Geomorphology and human palaeoecology of the Méma, Mali

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ABSTRACT

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The Méma is a semi-arid region in central-Mali with a rich archaeological heritage indicating the former existence of large urban settlements. Previous investigations suggest that the Méma is an important area in which to study the origins of Sahelian agriculture, metallurgy, and urbanism, the continuing effects of long-term desiccation, the fluvial history of the Niger River basin, human responses to desertification, and regional abandonment. As a basis for such future studies, a geomorphological map of the Méma was made based on remote sensing and field data. In this report the geomorphological map is presented with a discussion of the origin and chronology of the landforms. Following upon this discussion, the archaeology of the Méma is described, with theoretical considerations about the origin of urbanism and the abandoment of the urban settlements.

Keywords: archaeology, desertification, geomorphology, Mali, Méma, palaeoclimatology, urbanism.

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[Alterra-report 1244/december/2005]

With sadness we dedicate this volume to the memory of our friend and esteemed colleague, Dr. Téréba Togola, who added so much to our knowledge of the Méma.

Téréba, when they coined the phrase 'African Genius', they had you in mind.

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Preface

More than fifteen years ago, in 1989, the 'Projet Togué' started in central Mali. This joint Malian-Dutch enterprise aimed at an inventory of all archaeological sites of the southern Inland Niger Delta. Rapid degradation of the sites by illegal digging and robbery of cultural objects was the main reason for the inventory led by Prof. Dr. Diderik van der Waals. In this memorable project much attention was paid to the physical environment of the sites. My job, as a geomorphologist, was the systematic geomorphological mapping of the study area from stereo-photographs and a satellite image. It was clear that the history of human occupation of that area could only be understood with a proper knowledge of regional geomorphological and climatic history. This report on the Méma, which is located on the northwestern fringe of the Inland Niger Delta, continues in this research tradition in which archaeological sites are considered integral parts of a dynamic landscape. For the history of the present project I refer to chapter 1.

This report basically follows from an internship of Edwin de Vries at Alterra from September to December 2003. This internship was part of his geoarchaeological training within the M.A. program in archaeology at the Vrije Universiteit (Amsterdam). Under my supervision Edwin worked out material from the Méma. During his internship Edwin was a member of the 'Landscape systems' team in which the geomorphological expertise of Alterra is represented. Especially, team member Wim Nieuwenhuizen is thanked for his technical GIS support. We are also grateful to Alterra for offering facilities and an allowance for Edwin's work.

Our co-authors of this report, Joseph Tainter and Roderick McIntosh, set up the Méma project as a sequel to previous studies conducted in the Inland Niger Delta by Roderick McIntosh and his students, Téréba Togola and Kevin MacDonald. Most well-known are the excavations at Jenne-jeno, probably Africa's oldest sub-Saharan city. Roderick McIntosh presently is Professor of Anthropology at Rice University (Houston, USA), where he also teaches palaeoclimate in the Earth Science Department, and Visiting Professor of Archaeology in the Department of Anthropology and Archaeology at the University of Pretoria, South Africa. Joseph Tainter (United States Department of Agriculture Forest Service, Rocky Mountain Research Station, Albuquerque) is well-known for his work on pre-Columbian archaeology in the American Southwest and has worked with Roderick McIntosh on African archaeology in Mali since 1998.

In January-February 2000 Joseph Tainter and Roderick McIntosh undertook a reconnaissance trip to the Méma. I joined this trip on their invitation to investigate the potential for a geomorphological and palaeoclimatological study in the Méma as a part of their project. Much of the data worked out by Edwin de Vries were collected during this trip. With respect to this trip we thank the Institut des Sciences Humaines (ISH) in Bamako for support and we thank the Centre National de la Recherche Scientifique et Technique for granting research permission. We especially thank

Berthe Sekou and Mamadou Cissé for their participation. Funding for the trip and the production of this report by the USDA is also very much appreciated.

As editor of this volume, I want to stress that this is an open-ended report. As to the interrelationships of human occupation and dynamics of the physical environment there are no firm conclusions to be drawn yet. New field data from the Méma are needed to evaluate the hypotheses put forward in this report. Unsafe conditions in the Méma presently keep us away from the field, but hopefully better conditions will allow us to return in the not too distant future.

Bart Makaske, Wageningen, October 2005

Summary

The Méma is an isolated basin of the northern Sahel of Mali that has attracted archaeological interest since the first half of the 20th century. Previous work suggests that the Méma is an important area in which to study such topics as the origins of Sahelian agriculture, metallurgy, and urbanism, the continuing effects of long-term desiccation, the fluvial history of the Niger River basin, human responses to desertification, and regional abandonment. This report summarizes the state-of-the-art knowledge of Méma geomorphology and archaeology, aimed at providing a basis for future in-depth field research in the Méma. Preliminary field data collected during a short field mission in 2000 are also presented.

A geomorphological map of the study area was produced based on stereoscopic analysis of aerial photographs. A satellite image was used to aid in recognition of large-scale landforms. The map shows a tectonic basin with various generations of aeolian dunes at the surface. The oldest dunes are massive and longitudinal and probably originated in late-Pleistocene (Ogolian) times. Generations of smaller, presumably Holocene, dunes are superimposed on these older forms. Interdunal depressions seem to represent former lakes that were fed by now abandoned Niger River distributaries penetrating the area from the neighbouring Inland Niger Delta (located east of the Méma). Late-Pleistocene and Holocene climatic oscillations obviously have shaped the landscape of the Méma, besides tectonic forces as testified by some faults that clearly stand out at the surface. Many archaeological sites in the form of (occasionally huge) mounds occur scattered over the area. Frequently, clusters of sites occur. Site locations within the landscape suggest variable activities such as fishing, agriculture, iron working, *etc*.

Previous archaeological research in the Méma showed the existence of Late Stone Age and Iron Age sites representing millennia of occupation history. Site clustering and the apparent early development of specialization and urbanization followed by the presumably relatively sudden abandonment of the Méma, were intriguing but poorly understood phenomena. The explanation of the archaeological record of the Méma was hampered by: (1) a lack of systematic site inventories, (2) lack of a conceptual framework for the processes of specialization, urbanization and regional abandonment, and (3) lack of detailed knowledge on palaeogeographical and palaeoclimatological developments in the region.

In an attempt partly to solve the above-mentioned problems, a start with systematic site inventories in the Méma was made in 1989 by MacDonald and Togola. These investigations were motivated by a new theory about the origin of specialization and urbanization in the Middle Niger region called 'the Pulse Model', developed by McIntosh. In general, the Pulse Model predicts the locations where archaeologists may find the earliest and most emphatic expressions of site clustering and urbanism. It is hypothesized that diverse landscapes (such as that of the Méma) have encouraged close contact of increasingly specialized groups. Essential elements of the

Pulse Model are climate oscillations that create a 'pulse' of population movements north and south (in the Sahelian case) along shifting rainfall gradients. Humans adapted to the climatic stress by specialization and specialized groups became mutually dependent. The recurrent north-south shifts encouraged strong interaction among groups. The model supposes pre-urban emergence of specialization, with separate specialized and interdependent communities spatially organized as clusters. Gradually, ever-larger growing clusters have evolved into true towns. The physiography, climate history and archaeological record of the Méma suggest that this is an excellent area to test the Pulse Model.

Perspectives for understanding the abandonment of the Méma by the 14th or 15th century AD, can be derived from analysing the contrasting forces of sustainability and resiliency in human societies. It is believed that desiccation was a driving force behind the abandonment of the Méma. From historic and pre-historic (*e.g.* pre-Columbian societies in the American Southwest) analogues it follows that, in response to radically deteriorating environmental conditions, people either choose (1) continuity (sustainability) or (2) acceptance of dramatic change (resiliency). The first option means regional abandonment and continuity at a more favourable location. This is obviously a very expensive solution. The second option means collapse: *in situ* population reduction with simplified social and political systems. This option is cost-effective, but demands much flexibility to accomplish the necessary changes. In the case of the Méma the first option was preferred. To understand this we explicitly need data about the nature of the desiccation leading up to and during the 14th and 15th century AD as well as archaeological data representing the late urban period in order to delineate the social, political and economic organization of the society just before abandonment.

1 Introduction: the Méma project, 1998-2000

Joseph A. Tainter & Roderick J. McIntosh

The Méma is an isolated basin of the northern Sahel of Mali (Fig. 1.1). Home today to a few thousand Fulani and Moors, who live mainly by herding and rainfall millet farming, it held urban settlements until perhaps the 14th or 15th century AD. Thereafter the region was either unoccupied or occupied so sparsely that no human presence can be detected until after 1591. As detailed by McIntosh in this volume, the Méma has attracted archaeological interest for some time. Owing to its remote location, though, this work has been sporadic and limited. The Méma is an important area in which to study such important topics as the origins of Sahelian agriculture, metallurgy, and urbanism, the continuing effects of long-term desiccation, the fluvial history of the Niger River basin, human responses to desertification, and regional abandonment.

In 1989 and 1990, Téréba Togola and Kevin MacDonald conducted archaeological survey and excavations in the Méma for their respective doctoral dissertations (Togola, 1993; MacDonald, 1994). Our interest in the Méma owes much to their work. R. McIntosh and S. McIntosh directed Togola's dissertation, which was done at Rice University. MacDonald, who completed his dissertation at Cambridge University, had been an undergraduate student at Rice. Tainter first learned of the region from Togola during work in southern Mali in 1993. At that time the north of Mali was closed due to an insurgency, and it would be five years before Tainter had the opportunity to travel to West Africa again.

In June 1998, McIntosh and Tainter participated in the annual meeting of the Mande Studies Association, which was held that year in The Gambia. Since the security of northern Mali had improved during the intervening years, Tainter visited the Méma after this conference at Togola's invitation. In January 1999, Tainter returned to the Méma accompanied by Harry Rowe, then a doctoral student in geomorphology at Stanford University. During a ten-day visit, Rowe made preliminary observations on the geomorphology of the region, and the depositional history of several locations. Malian archaeologist Mamadou Cissé joined the project in 1998; both that year and in 1999 Berthe Sekou was field assistant. In 2000, McIntosh and Tainter returned for what was intended to be a three-week session investigating both the geomorphology and archaeology. Bart Makaske joined the project that year as geomorphologist. Cissé and Sekou were also part of the 2000 crew. Regrettably, this field season had to be ended after two weeks when we learned that bandits were approaching the Méma, and had almost certainly learned of our presence.

The 2000 field season consisted of extensive geomorphological investigations conducted by Makaske, and excavation in the site of Akumbu directed by McIntosh and supervised by Cissé. This report concerns that season. Makaske selected Edwin de Vries to prepare the major part of the assessment of the region's geomorphology. It was thought that the publication of de Vries' report would provide an opportunity also to discuss the archaeological background of the project, and some thoughts on the problem of the 14th century abandonment. We are pleased that Alterra provided an opportunity to publish all of our reports in this volume of the *Alterra-report* series. Funding for all phases of the project was provided by the USDA Forest Service, Rocky Mountain Research Station, Cultural Heritage Research Project, with contributions in kind from all participants.

As of this writing, the prospects for future work in the Méma are uncertain. Since our forced evacuation in 2000, reports from northern Mali have at some times indicated that the region was secure, while at other times we have received reports of new outbreaks of banditry and killing. Since we cannot predict when additional sustained research in the area will be possible, we offer the present report as a small contribution toward understanding the geomorphology and prehistory of a large and important area.

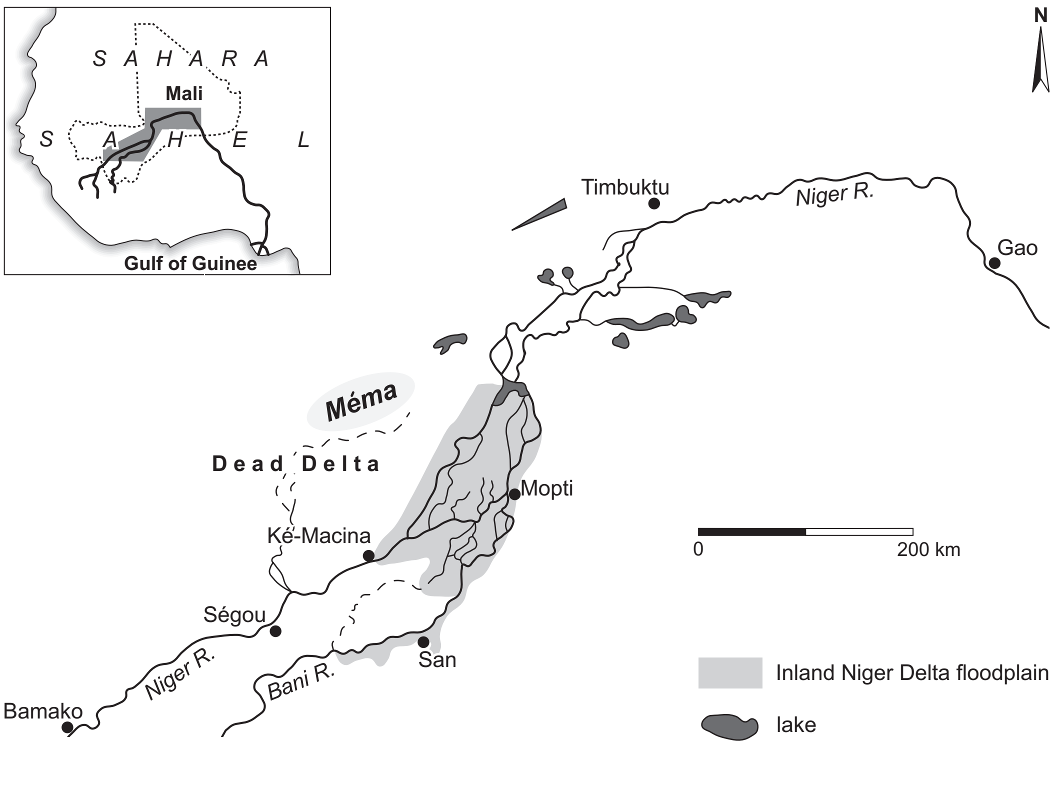

Fig. 1.1 The location of the Méma within the Middle Niger region. The channel in the 'Dead Delta' (dashed line) is the 'Fala de Molodo'.

2 The geomorphology of the Méma

Edwin de Vries & Bart Makaske

2.1 Introduction

In this chapter a geomorphological survey of the Méma is presented. The most important result of the survey is a geomorphological map (App. 1). The mapped landforms will be described and their genesis will be discussed. Also a tentative reconstruction of the geomorphological history of the Méma will be presented.

The area described in this chapter is located on the northwestern margin of the Inland Niger Delta in Mali. The mapped area covers roughly 1100 km^2 and is bordered to the north and west by an extensive field of longitudinal dunes. The southern border of the study area is formed by a geological structure known as the Boulel Ridge. South of this ridge runs the 'Fala de Molodo', which is an abandoned stream that once fed an extensive floodplain that bounds the study area to the east. The regional capital, Nampala, is located in the northwest of the study area. The study area is dominated by a northern chain of seasonal interdunal lakes and a single large seasonal lake in the south. The chain of lakes is called the 'Bras de Nampala' and is connected to the floodplain in the east by a narrow channel in the north of study area. A now abandoned channel formerly connected the southern lake, Niakéné Maoudo, with the Fala de Molodo.

A geological structure known as the Nara graben underlies the study area (Fig. 2.1). The graben runs ENE-WSW and is bounded by faults that seem still active. The fault marking the southern edge of the Nara graben, separates the rock outcrops of Boulel Ridge from the lake area. Within the Nara Graben, the geological basement is largely obscured by Quaternary deposits.

Presently, the study area has a semi-arid climate, with annual precipitation between 400 and 500 mm. Rainfall is concentrated in heavy showers during a wet season that lasts 3 to 4 months (June-September). The dry season is dominated by a northeast trade wind known as the Harmattan. Daily maximum temperatures vary over the year, roughly between 30 and 40° C.

2.2 Methodology

The geomorphological map of the study area (App. 1) was based on: (1) 41 aerial photographs from 1975 at scale 1:50.000 supplied by the *Direction Nationale de la Cartographie et de la Topographie* in Bamako, (2) topographical maps at scale 1:200.000 (IGN, Paris, 1956), (3) LANDSAT 4/5 image from *ca.* 1990.

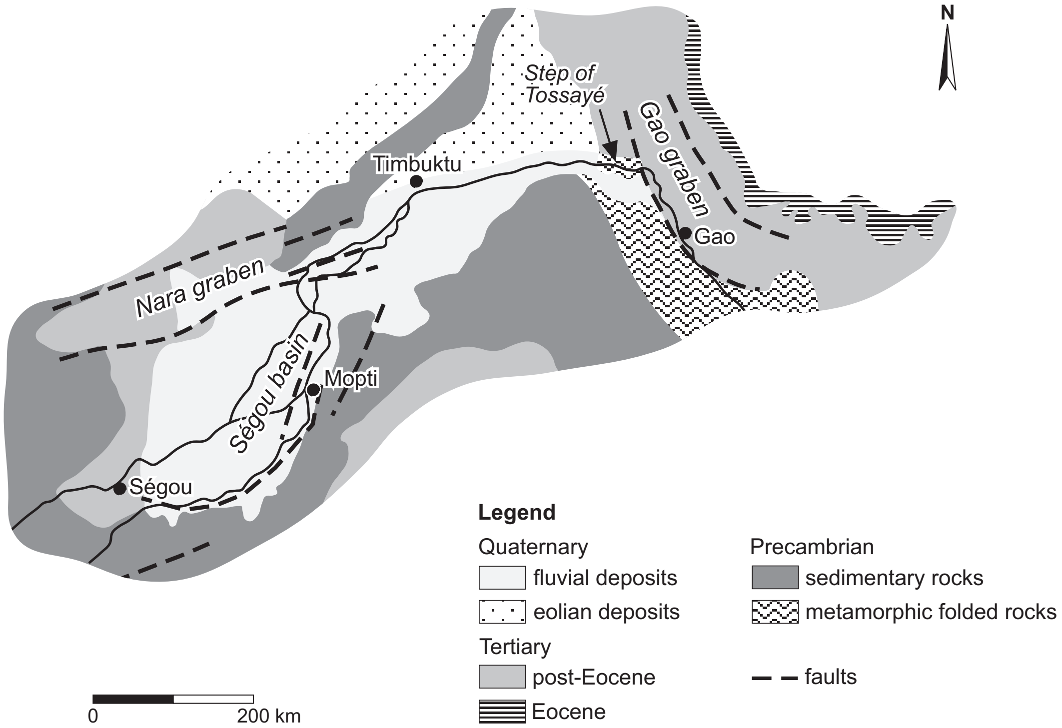

Fig. 2.1 Geological map of the Inland Niger Delta and its surroundings (from Makaske, 1998).

The map was produced in four steps. The first step was the stereoscopic analysis of the aerial photographs. The second step was comparison of the findings and drawings with the data of the remote sensing images and the topographic map, for a better identification of the landforms. The satellite image was especially useful for identifying larger structures. The third step was the retracing of the drawings made during the stereoscopic analysis onto the topographic map. In order to do so, the topographic map was enlarged to the same scale (1:50,000). During this step the photographs and the remote sensing images were used to check if the data were correct. In a fourth and final step, the retraced topographic map was digitized, using GIS software.

2.3 Landforms

2.3.1 Introduction

This section serves as a detailed explanation of the legend of the map, with a description of all distinguished landforms. The section is subdivided into subsections, based on the main genetic categories of landforms: aeolian landforms, fluvial landforms, tectonic landforms and remaining miscellaneous landforms, respectively. The genesis of the landscape will be addressed in the next section.

Integrated within the landform descriptions are the results of a field reconnaissance by Bart Makaske in 2000. This reconnaissance yielded a variety of sedimentary data, especially on the grain sizes of the dune and lake deposits. The grain size data are highly informative on the history and the nature of several landforms, and are presented in Appendix 2.

2.3.2 Aeolian landforms

Massive dunes

The study area lies on the border of the Sahara desert, and has experienced periods of severe aridity. During arid periods, wind action was the most important factor in landscape formation, causing aeolian landforms. During humid periods the aeolian landforms became stabilized by vegetation and soil formation. During subsequent arid periods, parts of these stabilized landforms may have been remobilized, resulting in new aeolian landforms. Therefore, one can distinguish different generations of aeolian landforms.

The first aeolian landforms we will pay attention to are the massive dunes. This term has been given to these landforms for their impressive size: the dunes can be over 2 km wide. These dunes are longitudinal, which means that their length axis is oriented parallel to the dominant formative wind direction (Easterbrook, 1999). They can be tens of kilometres long. Generally, longitudinal dunes are regularly spaced and are of more or less equal width. These massive dunes were formed during a period when the wind was blowing from the east. Since their orientation has not adjusted to the new dominant wind direction, one can safely conclude that the massive dunes within the area are no longer active (Tricart, 1965; Gallais, 1967; Makaske, 1998).

Within the study area the massive dunes are hard to recognize, for they are strongly degraded and obscured by younger landforms. The satellite image used for mapping covers a greater area, and east of the study area individual massive dunes are easier to recognize (Fig. 2.2). Although these dunes hardly surface within the study area itself, they have influenced later geomorphological processes. This makes it possible to sometimes trace the outlines of these massive dunes, even though the dunes themselves are hidden underneath younger deposits and landforms (Fig. 2.3). Pronounced soil formation in the top of the massive dunes (Fig. 2.4) probably largely dates back to early-Holocene humid climatic conditions. Comparably well-developed soil profiles are absent in other aeolian deposits, which are therefore presumed to be more recent. The massive dune deposits are distinctly red in colour, and grain size analysis indicates a relatively poorly sorted sand fraction and significant proportions of clay (6 %) and silt (16 %) (App. 2, sample 15). Comparable massive dune sediment characteristics were reported from the southern Inland Niger Delta (Makaske, 1998, pp. 150-151). The fine component in massive dune deposits probably originates from remote source areas.

Longitudinal dunes
The western and northwestern borders of the study area are formed by an extensive field of longitudinal dunes (Fig. 2.5). These dunes are much smaller than the massive dunes (up to about 500 meters width), and are therefore considered to represent a different generation of dunes. Furthermore these dunes have a different orientation that corresponds to the modern dominant direction of the wind, which is ENE (Tricart, 1965; Gallais, 1967).

In the central part of the study area, longitudinal dunes are either lacking or obscured by younger landforms. Only faint traces of these dunes can be recognized in this area (Fig. 2.6). One can therefore conclude that the field of longitudinal dunes must originally have spread further to the east, and that longitudinal dune formation has ceased.

Usually one will depict the crests of dunes on maps, but this has been hardly possible for these dunes that are convex-up in cross-section. Therefore, on the geomorphological map (App. 1) the more densely vegetated interdune depressions that are much easier to recognize, are marked. This applies especially to the remains of longitudinal dunes in the central part of the study area. The dunes themselves are hardly visible there; one can only detect faint traces of what once must have been interdune depressions (Fig. 2.6).

Two samples of longitudinal dunes were taken during the field reconnaissance. One was taken from the top of a dune, west of the lake Niakéné Maoudo. Another sample was taken on a place where these dunes are slightly obscured, in the aeolian plain northwest of Niakéné Maoudo. The two samples are very similar in composition (App. 2, samples 5 and 6). The surface of the longitunal dunes is cemented, which demonstrates that these dunes are inactive.

Transverse dunes
The relatively small transverse dunes represent another morphologically distinctive group of dunes in the study area. These dunes have their crests oriented perpendicular to the dominant direction of the wind (Easterbrook, 1999).

The transverse dunes are most likely formed by the remobilisation of material from older landforms, such as the massive dunes and the longitudinal dunes. Possibly some transverse dunes are active today, and may have been remobilized during the severe Sahel drought of the 1980s. The transverse dunes seem to concentrate on top of massive dunes (Fig. 2.7). They may also occur on longitudinal dunes.

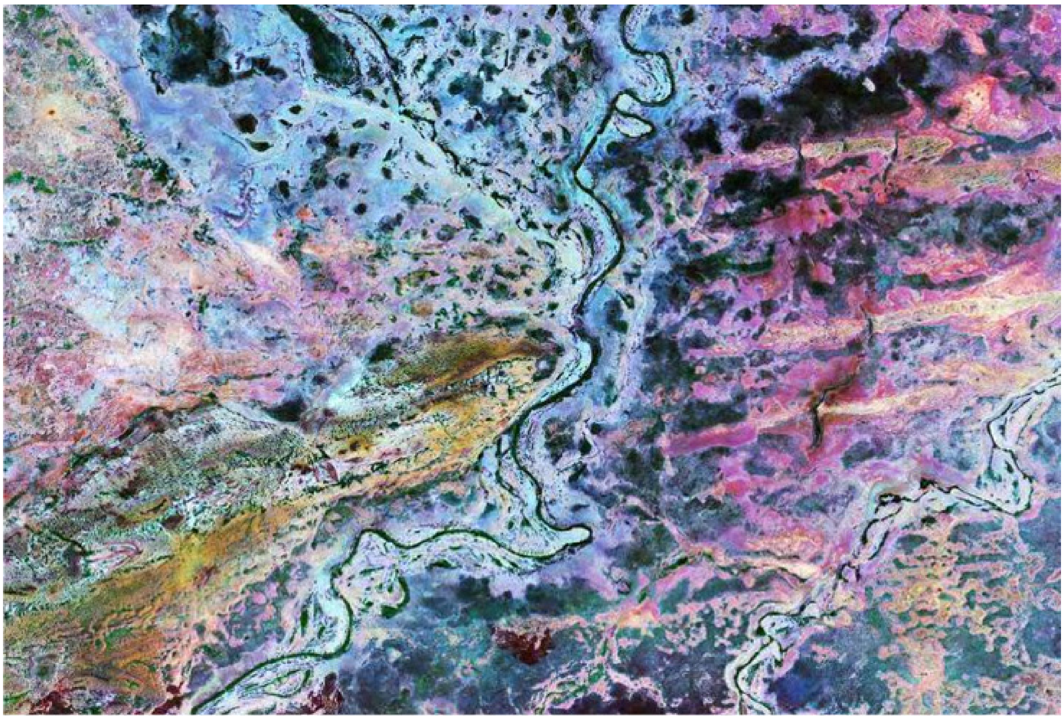

Fig. 2.2 LANDSAT image showing the abandoned Fala de Molodo channel passing around the eastern end of Boulel Ridge (yellow-brown) east of the study area. Linear structures east of the channel represent (nearly) E-W trended massive dunes. Width of area shown ~43 km; north is up.

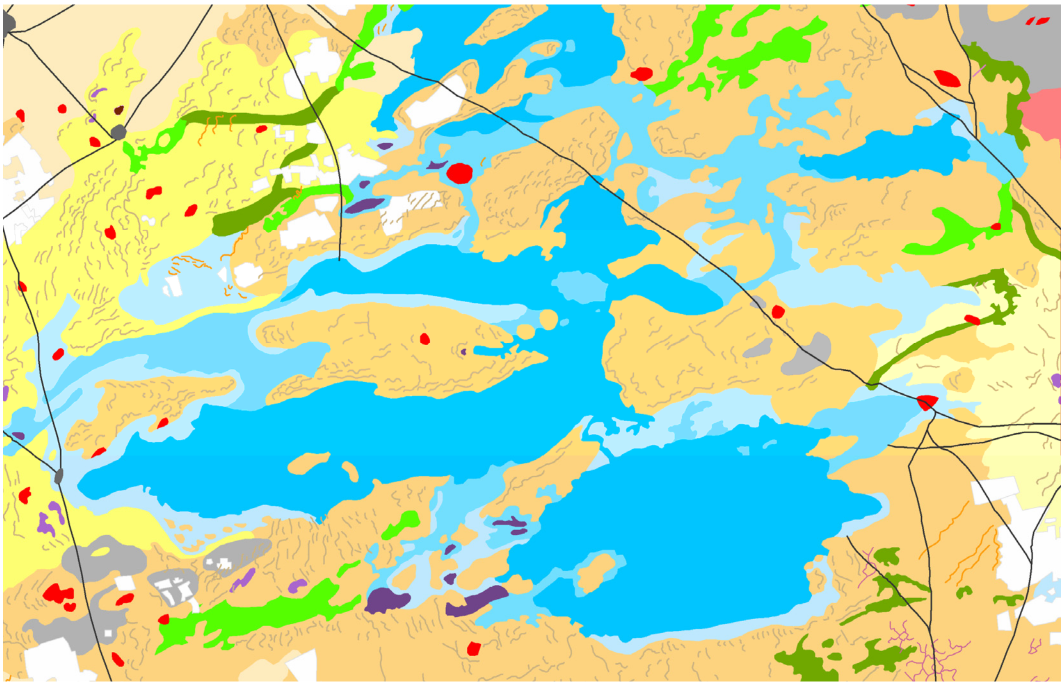

Fig. 2.3 Part of the geomorphological map showing massive dunes that are covered by younger transverse dunes (light-brown) in the central part of the study area. Lakes that are now mostly dry (blue) mark the depressions between the degraded massive dunes. Width of area shown ~17.5 km, north is up.

Fig. 2.4 Soil profile in a massive dune 6 km north of Toladié (diameter lens cap 6 cm). Sample 15 (App. 2) was taken just below the dark upper soil horizon.

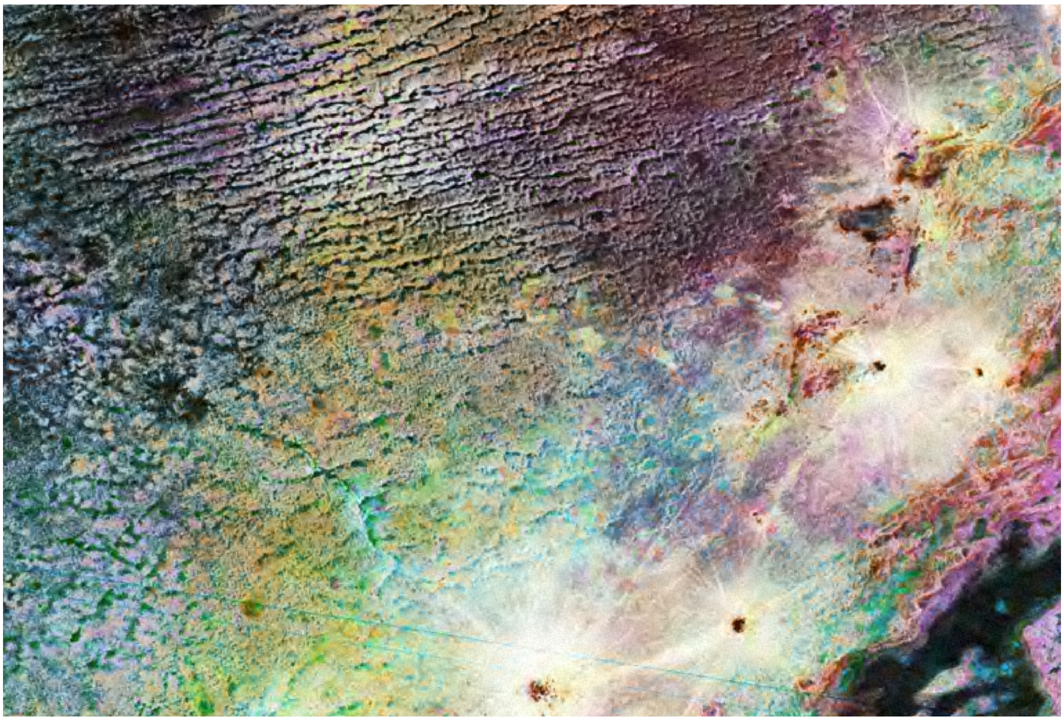

Fig. 2.5 LANDSAT image showing a vast field of ENE-WSW trended longitudinal dunes northwest of the study area. The town of Nampala is visible as a dark spot in the middle of the lower edge of the image. Width of area shown ~21.5 km; north is up.

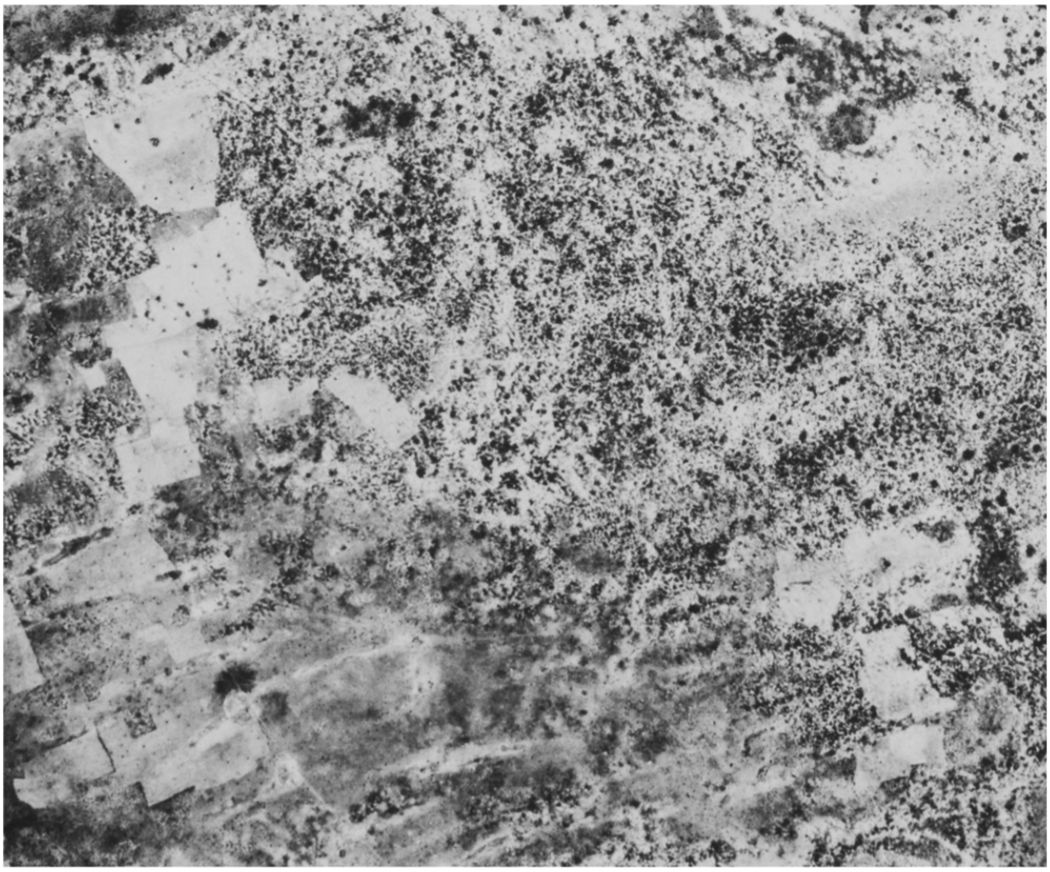

Fig. 2.6 Degraded ENE-WSW trended longitudinal dunes just south of the lakes in the central part of the study area (Fig. 2.3). To the northeast the much smaller transverse dunes dominate (see also Fig. 2.7). Width of area shown ~4 km; north is up. (© air photo: DNCT, Bamako)

However, it needs to be taken into account that probably not all transverse dunes are recent. Possibly some of these dunes are in fact part of an originally rippled surface of the massive dunes. In order to gain more conclusive evidence, additional field data are required. During the field reconnaissance no sediment samples were taken from transverse dunes.

Lake-bordering dunes

Along the western shores of the lakes, complexes of (predominantly) transverse dunes exist. These dunes are generally larger than the previously discussed transverse dunes and are termed lake-bordering dunes. The sediments of lake-bordering dunes may originate from various source areas. Firstly, the lake bottom may have been a source, with aeolian transport and deposition of silty lake sediments during dry periods with low lake levels. Secondly, sandy lake beaches may have been a source even during humid periods with high lake levels.

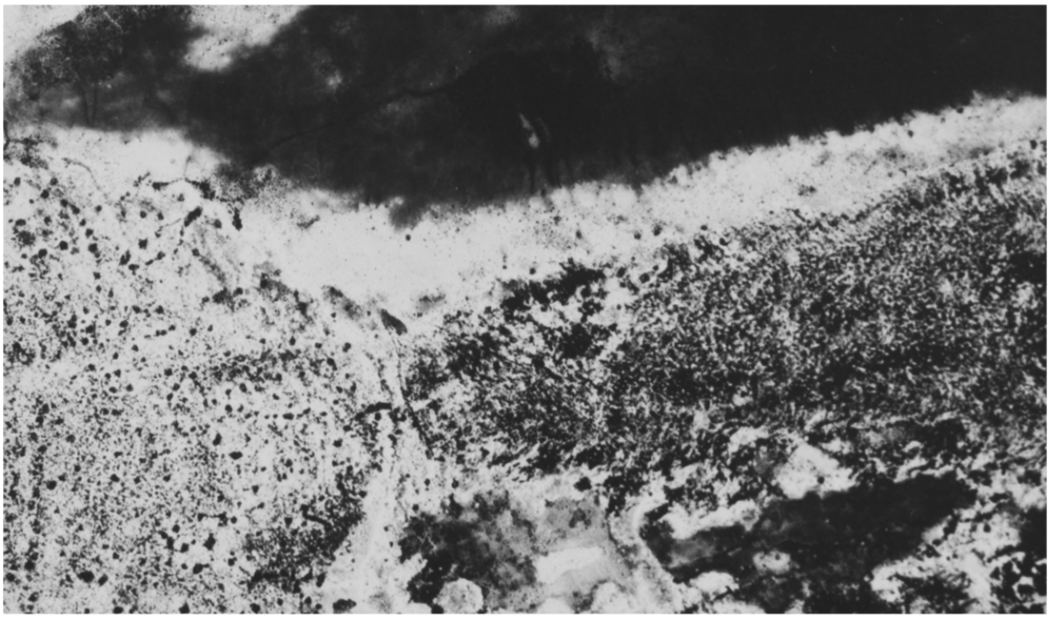

Fig. 2.7 Small-scale transverse dunes on top of older dune deposits along the southern shore of a lake in the central part of the study area (Fig. 2.3). To the west, this photo links up with Figure 2.6. Width of area shown ~4.5km; north is up. (© air photo: DNCT, Bamako)

Three samples were taken of lake-bordering dunes on the western end of the lake Niakéné Maoudo near the archaeological site of Akumbu. All three samples lack significant amounts of clay and silt, suggesting that the lake bottom was not the primary source of this material (App. 2, samples 1, 2 and 3). The grain size analyses of two samples reveal a slightly bimodal grain size distribution with an admixture of fine sand (grain size ~100 µm) to coarser material. These two samples were taken from the surface of the dune immediately west of the Akumbu site and therefore this admixture in the surface layer could relate to release of relatively fine sand from the site due to prehistoric human activities. With respect to morphology and sediment characteristics these dunes are not representative of most of the lake-bordering dunes in the study area. The relatively large size, the reddish colour and the degree of cementation of the sampled lake-bordering dunes suggest that they represent an old (possibly mid-Holocene) generation of lake-bordering dunes.

Irregular dunes

East of the lakes in the central part of the study area is a large area that has little to no supply of surface water. Due to this and to overgrazing by cattle, this area lies more or less bare, allowing aeolian sediment transport. The area consists of dunes and plains of deflation that seem to have been formed quite recently. Aeolian processes may still be active. Most of the dunes in the area are transverse dunes, but different types also occur. Therefore they are termed irregular dunes, thereby separating them from the regular transverse dunes. The desiccation of this area is probably exacerbated by tectonic activity (see sections 2.3.4 and 2.4).

Aeolian plains and individual dunes

Several relatively flat areas of aeolian origin exist within the study area. Some of them are erosive, whereas others seem to have been formed by accumulation. Aeolian plains formed by accumulation cover a large area west of the lakes. Aeolian plains formed by erosion (deflation) occur as much smaller patches, mainly in the east-central part of the study area where massive dunes are affected by deflation. In this section, an aeolian plain formed by accumulation will be simply called an 'aeolian plain', whereas an aeolian plain formed by deflation will be termed a 'deflated area'.

Within the study area, the deposits of aeolian plains (Fig. 2.8) may overlie longitudinal dunes. At some places, however, the deposits are thin, and the interdunal depressions of the longitudinal dunes are still visible. This is especially true in the west, near the extensive field of longitudinal dunes.

During the field reconnaissance a sample was taken from the aeolian plain and nearby another sample was taken from an underlying longitudinal dune. Both samples are quite similar in grain size composition, although the overlying deposits are somewhat coarser than the longitudinal dune material (App. 2, samples 6 and 7). Also, the longitudinal dune sand is reddish and slightly cemented, while the aeolian plain sand is yellow and loose.

The main source for the deposited material is most likely the fields of lake-bordering dunes. The lake-bordering dunes are adjacent to the aeolian plain and consist of fairly similar material (as far as can be concluded from the available few grain size analyses). The aeolian plain sands also seem to thin away from the lake-bordering dunes. Near the lake-bordering dunes, any older landforms are completely obscured by the aeolian plain sands. In the area between the lake Niakené Maoudo and the northern chain of lakes, the lake-bordering dunes are lacking. Here, the aeolian plain deposits are thin, and the underlying longitudinal dunes can easily be recognized.

Most of the aeolian landforms discussed hitherto include small isolated dunes that are either individual areas of aeolian accumulation, or different forms of aeolian accumulation within a greater field of accumulation. These features have been named individual dunes, allowing them to be mapped separately.

2.3.3 Fluvial and lacustrine landforms

Channels

The study area is cut by a number of fluvial channels. These channels were once fed by the Niger River, through the 'Fala de Molodo', which runs south and east of the study area (Figs 1.1 and 2.2). The channels in the study area only seasonally carry water from local rainfall and sometimes from river floods. Niger River waters can only reach the Méma in case of extremely high flood levels (see end of section 4.1). The Fala de Molodo is reported to have functioned during extreme Niger floods until its modification in 1932 as a part of the 'Office du Niger' irrigation works (Blanck & Tricart, 1990, p. 311). ORSTOM (1970, p. 19) reported that floodwaters from the Niger may penetrate the area from the east. Within the study area three types of channels were distinguished: (1) abandoned channels that are permanently dry, (2) abandoned channels that contain (stagnant) water during the wet season, and (3) 'active' channels that have been fed by Niger River floodwaters recently.

The largest channels are located in the north and the south of the study area and connect the interdunal lakes to the Inland Niger Delta floodplain (Fig. 2.9). The massive dunes strongly determined the location of the channels that tend to be located in the interdune depressions. Sealing of lake and channel bottoms by clayey deposits prevents seepage of surface water to underlying sandy dune deposits, in spite of very low groundwater levels. During dry climatic periods, channels in the study area were probably plugged by aeolian deposits, which forced the formation of new channels when the climate became wetter again (Tricart, 1965; Gallais, 1967; Makaske, 1998).

Lakes

In the northern half of the study area lies a chain of lakes. In the south lies another lake called Niakéné Maoudo (Fig. 2.10), which probably once was linked to the northern chain. The lakes represent zones of fluvial accumulation, as they form the endpoints of the floodchannels described above. Grain size analyses of samples taken from the bottom of the lake Niakéné Maoudo during the field reconnaissance show that the lake deposits consist of clayey and silty material (App. 2, samples 8 and 9).

Like the channels, the orientation of the lakes is mainly determined by the older landforms through which they were cut, especially the massive dunes. This also explains why the lakes form a chain from the north to the south. The lakes could most easily expand within the interdune depressions. At present, seasonal rainwater usually is collected in the deeper central parts of the lakes only. The shallower edges and the narrow connections between the lakes mostly remain dry throughout the year.

The samples taken from the lake bottom and the shoreline (Fig. 2.11) show strong differences in grain size distribution, indicating a zonation within the lakes. A sample from the middle of the lake Niakéné Maoudo contained 29 % clay and 45 % silt (App. 2, sample 8). A sample from the lake bottom approximately 50 m from the northwestern shoreline contained 18 % clay and 24 % silt (sample 9). A third sample from the top of a sub-recent beach face nearby contained only 4 % clay and 6 % silt (sample 10). The most likely explanation is that this results from selective transport of lake sediments to the shoreline by wave action. Due to this only the sand fraction becomes available for aeolian transport during periods with high lake stages. Only under vegetationless conditions (due to extreme aridity or overgrazing), the clayey sediments on the lake bottom become available for aeolian transport.

Fig. 2.8 Loose yellow aeolian sand on the aeolian plain north of the lake Niakéné Maoudo.

Fig. 2.9 Channel in the north of the study area, connecting the interdunal lake system to the Inland Niger Delta floodplain. Trees grow on the banks, but not on the bed, suggesting that the channel has been active recently. The channel is approximately 100 m wide and 1 m deep. Rod McIntosh on the right for scale.

Fig. 2.10 The central part of the completely dry lake Niakéné Maoudo.

Fig. 2.11 Shoreline of the now dried-up lake Niakéné Maoudo. The lake bottom is on the left. Sandy beach deposits in the middle of the photo probably were a major source of sediment for the formation of lake-bordering dunes, more to the right (outside the photo).

For geomorphological mapping, three hydrodynamic zones were distinguished within the lakes: (1) lake bottoms that experience flooding in an average wet season, (2) semi-dry lake bottoms that presently only get flooded in case of excessive precipitation, and (3) dry lake bottoms that remain dry throughout the year and testify to lake expansion under previous wetter climatic conditions.

Besides the chain of large lakes that dominate the study area, there are a few smaller lakes that are not connected to the other lakes. These lakes lie mostly in the east, near the field of irregular dunes. These lakes were formed by the same processes as the lakes in the chain, but became desiccated earlier in time, probably due to tectonic uplift of the area. This will be discussed in more detail in sections 2.3.4 and 2.4.

Floodplains

The study area is bordered on its eastern side by a vast floodplain, originally fed by the Fala de Molodo. The boundary between the low-lying floodplain and the higher grounds of predominantly aeolian origin to the west is rather abrupt and shows as a sharp NW-SE trended line on the satellite image. This line is interpreted to represent a fault, with differential crustal movements having caused the step in surface elevation. Immediately north of Boulel Ridge, the floodplain extends more to the west to Niakéné Maoudo. This is believed to be associated with a fault system that bounds Boulel Ridge to the north. We will return to the Boulel Ridge and the faults in section 2.3.4.

Gullies

The southern border of the study area is formed by Boulel Ridge. This ridge is carved by a multitude of local drainage channels. Some of these gullies feed the southern lake, Niakéné Maoudo, and obviously only function during the wet season.

2.3.4 Tectonic landforms

Ridge and inselbergs

Boulel Ridge is a tectonic feature bounding the Nara graben to the south (DNGM, 1987, fig. 3). The ridge is mainly composed of sandstone and its weathering products. It is the only place in the study area where bedrock crops out (Fig. 2.12). Outcropping sandstone is presumably mainly of Tertiary age ('Continental Terminal'), although Blanck & Tricart (1990) report outcrops of underlying Precambrian schists in gullies on the ridge, west of the present study area. Most of the ridge, however, is capped by ferricrete (Fig. 2.13), with some sandstone inselbergs remaining on top of the ridge. Locally, the ferricrete can be found directly on top of outcropping sandstone. Blanck & Tricart (1990) believe that Boulel Ridge is bounded to the north and to the south by semi-parallel faults, so that it can be considered a horst. They concluded that there was uplift along the presumed southern fault of at least 1000 m over a period of millions of years. The fact that Boulel Ridge presently rises only some 40 m above the surrounding plains indicates that tectonic deformation, if it still continues, has been slow or that deformation has stopped long ago. Anyway, weathering and denudation have caused modest relief in spite of (presumably) great tectonic movements.

Faults

Three faults are inferred to exist within the study area. On the geomorphological map only faults that have a geomorphological expression are indicated. Field observations, distribution of mapped landforms and literature suggest existence of more faults that influenced the geomorphological evolution of the study area.

The most pronounced fault runs NW-SE through the eastern part of the study area (Fig. 2.14) and was already mentioned above in the section on floodplains. Since the fault clearly stands out geomorphologically, relative uplift of the eastern part of the study area may have been fairly recent, in a geological sense, and may still continue today. The relative uplift severed channels and lakes in the study area from the Fala the Molodo, and strengthened processes of desiccation, especially in the most uplifted parts, resulting in dry lakes and the formation of fields of irregular dunes with deflated areas.

While the southern boundary fault of Boulel Ridge was first described quite recently by Blanck & Tricart (1990), the northern boundary fault was already known longer as the southern fault of the Nara graben (DNGM, 1987, fig. 3). This fault approximately follows the boundary between the old ferricreted surface of Boulel Ridge and the recent aeolian, lacustrine and fluvial deposits. In the eastern part of the study area, southwest of the Akumbu site, this fault is can be recognized as a clear straight-lined step in the terrain. This step is a few metres high only and is dissected by gullies draining the neighbouring parts of the ridge. Locally, dark-red, strongly cemented sediments crop out along the step. These could represent Ogolian or pre-Ogolian dune deposits. More to the east, this step disappears below lake-bordering dunes along the southern shore of the lake Niakéné Maoudo. As indicated by DNGM (1987, fig. 3) the fault, roughly following the northern edge of Boulel Ridge, slightly changes orientation near the eastern end of Niakéné Maoudo and turns some 10 to 15° more to the northeast in the eastern part of the study area.

Based on our geomorphological observations we hypothesize that there is another fault present in the zone immediately north of Boulel Ridge, which runs along the remarkably straight northern shore of Niakéné Maoudo. More to the east, this fault is believed to more or less follow the northern margin of the floodplain of the former feeder channel of Niakéné Maoudo. Further east, in the wide floodplain east of the study area, it cannot be recognized. West of Niakéne Maoudo the interpreted fault converges with the above-mentioned northern boundary fault of Boulel Ridge.

Fig. 2.12 Outcropping sandstone on Boulel Ridge.

Fig. 2.13 Ferricrete covering Boulel Ridge.

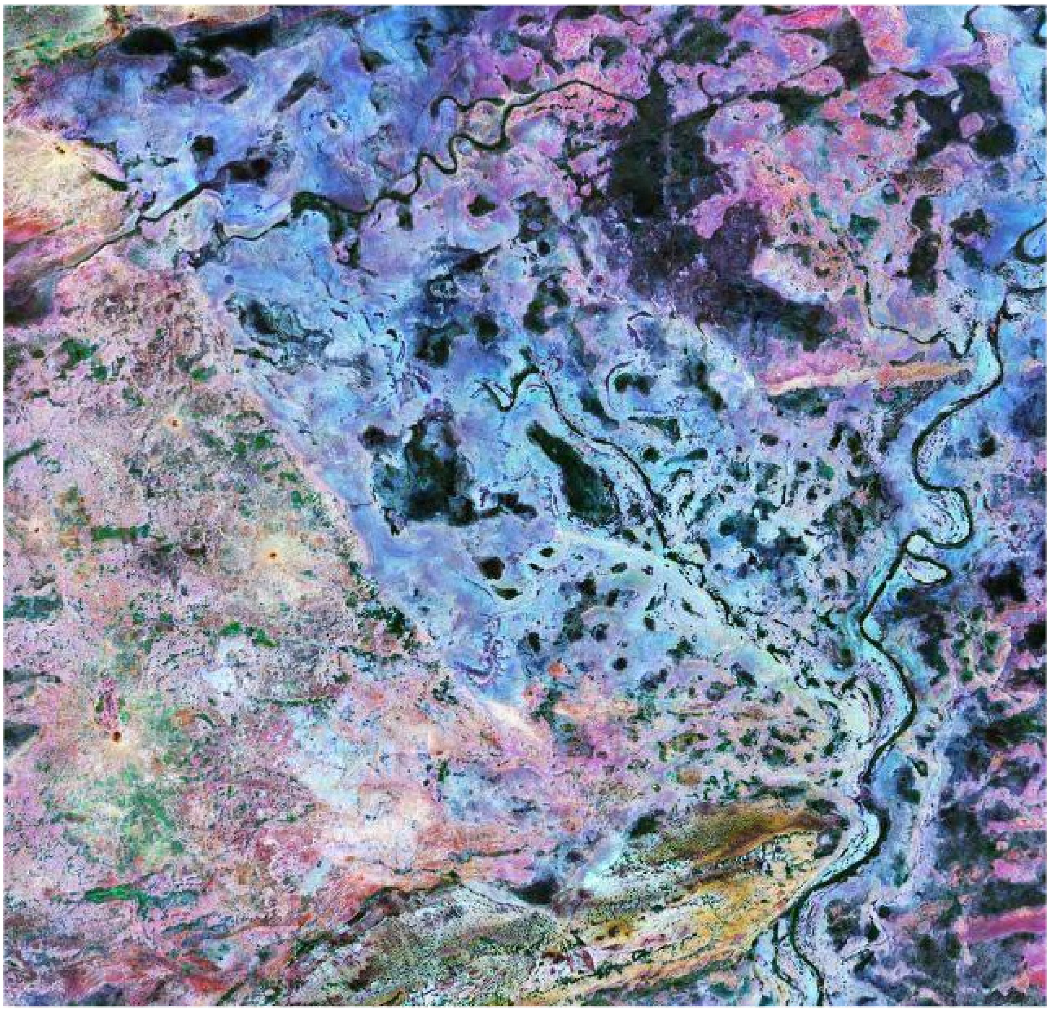

Fig. 2.14 LANDSAT image showing the western part of the study area, where a NW-SE trended fault separates the Inland Niger Delta floodplain (blue colours) from higher grounds in the west. Width of area shown ~36 km; north is up.

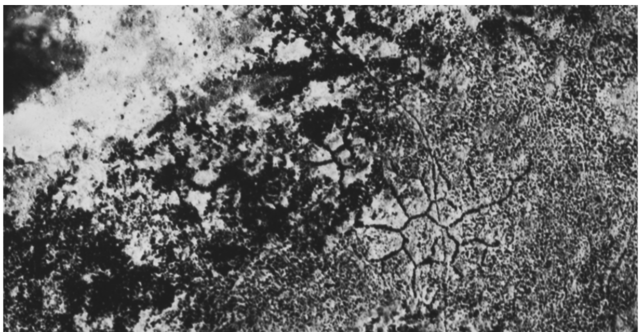

Fig. 2.15 Features of unknown origin, resembling giant desiccation cracks ~5 km southwest of Toladié. Width of area shown ~3.8 km; north is up. (© air photo: DNCT, Bamako)

Note that the triangular area enclosed by the (partly interpreted) faults west of Niakéné Maoudo is a fairly wet dune area with irregular topography and many small seasonal ponds and channels. These features are absent in the neighbouring longitudinal dune field. The area immediately north of Boulel Ridge seems to have experienced greater subsidence than the central part of the study area, which explains the existence of the lake Niakéné Maoudo (and the connected elongate floodplain to the east). Unlike the large interdunal lakes in the area, Niakéné Maoudo has an ENE-WSW orientation that can not be attributed to massive-dune topography.

Perhaps related to the northern boundary fault of Boulel Ridge is a pond near the village of Boundou-Boubou, which is located on the edge of Boulel Ridge south of the central part of Niakéné Maoudo. We observed that this pond still held water (1.5 m deep) in the middle of the dry season, while all lakes and ponds in the study area were completely dry. According to the local population the pond near Boundou Boubou holds water for at least 10 months per year. When surface water in the area has dried up later in the dry season, water is taken from a deep groundwater reservoir through wells that are up 60 m deep. Local rise of deep groundwater along the fault plane could explain the existence of the pond near Boundou Boubou. A similar remarkable wet pond was observed just outside of the study area near Boulel, on the southern edge of Boulel Ridge.

2.3.5 Miscellaneous landforms

Ponds and depressions

Throughout the study area generally small depressions and ponds occur. The exact genesis for each of these features is hard to establish, and may vary. It was therefore decided to classify these features as different landforms. Many of the depressions and ponds were most likely formed by fluvial processes. Parts of old channels may, for example, become isolated by dune formation within the channel and turn into ponds or depressions. All ponds and depressions can be expected to serve as basins for rainwater. Some ponds may be anthropogenic (*e.g.* clay pits).

Unexplained features

In the southeastern part of the study area (5 km southwest of Toladié) a feature of unknown origin was mapped. It looks like giant cracks in the surface (Fig. 2.15), which could be interpreted as desiccation cracks because of its circular-angular pattern. The size of the phenomenon (circles measuring hundreds of metres across) and its isolated occurrence are remarkable. Usually desiccation cracks are much closer spaced, while the regular pattern of attached semi-circular cracks covers large areas. Since such cracks tend to form in clayey fluvial soils, the fact that the feature in the study area is located on a massive dune is remarkable. Widespread floodplain microrelief (termed gilgai) associated with desiccation cracks (diameter of semi-circular components ~20 m) was described by Fagan & Nanson (2004).

2.4 Geomorphological history

2.4.1 Introduction

The study area has experienced pronounced climatic changes that still can be recognized in the present geomorphology (Fig. 2.16). During arid periods aeolian processes were dominant, while during humid periods the Niger River spilled water into the region resulting in fluvial and lacustrine landforms. Because of the location of the study area in the transition zone from savannah to desert, climatic changes have great impact.

In this section we will establish a chronology for the landforms in the area. This chronology will be based on the available field data, observations on the relative positions of landforms during the mapping process, and work on geomorphological history carried out in neighbouring regions (Tricart, 1965; Gallais, 1967; Makaske, 1998).

Geologically, most landforms mapped in the study area are fairly young. The underlying bedrock is mostly obscured by these landforms, except for the sandstone inselbergs of Boulel Ridge. Despite being hidden, faulting and tectonic deformation of the underlying bedrock profoundly influenced the geomorphological history of the study area.

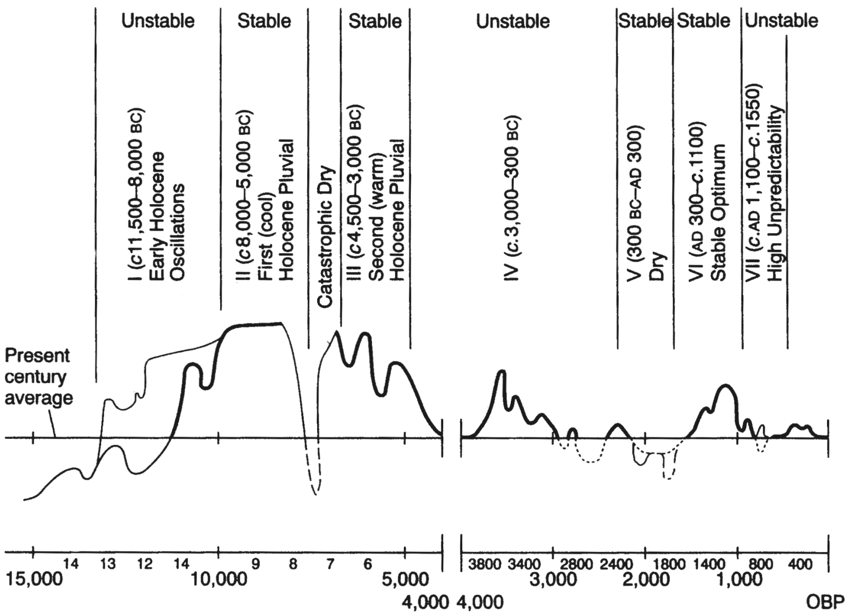

Fig. 2.16 Graph indicating Holocene climatic periods in the Inland Niger Delta region (from McIntosh, 1998).

2.4.2 The Ogolian arid period (20,000 – 12,500 BP)

Except for Boulel Ridge, the oldest visible features within the study area are the massive dunes. The impressive size of these features suggests that they were formed during a long arid period with strong winds, blowing from a fairly uniform direction. The massive dunes probably once covered the entire study area. Their planform pattern strongly influenced the position of later landforms. This is particularly true for the lakes in the area, which occupy the interdunal depressions between the massive dunes. One could therefore consider these dunes as the bones of the present landscape. Morphologically similar dunes in neighbouring areas were inferred to have been formed during the Ogolian period (Gallais, 1967; McIntosh, 1983; Makaske, 1998).

2.4.3 The early-Holocene humid period (12,500 – 8000 BP)

The Ogolian arid period was followed by a relatively long humid period during which the massive dunes became inactive and vegetated. Soil formation (Fig. 2.4) further contributed to dune stabilization. Increased precipitation in the Niger River catchment caused higher flood levels and, probably through the Fala de Molodo (or a precursor of this channel), Niger River floodwaters reached the area, with the formation of floodchannels in interdunal depressions. The long early-Holocene humid period was recognized in sedimentary records and landforms throughout sub-Saharan West-Africa, and fluviolacustrine deposits from this period were dated in the southern part of the Inland Niger Delta (Makaske, 1998). The available dating evidence suggests that this period lasted from 12.500 to 8000 (radiocarbon) years BP.

It is unknown to what extent the landforms formed during this humid period can still be recognized within the study area. Later geomorphological developments probably have obscured these early-Holocene forms. The incomplete geomorphological record hampers detailed reconstruction of the climatic conditions. During later humid periods, the study area seems to have experienced many climatic oscillations. Such oscillations may also have occurred during this early-Holocene humid period, but there is little evidence so far to support this case.

2.4.4 The mid-Holocene arid period (8000 - 7000 BP)

The fairly long early-Holocene humid period was followed by a relatively short period of intense aridity. During this period aeolian processes dominated again, and a vast field of longitudinal dunes was formed. Much of this field is still intact today, especially north and west of the study area. This field originally also extended further to the east, but there it was eroded and covered by later aeolian deposits. Remains of these longitudinal dunes, especially the interdunal depressions, can still be recognized in the central part of the study area (Fig. 2.6).

In the southern Inland Niger Delta, morphologically comparable (in size and orientation) longitudinal dunes were described. On the floodplain they are fragmented and isolated in occurrence, while constituting coherent fields along the (western) margin of the floodplain (Gallais, 1967; McIntosh, 1983; Makaske, 1998). These dunes were inferred to have been formed in an arid period between 8000 to 7000 years BP and, by analogy, longitudinal dunes in the present study area are believed to be of the same age. The aeolian deposits of this period must have filled fluvial channels and lakes, which were formed in the wet early-Holocene period.

During the mid-Holocene arid period, erosion and redeposition of older Ogolian dune sands took place. In a clay pit near Nampala red aeolian sand overlies a dark-grey clayey bed (Fig. 2.17). The red colour of the dune sand suggests that the material underwent a relatively long period of soil formation, probably during the wet early-Holocene period. The grain size distribution of the red deposits indicates poor sorting of the sand fraction and significant amounts of clay (5 %) and silt (9 %) (App. 2, sample 11), features that also characterize massive dune deposits (App. 2, sample 15). Since the red deposits overlie dark-grey, more clayey, material (App. 2, samples 12 and 13) interpreted as early-Holocene lake deposits (dark-grey colour indicates near-permanent waterlogged conditions, during or shortly after deposition), the overlying red sand is likely to have been deposited during the mid-Holocene arid period or later. Given its grain size characteristics it most likely represents locally eroded and redeposited Ogolian material.

2.4.5 The mid-Holocene humid period (7000 – 4000 BP)

Most of the fluvial and lacustrine landforms in the study area are believed to have been formed during the mid-Holocene humid period (7000 – 4000 years BP). During this humid period, the Niger River spilled floodwaters into the Méma, presumably through the Fala the Molodo, and new channels debouching into the interdune depressions formed. The relatively loose mid-Holocene aeolian sands were probably much easier to erode than the more cemented red Ogolian dune sands. Therefore the orientation of the channels appears strongly determined by the spatial structure of the underlying massive dunes. It is likely that the channels in fact follow the same routes as the early-Holocene channels.

The formation of the lakes within the study area also resulted in new aeolian landforms: the lake-bordering dunes. It seems likely that the first lake-bordering dunes were formed contemporaneously with lake beaches during the wet mid-Holocene period (although other source areas may have become important later). For example, lake-bordering dunes fringe the extreme western palaeoshoreline of the lake Niakéné Maoudo, presumably marking the greatest mid-Holocene expansion of the lake (Fig. 2.18).

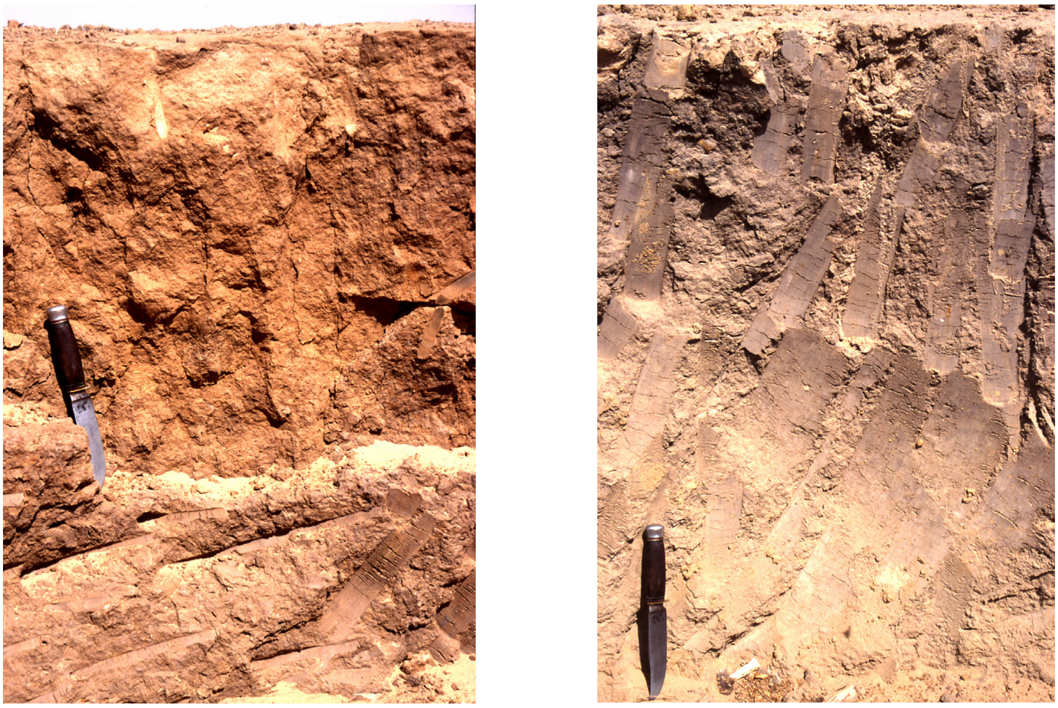

Fig. 2.17 Sediment profiles exposed in a pit near Nampala. Left: red dune sands abruptly overlying dark-grey clayey lake deposits. Right: light-grey lake deposits grading upward into dark-grey lake deposits. Covering red dune sand is absent in this profile. Lake deposits are interpreted to be early-Holocene in age; red dune sand is believed to be mid-Holocene. Knife measures 23 cm. Sediment grain size distributions for red, dark-grey and light-grey units are given in Appendix 2 (samples 11, 12 and 13 respectively).

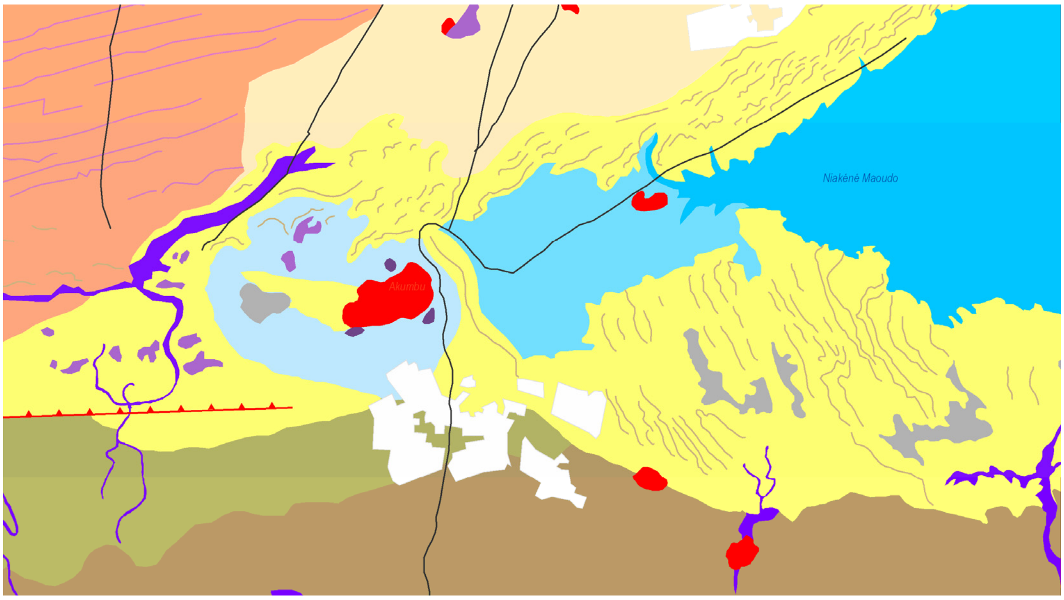

Fig. 2.18 Part of the geomorphological map (App. 1) showing the western end of the lake Niakéné Maoudo, with lake-bordering dunes (yellow) marking successive positions of the shoreline. Blue colours indicate lake bottom associated with various stages (light-blue is old, darker blue is recent). The site of Akumbu is the red patch in the westernmost part of the lake. Width of the area shown ~12.5 km; north is up.

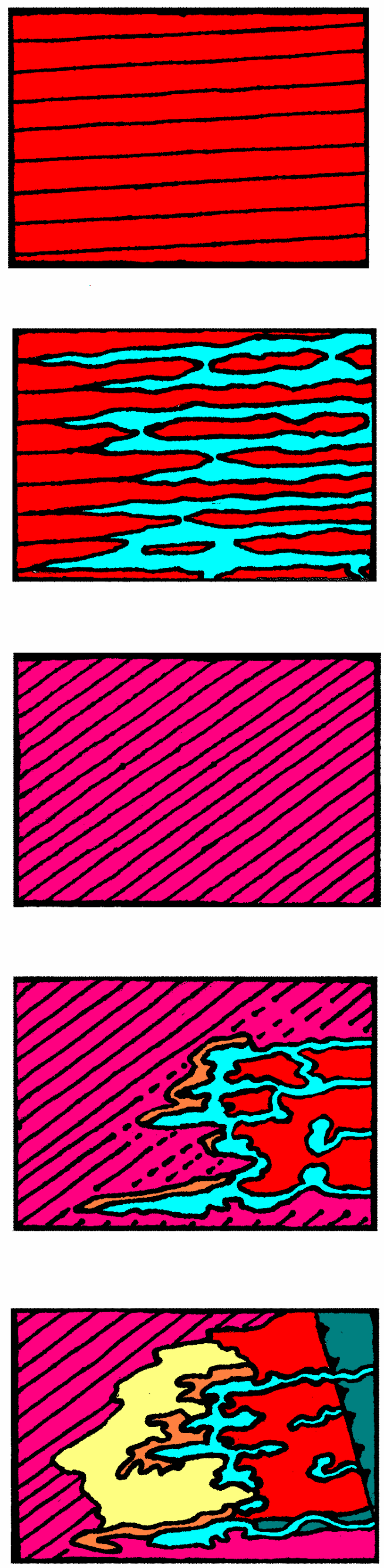

Fig. 2.19 Sketches of the main geomorphological events in the study area during the various Holocene climatic periods.

Ogolian arid period
(20,000-12,500 BP)

- Formation of massive dunes

Early-Holocene humid period
(12,500-8000 BP)

- Stabilization and degradation of massive dunes
- Formation of interdunal lakes

Mid-Holocene arid period
(8000-7000 BP)

- Formation of longitudinal dunes

Mid-Holocene humid period
(7000-4000 BP)

- Stabilization of longitudinal dunes
- Fluvial erosion
- Formation of interdunal lakes
- Formation of lake-bordering dunes

Late-Holocene aridification
(4000 BP – present)

- Formation of lake-bordering dunes, aeolian plains and irregular dunes
- Pronounced influence of fault tectonics on geomorphological evolution

As mentioned in section 2.3.4, a fault bounds the higher, predominantly aeolian grounds in the east-central part of the study area from the lower floodplain that extends far to the east. The clear step in the terrain suggests that relative crustal movements are fairly recent and possibly still going on. Given the fact that a number of presumably mid-Holocene fluvial channels cross the fault, it seems that the formation of significant morphologically visible fault offset postdates the humid mid-Holocene period. It can be hypothesized that fluvial aggradation east of the fault during humid mid-Holocene times was sufficiently rapid to enable the formation of flood-channels spilling water across the fault into the Méma. In response to late-Holocene aridification and lowering Niger River flood levels less sediments were transported to these remote parts of the Inland Delta floodplain. Therefore in this period vertical displacement rates along the fault outpaced fluvial aggradation rates east of the fault, giving the fault its present geomorphological expression. Due to this tectonic process the largest part of study area gradually became detached hydrologically from the Inland Niger Delta floodplain during a period of progressive climatic aridification that will be discussed below.

2.4.6 Late-Holocene climatic oscillations (4000 – Present)

During the late Holocene, the study area experienced many climatic oscillations, while average, climatic conditions gradually became more arid than during the previous period (Fig. 2.16). Geomorphologically, this period was characterized by an alternation of phases with dominance of fluvial and lacustrine processes and phases with dominance of aeolian processes. Within the study area four geomorphological products of these climatic oscillations are identified, which will be described below.

First, the climatic oscillations invoked the formation of palaeoshorelines with associated lake-bordering dune complexes. Throughout the late-Holocene period the overall tendency was lake regression, which is best illustrated by the geomorphology around the Akumbu site, at the western end of the lake Niakéné Maoudo (Fig. 2.18). It may be that the source area of the material that accumulated in the lake-bordering dunes varied depending on the climatic conditions. Under humid conditions with high lake levels, the beaches probably have been the most important source area, whereas under arid conditions the dry lake bottom and more remote sources may have provided material for lake-bordering dune building.

Second, the fields of transverse dunes seem to have been formed during this period, by remobilisation of especially the massive dune deposits during short periods of arid conditions.

Third, many small-scale ponds and depressions in the area are believed to be of late-Holocene age. Aeolian activity caused formation of deflation basins, and fragmentation of existing depressions, like abandoned channels, by dune formation. New channels may have been formed in response to degradation of existing channels during short arid periods.

Fourth, a large field of irregular dunes in the east–central part of the study area is believed to have formed relatively recently. Relatively strong tectonic uplift of this area probably contributed to the arid surface conditions favouring dune formation. Other factors leading to distinctive dune morphology in this area are the abundance of (abandoned) fluvial channels and, most likely, human activities.

In Figure 2.19 the geomorphological history of the study area since the Ogolian period is represented schematically. In these simplified sketches, tectonic features (including Boulel Ridge) are largely left out of consideration. The faults recognized in the study area are shown in Figure 2.20. In absence of subsurface data and knowledge about rates of displacements along the faults, one can only speculate about the influence of fault tectonics on early-Holocene and mid-Holocene geomorphological evolution. The NNE-SSW trended fault in the east of the study area (fault **a** in Fig. 2.20) that was apparent at the surface during the late-Holocene period probably affected geomorphological evolution during earlier periods also, with floodplain sedimentation gradually covering Ogolian (and mid-Holocene?) aeolian forms east of it. This remains to be investigated and is not shown in Figure 2.19. Uncertainty also exists about the age of the floodplain east of Niakéné Maoudo. Probably this floodplain was formed already in the wet mid-Holocene period, by sedimentation from a channel connecting Niakéné Maoudo with the Fala the Molodo. Increased influence of fault tectonics, due to decreasing fluvial sedimentation caused abandonment of the channel during the late-Holocene period. Probably this happened already early in the late-Holocene period, as east of fault **a** (Fig. 2.20) the abandoned channel silted up to such an extent that it is presently hard to recognize.

2.5 Modern land use

Three observations can be made concerning modern land use within the study area. Firstly, the aeolian plain in the west seems to be favoured for agriculture. This is surprising, since such land would seem the least fertile. The deposited material in the area, however, probably does not consist of poor aeolian sands only but may include finer material from lake bottoms, enhancing agricultural suitability. Furthermore, underlying fertile early-Holocene lake deposits may be at or near the surface in low parts of the plain. Since the main subsistence activity in the region is pastoralism, one can assume that the inhabitants have a reasonable supply of manure available to sustain the fields on the aeolian plain, which should make agriculture on the plain viable in sufficiently wet years.

The second observation is that the old lakes that dried up due to the region's uplift are also favoured locations for agriculture. This seems only logical, for on these locations farmers can benefit from fairly fertile deposits. Also, these locations serve as natural basins for precipitation, and retain moisture.

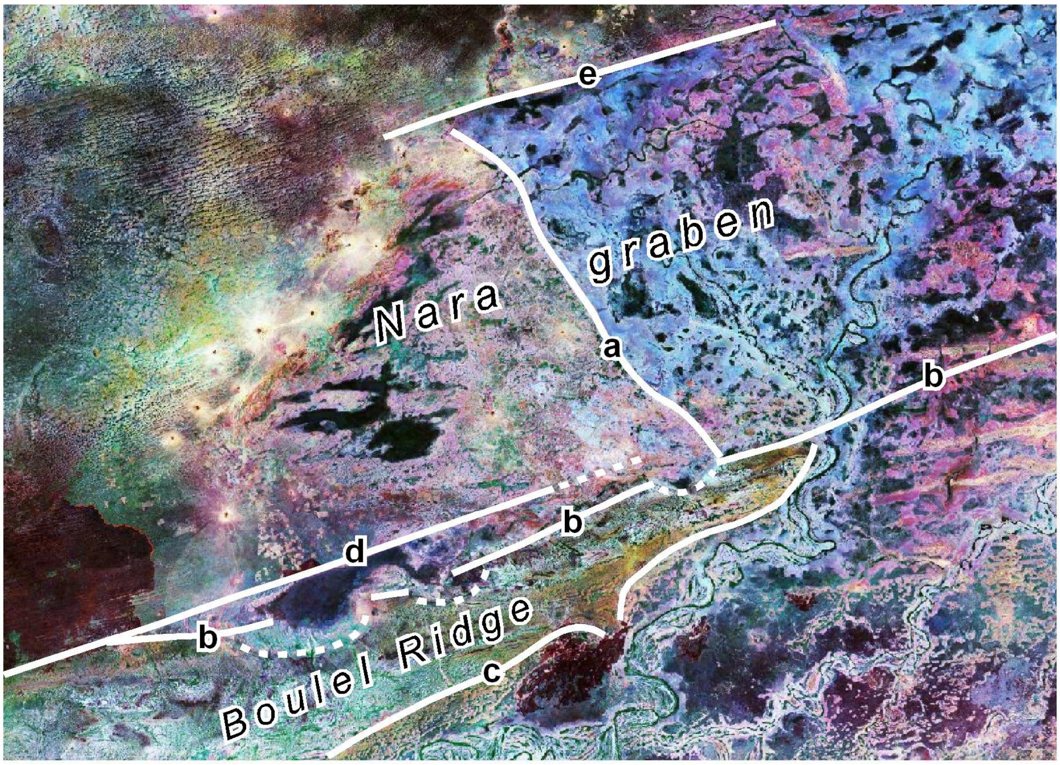

Fig. 2.20 The tectonic framework of the study area. Fault a is not known from the literature, but clearly stands out on the satellite image. Fault b was indicated by DNGM (1987, fig. 3) and represents the southern boundary of the Nara graben. Fault c was described by Blanck & Tricart (1990) and bounds Boulel Ridge to the south. Fault d was interpreted from geomorphological observations described in this report. Fault e is part of the fault system that bounds the Nara graben to the north and is not discussed in this report. Width of the area shown ~82 km; north is up.

Finally, one can observe that the present lake bottoms, although largely not inundated throughout the year now, are completely devoid of cultivated land. Probably this land is still too wet or moisture conditions in these areas are too unpredictable for the farmers.

3 Preliminary archaeological suggestions

Edwin de Vries

3.1 Introduction

In the following chapters I will pay attention to the archaeological data from the study area. In this chapter we will address some preliminary observations and considerations regarding the archaeological data, acquired during production of the geomorphological map. In the following chapters the archaeological data and potential of the study area will be further elaborated and placed in both historical and theoretical frameworks. None of the considerations presented in this chapter should be considered absolute facts, but rather as suggestions of archaeological potential.

During the production of the geomorphological map we were confronted with recurring themes with respect to the location and size of sites. These themes made it alluring to interpret the sites in terms of function or potential subsistence activity, based on both location and size. The main basis for interpretation has been the assumption that soils in the direct vicinity of the sites are used for subsistence activities.

3.2 Sites near areas of potential high agricultural diversity

During the first millennium AD the region enjoyed a relatively long period of humidity. It was during this period that famous sites like Jenne-jeno and Tombouctou grew large and prosperous. Probably during this same period the lakes within the study area were flooded regularly during the wet season, allowing extensive agriculture in their vicinity. The main crops cultivated may have been the same as those cultivated in the Inland Delta, being African rice, millet, and sorghum. Each of these crops has different needs for water, and therefore may have been cultivated on different landforms. African rice is the most demanding of the crops and needs the most water. Sorghum needs significantly less water, while millet needs the least.

Within the study area, one can find at least three large, perfectly located sites, in whose vicinity all three crops could have been grown. The first is the site of Akumbu, which lies on the western end of the lake Niakéné Maoudo (Fig. 2.18). The lake bottom in the vicinity of the site, which maybe experienced only short seasonal flooding, could have been ideal for growing sorghum. The area to the east must have been flooded much longer during the wet season, and would therefore have been more suitable for growing African rice. Finally one would have been able to grow millet on the dunes that mark the shores of the lake.

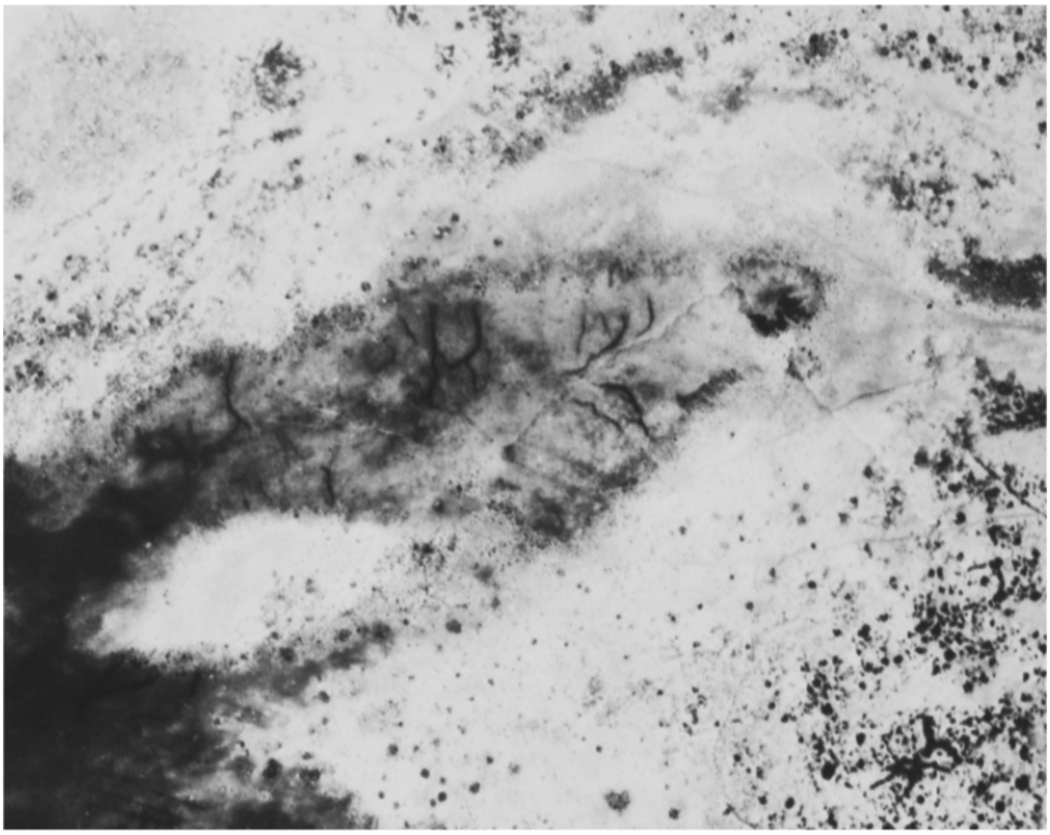

Fig. 3.1 Presumed agricultural site (dark spot NE centre) ~3 km west of Toladié. Width of area shown ~3.2 km; north is up. (© air photo: DNCT, Bamako)

The second site is located just southwest of Toladié (Fig. 3.1), and also enjoys the availability of three suitable soils. Firstly, there is a part of a lake that could have been used to grow African rice, just west of the site. Secondly, in the direct vicinity of the site, the lake was probably only flooded for a brief period, allowing the cultivation of sorghum. Thirdly, millet could have been grown on the massive dunes bordering the lakes.

Finally, a large site is located centrally within the northern chain of lakes (along the Nampala-Toladié road) (Fig. 3.2). This site also has three suitable soils in the direct vicinity of the site: firstly, due north, there is the lake itself for African rice; secondly, there are the infrequently flooded areas near the site; and thirdly, there are the remnants of massive dunes east and west of the site.

Obviously these examples do not cover all sites near soils suitable for agriculture. One can expect to find far more sites such as these in the vicinity of the lakes, and possibly also near the former lakes in the east. But there our view is distorted by relatively recent geomorphological events, especially the formation of the irregular dunes. This also raises the question whether significant uplift of the area has taken place during the human occupation of the area. If so, this may have greatly affected these sites, and the means of subsistence of the inhabitants.

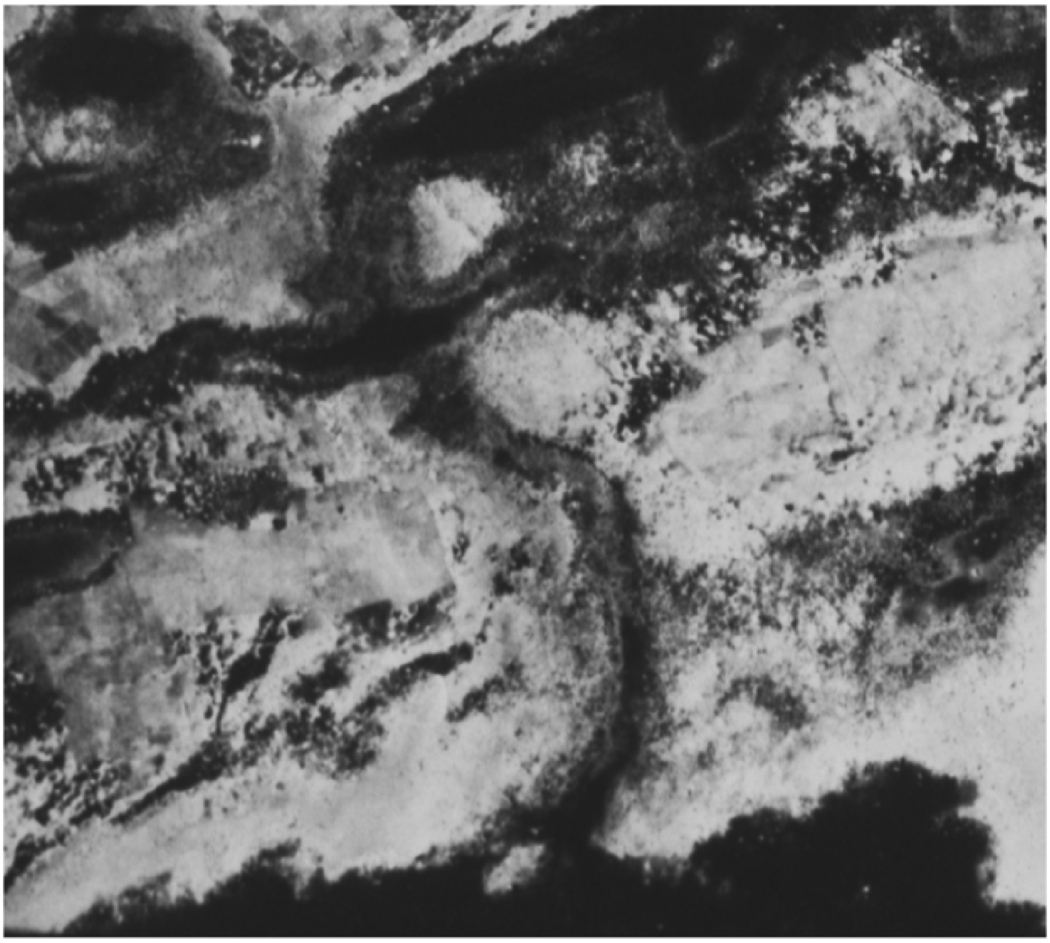

Fig. 3.2 Presumed agricultural site (rounded white area on the northern end of the channel, NE bank) on channel connecting two lakes, ~8 km east of Nampala. The site location may also have been favourable for fishing. Width of area shown ~3 km; north is up. (© air photo: DNCT, Bamako)

As discussed in chapter 5, resource diversity is particularly important under the Pulse Model. Around these sites there were soils that could have supported diverse crops and cropping regimes. In such a situation, future research might fruitfully explore whether there were coresident specialists cultivating different types of crops and exchanging produce.

3.3 Sites near areas favourable for fishing

The techniques employed by fishermen to obtain their food can be very diverse. This is due to a multitude of different factors, such as the species that are fished for, the fishing season, etc. It is therefore hard to establish from aerial photographs if a site in the study area can be considered to be a site related to fishing. However, during the production of the map we encountered several sites located near connections between larger lakes. These connections are scoured into the relatively resistant massive dunes, which causes them to be relatively narrow. These narrow connections were probably very suitable locations for obtaining fish. The large site on the

Nampala-Toladié road (Fig. 3.2), mentioned in the previous section, is a good example of such a site. Although the site was probably mainly inhabited by agriculturalists, its fortunate location may have facilitated fishing during the wet season. This site also might have supported specialists, in this case practising net fishing.

3.4 Sites near areas suitable for pastoralism

Within the fields of lake-bordering dunes that outline the western shorelines of the lakes (Fig. 3.3), numerous sites are located that are significantly smaller than most other sites visible on aerial photographs. These sites lack soils that would be ideal for agriculture in their immediate vicinity.

Fig. 3.3 Field of lake-bordering dunes on the northwestern shore of the lake Niakéné Maoudo, an area that could have hosted pastoral activities. Width of area shown ~6 km; north is up. (© air photo: DNCT, Bamako)

Also the aeolian plains and longitudinal dunes to the west of the lake-bordering dunes seem unfavourable for agriculture. The aeolian plain was more likely used by primarily pastoral people, roaming the plain in search of fresh grass for their cattle. Sites in the fields of the lake-bordering dunes have been identified during an earlier survey in the area. They contained abundant amounts of cattle-remains, suggesting a strong connection to pastoral activities on the aeolian plain (see Ch. 4). It seems unlikely however, that these sites are true pastoral sites, since pastoral people rarely leave sites large enough to be detected on aerial photographs. It would be worthwhile to further investigate these sites in future field research, to learn how they relate to the pastoral activities on the aeolian plain.

3.5 Iron working sites

The working of iron has been an important aspect of life in the Middle Niger, and quite often supernatural powers were imputed to those able to work iron. As a result, these workers often lived in separate communities. It has been shown in the Inland Delta region that such communities were not always situated near their most important resources, laterite and fuelwood. In the Méma, though, some iron-working sites such as Boulel were indeed situated near raw material. The ferricretes of Boulel Ridge could have served as a source raw material for iron. Several sites along the ridge may be associated with the extraction of iron-rich material, and perhaps also with the working of iron.

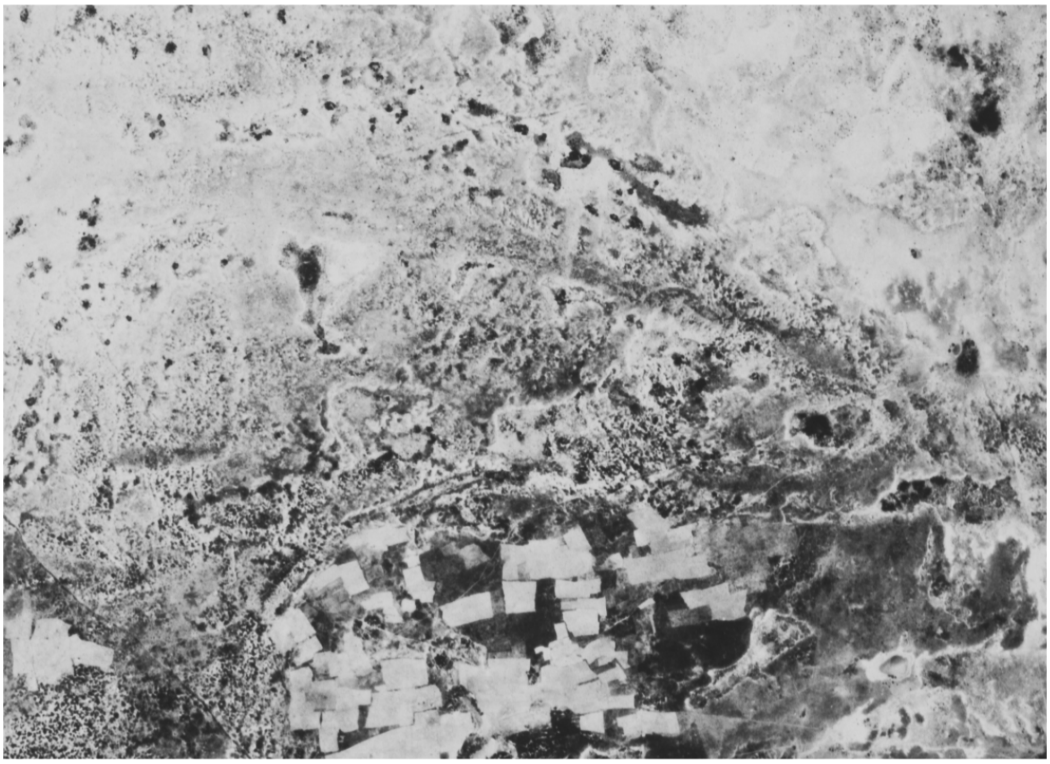

Fig. 3.4 Site cluster ~5 km southeast of Toladié. The site cluster covers the whole central area of the photo, with recent fields marking the southern edge and a tightly bended palaeochannel marking the southeastern and northern edge. Sites appear as dark spots with white 'halos'. Width of area shown ~4.5 km; north is up. (© air photo: DNCT, Bamako)

3.6 Site clusters

Southeast of Toladié a large concentration of sites of considerable size exists (Fig. 3.4). Such clusters of sites have also been reported from other parts of the Middle Niger region, and are associated with complex sociocultural developments. Ample attention will be paid to these processes in the following chapters. This section only serves to show such a cluster of sites within the study area, demonstrating the relevance of such processes for the study area.

4 Prior knowledge of the Méma: previously known sites and their interpretation

Roderick J. McIntosh

4.1 Colonial-era "prospections et sondage"

The spectacular sites of the Méma (Apps. 3 and 4) – those mute but eloquent witnesses to past centuries of rural abundance and urban prosperity in the midst of today's sad landscape of sand-blown desolation – first came to light in an indirect manner. Beginning in the 1920s, the French Colonial powers conceived a hugely confident irrigation and development scheme for the southern Méma and the Karéri (region of Dioura), the *Office du Niger* (Van Beusekom, 2000; R. McIntosh, 1998, pp. 1-5). The attention of engineers and administrators of the *Service Hydrographique* attached to the *Office du Niger,* particularly the attention of those responsible for the thorough mapping and admirable topographic analysis of these regions abutting the palaeochannel (the Fala de Molodo), quickly turned to the scores of abandoned mounds. Were they habitation sites or tumuli (such as those being excavated early in the Colonial period in the Lakes Region and Niger Bend of the Middle Niger)? What were their dates? What had caused regional depopulation on, evidently, such a catastrophic scale?

In the absence of scientific excavation and radiometric dating, the date of abandonment could only be speculated upon. As recently as the early 1960s, Raymond Mauny places the depopulation of the Méma at the thirteenth century AD. As it happens, his guess was not so very far off (at least for the final stages of regional abandonment) - but for the wrong reasons. Mauny speculates that Méma settlement abandonment was due to the wars accompanying the founding of the 'empire' of Mali. Mauny believed the process accelerated in the fifteenth century, with incursions of Tuareg (encouraged by the weakening of Mali), by the conquests of Sonni Ali Ber of Songhai, (AD 1468) and by the invasions of the Mossi in the 1480s (1961, pp. 93-95).

Mauny was crafting the masterful interpretations contained within his Tableau *Géographique* from very little empirical grounding. On the ground, the Méma has seen the good and the ugly. One of the best was a *Service Hydrographique* employee, Serge Urvoy, who from 1930-1944 produced fine maps, at 1:400,000 of the 'tumuli' (80 in total from Sokolo to Niafunké) (Mauny, 1961, p. 97, fig. 9) (Fig. 4.1). Our knowledge of Méma site distribution had not appreciably improved by the early 1980s, when a map of the 'tumuli' along the Middle Niger is published by Bedaux *et al.* (1978) (Fig. 4.2).

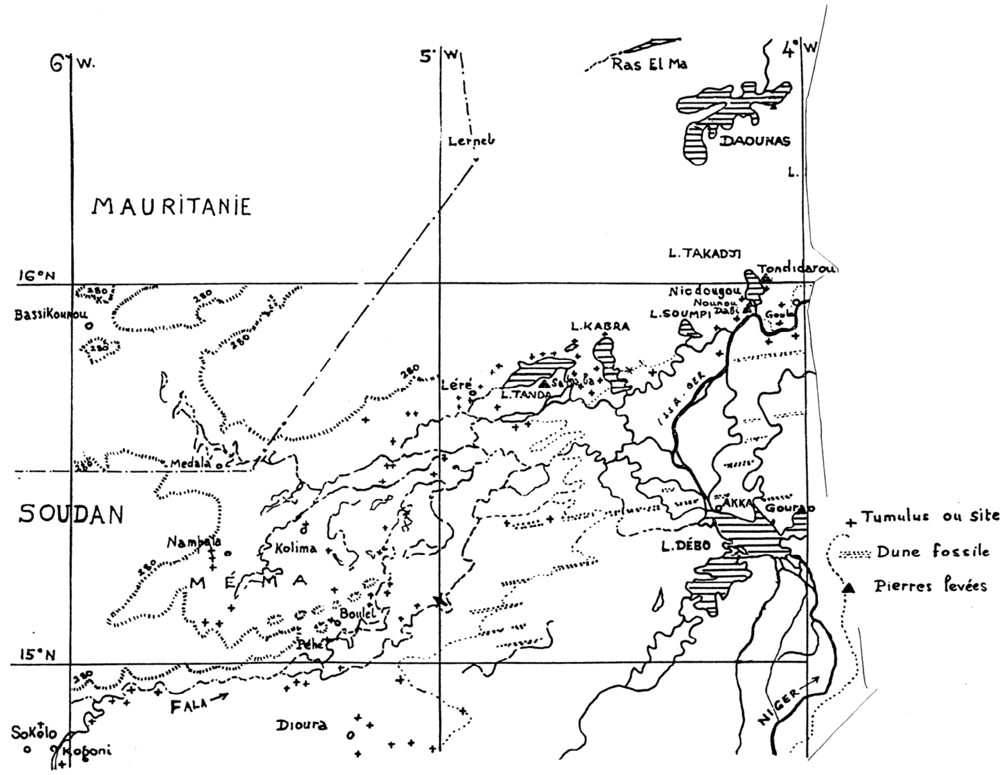

Fig. 4.1 Sites of the Méma, known at the end of the colonial era (from Mauny, 1961).

Contrasted with Urvoy were those unknown employees of the *Office du Niger* who, in 1930, 'excavated' the important site of Péhé (#101 in Apps. 3 and 4). Of these diggings we possess only a sketch plan and an incomplete inventory of 132 of the unknown total number of objects removed (Fig. 4.3). Known historically as the putative capital occupied by the king, the Tunka, of the Méma kingdom, ally to Sunjata of Mali, the site of Péhé rests on the banks of the Fala de Molodo south of the Boulel Ridge. Péhé measures 400 m by ca. 200 m and the 1930 diggings reached sterile soil at ca. 10 m depth. The sketchy report [disinterred by R. Mauny from the *Institut Fondamental de l'Afrique Noire* (IFAN) archives] records iron furnaces (to the west and south) and many offering hearths [similar to those seen on Lakes Region funerary tumuli, such as El-Oualadji (Fontes et al., 1991; R. McIntosh, 1998, pp. 224-27; Mauny, 1961, pp. 98-99). The *Institut Fondamental de l'Afrique Noire* researcher George Szumowski revisits the site in 1952, sinking 'plusieurs sondages' (Szumowski, 1957, pp. 231-34) and Mauny made a flying tour of the site in 1954-55.

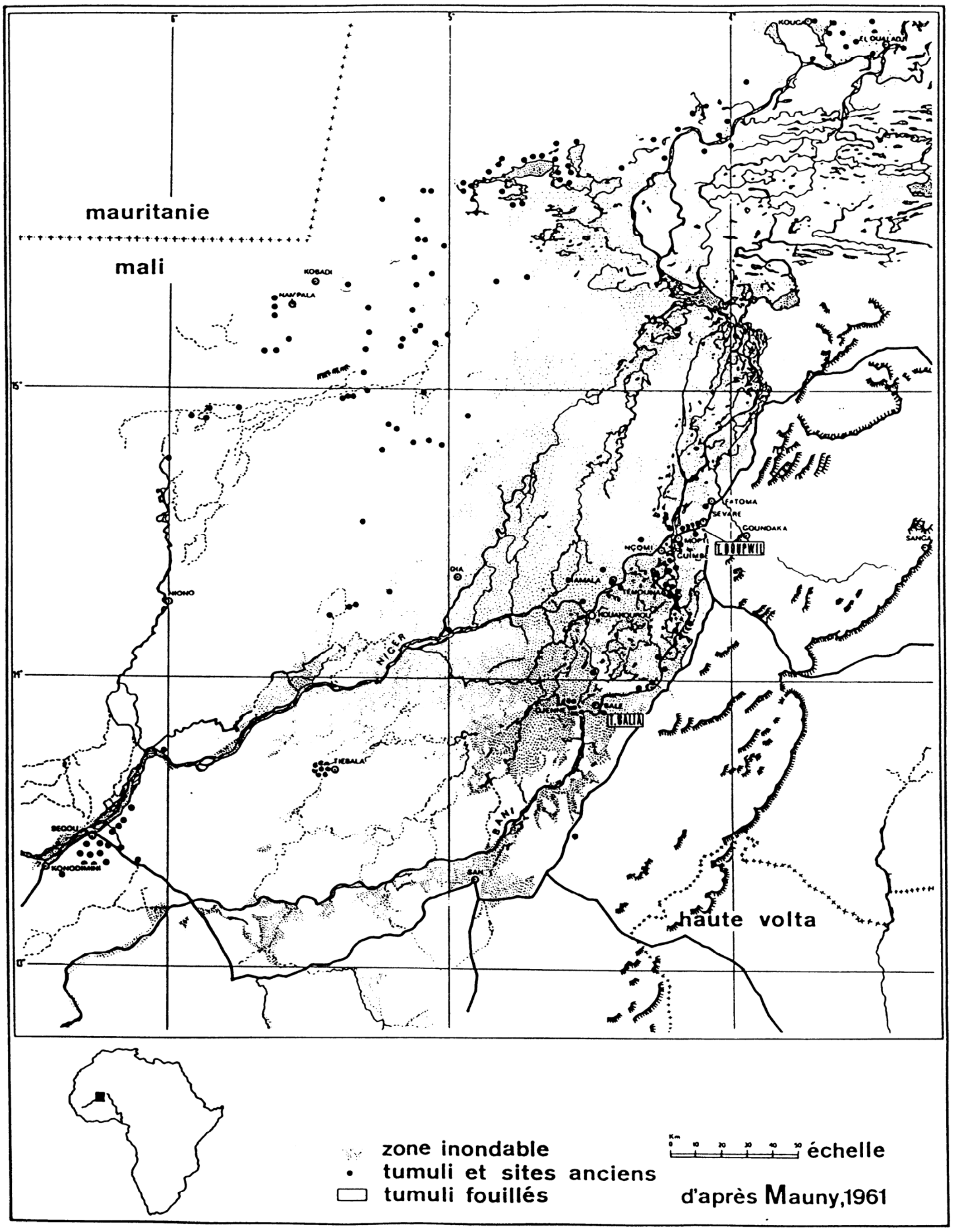

Fig. 4.2 'Tumuli' along the Middle Niger (from Bedaux et al., 1978).

Kolima fares only marginally better (# R & S in Apps. 3 and 4). Serge Christoforoff, also of the *Service Hydrographique*, investigated the two principal mounds by means of several trenches, each over 100 meters long (apparently also in 1930) (see Fig. 4.3). He inventories some 362 objects – amongst which were pottery, statuette(s) of horsemen, agate beads, ceramic 'pied de lit', and an iron lance (Mauny, 1961, p. 100). Mauny surface-records the site in 1954, noting the absence of tobacco pipes (suggesting an abandonment before AD 1600). Mauny also dug at Kolima. In 1980 the team of Fontes, Saliège and Person collected charcoal from (unrecorded) upper strata of Kolima, yielding a date of AD 1280-1310 (Fontes *et al.,* 1980, p. 38; Fontes *et al.,* 1991, p. 35).

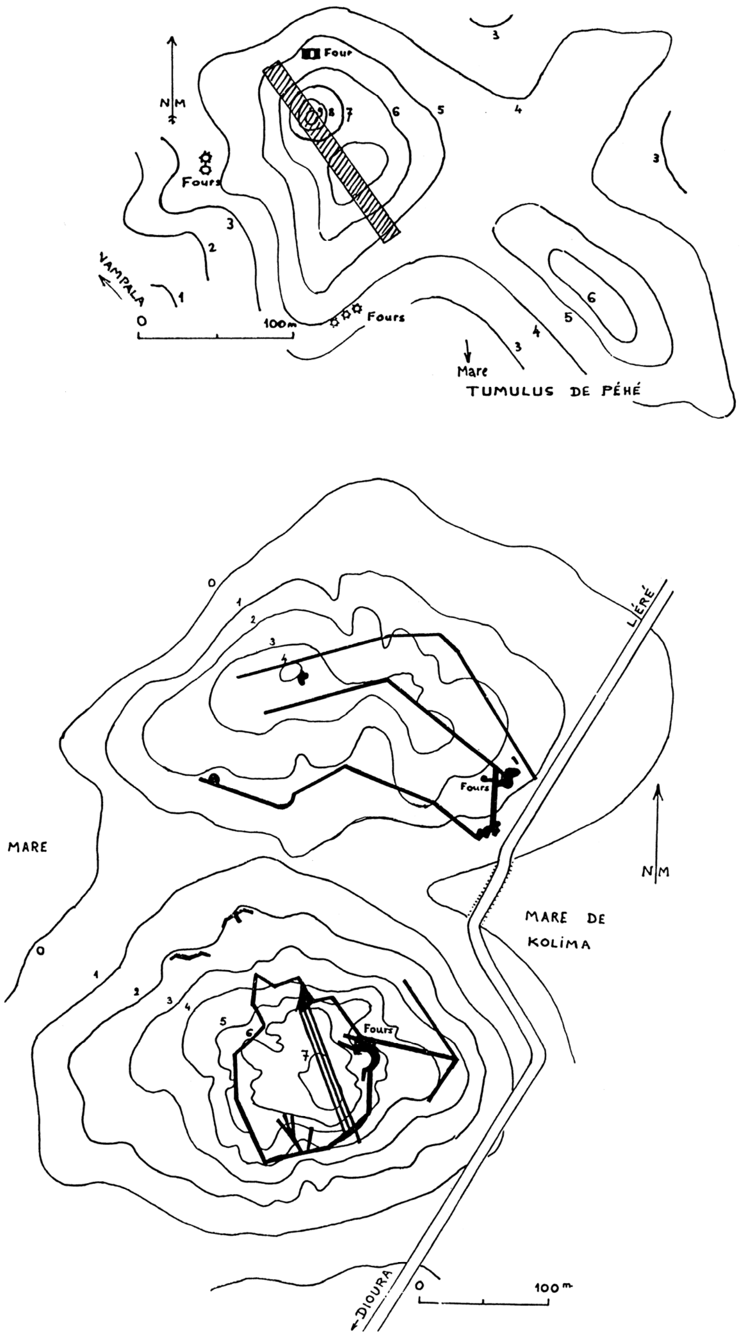

Fig. 4.3 Plans of the 1930 'excavations': (above) Péhé (perpetrators unknown) and (below) Christoforoff's trenches at Kolima (from Mauny, 1961).

Perhaps mercifully, there follows a long period of neglect – punctuated only by 'prospection' of somewhat unsystematic, if spotty, complexion. Mauny records many sites during his 1954-55 visit to the Méma and Lakes Region. It is presumably during this visit that he and Théodore Monod visit the Late Stone Age (hereafter, LSA) site of Kobadi) (#Q in Apps. 3 and 4). At Kobadi, they record much bone (especially fish), ceramics, mortar stones, and two bone harpoons of Saharan affiliation (Monod & Mauny, 1957; Mauny, 1967). It was largely due to their observations that Kobadi became enshrined in the West African literature as the eponymous site for the so-called 'Aqualithic' (a widespread pre-food-production adaptation heavily reliant upon fish, large aquatic mammals and reptiles, and gathered plants) (Sutton, 1974; discussed in S. McIntosh & R. McIntosh, 1983, pp. 229-30). (We will return to Kobadi, in the company of Michel Raimbault, in a moment.)

Monod and Mauny underscore the importance of Kobadi, at the same time bemoaning the then-ignorance of the true LSA occupation of the Méma: "…seul gisement ancien connu à 180 km à la ronde, le delta central du Niger n'ayant pas fourni jusqu'ici de matériel préhistorique" (1957, p. 245). When considering the importance of Kobadi in a landscape of late Holocene desiccation, Mauny does make the useful observation that, at an elevation of around 262-265 m above mean sea level, the site was just lapped by the waters of the unusually high floods of the early 1950s (1961, p. 206). One can only speculate as to whether floods extraordinary for the twentieth century might serve to provide an adequate analog for 'normal' inundations during a time when the Méma still ranked amongst the 'live' (annually flooded) basins of the Middle Niger.

4.2 Post-independence: small steps to systematic inventory

'Prospection' (non-probabilistic, unsystematic recording of sites) and site inventories continue with the Neolithic Sites map of Raymond Guitat (1972). In his map of Mali and Haut-Volta, only two Méma sites appear (Guitat #125, Kobadi; Guitat #34, Boulel) (Fig. 4.4). Guitat works from a literature search and from sites recorded in registers housed at the *Institut Fondamental de l'Afrique Noire* in Dakar. Things improve considerably with the "prospection" in 1984 by Téréba Togola and Michel Raimbault, conducted as part of the *Projet d'Inventaire* of the *Malian Division du Patrimoine Culturelle* and the *Institut des Sciences Humaines* (Togola & Raimbault, 1991). While not as systematic as surveys later to be carried out by Togola (see below), they record some 102 sites, most Iron Age (hereafter, IA) and historic in age (Togola & Raimbault, 1991, pp. 82-83) (Fig. 4.5). They rerecord the LSA site of Kobadi and record the important and massive shell midden (freshwater oyster (*Etheria elliptica*) of Tiabel Goudioudié (off App. 3). The Togola and Raimbault 'prospection' strategy is to visit sites indicated by local informants.

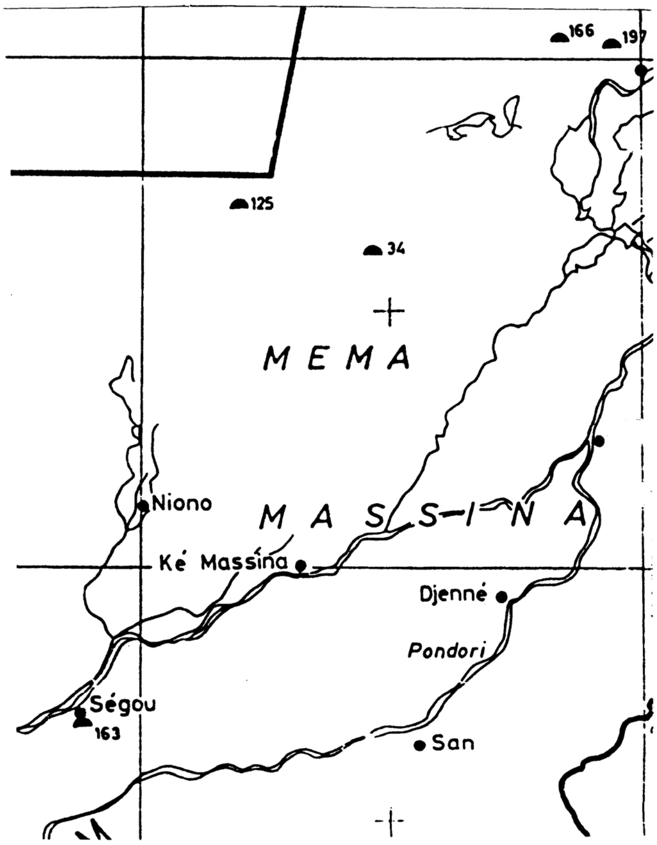

Fig. 4.4 Méma coverage in Guitat (1972).

The late 1970s and early 1980s are privileged by three campaigns, very different in nature, but all of high quality. In the late 1970s, participants in a pastoralism development project, begun in response to the devastation of the Sahel Drought *(Evolution de l'utilisation des terres et de la végétation dans la zone soudano-Sahelienne, CIPEA 1980*) used aerial photo evaluation to identify some 712 mounds (Haywood, 1981, p. 11, diagram 17, p. 17) (Fig. 4.6). These are plotted, by air photo boundaries, on a map of 1:200,000, covering an area of some 46,000 km^2. The investigators warn that many sites too small to be seen on air photos were not included.

The *Centre International pour l'Elevage en Afrique* (CIPEA) that sponsored the Haywood inventory also financed an excavation, in 1978, of three clustered mounds on the Fala de Molodo east of Boulel. Randi Haaland of the University of Bergen, selected the Poutchouwal Mounds B, D, and E (off App. 3) for test excavations because of the massive slag heaps associated and because of their potential to answer questions about the climatic contribution to abandonment of the Méma (Haaland, 1980). Mound B, the largest (diameter *ca.* 450 m) and surrounded by the most extensive evidence of iron production (a slag heap measuring 600 m by 50 m and bowl-bottomed furnaces), was excavated through four horizons to a depth of 3.1 m.

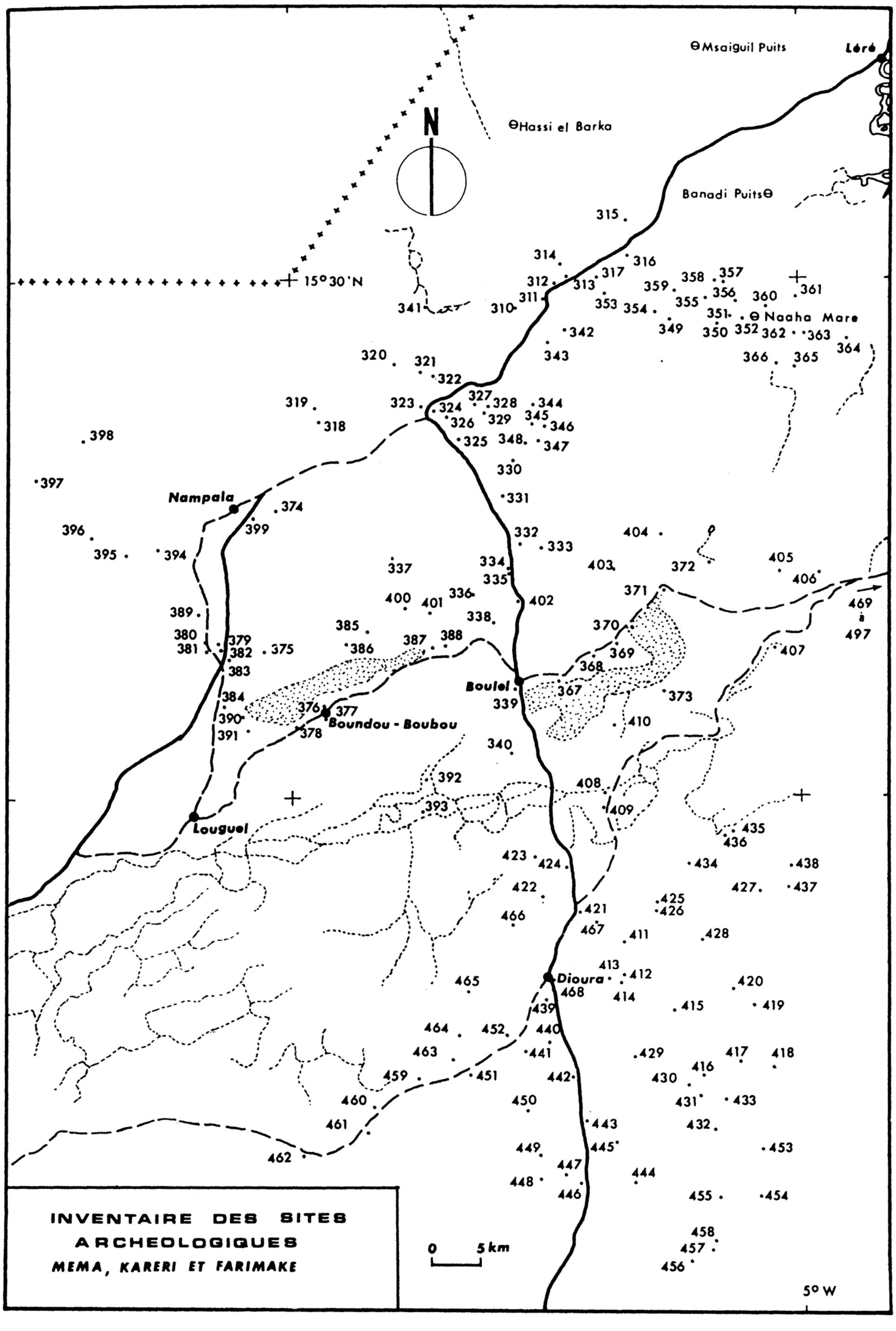

Fig. 4.5 Méma, Kareri and Farimake sites (from Togola & Raimbault, 1991).

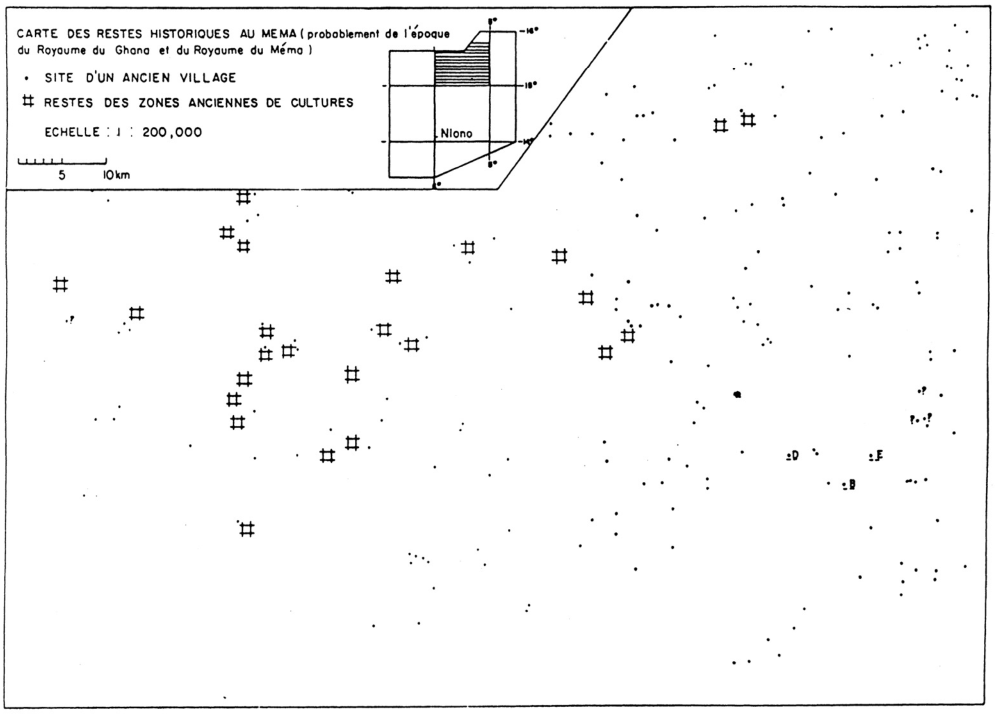

Fig. 4.6 Archaeological sites plotted from aerial photographs; CIPEA 1980 (from Haywood, 1981).

From mound B Haaland obtained two radiocarbon dates, of AD 1020-1180 (cal 1100 ± 80 AD; 2σ-range [MASCA calibration]) and AD 690-920 (cal 805 ± 115 AD; 2σ). Mounds D and E were only surface tested, but yielded (respectively) dates of AD 835-1015 (cal 925 ± 90 AD; 2σ) and AD 1080-1230 (cal 1155 ± 75 AD; 2σ). Haaland comes to the preliminary conclusion that conditions during the late first and early second millennia AD were closer to those of the present-day 'live' Middle Niger basins. She concludes also that industrial scale smelting to provide iron for the Ghana 'empire' may have so deforested the region that ecological deterioration was irreversible. In her brief report, this issue of how anthropogenic deforestation contributes to long-term landscape deterioration is pursued by analogy with processes ongoing today in The Sudan.

Lastly, Michel Raimbault returns to excavate the LSA of Kobadi in 1984-85 (two visits), with a follow-up season in 1989 (Raimbault, 1986; Raimbault & Dutour, 1989, 1990; Raimbault et al., 1987; Jousse & Chenal-Velarde 2001-2002; Urbain, 2001-2002) (Fig. 4.7). Raimbault and his team re-examine the surface of this 360 m by 15 m site and excavate a series of units providing four radiocarbon age determinations [465 ± 120 BC; 710 ± 145 BC; 930 ± 120 BC; 1385 ± 100 BC (all uncalibrated) (Raimbault & Dutour, 1989, p. 176)]. They reconfirm and augment the observation of Monod and Mauny that the site is rich in aquatic species: fish (esp. many species of catfish and Nile perch, Lates niloticus), tortoise, crocodile, hippo, lamantin (Manatus senegalensis); as well as many land animals: several antelope species, phacochere, and many, many small-size, short-horn cattle. The lithics are 'impoverished' (formed on a poor-quality quartz) but the tool assemblage does sport an unusual flat, polished point type, as well as tiny axes, herminettes, and stone (arm) rings. There are perforated discs, "plaquette de pierre à rainures" (perhaps for cord making), more bone harpoons and a ceramic industry with affinities to the north [Hassi-el-Adiod in the far Azawad (Petit-Maire & Riser, 1983)] and perhaps far to the east, to sites known from Niger. Of the 97 skeletons, up to 16 individuals had the burial contexts and physical anthropology allowing them to be identified as boasting the same 'mechtoïd' (late Cro-Magnon) affiliations as the Hassi-el-Abiod burials.

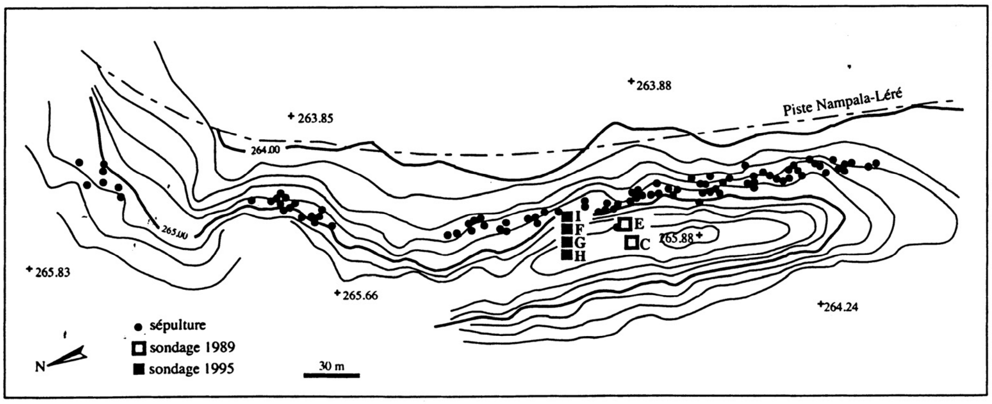

Fig. 4.7 Site of Kobadi, with burials and excavation units (from Jousse & Chenal-Velarde, 2001-2002).

Raimbault interprets the site locality as the slightly raised bench or beach of a palaeolake (not on a dune as originally thought). There, the inhabitants could have taken advantage of large tracks of open water. This water was permanent, deep, and well-oxygenated. Thus, the aquatic locale was a refuge for hunter-fisherfolk who had fled the progressive desiccation of regions like the Azawad (and perhaps farther afield) in the drying southern Sahara – a slow trickling into the Méma that began around 4500-4000 year ago (Raimbault & Dutour, 1989, p. 180). Here they could continue a conservative, LSA way of life for millennia longer, only adding pastoralism to their generalized stew. As we will soon see, others interpret the site slightly differently.

These early surface surveys and test excavations suggested a fantastic (and unexplained) degree of clustering of LSA and IA sites (esp., Haaland, 1980; Haywood, 1981; Togola & Raimbault, 1991). These sites display an obvious degree of differences in their surface material. Some early mounds, like the classic site of Kobadi are rich in fish bones and those of crocodiles and large aquatic mammals, while others are shell mounds (Tiabel Goudiodié) or are dominated by cattle bones. Later sites are also differentiated, even within clusters (*e.g.*, the difference in iron production evidence at Haaland's three mounds at Poutchouwal). And some clusters are excessive in their elaboration – witness the many sites clustered together at Boundou-Boubou (#34-64 in Apps. 3 and 4), remarked upon in report after report of 'prospection', from Mauny to Togola and Raimbault.

4.3 Ground-truthing the pulse model: the MacDonald-Togola surveys

The stage set, we turn to the work of Téréba Togola and Kevin Macdonald – a new chapter in the all too spotty book of survey in the Méma. In part, this work was done expressly to begin the task of testing ('ground-truthing') the Pulse Model of MacDonald and Togola's (undergraduate and graduate, respectively) professor, R. McIntosh. The Pulse Model is described in the next chapter of this volume. In the world of remote sensing, 'ground-truthing' means physically to verify the features identified or the patterns interpreted from the aerial photographs or satellite images. Extrapolated here, the concept of ground-truthing is extended to the search, in the field, for the settlement pattern predicted by the model. In this case, the Pulse Model predicts a slow, orderly increase over time in the numbers of multi-specialist occupations, and in the seasonal co-occupation of the same locale by those same specialists, clustered together. Ground-truthing is always a hard slog and is rarely as cerebral as hypothesizing from the images. These two admirable archaeologists began the long, labourious slog fully to ground-truth the model. MacDonald and Togola had other objectives for their survey and subsequent excavations, of course. However, here I will concentrate upon the results of their surveys as tests of the model predictions.

Now, the Pulse Model should apply particularly well to any of the many palaeochannel and playa situations throughout the southern Sahara and Sahel. The Méma, however, cries out for urgent attention. Unfortunately, previous research was not conducted in a way that would allow specialization and, generally, regional diversity and variability to be identified. And so, the Méma remained an unrealized promise of great things to come, until 1989-1990, when Téréba Togola and Kevin MacDonald arrived on the scene.

Together the two conducted the first archaeological landscape analysis. Together they conducted the first scientific sampling survey of the Méma. They investigated a series of LSA and IA sites, but divided up the analysis, MacDonald taking the 29 LSA sites and Togola the 109 IA sites. As graduate students, with limited time to spend in the field and even more limited resources, they conducted a (self-admittedly) less-than-ideal survey. They conducted thirteen one-kilometer wide vehicular transects, starting from a village that could be identified on topographic map and air photo and drove north and south from that point (MacDonald, 1994, pp. 72-74; Togola, 1993, pp 34-36, 38-40). Additionally, they did a total survey of a five-kilometer radius around the Akumbu site cluster (Fig. 4.8). In probability parlance, they did not cleave to a randomized sampling strategy, but they had an explicit strategy that covered roughly 20% of the Méma.

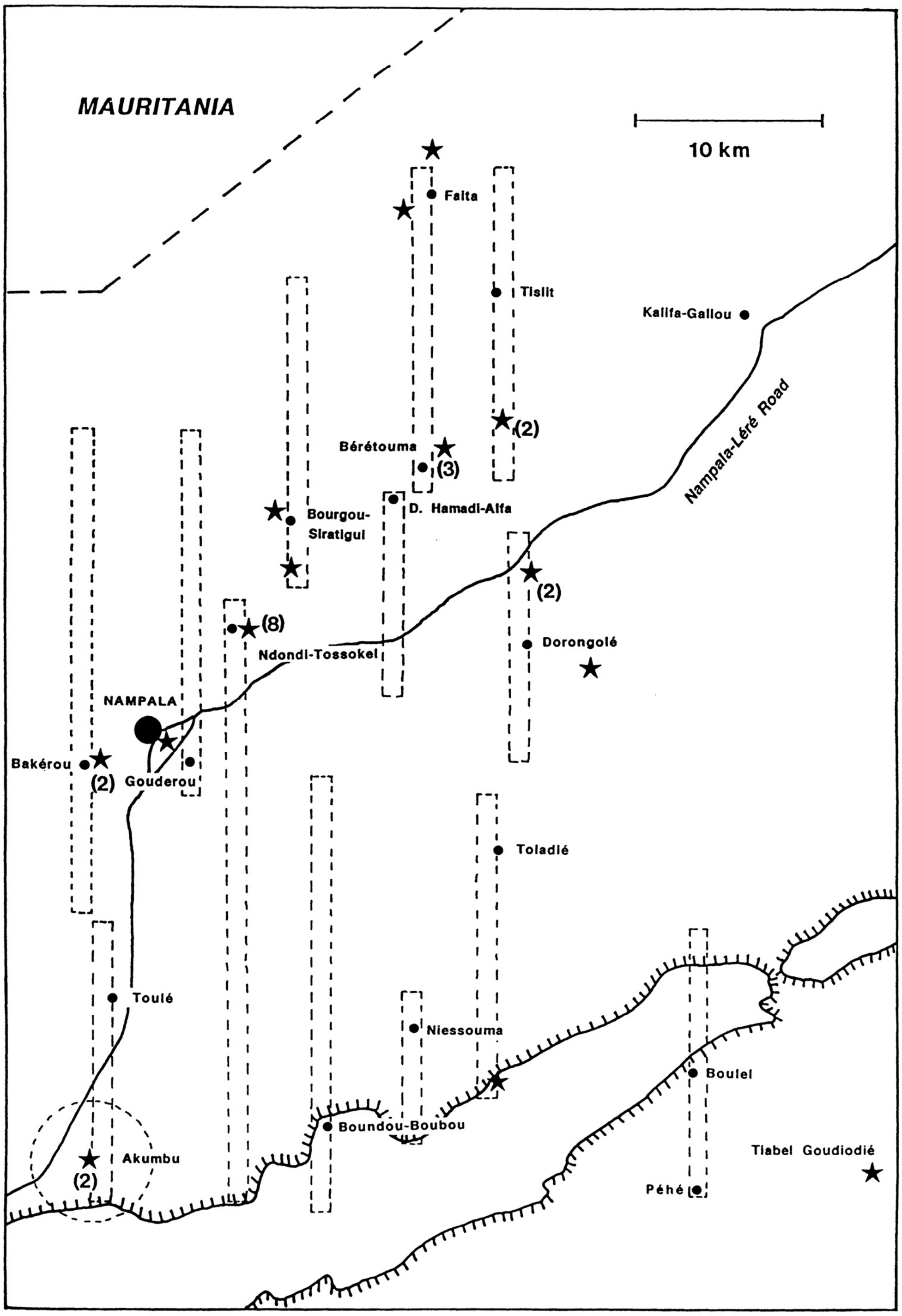

Fig. 4.8 1989-1990 MacDonald-Togola vehicular survey transects for the location of Late Stone Age localities (from MacDonald, 1994).

Togola was interested in urbanism, and in the clustering of urban sites in the Méma – we will return to his results below. It was MacDonald who took an explicit test ('ground-truthing') of the Pulse Model as the principal goal of his research. MacDonald (1994, p. 4) lists his objectives and questions as: 1) is there great time depth (going back into the last millennia BC) to the modern Middle Niger cultural mosaic; 2) does the modern symbiotic, multi-ethnic specialization of the Middle Niger peoples have roots going back into the LSA; and 3) if so, were environmental instabilities responsible?

MacDonald collected and analysed the Méma LSA settlement pattern and artifactual material in a way allowing at least a preliminary identification of a grid of subsistence strategies (Fig. 4.9). In a series of interpretive articles, he tries to formulate answers to a range of questions dealing with specialization, regional variability and interaction (MacDonald, 1996, 1997/1998; MacDonald & MacDonald, 2000; MacDonald & Van Neer, 1994). Were these people generalists ("coherent ethnicities incorporating significant agricultural, pastoral and/or hunting/gathering aspects within their subsistence" - 1994, p. 17)? That is, were they hunting/gathering/fishing generalists or mixed food producing generalists? If generalists, were they exclusively concerned with wild resources or did they mix in aspects of farming and pastoralism as well? Were they sedentary or were they semi-sedentary (more-or-less mobile) generalists? Or were they specialists ("coherent ethnicities exploiting one resource to the near exclusion of all others" – 1994, p. 21)? Were they specialized farmers? – pastoralists? – or even fisherfolk or hunters? And if specialized, were they isolated or did they establish (as predicted by the Pulse Model) a "mutually advantageous economic association of two or more entities, resulting in the acquisition of otherwise unavailable commodities through reciprocal exchange" (1994, p. 21)? In other words, were there multiple ethnic groups, defined by their specialized subsistence tasks (farmers, fisherfolk, herders), but living an existence apart from all others? Or had LSA specialists already developed regular, expected and peaceful exchange relationships with other specialists? If so, how did the requirements of exchange and contact affect the settlement pattern and seasonal movements of these specialists?

In other words, once one recognizes variability in the lithics, in the ceramics and, especially in the food debris left behind at these LSA sites, what does it all mean? How does one demonstrate exchange and regularity of relations between two specialist groups? And at what point can one go beyond description - recognition of diversity and evidence of exchange – to explanation of why specialization (or the generalists' resistance to same) and symbiosis came about?

Although surely more work is needed to firm up the identification of MacDonald's ethnicities (the 'corporations' of the Pulse Model), he convincingly shows that different groups co-occupied the Méma and regularly exchanged. Their co-evolution has elements of migration from the outside and of local transformations (MacDonald, 1994, pp. 70-118; MacDonald, 1996). In a nutshell, below is the story the archaeological data tell to MacDonald.

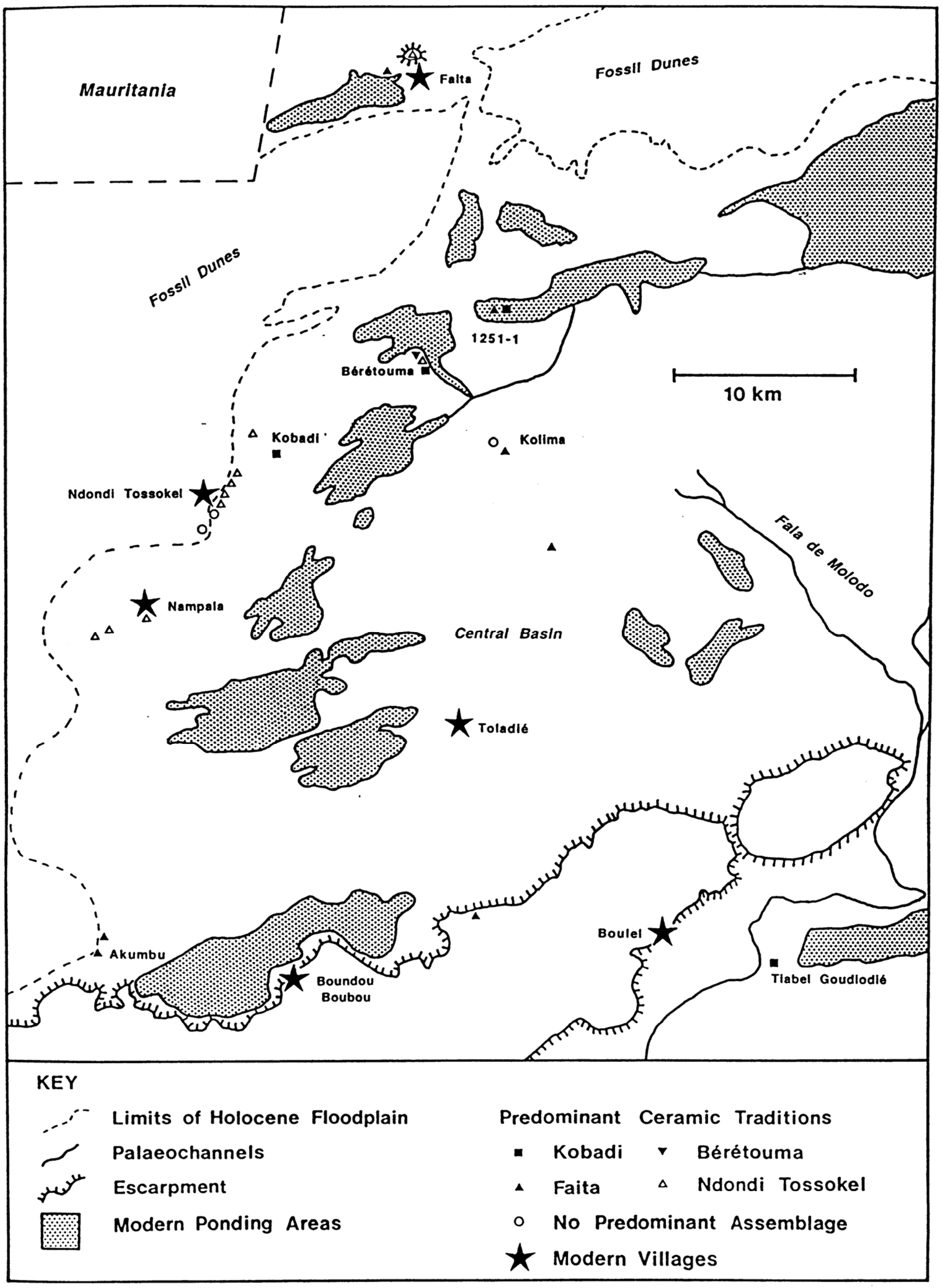

Fig. 4.9 Late Stone Age sites identified during the MacDonald-Togola survey (from MacDonald, 1994).

The first peoples into the Méma, perhaps as the pulsing desiccation of the southern Sahara opens up to occupation former lakes and swamps, were mixed aquatically-oriented hunters/gatherers/fisherfolk. Members of this cultural tradition ('Kobadi', *ca.* 2000-200 BC) are responsible for the large mounds of shellfish (Tiabel Goudiodié) and, especially, for the 'fisher-hunter' sites of fish bone mixed with aquatic mammals and crocodile [*e.g.*, Kobadi (Raimbault & Dutour, 1989; Raimbault *et al.*, 1987)]. Can the difference in these sites be explained as seasonal waystations along a seasonal round of exploitation by the same community? Or do they represent sub-specializations within a larger, generalized tradition? Where the Kobadi people came from is still somewhat a mystery, although the best candidate to date is far to the north, from the (drying) playas of northern Mali (in the vicinity of Hassi-el-Abiod). The Kobadi tradition, in some senses, represents a conservative carryover of an older non-food producing economy, but these folk were no slouches! They slew and ate impressive numbers of elephant, crocodile, hippos, and Nile perch (*Lates niloticus*) and various catfish that reached up to 2.5 meters in length!

Some of the fisher-hunters of the Kobadi tradition alter their material culture after a few hundred years in the Méma to become (in MacDonald's scheme) a separate identity, the Bérétouma (1300-800 BC). But while this local fissioning (?) is taking place, there appears to be an infusion of pastoralists (perhaps from the Mauritanian cliffs of Dhar Tichitt to the west – overlooking yet another distressed lake environment). MacDonald calls this the Ndondi Tossokel tradition (1300-800 BC), after sites of that name with an abundance of cattle remains. These sites have remains of sheep and goat as well, and even have terracotta statues of cattle. They tend to be small and ephemeral, not like the vast middens left behind by the fisher-hunters. Kobadi type sites begin to show a smattering of cattle bones and, presumably, the Ndondi Tossokel herders were eating fish and other aquatic delicacies from their new acquaintances! There appears to be an exchange of polished stone bracelets and of tiny groundstone axes. Later (850-300 BC) there is yet another cultural manifestation (Faita) – agriculturalists who are on the cusp of the Iron Age – as seen by the first signs of iron production at these sites.

Although nothing like the extreme proliferation of specialists we shall see in the later times, this is certainly not a homogeneous landscape of generalists. Much needs to be done to sort out food remains that are discards of seasonal exploitation of local resources by mobile, economically flexible communities. Yet the fact that Togola and MacDonald's systematic survey demonstrated clusters of different LSA sites, close together on the same landform certainly suggests some degree of symbiotic relationship between specialists – that is, if the strict contemporaneity of these sites can be established. Some clusters are of the same tradition (2 Ndondi Tossokel at Barkérou; 3 Faita at Akumbu; even the 1 Faita mixed with 7 Ndondi Tossokel at Ndondi Tossokel) - and so may simply represent successive occupations of the same locale by the same corporation. But what of the others? The Bérétouma cluster is composed of five sites, of which one is classic Kobadi in appearance and two have a mixed Bérétouma/Ndondi Tossokel assemblage. Kolima is composed of at least six sites, three IA, and a mixed fishing with later pastoral component to one (Kolima Sud) and an agricultural (and transitional LSA-IA) aspect to another (Kolima Sud-Ouest).

What does MacDonald say about these results? He freely admits that interpretations from surface remains must be verified by excavations – and he began trial excavations at Kolima Sud (two units and a third begun but uncompleted) (MacDonald, 1994, pp. 93-106). Despite the unfortunate lack of extensive excavation (because of unrest and banditry in the Méma during their field season) and despite the lack of palaeobotanical evidence, he feels he has sufficient cause to speak of "evidence that multiple groups co-existed regionally…", that "…these groups were driven into each others proximity by the desiccation of more northerly watercourses…", and that "…in the Méma there is evidence for interaction between a pastoral society (the Ndondi Tossokel tradition) and a fishing society (the Kobadi tradition)" (MacDonald, 1994, p. 274).

"Thus, it would appear overall that the 'Pulse Theory' has many aspects which are beginning to be supported by archaeological evidence. Still, our initial investigations have shown that the same amplitude of ethnic diversity which exists in the Inland Niger Delta today [that is, the Upper Delta and Macina of the Middle Niger—McIntosh, 1998] is unlikely to have occurred in any one region during prehistory." (MacDonald, 1994, p. 275). It is surely premature to say that the Middle Niger strategy of clustered specialists is unique in prehistory. Yet, MacDonald's survey does provide a qualified 'Yes' to the question: does ground-truthing support the hypothesis that the mechanisms of the Pulse Model can be traced back into the second and first millennia BC, amongst the first LSA colonists of the Méma?

As archaeologists of a scientific bent, all we can do is to generate hypotheses and then try to disprove them. With this tentative 'non-falsification' of the Pulse Model by MacDonald for the LSA of the Méma, what does a study of the transition into the IA in the same region contribute? Togola (1993, 1996) analysed the settlement data for the 109 Iron Age sites found during the 1989-1990 survey (Fig. 4.10), as well as from limited test excavations at several of the mounds comprising the LSA transition and IA cluster of Akumbu.

Most Méma Iron Age sites are more deeply stratified than the LSA sites and the ceramics on their surface give a greater impression of homogeneity. (Recall that homogeneity is not disallowed by the Pulse Model, once the mechanisms of accommodation are in place and mature.) Much more excavation will have to take place to know whether we are dealing here with a low level of specialization or with the kind of extreme elaboration of specialization we see in the Upper Delta (*e.g.* the Jenne-jeno Urban Cluster of 70 sites). Sadly, these Méma site surfaces are heavily looted by local Fulani and Moorish populations, as opposed to the surfaces of sites around Jenne that could be recorded by archaeologists, being in relatively pristine condition before the looting explosion of the late 1980s and early 1990s. Fifteen sites have primary evidence of iron production (slag heaps, tuyeres and smelting furnaces) and two have urn fields.

However, as Togola explains, "The phenomenon of site clustering appears to be prevalent in many regions in the Middle Niger…. In the Méma, clustering was a notable aspect of site distribution. Over 3/4 or 88 of the IA sites encountered during the survey occurred within 13 clusters of groups of sites, compared to 20 isolated IA sites. This phenomenon of site clustering in the Méma was already in expression during the LSA. Within clusters, each component was spatially separated from the other members." (Togola, 1993, p. 42).

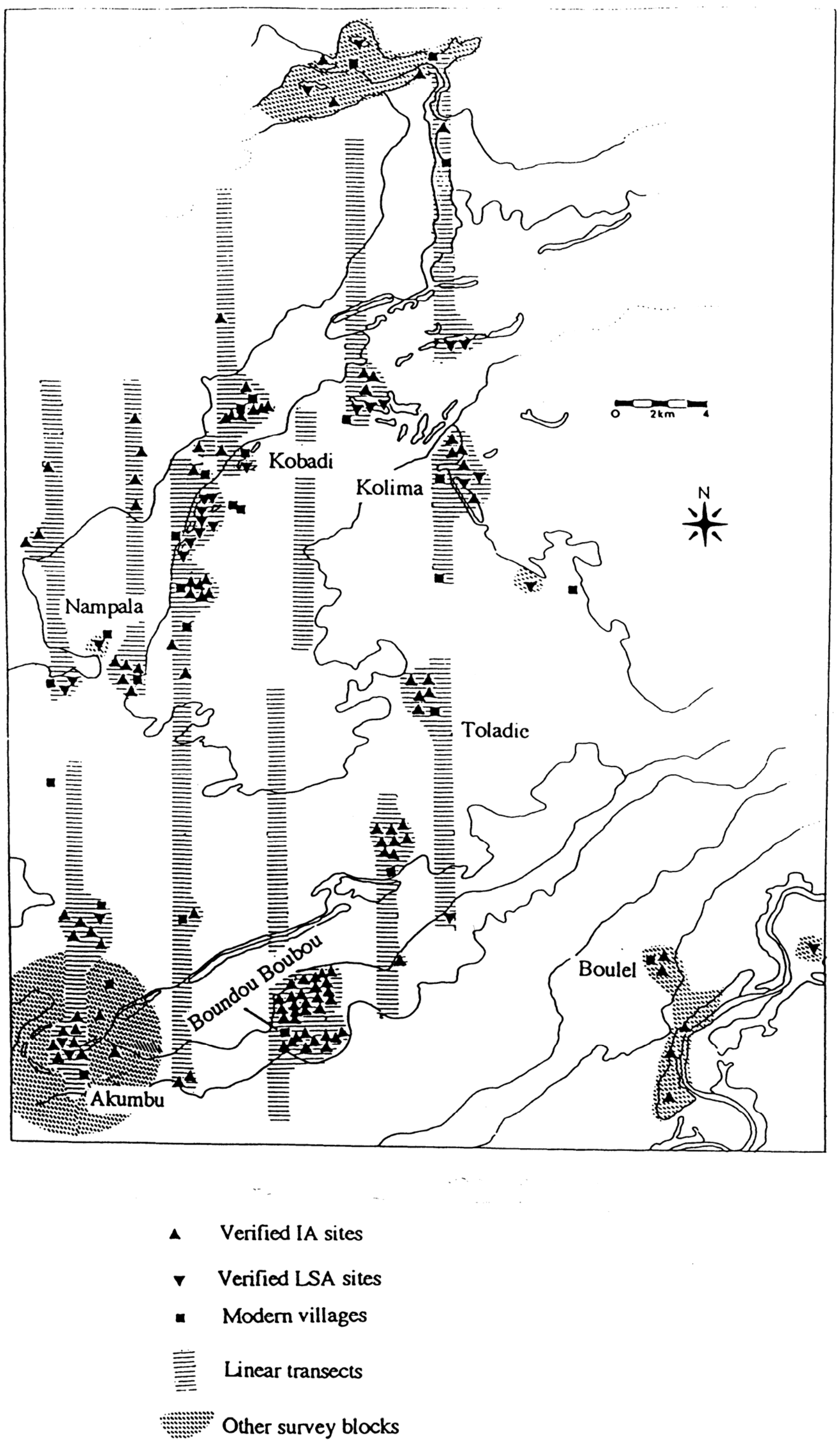

Fig. 4.10 1989-1990 Togola-MacDonald vehicular survey transects for the location of Iron Age localities (from Togola, 1993).

Some of Togola's clusters are impressive indeed: Akumbu with eight members, Niessouma with 9, Boundou Boubou South with 10 and Boundou Boubou North with 21! Further testing of these clusters will be required to know if all members were occupied simultaneously. However, abandonment evidence indicates a broad 'rule' that larger and smaller 'satellites' within the same cluster have, broadly, an equivalent range of occupation during the earlier parts of the IA. However, on the whole, the last occupation of the large 'focus' mounds of the more complex clusters was later than that of the smaller mounds (1993, p. 44, his Table 3.2). Many of the satellite sites were abandoned during the very earliest phase of the Iron Age.

Togola (1993, p. 56) makes the following conclusions about settlement pattern change during the Iron Age.

1. Densely clustered small settlements are flanking the banks of water corridors during the period of Early Assemblage (mid-first millennium AD).
2. Large settlements (often surrounded by smaller and satellite settlements) are distributed both along water corridors and within the degraded dunes (Togola's designation, see Fig. 4.11) during the Middle Assemblage period (seventh century AD to the twelfth to fourteenth century AD).
3. A handful of small settlements with shallow deposits (indicating an ephemeral occupation) mostly distributed within the longitudinal dunes (Fig. 4.11) during the period of Late Assemblage (second half of the second millennium AD).

Overall, it is Togola's conclusion that, during the mid-first millennium AD and, especially from the seventh century AD to twelfth or fourteenth century AD, the density and sizes of sites in the Méma are comparable to those in the Jenne and Dia hinterlands of the Upper Delta and Macina basins (respectively) of the 'live' Middle Niger.

Clustering explodes in the Méma in the first millennium AD…. and then occupation is aborted with ferocity. A very different, and highly attenuated, settlement pattern marks Togola's Late Assemblage period. The period of greatest population flux and relocation, ending then in an apparent abrupt regional abandonment phenomenon [not entirely dissimilar to that known from the American Southwest of the 12th and 13th centuries (Adler *et al.*, 1996; Tainter & Tainter, 1996)], is dated by him to the 12th to 14th centuries (1993, pp. 88-90). But what is this connection between clustering and the burgeoning of population concentrations – and of cities proper – in the Méma? The answer must await a new campaign of linked survey and excavation. Togola sunk three units into IA deposits at two of the Akumbu mounds (1993, pp. 65-86) (a fourth was sunk into LSA deposits and has not yet been published). A fifth Akumbu cluster unit was opened by R. McIntosh and M. Cisse in 2000 but closed after only 1.2 m depth because of banditry. The enormity of the task ahead is truly sobering.

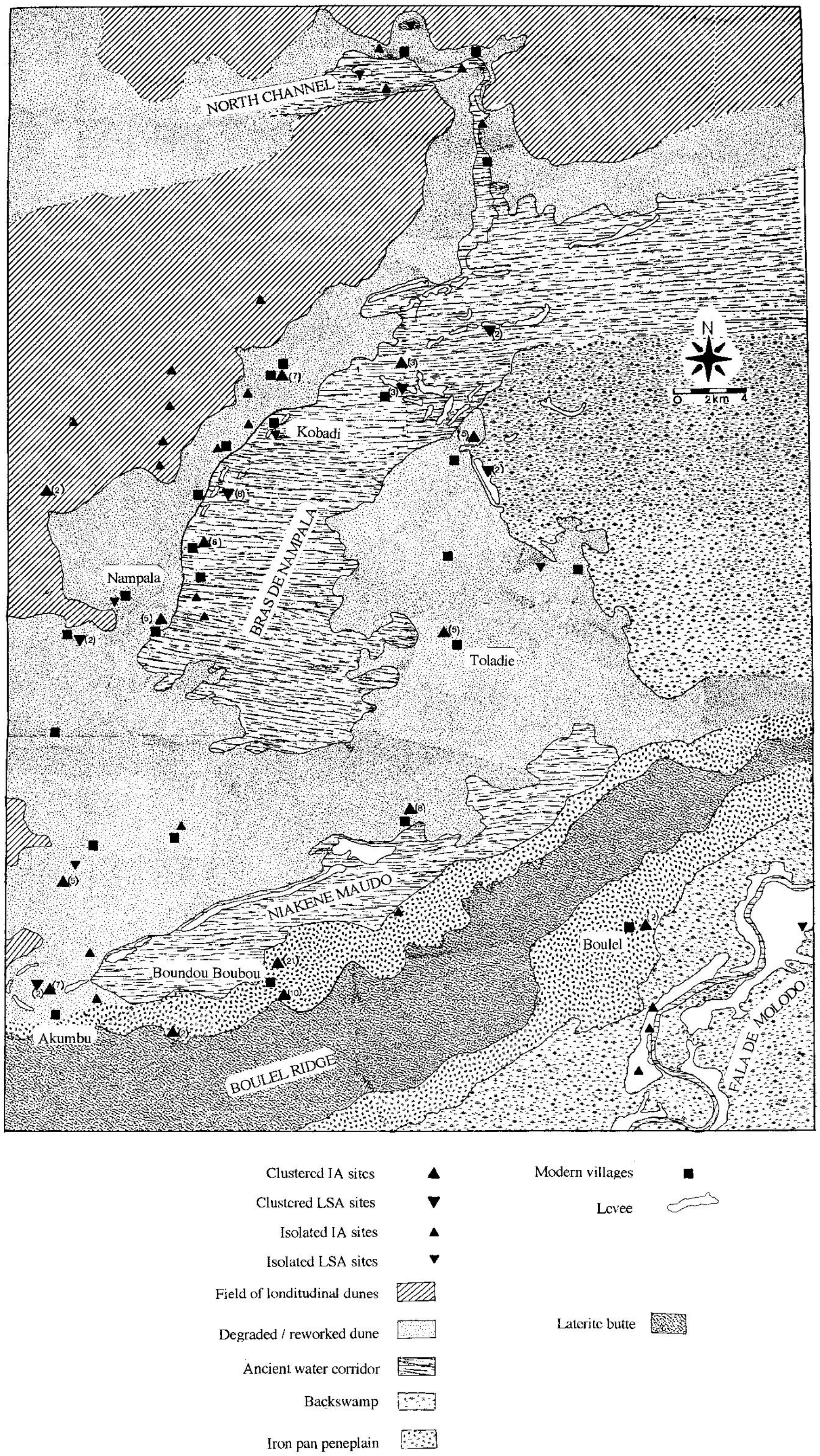

Fig. 4.11 Iron Age (and earlier) sites identified during the Togola-MacDonald survey, plotted against broad landscape features (from Togola, 1993).

5 Pulse of the Méma: deep-time risk strategies

Roderick J. McIntosh

5.1 What is the Pulse Model?

The Pulse Model was developed, ultimately, as an aid to the investigation of the conditions that gave rise to the curiously clustered urbanism of the ancient Middle Niger (R. McIntosh, 1993). Clustered cities are spatially componential – with satellite settlements (apparently occupied in some cases exclusively by specialist corporate groups) orbiting around larger focus sites, such as Jenne-jeno or Dia. The Pulse Model sets the conditions for pre-urban emergence of specialization, as the Middle Niger's solution to the problem of a superbly stressful, 'chaotic' climate. The Pulse Model predicts that there will be segmented, but articulated Late Stone Age communities in the Sahel and southern Sahara (Fig. 5.1). The people in these communities would have lived during significant periods of the year in small, clustered hamlets, the rest of the year moving about in a classic seasonal round. But for the period of gathering together, relations of complementary reciprocity between these communities encouraged increasing occupational specialization. Specialization might first have been in the subsistence domain, artisan or craft specialization appearing only later. Over a long period of time we might see the evolution of ever-larger clusters that, in time, took on the functions of true towns.

The Pulse Model predicts the locations where archaeologists may find the earliest and most emphatic expressions of early clustering. Situations of tightly-packed microenvironments, such as the Méma, would have encouraged close contact of increasingly specialized groups. Climate oscillations would create a 'pulse' of population movements north and south along the rainfall gradients of the West African monsoonal climate system – encouraging north-south shifts of population movements and of ecological adaptations. It is predicted that, during the last few millennia BC, the Méma would have seen particularly dynamic interaction among groups and particularly dynamic experiments in human adaptation to changing environments. The Pulse Model, as one such experiment, would only have worked with the successful integration of functional adaptation (reciprocal relations as a way to smooth over the surprises of high climatic unpredictability) with symbolic accommodation (new ways to express and maintain identity in an arena of exuberant contact). Lastly, in the Méma we should find excellent preservation of sites and of organic remains.

Fig. 5.1 Localities in West Africa. The Méma as indicated in this figure includes the Office du Niger and Karéri regions. Usually (and also in the remainder of this volume) the Méma is taken to comprise only the northern part (Boulel Ridge and the Nampala area).

5.2 Sustainability *vs.* flexibility: always mutually exclusive?

Beyond the entirely laudable quest for pure knowledge, a goal of any investigation of the deep past must be to contribute to strategies of sustainability. Occupying an environment of demonstrably extreme risk and stress, today and as far back as we have evidence for human occupation, how did the peoples of the Méma fare in the great sustainability balancing act? Would their descendants today say that their historic and prehistoric predecessors did a better job than they of balancing the struggle to maintain the basics of life, with the understandable human desire progressively to better their lot?

Taking the archaeologist's perspective, it would appear the moderns of the Méma would have to answer 'yes' – the population densities of the first millennia BC and AD and the dense urban network of the first and early second millennia AD simply do not exist today. Taking the historians perspective, they might also have to answer 'yes' – the long-disappeared 'kingdom' of the Méma was a major player in the emergence of the Imperial Tradition of centralized states and empires in the larger Western Sudan (R. McIntosh, 1998, pp. 247, 258; Levtzion, 1973, p. 50). This kingdom or state of Méma was symbolic heir to the Ghana imperial tradition. Some place its capital at Péhé, south of the Boulel Ridge (Togola, pers. comm.); Levtzion (1973, p. 49) places it at the ruins called Gallou at a small lake some 25 miles northeast of Nampala (Kalifa Gallou?). Could the *Tunka* of the long-established Kingdom of Méma, supporter of and provider of sanctuary to the outlawed Sunjata as he began the tedious consolidation of the state of Mali, ever have imagined his kingdom as desolate, depauperate, and depopulated a landscape as we see it today? There is a vast saga of soaring human ambition – and of cosmic dismay – to be told in the Méma.

Here, we subscribe to the somewhat unorthodox 'supply-side' definition of sustainability proffered by Allen *et al.* (2003, p. 26). Their emphasis is upon "…maintaining, or fostering the development of, the *systemic contexts* that produce the goods, services, and amenities that people need or value, at an acceptable cost, for as long as they are needed or valued" (my emphasis). Let us dissect this definition. The key phrase is "the *systemic contexts*". I take this to underscore the social construction of the peoples' productive activities, with particular emphasis upon the matrix of authority within which decisions are made and the larger symbolic environment (social memory, or *habitus*, depending on the situation) within which all the actors occupy. Emphasis upon the systemic contexts is certainly consistent with the emphasis on the recursive interaction between changes in the bio-physical world (including anthropogenic) and in the social world (including the world as perceived) that characterizes the emergent field of historical ecology (Balée, 1998; Crumley, 1994; R. McIntosh *et al.*, 2000a).

Returning to the 'supply-side' definition of sustainability, the producers of "goods, services, and amenities" in the Pulse Model hypothesis argued here, are precocious specialists. The hypothesis is about those circumstances in the very remote Late Stone Age that encouraged the gradual emergence of a generalized regional economy based upon the 'contractual' exchange of subsistence goods, artisan manufactures and amenities, and undoubtedly supernatural services through a network of equals. Of critical importance for the Pulse Model as a test of sustainability is the continuation of the distinctive social construction of pluri-corporate production and inter-ethnic relations into the landscape of emerging cities. Cities and, indeed, all manifestations of complex society, are the ultimate challenge for sustainability!

Prehistorians looking comparatively at the emergence of complex society have long known that one solution to the problem of providing everyone with the goods and services of an increasingly compartmentalized labour force is hierarchy. In hierarchy, the decisions of the elite few at society's apex are, all too often, reinforced by force.

The key to long-sustained heterarchy, then, is a built-in mechanism or ethos of resistance to authority grabs and power displays.

I argue here that, in the Méma from the distant past, exchange was conducted in the material and symbolic goods that people themselves came to regard as needed or valued (echoing the sustainability definition) – they did not relinquish their community or corporate authority to figures wielding power. That is, a key corollary of the Pulse Model is resistance to those who would use coercive means to wrest decision-making control from the majority (and, hence, resistance to the state). Critically, the "acceptable cost" of Allen *et al.*, was negotiated by equals. It was not imposed from on despotic high – to the asymmetrical advantage of some and the detriment of most.

Such a seemingly simple phrase: "…that people need or value". But on this phrase turns a vast calculus of needs-criteria that ranges from the most basic biological necessities of life to those esoteric and culture-specific symbolic packages that make life worth living. And the rules for generating the modes of producing these needed and valued elements are deeply rooted in deep time social memory! I have argued (2000) that earlier transforms of the Mande social memory were alive and well in all of the Middle Niger, the now dead deltas of the Azawad and Méma included, well within the several millennia through which the Pulse Model evolved.

Finally, Allen *et al.* (2003, p. 26) make it very clear that sustainability (a community's capacity to continue a desired condition of process, social or ecological) is distinct from resilience. Resilience is defined as the ability of a system to adjust its configuration and function under disturbance. A deep-time, archaeological investigation of resilience strategies in a high risk environment, such as the Méma, is aided enormously by the vast development anthropology (*e.g.* Raynault, 1997) and prehistoric (*e.g.* Halstead & O'Shea, 1989) literature on risk management and risk buffering. Halstead & O'Shea, for example, inventory a constellation of actions that might be a part of any 'bad year' strategy of resilience: mobility; diversification (broadening the base of the subsistence system, exploiting a wider range of landforms, *etc.*); storage; exchange and long-term habits of individual-on-individual and community-on-community reciprocity, *inter alia* (1989, pp. 3-7). Exchange and reciprocity are important buffering mechanisms. They factor temporal variability against spatial variability – exactly what the Pulse Model is all about. Yet elaboration of specialization rarely plays a part in most reconstructions of prehistoric risk management. And specialization, also, is what the Pulse Model is all about.

In one sense, then, the Pulse Model concerns the need to reconcile sustainability against resilience in the face of some of world's most extreme climatic and environmental risk, surprise and unpredictability. Allen *et al.* (2003, p. 26) are very clear that the two can conflict, if maintaining resilience also means abandoning sustainability. I submit that the prehistoric Méma of a 'positive' Pulse Model (meaning, also, positive demographics and positive growth of social complexity) was populated by peoples with "…social goals [that were] flexible and in harmony with underlying ecological processes" (2003, p. 26). 'Positive' is used here only in its traditional demographic sense. A demographic decline, as Tainter explains in Chapter 6, may simply indicate that many have fled adverse or unpredictable conditions in order to maintain an accustomed way of life. It may also, of course, signal a collapse!

Perhaps we also have to ask whether the Méma in collapse was sustainable but not resilient – with social goals feasible within the *perceived* parameters inherited from the past, yet not flexible enough to manage the extreme climatic conditions (and perhaps loss of active waterways due to geological processes) of the second millennium AD.

The desperate need for archaeological research in the Méma? What circumstances in the most distant Late Stone Age (and at the tumultuous end to the Second Holocene Pluvial, when the Méma apparently was first occupied) allowed the Pulse Model to thrive? What, then, after millennia of sustainability, caused the fatal decline in the Pulse Model? In order to keep that long-term template of sustainability alive, did occupants of the failing Méma cities and hinterland villages have to migrate to the still-inundated basins of the Middle Niger in order to maintain the "*systemic context*" of their past prosperity?

5.3 The bio-physical factors behind the pulse

At the heart of the argument is my assertion that the Pulse Model describes an unusual, even radical, departure upon the sustainability theme of flexibility. Flexibility ("society's capacity for revitalizing its organization and developing coping strategies" – Hassan, 1994, p. 159) is on trial here because of the *special challenges* of the Sahel climate. The unpredictability of the Sahelian climate, at least since the surprisingly-good instrumental data collection network came on line in *ca.* 1900, is so extreme that is stimulates geographers and climate scientists to unprecedented heights of hyperbole. Hyperbole? – Maybe not! On the one hand, Le Houérou (1989, p. 44) quite correctly points out that a few other locales (spatially more restricted) on the globe have greater absolute annual rainfall variability. But Le Houérou fails to factor in the extraordinarily higher Potential Evapotranspiration (PET) statistics for the Sahel, not to mention the real-time effects of high amplitude and high temporal variability on those subsistence producers trying to cope with a high PET landscape. On the other, Park (1992, pp. 91, 97) is so demoralized by the 'chaos' that characterizes the Sahel climate regime, past and present, that he believes no amount of knowledge of past trends will ever enable local peoples to manage that variability by means of storage or trade (exchange). Nicholson writes, "…the largely semi-arid African continent has undergone extreme climatic changes which are probably unmatched in their magnitude and spatial extent" (1994, pp 121; see also Koechlin, 1997, pp. 12-18). And the classic: "There is no other region of the globe of this size for which spatial and seasonal averaged climatic anomalies have shown such persistence" (Shukla, 1995, p. 44). How can anyone not be impressed by the heart-wrenching charts of Sahelian inter-annual and inter-decadal rainfall variation?

This is not the place to go into a full exposition of Sahelian palaeoclimate. Recent sequence reconstructions pertaining especially to the Middle Niger can be found in

R. McIntosh (1998, pp. 66-80; 2000, pp. 144-57; forthcoming, Ch. 2). The main points to emphasize here are the three listed below.

1) A new data day has dawned with the recent (past three decades) addition to the aforementioned network of continental meteorology stations of a fine complementary network of sea surface temperature (SST) monitors (satellite and floating platforms) and of a series of Ocean Drilling Program (ODP) coring sites off the West African coast. With these new data has emerged a debate about the forcing mechanisms of Sahelian precipitation variability – and of drought causes specifically. The debate is somewhat peripheral to our purpose here (except for its obvious eventual pertinence for understanding causation at the different time-scale of resolution that is clearly relevant here). The debate, on the one hand, features those who look to higher latitude (perhaps polar) dynamics affecting the position and intensity of the Intertropical Convergence Zone by way of the orientation, altitude, speed, and/or intensity of the African Easterly Jet (Fontain & Janicot, 1992; Fontaine *et al.*, 1995; Nicholson & Grist, 2001). On the other hand are those who argue for the precedence of SST differentials in the West African coastal Eastern Atlantic (DeMenocol *et al.*, 1993; Folland *et al.*, 1986; Janicot, 1992; Lamb & Peppler, 1992). The causal truth may, in fact, lie in the linking of the two.

2) Beyond the forcing mechanism debate, particularly exciting work is being done on the timing and nature of abrupt climate change, at several time scales. In West Africa, the last 15,000 years (15 Ka years) have witnessed several spectacular millennial-scale shifts of temperature and precipitation (Fig. 2.16). Some Saharan massif manifestations of this can easily be correlated with upper latitude events, such as the Younger Dryas (R. McIntosh, 2003). During these times, temperature can change within 8-10º C within a few centuries or even within decades. Several of these abrupt events (also called nickpoints, for their obvious threshold-like implications for human response) are documented (*e.g.*, at 14.8, 10.2, 9.3, 8.2, 5.5, and 3.1 Ka years) (DeMenocol *et al.*, 2000a, 2000b; Hassan, 1996; Oppo *et al.*, 2003). DeMenocol *et al.* (2000b) also very provocatively document two spectacular West African SST anomalies (cooling) coincident with the upper latitude Little Ice Age of AD 1300-1870 (and a warming consistent with the Medieval Warm Period of AD 800-1300). And these millennial-scale (that is, events playing out over centuries or decades, resolvable at the millennium time-scale) are complemented by (causally linked to?) highly abrupt climate changes at the decadal and interannual time-scales (Nicholson, 1978; Nicholson & Grist, 2001). These more staccato variations in temperature and precipitation appear also to be clumped in temporally and spatially-coherent phases.

3) One of the most interesting and promising (from a predictive potential) accomplishments of the recent interpretive breakthroughs made possible by decades of improved historical climate data is Nicholson's identification of six coherent 'anomaly types', or phases, for the continent (Nicholson, 1986, 1994, 2000). Transition between phases is usually very rapid, utterly unpredictable, and sometimes marked by an intervening cluster of years (lasting longer than a decade, in the case of the Sahel since *ca.* 1985?) of high temporal variability (HTV) [and High Amplitude Variability (HAV), at times?]. For example, rainfall patterns characterizing the classic

Sahel Drought of 1968 to 1985(?) were an echo of patterns recorded from *ca.* 1895-1917. Needless to say, the phase pattern of climate anomalies may have coherence to climate scientists, but that does not diminish the dire results, for people on the ground, of their internal unpredictability. And the abruptness of the phase shifts, as well as the possibility [as in the American Southwest (Dean, 2000)] of interdigitated episodes of totally-disruptive HTV and HAV, can only heighten the sense of stress, risk and surprise (nasty, to be sure) for the past and present peoples of the Méma.

5.4 Corporate belonging in clustered settlements

How can the dynamic, indeed 'chaotic', climate and resultant landscape of the Méma, and the larger Middle Niger, just described, be linked causally to the elaborate specialization and clustering of settlements that characterize urbanism here, apparently from the very origins of cities? The 'Pulse' of this hypothesis derives from the ecological and climatic patterns of the millennia preceding the mid-first millennium BC emergence of true cities on the Middle Niger alluvium. But the 'Pulse Model' (R. McIntosh, 1993) is primarily about the mental and symbolic circumstances of emergence and maintenance of occupational specialization. It gives a prehistoric slant to current thinking by historians and anthropologists to what lies behind the creation of individual and corporate identity – and, hence, to the mechanisms by which multiple, each quite discrete, corporate groups shared the mosaic Middle Niger landscape: accommodation.

Can processes of communal identity and of pluri-ethnic accommodation be identified in the very distant past? Are there testable implications of the Pulse Model that will increase our confidence that this is not just a story spun, conveniently but out of thin air, to fit troubling archaeological settlement data? Consider the myths and legends used historically, and even today, by the many, many happily-coexisting ethnic groups of the Middle Niger to define the boundaries between them. I argue (R. McIntosh, 1998) that many of these can be characterized as abstractions of their ecological places in a highly unpredictable, stressful environment.

So, too, are the rules (and the reinforcing myths and legends) for dealing with one another. Here, clearly we will be mixing a functional argument (occupational specialists accommodating each other in a generalized regional economy) with a symbolic one (identity based upon abstractions of one's place in the environment). Does this (indeed, do *any* arguments of symbolic motivation) go beyond the archaeological data? After all, we cannot interview these Late Stone Age peoples about how they saw themselves, or what motivated them! Yet, archaeologists increasingly understand a fundamental fact about their data: *All archaeologists have ever done is to interpret the (incomplete, often poorly-preserved) remains left behind after a prehistoric peoples' complex responses to the world as socially constructed.* Communities acted upon the world in accordance with their view of reality—and such actions left their imprint upon the physical remains later unearthed by archaeologists.

The Pulse Model attempts to go to the deep-time roots of the process of clustering that is at the core of urbanism, from the very beginning. Clustered urbanism prevails in the Méma (the dry Middle Niger basin) and in all four 'active' basins [Upper Delta, Macina, Erg of Bara and Lakes Region / Niger Bend (Fig. 5.1)]. I believe that Middle Niger clustering represents a solution to the dilemma of how to maintain boundaries between specialized sub-groups under conditions of growing population and of proliferating occupational corporations – but, apparently, without a coercive centralized authority. Physical clustering allows these corporate groups to remain socially and symbolically separate and yet to enjoy proximity to clients and availability of the services of many other corporations. By this model, clustered settlements serve several purposes. Satellite settlements maintain physical boundaries between specialist corporations and also serve as the spiritual or symbolic property of each corporation. Again, the classic definition of corporate groups requires that belonging be reinforced by a right of common possession or access to corporate property, including land or 'ancestral villages' (Cochrane, 1971; R. McIntosh, 1993, p. 188). The common property also serves as the signature, or *insignia* of the group, a code communicating identity. The code satisfactorily represents belonging and thereby constrains social ambiguity, one of the fundamental curses of city life.

In this, the Méma cities are highly anomalous. There are large isolated settlements, to be sure, one being Péhé. This was the putative capital city of the aforementioned Méma kingdom, seat of the Tunka (Togola, pers. comm.; Szumowski, 1957; Togola & Raimbault, 1991, p. 86). But many others are comprised of multiple settlements in close proximity. Sometimes these are arranged as smaller satellites orbiting around a larger site. Others are multiples of essentially the same size or of a size spectrum. But in all cases they are in close proximity – yet have resisted the implosion of settlements that characterizes the evolution of urbanism in Mesopotamia during the middle and later Uruk period. In the better understood Jenne vicinity, in the Middle Niger's Upper Delta basin, the argument can be made that different corporate groups occupied and 'owned' their own satellites (R. McIntosh, 1991; S. McIntosh & R. McIntosh, 1993). Some Méma clusters, such as Boundou-Boubou with its thirty-one mounds, if all occupied simultaneously, have taken the principle very seriously indeed!

What (from an urbanism perspective) was going on at Boundou-Boubou (or at Jenne/Jenne-jeno where the urban cluster comprises seventy mounds)? If each group is provided with unambiguous insignia of belonging and if the roles and complementarity of groups are agreed upon and reinforced by myths, metaphors and legends, then society can accommodate, over long periods of time, a process by which specialists become ever more specialized. Why? Because specialists can invest the time to develop and curate the intricate knowledge needed to successfully pursue their occupation in this highly variable, essentially unpredictable environment. The importance of this is paramount and creates the fundamental paradox of life on the Middle Niger. Without specialization, no one can master the complexities of this rich, but highly unpredictable landscape. But, if too specialized, too dependent exclusively on the produces and services of one specialization, odds are overwhelmingly good that one will perish during those not infrequent years that overwhelm even the most knowledgeable, the most skillful of specialists.

As Le Houérou reminds us, Sahelian annual rainfall is about 135-150% of the long-term mean during one year in ten and 50-65% of the mean or less one year in ten. With a 25% to 45% coefficient of variability, Sahelian rainfall effectively stretches peoples' risk management skills to the utmost (Le Houérou, 1989, p. 18). The best rice farmer can enjoy good crops, and even some spectacular surpluses, many if not most years. But it is a certainty that, say, two years out of each decade, two decades out of each century, that rice farmer will survive only on the exchanged milk and meat from neighbouring pastoralists. But if the rice farmer tries to become, himself, a generalized farmer-herder-fisher-gatherer-hunter, he will possess neither the knowledge nor the skill in *any* of those pursuits to *sustain* any quality of life. The Pulse Model attempts to generate, functionally, the landscape conditions for resolving this paradox and, symbolically, the clues by which the process of resolving the paradox might be recognized archaeologically in the deep-time of the Middle Niger.

This interpretation appears to satisfy the twin requirements of explaining clustering *physically* as a field of boundaries between emerging corporate groups and *symbolically* as space coded to encourage peace and co-operation within a regional population newly or increasingly confronted with greater scope for conflict. Ambiguity of identity will inevitably be a source of conflict in the early town. Kinship and other rules of identity adequate for simpler societies will increasingly fail to keep pace with the increasing scale of social space between participants. Clustering can be a way to address that ambiguity. And the Pulse Model gives the mechanisms by which this clever tool of accommodation comes to be.

The Pulse Model predicts that there will be segmented, but articulated Late Stone Age 'pre-urban' communities in the southern Sahara and in the 'driest' of the Middle Niger basins, the Méma and the Azawad (Fig. 5.1). These communities will live part of the year, each year, in small clustered hamlets. Relations of complementary reciprocity between these communities encourage occupational specialization. Over a long period of time we see the evolution of ever larger clusters that, in time, take on the function of true cities.

The Pulse Model predicts the locations where archaeologists may find the earliest or most emphatic expressions of early clustering. Many north-south trending palaeochannels of the southern Sahara and Sahel are composed of tightly-spaced microenvironments, where increasingly specialized groups would be in close contact. These, also, are precisely the landform characteristics of the mosaic landscapes of the six Middle Niger basins, including the Méma (Fig. 5.1). Climate oscillations create a 'pulse' north and south of population movements or shifts of ecological adaptations for some distance along these long, longitudinal fossil corridors and within the alluvial basins. This would be a scene of particularly dynamic interactions among groups and of dynamic human adaptation to changing environments.

The Pulse Model predicts greater intensification of specialization as the response to the ecological dynamism and, at the same time, a strengthening of reciprocal relations among specialists as a way to smooth over the stresses and surprises of a semi-arid tropical climate of high unpredictability. In the Saharan palaeochannels and Méma and Azawad basins we would see the emergence of those settlement and subsistence strategies that were later carried into the deep basins of the Middle Niger during the first millennium BC. And as these arid environments have had little occupation during the past two millennia, we should find excellent preservation of sites and of organic remains within the sites. For the success of the model there must be a social dynamic that evolves ways to establish identity, with the result of the successful accommodation of increasing numbers of specialists.

The Pulse Model requires an approach to ethnicity and to 'corporateness' in general that emphasizes the fluidity of the representation of self and of symbolic codes for communal mobilization. That is, as the numbers of corporate groups increase (and individuals have an increased capacity to self-identify as member of multiple groups – 'blacksmithing crocodile hunter of the *tilapia* lineage'), there must be symbolic clues to help identify that individual and others in contact with her or him. Happily for the prehistorian, traditions from the past and material items can be powerful symbolic resources.

Things or places serving as codes to expected behavior and insignia of identity are rarely rigid corpuses ready-made for the ethnographer to pluck and preserve behind museum glass. They are rather symbolic fragments that can lead to change by focusing ideas and mobilizing group support. Material culture, Vansina's "crystallizer of metaphors in tangible form" (Vansina, 1984) can be as powerful in this regard as myths, ideologies, or traditions. For example, in modern nation states, national flags are tangible symbols of sovereign identity and a peoples' aspirations. And as a system of active symbolic representation, the past need not be seen as exerting a dead hand. The past can provide criteria of which symbols are relevant to the reinvention of future identity. The historical ties of people and their traditions can provide an enormous, but selectively appropriated reservoir of symbols sending collective messages within the group (props for claims of common identity) and to those outside. Thus, one task for the archaeologist is to identify those stylistic attributes or artifact insignia that might in the past have communicated information about ethnicity, lineage affiliation, residence groups or other corporate belonging.

We appreciate better than ever before that among the several purposes of these social networks was the distribution of environmental (natural and social) risks and benefits among the participants (*e.g.* Halstead & O'Shea, 1989; Rautman, 1996; Tainter & Tainter, 1996). In this view, as environmental unpredictability rose, so would the integration of the non-hierarchical regional social networks comprised of kinship cross-cutting, pan-residential corporations that characterize many pre-state societies. The historical and prehistoric evidence shows the dominating effect of social approval and perception of environmental stresses on the decisions taken in response to climate. Indeed, if we wish to understand the ways in which the environment is socially, rather than externally known we must understand how a society's traditional perceptions of environmental constraints are a part of that community's social construction of reality.

Because people act upon those perceptions, social views of environment may be obscured, but are never entirely out of the prehistorian's realm. If one of the core values is the distribution of environmental risks, then archaeological materials will be created as people act upon that core value. These materials can direct the archaeologist to networks of interactions maintained by the different corporate subdivisions as part of that adaptive strategy. And, from symbolic representations of belonging among contemporary Middle Niger groups we can derive clues about how belonging and identity was constructed in the distant past. These representations are framed in terms of ecological abstractions. The ecological abstractions can be thought of as the Middle Niger population's 'mental technology' (social construction of reality) by which climatic change (objective reality) is mediated, environmental risks are reduced, and specialization encouraged as a consequence.

5.5 From seasonality to sedentarism to urbanism

The Pulse Model (Fig. 5.2) is a hypothetical alternative to the usual model of linear migrations of Late Stone Age peoples south (and east) out of the Sahara due to late-Holocene desiccation (*e.g.* Davies, 1967; Flight, 1976). The model is inspired by reconstructions of the inter-latitudinal ripple-effect resulting in the (eventual) advance south of the Sahara and the replacement by drier ecologies of savanna and forest to the south. Climatic variations at a 10^4 and 10^3 time-scale can be conceptualized as wave phenomena, expressed in the Sahel-Sahara as north-south oscillations of zones of ecological potential (S. McIntosh & R. McIntosh, 1983). With improving climate, for example, more northerly latitudes received more precipitation (hence building savanna soils and enjoying permanent surface water). But this advantage is lost at the end of the mini-pluvial with the weakening of the annual rains.

Over many thousands of years, but certainly since the second African Holocene Pluvial began to wind down at around 4,500 year ago, the latitudinal migrations of rainfall zones, vegetation populations, and human economies (*i.e.,* zones of ecological and social potential) would have the effect of forcing human populations to be flexible in their adaptations or willingness to undertake short-distance or medium-distance migrations. These are precisely the conditions expected to encourage the concentration of experience and knowledge about wild foods (and newly domesticated plants and animals) that help people survive a chaotic climatic regime. But the Pulse Model does not predict an infinitely repeating cycle. This is because: 1) the fragility of the dunes-based northern soils imposes a critical check; and 2) the hydrological and landform mosaics of certain wide channel and interior floodplain landscapes such as the Middle Niger provide the potential for the formation of a radically new social and settlement form.

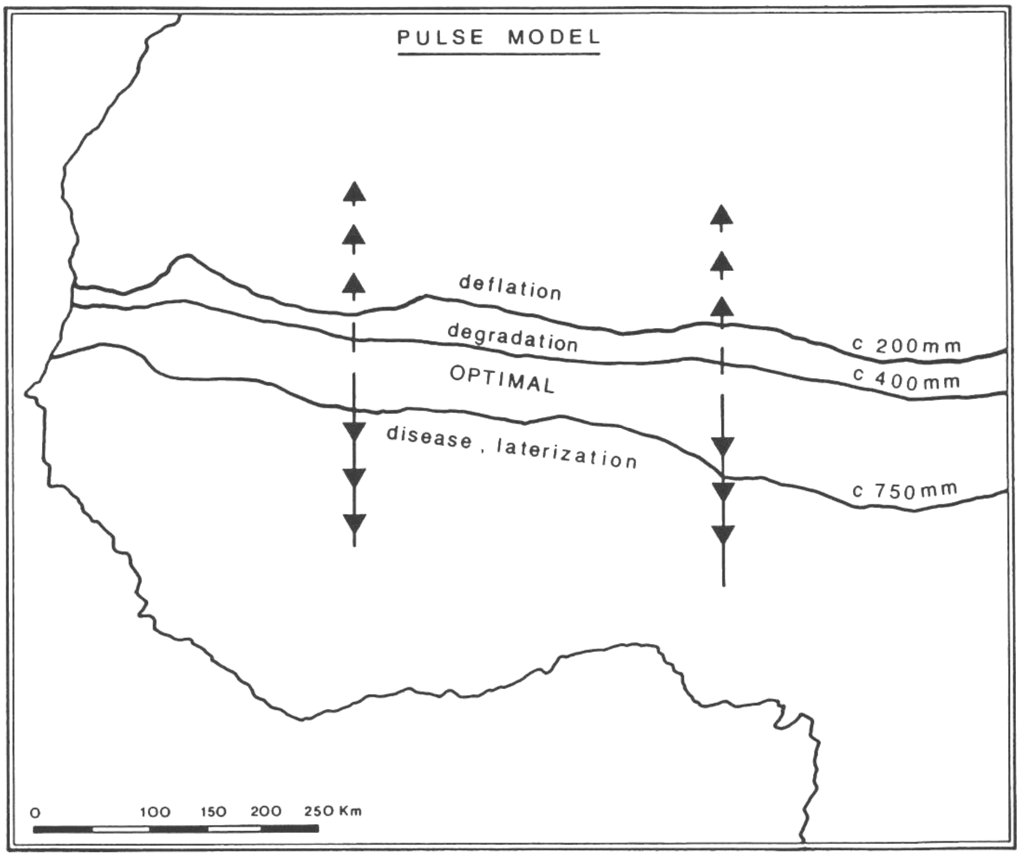

Fig. 5.2 Shifting of environmental zones in West Africa: a driving force of the Pulse Model.

During the many northern swings of the pulse, anthropogenic and fluvial-aeolian agencies will have inevitably begun damage to skeletal dune soils of the Saharan-Sahel frontier. This is a point important to remember in the case of the Méma, where the mosaic of landforms and the deterioration effects of wind *and* water are etched upon the landscape. At the commencement of the next arid cycle, irreparable damage is done. These thin soils (often a simple weathering of the ancient dunes) are directly subjected to the severe NE Trade winds, resulting in the massive aeolian soil losses (Mainguet *et al.,* 1980). Soil structure is disturbed, topsoil losses worsen and the integrity of protective soil crusts is reduced. Increasingly episodic but still violent rains cause deep gullying, especially at the 250-350 mm zones (Jacobberger, 1988; Talbot, 1980). After a lengthening dry season (reducing grass cover), monsoonal sheet wash eliminates soil clays and loams, leaving only sterile sand or reg surface. At the next northern pulse, moving populations confront a boundary to further northward penetration analogous to that existing today at the Saharan frontier of the Middle Niger. There an abrupt boundary separates rich Macina and Upper Delta floodplain from the seasonal transhumance plain of the Méma. We will be interested to confirm, through continued fieldwork, the hypothesis that the southward degradation of the Méma worked in precisely these ways (channel strangulation, soil deflation, loss of inundation basins) during the first millennium AD (Togola, 1993).

The scene is set: a zone of active soil degradation (corresponding roughly to the 100-400 mm rainfall isohyet zone) forms a ceiling over an optimal zone. Humid pulses occur at the time-scale perspective of 10^4, 10^3, and 10^2 years. Ideally, the Pulse Model would combine local exploitation shifts with northward migrations as the human response to mini-pluvials. But, because of the Sahara-side soil and stream degradation, the northern shift is constrained. Without the release of migration, ever denser populations are forced to adapt under conditions of *improving* rainfall.

However, this still occurs within the semi-arid belt of the Sahel-northern savanna zone that is most sensitive to drastic unpredictability, indeed to chaotic climate, with a (10^2) wavelength of 10-30 (or fewer) years. Most prehistoric Sahelian populations would have had limited options under these circumstances. Experiments in cereal domestication throughout an extensive zone may have been one response (Harlan *et al.*, 1976). Full-time devotion to camel or cattle pastoralism was another (Smith, 1992). However, although these adaptive pressures would have been felt along the whole of the Sahel, certain conditions of tightly-packed microenvironments in the north-south trending palaeochannels and in the mosaical now-dry basins of the Middle Niger allowed special potential for novel and plural responses to climatic variability.

Among the regions most interesting as a test of the Pulse Model, one can mention the Méma, Wadi El-Ahmar (Azawad), and Kolimbiné Valley of Mali and (in Senegal) the Ferlo Valley, as well as the Gorgol (White and Black Valleys) in Mauritania (Fig. 5.1). These regions very tightly conform to the physical requirements of the best field locales for the investigation of early occupational or corporate differentiation of the Saharan-Sahelian Late Stone Age societies. This is not to say that specialization could not have appeared elsewhere. But these would be my best bet as to the first places such specialization would be recognized by archaeologists working within expectations of the Pulse Model. All these regions have the attributes listed below.

1. They contain a field of tightly-spaced microenvironments. Groups increasingly specialized in the exploitation of one microenvironment would unavoidably be in close contact with other similarly-specialized groups. Close contact requires (symbolic rules of) accommodation.
2. Each area is 'serviced' by a long, longitudinal fossil fluvial or flood corridor, allowing a 'pulse' north and south of some distance.
3. Despite conditions for occupation locally better than the surrounding desert, the whole of the corridor lay roughly astride zones of recurrent rainfall scarcity and unpredictability during most of the later Holocene climatic oscillations.
4. These are areas not fluvially scoured or strongly aggraded, nor heavily disturbed by later settlement after the first millennium BC. Remains of more ancient or of more ephemeral seasonal occupation are likely to be found here, as opposed to the live, actively-alluviating parts of the Middle Niger.
5. Each area/corridor empties into or abuts upon present-day topographic mosaic floodplains where many inhabitants are subsistence and occupation specialists. The rules for inter-corporation interaction in place today among these specialists

may provide clues to the ways in which archaeologists can look for the codes arbitrating inter-specialist interactions in the more distant past.

These conditions of tightly-spaced microenvironments, enough water from runoff accumulation or piezometric ponding to attract settlement from the increasingly dry surrounding regions, and long corridors cross-cutting major biogeographical zones would have been met during the second and first millennium BC. Perhaps the very first glimmerings of the Pulse will one day be discovered going back to the commencement of the second African Holocene Pluvial (beginning with the *ca.* 8200 BP hyperarid event). With an active hydrology in place during the sub-pluvial northern climatic pulses, one could expect multiple, shifting channels for communication and the creation and dynamic remodelling of a mosaic of soils and landforms. The mosaic of microenvironments would have been a likely locale for subsistence experimentation with eventual crops such as rice, sorghum and millet and with variations of pastoralism. But those doing the experimentation still must have responded to significant climatic variability at the century and millennial time scales.

The landform diversity of the Méma and the southern Saharan palaeochannels offers opportunities for the earliest plural response to climatic unpredictability. The Pulse Model predicts in these locales the gradual appearance of settlements in regular association, occupied by groups increasingly specialized in their food production activities. These locales would have evolved into a cultural landscape of articulated, segmented communities: groups of specialists regarding themselves as different in identity, yet maintaining frequent and complementary exchange relations with the other communities. If non-coercive, this flexible articulation of communities electing to live nearby each other (at least for predictable seasons of the year) would allow increasing scope for even more concentration by each group on the particular potentials of one or two of the many microenvironments, *i.e.*, specialized responses to climatic change. By maintaining generous relations with neighbours, environmental stress and benefits would be shared. This hypothesis can resolve a major contradiction, or paradox, in the strategies of food production in any situation of high historical unpredictability of climate.

When reconstructing the origins of the remarkably stable subsistence system of the Middle Niger, one needs to resolve this paradox of a push to a specialized subsistence strategy versus the pull to a generalizing economy (R. McIntosh, forthcoming; R. McIntosh & S. McIntosh, 2003; S. McIntosh, 1995, pp. 377-79; S. McIntosh & R. McIntosh, 1979, pp. 240-41). On the one hand, studies of the present-day *crue/décrue* system (mixed agricultural strategies that take advantage of the flood rise and flood recession for the soil moisture requirements of different species) of crops and of pastoral strategies shows that only intense, highly particularistic knowledge of soils, rainfall patterns, flood cycles, and varieties of domesticates will ensure long-term adaptive success (Gallais, 1967, 1984; Galloy *et al.*, 1963). However, as in any context of unpredictable climate, any monocultural, too-specialized subsistence is enormously dangerous. Diversity (a generalized strategy) is the best response. The paradoxical pull of specialization versus the generalizing obligation has been resolved in the Middle Niger by the special relations that evolved between specialists (be they subsistence-defined ethnic groups or artisan associations). These relations allow each to pursue, in ever more particularistic ways, their individual occupations, while together sharing mutual obligations and accommodation. I believe these relations are of great antiquity (R. McIntosh, 2000, pp. 167-71).

Ecology is an important key to understanding the emergence of specialization in the Middle Niger, not solely in the functionalist terms of adaptive decisions and sustainability strategies, but in terms of how representation of identity is framed in terms of social strategy. Inter-ethnic social strategies are very often, but not exclusively, verbally presented or symbolically coded as ecological abstraction. In the creation of social identities, a key dynamic is the conceptualization of one's relations with another, mediated by stylized representations of ecological promise and disaster. These conceptualizations of identity are canonized in widely propagated myths, ideologies and material expressions.

Once these codes to inter-specialist behavior are in place, relationships develop between corporations (ethnic groups, artisan associations), which allow each to pursue, in ever more specialized ways, occupations concentrated upon the production of a narrow range of foods or manufactures. Specialists are thus allowed a deeper development of knowledge about and practical experience with a narrower range of pursuits, while at the same time enjoying the peace of mind of expectations of obligation and mutual accommodation.

This situation has best been studied in the Erg of Bara basin (Galloy *et al.*, 1963) and the hinterland of Jenne (McIntosh, 1998, pp. 89-105). It is not misplaced to imagine that the Méma resembled these still-active basins, even as recently as the early second millennium AD. Occupying the crazy-quilt geomorphology of the Upper Delta are fishermen (Bozo) and rice farmers Nono (Marka) established in prehistoric times. Pastoralists (Fulani) and dry crop farmers (Bambara) immigrated in sometime after the 13th century. It appears that the fishing-transport group (Somono) and merchants (Songhai) were absent before medieval times; and an agricultural client group (Rimaibe) and intrusive pastoralists (Tuaregs) are of relatively recent date. The Dogon of the floodplain's eastern periphery boast ancient relations with the Bozo and Marka (Dieterlen, 1941; Griaule, 1948; Sundström, 1972).

Let us take the example of the sophisticated decision-making required today of the rice cultivation specialists, the Marka **(**Bourgeon & Bertrand, 1984; Gallais, 1967, pp. 109-11; Gallais, 1984, pp. 23-30, 95-97; R. McIntosh, 1998, pp. 99-101; S. McIntosh & R. McIntosh, 1979; National Research Council, 1996 pp. 17-37). Domesticated African rice (*Oryza glaberrima)* has successfully held off the diffusion of the higher-yield Asian variety, *O. sativa*, because of its genetic plasticity. Varieties of African rice will survive variations in water depth of between one and three meters (*versus* a less-than one meter requirement for paddy rice, *O. sativa*). In the same field, Marka will sow a mixture of the over 42 varieties, with differing vegetative periods (from 90 to 210 days), tolerance to different soil porosity or pH, bathymetric profile (flood depth in any given year) and forgiveness of date of flood arrival, and variable sensitivity to weak or torrential rains after planting and before the floods arrive, or to the interval between the first rains (field preparation and planting) and the later sustained rains (germinative), or to predations of rizophagous fish. Clearly, a great deal of cumulative, specialist knowledge goes into getting the rice planting just right!

Marka farmers habitually sow a mixture of seeds with different adaptive characteristics; they plant in long narrow fields cross-cutting several soil units along a bathymetric progression. They keep intervals between multiple sowings of several days or weeks. Intricate cosmological observations are used to predict climate (Monteil, 1932, p. 35). This recondite knowledge is not possessed by all. Most tellingly, it is not freely shared.

Monographs on the Middle Niger document similar secret knowledge and subtleties of environmental response by the Bozo and the Somono, the Bambara, and the Fulani and Tuareg (see esp. Gallais, 1967; Galloy *et al.*, 1963; Imperato, 1972; R. McIntosh, 1998; Sundström, 1972). In part because of the subtlety of ecological responses, in part because of the close proximity of groups occupying different microenvironments and shifting occupation seasonally, there has developed a near infinity of conflicting conceptions of landform utility. Hence, there is enormous potential for interethnic conflict. Each subsistence-defined ethnic group has its own mental use-value map of the Middle Niger. The landform perception of the pastoral Fulani will differ radically from that of the dune-dwelling, millet-growing Bambara. When it is time for the Fulani herds to move into the floodplain on their annual transhumant rounds, the cattle must absolutely be kraaled at night on the dunes to keep their hooves from rotting. If, that year, the millet harvest is late, there may be conflict – leading not infrequently to homicide – between farmer and 'cowboy'!

It is in the Méma that we find the coincidence of conditions appropriate to a field test of the Pulse Model. One finds here a mosaic of microenvironments, never static, always being reformulated physically by the contesting agencies of wind and water and redefined 'symbolically' by the local peoples. Fisherfolk, herdsmen, farmers and hunters mixed and chose their various paths to their future. What was the role of specialization? Can a transitional specialization be distinguished from an antecedent seasonality? When did specialization first appear and how did the trajectory of urbanism intersect with that of corporate elaboration. Later, the Méma lost population, apparently precipitously, and the agencies of fluvial reworking of the landscape, alluviation to cover surface sites, *etc.*, took a backstage to aeolian processes that remain dominant today. Walking over the landscape, one has the impression of past edens gently covered by a light dusting of sand and silt. Wishful thinking? An empirical test of the Pulse Model demands the relative permanency of the archaeological record – our best hope for undisturbed testimonies to changing settlement patterns rests here.

Hence, the importance of careful, probabilistic or total, extensive and intensive survey of the region depicted in Appendix 1. Survey to plot distribution of ancient sites by landform (and multi-factoral landform associations) should go hand in glove with careful recording of surface artifacts and features. When this is done thoroughly, as in the case of the Jenne-jeno Urban Cluster (Clark, 2003; R. McIntosh & S. McIntosh, 2003; R. McIntosh, forthcoming, Ch. 5), one may have the first clues of exclusive corporate occupation, mound by mound. Excavation must follow, time-intensive and resource-costly as that might be. The linkage of survey and extensive excavation must be maintained if a proper, convincing test of the Pulse Model is to be conducted. And the Pulse Model is just that – a hypothesis, built of ethno-historical and ethnographic observations affixed to a puzzling archaeological problem, 'clustering in the extreme'. And so it will remain until it is rigorously tested in the field.

To conclude, the test of the Pulse Model is, ultimately, a test of prehistorians' ability to delve to the very core of the sustainability definition given by Allen *et al.* (2003, p. 26). Recall their emphasis is upon "…maintaining, or fostering the development of, the *systemic contexts* that produce the goods, services, and amenities that people need or value, at an acceptable cost, for as long as they are needed or valued". By any measure, the productive system (and urban landscape) of the Méma, and of the Middle Niger writ large, must be called a successful sustainability experiment – until, that is, the systemic collapse (alternatively: the adjustment of adaptation that disallowed a large population) during the first few centuries of the second millennium AD. Before that, demographics were remarkably positive, as were the dynamics of corporate elaboration. All this in the face of 'normally' high interannual and interdecadal climatic variability *and* the particular millennial-scale catastrophes of the onset of the present Sahelian and Saharan regimes, beginning in the fourth and third millennia BC.

The empirical test of the Pulse Model will, therefore, also serve to test archaeologists' ability to examine in the deep-time past the three foundational implications of the newly configured concept of historical ecology (R. McIntosh *et al.*, 2000b). The first implication is: Deep-time Presence of Humans. Contrary to an older genre of environmental and sustainability writing that has removed people from equations of landscape change, the actions of individual humans and their communities have been inscribed upon the landscape on the scale of millennia. Although urban civilization in the Méma apparently did not take the route of intensive public works (of the massed labour, coercively-managed, Mesopotamian style), we would still expect to see the symbiotic signature of the Pulse Model etched into the productive landscape. The second implication is: Landscape as a Result of Recursive Action. A true understanding of historical ecology can only be had by investigating the complex interaction of human responses to fluctuations in climate and to environmental alterations and the long-term response of the bio-physical world to cumulative human actions. As our understanding of the climatic sequence of the Sahel, and of the Méma as Sahelian subset, improves, as the implications on the ground of Nicholson's six 'anomaly types' become better understood, for example, this task will get easier. And the last implication is: Humans Act upon their Perception of Environment. There is a culturally-conditioned response to environmental change that is a product of these deep-time, recursive interactions. Archaeologists must attempt to go beyond mere functionality – to delve into prehistoric motivations – into the soul-land of sustainability!

6 Perspectives for understanding the abandonment of the Méma

Joseph A. Tainter

6.1 Introduction

The abandonment of the Méma in the 14th or 15th century AD was one of the formative processes in the history of the region. Previous formative processes had included (a) the establishment of a permanent hunter-gatherer occupation in the Late Stone Age, perhaps *ca.* 2000–1000 BC [as opposed to movement in and out of the study area as suggested in the Pulse Model (R. McIntosh, 1993, this volume Ch. 5)]; (b) the establishment of herding economies during the same time interval (*ca.* 2000–1000 BC); (c) the adoption of agriculture; (d) the adoption of iron smelting; and (e) the development of urban communities (S. McIntosh & R. McIntosh, 1984) sometime in the first centuries AD. Although the focus of this chapter is to discuss regional abandonment, that matter cannot be considered in isolation. Abandonment was in part a result of these earlier formative processes, especially the development of agriculture and urbanism.

Urbanism in the Méma, and the abandonment of the region, are examples of broader processes that recur in human history in different times and places. Urbanism, of course, developed several times in different areas of the world. The abandonment of large regions is also a recurrent process (*e.g.* Cameron & Tomka, 1993). Both, moreover, exemplify such fundamental matters as problem solving, complexification, sustainability, resiliency, and collapse. These are among the topics that must be discussed in untangling the problem of abandonment in the Méma and elsewhere.

6.2 Urbanism and complexity in the Méma

African urbanism, as Susan and Roderick McIntosh have pointed out, is a different matter from urbanism elsewhere (S. McIntosh, 1999a, 1999b; R. McIntosh, 1999). The traditional model of ancient cities is that they were characterized by wealth differentials, hierarchical political control, autocratic government, agriculture, and public works, and that they stood at the apex of a settlement hierarchy. Susan McIntosh (1999b) points out that the Middle Niger city of Jenne-jeno, as one example, shows little differentiation in wealth or power. It was a case of urbanism built on both cultivated and wild foods. There was little investment in public works before the building of its defensive wall. It does not, moreover, appear to sit at the top of a classic settlement hierarchy starting with farmsteads and extending to villages and cities. Very large settlements, rather, occur in clusters, indicating a mode of economic organization and exchange that is unfamiliar to many Western scholars.

Notwithstanding the above, cities of the middle Niger River valley were complex social systems. Urbanism here imposed many of the costs of complexity that it imposed elsewhere. Compared to communities of hunter-gatherers and simple agriculturalists, Middle Niger cities were large and more densely settled. Jenne-jeno, for example, may have held from 3200 to 6400 persons between AD 800 and 1000, while all sites within a 5 km radius of Jenne-jeno may have had between 11,000 and 22,000 persons packed into a settled area of 130 ha (S. McIntosh, 1999b, p. 73). Regardless of the degree to which there were hierarchies or wealth differentials, such agglomerations raised problems and led to increased complexity in the following areas, *inter alios*: (a) establishment of community norms or rules of behavior; (b) adjudication of disputes, enforcement of community norms or rules, and punishment; (c) provisioning and trade, including regulating transactions, weights and measures, *etc.*; (d) sanitation; (e) travel and transport to and from production areas; (f) residential and occupational segregation; (g) public works; and (h) gathering and processing public information. Middle Niger cities were complex places indeed.

In any complex system, size and diversification congest information channels. Transaction costs increase, and there are diminishing returns to scale. Decision-makers in a complex institution are constrained by bounded rationality (March & Simon, 1958; Simon, 1997). Humans can rarely absorb all of the complexities of a problem, so we make fallible decisions on the basis of rules that simplify complexity (March & Simon, 1958, pp. 169-171, 203; Simon, 1997, p. 119). Decision-making in a large, complex system may be surrounded by such confusion as to make the linkage between problem and solution tenuous (March & Olsen, 1986, p. 16). These are some of the problems that size and complexity would have brought to Middle Niger cities.

Problems arising from size and agglomeration, then, brought complexity to Middle Niger cities much like the complexity of early urban life elsewhere. Complexity imposed costs, as it always does (section 6.4, below). The cost of social overhead rose *per capita* in urban living. These costs may have manifested themselves both directly in the payment of taxes or tribute to support some level of administration and enforcement of rules, and/or indirectly through the investment of time to building and maintaining social consensus among populations numbering in the thousands. Urbanized Malians would have had to work harder than their non-urban forebears simply to support urbanism. Agricultural productivity and urbanism went hand-in-hand, since both aggregation and urban complexity require increases in the productivity of land.

During years of adequate rainfall, when the Fala de Molodo rose and water backed into the study area, these costs could apparently be sustained. When the Fala de Molodo failed, there would be famine. People would be weakened and more susceptible to disease. More children would die. When such conditions were prolonged, supporting the social overhead of urbanism would become increasingly difficult. Many archaeologists would be content to consider environmental failure such as this as an adequate explanation for regional abandonment. As will be discussed in the next section, though, this scenario alone cannot account for the abandonment of the Méma.

6.3 Comparative processes of regional abandonment

The work of Téréba Togola (1993, 1996) suggests that after millennia of occupation, the Méma was rather abruptly abandoned in perhaps the 14th or 15th century AD. This occurred during a period of severe variable droughts that extended from about AD 1250 to 1500, following a period of high unpredictability from about AD 1000 to 1250 (R. McIntosh, 1998, pp. 70-73; R. McIntosh, 2000, pp. 152-153). It has been logical to link drought and regional abandonment. With a lower Niger River flood between AD 1250 and 1500, the Fala de Molodo would have run at lower levels, or perhaps failed altogether. During flood season, less water would have backed into the ponds of the Méma, making it difficult or impossible to maintain the agricultural practices that sustained urban life. High variability and uncertainty in the flood levels could have been as detrimental as a consistently lower flood, and perhaps harder to adjust to. Urbanism itself could not be sustained, and so the region was abandoned. An alternative mechanism, raised by the finding by de Vries & Makaske (this volume Ch. 2) that the eastern part of the Méma has experienced tectonic uplift, is that such uplift could have caused failure of fluvial water supply to the Méma. Of course, tectonic uplift and drought could both have been at work, and the situation would have been that much worse if they were. By whichever mechanism, the outcome was the same: desiccation made it difficult or impossible to practice agriculture that depended on annual flooding.

It is worth evaluating this event in a comparative framework. The southwestern United States (Fig. 6.1) (hereafter, the Southwest) is another region that, at varying times, experienced widespread abandonment of regions that had, for centuries, supported villages of sedentary agriculturalists (Fish *et al.*, 1994; Cordell, 1997, pp. 365-397). Parts of the Mogollon highlands of west-central New Mexico and east-central Arizona, for example, were abandoned by about AD 1250 (Martin, 1979, p. 73). The region of the Colorado Plateau, where the states of Arizona, New Mexico, Colorado, and Utah join, was abandoned during the 13th and 14th centuries. The desert region of the Tularosa Basin seems to have been depopulated by AD 1350 (Cordell, 1997, pp. 365-397).

Traditional explanations for regional abandonment in the Southwest have included such factors as disease, invasion, internal conflict, agricultural exhaustion, deforestation, prolonged drought, or change in rainfall seasonality (*e.g.* Gumerman & Haury, 1979, p. 88; Cordell, 1997, pp. 365-397). While no consensus has emerged on this topic, most recent explanations are united in postulating environmental changes that produced a reduction in regional carrying capacity (Schlanger & Wilshusen, 1993). Whether caused by climate or resource depletion, this reduction in carrying capacity presumably caused large parts of the Southwest to be abandoned by agricultural villagers. In the northern Southwest, people clustered into a few areas that were at lower elevations, mostly better watered: the upper and middle Rio

Grande Basin, the middle and lower Rio Puerco Valley, the Rio San José, the Zuñi River, and the Hopi Mesas. Surrounding these areas of dense village settlement there were very large unoccupied stretches. These came in time to be filled in when the ancestors of today's Navajo and Apache peoples moved into the fringes around the Puebloan world.

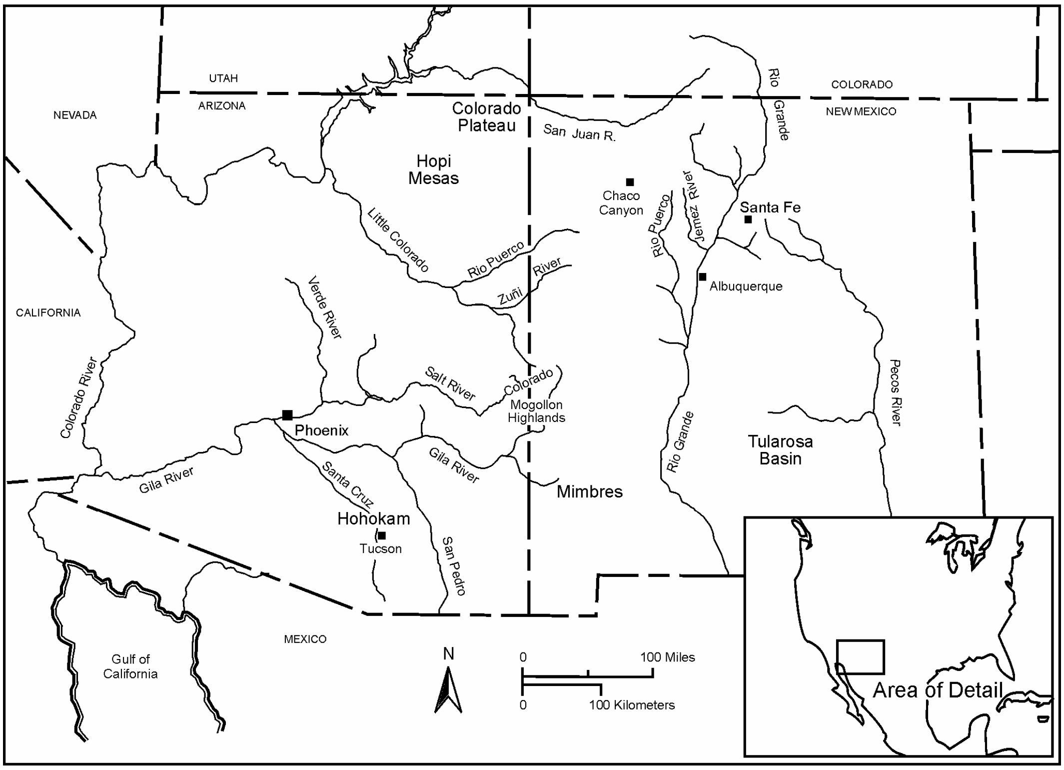

Fig. 6.1 The southwestern United States, showing areas, features, and cultural traditions mentioned in the text.

The problem with this scenario is that it does not explain why such large areas seem to have been completely abandoned. A reduction in regional carrying capacity would, by itself, call for a corresponding reduction in the human population, not for total abandonment. In some areas this seems to be what happened: there was a major reduction in population, and those remaining collapsed to a simpler organization. These areas seem to have responded to stresses by collapse [*sensu* Tainter (1988) where collapse is defined as rapid simplification] rather than by abandonment. One example is the southern Rio Grande Valley within New Mexico, which was occupied at the time of the Spanish *entrada* by low-density people called Mansos (Opler, 1983, p. 388; Beckett, 1985). In southern Arizona, similarly, Hohokam society after *ca.* 1350 was replaced by a lower-density occupation that some archaeologists call the Polvoron phase (Crown, 1991, pp. 153-154; Wells, 2002). Hohokam areas that had supported sedentary villages came to be lightly used for such activities as agave production (Fish & Fish, 1993, p. 108). In both areas, the post-collapse occupation has left an archaeological record so light that it is difficult to detect. In the Mimbres region of southwestern New Mexico, the abandonment of large villages by the middle of the 12th century, once interpreted as an abandonment of the region, actually coincided with expansion of smaller villages (Nelson & Hegmon, 2001).

We reach the same logical impasse when considering the abandonment of the Méma. Why was the Méma apparently abandoned in the 14th or 15th century in response to desiccation? If the carrying capacity of the region was reduced, a smaller population could have remained in place. In fact, the region was reoccupied within 200 years by a small population of Bambara farmers (Togola, 1993). Today the region supports about 8000 people who live mostly by herding cattle and sheep, and by rainfall farming of millet on a very small part of the potentially cultivable land. Unhappily, we must recognize that while desiccation may clarify the end of urban life in the Méma, it cannot explain why the region was abandoned.

At the same time, it is important to remember that the late urban archaeological record of the Méma is quite poorly known. We cannot yet definitely say that the area was completely abandoned at this time. Historical texts still refer to a Kingdom of the Méma as late as 1433 (R. McIntosh, 1998, pp. 246-247). In all such discussions, however, there is a tendency to employ European terms in situations where they may not apply, and to formalize political structures (*e.g.*, 'kingdom') that may have been more fluid than European concepts could recognize. The capital of this Kingdom of the Méma was supposedly at the site of Péhé, which is south of Boulel Ridge. We do not even know if its subordinate territory extended north of Boulel Ridge, our main study area.

For the sake of discussion, the abandonment of the Méma will be assumed, recognizing the need for much more work on the late urban occupation and more precise chronological control. To clarify the problem of regional abandonment it is necessary to discuss problem solving in human societies in some depth, as well as recent literature on collapse, sustainability, and resiliency.

6.4 Problem solving and complexity in human societies

The relationship of environmental conditions to human occupation of a region such as the Méma is indirect and subtle. The relationship is mediated by human capacities in problem solving (Tainter, 1988, 1995, 2000a, 2000b; Allen *et al.*, 2003). The trajectory of problem solving influences, even determines, the success or failure of human activities in the long run. Problem solving can have subtle and deleterious effects, for a solution that is successful now may set the stage for future failure.

The success of problem solving rests to a great degree on the complexity of the effort. If there is any historical generalization that seems beyond dispute, it is that human societies of the past 12,000 years have tended to increase in size and complexity. Yet in the full spectrum of hominid history—four million years or so—complexity is recent and rare. This is because every increase in complexity has a cost. The cost of complexity is the energy, labour, money, or time that is needed to create, maintain, and replace systems that grow to have more and more parts, more specialists, more regulation of behavior, and more information.

The development of complexity is a dilemma of human history. Over the past 12,000 years, we have responded to challenges with strategies that cost more labour, time, money, and energy, and that go against our aversion to such costs. We have done this for a simple reason: most of the time complexity works. It is a basic problem-solving tool. Confronted with problems, we often respond by such strategies as developing more complex technologies, establishing new institutions, adding more specialists or bureaucratic levels to an institution, increasing organization or regulation, or gathering and processing more information. Such increases in complexity work in part because they can be implemented rapidly, and typically build on what was developed before. While we usually prefer not to bear the cost of complexity, our problem-solving efforts are powerful complexity generators. All that is needed for growth of complexity is a problem that requires it. Since problems continuously arise, there is persistent pressure for complexity to increase.

The costliness of complexity is not a mere annoyance or inconvenience. It conditions the long-term success or failure of problem-solving efforts. Complexity can be viewed as an economic function. Societies invest in problem solving, assuming costs and expecting benefits in return. In any system of problem solving, early strategies that become institutionalized tend to be both effective and cost-effective. That is, they work and give high returns per unit of effort. This is a normal economic process: humans typically pluck the lowest fruit first, going to higher branches only when those low down no longer hold fruit. In problem-solving systems, inexpensive solutions are adopted before more complex and expensive ones. In the history of human food-gathering and production, labour-sparing hunting and gathering gave way to more labour-intensive agriculture, which in some places has been replaced by industrial agriculture that consumes more energy than it produces (Boserup, 1965; Clark & Haswell, 1966; Cohen, 1977). We produce minerals and energy whenever possible from the most economic sources. Our societies have changed from egalitarian relations, economic reciprocity, *ad hoc* leadership, and generalized roles to social and economic differentiation, specialization, inequality, and full-time leadership. These characteristics are the essence of complexity, and they increase the costliness of any society.

As the highest-return solutions are tried and exhausted, only more costly solutions remain. As the highest-return ways to produce resources, process information, and organize society are implemented, continuing problems must be addressed in ways that are more costly and less cost-effective. As the costs of solving problems grow, the point is reached where further investments in complexity do not give a proportionate return. Increments of investment in complexity begin to yield smaller and smaller increments of return. The *marginal* return (that is, the return per extra unit of investment) starts to decline. This is the long-term challenge faced by problem-solving institutions: diminishing returns to complexity. If allowed to proceed unchecked, eventually this brings economic stagnation and ineffective problem solving. Collapse then becomes a matter of mathematical probability. In time there will be a costly problem that cannot readily be overcome. The problem of diminishing returns to complexity produces an enhanced effect if it coincides with an extraordinary stress such as a prolonged drought (Tainter, 2000a). The society's problem-solving capacity will be impaired just when it is needed most.

6.5 Toward understanding abandonment and collapse

Abandonment and collapse may be alternative responses to situations where an environmental production system can no longer sustain an established human population in an accustomed way of life in a specific locale. To understand abandonments we must ask: what are the factors that dispose a population to one response or the other? That question cannot be fully answered here, but it is possible to elucidate some pertinent factors.

Recently the framework described above, derived from history and archaeology, has been turned toward understanding the problems of sustainability, sustainable development, and resiliency in both history and the contemporary world (Tainter, 1995, 2000a, 2000b; Allen *et al.*, 2003). Sustainability has various definitions. Most fundamentally it can be considered the capacity to continue a desired condition or process, social or ecological. Continuity is the essence of sustainability. Resiliency, on the other hand, is the ability of a system to adjust its structure and function under disturbance. Resiliency involves the cessation of continuity (Allen *et al.*, 2003, p. 26). Sustainability is, moreover, a matter of values: We sustain what we value, which for most people is an accustomed way of life. [In today's industrialized democracies, sustainability values range widely across societal values as a whole. These include, *inter alios*, economic opportunity, quality of life, open space, endangered species, the quality of environmental tangibles such as air and water, and abstractions such as undegraded ecological processes. What unites these disparate goals is that each reflects the implicit values of sustainability advocates (Tainter, 2003).] Resiliency, in contrast, embraces the possibility of dramatic change. The essence of resiliency is to change sustainability goals. Resiliency in human societies may be rare. A fully resilient society would be a valueless one, which cannot exist. One challenge for research into sustainability and resiliency is to understand why the normal desire for continuity (sustainability) gives way on occasion to the acceptance of dramatic change (resiliency). In one historical case studied in detail (the simplification of the Byzantine Empire in the 7th century AD), resiliency was accepted only when there was no alternative (Tainter, 2000b).

This discussion clarifies aspects of the alternative strategies of massive regional abandonment, in such places as the Méma and the American Southwest, *vs.* collapsing and remaining *in situ* with a smaller population. This is analogous to the distinction between sustainability and resiliency. Regional abandonment can be viewed as a sustainability strategy. This can be shown by comparing abandonment to the alternative: remaining *in situ* with massive reduction of population accompanied by pronounced simplification of social and political systems – in other words, collapsing. Collapse involves profound change. Terminating as it does an accustomed way of life, collapse can be considered in some cases a resilient strategy, especially if it is adopted deliberately. In contrast, relocation may offer the possibility of continuing an accustomed way of life, albeit in a different place and at great cost. In the Southwest, for example, prehistoric Puebloans who abandoned village life in one place seem to have taken it up elsewhere, either by joining existing villages or establishing new ones. Ethnographically, Puebloans who moved tended to retain their identity even when incorporated into a new population (Fish *et al.*, 1994, p. 143). Regional abandonment in the Southwest can be seen, therefore, as an attempt to maintain continuity, and thus as a strategy of sustainability. Abandonment of the Méma should be viewed similarly.

Of course, there is great variation in human behavior. It may simplify too much to present collapse *vs.* abandonment as an irreducible dichotomy. Responses to environmental deterioration may involve a combination of these, with part of a population moving elsewhere, while those remaining collapse to a simpler, less expensive way of life. In both the Méma and parts of the American Southwest, though, regional abandonment does appear to have been the preferred strategy. It is useful to speak of collapse and abandonment as a dichotomy, moreover, to illustrate the factors involved in choosing one or the other.

One implication of the research discussed above on the relationship of complexity to collapse (Tainter, 1988, 2000a, 2000b) is that the economics of problem solving influence any search for sustainability. If abandonment and migration are attempts to maintain continuity of a way of life, then abandonment is in part an economically irrational act. Abandonment is an acceptance of the high cost of migration, added to the existing costs of urban societal overhead, simply to maintain something as close to the *status quo* as is possible. Collapsing *in situ* would be less costly. While economically irrational behavior seems *a priori* implausible, the fact is that people did undertake massive regional abandonments even when it was not economical do to so. Clearly, factors other than the purely economic were at work. People are not motivated solely by what Western economists would consider rationality.

Here we venture into realms where the motivations and goals of past peoples must be considered. These are matters on which it is easy to speculate, and archaeologists often do. Ultimately, though, the archaeological record does not easily inform us of past motivations and goals, let alone whether these were powerful enough to overcome economic rationality. We do not clearly know whether the urban residents of the Méma preferred continuing urban life at high cost elsewhere to collapsing *in situ*. If in general people prefer continuity to very great change (Allen *et al.*, 2003; Tainter, 2003), then continuity of urban life through migration might be understandable. A further factor is that much of the Sahel is not densely populated, nor was it 600 years ago. Political power here is achieved not so much by the control of land as by the control of people, and in particular by rights to future labour (S. McIntosh, 1999a: 6-7, 17). Although, as noted above, political hierarchies and authoritarian control are not very prominent in African urbanism, political continuity may have played a role in regional abandonments.

Recent research by Janssen *et al.* (2003) suggests that an important factor in regional abandonments is what economists call 'sunk costs.' Sunk costs are past investments, and they often influence the making of current decisions. Humans are frequently committed to sunk costs, and make decisions that seem economically irrational because of those commitments. Sunk costs sometimes induce people to continue activities that appear, in hindsight, deleterious or irrational. In the Méma, prior investments in the social, political, and economic dimensions of urban life were a sunk cost. Relocation to maintain urban life may be seen as a sunk-cost effect.

Two important implications emerge from this discussion. Firstly, there has long been discussion within the historical sciences about whether major episodes of transformation, such as collapse or abandonment, can be attributed to factors external to a society, or to factors that are intrinsic. External factors would include such things as climate change and tectonic uplift. Internal factors would include social, political, or economic processes that might precipitate rapid change. Civil war and revolution are two examples. One lesson of this chapter is that external factors alone cannot account for the abandonment of the Méma. If collapse *in situ* was an alternative strategy to abandonment, then the economic, social, and political factors discussed above must be incorporated into any full explanation of abandonment.

The second implication is closely related to the first. When confronted with a dramatic episode of cultural change that is otherwise difficult to explain, archaeologists have long tended to fall back on single-factor, *deus ex machina* explanations. That is, the change must have been caused by such things as the migration of a new people into the area (*e.g.* Chadwick, 1976), a change in climate (*e.g.* Weiss *et al.*, 1993), or perhaps tectonic uplift (*e.g.* Moseley, 1983). The present discussion suggests that no single factor – no 'silver bullet' or 'smoking gun,' to use colloquial expressions – will explain the abandonment of the Méma. Neither drought nor tectonic uplift is, by itself, adequate to explain the end of urban occupation here.

6.6 Conclusion

Understanding the abandonment of the Méma will not be simple. Determining whether desiccation was brought on by drought or by tectonic uplift will contribute to our understanding, but this determination itself will not accomplish the goal of explanation. Rather, an explanation of the abandonment will involve weaving together external and internal dynamics, and understanding their intersection. It will be particularly important to locate archaeological sites, or areas within sites, that were occupied late in the urban period, and to excavate these. The full range of the social, political, and economic organization of the late urban occupation must be delineated.

The Méma research raises broader issues of sustainability and resiliency in human societies. Under what circumstances do people choose continuity or sustainability, as in regional abandonment, *vs.* resiliency and acceptance of dramatic change, as in collapse? Under what circumstances is the high cost of continuity, even though economically irrational, preferable to the adventure of cost-effective, but wrenching, change? It is only by asking such questions that the abandonment of the Méma, or other regions, will be understood.

6.7 Acknowledgments

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7 Epilogue

Bart Makaske

During our reconnaissance trip to the Méma in January-February 2000 we visited quite a number of the spectacular sites mentioned in this report, like Akumbu, Péhé, Toladie and Kobadi. Watching the impressive scale of the sites, the numerous surface artifacts and the vast and desolate landscape, the key research questions almost suggested themselves. Why did this area attract such large numbers of people in the past? How did they manage to survive in this landscape that seems so hostile today? When and why did they leave this area? Visiting the Méma, the fascination of previous researchers for this area appeared self-evident. The archaeological record convincingly indicates former existence of complex societies and a population far outnumbering the sparse, mainly nomadic, inhabitants of the area today.

Previous archaeological research in the Méma until the late 1980s demonstrated Late Stone Age and Iron Age sites representing millennia of occupation history. Site clustering and the apparent early development of specialization and urbanization followed by the abandonment of the Méma, were very interesting but poorly understood phenomena. The explanation of the archaeological record of the Méma was hampered by: (1) a lack of systematic site inventories, (2) lack of a conceptual framework for the processes of specialization, urbanization and regional abandonment, and (3) lack of detailed knowledge on palaeogeographical and palaeoclimatological developments in the region.

Evaluating the material brought together in this report, we can conclude that with respect to the above-mentioned limitations, considerable progress has been made in the past fifteen years. Systematic site inventories had a good start with the surveys of MacDonald and Togola in 1989-1990, but unfortunately have remained limited since then. On the other hand, much has been done on the development of a conceptual framework for understanding specialization, urbanization and regional abandonment. The Pulse Model described in Chapter 5 of this report and the theories about abandonment and collapse of societies described in Chapter 6, provide important guidelines for focussing future field research. Also with respect to the physical environment of the Méma there are important new developments. The geomorphological map published in this report and the tentative reconstruction of the geomorphological history of the Méma (Chapter 2) represent a foundation for further geoarchaeological field research that should aim at: (1) validation of the tentative geomorphological history with radiometric dates, and (2) establishing a more detailed climatic chronology for the area that can be linked to geomorphological and archaeological chronologies.

The Méma can be considered a rich archive of information on issues of world-wide interest like human adaptation to climatic stress, the rise of specialization, early urbanism and regional abandonment. Having summarized and evaluated all earlier work now, progress can only be made trough extraction of new (field) data from the Méma archive. Although presently locked, sooner or later the archive will open up again for further exploration, so that we can learn from the way human societies dealt with a dynamic physical environment in the deep past.

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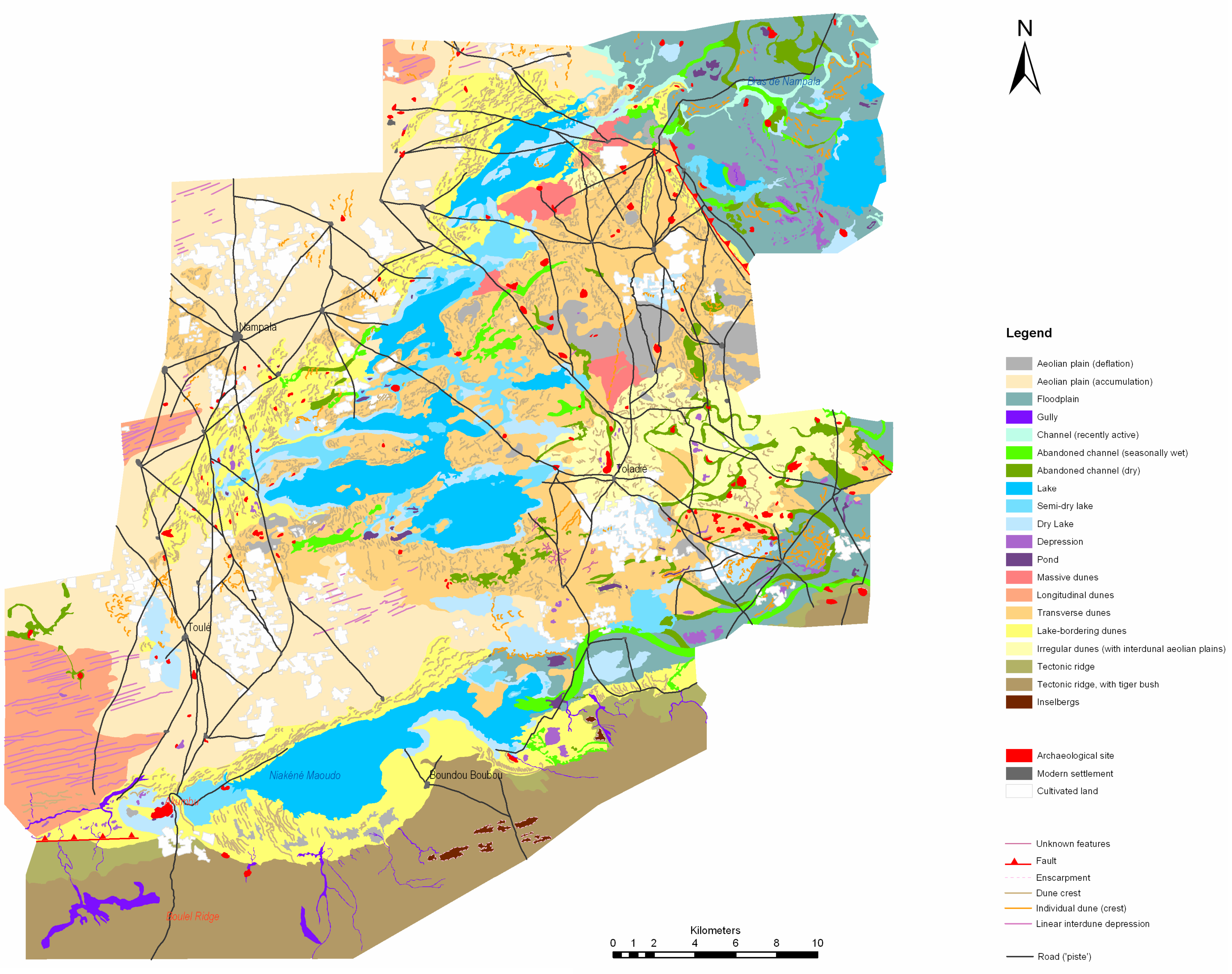
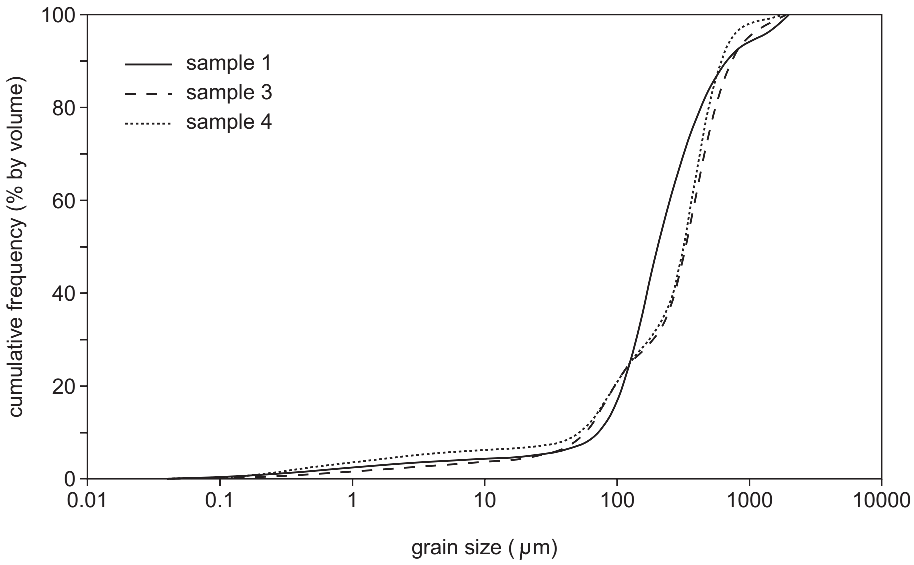
Appendix 1 Geomorphological map of the Méma



Appendix 2 Grain size distributions of sediment samples from the Méma

Sediment samples were taken from various landforms by Bart Makaske during the field survey in January-February 2000. Grain size analysis of these samples was carried out by the Laboratory of Soil Science and Geology of Wageningen University and Research Centre, using a laser particle sizer (Coulter LS Particle Size Analyzer).

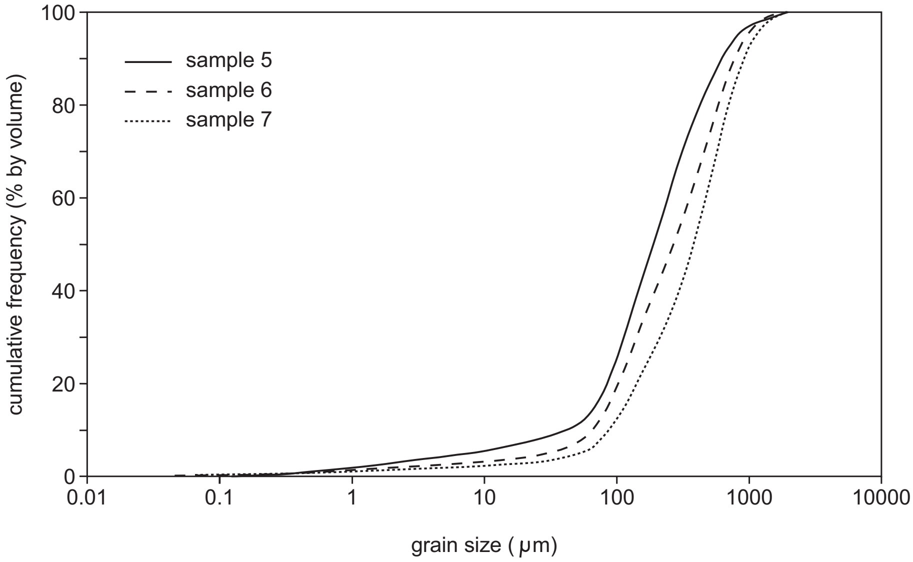


Description of material, sampled landforms and sampling locations

Sample 1: reddish-brown material from very high (~25 m) dune along the southern shoreline of the dry lake bottom around Akumbu, 1 to 2 km southwest of the Akumbu site.

Sample 3: loose reddish material from the top of the dune that is connected to the western flank of the Akumbu site, sample location less than 1 km west of Akumbu.

Sample 4: cemented reddish material from the base of the dune that is connected to the western flank of the Akumbu site, sample location less than 1 km west of Akumbu.

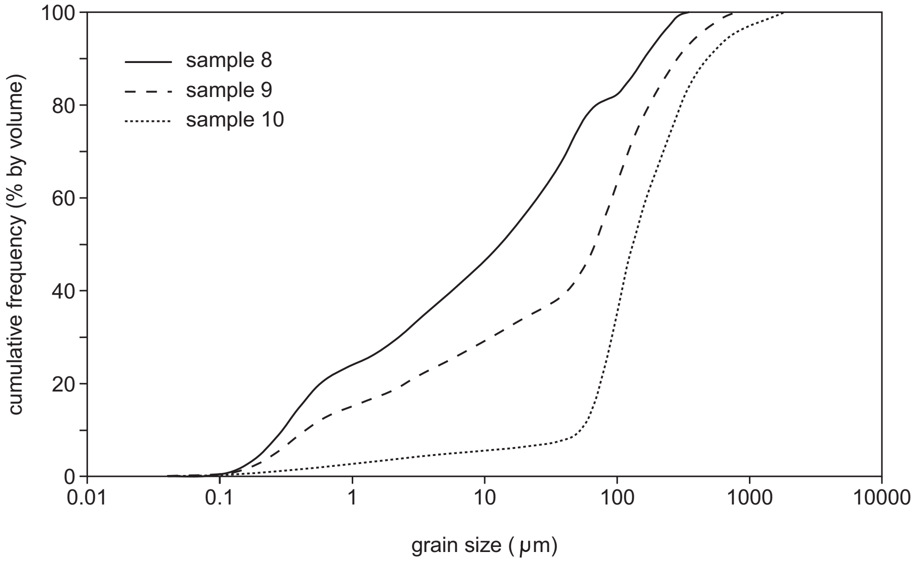


Description of material, sampled landforms and sampling locations

Sample 5: reddish cemented material from a longitudinal dune, ~8 km west of the Akumbu site.

Sample 6: reddish cemented material (buried longitudinal dune), covered by 5 cm loose yellow material, from the aeolian plain ~6 km north of the Akumbu site.

Sample 7: loose yellow material from the surface of the aeolian plain ~6 km north of Akumbu.

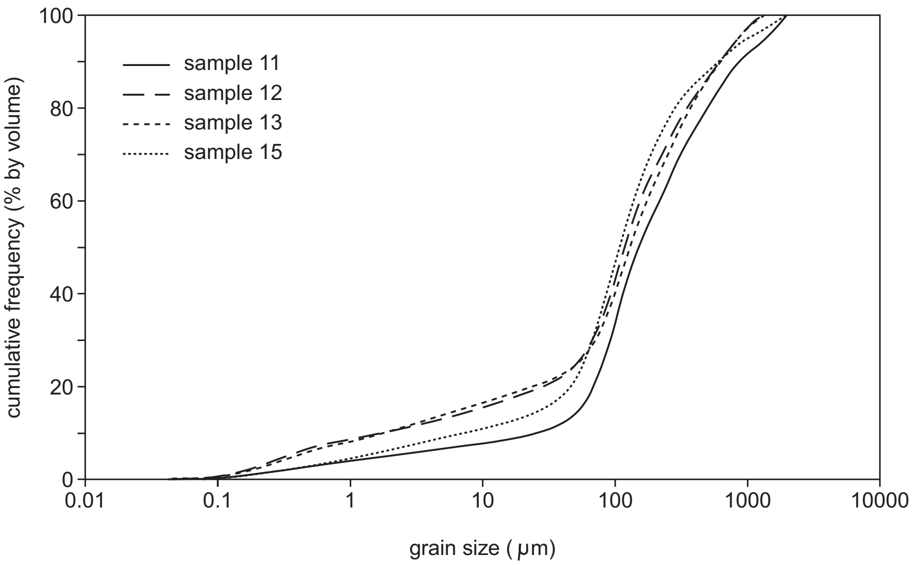


Description of material, sampled landforms and sampling locations

Sample 8: grey material from the cracked dry lake bottom in the west-central part of the lake Niakéné Maoudo, ~6 km east-northeast of the Akumbu site.

Sample 9: material sampled from the dry lake bottom ~50 m from the former northwestern shoreline of the lake Niakéné Maoudo, ~6 km northeast of the Akumbu site.

Sample 10: material from the top of an interpreted former beach face near the samping location of sample 9.



Description of material, sampled landforms and sampling locations

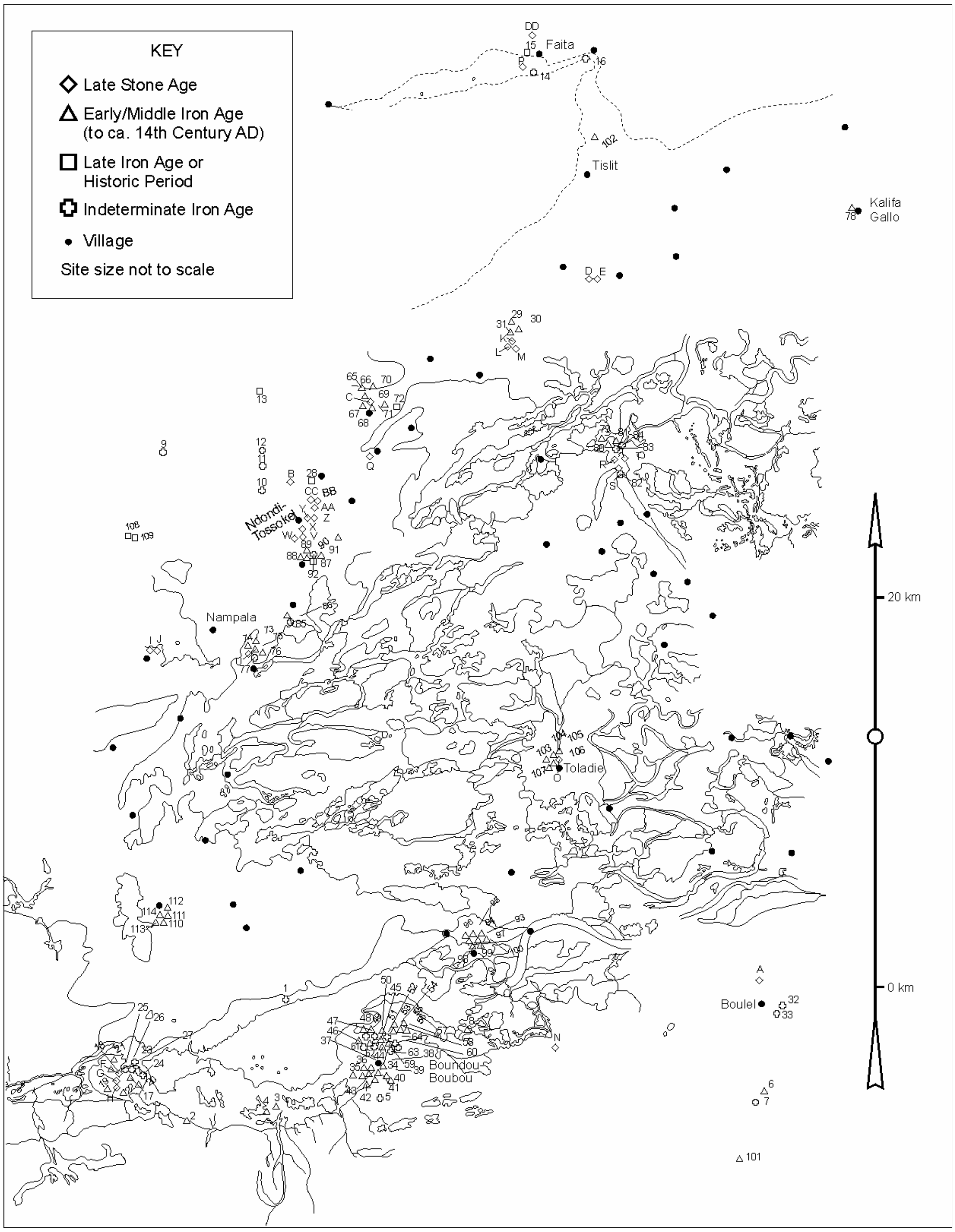
Sample 11: red, cemented material from a pit near Nampala (upper unit in left profile in Fig. 2.17).

Sample 12: dark-grey material from a pit near Nampala (top of dark-grey upper unit in right profile in Fig. 2.17).

Sample 13: light-grey material from a pit near Nampala (near the base of right profile in Fig. 2.17).

Sample 15: red, cemented material from an exposed massive dune soil profile, ~6 km north of Toladié (just below the dark upper soil horizon in Fig. 2.14).

Appendix 3 Archaeological sites in the Méma, known from prior surveys



Lines in this map correspond to landform outlines in the geomorphological map (App. 1); site numbers in this map correspond to numbers in Appendix 4 (column 1).

Appendix 4 Inventory of previously known archaeological sites of the Méma

MAP CODE	NAME/NUMBER	PERIOD (putative)	CLUSTER NAME? (if known)	SPECIALIZED? (putative)	DIMENSIONS	LAT./LONG.	GEOMORPHOLOGICAL POSITION	RADIOMETRIC DATES	COMMENT	REFERENCE
A	915-1	LSA (Faita)		(agricultural?)	negl	15°6''N/5°25'W	Duri-crust/ Channel		surface exam only	MacDonald 94:table 5.1
B	1117-3	LSA (Nd'Toss)(Faita)		(pastoral?)	negl	15°21'N/5°32'W	Aeolian plain/ Long.Dune		surface exam only	MacDonald 94:table 5.1
C	1119-15	LSA (Nd'Toss)		(pastoral?)	5mx5m	15°23'N/5°28'W	Aeolian plain		stratified; midden	MacDonald 94:table 5.1
D	1251-1	LSA (Kobadi)(also Nd'Toss)	1251	(aquatic; H/Fish/G)	581mx132m; 8ha.	15°27''N/5°22'W	Aeolian plain/ Lake		stratified	MacDonald 94:table 5.1; Togola 93: 242
E	1251-2	LSA (Faita)(also Nd'Toss)	1251	(agricultural?) (pastoral?)	151mx27m; 0.4ha.	15°27'N/5°22'W	Aeolian plain/ Lake		stratified; numerous burials	MacDonald 94:table 5.1; Togola 93: 241
F	Akumbu Mound B (AK3)	LSA (Faita) (early Fe?)	Akumbu	(agricultural?) early Fe?		15°4'N/5°35'W	misc. dunes/ dry Lake	before ADcal340-540	stratified under IA, Ph.II/III	
G	Akumbu LSA-5 [872-5]	LSA (Faita)	Akumbu	(agricultural?)	21mx20m, 0.1ha.	15°4'N/5°35'W	misc. dunes/ dry Lake		stratified [872-5]	MacDonald 94:table 5.1
H	Akumbu LSA-6 [872-6]	LSA (Faita)	Akumbu	(agricultural?)	64mx54m, 0.4ha.	15°4'N/5°35'W	misc. dunes/ dry Lake		stratified-0.5m [872-6]	MacDonald 94:table 5.1
I	Barkérou 1043-6	LSA (Nd'Toss)	Barkérou	(pastoral?)	14mx34m	15°16'N/5°35'W	Aeolian plain/transverse dune		surface exam only	MacDonald 94:table 5.1
J	Barkérou 1043-7	LSA (Nd'Toss)	Barkérou	(pastoral?)	22mx34m	15°16'N/5°35'W	Aeolian plain/transverse dune		surface exam only	MacDonald 94:table 5.1
K	Bérétouma 1121-3	LSA (Kobadi)	Bérétouma	(aquatic; H/Fish/G)	188mx106m; 2ha.	15°25'N/5°24'W	Aeolian plain/ Lake		stratified; numerous burials	MacDonald 94:table 5.1; Togola 93: 241
L	Bérétouma 1121-4	LSA (Bere)(Nd'Toss)	Bérétouma	(agro-pastoral?)	71mx36m; 0.2ha.	15°25'N/5°24'W	Aeolian plain/ Lake		stratified	MacDonald 94:table 5.1; Togola 93: 242
M	Bérétouma 1121-5	LSA (Bere)(Nd'Toss)	Bérétouma	(agro-pastoral?)	275mx136m; 5ha.	15°25'N/5°24'W	Aeolian plain/ Lake		stratified	MacDonald 94:table 5.1; Togola 93: 242
N	Boulel	LSA			?	15°12'N/5°16'W	Duri-crust		Mauny collection	Guitat 72:902 (#34)
O	Diaguina [1037-1]	LSA (Faita)	Toladié	(agricultural?)	100mx10m; 0.1ha.	15°13'N/5°23'W	Irreg.dunes/channels & lakes		stratified	MacDonald 94:table 5.1; Togola 93: 243
P	Faita Ouest 1167-3	LSA (Faita) (early Fe?)		early Fe?	120mx43m; 0.5ha.	15°34'N/5°25'W	Channel (present)/Lake (semi dry?)		surface exam only	MacDonald 94:table 5.1
Q	Kobadi [1119-8]	LSA (Kobadi)(also Nd'Toss)		(aquatic; H/Fish/G)(late pastoral?)	475mx40m	15°22'N/5°39'W	Aeolian plain (former lake)/ lake-b. dune	1760-200calBC (4 dates)	0.2m depth	Monod&Mauny 57; Guitat 72:#125; MacD 94; Raimb 86 & etal 87
R	Kolima Sud [1121-10]	LSA (Bere)(Kobadi)(Nd'Toss)	Kolima	deep=>shallow fishing/pastoral	502mx249; 14ha	15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune	1440-1160calAD	stratified; 2.50m; 2 test units: Mauny sondage	MacDonald 94:table 5.1; Mauny 61:
S	Kolima-Sud-Est [1121-13]	LSA (Faita) (early Fe?)	Kolima	early Fe?	350mx350m	15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune		stratified; some later IA	MacDonald 94:table 5.1;MacDonald & VanNeer 94: fig. 2
T	Kolima - unid. LSA	LSA(?)	Kolima			15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune			MacDonald & VanNeer 94: fig. 2
U	Nampala [1043-10]	LSA (Nd'Toss)		(pastoral?)	negl	15°16'N/5°32'W	Aeolian plain/ abandoned channel		surface exam only	MacDonald 94:table 5.1
V	Ndondi Tossokel 1041-1	LSA (Faita)	Ndondi Tossokel	(agricultural?)	negl	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		surface exam only	MacDonald 94:table 5.1
W	Ndondi Tossokel 1041-2	LSA (Nd'Toss)	Ndondi Tossokel	(pastoral?)	negl	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		surface exam only	MacDonald 94:table 5.1
X	Ndondi Tossokel 1119-1	LSA (Nd'Toss)	Ndondi Tossokel	(pastoral?)	108mx37m; 0.4ha	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		stratified; midden	MacDonald 94:table 5.1
Y	Ndondi Tossokel 1119-2	LSA (Nd'Toss)	Ndondi Tossokel	(pastoral?)	negl	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		surface exam only	MacDonald 94:table 5.1
Z	Ndondi Tossokel 1119-3	LSA (Nd'Toss)(Faita)	Ndondi Tossokel	(agro-pastoral?)	115mx103m; 1ha.	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		stratified	MacDonald 94:table 5.1
AA	Ndondi Tossokel 1119-4	LSA (Nd'Toss)	Ndondi Tossokel	(pastoral?)	97mx103m; 1ha.	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		stratified; midden	MacDonald 94:table 5.1
BB	Ndondi Tossokel 1119-5	LSA (Nd'Toss)(Faita)	Ndondi Tossokel	(agro-pastoral?)	negl	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		surface exam only	MacDonald 94:table 5.1
CC	Ndondi Tossokel 1119-6	LSA (Nd'Toss)	Ndondi Tossokel	(pastoral?)	12mx26m; 1ha.	15°20'N/5°30'W	Aeolian plain/ (misc. dunes)		stratified; 0.3m	MacDonald 94:table 5.1
DD	Saberi Faita 1167-1	LSA (Nd'Toss)		(pastoral?)	200mx300m; 6ha.	15°34'N/5°23'W	Duri-crust ridge?/ Channel/Long. Dune		superficially stratified	MacDonald 94:table 5.1

MAP CODE	NAME/NUMBER	PERIOD (putative)	CLUSTER NAME? (if known)	SPECIALIZED? (putative)	DIMENSIONS	LAT./LONG.	GEOMORPHOLOGICAL POSITION	RADIOMETRIC DATES	COMMENT	REFERENCE
1	872-1	IA-uncertain			scatter	15°6'N/5°31'W	dunes/ Lake		scatter only	Togola 93: 236
2	872-11	IA-early			3ha.	15°3'N/5°33'W	dunes/ Duri-crust/ Lake		(some slag)	Togola 93: 237
3	874-1	IA-early	874-1&2		3ha.	15°2'N/5°31'W	dunes/ Duri-crust/ Lake		some laterite and slag	Togola 93: 238
4	874-2	IA-early	874-1&2		1ha.	15°2'N/5°31'W	dunes/ Duri-crust/ Lake		some laterite and slag	Togola 93: 238
5	874-3	IA-uncertain			?	15°3'N/5°28'W	Duri-crust/(dunes)		grindstones	Togola 93: 239
6	878-2	IA-middle			6ha.	15°4'N/5°17'W	Channel/ Floodplain		burnt clay structures	Togola 93: 244
7	878-3	IA-uncertain		Fe	?	15°4'N/5°17'W	Channel/ Floodplain		furnace remains, slag heaps	Togola 93: 244
8	917-1	IA-early			1ha.	15°5'N/5°25'W	dunes/ Duri-crust/ Lake			Togola 93: 242
9	1117-1	IA-uncertain			scatter	15°22'N/5°36'W	Aeolian plain/ Long.Dune			Togola 93: 235
10	1117-2	IA-uncertain			scatter	15°21'N/5°32'W	Aeolian plain/ Long.Dune			Togola 93: 235
11	1117-3	IA-uncertain			scatter	15°21'N/5°32'W	Aeolian plain/ Long.Dune			Togola 93: 235
12	1117-4	IA-uncertain			scatter	15°22'N/5°32'W	Aeolian plain/ Long.Dune			Togola 93: 235
13	1117-5	IA-late			0.1ha.	15°24'N/5°32'W	Aeolian plain/ Long.Dune		rect. structures	Togola 93: 235
14	1167-2	IA-uncertain		Fe	?	15°32'N/5°25'W	Aeolian plain/ Lake (semi dry?)		furnace remains, slag heaps; tuyeres	Togola 93: 241
15	1167-4	IA-late			?	15°33'N/5°24'W	Channel (present)/ Lake (semi dry?)		tobacco pipes	Togola 93: 241
16	1167-5	IA-uncertain		Fe	?	15°33'N/5°22'W	Channel (recent)		furnace, slag conc.	Togola 93: 241
17	Akumbu Mound A (AK1,4)	IA -middle	Akumbu	(habitation?)	21ha.	15°4'N/5°35'W	misc. dunes/ dry Lake		5m. high mound/cluster "core"? [872-2]	Togola 93: 236
18	Akumbu Mound B (AK3)	IA-middle	Akumbu	(habitation)	7ha	15°4'N/5°35'W	misc. dunes/ dry Lake	ADcal340-540	4m. High mound [872-3]	Togola 93: 236; MacDonald 94:92
19	Akumbu Mound C	IA-middle	Akumbu	(habitation)	3ha	15°4'N/5°35'W	misc. dunes/ dry Lake		7m. High mound [872-4]	Togola 93: 236
20	Akumbu Mound D	IA-middle	Akumbu	(habitation?)	0.2ha.	15°4'N/5°35'W	misc. dunes/ dry Lake		[872-7]	Togola 93: 236
21	Akumbu Jar Field 1	IA-middle	Akumbu	urn burials		15°4'N/5°35'W	misc. dunes/ dry Lake		[872-9]	Togola 93: 236
22	Akumbu Jar Field 2	IA-middle	Akumbu	urn burials		15°4'N/5°35'W	misc. dunes/ dry Lake		[872-12]	Togola 93: 237
23	Akumbu Furnace 1	IA-uncertain	Akumbu	Fe		15°4'N/5°35'W	misc. dunes/ dry Lake		[872-8]	Togola 93: 236
24	Akumbu Furnace 2	IA-uncertain	Akumbu	Fe		15°4'N/5°35'W	misc. dunes/ dry Lake		[872-10]	Togola 93: 237
25	Akumbu outlier	IA-uncertain	Akumbu			15°4'N/5°35'W	misc. dunes/ dry Lake		[872-1?]	Togola 93: fig. 4.1
26	Akumbu outlier	IA-uncertain	Akumbu			15°4'N/5°35'W	misc. dunes/ dry Lake			Togola 93: fig. 4.1
27	Akumbu outlier	IA-uncertain	Akumbu			15°4'N/5°35'W	misc. dunes/ dry Lake			Togola 93: fig. 4.1
28	Amakobé	IA-late			0.4ha.	15°21'N/5°31'W	Aeolian plain/ Long.Dune		[1119-7]	Togola 93: 237
29	Bérétouma-A	IA-middle	Bérétouma		13ha.	15°25'N/5°24'W	Aeolian plain/ Lake		[1121-1];walls &burnt clay structures;copper	Togola 93: 241
30	Bérétouma-B	IA-middle	Bérétouma		10ha.	15°25'N/5°24'W	Aeolian plain/ Lake		[1121-2]; walls &burnt clay structures; figurine	Togola 93: 241
31	Bérétouma-C	IA-middle	Bérétouma		0.2ha.	15°25'N/5°24'W	Aeolian plain/ Lake		[1121-6]	Togola 93: 241
32	Boulel 1	IA-uncertain	Boulel	Fe	7ha.	15°6'N/5°16'W	Duri-crust/ Floodplain		[913-1]	Togola 93: 244
33	Boulel 2	IA-uncertain	Boulel	Fe	0.5ha.	15°6'N/5°16'W	Duri-crust/ Floodplain		[913-2]	Togola 93: 244
34	Boundou-Boubou S-A	IA-early	Boundou-Boubou	Fe	2ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		burnt clay structures [874-4]	Togola 93: 239
35	Boundou-Boubou S-B	IA-middle	Boundou-Boubou	Fe	5ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		burnt clay structures [874-5]	Togola 93: 239
36	Boundou-Boubou S-C	IA-early	Boundou-Boubou		0.1ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		[874-6]	Togola 93: 239
37	Boundou-Boubou S-D	IA-early	Boundou-Boubou		1ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		[874-7]	Togola 93: 239
38	Boundou-Boubou S-E	IA-early	Boundou-Boubou		0.1ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		[874-8]	Togola 93: 239
39	Boundou-Boubou S-F	IA-early	Boundou-Boubou		0.2ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		[874-9]	Togola 93: 239
40	Boundou-Boubou S-G	IA-early	Boundou-Boubou		1ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		[874-10]	Togola 93: 239
41	Boundou-Boubou S-H	IA-early	Boundou-Boubou		1ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		[874-11]	Togola 93: 239
42	Boundou-Boubou S-I	IA-early	Boundou-Boubou		0.3ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		[874-12]	Togola 93: 239
43	Boundou-Boubou S-J	IA-early	Boundou-Boubou		0.1ha.	15°5'N/5°28'W	dunes/ Duri-crust/ Lake		possible architecture [874-13]	Togola 93: 239
44	Boundou-Boubou N-A	IA-middle	Boundou-Boubou		12ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		burnt clay structures [874-27]	Togola 93: 240
45	Boundou-Boubou N-B	IA-early	Boundou-Boubou		0.1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-15]	Togola 93: 240

MAP CODE	NAME/NUMBER	PERIOD (putative)	CLUSTER NAME? (if known)	SPECIALIZED? (putative)	DIMENSIONS	LAT./LONG.	GEOMORPHOLOGICAL POSITION	RADIOMETRIC DATES	COMMENT	REFERENCE
46	Boundou-Boubou N-C	IA-early	Boundou-Boubou		1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-16]	Togola 93: 240
47	Boundou-Boubou N-D	IA-early	Boundou-Boubou		1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		burnt clay structures [874-17]	Togola 93: 240
48	Boundou-Boubou N-E	IA-early	Boundou-Boubou		0.2ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-18]	Togola 93: 240
49	Boundou-Boubou N-F	IA-early	Boundou-Boubou		0.1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-19]	Togola 93: 240
50	Boundou-Boubou N-G	IA-early	Boundou-Boubou		2ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-20]	Togola 93: 240
51	Boundou-Boubou N-H	IA-early	Boundou-Boubou		1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-21]	Togola 93: 240
52	Boundou-Boubou N-I	IA-early	Boundou-Boubou		0.3ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-22]	Togola 93: 240
53	Boundou-Boubou N-J	IA-early	Boundou-Boubou		0.3ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-23]	Togola 93: 240
54	Boundou-Boubou N-K	IA-early	Boundou-Boubou		2ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		urns [874-24]	Togola 93: 240
55	Boundou-Boubou N-L	IA-early	Boundou-Boubou		1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-25]	Togola 93: 240
56	Boundou-Boubou N-M	IA-early	Boundou-Boubou		1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		burnt clay structures [874-26]	Togola 93: 240
57	Boundou-Boubou N-N	IA-early	Boundou-Boubou		1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-27]	Togola 93: 240
58	Boundou-Boubou N-O	IA-early	Boundou-Boubou		1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-28]	Togola 93: 241
59	Boundou-Boubou N-P	IA-early	Boundou-Boubou		0.1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-32]	Togola 93: 241
60	Boundou-Boubou N-Q	IA-early	Boundou-Boubou		0.1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		[874-33]	Togola 93: 241
61	Boundou-Boubou N [874-29]	IA-uncertain	Boundou-Boubou	Fe	0.1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		furnace remains, slag conc. [874-29]	Togola 93: 241
62	Boundou-Boubou N [874-30]	IA-uncertain	Boundou-Boubou	Fe	0.1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		furnace remains, slag conc. [874-30]	Togola 93: 241
63	Boundou-Boubou N [874-31	IA-uncertain	Boundou-Boubou	Fe	0.1ha.	15°6'N/5°28'W	dunes/ Duri-crust/ Lake		furnace remains, lg.slag conc. [874-31]	Togola 93: 241
64	Boundou-Boubou N [874-?]	IA-uncertain	Boundou-Boubou			15°6'N/5°28'W	dunes/ Duri-crust/ Lake		no site number assigned	Togola 93: fig. 3.5
65	Bourgou Silatigui-A	IA-middle	Bourgou Silatigui		15ha.	15°24'N/5°30'W	Aeolian plain		[1119-9]	
66	Bourgou Silatigui-B	IA-early	Bourgou Silatigui		0.2ha.	15°24'N/5°30'W	Aeolian plain		[1119-10]	
67	Bourgou Silatigui-C	IA-early	Bourgou Silatigui		0.4ha.	15°24'N/5°30'W	Aeolian plain		[1119-11]	
68	Bourgou Silatigui-D	IA-early	Bourgou Silatigui		0.2ha.	15°24'N/5°30'W	Aeolian plain		[1119-12]	
69	Bourgou Silatigui-E	IA-ear;y	Bourgou Silatigui		0.4ha.	15°24'N/5°30'W	Aeolian plain		{1119-13]	
70	Bourgou Silatigui-F	IA-early	Bourgou Silatigui		3ha.	15°24'N/5°30'W	Aeolian plain/ Long.Dune		[1119-17]	
71	Bourgou Silatigui-(G)	IA-early	Bourgou Silatigui	Fe	?	15°24'N/5°30'W	Aeolian plain/ Long.Dune		furnace? [1119-14]	
72	Bourgou Silatigui-(H)	IA-late	Bourgou Silatigui		0.2ha.	15°24'N/5°30'W	Aeolian plain		[1119-16]	
73	Goudourou-A	IA-early	Goudourou		3ha.	15°16'N/5°32'W	Aeolian plain/ abandoned channel		burnt clay struc.; looting, [1043-1]	Togola 93: 243
74	Goudourou-B	IA-middle	Goudourou		14ha	15°16'N/5°32'W	Aeolian plain/ abandoned channel		burnt clay structure, [1043-2]	Togola 93: 243
75	Goudourou-C	IA-middle	Goudourou		0.3ha.	15°16'N/5°32'W	Aeolian plain/ abandoned channel		[1043-3]	Togola 93: 243
76	Goudourou-D	IA-middle	Goudourou		5ha.	15°16'N/5°32'W	Aeolian plain/ abandoned channel		burnt clay structure, [1043-4]	Togola 93: 243
77	Goudourou-furnaces	IA-uncertain	Goudourou	Fe	0.1ha.	15°16'N/5°32'W	Aeolian plain/ abandoned channel		furnace remains; slag heaps, [1043-5]	Togola 93: 243
78	Kalifa-Gallou	IA-middle				15°29'N/5°15'W	Channel (present)	AD500-1300		Raimbault&Togola 91
79	Kolima-A	IA-middle	Kolima		11ha.	15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune	AD500-1300	Christoforoff sondage; [1121-7]; burnt clay struc.	MacDonald 94:71; Togola 93: 243
80	Kolima-B	IA-middle	Kolima		6ha.	15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune		[1121-8]; burnt clay struc.	Togola 93: 243
81	Kolima-C	IA-early	Kolima		0.6ha.	15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune		[1121-9]	Togola 93: 243
82	Kolima - Sud East	IA-(uncertain)	Kolima			15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune		also LSA [1121-13]	MacDonald & VanNeer 94: fig. 2
83	Kolima - unid. furnaces	IA-uncertain	Kolima	Fe	0.3ha.	15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune		[1121-11(a)]; furnace/tuyere remains	Togola 93: 243
84	Kolima - unid. furnaces	IA-uncertain	Kolima	Fe	0.2ha.	15°22'N/5°22'W	Aeolian plain/ Channel (rec)/ lake-b. dune		no site number assigned	Togola 93: 243
85	Ndoupa	IA-middle	Ndoupa		14ha.	15°17'N/5°31'W	Aeolian plain/ transverse dune		burnt clay structures [1041-9]	Togola 93: 238
86	Ndoupa-furnaces	IA-uncertain	Ndoupa	Fe	?	15°17'N/5°31'W	Aeolian plain/ transverse dune		furnaces [1041-10]	Togola 93: 238
87	Niakéré Ndondi-A	IA-late	Niakéré Ndondi		1.5ha.	15°19'N/5°21'W	Aeolian plain/ (misc. dunes)		[1041-3]	Togola 93: 247
88	Niakéré Ndondi-B	IA-early	Niakéré Ndondi		1ha.	15°19'N/5°21'W	Aeolian plain/ (misc. dunes)		[1041-4]	Togola 93: 247
89	Niakéré Ndondi-C	IA-early	Niakéré Ndondi		1ha.	15°19'N/5°21'W	Aeolian plain/ (misc. dunes)		[1041-5]	Togola 93: 247

MAP CODE	NAME/NUMBER	PERIOD (putative)	CLUSTER NAME? (if known)	SPECIALIZED? (putative)	DIMENSIONS	LAT./LONG.	GEOMORPHOLOGICAL POSITION	RADIOMETRIC DATES	COMMENT	REFERENCE
90	Niakéré Ndondi-D	IA-early	Niakéré Ndondi		0.2ha.	15°19'N/5°21'W	Aeolian plain/ (misc. dunes)		[1041-6]	Togola 93: 248
91	Niakéré Ndondi-E	IA-early	Niakéré Ndondi		0.1ha.	15°19'N/5°21'W	Aeolian plain/ (misc. dunes)		[1041-7]	Togola 93: 248
92	Niakéré Ndondi-furnaces	IA-uncertain	Niakéré Ndondi	Fe	?	15°19'N/5°21'W	Aeolian plain/ (misc. dunes)		[1041-8]	Togola 93: 248
93	Niessouma A	IA-early	Niessouma		3ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes	(AD200-600 = 917-2?)	round houses	Togola 93: 242; MacDonald 94:92
94	Niessouma B	IA-early	Niessouma		1ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes		round houses, 917-3	Togola 93: 242
95	Niessouma C	IA-early	Niessouma		0.5ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes		917-4	Togola 93: 242
96	Niessouma D	IA-early	Niessouma		1ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes		917-5	Togola 93: 242
97	Niessouma E	IA-early	Niessouma		2ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes		round houses, 917-6	Togola 93: 242
98	Niessouma F	IA-early	Niessouma		0.5ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes		917-7	Togola 93: 242
99	Niessouma G	IA-early	Niessouma		1ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes		burnt clay structures, 917-8	Togola 93: 242
100	Niessouma H (?-917-9)	IA-early	Niessouma		0.1ha.	15°9'N/5°25'W	dry Lake/ Channel/ dunes		917-9	Togola 93: 242
101	Péhé	IA-middle			30ha.	15°2'N/5°17'W	Channel/ Floodplain		Christoforoff sondage	MacDonald 94:71; Szumowski 1957; Togola 93: 243
102	Tissilit	IA-middle			2ha.	15°31'N/5°22'W	Channel (present)/ Lake (semi dry?)		[1167-6], ?"Dianweli Ruins" on topo	Togola 93: 242
103	Toladié-A	IA-middle	Toladié		>2km; 76ha.	15°13'N/5°23'W	Irreg.dunes/channels & lakes	ADcal540-660	485+_60 in Raimbault '86, [988-1]	Raimbault&Togola 91: 82; Togola 93: 243
104	Toladié-B	IA-middle	Toladié		8ha.	15°13'N/5°23'W	Irreg.dunes/channels & lakes		[988-2]	Togola 93: 243
105	Toladié-C	IA-middle	Toladié		17ha.	15°13'N/5°23'W	Irreg.dunes/channels & lakes		[988-3]	Togola 93: 243
106	Toladié-D	IA-middle	Toladié		14ha	15°13'N/5°23'W	Irreg.dunes/channels & lakes		[988-4]	Togola 93: 243
107	Toladié-E	IA-middle	Toladié		6ha.	15°13'N/5°23'W	Irreg.dunes/channels & lakes		[988-5]	Togola 93: 243
108	Togal Famé-A	IA-late	Togal Famé		3ha.	15°19'N/5°36'W	Aeolian plain		tobacco pipes. (>AD1600), [1043-8]	Togola 93: 243
109	Togal Famé-B	IA late	Togal Famé		?	15°19'N/5°36'W	Aeolian plain		tobacco pipes (>AD1600), [1043-9]	Togola 93: 235
110	Toulé-A	IA-middle	Toulé		5ha.	15°9'N/5°34'W	Aeolian plain/ dry Lake		[921-2]	Togola 93: 236
111	Toulé-B	IA-middle	Toulé		6ha.	15°9'N/5°34'W	Aeolian plain/ dry Lake		[921-3]	Togola 93: 236
112	Toulé-C	IA-early	Toulé	habitation?	?	15°9'N/5°34'W	Aeolian plain/ dry Lake		[921-4]	Togola 93: 236
113	Toulé-D	IA-middle	Toulé		4ha.	15°9'N/5°34'W	Aeolian plain/ dry Lake		[921-5]	Togola 93: 236
114	Toulé-E	IA-middle	Toulé		12ha.	15°9'N/5°34'W	Aeolian plain/ dry Lake		[921-6]	Togola 93: 236
	Tiabel Goudiodié	LSA (Kobadi)		shellfish (aquatic; H/Fish/G)	210mx240m, 5ha.	15°4'N/5°11'W		2580-2340calBC [≥2000BC?]	stratified habitation &shell midden (3.0m depth)	MacDonald 94:72, table 5.1; Raimbault&Togola 91
	Poutchouwal Mound B	IA-middle	Poutchouwal	iron smelting	450m diam./3.1 depth	15°10'12"N/5°00'50"W		ADcal1100+80,805+115	Haaland 3 units; 30K m-2 slag heaps	Haaland 80:33-9
	Poutchouwal Mound D	IA-middle	Poutchouwal			15°10'25"N/5°10'10"W		ADcal925+95	Haaland surface test	Haaland 80:33
	Poutchouwal Mound E	IA-middle	Poutchouwal	(iron?)		15°10'25"N/5°00'40"W		ADcal1155+75	Haaland surface test	Haaland 80:33