Rachel Carson Center
Perspectives

# Sickness, Hunger, War, and Religion

## Multidisciplinary Perspectives

Edited by
MICHAELA HARBECK
KRISTIN VON HEYKING
HEINER SCHWARZBERG

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RCC Perspectives

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## Volume Editors

**Michaela Harbeck** studied biology, forensic medicine, and biochemistry at the University of Kiel. She received a doctorate in physical anthropology from LMU Munich, where she then worked as an assistant professor in the Department of Anthropology and Human Genetics. Since 2010 Harbeck has worked as a curator for the Bavarian State Collection of Anthropology and Palaeoanatomy in Munich. She has published numerous articles on applying the methodology of modern natural sciences to research in osteology. Currently, she is using molecular biology and archaeometric analyses of skeletal material to investigate the social structures, the burden of disease, and living conditions of past populations of the early Middle Ages in particular.

**Kristin von Heyking** majored in anthropology and human genetics and minored in biology at LMU Munich, where she went on to work as a biological and technical assistant for the Working Group on Anthropology and Environmental History in the Department of Anthropology and Human Genetics. She also participated in the international project "A Global History of Health" and was a research associate at the Rachel Carson Center for Environment and Society. In her soon to be completed PhD in physical anthropology, von Heyking applies a broad range of scientific methods to analyze the health of individuals from an urban, late medieval poorhouse. Currently working as a freelance anthropologist, she has published her first results from this research as well as further anthropological analyses of medieval lifestyles.

**Heiner Schwarzberg** studied prehistoric archaeology, prehistoric anthropology, and history of art at the Universities of Halle (Saale), Jena, and Berlin. After working at the German Archaeological Institute in Berlin and the Martin-Luther-University Halle, he took on an assistant professorship at LMU Munich in 2008. He has specialized in the archaeology of Neolithic early farming communities in Europe and Asia Minor. In a Turkish-German joint project funded by the German Research Foundation, Schwarzberg is cooperating with Istanbul University, the Prussian Cultural Heritage Foundation and the German Archaeological Institute to excavate the sixth- and seventh-millennium BCE settlement mound of Aşağı Pınar in Eastern Thrace—a key site for Neolithization processes of southeastern Europe. Schwarzberg has published several books and papers on the Early Neolithic and the prehistoric cults and religion of the earliest European farmers.

## Contents

Michaela Harbeck, Kristin von Heyking, and Heiner Schwarzberg

## Introduction

"A peste, fame et bello libera nos, Domine! From pestilence, famine and war, O Lord, deliver us!" This prayer from the Litany of Saints, with its origins in the Middle Ages, contains four fundamental elements that have shaped human existence over centuries: disease, hunger, war, and religion.

But while these big issues are central to many academic disciplines, there are surprisingly few attempts to examine them across disciplines. This volume brings together the discussions from an innovative and lively workshop held at the Museum Mensch und Natur (*Museum of Man and Nature*) in Munich in March 2011.[1] The workshop, which was the brainchild of Christof Mauch, Director of the Rachel Carson Center for Environment and Society, and anthropologist Kristin von Heyking, brought together scholars from the disciplines of prehistoric, early historic, and medieval archaeology, from history, and from physical anthropology, in order to present and synthesize their approaches to a number of key historical questions.

The event, which was jointly organized by the RCC and the Society for Anthropology's *Arbeitsgemeinschaft Prähistorische Anthropologie und Paläoanatomie* (Working Group for Prehistoric Anthropology and Paleoanatomy, APPA), deviated from the standard procedure of inviting individual contributions, instead asking for groups of researchers representing different disciplines to send in their own suggestions for a panel, in which a representative of each discipline would present their perspectives on a common theme. The response to this call was indicative of a widespread recognition of and excitement about the interdisciplinary approach, with a high number of excellent suggestions ultimately whittled down by the selection committee[2] to six panels.

1 We would like to take the opportunity to reiterate our gratitude to Michael Apel and Gilla Simon from the Museum für Mensch und Natur for their energetic support. Our thanks also go to the Bavarian State Collection for Anthropology and Paleoanatomy for their logistical assistance. A particular thank you is due to the volunteers (Janina Deppe, Andrea Grigat, Ramona Schleuder, Anja Staskiewicz, Caroline Lang, Tanja Plötz, Negi Moghaddam, and Annika Wisknowsky) who were responsible for the smooth running of the workshop.

2 The committee was made up of the following people: Gisela Grupe, Michaela Harbeck (Working Group for Anthropology and Environmental History, LMU Munich and/or Bavarian State Collection for Anthropology and Paleoanatomy), Uwe Lübken, Christof Mauch (Rachel Carson Center for Environment and Society), Carola Metzner-Nebelsick, Heiner Schwarzberg, Wolf-Rüdiger Teegen (LMU Munich, Institute for Prehistoric and Protohistoric Archaeology and for Archaeology of the Roman Provinces). Thanks are due to the members of the committee for performing their difficult task so well.

Thus, we have here topics ranging across the historical spectrum, from the transition period of Mesolithic and Neolithic societies, via Ancient Egypt and the Roman Empire, to historical manifestations of diseases still circulating today.

The disciplines involved center around very different source materials, which approach and explain the past: while, to put it simply, historians are concerned with written sources, archaeologists examine the material remains of past cultures. The subgroup (pre)historic anthropology, which is a part of the discipline of physical anthropology, has a very specific interest in skeletal remains of anatomically modern human beings. The fact that each of these disciplines focuses on different sources to draw its conclusions means that each can only tell us about certain aspects of historical reality. Bringing them together presents us with a richer, more faceted picture of the past.

The workshop featured thirty-eight speakers from a range of European countries, and, again indicative of the level of interest, was attended by a large number of interested workshop participants who did not deliver a paper, hailing not just from Munich, but from academic institutions across several countries. In total, the workshop was attended by around one hundred people. Given this enthusiastic attendance, we are delighted that we were able to reassemble almost all of the original panels in this issue of the *RCC Perspectives*. Presenters have provided a synthesis of the panel; of the six panels, only the one devoted to the history of the Plague is incomplete. However, the individual abstracts that appear here are complemented by an introduction by our colleague here in Munich, Ingrid Wiechmann. In total, the contributions presented here have involved nineteen different authors located across a range of countries.

Life in Ancient Egypt during the Eighteenth Dynasty (sixteenth to fourteenth centuries BC) is the subject of the contributions by Albert Zink and his colleagues, and by Barry Kemp. Kemp describes the historical situation during the reign of the Pharaoh Akhenaten, who brought about changes in religious custom that had a huge effect on the lives of the population. Albert Zink and colleagues have identified the mummies of the ruling family centered around Akhentanen und Tutankhamun, and in doing so have cleared up the debate about kinship which date back some century and a half of research. They were moreover able to show which illnesses plagued members of the ruling family, in particular Tutankhamun.

Moving back further in time to the Mesolithic populations of the Balkans, Dušan Borić, Marija Radović, and Sofija Stefanović are able to show that the combination of archaeological and anthropological data can give us a much richer picture of nutrition, illness, migration, and cultural changes in prehistoric societies. They examine the progression from the culture of the last hunter-gatherer societies to subsistence farming communities between the eighth and sixth millennia BC using burial sites at the Iron Gate, a distinctive gorge of approximately 130 kilometers in length, situated on the Danube, where it marks the border between modern-day Serbia and Romania. Among other things, they are able to connect changes in diet with possibly religiously motivated changes in burial practices.

The question of the living conditions of the pre-hispanic population of Bolivia is the central question for Heiko Prümers, Martin Trautmann, Sandra Lösch, and Iris Trautmann, in particular the remarkably high incidence of syphilis. The successful molecular genetic characterization of the precursor of the modern bacterial source of syphilis, *Treponema pallidum*, confirms the incidence of this infectious disease in pre-conquest South America and contributes to a much greater understanding of the origins and history of syphilis.

The history of another devastating disease that wrought havoc on the medieval world, in this case the Plague, was the subject of discussion by a further panel. Out of the original panel contributions, which were part of a rather more broadly defined set of questions, we present here the papers by Ole Benedictow, Raffaella Bianucci, and Sacha Kacki, complemented by Ingrid Wiechmann's introduction to the topic. Benedictow discusses the seemingly irreconcilable findings from molecular biology and historical sources regarding the origins and transmission of the Plague. Bianucci and Kacki identify differing burial practices during Plague epidemics for urban and rural dwellers respectively, and explain these differences.

Christina Papageorgopoulou, Kaspar Staub, and Frank Rühli concern themselves with the epidemiology of hypothyroidism, a condition caused by iodine deficiency; specifically, in its occurrence in Switzerland during the medieval and early modern periods. They explain the medical basis of the condition, and go on to look at its endemic occurrence and its effects in Switzerland since the nineteenth century; for the first time, they can document the incidence of hypothyroidism in the medieval population by looking at osteological data.

Finally, Birgit Großkopf, Susanne Wilbers-Rost, and Achim Rost describe and interpret the remains of an ancient battlefield near Kalkriese, close to Osnabrück in the German federal state of Lower Saxony. The authors are able to link this battlefield to the historical accounts of the "Battle of Teutoberg Forest" in the year 9 AD, in which three Roman legions suffered a devastating defeat at the hands of Germanic troops. The authors discuss how to account for the disparities between the historical sources describing the course of the battle and the treatment of the dead after the end of the battle, and their own archaeological and anthropological findings.

Taken together, these contributions show the huge potential provided by an interdisciplinary examination of the interrelatedness of sickness, hunger, war, religion, and human populations in attempts to reconstruct historical processes and events. We very much hope that this approach will be adopted more frequently and consistently in the future, so that the fascinating and illuminating research within the various disciplines can contribute to a more detailed and complete picture of our common past.

# Life in Ancient Egypt
# Akhentanen, the Amarna Period, and Tutankhamun

Barry Kemp and Albert Zink

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## An Unintended Social Experiment: Pharaoh Akhenaten at Amarna

The royal mummies of the family that included Tutankhamun span a period of some fifty years that centers on the seventeen-year reign of Pharaoh Akhenaten (*ca.* 1351–1334 BC). The people who lived at the time experienced the effects of a religious revolution. Instigated by Akhenaten, it led to the rapid creation of a new capital city: the modern archaeological site of Tell el-Amarna. Simultaneously, the country seems to have been affected by an epidemic that spread into neighbouring countries, at least as far as the Hittite kingdom in Anatolia.

Akhenaten lived at a time of great prosperity and international exchanges, in which trade, diplomacy, and limited warfare were constants. It was Egypt's principal imperial age, celebrated at home with temple building on a large scale (much of Karnak and Luxor temples belong to this period, as do the "Colossi of Memnon," created for Akhenaten's father, Amenhotep III).

We know next to nothing about the influences that led Akhenaten to behave as he did. The sources give the impression of a man driven by a vision that dictated a course of action that was bound to lead to conflict. That vision was for the zealous purification of the one source of power that lay beyond human reach, yet was visible: namely, the sun and its light.

His purification took two forms. One was to ignore conventional theology and, in the case of the principal deviation from a purist's view of the sun—the human-shaped god Amun, who had partially absorbed the solar cult—to go on the attack and attempt to erase his existence. This Akhenaten pursued thoroughly (though his attack on the existence of other gods and goddesses was minor and inconsistent).

The other was to identify a place where the sun could be worshipped, uncontaminated by prior human or divine associations. As chosen by Akhenaten, this was a semicircle of desert on the east bank of the Nile, bounded by cliffs cut by wadi mouths that created a horizon line above which the sun rose clearly and dramatically. He called the place Akhetaten, "The Horizon of the Aten." It is the modern archaeological site of Tell el-Amarna. We know something of what was in his mind from a first-person narrative recorded in a series of boundary texts carved into the faces of the cliffs. It includes his list of important constructions, comprising temples to the Aten, palaces and other places for the royal family, and tombs for them all and for those most closely associated with him (his "priests").

Nothing is said about a city. He must have known, nonetheless, that many thousands of people would come to live there: junior officials, soldiers, people involved in manufacture, and even more whose place in life was to serve others. Although they were necessary, their needs fell outside his vision. They were left to build their own city, which they did rapidly and in a way that remains a remarkable witness to the power of self-organization. Perhaps as many as twenty or thirty thousand people found themselves making a home within a long, narrow city that had the river on one side, and empty desert on the other. They became the subjects (and in many cases the victims) of an experiment in community creation, which was an unintended by-product of Akhenaten's determination to convert his vision into a large-scale reality.

To judge from the language that he used, he acted out of piety, a wish to re-establish the spiritual basis of Egypt on purer lines. It is likely that he instructed those around him to live more righteous lives, but it was not in his mind to create a popular movement of "Atenists" who would stand apart from unbelievers. This kind of division, which has been a striking characteristic of religion since Hellenistic times, still lay in the future.

This is the background to the following study made by Albert Zink and his colleagues, which looks at the identities of the mummies preserved on the site. The individuals who make up the group of mummies include Akhenaten himself (this identification is a major result of the research), his father (Amenhotep III) and grandparents (Yuya and Thuya), and his successor king-but-one, Tutankhamun (almost certainly a son), in whose reign Akhenaten's experiment was brought to an end.

Since 2006, archaeological excavation at Amarna has begun to yield a parallel human population: the people of the city itself, who willingly or unwillingly bore the brunt of Akhenaten's grand scheme. The site of the excavation is one of several cemeteries of Amarna's people. We have called it the South Tombs Cemetery, because it lies behind one of the two groups of rock-cut tombs made for Akhenaten's officials.

The cemetery had been robbed in ancient times and most of the burials disturbed. But careful recovery and recording is enabling a team of anthropologists from the University of Arkansas (led by Professor Jerry Rose) to reassemble skeletons, partially or wholly. As a result, we have a total of around two hundred individuals to work with, with a target of four hundred to aim for. A profile of their health is emerging that has several marked features. Inadequacy of diet in childhood showed itself in several ways, including retardation of body growth. Injuries were common, often spinal and produced by having to bear loads that were too heavy. An abnormal peak of deaths amongst people in their late teens and twenties is consistent with written sources from the eastern Mediterranean that speak of an epidemic.

The picture stands in marked contrast to the images of abundance which accompanied the cult of the Aten. The temples were designed to supply food on a large scale, but the system seems to have been inadequate. Perhaps it needed a longer time to settle down to being the city's main provider of food. The epidemic must have hindered its development.

Anthropology offers a new angle from which to view Akhenaten's reign, a source that is independent of the evidence we have previously relied on. It would be of great benefit if representatives of our citizen population could be examined in the same way that the royal mummies have been. Then we might better know to what extent kings and commoners shared some of life's experiences.

**Albert Zink***

## King Tutankhamun and the Royal Family of the Eighteenth Dynasty of Ancient Egypt

The genealogy of Tutankhamun is one of the greatest remaining unsolved mysteries in Egyptology (Carter and Mace 1927). For decades, experts all over the world have studied and debated the pharaoh's true lineage. However, due to the lack of concrete archaeological and Egyptological evidence, no conclusion was reached until now.

* In collaboration with Zahi Hawass (Egyptian Supreme Council of Antiquities), Yehia Z. Gad (Egyptian National Research Center), Somaia Ismail (Central Hospital Bolzano), Paul Gostner (Kasr Al Ainy Faculty of Medicine), Ashraf Selim, and Carsten M. Pusch (University of Tübingen)

In 1922 Howard Carter uncovered the almost undisturbed tomb and the royal mummy of a nineteen-year-old boy from the late Eighteenth Dynasty, now popularly known as King Tut. This burial trove remains one of the most remarkable discoveries in Egyptology to date, capturing the public imagination in an unprecedented way, and Tutankhamun's life (and the causes of his premature death) 3,300 years ago continues to be a subject of fascination. However, despite the wealth of artifacts found, the tomb contained very little information about Tutankhamun's origins and family. Some names of key figures from the period appear amongst the artifacts, but no one inscription definitively tells us who the pharaoh's parents were. Furthermore, few other mummies from the Amarna period have been definitively identified. Many Egyptologists believe that Tutankhamun was born to the pharaoh Akhenaten and his great royal wife Nefertiti, or his second wife Kiya, but these claims are highly debated.

**Figure 1:** The mummified head of Tutankhamun, whose mummy is exhibited in Luxor, Egypt

Our study, which finally presents the real pedigree of the Eighteenth Dynasty royal family, constitutes a milestone in palaeogenetics (see Hawass et al. 2010). Using a multidisciplinary working model, we were able to identify and interpret nuclear DNA in a number of different royal mummies and put the existing hypotheses about their identities to the test.

This was facilitated by the preservation of nucleic acids in the corpses, which we speculate was a result of the particular (but as yet poorly understood) embalming techniques of the ancient priests. As these techniques reached their peak with the Eighteenth Dynasty, we were provided with DNA of extraordinary quantity and quality.

**Previous Identifications**

On Tutankhamun's paternal side, most Egyptologists turn to the skeletonized mummy found in tomb KV55, widely considered to be that of Akhenaten (Baker 2008). There is a great deal of archaelogical evidence to support this claim, although previous anthropological studies identified the mummy as a man in his early twenties, leading to the hypothesis that he could be the enigmatic pharaoh Smenkhkare (Harrison 1966). Little is known about Smenkhkare, other than that he seems to have ruled for a brief period around the time of Akhenaten's death. In either case, this mysterious KV55 mummy is a good candidate to be Tutankhamun's father.

The mother of Tutankhamun may be one of the two female mummies found in tomb KV35 in the Valley of the Kings, Luxor. These two mummies were named according to their different ages at death: the Younger Lady and the Elder Lady (Harris and Wente 1980). Besides the style of their mummification, which is consistent with royal females of the Eighteenth Dynasty, there is no clear evidence about the identity of these mummies. However, the Younger Lady mummy has been claimed at times to be Nefertiti or Kiya, either of Akhenaten's two wives, which makes her a prime subject to be Tutankhamun's mother. Some scholars also believed that the beautifully preserved Elder Lady may be the mummy of Nefertiti, or of Queen Tiye, the royal wife of the long ruling pharaoh Amenhotep III and the mother of Akhenaten.

Apart from Tutankhamun himself, the only mummies whose identities are known with complete certainty, and are known to be members of Tutankhamun's family group, are the mummies of his putative paternal great-grandparents, Thuya and Yuya. These two nobles were also found in an almost undisturbed tomb in the Valley of the Kings, clearly identified, and provide a good control group for genetic analyses. To further investigate Tutankhamun's family tree, the two fetuses found in his tomb—possibly his offspring—were also examined, as well as the two female mummies from the tomb of KV21, either of whom might be his wife.

## Material and Methods

Eleven mummies of the Eighteenth Dynasty (ca. 1550–1295 BCE) of the New Kingdom (ca. 1570–1070 BCE) underwent a detailed anthropological and radiological study in order to determine the preservation status, the individual's age and sex, and also to reveal any evidence of disease or the cause of death. For the radiological analysis, the mummies were scanned using a multidetector CT unit "emotion 6" by Siemens Medical Systems. This information was further used to identify the exact locations to take tissue samples for later DNA extraction in the laboratories.

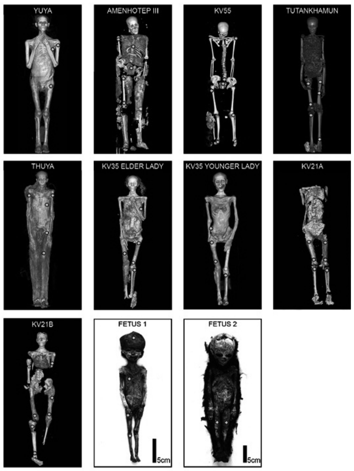


**Figure 2:** Compilation of full-body images of the examined Eighteenth Dynasty mummies. All mummies are shown as 3D VRT-CT images, except for the fetuses, which are photographic images. Names of the individuals or tomb are indicated.

Subsequently, the mummies were sampled by taking small bone punch biopsies from at least four different areas of the corpse. The samples were stored in sterile tubes and transferred to dedicated ancient DNA laboratories for further processing. The ancient DNA extractions of the bone samples and all further analytical steps, such as polymerase chain reaction (PCR) amplification, cloning, and sequencing, were all performed following strict and widely accepted guidelines (Richards, Sykes, and Hedges 1995). Along with these precautions, detailed contamination monitoring protocols for the PCR experiments were included in the research (mock and negative controls, separate working areas, etc.). Moreover, all involved lab members were tested for their Y-chromosomal and autosomal markers. For authentication of the results, all analytical steps were repeated at least five times; in addition, a subset of the data was independently replicated in a newly equipped lab exclusively dedicated to ancient DNA work.

The analyses of the ancient Egyptian mummy samples included laborious optimization strategies by applying several different DNA extraction and purification protocols. Inhibition PCR experiments were performed in a third lab, located at the National Research Center, Cairo, to titrate for the proper amount of amplifiable ancient DNA. After the successful extraction of DNA, we performed an intensive genetic testing of nuclear DNA loci including sixteen Y-chromosomal (AMPFLSTR Yfiler PCR Amplification kit, Applied Biosystems) as well as eight autosomal microsatellite markers (AMPFLSTR Minfiler PCR Amplification kit, Applied Biosystems).

## Results and Discussion

### *Kinship Analyses*

The optimization protocols for extraction and purification of DNA, PCR amplification, sequencing and fragment length analyses yielded results for all mummies under investigation. The genetic data clearly identified the mummies of KV35 Elder Lady, and KV55. Our results, in conjunction with archaeological data, provide substantial evidence that the mummy found in KV55 is indeed Akhenaten, and that the KV35 Elder Lady is Tutankhamun's paternal grandmother, Queen Tiye. Moreover, the KV55 mummy and the KV35 Younger Lady mummy can safely be identified as the father and mother of Tutankhamun. This is demonstrated by the following results:

Alleles deriving from Amenhotep III — Alleles deriving from Yuya — Alleles deriving from Thuya

| Marker | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mummy | D13S317 | | D7S820 | | D2S1338 | | D21S11 | | D16S539 | | D18S51 | | CSF1PO | | FGA | |
| TY | 9 | 12 | 10 | 13 | 19 | 26 | 26 | 35 | 13 | 11 | 8 | 19 | 7 | 12 | 24 | 26 |
| YU | 11 | 13 | 6 | 15 | 22 | 27 | 29 | 34 | 6 | 10 | 12 | 22 | 9 | 12 | 20 | 25 |
| EL* | 11 | 12 | 10 | 15 | 22 | 26 | 26 | 29 | 6 | 11 | 19 | 22 | 9 | 12 | 20 | 26 |
| AM | 10 | 16 | 6 | 15 | 16 | 27 | 25 | 34 | 8 | 13 | 16 | 22 | 6 | 9 | 23 | 31 |
| KV55* | 10 | 12 | 15 | 15 | 16 | 26 | 29 | 34 | 11 | 13 | 16 | 19 | 9 | 12 | 20 | 23 |
| YL* | 10 | 12 | 6 | 10 | 16 | 26 | 25 | 29 | 8 | 11 | 16 | 19 | 6 | 12 | 20 | 23 |
| KT* | 10 | 12 | 10 | 15 | 16 | 26 | 29 | 34 | 8 | 13 | 19 | 19 | 6 | 12 | 23 | 23 |
| KV21A | 10 | 16 | NDO | NDO | NDO | 26 | NDO | 35 | 8 | NDO | 10 | NDO | NDO | 12 | 23 | NDO |
| KV21B | 10 | NDO | NDO | NDO | 17 | 26 | NDO | NDO | 11 | 13 | NDO | NDO | NDO | 12 | NDO | NDO |
| F1 | 12 | 16 | 10 | 13 | 16 | NDO | 29 | NDO | 8 | NDO | NDO | 19 | NDO | 12 | 23 | NDO |
| F2 | 10 | NDO | 6 | 15 | NDO | 26 | 29 | 35 | 8 | 13 | 10 | 19 | NDO | 12 | 23 | NDO |

**Figure 3:**
Microsatellite data of mummies thought to belong to the Tutankhamun kindred. Segregation of alleles is indicated by color. Note that data replication for Tutankhamun, Elder Lady, Younger Lady, and KV55 was successfully performed in the second Cairo laboratory (*). KT, Tutankhamun; AM, Amenhotep III; KV55, Akhenaten; F1, fetus 1; F2, fetus 2; KV21A; KV21B; TY, Thuya; YU, Yuya; EL, Elder Lady; YL, Younger Lady. "NDO" is abbreviated for "no data obtained." All established genotypes differ from those of the lab staff.

1. The established Y-chromosomal profiles show identical patterns in Amenhotep III, KV55, and Tutankhamun. This provides evidence that these individuals share the same paternal lineage. Control mummies examined along with Tutankhamun's putative family members yielded different Y-specific alleles.

2. Fine analysis of the genetic relationship between the mummies was achieved by a genetic fingerprint typing exploring autosomal alleles. We obtained complete fingerprint profiles of all individuals except for one of the KV62 fetuses and both mummies from KV21, who yielded partial data sets. By evaluating the segregation of alleles through the generations, we reconstructed the most plausible royal pedigree: a five-generation family tree.

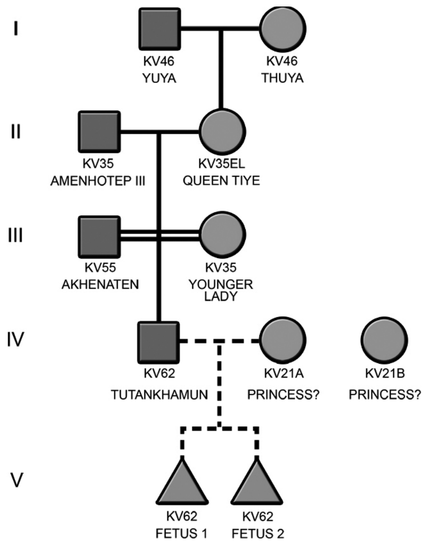


**Figure 4:**
Pedigree showing the genetic relationships of the tested Eighteenth Dynasty mummies. Quadrants define males, circles illustrate females, and triangles stand for still-birth. A double line represents an interfamilial marriage (here it is a first degree brother-sister relationship). Dotted lines indicate insufficient data; thus, the relationship is meant to be a proposal. Note that fetus 1 and fetus 2 could be daughters of Tutankhamun; however, the mother is not known to date. The few data obtained from KV21A are not enough to identify her as Ankhensenamun, wife of the boy pharaoh.

- Yuya and Thuya are the parents of the KV35 Elder Lady, indicating that she is most likely Queen Tiye, the royal wife of Amenhotep III.
- Both Amenhotep III and the now identified Queen Tiye are the parents of the mummy found in KV55 and also the Younger Lady found in KV35.
- Anthropological and radiological analysis of the KV55 mummy showed that he was much older than previously assumed, which provided evidence that this mummy could be the pharaoh Akhenaten, and not Smenkhkare. Further support for this claim was found on the sarcophagus of KV55: gold sheets that were once attached to the lid of the coffin identify the pharaoh Akhenaten, sun god. The proof that Amenhotep III and Queen Tiye are the parents of KV55, combined with this anthropological and archaeological evidence, clearly indicates that the mummy in KV55 is Akhenaten.
- The KV35 Younger Lady could be Nefertiti or Kiya, or possibly one of Akhenaten's sisters, who would have been the right age to give birth to Tutankhamun. Specifically, we should also mention the eldest sister of Akhenaten, Sitamun, as a possible identity for KV35 Younger Lady. Daughter of Amenhotep III and Queen Tiye, Sitamun was the most well-known of their offspring, and could also be Tutankhamun's mother.
- Subsequently, Akhenaten and KV35 Younger Lady are the parents of Tutankhamun.
- Additionally, Tutankhamun might be the father of at least one of the fetuses found in KV62.

*Gynecomastia and Syndromes*

The most prominent feature of the Amarna portrayals of Akhenaten—and, to a lesser degree, Tutankhamun—is their feminine appearance in some busts and statuettes. Disregarding artistic considerations, this might reasonably suggest some form of gynecomastia, abnormal breast enlargement in the male, as an underlying disease (Paulshock 1980).

**Figure 5:** Examples of El Amarna art (ca. 1351–1334 BC) showing Akhenaten. JE49528, colossus statue that once lined a colonnade in the Precinct of the Aten at Karnak temple, Eighteenth Dynasty, reign of Akhenaten (left).

JE49529, colossus of Akhenaten, Karnak, Precinct of the Aten, 18th Dynasty, reign of Akhenaten. The king wears a pleated kilt that hangs low on a swollen belly, and a double crown symbolizing dominion over Upper and Lower Egypt (right).

However, it is impossible to examine the mummies of Tutankhamun and Akhenaten (KV55) for putative breasts. KV55 is a mummified skeleton with no soft tissue remains, and Tutankhamun is missing the entire frontal chest wall, including ribs. Although Tutankhamun's pelvic bones are absent, KV55's pelvis is present but fragmented. It does not show any feminine features. We therefore cannot support the diagnosis of any form of gynecomastia or feminity.

It has also been suggested that Akhenaten and other family members may have suffered from Marfan syndrome (Braverman, Redford, and Mackowiak 2009). One criterion is the presence of dolichocephaly, that is an abnormally long head (Pyeritz and McKusick 1979). We tested for this by establishing the cephalic indices for 15 mummies. Many scholars believe that dolichocephaly is present in individual members of the Eighteenth Dynasty. Dolichocephaly is frequently seen in busts and statuettes of the Amarna period (Nefertiti, Akhenaten and Tutankhamun are prominent examples). Technically, dolichocephaly is defined as a skull with a cephalic index (CI) of 75 or less. Apart from Yuya (CI = 70.3), no mummies from the Tutankhamun lineage satisfy the criterion. However, Akhenaten's CI is 81.0 and Tutankhamun's 83.9, which defines their skulls as brachycephalic, or abnormally wide.

The diagnosis of Marfan syndrome is based on a combination of the major and minor clinical features (De Paepe et al. 1996). The presence of either two major features or one minor feature, or of one major feature and four minor features, supports a diagnosis of Marfan syndrome. Following this classification, we could not find evidence to add weight to a Marfan diagnosis.

*Radiological Findings*

Previous X-ray analyses have revealed much about the life of the pharaoh; however, they have also left plenty of questions unanswered over the years. Our study was designed either to confirm or refute the conclusions of previous examinations, and it focused on details that earlier studies might have overlooked. We specifically looked for life-threatening elements that might have directly caused the king's death, or been linked to his cause of death. While our inspection of the rest of his body did not result in any new information, a detailed examination of his feet was revealing. The arch of his right foot is low (angle after Rocher: 132°, normal value 126°); there are no pathological findings on the bone structure of the right foot. The tarsal, metatarsal, and phalanges are completely preserved.

The left foot has a slightly higher-than-normal arch (angle after Rocher: 120°). The forefoot is supine and inwardly rotated in a position suggesting equinovarus deformity (club foot). Despite significant bone degradation, the structure of the second metatarsal head is visibly altered, with areas of both increased and decreased bone density. There is a crater-shaped bone and a soft-tissue defect on the plantar surface. Furthermore, the metatarso-phalangeal joint space is widened. The articulating surface of the phalange

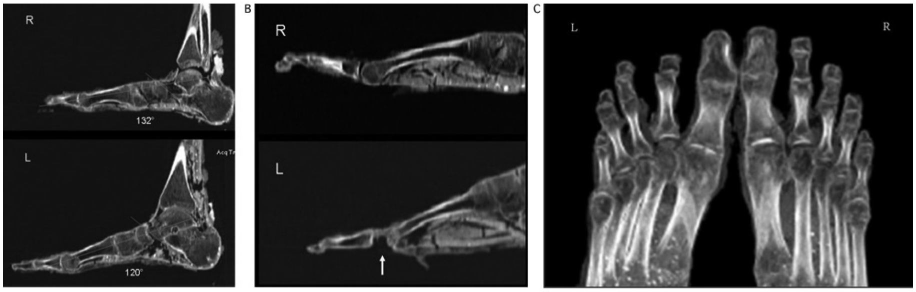


**Figure 6: Feet pathology in Tutankhamun.**

A) Axial CT cross section with sagittal CT reconstruction of the feet. The right foot arch is flat compared to the left, displaying features of a flat foot.

B) Axial CT reconstruction of the second metatarsal of the right and left feet: The second metatarsal bone head shows evidence of bone destruction with loss of bone substance and soft tissue. The second toe of the left foot lacks the second phalanx (oligodactyly). The right foot is without pathological findings.

C) CT reconstruction of both forefeet: The right foot shows no pathological findings. The second toe of the left foot misses the second phalanx (oligodactyly). This toe is anteriorly displaced. The ungual phalanx is subluxated, the first toe is splayed. The bone necrosis of the second metatarsal head can be unambiguously identified.

is normal. The third metatarsal head is only slightly deformed, but its structure shows signs of apparent bone necrosis. The remaining metatarsal heads of the left foot appear normal; the second and third toes are in abduction. The second toe is shortened, because it lacks a second phalanx; the first phalanx joins directly with the ungual phalanx. These findings show that Tutankhamun suffered from a juvenile aseptic bone necrosis of the second and third metatarsal bones of his left foot (Köhler´s disease II, Freiberg-Köhler syndrome). The widened joint space and the secondary changes to the second and third metatarsal heads indicate that the disease was still flourishing. Bone and soft tissue loss at the second metatarsophalangeal joint could further indicate an acute inflammatory condition resulting from ulcerative osteoarthritis and osteomyelitis.

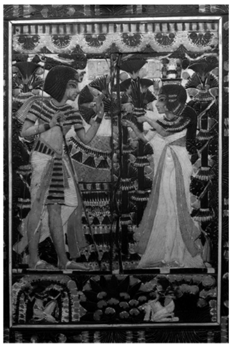

**Figure 7:** Private illustration showing the king essentially resting upon a cane while he is accompanied by his wife Ankhensenamun. Relief in KV62.

There is concrete evidence that the pharaoh may have had this impairment for quite some time. Using a cane can considerably ease the impairment in walking caused by the syndrome. Howard Carter found 130 sticks and staves—counting whole and partial examples—in Tutankhamun’s tomb. An inscription on one staff records that the king himself cut it from a bed of reeds while visiting a temple.

*Infectious Diseases*

As the various macroscopic inspections, X-rays, and CT examinations conducted in the past did not yield any conclusive data, we considered various life-threatening diseases as potential causes of death. In order to test for the malaria-causing parasite *Plasmodium falciparum*, DNA PCR primers were designed that specifically amplify small *Stevor, Ama1*, and *Msp1* gene fragments, thereby yielding amplicons in the range of circa 100–250 bp. PCR products and cloned DNA fragments were sequenced. We identified *Plasmodium falciparum* DNA in the mummies of Tutankhamun, Yuya, and Thuya. Since we applied primers that are highly specific for the *P. falciparum* genome, we can safely conclude that our positively typed mummies suffered from *malaria tropica*, the most severe form of malaria.

*Cause of Death*

Tutankhamun suffered from multiple physical disorders, and it is possible that some of them may have cumulated in an inflammatory, immunosuppressive syndrome, which would seriously undermine his health. We can imagine a young, frail king, who walked with a cane due to Köhler's Disease II (osteonecrotic and sometimes painful) together with oligodactyly in the right foot and club foot in the left. A sudden leg fracture, perhaps from a fall, would be life-threatening when combined with a *malaria tropica* infection.

## Conclusions

This multidisciplinary study (incorporating genetic, archaeological, anthropological, and Egyptological research) is the first concretely to clarify the lineage of Tutankhamun. As most of the archaeological and Egyptological data are still subject to debate, we established thorough genetic fingerprints of King Tutankhamun and his putative family members. By conducting a detailed ancient DNA study, we identified the mummies' origins and shed light on the pharaoh's family bonds.

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# Mesolithic-Neolithic Transformations
# The Populations of the Danube Gorges

Dušan Borić, Marija Radović, and Sofija Stefanović

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## Introduction

In the Danube Gorges that lie between Serbia and Romania, several archeological sites critical for the understanding of the transitions between the Mesolithic and Neolithic in southeastern Europe have been discovered. In particular, several preserved burial sites, containing around 500 individual skeletal remains, offer a unique opportunity to examine the life- and deathways of these communities. Through an analysis of skeletal remains and patterns of interment, this paper discusses questions of local versus non-local identities, as well as changes in diet throughout the Neolithization. One site in particular, Lepenski Vir, is the basis for research into the paleopathology of local populations. This study concludes that skeletal health parameters suggest a relatively good health status of this population over time, although treponemal infection (a group of diseases including syphilis, bejel, pinta, and yaws) affected large numbers of individuals at the Danube Gorges, and occur as a major pathological condition in all periods. Dental evidence also suggests relatively good health of the community, in contrast to other populations of the forager-farmer transition. Results of dental-based study indicate that changes in the biology of this population led to an increase of general health, though these changes were not the same for females and males.

Dušan Borić

## Isotopic and Symbolic Identities: Mesolithic-Neolithic Transformations Among the Inhabitants of the Danube Gorges

In the past decade or so, several research teams carried out isotopic analyses on human burial remains and animal bones from the Danube Gorges Mesolithic and Neolithic sites.[1] This suite of new data has contributed significantly to our current understanding of dietary preferences and historical changes in this micro-region at the time of Mesolithic-Neolithic transformations (ca. 6300–5900 BCE).[2] This new research

1 The following isotopes have been analyzed: $\delta^{13}C$, $\delta^{15}N$ (Bonsall et al. 1997; Cook et al. 2009; Borić et al. 2004; Grupe et al. 2003) and $\delta^{34}S$ (Nehlich et al. 2010) for dietary patterns and trophic levels; $\delta^{18}O$ for ecological provenance (Grupe and Borić 2010); and $^{87}Sr/^{86}Sr$ for patterns of individual and population mobility (Borić and Price forthcoming).

2 This article uses the dating systems BCE and CE (Before the Common Era and Common Era), which are an alternative to BC and AD.

suggests that the pattern of fish-dominated diet—characteristic of the Late Mesolithic in the Danube Gorges—remained largely unaltered during Mesolithic-Neolithic transformations. However, dietary signatures of several individuals from the central site of Lepenski Vir indicate diets less reliant on fish, representing the trend that continued with the appearance of the first crouched (Neolithic) burials at the same site. Moreover, the same individuals contained non-local strontium signals, suggesting that they might have been (Neolithic?) migrants that came from the surrounding regions or from further afield (Borić and Price forthcoming). Based on these findings, this paper discusses the possible impact of Neolithic migrants on local populations and identities.

The earliest human remains in the Danube Gorges area date to the Early Mesolithic (ca. 9500–7300 BCE).[3] At Padina, for instance, one whole area at Sector III of this site was used for burial within several layers of a linear stone construction during the Early Mesolithic (Borić and Miracle 2004; Borić 2011). While some burials date to the last half of the tenth millennium BCE, others are from the turn of the ninth and eighth millennia BCE. Some are characterized by specific body positions, such as seated position with crossed legs—the "lotus" body posture.

Isotopic analysis of these human burial remains suggests a shift in dietary patterns in the region. For instance, isotopic analyses of nitrogen ($\delta^{15}$N) of burials from Padina, Lepenski Vir, and Vlasac show higher trophic levels (>13%) and indicate heavy protein intake, most likely due to the consumption of fish, a staple food in the Late Mesolithic of the Danube Gorges. However, this pattern of fish-dominated diet for the Early Mesolithic burials from Padina has been recently challenged by new isotope results (sulfur $^{34}$S) that indicate no significant intake of fish at Padina, Vlasac, or Lepenski Vir during this period (Nehlich et al. 2010).[4] While these findings contradict our initial understanding of dietary preferences in the Early Mesolithic on the basis of carbon and nitrogen isotopic values, a more robust sample of individuals is needed to confirm these initial sulfur isotope results. Such work is currently in progress.

3 Only one burial—from the site of Climente II— might be from the Epipalaeolithic period (ca. 13,000–9500 BCE) but it has not been AMS-dated at present.

4 Early Mesolithic humans from Padina (Burials 12, 16, and 19a), Vlasac (Burials 16 and 17) and Lepenski Vir (Burials 67 and 68) have low $^{34}$S values despite $\delta^{15}$N values that are for the same individuals higher than 13% (Nehlich et al. 2010).

On the other hand, isotopic findings from a large number of later burials, dated to the Late Mesolithic (ca. 7300–6200 BCE), suggest the importance of fish in the diet of communities inhabiting the region. Burial practices may also reflect the significance of fish in local diets. The dominant burial position during this period is supine, with many individuals placed parallel to the Danube, often with their heads pointing in the downstream direction. This position may be related to the importance of anadromous sturgeon fish that migrate upstream to breed and might have held totemic, as well as dietary, significance (Borić 2005; Radovanović 1997).

This same burial position remains dominant in the period of Mesolithic-Neolithic transformations (ca. 6200–5900 BCE) during which the Danube Gorges foragers came into close contact with highly mobile Early Neolithic groups. Mesolithic supine burials along the Danube Gorges contain ample evidence of this contact, from the mixing of the local type of body decoration made from Cyprinidae (carp) pharyngeal teeth to new types of ornaments, such as Spondylus beads or red and white discoid limestone beads (Borić 2007). During this same period, the proliferation of carved sandstone boulders with hybrid human-fish depictions suggests an elaboration on local Mesolithic beliefs that stressed the importance of certain species of fish (Borić 2005).

These new cultural contacts altered dietary habits. Isotopic data reveal the seeds of change. In particular, a number of individuals found at the site of Lepenski Vir have reduced trophic levels, possibly indicating a reduction of fish in their diet (Bonsall et al. 1997; Cook et al. 2009). Strontium isotopic results suggest that several of these same individuals were migrants into this region, even though their burial position remained supine. Another migrant, buried in a crouched position, was discovered at the Neolithic site of Ajmana, situated some hundred kilometers downstream from Lepenski Vir. Ajmana and similar sites might have been contemporaneous with the continuation of local forager settlements in the upstream area of the region. In the period following circa 5900 BCE and lasting until the mid-sixth millennium BCE, new waves of migrants entered the region, their traces found at Lepenski Vir in particular (Borić and Price forthcoming). This pattern is also corroborated by lower $\delta^{15}N$ values, suggesting that fish became less important to the diet of these migrants. That these apparent changes in diet correspond to the spread of crouched rather than supine burials suggests that the community's symbolic identities were being constructed along new and foreign ideological, cultural, or religious values when compared to the Mesolithic.

**Sofija Stefanović**

## Pathological Conditions on Skeletal Remains from the Site of Lepenski Vir

While research on the Danube Gorges populations suggests a relatively good health status over time, treponemal infections were widespread and constituted a major pathological condition in all periods. Although various studies indicate increases in infections as a consequence of Neolithic transitions, there are still no detailed studies explaining which infections might have affected human health at the start of the Neolithic period. Evidence for one kind of infection, caused by the bacterium *Treponema pallidum*, has been found at the Danube Gorges sites from the Mesolithic period, with a slight increase in the Neolithic period.

In this study, health changes in Neolithic transition were analyzed on 60 adult skeletons from the site of Lepenski Vir situated in the Danube Gorges. The skeletons date to the Early Mesolithic, Mesolithic-Neolithic transformation, and the Early/Middle Neolithic periods. (No Late Mesolithic burials or layers have been confirmed at Lepenski Vir.) Three kinds of pathological conditions have been identified: 1) trauma (observed on skulls and major bones of limbs); 2) cribra orbitalia and porotic hyperostosis (skull lesions, generally caused by anemia and iron deficiency, both characteristics of the transition from hunther-gatherer to agricultural populations); and 3) infection and periosteal reaction (observed on skulls and postcranial bones).

Evidence of trauma comes only from two individuals: one Early Mesolithic male with a trauma on the left tibia, and one Early/Middle Neolithic female with a trauma on the skull. Low frequencies of traumas indicate low rates of violence in all periods.

Evidence of skull lesions associated with anemia is more widespread. Cribra orbitalia is not present among the adults from Lepenski Vir during the Early Mesolithic and Early/Middle Neolithic, while seven individuals (four females and three males) have traces of cribra in the Mesolithic-Neolithic transformations. Cribra orbitalia in the form of gross lesions with excessive expansion only appears in three individuals, each of whom probably experienced severe health problems as a result. Based on available evidence, then, it appears that individuals from Lepenski Vir did not experience the same health problems during the Neolithic transition as seen in many other transitional populations.

In contrast to cribra, porotic hyperostosis was much more frequent among individuals from Lepenski Vir, appearing in all periods (three individuals from the Early Mesolithic, ten from the Transformation phase, and five from the Early/Middle Neolithic). However, only modest lesions and scattered fine-pitting on parietals and occipital bones were present, without cases of gross lesions with excessive cranial expansion and areas of exposed diploe. The causes of cribra and porotic hyperostosis are complex: they may have been caused by iron deficiency, various diseases, and/or parasites (Goodman and Martin 2002). Also, porotic hyperostosis might have been caused by inflammatory processes after scalping (Schultz 1993; Schultz 2001). Walker et al. (2009) suggest that porotic hyperostosis and many traces of cribra might have been caused by megaloblastic anemia (a form of anemia that results from inhibition of DNA synthesis in red blood cell production) but with different etiologies—cribra is caused by vitamin C deficiency while porotic hyperostosis is the outcome of the depletion of vitamin B12 reserves. With little evidence of cribra, inhabitants of Lepenski Vir appear to have been well supplied with vitamin C, with some exceptions during the Transformation phase. On the other hand, a high prevalence of porotic hyperostosis suggests that vitamin B12 reserves were depleted. However, since few cases of cribra and only modest forms of porotic hyperostosis have been found, such deficiencies probably had only a limited affect on the overall health of the prehistoric inhabitants of Lepenski Vir.

In addition to trauma and anemia, infection is also an indicator of the state of overall health in the Danube Gorges populations. Traces of infection caused by bacteria *Treponema pallidum*—found on cranial and postcranial bones, of 121 individuals—present important evidence of treponemal disease (Stefanović 2012). Traces of infection were studied on all bones and bone fragments and a numerical value was assigned to each type of pathological change. In the cases of postcranial skeletons, either an osteoblastic or osteoclastic reaction was determined, as well as whether the reaction was active or healed (or both). On skulls, lesions and other changes were recorded—necrotic and osteolytic damages, stellate scars, necrotic destructions and healing processes, and new bone formation.

Lesions were found on 24 individuals (seven in the Early Mesolithic, eight in the Transformation phase and nine in the Early/Middle Neolithic). On postcranial bones, the lesions are predominantly osteoblastic and affect the diaphyses of the many various bones. The pattern of many affected bones of an individual with bilateral symmetric lesions suggests system infection. No individual has been found with periostal reaction affecting only the upper limbs. Osteoclastic lesions are much less present and also attack mostly lower limbs, especially the tibia. All the individuals with an osteoclastic reaction also have an osteoblastic reaction on many of their bones. Presence of bilateral symmetrical osteoclastic lesions suggests that treponemal infection contributed to the development of lesions, and we may assume the same etiology for most other osteoblastic reactions.

Although the sample size from Lepenski Vir is too small to compare the presence of disease in Mesolithic and Neolithic periods, the fact that there were many more individuals with an advanced stage of the disease at Lepenski Vir than at the (mostly) Mesolithic site Vlasac suggests that intensity of the infection increased during the Neolithic period. It is possible that population growth in the Transformational period, combined with an influx of migrants, may have increased pathogens in the Danube Gorges population.

Whether prehistoric people had attempted healing treatments for various infections is hard to ascertain, but some cut marks on skulls from Lepenski Vir indicate such a possibility. On some skulls, traces of cutting by thin and sharp tools have been detected, as well as possible instances of scalping. If these cuts were not post-mortem, they might indicate efforts to heal through the removal of soft tissue on the infected patients. If such interventions took place, it is possible that inflammation after cutting might have caused porotic hyperostosis in some cases, especially since porotic hyperostosis on many individuals has the form of scattered fine-pitting, and was unconnected with dietary problems.

The results of this study suggest a relatively good health status of inhabitants of Lepenski Vir over time, with the exception of infections, which occur as a major pathological condition in all periods represented in the sample of analyzed individuals. Changes in health status observed in other populations spanning the forager-farmer transition around the world—such as a decline in overall quality of nutrition—were not detected at Lepenski Vir. While higher rates of cribra orbitalia and porotic hyperostosis are found in the Transformation period, the small number of cases and their moderate appearance indicate stability in health over time. At the very least, they suggest no dramatic changes in the quality of life.

Marija Radović

## Dental Pathologies and Tooth Wear at the Site of Lepenski Vir

The shift towards Neolithic lifestyles affected human biology significantly. In many instances, the transition to agriculture resulted in the increase of "stress," defined as a series of interrelated pathological conditions coupled with changes in dietary patterns and living conditions. Here, I examine differences in dietary patterns and subsistence on the basis of dental pathologies and tooth wear from the Danube Gorges during the period of Mesolithic-Neolithic transformations. I chose the site of Lepenski Vir as a case study for this research, and studied the dental status on 29 adult individuals, 14 males, and 15 females.[5] I examined 195 teeth for enamel hypoplasia (enamel defects), the rate of dental wear, and dental calculus, or plaque—all indicators of oral and general health in relation to food composition. I studied the defects in order to trace physiological stress and growth disturbance in childhood

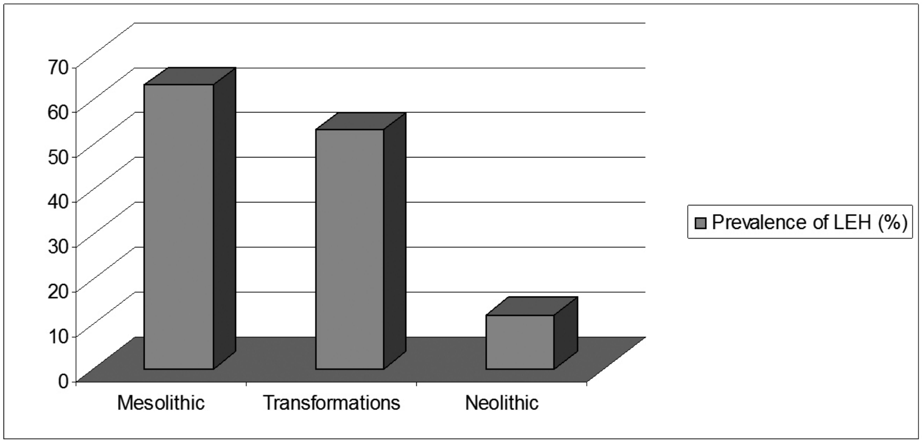


**Table 1:** Prevalence of linear enamel hypoplasia, LEH, through chronological periods.

Changes in lifestyle adopted from the "Neolithic package"[6] may explain the evident decrease of systematic childhood stress from the Mesolithic to the Neolithic (Table 1). The distribution frequency of linear enamel hypoplasia (LEH) by sex of the individuals shows

5 Of the 29 specimens, six males date from the Mesolithic; five males and 11 females date from the Transformation phase; and three males and four females date from the Neolithic.
6 The term "Neolithic package" means a general shift to a sedentary way of life, cultivation of plants, domestication of animals, and/or labor specialization.

that females were less affected by growth disturbance or less exposed to physiological stress, though the sample is somewhat biased due to the absence of (Early) Mesolithic females at Lepenski Vir. Another possible explanation for differences in the rate of LEH between males and females may relate to females' premature mortality. The etiology of LEH does not indicate a single crisis episode. LEH defects generally first appear between two and five years of age. These results indicate weaning stress as a possible explanation.

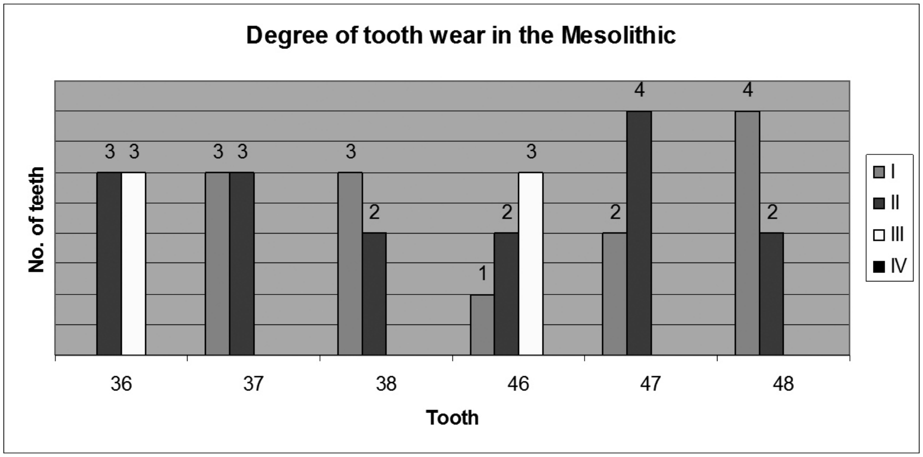


**Table 2:** Differences in degree of tooth wear of molars in the Mesolithic

Tables 2 and 3 show the results of changes in tooth wear pattern of molars from the Early Mesolithic to the Neolithic (the numbers 36, 37, 38, 46, 47, 48 represent the type of molar while the numerals I, II, III , IV represent degree of tooth wear). A high degree of tooth wear is evident in each chronological period, but there are no heavily worn teeth during the Early Mesolithic. Also, there is uneven wear on teeth from the right and left sides. These results suggest possible non-masticatory tooth use during the Transformation period and the Early/Middle Neolithic. Analysis of dental calculus or of mineralized plaque (which forms on teeth during one's life as result of specific food composition and also as result of oral hygiene) shows no evidence of change in the presence of dental calculus over time and that one-third of the crown was covered in half of the sample. With regard to the etiology of dental calculus, no subgingival calculus was found. This means that the calculus did not result from some tooth pathology but rather was the result of the high protein component of the local diet.

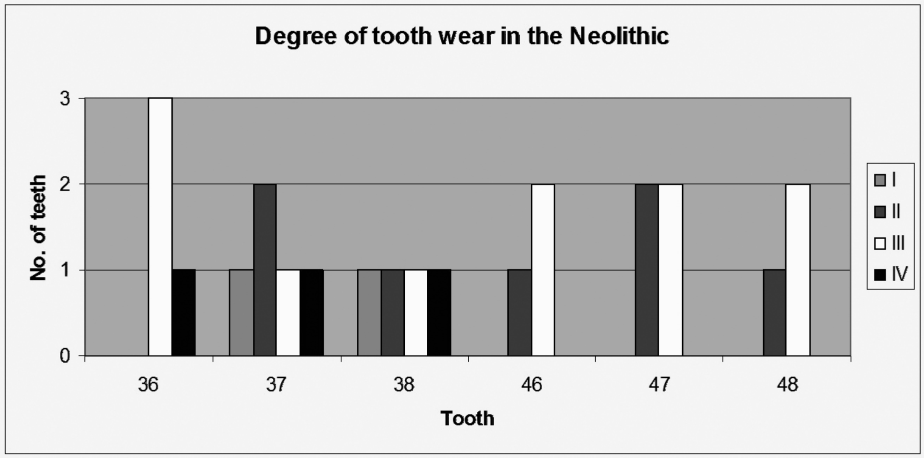


**Table 3:** Differences in degree of tooth wear of molars in the Neolithic

In the Early/Middle Neolithic an evident decrease of LEH was accompanied by more frequent distribution of LEH in males. The common age at which LEH defects were initiated was between two and five years of an individual life. The study of tooth-wear pattern showed non-masticatory tooth use after the Early Mesolithic, such as during the Transformation and Early Neolithic phases. Also, subgingival calculus was not found in the sample of analyzed individuals.

The results indicate a suboptimal level of health among subadults in the Danube Gorges. It seems that weaning stress decreased from the Early Mesolithic to the Early/Middle Neolithic. With the exception of the Early Mesolithic, Lepenski Vir females might have suffered premature mortality. There is evidence of new activities involving teeth after the Mesolithic, possibly due to the specialization of labor and/or new types of physical activities in the Transformation and Early Neolithic phases at Lepenski Vir. High protein diets remained constant over time.

In conclusion, this analysis of individuals from Lepenski Vir indicates a change in human biology of the prehistoric inhabitants of the Danube Gorges after Mesolithic-Neolithic transformations. That change was not equal for females and males. Overall, however, there was no decrease of general health in this population, most likely due to lifestyle and/or dietary changes over time.

## Conclusions: Integration of Archaeological and Osteological Data from the Danube Gorges

Spanning the period from the Early Mesolithic through the Early/Middle Neolithic, the abundance of human remains found in the Danube Gorges offers a unique opportunity to examine life- and deathways of these communities through an analysis of skeletal remains and burial practices. Our three contributions have looked at both aspects of the data, trying to integrate archaeological findings with an array of new data obtained by studying skeletal remains. These include studies of isotopes for dietary patterns and mobility, pathological conditions (such as the incidence of traumas, cribra orbitalia and porotic hyperostosis, traces of infections and periosteal reaction), and a dental examination of linear enamel hypoplasia (LEH) and tooth wear.

While we used isotopic data to analyze several key Mesolithic-Neolithic sites in the Danube Gorges, our discussion of pathological conditions and teeth was restricted to Lepenski Vir, considered the most representative site of the later Mesolithic–Neolithic sequence (comprising the Mesolithic-Neolithic transformation, ca. 6200–5900 BCE, and Early/Middle Neolithic, ca. 5900–5500 BCE). However, we should add that at present Late Mesolithic (ca. 7300–6200 BCE) occupation has not been found at this site, either by direct dating of human remains or settlement deposits. On the other hand, there is a prominent presence of Late Mesolithic groups at other sites along the Danube Gorges, evidenced by a large number of burials, among other archaeological features. The lack of Late Mesolithic burials at Lepenski Vir to some extent limits our discussion of changing patterns of health status. For instance, while human remains from Lepenski Vir show a low level of violent injuries in all three bracketed periods, we have clear evidence of a number of violent injuries by bone projectile points found at the site of Schela Cladovei and Vlasac, all dated to the Late Mesolithic (Roksandić 2004).

No signs of major pathological conditions appear in populations at Lepenski Vir. However, there are clear skeletal traces of various infections, possibly indicating treponemal infections. In addition, evidence of apparent cuts on some skeletal elements, in particular skull bones, may point to attempts to heal such infections by removing soft tissue. This procedure, in turn, might have caused a higher level of porotic hyperostosis, which peaks in the Transformation period. It remains unclear and open to speculation whether such infections during this period might have related to contacts with possible (Neolithic?) migrants, suggested by the presence of strontium at Lepenski Vir.

In particular, the examination of teeth shows little variation throughout the periods with regard to the changes in the quality of life. While enamel defects (LEH) appeared to affect males more, this pattern might be due to females' higher mortality, the likely consequence of frequent deaths while giving birth. It is interesting to note that the decrease of enamel defects in the Early/Middle Neolithic may be the consequence of improvements in dietary practices during this period. Isotopic data suggest that there was a general reduction in the reliance on fish in this phase. The level of subadult health is suboptimal in all periods, but is biased by the small number of burials. The level of wear on teeth is high in all periods, but there are no heavily worn teeth in the Early Mesolithic, while in the Transformation period, and the Early/Middle Neolithic teeth were used in a non-masticatory way for specialized everyday activities, which caused very specific wear patterns on certain teeth.

In sum, with some variations over time, the sample of human burials from the Mesolithic-Neolithic Danube Gorges of the Balkans suggests relative stability and good overall health conditions despite other major changes that the introduction of a food-producing economy and the arrival of foreign groups might have triggered. Such stability might have been the consequence of a rich and diverse environment along the Danube, which allowed the intake of high levels of protein, primarily coming from fish. The overall intake of fish was reduced in the Neolithic but, judging by the decrease in the incidence of LEH in this period, the introduction of food-producing practices was a risk-buffering step that might have reduced dietary shortages and episodes of famine. Still, one should not rule out the possibility that occasionally dietary stress and any subsequent health-related issues might also have been the consequence of cultural practices with social, ideological, and religious reasons ruling people's attitudes to foods and health.

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# Syphilis in South America
# A Closer Look at Pre-Contact Bolivia

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## Introduction

The origin of syphilis, the apparently new venereal epidemic that swept Europe in the sixteenth century, is a longstanding question in the history of medicine.

Treponemal diseases are among the most widespread infections found in humans, and may have affected hominines since the Pleistocene (Rothschild 2005). Venereal syphilis, caused by *Treponema pallidum ssp. pallidum*, was especially dreaded because of its insidious contagion and its painful, disfiguring, and potentially lethal course. This disease was first recognized and described in Europe in the early sixteenth century AD (Fracastoro 1530). At the time, it was already thought to be a plague introduced from the New World. And, indeed, while skeletons from several pre-contact sites in the Americas show symptoms of one of the treponemal diseases, there are no unambiguous cases from Europe before 1500 AD (Roberts 1994).

Here we will present some findings from our interdisciplinary study of the Loma Salvatierra archaeological site that contribute to this discussion by further clarifying a likely origin and route of transmission of syphilis from the Old World to the New.

**Heiko Prümers**

## Archaeology

From 2003 to 2006, the German Archaeological Institute, in collaboration with the Bolivian "Unidad Nacional de Arqueología," undertook excavations at the pre-Hispanic site of Loma Salvatierra (fig. 1) in the northern lowlands of Bolivia (Prümers 2004, 2008, 2009).

The region, called Llanos de Moxos, is one of the largest seasonally inundated savannahs in the world. It forms part of the hydrological system of the Amazon basin, but constitutes a geographic subregion on its own.

Acknowledgments
We want to thank our colleague Dr. Zuzana Obertová, who was involved in the anthropological examination of the first sample of skeletons and found the first tell-tale saber-shin tibia, with which everything started.

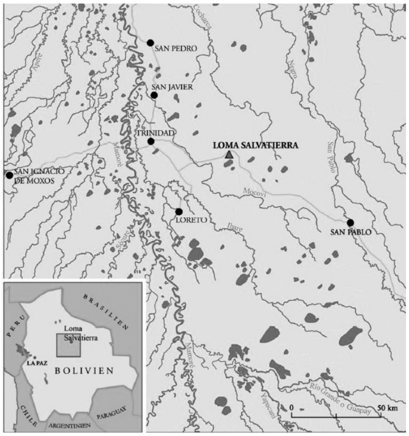



**Figure 1:** Location of the Loma Salvatierra site (Map: H. P. Wittersheim)

In a archaeological literature, the Llanos de Moxos are well known for their earthworks (ridged fields, canals, causeways), built in pre-Hispanic times for agricultural use, which cover extensive areas to the west of the Mamoré river (Barba 2003; Denevan 1964, 1966, 2001; Erickson 1980, 2006, 2008; Lee 1976, 1995, 1996; Lombardo 2010; Lombardo et al. 2011; Michel López 1993, 1999; Saavedra 2009; Walker 2004, 2008). Much less is known about the habitation sites and, consequently, the pre-Hispanic population of the region. Prior to our project, no survey had been carried out, none of the habitation sites had been properly mapped, and only limited excavations had been conducted at the habitation sites (Nordenskiöld 1913; Dougherty and Calandra 1981, 1981–82, 1984).

The Loma Salvatierra site is located in the southeastern part of the Llanos de Moxos, a region that is not exposed to regular flooding and therefore lacks traces of ridged field agriculture. A survey undertaken by our project over an area of 4500 km$^2$ revealed the existence of more than a hundred mound sites, generally situated on fluvial deposits of inactive rivers (Lombardo and Prümers 2010). The size of the mounds ranges from one to more than 20 ha, and their height ranges from two to 21 m. According to the radiocarbon dates from our excavations at Loma Salvatierra and nearby Loma Mendoza, the mounds were occupied between 500 and 1400 AD. A detailed analysis of the ceramics found at the sites allowed us to subdivide the occupation period into five phases (Jaimes Betancourt 2004, 2010; Kupferschmidt 2004) that fit well with major changes made to the outline of the platform buildings.

The center of the Loma Salvatierra site is formed by a low artificial terrace, lying in an oxbow of a palaeoriver. The major platform building (mound 1), rising to a height of 7 m, and some lower platforms (fig. 2) were built on this terrace.

On top of mound 1, low platforms are arranged in a U-shape, enclosing a space that opens to the northwest. The site is delimited by a polygonal causeway running at a distance of approximately 100 m from the central terrace and enclosing an area of 21 ha. To the south are canals, ponds, and dykes, which were most probably used to regulate and/or capture water from the savannah in the south.

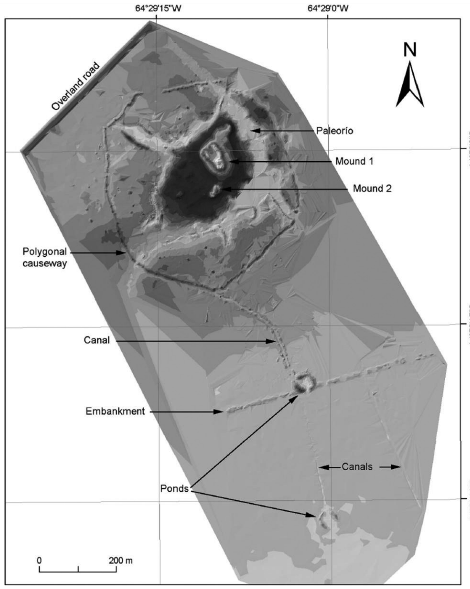



**Figure 2:** Elevation map of the Loma Salvatierra (Graphic: H. Prümers)

Excavation units were placed at different parts of the site. Two of them, located on top of the major platform building (mound 1), revealed a complex stratigraphy, with the events that formed it corresponding to phases 3 to 5. Only a few graves were found here, but in a very good state of preservation. The ceramic found in this excavation unit was of "high quality" throughout the sequence, indicating that the top of mound 1 might have been reserved for special purposes or was perhaps the residence of the "élite."

The excavation unit located on the terrace to the south of mound 1 revealed contexts from all five phases of the sequence. Large amounts of ceramic fragments and animal bones were found in the refuse layers, as well as some graves. Instead of fancy ceramics, domestic wares prevailed, and a high number of spindle whorls and bone tools suggest that the people living here passed much of their time working. So the area corresponds best to what one would call a "domestic area."

An area of more than 200 m$^2$ was excavated in mound 2, an L-shaped platform located to the south of mound 1. Almost fifty graves were uncovered here, and only shallow refuse layers were encountered. These refuse layers are probably the result of funerary rites, although they might also result from a short-lived occupation of the mound.

The graves found across the excavation units were astonishingly diverse in the deposition of the body and its orientation. Seated bodies, and some buried face down, are among the most unusual examples. The intriguing pattern of different positions and orientations is clearly visible in the plan of the graves found in mound 2 (fig. 3).

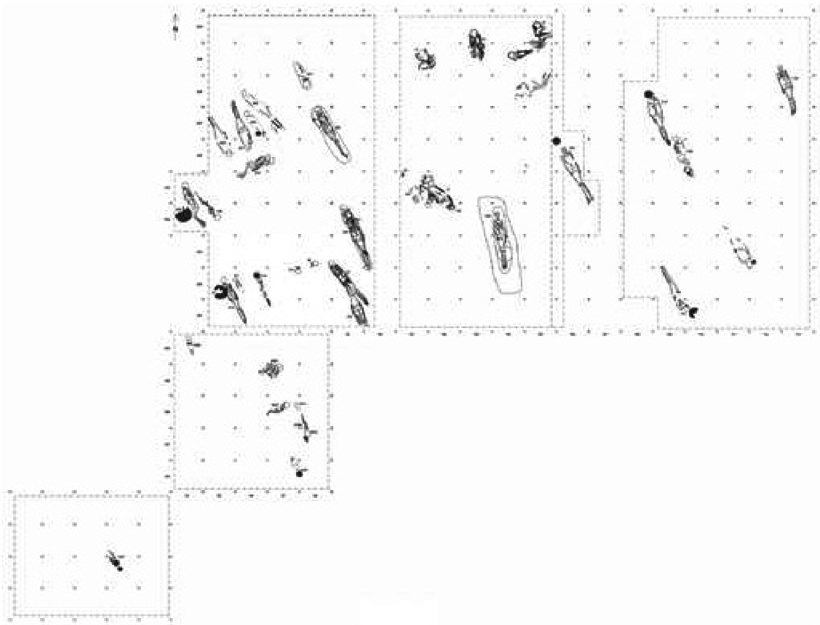


Figure 3:
Plan of the graves found in Mound 2, Loma Salvatierra (Graphic: H. Prümers)

Some graves overlie older ones, clearly indicating that they do not correspond to a single point in time. In determining the chronological order of the burials, we faced two major problems. Firstly, the burial pits were, with very few exceptions, invisible, due to the fact that the fill had the same texture and color as the surrounding soil. Secondly, most of the graves had no offerings at all that would have helped in their dating. Nevertheless, most of them could be ascribed to one of the five occupation phases. The plot in figure 4 illustrates some of the changes detectable in burial practice.

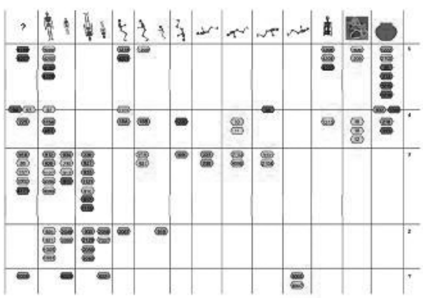


Figure 4:
Distribution of different burial types per occupation phase.

Extended burials with the head to the southeast are present only in phases 2 and 3; burials of children with ceramic plates covering the head are restricted to the early phases as well; burials oriented east-west are present in phases 3 and 4; and urn burials, mostly children, make their appearance in phase 4, along with the seated and face-down burials mentioned above.

An outstanding grave, dating to phase 2, was found in the center of mound 2 at a depth of 3 m. It contained the extended skeleton of an adult man who died at the age of approximately thirty-five (fig. 5).

**Figure 5:**
Grave 1005, Loma Salvatierra. This grave was outstanding for its location at the centre of mound 2 and for the rich grave goods it contained, including copper discs.

Four jaguar tusks and three pendants of blue stone, once part of a collar, were found on the corpse's chest. More than five thousand shell beads were recovered from the torso region, some still aligned in up to seven different strings. The left wrist housed a bracelet of forty-seven carefully worked and polished bone segments. His forehead was covered by a copper disc that probably formed part of a headdress made of organic materials, and thus not preserved. He also wore ear ornaments consisting of smaller copper discs with round segments of armadillo shell on the reverse, and a lip plug made of green stone (amazonite).

To learn more about the 123 individuals whose graves were unearthed in Loma Salvatierra, an interdisciplinary project, funded by the DFG (German Research Foundation), was started in 2009. Some results of this project, which included radiocarbon dating, isotope analysis, and genetics, as well as osteological studies, are presented below.

**Martin Trautmann and Iris Trautmann**

## Anthropology

### Material

Tropical climates are notoriously bad for the preservation of skeletal material. Mineral-poor soil, heavy rainfall, and abundant plant growth cause a rapid deterioration of the bones' mineral structure; they usually vanish completely in a matter of decades. Nonetheless, most of the skeletons found at the Loma Salvatierra site are fairly well preserved, allowing for extensive anthropological and archaeometric study. The position of the graves, deep in the compact clay of the tell-like hill, probably protected the bones from elutriation by rainwater and annual flood, and from destruction by plant roots.

With around 123 skeletons, the Loma Salvatierra site has possibly the largest and best-preserved collection of a pre-contact population in the Amazon region. The skeletons show a mean completeness of 33 percent. Losses were mainly caused by disturbance, rather than erosion. In most cases, the bone matrix is strong and undamaged with only slight surface alterations.

Receiving a DFG grant allowed us to supplement our osteological analysis with more costly physical and chemical methods. Our aim was a complete anthropological assessment of the material, including demography, metric documentation, kinship analysis by anatomical variants as well as aDNA, diet and lifestyle reconstruction, palaeopathology, and mobility behavior.

The C-14 dating of twenty-one selected skeletons was very important, providing us with a sound chronological frame for the study. The dead were interred between the fifth and thirteenth centuries AD, predominantly between circa 650 and 1150. Around 1000 AD, there seems to have been a phase of reduced activity and, perhaps, population: possibly a crisis in the history of the settlement. Although contemporary to the neighboring Tihuanaco culture of the Andean highlands, the region had its own cultural character, with particular ways of adapting to the unfavorable environment.

*Population Characteristics*

The unearthed sample seems representative of a complete, natural population. Spread over the entire period of the settlement's existence, the sex ratio is fairly balanced at fifty-one males to forty-six females; individuals of all ages, from the newborn to the elderly, are represented. Subadult mortality is well within expectations; a somewhat increased mortality of female children may indicate preferential treatment of male offspring. The relative number of very elderly people seems rather low, perhaps because of a slightly above-average mortality rate in all age groups.

Information about external kinship is difficult to obtain, but analysis of the aDNA remains of eighteen individuals put them all in mitochondrial haplogroup C, which is mostly found today in northeastern South America: for example, in northern Brazil and Guyana. Moreover, historical sources report that the former inhabitants of the Beni region were Arawak-speaking tribes, who can still be found in the north of the continent and in the Caribbean. Our data indicate uninterrupted habitation of the Loma Salvatierra site, perhaps with an influx of new settlers around 1000 AD, but with no general replacement of the earlier population. The settlement died out after the early fourteenth century.

*Subsistence*

Information about diet and subsistence strategies is the foundation for all further reconstruction of lifestyle and living conditions. The examined skeletons show typical signs of dental disease closely related to the regular consumption of sticky, high-carbohydrate foods. This type of food—usually grain, or starchy tubers—is cariogenic, and an exceedingly high rate of dental decay is present: almost two or three times that of most mixed agricultural premodern populations. Dental abrasion is also high and of a type characteristic of high cereal consumption and caused by the abrasive grit in flour ground in stone or ceramic mills.

The analysis of nitrogen and carbon isotopes indicates an important role for plant food sources, especially C4 plants, such as maize. Maize was documented at the site by the analysis of starch residues in pottery and by burnt seeds. Animal food sources, such as game and fish, seem to have been a dietary staple until circa 1000 AD. The tall stature of the Loma Salvatierra people, compared with genetically close populations, hints at a stable, high-quality food supply. Later on, isotope data as well as a decline in mean body height indicate a decrease in the availability of animal food sources and maize in the later settlement phases after 1000 AD.

*Palaeopathology*

Skeletons usually show a certain number of stress markers related to physical workload. The Loma Salvatierra population shows an overall high degree of degenerative joint disease, and most individuals also possess strongly developed marks on their bones caused by muscular activity. A handful of individuals seems only slightly affected by heavy work, and, since they also have less dental abrasion (and therefore perhaps higher quality food), it would be logical to identify them as members of a privileged group.

Of special interest is the uncommon absence of physical trauma caused by interpersonal violence. Although the settlement hill has structures that could be fortifications, we found very few injuries, and those were more typical of accidents than violence. The Spanish labeled the Arawak tribes as “peaceful.” Perhaps they were right?

There is no clear evidence of malnutrition: although stress markers suggestive of arrested development phases during childhood—such as cribra orbitalia and enamel hypoplasia—are frequent, the generally tall and robust stature of the subjects indicates a sufficient diet. Therefore, we assume that the stress markers were caused by periods of illness. The Loma Salvatierra population was clearly exposed to a multitude of infectious diseases. For example, the skulls of five children show signs of heavy periostitis (inflammation of the connective tissue surrounding the bones) with plaques of woven bone on the interior side of the skull: probably a symptom of infectious meningitis.

**Figure 6-9:** Skeletal symptoms of treponemal infection

Up to twenty-five individuals show patches of reaction to inflammation on their long bones, especially the tibiae. Although there are many causes for periosteal woven bone growth, the symptoms we found here are peculiar to treponemal infection.

There are multiple active and healed foci of periostitis with woven bone growth and vascularisation, extensive excrescences, and, in some cases, bloated diaphyses with rough thickening of the compacta and spongy filling of the medulla in tibiae, fibulae, ulnae, femora, and humeri.

We also observed a sabre-shin deformation with thickened anterior compacta in the tibiae of at least two individuals, and short and slightly barrel-shaped upper and lower first deciduous incisors, with a central notch (Hutchinson's sign), in one case.

Although these symptoms are pathognomonic for treponemal infections, they are not specific to a particular one. In humans, there are four different afflictions caused by four closely related pathogens (Petzold 2005):

*T. pallidum ssp. pallidum:* venereal syphilis
*T. pallidum ssp. pertenue:* non-venereal yaws
*T. pallidum ssp. endemicum:* non-venereal bejel
*T. carateum:* pinta

Pinta, found in Central and Southern America, is a mild disease of the skin and does not affect the skeleton; it may be therefore ruled out as cause of the observed symptoms. Bejel was common in arid regions of the Old World, as in the Near East, North Africa, and even Bosnia. Yaws, in contrast, is found in warm and humid regions of Africa, Asia, Oceania, and the Americas. Syphilis, which is exclusively a sexually transmitted disease, seems to prefer temperate zones; but today it can be found globally (Idsøe and Guthe 1967).

With the exception of pinta, all treponematoses show the same set of symptoms, albeit with varying degrees of occurrence. Only syphilis can be transmitted to the fetus *in utero* and interferes with dental growth, causing the so-called dental stigmata (notched incisors typical of congenital syphilis). The following table compares the frequency of certain symptoms of these three treponematoses with the findings of the Loma Salvatierra population:

| | syphilis | bejel | yaws | Loma Salvatierra |
|---|---|---|---|---|
| periostitis | + | + | + | + |
| ulcerous lesion | + | (+) | (+) | + |
| gumma | + | (+) | – | – |
| caries sicca | + | (+) | (+) | – |
| medullary closing | + | (+) | | + |
| sabershin-tibia | + | + | + | + |
| gangosa | + | (+) | + | – |
| dental stimata | + | – | – | (+) |

**Table 1:** Symptoms of treponematoses

**Table 2:** Epidemiological characteristics of treponematoses

| | syphilis | bejel | yaws | Loma Salvatierra |
|---|---|---|---|---|
| **% of pop. w/ symptoms** | 5% | 25% | 33% | 6.5 - 20% |
| **# of affected bone parts** | <3 elements | <3 elements | >3 elements | >3 elements |
| **usually affected bone parts** | tibia, frontal bone, ulna, ribs | tibia, frontal bone, ulna, ribs | tibia, ulna, hand, frontal bone | tibia, femur, ulna, fibula |

Although we had some convincing symptoms of treponematosis, we could not arrive at a differential diagnosis with a final degree of certainty due to a considerable overlap in symptoms and the rather atypical picture we got from the Loma Salvatierra finds. Therefore, following Rothschild (2005), we also assessed population epidemiology parameters in the hope of further clarity.

Again, the pattern we encountered was not typical for any of the three infections specifically. The age distribution was also inconclusive: we found nine possible cases in infants up to five years old; only one in a subadult between five and twenty; and fifteen cases in adults over twenty years old. As observed in modern populations, syphilis is usually contracted primarily by sexually active juvenile or adult individuals and only rarely passed on as a congenital infection; yaws, on the other hand, is transmitted by skin contact, the first infection usually occurring at an age of six to ten years (Rothschild and Rothschild 1995).

Since the macroscopic findings alone were not convincing with regard to an unambiguous differential diagnosis, we decided to try for a palaeogenetic proof of the pathogen (DeMelo et al. 2010).

**Sandra Lösch and Carsten Pusch**

## Palaeogenetics

Even in fresh sample material, the identification of *T. pallidum* via polymerase chain reaction (PCR) is not without problems. Bouwman and Brown 2005 showed that ancient samples were useless in their hands and concluded that it is generally impossible to detect treponemal DNA. Due to the DNA degradation in ancient samples, it becomes more difficult to obtain positive PCR results from extracted DNA, even when the morphological symptoms clearly indicate advanced stage III treponematosis.

However, we were able to recover and specifically amplify the polymerase A gene of *T. pallidum* from skeleton samples of the Loma Salvatierra site independently in separate aDNA laboratories in Tübingen (C. Pusch, M. Ball, N. Gaultier) and Munich (A. Nerlich, S. Lösch).

**Sampling and Preparation**

Our investigation used selected samples of thirty individuals from the burial site for testing.

Negative control samples were also obtained from individuals of this population who showed no symptoms of a treponemal infection. All samples were obtained after excavation, during the subsequent thorough examination of the skeletal remains.

Undamaged teeth—mostly molars—were extracted from the jaw and used as sample material. All necessary precautions to avoid contamination were taken (Roberts and Ingham 2008). Sampling was performed under strictly sterile conditions in laboratories dedicated to work with ancient DNA; all involved were wearing clean clothes, sterile gloves, and masks in an environment uncontaminated by modern samples from patients affected by syphilis. Samples were prepared and sent directly from sample suppliers to cooperating laboratories.

To eliminate contamination, all bone surfaces were first cleaned with a 0.5% sodium hypochlorite solution, and then the outer surface was removed mechanically by sterile instruments. After that, the bones were irradiated with UV-light with a wavelength of 255 nm. Material was then taken from the dentine inner part next to the pulpa cavity. This was then used to produce a homogeneous bone powder using a mixer mill.

Other precautions against contamination were also taken, including a strict separation of work areas between sample handling, DNA extraction, PCR set-up, and post-PCR procedures using different laboratories. Fresh sterile filter tips were routinely used, and surfaces and equipment in contact with sample tubes were cleaned before and after each assay. The results were replicated independently in the Munich laboratories. Here, a different methodological approach was used.

None of the laboratories had previous contact with treponemal DNA of either recent or historic origin. Furthermore, extraction protocols of aDNA and work-up of the samples were different in the two laboratory sets, further ruling out mere carry-over or handling contamination.

### Methods of Amplification and Identification of Treponemal DNA

DNA was extracted from all samples according to Scholz and Pusch (1997), purified in a number of subsequent steps, and then subjected to PCR. Some of the crude DNA extracts turned out to be inhibitory, which somewhat correlated with the extracts' color.

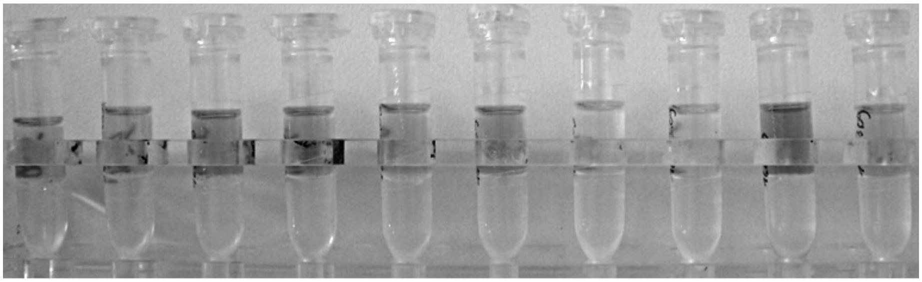


**Figure 10:** Exemplary extraction of ancient DNA from 10 LoSa specimens. Chloroform phase is at the bottom, the aqueous phase showing a spectrum of colors contains nucleic acids.

In these cases, further purification and/or sample dilution prior to PCR was required. The target of the two-step amplification was the gene encoding for the polymerase A of *T. pallidum*. Sanger sequencing of the assays yielding PCR bands of the correct size confirmed that the amplification was specific to the species *T. pallidum.*

Firstly, in order to track the extraction efficiency and to rule out inhibition of the PCR reaction, the presence of DNA was investigated by analysis of the presence of a cytoplasmic human multicopy ß-actin-gene (Nakajima-Iijima et al. 1985). Negative PCR controls were always included. We carried out 40 cycles with an annealing temperature of 60°C using the Veriti 96-w Thermal Cycler (Applied Biosystems, Darmstadt).

For detection of *T. pallidum*, a heminested PCR protocol (Behrhof et al., 2007) was performed with a total volume of 25 µl for each sample, utilizing FastStart Polymerase (Roche). Cycling conditions for the first round of PCR were set with five minutes at 95°C, followed by forty cycles of thirty seconds each at 95°C, thirty seconds at 53°C, thirty at

72 °C, followed by seven minutes at 72 °C. For the subsequent nested PCR, the same conditions were observed, but applying thirty-six cycles. The nested primers locate to the polymerase A coding region of *Treponema pallidum*. We used the primers TPmod-R1, TPmod-F1, and TPmod-F2 according to Behrhof and coworkers (2007). TPmod-R1 and Tpmod-F1 yielded an amplification product of 150bp, and TPmod-R1 and TPmod-F2 finally resulted in a treponemal-specific amplification product of 125bp.

Samples from seven individuals repeatedly provided a positive amplification product of *Treponema pallidum* DNA of the expected size of 125 bp.

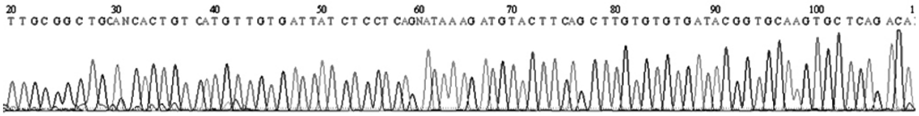



**Figure 11:**
Electropherogram showing the region of the polymerase A gene of *T. pallidum* from sample LoSa0018. The highlighted segment covers the region of the DNA sequence deposited under accession number CP001752.1 in NCBI nucleotide collection.

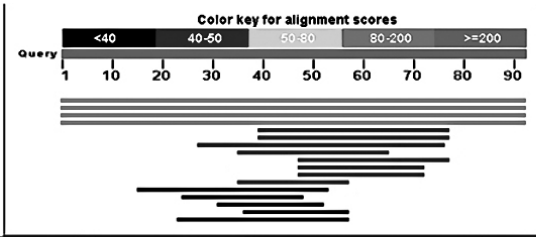
Successful replication tests on one sample were performed in Munich under different conditions: A 50 µL reaction mix was used with 2.5 µL of DNA extract, hot start Taq polymerase (1.25 U), negative and blank extraction PCR controls were always included. We carried out forty cycles of a touch-down PCR, starting annealing at 64 °C, and reducing the temperature after the first five cycles by 0.1 °C every further cycle using the Veriti 96-w Thermal Cycler (Applied Biosystems, Darmstadt).

PCR products were detected on 2 % agarose gels after staining with ethidium bromide and visualisation under UV light. Purification of the PCR products in solution after amplification was performed with “High Pure PCR Product Purification Kit” (Roche, Penzberg Germany), and gel purification of DNA fragments was performed with “NucleoSpin Extract II” (Macherey-Nagel, Germany). DNA sequence integrity of the obtained PCR products was determined by Sanger sequencing employing the initial PCR primers.

Database analyses were done utilizing the BlastN algorithms at the NCBI platform.

## Results

The sequencing of the PCR products resulted in a 100% coverage and a 100% identity of our sequence to the polymerase A gene of *T. pallidum* deposited in the NCBI nucleotide collection with blastN. This result was also replicated in Munich.




| Accession | Description | Query coverage | Max ident |
|---|---|---|---|
| CP001752.1 | Treponema pallidum subsp. pallidum str. Chicago, complete genome | 100% | 100% |
| CP000805.1 | Treponema pallidum subsp. pallidum SS14, complete genome | 100% | 100% |
| AE000520.1 | Treponema pallidum subsp. pallidum str. Nichols complete genome | 100% | 100% |
| U57757.1 | Treponema pallidum PolA gene, partial cds | 100% | 100% |
| CP001357.1 | Brachyspira hyodysenteriae WA1, complete genome | 41% | 86% |
| AF038544.1 | Serpulina hyodysenteriae DNA polymerase I (polA) gene, complete cds | 41% | 86% |
| AJ238762.1 | Rickettsia helvetica ftsY (partial), polA, dnaE (partial) and hicB genes and metK pseudo | 53% | 79% |

**Figure 12:** Blast results against NCBI nucleotide collection with blastN

The data for the polymerase A gene from different subspecies of *T. pallidum* are not yet represented in the databases. Our genetic findings point to *T. pallidum ssp. pallidum*, which is causative for syphilis; but we cannot exclude the possibility that, for example, the closely related disease yaws, caused by *T. pallidum ssp. pertenue*, shows the same nucleotide sequence in the targeted PCR amplicon. Therefore, ongoing research will focus on the known SNPs of different treponemal strains and substrains for clarification of the exact pathogen and its evolutionary context in history.

Furthermore, we suggest that good results can only be expected with samples from individuals suffering from stage I or II treponematosis, but not manifest stage III showing the more obvious morphologically diagnostic osseous symptoms. This is presumably because treponematoses are refractory to PCR amplification, since the treponemal titer is obviously far too low in the respective individuals (Behrhof et al. 2007). Higher titers are known from the early stages of syphilis corresponding to stage I and II. In other words, bones with an obvious pathology of treponematosis would be less useful in ancient DNA analyses.

## Conclusions

The excavations at the pre-contact settlement site of Loma Salvatierra in lowland Bolivia turned out to be an archaeological source of the highest importance. It became evident that large, independent, specialized, and complex societies existed in the Amazonian basin, contemporary to the Andean civilizations, showing a high degree of adaptation to a challenging environment.

Even in the first millennium AD, these populations were plagued by an insidious disease: venereal syphilis, which caused a global epidemic starting in the Age of Exploration, about 1500 AD. Our results demonstrate conclusively that the pathogen *Treponema pallidum ssp. pallidum* was already present in populations that settled northeastern South America, and presumably also the Caribbean.

In accordance with Harper et al. (2008), who reconstructed a phylogenetic tree of Treponema, we suggest that an American branch of yaws may have developed into an early strain of syphilis. The close vicinity of warm, humid conditions to cool and arid ones in the Amazonian-Andean transition zone would have been the perfect stimulus for the pathogen's adaptive changes. After 1300 AD, when the Llanos de Moxos were deserted, the disease could have spread—presumably through migrating Arawak-speaking tribes—towards the Caribbean.

This model would strongly support the hypothesis that Columbus's crew contracted the disease from contact with native peoples and brought it to Europe, from whence it spread worldwide.

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# History of the Plague

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## The Plague—An Introduction

The infectious disease known as the Plague is caused by the bacterium *Yersinia pestis*, a gram-negative, facultative anaerobic, rod-shaped bacterium belonging to the *Enterobacteriaceae* family. It is a zoonosis found chiefly in feral rodents, spread in the main by infected fleas. Plague epidemics in human populations can, however, occur when the *Yersinia pestis* pathogen invades rat populations that live in close proximity to humans. Once the rats have been largely killed off by the disease, the infected fleas move to human hosts.

In human infections, we differentiate between four possible forms of the plague: bubonic plague, septicemic plague, pneumonic plague, and abortive plague. Bubonic and pneumonic plague are the two most common variants. Bubonic plague is usually triggered by a bite from an infected flea. Following an incubation period of two to seven days, the first symptoms appear: severe malaise, fever, headaches and joint pain, and dizziness. Lymph nodes and lymphatic vessels in the area of the flea bite swell to form sores with a diameter of up to ten centimeters. These sores change color in the course of the sickness, often appearing blue or black due to internal bleeding in the lymph nodes. Without treatment, bubonic plague often leads to septicemic plague, in which the pathogens (*Yersinia pestis*) enter the bloodstream and thus attack the whole body. Septicemic plague causes large-scale bleeding in the skin and internal organs, and is almost always fatal without treatment. If pathogens spread to the lungs, pneumonic plague can develop (secondary pneumonic plague). In this form, pathogens can also be transmitted from person to person by droplet infection (primary pneumonic plague). The incubation period until the first symptoms appear can be from only a few hours up to a full day. Without treatment, pneumonic plague leads inevitably to death in between two and five days. By comparison, the abortive plague is rather less drastic; its symptoms are usually a mild fever and some swelling in the lymph nodes, and it provides long-term immunity to the plague bacterium.

The Plague, and thus its originator *Yersinia pestis*, have been linked to many epidemics in the history of humankind. The only completely proven incidence of the Plague, however, is the most recent worldwide outbreak, which occurred at the end of the nineteenth century (the Third Pandemic); the *Yersinia pestis* pathogen was first identified during this pandemic (Yersin 1894).

Whether the Plague of Justinian in late antiquity (the First Pandemic) was caused by the same bacterium remains to be seen: molecular geneticists have so far not been able to find conclusive proof. The outbreaks known as the Antonine Plague (165–180 AD) and the Plague of Athens (430–426 BC) are generally assumed to have been expressions of other infectious diseases rather than the plague in its strictly medical sense. However, in recent years, the fields of molecular genetics and immunology have been able to provide ever more convincing evidence that *Yersinia pestis* was the pathogen that caused the Black Death (the Second Pandemic) in the Middle Ages (Raoult et al. 2000; Garrelt and Wiechmann 2003; Drancourt et al. 2007; Wiechmann, Harbeck and Grupe 2010; Haensch et al. 2010; Tran et al. 2011; Kacki et al. 2011; Schuenemann et al. 2011).

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**Ole Jørgen Benedictow**

## The Origin and Early Spread of *Yersinia pestis* and of Epidemic Plague: Palaeobiological and Historical Viewpoints

A recent paper by a team of microbiologists headed by G. Morelli, Y. Song, and C. J. Mazzoni demonstrates the great opportunities offered by the new science of palaeobiology for advancing knowledge of the evolutionary development of infectious diseases—in this case, the bubonic plague—and the indispensable importance of interdisciplinary cooperation with historians (Morelli et al. 2010). They conclude convincingly that "plague originated in East Asia, perhaps in China Proper, more likely in Mongolia or Eastern Russia (Eastern Siberia) "[over] 2,600 years ago" and "spread through multiple radiations to Europe, South America, Africa, and Southeast Asia." However, they also refer to the development of biovars and various strains in claiming that "the geographical sources and evolutionary branch order of [the biovar of] 2.MED[ievalis] subpopulations, which arose [over] 545 years ago" and that other data "supports the westward spread of 2.MED from China through trade articles that were carried along the Silk Road," the extensive trade route from China to Western Asia "between 200 [BCE][1] and 1400." They also claim that "the estimated age of [the biovar of] 1.ANT[iqua]1 (628–6,914 years ago) slightly predates the extensive voyages from China led by Zheng He between 1409 and

1433. They conclude that, "It seems highly likely that these ships were infested by rats, which could have transmitted *Yersinia pestis* from China to Africa."

A historian of epidemic diseases will note that, firstly, the indicated routes of spread are not supported by concrete, tenable evidence; in fact, they are at variance with the evidence, and out of chronological/historical sync with other data and events. Secondly, the references to bubonic plague in Chinese sources are both late and sparse when compared with the much earlier, quite numerous references in classical Greek, Hellenistic Greek, and ancient Roman sources. There are also substantially earlier references to bubonic plague, especially the Biblical account of epidemic events associated with the war between the Philistines and the Israelites in approximately 1100 BCE.

Morelli et al.'s biological determination of an East Asian origin of *Yersinia pestis* seems convincing and undoubtedly represents a major scholarly achievement. However, the fact that the earliest references by far to the bubonic plague concern regions on the Mediterranean littoral needs explanation, in order to make these seemingly disparate pieces of information compatible.

Morelli et al.'s attempts at explaining the historical spread of *Yersinia pestis* across the Eurasian continent by transportation along the Silk Roads, or transportation to Eastern Africa by Zheng He's maritime expeditions in the period 1409–1433, must be deemed untenable. There are also serious problems or at least weaknesses associated with their dating of the time of its origin, and the spatio-temporal pattern of its spread, using biomolecular clocking techniques.

This calls for a possible alternative explanation(s) of how *Yersinia pestis* could have spread out of its original homeland in East Asia, which should be compatible with the spatio-temporal perspectives provided by historical sources. Such an explanation could be based on a notion of the natural pace of the spread of plague disease, caused by *Yersinia pestis*, in sylvatic (wild) rodent populations.

A similar event can serve as a useful basis for clarification of this question. In June 1900, plague entered a new continent, namely North America, in San Francisco. Seventy-five years later, plague had penetrated into 12 states and had crossed the middle of the United States at 100$^{o}$ longitude, a distance of around 2000 km (1250 miles) from

San Francisco, and had also invaded Canada in the north and Mexico in the south. The average spread rate had thus been of the order of 25 km (16 miles) a year. McNeill (1979, 152–55, 272) concludes his discussion by saying that "the geographic spread of plague infection in North America occurred naturally." It was basically passed on between colonies of ground-burrowing rodents.

At a similar pace of spread, plague would have covered the roughly 8000 km from a central location in East Asia to the Middle East in about 320 years; or about 400 years at 20 km per year. This estimate can now be juxtaposed with Morelli et al.'s conclusions that "*Yersinia pestis* evolved in or near China" over 2,600 years ago, but also that 1.ANT1 developed 628–6,914 years ago; they seem to envisage an age of *Yersinia pestis* in East Asia 6,914 years ago, and that the real age would include the time of its spread to East Africa and the development of the biovar. The natural spread rate of plague is compatible with the historical data, and within the enormous margins of uncertainty inherent in biomolecular dating techniques.

In the Middle East, *Yersinia pestis* would become connected to the black rat and *Xenopsylla cheopi*s, "the rat flea *par excellence*," as it has often been called. Black rats and their fleas have been central in all plague epidemics studied by modern physicians and epidemiologists and the specific defining features of rat-borne plague can be observed with respect to historical plague epidemics. Maps of the global distribution of plague foci of various species of wild rodents show that they stretch almost continuously from Manchuria to the Middle East. After arrival in the Middle East, *Yersinia pestis* could easily have been spread by human agency to western Arabia and further to Central East Africa, triggering the formation of plague foci there.

Clearly, the bubonic plague pathogen originated in East Asia and spread westwards from there. The epidemic powers of plague (as distinct from the epizootic powers) may have evolved in the Middle East, where the black rat and *Xenopsylla cheopis* were present, producing the basic requirements for the adaptation and spread of the plague in human populations. In order to become an epidemic disease spreading in human habitats the disease would have to be introduced among rodents in human habitats with fleas that would also attack and transmit the disease to human beings. Conditions in the Middle East were well suited to allow a transformation of the patterns of the spread of plague. If so, this could have triggered a new phase of plague that spread back eastwards, with profound epidemic implications that may not be easily identifiable with palaeobiological tools.

Clearly, *wherever* plague's ancestral homeland was, the temporal perspectives provide superabundant time for plague to spread westwards all the way across the Eurasian continent, cross into Africa, and establish the plague foci of the Middle East, the western coastal areas of Iran and Arabia, and Central Eastern Africa. The establishment of these foci would constitute the basis for the biblical account of pre-classical plague, and the classical plague epidemics and clinical descriptions of plague in classical medical works.

This transcontinental spread of *Yersinia pestis* could quite likely have occurred long before antiquity and have caused spread all the way back to China, in time to establish the epidemic combination of the black rat and *Xenopsylla cheopis* and the necessary conditions for plague epidemics much earlier—perhaps even thousands of years earlier—than the "2,600 years ago" suggested by Morelli et al. It raises essential and interesting questions about the possible adaptations between the black rat and *Xenopsylla cheopis* and the biovars and various strains of *Yersinia pestis* encountered on such a journey. Would significant adaptation by selection be necessary at all? Or would the existing adaptations selected by *Yersinia pestis* in relation to various combinations of rodent fleas and their sylvatic rodent hosts function readily and well with *Xenopsylla cheopis* and the black rat?

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Raffaella Bianucci and Sacha Kacki

## The Archaeology of the Second Plague Pandemic: An Overview of French Funerary Contexts

Over the last 20 years, several plague mass graves have been unearthed in France, thus enhancing our knowledge of historical plague pandemics. Moreover, recent archaeo-anthropological and palaeoimmunological investigations have shown that abrupt mortality crises caused by plague have been handled differently in urban and rural communities (Kacki et al. 2011). In this paper, we report on the different funerary contexts and the related practices adopted by some French urban and rural communities during the Second Pandemic (1348–1722 CE).

Several eighteenth-century urban plague burial sites have been uncovered in France. Most of them date to the "Great Plague," which occurred in Provence and Languedoc during 1720–1722. It has been estimated that the Marseilles "Great Plague," which started on 20 June 1720, affected 242 localities and resulted in 119,811 deaths out of a population of 394,369 individuals (Signoli et al. 2002). In urban centers, such as Marseilles ("The Observance Pit" and "The Major Pit") and Martigues ("Le Délos" and "Le Couvent des Capucins"), plague epidemics caused the death of dozens or even hundreds of people daily. This led to the digging of large pits or trenches, where the deceased were buried. We can pinpoint a number of differences in the funerary treatments of these eighteenth-century victims, mainly linked to the patients' admission through the plague infirmaries. To sum up, two different kinds of plague victims can be identified within the mass burials:

1. Those skeletons found together with personal belongings correspond to the plague victims who died outside the infirmaries and who were found dead several hours, or even days, later. They were buried fully dressed, along with their belongings, because gravediggers wanted to minimize contact with the infected bodies.

2. Skeletons found without any personal belongings correspond to the victims who died in the plague infirmaries and were buried according to the sanitary restrictions adopted during the plague epidemics, i.e., undressed and wrapped in shrouds. The transit through the plague infirmaries resulted in a slower rhythm of inhumations,

which corresponded, in general, to the period of time between the declaration of the patients' contagion and their deaths. This, in turn, resulted in a more rational handling of the infected corpses.

Working backwards from the eighteenth to the seventeenth century, and moving away from urban contexts to rural ones, we have a single example of a plague cemetery at our disposal. This site, located close to the Puy-Saint-Pierre village (Hautes-Alpes), dates back to the plague epidemic that devastated the upper Durance River valley between 1629 and 1631 (Signoli et al. 2007). In this plague cemetery, there was an attempt to maintain the customary funerary practices, with interments in individual graves. Whenever higher rates of mortality were reached, double graves were dug; and, finally, multiple graves were dug at the highest peak of the epidemic. It is likely that this cemetery was connected to a nearby infirmary. The construction of temporary wooden burial structures was common in France, starting from the plague epidemics at the end of the fourteenth century. These structures were built in haste at the very beginning of the contagion and were burned at the end of the epidemic.

For the period between the fourteenth to the sixteenth centuries, very few data concerning the impact of plague on the demographic structure of rural communities are available, although 90 percent of the French population was living in the countryside at that time (Benedictow 2004). Therefore, only archaeological data can provide information both about the spread of plague in rural areas and about changes to funerary practices during the epidemics. However, few examples of French rural plague cemeteries are known so far, which might be influenced by the demographic structure of rural populations. In fact, while plague epidemics caused the deaths of several dozens or hundreds of people daily in urban centers and often led to the digging of huge plague pits or trenches, in small rural communities the death toll was much lower. The number of victims to be buried was thus far smaller. It would therefore be managed much more easily by the gravedigger(s), and this made it easier to uphold the tradition of interment in single graves.

One example of the ordered and rational handling of plague victims achieved by the digging of a majority of single graves has been reported at "Les Fédons" rural plague cemetery (Bizot et al. 2005). This graveyard was associated with a plague infirmary and dates to the outbreak that occurred in Lambesc, southeastern France, between April and September 1590. Almost all corpses were laid in dorsal decubitus position (i.e., lying stretched out on their backs) with their heads oriented to the east. Once again, it appears that the funerary practices observed here are similar to those adopted in a context of normal mortality.

Finally, concerning the "Black Death" rural plague cemeteries, there is evidence so far of only two cemeteries, which are located close to the villages of Vilarnau (Passarius et al. 2008) and Saint-Laurent-de-la-Cabrerisse (Haensch et al. 2010; Kacki et al. 2011). In both cemeteries, most of the plague victims may have been buried in single graves, and mass graves were dug only when the mortality rate peaked. Even in these cases, most of the individuals were deposed in dorsal decubitus position, showing the same orientation as the other deceased (fig. 1). This shows that, although the increased mortality may have led to the simultaneous inhumations of several individuals in the same pit, customary funerary practices were not substantially modified.

**Figure 2:** Positive identification of *Yersinia pestis* F1 antigen and caf1 gene in sample SLC1006 from Saint-Laurent-de-la-Cabrerisse burial site.

Where plague victims are buried in single graves and the usual funerary practices maintained, no archaeological evidence allows us to distinguish between plague burials and ordinary graves. On these grounds, the application of biological techniques such as RDT and PCR may permit us better to characterize the demographic impact of plague on rural communities (fig. 2).

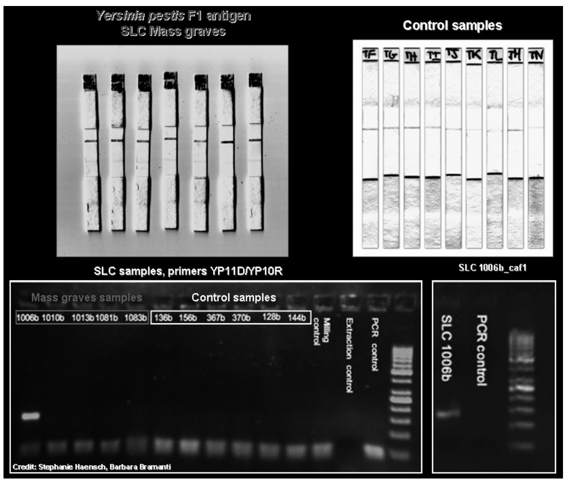


**Figure 1:** Double grave SLC141 from Saint-Laurent-de-la-Cabrerisse burial site. The excavation of double graves might correspond to punctual peaks of mortality. © A. Gaillard (Acter archéologie) / S. Kacki (Inrap).

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# Hypothyroidism in Switzerland

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## Introduction

Hypothyroidism is a condition of mild to severe impairment of physical and mental development due to an untreated deficiency of thyroid hormones, and can be endemic, genetic, or sporadic. Endemic hypothyroidism arises from a diet deficient in iodine. The most common iodine deficiency disorders are goiter (enlarged thyroid gland) and hypothyroidism at all ages, as well as endemic cretinism,[1] mental impairment, delayed physical development in growing children (Iglesias and Diez 2008; Zimmermann, Jooste, and Pandav 2008; Zimmermann 2009, 2010).

Populations living in iodine deprived areas such as the Himalayas, the Andes, and the European Alps, are most at risk. In the Alpine region of Switzerland endemic hypothyroidism was very common until the beginning of the twentieth century. The aim of this study is to present the theme from three different, but complementary perspectives. The medical perspective lays the groundwork regarding the pathophysiology, the clinical picture, and the differential diagnosis of the condition. The historical perspective presents contemporary scientific studies on conscription and published data on goiter and cretinism as endemic manifestations of hypothyroidism (since 1900) and the archaeo-anthropological perspective reports one of the first documentations of the condition in an archaeological population from Switzerland (11th–15th century AD). Together, they offer insights into a significant health problem and contribute significantly to the biological history of the Alpine regions.

The interdisciplinary approach of this contribution brings together different fields with different methods and sources of information. This is necessary, since medical, historical, and anthropological sources for the period before 1900 are extremely limited and, in some cases, completely absent. By comparing medical background, skeletal manifestations

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1 The use of the term cretinism and cretin—referring to severely stunted physical and mental development due to lack of thyroid hormones—is made for the sake of medical, historical, and social facets that the disease shaped during the beginning of the twentieth century and by no means entails a negative connotation.

in the Swiss population past and present, and historic and modern survey data, we gained new insights into a highly complicated, but also significant, health and social problem, namely hypothyroidism. The overlap between the three disciplines both in terms of actual data—e.g., variation in stature between hypothyroid and non-hypothyroid individuals—and also in terms of theoretical background underlines the need for interdisciplinary studies such as this. To our knowledge, this is the first time that hypothyroidism in Switzerland has been the subject of a multidisciplinary study, and we hope that this paper will offer insights and motivation for the study of the condition in the neighboring Alpine regions of Germany, Italy, and Austria.

**Frank Rühli**

## Hypothyroidism: A Medical (Bone) Perspective

The aim of this first, medically oriented section is not only to list the clinical classification of various types or etiologies of hypothyroidism, but also to present specifically selected cases of hypothyroidism as found in the so called "Galler collection," a bone pathology reference series from the University Hospital, Zurich, mostly circa 1940–1970 (for some general information on this, see Rühli, Hotz, and Böni 2003).

Within the thyrotrophin cycle, hypothyroidism is defined as a lack of lack of triiodothyronine (T3) and thyroxine (T4), and can severely affect tissue development and remodeling. The main skeletal manifestation of hypothyroidism is delayed epiphyseal fusion (affecting the axial skeleton and long bones), resulting in short hands, limb asymmetries, changes in skull form such as sella turcica, or osteoporosis. Other manifestations (psychological, soft tissue) are: fatigue, decreased heart rate, weight gain, problems with memory and concentration, depression, goiter (enlarged thyroid gland), muscle pain, dry swollen skin, and irregular menstrual periods (in women).

Thyrotrophin-releasing hormone (TRH) is released from the hypothalamus via specific vessels to the hypophysis (pituitary gland), and, in turn, thyrotrophin or thyroid-stimulating hormone (TSH) from the hypophysis regulates the thyroid function. Iodine is needed (ca. 200 µg/day) in order to correctly synthesize the hormones T3 and T4 produced by the thyroid. T3 and T4 increase the general metabolism, sensitivity to catecholamines (organic compounds that act upon the heart among other organs); or calcium, and phosphate metabolism. Inborn variants of hypothyroidism (thyroid hypofunction) are aplasia (absence of an organ), dysplasia (alteration of cells or of a structure), and hormone resistance (receptor defects), and acquired variants are iatrogenic (i.e., resulting from medical treatment, such as through iodine exposition or following an operation). Primary variants are a lack of iodine or autoimmune thyroiditis (inflammation of thyroid gland; "Morbus Hashimoto"); a secondary variant is a lack of TSH (hypopituitarism); tertiary variants are a lack of TRH or disruption of the portal system (Pickardt syndrome, or interruption of the vein system connecting hypothalamus and pituitary, e.g. due to tumors). In Switzerland, 757 cases of hypothyroidism in newborns have been reported since 1977 (ca. 1:3500). There is regular screening of infants at day four or five after birth. Severity grades are: latent/compensated (only TSH is elevated); subclinical (T3 and T4 lowered, but no symptoms); and manifest (symptoms).

An exemplary case of "cretinism" from the Galler pathological bone-reference series from the nineteenth and twentieth centuries in Switzerland (Rühli, Hotz, and Böni 2003) is presented here, together with clinical case reports, as well as autopsy findings. One 79-year-old male individual in the Galler series, who was 160 cm tall, had particularly strong signs of hypothyroidism. The autopsy findings reported, among other indications, a cretinoid habitus as well as a struma diffusa on the x-rays.

In general, skeletal manifestations of hypothyroidism (thyroid hypofunction) in the Galler cases are: kyphoscoliosis, large cranium, proportional dwarfism, cretinoid habitus, renal osteopathy (fibro-osteoclasia), hyperostosis frontalis interna (thickening of the inner table of the frontal bone), coxarthritis, osteoporosis (mild/severe), and club foot. Causes of death were: subdural hematoma (cerebral hemorrhage) from a fall, pneumonia, heart failure, and uterus corpus carcinoma.

Kaspar Staub

## Historical Perspectives on Hypothyroidism in Switzerland: Endemic Iodine Deficiency, Goiter, and Cretinism since the Late Nineteenth Century

Switzerland was one of the few countries to become completely iodine sufficient before 1990 (together with some of the Scandinavian countries, Australia, USA, and Canada), and was a world pioneer, introducing its iodized salt program in 1922 (first in Canton Appenzell AR, then subsequently all over Switzerland, operating uninterrupted since then). The consensus among researchers is that iodine prophylaxis was the decisive factor in eradicating substantial risks of iodine deficiency and preventing endemic goiter and cretinism during the first half of the twentieth century (Bürgi, Supersaxo, and Selz 1990; Zimmermann 2008). This section will summarize this process since its inception in the late nineteenth century.

Prior to the introduction of the iodized salt program, Switzerland was severely iodine deficient. Goiter and "cretinism" were widespread in alpine areas and the foothills of the Alps. Surveys have been made since the beginning of the nineteenth century. For example, a census ordered by Napoleon reported four thousand cretins among the 70,000 inhabitants of Canton Valais in 1800. Many travelers to Switzerland reported the devastating endemic of goiter and cretinism; for example, Mark Twain, who stated in 1884: "I am satisfied. I have seen the principal features of Swiss scenery—Mount Blanc and the goiter—and now for home." Goiters appeared also in numerous illustrations and chronicles (Bürgi, Supersaxo, and Selz 1990; Zimmermann 2008; Merke 1971).

Since the 1880s, scientific studies and surveys based on data from schoolchildren and military conscripts showed the degree and regional spread of goiter and cretinism. In 1889, Theodor Kocher showed in his goiter survey of around 80,000 schoolchildren in the Canton of Bern that 20 to 100 percent of the seven to sixteen-year-old children had goiters. In 1883, Heinrich Bircher had already demonstrated the regional prevalence of military service exclusion due to large goiters in Swiss conscript data for the period 1875–1880, mapped down to village level. The enormous variation from one village to another was explained by differences in soil geology and water supply (the presence of some kind of goitrogenic agent). These early researchers failed to consider iodine deficiency as the cause, even though the relationship between iodine deficient soil/water and goiter had already been established by Chatin in 1850/1860 (Bircher 1883; Bürgi, Supersaxo, and Selz 1990; Zimmermann 2008; Merke 1971).

For the period 1884–1891, the Swiss Army published the percentage of 19-year-old conscripts found unfit for service because of large goiters (N≈170,000), mapped down to district level.[2] Various contemporary studies mapped the prevalence of goiter across districts, highlighting the comparative rarity of large goiters causing military unfitness (less than 4 percent) in the western part of Switzerland (Cantons Jura, Neuchatel, Vaud, and Geneva), whereas the Alps, the foothills, and the midlands from southwest to northeast were areas of high prevalence (greater than 7 percent). For the conscription years 1920/21, Otto Stiner drew a new district map, including not only large goiters leading to unfitness in his calculations, but also smaller goiters of conscripts fit for service (fig. 1). Stiner's map consolidated the findings on regional goiter prevalence, but this had now risen to 30 percent of young men in certain regions. In the literature, the low goiter prevalence in western Switzerland is explained by the fact that the Jura was not covered by ice during the last two ice ages, so iodine in the soil had not been washed out. Furthermore, the marked contrast in goiter prevalence between the two Cantons of Vaud (low) and Fribourg (high) can be explained by the fact that, in contrast to Fribourg and other Cantons, Vaud had its own salt mine at Bex, which was rich in iodine. In 1924/25, new exact instructions on the grading of palpable goiters were implemented. The goiters did not have to be large enough (e.g. leading to unfitness) to be recorded. Now, the district-wide prevalence increased to a range from 5 to 82 percent of young men having goiter, with 29 of the 136 districts reporting a prevalence of over 50 percent (Bürgi, Supersaxo, and Selz 1990; Eggenberger 1923; Stiner 1924; Stiner 1928).

Between 1900 and 1920, iodine deficiency became accepted as the main causative factor for endemic goiter and cretinism in Switzerland. Between 1910 and 1920, Theodor Fellenberg, a federal chemist, measured iodine levels and confirmed that in goitrous regions soil, rock, water, milk, and other locally produced food contained little iodine. He stated that large areas of Switzerland were grossly iodine-deficient (Solca et al. 1999). Around 1920, the idea of iodine prophylaxis in schools was put into practice in the cities of Zurich and Bern, with great success. Medical examination by the

2 According to the instructions, a large goiter that caused breathing problems or which was strongly disfiguring was a reason for unfitness to serve. Medical examination during conscription was standardized and compulsory from 1875 onwards.

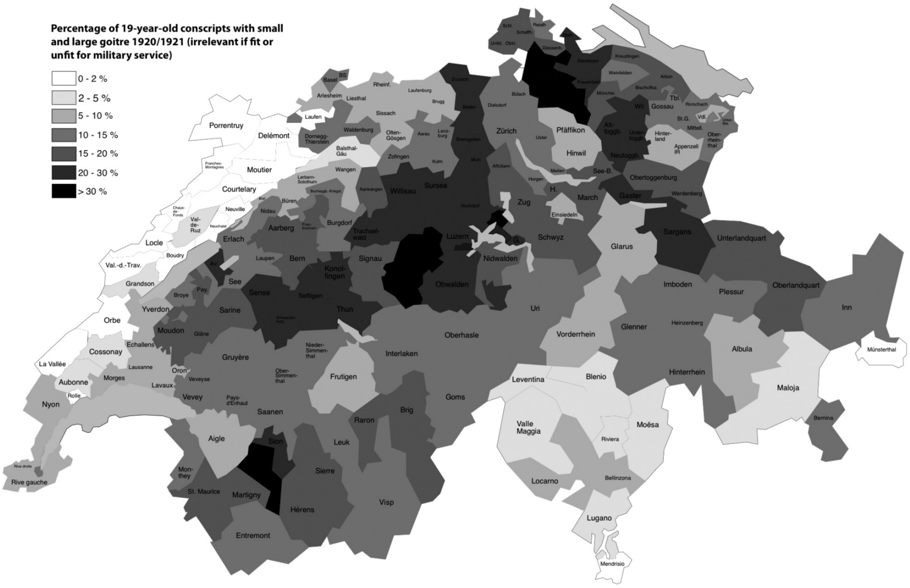


Figure 1: Percentage of small and large goiters in Swiss conscripts 1920/21 (Stiner 1924, 1928).

school medic in the City of Bern showed that 60 percent of all fifth graders had at least a visibly enlarged thyroid. Gradually, beginning in 1921, all first graders, and then every subsequent year all children of other grades, were supplied with one tablet of 0.003 g iodine each week. The fifth graders first received the tablets primarily in 1926, and the prevalence of enlarged thyroids immediately decreased (Bürgi, Supersaxo, and Selz 1990; Lauener 1936; Zimmermann et al. 2008; Staub 2010).

Final steps towards the introduction of iodized salt were made by successful *in situ* tests by H. Hunziker and O. Bayard around 1920 (Bürgi et al. 1979). Hans Eggenberger, a surgeon in Herisau (Canton Appenzell AR), started a campaign and petition to the government, which in 1922 allowed the distribution of salt containing 7.5 mg iodine per kg. The salt was first iodized by Eggenberger himself and his family. The results were spectacular: within a year, existing goiters had shrunk in 66 percent of the schoolchildren whose families used iodized salt on a regular basis, and the average surface area of the thyroid shrank to an invisible and normal level after four years of prophylaxis. Furthermore, newborn goiter disappeared; no babies showed physical signs of hypothyroidism (Bürgi, Supersaxo, and Selz 1990; Zimmermann 2008; Eggenberger 1922).

In 1922, the Swiss Federal Office of Public Health appointed most of the people engaged in goiter research as members of the Swiss Goiter Commission in an advisory function. In June 1922, the committee cautiously recommended that the twenty-five Cantons commence sale on a voluntary basis of salt containing 1.9 to 3.75 mg iodine per kg; non-iodized salt remained available. Every Swiss Canton had its own salt monopoly, and each cantonal government could decide whether to iodize its salt. After the breakthrough in Appenzell AR, other Cantons complied with the recommendations with varying degrees of zeal; by 1930, iodized salt had reached 50 percent of all salt sales in only thirteen of the twenty-five Cantons. Opposition came from ignorance of the iodine deficiency theory and from fear of a massive outbreak of hyperthyroidism (Bürgi 2010). Iodine prophylaxis did not attain full acceptance in all Cantons until the 1950s (Bürgi, Supersaxo, and Selz 1990; Zimmermann 2008).

Thus, iodized salt was the decisive factor in eradicating endemic goiter and cretinism in Switzerland, and also in preventing other iodine deficiency disorders (fig. 2). The percentage of conscripts unfit for duty due to large goiters, severe mental deficiency, and height of under 156 cm decreased markedly as the use of iodized salt increased between 1920 and 1950. Large goiters in recruits had disappeared by 1950 (except in two Cantons, which had not introduced iodized salt: Basel-Land and Aargau).

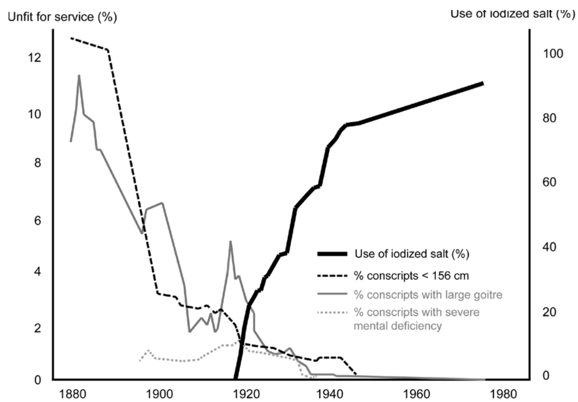


**Figure 2:** The results of the Swiss iodized salt program since the 1920s (Bürgi, Supersaxo and Selz 1990).

In the 1980s, only 5.2 percent of conscripts had a palpable but not visible goiter, 0.26 percent a slightly visible goiter, and 0.04 percent a visible goiter, but not one single conscript was found unfit because of goiter (Schmid et al. 1980). Although it has clearly declined, goiter may still occur today; but only at a clinically irrelevant level (Bürgi, Supersaxo, and Selz 1990; Zimmermann 2008). Iodized salt has without any doubt been the most cost-effective preventive health measure ever applied in Switzerland (Bürgi, Supersaxo and Selz 1990; Bürgi 1986; Steck et al. 1999).

Christina Papageorgopoulou

## Hypothyroidism in Alpine Medieval Switzerland

Hypothyroidism has practically never been described in a historic or prehistoric population, except in clinically documented case studies (Ortner and Hotz 2005). This section reports one of the first documentations of hypothyroidism due to iodine deficiency in archaeological populations, in this case the presence of endemic hypothyroidism in a medieval Swiss Alpine community, thus contributing significantly to the biological history of the Alpine regions. Furthermore, the large sample number adequately describes the variability of the skeletal manifestations and the epidemiological pattern of the disease.

The skeletal sample consists of 404 adult and subadult individuals, originating from the archaeological site of Tomils/Sogn Murezi and dating from the eleventh to fifteenth centuries AD. Tomils is located in the Alpine region of the canton Grisons, Switzerland, a thousand meters above sea level. The skeletal material was examined for all standard anthropological variables (e.g., age and sex determination, cranial and postcranial metrics, pathological conditions; Papageorgopoulou 2008). Where necessary, the bones were x-rayed at the University Clinic Balgrist (Zurich, Switzerland).

For the diagnosis of hypothyroidism, a list of observed pathological features characteristic for the condition were examined and statistically tested based on related literature (e.g., Borg, Fitzer, and Young 1975; Guggenbühl 1853; Evans 1952; Reilly and Smyth 1937; Scholz 1906) and clinical studies from the region of Switzerland (e.g., De Quervain and Wegelin 1936; König 1968; Weygand 1904; Wieland 1940). We also performed macroscopic and radiological comparisons of diagnosed cases of hypothyroidism from Switzerland in the nineteenth and twentieth centuries (Galler pathological reference series, University of Zurich). The epidemiological pattern of the disease was analyzed, and further pathological (dental condition, degenerative joint disease, trauma) and archaeological parameters (interment within the cemetery) were tested.

A high frequency of delayed epiphyseal fusion, in both the axial skeleton and the long bones; hip and shoulder epiphyseal dysplasias; limb asymmetries and/or abnormal length of the long bones; and epiphyseal growth plate problems (osteochondritis dissecans) were present in the skeletal material (table 1). Additionally, cranial characteristics such as short face; large piriform aperture; wide nasal root; brachycephalisation; prognathism; and anomalies in tooth position and eruption were observed in hypothyroid individuals. Statistically significant differences have been noted between hypothyroid and non-hypothyroid skulls, mainly concerning facial cranial measurements (M7, M9, M10, M11, M16, M40, M42, M45, M61, M63, M66, M79 after Martin 1914).

| **Skeletal Manifestations of Hypothyroidism in Tomils** | |
|---|---|
| Vertebra column: delayed apophyseal fusion, unfused odontoid | 20.3% |
| Sternum: delay in ossification | 10% |
| Extremities: delayed epiphyseal fusion, asymmetry | 15.2% |
| Hip and shoulder unilateral and/or bilateral dysplasias | 2.2% |
| Epiphyseal growth plate problems (osteochondritis dissecans) | 3.2% |

**Table 1:** Frequencies of single growth disturbances in hypothyroidism from Tomils (calculated per skeleton).

Most of the above manifestations appear in combination in the same skeleton. Of 404 individuals, 7.4 percent show two of the above diagnostic criteria; 3.5 percent three diagnostic criteria; 2 percent four diagnostic criteria; and 0.7 percent five diagnostic criteria. The individuals showing only one diagnostic criterion were excluded from further analysis, since they do not provide enough evidence for a univocal hypothyroidism diagnosis. Individuals exhibiting more than two diagnostic criteria (13.6%) were grouped together. The rate of hypothyroidism in Tomils, although high, is similar to modern (nineteenth and twentieth century) clinical data for this region (Lorenz 1895), which is considered one of the most affected regions in Switzerland.

No statistically significant differences were found between males and females. Juveniles and young adults were more affected than older adults; the difference was significant. This is associated with the lower life expectancy of juvenile individual, with hypothyroidism (life expectancy of a juvenile $e_{juv}$= 39.0 years) compared to non-hypothyroid individuals (life expectancy of a juvenile $e_{juv}$= 45.6 years). Hypothyroidism was not observed in children. We interpret this more as a problem of diagnosis in immature individuals than as the absence of the condition.

Hypothyroid male individuals were 2 to 3 cm shorter than non-hypothyroid individuals (statistically significant, Mann-Whitney non-parametric test). Hypothyroid females were

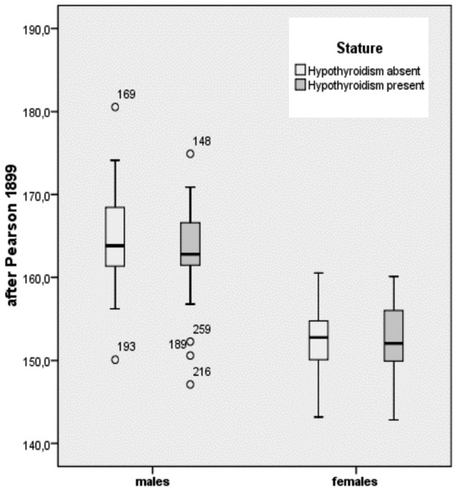


Figure 3:
Hypothyroid male individuals are 2 cm shorter (shorter hypothyroid individual 145 cm) compared to non-hypothyroid individuals; statistically significant differences for males, Mann-Whitney non-parametric test.

0.5 to 1 cm shorter, but in this case there was no statistical significance (fig. 3). Hypothyroid individuals exhibited a higher frequency of caries, calculus, dental wear, and linear enamel hypoplasia than non-hypothyroid individuals, and the differences are statistically significant. No statistically significant differences between hypothyroid and non-hypothyroid individuals were observed regarding the frequency of Harris lines, fractures/traumas, and degenerative joint diseases of the spine and the long bones. No differences were found between the two groups in terms of grave goods, place of interment, and type of burial.

A differential diagnosis for the single bone elements may include, for example Perthes for hip dysplasias, bilateral humerus varus for shoulder dysplasias, or multiple epiphyseal dysplasias. However, in the presence of a combination of delayed ossification, long bone asymmetries, and the characteristic features of the skull, a diagnosis of hypothyroidism is more probable. A differential diagnosis for the combined skeletal manifestations may include achondroplasia, although the stature of the individuals, within normal limits, does not support a diagnosis of achondroplastic dwarfism.

## Conclusion

In our contribution, we presented hypothyroidism in Switzerland from three different, but complementary, perspectives: medical, historical, and archaeological. The medical perspective lays the non-time-specific and scientific groundwork regarding definition, anatomy, variants, pathophysiology, severity grades, clinical picture, and differential diagnosis of hypothyroidism. It also presents some cases from the Galler pathological bone-reference series (twentieth century), particularly the case of a seventy-nine-year-old individual whose clinical case report, autopsy findings, and remaining bones indicate clear signs of hypothyroidism.

The historical perspective takes other sources of information about the past into consideration: contemporary scientific studies on conscription, as well as published data on goiter and cretinism as endemic manifestations of hypothyroidism due to iodine deficiency since the late nineteenth century. In certain regions of Switzerland, 0.5 percent of inhabitants suffered from hypothyroidism (cretinism), circa 100 percent of schoolchildren had large goiters, and up to 30 percent of young men were unfit for military service before the implementation of iodine in salt (Bürgi, Supersaxo, and Selz 1990).

The anthropological perspective reports one of the first documentations of hypothyroidism due to iodine deficiency in archaeological populations, contributing significantly to the biological history of the Alpine regions. The large size of the skeletal sample (404 adult and subadult individuals) originating from the archaeological site of Tomils/Sogn Murezi and dating to the eleventh to fifteenth centuries AD, adequately describes the presence and variability of the skeletal manifestations and the epidemiological pattern of endemic hypothyroidism in a medieval Swiss Alpine population. This can be used as the basis for diagnosis of skeletal material originating from high-risk regions, which, until now, was absent in the palaeopathological literature. From an archaeo-anthropological point of view, the medical and the historical perspectives contribute significantly to the identification and positive diagnosis of the condition, since they both provide the necessary evidence. Both the presentation of the Galler hypothyroid cases and the historical documentation reinforce the anthropological and the archaeological data.

Furthermore, the historical perspective bridges medieval times with the present, when the implementation of the pioneering iodized salt program eradicated endemic goiter and cretinism in Switzerland. Iodized salt has with any doubt been the most cost-effective preventive health measure ever applied in Switzerland. Looking back, the prolonged administration of iodine or of thyroid hormone has been found highly effective in reducing the size of endemic iodine deficiency, and thus hypothyroidism. Switzerland was one of the few countries to be completely iodine sufficient before 1990 (together with some of the Scandinavian countries, Australia, USA, and Canada), and iodine intake in schoolchildren can be assumed to have been constant since 1980. We demonstrate that this was not the case in medieval times or in the nineteenth century: iodine deficiency, goiter, and hypothyroidism were major problems for the local populations.

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# The Ancient Battlefield at Kalkriese

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## Results of Excavations on the Oberesch Site

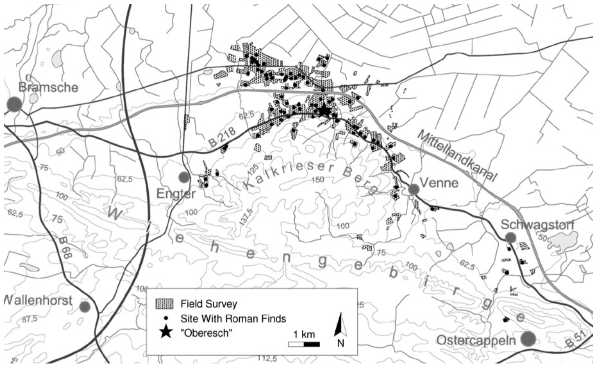



Figure 1: Study area of the "Kalkriese" project.

Since the rediscovery more than five hundred years ago of ancient reports of the "Battle of the Teutoburg Forest," historians and local history enthusiasts have searched for the site that saw the Roman troops of Publius Quintilius Varus conclusively defeated in battle by the Germanic forces in the year 9 AD (Mommsen 1885). But it wasn't until 1987 that the findings of an amateur archaeologist armed with a metal detector gave rise to systematic excavation (Schlüter 1999; Wilbers-Rost et al. 2007). Interdisciplinary research has proved the existence of a military event in the bottleneck between the Kalkriese Hill, a foothill of the Wiehen Hills, in the south, and the Great Bog in the north (fig. 1). Roman military remnants, as well as some unusual features point to a battlefield; the coin finds in particular link the site to the Varian disaster (Berger 1996).

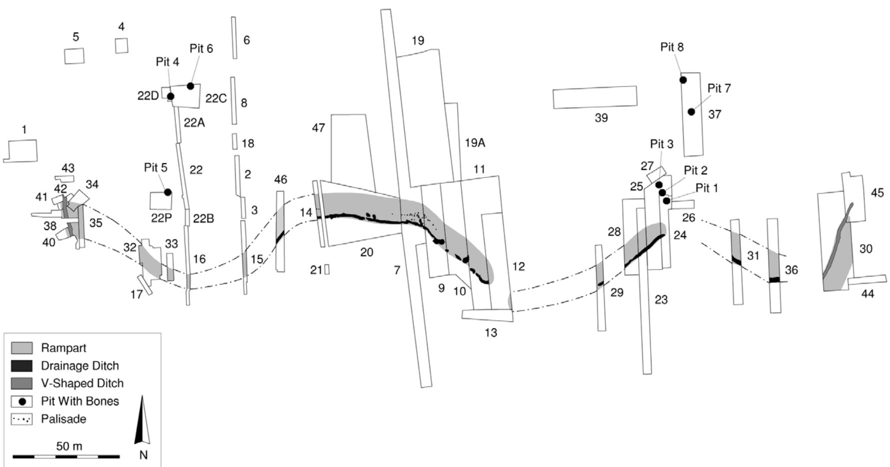



Figure 2: Kalkriese, Oberesch. Excavation trenches up until 2009, showing the position of the rampart and the burial pits.

In a wide area covering at least thirty square kilometers, metal detection and excavations identified sites with remains of Roman military gear, especially in the dry sandy soil at the foot of Kalkriese Hill and on the edge of the bog. Between these two zones is an area of difficult terrain with damp, sandy soil called the Kalkriese-Niewedder depression. The Oberesch site is situated at the narrowest point of this strait, and excavations have been ongoing there for more than twenty years (Wilbers-Rost 2007, 2009). As well as approximately five thousand Roman finds, there have been some remarkable discoveries which shed light on the battle—for example, a turf wall that had evidently been planned and constructed by Germanic warriors shortly prior to the Roman arrival in order to better attack them (fig. 2). The wall had a height of around 1.5 meters and was around three meters wide; it extended almost four hundred meters in length and did not follow a straight line, but was curved in several places instead. Passageways afforded the Germanic attackers the opportunity of retreat behind the rampart.

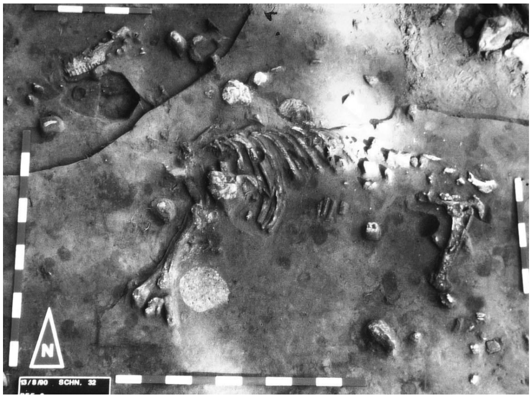


**Figure 3:** Mule skeleton in trench 32, almost completely preserved by the collapsed turf wall.

The finds indicate intense clashes involving heavily equipped Roman legionaries, auxiliary troops, and a large baggage train. Among the discoveries were the remains of offensive and defensive weapons, tools, personal equipment, equipment used by medical officers and orderlies, horse-gear, fragments of wagons, but also fragments of luxury items such as glass and silver vessels, and probably even furniture (Harnecker 2008, 2011). The high number of Roman finds and the special features suggest that the Oberesch was a key site within the extended battle area.

Another group of finds included bones, both human and animal, which archaeologists had scarcely hoped to recover due to the poor likelihood of preservation in the sandy soil (Großkopf 2007; Uerpmann et al. 2007). Besides the teeth and isolated bone fragments from mules and horses, some more extensive portions of two mule skeletons (fig. 3) and one horse skeleton were excavated. Evidently, some sections of the turf wall collapsed during the battle itself and covered the cadavers, removing them from the attentions of both robbers and wild animals and leading to their preservation.

**Figure 4 (l):** Bone pit 1 (excavation trench 24, feature 3).

**Figure 5 (r):** Bone pit 7 (excavation trench 37, feature 3).

Isolated human bones were also found at the surface; many more, however, had been put into pits, together with animal bones (fig. 4–5). From the absence of anatomical contexts it was immediately clear that the dead had lain on the surface for some time before they were finally buried. Written records of the time could help to explain this fact: Tacitus (*Annales* 1.60–62) reports that Germanicus visited the site of the battle with his troops in the year 15 AD, six years after the event, in order to bury the remains of the fallen. Thus there was an exciting link between the archaeological and anthropological findings and the historical record, a link that invited further investigation. These burial pits—we have found eight on the Oberesch site so far—have been the subject of some controversy, particularly since there are no other known burial finds of this nature. Some interpretations doubt that the Romans were the initiators of these burials, because the remains do not conform to what we know of Roman burial practice at this time (Zelle 2008).

It is, however, unlikely that the Germanic tribes were responsible for these pits. As the victors in this battle, they could afford to bury their own fallen in the traditional fashion; the fallen enemy could have been buried in mass graves shortly after the battle in order to avoid the stench of decomposing bodies and the risk of epidemics. After some years on the surface, the last remaining fragments of bones would have been easy to destroy through ploughing. There is no evidence of either of these practices, however.

In some of the bone pits it was possible to observe that some of the skeletal remains had been treated with a certain amount of respect, especially the human skulls (fig. 6). This also suggests that it was Roman legionaries who wanted to commit the remains of their fallen comrades to the ground. Likewise, the fact that it was mostly human bones in the pits, compared to the mixture of identifiable bones on the surface (Uerpmann et al. 2007, 144), points to a preference for collecting human remains for the burials.


**Figure 6:** Bone pit 5 (excavation trench 22P, feature 1). Two human crania, positioned on several long bones and limestone pieces.

There are no signs that human remains were cremated, which would have been the usual practice for the Romans. However, after a number of years on the surface, the human remains would have been devoid of the flesh and fatty tissue needed to sustain a fire. It would have needed a considerable amount of wood to reduce these bones to ashes (Großkopf 2009b, 86). Since the land that Germanicus was passing through had not been subdued, it is unlikely that he would have had the necessary resources at his disposal. It was in fact acceptable to depart from tradition in the burial of those fallen in battle when circumstances dictated. The golden rule was that the dead should be covered with earth (Hope 2003, 85 ff.). This was achieved through the deposition of the bones in the pits.

The absence of burial objects, such as vials of oil, in the bone pits, is also unsurprising if we consider the improvised circumstances of the burial. The few Roman finds in the pits conform to our expectations as objects that remained on the battlefield after looters and plunderers had done their work. They were presumably pushed into the pits as they were being filled—nothing points to their being burial objects. It is in any case highly unlikely that Germanicus's soldiers would have been carrying burial objects with them during their military campaign in the year 15 AD. So in this point too, the departure from the customs of civil or peacetime military burials close to Roman camps was inevitable.

The lack of any sign of the grave mound mentioned by Tacitus (*Annales* 1.62.1), allegedly constructed by Germanicus, has also been the subject of discussion. Apart from the question whether such a mound, which was supposedly flattened relatively quickly by the Germanic tribes (Tacitus, *Annales* 2.7.3), could even be archaeologically proven, we need to bear in mind that Tacitus's assertion might have been a topos employed to demonstrate the extent of Germanicus's devotion to the fallen rather than a literal description of his actions.

From the archaeological perspective, there is thus no fundamental discrepancy between the bone pits on the Oberesch site and the written sources that describe Germanicus's burial act (Rost/Wilbers-Rost, forthcoming). Six years after the defeat itself, Germanicus was able to fulfil the duty under unusual conditions: the burial of the fallen. He covered the skeletons with earth and thus paid them his last respects. In the context of discussions about the interpretation of the burial pits, the osteological analysis and evaluation of the bone fragments are of great significance.

**Birgit Großkopf**

## The Human Remains from the Oberesch Site

Most of the human bone fragments from the Oberesch site were discovered in pits located in close proximity to the wall (fig. 7). Only isolated bone fragments comingled with animal bones were present in these pits. Articulated, complete skeletons were not documented. The bones are fragmentary and exhibit signs of advanced decomposition, particularly, surficial erosion.

The eight bone pits that have been excavated so far are markedly different from each other. The surface areas of the pits vary in size from 40–60 cm to 4 m square. The three neighbouring bone pits (1–3) contained various amounts

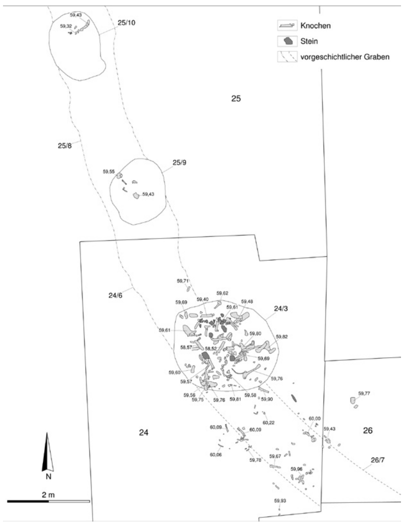



**Figure 7:** Bone pits 1, 2 and 3 (excavation trenches 24 and 25), showing different levels of bone content.

of fill material. While pit 1 contained numerous bone finds, pits 2 and 3 contained only a small number of fragments (fig. 7). The degree of bone preservation also differed significantly. In some bone pits there were pieces of limestone that were found in the soil and occasionally on the surface. Bone preservation was best when limestone was present. The bones in pit 5 belonged to two individuals and were sufficiently well-preserved to permit an estimate of stature (Großkopf 2007). Although the bones appeared stable and intact macroscopically, the internal bone structure displayed signs of significant decomposition. This poor level of preservation prevented DNA analysis. Even the best-preserved bones and tooth roots proved unusable to provide us with reproducible data.

Anthropological conclusions are therefore based only on evidence collected from isolated bones or bone fragments. The sexing of skeletons relies in part on specific features of the pelvic anatomy. Functional differences of the innominate bone are manifested as sex-specific morphological characteristics that in turn provide the most important criteria for an accurate sex differentiation. Due to the proportionally thin compact bone structure, preservation of pelvic bones at Oberesch was rarely sufficient to allow for sexing. However, skull bones also exhibit numerous markers of individual sex, and these are readily discernible, even from fragments. Long bones give us information primarily with regard to robustness and muscle development, however, they can provide additional information on the sex of an individual. The approximate age of death can be estimated morphologically based on the degree of skull suture ossification and diploe structure. Occlusal wear of the dentition is another criterion for approximating age at death. Results from the morphological examination were checked against those provided by the tooth cementum annulation method (Großkopf 1990). This histological technique for age estimations focuses on the analysis of tooth root cementum.

In addition to determining the age and the sex of those buried at the Oberesch site, a further step was to identify the minimum number of individuals. One of the first tasks was to group bone finds together in order to determine whether bones were fragmented prior to being buried in the pits. Considering the extent of fragmentation, this was an ambitious undertaking. Often, the only helpful characteristics were provided by unusual fragments or fracture edges. The advanced state of bone surface decomposition and erosion of broken edges (fig. 8) complicated this task further. Based on lower jawbone fragments, specifically a segment from near the left first molar, a minimum number of 17 individuals from the burial site was calculated. The number of other jaw and skull fragments was slightly under 17. However, it should be assumed that these remains belong to more than the 17 individuals who can be identified from this fragment type. In bone pit 5, which contained the remains of two individuals, the fragment of a shoulder bone from a third individual was also found. Yet, the total number here must remain as two individuals for methodological reasons, since estimation of the minimum number of individuals was determined using a fragment of the lower jaw.

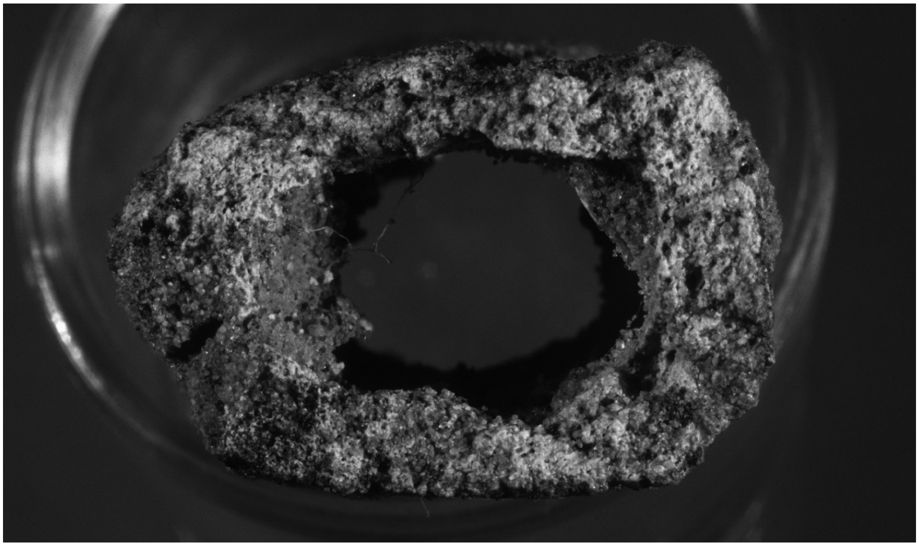


**Figure 8:** Advanced erosion on the fracture site of a long bone.

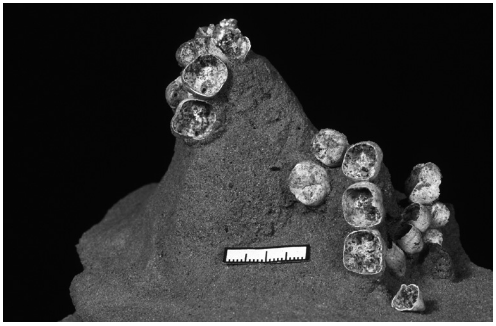
Evaluating anthropological data was also made difficult by the incidence of isolated bone fragments and the fact that animal bones were mixed in with the human remains in the bone pits. Conversely, the nature of the burial gives us some important clues to the situation after the defeat. If the fallen had been buried directly after the battle, we would have found mass graves with complete skeletons. Apart from a few exceptions, however, the Oberesch pits contain isolated bone finds. The burial must thus have been preceded by a period during which the dead lay on the surface during which skeletonization and decomposition of all soft tissue occurred, no doubt in part due to the activities of scavenger species. The bones likely remained on the surface for at least one to two years. It is unlikely that the corpses remained unburied on the ground for a period significantly longer than ten years, since forensic research has shown that after this length of time, taphonomic processes would result in their being almost no visible remains left (Morse 1983).

**Figure 9:** Evidence of blunt force to the cranium from bone pit 5 (item number 24551).

The results of the anthropological analysis support the assumption that the bones recovered at this site are the remains of soldiers who fell during the Battle of the Teutoburg Forest. The bones (with one exception) are exclusively from male individuals who were between the ages of approximately twenty-five and forty-five years when they died. The individual skeletons show a high level of robustness and there is no sign of any significant pathological changes that may otherwise have rendered them physically handicapped. Three of the skulls bore clear evidence of injuries caused by traumatic blows (fig. 9). Other possible injuries caused by blunt force could not be detected due to the heavy fragmentation of the bone remains.

The relatively small minimum number of individuals determined seems not to support the presumption of a large and historically important battle. It should be noted however that only a small area of the site has been excavated. Despite the well-preserved long bones of two individuals in pit 5, only one from each individual was buried there. The reason was perhaps because of lack of visibility due to vegetation cover or a thick layer of fallen leaves on the surface. This could have caused the apparent "disappearance" of bones. We can be certain that not all original bone remains were collected and buried.

The geochemical conditions at this site were far from ideal for the preservation of skeletal remains. This can be seen from a find of tooth crowns (fig. 10), which was all that remained of a complete skull. The entire bone substance and even the tooth roots had eroded. It must therefore be regarded as a stroke of luck that we were able to find any skeletal remains in this area at all. The finds from bone pit 7 illustrate very clearly how the remains continued to decompose significantly after their burial in the pits (fig. 11). Had it not been for the layer of turf, which was spread in some places up to a meter thick as part of medieval fertilizing practices, the remains would have been in an even poorer condition.



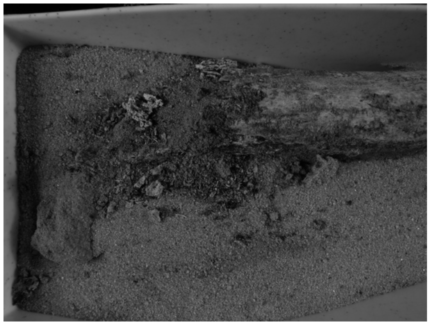


**Figure 10 (l):** Tooth crowns, the only remaining parts of a complete skull (item number 21209).

**Figure 11 (r):** Advanced decomposition of a long bone from bone pit 7.

Thus, analysis of the skeletal remains in the bone pits provides strong evidence for this area as the site of the "Battle of the Teutoburg Forest." As already discussed, historical sources (Tacitus, *Annales* 1.62) describe how Germanicus and his legions "on the spot, six years after the disaster, in grief and anger, began to bury the bones of the three legions, not a soldier knowing whether he was interring the relics of a relative or a stranger."

Achim Rost

## Methods in Battlefield Archaeology: A Critical Analysis of the Distribution Pattern

The finds at the Oberesch site should not be considered in isolation, but as a segment of a much larger-scale military event (fig. 1). Furthermore, we should not forget that battlefields are never preserved in their exact state at the end of the fighting. To understand how the archaeological finds come to be the way they are, we need to conduct a systematic, critical analysis of the sequence of events that followed the battle, based on models of human behavior that can be developed from historical sources, including from more recent military conflicts (Rost 2008, 2009a, 2009b).

In the normal course of events, battlefields would have been plundered or at least tidied up; unlike with military siege events, we do not usually expect to find much archaeological evidence (e.g., traces of earthworks, entrenchments) from pitched battles. Thus, battlefield archaeology—a relatively new field of research—is usually concerned with objects left behind on the battlefield, often small fragments of metal. The mass graves to bury fallen soldiers, for example those found in Wittstock (the site of a 1636 battle during the Thirty Years War; Grothe/Jungklaus 2009), number amongst the most striking legacies of pitched battles. Modern battlefield sites, with their enormous dispersal of spent firearm munitions, perhaps best represent our sense of what a battlefield should have looked like. But the evidence of military battles in ancient times tend to be rather thin on the ground, in particular when comparably "disposable" munitions, such as lead sling bullets, were not used. It has gradually become clear that the battlefield needs to be viewed as a category of its own in terms of archaeological research: conditions for the preservation of archaeological remains are very different from those for finds from settlements, graveyards, and cult sites. There is a distinct need to develop a new methodological framework for an appropriate interpretation of battlefield sites, including the sites of ancient battles.

It is remarkable to note that there have been around five thousand Roman finds on the Oberesch site, compared with only around five hundred military finds in the entire remaining area of the Kalkriese study, even though the excavated areas are of a similar size (Harnecker and Tolksdorf-Lienemann 2004).

Nevertheless, the analysis of excavations in Kalkriese has proved that the rate of recovery of military items is not linked to the intensity of the battle itself. A large part of the finds from Kalkriese are shown to be the result of a mixture of processes following the battle, including salvage and plunder, rather than direct relics of the fighting on the site. Ancient accounts of the military conflicts between Germanic tribes and Romans in the first decades after the birth of Christ have given us some points of reference regarding the behavior patterns of both parties. We know, for example, that the Germanic combatants were motivated to fight by the promise of plunder later (Cassius Dio, *Historia Romana* 56.21.4); elsewhere, we learn that the Roman army was trained to rescue their wounded even under dangerous conditions, and to bring their baggage train into safety (Tacitus, *Annales* 1.64.4).

The effects of these actions in terms of archaeological finds can be clearly seen from the sites at Kalkriese. The battle events on Kalkriese Hill look to have been a series of guerilla attacks by the Germanic tribesmen on the extended flank of the Roman army, which was moving from east to west in a long formation. The attacks came along a long, narrow stretch of land—at least 10 km in length—between the hill and the bog. It would have scarcely been possible for the Roman legions to take up efficient battle formations in such terrain. Nevertheless, the Romans were initially able to fight off the attacks that came from points along the route several kilometers east of the Oberesch site. More intensive fighting occurred in the course of these attacks and must have resulted in increasing numbers of Roman losses, but it would be wrong to expect any correspondingly large-scale archaeological finds here: as long as the Roman army's usual procedures for medical care and transport of the wounded were functional, we can assume that neither dead nor injured soldiers remained in any great numbers on the battlefield; they would have been rescued, together with arms or equipment. Thus, the scarcity of Roman finds along this section of the extended battle area is logical.

The archaeological finds should be rather different in those areas where the Roman logistical operations disintegrated. The Oberesch site probably represents such an area: the dead and wounded, together with equipment and military supplies, remained on the site at the mercy of the victorious Germanic attackers. The numerous fragments, especially fittings from Roman legionary equipment (fig. 12)—fragments from helmets, clasps, isolated segments from the *lorica segmentata* body armor, buckles, and metal fittings from sword sheaths—allow us to assume that the defeated Romans were plundered directly on the battlefield. As the Germanic victors stripped the bodies of their enemies, these small parts became detached and remained on the site. Large numbers of smaller fragments of silver sheet and bronze plate, which are mainly concentrated along the site of the wall, show that parts of the Roman armor were in fact destroyed for scrap, within only the "valuable" metal taken away to be melted down and re-used. Fragments of the bronze frameworks of large Roman shields (fig. 13), items for which the Germanic people found no use as weapons, are good examples of this: the shields were collected at the wall (fig. 14); the frames were dismantled and, apart from some tiny, disregarded fragments, removed; the wooden parts of the shields, however, were left there to rot.

**Figure 12:** A Roman legionary at the beginning of the first century AD. The shaded parts indicate the fragments found in Kalkriese.

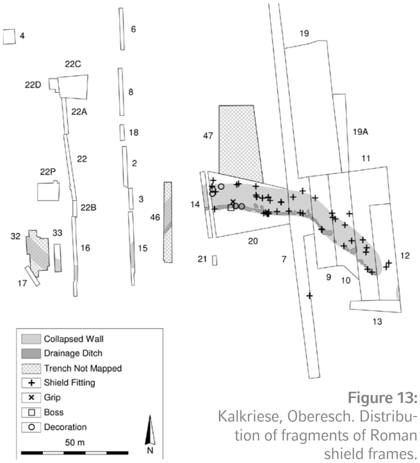



**Figure 13:** Kalkriese, Oberesch. Distribution of fragments of Roman shield frames.


**Figure 14:** A large fragment of a Roman shield frame, from the Oberesch site, Kalkriese; most recovered fragments are much smaller.

Sites such as this one, where Roman military structure completely collapsed, also meant the death of those Romans who were part of wounded convoys from a previous attack, and who were thus not combatants in the battle at the Oberesch site. Their armour remained at the site, adding to the archaeological finds. Thus, the finds at a certain section of the battlefield should not necessarily be taken as an indication of the intensity of the battle at this section.

**Figure 15 (l):** Silverwork from a Roman sword sheath (reconstruction).

**Figure 16 (r):** Roman silver coins (denarii) from a hoard discovered in Kalkriese in 1987.

West and especially northwest of the Oberesch site, the rate of archaeological finds dwindles again, but here there are some small groupings of valuable items; among others, the silver fittings from a sword sheath (fig. 15) and several hoards of Roman silver coins (fig. 16). Regarding their significance for the further development of the battle, we can interpret these areas as zones of subsequent skirmishes, flight, and capture. Romans might have tried to hide valuable possessions before they fell into the hands of the enemy. Isolated items escaped the eye of plunderers more easily than in the central battle zone at the Oberesch. There must have been similar items there too, and far more numerous, but since they lay together with fallen soldiers they would have been easy for the victors to recover.

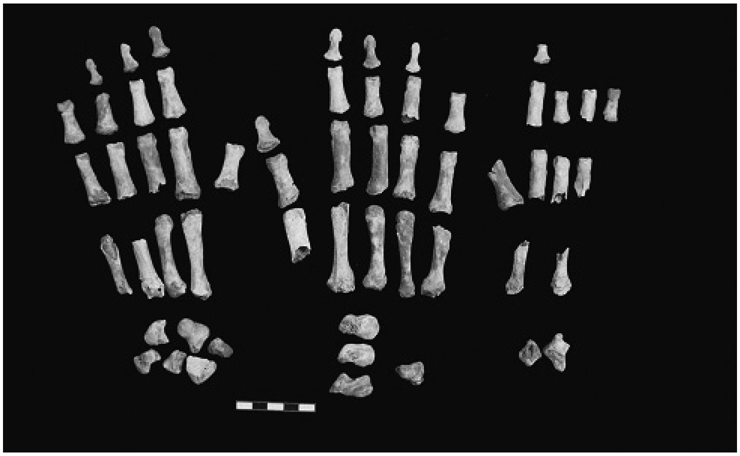


**Figure 17 (l):** Bone pit 1 (item number 18059). An anatomical grouping of lower arm, carpal, and metacarpal bones.

**Figure 18 (r):** Bone pit 1 (item number 18082). Three hands, reconstructed from the group of bones found close together.

By using archaeological evidence to reconstruct the different phases of the battle leading up to the ultimate and complete defeat of the Roman army, we were able to suggest some pointers for an interpretation of some of the groups of bone finds in pit 1, which seem to be exceptions to the observation of completely decomposed soft tissue (Großkopf 2007, 166f.). Thus we found one skull, complete with lower jaw and the uppermost cervical vertebrae, in almost its original anatomical context, besides a lower arm with ulna and radius and some hand bones (fig. 17), and in another part of the pit a concentration of hand and finger bones out of which we were able to reconstruct almost three complete hands (fig. 18). Since we were unable, in the context of the usual situation in the burial pits, to give anthropological or scientific explanations for these unusual groupings of finds, we suspect anthropogenic factors, such as gloves employed to protect the hands. But there is no evidence of gloves being part of the military equipment in the Roman army, and the groups of bone finds are from different parts of the body; however, both the lower arms/hands and the head and neck of a Roman legionary are in particular danger of injury in battle.

**Figure 19:** Kalkriese, Oberesch. Surgical instruments made of bronze (elevator and scalpel handle)

Given the proven presence of military doctors and medical orderlies in Kalkriese (fig. 19), medical care should be considered a possible explanation for the preservation of certain skeleton parts (Rost 2009c). It is not unthinkable that Roman legionaries who had been injured further back, in the early part of this extended assault along the length of the Roman flank, had had bandages applied to parts of their bodies. They would have been transported by the still intact military formations as far as possible, but would have lost their lives as the Roman army was defeated, and their remains would likewise have been plundered and left for scavengers on the battlefield. Some years later—by which time all soft tissue had decomposed and the last remaining bones were being gathered for burial in the pits—some of the linen bandages were perhaps partially intact. The plaster, or rather the ointments used by the Romans (Celsus, *De medicina*, 5.19) probably contributed to the preservation of these bandages. If the remains of these bandages were then used as a kind of bag to transport the bones to the burial pit and deposit them there, this would explain how some skeletal ensembles remained together. This example shows very clearly the ways in which archaeological and anthropological questions and answers can complement one another.

The interpretation of the archaeological evidence goes some way to both explain and relativize the unique nature of the finds at the Oberesch site. By drawing on the source-critical aspects—the effects of salvage and plunder, including body stripping and the scrapping of armour to recover valuable metals—we present a more favourable scenario for the analysis of the osteological finds from the burial pits at the Oberesch. The concentration of skeletal remains and fragments of military equipment on this segment of the extended battle area is probably due to the fact that a large part of the Roman army, including its system for medical assistance and logistics, collapsed here.

## Conclusion

Battlefield archaeology is a relatively new subdiscipline in the field of archaeology, which has been able to develop in the last couple of decades due to the systematic use of metal detectors (Rost 2009a). For this reason, there is currently little experience in the evaluation of the significance of archaeological items excavated from the sites of armed conflict. Often, written accounts of "world-changing conflicts" provoke us by citing the huge number of battle dead and the loss of equipment, leading us to harbor expectations of a correspondingly large amount of finds in our excavations.

The analysis of the finds in Kalkriese has already shown the extent to which post-battle processes affected the archaeological preservation of military remains, not just contributing to their reduction, but also manipulating and influencing them in many other ways. In this context, the osteological analysis of the bones from the eight bone pits is highly significant. The reburial of battle dead is not unusual; however, we cannot usually draw reliable conclusions about the chronology of the processes following the battle using archaeological evidence alone. The fact that we were able to prove here that the bodies of those fallen in battle lay on the surface for a number of years before their burial represents an unusual preservation history, and, thanks to the putative link to historical written sources, initiates an exciting discussion.

The archaeological, source-critical considerations regarding the course of the attacks on the Roman army train give a plausible reason for the astounding concentration of the bone finds in one segment of the battle area; the lack of grave gifts in the bone pits could also be explained by reference to cultural and historical factors. On the other hand, scientific knowledge goes some way to explaining the fact that the skeletal remains were not cremated. Moreover, the delimitation of the time period during which skeletal remains were on the surface of the battlefield prior to being buried was only possible by means of osteological analysis. These include both anthropological and archaeozoological studies (Uerpmann et al. 2007). Thus X-ray diffraction measurements on mule teeth showed that skeletal remains from the pits had had longer exposure to sunlight than the mules, which were covered soon after their death by the collapse of the turf wall.

By using the opportunity to apply different methodological approaches to the same questions, and to compare and discuss the results of the interdisciplinary analysis from different angles, we have been gradually able to foster an understanding of the sometimes unexpected patterns of finds excavated at the Kalkriese battlefield. The methods and theses that we have developed at Kalkriese in turn provide a basis for the examination of other historical, and not necessarily ancient, battlefields.

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