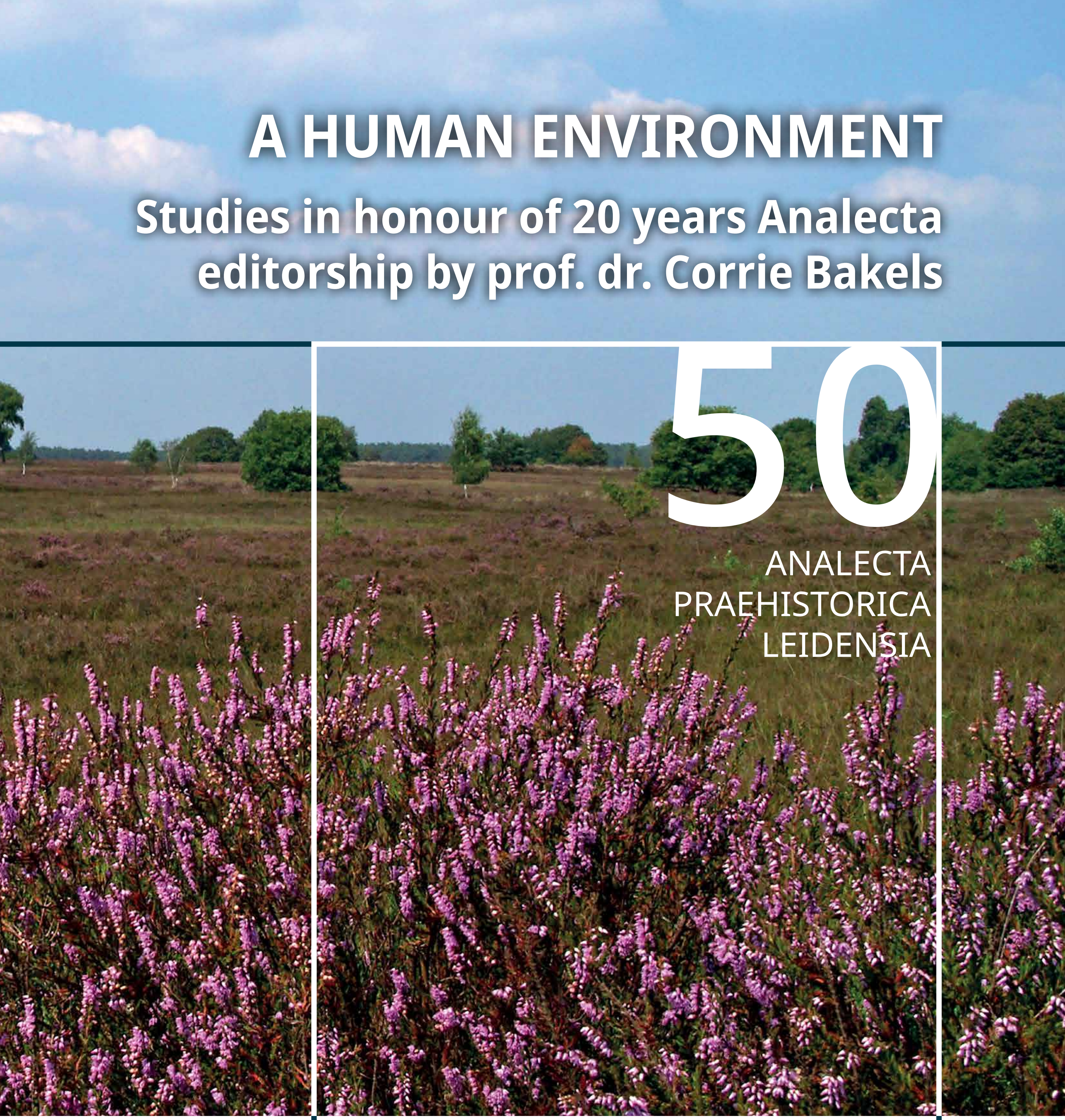

# A HUMAN ENVIRONMENT

## Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels

50

ANALECTA PRAEHISTORICA LEIDENSIA

edited by

VICTOR KLINKENBERG, ROOS VAN OOSTEN AND CAROL VAN DRIEL-MURRAY

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Our first 49 volumes. Photo: M.J. Pot.

# Editorial

This volume celebrates two defining moments in the history of our journal: the appearance of the 50th title in the series of publications devoted to research carried out by the Faculty of Archaeology of Leiden University and the retirement of Prof. Dr. Corrie Bakels, the long-term (co-)editor of the series, a stable factor in a changing team that at various points included Prof. Dr. Leendert Louwe Kooijmans and Dr. Hans Kamermans. From 1984 till 2019 she oversaw the production, checked the manuscripts and harried tardy authors unmercifully for their copy. During the last year she also initiated the transition from printed journal printed by Peeters Publishers in Louvain to digital production and open access format, published by Sidestone Press in Leiden. Whether the new editorial committee will be able to maintain the discipline Corrie's natural authority imposed on contributors remains to be seen, but we aim to continue the mixed production of themed edited volumes with monograph publications related to the research carried out in our Faculty.

To celebrate the influence Corrie Bakels has exerted on the research profile of the Faculty, the 50th volume focuses on the cultural dimensions of ecological analysis. Even though most would now reject 'environmental determinism', the natural world remains the most formative influence on human social and economic development. But as these contributions stress, people also help create the environment they respond to. Furthermore, it is the meticulous analysis of organic ecological remains that has led to the re-discovery of long-forgotten agricultural and craft practices. Locating human activity in its original setting sheds light on the choices available, and leads to further questioning of the reasons why particular resources or landscapes were, or were not, exploited.

The research articles in this book are organized in a loosely chronological order, from Palaeolithic exploitation of the natural environment to the profound effects of human presence on the flora, fauna and physical geography of Holocene landscapes. This environmental perspective of the human past unsurprisingly reinforces a notion of the human-nature relationship as reciprocal and necessary. The palaeo environment is not only a crucial context for human habitation but also forms an indispensable archive of past human interactions. The study of Human Paleoecology therefore rightfully still finds fertile ground in the institute at which Corrie Bakels finished her PhD thesis, published as APL 11, on this very subject, over forty years ago.

The contributions to this volume celebrate Corrie's wide interests in both ecology and cultural archaeology and reinforce her contention that ecological research needs to be fully integrated into every archaeological project for the full potential of both traditions to be realised. We begin with an interview in which she sets out some of the principles that have guided her throughout her distinguished career.

Victor Klinkenberg
Roos van Oosten
Carol van Driel-Murray

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# A life dedicated to science. Portrait of professor emerita Corrie Bakels, pioneer of paleoeconomy

Monique van den Dries and Harry Fokkens

## Introduction

This 50th issue of the Analecta Praehistorica Leidensia marks the end of an era, as Corrie Bakels will step down after more than 35 years as editor-in-chief for the Faculty serial, passing on her title to the next generation. The current issue will therefore be a homage to this remarkable scientist. As part of this tribute, we seek to paint a picture of the face behind the Analecta's; of an inspired editor who has been, and still is, of great importance to the archaeology and palynology of Leiden University. Corrie Bakels is an extraordinary multifaceted woman, a biologist by training who checked every biotope on our planet off her bucket list and whose portrait graces the Senate Chamber of the Leiden Academy Building. She is a scientist to the core, who describes herself as someone who likes to poke her nose into everything but always charts her own course. In every way.

It is a beautiful summer evening when we invite her for a pleasant meal in a casual homely setting, to look back on her rich and vibrant career during an almost three hour long participatory interview. We discuss how she became a pioneer in pollen analyses with only a crash course in palynology to start from, how she found her scientific niche in burnt macro remains from crop plants, and how she continues to search for and carve out new research paths. We also discuss her role as the first female professor in archaeology at the University of Leiden, and how this inspired others. We go on to talk about how her field of research is developing, and reflect on the past, present and future of the discipline, the education, the Faculty and the Analecta.

**Monique van den Dries**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
M.H.van.den.Dries@arch.leidenuniv.nl

**Harry Fokkens**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
H.Fokkens@arch.leidenuniv.nl

## From potable water conduits to an archaeobotanical nursery garden

*In the course of the past 50 years, you have seen a lot of advances occur in your field. What do you think is the most important development?*

"I started in Leiden back in the day (in 1968) under professor Modderman, as a specialist for off-site archaeology. At the time, there was nothing of the kind in Leiden. I was a biologist. My professor was Modderman's neighbor, and he told him I'd be a good fit. Modderman and I were already somewhat acquainted as I had attended his lectures in my free time and had gone along to the Linear Pottery Culture burial site dig to do the grunt work. I couldn't believe my luck! I had graduated in sewer water purification and the preparation of potable water. For my first job, I'd inspected the subterranean network of pipes in the Hague, dressed in one of those white suits. I knew all about water conduits, but was completely new to archaeology. I had to figure it all out on my own in that first year with Modderman, even the line of research I would pursue was entirely open and up to me. Nothing was handed to me. So, I started by doing an internship at the Dutch Geological Service. That's where I learned to bore and chart, in Southern Limburg and the Zak van Zuid-Beveland, as the first and only woman amongst the "coring-men", who, naturally, challenged me at every turn. After a very intensive three-week crash course in pollen analyses, under professor Van der Hammen in the biology group at Amsterdam University, I mastered the domain. What I didn't know yet at that time was how this could be used in environmental reconstructions. That knowledge came later, after the first field campaign with Modderman in Hienheim (Germany). That's where I first discovered charred plant remains from crop plants that could be determined (figure 1). In this project I envisioned how analyses of the landscape through botany and the insights it can give us on what people produced could be a compelling niche. Not a soul in Leiden was even considering this type of research at the time."

In the five decades that followed, Corrie saw her field of research grow exponentially. "We started very small with archaeobotany. At first, we were only doing research at the three Dutch universities [Leiden, the University of Amsterdam, and the University of Groningen], but nowadays we see this type of study being integrated into archaeological research everywhere. Even in contract archaeology this trend is visible, with more and more companies hiring specialists specifically for this subfield. Many of these specialists were schooled in Leiden, all people whom I trained. Leiden was thus a bit of an academic nursery garden for archaeobotany. The field has now outgrown the universities and is widely applied, it has really become established. Archaeology can no longer shun archaeobotany without losing face. Every *Programma van Eisen* [the Dutch version of a written scheme of Investigations, a requirement of an archaeological excavation, ed.] of a development-led archaeological project now contains a section on archaeobotany. I consider this a great success."

"The drawback of this development is that the field is losing some of its scientific depth here and there. Meanwhile universities are focusing less on archaeobotany. They assume it is now being covered sufficiently elsewhere. Teaching in palynology at the universities is in a bit of a slump these days and should, in my opinion, be put on the red list. The general environmental aspects are still being taught, for example at the University of Amsterdam and in Leiden, notably reconstructions of Pleistocene swamp vegetations, but the focus is much less on what humans do to their environment."

Figure 1: Corrie Bakels in 1973 in Hienheim, seeking for charred plant remains in sediments (Photo: P.J.R. Modderman).

*Is this a specific Dutch issue or a general European trend?*

"These fluctuations depend on people and their research interests. It's an ebb and flow everywhere. For instance, Leiden used to be the hotspot for Linear Pottery Culture research, but that disappeared when professor Modderman retired in the early nineteen eighties. In other countries, however, the interest in plant macro remains is only increasing, while pollen analysis remains a constant. There used to be only about 15 of us doing this type of research in the whole of Europe, now there are hundreds of specialists. And the man-woman ratio is, on average, relatively equal."

## Own course

*The archaeological sciences have been repeatedly accused of 'environmental determinism'. What is your stance in this debate?*

"Environmental determinism did reign supreme for a while, but there was also a countermovement. In my perception the pendulum swung too far over to the other side at one point, when everything became social. I have never believed in determinism, either social or environmental. I believe both are part of the truth; humans can't function without taking into account their environment, but that environment does not determine everything. Humans are always trying to manipulate their environment in a way that they think will improve it for them. This was the case for Neanderthals and continues to be the case for us today. The whole commotion and controversy around the climate crisis and the $CO_2$ debate can be understood from that perspective. Societies always try to adjust their surroundings to their advantage, and this is a constant I have observed throughout prehistory. In Mesolithic times this entailed the use of fire to increase hunting opportunities and harvest hazelnuts, but the later Neolithic crop farming and animal husbandry were of course also means of increasing control. Subsequently, people will start irrigation, fertilizing, etc. Humans never truly live completely in balance with nature. I don't think that balance exists. And things will go wrong from time to time."

"I've always chosen the middle ground in the whole nature/nurture debate, because I don't like to take a pointed public stance. I always chart my own course, and that was looked upon favourably. Hodder once said that the only person he appreciated who worked deductively rather than inductively, was Corrie Bakels."

## 'People don't like trees'

*Many societies in the past have dealt with both omni-present and rare natural resources. To what extent do you think is it possible to identify different approaches in the past to sustainable management of these resources?*

In response to this question Corrie Bakels refers to how she sees humans; as opportunists who always want to change their environment to what they want it to be. "But of course, that never fully succeeds, and people often had no concept of sustainability. If we look for instance at the depletion of copper, gold, or silver veins, people simply mined them until they were gone, often without further consideration. In the times of the Linear Pottery Culture (5300-4900 BC) we can see the onset of human deforestation. I always say, "people don't like trees", because my pollen analyses keep showing how whenever humans arrive somewhere they start felling trees. Quite soon after, you can also observe the first signs of erosion. Whether this led to the disappearance of the Linear Pottery Culture people we cannot say. They started killing each other at a certain point, but why they did that… An environmental crisis is not observable, but the use of the surroundings was never truly balanced, and therefore, not sustainable."

## Scientific grandchildren

*You have an impressively long service record. In what do you take the most pride in your own scientific career?*

"In having trained so many people, and thus contributed to the growth of the research field. Not just in the Netherlands, but internationally as well. I have had a lot of PhD students, many of which abroad. There are lists somewhere, but the exact numbers escape me. The field has in any case been well developed. In France and Spain especially, where no one used to do any analyses of crop plant macro remains, I now encounter people who have been trained by scientists whom I trained, so who are in a certain sense my scientific grandchildren. That kind of thing feels very nice."

When asked whether, in retrospect, there are things which she wished would have done differently, she answers concisely, with a resolute "NO! No, I would do it the exact same way again.".

## Cloud of fiancés

*Which of your research projects has been the most fun, content-wise?*

"I enjoy when a research project has a broad scope, concerning both topic and sources of information. I had a lot of fun doing my thesis on the Linear Pottery Culture and their environment. It concerned people, and what these pioneering farmers where doing with their surroundings. I always used a comprehensive approach for this type of research, because I'm a curious person and love poking my nose into things. I wanted to know what other specialists were doing, such as soil scientists, to see whether I could apply their knowledge. Of course, I could not master all those disciplines myself, so I engaged with people with specific specializations and asked them if they would be willing to do something for me. Nearly no one said no when I asked for something 'weird'. Most people were willing to do things for me, which was cause for much amusement among my colleagues. Those specialists were usually men, so colleagues liked to talk about 'Corrie and her cloud of fiancés'."

"What I have learned, is that you have to take the beta-approach: you have to phrase your requests concisely, ask exactly what you want and avoid asking open questions. Those are the conditions if you want to get things done. Take for instance an article I am working on right now, on the shape of plough tracks and soil use, with different types of ards and the transition to the turn plough. I need materials for this project, such as sections of the soil traces, but archaeologists seldom make sections of plough tracks. The shape of them is never analyzed. At my request, Archol [the archaeological company affiliated with the Faculty of Archaeology, ed.] recently made a large number of pictures of plough tracks, hundreds of them, and other companies are now following suit! They did exactly what I asked of them, and *that* is exactly what's so great."

## Weird lady?

*Most people think longingly of their retirement, but you still go to Faculty every day. What drives you and what do you still wish to do?*

"I still enjoy my work, but I have to admit that I am very glad to no longer have the pressure of being obliged to do things, of deadlines. As retirement approached, I found giving lectures increasingly taxing. That's something I stopped feeling the need to do."

Figure 2: Corrie Bakels at work in Oss (Zevenbergen), 2007 (Photo: A. Louwen).

"I don't have a bucket list; I just do things that appear on my path. Time and time again something will pop up and I will want to know more about it. That's when I start thinking 'how do I figure this out?'. That's science, and that's fun. That's why I have persisted past my retirement (figure 2). At the moment I am greatly enjoying modelling the deposition context of the sword of Ommerschans. There is no pollen analysis involved, for this project I am looking at the hydrology by consulting maps from the Drents Overijsselse Delta Water Management company. From these maps, I can make a 3-dimensional model of the place of offering. I'm sending that model to a hydrologist, a specialist in Zürich, to see whether my hypothesis is correct. If you contact people with this kind of kooky question you always get an immediate response, everybody loves these things. It makes them think 'who is this weird lady?'."

## Archaeology beyond entertainment

*Current societal and political trends indicate that demonstrating societal relevance is a growing aim for the Faculty, both in education and in research (the so-called 'third mission'). Do you think your specialism, (paleo-)ecology and botany, could play a crucial role in connecting the past with the present and the future? As it can elucidate the long-term impact of humanity and climate on the natural environment, it can help explain and possibly predict patterns.*

"There is indeed an increasing demand for societal relevance. Take for instance the project in Rhenen-Elst, where Staatsbosbeheer [the Dutch State Forest Service, ed.] wants to know what the environment of the Bronze Age burial mounds would have looked like at the time. They want to recreate that setting. Why they want this is their concern, but the simple fact that they want it makes it 'societally relevant'. One can ask oneself how this helps humanity, though."

"When people ask me what value archaeologists add to our world, I always say that at the very least we provide entertainment. Look at how often archaeology is featured in the news, it appeals to people, they find it interesting. Our discipline falls under 'bread and circuses'. In my opinion that also counts as 'societal relevance'."

*Don't you think we can use our knowledge of the past for the present?*

"I wonder whether our knowledge of the past is useful for the present. History never fully repeats itself."

*We can see humanity's influence on the environment though, right?*

"Of course, large events such as desertification and salinization, and the depletion of ground water tables, are clearly observable. Nobody seems to care, but we can warn about these situations. The same goes for pollution. Copper-smelting places from the Hallstatt period (12$^{th}$ to 6$^{th}$ Century BC) in Austria can be localized based on plant growth; even now, there are only a few plants which will grow on those toxic foundry locations. That's an example of an effect that persists millennia after the pollution occurred."

*Why do we rarely draw these parallels between past and present in our education system? Isn't it a shame that we aren't trained to think about the future as well?*

"It's true, perhaps we should focus on that more, that's actually not a bad idea. The big international climate club which I'm a member of PAGES (Past Global Changes), does take this kind of thing into account. I participated in research of theirs on how the sun's radiation impacts the temperature when tree-cover declines. There was also a conference I attended in Sweden on how humans don't endure under marginal circumstances. At that conference I was the odd one out; I talked about the drowned landscapes in the West-Dutch prehistory, while most contributions pertained to the 19$^{th}$ century. I demonstrated how, when you reach the point at which you no longer have technical or cultural solutions for the changing circumstances, you will succumb, or at least you will not be able to subsist any longer in that location."

*Do you think that we, as archaeologists, cannot contribute to increasing awareness of our impact on the environment?*

"You can warn people. There are a lot of calculations which you can make and show, but there will always be caveats and disclaimers."

## Running our own show

*Our own Faculty has also changed a lot during your career. What would you say is the most important development since the dawn of our (inter-)faculty?*

Without hesitation, Corrie chooses "The Fusion" [the merger of the Interfaculty of Geography and Prehistory with the archaeologists at the Faculties of Theology and the Humanities, to form an independent Faculty of Archaeology in the early nineties, ed.]. "That fusion is something I have always supported". She also contributed to it from a managerial position. "There was a lot of resistance at first, but it was a rather gradual process. We started by 'cohabiting' at the Reuvensplaats to get acquainted and used to one another. And now we have a strong, solidly founded Faculty! Another crucial step was the formation of our own *propedeuse* [first year degree of the bachelor program, in 1987, ed.]. The ministry [of Education, Culture and Science, ed.] wasn't fully on board with the idea at the time, but they did allow us to try it out for four years as a pilot. It was an enormous success and gave us a substantial head start compared to other archaeological programs."

*Things are still changing constantly. In recent years universities, including Leiden, have focused strongly on internationalization. In Leiden, this started with the master-and research master programs, and more recently the bachelor programs have been updated as well. What do you think of this development?*

"The effect is hard to gauge. We have become quite a large Faculty and must guard against an imbalance in student numbers with more students flocking to popular lecturers, as well as ensuring that the cohesion between specializations and departments is not lost. It would not be beneficial if one research field expands disproportionately, as that would create a state within a state. Perhaps we can't truly put a stop to these developments, but we must be aware of the situation. We also have to guard against becoming too diffuse by creating too many different specializations."

*Are there things you miss from the old days?*

Again, Corrie does not hesitate before answering. "The library. If only we still had that... When we surrendered our own Faculty library [some ten years ago, ed.], we did get some form of compensation from the University's executive board and requesting books from the University Library works perfectly nowadays, but I still count it as a loss. You can no longer just go in to leaf through the new arrivals. There are a lot of local, non-English journals, from countries like France and Germany, with wonderful pictures of the latest excavations that are not easily found elsewhere. I miss these greatly. It would be lovely if we could reinstate the shelf of new arrivals in the Van Steenis building [the current Faculty building, ed.]. But other than that, the facilities are good. Of course, nothing is the way it used to be in Modderman's era, we no longer have one non-scientific assistant per archaeologist, as used to be the case back then. I used to have my own analyst, Wim Kuijper, and I must say we made a great team throughout all those years. But I can't complain, it is amazing just to have everybody under one roof. At the Reuvensplaats [the previous Faculty building, ed.], the lack of space led to the establishment of dispersed annexes and things just weren't working out anymore. I love having daily lunch with our colleagues at the Van Steenis to hear about the research they are up to, and we should really cherish this proximity. Of course, we have our issues as a faculty, but they are *our* issues, and as far as I'm concerned, we will keep running our own show."

*Lecturers have a profound impact on their students, but students, in turn, also influence their teachers, perhaps more than they will ever know. Without naming names, are there students (or PhD's) that have stuck with you, and students who have influenced you?*

"YES!", Corrie responds enthusiastically, "My Spaniards! I had a profound respect for these PhD students because of their socioeconomic background. Their parents had limited means and worked hard to allow their children the opportunity to study. Their work paid off; their children now have good jobs. It is experiences like this one which ensure that you don't become an ivory tower-researcher. Your students keep you grounded."

## Star status

*A few years ago, your portrait was put up in the Senate Chamber of the Academy building (figure 3). On that wall you are surrounded by other 'stars', included in the rich history of our university. How do you feel about your portrait being there?*

"When they asked me to be part of the wall of portraits, I felt honored. I was stunned that they had picked me, I never saw it coming. I had gradually built my career and spent a lot of years at the university, but I do not see that as a merit in and of itself. Apparently, or so they told me, I had become a role model. Of course, I myself had no idea that that was the case."

*The Leiden 'club' of careerwomen in archaeology picked you as their icon some years ago. This shows the impact you have had and it is a nice symbolic nod.*

"I did find that surprising at the time. I assume it is because if you just keep going, pursuing your goals, you show others that things are possible. I have had students come up to me to tell me I had given them the confidence to pursue a career in archaeology, but even then, it never really dawned on me how I was seen. I do see it as a valuable accomplishment, yet I never consciously promoted any of this."

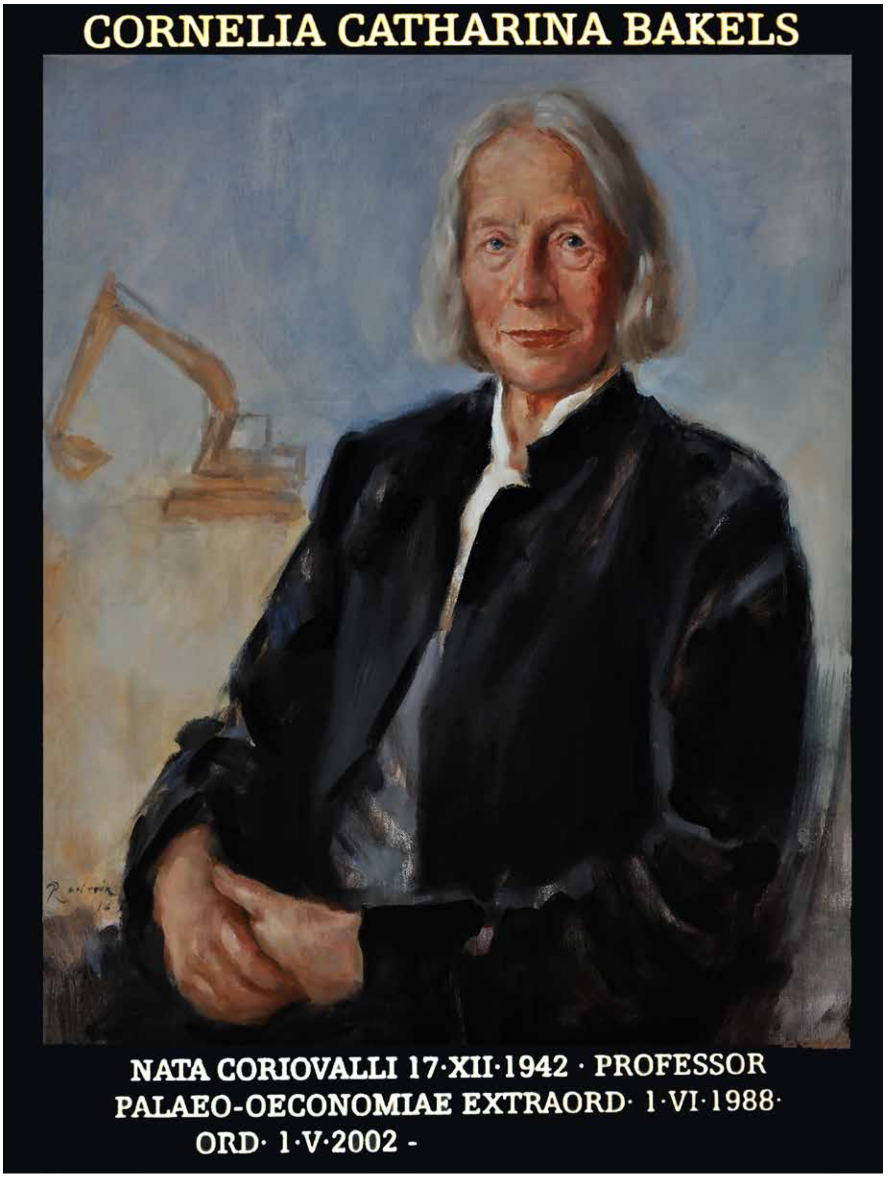


Figure 3: Corrie Bakels' portrait in the Senate Chamber of Leiden University (Portrait by R. van Schaardenburg).

*Do you feel the painting in the Senate Chamber is a nice show of appreciation?*

"Definitely! I also really like the writing underneath the portrait. It states my place of birth, in Latin, as Coriovallum. Corriovallum can be found on the Peutinger map, a Roman road map, but people don't recognize the name. Most assume that it is some exotic location in Italy, while it is simply our own Dutch Heerlen. My rather unusual lecturing topic is also included: 'paleoeconomy'. That covers the economies of the past, how people subsisted in their environment in regard to food production, finding raw materials, etcetera."

*Academia has always made it harder for women to climb up the ladder and become full professors, as compared to men. Our Faculty was and is no exception to this reality. Do you feel like you had to make more sacrifices than your male colleagues?*

"I never had to combine my career with a family or partner, so I can't speak from experience on that topic. I had the misfortune of losing three men, so

I'm not really an example on that front. Throughout those hardships it was my work that kept me going, and science remains the most stable factor in my life. If I had had a family, it might all have been more difficult, but I would never have stopped working just because my husband became a professor, as other wives of male fellow professors were prone to do." Valiantly she adds "I wouldn't even have considered it, are you crazy?!"

*These days a group of female Leiden scientists known as Athena's Angels are committed to improving women's situation in science. Their website opens as follows: "Many people assume that men and women have equal opportunities to be successful in an academic career. Yet women continue to be approached and treated differently than men, in ways that impact on their scientific career prospects.". They gathered real-life incidents to demonstrate this gap, using pointed illustrations, in a section of their website called "Angel Alerts". We can assume that this was even more of an issue in your time. Did you ever encounter this type of barrier, and if so, how did you handle this?*

"I looked at that website, it seems that some women have encountered truly strange situations. I myself also encountered some weird things, especially in my early days. At that time Leiden only had a few female professors, less than 15. Things did happen occasionally that made me think "what the…?!". But I let it pass me by. I adopted an attitude of "whatever, I'm still doing it my way". As I said, I always charted my own course. Incidentally, no one ever mistook me for the coffee lady, so apparently, I don't come across that way. In the Leiden club of professors and their – usually female-spouses, wives have asked me 'so which subject does your husband teach?'. I was also at times ignored by male professors, particularly in the meetings of the former Academic Council where I was the only woman. The chairman was a rather old-fashioned professor who couldn't abide women being scientists, so he always passed over me in the round of questions before closure of the meeting. I never let that get to me. I've never been much of a feminist; I don't like creating conflict. One way or another I will reach my goal, no matter what. So, I just thought 'Just you wait', and then the other male colleagues on the council who found it embarrassing that I was ignored joined me in finding a solution so I could have my turn anyway."

"As a professor at my Faculty, being a woman was never really an issue. I did find it challenging to deal with deans who want to push you into certain research niche or who keep you from charting your own scientific course. Of the women I know in other disciplines, most don't encounter issues, but at some faculties, things are more problematic. In some disciplines women really do have a hard time. It's usually a cultural thing, occurring in disciplines where men are also viciously competitive amongst themselves, but it must also be said that some women tend to make each other's lives harder as well."

*Looking back over the years, are there things you would have done differently when it comes to this aspect?*

Here, as well, her answer is a simple, resolute "No."

*If you could give the next generation of female scientists some advice, what would it be?*

"If you want something, go get it, keep your back straight and don't let anyone intimidate you."

## Crowbar

*Together with Hans Kamermans, you have been the editor of Analecta for many years. Throughout this time the publishing world has changed as well, especially recently with the rapid onset of digitalization, and with on-line access becoming the new standard, preferably with an open access policy. On top of all that, competition for ranking has become fierce and scientists are stuck in a rat race to publish in the top journals. All these evolutions are bound to affect the Analecta as well. What is your vision of the future of the Analecta as a 'Faculty journal'?*

"The Analecta were never meant to be a 'journal', rather they are a series for the Faculty, providing a place to publish materials -such as detailed excavation reports- that can't be published in any typical scientific journal. It also aims to provide a podium for manuscripts that don't fit in a journal because they are too local, or too much of a hybrid study. Because Analecta doesn't aspire to publish potentially prestigious articles, it isn't peer-reviewed, which means it gets an automatic B-ranking. Despite of this, the Analecta occupy a spot in the middle of the ranking of all archaeological journals, and definitely generate impact. I myself once used Analecta to publish an article that I couldn't place anywhere else, but which did end up being the crowbar that opened up NWO funding."

"The *excerpta's* we published at times in recent years have had yet another purpose; namely to showcase the scope of research being done within our Faculty. The first *excerpta* was requested by Willem Willems when he was dean, to celebrate the anniversary of the Faculty. The wide array of research topics addressed within our Faculty could never be combined in any journal but could be bundled in the Analecta."

"As regards the future: I honestly have no clue, that all depends on the policy of the new editors. I have taken myself out of the picture completely. Analecta could easily maintain its important role. It is not impossible that it could become an online series, but I think there will always be those who prefer a hard copy. The current production costs form no barrier; people always think printing is very expensive, but it truly isn't. Don't forget that open access also costs a substantial amount, something that is often overlooked. It is assumed that 'your project will cover the costs', but if you don't have external funding for your project, as is the case for me, then the Faculty will have to pay up, or not publish."

## Mission accomplished?

*We've talked a lot about work, but there has also been a private life. As colleagues we know that you travel a lot in your free time, often to less-than common destinations. The exceptional nature and landscapes were often the motivation behind your choice of destination. Of all the journeys you have made, which one would you label as being the most fascinating?*

"That is a tough question, because I have travelled to many, many, wonderful places. Even as a five-year-old, I was already hiking up the Vesuvius with my parents. That wasn't altogether odd, as my father was a mining engineer. He was drawn to mines and mountains everywhere. My mother was equally adventurous. As a young girl she became governess at the Dutch embassy, first in Athens and later in Bolivia. That is where she met my father."

Corrie mulls over her past voyages for a bit, then settles on her trip to Mauritania as being exceptionally special. "In Mauritania literally *everything* was different from here, from the lives people led to the flora and the fauna we encountered. We sailed on a body of water similar to our Dutch Waddenzee, in a flat-bottomed boat that kept getting stranded, until we gave up and rented a small local wooden boat with rather prehistoric dimensions. We ate mullet caught by the captain in the sea and grilled on a steel car rim."

With enthusiastic cheer Corrie tells us of many more memorable voyages. At one point she travelled to Namibia, just to see the *Welwitschia mirabilis* plant. "This plant is categorized as a living fossil and can only be found in the Namib desert. It can live for centuries; some specimens are even over a thousand years old."

When asked whether any destinations remain on her bucket list, she answers no. "As a biologist, I wanted to visit all of earth's biotopes, and I have completed that mission, so that finishes off my bucket list." However, this doesn't stop her from having more dreams for future travels, even if she has to lower her ambitions to accommodate physical limitations. "I would like to go to Australia, but the flight there takes too long. I have also always wanted to visit Kamchatka, which was inaccessible for the longest time. Now that it is open to the public, I can no longer make it. I enrolled for a trip to Madagascar several times, yet each time it was cancelled due to an insufficient number of participants. As an extra complicating factor, I can no longer lift heavy loads, so my suitcase can only weigh five kilos at most. And then, to find travelling companions…at my age, very few people still want to come along."

In any case, Corrie does not have to fear for a lack of scientific and social contacts at the Faculty. Students, PhD students, and colleagues still respect and perceive her as an inspiring, innovating colleague who is always willing and enthusiastic to have her brain picked on any topic. A colleague who steadily charts her own course, yet never in isolation or to the detriment of others.

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# The Middle Palaeolithic site Lingjing (Xuchang, Henan, China): preliminary new results

Thijs van Kolfschoten, Zhanyang Li, Hua Wang and Luc Doyon

**Thijs van Kolfschoten**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden, The Netherlands
T.van.Kolfschoten@arch.leidenuniv.nl
also:
Institute of Cultural Heritage
Shandong University

**Zhanyang Li**
Institute of Cultural Heritage
Shandong University
72 Binhai Highway
Qingdao, 266237
People's Republic of China
lizhanyang2622@sina.com

**Hua Wang**
Institute of Cultural Heritage
Shandong University
wanghua99@sdu.edu.cn

**Luc Doyon**
Centre National de la Recherche Scientifique
UMR 5199 PACEA
Université de Bordeaux
Pessac, Cedex, France
luc.doyon@umontreal.ca
also:
Institute of Cultural Heritage
Shandong University

*Lingjing is an open-air archaic hominin site in northern China where, apart from two incomplete human skulls, thousands of lithic artefacts as well as abundant, well-preserved mammalian remains with OSL ages ranging between ≈105 ka and ≈125 ka. It has been excavated yearly since 2005. The mammalian faunal assemblage from the site is very diverse with 22 different taxa. Equids and a large bovid* Bos primigenius *dominate the fauna; the mortality profiles of these herbivores indicate hominin/human hunting. Detailed taphonomic analyses demonstrate that Lingjing is a kill-butchery site and not a base camp.*

*The Lingjing fauna and bone tool record shows remarkable similarities with the archaeological record from the Lower Paleolithic site of Schöningen 13 II-4, Germany, i.e., the Schöningen Spear Horizon, which is ca. 200 ka older than the Lingjing site. Both sites yielded well-preserved material, a very diverse fauna and a large amount of bone tools with identical features.*

*Keywords: Stone tools, bone tools, mammalian fauna, kill-butchery site*

## 1. Introduction

In 1965, the Middle Palaeolithic site of Lingjing was discovered when microblades and microcores, as well as mammalian fossils were collected on the surface of an open-air site (Zhou 1974) and, in 2005, researchers from the Henan Provincial Institute of Cultural Relics and Archaeology started to excavate the site. The site is situated in a transitional area between the eastern foot of the Songshan Mountains and the Huang-Huai Plain, at the southern end of the North China Plain, about 120 south of the Yellow River; it is located in the western part of Lingjing town, ca. 15 km to the northwest of Xuchang, Henan Province, $34^{0}04$'N, $113^{0}41$'E (figure 1) at an elevation of 121 meters above sea level (Li *et al.* 2017a).

Since 2005, more than 550 $m^2$ were excavated; most of the area to a depth of ca. 9 meters. Eleven geological layers are identified (figure 1) (Li *et al.* 2017a) and three archaeological horizons yielded cultural remains. Layers 1-4 (Holocene in age) yielded cultural materials representing the Neolithic to the Shang-Zhou Bronze Age. Layer 5, dated to ca. 13,500 ± 406 BP, contains microblade technology, microcores, bone artefacts, perforated ostrich eggshells, ochre, faunal remains, and the first evidence of pottery appearing in the region (Li and Ma 2016; Li *et al*. 2017a; 2017b). Layers 6-9 are sterile; they do not yield stone artefacts or bone material. Layers 10 and 11 were deposited during the early Late Pleistocene. At the base of layer 10, a relatively small number of lithic artefacts, animal bones and small pebbles were

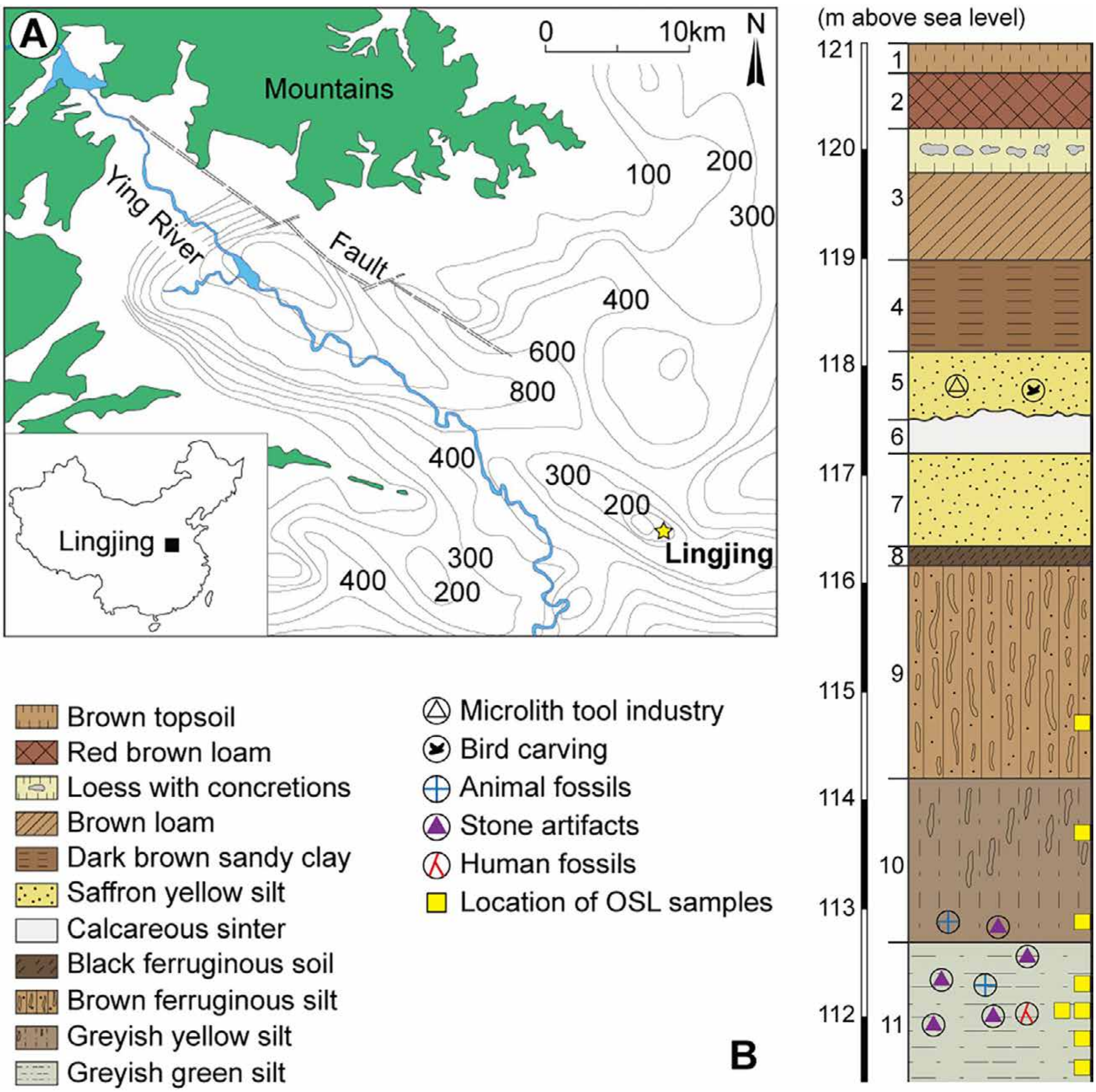


Figure 1: (a) Location of Lingjing (Henan, China); (b) Stratigraphy indicating the geological and cultural layers (after Doyon *et al*. 2018).

unearthed. Two OSL samples collected from layer 10 were dated between ~96 ± 6 ka and ~102 ± 2 ka (Nian *et al.* 2009). Layer 11 yielded so far more than 50,000 finds, the largest archaeological assemblage, and includes archaic human remains, abundant lithic artefacts and animal bones, some of which were used as tools (Li *et al.* 2017a; Doyon *et al*. 2018, 2019). OSL samples from Layer 11 are dated to between ≈105 ka and ≈125 ka, corresponding to the early Marine Isotope Stage 5 (MIS 5; MIS 5e to 5d) and the last interglacial paleosol S1 in the Loess Plateau of China (Nian *et* al. 2009; Li *et al.* 2017a).

This paper focusses on the finds from Layer 11 excavated since 2005. The faunal assemblages excavated in 2005 and 2006 were studied in detail and the results are presented in a number of publications (a.o. Li and Dong 2007; Dong and Li 2009; Wang *et al.* 2015; Zhang 2009; Zhang *et al.* 2009; 2011a; 2011b; 2012). The hominin remains were described in *Science* in 2017 (Li *et al.* 2017a). Recently, a detailed investigation of material excavated during the period 2007 – 2017 has started. The aim of the present paper is to provide an overview of the published (archaeological as well as palaeontological) data from Layer 11, and supplement it with preliminary new data obtained during the latest investigations of the faunal remains. Data that will, after detailed analyses, give a better idea about: a) the age of the archaic human remains, b) the environment in which Xuchang Man operated and c) Xuchang Man's subsistence and behaviour.

## 2. The archaeological record from Lingjing – Layer 11 and the base of Layer 10

Layers 10 and 11 (figure 2) yielded more than 50,000 finds (bones and lithic artefacts) distributed over an area of ca 550 $m^2$. Li *et al.* (2016) presented the spatial distribution of the 2014 excavations of Layer 11, which covered a 36 $m^2$ area. Refits are documented with a distance up to more than 5 meters. The vertical distribution of the finds in that specific area is about 15 cm. Li *et al.* (2018) studied the site formation process of an area of 9 $m^2$ during the 2017 excavation and spatially recorded 3894 specimens (2148 animal bones and 1746 stone artefacts) from layers 10 and 11. The vertical distribution of the finds is ca. 1 meter. Based on their analyses of the processes that might have influenced the site formation, employing sedimentary indicators, they concluded that disturbance is limited and the assemblage integrity at the Lingjing site is high, which entails that human behavioural information is well preserved (Li *et al.* 2018).

### *2.1 Human remains*

Two fragmented, incomplete human skulls (Xuchang 1 and Xuchang 2) were excavated in Layer 11, in situ between 2007 and 2014 (Li *et al.* 2017a; Trinkhaus and Wu 2017). Xuchang 1 (26 pieces) is the most complete; it retains most of the neurocranial vault and portions of the cranial base, as well as part of the left frontal bone. Xuchang 2 (16 pieces) is less complete with large part of the occipital bone and the temporal bones (see Li *et al.* 2017a). The Xuchang Man skulls derive from young adults and exhibit a mosaic of morphological features with differences from and similarities with their western contemporaries, which suggests complex dynamics between Eastern and Western Eurasian populations at the time. Given their low and broad neurocrania with the maximum breadth inferiorly, they are considered as eastern Eurasian late archaic hominins (Li *et al.* 2017a; Trinkhaus and Wu 2017). Both skulls exhibit external auditory exostoses most pronounced in Xuchang 2 implying conductive hearing loss (Trinkhaus and Wu 2017).

Figure 2: The 2011 excavation at Lingjing (Xuchang, Henan, China): Layer 11, Trench 11.

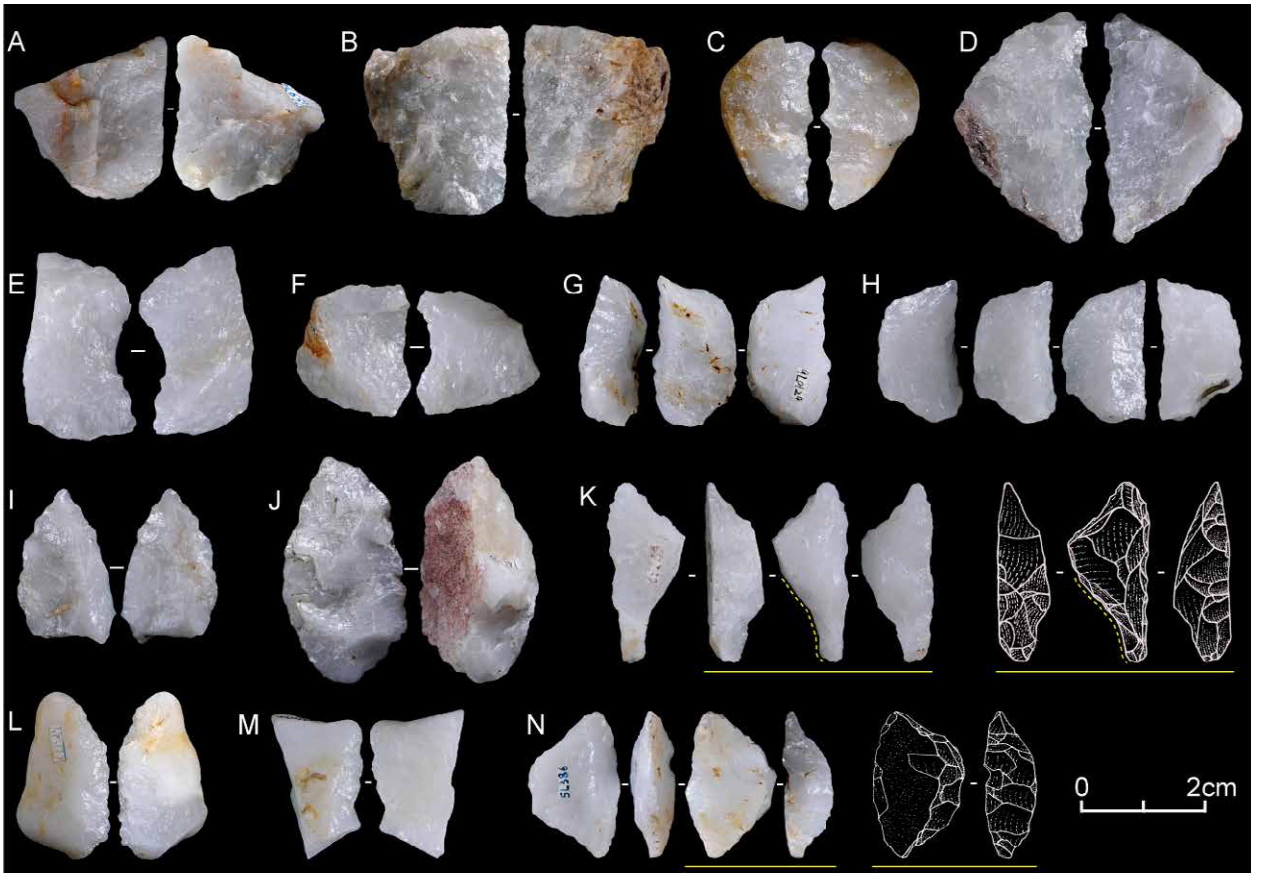


Figure 3: Formal tools at Lingjing. Examples of scrapers (a, b), denticulates (c, d), notches (e, f), borers (g, h), points (i-k), tools made on pebble blanks (l, m), and an example of a backed tool (n). Yellow underlines show specimens with drawings, dashed yellow lines indicate the likely basal retouch for hafting. (after Li *et al*. 2019).

### *2.2 Lithics*

Stone artefacts including cores, flakes, formal tools (i.e., scrapers, notches, denticulates, borers, points, choppers, etc.) made of quartz and quartzite dominate (>99%) the lithic assemblage (figure 3) (Li *et al.* 2019). Chert is marginally represented (<1%). The abundance of debitage flakes and evidence for use wear on lithic artefacts suggests that the manufacture, use, re-sharpening and discard of lithic tools occurred at the site (Doyon *et* al. 2019; Li 2007; Li *et al*. 2019). Despite the absence of Levallois debitage, discoidal core preparation akin to the penecontemporaneous Western Eurasian assemblages is documented in layer 11 which, combined with the presence of bone tools, allows its attribution to Chinese Middle Palaeolithic (Doyon *et al.* 2018; 2019; Li *et al.* 2019).

### *2.3 Animal bones*

The more than 40,000 faunal remains from the lower part of Level 10 and from Level 11 represent a variety of mammalian species (table 1). The faunal analyses of the finds excavated in 2005 and 2006 (Li and Dong 2007; Zhang 2009) resulted in an extensive list of 18 taxa; recently three “new” taxa could be added after a quick scan of the finds excavated since 2006. The carnivore guild from Lingjing is diverse. The larger carnivores *Ursus* sp., *Panthera* cf., *Tigris* and *Pachycrocuta* cf. *sinensis* are represented by cranial/dental as well as post-cranial material. Dozens of coprolites from a medium-sized carnivore, most likely a hyaena, have been recovered from the site. Wang *et al.* (2015) describe the identification of microbiological remains (parasites, fungi and hairs) preserved in the coprolites. This data provides information on the diet and health of ancient hyaena species.

| | |
|---|---|
| **Rodentia** | |
| Rodentia fam. gen. et sp. indet. 1 | x |
| Rodentia fam. gen. et sp. indet. 2 | x |
| **Lagomorpha** | |
| Lagomorpha fam. gen. et sp. indet.* | x |
| **Carnivora** | |
| *Canis* cf. *lupus** | xx |
| *Vulpes* sp.* | xx |
| *Ursus* sp. | xx |
| *Meles* sp.* | x |
| *Panthera* cf. *tigris** | xx |
| *Pachycrocuta* cf. *sinensis* | xxx |
| **Proboscidea** | |
| *Palaeoloxodon* sp. | x |
| **Perissodactyla** | |
| *Coelodonta antiquitatis* | xxxx |
| *Dicerorhinus mercki* | x |
| *Equus przewalskii* | xxx |
| *Equus hemionus* | xxxxx |
| **Artiodactyla** | |
| *Sus lydekkeri* | xxx |
| *Hydropotes pleistocenica* | x |
| *Cervus ( Sika)* sp.* | xx |
| *Cervus (E.) elaphus* | xxx |
| *Elaphurus davidianus** | x |
| *Sinomegaceros ordosianus* | x |
| *Bos primigenius* | xxxxx |
| *Procapra przewalskii* | xxx |

Table 1: List of mammalian taxa represented in the faunal assemblage from Lingjing Layer 11 and the base of Layer 10. The list is based on the faunal analyses of the finds excavated in 2005 and 2006 (Li and Dong 2007; Zhang 2009). In more recent excavations additional species, indicated with a *, are represented. x=1-5 specimen; xx=6-20 specimen; xxx=21-100 specimen; xxxx=201-500 specimen; xxxxx=more than 501 specimen.

A limited number of remains (a molar as well as tusk and bone fragments) of the elephant *Palaeoloxodon* sp. have been identified so far. The Perissodactyla are represented by four different taxa: *Coelodonta antiquitatis, Dicerorhinus mercki, Equus przewalskii* and *Equus hemionus*. The woolly rhinoceros *Coelodonta antiquitatis* remains include at least 9 different individuals (the majority juvenile). The occurrence of *Dicerorhinus mercki* is based on the identification of a single lower molar (Li and Dong 2007). The equids, together with the bovid *Bos primigenius*, dominate the faunal assemblage. Dental as well as postcranial remains of *Equus przewalskii* and *Equus hemionus* are abundant. Based on the dimensions of the fossil remains it is apparent that the majority of the equid remains correspond to the more slender Onager or Asiatic wild ass *Equus hemionus*.

The group of Artiodactyla is very diverse with eight species (*Sus lydekkeri, Hydropotes pleistocenica, Cervus (Sika)* sp., *Cervus (E.) elaphus, Elaphurus davidianus, Sinomegaceros ordosianus, Bos primigenius, Procapra przewalskii*). The aurochs *Bos primigenius* is by far the most dominant species. Hundreds of molars, horn cores as well as abundant cranial and postcranial remains have been excavated. Other taxa, e.g., the suid *Sus lydekkeri*, the red deer *Cervus (E.) elaphus* and the gazelle *Procapra przewalskii*, are also well represented but less abundant. The remaining Artiodactyla taxa are relatively rare.

## 3. Human impact

Given the mortality patterns, skeletal element profiles, and bone surface-modifications, it is obvious that humans have an important impact on the Lingjing assemblage from Layer 11 and the base of Layer 10 (Zhang *et al.* 2009; 2011a; 2011b; 2012). The fossil assemblage is dominated by bone elements from body parts with lower nutritional value, such as teeth and lower limb bones (Zhang *et al.* 2011a; 2011b). Finally, the mortality profile of the two dominant prey species, i.e., the Onager *Equus hemionus* and the Aurochs *Bos primigenius*, is almost exclusively represented by prime-adult individuals (Zhang *et al.* 2009; 2011a; 2011b), a feature that demonstrates the focussed hunting strategy of Xuchang Man.

Zhang *et al.* (2011a; 2011b) concluded based on the analyses of the 2005 and 2006 record that the Lingjing site was a kill-butchery site rather than a home base for early humans. The taphonomic and zooarchaeological characteristics of the animal remains, *i.e.* species richness, mortality patterns, skeletal element profiles, and bone surface-modifications support this conclusion. The natural component in the accumulation of the faunal material is most probably very limited.

Li *et al.* (2018) concluded, based on their studies of the formation processes of the site, that the uninterrupted vertical distribution (up to >1 m) of the remains throughout the sequence along with the large number of faunal remains representing different taxa, demonstrates that the site was occupied by humans repeatedly over a relatively long period.

Cut marks are very abundant, in particular on the upper and lower limb bones, indicating disarticulation and meat exploitation. There are no scraping marks on the bones of the 2005 and 2006 excavations, which indicates a non-intensive processing technique (Zhang *et al.* 2011a). The number of complete bones in the Lingjing assemblage is very limited. The vast majority of the bones are fragmented and the breakage pattern shows that we are dealing with green-bone fractures, which suggests the human exploitation of marrow. However, it is well-known that hyenas also have the capacity to break bones. Future analyses of the faunal assemblage, focussing on the bone breakage patterns and the occurrence of surface modifications by carnivores should clarify the role of the large carnivores in the fragmentation of the Lingjing bone assemblage.

In the Lingjing assemblage there is convincing evidence that bones and bone fragments are used as tools. Luc Doyon investigated a randomly selected sample of 4,604 bone fragments from Layer 11 and the base of Layer 10 (the 2005-2017 excavations), and he discovered 10 bone retouchers; one organic soft hammer, one active as well as one passive pressure flakers used to shape stone tools (Doyon *et al.* 2018; 2019). In addition to representing the earliest evidence for pressure flaking in the world, these tools indicate the Lingjing hominin possessed an extensive knowledge of the mechanical properties of bone materials, and knew how to take advantage of them in their knapping activities. This conclusion is further supported by a recent screening of a larger sample of the excavated bone material, which indicates that the actual number of bone retouchers in the Lingjing assemblage is much higher than originally described by Doyon *et al.* (2018; 2019). This is also supported by the more recent discovery of a large number of metapodial bone hammers. Aurochs metapodials, but also a restricted number of equid metapodials, show unusual flaking and percussion damage on the distal ends. The metapodials with flaked and rounded epiphyses are interpreted as hammers used to break marrow bones akin to those from Schöningen 13 II-4 (van Kolfschoten *et al.* 2015a).

Finally, layer 11 has also yielded two bone fragment, probably ribs of large-sized mammals, bearing each 10 and 13 sub-parallel lines. The morphology of the bone surface and of the incisions indicate that the two fragments were engraved with a sharp point on weathered bone. On one of the two, residue analyses identified the presence of hematite, which suggests the Lingjing hominin smeared ochre to highlight the engraved pattern (Li *et al.* 2019). This discovery represents the oldest known engravings and the earliest use of ochre for non-utilitarian purposes in East Asia.

## 4. Discussion and Conclusions

The Middle Palaeolithic site of Lingjing is unique not only because of the discovery of the human skulls but also for the richness of its faunal and lithic assemblages. The surface of the bones is, in most cases, very well preserved and shows a variety of anthropogenic modifications (*e.g.* cutmarks) that give insights in past hominin/human behaviours and subsistence activities.

The Lingjing site has much in common with the Lower Palaeolithic site Schöningen 13 II-4, the so-called Schöningen Spear Horizon (Germany), with an age of ca. 300 ka (van Kolfschoten 2014; Serangeli *et al.* 2015). The preservation of the material at both sites is excellent, the encountered faunas at both sites show many similarities. The faunal lists of both sites include a diverse carnivore guild, an elephant, two different rhinoceros species, two different equids, different cervids and large bovids (van Kolfschoten *et al.* 2015b). Both sites also yield a large amount of bone retouchers as well as a unique amount of bone hammers that show identical, unusual flaking and percussion damage. These similarities are remarkable if one takes into account the difference in age (ca. 200 ka) and the geographical distance of ca. 8000 km between the two. Detailed investigation of the battering damage observed at the distal ends of the metapodials from Schöningen indicated that the bone tools have not been used for the percussion of stones; stone (flint) particles are not embedded in the damaged bone cortex (van Kolfschoten *et al.* 2015a). The authors suggest that the damage reflect the use of bone hammers to extract marrow from the limb bones and the mandibles. The battering damage at the Lingjing bone hammers show almost identical features for example the lack of stone particle in the damaged bone cortex. We, therefore, assume that the Lingjing bone hammers are also used in the marrow exploitation process. We assume that the observed similarities show more or less identical, opportunistic behaviour at both sites. This, combined with the comparable taphonomic circumstances of the two sites, results in the fact that Lingjing and Schöningen have so much in common.

Most of the data published on Lingjing are based on faunal remains excavated in 2005 and 2006. The analyses of the more recently excavated finds are in progress and the combined old and new data will result in a large dataset that will surely result in making Lingjing a site of reference for Middle Palaeolithic research in East Asia. The analyses of the data will also result in detailed knowledge of human behaviours and subsistence in northern China during the earliest Late Pleistocene, a period that is linked to the dispersal of modern humans out of Africa (Bae *et al.* 2017). This makes the Lingjing site significant in the discussion of the evolutionary background of modern humans in northern China (Li *et al.* 2018).

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## References

Bae, C.J., K. Douka and M.D. Petraglia 2017. On the origin of modern humans: Asian perspectives. *Science* 358 (6368), 1269-1275.

Dong, W. and Z. Li. 2009. New Cervids (Artiodactyla, Mammalia) from the Late Pleistocene of Lingjing Site in Henan Province, China, *Acta Anthropologica Sinica* 28, 319-326.

Doyon, L., Z. Li, H. Li and F. d'Errico 2018. Discovery of circa 115,000-year-old bone retouchers at Lingjing, Henan, China, *PLOS ONE* 13, e0194318.

Doyon, L., H. Li, Z. Li, H. Wang and Q. Zhao 2019. Further Evidence of Organic Soft Hammer Percussion and Pressure Retouch from Lingjing (Xuchang, Henan, China), *Lithic Technology* 44:2, 100-117.

Li, Z. 2007. A primary study on the stone artifacts of Lingjing site excavated in 2005, *Acta Anthropologica Sinica* 26, 138-154.

Li, Z., and W. Dong. 2007. Mammalian fauna from the Lingjing Paleolithic site in Xuchang, Henan Province, *Acta Anthropologica Sinica* 26, 345-360.

Li, Z., Q.B. Zhao and Y.N. Li 2016. 2014-year excavation on the site of Xuchang Man in Lingjing [in Chinese], *Huaxia Archaeol.* 1, 3-25.

Li, Z. and H. Ma 2016. Techno-typological analysis of the microlithic assemblage at the Xuchang Man site, Lingjing, central China, *Quaternary International* 400, 120-129.

Li, Z., X. Wu, L. Zhou, W. Liu, X. Gao, X. Nian and E. Trinkhaus 2017a. Late Pleistocene archaic human crania from Xuchang, China, *Science* 355, 969-972.

Li, Z., D. Kunikita and S. Kato 2017b. Early pottery from the Lingjing site and the emergence of pottery in northern China, *Quaternary International* 441, 49-61.

Li, H., Z. Li, M.G. Lotter and K. Kuman 2018. Formation processes at the early Late Pleistocene archaic human site of Lingjing, China, *Journal of Archaeological Science* 96, 73-84.

Li, H., Z. Li, X. Gao, K. Kuman and A. Sumner 2019. Technological behavior of the early Late Pleistocene archaic humans at Lingjing (Xuchang, China), *Archaeological and Anthropological Sciences* https://doi.org/10.1007/s12520-018-0759-7.

Li, Z., L. Doyon, H. Li, Q. Wang, Z. Zhang, Q. Zhao and F. d'Errico 2019. Engravings on bone from the archaic hominin site of Lingjing 1 (Xuchang, Henan, China), *Antiquity*.

Nian, X.M., L.P. Zhou and J.T. Qin 2009. Comparisons of equivalent dose values obtained with different protocols using a lacustrine sediment sample from Xuchang, China, *Radiat Meas* 44, 512-516.

Serangeli, J., U. Böhner, T. van Kolfschoten and N.J. Conard 2015. New results from large-scale excavations in Schöningen, *Journal of Human Evolution* 89, 27-45.

Trinkaus, E. and X.-J. Wu 2017. External auditory exostoses in the Xuchang and Xujiayao human remains: Patterns and implications among eastern Eurasian Middle and Late Pleistocene crania, *PLOS ONE* 12, e0189390.

Van Kolfschoten, T. 2014. The Palaeolithic locality Schöningen (Germany): A review of the mammalian record, *Quaternary International* 326-327, 469-480.

Van Kolfschoten, T., S.A. Parfitt, J. Serangeli and S.M. Bello 2015a. Lower Paleolithic bone tools from the 'Spear Horizon' at Schöningen (Germany), *Journal of Human Evolution* 89, 226-263.

Van Kolfschoten, T., E. Buhrs and I. Verheijen 2015b. The larger mammal fauna from the Lower Paleolithic Schöningen, *Journal of Human Evolution* 89, 138-153.

Wang, W., Z. Li, G. Song, G. and Y. Wu 2015. A study of possible hyaena coprolites from the Lingjing site, Central China, *Acta Anthropologica Sinica* 34, 117-125.

Zhang, S. Q. 2009. *Taphonomic study of the faunal remains from the Lingjing Site, Xuchang, Henan Province (in Chinese),* Dissertation for the Doctoral Degree. Beijing: Institute of Vertebrate Paleontology and Paleoanthropology, the Chinese Academy of Sciences, 1—216

Zhang, S., Z. Li, Y. Zhang and X. Gao 2009. Mortality profiles of the large herbivores from Lingjing Xuchang Man Site, Henan Province and the early emergence of the modern human behaviours in East Asia, *Chin Sci Bull* 54, 3857-3863.

Zhang, S., Z. Li, Y. Zhang and X. Gao 2011a. Cultural Modifications on the Animal Bones from the Lingjing Site, Henan Province, *Acta Anthropologica Sinica* 30, 313-326.

Zhang, S, X. Gao, Y. Zhang and Z. Li 2011b. Taphonomic analysis of the Lingjing fauna and the first report of a Middle Paleolithic kill-butchery site in North China, *Chin Sci Bull* 56, 3213-3219.

Zhang, S., Z. Li, Y. Zhang and X. Gao 2012. Skeletal element distributions of the large herbivores from the Lingjing site, Henan Province, China, *Sci China Earth Sci* 55, 246-253.

Zhou, G.X. 1974. Stone age remains from Lingjing, Xuchang of Henan province [in Chinese], *Archaeol* 2, 91-108.

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# Neandertal advice for improving your tinder profile: A pilot study using experimental archaeology to test the usefulness of manganese dioxide ($MnO_2$) in Palaeolithic fire-making

Andrew C. Sorensen

*The collection of the black minerals comprised primarily of manganese dioxide ($MnO_2$) by Neandertals in France is a known archaeological phenomenon, with some of these blocks exhibiting evidence of having been abraded to produce powder. This has generally been interpreted as the production of black pigment that may have been applied to the body as a form of symbolic expression. However, Heyes and colleagues (2016) demonstrate that $MnO_2$ can reduce the auto-ignition temperature of wood by upwards of 100°C and suggest that this special pyrotechnic property of powdered $MnO_2$ may have been appreciated by Neandertals. Specifically, they suggest that the addition of $MnO_2$ to tinder materials may have aided in fire-making. The purpose of the pilot study described here is to test the utility of $MnO_2$ as a tinder enhancer during actualistic fire-making experiments. The flint-and-pyrite fire-making method was employed to produce sparks that were directed onto fluffed tinder fungus (Fomes fomentarius) with and without added $MnO_2$ to determine if and the degree to which this material improves the ability of the tinder to capture and propagate sparks into a glowing ember. The results of this pilot study lend support to the hypothesis of Heyes and colleagues by demonstrating that $MnO_2$ improves the spark capturing efficiency of tinder material over untreated tinder, thereby reducing the time and energy required to produce fire using the percussive fire-making method. However, it was also observed that the incorporation of pyrite ($FeS_2$) dust into the untreated tinder over the course of the experiments appeared to improve its ability to capture sparks, lending to the idea that pyrite powder added to tinder prior to making fire could also expedite the process and largely negates the need for collecting $MnO_2$ for this purpose.*

*Keywords: Fire-making, Neandertals, manganese dioxide, tinder, Palaeolithic, experimental archaeology*

## 1. Introduction

The ability to make fire is an exclusively human trait. Yet, the origins of fire production technology remain largely a mystery. Sporadic evidence for hominin fire use is known from at least 1.5 Mya (Berna *et al.* 2012; Gowlett and Wrangham 2013; Hlubik *et al.* 2017), with this practice appearing in the archaeological record with more frequency after around 400-300 kya with the appearance of Neandertals at the dawn of the Middle Palaeolithic (Roebroeks and Villa 2011a; Shimelmitz *et al.* 2014). It is still unclear, however, if this apparent increase in fire use is due to their

**Andrew C. Sorensen**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
a.c.sorensen@arch.leidenuniv.nl

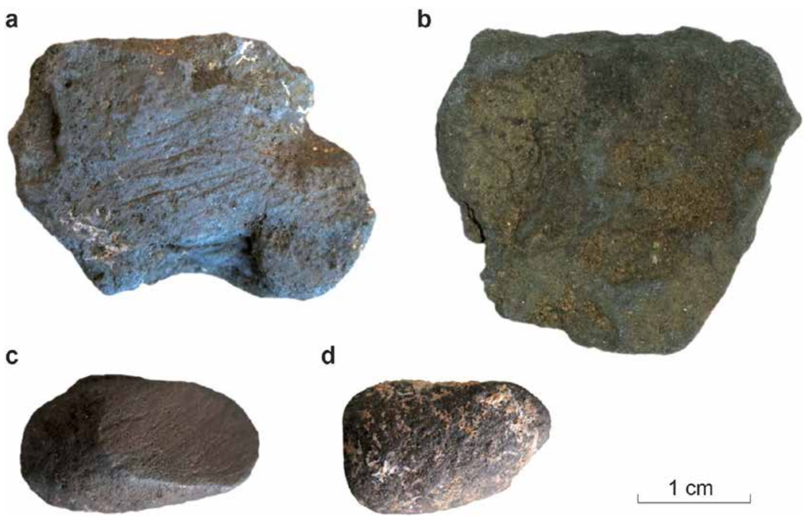


Figure 1: Examples of manganese dioxide ($MnO_2$) blocks collected from Middle Palaeolithic layers at Pech de l'Azé I (Dordogne, France). Blocks (a) and (c) exhibit evidence of grinding, while blocks (b) and (d) are unmodified. After Heyes *et al.* 2016.

having developed the ability to make fire from scratch. The tools used to perform this task – so-called flint 'strike-a-lights' used to percuss fragments of pyrite to produce sparks – do not appear until much later in the Palaeolithic, first among late Neandertals in France (Sorensen and Rots 2014; Rots 2015; Sorensen *et al.* 2018), and then among Upper Palaeolithic modern humans in Western Europe (Weiner and Floss 2004; Slimak and Plisson 2008; Sorensen *et al.* 2014). This is especially true after the Last Glacial Maximum ca. 20 kya when archaeological instances of fire-making tools, though still rare, begin to appear with more regularity (Stapert and Johansen 1999; Winiarska-Kabacińska 2009; 2010; Pyżewicz 2015; Osipowicz *et al.* 2018).

The idea that Neandertals could make fire remains contentious, with some authors arguing that they very likely possessed this capability (Roebroeks and Villa 2011b; Sorensen 2017), while others suggest fire-making rests solely in the realm of modern humans (Sandgathe *et al.* 2011a; 2011b; Dibble *et al.* 2017; 2018). Claims of direct evidence of fire-making by Neandertals in the form of dozens of Mousterian of Acheulean Tradition (or MTA) bifaces in France possessing microwear related to the production of fire have been put forward recently by Sorensen *et al.* (2018) and lend strong support to the former argument.

Prior to these findings, a novel study by Heyes *et al.* (2016) sought to test the pyrotechnic properties of manganese dioxide ($MnO_2$), a black mineral found in abundance at some late Neandertal sites in France, often exhibiting traces of having been ground into powder (figure 1). The traditional interpretation of this evidence has been that the powder was likely used as a pigment for body painting (Soressi and d'Errico 2007). Heyes *et al.* challenged this traditional interpretation on the grounds that 1) for use as black pigments, other materials (charcoal, soot) were more readily available for less search costs, and 2) through compositional analyses of the manganese blocks. Concerning this latter point, Heyes *et al.* found that adding powdered $MnO_2$ to wood turnings lowered the ignition temperature of this material by upwards of 100°C, ultimately suggesting that $MnO_2$ may have been collected by Neandertals to aid in fire-making by acting as a tinder enhancer. It remains difficult to prove definitively that Neandertals were using $MnO_2$ for this purpose, however, and further investigation is warranted.

One aspect of the Heyes *et al.* study that remains to be explored is the applicability of $MnO_2$ as a tinder enhancer under actualistic fire-making conditions. In their study, the experiments were performed under lab conditions using machined wood turnings as the tinder material, which could be considered much too coarse for use in more traditional fire-starting methods, and matches to ignite the tinder material. To add validity to their hypothesis, the utility of $MnO_2$ as a tinder enhancer should be tested using a fire-production method known to Palaeolithic peoples, specifically the stone-on-stone method (Sorensen *et al.* 2014; 2018), which can be described as follows. A piece of flint (commonly referred to as a 'strike-a-light') is brought together forcefully with a fragment of the mineral pyrite ($FeS_2$) to produce sparks. These sparks are directed onto and eventually 'captured' by a bed of generally fibrous or fluffy tinder material, producing a glowing ember that can ultimately be blown into a flame and used to start a fire. For the small pilot study presented here, a series of six fire-making experiments using hoof fungus (*Fomes fomenatarius*) as tinder were performed in order to determine if, and to what extent, the addition of $MnO_2$ to a tinder material improves its ability to capture sparks, thus expediting the fire-making process.

## 2. Materials and Methods

Fire-making experiments were performed indoors at the Leiden University Faculty of Archaeology Laboratory for Artefact Studies using a Grand-Pressigny flint crested blade strike-a-light and a halved pyrite nodule collected from the beach near Cap Gris-Nez (France), where the tip of the strike-a-light was rubbed forcefully against the broken surface of the pyrite to produce sparks (figure 2). Both elements of fire-making set were used throughout the experiments in an effort to control for possible spark production variability between different strike-a-light/pyrite combinations. Moreover, both elements had been used previously by the author to make fire, with the surface of the pyrite nodule fragment homogenously flattened and the end of the strike-a-light already rounded from use. This was done to ensure that the morphologies of these contact surfaces would be largely similar for all experiments (as opposed to, for example, using a freshly made strike-a-light tool whose end would start sharp and become increasingly dull over the course of the experiments, likely creating variability in spark production).

The sparks produced by the flint and pyrite were directed onto a bed of tinder made of finely shredded *Fomes fomentarius* (collected by the author in Skåne Province, Sweden). Colloquially known as tinder fungus or hoof fungus, *Fomes fomentarius* is a well-known tinder material that has been used by Stone Age (Stapert and Johansen 1999; Pétrequin 2015; Wierer *et al.* 2018) and modern peoples alike in temperate and boreal zones across the Northern Hemisphere (see Roussel 2005, and sources therein). The tinder was processed into a fluffy mass for the experiments by scraping the well-dried velvety *amadou* portion of the fruiting body with a flint flake (figure 3). For each of the experiments, 0.3 g of tinder was used either 'as is' (control) or thoroughly mixed with 0.1 g commercial manganese dioxide ($MnO_2$; specifically, pyrolusite) powder acquired from Sigma-Aldrich (product reference 310700). The tinder for each experiment was placed inside a 4.5 cm diameter and 2.2 cm deep ceramic bowl to control for the surface area exposed to the sparks (figure 2). The tinder was tamped down into the bowl to form a continuous and more or less uniformly thick bed (3-5 mm) to increase connectivity between the tinder fibres and ensure consistency between experiments.

The experimental program was divided into three series (A-C) of two experiments, with one experiment using tinder treated with $MnO_2$ and another using

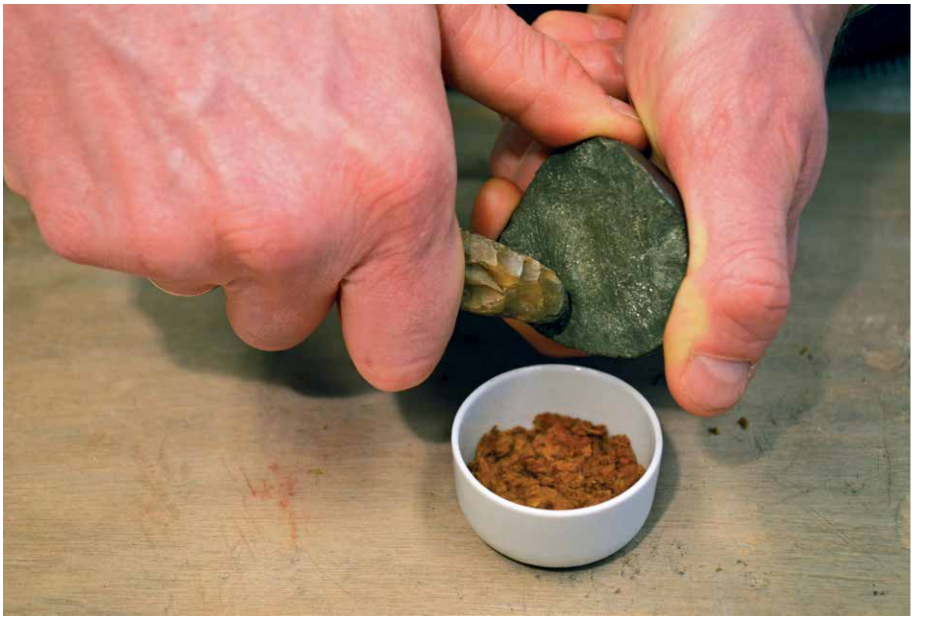

Figure 2: Materials and gesture used for fire-making experiments. The flint crested blade (right hand) was pressed firmly against the flat broken face of the halved pyrite nodule (left hand) and then forcefully pulled upwards to produce showers of sparks that fell into the small ceramic bowl containing the tinder.

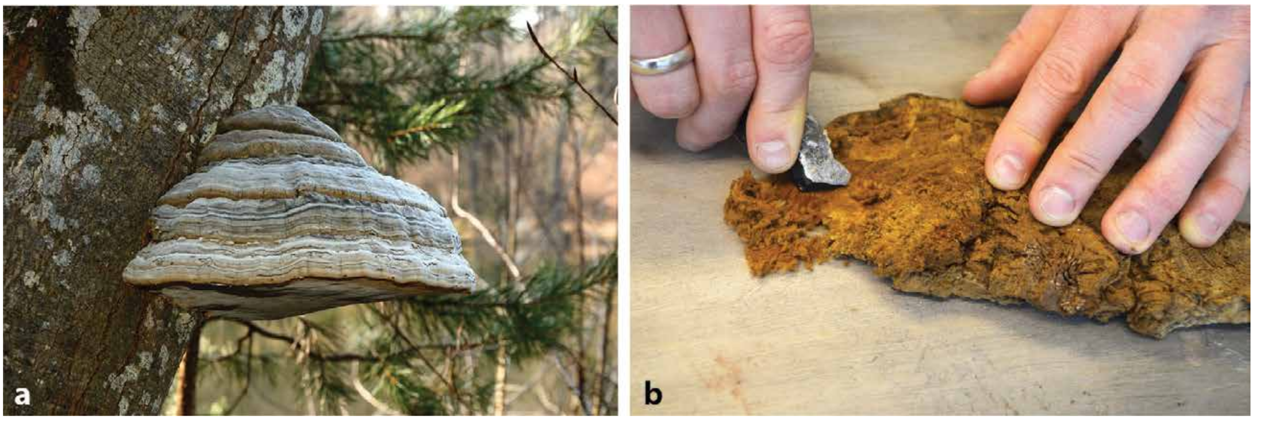

Figure 3: Photos of hoof fungus (*Fomes fomentarius*) used as tinder in the fire-making experiments, both in its natural state still adhering to a tree (a) and during processing (b), where the velvety, upper portion of the fruiting body interior (the *amadou*) was scraped into a fluffy mass using a flint flake.

untreated tinder, for a total of six experiments (1-6). Each experiment was comprised of 20 sets of five strokes (of the flint against the pyrite) that produced sparks (100 total), with the number of strokes per set in which sparks were captured recorded. The total number of strokes needed to achieve five spark-producing strokes per set was also recorded. These data were analysed and plotted using Microsoft Excel.

## 3. Results

A total of six fire-making experiments were performed for this small pilot study: Experiments 1, 3 and 5 used *F. fomentarius* tinder treated with $MnO_2$, and Experiments 2, 4 and 6 used untreated tinder (table 1). On average, it took 144.7 strokes of the flint strike-a-light against the pyrite to produce sparks 100 times (range: 131-158 total strokes).

Of these 100 spark-producing strokes for each experimental series, Experiments 1, 3 and 5 using tinder treated with $MnO_2$ achieved 40, 34 and 27 spark captures, respectively (average: 33.7). For Experiments 2, 4 and 6 using untreated tinder, 19, 6 and 17 sparks were captured, respectively (average: 14). Overall, this suggests a 140.7% increase in the rate of spark capture for tinder treated with $MnO_2$ over untreated tinder.

Each experiment was broken into 20 sets of five spark-producing strokes. Of these 20 sets, experiments using tinder treated with $MnO_2$ (1, 3 and 5) were able to capture at least one spark in 100%, 90% and 95% of the sets, respectively, while experiments using untreated tinder captured at least one spark in only 60%, 25% and 55% of the sets, respectively.

Figure 4 plots the number of sparks captured per set of five spark-producing strokes over 20 sets in order to determine if there were any changes in tinder effectiveness over time. The trendlines show that the tinder treated with $MnO_2$ had higher and relatively consistent spark-capturing capacities over the course of the fire-making experiments (*i.e.*, between 1.3 and 2.4 sparks captured per set) compared to experiments using untreated tinder. These, on the other hand, exhibit trendlines suggesting an increase in spark-capturing efficacy over the course of the experiments, with no sparks being captured early on followed by increasing numbers of sparks being captured in later sets approaching the spark-capture rates of the $MnO_2$-treated tinder (*i.e.*, between 0.7 to 2.2 sparks captured per set near the ends of the experiments).

Another way to visualize this improvement in untreated tinder over time is seen in figure 5. Here, the sets of five spark-producing strokes are combined into four groups of five sets (*i.e.*, Group 1 = Sets 1-5, Group 2 = Sets 6-10, etc.), with the bars presenting the percentage of individual sets per group having captured at least one spark. Again, we see that the ability of the $MnO_2$-treated tinder to capture sparks remains high throughout the experiments (80-100% of sets capturing sparks per grouping), while the untreated tinder captured no sparks in any of the experiments during the first five sets, but captured progressively more sparks during subsequent sets, ul-

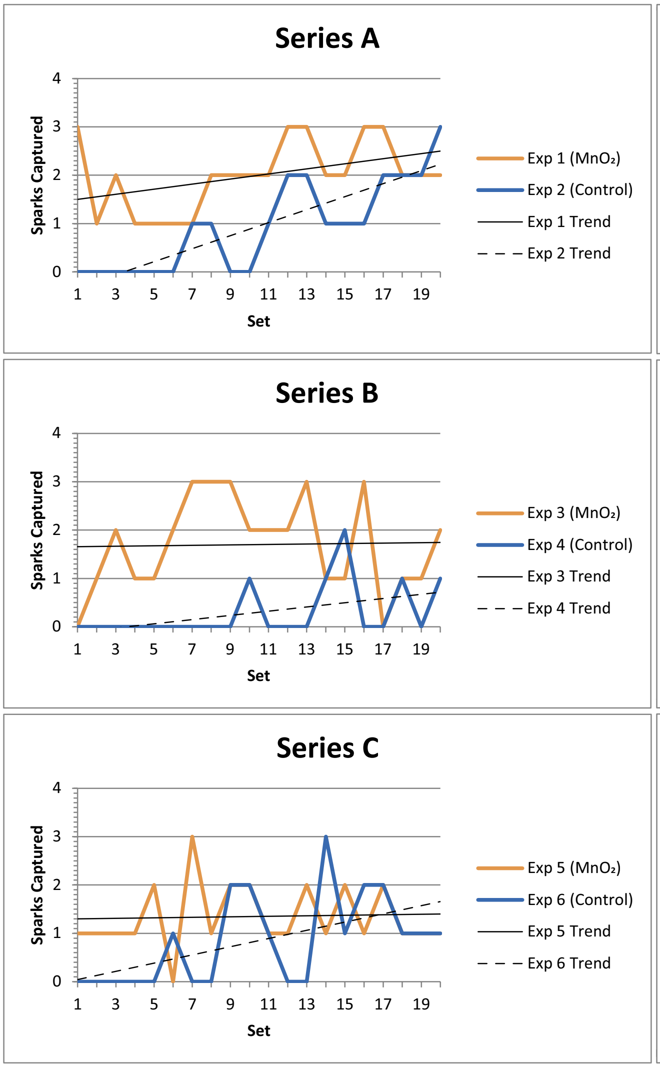


Figure 4: Line graphs plotting the number of sparks captured per set of five spark-producing strokes during fire-making experiments using tinder mixed with manganese dioxide ($MnO_2$) and untreated tinder (Control).

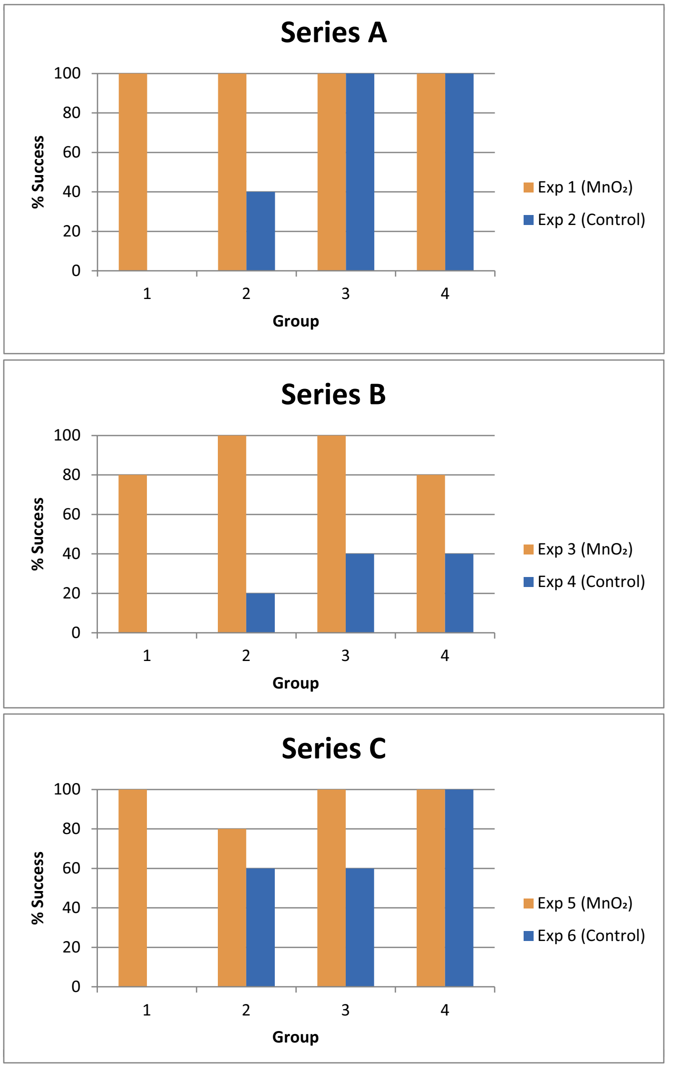


Figure 5: Bar graphs indicating the rate of spark capturing success over the course of the fire-making experiments using tinder mixed with manganese dioxide ($MnO_2$) and untreated tinder (Control). Each group is comprised of five sets of five spark-producing strokes, with the rate of success measured as the percentage of sets within a group where at least one spark was captured.

timately reaching a 100% success rate in line with the $MnO_2$-treated tinder in two of the three experimental sets (Series A and C in figure 5).

## 4. Discussion

Fire was very likely an important aspect of the day-to-day lives of Neandertals, as it is among all hunter-gatherer societies of today, and any means to improve the success rate of fire-starting events would have been viewed favourably by these peoples. Possessing the ability to produce fire when and where it was needed would have been extremely advantageous, allowing Neandertals to cook their food (Henry *et al.* 2011; Barkai *et al.* 2017), to produce tools (Wragg Sykes 2015; Kozowyk *et al.* 2017; Aranguren *et al.* 2018) and to very effectively control their environment (see Clark and Harris 1985 for an overview of the many advantages fire affords). This includes both the means to regulate their microclimate by warming up their bodies and living spaces, but also to shape the landscape to their benefit, perhaps using fire to clear areas to make way

| Material | Series | Exp. # | MnO$_2$/ Control | Set | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Group** | 1 | | | | | 2 | | | | | 3 | | | | | 4 | | | | | |
| *Fomes fomentarius* (F) | A | 1 | M | Strokes | 9 | 8 | 8 | 6 | 5 | 5 | 7 | 8 | 5 | 11 | 7 | 9 | 8 | 7 | 8 | 7 | 6 | 8 | 11 | 10 | 153 |
| | | | | Sparks | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |
| | | | | Captures | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 40 |
| | | | | % Success | 100 | | | | | 100 | | | | | 100 | | | | | 100 | | | | | 100 |
| *Fomes fomentarius* (F) | A | 2 | C | Strokes | 10 | 6 | 8 | 9 | 7 | 8 | 13 | 10 | 11 | 10 | 10 | 6 | 5 | 5 | 6 | 6 | 6 | 6 | 6 | 10 | 158 |
| | | | | Sparks | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |
| | | | | Captures | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 19 |
| | | | | % Success | 0 | | | | | 40 | | | | | 100 | | | | | 100 | | | | | 60 |
| *Fomes fomentarius* (F) | B | 3 | M | Strokes | 12 | 11 | 5 | 7 | 6 | 8 | 6 | 5 | 7 | 5 | 5 | 6 | 8 | 9 | 5 | 7 | 8 | 5 | 8 | 6 | 139 |
| | | | | Sparks | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |
| | | | | Captures | 0 | 1 | 2 | 1 | 1 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 1 | 1 | 3 | 0 | 1 | 1 | 2 | 34 |
| | | | | % Success | 80 | | | | | 100 | | | | | 100 | | | | | 80 | | | | | 90 |
| *Fomes fomentarius* (F) | B | 4 | C | Strokes | 7 | 5 | 6 | 8 | 5 | 5 | 6 | 10 | 6 | 6 | 7 | 7 | 8 | 6 | 6 | 6 | 7 | 6 | 6 | 8 | 131 |
| | | | | Sparks | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |
| | | | | Captures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 6 |
| | | | | % Success | 0 | | | | | 20 | | | | | 40 | | | | | 40 | | | | | 25 |
| *Fomes fomentarius* (F) | C | 5 | M | Strokes | 8 | 8 | 7 | 7 | 9 | 5 | 9 | 10 | 9 | 10 | 5 | 7 | 8 | 7 | 7 | 7 | 5 | 6 | 7 | 8 | 149 |
| | | | | Sparks | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |
| | | | | Captures | 1 | 1 | 1 | 1 | 2 | 0 | 3 | 1 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 27 |
| | | | | % Success | 100 | | | | | 80 | | | | | 100 | | | | | 100 | | | | | 95 |
| *Fomes fomentarius* (F) | C | 6 | C | Strokes | 6 | 7 | 6 | 8 | 8 | 9 | 6 | 6 | 6 | 6 | 6 | 8 | 6 | 8 | 7 | 6 | 7 | 7 | 9 | 6 | 138 |
| | | | | Sparks | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |
| | | | | Captures | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 3 | 1 | 2 | 2 | 1 | 1 | 1 | 17 |
| | | | | % Success | 0 | | | | | 60 | | | | | 60 | | | | | 100 | | | | | 55 |

Table 1: List of experiments performed and the resultant number of strokes, spark-producing strokes and sparks captured per set (see figure 4) and in total. The grey bars delineate the percentage of sets wherein at least one spark was captured in both groups of five sets (see figure 5) and in total for each experimental series.

for preferred plant species or to attract hunted prey species (see Scherjon *et al.* 2015 for an overview).

The three elements necessary for producing fire using the stone-on-stone method are a piece of flint (or another siliceous raw material), pyrite and tinder. If one of these is lacking, including suitable tinder, then fire-production is extremely difficult, if not impossible. The fine nature of the individual fibres comprising typical tinder materials and the high connectivity between these fibres allows for the easier capture and propagation of sparks produced during fire making. The short-lived nature and relatively low temperature of the sparks produced by pyrite (760-870°C, compared to >1200°C for sparks produced using flint and high-carbon steel; Bois 2004) often prove to be inadequate for igniting more coarse fibered, subpar tinder materials. The addition of $MnO_2$ to a tinder material appears to aid in the capture and propagation of a spark through a few different mechanisms. Heyes *et al.* (2016) has shown not only that the ignition temperature of a tinder material mixed with $MnO_2$ is lowered by around 100°C, but also that oxygen atoms released during the combustion of $MnO_2$ helped to feed the reaction. Moreover, based on observations from the current study, it appears that the powder, by filling in gaps within the tinder, increases the connectivity between the individual tinder fibres, thereby allowing an ember to more effectively propagate. This latter idea is potentially supported by the control experiment trends visible in figures 4 and 5 that appear to indicate the addition of pyrite powder during the fire-making process similarly improves the effectiveness of the untreated tinder over time. These findings suggest that, in lieu of $MnO_2$, pyrite powder could also be ground into tinder prior to making fire to increase the chances of successfully capturing a spark from the onset.

Nevertheless, the incorporation of $MnO_2$ into the Neandertal fire-making kit may have been a novel approach to improving the effectiveness of subpar tinders in environments where more suitable tinders were unavailable, or to expedite the fire-making process during the glacial climatic conditions of Marine Isotope Stage (MIS) 4 when the occurrence of $MnO_2$ in Middle Palaeolithic archaeological layers becomes more regular (Demars 1992; Heyes *et al.* 2016). Whether this was the primary purpose for collecting $MnO_2$ or simply a secondary use of a material already on hand for other reasons is difficult to say. However, the small amount of $MnO_2$ needed to improve tinder is in contrast to the high abundance of $MnO_2$ present in some Middle Palaeolithic archaeological layers, suggesting this material likely had multiple uses. Nevertheless, the co-occurrence of abraded $MnO_2$ blocks (figure 1), fireplaces and a probable fire-making tool in Layer 4 at the French Middle Palaeolithic site of Pech de l'Azé I (Soressi *et al.* 2008; Sorensen *et al.* 2018) lends strongly to the idea that fire-making was among these uses.

## 5. Conclusion

There are two primary findings of this small experimental study. First, the addition of $MnO_2$ to the *F. fomentarius* increased the effectiveness of this tinder material by 140.7% over the untreated control groups, overall, and importantly, allowed the tinder to more readily capture sparks at the onset of each series of fire-making experiments. Second, it was observed that despite the initial poor performance of the untreated control tinders, the spark capturing efficiency of these tinders increased over the course of the experiments, suggesting the gradual incorporation into the tinder of pyrite dust produced while attempting to make fire also enhanced the overall quality of the tinder. These findings largely support the conclusions of Heyes *et al.* (2016) by demonstrating the utility of adding $MnO_2$ to tinder to improve its ability to capture sparks from the onset of a fire-making episode, thus decreasing the time and effort needed to make a fire. However, the improved performance of the untreated tinder over the course of the experiments suggests that the addition of pyrite powder prior to making fire would also improve the initial performance of the tinder, making the acquisition and use of $MnO_2$ specifically for this task largely superfluous. More experiments are currently underway to determine whether or not these trends of improved fire-making efficiency hold for other natural tinders of variable quality.

## References

Aranguren, B., A. Revedin, N. Amico, F. Cavulli, G. Giachi, S. Grimaldi, N. Macchioni and F. Santaniello 2018. Wooden tools and fire technology in the early Neanderthal site of Poggetti Vecchi (Italy), *Proceedings of the National Academy of Sciences* 115, 2054-2059.

Barkai, R., J. Rosell, R. Blasco and A. Gopher 2017. Fire for a reason: Barbecue at middle Pleistocene Qesem cave, Israel, *Current Anthropology* 58, S314-S328.

Berna, F., P. Goldberg, L. Kolska Horwitz, J. Brink, S. Holt, M. Bamford and M. Chazan 2012. Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape province, South Africa, *Proceedings of the National Academy of Sciences* 109, E1215-E1220.

Bois, S. 2004. *Principe et fonctionnement d'un briquet médiéval.* Maîtrise de Physique, Lyon 1 (Université Claude Bernard).

Clark, J.D. and J.W.K. Harris 1985. Fire and its roles in early hominid lifeways, *The African Archaeological Review* 3, 3-27.

Demars, P.Y. 1992. Les colorants dans le Moustérien du Périgord. L'apport des fouilles de F. Bordes, *Bulletin de la Société préhistorique française* 47, 185-194.

Dibble, H.L., A. Abdolahzadeh, V. Aldeias, P. Goldberg, S.P. McPherron and D.M. Sandgathe 2017. How did hominins adapt to ice age Europe without fire? *Current Anthropology* 58 (S16): S278-S287.

Dibble, H.L., D. Sandgathe, P. Goldberg, S. McPherron and V. Aldeias 2018. Were Western European Neandertals Able to Make Fire? *Journal of Paleolithic Archaeology* 1, 54-79.

Gowlett, J.A.J. and R.W. Wrangham 2013. Earliest fire in Africa: towards the convergence of archaeological evidence and the cooking hypothesis, *Azania: Archaeological Research in Africa* 48, 5-30.

Henry, A.G., A.S. Brooks and D.R. Piperno 2011. Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium), *Proceedings of the National Academy of Sciences* 108, 486-491.

Heyes, P., K. Anastasakis, W. de Jong, A. van Hoesel, W. Roebroeks and M. Soressi 2016. Selection and Use of Manganese Dioxide by Neanderthals, *Scientific Reports* 6, 22159.

Hlubik, S., F. Berna, C. Feibel, D. Braun and J.W.K. Harris 2017. Researching the nature of fire at 1.5 mya on the site of FxJj20 AB, Koobi Fora, Kenya, using high-resolution spatial analysis and FTIR spectrometry, *Current Anthropology* 58, S243-S257.

Kozowyk, P.R.B., M. Soressi, D. Pomstra and G.H.J. Langejans 2017. Experimental methods for the Palaeolithic dry distillation of birch bark: implications for the origin and development of Neandertal adhesive technology, *Scientific Reports* 7, 8033.

Osipowicz, G., I. Sobkowiak-Tabaka and M. Bosiak 2018. The oldest strike-a-lights in Poland. The preliminary results of microwear and chemical analysis. In: P. Valde-Nowak, K. Sobczyk, M. Nowak and J. Źrałka (eds), *Multas Per Gentes Et Multa Per Saecula: Amici Magistro Et Collegae Suo Ioanni Christopho Kozłowski Dedicant*, Kraków (Institute of Archaeology, Jagiellonian University), 219-228.

Pétrequin, P. 2015. Pyrites et amadou. In: P. Pétrequin and A.-M. Pétrequin (eds), *Clairvaux et le "Néolithique Moyen Bourguignon"*, Besançon (Presses universitaires de Franche-Comté).

Pyżewicz, K. 2015. The use-wear analysis of the artefacts found at the Magdalenian site in Klementowice. In: T. Wiśniewski (ed), *Klementowice: a Magdalenian site in eastern Poland*, Lublin (Institute of Archaeology Maria Curie-Skłodowska University).

Roebroeks, W. and P. Villa 2011a. On the earliest evidence for habitual use of fire in Europe, *Proceedings of the National Academy of Sciences* 108, 5209-5214.

Roebroeks, W. and P. Villa 2011b. Reply to Sandgathe *et al.*: Neandertal use of fire, *Proceedings of the National Academy of Sciences* 108, E299.

Rots, V. 2015. Hafting and the interpretation of site function in the European Middle Palaeolithic. In: J. Conard and A. Delagnes (eds), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age*, Tübingen (Kerns Verlag).

Roussel, B. 2005. *La production du feu par percussion de la pierre: Préhistoire, ethnographie, expérimentation,* Montagnac: Editions Monique Mergoil.

Sandgathe, D.M., H.L. Dibble, P. Goldberg, S.P. McPherron, A. Turq, L. Niven and J. Hodgkins 2011. On the Role of Fire in Neandertal Adaptations in Western Europe: Evidence from Pech de l'Azé and Roc de Marsal, France, *PaleoAnthropology*, 216-242.

Sandgathe, D.M., H.L. Dibble, P. Goldberg, S.P. McPherron, A. Turq, L. Niven and J. Hodgkins 2011. Timing of the appearance of habitual fire use, *Proceedings of the National Academy of Sciences* 108, E298.

Scherjon, F., C. Bakels, K. MacDonald and W. Roebroeks 2015. Burning the Land: An Ethnographic Study of Off-Site Fire Use by Current and Historically Documented Foragers and Implications for the Interpretation of Past Fire Practices in the Landscape, *Current Anthropology* 56, 299-326.

Shimelmitz, R., S.L. Kuhn, A.J. Jelinek, A. Ronen, A.E. Clark and M. Weinstein-Evron 2014. 'Fire at will': The emergence of habitual fire use 350,000 years ago, *Journal of Human Evolution* 77, 196-203.

Slimak, L. and H. Plisson 2008. La sépulture paléolithique de l'enfant du Figuier (Ardèche, France). Emboîtement d'une symbolique funéraire, *Préhistoires Méditerranéennes* 14.

Sorensen, A.C., E. Claud and M. Soressi 2018. Neandertal fire-making technology inferred from microwear analysis, *Scientific Reports* 8, 10065.

Sorensen, A.C. 2017. On the relationship between climate and Neandertal fire use during the Last Glacial in south-west France, *Quaternary International* 436, 114-128.

Sorensen, A., W. Roebroeks and A.-L. van Gijn 2014. Fire production in the deep past? The expedient strike-a-light model, *Journal of Archaeological Science* 42, 476-486.

Sorensen, A.C. and V. Rots 2014. Testing the 'expedient strike-a-light model': An experimental assessment based on the first identified Middle Palaeolithic fire-maker from Bettencourt (France). Paper presented at the Union Internationale des Sciences Préhistoriques et Protohistoriques (UISPP) XVII, Burgos, 1-7 September.

Soressi, M. and F. d'Errico 2007. Pigments, gravures, parures : les comportements symboliques controversés des Néandertaliens. In: B. Vandermeersch and B. Maureille (eds), *Les Néandertaliens. Biologie et cultures*, Paris (Comité des Travaux Historiques et Scientifiques, Documents Préhistoriques 23).

Soressi, M., W. Rendu, J.-P. Texier, E. Claud, L. Daulny, F. D'errico, V. Laroulandie, B. Maureille, M. Niclot, S. Schwortz and A.-M. Tillier 2008. Pech-de-l'Azé I (Dordogne, France): nouveau regard sur un gisement moustérien de tradition acheuléenne connu depuis le XIX siècle. In: J. Jaubert, J.-G. Bordes and I. Ortega, *Les sociétés Paléolithiques d'un grand Sud-Ouest: nouveaux gisements, nouvelles méthodes, nouveaux résultats*, Paris (Société Préhistorique française).

Stapert, D. and L. Johansen 1999. Flint and pyrite: making fire in the Stone Age, *Antiquity* 73, 765-777.

Weiner, J. and H. Floss 2004. Eine Schwefelkiesknolle aus dem Aurignacien vom Vogelherd, Baden-Württemberg- Zu den Anfängen der Feuererzeugung im europäischen Paläolithikum, *Archäologische Informationen* 27, 59-78.

Wierer, U., S. Arrighi, S. Bertola, G. Kaufmann, B. Baumgarten, A. Pedrotti, P. Pernter and J. Pelegrin 2018. The Iceman's lithic toolkit: Raw material, technology, typology and use, *PLoS ONE* 13, e0198292.

Winiarska-Kabacińska, M. 2009. Analiza funkcjonalna materiałów krzemiennych ze stanowiska 2 w Cichmianie (Aut 441). In: J. Kabaciński and I. Sobkowiak-Tabaka (eds), *Późny paleolit i mezolit basenu środkowej Warty*, Poznań (Instytut Archeologii i Etnologii PAN).

Winiarska-Kabacińska, M. 2010. Analiza traseologiezna. In: J. Kabacinski, I. Sobkowiak-Tabaka and M. Jordeczka (eds), *Materialy do wczesnych pradziejow Zachodniej Wielkopolski. Osadnictwo poznopaleolityczne i mezolityczne na stanowisku 7 w Osnie Lubuskim*, Poznań (Instytut Archeologii i Etnologii PAN).

Wragg Sykes, R.M. 2015. To see a world in a hafted tool: birch pitch composite technology, cognition and memory in Neanderthals. In: F. Coward, R. Hosfield, M. Pope and F. Wenban-Smith (eds), *Settlement, Society and Cognition in Human Evolution: Landscapes in the Mind*, Cambridge (Cambridge University Press).

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 39-48.

# Landscape dynamics near the late Middle Palaeolithic and Early Upper Palaeolithic cave site of Les Cottés (France)

Joanne Mol, Lars den Boef and Marie Soressi

*The cave site Les Cottés (Central France), famous for its occupation by both Neanderthal and anatomically modern humans and its Les Cottés Interstadial, is located in the steep side of the incised Gartempe River valley at about 5.5 m above the present floodplain. So far, little is known about the landscape at the time of occupation, about 48-37 ka. The erosional nature of this type of fluvial landscape complicates such a research – when no traces are left, it is difficult to assess how such a landscape looked like.*

*We were able to study the present floodplain through a series of hand cores. A coring transect stretching from the front of the cave towards the present river course showed that the flood deposits covered an older terrace remnant and an abandoned channel, just in front of the cave. The channel fill of this palaeochannel contained a thin layer of peat at the base that has been studied by means of pollen analysis. It pointed to an open landscape, dominated by Pinus, Betula and Artemisia. Two additional radiocarbon dates dated the channel fill to 11,286-11,094 yrs cal BC and 11,140-10,849 yrs cal BC, respectively, which fits with the results of the pollen analysis. It showed that the channel became inactive in the Weichselian Lateglacial, leading to a minimum age of Weichselian Pleniglacial for the underlying terrace, which postdates the time of occupation of the cave site.*

*Another important discovery was the presence of a terrace remnant, covered by flood and slope deposits, in between the site and the underlying floodplain. This terrace could not be dated, but it is likely that this terrace already existed as an inactive terrace at the time of occupation, since the height of this terrace is only 5 m lower than the cave site, in which no flood deposits have been found. We therefore conclude that the terrace located in the subsurface of the present floodplain probably represents the active river at the time of occupation, when the site was located 5 m above a small plateau that was still flooded regularly, and 7.5 m above the active river.*

*The study has shown that the Gartempe River valley underwent considerable changes during the Last Glacial. The small terrace remnant in front of the cave site is part of a former floodplain that was eroded. This erosion likely occurred during the time of occupation, as well, and shows that the river was much more active then than it is nowadays.*

*Keywords: Late Pleistocene, Weichselian Lateglacial, palaeoenvironment, fluvial dynamics, terrace sequence, France*

**Joanne Mol**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
j.a.mol@arch.leidenuniv.nl

**Lars den Boef**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
l.den.boef@umail.leidenuniv.nl

**Marie Soressi**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
m.a.soressi@arch.leidenuniv.nl

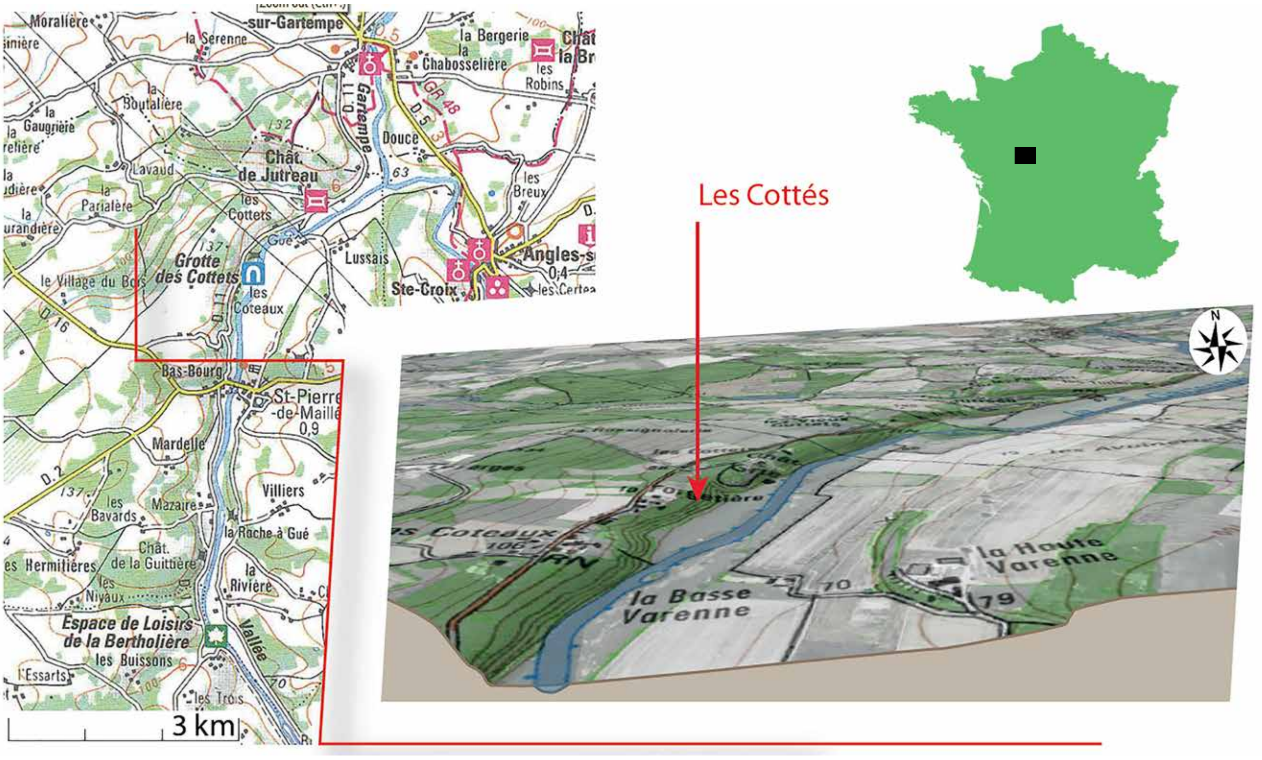


Figure 1: Location of Les Cottés and profile of the valley. Data derived from www.geoportail.gouv.fr.

## 1. Introduction

The French cave site of Les Cottés (Vienne) is a one of the rare recently excavated sites that has been occupied by both Neanderthals and early anatomically modern humans (Soressi *et al.* 2010). It is the location where the Les Cottés Interstadial, one of the many climatic events happening during Marine Isotope Stage (MIS) 3, defined based on pollen analysis (Bastin *et al.* 1976). Its archaeological deposits were originally discovered at the end of the nineteenth century. The archaeological sequence is 1.5-4 m thick and comprises five main archaeological layers attributed to the final Middle Paleolithic and the Early Upper Paleolithic (Roussel and Soressi 2013). Radiometric dating has shown the archaeological sequence to be at least 48-37,000 years old (Jacobs *et al.* 2016; Talamo *et al.* 2012).

The site is located on a steep slope of the incised valley of the Gartempe River (figure 1), a tributary of the larger Creuse River. The site location choice is clearly connected to the presence of the river; it has been in use as a resource area for quartz, as shown by the presence of fluvial gravel in the finds layers. The site is located at 5 m above the present river valley floor. The present geomorphology shows an extensive floodplain in front of the site that is still flooded regularly. Older terraces appear to be absent. So far, it is unclear how the landscape looked like during the time of occupation. In an erosional landscape, as is the case at Les Cottés, it is difficult to obtain this type of data, because much information is missing. Some information may be inferred from the deposits that have been preserved.

In this study, we intend to shed some light on the chronology of the landscape dynamics around this important site. The research concentrated on the sedimentary composition of the floodplain, since a similar campaign in the Vézère River valley revealed the presence of a series of terraces covered by a thick layer of overbank deposits. The top of the fluvial deposits that formed the terraces were sandy in nature, which allowed luminescence dating. It pointed to the existence of two different terrace levels that were both dated to the Last Glacial. It showed that a similar erosional landscape had preserved traces that allowed us to extract palaeoenvironmental data (Mol *et al.* 2004; Roebroeks *et al*. 2009).

In 2015, some trial cores in the floodplain of the Gartempe indicated that it was possible to sample the fluvial deposits up to several meters: the top consisted of loams, with some occasional fluvial gravel (rounded) and angular limestone fragments. This paper shows the results of a coring campaign in the Gartempe River valley and additional pollen analysis and dating of a peat layer that was recovered during the fieldwork. The initial results have been described earlier in the excavation report of Les Cottés (Roussel *et al.* 2017) and in an (unpublished) bachelor thesis (Den Boef 2017). In this research, we have combined the results and present two additional radiocarbon dates.

During the fieldwork, a small platform of about 10 m wide was discovered between the floodplain and the cave site. It was covered by excavation and slope debris from earlier excavations and was fully overgrown by trees. This plateau had a natural origin, since it was clearly separated from the present floodplain by an escarpment with a height difference of almost 2 m, and its age is therefore older that the present floodplain. It was believed to be a terrace remnant of an earlier fluvial stage that may be related to the time of occupation, but this assumption needed evidence.

## 2. Sedimentary sequence of the river valley

### *2.1 Methods*

Geomorphologically, the cave site Les Cottés is located in the steep terrace scarp of the entrenched Gartempe River valley. The river has incised into a limestone plateau and created a narrow river valley in which clear terraces appear to be absent. The present river flows in an extensive floodplain that is still flooded regularly. The top of this floodplain is located at a height of c. 5 m below the cave site. It is currently in use as pastureland, allowing us to easily sample the fluvial deposits.

In July 2016, a geological coring transect was laid out from just below the cave towards the present river channel (figure 2). The cores were made using a 7 cm Edelman hand auger and a 3 cm gouge for the fine-grained deposits below the water table. A core was abandoned when the gouge hit impenetrable coarse gravel and rock fragments. The top of these coarser units could be usually be sampled, facilitating the interpretation of these units. The transect is shown in Figure 3. The cave site is shown schematically, allowing us to compare its height to the height of the deposits studied.

### *2.2 Results: The lithostratigraphic units*

The cores were made every 10 m, and their locations are shown by arrows in the transect (figure 3). The maximum depth reached was almost 4 m below the surface (core 14). In most cases, the transect shows the maximum depth reached. Only the core nearest to the cave entrance, number 12, did not sample the entire unit. The lower boundary has been extrapolated, which is shown by a dotted line. This extrapolation will be discussed below in more detail below.

The cave site is shown schematically to show the different elevation levels identified in relation to the site. The deposits have been subdivided into nine lithostratigraphic units, of which the interpretations are shown in the legend.

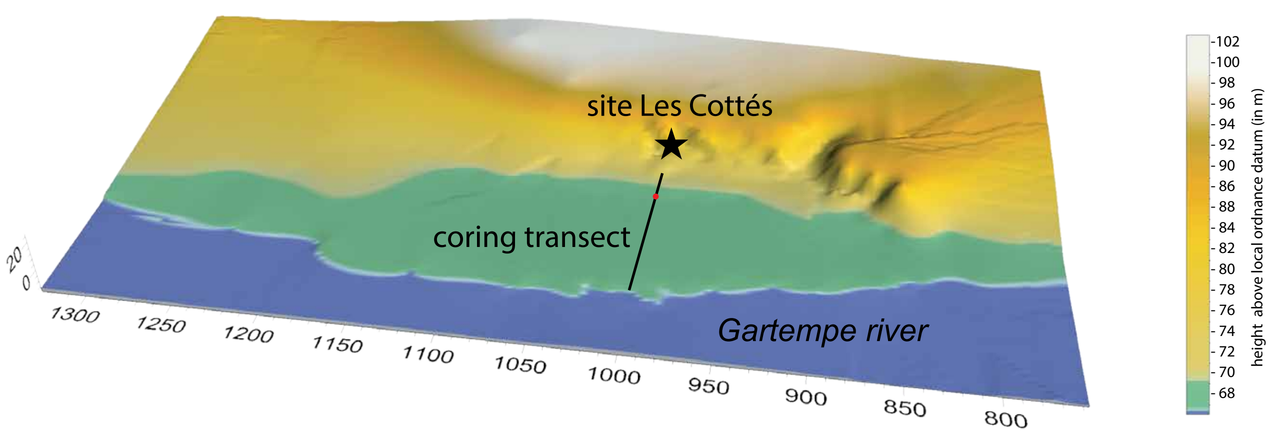


Figure 2: Location of the transect in relation to the river and the site, shown on a shaded relief map. The coordinates refer to the local coordinates used in the excavation.

The majority of the cores sampled the deposits in the present floodplain (n = 9). Ten different litho-stratigraphic units have been distinguished and are described below in table 1 from old to young.

Unit 1 represents the bedrock of the plateau into which the river incised. It consists of white (Jurassic) limestone, of which small (1 cm) to sometimes very large, angular fragments (5 cm) were frequently

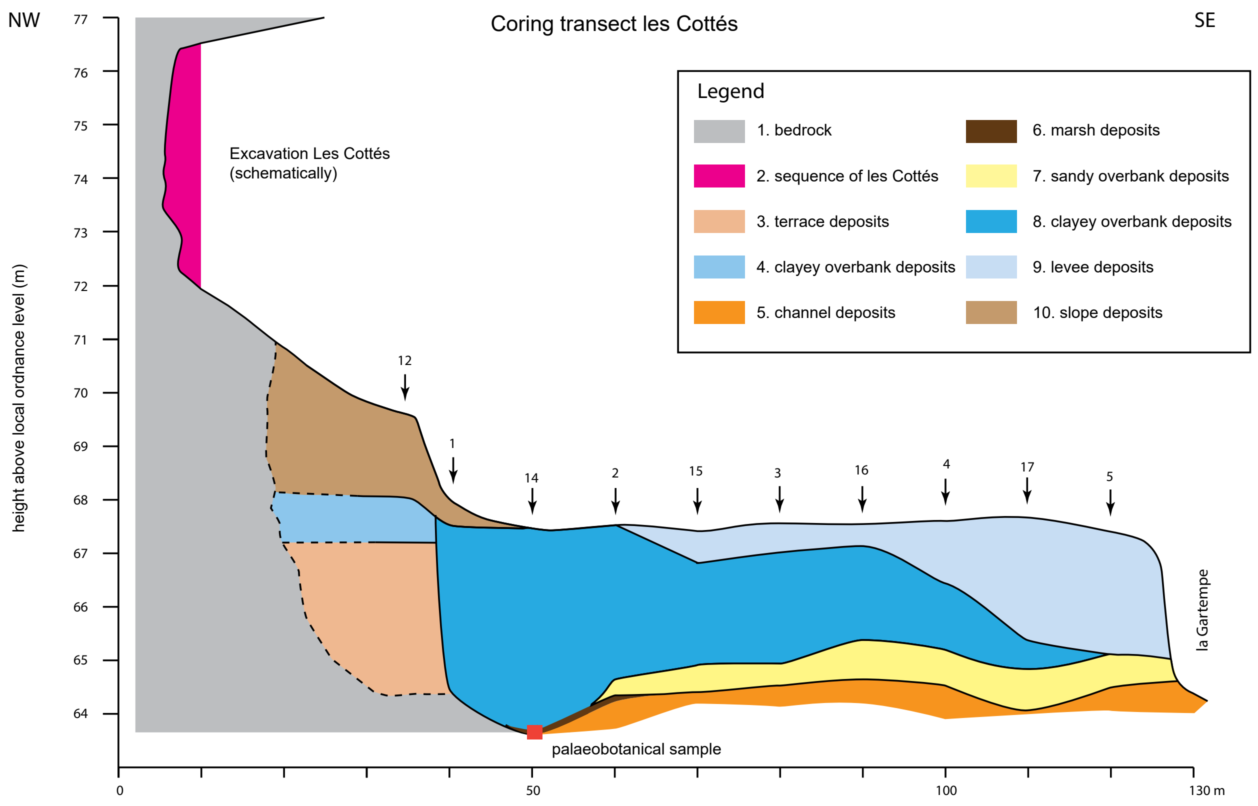


Figure 3: The coring transect, in front of the Palaeolithic site Les Cottès.

| unit | composition | interpretation |
|---|---|---|
| 1 | Limestone | Jurassic bedrock |
| 2 | Angular fragments of limestone, containing bone and flint | Scree slope deposits, archaeological levels |
| 3 | Gravelly coarse sand, mainly containing quartz, slightly clayey | Fluvial channel deposits |
| 4 | Very firm clay loam | Overbank deposits |
| 5 | Slightly silty, slightly gravelly sand with gravel up to 2 cm | Fluvial channel deposits |
| 6 | Clayey peat | Marsh |
| 7 | Coarse- to fine-grained sand, alternating with clay layers and organic detritus | Sandy overbank deposits |
| 8 | Humic clay loam, containing angular limestone fragments and rounded quartz pebbles up to 2 cm | Clayey overbank deposits |
| 9 | Sandy loam to silty sand with some local clayey intervals | Levee deposits |
| 10 | Very firm, humic silty clay with angular limestone fragments up to several dm | Slope deposits: colluvium |

Table 1: Descriptions of the lithostratigraphic units identified in the transect.

encountered in the cores. In core 1, we could not penetrate as deeply as the other cores, because of an obstruction, either a very large boulder of limestone, or perhaps the bedrock itself.

Unit 2 represents the archaeological sequence of Les Cottés, shown in the transect to allow us to compare the heights of the archaeological units with the units sampled in the cores. The excavated layers consist mainly of scree slope deposits; fluvial deposits have not been found in the excavations. This sequence is not described here, since it has already been intensively excavated and described by the team of Soressi (Soressi *et al*. 2010).

Units 3 and 4 were encountered in core 12 only. This core is located on the small platform in between the cave and the floodplain. These units represent the deposits that form the plateau.

Unit 3 is composed of gravelly coarse sand containing many quartz grains. It also contained some clay that is believed to have infiltrated from the overlying clayey layer (unit 4). The top of these deposits is located at an elevation of c. 67.2 m. The unit is interpreted as fluvial (channel) deposits, representing deposition in an active river channel. The presence of quartz sand at this height clearly proves that the small plateau is a terrace remnant and is older than the present floodplain. Sampling these deposits proved to be extremely difficult due to the vast amount of rocky slope fragments at the surface and the firmness of the overlying loam. Therefore, we were only able to sample this unit once.

In the transect, these units have been extrapolated to the valley side and to a much deeper depth than we have sampled, to illustrate our interpretation of the sedimentary sequence. We have sampled only 25 cm of these channel deposits, but they were indisputably fluvial in origin, as evidenced by the rounded quartz grains. The exaggerated thickness exemplifies the origin of the plateau, a terrace remnant, which is very important new evidence. The boundary with the underlying bedrock is based on data obtained in core 1, where we assumed that we reached the bedrock.

Unit 4 overlies the terrace remnant of unit 3. It consists of very firm clay loam that is interpreted as overbank deposit. It does not contain any lime, in contrast to the clay loam that was sampled on the floodplain. Given its height, this clay loam may still be young in age, but given its other characteristics, its firm appearance and lack of lime and limestone fragments, it clearly differs from the lower clay loam deposits (unit 8) located in the present floodplain. Therefore, it is believed that this deposit represents an older flooding phase. These loamy deposits have been sieved to look for any datable material, but regrettably, nothing was found. The clay loam was also sampled to check if it contained any pollen, but similarly, no pollen was preserved. Unit 4 is overlain by unit 10, which is described last.

The younger units have all been sampled in the floodplain. Unit 5 is the lowermost unit and composed of slightly silty gravelly sand containing gravel up to 2 cm. It is located below the water table, at a depth of about 3 m below the surface. It was usually not preserved in the gouge (or only a few quartz grains that were left), because of the high water table: all deposits that do not contain much loam (or clay) will not stay in the gouges that were used. Unit 5 is interpreted as channel deposits, representing the active river.

The relationship between these channel deposits and the channel deposits of unit 3 can be established by comparing the height of the deposits. The tops of both units are covered by loams, indicating that no erosion occurred: the tops of these units represent the maximum height of the channel deposits (point bar and lag deposits). The top of unit 5 is located at an elevation of c. 64.7 m, almost 2.5 m lower than unit 3. Based on this height difference, it can be concluded that these depositional events are separated by an incision phase, which resulted in the formation of a new floodplain with new channel deposits located at a lower elevation. Hence, it shows that unit 5 represents a younger fluvial phase: unit 5 is clearly younger than unit 3.

Another remarkable feature is the variation in height of the top of this unit. As shown in the transect, the top of the unit decreases in height towards the valley side; unit 5 is almost 1 m deeper in core 14 than in the other cores. It points to the presence of a natural depression in the landscape and is believed to represent a residual channel.

Unit 6 was encountered in cores 14 and 2, just near the terrace scarp, and is located directly on top of unit 5. It is composed of a maximally 10 cm thick layer of slightly clayey peat. The unit is located at the base of the residual channel, pointing to marshy, stagnant water conditions after the abandonment of the channel. The clay shows that the floodplain was still flooded irregularly, resulting in clay deposition in a vegetated, marshy depression.

Unit 7 overlies unit 5 in all cores (2-15-3-16-17-5), except for the part where the residual channel is located. It has a sandy character, similar to unit 5, but this sand shows more variety. It ranges from very coarse to fine-grained and is intercalated with clay layers and detritus. The presence of clay layers show that this deposit is unlikely to have been deposited within an active channel; therefore, the unit has been interpreted as sandy overbank deposits, probably related to the fluvial system that deposited unit 5.

Unit 8 is located on top of unit 6 and consists of slightly humic clay loam that often contains limestone fragments and (rounded) quartz pebbles. It has been interpreted as clayey overbank deposits that have formed the present floodplain.

Unit 9 overlies unit 8 locally and replaces it near the present river. It is composed of sandy loam to silty sand with some local clayey intervals. It has been interpreted as sandy overbank deposits, that, given the location, can be interpreted as levee deposits. Units 8 and 9 together have formed the present floodplain, of which the levee has developed next to the present channel course, and the finer-grained overbank deposits have silted up the more distal parts of the floodplain. Both units have gradually covered the underlying landscape during irregular flooding events.

The final unit is unit 10. It consists of very firm, humic silty clay that contains many angular limestone fragments in all sizes and does not contain rounded pebbles. This unit is located on a slope and overlies units 8 and 10 in the northwestern part of the transect (cores 12 and 1), covering both the plateau and the present floodplain near the scarp. It has been interpreted as slope deposits and likely formed as a result of slope processes, such as surface creep, that remains active today. Regrettably, it obscures much of any older terrace remnants. After several attempts, we could core through this unit and could show that the older platform in front of the site was covered by at least 160 cm of this rocky, firm clay. Its firmness and the presence of large clasts – sometimes too large to bypass using the hand auger – made sampling of the underlying deposits extremely difficult.

### *2.3 Fluvial development of the Gartempe*

The present fluvial activity appears to be very low, with mainly overbank deposition during flooding events. During floods, sand is deposited on the levees near the present channel and clay loam further away. The coring campaign demonstrated the presence of terrace remnants consisting of older channel deposits located at two different levels. The deposits of the present floodplain overlie an older fluvial landscape comprised of floodplain deposits and associated channel deposits. These older deposits appear to reflect an older, more active, fluvial phase, of which a palaeochannel near the valley side represents its final phase.

Only one core proved the presence of a small terrace remnant at a higher level that is separated from present floodplain by an erosional scarp and is, therefore, older than the present floodplain. It is also older than the terrace underlying the present floodplain, since its top is located 2.5 m higher. These terrace levels reflect the level of deposition by the (active) channel; individual flooding events will likely have reached much higher levels.

The age of the deposits is difficult to establish without any chronological data. The present floodplain still experiences deposition and is therefore probably relatively young. The clayey overbank deposits on top of the highest terrace, though, may be older. These deposits have been covered by slope deposits, and their characteristics differ from the flood deposits on the present floodplain. They may very well be deposited by the river system that now forms the lower, buried terrace, similar to the more sandy unit 7, but that relationship could not be established. Perhaps luminescence dating on the fluvial sandy deposits could help to answer this question in a future campaign.

The basal infill of the residual channel near the terrace scarp is peat and allowed for palynological investigation and radiocarbon dating. These enabled us to put the relative chronology into a chronostratigraphic framework. Their results are described below.

## 3. Environmental evidence

The coring campaign showed the existence of sediments that represented older phases of fluvial activity. Acquisition of this information was one of the key aims of the field campaign. For correlation with the site, however, we also needed chronological information. The discovery of a fossil channel in front of the site, which contained peat at its base, was therefore very useful. The deepest part of the channel fill was located at 385 cm below the surface (63.5 masl) and contained a clayey peat layer of 10 cm thick at its base (unit 6). This peat was sampled for pollen analysis and radiocarbon dating, allowing us to assess the environment at the time of the peat formation, and to provide a biostratigraphic correlation. Three samples were taken for pollen analysis: at the base, in the middle and at the top.

### *3.1 Preparation of the pollen samples*

The sample treatment followed standard methods (Moore and Webb 1978, 23). *Lycopodium* pollen grains were added to samples of 2 $cm^3$, mainly to test for

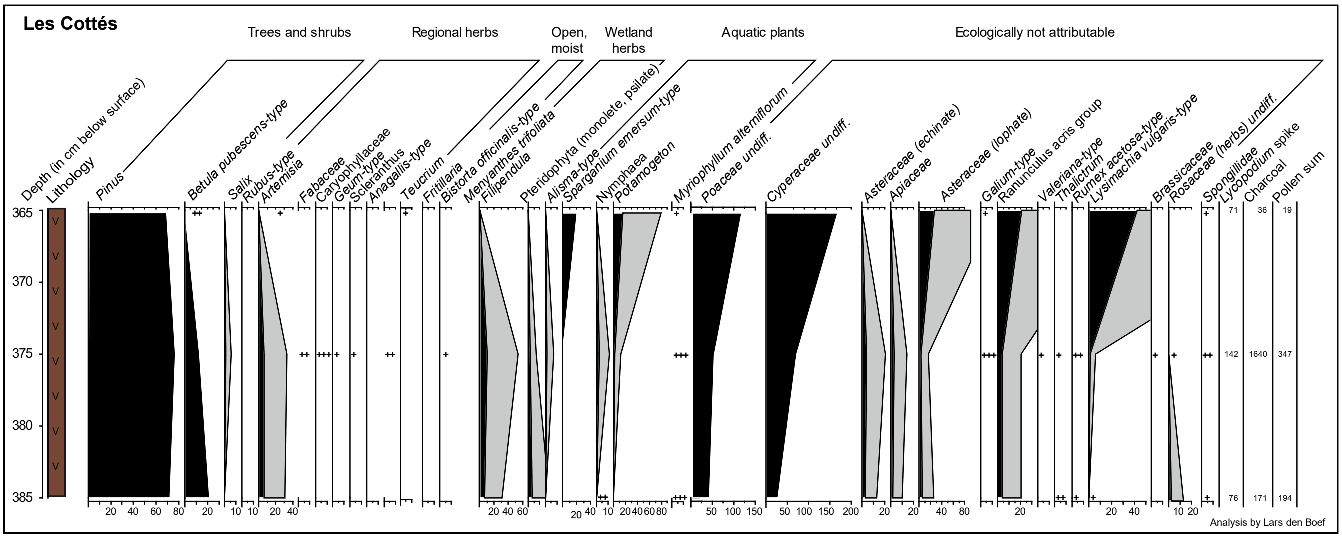


Figure 4: Percentage diagram of the channel fill of the lower terrace in front of Les Cottés (core 14, 365-385 cm below surface, 63.5-63.3 m above sea level. The percentages are based on a terrestrial pollen sum only including the trees, shrubs and regional herbs. The name of the taxa are based on Beug (2004). Percentages exaggerated 5x are shown in grey. Rare taxa are shown in absolute numbers, indicated with +. The basal part dated to 11,100 ± 50 yrs BP (GrM 12581) ) (11,140-10,849 yrs cal BC)., the top dated to 11,260 ± 65 years BP (GrM 12700) (11,286-11,094 yrs cal BC). The calibrations were performed in Oxcal, version 4.3.2, using IntCal 13. (Bronck Ramsey 2017; Reimer *et al.* 2013).

irregularities during the sample processing, but also to allow the construction of a concentration diagram. The samples were treated with potassium hydroxide (KOH) to remove the humic acids. Next, the KOH was carefully washed out with alcohol, and in the following step, the pollen grains were separated from the bulk by bromoform ($CHBr_3$) and alcohol solution with a specific gravity of 2.0. In the last step, the cellulose was removed from the residue by means of acetolysis, and the final residue was mounted on microscope slides in glycerol. The resulting samples contained pollen grains and some other microfossils, such as non-pollen palynomorphs (NPP).

### *3.2 Results of the pollen analysis*

Firstly, a concentration diagram was created, which showed a significant decrease in the amount of pollen for all taxa in the top sample (Den Boef 2017). The fact that this decrease occurred in all taxa suggests that it was not related to ecological changes, but was likely caused by the landscape dynamics.

The peat layer was overlain by humic clay that contained pieces of limestone and gravel, interpreted as a floodplain deposit (unit 8). Generally, these sediments tend to be deposited irregularly, allowing time for oxidation of the top of the peat. Another indication for this degradation is that little datable material was found at the top of the layer.

A percentage diagram includes the different taxa that have been identified in the samples (figure 4). The peat contained taxa from both aquatic and dry environments. This corresponds to the location of the sample; the aquatic taxa reflect the local environment, a small basin in a residual channel (cut-off) on a floodplain, whereas the dry taxa can be traced back to the high plateau, located directly above the sample location.

The regional vegetation was dominated by pine (*Pinus*) and low percentages of birch (*Betula*). Additionally, the assemblage was characterized by mugwort (*Artemisia*), sedges (Cyperaceae) and different taxa of the carnation family (Caryophyllaceae), such as the knawel (*Scleranthus*), which together point to an open landscape. The local plants, such as pondweed (*Potamogeton)* and the white water-lily (*Nymphea*), yellow water-lily (*Nuphar*), reflect the open water conditions that occurred when the residual channel was no longer active. At the edge of this water body, meadow conditions existed, shown by the presence of bogbean (*Menyanthes trifoliata)* and water plantains (*Alisma*), and likely also sedges, although these may also reflect the regional signal.

### *3.3 Dating the channel fill*

Chronologically, this assemblage points to the onset of a warm stage and hence may point to a Late Glacial or Preboreal age (Bakels 1995; Barbier and Visset 2003). Two radiocarbon dates obtained from the base and top of the peat layer, respectively, allowed a more accurate age estimation. The samples dated were seeds from a terrestrial source. The top sample contained only a very small amount of datable material, but the Groningen Center for Isotope Research was able to date the sample by the "small sample batch procedure" (de Rooij *et al.* 2010). Table 2 shows the dating results of both samples. Their dates are consistent and point to a reliable age estimation: the lower sample (GrM 12700) was dated to 11,260 ± 65 yrs BP (11,286-11,094 yrs cal BC), whereas the upper sample was dated to 11,100 ± 50 yrs BP (GrM 12581) (11,140-10,849 yrs cal BC). The calibrations were performed in Oxcal, version 4.3.2, using IntCal 13. (Bronck Ramsey 2017; Reimer *et al.* 2013) and have a standard deviation of 2σ (95.4% confidence). The calibrated dates point to a Late Glacial age, which is in accordance with the results of the pollen analysis that indicate an open environment at the time of the peat formation.

In a sequence in the Aisne River valley (Northern France), a similar assemblage was found, dating to the Younger Dryas: *Pinus* and *Betula* with *Cyperaceae* and P*oaceae,* pointing to open but dry (steppe) conditions (Boulen 2000). Pollen and Coleoptera data from Aubrac, a plateau in the central part of France, showed a dry and cold environment around 11,000 yrs cal BP. The vegetation was characterized by steppic herbs (*Artemisia*, *Helianthemum,* Chenopodiaceae, Caryophyllaceae, Poaceae), but low percentages of *Pinus* and *Betula* compared to our results (Ponel *et al.* 2016), probably related to its geomorphological setting on a high plateau.

## 4. Sedimentary history of the Gartempe: chronology

The existence of river deposits associated to the time of occupation of Les Cottés could not be established with certainty. They may have been eroded completely during later stages. The fieldwork proved the existence of two levels of channel deposits, pointing to two terrace remnants, of which the age is difficult to assess. These channel deposits reflect active deposition inside a river channel. Floodplain deposits, which have been sampled as well, are even more difficult to date and relate to an active river channel. They are deposited during floods that may reach considerable heights, and may even cover higher levels, such as older terraces, when the flooding is exceptionally large. Hence, the elevation of channel deposits is a better reflection of the activity of a river than the irregular deposition during flooding events.

The Late Glacial age of the channel fill of the lowest (and therefore youngest) terrace allows us to shed some light on the chronology of the terraces: it shows that all deposits underlying this residual channel have a *terminus ante quem* age older than c. 11,000 yrs BP and hence undisputedly date to the Last Glacial. These are all channel deposits, and this age shows that the present floodplain covers an older terrace that reaches an elevation of c. 64.5 m.

The small terrace remnant located in front of the cave site could not be dated in a direct way. It is an older terrace than the terrace covered by the floodplain. Its formation was preceded and followed by erosional phases, as shown by the presence of the escarpments above the plateau and towards the present floodplain. The elevation of this terrace is 67 m, about 2.5 m higher than the top of the younger terrace.

Comparison to the age of the archaeological sequence of Les Cottés helps us to refine this relative chronology. The base of these deposits is located at an elevation of c. 72 m, which is only 5 m higher than the top of the channel deposits of the oldest terrace. Given that no fluvial deposits have been found in the archaeological sequence, it implies that from the time of occupation, dated to 46-35 ka cal BP, all flooding events only occurred up to elevations lower than 72 m.

The oldest terrace found is only 5 m lower than the cave site, a difference that could easily be bridged

| Sample name | Dated material | GrM code | $F^{14}C \pm 1\sigma$ | $^{14}C$ Age ± 1σ (yrs BP) | %C | $\delta^{13}C \pm 1\sigma$ ($^{0}/_{00}$) |
|---|---|---|---|---|---|---|
| CTS'17 – 18 TOP | charred seeds | 12700 | 0.2511 ± 0.0021 | 11,100 ± 65 | 57.3 | -27.58 ± 0.05 |
| CTS'17 – 18 BOTTOM | charred seeds | 12581 | 0.2461 ± 0.0007 | 11,260 ± 50 | 58.7 | -27.93 ± 0.12 |

Table 2: Results of the AMS dating of the top and bottom of the peat layer in the residual channel fill in core 2016-14 *(CTS'17-18 TOP was analysed in a "small sample batch" with AMS).*

during a large flooding event in a confined river valley such as the Gartempe. Therefore, it is likely that this small terrace remnant was already inactive during the occupation of Les Cottés, although deposition of loam during flood events likely still occurred on top of the terrace, as shown by the presence of unit 4. This would imply that the underlying terrace probably represents the active river channel, from which overbank loam was occasionally deposited on higher levels, including the 2.5 m higher terrace, but did not reach the 7.5 m higher cave site. It should be noted that this active river was responsible for the erosion of almost all deposits that formed the upper terrace, of which only a small part in front of the cave is presently preserved. It shows that the Gartempe River was much more active during the Last Glacial than it is nowadays.

## 5. Conclusions

The field survey has resulted in more insights into the fluvial dynamics of the Gartempe River during the Last Glacial. Initially, it appeared that the river eroded any older deposits, but we could identify two terrace levels, of which the upper one already existed, and the lower one possibly reflects the active floodplain at the time of occupation of the cave.

A residual channel fill in the lowest terrace, located directly in front of the excavation, could be dated to the Younger Dryas, the last part of the Last Glacial. The Late Glacial age of the channel fill allowed us to put the sedimentary sequence in a chronological framework: the lowest terrace, covered by the present floodplain, dates to the Last Glacial. It may have been active up to the Alleröd interstadial. The upper terrace most likely dates to before the occupation of the cave, since the small elevation difference between this terrace and the cave site would have resulted in occasional flooding and hence loam deposition inside the cave, and this is not the case.

Therefore, during the time of occupation the site was likely located 5 m above a former terrace that was occasionally flooded. Only a small remnant of this terrace has been preserved; the largest part has been eroded by the Gartempe River, of which its floodplain was located at 7.5 m below the cave site. This is much lower than today and allowed the humans to use the valley as a resource for water and materials at safe distance from any floods. Direct dating of the sandy channel deposits in both terrace levels using OSL would improve the understanding of the proximity of the water relative to the cave during the cave occupation.

Additionally, pollen analysis of a residual channel of the lowest terrace pointed to an open landscape during the Younger Dryas, with *Pinus, Artemisia,* Poaceae and low percentages of *Betula*. The dry taxa were initially attributed to the geomorphological setting, below a plateau, but since pollen diagrams of other regions in France also contain these dry taxa, they may also reflect a regional signal.

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## References

Bakels, C.C. 1995. Late Glacial and Holocene pollen records from the Aisne and Vesle valleys, Northern France: the pollen diagrams Maizy- Cuiry and Bazoches, *Mededelingen Rijks Geologische Dienst* 52, 221-234.

Barbier, D, and L. Visset 2003. Pollen analysis of the Saint-Ursin peat bog (Mayenne Massif armoricain, Northwest France): detection of Late Glacial and Holocene sequence, *Revue d'Archeometrie* 27, 55-56.

Bastin, B., F. Leveque, and L. Pradel 1976. Mise en évidence de spectres polliniques interstadiaires entre le Moustérien et le Périgordien ancien de la grotte des Cottés (Vienne), *Comptes rendus hebdomadaires des seances. Serie D. Sciences naturelles*, 282, 1261-1264.

Beug, H.J., 2004. *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete*, Verlag Friedrich Pfeil, München, Germany.

Boulen, M. 2000. Un enregistrement pollinique tardiglaciaire à Chivres-Val «Le Marais maudit » (Aisne, France), *Quaternaire* 11-2, 123-128.

Bronk Ramsey, C. 2017. Methods for Summarizing Radiocarbon Datasets, *Radiocarbon* 59(2), 1809-1833.

De Rooij, M., J. van der Plicht and A.J. Meijer 2010. Porous iron pellets for AMS$^{14}$C analysis of small samples down to ultra-microscale size (10-25lgC), N*uclear Instruments and Methods in Physics Research B* 268, 947-951.

Den Boef, L. 2017. *Following the river. Reconstructing the environmental and geomorphological processes forming the Gartempe river valley during the Late Glacial and Holocene period,* Leiden (unpublished MSc thesis University of Leiden).

Jacobs Z., N.R. Jankowski, H.L. Dibble, P. Goldberg, S. McPherron, D. Sandgathe and M. Soressi 2016. The age of three Middle Palaeolithic sites: Single-grain optically stimulated luminescence chronologies for Pech de l'Azé I, II and IV in France, *Journal of Human Evolution* 95, 80-103.

Mol, J., W. Roebroeks, H. Kamermans, Th. van Kolfschoten and A. Turq, 2004. Weichselian and Holocene fluvial evolution of the Vézère river valley (Dordogne, France), *Quaternaire* 15, 187-193.

Moore, P.D. and J.A. Webb, 1978. *An illustrated guide to pollen analysis,* Hodder and Stoughton, London.

Ponel, P., F. Guitera, E. Gandouina, C. Pailles, P. Rioual, M. Djamalie, V. Andrieu-Ponela, M. Leydet, N. Van der Putten and J.L. de Beaulieu 2016. Novel insights from coleopteran and pollen evidence into the Lateglacial/Holocene transition in Aubrac, French Massif Central, *Palaeogeography, Palaeoclimatology, Palaeoecology* 463-1, 83-102.

Reimer, P. J., E. Bard, A. Bayliss, J.W. Beck, P.G. Blackwell, C. Bronk Ramsey, P.M. Grootes, T.P. Guilderson, H. Haflidason, I. Hajdas, C. Hatté, T.J. Heaton, D.L. Hoffmann, A.G. Hogg, K.A. Hughen, K.F. Kaiser, B. Kromer, S.W.Manning, M. Niu, M. R.W. Reimer, D.A. Richards, E.M. Scott, J.R. Southon, R.A. Staff, C.S.M. Turney and J. van der Plicht, 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP, *Radiocarbon*, 55(4), 1869-1887.

Roebroeks, W., A. Turq, H. Kamermans, J.Mol and Th. van Kolfschoten 2009. Watching The River Flow: A small-scale survey of the floodplain deposits in the Vézère valley, between Le Moustier and Les Eyzies (Dordogne, France), *Analecta Praehistorica Leidensia* 41, 1-49.

Roussel, M., and M. Soressi 2013. Une nouvelle séquence du Paléolithique supérieur ancien aux marges sud-ouest du Bassin parisien: Les Cottés dans la Vienne. In: P. Bodu, L. Chehmana, L. Klaric, L. Mevel, S. Soriano, and N. Teyssandier (eds), *Le Paléolithique supérieur ancien de l'Europe du nord-ouest (35 000-15 000 BP). Réflexions et synthèses à partir d'un Projet Collectif de Recherches sur le Paléolithique supérieur ancien du Bassin parisien,* Mémoire LVI de la Société Préhistorique Française. Société Préhistorique Française, Paris, 283-297.

Roussel, M., M. Soressi and S. Porter 2017. *Saint-Pierre-de-Maillé: Les Cottés. Bilan Scientifique 2015.* Direction Régionale des Affaires Culturelles. Poitou-Charentes, SRA.

Soressi, M., M. Roussel, W. Rendu, J. Primault, S. Rigaud, J.P. Texier, D. Richter, S. Talamo, F. Ploquin, B. Larmignat, C. Tavormina, and J.J. Hublin 2010. Les Cottés : nouveaux travaux sur l'un des gisements de référence pour la transition Paléolithique moyen-supérieur. In: J. Buisson-Catil and J. Primault (eds) *Préhistoire entre Vienne et Charente: Hommes et Sociétés du Paléolithique,* Association des Publications Chauvinoises, Chauvigny, France, 221-234.

Talamo, S., M. Soressi, M. Roussel, M. Richards and J.J. Hublin 2012. A radiocarbon chronology for the complete Middle to Upper Paleolithic transitional sequence of Les Cottés (France), *Journal of Archaeological Science* 39, 175-183.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 49-54.

# Een ziltige geur – halophytic macroscopic plant remains from Happisburgh Site 1, UK indicating Middle Pleistocene hominin activity in an estuary prior to the Anglian Stage (MIS 12) ice advance

Michael H. Field

*An investigation of Middle Pleistocene fossil river channel sediments located at Happisburgh Site 1, Norfolk, UK (52.819409 N, 1.544272 E, approximately 20 miles north-east of Norwich) yielded a small assemblage of lithic artefacts. The fluvial sediments were predominantly decalcified, however, plant macrofossil preservation was found to be good allowing a detailed, local vegetation and environment reconstruction. Presented here is plant macrofossil evidence that shows sediment deposition took place at the coast. The investigation at Happisburgh Site 1 adds weight to the ideas that in the Middle Pleistocene hominins were using the coastline, together with river valleys, as convenient routes to get around, as localities to acquire natural resources, and to enjoy the warm-temperate conditions that prevailed on the edge of the Atlantic Ocean in northwest Europe.*

*Keywords: Middle Pleistocene, coastline, lithic artefacts, plant macrofossils*

## 1. Introduction

Our early ancestors should be regarded as organisms existing in an ecosystem influenced by a range of biotic and abiotic factors. But what ecological tolerances did extinct *Homo* species have, which habitats did these species prefer to exploit, and what distributions did they have? There is debate about the answers to these questions. Views on these matters can be theoretical or based on data from the fossil record (either actual hominin bones or trace fossils such as cut-marks on animal bone or lithic artefacts) which, of course, is 'discovery driven'. Going further back in time the number of archaeological sites available to make conclusions becomes fewer – preservation being an issue. Reconstructions of past interglacial (warm stage) environments in north-west Europe show that as climatic conditions improved the vegetation developed towards a climax forest (West, 1980). It is likely these forests were dense and posed challenges to hominins not only for movement but also for access to resources. It has been proposed that river valleys and coastal areas may have been a magnet to extinct *Homo* species because these areas offered ease of movement and the possibility to exploit a range of natural resources (Cohen *et al.*, 2012). In a coastal situation resources would be available landward as well as in the littoral zone. Coastal erosion may also have exposed useful resources, such as flint, on a regular basis. In addition, Cohen *et al.* (2012) talk about hominins having an Atlantic habitat preference because they preferred warm-temperate conditions

**Michael H. Field**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
m.h.field@arch.leidenuniv.nl

which were to be found in an oceanic setting. The problem is finding fossil coastal sediment containing archaeology to explore these ideas. Cohen *et al.* (2012) argue that there are differences for the potential preservation of archaeological remains in fluvial and coastal depositional contexts with relatively poor preservation of archaeological artefact yielding sediments from a coastal origin.

A Leiden University directed excavation (2009-2012) of Middle Pleistocene fossil river channel sediments located below the modern beach and Anglian Stage diamicton (Happisburgh Till) at Happisburgh Site 1 discovered a small assemblage of lithic artefacts. Access to this fossil channel was aided by the rapid retreat of the cliff after the sea defences ceased to be maintained. The fluvial sediments were predominantly decalcified, however, plant macrofossil preservation was found to be good allowing a detailed, local vegetation and environment reconstruction. Presented here is plant macrofossil evidence from a Middle Pleistocene archaeological site on the present-day coastline at Happisburgh (Site 1), Norfolk, UK (52.819409 N, 1.544272 E, approximately 20 miles north-east of Norwich) that shows hominins were active in a coastal location. The investigation at Happisburgh Site 1 adds weight to the ideas that in the Middle Pleistocene hominins were using the coastline, together with river valleys, as convenient routes to get around, as localities to acquire natural resources, and to enjoy the warm-temperate conditions that prevailed on the eastern side of the Atlantic Ocean.

## 2. Geological context of the fossil river channel

The stratigraphical and sedimentological context of the fossil channel deposits at Happisburgh Site 1 is described in detail in Lewis *et al.* (2019). In summary, directly below the channel is a Crag Group set of sediments below which occurs chalk. The excavations undertaken by a Leiden University team and earlier by an Ancient Human Occupation of Britain (AHOB) project team exposed channel deposits (which can be divided into a lower grey sand and an upper organic mud) overlain by Happisburgh Till – the boundary between these two deposits is sharp and probably represents an unconformity. Lewis *et al.* (2019) propose that the channel sediment deposition took place around 500,000 years ago.

## 3. Archaeological artefacts

Two in situ lithic artefacts were discovered at the very top of the grey sand horizon with a total of 218 artefacts recovered by sieving the grey sand during the Leiden University excavation between 2009 and 2012. Most were flakes that were in mint condition. This, together with the identification of two refitting groups of flakes, suggests that little or no transportation of the lithic artefacts occurred and that knapping took place at the margin of the channel (Lewis *et al.* 2019).

## 4. The local vegetation and environment reconstruction for the Happisburgh Site 1 channel feature based on plant macrofossil data

Plant macrofossil analysis is ideally suited to reconstructing the vegetation and environment at a site for the duration of sediment deposition. Firstly, this is because, more often than not, macroscopic plant remains are not transported very far from the source plants. Secondly, it is often possible using morphological features to identify both carpological and vegetative macroscopic remains to species level. Both these taphonomic and taxonomic considerations allow detailed, local vegetation and environment reconstructions to be made.

Although deposition of the fluvial sediments at Happisburgh Site1 probably occurred over tens or hundreds of years, during the latter half of an interglacial cycle, changes in the local vegetation can be detected in the plant macrofossil assemblages. The palaeobotanical data shows the channel was located in an estuary. The plant nomenclature for the following discussion comes from Stace (2010).

The lower facies (grey sand) within the channel feature contained plant macrofossils from different taxa compared with the overlying organic mud. The assemblage from the grey sand is noticeable because it contains saltmarsh taxa (*Aster tripolium*, *Salicornia* and *Triglochin maritima*). In addition to these halophytic taxa *Potamogeton pectinatus* and *Zannichellia palustris* were also recorded. Both species can also tolerate a degree of brackishness. However, other aquatic plants represented point to freshwater conditions suggesting a freshwater channel entering a saltmarsh. The margin of the channel was occupied by a range of plants including Typha and *Alnus*. The grey sand yielded a fragment of a seed of *Actinidia faveolata* – the first British record of this extinct species (Field, 2012). Further afield in the catchment were

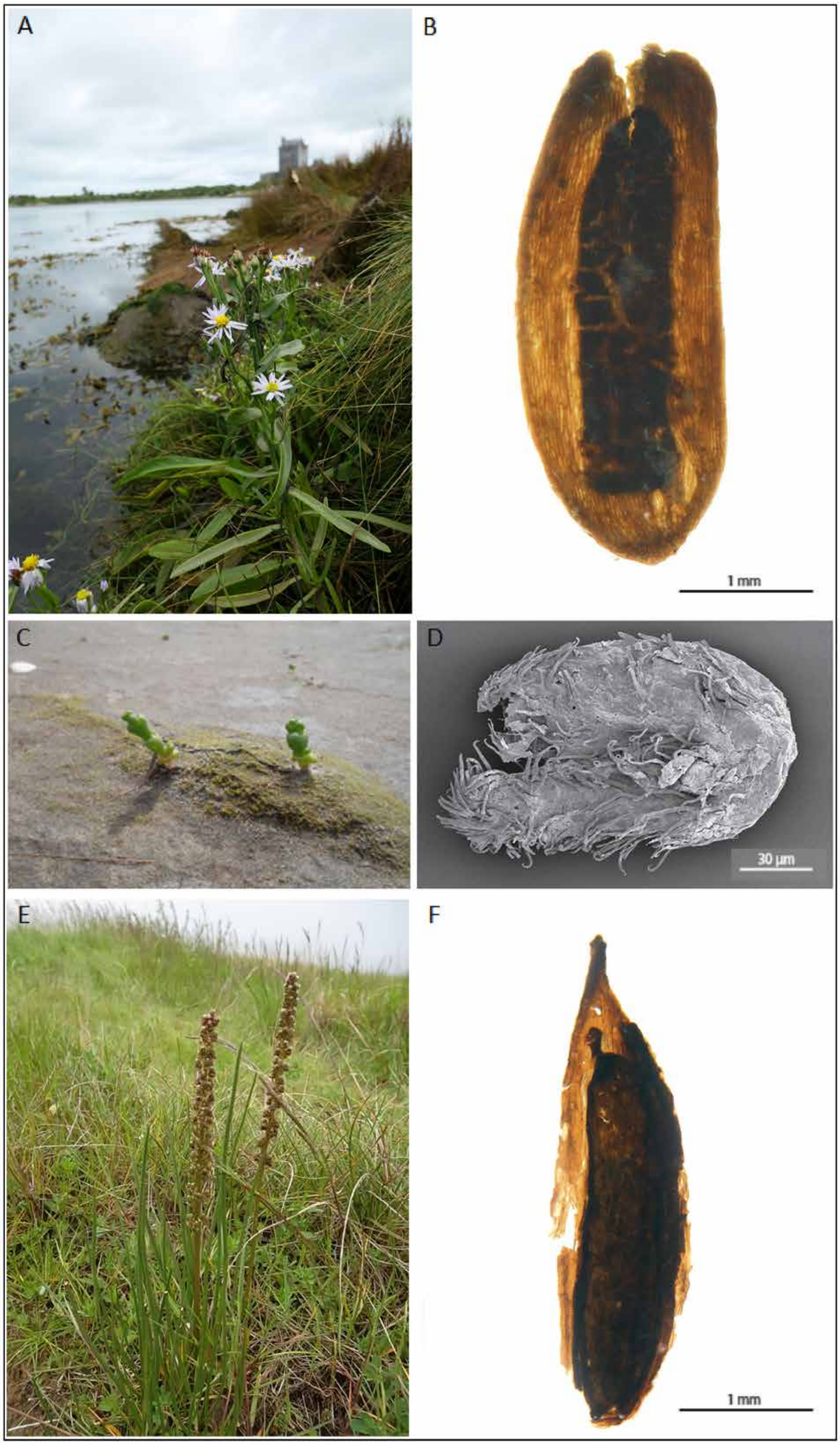


Figure 1: (a) *Aster tripolium* growing on the sea shore at Kinvarra, County Galway, Ireland with Dunguaire castle in the background (Photo: M.H.Field, August 2018). (b) a fossil *Aster tripolium* achene from the grey sand at Happisburgh Site 1. (c) *Salicornia* sp. colonizing the beach at Kwade Hoek, Zuid Holland (Photo: M.H.Field, May 2015). (d) a fossil *Salicornia* seed from the grey sand at Happisburgh Site 1. (e) *Triglochin maritima* on the seaward side of a coastal dune near Oostdijk, Kwade Hoek, Zuid Holland (Photo: M.H.Field, May 2013). (f) a fossil *Triglochin maritima* achene from the grey sand.

areas of heath indicated by the occurrence of *Erica* cf. *tetralix* and *Empetrum nigrum* as well as some coniferous forest composed of *Picea*.

The nature of the contact between the lower grey sand and the overlying organic mud is debatable. It may be an unconformity representing either an erosional episode or a break in sedimentation. Alternatively, it may suggest a transition from in channel deposition to still water deposition of organic mud following the abandonment of the channel. The assemblage from the lower part of the organic mud is characterized by the dominance of waterside and damp ground taxa. The taxa represented indicate that open, muddy conditions prevailed (*e.g.* some *Carex* spp., *Cyperus fuscus*, *Eleocharis palustris* and *Lythrum portula*). The waterbody at this time was occupied mainly by *Callitriche* species. Aquatic taxa become dominant in the upper part of the organic mud. The submergent, emergent and floating taxa recorded suggest slow moving or still, clear, basic, mesotrophic to eutrophic, freshwater that was possibly up to 2 metres deep and contained an organic substrate at the bottom of the water column. *Rumex maritimus* grew on the shore of the waterbody. Trees are poorly represented in the carpological assemblages from the organic mud facies with only *Alnus glutinosa* and *Betula* recorded, the former growing at the channel edge. It was possible to determine cf. *Alnus*, *Salix* and *Ulmus* from the compressed wood fragments (Caroline Vermeeren, personal communication).

These two fluvial facies are overlain by a diamicton (Happisburgh Till) which yielded no plant remains.

## 5. The halophytic component of the plant macrofossil assemblages

Three taxa indicate brackish conditions at the site at the time of sediment deposition. Their presence clearly shows that the site was located at the coast. *Aster tripolium* (Asteraceae family) is a biennial or sometimes annual plant predominantly found in coastal saltmarshes, but occasionally on sea cliffs (Clapham *et al*., 1942) (figure 1a). The fossils of this species recovered from the grey sand at Happisburgh Site 1 were elongated achenes with a surface composed of characteristic elongated cells (figure 1b). *Salicornia* (Amaranthaceae family) is a genus that contains annuals with great phenotypic plasticity and inbreeding making species determinations extremely difficult even when a whole plant specimen is available for examination (Stace, 2010). The plants in this genus are obligate halophytes common in saltmarsh habitats (figure 1c). *Salicornia europaea* grows rapidly at moderate salt concentrations (150 to 300 mM NaCl) and can survive at extreme salinities, including seawater concentrations (Muscolo *et al*., 2014). The seeds recovered from the grey sand are elliptic in shape, laterally compressed, with the radicle about the same length as the cotyledons, and are covered in hairs (figure 1 d). Finally, *Triglochin maritima* (Juncaginaceae family) is a native rhizomatous perennial herb in the UK today occurring in coastal saltmarshes and salt-sprayed grassland (Stace, 2010) (figure 1e). Davy and Bishop (1991) comment that this species prefers upper 'emergence' marshes where there are less than 360 submergences per year and a minimum period of continuous exposure of 22 days. The grey sand yielded achenes of *Triglochin maritima* (figure 1f). These were rounded at the base, elongated, and the apex narrowing to the remains of the style.

## 6. Conclusions

In summary, the plant macrofossil assemblages show that at Happisburgh Site 1 a freshwater channel flowed into a brackish saltmarsh located in an estuary that was surrounded by some heathland and in places coniferous woodland. At this time hominins were knapping flakes on the margin of the channel at the site. Later a change took place and open freshwater mud existed to be later replaced by a slow-moving freshwater channel. No evidence of anthropogenic activity was found in this later period during the Leiden University excavations between 2009 and 2012 despite earlier excavations undertaken by a AHOB team recovering lithic artefacts from this level. This may reflect activity at only certain points along the channel margin at that time. It is not difficult to imagine this sequence of environmental change occurring in a dynamic coastal landscape. Cohen *et al*. (2012) argued that prior to approximately half a million years ago hominins could only thrive in warm-temperate conditions and their distribution would have reflected this. They talk about the 'Atlantic habitat preference'. The fact that hominins were active in a coastal setting in southeast England (at Happisburgh Site 1) around 500,000 years ago adds weight to the idea that at this time our ancestors had an oceanic distribution at the margins of the eastern Atlantic Ocean. The littoral zone may also have had an additional advantage of ease of movement and access to useful natural resources, such as flint, exposed by wave action.

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## References

Clapham, A.R., W.H. Pearsall and P.W. Richards 1942. Biological flora of the British Isles. No. 8: *Aster tripolium* L., *Journal of Ecology* 30, 383-395.

Cohen, K.M., K. MacDonald, J.C.A. Joordens, W. Roebroeks, P.L. Gibbard 2012. The earliest occupation of north-west Europe: a coastal perspective, *Quaternary International* 271, 70-83.

Davy, A.J. and G.F. Bishop 1991. Biological flora of the British Isles: *Triglochin maritima* L., *Journal of Ecology* 72, 531-555.

Field, M.H. 2012. The first British record of *Actinidia faveolata* C.Reid and E.M.Reid (Actinidiaceae family), *Quaternary International* 271, 65-69.

Lewis, S.G., N. Ashton, M.H. Field, P.G. Hoare, H. Kamermans, M. Knul, H.J. Mücher, S.A. Parfitt, W. Roebroeks and M.J. Sier 2019. Human occupation of northern Europe in MIS 13: Happisburgh Site 1 (Norfolk, UK) and its European context, *Quaternary Science Reviews* 211, 34-58.

Muscolo, A., M.R. Panuccio and A. Piernik 2014. Ecology, distribution and ecophysiology of Salicornia europaea L. In: M.A. Khan, B. Böer, M. Öztürk, T.Z. Abdessalaam, M. Clüsener-Godt and B. Gul (eds), *Sabkha ecosystems. Tasks for vegetation science* 47, Springer, Dordrecht.

Stace, C. 2010. *New Flora of the British Isles*. Third Edition, Cambridge University Press, Cambridge, UK.

West, R.G. 1980. Pleistocene forest history in East Anglia, *New Phytologist* 85, 571-622.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 55-72.

# Palaeoenvironment and human occupation patterns: a case study for the first half of the Holocene at Cova Fosca (Eastern Spain)

Laura Llorente-Rodríguez, Arturo Morales-Muñiz, María-Teresa Aparicio, Salvador Bailón, Paloma Sevilla and Carmen Sesé

**Laura Llorente-Rodríguez**
Laboratory for Archaeozoological Studies
Faculty of Archaeology
Leiden University
Einsteinweg 2
2333 CC Leiden, The Netherlands
l.llorente.rodriguez@arch.leidenuniv.nl
also:
Laboratorio de Arqueozoología
Universidad Autónoma de Madrid

**Arturo Morales-Muñiz**
Laboratorio de Arqueozoología
Edificio de Biología
Universidad Autónoma de Madrid
C/ Darwin, 2, 28049 Madrid, Spain
arturo.morales@uam.es

**María-Teresa Aparicio**
Museo Nacional de Ciencias Naturales
C/ José Gutiérrez Abascal, 2
28006 Madrid, Spain
teresa@mncn.csic.es

**Salvador Bailón**
CNRS, MNHN,
UMR 7209 Archéozoologie – Archéobotanique. Sociétés, pratiques et environnements
55 rue Buffon, 75005 Paris, France
salvador.bailon@mnhn.fr

**Paloma Sevilla**
Departamento de Paleontología
Universidad Complutense de Madrid
C/ José Antonio Novais, 12
28040 Madrid, Spain
psevilla@ucm.es

**Carmen Sesé**
Museo Nacional de Ciencias Naturales
C/ José Gutiérrez Abascal, 2
28006 Madrid, Spain

*The environmental interpretation of an archaeological site requires a combined assessment of all the taxa of proven bioindicator value. Some animal groups, such as rodents, are routinely used as proxies to this end. Combining such results with those of other animal groups strengthens the validity of inferences about the palaeoenvironment and regarding settlement.*

*The rock shelter of Cova Fosca (Ares del Maestrat, Spain) features human occupations from the Late Pleistocene to the Middle-Early Late Holocene periods. Such a wide time span grants the possibility to explore the climatic and ecological changes that took place during the final stages of the Pleistocene-Holocene transition, as well as those associated with the onset of the Neolithic economies in the region. While several groups of bioindicators present in the shelter converge on an essentially unified view of Cova Fosca's environmental history, each specific group sheds light on different aspects of the ecosystem. Therefore, data from small vertebrates and terrestrial molluscs are combined here in an effort to provide a more comprehensive view of the seasonal human occupation of this shelter and territorial use through time.*

*Keywords: Palaeoenvironment, archaeozoology, Late Pleistocene, Holocene, Eastern Spain, Cova Fosca*

## 1. Introduction

The discussion surrounding the first evidence of production economies in the Iberian Peninsula primarily focuses on archaeological sequences incorporating both Mesolithic and Early Neolithic levels, which allow assessment of the signatures of each culture as well as the processes that eventually led to the demise of the hunter-gatherers' lifeways and their replacement by agriculturalists.

The site of Cova Fosca (Ares del Maestrat, Castellón, Spain; figure 1) stands out among its regional equivalents, both due to the richness and quantity of its zooarchaeological assemblages and due to the contentious 'pre-domestication' process of the Spanish ibex, postulated prior to the onset of the Neolithic by the first monograph on the site (Olària 1988; Estévez 1988). The pre-domestication hypothesis was linked to the presence of cardial and incised ceramics at what appeared to be a very early stage of the Early Neolithic period, when domestic stocks were apparently very scarce and the presence of cultigens far from clear. Given that the

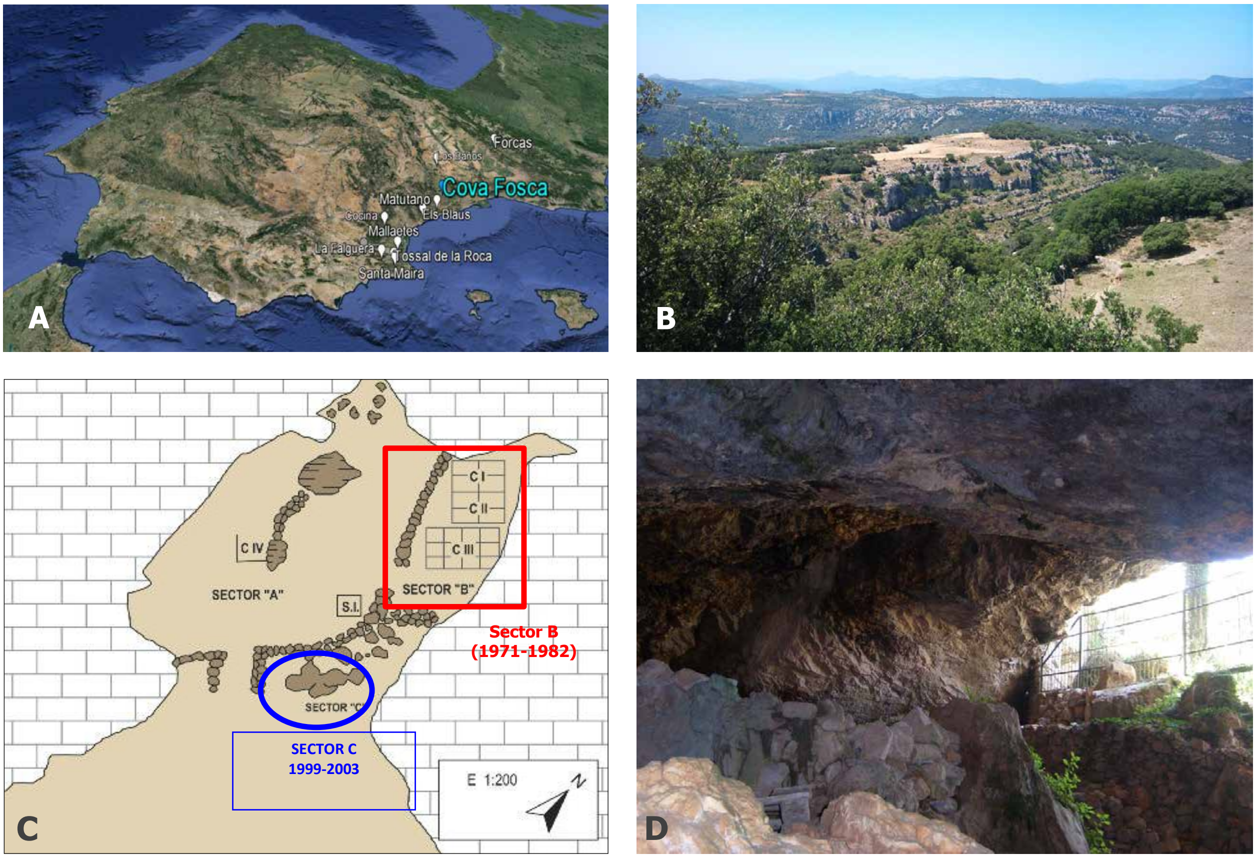


Figure 1: A: Location of the site of Cova Fosca in the Spanish Levant with reference to some Mesolithic and Neolithic sites in the region. B: Overview of the landscape surrounding the site today (Photo: L. Llorente-Rodríguez). C: Ground plan of Cova Fosca with indication of the sectors and squares where excavations took place (based on figure 3 of Gusi and Olària 1988, 70). D: View of the shelter from the inside (entrance is located to the south) (Photo: L. Llorente-Rodríguez).

Neolithic production economies incorporated both agriculture and livestock, Cova Fosca's evidence of early production could represent another instance where a Mesolithic hunting camp's deposits became contaminated with Neolithic materials percolating from overlying levels (Zilhão 1993).

Zooarchaeological analyses were carried out at the site with the aim of specifying the nature of the faunal signatures, in order to clarify the cultural and environmental processes involved in the formation of the deposits. By doing so, we aimed to determine the import of the faunal data. One major issue concerning the cultural processes taking place at Cova Fosca has to do with determining the patterns of occupation of the shelter throughout the sequence. For such purposes, both the largely environmental-related data on the features of the landscape around the site and the cultural and taphonomic evidence concerning the nature of the human occupation of the shelter – whether permanent or sporadic – may offer clues as to how and when hunter-gatherers and herders made use of the shelter. Addressing these issues will, furthermore, yield data concerning some broader patterns relating to the territorial exploitation of the faunal resources by each of these cultural traditions.

In this paper, we address such points through an assessment of the data on human occupation patterns at the site through time. The paper considers only faunal groups categorised taphonomically as diachronic natural assemblages (*i.e.* not accumulated by humans). Four groups of non-comparable taxonomic rank qualify for this category according to the taphonomic data, namely: (1) micromammals, (2) birds, (3) reptiles, and (4) terrestrial molluscs.

### *1.1 The site*

Cova Fosca is a small rock shelter (20 m deep x 27 m wide), where the roof reaches from 5 m to 2 m in height. It is located 900 metres above sea level (m.a.s.l) in a steep ravine of the Maestrazgo Mountains (Olària 1988; see figure 1). The interior of the shelter was first excavated in the 1970s and 1980s (sectors B and D; Olària 1988) but a second set of campaigns followed at the entrance (sector C) between 1999 and 2003 (figure 1C). The faunal remains derived from this latter sector were the subject of our analysis.

Cova Fosca's Sector C (henceforth CFSC) incorporates 34 levels ranging from the Late Pleistocene to the Middle Holocene bearing Epipalaeolithic (12,300-10,885 cal BC), Mesolithic (9,569-6,608 cal BC on charcoal; 5,056-4,855 cal BC on one bone sample), Early Neolithic (5,239-5,038 cal BC) and Middle Neolithic (levels -32.3/-130 cm; 4,764-4,628 cal BC) material cultures (Olària 2000; López and Olària 2008; Llorente-Rodríguez 2010, 2015; Llorente-Rodríguez *et al.* 2011, 2014; Gutiérrez *et al.* 2018). All sediments from this sector were sieved through 0.5 mm and 0.3 mm meshes, which explains both the substantial faunal collections retrieved and their taxonomical diversity (close to 95,000 remains from *ca.* 130 species of vertebrates and molluscs; Llorente-Rodríguez 2015). Most importantly for this study, such thorough retrieval brought to light the microfaunas, enabling a more accurate reconstruction of the palaeoenvironment and the pattern of human occupation.

The faunal deposits include consumption refuse, ornaments, tools and tool waste assemblages accumulated by humans (*i.e.* ungulate, marine molluscs and marine fishes; 55.6% of the identified fraction), along with natural and predator accumulations (bats, insectivores, rodents, Iberian hare, birds, reptiles and terrestrial molluscs; 13.6%) and mixed assemblages with evidence of human and biological or natural accumulations (rabbit and carnivores; 30.8%) (tables 1, 2 and 3; Llorente-Rodríguez 2010, 2015; Llorente-Rodríguez *et al.* 2014).

## 2. The faunal groups

The faunal groups analysed in this study are those accumulated naturally or by predators. The Iberian hare is excluded, given the more restricted bioindicator information that this species provides. Identification was carried out with the help of the reference collection of one of the authors (AMM) housed at the Laboratorio de Arqueozoología of the Universidad Autónoma de Madrid (Madrid, Spain), as well as those from the Museo Nacional de Ciencias Naturales (MNCN, Madrid, Spain) and that of the Muséum National d'Histoire Naturelle de Paris (MNHN, France). Additionally, atlases and references to determine specific groups were used in the case of birds (Cohen and Serjeantson 1996; Moreno Mañas 1983, 1985, 1986; Morales-Muñiz 1993; García Matarranz 2013) and terrestrial molluscs (Aparicio 2001; Fechter and Falkner 1993; Moreno-Nuño 1994, 1995). Abundances follow the two classical estimators in archaeozoology, namely the NISP (number of identified remains) and the MNI (Minimum Number of Individuals) (Lyman 2008). In the case of insectivores and rodents, only teeth and the tooth-bearing elements (*i.e.* crania and mandibles) were used for taxonomical identification. For molluscs, NISP and MNI values were calculated according to categories following Moreno-Nuño (1994).

### *2.1 Terrestrial gastropods (Pulmonates)*

The collection of pulmonates constituted 4.2% of the identified faunal remains from CFSC (total NISP=1,195; Tables 1 and 2). Both NISP and MNI values were similar, indicating a non-intensive fragmentation of shells that allowed us to equate almost all specimens to an individual (table 2). All pulmonates represent small-sized taxa below 31 mm, and thus cannot be considered edible items for humans but rather elements of the local biocoenoses (table 2).

Pulmonate collections are dominated by two species (*ca.* 97% of the pulmonate samples). These are the Round-mouthed snail (*Pomatias elegans* Müller,

| PERIOD | Epipalaeolithic | | | Mesolithic | | | Early Neolithic | | | Middle Neolithic | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NISP | % | MNI | NISP | % | MNI | NISP | % | MNI | NISP | % | MNI | NISP | % | MNI |
| Identified | 6232 | 63.3 | 508 | 1474 | 45 | 353 | 16746 | 24.6 | 1630 | 3890 | 27.3 | 369 | 28369 | 29.8 | 2860 |
| Unidentified | 3607 | 36.7 | - | 1800 | 55 | - | 51238 | 75.4 | - | 10328 | 72.7 | - | 66973 | 70.2 | - |
| **TOTAL studied** | **9839** | **100** | **508** | **3274** | **100** | **352** | **67981** | **100** | **1630** | **14248** | **100** | **370** | **95342** | **100** | **2860** |

Table 1: Grand NISP and MNI totals of the Cova Fosca Sector C faunal assemblages.

1774; 79% of the NISP and 76% of the MNI), and the Decollate snail (*Rumina decollata* Linnaeus, 1758; 19% of the NISPs and 13% of the MNI) (table 2). This pattern is constant throughout the sequence, though frequencies are slightly lower on the oldest levels due to the presence of more taxa within the assemblage; such diversity seems to progressively decline in subsequent periods. This pattern is noteworthy, given that rare taxa are unexpected in deeper levels due to the fragility of their shells, and may well reflect episodes of non-occupation of the shelter by humans at the beginning of the sequence. Additionally, this may also reveal harsher conditions existing during the Epipalaeolithic, forcing snails to hibernate/aestivate in the shelter for longer time periods. With regard to the Late Pleistocene levels, it is also interesting to note that the Decollate snail slightly outnumbers the Round-mouthed snail in this single stage (*i.e.* 45% and 42% of the NISP respectively at that time). These frequencies are inverted in subsequent periods, which may well reflect climatic and environmental changes.

Indeed, although the Round-mouthed snail inhabits a broad spectrum of environments on carbonate soils, it is sensitive to low temperatures, with values below 0ºC considered a limiting factor (Kerney and Cameron 1979; Evans 1972). This snail looks for shelter in fissures and crevices during winter, where individuals aggregate to hibernate, often in large numbers (Bragado *et al.* 2010). Such behaviour, along with the retrieval of 28 opercula of this species, may explain the large Round-mouthed snail assemblages at CFSC (table 2). Some opercula were still attached to the stoma, suggesting that the animals died during diapause. The range of sizes attested suggests the presence of juvenile and adult individuals together (Francisco 2009) which conforms best with natural death assemblages.

The Decollate snail inhabits dry open lands – including xeric environments – in exposed, sunny areas in carbonate soils. This species is more tolerant of low temperatures than the Round-mouthed snail and also aggregates for hibernation in fissures and hollows. The range of sizes indicated the presence of both juvenile and adult individuals, again reinforcing a scenario of natural death during the diapause (Francisco 2009).

In addition to these two species, the remaining nine represented 2% of the combined NISPs (table 2). Interestingly, these species were registered exclusively during the Epipalaeolithic, with the exception of *Pseudotachea splendida* (Drapanaud, 1801) and *Theodoxus baeticus* (Lamark, 1822) which were also documented in the Early Neolithic stage. Most of these taxa reflect xeric (*i.e.* dry) conditions in rocky calcareous areas, as is the case for *Pseudotachea splendida* and *Jaminia quadridens* (Müller, 1774), as well as *Granaria braunii* var. *marcusi* (Gittenberger and Ripken, 1993) which reaches to altitudes ranging from 200-1,352 m.a.s.l., and *Xerocrassa subrogata* (Pfeiffer, 1853) (Gittenberger and Ripken 1993; Kerney *et al.* 1999; Kerney and Cameron 1979; Ruiz-Ruiz *et al.* 2006). The species *Testacella maugei* (Ferussac, 1819) is associated with eutrophic soils, suggesting the accumulation of organic matter at CFSC (Kerney and Cameron 1979). Two species appear in slow-flowing streams and still waters but are likewise adapted to periodical drying of their biotopes; these are *Radix balthica* (Linnaeus, 1758) and *Theodoxus baeticus* (Lamark, 1822). The latter additionally requires high pH in the water, which fits well with the carbonate substrate of the Maestrazgo Mountains where Cova Fosca is located (Martínez-Ortí and Robles 2003; Fechter and Falkner 1993).

### *2.2 Micromammals*

This non-taxonomical category incorporates the remains from three orders of mammals, namely: (a) insectivores (order Eulipotyphla), (b) bats (order Chiroptera) and (c) rodents (order Rodentia).

In terms of general trends, micromammals decrease in number from the start to the end of the sequence (representing up to 70% of the faunal assemblages in some of the oldest levels) and exhibit the highest diversity (8 species; tables 1 and 2). The contribution of these groups of mammals to the whole of the faunal assemblages per period at the site is *ca.* 17% in the Epipalaeolithic, which decreases to 10.6% during the Mesolithic and plummets to 0.5% and 0.1 % in the Early and Middle Neolithic levels respectively (tables 1 and 2).

Insectivores are rare at the site, with only one European hedgehog (*Erinaceus europaeus* Linnaeus, 1858) and two shrew (*Crocidura* sp.) remains identified. Bats are slightly better represented, particularly in the oldest levels of the sequence. Both bat species (Schreiber's long-fingered bat, *Miniopterus schreibersii* Natterer in Kuhl, 1819) and the Lesser mouse-eared bat (*Myotis blythii* Tomes, 1857) in general avoid the presence of humans.

Table 2: NISP and MNI of terrestrial molluscs, bats, insectivores, rodents and reptiles through time/ cultural period at CFSC. Numbers within brackets refer to opercula.

| | STAGE | Epipalaeolithic | | Mesolithic | | Early Neolithic | | Middle Neolithic | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **TAXA** | **NISP** | **MNI** | **NISP** | **MNI** | **NISP** | **MNI** | **NISP** | **MNI** | **NISP** | **MNI** |
| Terrestrial molluscs | *Pomatias elegans* | 50 (1) | 37 | 177(1) | 163 | 707 (26) | 634 | 7 | 7 | 941 (28) | 841 |
| | *Rumina decollata* | 54 | 32 | 56 | 38 | 110 | 68 | 4 | 3 | 224 | 142 |
| | *Testacella maugei* | | | | | 1 | 1 | | | 1 | 1 |
| | Chondrinidae | | | 1 | 1 | | | | | 1 | 1 |
| | *Pseudotachea splendida* | 10 | 9 | | | 11 | 7 | 1 | 1 | 22 | 17 |
| | *Theodoxus baeticus* | | | | | 1 | 1 | | | 1 | 1 |
| | *Radix balthica* | 1 | 1 | | | | | | | 1 | 1 |
| | *Jaminia quadridens* | 1 | 1 | | | | | | | 1 | 1 |
| | *Granaria braunii marcusi* | 1 | 1 | | | | | | | 1 | 1 |
| | *Xerocrassa subrogata* | 1 | 1 | | | | | | | 1 | 1 |
| | Succeneidae | 1 | 1 | | | | | | | 1 | 1 |
| | **TOTAL** | **119 (1)** | **83** | **234 (1)** | **202** | **830 (26)** | **711** | **12** | **11** | **1195 (28)** | **1108** |
| Micro-mammals | *Erinaceus europaeus* | | | | | 1 | 1 | | | 1 | 1 |
| | *Crocidura* sp. | 2 | 2 | | | | | | | 2 | 2 |
| | *Myotis blythii* | 4 | 3 | 1 | 1 | 2 | 2 | | | 7 | 6 |
| | *Miniopterus schreibersii* | 1 | 1 | | | | | | | 1 | 1 |
| | Chiroptera indet. | 35 | | 1 | | 1 | | | | 37 | - |
| | *Sciurus vulgaris* | 3 | 2 | 2 | 2 | 7 | 2 | | | 12 | 6 |
| | *Microtus duodecimcostatus* | 33 | 15 | 13 | 6 | 53 | 6 | | | 99 | 27 |
| | *Microtus cabrerae* | 4 | 2 | 2 | 1 | 3 | 2 | | | 9 | 5 |
| | *Microtus* sp. | 54 | 19 | 14 | 4 | 57 | 11 | 5 | 2 | 130 | 36 |
| | Microtinae indet. | | | | | 4 | - | | | 4 | - |
| | Muridae indet. | 12 | | | | 4 | - | | | 16 | - |
| | *Apodemus sylvaticus* | 172 | 47 | 58 | 20 | 148 | 15 | | | 379 | 82 |
| | *Eliomys quercinus* | 14 | 14 | 2 | 1 | 47 | 6 | | | 63 | 21 |
| | Rodentia indet. | 1356 | - | 258 | | 22 | - | 11 | - | 1647 | - |
| | Undetermined small mammals | - | - | - | - | 6 | - | - | - | 6 | - |
| | **TOTAL NISP** | **299** | **105** | **93** | **36** | **320** | **46** | **5** | **2** | **717** | **189** |
| | **TOTAL undetermined** | **1391** | **-** | **255** | **-** | **29** | **-** | **11** | **-** | **1686** | **-** |
| | **Total studied** | **1690** | **105** | **352** | **36** | **349** | **46** | **16** | **2** | **2407** | **189** |
| Reptiles | cf. *Mauremys leprosa* | | | | | 2 | 2 | | | 2 | 2 |
| | *Timon lepidus* | 6 | 3 | 3 | 2 | 30 | 9 | 2 | 2 | 41 | 16 |
| | *Zamenis scalaris* | 6 | 2 | | | 1 | 1 | 1 | 1 | 8 | 4 |
| | *Vipera latasti* | | | | | 1 | 1 | | | 1 | 1 |
| | Reptilia indet. | | | | | 18 | - | | | 15 | |
| | **TOTAL** | **12** | **5** | **3** | **2** | **52** | **13** | **3** | **3** | **67** | **23** |

Rodents are the most frequent group of small mammals (table 2). However, total rodent numbers decrease considerably from the pre-Neolithic to the Neolithic levels, as do numbers of the most abundant species in all levels, namely the Wood mouse (*Apodemus sylvaticus* Linnaeus, 1758). Voles (*i.e.* remains from the genus *Microtus*) follow in terms of abundance and are ultimately the only micromammal remains identified at the end of the sequence. With regard to the two species identified on Sector C, the Mediterranean pine vole (*Microtus duodecimcostatus* de Sélys-Longchamps, 1839) was more abundant than Cabrera's vole (*Microtus cabrerae* Thomas, 1906) at all times, though the ratio of *Microtus duodecimcostatus* to *Microtus cabrerae* decreased steadily through time (Epipalaeolithic: 15:1; Mesolithic: 6.5:1; Early Neolithic: 3:1). The Garden dormouse (*Eliomys quercinus* Linnaeus, 1766) represented *ca.* 9% of both the total NISP and MNI; however, its frequency fluctuated through time. Finally, the Eurasian red squirrel (*Sciurus vulgaris* Linnaeus, 1758) was the least represented of the rodent species.

### *2.3 Reptiles*

Four species of reptiles have been identified at the site (table 2): the Ocellated lizard (*Timon lepidus* Daudin, 1802), Ladder snake (*Zamenis scalaris* Schinz, 1822), Lataste's viper (*Vipera latastei* Bosca, 1822) and a turtle, which most likely corresponds to the Spanish terrapin (cf. *Mauremys leprosa* Schweigger, 1812).

The Ocellated lizard is the most abundant reptile species (61% of the total reptile NISP), being present in all cultural stages, followed by the ladder snake (12%), which was only absent in the Mesolithic levels. The viper and the terrapin were identified exclusively in Early Neolithic levels. The Ocellated lizard remains from the Epipalaeolithic and Early Neolithic levels and the Spanish terrapin finds all exhibit traces of light digestion, suggesting the activity of predators at the cave at those times.

The collection of reptiles from Sector C indicates a mixed landscape including still waters and a Mediterranean climate, with the presence of the Ladder snake indicating temperatures down to a minimum of 10°C during the Epipalaeolithic and Early Neolithic. All these species hint at a clear seasonal signal, being active preferentially between March and September. This would reflect a preferential early spring / summer presence of predators in the shelter, thus indirectly indicating that humans were not present at those times. Although the reptile collections are extremely small when viewed against the total faunal assemblages, they do corroborate the drop in abundance documented for other microfaunal groups, albeit in a far more gradual manner (Epipalaeolithic: 0.12%; Mesolithic: 0.09%; Early Neolithic: 0.07%; Middle Neolithic: 0.03%).

### *2.4 Birds*

The total bird NISP (482) represents just 1.7% of the total faunal assemblage at Cova Fosca (tables 1 and 3). Although birds can be considered incidental on the site, they corroborate the decrease through time of microfauna that was recorded in the aforementioned groups (tables 2 and 3).

The taxonomically identified fraction represents only 16% of the total bird NISP; however, the diversity is remarkably high with a total of 30 species (table 3). Small-sized passerines were the most recorded among the identified bird assemblage which, alongside the low values in abundance, suggests a non-anthropic accumulation. Indeed, human-derived (*i.e.* hunted) bird assemblages are typically represented by very few taxa (often only one), such as partridges and/or waterfowl.

Within the bird collection, the Epipalaeolithic and Early Neolithic outnumber the Mesolithic and Middle Neolithic in terms of NISP values (40% and 45% of the total bird NISP, respectively) and diversity (17 species in the Early Neolithic, 7 in the Epipalaeolithic). Mesolithic birds constitute 13% of the total bird sample with 7 species, while the Middle Neolithic constitutes 2%, represented by 2 species (table 3).

The birds identified at the site provide valuable information concerning both environment and seasonality. Concerning the latter, there is a notable abundance of aestival (summer) taxa throughout the sequence (*i.e.* 11 out of 34 species, 33% of the identified fraction; Table 3). Additionally, two species which can currently be seen in the Iberian Peninsula during short periods of the spring and autumn migrations only (the European pied flycatcher, *Ficedula hypoleuca* Pallas, 1764; and the Lesser white-throat, *Sylvia curruca* Linnaeus, 1758) complete this singular seasonal signature. The ratio of 'resident to aestival' taxa in the Epipalaeolithic and Mesolithic of *ca.* 1:0.8 suggests an accumulation of birds by predators throughout the year. However, this ratio decreases in the most recent levels to *ca.* 1:0.4. Such a decline hints at more frequent

Table 3 (next page): NISP and MNI of birds by cultural period at CFSC.

| TAXA | Phenology | PERIOD > Habitat | Epipalaeo-lithic | Mesolithic | Early Neolithic | Middle Neolithic | TOTAL |
|---|---|---|---|---|---|---|---|
| *Haliaetus albicilla* | Undetermined | Mixed forests | | | 4 | | 4 |
| *Hieraaetus pennatus* | Aestival | Mixed forests | | | | 1 | 1 |
| Accipitridae indet. | Undetermined | Undetermined | | | 1 | | 1 |
| *Alectoris rufa* | Resident | Open landscpaes | 4 | | 3 | 2 | 9 |
| *Coturnix coturnix* | Aestival | Open landscpaes | 1 | | | | 1 |
| *Otus scops* | Aestival | Forest species | | 1 | 1 | | 2 |
| *Athene noctua* | Aestival | Mixed forests | | | 1 | | 1 |
| *Strix aluco* | Resident | Forest species | | | 1 | | 1 |
| *Columba livia/oenas* | Resident | Undetermined | 6 | | | | 6 |
| *Caprimulgus ruficollis* | Aestival | Open landscpaes | 1 | | | | 1 |
| *Cuculus canorus* | Aestival | Forest species | 1 | | | | 1 |
| *Jynx torquilla* | Aestival | Forest species | | 1 | | | 1 |
| *Dendrocopos major* | Resident | Forest species | | 1 | | | 1 |
| *Dendrocopos minor* | Resident | Forest species | | 1 | | | 1 |
| *Ptyonoprogne rupestris* | Aestival | Rocky outcrops | | 1 | | | 1 |
| *Phoenicurus phoenicurus* | Resident | Forest species | | | 1 | | 1 |
| *Saxicola torquata* | Resident | Mixed forests | | | 1 | | 1 |
| *Turdus* sp. | Undetermined | Undetermined | 3 | 1 | 4 | 1 | 9 |
| *Sylvia curruca* | Migration | Mixed forests | | | 1 | | 1 |
| *Sylvia communis/ atricapilla* | Resident | Mixed forests | | | 1 | | 1 |
| *Phylloscopus collybita* | Resident | Forest species | | | 1 | | 1 |
| *Muscicapa striata* | Aestival | Forest species | | | 1 | | 1 |
| *Ficedula hypoleuca* | Aestival | Forest species | | | 1 | | 1 |
| *Parus major* | Resident | Forest species | | | 1 | | 1 |
| *Lanius excubitor* | Aestival | Open landscpaes | | | 1 | | 1 |
| *Garrulus glandarius* | Resident | Forest species | | | 6 | | 6 |
| *Pyrrhocorax pyrrochorax* | Resident | Rocky outcrops | 4 | | | | 4 |
| cf. *Pica pica* | Resident | Mixed forests | | | 1 | | 1 |
| *Garrulus glandarius* | Resident | Forest species | 1 | | | | 1 |
| *Garrulus glandarius/ Pica pica* | Resident | Undetermined | | | 1 | | 1 |
| *Cyanopica cyaenus / Pica pica* | Resident | Mixed forests | | | 1 | | 1 |
| *Corvus corone/ frugilegus* | Resident | Undetermined | | | 4 | | 4 |
| *Coccothraustes coccothraustes* | Resident | Forest species | | | 3 | | 3 |
| *Ficedula hypoleuca* | Migration | Forest species | 1 | | | | 1 |
| *Anthus* cf. *trivialis* | Resident | Mixed forests | | 2 | | | 2 |
| *Fringilla coelebs* | Resident | Forest species | | 1 | | | 1 |
| *Emberiza citrinella/ cirlus* | Undetermined | Mixed forests | 1 | | 2 | | 3 |
| Aves indet. | Undetermined | Undetermined | 172 | 52 | 176 | 4 | 404 |
| **TOTAL** | | | **195** | **61** | **218** | **8** | **482** |

human occupation of the shelter during the spring/summer in later times.

In terms of biocoenoses, Epipalaeolithic birds essentially indicate an open landscape, given the presence and relative abundance of the Red-legged partridge, Common quail (*Coturnix coturnix* Linnaeus, 1758) and Red-necked nightjar (*Caprimulgus ruficollis* Temminck, 1820) (table 3). Occasional woodland species, such as the Eurasian jay and the Common cuckoo (*Cucculus canorus* Linnaeus, 1758), indicate the presence of pockets of forest, whereas the remaining taxa indicate either the presence of rocky outcrops or else an unspecified environment. A drastic faunal turnover took place during the Mesolithic, when strictly woodland birds -including three species of woodpeckers – attain *ca*. 78% of the total bird NISP of that stage (table 3). The woodland signal was still strong during the subsequent Neolithic, although the presence of birds inhabiting more open landscapes hints at a clearance of the forest (table 3).

## 3. Assessing climate and landscape through time

The various groups considered in this analysis converge to signal similar conditions at Cova Fosca through time, although each specific group yields slightly different information. This complementary information reveals different aspects of the surrounding ecosystems.

In the case of pulmonates (*i.e.* terrestrial molluscs), these constitute a reliable group of bioindicators at CFSC due to their often restricted mobility. Generally speaking, land snail requirements are often strict in terms of air temperature (with optima ranging here from 10ºC to 27ºC) and relative humidity (normally above 70%). Such narrow margins often force land snails to restrict their activity during the coldest and driest months of the year, when they tend to hibernate and/or aestivate, often in aggregations that depend on various circumstances (Cook 2001). The behavioural repertoire to avoid freezing includes hibernating in caves or shelters where abrupt shifts in temperature are unlikely. It is unsurprising that the two dominant species at CFSC (*i.e.* the Round-mouthed snail, *Pomatias elegans* and the Decollate snail, *Rumina decollata*) both exhibit such behaviour. However, ecologically there are some differences between these two species. The Decollate snail is more tolerant (*i.e.* more eurioic) of shifting temperatures and moisture year-round, being able to prosper both in the harsher conditions of Mediterranean and mountainous environments, as well as in drier places (Moreno-Rueda 2002). In contrast, *P. elegans* is a more thermophilic (*i.e.* warmth-loving) and moisture-dependent snail, whose lower tolerance renders it a more precise indicator of climate (Sparks 1969). Therefore, the fluctuating NISP values exhibited by both species hint in particular at temperature and humidity changes that took place from the end of the Pleistocene to the end of the Middle Holocene. Such climatological changes are supported by the presence of the Ladder snake in the Holocene levels, whose distribution is restricted to areas were the mean annual temperature is above 10ºC.

At Cova Fosca, the Round-mouthed snail exhibits its lowest frequencies during the cold and arid stages of the Late Pleistocene. Meanwhile, it dominates the terrestrial mollusc assemblages during the so-called humid and transitional stages of the Middle and early Late Holocene in the Iberian Peninsula, characterised by higher temperatures and more moist conditions (figure 2) (Carrión *et al.* 2004; Pérez-Obiol *et al.* 2011). This pattern of shifting frequencies through time in the two pulmonate species seems best explained in strictly climatological terms. An alternative explanation based on the feeding habits of these species is less consistent with the data. This is because the abundance of the Decollate snail -- a carnivore/scavenger – relies on the availability of animal foodstuffs, and such animal (macromammal) waste actually increases towards the youngest levels, where the presence of humans, and their prey, becomes more frequent (table 1). Indeed, the single relevant discordance visible in figure 2 – that is, the maxima in the frequencies of *R. decollata* at the nearby Mesolithic site of Mas Nou – again suggests a climatological constraint. Mas Nou is an open-air site where the possibilities for avoiding dehydration, as well as the possibilities for penetrating into crevices or burrowing deep into the soil during diapause periods, are far more restricted than at Cova Fosca. Climate, then, rather than feeding habits, would explain in a far more consistent manner the differences in the frequencies between the two species, both temporally and spatially. The fact that these frequencies were markedly different at a site lying a mere 500 m from CFSC is consistent with the restricted capacity for movement that pulmonate snails exhibit, and highlights their potential for revealing local (*i.e.* micro-environmental) conditions rather than regional, macro-scale differences. Therefore, it seems that the decrease of the Round-mouthed snail at the end of the Middle Neolithic hints at the onset of more arid conditions that benefit the Decollate snail.

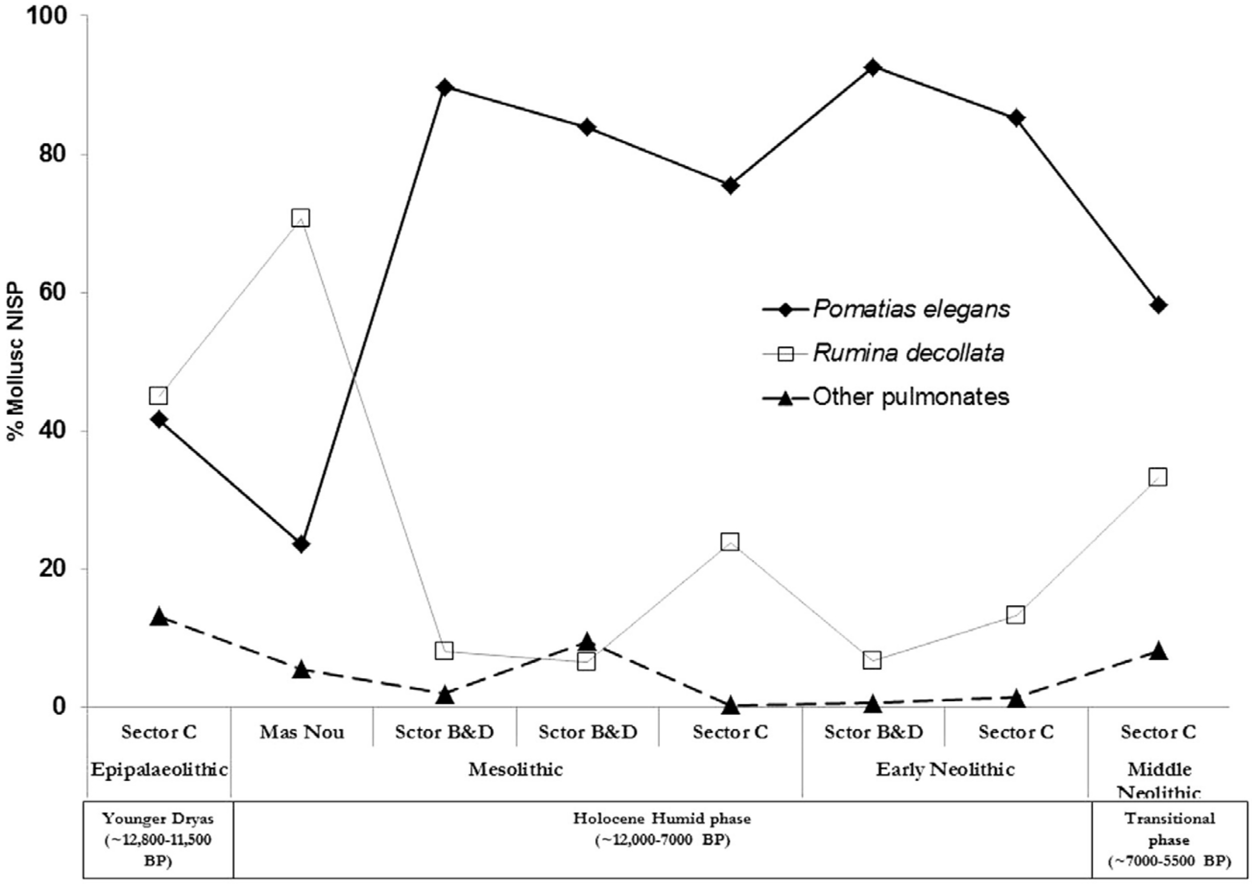


Figure 2: Frequencies of terrestrial molluscs through time in the inner area of Cova Fosca (Sectors B and D) and the entrance (Sector C) as well as from the Mesolithic site of Mas Nou (Vásquez and Rosales 2003). The samples follow a chronological order.

Birds have also been extremely useful in depicting the landscape around Cova Fosca, in terms of the shifting frequencies of open *vs.* woodland species through time (table 3). As expected, the latter group was predominant during the Mesolithic and Early Neolithic that coincided with the Holocene Climatic Optimum. In particular, the presence of three species of woodpeckers in the Mesolithic assemblages reveals the development of a forest around the site that, according to the palynological analyses, corresponds to a Mediterranean sclerophilous woodland mixed with shrubland and riparian forests (Yll 1988). Forest birds were still an important component of the avian assemblages during the Neolithic, where they represent 52% of the bird NISP. The bird assemblages from the inner sectors at Cova Fosca (*i.e.* B and D), of which the time range also covers the Mesolithic and Early Neolithic, reveal the presence of forests mixed with open land (Vilette 1988). In the latter case, partridges would be the only representatives from open land environments, and the Eurasian jay the sole forest indicator (it should be noted, however, that the identification of the Barbary partridge *Alectoris barbara* requires confirmation, as it is an alien species in the Iberian Peninsula today). The remaining species from these periods all inhabit mixed landscapes and only the Lammergeier (*Gypaetus barbatus* Storr, 1784) is associated with rocky outcrops.

The woodland signature during the Atlantic period is also hinted at by rodents (Sesé 2011). In this way, the absence of the squirrel in the Middle Neolithic levels can be tentatively associated with an opening of the forests that apparently started around this time in the region (see Carrión 2012). Likewise, the presence of both Cabrera’s vole (*Microtus cabrerae*) and the Mediterranean pine vole (*M. duodecimcostatus*) up until the Early Neolithic can be interpreted along the same lines as the absence of the squirrel. Compared with the taxa reported for the interior of the shelter by Alcalde (1988), CFSC incorporated five additional species of micromammals (*i.e.* the two insectivores and the two bats, in addition to the squirrel and Mediterranean vole among the rodents). Still, despite our far larger samples, we failed to retrieve remains of the European snow vole (*Chionomys nivalis* Martins, 1842) recorded by Alcalde.

To summarise the available data, it seems clear that despite evidence of a trend of increasing temperature from the earliest to the latest stages of the occupation, the data on moisture and woodland development do not seem to exhibit such a directional trend. Indeed, all of the bioindicator groups that have been analysed suggest that the Epipalaeolithic and Middle Neolithic were the driest stages but in opposite scenarios of cold (Epipalaeolithic) and warm (Middle Neolithic) temperatures, when in both cases more open landscapes prevailed. The Mesolithic and Early Neolithic levels, on the other hand, provided the clearest faunal evidences of dense forests that, in view of the presence of woodpeckers as well as other forest species such as pine martens (Llorente-Rodríguez *et al.* 2016), must have been mature by all standards, albeit spotted with bushy areas for the Ocellated lizard and Ladder snake to prosper. The extent to which the opening of the Early Neolithic woodlands was brought about exclusively by climatic changes, or by deforestation resulting from the activities of Neolithic herders and their flocks, requires further research. However, our results fit well with the Holocene palaeobotanical record, which points towards an important vegetation turnover taking place at *ca. 5,*500 BP derived from an aridification process (Carrión *et al.* 2004; Pérez-Obiol *et al.* 2011). This situation became more marked from the third millennium cal. BC onwards when the first drastic human landscape transformations took place in the eastern Iberian highlands, as the palaeobotanical record shows (López-Sáez *et al.* 2010). For such reasons, it seems that the earliest presence of the production economies in the Levantine Mountains must have been restricted.

## 4. Assessing the human occupation

The level of resolution is one of the key issues one faces when trying to address problems dealing with synchronicity and associations in both the palaeontological and the archaeological records. As such, it constitutes a basic tool for taphonomic analysis *sensu* Lyman (2010). An inadequate level of resolution can often lead to the identification of pseudo-associations of items, with seriously misleading consequences when attempting to reconstruct past sequences of events or behaviours. This problem is compounded when, as is so often the case with animal remains, items do not exhibit a precise chronological signature but instead range over a large time interval, or when archaeological levels do not represent short-term episodes but rather time-averaged series.

In such scenarios, animal remains can be of use when they exhibit and/or imply features that provide clues about the homogeneous nature of the deposits where they accumulated. If, as part of those features, they additionally incorporate traits (*i.e.* signs) hinting at past human behaviour, those taxa could further be taken as direct or indirect proxies of anthropic activity.

That humans occupied Cova Fosca at different stages seems beyond question (see *e.g.* Olària 1988; López and Olària 2008; Llorente-Rodríguez *et al.* 2014). However, more remains to be said about the nature of that occupation, whether permanent or seasonal, and whether different occupation patterns existed that could be associated with hunter-gatherers or with herders. We thus turn again to the microfaunal record at Cova Fosca to see whether it can help us address some of these points.

Ethnographical studies indicate that while land snails are consumed regularly, those below 5 cm are never consumed (Claassen 1998). In addition, most land snails have well-defined requirements, including preference for or aversion to human occupation (Davies 2008). This information can be used to investigate the nature of the occupation that took place at any given site, and can thus help to shed light on Cova Fosca.

The biology of the two main species of pulmonates (*i.e. Pomatias elegans* and *Rumina decollata*) indicates that both form aggregations when entering diapause, often involving large numbers of individuals, whether during the winter or the summer (Evans 1972). Given the altitude of Cova Fosca and its associated oro-Mediterranean climate of very harsh winters and relatively mild summers, one can therefore assume that the majority of the snails retrieved in the excavations represent natural deaths that took place during hibernation/aestivation.

That these two species – and land snails in general – took refuge in caves when these were abandoned by humans is an idea that has been repeatedly put forward and which relies upon contemporary information regarding behaviour during diapause (Aparicio

2001; Bragado *et al.* 2010; Evans 1972; Martinez-Ortí 1999; Martinez-Ortí and Robles 2003, 2005). Higher frequencies of small-sized land snails would thus hint at sporadic and/or seasonal human occupations. Given that the frequencies of the Open-mouthed and Decollate snails at CFSC represented more than 50% of the sample in almost all of the levels, a continuous occupation by humans seems highly doubtful. The fact that the terrestrial molluscs from inside the shelter exhibit similar trends in terms of taxonomic diversity, abundance (350 remains, 3 species, 4 genera) and dominance, as well as the fluctuation of *P. elegans* and *R. decollata*, lends support to the scenario of seasonal/sporadic human occupation, as this allows terrestrial molluscs to aggregate in larger numbers during periods of abandonment (Oller 1988).

Birds often constitute excellent bioindicators in zooarchaeological studies, not only due to their close association with specific aspects of the landscape – especially those relating to roosting and nesting places – but also because of their migratory behaviours (Morales-Muñiz 1996, 1998). Their diversity, the highest among the terrestrial vertebrates at CFSC, favours such bioindicator potential. Birds additionally constitute a valuable tool from a taphonomic standpoint, since most species can be straightforwardly allocated as items preyed on by humans (*e.g.* waterfowl, gallinaceous birds and some other terrestrial taxa of large size such as Bustards, etc.), predators (*e.g.* all the non-gregarious passerines) or birds living in the shelter or surrounding landscape, as is the case for several corvid species and certain raptors that nest on cliffs and rocks (Morales-Muñiz 1996, 1998).

Bird studies are not without problems, such as the difficulty of identifying vertebrae, phalanges, ribs or skull bones to species level, as well as the taphonomic biases dealing with their usually small bone size and the real challenge for many passerine families to be determined to species level (*e.g.* Bochenski and Tomek 1995; Morales-Muñiz 1993). In addition, many species exhibit latitudinal size gradients (clines), and their sizes fluctuated as temperatures shifted during glacial and interglacial cycles. The birds from CFSC exemplify most of these drawbacks. Firstly, and despite the meticulous retrieval techniques employed, their numbers pale in comparison with those of mammals, as they amount to fewer than 500 remains within a faunal collection of close to 100,000 items (*i.e.* 1.7% of the NISP; tables 1 and 3). Secondly, less than a fifth of the bird assemblages could be identified taxonomically (*ca.* 16%) and only 80% of the 35 taxonomically recognised categories were species (table 3). Nonetheless, their great bioindicator potential can still be valuable for interpreting occupation patterns at Cova Fosca.

To start with, the bird assemblage from Cova Fosca does not feature a single aquatic species, something that indicates little or no development of shores around the site, including those along water bodies, rivers, and so forth. By contrast, when compared with other Spanish Levantine sites (table 4) the contribution of passerine birds at Cova Fosca is the most significant, not only in terms of NISP but, above all, in terms of taxonomic diversity. Indeed, the passerines at Cova Fosca represent 60% of all bird taxa recorded, an unusual feature among Spanish Levantine sites.

In the case of CFSC, a majority of taxa were represented by a single bone and a good many others by two or three remains (table 3). Such a pattern runs contrary to human predation behaviour, which tends to focus on few taxa but exploit them intensively. The more eclectic behaviour on the part of most (animal) predators not only yields far more diverse assemblages but also a dominance pattern where the most frequent

| **SITE** | **Aquatic non passerines** | **Terrestrial non passerines** | **Passerines** | **TOTAL** |
|---|---|---|---|---|
| Cova Negra | 2 | 14 | 18 | 34 |
| Cova Beneito | 2 | 11 | 8 | 21 |
| Cova Fosca (C) | - | 13 | 15 | 28 |
| Volcan de Faro | 6 | 8 | 4 | 18 |
| Els Blaus | - | 6 | 4 | 10 |
| Les Cendres | 3 | 10 | 8 | 21 |
| Cova Matutano | - | 13 | 4 | 17 |
| **TOTAL** | **12** | **39** | **31** | **82** |

Table 4: Number of taxa from selected categories in the sites considered. [Data taken from Martínez-Valle (1996) and Albiol *et al.* (1999)].

taxa tend to exhibit far less marked abundances (Stephens and Krebs 1986).

Even in the case of taxa that can be exploited by humans, there are at Cova Fosca three instances of skewness in terms of abundance, namely the Rock pigeon / Stock dove (referred to as *Columba livia/oenas* in table 3) which constitutes 23% of the birds, the Red-legged partridge representing 18% (a figure that would rise to 38% if the specimens identified to genus (*Alectoris*) and family level (Phasianidae) were shown to belong to that species), and the two chough species that, combined, represent *ca.* 15% of the identified bird remains. In terms of taphonomic considerations, whereas the Red partridge and the Rock pigeon are often documented as items regularly hunted by people (the former particularly so in the Iberian Peninsula, see Hernández-Carrasquilla 1992), corvids in general – and choughs in particular – are rarely hunted in a systematic way. Since choughs nest in caves, their presence in an archaeological cave deposit can most plausibly be taken to represent natural deaths, and this is a condition that one could equally apply to other birds nesting in caves, rocks, cliffs, and so forth, such as the Rock pigeon. Thus, although it is always impossible to achieve a reliable characterisation whenever Rock pigeons, a potential hunted item, appear in very low frequencies (*e.g.* below 10% of the NISP/MNI) at a cave site one needs to consider the possibility that these may represent natural accumulations, rather than items preyed on by people. This same argument applies to partridges, although in this case, and given that in Iberia partridges constitute regular prey for a wide range of animals, low frequencies of partridges could be interpreted in terms of samples preyed on by raptors or carnivores. The fact that this same 'pattern' was recorded in Sectors B and C indicates that this was a robust feature of the bird assemblages from Cova Fosca (Vilette 1988).

From this standpoint, the notion is reinforced that bird faunas from Cova Fosca largely represent accumulations of animal predators, most probably raptors. Notably, this scenario fits two other lines of evidence, namely (i) the total absence of traces of anthropic manipulation in the bird bones, and (ii) the correlation of the bird abundances with those from other microfaunal groups at any given level (see above). As such, most, if not all, of the Cova Fosca birds were deposited as a result of natural deaths or biological agents unconnected with human activities, thus taking place at moments when humans were not in the shelter. This emphasises the discontinuous nature of the occupation of the site throughout the whole sequence, and brings us to the related issue of seasonality.

It is important to be especially cautious when assigning season to birds, as migratory habits may change abruptly; for example, what today qualifies as a winter visitor might have qualified as a resident in the colder pulses of the Pleistocene (Morales-Muñiz 1998). In our analysis, we have considered as resident such species as the Woodcock, Red kite, Sparrowhawk, Wryneck, Robin, Mistle thrush and Hawfinch, which, despite being well-established breeders in Iberia at the present time, undertake partial migrations that bring many wintering individuals down from northern European latitudes. A more complicated situation is that of the Chiffchaff, which is presently typified as a wintering species, even though it maintains a reduced population of breeders in the Pyrenees, and the situation of the Tree pipit that, qualifying today as a summer visitor, never reaches further south of the river Ebro (Díaz *et al.* 1996, 1999). These two species have been characterised here as resident and summer visitors, respectively. Finally, we have the case of the White throat, which is currently recorded in the Spanish Levant as a migratory species (*i.e.* records peaking during March/April and August/September; Díaz *et al.* 1999; Polo and Polo 2007) and has been considered as such in our study.

Once these phenological considerations are taken into account, a third and most remarkable feature emerges from the bird assemblages at CFSC: namely, the comparatively high number of summer visitors it exhibits (table 3). As previously noted, an intense summer signal exists at Cova Fosca, which is based on 10 bird taxa. In terms of taxa, summer visitors represent 37.5% of all birds recorded during the Epipalaeolithic, 25% during the Mesolithic, 21.7% during the Early Neolithic and 33% during the Middle Neolithic (table 3). Likewise, in terms of NISP these values would be 13%, 33%, 12% and 25% respectively (table 3). In other words, the summer signal appears to have been highest in the stages prior to the onset of the Neolithic and lowest at the very beginning of this period. Though the samples at our disposal obviously do not allow us to push the argument too far, if the birds at CFSC indeed represent assemblages unlikely to accumulate during human occupation of the shelter, then their shifting abundances through time point to a correlation between the intensity of the human occupation and the (decreasing) strength of the summer signal. As a corollary, the onset of the Neolithic at the site demonstrates an intensification of human occupation during the benign time of the year, which is not only counterintuitive, but also runs counter to the human occupation strategy recorded for the two pre-Neolithic stages.

An equally informative, and complementary, signal from the standpoint of seasonality has to do with the complete absence of wintering birds at CFSC. It is true that wintering species often represent rare items in terms of NISP in bird assemblages, but wintering birds have been widely recorded at other sites of the Spanish Levant, such as Cova de les Cendres, Cova Beneito or Cueva del Volcán de Faro, although this may be due to their proximity to the coast (Martínez-Valle 1996; Albiol *et al*. 1999). In this context, the general absence of wintering birds and particularly waterfowl at Cova Fosca could be taken as indicative of an abandonment of the cave during the harshest part of the year. This would reinforce the idea of a seasonal movement of people, whether hunter-gatherers or herders, outside the shelter during winter. If humans were keen to exploit this resource of wintering birds that often concentrate in huge numbers, we would expect them to have moved during winter to the numerous coastal lagoons, marshlands and wetlands that still dot the Levantine shoreline to this day.

In terms of seasonality, therefore, when one combines the presence of summer and occasional migratory birds with the total absence of wintering taxa at Cova Fosca, we may suggest the following:

A. During the Epipalaeolithic and Mesolithic, the (sporadic) human occupation does not seem to have taken place during summer or winter, at least not in a preferential manner. This, in turn, suggests that human visits to the shelter probably coincided with the equinoxes.

B. Seasonality might also have been the case during the Early Neolithic, yet the decrease in summer birds at this time suggests that the intensity of the occupation was at its highest during spring/summer, in that the predators preying on those birds did not leave a clear signal during that part of the year. The connection between this 'new' pattern of seasonal occupation and the appearance of the first domestic animals in the deposits seems compelling.

C. The 'summer signal' continued, albeit apparently in a less marked manner, during the Middle Neolithic. This may be equivalent to saying that the stockbreeding practices became more intense. Still, if one considers the sharp decrease in bird remains attested in these levels, such a conclusion might not be warranted; it is thus important to seek additional lines of evidence to confirm this.

### *4.1 Microfaunas in, humans out*

Natural aggregations of hibernating/aestivating land snails, bats and reptiles, as well as owl pellets featuring rodents and birds, appear to account for most of the microfaunal assemblages at Cova Fosca. As these accumulations presumably took place at times when humans were not occupying the shelter, the pooled frequencies of these faunas serve also as proxies of the intensity of the human occupation through time. When contrasted with the pooled frequencies of taxa assumed to have been hunted by humans (*i.e.* ungulates; figure 3), patterns emerge of the human use of the shelter as well the intensity of the occupation. The data gathered from these two categories of faunal groups through time hint at a more sporadic human use of the shelter during the Epipalaeolithic. During the Mesolithic this occupation apparently intensified, despite a discontinuity exhibited by the comparatively high frequencies of microfaunas (figure 3). Despite the seasonal signal mentioned for birds, it appears that human occupation gained momentum gradually throughout the Early Neolithic, with the domestic ungulates associated with human agropastoralists becoming the dominant signal coinciding with the end of the sequence during the Middle Neolithic.

Similarly, 25% of the sample of 544 identified remains from the second-richest of the levels incorporating pulmonates (*i.e.* level -255/262) were rodents, and a further 4% were small birds (*i.e.* mostly passerines) (figure 3). Likewise, the third-richest level in terms of pulmonates (*i.e.* level -298/308) incorporated 1,401 identified faunal remains, of which 58% were rodents and 7% small birds. In addition, this level featured some 25% of the bats documented at Cova Fosca. These bats belonged to the species *Myotis blythii*, well known for its wintering colonies (Mitchell-Jones *et al*. 1999). Finally, in the fourth-richest level in terms of pulmonates (*i.e.* level -235/242), almost all of the remains (84%) belonged to land snails, with vertebrates there amounting to a mere 3%.

A most noteworthy feature of these levels where pulmonates and micro-vertebrates dominated the faunal spectra is their location in the chronostratigraphic sequence. Indeed, all levels appeared at the transition between cultural horizons (*i.e.*

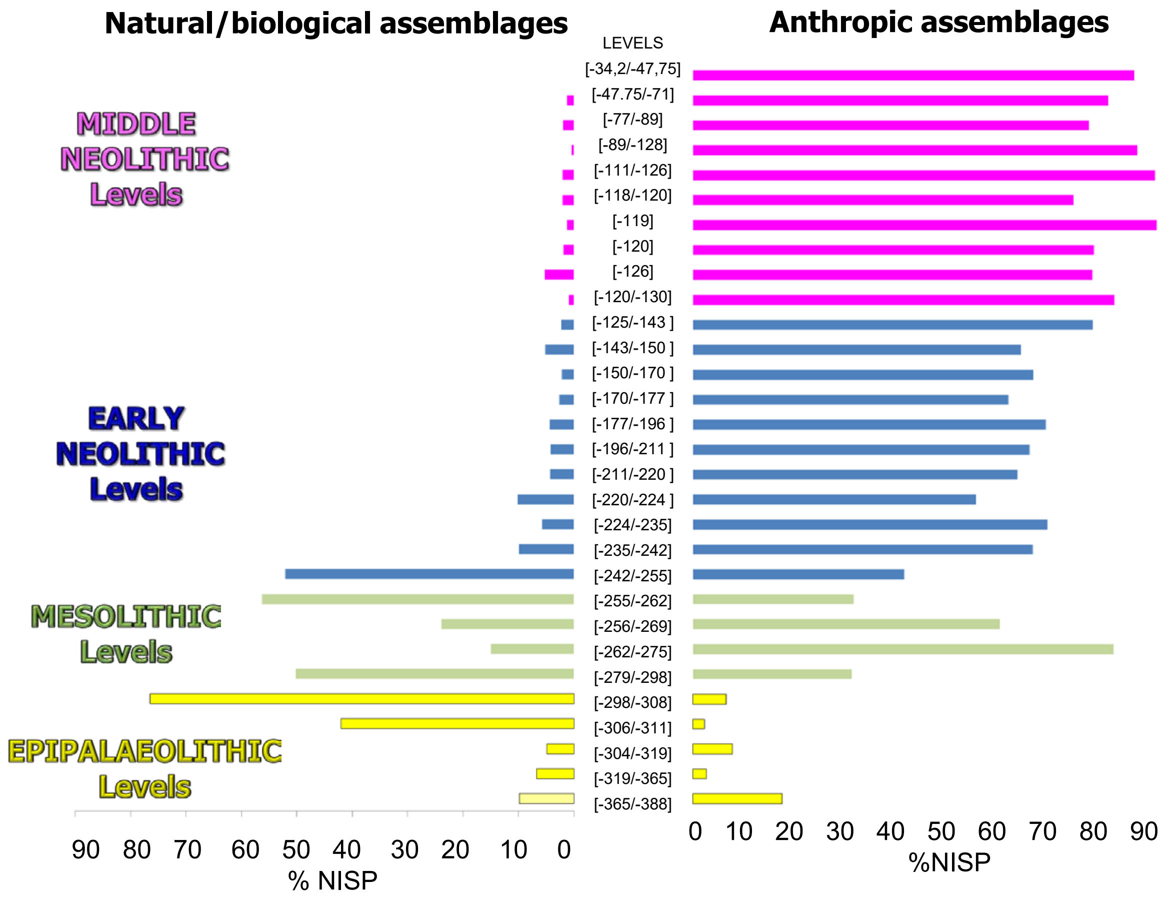


Figure 3: Pooled frequencies of NISP microfaunas throughout the stratigraphy compared with the pooled frequencies of ungulates at CFSC.

the Early Neolithic-Mesolithic and the Mesolithic-Epipalaeolithic), suggesting that it was precisely during these transitional periods when humans made less intensive use of the shelter. These hiatuses in terms of human occupation underscore that the anthropogenic assemblages at CFSC represent discrete horizons.

## 5. Conclusions

The data emerging from the best bioindicator groups within the faunal assemblages from Cova Fosca inform us not only about the different environmental episodes widely accepted for the Late Pleistocene and Early-Middle Holocene stages, but also about the nature of the occupations taking place at the shelter. In this way, the Epipalaeolithic was characterised by open-dry landscapes and colder temperatures, the latter increasing during the ensuing stages. Warmer temperatures and humidity in the area seem to have peaked in the Middle Holocene levels, which would explain the significant increase in woodland species at that time. Alongside the palaeobotanical data of the region, the microfauna from Cova Fosca reinforces the hypothesis of an important development of forests within the last half of the sixth millennium BC. This situation changed in the ensuing 500 years, when the driest stage with open landscapes dominated. A combination of environmental and anthropic events may lie behind this landscape clearance, but to come to a more detailed picture it will be necessary to conduct more in-depth and interdisciplinary research.

Both hunter-gatherers and herders seem to have visited the shelter sporadically, although an intensification of human activity seems to occur at the end of the sequence. This might be related to herding activities becoming more frequent on the site. In terms of seasonality, independent of the cultural group involved, humans seem to have occupied the shelter preferentially during spring and late summer/autumn, to take advantage of the plentiful resources offered by this oro-Mediterranean region during these seasons.

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## References

Albiol, A., Q. Galobart, M. Martin and S. Menendez 1999. Estudio de la macrofauna del sector 2. In: C. Olària (Ed.), *Cova Matutano (Vilafamés, Castellón). Un modelo ocupacional del Magdaleniense superior-final en la vertiente mediterránea peninsular*, Monografies de Prehistoria i Arqueologia Castellonenques, 5, Diputación de Castellón, Castellón, 297-307.

Alcalde, G. 1988. Análisis de microfauna. In: C. Olària (Ed.), *Cova Fosca. Un asentamiento Meso-Neolítico de cazadores y pastores en la serranía del Alto Maestrazgo*. Monografies de Prehistoria i Arqueología Castellonenques, 3-SIAP, Diputación de Castellón, Castellón de la Plana, 339-344.

Aparicio, M.T. 2001. Malacofauna terrestre del yacimiento de Cubío Redondo (Matienzo, Cantabría), *Munibe* 53, 61-66.

Bochenski, Z.M. and T. Tomek 1995. How many comparative skeletons do we need to identify a bird bone? *Courier Forschungsinstitut Senckenberg* 181, 357-361.

Bragado, M.D., R. Araujo and M.T. Aparicio 2010. *Atlas y Libro Rojo de los Moluscos de Castilla-La Mancha. Organismo Autónomo Espacios Naturales de Castilla-La Mancha*, Junta de Comunidades de Castilla-La mancha, Guadalajara.

Carrión, J.S. (Coord.) 2012. *Paleoflora y paleovegetación de la Península Ibérica e Islas Baleares: Plioceno-Cuaternario*, Ministerio de Economía y Competitividad and Universidad de Murcia, Murcia.

Carrión, J.S., E.I. Yll, K.J. Willis and P. Sánchez 2004. Holocene forest history of the eastern plateaux in the Segura Mountains (Murcia, southeastern Spain), *Review of Palaeobotany and Palynology* 132 (3-4), 219-236.

Claassen, C. 1998. *Shells*, Cambridge University Press, Cambridge.

Cohen, A. and D. Serjeantson 1996. *A manual for the identification of bird bones from archaeological sites*, Archetype Publications, London.

Cook, A. 2001. Behavioural Ecology: on doing the right thing, in the right place at the right time. In: G.M. Barker (Ed.), *The Biology of Terrestrial Molluscs*, CABI, 447-487.

Davies, P. 2008. *Snails. Archaeology and landscape change*, Oxbow Books, Oxford.

Díaz, M., B. Asensio and J.L. Tellería 1996. *Aves ibéricas. I. No Paseriformes*, J.M. Reyero Editor, Madrid.

Díaz, M., B. Asensio and J.L. Tellería 1999. *Aves ibéricas. II. Paseriformes*, J.M. Reyero Editor, Madrid.

Estévez, J. 1988. La fauna. In: C. Olària (Ed.), *Cova Fosca. Un asentamiento Meso-Neolítico de cazadores y pastores en la serranía del Alto Maestrazgo*, Monografies de Prehistoria i Arqueología Castellonenques 3. SIAP-Diputación de Castellón, Castellón de la Plana, 281-337.

Evans, J.G. 1972. *Land Snails in Archeology*, Seminar Press, London.

Fechter, R. and G. Falkner 1993. *Moluscos europeos marinos y de interior*, Editorial Blume Naturaleza, Madrid.

Francisco, C. de. 2009. *La malacofauna de Cova Fosca (Ares del Maestrat, Castellón)*. Bachelor thesis, Universidad Autónoma de Madrid, Madrid.

García Matarranz, V. 2013. G*uía de identificación de rapaces ibéricas por restos óseos (1ª parte, grandes rapaces)*, Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid.

Gusi, F. and C. Olària 1988. Trabajos arqueológicos: métodos aplicados y unidades de excavación. In: C. Olària, *Cova Fosca. Un asentamiento meso-neolítico de cazadores y pastores en la serranía del Alto Maestrazgo*, SIAP, Diputación de Castellón, Castellón de la Plana, 67-85.

Hernández-Carrasquilla, F. 1992. Some comments on the introduction of domestic fowl in Iberia, *Archaeofauna* 1, 45-53.

Kerney, M.P. and R.A.D. Cameron, 1979. *A Field Guide to the Land Snails of Britain and North West Europe*, Collins, London.

Kerney, M.P, R.A.D. Cameron and A. Bertrand 1999. *Guide des escargots et limaces d´Europe*, Delachaux et Niestlé, Neuchatel.

Llorente-Rodríguez, L. 2010. The hares (*Lepus granatensis*, Rosenhauer 1856) from Cova Fosca (Castellón, Spain), *Archaeofauna* 19, 59-97.

Llorente-Rodríguez, L. 2015. *Cova Fosca (Ares del Maestrat, Castellón): Zooarchaeology of the Neolithic Revolution in the Iberian Levant*, Unpublished PhD. Universidad Autónoma de Madrid, Madrid.

Llorente-Rodríguez, L., C. Montero García and A. Morales-Muñiz 2011. Earliest occurrence of the beech marten (*Martes foina* Erxleben, 1777) in the Iberian Peninsula. In: J. Brugal, A. Gardeisen and A. Zucker (eds), *Actes de les XXXIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes, Prèdateurs dans tous les ètats*, Éditions APDCA, Juan-les-Pins, 189-209.

Llorente-Rodríguez, L., J.J. García Ruíz and A. Morales-Muñiz 2014. Herders or hunters? Discriminating butchery practices through phalanx breakage patterns at Cova Fosca (Castellón, Spain), *Quaternary International* 330 (30), 61-71.

Llorente-Rodríguez, L., C. Nores Quesada, J.A. López-Sáez and A. Morales-Muñiz 2016. Hidden signatures of the Mesolithic-Neolithic transition in Iberia: The pine marten (*Martes martes* Linnaeus, 1758) and beech marten (*Martes foina* Erxleben, 1777) from Cova Fosca (Spain), *Quaternary International* 403,174-186.

López, J.L. and C. Olària 2008. Hallazgos antropológicos del 12000 al 7000 BP (Ares del Maestre, Castellón). In: C. Roca de Togores and F. Rodes Lloret (eds), *Actas de las jornadas de Antropología Física y Forense (Alicante, 2006)*, Instituto Alicantino de Cultura Juan Gil-Albert, Alicante, 47-55.

López-Sáez, J.A., L. López-Merino, S. Pérez-Díaz and F. Alba-Sánchez 2010. Paleopaisajes de Andalucía oriental durante la transición Mesolítico-Neolítico Antiguo. In: J.F. Gibaja and A.F. Carvalho (eds), *Os Últimos Caçadores-Recolectores e as Primeiras Comunidades Produtoras do Sul da Península Ibérica e do Norte de Marrocos*, Universidade do Algarve, Faro, 213-220.

Lyman, R.L. 2008. *Quantitative Paleozoology*, Cambridge University Press, Cambridge.

Lyman, R.L. 2010. What Taphonomy Is, What it Isn't, and Why Taphonomists Should Care about the Difference, *Journal of Taphonomy* 8 (1), 1-16.

Martínez-Ortí, A. and F. Robles 2003. *Moluscos continentales de la Comunidad Valenciana*, Generalitat Valenciana, Conselleria de Territori i Habitatge, Valencia.

Martinez-Ortí, A. and F. Robles 2005. Los caenogasterópodos terrestres (Mollusca, Orthogastropoda) de la Comunidad Valenciana (España), *Iberus*, 23(2): 7-24.

Martínez-Valle, R. 1996. *Fauna del Pleistoceno Superior en el País Valenciano: aspectos económicos, huellas de manipulación y valoración paleoambiental*, Valencia (Unpublished PhD thesis, Universidad de Valencia).

Mitchell-Jones, A.J., G. Amori, W. Bogdanowicz, B. Kryštufek, P.J.H. Reijinders, F. Spitzenberger, M. Stubbe, J.B.M. Thissen, V. Vohralik and J. Zima 1999. *The Atlas of European Mammals*, T and AD Poyser, London.

Morales-Muñiz, A. 1993. Ornithoarchaeology: the various aspects of the classification of bird remains from archaeological sites, *Archaeofauna* 2, 1-13.

Morales-Muñiz, A. 1996. Algunas consideraciones teóricas en torno a la fauna como indicadora de espacios agrarios en la Prehistoria, *Trabajos de Prehistoria* 53 (2), 5-17.

Morales-Muñiz, A. 1998. The Mobile Faunas: Reliable Seasonal Indicators for Archaeozoologists? In: T.R. Rocek and O. Bar-Yosef (eds), *Seasonality and Sedentism. Archaeological Perspectives from Old and New World Sites*, Peabody Museum Bulletin 6, Cambridge, 25-40.

Moreno Mañas, E. 1983. Una variación del patrón general del sternum de los Passeriformes, *Ardeola* 30, 109-113.

Moreno Mañas, E. 1985. Clave osteológica para la identificación de los Passeriformes ibéricos I: Aegithalidae, Remizidae, Paridae, Emberizidae, Passeridae, Fringillidae, Alaudidae, *Ardeola* 32 (2), 295-377.

Moreno Mañas, E. 1986. Clave osteológica para la identificación de los Passeriformes ibéricos, 2. Hirundinidae, Prunellidae, Sittidae, Certhiidae, Troglodytidae, Cinclidae, Laniidae, Oriolidae, Corvidae, Sturnidae, Motacillidae, *Ardeola* 33 (1-2), 69-129.

Moreno-Nuño, R. 1994. *Análisis Arqueomalacológicos en la Península Ibérica. Contribución Metodológica y Biocultural*, Madrid (Unpublished PhD thesis, Universidad Autónoma de Madrid).

Moreno-Nuño, R. 1995. Catálogo de Malacofaunas de la Península Ibérica, *Archaeofauna* 4, 143-272.

Moreno-Rueda, G. 2002. Selección de hábitat por Iberus gualtieranus, Rumina decollata y *Sphincterochila candidissima* (Gastropoda: Pulmonata) en una sierra del sureste español, *Iberus* 20 (1), 1-8.

Olària, C. 1988. *Cova Fosca. Un asentamiento meso-neolítico de cazadores y pastores en la serranía del*

*Alto Maestrazgo*, SIAP, Diputación de Castellón, Castellón de la Plana.

Olària, C. 2000. Nuevas dataciones de C-14 para el neolítico mediterráneo peninsular, *Quaderns de Prehistòria i Arqueologia de Castelló* 21, 27-34.

Oller, J. 1988. Estudio conquiológico y malacológico. In: C. Olària, (Ed.), *Cova Fosca: un asentamiento meso-neolítico de cazadores y pastores en la serranía del Alto Maestrazgo*, SIAP, Diputación de Castellón, Castellón de la Plana, 345-350.

Pérez-Obiol, R., G. Jalut, R. Julià, A. Pèlachs, M.J. Iriarte, T. Otto and B. Hernández-Beloqui 2011. Mid-Holocene vegetation and climatic history of the Iberian Peninsula, *The Holocene* 21(1), 75-93.

Polo, A. and M. Polo (eds). 2007. *Aves de la Comunidad Valenciana 2000-2001-2002*, Societat Valenciana d'Ornitologia, València.

Ruiz-Ruiz, A., A. Cárcaba Pozo, A. Porras Crevillen and J. Arrébola Burgos 2006. *Caracoles terrestres de Andalucía. Guía y manual de identificación*, Fundación Gypaetus-Junta de Andalucía, Sevilla.

Sesé, C. 2011. Micromamíferos (Erinaceomorfos y Roedores) del final del Pleistoceno Superior y primera parte del Holoceno de Cova Fosca (Alto Maestrazgo, Castellón): Reconstrucción paleoambiental del entorno del yacimiento, *Archaeofauna* 20, 119-137.

Sparks, B.W. 1969. Non-Marine Mollusca and Archaeology. In: D. Brothwell and E. Higgs (Coords.), *Science in Archaeology. A survey of progress and research. Revised and enlarged edition*, Thames and Hudson, London, 395-406.

Stephens, D.W. and J.R. Krebs 1986. *Foraging theory*, Princeton University Press, Princeton.

Vásquez, V. and T. Rosales 2003. *Informe sobre la malacofauna del yacimiento de Cingle del Mas Nou (Ares del Maestrat, Castellón)*, Unpublished LAZ-UAM interim report 2003/4.

Vilette, P. 1988. Análisis de los restos de avifauna. In: C. Olària (Ed.), *Cova Fosca. Un asentamiento Meso-Neolítico de cazadores y pastores en la serranía del Alto Maestrazgo*, Monografies de Prehistoria i Arqueología Castellonenques 3, SIAP-Diputación de Castellón, Castellón de la Plana, 329-337.

Yll, R. 1988. Análisis de polen y palinograma. In: C. Olària (Ed.), *Cova Fosca. Un asentamiento meso-neolítico de cazadores y pastores en la serranía del Alto Maestrazgo,* Monografies de Pre- historia i Arqueología Castellonenques 3, SIAP, Diputación de Castellón, Castellón de la Plana, 281-337.

Zilhão, J. 1993. The Spread of Agro-Pastoral Economies across Mediterranean Europe: A View from the Far West, *Journal of Mediterranean Archaeology* 6 (1), 5-63.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 73-88.

# Exploring the archaeological heritage of the Uddeler Heegde: an experiment

Alexander Verpoorte, David Fontijn and Arjan Louwen

*In the summers of 2013 and 2014 the Faculty of Archaeology of Leiden University has carried out archaeological fieldwork in a rather exceptional environment. Where since the implementation of the Valetta Treaty most excavations are aimed at ex-situ preservation of archaeological sites threatened by building activities, the site that was under investigation in 2013 and 2014 found itself in a nature reserve. As nature reserves are aimed at the very purpose of preservation, why then investigate an archaeological site that could easily profit from such a protected status? The recent access to high resolution LIDAR data for the entire surface of the present day Netherlands is only just beginning to reveal the richness of archaeological sites hidden beneath the foliage and undergrowth of the forests and heaths crammed in between the vast field systems of the Dutch countryside. From late prehistoric barrow landscapes and celtic fields to Medieval cart tracks, all these features still find themselves at the very surface in these nature reserves. These sites of various age can provide a unique glimpse into the past but their location at the very surface also makes these sites vulnerable and, as is becoming more clear in recent years, are threatened by nature itself. Tree roots, burrowing animals and ongoing podzolization are all examples of natural processes that gradually obscure these sites from sight. To map both the state as well as the research potential of such an archaeological 'palimpsest' an archaeological field experiment was carried out in one of the largest nature reserves of the Netherlands at a site called 'Apeldoorn – Uddeler Heegde'. This article reports on the most important new insights of the fieldwork in the form of a landscape biography.*

*Keywords: Nature reserves, landscape biography, AHN, barrows*

**Alexander Verpoorte**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
a.verpoorte@arch.leidenuniv.nl

**David Fontijn**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
d.r.fontijn@arch.leidenuniv.nl

**Arjan Louwen**
Faculty of Archaeology
Leiden University
P.O. Box 9514
2300RA Leiden
The Netherlands
a.j.louwen@arch.leidenuniv.nl

## 1. Introduction

Natural parks and nature reserves are perhaps the most important areas for the protection of archaeological heritage for the long term in the Netherlands and beyond. The archaeological richness of nature reserves has become even more visible by the availability of detailed Digital Elevation Models (AHN = Actueel Hoogtebestand Nederland). A pilot study in the municipality Apeldoorn, for example, found a significant number of prehistoric, medieval and post-medieval features on the second generation AHN (Van Heeringen *et al.* 2012). They included forty-two possible prehistoric burial mounds that were unknown so far and had no archaeological status as protected monuments. Most of these mounds were located in the national park of the Veluwe. This paper reports on a small experiment in the archaeology of nature reserves.

From an archaeological perspective, (at least) four issues regarding the archaeology in nature reserves come to the fore:

1. Nature reserves and natural parks are richer in archaeological heritage than expected on the basis of archives like Archis (Dutch National register of archaeological observations);
2. The AHN provides information about the 'visible' archaeology, the top of the 'iceberg' of less visible archaeological traces such as subsurface features, find scatters and other ephemeral traces;
3. Nature reserves are dynamic parts of the landscape where economic activities impact the soil, *e.g.* due to forestry and nature management; the quality of archaeological preservation in nature reserves is not as obvious as it may seem;
4. The implementation of archaeological field methods such as large surface stripping using mechanical diggers is problematic in a natural park where vegetation, soil life, and fauna require protective measures as well; investigation and protection of the archaeological heritage in nature reserves therefore requires an integrative approach (Elerie and Spek 2007; 2010).

The archaeological investigations in the Uddeler Heegde, municipality of Apeldoorn, Central Netherlands (figure 1), offered a unique opportunity to think about these issues. The Uddeler Heegde is a forested area that is part of the Royal Domain "Het Loo". It consists partly of 'old' forest, going back to medieval times (a so-called *malebos*) and new forest, dating to the reforestation in the 19th century for commercial purposes (de Rijk 1990, Jochems 1990). The research area is located on the western slope of the central, Saalian-aged, ice-pushed ridge of the Veluwe. The area was chosen because it contains a row of four possible prehistoric burial mounds, that were recently recognized on the AHN, as well as one mound, recog-

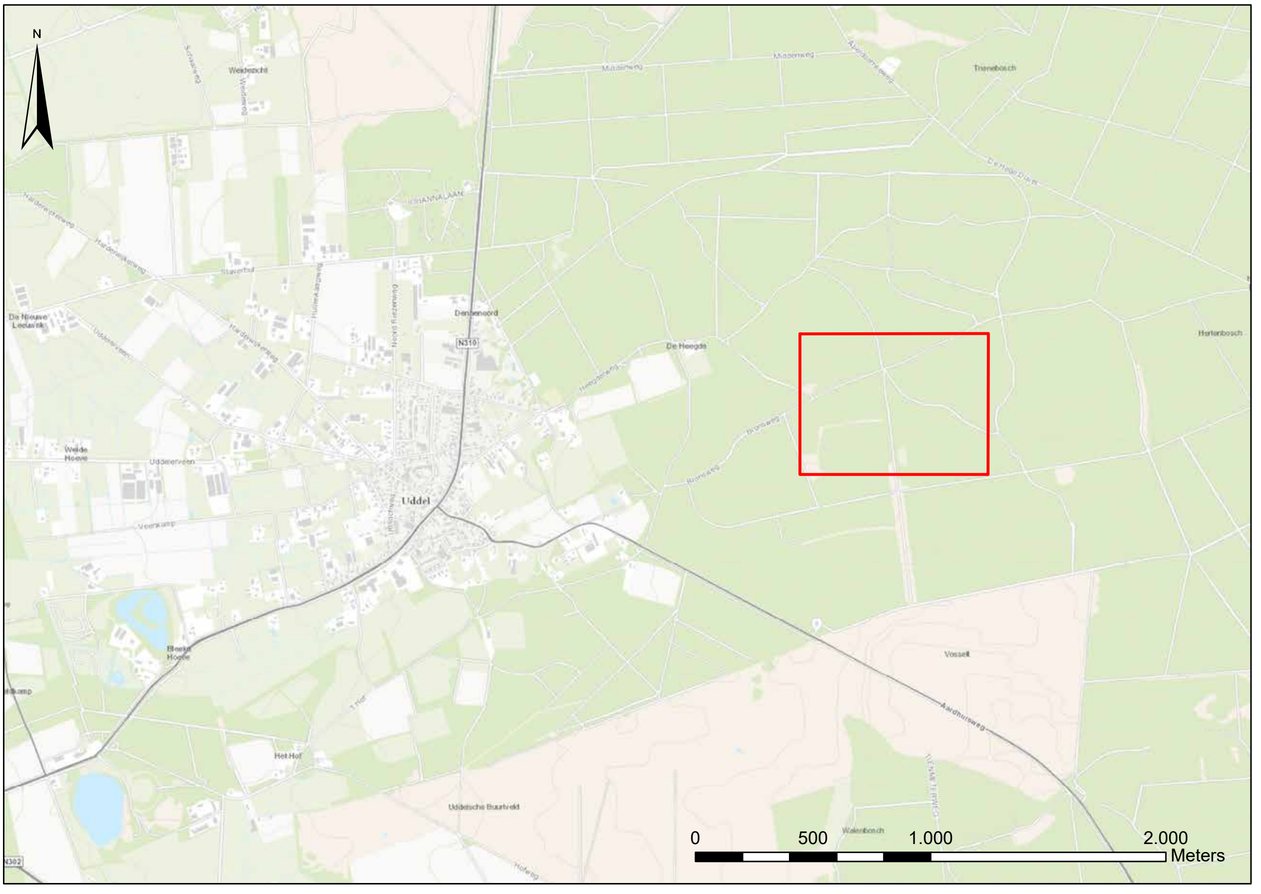



Figure 1: Location of the research area.

nized and protected as an archaeological monument. The aim of the fieldwork was: 1) to check whether the mounds were indeed anthropogenic, 2) document the barrow landscape, and 3) evaluate the preservation of archaeological traces. Another aim was to advice on protective measures. Specifically, we were interested in the effects of the so-called "10-meter-zone" of protection around burial mounds, and the minimum depth of disturbance before archaeological investigations are obligatory. Training of students was another important goal of our fieldwork. The fieldwork consisted of two campaigns of three weeks in 2013 and 2014 (Louwen *et al.* 2014, Fontijn *et al.* 2016).

## 2. Approach and Methodology

The approach for the Uddeler Heegde is to minimize the impact while trying to maximize information. The strategies were inspired by a number of sources. One source of inspiration was a paper titled 'Making time work' by Evans *et al.* 2014. The question of what is lost by the routine method of machine stripping made us aware of the importance of ploughsoil archaeology. Artefact distributions such as scatters of pottery or lithics may signal human activities that are easily overlooked when the focus is only on (cut-and-fill) features such as ditches, pits and postholes. Another source of inspiration was the issue of palimpsests and place

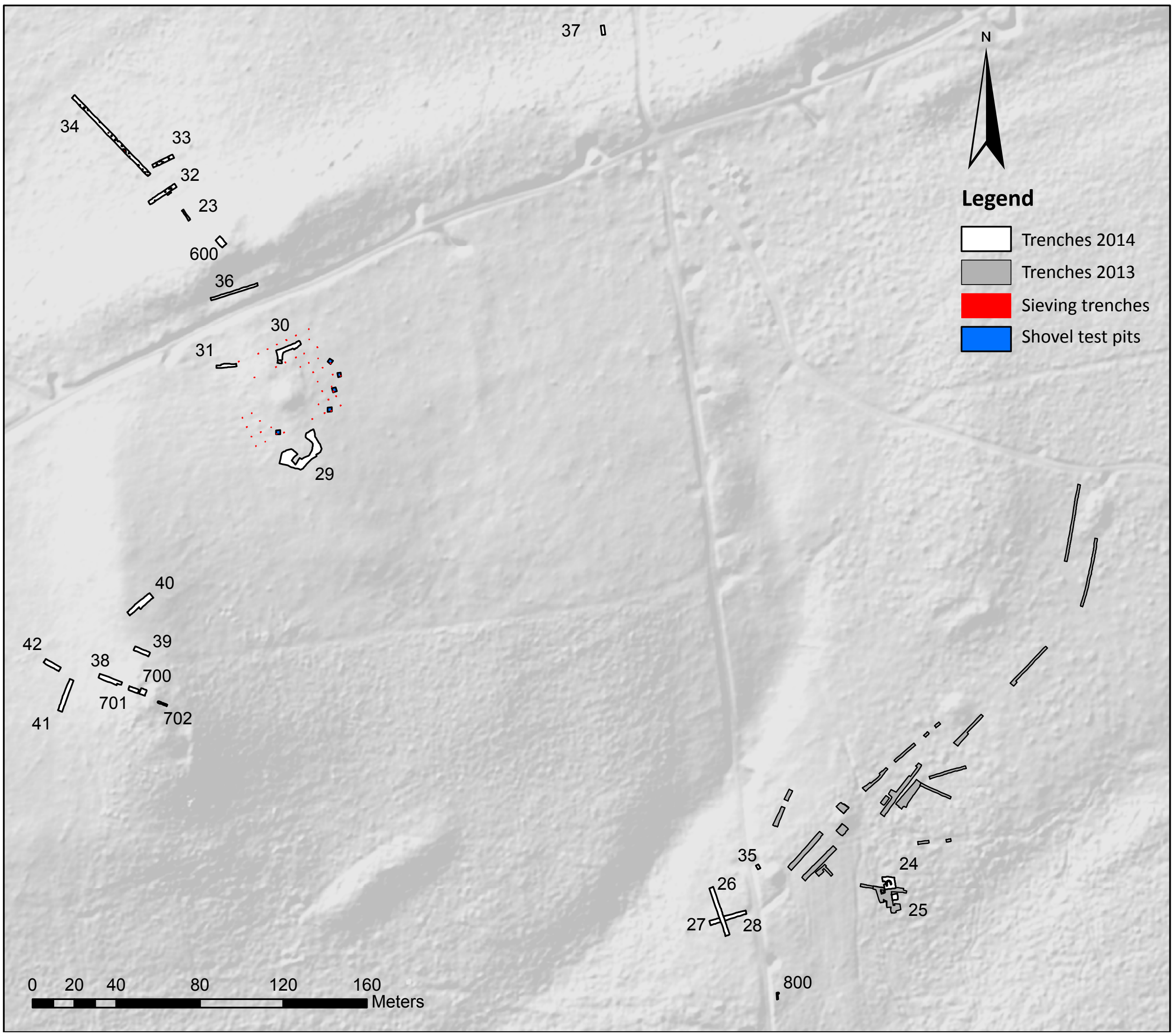



Figure 2: Location of test trenches in the research area.

use histories (*e.g.* Binford 1982, Bailey 2007, Fanning *et al.* 2009). Focusing on the prehistoric barrows, this made us think about the extent to which the building of barrows 'disturbed' an already inhabited landscape or 'protected' earlier, inhabited land surfaces, and to what extent the prehistoric barrows 'structured' later uses of the landscape. The place use history includes geological history, landforms, soil development as well as the traces of 19th century forestry activities. Overall, we may consider our approach as a form of microarchaeology (cf. Weiner 2010). Protecting the ever scarcer, diverse and more valuable heritage demands a strategy of minimizing the use of destructive and invasive methods like standard excavation, while maximizing the information gained from new investigations, given budgetary and organizational constraints.

Based on these broader considerations, the following mix of methods was applied in the research area of the Uddeler Heegde:

1. Trenches were dug with a small excavator (3.5 ton), mostly narrow (120cm – one bucket wide), sometimes irregular in shape to keep at least four meters away from the trunk of beech trees, deepened until 5 to 15 cm below the ploughsoil; small parts (1 meter wide) were deepened with an excavator for geological investigation;
2. Test pits were dug by hand (2x2 m and 50x50 cm), mostly removing the A-horizon with shovel, and the B-horizon with trowel; a sample of 25 liter was dry sieved and checked in the field;
3. So-called "Boxes" in (possible) mounds were excavated by hand using a shovel, sized 3x3 m to 5x5 m, with extensions if needed, with one level each 15 cm; sections with paleosols were sampled for pollen;
4. Metal detection was used systematically in all trenches and boxes;
5. Augerings to identify soil types, lithology, and plowing were made with an Edelman auger (7cm, 10cm or 12cm in diameter), in rows (lines), every 10 meter, up to a depth of ca 100cm below plough-soil, maximum over 200cm;
6. Small sections along roads and water pits were cleaned by shovel for additional observations.

The distribution of trenches is illustrated in figure 2.

## 3. Results

We present the results in the form of a landscape biography of the Uddeler Heegde. But it is a biography with gaps and breaks, with periods of amnesia and parts unmemorized.

The oldest traces that we documented date back to the Saalian age. Fine sands, dated to 250,000 years ago, were probably deposited by the Rhine-Meuse river system (Busschers 2008). These deposits were transformed by the activity of the Late Saalian glaciers that shaped the landscape and created the main aspect of the current relief. With the melting of the glaciers at the end of the Saalian, large amounts of sediments were transported by meltwater streams and filled in glacial basins. The deepened section in trench 29 exposed laminated, more or less gravelly, sands with cross-beddings, occasional microloadings and some imbrications (figure 3). We interpret the sediments as

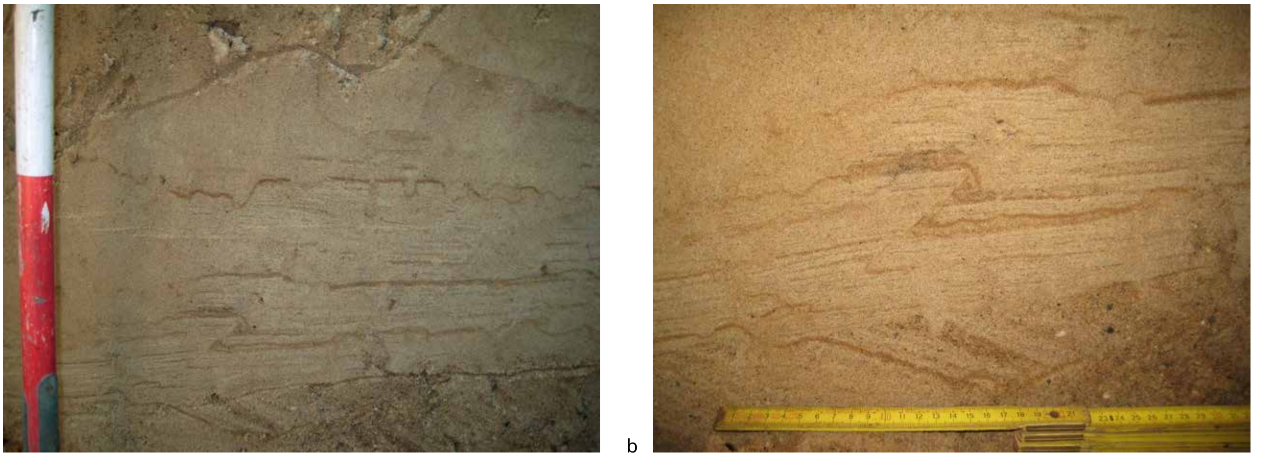
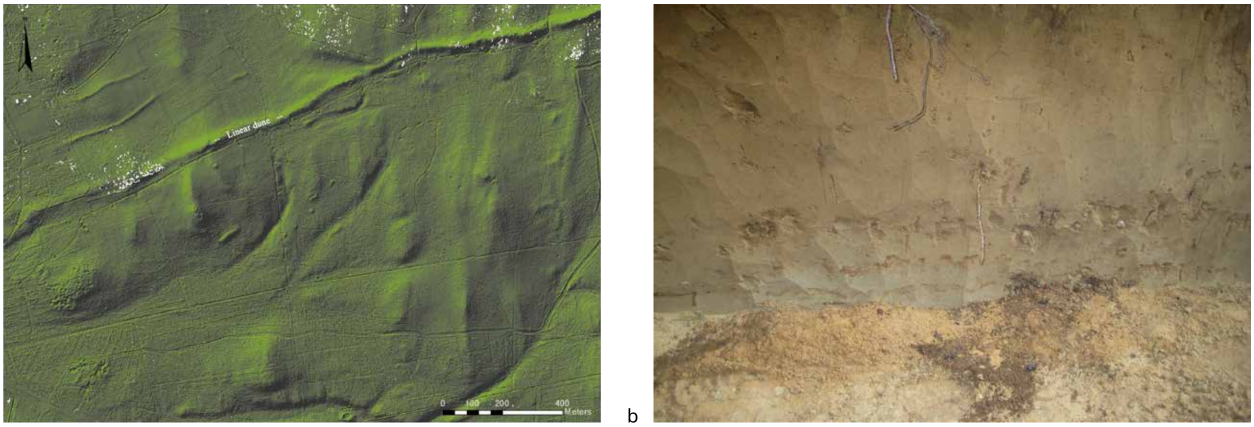
a  b

Figure 3: Details of sedimentary structures: (a) microloadings (red pole is 20 cm); (b) fault (scale in cm).




a b

Figure 4: (a) Partial view of the linear dune (from west to northeast corner) with (b) section with gravel layer interpreted as Beuningen Gravel Bed (section is ~150cm wide).

melt water deposits near the edge of the stagnant or retreating glacier (cf. kame terraces as described by Eilander *et al.* 1982). Cover sands were deposited on the landscape during the Weichselian.

We documented two features associated with aeolian action at the end of the Weichselian. Across the Uddeler Heegde runs an east-west oriented linear dune, dating to the Younger Dryas period (figure 4a). Linear dunes are formed by two prevailing wind directions approximately perpendicular to each other, in this case a northwesterly and a southwesterly wind. A small trench at the base of the dune exposed a section with a line of small gravels, predating the formation of the linear dune (figure 4b). We interpret this gravel bed as the Beuningen Gravel Bed, formed by deflation around 16,000 years ago (Vandenberghe *et al.* 2013). At the end of the last ice age, near-surface sediments dominated by coarser to finer sands have the relief that is more or less the same as can be observed today.

Evidence of human presence is documented in the vicinity of the Uddeler Heegde from the Late Paleolithic onwards. A surface collection with Hamburgian material is known from the Groot Zeilmeer as well as Elspeet and we may assume that Paleolithic and/or Mesolithic hunter-gatherers visited the research area. However, we have not found any traces from this period in our excavation. The earliest evidence of human habitation is a weathered ceramic fragment that may date to the Late Neolithic.

More substantial evidence of human land use dates back to the Bronze Age. It consists at least partially of a landscape of barrows, including a short alignment of four mounds with a length of approximately 250 meters, and an isolated burial mound approximately 300 meters to the west. Barrow H5 is the largest and protected as an archaeological monument, but the age and exact nature of the mound remain unknown and it is not evident that it has a Bronze Age construction date (figure 5; table 1).

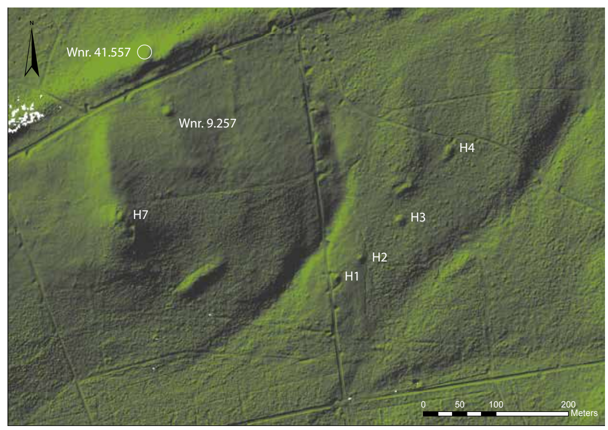



Figure 5: Overview of the barrow landscape. H1 to H4 indicate four mounds of an alignment. Wnr 41.557 turned out to be a natural elevation of the top of the linear dune. Wnr 9.257, in the text indicated as barrow H5, is a protected archaeological monument. The mound indicated with H7 proved to be also an anthropogenic mound.

The four barrows in alignment are between 50 and 100 meter apart. Barrow H2 was partially excavated using two boxes in the margins of the mound. An old surface with paleosol and dispersed charcoal was visible below an overlying unit in which the topsoil (a humuspodzol) was formed

Figure 6: Section of barrow H2.


Figure 7: Section of barrow H7.

(figure 6). No strata or sods could be recognized due to bioturbation and soil formation. Two charcoal samples from the top of the paleosol have been dated and provide a *terminus post quem*. The results indicate that the mound was probably constructed during the Middle Bronze Age in an open environment where alder trees were present in the wetter parts of the landscape (Doorenbosch 2013, 139). For the moment, our hypothesis is that the alignment was erected during the Middle Bronze Age; at least we have no indications for a Late Neolithic origin.

Barrow H7 was also tested to check whether the mound was of anthropogenic origin. It is positioned on a marked location on a high ridge. Despite significant

| | | Barrow type | Burial type | Diameter | Height | Phases | Dating | Remarks |
|---|---|---|---|---|---|---|---|---|
| alignment | H1 | n.d. | n.d. | < 10 m | < 1 m | n.d. | n.d. | |
| | H2 | Featureless | n.d. | ~ 10 m | > 0.5 m | Not visible | Terminus post quem<br>1858-1627calBC<br>1900-1691calBC | Small posthole below barrow |
| | H3 | n.d. | n.d. | 10-20 m | ~ 1 m | n.d. | n.d. | |
| | H4 | n.d. | n.d. | 10-20 m | ~ 1 m | n.d. | n.d. | Small mound attached |
| isolated | H5 | n.d. | n.d. | > 20 m | > 2 m | n.d. | n.d. | Protected monument (AMK nr 116) |
| | H7 | Featureless | n.d. | ~ 10 m | > 0.5 m | Not visible | Middle Bronze Age (ceramic, typology) | Sods? |

Table 1: Overview of the barrows of the Uddeler Heegde (n.d. = no data).

disturbances in the immediate surroundings, an old surface with dispersed charcoals and the overlying sediment unit were recognizable (figure 7). Whether or not the mound was constructed with sods remains ambiguous, because the field observations were not straightforward. Phases of construction were not visible. No distinct, peripheral features were found.

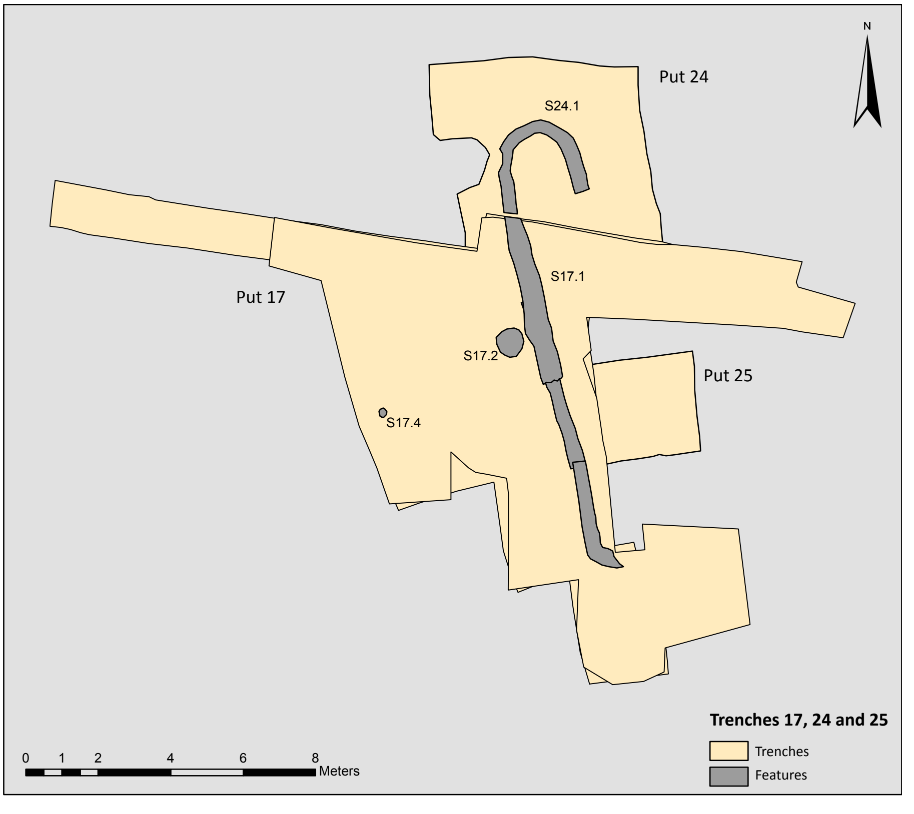
The small barrow group of the Uddeler Heegde fits well in a wider pattern. Bourgeois (2013) describes an increase of barrow construction activities including the reuse of older barrows during the Middle Bronze Age. New barrows were constructed in Late Neolithic barrow landscapes for example at nearby Ermelo. In addition, new locations were chosen for mound building, probably on already existing heathlands that were used as pastures and commons. As we found no evidence of Late Neolithic barrows, the Uddeler Heegde seems to be a case of this Middle Bronze Age expansion of the barrow landscape.

Almost a millennium later, the barrow landscape was reused for cremation burials. We uncovered a small urnfield in the vicinity of barrow H2. The full extent of the urnfield cannot be reconstructed anymore, because large parts of the surroundings have been disturbed by ploughing. We found positive evidence of four ring ditches, one more elongated or oval ring ditch, and one so-called *langbed* (elongated ditch). One of the ring ditches had an opening towards the southeast. Two ring ditches contain a cremation grave. Another ring ditch contained a concentration of charcoal, perhaps the last remnants of a cremation grave (figure 8).

The two cremation graves were dated using the apatite fraction of cremated bone. S8.1 is dated in the range 916-836 calBC (95.4% probability), whereas S14.4 falls between 902 and 822 calBC (95.4% probability) (table 2). The results are virtually the same, dating both cremation graves in the Late Bronze Age. Cremation grave S8.1 (figure 9a) was lifted as a block and carefully excavated in the laboratory (de Bondt 2015). It consists of a small, bowl-shaped pit of circa 60 cm diameter, with some grave goods, mainly in the top of the fill, and almost 900 grams of cremated human remains mostly in the lower part of the fill. Charcoal fragments were dispersed throughout the fill, but the majority was found at the top. It seems that little of the infill has been lost. The remains are highly fragmented, but still provide important clues. The cremation contains the remains of at least two individuals, one male and one possible female. Both are adults, one possibly an older individual. Two vertebral fragments have some indication of osteoarthritis, but it is not conclusive; no other pathologies were observed. The amount of cremation is far too small for complete individuals, indicating that skeletal elements were carefully selected from the pyre.

Grave goods were found in the top of the fill and consists of about 50 ceramic sherds and one bronze fragment. No animal bones were discovered. Some of the sherds have a distinct decorative pattern of fields with horizontal or vertical incisions and recall the shape of a *Henkeltasse* (figure 10). Some sherds were secondarily heated. It is not clear whether all the sherds belong to one and the same pot, however, it is clear that the pot or pots are not complete and were probably included with the cremated remains as pottery fragments. The bronze fragment is a 2 cm long and 2 cm wide thin sheet of bronze with six triangular dentitions, possibly a small part of a serrated knife, serrated sickle (cf. Steensberg type


a




b

Figure 8: Overview of ring ditches, elongated ditch and barrows. A. Plan of the ring ditches. B. Plan of the elongated ditch.

V) or perhaps a grooming tool (figure 11). It was not burned secondarily.

The second cremation grave S14.4 has not been studied in the same detail (figure 9b). It consists of a small, bowl-shaped pit of circa 50 cm diameter. At least fragments of cranium, ribs, vertebrae, pelvis and femur could be recognized among the cremated human remains. They were concentrat-


a

b

Figure 9: A. View of cremation grave S8.1 in the field. B. View of cremation grave S14.4 with ring ditch with opening.

ed in a compact cluster of approximately 20 cm diameter. Small charcoal fragments were only observed at the base of the infill. It seems likely that the remains do not represent a complete individual, but are a selection of fragments from the pyre. No grave goods such as pottery or bronze were found.

Almost another millennium later, during Roman times, two cremations were buried in the immediate vicinity of the largest barrow H5 (figure 12). One

Figure 10. Decorated pottery sherd, probably fragment of a *Henkeltasse* (scale in cm).

Figure 11: Thin bronze fragment with serrated edge (scale in mm).

| Sample name | Dated material | Lab Code | $^{14}C$ age (yrs BP; 1σ | Calibrated result (95.4% probability) |
|---|---|---|---|---|
| S8.1_v336 | Apatite | GrM-12324 | 2742 ± 15 | 916 – 836 calBC |
| S14.4_v525 | Apatite | GrM-12326 | 2715 ± 15 | 902 – 822 calBC |
| S30.1_v500 | Apatite | GrM-12323 | 1988 ± 15 | 40 calBC – 56 calAD |
| S30.5_v634 | Apatite | GrM-12082 | 1880 ± 15 | 74 – 210 calAD |

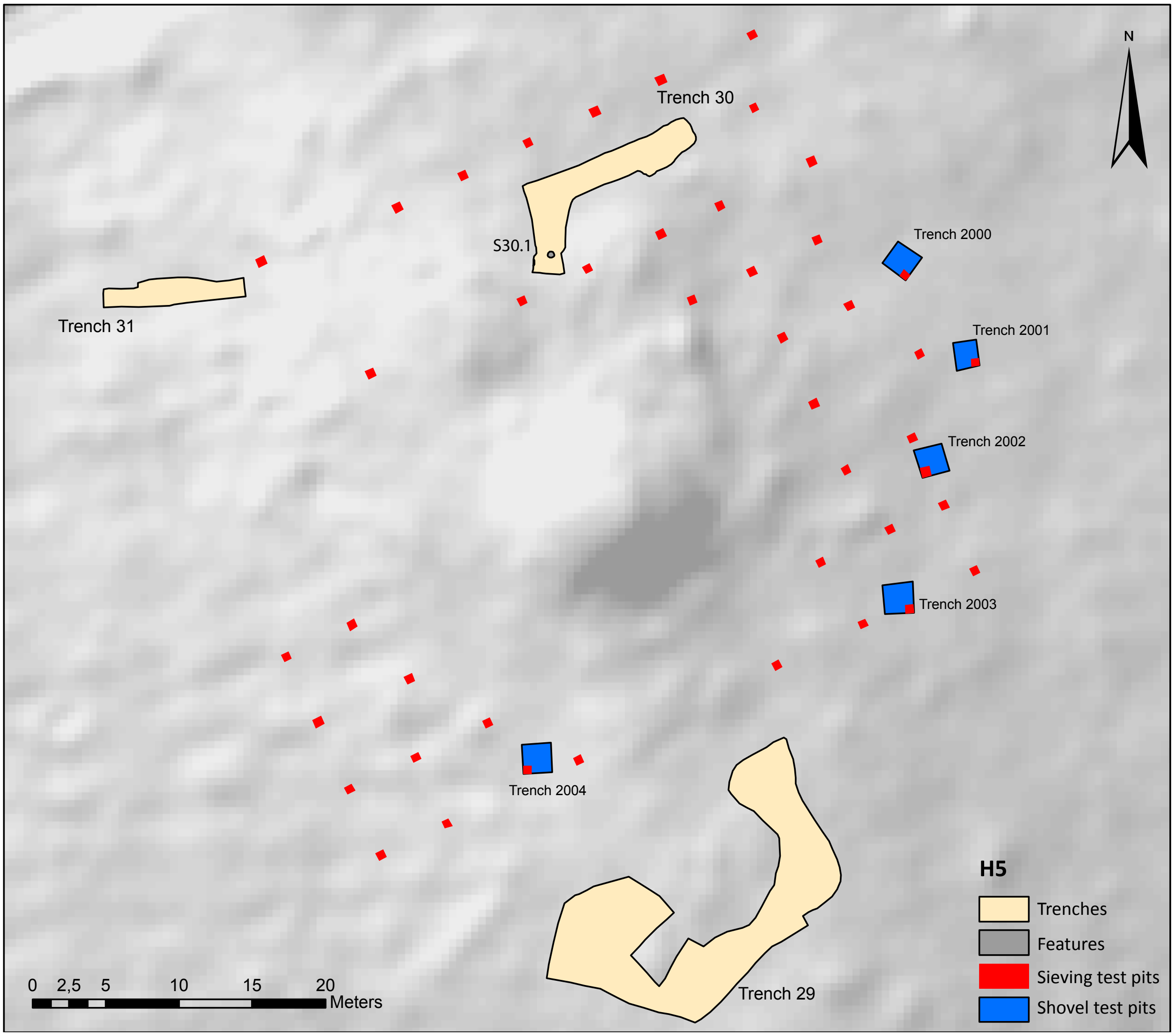
Table 2: Radiocarbon dating of cremated remains from the Uddeler Heegde.

cremation grave S30.1 consists of a small, bowl-shaped pit of circa 50 cm cross-section with dispersed cremated remains and charcoal in the infilling. Radiocarbon dating of the apatite fraction returned an age range of 40 calBC to 56 AD (table 2). The other cremation grave S30.5, dated to 74-210 AD (table 2), was only documented in a section. The grave is also a small, bowl-shaped pit with dispersed cremated remains and charcoal. No other finds such as grave goods were found and no ring ditch or other peripheral features were encountered in the area.

Except for burial practices, ephemeral traces of other practices have been discovered in the surroundings of barrow H5. Thirty five sherds of hand-formed pottery were found scattered near the surface to the north of the barrow. The sherds are all weathered with abraded breaks indicating that they were lying on or near the surface for quite some time. Two sherds exhibit possible rodent gnaw marks. The majority of the sherds date approximately to the Bronze to Roman Age, one could be Late Neolithic and another is probably late medieval. The sherds do not seem to relate to habitation as we did not find any features such as postholes. Many scenarios can be offered in explanation such as broken pots from collecting food and materials in the woods, post depositional disturbance of the graves of which the sherds were originally part, or ritual fragmentation as part of the mortuary practices that also involved the burial of the cremations.

More than a millennium later, during the 11-13th century AD, the Uddeler Heegde was used for the production of charcoal. This land use is documented by the discovery of one *Grubenmeiler* in trench 34 (figure 13). The pit was approximately 140 cm in cross-section with a depth of about 80 cm below current surface. Based on the sharp boundary between the A- and B-horizon, an estimated 10 to 15 cm was later removed from the surface, probably as a result of collecting litter and sods probably from the 17$^{th}$ to

Figure 12 (next page): Plan of trenches and test pits surrounding barrow H5 (center), with detail of the cremation graves S30.1 (a) and S30.5 (b).


N
Trench 30
S30.1
Trench 31
Trench 2000
Trench 2001
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Trench 2004
Trench 29
H5
Trenches
Features
Sieving test pits
Shovel test pits
0 2,5 5 10 15 20
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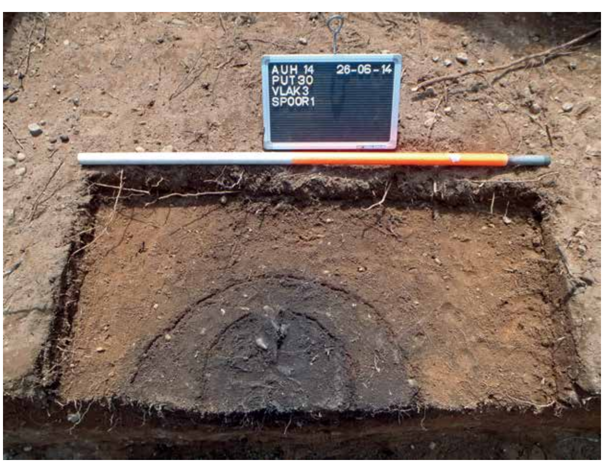

AUH 14 26-06-14
PUT 30
VLAK 3
SPOOR 1

a


AUH 14 26-06-14
PUT 30
VLAK 94
SPOOR 5

b


Figure 13: Location of the Grubenmeiler in section.

early 20th century. The pit has a flat base with straight sides. The infill consists of three units: a charcoal-rich, 20 cm thick layer at the base containing charcoal over 3 cm in diameter, a grey layer of 15 cm with dispersed charcoal fragments, and an upper, brownish layer of 40 cm with dispersed charcoals. There is no red discoloration of the sand below or beside the pit. All identifiable charcoals were determined as oak (*Quercus* sp.), mostly from the stem, some branches, and one possible root. A maximum of 23 tree-rings could be counted. Thirteen out of 100 fragments showed cavities filled with small charred pellets. They are the charred excrement of insect larvae that hatched in the wood (van Hees 2015, see also Van Hees *et al.* in this volume). Our hypothesis is that the Uddeler Heegde was in use for cutting wood and producing charcoal as well as keeping of animals such as pigs. The production of charcoal is frequently connected to iron production. We did not find indications of iron production in the Uddeler Heegde. Other late medieval traces have not been found – perhaps except for a small fragment of pottery in sieving residue of a shovel pit.

A significant change in the landscape of the Uddeler Heegde took place in the 19th century when parts of the area were planted with oak and douglas pine (figure 14). The most significant archaeological traces of this transformation in vegetation and landuse are ploughmarks. Large stretches of the research area are disturbed by ploughing. We documented parallel stripes of about 150 cm wide at regular intervals and found changes in the direction of ploughing, variation in types and sizes of ploughs, and differences in depth. The zonation of the original soil could be read in the horizontal plane with sometimes quite distinct A, E and B horizons. Other traces probably linked to forestry consist of shovel marks, indicating smaller scale turning of the soil. Parts of the research area, in particular north of the linear dune, were used for cutting sods or stripping the surface, resulting a sharp boundary between the current A-horizon and B-horizon in the soil profile. An estimated 15 cm of the soil profile has been removed. Only one part of the research area was not disturbed by ploughing: that is the beech forest, a remnant of the late medieval *malebos*. Here, the dominant soil type is the moder podzol in contrast to the dominance of humus podzols in the other areas (figure 15).

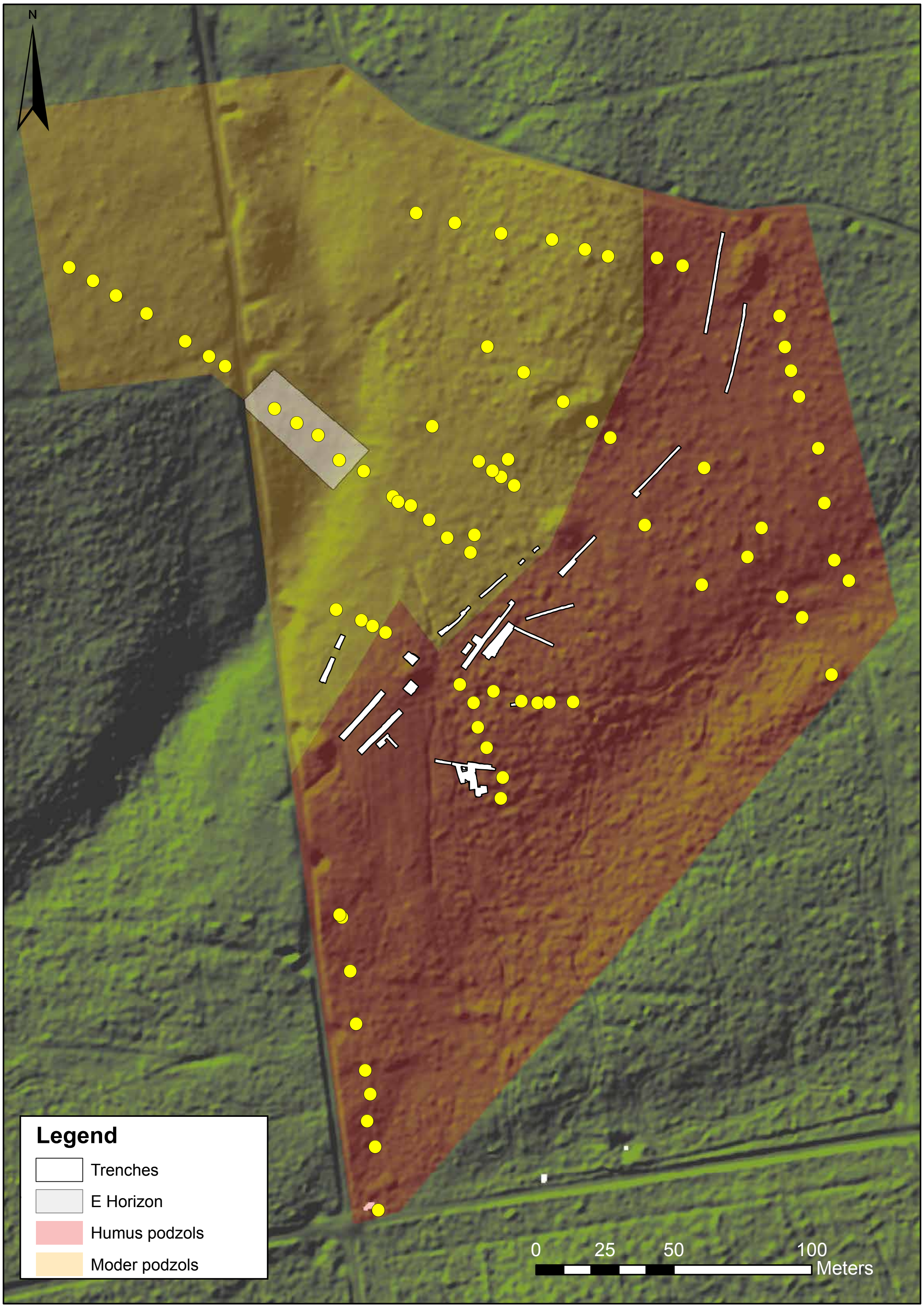
## 4. Discussion and conclusion

The investigations of the Uddeler Heegde illustrate the potential of nature reserves as archaeological archive. Its millennial-scale rhythm of human practice resulted in a variety of traces. However, none of these are related to houses, settlements or farming. Judging from the findings, there are at least three issues that deserve

Figure 14: Examples of plough and shovel marks.

further discussion: the methodology, the barrow landscape, and the preservation conditions.

The first issue concerns the advantages and disadvantages of the chosen methodology. The main advantage is the limited scale of impact of the methods which takes into account other, ecological values like vegetation and fauna as well as other types of landuse like the experience of visitors. Another advantage is that the combination of methods allowed us to scan a relatively large area in a limited amount of time with a restricted budget. In other words, it is a cost-efficient methodology to evaluate the preservation conditions in the research area. However, we should not disregard the disadvantages. The limited scale of impact also restricts the amount and quality of information. This is clearly demonstrated by the information about the barrows: for many aspects of the individual barrows, no data is available, which also limits the statements about the barrow group as a whole. The small boxes in the barrows are insufficient to recognize important aspects of mound construction such as phasing. The narrow trenches make recognizing pit-and-fill features and patterns of features such as postholes difficult because there is little contrast with the surrounding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sediment. In terms of a historical narrative, the information gained is limited and lacking in detail.

A second issue, related to the insights into prehistory that were gained, concerns the relation between the highly visible barrows and the invisible subsurface features, find scatters, and ephemeral traces. Taking into account the limitations of the data, the current evidence from the Uddeler Heegde is in accordance with a chronology of barrow landscape evolution where barrow construction increases significantly in the Middle Bronze Age. In contrast to the long time depth of the nearby Ermelo barrow landscape, the Uddeler Heegde can be interpreted as a new construction. The short alignment associated with a more isolated barrow on a marked location fits in a wider pattern of Middle Bronze Age barrow landscapes. The evidence of Late Bronze Age and Roman Age cremation burials as well as a scatter of Bronze to Roman Age ceramic sherds is testimony to the later reuse of this barrow landscape and the extent to which older barrows structured later activities. A brief scan of the evidence in the surroundings of barrows in the Netherlands makes clear how diverse the types of activities can be. There is not just evidence for other barrows, addition to barrows and secondary burial in existing barrows, but also evidence of houses, *spiekers*, alignments of posts, alignments of pits (with stones), round structures of postholes, cremation burials, urnfields, and depositions of pottery. Not to forget that the pollen evidence points to heathlands in use as pastures and as corridors for travelling, visiting, exchange and trade. It shows that barrows themselves are to some extent like the panda or polar bear: they are a pars *pro toto*, a symbol for a wider landscape.

A final issue to address is the preservation conditions and conservation measures adequate to the protection of the archive in nature reserves. Judging from the results of the Uddeler Heegde, two conditions are critical for preservation: 1) the history of forestry, and 2) soil formation. The history of forestry determines the degree of ploughing in plots. However, even in plots with significant disturbance by ploughing, small islands can be relatively well preserved as the case of the small urnfield demonstrates. Soil formation and associated bioturbation has a significant impact because traces are preserved in the upper part of the soil profile. Natural processes like tree-falls also lead to degradation of the archaeological archive. Small-scale soil disturbance during the cutting of trees for example can already touch on archaeological traces. If nature reserves are key to the long-term preservation of parts of the archaeological archive, then conservation measures need to be taken that are adequate for the factors that potentially disturb the archive, but also regarding the archive itself. Two measures are clearly inadequate for nature reserves. They are the 10-meter-zone around protected barrows and the minimum depth of disturbance before archaeological investigations have to take place. Based on the results of the Uddeler Heegde, there is no justification for either of these measures and certainly not for limiting protective measures to barrows only. Cremation burials, an urnfield and a scatter of ceramics were located outside the 10-meter-zone surrounding barrows demonstrating the range of human activities in the landscape. Any disturbance depth beyond the A-horizon would have disturbed if not destroyed these traces. To ensure that nature reserves function as long-term archaeological archives, the measures for securing conservation need to be adjusted to protect large areas and entire landscapes as well as entire soil profiles.

Figure 15 (previous page): Distribution of two podzol types in part of the research area.

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## References

Bailey, G. 2007. Time perspectives, palimpsests and the archaeology of time, *Journal of Anthropological Archaeology* 26 (2), 198-224.

Binford, L. 1982. The archaeology of place, *Journal of Anthropological Archaeology* 1 (1), 5-31.

Bourgeois, Q. 2013. *Monuments on the horizon. The formation of the barrow landscape throughout the 3rd and 2nd millennium BC*, Leiden: Sidestone Press.

Busschers, F.S. 2008. *Unravelling the Rhine. Response of a fluvial system to climate change, sea-level oscillation and glaciation*, PhD dissertation Free University Amsterdam.

De Bondt, E. 2015. A human cremation up close. Insights in the burial process of a Late Bronze Age/ Early Iron Age human cremation grave from Apeldoorn, the Uddeler Heegde, (Unpublished Research Master thesis Leiden University).

De Rijk, J.H. 1990. Vergeten Veluwse malebossen, *Nederlands Bosbouwtijdschrift* 62, 68-77.

Doorenbosch, M. 2013. *Ancestral heaths. Reconstructing the barrow landscape in the Central and Southern Netherlands*, Leiden: Sidestone Press.

Eilander, D.A., J.L. Kloosterhuis, F.H. De Jong, J. Koning 1982. *Toelichting bij de kaartbladen 26 Oost Harderwijk en 27 West Heerde*, Wageningen: Stiboka.

Elerie, H. and T. Spek 2007. Integratie van natuurbeheer en erfgoedzorg in De Strubben/Kniphorstbosch. Bouwstenen voor een historisch-ecologische benadering. In: J. Neefjes, Strootman Landschapsarchitecten (Amsterdam), and NovioConsult Van Spaendonck (Nijmegen), *Strubben Kniphorstbosch : Inrichtings- & Beheerplan*, Amsterdam: Strootman Landschapsarchitecten.

Elerie, H. and T. Spek 2010. The cultural biography of landscape as a tool for action research in the Drentsche Aa National Landscape (Northern Netherlands). In: J.H.F. Bloemers, H. Kars, A. van der Valk & M. Wijnen (eds) *The Cultural Landscape Heritage Paradox. Protection and development of the Dutch archaeological-historical landscape and its European dimension*, Amsterdam University Press, Amsterdam, 83-113.

Evans, C., J. Tabor and M. Vander Linden 2014. Making time work: sampling floodplain artefact frequencies and populations, *Antiquity* 88 (339), 241-258. doi:10.1017/S0003598X0005033X

Fanning, P.C., S.J. Holdoway, E.J. Rhodes and T.G. Bryant 2009. The surface archaeological record in arid Australia: geomorphic controls on preservation, exposure, and visibility, *Geoarchaeology* 24 (2), 121-146. https://doi.org/10.1002/gea.20259

Fontijn, D., A.J. Louwen, A. Verpoorte (eds) 2016. *Onder de bomen. Inventariserend veldonderzoek van het grafheuvellandschap van de Uddeler Heegde (Uddel, gemeente Apeldoorn)*, Leiden: Faculty of Archaeology, Leiden University.

Jochems, G.M. 1990. Inventaris Marken in de gemeente Apeldoorn (1452) 1458-1943 (unpublished electronic document) Apeldoorn: CODA Gemeentearchief Apeldoorn.

Louwen, A.J., D. Fontijn and A. Verpoorte 2014. *Vergeten graven. Inventariserend veldonderzoek in de directe omgeving van vier recentelijk ontdekte grafheuvels in de Uddeler Heegde (Uddel, gemeente Apeldoorn)*, Leiden: Faculty of Archaeology, Leiden University.

Vandenberghe, D.A.G., C. Derese, C. Kasse and P. Van den Haute 2013. Late Weichselian (fluvio-)aeolian sediments and Holocene drift-sands of the classic type locality in Twente (E Netherlands): a high-resolution dating study using optically stimulated luminescence, *Quaternary Science Reviews* 68, 96-113.

Van Heeringen, R.M., M.M. Janssens, B.A. Brugman and R. Schrijvers 2012. *Actualisering archeologische waardenkaart Gemeente Apeldoorn (*Vestigia rapport V911-1). Amersfoort: Vestigia.

Van Hees, E., 2015. *Insect infested wood used in charcoal production in a medieval pitkiln in the Veluwe, the Netherlands*, Poster at the 6th International Anthracology Meeting, Freiburg, Germany, 30/8 to 6/9 2015.

Van Hees, E., J. Pijnnaken-Vroeijenstijn and M. van Zon, 2020. Fiery forest management: an anthracological approach on the charred remains of medieval Noord-Brabant in Tilburg-Udenhout-Den Bogerd. In: V. Klinkenberg, R.M.R. van Oosten, C. van Driel-Murray (eds.), *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels APL 50* (Analecta Prehistorica Leidensia 50), Leiden: Sidestone Press.

Weiner, S., 2010. *Microarchaeology: beyond the visible archaeological record*, Cambridge: Cambridge University Press.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 89-106.

# Walking and marking the desert: Geoglyphs in arid South America

Karsten Lambers

*The narrow desert wedged between the Pacific Ocean and the Andes in South America is one of the most arid and inhospitable regions in the world. Yet it is also a striking example of human interaction with extreme environments. Geoglyphs – man-made markings of the ground surface in naturalistic or geometric shapes – cover portions of the desert in Chile and Peru at large scale, showing how the arid environment was used and shaped according to socio-cultural ideas and needs. Dating mostly from pre-historic times, the geoglyphs are preserved due to extreme environmental conditions and can still be appreciated today.*

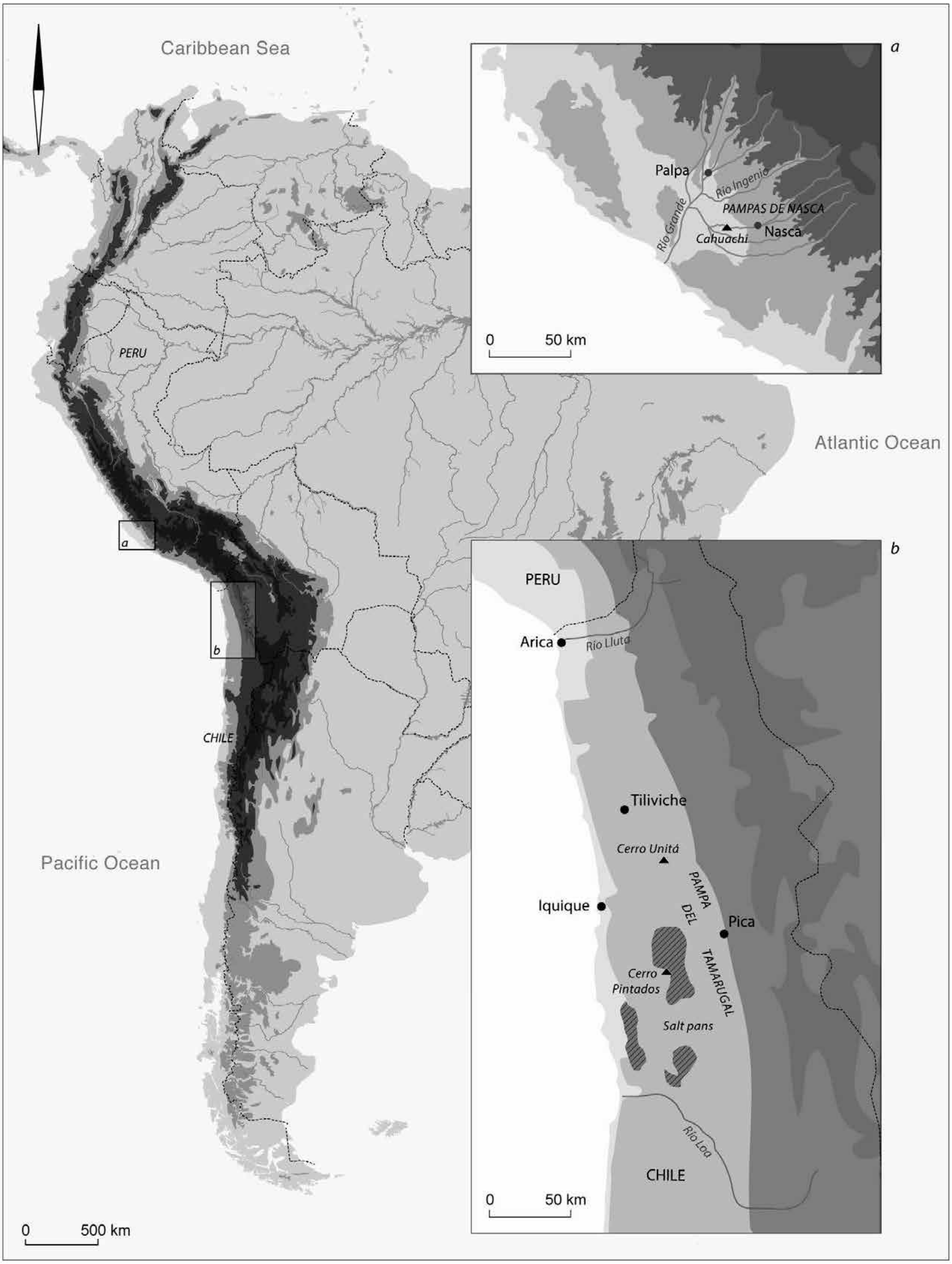
*This paper reviews archaeological evidence of geoglyphs in arid South America in order to shed light on their function and meaning. The two largest geoglyph concentrations, in the Nasca basin in south-central Peru and in the Atacama desert in northern Chile, serve as examples to discuss shared traits and differences between various geoglyph traditions. In spite of formal, functional, and chronological differences between geoglyphs of the two regions, there is evidence of a common conceptual framework in which ancient Andean societies interacted with the arid environment in diverse and complex ways.*

*Keywords: Geoglyphs; South America; Arid Environment; Landscape Archaeology*

## 1. Introduction

Geoglyphs are a distinctive element of the South American archaeological record. They are found in a variety of locations along the Pacific coast of the Americas, from California to Chile (Clarkson 1999; Rodríguez 1999; Valenzuela and Clarkson 2018). The term "geoglyphs" (Greek for "ground carvings") refers to man-made drawings of different size, shape and motif on the ground surface. They are most easily made, and best preserved, in a stable, arid environment where the ground surface may be easily altered manually yet is little affected by rain or wind erosion. In South America, such favorable conditions prevail in the coastal desert along the western foot of the Andes, where the ground surface is composed of a dark layer of oxidized stones covering a finer and lighter sediment beneath. The largest and best-known concentrations of geoglyphs are located in two such regions, the Nasca basin in south-central Peru and the Atacama desert in northern Chile (figure 1). While the geoglyphs in both regions exhibit a wide variety of shapes, proportions, and iconographic motifs, lines and trapezoids predominate in the Nasca region, whereas biomorphic and geometric figures are more common in northern Chile. The pre-historic earthworks in the Amazonian basin east of the Andes that were also called 'geoglyphs' in recent research (*e.g.*, Pärssinen *et al.* 2009; Watling *et al.* 2017) do not conform to the definition used here and are thus not treated in this overview.

**Karsten Lambers**
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
k.lambers@arch.leidenuniv.nl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PAMPA DEL TAMARUGAL
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Pica
Cerro Pintados
Salt pans
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Geoglyphs in the Nasca basin, the Atacama and other regions (*e.g.*, Bikoulis *et al.* 2018; Stanish and Tantaleán 2018) have long posed considerable challenges to archaeologists. As shallow surface features in often inaccessible terrain they are not easy to detect, let alone to map. Aerial images have been successfully used for this purpose at some sites (Aveni 1990; Rodríguez 1999; Lambers 2006). More recently, high-resolution optical and radar images taken from airborne and spaceborne platforms have been used as base data for regional mapping (Hanzalová and Pavelka 2013; Tapete *et al.* 2013; Masini *et al.* 2016; Chapman *et al.* 2016; Sakai and Olano 2017; Pavelka *et al.* 2018). In spite of these efforts, many geoglyph sites have not been adequately recorded until today, and few detailed, reliable maps are available.

Geoglyph dating is another issue (Clarkson 1996). In spite of promising initial results, attempts of chronometric dating that rely on rocks either exposed during geoglyph construction (Clarkson and Dorn 1991; Rink and Bartoll 2005) or covered in the process (Greilich and Wagner 2009) have so far largely failed to provide archaeologists with sufficiently reliable and fine-grained direct dating. Therefore, iconographic comparison and cross-dating of associated ceramics remain the most important vehicles of geoglyph dating. The difficulties involved in geoglyph documentation and dating have often hampered the understanding of the socio-cultural context in which the geoglyphs were conceived, built and used, which in turn affected the interpretation of their function and meaning.

In spite of these challenges, since the 1980s geoglyph studies in both Peru and Chile, building on archaeological, anthropological and scientific evidence, have opened up new avenues for geoglyph interpretation. The geoglyphs in both the Nasca basin and the Atacama desert are now understood in the context of the Andean worldview. According to these studies the Nasca geoglyphs fulfilled a crucial role for social organization and cohesion, while the Atacama geoglyphs had an important socio-economic dimension.

In what follows the southern Peruvian geoglyphs and the northern Chilean geoglyphs serve as examples to discuss the environmental, archaeological, and socio-cultural contexts of South American geoglyphs as a basis for their interpretation.

Figure 1 (previous page): South America with the Nasca basin in south-central Peru (a) and the Atacama desert in northern Chile (b). Both arid regions are situated between the Pacific Ocean in the west and the Andes mountain range in the east. Map: J. Porck and K. Lambers.

## 2. Major South American geoglyph complexes

### *2.1 Nasca basin, south-central Peru*

#### *2.1.1 Environmental, chronological and archaeological context*

Probably the best-known geoglyph complex in South America (and beyond) is located on the *pampas* of Nasca, a vast desert plain of approx. 250 km² bordered by the Andean foothills to the east, the Ingenio river to the north, and the Nasca river to the southwest (figure 1a). Prominent animal figures such as the monkey, the spider, the pelican, the whale, the hummingbird and others are located in this area, mainly along its northern and southern margins (Aveni 2000; Eda *et al.* 2019). Much of the plain´s interior is transected by long, straight lines that often converge in so-called line centers located on elevated terrain (figure 2; Aveni 1990, 2000; Reiche 1993; Ruggles and Saunders 2012; Sakai *et al.* 2014). It is these lines that are the most common geoglyph type and predominate at many geoglyph sites. Other geometric geoglyphs include large trapezoidal or rectangular cleared fields (Hawkins 1974; Orefici 2009).

Smaller but similar geoglyph sites are found along all the Grande river tributaries, *e.g.* to the south of the monumental site of Cahuachi on the Nasca river, along the Ingenio river and around the Palpa alluvial plain in the northern part of the drainage (Silverman 1990, 1993; Silverman and Browne 1991; Lambers 2006; Masini *et al.* 2016). The Nasca basin, wedged between the coastal cordillera to the southwest and the Andean foothills to the northeast, thus consists of narrow but fertile river oases that sustained the ancient population, and in-between and above them vast stretches of desert that served as ideal drawing grounds for geoglyphs. As recent geomorphological and palaeoclimatic studies have shown (Eitel *et al.* 2005; Hesse 2008; Eitel and Mächtle 2009; Mächtle *et al.* 2010; Mächtle and Eitel 2013), this setting largely prevailed since the time of the Early Horizon (800 to 200 BC) and thus provided the arid environmental framework for the Nasca geoglyph phenomenon.

The geoglyphs in the Nasca region were conceived, built and used by the Paracas (800 to 200 BC – Early Horizon) and Nasca (200 BC to AD 650 – Early Intermediate Period) societies (Silverman and Proulx

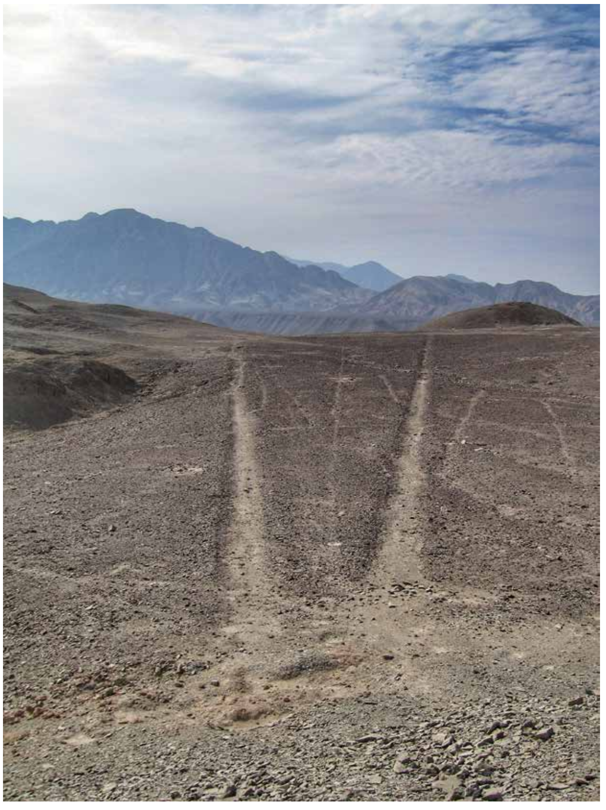

Figure 2: Linear geoglyphs of various widths converging on slightly elevated terrain on Cerro Carapo, to the east of Palpa in the Nasca basin, looking south. Photo: K. Lambers.

2002; Reindel 2009; Conlee 2016; Isla 2017). Their economy was based on the agricultural use of the fertile soils of the river valleys. Due to a slow but constant process of aridification and the up-valley shift of the eastern desert margin (Eitel *et al.* 2005; Eitel and Mächtle 2009; Mächtle and Eitel 2013; Soβna 2015) the use of seasonal rivers and perennial aquifers as water sources for field irrigation became ever more sophisticated over time (Schreiber and Lancho 2006). Ultimately, however, at some point during the Early Intermediate Period to Middle Horizon transition around AD 700 it failed to provide a sufficient basis to sustain the formerly dense population. Water and its source, mountains, apparently played important roles in the Nasca worldview (Reinhard 1996), as did a variety of mythical beings depicted on ceramics, textiles, and in some instances in petroglyphs and geoglyphs (Silverman and Proulx 2002; Clados 2006; Proulx 2006; Carmichael 2016). The highest level of political complexity in the Nasca region was reached in Early Nasca times (AD 1 to 250), when the whole basin shared common cultural traits, and the monumental site of Cahuachi on the Nasca river served as a center of ritual activity, if not political power (Silverman 1993; Vaughn 2009; Conlee 2016; Orefici 2016b). Towards the end of the Nasca period, along with increasing aridification, the political landscape became more fragmented, regional centers arose, and a strong external influence became apparent in Nasca iconography (Proulx 2006). While some parts of the Nasca region saw a considerable demographic decline at the beginning of the Middle Horizon (from AD 700 – Reindel 2009; Soβna 2015), other parts were clearly integrated into the sphere of the highlands-based Wari society (Schreiber 1999, 2000; Isla 2001; Conlee 2016). Although the Early Intermediate Period to Middle Horizon transition (ca AD 700) in the Nasca basin and its socio-political, cultural, and environmental parameters are still poorly understood, it seems clear that it brought about the end of the Nasca geoglyph tradition. The construction of new geoglyphs ceased completely, although geoglyph use may have continued for some time in the southern part of the basin (Sakai *et al.* 2014; Sakai and Olano 2017).

### *2.1.2 The geoglyphs*

During the Paracas and Nasca periods, the vast desert portions of the Nasca basin were incorporated into the social and cultural domain of the valley-based society like never before or after. The inhabitants of the valleys frequently gathered in the desert for geoglyph construction and use, marking the landscape at large scale according to their needs. While the apparent maze of geoglyphs seen today is the result of more than a thousand years of intensive desert use, stratigraphic evidence reveals that biomorphic figures located on hillsides are among the oldest geoglyphs (Lambers 2006, 2012, 2017). Many of them have suffered erosion or destruction by human activity already since Nasca times. Early geoglyphs include birds, felines, and anthropomorphic figures, often in groups (figure 3). Among the human figures are full-body depictions, some of them with headdresses, staffs held in hands, or even trophy heads tied to their belts, but also head-only depictions and figures featuring human and non-human traits, *e.g.* snakes emerging from body parts. Like later geoglyphs, the early figures were made by removing dark stones from lighter sediments. But unlike later geoglyphs, the removed stones were not just used to mark the outlines of the figures, but were also piled up in the

Figure 3: Paracas-style anthropomorphic geoglyphs on a slope near Llipata in the Nasca basin, looking north. The geoglyphs were restored in the early 2000s. Photo: Nasca-Palpa Archaeological Project, used with permission.

interior of the figures to form eyes, mouths, and other anatomical features. Their position on sloped terrain allowed these early geoglyphs to be seen from a distance. Hardly a trace of use is usually associated with these figures, in marked contrast to later geometric geoglyphs on which traces of varied human activity abound.

The motifs, style, and topographic setting of these early geoglyphs closely resembles petroglyphs, of which many are found in the Nasca basin (Nieves 2007; Fux *et al.* 2009; Fux 2012; Orefici 2016a), most of them dating to the Paracas period (800 to 200 BC – Early Horizon). The geoglyph phenomenon thus seems to have evolved out of the older petroglyph tradition by transferring common motifs from rock surfaces to the nearby ground surface.

Another strand of tradition may have contributed to this development. At certain places on the desert plateaus in the Palpa region Paracas ceramic vessels were deposited on the desert surface in remote locations over extended periods of time, an activity originally not accompanied by any kind of surface markings or structures (Lambers 2012, 2017). While the context of this activity is unknown, at some point during the Paracas-Nasca transition it seems to have been combined with desert surface marking. At that point the main purpose of geoglyphs became walking upon them, and placing ceramic vessels on, along or around them, as evidenced by heavily compacted line surfaces and numerous surface finds (Gorka *et al.* 2007). Judging from these associated finds, straight lines on hillsides and flat plateaus are among the oldest geometric geoglyphs, dating to the Late Paracas (400 to 200 BC) or Initial Nasca period (200 to 1 BC).

By Early Nasca times (AD 1 to 250), a wide variety of new shapes, proportions and motifs of geoglyphs had developed, among them different types of lines (straight, zigzag, meandering, spiral), trapezoids and rectangles, and diverse zoomorphic figures (Lambers 2006; Sakai and Olano 2017). Most of these new geoglyphs were now located on flat terrain on the desert plateaus above the valley, on which many new geoglyph sites had been opened up (figures 4, 5). New geoglyphs often crossed or covered older geoglyphs, and existing geoglyphs were frequently enlarged or altered, indicating the importance of geoglyph construction as a social activity in its own right (as opposed to geoglyph use). Many unfinished geoglyphs, noticeable through stone heaps awaiting removal on partially cleared surfaces, provide additional evidence for the frequent construction and remodeling activity on geoglyph sites (figure 6). Stone platforms on hills or along plateau edges overlooking the valleys communicated geoglyphs on plateaus with lines fanning out over the hillsides. On trapezoids, stone platforms near the wide and the narrow ends, sometimes accompanied by wooden posts, served as places for gatherings and offerings (figure 4; Reindel *et al.* 2006).

In terms of variety and quality, Early Nasca was clearly the apogee of the Nasca geoglyph tradition. During Middle and Late Nasca times (AD 250 to 650), new geoglyphs and stone platforms were still built, among them some of the largest of which we know (figure 5), and activities on geoglyph sites still flourished. However, the formal repertoire was gradually reduced to a limited set of geometric lines and trapezoids, some sites were abandoned, and no new sites were added. The end of the geoglyph tradition is

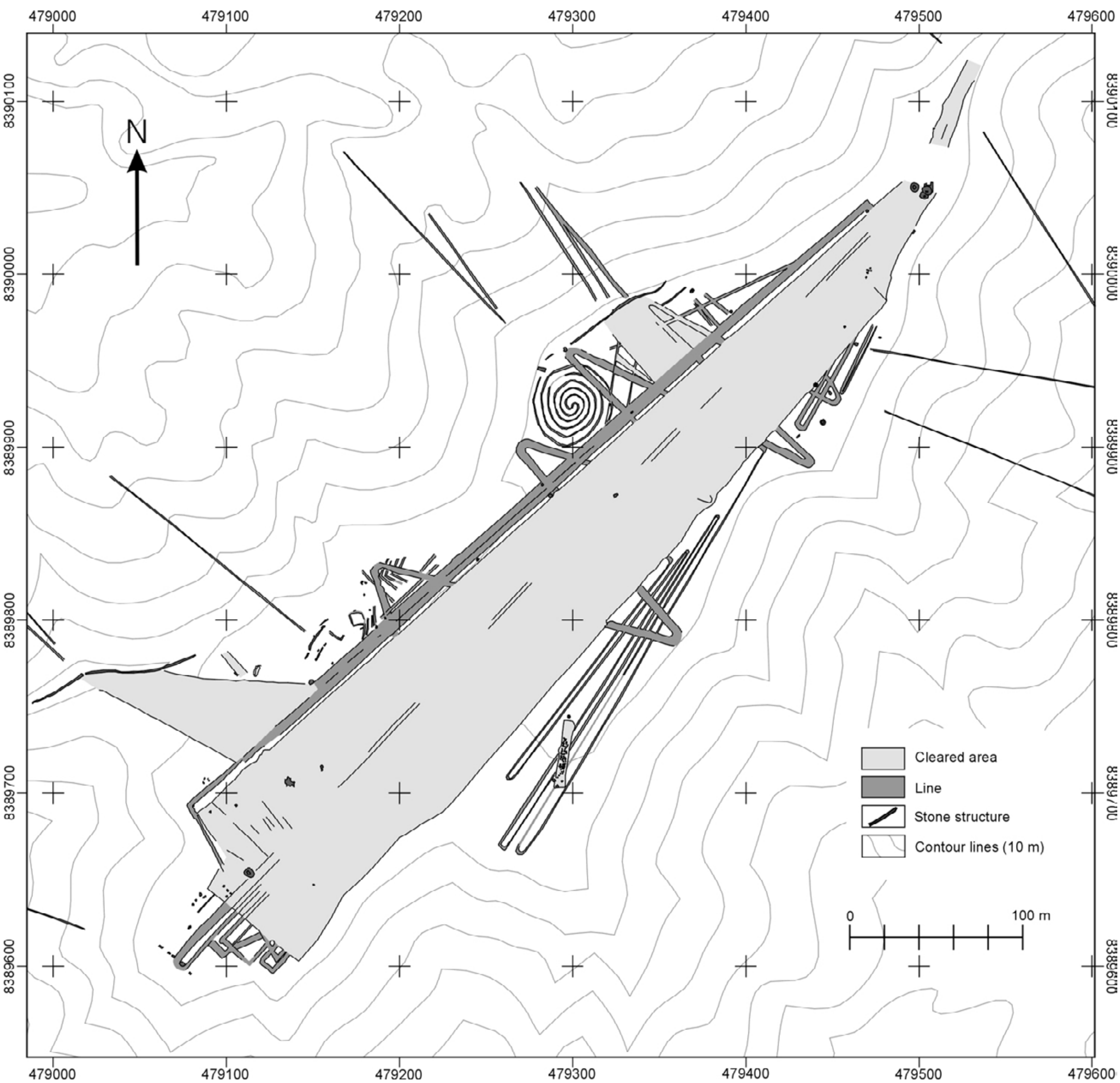


Figure 4: Typical combination of geometric geoglyphs on a plateau above Llipata in the Nasca basin. A central trapezoid, enlarged at least on one occasion, is flanked by parallel lines and crossed by a zig-zag line. Smaller lines, trapezoids and a spiral accompany these geoglyphs. Stone platforms are located on both ends of the central trapezoid. Coordinates: WGS84, UTM 18S. Map: K. Lambers.

marked by some ceramic vessels dating to the early Middle Horizon that were still placed along lines and trapezoids in the old fashion (Lambers 2006).

During the Late Intermediate Period (1000 to 1450 AD), when parts of the northern Nasca basin were resettled from the east during a short period of humidification of the local climate (Soβna 2015), some settlements were built on top of large geoglyph complexes, indicating that by then the geoglyphs were no longer valued nor understood. In the southern Nasca basin, which probably saw a more continuous occupation, associated finds seem to indicate a continued use of linear geoglyphs (Sakai *et al.* 2014; Sakai and Olano 2017), although the main context may now have been traffic across the *pampas* along the lines.

Figure 5: Complex geoglyph site on the Pampa de San Ignacio to the south of Palpa in the Nasca basin, looking east. This site is one of the largest and densest concentrations of geoglyphs in the Nasca basin, and at 1.9 km length, the central trapezoid is the largest known geometric geoglyph. Photo: Nasca-Palpa Archaeological Project, used with permission.

Figure 6: Unfinished geoglyph on the Pampa de San Ignacio to the south of Palpa in the Nasca basin, looking south. Unremoved small heaps of stones on a partly cleared surface are visible in the foreground. The border of the geoglyph is visible as a sharp line in the middle ground between the undisturbed desert surface and the partly cleared area. Other portions of this large trapezoid were completely cleared. Photo: K. Lambers.

### *2.1.3 Social, cultural and historical context*

Concerning the socio-cultural context of the Nasca geoglyph tradition, the earliest geoglyphs were clearly part of the Paracas symbolic and artistic repertoire. Originally Paracas geoglyphs were but one among several artistic expressions that were very similar in terms of style and motifs, *e.g.* decorations on textiles and ceramics or petroglyphs (Paul 1991).

The subsequent developments into a prominent independent phenomenon during the Initial and Early Nasca period (200 BC to AD 250) coincided with other important transitional processes, such as technological innovation, population growth, increasing social complexity, the rise of Cahuachi as the socio-cultural capital of the region, the development of new art styles etc. during the early Early

Intermediate Period (Carmichael 2016; Conlee 2016). In these dynamic times, geoglyphs emerged as a key element of “Nascaness” (Silverman 2002). Since monumental architecture was largely absent, communal labor went into geoglyph construction and use. The importance of geoglyph visibility stresses the public character of the gatherings and ceremonies held there (Lambers and Sauerbier 2007, 2009; Vaughn *et al.* 2016). These activities thus might have played an important role in the constitution of social groups and the negotiation of their position within the society, or the role of individuals within these groups (Lambers 2006, 2012, 2017). Though difficult to judge for a lack of reliable maps, the geoglyphs in the Nasca basin seem to show little regional variation (just like Nasca ceramics), meaning that the cultural concepts behind this tradition were shared among the inhabitants of the whole basin.

The importance of the geoglyphs for social cohesion became evident in Middle and Late Nasca times (AD 250 to 650). In spite of the fragmentation of the political landscape, the geoglyph tradition remained a unifying basin-wide element of Nasca culture, its importance being underlined by the fact that activities on geoglyph sites went on even when nearby settlements were abandoned. The geoglyphs thus literally constituted a “common ground” (as aptly termed so by P. Clarkson in the English pre-print of her 1999 article published in German) for the Nasca society during most of its history.

### *2.2 Atacama desert, northern Chile*

#### *2.2.1 Environmental, chronological and archaeological context*

The Atacama geoglyphs are distributed over a larger area than the Nasca geoglyphs, but in lesser density. Their iconography is much more diverse, allowing us to distinguish a variety of local styles. While geoglyphs in the Nasca region were never far removed from settlements, many Atacama geoglyphs are located in uninhabitable stretches of desert. However, they were often associated with ephemeral camp sites pertaining to caravans crossing the desert between the Pacific coast and the Andean highlands, two more densely populated regions with access to different resources. The northern Chilean geoglyphs are found between the Lluta valley in the north and the Loa valley in the south (figure 1b), with minor sites beyond these limits. The central and southern portion of this region is the Tamarugal *pampa*, a vast and hyperarid stretch of desert between the coastal cordillera to the west and the Andean foothills to the east. Within this region, most of the geoglyphs are located either along the dry valleys or the few rivers crossing the *pampa*, or on isolated hills in the midst of the desert, the most

Figure 7: Anthropomorphic geoglyph on the slopes of Cerro Unitá, looking north-east. The figure measures ca 90 m from head to toe and is accompanied by other geoglyphs. It is the biggest human figure known to have been produced in prehistory. Photo: P. Bahn, used with permission.

famous of which is Cerro Unitá featuring the largest known anthropomorphic geoglyph (figure 7).

In the southern portion of the Tamarugal *pampa* there are several large salt pans. To the east, the western cordillera of the Andes reaches elevations of around 6000 m.a.s.l. While the Atacama is quite active in tectonic terms, its arid climate has remained rather stable for a long time, with variations through time mainly affecting the sparsely populated river oases. The general scarcity of water below 3500 m.a.s.l. – *i.e.*, in the area with geoglyphs – seems to have been a persistent environmental feature over the last 5000 years (Grosjean and Núñez 1994; Seyfried *et al.* 1998; Santoro *et al.* 2017), thus creating the desertic conditions that were a prerequisite for geoglyph making and use.

Due to such inhospitable conditions, human population was always sparse and restricted to sites along the desert margins (Rivera 2008). However, the interior of the desert is not devoid of archaeological relics. A dense network of ancient paths crossing the Tamarugal *pampa* is accompanied by remains of ephemeral camp sites such as makeshift shelters, fire places, simple corrals, and occasional burials (Núñez 1976; Briones *et al.* 2005; Pimentel *et al.* 2017). This inter-nodal network of mobility and exchange has been the focus of much recent research (*e.g.*, Nuñez and Nielsen 2011; Berenguer and Pimentel 2017; Nielsen *et al.* 2019). While most of the scarce finds associated with these camp sites date to the period of Regional Developments (AD 900 to 1450; Berenguer 2004; Valenzuela *et al.* 2011; Nielsen *et al.* 2019), there is evidence of extensive interchange with the highlands since at least Tiwanaku times (AD 300 to 1100; Rivera 2008), and radiocarbon dating of organic materials from some camp sites even resulted in much earlier dates (Briones *et al.* 2005; Nielsen 2013; Pimentel *et al.* 2017). The paths and camps are generally understood as vestiges of llama caravans regularly crossing the desert over many centuries. This interpretation is supported by materials associated with the camps, such as ceramics, stone tools, fish bones, sea shells, minerals, semiprecious stones, and metals, most of which originate outside the desert. The Pacific seashore to the west and the Andean highlands to the east seem to have constituted the end points of trade routes crossing the Tamarugal *pampa* (Ross *et al.* 2008).

### *2.2.2 The geoglyphs*

The Atacama geoglyphs are frequently found along the mentioned paths (figure 8), and often close to camps. Most geoglyphs occupy sloped terrain such as hillsides or valley slopes, a position that renders them easily visible from the surrounding terrain (Valenzuela *et al.* 2011; Nuñez and Briones 2017). Some geoglyphs occur in isolation, but most of them are grouped in complexes that may contain up to 80

Figure 8: Anthropomorphic geoglyphs in the Lluta style and other biomorphic geoglyphs above a trail in the Lluta valley. Photo: D. Valenzuela, originally published by Ross *et al.* (2008: fig. 7), used with permission.

drawings (Briones 2006). While the basic method of geoglyph marking was the same as in Nasca – namely, the removal of dark stones from a lighter sandy layer beneath, and their re-deposition in another place – a more varied application of this method and a wide variety of motifs resulted in a much greater formal diversity of geoglyphs.

Some of the more naturalistic anthropomorphic figures feature headdresses, garments, and objects held in hands. Others are engaged in different kinds of activity, *e.g.* dancing or jumping, or are shown together with llamas (figures 8, 10). Some anthropomorphic figures are depicted in heavily reduced, abstract fashions that show some regional variation, allowing the identification of different iconographic styles such as Lluta and Pintados (figures 8, 9; Briones 2006). This has led some researchers to suggest that even purely geometric motifs such as the common stepped rhombus pattern may be understood as stylized human figures as well (Briones *et al.* 2005). Other geometric forms include circles, crosses, triangles, stepped patterns, and arrows. Among the zoomor-

Figure 9: Anthropomorphic figures in the Pintados style on the slopes of Cerro Pintados, near Pica. Photo: P. Bahn, used with permission.

Figure 10: Geoglyph panel showing a llama herd and herders near Tiliviche. Photo: P. Bahn, used with permission.

phic figures, groups of llamas are the most common motif, ranging from single llamas to pairs of llamas facing each other to whole herds of llamas (figure 10), sometimes depicted in single file as in a caravan. Other motifs include animals living in the desert (lizards, foxes, serpents), in the sea (dolphins, sharks), along the whole caravan route (dogs, birds) or even somewhere around the far end of the routes beyond the mountains (monkeys). These motifs, most of which also appear in petroglyphs (*e.g.*, Valenzuela *et al.* 2019) clearly demonstrate the far-flung connections of the people travelling along these routes.

Contrary to the Nasca geoglyphs, superimpositions are rare among the Atacama geoglyphs, such that no clear sequence of motifs can be deduced from stratigraphic evidence. Compared to the Nasca geoglyphs, the Atacama geoglyphs occur less often on flat terrain, are usually much smaller, and encompass much less lines and cleared areas. This strengthens the notion that the Atacama geoglyphs were mainly meant to be seen from a distance, not to be walked upon.

### *2.2.3 Social, cultural, and historical context*

The close association of paths, camp sites, and geoglyphs (as well as petroglyphs) clearly indicates that geoglyphs were made and seen by people crossing the Tamarugal *pampa* in caravans. Trade relations between the coast, the valleys and the highlands seem to have existed at least since Tiwanaku times, if not much earlier (see above). They allowed an exchange of goods like marine resources, minerals, and agricultural products between different ecological zones, some of which were depicted in geoglyphs and petroglyphs (Ross *et al.* 2008; Valenzuela *et al.* 2015). This trade simultaneously enabled a constant flow of people and ideas along the path network (Nuñez and Nielsen 2011; Nielsen *et al.* 2019). Consequently, the iconography of the Atacama geoglyphs shows clear Andean traits, and certain geoglyph styles and motifs are also present in other spatial and temporal contexts as well as in other media (ceramics, textiles).

Generally, the Atacama geoglyphs seem to have served as landmarks indicating the course of the trade route. Some geoglyphs may have marked places of resting stations, water sources, exchange, rituals etc. (Nuñez and Briones 2017; Valenzuela *et al.* 2019). But, this is unlikely to have been their sole function, as paths through the desert are easily visible, and knowledge about trade routes was probably deeply rooted among the people involved in caravan traffic. Furthermore, the great variety of motifs (figure 11) indicates additional meanings and functions.

There has been some debate whether in prehistoric times caravan traffic was part of a transhumance economy in which a single society controlled economic resources in different ecological niches along such routes, or rather a means of inter-societal trade relations (Núñez and Dillehay 1995; Berenguer 2004; Nielsen 2013; Nielsen *et al.* 2019). In either scenario, which are not mutually exclusive, certain geoglyph

Figure 11: Geoglyph panel showing a variety of geometric and biomorphic geoglyphs on a slope at Cerro Pintados, near Pica. Photo: P. Bahn, used with permission.

(and petroglyph) types and motifs may have represented particular ethnic or social groups involved in caravan traffic (Briones 2006), possibly serving as symbolic placeholders for such groups during their temporary absence from a given place (Jensen 2003) or marking their access to certain resources (Nuñez and Briones 2017; Nielsen *et al.* 2019). The geoglyphs evidently had an important symbolic dimension, but we will never fully understand the specific meaning of particular geoglyphs panels with their unique mix of depictions of real-world objects, biomorphic figures, some of which featured super-natural elements, and geometric motifs (figure 11). While caravan traffic in northern Chile persisted well into the 20th century (Núñez 1976; Clarkson and Briones 2001), the Atacama geoglyph tradition essentially ended during the Contact Period (AD 1540 to 1550; Briones 2006), so there is no ethnographic evidence for the interpretation of particular geoglyph sites.

## 3. Constants and variations in South American geoglyphs

As the discussion of the contexts of the Nasca and Atacama geoglyphs has shown, both can best be understood in their socio-cultural context. The group rituals on large geoglyph sites in Nasca were markedly different from the caravan traffic through the Atacama desert. In terms of formal repertoire, context, and function, the Nasca and the Atacama geoglyphs seem to have little in common. This is true for their chronological placement as well. While the apogee of the Nasca geoglyphs occurred during the Early Intermediate Period (200 BC to AD 650), the Atacama geoglyphs flourished in the period of Regional Developments (AD 900 to 1450). Thus, the heyday of the Chilean geoglyph tradition occurred when the Peruvian geoglyph tradition had essentially ended.

However, in both regions the earliest geoglyphs date to at least 400 BC, if not considerably earlier, and show close resemblance in terms of origin, motifs, topographic contexts, and function as landmarks. While there is no evidence for a direct link between these regional developments, both can be understood in a broader Andean framework of cultural concepts and traditions. The marking of the landscape through physical signs on the ground has a long history in the Andes that culminated in the famed *ceques* – physical and imaginary straight lines radiating out from the Inka capital of Cuzco and structuring the ritual landscape that surrounded it (Bauer 2000) – and derived spatial markers described in ethnographic sources (Aveni 1990). Even though both geoglyph traditions took on quite different directions from their shared conceptual origin, two important common traits persisted: movement and visibility.

In both regions, geoglyphs were seen and used by people moving through the desert. In Nasca this movement occurred in large parts upon the geoglyphs, its direction and scope directed by them, whereas in the Atacama people passed by the geoglyph sites while travelling through the desert. Geoglyphs thus had a strong dynamic dimension of which they today seem largely devoid. Except during their construction, neither in Nasca nor in the Atacama were the geoglyphs occupied over long periods of time; rather, they were briefly visited and then left alone until the next visit. During these visits, rituals were certainly held on the Nasca geoglyphs, and probably near the Atacama geoglyphs as well. The geoglyphs, placed in an inhospitable and extreme environment, were thus experienced in a strong and intense yet rather short-lived fashion. Whatever their symbolic meaning, its effect was certainly intensified by these circumstances.

Another common trait is geoglyph visibility. In the Atacama, the sloped terrain on which the large majority of geoglyphs was placed ensured visibility from the surrounding terrain, even though not all details may have been discernable due to a low viewing angle. The repetitive and thus highly recognizable motifs were probably understood even if only parts of them could actually be discerned. The Atacama geoglyphs were thus clearly conceived in relation to observers. The same is true for the Nasca geoglyphs, although in a different way. For a long time, the view *from* the Nasca geoglyphs on their environment was one of their most discussed aspects. The geoglyphs were understood as visual markers of points on the horizon where celestial bodies rose, set, or passed their zenith at important calendar dates (Reiche 1993). Several independent tests found that the orientation of the large majority of geoglyphs cannot be accounted for by this hypothesis (Hawkins 1974; Aveni 1990). A more recent study looking for orientations of geoglyphs to mountain tops, which were likely regarded as sources of water and seats of deities (Reinhard 1996), likewise yielded negative results (Lambers and Sauerbier 2007, 2009). But a clear pattern emerges when one reverses the viewing direction to look *on* the geoglyphs. As GIS-based spatial analyses have shown, most of the Palpa geoglyphs in the northern part of the Nasca basin were clearly placed in such a way that they could easily be seen from the surrounding terrain (Lambers 2006; Lambers and Sauerbier 2007, 2009). Thus, just like in the Atacama desert the Nasca geoglyphs were meant to be seen. However, considering the overwhelming evidence of group rituals on geoglyph sites, it is plausible to assume that it was these rituals, and the people involved in them, that were the main focus of attention, rather than the geoglyphs themselves.

Both shared aspects, movement and visibility, remind us that geoglyphs can only be understood in their socio-cultural context (Rodríguez 1999; Valenzuela *et al.* 2014). Our modern notion of both the Nasca and the Atacama geoglyphs is heavily shaped by (aerial) images of an empty and uninhabitable desert environment in which the geoglyphs are located in apparent isolation. But two important elements are missing in this picture: the people who went out into the desert to construct and use the geoglyphs, and the recurring activities taking place on or around geoglyph sites. As the examples from Peru and Chile have shown, this context is crucial for an understanding of the South American geoglyphs. It illustrates the varied and complex ways in which ancient societies interacted with their arid environment, transforming it according to their concepts and needs, the traces of which can be appreciated to the present day.

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## References

Aveni, A.F. (ed) 1990. *The lines of Nazca,* Philadelphia (Memoirs of the American Philosophical Society 183).

Aveni, A.F. 2000. *Between the lines: The mystery of the giant ground drawings of ancient Nasca, Peru*, Austin.

Bauer, B.S. 2000. *El espacio sagrado de los Incas: el sistema de ceques del Cuzco*, Cusco (Archivos de Historia Andina 33).

Berenguer, J. 2004. *Caravanas, interacción y cambio en el desierto de Atacama,* Santiago de Chile.

Berenguer, J. and G. Pimentel 2017. Introducción al estudio de los espacios internodales y su aporte a la historia, naturaleza y dinámica de las ocupaciones humanas en zonas áridas, *Estudios Atacameños* 56, 3-11. DOI: 10.4067/S0718-10432017000300001.

Bikoulis, P., F. Gonzalez-Macqueen, G. Spence-Morrow, S. Bautista, W. Yepez Alvarez and J. Jennings 2018. Ancient pathways and geoglyphs in the Sihuas valley of southern Peru, *Antiquity* 92, 1377-1391. DOI: 10.15184/aqy.2018.197.

Briones, L. 2006. The geoglyphs of the north Chilean desert: An archaeological and artistic perspective, *Antiquity* 80, 9-24. DOI: 10.1017/S0003598X00093224.

Briones, L., L. Núñez and V.G. Standen 2005. Geoglifos y tráfico prehispánico de caravanas de llamas en el desierto de Atacama (norte de Chile), *Chungará* 37, 195-223. DOI: 10.4067/S0717-73562005000200007.

Carmichael, P. 2016. Nasca origins and Paracas progenitors, Ñawpa Pacha 36, 53-94. DOI: 10.1080/00776297.2016.1239874.

Chapman, B.D., D.C. Comer, J.A. Isla and H. Silverman 2016. The measurement by airborne synthetic aperture radar (ASAR) of disturbance within the Nasca world heritage site, *Conservation and Management of Archaeological Sites* 17, 270-286. DOI: 10.1080/13505033.2015.1129801.

Clarkson, P.B. 1996. Técnicas en la determinación de las edades cronológicas de geoglifos, *Chungará* 28, 419-460.

Clarkson, P.B. 1999. Geoglyphen als Artefakte, Geoglyphen als Erfahrung – Bodenzeichnungen auf dem amerikanischen Kontinent. In: J. Rickenbach (ed), *Nasca: Geheimnisvolle Zeichen im alten Peru*, Zurich, 165-175.

Clarkson, P.B. and L. Briones 2001. Geoglifos, senderos y etnoarqueología de caravanas en el desierto chileno, *Boletín del Museo Chileno de Arte Precolombino* 8, 35-45.

Clarkson, P.B. and R.I. Dorn 1991. Nuevos datos relativos a la antigüedad de los geoglifos y pukios de Nazca, Perú, *Boletín de Lima* 78, 33-47.

Clados, C. 2006. Neue Erkenntnisse zur Ikonographie der Geoglyphen von Nazca, *Ethnographisch-Archäologische Zeitschrift* 47, 299-324.

Conlee, C.A. 2016. *Beyond the Nasca lines: Ancient life at La Tiza in the Peruvian desert*, Gainesville.

Eda, M., T. Yamasaki and M. Sakai 2019. Identifying the bird figures of the Nasca pampas: An ornithological perspective, *Journal of Archaeo-*

*logical Science: Reports* 26, 101875. DOI: 10.1016/j.jasrep.2019.101875.

Eitel, B., S. Hecht, B. Mächtle, G. Schukraft, A. Kadereit, G.A. Wagner, B. Kromer, I. Unkel and M. Reindel 2005. Geoarchaeological evidence from desert loess in the Nazca-Palpa region, southern Peru: Paleoenvironmental changes and their impact on pre-Columbian cultures, *Archaeometry* 47, 137-158. DOI: 10.1111/j.1475-4754.2005.00193.x.

Eitel, B. and B. Mächtle 2009. Man and environment in the eastern Atacama desert (southern Peru): Holocene climate changes and their impact on pre-Columbian cultures. In: M. Reindel and G.A. Wagner (eds), *New technologies for archaeology: Multidisciplinary investigations in Palpa and Nasca, Peru*, Heidelberg, 17-37. DOI: 10.1007/978-3-540-87438-6_2.

Fux, P., M. Sauerbier, T. Kersten, M. Lindstädt and H. Eisenbeiss 2009. Perspectives and contrasts: Documentation and interpretation of the petroglyphs of Chichictara using terrestrial laser scanning and image-based 3D modeling. In: M. Reindel and G.A. Wagner (eds), *New technologies for archaeology: Multidisciplinary investigations in Palpa and Nasca, Peru*, Heidelberg, 359-377. DOI: 10.1007/978-3-540-87438-6_21.

Fux, P. 2012. The petroglyphs of Chichictara, Palpa, Peru: Documentation and interpretation using terrestrial laser scanning and image-based 3D modelling, *Zeitschrift für Archäologie Außereuropäischer Kulturen* 4, 127-205.

Gorka, T., J. Fassbinder and K. Lambers 2007. Magnetometry on the geoglyphs of Palpa and Nasca (Peru), *Studijné Zvesti* 41 (Special theme: Archaeological prospection), 176-179.

Greilich, S. and G.A. Wagner 2009. Light thrown on history – The dating of stone surfaces at the geoglyphs of Palpa using optically stimulated luminescence. In: M. Reindel and G.A. Wagner (eds), *New technologies for archaeology: Multidisciplinary investigations in Palpa and Nasca, Peru*, Heidelberg, 271-283. DOI: 10.1007/978-3-540-87438-6_16.

Grosjean, M. and L. Núñez 1994. Lateglacial, Early and Middle Holocene environments, human occupation, and resource use in the Atacama (northern Chile), *Geoarchaeology* 9, 271-286. DOI: 10.1002/gea.3340090402.

Hanzalová, K. and K. Pavelka 2013. Map of Nasca geoglyphs, *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XL-5/W2, 309-311. DOI: 10.5194/isprsarchives-XL-5-W2-309-2013.

Hawkins, G.S. 1974. Prehistoric desert markings in Peru. In: P.H. Oehser (ed), *National Geographic Society research reports 1967*, Washington D.C., 117-144.

Hesse, R. 2008. *Fluvial dynamics and cultural landscape evolution in the Rio Grande de Nazca drainage basin, southern Peru,* Oxford (BAR International Series 1787).

Isla, J. 2001. Wari en Palpa y Nasca: perspectivas desde el punto de vista funerario, *Boletín de Arqueología PUCP* 5, 555-584.

Isla, J. 2017. Nasca: cultura y sociedad en la costa sur del Perú. In: R. Vega-Centeno (ed), *Repensar el antiguo Perú: aportes desde la arqueología*, Lima, 238-274.

Jensen, D. 2003. Geoglyphs and GIS: Modeling transhumance in northern Chile. In: M. Doerr and A. Sarris (eds), *The digital heritage of archaeology: Proceedings of the 30th Computer Applications and Quantitative Methods in Archaeology conference, Heraklion, Crete, April 2002*, Athens, 179-184. DOI: 10.15496/publikation-3219.

Lambers, K. 2006. *The geoglyphs of Palpa, Peru: Documentation, analysis, and interpretation*, Aichwald (Forschungen zur Archäologie Außereuropäischer Kulturen 2).

Lambers, K. 2012. Von Bildern zu Bühnen: Die Geoglyphen von Palpa und Nasca (Süd-Peru) in ihrem räumlichen und sozialen Kontext. In: O. Dally, S. Moraw and H. Ziemssen (eds), *Bild – Raum – Handlung: Perspektiven der Archäologie*, Berlin, 47-68. DOI: 10.1515/9783110266344.47.

Lambers, K. 2017. Los geoglifos: imágenes y escenarios en el desierto de Nazca y Palpa / The geoglyphs: Images and settings in the desert of Nazca and Palpa. In: C. Pardo and P. Fux (eds), *Nasca*, Lima, 112-123, 363-366.

Lambers, K. and M. Sauerbier 2007. A fresh view on the Nasca lines: Investigating geoglyph visibility in Palpa (Ica, Peru). In: J.T. Clark and E.M. Hagemeister (eds), *Digital discovery: Exploring new frontiers in human heritage. Computer applications and quantitative methods in archaeology. Proceedings of the 34th conference, Fargo, United States, April 2006*, Budapest, 215-225. DOI: 10.15496/publikation-2774.

Lambers, K. and M. Sauerbier 2009. Context matters: GIS-based spatial analysis of the Nasca geoglyphs of Palpa. In: M. Reindel and G.A. Wagner (eds), *New technologies for archaeology: Multidisciplinary investigations in Palpa and Nasca, Peru*, Heidelberg, 321-338. DOI: 10.1007/978-3-540-87438-6_19.

Mächtle, B. and B. Eitel 2013. Fragile landscapes, fragile civilizations – How climate determined societies in the pre-Columbian south Peruvian Andes, *Catena* 103, 62-73. DOI: 10.1016/j.catena.2012.01.012.

Masini, N., G. Orefici, M. Danese, A. Pecci, M. Scavone and R. Lasaponara 2016. Cahuachi and Pampa de Atarco: Towards greater comprehension of Nasca geoglyphs. In: R. Lasaponara, N. Masini and G. Orefici (eds), *The ancient Nasca world: New insights from science and archaeology*, Cham, 239-278. DOI: 10.1007/978-3-319-47052-8_12.

Nielsen, A.E. 2013. Circulating objects and the constitution of south Andean society (500 BC – AD 1550). In: K.G. Hirth and J. Pillsbury (eds), *Merchants, markets, and exchange in the pre-Columbian world*, Washington D.C., 389-418.

Nielsen, A.E., J. Berenguer and G. Pimentel 2019. Inter-nodal archaeology, mobility, and circulation in the Andes of Capricorn during the Late Intermediate Period (AD 1000-1450), *Quaternary International*, 2019. DOI: 10.1016/j.quaint.2018.09.044.

Nieves, A.C. 2007. *Between the river and the pampa: A contextual approach to the rock art of the Nasca valley (Grande river system, department of Ica, Peru),* Austin (unpublished Ph.D. thesis, University of Texas at Austin).

Núñez, L. 1976. Geoglifos y tráfico de caravanas en el desierto chileno. In: *Homenaje al Dr. Gustavo Le Paige, S.J.*, Antofagasta, 147-201.

Núñez, L. and T. Dillehay 1995. *Movilidad giratoria, armonía social y desarrollo en los Andes meridionales: patrones de tráfico e interacción económica,* 2nd ed., Antofagasta.

Núñez, L. and A.E. Nielsen (eds) 2011. *En ruta: arqueología, historia y etnografía del tráfico sur andino*, Córdoba.

Núñez, L. and L. Briones 2017. Tráfico e interacción entre el oasis de Pica y la costa arreica en el desierto Tarapaqueño (norte de Chile), *Estudios Atacameños* 56, 133-161. DOI: 10.4067/S0718-10432017000300006.

Orefici, G. 2009. Los geoglifos: espacios abiertos y ceremonias colectivas / The geoglyphs: Open spaces and collective ceremonies. In: G. Orefici (ed.), *Nasca – El desierto de los dioses de Cahuachi / The desert of the Cahuachi divinities*, Lima, 92-111.

Orefici, G. 2016a. Petroglyphic images and the sacred valleys. In: R. Lasaponara, N. Masini and G. Orefici (eds), *The ancient Nasca world: New insights from science and archaeology*, Cham, 197-215. DOI: 10.1007/978-3-319-47052-8_10.

Orefici, G. 2016b. The ceremonial center of Cahuachi: Its origins and evolution. In: R. Lasaponara, N. Masini and G. Orefici (eds), *The ancient Nasca world: New insights from science and archaeology*, Cham, 329-342. DOI: 10.1007/978-3-319-47052-8_14.

Pärssinen, M., D. Schaan and A. Ranzi 2009. Pre-Columbian geometric earthworks in the upper Purús: A complex society in the upper Amazon, *Antiquity* 83, 1084-1095. DOI: 10.1017/S0003598X00099373.

Paul, A. (ed) 1991. *Paracas art and architecture: Object and context in south coastal Peru*, Iowa City.

Pavelka, K., J. Šedina and E. Matoušková 2018. High resolution drone surveying of the Pista geoglyph in Palpa, Peru, *Geosciences* 8, 479. DOI: 10.3390/geosciences8120479.

Pimentel, G., M. Ugarte, F. Gallardo, J.F. Blanco and C. Montero 2017. Chug-Chug en el contexto de la movilidad internodal prehispánica en el desierto de Atacama, Chile, *Chungará* 49, 483-510. DOI: 10.4067/S0717-73562017005000102.

Proulx, D. 2006. *A sourcebook of Nasca ceramic iconography: Reading a culture through its art*, Iowa City.

Reiche, M. 1993. *Contribuciones a la geometría y astronomía en el antiguo Perú*, Lima.

Reindel, M. 2009. Life at the edge of the desert – Archaeological reconstruction of the settlement history in the valley of Palpa, Peru. In: M. Reindel and G.A. Wagner (eds), *New technologies for archaeology: Multidisciplinary investigations in Palpa and Nasca, Peru*, Heidelberg, 439-461. DOI: 10.1007/978-3-540-87438-6_25.

Reindel, M., J. Isla and K. Lambers 2006. Altares en el desierto: las estructuras de piedra sobre los geoglifos Nasca en Palpa, *Arqueología y Sociedad* 17, 179-222.

Reinhard, J. 1996. *The Nazca lines: A new perspective on their origin and meaning*, 6th ed., Lima.

Rink, W.J. and J. Bartoll 2005. Dating the geometric Nasca lines in the Peruvian desert, *Antiquity* 79, 390-401. DOI: 10.1017/S0003598X00114176.

Rivera, M.A. 2008. The archaeology of northern Chile. In: H. Silverman and W.H. Isbell (eds), *Handbook of South American archaeology*, New York, 963-977. DOI: 10.1007/978-0-387-74907-5_48.

Rodríguez, A. 1999. *Los campos de geoglifos en la costa central del Perú*, Lima.

Ross, J., D. Valenzuela, M.I. Hernández, L. Briones and C.M. Santoro 2008. More than the motifs: The archaeological analysis of rock art in arid regions of the southern hemisphere, *Chungará* 40, 273-294.

Ruggles, C. and N.J. Saunders 2012. Desert labyrinth: Lines, landscape and meaning at Nazca, Peru, *Antiquity* 86, 1126-1140. DOI: 10.1017/S0003598X00048298.

Sakai, M. and J. Olano 2017. Líneas y figuras de la pampa de Nazca / Lines and figures of the Pampa de Nazca. In: C. Pardo and P. Fux (eds), *Nasca*, Lima, 124-131, 366-368.

Sakai, M., J. Olano, Y. Matsumoto and H. Takahashi 2014. *Centros de líneas y cerámica en las pampas de Nasca, Perú, 2010*, Yamagata.

Santoro, C.M., J.M. Capriles, E.M. Gayo, M.E. de Porras, A. Maldonado, V.G. Standen, C. Latorre, V. Castro, D. Angelo, V. McRostie, M. Uribe, D. Valenzuela, P.C. Ugalde and P.A. Marquet 2017. Continuities and discontinuities in the socio-environmental systems of the Atacama desert during the last 13,000 years, *Journal of Anthropological Archaeology* 46, 28-39. DOI: 10.1016/j.jaa.2016.08.006.

Schreiber, K. 1999. Regional approaches to the study of prehistoric empires: Examples from Ayacucho and Nasca, Peru. In: B.R. Billmann and G.M. Feinman (eds), *Settlement pattern studies in the Americas – Fifty years since Virú*, Washington D.C., 160-171.

Schreiber, K. 2000. Los Wari en su contexto local: Nasca y Sodondo, *Boletín de Arqueología PUCP* 4, 425-447.

Schreiber, K. and J. Lancho 2006. *Aguas en el desierto: los puquios de Nasca*, Lima.

Seyfried, H., G. Worrier, D. Uhlig, I. Kohler and C. Calvo 1998. Introducción a la geología y morfología de los Andes en el norte de Chile, *Chungará* 30, 7-39. DOI: 10.4067/S0717-73561998000100002.

Silverman, H. 1990. Beyond the pampa: The geoglyphs in the valleys of Nazca, *National Geographic Research* 6, 435-456.

Silverman, H. 1993. *Cahuachi in the ancient Nasca world,* Iowa City.

Silverman, H. 2002. Nasca settlement and society on the hundredth anniversary of Uhle´s discovery of the Nasca style. In: W.H. Isbell and H. Silverman (eds), *Andean archaeology I: Variations in sociopolitical organization*, New York, 121-158. DOI: 10.1007/978-1-4615-0639-3_5.

Silverman, H. and D. Browne 1991. New evidence for the date of the Nazca lines, *Antiquity* 65, 208-220. DOI: 10.1017/S0003598X00079667.

Silverman, H. and D. Proulx 2002. *The Nasca*, Malden.

Soßna, V. 2015. *Climate and settlement in southern Peru: The northern Río Grande de Nasca drainage between 1500 BCE and 1532 CE*, Wiesbaden (Forschungen zur Archäologie Außereuropäischer Kulturen 13).

Stanish, C. and H. Tantaleán 2018. The Chincha lines. Ñawpa Pacha 38, 77-101. DOI: 10.1080/00776297.2018.1444949.

Tapete, D., F. Signa, N. Masini and R. Lasaponara 2013. Prospection and monitoring of the archaeological heritage of Nasca, Peru, with ENVISAT ASAR, *Archaeological Prospection* 20, 133-147. DOI: 10.1002/arp.1449.

Valenzuela, D. and P.B. Clarkson 2018. Geoglyphs. In: C. Smith (ed), *Encyclopedia of global archaeology*, Cham. DOI: 10.1007/978-3-319-51726-1.

Valenzuela, D., C.M. Santoro and L. Briones 2011. Arte rupestre, tráfico caravanero e interacción social: cuatro modalidades en el ámbito exorreico de los valles occidentales, norte de Chile (períodos Intermedio Tardío y Tardío, ca. 1000-1535 d.C.). In: L. Núñez and A.E. Nielsen (eds), *En ruta: arqueología, historia y etnografía del tráfico sur andino*, Córdoba, 199-245.

Valenzuela, D., M. Sepúlveda, C.M. Santoro and I. Montt 2014. Arte rupestre, estilo y cronología: la necesidad de un contexto histórico para las manifestaciones rupestres en costa y valles del extremo norte de Chile, *Interciencia* 39, 444-449.

Valenzuela, D., C.M. Santoro, J.M. Capriles, M. José Quinteros, R. Peredo, E.M. Gayo, I. Montt and M. Sepúlveda 2015. Consumption of animals beyond diet in the Atacama desert, northern Chile (13,000-410 BP): Comparing rock art motifs and archaeofaunal records, *Journal of Anthropological Archaeology* 40, 250-265. DOI: 10.1016/j.jaa.2015.09.004.

Valenzuela, D., I. Cartajena, C.M. Santoro, V. Castro and E.M. Gayo 2019. Andean caravan ceremonialism in the lowlands of the Atacama desert: The Cruces de Molinos archaeological site, northern Chile, *Quaternary International* 533, 37-47. DOI: 10.1016/j.quaint.2018.09.016.

Vaughn, K.J. 2009. *The ancient Andean village: Marcaya in prehispanic Nasca*, Tucson.

Vaughn, K.J., C.A. Conlee, V. Whalen and H. Van Gijseghem 2016. Plazas and communal space in Nasca: Changing patterns of public ritual through the Formative and Early Intermediate periods (800 B.C.- A.D. 650) on the south coast of Peru, Ñawpa Pacha 36, 111-138. DOI: 10.1080/00776297.2016.1239800.

Watling, J., J. Iriarte, F.E. Mayle, D. Schaan, L.C.R. Pessenda, N.J. Loader, F.A. Street-Perrott, R.E. Dickau, A. Damasceno and A. Ranzi 2017. Impact of pre-Columbian “geoglyph” builders on Amazonian forests, *Proceedings of the National Academy of Sciences* 114, 1868-1873. DOI: 10.1073/pnas.1614359114.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 107-120.

# Pre-Hispanic and contemporary raw materials use in earthenware production in the Río Mayales subbasin, Chontales, central Nicaragua

Simone Casale, Natalia R. Donner, Dennis Braekmans and Alexander Geurds

**Simone Casale**
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden, The Netherlands
casale@kitlv.nl

**Natalia R. Donner**
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden, The Netherlands
n.r.donner@arch.leidenuniv.nl

**Dennis Braekmans**
Cranfield Forensic Institute
Cranfield University
SN6 8LA Shrivenham, United Kingdom
dennis.braekmans@cranfield.ac.uk
also:
Materials Science and Engineering
Delft University of Technology
also:
Division of Geology
Earth and Environmental Sciences
KU Leuven

**Alexander Geurds**
School of Archaeology
University of Oxford
36 Beaumont St Oxford
OX1 2PG, United Kingdom
also:
Department of Anthropology
University of Colorado-Boulder
also:
Faculty of Archaeology
Leiden University
a.geurds@arch.leidenuniv.nl

*Since 2007, the Proyecto Arqueológico Centro de Nicaragua (PACEN), directed by Alexander Geurds, has conducted archaeological research in the Río Mayales subbasin, located on the eastern side of Lake Cocibolca in the Chontales province of central Nicaragua. Through the study of procurement strategies of raw materials in the context of archaeological ceramic and lithic industries, the project focuses on understanding pre-Hispanic and contemporary human-environmental relationships in a valley drained by the Río Mayales. This paper provides the results of the first systematic clay-rich soils survey combined with an ethnographic approach to present-day uses of geological resources. Chemical analysis by means of portable X-ray fluorescence (p-XRF) was applied to characterise geologically-based compositional groups throughout the valley. This resulted in an improvement of the limited geological data resolution previously available and the creation of a reference database of p-XRF values for future research in the area that can potentially link ceramic paste composition with clay outcrops. In addition, the ethnographic study generated valuable data regarding contemporary taxonomic soil knowledge in the area, which is transmitted from generation to generation in the context of declining clay-based production strategies, such as pottery manufacture.*

*Keywords: Pre-Hispanic southern Central America, Pottery technology, Human-environment interaction, Clay raw materials, X-Ray Fluorescence, Ethnoarchaeology*

## 1. Introduction

The Río Mayales subbasin is located approximately 25 km northeast of Lake Cocibolca, the largest freshwater lake in Central America. The valley of Juigalpa is part of the area drained by the Mayales and its tributaries. In the last twelve years, evidence for human presence has been recorded in the valley, including *circa* 1700 man-made mounds distributed in a range of concentrations varying from small sites to large clusters, some numbering in the hundreds of structures (Geurds *et al.* 2009; Geurds and Van Broekhoven 2010; Vlaskamp *et al.* 2014; Arteaga 2017; Donner *et al.* 2018) (figure 1). Recent radiocarbon dates on mounded sites indicate long-term interactions between human groups and the valley, spanning from pre-Hispanic times (cal 400 CE) to the present (Donner and Geurds 2018).

Since 2007, the *Proyecto Arqueológico Centro de Nicaragua* (PACEN), directed by Alexander Geurds, has studied these sites featuring architectural remains. In recent years, efforts have concentrated in Aguas Buenas, the archaeological site with the highest construction investment not only within the area, but throughout Nicaragua. Aguas Buenas is composed of 371 man-made mounds organized in six circular concentric arcs with a central rectangular area (Geurds and Terpstra 2017; Auzina 2018). In order to understand Aguas Buenas' role within its surroundings, PACEN adopted a micro-regional research approach. Since 2014, the project carried out a systematic high-intensity archaeological survey fully covering 52 $km^2$ of the valley, as well as excavations of different mounded (n=16) and un-mounded (n=3) sites (Donner *et al.* 2018), followed by analysis of a diverse set of archaeological materials, such as faunal and botanical remains, and lithic industries. Furthermore, PACEN considered the history and variability of earthenware manufacturing practices in the valley (from 400 CE through the present), through technological, petrographic and compositional analysis (Casale 2017; Donner *et al.* 2019). The main goals of these inquiries were to understand human-environmental relationships, in particular procurement strategies of raw materials (clays, rocks, minerals, water, fuel), in the context of ceramic production, as well as any functional uses of vessels (Ciofalo *et al.* 2020).

Since thorough geological studies are lacking in the research area, this study started with a systematic micro-regional clay survey, which was conducted in an attempt to link the ceramic materials retrieved during archaeological excavations with the available mineral resources in the landscape. The survey integrated an ethnographic approach (Vaughn and Neff 2004; Peacock 1982; Yankowski 2008), so modern uses of clay raw materials in the valley were also examined. The combination of different methods ultimately aimed at

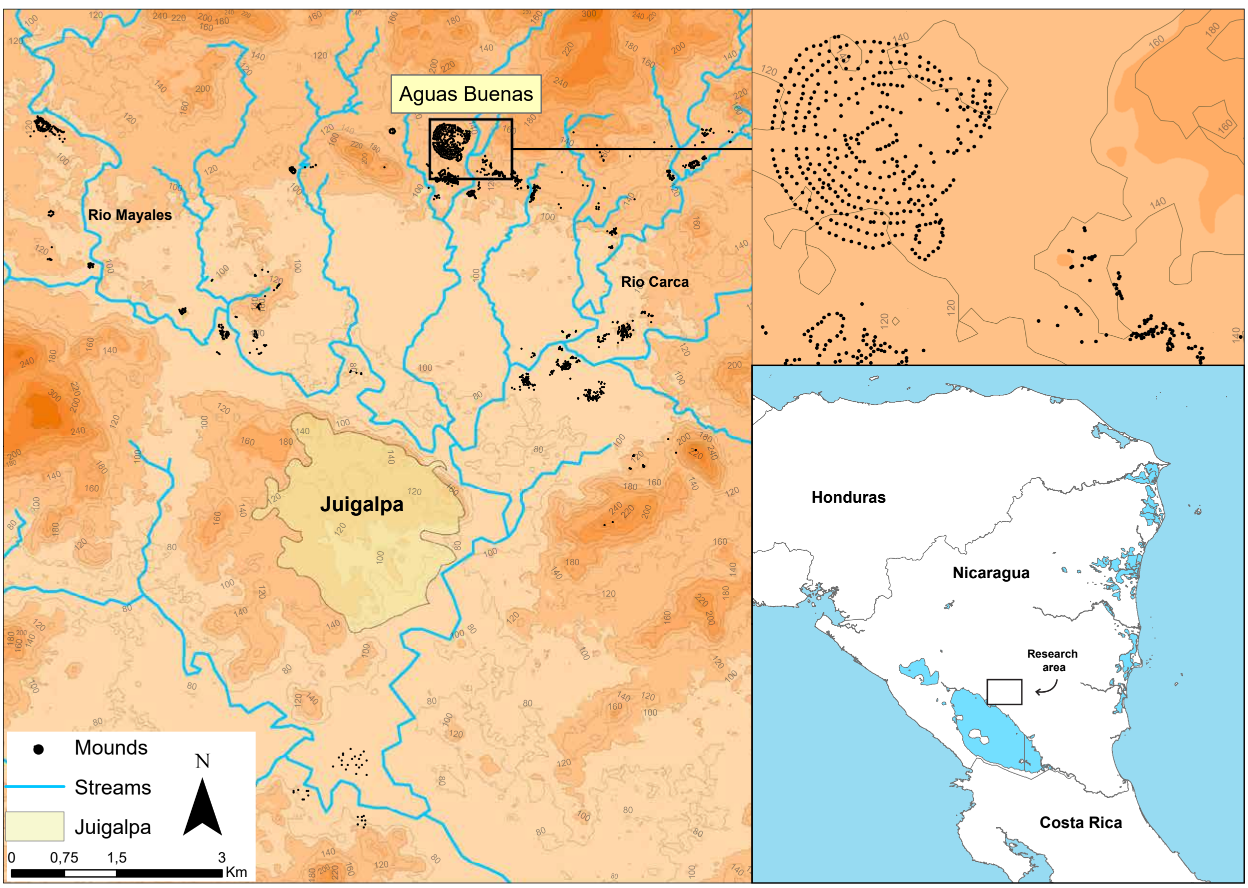


Figure 1: Location of the research area, the valley of Juigalpa, in Central Nicaragua, highlighting mounded sites recorded by PACEN and particularly Aguas Buenas.

providing a historical understanding of the interactions between humans and landscape in the valley of Juigalpa, from pre-Hispanic times through to the present.

### *1.2 Geological context*

The study area is located in the geological province referred to as the Interior Highlands of central Nicaragua (McBirney and Williams 1965), in the present province of Chontales, which is characterised by an Oligocene-Miocene arc. The region is composed of two main geologic units, the Matagalpa and Coyol Groups, both located to the east of the central Nicaraguan Depression. The geology of the area of study mainly comprises porphyritic basalt, basaltic andesite, and andesite to dacitic pumice (Arengi and Hodgson 2000). The topography encompasses elevations, plains, the lakeshore and its islands, as well as the drainage of the Mayales river and its tributaries (Garayar 1972). The geomorphology can be described as a combination of isolated hills together with a plateau and gentle slopes often marked by sharp endpoints.

## 2. Methods

### *2.1 Methodology for tracing clay sources*

The clay survey focused on two areas: north of Juigalpa, between the Mayales and Carca rivers; and south of Juigalpa, in the area surrounding the archaeological site of La Pachona. The area selected, which has an estimated surface of 50 km$^2$, reflects the extension of the pedestrian survey conducted in 2015 and 2016 for identifying and mapping archaeological sites (Donner *et al.* 2018).

The methodology applied in the clay survey consisted of a comprehensive approach that combined ethnographic, systematic, and archaeological sampling to extensively explore the area. First, semi-structured individual and group interviews (Costin 2000) were conducted with active potters and with workers of the various local brick manufactories that are spread across the valley. The goal of the ethnographic approach was to assess the clay-related knowledge and use of the local population as well as to assess ongoing exploitation of clay-rich soils and other pedological materials. These interviews with local craftsmen allowed us to design a preliminary map of the different clay sources that are currently exploited in the area, their general characteristics, local perceptions regarding the materials, as well as their specific location.

The research area was divided in grids of 1 km$^2$ and systematically explored to achieve a low intensity, full coverage pedestrian survey. Grids that included major rivers, streams, creeks, and archaeological architectural remains received a higher attention in order to glean a more comprehensive knowledge of the environment that surrounds each site. The primary objective was to take at least one systematic sample for each grid and then to overlay the dataset with the knowledge of local inhabitants and modern potters. Additionally, it was vital to consider the geology and geomorphology of the area as well as the existing archaeological knowledge (Gorin and Rigat 1993; Hasegawa 1998; Geurds *et al.* 2009; Arteaga 2017; Donner *et al.* 2018) and comparative clay surveys (Vaughn and Neff 2004; Sharratt *et al.* 2009). Therefore, besides the exploration of the main river (Mayales) and largest stream (Carca), a survey of the secondary streams, creeks, slopes and alluvial plains was also conducted. Particular attention was paid to areas featuring presence of archaeological ceramic materials on the surface and man-made mounds. The position of each soil sample was recorded using a handheld GPS, and the geomorphological and archaeological features surrounding the sample area were registered and photographed. Approximately 500 grams of clay were recovered from each outcrop for compositional and experimental analysis.

### *2.2 Chemical and statistical analysis*

The clay-rich samples were analysed by means of portable X-ray Fluorescence (p-XRF), which is a well-established field and laboratory technique for provenance analysis of soil (Shugar and Mass 2012). Prior to running the geochemical analysis, pressed pellets were created by mixing the clay with distilled water and using a plastic tube to make small cylindrical bricks (*circa* 1 cm thick). After that, the clay samples were left to dry for two days and then fired at 350 °C. Then, one side of each pellet was polished with ground paper to flatten and smooth the surface, optimizing the conditions for p-XRF analysis.

A Bruker Tracer III-SD p-XRF device was used to carry out the analysis. For each sample, three measurements in separate areas were taken. The time of analysis was 120 seconds with 40kV and a 14 µA. An Al-Ti-Cu filter was fitted to enhance the instrument's sensitivity in measuring mid-Z trace elements (Rb, Sr, Zr, Y, Nb). The quality of the measurement was monitored through the analysis of five rock and soil certified reference materials (SRG-1 (Green River

Shale), BIR-1 (Icelandic basalt), GSP-2 (Granodiorite Silver Plume), BCR-667 (Estuarine sediments), and CRM NIST-98b (Plastic clay). Semi-quantitative results were gathered using a custom empirical calibration for soil materials.

In order to assess the extent of variability and the potential to differentiate between these clay materials in relation to other areas, five additional raw clay samples were collected on the Zapatera Archipelago, located in Lake Cocibolca. This area is connected to a different geological formation, so compositional differences were expected to be observed in the p-XRF data.

The interpretation of the semi-quantitative data of the soil samples was done through multivariate statistic calculations. Principal component analysis

Figure 2: Clay collection and testing procedure in the field with the help of local experts.

(PCA) was applied for comparisons and to reduce the multivariable dataset to two dimensions for cluster identifications (Baxter 2003).

## 3. Results and Discussion

### *3.1 Results of the pedestrian clay survey*

A systematic exploration integrating ethnographic and geological survey data provided a representative number of samples to cover the area of interest. Preliminary observations spotted several large clay deposits, mostly located in the proximity of rivers and reasonably close to pre-Hispanic settlements (< 500 m).

Various geological differences were noted in the landscape surrounding the Mayales river and the Carca stream. The former has numerous clay deposits along its banks, of which some show evidence of modern exploitation. In contrast, the Carca stream revealed a much smaller number of clay deposits on its banks, while its tributary streams, creeks, and alluvial plains show again an increase in potential mineral resources. The water flow of the Carca is subject to seasonal changes, and during the dry season (November to April) less material is transported. In contrast, the Mayales is a perennial river, which provides better conditions for the formation of deposits along its banks and tributaries. The research focused especially on small streams, which resulted in the most valuable sources of riverine clay outcrops suitable for manufacturing ceramics. When an outcrop was found, water was added to test its plasticity and overall workability (figure 2). In total, 89 samples were collected, of which 39 were adequate for manufacturing items.

Results indicate that clays are widely available in the valley and they feature compositional variability, showing the presence of different geological units with distinctive chemical profiles. Several types of clays were locally identified according to their colour. Local inhabitants differentiate clays by colour to define "*barro*", "*barro amarillo*", and "*barro negro*",[1] while differences in composition and texture are identified as "*barro arenoso*" and "*barro barrial*".[2] Figure 3 shows the location of the clay samples collected, archaeological mounded sites, and the distribution of pre-Hispanic ceramic materials found on the surface (Arteaga 2017; Donner *et al.* 2018). Each archaeological site has one or more clay outcrops located in their proximity (< 500 m), together with fresh water sources; AB has six clay outcrops within a two-kilometre radius.

### *3.2 Compositional analysis of raw clay samples*

The chemical composition of 39 clay samples from the Río Mayales subbasin and five from the Zapatera archipelago was analysed for clustering through multivariate statistics. Table 1 indicates the results of the p-XRF analysis for the soil samples grouped according to the results of the PCA. A selection of elements ($Fe_2O_3$ (wt. %), CaO (wt. %), $TiO_2$ (wt. %), Cr (ppm), Sr (ppm), Zr (ppm) was $log_{10}$ normalized and statistically analyzed to identify variability among the different clay samples (Baxter 2003). XLSTAT 2018 was used for PCA calculations and analysis.

Four groups were identified by comparing PCA, single elements, and oxide compositions. The soil samples collected on Zapatera clustered significantly away from the rest of the dataset as expected, creating one independent group. Figure 4 plots the first two principal components, accounting for 81% of the total variance in the dataset, and indicates a systematic chemical variation within the clay samples of different rivers and streams within the Juigalpa valley and from the Zapatera archipelago.

Group 1 includes only the samples from Zapatera, which yielded high values of $TiO_2$ (1,9-2,4 wt. %) and $Fe_2O_3$ (15,5-18,6 wt. %) in contrast to the other groups. $Fe_2O_3$ can be connected to clay minerals, which absorb ferric ($Fe^{3+}$) oxides derived from weathering (Degryse and Braekmans 2013). Other sources of iron are Fe-bearing minerals, such as olivine, biotite, amphibole, and orthopyroxene. The presence of these minerals is usually related to volcanic rocks, which are predominant on the island. The limited insular surface extension may not allow a high level of weathering, suggesting a higher quantity of volcanic minerals in the outcrops when compared to the groups in the research area. The high value of iron is a consequence of the mafic origin of the island. Furthermore, the clay samples are depleted in Sr in contrast with other groups from the Río Mayales subbasin. Sr can vary due to water percolation, but the element is rather connected to the presence of plagioclase and carbonates (Nesbitt *et al.* 1980; Wronkiewicz and Condie 1987), so it may reflect environmental differences.

1 In Spanish, *barro* means mud, so *barro amarillo* and *barro negro* stand for yellow and black mud, respectively.

2 *Barro arenoso* means sandy mud and *barro barrial* refers to vertisols (van Dijk 2017).

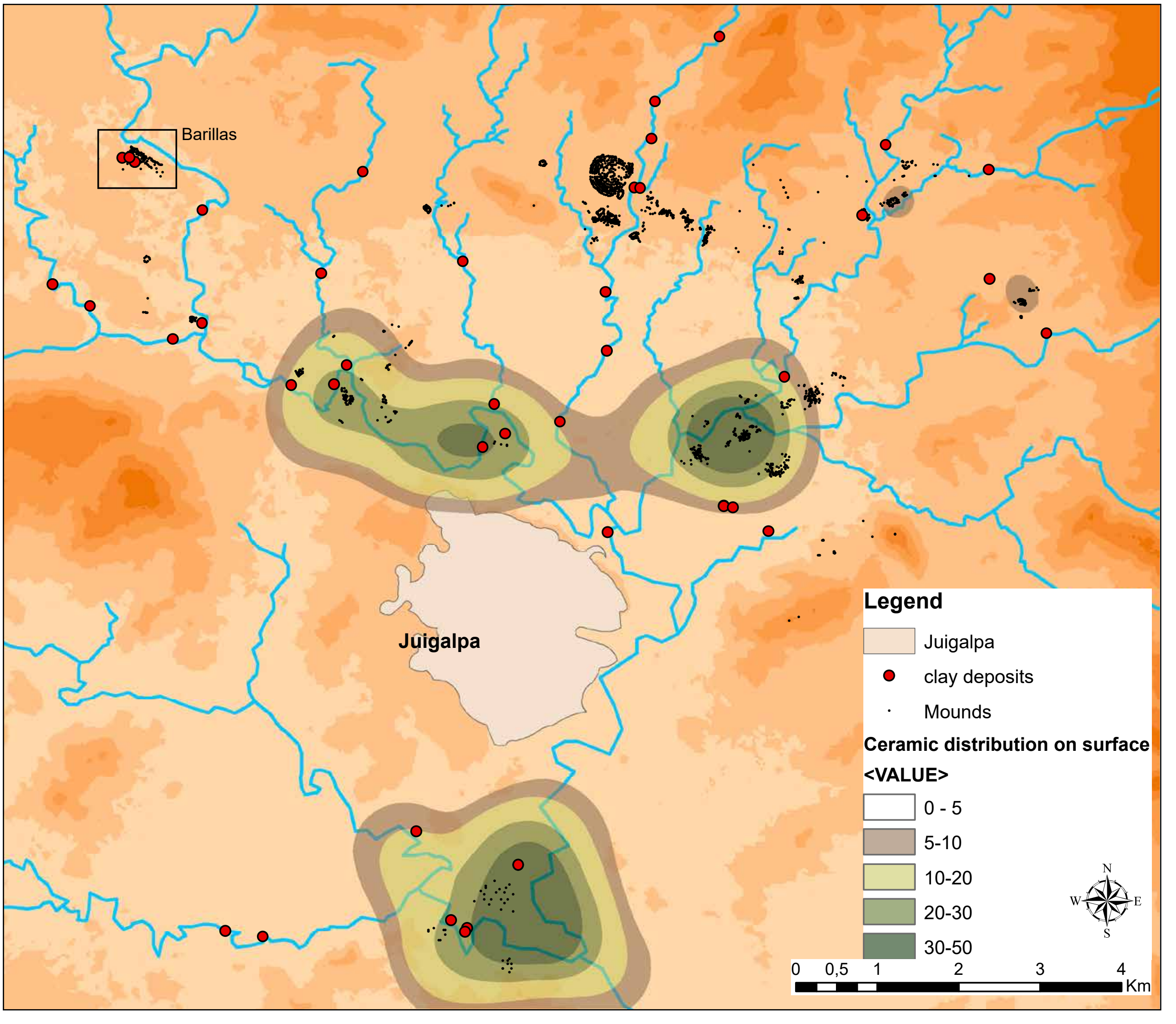


Figure 3: Geographic distribution of clay samples suitable for manufacturing ceramics (red dots) together with mounds (black dots), and densities of surface ceramic remains (based on Donner *et al.* 2018).

| | $Fe_2O_3$ (wt.%) | $Fe_2O_3$ (st. dev) | CaO (wr.%) | CaO (st. dev) | $TiO_2$ (wt.%) | $TiO_2$ (st. dev) | Sr (ppm) | Sr (st. dev) | Zr (ppm) | Zr (st. dev) | Cr (ppm) | Cr (st. dev) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 | 16,9 | 1,2 | 3,1 | 1,1 | 2,2 | 0,2 | 132 | 28,4 | 108 | 6,7 | 286 | 33,7 |
| Group 2 | 11,1 | 1,5 | 2,4 | 0,5 | 1,1 | 0,1 | 302 | 93,6 | 98 | 18,9 | 219 | 105,4 |
| Group 3 | 8,7 | 1,6 | 2,3 | 0,4 | 1,2 | 0,2 | 296 | 53,9 | 124 | 22,7 | 49 | 24,0 |
| Group 4 | 5,9 | 2,4 | 1,8 | 0,36 | 0,8 | 0,3 | 229 | 98,8 | 174 | 30,5 | 0 | 0 |

Table 1: Results of the p-XRF analysis with average and standard deviation (STD) for each group identified through the PCA (Casale 2017).

Group 2 (C3.1, F4.1, F6.1, G6.1, M3.1, M3.2, N3.1, H5.1, N4.2, F6.3, D12.1, H2.2, H2.3, I11.1, H3.1, H3.2, F12.3) is characterised by high values in Sr, CaO, $Fe_2O_3$ and $TiO_2$. Sr and CaO are likely connected to the presence of carbonate materials. $Fe_2O_3$ can be especially related to iron-rich minerals like hematite, orthopyroxene, and hornblende. These minerals are commonly found in intermediate andesitic rocks (Dennett 2016), and can be related to its weathering products. Iron and titanium can be associated to the fractionation of Fe-Ti oxides such as ilmenite, titano-magnetite, sphene or rutile (Degryse and Braekmans 2013). The mountainous formation that is located north of AB is characterised by igneous rocks, which vary from basalt to andesite in association with tuff layers. This geological substrate would explain the composition of the clay samples in this area, and it is likely that this formation is the parent material for most of the clay deposits that are located in its surroundings.

Group 3 (C5.1, D5.1, E5.1, H7.1, I7.1, L7.1, M2.1, 05.1, D5.2, I7.2, L5.2, G11.2, C12.1, B2.4, F12.1) is discerned by a clay composition with a high quantity of $Fe_2O_3$ (~3,9-10,6 wt.%), $TiO_2$ (0,6-1,2 wt. %), and Cr (0-84 ppm), which suggests the presence of more mafic volcanic rich parent rocks. In particular, $Cr^{3+}$ and $Fe^{3+}$ ions behave similarly during the weathering process. High values of chromium can be connected with mafic rocks, and this element can be concentrated mostly in chromite, spinel and clinopyroxene (Degryse and Braekmans 2013). The clay samples in this group are derived from different streams, and variations in water flow during the year may have affected weathering processes and produced a different fractionation of the elements (Wronkiewicz and Condie 1987).

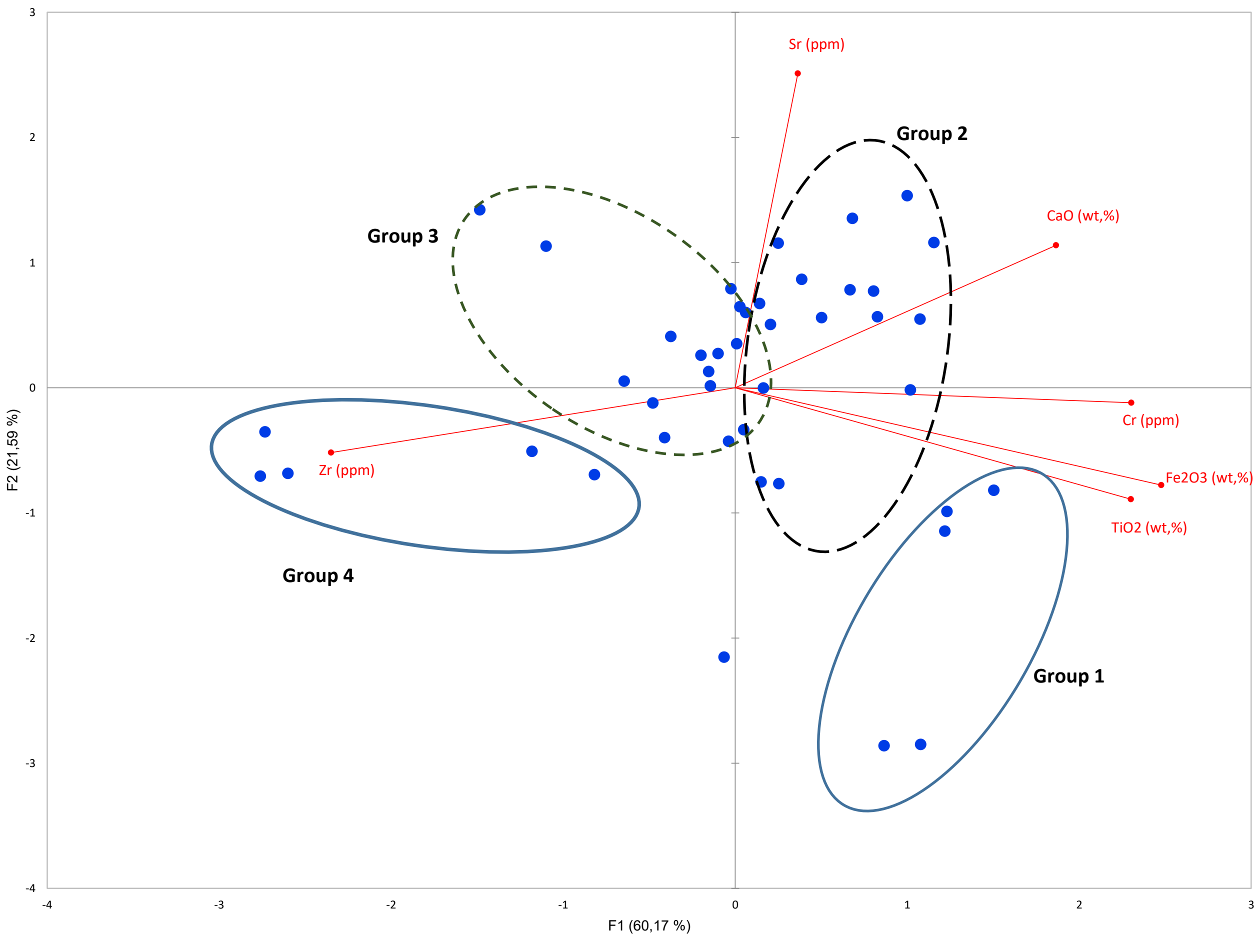


Figure 4: PCA biplot components 1 and 2 of p-XRF compositional data for the clay samples retrieved in the Río Mayales river subbasin and the Zapatera Archipelago.

Group 4 (B2.5, B2.6, B2.7, G11.3, A4.2, I7.3) shows a composition that substantially diverges from the other clusters and thus from the volcanic outcrops. A high value in Zr characterises these clays, which is resistant to weathering and associated with heavy minerals (Nyakairu and Koeberl 2001). The low values for this group in Sr and Ca can be associated with the grade of weathering that the sediments were subjected to before being deposited. Usually, strontium and calcium are lost rapidly and more easily than Zr during chemical weathering, and the amount of loss can be related to the extent of weathering (Wronkiewicz and Condie 1987; Degryse and Braekmans 2013). The alteration of plagioclase crystals might also be of potentially significant influence. Three clay samples (B2.5, B2.6, B2.7) were recovered from an archaeological excavation in the site of Barillas, northwest of AB, at a depth of 1.0 and 1.5 m respectively. The site is located by a large alluvial terrace in immediate proximity to the Mayales river, though the composition notably diverges from the samples collected at the same river.

The behaviour of the different chemical elements during sedimentary processes is complex and is influenced by several natural factors, such as weathering, physical sorting, absorption of ions by clays and other fine-grained particles, coarse grain-effect, diagenesis and metamorphism (Wronkiewicz and Condie 1987; Mahjoor *et al.* 2009; Degryse and Braekmans 2013). However, these chemical results clearly showed the ability to compositionally discriminate two different geological formations, the Zapatera Archipelago and the Río Mayales subbasin, as well as to further divide the Mayales area in three distinct chemical groups. Since these environments are characterised by measurable chemical differences, they demonstrate how the variability in different geological substrates of this region can contribute to create these distinguishable compositional clay groups. Moreover, this partly reflects the diverse geological units described by Garayar (1972). Results of chemical analysis on both clay and ceramics materials from archaeological excavations in the valley show that some clays were selected by pre-Hispanic populations for manufacturing pottery (Casale *et al*. 2020).

### *3.3 Ethnographic survey*

The geochemical analysis of clay beds is an ideal method to connect ceramic objects with various mineral resources. Apart from these chemical characteristics, artisans in past and present may select their material on properties beyond solely the suitability of clay. The data from an ethnographic survey therefore, presented in this section, is based on a series of conversations with local inhabitants of the valley to elucidate these choices and connections. The ethnographic survey started with interviews with both local potters and brick factory workers. Interviews consistently showed that local soils are divided in six major types, according to plasticity, colour and current use for the local economy, such as agriculture, building, and pasture. Table 2 shows the types and local uses attributed to the different clays. The production of bricks and clay-based architecture are the most important activities related to this soil exploitation. Brick manufactories are always located next to water sources and in direct vicinity of the soil deposits used in the production process. There is very little movement of raw materials from different locations, and only *in situ* materials are processed. Factories produced goods with every type of soil and usually the choice of the location is mainly driven by the availability of water and the economic capacity of the owners. For instance, one manufactory produces bricks with only pure sandy material, so their end products are extremely friable specimens of low quality. Another manufactory employed a mix of sandy and clayish materials resulting in a product of higher quality. However, this combination was not linked to a technological choice, but rather to a geological condition. The brick manufactory owner was unaware of the presence of a clay-rich soil layer located between two layers of sandy river accumulation prior to the founding of the factory.

Even though the production of building materials has a wide development in the area, and the use of cement and sheet metal is increasing, houses in these rural areas are sometimes still built using wood and a type of soil called *lanilla*[3]. Figure 6 shows some examples of the current uses of this soil for building walls, kitchens, fireplaces and ovens. *Lanilla* is mixed with water and grasses after which the mixture is added to the wood structure to create the walls. The great advantage of this material is that it is waterproof without the need for firing, creating a strong, insulating wall surface.

A large number of man-made mounds is located on *lanilla* deposits (van Dijk 2017), or in direct proximity to them, and *lanilla* soil is often found during the

3 For more information about modern house construction in *lanilla* and wood, please refer to Arnau Llaudet (in press).

| Local name | Description according to Taylor (1963) and van Dijk (2017) | Modern use | Variations |
|---|---|---|---|
| *Lanilla* | *Young volcanic ash/alluvial soil* | Production of bricks, house walls, pavement, kitchen and oven. Pasture and agriculture. | From beige to light brown |
| *Barro* | *Tropical alluvial soil* | Bricks, tiles, and ceramics. | *amarillo, negro, barro/arenoso* |
| *Barrial* | *Tropical Black soil/Vertisol* | Crops and pasture activities. | *bajo, negro, cafè, barro barrial* |
| *Tierra* | *Tropical brown/alluvial soil* | Crops and pasture activities. | *normal, fina, negra* |
| *Arenoso* | *Alluvial deposits* | Production of bricks. | *barro arenoso* |
| *Arena* | *Alluvial deposits* | Production of bricks. | No variations |

Table 2: Description of local soil names and their uses.

excavation near and within mounds. It seems likely, therefore, that pre-Hispanic populations might have consciously sought out *lanilla* as building materials, similar to the current day strategies.

### *3.4 20th century pottery manufacture*

Regarding the production of earthenware and kitchen goods, the main outcome of the ethnographic survey is that the local production of ceramics has dramatically declined with the advent of cheaper plastic and metal items in the last few decades. The general picture that emerges through interviews is that the majority of the current day population is not familiar with pottery practices or aware of the location of clay sources. Mostly, only people older than 60 years of age are aware of the presence of clay outcrops, while most of them have never produced pots, whereas earlier relatives used to manufacture pottery at the household level.

Even with some exceptions, production in the past was mostly related to the domestic consumption and not for export and/or sale to the local market. The knowledge of clay deposits, the quality and the way of working with raw materials, were all shared between a few individuals or small clusters of families. Such knowledge of a single or dual clay sources was typically used for the entire life span, transmitting the knowledge from generation to generation. All the clay outcrops, except for one, were located within a 500 meter radius from houses, while the longest distance recorded between the production's place and the used clay deposit is around one kilometre. Rarely, different clays are mixed, but most of the time potters use clays without prior processing or preparation, such as sorting, sieving, or tempering. In a single case, one woman, Doña Guadalupe, who lives north of Juigalpa along the Cuapa road, used to produce ceramics for her own consumption. Her clay preparation practices involved mixing two different kinds of clay, a very fine one and a sandier one. One of these two clay outcrops is located one kilometre from her house, representing the longest distance between a potter's household and their raw material source for the research area.

Integral and detailed descriptions of manufacturing practises were documented in two separate communities. The first community, San Isidro, is located very close to AB, where we interviewed Antonia Villegas Ruiz, the last person knowledgeable of how to make ceramic vessels in the area. The second community, Güegüestepe, is a small hamlet where families were fully dedicated to pottery and brick production, located about two km from Juigalpa.[4]

At San Isidro, clay procurement involved an outcrop located 300 meters west of the potter's household, at the shore of a stream. Paste preparation only entailed the addition of water, as well as kneading and percussion gestures to obtain the desired plasticity. Fashioning was done with a clay mass, placed over a convex mould. Percussion is applied on the mold until the desired shape is achieved, and then immediately after a corn cob is hydrated and applied to continue the pre-forming process. Later, pinching and beating are applied to homogenize walls. After drying for a few days, surface treatment is done with a *zapoyol* seed (from the Sapotaceae family). Finally, pots are fired on an open hearth.

4 The medium-length documentary film "Barro Somos", jointly produced by Espora Productions (Mexico) and PACEN is an audiovisual testimony of the experiences of these two case studies (https://vimeo.com/146862913).


Figure 5: From top left to bottom right: different uses of *lanilla* soil to build kilns (figure 5a, courtesy of Espora Productions), houses, kitchen ovens (figure 5c, courtesy of Alejandro Arteaga), and an example of a brick manufactory.

Although pottery production declined, the Güegüestepe community still bases its economy on manufacturing earthenware. In particular, griddles and cooking pots are produced, and then sold on the local market in Juigalpa. Clay procurement practices involve exploiting a clay outcrop located 400 meters south of the village, on the banks of the Mayales river. Paste preparation practices only involved hydration, kneading, and pounding. Fashioning is conducted on a clay mass, a concave mould serves as a rotative support for finishing the griddles, while for jars, a convex mould is employed. Palmar beating is predominant, but pinching and drawing are also applied. A plastic tool is used for scraping, and after drying, surface treatment involves burnishing with a *zapoyol* seed. In contrast to San Isidro, a kiln is used to fire the pots. Apart from that, production in Güegüestepe is commercially oriented rather than satisfying demands at the household level, as is the case in San Isidro.

## 4. Conclusion

Through the combination of both systematic archaeological pedestrian surveying and ethnographic interviewing (Geurds *et al.* 2015, Casale 2017), this research has created an understanding of clay availability across the valley, and how this relates to the use of raw clay materials suitable for ceramic manufacture in the past and present. Previous archaeological studies in the area investigated ceramic through a morphological focus (Gorin 1990), while the results of this study substantially increase information for further research into the longterm ceramic production and selective use of mineral resources from the pre-Hispanic period onwards. This study provides an extensive overview of present day ceramics manufacturing traditions that feeds back across time in the valley of Juigalpa. Today, local potters use and identify only clay outcrops close to their residential or manufacture area. However, the results of the research showed that the quantity of


Figure 6: Modern ceramics production at the Güegüestepe (figure 5a, courtesy of Espora Productions) and San Isidro communities, examples of *ollas* (cooking pots, figure 5b, courtesy of Espora Productions) and *comales* (griddles).

clay suitable for producing ceramics is far greater than what local potters are currently aware of. Petrographic analysis on ceramic materials excavated in other sites located in the valley have shown connections to the clay outcrop exploited in the community of Güegüestepe, demonstrating a continuity in clay procurement practices that goes deep into the present. Figure 3, for instance, shows that each archaeological site has several suitable clay outcrops in a one or two kilometres radius.

In addition, the reported chemical analysis demonstrates that p-XRF in this setting is a reliable technique for studying geological samples in field and laboratory environments, being able to clearly differentiate between clay samples of distinct regions such as the Zapatera Archipelago and the Río Mayales subbasin. The analysis also shows that the valley is not compositionally homogeneous, and substantial geochemical data have allowed for the characterisation of distinct, geologically-based compositional groups throughout the landscape. In these efforts for creating clay chemical profiles as a reference for future studies, three main heterogeneous groups were identified. This resulted in a significant improvement of the limited geochemical data resolution previously available, and it encourages further high-resolution chemical analysis that aims to link clay outcrops with ceramic materials. Future comparisons of ceramics with the raw mineral resources will generate undoubtedly more hypotheses regarding the role of Aguas Buenas as a shared place among different communities in the Río Mayales subbasin.

Lastly, interviews with local potters and manufactory workers revealed significant aspects of the production processes concerning raw materials selection and fabrication sequences. The main conclusion is that artisans are satisfied with a very limited range of clays, regardless of the manufacturing techniques or final use of the objects. Griddles and pots are produced with the same clay, even if they might have two completely different functions, such as cooking or water containers. Differences in firing seem to be connected to the type of production, either related to a manufacture for satisfying domestic demands through the use of open hearths or alternatively kiln firing applied by specialized potters.

The information gained through this study creates a reference baseline for future research in the area, providing a new solid research framework of investigation that can be employed for more detailed and extensive future studies on pre-Hispanic human groups and their use of mineral resources in central Nicaragua.

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## References

Arengi, J. T. and G.V. Hodgson 2000. Overview of the Geology and Mineral Industry of Nicaragua, *International Geology Review* 42(1), 45-63. https://doi.org/10.1080/00206810009465069

Arteaga, S.A. 2017. *Reconstrucción del paisaje social prehispánico en la microcuenca del río Mayales, Chontales, Nicaragua*, Mexico City (Unpublished Master thesis National Autonomous University of Mexico).

Auzina, D. 2018. *Monumentality by Communities. Mapping the Spatial Logic of the Pre-Hispanic Site Aguas Buenas (AD 400-1600) in Central Nicaragua*, Leiden (unpublished Master thesis University of Leiden).

Baxter, M. 2003. *Statistics in Archaeology*,Hodder Arnold, London.

Casale, S. 2017. *Pre-hispanic clay roads. Evaluation and interpretation of ceramic product and raw clay procurement in the Rio Mayales Subbasin, Chontales, Nicaragua*, Leiden (unpublished Master thesis Leiden University).

Casale, S., N. Donner, D. Braekmans, A. Geurds 2020. Geochemical and petrographic assessment of clay outcrops and archaeological ceramics from the pre-Hispanic site of Aguas Buenas (cal 400 -1250 CE), central Nicaragua, *Microchemical Journal*.

Ciofalo, A., N.R. Donner, C.L. Hofman, A. Geurds 2020. Uses of pre-Hispanic cooking implements from central Nicaragua: Implications for understanding botanical foodways, *Journal of Archaeological and Anthropological Sciences* 12:13.

Costin C. 2000. The Use of Ethnoarchaeology for the Archaeological Study of Ceramic Production, *Journal of Archaeological Method and Theory* 7 (4), 377-403.

Degryse, P. and D. Braekmans 2013. Elemental and Isotopic Analysis of Ancient Ceramics and Glass. In: H. H. Turekian (eds), *Treatise on geochemistry*, Oxford: Elsevier, (Vols. 2nd Edition, vol. 14, 191-207).

Dennett, C. 2016. *The Ceramic Economy of Pre-Columbian Pacific Nicaragua (AD 1-1250)*, Calgary (Unpublished Ph.D. thesis University of Calgary).

Donner, N.R., A. Arteaga, A. Geurds and K. van Dijk, 2018. Caracterización inicial de los sitios arqueológicos en la subcuenca del río Mayales, Departamento de Chontales, Nicaragua, *Cuadernos de Antropología* 28(1): 1-26. DOI 10.15517/CAT.V28I1.32358DOI 10.15517/CAT.V28I1.32358

Donner, N. and A. Geurds 2018. The valley of Juigalpa, Mayales River Sub-basin Microregion (Chontales, Nicaragua) Date list I, *Radiocarbon*, 1-10. doi:10.1017/RDC.2017.147

Donner, N. R., S. Casale, D. Braekmans, A. Geurds 2019. Ceramic comales at the Barillas site (cal 1255-1390 CE), central Nicaragua: Defining a local technical tradition of griddle manufacture, *Journal of Archaeological Science: Reports* 24: 829-842.

Garayar, J. 1972. *Geología y depósitos de minerales de la región de Chontales y Boaco*, Catastro y Reservas Minerales. División de Geología, Report, (11), Managua.

Geurds, A., J. Zambrana and L.N.K. Van Broekhoven 2009. Investigaciones recientes en el Departamento de Chontales, *Mi Museo y Vos* 3(8): 4-7.

Geurds, A. and L.N.K. Van Broekhoven, 2010. The similarity trap: engineering the Greater-Caribbean, a perspective from the Isthmo-Colombian area, *Journal of Caribbean Archaeology*, Special Publication 3: 52-75.

Geurds, A., N. Donner, S.A. Arteaga, F.R. Angeles, I. Torreggiani, D. Donner, L.A. Ayala, C. Mendoza, L.J. Murguia 2015. *Reporte Preliminar Proyecto Arqueológico Centro de Nicaragua (PACEN) Novena etapa*, Unpublished report, INC, Managua.

Geurds, A. and D. Terpstra 2017. Circular reasoning in mound building? Large-scale planned construction patterns at the Aguas Buenas site (A.D. 400-1525). In: A.K. Benfer (ed) *War & Peace: Conflict and resolution in archaeology. Proceedings of the 45th Annual Chacmool archaeology conference*, University of Calgary, Calgary, 47-59.

Gorin, F. 1990. *Archéologie de Chontales, Nicaragua* (3 vols.), Dissertation, Université de Paris I, Paris.

Gorin, D. and F. Rigat 1993. "Proyecto Chontales": Informe Final. In: J.E. Arellano (ed), *30 años de arqueología en Nicaragua*, Museo Nacional de Nicaragua, Instituto Nicaragüense de Cultura, Managua, 97-101.

Hasegawa, E. 1998. *Informe del Proyecto Arqueológico Chontales II*, Unpublished report, Instituto Nicaragüense de Cultura, Managua.

Llaudet, A. (in press). Rural architecture in Juigalpa, Chontales: An ethnoarchaeological contribution. In: A. Geurds and N.R. Donner (eds) *Participating in PACEN: Reflections on collaborative archaeology in Juigalpa, Nicaragua*, Leiden: Sidestone Press.

Mahjoor, A.S., M. Karimi, A. Rastegarlari 2009. Mineralogical and geochemical characteristics of clay deposits from South Abarkouh district of clay deposit (Central Iran) and their applications, *Journal of Applied Clay Science*, 9: 601-14.

McBirney, A.R. and H. Williams, 1965. *Volcanic history of Nicaragua*, University of California, Publications in Geological Sciences 55, 1-65.

Nesbitt, H.W., G. Markovics and R.C. Price 1980. Chemical processes affecting alkalis and alkali earths during continental weathering, *Geochimica et Cosmochimica Acta* 44, 1659-1666.

Nyakairu, G.W. A. and C. Koeberl 2001. Mineralogical and chemical composition and distribution of rare earth elements in clay-rich sediments from central Uganda, *Geochemical Journal* 35, 13-28.

Peacock, D., 1982. *Pottery in the Roman World: an ethnoarchaeological approach*, London and New York: Longman.

Sharrat, M., P. Golitko, R. Williams and L. Dussubieux, 2009. Ceramic Production during the Middle Horizon: Wari and Tiwanaku Clay Procurement in the Moquegua Valley, Peru, *Geoarchaeology* 24(6), 792-820.

Shugar, A. and L. Mass, 2012. *Handheld XRF for Art and Archaeology*. Vol. 3, University Press, Leuven.

Van Dijk, K. 2017. *Mound in Context. Environmental Variable and Pre-Columbian Mounds Distribution in the Mayales River Subbasin, Chontales, Nicaragua*, Leiden (Unpublished Bachelor thesis Leiden University).

Vaughn, K., J. and H. Neff 2004. Tracing the clay source of Nasca polychrome pottery: results from a preliminary raw material survey, *Journal of Archaeological Science*, 31 (11), 1577-1586. https://doi.org/10.1016/j.jas.2004.03.021

Vlaskamp, R. J.C., A. Geurds and R. Jansen 2014. Reporte de las investigaciones arqueológicas entre 2011-2014 en el sitio prehispánico de Aguas Buenas, Chontales, Nicaragua, *Mi Museo y Vos* 8 (29), 6-12.

Wronkiewicz, D.J. and K.C. Condie 1987. Geochemistry of Archean shales from the Witwatersrand Supergroup, South Africa: Source-area weathering and provenance, *Geochimica et Cosmochimica Acta*, 51, 2401-2416.

Yankowski, A. 2008. Earthenware Production and Trade: Using ethnographic data and petrographic analyses to compare prehistoric and contemporary pottery traditions from the island of Bohol, Philippines, *Bulletin of the Indo-Pacific Prehistory Association* 28: 1-5.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 121-142.

# A long slow goodbye – Re-examining the Mesolithic – Neolithic transition (5500 – 2500 BCE) in the Dutch delta

Gerrit L. Dusseldorp and Luc W.S.W. Amkreutz

*During the Neolithic, Neolithic societies in the Dutch wetlands are characterised as "extended broad-spectrum hunter-gatherers". They adopted agricultural elements only gradually and wild resources continue to play an important role in subsistence. However, the exact duration of the process of neolithisation in the Dutch wetlands is debated. We analyse the taxonomic diversity of faunal assemblages from the late Mesolithic and Neolithic in the Netherlands. We demonstrate that the diversity of exploited faunal resources remains remarkably constant throughout the Neolithic. We interpret this to show that the reliance on an extended broad-spectrum economy was not a transitional phase, but was a viable economic system in its own right.*

*Keywords: Mesolithic, Neolithic, subsistence economy, foraging, agriculture, extended broad spectrum, Archaeozoology*

## 1. Introduction

The adoption of agriculture in the coastal regions of North-western Europe occurred more gradually than in the interior loess belt and adjacent areas (Raemaekers 1999; Bakels 2000; 2009; Louwe Kooijmans 2007). In the Dutch wetlands, it may have taken over a millennium (*e.g.* Louwe Kooijmans 1987). It appears that Mesolithic hunter-gatherers gradually and selectively adopted elements of a farming way of life. The Early and Middle Neolithic inhabitants are proposed to have an "extended broad-spectrum" economy, including hunting, gathering and farming (Louwe Kooijmans 1993, 102-103).

However, the duration of the transitional period is contested. Proposals range from a short transition that may have been completed during the Middle Neolithic to a transition that only ended in the Early Bronze Age (compare Raemaekers 2003, 744-745; Amkreutz 2013, 435). The debate concerns when agricultural methods came to dominate the subsistence economy, but also when an agricultural way of life became central in societies' worldviews. We examine the diversity of represented animal species in Mesolithic and Neolithic faunal assemblages to determine if the extended broad-spectrum economy gave way to the exploitation of a more narrow set of mainly agricultural resources over time.

Existing approaches focus on the proportion of domestic and wild resources in the faunal spectrum of archaeological sites (*e.g.* Raemaekers 2003; also see Amkreutz 2013, 312-324). Here we focus on the diversity of represented resources to evaluate the extended broad-spectrum aspect. This complements proportional analysis of the subsistence economy. It is also less vulnerable to certain biases such as field processing (*e.g.* Faith 2007; Dusseldorp and Langejans 2013; Morin and

**Gerrit L. Dusseldorp**
Centre for Anthropological Research
University of Johannesburg
also:
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
g.l.dusseldorp@arch.leidenuniv.nl

**Luc W.S.W. Amkreutz**
National Museum of Antiquities
PO box 11114
2301 EC Leiden
The Netherlands
l.amkreutz@rmo.nl
also:
Faculty of Archaeology
Leiden University

Ready 2013), cultural discard patterns (cf. Sadr 2008; Huffman 2010) and taphonomic and post-depositional processes (*e.g.* excavation methods, sieving practices).

One of us, has analysed the process from an emic perspective, foregrounding lived experience and *mentalité* (Amkreutz 2013) arguing aspects of the hunter-gatherer worldview remain visible until at least 3000 BCE. Raemaekers (2019) also develops an emic perspective, arguing that in terms of societal relevance cattle and cereals had taken centre stage by 4000 BCE. Looking at changes and continuities in the diversity of faunal assemblages may also help evaluate the societal relevance of different subsistence strategies.

To study changes in the diversity of faunal assemblages, we adopt a "big-data" approach. We compiled a database of Late Mesolithic and Neolithic assemblages from the Netherlands, which we analyse in terms of taxonomic richness (*i.e.* the number of represented species) as a function of assemblage size. We demonstrate that a diverse spectrum of resources is exploited throughout the Neolithic, suggesting the uptake of an agricultural way of life was a very gradual process.

## 2. Background

### *2.1 Ecological background*

Neolithic bone assemblages from the Netherlands are virtually only known from wetland settings. These were not marginal areas and communities in the Late Mesolithic-Neolithic succession clearly focused on them (Amkreutz 2013, ch. 7, ch. 9; also see Raemaekers 2019). Our emphasis lies with these communities in the Lower Rhine Area delta region between the Scheldt in the south and the Elbe in the north. With respect to food and raw materials these wetlands are among the richest areas hunter-gatherers inhabit (Van de Noort and O'Sullivan 2006; Nicholas 2007a; 2007b), explaining why they could afford to be selective compared to upland communities in their uptake of elements from an agricultural subsistence economy (Amkreutz 2013, 427).

The Lower Rhine delta comprises different zones with varied characteristics. From east to west these include a riverine area with extensive Pleistocene upland, an extensive freshwater peat marsh interspersed with riverine elements, levees, lakes and Pleistocene river dunes ('donken') (Verbruggen 1992; Louwe Kooijmans 1993; Westerhof *et al.* 2003; Amkreutz 2013). Further west there are salt marshes dissected by creeks, followed by tidal flats and coastal barriers with low dunes and wide estuaries. Further north in the IJsselmeer basins and south in the Scheldt valley water was an equally dominant factor (Crombé *et al.* 2011; Ten Anscher 2012; Schepers 2014). Site-based faunal and botanical research indicates habitation of a wide range of settings (*e.g.* Bakels 1986; Out 2009b; Amkreutz 2013, 298; Schepers 2014). In general a difference in subsistence strategies may exist between freshwater (riverine and freshwater peat districts) and coastal wetlands (Zeiler *et al.* 2011).

The area was subject to temporal changes as well. Cycles of transgression and regression first precipitated an inland coastline shift until 4000 cal BCE resulting in peat growth and an eastward shift of the entire system of beach barriers, lagunas and peat marsh. Around the turn of the 5th millennium BCE this reversed due to the drop in relative sea level rise and resulted in increased freshwater influence and outward extension of the beach barriers (Van Gijssel and Van der Valk 2005; Vos and Kiden 2005). Marine incursions and peat growth made certain landscapes uninhabitable. Additionally, changing river systems and seasonal changes in habitability, such as flooding of important sites (cf. Schepers 2014) greatly influenced people's lives.

To hunter-gatherers, the stable uplands afforded very different foraging opportunities than these dynamic wetlands. The Holocene fauna lacks megafauna that play a key role in landscape engineering (Crégut-Bonnoure 1995, 233; Von Koenigswald 2007, table 29.1). In the dense forests covering the loess and coversand landscapes, available prey biomass was low, mainly consisting of red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) (Delpech 1999, also see Binford 2007). These "infertile uplands" (Svenning 2002), were covered by closed forest during the Mesolithic. Small-scale agricultural activity resulted in a gradual opening up during the Neolithic, and a largely open character by the Late Neolithic (Van den Brink and Paulussen 2013, 21).

The herbivore biomass of the wetland regions was larger, as vegetation was more open in places (Zeiler 1999; Svenning 2002). Some herbivores were adapted to wetland settings (*i.e.* aurochs (*Bos primigenius*) and elk (*Alces alces*)) (Hall 2008). Moreover, beaver (*Castor fiber*) and otter (*Lutra lutra*) were present in large numbers. Additionally, the wetlands were characterised by the presence of rich fish and fowl stocks, and more abundant edible plant foods (see overview in Amkreutz 2013).

Clearly the wetland and upland landscapes merged into each other, yet in general, the biodiver-

Figure 1: Exploited food remains from Hardinxveld (Polderweg and De Bruin). Note typical wetland resources such as otter and beaver skulls (elevated at back), fish vertebra and grey seal jaw (center right) as well as waternuts, (front right). Photo: National Museum of Antiquities, Leiden.

sity in the 'upland' regions is lower. The wetlands on the other hand offered less ideal circumstances for animal husbandry and crop cultivation (see Bakels 1988; Dusseldorp and Amkreutz 2015). Within the wetland group geographic difference and temporal change intersected with the traditions and choices of the communities living there (*e.g.* Louwe Kooijmans 2009; also see Amkreutz 2013, ch. 7-9). It appears that both the wetland ecology, and its inhabiting societies therefore favoured an extended broad spectrum economy.

### *2.2 Archaeological background*

The loess and coversand uplands in the southern Netherlands witness a relatively quick transition to agricultural societies (Amkreutz 2013; Dusseldorp and Amkreutz 2015). We have argued this is partly caused by these landscapes being relatively more suitable for agriculture than foraging (Dusseldorp and Amkreutz 2015). The wetlands were less suitable for agriculture; smaller areas for fields were available and in some regions grazing was limited (Bakels 1988; Amkreutz 2013; Dusseldorp and Amkreutz 2015). Moreover,

| Culture | Chronology | Characteristics |
|---|---|---|
| Late Mesolithic | Up to 5000 BCE | Broad-spectrum hunter-gatherers in the wetlands |
| Early Swifterbant | 5100/5000-4500 BCE | Pottery production in the wetlands; broad-spectrum hunter-gatherers |
| Middle-Late Swifterbant | 4500-3800/3400 BCE | Livestock, cultivars introduced in wetlands; "extended broad-spectrum" hunter-gatherers (cf. Louwe Kooijmans 1993) |
| Hazendonk | 3800/3400 BCE | "Extended broad-spectrum" farmers; farming thought to increase in economic importance (cf. Raemaekers 2003) |
| Vlaardingen | 3400-2500 BCE | "Extended broad-spectrum" farmers, related to Stein group further inland. |
| Funnel Beaker Culture | 3400-2900 BCE | Farming communities on uplands in N. Netherlands (Pleistocene till deposits). Associated with megalithic structures. |
| Single Grave | 2900-2500 BCE | Farming communities, but intensive use of other resource in coastal and wetland areas |
| Bell Beaker | 2500-2000 BCE | |

Table 1: Chronological overview of cultural entities across the Late Mesolithic and Neolithic periods.

the area may have been unsuited to some of the crop plants and livestock species such as sheep/goat would be vulnerable to liver fluke (Louwe Kooijmans 1987).

In the wetlands, Late Mesolithic hunter-gatherers give way to the so-called Swifterbant culture (table 1). Both Mesolithic and early Swifterbant societies subsisted on a very broad range of wild resources to which the latter added pottery (figure 1). From the Middle phase of the Swifterbant culture, domestic animals and cereals are found at sites. The date of adoption of the earliest domesticates is debated as previously reported specimens from Brandwijk appear to be younger than originally thought (Çakirlar *et al.* in press). At De Bruin, early domestic animals are present during phase 3, prior to 4450 BCE (Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001). However, numbers are small; transport of domestic remains to the site from elsewhere is likely (Louwe Kooijmans 2007; 2017). Domestic crops appear slightly later at *e.g.* Swifterbant S3 and P14 (Out 2008; Amkreutz 2013; Dusseldorp and Amkreutz 2015). Raemaekers and colleagues have shown that small-scale cereal cultivation also took place, even though the area was previously thought unsuitable (Bakels 1988; Cappers and Raemaekers 2008; Huisman and Raemaekers 2014; also see Out 2009a). However, wild animals remain present in large numbers (Zeiler 1997; Raemaekers 2003; Amkreutz 2013).

During the subsequent Hazendonk period, farming becomes more important and in the Vlaardingen period some faunal assemblages are clearly dominated by cattle (Louwe Kooijmans 2009; Bulten and Stokkel 2017). However, wild mammals remain important at many sites and foraging plays an important role until the early Bronze Age (Zeiler 1997; Fokkens *et al.* 2016).

Based on the foregoing, a specific wetland formula combining small-scale agricultural activities with foraging, *i.e.* an extended broad-spectrum economy continues well into the Late Neolithic. In the coastal dunes, some cattle-dominated assemblages occur. Elsewhere, however, communities remain characterized by a varied spectrum at what are clearly living sites (*e.g.* Amkreutz 2013). During the Late Neolithic Single Grave Culture in wetland settings, evidence still abounds for an intensive use of a variety of wild resources (*e.g.* Zeiler and Brinkhuizen 2012; 2013), probably increasingly exploited in a logistical system.

## 3. Materials and Methods

Against the ecological and cultural background introduced above we explore the diversity of Dutch Late Mesolithic and Neolithic faunal assemblages as a function of their size (Grayson 1991; Grayson and Delpech 1998; Faith 2008; Lyman 2008; Broughton *et al.* 2011; Dusseldorp 2012; 2016; Lyman 2015). We first discuss the methodological background before presenting our dataset and methodology.

### *3.1 Methodological background*

We examine taxonomic richness (*i.e.* the number of represented taxa; NTAXA) of faunal assemblages to evaluate whether an "extended broad-spectrum" economy was in place throughout the Neolithic period. This analysis complements proportional analyses focusing on wild versus domestic resources (cf. Raemaekers *et al.* 1997; Raemaekers 2003), yet circumvents some of the problems associated with such analyses, especially the underrepresentation of specific resources due to behavioural and taphonomic factors.

We assume all subsistence activities are interrelated, and that increases in the importance of one aspect of the subsistence economy (*e.g.* animal husbandry) are reflected in other aspects (*e.g.* decrease in time spent foraging) (Broughton *et al.* 2010, 409-410; Dusseldorp 2016, 364). Evaluating the faunal richness provides a good way to determine changes in allocation of effort between foraging and agricultural activities. This means that increased time allocation in agricultural subsistence methods will lead to a decrease in foraging effort and hence lower NTAXA values (cf. Dusseldorp 2012; 2016).

NTAXA is influenced by assemblage size. Larger assemblages are more likely to sample additional taxa than smaller assemblages (Lyman 2008; 2015). However, the diet breadth (*i.e.* the number of species habitually exploited) determines the rate of skeletal input in assemblages (Lyman 2008; 2015). Hence, in an extended broad-spectrum economy, more taxa will be represented in a faunal assemblage of the same size than if the assemblage were accumulated in a farming society focusing on livestock exploitation.

We omit birds and fish from our analysis for several reasons. First, due to recovery methods, they are likely underrepresented. Second, having a different anatomical structure from mammals, these categories behave differently in our measure of taxonomic richness (Lyman 2015). However, in a qualitative evaluation of the importance of foraging relative to agriculture they should be incorporated.

By studying NTAXA, we work around a number of analytical problems. First, classification of suid remains to wild boar (*Sus scrofa*) or domestic pig (*Sus domesticus*) is problematic (Gehasse 1995; Raemaekers 2003). Genetic analysis presents similar problems as wild boar admixture is present in domestic pigs from very early on in Northwestern Europe. This is alongside the independent domestication of European wild boar at the time of the introduction of domesticated suids with a Near Eastern origin (Krause-Kyora *et al*. 2013). Based on aDNA, the proportions of wild versus domestic suids are therefore also impossible to determine. Our approach circumvents this: a small number of remains generally can be determined reliably to wild boar and pig. Hence both will be reflected. This means a reliable reflection of NTAXA can be attained when no reliable reflection of the proportions of domestic and wild animals can be ascertained.

Second, behavioural patterns in Meso- and Neolithic societies lead to differential representation of resources. Field processing and selective transport of carcasses lead to the underrepresentation of hunted prey (*e.g.* Faith 2007; Dusseldorp and Langejans 2013; Morin and Ready 2013) over livestock butchered on-site. Smaller species are more likely to be transported as whole carcasses than larger ones (*e.g.* Metcalfe and Barlow 1992; Winterhalder 2001, 22-23; Faith *et al.* 2009). This means the proportion of especially larger wild animals is likely an underestimate. However NTAXA will still reflect their exploitation.

This problem may be exacerbated for marine mammals. Seals and cetaceans are present in small numbers at many sites. Their most nutritious part is the so-called sculp, consisting of blubber and skin. Field processing of sculp may render these animals virtually invisible in the archaeological record (Smith and Kinahan 1984; Dusseldorp and Langejans 2013). Sometimes the only archaeological evidence for cetacean exploitation is the presence of species-specific whale barnacles demonstrating sculp presence (Kandel and Conard 2003; Parkington 2006). All local marine mammal species are large and likely to be field-processed; harbour porpoise (Phocoena phocoena): 40-80 kg.; harbour seal (*Phoca vitulina*): 50-170 kg.; grey seal (*Halichoerus grypus*): 100-300 kg (MacDonald 2006). Much larger species such as sperm whale (*Physeter macrocephalus*) are also occasionally represented (Groenman-Van Waateringe *et al.* 1968). Cetacean scavenging opportunities were also probably much more frequent during the Late Mesolithic and Neolithic, as modern population declines due to whaling have been severe (Lotze and Worm 2009, 256, 259).

Other behavioural factors influencing the archaeological visibility of specific species may be cultural discard patterns. Ethnographic evidence suggests rules regarding the discard of specific categories of animal remains influences archaeological visibility (cf. Sadr 2008; Huffman 2010).

### *3.2 Analysis*

To evaluate if the diversity of exploited animal resources (*i.e.* the diet breadth) changes across the Late Mesolithic and Neolithic periods, we compiled a database of published faunal assemblages (n=67) (Appendix at end of paper).

We compare different groups of bone assemblages to determine trends in the taxonomic richness of different subsistence economies, plotting taxonomic richness (NTAXA) as a function of total assemblage size (log∑NISP) (Lyman 2008; Dusseldorp 2016). We plot groups of assemblages to determine if NTAXA increases more quickly relative to assemblage size in earlier than in later groups. This would signify a broader exploited set of resources in the earlier than in the later groups. We also plot freshwater wetland groups and coastal groups from the same period to determine if NTAXA rises more quickly in the former. This would be expected if freshwater sites were special activity locations, whereas coastal locations were residential farming settlements (as suggested by Raemaekers 2003, 744-745).

We subdivided our dataset into three chronological groups, to test whether diversity changes through time. We defined an Early phase, prior to the introduction of livestock, comprising Late Mesolithic and Early Swifterbant sites (5500-4500 cal BCE). A Middle phase consisting of Middle and Late Swifterbant sites (4500-3400 cal BCE), witnessing the introduction of livestock and cultivars, often interpreted as a transitional phase (sensu Zvelebil 1986). And a Late phase with Hazendonk, Vlaardingen and Late Neolithic Beaker Culture sites (3700-2000 cal BCE). Raemaekers (2003, 744) suggested that by the Late phase, the majority of consumed calories would be from domestic resources. Note that our dataset contains no assemblages from the Early phase in the coastal group as this area was subject to large-scale erosion at that time.

We subdivided our dataset into two geographic groups: a coastal group, containing sites from coastal dunes, estuaries and salt marshes, and a freshwater group containing sites from inland wetland contexts including freshwater tidal environments. This represents a trade-off: dividing the dataset into more environmentally specific groups might increase the sensitivity. There would be greater similarities in the resource spectrum available for exploitation, however, these groups would be very small, decreasing the power of the method to determine larger-scale patterns.

Figure 2 presents an example: A plot of log∑NISP and NTAXA from two groups of South African Later

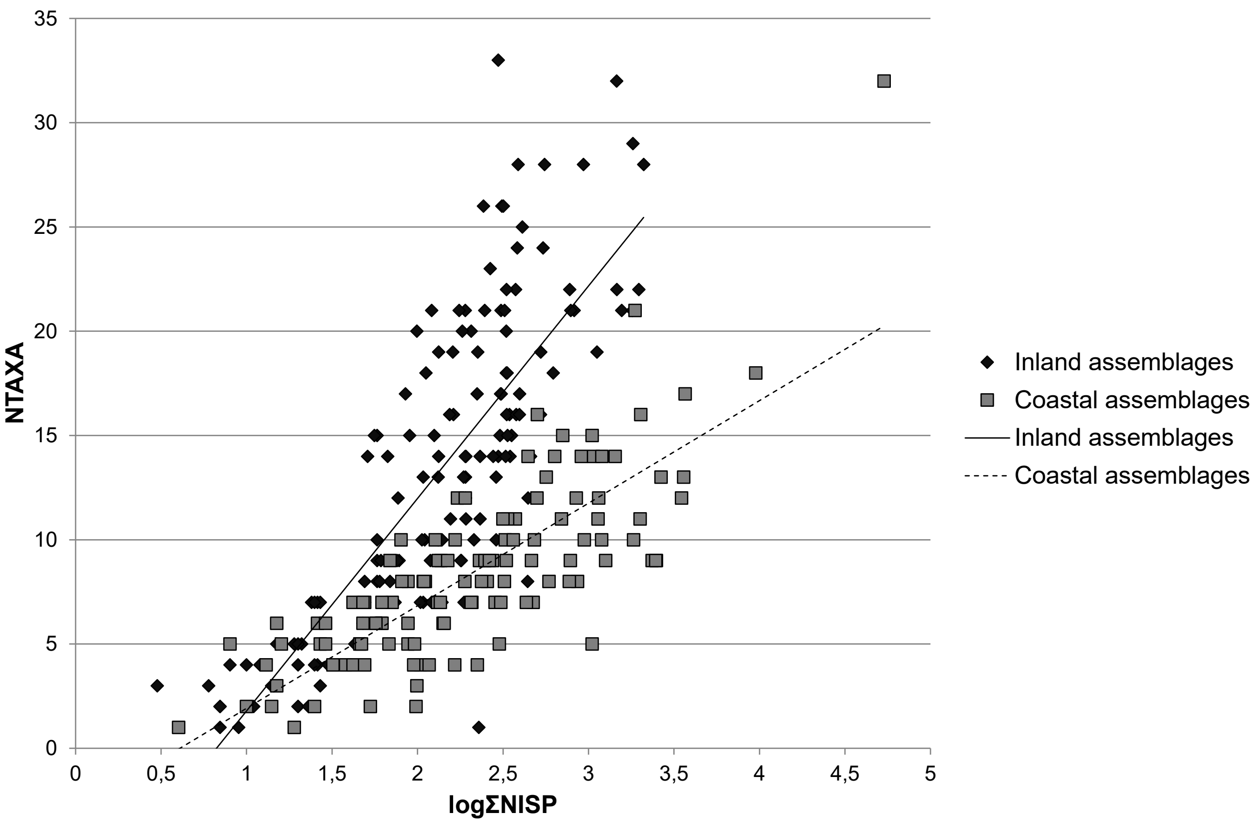


Figure 2: Example of a plot of two groups of assemblages showing clear difference in taxonomic diversity (Dusseldorp 2016, fig. 3).

Stone Age sites, demonstrating that in the rich coastal environment, faunal assemblages are less diverse than at inland sites (from Dusseldorp 2016). If farming provided an important, reliable source of calories, we expect assemblages accumulated by farmers to be similarly less diverse than those of extended broad-spectrum foragers.

Unfortunately, most recent excavation reports do not include data by minimum number of individuals (MNI). Hence we could not plot NTAXA and log∑MNI. This is a limitation, as a high degree of fragmentation is often mentioned (Zeiler 1997; Laarman 2001; Zeiler 2006). MNI provides a way to control for differential fragmentation (Lyman 1994; 2008). It is also the most reliable index to study the relative abundance of different taxa in faunal assemblages (Domínguez-Rodrigo 2012).

Another limitation is our focus on mammal bone assemblages. Based on ethnographic parallels, terrestrial hunter-gatherers in the Low Countries are expected to get >50% of their caloric intake from plant foods. In wetland environments, aquatic resources are expected to be most important (Binford 2001; 2007; Johnson 2014).

Data on specimens only identified to mammal size class are not available for all sites, due to intensive calcination and fragmentation in some assemblages (*e.g.* Laarman 2001; Zeiler 2006). Therefore we have plotted ∑NISP of specimens identified to taxon or specific category (*i.e.* carnivore sp., cervidae sp., etc. where included). We have included all non-human macromammals, also dog (*Canis familiaris*). As tables excluding antler specimens are not given for some assemblages, we have used counts including antler for all assemblages for the sake of consistency. At some sites, micromammals (*e.g.* “rodent sp.”, *Arvicola* sp.) were listed. We regard these as background fauna and excluded them.

For assemblages where bones were listed as “pig/wild boar”, but the accompanying text states that some specimens from that category were identified with certainty to pig and others to wild boar (*e.g.* Gehasse 1995), we have counted both. We counted general categories as one represented taxon when no specimens

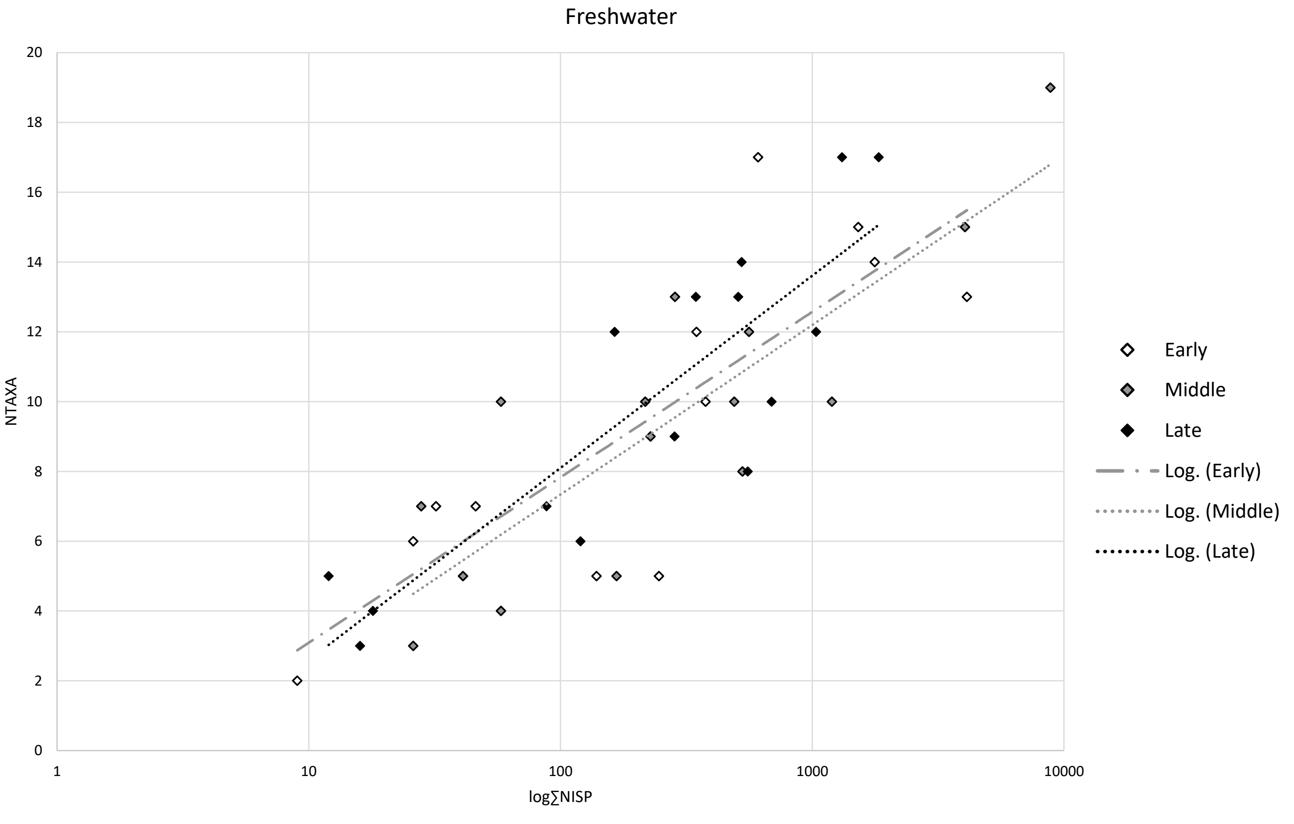


Figure 3: Plot of log∑NISP and NTAXA for freshwater assemblages divided into three chronological groups.

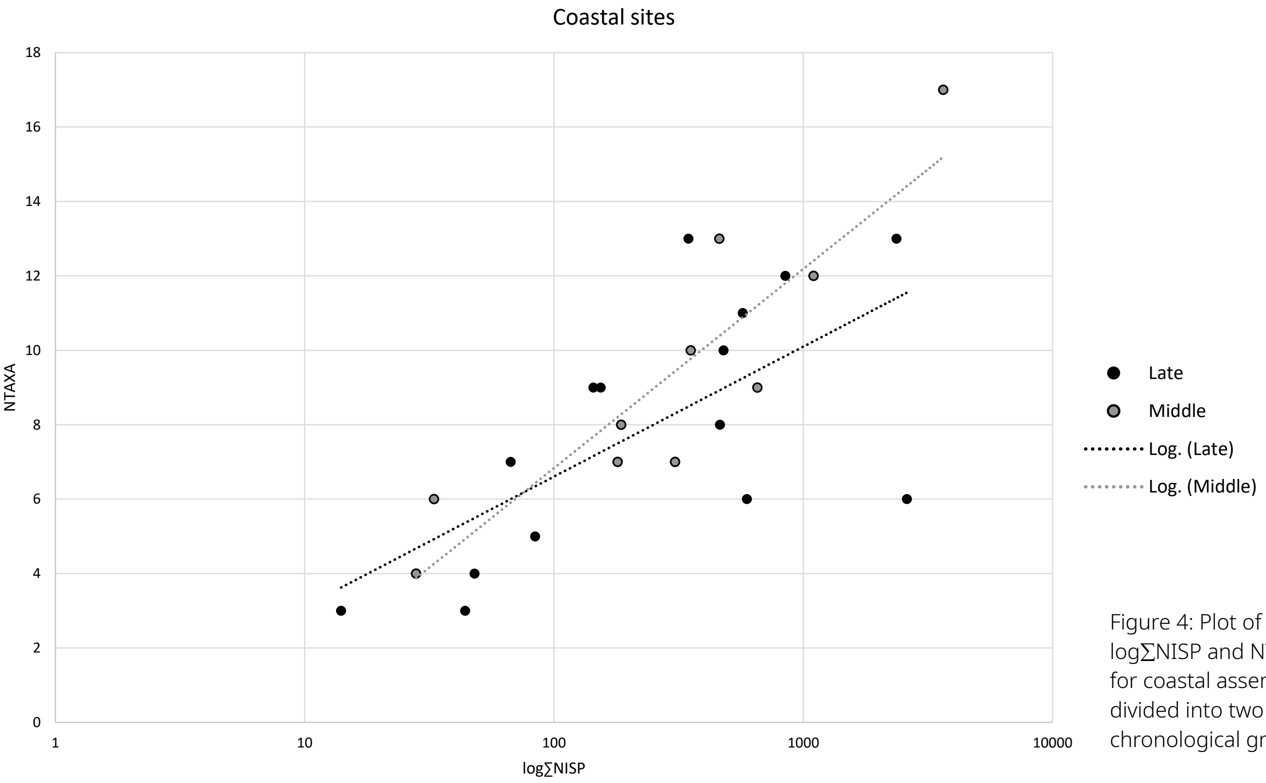


Figure 4: Plot of log∑NISP and NTAXA for coastal assemblages divided into two chronological groups.

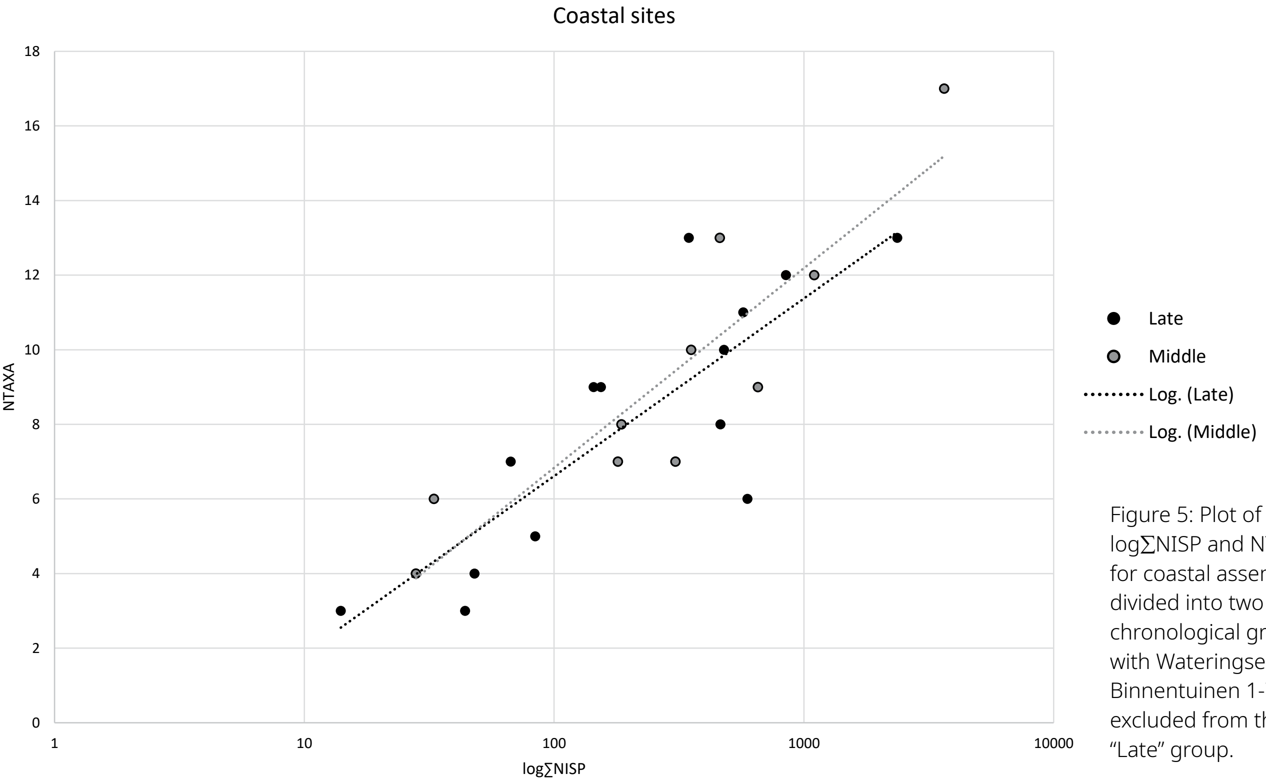


Figure 5: Plot of log∑NISP and NTAXA for coastal assemblages divided into two chronological groups with Wateringse Binnentuinen 1-7 excluded from the "Late" group.

were determined to any species from that category (*i.e.* "cetacean" would be counted as a represented taxon when no bones belonging to a specific whale species were reported in that assemblage).

## 4. Results

We plot the different groups of assemblages in a series of graphs to illustrate trends in NTAXA across groups of sites.

In the freshwater category, there are three groups of assemblages: Early (n=12), Middle (n=15) and Late (n=15). All groups have high $r^2$ values, demonstrating the categorisation explains an important part of the variability in the dataset (Early $r^2$: 0.68; Middle $r^2$: 0.72; Late $r^2$: 0.75; P<0.05). The slope of the regression lines through the groups (figure 3) is almost identical. This suggests that the diversity of the faunal assemblages in freshwater wetland contexts remains constant through time. This contrasts with expectations as in the Late group the increased role of agriculture is expected to result in a reduced diversity of faunal assemblages.

In the coastal area, the slope of the regression lines through the Middle (n=10) and Late (n=15) phases differ (figure 4). NTAXA values are lower relative to assemblage size in the Late period. This means a less diverse set of resources was exploited. This is the predicted pattern for an increased role of livestock in the subsistence economy. The $r^2$ value of the regression line through the "Late" group is relatively low, but statistically significant ($r^2$: 0.44; P <0.05). The "Middle" group has a high $r^2$ value ($r^2$: 0.80; P <0.05). We performed a t-test, which demonstrates the difference between the slopes of the regression lines is not statistically significant (t-value: 1.3; t-critical: 2.08; p: 0.21).

The low $r^2$ value of the "Late" group is due largely to the inclusion of one single assemblage: Wateringse Binnentuinen zone 1-7, which is dominated by cattle (*Bos taurus*). Its exclusion leads to a higher $r^2$ value ($r^2$: 0.68; P <0.05), but also to a changed slope of the regression line, which becomes virtually indistinguishable from that of the Middle group (fig. 5). The lower faunal diversity of the Late group is thus not a very robust pattern.

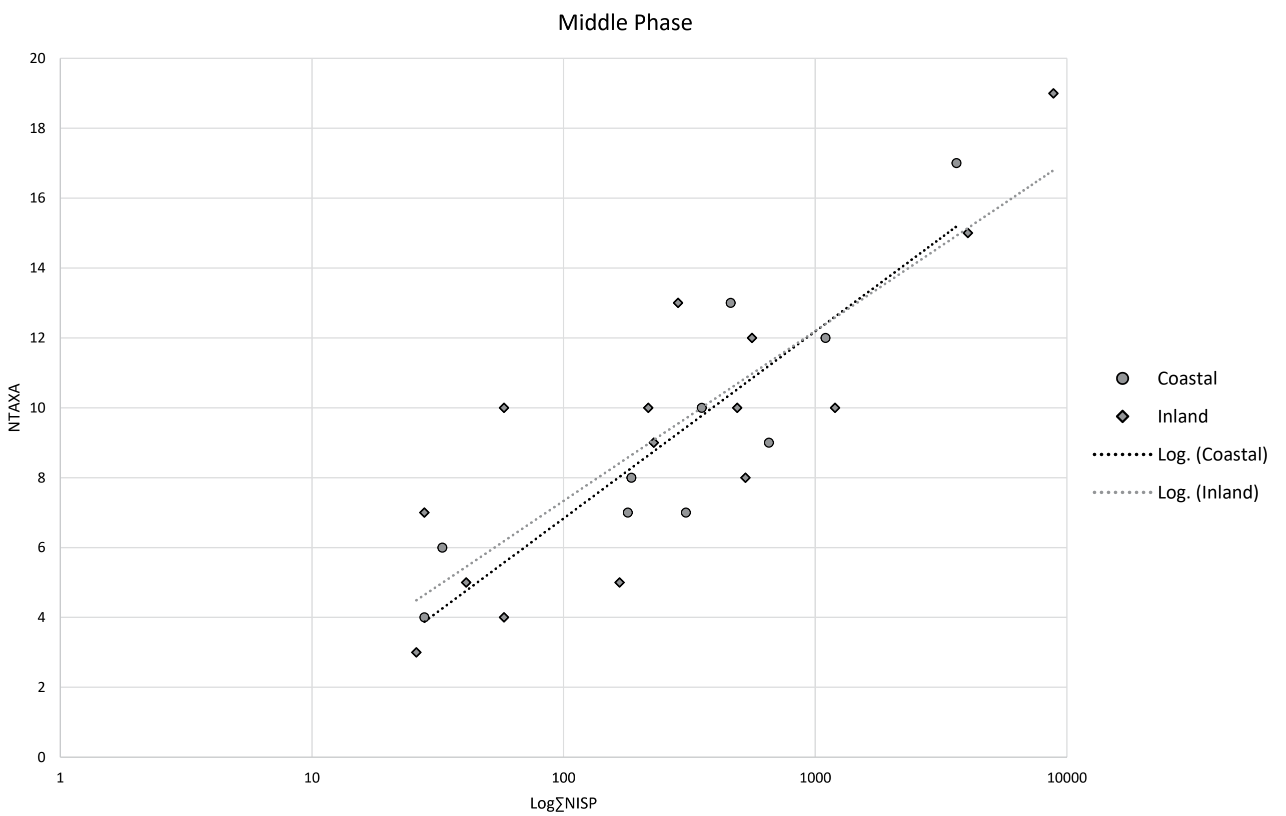


Figure 6: Plot of log∑NISP and NTAXA of assemblages from the "Middle" phase.

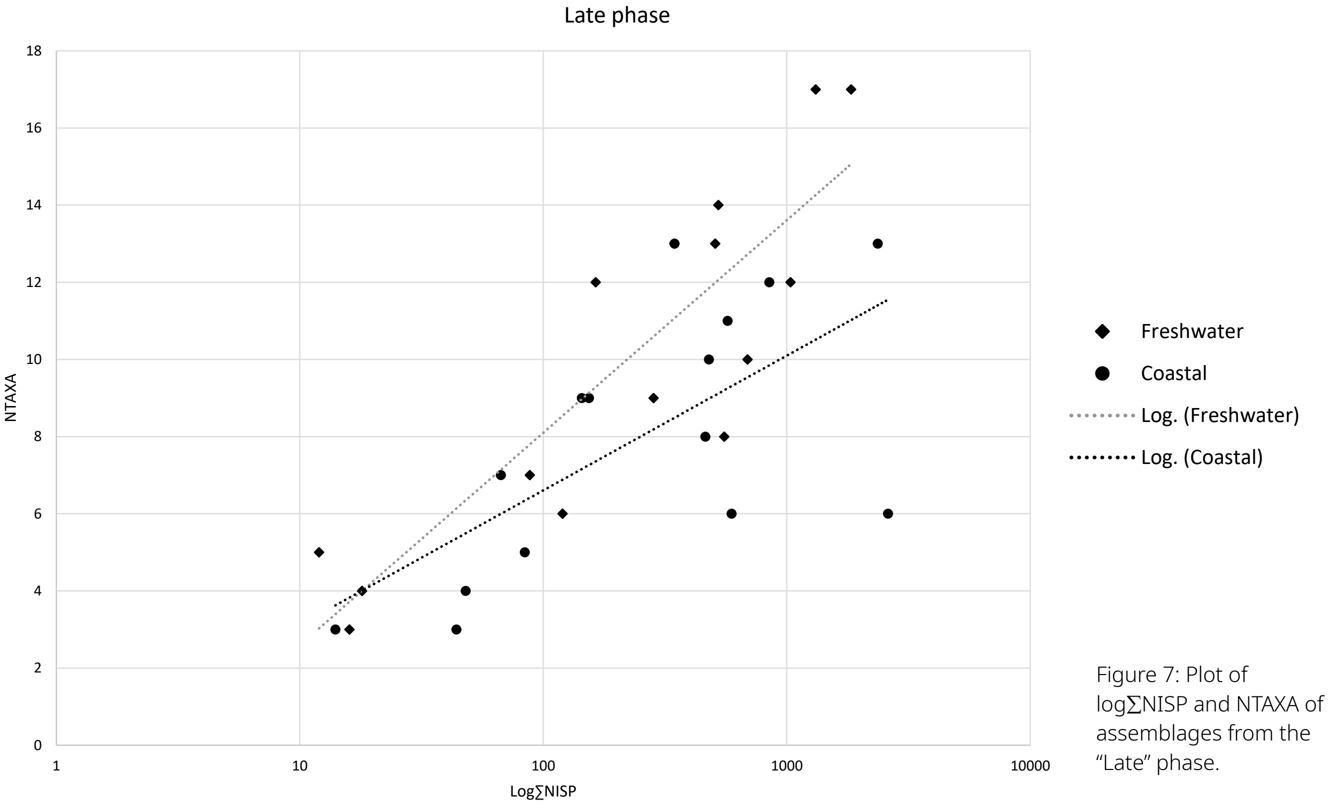


Figure 7: Plot of log∑NISP and NTAXA of assemblages from the "Late" phase.

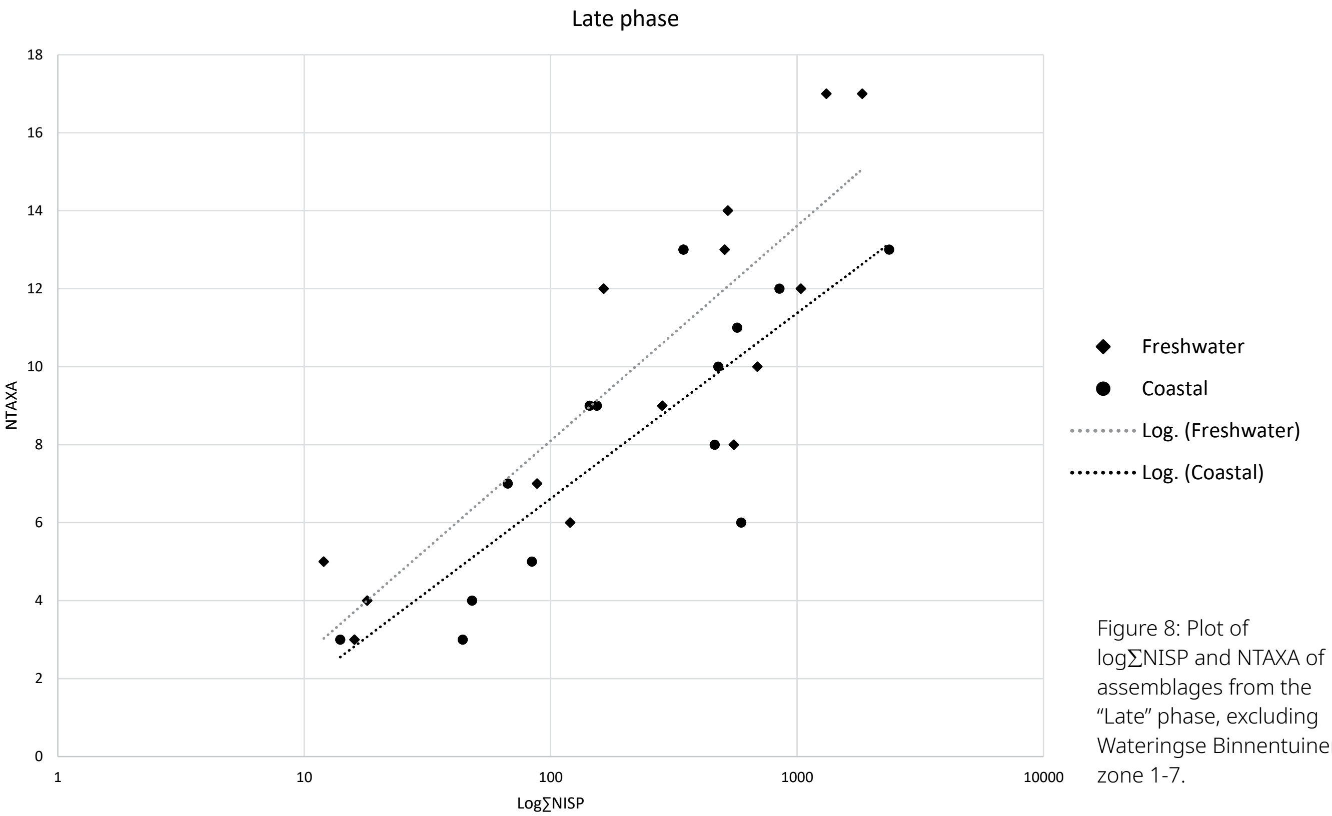


Figure 8: Plot of log∑NISP and NTAXA of assemblages from the "Late" phase, excluding Wateringse Binnentuinen zone 1-7.

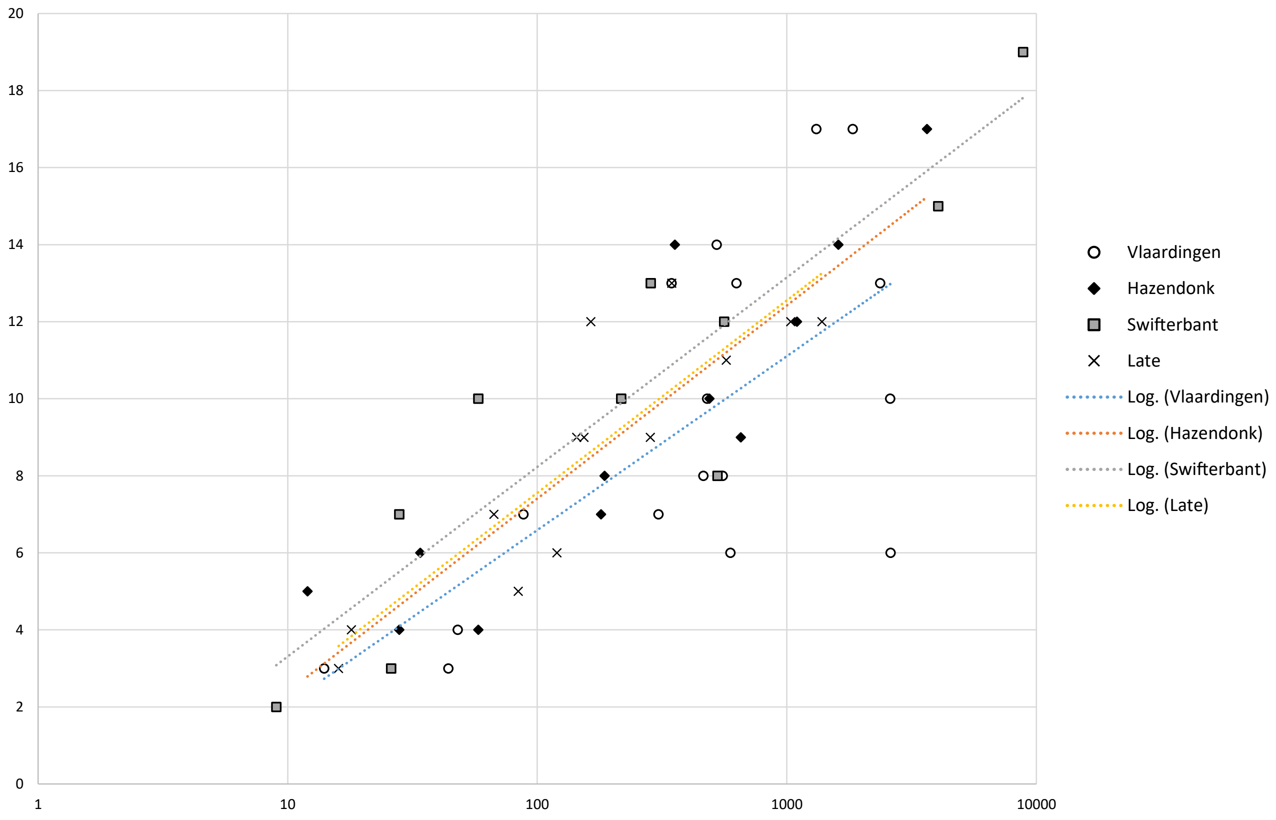


Figure 9: Plot of log∑NISP and NTAXA of assemblages from different cultural groups.

We also compare different geographical zones. Figure 6 shows that in the Middle phase, the freshwater and coastal groups exhibit very similar NTAXA values. Figure 7 shows that the "Late" assemblages from the freshwater area are more diverse than the coastal assemblages. However, the difference between the slopes of the regression lines is not significant (t-value: 1.45; t-critical: 2.06; p: 0.16). Excluding Wateringse Binnentuinen zone 1-7 from the coastal group leads to more similar taxonomic richness in the freshwater and coastal datasets. Still, coastal assemblages exhibit slightly lower NTAXA values (figure 8).

Finally, we have plotted the assemblages by cultural group (figure 9) to examine if different cultural groups produce different types of faunal assemblages cross-cutting our geographic division. We have plotted Middle and Late Swifterbant (n=10; $r^2$: 0.83; P<0.05), Hazendonk (n=12; $r^2$: 0.80; P<0.05), Vlaardingen (n=16; $r^2$: 0.44; P<0.05), and a Late Neolithic group with assorted beaker phenomena (n=13; $r^2$: 0.77; P<0.05). No clear difference in the diversity of the faunal assemblages is apparent. The variety of the Vlaardingen group is caused in part by the assemblage from Wateringse Binnentuinen zone 1-7, omitting it yields an $r^2$ value of 0.6 (P<0.05).

## 5. Discussion

Our analysis shows that the diversity of faunal assemblages is remarkably constant throughout the Late Mesolithic and Neolithic in Dutch wetland contexts. This suggests a persistence of the extended broad-spectrum economy throughout the Late Neolithic. Our results are surprising in view of existing models (*e.g.* Raemaekers 2003; Amkreutz 2013). One possible explanation is that our analysis is not sensitive enough to pick up important changes in taxonomic diversity. We consider this unlikely as the method has been shown to be sensitive to differences across landscape context and differences in hunter-gatherer subsistence strategies (*e.g.* Grayson 1991; Faith 2008; Dusseldorp 2016). If current patterns are confirmed at more sites, the slight differences between some groups may attain statistical significance. For instance, the slightly lower diversity in the coastal zone during the Late Neolithic could be shown to reflect a greater importance of farming in this area.

Another factor is the composition of the dataset. The distribution of known assemblages is uneven across periods and landscape settings. This is illustrated by the Early phase, with no known coastal sites. Similarly, assemblages from estuary contexts are almost exclusively late and from one specific area. Hypothetical future discoveries of *e.g.* Swifterbant sites in a coastal dune setting would complement our analysis and might reveal an increased reliance on agricultural subsistence methods in more suitable landscape areas (cf. Wateringse Binnentuinen for the Vlaardingen period).

The influence of the biased distribution of faunal assemblages should not be underestimated. For the Vlaardingen phase, Raemaekers (2003, 744-745) proposes a division of three types of sites: permanent settlements in the dunes, and seasonally inhabited special activity camps in wetland contexts. The former are characterised by the presence of house sites, cereal remains, a wide activity spectrum and faunal assemblages dominated by domestic animals. However, bone remains at these locations are often poorly preserved and hence we could not include all of these sites in our dataset (*e.g.* Haamstede-Brabers, yielded only a single identifiable specimen (Amkreutz 2013)). Recently discovered sites such as Wateringse Binnentuinen (Bulten and Stokkel 2017) may confirm this classification. However, if the "consolidation phase" (sensu Zvelebil 1986) had started, we would expect the "Wateringse Binnentuinen-pattern" to be commonplace, while it appears to represent an exception. The influence of taphonomic bias here is difficult to evaluate.

An interpretation in terms of foraging behaviour suggests that although many late assemblages are dominated by cattle bones, the persistent representation of varied wild resources shows that this numerical dominance need not imply caloric dominance. The apparent contradiction between our results and those of proportional analyses can be explained at least in part by field processing and transport, leading to the underrepresentation of wild resources. This is likely most severe for marine mammals in the coastal zone.

Continued investment in foraging is demonstrated by the identical taxonomic diversity through time. Some of the most diverse assemblages from our Middle and Late phases are numerically as large as the Wateringse Binnentuinen zone 1-7 assemblage (Appendix). Hence the activities responsible for the accumulation of diverse assemblages were not occasional, but represented a crucial element of subsistence economies.

One potential distorting factor is if the introduction of agriculture led to changed foraging strategies masking the expected narrowing of the resource base. With less time available for foraging, hunting may have been less selective, targeting "anything that moved". This would increase faunal assemblage diversity, for an activity of minor importance. We think this is unlikely as investments in foraging for *e.g.* fish and birds remains high and hence considerable effort in hunting was coupled with deliberate prey selection.

Birds are of prominent importance especially in the coastal zone (Bakels and Zeiler 2005; Zeiler *et al.* 2011). Fish are present in moderate numbers in many assemblages and are likely underrepresented especially in older excavations due to absence of sieving. Ironically, in the most recent excavations, only selective sieving in samples taken for botanical analysis is practised (see site comparison in Van Dijk *et al.* 2017). The importance of aquatic resources thus continues to be overlooked.

The importance of wild resources in the subsistence economy is further confirmed by stable isotope analysis at the site of Schipluiden. Here $\delta^{15}N$ values suggest that many people here consumed a largely aquatic diet (Smits and Van der Plicht 2009, 80-81). Discrepancies between bone assemblages and stable isotope analysis are sometimes difficult to resolve and elevated $\delta^{15}N$ values may be caused by other factors than fish consumption (*e.g.* Dusseldorp 2011). However, there is ample evidence of continued extreme investment expended on the exploitation of fish, for instance from the recovery of fishing weirs at Emmeloord and Almere (Bulten *et al.* 2002; Ter Voorde 2017). These were extensive, permanent installations (sensu Torrence 1983), in the case of the Middle to Late Neolithic Almere weir, over 190 meters (Ter Voorde 2017).

Much variation is hidden within the groups. Especially in the Vlaardingen phase (Zeiler *et al.* 2011). This points to the potential of examining more fine-grained environmental groupings (Raemaekers 2003; Amkreutz 2013). It also suggests that people, or groups of people behaved variably during the period under consideration. The dynamic nature of the landscape and the myriad possibilities afforded by the available resource spectrum may have given rise to this. There were fewer factors constraining individual agency than in later periods with more depleted environments and more interconnected relationships with fully-fledged farming communities on the Pleistocene soils, or in earlier periods when agricultural options were not yet available.

From an economic perspective, practicing an extended broad-spectrum foraging economy may have become increasingly lucrative during the Neolithic. The small-scale agriculture in evidence at *e.g.* the Swifterbant sites (Huisman *et al.* 2009; Huisman and Raemaekers 2014) can be seen as landscape engineering similar to fire use (Scherjon *et al.* 2015). Such small-scale clearings in the landscape likely increased the productivity for game species. At the Hazendonk, this appears to lead to an increase in cervid exploitation (Zeiler 1999). This landscape engineering contributed to the limited relative advantage of farming over foraging (cf. Rogers 1995). However, it suggests a situation in which some Neolithic groups could eat their cake and have it too: with increased foraging productivity, more time may have been available for other activities, such as experimenting with agriculture. We think such niche construction may play an important part in explaining the long persistence of the extended broad-spectrum economy.

## 6. Conclusion

We contend that the transition from foraging to agriculture in the Dutch wetlands lasted throughout the Neolithic period into the Early Bronze Age. Due to varied biases, we argue that focussing on taxonomic diversity of faunal assemblages may be more informative to determine whether extended broad-spectrum foraging was practiced. The similar diversity of faunal assemblages suggests that many individuals and groups subsisted on an extended broad-spectrum menu throughout the Neolithic. Our results support the suggestion that the adoption of small-scale agriculture may actually have reinforced foraging economies and worldviews. The extended broad-spectrum economy is not simply a transitional system, but a successful solution to living in the wetlands in its own right. Studying this period from the perspective of Neolithisation suggests a teleological bias.

No single proxy can determine the nature of past livelihoods, and complementary analyses of other proxies will increase our understanding of diachronic changes in wetland societies' subsistence methods amd the role of food production in the region. This extended broad perspective is a lesson learned from Corry Bakels who always ventured widely, both in science and in the world. By her extended sojourn in her Leiden home range she continues to bring along new ideas and angles to our research of past communities. By doing so she inspired many to also broaden their horizon and even managed to demonstrate the beauty hidden in a pollen diagram.

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## References

Amkreutz, L.W.S.W. 2013. *Persistent traditions: a long-term perspective on communities in the process of Neolithisation in the Lower Rhine Area (5500-2500 cal BC)*, Leiden.

Bakels, C.C. 1986. Akkerbouw in het moeras? In: Van Trierum, M.C. and H.E. Henkes (eds), *Rotterdam Papers V: A contribution to prehistoric, Roman and medieval archaeology*, Rotterdam, 1-6.

Bakels, C.C. 1988. *Een lading graan*, Inaugural lecture Leiden University.

Bakels, C.C. 2000. The neolithization of the Netherlands: Two ways, one result. In: A.S. Fairbairn, (ed.) *Plants in Neolithic Britain and beyond*, Oxford, 101-106.

Bakels, C.C. 2009. *The western European loess belt: Agrarian history 5300 BC – AD 1000*, New York.

Bakels, C.C., J. Zeiler 2005. De vruchten van het land: De neolithische voedselvoorziening. In: L.P. Louwe Kooijmans, P.W. Van den Broeke, H. Fokkens and A. Van Gijn (eds), *Nederland in de prehistorie*, Amsterdam, 311-335.

Besselsen, E.A., M.J. Van der Heiden 2008. Cultuurlandschap. In: E.A. Besselsen and M.J. Van der Heiden (eds), *Vindplaats Vleugel 20: Archeolo-*

*gisch onderzoek naar een cultuurlandschap uit de Bronstijd*, Amsterdam (AAC rapport 49), 31-46.

Binford, L.R. 2001. *Constructing frames of reference, An analytical method for Archaeological theory building using ethnographic and environmental data sets*, Berkeley/Los Angeles/London.

Binford, L.R. 2007. The diet of early hominids: Some things we need to know before "Reading" the menu from the archaeological record. In: W. Roebroeks (ed.) *Guts and Brains: An integrative approach to the hominin record*, Leiden, 185-222.

Broughton, J.M., M.D. Cannon, E.J. Bartelink 2010. Evolutionary Ecology, Resource Depression, and Niche Construction Theory: Applications to Central California Hunter-Gatherers and Mimbres-Mogollon Agriculturalists, *Journal of Archaeological Method and Theory* 17, 371-421.

Broughton, J.M., M.D Cannon, F.E. Bayham, D.A. Byers 2011. Prey Body Size and Ranking in Zooarchaeology: Theory, Empirical Evidence, and Applications from the Northern Great Basin, *American Antiquity* 76, 403-428.

Bulten, E.E.B., P.J.A. Stokkel 2017. Synthese. In: P.J.A. Stokkel and E.E.B. Bulten (eds), *De Wateringse Binnentuinen Gemeente Den Haag: Een Vlaardingennederzetting in het Wateringse Veld*, Den Haag, 283-305.

Bulten, E.E.B., F.J.G. Van der Heijden, T. Hambrug 2002. *Emmeloord, prehistorische visweren en fuiken*, Amersfoort (ADC rapport 140).

Çakirlar, C., R. Breider, F. Koolstra, K. Cohen, D.C.M. Raemaekers. in press. Dealing with domestic animals in fifth millennium cal BC Dutch wetlands: new insights from old Swifterbant assemblages.

Cappers, R.J.T., D.C.M. Raemaekers 2008. Cereal cultivation at Swifterbant? Neolithic wetland farming on the North European Plain, *Current Anthropology* 49, 385-402.

Clason, A.T. 1967. *Animal and man in Holland's past: An investigation of the animal world surrounding man in prehistoric and early historical times in the provinces of North and South Holland*, Groningen.

Crégut-Bonnoure 1995. La faune de grands mammifères en Provence de la fin du Pléistocène supérieur à l'Holocène, *Forêt méditerranéenne* 16, 233-238.

Crombé, P., J. Sergant, E. Robinson, J. De Reu 2011. Hunter-gatherer responses to environmental change during the Pleistocene-Holocene transition in the southern North Sea basin: Final Palaeolithic-Final Mesolithic land use in northwest Belgium, *Journal of Anthropological Archaeology* 30, 454-471.

De Vries, L.S. 2004. *Luilekkerland aan de kust: De faunaresten van de neolithische nederzetting bij Rijswijk-Ypenburg*, Amersfoort (Rapportage Archeologische Monumentenzorg 106).

Delpech, F. 1999. Biomasse d'ongulés au Paléolithique et inférences sur la demographie, *Paleo*, 11, 19-42.

Domínguez-Rodrigo, M. 2012. Critical review of the MNI (minimum number of individuals) as a zooarchaeological unit of quantification, *Archaeological and Anthropological Sciences* 4, 47-59.

Dusseldorp, G.L. 2011. Studying Pleistocene Neanderthal and cave hyena dietary habits: Combining isotopic and archaeozoological analyses, *Journal of Archaeological Method and Theory* 18, 224-255.

Dusseldorp, G.L. 2012. Tracking the influence of Middle Stone Age technological change on modern human hunting strategies, *Quaternary International* 270, 70-79.

Dusseldorp, G.L. 2016. Faunal Assemblage Structure Suggests a Limited Impact of the Introduction of Domestic Stock on Later Stone Age Subsistence Economies in South Africa, *African Archaeological Review* 33, 363-383.

Dusseldorp, G.L. and L.W.S.W. Amkreutz, 2015. Foraging for farmers? An evolutionary perspective on the process of Neolithisation in NW Europe – A case study from the Low Countries, *Praehistorische Zeitschrift* 90, 20-44.

Dusseldorp, G.L. and G.H.J. Langejans 2013. Carry that weight: Coastal foraging and transport of marine resources during the South African Middle Stone Age, *Southern African Humanities* 25, 105-135.

Faith, J.T. 2007. Changes in reindeer body part representation at Grotte XVI, Dordogne, France, *Journal of Archaeological Science* 34, 2003-2011.

Faith, J.T. 2008. Eland, buffalo, and wild pigs: were Middle Stone Age humans ineffective hunters? *Journal of Human Evolution* 55, 24-36.

Faith, J.T., M. Dominguez-Rodrigo, A.D. Gordon 2009. Long-distance carcass transport at Olduvai Gorge? A quantitative examination of Bed I skeletal element abundances, *Journal of Human Evolution* 56, 247-256.

Fokkens, H., B.J.W. Steffens, S.F.M. Van As 2016. *Farmers, fishers, fowlers, hunters: Knowledge generated by development-led archaeology about the Late Neolithic, the Early Bronze Age, and the start of the Middle Bronze Age (2850 – 1500 cal BC) in the Netherlands*, Amersfoort (Nederlandse Archeologische Rapporten 53).

Gehasse, E.F. 1995. *Ecologisch-archeologisch onderzoek van het Neolithicum en de vroege Bronstijd in de Noordoostpolder met de nadruk op vindplaats P14, gevolgd door een overzicht van de bewoningsgeschiedenis en de economie binnen de Holocene Delta*, PhD-thesis, University of Amsterdam.

Goossens, T. 2009. *Opgraving Hellevoetsluis-Ossenhoek*, Leiden (Archol rapport 87).

Grayson, D.K. 1991. Alpine faunas from the White Mountains, California: Adaptive change in the late prehistoric great basin? *Journal of Archaeological Science* 18, 483-506.

Grayson, D.K., F. Delpech 1998. Changing Diet Breadth in the Early Upper Palaeolithic of Southwestern France, *Journal of Archaeological Science* 25, 1119-1129.

Grimm, J.M. 2010. *Archeozoölogisch onderzoek van het Neolithische botmateriaal van de opgraving Hazerswoude-Rijndijk*, Salisbury.

Groenewoudt, B.J., J. Deeben, B. Van Geel, R.C.G.M. Lauwerier 2001. An early Mesolithic assemblage with faunal remains in a stream valley near Zutphen, the Netherlands, *Archäologisches Korrespondenzblatt* 31, 329-348.

Groenman – Van Waateringe, W., A. Voorrips, L.H. Van Wijngaarden-Bakker 1968. Settlements of the Vlaardingen Culture at Voorschoten and Leidschendam (ecology), *Helinium* 8, 105-130.

Hall, S.J.G. 2008. A comparative analysis of the habitat of the extinct aurochs and other prehistoric mammals in Britain, *Ecography* 31, 187-190.

Hamburg, T. 2005. *Neolithische bewoningsresten te Leidschendam: Begeleiding, Inventariserend veldonderzoek (IVO), en opgraving (DO) Leidschendam-Prinsenhof*, Leiden (Archol rapport 59).

Hogestijn, J.W.M., E. Drenth 2000/2001. In Slootdorp stond een Trechterbeker-huis? Over Midden- en Laat-Neolithische huisplattegronden uit Nederland, *Archeologie* 10, 42-79.

Hübner, K.-D., R. Saur, H. Reichstein 1988. Die Saugetierknochen der neolithischen Seeufersiedlung Hüde I, *Göttinger Schriften zur Vor- un Frügeschichte* 23, 35-142.

Huffman, T.N. 2010. Debating the Central Cattle Pattern: A reply to Badenhorst, *The South African Archaeological Bulletin* 65, 164-174.

Huisman, D.J., A.G. Jongmans, D.C.M. Raemaekers 2009. Investigating Neolithic land use in Swifterbant (NL) using micromorphological techniques, *Catena* 78, 185-197.

Huisman, D.J. and D.C.M. Raemaekers 2014. Systematic cultivation of the Swifterbant wetlands (The Netherlands). Evidence from Neolithic tillage marks (c. 4300-4000 cal. BC), *Journal of Archaeological Science* 49, 572-584.

Johnson, A.L. 2014. Exploring adaptive variation among hunter-gatherers with Binford's frames of reference, *Journal of Archaeological Research* 22, 1-42.

Kandel, A.W. and N.J. Conard 2003. Scavenging and Processing of Whale Meat and Blubber by Later Stone Age People of the Geelbek Dunes, Western Cape Province, South Africa, *South African Archaeological Bulletin* 58, 91-93.

Kleijne, J.P. 2013. Synthesis – A matter of life and death at Mienakker. In: J.P. Kleijne, O. Brinkkemper, R.C.G.M. Lauwerier, B.I. Smit and E.M. Theunissen (eds), *A matter of life and death at Mienakker (the Netherlands)*, Amersfoort (Nederlandse Archeologische Rapporten 45), 249-260.

Krause-Kyora, B., C. Makarewicz, A. Evin, L. Girdland Flink, K. Dobney, G. Larson, S. Hartz, S. Schreiber, C. Carnap-Bornheim, N. Von Wurmb-Schwark and A. Nebel 2013. Use of domesticated pigs by Mesolithic hunter-gatherers in northwestern Europe, *Nature Communications* 4, 2348.

Laarman, F.J. 2001. *Archeozoölogie: Aard en betekenis van de dierlijke resten*, Amersfoort (De mesolithische en vroeg-neolithische vindplaats Hoge Vaart-A27 (Flevoland) 16).

Laarman, F.J. 2004. Rijswijk Rijksweg A4. In: L.S. De Vries (ed.) *Luilekkerland aan de kust*, Amersfoort (Rapportage Archeologische Monumentenzorg 106), 53-56.

Lotze, H.K., B. Worm 2009. Historical baselines for large marine animals, *Trends in Ecology & Evolution* 24, 254-262.

Louwe Kooijmans, L.P. 1974. *The Rhine/Meuse Delta: four studies on its prehistoric occupation and holocene geology*, Leiden (Analecta Praehistorica Leidensia 7).

Louwe Kooijmans, L.P. 1987. Neolithic settlement and subsistence in the wetlands of the Rhine/Meuse delta of the Netherlands . In: J.M. Coles and A.J. Lawson (eds), *European wetlands in Prehistory*, Oxford, 227-251.

Louwe Kooijmans, L.P. 1993. Wetland exploitation and upland relations of prehistoric communities in the Netherlands. In: J. Gardiner (ed.) *Flatlands and wetlands : current themes in East Anglian archaeology*, Norwich, 71-116.

Louwe Kooijmans, L.P. 2007. The gradual transition to farming in the Lower Rhine Basin. In: A. Whittle and V. Cummings (eds), *Going Over: The Mesolithic-Neolithic Transition in North-West Europe*, Oxford (Proceedings of the British Academy 144), 287-309.

Louwe Kooijmans, L.P. 2009. The agency factor in the process of Neolithisation-a Dutch case study, *Journal of Archaeology in the Low Countries* 1, 27-54.

Louwe Kooijmans, L.P., J. Mol 2001. Stratigrafie, chronologie en fasering. In: L.P. Louwe Kooijmans (ed.) *Hardinxveld-Giessendam Polderweg: Een Mesolithisch jachtkamp in het rivierengebied (5500-5000 v. Chr)*, Amersfoort (Rapportage Archeologische Monumentenzorg 83), 55-72.

Lyman, R.L. 1994. *Vertebrate taphonomy*, Cambridge (Cambridge Manuals in Archaeology).

Lyman, R.L. 2008. *Quantitative Paleozoology*, Cambridge (Cambridge Manuals in Archaeology).

Lyman, R.L. 2015. On the variable relationship between NISP and NTAXA in bird remains and in mammal remains, *Journal of Archaeological Science* 53, 291-296.

MacDonald, D.W. 2006. *The Encyclopedia of Mammals*, New edition, Oxford.

Metcalfe, D. and K.R. Barlow 1992. A Model for Exploring the Optimal Trade-off between Field Processing and Transport, *American Anthropologist* 94, 340-356.

Meylemans, E., Y. Perdaen, J. Sergant, J. Bastiaens, P. Crombé, S. Debruyne, K. Deforce, E. Du Rang, A. Ervynck, A. Lentacker, A. Storme and W. Van Neer 2016. *Archeologische opgraving van een midden-mesolithische tot midden-neolithische vindplaats te Bazel-Sluis 5 (Gemeente Kruibeke, provincie Oost-Vlaanderen)*, Brussel (Onderzoeksrapport Agentschap Onroerend Erfgoed).

Mol, J. and L.P. Louwe Kooijmans 2001. Stratigrafie, chronologie en fasering. In: L.P. Louwe Kooijmans (ed.) *Hardinxveld-Giessendam De Bruin: Een kampplaats uit het Laat-Mesolithicum en het begin van de Swifterbant-cultuur*, Amersfoort (Rapportage Archeologische Monumentenzorg 88), 57-74.

Mol, J., L.P. Louwe Kooijmans, T. Hamburg 2006. Stratigraphy and chronology of the site. In: L.P. Louwe Kooijmans and P. Jongste, *Schipluiden : a neolithic settlement on the Dutch North Sea coast c. 3500 CAL BC*, Leiden (Analecta Praehistorica Leidensia 37/38), 19-38.

Moree, J.M., C.C. Bakels, S.B.C. Bloo, J.T. Brinkhuizen, R.A. Houkes, P.F.B. Jongste, M.C. Van Trierum, A. Verbaas and J.T. Zeiler 2011. Barendrecht-Carnisselande: bewoning van een oeverwal vanaf het Laat-Neolithicum tot in de Midden-Bronstijd. In: A. Carmiggelt, M.A. Van Trierum and D.A. Wesselingh (eds), *Boor balans 7*, 15-154.

Morin, E. and E. Ready, 2013. Foraging Goals and Transport Decisions in Western Europe during the Paleolithic and Early Holocene. In: J.L. Clark and J.D. Speth (eds), *Zooarchaeology and Modern Human Origins: Human Hunting Behavior during the Later Pleistocene*, Dordrecht, 227-269.

Nicholas, G.P. 2007a. Prehistoric hunter-gatherers in wetland environments: mobility/sedentism and aspects of socio-political organisation. In: M. Lillie and S. Ellis (eds), *Wetland archaeology and environments. Regional issues, global perspectives*, Oxford, 245-257.

Nicholas, G.P. 2007b. Prehistoric hunter-gatherers in wetland environments: theoretical issues, economic organisationand resource management strategies. In: M. Lillie and S. Ellis (eds), *Wetland archaeology and environments. Regional issues, global perspectives*, Oxford, 46-64.

Out, W.A. 2008. Growing habits? Delayed introduction of crop cultivation at marginal Neolithic wetland sites, *Vegetation History and Archaeobotany* 17, 131-138.

Out, W.A. 2009a. Reaction to “Cereal Cultivation at Swifterbant? Neolithic Wetland Farming on the North European Plain”, *Current Anthropology* 50, 253-254.

Out, W.A. 2009b. *Sowing the seed? Human impact and plant subsistence in Dutch wetlands during the Late Mesolithic and Early and Middle Neolithic*, Leiden (Archaeological Studies Leiden University 18).

Oversteegen, J.F.S. 2001. Archeozoölogie. In: F.J.C. Peters and J.H.M. Peeters (eds), *De opgraving van de mesolithische en neolithische vindplaats Urk-E4 (Domineesweg, gemeente Urk)*, Amersfoort (Rapportage Archeologische Monumentenzorg 93), 43-47.

Oversteegen, J.F.S., L.H. Van Wijngaarden-Bakker, C.H. Maliepaard and T. Van Kolfschoten, 2001. Zoogdieren, vogels en reptielen. In: L.P. Louwe Kooijmans (ed.) *Hardinxveld-Giessendam De Bruin: Een kampplaats uit het Laat-Mesolithicum en het begin van de Swifterbant-cultuur*, Amersfoort (Rapportage Archeologische Monumentenzorg 88), 209-298.

Parkington, J. 2006. *Shorelines, strandlopers and shell middens*, Cape Town (Archaeology of the Cape Coast).

Peters, F.J.C. and J.H.M. Peeters 2001. *De opgraving van de mesolithische en neolithische vindplaats Urk-E4 (Domineesweg, gemeente Urk)*, Amersfoort (Rapportage Archeologische Monumentenzorg 93).

Prummel, W. 1987. The faunal remains from the Neolithic site of Hekelingen III, *Helinium* 27, 190-258.

Prummel, W., D.C.M. Raemaekers, S.M. Beckerman, J.N. Bottema-MacGillavry, R.T.J. Cappers, P. Cleveringa, I. Devriendt, H. De Wolf and J.T. Zeiler 2009. Terug naar Swifterbant: Een kleinschalige opgraving te Swifterbant-S2 (Gemeente Dronten), *Archeologie* 13, 17-45.

Raemaekers, D.C.M. 1999. *The Articulation of a new Neolithic, The meaning of the Swifterbant culture for the process of neolithization in the western part of the North European Plain*, Leiden (ASLU 3).

Raemaekers, D. 2003. Cutting a long story short? The process of neolithization in the Dutch delta re-examined, *Antiquity* 77, 740-748.

Raemaekers, D.C.M. 2019. Taboo? The process of Neolithisation in the Dutch wetlands re-examined (5000-3400 cal BC). In: R. Gleser and D. Hofmann (eds), *Contacts, boundaries & innovation in the fifth millennium: Exploring developed Neolithic societies in central Europe and beyond*, Leiden, 91-102.

Raemaekers, D.C.M., Y.I. Aalders, S.M. Beckerman, D.C. Brinkhuizen, I. Devriendt, H. Huisman, M. De Jong, H.M. Molthof, W. Prummel, M.J.L.T. Niekus and M. Van der Wal, 2011/2012. The submerged pre-Drouwen TRB settlement site Wetsingermaar, c. 3500 cal. BC (province of Groningen, the Netherlands), *Palaeohistoria* 53/54, 1-24.

Raemaekers, D.C.M., C.C. Bakels, B. Beerenhout, A.L. Van Gijn, K. Hänninen, S. Molenaar, D. Paalman, M. Verbruggen and C. Vermeeren 1997. Wateringen 4: a settlement of the Middle Neolithic Hazendonk 3 Group in the Dutch coastal area, *Analecta Praehistorica Leidensia* 29, 143-192.

Rogers, E.M. 1995. *Diffusion of innovations, fifth edition*, New York.

Sadr, K. 2008. Invisible herders? The archaeology of Khoekhoe pastoralists, *Southern African Humanities* 20, 179-203.

Schepers, M. 2014. Wet, wealthy worlds: The environment of the Swifterbant river system during the Neolithic occupations, *Journal of Archaeology in the Low Countries* 5, 79-104.

Scherjon, F., C. Bakels, K. MacDonald and W. Roebroeks 2015. Burning the Land: An Ethnographic Study of Off-Site Fire Use by Current and Historically Documented Foragers and Implications for the Interpretation of Past Fire Practices in the Landscape, *Current Anthropology* 56, 299-326.

Schiltmans, D.E.A. 2013. Rotterdam Groenenhagen-Tuinenhoven De Zwanen-Rietpark Een opgraving van een vindplaats uit het Neolithicum op een rivierduin op IJsselmonde (vindplaats 13-78), Rotterdam (Boor Rapporten 491).

Slopsma, J. 2008. Archeozoölogie. In: E.A. Besselsen and M.J. Van der Heiden (eds), *Vindplaats Vleugel 20: Archeologisch onderzoek naar een cultuurlandscap uit de bronstijd*, Amsterdam (AAC rapport 49), 47-64.

Smit, B.I., S.M. Beckerman, D.C. Brinkhuizen, V. Garcia-Diaz, L. Kubiak-Martens, G.R. Nobles, T.F.M. Oudemans, J.T. Zeiler, O. Brinkkemper, J.P. Kleijne, R.C.G.M. Lauwerier, E.M. Theunissen, A. Van Gijn and D. Raemaekers 2012. Synthesis – Keinsmerbrug: A kaleidoscope of gathering. In: B.I. Smit, O. Brinkkemper, J.P. Kleijne, R.C.G.M. Lauwerier and E.M. Theunissen (eds), *A kaleidoscope of gathering at Keinsmerbrug (the Netherlands)*, Amersfoort (Nederlandse Archeologische Rapporten 43), 211-222.

Smith, A.B. and J. Kinahan 1984. The invisible whale, *World Archaeology* 16, 89-97.

Smits, E. and J. Van der Plicht 2009. Mesolithic and Neolithic human remains in the Netherlands: physical anthropological and stable isotope investigations, *Journal of Archaeology of the Low Countries* 1, 55-85.

Stokkel, P.J.A., E.E.B. Bulten (eds) 2017. *De Wateringse Binnentuinen Gemeente Den Haag: Een Vlaardingennederzetting in het Wateringse Veld*, Den Haag (Haagse Oudheidkundige Publicaties 20).

Svenning, J.-C. 2002. A review of natural vegetation openness in north-western Europe, *Biological Conservation* 104, 133-148.

Ten Anscher, T. 2012. *Leven met de Vecht. Schokland-P14 en de Noordoostpolder in het neolithicum en de bronstijd*, PhD-thesis University of Amsterdam.

Ten Anscher, T. 2018. *Archeologische opgraving Medel-De Roeskamp. Evaluatie- en selectierapport*, RAAP-ADC-Archol.

Ter Voorde, M. 2017. *Opgraving Almere blijkt vissenval uit de Steentijd*, 2019. Nemo Kennislink

Van de Noort, R., A. O'Sullivan 2006. *Rethinking wetland archaeology*, London.

Van den Brink, V.B. and R. Paulussen 2013. Landschap en bodem. In: J. Van Kampen and V.B. Van den Brink (eds), *Archeologisch onderzoek op de Habraken te Veldhoven: Twee unieke nederzettingen uit het Laat Neolithicum en de Midden Bronstijd en een erf uit de Volle Middeleeuwen*, Amsterdam (Zuidnederlandse Archeologische Rapporten 52), 19-28.

Van den Broeke, P.W. 2007. Aardkundige en chronologische aspecten. In: E. Ball and P.W. Van den Broeke (eds), *Opgravingen op 't Klumke te Nijmegen-Oosterhout*, Nijmegen (Archeologische Berichten Nijmegen 6), 11-20.

Van Dijk, J. 2009. Zoogdieren, vogels en reptielen. In: T. Goossens (ed.) *Opgraving Hellevoetsluis-Ossenhoek*, Leiden (Archol rapport 87), 113-144.

Van Dijk, J. And B. Beerenhout 2014. Archeozoölogie. In: H. Siemons and E.E.B. Bulten, (eds), *Archeologie in het Wateringse Veld, gemeente Den Haag: Van steentijd tot nieuwe tijd*, Den Haag (Haagse Oudheidkundige Publicaties 17), 158-169.

Van Dijk, J., F. Kerklaan and M. Rijkelijkhuizen 2017. De dierlijke resten. In: P.J.A. Stokkel and E.E.B. Bulten (eds), *De Wateringse Binnentuinen Gemeente Den Haag: Een Vlaardingennederzetting in het Wateringse Veld*, Den Haag (Haagse Oudheidkundige Publicaties 20), 205-223.

Van Gijssel, K. and B. Van der Valk 2005. Aangespoeld, gestuwd en verwaaid: de wording van Nederland. In: L.P. Louwe Kooijmans, P.W. Van den Broeke, H. Fokkens and A. Van Gijn (eds), *Nederland in de prehistorie*, Amsterdam, 45-76.

Van Heeringen, R.M. and E.M. Theunissen (eds) 2001. Deel 2: *Site-dossiers Kwaliteitsbepalend onderzoek ten behoeve van duurzaam behoud van neolithische terreinen in West-Friesland en de Kop van Noord-Holland*, Amersfoort (Nederlandse Archeologische Rapporten 21).

Van Neer, W. 2005. Archaeozoological analyses. In: P. Crombé (ed), *The last hunter-gatherer-fishermen in Sandy Flanders*, (Archaeological Reports Ghent University 3), 279-294.

Van Wijngaarden-Bakker, L.H., C. Cavallo, T. Van Kolfschoten and J.F.S. Oversteegen 2001. Zoogdieren, vogels, reptielen. In: L.P. Louwe Kooijmans (ed), *Hardinxveld-Giessendam Polderweg: Een Mesolithisch jachtkamp in het rivierengebied (5500-5000 v. Chr)*, Amersfoort (Rapportage Archeologische Monumentenzorg 83), 181-242.

Von Koenigswald, W. 2007. Mammalian faunas from the interglacial periods in Central Europe and their stratigraphic correlation. In: F. Sirocko, M. Claussen, M.F. Sánchez Goñi and T. Litt (eds), *Developments in Quaternary Sciences*, 445-454.

Verbruggen, M. 1992. Geoarchaeological prospection of the Rommertsdonk, *Analecta Prehistorica Leidensia* 25, 117-128.

Vos, P.C. and P. Kiden 2005. De landschapsvorming tijdens de steentijd, *Archeologie* 11/12, 7-38.

Westerhof, W.E., T.E. Wong and F.J. De Mulder 2003. Deel 2: Geschiedenis van de ondergrond. In: F.J. De Mulder, M.C. Geluk, I. Ritsema, W.E. Westerhoff and T.E. Wong (eds), *De ondergrond van Nederland*, Herent, 119-246.

Winterhalder, B. 2001. The behavioural ecology of hunter-gatherers. In: C. Panter-Brick, R.H. Layton and P. Rowley-Conwy (eds), *Hunter-gatherers, An interdisciplinary perspective*, Cambridge (Biological symposium series), 12-38.

Zeiler, T.J. 1997. *Hunting, Fowling and Stock-Breeding at Neolithic sites in the Western and Central Netherlands*, Groningen.

Zeiler, J.T. 1999. Fauna en landschap in prehistorisch Nederland, *De levende natuur* 100, 19-21.

Zeiler, J. 2006. Mammals, *Analecta Praehistorica Leidensia* 37/38, 375-420.

Zeiler, J.T. 2007. Dierlijk botmateriaal. In: E. Ball and P.W. Van den Broeke (eds), *Opgravingen op 't Klumke te Nijmegen-Oosterhout*, Nijmegen (Archeologische Berichten Nijmegen 6), 117-128.

Zeiler, J.T. 2013. Botmateriaal. In: D.E.A. Schiltmans (ed.) *Rotterdam Groenenhagen-Tuinenhoven De Zwanen-Rietpark*, Rotterdam (BOOR rapporten 491), 81-85.

Zeiler, J.T. and D.C. Brinkhuizen 2005. *Jachtwild, vis en vee uit Vrijenburg*, Leeuwarden.

Zeiler, J.T. and D.C. Brinkhuizen 2012. The faunal remains. In: B.I. Smit, O. Brinkkemper, J.P. Kleijne, R.C.G.M. Lauwerier and E.M. Theunissen (eds), *A kaleidoscope of gathering at Keinsmerbrug (the Netherlands)*, Amersfoort (Nederlandse Archeologische Rapporten 43), 131-147.

Zeiler, J.T. and D.C. Brinkhuizen 2013. Faunal remains. In: J.P. Kleijne, O. Brinkkemper, R.C.G.M. Lauwerier, B.I. Smit and E.M. Theunissen (eds), *A matter of life and death at Mienakker (the Netherlands)*, Amersfoort (Nederlandse Archeologische Rapporten 45), 155-173.

Zeiler, J.T., D.C. Brinkhuizen, D.L. Bekker and A.Verbaas 2015. Fauna. In: J.M. Moree and M.M. Sier (eds), *Twenty metres deep! The Mesolithic period at the Yangtze Harbour site – Rotterdam Maasvlakte, the Netherlands: Early Holocene landscape development and habitation*, Rotterdam, 201-222.

Zeiler, J.T., O. Brinkkemper and E. Drenth 2011. An outline of the subsistence of the Vlaardingen culture from the Netherlands, *Revue archéologique de Picardie*, 207-220.

Zvelebil, M. 1986. Mesolithic prelude and Neolithic revolution. In: M. Zvelebil (ed), *Hunters in transition, Mesolithic societies of temperate Eurasia and their transition to farming*, Cambridge, 5-15.

## Appendix: Inventory of assemblages included in the analysis

| Assemblage | Cultural attribution | Date | ∑NISP | NTAXA | Category | Reference |
|---|---|---|---|---|---|---|
| Barendrecht- Carnisselande 1 | Vlaardingen | 2500-2200 BCE | 88 | 7 | Freshwater | (Moree *et al.* 2011) |
| Barendrecht- Carnisselande 2 | Bell Beaker | ~2200 BCE | 18 | 4 | Freshwater | (Moree *et al.* 2011) |
| Barendrecht- Carnisselande 3 | Bell Beaker – Early Bronze Age | 2275-1886 BCE | 1036 | 12 | Freshwater | (Moree *et al.* 2011) |
| Barendrecht- Vrijenburg | Hazendonk 3 | 4789 ± 45 BP | 12 | 5 | Freshwater | (Zeiler and Brinkhuizen 2005) |
| Bazel-Sluis | Mesolithic – Swifterbant | | 211 | 10 | Freshwater | (Meylemans *et al.* 2016) |
| Hardinxveld-Giessendam De Bruin Fase 1 | Late Mesolithic | 5475-5100 BCE | 347 | 12 | Freshwater | (Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001) |
| Hardinxveld-Giessendam De Bruin Fase 2 | Swifterbant | 5100-4800 BCE | 1772 | 14 | Freshwater | (Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001) |
| Hardinxveld-Giessendam De Bruin Fase 3 | Swifterbant | 4685-4459 BCE | 5262 | 17 | Freshwater | (Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001) |
| Doel – Deurganckdok | Swifterbant | 4550-3960 BCE | 26 | 3 | Freshwater | (Van Neer 2005) |
| E170 | Swifterbant | 3900 BCE | 28 | 7 | Freshwater | (Gehasse 1995) |
| Ewijk – Ewijkse Velden | Vlaardingen | 3000 BCE | 554 | 8 | Freshwater | (Bakels and Zeiler 2005; Amkreutz 2013a) |
| Groenenhagen-Tuinendonk De Zwanen-Rietpark | Swifterbant, vroeg | 5000-3900 BCE | 9 | 2 | Freshwater | (Schiltmans 2013; Zeiler 2013) |
| Hazendonk 1&2 | Swifterbant | 4020-3790 BCE | 167 | 5 | Freshwater | (Zeiler 1997; Amkreutz 2013) |
| Hazendonk 3 | Hazendonk groep | 3670-3610 BCE | 490 | 10 | | (Zeiler 1997; Amkreutz 2013) |
| Hazendonk Vl1b | Vlaardingen | 3270-3090 | 524 | 14 | Freshwater | (Zeiler 1997; Amkreutz 2013) |
| Hazendonk Vl2b | Vlaardingen | 2580-2480 BCE | 2597 | 10 | Freshwater | (Zeiler 1997; Amkreutz 2013) |
| Hazerswoude Rijndijk | Vlaardingen-EGK | | 345 | 13 | Freshwater | (Grimm 2010) |
| Hekelingen I | Vlaardingen | | 628 | 13 | Freshwater | (Clason 1967) |
| Hekelingen III | Vlaardingen | 3200-2800 BCE | 1314 | 17 | Freshwater | (Prummel 1987: Amkreutz 2013) |
| Hellevoetsluis-Ossenhoek | Vlaardingen | 3330-2700 BCE | 2366 | 13 | Coastal | (Goossens 2009; Van Dijk 2009) |
| Hoge Vaart | Mesolithic/Swifterbant | 5500-4500 BCE | 1523 | 15 | Freshwater | (Laarman 2001) |
| Houten Vleugel | Late-Neolithic/Early Bronze Age | | 120 | 6 | Freshwater | (Besselsen and Van der Heiden 2008; Slopsma 2008) |

| Assemblage | Cultural attribution | Date | ∑NISP | NTAXA | Category | Reference |
|---|---|---|---|---|---|---|
| Hüde | Swifterbant | 4700-3500 BCE | 8843 | 19 | Freshwater | (Hübner *et al.* 1988) |
| J78 | Single Grave Culture | | 41 | 5 | Freshwater | (Gehasse 1995) |
| Keinsmerbrug | Single Grave Culture | 2580-2450 BCE | 144 | 9 | Coastal | (Smit *et al.* 2012; Zeiler and Brinkhuizen 2012) |
| Kolhorn Northern site | Single Grave Culture | 4100-3900 BP | 346 | 13 | Coastal | (Zeiler 1997; Van Heeringen and Theunissen 2001) |
| Kolhorn Southern site | Single Grave Culture | 4100-3900 BP | 154 | 9 | Coastal | (Zeiler 1997; Van Heeringen and Theunissen 2001) |
| Leidschendam | Vlaardingen | | 463 | 8 | Freshwater | (Groenman – Van Waateringe *et al.* 1968) |
| Leidschendam-Prinsenhof | Vlaardingen | 3400-2600 BCE | 14 | 3 | Freshwater | (Hamburg 2005) |
| Mienakker | Single Grave Culture | 2880-2581 BCE | 572 | 11 | Coastal | (Kleijne 2013; Zeiler and Brinkhuizen 2013) |
| Molenaarsgraaf | Bell Beaker | 3630 40<br>3780 50<br>3635 60<br>3640 30<br>3635 40 | 284 | 9 | Freshwater | (Louwe Kooijmans 1974; Bakels and Zeiler 2005) |
| Nijmegen 't Klumke | Hazendonk 3 | 3770-3630 BCE | 58 | 4 | Freshwater | (Van den Broeke 2007; Zeiler 2007) |
| P14 A | Swifterbant | 4400-4100 BCE | 217 | 10 | Freshwater | (Gehasse 1995) |
| P14 B | Swifterbant | 4100-3800 BCE | 561 | 12 | Freshwater | (Gehasse 1995) |
| P14 C | Swifterbant | 3800-3600 BCE | 285 | 13 | Freshwater | (Gehasse 1995) |
| P14 E | Swifterbant | 3600-3300 BCE | 58 | 10 | Freshwater | (Gehasse 1995) |
| P14 EKW | Single Grave Culture | 2600 BCE | 164 | 12 | Freshwater | (Gehasse 1995; Amkreutz 2013a) |
| Hardinxveld-Giessendam Polderweg fase 0 | Mesolithic | Pre 5500 BCE | 46 | 7 | Freshwater | (Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001) |
| Hardinxveld-Giessendam Polderweg fase 1 | Mesolithic | 5500-5300 BCE | 4119 | 13 | Freshwater | (Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001) |
| Hardinxveld-Giessendam Polderweg fase 1/2 | Swifterbant | 5100 +/- 100 BCE | 377 | 10 | Freshwater | (Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001) |
| Hardinxveld-Giessendam Polderweg fase 2 | Swifterbant | 5100-4900 | 246 | 5 | Freshwater | (Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001) |
| Rijswijk A4 locatie 1 | Hazendonk group | 3940-3200 BCE | 186 | 8 | Coastal | (Laarman 2004; Amkreutz 2013) |

| **Assemblage** | **Cultural attribution** | **Date** | **∑NISP** | **NTAXA** | **Category** | **Reference** |
|---|---|---|---|---|---|---|
| Rijswijk A4 locatie 4 | Hazendonk group | 4350 – 3380 BCE | 28 | 4 | Coastal | (Laarman 2004; Amkreutz 2013) |
| Rijswijk Ypenburg laag 1 | Hazendonk group | 3860 – 3200 BCE | 33 | 6 | Coastal | (De Vries 2004) |
| Rijswijk Ypenburg laag 2 | Hazendonk group | 3860 – 3200 BCE | 461 | 13 | Coastal | (De Vries 2004) |
| Rijswijk de Schilp | Vlaardingen | | 594 | 6 | Coastal | (Zeiler *et al.* 2011) |
| Schipluiden phase 1 | Hazendonk group | 3630-3550 BCE | 180 | 7 | Coastal | (Mol *et al.* 2006; Zeiler 2006) |
| Schipluiden phase 2a | Hazendonk group | 3550-3490 BCE | 3642 | 17 | Coastal | (Mol *et al.* 2006; Zeiler 2006) |
| Schipluiden phase 2b | Hazendonk group | 3550-3490 BCE | 1610 | 14 | Coastal | (Mol *et al.* 2006; Zeiler 2006) |
| Schipluiden phase 3 | Hazendonk group | 3490-3380 BCE | 1099 | 12 | Coastal | (Mol *et al.* 2006; Zeiler 2006) |
| Slootdorp Bouwlust | TRB | c. 3500-3100 BCE | 1383 | 12 | Coastal | (Hogestijn and Drenth 2000/2001) |
| Swifterbant S2 | Swifterbant | 4300-4000 BCE | 528 | 8 | Freshwater | (Prummel *et al.* 2009) |
| Swifterbant S3 | Swifterbant | 4300-4000 BCE | 4043 | 15 | Freshwater | (Zeiler 1997) |
| Tiel-Medel | Swifterbant-Hazendonk | | 1198 | 10 | Freshwater | (Ten Anscher 2018) |
| Urk-E4 | Swifterbant | 4200-3400 BCE | 228 | 9 | Freshwater | (Oversteegen 2001; Peters and Peeters 2001) |
| Vlaardingen | Vlaardingen | 3200-2600 BCE | 1837 | 17 | Freshwater | (Clason 1967; Amkreutz 2013a) |
| Voorschoten Boschgeest | Vlaardingen | 2870-2500 BCE | 479 | 10 | Freshwater | (Groenman – Van Waateringe *et al.* 1968; Amkreutz 2013a) |
| Wateringen 4 | Hazendonk | 3625-3400 BCE | 654 | 9 | Coastal | (Raemaekers *et al.* 1997) |
| Wateringse binnentuinen zone 8 | Vlaardingen | | 44 | 3 | Coastal | (Stokkel and Bulten 2017) |
| Wateringse binnentuinen zone 1-7 | Vlaardingen | | 2606 | 6 | Coastal | (Stokkel and Bulten 2017) |
| Wateringse veld | Vlaardingen-EGK | 2650-2300 BCE | 306 | 7 | Coastal | (Van Dijk and Beerenhout 2014) |
| Wetsingermaar | TRB | 3500 BCE | 16 | 3 | Freshwater | (Raemaekers *et al.* 2011/2012) |
| Yangtzehaven trench 2 | Mesolithic | 8555-8300 BCE | 32 | 7 | Freshwater | (Zeiler *et al.* 2015) |
| Yangtzehaven trench 1 | Mesolithic | 8555-8300 BCE | 139 | 5 | Freshwater | (Zeiler *et al.* 2015) |
| Zandwerven | Vlaardingen | 2900-2300 BCE | 50 | 4 | Coastal | (Clason 1967; Amkreutz 2013a) |
| Zeewijk context A | EGK | 2600-2450 BCE | 67 | 7 | Coastal | (Van Heeringen and Theunissen 2001) |
| Zeewijk context B | EGK | 2600-2450 BCE | 84 | 5 | Coastal | (Van Heeringen and Theunissen 2001) |
| Zutphen Ooijerhoek | Mesolithic | 9400-8700 | 26 | 6 | Freshwater | (Groenewoudt *et al.* 2001) |

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# House Societies or societies with houses? Bandkeramik kinship and settlement structure from a Dutch perspective

Ivo M. van Wijk and Pieter van de Velde

*The distinct and uniform lay out of LBK house plans are often regarded as a marker for stratified social organization. This article sheds light on the ambiguity of LBK houses and their role in LBK society and kinship by comparing the various house types within their settlement structure.*

*Keywords: Linear Band Keramik culture, House Societies, LBK society, Maastricht-Cannerberg settlement*

## 1. Introduction

The Linear Band Keramik culture or LBK settled in Hungary in Central Europe from the early 54th century BC on (Jakucz *et al.* 2016). From there the bearers of this culture spread rapidly across most of Central and Western Europe. Bandkeramik settlements are known from near the Black Sea in eastern Rumania to the Channel coast in Normandy and from the Danube to the Baltic in the Polish-German border region. In the Netherlands occupation started in the 53th century BC, where LBK settlements focused on the fertile loess terraces of the Meuse and its tributaries, on its right bank on the Graetheide plateau between Sittard and Stein, and on its left bank around Maastricht (Bakels 1978, 1982; Van Wijk *et al.* 2014). Architecture, grave good assemblages, and the circulation of exotic goods are indicative of their social differentiation (Hachem 2000; Bentley *et al.* 2012; Louwe Kooijmans 2017). However, as yet it is still debated whether this was an egalitarian or a more stratified social organization (Bentley *et al.* 2012). In this article we will focus on the houses of the LBK and their social significance.

As late as 2008 Dusan Boric attempted the introduction of an ethnographic concept into archaeological discourse on Europe's neolithic period: according to him, the earliest neolithic societies in the Balkans (as well as their successors, the Linear Band Keramik culture), should be understood as House Societies, a concept introduced more than a generation ago into cultural anthropology by Claude Lévi-Strauss (1975). The Balkans are beyond our scope, but regarding the Western LBK we think his claim is exaggerated, when not off the mark. Indeed, some signs may point to conscious avoidance or rejection of such a social structure on the part of Bandkeramians. Specifically, in this article we shall focus on the houses of the LBK and their contribution to this debate. More specifically we shall discuss the a-typical village on the Cannerberg near Maastricht stressing the contrasts with the more regular or standard LBK villages across the Meuse River -excavations where Corrie Bakels also took part in.

**Ivo van Wijk**
Archol
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
ivomvanwijk@gmail.com

**Pieter van de Velde**
Oude Vest 53
2312 XS Leiden
pvandevelde@kpnmail.nl

## 2. House Societies in cultural anthropology

As an extension of his earlier structuralist texts, the concept of House Societies first appears in Lévi-Strauss' Way of the Masks-book (1975) where he discusses the social organizations of several native American Westcoast societies which do not fit to his earlier defined Elementary [or Kinship] Structures (Lévi-Strauss 1975, 141-164; resp. 1967; cp. Stone 2004: 247-248). On that coast, people are grouped into 'Houses', living communally in a large house, or in a group of houses on the same plot. As members of such a House they act jointly; theirs' is a chief and a chiefly family. Membership of a House is obtained by marrying a partner belonging to that House; very much like in elementary kin organizations one becomes a member of the partner's kin group, but now tied to the physical structure of a named House rather than to a prescribed descent line. Beyond, Houses are grouped into 'cities', and several such cities into a tribe. Although membership is worded in terms of belonging to (because descended from, or married into) a kin group (the 'House') the underlying interest is the social or economic appeal or attraction of being a partner of such a 'House'. In these societies dynastic continuity is framed in kinship labels; social and political manoeuvring is covered by the cloak of kinship. That is, 'House Societies' equate more or less with the old evolutionist category of non-centralized 'chiefdoms' (Fried 1967; Service 1971; and especially Earle 1989). Convincing archaeological instances of House Societies are found around the Mediterranean, albeit many centuries later than the LBK, in the Bronze Age (*e.g.* Chesson 2003; González-Ruibal and Ruiz-Galvez 2016; their examples are taken from the Book of Kings in the Bible, and from Homer).

Structuralism being rejected in evolutionist thought (and vice versa), constructs and concepts did not cross academic borders, 'Chiefs' drew evolutionist attention, and 'House Societies' remained in the (post-) structuralist realm. Thus Godelier, Lévi-Strauss' former assistant, has written on this topic consciously avoiding evolutionary stages and proposing graded descriptions instead:

> *"In no society, 'primitive' or otherwise, have kinship relations ever been sufficient to constitute the armature of society. The armature of a society is provided by the combining, each time in a different way, of two sets of social relations: kinship relations, on the one hand, and political-religious relations, on the other. The first generate and structure social groups, kin groups made up in a variety of ways. The second intervene at other levels and have the capacity to gather the kin groups into a whole that exercises a form of sovereignty on a territory, its resources and its inhabitants; this whole forms a society … rivalries and conflicts must be contained…",* Godelier 2018, 174.

As clearly implied by Godelier the conceptual border between 'egalitarian' and 'ranked' (including 'House Societies') societies is vague. In both types of society people are grouped in families, part of often numerically and geographically extensive kin groups. Even in the most egalitarian societies experience and age present (albeit slight) advantages; similarly, family heads in egalitarian societies have commonalities with chiefs in ranked or house societies -conceptual (theoretical) divisions are clearer than are social (practical) ones. Perhaps the best way to express the difference with egalitarian groups is that in House Societies residence and 'political-religious relations' are behaviourally more important than true family membership.

## 3. The Linear Bandkeramik case

Turning to the Central European Early Neolithic Linear Band Keramik culture and Boric' claim of its being a House Society (Boric 2008), a first observation is that there is nowhere any indicator for centralisation of that society visible in the excavated material culture (as required by the notion of 'cities' in the definition of such a type of community). Regional clusters of settlements existed, certainly: one of these being the NW-LBK, predominantly on the Lower Rhine's left bank in Germany and extending towards the West into the Southern Netherlands and Eastern Belgium. This is the group we shall restrict our discussion to. Other LBK groups centred on the Aisne valley in France, on the Middle Rhine in the Black Forest and the Alsace, yet another group along the Main in Germany, and still other groups further eastward in Czechoslovakia, Austria, Poland and Hungary. In none of these groups can a central authority be discerned; their internal coherence must have been secured by other means such as traditional relations between descent groups, with the families in customary and regular exchange of marriage partners and goods. Distinctions between these regional groups refer to pottery styles, neighbourhood/clustering of villages and the like. Their overall culture shows rather a mosaic of tribal polities, perhaps with time gradually and increasingly differ-

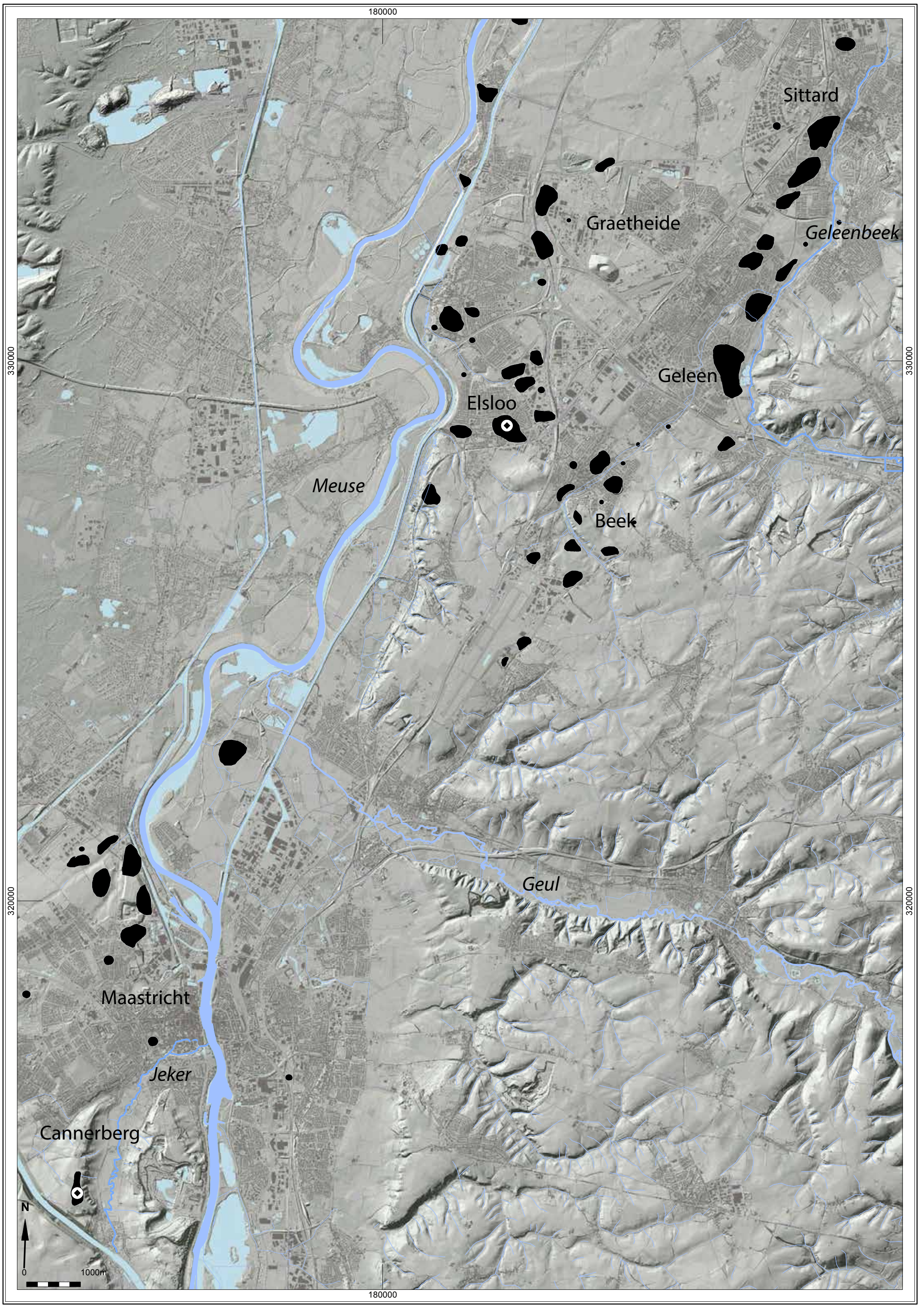


Figure 1: Distribution map of Dutch LBK settlements at the loess covered terraces between Sittard en Stein (Graetheide plateau) and around Maastricht (Caberg and Cannerberg).

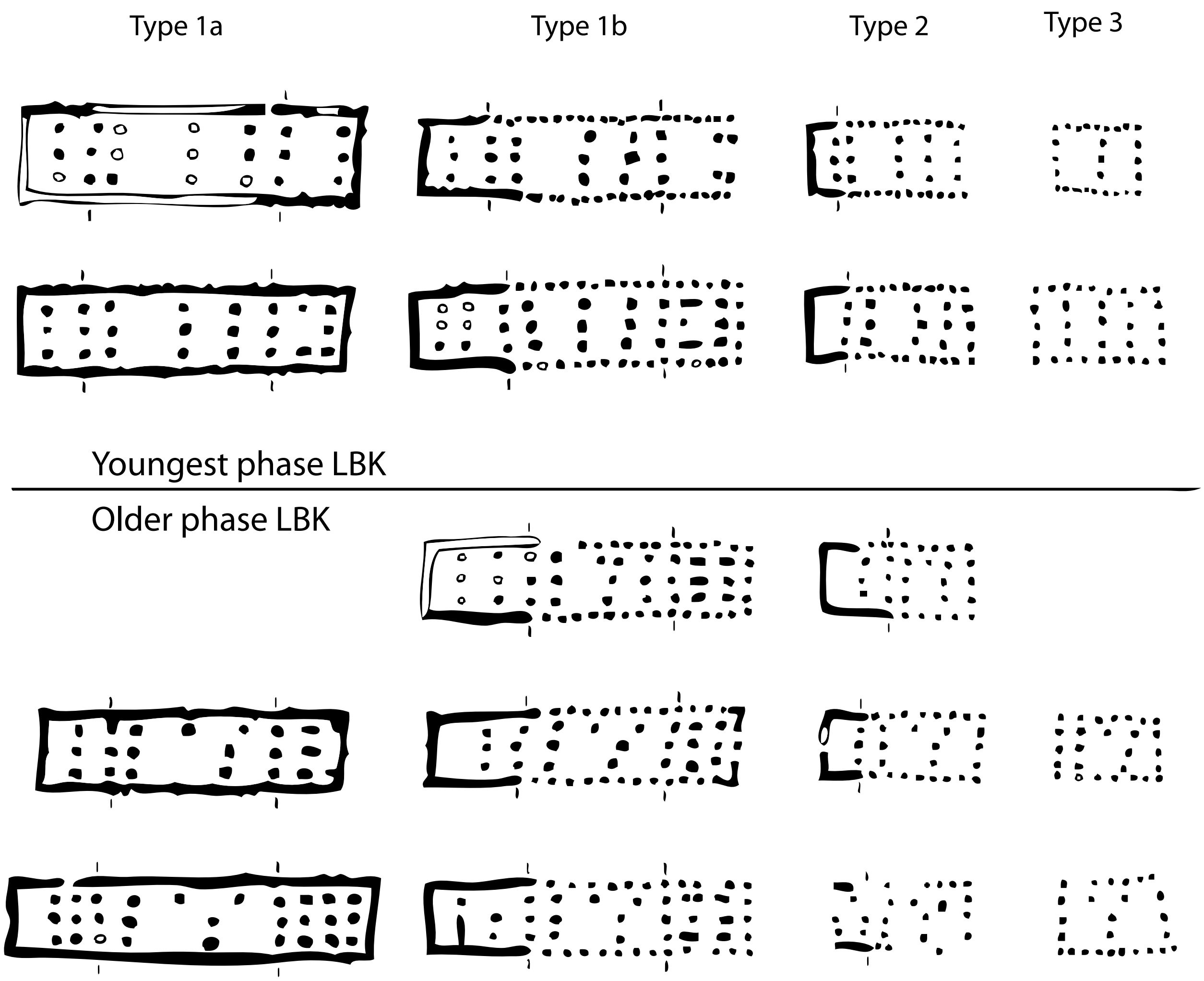


Figure 2: Typology of Bandkeramik house plans (after Modderman 1970, 111) into three different types of construction. The bottom shown house plans are indicative of the oldest phase of the LBK while the top ones are more common for the younger phases.

ently constituted as suggested by the later, Middle-Neolithic trajectories of their descendants.

Although off the mark, Boric' claim is not outrageous, for, especially in German literature much print has been dedicated to the constructional evolution of LBK houses[1] – especially as chronological indicators (Boelicke 1982; Boelicke 1988; Stehli 1988; Zimmermann 2012 – to quote only some of the texts relevant to the present argument). There, a 'Hausplatz' or 'Hof' (yard, farmyard) is defined as the area around a [LBK] house, the plot on which daily tasks associated with the household were performed; its size being in the order of 20-25 metres measured from the house's walls (together some 50x40 metres per yard) – even in recent writings this farmyard is emphatically an archaeometrical entity only (Cladders

1 We are aware that in written German the English word 'house' is rendered with a capital initial:'Haus'. Its lexical domain is just as extended as that of the English 'house', covering both a building as construction as well as a descent line (as in the House of Charlemagne.) However, as yet we have not seen a discussion of this latter, extended meaning in German archaeological literature.

| site | 1a | 1 (a,b,c) | 2 (b,c) | 3 | unknown | n | % excavated area of settlement |
|---|---|---|---|---|---|---|---|
| **Graetheide** | | | | | | | |
| Elsloo-Koolweg | 7 | 32 | 24 | 18 | 40 | 114 | 40% |
| Geleen-De Kluis | 1 | 5 | 0 | 0 | 2 | 7 | 10% |
| Geleen-Janskamperveld | 5 | 20 | 16 | 14 | 19 | 69 | 40% |
| Sittard-Mgr. Claessenstraat | 2 | 13 | 16 | 5 | 30 | 64 | 35% |
| Stein-Heidekampweg | 1 | 5 | 1 | 1 | 7 | 14 | 20% |
| Stein-Keerenderkerkweg | 8 | 15 | 5 | 4 | 26 | 50 | 30% |
| **Hesbaye** | | | | | | | |
| Maastricht-Cannerberg | 0 | 0 | 10 | 4 | 14 | 28 | 35% |
| Maastricht-Klinkers | 0 | 1 | 0 | 0 | 6 | 7 | 10% |
| Maastricht-Lanakerveld | 1 | 2 | 0 | 0 | 8 | 10 | 5% |

Table 1: Incidence of house types in selected (larger) Dutch LBK villages*. Difference is made between type 1a houses exclusively, and all variations of type 1, type 2 and type 3 houses. 'Unknown' houses are house structures which for various reasons cannot be classified.
* Many villages have been inhabited for 10 to 12 or more generations (200 or more years); houses stood some 15-20 years; rebuilding occurred on empty, adjacent plots; "percentage excavated" refers to the assumed total extent of the former LBK settlement.

*et al.* 2016: 153). It is also thought that successor farmhouses were built on the border of the same premises (Claßen 2005; Van Wijk 2016), giving rise to 'House Generations' of 11 – 25 years (Zimmermann 2012). In France, considerable consideration is also given to the architectural complexity and diversity of the houses per settlement, leading to the suggestion of different (mainly economic) roles of the several households (e.g., Coudart 2011a; Coudart 2011b, Hachem 2017).

Being relevant to the argument, a short summary of the typology of LBK houses (figure 1) may be presented. From the early days of LBK archaeology it is known that their houses were combinations of modules: common to all their houses is a so-called 'central part' which may or may not stand alone. Then there is a 'rear part', occurring with middle and large houses; and finally, 'front parts' are recognised in the large houses. Houses with the central module only are labelled 'type 3', with central and rear modules 'type 2', and with front, central and rear modules 'type 1'. There is variation in the construction of the walls of the houses; with standing boards all around, the house is of the '-a' category, with boards only along one (always the rear) part and wattle-and-daub elsewhere it belongs to the '-b' group; and when there are exclusively wattle-and-daub walls, the house is said to be of the '-c' variety. Thus, there exist houses of types 1a,1b, 1c; 2a, 2b (and rarely 2c); and of type 3c which is generally abbreviated to type 3 (Modderman 1970; Van de Velde and Van Wijk 2014).

Clearly, from an ethnographical point of view there is more to LBK houses than their typology, as the gradual evolution of their design over time and the differences over space stimulate speculation about the sociology of their inhabitants. In the LBK NW-group there was from the start a differentiation in construction method between the tripartite type 1a and type 1b houses (figure 2) – the walls of the first being characterized by wooden boards set in a trench all around, the second by wooden boards in only their rear parts and wattle-and-daub in most or all walls (types 1b and 1c, respectively), the first one (type 1a) on average slightly larger (Modderman 1970; Van de Velde and Van Wijk 2014). Since saws were unknown to these people, when constructing a type 1a house LBK craftsmen had to procure planks by splitting trunks, which requires a lot of effort, tools and resources; the application of wattle-and-daub (as with types 1b and 1c houses) is much easier. Type 1a houses do occur in most larger settlements, and if so, probably only one at any time in contrast with the other house types which constitute the majority of houses in a settlement. The other type

| phase | 1b | | 1c | | 1d | | 2a | | 2b | | 2c | | 2d | | total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **type** | min | max | min | max | min | max | min | max | min | max | min | max | min | max | min | max |
| **type 1a** | 5 | 5 | 3 | 3 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 4 | 2 | 4 | 11 | 19 |
| **type 1** | 12 | 13 | 8 | 9 | 3 | 5 | 5 | 11 | 2 | 8 | 7 | 13 | 4 | 8 | 41 | 67 |
| **type 2** | 10 | 10 | 3 | 3 | 1 | 2 | 2 | 4 | 3 | 8 | 7 | 15 | 4 | 8 | 30 | 50 |
| **type 3** | 6 | 6 | 1 | 1 | 2 | 4 | 1 | 5 | 2 | 4 | 5 | 7 | 4 | 4 | 21 | 31 |
| **uncertain** | 4 | 5 | 10 | 17 | 4 | 13 | 6 | 16 | 12 | 19 | 3 | 7 | 8 | 8 | 47 | 85 |
| **total** | **32** | **34** | **22** | **30** | **10** | **24** | **14** | **36** | **19** | **39** | **22** | **42** | **20** | **28** | **139** | **233** |

Table 2: Incidence of excavated and dated house types per archaeological phase in selected (larger) Dutch LBK villages (typology and periodization after Modderman 1970). The numbers of exactly dated houses are listed in the columns 'min', houses only cursory dated added in columns 'max'. Type 1 houses also include type 1a houses.

1 houses (types 1b and 1c) as well as the smaller two partite houses (types 2b and 2c) occur in more or less similar numbers in the various settlements. The small single part houses (type 3) are also evenly distributed within settlements and over the full time span of Dutch NW-LBK settlement. However, not many settlements have been completely excavated in this area but it is clear that type 1a houses are rare in comparison with the other types which by itself suggests a special role for this house in LBK society. Moreover, hardly any regular refuse is retrieved from their accompanying pits, which suggests that these houses had no domestic functions but rather a social or ritual role. It is evidently not the domestic area of a village chief and his family (Louwe Kooijmans 2017: 445) and emphatically does not support the idea of the LBK's being a stratified society as Boric would have it.

A more or less egalitarian society is demonstrated by the burial practices in the LBK-cemetery of Elsloo, dated to the final stages of LBK presence in the area (Modderman 1970). The three ways of treatment of the corpses practiced in the LBK (burial, cremation, and the more traditional abandonment in the forest) might be indicative, but we would not be able to pronounce on this. Moreover, in terms of quantities and qualities of grave gifts those cremated are not (or no longer visibly) to be distinguished from those corporally buried (Van de Velde 1979; Van de Velde 2011). In other words, the cemetery data are not indicative of chiefly types, or of non-egalitarian practices such as hereditary chieftainship; instead there were family heads, but apparently no heads ('chiefs') of these heads. Then, although in the villages a considerable variation in the sizes and types of the houses can be noted, neither the larger nor the smaller types are found in separate areas -they occur everywhere (cf. phase plans in Van de Velde 2008.) Again, no reason to assume chiefs and non-egalitarian practice: certainly, differences existed, but they did not stratify LBK society.

## 4. LBK: not a House Society

Within the LBK villages marked differences between the houses appear. Very roughly, for every large house ("type 1a") there are at least three times as many smaller houses ("types 1b down to 3c") in every phase (tab. 2). Types 1b/c and 2b/c houses are represented in more or less even numbers. On the excavation plans, smaller and larger houses are situated one next to the other, with no apparent fixed spatial relation or configuration; simultaneous occupation has often been proven for adjacent buildings. Regional LBK cemeteries have attested to patrilocal residence and matrilineal succession (Van de Velde 2011); it does not seem a wild supposition that groups of houses "belonged to" (were inhabited by) members of the same patrilinear family.

The data presented in Tables 1 and 2 show that the villages consisted of several 1b/c- and type 2-houses at any time; between them, there were smaller houses (type 3) as well. None of these houses had a standard size, their lengths and widths differed from house to house and from generation to generation. It was rather the general partition (internal structure) of the houses, the root of their typological attribution, that was more or less constant over the generations.

The type 1a houses are found in nearly every larger Graetheide LBK village. As noted above, they differ in a qualitative way from the other types, not only in their having plank walls all around; but also in their poverty in finds. Per village probably only one such 1a-type house was standing at any moment; when a new house of this type was built, it was rarely (if ever) on the same plot, generally another Hofplatz was selected. Moreover, at the end of their service these houses may have been burnt down intentionally -at least a number of them show traces of a fiery end (Van de Velde and Van Wijk 2014). This all suggests a special function for houses of this construction. Their relocation at other, distant yards, combined with the patrilocal-matrilineal make-up of the social fabric, induces us to propose a function as men's house, as specific communal functions would be tied to specific matri-lineages, of which the next incumbent would be associated through the same matriline with another patrilocality every generation.

The matrilineal emphasis expressed in the grave gifts, the matrilinearly structured re-location of the type 1a houses over plots in different locations every generation; which both seem to be combined with patrilocal arrangements, are arguments that point to a predominance of their kinship organization over political considerations. It is likely that this so-called disharmonic social structure prevented the emergence of 'House' arrangements, of a true House Society in which one "House" or line of descent lorded it over other families of the settlement.

## 5. A different story: the LBK settlement on the Cannerberg

Comparing the houses from the late LBK Maastricht-Cannerberg settlement (Van Wijk 2016) with those in the Graetheide villages as detailed above, a larger contrast seems hardly possible. On the Cannerberg site, all houses are almost of the same size and typologically quite similar whereas contemporaneous villages on the Graetheide are markedly (when not conspicuously) differentiated as to types and sizes of the houses. Especially the absence of the largest houses (types 1a/b/c) at the present site is striking. Also, the Graetheide settlements have generally been inhabited much longer, and during that period the distribution of house types has hardly changed there. The Cannerberg village (figure 3), though, started only at the beginnings of the LBK-II period of the Dutch chronology (Modderman phase 2a); its two to four houses were time and again rebuilt near their predecessors on the edge of the domestic areas for some six to eight generations. It was here that for the first time in Dutch LBK investigations we were able to establish repeated succession on the same Hausplatz. On the Cannerberg site, houses remained similar in type and size, their archaeological inventories came also not to differ qualitatively either. Apparently, no social differentiation emerged here -if primitive communism was ever established anywhere, it was here, on the Cannerberg. And to suggest the existence or establishment of a 'House Society', seems to be out of question. Not only the almost fundamental similarity of the houses in this settlement but their flint procurement strategy is just as, when not more, suggestive on this point; as is discussed below.

### *5.1 Flint production and 'House Society' on the Cannerberg*

The most surprising finds of the excavation on the Cannerberg are the so called 'flint working pits' each yielding considerable quantities of flint, from the local third house generation on. Almost all these pits are located on the peripheries of the yards; i.e., at the edges of the domestic spaces. There, massive quantities of the same type of flint, Lanaye, were deposited. The huge quantities of waste making up these debitage concentrations, including dozens of cores per pit, point to 'surplus' production far beyond the domestic sphere, amply surpassing the needs of the village community. The source of this flint was within arm's length for the settlers there, at not even one kilometre away down the slope. Still, the presence of these flint outcrops has apparently not been the reason for settling at this location, as in the earliest occupation phases (non-local) Rullen flint was used. Apparently the Cannerberg community only started making surpluses of blades well after being settled there. The Cannerberg community kept on obtaining exotic Haspengouw and other flints even after it had started the production of blades on local flint. This suggests that the distribution and exchange of flint did not primarily serve an economic goal, but had a more social function in which the continuity of inter-settlement relationships as well (kin, allies, marriage partners etc.) was the primary goal. The flint assemblages from the various yards show a pattern which is in line with other settlements in the area although larger quantities of Hesbaye and Rullen flint have been found there. Yet, despite the latent social potentionalities of this flint source there is absolutely no sign of changing intra-communal relationships, neither in the find assemblages nor in the distribution of houses. Thus, no intra-settlement competition and social differentiation (and with it, ranking, as minimally required for a House Society) can be inferred for this settlement. Therefore, if there was (properly speaking) no House Society on the Graetheide, the community on the Cannerberg was consciously egalitarian.

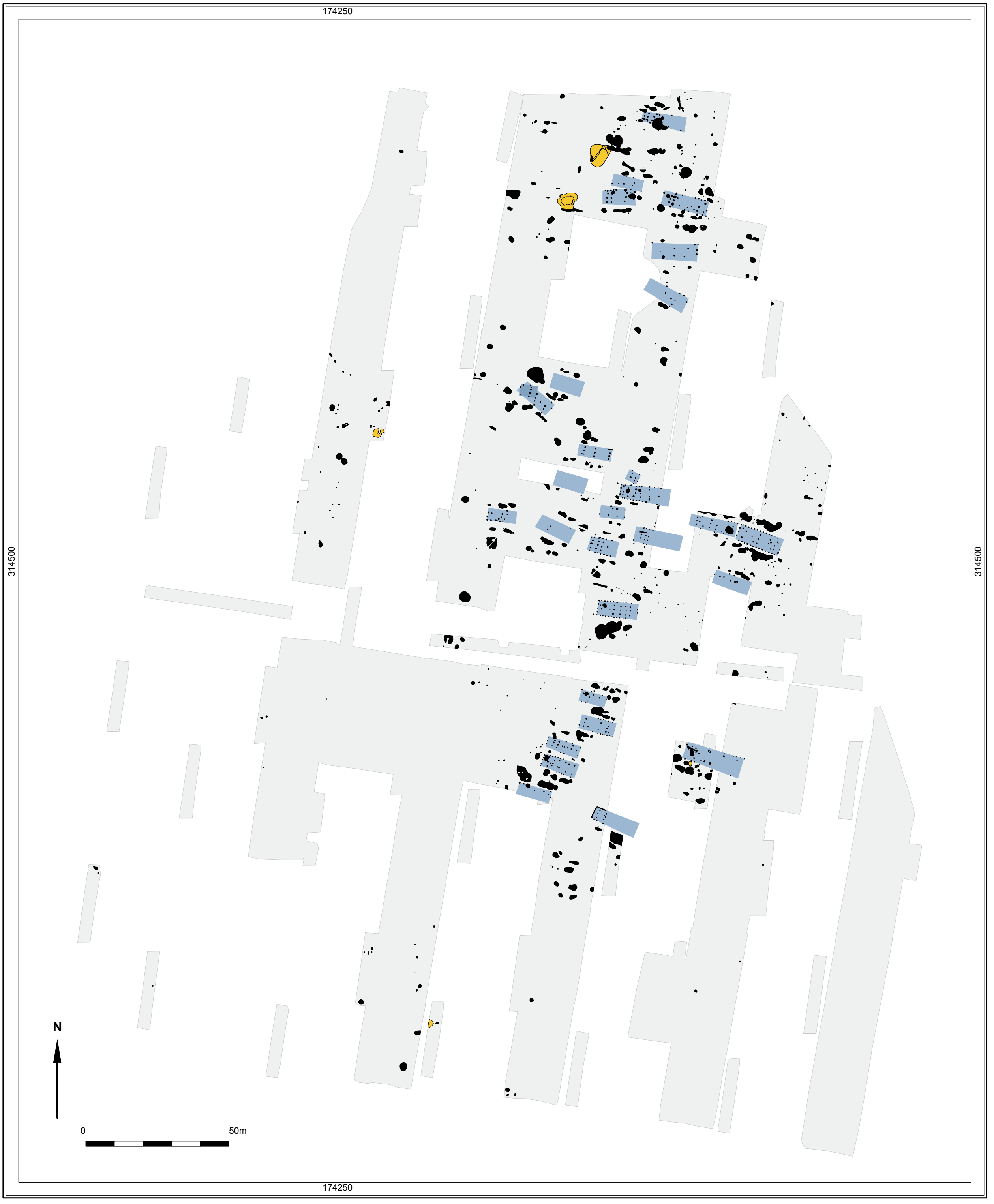


Figure 3: Site plan of the Maastricht-Cannerberg LBK settlement with all LBK features (in black). The house plans (represented in blue) hardly overlap each other. The flint working pits are highlighted in yellow.

## 6. Conclusion

Boric 2008's contention that the pan-european LBK should be classified as a 'House Society' (or 'Chiefdom' in evolutionist contexts) cannot be upheld: neither the villages nor the graveyards of that culture show any sign of centralization beyond the narrow family sphere, as we demonstrate with archaeological data from the Dutch province of Limburg. We also present evidence that at least in some places (here represented by the Cannerberg excavations) there even seems to have been a conscious avoidance of centralizing practices.

## Acknowledgements

Since the early days of the present Faculty of Archaeology, then Institute of Prehistory, Corrie Bakels has been involved in its excavations, laboratory research, publications as well the instruction of its students and the further development of archaeological investigation. The authors of the present text have benefited from her lectures and her participation in their excavations, especially those dealing with the Linearbandkeramik. We offer Corrie the present text as a small retribution for her inspired contributions in the classroom and in the field.

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## References

Bakels, C.C. 1978. *Four Linearbandkeramik settlements and their environment: a palaeoecological study of Sittard, Stein, Elsloo and Hienheim,* Analecta Praehistorica Leidensia 11, Leiden: Leiden University Press.

Bakels, C.C. 1982. *The settlement system of the Dutch Linearbandkeramik*, Analecta Praehistorica Leidensia 15, Leiden: Leiden University Press, 31-45.

Bentley, R. Alexander, Penny Bickle, Linda Fibiger, Geoff M. Nowell, Christopher W. Dale, Robert E. M. Hedges, Julie Hamilton, Joachim Wahl, Michael Francken, Gisela Grupe, Eva Lenneis, Maria Teschler-Nicola, Rose-Marie Arbogast, Daniela Hofmann and Alasdair Whittle 2012. *Community differentiation and kinship among Europe's first farmers. Proceedings of the National Academy of Sciences*, vol. 109, 9326-9330.

Boelicke, Ulrich 1982. "Gruben und Häuser: Untersuchungen zur Struktur bandkeramischer Hofplätze." In: J. Pavúk (ed): *Siedlungen der Kultur mit Linearkeramik in Europa.* (Nitra 1981 Symposium), 17-28.

Boelicke, Ulrich 1988. "Die Gruben." In: U. Boelicke, D. von Brandt, J. Lüning, P. Stehli and A. Zimmermann: *Der bandkeramische Siedlungsplatz Langweiler 8, Gemeinde Aldenhoven, Kreis Düren*, Köln/Bonn: Habelt (Rheinische Ausgrabungen, Bnd 28), 300-394.

Boric, Dušan 2008. "First households and 'House Societies' in European prehistory." In: A. Jones (ed), *Prehistoric Europe: theory and practice*, Oxford: Blackwell, 109-142.

Cladders, Maria, Christiane Frirdich, Harald Stäuble and Ulrich Veit 2016. "Ueberlegungen zur bandkeramischen Siedlungsentwicklung in Eythra." In: H. Stäuble and U. Veit (Hrsg.), *Der bandkeramische Siedlungsplatz Eythra in Sachsen --Studien zur Chronologie und Siedlungsentwicklung*, Leipzig: Professur für Ur- und Frühgeschichte, 149-162.

Claßen, Erich 2005. "Siedlungsstrukturen der Bandkeramik im Rheinland." In: J. Lüning, Chr. Frirdich and A. Zimmermann (Hrsg.), *Die Bandkeramik im 21. Jahrhundert ---Symposium in der Abtei Brauweiler bei Köln vom 16.9-19.9.2002*, Espelkamp: Leidorf, 113-124.

Coudart, Anick 2011a. "La maison européenne des populations néolithiques 'rubanées'." In: A. Hauzeur, I. Jadin and C. Jungels (dir.), *5000 ans avant J.-C., La grande migration? --Le Néolithique ancien dans la collection Louis Éloy*, Fédération Wallonie-Bruxelles: Service du Patrimoine culturel, 27-32.

Coudart, Anick 2011b. "The Bandkeramik longhouses --a material, social, and mental metaphor for small-scale sedentary societies." In: Chr. Fowler, J. Harding, and D. Hofmann (eds), *Oxford Handbook of Neolithic Europe*, Oxford University press, 309-325.

Chesson, Meredith S. 2003. Households, houses, neighbourhoods and corporate villages: modelling the Early Bronze Age as a House Society, *Journal of Mediterranean Archaeology* 16(1), 79-102.

Earle, Timothy K. 1989. The evolution of chiefdoms, *Current Anthropology* 30(1), 84-88.

Fried, Morton H. 1967. *The evolution of political society –an essay in political anthropology*, New York: Random House.

Godelier, Maurice 2018. *Claude Lévi-Strauss --a critical study of his thought*, London/New York: Verso (transl. of *Claude Lévi-Strauss*. Paris: Seuil, 2013).

González-Ruibal, Alfredo and Marisa Ruiz-Gálvez 2016. House Societies in the Ancient Mediterranean (2000-500 BC). *Journal of World Prehistory* 29: 383-437.

Hachem, Lamys 2000. New observations on the Bandkeramik house and social organization, *Antiquity* 74, 308-312.

Hachem, Lamys 2017. Animals in LBK society: identity and gender markers, *Journal of Archaeological Science: Reports* 20, 910-921. https://doi.org/10.1016/j.jasrep.2017.09.020

Jakucs, J., E. Bánffy, K. Oross, V. Voicsek, C. Bronk Ramsey, E. Dunbar, B. Kromer, A. Bayliss, D. Hofmann, P. Marshall and A. Whittle 2016. Between the Vinča and Linearbandkeramik worlds: the diversity of practices and identities in the 54th-53rd centuries cal BC in Southwest Hungary and beyond, *Journal of World Prehistory* 29, 267-336, doi:10.1007/s10963-016-9096-x.

Lévi-Strauss, Claude 1969 (1949). *The elementary structures of kinship*, Boston: Beacon Press (English translation from 1949 *Les structures élémentaires de la parenté*, (Paris-La Haye).

Lévi-Strauss, Claude 1979. *La voie des masques*, Genève: Skira. Édition revue, augmentée, suivie de trois excursions, Paris: Plon.

Louwe Kooijmans, Leendert 2017. *Onze vroegste voorouders. De geschiedenis van Nederland in de steentijd, van het begin tot 3000 vC*, Amsterdam: Uitgeverij Bert Bakker.

Modderman, Pieter J.R. 1970. *Linearbandkeramik aus Elsloo und Stein*, Analecta Praehistorica Leidensia 3 (3 Bnd.)

Service, Elman R. 1971. *Primitive social organization –an evolutionary perspective*, New York: Random House (2nd ed.)

Stehli, Petar 1988. “Zeitliche Gliederung der verzierten Keramik.” In: U. Boelicke, D. von Brandt, J. Lüning, P. Stehli and A. Zimmermann (eds), *Der bandkeramische Siedlungsplatz Langweiler 8, Gemeinde Aldenhoven*, Kreis Düren. Köln/Bonn: Habelt (Rheinische Ausgrabungen, Bnd 28), 441-482.

Stone, Linda 2004. “Introduction [to Part II: Kinship as culture, process, and agency; Section 2: Contemporary directions in kinship].” In: R. Parkin and L. Stone (eds), *Kinship and family ---an anthropological reader*, Oxford: Blackwell, 331-341.

Van de Velde, Pieter 1979. *On Bandkeramik social structure*, Analecta Praehistorica Leidensia 12. Leiden: Leiden University Press.

Van de Velde, Pieter (ed) 2008. *Excavations at Geleen-Janskamperveld 1990/1991*, Analecta Praehistorica Leidensia 39 (2007).

Van de Velde, Pieter 2011. “Aspects du monde funéraire rubané: à propos de l’organisation des cimétières danubiens nord-occidentaux.” In: A. Hauzeur, I. Jadin and C. Jungels (dir), *5000 ans avant J.-C., La grande migration? --Le Néolithique ancien dans la collection Louis Éloy. Fédération*, Wallonie-Bruxelles: Service du Patrimoine culturel; pp. 57-63.

Van de Velde, Pieter and Ivo Maarten van Wijk 2014. “De huizen van de bandkeramiek (LBK) in Nederland.” In: A.G. Lange *et al* (eds), *Huisplattegronden in Nederland --archeologische sporen van het huis*, Amersfoort: Bakhuis and Rijksdienst voor het Cultureel Erfgoed, 29-60.

Van Wijk, I.M., L. Amkreutz, P. Van de Velde, M. De Grooth, F. Brounen and A. Verbaas 2014. De Odyssee beschouwend: een synthese. In: I.M. van Wijk, L. Amkreutz and P. van de Velde (eds), *“Vergeten bandkeramiek”. Een Odyssee naar de oudste neolithische bewoning in Nederland*, Leiden: Sidestone, 487-535.

Van Wijk, Ivo Maarten (ed) 2016. *Settlement dynamics on the Cannerberg -- Archaeological Research of Bandkeramik and Iron Age settlements*, Leiden: Archol Rapport 300.

Zimmermann, Andreas 2012. “Das Hofplatzmodell--Entwicklung, Probleme, Perspektiven.” In: H. Stäuble and S. Wolfram (Hrg.), *Siedlungsstruktur und Kulturwandel in der Bandkeramik --Beiträge der internationalen Tagung ‘Neue Fragen zur Bandkeramik oder alles beim Alten?!’ (Leipzig, 23. bis 24. September 2010)*, Dresden: Landesamt für Archäologie; 11-19.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 153-166.

# Reflections on an Environmental History of Resistance: State Space and Shatter Zones in Late Antique North Africa

Jip Barreveld

*Ecologically and politically peripheral areas, such as mountains, deserts and marshes have often been seen as zones of resistance against the encroaching state. At first sight, the mountainous uplands and the desert fringe of North Africa seem to be such an area of resistance: in the Late Roman and Byzantine period, the Atlas Mountains and the Tripolitanian Sahara were epicentres of indigenous revolt against the Roman state, particularly during the Moorish Wars c. 533-548 AD. The question is whether the physical geography truly determined a cultural antagonism between inland zones and the Mediterranean coast. Using evidence from survey archaeology, epigraphy and literary sources, this paper tests models on connectivity and resistance, disputing the simple opposition between an inland, indigenous world on the one hand, and a cosmopolitan, Mediterranean and Roman world on the other. Instead, evidence shows that the relationship between "Roman" and "native" was much more complex, entangled and ambivalent, despite the peripheral nature of the inland landscapes. The cultural landscape was determined as much by historical factors as environmental.*

*Keywords: Late Antiquity, Roman frontier, Northern Africa, connectivity*

## 1. Introduction

In the late fourth century of our era, if St. Augustine peered over the city walls of Hippo Regius (Annaba) in modern-day Algeria, he would have first seen the surrounding countryside, ruled over by ruthless landowners.[1] Further away, towards the horizon, he would perceive another world from his own altogether, one of hilltop villages where people spoke 'Punic', not Latin, of heretical Donatists and wild animals. At least, that is how Peter Brown describes the situation in his landmark study on St. Augustine (Brown 1967: 186-187). Elsewhere, speaking in more general terms, Brown (1971: 13) remarks that '[T]he Roman empire always consisted of two overlapping worlds', referring to the world of the urban elite and the provincial rural inhabitant. Brown's words recall the scholarly drive to understand the cultural wedges of the Roman Empire under the now much-maligned term Romanisation (Freeman 1997; Hingley 2005). For North Africa, this supposed

**Jip Barreveld MA**
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
j.barreveld@arch.leidenuniv.nl

1 This paper is based on my MA-thesis, *Two Worlds? State Space and Marginal Peoples in Late Antique North Africa* (Leiden 2018), written as the concluding element for the Research Master Ancient History at Leiden University, with L.E. Tacoma as first supervisor (any potential errors are, of course, mine). The MA-thesis has been awarded with the 2018 Fruin-award for the best MA History thesis of the year in Leiden.

cultural divide between Roman and 'native' has often been framed in environmental terms of an opposition between the harsh inland landscapes of mountains and deserts (Sahara) and the cultured world of the Mediterranean coast (Tell).

This inland world was inhabited by peoples usually called 'Moors' by Late Antique sources and often identified with the modern Berber.[2] Berbers had long inhabited the North African inlands, already in the first few centuries BC, Numidian states coexisted with the Mediterranean-facing empire of Carthage. The Romans managed to subjugate most Berber tribes in the region, but from the fourth century AD, various Berber strongmen appear in the literary sources, first with the revolt of Firmus in 372. With the collapse of Roman authority in North Africa following the Vandal conquest of Carthage in 439, various Berber principalities controlled much of Mauritania, Byzacena and part of Tripolitania. When general Belisarius was sent by the Byzantine emperor Justinian in 533 to reconquer North Africa from the Vandals, he defeated the Vandal forces in only a few months, but for the next fifteen years, his successors faced various Berber revolts. Only in 538 was the general John Troglita able to finally quench resistance (Brett and Fentress 1996).

To what extent is the unrest reported in the ancient sources symptomatic of a more fundamental antithesis between Sahara and Tell? As will be discussed below, the environmentalist framing of this opposition between Roman and barbarians goes a long way back. A more theoretically sophisticated analysis is made possible through the work of anthropologist James C. Scott. In his *The Art of not Being Governed* (2009), Scott departs from an environmental perspective to research the dialectic between what he calls 'state space' and stateless 'shatter zones'. The question here is whether the rebellious Berber populations in the marginal hinterlands of Late Antique North Africa can be seen as stateless peoples in opposition to Roman state space, following the thesis put forward by Scott.

In many ways, the 'Moors' of Roman North Africa are a "people without history", having produced no texts of their own (except some inscriptions, discussed below). The Romans, when writing about them, usually did so in very pejorative terms. However, a set of Late Antique texts, when read against the grain, can throw some light on the African inlands during the Late Antique period (here, roughly fourth to sixth centuries AD). This paper discusses models of Mediterranean connectivity and resistance and compares it with survey archaeology conducted in modern Algeria, Tunisia and Tripolitania, as well as the narrative texts by Ammianus Marcellinus, Procopius and Corippus and epigraphic texts left behind by 'Moorish' chiefs. Putting the evidence together and relying on a critical discursive reading of the texts, a more nuanced picture emerges of the interaction between 'Roman' and 'local' in North Africa.

## 2. Models of Connectivity and Resistance: State Space and Shatter Zones

In *The Art of Not Being Governed*, Scott studies an area called Zomia, the mountainous uplands of Southeast Asia. As a leading question, he asks: 'how might we best understand the fraught dialectical relations between […] projects of rule and their agents, on the one hand, and zones of relative autonomy and their inhabitants, on the other?' (Scott 2009: 2). According to Scott, environmentally marginal zones such as mountainous Zomia were places of refuge for people seeking to escape the tyranny of the premodern state. Here, men and women could escape the imposition of taxes, corvée, servitude, war and disease which would inevitably follow the establishment of sedentary and hierarchical states. These places of refuge, or 'shatter zones', were made possible by environmental circumstances. Scott characterises the state as a lowland phenomenon. The reach of the state was obstructed by the problem of distance: armies needed to be moved and fed, land to be surveyed by agents of the state, taxes in kind to be collected. Difficult terrain like mountains, marshes or deserts made overland transport more difficult so that many premodern states concentrated into fertile river valleys, and the state's hegemonial culture spread across flat plains. To escape state space and the burdens of the state, people fled to difficult terrain, called shatter zones, and became 'barbarians by design', living in opposition to the state in acephalous, illiterate, fluid communities with mobile

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2 The word 'Berber' is derived from Latin *barbarus* and usually refers to the indigenous people of North Africa (as opposed to Arabs, Phoenicians, Romans, etc.). Ancient ethnonyms are for example Moors (Mauri), Numidians, Garamantes, etc. Berber can also refer to the related indigenous language. While not a perfect term, I will use the term here, following Brett and Fentress (1996: 3-5), to use it to refer to those people who are, or were, perceived to be indigenous North Africans both in the past and the current day.

residences and dispersed agriculture. Variations of this pattern occur all over world history according to Scott, and everywhere the discourse of civilised states is to portray stateless people as 'barbarians' (Scott 2009).[3]

One such people fleeing the state and living in shatter zones mentioned by Scott (2009: 328) are the Berbers in North Africa. Indeed, the history of North Africa has long been interpreted in terms of an opposition between the state and the stateless, siba and makhzen (Gellner 1969: 1-29). According to the Medieval African scholar Ibn Khaldun, history could be explained through the opposition between sedentary peoples (Arabs, in his case), and barbarian nomads (Berbers) (Ibn Khaldun I.221; Wickham 2005: 18). This opposition has often been framed in geographic or environmental terms, a simple opposition between coast and desert, an opposition that has been especially prominent since the French colonization of North Africa (Lawless 1972; Brent 1986). Thus, one could speak of a struggle between the desert and the Mediterranean world (Birot and Dresch 1953: 452), or between 'desert' and 'sown' (Despois 1964: 108). Most forcefully, the argument has been put forward in Christian Courtois' *Vandales et l'Afrique*, who, like Scott, uses the metaphor of Roman civilisation flowing around the landscape like water, covering the plains but leaving the mountains dry, home to 'l'Afrique oubliée' (Courtois 1955: 65-128). Subsequently, criticism on the dichotomy urban/rural, plain/mountains and Roman/African has mounted, seeing it as a simplification of reality and a relic of colonial thought (Lawless 1972; Leveau 1977).

It is important to realise that Scott's thinking is more sophisticated. *The Art of Not Being Governed* explicitly characterises the stateless as the product of state formation; paradoxically, the stateless are fundamentally entangled with the state, according to Scott. It is only in the discourse of the state, through the written texts passed down and studied by historians, that the stateless become othered into a categorical opposite, barbarians that remain to be civilised by the state (Scott 2009: 98-126). I will return to this point later.

At first sight, Scott's thesis seems appealing for the Roman Empire and Roman North Africa specifically. It is a well-known fact that most Roman towns are distributed along the Mediterranean coastline or major river ways (Noreña 2015) a basic fact which had not changed by Late Antiquity if we can judge from the location of early medieval bishoprics (Brown 2012: 7). The Mediterranean coastal zone thus also produced specific cultural landscapes where traditional 'Roman' life was replicated. Here lived the aristocrats who wrote the texts that we read to the current day, from bishops like St. Augustine who guided their flock, to governors who administered the province. The hinterlands, on the other hand, were home to estates, villages, military fortifications and tribal areas, but much more sparsely populated by towns.

This sharp contrast in urbanisation and cultural landscapes was an effect of the 'problem of distance'. Distance plays a central in Scott's argument, which goes back to Fernand Braudel's landmark study on the Mediterranean (1949: 355-358). Braudel (1949: 25-51) too, already argued that the mountains had always been a world apart from the Mediterranean coastal plains, refuges of liberty for peasant republics. Recently, distance as *ennemi numéro uno* has received renewed attention among ancient and medieval historians studying the Mediterranean. Horden and Purcell (2000) in their environmental, neo-Braudelian monograph, *The Corrupting Sea*, see the Mediterranean Sea as enabling connectivity. Because the Mediterranean connects and land divides, Mediterranean geography is essentially 'inside out'. 'Distance is, in effect, inverted: places linked by the sea are always "close", while neighbours on land may, in terms of interaction, be quite distant' (Horden and Purcell 2000: 133).

While the importance of the Roman roads should not be forgotten (*e.g.* Laurence 1991), they can best be seen as complementary to the greater importance of waterways. The centrality of the Mediterranean has been powerfully corroborated by Walter Scheidel's ORBIS project. In a GIS-model based on Diocletian's Price Edict and papyri the time and costs of travel-routes are simulated (Scheidel 2014). The resulting maps perfectly plot the problem of distance and the 'inverted Mediterranean' of Horden and Purcell (figure 1). The Mediterranean becomes a pond of connectivity, while the far-flung inland regions such as Numidia and Mauretania were further away from the city of Rome than, for example, the Levantine coast in terms of relative distance. Such a map of connectivity perfectly fits the distribution of Roman cities. Since cities were the cornerstone of Roman governance,

3 For critique on Scott from the discipline of Southeast Asia studies, see Lieberman 2010. For application within ancient history and classical archaeology, see Woolf 2016.

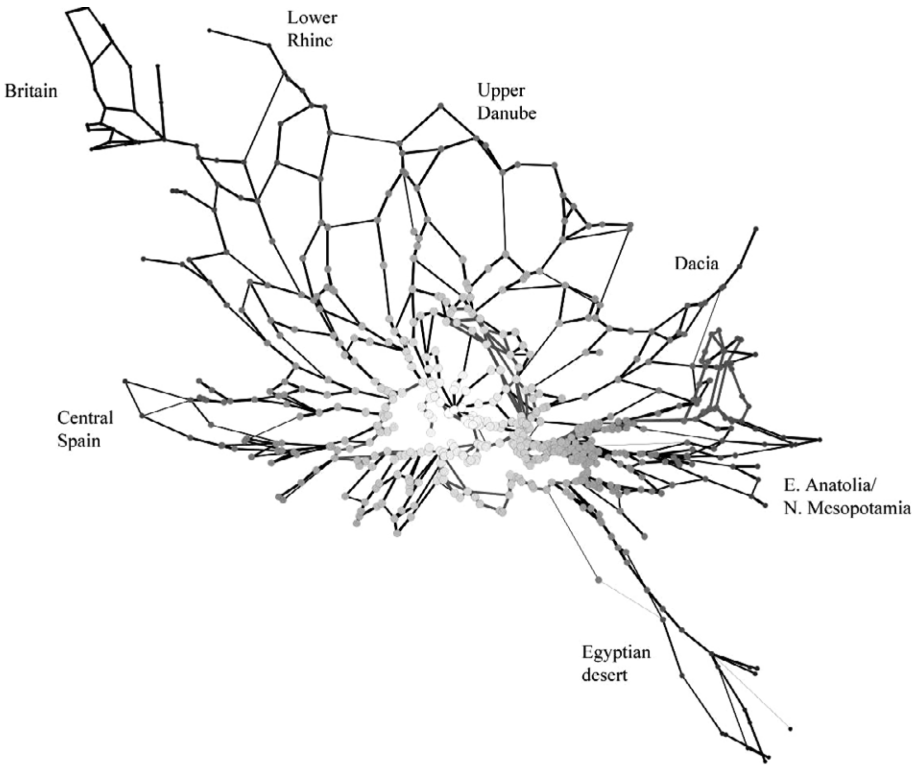



Figure 1: Visualisation of Mediterranean connectivity based on Walter Scheidel's GIS model, computing the time cost from Rome at high military speed. Note the relative distance of inland Africa compared to the coast (Scheidel 2014: 15).

even in the Late Empire,[4] this brings us back to Scott's theory: the Mediterranean Sea itself becomes the Roman state-space, similar to the river valleys of Scott's Southeast Asia, while the peripheral inland territories become potential shatter zones. From the point of view of the Roman state, inland zones would be harder to reach and control, forming possible landscapes of resistance. The question is whether this model can be corroborated by the ancient evidence.

## 3. The African Landscape

Since the 1970s, a series of archaeological surveys have been conducted across North Africa, revealing hundreds of sites across modern Algeria, Tunisia and Libya. Generally, these surveys, some intensive and others extensive, have relied on fieldwalking, collecting pottery sherds and mapping remains of archaeological structures, still visible above ground. The main problem with the African surveys, familiar to anyone who has attempted to synthesise the results from a plethora of surveys performed by different archaeological teams, is the lack of comparability between the surveys, since each survey has had its own parameters, research decisions, methodologies, chronological demarcations, thoroughness and quality of execution (Alcock 1996: 36; Leone and Mattingly 2004: 136-142). This paper will therefore rely to a large extent on the authors' own interpretations.

Here, three surveys will be discussed in detail: The Africa Proconsularis Survey near Thugga, the Kasserine survey near Cilium and Thelepte in Byzacena, and the UNESCO Libyan Valleys Archaeology Survey in Tripolitania (cf. figure 2). The Africa Proconsularis survey,[5] which found up to 634 sites in the hinterland of Thugga over an area of sixty-nine square kilometres, is located in the north of modern Tunisia and represents here the more 'archetypical' state space of the Mediterranean littoral or Tell. Towards the south in the province of Byzacena,

4 There is no room here to discuss the continuing centrality of towns in Late Antiquity. A recent and powerful argument for towns as foci of late antique administration and governance, see e.g. Dey 2014.

5 The data of the Africa Proconsularis survey is freely available online: *Rus Africum. Thugga Survey*, http://www.rusafricum.org.

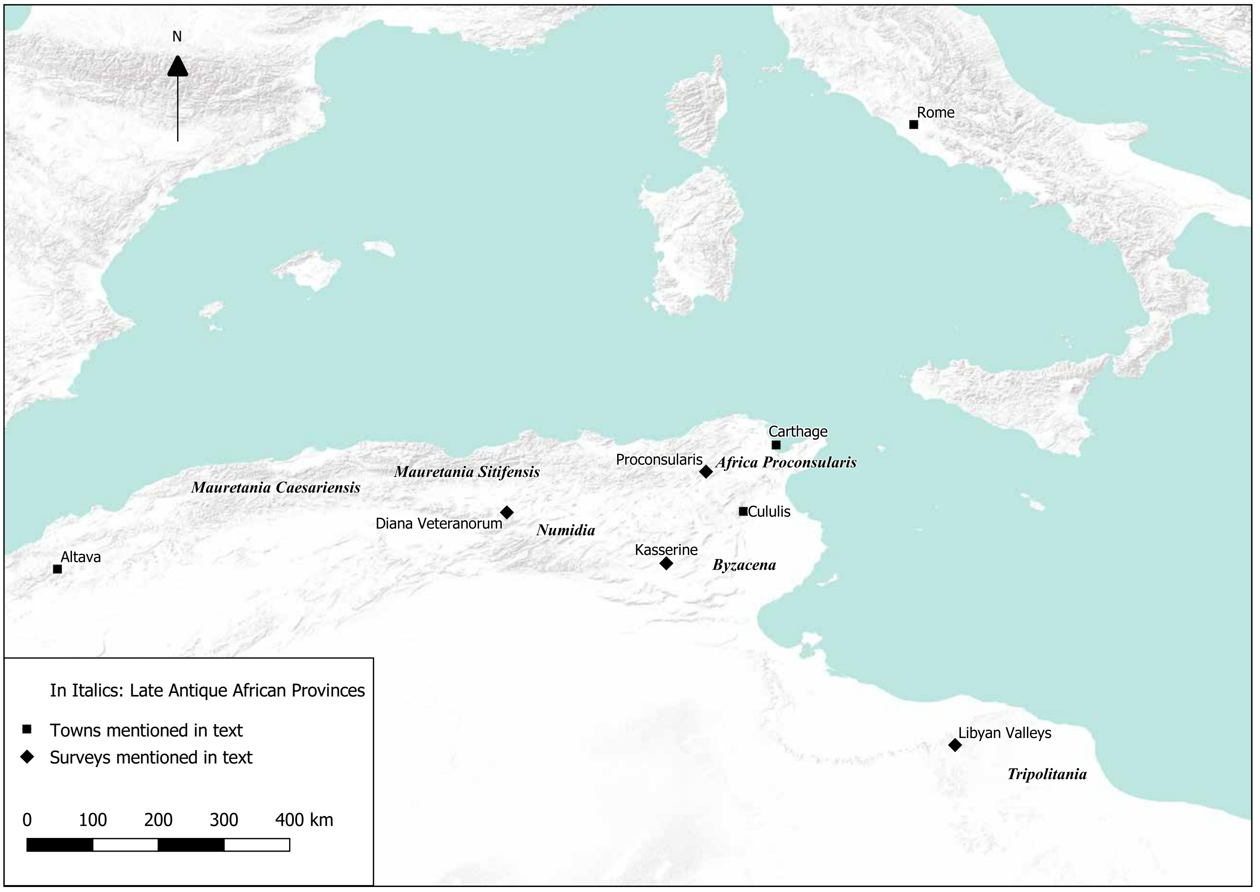



Figure 2: A map of North Africa, showing towns and the surveys discussed in this article, alongside the Late Roman provinces. Basemap: Esri Terrain, made in QGIS.

the Kasserine survey was conducted in the harsh landscape of the pre-desert, recording over 200 sites in 75 square kilometres. Finally, the harshest and most peripheral landscape is represented by the Libyan Valleys Survey, which covered over 50,000 square kilometres and recorded roughly 2,500 sites.[6] These three surveys have been selected for their differing environmental and geographic conditions. This way, we can find out whether different environments caused differences in terms of settlement patterns, material culture and thus, tentatively, the imposition of a Roman state space. This question can also be turned around: what evidence for shatter zones can be found in these surveys?

6 Summaries of the North African surveys can be found in Dyson (2003, 42-45) and Mattingly (2011, 155-159) among others.

### *3.1. Micro-ecologies and settlements*

North Africa is characterised by the Atlas Mountains, a parallel range of mountains extending from Mauretania Tingitana (Morocco) in the west to Africa Proconsularis (Tunisia) in the east. These create a variety of ecological niches, from highland plateaus to forested mountain slopes and an arid pre-steppe preceding the Saharan desert. Only in the East, in Tripolitania (modern Libya) is there a sharp break between coastal and desert zone (Sherwin-White 1944; Amin 1970: 11-21). This variability accords well with the model put forward in Horden's and Purcell's Corrupting Sea of the Mediterranean consisting of micro-ecologies, a variety of small-scale local ecological zones each with their own distinct environmental conditions. We can try to cross-reference this environmental variability with human settlement patterns through the survey archaeology. Here, the landscape of the fertile and densely populated Thugga survey will be contrasted with the peripheral landscapes of Kasserine and the Libyan Valleys surveys.

Thugga here represents the archetypical 'state space', located in the hinterland of Carthage in the Medjarda valley in the prosperous Roman province of Africa Proconsularis. Located close to the crucial Medjerda river which connected the area to the Mediterranean sea, the survey area was well connected to the outside area. The valley is hilly but received enough rain (400-500 mm annually) to produce cereal crops in the valley bottom, while the hill slopes were used for olive production. Notably, the survey area was densely populated by minor towns, in addition to numerous smaller settlements. The most predominant type of settlement found were those of circa 2000 square metres in size, although smaller 'settlements' around 1000 square metres (interpreted as farmsteads), were also found. Hill settlements consisted of mud-brick buildings. Generally, the area is known from written sources to have consisted of sizable imperial holdings leased to coloni under the conditions of the Lex Manciani, and later also the church became a major beneficiary of land (De Vos 2013).

Moving to southern Tunisia in the ancient province of Byzacena, Kasserine is part of the high steppe and is rather arid with only 400 mm of precipitation, making the area best suited for pastoralism. Yet, the survey area was home to two Roman coloniae, Cillium and Thelepte. Away from the main urban centres, survey archaeology has located secondary settlements, called 'agrovilles' by the surveyors. Agrovilles could sometimes be rather large and even resemble Roman towns in terms of monumentality, such as Ksar el Guellal. Simple courtyard buildings were often located on ridge tops with surrounding field systems and irrigation, orbiting larger or more prestigious sites in the lowland. Judging by the irrigation infrastructure and the large numbers of olive presses found, much of the arid land had been converted into agricultural land for olives. This could generate quite some wealth for some: villas such as Henchir el Guellali were equipped a peristyle court with outbuildings, such as bathhouses, and presumably formed as estate centres for the surrounding ridgetop villages (Hitchner *et al.* 1988; Hitchner 1990). Interestingly enough, the archaeological picture is closely corroborated by a written source in the form of the Albertini Tablets. These inscriptions from the Vandal period were found nearby, only 60 km to the southwest. The tablets deal with the sale of land, revealing the cultivation of olives in the region and the existence of irrigation works (aquaria) that were used to sustain this agricultural regime (Mattingly 1989).

Perhaps the most stunning agricultural accomplishments took place in Tripolitania. Here, the UNESCO Libyan Valleys survey found a landscape rich in wadi agriculture and settlements interspersed through the desert, despite the extreme climatic and environmental conditions. With only 25mm-70mm of rain per year and thin soil, much of the land can truly be called inhospitable. Yet water is naturally collected in the wadis (riverbeds), which allowed the local population to flourish, building walls, cisterns and irrigation networks. Surveys recorded more than 2500 sites, which have been grouped into military sites, huts, courtyard farms (sometimes built in opus africanum or opus quadratum). The most controversial structures are the so-called gsur, fortified structures named after their castle-like appearance (gasr, plural gsur, cf. Arabic qasr) but, which appeared rapidly around the third and fourth centuries AD. Rather than seeing them as the abodes of soldier-farmers, Mattingly has interpreted the gsur as the estate centres of local elites. These or similar elites may have been responsible for building the site of Ghirza, a remarkable fourth-century site where mausolea are constructed in a Romano-Libyan style celebrating local Libyan chiefs (Barker *et al.* 1996; Mattingly 1995; Mattingly 2011: 146-166).

However, there are some crucial differences between the different regions in terms of chronology. The surveys in the 'core areas' of Africa Proconsularis and Byzacena (possibly Numidia too) generally show a general rise of sites in Late Antiquity (dated by means of ARS) with a peak between 350-500/550 AD, while the more peripheral provinces of the Mauretaniae and Tripolitania peaked earlier in the third century, with a decline in the fifth century (Dossey 2010: 62-69). In Tripolitania, the decline of ARS matches the rise of the fortified gsur, which on their turn decline in the sixth and seventh centuries (Mattingly and Dore 1996; Mattingly and Flower 1996). It may well be that the Vandal invasion disrupted state power in the peripheral provinces of Tripolitania and the Mauretaniae, coinciding with the rise of the autonomous Berber kingdoms discussed below. Then, in the sixth century, the period following the Byzantine invasion seems to have been characterised by economic decline in Byzacena and Proconsularis.

To sum up, generally, survey evidence points towards an intensification of the rural landscapes in later antiquity (from the third century onwards), with the appearance of structures in the landscape, such as winepresses, bathhouses and villas that are linked to a Romanising koine (cf. Fentress 2006: 27). In terms of site density, land use and intensity of agriculture there are significant similarities between each of the survey areas, despite the ecological differences. All of these landscapes were transformed under the Roman Empire into landscapes of production, showing interconnectivity with the Mediterranean world even for the more marginal landscapes. It needs to be stressed once again that this does not suppose a model of Romanisation, since the capacity of irrigation and dryland farming which allowed the transformation of these landscapes may have well have been based on indigenous knowledge of the landscape. On the other hand, differing chronological trends may suggest that Vandal invasion allowed local polities to flourish in the the peripheral areas of Mauretania and Tripolitania.

### *3.2. Indications of Shatter Zones in Roman North Africa*

Is there no evidence for shatter zones in the survey archaeology of North Africa at all? In order to recognize a shatter zone, we need to have archaeological evidence for societies that evaded or resisted the state, or had cultural expressions very different from the Romans. David Mattingly has done preliminary research of what he calls 'landscapes of resistance' (Mattingly 2011: 159-162). Let us briefly consider his examples.

In Tripolitania, the main question revolves around the fortified gsur. Were these castle-like structures fortified centres for soldier-farmers guarding the limes, or rather prestigious estate centres for a landowning elite? We know that from the third century onwards, there was increasing pressure on this region from beyond the limes by the Laguatan confederation, a group of Berber people who challenged Roman authority in the region between the third and sixth centuries, coinciding with the appearance of the gsur. It could be that these structures belonged to local strongmen integrated into the Laguatan confederation. (Mattingly 1996: 319-342). Unfortunately, the evidence remains ambiguous and will require further archaeological investigation. Another indication for the Tripolitanian pre-desert as a shatter zone could be the clausurae, walls in the frontier region that may have been used to channel the movement of pastoralists. If so, they indirectly attest people of 'another world', although if pastoralists traded with Roman citizens on a regular basis, this would rather be proof of symbiosis instead of opposition (Mattingly 1995: 113-114).

Throughout North Africa, there are the remains of hillforts (called oppida by the Romans). Perched on hilltops, they often have sloping and winding paths and walls making access difficult. Excavation has revealed that some of these hilltops may even have had residences inside, although in far too small numbers for permanent habitation. Perhaps they should be understood as centres of refuge or as strategic centres protecting water access (Mattingly 1995: 42-44). Several of such hilltops have been found in the Thugga, Libyan Valleys and the Diana Veteranorum surveys. The question is when these forts were used, although the hilltops in Tripolitania have ceramics dating to the third and fourth centuries (Mattingly 2011: 160; Fentress 2013: 322-325).

There may be another type of evidence which Mattingly does not consider: settlements. Already in 1911 under the colonial French regime, a rudimentary survey was conducted in Algeria, mapping 'Roman' and 'indigenous' sites, published as the Atlas Archéologique de l'Algérie (Gsell 1911). This has been studied in detail by R. Lawless for the area of Mauretania Caesariensis. Here, 'native' Berber sites could be identified by their simple architecture, consisting of dry-stone houses, located as isolated hamlets or in small villages. Although these sites are hard to date, the presence of some Roman fine ware suggests that at least some such sites were inhabited during the Roman period (while at the same attesting interconnectedness with the Mediterranean world). In terms of spatial distribution, these sites are rare in the coastal mountains, and more common further inland (Lawless 1969). However, the study is based on the essentialist premise that dry-stone villages are Berber or 'native' and antithetical to the Mediterranean, Roman way of life. Furthermore, 'ruines romaines' can still be found in the lowlands and valley bottoms of the province, often in proximity to the 'sites indigènes' (*e.g.* Gsell 1911: f. 31). Furthermore, dry-stone villages have been found in core areas such as the Africa Proconsularis survey, described above.

More research on these 'landscapes of resistance' could be done and much more can be said about the gsur, clausurae, hilltop forts and settlements. For now, a fundamental opposition between coastal state space and inland shatter zones seems to be weakly supported by the archaeology. And even if some of these 'landscapes of resistance' truly document societies opposing the Roman state, then the presence of the fortified gsur and hilltop forts at least seem to indicate some kind of hierarchy, instead of an anarchistic, acephalous society of Scott's model.

## 4. Reading against the Grain: Romans and Berbers

Postcolonial theory in archaeology shows us that we need to be wary of making a rigid distinction between coloniser/colonised (Van Dommelen 1998: 212-216). Indeed, rather than a binary opposition between Romans and natives, we have seen that the survey evidence hints towards a more entangled relationship of both cooperation and resistance. A unique corpus of texts which discusses the revolt of Firmus (372-375 A.D.) and the Moorish Wars (534-548 AD) further reveals the relationship between Romans and Berbers. Archaeologists often point out that texts provide little (neutral) information about non-state agents (cf. Moreland 2001), and certainly most texts for Roman North Africa were written by agents of the Late Roman state with a hostile, elitist perspective. Nevertheless, a deep reading of the discursive strategies employed in these texts allows a reading against the grain, enabling us to deconstruct the dichotomies put forward by the Roman authors and bring the texts more in line with the archaeology. A second body of texts can corroborate the first: fifth and sixth-century epigraphic texts, many of them written from the perspective of Berber chiefs from Numidia and Mauretania.

The Roman perspective is told by three different authors. The first is Ammianus Marcellinus, living in the fourth century and reporting on the rebellion by Firmus and his brother Gildo. In brief, the narrative of Firmus' revolt against Romanus, the count of Africa, can be read from the perspective of a nativist rebellion against the Roman state. However, recent work has emphasised how Firmus himself operated in a Roman framework (as did another brother of his, Sammac, whom we will meet below) (Drijvers 2007: 139-142). Rather than an outright bid for Berber independence, Firmus may have instead played games of high politics, aligning himself with the eastern court in Constantinople rather than the western court in Italy (Blackhurst 2004: 59-75).

The other two authors are Procopius and Corippus, who report on the Moorish wars in the sixth century. Procopius travelled in Belisarius' army and reports, with some important caveats, the viewpoint from Constantinople. It is well known Procopius was critical towards Justinian's rule, especially in his notorious Secret History (Cameron 1985; Greatrex 2014: 83-91). The Wars, too, could be seen as being implicitly critical of Justinian's rule in reporting its inability to maintain an adequate occupation force after the initial (re) conquest. The overall narrative seems to have little interest in Africa or its inhabitants, who are barely mentioned, and the focus is almost solely on the Byzantine army (Cameron 1985: 171-187). Instead, Corippus himself was born in Africa. Instead of a historical text, his Iohannes or the Libyan War was written as an epic in Virgilian style, commemorating the heroic deeds of general John Troglyta. Corippus may have been an apologist for the Byzantine regime, justifying the presence of the Byzantine army towards his elite urban compatriots by stressing their role in keeping the barbarian Moors at bay (Shea 1998: 1-62).

It is well known that Procopius and Corippus speak in very negative terms of the Berbers. In the age-old tradition of classical rhetoric, they presented the Berbers as the polar opposite of their own, Graeco-Roman civilisation (Conant 2012: 252-273). In both Corippus' Iohannes and Procopius' Wars, a

| **Traits** | **Examples** | **Citation** |
|---|---|---|
| Craven | Fleeing, unfair fighting | Corippus, *Iohannis* 5.154-155, Procopius, *BV* 2.11.47-56 |
| Faithlessness | Breaking promises | Corippus, *Iohannis* 1.522-578, *BV* 2.8.9-11, Procopius, *BV* 2.25.16 |
| Cruel | Burning, slaughtering, pillaging | Procopius, *BV* 2.23.26-27, Corippus, *Iohannis* 3.380-400. |
| Innumerable | Innumerable armies | Corippus, *Iohannis* 2.196-196, Ammianus, 29.25.29 |
| Irrational | Howling at each other | Corippus, *Iohannis* 4.350-355 |
| Uncivilised | Not wearing proper clothes, not eating proper food | Corippus, *Iohannis* 4.350-355, Procopius, *BV* 2.11.26, 2.6.5-13. |
| Black-skinned | Roman mothers scare their children with the black skin of the Moors | Corippus, *Iohannis* 6.29-98. |
| Pagan | Worship Gurzil and Jupiter-Ammon | Corippus, *Iohannis* 6.145-188, 3.82-155, 1.282-1.322 |

Table 1: A discursive analysis of traits ascribed to the 'Moors' in Procopius and Corippus. Citations are illustrative, not exhaustive.

very similar discourse of negative traits is ascribed to the Berbers, as is summarised in table 1. A notable departure from classical discourse is the addition of the Berbers' paganism (*e.g.* Iohannis 6.145-188), which is contrasted by Corippus with the noble piety of Iohannis (*e.g.* Iohannis 4.269-278).

More relevant for our current purposes is the specific environmental associations that were made by the texts. Ammianus, Corippus and Procopius all have a tendency to associate Berbers with marginal, wild and uncultivated terrain which forms an analogy to their supposed wild and animal nature. The most common association is between Berbers and mountains. Common tropes include: fleeing to the mountains when defeated; using the mountains to ambush the Roman army; or 'pouring forth' from the mountains (*e.g.* Procopius, BV 2.19.16-20; Corippus, *Iohannis* 1.5.529-536) For example in the following passage by Corippus: 'Their fear threw them into confusion and so they took refuge on the mountain heights. They set up and fortified their grim huts in the forests, and the hollow valleys, and the sloping hills were filled with their innumerable tribes' (Corippus, *Iohannis* 2.4-7, translation from Shea 1998). Another type marginal terrain often mentioned by Corippus is the desert. Specifically, the case where the Tripolitanian tribes under Carcasas lure general John into the desert, a fatal strategical mistake made by the Roman general, since the desert is too hot and dry for his armies to survive (Corippus, *Iohannis* 6.220-6.773).

The point here is not that Berbers lived in mountains and deserts. As we have seen, it is a perfectly reasonable supposition to believe this to be true. The point is, rather, that this is, as an imagined geography, the perspective of the Roman elite of this landscape. In other words, the specific environment is framed in a negative way as the opposition of civilisation. This, too, relies on an older literary topos of loca horrida, or terrible 'non-places' such as marshes or mountains, that were considered opposite to the idealised Roman life (Fabrizi 2015). The literary device of the locus horridus, then, marginalised Berbers into the uncivilised 'other'. Here we return to Scott's point that written texts usually represent the perspective of the lowlands elite and their perceptions of marginal peripheries and their inhabitants (Scott 2009: 99-105). Through the act of discursively marginalising difficult terrains such as mountains or deserts, state agents such as Corippus and Procopius also claimed their own cultural superiority and justified the state's attempt at domination.

That such a dichotomy between Roman and Berber is more ideological than real, can, in fact, be gleaned from these very same texts. Several Berber chiefs feature as allies to the Romans in Corippus. The case in point is 'the most loyal Cusina', who despite the flowery terms in Corippus, was still an enemy to the Roman army before general John's arrival in Africa, as stated by Procopius (Shea 1998: 9). Berber chieftains could, therefore, position themselves as friends or allies to the Romans. When Belisarius arrived, many Berber chiefs asked him the diplomatic honour of the 'symbols of office' (possibly the items of a silver cap, a silver staff and a white cloak) (Procopius, *BV* 1.25.1-9). According to Brett and Fentress (1996: 65), such giving of honours was part of a long tradition of Roman-African diplomacy: 'Rome had become a source of legitimation on its periphery, outside the areas which it directly controlled'.

Epigraphy confirms the close ties between the Berber elites and the wider Roman world. In an intriguing inscription from the fourth century, we meet another one of Firmus' brothers, Sammac, known for his estates from Ammianus Marcellinus (29.5.13). The inscription is written in beautiful and classicising Latin, with Sammic playing the role of a Roman aristocrat. At the same time, his power play of controlling the local tribes as a Berber chief can be read as a veiled threat towards the Roman provincial government. Another literary motive in the inscription itself is again the association with marginal terrains, such as mountains and rivers:

> *'With prudence he* [Sammac] *establishes a stronghold of eternal peace, and with faith he guards everywhere the Roman state, making strong the mountain by the river with fortifications, and this stronghold he calls by the name of Petra. At last the tribes of the region, eager to put down war, have joined as your allies, Sammac, so that strength united with faith in all duties shall always be joined to Romulus' triumphs',* ILS 9351; transl. Brett and Fentress 1996, 72 (the emphasis is mine)

While this is the most elaborate inscription, we find a similar ambivalence in the fifth and sixth -century inscriptions. One inscription from the Aurès mountains in Tunisia names Masties as dux and imperator, who 'never broke faith with either the Romans or the Moors' (Carcopino 1944). To the West, in Mauretania Caesariensis, near the royal centre of Altava, an inscription records Masuna, regis Masunae gentium

Maurorum et Romanorum, king of the Romans and the Moors (CIL 8: 9835). Sammac, Masties and Masuna can perhaps best be described, following Blackhurst, as examples of 'the frontier man who lived simultaneously in both worlds' (2004: 60). Much rather than seeing these Late Antique Berber principalities in the Atlas mountains and the Saharan pre-desert as the antithesis of Roman life, we should see the inherent cultural ambiguity that their rulers expressed. As such, these principalities were 'dual-states', composed both of Romans and Berbers, with a political core in the intermediate zone between Sahara and Tell (Rushworth 2004: 77-98).

Conant (2012: 252) writes that 'one gets the sense from Corippus that there were in fact two Africas'. Clearly, then, the dichotomy between Sahara and Tell goes back to ancient discourse itself. Corippus and Procopius relied on this ideological superstructure to justify Emperor Justinian's wars of 'reconquest'. Scholars have often remarked how Justinianic ideology delegitimised the western successor-kingdoms, such as the Vandal kingdom in Africa, transforming them into lost provinces to be reconquered (Amory 1997: 10). The Berber kingdoms, often forgotten in discussions on Justinian's bellicose ideology, underwent the same treatment after Belisarius' victory over the Vandals. Thus, in his law code, Justinian declares both Vandals and Moors to have been invaders (invasionem vvandalorum et maurorum) (Codex Justinianus 1.27.2.4). This rhetoric is also found in a fascinating sixth-century inscription from the town of Cululis at the foot of the Aurès mountains, close to territories of Berber principalities, which praises the Byzantine armies for saving the town: 'Finally you [Cululis] have been delivered from the fear of the Moors' (AE 1996: 1704).

What may have led to the break between Justinian and the African Berbers following centuries of cooperation and co-option? Justinian's regime was firmly based in the Eastern Mediterranean, and thus lacked knowledge about local power networks and relations. The dichotomy between Tell and Sahara, then, was not only an ideological construct but also an epiphenomenon of the specific historical conditions of the sixth century. Here we can join text and archaeology: the decline in surveyed sites roughly coincides with Justinian's wars. Following the classic thesis put forward by Y. Modéran, we may conclude that the destructive wars of reconquest that Justinian waged not only destroyed the economy but also drove a wedge between Roman and Berber, where formerly this divide had not been so pronounced (Modéran 2003).

## 5. Conclusion

This paper began with the question whether Scott's theory on the dialectic between state space and anarchist shatter zones could hold true for Late Antique North Africa. On the basis of theoretical models of connectivity, it has here been argued that the Roman Empire, in some sense, formed a Mediterranean state space, with the mare nostre having the same function as that of the lowland plains in Southeast Asia. Yet, when zooming in on North Africa and turning to empirical evidence, a much more complicated and nuanced picture emerges of interlocking micro-ecologies and ways of life. Survey archaeology has shown the entanglement of these various micro-ecological zones in the form of a productive and fundamentally transformed landscape in Late Antiquity, even in environmentally marginal areas. Finally, written texts show that while this idea of a dichotomy between sown and desert is as old as antiquity itself, interaction coexisted with exclusion. Berber chiefs like Firmus, Sammac and Masties could straddle both Roman and 'native' worlds. Only with Justinian's wars of reconquest did a more narrow, exclusive definition of what it meant to be Roman emerge to enforce a strict dichotomy between Roman and Berber. Where the situation had first been ambiguous, for various peoples throughout the former imperial West including the Berbers, they were now firmly categorised as barbarian.

While the reach of the Roman state was indeed impeded by mountain and desert, the question is whether the latter can truly be seen as a shatter zone. Between the fourth and the sixth centuries, it instead looks like Berber chiefs started implementing their own ministates, often framed specifically in Roman framework of state power, using terms like rex and dux. The Romans, in their turn, needed middlemen like Firmus or Sammac to govern the difficult terrain of the North African interior. In that sense, the physical geography did check the power of the lowland states of the Romans and Vandals. But this does not make an anarchist zone. While pastoralism could be used as an economic subsistence model to distance oneself from the state, in fact, we have seen the spread of irrigated agriculture in even the more remote areas in this period, not the dispersed agriculture of Scott's model. Similarly, while illiteracy remained the norm, it may be questioned who the audience was for the inscriptions put up by men like Masuna and Masties. The epigraphy is corroborated by the archaeology of peripheral areas such as Tripolitania and Byzacena. Surely, hilltop castles and the fortified gsur hardly fit into the picture of an acephalous society.

Thus, if Scott's thesis can explain why the Romans had difficulty controlling the tribes of the Atlas Mountains and the Saharan (pre-)desert, this does not make it automatically a zone without a state. On the other hand, Scott's model is correct on another point: the worlds of mountains and the Sahara were not some primordial left-over waiting to be civilised by the Romans. To truly advance our understanding of non-state spaces, there is much room for the development of an anarchist archaeology, although progress is being made (Borck and Sanger 2017: 10-11). For Roman North Africa, more archaeological attention for the hinterlands and the limes, instead of the Mediterranean Tell, could help advance our knowledge of the unique sub-Roman, Berber states from the fourth to seventh centuries.

To conclude, I have tried to show the value of approaching the relationship between humans and environment from multiple perspectives. On the one hand, this paper has described the influence of physical geography in the settlement choices of ordinary peoples, and its influence on a much larger level in the formation of state space. At the same time, the mental modes of conceiving space, found in the written texts, were just as important as the physical manifestations of space. Explicitly through linking barbarism and marginal terrain, Roman ideology created the dichotomy between desert and sown which marginalised the Berber populations more than landscapes ever had.

## References

### *Primary Sources*

AE = l'Année Épigraphique.

Ammianus Marcellinus, J.C. Rolfe (ed) 1939. *History, Volume III: Books 27-31. Excerpta Valesiania*, Cambridge, M.A.: Harvard University Press.

CIL = *Corpus Inscriptionum Latinarum*.

Codex Justinianus, S.P. Scott (ed) 1932. *The Civil Law*, Cincinnati: The Central Trust Company.

Corippus, G.W. Shea (ed) 1998. *The Iohannis or De bellis Libycis of Flavius Fresconius Corippus*, Lewiston: The Edwin Miller Press.

Ibn Khaldun, Franz Rosenthal (ed) 1958. *The Muqaddimah. An Introduction to History* vol. 1, Princeton University Press, London.

ILS = H. Dessau, 1892-1916. *Inscriptiones Latinae Selectae*, Berlin: Weidmannsche Buchhandlung.

Procopius, H.W. Dewing (ed) 1916. *History of the Wars*, Volume II: Books 3-4 (Vandalic War), Cambridge, M.A.: Harvard University Press.

### *Secondary Sources*

Alcock, S. 1996. *Graecia Capta: The Landscape of Roman Greece*, Cambridge: Cambridge University Press.

Amin, S. 1970. *The Maghreb in the Modern World: Algeria, Tunisia, Morocco*, Baltimore: Penguin African Library.

Amory, P. 1997. *People and Identity in Ostrogothic Italy*, Cambridge: Cambridge University Press, 489-554.

Barker, G., D. Gilbertson, J. Barri and D. Mattingly 1996. *Farming the Desert. The UNESCO Libyan Valleys Archaeological Survey*, Tripoli: UNESCO Publishing/ Department of Antiquities (Tripoli)/Society for Libyan Studies.

Birot, P. and J. Dresch 1953. *La Méditerranée et le Moyen-Orient: tome premier, la Méditerranée occidentale*, Paris: Presses Universitaires de France.

Borck, L. and M.C. Sanger 2017. An Introduction to Anarchism in Archaeology, *The SAA Archaeological Record* 17.1.

Blackhurst, A. 2004. The House of Nubel: Rebels or Players? In: A.H. Merril (ed), *Vandals, Romans and Berbers. New Perpsectives on Late Antique North Africa*, London and New York: Routledge, 59-75.

Braudel, F. 1949. *The Mediterranean and the Mediterranean World in the Age of Philip II*, Berkeley: Harper and Row, transl. Siân Reynolds.

Brent, S. 1986. Autonomy and Tribute: mountain and plain Mauretania Tingitana, republished. In: Brent D. Shaw (ed) 1995., *Rulers, Nomads, and Christians in Roman North Africa*, Aldershot: Routledge, 66-89.

Brett, M. and E. Fentress 1996. *The Berbers*, Oxford: Blackwell Publishers.

Brown, P. 1967 (2000 reprint). *Augustine of Hippo: A Biography*, Berkeley and Los Angeles: University of California Press.

Brown, P. 1971 (2013 reprint). *The World of Late Antiquity*, Thames and Hudson LTD, London.

Brown, P. 2012. *Through the Eye of a Needle. Wealth, The Fall of Rome, and the Making of Christianity in the West, 350-550 AD*, Princeton: Princeton University Press.

Cameron, A. 1985. *Procopius and the Sixth Century*, Berkeley and Los Angeles: University of California Press.

Carcopino, J. 1944. Un "empereur" maure inconnu d'après une inscription latine récemment découverte dans l'Aurès, *Revue des Études Anciennes* 46.1-2, 94-120.

Conant, J. 2012. *Staying Roman: Conquest and Identity in Africa and the Mediterranean, 439-700*, Cambridge: Cambridge University Press.

Courtois, C. 1995. *Les Vandales et l'Afrique*, Paris: Arts and Métiers.

Despois, J. 1964. *L'Afrique du Nord*, Paris: Presses Universitaires de France.

Dey, H.W. 2014. *The Afterlife of the Roman City: Architecture and Ceremony in Late Antiquity and the Early Middle Ages*, Cambridge: Cambridge University Press.

De Vos, M. 2013. The Rural Landscape of Thugga: Farms, Presses, Mills and Transport. In: A. Bowman and A. Wilson (eds), *The Roman Agricultural Economy: Organisation, Investment and Production,* Oxford: Oxford University Press, 144-210.

Dossey, L. 2010. *Peasant and Empire in Christian North Africa*, Berkeley: University of California Press.

Drijvers, J.W. 2007. Ammianus on the Revolt of Firmus. In: J. den Boeft et al. (eds), *Ammianus after Julian. The Reign of Valentinian and Valens in Books 26-31 of the Res Gestae*, Leiden and Boston: Brill, 129-155.

Dyson, S.L. 2003. *The Roman Countryside*, Bloomsbury, London.

Fabrizi, V. 2015. Hannibal's March and Roman Imperial Space in Livy, Ab Urbe Condita, Book 21, *Philologus* 159.1, 118-155. https://doi.org/10.1515/phil-2015-0007

Fentress, E. 2006. Romanising the Berbers, *Past & Present* 190, 3-33.

Fentress, E. 2013. Diana Veteranorum and the Dynamics of an Inland Economy, *Late Antique Archaeology* 10.1, 315-342.

Freeman, P.W.M. 1997. Mommsen through to Haverfield: the origins of Romanization studies. In: D.J. Mattingly (ed), *Dialogues in Roman imperialism: power, discourse, and discrepant experience in the Roman Empire (Journal of Roman archaeology. Supplementary series 23)*, Portsmouth, R.I.: JRA, 27-50.

Gellner, E. 1969. *Saints of the Atlas*, Chicago: Weidenfeld & Nicolson.

Greatrex, G. 2014. Perceptions of Procopius in recent scholarship, *Histos*, 76-121.

Gsell, S. 1911. *Atlas Archéologique de l'Algérie*, Alger: Agence nationale d'archéologie et de protection des sites et monuments historiques.

Hingley, R. 2005. *Globalizing Roman Culture. Unity, Diversity and Empire*, London and New York: Routledge.

Hitchner, B. 1988. The Kasserine Archaeological Survey, 1982-1986, *Antiquités Africaines* 24, 7-41.

Hitchner, B. 1990. The Kasserine Archaeological Survey, 1987, *Antiquités Africaines* 26, 231-259.

Horden, P. and N. Purcell 2005. *The Corrupting Sea: A Study of the Mediterranean*, Oxford: John Wiley and Sons Ltd.

Laurence, R. 1991. *The Roads of Roman Italy: Mobility and Cultural Change*, London and New York: Routledge.

Lawless, R.I. 1972. The Concept of Tell and Sahara in Maghreb. A Reappraisal, *Transactions of the Institute of British Geographers* 57, 125-137.

Leone A. and D.J. Mattingly 2004. Vandal, Byzantine and Arab Rural Landscapes in North Africa. In: N. Christie (ed), *Landscapes of Change: Rural Evolutions in Late Antiquity and the Early Middle Ages*, Aldershot: Routledge, 135-161.

Leveau, P. 1977. L'Opposition de la montagne et de la plaine dans l'historiographie, *Annales de Géographie* 474, 201-205.

Lieberman, V. 2010. A zone of refuge in Southeast Asia? Reconceptualizing interior spaces, *Journal of Global History* 5.2, 333-346. https://doi.org/10.1017/S1740022810000112

Mattingly, D.J. 1989. Olive Cultivation and the Albertini Tablets, *l'Africa romana* 6, 403-415.

Mattingly, D.J. 1995 (reprint 2005). *Tripolitania*, Routledge, London.

Mattingly, D.J. 1996. Explanations: People as Agency. In: G. Barker, D. Gilbertson, J. Barri and D. Mattingly (eds), *Farming the Desert. The UNESCO Libyan Valleys Archaeological Survey.* Tripoli: UNESCO Publishing/Department of Antiquities (Tripoli)/Society for Libyan Studies.

Mattingly, D.J. 2011. Calculating Plough-Zone Demographics. In: A. Bowman and A. Wilson (eds), *Settlement, Urbanization, and Population*, Oxford: Oxford University Press, 76-91.

Mattingly, D.J. and J. Dore 1996. Romano-Libyan settlement: typology and chronology. In: G.Barker, D. Gilbertson, J. Barri and D. Mattingly (eds), *Farming the Desert. The UNESCO Libyan Valleys Archaeological Survey*, Tripoli: UNESCO Publishing/Department of Antiquities (Tripoli)/Society for Libyan Studies, 111-158.

Mattingly, D.J. and C. Flower 1996. Romano-Libyan Settlement: Site Distributions and Trends, In: G. Barker, D. Gilbertson, J. Barri and D. Mattingly (eds), *Farming the Desert. The UNESCO Libyan Valleys Archaeological Survey*, Tripoli: UNESCO Pub-

lishing/Department of Antiquities (Tripoli)/Society for Libyan Studies, 158-190.
Modéran, Y. 2003. *Les Maures et l'Afrique Romaine (IVe-VIIe siècle)*, Rome: Publications de l'École française de Rome.
Moreland, J. 2001. *Archaeology and Text* (Duckworth Debates in Archaeology), Bristol Classical Press, London.
Noreña, *C.F.* 2015. Urban Systems in the Han and Roman Empires: State Power and Social Control. In: W. Scheidel (ed), *State Power in Ancient China and Rome*, Oxford: Oxford University Press, 181-203.
Rushworth, A. 2004. From Arzuges to Rustamids: State Formation and Regional identity in the Pre Saharan Zone'. In: A.H. Merrils (ed), *Vandals, Romans and Berbers: New Perspectives on Late Antique North Africa*, Aldershot: Routledge, 77-98.
Scheidel, W. 2014. The shape of the Roman world: modelling imperial connectivity, *Journal of Roman Archaeology* 27, 7-32.
Scott, J.C. 2009. *Art of Not Being Governed: An Anarchist History of Upland Southeast Asia*, New Haven: Yale University Press.
Shea, G.W. 1998. Introduction. In: G.W. Shea (ed), *The Iohannis or De Bellis Libycis of Flavius Cresconius Corippus*, New York: Edwin Mellen Pr.
Sherwin-White, A.N. 1944. Geographical Factors in Roman Algeria, *The Journal of Roman Studies* 34.1-2, 1-10.
Van Dommelen, P. 1998. *On colonial grounds: A comparative study of colonialism and rural settlement in the first millenium BC west central Sardinia*, Dissertation: Leiden University.
Wickham, C. 2005. *Framing the Early Middle Ages: Europe and the Mediterranean 400-800*, Oxford: Oxford University Press.
Woolf, G. 2016. Moving Peoples in the Early Roman Empire. In: Elio Lo Cascio and L.E. Tacoma (eds), *The Impact of Mobility and Migration in the Roman Empire. Proceedings of the Twelfth Workshop of the International Network Impact of Empire*, Leiden: Brill, 25-41.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 167-176.

# Fiery forest management: an anthracological approach on the charred remains of medieval Noord-Brabant in Tilburg-Udenhout-Den Bogerd

Erica van Hees, Jorinde Pijnnaken-Vroeijenstijn and Marleen van Zon

*The limited presence of botanical remains at an archaeological excavation at Den Bogerd near Udenhout (Brabant, The Netherlands) required the systematic analysis of charcoal-rich contexts to better understand the arrangement of the cultural landscape and the history of the site. Species represented in the charcoal contexts indicate that a pioneer- or climax vegetation was present. Identification of wood species used in the charcoal pits help establish their function, like a hearth or kiln. The spatial distribution of these features and their relation to other excavated features dating from the Bronze, Iron, and Middle Ages contributes to their relative date. The results offer insights into the landscape developments and potential woodland exploitation.*

*All pit shaped contexts containing charcoal-rich layers were analyzed. The data set was used to establish a definition of actual pit kilns, aimed at charcoal production, on the basis of the archaeological record. The similarities and differences indicate that not all contexts can be interpreted as definite pit kilns. Moreover, a trend in the variation of pruning patterns leads to the phasing of certain contexts. These results are confirmed by the outcome of $^{14}$C dates. This method of phasing charcoal contexts on the basis of pruning patterns offers an approach to address changes in woodland management and the anthropogenic exploitation and alteration of the landscape.*

*Keywords: Charcoal, pit kilns, Anthracology, land-use history, forest management, metallurgy, medieval*

**Erica van Hees**
Archol
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
e.vanhees@archol.nl

**Jorinde Pijnnaken-Vroeijenstijn**
De Hollandsche Molen
Zeeburgerdijk 139
1095 AA Amsterdam
The Netherlands
dhm@molens.nl

**Marleen van Zon**
Onderzoeksgroep Archeologie
Celestijnenlaan 200e - bus 2409
3001 Leuven
Belgium
marleen.vanzon@kuleuven.be

## 1. Introduction

Recent excavations at the Den Bogerd development area in Tilburg-Udenhout (figure 1) brought to light several charcoal-rich pits which can be dated to the 13th century and are interpreted as the result of charcoal production and other forest management practices (Van Zon 2018).

The pits date to the earliest phase of land reclamation of the area. In the year 1232 the Duke of Brabant gave the forests of Tilburg-Udenhout to the abbey of Tongerloo for exploitation, later followed by the abbey of Kameren and several private individuals. In this paper we present the anthracological analysis (the analysis of charcoal remains) of these pits and place these in a broader context of 13th century forest management in Tilburg-Udenhout.

The site of Den Bogerd is located on aeolian soils that cover large parts of Noord-Brabant in a fluvio-periglacial landscape. The sandy sediments generally offer poor


Figure 1: Map of the research area (Van Zon, 2018: 10).

Figure 2: A pit kiln (above) and a charcoal kiln (below) for charcoal production in metallurgy (after Biringuccio 1540 in Smith and Gnudi 1990, 176 and 178).

conditions for the preservation of organic remains (Van Beurden, 2002, 287). Botanical remains are usually not retrieved from these contexts unless they are charred. The charcoal-rich pits from Den Bogerd therefore offer an exciting opportunity to investigate both the woody part of the surrounding vegetation and the activities which were carried out in this area.

Wood charcoal is found in archaeological contexts from all periods and the analysis and interpretation of these macro-remains is carried out to select tissue for carbon dating as well as to reconstruct past vegetation (Asouti and Austin 2005: 1). Besides dating, charcoal can contribute to palaeoecological and palaeoeconomical research (Scott and Damblon 2010: 7) and the charred wooden remains from archaeological sites can contribute to insights into both on and off-site activities (Groenewoudt 2007). In prehistoric contexts charcoal can be found as a product of activities such as cooking, tar extraction or hide smoking. Charcoal production with the aim of yielding charcoal itself, can relate to activities that require high energy fires like iron melting or smelting. The high temperatures needed for iron working cannot be obtained by burning 'fresh' (uncharred) wood and not all species will produce the quality of charcoal that is needed for this purpose.

The interaction between people and the natural resources influences the selection criteria for the harvest of timber (Théry-Parisot *et al*. 2010, 146) or firewood (Out 2009). The charred remains described in this paper similarly yield evidence for both the local vegetation and for human activities such as deforestation, pruning and charcoal production. In addition, as the pit features at Den Bogerd were thought to be pit kilns (figure 2), built for the production of charcoal, it was attempted to devise a standard method to recognize pit kilns for charcoal production in the field (Pijnnaken-Vroeijenstijn 2017).

## 2. Methodology

### *2.1 Anthracological methods*

Seventeen charcoal-rich features were excavated and documented at Den Bogerd. All features were drawn and described in the field, and from seven pits, seven five-litre soil samples were taken and four samples were collected by hand. These were processed at the archaeobotanical laboratory of the Faculty of Archaeology in Leiden, where one litre from each sample was sieved. After wet sieving the sediment samples, the residues were dried. A dating sample was taken from six contexts. These were preferably single year seeds or in the absence of these, outer rings of tree fragments. The remaining material was used for further anthracological analysis.

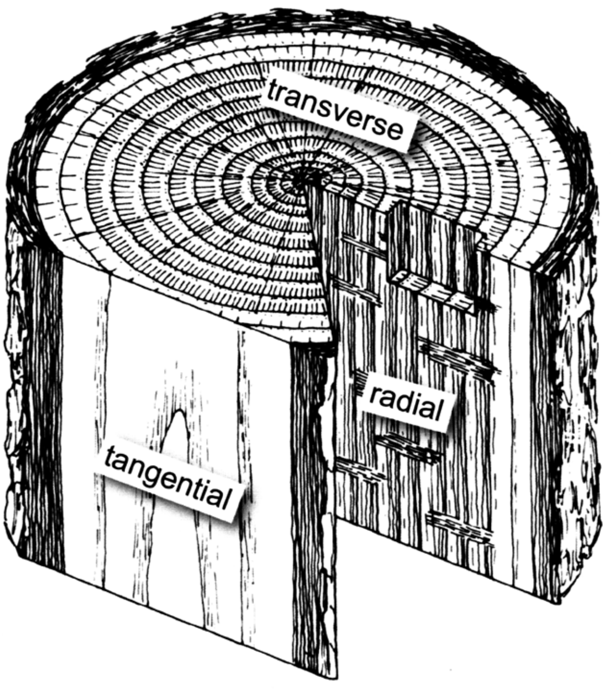




Figure 3a and b. Aspects of wood structure that were investigated for the charcoal fragments of Den Bogerd. a) Different planes after Gärtner en F.H. Schweingruber 2013: 19 and b) the curvature of year-rings after Marguerie and Hunot 2006: 1421.

From sieved residues the standard of 100 charcoal fragments (Asouti and Austin 2005: 7) were randomly selected, since different wood species fragment consistently, but in various sizes (Chabal 1992). Some of the samples have been analysed completely, because there were not enough to meet the minimum number of 100, or there were not that many more to be able to take all the present fragments in the sample into account. Both the residues and the individual fragments were weighed.

Identification and description of degradation features was conducted both macroscopically as well as microscopically (Leitz Ortholux, max. magnification 400x). The species or genus was identified by the wood anatomical features (figure 3a) which generally preserve well in charcoal. To create a freshly broken plane the fragments are split and the cell structures can be discerned under a microscope. A saturation curve was kept to track new species (Van Rijn 1995).

Apart from mechanical degradation, the fragmentation and biological and chemical degradation of the sampled charcoal fragments was examined. Biological degradation such as insect boreholes, that are created in a living tree, or the remains of charred insects or fungi that lived in dead wood may indicate pre- or post-depositional processes which influenced the material.

Chemical degradation, such as sintering, may occur during a change in oxygen levels, and leaves traces that can give the charcoal a 'glassy' appearance. A final observable degradation feature is the 'pop'-effect, a feature where cell walls expand and the cellular structure is disrupted, as if it had burst or 'popped'. The presence of fluids in wood can cause such an expansion when heated (McParland *et al.* 2010).

The presence of certain anatomical features like marrow, bark or cambium cells can help to differentiate tree parts like trunks, roots, branches, twigs, sapwood and heartwood. The cellular arrangement, like the weak, modest or strong curvature of the annual ring, can also be used to identify the position of the fragment in a tree, *e.g.* on the outside or more to the heart of a tree (figure 3b). Also, the number of annual rings was counted per fragment. These aspects of charcoal fragments helped to determine the felling season of some pieces. Other features that can be observed are for example cut- or saw marks or the structural fragility of the remains.

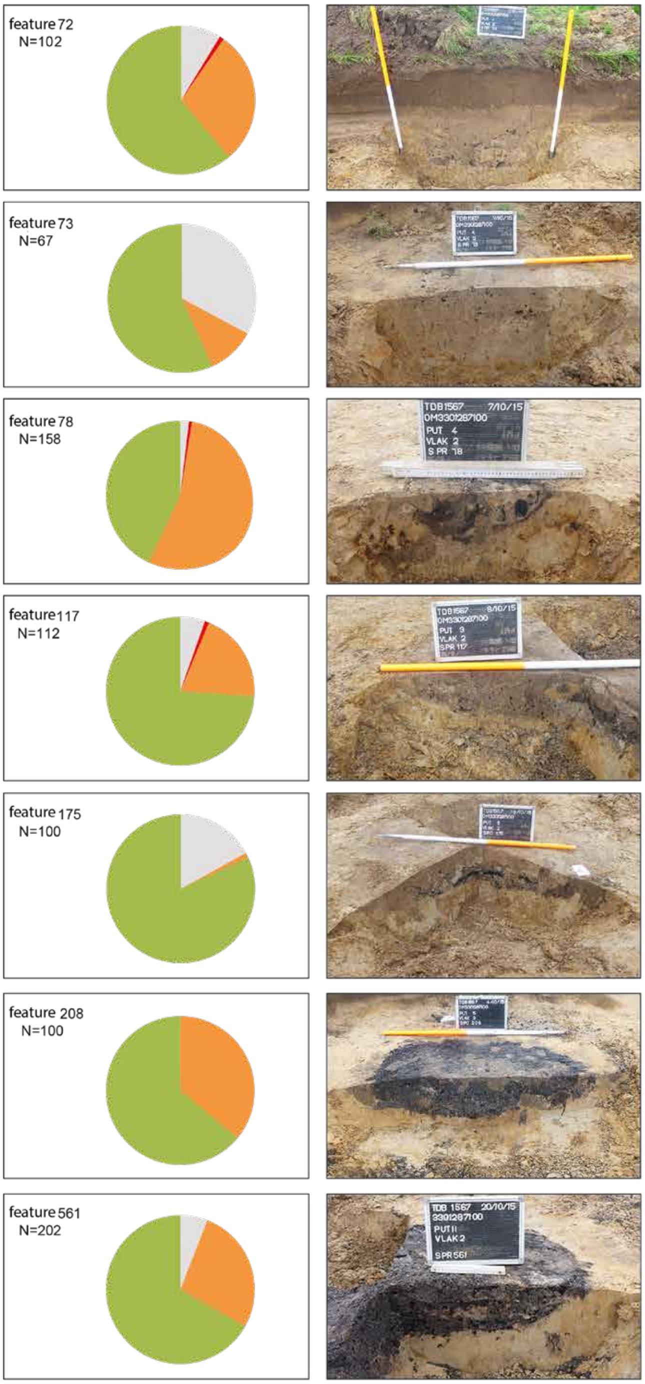
### *2.2 Determination of pit kilns*

Many different activities in the past may have yielded pits with charcoal remains. To ascertain whether a pit was used to produce charcoal, six characteristics were established that a feature must meet for positive identification (table 2; Pijnnaken-Vroeijenstijn 2017). The shape and dimensions of the feature should correspond to these standards. Pit kilns usually measure around 1 meter (Smith and Gnudi 1990: 179), unlike the kilns that are placed above ground, which measure between 4-6 and 8-10 metres (Boeren *et al.* 2010). The depth also plays a role in the interpretation of the feature; a cooking place with an open fire will generally leave a shallow layer of ash and is not placed in a dug pit. For the production of charcoal the wood is placed in a pit which is then covered to create a reducing atmosphere. Keeping the charcoal in a reducing atmosphere while it cools down yields the best results. The presence of a black charcoal layer is also a clue for oxygen reduced circumstances and should also be considered prerequisite for an interpretation as pit kiln.

Other features which can help identify a pit kiln relate to the charcoal discovered within. Different species produce charcoal of various qualities. Species like beech and oak generate charcoal with a high energy value that can reach temperatures needed for to melt or smelt metals. Other species, like alder, or fresh, undried wood have properties such as the production of smoke for the treatment of hides to conserve these (Van Zon 2018). A maximum of two taxa in the sample and the dominance of a taxon that is appropriate for charcoal production, are other features that are linked to (pit)kilns. Finally, chemical degradation of charcoal such as swelling and 'glassification' or 'blending' indicate the heating of fresh wood in reducing circumstances, and are therefore also suggested as another proxy for the use as pit kiln (Pijnnaken-Vroeijenstijn 2017).

## 3. Results

The measurements and dating results from the pit features from which samples were retrieved, are shown in table 1. The pits date between 1200-1400 AD, with most dating to the 13th century. As such, the pits may be contemporaneous to other medieval features discovered at Den Bogerd, such as ditches and a houseplan (Van Zon 2018). The dating evidence from the pits further indicates that they



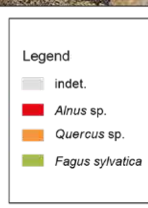




Figure 4: Proportion of species in features and charcoal-rich layers in the field. After Van Zon 2018: 116 and 117.

were used at different moments in time which may represent continual use of the area.

From eleven samples a total number of 841 fragments was analysed. In five samples (numbers 164, 165, 166, 167 and 181) the minimum number of 100 fragments was not reached. For feature 72 the samples were combined to reach the minimum number of 100 fragments. Samples from feature 73 only yielded 67 fragments in total.

The proportion of wood species in the analysed samples and the appearance of the features in the field are shown in Figure 4. In all samples, beech (*Fagus sylvatica*) is dominant over oak (*Quercus*), except in pit 78, where oak is dominant over beech. In feature 78, as well as in 72 and 117, a few alder (*Alnus*) fragments were found. None of the pits contain a single exclusive wood taxon.

Amongst the charcoal fragments only stem and branch wood were discerned, although some pieces had unclear features. In three samples (samples 180, 350 and 351) a total of twelve insect boreholes were observed. No fungal remains were found in any fragments. Chemical degradation, like swelling and glassy features, were present in all samples (table 2).

In all samples annual rings could be counted for most of the complete fragments. In a total of 27 fragments from five features (samples 166, 167, 180, 320, 392) the felling season could be established. In four features (sample numbers 166, 167, 180 and 320) this was fall/winter and in 392 both spring/summer as well as fall/winter were represented.

Finally, cut marks are present on two fragments from sample number 180 (figure 5).


Figure 5: Cutting or chopping mark (on the right side) of a charcoal fragment (180-1). A fresh breach on the radial plane is visible.

| Feature nr | Shape plan | Shape profile | Dimensions (m) | Depth (cm) | Sample nrs | Charcoal (fragments) | $^{14}$C-date |
|---|---|---|---|---|---|---|---|
| 72 | oval | square | 1.2 x 1 | 31 | 164MA | 55 | |
| | | | | | 166MHK | 47 | 166MHK: 1049-1257-cal. A.D. (95.4%; Poz-81853: 860 +/- 30 BP) |
| 73 | oval | square | 2.1 x 0.8 | 22 | 165MA | 45 | 165MA: 1217-1282 cal. A.D. (95.4%; Poz-81852: 770 +/- 30 BP) |
| | | | | | 167MHK | 22 | |
| 78 | oval | round | 0.5 x 0.4 | 21 | 180MA | 100 | 180MA: 1223-1291 cal. A.D. (95.4%; Poz-81855: 740 +/- 30 BP) |
| | | | | | 181MHK | 58 | |
| 117 | oval | round | 1.3 x 1 | 20 | 320MHK | 12 | 320MHK: 1292-1400 cal. A.D. (95.4%; Poz-81856: 620 +/- 30 BP) |
| | | | | | 321MA | 100 | |
| 208 | oval | round | 1.2 x 1 | 22 | 350MA | 100 | 350MHK: 1276-1392 cal. A.D. (95.4%; Poz-81857: 665 +/- 30 BP) |
| 561 | oval | round | 1.3 x 1 | 24 | 392MA | 100 | 392MHK: 1220-1285cal. A.D. ( 95.4%; Poz-81858: 755 +/- 30 BP) |

Table 1: Shape, dimension and $^{14}$C-dates of charcoal-rich features from which samples were taken. After Van Zon 2018.

| feature – sample number | shape and dimensions | black charcoal layer | maximum of two taxa | selection of suitable species | swelling features | 'glassification' | number positive | number negative |
|---|---|---|---|---|---|---|---|---|
| 72-164 | + | - | - | + | + | + | 4 | 2 |
| 72-166* | + | - | - | + | + | + | 4 | 2 |
| 73-165* | + | - | + | + | + | + | 5 | 1 |
| 73-167 | + | - | + | + | + | + | 5 | 1 |
| 78-180* | - | + | - | + | + | + | 4 | 2 |
| 78-181 | - | + | + | + | + | + | 5 | 1 |
| 117-320* | + | + | - | + | + | + | 5 | 1 |
| 117-321 | + | + | - | + | + | + | 5 | 1 |
| 208-350* | + | + | + | + | + | + | 6 | 6 |
| 175-351 | + | + | + | + | + | + | 6 | 6 |
| 561-392* | + | + | + | + | + | + | 6 | 6 |

Table 2: Score of features that indicate charcoal pit kilns. The asterisks indicate the samples that have been radiocarbon dated.

## 4. Discussion

The $^{14}$C dates of the charcoal indicates that the pits may have been contemporary with other features such as ditches and a houseplan. Generally, the pits are from the 13th century, and most indications of habitation are at least a century later. The dating of the pits corresponds to the exploitation of the area by the Tongerloo abbey, whereas the shift in annual ring distribution seemingly takes place after 1232 when the manorial rights were transferred. The chronological sequence of use of the pits indicates that the area was used continuously for a period of at least 100 years.

Comparing the dimensions and contents of the pits discovered during excavation to the signature characteristics of charcoal kilns suggests that this is a valid interpretation of their function. All pits adhere to at least four out of six characteristics and three of the pits score positively on all six. Interestingly, the two samples from feature 78 score differently on the number of taxa but given the small number of fragments which could be positively identified as other than beech or oak, this does not stand in the way of the present interpretation. It also indicates that the determinant of a maximum of two taxa per pit should not be taken too rigorously.

Although the choice of wood species for these pit kilns would likely lead to a high-end product, charcoal is a versatile fuel and it can be a domestic fuel supply as well as for industrial application. (Scott and Damblon 2010: 3). The aim of the charcoal production itself is hard to establish here. The features cannot be associated directly with residential structures which date centuries later. Their inhabitants relied on the exploitation of peat bogs (such as area ‘De Brand’) for fuel. The pits contain no other material remains, like slag, that hint at activities like iron melting or smelting.

The occurrence of cut- or chop marks and the high proportion of branch wood in most of the samples raised the question of whether we are dealing with copse wood or pruning waste. To find out if this is the case the annual rings were counted and plotted for the branch wood with the outer annual rings and most of the heartwood present, from the samples with a minimum number of 100 fragments. A shift in the pattern seems to be visible (figures 6-8), similar to the shift from medieval pruning cycles of 3-5 years to more contemporary cycles of 5 to 15 and 15 to 30 years according to Rackham (1990).

Sample number 351 contains only beech wood and is not $^{14}C$ dated. If it fits the trend, it would suggest that pit 175 is the oldest feature. Furthermore, amongst the beech branches there is an outlier with 80 counted annual rings. This wood is likely harvested from an unmanaged tree, since in managed wood the diameter increases relative to the number of annual rings (Out *et al.* 2013). To tighten the conclusions drawn from these results, measurements of the diameter as well as the mean vessel diameter could be taken. These measurements can also distinguish young branch wood, collected towards the end of the branch, from older branch wood, collected towards the base of the branch. Since these methods are still being developed, they were not applied yet in this research.

Although it cannot be concluded, based on outliers like the branch with 80 annual rings and

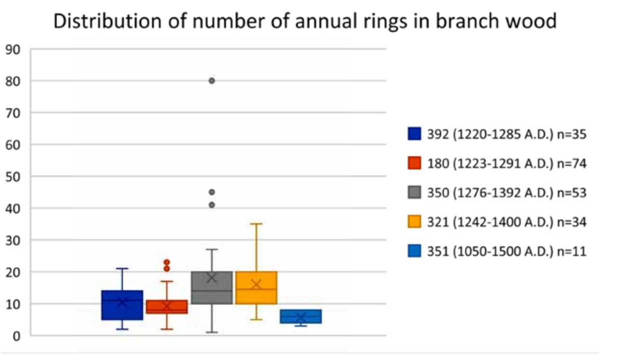



Figure 6: Distribution of annual rings in branch wood.

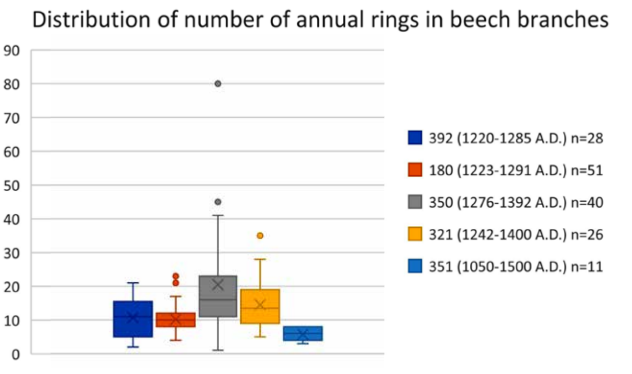



Figure 7: Distribution of annual rings in beech branches.

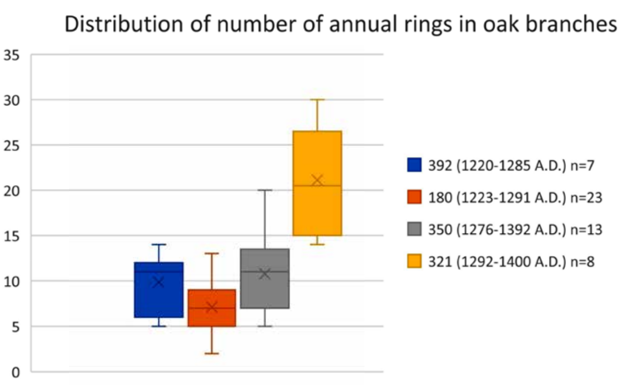



Figure 8: Distribution of annual rings in oak branches.

a relatively small diameter, that all of the branch wood originates from copse wood, a pruning trend seems to be present in the charcoal samples from Den Bogerd. The trend in the (dated) branch wood remains indicates a difference in management of the nearby woodlands or a shift in land reclamation of another part of the woods. Possibly, this was instigated by the transfer of manorial rights concerning the regional forests in 1232.

## 5. Conclusion

Although a $^{14}C$ date and some ceramic remains, found on the archaeological site of Tilburg-Udenhout-Den Bogerd, may indicate activities in the 10th to 12th centuries, the earliest abundant indications for habitation or use date from the 13th and 14th centuries (Van Zon 2018). For this period, we see various charcoal-rich pits that are likely to be labelled as pit kilns that are used for the production of charcoal. The determination of signature characteristics of charcoal kilns from archaeological contexts is presented as a method for the verification of this important feature at archaeological sites. It combines field observations of feature dimensions and macroscopic content with anthracological data. In particular, the presence of chemical degradation features in charcoal such as swelling and 'glassification' are suggested to aid in the identification of charcoal kilns.

The charcoal production can occur here as a by-product of land reclamation (figure 9) rather than the use of branches of possible copse wood to produce charcoal solely because of logistical reasons.

The ultimate purpose of the charcoal produced remains uncertain, even though charcoal research shows that specific species were selected (oak and beech) which result in high quality charcoal that can be used for various activities, one of them being metallurgy. There appears to be a noticeable shift in pruning cycles, which indicates a change in maintenance of the wood stock. The dataset is small but a methodological approach has potential to draw conclusions based on annual ring patterns. Changes in the way or regularity of wood management and land reclamation is reflected in changes in the landscape which influences antropogenic selection as well as the natural environment.

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The authors would like to mention the thesis of W. van den Berg, who attempted a methodological approach using GIS to identify pit kilns in a non-destructive manner for her Bachelor thesis at Saxion Hogeschool, Deventer, titled *Houtskoolkuilmeilers in Nederland. Een inventariserend onderzoek naar houtskoolkuilmeilers en hun landschappelijke kenmerken.*

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We would like to especially thank Professor Bakels for inspiring and motivating us to finish theses and publications by simply being Corrie. Her incisive setting up of the archaeobotanical laboratory at the

Figure 9: Original caption: 'Measuring the length and girth of a felled oak log; *branchwood will be used for fuel or charcoal'*. From: *The New Forest. Forestry commission guide*, 1969.

Faculty of Archaeology in Leiden during her long career led us to be able to perform research today in unforeseen areas of the field. With her relentless energy and inexhaustible knowledge, this academic 'mother' sparks ambition throughout our lives and careers and we are glad to profit from her presence and the interactions that follow from it.

## References

Asouti, E. and Ph. Austin 2005. Reconstructing woodland vegetation and its exploitation by past societies, based on the analysis and interpretation of archaeological wood charcoal macro-remains, *Environmental Archaeology* 10, 1-18.

Boeren, I., K. Vandekerkhove, D. Tys, K. Deforce, K. Haneca, and J. Bastiaens 2010. Relicten van houtskoolmeilers in het Zoerselbos, *Monumenten en Landschappen*, 29-6, 20-34.

Chabal, L. 1992. La representative paléo-écologique des charbons de bois archéologiques issus du bois de feu, *Bulletin de la société botanique de France* 139, 213-236.

Gärtner H. and F.H. Schweingruber 2013. *Microscopic preparation techniques for plant stem analysis*, Birmensdorf

Groenewoudt, B.J. 2007. Charcoal Burning and Landscape Dynamics in the Early Medieval Netherlands, *Artisanat Rural Dans Le Monde Médiéval* 6, 327-337.

Edlin H.L. (ed) 1969. *The New Forest. Forestry commission guide,* HMSO.

Marguerie, D. and J-Y. Hunot 2007. Charcoal analysis and dendrology: data from archaeological sites in North-western France, *Journal of Archaological Science* 34, 1417-1433.

McParland, L.C., M.E. Collinson, A.C. Scott, G. Campbell, G. and R. Veal 2010. Is vitrification in charcoal a result of high temperature burning wood? *Journal of Archaeological Science* 37, 2679-2687.

Pijnnaken-Vroeijenstijn, J.R. 2017. *De vonken gewoon. A fieldwork laboratory resarch of charcoal pits in Udenhout-Den Bogerd, Tilburg*, Leiden (unpublished MA thesis Leiden University).

Out, W.A. 2009. Firewood collection strategies at Dutch wetland sites in the process of Neolithisation, *The Holocene* 20, 191-204.

Out, W.A., C. Vermeeren and K. Hänninen 2013. Branch age and diameter: Useful criteria for recognising woodland management in the present and past? *Journal of Archaeological Science* 40 (11), 4083-4097.

Rackham, O. 1990. *Trees and woodland in the British landscape. The complete history of Britain's trees, woods and hedgerows*, New York.

Schweingruber, F.H. 1978. *Holzanatomie*, Birmensdorf.

Scott, A. and F. Damblon 2010. Charcoal recognition, taphonomy and uses in palaeoenvironmental analysis, *Palaeogeography, palaeoclimatology, palaeoecology* 291, 1-10.

Smith, C.S. and M.T. Gnudi 1990. *The pirotechnia of Vannoccio Biringuccio. The classic sicteenth-century treatise on metals and metallurgy*, Dover.

Théry-Parisot, I., L. Chabal and J. Chravzez 2010. Anthracology and taphonomy, from wood gathering to charcoal analysis. A review of the taphonomic processes modifying charcoal assemblages, in archaeological contexts, *Palaeogeography, palaeoclimatology, palaeoecology* 291, 142-153.

Van Beurden, L. 2002. Vegetatieontwikkeling en landgebruik vanaf het Laat-Mesolithicum tot in de Middeleeuwen in de omgeving van 's-Hertogenbosch. In: H. Fokkens and R. Jansen (eds), *2000 Jaar bewoningsdynamiek. Brons- en ijzertijdbewoning in het Maas-Demer-Scheldegebied,* Leiden: Faculty of Archaeology, Leiden University, 271-285.

Van Rijn, P. 1995. *Houtskool. Overzicht van mogelijkheden en methoden een veronachtzaamde materiaalgroep*, Biaxiaal 17, BIAX: Zaandam.

Van Zon, M. 2018. *Den Bogerd van neolithicum tot nu – Deel I. Definitieve onderzoeken en een inventaiserend onderzoek in plangebied Den Bogerd, Udenhout (gemeente Tilburg)*, Archol-rapport 312, Archol: Leiden.

M.V. Klinkenberg, R.M.R. van Oosten and C. van Driel-Murray (eds) 2020. *A Human Environment. Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels*, Leiden: Sidestone Press, pp. 177-196.

# Mysterious medieval manure pits: an indication of urban horticulture?

Roos van Oosten, Sander Aerts, Jantine Hos and Erica van Hees

*The central question of this article is whether medieval manure pits that have been uncovered by archaeologists may have functioned as hotbeds. We tackled this issue in three ways: 1) We surveyed archaeology reports of manure pits for information on archaeological appearance and information on plant and insect remains from the pits. 2) We built hotbeds at the living museum Archeon in which we cultivated chard, a type of spinach. 3) We chose three pits that had been designated as manure pits during field work to determine whether they could have been hotbeds. Applying our hotbed 'method' to manure pits in published reports to determine whether they were hotbeds was challenging because no one single manure pit met the basic requirements that it had been designated as such in the field and that both the top and bottom layers had been studied for fauna and insect remains. The few positive indicators we found in the manure pits we studied are promising and the hotbed hypothesis is worth testing further.*

*Keywords: Manure pits, hotbeds, horticulture, plant remains, insect remains, environmental archaeology*

**Roos van Oosten**
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden,
The Netherlands
r.m.r.van.oosten@arch.leidenuniv.nl

**Sander Aerts**
Museum of London Archaeology
Crofton Oak, unit 2
North Portway Close
NN3 8RD Northampton
United Kingdom
Sander.e.i.aerts@gmail.com

**Jantine Hos**
Ged. Burgwal 16-D
2512 BT The Hague
The Netherlands
hjspier@planet.nl

**Erica van Hees**
Archol
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
e.vanhees@archol.nl

## 1. Introduction

Hundreds of pits that archaeologists have designated as manure pits have been uncovered in Dutch urban excavations. Dating from the 13th to the 15th century, the traditional explanation is that they were used to store manure for agricultural use. However, this explanation raises some questions. Digging large manure pits requires considerably more effort than piling manure in dung heaps, and when archaeologists uncover manure in these pits, it is obvious that the manure remained in the pits and had not been used as fertilizer.

Historical texts, including the 14th-century manuscript *Ruralia commoda*, describe the horticultural method of hotbeds, or heated vegetable beds. Horse manure was spread on the floor of a pit, and once fermentation had started, a layer of soil was spread on the steaming manure, ready to be planted with cucumber, melon and lettuce. The heat produced by the manure ensured that vegetables could be harvested considerably earlier than if conventional gardening methods were used.

The central question in this article is whether the pits designated by archaeologists as manure pits were in actuality hotbeds. We tackled this issue in three ways: We surveyed archaeology reports of manure pits for information on plant and insect remains from the pits, we set up a hotbed experiment at the living museum Archeon and cultivated chard, a kind of spinach and finally, we chose three pits that had been designated as manure pits during field work, to study in more detail.

## 2. Hallmarks of archaeological manure pits

Manure pits are common in urban archaeology in the Netherlands: it seems that every excavation that reaches 14th-century layers encounters some. More than 100 manure pits have been uncovered in the town of Rotterdam as a result of the many large archaeological excavations in recent years at construction sites. The sites Rotterdam-de Hofdame (Hallewas and Guiran 2011) and Rotterdam-Laurenshof (Ploegaert 2009) revealed more than 60 manure pits. Similar to other towns, these manure pits have not received much attention: the dimensions of only seven are provided in the reports and no attempt has been made to explain their presence. Fortunately, in a more recent excavation at Rotterdam-Markthal, the dimensions of all 55 pits were provided. These results, together with those from the excavations at Kampen-Myosotis (N=84) and Gouda-Bolwerk (N=50), reveal that manure pits were mostly quadrangular in shape. Only a minority were circular (5%). The most common dimensions at both the Kampen-Myosotis excavation and the Rotterdam excavation were 1.2 m x 1.8-1.9 m. Most of the pits were approximately 30-40 cm deep. The results are summarized in table 1.

While the reports from these three sites provide elaborate details about the pits, their stratigraphy is not discussed, nor are section drawings published. We are better informed about their dates. Manure pits at Kampen-Myosotis are mostly, though not exclusively, 14th century, just as in Gouda (mainly 1300-1350). At Rotterdam-Markthal, most of the pits date a little later, from the 15th century. The results from these three sites correspond with other excavations where there are a more limited number of manure pits, such as Leiden-Pelikaanstraat (10 manure pits; Van Oosten 2007) and Alkmaar-Wortelsteeg (10 manure pits; Esser and Gehasse 1997: 77-80).

In sum, manure pits were large and quadrangular, common in the medieval period (14th-15th century), but their stratigraphy and function have rarely been explored. Another hallmark is that they were situated within or near town walls. However, it is not possible to call them a typical urban phenomena. In contrast to cesspits, which are found in densely populated areas, manure pits mostly, but not always, preceded urban development of an area, that is, when areas became densely populated, manure pits tended to disappear.

### *3.1 Traditional explanations for manure pits*

The reports on Rotterdam-Markthal (Ploegaert 2013: 127) and Gouda-Bolwerk (Ostkamp and Dijkstra 2010: 329) designate some manure pits as compost pits. As such, manure would have been collected in pits to mature, then dug out and used as fertilizer. While the authors of these reports do not reference any litera-

| **Kampen-Myosotis (N=84), including 2 circular manure pits. Data from Klomp *et al.* 2017.** | | | | | |
|---|---|---|---|---|---|
| | **N total** | **Smallest** | **Largest** | **Median** | **Average** |
| Length | 69 | 0.7 | 6.5 | 1.8 | 3.9 |
| Width | 65 | 0.4 | 5.1 | 1.2 | 1.9 |
| Depth | 30 | 0.1 | 1.3 | 0.4 | 0.5 |
| **Rotterdam-Markthal (N=55), including 4 circular manure pits. Data from Ploegaert 2013.** | | | | | |
| | **N total** | **Smallest** | **Largest** | **Median** | **Average** |
| Length | 49 | 0.5 | 6.5 | 1.9 | 2.2 |
| Width | 49 | 0.2 | 3.0 | 1.2 | 1.1 |
| Depth | 1 (0.8) | - | - | - | - |
| **Gouda-Bolwerk (N=50), including 3 circular/oval pits. Data from Dijksta *et al.* 2010.** | | | | | |
| | **N total** | **Smallest** | **Largest** | **Median** | **Average** |
| Length | - | - | - | - | - |
| Width | - | - | - | - | - |
| Depth | 26 | 0.1 | 0.8 | 0.3 | 0.3 |

Table 1: Dimensions (in meters) of manure pits at Kampen-Myosotis, Rotterdam-Markthal and Gouda-Bolwerk. Note that the dimensions of not all pits are known, hence the totals vary per variable (length, width, depth).

ture, this idea seems to have stemmed from an article by Clevis (1999) in which he discusses 15th-century manure pits at a location, up until 1480, outside the town walls of Zwolle called the Eiland, an area without any farmyards or stables. The pits were dug in sandy soil, were quadrangular (dimensions unknown), and only a thin layer of manure was found on the bottoms and sides (Clevis 1999: 70). Clevis (1999: 71) assumed that the contents of cesspits had been dumped into the pits to decompose. However, what Clevis failed to realize was that when cesspits were emptied, they would have contained human excrement, not animal manure. This contradiction went unnoticed by van Oosten (2007) as well. Following Clevis, she identified a series of manure pits on the outskirts of 14th-century Leiden (site: Leiden-Pelikaanstraat) that also contained a thin layer of manure on the bottom and sides as compost, or fertilizer, pits.

It is worth asking whether manure pits like the ones in Zwolle-Eiland and Leiden-Pelikaanstraat were indeed dug for composting manure. If they were, why were the pits never re-opened and the composed manure used on the fields? This question also came up for Clevis, who wondered, 'could the pits not be found?' (Clevis 1999: 73). We believe that such pits would have been perfectly findable as any pit filled with manure would have left depressions in the surface soil as the manure matured. As our hotbed experiment shows, manure shrinks considerably as it ages. In our experiment, it shrunk by roughly 50% in eight months. The effect of the shrinking is visible in the cross-section of a manure pit in figure 3.

In addition to the matter of manure remaining in the pits, another reservation that manure pits were for composting is why medieval farmers would have exerted so much effort to dig a hole to store manure. Digging out two cubic meters of soil for a hotbed in our experiment and filling it with stable manure from a nearby manure heap (23 wheelbarrows full) took several hours (figure 4). For medieval farmers, making a dung heap on the farmyard near the stables would definitely have saved time and energy over digging a pit. Was digging a hole worth the effort to realize better quality manure or a faster decomposition process?

A second explanation for manure pits, which is given in the archaeological report of Gouda-Bolwerk, is that manure pits were rubbish pits, or in other words, landfills or middens (Ostkamp and Dijkstra 2010: 329). This interpretation assumes that manure in medieval society was considered waste rather than fertilizer. While nowadays modern agriculture in the Netherlands is notorious for its manure overload (Levitt 2018), this was not necessarily the case in medieval times. Especially in sandy soil, like that of the Eiland in Zwolle, manure was needed to make the soil more fertile. Designating the pits as landfills appears to be driven by the fact that artefacts were occasionally (Rotterdam-Markthal) or frequently (Kampen-Myosotis) recovered from manure pits. From two of the three sites listed in table 1, the nature and number of finds has been systematically published. In Rotterdam-Markthal, half of the manure pits (28 out of 55) contained artefacts, while at Kampen virtually all manure pits (82 out of 84) contained finds. However, it is too premature to conclude therefore that *all* manure pits in Kampen functioned as rubbish pits. There were more manure pits containing a single sherd than manure pits containing a significant number of artefacts. In addition, it is unclear whether the finds came from the bottom (primary) manure layer, meaning that the artefacts and the manure were dumped into the pit in one instance, or whether the artefacts came from the top layer and were dumped in after the manure had shrunk. Making this distinction is pivotal to understanding the function of manure pits. In our archaeological experiment, it was not necessary to fill the impression in the soil left by shrinking manure, but, in the past, keeping the pit full (with rubbish) was important to prevent people or animals from falling in.

A third possible explanation for large and deep manure pits is that they were part of a deep litter system. In such a system, a deep pit is situated below a stall and fresh dung, together with a spreading of straw, yields a layered deposit. This would have supplied heat for the animals in the stall in the winter and compost for the fields in the spring. A prerequisite for a manure pit being used in this way is that the manure pit must be beneath a building, most often a stall. A rectangular pit (~4 m x 2.5 m x >1 m deep) found in 's-Hertogenbosch could be identified as such (Van Haaster 1997: 143-146).

### *3.2 Alternative explanations: hotbeds*

We have seen that the current explanations for manure pits are not fully adequate. An alternative explanation is that manure pits were hotbeds (Van Oosten 2015: 299-303). We now know hotbeds as a type of greenhouse (Van den Muizenberg 1980: 11), described in an online dictionary as 'a bottomless, boxlike, usually glass-covered structure and the bed of earth it covers, heated typically by fermenting manure or electrical cables, for growing plants out of season'. While in the 20th century, hotbeds and cold frames were grouped together, they are not necessarily the same thing. Cold frames were wooden frames (box-like wooden frames with glass windows) that were placed on top of a bed to protect the plants from the cold and wind (Groen 1670: 30). Hotbeds do not need to have frames or glass windows, but essential to a hotbed is that a considerable quantity of manure is needed to provide insulation and heat.

According to gardening literature, using a hotbed has two advantages:

1) it allows early sowing of crops resulting in an earlier harvest and 2) it makes possible the growing of melons, which only germinate at a temperature of 22-25°C, and crops like cucumbers and pumpkins that require a greenhouse to be cultivated in a cold climate such as that of the Netherlands.

Before we discuss the advantages of hotbeds as revealed by our hotbed experiment, some remarks on the early modern use of hotbeds. Hotbeds were used extensively in the Netherlands until the second half of the 20th century. In 1904, two thirds of Dutch horticulture consisted of cold frames and hotbeds and only one third of glass houses. It was only in 1970 that glass houses made up more than 95% (Van den Muizenberg 1980: 286).

Frames with glass windows were used in the 17th century as the gardeners' handbook for Dutch horticulturists attests (Groen 1670: 30, 40, figures. 1b and c). Covering crops in wintertime with straw (figure 1a) was a much older (and cheaper) method already being used in the early 14th century, described in the well-known *Ruralia Commoda* (De Crescenzi 1305 cited in: Van den Muizenberg 1980: 28).

The hotbed method is described in several historical texts on horticulture, mostly dating from the 17th century and later (Groen 1670: 40; Chomel 1725: n. p., entry 'hotbeds'; Munting 1696: 524-525; Miller 1745: 143-145; Enklaar 1859: 21-22; De Beucker 1869: 5-6). The medieval *Ruralia Commoda*, written by Petrus Crescentiis from Bologna in 1305 and first printed in 1471, also describes hotbeds. Crescentiis explicitly noted that 'pumpkins have to be planted in March in fine soil on warm manure, direct from the stable' (Crescentiis cited in: Van den Muizenberg 1980: 28).

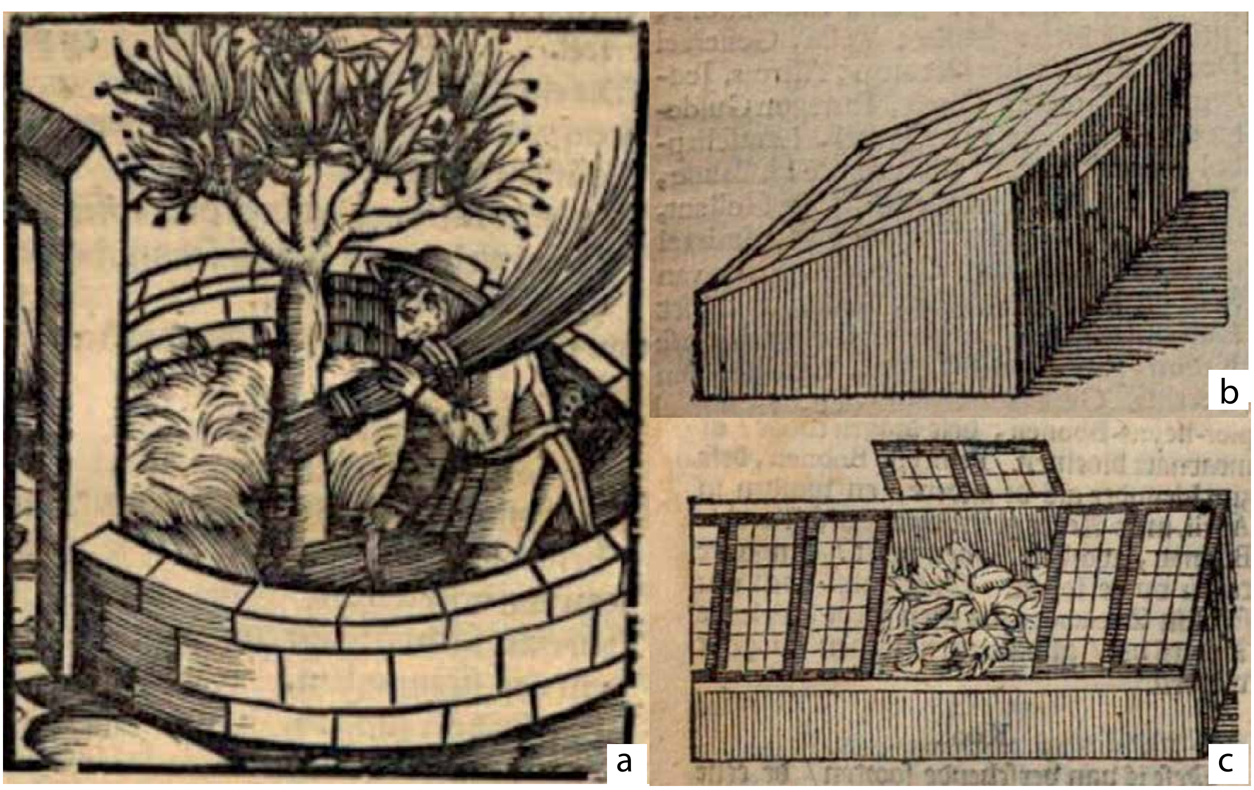


Figure 1a: Covering a bed with straw (Crescentiis 1518); b and c: frames with glass (Groen 1670: 30, 40).

More elaborate manuals on the 'curious and useful phenomena of hotbeds' (Chomel 1725, entry 'hotbed') were published much later and included in Chomel's *Dictionnaire œconomiquet*. This dictionary was published originally in French in 1709 and was translated into English (1725) and Dutch (first print 1743, second print 1778). He prescribed that hotbeds were to be more than three feet wide (~1.20 m) 'answerable to the size of your frames' and seeds should be sown in a 'layer of five or six inches [of] earth [about 13 cm] to prevent the extreme heat of the dung from spoiling your crop' (Chomel 1725). The historical texts may vary in the details, but they all insist that horse manure 'such as taken fresh out of the stables or stalls' (Chomel 1725) is the best manure to be used.

In addition to hotbeds, Chomel also mentions tan beds, or tan frames, in the Dutch edition (Chomel 1778, entry 'run'). Tan is the crushed bark of oaks (Dutch: 'run' or 'eek') and was used in tanneries to process black leather, i.e., leather made from the hides of cattle and horses, rather than white leather, made from sheep or goat hide (Ervynck 2018: 75). Tan was even better than horse manure, according to Chomel (1778: 3126), as it produced a more continuous heat, making it possible to cultivate coffee beans (401) and pineapples (1138).

## 4. Identifying hotbeds: a flowchart

The fact that hotbeds are described in historical texts on horticulture known in the Low Countries and in medieval texts written in Mediterranean Europe, indicates that the hotbed hypothesis should be seriously considered. To do this as systematically as possible, we identified four conditions that must be

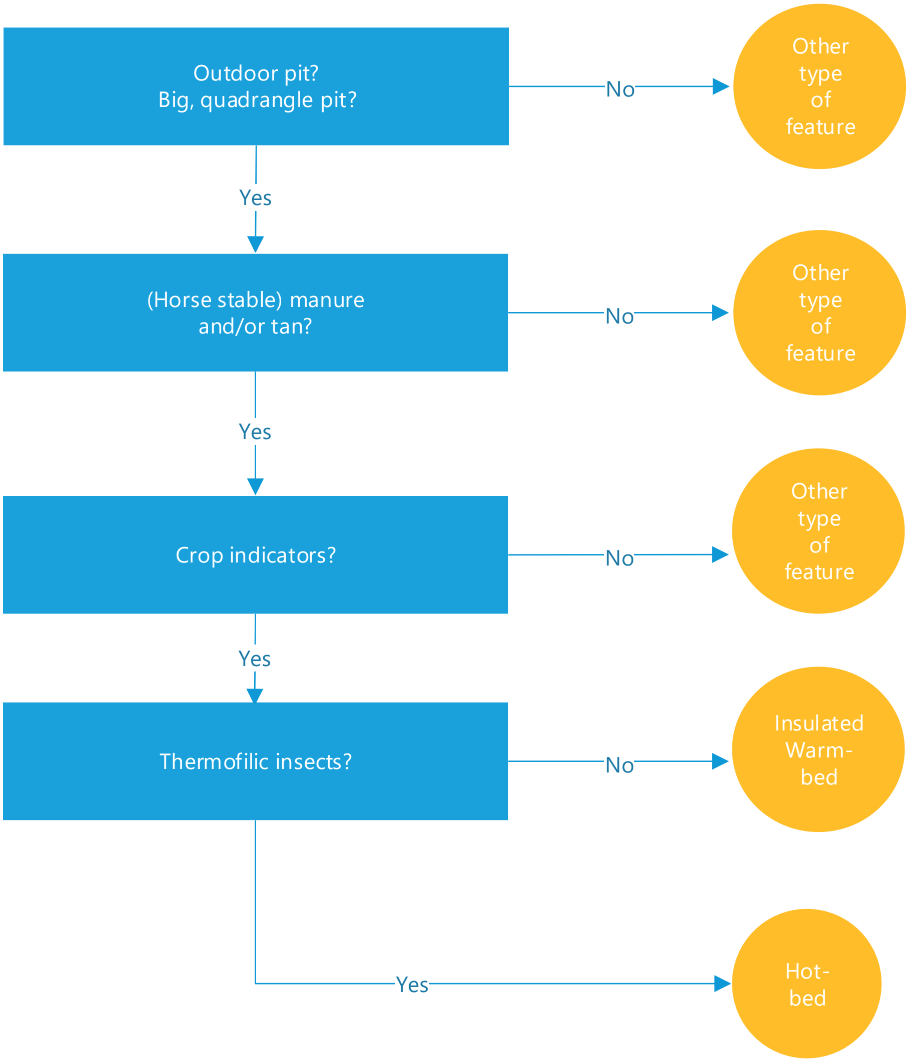


Figure 2: Flow chart for identifying hotbeds and insulated 'warmbeds'.

met for an archaeological pit to be considered a hotbed (see the flowchart in figure 2). The first condition is that the pit must be situated outdoors and be of a considerable size. Following Chomel, we believe that a bed must be in the range of 1.20 m x 1.80 m and 0.3-0.6 m deep. But while the outdoor criterion is a must, the size can vary.

The second condition is that the pit must contain a heat-producing material, preferably horse manure and/or tan. The presence of such material can be demonstrated by studying archaeo-botanical and paleo-entomological remains, but not on the basis of sensory perception during fieldwork only (Kenward and Hall 1997: 666). Pits that look like manure pits may contain human excrement or garden waste (see paragraph 6.1), and pits that have not been tagged as manure pits during fieldwork may contain manure.

The third condition is that there are crop indicators. The top layer is the most likely place to find them. This sounds straightforward enough, but as we shall see, archaeological sampling strategy focuses on the bottom layer. Theoretically, both archaeo-botanical and paleo-entomological indicators can be found in the top layer, but there is a higher probability of finding paleo-entomological indicators than archaeo-botanical indicators in the top layer. The archaeological visibility of vegetables is poor. Remains decay rapidly, and several vegetables are harvested prior to their seed formation. If any seeds can be found, then they are probably from plants that were not harvested but kept for seed production, such as biennial chard and spinach. They could also be seeds that had not germinated. Today the germination rate of seeds is high. In pre-industrial times, however, the germination percentage was much lower.

The fourth condition is the presence of thermophilic (heat-loving) insects.

## 5. Hotbed experiment: set up

We undertook a two-year hotbed experiment in the living museum Archeon in Alphen aan den Rijn. The experiment served two purposes: 1) we wanted to see whether we were able to produce an early harvest using hot- and coldbeds and 2) we also needed a reference to compare botanical macro-remains and insect fauna from archaeological manure pits.

Using Chomel's manual, we dug two hotbeds (1.20 m x 1.80 m), one 60 cm deep and the other, 30 cm deep (figure 4). To compare the results from the hotbeds we also set up a conventional vegetable bed of the same size, hereafter referred to as a coldbed. In the 2017 season, the coldbed was located behind the reconstructed outhouse, or privy house (figure 4c), which was a shaded area. In 2018 we moved the coldbed into the sunshine, nearer the hotbeds, which made the results of the two beds more comparable.

In the first season, we dug the beds in mid-January 2017. The deeper pit required 23 wheelbarrows of stable manure and the shallower one approximately 18 wheelbarrows, which we obtained from the nearby dung hill (figure 4a). We covered the manure with 360 litres of potting soil. We sowed chard (a subspecies of *Beta Vulgaris*) because it has been found in several medieval (manure) pits (table 5) and is known for its high yield and easy cultivation. To determine germination, we spread a hundred seeds on a damp paper towel, and after a series of steps, the number of germinated seeds were counted. According to our germination test, 100% of the seeds germinated.[1]

One week after the pits had been dug, the seeds were sown. After the first season (in mid-March 2018), we excavated half of each pit so that we could see the cross-sections of the three beds. In the subsequent year, we filled the dug-out halves of the pits with fresh manure. We covered the manure with a 120 litres of potting soil and sowed the seeds on the same day.

The temperatures of the three beds were taken by inserting a soil thermometer 30 cm deep into the soil. In the 2017, we installed an Askey Key data-logger in one hotbed. This device measured the temperature at regular intervals. In the 2018 season, we installed a data logger in every bed, but, for reasons unknown, none of them generated data. This means that we don't have continuous series of temperature measurements.

### *5.1 Hotbed experiment: late but considerable harvests*

The highest temperature recorded in the dung heap was 48°C. This was in mid-January when we filled the beds with manure. It is clear that the manure in the beds never produced as high a temperature as the dung heap did. The 60-cm deep hotbed was 20° when we filled it, and it rose to 27°. This temperature was maintained for one week, after which it decreased. The temperature of the 30-cm deep bed only decreased but remained 4° higher than the coldbed (the coldbed was 3°). For this reason, it would be more appropriate to call our beds insulated beds rather than hotbeds.

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1 The gemination test was carried out by Trudy van den Bos, with thanks to prof. Bakels for the suggestion.

While the experiment was not monitored on a day-to-day basis, it was obvious that the chard did not grow significantly quicker in the hotbeds than it did in the coldbed. In both years, our first harvest was in June, and not in early spring (March or April). In that sense, our hotbeds were not successful. Given the fact that our manure did not reach very high temperatures, this should not come as a surprise.

However, the hotbed experiment showed two results that do not appear in the literature. First, our hotbeds showed that clamping (burying) manure works like a pressure cooker. Manure shrinks considerably (figure 3), and the farmyard manure mixed with straw decomposed completely within 14 months (January 2017-March 2018). Second, the experiment

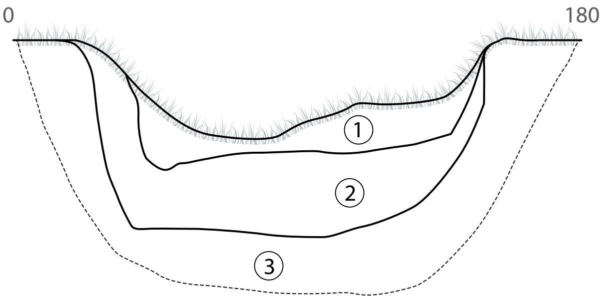


Figure 3: Hotbed experiment. Cross-section of the 60-cm deep hotbed after eight months. 1=top layer (potting soil), 2=manure layer, 3=natural soil.


Figure 4: Hotbed experiment 2017. a) 14 January: dung heap from which the stable manure was taken; b) 14 January; steaming manure in the pit before the top soil was added; c) 11 February: two hotbeds covered with straw; d) 20 May: chard sprouts, e) 12 August: taking a sample from the top soil and the manure layer using a monolith box. The harvest is visible in the background. Figures 4c and 4d: photo Trudy van den Bos. Figure 4e: photo Merit Hondelink.

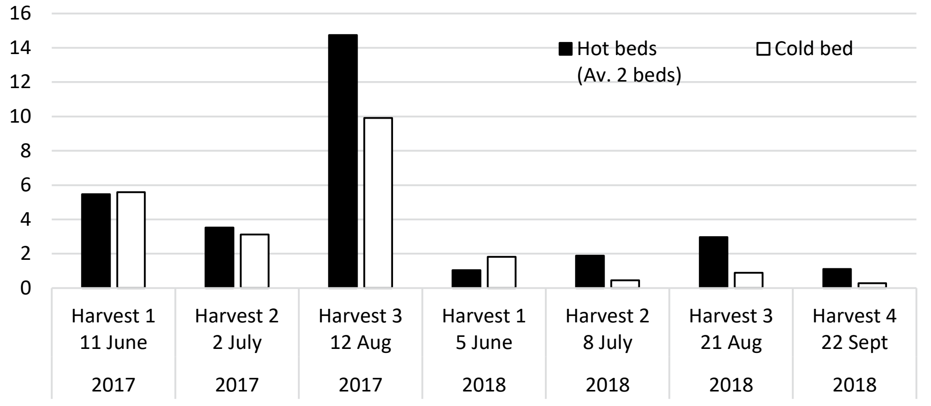


Figure 5: The 2017 and 2018 average yield in kilograms of the two hotbeds compared with the coldbed harvests. NB: the 2017 and 2018 season are not perfectly comparable (see text).

showed that intensive manuring paid off in the long run. In the first season, we had three harvests, resulting in roughly 47 kilos of chard from the two manure pits combined (23.5 kilos on average). In the first season, we had four harvests, resulting in only 14 kilos. In the second year, the coldbed produced a much lower yield than the previous year, three kilos instead of 19 kilos, a difference of 75% (figure 5).

There were three reasons for this difference. First, the crops were exposed to extreme heat and drought in the summer of 2018 (heat waves in the Netherlands were recorded 15-27 July and 29 July-7 August), which adversely affected growth. Modern horticulture in the Netherlands in 2018 yielded from 10% to 50% less than conventional years (Caris and Duijn 2018: 11). However, this cannot explain the drop completely: our first harvest, before the heat waves, in June, was already 50% less than in the previous year. A second factor that helps explain the difference between the two seasons is that over a longer period, the hotbeds ensured a higher yield. The hotbeds showed a 70% drop in the yield and the coldbed an 81% drop. More important than the comparison between the years, however, is that we saw the sustainability of the hotbeds confirmed in the two years. In both seasons, in the first harvest, the coldbed produced a little more than the average yield of the two hotbeds, but the hotbeds produced significantly more in the subsequent harvests. Third, the biggest difference between the 2017 and 2018 yields was the number of seeds sowed. Both in 2017 and 2018, the seeds were sown in regular marked rows. In 2018, the seeds were sown every 2 cm, probably resulting in a less dense seed pattern than in 2017. This compromised the comparability of the two seasons.

### *5.2 Bio-archaeological results of the hotbed experiment*

We sampled both the top layer and the bottom layer of the hotbeds for archaeo-botanical and insect remains using a monolith box (figure 4e). In this way, the stratigraphy was perfectly reflected, making it possible to compare the top and the bottom layers, which is necessary particularly for an analysis of insect remains.

In the hotbed we took samples from, 15 various archaeo-botanical remains were recorded; only three were recorded in the coldbed (table 2). The differences were present because of the manure, which came from the dung heap. The stable manure contained typical nitrogen-loving field weeds but also a common sunflower, which was likely the remains of horse feed. Botanical remains of an alder and an elder that stood next to the dung heap (figure 4a) and remains of a European white water lily, probably from the nearby pond (figure 4c), were recorded. It is important to stress that we did not find evidence of the chard we cultivated, in other words, both in the hotbeds and coldbed, the crops we cultivated were archaeologically invisible (see also, paragraph 4).

The insect samples (table 3) showed considerably more insects from the top layer than from the bottom (manure) layer, both in absolute numbers in density per gram. The manure was obviously reflected: *Oxytelus laqueatus,* a common inhabitant of herbivore dung, was superabundant in both layers. One element of facultative synanthrope, *Anobium puncatum* (the common furniture beetle), was observed in the lower fill, which is probably associated with the fauna living in the stables. Particular attention was paid to agricultural pests, i.e., insects that damage crop leaves, such as *Chaetocnema* (*concinna/picipes*), but these were not

| Hotbeds | Coldbed | Common name |
|---|---|---|
| **Cultivated crops** | | |
| *Helianthus annuus* | | common sunflower |
| *Pyrus* sp. | | pear |
| **Field weeds** | | |
| *Agrostemma githago* | | common corn cockle |
| *Chenopodium glaucum/rubrum* | | goosefoot |
| *Potentilla erecta* | | tormentil |
| *Ranunculus* sp. | | buttercup/spearwort |
| *Rumex* sp. | | herbs in buckwheat family |
| Wild plants | | |
| *Carex* sp. | | sedges |
| *Eleocharis palustris* | | common spike-rush |
| *Shagnum* sp. | | peat moss |
| | *Nymphaea alba* | European white water lily |
| Cyperaeae | | sedge family |
| | Lamiaceae | mint family |
| Poaceae | | grass family |
| **Trees and shrubs** | | |
| *Alnus* sp. | | Alder |
| *Betula* sp. | | Birch |
| *Sambucus* sp. | | Elder |

Table 2: Results from the macro-botanical quickscan from the hotbeds and the coldbed at Archeon.

| | **Top layer Sample 890 g** | | **Bottom layer (manure) Sample 580 g** | |
|---|---|---|---|---|
| **Taxon** | **Number** | **Deposition** | **Number** | **Deposition** |
| **Staphylinidae** | | | | |
| *Anotylus/ Oxytelus* sp. | 3 | Primary | 0 | |
| *Oxytelus laqueatus* | 29 | Primary | 15 | Primary |
| *Lathrobium* sp. | 3 | Primary | 0 | |
| *Paederus* sp. | 1 | Secondary | 0 | |
| Indet. | 0 | | 2 | Unknown |
| **Anobiidae** | | | | |
| *Anobium punctatum* | 0 | | 1 | Secondary |
| *Total MNI* | 36 | | 18 | |
| *Density per gram* | 0.04 | | 0.03 | |

Table 3: A minimum number of individuals per taxon of two fills from the modern 60-cm hotbed at Archeon.

recorded. Either Archeon is in the fortunate position of not having pests or such agricultural pests were more common in periods prior to chemical pesticides. This means that in the insect sample as well, our cultivated crops were archaeologically invisible.

Thermophilic insect fauna were not recorded either. When this is combined with temperature readings, it points to the fact that the hotbeds did not get hot enough to function as hotbeds. This means that we could not tick all the boxes of our hotbed flowchart. Our experimental hotbeds functioned as well-fertilized, insulated, warm vegetation beds.

## 6. Archaeological manure pits: dataset

Our literature study (table 1) showed that 189 manure pits have been uncovered in archaeological digs. Only eight of them (4%) have been studied for plant remains. While paleo-entomology is known as an 'excellent tool for reconstructing archaeological environments' (Buckland *et al*. 2018: 2), it is rarely applied in Dutch archaeology, and only two (1%) of the manure pits from table 1 have been tested for insect fauna. We expanded the dataset from the literature (tables 5 and 6), but the considerable dataset notwithstanding, its potential remains limited. Stratigraphy is rarely discussed and by default only the 'wrong' layer (i.e., manure layer) is sampled rather than the top layer (an exception to this rule: Hos 2008). It seems that the nature of the pit is rarely discussed explicitly, at least concepts such as 'indicator groups' (Kenward and Hall 1997; Kenward and Hall 2012: 90-93; Smith 2013) are not systematically applied in Dutch archaeological reports when it comes to urban medieval sites. This makes it difficult for non-specialists to understand which species played a key role in identifying the contents.

We tried to address these issues by examining six extra samples in more detail (table 4). Two samples were tested for plant remains (Hos 2015) and four extra samples for insect remains (Aerts 2016b). The selection of samples depended heavily on what samples were available from pits that had been designated as manure pits. The samples come from the sites 's-Hertogenbosch Postkantoor/Kerkstraat and Dordrecht Statenplein (Dorst *et al*. 2014). Both sites were old excavations, and the authors had no influence on how the samples were taken. The sample from an excavation at Leiden-Aalmarkt (Hoogendijk in prep.) was taken by one of the authors (Aerts), which enabled sampling from both the top and bottom layers.

The shape of the three manure pits was more square than rectangular in line with early-modern garden literature. They were not too deep to qualify as hotbeds (too deep is more than 1 m), and given their appearance, they could well have been hotbeds.

The Dordrecht-Statenplein sample is almost square (1.4 m x 1.15 m) and is 0.3 m deep (S583). During the fieldwork (1997), the pit was classified as a manure pit, and in the overview drawing in the archaeological report (2014), it is identified as the dump of a scabbard or shoemaker (Dorst 2014: 33). The pit is located on the same yard as an 14th-century urban, wooden house. A nearby pit produced much shoe production waste, and it is assumed that the house was occupied by a shoemaker.

The 's-Hertogenbosch Postkantoor/Kerkstraat sample comes from a pit 1 m x 0.7 m x ~.35 m (F77). It is located near a well from the same period indicat-

| Samples | Dim. (m) (w x l x d) | Date | Finds | Archaeo-botany | Insect-fauna | Source |
|---|---|---|---|---|---|---|
| Dordrecht-Statenplein S583-M145 | 1.4 x 1.15 x .3 | 14th c. | Pieces of leather, 6 leather scabbards, 1 belt | Possibly manure | Stable manure, no thermophilic species | Hos 2015; Dorst *et al*. 2014; Aerts 2016b |
| 's-Hertogenbosch Postkantoor/ Kerkstraat F77-M424 | 1. x .7 x approx. .35 | 1275-1300 | Yes | No manure | No manure | Hos 2015; Aerts 2016b; Cleijne 2013 |
| Leiden-Aalmarkt S9001, M1070 and M1071, from top and bottom layers | approx. 1 x 1 x .4 | 14th c.? | Preliminary results: some pottery sherds | No | Stable manure, no thermophilic species | Aerts 2016b; Hoogendijk in prep. |

Table 4: Summary of the bio-archaeological results from the three pits that we studied in more detail.

ing that the plot of land was occupied in that period (Cleijne 2013: 139).

The Leiden-Aalmarkt samples come from the top and the bottom layers of a pit ~1 m x 1 m x 0.4 m. The site is located in the 13th-century town-centre, but as the archaeological report has not be published yet (Hoogendijk in prep.), more contextual information is not available.

### *6.1 Do 'manure' pits contain manure?*

Before we turn to the question of whether the three pits (table 4) contained manure, we examine the total dataset from the literature. It comprises 29 archaeo-botanical manure pits (table 5), including the three we selected. Fifteen were tested for macro-botanical remains (pits and seeds), three for pollen and nine for both. In all but one case, the nature of the fill could be identified (28). Five pits did not include manure. Four pits contained human excrement, and the 's-Hertogenbosch Postkantoor/Kerkstraat pit contained garden waste. In the field, one pit was identified as containing human excrement, but it turned out to be manure (Rotterdam Hofdame V60-S22, Brinkkemper 2011: 237-238). This means that six pits out of 28 (20%) were not correctly identified in the field. This confirms that a pit designated as a manure pit is, in fact, not always a manure pit, and bio-archaeologically research is needed to classify the content.

Seven samples from six pits were examined for insect remains (tables 6 and 7). Hakbijl studied four contexts at Gouda-Bolwerk, and all four contained stable manure (table 6 and Hakbijl 2010: 290, 480), but given their shape (round and irregular) and content (tannery waste), they cannot be classified as hotbeds. Aerts studied four samples from three manure pits and applied an elaborated flowchart to find out whether the pits were hotbeds (figure 6). To identify organic substances, he used a hotbed indicator package (table 7 and Aerts 2016b) inspired by the article of Kenward and Hall (1997).

The outcome of the analysis of insect remains from the 's-Hertogenbosch sample was in line with the archaeo-botanical results showing that this manure pit did not contain manure, but garden waste. 's Hertogenbosch met only four out of eight conditions. Typical decomposer fauna and grain pests were absent. The species assemblage of 's Hertogenbosch Postkantoor/Kerkstraat indicated a compost-like mixture, with mainly eurytopic species: *Oxyomus sylvestris* (dung beetle), various *Cercyon* species, one individual of *Clivina collaris* and a number of *Oxytelinae*. The Dordrecht-Statenplein and Leiden-Aalmarkt assemblages most likely contained stable

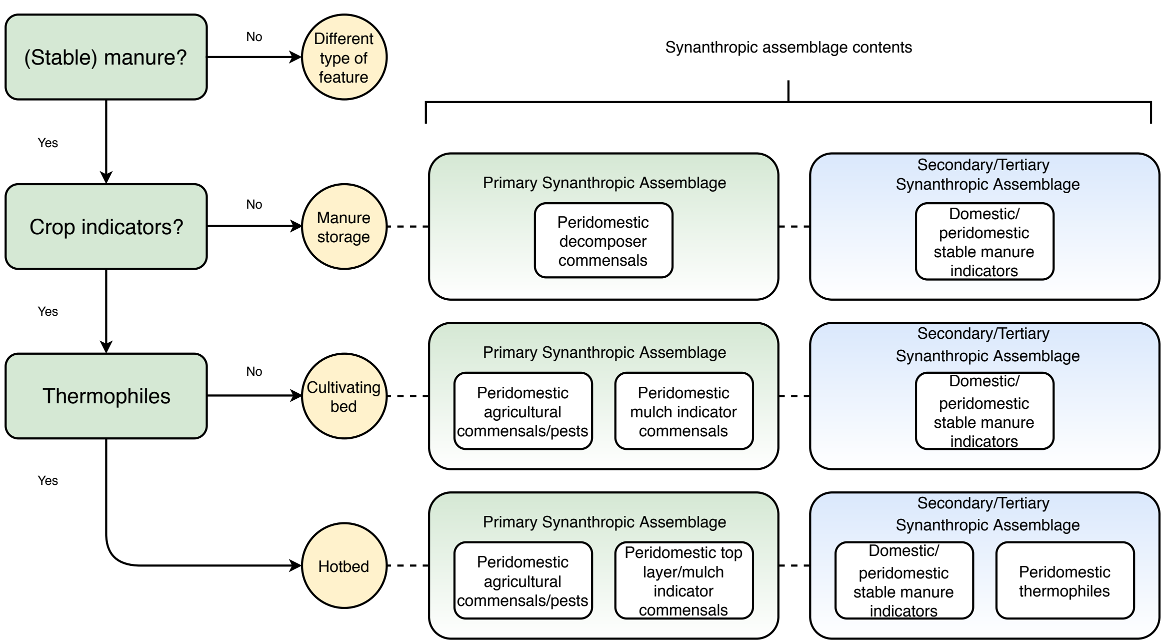


Figure 6: Flowchart for identifying hotbeds using insect fauna (based on Aerts 2016a).

| Excavation | Context | Macro remains | Date | Possible hotbed crops (except for *Ficus carica*) and number of macro remains | Contents: Manure (M) Faecas (F) Sod (S) |
|---|---|---|---|---|---|
| Gouda-Bolwerk (Bos *et al*. 2010) | 443-8-S26 | M | 1500-1600 | - | M/S |
| | 446-8-S2 | M | 1350-1450 | *Beta vulgaris* (beets) (tens) | ? |
| | 447-6-S195 | M | 1350-1425 | - | M |
| | 716-7-S122 | M | 1350-1450 | *Fragaria* (strawberries, some); *ficus carica* (tens) figs | M/F/S |
| | 744-6-S303 | P | 1300-1400 | - | M |
| | 748-6-S298 | P | 1350-1450 | - | M |
| | 754-6-S326 | P | 1300-1350 | *Beta* type (pollen) beets *Humulus lupulus* | M |
| Alkmaar-Worstelsteeg (Esser-Gehasse 1995) | 74 | M | 1475-1550 | | |
| | 75 | M | 1475-1550 | | |
| | 76 | M | 1475-1550 | | |
| | 77 | M | 1475-1550 | | |
| | 78 | M | 1475-1550 | | |
| | 79 | M | 1475-1550 | *Ficus carica* (4) | |
| | 80 | M | 1475-1550 | | |
| | 81 | M | 1475-1550 | *Ficus carica* (26) | |
| | 82 | M | 1475-1550 | *Ficus carica* (4) | |
| | 86 | M | 1475-1550 | | |
| Rotterdam Markthal (Brinkkemper 2013) | 91-9-S101 | M/P | 1300-1425 | Amongst others: *Beta vulgaris* (1), *Ficus carica* (1180) | M/F |
| Rotterdam De Hofdame (Brinkkemper 2011) | 609- S622 | M/P | 1300-1325 | *Ficus carica* (5) | M |
| | 611-S623 | M/P | 1325-1375 | - | M |
| | 634-S643 | M/P | 1325-1350 | *Ficus carica* (2) | M |
| | 636-S644 | M/P | 1300-1400? | - | M |
| | 813-S803 | M/P | 1325-1375 | - | Not mentioned Indoor house OW12 |
| | 827-S851 | M/P | 1375-1425 | *Ficus carica* (251) *Fragaria moschata/vesca* (8) | F indoor privy, house OW12 |
| | 830-S841 | M/P | 1350-1400 | *Ficus carica* (5) *cf Cucumis* spec. *fragm.* (1) | M/F? indoor privy house OW12 |
| | 60-S22 | P | 1325-1375 | *Reseda luteola, Spinacia oleracea, Anthriscus cerefolium* | M |
| Dordrecht Statenplein (Hos 2015) | 145-S583 | M | 1300-1400 | *Beta vulgaris* (3) *Foeniculum vulgare* (1) *Spinacia oleracea* (1) | M? |
| Den Bosch-Postkantoor/ Kerkstraat (Hos 2015) | 424-S77 | M | 1275-1325 | - | No M or F |

| Excavation | Context | Date | Possible hotbed crops | Manure (M) |
|---|---|---|---|---|
| Gouda-Bolwerk (Hakbijl 2010) | 619-8-S91 | 1350-1450 | rectangular pit (2.4 m x 1.4 m x 0.84 m) | Manure and tannery waste (a.o. horns of goats) |
| | 861-8-S159 | 1350-1450 | irregular wickerwork-lined pit (.52 m deep) | Manure |
| | 796-8-S137 | 1350-1450 | wickerwork-lined round pit with a supply gutter (.62 m depth) | Manure |
| | 792-8-S102 | 1350-1450 | round wickerwork-lined pit (1 m deep) | Manure |

Table 6: Overview of the manure pits from the literature studied for insect remains.

| Indicator Group | 's Hertogenbosch Postkantoor/Kerkstraat F77 | Dordrecht-Statenplein S583 | Leiden-Aalmarkt S9001 |
|---|---|---|---|
| Compressed straw litter | Yes | No | Yes |
| Cereals and pulses | No | No | ? |
| Grain pests | No | Yes | Yes |
| Hay-meadow plants and insects | Yes | Yes | Yes |
| Stored hay decomposers | No | Yes | Yes |
| Twigs and leaves from brushwood | Yes | Yes | Yes |
| Grazing land biota | Yes | Yes | Yes |
| Characteristic decomposer insects | No | Yes | Yes |

Table 7: Presence of indicator groups from 's Hertogenbosch, Dordrecht and Leiden, as described by Kenward and Hall (1997).

manure because typical stable manure decomposer fauna such as *Mycetaea subterranea* and *Aglenus brunneus* were identified.

### *6.2 Do manure pits reveal crop indicators?*

Following the flow chart (figure 2), we need to pay attention to crop indicators once the presence of stable manure has been positively identified.

The historical texts on horticulture detail that hotbeds were used to cultivate crops with a high germination temperature, such as cucumber and melon. In the more than 20 manure pits studied for archaeo-botanical remains, the only record of a cucumber or melon seed was in the Rotterdam-Hofdame pit (S841) (table 5). It is not clear whether this seed can be considered a crop indicator. It was found together with figs (*Ficus carica*) and black mulberry (*Morus nigra*) seeds. Generally, the presence of hundreds of these fruits indicate that faecal matter, not manure, is present (Smith 2013: 538). Indeed, the cesspits from the same excavation that were sampled produced hundreds of figs and black mulberry seeds (Brinkkemper 2013: 297), and, therefore, Brinkkemper cautiously suggested that the sample from the manure pit contained manure mixed with a small amount of human excrement (2011: 229). It cannot be excluded that the cucumber or melon seed was a non-germinated seed, which would be expected in the top layer of a hot bed. But this assumption is too insubstantial, and a mix of manure and human excrement is more probable.

While historical texts focus on crops with high germination temperatures, we cultivated chard in our experimental hotbeds. The harvest from the beds with manure was not necessarily earlier in the season, but the intensive fertilization generated a visibly greater yield. If we assume that crops with a lower germination temperature, like chard, can be expected to be found in hotbeds, then more positive indications in manure pits favouring horticulture can be identified.

Table 5 (previous page): Overview of (intramural) manure pits studied for macro remains (M) and pollen (P).

The botanical study of the sample of Dordrecht Statenplein (S583) identified *Beta vulgaris* (chard), *Foenicum vulgare* (fennel), and *Spinacia oleracea* (spinach). While chard and fennel are regularly seen in archaeo-botanical samples, the presence of spinach is exceptional in late medieval contexts. Spinach, like chard, is a vegetable that is harvested prior to seed formation. What is interesting about the Dordrecht Statenplein pit is that not only were botanical remains studied, but insect remains as well. The study of insect fauna showed the presence of several agricultural pests of the cabbage family (*Brassicaceae*) (table 7). Among them was *C. concinna/picipes.* This beetle is polyphagous, *i.e.*, it eats many types of plants but is a known pest of *Beta vulgaris*. It is therefore plausible that chard was cultivated in this bed and that this pit functioned as an insulated warmbed for crops.

If chard and spinach were warmbed crops, then we can turn our attention again to crop indicators in manure pits (table 5). Focusing on pits with chard that have a filling classified as manure, only Gouda-Bolwerk S326 remains as a potential hotbed. Its bed shape is not typical, as it appears to be an elongated pit or ditch, and in addition to chard, it also contained the remains of *Humulus lupus* (hops). It was not the only 14th-century feature containing hops, and it is noteworthy that hops require intensive manuring (Bos *et al*. 2010: 213-214). The manure present in the pit may have been used for such. While this find may indicate manuring, it is another type of manured bed than we are looking for. From the literature overview (table 5), the pit that most probably can be classified as a warmbed is a pit from Rotterdam-Hofdame (S22, 1325-1375). It was located on a yard that was unoccupied when it was dug. The pit is positioned on top of a fireplace and shortly after it was dug, it was again covered by another fireplace of a house. It is more square than rectangular (~3 m x 2 m and 0.5 m deep; depth estimated from Hallewas and Guiran: 86, figures. 76 and 119) and revealed evidence of spinach. Unlike chard, which is frequently present in various contexts, spinach is an exceptional find and is, therefore, a more 'straightforward' indicator (Kenward and Hall 1997: 664) of cultivation of crops.

As Kenward and Hall (1997: 670) already noted, '[w]here only insects or plant remains have been examined, conclusions concerning the nature of the deposit are inevitably less secure'. If only one bio-archaeological sample is studied, insect remains provide more solid evidence as insects may have died *in situ*. The Leiden-Aalmarkt samples were only studied for insect remains and revealed several insects that damage crop leaves, among them the pea leaf weevil (*Sitona lineatus*), indicating *Leguminosae* (legumes). Thermophile insects were absent and brewing did not take place. Therefore, Leiden-Aalmarkt (S9001) is not a hotbed, but after Dordrecht-Statenplein (S583) and Rotterdam-Hofdame (S22), it is the third potential warmbed.

## 7. Conclusions

In this article we have explored the possibility that manure pits identified in archaeological reports could also have been hotbeds. While hundreds of manure pits have been excavated, the nature of the pits has rarely been questioned. We chose three manure pits to examine in more detail, 's-Hertogenbosch Postkantoor/

| **Species** | **Dordrecht-Statenplein Sample 1400 gr.** | **Leiden-Aalmarkt Sample Upper 2100 gr.** | **Leiden-Aalmarkt Sample Lower 2100 gr.** | **Indicator** |
|---|---|---|---|---|
| *Meligethes aenus* | 0 | 2 | 0 | Brassicaceae |
| *Phyllotreta undulata* | 3 | 5 | 1 | Brassicaceae |
| *Chaetocnema concinna/ picipes* | 5 | 4 | 2 | Brassicaceae |
| *Chaetocnema aridula* | 0 | 1 | 0 | Cereal crops |
| *Sitona lineatus* | 0 | 8 | 0 | Leguminosae |
| *Ceutorhynchus pallidactylus* | 1 | 4 | 0 | Brassicaceae |
| MNI | 9 | 24 | 3 | |
| Density | 0.006 | 0.01 | 0.001 | |

Table 8: Facultative synanthropes possibly associated with crops from Dordrecht-Statenplein and Leiden Aalmarkt. Note that the greatest number of agricultural indicators were from the top layer and not the bottom layer.

Kerkstraat, Dordrecht-Statenplein and Leiden-Aalmarkt (table 4). To this end, we set up a flow chart (figure 2) that shows the four conditions that must be present for a pit to be positively identified as a hotbed: The pit must 1) be big, quadrangular and outdoors, 2) contain manure 3) must have crop indicators and 4) must contain thermophilic insects.

Utilizing our hotbed flow chart properly for pits in published reports is difficult. The physical appearance the field is not always published and sampling from both the top and the bottom layers is a rarity, let alone that both layers are studied for fauna and insect remains.

Of our three manure pits we studied in more detail, ‘s-Hertogenbosch Postkantoor/Kerkstraat is definitely not a hotbed. It contained garden waste, not manure. The other two pits, Dordrecht-Statenplein and Leiden-Aalmarkt, did contain manure and crop indicators. But can we call them hotbeds? Thermophile insects were absent and brewing did not take place.

Our hotbed experiment showed that the fourth condition should be applied with flexibility. We used tens of wheelbarrows-full of manure from a dung heap, but the hotbeds did not produce enough heat, and thermophilic insects were not recorded. Notwithstanding these conditions, our insulated, warmbeds produced visibly bigger harvests of chard than did the coldbed. This leads us to surmise that medieval archaeological manure pits with crop indicators were not hotbeds in the way described in early modern horticultural texts. They functioned as warmbeds, not for growing hard-to-cultivate melons and cucumbers, but for ensuring a solid yield of vegetables like chard and spinach. Using this definition, the Dordrecht-Statenplein pit can be classified as a warmbed, as both botanical and insect remains were present. The evidence for Leiden-Aalmarkt (insect remains only) and Rotterdam-Hofdame (botanical remains only) is less firm, but potentially they also functioned as warm, insulated beds for cultivating crops.

Probably, several (but not all!)[2] manure pits functioned as warm, insulated beds. The hot- and the warmbed hypothesis is worth testing further, not by tagging every manure pit that is uncovered as a hotbed, but by systematically and properly sampling and testing for plant remains and insect fauna. If manure pits were warmbeds, the implication would be that in an agrarian town (*Ackerbürgerstadt*) not only husbandry but also market gardening was commonplace. To make this gardening work, towns people engaged in a form of circular economy that shows how closely husbandry and horticulture were interconnected within the town walls.

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2 At the same time, we must remember that these pits could have been used for something else as well. For example, the relation between manure, shoemaking and tannery waste has not been studied. The Statenplein manure pit (F583) and the Gouda-Bolwerk pit (619-8-91) are not the only manure pits containing shoemaker waste. Another notable example comes from Kampen-Myosotis (Derks 2017). The relation between manure and shoemaking waste is beyond the scope of this study.

## References


Aerts, S.E.I. 2016a. Detecting cultural formation processes through arthropod assemblages: a conceptual model for urban archaeological waste-/cesspits, *Inter-Section* 2, 22-28.

Aerts, S.E.I. 2016b. *Storytelling Sclerites: A Coleopteran analysis of late medieval Dutch manure pits*, Leiden (Unpublihed MSc thesis University of Leiden).

Bos, J.A.A., C. Moolhuizen, M.T.I. Bouman and L. Haaring 2010. 'Archeobotanisch onderzoek'. In: J. Dijkstra, M.C. Houkes, S. Ostkamp (eds), *Over leven aan de rand van Gouda: een archeologische opgraving en begeleiding in het plangebied Bolwerk,* Amersfoort (ADC-rapport 1770), 203-235.

Brinkkemper, O. 2011. 'Archeobotanisch onderzoek van de stedelijke periode'. In: D.P. Hallewas en A.J. Guiran (eds), *Rotterdam De Hofdame. Archeologisch onderzoek op de voormalige Ichthus-locatie bij de Binnenrotte. Bewoningssporen van de prestedelijke nederzetting Rotte uit de 11e eeuw en de stedelijke ontwikkeling langs de Oppert vanaf de 13e eeuw*, BOOR-rapport-489, Rotterdam, 225-262.

Brinkkemper, O. 2013. 'Archeobotanisch onderzoek'. In: P.H.J.I. Ploegaert (ed), *Rotterdam Markthal. Archeologisch onderzoek 2. Bewoningssporen en vondsten uit de stedelijke periode (14e-18e eeuw); de bedijking van en de bewoning op het voormalig Westnieuwland in Rotterdam*, BOOR-rapport 469, deel 2, Rotterdam, 263-277.

Buckland, Ph.I, P.C. Buckland and F. Olson 2018. 'Paleoentomology: insects and other arthropods in environmental archaeology'. In: C. Smith (ed.), *Encyclopedia of global archaeology*, Cham: Springer. DOI: 10.1007/978-3-319-51726-1_2333-2

Caris, L. and S. Duijn 2018. *Winnaars en verliezers van de extreme zomer van 2018*, ABN-AMRO Commercial banking. Electronic Document.

Chomel, Noël 1725. *Dictionaire oeconomique, or, The family dictionary (..) Done into English from the 2d edition*, London.

Chomel, Noël 1778. *Algemeen huishoudelijk- natuur-, zedekundig- en konstwoordenboek etc.*, Leiden/Leeuwarden.

Clevis, H. 1999. 'Tussen Melkmarkt en Kalverstraat. Archeologisch onderzoek in Zwolle'. In: A. Carmiggelt, T.J. Hoekstra, M.C. van Trierum and D.J. de Vries (eds), *Rotterdam Papers 10. A contribution to medieval and post-medieval archaeology and history of building,* Rotterdam.

Cleijne, I.J. 2013. 's-Hertogenbosch Postkantoor/Kerkstraat. Opgraving, *BAAC rapport A-09.0372*. BAAC bv. Onderzoeks- en adviesbureau voor Bouwhistorie, Archeologie, Architectuur- en Cultuurhistorie, 's-Hertogenbosch.

Cox, M. L. 2007. *Atlas of the seed and leaf beetles of Britain and Ireland*, Newsbury: Pisces Publ.

Crescentiis, Petrus 1518. *Von dem nutz der ding die in äckeren gebuwt werden,* Straßburg.

De Beucker, J.I. 1869. 'Moeshovenierderij. De Meloenen-kweek in open grond', *Tijdschrift over land- en tuinbouwkunde en verdere natuurwetenschappen* 4, 1-14.

Derks, M. 2017. 'Leersnippers'. In: M. Klomp (ed) *Myosotis, in de schaduw van het Sint Geertruidengasthuis. Archeologisch onderzoek tussen Boven Nieuwstraat en Burgwal,* Zwolle (Archeologische Rapporten Kampen 4), 299-308.

Dijkstra, J., M.C. Houkes and S. Ostkamp (eds) 2010. *Over leven aan de rand van Gouda: een archeologische opgraving en begeleiding in het plangebied Bolwerk,* Amersfoort (ADC-rapport 1770).

Dorst, M.C., J. Hoevenberg and D.B.S. Paalman 2014. *Stadsontwikkeling op het Statenplein – een archeologisch onderzoek. Opkomst en ondergang van een 14e-eeuwse ambachtswijk in Dordrecht* (Dordrecht ondergronds 40) Dordrecht: sector Stadsontwikkeling, afdeling Ruimtelijke Realisatie/Archeologie.

Enklaar, E.C. 1859. *Tuinboek: Volledige beschrijving van het tuinwerk in het algemeen, van het kweeken van meer dan 70 verschillende tuingewassen en van de broeijerij onder vlak glas*, Zwolle.

Ervynck, A. 2018. 'Vettige vellen. Hoe een huid leer werd'. In: G. Vermeiren, M-A Bru, A. Ervynck (eds), *De Krook. Een leerrijk boek,* Gent, 67-79.

Esser, K. and E. Gehasse 1997. 'Onderzoek van huisafval. Het organisch materiaal'. In: P. Bitter (ed), *Geworteld in de bodem. Archeologisch en historisch onderzoek van een pottenbakkerij bij de Wortelsteeg in Alkmaar* (Publicaties over de Alkmaarse Monumentenzorg en Archeologie, 1) 77-87.

Franken, L. 2019. *Een broeiende verklaring voor middeleeuwse mestkuilen. Een inventariserend onderzoek naar mestkuilen in Rotterdam,* Leiden (Unpublihed BA thesis University of Leiden).

Groen, J. 1670. *Den Nederlandtsen hovenier, zijnde het I. deel van Het vermakelijck landt-leven ... : Beschrijvende alderhande princelijke en heerlijcke lust-hoven en hofsteden, en hoemen de selve, met veelderley* *uytnemende boomen … kan beplanten, bezayen, en vercieren*, T'Amsterdam: voor Marcus Doornick.

Hakbijl, T. 2010. 'Insectenresten'. In: J. Dijkstra, M.C. Houkes and S. Ostkamp (eds), *Over leven aan de rand van Gouda: een archeologische opgraving en begeleiding in het plangebied Bolwerk,* Amersfoort (ADC-rapport 1770) 287-291 and Appendix 7: 479-480.

Hallewas, D.P. and A.J. Guiran 2011. *Rotterdam-De Hofdame. Archeologisch onderzoek op de voormalige Ichtus-locatie bij de Binnenrotte; bewoningssporen van de prestedelijke nederzetting Rotte uit de 11e eeuw en de stedelijke ontwikkeling langs de Oppert vanaf de 13e eeuw*, (BOORrapport 489) Rotterdam: Bureau Oudheidkundig Onderzoek van Gemeentewerken Rotterdam.

Hoogendijk, T. in prep. *Leiden, Aalmarkt: archeologische opgraving, 's-Hertogenbosch* (BAAC-rapport A-15.0175).

Hos, T.H.L. 2008: *Wouw! Ververijen! Onderzoeksgebied Elfhuizen. Een bureauonderzoek en een definitieve opgravingen in de binnenstad van Dordrecht*, Dordrecht (Dordrecht Ondergronds 3).

Hos, J. 2015. *Mysterieuze middeleeuwse mestkuilen. Archeobotanisch onderzoek naar tuinbouwmethoden in de Late Middeleeuwen in stedelijke context*, Leiden (Unpublished BA thesis University of Leiden).

Kenward, H.K. and A. Hall 1997. Enhancing Bioarchaeological Interpretation Using Indicator Groups: Stable Manure as a Paradigm, *Journal of Archaeological Science* 24, 663-673.

Kenward, H.K. and A. Hall 2012: 'Dung and stable manure on waterlogged archaeological occupation sites: some ruminations on the evidence from plant and invertebra remains'. In: R. Josns (ed), *Manure matters: historical archaeological and ethnographic perspectives*, Oxon/New York: Routledge.

Klomp, M., H. Clevis and G. Havers 2017. 'Contextcatalogus'. In: M. Klomp (ed), *Myosotis, in de schaduw van het Sint Geertruidengasthuis. Archeologisch onderzoek tussen Boven Nieuwstraat en Burgwal*, Zwolle (Archeologische Rapporten Kampen 4).

Levitt, T. 2018. 'Dutch cow poo overload causes an environmental stink', *The Guardian*, 16 February 2018.

Miller, Philip 1745. *Groot en algemeen kruidkundig, hoveniers, en bloemisten woordenboek, behelzende de manier om moes- bloem-, vrugt-, kruid-tuinen, wildbossen, wijngaarden, oranje-huizen, stookkassen enz. aan te leggen, etc.* Leiden: Pieter vander Eyk en De weduwe Jacob vander Kluis, P.Z.

Munting, A. 1696. *Naauwkeurige beschryving der aardgewassen, waar in de veelerley aart en byzondere eigenschappen der boomen, heesters, kruyden, bloemen, met haare vrugten, wortelen en bollen, nevens derzelver waare voortteling, gelukkige aanwinning, en heylzaame geneeskrachten, na een veel-jarige oeffening en eigen ondervinding, in drie onderscheiden boeken, naauwkeuriglijk beschreven worden,* Leiden.

Ostkamp, S. and J. Dijkstra, 2010. 'Synthese en beatnwoording onderzoeksvragen'. In: J. Dijkstra, M.C. Houkes and S. Ostkamp (eds), *Over leven aan de rand van Gouda: een archeologische opgraving en begeleiding in het plangebied Bolwerk,* Amersfoort (ADC-rapport 1770), 305-343.

Ploegaert, P.H.J.I. 2009. *Rotterdam Laurenshof : een opgraving op de locatie Rotterdam Laurenshof,* BOOR-rapport 387, Rotterdam: Bureau Oudheidkundig Onderzoek van Gemeentewerken Rotterdam.

Ploegaert, P.H.J.I. 2013. *Rotterdam Markthal. Archeologisch onderzoek 2. Bewoningssporen en vondsten uit de stedelijke periode (14e-18e eeuw); de bedijking van en de bewoning op het voormalig Westnieuwland in Rotterdam*, BOOR-rapport 469, deel 2, Rotterdam: Bureau Oudheidkundig Onderzoek van Gemeentewerken Rotterdam.

Sangers, W.J. 1963. *Structuur-en conjunctuurverschijnselen in de Nederlandse tuinbouw, in het bijzonder ten aanzien van de groenteteelt*, Wageningen: Pudoc.

Smith, David N. 2013. Defining an indicator package to allow identification of 'cesspits' in the archaeological record, *Journal of Archaeological Science*, 40(1), 526-543.

Van den Muijzenberg, Erwin W.B. 1980. *A history of greenhouses,* Wageningen.

Van Haaster, H. 1997. 'Plantaardig en dierlijke resten uit de middeleeuwen. De resultaten van het oecologisch onderzoek op het Sint Janskerkhof'. In: H.W. Boekwijt and H.L. Janssen (eds), *Bouwen & Wonen in de schaduw van de Sint Jan,* 's-Hertogenbosch: Kring Vrienden van 's-Hertogenbosch (Kroniek bouwhistorisch en archeologisch onderzoek 's-Hertogenbosch nr. 2) 140-162.

Van Haaster, H. 2008. *Archeobotanisch onderzoek aan enkele (post)middeleeuwse monsters van de locatie Elfhuizen in Dordrecht*, BIAXiaal 330, BIAX Consult, Zaandam.

Van Oosten, R.M.R. 2007. ‘Daar zit een luchtje aan! Een opgraving in de Pelikaanstraat’. In: H. van den Ende, R.M.R. van Oosten, E.D. Orsel and M.F. Roscher (eds), *Dwars door de stad. Archeologische en bouwhistorische ontdekkingen in Leiden*, 37-44.

Van Oosten, R.M.R. 2015. *De stad, het vuil en de beerput : De opkomst, verbreiding en neergang van de beerput in stedelijke context,* Leiden: Sidestone Press.

Vorst, O. 2010. *Catalogus van de Nederlandse kevers*, Amsterdam: Nederlandse Entomologische Vereniging.

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