional societies of South Cameroon]. Ibadan. *West African Journal of Archaeology,* No. 16, pp. 1–24.

——. 1988. *Trois ans de recherches archéologiques au Sud-Cameroun: bilan et perspectives (1984–1987)* [Three years of archaeological research in southern Cameroon: results and prospects]. University of Yaoundé. (Duplicated.)

——. 1989. Dix ans de recherches archéologiques au Cameroun méridional (1979–89) [Ten years of archaeological research in southern Cameroon (1979–89)]. *Nsi* (Libreville), No. 6, pp. 33–57.

——. 1992a. Archéologie du Sud-Cameroun. Notes préliminaires de recherches au site de Nkometou (Mfomakap) [The Archaeology of South Cameroon: preliminary research notes on the Nkometou site (Mfomakap)]. In: J.-M. Essomba (ed.), *L'archéologie au Cameroun,* (Conference in Yaoundé, January 1986.) Paris, Karthala, pp. 228–45.

——. 1992b. *Civilisation du fer et sociétés en Afrique centrale* [Iron civilization and societies in Central Africa]. Paris, L'Harmattan.

——. 1998. L'archéologie de l'âge de fer au Cameroun méridional [Iron Age Archaeology in Southern Cameroon]. In: M. Delneuf; A. Froment; J.-M. Essomba (eds.), *Paléo-anthropologie en Afrique centrale*, Paris, L'Harmattan, pp. 233–47.

EVIN, J. and OBERLIN, C. 1998. La méthode de datation par le radiocarbone (Radiocarbon dating methodology). In: J. Evin; G.-N. Lambert; L. Langouët; P. Lanos; C. Oberlin (eds.), *La datation en laboratoire,* Paris, Éditions Errance, pp. 75–117.

FAGAN, B.M. 1967. Radiocarbon dates for Sub-Saharan Africa. *Journal of African History* (Cambridge), Vol. 8, pp. 513–27.

——. 1969. Radiocarbon dates for Sub-Saharan Africa. *Journal of African History* (Cambridge), Vol. 10, pp. 495–506.

——. 1999. Early trade and raw materials in South Central Africa. *Journal of African History* (Cambridge), Vol. 40, pp. 1–16.

FAGG, B. 1969. Recent work in West Africa: new light on the Nok culture. *World Archaeology,* Vol. 1, pp. 41–50.

FALL, A. 1985. *Situation actuelle de l'environnement et de l'utilisation du parc de matériels de culture attelée en Basse Casamance: enquêtes menées dans quatre*

villages du département de Bignona [Present state of the environment and of the use of cultivation implements in Basse Casamance: studies carried out in four villages of Bignona]. Mémoire de confirmation. Dakar, ISRA, Département de recherches sur les systèmes de production et le transfert de technologies en milieu rural.

——. 1995. *Methodology for evaluating the impact of animal traction at the farm level in a small-scale multi-cropping system (Basse Casamance, Sénégal)* Vols. 1 and 2. Partial Ph.D. thesis, Michigan State University, USA.

——. 1997. Étude sur la situation et les perspectives de l'industrie du machinisme agricole au Sénégal. Première consultation régionale sur le développement de l'industrie du machinisme agricole en Afrique, November 1981 [Study of the state and prospects of the industry of mechanized agriculture in Senegal. First Regional Consultation on the development of mechanized agricultural industry in Africa, November 1981]. ONUDI/OUA/CEA/FAO.

FELLS, S. 1983. The Structure and Constitution of Archaeological Ferrous Process Slags. Unpublished Ph.D. thesis, Aston, University of Aston in Birmingham.

FLUZIN, P. 1983. Notions élémentaires de sidérurgie [Introduction to ironmaking]. In: N. Echard (ed.), *Métallurgies africaines. Nouvelles contributions*, Paris, Société des Africanistes (Mémoires de la Société des Africanistes), pp. 13–44.

——. 1994. Interprétations des études métallographiques des scories; recherches d'éléments discriminatoires [Interpretations of metallographical studies of slag: the search for distinguishing factors]. In: Mangin, M. (ed.), *La sidérurgie ancienne de l'Est de la France dans son contexte européen, archéologie et archéométrie* [Ancient ironworking of eastern France in its European, archaeological and archaeometrical context], Actes du Colloque de Besançon, 10–13 Nov. 1993. Paris, Les Belles Lettres (Annales Littéraires de l'Université de Besançon), pp. 24–30.

——. 1999. Ponte di val Gabbia III (Bienno) i reperti metallici dalla forgia. Primi risultati dello studio metallografico [The Val Gabbia III Bridge (Bienno): the forged metal parts. Preliminary findings of the metallographical study]. In: C. Cucini Tizzoni and M. Tizzoni (eds.), *La miniera perduta. Cinque anni di ricerche archeometallurgique nel territorio di Bienno* [The Lost Mine: five years of archaeometrical research in Bienno territory], Bienno, Breno, pp. 61–92 and 189–94.

——. 2000a. Ponte di val Gabbia III (Bienno): les premiers résultats des études métallographiques. Proceedings of International Conference on Iron in the Alps. Deposits, mines and metallurgy from antiquity to the 15th century. Bienno, Italy, 2–4 October 1998. In: C. Tizzoni (ed.), *Iron in the Alps*, Bienno, Breno, pp. 24–31.

——. 2000b. *Études métallographiques préliminaires concernant les vestiges sidérurgiques du site de Montagney (Doubs)* [Preliminary metallographical studies of ironworking remains at the Montagney (Doubs) site]. Basel, Minaria Helvetica, pp. 91–104.

FLUZIN, P.; BENOÎT, P.; KIENON, H.T.; KIETHEGA, J.B.; EL KEDIM, O. 1995. Apports de l'archéométrie à la restitution de la chaîne opératoire des procédés directs à partir des vestiges archéologiques: intérêts des comparaisons ethnoarchéologiques [Contribution of archaeometry to restoring the sequence of direct process operations from archaeological remains: benefits of ethnoarchaeological comparisons]. In: G. Magnusson (ed.), *The Importance of Ironmaking. Technical Innovation and Social Change.* Norberg Conference, May, 2 vols. Stockholm, Jernkontorets Berghistoriska Utskott, pp. 56–64.

FLUZIN, P. and GAFFET, E. 1997. *La poudre et l'enclume* [Power and anvil]. Paris, La Villette. CNRS Audiovisuel (video film).

FLUZIN, P.; GAFFET, E.; HERBACH, R.; DILLMAN, P. 2001. *Études métallurgiques et thermodynamiques des expérimentations de la forge d'Agorregi* [Metallurgical and thermodynamic studies of experiments at Agoreggi forge]. San Sebastian, Arkéolan.

FLUZIN, P.; GAFFET, E.; LECLÈRE, D. 1998. État de l'interprétation des scories sidérurgiques (procédés directs) à partir des investigations métallographiques [State of interpretation of iron and steel slags (direct processes): metallographical studies]. In: G. Nicolini and N. Dieudonné-Glad (eds.), *Actes du colloque sur les métaux dans l'Antiquité: travail et conservation.* 28–30 September 1995. Vol. 6, Editions Instrumentum, pp. 135–44.

FLUZIN, P.; GAFFET, E.; SERNEELS, V.; BENOÎT, P.; KIENON, H.T. 1999. Reconstitution of operating chain palaeo-iron and steel metallurgy from the archaeological remains: comparative studies with the African ethnoarchaeology. In: S. Beyriees and P. Pétrequin (eds.), *Ethno-Archaeology and its Transfer,* Bournemouth, BAR, pp. 1–10.

GASCO, J. 1985. Histogrammes et dates radiocarbone [Histograms and radiocarbon dating]. *Bulletin de la Société préhistorique française,* Vol. 82, No. 4, pp. 108–11.

GAUTHIER, J.G. 1981. Les Fali du Cameroun septentrional [The Fali of northern Cameroon]. In: C. Tardits, *Contribution de la recherche ethnologique à l'histoire des civilisations du Cameroun* [Contribution of ethnological research to the history of the civilizations of Cameroon], Vol. 1, Paris (CNRS symposium, No. 551), pp. 187–203.

——. 1986. Recherche sur l'identité ethnique des Fali du Cameroun: contribution de l'archéologie [Research on the ethnic identity of the Fali of Cameroon: the contribution of archaeology]. In: *Archéologie africaine et sciences de la nature appliquées à l'archéologie* [African archaeology and natural sciences applied to archaeology], (Bordeaux, 1983.) Paris, Organisation internationale de la francophonie (ACCT)/Centre national de la recherche scientifique (CNRS)/Centre régional inter-africain d'archéologie (CRIAA), pp. 519–34.

GOUCHER, C. 1984. *The Iron Industry of Bassar, Togo: An Interdisciplinary Investigation of African Technological History.* Ph.D. thesis, Los Angeles, University of California.

GRÉBÉNART, D. 1983a. Les métallurgies du cuivre et du fer autour d'Agadez (Niger): des origines au début de la période médiévale. Vues générales [Copper and iron metallurgy in the region of Agadez (Niger): from the origins to the start of the medieval period. Overall view]. In: N. Echard (ed.), *Métallurgies africaines. Nouvelles contributions*, Paris, Société des Africanistes (Mémoires de la Société des Africanistes, Vol. 9), pp. 109–26.

——. 1983b. *L'âge ancien du fer au Niger antérieurement à l'ère chrétienne* [The Ancient Iron Age prior to the Christian Era]. Communication au colloque 'Histoire de la métallurgie du fer de la mine au métal avant l'adoption du procédé indirect'. Paris, Centre de recherches archéologiques (CRA).

——. 1985. Le Néolithique final et l'âge des métaux autour d'Agadez (Niger) [The final Neolithic and metal ages in the region of Agadez (Niger)]. *Études nigériennes,* Vol. 49.

——. 1987. Characteristics of the final Neolithic and metal ages in the region of Agadez (Niger). In: A. Close (ed.), *Prehistory of arid North Africa: Essays in Honour of Fred Wendorf*, Dallas, Southern Methodist University Press, pp. 287–316.

——. 1988. *Les premiers métallurgistes en Afrique occidentale. Les origines de la métallurgie en Afrique occidentale* [The first metallurgists in West Africa]. Paris/Abidjan, Errance/Les Nouvelles Éditions Africaines.

GRIAULE, M. 1966. *Dieu d'eau* [God of water]. Paris, Fayard (1st ed., 1948).

GRIFFON, R. 1999. *Le dernier forgeron* [The last blacksmith]. Paris, Fayard.

GROUPE DE TRAVAIL SUISSE D'ARCHÉOLOGIE DU FER. 1997. Minerais, scories, fer: cours d'initiation à l'étude de la métallurgie du fer ancienne et à l'identification des déchets de cette industrie [Minerals, slags, iron: introductory course for the study of ancient iron metallurgy and identification of the slags of that industry]. *Technique des Fouilles* (Basel), Special Issue.

GUILLOT, I.; FLUZIN, P.; CLAVEL, M.; BERANGER, G. 1987. Structure d'outils miniers des XV[e] et XVIII[e] siècles; interprétation thermomécanique [Structure of mining tools of the fifteenth and eighteenth centuries: thermomechanical interpretation. *Matériaux et techniques,* No. 10, (October), pp. 411–19.

GUTHRIE, M. 1970. Contributions from comparative Bantu to the study of African prehistory. In: D. Dalby (ed.), *Language and History in Africa.* London, Dalby.

GUTZEIT, G. 1934. La fonte de la monnaie (croisettes) chez les Baluba du territoire de Musonoï (Haut-Katanga Ouest) [Baluba money casting (crosses) in Musonoï territory (western Upper Katanga)], *Archives suisses d'Anthropologie générale,* Vol. 7, No. 1, pp. 73–81.

HARTLE, D.D. 1967. Archaeology in Eastern Nigeria. *Nigerian Magazine,* No. 93, pp. 143.

——. 1989a. Traditional iron-smelting methods by the Biroin of Plateau State, Nigeria. *Nyame Akuma*, No. 23.

——. 1989b. *A Survey of Traditional Methods of Iron Smelting in Parts of the Northern States, Nigeria.* Communication presented at the 8th Annual Conference of the Archaeological Association of Nigeria, Minna, (25 June–1 July 1989).

HAWKES, J. and WOOLLEY, L. 1963. *Prehistory and the Beginnings of Civilization.* London, Allen and Unwin.

HERBERT, E. 1993. *Iron, Gender and Power: Rituals of Transformation in African Societies.* Bloomington, Indiana University Press.

HEUSCH, L (de). 1956. Le symbolisme du forgeron en Afrique noire [The symbolism of the blacksmith in Black Africa]. *Reflets du Monde,* Vol. 10, pp. 139–50.

——. 1982. *Rois nés d'un cœur de vache* [Kings born in the heart of a cow]. Paris, Gallimard.

HOLL, A. 1983. *La question de l'âge du fer ancien de l'Afrique occidentale: essai de méthode. Communication au colloque 'Histoire de la métallurgie du fer de la mine au métal avant l'adoption du procédé indirect'* [The question of the ancient Iron Age in West Africa: a trial method. Paper presented to the symposium on The history of iron metallurgy from mine to metal before the adoption of the indirect process]. Paris, Centre de recherches archéologiques (CRA).

——. 1985. Background to the Ghana Empire: archaeological investigations on the transition to the statehood in the Dhar Tichitt region (Mauritania). *Journal of Anthropological Archaeology,* Vol. 4, No. 1, pp. 73–115.

——. 1988. Transition du néolithique à l'Âge du fer dans la plaine péritchadienne. Le cas de Mdaga [The transition from the Neolithic Period to the Iron Age in the Perichad Plain: the case of Mdaga]. In: D. Barretteau and Tourneaux (eds.), *Le milieu et les hommes: recherches comparatives et historiques dans le bassin du lac Tchad* [The environment and humankind: comparative and historical research in the Lake Chad basin]. Paris, ORSTOM.

——. 1991. L'âge du fer au Cameroun [The Iron Age in Cameroon]. In: R. Lanfranchi and B. Clist (eds.), *Les origines de l'Afrique Centrale.* Paris, Sepia.

——. 1993. Transition from late Stone Age to Iron Age in the Sudano-Sahelian Zone: a case study from the Perichad Plain. In: T. Shaw, P. Sinclair, B. Andah and A. Okpoko (eds.), *The Archaeology of Africa: Food, Metal and Town*, London, Routledge, pp. 330–43.

——. 1997. Metallurgy, iron technology and African late holocene societies. In: R. Klein-Arendt (ed.), *Traditionelles Eisenhandwerk in Afrika*, Cologne, Heinrich Barth Institut, pp. 13–54.

——. 2000. Metal and pre-colonial African society. In: J.O. Vogel (ed.), *Ancient African Metallurgy,* Wallnut Creek, California, Altamira Press, pp. 1–83.

HUARD, P. 1960. Contribution à l'étude du fer et du chameau au Sahara occidental, I. *Bulletin de l' IFAN,* Serie B, Vol. 22, Nos. 1–2, pp. 134–78.

——. 1964. Nouvelle contribution à l'étude du fer et du chameau au Sahara et au Tchad [A new contribution to the study of iron and the camel in the Sahara and Chad]. *Bulletin de l'IFAN*, Serie B, Vol. 26, Nos. 3–4, pp. 297–396.

——. 1969. Introduction et diffusion du fer au Tchad [Introduction and dissemination of iron in Chad]. *Journal of African History,* Vol. 8, No. 3, pp. 377–404.

IDOWU, E.B. 1975. *Olodumare, God in Yoruba Belief.* London, Longman.

IZARD, M. 1980. *Les archives orales d'un royaume africain: recherches sur la formation du Yatenga* [Oral archives of an African kingdom: research on the formation of Yatenga]. Thesis for doctorat d'État. Paris I, Université René-Descartes/Paris V, Sorbonne (2 vols).

——. 1983. Le royaume du Yatenga et ses forgerons: une recherche d'histoire du peuplement [The Yatenga kingdom and its blacksmiths: research on the history of a settlement]. In: N. Echard (ed.), *Métallurgies africaines. Nouvelles contributions.* Paris, Société des Africanistes, pp. 253–80.

——. 1985. *Le Yatenga précolonial; un ancien royaume du Burkina* [Precolonial Yatenga: an ancient kingdom of Burkina]. Paris, Karthala.

JEMKUR, J.-F. 1989. Traditional iron-smelting methods by the Beron of Plateau State, Nigeria. *Nyame Akuma,* No. 32, pp. 21–4.

——. 1992. *Aspects of the Nok Culture.* Zaria, Amadou Bello University Press.

JOHNSON, S. 1921. *A History of the Yorubas.* Lagos, Church Missionary Society.

JUNOD, H.A. 1908. Le Balemba of the Zoutspansberg. *Folk-Lore*, No. 19, pp. 279–80.

——. 1910. Les conceptions physiologiques des Bantous sud-africains et leurs tabous [The physiological conceptions of South African Bantus and their taboos]. *Revue d'ethnographie et de sociologie,* No. 1, pp. 126–69.

——. 1913. The conditions of the natives of south-eastern Africa in the sixteenth century according to the early Portuguese documents. *South African Journal of Science,* No. 10, pp. 136–61.

KENSE, F.J. 1983. *Traditional African Ironworking.* Calgary, University of Calgary (African Occasional Papers, Vol. 1).

KENSE, F.J. and AKAO OKORO, J. 1993. Changing perspectives on traditional iron production in West Africa. In: T. Shaw, P. Sinclair, B. Andah and A. Okpoko (eds.), *The Archaeology of Africa: Food, Metal and Town,* London, Routledge, pp. 449–58.

KILLICK, D. 1995. *Iron in Pre-Industrial Africa: A Bibliography.* Paris, UNESCO.

KILLICK, D.; VAN DER MERWE, N.; GORDON, R.B.; GRÉBÉNART, D. 1988. Reassessment of the evidence for early metallurgy in Niger. *West Africa Journal of Archaeological Science,* No. 15, pp. 367–94.

LAMBERT, N. 1971. Les industries sur cuivre dans l'Ouest Saharien [Copper industries in western Sahara]. *West African Journal of Archaeology,* (London, West Africa Publishing) No. 1, pp. 9–21.

LANFRANCHI, R.; CLIST, B.; LA CROIX, Y. 1991. *Aux origines de l'Afrique Centrale* [At the origins of Central Africa]. Saint-Maur, Sépia.

LAVACHERY, P. 1997–8. *De la pierre au métal. Archéologie des dépôts holocènes de l'abri de Shum Laka (Cameroun)* [From stone to metal: archaeology of holocene deposits at Shum Lake (Cameroon)]. Ph.D. thesis, 3 vols. Brussels, Université Libre de Bruxelles, pp. 460–5.

LEBEUF, J.P. and LEBEUF, A. 1997. *Les arts des Sao* [The arts of the Sao]. Paris, Éditions du Chêne.

LECLANT, J. 1956. Le fer dans l'Égypte ancienne, le Soudan et l'Afrique [Iron in ancient Egypt, the Sudan and Africa]. *Annales de l'Est* (Nancy), Vol. 16, pp. 83–91.

LEROI-GOURHAN, A. 1964. *Le geste et la parole. Technique et langage* [Gesture and word. Technique and language], Vol. 1. Paris, Albin Michel.

LEROY, M. 1997. *La sidérurgie en Lorraine avant le haut fourneau. L'utilisation du minerai de fer oolithique en réduction directe* [Ironworking in Lorraine before the blast furnace: use of oolithic iron ore in direct reduction]. Paris, Éditions du CNRS (Monographie du CRA, 18).

LEROY, M.; MERLUZZO, P.; FLUZIN, P.; LECLERE, D.; AUBERT, M.; PLOQUIN, A. 2000. La restitution des savoir-faire pour comprendre un procédé technique: l'apport de l'expérimentation en archéologie du fer [The restitution of know-how for the understanding of a technical procedure: the contribution of experimentation in iron archaeology]. In: P. Petrequin, P. Fluzin, J. Thiriot and B. Benoît (eds.), *Arts du Feu et productions artisanales,* Actes des XX[e] rencontres internationales d'archéologie et d'histoire d'Antibes, 1999. Antibes, CNRS/APDCA, pp. 37–53.

LEVIN, E.M.; ROBBINS, R.C.; MCMURDIE, H.F. 1964. *Phase Diagram for Ceramist.* Ohio, Columbus, American Ceramic Society, p. 241.

LHOTE, H. 1952. La connaissance du fer en Afrique occidentale [Knowledge of iron in West Africa]. *Encyclopédie mensuelle d'Outre-Mer* (September), pp. 269–72.

——. 1966. La route des chars de guerre lybiens, Tripoli-Gao [The road taken by Libya's battle tanks: Tripoli-Gao]. *Archeologia,* No. 9, pp. 28–35.

MACEACHERN, S. 1996. Iron Age beginnings north of the Mandara Mountains, Cameroon and Nigeria. In: G. Pwiti and R. Soper (eds.), *Aspects of African Archeology,* pp. 489–95. Papers from the 10th Congress of the Pan-African Association for Prehistory and Related Studies. Harare, University of Zimbabwe Publications.

MAES-DIOP, L.M. 1968. Métallurgie traditionnelle du fer en Afrique [Traditional iron metallurgy in Africa]. *Bulletin de l'IFAN,* Série B, Vol. 30, No. 1, pp. 10–38.

MAGNUSSON, G. (ed.). 1995–6. *The Importance of Ironmaking. Technical Innovation and Social Change* (2 vols). Norberg Conference, May 1995. Stockholm, Jernkontorets Berghistoriska Utskott, H 58/1995, H 62/1996.

MANGIN, M. (ed.) 1994. *La sidérurgie ancienne de l'Est de la France dans son contexte européen, archéologie et archéométrie* [Ancient ironmaking in eastern France in the European, archaeological and archaeometric context]. Actes du Colloque de Besançon, 10–13 Novembre 1993. Paris, Les Belles Lettres (Annales littéraires de l'Université de Besançon).

MANGIN, M.; COURTADON, J.L.; FLUZIN, P.; DE LACLOS, E. 2000a. *Village, forge et parcellaire aux sources de la Seine: l'agglomération antique de Blessey-Salmaise (Côte-d'Or)* [Village, smithy and land division at the sources of the

Seine: the ancient town of Blessey-Salmaise (Côte d'Or)]. Besançon, Presses universitaires franc-comtoises. (Literary annals of the Université de Franche-Comté, Vol. 700, June 2000).

MANGIN, M.; FLUZIN, P.; COURTADON, J.L.; FONTAINE, M.-J. 2000b. *Forgerons et paysans des campagnes d'Alésia. Haut Auxois (Côte d'Or), Ier siècle av. JC-VIIe siècle ap. J.-C.* [Blacksmiths and peasants of the Alesia countryside. Haut Auxois (Côte d'Or), 1st cent. B.C. – 7th cent. A.D.] Paris, CNRS, 2000b.

MARET, P. (de). 1977. Sanga: new excavations, more data and some related problems, *Journal of African History,* No. 18, pp. 321–37.

——. 1979. Luba roots: the first complete Iron Age sequence in Zaire. *Current Anthropology,* No. 20, pp. 233–5.

——. 1980. Ceux qui jouent avec le feu: la place du forgeron en Afrique centrale [Those who play with fire: the role of the blacksmith in Central Africa]. *Africa*, Vol. 50, No. 3, pp. 263–77.

——. 1982a. New survey of archaeological research and dates for West-Central and North-Central Africa. *Journal of African History,* No. 23, pp. 1–15.

——. 1982b. The Iron Age in the West and South. In: F. van Noten (ed.), *The Archaeology of Central Africa,* pp. 77–96. Graz, Akademische Druk.

——. 1985. Fouilles archéologiques dans la vallée du Haut-Lualaba, Zaïre, II: Sanga et Katongo, 1974 [Archaeological excavations in the Upper Lualaba Valley, Zaïre, 2: Sanga and Katongo, 1974]. *Annales du Musée royal de l'Afrique Centrale*, No. 120, pp. 1–326.

——. 1992. Sédentarisation, agriculture et métallurgie du Sud-Cameroun: synthèse de recherches depuis 1978 [Sedentarization, agriculture and metallurgy in southern Cameroon; survey of research since 1987]. In: J.-M Essomba (ed.), *L'Archéologie au Cameroun* [Archaeology in Cameroon], (Yaoundé symposium, January 1986). Paris, Karthala, pp. 228–45.

MARET, P. (DE) and CLIST, B. 1989. Le contexte archéologique de l'expansion bantu en Afrique centrale [The archaeological context of the Bantu expansion in Central Africa]. In: T. Obenga (ed.), *Les peuples bantu: migrations, expansion et identité culturelle* [The Bantu peoples: migrations, expansion and cultural identity]. Vol. 1, Proceedings of the Libreville symposium, January 1986. Paris, L'Harmattan, pp. 118–38.

MARET, P. (DE) and THIRY, G. 1996. How old is the Iron Age in Central Africa? In: P.R. Schmidt (ed.), *The Culture and Technology of Iron Production*, Gainesville, University Press of Florida, pp. 29–39.

MARET, P. (DE) and NSUKA, F. 1977. History of Bantu metallurgy: some linguistic aspects. *History in Africa,* No. 4, pp. 43–65.

——. 1980. Étude comparative de quelques termes métallurgiques dans les langues bantoues [Comparative study of some metallurgical terms in Bantu languages]. In: L. Bouquiaux (ed.), *L'expansion bantoue,* Vol. 3, Actes du Colloque international du CNRS, Viviers 1977. Paris, SELAF, pp. 731–42.

MARLIAC, A. 1981. L'état des connaissances sur le Paléolithique et le Néolithique du Cameroun (prospections de 1968, 1969, 1970, 1971) [State of knowledge of the Palaeolithic and Neolithic in Cameroon (explorations in 1968, 1969, 1970, 1971)]. In: C. Tardits (ed.), *Contribution de la recherche ethnologique à l'histoire des civilisations du Cameroun* [Contribution of ethnological research to the history of the civilizations of Cameroon], Vol. 1, Paris, CNRS (CNRS symposium, 1973, No. 551), pp. 27–77.

MARTINELLI, B. 1982. *Métallurgistes bassar: techniques et formation sociale* [Bassar metalworkers: techniques and social training]. Lomé, University of Benin (Studies and documents in social sciences).

——. 1993a. Agriculteurs métallurgistes et forgerons en Afrique soudano-sahélienne. [Farmer-metalworkers and blacksmiths in Sudanese and Sub-Saharan Africa]. *Etudes rurales*, Nos. 125–6, (Special issue on 'Mines et métallurgie dans le monde rural'.), pp. 25–41.

——. 1993b. Fonderies ouest-africaines: classement comparatif et tendances [West African founderies: comparative classification and trends]. Atouts et outils de l'ethnologie des techniques. Sens et tendance en technologie comparée. *Revue Techniques et culture*, No. 21, pp. 195–221.

——. 1995a. Transmission de savoirs et évolution technologique dans la métallurgie ouest-africaine [Knowledge transmission and technological evolution in West African metallurgy]. *Cahiers d'Histoire des techniques*, No. 3, (Special number: 'La transmission des connaissances techniques'.), pp. 163–88.

——. 1995b. Les forgerons et la statuaire dogon [Blacksmiths and Dogon sculpture]. *L'art du Pays Dogon.* Paris/Zurich, Museum Rietberg, (Collections du Musées de l'Homme, exhibition catalogue.), pp. 76–82.

——. 1996. Sous le regard de l'apprenti: paliers de savoir et d'insertion chez les forgerons moose du Yatenga – Burkina Faso [The apprentice's view: threshold of knowledge and integration among the Mossi (*Moose*) blacksmiths of Yatenga – Burkina Faso]. *Revue Techniques et Culture,* No. 58, pp. 9–47.

——. 1998. *La mémoire en travail. À propos de la forge au Burkina Faso* [Memory at work: the forge in Burkina Faso]. *Les territoires du travail.* Mémoires en Actes, CATEIS, No. 1, pp. 65–76.

——. 2000. Le choix de la combustion lente. Mutation technique et mutation sociale au Yatenga, Burkina Faso [The choice of slow combustion. Technical and social change in Yatenga, Burkina Faso]. In: P. Petrequin, P. Fluzin,

J. Thiriot and B. Benoît (eds.), *Arts du feu et productions artisanales,* Actes des XXe rencontres internationales d'archéologie et d'histoire d'Antibes, 1999. Antibes, CNRS/APDCA, pp. 123–42.

MAUNY, R. 1952. Essai sur l'histoire des métaux en Afrique occidentale [Essay on the history of metals in West Africa]. *Bulletin de l'IFAN,* Série B, Vol. 14, No. 2, pp. 545–95.

——. 1953. Compte-rendu de H. Lhote, 'La connaissance du fer en Afrique occidentale' [Report on H. Lhote, 'Knowledge of iron in West Africa'], *Encyclopédie mensuelle d'outre-mer,* Paris, September 1952. *Bulletin de l'IFAN*, Série B, Vol. 15, No. 2, p. 880.

——. 1971. *Les siècles obscurs de l'Afrique noire. Histoire et archéologie* [Black Africa's dark centuries. History and Archaeology]. Paris, Fayard.

——. 1978. Trans-Saharan contacts and the Iron Age in West Africa. In: J.D. Fage (ed.), *Cambridge History of Africa,* Vol. 2, Cambridge, Cambridge University Press, pp. 272–341.

MBIDA, C. 1992. Étude préliminaire du site de Ndindan et datation d'une première série de fosses [Preliminary study of the Ndindan site and dating of a series of pits]. In: J.-M. Essomba (ed.), *L'archéologie au Cameroun* [Archaeology in Cameroun], (Yaoundé symposium, January 1986). Paris, Karthala, pp. 263–84.

MCDONNEL, G.J. 1986. *The Classification of Early Iron Working Slags.* Unpublished Ph.D. thesis. Aston, Birmingham, University of Aston.

MCINTOSH, S.K. 1994. Changing perceptions of Africa's past: archaeological research since 1988. *Journal of Archaeological Research,* Vol. 2, No. 2, pp. 165–98.

MCIINTOSH, R.G. and MCINTOSH, S.K. 1988. From siècles obscurs to revolutionary centuries on the Middle Niger. *World Archaeology,* Vol. 20, No. 1, pp. 141–65.

——. 1981. West African prehistory. *American Scientist*, No. 69, pp. 602–13.

MCNAUGHTON, P.K. 1988. *The Mande Blacksmiths: Knowledge, Power and Art in West Africa.* Bloomington/Indianapolis, Indiana University Press.

MCPHEE, A. 1926. *The Economic Revolution in British West Africa.* London, Routledge.

MILLER, D.E. and MAGGS, T. 1998. *Precolonial Metalworking in Africa: A Bibliography.* Cape Town, University of Cape Town, Department of Archaeology.

MILLER, D.E. and VAN DER MERWE, N.J. 1994. Early metal working in sub-Sahara Africa: A review of recent research. *Journal of African History,* Vol. 35, Nos. 1–36.

MOHEN, J.P. 1990. *Métallurgie préhistorique, introduction à la paléométallurgie* [Prehistoric metallurgy: introduction to palaeometallurgy]. Paris, Masson.

——. 2001. *Histoire de l'humanité* [History of Humanity], Vol. 2, p. 67. Paris, Éditions UNESCO.

MORTILLET, G. (de). 1903. *Musée préhistorique* [Prehistoric museum]. Scheicher Frères et C^{ie}.

MORTON, G.R. and WINGROVE, J. 1969. Constitution of bloomery slags, Part I: Roman. *Journal of the Iron and Steel Institute,* No. 207, 1969, pp. 1556–64.

——. 1972. Constitution of bloomery slags, Part II: Medieval. *Journal of the Iron and Steel Institute,* No. 210, pp. 478–88.

NICKLIN, K. 1981. Archaeological site in Northern Cross River State. *Nyame Akuma,* No. 21, p. 15.

NJOKU, O.N. 1886. *A History of Iron Technology in Igboland, c. 1542–1900.* Unpublished Ph.D. thesis. Nova Scotia, Dalhousie University.

NOSEK, E. 1994. The metallography of gromps. In: M. Mangin (ed.), *La sidérurgie ancienne de l'Est de la France dans son contexte européen, archéologie et archéométrie.* Actes du Colloque de Besançon, 10–13 November 1993. Paris, Les Belles Lettres (Annales littéraires de l'Université de Besançon, No. 536; *Archéologie*, No. 40, pp. 65–73.)

OBAYEMI, A. 1977. The Yoruba- and Edo-speaking peoples and their neighbours. In: J.F. Ajayi and M. Crowther (eds.), *History of West Africa,* Vol. I, London, Longman, pp. 255–322.

OGUAGHA, P.A. 1982. The conquest hypothesis in Igbo/Igala relations: a re-examination. *West African Journal of Archaeology.* Vol. 12, p.58.

OJO, G.J.A. 1971. *Yoruba Culture.* London, University of London Press.

OKAFOR, E.E. 1976. *Awka Blacksmiths in Pre-Colonial Times.* Ibadan, University of Ibadan. Unpublished 13-A. Project.

——. 1983. Metallurgy in ancient Igboland. *Nyame Akuma,* No. 23, pp. 14–15.

——. 1984a. *A Study of Ironworking in Orba, Nsukka.* Ibadan, Ibadan University. M.Sc. project (unpublished).

——. 1984b. *Ironworking in Orba, Nsukka.* M.Sc. thesis. Ibadan, Ibadan University, Department of Archaeology.

——. 1984c. Ancient mines in the north of Igboland. *Nyame Akuma,* No. 24, pp. 14–15.

——. 1990–91. *Archaeological Survey and Sampling Excavations at Opi, Orba, Owerre-Elu, and Umundu,* unpublished.

——. 1992a. *Early Iron-Smelting in Nsukka, Nigeria: Information from Slags and Residues.* Unpublished Ph.D. thesis, Sheffield, University of Sheffield.

——. 1992b. New evidence on early iron-smelting from South Eastern Nigeria. In: B.W. Andah, P. Sinclair, T. Shaw and A.I. Okpoko (eds.), *Foods, Metals and Towns in Archaeology of Africa.* London, Routledge.

——. 1993. New evidence on early iron-smelting from South Western Nigeria. In: T. Shaw, P. Sinclair, B. Andha and A. Opoko (eds.), *The Archaeology of Africa: Food, Metals and Towns,* London, Routledge, pp. 432–48.

OKAFOR, E.E. and PHILLIPS, P. 1992. New ^{14}C ages from Nsukka, Nigeria and the origins of African metallurgy. *Antiquity,* Vol. 66, pp. 686–8.

OLIVIER DE SARDAN, J.-P. 1982. *Concepts et conceptions Songhay-Zarma* [Concepts and conceptions among the Songhay-Zarma]. Paris, Nubia.

ONYEKE, C. 1986. *Ironworking in Eha, Alumona and Opi, Nsukka 3.* B.A. Project (unpublished), p. 68.

OSLISLY, R. 1993. The neolithic/Iron Age transition in the middle reaches of the Ogodue Valley in Gabon: chronology and cultural change. *Nyame Akuma,* No. 40, pp. 17–21.

OSMOND, F. 1898. Méthode générale pour l'analyse micrographique des aciers au carbone [General method for micrographic carbon analysis of steels]. *Bulletin de la Société d'encouragement pour l'industrie nationale* (Paris), No. 4, p. 10.

PARIS, F.; PERSON, A.; QUÉCHON, G.; SALIÈGE J.-F. 1992. Les débuts de la métallurgie au Niger septentrional (Aïr, Azawagh, Ighazer, Termit) [The beginnings of metallurgy in northern Niger]. *Journal de la Société des Africanistes,* Vol. 62, No. 2, pp. 55–68.

PARK, M. 1813. *Travels in the Interior Districts of Africa Performed under the Direction and Patronage of the African Association in the Years 1795, 1796 and 1797.* (Microform.) New York, Evert Duyckinck.

PELET, P-L. 1982. Recherches sur la métallurgie du fer dans le Jura vaudois [Research on iron metallurgy in the Waudois Jura]. In: *Mines et fonderies antiques de la Gaule.* Table ronde du CNRS, Toulouse, October 1980. Paris, CNRS, pp. 205–14.

——. 1983. Une industrie reconnue. Fer, charbon, acier dans le pays de Vaud [A recognized industry: iron, coal and steel in the Canton of Vaud]. Lausanne, *Cahier d'Archéologie Romande,* No. 60.

PERSON, Y. 1970. *Samori, une révolution dyula.* Dakar, IFAN.

PERSON, A. and QUÉCHON, G. 1997. Paléoenvironnements et sites néolithiques au Sahara méridional [Palaeoenvironments and Neolithic sites in western

Sahara]. Communications presented at the XIIIth Congress of the Société des archéologues africanistes (SAFA), Poznan (Poland), 3–6 September 1996. *Dossiers et recherches sur l'Afrique* (UPR 311 CNRS, Meudon), No. 4.

PETREQUIN, P.; FLUZIN, P.; THIRIOT, J.; BENOÎT, P. 2000. *Arts du feu et productions artisanales* [Ceramics and craft production]. Actes des XX^{e} rencontres internationales d'archéologie et d'histoire d'Antibes, 1999. Éditions CNRS/APCDA, Antibes.

PHILLIPSON, D.W. 1970. Notes on later prehistoric radiocarbon chronology of Eastern and South Africa. *Journal of African History,* No. 11, pp. 1–15.

——. 1985. *African Archaeology.* London, Cambridge University Press.

PLEINER, R. 2000. *Iron in Archaeology: The European Bloomery Smelters.* Prague, Archaeologicky USTAV AV CR.

PLOQUIN, A. 1994. L'analyse chimique en paléosidérurgie [Chemical analysis in palaeo-iron and steelmaking]. In: M. Mangin (ed.), *La sidérurgie ancienne de l'Est de la France dans son contexte européen, archéologie et archéométrie,* Actes du Colloque de Besançon, 10–13 November 1993. (Annales Littéraires de l'Université de Besançon.) Paris, Les Belles Lettres, pp. 16–23.

POLE, L.M. 1985. Furnace design and the smelting operations. In: R. Haaland and R. Shinnie (eds.), *African Ironworking*, Oslo, Norwegian University Press.

PORTÈRES, R. 1938. À propos de l'industrie du fer en Afrique occidentale dans la zone forestière [Concerning the iron industry in the forest zone of West Africa]. *Bulletin du Comité d'études historiques et scientifiques de l'AOF,* Vol. 21, No. 3, pp. 463–6.

POSNANSKY, M. and MCINTOSH, R.G. 1979. New radiocarbon dates for Northern and Western Africa. *Journal of African History,* Vol. 17, pp. 161–95.

QUÉCHON, G. 1995. *La fin du néolithique et les débuts de la métallurgie dans le massif de Termit (Niger)* [The close of the Neolithic Period and the beginnings of metallurgy in the Termit massif (Niger)]. Communication au colloque 'L'homme du Maghreb et son environnement depuis 100,000 ans, Maghnia, 27–30 November 1995. ORSTOM, Karthala. (Collection 'Milieux, sociétés et archéologues'.)

QUÉCHON, G.; PARIS, F.; SALIÈGE, J.F.; PERSON, A. 1992. Les débuts de la métallurgie au Niger septentrional [The beginnings of metallurgy in northern Niger]. *Journal des Africanistes,* No. 62, pp. 55–68.

QUÉCHON, G. and PERSON, A. 1997. Questions sur le peuplement holocène au Sahara [Aspects of the Holocene population of the Sahara. *Dossiers et recherches sur l'Afrique,* No. 4, (Communication au XIII^{e} congrès de la Société des

archéologues africanistes [SAFA], Poznan [Pologne], 3–6 September 1996.), pp. 125–30.

QUÉCHON, G. and ROSET, J.-P. 1974. Prospection archéologique du massif de Termit (Niger) [Archaeological prospection of the Termit massif (Niger)], Cahiers de l'ORSTOM, *Série Sciences humaines,* Vol. 11, No. 1, pp. 85–104.

REINACH, S. 1913. *Répertoire de l'art quaternaire* [Repository of quaternary art]. Paris, Leroux.

ROOZEBOOM, H. 1889. Le fer et l'acier du point de vue de la doctrine des phases [Iron and steel from the point of view of the doctrine of phases]. (Translation by F. Osmon of an article: 'Eisen und stahl vom Standpunkte des Phasenlehre'.) *Z. Phys. Chem,* No. 34, pp. 437–87.

ROUTHIER, L. 1963. *Les gisements métallifères, géologie et principes des recherches* [Metalliferous deposits, geology and principles of research]. Paris, Masson.

RUSTAD, J.A. 1980. *The Emergence of Iron Technology in West Africa.* La Haye, B.K. Swartz.

SALIÈGE, J.-F. and PERSON, A. 1991. Matières organiques des céramiques archéologiques et datations par la méthode du radiocarbone [Organic matter from archaeological pottery and radiocarbon dating]. In: M. Raimbault and K. Sanogo (eds.), *Recherches archéologiques au Mali*, Paris, Karthala, pp. 113–448.

SANDRA, T.B. 1980. *Ogun, An Old God for a New Age*, Vol. 3. Philadelphia, ISHI.

SASSOON, H. 1964. Iron-smelting in the hill village of Suku, Northeastern Nigeria. *Man,* Vol. 64, No. 215, pp. 174–8.

SCHMIDT, P.R. 1977. Steel production in prehistoric Africa: insight from ethno-archaeology, West Lake Tanzania. In: R.E. Leakey and B.A. Ogot (eds.), *Proclamation of the 8th Pan African Congress on Prehistory and Quarternary Studies,* Nairobi, pp. 335–40.

SCHMIDT, P.R. and AVERY, D.H. 1978. Complex iron-smelting and prehistory culture in Tanzania. *Science,* Vol. 201, No. 4361, pp. 1085–9.

SERNEELS, V. 1993. Archéométrie des scories de fer. Recherches sur la sidérurgie ancienne en Suisse occidentale [Archaeometry of iron slag: research on ancient ironmaking in western Switzerland]. Lausanne, *Cahiers d'archéologie romande,* No. 61.

——. 1994. L'apport des analyses chimiques de minerai, scories et produits associés à l'étude de la sidérurgie ancienne [Contribution of chemical analyses of ore, slags and associated products to the study of ancient ironmaking]. In: M. Mangin (ed.), *La sidérurgie ancienne de l'Est de la France dans son contexte*

européen, archéologie et archéométrie. Actes du Colloque de Besançon, 10–13 November 1993, Paris, Les Belles Lettres (Annales Littéraires de l'Université de Besançon), pp. 75–82.

——. 1998. La chaîne opératoire de la sidérurgie ancienne [The operating chain of ancient ironmaking]. M. Feugere and V. Serneels (eds.), *Recherches sur l'économie du fer en Méditerranée nord-occidentale,* Montagnac, Édition Monique Mergoil (Monographie Instrumentum 4), pp. 7–44.

SHAW, C.T. 1969. On radiocarbon chronology of Iron Age in Sub-Saharan Africa. *Current Anthropology,* Vol. 10, pp. 226–31.

——. 1970. *An Account of Archaeological Discoveries in Eastern Nigeria.* Evanston, Faber and Faber.

——. 1976. Preliminary report on archaeology work carried out in Wushishi Area, December 1975–March 1976. *Nyame Akuma,* No. 9.

——. 1978. *Nigeria: Its Archaeology and Early History.* London, Thames and Hudson.

——. 1981. The prehistory of West Africa. In: *UNESCO General History of Africa,* Vol. 1. Paris, UNESCO (Methodology and African Prehistory).

SHINNIE, P.L. 1967. *Meroe: A Civilization of the Sudan.* London, Thames and Hudson (Ancient People and Places, 25).

——. 1971. *The African Iron Age.* Oxford, Clarendon Press.

——. 1985. Ironworking at Meroë. In: R. Haaland and Peter Shinnie (eds.), *African Ironworking: Ancient and Traditional,* Bergen, Norwegian University Press, pp. 28–35.

SIMONDON, G. 1969. *Du mode d'existence des objets techniques* [On the mode of existence of technical objects]. Paris, Aubier. (Collection 'Analyse et Raison'.)

SPERL, G. 1980. Über die Typologie urzeitlicher, frügeschichtlicher und mittelalterlicher Eisenhuttenschlacken [Prehistoric, protohistoric and medieval typology of ironworking slag]. *Studien zur Industrie-Archäologie, 7.* Vienna, Osterreichische Akademie der Wissenschaften.

STAINIER, L. 1897. Archéologie préhistorique [Prehistoric archaeology]. In: T. Matsui (ed.), *Guilde de la section de l'État Indépendant du Congo à l'exposition de Bruxelles-Tervuren en 1897,* Brussels, Monnom, pp. 279–80.

STUIVER, M. and PEARSON, G.W. 1986. High-precision calibration of the radiocarbon timescale, A.D. 1950–500 B.C. *Radiocarbon,* Vol. 28, No. 2B, pp. 805–9.

SUTTON, J.E.G. 1976. Ironworking around Zaria with preliminary account of the excavations at Samaru West. *Zaria Archaeology Papers,* Vol. 6, No. 8, p.18.

——. 1977. Radiocarbon date for the Samaru ironworking. *Zaria Archaeological Papers,* No. 8 (Addendum.), p. 34.

——. 1985. Temporal and spatial variability in African iron furnaces. In: R. Haaland and P.L. Shinnie (eds.), *African Ironworking: Ancient and Traditional,* Bergen, Norwegian University Press, pp. 164–96.

TAMARI, T. 1997. *Les castes de l'Afrique occidentale. Artisans et musiciens endogames* [Castes in West Africa: endogamous craftspeople and musicians]. Nanterre, Société d'ethnologie.

TRIGGER, B.G. 1969. The myth of Meroe and the African Iron Age. *African Historical Studies,* Vol. 2, No. 1, pp. 23–50.

TYLECOTE, R.F. 1965. Iron-smelting in pre-industrial communities. *Journal of the Iron and Steel Institute*, Vol. 203, pp. 340–8.

——. 1975a. Iron-smelting at Taruga, Nigeria. *Journal of the Historical Metallurgy Society,* Vol. 9, No. 2, pp. 49–56.

——. 1975b. The origin of iron-smelting in Africa. *West African Journal of Archaeology,* Vol. 5, No. 1.

——. 1987. *The Early History of Metallurgy in Europe*. London, Longman (Archaeology Series).

UMEJI, A.C. 1980. Tertiary plantation surfaces on the Cuestain southeastern Nigeria. *Journal of Mining and Geology,* Vol. 17, No. 2, pp. 109–18.

UNESCO. Internet Site 'Iron Routes in Africa': www. unesco.org/culture/dialogue/iron/html.fr/activity.htm

UZOEZIE, L.C. 1972. Agricultural land use in Nsukka Division. *Nsukka: The Problems of Change and Continuity.* Nsukka, Institute of African Studies Seminar, University of Nigeria, pp. 42–50.

VAN DER MERWE, N.J. 1969. The carbon-14 dating of iron. Chicago, University of Chicago Press.

——. 1980. The advent of iron in Africa. In: T.A. Wertime and J.D. Mulhy (eds.), *The Coming of the Age of Iron.* New Haven, Yale University Press, pp. 463–506.

VAN DER MERWE, N.J. and KILLICK, D.J. 1979. Square and iron-smelting site near Phalaborwa, Johannesburg. *South African Archaeological Society, Gowin Series*, No. 3, pp. 86–93.

VAN DER PLICHT, J. and MOOK, W.G. 1989. Calibration of radiocarbon age by computer. *Radiocarbon*, Vol. 31, pp. 805–16.

Van Grunderbeek, M.C. 1982. L'âge du fer ancien au Rwanda et au Burundi [The Early Iron Age in Rwanda and Burundi]. *Journal des Africanistes,* No. 52, p. 52.

——. 1992. Essai de délimitation chronologique de l'âge du fer ancien au Burundi, au Rwanda et dans la région des Grands Lacs [Approach to a chronological demarcation of the Early Iron Age in Burundi, Rwanda and the region of the Great Lakes]. *Azania* (Nairobi, Kenya), No. 27, pp. 53–80.

Van Grunderbeek, M.C.; Roche, E.; Doutrelepont, H. 1983. La métallurgie ancienne au Rwanda et au Burundi [Ancient ironworking in Rwanda and Burundi]. *Journées de paléométallurgie.* Actes du colloque de Compiègne, 22–23 February. Brussels, Archéologie et Environnement, pp. 407–23.

Van Noten, F. 1982. *The Archaeology of Central Africa.* Gräz, Akademische Druck-U Verlagsanstalt.

——. 1981. *Histoire générale de l'Afrique. Afrique Centrale* [General History of Africa. Central Africa], Vol. 2, Chapter 25. Paris, UNESCO, p. 690.

Vignati-Pagis, E. 1995. *Du fourneau à la fosse: changements techniques dans la métallurgie du fer au Burundi au cours des deux derniers millénaires. Approches archéologique, ethnographique et historique* [From furnace to pit: technical changes in iron metallurgy in Burundi over the past two thousand years: archaeological, ethnographical and historic approaches]. Ph.D. thesis, Paris, Université de Paris I (Panthéon-Sorbonne).

Von Luschan, F. 1909. *Eisentechnik in Afrika* [Ironwork in Africa]. New York, Zeit. F. Ethn.

Voruz, J.L. 1995. Chronologie absolue de la fin du néolithique dans le bassin Rhodanien [Absolute chronology at the end of the Neolithic in the Rhodanian basin]. In: J.-L. Voruz (ed.), *Chronologies néolithiques de 6000 à 2000 avant notre ère dans le bassin Rhodanien.* Actes du colloque d'Ambérieu-en-Bugey, 19 and 20 September 1992. Ambérieu-en-Bugey, Éditions de la Société préhistorique Rhodanienne.

Warmington, B.H. 1969. *Carthage.* London, Robert Dale (1st ed., 1964).

Wente-Lukas, R. 1972. Eisen und schmied im Südlichen Tschadraum [Iron and the blacksmith in the southern Chad region]. *Paideuma,* Vol. 18, pp. 112–43.

——. 1977. Fer et forgerons au sud du lac Tchad (Cameroun, Nigeria) [Iron and blacksmiths south of Lake Chad (Cameroon, Nigeria)]. Summary translation by N. Échard and J.F. Vincent, *Journal des Africanistes*, Vol. 47, No. 2, pp. 107–22.

WIESMULLER, B. 1996. Untersuchengen zur Chronologie der frühen Eisenzeit in Afrika anhand linguisticher, archaologischer und aturwissenschaftlicher Quellen [Studies of the chronology of the Early Iron Age in Africa on the basis of linguistic, archaeological and natural science sources]. *Beitrage zur Allgemeinen und Vergleichenden Archäologie,* No. 16, pp. 139–214.

——. 1997. Möglichkeiten des interdiziplinaren Zusammenarbeit von Archäologie und linguistik am Beispiel des frühen Eisenzeit in Afrika [Potential interdisciplinary cooperation between archaeology and linguistics: example of the Early Iron Age in Africa]. R. Klein Arendt. *Traditionelles Eisenhandwerk in Afrika.* Koln, Heinrich Barth Institut.

WILLETT, F. 1971. Nigeria. In: P.L. Shinnie (ed.), *The African Iron Age.* Oxford, Clarendon Press.

WILLIAMS, D. 1973. Art in metal in sources of Yoruba history. In: S.O. Biobaku (ed.), *Sources of Yoruba*, Oxford, Clarendon Press, pp. 140–64.

WOODHOUSE E.J. 1998. Iron in Africa: metal from nowhere. In: G. Connah (ed.), *Transformations in Africa*, London, Leicester University Press, pp. 160–85.

YORK, R.N. 1978. Excavations at Dutsen Kongba, Plateau State, Nigeria. *West African Journal of Archaeology,* Vol. 8.

ZANGATO, E. 1993. La question des datations des mégalithes du Centrafrique: nouvelles perspectives [Dating of megaliths in Central Africa: new prospects]. In: D. Barreteau and C. Von Graffenried (eds.), *Datations et chronologie dans le bassin du lac Tchad,* Paris, ORSTOM, pp. 51–75.

——. 1995. Variantes architecturales du nord-ouest de la République Centrafricaine et évolution chronoculturelle régionale [Architectural variations in the north-east of the Central African Republic and regional chronocultural evolution]. *Journal des Africanistes*, No. 65, pp. 95–102.

——. 1999. Sociétés préhistoriques et mégalithes dans le nord-ouest de la République Centrafricaine [Prehistoric and megalithic societies in the north-east of the Central African Republic]. *African Archaeology,* No. 45. Cambridge, BAR (Monograph series).

International Consultative Meeting of Specialists (Maputo 10–13 December 1991)

Excerpts from the *Report*

At the invitation of the Mozambique National Commission for UNESCO, an international consultative meeting of specialists for the launching of the Iron Roads in Africa Project was held in Maputo, Mozambique, from 10 to 13 December 1991.

I Recommendations made at the meeting concerning the feasibility study

The specialists recommended:

- Focusing on two principal objectives, (a) the evaluation of the role of iron in African development, and (b) the construction of a positive image of Africa through the project.
- Setting up a databank on iron in Africa, to be linked to similar networks worldwide.
- Drawing up an annotated bibliography on the various relevant academic fields (archaeology, history, metallurgy, anthropology, sociology, development, environment, geology and so forth).
- Drawing up an inventory of unpublished theses relating to the subject of iron in Africa.
- Establishing ties with iron companies in Africa in order to request financial support for research projects in the field.
- Defining cultural zones and highlighting cultural similarities, drawing on oral traditions.

- Studying the vocabulary of iron in African languages.
- Carrying out a cost and profitability study comparing imported modern techniques and the revival of ancient artisanal ironworking techniques.
- Publishing history books, and comics and children's books.
- Classifying the monument *A Casa dos Mabyaias* ('House of the Mabyaias') as part of the heritage of Mozambique. (Made chiefly of iron by the master sculptor Malangatana, the monument fully symbolizes the role and goals of the 'Iron Roads in Africa' Project.)
- Adopting that monument as the logo for the Iron Roads in Africa Project.
- Carrying out all technical operations necessary to preserve the monument from rusting.
- Carrying out studies on the following topics:
  - iron in the oral tradition,
  - iron in matrimonial exchanges,
  - iron and mythology,
  - iron and music,
  - social status of the blacksmith,
  - iron and power,
  - iron as a form of currency,
  - iron in the development of agriculture,
  - iron and technology,
  - iron and industrial development: profitable use of the iron industries in Africa,
  - history of railways in Africa,
  - the first cars in Africa,
  - iron and the environment,
  - iron and public health,
  - iron in museums,
  - geographic distribution of iron in Africa,
  - iron ore,
  - iron in daily life,
  - iron and the Bantu expansion,
  - iron and architecture,
  - the iron industry in relation to regional integration.

This list of recommendations is not exhaustive and is added to those in the preliminary project document.

II Scientific and technical papers

The papers presented to the meeting (see below) gave the participants an opportunity to discover the wealth and diversity of the research work already carried out on the common theme of iron in various regions of Africa.

Appendix I

Agenda

1. Opening of the meeting.
2. Election of officers.
3. Adoption of the agenda.
4. Reflection on the issue of iron in Africa.
5. History and anthropology of iron (history, culture, philosophy, religion and development):
   – history of iron in Africa: state of research, problems and prospects;
   – man and metal: myths, traditions and religions;
   – ironworkers: lifestyle, brotherhoods and social status;
   – iron in daily life: food, pharmacopoeia and traditional therapies.
6. Iron technology and industries:
   – ironworking techniques in Africa;
   – iron metallurgy and iron industries in Africa.
7. Iron, cultural heritage and environment:
   – archaeology, geology and geography of iron ore in Africa;
   – operation of iron mines and protection of the environment;
   – iron in public works (monuments, buildings, bridges), elements of the cultural heritage.
8. Examination of the draft document *Iron Roads in Africa* (CNUM/RF/02/91/Rev.1).
9. Implementation and coordination of the Iron Roads in Africa Project.
10. Approval of the final report and recommendations.
11. Closure of the meeting.

Appendix II

Participants

BACCAR, Mounira: Sector for Culture, UNESCO

CHAMBAL, Frederico Jeremias (Mozambique): Instituto Nacional de Geologia, Departamento Laboratório, Maputo, Mozambique

FAYE, Safi (Senegal): Ethnologist, film-director, Dakar, Senegal

JOSÉ, Alexandrino (Mozambique): Centro de Estudos Africanos, Universidade Eduardo Mondlane, Maputo, Mozambique

KARAYENGA, Athanase (Burundi): Chief executive officer, BONEICA (multimedia communication company), Paris

KIPRÉ, Pierre (Côte d'Ivoire): Direction de la Recherche et de la Coopération Scientifique, École Normale Supérieure, Abidjan, Côte d'Ivoire

KOSSOU, Basile (Benin): Secretary of the World Decade for Cultural Development, UNESCO

LAIFA, Embarek (Algeria): Technical adviser in mine geology, Ministry of Mineral Resources, Maputo, Mozambique

LEYTEN, Harrie M. (the Netherlands): Curator, Tropenmuseum, Amsterdam, the Netherlands

LIESEGANG, Gerhard (Mozambique): Departamento de História, Faculdade de Letras, Universidade Eduardo Mondlane, Maputo, Mozambique

LUCAS, Carlos (Mozambique): Engenheiro químico, Departamento de Engenharia Química, Faculdade de Engenharia, Universidade Eduardo Mondlane, Maputo, Mozambique

MACHUNGO, Inês Beatriz Fernandes (Mozambique): Assistante, Departamento de Letras Modernas, Faculdade de Letras, Universidade Eduardo Mondlane, Maputo, Mozambique

M'BOKOLO, Elikia (Zaire): Directeur d'Études, École des Hautes Études en Sciences Sociales, Paris

MEDEIROS, Eduardo (Mozambique): Departamento de Antropologia, Instituto Superior Pedagógico, Maputo, Mozambique

NGUNGA, Armindo (Mozambique): Faculdade de Letras, Universidade Eduardo Mondlane, Maputo, Mozambique

SANTANA AFONSO, Ana Elisa (Mozambique): Coordinator of Iron Roads in Africa Project, CNUM (Mozambique National Commission for UNESCO), Maputo, Mozambique

SIBANDA, Eric (Swaziland): Department of African Languages and Literature, Sandile University of Swaziland, Swaziland

SIMBI, David Jambuwa (Zimbabwe): Chairman and Lecturer, Department of Metallurgical Engineering, University of Zimbabwe, Mount Pleasant, Harare, Zimbabwe

Secretariat

COVANE, Luís António (Mozambique): Departamento de História, Universidade Eduardo Mondlane, Maputo, Mozambique

MANUENSE, Hermínia (Mozambique): Projecto ARPAC (Arquivo do Património Cultural), Ministérió da Cultura, Maputo, Mozambique

RIBEIRO, Fátima (Mozambique): Departamento de Português, Instituto Superior Pedagógico, Maputo, Mozambique

Appendix III

List of Addresses and Papers

Address of welcome: Ms Ana Elisa Santana Afonso, Secretary-General of the Mozambique National Commission for UNESCO

Speech by Ms Graça Machel, Chairperson of the Mozambique National Commission for UNESCO

Speech by Mr Basile Kossou, Secretary of the World Decade for Cultural Development (WDCD), representing the Director-General of UNESCO

Opening address by H. E. the Minister of Culture of Mozambique, Mr José Mateus Kathupa

General introduction to the work by Ms Ana Elisa Santana Afonso

Chapter I: Reflection on the Theme of Iron in Africa

Topic 1: Iron in Mozambique, problems and perspectives – Mr Alexandrino José (Mozambique)

Topic 2: General overview of the theme of iron in Africa – Mr Leyten (the Netherlands)

Topic 3: Interdisciplinarity, history and anthropology of iron: the ambiguities of iron in the Kongo-Teke zone – Mr Elikia M'Bokolo (Zaire)

Examination of the project document *Iron Roads in Africa*

Examination of the document *Broad Outlines of the Coordination Mechanism for, and Execution of, the Iron Roads in Africa Project*

Chapter II: History and Anthropology of Iron in Africa

Topic 4: The iron-smelting process in Africa and Mozambique and its documentation: Produção e trabalho do Ferro na Província do Niassa (iron production and ironworking in the province of Niassa) – Mr Liesegang (Mozambique)

Topic 5: The growth and spread of iron technology in northern Mozambique – Mr Adamowicz (Mozambique)

Chapter III: Iron, Cultural Heritage and Environment

Topic 6: Iron skills in Burundi – Mr A. Karayenga (Burundi)

Topic 7: Anthropology and filmography of iron in West Africa – Mr Safi Faye (Senegal)

Topic 8: A lexicon of iron terms in some Mozambican languages (O léxico do Ferro em algumas línguas moçambicanas) – Mr Armindo Ngunga (Mozambique)

Chapter IV: Iron Technologies and Industries

Topic 9: Technology and iron industries in Africa – Mr Simbi (Zimbabwe)

Topic 10: General review of iron and steelmaking techniques (Generalidades sobre o processo technológico da fabricaçao do ferro e aço) – Mr Carlos Lucas (Mozambique)

Topic 11: Iron in Yorubaland – Mr I.A. Akinjogbin (Nigeria)

Topic 12: The iron roads in the structuring of West Africa in the nineteenth century: the example of Côte d'Ivoire – Mr Pierre Kipré (Côte d'Ivoire)

Topic 13: Mining and ironwork in the ancient agricultural communities of Mozambique – Mr E. Medeiros (Mozambique)

Members of the International Scientific Committee on the Iron Roads in Africa Project

Frank Aig-Imoukhuede, Chairperson of the Committee
Former Director for Culture, Federal Ministry of Information and Culture
Lagos, Nigeria

Herman M. Batibo, linguist
Chairman of the Linguistics Association for SADC Universities from 1987 to 1995
President of the World Congress of African Linguistics Standing Committee
Head of the Department of African Languages and Literature
University of Botswana
Gaborone, Botswana

Hamady Bocoum, archaeologist
Director of Cultural Heritage of the Republic of Senegal
Ministry of Culture
Head of the Prehistory and Protohistory Laboratory of Cheikh Anta Diop University
Specialist in the technical and social history of iron metallurgy in West Africa
Dakar, Senegal

Pierre de Maret, archaeologist, anthropologist
Rector of the Free University of Brussels (ULB)
Director of the Centre of Cultural Anthropology of the ULB
Professor at the L.S. Senghor University of Alexandria
Brussels, Belgium

Jean Devisse, historian, archaeologist
Specialist in North-West African history, fourth–eleventh centuries
Paris, France

Melvin Edwards, artist
State University of New Jersey
Department of Visual Arts
Mason Gross School of the Arts
New Brunswick, New Jersey, United States

Martin Eno Belinga, geologist
Head of the Department of Earth Sciences
Faculty of Science
University of Yaoundé
Yaoundé, Cameroon

Pierre Kipré, historian
Specialist in the history of West Africa, particularly contemporary Côte d'Ivoire
Former Minister of Education and Basic Training
Abidjan, Côte d'Ivoire

Joseph Ki-Zerbo, historian
Specialist in the methodology of African history
Director of the Research Centre for African Development (CEDA)
Ouagadougou, Burkina Faso

Lech Krzyzaniak, archaeologist
Director of the Archaeological Museum
Poznan, Poland

Alberto Lescay Merencio, artist
President of the Caguayo Foundation
Santiago de Cuba, Cuba

Harrie Leyten, former Curator of the Museum of the Royal Tropical Institute
Former Vice-Chairperson of the International Scientific Committee on the Iron Roads in Africa Project
Amsterdam, Netherlands

Elikia Mbokolo, historian, sociologist
Specialist in the history of Africa, particularly East Africa, and pioneer in oral history techniques
Research Director
Centre for African Research
School of Higher Studies in Social Sciences
Paris, France

Jose Mateus Muaria Katupha, linguist
Specialist in Bantu languages
Former Minister of Culture, Youth and Sport
Deputy in the Assembly of the Republic
Vice-Chairperson of the International Scientific Committee on the 'Iron Roads in Africa' Project
Maputo, Mozambique

Théophile Obenga, historian
Specialist in African languages
Former Director of the International Centre for the Bantu Civilizations
Former Minister of Foreign Affairs of the Congo
Department of Black Studies
San Francisco State University
San Francisco, California, United States

Bethwell Allan Ogot, historian
Specialist in the history of Africa, particularly East Africa, and pioneer in oral history techniques
Head of the Institute of Research and Postgraduate Studies
Maseno, Kenya

Mohamed Ould Khattar, archaeologist
Former Deputy Permanent Delegate of Mauritania to UNESCO
Programme specialist in the Cultural Heritage Division at UNESCO
Paris, France

Klena Sanogo, archaeologist
Head of the Institute of Human Science (ISH)
Ministry of Secondary and Higher Education and Scientific Research
Bamako, Mali

D. J. Simbi, metallurgical engineer
Department of Metallurgical Engineering
University of Zimbabwe
Harare, Zimbabwe

Index of Persons

E

F

G

H

I

J

K

L

Index of Places

O

P

R

S

T

U

V

W

Y

Z