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Proboscideans and other vertebrates from Anchrif, Morocco

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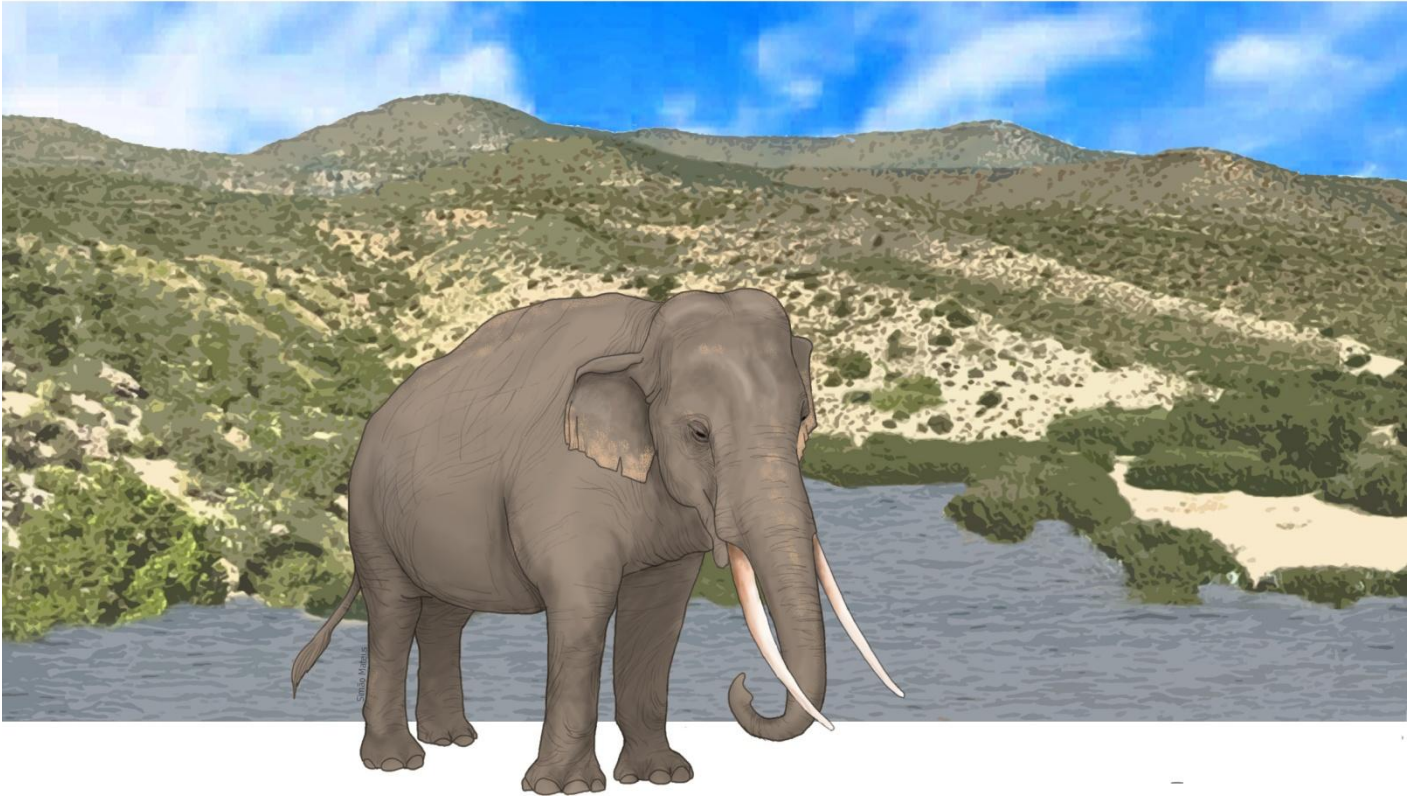
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Elephas reconstruction and Anchrif during the Middle Pleistocene. Illustration by Simão Mateus.

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Abstract

The paleontological richness of Morocco has been scientifically known since at least the early 20th century. The region of the Middle Atlas, more specifically the Boulemane area, has been however only sparsely studied since the 60's when it supplied various vertebrate fossils from the Middle Jurassic. In the beginning of the 2000's some fossil bones were discovered in a new fossil-site near the village of Taghrout, in the Boulemane area and in September 2013 a Moroccan-Portuguese expedition made excavations in the site with the help locals from the village of Taghrout.

The site is Pleistocene in age and is located on a rare bone bearing small high-altitude sedimentary basin, non-charted in previous geological maps. The excavations yielded new bone material from large mammals. The most common findings are elephants ascribed to the genus *Elephas*, but artiodactyls, turtles, and in-situ hominid Acheulean tools were also collected. During the excavation campaign the Jurassic sites were revisited and new dinosaur trails and possible crocodylomorph bones were discovered.

Surface collection of in a cave near Taghrout with Holocene mammal material, including the genera *Canis*, *Capra*, *Bos*, *Panthera* and *Hystrix* was also conducted and its fossils elements identified.

Key Words: Middle-Atlas, Morocco, Pleistocene, Proboscidea

Resumo

A riqueza paleontológica de Marrocos é conhecida desde pelo menos o início do século 20. A região do Médio Atlas, mais especificamente a área de Boulemane, foi escassamente estudada desde a década de 60, quando foram descobertos vários fósseis de vertebrados do Jurássico Médio. No início da década de 2000 alguns ossos fossilizados foram descobertos numa nova localidade perto da aldeia de Taghrout e em Setembro de 2013 uma expedição marroquina-portuguesa fez escavações no local com ajudantes locais da aldeia. A nova jazida tem idade Plistocénica e está localizada numa pequena e rara bacia sedimentar de elevada altitude com material osteológico fossilizado, não cartografada em mapas geológicos anteriores. As escavações produziram novo material ósseo de grandes mamíferos. Os achados mais comuns elefantes atribuídos ao géneros *Elephas*, embora artiodáctilos, tartarugas e ferramentas acheulenses in-situ de homínídeos também tenham sido recolhidos. Durante a campanha de escavações as jazidas Jurássicas foram revisitadas tendo sido encontrados novos trilhos de dinossauros e ossos de possíveis crocodylomorfos.

Uma recolha de superfície de uma gruta com vestígios de mamíferos holocénicos perto de Taghrout, incluindo os géneros *Canis*, *Capra*, *Bos*, *Panthera* e *Hystrix* foi também feita e os seus elementos fósseis identificados.

Palavras-Chave: Médio-Atlas, Marrocos, Plistocénico, Proboscídea

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Introduction

Objectives and Framework

One of the original objectives of this dissertation was the taxonomical description and the identification of the fossil fauna discovered during two expeditions in 2013 in Taghrout, Morocco, mainly the proboscidean material as well as determining the chronology of the Quaternary sites with proboscids. During the field work several hominid tools were found which limited the age of the quarry to the Middle Pleistocene. This area is relatively unknown paleontologically especially in the case of the Pleistocene and although there are several localities with Quaternary material in Morocco this period of time in the Middle Atlas has not provided mega fauna to our knowledge until now. This epoch, besides the interesting material it can provide, is important as a way to understand how our world of today has evolved to what it is nowadays in terms of climate, faunal and floral turnovers, human evolution and wildlife in general. The rare geographical context the findings, in high mountain lakes, as opposed to the relatively flat plains around the quarries of Casablanca for example, also give a unique insight of mammalian fauna in the country at the time.

This thesis was integrated in the framework of a protocol between the FCT-UNL and the Direction du Patrimoine Culturel of Morocco signed in 2013. It was initially planned that some of the fossils, mainly the proboscidean material, were temporarily exported to Portugal for preparation and description that did not happen. Therefore, detailed measurements and analyses were not possible. As consequence, the objectives adapted to the new limitations and broaden the aspects of the work, including Holocene cave remain of Taghrout and the surrounding Jurassic findings.

History of the Anchrif locality and the Atlas Mémoire project

The Anchrif locality described in this work is located 1,5 Km West of the village of Taghrout (Fig.1,2), in the province of Fès-Boulemane Province in the Kingdom of Morocco (GPS coordinates N33° 29.117' W4° 36.548'). The written name of the village has variations in some sources, like Tagheroute or Taghroute in the Google Maps and Google Earth services, but for the sake of consistency the form Taghrout will be used for the rest of this work.

Morocco presents a number of rich vertebrate fossil localities, like the well-known Kem Kem beds from the Upper Cretaceous (McGowan & Dyke, 2009). Taghrout however is scarcely mentioned and the one of the few mentions to it is that of the French paleontologist Alfred de Lapparent, in 1955, in which work is described a *Cetiosaurus* specimen consisting in several limb bones, a pectoral girdle, pelvis and a series of vertebrae. The Anchrif locality does not seem to be documented in previous works in the area, in part because it refers solely to the small uninhabited valley west of the village of Taghrout (Fig. 3).

In 2003 villagers from Taghrout discovered in Anchrif several large bones which were thought to belong to dinosaurs due to the large size of the bones and to the known Moroccan abundance of dinosaur remains. At the request of the villagers in 2009 a group of geology researchers from the University of Fès visited the site to investigate the findings of 2003. The bones continued to be attributed verbally to dinosaurs. This first erroneous attribution is understandable taking in account the large dimensions of the fossils and the fact there are no mentions of any but Mesozoic sediments the in geological charts and scientific literature within 10 Km distance. This visit to the fossil site came to knowledge of the Direction of Cultural Heritage of the Ministry of Culture. Afterwards there was a search for paleontologists that could

come to the site and confirm the presence of dinosaurs near the village, which could be a means of raising tourism in the area, adding to a raise of importance to the region, besides the scientific research. Several paleontologists were contacted in the following years but the findings did not raise sufficient interest for the project to advance with them. The Director of Cultural Heritage of Morocco, Doctor Abdellah Alaoui, talked with Mr. João Urbano, a Portuguese entrepreneur from the company Arte Conseil, which had been working with the Ministry of Culture in other projects about the findings. Mr. Urbano in turn contacted Professor Eugénia Cunha from the Universidade de Coimbra, Portugal to inquire her interest in participating. Professor Cunha forwarded this contact to the paleontologist Professor Octávio Mateus, from the FCT-Universidade Nova de Lisboa. After conversations between Doctor Alaoui, Doctor Mateus and Mr. Urbano, a preliminary visit to Anchrif was planned and made on March 23rd, 2013.

In this trip it was discovered that the large fossil bones did not belong to dinosaurs but instead to large mammals, most likely of proboscids. The find of an ilium with a closed mammalian acetabulum and an elephantid-like mastication tooth provided the strongest evidence of proboscids in Anchrif. The identification of these bones confirmed the presence of a Plio-Pleistocene basin of small dimensions, formed by a paleolake about 50.000 m².

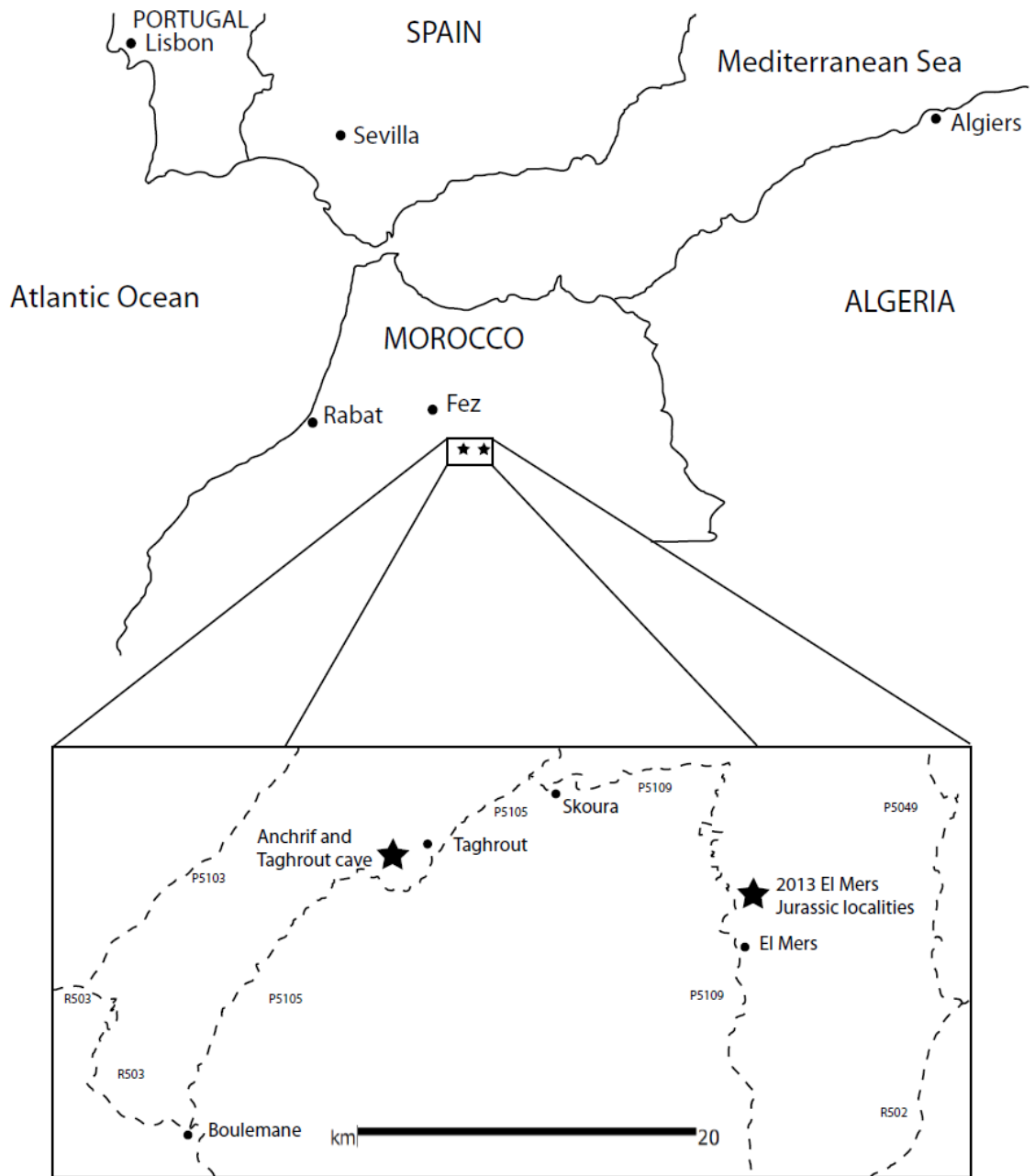


Fig.1: Geographical location of the regions visited during this study. Stars represent the fossil localities and dashed lines the main roads in the Boulemane and Skoura general area.



Fig. 2: The village of Taghrouit, Morocco, seen from the West. Most outcrops shown are from Middle Jurassic formations.



Fig. 3: View from the Southwest over the Anchraf sedimentary basin, near Taghrouit, Morocco. Note the white Pleistocene sediments, along the talweg, and the light brownish mid Jurassic sediments in the background reliefs around.

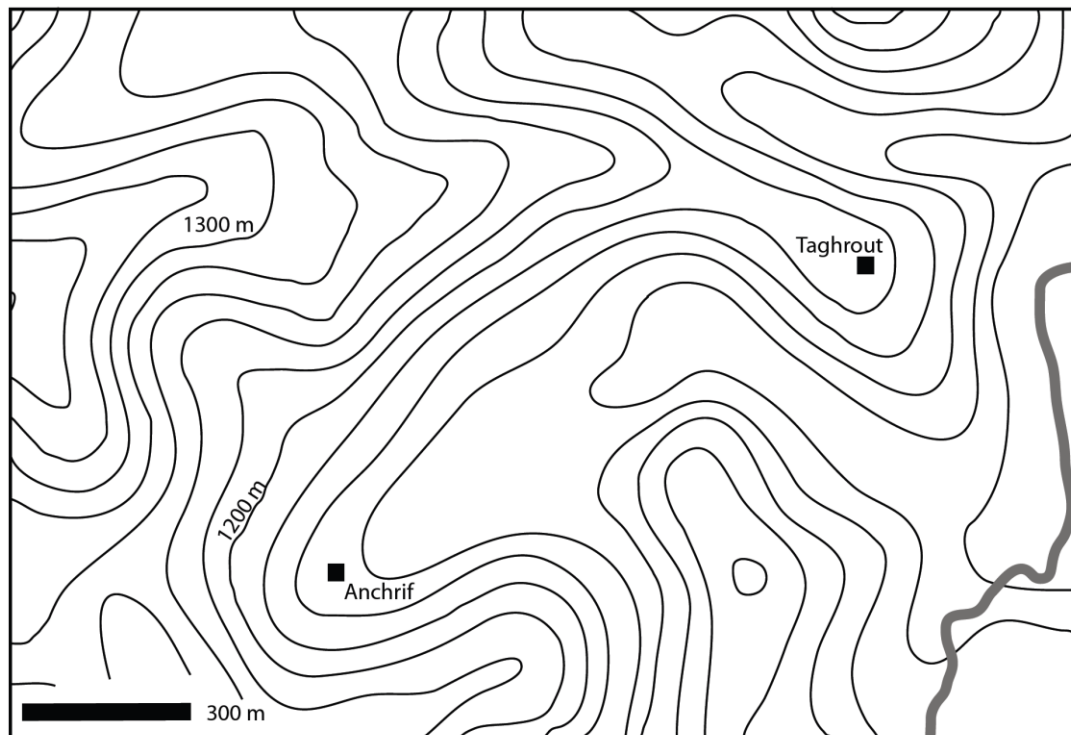


Fig. 4: Topographical map of the Taghrout region. Altered by the author based on data from the OpenStreetMap Foundation (www.openstreetmap.org)

The elephantidae material returned from the digs of March 2013 included two ribs, part of an ilium, a molar and several other unidentified bones. Apart from proboscids there were remains of artiodactyls (a calcaneum and a limb bone) and an Acheulean biface found in the same site. This biface was not found in situ. Due to time constraints other bones, some of large dimensions were left in the site to be dug out in a latter date (Mateus, 2013).

In the following months after the preliminary visits a protocol was made and signed between the Direction of Cultural Heritage of Morocco (Direction du Patrimoine Culturel) and the FCT- Universidade Nova de Lisboa in order to establish the cooperation of the two institutions in the paleontological and archaeological study of the Anchrif locality and the surrounding Middle-Atlas region. The protocol was signed in September 2013. The two parties agreed to provide the human, technical and financial means at the possible extent for this until then unnamed project. The scientific studies coming out of the research were to be thereafter made with permission of both institutions. Also material collected from the expeditions had the possibility of being temporarily transferred to Portugal for laboratorial preparation and scientific study. Upon completion of this study the specimens were to be sent back to Morocco.

Field work was scheduled to late September 2013 and a Portuguese-Moroccan team was assembled to take part in the endeavour. The team that was to dig in the field consisted in the following members (Fig. 5):

- Doctor Fethi Amani, Direction du Patrimoine Culturel
- Doctor Mustapha Nami, Direction du Patrimoine Culturel
- Professor Octávio Mateus, FCT-Universidade Nova de Lisboa and researcher at Museu da Lourinhã
- João Marinheiro, Master student at FCT-Universidade Nova de Lisboa/ Universidade de Évora and collaborator at Museu da Lourinhã
- João Russo, Master student at FCT-Universidade Nova de Lisboa/ Universidade de Évora and Fellow at FCT-UNL and collaborator at Museu da Lourinhã

Marco Marzola, Fellow at FCT-Universidade Nova de Lisboa and collaborator at Museu da Lourinhã



Fig. 5: Scientific team of 2013 field season, from left to right: Mustapha Nami, Fethi Amani, João Marinheiro, João Russo, Marco Marzola, and Octávio Mateus. Note the two elephant tusks at the feet of the researchers.

The field work began in the 19th of September and they continued to until the 26th. The work was made not only in the Anchrif dig site but there was also prospection work in the surrounding area. In Anchrif a number of new proboscidean elements were collected including a partial skull, two tusks, limb bones and several ribs. Besides the previously mentioned material an artiodactyl astragalus, turtle shells fragments and more acheulean bifaces, including one in situ in the same layer as the fossil bones. The in situ biface not only provided a mean to date the layers of Anchrif, but it gave a new importance to the site, giving an archeological context to locality besides the paleontological one.

The prospection work provided the find of a previously undocumented cave near Taghrout with a relatively large amount of bones from various mammals, reptiles and birds, with some species belonging to species nowadays extinct in Morocco, like the genus *Syncerus*. Some Mesozoic localities previously mentioned in Lapparent (1955) were revisited and they provided a new footprint locality for the region as well as some bones, probably from a crocodylomorph. During the digs some sediment, tusk and bone samples were taken for future chemical and microscopical analysis in Portugal.

In September the project became officially a national project with the name Atlas Mémoire.



Fig. 6: Way of transportation from the village to the fossil site. Mule used in the September digs carrying an electric generator during the packing of the equipment at the end expedition.

The order of work during the digs was as follows:

September 18th: Arrival of the Portuguese team at Morocco and arrival of the Moroccan team at Taghrout. Purchase of light equipment in Rabat (brushes, buckets, batteries, gloves, hammers, chisels, rope and plastic wrap). Transfer of heavy equipment to the dig locality (electric generator, diesel, jerry cans, digging equipment from INSAP) and mounting of the tent of the main camp.

September 19th: Arrival of the Portuguese team at the dig site. Preliminary stratigraphical work and start of the dig in the main site, in the Southeastern area of the valley. The digs in the main site would continue until the final day of the expedition. Visit to a cave ("Taghrout" cave) near the dig site. Collection of bones of several species of reptilian, avian and mammalian fauna from that site.

September 20th: Continuation of stratigraphical work. Elaboration of a simplified stratigraphic column. Digging work in the two tusks in the main site and the ilium, also in the main site. Departure from the dig site one hour earlier due to the threat of a rain storm in a region.

September 21st: Start of the dig at the site of ANCH008. Departure from the dig site earlier once more due to a storm nearby. Visit by the Portuguese team to the outskirts of Skoura. The visit provided no fossils.

September 22nd: Visit to the locality of El Mers by Professor Octávio Mateus, Doctor Mustapha Nami and João Russo. The prospection work from the trip produced a new footprint locality and bones from a crocodilian, left uncollected.

September 23rd: Continuation of dig work in all sites in Anchrif.

September 24th: Continuation of dig work in all sites in Anchrif. Identification of the majority

of bones found in the cave of Anchrif.

September 25th: Continuation of dig work in all sites in Anchrif. Collection of gastropod specimens, recent and fossil in Anchrif for the comparison of species and environment of the different ages.

September 26th: Collection of rock, bone and tusk samples for posterior chemical analysis. Closing of the dig site. Several bones remain in the site and were reburied for protection until new digs: ANCH005/029, ANCH009 and at least two not yet numbered more bones in the main dig site.

The team of the September digs was lodged in the house of locals in Taghrout for the entire time of the digs which also provided assistance during the excavations. Travel to the dig site was made by foot on the gravel path that goes from the village to Anchrif. The digging material and the specimens had to be transported by donkey and mules (Fig. 5) because the path was too hard to transverse with a motorized vehicle.

The large blocks had to be taken by hand with the help of several people to the campsite, where they were stored until the beasts of burden could carry them to the village.

The list of material collected in the Taghrout digs and respective numbering were as follows:

ANCH001: skull	ANCH021: proximal end of a femur
ANCH002: tusk 1	ANCH022: bone epiphysis?
ANCH003: tusk 2	ANCH023: unidentified bone
ANCH004: ilium	ANCH024: rib
ANCH005: scapula	ANCH025: rib
ANCH006: femur	ANCH026: float bone in valley under
ANCH007: unidentified bone	ANCH001
ANCH008: ulna?	ANCH027: unidentified bone
ANCH009: ilium	ANCH028: unidentified bone
ANCH010: molar	ANCH029: scapula
ANCH011: rib	ANCH030: ilium
ANCH012: rib 240	ANCH031: rib
ANCH013: tusk 350	ANCH032: rib
ANCH014: rib (246)	ANCH033: rib
ANCH015: cervical vertebra (349)	ANCH034: artiodactyl tooth
ANCH016: unidentified bone	ANCH035: diaphysis (artiodactyl?)
ANCH017: unidentified bone	ANCH036: rib
ANCH018: tarsal?	ANCH037: rib over ANCH008
ANCH019: phalanx	ANCH038: Turtle nuchal (float)
ANCH020: unidentified bone	

At the time this work was finished most of the fossils remain in Morocco, in the University of Rabat. Partial results were published in Marinheiro et. al 2014.

Proboscids of Morocco and Northern Africa

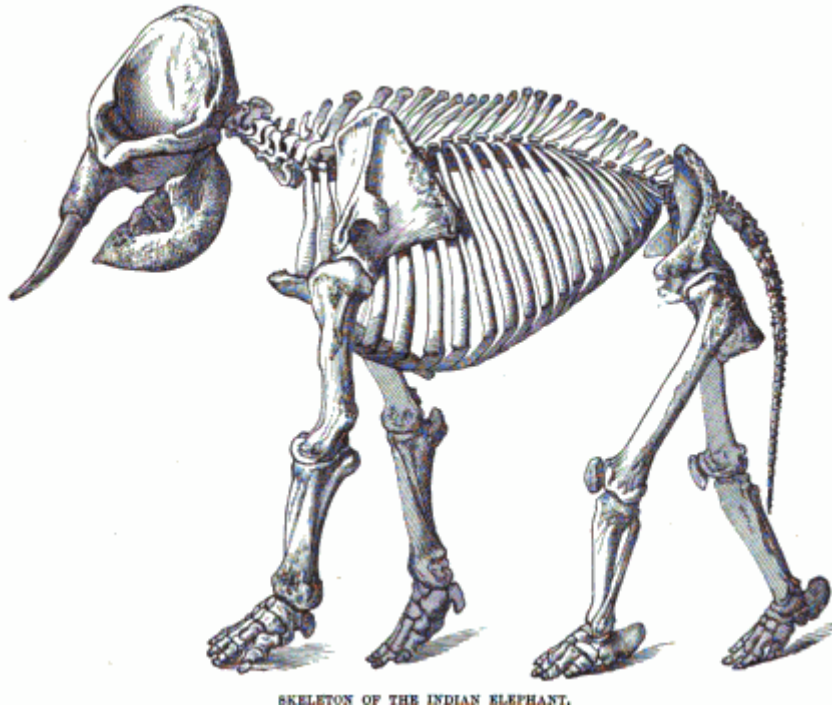


Fig. 7: *Elephas maximus*: skeleton drawing from Lydekker (1894).

Living proboscideans are restricted to two genera: *Loxodonta* (the african elephant) and *Elephas* (the asian elephant (Fig. 6)). The Proboscidea were however much more diverse in the past (Roth, 1992; Todd, 2010). The clade is one of the oldest of placental mammals and its origins can be traced to Africa with the oldest remains being found in the Upper Paleocene, from Sidi Chennane, in Morocco, belonging to *Eritherium azzouorum* (Gheerbrant, 2002; 2009; Alberdi et al., 2011). The following evolution was fast and resulted in a vast diversity of the members of the clade (Roth, 1992). There were three main peaks in proboscidean diversity: the first in the late Oligocene/ early Miocene, the second in the middle of the Miocene and a last one in the Pliocene (Todd, 2006).

The most diverse group of the descendants of these first proboscideans were the gomphotheroids. Members of this group had similar dental structures with the exception of a few cases, with more brachyodont teeth than the more derived clades and generally large tusks in the dentals (lower tusks) as well as the usual upper tusks known in recent species. From this clade other lineages descended like the Mammutidae (mastodons and stegodons) and the Elephantidae (elephants and mammoths). With the emergence of the elephantid clade gomphotheriid diversity declined and long jawed gomphotheres eventually went extinct. Derived short jawed gomphotheriids survived in Africa, including Morocco until the end of the Pliocene in the form of the monospecific subfamily Anancidae (Maglio, 1973; Sanders, 2010), represented by genus *Anancus* (Geraads, 2001). It was a fairly widespread genus with at least four species that ranged in Europe from France to Turkey and southern Russia to Italy (Mayda et al. 2014) and in Africa from Tunisia to Morocco (Arambourg, 1979; Sanders, 2010).

After a period of diversification in the Miocene the proboscideans experienced the greatest peak in diversity during the Pliocene (Todd, 2006) when the fossil record is represented by the Anancidae, Stegodontidae and Elephantidae. The stegodons were likely a group of forest dwelling browsers with several convergences with elephantids, including the anteroposteriorly compressed skull. Their molars are also homoplastic with modern elephants

with plaque-like lophs. The “plaques” were apparently constituted by many enamel cones with bilateral compression. They went extinct by the Late Pleistocene probably due to competition against ungulates with higher hypsodonty, and consequently more efficient dentition (Sanders, 2010).

It was the more derived clade Elephantidae that contributed the most for the increase of proboscidean diversity (Todd, 2006), with the genera *Loxodonta* (that comprises the modern African Elephant), *Elephas* (including the modern Asian Elephant) and *Mammuthus* (mammoths). The members of this group are the proboscideans with the highest rate of hypsodonty and the more derived lost all traces of the lower tusks that were present in their ancestors. The genus *Mammuthus* appeared by the end of the Miocene (5,6 Ma ago) with the first species *Mammuthus subplanifrons* from Africa (Maglio, 1973; Todd, 2006; Werdelin & Sanders, 2010). Another african mammoth taxa is the more recent *Mammuthus africanavus*, with a time range of 3,5 to 1,88 Ma ago (Todd, 2006). Mammoths then spread to the Eurasia and eventually America becoming a successful group in these two continents, although they became extinct in their place of origin. The last mammoths of Africa belong to *Mammuthus meridionalis* in the North of the continent in the Early Pleistocene (Werdelin & Sanders, 2010). In contrast more derived species like *Mammuthus primigenius* survived until the end of the Pleistocene with a relict population living until the middle Holocene in the remote Wrangel island, of the coast of Siberia (Lister & Bahn, 2007).

Both genera of living elephants also trace their origins to the African continent. The genus *Loxodonta*, the most basal genus, first appeared in the fossil record in the late Miocene. The first species, *L. cookei* comes from southern and eastern Africa, with the oldest specimen being discovered in Kenya (Werdelin & Sanders, 2010). *Loxodonta* presently has two forms, *Loxodonta africana* and *Loxodonta cyclotis*. Although both forms are regarded as subspecies of *L. africana* by some authors (Todd, 2010), molecular phylogenetic analysis strongly points to two distinct species (Debruyne, 2003; Rohland et al., 2010; Nishihara, 2011). Recently *Loxodonta* is restricted to subsaharian Africa, although its former range extended to North Africa until the 7th century (Lee & Graham, 2006).

The genus *Elephas* is the more derived of the two extant genera, being a sister clade to *Mammuthus*. It traces its origins to Eastern Africa in the Early Pliocene with the species *E. ekorensis* (Sanders et. al, 2010). Posterior migrations brought the genus to the rest of Africa, Asia and Europe (Maglio, 1973) where it expanded as far away as Portugal (Cardoso, 1993; Antunes & Cardoso, 2009). *Elephas* presents dental morphology and enamel characteristics that make them more suited to graze on abrasive plant material of the grasslands than their *Loxodonta* counterparts. The genus *Loxodonta* is rare in the fossil record and is characterized as having low genetic diversity, with the forest elephants having the higher degree of diversity. Having this data in account it seems reasonable to believe that African elephants became widespread in the continent after the genus *Elephas* became extinct there. The mainly forest elephants then occupied the grassland habitat previously occupied by *Elephas* (Haradan, 2010; Werdelin & Sanders, 2010). One of the reasons for the demise of the *Elephas* genus in Africa may be the environmental changes that occurred at the end of the Middle Pleistocene. The more adaptable feeding habits as a mixed feeder and browser of *Loxodonta* gave it the edge against the presumably grazing *Elephas* (Werdelin & Sanders, 2010).

The genus *Elephas* is today confined to the species *E. maximus* (Todd, 2010). Until a few centuries ago the range of this species extended more westernly than today, with the now extinct *Elephas maximus asurus* reaching Syria. This subspecies disappeared around the 4th century A.D.. To the East the asian elephant reached Northern China as the subspecies *Elephas maximus rubridens* (Yong & Zhong, 1994). The reason for the extinction of both the Syrian Elephant and the North African *Loxodonta* could be hunting by humans for their ivory (Lee & Graham, 2006). Elephants of both extinct forms and living *Elephas maximus* subspecies were also captured alive so that they could be tamed and used as war elephants (Nossov, 2012).

Until the end of the Pleistocene the range of the genus *Elephas* was even greater than in Antiquity, with several extinct species living in the Mediterranean region, both in the coasts of Africa and Europe, as well as in what are today the bigger mediterranean islands, a range that could overlap at least in part that of *Loxodonta* in North Africa since there are different quarries with *Elephas* or *Loxodonta* with roughly the same age in Morocco. In the Late Pleistocene it is the case of the Thomas locality for *Loxodonta atlantica* (Geraads, 2002) and Ahl al Oughlam for *Elephas recki* (Geraads & Metz-Muller, 1998).

Elephas taxa in Morocco include the species *Elephas recki*, a widespread Pleistocene african species that ranged from Eritrea (Navarro et al. 2004) to the Atlantic coast of Morocco. This species is usually separated in several different subspecies representing different stages of evolution of the same lineage. As such they were used for stratigraphical dating purposes. The oldest subspecies of *E. recki* (*E. r. brumpti*) ranged from 3,7 My to 2,8 Mya and the most recent subspecies is *E. recki recki* ranging from 1,2 Mya to 0,5 Mya (Chaix et al., 2000; Todd, 2001). However some of the subspecies seem to overlap in time and the biostratigraphical importance of this subspecies has been questioned by some authors (Todd, 2001). The last element from the genus, *E. iolensis*, ranges in the Late Pleistocene. This species follows the evolutionary trend of *E. recki* of a diminishing thickness of the enamel rings and tightly arranged enamel figures. It has however a lesser number of plaques per teeth than *E. recki* and more strongly folded figure patterns (Werdelin & Sanders, 2010). Similarities between *E. iolensis* and *E. r. recki* are many to the point that they can be easily confused with each other, with the possibility *E. iolensis* is the last member of the *E. recki* evolution line. *E. iolensis* is the last non-*Loxodonta* elephant in the African continent (Todd, 2010; Sanders, 2010).

Quaternary quarries in mountainous terrain seem to be rare in Morocco although there were other localities with *Elephas antiquus* material found in similar altitude, such as in the island of Crete where remains of this species were found at 1000 meters above sea level (Poulakakis et al., 2002).

High altitude elephant populations exist today as well. Several asian elephant populations live above 1000 meters. Particularly in West Kameng, India there is a population known to occasionally ascend to 3100 meters during the Summer, with the purpose of using salt licks available in the area (Choudhury, 1999).

Plio-Pleistocene (Villafranchian) proboscidean remains in Northern Africa include the species in the following localities (as in Arambourg, 1979; Werdelin & Sanders, 2010):

1. *Anancus osiris*: Fouarat, A. Boucherit (Algeria), Ichkeul (Tunisia) and perhaps A. Hanech (Algeria)
2. *Mammuthus africanavus*: Oued Akrech (Morocco), Fouarat (Morocco), A. Boucherit (Algeria), Ichkeul (Tunisia), A. Brimba (Tunisia) and perhaps A. Hanech (Algeria)
3. *Elephas moghrebiensis*: A. Hanech (Algeria), Bel Hacel (Algeria) and perhaps Mansoura (Algeria)
4. *Elephas cf. hyudricus recki*: Salé (Morocco)
5. ?*E. recki shungurensis*: Ahl al Oughlam (Morocco)
6. *E. iolensis*: Sidi Abderrahmane (Algeria) , Beausejour Farm, (Algeria), Port de Mastaganem (Algeria), El Douira, Tunisia

Note that some of the taxa listed above may be subjected to taxonomical changes.

Although being a diverse clade during the Cenozoic proboscideans are a somewhat conservative clade in respect of the postcranial skeleton. The majority of the characters for the identification of the several clades that were searched for in this work are present in the skull or to the teeth, with the molars accumulating most of the characters (Maglio, 1973; Todd, 2010).

One thing worth noting on elephants is that they are some of the few mammals that have more than tooth replacement along their lives. This special replacement is characterized by having the eruption of the different teeth delayed so generally only one or two of the chewing teeth are present at a same time in each dentals or maxillae. Most elephants have a six substitutions of teeth along their lives and more rarely seven (Lister & Banh, 2007). The eruption is also very peculiar in the sense that as opposite of the vertical tooth displacement in other mammals it occurs horizontally, with the new teeth forming behind the older ones and pushing them forward in the direction on the mouth. The teeth keep moving forward while they get worn out and during this process fragments of the teeth like the laminae either fall of through the mouth or are swallowed and excreted (Shoshani, 2002).



Fig. 8: *Loxodonta* palate and upper molars, Dp4 and M1. Note the large medial sinus in the enamel figures, characteristic of this genus. The first teeth have a lower crown than the seconds since they are more worn out. Specimen from the Museu de História Natural da Faculdade de Ciências do Porto.

Geology and paleoenvironment of the Anchrif locality

Geology in the area of Taghrout is characterized mostly by Middle Jurassic formations, more specifically of the Bathonian in age. These sediments, although limited throughout the Middle-Atlas accumulate in depressions of the syncline located around the El-Mers, Skoura and Marmoucha (Soufiani & Fedan, 2002) (Figs. 9 and 10). These Mesozoic basins formed due to the compression caused by the approximation of Europe and North Africa at the time (Arboleya et al., 2004). The uplift of the mountains themselves happened in the Cenozoic, with the possibility of some of that uplift being post- Miocene (Babault et al., 2008).

The basin of Anchrif was previously undetected by geological studies and it is not present in geological charts until the present date. The main reason for this seems to be the very area in which the deposits are distributed, around 50.000 square meters in a relatively remote area. The outcrops are located in a valley west of a bent in the river that passes just South of Taghrout. This valley is around 20 meters higher than the current level of the above mentioned river.

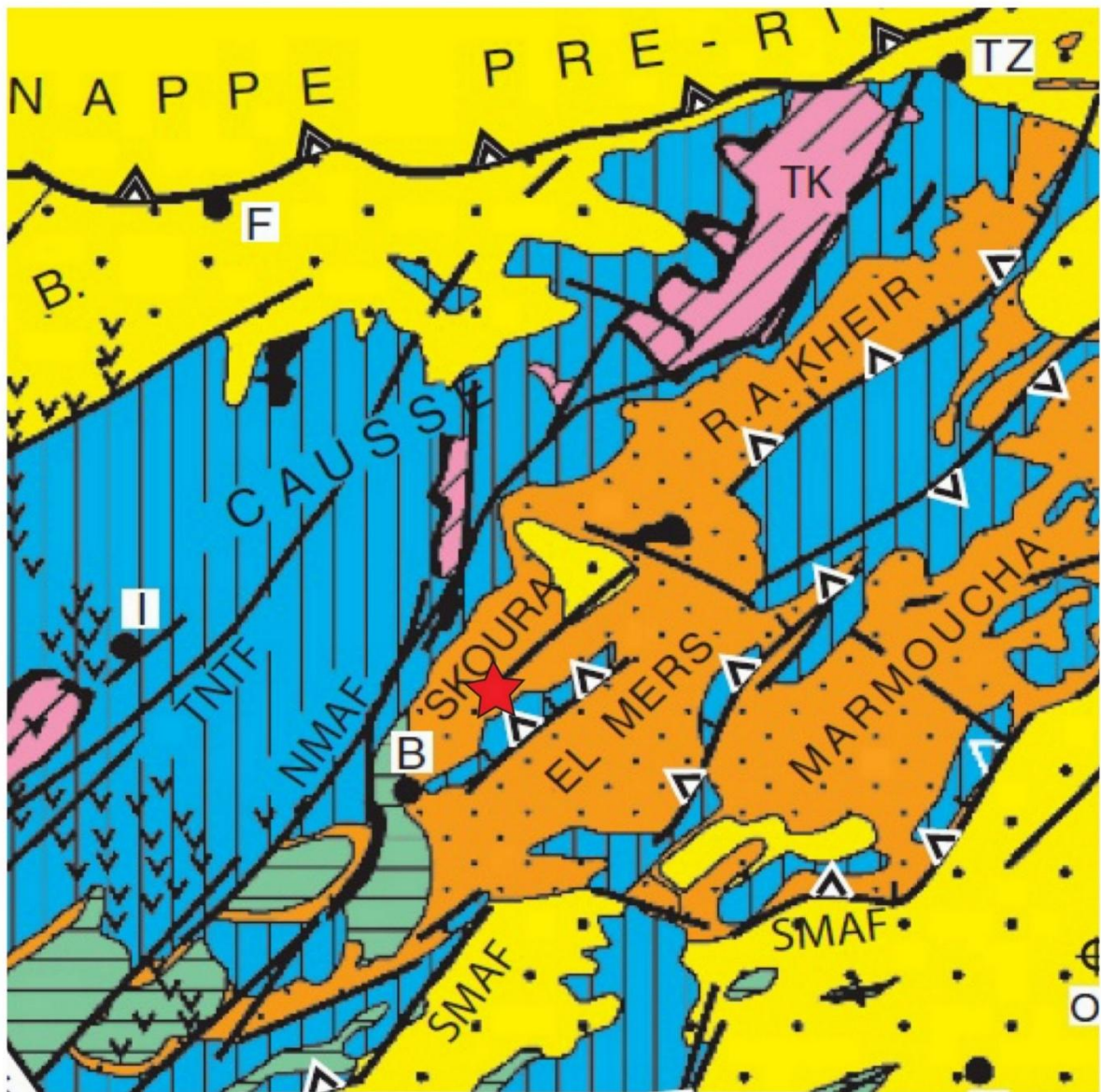
The Cenozoic sediments were deposited in the bottom of a paleolake whose dimensions should correspond roughly to the size of the valley that we have today (Figs. 11 and 12). The base of the formation is a detritic rock, a ferruginous conglomerate. The conglomerate is poorly sorted and most of the grains can be classified as fine gravel (not exceeding 3 cm in size). Heavy and short duration rains are common nowadays in Taghrout and the bottom of the Anchrif valley is often temporarily flooded during some of these events, as was the case just before the digs of September 2013. The water flows downstream and falls down to the main river bed below.

On top of the conglomeratic layer soft carbonated sediments are found. The limestone layers have several hard concretions made by concentric layers of carbonates. These concretions are mostly tube like in shape and many exhibit a empty tube in its center and are more likely rhizoconcretions. It is possible the formation of the carbonated rocks should not be very different than as it is today in a waterfall in the nearby town of Skoura.

In this area the carbonates in the rocks are accumulated by freshwater algae and are deposited with the development of the algae colonies. The constant accumulation of carbonates forms layers of limestone along time and ends up forming the dolomitic structures we can see today near the stream that feeds the water fall. Anchrif concretions could be formed by the accumulation of carbonates using the same method in plant roots, which would explain the tube like shape of these structures and the hollow interior.

The carbonated layers have a dip towards the center of the basin. As such the margins of the lake were at the time the carbonates were forming the top of the formation as steep as they are today.

Even though Anchrif was a new discovery is it possible other undiscovered sedimentary basins with similar characteristics are present in the region.



50 Km

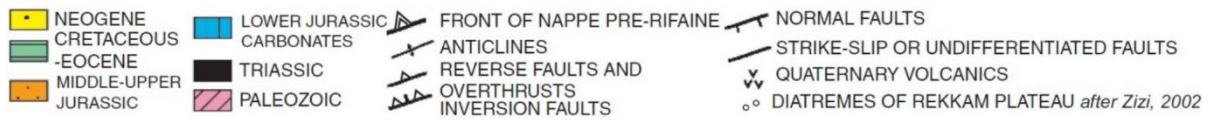


Fig. 9: Tectonic map near the El-Mers syncline. Approximate location of Anchrif Is marked by the red star near Skoura. B is the localization of Boulemane. Orange marks The middle jurassic deposits and blue Lower Jurassic carbonates. In this map the closest Cenozoic locality to Anchrif is the basin located Northeast of the A in "Skoura". Modified after De Lamotte et al., 2008.

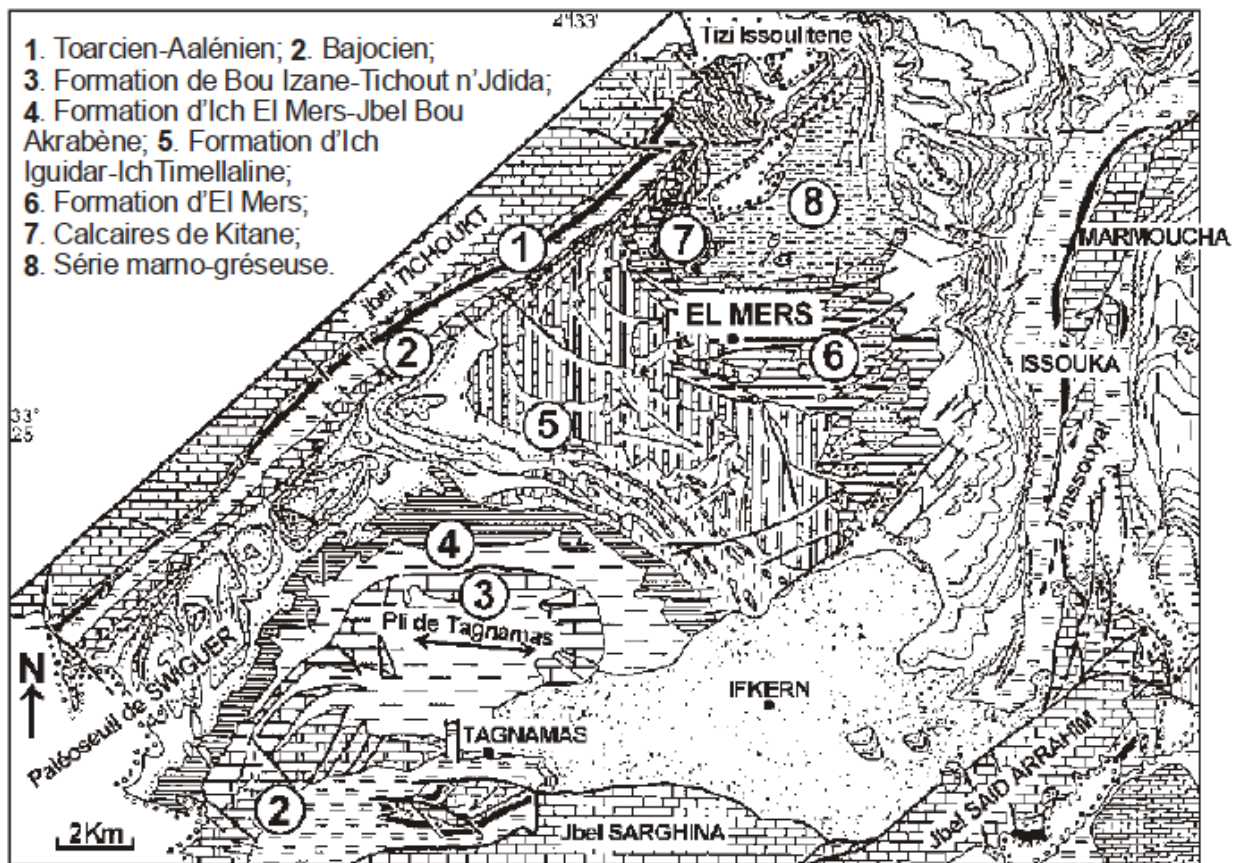


Fig. 10: Simplified geological chart of the El mers region. After Soufiani & Fedan, 2002.



Fig. 11: General view of the Anchrif dig site as seen looking North to South. The whitish beds on the cliffside correspond to the visible Pleistocene layers (between the two arrows).

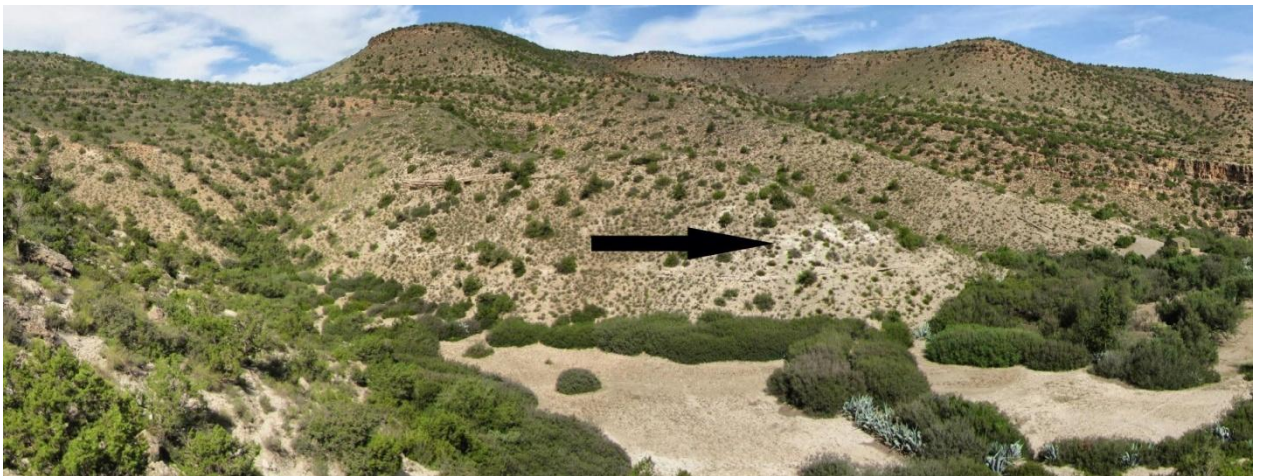


Fig. 12: View from South to North of the Anchrif locality. Located roughly halfway in the layers above the small floodplain was a very fragmented elephant tusk, which rough location is marked by the arrow.

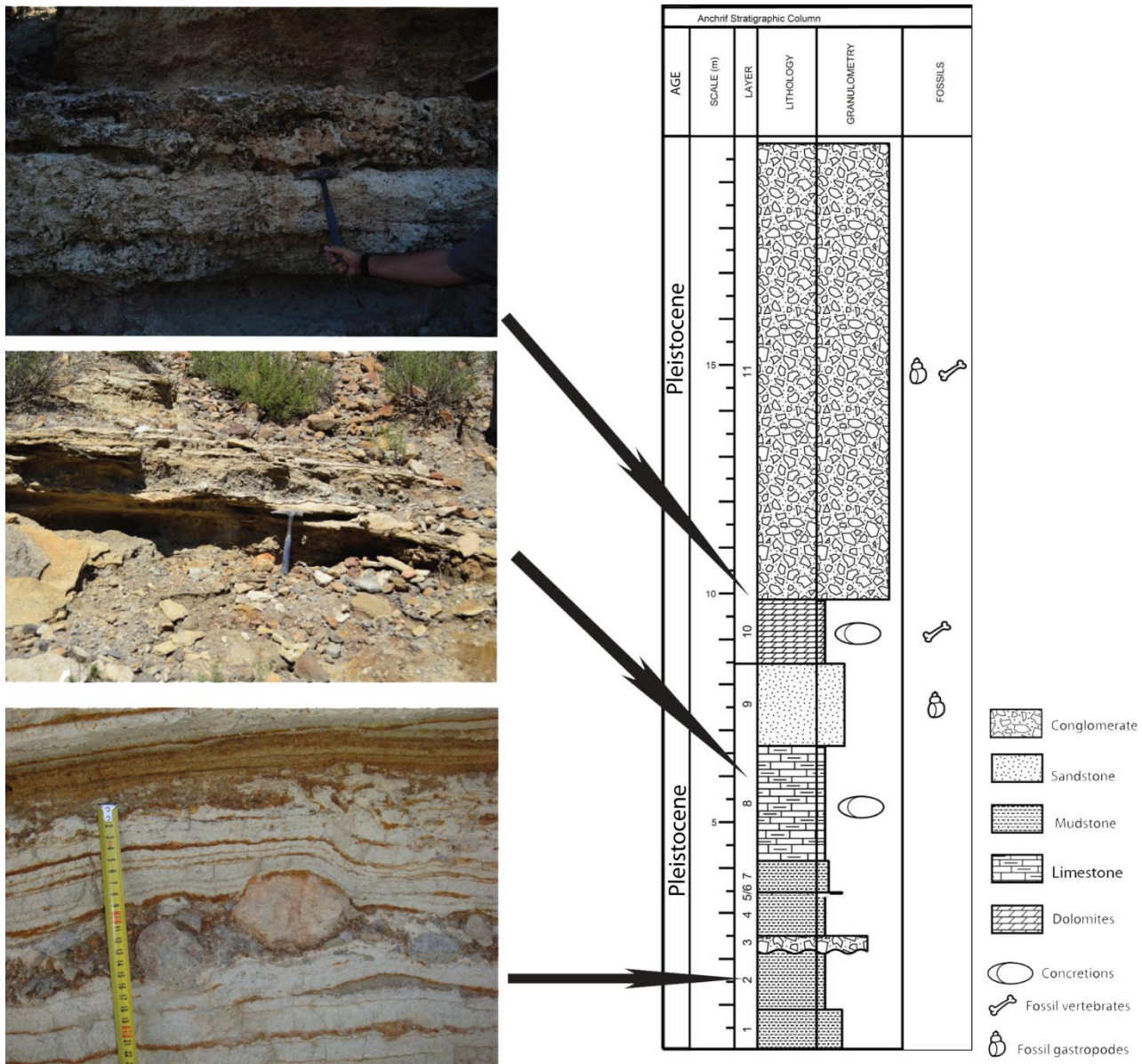


Fig. 13: Stratigraphical column of Anchrif. Field photos on the left from top to bottom: layers 10, 8 and 2. The entire sequence pictured is Pleistocene.

The Pleistocene layers succession were measured in the south flank of the valley roughly at GPS coordinates N33° 28.836' W4° 37.255' from bottom to top (see Fig.12). The following stratigraphical log results from field description and granulometry tests were not performed, therefore the use of terms and mud and siltstone referred here consists in *sensu lato* detrital fine pelite.

Layer 1: 0.9 m; Mudstone, coarser at the base with four sandstone intercalation laminae (0,5-2 cm). One unsorted conglomerate intercalation with slightly angular clasts up to 4 cm. Yellowish-grayish coloration.

Layer 2: 1,30 m; mudstone with more than 13 intercalations of finely grained sandstone. Gradual change at the base and erosional at the top. Gray to yellow.

Layer3: 0,30 m. Coarse conglomerate up to 20 cm unsorted and slightly angular clasts. Finer towards the top. Gray coloration.

- Layer 4: 0,9 m: Mudstone with non-laminated sandstone intercalations. Gradual transitions (except when bordered by thin iron concretions). The sandstone laminae coarsens towards the base. Occasional clasts in the mudstone up to 5 cm.
- Layer 5: 1 m: Marly mudstone, with two fine sandstone intercalations at the base. More than ten ferruginous intercalations with varying thickness (0,1-3,0 cm), parallel lamination. Three one meter lenses of unsorted conglomerate (clasts up to 2 cm) that prograde laterally into mudstone. The layer ends at an unconformity.
- Layer 6: 0,04 m. Laminated sandstone, reddish , from bright rust to grey.
- Layer 7: 0,7 m. Marly mudstone with up to five ferruginous laminations (0,1 to 0,5 cm) in the lower half. Intercalation of conglomerate lenses and laminae of very fine sandstone (up to three).
- Layer 8: 2,5 m: Siltstone with carbonate laminae (up to 5 cm) intercalations. Bioturbations at the base of the carbonate laminae (siltstone/carbonate interface). Light gray coloration.
- Layer 9: 1,8 m. Marly sandstone with pulmonata gastropod shells. Some lamination. Coarsening upward. The top is irregular. The top is irregular due to the presence carbonate concretions. Yellowish gray coloration.
- Layer 10: 1,8 m. Carbonate layer dominated by rhizoconcretions (up to 20 cm). Elephant bones in the entire layer. Occasional snail shells.
- Layer 11: 10 m: Conglomerate with fine sandy matrix and intercalations of sandstone and siltstone. Unsorted with clasts up to 30 cm. Pulmonata shells and elephant bones. Erosive surface at the top. Gray coloration.

We are not aware of any published geological map that includes Anchrif quaternary layers. The figure in the following page is a proposed geological map for the area (Fig. 15). The map was made with information taken from the field work and available satellite imagery (Google Maps).



Fig. 14: Bioturbation at the base of layer 8 in Anchrif.

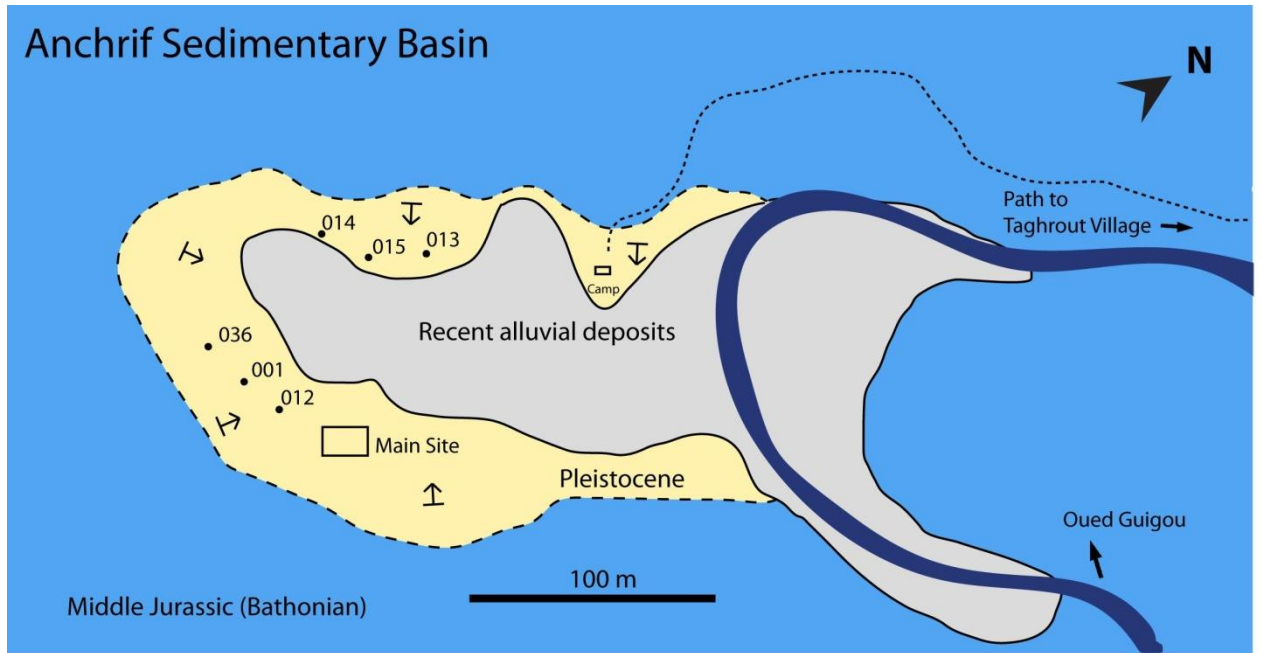


Fig. 15: Geological map of the Anchrif Basin proposed in this work. Numbers indicate locations of the areas where bones were found outside the main site. The strike and dip of the layers was observed in the field but the angles of dip were not recorded. The squared area corresponds to the main quarry, whose field map is present in this work as Supplement A.

Paleoenvironment

The faunal and flora association in the Anchrif locality indicates a climate very similar to the one currently found in the same location. The Pleistocene land gastropod faunal assemblage is remarkably close to the one we have today at Taghrout and the surrounding region. The tree *Celtis australis*, from which seeds are present in the site is a tree adapted to Mediterranean climates (Garfi, 2000).

The presence of *Elephas* also correlates with a grassland environment instead of a forested habitat. The resistance of the teeth given by the relatively thin enamel and tooth morphology of *Elephas recki* are consistent to an adaptation to a diet that includes abrasive items like grasses than the more forest adapted *Loxodonta* (Haradon, 2010; Juan et al., 2006).

This environment was most likely not very different from the nowadays landscape of the Skoura-Boulemane region. The vegetation is Mediterranean in assemblage with an abundance of shrubland and sparse cedar forests in the steep slopes of the hills and mountains in the Skoura-Boulemane valley. Olive trees are also common around the Oued Guigou and along the road from Skoura to Boulemane.

Methodology

Since the bones from Anchrif remain in the plaster jackets detailed description could not be conducted because the fossils never arrived to labs in Portugal as originally planned. Field notes, photographs and observations could be used to provide a preliminary description and identification. Some of the bones described here had to be left in the site for posterior collecting. For example, in the site of ANCH008 there were large unidentified and uncollected bones in close association with ulna, the only found in articulation.

The identification and comparisons of proboscidean bones were mainly made using Todd, 2010, Werdelin & Sanders, 2010 and University of Michigan Online Repository of Fossils (<https://umorf.ummp.lsa.umich.edu/wp>). Some of the pictures present in the description chapter are field photos since the material was not prepared.

The same challenges of the analysis of the Anchrif material can be applied to the cave material. The mammal material was left in Morocco and since it was not in the original purpose of the project detailed measurements were not taken in the field season. The photos and the anatomical information taken during that time however provided enough information for the identification of many remains at least to the generic level. For this identification the guide about teeth by Hillson, 2005 and Schmid, 1972 were used for the identification of the dental material. The guides used for the remaining bone material were Hilson, 1992 and Walker, 1985, the latter about fauna from East Africa. Since the difference between the genera *Capra* and *Ovis* is hard to make a more specific method was require besides the usual guides and the method used for this work was the same in Zeder & Pilaar, 2010. For the *Capra* material the Deniz-Payne method of determining age in goats was used. This method is based on the mount of tooth wear that the molars suffer depending on the age and the different shapes that the enamel and cementum take in occlusal view depending on that wear state (Davis, 1987).

Bone and tusk samples were analyzed using an Optical Microscope, Scanning Electronic Microscope and Fourier Transform Infrared Spectroscopy Microscope. The first two were used to make detailed images of the thin sections from the samples and enable the identification of different histological details in the material. The latter was used to see if it was possible to differentiate different types of ivory based on molecular structure spectra. The Schreger Pattern angles were measured in the ivory to help determinate the genus.

For the excavation the material was excavated at first with shovels and hoes and as the digging went closer to the bones, with chisels and hammers. The smaller fossils were covered in plastic film and the bigger specimens using a jacket of plaster and burlap. Before the plastering the bones were protected by a layer of wet paper so that the plaster would not glue to the bones to facilitate the posterior lab preparation. The method of excavation in Anchrif followed general paleontological excavation procedures (Araújo et al. 2009) and is used on a regular basis. A squared grid of 1:1 m cells was made for mapping the main quarry site.

Photographs were also taken for photogrammetry using the software Agisoft.

Elephantini and artiodactyla from Anchrif

Systematics paleontology

Mammalia, Linnaeus 1758

Proboscidea, Illiger 1811

Elephantidae, Gray 1821

Elephas, Linnaeus 1758

Elephas recki Dietrich 1915

Material described in this work: Three tusks (incisors), upper molar, C6 cervical vertebra, ribs, right scapula, ulna and radius from an undetermined side, right ilium, right femur, tarsal and phalanx.

Amended diagnosis for *E. recki* (as in Werdelin & Sanders, 2010): “Medium-sized elephant with hypsodont molars that in later forms have finely folded, thin enamel, and a greater number of closely spaced plates than in *Loxodonta*. Unlike *Mammuthus*, tusks are not spirally twisted, and the forehead is demarcated from the temporal fossae by sharp, acute ridges. Frontoparietal surface more vertical than in *E. ekorensis*”.

Holotype of *E. recki*: IPUB XVII 1382, housed in Humboldt Universität, Berlin.

Occurrences: Throughout North and East Africa, from Morocco to Tanzania, with some rare occurrences in central and southern Africa.

Age and Horizon: Villafranchian. The age of the lithic industry with the amygdaloid acheulean bifaces found *in situ* in the uppermost bone layer is Middle Pleistocene, 0,781 to 0,126 Mya (Aguirre, 2006). The age span of *E. recki* is referenced from 1,64 to 0,40 Ma (Sanders et. al. 2010).

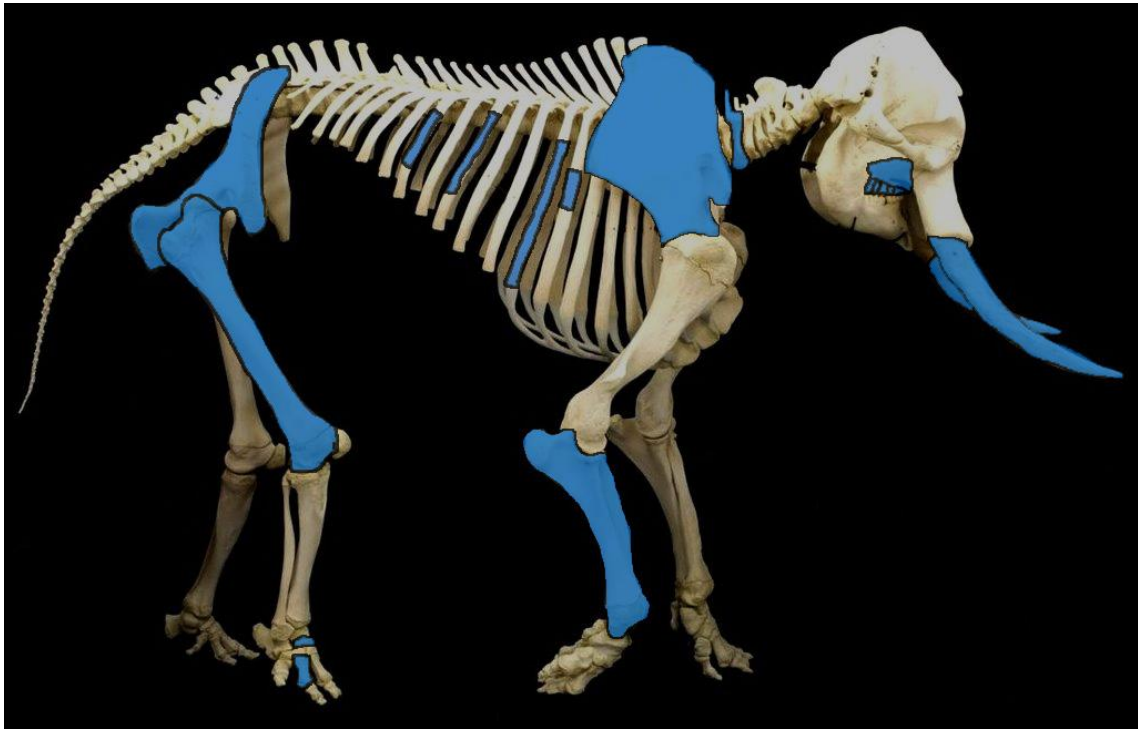


Fig. 16: Skeleton elements from Anchrif. Discovered bones in blue. This image does not represent an single individual but is a compilation of bones from all the specimens found in the locality. Adapted from image by Skulls Unlimited International available at Wikipedia.org under Creative Commons licence.

Description

The material present in Anchrif indicates at least 3 specimens if we take in account the number of bones. The localization of the findings suggests that around 5 specimens may be present. Maps of the findings are present in Fig. 14 and appendixes A and B. Most of the material was found in the main quarry, the only place in Anchrif so far with a considerable amount of associated bones. The rib ANCH012, the skull ANCH001 and the possible ulna ANCH008 were found in other sites. Here follows the description of osteological material of Elephantini from Anchrif collected until the end of 2013.

Skull

The partial skull ANCH001 (Fig. 17) was collected in 2013 and it is still in a field jacket in Rabat and not prepared so the description was made based on field notes and photographs. It was found associated with an atlas. The skull is a 26,5 cm long fragment of the ventral side of the skull, consisting of the maxillae and molars.

Some thin and flat bones were found in the main site, close to the tusks ANCH002 and ANCH003 that could belong to a second skull, possibly the one bearing the tusks. Those bones were not dug out as of yet.



Fig. 17: *Elephas recki* partial skull ANCH001 from Tahgrout, Morocco, with maxillary and molar, in lateral view shortly before collecting.

Tusks (incisors)

The digs of September 2013 unearthed two tusks (Fig. 18 and 19), ANCH002, the most complete one 1,49 m long and 14,5 cm of width in the most basal part and the other, ANCH003 consisting a fragment 88 cm long. The width of the smallest fragment could not be measured due to the amount of sediment in the extremities before the specimen was plastered. ANCH002 presented the hollow cavity for the pulp in its most basal extremity. They were found centimeters away from each other and due to the similar size may and proximity they seemingly belong to the same animal.

The tusks were mostly undamaged but the posterior parts of both were covered in plant roots growth that weakened the structure of the specimens. The tusks are untwisted, laterally straight, curving slightly upwards and have a slightly ellipsoid section.

In adding to ANCH002 and ANCH003, there is an uncatalogued tusk of a juvenile (Fig. 20) previously collected before 2013 and now in Rabat. Numerous fragmentary pieces of ivory from an adult's tusk (ANCH013) were also found in the northern side of the Anchrif basin and were the origin of the samples used for the microscopical analysis.



Fig. 18: *In situ* Elephantid *Elephas recki* tusks ANCH003 (upper) and ANCH002 (lower) in lateral view from Anchrif, Morocco. A rib can be seen in the lower part of the picture associated with the ANCH002.



Fig. 19: Tusk section ANCH002 of *Elephas recki* from Anchrif, Morocco.



Fig. 20: Tusk of juvenile elephant, *Elephas recki* from Anchrif, Morocco, in anterior, lateral, and posterior

views.

The tusks are easy to recognize in the field, thus the number of tusks in the site allow establishing the minimum number of animals. These sediments bear at least three individuals: two adults and one juvenile.

Premolar and molar

There are at least two teeth in the Anchrif material. The first one was collected in March 2013 (Fig. 21) and the other belongs to skull ANCH001. The premolar from ANCH001 requires preparation for a detailed analysis so only the molar collected in March will be the one described in more detail this work.

The molar of ANCH001 is 17,5 cm long and in lateral view has at least 10 rectangular shaped laminae. This number of laminae is consistent with a M2.

The molar enamel is thin (less than 2 mm) and does not present a median sinus or fold so that the median edges of the enamel figures are not in direct contact but the posteriormost three enamel figures are very tightly spaced, almost touching along their anterior and posterior edges. It does not have apical (rounded) digitations. The enamel figures are symmetrical and parallel sided, with almost no folding. The enamel folds that do exist are spaced very tightly towards one another. The direction of the lateral sides of the enamel is even. The first enamel figure is oval and the following figures turn progressively more rectangular. The accessory conules (small circular enamel figures) are absent and seem absorbed by the enamel plaques.

The tooth has 6 clear enamel figures. That number of laminae is consistent with the upper premolar DP4 in *E. recki* as in Werdelin & Sanders, 2010.



Fig. 21: Elephantid *Elephas recki* tooth DP4 in apical view from Anchrif, Morocco *in situ*.

Cervical vertebra

The material dug out includes vertebra ANCH015 (Fig. 22). The element is constituted mostly by a centrum 15 cm in diameter circular in anterior view. Part of the dorsal part of the transverse processes also present. Part of the dorsal edge of the foramen transversarium is present in the better preserved left transverse process. This foramen indicates that the vertebra

is not cervical number 7 (Bezuidenhout and Seegers, 1996). It is here described as cervical vertebra 6 since the transverse processes are arranged tightly against the centrum, more so than in than in the more posterior vertebra.



Fig. 22: Cervical vertebrae of elephantids in anterior view. Left: 6th cervical vertebra of *Elephas recki* from Anchrif. Right: Cervical vertebra 7 from *Mammuthus jeffersoni* from the Online repository of fossils from the Museum of Paleontology of the University of Michigan (https://umorf.ummp.lsa.umich.edu/wp/wp-content/3d/viewer.html?name=RIL_C7).

Ribs

Of the ribs found in 2013 most consisted in fragmentary remains and were found in the main site. The most complete element, the dorsal rib ANCH012 (Fig. 23) was discovered outside the main site, near the site of skull ANCH001. This specimen is 70% complete fragment around 80 cm long.



Fig. 23: *Elephas recki* left rib ANCH012 in Anchrif, Morocco.

Scapula

A very fragmented right scapula (ANCH005, Fig. 24) was found in the main site of Anchrif with at least three unarticulated associated ribs. It was left in the field without a significant digging work so only the medial side which was already exposed could be visible to describe. Erosion destroyed most of the bone material but the underside mold was still visible. The collum scapulae and the ventro-posterior part of the scapula were not present in the element. The Facies serrata could not be seen since it was covered by an associated rib. The scapula is triangular in shape. The ossified scapular cartilage is present but not yet fused with the rest of the bone.



Fig. 24: Scapula ANCH005 of *Elephas recki* from the main dig site of Anchrif with several ribs are in association that can be seen in the right side (on top of the scapula), mid-top (also on top of the scapula) and bottom left side of the photo.

Radius

The radius found in Anchrif was found during the preliminary expedition (Fig. 25). It is around 50% complete and is constituted by a distal end of the bone 9 cm wide in the articular margin and 33 cm at its longest length. The bone is relatively thin when compared to the other appendicular bones. The extremity of the bone is wide, with the medial side of the extremity being more projected than the lateral side.



Fig. 25: Proximal end of right radius of the proboscidean *Elephas recki* from Anchrif.

Ulna

A possible ulna articulated with the radius (Fig. 26) was a few meters away from skull ANCH001 and in the site of the element ANCH036. The material was however covered in matrix and no further characters can be taken from the bones until the material is prepared.

It was described as such bones because of their large dimensions and since the material dug out appeared to have two parallel bones.



Fig. 26: *Elephas recki* possible ulna and radius ANCH008 in situ.

Ilium

There was one pelvic specimen dug in September 2013. It was a well preserved right ilium and it was protected by a plaster jacket but not collected due to time constraints (Fig. 27). Only the posterior part of the bone was exposed. The ilium is moon crescent in shape and the upper part of the latero posterior rim of the crista iliaca bears a lip that projects posteriorly.

The ventral most part of the alla ossis ilii, including the tuber coxae, is broken and absent in the specimen. The alla ossis ilii is completely flat with the exception of a bulge in the dorsal-lateral margin that touches the crista iliaca. The middle medial part of the alla ossis ilii curves gently when it gives way to the corpus ossis ilii.

Another element, a right Ilium with acetabulum from an adult specimen (Fig. 29), was found in the March preliminary visit. It was reburied and was not recovered during the September excavations. As such only a few photos of the specimen are available at the time.



Fig. 27: Right Ilium ANCH004 in posterior view.



Fig. 28: *Loxodonta africana* pelvis in anterior view. From the mounted specimen of the Museu de História Natural do Porto.



Fig. 29: *Elephas recki* right Ilium with acetabulum as found in the 2013 preliminary visit.

Femur

There were two femura present in the main Anchrif site. The first one was very fragment because of exposure to the environmental conditions and plant roots and it was possibly articulated with a pelvis, also very fragmented. Due to the heavy degradation of the material and time constraints the femur was buried and left in the field for a posterior excavation.

The second femur, ANCH006 (Fig. 30) was better preserved and dug out in two pieces consisting on the distal and proximal parts of the bone. It had light degradation on the femoral head and good preservation on the distal part.

The femur was 79 cm in length with a femoral head 16 cm long. The outer condyle and the inner condyle were 8,7 cm and 11 cm wide in their widest area respectively. The widest part of the distal extremity of the femur was 24 cm wide. No further measurements were made due to the presence of sediment and carbonated layers around the bone that require laboratorial preparation to be removed.



Fig. 30: *Elephas recki* distal part of the Anchrif elephant right femur ANCH006 in postero proximal view.

Microscopical analysis and Histology

Sediment samples from the limestone layer were studied by x-ray diffraction. The rock samples were crushed with a mortar and pestle until the grain was uniformly about the same granulometry as talcum powder. The consistency was tested by pressing the grain against the tip of the fingers.

Sediment samples from the detritic layer were also crushed. Since this layer was formed by rocks from at least three different sources, the samples were separated in three fractions.

Five thin sections were made, one of the carbonate rock, two from tusk samples and another two from a bone sample. The tusk sections were made in radial and transversal cuts. The samples were taken from the northern part of the Anchrif basin. These elements were found in the ground exposed to the atmosphere and sun in an amalgamation of ivory fragments with the bigger piece not exceeding 3-4 cm. They seemed to belong to the same, very fragmented, tusk.

SEM sample observation

Four tusks samples were observed in Scanning Electronic Microscope of the Hercules lab in the University of Évora, all from longitudinal cuts. Sample 1 was left unpolished during preparation and the samples 2-4 were polished with silicon carbide powder. No sample was metalized prior to observation.

The samples presented at the naked eye several lines and dots made by magnesium precipitation during fossilization.

Chemical analysis was made using the EDS apparatus connected to the SEM. This analytical setting is able to make qualitative and semi-quantitative elemental analysis but the quantification of the chemical elements present is not possible..

The main elements found in the tusks were Manganese, Phosphorous, Calcium, Carbon, Iron, Silicium and Aluminium (not ordered by abundance). The iron is mostly present in small nodules scattered along the surface. The manganese artifacts (Fig. 31) could be related with the fossilization process since the presence of this element in recent ivory is relatively low (Singh et al. 2006). This same principle should apply to aluminium.

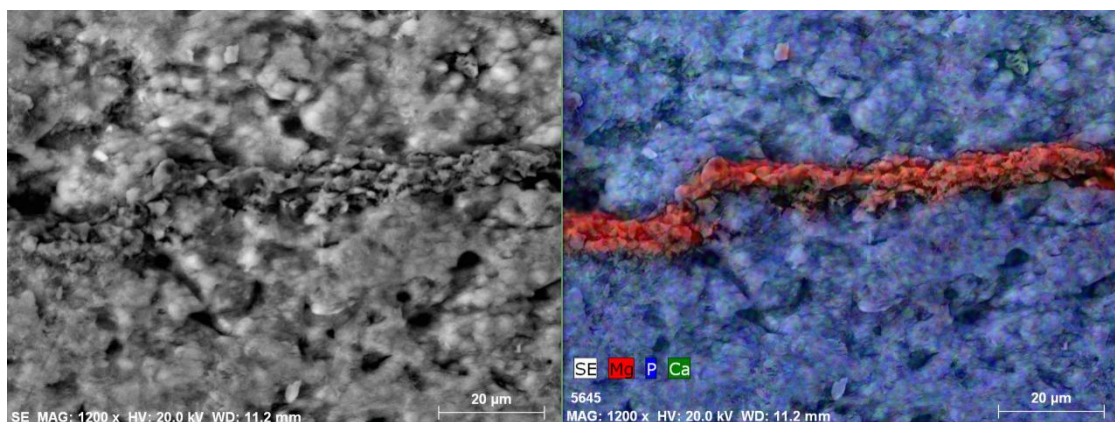


Fig. 31: Manganese linear artifact on tusk sample 4. Left: Raw SEM image. Right: Chemical element map for Manganese, Phosphorous and Calcium.

Detailed observations of ivory morphology are relatively rare in last few decades.

Some of the elements like Calcium and Phosphorous are present in recent ivory, however they are not useful to differentiate different taxa or for other information, since the amounts of the these elements are only marginally different between recent genera (Singh et al. 2006).

Although ivory fragments of different proboscidean species may seem similar at the first glance there are several differences in micromorphology. In transverse view an ivory sample will exhibit series of triangular shaped figures named after Bernhard Schreger, which described these patterns, now known as Schreger Pattern for the first time in 1800. The angles of the triangular shapes can be helpful to distinguish the species of proboscidean which the ivory belong to. According to Espinoza & Mann, 1993 the angles in the genus *Mammuthus* tend to be acute ($<90^\circ$) and modern ivory the angles are more obtuse ($>115^\circ$). Between modern proboscideans the angles are usually $<120^\circ$ in *Elephas* and $>120^\circ$ in *Loxodonta* (Singh et al. 2006). In gomphoterids and mammutids these values have a wide range going from 35 to 115° .

The *Mammuthus* ivory sample (Fig. 32) used for comparison purposes angles measuring $80-90^\circ$. The samples of Anchrif were more difficult to establish the angle due to the worn material and the fact that the most samples were not broken in a perfect transverse section and were too small to make a clean cut with the rock saw available. One of the fragments were it was possible to observe the Schreger Pattern showed a low angle around 110° being consistent with the modern elephant genera, specially the genus *Elephas*.

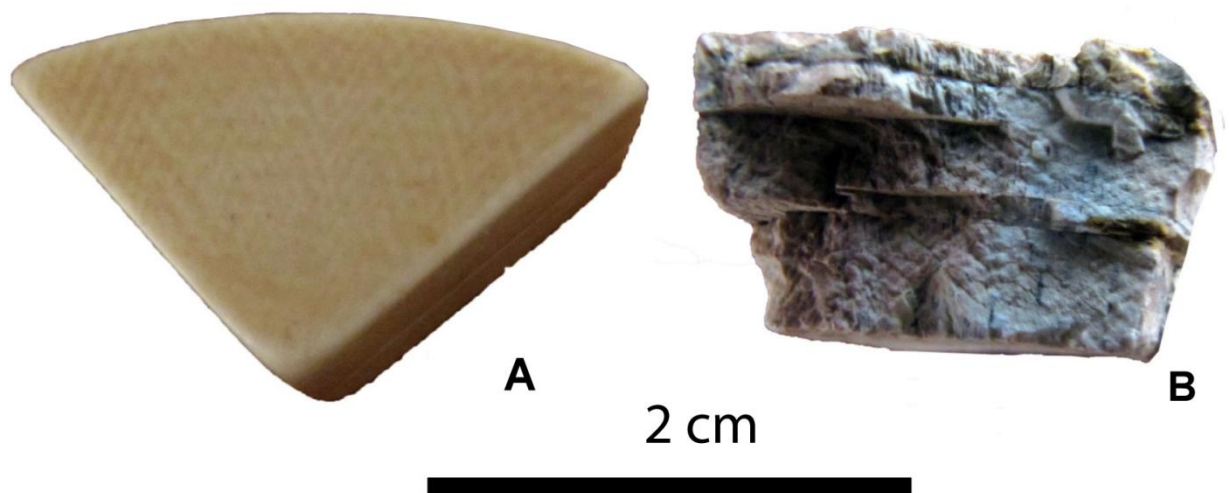


Fig. 32: Elephantid ivory samples. A: *Mammuthus* ivory sample. Note the triangular Schreger Pattern in the surface. B: Anchrif ivory sample. The measurements of Schreger Pattern angles were taken from the bottom area of the sample.

The pore density in radial section is higher in the genus *Mammuthus* than in the genus *Loxodonta* (Espinoza & Mann, 1993). The pores of the Anchrif specimen were easily observed in the scanning electron microscope (Fig. 34). The section was not a perfect radial section because the small size of the original did not permit the exact positioning of the cut during the sample preparation but the stipulation of the pore density can be determinate nevertheless. When it is compared with *Mammuthus* or *Loxodonta* the pore density of the *Elephas* of Anchrif is slightly higher than the *Loxodonta* but lower than *Mammuthus*. This density however changes in the position of the sample, and as it can be observed in Fig. 33 the density in the upper part of the picture is more reduced than in the lower part. This difference can be due to the section including two dentinal tubules that form the Schreger patterns, which would have put the pores in slightly different angles.

Several thin lines are observed in the SEM images going along the pore orientation but these seem to be cracks in the ivory related to the degradation of the material.

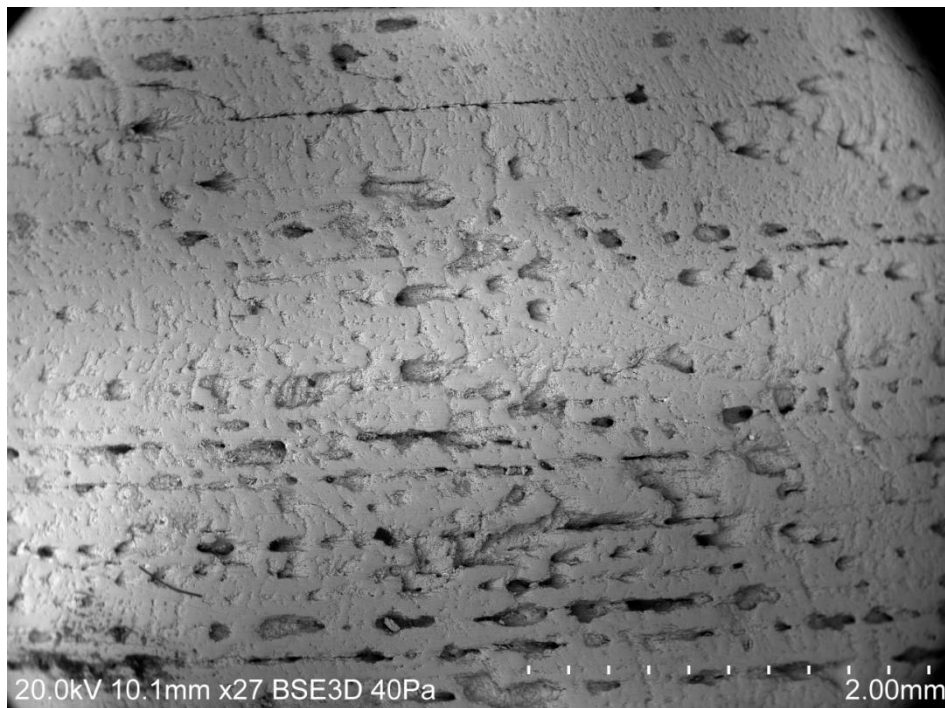


Fig. 33: View of the ivory pores from Sample 2, a radial transverse section.

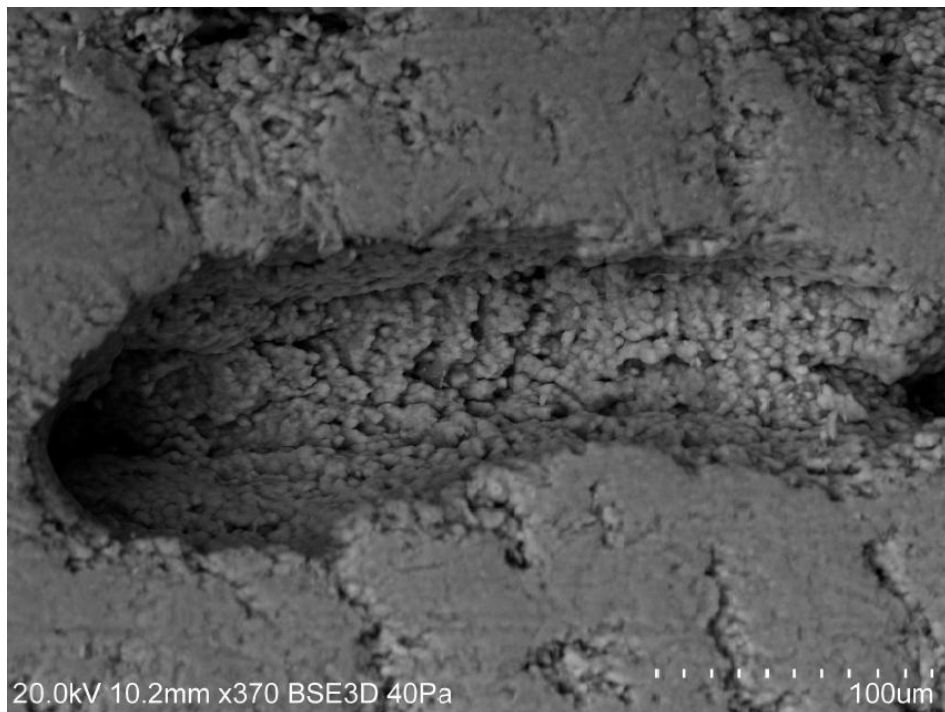


Fig. 34: Closeup of one of the pores from Sample 2. This section shows that the degree of the cut was oblique and not perfectly radial.

In the bone thin sections (Fig. 35) the high porosity with wide Volkmann channels (>0,5 mm), thin periosteum and subsequent lack of pachyostosis, the thickening of the bone that is

prevalent in limb bones, excludes this bone from being a diaphysis of a long bone. The sample presents secondary osteons which indicate that the specimen is an adult or subadult.

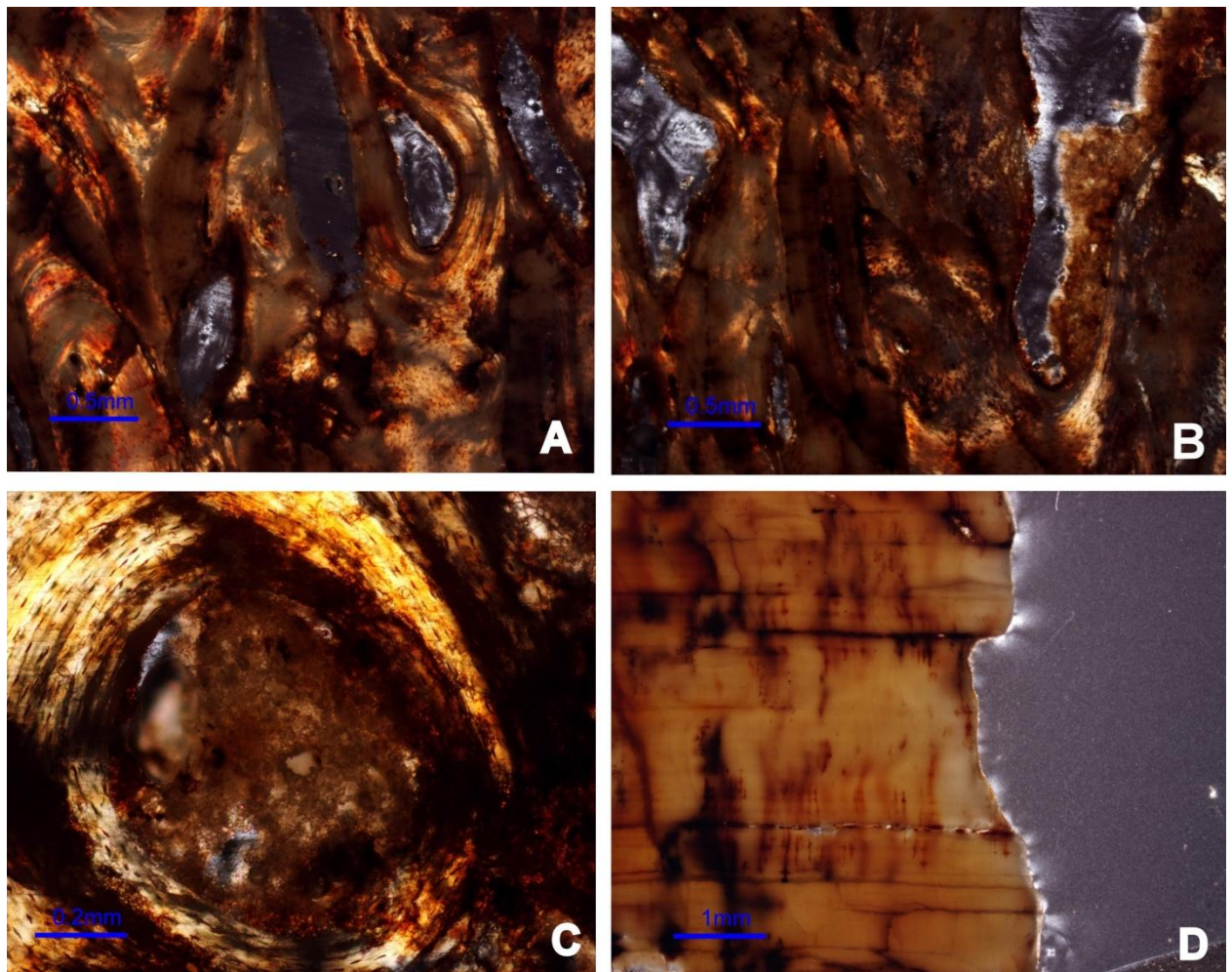


Fig. 35. A-C thin section optical microscope images from Anchrif bone sample taken from the inner part of the bone. A, B: high porosity texture. In figure D on the middle left side of the pictures there is a secondary osteon in sagittal view. C: closeup view of one Volkmann channel. D: Thin section from ivory sample.

On September 2014 ivory samples, from the *Elephas* of Anchrif, modern *Loxodonta africana* and the mammoth *Mammuthus primigenius*, were observed in a analysed by FT-IR (Fourier Transform Infrared Spectroscopy) as a first approach to try to distinguish different ivory samples in terms of molecular composition. This method was previously used by other authors as a mean to distinguish the several types of ivory, including modern *Elephas* and *Loxodonta* and also *Mammuthus* (Banerjee & Dindorf, 2008). The *Loxodonta* sample was taken from a specimen in the Museu de História Natural da Universidade do Porto. The mammoth sample was from a set of hand samples in the GeoCenter Møns Klint museum of Denmark that were used to exemplify Stone Age tool making for children visiting the museum. The exact provenience of the sample is unknown, but most likely the source is Siberia or the Northern Sea, since it was well preserved enough to give a signal for the amida group content in the spectral analysis and the large quantity of mammoth ivory remains that come from that region of the globe for sale.

Three smaller samples, around 50 μm in diameter were removed from the main fragments. Three specters were acquired in each small sample from different points in the piece, making 9 specters for ivory type, plus an extra three specters for the *Elephas* tusk. The

total 12 results were analysed to give an insight on the molecular composition of the remains.

Although the number of samples were not very high, mainly due to the difficulty in acquiring ivory samples the results showed promise in regard to the distinction of the ivory samples from one another, although it should be noted that the samples are from different ages and as such the chemical composition may have differences because of this (Fig. 36). The position of the samples in the tusk also gave distinct results in the amina groups. This could be related with the state of the protein or it's crystalline structure, as well as the amount of phosphates (Miguel, 2014). In the future to confirm the conclusions of this first work the same process should be done with a bigger amount of samples from different individuals and of different ages.

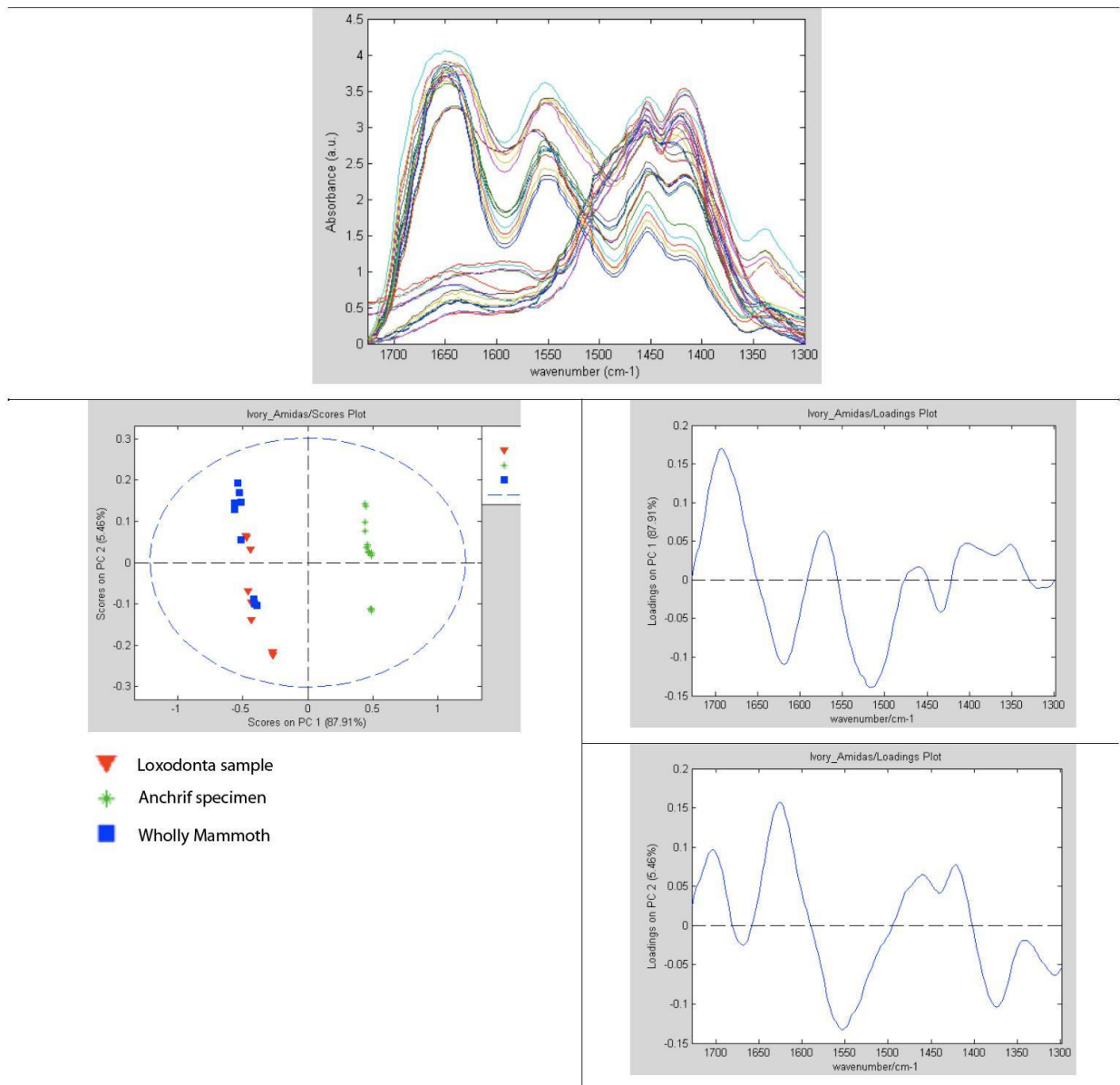


Fig. 36: FT-IR results for the amina group in the 3 studied samples.

Taxonomical identification of the Elephantini specimens of Anchrif

The fact that the material from Anchrif is incomplete and unprepared and belongs to several specimens makes the task of taxonomically classifying the species that the bones belong to more difficult. Some characters can nevertheless help in the classification.

The teeth morphology with molars with enamel figures and lack of lophus indicate the Anchrif proboscidean is a member of the Elephantidae group. The absence of a median sinus or fold in the enamel figures as in the genus *Loxodonta* is generally indicative of the either an elephantid of the genus *Mammuthus* or *Elephas* (Todd, 2010; Sanders, 2010). The Middle Pleistocene age given by the acheulean bifaces makes the presence of *Mammuthus* very unlikely since no remains from this genus are present in Africa in such a late date. The almost straight, untwisted tusks with an obtuse angle Schreger Pattern microstructure also set the Anchrif elephant specimen apart from *Mammuthus*. The tusks do not curve laterally, only slightly upwards, a characteristic shared with *E. recki* (Sanders, 2010).

The genus *Elephas* is characterized by an anterior-posteriorly short and dorso-ventrally high skull with expanded parietals with robust parietal ridges and large occipitals in comparison with other Elephantidae taxa (Maglio, 1973; Sanders, 2010). Another diagnostic factor is the high prominent ridges bordering the upper edges of the temporal fossae (Sanders, 2010). The fact that the skull fragment found in Anchrif only includes part of the inferior part of the skull, the classification of the genus by cranial anatomy could not be made using these characteristics. The skull and other associated bones could give an estimate of the size of the individuals however. The size of the biggest specimen of Anchrif represents a medium sized elephant based on the maximum dimensions of the recent *E. maximus* (Osborn, 1942).

The African members of the *Elephas* group mainly represented by *Elephas recki* and associated subspecies show a progressive change of the enamel plaque shape, increased hypsodonty and decrease in enamel thickness (Maglio, 1973; Haradon, 2010; Werdelin & Sanders, 2010). The late species *E. iolensis* however, showed the opposite trend with enamel thickness and folding increased and decreased number of molar plaques (Sanders et al. 2010).

Cranial and other skeletal material in good condition is relatively rarer than finding of complete molars so teeth morphology is a frequently used method for the identification of elephant species. In the particular case of *Elephas recki* measurements and characters like lamellar morphology is consistent enough for detailed classification even though the teeth morphology is very variable even in individuals of the same subspecies (Haradon, 2010). The thin teeth enamel indicates the elephant species of Anchrif is a derived species of *Elephas*. The most common elephant of the Pleistocene in Northern Africa is *Elephas recki* and the characteristics of the remains seem to point at least to a related species of that clade the elephant can be classified as *Elephas recki recki* or *E. iolensis*, the most recent species of the genus *Elephas* in Northern Africa. *Elephas recki recki* is the form with most regular and thinly folded enamel, as comparable with Anchrif specimen. Taking this in consideration, we classify the Anchrif specimen as *Elephas recki recki* (Fig.37).

Such attribution is consistent to the age and geography of the bones: the age range of *E.r. recki* and *E. iolensis* is in accordance to the age of the lithic industry that made the amygdaloid acheulean bifaces found *in situ* in the uppermost bone layer, Middle Pleistocene, 0,781 to 0,126 Mya (Aguirre, 2006).

It was excluded that this specimen could belong to an elephantid from the European lineage like *E. antiquus* since no members of the group are mentioned in the literature on the African continent. The tightly spaced and thinly folded enamel figures also exclude this hypothesis.

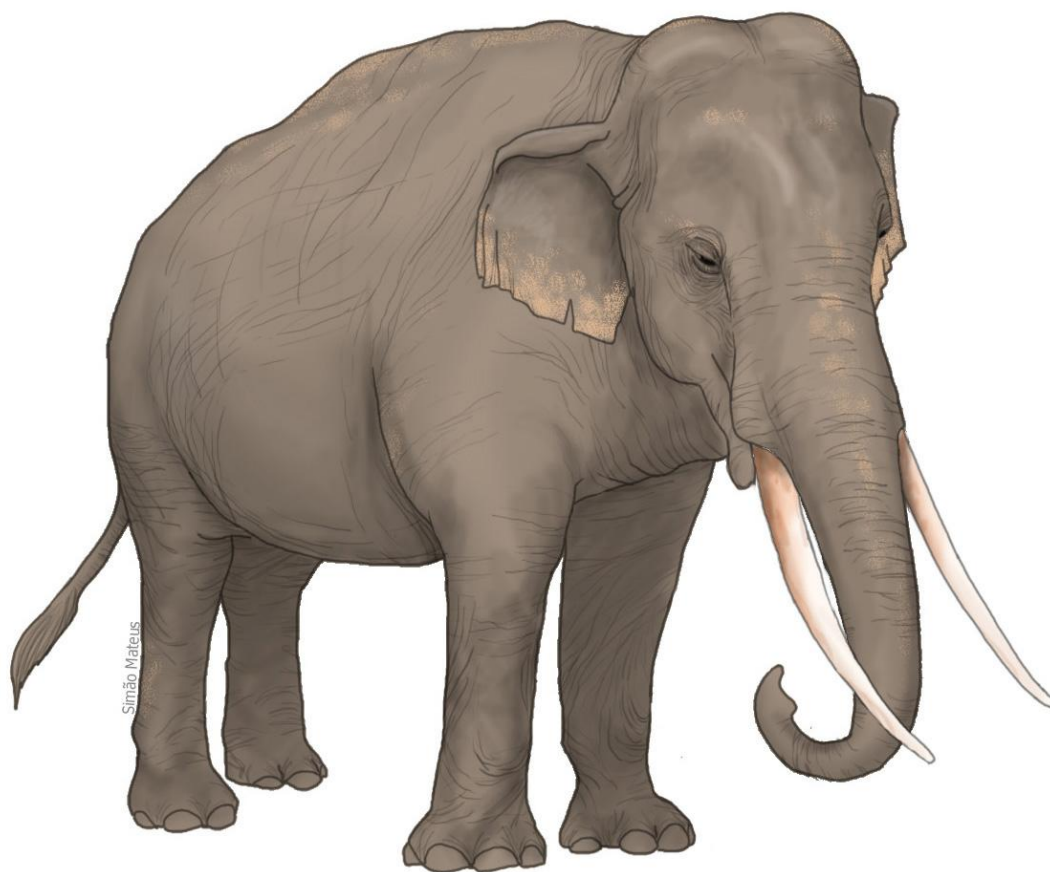


Fig. 37: *Elephas recki* from Anchrif reconstruction. Illustration by Simão Mateus

Other fauna and Flora of Anchrif

Other Pleistocene vertebrates

Although the proboscidean material was the most common in the locality material from other animals found in 2013 are worth mention. A pelvic bone (Fig. 38) and an astragalus belonging to a bovid artiodactyl (Fig. 40) were discovered in the preliminary visit to Anchrif.

The pelvic bone is constituted by a left ischium fragment 15 cm in length. The bone is slender and the anterior process of the ischium curves sharply dorso-anteriorly to the point that the anterior-most part of the ischium fragment is almost pointing dorsally. The anterior part of the ischium is laterally flattened and blade-like. The posterior part of the ischium starts to decrease in length dorso-ventrally in the last two thirds of the length of the acetabulum.



Fig. 38: Bovid right pelvic fragment from Anchrif. A: ventro lateral view. B: ventral view. C: Medial view.

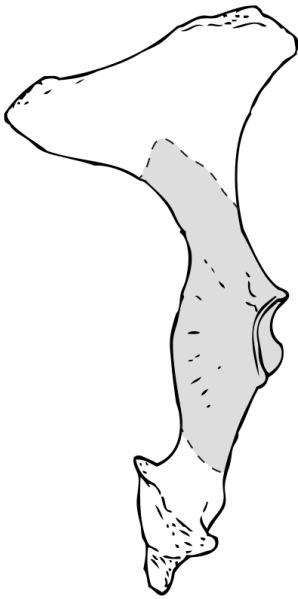


Fig. 39: Schematic artiodactyl pelvis (female). The element from Anchrif and its general position in the complete girdle in grey. Adapted from Walker, 1985.

Astragalus

A small astragalus was collected in association with the proboscidean material. This bone belongs to a small bovid, probably an antelope. Its shape is almost cuboid with the neck of the bone being almost as wide as the articular extremities. The lateral articular facet is wider than the medial articulation facet.

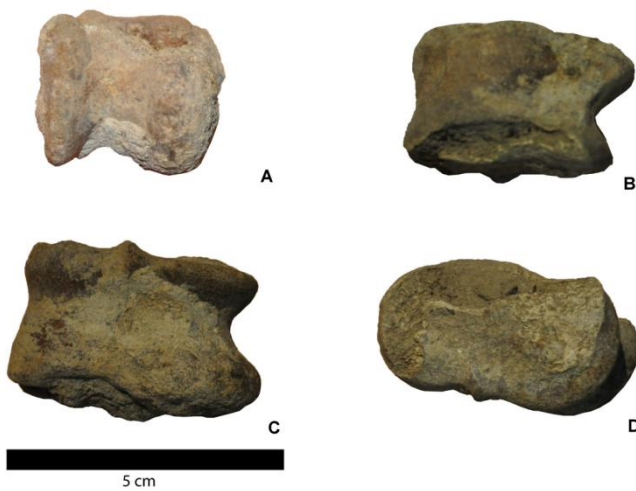


Fig. 40: Right astragalus of bovid from Anchrif in A) frontal , B) plantar, C) dorsal and D) medial views .

The anatomy of the pelvis is similar to an antelope. The shape of the anterior part of the ischium seems to be different from that of a Barbary sheep (*Ammotragus lervia*) since the ischium in this species is very slender and the anterior processes are not well developed. On the contrary the angle from the dorsal part of the anterior part of the ischium from Anchrif shows a well defined dorsal process.

Artiodactyl taxa with a record for Morocco include the genera *Gazella*, *Addax*, *Alcelaphus*, *Oryx* and *Cervus*. The size of the ilium indicates a medium to large sized antelope. As such the smaller species of *Gazella* can be excluded since the distance from the center of the acetabulum to the extreme of the ischium is around or over 100 mm. In the case of the small Thomson's gazelle for example this distance is 73,5 mm (Walker 1985). In terms of size the most similar extant artiodactyls in size would be the genus *Addax*, *Alcelaphus* or *Cervus*.

Hominid tools

Several acheulean bifaces were found in the area since the first trip of March 2013 although none *in situ*. More were found in September and a specimen was discovered still in the original layer, the same as the proboscidean limb bones, skull fragment and vertebra, just around 2 meters away from the limb bones. It is then assumed the tools and tool makers were contemporary to the rest of the fauna of Anchrif.

The Acheulean biface found *in situ* (Fig. 41) has an amygdaloidal morphology. The period of time consistent with this age for Northern Africa, including Morocco is the lower Middle Pleistocene (Aguirre, 2006). Several quarries in Africa, especially in the East of the continent, were remains of Oldowan and Acheulean *Elephas* butchery sites (Berthelet, 2001). The proboscidean material in Anchrif has not provided evidence of the same situation so far due to the lack of observable butchery marks in the bones. Also no further Pleistocene hominid material was found in the area.

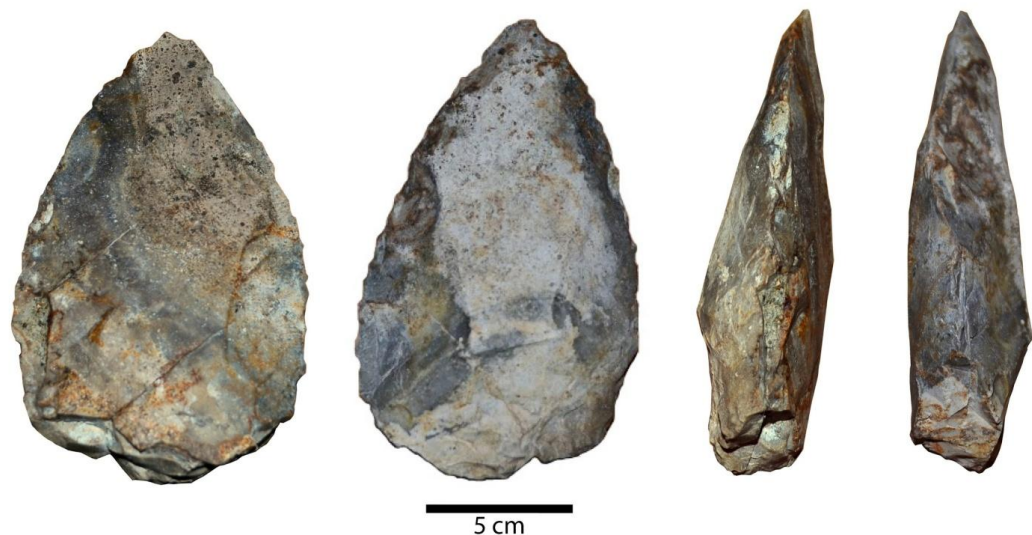


Fig. 41: Acheulean biface found *in situ* at Anchrif in four views.

Invertebrates

The fauna of fossil land gastropods is relatively rich and almost identical to the one we have today in Anchrif, based on collections from live specimens and recent shells done during the fieldwork.

Gastropoda

The snail species from Anchrif found in 2013 were the following:

Sphincterochila marteli (Pallary, 1918)
Theba pisana (Müller, 1774)
Rumina decollata (L., 1758)
Sphincterophila candidissima (Draparnaud, 1801)
Leonia mamillaris var. *turriculata* Pallary, 1920
Xerosecta reboudiana (Bourguignat, 1864)
Xerophila subapicina (Mousson, 1881)
Limmaea cf. *peregra* (Müller, 1774)
Planorbis indet. (juvenile)
Cornu aspersa (Müller, 1774)
Alabastrina rufa (Pallary, 1926)
Tingitana laffitteana, Pallary 1928
Melanopsis acutula Pallary, 1920
Xerophila ephorcella youssiana (Pallary, 1927)

Modern gastropod samples were taken from the field around Taghrout during the digging season. The only species present in the recent record and not present on the fossil fauna is the *Melanopsis acutula*. This is however an aquatic snail (Elkarmi & Ismail, 2006) that was found in a stream of Skoura, approximately 20 Km from the fossil site. In the reversed case, the only species not found in the recent record that was found in the fossil site, was the one belonging to *Planorbis*, also a freshwater snail (Morgan et al., 2002). All of the gastropods were identified by Professor Pedro Callapez from the University of Coimbra.

Flora of Anchrif

One fossil plant remain was recovered from the Anchrif locality. Since the main focus of the digs was the extraction of the bone material more plant material exists at the site but was not discovered during the campaign. The material consisted of a seed of *Celtis australis* (Fig. 42).

Systematic Paleontology:

Magnoliopsida, Cronquist et al., 1996
Rosales, von Berchtold and Presl, 1820
Celtis australis Linnaeus, 1753

Nowadays the geographical range *Celtis australis* includes the Mediterranean region.



Fig. 42: *Celtis australis* seed from the Anchrif locality. Scale at 0,5 mm.

Fauna from the surrounding region

Besides the proboscideans of Anchrif, the locality and the surrounding region of the Middle Atlas the expedition of September 2013 provided more fossil material from the Pleistocene of Taghrout, Middle Jurassic of the El-Mers Formation and Holocene from a cave near the village of Taghrout.

The fauna of the Middle Jurassic of El-Mers and Taghrout

The area surrounding Skoura and Boulemane is known for several decades to have several localities with vertebrate fossils from the Jurassic, with the main locality being El-Mers, 15 Km SE of Taghrout. The main work about this subject was made by the French Paleontologist Albert F. de Lapparent in 1995. This article describes three main fossiliferous quarries and several smaller discoveries all around 20 Km the area being studied in the September digs. The material described for the area include various dinosaur remains, crocodylians and fishes. During half a day during the digs prospection work was made to try to rediscover those quarries, since they were not thoroughly explored since the times of Lapparent. An half-day prospection near El-Mers allowed the discovery of one site with three track layers (tridactyl and sauropod) and fossil bones, probably belonging to a crocodylian were discovered near El-Mers, which show the potential that such area has regarding fossil sites. Further work in the sites is planned to be made in these zones in future campaigns.

From Taghrout to Anchrif several other fossils can be seen in the path connecting both areas. There are layers with abundant bivalve and brachiopod shells (Fig. 44), plant remains and at least one layer presenting tridactyl dinosaur tracks (Fig. 43). None of these sites seem to be referenced in previous bibliographical work.

West of the town of Boulemane there are Cretaceous outcrops that produced dinosaur material mentioned also by Lapparent in 1955. This area was not visited during the fieldwork due to time constraints.



Fig. 43: Example of bathonian theropod dinosaur footprints from Taghrout-Anchrif path found in 2003. The outlines of the prints are marked with chalk to enhance features.



Fig. 44: Bivalve and brachiopod shells from the Bathonian of Taghrout.

Taghrout Holocene Cave Fauna

The cave of Taghrout (Fig. 45) explored in 2013 is located less than 400 m of the Anchrif basin in the opposite slope of the hills that make the southern limit of the Anchrif valley. In the southern slopes there are several small cave entrances but due to time restrictions only one was explored. The caves formed in the Bathonian limestones of that locality at least during the Quaternary and they were found during a prospection trip along the Jurassic and the remains were recovered from a surface collection that lasted only a few minutes due to the lack of equipment suitable for the exploration of the cave and the proper collection of the material. There were more bones in the area but they could not be collected at the time.

The entrance of the explored cave is also facing South with it's GPS coordinates being N 33°28.704' W 4°37.084'. The lack of human footprints or other signs of recent intervention make the cave seemingly undisturbed for an undetermined period of time until recently. Several fragments of pottery of and aged pieces of rope made with natural fibers indicate previous human occupation.



Fig. 45: View of the entrance of the 2013 Taghrout cave. Photograph taken facing North.

The fauna of the cave explored near Anchrif provided Bone material from reptiles and mammals. Some specimens had bite marks (Fig. 45), most probably made by porcupines, known for eating bones left in caves. Porcupines are known for being one of the few animals that collects bones and stores them in caves, along with hyenas and humans (Klein et al., 1991). Due to this behavior there is the possibility that part of the bone material present in the cave has been carried over from outside of the cave to the shelter by the porcupine and that they are partially responsible for the abundance of the material found in the surface collection. Another hypothesis is that the porcupine occupied the cave after the accumulation of material

due the abundance of bones already inside. As such it is possible the porcupines are intrusive in this context and not contemporary with the rest of the fauna found inside the cave.

Mammalia

Systematic Paleontology:

Mammalia Linnaeus, 1758

Rodentia Bowditch, 1821

Hystricidae Fischer de Waldheim 1817



Fig. 46: Scapula-coracoid fragment of an unidentified large mammal bone with porcupine bite marks.



Fig. 47: *Hystrix cristata?* quill found in the cave of Taghrout.

The presence of porcupines is confirmed by a quill found in the cave floor (Fig. 47). There are also incisive bite marks on some chelonian and large mammal bones that may have been produced to this animal. The marks are very smooth, always in the edge of the bone, in some specimens all around the perimeter of the bone, like in the scapula-coracoid in Fig. 46 and in some places the bite have a parallel ridge pattern, perpendicular to the edge of the bone,

probably cause by the paired incisors during the biting process .The alternated pattern white and black bands indicates the African porcupine species *Hystrix cristata*. This species is present nowadays in Morocco, ranging from Northern Africa south to the equator of this continent, being absent in desert climate regions (Santini, 1980; Aouraghe et al., 2010).

Systematic Paleontology:

Mammalia Linnaeus, 1758
 Carnivora Bowditch, 1821
 Canidae Fischer de Waldheim 1817
Canis lupus cf. *familiaris* Linnaeus, 1758

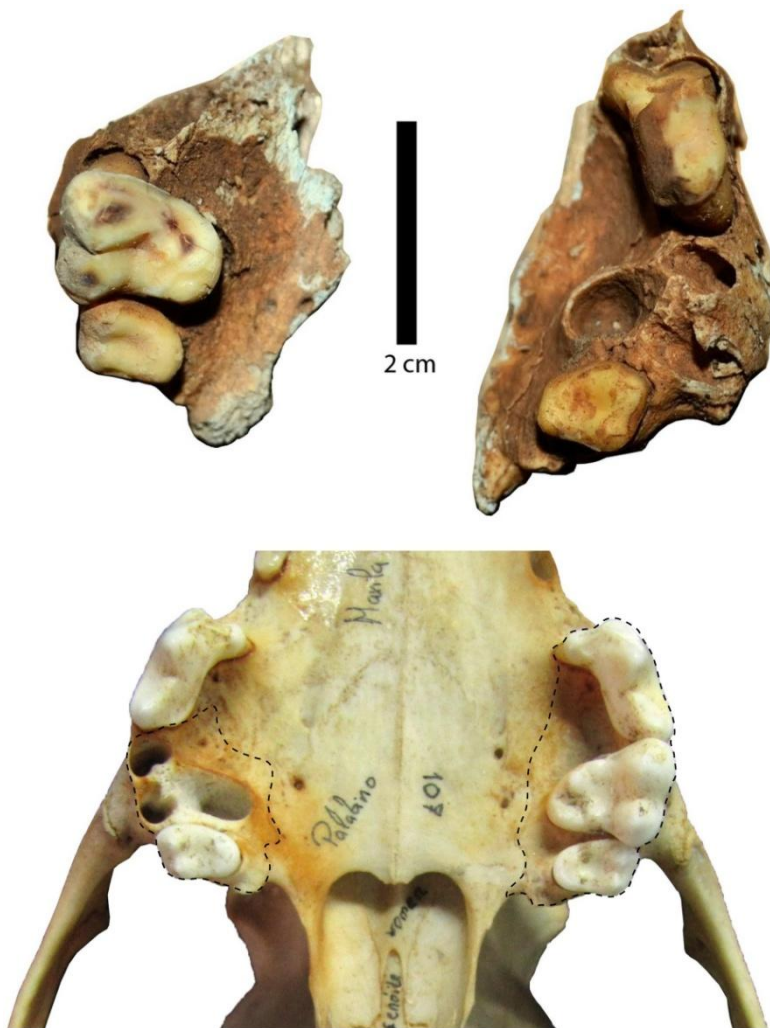


Fig. 48: Upper: *Canis lupus* from Taghrout cave in left and right maxilla in ventral view. Lower: Ventral side of a skull from a recent specimen of a dog (*Canis lupus familiaris*) for comparison. Dashed lines mark the rough location of the bones from the Anchrif specimens in the skull. The recent specimen is from a FCT-Mateus osteological collection.

The two maxillae fragments were found in the Taghrout cave (Fig. 48). The left maxilla has the M2 and M3. In the right maxilla the M1 and M3 are present. The triangular (tribosphenic) shape of the M2 and the very small M3 are consistent with a canid. The Gray wolf is probably present in North Africa in the form of *Canis lupus lupaster*, tending to be of

small dimensions and being often confused with the Golden jackal (*Canis aureus*), which is of even smaller dimensions (Gaubert et al. 2012). The maxillae are between the size of the two biggest dog skulls used for, with roughly 35 mm between the anterior part of the M1 to the posterior of the M3. The first skull for comparison is pictured in Fig.1 and is 33 mm for the same measurement and the second comparison skull was 39 mm. Both belong to dogs with the total length of both skulls slightly more than 200 mm. The skulls of jackals used for comparison, two skulls of the species *Canis adustus*, the side-striped jackal, were both around 20 mm from M1 to M3. All comparison specimens belong to the comparative anatomy collection of the FCT-UNL. Not only because of the size but also due to the presence of other domestic fauna like goats and cattle in the cave it is likely that the canid present in the site is a dog, *Canis lupus familiaris* (sensu *Canis familiaris*).

Systematic Paleontology:

Class Mammalia, Linnaeus, 1758
 Order Carnivora, Bowditch, 1821
 Family Feliidae, Gray 1821
Panthera, Oken, 1816 sp.



Fig. 49: Possible *Panthera* canine fragment from Taghrout cave.

A tooth of *Panthera* (Fig. 49) was very fragmented but its straightness and its elongated conical shape with a circular transverse section indicate a Felidae canine (Melendez, 1990).

The apex and the root of the tooth are missing. The relatively large size is coherent to the genus *Panthera*. Members of this genus in Morocco during the Holocene include *Panthera leo* and *Panthera pardus* (Barnett et al., 2006; Burger & Hemmer, 2006; Myers, 1976).

Systematic Paleontology:

Mammalia, Linnaeus, 1758
 Bovidae, Gray 1821
 ? *Syncerus* sp., Hodgson 1847



2 cm

Fig. 50: *Syncerus?* horn core fragment from Taghrout cave.

The possible *Syncerus* (Cape buffalo) horn core fragment (Fig. 50) was preliminarily identified by Doctor Fethi Amani in the field as belonging to a cape buffalo based on distinctive ridges in the interior portion of the horn. We did not find any literature to support this claim.

Systematic Paleontology:

Mammalia, Linnaeus, 1758

Bovidae, Gray 1821

Bos cf. *taurus*, Linnaeus 1758

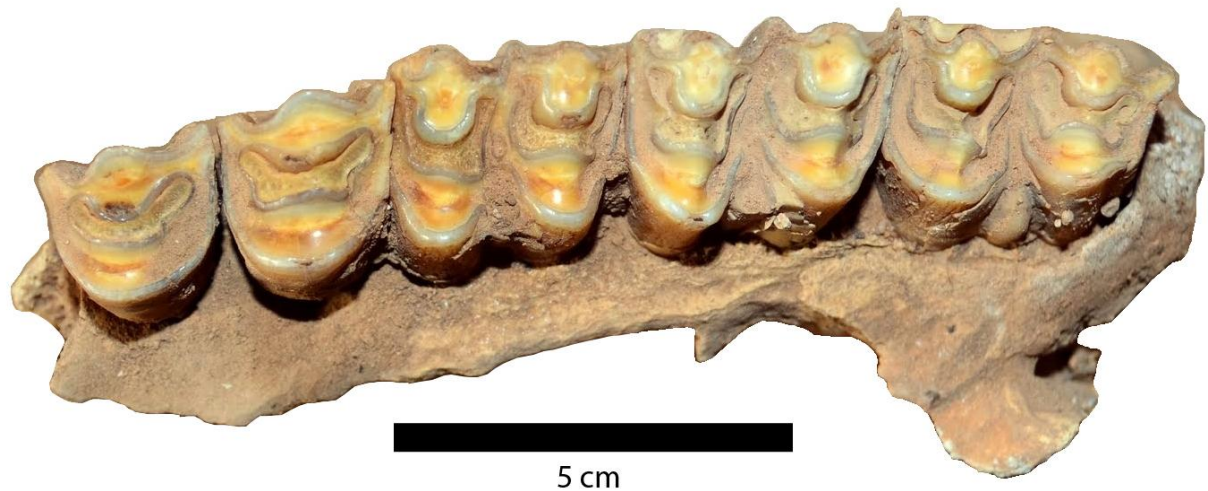


Fig. 51: *Bos* left maxilla from Taghrouit cave in ventral view, with p3-4, and m1-3 in occlusal view.

The *Bos* left maxilla from Taghrouit (Fig. 51) is a fragment consisting mostly of the ventral part of this bone with the teeth P3, P4 and M1-3 still inserted. It belongs to an adult, deduced by the presence of the M3 and the slightly worn teeth.

The maxilla presents the P3, P4, M1, M2 and M3 teeth. Although no accurate measurements could be taken the length of the M3 (around 25 mm) is consistent with the domestic species of *Bos*, *B. taurus* from previous works (Cavaleriu et al. 2008). One cannot exclude *B. primigenius* since more detailed measurements would have to be taken. The latter species of wild cattle was present in Morocco and there were findings as close as the Rif Mountains in Northeastern Morocco (Aouraghe, 2010). The lack of pronounced cusps in the labial and posterior sides of the M3 exclude the classification as a buffalo that gives the latter a slightly convoluted and wavy profile in the upper M3 in occlusal view (Hillson, 2005), not present in the specimen from Anchrif.

Systematic Paleontology:

Mammalia, Linnaeus, 1758
 Bovidae, Gray 1821
 Caprinae, Gray 1821
Capra Linnaeus, 1758 sp.

The subfamily Caprinae is constituted by small bovids of similar size that also have teeth with similarities that make the distinction of its members difficult (Hillson 2005). Goats and sheep in particular are two genera fairly hard to differentiate from one another by postcranial material and worn dentition (Zeder & Lapham, 2010; Zeder & Pilaar, 2010). There are however several characters that may enable the distinction between the two. The material from Anchrif includes a dental with the teeth M2 and M3 (Fig. 52).

The criteria which determine that the dental remains are from a *Capra* are the following in accordance with Zeder & Pilaar, 2010 for the M3: usually concave mesial part of the buccal edge of the mesiobuccal cusp, the buccal edge of the centro-buccal cusp is pointing slightly posteriorly. The buccal edges of the mesial and central parts have a pointed and triangular appearance with a flat and pointed profile, the buccal edge of the distal cusp is slightly pointed, a narrow flange on the mesial face.

There is however a buccally defined flute, suggestive of a sheep, although goats may show this trait as well.

Using the Deniz-Payne method of determining age in goats based on tooth wear (as in Davis, 1987) the approximate age of the specimen from the Taghrout cave can be established. The longest stage in the tooth wear of a goat is when the infundibular enamel starts to form isolated "lake" structures in the middle of the masticatory facet of the molar, until the most frontal one gets completely worn out (Davis, 1987). Since the Taghrout specimens still has the most posterior enamel figure partially attached to the outermost layer of enamel that goes around the entire tooth, the age of the specimen should be around 14 to 20 months old. An incisor was also found in the cave. It was in a very worn state so it should not belong to the same specimen as the dental.

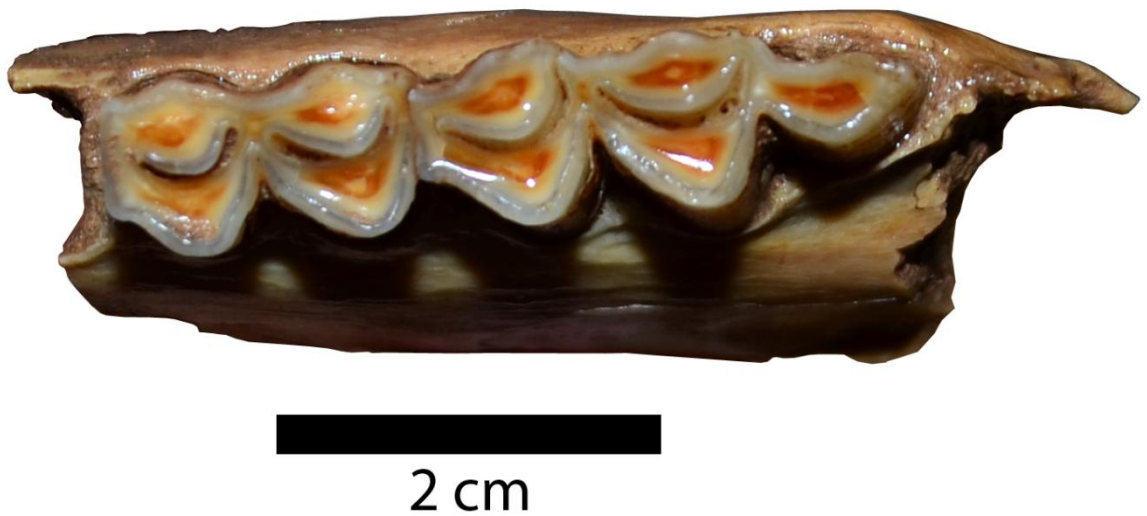


Fig. 52: *Capra* left dental from Taghrout cave in occlusal view.

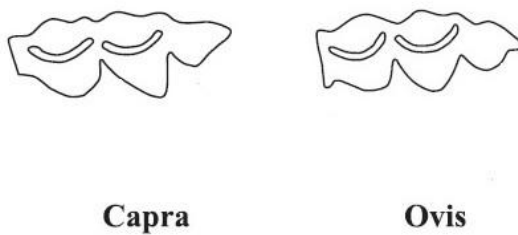


Fig. 53: Schematic representation of *Capra* (left) and *Ovis* (right) M3. Adapted from Zeder & Pilaar, 2010.

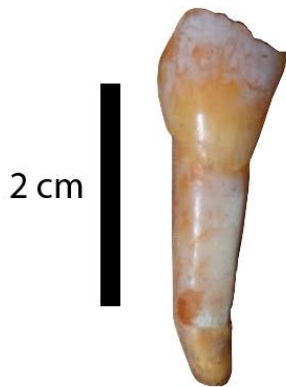


Fig. 54: *Capra* Incisive tooth from Taghrout cave in posterior view.

A fragment of a horn was also found in the area (Fig. 54).



Fig. 55: *Capra?* right horn from Taghrout cave in frontal view.

Systematic Paleontology:

Mammalia, Linnaeus, 1758
Lagomorpha, Brandt, 1885
Lepus Linnaeus, 1758 sp.

A proximal end of a lagomorph femur was discovered in the Taghrout cave (Fig. 56). The relative size indicates an hare. The species is difficult to ascertain due to the similarities between the *Lepus* species. The two species present in modern times are *L. capensis* and *L. microtus*, of which *L. capensis* is the most common one in the country nowadays (Moores et al., 2012). They are very similar species with few distinctive characters, being mostly distinctive by marked grooves in the incisors of *L. microtus* that *L. capensis* lacks and a few exterior characteristics. As such the specimen from the Taghrout cave is here only referred as *Lepus* sp.

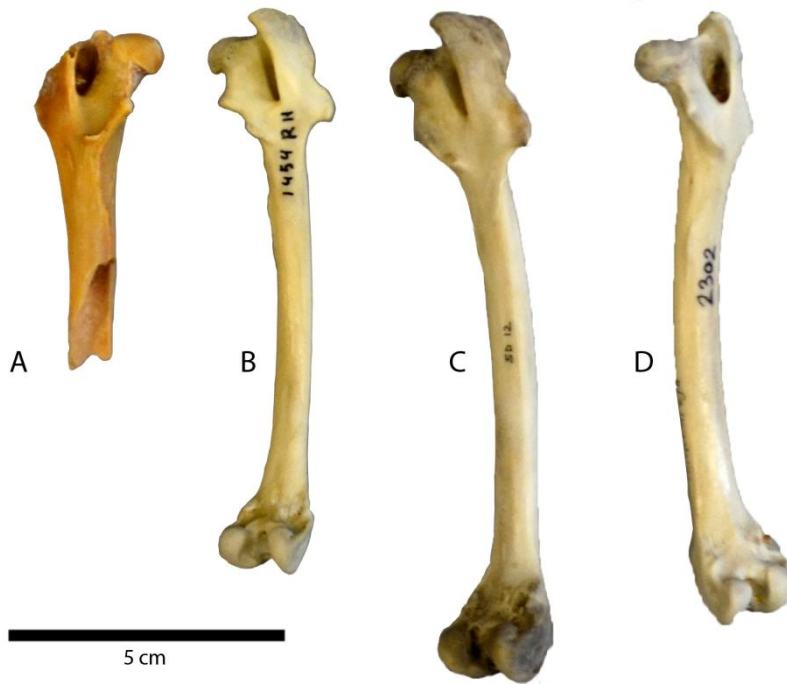


Fig. 56: *Lepus* femura in postero-lateral views. A: Left femur from from Taghrouit cave; B: *Lepus granatensis* right femur; C & D: Two right femura of *Lepus europaeus*. The recent specimens B, C and D are from the Laboratório de Arqueociências (LARC) in Lisbon.

Reptilia

Besides the mammals bone there were three testudine shell plaques, two belong to nuchal plaques (Fig. 57) and one costal plaque. One of the nuchals was chewed by a porcupine in its most posterior part. All of the bone were identified as belonging to the genus *Testudo*. The bitten specimen seems to belong to *Testudo graeca*, when compared with nuchal from the same species. The other nuchal is from a smaller specimen and is complete, without bite marks. It share some affinities with the modern specimen of *Testudo hermanni*, like its more polygonal shape than the previous nuchal and the small area for the marginal scutes, about the same size as the nuchal dermal scute.

Systematic Paleontology:

Reptilia Laurenti, 1768
 Testudines Batsch, 1788
Testudo sp., Linnaeus, 1758

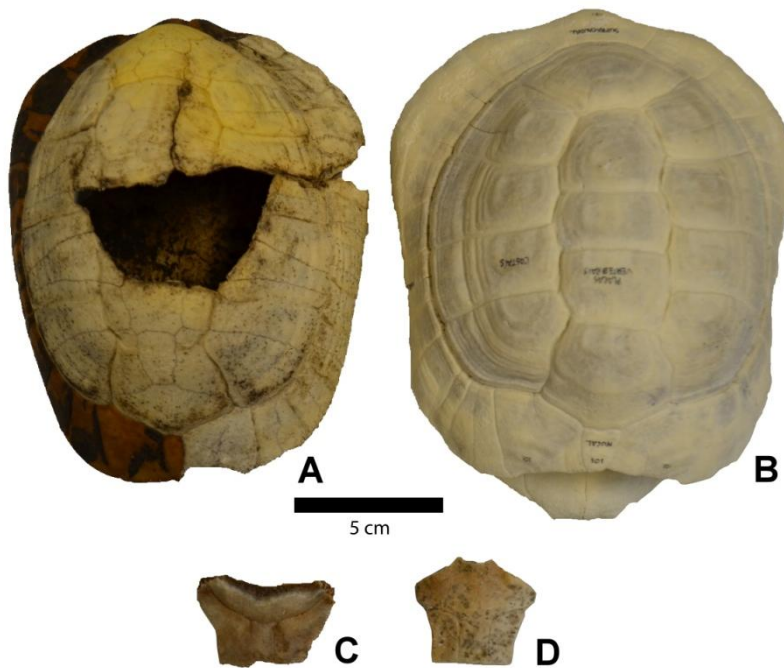


Fig. 57: *Testudo* specimens in dorsal view A: *Testudo graeca* modern specimen. B: *Testudo hermanni* modern specimen. C: *Testudo graeca* nuchal from Taghrout cave. D: *Testudo* cf. *hermanni* from Taghrout cave. Modern specimens from the Laboratório de Arqueociências (LARC).



Fig. 58: *Testudo* second left costal from Taghrout cave. Left: dorsal view. Right: ventral view.

The last of the testudine bones is a second left dorsal plaque of an undetermined *Testudo* species. The fragment is missing the distal end and it bears the mark of the edge of intersection of the first and the second dorsal scutes. It also shows the parallel ridge pattern as seen in modern *Testudo* and *Mauremys* specimens that were observed in this study.

Discussion

The Anchrif locality can be dated as Middle Pleistocene in age due to the combined presence of amygdaloid Acheulean bifaces and *Elephas recki recki*. This represents one of the few Pleistocene sites in the Middle-Atlas region and one of the most recent *Elephas* localities in Morocco. The Acheulean tools found in the same layers of the bones can be comparable to other quarries in Europe and Africa with signs of butchery, where *E. recki* was one of the species predated by hominids (Piperno, & Tagliacozzo, 2001 Berthelet, & Chavaillon, 2001). In contrast, signs of predation have not been detected in the bones of Anchrif.

The site leads to some interesting taphonomical questions. The steep margins of the lake associated to slippery surface could have resulted fatal falls which is even more severe to heavy animals that are prone to injury from even a short fall. This peculiar situation may result in a natural trap for elephants and may explain the accumulation of elephant bones. The steep and maybe slippery margins of the lake would prevent the injured animal from getting out, as is the case of the mammoth traps of Hot Springs, in South Dakota, USA (Lister, 2007). The main quarry here studied was the only place dug with more than two bones in association, although none was found articulated. The bone dispersal and position could be associated with predation, gravity or with the water current. The taphonomical calibration, with heavier bones like the femur and tusks being positioned together and away from the lighter bones like the scapula and pelvic girdle in the other extreme seem to support the water transport hypothesis.

The known faunal assemblage of Anchrif includes at least five elephant specimens, unidentified artiodactyls, *Testudo*, and twelve terrestrial gastropod species. The environment of the area should not be very different from what it is today with a Mediterranean type flora and microfauna, as shown by the invertebrates and *Celtis australis*. The sedimentary layers in the basin also show an alternation of low energy periods (carbonated mudstones) with high energy periods (conglomerates) which may constitute either seasonal change along the years, with periods of heavy rains, still experienced today, or perhaps may be explained by the cyclicity of the sedimentary environment being related with alternate glacial and interglacial periods, but these hypotheses still require testing.

Bones and quill were found in the nearby cave as result of preliminary surface collecting to assess the paleontological potential of the cave. The fauna is similar to other sites in Morocco, such as the Holocene sites of Chrafate and Ez Zarka in Northern Morocco and Guenfouda the East of the country (Ouahbi et. al 2013; Aouraghe et al., 2010). The fauna of Chrafate and Ez Zarka did not provided human remains while Guenfouda contains several archeological findings and domesticated fauna so they are useful when comparing with the faunal assemblage of the Taghrout cave. The site in this study seems to show a mix of situations but with higher diversity of domesticated animals (*Bos*, *Capra* and *Canis*) than wild fauna, makes it more similar to Guenfouda. This last site also shows the presence of *Hystrix cristata* in the form of bite marks as in Taghrout. In contrast, the *Panthera* (present in the Northern Morocco sites) and the possible *Syncerus* are not described for Guenfouda. This bovid along with the testudines are the only species that are found in Taghrout that are not present or not described in the Holocene localities previous mentioned. *Lepus cf. capensis* occurs in every site. The abundance of paleontological and archaeozoological specimens in the Taghrout cave is remarkable. The cave seems undisturbed for an indeterminate time period and all the samples were result of a preliminary surface collecting that show the potential for a long-term excavation that could provide a bigger amount of specimens. The karstic landscape also potentiates the presence of more caves in the surrounding area.

Lastly, a on note the paleontological findings in the Jurassic rocks in the region. The tracks reported show the presence of theropods and ornithopods dinosaurs, that deserve further study. Interestingly, the tracks of ornithopods are less common in Africa. At El Mers, Middle Jurassic bones were found but not excavated during the visit of 2013. The Bathonian age, the marine facies, and the preliminary morphological anatomy suggest identification as putative crocodylomorph. Lapparent (1955) reported already the presence of vertebrate that named as *Megalosaurus mersensis*, which later were reinterpreted as crocodylomorph *Steneosaurus* (Chabli, 1986).

Conclusions

In sum, the following points can be concluded from the work in the three distinct ages and localities addressed in this thesis: Holocene cave in Taghrout, Middle Plistocene of Anchrif, and Bathonian of Taghrout and El Mers.

- The localities studied in during the field work of 2013 show the high paleontological potential of a relatively unexplored area.
- The Jurassic of the surrounding area has an abundance of fossils including a few archosaur bones and tracks, which are the first reports for this clade in the area since the 1950's. The dinosaur tracks of Taghrout and El-Mers are the first reported to both areas.
- The Anchrif site shows the presence of several vertebrates, in particular the *Elephas recki recki*. These findings of *E. recki* are the first to be reported in Middle Atlas and corroborates with the mountain habitat of this species from Algeria. The Anchrif locality can be dated as Middle Pleistocene in age due to the combined presence of amygdaloid Acheulean bifaces and *Elephas recki recki*, but being one of the most recent *Elephas* in Morocco. The Anchrif site has at least five individuals of *Elephas*, explained by the topographical conditions of the locality (a mountain lake with steep and slippery margins) that could have worked as natural trap.
- The environment of that area during the Middle Pleistocene was probably similar from today, as attested by the fossil invertebrates and flora, and by the presence of the *Elephas*-lineage elephants that especially adapted for grazing and contrast with more browsers *Loxodonta*.
- The material collected in the Holocene Taghrout cave assesses the paleontological potential of the cave, with about 10 species as result of a short and preliminary surface scanning. The fauna is a mix between wild and domesticated that can be found in Morocco today. In addition there are some recently extinct representatives as in the case of *Panthera* and possible *Syncerus*.

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Supplements:

Supplement A: Map of the main quarry with the bones (in dashed-line in supplement B and squared area in Fig.15), hand sketched during the digs.

