Before and After "Out of Africa": Evolution of Early *Homo sapiens* in Northwestern Africa

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Project Summary

The project will investigate the biological and cultural evolution of early *Homo sapiens* by focusing on human fossil, artifact, and environmental records from the Middle and Later Stone Age deposits in north-western Africa, in two cave sites in Morocco: Dar Es-Soltane 2 and Contrebandiers Cave. Together with the existing morphological data on human fossils and published material collections from other sites across the regions, with the newly produced multi-proxy data from this project several specific questions related to the evolution of human anatomy will be addressed, as will early human population diversity, evolution of tool and fire making technologies, the earliest exploitation of marine and plant food resources, and the origins of symbolic behaviour, all placed within the paleoenvironmental background. The most up-to-date methods of fossil, bone, plant, artifact, and sediment analysis, like ancient DNA retrieval, palaeoproteomics, plant wax profiling, and isotope analysis will be applied. Both the fieldwork and the lab components of this project will involve early career scientists, Moroccan researchers, as well as our extensive network of external specialists. At the end of the project, the resulting collections and all the data will be made available and open access.

Introduction

The biological and cultural evolution of *Homo sapiens* in the last 150,000 years is one of the greatest research subjects of evolutionary science. Major issues in palaeoanthropology address questions such as when, where, and how the modern forms of our species emerged and dispersed across the continents; how it adapted behaviourally to different landscapes and climates; and what the extent

of interaction with archaic humans like Neanderthals and Denisovans shaping our behavioural and genotype diversity was.

Over the last twenty years, northwest Africa has emerged as one of the most important regions for the study of our origins and evolution, especially present-day Morocco. The rich record of artifacts and human fossils – including the earliest known *Homo sapiens* – is not only generating new pan-African models of our species' origin (Hublin et al. 2017) but is also producing new knowledge about the early behaviour, adaptation, and survival of the humans who people the entire planet today.

Sites like Jebel Irhoud (Hublin et al. 2017; Richter et al. 2017), Ifri N'Ammar (Nami and Moser 2010), Taforalt (Barton et al. 2016), and Rhafas (Bouzouggar et al. 2019), caves on the Atlantic coast in Rabat-Temara (Bouzougar and Barton 2012; Debénath 1976; Dibble et al. 2012; El Hajraoui 1994; Nespoulet et al. 2008), around Essaouira (Sehasseh et al. 2021), and in the vicinity of Casablanca (Raynal et al. 2010), as well as areas like Ain Béni-Mathar Basin (Sala-Ramos et al. 2022), have provided an invaluable record of the evolution of human morphological traits, more than one million years developments in stone toolmaking and other technologies, diversity in hunting and food procurement, the earliest exploitation of marine resources, and the evidence of some of the earliest human symbolic behaviour, cultural signalling, and abstract thought.

This project will focus on the Middle and Later Stone Age deposits in two Moroccan cave sites in the Rabat-Témara area, the cave of Dar Es-Soltane 2, and Contrebandiers Cave. The research subject of the project is tracing the developments in the biological and cultural evolution of *Homo sapiens* in north-western Africa from 130,000 until 10,000 years ago. The goal is to construct a precise absolute chronology and paleoenvironmental conditions for some of the major events in this evolution. We have chosen to focus on these two caves because they contain a wealth of well-preserved fossil and material records. Additionally, the senior project members have already completed some preliminary work for commencing new excavations at these sites, making us familiar with their geological deposits, research potential, and scientific significance.

The Research Questions and Objectives

The research subject of the proposal involves six specific questions related to human biological and cultural evolution, and its absolute chronology and paleoenvironmental conditions. These are structured as follows.

 # Human biological evolution

1) What were the morphological trajectories in the evolution of *Homo sapiens'* face, dentition, and skull, and how are the morphological features of *Homo sapiens* of Northwest Africa related to those of contemporary early human groups of Eastern Africa and of the Levant?

2) What was the population diversity of early *Homo sapiens*? Did the transition between the Middle and Later Stone Age, occurring around 20-40,000 years ago, involve population

continuity or a demographic replacement?

Human cultural evolution

3) What was the course of evolution and innovation in the technologies of stone and bone toolmaking and in the management of fire?

4) What were the strategies of terrestrial and marine resource exploitation and prey (animal taxa) and plant targeting?

5) What was the scope of some of the earliest human symbolic behaviour? Can its material presence and absence in the record over time (within the cultural stratigraphy) be related not only to social and cognitive but also to environmental factors (such as the possibility of seashells turned into pendants to be collected on the shore by those humans only during periods of low sea levels)?

Absolute chronology and paleoenvironment

6) What is the absolute chronology (by the methods of optically stimulated luminescence, electron-spin resonance, and tephrochronology) and paleoenvironmental context (by plant leaf-wax biomarkers and tephra-based environmental correlations) behind the major events in the Middle and Late Pleistocene human evolution of this region?

Dar Es-Soltane 2 and Contrebandiers Caves

These two caves are among several caves that were formed in a calcareous sandstone of Quaternary origin along the Atlantic Ocean in Rabat-Témara area. From the mid-twentieth century, several scholars have been intermittently excavating these caves to various extents.

Dar Es-Soltane 2 and Contrebandiers in October 2022 and May 2023 were revisited to re-examine the deposits and assess the potential for a new excavation campaign. This involved assessing the applicability of new methods developed in archaeological science, such as the analysis of ancient DNA and proteins, plant remains, sediments, and traces of fire. Both caves share a history of sediment deposition and site formation, along with major similarities in the material they yield (Schwenninger et al. 2010). They boast long, continuous cultural sequences dating back to about 130,000 years ago, encompassing several Middle Stone Age (Aterian) occupations overlain by Later Stone Age occupations (the Iberomaurusian culture) up to the beginning of the Holocene around 12,000 years ago (Debénath 1976; Dibble et al., 2012; Schwenninger et al. 2010).

Both of these caves contain rich human fossil remains in several layers (Ferembach 1976, 1998; Hublin et al. 2012; Roche and Texier 1976), abundant fauna, shell pendants, distinctive stone tools across all the occupations (pedunculates, bifacial points, microlithic implements) (Debénath 1978; Dibble et al 2012), numerous hearths and remains of plants (including new evidence for olive consumption 110,000 years ago), and bone tools used for the earliest manufacture of clothing (Hallett et al 2021). The human remains from Dar Es-Soltane 2 Middle Stone Age deposits found in the past include an adult cranium, the calvarium of an infant, and the mandible of a teenager, but these are only the most complete fossils in the collection (Ferembach 1976). The Later Stone Age deposits yielded several complete individuals in a burial context (Debénath 1978). From Contrebandiers, the

most notable fossil find is a complete skull, with clavicles and vertebrae of a six-year-old child from the 115,000-year-old layer discovered in 2009. These sites are crucial to investigate, given their geological age and the nature of human fossil and archaeological materials. They represent a link between the earliest known *Homo sapiens* at Irhoud (310,000 years ago) and thoroughly anatomically and behaviourally modern humans toward the end of the Pleistocene. However, as of now, all this material remains poorly described and analysed.

The Workplan and Methodology

Timeline. This research would include field work and a whole series of laboratory analyses, part of which are to be conducted in the frame of a new PhD project. The project will start with excavations of Dar Es-Soltane 2 and Contrebandiers Cave in Spring 2024 and be completed with the analyses of all the relevant materials, samples, and data provisionally by the end of 2027.

Field excavation. The project will involve three excavation seasons (2024-2026) in collaboration with the head institution for archaeology in Morocco (*Institut National des Sciences de l'Archéologie et du Patrimoine* in Rabat), during which both of the sites will be excavated in parallel. These field seasons will also be used to analyse stone tools, bone tools, fauna, and plant macroscopic remains (sediment flotation). Handheld data-collectors attached to the total station will be used to record the precise 3D position of all bones, shells, and artifacts 2 cm and larger. Smaller objects are collected in provenienced 7-liter aggregate samples (buckets), which are then dry-screened using nested 5 mm and 2 mm screens. All non- artefactual samples (dating, DNA, plant wax, etc.) will be recorded in the same manner, and the excavated material will be processed (wash, label, bag, etc.) accordingly in the field-house lab.

Human fossil morphological and DNA analysis. All fossil finds will be 3D-scanned and analysed geometric-morphometric standard procedure. The library of the 3D scans will be made publicly available after the completion of the project and publishing of the results. A large library of 3D morphological data from the fossils of *Homo sapiens* found in other regions of Africa and southwest Asia and the ancient DNA data for some of the later specimens already exists. Part of the funding will be used to support a Moroccan PhD candidate (6 months) to complete a study on the Aterian dental material yielded by these sites. When possible, our collaborators at the Max Planck Institute of Evolutionary Anthropology in Leipzig will perform a DNA profiling of human bone samples. Sediment samples will also be systematically collected to be screened for ancient DNA. Both morphological and DNA data will make it possible to undertake comparative studies and to reconstruct some parts of the species' early population structure and diversity.

Faunal analysis. All bones and marine shells will be analysed macroscopically for species identification, cut marks, and traces of heating. In addition, bone tools will be examined for polish and shaping, and *Tritia* shells (Sehasseh et al 2021) used as pendants for perforation and use-wear.

Paleoproteomics. In addition to faunal morphological and macro-trace analysis, since the largest component of bone collections at archaeological sites in general are small fragments that are morphologically non-diagnostic, zooarchaeology-by-mass-spectrometry (ZooMS) will be applied. This method analyses the collagen type 1 peptide protein to elucidate the species or genus assignment of morphologically non-identifiable bone material (Welker et al 2015, 2016). ZooMS will also be employed to identify species used for bone tools to assess the level of animal electivity and preference among those early humans. This part of the research will represent the core of a new PhD project starting in fall 2024.

Isotopes and macrobotanical remains. Multi-isotope analysis using zinc ($\delta^{66}Zn$), strontium ($^{87}Sr/^{86}Sr$), carbon ($\delta^{13}C$), and nitrogen ($\delta^{15}N$) isotope will be applied to dentin and bone collagen from Middle and Later Stone Age human fossils to assess the levels of plant-based food reliance. Part of these studies will be conducted in the frame of the PhD project mentioned above. This will be complemented with the analysis of macro-botanical remains (mostly seeds and fragments of nuts extracted from sediments by flotation).

Stone tool analysis. Stone tool assemblages from the Middle and Later Stone Age occupations will be analysed using a standardized technological and metrical attribute analysis to obtain information on the evolution of efficient flaking stone, tool making, and management of stone raw material resources.

Pyrotechnology. Both of the caves contain hearth features in a number of occupations. These will be sampled for micromorphology to study their formation and re-use and to carry out anthracological analysis (analysis of a kind of fuel) to better understand diachronic changes in fire technology. In addition, carbonate clumped isotope thermometry (Müller et al. 2017) and Fourier transform infrared spectroscopy (Gallo et al. 2021) will be used on burned mollusc shells and burned bone fragments present in these hearths. This will help reconstruct the differences between the temperatures reached and burning intensity.

Absolute dating. Optically stimulated luminescence (OSL) and combined Uranium-series electron spin resonance (US-ESR) will be used for absolute dating. OSL measures the time since minerals like quartz and feldspar were last exposed to light. Tephra shards extracted from sediments will be identified using polarizing light microscopy. Shards will then undergo electron probe microanalysis and laser-ablation-inductively coupled plasma mass spectrometry to geochemically match them with volcanic sources or well-dated paleoenvironmental archives. Both caves are located approximately 1,700 km and 900 km from the Azores and the Canary Islands, respectively. Volcanoes on these islands (e.g., Sete Cidades volcano) have generated numerous large explosive eruptions over the last 500,000 years (e.g., Brown et al. 2003) that have dispersed tephra over wide areas of Northwest Africa and southwest Europe.

Paleoenvironment. In addition to the analysis of macro-botanical remains, leaf wax n-alkanes of terrestrial plant leaves that can be found microscopically in the soil sediments will be analysed.

The stable hydrogen isotopic composition (δD) of these hydrocarbon compounds is a powerful tool to reconstruct hydrological fluctuations in precipitation and water supply in the environment. Furthermore, due to physiological differences in CO2 acquisition during photosynthesis, measurements of leaf wax δ13C can be used to differentiate between C3 and C4 vegetation. Therefore, leaf wax carbon isotopic composition (δ13C) serves as an excellent proxy for determining changes in the composition and origin of continental vegetation.

Project Members

This project will be conducted in collaboration with Prof. Abdelwahed Ben-Ncer and Prof. Abdeljalil Bouzouggar of the *Institut National des Sciences de l'Archéologie et du Patrimoine* (INSAP) in Rabat. Two PhD students and two postdoctoral researchers from the Collège de France will be core members of this project, participating in both fieldwork and material analysis, including paleoproteomics, burned shell and bone temperature analysis, and stone tool analysis. The rest of the materials and samples will be analysed in conjunction with our external collaborators at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Centro Nacional de Investigación sobre la Evolución Humana (CENIEH) in Burgos, NORCE Norwegian Research Centre, University of Cambridge, Oxford University, as well as by local researchers in INSAP in Rabat. Critically, the project will involve a new doctoral candidate and the funding provided by the Balzan Foundation will support this PhD project.

PhD project: ***Expanding the potential of biomolecular analyses on archaeological bone from north African Middle-Late Stone Age contexts***

Recent years have seen huge advancements in the analyses of biomolecules (e.g. proteins, isotopic compositions, DNA) from ancient animal tissues. However, biomolecules degrade over time, and especially in hot and arid regions with wide temperature fluctuations, molecular diagenesis gets accelerated (Jensen *et al.*, 2023). The aim of this PhD is to better understand this biomolecular degradation and to develop and apply new workflows to maximise the biomolecular data that can be retrieved from archaeological bone fragments from more challenging preservation conditions in north African palaeolithic sites.

This project will apply and integrate cutting-edge methods from archaeological science and palaeoproteomics to faunal assemblages from the Moroccan key sites documenting this period with a focus on material recovered during the fieldwork in Dar-es-Soltane 2 and Contrebandiers Cave. To reflect the multidisciplinary nature of the project, the PhD candidate will be supported by a supervisory team consisting of Prof. J-J. Hublin (Collège de France), Dr. K. Ruebens (ZooMS, Collège de France), Dr. F. Welker (palaeoproteomics, University of Copenhagen) and Dr. K. Britton (stable isotopes, University of Aberdeen).

Recently, **near-infrared spectroscopy (NIR)** has been applied successfully to Palaeolithic bone

fragments as a fast, non-destructive method to predict their collagen preservation (Sponheimer et al. 2019, Fewlass et al., 2019; Talamo et al., 2021; Ruebens et al., 2023). At sites where collagen preservation is variable, about 100 bones will be selected for NIR screening to assess the biomolecular preservation of the bones. A portable LabSpec 4 hi-res NIR spectrometer (Malvern Panalytical) will be used, following protocols outlined by Sponheimer *et al.* (2019). Bones with the highest predicted collagen values will then be selected for further palaeoproteomic analysis.

Zooarchaeology by Mass Spectrometry (ZooMS) allows the identification of non-diagnostic bone fragments through variations in their collagen peptides (Buckley et al., 2009, Welker et al., 2016). As a result, ZooMS provides the exciting potential to discover otherwise invisible human remains in collections of archaeological bone, as well as providing full reconstructions of past environments, and human diet and subsistence practices. ZooMS has not yet been applied widely to African faunal assemblages (Prendergast et al., 2017, 2019; Desmond et al., 2018), although a series of pilot studies have had promising results. ZooMS can also be applied to identify the taxonomic origin of bone that was used in the production of bone tools (Desmond et al., 2018). Recent work has shown that altering certain steps of the ZooMS protocol (e.g. digestion in EDTA, Jensen et al., 2023) increases chances of getting ZooMS identifications and as part of this project we will explore further avenues of methodological development.

Stable isotope analysis (SIA) of faunal remains can provide valuable information about the diet, health, and mobility of ancient humans and animals (Makarewicz and Sealy, 2015). This project will apply SIA to animal and newly identified human remains from north African palaeolithic sites. Dietary isotope studies often rely on the preservation of collagen in bone and tooth dentin and therefore such analyses are challenging in environments where collagen degradation is high. A recent study successfully applied carbon and nitrogen bulk isotope analysis and single amino acid analysis to human and animal bones and teeth from Taforalt, Morocco (Ramírez-Pedraza et al., 2023, Moubtahij et al., under review). A workflow will be set up, where NIR, ZooMS and SIA are integrated (also reducing the amount of destructive sampling) to gain new insights into animal and human ecology and diet at the study sites.

During this project, the PhD candidate will also be trained in **Liquid Chromatography with tandem mass spectrometry (LC-MS-MS)**, which is a powerful analytical technique that combines the separating power of liquid chromatography with the highly sensitive and selective mass analysis capability of triple quadrupole mass spectrometry. This will be achieved through a secondment at the University of Copenhagen under the supervision of Ass. Prof. Frido Welker. The aims of this are twofold: firstly, to increase the number of African taxa available in peptide marker reference databases, expanding on recent work on African bovids (Janzen et al., 2021). This can be achieved by sampling identifiable bones of certain taxa and then sequence their proteins through LC MS-MS. Secondly, the newly developed shotgun proteomics method of "Species by Proteome INvestigation" (SPIN, Rüther et al., 2022) will be applied to selected bone samples, which allows a more fine-grained taxonomic identification. This will be the first application of SPIN to African fauna and human fossils.

Importance and Impact

Next to the importance of the research subject itself, which is of great interest to the general public and not only to academe, this project has a methodological importance because it engages a wide array of state-of-the-art methods of analysis of current evolutionary and environmental studies. Several of the methods proposed here (ZooMS, clumped isotope analysis, etc.) will be applied for the first time on the material from this part of the world and may provide unique insights in the context of Middle-Late Stone Age human behavioural evolution in interaction with its environment. The project will also allow training of Moroccan students in the most up-to-date excavation techniques and methods of fossil, fauna, and stone tool analysis. It will represent a unique opportunity to contribute to the skills development of the local academic community. Critically, it will support an entirely new PhD project on a very innovative topic.

Results will be disseminated in a number of scholarly articles submitted to the appropriate peer-review journals and at annual meetings of the major palaeoanthropology conferences. A workshop will be organized in Paris in 2027 on the project research subject but from the pan-African interregional perspective; some of the most prominent experts in the field will be invited.

Primary data will be shared by publishing them together with the resulting articles or uploading them into freely accessible data repositories online. Eventually, all the recovered materials will be stored in INSAP in Rabat, where they will be available for future studies by local and foreign researchers and Moroccan students for their master theses and doctoral dissertations.

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