DIPLOMARBEIT

Titel der Diplomarbeit

USE OF ANTIBIOTICS IN PREHISTORY – THE PREVALENCE OF TETRACYCLINE LABELLED OSTEONS IN EARLY CHRISTIAN POPULATIONS OF SUDANESE NUBIA (550-850 AD)

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Figure 1. Saint Anne,
8-9th century, Faras cathedral fresco,
from (Martens-Czarnecka 2002)

CONTENT

Acknowledgements

“Don’t Panic”

Douglas Adams

Without George Armelagos supplying me with a project and everything else right down to a diamond saw blade this thesis would not exist. Without Harald Wilfing I could not have undertaken to start *or* finish it. Margit Berner taught me how to produce thin sections, and above all, how *not* to panic. Results one never expected or could ever hope to explain, only caused her to smile, “That’s ok, biology is like that” – a remarkable thing indeed.

Without Guy N.L. Jameson, the most remarkable scientist and person I know, I would have never brought up the courage. Without Thomas Zidek the performance of a significance test would still remain a mystery to me, and without Robert Sailer I would be forever stuck trying to talk my computer into doing anything other than crashing. Without Douglas W. Ludwig and all my other friends I would have developed an alarmingly close relationship with my computer, chair, and potted plants. One person can live a long time on a big bag of rice, and without ever moving more than a few steps. I am grateful I was spared this fate. Without my parents and my family, well, I would not be here or me.

I would also like to thank a number of unsuspecting attendants of the 11th International Conference for Meroitic Studies in Vienna. I thrust my hand and a number of presumably rather unusual questions into their general direction and they were kind enough not to take flight, instead assisting me in every possible way. I am delighted to have met – among others – William Y. Adams, Bruce Williams, Pamela Rose, Dorian Q. Fuller.

Having had a chance to talk to Reginald F. Jameson, David N. Edwards, and Simron J. Singh while writing this thesis, reminded me of what I love doing, and where I will go. Thanks.

Aim

Several studies of the last 25 years have shown that the ingestion of tetracycline – a broad band antibiotic – is not limited to the modern day and age. Thin sections of skeletal remains from people living in the Sudan as far back as 2.000 years ago show traces of tetracycline consumption. One Sudanese Nubian population from the X-Group period (350-550 AD) exhibits particularly high levels of tetracycline ingestion, and low levels of infectious disease, suggesting a therapeutic benefit from the antibiotic uptake. Both (mouldy) grain, and beer have been discussed as the source of the ancient antibiotic.

The aim of this thesis was to investigate remains from two burial sites (6B13 and 6G8) from the early Christian period of Sudanese Nubia (AD 550-850), immediately following the X-Group period, and located in the same region where the previously studied X-Group remains were uncovered. Can any differences in tetracycline consumption be seen? If so, could these differences be related to a changing political system and a newly emerging religious belief? After all, X-Group populations were ruled by local leaders, while Christian Nubia saw a reunification of the country both in political and religious terms. Through changing regulations like taxation a new government and clergy could have influenced availability of (mouldy) grain and beer, which may in turn have had an effect on tetracycline consumption.

Regarding part of the title of this thesis "Use of Antibiotics in Prehistory" – *prehistory* here is referring to times prior to the modern discovery and use of antibiotics.

I. Introduction and background

"Imagination is the beginning of creation.
You imagine what you desire,
you will what you imagine
and at last you create what you will." G.B. Shaw

1. The Aswan Dam

The Aswan Dam was the beginning and the end: Before burying countless remains of ancient civilizations underneath a vast water reservoir, building and enlargement of the Aswan Dam initiated and advanced archaeological research of the region.

In 1899 Egypt secured control of Lower Nubia by treaty and embarked on the project of dam-building. The world's first organised salvage campaign, starting in 1907, was the First Archaeological Survey of Nubia. By the end of the first season of excavations, its earliest director, George A. Reisner, had already encountered four distinctly Nubian cultural stages without an Egyptian equivalent. Within a few years after the completion of the Aswan Low Dam however, the northernmost 100 miles of Nubia – held for centuries by Egypt as a route to desert gold mines – disappeared. A second survey was undertaken 1929 to 1934, when the dam was further enlarged. Most of the rest of Egyptian Nubia was covered in water shortly afterwards. (Adams 1977)

As the Dam grew larger so did the surveys accompanying it. The third, and by far the biggest, Nubian Salvage Campaign lasted from 1959 until 1969. The UNESCO (United Nations Educational, Scientific and Cultural Organisation) had launched it to save monuments like the temple of Ramses at Abu Simbel. In addition to preserving known monuments, around 60 international expeditions engaged in archaeological explorations in Egypt and the Sudan. The same industrial nations who contributed most of the capital for the building of the Aswan dams – which finally led to the flooding of Lower Nubia, as well as parts of Sudanese Nubia – tried to rescue as much as possible of Nubia's elusive past. (Adams 1977; George 2005) Nubia, though having lost its importance, claimed attention once more.

Among the participants undertaking excavations in Nubia was the University of Colorado. In 1962 at a 14 square kilometre concession opposite the town of Wadi Halfa (see figure 2) in the Republic of Sudan excavations were started. (Armelagos, Ewing et al. 1968)

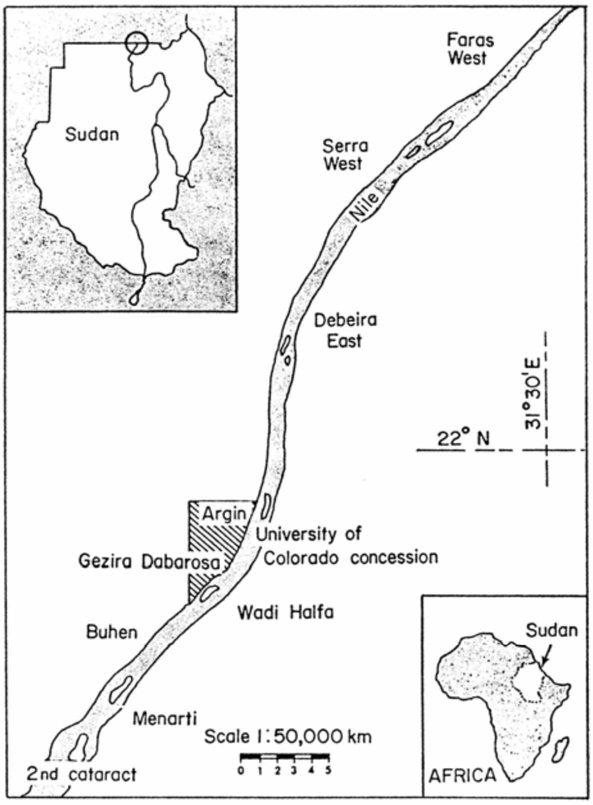

Figure 2. The Wadi Halfa area of Lower Nubia with the University of Colorado concession, from (Armelagos, Mielke et al. 1972)

The data gathered in Egypt and the Sudan by various expeditions of the Nubian Salvage Campaign (Wendorf, Daugherty et al. 1964; Wendt 1966; Säve-Söderbergh, Nordström et al. 1981) and later excavations venturing further south to the Batn el Hajar (Van Gerven, Sheridan et al. 1995) have been extensively used for a multitude of studies. Anthropological research alone has been investigating a variety of subjects, among them dentition (Greene, Ewing et al. 1967; Calcagno 1986), bone growth, remodelling and osteoporosis (Dewey, Jr. et al. 1969; Mielke, Armelagos et al. 1972; Carlson, Armelagos et al. 1976; Martin and Armelagos 1979; Hummert and Gerven 1982; Sibley, Armelagos et al. 1992), as well as health and disease in ancient populations (Armelagos 1969; Armelagos, Jacobs et al. 1981; Van Gerven, Sandford et al. 1981; Van Gerven, Sheridan et al. 1995). Some researchers studied morphology and led the way to a new perspective explaining the mechanisms underlying cultural change (Van Gerven, Carlson et al. 1973;

Van Gerven, Armelagos et al. 1977; Carlson and Gerven 1979; Schindler, Armelagos et al. 1981; Van Gerven 1982).

Thus, the information gained from Nubian studies not only added to the archaeological knowledge of Ancient Nubia, but throughout the years also proved helpful for a better understanding of various biological processes related to political and cultural developments.

2. Nubia

A paradigm shift

"We don't see things as they are, we see things as we are."

Anais Nin

Originally, without a specific problem orientation, the physical anthropologists in the Colorado expedition team were asked to see if they could link cultural changes observed in Nubia (see figure 3 for a map of modern Nubia) over time to biological changes, which have possibly occurred. Specifically, that meant the question of "Negroid" influences throughout the history of Nubia. (Armelagos, Ewing et al. 1968)

During their work, the Colorado anthropologist's approach to Nubian culture underwent significant changes, but having been posed this particular question at the beginning of their studies could hardly have come as a surprise, since it followed the traditional approach to the cultures of Nubia.

The systematic investigation of Nubian history has been carried out almost entirely in the 20th century – a century that has seen the study of "human races" advance and linger, before being overthrown. Unfortunately at present many people still believe that the lack of studying human "races" is founded mainly in a changed attitude: Questions of that kind are understood to be ethically improper. The truth however is, that the decades of studying human "races" have yielded no coherent results and had to be abandoned for reasons beyond the ethical question. There is no sufficient biological basis for the construct of "race" within human populations. Much overrated obvious differences – visible traits such as a darker or lighter skin colouring etc. – are not even vaguely sufficient for a taxonomic differentiation to the extent of a subspecies (being itself a taxonomic subcategory lacking a precise definition). (See also (AAPA 1969))

Keeping in mind, that this development in anthropology had yet to take place, the First Archaeological Survey of Nubia, under the direction first of George A. Reisner and later headed by C.M. Firth, produced a picture of its time in portraying Nubian history as a series of distinct periods with little or no continuity. This was considered to be true for the cultural remains as well as for the human remains. G. Elliot Smith, Douglas Derry and F.

Wood Jones analysed Nubian skeletal material and "concluded that distinct races reflecting various combinations of Negroid, Caucasoid and alien races could be associated with each cultural period. It was further argued that migrations and mixtures of these races were a major cause of cultural progress and decline in Nubia."(Van Gerven, Sandford et al. 1981)

The commitment to racial determinism continued with the second Archaeological Survey, where Ahmed Batrawi continued the search for racial correlates. He interpreted A-Group people to belonging to a hybrid race resulting from the mixture of pure "Negroids" with "Caucasoids". The C-Group population showed a continuation of A-Group features, but with an increase in "Negroid" characteristics among its females. According to Batrawi "this mixing of Caucasoid men and Negroid women continued through Meroitic times, but ended with the arrival of a new alien race at the beginning of the X-Group period." (Van Gerven, Sandford et al. 1981) Though Batrawi rejected a causal link between race and cultural achievement, he continued to approach biological variation with concepts of typology. (Van Gerven, Carlson et al. 1973)

As was the case with many racial studies, the specific results were modified and re-modified – but the view of Nubian history as a series of disconnected episodes resulting from the infusion of different races continued unchallenged until the Nubian Salvage Campaign. Only after the excavation of over a 1.000 sites, a new view of Nubian history emerged.

Typology and a racial approach to research were recognized as being deeply rooted within the structure and philosophy of Western civilisation – a characterisation which improperly portrays human populations as internally static, changing only with external forces such as genetic flow. "Even if the constellation of traits defining a racial type were demonstrably linked, which they are not, the type would only persist through generations to the extent selective mechanisms acted to favour it." (Van Gerven, Carlson et al. 1973)

Newer studies had been undertaken, suggesting that the ability to link the waxing and waning of "Caucasoid" and "Negroid" genes to the biological transformation of Nubian populations had to be doubted. The analysis of discrete dental traits in Meroitic, X-Group and Christian populations was unable to show significant shifts in the frequency of these genetic features, as would have been expected with an extensive gene flow. Analysis of distinct cranial traits reached a similar conclusion (Armelagos, Jacobs et al. 1981): “We are conscious now of a continuum of cultural evolution within the borders of Nubia, heavily influenced by events and ideas from abroad, but involving the same basic population from beginning to end. There is no reason why the Nubians today should not claim to be the direct descendants, culturally as well as racially, of their Neolithic, and perhaps even their Paleolithic, forebears.” (Adams, 1966 as cited by (Van Gerven, Sandford et al. 1981))

The scholarly perspective thus shifted from emphasising the differences to focussing on the similarities of successive populations. Nevertheless, the differences were still acknowledged: “Yet while there is seemingly sound evidence for genetic continuity through several thousand years of Nubian populations, there is nonetheless compelling evidence for concomitant changes, especially in the cranio-facial complex.”(Armelagos, Jacobs et al. 1981) As Carlson and Van Gerven (1979) wrote, “There is no doubt that differences exist between the inhabitants of the major successive indigenous Nubian horizons. However, alternative explanations for these differences have been relatively unexplored because of the overriding concern for migration and diffusion.”

Recognizing a long-term cultural and biological continuity in the Nile Valley did not negate morphological differences. But assessing variations among Nubian populations without an a priori commitment to the racial admixture finally made it possibly to seek explanations elsewhere.

Nubian Mesolithic populations possess robust crania with large brow ridges, large flattened faces and a bun shaped occiput. (Armelagos, Jacobs et al. 1981) Furthermore, the dentition of the Nubian Mesolithic population had a similarly large – exceeding even that of the Skhul Neanderthal population – and complex dentition. (Greene, Ewing et al. 1967)

Changes in later Nubian populations, “involve a progressive decrease in the robusticity of the entire cranio-facial complex, a rotation of the midface and lower face to a position more inferior to the cranial vault, and a relative increase in cranial height, with a decrease in cranial length.” (Armelagos, Jacobs et al. 1981)

To explain these morphological changes, two models have been proposed. The “masticatory function hypothesis” by Carlson and Van Gerven suggests, that dietary changes from the Mesolithic through to Christian times would produce a decrease in muscular stress on the jaws and teeth. Reduced neuromuscular activity could then decrease the mechanical stimulation of the periosteal membranes. Together with changes in maxillo-mandibular growth patterns, this would lead to the observed changes over time. The "dental reduction hypothesis", proposed by Greene and Armelagos, suggests, that dietary changes have precipitated selection for smaller, morphologically less complex teeth. The authors claim, that the characteristics of the Mesolithic population most likely reflect an adaptation to heavy masticatory stress with associated dental wear. The transition from a gritty Mesolithic diet to a Neolithic diet higher in carbohydrates would have resulted in a selective shift favouring smaller, morphologically simpler teeth. These smaller teeth would in turn have led to a reduction of the facial structures with the same compensatory changes in the cranial vault and base as discussed above. (Greene, Ewing et al. 1967; Carlson 1976; Van Gerven, Armelagos et al. 1977; Armelagos, Jacobs et al. 1981; Schindler, Armelagos et al. 1981; Van Gerven 1982) While the Mesolithic populations relied on large game, fish and collecting seeds, the following periods saw a transition from hunting and gathering to primary food production until the Meroitic, X-Group and Christian people, who relied on intensive agriculture. (Armelagos, Jacobs et al. 1981)

Thus, the racial approach in studying human remains gave way to a biocultural approach, emphasising an interaction between environment, culture and biology . The environment can put constraints on a population in the form of limited essential resources or specific disrupting stressors. Culture may buffer the effects of environmental constraints, or may itself act as a stressor. (Armelagos 1968; Armelagos, Jacobs et al. 1981)

Adams (1977) explains the shift in interest, the changeover from a racial to a biocultural perspective with care, "While I have considerable sympathy with the current ideological ferment on the southern continent, it is not my place or my intention to make propaganda for nationalist or racist movements. Consequently, I have made relatively little of the Nubians' 'Africanness'. Their interest for me has nothing to do with their skin colour or with the continent on which they happen to live; they are in their own right a fascinating people with a fascinating history. If I deplore the earlier tendency of Egyptologists to see the Nubians as nothing more than second-class Egyptians, I am equally resentful of efforts to place them in another historical pigeonhole as 'Africans' or 'blacks'."

Adams further states, that he “seldom referred to the Nubians as ‘black’, not out of any racial sensitivity but because they have only intermittently been black. By that I do not mean that their skin colour and facial features have changed significantly in the historic period; I believe in fact that they have remained pretty much the same since the earliest times. But race is largely in the eye of the beholder; it is more a matter of social ascription than of biology, and its defining characteristics have changed from age to age and from place to place. To be technically accurate the Nubians are mostly of a chocolate-brown colour; one could, and can, see them either as ‘black’ or as ‘white’ according to the prejudices of one’s time and temperament.” At times the Nubians may have suffered from prejudice due to their dark skin colour, or prejudice due to the fact that they were unlettered barbarians, or because they were Christians surrounded by Moslems. At other times the Nubians have joined with their northern neighbours in oppressing and exploiting the darker people of inner Africa – then it would be sociologically more meaningful to refer to them as “white”. (Adams 1977)

While various researchers thus started to approach Nubia’s ancient populations from this biocultural, rather than from a racial viewpoint, they regretted the lack of study of living populations in the area before it had been flooded. While, during their later research, they spent considerable time and effort evaluating environmental effects on the health and diseases of ancient populations, an opportunity to study the effect of a new physical and cultural environment at first hand had been lost, “In the area of Nubia where we were located, the populations were moved from an area of desert to one of heavy rainfall. Although WHO did prepare these people with immunization necessary for their new environment, a number of other studies would have been valuable.” (Armelagos, Ewing et al. 1968)

But, most importantly, aside from any research, one must also ask about the treatment of the relocated people – of the Nubians, who were relocated in the sixties, and of the people being relocated now, that the Merowe Dam at the 4th cataract in the Sudan is being flooded. Furthermore, troublesome events have already taken place in conjunction with the planning for the next Dam at the 3rd cataract. Whereas the Aswan High Dam was financed by Russia, the main financier for the Sudanese Dams is China. Although Chinese technicians are already in the area, whatever is being done, is done very secretively. Local protestors have reportedly been killed. – See (Abdulmannan 2007) and a you tube video titled “Kajbar Massacre in Nubian Land”. Apparently for larger political and economic interests people are being driven from their possibly meagre but nevertheless productive homeland to settle in concrete urban houses where their quality of life can be safely expected to decrease. (Personal communication with participants of the 11th International Conference for Meroitic Studies in Vienna, Sept. 1st-4th 2008)

A matter of perspective

“In the beginning, and for many centuries afterwards,
Nubia *was* Africa so far as the outside world was concerned.”
(William Y. Adams)

Disconnecting skin colour from cultural achievement made a new perspective on Nubian culture indispensable. It could no longer be explained simply by culturally advanced “Caucasoids” moving in or being replaced again by their southern neighbours.

Until the 20th century Egyptologist held essentially the same view of Nubia as did Ancient Egypt. The way Egyptians had approached Nubia was naturally followed by Egyptologists.

In Egyptian texts, Nubia is treated as a remote, inhospitable land, hardly more than a private hunting preserve for human and animal game. The discovery and decipherment of hieroglyphic texts throughout the 19th century, following the Napoleonic occupation of Egypt in 1798 – 1801, had rooted the ancient Egyptian attitude towards Nubia deep in the minds of European scholars. And although Islamic scholars had composed histories and geographies of Nubia in the Middle Ages, when the trans-Saharan caravan trade had been opened, few of them were translated. Thus, perceived through the eyes of Egyptologists, Nubia appeared to be a poor and barbarous frontier province, which had been exploited and tyrannized by the Egyptians at will, mainly for its gold, ivory and slaves. (Adams 1977; Adams 1994)

However, after the archaeological surveys alongside the building of the Aswan dams had started, the Egyptologists approach to Nubian culture soon sufficed no longer. As stated above, George A. Reisner could immediately identify no less than four cultural stages without an Egyptian equivalent. Due to his surprising finds and the remarkable achievement of recognising their meaning, the Nubian's unique cultural accomplishments quickly became apparent.

A similar perspective of Nubia had been captured by Ancient Greek and Roman scholars. Their view of Nubia was diametrically opposed to that of Egypt: Romantic legends about the sources of the Nile, its outlandish fauna and its black skinned people flourished. (Adams 1977) As one example: "Kush and its last and most famous capital, the city of Meroë were well known to the Greeks and Romans under the name Aithiopia ("land of the burnt faced people"). Greek writers made it the home of astrology and told a romance between Alexander the Great and the queen of Meroë …" (Burstein 1997)

After Lake Nasser had been filled, Lower Nubia from Aswan to the Second Cataract had been flooded, and the archaeological work in the biggest part of Lower Nubia has thus been put to a permanent end. William Y. Adams gathered the data from various expeditions and opened a new perspective onto Nubia. Adams, without an Egyptologist's training, offered an – as he called it – "Nubiocentric" point of view. (Adams 1977)

The land in between

> "Adams tells you everything about Nubia,
> including everything you never wanted to know."
> (George Armelagos, personal communication)

Nubia has doubtlessly fascinated, but it may not have enthralled as many people as Egypt. While almost everyone nowadays has a good guess of where Egypt was and is situated, even scholars struggle, when it comes to defining the borders of Nubia. In part, this is due to the records, or the lack thereof. "Egypt, at the lower end of the Nile, has the longest recorded history in the world. Inner Africa, at the headwaters of the same river, has almost the shortest. Nubia, the land between, alternates for 5.000 years between history and dark ages. The oldest written record from Nubia may date from the fourth millennium BC; the last dark age ended in 1813." (Adams 1977)

Furthermore, Nubia, as such, ceased to exist. There is no political or administrative region carrying this name any longer. What was at some point known as the Land of Kush, to Herodot as Aethiopia, and since medieval times as Nubia, lies today partly in Egypt and partly in the Republic of Sudan, but comprises only a small part of either country (see figure 3).

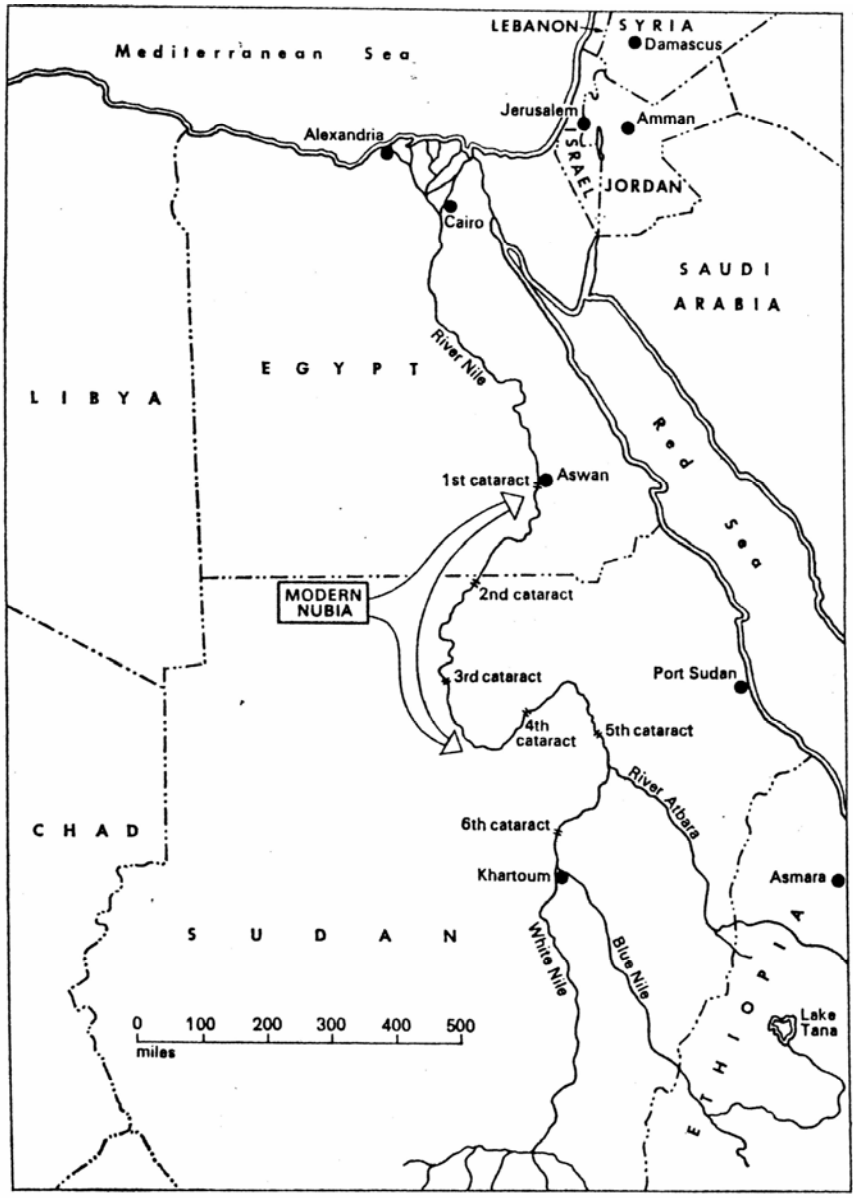

Figure 3. Modern Nubia, from (Adams 1977)

In the past, Nubia "is part cultural province, part historical province, and part geographic province – a region in which human destiny has been shaped … by a unique combination of historical advantages and environmental disadvantages. It … has never been permanently colonized by foreign peoples but has always been influenced by them.” (Adams 1977)

Since “Nubia” is merely a linguistic term, its borders on a map are difficult to define. However, Nubia through all its stages, always centred around the Nile. “Like Egypt, Kush was a gift of the Nile, albeit a less generous and more ambiguous gift.” (Burstein 1997) To follow Adams (1977), Nubia “is the land of the Nile cataracts: that part of the Nile Valley, directly south of Egypt, which is occupied by peoples African in origin and speech but strongly influenced by Egyptian and Mediterranean culture.”

The northern border of Nubia was always the 1st Cataract. The eastern and western limits were the limits of cultivation and habitation – one to two miles to either side of the Nile. The desert beyond was either lifeless or inhabited by nomads, who are not considered historically or culturally Nubians. Throughout history the southern limit of Nubia was repeatedly shifted, depending on the extent of Egyptian influence and internal politics. Conventional practice divides Nubia into Lower Nubia, extending from the 1st to 2nd Cataract, and Upper Nubia, above the 2nd Cataract. The cataracts, successions of swift rapids, canyons and rocky outcrops, impede or prevent navigation on the Nile. The 1st cataract at Aswan has always formed a natural border to Egypt. Egyptian pharaohs often crossed that border to invade Nubia looking for gold, ivory and slaves. But Egyptian peasants only rarely colonised Nubia with its comparatively harsh living conditions, which result primarily from Nubia’s geology. Different erosion patterns of limestone, sandstone and hard igneous rock (mainly granite) formed a variety of different environments along the Nile (see also figure 4): Wherever granite erodes it produced sharp ridges of stone, separated by narrow and deep wadis (dry river beds). The river-bed is narrow, steep and broken by islands and cataracts. There are only few sizeable areas of alluvial soil. Erosion of Nubian sandstone results in more or less level terraces with flat-topped remnants of higher formations and shallow wadis. The Nile in these areas is broad and smooth and produces an almost continual, if not very broad, alluvial floodplain. Changes from one geological formation to the other can be seen in the cataracts. (Adams 1977)

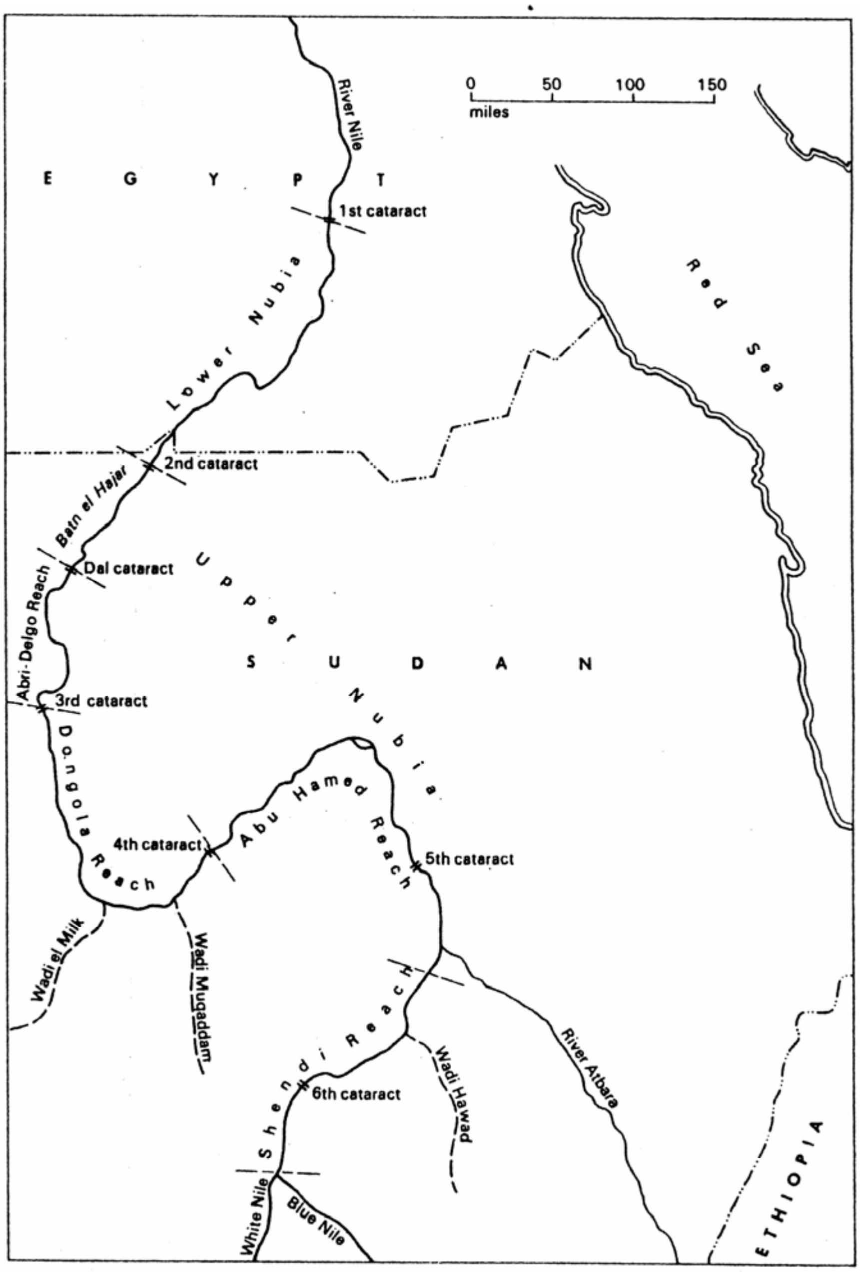

Figure 4. Physiographic subdivisions of Nubia, from (Adams 1977)

- Lower Nubia, today, is almost entirely covered by Lake Nasser. Aside from the region around the 1st cataract it is based on sandstone, and its topography is similar to that found in Egypt. Though floodplain was not continuous, there used to be extensive alluvial deposits supporting farming. Though Egypt's rulers often invaded Nubia, ordinary Egyptians were generally content not crossing the geographical border of the 1st Cataract. Few Egyptian colonists entered Nubia and occupations lasted only as long as the pharaoh's funding. "At the first weakening of royal authority, garrisons, administrators, and colonists came streaming back across the Aswan frontier, while, as often as not, the resentful Nubian populace rose at their heels and hastened their departure. The story was to be repeated at least five times in the long course of Egyptian-Nubian relations."(Adams 1977) Thus the frontier at Aswan, though politically unstable, remained for the most part a cultural frontier.

- The Batn el Hajar ("belly of rock") from the 2nd Cataract to the Dal Cataract is the most forbidding Nubian environment. Alluvium only exists in protected pockets. Thus, far fewer efforts were ever made to penetrate the land beyond the 2nd Cataract. It was in this region, that Christians held out longest against the Islam.
- The Abri-Delgo Reach from the Dal Cataract to the 3rd Cataract is also based on granite, but with an unusually wide floodplain
- The Dongola Reach from the 3rd to 4th Cataract, based on sandstone, was the source of most of Nubia's prosperity and the heart of ancient Nubia. The river is broad, placid and navigable. Alluvium is extensive and uninterrupted and the border of cultivation here depends less on topographic limitations and more on human ambition. Egyptian control never extended beyond the Dongola Reach.
- The Abu Hamed Reach from the 4th Cataract to the mouth of Atbara River is once again granite country. Though less rugged than the Batn el Hajar, the land is no more productive. Spread of civilization beyond the 4th Cataract may have had to wait for overland caravan trade in the last centuries BC since here the direction of the wind and the current of the Nile are the same. Though downstream travel may be fast, upstream sailing is not a practical possibility.
- The Shendi Reach, extending from the mouth of Atbara River to the confluence of the Blue and White Niles is mostly situated on sandstone and shares similarities with the Dongola Reach. (Adams 1977)

Though "Nubia has always been a hot, dry and barren land of few resources and limited subsistence potential", for thousands of years it was the only dependable route across the Sahara "and the only contact between the civilised world and Africa." (Adams 1977) The resources Egypt and the Mediterranean world sought in Nubia were gold, ivory, animals, and above all, slaves. Gold, the "Flesh of the Gods" as the Egyptians called it, though scarce, could be found in most of Nubia. The most productive gold mines were situated in the desert between Lower Nubia and the Red Sea. They were not necessarily part of Nubia, but due to their location, Egypt was obliged to control the Nile Valley up to 70 miles upstream of Aswan, in order to keep the main caravan route to the mines open. (Adams 1977; Burstein 1997)

Nubian history

> If beauty is in the eye of the beholder,
> history is in the hand of the writer.

The oldest records of human settlement in Nubia are of Paleolithic origin, and date back as far as 300.000 years (they are attributed to *Homo erectus*). The Neolithic in the Sudan lasted from 4.900 to 3.000 BC. The climate at the beginning of the Neolithic was warm and humid, though becoming more arid. People increasingly adjusted to an oasis-like environment. Farming spread from the Near East into Egypt. In the Upper Nile regions it was mainly used to enrich a diet dependent on hunting, gathering and fishing. Only at the end of the Neolithic did farming finally become established. (Adams 1977; Garcea 2004) Diet contained “meat, milk and probably the blood of cattle, supplemented by fish, molluscs and vegetable food.” (Caneva 1988 in (Jesse 2004))

During the A Horizon (see figure 5 for a chronology of cultural periods), the Nubians were drawn into commercial relations with Egypt and partially lost their earlier cultural autonomy. The influence of Egypt, at first beneficial, grew oppressive. Trading, during all the Old, Middle and New Kingdom, repeatedly gave way first to raiding and then to subjugation. “Thus it came about that the periods of Nubia’s greatest prosperity were usually those of Egypt’s greatest weakness.” (Adams 1977) Upper Nubia was, contemporary with and later than the A-Group, home to a Pre-Kerma population with ceramics distinct from Lower Nubian pottery. (Honegger 2004) During the C-Horizon prosperity returned. By the end of the period the first nucleated villages and fortifications appeared. Subsistence was based on cereal agriculture, augmented by hunting, fishing and animal husbandry – domestic cattle were a symbol of wealth. (Adams 1977)

One of the first African kingdoms, the Nubian kingdom of Kerma, emerged in Upper Nubia. Its capital of the same name was situated just south of the 3rd Cataract. Kerma’s wealth depended on trade with Egypt. The kingdom was independent, self-governing, had a well-developed administrative system, and defended its own territory. At some point it extended as far as the 1st Cataract. Kerma's dynastic culture, its material and social institutions were still tribal, its autocratic king and state-organized trade were signs of an empire. However, before an imperial system could be fully established, Egypt took over the land from the 1st to 4th Cataract. (Adams 1977; Bonnet 2004) A rite for human sacrifices can be observed since the Neolithic, the "last rulers of Kerma pushed this custom to the limits of demographic possibility, since the human sacrifices associated with the great royal tumuli were in their hundreds." (Reisner 1923; as cited by (Bonnet 2004))

After 18th Dynasty Egyptian pharaohs expelled the Hyksos they re-conquered Nubia. Within 50 years the region was overrun and the native dynasty at Kerma disappeared. An Egyptian viceroy governed the Egyptian province Nubia. Fortresses, and later temples, were built by the Egyptians, legitimizing their rule through ideology. The native people were Egyptianised. (Adams 1977; Bonnet 2004)

When internal problems forced Egypt to withdraw from Nubia in the 1060s BC, an alliance of native rulers and an Egyptianised priesthood led the rise of the Kushite monarchy and a semi-theocratic state. In the 7th century BC, for a period of about 100 years, the rulers of Kush, as pharaohs of the 25th Dynasty, also controlled Egypt. Kushite culture was Egyptianised, the language was Egyptian and Kush's most numerous and distinctive monuments were its pyramidal royal tombs. Different environments allowed for different modes of subsistence and surplus-producing economies. After loosing Egypt to the Assyrians, the Kushites withdrew to the Middle Nile. There, their regime, with the semblance of a pharaonic court, continued for almost 1.000 years. The Napatan phase of Kushite civilization centred around Napata, close to the 4th Cataract. In Meroitic times, several important settlements, Meroë among them, were located in the area between the 5th and 6th Cataract. In the 2nd century BC the Nubians, for the first time, created hieroglyphic and cursive scripts to write their own language. Caravan trade extended settlements into the land beyond the Nile while Egypt got aligned with Hellenistic maritime trade. Nubia flourished through this commerce, and before long, a large part of the trade was no longer a royal monopole but lay in the hands of private merchants. With the urbanisation of Nubian society a wealthy middle class emerged. In Lower Nubia this middle class weakened the power of the monarchy. (Adams 1977; Williams 1979; Brier 2002; Török 2004; Lison 2006)

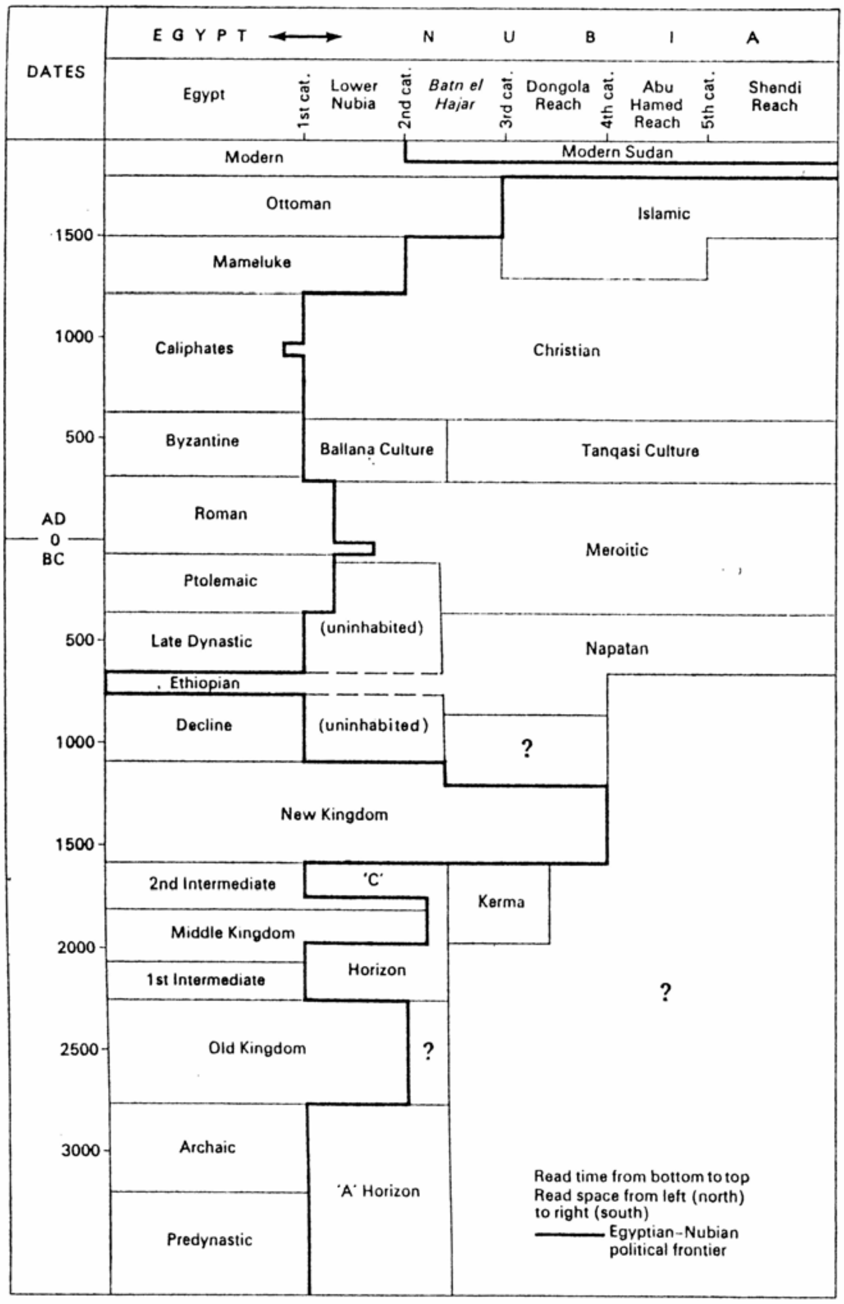

Figure 5. Cultural periods, from (Adams 1977)

Declining trade, pressure from surrounding populations and the Axumite kingdom of Abyssinia, and the extinction of the Kushite ruling dynasty must have contributed to the breaking up of the empire in the 4^{th} century AD. During the Nubian X-Horizon a collection of chieftainships spread. From the west, Noba tribesmen took over and reverted Upper Nubia to the primitive conditions of the tribal age. In Lower Nubia, the Ballana kings, whose origins are unknown and who regarded themselves as heirs of Kush, ruled. They lacked the differentiated power structure of previous Kush and established an absolute monarchy. By this time the culture of Lower Nubia was a mixture of Meroitic and

Byzantine Egyptian. The Ballana kingdom, later known as Noubadia, dispensed with writing, art and the erection of monumental architecture. The population was smaller and more dispersed and suffered a decline in prosperity. (Adams 1977; Török 1987) However, the excellence of pottery and jewellery, as well as bronze and iron works points to a "healthy culture". (Roberts 1993) The secession of Lower Nubia reduced the diplomatic influence of Meroë and its access to prestigious Mediterranean products. Faras controlled trade with Egypt "and benefited from occasional alliances with the Roman/Byzantine Empire, whose constant policy was to protect its frontiers by federating and Christianising bordering barbaric ethnic groups." (Lenoble 2004)

Christianity and beyond

Christianity was introduced into Nubia (which in X-Group times had already been permeated by Christian folk beliefs) during the mid-6th century AD, at a time when Nubia was split into three kingdoms: Noubadia (Nobatia, Nobadia) with its capital Faras in the north, Makouria with its centre Old Dongola in Upper Nubia, and Alwa (or Alodia) with its capital Soba East in the south (see figure 6 for a map of Christian Nubia). "Christianity swiftly swept across the Middle Nile region as the state-sanctioned religion, and by AD 580 all the Nubian kingdoms had officially converted to Christianity." (Anderson 2004) Though the Noubadian and Makourian kingdoms were originally hostile towards one another, they were united under the Makourian king around the end of the 7th century. While the king remained in Old Dongola, the eparch, his deputy, governed Noubadia. (Adams 1965; Adams 1977; Jakobielski 1987; Krause 1987; Mierzejewska 2002; Satzinger 2002; Anderson 2004)

640 to 642, less than a century after Nubia had been Christianised (to follow the Egyptian Coptic Church, considered heretical by Rome and Constantinople), Egypt fell to the armies of Islam. These armies moved south twice in an attempt to conquer Old Dongola. They were unsuccessful and the battles ended with a bilateral peace treaty, known as the *Baqt*. (Adams 1965; Adams 1977; Anderson 2004) "Arab armies, which elsewhere swept Christianity from the face of North Africa, arrived before Dongola within ten years of Mohammed's death – and there concluded a treaty which left Nubia in Christian hands for another 800 years. Salah-ed-Din (Saladin), conqueror of Richard Cœr de Lion and of

Egypt and Syria, gave up all thought of adding Nubia to his domain after the briefest of forays." (Adams 1977)

The *Baqt* guaranteed Makouria, a non-Moslem nation, unique sovereignty and determined Nubian-Moslem relations for the next 600 years. Nubians were to deliver an annual quota of around 400 slaves to Egypt, in exchange for various manufactured goods, grains, pulses, oil, "drink", cloth, horses etc. Initially the treaty ensured prosperity and peace, but might eventually have encouraged or forced the Nubians to turn away from traditional agricultural and economic pursuits towards slave-raiding. In the meantime, non-compliance (due to inability or refusal) to the *Baqt* – largely on the part of the Nubians – increased as the centuries passed. (Adams 1977; Anderson 2004)

However, in a reconsideration of the *Baqt* Spaulding (1995) points out, that even in the early days of the treaty, Makouria could not have delivered such a large quantity of slaves. He explains, that virtually all of the very few written sources on the *Baqt* are of Islamic origin following a scholarly tradition that puts more weight on authoritative text rather than on observable experience of ancient writers. "In only one specific instance do surviving records from independent Makouria specify the actual number of slaves sent to Egypt as a *baqt* payment; that number is two." (Spaulding 1995) He argues, that the *Baqt* simply follows a distinctly Nubian tradition on the conduct of diplomatic and economic relations – the tradition of royal exchange. While Islamic historiography may have found the defeat of a Muslim army difficult to accept, they could in the following centuries reinterpret the propensity of Makurian kings to periodically send shipments of valuable goods to Egypt, and view these shipments not as a traditional initiation of reciprocal royal exchange, but as a unilateral obligatory tribute. (Spaulding 1995)

Makouria persisted at least until the 14^{th} century. Lower Nubia remained under Makourian control, but after the 9^{th} century was given the status of a free trading zone: Foreign merchants could travel and settle, goods were freely exchanged, and money was being used, resulting in a relatively higher standard of living for the inhabitants of Lower Nubia as opposed to Upper Nubians, who were more directly governed by their king holding a trade monopoly. Christianity in Nubia replaced obsolete traditions; church and state were finally separated. With the onset of a secular judiciary, new political and legal styles could be developed. The church on the other hand was free from subservience to worldly rulers and could grow closer to the community. Unlike the temples of earlier times churches were located in or beside every village. They were enlarged not for the glorification of rulers, but simply to house growing congregations. (Adams 1977)

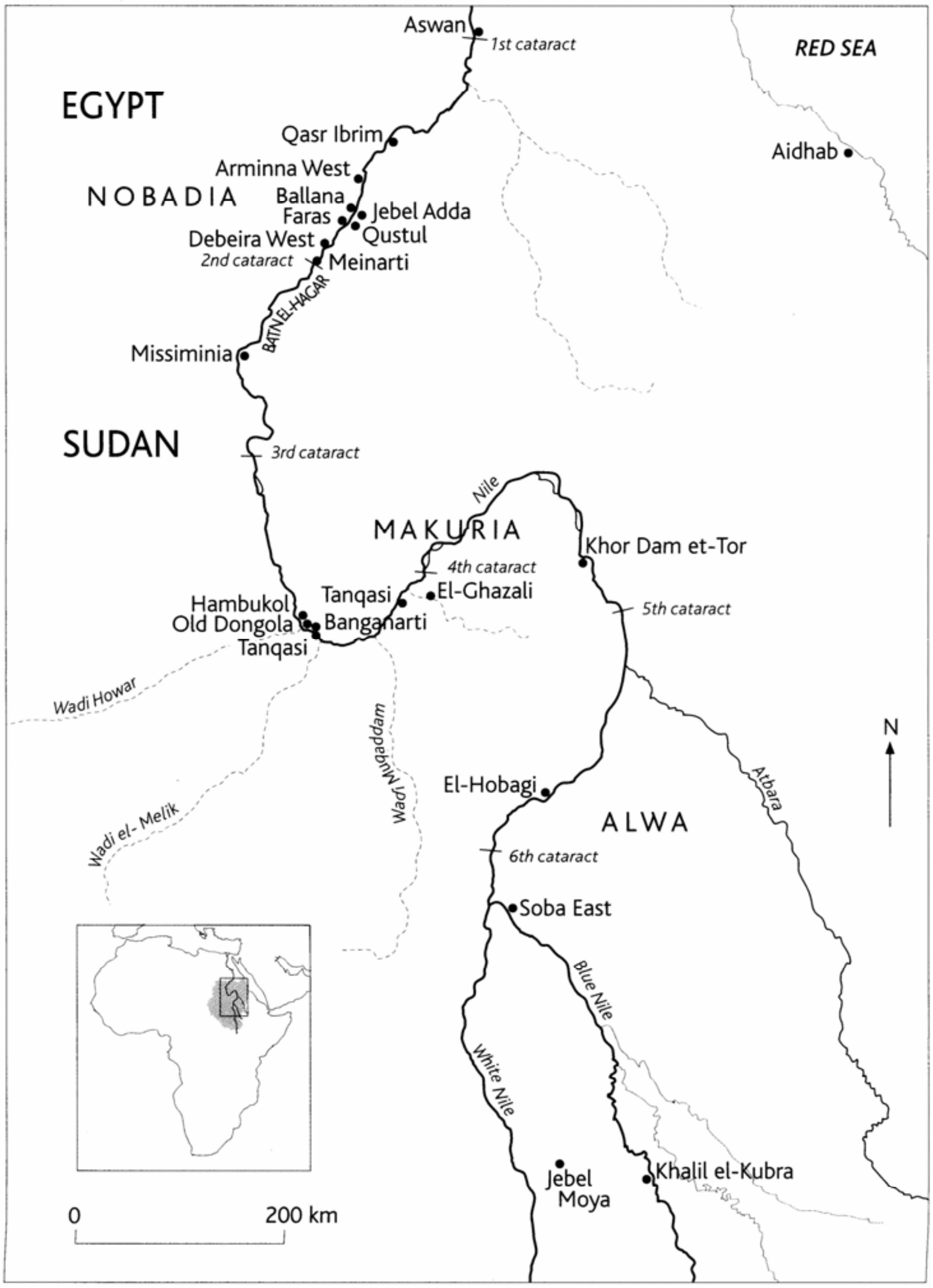

Figure 6. Christian Nubia, from (Anderson 2004)

The transcendental Christian faith with its new burial customs set an end to burials with sumptuous goods or food offerings. Churches, monasteries, written text and abandoned objects and living quarters show up in the archaeological record. Respective to everyday life, the introduction of Christianity does not seem to have had crucial consequences. Concerning the material culture the evidence of cultural continuity between the X-Group and Christian period is strong: Urban development continued, economic and social life seem unaffected, and only much later does art begin to incorporate different values and symbols. While there is little evidence for widespread literacy during X-Group times, a greater proportion of Christians seems to have been literate. (Adams 1977; Anderson 2004)

Starting in the 12th century AD, pressures from within and beyond Nubia's borders (the rise of military feudalism and settling Bedouin Arabs forced out of Egypt), led to the decline of the Nubian kingdoms. As Makouria disintegrated, Dotawo, an independent Christian kingdom, appeared in Lower Nubia. Being left with splinter states and Bedouin warlords, the country reverted to a purely agrarian economy, and peasant farmers clustered around castles of local barons. Nubia shifted from a medieval polity to the Arab tribal system. Until the 14th century Christianity remained the official faith, but as successive parts of Nubia fell under Moslem rule, the church was deprived of its support from monarchies and Alexandria, where the Egyptian church was similarly weakened under the Mameluke regime. (Adams 1977; Anderson 2004)

While becoming Arabs, the Nubians also became Moslems. The knowledge of Islam was acquired from unschooled Bedouins and pious teachers, mostly of the mystical Sufi orders, resulting in the rise of local cults and the belief in saints and miracles. The adoption of Islam also altered the Nubian's view of themselves. Poverty and political disunity, which had started before the Arabs arrived, continued. Thus, together, the Christian and Islamic periods make up the medieval horizon in Nubian cultural development – which, Adams (1977) argues, remained until the 20th century. The traditional Arab sheikhdom is based on the tribe. The sheiks of the 16th century became the meks (derived from melik, the Arabic for "king") of the 17th century, ruling over small territories from fortified castles along the river. Nubia's far north was nominally an Ottoman dependency. The feudal age ended with the re-imposition of Egyptian colonial rule in 1821. The Egyptians created a centralised bureaucratic government, backed up by an army. Though it brought a certain amount of order and stability to the Sudan, its aim was once again to obtain slaves and gold. After 1843, slave trade was increasingly privatised and merchant princes from Khartoum gained power. A campaign to control slave trade in the 1860s and 1870s merely alienated Sudanese people, whose prosperity depended on the trade, and undermined their confidence in the power of the colonial regime. Thus, when the Mahdist movement was proclaimed in 1881, it flamed into a national rebellion. After 1885, and the death of the Mahdi, the movement founded on principles of religious reformation, turned into secular despotism. (Adams 1977)

Popular support was soon lost, and the Anglo-Egyptian army invading the Sudan in 1896 met with little resistance upon ending the Mahdist regime. In 1899 Egypt and Great Britain assumed joint sovereignty over the Sudan: Lower Nubia fell under Egyptian rule, ruling Governor-generals until 1955 in the Sudan were the British. The British regime in the Sudan was developing and modernising the country according to its modest resources. After 1912, however, political unrest manifested itself as nationalism. "In the Sudan as elsewhere in the colonial world, the advent of public education had created hopes and expectations which the colonial rulers were in no position to fulfill." (Adams 1977)

Following the assassination of the British Governer-general of the Sudan in 1924 by an Arab nationalist, the British ended the Egyptian participation in the government and adopted a policy of "native administration" to counteract nationalism: The educational system was allowed to stagnate, and the government of an educated civil service was to be replaced by (in the meantime lost) tribal chiefs and elders. After the Second World War, nationalism reappeared in the form of two groups, one wanting to get rid of British rule, the other, of Egyptian influence. These groups evolved into political parties, the pro-Egyptian National Union Party (gaining support from the riverain peoples of the north, including the Nubians), and the more pro-British Umma ('nation') Party (gaining support from the same anti-Egyptian forces supporting the Mahdi eighty years ago). (Adams 1977)

At the turn of 1955/56 the Sudan became independent. An offer of American aid in 1958 drew the Sudan into Cold war politics and was one factor contributing to the downfall of the parliamentary government. Successive military and democratic régimes, receiving American, Russian or Egyptian support, had to struggle not only with political instability and underdevelopment, but also with a rift between south and north Sudan. (Adams 1977) Even in 2003 an article on the Sudan in National Geographic magazine is still subtitled "The oldest civil war in the world" and "A nation divided: Arab North, African South, and Contested Middle" (Salopek 2003)

Whatever powers ancient Nubia once held, today large parts of the country are flooded. The High Dam dispossessed just over 100.000 Nubians in Egypt and the Sudan – about half of the surviving Nubian-speakers. (Kirwan 1962; Adams 1977; Fernea and Rouchdy 1987; Kronenberg 1987) “No aspect of twentieth century civilization has had a more direct and immediate impact upon the Nubians than the succession of dams which have been built at Aswan.”(Adams 1977) And the Merowe Dam will see over 48.000 people relocated. (Ahmed 2004)

3. Tetracycline

In modern times

> "Some have called this molecule [tetracycline] a biologist's dream because of its versatility, but others have seen it as a chemist's nightmare because of the synthetic chemistry challenges and 'chameleon-like' properties." (Levy 2001)

For the general western European citizen it is difficult to imagine a life without antibiotics. It is, however, easy to catch a cold and buy antibiotics to cure it. Antibiotics work wonders; that they must also defeat viruses is still a common misconception – after all, they cure a vast range of other (as in bacterial) infections and superinfections.

The discovery of antibiotics went, as many scientific discoveries go: Sheer luck met with hard work. In 1928 Alexander Fleming stumbled across penicillin by chance. A culture of *Staphylococcus aureus* was contaminated with the fungal mold *Penicillium notatum*. Around the fungi colonies, the colonies of *Staphylococcus* were lysed. The mold obviously produced a substance that inhibited the growth of the bacteria. But it took a team of scientists years before penicillin could be produced and used as a medicine.

In 1944 streptomycin was discovered from the soil bacterium *Streptomyces griseus*. It was one of the first cures against tuberculosis, which up until then could only be treated with isolation and rest. And in 1947 the botanist Benjamin M. Duggar identified a yellow coloured microorganism, which he named and described in 1948 as *Streptomyces aureofaciens*. The strain produced yellow aureomycin, which, chemically modified, produces the more stable and usable antibiotic tetracycline. (Nelson 2001)

Other members of the order Actinomycetales (containing over 3.000 species) also produce tetracyclines; and in fact more than half of all known antibiotics are derived from these soil organisms. Other sources of antibiotics include bacteria, Fungi imperfecti, Basidiomycetes, algae, lichens, as well as higher plants and animals (maggots, insects, molluscs, blood etc.). (Keith and Armelagos 1983)

Since tetracyclines were soon found to possess the ability to inhibit the growth of a broad range of gram-positive, as well as gram-negative bacteria, the term “broad spectrum” was deemed appropriate. As microbial metabolites, tetracyclines influence their environment and establish territorial boundaries against prokaryotes and eukaryotes. In modern medicine “natural” tetracyclines are used to a lesser extent, while semi-synthetic tetracylines are some of the most widely applied antibiotics. They are orally active, with low toxicity. (Davies 1990; Greenwald and Golub 1998; Nelson 2001)

The main mechanism of tetracycline action against bacteria is the inhibition of protein-synthesis: Their sites of action are ribosomes and their components, where tetracyclines e.g. inhibit codon-specific binding of aminoacyl-tRNA to ribosomes, thus effectively blocking protein synthesis. Some tetracyclines are thought to change bacterial membrane integrity and mechanical properties, eventually causing dysfunction, cell lysis and death. (Nelson 1998; Nelson 2001)

Beside their antibiotic effect, tetracyclines have shown numerous other properties. Since they are able to interact with a variety of receptors, tetracyclines exhibit a diverse range of activities against both prokaryotes and eukaryotes. They affect ribosomal function not only in bacteria, but also in eukaryotic cells. In addition, tetracyclines also show activity against mammalian mitochondria. “This might explain certain aspects of tetracyclines as immunosuppressive agents, where tetracyclines may impair lymphocyte function through inhibition of their mitochondria.” (Van den Bogert 1989 in (Nelson 2001)) Perhaps also due to inhibitory effects against mitochondria, tetracyclines act as antiparasitic agents. Furthermore, tetracyclines affect regulation of gene-expression. (Nelson 1998; Nelson 2001)

The first non-antibiotic property of tetracyclines was investigated in the eighties: Their ability to inhibit matrix metalloproteinases such as collagenase.(Golub, Lee et al. 1998) Osseous destructive diseases (malignancy, arthritis, periodontitis) are associated with excessive collagenase activity and collagen breakdown. Since the biggest part of bone consists of collagen, inhibiting collagenase can halt bone resorption. Additionally, modified tetracyclines also inhibit osteoclast function while inducing new bone formation, and thus may act similar to bisphosphonates (Sasaki, Ramamurthy et al. 1998; Vernillo and Rifkin 1998), which are widely used in osteoporosis prophylaxis.

Furthermore, tetracyclines soon became known to inhibit angiogenesis, cancer cell invasion and metastasis, ameliorate complications of diabetes, and to inhibit pro-inflammatory cytokines. While they were, in the first decade after their discovery, being applied to several skin diseases such as acne, they thus soon proved useful in treating periodontal disease, arthritis, cancer, osteoporosis, and other health conditions. (Greenwald and Golub 1998; Ryan and Ashley 1998)

Tetracycline in prehistory

> "[The presence of tetracycline is] like finding a nylon stocking in the wrapping of an Egyptian mummy."
> George J. Armelagos, as cited by (Van Gerven 1981)

Another scientific discovery relating to tetracycline took place around 1980. Yet again, it was a product of chance: When Debra Martin was visiting the Calcified Tissue Laboratory at Henry Ford Hospital in Detroit, Michigan, to learn how to produce thin sections of undecalcified archaeological bone, she wanted to examine a section under the light transmitting microscope to check its thickness. Fortunately, another researcher was just using the microscope, and Martin had to use the only available microscope, which was one transmitting ultraviolet light. It was employed in the laboratory to detect tetracycline in bone, which emits a yellowish-green fluorescence when exposed to UV-light at 490 nm wavelength. To Martin's surprise, her bone sample showed marked fluorescence indicative of tetracycline presence. (Armelagos 2000; Armelagos, Kolbacher et al. 2001)

Tetracycline labelling was used in the laboratory as a way to measure bone formation (Frost 1969): Once ingested, the tetracycline will bind to free ions in the blood, like calcium and phosphorus, and will be – along with the ions – deposited in the currently forming osteons during mineralisation, thus leaving a label on all areas of bone which are metabolically active at the time of exposure. If administered at intervals, the amount of formed bone during the interval can be measured when a biopsy is taken. (Keith and Armelagos 1983; Keith and Armelagos 1988; Armelagos 2000; Armelagos, Kolbacher et al. 2001)

However, the bones Martin was studying were obtained from a population of X-Group Nubians (350 to 550 AD). Still, the fluorescence of the ancient bone occurred at the diagnostic wavelength of tetracycline, and the pattern of the fluorescence was found to be identical to that of modern labelled bone. All histological evidence pointed to the fact, that tetracycline had been ingested in vivo (and not introduced through a post mortem mold infestation). (Keith and Armelagos 1988) A subsequent extraction of tetracycline from the bone and chemical analysis further supported the nature of the substance to be tetracycline. (Armelagos 2000) "James Boothe, one of the scientists who developed the initial commercial applications of tetracycline for American Cyanamid, was able to extract the antibiotic from the Nubian bone. Most impressively, Boothe showed that extracted tetracycline retained its antibiotic potential to kill bacteria after 14 centuries." (Armelagos, Kolbacher et al. 2001)

In tackling the question of the source of tetracycline, which the ancient Nubians consumed, the researchers found, that streptomycetes, the mould like bacteria commonly found in soils, produce tetracycline. In fact, streptomycetes, comprise 60 to 70% of the bacteria in the desert soil of Sudanese Nubia. (Waksman, 1967; as cited by (Bassett, Keith et al. 1980)) Streptomycetes are slow growing, and at a selective disadvantage in the wet, acidic soil where most bacteria flourish. But in hot (28-38°C), dry and alkaline or neutral environment, streptomycetes are at a distinct reproductive advantage. (Bassett, Keith et al. 1980; Armelagos, Kolbacher et al. 2001)

Still the question remained, as to how the Nubians ingested the tetracycline. To answer this question, one must look at what kind of food and drink was available to the Nubians, and what food consumption depends upon.

4. Food, and especially drink

> "When all questions of space, time, matter and the nature of being have been resolved, only one question remains - 'Where shall we have dinner?'" (Douglas Adams)

You are what you eat

Eating habits are influenced by social and political factors, as well as by religious beliefs. (Samuel 1996) Religions often give strict rules as to what food should and should not be eaten – though seemingly irrational, ideological food taboos are often connected to ecological factors. Systems of taxation helped rulers keep their riches and power for long periods of time. "The beginnings, more than 10,000 years ago, of horticulture and pastoralism led to the emergence of privileged classes whose diet differed greatly from that of the labouring and peasant populations." (Farb and Armelagos 1980)

Tax, whether paid in terms of food, money or possibly labour, influences nutritional status, which in turn influences the health status and the occurrence of disease. An anthropological investigation of human remains may show signs of the latter and thus allow for some inferences on nutrition and environmental conditions within investigated populations.

Food and human behaviour are intricately linked: Which food is eaten, how it is obtained, by whome it is prepared, where, when and with whome it is eaten etc. contains information on a society and the relationships of its members. "In all societies, both simple and complex, eating is the primary way of initiating and maintaining human relationships. In fact, the English word "companion" is derived from French and Latin words that mean 'one who eats bread with another'." (Farb and Armelagos 1980)

Virtually no event in a persons' life takes place without food: Birth, coming of age, marriage and death are all associated with food and drink. "To know what, where, how, when and with whom people eat is to know the character of their society." (Farb and Armelagos 1980)

You are what you drink

It is a fairly safe assumption that, as long as there has been food, there has also been food going off; fermenting, in some instances into something tasty. One such fermentation product is alcohol. Alcohol production may even have, to some degree, aided the success and spread of agriculture. A wide variety of alcohol is being processed today, and drinking brings about a pleasurable feeling to the moderate consumer. Ancient people needed their food and will have liked their drink just as much as people do today.

"Indigenous societies in nearly every part of the world, aside from the South Pacific and most areas of North America, developed their own alcoholic drinks."(Farb and Armelagos 1980) The first fermented liquors were in all likelihood consumed before the development of agriculture. Mead is made from fermented honey and water, and wild fruits collected by hunter-gatherers will also have had a high enough sugar content to be fermented. The advent of domesticated cereal grains incited beer production: Sumerian tablets dating to almost 5.000 years ago already mention 19 different kinds of beer. (Farb and Armelagos 1980)

What "bread and butter" is to modern Western civilisation, used to be "bread and beer" in ancient Egypt (Darby, Ghalioungui et al. 1977; Mills 1992), Nubia's next door neighbour. Egypt developed a bread culture, easily comparable to modern speciality bakeries. (Adrario 2002)

Besides being used for eating, lightly cooked bread was fermented to make beer. "Many hymns to Hathor depict her as the goddess of inebriety and as the inventor of beer whereby she was turned from a wild lioness into an amiable fun-loving lady." (Darby, Ghalioungui et al. 1977) Beer was cheap and compared to wine, easy to produce. "Beer was thus next in preference to water, the popular beverage *par excellence*." (Darby, Ghalioungui et al. 1977) It nourished wealthy and poor, was offered to gods, and placed in tombs for the afterlife. (Samuel and Bolt 1995) This universal popularity may be partly explained by the state of sanitation, which made water a risky drink. Alcohol and natural acids in wine and beer kill many bacteria. (Vallee 1998) By improving keeping qualities, alcohol can also be advantageous for food preservation and storage. In ancient beer the activity of yeast, and probably also of lactic acid bacteria (through lactic acid fermentation creating an acidic environment), produced an environment toxic to many other bacteria and fungi. (Samuel 2000)

Beer can be brewed from any grain. Barley and emmer have been found in Egyptian archaeological baking and brewing sites. (Samuel and Bolt 1995) Malting is the process converting starches in grain into sugar: While grain is allowed to germinate, starch is converted to maltose and diastase. Therefore, in modern processes grain is germinated, heated and dried to stop germination. The malt (deliberately germinated grain) is boiled with water, strained and incubated with yeast. (Darby, Ghalioungui et al. 1977; Samuel 1996; Armelagos, Kolbacher et al. 2001)

The conventional view of Egyptian brewing, as derived from tomb scenes, holds, that lightly baked bread (already containing yeast) was crumbled and strained through a sieve with water. Additional ingredients like dates may have been added. The dissolved mixture was fermented and the liquid decanted. However, analyses of starch granules indicates, that ancient Egyptian beer may have been made with both malt and unsprouted grain. The malted grains would have contained active enzymes for breaking starch down into fermentable sugars. A mixture of the two would have been sieved (chaff was sieved out) and fermented. Bread would not have played a role in this process. (Darby, Ghalioungui et al. 1977; Samuel and Bolt 1995; Protz 1996; Samuel 2000)

In any case – “Ancient beer ... was rather different from its modern counterpart. It was probably an opaque liquid looking like a gruel or soup, not necessarily very alcoholic but highly nutritious. Its prominence in Egyptian diet reflects its food value as much as he mildly pleasurable sensation that went with drinking it.” (B.J. Kemp, 1989; as cited by (Armelagos, Kolbacher et al. 2001))

Beer was liquid staple food and thus widespread – not only on the African continent. The Prussian king Friedrich der Große (1712 – 1786) complained about coffee imports in the 1770-ies and 80-ies. He abhorred watching people drink increasing amounts of coffee. The king, his ancestors and officers had been brought up with beer-soup – which he considered a lot healthier than coffee. (Vallee 1998)

Consuming antibiotics

Antibiotics are ubiquitous, yet humans were and are not constantly subjected to them. Growth of antibiotics and exposure to them are influenced by cultural factors. An agricultural life-style with its practice of food storage benefited growth of antibiotics in dietary items. Both the length and methods of food storage influence the microclimates affecting the selective dis/advantages of certain microorganisms. Food processing can either destroy a substance or aid its absorption through the human gut. Dietary items themselves may influence antibiotic uptake: E.g., dairy products bind tetracycline and thus effectively prevent absorption. (Keith and Armelagos 1983; Mills 1992)

"An analytical approach could then be applied to anecdotal evidence for antibiotic use in anthropological populations. Perhaps the radish-onions-garlic diet of workers on Cheop's pyramid was a key factor in preventing infectious disease. Perhaps heparin, an antimicrobial agent in liver tissue, did affect the health of recipients of human gladiator liver." (Rosett et al, 1980; and Majno, 1975; as cited by (Keith and Armelagos 1983))

Nubian diet and possible sources of tetracycline

"Wheat, barley, and millet were staples of the Nubian diet, and beer and bread comprised 70 percent of their caloric intake, as it does today." (Keith and Armelagos 1983)

Bread

Nubians were agriculturalists, practising irrigation farming. For the past 5.000 years they lived by producing sorghum, millet, barley, beans, lentils, peas, dates, and wheat. Animals (cattle, pigs and sheep) constituted a minor part of the Nubian diet. (Bogin 1997)

Initially researchers thought Nubians might have been forced to eat mouldy grain during periods of famine or drought. Indeed, streptomycetes could be isolated from grain and barley cultured at 55°C on Sudanese soil samples. (Bassett, Keith et al. 1980) Storing grain in mud bins and clay pots provides an ideal environment for streptomycetes. Their preferred warm, dry, and alkaline environment is replicated in the mud storage bin "and their ability to grow on solid substrates would allow them to grow on the grain." (Keith and Armelagos 1983; Armelagos, Kolbacher et al. 2001) Even one or two grams of the antibiotic consumed in a day will result in fluorescence in the bone. But, when growing well, streptomycetes actually produce little tetracycline. (Armelagos 2000)

So given the extent of tetracycline labelling in the examined X-Group population, and its frequency (many X-Group Nubians received continuous doses of tetracycline) other possibilities had to be explored. The researchers looked for other commonly consumed food or medicine. Also, given the minimal production of tetracycline by streptomycetes in the soil, a process was sought after that would provide the significant levels of tetracycline that had been detected in the bone. One process that could yield high enough quantities of tetracycline from "contaminated" grain, was brewing. (Armelagos 2000; Armelagos, Kolbacher et al. 2001)

Beer

In the Middle Nile region, sorghum-based foodstuffs are diverse and hint at a long history. Among them are fermented alcoholic beers (typically *merissa*) with about 30-50 varieties, and a number of porridges based on fermented sorghum dough. (Dirar 1993 and 1994, as cited by (Edwards 1996)) Alcoholoic food beverages are an integral part of Sudanese subsistence. (El Tayeb, 1974; as cited by (Edwards 1996)) *Merissa* and a*ssaliya* were brewed according to early European traveller reports. Mediaval Arabic sources talk of such beverages as *mizr*. (Edwards 1996)

Assumptions about ancient Nubian beer production, can rely on several sources:

- A comparison with booza-production: The present day method of preparing booza, a common drink in today's Sudan, and "made all over Egypt by Nubians, … consists first in kneading ground wheat, barley, or other cereal with water and yeast. After a short leavening, this dough is lightly baked into thick loaves. Separately another fraction of wheat is moistened, exposed to air for some time, crushed, and then added to the previously prepared loaves after they have been crumbled. The fermentation is then promoted by the addition of some old *booza*.

No flavouring material and no hops are added. The result is a thick beverage with a strong yeasty odour."(Darby, Ghalioungui et al. 1977)

- A comparison with ancient Egyptian brewing, as described above. Though beer production can be assumed to have been similar in Egypt and Nubia, regional variation in producing the various types of beer can be expected. One known difference concerns brewing vats; while in Egypt they were covered with a lid (Delwen Samuel, personal communication), in Nubia they remained open (David Edwards, personal communication). This is an interesting detail, since Nubian vats would thus have been more susceptible to catching airborne yeast and possibly also streptomycetes.

  If the conventional view on Egyptian brewing (as described above) is correct, then bread dough would have been used in beer production. In some traditional recipes this dough would have been set out in theair to capture airborne yeast. At this point in the process streptomycetes spores could also have been caught. In other recipes booza from a previous batch of beer is added, already containing the necessary yeast. The slightly baked bread would still contain a raw centre allowing the yeast to grow and streptomycetes to produce tetracycline. (Armelagos, Kolbacher et al. 2001)
- Sudanese recipes dervived from another source (Culwick, 1951; as cited by (Armelagos, Kolbacher et al. 2001)) describe a process, where sorghum is malted by soaking in water, after which it is spread out and covered with a cloth. "The sprouting grain grows under the cloth for 4 days and a thick layer of mould covers the plants and the cloth. On the fifth day the sprouted grain is spread out to dry." (Armelagos, Kolbacher et al. 2001) At this point the malted grain can be stored or ground to be used as flour, if more coarsely ground is can be used for beer production: Coarsely ground malted grain is put in water for 4 days creating a soft dough on which green mould is allowed to grow. Formed into a loaf, the dough is then covered with suet, placed on a baking sheet, scorched and put in old beer pots for an additional 30 hours in order to allow more mould to form. Only then is it ready for brewing. (Armelagos, Kolbacher et al. 2001)
- Experiment: Two undergraduates at Emory University modified Egyptian and Sudanese recipes to brew beer from bread and grain. Their aim was to investigate the potential for tetracycline production at the various stages of the brewing process. Streptomycetes were added during two phases of the brewing process. "In

> the first experiment a small colony of streptomycetes was added to the just-baked bread. In the second experiment, they added the streptomycetes to the mix of the grain and bread. The second experiment was the most successful and produced significant amounts of tetracycline." (Armelagos 2000; Armelagos, Kolbacher et al. 2001)

Streptomycetes could thus have been growing on the grain in storage bins or during malting; they could also have been caught in the raw dough at the time it was put outside to catch airborne yeast.

Nowadays pharmaceutical companies deliberately control and limit certain nutrients as a way of forcing streptromycetes to produce tetracycline. Fermenting brews provided this harsh environment, in which sreptomycetes were stimulated to yield tetracycline in quantity. (Armelagos 2000) Antibiotic activity would have been advantageous during brewing, since tetracycline kills off competing bacteria but allows fermentation by yeast. "modern German breweries take advantage of this fact by introducing tetracycline-impregnated filters into the brewing process." (Keith and Armelagos 1983)

5. The microscopic structure of bone

Macroscopically there are two types of osseous tissue: About 80% are cortical (or compact) bone and 20% are trabecular bone (also known as cancellous bone or spongiosa). Trabecular bone is made of rods and plates, and can be found e.g. in vertebral bodies, the cranial diploe, and in metaphyseal spaces of the long bones. Cortical bone is the dense bone of the long bones, as well as the surface of most other bones. (Garland 1989; Junqueira and Carneiro 1996; Fanghänel, Pera et al. 2003)

Histologically, woven and lamellar bone can be distinguished. Woven bone is formed by osteoblasts (bone forming cells) during the initial formation of the skeleton, and as a response to fractures or some diseases. In infants and children, woven bone is a substantial proportion of the skeleton. This proportion decreases to very low levels in adults, except where the bone is affected by trauma or disease. In general woven bone is formed relatively fast and its structure is more disorganised than cortical or trabecular bone. Lamellar bone is a layered, structured bone formed by an ordered accumulation of bone matrix in response to normal bone growth and remodelling. It is therefore relatively dense and strong. (Stout and Simmons 1979; Junqueira and Carneiro 1996; Fanghänel, Pera et al. 2003)

Trabecular bone also shows lamellae, but in cortical bone these lamellae form special structures: Osteons (or Haversian systems) are concentric lamellar systems with associated osteocytes (bone cells) built around a Haversian canal. Haversian canals (longitudinal canals in figure 7) are circulatory canals in cortical bone. They contain arterioles, veins, and nerves, enabling bone metabolism in the cortical skeleton. The canals are intertwined and interconnected with one another as well as with Volkmann's canals (transverse canals in figure7). The latter proceed perpendicular from the inner and outer surfaces of the bone inwards. (Martin and Burr 1989; Junqueira and Carneiro 1996) At the right hand side of figure 7: An osteon, a Haversian canal, and a blood vessel in its middle. The slightly spiky structures are osteocytes (bone cells).

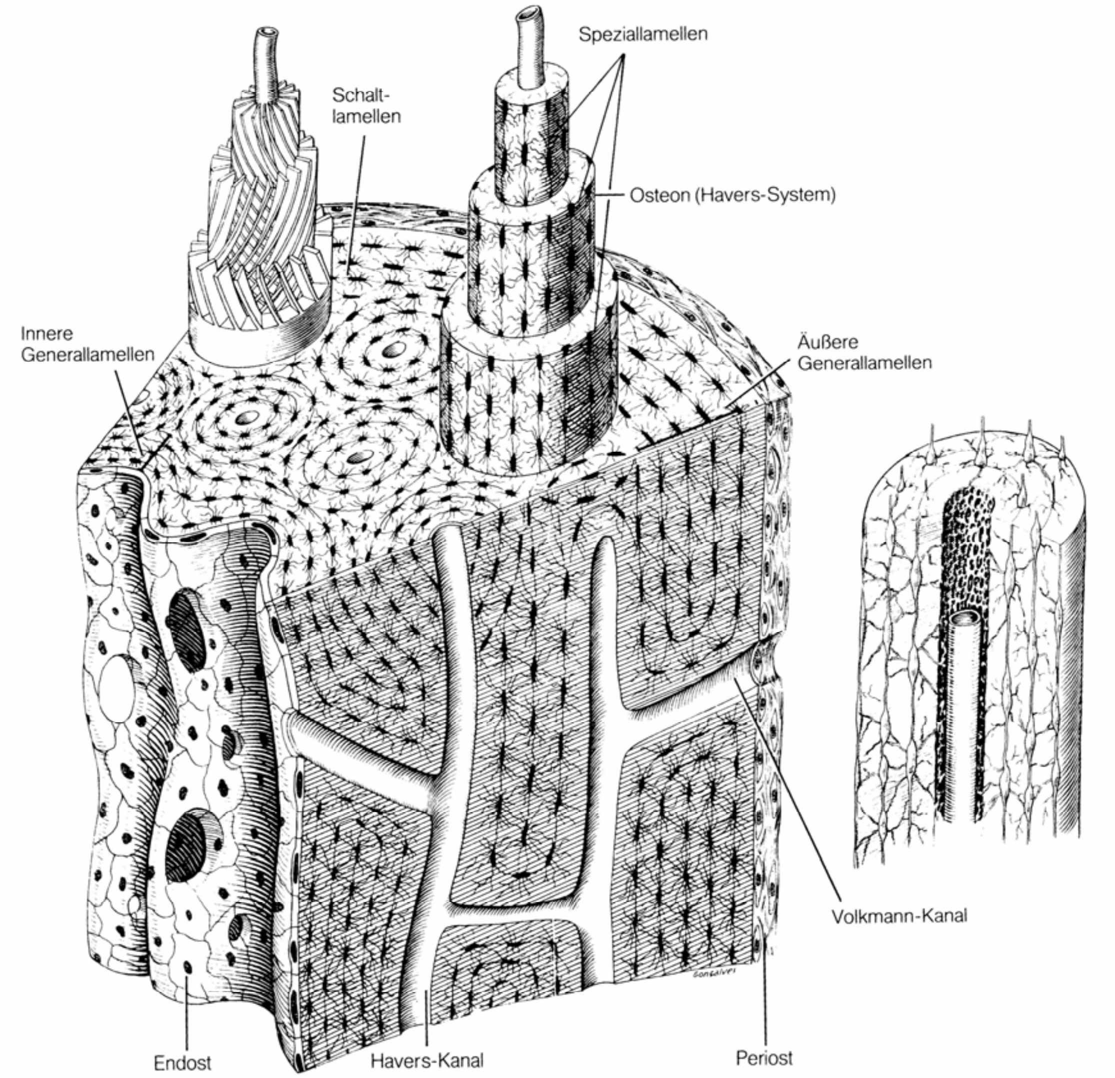

Figure 7. Schematic drawing of compact bone, from (Junqueira and Carneiro 1996)

Bone is an active tissue and is permanently being remodelled. Bone remodelling causes the intersection and successional overlay of osteons. (Junqueira and Carneiro 1996) Figure 8 shows the new formation of compact bone with three successive generations of osteons. Indicated above are interstitial lamellae – lamellae of partially resorbed osteons left between more recently built osteons.

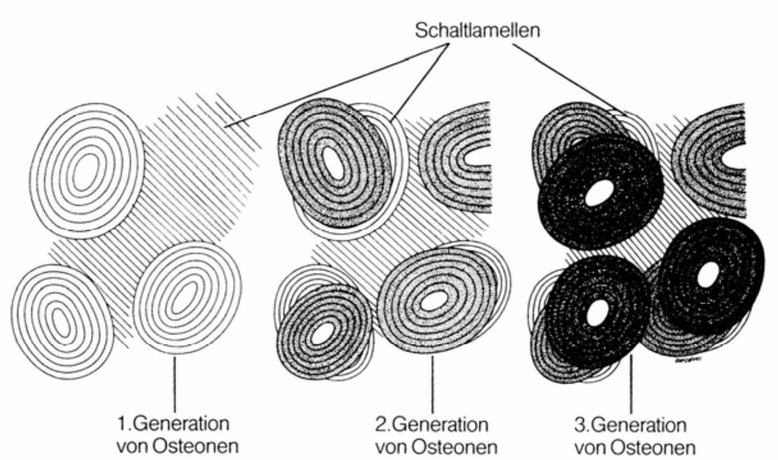

Figure 8. Three generations of osteons, from (Junqueira and Carneiro 1996)

Since primary osteons do not result from bone remodelling, they do not show cement lines (reversal lines). Secondary osteons are the product of the resorption of previously existing bone tissue and the deposition of new bone tissue in its place. A cement line separates the osteon from the extraosteonal bone matrix. (Burr, Ruff et al. 1990) The cement lines indicate the point where osteoclasts stop resorbing bone and osteoblasts start bone deposition. (Ortner and Putschar 1981, as cited by (Armelagos, Kolbacher et al. 2001))

II. Materials and Methods

"There is no such thing on earth as an uninteresting subject;
the only thing that can exist is an uninterested person." G. K. Chesterton

1. The burial sites: 6B13 and 6G8

In the present study bone from two Christian burial sites is examined. Both burial grounds were excavated by the University of Colorado team (see figure 9 for the location of the burial sites). From 6G8 at Dabarosa West 33 skeletons were obtained. 37 were excavated from 6B13 in south Argin. Both burial grounds produced very little pottery other than random shards. The majority of graves had been opened and pottery presumably had been removed, leaving the human remains with little or no disturbance. (Armelagos, Ewing et al. 1965)

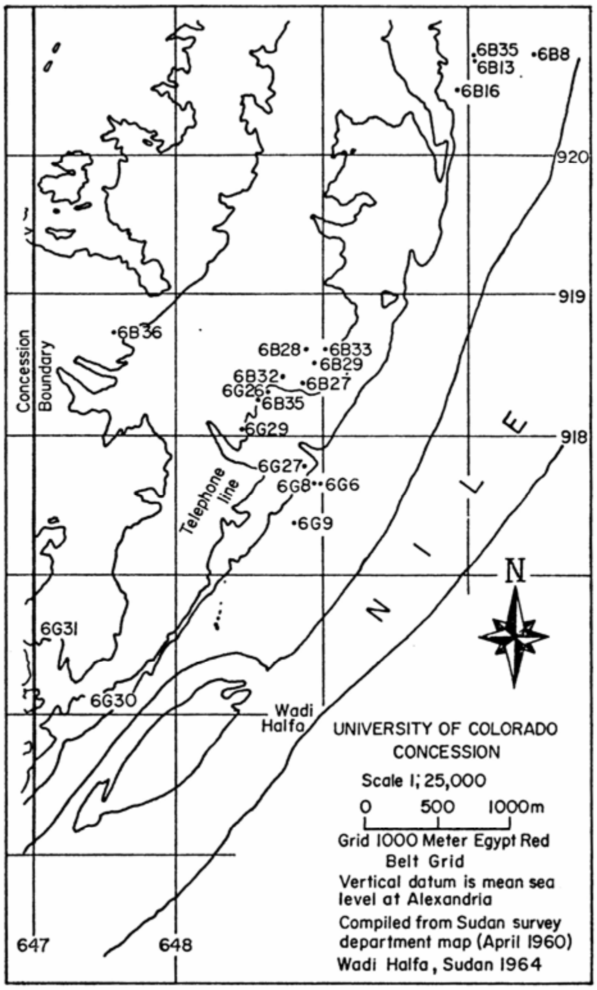

Figure 9. The University of Colorado concession, from (Armelagos, Mielke et al. 1972)

Christian graves were mostly simple tombs with a small rectangular superstructure of brick covering the narrow grave shaft. (Williams 1979; Anderson 2004) While bishops were buried in their religious garments, other people were wrapped in a shroud or laid in a coffin. (Anderson 2004; Geus 2004) "More elaborate superstructures were plastered white, cruciform in shape or had rounded rather than flat tops. Some were provided with small niches for lamps. Vaulted communal tombs containing many individuals were also used." (Adams 1998a in (Anderson 2004))

Taking the non fossilized remains of their excavations with them, would have exceeded the budget of the University of Colorado expedition. Furthermore, the time involved in packing the material for transport would have reduced their excavation time. Though, during later analysis, they regretted no longer having the material at hand, they could but take a few samples with them. (Armelagos, Ewing et al. 1965)

In order to systematically approach measuring the Nubian remains, the Colorado team used cards developed at the University of Michigan by Charles Eyman and Mark L. Papworth. The cards were revised for use and could later be used as key sort cards. (Armelagos, Ewing et al. 1968) Burial number ("burial" in all tables), age and sex as indicated in the following tables stem from these cards.

Every remaining bone sample was also cross checked with the handwritten Field Catalogue of the University of Colorado Nubian Expedition, as recorded by George Armelagos in the 1963/64 season. The field catalogue gives the field catalogue number (running numbers), site, date, burial, cultural provenience, specimen (bone, tissue etc.) and sometimes an additional comment. Bone samples, whose origin could not be confirmed, were omitted from further study.

In the following, table 1 gives an overview of sex and age of excavated individuals in population 6B13; table 3 shows the same for population 6G8.

Tables 2 and 4 list pathologies of the respective individuals as noted by the Colorado team. The records describe the type of pathology, the localisation, and (with the skull) whether the pathologies found on certain bones are slight/medium or marked. Some, but not all, records note when the remains are fragmentary. Sometimes the measurements taken indicate a fragmentary state of the burial remains, but no specific note is taken. While measurements, including pathologies, of 6B13 individuals were recorded by only one observer, 6G8 records stem from at least 5 different observers.

Burials 6B13	Sex	Age
1	?	subadult
2	M	adult (27-30)
3	F	subadult
4	M	adult
5	M	subadult-adult (18)
6	F	adult
7	F	subadult-adult (18-21)
8	M	adult
9	?	? at least subadult
10	F	adult (30)
11	M	subadult-adult (18)
12	M	adult (27-30)
13	F	adult
14	?	subadult
15	?	? at least subadult
16	F	subadult (18)
17	M	subadult-adult (18)
18	?	subadult
19	?	subadult
20	?	subadult
21	M	adult (21)
22	M	adult (44)
23	M	adult (48)
24	? (no record)	adult
25	?	subadult (infant)
26	?	subadult
26 A (27)	?	subadult (infant)
27 / 27(28)	?	subadult
28	? no record	no record
29	?	subadult
30	M	adult (32)
30A / 30A(31)	F	subadult-adult (18)
31 / 31(32)	M	adult (28)
32 / 32(33)	? (no record)	adult
33 / 33(34)	M	subadult-adult (18)
34		
34 (35)	M	adult (22)
35 / 35(36)	F	adult (30)
37	? (no record)	adult

Table 1. 6B13 records

To burials 9 and 15 neither sex nor age were ascribed. Taking into account the measurements taken of the remaining bones, the individuals must have been fully grown subadults or adults.

Burials 6B13	Pathologies Skull	Postcranial Pathologies
1	marked syphilitic-like lesions	syphilitic-like lesions on the long bones, ? (missing records)
2	marked abscess on one bone, pitting, medium resorption mand. + max. alveolar	vertebral lipping, ankylosis of two lumbars, condylar lipping distal tibia, abscess on humerus
3	partly marked; numerous abscesses, pitting, resorptions, syphilitic-like lesions	none
4	medium abscesses on two bones, pitting	femoral condylar lipping, abscesses on long bones, arthritic eburnations on femora and a healed femoral fracture, exostosis on distal radius; pierced fossa olecrani
5	medium pitting over an extensive area, medium resorption mand. + max. alveolar, exostoses	pitting on various long bones, ribs show distortions, roughening and erratic growth, small abscess on tibia
6	? (poor preservation - observation impossible)	pierced fossa olecrani
7	medium but extensive pitting on parietal, medium resorption mand. + max. alveolar	pitting of vertebrae and long bones, small region of pitting and abscess on distal clavicle, marked tubercle on pubic
8	medium pitting and abscess only at foramen magnum	vertebral condylar lipping, pierced fossa olecrani, ? (bones badly preserved)
9	? (missing record)	pierced fossa olecrani
10	? (poor preservation) no apparent pathologies	pierced fossa olecrani
11	mastoids show marked erosion probably caused by infection, medium resorption mand. + max. alveolar	pierced fossa olecrani
12	marked pitting at aud. meati and foramen magnum, slight depression in molar region of mandible, medium to marked resorption mand. + max. alveolar	pierced fossa olecrani, exostosis in subtrochanteric fossa
13	no gross pathologies; slight pitting on mastoids, marked resoprtion of 1/2 mandible due to tooth loss, traumatic lesion to frontal and left temporal, medium to marked resorption mand. + max. alveolar; abscess above left 1st pm.	vertebral lipping, healed fractures of ribs, right femur, left fibula and ulna
14	medium syphilitic-like lesions – three of which seem to involve the diploe, two abscesses in the asc. ramus	numerous lesions on the long bones
15	? (missing record)	pierced fossa olecrani
16	atlas fused to foramen magnum, medium pitting of one bone, exostoses, medium to marked resorption mand. + max. alveolar	pierced fossa olecrani
17	none - except medium resorption mand +	pierced fossa olecrani

	max. alveolar	
18	extreme syphilitic-like lesions, exostoses, medium abscess, resorption of mand. alveolar	large abscess on scapula,
19	very fragmentary – orbita with marked exostosis, medium abscesses on two bones	various abscesses
20	medium- marked abscesses	six abscesses on long bones
21	medium to marked pitting on parietals and on the superior portion of the orbits, medium resorption mand. + max. alveolar; bulge on one temporal crest, enlarged jugular foramen	pierced fossa olecrani
22	medium to marked abscesses, sinus infection of the left maxillary sinus involving the arc above the molars, medium resorption mand. + max. alveolar; left zygomatic appears to have been fractured	condylar lipping on long bones, metacarpals show severe osteoma in several digits
23	medium abscess on one bone	condylar lipping on hands and feet, one lumbar showing extreme lateral compressions
24	? (fragmentary)	long bones with lots of infections lesions OR animal gnawing
25	a number of abscess-lesions on the parietals	gross abscess-lesions on long bone shafts
26	fragmentary - abscess/ lesions in orbit	two abscesses in long bones
26 A (27)	? (missing record)	very fragmentary - no apparent pathologies
27 / 27(28)	? (fragmentary)	fragmentary, pierced fossa olecrani
28	? (missing record)	? (missing record)
29	medium to marked syphilitic-like lesions on four bones	deep syphilitic-like lesions on long-bones
30	no pathologies apart from marked resorption on mand. alveolar	vertebral lipping, one lumbar with lateral compression
30A / 30A(31)	small abscess on one bone	no gross pathologies, only one ulnar abscess
31 / 31(32)	marked abscess on one bone	? (very fragmentary) both fossae olecrani pierced
32 / 32(33)	fragmentary - only medium to marked resorption on mand. alveolar	fragmentary, exostosis on ulna below radial notch
33 / 33(34)	medium abscesses on four bones, exostoses, medium resorption mand. + max. alveolar, marked compression on the parietal	none
34 (35)	medium to marked abscesses on three bones, medium arthritic exostosis and pitting at foramen magnum, medium resorption mand. + max. alveolar	extreme condylar lipping and exostosis in fossa olecrani
35 / 35(36)	fragmentary – only medium resorption on mand. alveolar	fragmentary – pierced fossa olecrani
37	medium resorption on mand. alveolar	condylar lipping on humerus

Table 2. Summary of pathologies of 6B13 individuals, as recorded on key sort cards

Burials 6G8	Sex	Age
1	M	adult
2	?	subadult
3	?	subadult (child)
4	F	adult (23)
5	M	adult (29)
6	?	subadult
7	?	adult
8	M	adult (27)
9	?	subadult
10	M	adult (27)
11	F	adult
12	?	subadult
13	F	adult (33)
14	M	adult
15	?	subadult (7 months)
16	F	adult
17	?	subadult
18	F	adult (43)
19	F	adult
20	?	subadult (child, 2-6)
21	M	adult (37)
22	?	subadult (under 7 months)
23	?	subadult (child, 2-6)
24	?	subadult (child, 2-6)
25	?	subadult (child, 2-6)
26	F	adult (44)
27	F	adult (39)
28	F	adult (38)
29	M	adult
30	F	adult
31	?	subadult (child, 2-6)
32	F	adult
33	? (incomplete records)	adult

Table 3. 6G8 records

Pathologies for 6G8 are listed in table 4 below:

Burials 6G8	Pathologies skull	Postcranial Pathologies
1	dense bone – possibly osteopetrosis, lipping on occipital condyles, sub meatal bone growth, pitting, medium resorption mand. + max. alveolar	very dense bone - osteopetrosis?, party extreme vertebral condylar lippig – osteoarthritis?, ankylosis and other fusions of vertebrae, scapulae with lipping on glenoid cavities, exostoses on scapula, pitting and abscess on humerus, condular lipping on femur
2	pitting, abscess on left asc. ramus	pitting on tibia and fibulae, smooth inflammatory lesion on ulna, abscesses on clavicles, perforated

		scapula, abscess on hip; osteomyelitis?
3	none	pitting near proximal and distal ends of long bones - questional whether inflammable
4	exostoses, marked resorption mand. alveolar	exostoses in femoral fossa subtrochanterica, vertebral lipping and pitting
5	medium pitting, marked resorption of max. and mand. alveolar and asc. rami	vertebrae with condular lipping, lumbar vertebrae with exostoses, thoracic vertebrae with pitting, exostoses on scapula, pitting and abscesses on femur and tibia
6	exostoses, medium pitting and resorption of mand. alveolar, 1/4 cm high curved growth near one molar	pitting on humerus, tibia and vertebrae
7	medium and marked abscesses on six bones, abscessing on roof of left orbit	pitting, inflammatory lesion on humerus, pierced fossa olecrani, abscesses on hip
8	traumatic lesion on the frontal, abscesses on two bones, marked resorption of max. and mand. alveolar, exostosis on left styloid	pitting, deformities on the humerus
9	pitting and abscess on one bone	none
10	abscesses on two bones, exostoses, marked resorption of max. and mand. alveolar, maxillary alveolar and maxillary perforated with abscesses probably due to tooth infections	rough inflammatory lesion on humerus, exostoses on femur, pitting, condylar lipping on vertebrae probably due to old age
11	cracks from a fracture (?) on frontal, marked resorption of max. and mand. alveolar	abscesses on clavicle and sacrum, exostosis, pitting, lipping on vertebrae and iliac crest
12	? (missing record)	? (too fragmentary)
13	pitting, marked resorption of max. and mand. alveolar, one abscess or canine incisors?	exostoses on femur, condylar lippig on ulna, pitting, abscesses on sacrum, vertebral lipping probably due to old age
14	pitting, medium abscess on two bones - syphilitic?	pitting on scapula, deep pits on ilium
15	?	none
16	medium abscess on one bone, marked resorption of max. and mand. alveolar; nothing drastic	several abscesses
17	only medium pitting in max.	none
18	medium abscess on one bone, pitting, marked resorption of max. and mand. alveolar	exostoses, pitting, abscesses on humerus, femur and vertebrae, pierced fossa olecrani,
19	extreme pitting, marked abscesses on two bones, resorption on palate	exostosis, condylar lipping on scapula, pitting, abscesses, fossae olecrani pierced,
20	medium to marked exostoses on four bones	pitting on femur
21	exostoses, abscess on one bone, marked resorption of max. and mand. alveolar	healed rib fracture, ankylosis and abscess on hip
22	pitting, marked abscesses on four bones among them extreme abscesses on mastoids, marked inflammatory lesions on 7 bones - concentrated in suture areas	? (badly decomposed body), some pitting visible

23	only pitting on asc. rami, appears in good health	only pitting on fibula, no marked pathologies
24	only exostosis on palate	none
25	medium abscess on one bone	none
26	only medium resorption of max.and mand. alveolar	healed fracture of clavicle, pitting, abscess on sacrum, pierced fossae olecrani,
27	medium exostosis and pitting on one bone, marked resorption of max.and mand. alveolar	exostoses on scapulae and femora, pitting, pierced fossa olecrani, lumbar lipping
28	medium abscess on max. alveolar	vertebral lipping, condylar lipping on femur, abscess on 1^{st} rib, pierced fossa olecrani
29	medium traumatic lesion to frontal, marked abscesses on two bones, pitting	slight lipping in lumbars, ankylosis in vertebrae
30	medium abscesses in two bones, medium resorption max. and mand. alveolar; possible complications or sinus condition	condylar lipping on sacrum and vertebrae, marked compressions among cervicals and one lumbar
31	none	none
32	marked pitting on palate and max. and mand. alveolar	condylar lipping on humerus, helaed fracture on humerus, pierced fossa olecrani, exostosis on femur, extreme lipping of lumbars, moderate lipping of thoracic vertebrae,
33	medium arthritic exostosis and pitting in aud. meati	? (missing record)

Table 4. Summary of pathologies of 6G8 individuals, as recorded on key sort cards

2. Thin sectioning

Sampled bone used to produce thin sections is reported to have been taken from femora just below the lesser trochanter. Although the exact origin of the embedded bone could not always be precisely ascertained, the sampled bone generally resembles a femur.

Femoral cross sections had already been embedded in epoxy prior to this investigation. Furthermore, some sections (in the following referred to as "old sections") had been completed at a previous date. Unfortunately, old sections were rarely covered with a covering slip. Thus, they were in the most part fragmented or broken.

The thickness of the old sections could not always be precisely determined. Due to a different sectioning method in the past any thickness measured included not only the slice of bone but also some extra resin on top and/or below. Measured thicknesses could exceed 500 µm; the actual thickness of the bone – though decidedly thinner – is still likely to, in some cases, exceed 150 µm. In most cases further grinding of the old sections had to be abandoned due to the minor preservation of the majority of old sections. Polishing was, however, in most cases possible. Whenever the preservation was sufficient, old sections were ground and /or polished before being covered in order to ease future handling and ensure ideal preservation.

New sections were produced for this study whenever there was remaining bone that could be identified as belonging to a certain individual. As many new sections as possible were then obtained per bone in order to insure against sampling error (compare (Hummert and VanGerven 1982)). A maximum of 5 sections per individual (including both, new and old sections) could be made available for further study. – Old sections were labelled, but their labels were not always completely legible. Furthermore, while the old sections were often fractured, their origin could not always be ascertained beyond doubt. But since all sections from one individual can be expected to share similar characteristics (also in terms of tetracycline presence and number of labelled osteons) the bigger sample of new sections helped distinguish individual bone characteristics and aided in determining whether an available old section with corresponding characteristics could be safely assumed as belonging to that same individual.

All the sections of labelled individuals in the 6B13 population were closely examined not only for tetracycline presence, but also for the number of osteons and the minimum number of labelled osteons. These data were then compared (see part 2 in the results chapter).

Prior to sectioning, the block of resin with the embedded bone was sonicated for several minutes to remove grinding residues. The resin mixture (Buehler epoxy resin and hardener) used for mounting the block on a glass slide was prepared and placed in a vacuum chamber to remove air bubbles.

Then the block of resin was mounted on a clean microscopic glass slide. After the resin had dried and the block was firmly stuck to the slide, superfluous resin was cleaned off the glass with a razor blade. With the help of a triangular rasp the side of the mounted block adjacent to the glass could be grated to obtain a 90° angle between glass and the block of resin. This created an ideal point of contact for the diamond saw, preventing the blade from slipping into a unfavourable position.

The bone sections, already attached to the glass slides, were cut off with a Buehler Isomet™ 1000 Precision Saw. The thickness of the newly produced sections ideally ranged between 100 and 150 µm. To check the thickness of a section, two measures were taken from opposite corners of the slice and averaged. The slice of bone was ground and polished with the aid of a Buehler Ecomet® 3 variable speed grinder/polisher until the desired thickness was obtained. Eukitt was used to attach a covering slip.

Tables 5 and 6 give an overview of the number of previously produced old sections, as well as new sections, per individual of 6B13 and 6G8 respectively.

Burials 6B13	Sex	Age	Bone	No. of Old Sections	No. of New Sections
1	?	subadult	femur		2
2	M	adult (27-30)	femur	1	
5	M	subadult-adult (18)	femur	1	
7	F	subadult-adult (18-21)	femur	3	
12	M	adult (27-30)	femur ?	3	1
17	M	subadult-adult (18)	femur	1	
18	?	subadult	femur ?	2	1
21	M	adult (21)	femur	2	2
23	M	adult (48)	femur	1	
27 / 27(28)	?	subadult	? (too fragmented)	2	
30	M	adult (32)	femur	3	2
31 / 31(32)	M	adult (28)	femur	2	1
32 / 32(33)	?	adult	femur	1	1
35 / 35(36)	F	adult (30)	femur	1	
37	?	adult	femur	2	1

Table 5. Number of old and new sections taken from 6B13 individuals

Burials 6G8	Sex	Age	Bone	No of Old Sections	No of New Sections
1	M	adult	femur		2
2	?	subadult	femur		2
3	?	subadult (child)	femur ?	3	2
4	F	adult (23)	femur	1	2
5	M	adult (29)	femur		2
6	?	subadult	femur ?		1
9	?	subadult	femur ?	1	
11	F	adult	femur	3	
12	?	subadult	femur ?	2	2
13	F	adult (33)	femur	1	1
14	M	adult	femur	1	2
17	?	subadult	femur ?	1	
20	?	subadult (child, 2-6)	femur ?	1	1
21	M	adult (37)	femur		2
23	?	subadult (child, 2-6)	femur	1	
24	?	subadult (child, 2-6)	?	2	
25	?	subadult (child, 2-6)	femur ?	2	
26	F	adult (44)	femur	1	2
27	F	adult (39)	femur	1	1
28	F	adult (38)	femur	1	
29	M	adult	femur	1	2
30	F	adult	femur	1	
31	?	subadult (child, 2-6)	?	4	1
32	F	adult	femur ?		1

Table 6. Number of old and new sections taken from 6G8 individuals

Available thin section that could not be used for analysis include: Old section of individual 4 (the bone in the section did not match the other sections taken from the individual – perhaps because of a wrong inscription on the slide?) and one old section of individual 12 (the bone fragment is too small for analysis).

3. Site selection

Previous analyses of tetracycline in ancient bone followed Frost's triple surface system (see figure 10) in examining thin sections. The aim was to systematically collect data from the endosteal, middle, and periosteal part of the cortical cross sections. With Frost's triple surface system 24 evenly spaced sites on a section could be closely investigated. Osteons and tetracycline labelled osteons were counted inside these 24 fields. However, the sites often had to overlap, since the diameter of the bone was often insufficient to allow for the investigation of three distinct sites. This did not pose a big problem, since the percentage of total osteons/labelled osteons and not the total number of osteons or the number of labelled osteons was of major interest.

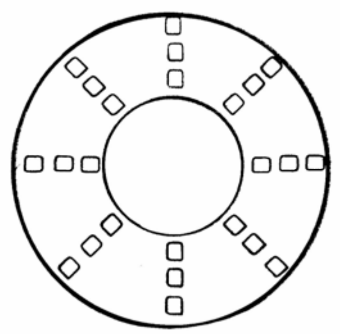

Figure 10. Frost's triple surface system

However, many of the sections of the two Christian populations were incomplete (see figure 13). Thus, locations for observation, as spaced in the Frost triple surface system, would have yielded very few sites per bone for close investigation. Therefore the triple surface system was adapted (see figures 11 and 12).

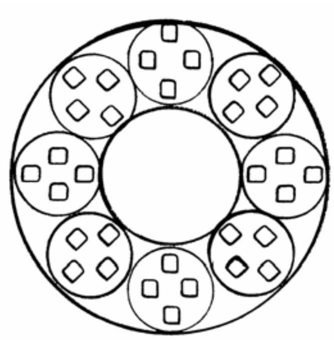

Figure 11. Adapted surface system for complete bone sections.

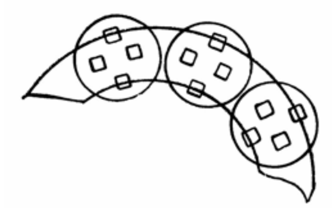

Figure 12. Adapted surface system for incomplete bone sections.

Circles of the same size were evenly spaced around the bone surface. (These circles could be easily marked and numbered on the bottom of the glass slides to ensure the investigation of every site.) Inside every one of these circular “sites” 4 “subsites” were investigated: One periosteal, one endosteal and two in the centre of the bone each. These subsites are in the following termed “inside”, “middle”, and outside. Periosteal and endosteal sites were located immediately on the edge of the bone. Bones with a smaller diameter sometimes lack one type of subsite.

Circular sites were ascribed running numbers. With a complete femoral cross section, a maximum of 8 sites (with respective 32 subsites) could be examined per section. The example in Figure 13 shows an incomplete bone section with 3 sites, and 12 respective subsites: 3 endosteal “inner”, 3 periosteal “outer” and 6 “middle” subsites.

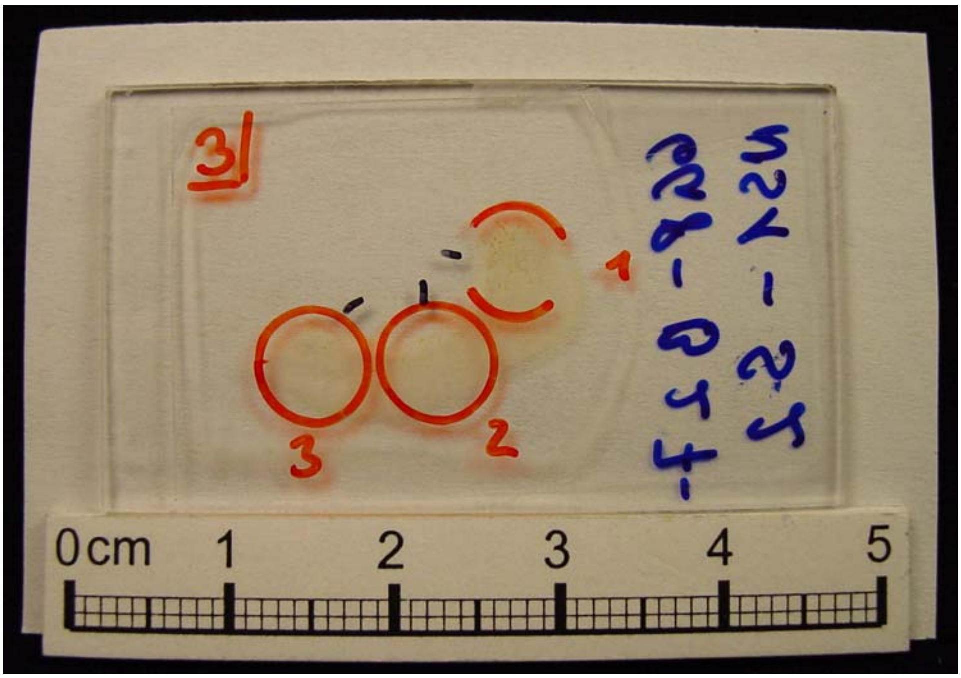

Figure 13. Example of the applied adapted surface system (6G8, burial 27, NS1-S2)

4. Tetracycline detection

Every subsite was examined and digital photographs were taken under normal, polarised, and UV-light.

Polarised light can determine collagen fibre orientation in osteons. Collagen is the predominant protein (90-95%) in bone matrix. It provides strength against bending and tension in bone, and also provides a matrix where mineralization occurs. Fibre orientation between osteonic lamellae vary. Fibre bundles parallel to the section plane appear bright under polarised light because they rotate the plane of polarised light with respect to the viewing plane; fibre bundles perpendicular to the section plane appear dark under polarised light. (Martin and Burr 1989; Schoeninger, Moore et al. 1989; Junqueira and Carneiro 1996)

Thus, polarised light can be utilised to check the structural preservation of bone collagen on the submolecular level. "… osteons from modern or well-preserved bone show the characteristic birefringence, seen as alternating bright and dark fields or 'Maltese crosses'. Birefringence is due to the alternating orientation of the collagen fibers." Within each lamella of a Haversian system collagen fibres are parallel, but the direction of orientation in successive lamellae changes. Deterioration of collagen would result in a loss of birefringence. (Armelagos, Kolbacher et al. 2001)

Viewing the sections under polarised light made references to the preservation of the bone possible. The preservation is specifically referred to in tables 7 (for 6B13) and 8 (for 6G8) and was generally excellent. Figure 14 shows an example of Maltese crosses under polarised light.

Figure 14. “Maltese crosses” (6G8, burial 13, NS1-S2)

Viewed under the fluorescence microscope with exciter and barrier filters to eliminate autofluorescence and other fluorophors, the presence or absence of tetracycline could be determined. Present tetracycline would emit a characteristic yellowish-green light. Figure 15 shows one fully labelled osteon and a labelled endosteal lamella.

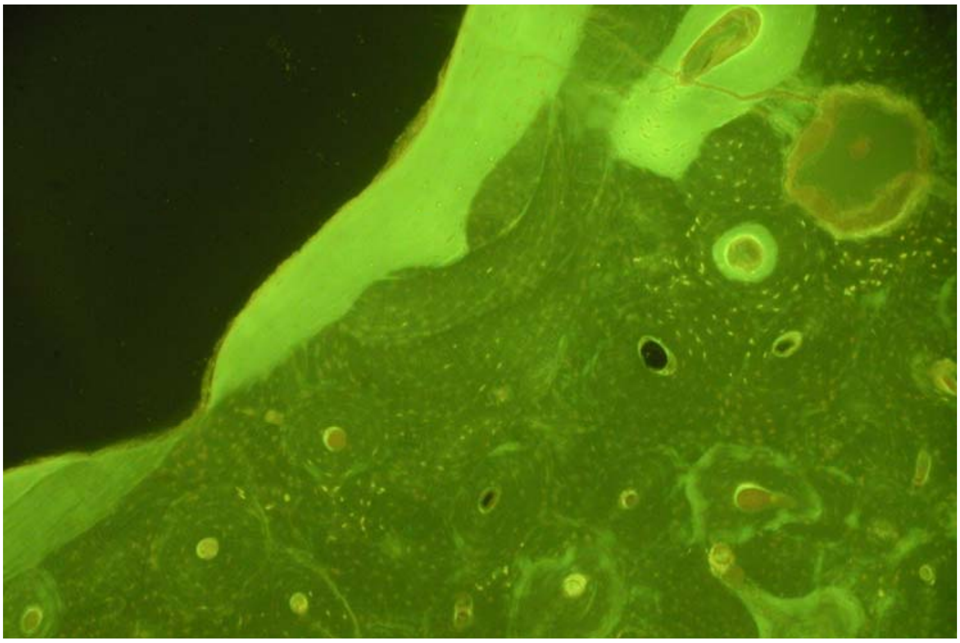

Figure 15. A fully labelled osteon under UV-light (6G8, burial 3, NS1-S4)

When labelling was determined in any subsite of a section, the individual was deemed "labelled", and osteons were counted on all subsite of the respective section. Osteons of "unlabelled" individuals were not counted.

With "labelled" individuals, osteons (secondary or, in some cases, primary) were counted, whenever they possessed a Haversian canal. Secondary osteons which had been replaced by other osteons and "lost" their Haversian canal in the course of the remodelling processes were not taken into account. Osteons with at least 1/2 of their Haversian canal visible on all four edges of the picture were taken into account; osteons with less than 2/3 of a Haversian canal visible on the picture were not counted. As an example: In the left picture of figure 8 three osteons would have been accounted for, in the two pictures to the right four osteons would have been counted each time – three with the entire diameter or their Haversian canal visible, and one with half a canal on the right hand border of the picture (where it could be assumed that this osteon's Haversian canal was still complete as well). Labelling was carefully ascribed.

- A label was assumed when the entire osteon was labelled – as seen in figure 15, the osteonal structure (as cross-checked under polarised light) was intact, and the osteon could be clearly outlined and distinguished from ist surrounding.
- Some osteons were only labelled in their inner one or two thirds. Whenever the labelling covered less than the inner third of the osteon (such as can be seen below the fully labelled osteon in figure 15) the labelling was not taken into account. Anything exceeding a labelling of the inner third of the Haversian system, was counted.
- In addition some concentrically labelled osteons (see figure 16) were observed. These were only taken into account when the concentric label was clearly discernible and could not be mistaken for an air bubble or the outline of an Haversian canal.
- Feathered labelling could be observed among 6G8 individuals. Feathered osteons appeared in different variations (see figure 17): They were accounted for when the feathering was evenly spread and extended from the outer rim of the osteon to the Haversian canal in its centre or at least from the outer rim about two thirds into the osteon. Furthermore, feathered osteons whose light coloured regions were much brighter than the surrounding osteons, were taken into account even when these bright coloured regions only crowded along the outer rim of the osteon. On the

contrary, very lightly coloured feathered osteons with their brighter regions more or less contained along the outer rim of the osteonal structure, were not taken into account in accordance with the conservative counting methods applied.

Wherever labelling appeared diffuse (covering only parts of several osteons and not appearing sufficiently distinct) the bone was not considered labelled.

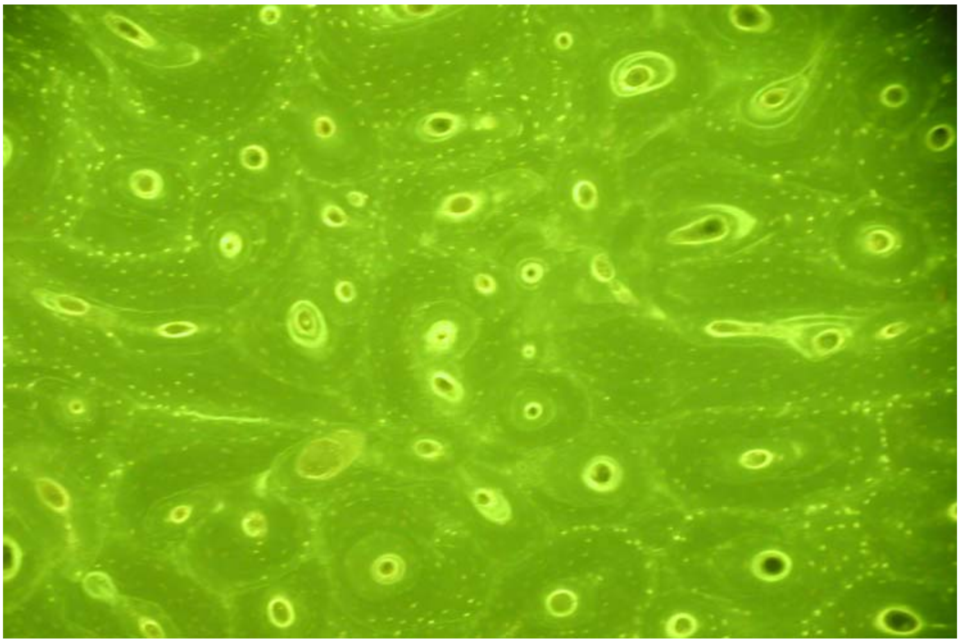

Figure 16. Some concentrically labelled osteons (6B13, burial 1, NS1-S1)

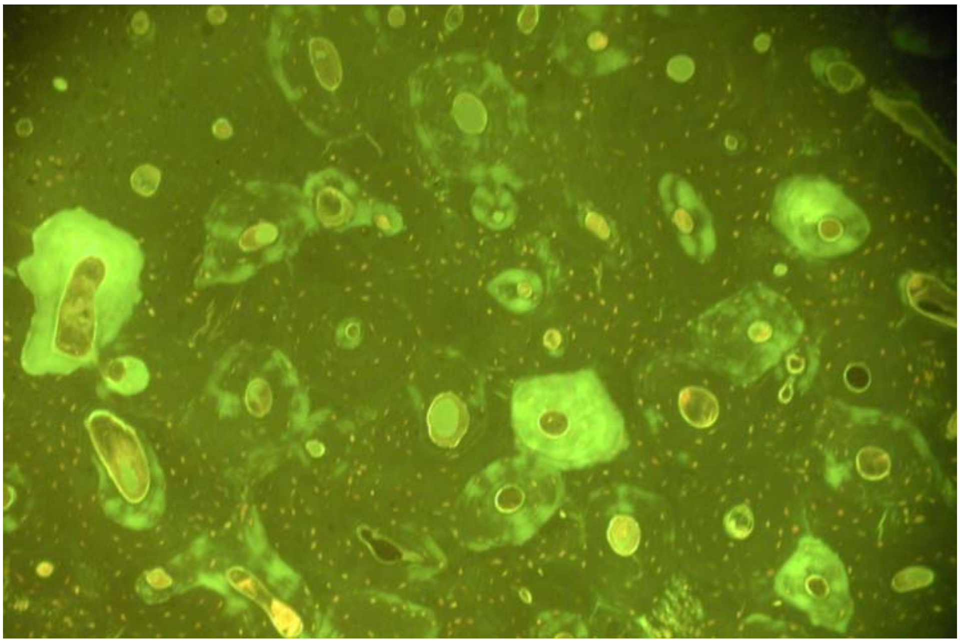

Figure 17. Various feathered osteons (6G8, burial 1, NS1-S1)

III. Results

> "Science ... warns me to be careful how I adopt a view
> which jumps with my preconceptions,
> and to require stronger evidence for such belief
> than for one to which I was previously hostile.
> My business is to teach my aspirations to conform themselves to fact,
> not to try and make facts harmonize with my aspirations."
> (Thomas H. Huxley)

1. Presence of tetracycline

In the 6B13 burial ground, 37 individuals had been excavated. Thin sections could be examined from 15 individuals. Of these 15, one was impossible to evaluate, and five (= 35,71 %) exhibited evidence of tetracycline labelling (see table 7 below).

Table 8 (in appendix A) lists the total number of osteons and minimum number of labelled osteons, that were counted in all subsites of all 6B13 sections exhibiting tetracycline.

In the 6G8 burial ground, 33 individuals had been excavated. From 24 individuals thin sections could be obtained. Of these 24 individuals, 20 (= 83,33%) showed presence of tetracycline (see table 9 below).

Table 10 (also in appendix A) lists the total number of osteons and minimum number of labelled osteons, that were found in all subsites of the 6G8 sections exhibiting tetracycline.

Burials 6B13	Sex	Age-Group	Section	Section Size	Preservation	Tetracycline Present
1	?	subadult	NS1 - S1	approx. half the cross section	good	YES (concentric)
			NS2 - S2	approx. half the cross section	good	YES (concentric)
2	M	adult	OS1 - S1	almost entire cross section	good	YES (fully labelled, one concentric osteon)

5	M	adult	OS1 - S1	almost entire cross section	good, small fractures, artefacts of preparation / storage	YES (concentric)
7	F	adult	OS1 - S1	almost entire cross section	good	YES (concentric)
			OS2 - S2	almost entire cross section	good	YES (concentric)
			OS3 - S3	almost entire cross section	good, inclusions	YES (concentric)
12	M	adult	OS1 - S1	approx. half the cross section	good, small fractures, some inclusions, in very few instances possibly diagenetic changes	no
			OS2 - S2	almost entire cross section	good, small fractures, inclusions, artefacts of preparation / storage, in very few instances possibly diagenetic changes	no
			OS3 - S3	small part of cross section	good, small fractures	no
			NS1 - S4	small part of cross section	good	no
17	M	adult	OS1 - S1	approx. 2/3 of the cross section	good, inclusions	YES (fully labelled)
18	?	subadult	OS1 - S1	almost entire cross section	good, small fractures	no
			OS2 - S2	approx. half the cross section	good, small fractures, inclusions	no
			NS1 - S3	small part of cross section	good	no
21	M	adult	OS1 - S1	almost entire cross section - outer rim missing	good, small fractures	no
			OS2 - S2	almost entire cross section - outer rim partly missing	ok, small fractures, in some instances possibly diagenetic changes	no
			NS1 - S3	entire cross section	good, small fractures	no
			NS2 - S4	entire cross section	good, small fractures	no
23	M	adult	OS1 - S1	approx. half the cross section	ok, small fractures, inclusions, in some instances possibly diagenetic changes	impossible to evaluate
27 / 27(28)	?	subadult	OS1 - S1	small part of cross section	good, small fractures, artefacts of preparation / storage	no
			OS2 - S2	almost entire cross section	good, small fractures	no
30	M	adult	OS1 - S1	almost entire cross section	good, small fractures, in some instances possibly diagenetic changes	no

			OS2 - S2	almost entire cross section	good, small fractures	no
			OS3 - S3	approx. half the cross section	small fractures, in some instances possibly diagenetic changes	no
			NS1 - S4	almost entire cross section	good, small fractures	no
			NS2 - S5	small part of cross section	good, small fractures	no
31 / 31(32)	M	adult	OS1 - S1	almost entire cross section	good, small fractures	no
			OS2 - S2	approx. half the cross section	small fractures, in some instances possibly diagenetic changes	no
			NS1 - S3	approx. half the cross section	good, small fractures	no
32 / 32(33)	?	adult	OS1 - S1	almost entire cross section	good, small fractures	no
			NS1 - S2	small part of cross section	good, small fractures	no
35 / 35(36)	F	adult	OS1 - S1	almost entire cross section	good, small fractures	no
37	?	adult	OS1 - S1	approx. 2/3 of the cross section	good, small fractures	no
			OS2 - S2	approx. 2/3 of the cross section	good,small fractures, inclusions	no
			NS1 - S3	small part of cross section	good, small fractures	no

Table 7. 6B13, Presence of tetracycline

Age Group: For better evaluation ages were grouped into three categories: Children (from the original records: infants, children, and children 2-6), subadults, and adults (from the original records: subadults with an approximated age of 18, sudadults-adults 18-21, and adults).

Section: Each section can be distinguished by its description: OS (old section) or NS (new section). S (section) gives the total number of available sections. E.g. NS1 – S3 is the 1st new section, but the third section overall of the individual.

Section Size: The section size indicates how much of the entire bone diameter was present and could be examined. The bone in figure 12, for example, is listed as “approx. half the cross section“.

Preservation: Preservation of the bone was, in general, excellent. Maltese crosses could be observed in every section. Old sections show fractures mainly due to storage without covering slips. The note in table 4 "in some instances possibly diagenetic changes" indicates that parts of single subsites appear black under normal light. Fluorescences possibly corresponding with this localised phenomenon were in no case accounted for as osteonal labelling. Small signs of possible tunnelling (compare (Hackett 1981; Garland 1987) and (Stout and Teitelbaum 1976; Stout 1978; Schoeninger, Moore et al. 1989; Garland 1993) for preservation of bone preservation in archaeological samples) were only rarely noted, and then in limited areas of a few sections (see figure 18). Easy recognition of osteonal structure and possible labelling was still possible in every case, and osteonal structure appeared intact under polarised light.

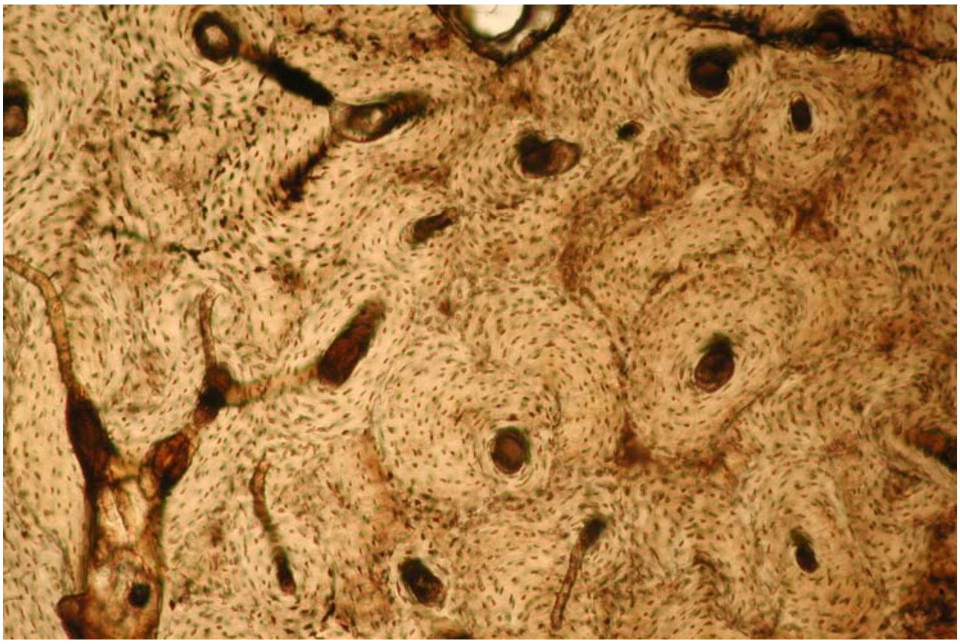

Figure 18. One of the most pronounced cases of tunneling observed.

Tetracycline presence, as observed fort he 6G8 individuals:

Burials 6G8	Sex	Age-Group	Sections	Section Size	Preservation	Tetracycline Present
1	M	adult	NS1 - S1	small part of cross section	good, inlcusions	YES (fully labelled and feathered)
			NS2 - S2	small part of cross section	good, inlcusions	YES (fully labelled and feathered)

2	?	subadult	NS1 - S1	almost entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, very few concentric and feathered)
			NS2 - S2	entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, very few concentric and feathered)
3	?	subadult	OS1 - S1	entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, possibly a few feathered)
			OS2 - S2	almost entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, possibly a few feathered)
			OS3 - S3	entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, possibly a few feathered)
			NS1 - S4	entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, a few feathered)
			NS2 - S5	entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, a few feathered)
4	F	adult	NS1 - S3	small part of cross section	good, inclusions	YES (fully labelled, possibly concentric)
			NS2 - S4	entire cross section	good, inclusions	YES (fully labelled, concentric)
5	M	adult	NS1 - S1	entire cross section	good, inclusions	YES (fully labelled, a few feathered)
			NS2 - S2	almost entire cross section	good, inclusions	YES (fully labelled, a few feathered)
6	?	subadult	NS1 - S1	almost half of the cross section	good, inclusions, few artefacts of preparation/storage	YES (fully labelled)
9	?	child	OS1 - S1	entire cross section	good, inclusions, artefacts of preparation/storage	YES (one osteon fully labelled)
11	F	adult	OS1 - S1	approx. 2/3 of the cross section	good, inclusions, few artefacts of preparation/storage	YES (fully labelled, very few

						concentric)
			OS2 - S2	small part of cross section	good, inclusions	YES (fully labelled, very few concentric)
			OS3 - S3	entire cross section	good, inclusions	YES (fully labelled, very few concentric)
12	?	child	OS1 - S1	entire cross section	good, inclusions, artefacts of preparation/storage	no
			NS1 - S3	entire cross section	good, inclusions, artefacts of preparation/storage	no
			NS2 - S4	entire cross section	good, inclusions, artefacts of preparation/storage	no
13	F	adult	OS1 - S1	approx. 2/3 of the cross section	good, artefacts of preparation/storage	YES (fully labelled)
			NS1 - S2	small part of cross section	good	YES (fully labelled)
14	M	adult	OS1 - S1	entire cross section	good, few small fractures, inclusions, few artefacts of preparation/storage	YES (fully labelled, possibly very few feathered)
			NS1 - S2	entire cross section	good, inclusions, few artefacts of preparation/storage	YES (fully labelled, very few feathered)
			NS2 - S3	entire cross section	good, inclusions	YES (fully labelled, very few feathered)
17	?	child	OS1 - S1	entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled)
20	?	child	OS1 - S1	almost entire cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled)
			NS1 - S2	approx. half the cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled)
21	M	adult	NS1 - S1	approx. half the cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, feathered)
			NS2 - S2	small part of cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, feathered)
23	?	child	OS1 - S1	almost entire cross section	good, inclusions, artefacts of preparation/storage, in some instances possibly diagenetic changes	no
24	?	child	OS1 - S1	entire cross section	ok, artefacts of preparation/storage,	no

					in some instances possibly diagenetic changes	
			OS2 - S2	entire cross section	good	no
25	?	child	OS1 - S1	entire cross section	good, inclusions, artefacts of preparation/storage, in some instances possibly diagenetic changes	YES (fully labelled)
			OS2 - S2	almost entire cross section	good, inclusions, artefacts of preparation/storage, in some instances possibly diagenetic changes	YES (fully labelled)
26	F	adult	OS1 - S1	approx. half the cross section	good, inlcusions	YES (fully labelled, feathered)
			NS1 - S2	approx. half the cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, feathered)
			NS2 - S3	small part of cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, feathered)
27	F	adult	OS1 - S1	entire cross section	good, inclusions, few artefacts of preparation/storage	YES (fully labelled, a few feathered)
			NS1 - S2	approx. half the cross section	good, inclusions, artefacts of preparation/storage	YES (fully labelled, a few feathered)
28	F	adult	OS1 - S1	entire cross section	good, inclusions	YES (fully labelled, very few feathered)
29	M	adult	OS1 - S1	approx. 2/3 of the cross section	good, inclusions	YES (fully labelled, a few feathered)
			NS1 - S2	almost entire cross section	good, inclusions	YES (fully labelled, feathered)
			NS2 - S3	almost entire cross section	good, inclusions	YES (fully labelled, feathered)
30	F	adult	OS1 - S1	approx. 2/3 of the cross section	good, few small fractures, inclusions	YES (fully labelled, a few feathered)
31	?	child	OS1 - S1	approx. 2/3 of the cross section	good, small fractures, inclusions	no
			OS2 - S2	approx. 2/3 of the cross section	good, small fractures, inclusions	no
			OS3 - S3	approx. half	lots of artefacts of	impossible to

				the cross section	preparation/storage	evaluate
			OS4 - S4	small part of cross section	ok, fractures, inclusions,	no
32	F	adult	NS1 - S1	approx. half the cross section	good, inclusions	YES (fully labelled, a few feathered)

Table 9. 6G8, Presence of tetracycline

Feathered osteons could not always be equally well observed in all the sections within one individual (e.g. B3, B14, B27). It is also interesting to note, that the abundance of feathered osteons varies greatly from one subsite to the next (often with only one or two sites per section showing feathered osteons at all).

2. Comparison of sections

To determine variation between different sections for one individual, all labelled sections per individual were counted for 6B13 (see appendix, table 8 for details). A summary of the results is shown in table 11:

Burial		1st section	2nd section	3rd section	Total
1	Labelled Osteons	25	21		46
	Osteons total	442	317		759
2	Labelled Osteons	37			37
	Osteons total	930			930
5	Labelled Osteons	17			17
	Osteons total	750			750
7	Labelled Osteons	18	19	15	52
	Osteons total	479	496	464	1439
17	Labelled Osteons	53			53
	Osteons total	554			554

Table 11. 6B13, Number of total and minimum number of labelled osteons per section

Thus, the 1st section of individual 1 contained 5,66% labelled osteons, the 2nd section 6,62% labelled osteons. The 1st section of individual 7 contains 3,76%, the 2nd section 3,83%, and the 3rd section 3,23% labelled osteons. This compares with the following values in table 12, where all the available sections are summed up:

Burial	Σ Osteons total	Σ Labelled Osteons	%
1	759	46	6,06
2	930	37	3,98
5	750	17	2,27
7	1439	52	3,61
17	554	53	9,57
Total	4432	205	4,63

Table 12. 6B13, Percentage of labelled osteons per individual

Since all old and new sections for one individual in population 6B13 yielded a similar ratio of total/labelled osteons, the number of osteons has been counted only in one section per individual in population 6B8. This section was selected based on preservation of the thin section and size of the remaining piece of bone.

3. Results for subsites

Positioning of the subsites allowed to analyse the percentage of labelled osteons located in the endosteal, periosteal or middle part of the femora. This analysis was only undertaken for adult individuals (see table 13), since the femora of younger individuals did not always allow for sampling of middle subsites.

Subsite	Σ Osteons total	Σ Labelled Osteons	%
inside	2188	137	6,26
middle	6915	402	5,81
outside	2695	197	7,31
Total	11798	736	6,24

Table 13. 6B13 and 6G8, Distribution of labelled osteons regarding to subsites in adult individuals

The results are very similar. Indeed, statistical analysis with the Kruskal-Wallis rank sum test does not show a statistically significant difference.

4. Results of the Christian burial sites 6B13 and 6G8

A total of 70 individuals had been excavated from Christian burial sites. Of 39 individuals a total of 35 old sections had been prepared, and 37 new thin sections could be made for the present study (see tables 5 and 6 for details). The single section of individual 23 of 6B13 could not be evaluated.

Of the 38 individuals represented by thin sections, 25 (= 65,79%) exhibit presence of tetracycline (see table 16 below). A total of 12.533,2 (",2" since for individuals 1 and 7 of 6B13 the mean of all counted sections was used for further calculations) osteons were counted. Of these, a minimum number of 818,3 (= 6,53 %) are labelled. The frequency of labelling in one individual ranges from 0,84 % to 20,60 %. 14 individuals have more than 5% of their osteons labelled.

Site	Burials	Age-Group	Sex	Σ Osteons total	Σ Labelled Osteons	%
6G8	4	adult	F	1198	35	2,92
6G8	11	adult	F	755	13	1,72
6G8	13	adult	F	330	3	0,91
6G8	26	adult	F	324	35	**10,80**
6G8	27	adult	F	381	46	**12,07**
6G8	28	adult	F	572	43	**7,52**
6G8	30	adult	F	572	39	**6,82**
6G8	32	adult	F	391	17	4,35
6B13	7	adult	F	479,7	17,3	3,61
6G8	1	adult	M	267	55	**20,60**
6G8	5	adult	M	1061	55	**5,18**
6G8	14	adult	M	732	70	**9,56**
6G8	21	adult	M	765	65	**8,50**
6G8	29	adult	M	777	101	**13,00**
6B13	2	adult	M	930	37	3,98
6B13	5	adult	M	750	17	2,27
6B13	17	adult	M	554	53	**9,57**
6G8	9	child	?	119	1	0,84
6G8	17	child	?	117	5	4,27
6G8	20	child	?	108	4	3,70
6G8	25	child	?	76	2	2,63
6G8	2	subadult	?	455	30	**6,59**
6G8	3	subadult	?	238	30	**12,61**
6G8	6	subadult	?	202	22	**10,89**
6B13	1	subadult	?	379,5	23	**6,06**
Total				12.533, 2	818,3	Mean: 6,53

Table 14. 6B13 and 6G8, Percentage of labelled osteons per section / individual

Analyses for sex and age are shown in tables 15 and 16:

Of 10 females, 9 show presence of tetracycline, with 5,64 % of their osteons labelled. Of 12 males, 8 exhibit osteons with tetracycline labelling, with 9,08 % of their osteons labelled. Of the 16 individuals without ascribed sex (all children and subadults), 8 show presence of tetracycline, with an average of 5,95 % osteons labelled. The Kruskal-Wallis rank sum test shows no significance for the results regarding sex.

	Total Individuals Sampled	**Individuals Labelled**	**% Individuals Labeled**	**Mean % Labelled Osteons**
Female	10	9	90,00	5,64
Male	12	8	66,67	9,08
unknown	16	8	50,00	5,95
Total	38	25	65,79	

Table 15. 6B13 and 6G8, Mean percentage of labelled osteons by sex

Of 8 children only 4 show labelling (2,86 %). Out of the 6 subadults 4 have 9,04 % of their osteons labelled. Of the 24 adults, 17 have 7,26 % of their osteons labelled. The Kruskal-Wallis rank sum test almost shows significance for the results in table 16 – there is a trend of labelling in respect to age.

	Total individuals sampled	**Individuals labelled**	**% Individuals labeled**	**Mean % labelled osteons**
child	8	4	50,00	2,86
subadult	6	4	66,67	9,04
adult	24	17	70,83	7,26
Total	38	25	65,79	

Table 16. 6B13 and 6G8, Mean percentage of labelled osteons by age

In order to further analyse these data, the populations were examined separately.

5. Results for 6B13

A total of 37 individuals had been excavated from the burial site 6B13. Of 15 individuals a total of 25 old and 11 new thin sections could be analysed (see tables 5). The section for individual 23 was impossible to evaluate.

Of the 14 individuals thus represented by thin sections, 5 (= 35,71%) exhibit presence of tetracycline. Of a total 3.093,2 osteons, 147,3 (= 4,76 %) are labelled (see table 17 below)

The frequency of labelling in one individual ranges from 2,27 % to 9,57 %.
2 individuals have more than 5% of their osteons labelled.

Burial	Age-Group	Sex	Σ Osteons total	Σ Labelled Osteons	%
1	subadult	u	379,5	23	**6,06**
2	adult	M	930	37	3,98
5	adult	M	750	17	2,27
7	adult	F	479,7	17,3	3,61
17	adult	M	554	53	**9,57**
Total			3093,2	147,3	**4,76**

Table 17. 6B13, Mean percentage of labelled osteons per individual

Analyses for sex and age can be seen in tables 18 and 19:

Of 2 females, 1 shows presence of tetracycline, with 3,61 % of her osteons labelled. Of 7 males, 3 exhibit osteons with tetracycline labelling, with 5,27 % of their osteons labelled. Of the 5 individuals without ascribed sex (all subadults), 1 shows presence of tetracycline, with an average of 6,06 % osteons labelled. The Kruskal-Wallis rank sum test shows no significance for the results regarding sex.

	Total individuals sampled	Individuals labelled	% Individuals labeled	Mean % labelled osteons
Female	2	1	50,00	3,61
Male	7	3	42,86	5,27
unknown	5	1	20,00	6,06
Total	14	5	35,71	

Table 18. 6B13, Mean percentage of labelled osteons by sex

Of the 3 subadults 1 has 6,06 % of its osteons labelled. Of the 11 adults, 4 have 4,85 % of their osteons labelled. The Kruskal-Wallis rank sum test shows no significance for the results regarding age either.

	Total individuals sampled	**Individuals labelled**	**% Individuals labeled**	**Mean %labelled osteons**
child	0	0		
subadult	3	1	33,33	6,06
adult	11	4	36,36	4,85
Total	14	5	35,71	

Table 19. 6B13, Mean percentage of labelled osteons by age

6. Results for 6G8

A total of 32 individuals had been excavated from Christian burial sites. Of 24 individuals a total of 28 old sections had been prepared, and 37 new thin sections could be made for this study (see tables 6 for details).

Of the 24 individuals represented by thin sections, 20 (= 83,33 %) exhibit presence of tetracycline (see table 20 below). A total of 9.440 osteons were counted. Of these, a minimum number of 671 (= 7,11 %) are labelled.

The frequency of labelling in one individual ranges from 0,84 % to 20,60 %.
12 individuals have more than 5% of their osteons labelled.

Burial	Age-Group	Sex	Σ Osteons total	Σ Labelled Osteons	%
1	adult	M	267	55	**20,60**
2	subadult	u	455	30	**6,59**
3	subadult	u	238	30	**12,61**
4	adult	F	1198	35	2,92
5	adult	M	1061	55	**5,18**
6	subadult	u	202	22	**10,89**
9	child	u	119	1	0,84
11	adult	F	755	13	1,72
13	adult	F	330	3	0,91
14	adult	M	732	70	**9,56**
17	child	u	117	5	4,27
20	child	u	108	4	3,70
21	adult	M	765	65	**8,50**
25	child	u	76	2	2,63
26	adult	F	324	35	**10,80**
27	adult	F	381	46	**12,07**
28	adult	F	572	43	**7,52**
29	adult	M	777	101	**13,00**
30	adult	F	572	39	**6,82**
32	adult	F	391	17	4,35
Total			9440	671	7,11

Table 20. 6G8, Percentage of labelled osteons per section/ individual

For analyses regarding sex and age, see tables 21 and 22:

All 8 females show presence of tetracycline, with 5,89 % of their osteons labelled. All 5 males exhibit osteons with tetracycline labelling, with 11,37 % of their osteons labelled. Of the 11 individuals without ascribed sex (all children and subadults), 7 show presence of tetracycline, with an average of 5,93 % osteons labelled. The Kruskal-Wallis rank sum test, however, shows no significance for the results regarding sex.

	Total individuals sampled	Individuals labelled	% Individuals labeled	Mean %labelled osteons
Female	8	8	100,00	5,89
Male	5	5	100,00	11,37
unknown	11	7	63,64	5,93
Total	24	20	83,33	

Table 21. 6G8, Mean percentage of labelled osteons by sex

Of 8 children only 4 show a labelling of an average 2,86 %. All 3 subadults have labelled osteons (10,03%). All 13 adults have an average of 8,00 % of their osteons labelled. The Kruskal-Wallis rank sum test shows a trend of labelling in respect to age.

	Total individuals sampled	Individuals labelled	% Individuals labeled	Mean %labelled osteons
child	8	4	50,00	2,86
subadult	3	3	100,00	10,03
adult	13	13	100,00	8,00
Total	24	20	83,33	

Table 22. 6G8, Mean percentage of labelled osteons by age

7. Pathologies and tetracycline labelling

Lots of pathologies have been recorded for the two burial sites (see tables 2 and 4), but unfortunately almost never with the assignment of a specific diagnosis (such as e.g. tuberculosis, another infectious disease, vitamin deficiency etc.). It is therefore impossible to link a certain disease to the recorded pathologies, and impossible to tell whether tetracycline ingestion had a beneficial impact on the consumer.

Armelagos and colleagues (2001) have arbitrarily designated levels of tetracycline greater than 4,99 % as “therapeutic”. 36, 84 % of individuals (6B13 + 6G8) exceed that number.

Individual 17 (from the 6B13 population) has 9,57 % osteons labelled, and no apparent pathologies, which would seemingly support the indicated proposition. But at the same time individual 1 – with labelling of 6,06 % osteons – seems to have suffered from marked (syphilitic-like) lesions on skull and long bones. Thus, comparison of tetracycline consumption and pathology status remains confusing for these Christian populations. Further no apparent connection or trend can be established for tetracycline ingestion and disease frequency in regard to the burial sites 6B13 and 6G8.

IV. Discussion and Conclusion

"You see things; and you say, 'Why?'
But I dream things that never were; and I say, 'Why not?'" G.B. Shaw

Traces of tetracycline have been found in several Nubian populations in the last 25 years. In the two early Christian populations investigated in this thesis, a mean labelling of 6,53 % osteons in labelled individuals has been observed (4,76 % for 6B13, and 7,11 % for 6G8 respectively).

Age and gender patterns

Differences regarding gender from the 6B13 and 6G8 populations (individually as well as combined) are not significant (see tables 15, 18 and 21). However, there is a tendency towards increased labelling with age (see tables 16, 19 and 22).

No other age or gender pattern could be discerned in X-Group femurs. (Bassett, Keith et al. 1980) The analysis of Christian populations at Kulubnarti (Hummert and VanGerven 1982) revealed no statistically significant differences regarding sex or age. The investigation of the combined X-Group samples (Armelagos, Kolbacher et al. 2001) showed that in subadults labelled osteons declined with age (though differences in labelled osteons by sex and age are not significant). However, this may be an artefact of osteon formation, since there is a high formation of osteons in infants and children, and these are labelled (Armelagos, Kolbacher et al. 2001). Regarding the bone of infants labelled with tetracycline, Armelagos and colleagues (2000) note, that the antibiotic was passed on with their mother's milk.

Subsite patterns

Bassett and colleagues (1980) had observed that most of the fluorescing osteons of their X-Group sample were located in the endosteal third of the compact bone. In the two Christian burial grounds 6B13 and 6G8 no such tendency is seen (see table 13)

Determining in vivo tetracycline labelling

The type of labelling, i.e. whether an osteon is fully labelled, concentric or feathered, sheds some light on the manner of tetracycline consumption, which can be continuous, periodical or sporadic. Bone tissue is continually remodelled in response to physical stress; it is broken down and replaced, resulting in the formation of new osteons. In the presence of tetracycline the type of labelling is the result of bone remodelling. One osteon takes about 4 months to become fully mineralised (Armelagos 2000). If tetracycline is present during this process, it binds calcium and is incorporated into actively calcifying tissue. Only osteons formed during the ingestion and metabolism of the antibiotic will be labelled. Therefore, a labelled osteon may be found next to an unlabelled one. (Keith and Armelagos 1983; Keith and Armelagos 1988)

While it is possible, that fluorescent post-mortem mould may infest a bone (Piepenbrink 1984), characteristsic patterns of tetracycline fluorescence due to in-vivo consumption can be distinguished (Keith and Armelagos 1988). Taphonomic changes necessary to induce post mortem tetracycline labelling result in collagen degradation and bone destruction (Armelagos, Kolbacher et al. 2001).

While some signs of tunnelling have been observed within certain subsites of a few individuals of 6B13 and 6G8, the remaining bone was generally very well preserved and the integrity of the collagen structure could be affirmed under polarised light. Labelled lamellae were occasionally observed, but they could have been expected to be much more predominant with post mortem pseudo-labelling, since bone surfaces are most accessible to microbial attack. However, it would still be interesting to investigate diagenesis further, in order to better understand some of the observed fluorescences (especially regarding population 6B13).

Aside from observation under polarised light X-Group bone was also subjected to chemical analysis of tetracycline and collagen extraction, supporting the identity of the antibiotic and the excellent preservation of collagen. (Armelagos, Kolbacher et al. 2001)

Apart from these techniques, characteristics of in vivo labelling can include labelled cement lines (hyper-mineralised bone, eliminating the argument that only under-mineralised bone would be labelled, as would be the case with post mortem labelling) (Armelagos, Kolbacher et al. 2001), unlabelled young osteons within their fully fluorescent predecessors (Armelagos, Kolbacher et al. 2001), labelling of alternating layers of lamellar bone (evidence of rapidly growing bone) (Cook, Molto et al. 1989), labelling in the tooth enamel (Cook, Molto et al. 1989), and the following phenomena:

- Layers of bone including tetracycline, alternating with layers free of the antibiotic (concentric labelling), also indicate in vivo tetracycline consumption. This pattern further indicates either periods of cessation of osteonal growth, or the intermittent ingestion of tetracycline as a particular osteon was being formed. (Armelagos 2000; Armelagos, Kolbacher et al. 2001)
- Feathering represents incompletely mineralised bone matrix, which in vivo is relatively impermeable to tetracycline – the feathered portion remains unlabelled. The normally mineralised portion is labelled in the presence of tetracycline(Bassett, Keith et al. 1980) , thus giving the osteon a mottled appearance.
- Osteons with only their inner third labelled may either represent a labelled osteon forming within an unlabelled predecessor, or tetracycline ingestion only during part of the formation of the osteon. Bassett and colleagues (1980) find that in most of the labelled osteons, the brightest fluorescence was present in the inner one-third, followed by the outer and middle thirds. While the observations regarding the outer and middle thirds could not be made with populations 6B13 or 6G8, labelling of only the inner third or slightly more could be seen in various samples and probably correlates to the brightest fluorescence found in the inner third as described above. Also in concordance with Bassett and colleagues, areas of high mineral density surrounding Haversian canals were seen to fluoresce brightly.
- Fully labelled osteons suggest continuous ingestion of tetracycline. (Armelagos 2000)

Dosage

The percentage of labelled osteons can be used as a basis for drafting a hypothesis on the quantities of consumed tetracycline. The amount of tetracycline required to label osteons is very small: Tetracycline ingested at a ratio of less than 25 mg per kilogram body weight can be detected microscopically (Frost et al, 1961; as cited by (Hummert and VanGerven 1982)). Both gross and microscopic bone fluorescence is obvious in human subjects after a single day in which dosages of only one or two grams of tetracycline were administered (Milch et al., 1958; as cited by (Hummert and VanGerven 1982)) However, increased fluorescence is more specifically correlated with rates of osteoid mineralization and with the total duration of therapy rather than with actual dosage units (Frost et al, 1961; as cited by (Hummert and VanGerven 1982)). From 3 % to 11 % of ingested tetracycline in clinical studies is incorporated into the inorganic phase of bone (Oklund, Prolo et al. 1981).

Although time and unit dosage of tetracycline are impossible to determine, a mean labelling of 4,76 % for population 6B13, and 7,11 % for population 6G8 in the present study are suggestive of a limited exposure to tetracycline.

Comparing results

So far several publications have described tetracycline labelling in ancient human bone in Egypt, the Sudan and the Near East. They represent a time period from approximately 200 BC to 1450 AD. In the following, the pattern of tetracycline labelling in these samples is discussed together with recorded pathologies and possible therapeutic effects of the antibiotic.

The Hesbon material from the early Roman to the early Byzantine period is poorly preserved. Quantification of the amount of fluorescence is thus impossible. There was no evidence for diffuse fluorescence characteristic of mould infestation. Beer is considered a possible source of tetracycline. (Grauer and Armelagos 1998) So far only an abstract has been published of the investigated Meroitic sample from the Wadi Halfa area (Stokol and Armelagos 2002). It does not state the number of investigated individuals. The result is questionable.

The X-Group individuals, excavated from a burial gorund on the Nile's west bank, opposite the town of Wadi Halfa in the Sudan, showed excellent preservation. In many cases with hair and naturally mummified tissue adhering to the skeleton were preserved. Even though the X-Group population is characterised by a high frequency of parasitic infestation (especially head lice, the vector for typhus and relapsing fever) (Armelagos 1969), and dietary iron deficiency is documented (Carlson, Armelagos et al. 1974), only about 8,5 % of the X-Group exhibit infectious lesions. (Armelagos 1968; as cited by (Keith and Armelagos 1983) Tetracycline consumption of this population may explain the extremely low rates of infectious disease (Bassett, Keith et al. 1980), since tetracycline is a broad spectrum antibiotic effective against Gram-negative and Gram-positive Rickettsiae, spirochaetes, bacteria, and some viruses (Keith and Armelagos 1983).

In the combined X-Group sample only 8,01 % labelled osteons were counted. However, these include only fully labelled osteons, that were initially counted. Later results show that an average of 6,98 % of all bone was labelled (This includes tetracycline that was present in osteon fragments and lamellar bone). Levels of tetracycline greater than 4,99 % were arbitrarily designated as “therapeutic”. 56,4 % of individuals exhibited such levels. Only 6 % of the X-Group individuals show evidence of a periosteal reaction indicating infection (Armelagos, Kolbacher et al. 2001).

Another sample for comparison was excavated at Dakleh oasis is 660 km SSW of Cairo. The skeletons are from a late Roman period tomb. Differential (concentric) labelling is a constant pattern in the Dakleh oasis. It is equivalent to the pattern of labelling found in modern patients with interval (periodical) doses occurring at two- to three-week intervals (Armelagos 2000). Tetracycline was ingested occasionally, probably on a seasonal basis. Contaminated grains were probably consumed when fresh food supplies were limited. (Cook, Molto et al. 1989; Armelagos, Kolbacher et al. 2001) Bone infection was absent in the adults (and high in the subadults). Thus, if the tetracycline played a therapeutic role in this population, its influence was restricted to older subadults and adults. However, an alternative theory bases the low infection rates on the absence of pathogens in the dry environment. The amounts of tetracycline ingested would have been considerably less than modern prescribed dosages. Tetracycline seems to have functioned here in preventing infections rather than treating thm. (Cook, Molto et al. 1989) Cook and colleagues also give a value for the percent of labelled surface which ranges from 6,03 % to 59,34 %. This is the sum of the length of the fluorescent labels, calculated: (first and second label/2 + single label x 100)/total length of canal.

Two other Christian burial grounds have been investigated. They are culturally most similar to the 6B13 and 6G8 populations investigated in this thesis. However, the environment of the Batn el Hajar, located south of Wadi Halfa in the most northern part of Upper Nubia, is harsh. One Kulubnarti burial ground (21-S-46) dates to early Christian times, the other (21-R-2) is from a later period. The percentage difference of labelled individuals (51 and 71 %) is not significant. (Hummert and VanGerven 1982) The early Christian period was highly centralised. Taxes were paid in the form of food surplus and labour. By the late Christian period, the central state authority was in decline, essentially ignoring satellite communities such as Kulubnarti, leaving them independent, under local political control and free of taxation. Infant and child mortality was highest in the early Christian period in Kulubnarti. Enamel hypoplasias occurred at earlier ages and were more frequent, as was evidence for anemia. Late Christian people also suffered from these indicators of poor health, but to a lesser extent. (Bogin 1997) To determine whether uptake of tetracycline had a positive effect on health, long bones were examined for signs of periostitis: Periosteal indications of infectious disease were present in 42 % of the individuals from the early burial ground, and in 45 % of the individuals from the later burial ground. While the periostitis at Kulubnarti was low grade, its overall frequency was considerably higher than the rates reported for the X-Group. In Kulubnarti, no periostitis was observed among subadults. Fewer males than females showed signs of periostitis. But at the same time sex and age had no effect on tetracycline ingestion. The occasional ingestion of low concentrations of tetracycline had no impact on the occurrence of disease in this population. (Hummert and VanGerven 1982) Although ingested over a period of 900 years, the small amounts of labelled bone suggest that reliance on soured grains over prolonged periods of time, even episodically, such as during famines or years of poor agricultural yield, was not occurring. The labelling indicates that such consumption was minor and irregular. Also, small family owned agricultural plots were not overly productive, yet subject to taxation (in the form of grain) to the church. Grain was stored on a familial level, and there was probably little in the way of long term stores, which would have minimised grain spoilage and thus ingestion of tetracycline. (Hummert and VanGerven 1982) – These interpretations were obviously developed before the hypotheses of beer as the origin of tetracycline.

For further comparison table 23 summarises these results, together with the results obtained from populations 6B13 and 6G8.

Sample	Time	Number of Sampled Individuals	% Individuals Labelled	Frequency of labelled Osteons	Mean labelling	Type of labelling
Hesban[1] (Jordan)	BC 198-AD 400	10	62,5 % ?			fully and feathered
Meroitic[2]	AD 0-350				6,4 %	
X-Group[3] (Wadi Halfa)	AD 350-550	15	100 %		~ 30 %	fully and feathered
Combined X-Group sample[4] NAX + 24-I-3		78	94,9 %		8,01 %	
Dakleh oasis[5] (Egypt)	AD 400-500	25 ? (only adults – 29 adults were excavated, probably not all of them sampled)	100 %			differential (=concentric)
Kulubnarti[6] 21-S-46 + 21-R-2 (Batn el Hajar)	AD 550-1450	110	63 %	2 – 20 %	3,6 %	fully, feathered, some labelled primarily in their central third
21-S-466	AD 550-750	45	51 %		3,2 %	
21-R-2[6]	AD 550-1450	65	71 %		3,1%	
6B13 + 6G8	AD 550-850	38	65,79 %	0,84 - 20,6 %	6,53 %	fully, concentric, feathered some only labelled in ~ the inner third
6B13	AD 550-850	14	35,71 %	2,27 - 9,57%	4,76 %	fully, concentric, some only labelled in ~ the inner third
6G8	AD 550-850	24	83,33 %	0,84 - 20,6 %	7,11 %	fully, concentric, feathered, some only labelled in ~ the inner third

Table 23. Comparison with other studies on tetracycline labelling of ancient human bone, cited after [1](Grauer and Armelagos 1998), [2](Stokol and Armelagos 2002), [3](Bassett, Keith et al. 1980), [4](Armelagos, Kolbacher et al. 2001), [5](Cook, Molto et al. 1989; Armelagos, Kolbacher et al. 2001), [6](Hummert and VanGerven 1982)

The mean labelling as observed in 6B13 and 6G8 is similar to both that of Kulubnarti and the combined X-Group sample. Very few 6B13 individuals were labelled at all (though this may represent a sampling error due to the small sample size).

The pattern of labelling resembles that described in Kulubnarti. The few cases of concentric labelling in the 6B13 and 6G8 populations consist mostly of only one concentric ring and can this not be compared to Dakleh oasis patterns. Thus concentrically labelled osteons do not indicate periodical ingestion of tetrycacline with the Christian populations.

Therefore, the labelling of 6B13 and 6G8 individuals suggests a limited and sporadic exposure to tetracycline with a doubtful effect on infection rate.

Although no conclusions can be drawn on specific pathologies from the present records, there is some data published on the pathologies of Christian populations which includes 6B13 and 6G8. These data show that arthritic lesions (a form of degenerative lesion revealing stress) are fairly constant throughout Meroitic, X-Group and Christian times. Average age at death for the 6G8 adults (15 years or older) is 35,6 years. X-Group people seem to have died on average some 5, Meroitic people some 9, years earlier. Females of all Nubian sampled populations show an equally rapid loss of bone. Carious lesions reveal an increasing frequency of occurrence: from 1 % in Mesolithic to 18 % in Christian times. This is probably due to the rising proportion of agricultural products in the Nubian diet. (Armelagos 1969) Frequencies for periosteal lesions, anemia etc. which would allow for comparisons with the results from X-Group and Kulubnarti remains, are however, not given for 6B13 and 6G8.

Therapeutic effects

As the comparison of results shows, only the X-Group individuals appear to have received consistent and substantial amounts of tetracycline with direct evidence of therapeutic effects (Bassett, Keith et al. 1980; Armelagos, Kolbacher et al. 2001). But whether this holds true for the combined X-Group sample is not at all obvious. The pattern of labelling at Kulubnarti suggests a low level of sporadic ingestion without a significant association between labelling and periosteal infection. The amount of antibiotic these individuals were receiving probably had little therapeutic effect. The same seems to be true for 6B13 and 6G8 individuals. People from the Dakleh oasis received lower, seasonal doses of tetracycline compared to the X-Group individuals (Armelagos, Kolbacher et al. 2001). The ingested tetracycline may or may not have had an influence on the absence of infections.

As opposed to the region around Wadi Halfa where the X-Group samples were excavated, Armelagos and colleagues (2001) argue, that harsher living conditions in Kulubnarti and the grain tax of the church could have decreased the potential for storage and the use of mouldy grain for bread and presumably beer production in Kulubnarti.

However, with regard to the results for the single X-Group population, it seems unlikely that their continuous uptake of tetracycline would have depended on beer brewed from mouldy grain. There is no apparent reason why their grain alone would have been almost constantly mouldy. Thus, it seems much more likely that streptomycetes would have accumulated during the beer brewing process.

But, if this was true, why then did they fail to accumulate during the brewing process in Christian times (and possibly even in another X-Group population)? Was the beer brewed of a different kind, maybe less susceptible to catching streptomycetes? And did the Christians perhaps receive their low and sporadic doses of tetracycline from the rare ocaasions when full storage facilities were emptied down to the last mouldy grain? Or, were there simply different beers brewed at all times, with shifting preferences due to taste or custom?

Since in every case tetracycline uptake is linked to the brewing process and/ or the availability of mouldy grain (possibly symptomatic of a grain shortage), changes in beer and grain availability between X-Group and Christian times need to be considered first in order to explain differing tetracycline content in Nubian bone. Secondly, it should be considered, that the role of any individual food in Nubian culture, and thus diet, may have changed over time. Beer consumption could have varied with the extent of consumption of other foods. Thirdly, regional rather than periodical, differences may account for the observed differences in tetracycline labelled bone.

In the following sections, factors are listed that could have influenced availability of grain/ beer and/or influenced consumption patterns. Though no one of these possibilities will solve the question of why tetracycline uptake decreased so markedly with the advent of Christianity, they all contribute to a discussion of the intricate connections between culture and health.

Possible changes in availability of grain and/or beer

Availability of grain and beer may have changed from X-Group to Christian times. Such a change could have been influenced by a number of factors, such as:

- **Carrying capacity**

In the Meroitic period the riverine zones in Lower and Upper Nubia were settled by people living from agriculture combined with sedentary animal husbandry. "The carrying capacity of the Nubian Nile Valley was probably low. By the early centuries AD there were about fifteen to twenty-five settlements inhabited by about 1.000 individuals, and one to two hundred villages, with about fifty to a hundred individuals between Aswan and the Khartoum region. Consequently, the total population of the settlements could have been around 30.000-50.000 ..." (Török 2004)

The X-Group period was politically decentralised. People were living in smaller, but more self- sufficient settlements. (Bogin 1997) Overall, their health status was better than in Meroitic times. "The results of pathological analysis and mortality patterns suggest that the X-Group may not have experienced the cultural decline suggested by the archaeological record, and that the X-Group period may have been one of cultural growth relative to the earlier, Meroitic period in Lower Nubia."(Armelagos 1969)

In Christian times, the Nubian economy was still largely agrarian-based. This agrarian base was dramatically enlarged during the Christian times through the extensive adoption of the *saqia* waterwheel.(Fuller 1999; Anderson 2004) Remains of *saqia*-pots are ubiquitous in Christian sites, and "use of the *saqia* widened the available cultivatable land along the Nile and enlarged large fertile basins to be irrigated year-round."(Anderson 2004) This new introduction of the *saquia* may well have also facilitated population growth (Fuller 1999) until a new carrying capacity would have been reached.

At least in the north urbanisation was more dense than ever before, indeed. Settlements like Faras may have been home to several thousand inhabitants. Farming villages like Meinarti will have numbered between 200 and 400 inhabitants.(Adams 1977)

While during X-Group times the amount of available grain per capita will have been high this amount *could* have in *some* areas decreased after the new carrying capacity was reached during Christian times. With less grain/ more people, turnover in storage bins would have increased and mould infestation may have had less chance to develop.

However, estimates of population growth (as based on settlement patterns from excavated archaeological sites in Lower Nubia) do not find a large scale increase in population in Lower Nubia during Christian times. (Martin, Armelagos et al. 1984) Martin and colleagues (1984) argue, that agricultural intensification simply catered a greater demand in the cities.

While food thus seems to have been produced in abundance, some other factors may still have interfered with its availability to the individual consumer – either population growth or, as Martin and colleagues (1984) suggested, increased flow of goods. Other factors influencing food availability are:

- **Hostilities**

When examining intentional postcranial lesions, Christian populations (the sample includes 6B13, 6G8, and Meinarti) show 11,3 % incidence – as opposed to 5,6 % in the Meroitic, and 3,1 % in the X-Group samples. Overall such lesions are seen mostly among male individuals. There is an increase both in injuries from aggression and from accidents during the Christian period. (Armelagos 1969)

- **Political systems**

From about 500 to 700 AD Lower Nubia was organised within the kingdom of Noubadia. It then became part of the southern kingdom of Makouria. Even so, Lower Nubia probably retained some sort of independence, as it was ruled by an eparch. (The first mention of this royal deputy dates to 707.) (Jakobielski 1987)

The eparch was essentially a viceroy with the right to found churches and celebrate mass (appointing of bishops – at least from 8th century on - was undertaken by the Coptic Patriarch in Alexandria) His most important function seems to have been the conduct of relations with Moslem Egypt. (Adams 1977)

Regional differences in terms of leadership thus existed, at least between Upper and Lower Nubia. This will have influenced living conditions, productivity, economy and cultural inclinations. Adams (1977) describes Lower Nubia in medieval times as having a relatively free society and economy. At least after the 8th century, when it had become a kind of free-trade zone, Lower Nubia enjoyed a considerably higher standard of living than southerly parts of Nubia. Here the church probably also performed some of the functions of a local government. Upper Nubia on the other hand, was more directly and possibly more oppressively, governed by its king, while churches were not nearly as numerous or as wealthy. (Adams 1977)

The comparison of Kulubnarti and 6B13/6G8 is not sufficient to draw a complete picture. With more remains sampled, it would be interesting to investigate whether political and thus economic differences between Upper and Lower Nubia in Christian times influenced tetracycline prevalence.

- **Taxation**

Under the Ptolemies and the Romans, beer was subjected to producer taxes paid in copper in Egypt. (Darby, Ghalioungui et al. 1977) When there was no tax paid *for* beer, beer itself (or grain) may have been a tax payment. More staple foods paid as tax would have resulted in less remaining for people to consume. During times of poor harvest this may have influenced their nutritional status and susceptibility to disease, as well as possible tetracycline uptake.

Taxation payments in Lower Nubia could have been paid to the church, the king/ the eparch and used for *baqt* payments. There is serious doubt that *baqt* payments were substantial (see introduction) (Spaulding 1995). Little is known about the role of the church in Nubian economy: Did it gather local taxes? If so, was it for church use or was it also collected for secular leaders? Monasteries presumably possessed enough land for self subsistence. The pattern of the remaining settlements and fields suggests that most of the land was in small familial holdings devoted to subsistence crops. If state and church were to benefit from agriculture, it would have been mainly through taxing on land (and possibly also on animals and/or irrigation devices). Theoretically all land belonged to the king. But it is conceivable that the church imposed tithes in addition to the royal levy. Possibly the church also held the right to exclusively tax certain areas. Since nothing is known about the system of taxation in medieval Nubia, it can only be speculated that the apparent prosperity of early Nubian churches was based on clergy tax collectors. (Adams 1977)

- **Trade and industry**

International trade was an important factor of Nubian economy, also in medieval times. But the volume and variety of imported goods fluctuated from century to century. The church probably took no hand in international trade. (Adams 1977) The main import item (until the 8th century) was wine. Another was pottery wares, produced at a factory at or near Aswan. They seem to have been manufactured for import into Nubia, and comprised between 2 and 50% of the Nubian ceramic complex between 200 and 1350 AD. In exchange for wine, pottery, and luxury items, Nubia exported primarily slaves. However, who controlled the slave trade, how and where the slaves were obtained, and what part slave trade played in medieval Nubian economy, is still largely unknown. It can only be assumed that slaves were chiefly captives of war. This would make slave-raiding mainly a state enterprise, and possibly even the economic mainstay of the medieval Nubian crown. (Adams 1979)

Textiles from the Christian period are made from linen, cotton and above all animal hair (goats, camels or sheep). Sheep are among the oldest domesticated animals, and camels and goats are well known from the X-Group period. Cotton, though known from the Indus Valley already in the 3rd millennium BC, and possibly known as a plant in Nubia for almost as long, is documented as a textile much later. It is definitely present in Roman times, perhaps even earlier. (Thurman 1979) “In any case, the cotton industry became important in the Sudan. Ezana of Aksum, in the description of his campaign to the Nile about 350 AD, said, ’I destroyed their provision of corn and cotton …’” (Griffith and Crowfoot in (Thurman 1979))

Indicative of changing trade relations or at least preferences, Thurman (1979) notes, that in comparison to earlier Meroitic times, during the X-Group period, cotton and linen almost ceased to be used. They were replaced by animal fibres, which had not been used much up to that time. In the Early Christian period another, though less important, change occurred. Once again, vegetable fibres, although not dominating the textiles of the period, became common. (Thurman 1979)

However, even if the overall prosperity as seen in the archaeological records may have declined in X-Group times, individual farmers/ farming communities may still have been better off in terms of available nutrients and fewer tax obligations. (Armelagos 1969)
An increase of prosperity and more labour-intensive (e.g. cotton production) industrial output in Christian times *may* hint at the reverse process.

However, a look at the pottery industry shows, that the impact of Christianity and the establishment of the medieval kingdoms was perhaps not prominent enough to allow such conclusions to be drawn: Nubian wheel-made pottery comprised, at most times, at least 60 % of the total Nubian ceramic complex. They were commercially mass-produced at a few major factories and widely traded. Though between AD 200 and 1550 at last six factories were involved in the production of wheel-made wares (one of them near Faras was probably part of a monastic establishment), probably no more than two or three were in production at any one time. "The introduction of Christianity in the 6^{th} century, although it was immediately reflected in architectural, artistic, and literary canons, had no measurable impact on Nubian pottery until 250 years later." (Adams 1979)

- **Social system**

Though the archaeological record may be deceptive, what it shows is medieval Nubia to be a prosperous, free and egalitarian society. (Adams 1977)

Beside its nutritional value, beer will have also shaped social life. Europeans prove an exception when drinking on their own (Farb and Armelagos 1980), since consuming alcohol is almost universally a social act. (Dietler 1990; as cited by (Edwards 1996))
During Meroitic times beer had considerable significance in ritual contexts. (Edwards 1996)

The value of alcohol in socioeconomic terms is even more readily understood, since it is known in Western European culture too: It is common practice, if you need help but cannot pay, to invite friends and family and offer food. It goes without saying, however, that offering drink is much more crucial in getting any work done.

Traditionally, brewing of beer is strongly linked with mobilising labour, and up to half of the production is consumed during work parties. Beer may also play an important role as part of the bride-price or other systems of gift-exchange, and may even be used to acquire wealth through organising beer-working-parties. Drinking practices can be utilised for status differentiation (gender or age-based or otherwise). While women's labour in grain preparation is prominent, they generally consume less alcohol than men. (Edwards 1996)

Alcohol may also play a role in maintaining (political) authority: Through hospitality by superiors and as a form of tribute payment. (Pryor, 1977; as cited by (Edwards 1996))

- **Religion**

Until about 600 AD there was no established religion (locally important was e.g. the cult of Isis). After about 600 AD people converted to the Melkite (Byzantine) and Monophysite Christian faiths; around 700 AD – after the subjugation of Noubadia to Makouria – Monophysite (Coptic) Christianity was generally adopted. (Adams 1977; Adams 1979) Starting at about 625 AD the Noubadian capital Faras was also home to bishops subordinate to the patriarch of Alexandria. Many Nubian cloisters served also as hospitals and centres of Byzantine medicine; the monks tended to soul and body. (George 2005)

Religion became the dominant force in literature, iconography and art. (Anderson 2004) Being so predominant, religion will also have had a say in people's diet, either through direct taboos or explicit preferences, or due to the fact that from that point on a class of clergymen had to be sustained as well.

One of the marked changes Christianity brought about regarded mortuary rituals. Late and post-Meroitic funerary rites probably contained some form of funerary banquet including substantial quantities of beer. Possibly the tumulus mounds covering burials were erected with the help of sufficient provisions of beer. Christianity made such efforts superfluous. (Edwards 1996) Were other feasts introduced? Was drinking still as important there?

While beer could well have remained important, the new religion could possibly substitute some social significance of alcohol by forming social bonds and obligations through other means.

Possible changes in consumption of grain and/or beer

Pointing out factors possibly influencing availability of grain and beer demonstrates the complexity of the socio-economic system of food production. The analysis grows even more complex when cultural factors influencing the consumption of grain and/or beer are taken into account.

Sorghum, millet, pulses, date-stones, figs, cucumber seeds, wheat, dom palm nuts and grape seeds have been recovered from several archaeological sites. Domestic animals (mainly cattle, goats, sheep and pigs) provided milk, wool, meat, leather and transport. (Anderson 2004) Although the types of food consumed seem to remain largely the same as before, the role of any individual food for Nubian diet and culture (and thus the quantities consumed), may have changed.

- **Milk**

Milk was available and at least during the Meroitic period it is thought to have also been consumed. Increased consumption of milk would have interfered with tetracycline absorption. However, there is no factual reason to believe that such an increase had taken place.

- **Moulded food**

Deliberately moulded food could have been a source of tetracycline in an environment rich with streptomycetes. Cheese is a moulded food that is extensively consumed nowadays. There are however, no records of Nubian cheese production (Pamela Rose, personal communication). So unless either some evidence of cheese production is discovered or another mouldy food specified, this line of thought remains purely hypothetical.

- **Wine**

Wine, likewise, should be given some consideration but probably not much. Wine was already imported from Egypt throughout the first millennium BC, possibly even earlier, but was enjoyed only by the elite. (Edwards 1996) Adams (1977) hints, that the chief Nubian import demand in X-Group *and* early Christian times was wine, but does not state whether the overall imported quantity increased during early Christian times. After the 8th century there was a drastic reduction in wine imports. Reasons probably lie with the importer rather than with a declining demand, since around the same time the Nubians seem to have taken up viticulture to compensate for their losses. (Adams 1977)

Since medieval Nubian vineyards were concentrated in the area of monasteries and viticulture requires a considerable communal effort, vineyards were probably under monastic control. (Adams 1977) Though there could have been an increase in the ritual uses of wine in Christian ceremonies, it is unlikely to have replaced beer in everyday life. Wine probably remained a drink for the elite (Dorian Q. Fuller, personal communication).

- **A shift from bread to beer**

The most plausible argument is a (slight) shift from beer to bread: "… as much as 75 % of vessels in Meroitic and post-Meroitic assemblages comprising liquid containers of one sort or another. This may not be a wholly representative sample due to the over-representation of mortuary assemblages in the study material, but it is worth noting that, during the medieval (Christian) period the character of assemblages changed markedly. Many new pot forms appear, but with a marked decline in liquid containers to no more than 25 % of vessel." (Adams, 1986; as cited by (Edwards 1996)) At the same time the pottery form used in the production of flat breads only seems to appear in the ceramic repertoire at about the middle of the first millennium AD, signifying a change in food preparation and culinary culture. (Edwards 1996)

Regional differences in availability and/or consumption of grain and beer

There are times, when the allusion to the necessity of further studies is hardly more than a set phrase. With the study of antibiotics in ancient human remains, however, stressing the importance of further research before drawing too many conclusions is justified and necessary.

Any inferences from the present data on tetracycline consumption need to be drawn with care: Whether a shortage of previously abundant food, and thus possibly ample mouldy grain at the bottom of storage bins led to an increased consumption of mouldy grain and tetracycline containing beer is still unresolved. The opposite could also be true, i.e. an abundance of food leading to various beers being produced, one of which could have been produced by a process that provided for ample streptomycetes from the environment being caught and successive tetracycline enrichment during brewing.

Furthermore, whether the consumption of tetracycline was merely high in one of the examined X-Group populations, or all, is not obvious. Tetracycline uptake may have varied at all times, due to regional differences in food availability and due to regional customs – a changed preference for one or the other type of beer. A closer investigation of differences between populations of the same time, in terms of antibiotic uptake, are invaluable for better comparison of populations from different times or cultural periods.

Differences between individual communities of any one region may well have been sufficient in influencing availability of food or preparation preferences, thus also influencing tetracycline uptake. X-Group people were largely self-sufficient and governed by local leaders. As for the Christians, Adams (1977) remarked, that in order to judge the social and economic condition of medieval Nubians archaeologists must for the most part rely on their houses and refuse. “Here we can observe a surprising uniformity among the dwellings in any one community, but considerable variation from village to village, as though prosperity were more a communal than an individual or familial affair.“ (Adams 1977)

If tetracycline in Christian populations derives from mouldy grain, storage conditions will greatly influence antibiotic uptake. Since grain was presumably stored by each village or family individually (compare (Samuel 2000)), these conditions and the amounts of grain stored may have varied greatly, influencing possible contact with streptomycetes and their growing conditions.

If, on the other hand, beer remains the main source of tetracycline for Nubian populations, then, with up to 50 types of beer prepared in the Sudan in recent times (Dirar, 1994; as cited by (Edwards 1996)), it is easily conceivable that production methods from one village to the next, or one family to the other varied. While the result of the brewing process may still have contained the same amount of nutrients, the conditions for catching streptomycetes and producing tetracycline may have varied considerably. Even if people were familiar with the same types of beers, they may not have brewed them in the same quantities: While one beer in one village may have been consumed during everyday life, it could have been reserved only for special occasions in the next village. Or, if X-Group results for tetracycline labelling prove consistently high, a type of brewing favoured in X-Group times may simply have gone out of fashion with Christian home brewers.

Conscious uptake?

Analysis of the early Christian population 6B13 and 6G8 showed, that both contained tetracycline labelled individuals. Although a definite explanation of the labelling is impossible, some or all of the above discussed factors influencing availability and consumption of grain and/or beer may have played a role in determining tetracycline uptake.

However, as can be seen from the pattern and frequency of labelling, the 6B13 and 6G8 individuals probably ingested limited amounts of tetracycline sporadically. A beneficial effect on the infection rate is doubtful.

Although antibiotics were unknown to the people of ancient times, and as such they will not have knowingly consumed antibiotics, they may well have experienced benefits from drinking beer – at least due to the contained nutrients, and the alcohol. Some of them may also have ascribed medical value to it. Egyptian medical papyri cite at least 17 varieties of beer. It seems to have been used as a constituent of mixtures. "…although its mild sedative or euphoric action was recognized, there are reasons to believe that in all these prescriptions it was utilized as a vehicle or base." (Darby, Ghalioungui et al. 1977) Beer was included in medicines to be chewed, "to treat the gums with rinsing of the mouth", injected in enemata or vaginal douches, and constituted part of anal fumigations to treat diseases of the anus, and of dressings. (Darby, Ghalioungui et al. 1977)

Also, keeping in mind the recognition of zoopharmacognosy, Keith and Armelagos (1983) seem convincing in their argument that at least some (X-Group) Nubians would recognise the beneficial effect of contaminated grain to the beer-making process. If other Nubians populations also held this notion, or never knew of it, remains speculative.

Summary

The prescription of tetracyclines as broad-spectrum antibiotics in the 1950's led to the discovery that their use causes staining and fluorescence in calcifying tissues. In compact bone tetracycline labels osteons, which are actively mineralising at the time of administration.

During the last 25 years several studies on human skeletal remains from Egypt, the Sudan and Jordan found that tetracycline consumption is not restricted to the 20th century. Thin sections of human femora revealed signs of in vivo tetracycline labelling from 200 BC to 1450 AD. In some cases high levels of tetracycline uptake have been assumed to correlate with low levels of infectious disease. Beer and/ or mouldy grain have been proposed as sources for the antibiotic.

In this study 72 thin sections of 39 femora from the two populations 6B13 and 6G8 dating from the early Christian period (AD 550-850) in Lower Nubia were examined. 25 of 38 individuals (=65,79 %) show in vivo tetracycline labelling. A mean of 6,53 % labelled osteons were observed in labelled individuals. Differences in respect to sex are not significant, but there is a tendency towards increased labelling with age.

The pattern of labelling suggests a sporadic consumption of limited amounts of tetracycline in both, 6B13 and 6G8, populations. Although specific pathological diagnoses are lacking, a beneficial effect of the ingested amount of tetracycline on the rate of infection is unlikely.

A number of factors influencing availability and consumption of beer and (mouldy) grain, and thus tetracycline ingestion, in early Christian Sudanese Nubia are discussed. Furthermore it is hypothesised that differences in antibiotic uptake could not only be due to changes in political and religious systems, but also depend upon regional environmental differences and localised cultural variation on a small scale.

Zusammenfassung

Die Verordnung von Tetrazyklinen als Breitbandantibiotika in den 1950-ern führte zu der Entdeckung, dass ihr Einsatz Verfärbungen und Fluoreszenzen in kalzifizierendem Gewebe hervorruft. In der substantia compacta markiert Tetrazyklin Osteone, die zur Zeit der Aufnahme des Antibiotikums aktiv mineralisieren.

Während der letzten 25 Jahre konnten verschiedene Studien an menschlichen Skelettresten aus Ägypten, dem Sudan und Jordanien zeigen, dass sich der Konsum von Tetrazyklin nicht auf das 20. Jahrhundert beschränkt. Dünnschnitte menschlicher Femora ließen in vivo Tetrazyklin-Markierungen aus der Zeit zwischen 200 BC und 1450 AD erkennen. In einigen Fällen wurde angenommen, dass die hohen Level an aufgenommenem Tetrazyklin mit niedrigen Raten infektiöser Erkrankungen korrelierten. Bier und/oder schimmelndes Getreide wurden als Quelle des Antibiotikums diskutiert.

In der vorliegenden Arbeit wurden 72 Dünnschnitte von 39 Femora von den Populationen 6B13 und 6G8 aus der frühen christlichen Periode (AD 550-850) des unteren Nubien untersucht. 25 von 38 Individuen (=65,79 %) zeigen in vivo Tetrazyklin-Markierungen. Bei Individuen, deren Knochen Spuren von Tetrazyklin enthalten, sind durchschnittlich 6,53 % der Osteone markiert. Unterschiede in Bezug auf Geschlecht und Alter sind nicht signifikant, aber es gibt eine Tendenz zu vermehrter Markierung mit steigendem Alter.

Die Art der Markierungen lässt auf den sporadischen Konsum einer beschränkten Menge Tetrazyklin der Populationen 6B13 und 6G8 schließen. Obwohl spezifische pathologische Diagnosen nicht vorliegen, erscheint ein günstiger Effekt der aufgenommenen Mengen Tetrazyklin auf die Infektionsrate unwahrscheinlich.

Eine Reihe von Faktoren, die das Vorhandensein und den Konsum von Bier und (schimmeligem) Getreide, und damit die Aufnahme von Tetrazyklin, im frühen christlichen unteren Nubien beeinflussen, werden diskutiert. Darüber hinaus wird vermutet, dass Unterschiede in der Antibiotika-Aufnahme nicht nur von Veränderungen der politischen und religiösen Systeme beeinflusst wurden, sondern auch von regionalen Umweltunterschieden und lokalen kulturellen Variationen im kleinen Rahmen abhängig waren.

Appendix A: Tables 8 and 10

The following tables 8 and 10 show the number of total osteons and minimum number of labelled osteons for all the examined subsites of sections exhibiting presence of tetracycline (6B13 and 6G8 resepectively).

Labelled Osteons: Minimum number of labelled osteons.
For further explanation of **sites** and **subsites**, see figures 11, 12 and 13.

Burials 6B13	Sex	Age-Group	Section	Site	Subsite	Osteons Total	Labelled	Type of Labelling
1	?	subadult	NS1 - S1	1	inside	19	2	concentric
1	?	subadult	NS1 - S1		middle	28	1	concentric
1	?	subadult	NS1 - S1		middle	30	2	concentric
1	?	subadult	NS1 - S1		outside	25	1	concentric
1	?	subadult	NS1 - S1	2	inside	18	1	concentric
1	?	subadult	NS1 - S1		middle	32	0	
1	?	subadult	NS1 - S1		middle	53	7	concentric
1	?	subadult	NS1 - S1		outside	25	0	
1	?	subadult	NS1 - S1	3	inside	26	1	concentric
1	?	subadult	NS1 - S1		middle	44	4	concentric
1	?	subadult	NS1 - S1		middle	36	1	concentric
1	?	subadult	NS1 - S1		outside	23	2	concentric
1	?	subadult	NS1 - S1	4	inside	10	0	
1	?	subadult	NS1 - S1		middle	26	1	concentric
1	?	subadult	NS1 - S1		middle	27	2	concentric
1	?	subadult	NS1 - S1		outside	20	0	
1	?	subadult	NS2 - S2	1	inside	17	2	concentric
1	?	subadult	NS2 - S2		middle	24	1	concentric
1	?	subadult	NS2 - S2		middle	32	2	concentric
1	?	subadult	NS2 - S2		outside	20	2	concentric
1	?	subadult	NS2 - S2	2	inside	17	0	
1	?	subadult	NS2 - S2		middle	33	2	concentric
1	?	subadult	NS2 - S2		middle	27	1	concentric
1	?	subadult	NS2 - S2		outside	24	1	concentric
1	?	subadult	NS2 - S2	3	inside	24	2	concentric
1	?	subadult	NS2 - S2		middle	33	5	concentric
1	?	subadult	NS2 - S2		middle	40	2	concentric
1	?	subadult	NS2 - S2		outside	26	1	concentric
2	M	adult	OS1 - S1	1	inside	23	1	fully labelled
2	M	adult	OS1 - S1		middle	36	2	one fully labelled, one concentric
2	M	adult	OS1 - S1		middle	36	3	fully labelled
2	M	adult	OS1 - S1		outside	36	7	fully labelled
2	M	adult	OS1 - S1	2	inside	26	0	

2	M	adult	OS1 - S1		middle	29	2	fully labelled
2	M	adult	OS1 - S1		middle	41	3	fully labelled
2	M	adult	OS1 - S1		outside	37	3	fully labelled
2	M	adult	OS1 - S1	3	inside	23	1	fully labelled
2	M	adult	OS1 - S1		middle	33	0	
2	M	adult	OS1 - S1		middle	33	0	
2	M	adult	OS1 - S1		outside	34	1	fully labelled
2	M	adult	OS1 - S1	4	inside	24	0	
2	M	adult	OS1 - S1		middle	38	0	
2	M	adult	OS1 - S1		middle	44	0	
2	M	adult	OS1 - S1		outside	36	2	fully labelled
2	M	adult	OS1 - S1	5	inside	23	0	
2	M	adult	OS1 - S1		middle	36	0	
2	M	adult	OS1 - S1		middle	30	0	
2	M	adult	OS1 - S1		outside	40	1	fully labelled
2	M	adult	OS1 - S1	6	inside	24	0	
2	M	adult	OS1 - S1		middle	33	2	fully labelled
2	M	adult	OS1 - S1		middle	37	0	
2	M	adult	OS1 - S1		outside	38	3	fully labelled
2	M	adult	OS1 - S1	7	inside	26	1	fully labelled
2	M	adult	OS1 - S1		middle	42	3	fully labelled
2	M	adult	OS1 - S1		middle	39	1	fully labelled
2	M	adult	OS1 - S1		outside	33	1	fully labelled
5	M	adult	OS1 - S1	1	inside	27	0	
5	M	adult	OS1 - S1		middle	evaluation impossible		
5	M	adult	OS1 - S1		middle	evaluation impossible		
5	M	adult	OS1 - S1		outside	evaluation impossible		
5	M	adult	OS1 - S1	2	inside	31	1	concentric
5	M	adult	OS1 - S1		middle	29	0	
5	M	adult	OS1 - S1		middle	39	0	
5	M	adult	OS1 - S1		outside	40	0	
5	M	adult	OS1 - S1	3	inside	19	0	
5	M	adult	OS1 - S1		middle	32	0	
5	M	adult	OS1 - S1		middle	46	2	concentric
5	M	adult	OS1 - S1		outside	27	0	
5	M	adult	OS1 - S1	4	inside	20	0	
5	M	adult	OS1 - S1		middle	41	2	concentric
5	M	adult	OS1 - S1		middle	36	2	concentric
5	M	adult	OS1 - S1		outside	evaluation impossible		
5	M	adult	OS1 - S1	5	inside	32	0	
5	M	adult	OS1 - S1		middle	65	6	concentric
5	M	adult	OS1 - S1		middle	60	3	concentric
5	M	adult	OS1 - S1		outside	40	0	
5	M	adult	OS1 - S1	6	inside	14	0	
5	M	adult	OS1 - S1		middle	48	0	
5	M	adult	OS1 - S1		middle	46	1	concentric
5	M	adult	OS1 - S1		outside	36	0	
5	M	adult	OS1 - S1	7	inside	22	0	
5	M	adult	OS1 - S1		middle	evaluation impossible		
7	F	adult	OS1 - S1	1	inside	22	0	
7	F	adult	OS1 - S1		middle	33	1	concentric

7	F	adult	OS1 - S1		middle	35	4	concentric
7	F	adult	OS1 - S1	2	inside	21	1	concentric
7	F	adult	OS1 - S1		middle	26	3	concentric
7	F	adult	OS1 - S1		middle	27	1	concentric
7	F	adult	OS1 - S1		outside	41	0	concentric
7	F	adult	OS1 - S1	3	inside	17	0	
7	F	adult	OS1 - S1		middle	36	2	concentric
7	F	adult	OS1 - S1		middle	39	2	concentric
7	F	adult	OS1 - S1		outside	30	1	concentric
7	F	adult	OS1 - S1	4	inside	27	0	
7	F	adult	OS1 - S1		middle	43	2	concentric
7	F	adult	OS1 - S1		middle	26	1	concentric
7	F	adult	OS1 - S1		outside	18	0	
7	F	adult	OS1 - S1	5	inside	14	0	
7	F	adult	OS1 - S1		middle	24	0	
7	F	adult	OS2 - S2	1	inside	21	0	
7	F	adult	OS2 - S2		middle	38	0	
7	F	adult	OS2 - S2	2	inside	23	0	
7	F	adult	OS2 - S2		middle	33	1	concentric
7	F	adult	OS2 - S2		middle	32	0	
7	F	adult	OS2 - S2		outside	28	1	concentric
7	F	adult	OS2 - S2	3	inside	11	0	
7	F	adult	OS2 - S2		middle	25	2	concentric
7	F	adult	OS2 - S2		middle	33	2	concentric
7	F	adult	OS2 - S2		outside	24	0	
7	F	adult	OS2 - S2	4	inside	17	1	concentric
7	F	adult	OS2 - S2		middle	25	3	concentric
7	F	adult	OS2 - S2		middle	41	3	concentric
7	F	adult	OS2 - S2		outside	37	1	concentric
7	F	adult	OS2 - S2	5	inside	16	1	concentric
7	F	adult	OS2 - S2		middle	28	2	concentric
7	F	adult	OS2 - S2		middle	38	2	concentric
7	F	adult	OS2 - S2		outside	26	0	
7	F	adult	OS3 - S3	1	inside	19	1	concentric
7	F	adult	OS3 - S3		middle	30	0	
7	F	adult	OS3 - S3		middle	26	0	
7	F	adult	OS3 - S3	2	inside	20	1	concentric
7	F	adult	OS3 - S3		middle	29	3	concentric
7	F	adult	OS3 - S3		middle	26	1	concentric
7	F	adult	OS3 - S3		outside	evaluation impossible		
7	F	adult	OS3 - S3	3	inside	5	0	
7	F	adult	OS3 - S3		middle	38	1	concentric
7	F	adult	OS3 - S3		middle	41	2	concentric
7	F	adult	OS3 - S3		outside	17	0	
7	F	adult	OS3 - S3	4	inside	18	2	concentric
7	F	adult	OS3 - S3		middle	34	1	concentric
7	F	adult	OS3 - S3		middle	32	2	concentric
7	F	adult	OS3 - S3		outside	22	0	
7	F	adult	OS3 - S3	5	inside	33	0	
7	F	adult	OS3 - S3		middle	36	0	
7	F	adult	OS3 - S3		middle	38	1	concentric

17	M	adult	OS1 - S1	1	inside	22	1	fully labelled
17	M	adult	OS1 - S1		middle	43	1	fully labelled
17	M	adult	OS1 - S1		middle	35	4	fully labelled
17	M	adult	OS1 - S1	2	inside	26	4	fully labelled
17	M	adult	OS1 - S1		middle	41	4	fully labelled
17	M	adult	OS1 - S1		middle	40	8	fully labelled
17	M	adult	OS1 - S1		outside	28	4	fully labelled
17	M	adult	OS1 - S1	3	inside	12	1	fully labelled
17	M	adult	OS1 - S1		middle	24	4	fully labelled
17	M	adult	OS1 - S1		middle	32	0	
17	M	adult	OS1 - S1		outside	evaluation impossible		
17	M	adult	OS1 - S1	4	inside	15	3	fully labelled
17	M	adult	OS1 - S1		middle	28	1	fully labelled
17	M	adult	OS1 - S1		middle	18	1	fully labelled
17	M	adult	OS1 - S1		outside	25	1	fully labelled
17	M	adult	OS1 - S1	5	inside	23	2	fully labelled
17	M	adult	OS1 - S1		middle	25	5	fully labelled
17	M	adult	OS1 - S1		middle	24	3	fully labelled
17	M	adult	OS1 - S1		outside	13	1	fully labelled
17	M	adult	OS1 - S1	6	inside	21	0	
17	M	adult	OS1 - S1		middle	27	1	fully labelled
17	M	adult	OS1 - S1		middle	32	4	fully labelled

Table 8. 6B13, Minimum number of labelled osteons

Burials 6G8	Sex	Age-Group	Section	Site	Subsite	Osteons Total	Labelled	Type of Labelling
1	M	adult	NS1 - S1	1	middle	38	4	feathered
1	M	adult	NS1 - S1		middle	47	6	feathered
1	M	adult	NS1 - S1		outside	50	9	feathered, one concentric
1	M	adult	NS1 - S1	2	middle	46	16	feathered, one fully labelled
1	M	adult	NS1 - S1		middle	49	12	feathered
1	M	adult	NS1 - S1		outside	37	8	feathered, 2 fully labelled
2	?	subadult	NS2 - S2	1	inside	21	6	fully labelled, 2 concentric, 1 feathered
2	?	subadult	NS2 - S2		middle	31	3	fully labelled
2	?	subadult	NS2 - S2		middle	33	6	fully labelled
2	?	subadult	NS2 - S2		outside	36	1	concentric
2	?	subadult	NS2 - S2	2	inside	23	1	fully labelled
2	?	subadult	NS2 - S2		middle	35	1	fully labelled
2	?	subadult	NS2 - S2		middle	38	2	fully labelled
2	?	subadult	NS2 - S2		outside	54	2	fully labelled
2	?	subadult	NS2 - S2	3	inside	20	1	fully labelled
2	?	subadult	NS2 - S2		middle	32	0	
2	?	subadult	NS2 - S2		middle	37	1	fully labelled
2	?	subadult	NS2 - S2		outside	23	0	

2	?	subadult	NS2 - S2	4	inside	35	0	
2	?	subadult	NS2 - S2		outside	37	6	fully labelled
3	?	subadult	OS1 - S1	1	inside	13	1	fully labelled
3	?	subadult	OS1 - S1		middle	20	3	fully labelled
3	?	subadult	OS1 - S1		middle	20	6	fully labelled
3	?	subadult	OS1 - S1		outside	17	1	fully labelled
3	?	subadult	OS1 - S1	2	inside	10	2	fully labelled
3	?	subadult	OS1 - S1		middle	16	0	
3	?	subadult	OS1 - S1		middle	12	1	fully labelled
3	?	subadult	OS1 - S1		outside	11	1	fully labelled
3	?	subadult	OS1 - S1	3	inside	8	2	fully labelled
3	?	subadult	OS1 - S1		middle	22	5	fully labelled
3	?	subadult	OS1 - S1		middle	16	0	
3	?	subadult	OS1 - S1		outside	17	0	
3	?	subadult	OS1 - S1	4	inside	6	2	fully labelled
3	?	subadult	OS1 - S1		middle	23	3	fully labelled
3	?	subadult	OS1 - S1		middle	18	1	fully labelled
3	?	subadult	OS1 - S1		outside	9	2	fully labelled
4	F	adult	NS2 - S4	1	inside	35	2	fully labelled
4	F	adult	NS2 - S4		middle	33	0	
4	F	adult	NS2 - S4		middle	40	0	
4	F	adult	NS2 - S4		outside	54	2	fully labelled
4	F	adult	NS2 - S4	2	inside	28	0	
4	F	adult	NS2 - S4		middle	44	1	fully labelled
4	F	adult	NS2 - S4		middle	40	0	
4	F	adult	NS2 - S4		outside	15	0	
4	F	adult	NS2 - S4	3	inside	38	0	
4	F	adult	NS2 - S4		middle	50	0	
4	F	adult	NS2 - S4		middle	48	2	concentric
4	F	adult	NS2 - S4		outside	44	2	concentric
4	F	adult	NS2 - S4	4	inside	27	0	
4	F	adult	NS2 - S4		middle	44	0	
4	F	adult	NS2 - S4		middle	58	6	fully labelled, three concentric
4	F	adult	NS2 - S4		outside	48	6	fully labelled, three concentric
4	F	adult	NS2 - S4	5	inside	24	1	fully labelled
4	F	adult	NS2 - S4		middle	42	1	fully labelled
4	F	adult	NS2 - S4		middle	40	1	fully labelled
4	F	adult	NS2 - S4		outside	42	1	fully labelled
4	F	adult	NS2 - S4	6	inside	24	1	fully labelled
4	F	adult	NS2 - S4		middle	43	4	fully labelled
4	F	adult	NS2 - S4		middle	33	2	fully labelled
4	F	adult	NS2 - S4		outside	33	0	
4	F	adult	NS2 - S4	7	inside	26	0	
4	F	adult	NS2 - S4		middle	37	0	
4	F	adult	NS2 - S4		middle	37	0	
4	F	adult	NS2 - S4		outside	34	2	fully labelled
4	F	adult	NS2 - S4	8	inside	22	0	
4	F	adult	NS2 - S4		middle	41	0	

4	F	adult	NS2 - S4		middle	46	0	
4	F	adult	NS2 - S4		outside	28	1	fully labelled
5	M	adult	NS1 - S1	1	inside	23	3	fully labelled
5	M	adult	NS1 - S1		middle	33	3	fully labelled
5	M	adult	NS1 - S1		middle	43	2	fully labelled
5	M	adult	NS1 - S1	2	inside	35	2	fully labelled
5	M	adult	NS1 - S1		middle	49	0	
5	M	adult	NS1 - S1		middle	47	0	
5	M	adult	NS1 - S1		outside	40	1	feathered
5	M	adult	NS1 - S1	3	inside	19	2	fully labelled
5	M	adult	NS1 - S1		middle	44	0	
5	M	adult	NS1 - S1		middle	38	0	
5	M	adult	NS1 - S1		outside	43	1	feathered
5	M	adult	NS1 - S1	4	inside	26	2	fully labelled
5	M	adult	NS1 - S1		middle	34	0	
5	M	adult	NS1 - S1		middle	38	5	feathered
5	M	adult	NS1 - S1		outside	32	5	feathered
5	M	adult	NS1 - S1	5	inside	20	4	fully labelled
5	M	adult	NS1 - S1		middle	51	0	
5	M	adult	NS1 - S1		middle	43	1	feathered
5	M	adult	NS1 - S1		outside	39	2	one fully labelled, one feathered
5	M	adult	NS1 - S1	6	inside	30	2	feathered
5	M	adult	NS1 - S1		middle	44	0	
5	M	adult	NS1 - S1		middle	44	0	
5	M	adult	NS1 - S1		outside	38	2	one fully labelled, one feathered
5	M	adult	NS1 - S1	7	inside	16	2	
5	M	adult	NS1 - S1		middle	43	0	
5	M	adult	NS1 - S1		middle	43	0	
5	M	adult	NS1 - S1		outside	43	4	feathered
5	M	adult	NS1 - S1	8	inside	19	5	
5	M	adult	NS1 - S1		middle	23	2	
5	M	adult	NS1 - S1		middle	21	5	
6	?	subadult	NS1 - S1	1	inside	31	4	fully labelled
6	?	subadult	NS1 - S1		middle	27	3	fully labelled
6	?	subadult	NS1 - S1		middle	27	3	fully labelled
6	?	subadult	NS1 - S1		outside	13	3	fully labelled
6	?	subadult	NS1 - S1	2	inside	21	3	fully labelled
6	?	subadult	NS1 - S1		middle	31	1	fully labelled
6	?	subadult	NS1 - S1		middle	29	2	fully labelled
6	?	subadult	NS1 - S1		outside	23	3	fully labelled
9	?	child	OS1 - S1	1	inside	22	0	
9	?	child	OS1 - S1		outside	31	0	
9	?	child	OS1 - S1	2	inside	19	0	
9	?	child	OS1 - S1		outside	27	1	fully labelled
9	?	child	OS1 - S1	3	inside	20	0	
9	?	child	OS1 - S1		outside	impossible to evaluate		
11	F	adult	OS1 - S1	1	inside	27	1	fully labelled
11	F	adult	OS1 - S1		middle	32	2	fully labelled

11	F	adult	OS1 - S1		middle	42	3	fully labelled, one concentric
11	F	adult	OS1 - S1		outside	29	0	
11	F	adult	OS1 - S1	2	inside	23	1	fully labelled
11	F	adult	OS1 - S1		middle	45	1	fully labelled
11	F	adult	OS1 - S1		middle	44	0	
11	F	adult	OS1 - S1		outside	54	0	
11	F	adult	OS1 - S1	3	inside	32	1	concentric
11	F	adult	OS1 - S1		middle	43	0	
11	F	adult	OS1 - S1		middle	25	1	concentric
11	F	adult	OS1 - S1	4	inside	26	0	
11	F	adult	OS1 - S1		middle	37	0	
11	F	adult	OS1 - S1		middle	25	0	
11	F	adult	OS1 - S1		outside	27	0	
11	F	adult	OS1 - S1	5	inside	23	0	
11	F	adult	OS1 - S1		middle	23	0	
11	F	adult	OS1 - S1		middle	39	0	
11	F	adult	OS1 - S1		outside	29	1	fully labelled
11	F	adult	OS1 - S1	6	inside	31	0	
11	F	adult	OS1 - S1		middle	32	1	fully labelled
11	F	adult	OS1 - S1		middle	34	0	
11	F	adult	OS1 - S1		outside	33	1	fully labelled
13	F	adult	NS1 - S2	1	inside	27	1	fully labelled
13	F	adult	NS1 - S2		middle	45	0	
13	F	adult	NS1 - S2		middle	42	1	fully labelled
13	F	adult	NS1 - S2		outside	39	1	fully labelled
13	F	adult	NS1 - S2	2	inside	25	0	
13	F	adult	NS1 - S2		middle	52	0	
13	F	adult	NS1 - S2		middle	52	0	
13	F	adult	NS1 - S2		outside	48	0	
14	M	adult	NS2 - S3	1	inside	29	0	
14	M	adult	NS2 - S3		middle	22	0	
14	M	adult	NS2 - S3		middle	34	0	
14	M	adult	NS2 - S3		outside	25	2	one fully labelled, one feathered
14	M	adult	NS2 - S3	2	inside	18	1	fully labelled
14	M	adult	NS2 - S3		middle	28	0	
14	M	adult	NS2 - S3		middle	40	2	fully labelled
14	M	adult	NS2 - S3		outside	40	3	fully labelled
14	M	adult	NS2 - S3	3	inside	25	1	fully labelled
14	M	adult	NS2 - S3		middle	39	0	
14	M	adult	NS2 - S3		middle	32	2	fully labelled
14	M	adult	NS2 - S3		outside	20	2	fully labelled
14	M	adult	NS2 - S3	4	inside	17	2	fully labelled
14	M	adult	NS2 - S3		middle	33	3	fully labelled
14	M	adult	NS2 - S3		middle	45	8	fully labelled
14	M	adult	NS2 - S3		outside	21	7	fully labelled, one feathered
14	M	adult	NS2 - S3	5	inside	21	3	fully labelled
14	M	adult	NS2 - S3		middle	25	5	fully labelled
14	M	adult	NS2 - S3		middle	32	4	fully labelled

14	M	adult	NS2 - S3		outside	19	4	fully labelled
14	M	adult	NS2 - S3	6	inside	12	1	fully labelled
14	M	adult	NS2 - S3		middle	26	0	
14	M	adult	NS2 - S3		middle	20	5	fully labelled
14	M	adult	NS2 - S3		outside	13	5	feathered
14	M	adult	NS2 - S3	7	inside	22	2	fully labelled
14	M	adult	NS2 - S3		middle	25	1	fully labelled
14	M	adult	NS2 - S3		middle	26	0	
14	M	adult	NS2 - S3		outside	23	7	fully labelled, two feathered
17	?	child	OS1 - S1	1	inside	21	2	fully labelled
17	?	child	OS1 - S1		outside	23	0	
17	?	child	OS1 - S1	2	inside	15	2	fully labelled
17	?	child	OS1 - S1		outside	36	0	
17	?	child	OS1 - S1	3	inside	7	0	
17	?	child	OS1 - S1		outside	15	1	fully labelled
20	?	child	NS1 - S2	1	inside	25	1	fully labelled
20	?	child	NS1 - S2		outside	21	1	fully labelled
20	?	child	NS1 - S2	2	middle	27	0	
20	?	child	NS1 - S2		outside	35	2	fully labelled
21	M	adult	NS1 - S1	1	inside	30	8	fully labelled
21	M	adult	NS1 - S1		middle	38	3	feathered
21	M	adult	NS1 - S1		middle	34	3	feathered
21	M	adult	NS1 - S1		outside	24	3	fully labelled, one feathered
21	M	adult	NS1 - S1	2	inside	40	2	fully labelled
21	M	adult	NS1 - S1		middle	42	2	feathered
21	M	adult	NS1 - S1		middle	43	4	fully labelled
21	M	adult	NS1 - S1		outside	27	0	
21	M	adult	NS1 - S1	3	inside	27	3	fully labelled
21	M	adult	NS1 - S1		middle	44	2	featheted
21	M	adult	NS1 - S1		middle	54	2	fully labelled
21	M	adult	NS1 - S1		outside	62	9	fully labelled
21	M	adult	NS1 - S1	4	inside	23	1	fully labelled
21	M	adult	NS1 - S1		middle	38	3	featheted
21	M	adult	NS1 - S1		middle	47	0	
21	M	adult	NS1 - S1		outside	31	2	fully labelled, one feathered
21	M	adult	NS1 - S1	5	inside	29	2	feathered
21	M	adult	NS1 - S1		middle	49	2	feathered
21	M	adult	NS1 - S1		middle	46	2	fully labelled
21	M	adult	NS1 - S1		outside	37	12	fully labelled, three feathered
25	?	child	OS2 - S2	1	inside	16	1	fully labelled
25	?	child	OS2 - S2		outside	19	0	
25	?	child	OS2 - S2	2	inside	17	1	fully labelled
25	?	child	OS2 - S2		outside	15	0	
25	?	child	OS2 - S2	3	inside	2	0	
25	?	child	OS2 - S2		outside	7	0	
26	F	adult	NS1 - S2	1	inside	19	6	feathered
26	F	adult	NS1 - S2		middle	29	0	
26	F	adult	NS1 - S2		middle	27	4	feathered

26	F	adult	NS1 - S2		outside	28	0	
26	F	adult	NS1 - S2	2	inside	24	1	fully labelled
26	F	adult	NS1 - S2		middle	34	4	feathered
26	F	adult	NS1 - S2		middle	32	1	feathered
26	F	adult	NS1 - S2		outside	30	5	fully labelled, three feathered
26	F	adult	NS1 - S2	3	inside	20	3	feathered
26	F	adult	NS1 - S2		middle	29	3	feathered
26	F	adult	NS1 - S2		middle	31	4	feathered
26	F	adult	NS1 - S2		outside	21	4	feathered
27	F	adult	NS1 - S2	1	inside	23	3	fully labelled
27	F	adult	NS1 - S2		middle	29	5	fully labelled
27	F	adult	NS1 - S2		middle	34	2	fully labelled
27	F	adult	NS1 - S2		outside	33	8	fully labelled, five feathered
27	F	adult	NS1 - S2	2	inside	28	4	fully labelled
27	F	adult	NS1 - S2		middle	25	4	fully labelled
27	F	adult	NS1 - S2		middle	34	6	fully labelled, three feathered
27	F	adult	NS1 - S2		outside	42	5	feathered
27	F	adult	NS1 - S2	3	inside	24	2	fully labelled
27	F	adult	NS1 - S2		middle	33	2	fully labelled
27	F	adult	NS1 - S2		middle	36	4	fully labelled
27	F	adult	NS1 - S2		outside	40	1	feathered
28	F	adult	OS1 - S1	1	inside	20	0	
28	F	adult	OS1 - S1		middle	30	1	fully labelled
28	F	adult	OS1 - S1		middle	23	1	fully labelled
28	F	adult	OS1 - S1		outside	26	1	fully labelled
28	F	adult	OS1 - S1	2	inside	11	1	fully labelled
28	F	adult	OS1 - S1		middle	26	3	fully labelled
28	F	adult	OS1 - S1		middle	11	1	fully labelled
28	F	adult	OS1 - S1		outside	28	2	fully labelled
28	F	adult	OS1 - S1	3	inside	18	3	fully labelled
28	F	adult	OS1 - S1		middle	25	1	fully labelled
28	F	adult	OS1 - S1		middle	25	2	fully labelled
28	F	adult	OS1 - S1		outside	16	1	fully labelled
28	F	adult	OS1 - S1	4	inside	10	3	fully labelled
28	F	adult	OS1 - S1		middle	30	1	fully labelled
28	F	adult	OS1 - S1		middle	27	3	fully labelled, two feathered
28	F	adult	OS1 - S1		outside	29	4	fully labelled
28	F	adult	OS1 - S1	5	inside	18	1	fully labelled
28	F	adult	OS1 - S1		middle	29	1	fully labelled
28	F	adult	OS1 - S1		middle	30	0	
28	F	adult	OS1 - S1		outside	34	4	fully labelled
28	F	adult	OS1 - S1	6	inside	3	1	fully labelled
28	F	adult	OS1 - S1		middle	5	1	fully labelled
28	F	adult	OS1 - S1		middle	23	1	fully labelled
28	F	adult	OS1 - S1		outside	32	3	fully labelled
28	F	adult	OS1 - S1	7	inside	2	1	fully labelled
28	F	adult	OS1 - S1		middle	28	1	fully labelled
28	F	adult	OS1 - S1		outside	13	1	fully labelled

29	M	adult	NS2 - S3	1	inside	11	2	one fully labelled, one feathered
29	M	adult	NS2 - S3		middle	40	5	feathered
29	M	adult	NS2 - S3		middle	42	12	feathered
29	M	adult	NS2 - S3	2	inside	22	3	one fully labelled, two feathered
29	M	adult	NS2 - S3		middle	31	7	fully labelled, four feathered
29	M	adult	NS2 - S3		middle	30	7	fully labelled
29	M	adult	NS2 - S3		outside	29	6	fully labelled, three feathered
29	M	adult	NS2 - S3	3	inside	21	5	fully labelled, two feathered
29	M	adult	NS2 - S3		middle	30	0	
29	M	adult	NS2 - S3		middle	29	1	fully labelled
29	M	adult	NS2 - S3		outside	18	3	feathered
29	M	adult	NS2 - S3	4	inside	20	2	feathered
29	M	adult	NS2 - S3		middle	32	2	feathered
29	M	adult	NS2 - S3		middle	22	3	fully labelled
29	M	adult	NS2 - S3		outside	23	0	
29	M	adult	NS2 - S3	5	inside	23	3	fully labelled, one feathered
29	M	adult	NS2 - S3		middle	40	2	feathered
29	M	adult	NS2 - S3		middle	31	3	fully labelled, one feathered
29	M	adult	NS2 - S3		outside	32	3	fully labelled, two feathered
29	M	adult	NS2 - S3	6	inside	27	2	fully labelled
29	M	adult	NS2 - S3		middle	35	6	feathered
29	M	adult	NS2 - S3		middle	36	8	fully labelled, two feathered
29	M	adult	NS2 - S3	7	inside	28	3	feathered
29	M	adult	NS2 - S3		middle	49	5	fully labelled, three feathered
29	M	adult	NS2 - S3		middle	44	6	fully labelled, four feathered
29	M	adult	NS2 - S3		outside	32	2	feathered
30	F	adult	OS1 - S1	1	inside	27	1	fully labelled
30	F	adult	OS1 - S1		middle	29	0	
30	F	adult	OS1 - S1		middle	28	0	
30	F	adult	OS1 - S1		outside	30	0	
30	F	adult	OS1 - S1	2	inside	25	1	fully labelled
30	F	adult	OS1 - S1		middle	31	0	
30	F	adult	OS1 - S1		middle	28	1	fully labelled
30	F	adult	OS1 - S1		outside	33	0	
30	F	adult	OS1 - S1	3	inside	25	3	fully labelled
30	F	adult	OS1 - S1		middle	28	5	fully labelled
30	F	adult	OS1 - S1		middle	32	5	fully labelled, four feathered
30	F	adult	OS1 - S1		outside	33	1	fully labelled
30	F	adult	OS1 - S1	4	inside	11	2	fully labelled
30	F	adult	OS1 - S1		middle	27	3	fully labelled

30	F	adult	OS1 - S1		middle	30	2	fully labelled
30	F	adult	OS1 - S1		outside	26	1	fully labelled
30	F	adult	OS1 - S1	5	inside	23	1	fully labelled
30	F	adult	OS1 - S1		middle	33	4	feathered
30	F	adult	OS1 - S1		middle	39	3	fully labelled, one feathered
30	F	adult	OS1 - S1		outside	34	6	fully labelled, four feathered
32	F	adult	NS1 - S1	1	inside	9	0	
32	F	adult	NS1 - S1		middle	32	1	fully labelled
32	F	adult	NS1 - S1		middle	43	1	fully labelled
32	F	adult	NS1 - S1		outside	35	0	
32	F	adult	NS1 - S1	2	inside	14	1	fully labelled
32	F	adult	NS1 - S1		middle	36	7	fully labelled, five feathered
32	F	adult	NS1 - S1		middle	26	1	fully labelled
32	F	adult	NS1 - S1		outside	39	4	fully labelled, one feathered
32	F	adult	NS1 - S1	3	inside	14	0	
32	F	adult	NS1 - S1		middle	31	0	
32	F	adult	NS1 - S1	4	inside	12	1	fully labelled
32	F	adult	NS1 - S1		middle	32	1	feathered
32	F	adult	NS1 - S1		middle	36	0	
32	F	adult	NS1 - S1		outside	32	0	

Table 10. 6G8, Minimum number of labelled osteons

Appendix B: List of figures and tables

References

AAPA (1969). "AAPA Statement on Biological Aspects of Race." American Journal of Physical Anthropology(101): 569-570.

Abdulmannan, N. (2007, 15.06.2007). "Kajbar Massacre." Retrieved 19.09., 2008, from http://www.sudaneseonline.com/cgi-bin/esdb/2bb.cgi?seq=print&board=12&msg=1181888953&rn=.

Adams, W. Y. (1965). "Post-Pharaonic Nubia in the Light of Archaeology. II." The Journal of Egyptian Archaeology **51**: 160-178.

Adams, W. Y. (1977). Nubia. Corridor to Africa. Princeton, New Jersey, Princeton University Press.

Adams, W. Y. (1979). "On the Argument from Ceramics to History: A Challenge Based on Evidence from Medieval Nubia." Current Archaeology **20**(4): 727-735.

Adams, W. Y. (1994). "The Invention of Nubia." 2003.

Adrario, C. (2002). ""Ta" - Getreide und Brot im Alten Ägypten." Antike Welt **5**: 559-563.

Ahmed, S. E. M. (2004). The Merowe Dam Archaeological Salvage Project. . Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Anderson, J. R. (2004). The Medieval Kingdoms of Nubia. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Armelagos, G. J. (1968). "Aikens' Fremont Hypothesis and Use of Skeletal Material in Archaeological Interpretation." American Antiquity **33**(3): 385-386.

Armelagos, G. J. (1969). "Disease in Ancient Nubia." Science **163**: 255-259.

Armelagos, G. J. (2000). "Take two beers and call me in 1.600 years." Retrieved 18.09., 2008, from http://findarticles.com/p/articles/mi_m1134/is_4_109/ai_62324477.

Armelagos, G. J., G. H. Ewing, et al. (1968). "Physical Anthropology and Man-Made Lakes." Anthropological Quarterly **41**(3): 122-131.

Armelagos, G. J., G. H. Ewing, et al. (1965). "Report of the Physical Anthropology Section University of Colorado Nubian Expedition." Kush -- Khartoum **13**: 24-27.

Armelagos, G. J., K. H. Jacobs, et al. (1981). Death and Demography in Prehistoric Sudanese Nubia. Mortality and Immortality. London, Academic Press**:** 33-57.

Armelagos, G. J., K. Kolbacher, et al. (2001). Tetracycline consumption in prehistory. Tetracyclines in Biology, Chemistry and Medicine. M. Nelson, W. Hillen and R. A. Greenwald, Birkhäuser Verlag.

Armelagos, G. J., J. H. Mielke, et al. (1972). "Bone Growth and Development in Prehistoric Populations from Sudanese Nubia." Journal of Human Evolution **1**: 89-119.

Bassett, E. J., M. S. Keith, et al. (1980). "Tetracycline-Labeled Human Bone from Ancient Sudanese Nubia (A.D. 350)." Science **209**: 1532-34.

Bogin, B. (1997). The Evolution of Human Nutrititon. The Anthropology of Medicine. From Culture to Method. L. Romanucci-Ross, D. E. Moerman and L. R. Tancredi. Westport, Bergin and Garvey: 96-142.

Bonnet, C. (2004). The Kerma Culture. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Brier, B. (2002). "The Other Pyramids." Archaeology **55**(5): 54-58.

Burr, D. B., C. B. Ruff, et al. (1990). "Patters of Skeletal Histological Change Through Time: Comparison of an Archaic Native American Population with Modern Populations." The Anatomical Record **226**: 307-313.

Burstein, S., Ed. (1997). Ancient African Civilizations. Kush and Axum. . Princeton, Markus Wiener Publishers.

Calcagno, J. M. (1986). "Odontometrics and Biological Continuity in the Meroitic, X-Group, and Christian Phases of Nubia." Current Anthropology **27**(1): 66-69.

Carlson, D. S. (1976). "Temporal Variation in Prehistoric Nubian Crania." American Journal of Physical Anthropology **45**(3): 467-484.

Carlson, D. S., G. J. Armelagos, et al. (1974). "Factors Influencing the Etiology of Cribra Orbitalia in Prehistoric Nubia." Journal of Human Evolution **3**: 405-410.

Carlson, D. S., G. J. Armelagos, et al. (1976). "Patterns of Age-Related Cortical Bone Loss (Osteoporosis) Within the Femoral Diaphysis." Human Biology **48**(2): 295-314.

Carlson, D. S. and D. P. V. Gerven (1979). "Diffusion, Biological Determinism and Biocultural Adaptation in the Nubian Corridor." American Anthropologist **81**(3): 561-580.

Cook, M., E. Molto, et al. (1989). "Fluorochrome Labelling in Roman Period Skeletons from Dakleh Oasis, Egypt." American Journal of Physical Anthropology **80**: 137-143.

Darby, W. J., P. Ghalioungui, et al. (1977). Food: The Gift of Osiris. London, Academic Press.
Darby, W. J., P. Ghalioungui, et al. (1977). Food: The Gift of Osiris. London, Academic Press.
Davies, J. (1990). "What are Antibiotics? Archaic Functions for Modern Activities." Molecular Microbiology **4**(8): 1227-1232.

Dewey, J. R., M. H. B. Jr., et al. (1969). "Rates of Femoral Cortical Bone Loss in Two Nubian Populations." Clinical Orthopaedics and Related Research **65**: 61-66.

Edwards, D. N. (1996). "Sorghum, Beer and Kushite Society." Norwegian Archaeological Review **29**(2).

Fanghänel, J., F. Pera, et al., Eds. (2003). Waldeyer. Anatomie des Menschen. , Walter de Gruyter.

Farb, P. and G. Armelagos (1980). Consuming Passions. The Anthropology of Eating. Boston, Houghton Mifflin Company.

Fernea, R. A. and A. Rouchdy (1987). Contemporary Egyptian Nubians. Nubian Culture Past and Present. T. Hägg. Stockholm, Almquist and Wiksell International**:** 365-388.

Frost, H. M. (1969). "Tetracycline-Based Histological Analysis of Bone Remodeling." Calc. Tiss. Res. **3**: 211-237.

Fuller, D. Q., Ed. (1999). A Parochial Perspective on the End of Meroe: Changes in Cemetery and Settlement at Arminna West. Recent Research in Kushite History and Atchaeology. Proceedings of the 8th International Conference for Meroitic Studies. . London, British Museum Press.

Garcea, E. A. A. (2004). The Paleolithic and Mesolithic. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. . D. A. Welsby and J. R. Anderson, The British Museum Press.

Garland, A. N. (1987). A histological study of archaeological bone decomposition. Death, decay and reconstruction. Approaches to archaeology and forensic science. A. Boddington, A. N. Garland and R. C. Janaway, Manchester University Press.

Garland, A. N. (1989). "Microscopical analysis of fossil bone." Applied Geochamistry **4**: 215-229.

Garland, A. N. (1993). An introduction to the histology of exhumed mineralized tissue. Histology of Ancient Human Bone: Methods and Diagnosis. G. Grupe and A. N. Garland. Berlin, Springer**:** 1-16.

George, U. (2005). Ein Vatikan in der Wüste. GEO. Hamburg, Gruner + Jahr**:** 19-40.

Geus, F. (2004). Funerary Culture. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Golub, L. M., H. M. Lee, et al. (1998). "Tetracyclines Inhibit Connective Tissue Breakdown by Multiple Non-Antimicrobial Mechanisms." Advances In Dental Research **12**(November 1998): 12-26.

Grauer, A. L. and G. J. Armelagos (1998). Skeletal Biology of Hesban: A Biocultural Interpretation. The Necropolis Of Hesban: A Typology of Tombs. S. D. Waterhouse. Berrien Springs, Michigan, Andrews University Press**:** 109-131.

Greene, D. L., G. H. Ewing, et al. (1967). "Dentition of a Mesolithic Population from Wadi Halfa, Sudan." American Journal of Physical Anthropology **27**(1): 41-56.

Greenwald, R. A. and L. M. Golub (1998). "Preface." Advances In Dental Research **12**(November 1998): 1.

Hackett, C. J. (1981). "Microscopical Focal Destruction (Tunnels) in Exhumed Human Bones." Medicine, Science, and the Law **21**(4): 243 - 265.

Honegger, M. (2004). The Pre-Kerma Period. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Hummert, J. R. and D. P. V. Gerven (1982). "Skeletal Growth in a Medieval Population from Sudanese Nubia." American Journal of Physical Anthropology **60**: 471-478.

Hummert, J. R. and D. P. VanGerven (1982). "Tetracycline-Labeled Human Bone from a Medieval Population in Nubia's Batn el Hajar (550-1450 A. D.)." Human Biology **54**(2): 355-371.

Jakobielski, S. (1987). North and South in Christian Nubian Culture: Archaeology and History. Nubian Culture Past and Present. T. Hägg. Stockholm, Almquist and Wiksell International**:** 231-235.

Jesse, F. (2004). The Neolithic. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Junqueira, L. C. and J. Carneiro (1996). Histologie. Zytologie, Histologie und mikroskopische Anatomie des Menschen. , Springer.

Keith, M. and G. J. Armelagos (1983). Naturally Occuring Dietary Antibiotics and Human Health. The Anthropology of Medicine. L. Romannuci-Ross, D. Moerman and R. R. Trancreddi. New York, Preager Press.

Keith, M. S. and G. J. Armelagos (1988). "An Example of In Vivo Tetracycline Labelling: Reply to Piepenbrink." Journal of Archaeological Science **15**: 595-601.

Kirwan, L. P. (1962). "Nubia-An African Frontier Zone." Advancement of Science: 330-337.

Krause, M. (1987). Zur Kirchengeschichte Nubiens. Nubian Culture Past and Present. T. Hägg. Stockholm, Almquist and Wiksell International**:** 293-308.

Kronenberg, A. (1987). Nubian Culture in the Sudan in the 20th Century: State of Research. Nubian Culture Past and Present. T. Hägg. Stockholm, Almquist and Wiksell International**:** 389-418.

Lenoble, P. (2004). The Pre-Christian Empire and Kingdoms. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Levy, S. B. (2001). Forword. Tetracyclines in Biology, Chemistry and Medicine. M. Nelson, W. Hillen and R. A. Greenwald, Birkhäuser Verlag.

Lison, C. (2006). Das Geheimnis der schwarzen Pharaonen. National Geographic**:** 40-68.

Martens-Czarnecka, M. (2002). "Die christliche Malerei in Faras und Dongola." Vernissage. Die Zeitschrift zur Ausstellung. **13**(02).

Martin, D. L. and G. J. Armelagos (1979). "Morphometrics of Compact Bone: An Example from Sudanese Nubia." American Journal of Physical Anthropology **51**: 571-578.

Martin, D. L., G. J. Armelagos, et al. (1984). The Effects Of Socioeconomic Change In Prehistoric Africa: Sudanese Nubia As A Case Study. Paleopathology at the Origins of Agriculture. M. N. Cohen and G. J. Armelagos. Orlando, Academic Press, Inc.**:** 193-214.

Martin, R. B. and D. B. Burr (1989). Structure, Function, and Adaptation of Compact Bone. New York, Raven Press.

Mielke, J. H., G. J. Armelagos, et al. (1972). "Trabecular Involution in Femoral Heads of a Prehistoric (X-Group) Popluation from Sudanese Nubia." American Journal of Physical Anthropology **36**: 39-44.

Mierzejewska, B. (2002). "Die Anfänge des Christentums in Nubien." Vernissage. Die Zeitschrift zur Ausstellung. **13**(02).

Mills, J. O. (1992). Beyond Nutrition: Antibiotics Produced through Grain Storage Practices, Their Recognition and Implications for the Egyptian Predynastic. The Followers of Horus. R. Friedman and B. Adams, Egyptian Studies Association Publication. **Monograph 20:** 27-35.

Nelson, M. L. (1998). "Chemical and Biological Dynamics of Tetracyclines." Advances In Dental Research **12**(November 1998): 5-11.

Nelson, M. L. (2001). The chemistry and cellular biology of the tetracyclines. Tetracyclines in Biology, Chemistry and Medicine. M. Nelson, W. Hillen and R. A. Greenwald, Birkhäuser Verlag.

Oklund, S. A., D. J. Prolo, et al. (1981). "The Significance of Yellow Bone. Evidence for Tetracycline in Adult Human Bone." The Journal of the American Medical Assiciation **246**(7): 761-763.

Piepenbrink, H. (1984). "beispiele biogener Dekompositionserscheinungen an Knochen unter längerer Liegenzeit." Anthropologischer Anzeiger **42**(4): 241-251.

Protz, R. (1996). Calling up Beer from Old World. What's brewing**:** 17.

Roberts, D. (1993). "Nubia: the unfolding story of a storied land." Smithsonian **24**(3): 90-104.

Ryan, M. E. and R. A. Ashley (1998). "How Do Tetracyclines Work?" Advances In Dental Research **12**(November 1998): 149-151.

Salopek, P. (2003). Shattered Sudan: Drilling for Oil, Hoping for Peace. National Geographic**:** 38-63.

Samuel, D. (1996). "Investigation of Ancient Egyptian Baking and Brewing Methods by Correlative Microscopy." Science **273**: 488-490.

Samuel, D. (2000). Brewing and Baking. Ancient Egyptian Materials and Technology. P. T. Nicholson and I. Shaw, Cambridge University Press**:** 537-576.

Samuel, D. and P. Bolt (1995). Brewing Archaeology: Rediscovering Ancient Egyptian Beer. Brewers' Guardian. **125:** 26-31.

Sasaki, T., N. S. Ramamurthy, et al. (1998). "Long-Term Therapy with a New Chemically Modified Tetracycline (CMT-8) Inhibits Bone Loss in Femurs of Ovariectomized Rats." Advances In Dental Research **12**(November 1998): 76-81.

Satzinger, H. (2002). "Das Volk der Nobaden." Vernissage. Die Zeitschrift zur Ausstellung. **13**(02).

Säve-Söderbergh, T., H.-A. Nordström, et al. (1981). The cultural and historical background. Scandinavian Joint Expedition to Sudanese Nubia, Scandinavian University Books. **6:** 15-21.

Schindler, D. L., G. J. Armelagos, et al. (1981). Biocultural Adaptation: New Directions in Northeastern Anthropology. Foundations of Northeast Archaeology, Academic Press**:** 229-259.

Schoeninger, M. J., K. M. Moore, et al. (1989). "Detection of bone preservation in archaeological and fossil samples." Applied Geochemistry **4**: 281-292.

Sibley, L. M., G. J. Armelagos, et al. (1992). "Obstetric Dimensions of the True Pelvis in a Medieval Population From Sudanese Nubia." American Journal of Physical Anthropology **89**: 421-430.

Spaulding, J. (1995). "Medieval Christian Nubia and the Islamic World: A Reconsideration of the Baqt Treaty." International Journal of African Historical Studies **28**(3): 577-594.

Stokol, T. and G. J. Armelagos (2002). "Tetracycline in a Meroitic Population (0CE-350 CE) from Sudanese Nubia." American Journal of Physical Anthropology **Supplement 34**: 149.

Stout, S. and D. J. Simmons (1979). Use of histology in ancient bone research. Yearbook of Physical Anthropology. Yearbook Series Volume 22. K. A. Bennett. Washington, The American Association of Physical Anthropologists.

Stout, S. D. (1978). "Histological Structure and its Preservation in Ancient Bone." Current Anthropology **19**(3): 601-604.

Stout, S. D. and S. L. Teitelbaum (1976). "Histological Analysis of Undecalcified Thin Sections of Archaeological Bone." American Journal of Physical Anthropology **44**: 263-270.

Thurman, C. C. M. (1979). The Textiles. Ancient Textiles from Nubia: Meroitic, X-Group and Christian Fabrics from Ballana and Qustul, Art Institute of Chicago**:** 36-46.

Török, L. (1987). The Historical Background: Meroe, North and South. Nubian Culture Past and Present. T. Hägg. Stockholm, Almquist and Wiksell International**:** 139-229.

Török, L. (2004). The Kingdom of Kush: Napatan and meroitic Periods. Sudan. Ancient Treaures. An exhibition of recent discoveries from the Sudan National Museum. D. A. Welsby and J. R. Anderson, The British Museum Press.

Vallee, B. L. (1998). "Kleine Kulturgeschichte des Alkohols." Spektrum der Wissnschaft. **08** 54-59.

Van Gerven, D. P. (1981). "Nubias Last Christians: The Cemeteries of Kulubnarti." Archaeology **34**(3): 22-30.

Van Gerven, D. P. (1982). "The Contribution of Time and Local Geography to Craniofacial Variation in Nubias Batn el Hajar." American Journal of Physical Anthropology **59**: 307-316.

Van Gerven, D. P., G. J. Armelagos, et al. (1977). "Continuity and Change in Cranial Morphology of Three Nubian Archaeological Populations." Man **12**: 270-277.

Van Gerven, D. P., D. S. Carlson, et al. (1973). "Racial History and Bio-Cultural Adaption of Nubian Archaeological Populations." Journal of African History **14**(4): 555-564.

Van Gerven, D. P., M. K. Sandford, et al. (1981). "Mortality and Culture Change in Nubias Batn el Hajar." Jounal of Human Evolution **10**: 395-408.

Van Gerven, D. P., S. G. Sheridan, et al. (1995). "The Health and Nutrition of a Medieval Nubian Population." American Anthropologist **97**(3): 468-480.

Vernillo, A. T. and B. R. Rifkin (1998). "Effects of Tetracyclines on Bone Metabolism." Advances In Dental Research **12**(November 1998): 56-62.

Wendorf, F., R. D. Daugherty, et al. (1964). "The Museum of New Mexico-Columbia University Nubian Expedition: The 1962-63 Field Programme." Kush -- Khartoum **12**: 12-18.

Wendt, W. E. (1966). "Two Prehistoric Archaeological Sites in Egyptian Nubia." Postilla - Peabody Museum of Natural History, Yale University **102**: 1-46.

Williams, B. (1979). The Circumstances of Discovery. Ancient Textiles from Nubia: Meroitic, X-Group, and Christian Fabrics from Ballana and Qustul, Art Institute of Chicago**:** 32-35.

Williams, B. (1979). The Geographical, Historical, and Archaeological Background of Ancient Nubia and Northern Sudan. Ancient Textiles from Nubia: Meriotic, X-Group, and Christian Fabrics from Ballana and Qustul, Art Institute of Chicago**:** 17-32.

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Education

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1994-1995	Studied German and Russian at the University of Vienna
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Scholarships

2002 - 2003	Scholarship by the "Büro für internationale Beziehungen" for a short term research project at Emory University, Atlanta, USA
July-Sep. 2002	Scholarship from DANUBE (Association for European Training and RTD) for a three month internship with the German popular science magazine "Bild der Wissenschaft"
July 2001	The "Kuratorium für Journalistenausbildung" granted a scholarship for a one month internship with the Austrian daily newspaper "Kurier"

Experience

since 2008	- Freelance journalist for the "Standard"
since 2007	- Editor at Langbein & Skalnik, responsible for a medical project for a German health insurance company - Fire performances
since 2006	- Teaching Tango Argentino
since 2004	- Editor and medical ghostwriter for MedNews Public Relations
2004	- Internship with the Public Information Unit of the UN-Refugee Agency (UNHCR) - Texts and translations (German to English) for MedLance
2003	- Research Project at Emory University, Atlanta, USA - German tutor at Emory University - Translation (German to English) of personal letters of a Jewish Holocaust victim on behalf of the Anthropological Department of the Natural History Museum, Vienna
2002	- Internship and subsequently contracted author with "Bild der Wissenschaft" in Stuttgart, Germany
2001	- Internship and subsequently freelance journalist with the "Kurier" - Preparation and anthropological analysis of skeletons from a "Langobarden" burial ground (600AD) near Pottenbrunn - Editing of final reports for the ibw (Institute for Research on Qualification and Training of the Austrian Economy)
2000	- Research Assistant at the Anthropological Department of the Natural History Museum Vienna (Project: Functional adaptations of primate hand and wrist bones)
1999	- Employed by the "Österreichischer Naturschutzbund" to map biotopes