Vegetation History in the Oukaïmeden Valley. Human Action and the Evolution of the Landscape

Historia vegetal del Valle de Oukaïmeden. Acción humana y evolución del paisaje

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Abstract

The archaeobotanical (Palynology and Anthracology) analysis of eight series from Oukaïmeden Valley (Atlas Mountains, Morocco) shows an archaeobotanical record that has undergone climatic and anthropic changes for the last 5147 ± 55 years BP (4050 - 3780 call BC). Climatic changes have been detected and human impact has been observed on the environment as regards to the use and exploitation of the resources of the territory. The territorial context shows several archaeological settlements from the end of the Neolithic and the Bronze Age. Archaeobotanical information displayed an open vegetation landscape. Its composition reveals a dry and high-altitude mountain Mediterranean environment. At a lower height we find Mediterranean taxa. Riparian vegetation and deciduous forest appear related to the bottom of the valley. The development of the different taxa progressively defines a combination of wet and dry periods in a territory highly affected by its excessive use as pastures. This fact culminates with the development of scrub vegetation associated to an important phytodiversity loss. The variability of the identified fragments of charcoal defines a diverse collection of firewood following an altitudinal gradient in the studied area.

Key words: *Pollen, Anthracology, Vegetation History, Climatic Changes, Human Impact, Morocco*.

Resumen

El análisis de carácter arquebotánico (Palinología y Antracología) de ocho secuencias procedentes del Valle de Oukaïmeden (Alto Atlas, Marruecos), muestra un registro sensible a cambios de naturaleza climática y antrópica a partir de los últimos 5147 ± 55 BP (4050 - 3780 cal BC). Se han detectado momentos de variabilidad climática, así como el impacto del hombre sobre el medio, en cuanto al uso y explotación de los recursos del territorio. Se trata de un contexto territorial rico en ocupaciones arqueológicas ubicadas desde un Neolítico Final y Edad del Bronce. La información arqueobotánica ha puesto de manifiesto el desarrollo de un paisaje vegetal abierto, cuya composición define un ámbito mediterráneo de alta montaña y de caracter seco. A menor cota se ubicarían los taxones mediterráneos y ligados a taxones de ribera en fondos de valle, así como componentes del bosque caduco. El desarrollo de los distintos taxones va definiendo una alternancia de fases húmedas y secas, en un ámbito fuertemente afectado por fenómenos de sobrepastoreo que culminan con el desarrollo de matorrales asociados a una importante pérdida de la fitodiversidad. La variabilidad de los fragmentos de carbón identificados define una posible recolección diversa de la leña siguiendo un gradiente altitudinal de la zona de estudio.

Palabras clave: *Polen, Antracología, Historia de la Vegetación, Cambios Climáticos, Impacto Antrópico, Marruecos.*

Introduction

Irini River Valley (Oukaïmeden) is located on the *Tizrag* plateau 70 km south of Marrakech (611630-3454176 UTM Time Zone 29N), and it constitutes the northern limit of *Toubkal* National Park (Morocco). At an altitude of 2630 m, it presents a high-mountain mediterranean climate (cold and slightly wet). Annual precipitation varies between 400 and 500 mm. and snowfalls are significantly frequent from December to March. Temperatures are quite low. The average temperatures of the coldest and the hottest month are -2.69 ºC and 23.5 ºC, respectively (Alaoui *et al*. 2009). The current dominant vegetation are xerophytic herbaceous plants, while in the montane level there are dense forests of deciduous *Quercus* along with *Juniperus thurifera*. Walnut and chestnut trees are common at the bottom of the narrow valleys (Rhazi *et al.* 2006), along with numerous wet pastures which hold great floristic biodiversity and are rich in endemic species (Alaoui *et al,* 2005). Long term conservation of these communities of endangered vegetation must be based on the understanding of their dynamics on the past (Alaoui *et al.* 2009).

The main goal of this work it is to reconstruct the vegetal landscape and its evolution in a territory where archaeological settlements are abundant (shelters, burial mounds) between the end of the Neolithic and historic times (Salih *et al.* 1998; Rodrigue 1999; Searight 2004; El Graoui *et al.* 2008). We will attempt to understand the rock art in the context of the societies that produced them (Ruiz-Gálvez *et al*. 2010) through the lens of Landscape Archaeology (Chapman 2006; Wagstaff 1987). By focusing on the evolution of the natural environment, we will explain the underlying logical reasoning for territorial planning and its variation through time and historical circumstances (fig. 1).

The first human settlement on this high-altitude valley does not appear to have occurred before the environmental changes that affected the continent between 3550 and 2050 calBC. These changes also mark the beginning of the Subboreal phase in Europe. In this particular region, they indicate the formation of the Sahara desert. In northern areas (Fauquette *et al*. 2006) the climate experimented a larger seasonal variance, with summer droughts that explain the seasonal but regular settlement patterns of the Oukaïmeden Valley summer pastures, which are the main goal of our study (Ruiz-Gálvez *et al*. 2010).

Pollen ranges provide archeobotanic information on the vegetation and the climate, on a regional and local scale. This information is complemented by the use and exploitation of wood revealed by anthracological data. However, archaeobotanic studies have been long used as a useful tool to explore the interactions between prehistoric populations and their environment (Iversen 1941; Behre 1981,

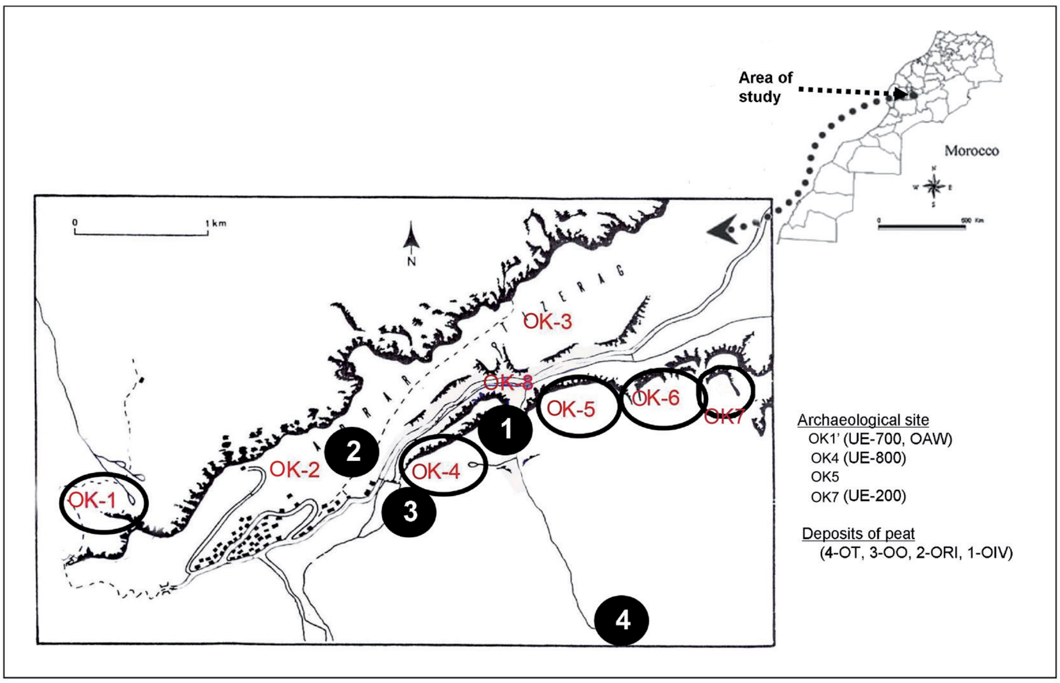

Fig. 1. Map showing the sampled points.

CODE	MATERIAL	LAB CODE	C-14 AGE (years BP)	CALIBRATED AGE (years cal BC/AD)
SU 204	BONE	CNA 806	495 ± 35 BP	1320-1350 AD (2,9%) 1390-1460 AD (92,5%)
OIV SAMPLE 80 cm	SEDIMENT	CNA-943	511 ± 28 BP	1320 - 1340 AD (3,6%) 1390 - 1450 AD (91,8%)
ORI 1 SAMPLE 80-85 cm	SEDIMENT	CNA-805	564 ± 44 BP	1290 - 1440 AD (95,4%)
SU 205	CHARCOAL	CNA-800	947 ± 44 BP	1010-1210 AD (95,4%)
OT SAMPLE 70-75 cm	SEDIMENT	CNA-941	1013 ± 41 BP	890 - 920 AD (3,6%) 940 - 1160 AD (91,8%)
SU-702	BONE	CNA-808	1240 ± 30 BP	680-880 AD (95.4%)
SU-806	SEDIMENT	CNA-802	1560 ± 30 BP	420 - 570 AD (95,4%)
SU-807	SEDIMENT	CNA-803	1615 ± 30 BP	380-540 AD (95,4%)
SU-209/211	CHARCOAL	CNA-937	1770 ± 32 BP	130 - 350 AD (95,4%)
OO SAMPLE 80-85 cm	SEDIMENT	CNA-942	1970 ± 38 BP	50 BC-130 AD (95.4%)
SU-809	SEDIMENT	CNA-939	2470 ± 37 BP	770-480 BC (85,0%) 470-410 BC (10,4%)
SU-808	SEDIMENT	CNA-804	2790 ± 30 BP	1010-840 BC (95,4%)
OAW-6	SEDIMENT	CNA-940	3143 ± 31 BP	1500-1370 BC (90.9%) 1340-1310 BC (4.5)
SU-703	SEDIMENT	CNA-938	3200 ± 39 BP	1610-1580 BC (2.4%) 1540-1400 BC (93.0%)
SU-213	CHARCOAL	CNA-801	4009 ± 51 BP	2840-2810 BC (2,9%) 2680-2340 BC (92,5%)

Table 1. C14 dates to which the samples are referred.

1986, 1988), especially in Neolithic studies on the spread of agriculture (López-García *et al*. 1997), due to the great impact that human activity has had on the vegetation since then.

It is not easy to differentiate cultural landscapes by means of paleobotanic and archaeobotanic analysis on this high-altitude environment because the signs of anthropic pressure do not leave a clear trace on the pollen record (Carrión 2001, López-Merino *et al.* 2009). A combined study including charcoal particles and pollen and non-pollen palynomorphs shed light on the influence that human activities had on the vegetation changes during the Holocene on these high-mountain areas of the Spanish Mediterranean region (for instance, Franco-Múgica *et al.,* 1998; Carrión 2002; Carrión *et al*. 2001b 2007a; Lopez *et al.* 2009; Carrión *et al.* 2010;. López *et al.* 2010; Morales *et al.*2013). At the same time, such information could be completed with anthracological, carpological and archaeofaunistical studies that could help to define the evolution of bio-geographical management in greater detail.

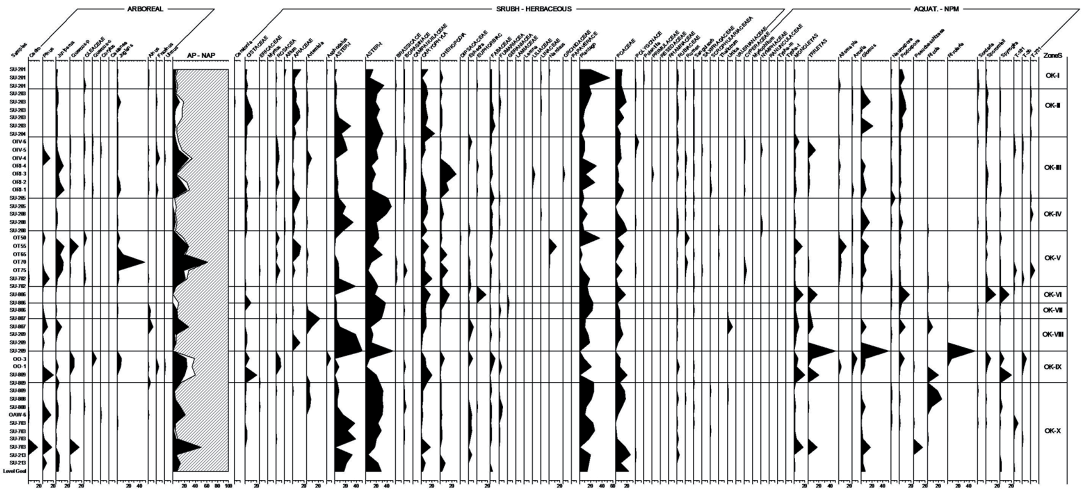

Fig. 2. Pollen diagram of the Oukaïmeden sequence.

Material and Methods

Pollen

The pollen analyses were performed on the samples recovered from sediments pertaining to both archaeological contexts (UE-200, UE-700, UE-800, OAW-6) and natural deposits (OT, OO, OIV, ORI). The eight studied sequences exhibit appropriate chronological control, for we have 14C dating on 15 samples (table 1), carried out in the *Centro Nacional de Aceleradores* (CNA) in Sevilla (Spain) and *the Consejo Superior de Investigaciones Científicas* (C.S.I.C) in Madrid (Spain). This allowed a general sequence (OK) to be built containing the changes to vegetation that occurred in the valley for the past 5147± 55 years BP (4050 - 3780 calBC).

The extraction of pollen grains, which involved the use of alkalis and acids, was performed following standard procedures (Couteaux 1977; Faegri *et al*. 1989; Girard y Renault-Miskovsky 1969; Moore *et al*. 1991). The sample residue was improved by using techniques such as flotation in Thoulet heavy liquid in order to concentrate the pollen (Goeury and Beaulieu 1979) and preserved in eppendorff tubes with glycerine. The palynology collection of the Alcala University and the manuals by Valdés *et al.* (1987), Moore *et al*. (1991) and Reille (1992) were taken as reference for the determination of the pollen grains. Non-pollen microfossils (NPM), which provide an additional tool to interpret the surrounding environmental conditions (López *et al*. 2000 and 2005; López and López 2007; Riera *et al*. 2006) were identified following the numerical Types defined by B. van Geel (Geel 1978, 2001; Geel *et al*. 1981 and 2003) according to their local distribution.

Data processing and graphical representation in a pollen diagram (fig. 2) were carried out using TILIA and TGview programs (Grim 1992, 2004). To calculate the percentage presence (relative frequency) of each taxon on the pollen diagram, aquatic taxa and NPM were excluded from the data set due to its local or extralocal distribution and because they were over-represented.

Data viewing was enhanced by developing a synthetic pollen diagram based on the chronology obtained (fig. 3), where taxa are grouped either by ecological affinity (Mediterranean, Riparian, Xeric, Aquatic) or in association with anthropization (nitrophilous). The most significant taxa in the sequence (*Juniperus, Cistaceae* and Neurospora) are represented separately on the same graph. Thus, we have the curves that include the taxa of the Mediterranean Forest (Oleaceae and *Quercus* evergreen) and Riparian Forest (*Alnus, Fraxinus y Ulmus*). For the herbaceous group we show the curve of xeric taxa (*Asteraceae* and *Poaceae*). The connection of this curve with Aquatic group taxa (*Cyperaceae*, *Myriophillum*, Nymphaceae, Ranunculaceae, *Typha monada* and *tetrada*) define the moisture changes / water availability, along the profile. The Nitrophyllous taxa curve (*Chenopodiaceae* / *Amaranthaceae*, *Geraniaceae*, *Polygonaceae*, *Plantago*, *Rubiaceae* and *Urtica dioica* type), as an indicator of the presence of organisms, is related to the corresponding *Neurospora* (type 55 C) which is a charcoal-growing NPM associated with fire activities. *Juniperus* do not share the expansion area with the above arboreal taxa, thus it is shown separately. This is also the case of *Cistaceae*, because it represents the main shrub vegetation component.

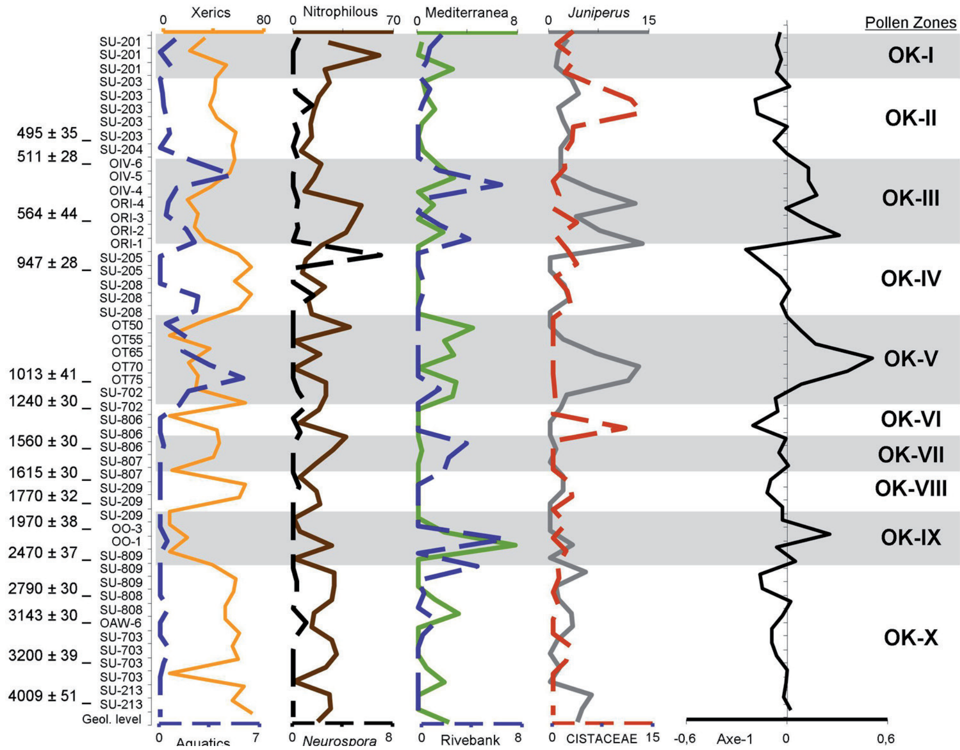

Fig. 3. Synthetic pollen diagram of the Oukaïmeden sequence and the weight curve of component 2 in every sample.

Lastly, we performed the Principal Component Analysis (fig. 4) using the Biplot application from Microsoft Office Excel © 2007. The analysis included all taxa and the complete sample set included in the OK sequence (See figs. 2-3).

Charcoal

The samples for the anthracological analysis were extracted respectively from Dr. El Graoui's test pits performed in 2006 and during the current research project's excavation campaign of 2009.
The first were collected directly and the second were collected with different volumes of sediment, and processed afterwards using a flotation machine. In the first case we collected three samples. One corresponds to the Survey 6, in the OK1 area, and the remaining two come from the Survey 4 besides the *Gar Ifassen* Rockshelter in the OK3 area).

The 2009 anthracological samples come from different contexts and archaeological sites of the valley (Elephants' Frieze in the OK4 area; Elephants' Shelter (or *Abadsan* Shelter) in the OK7 area; the funerary context of tumulus 2 in the OK5 area, and Context C-700 in OK1'). Unlike the 2006 samples, the sequence of these samples was elaborated by absolute dating and material contexts appeared in each of the excavations. Therefore, we were able to obtain a preliminary overview on the evolution of the vegetation in the valley, the use of resources and the human impact on the landscape.

These latter samples were collected systematically during the excavation processes. Different amounts of sediment were recovered and then treated with flotation. We used a machine made with a large plastic bucket (which facilitated its transportation). Placed inside was a 1 mm. mesh sieve where the sediment was deposited. Its disintegration allowed the plant elements, usually carbonized, to float outwards through a mouth or spout that poured the sample into a 0.25 mm. mesh sieve (Alonso 1999).

All of the resulting sediments were processed. The coarse fraction (the remains inside the machine) was examined *in situ* in order to recover any ecofact or device that it contained. Meanwhile, the fine fraction was separated in the *Laboratorio de Prehistoria de la Universidad de Extremadura* by dry sieving with a 2 mm-mesh sieve. With this procedure we excluded part of the sample from the further analysis because of the difficulty in obtaining optimal taxonomic determination of fragments below that size.

Once processed, the charcoal fragments from the different samples were examined with an Olympus optical microscope with 50 x to 500 x magnification lenses, under reflected light brightfield and darkfield. To carry out the observation, we obtained several fresh cuts: transversal, tangential longitudinal and radial longitudinal. This allowed us to observe the anatomical elements of each fragment to identify them by using the reference collections of modern carbonized wood and reference books (Greguss 1955 and 1959; Jacquiot 1955; Jacquiot *et al.* 1973; Schweingruber 1990; Vernet *et al.* 2001). The counting unit was the piece of charcoal. We used it to organise the data in different tables and graphs. The provisional anthracological diagram emerges as a synthesis of the records of Oukaïmeden Valley.

Results

Pollen

All the selected pollen records (Ruiz *et al*. 2010) meet the statistical and taphonomical criteria which ensure the reliability of this data and, therefore, the recovered pollen spectrum (Lopez- *et al.* 2006). Thus, the information obtained whatever its origin is highly consistent and can be used in the overall reconstruction of the vegetation history of this environment. It can be used as well to determine the causes of the environmental evolution and human influence on this landscape during the last 5147 ± 55 BP years (4050-3780 calBC).

In all cases, the landscape reconstruction shows a very open structure during the formation of the natural and archaeological deposits (See fig. 2), dominated by Asteraceae liguliflorae and tubuliflorae (*Compositae*), Poaceae (grasses) and *Plantago* (plantains) which, along with the rest of the herbaceous ensemble reveals the relatively dry Mediterranean conditions. We also noticed a certain pattern for all the sequences, which include the evidence of regional *Juniperus* forests (holm oak/juniper) and also *Pinus* to a lesser extent. More sporadically, we also detected Oleaceae (*Olea europaea*) and *Quercus* evergreen type (holm oak). The presence of deciduous *Quercus* (oak), *Castanea* (chestnut tree), *Corylus* (common hazel) and *Juglans* (walnut tree) is unusual and its development is related to the valley bottoms, as is the case with *Alnus* (alder), *Fraxinus* (ash), and *Ulmus* (elm). There are other elements to consider, because of their climatic and / or anthropogenic significance: *Ephedra* (Ephedra) -which remains practically constant along the profile - and Non Pollen Microfossils (NPM) type 3B (*Pleospora* sp.) both indicators of dry conditions; and also *Asphodelus* which, associated with the NPM *Neurospora* or 55C type, are indicators of the presence of fire. The presence of *Pseudoeschizaea circula* (remains of an organism of uncertain affinity) is related to *in situ* erosion processes, and in this case it could have been favoured by over-shepherding phenomena. This phenomenon is confirmed through deforestation that favours the development of NPM type 207 or *Glomus fasciculatum* (fungal spore), present along the sequence, and by the development NPM of coprophilous affinity (*Riccia sorocarpa, Podospora* or type 55 a, *Sporomiella* or *Sordaria* type or types 113 and 368) which have a similar curve to that of nitrophyllous taxa. Finally, it is noteworthy to mention the detection of oligotrophic NPM (type 170 or type *Rivularia* and *Arcella* or 352) and mesoeutrophic NPM (types 181, 315 or *Spyrogira* and 731), present along the entire profile. The alternation between both groups responds to the greater or lesser presence of nutrients in the environment, related to the presence of organisms (Geel *et al*. 1981; Geel *et al.* 2003; Geel and Aptroot 2006; Riera *et al.* 2006, López and López 2007 y López *et al.* 2005). In general, this relatively homogeneous composition reveals a stress component in the places near the studied area. These places have suffered humidity and -to a lesser extent- temperature fluctuations, and significant anthropogenic influence.

The vegetation in Oukaïmeden Valley was reconstructed by building an overall pollen sequence (sequence OK), determined by the units / levels with numerical dating (Figures 2-3). In general, it is characterized by a homogeneous composition, where the most relevant facts can be summarized as follows:

1. The close relation between the curve reflecting the total amount of arboreal pollen (AP) and that of 1 NPM type 207 or *Glomus fasciculatum*, as a clear example of deforestation.

2. *Juniperus* as the main taxon in the arboreal group, indicating more severe climatic conditions.

3. The development of Mediterranean arboreal taxa (Oleaceae and evergreen *Quercus*) did not occur simultaneously to the development of deciduous *Quercus*, which is evidence of the fluctuations in the humidity and / or use of resources.

4. The expansion of riparian taxa, such as *Alnus* (alder), *Fraxinus* (ash), and *Ulmus* (elm), is followed by the development of deciduous *Quercus*, *Corylus* (common hazel)

and *Juglans* (walnut tree) as well as the other taxa conforming the aquatic group, mainly Cyperaceae, which are typical in humid ecosystems, reflecting phases of increased humidity associated with richer arboreal resources.

5. We identified drier stages by the increase of Asteraceae liguliflorae, Asteraceae tubuliflorae and Poaceae; by the development of NPM type 3b or *Pleospora s*p., associated to the reduction of aquatic taxa. At this time the loss of arboreal resources causes the exploitation of the herbaceous stratum.

6. The strong human impact on the landscape is detected by the predominance of the taxa constituting Pasture groups. This human component is also evidenced through constant permanence of nitrophilous taxa and NPM of coprophilous affinity.

7. The greater or lesser presence of organisms is also responsible for the eutrophication of the environment, expressed in the alternating oligotrophic and mesoeutrophic NPM.

8. Detection of charcoal-living NPM *Neurospora* (type 55 C) and *Asphodelus*, reveals the presence of recurrent fires. The relationship of these fires with the nitrophilous taxa curve could be interpreted as the result of controlled burns, the main goal of which would be to clear the land.

9. The increase of nitrophyllous taxa and NPM of coprophilous affinity towards the top of the sequence can be interpreted as a response to the intensification of this activity, either by the greater or longer presence of these organisms in the area.

10. The higher diversity at the top of the sequence may be explained as a result of a greater presence of nitrogen in the soil due to increased shepherding pressure.

The pollen diagram of the Oukaïmeden sequence (figs 2-3), which covers the last 5147 ± 55 years BP (4050-3780 calBC) is divided into ten pollen areas (OK-I to OK-X). The development and evolution of these areas show the vegetation changes during approximately the last 5147 ± 55 years BP (4050-3780 calBC). The vegetation experiences a cyclic process: the forested area increases / decreases, always in the context of an open landscape and a clear trend towards the progressive loss of the arboreal stratum that favours the growing of dry herbaceous vegetation, where glimpses of scrubland development are detectable only occasionally. The pollen zones are described in detail below:

AREA OK-X: This is the basal level of the sequence and occurs between 4009±51 years BP (2680 - 2340 calBC) and 2790±30BP (1010 - 840 calBC). The development of an open landscape is observed during this time period. Nitrophilous taxa are well represented and *Neurospora* experimented a slight increase. The regional presence of *Pinus* and *Juniperus* are also seen. Everything seems to indicate intense human activity on the environment, together with fresh climatic conditions which make the development of local forests more difficult. This development would have been further limited by low rainfall, as indicated by the abundance of xeric taxa, and the absence of aquatic and riparian taxa.

AREA OK-IX: This phase develops prior to the interval of 2470±37 BP (770 – 480 calBC) reaching to 1970 ± 38 years BP (50 calBC - 130 calAD). It is marked by the recovery of the forest, affecting all tree taxa but especially to the Mediterranean Pine. Riparian taxa and -to a lesser extent- nitrophilous taxa experimented an increase, while xeric taxa shows a sharp decline, indicating an improvement in weather conditions with higher temperatures and precipitations that allowed the recovery of these forests.

AREA OK-VIII: This area developed between 1970 ± 38 years BP (50 calBC - 130 calAD) and 1615 ± 30 years BP (380-540 calAD). Initially, we perceive a significant decrease of arboreal vegetation during this period, due to the decline of the Mediterranean forest, which eventually disappeared. This favours sparse development of Mediterranean shrub, mainly *Cistaceae* (rockrose). Simultaneously, we observe the disappearance of riparian and aquatic taxa, as a result of the significant decline in rainfall, which is consistent with the spectacular increase of xeric taxa. The increase of nitrophilous taxa associated with an increase of coprophilous NPM, demonstrates the intensification of the pressure of human activity on the environment. Shepherding activities seem to occur during more months of the year.

AREA OK-VII: Located around 1560 ± 30 years BP (420-570 calAD) when a slight increase in *Pinus* occurs, although the vegetation is somewhat dominated by xeric taxa and by *Cistaceae* shrubs. Everything indicates that the local dry conditions were maintained, although the increase of riparian and - to a lesser extent- aquatic taxa indicates a slight increase of humidity at a regional level, which would have allowed the development of gallery forest in the valley. The increase of *Neurospora* and nitrophilous taxa indicates an increase in human activity, using fire to improve exploitation of pastures.

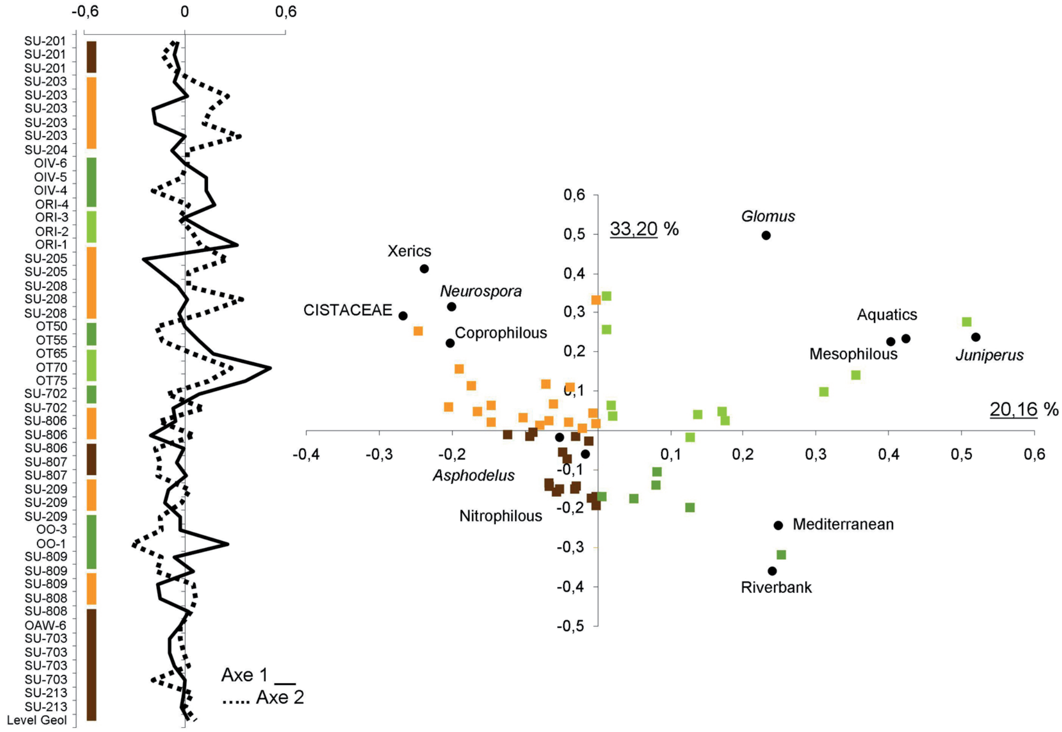

Fig. 4. Principal Component Analysis of samples and taxa of the Oukaïmeden pollen Sequence.

AREA OK-VI: This area developed prior to 1240±30BP (680 - 880 calAD). During this period we observe a sharp decline of forests that allows an increase of shrub vegetation and xeric taxa within an open landscape. All this indicates the persistence of dry conditions both locally and regionally. Under these conditions, we still observe livestock pressure.

AREA OK-V: The development of this area began around 1240±30BP (680 - 880 calAD), but around 1013 ± 41 years BP (940-1160 calAD) reaches its main features. At that moment, the arboreal cover reached its highest recovery phase (> 50%) initially due to the increase of both Mediterranean taxa such as pine forest, and *Juniperus;* as well as the expansion of *Juglans* (walnut) which occurred at the same time as an important increase in aquatic taxa. These data are consistent with the local and regional temperature and precipitation increase during this period. These climatic conditions were more advantageous for the development of arboreal taxa in need of greater humidity conditions, such as *Juglans*, located at a lower altitude. Nevertheless, man-enhanced development cannot be discarded; walnut trees are wood resources of great economic value. Thus, shepherding pressure dropped, as evidenced through a slight reduction of nitrophilous taxa and the absence of *Neurospora*.

AREA OK-IV: Prior to 947 ± 44 years BP (1010-1210 calAD), the arboreal cover disappeared again. Only *Juniperus* is detected -at very low percentages- alternating with Cistaceae (rockrose). The expansion of xeric taxa occurs simultaneously to the contraction of aquatic taxa. These data support the existence of a highly degraded landscape, due to extremely dry conditions. This climate limited the development of plant resources and therefore shepherding pressure, which explains the decline in nitrophilous taxa.

AREA OK-III: It starts prior to 564±44BP (1290 – 1440 calAD) and reaches to 511 ± 28 years BP (1390-1450 calAD). During this level the arboreal cover experimented two phases of recovery (40%). Initially, we observe the development of *Juniperus* and riparian taxa. Later, Mediterranean forest and deciduous forest experiment a weaker increase, simultaneously with aquatic taxa. Therefore, forest development was intensified with better climatic conditions and higher precipitation that enhanced the development of riparian forest in the valley and aquatic taxa in the vicinity of the site. This was followed by a rapid decline of the forest. Simultaneously, we observe an increase of nitrophilous taxa explained by greater human activity on the territory. The presence of both *Asphodelus* (a pyrophytic tax-

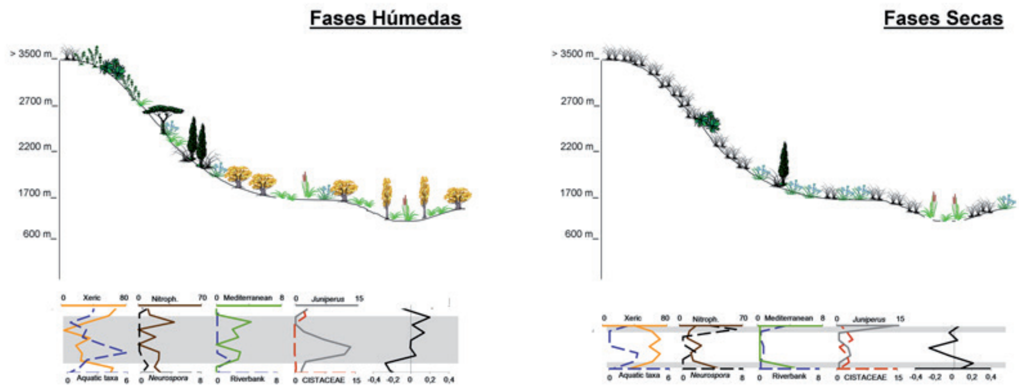

Fig. 5. Recreation of the structure and composition of vegetation during humid phases (positive values of component 2) and dry phases (negative values of component 2).

on) and NPM as *Neurospora*, suggests the existence of isolated anthropogenic fires. Then, a new arboreal recovery took place. The higher presence of *Pinus*, riparian taxa and -to a lesser extent- the Mediterranean forest, occurred once again simultaneously with the increase of aquatic taxa. This was probably due to more humid conditions that favoured forest development. This recovery was enhanced by lower human pressure on the environment.

AREA OK-II: This period starts at 511 ± 28 years BP (1390-1450 calAD). The main characteristic of this period is the largest development of *Cistaceae* (rockrose) of the whole sequence, from 495 ± 35 years BP (1390-1460 calAD). This coincides with a significant decrease of the forest, only represented in very low percentages by *Juniperus*. We also observe the decline of riparian forest and aquatic taxa. This, together with the higher presence of xeric taxa, defines the installation of dry conditions. The progressive increase of nitrophilous taxa and the sporadic presence of Neurospora, reveal greater anthropogenic pressure with the goal of obtaining new pastures.

AREA OK-I: Although we lack dating for this period, it represents the closest stage to the present. Here we observe a significant loss of shrub stratum; a slight development of a forest initially constituted by *Juglans*, followed by the development of Mediterranean and riparian forest that would indicate more humid conditions favouring the presence of aquatic taxa in the vicinity of the site. These climatic conditions would have allowed a greater exploitation of pastures conducted during longer settlements throughout the year, which would explain the stronger presence of nitrophilous taxa and coprophilous NPM.

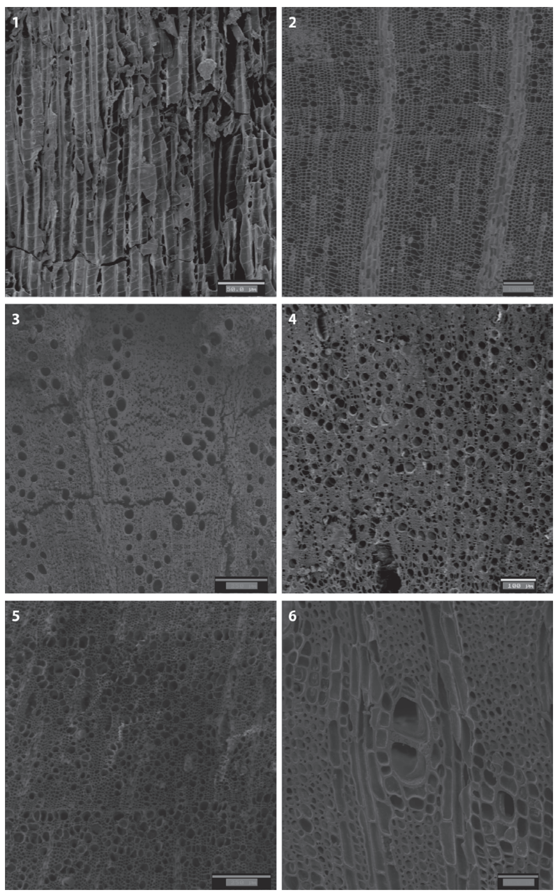

Fig. 6. Selection of taxa, anthracologically analyzed and documented in different environments of Oukaïmeden: 1 Longitudinal Tangential Plane of *Taxus baccata*; 2 Transverse Plane of *Ilex aquifolium*; 3 Transverse Plane of *Quercus ilex-coccifera*; 4 Transverse Plane of *Cistacea esp.*; 5 Transverse Plane of *Arbutus unedo*; 6 Transverse Plane of *Fraxinus sp*.

	2006 campaign					
	Probe 6		Probe 4			
	Sample nº 2		Sample nº 8		Sample nº 9	
	Nº	%	Nº	%	Nº	%
Juniperus sp.			3	4.29	2	2.67
Taxus baccata	27	45.00	1	1.43	15	20.00
Picea/Larix			1	1.43		
Ilex aquifolium			7	10.00	7	9.33
Quercus ilex-coccifera			5	7.14	4	5.33
Arbutus unedo	4	6.67				
Rosaceae sp. t. maloidea			13	18.57		
Leguminosae sp.	1	1.67	15	21.43	44	58.67
Cistaceae sp.			10	14.29	3	4.00
Labiatae sp.			1	1.43		
Fraxinus sp.	6	10.00	6	8.57		
Ceratonia siliqua	22	36.67	6	8.57		
Indeterminate			2	2.86		
TOTAL	**60**	**100.00**	**70**	**100.00**	**75**	**100.00**

Table 2. Absolute and relative frequencies of the samples collected in 2006.

A Principal Component Analysis (PCA) was performed to visualize the evolution of the vegetation and explain its changes (fig. 4). This PCA analysis highlighted the first two components, which together represent 53.36% of data variability. The first axis discriminates the vegetation structure, since all arboreal taxa are clustered in positive values contrary to non-arboreal ones that are concentrated in negative ones. However, taxa distribution along the second component, defines moisture control as well as lighter or stronger human pressure. In order to analyse the distribution of samples and its meaning, a different colour has been attributed to every quadrant (light green for moister conditions; dark green for Mediterranean conditions; brown for open areas with marked nitrification and shepherding

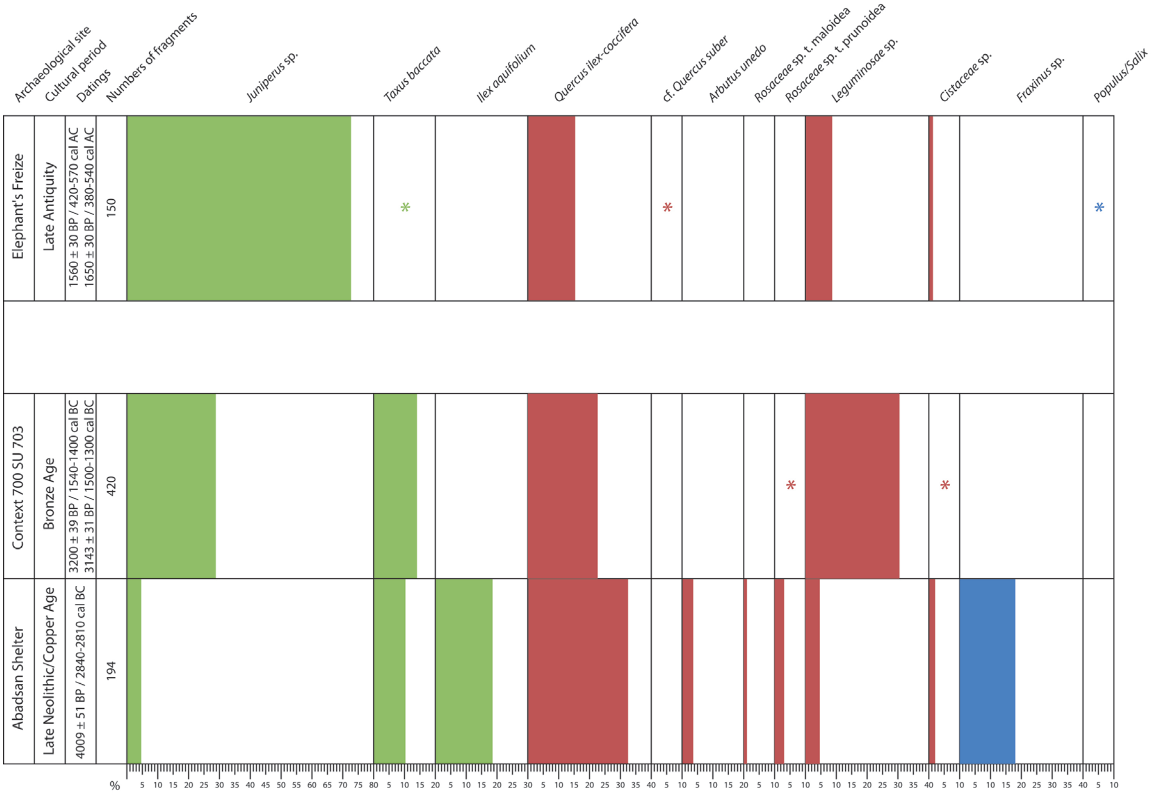

Fig. 7. Relative sequences of the samples collected in 2006.

	ELEPHANTS' FRIEZE			
	OK4			
	SU. 807	SU. 806	TOTALS	
	Nº	Nº	Nº	%
Juniperus sp.	48	61	109	72.67
Taxus baccata		1	1	0.67
Quercus ilex-coccifera	20	3	23	15.33
cf. *Quercus suber*	1		1	0.67
Leguminosae sp.	6	7	13	8.67
Cistaceae sp.		2	2	1.33
Populus/Salix		1	1	0.67
TOTALS	75	75	150	100.00

Table 3. Anthracological frequencies of the Elephants' Frieze (OK4).

pressure; orange for open and xeric landscape. The temporal distribution of samples is translated into a curve, together with the weight of components 1 and 2 that are expressed in curves. In that way, the alternation between periods of greater or lesser water availability is shown, as much as the periods of greater shepherding pressure. In view of the great discrimination caused by the second component, its importance has been highlighted in each of the samples. The behaviour of this curve identifies each of the defined pollen areas, either by its positive values (OK-IX, OK-VII, OK-V, OK-III and OK-I), indicating stages of higher levels of humidity, in contrast to those defined by its negative values (OK-X, OK-VIII, OK-VI, OK-IV, OK-II). This has helped to identify wetter and more favourable phases alternating with less favourable and drier episodes with significant impact on vegetation development (fig. 5).

Charcoal

The anthracological information comes from samplings performed in the 2006 and 2009 excavations. A total of 1071 charcoal pieces were analysed. We obtained 15 taxonomic determinations: *Arbutus unedo* (strawberry tree); *Ceratonia siliqua* (carob tree); *Cistaceae* sp. (rockrose); *Fraxinus* sp. (ash); *Ilex aquifolium* (holly); *Juniperus* sp. (junipers); Labiatae sp. (labiates); Leguminosae sp. (leguminous plant); *Picea/Larix* (abies/larch); *Populus/Salix* (poplar/willow); *Quercus ilex-coccifera* (holm oak-kermes oak); cf. *Quercus suber* (cork oak); Rosaceae sp. t. maloidea (rosaceae such as whitebeam, rowan, common pear, apple tree, etc.); Rosaceae sp. t. prunoidea (rosaceae such as prunus) y *Taxus baccata* (yew) (fig. 6).

The presence of two charcoal fragments classified as unidentified should also be noted: we did not have enough anatomical references to include them in the family, genus or species described in the atlas (Schweingruber 1978 and 1990; Jacquiot 1955; Jacquiot *et al.* 1973; Vernet 2001) and the reference collection of the *Departamento de Prehistoria de la Universidad de Extremadura* used in the analysis. Another group of non-identified fragments are those with anatomical features that cannot be clearly observed due to poor conservation condi-

	ABADSAN OR ELEPHANTS' SHELTER												
	OK7												
	SU. 203	SU. 205	SU. 205 M2	Almoravide/almohad		SU. 209	Antiquity	SU. 213	SU. 213	UE. 213 JPF	Late Neolithic/Copper Age	
	Nº	Nº	Nº	Nº	%	Nº	%	Nº	Nº	Nº	Nº	%
Juniperus sp.	1	1	-	2	7.41	41	91.11		9		9	4.64
Taxus baccata	3		-	3	11.11				20		20	10.31
Ilex aquifolium	3		-	3	11.11			1	21	14	36	18.56
Quercus ilex-coccifera	2		-	2	7.41			15	2	46	63	32.47
Arbutus unedo	4		-	4	14.81					7	7	3.61
Rosaceae sp. t. maloidea			-						2		2	1.03
Rosaceae sp. t. prunoidea									6		6	3.09
Leguminosae sp.	3		-	3	11.11	4	8.89		8	1	9	4.64
Cistaceae sp.			-							4	4	2.06
Fraxinus sp.	8		-	8	29.63			1	31	3	35	18.04
Indeterminable	1	1	-	2	7.41			2	1		3	1.55
TOTALS	25	2	-	27	100.00	45	100.00	19	100	75	194	100.00

Table 4. Relative and absolute frequencies of *taxa* from Abadsan Shelter organized by chronological/cultural periods.

	Context C-700 AOUGNIN n'ait OURIGH OK1'					
	SU. 703	SU. 703 MC	SU. 703 MC	SU. 703 ESQ. N F	TOTALS	
	Nº	Nº	Nº	Nº	Nº	%
Juniperus sp.	102		14	5	**121**	**28.81**
Taxus baccata	24	3		32	**59**	**14.05**
Quercus ilex-coccifera	86		3	6	**95**	**22.62**
Rosaceae sp. t. prunoidea				4	**4**	**0.95**
Leguminosae sp.	78	36	3	11	**128**	**30.48**
Cistaceae sp.	2				**2**	**0.48**
Indeterminable	8	1		2	**11**	**2.62**
TOTALS	**300**	**40**	**20**	**60**	**420**	**100.00**

Table 5. Absolute frequencies by type of sample and relative frequency of the whole samples of SU-703. Context-700 (OK1').

tions, excessive burning or because the fragment belonged originally to a wood knot.

Samples collected in 2006 correspond to the Survey 6, in the OK1 area, and the remaining two come from the Survey 4 in the *Gar Ifassen* Rock-shelter in the OK3 area (fig. 1). The lack of absolute dating and clear archaeological contexts does not allow building a sequence. However, we were able to establish some conclusions from the 205 pieces of charcoal, where we observed a total amount of 12 taxa (table 2).

It should be noted that yew (*Taxus baccata*) and legumes (Leguminosae sp.) are present in all samples when we examined the frequencies of occurrence of taxa per sample (fig. 7). This reveals the importance of mountain vegetation, observed in Survey 4 with the detection of *Juniperus* sp., *Ilex aquifolium*, *Quercus ilex-coccifera* and *Cistaceae* sp. This mountain vegetation defines an altitudinal gradient of vegetation together with an anthropogenic impact, revealed by the presence of shrubs and bushes (*Cistaceae*, *Leguminosae*, *Arbutus unedo* and Labiatae sp.). There is also evidence of elements associated to valley bottoms along watercourses (*Fraxinus* sp.). The isolated finds of *Picea/Larix* (abies/larch) and *Ceratonia siliqua* (carob tree) are difficult to interpret. An explanation for the first would be its mountainous nature. The second one could possibly be cultivated to feed the livestock.

The 2009 anthracological samples come from the following contexts: Elephants' Frieze (OK4 area), Abadsan or Elephants' Shelter (OK7 area), the funerary context of tumulus 2 (Zone OK5) and Context 700 (Zone OK1'). Where possible, these samples have been introduced into a sequence, using absolute dating and material contexts that appeared in each intervention. This allowed us to build a general -and provisional- overview reflecting the vegetation changes inferred from the anthracological data from Oukaïmeden Valley. This overview goes from Neolithic to modern times, with large time gaps yet to be filled.

A total amount of 866 charcoal pieces were analysed in the 2009 campaign, through which we obtained 12 taxonomic determinations: The main results can be summarized according to each of the archaeological contexts:

Elephants' Frieze (OK4): The identified remains belong to historical times. Datings reveal that they could belong to late antiquity (see above this book). The presence of different types of vegetation can be explained by varied gathering of firewood. This reveals the presence of montane elements (*Juniperus* and *Taxus baccata*), montane or submontane (*Quercus ilex-coccifera* and cf. *Quercus suber*) with *Cistaceae* shrubs and Leguminosae and riparian vegetation (*Populus/Salix*) associated to them (table 3).

Abadsan Shelter (OK7): We used 7 samples to determine the different chrono-cultural phases (Table IV) of this shelter. From SUs 203 and 205 (947 ± 44 years BP / 1010-1210 calAD), related to Almoravid/Almohad chronology, the few determined remains did not allow a quantitative assessment. Nevertheless, its taxonomic richness (7 determinations) should be noted. Something similar occurred in the SU 209 (related to an imprecise time of antiquity). However, even with a greater number of charcoal samples, there were very few determinations (two taxa). The SU 213 (4009 ± 51 years BP / 2680-2340 calBC) is the richest and its chronology reveals an imprecise moment in the Late Neolithic-Copper Age. Except for SUs-209, the data allows us to detect different formations. The first is of mountainous nature (*Juniperus*, *Ilex aquifolium* and *Taxus baccata*). This would have been followed by a submontane oak forest (*Quercus ilex-coccifera*), with riparian vegetation growing in the rivers and stream valleys (*Fraxinus sp*). In principle, its composition is very similar to Elephants' Frieze vegetation, showing the diversity of spaces used by human groups to travel and collect firewood. In addition, while considering the quantitative limitations of the historic-period samples, sequence information could help us to unravel the evolution of vegetation around the shelter. It shows a clear process of alteration of the oak forests, which were very scarce in Almoravid/Almohad times, associated with an increase of shrub taxa (strawberry tree or legumes) and a slight recovery of holm oak forest. The presence of ash trees indicates the relevance of riparian valley bottoms. Its greater abundance in the Almoravid period could be the result of a necessity to gather this kind of firewood in this ecotope, due to the scarcity of oak trees.

Tumulus 2 at the *Igountar Pass* (OK5): In a single sample we detected *Juniperus* (5 fragments/16.67%), *Quercus ilex-coccifera* (3 fragments/10%), Leguminosae (20 fragments/66.67%) and *Cistaceae* (2 fragments/6.67%), confirming the presence of the dominant taxa found in other records.

Context-700, OK1'(SU 703). Findings done at C-700 belong the Bronze Age (CNA-938; 3200 ± 39 years BP / 1540-1400 calBC and CNA-940; 3143 ± 31 BP/1500-1300 calBC). The 420 charcoal fragments have allowed identification of *Juniperus* sp. and *Taxus baccata* as the main relevant taxa of this high mountain vegetation. The high values of *Quercus ilex-coccifera* and -even higher- Leguminosae sp. indicate the presence of holm oak forests that would have been the expression of human impact at that time. Serial and substitutive phases may be relevant, manifesting the relative and higher quantitative importance of legumes, sometimes accompanied by *Cistaceae*. Alongside these species we find a kind of prunus that could be part of the vegetation traditionally present in these formations (table 5). The absence of vegetation associated with watercourses could be due to micro-biogeographic parameters of the environment on Survey 2, or a low presence of these kinds of formations during the Second Millennium BC.

Discussion

The characteristics of the events mentioned above -in the Introduction- can be recognized in the Oukaïmeden sequence. This sequence provides further evidence of climate variability over the last millennia of the Holocene, usually masked by human impact and by the low resolution records for the end of the Holocene (Desprat *et al*., 2003). Although the symptoms of human impact on the landscape can be detected from the beginning of the pollen diagram, both the evolution of taxa clusters with the same ecological affinity and the discrimination of axis 2 of PCA have proven to be very useful to detect climate changes (See fig. 3).

The consistency between the information provided by pollen and anthracological data, both in terms of composition and changes, enable the reconstruction of the vegetable landscape over the last 5147 ± 55 years BP (4050-3780 calBC) in the Oukaïmeden Valley (See figs. 2). While 14C datings show ages around 4050-3780 cal years BC (5147 ± 55 BP), the initial phases of the pollen and anthracological record starts developing from 2680 to 2340 cal years BC (4009 ± 51 BP). From this moment until 1500-1370 cal years BC (3143 ± 31 BP) the data show the development of an open landscape mainly consisting of xeric and -to a lesser extent- nitrophilous herbaceous taxa. The low arboreal cover detected in the sequence would have consisted of small forests of *Juniperus* and *Pinus*. The Mediterranean taxa grew at lower heights while riparian taxa were present in the valley bottoms, sometimes accompanied by deciduous species. At that time there was a clear use of the wood belonging to these taxa, as well as of *Taxus* and *Ilex*, which couldn't be detected in pollen analysis. The presence of Mediterranean and riparian taxa in the forest increased from 2790 ± 30 to 1970 ± 38 years BP (1010-840 cal BC to 50 cal BC-130 cal AD), although the forest shows an overall reduction. This accounts for the greater humidity in the landscape. At this moment, there is greater presence of the shrub stratum, which could be caused by further exploitation of the mountain vegetation. Dry conditions returned from 50 cal BC-130 cal AD to 380-540 cal AD (1970±38 to 1615±30 BP), associated with an increase of xeric taxa. An increase in humidity is detected from 420-570 cal AD to 650-780 cal AD, (1560 ± 30 to 1310 ± 30 years BP), associated with a higher presence of nitrophilous and riparian plants. Cistaceae increased simultaneously, possibly due to a higher incidence of grazing exploitation of the forest. From 650-780 cal AD to 680-880 cal AD (1310±30 to 1240 ± 30 years BP), a new expansion of xeric plants defines a dry period. The expansion of aquatic, Mediterranean, riparian, nitrophilous and *Juniperus* taxa should be noted from this time until 1390-1450 cal AD (511 ± 28 years BP), while the previous trend -alternating drier stages associated with the expansion of xeric taxa- continued. Finally, from 1390-1460 cal AD (495±35 BP) xeric plants dominate the record. This is followed by an increase in Cistaceae and -later- nitrophilous taxa, along with a significant reduction of *Juniperus* and the rest of arboreal taxa.

This vegetation developed during alternating dry and wet phases, with a strong presence of human activity, evidenced by the use of the land for livestock activities, mainly. We observe a growing environmental and anthropic impact as we move forward in time. It is broadly reflected in the anthracological diagram by the decrease and even disappearance of sensitive species such as yew and holly tree in high mountains and an increased use of holm oak forests for firewood. The progressive decrease of *Quercus* and a corresponding increase in the diversity and number of species of shrubs and bushes that replaced it should also be noted. Among those species we find legumes, perhaps favoured by man since their continued presence ensured nitrogen-fixation that improved grazing productivity and palatability. No wood from valley banks and ravines has been found since the Bronze Age.

We can also determine the limits of the incidence of livestock activity from the presence of spores of *Podospora* (Type 368) (fig. 2), a coprophilous fungus that lives on the faeces (Geel 1978; Geel *et al.* 1983, 2003) and indicates local (not regional) establishment of livestock (López *et al*. 2000; López and López 2007). This use may also be related to the widespread presence of *Neurospora* spores (figs. 2-3) a charcoal-growing fungus used as an indicator of fire (Geel 1978; Kuhry 1985). These fires were probably anthropic when, as in this case, there is a close relationship between their presence and the anthropic landscape (López *et al*. 1998, 2000). These fires were used to create the landscape, favouring the proliferation of *Glomus* cf. *fasciculatum* chlamydospores, an indicator of erosive processes (Geel *et al.* 1989). The absence of cereal pollen in our sequence can be explained as a result of a temporary settlement in this territory, mainly used for livestock grazing. It should also be noted that nowadays the wet grasslands of the Oukaïmeden plateau have a great grazing value. Indeed, the studied area corresponds to a collective pasture called *Agdal*, a traditional and institutional form of collective management of livestock grazing in the High Atlas (Mahdi 1999). This particular and traditional management of the area and its resources consists of limited access rights and/or use of these rights (Ilahiane 1990; Auclair 1998), which allows renewal of the environment and guarantees resource sustainability.

Previously, the climate of the first half of the Holocene in the Middle Atlas (Tigalmamine site, Chedadi *et al.* 1998) is considered a warm and dry period. It was not until the Middle Holocene (Lambs and Kaars 1995) that the temperature started fluctuating, with short dry periods, due to lower rainfall in winter. This caused a significant drop in arboreal taxa, associated with a large increase in Poaceae (true grasses). This indicates anthropization of the environment due to grazing and agriculture. Despite the absence of 14C datings, the study carried out in Tighaslant (Bernard and Reille, 1987), stars the climate sequence in the Boreal phase, characterized by the development of a thick forest where *Pinus* was replaced with Algerian oak (*Quercus canariensis*) as the most significant development. According to the authors, forest cover retreated after the phase known as the Subboreal phase. The forest, which consisted of *Quercus* and *Olea*, suffered a major withdrawal (20-30%) during the Subatlantic phase, associated with the increase of *Cistaceae* (rockrose), P*oaceae* (true grasses), *Asteraceae* (compositae) and *Plantago* (plantago). These changes are interpreted by the authors as the result of human impact on the environment, due to the arrival of Arabic populations.

Regarding the impact of human activity, the vegetation study conducted in *Ifri Oudadane* (Morales *et al.,* 2013) has revealed epipalaeolithic landscapes characterized by a great presence of *Quercus*, riparian and other Mediterranean taxa, and an under-representation of nitrophilous taxa. This landscape changed during the Neolithic. Thereafter, open landscapes were dominated by shrub vegetation and there are many indicators of pastoral activity along and the presence of cereals. Nevertheless, the growth of wild plants would have been the financial support in the diet, given its content of basic nutrients, which are common around the Mediterranean forest. These events would have occurred in areas were seasonal settlements took place, aiming to maximize resources. Thus, crops may have played a marginal role.

Conclusions

The analysis of both anthracological pollen and non-pollen microfossils from the extracted sequence of eight records (four from archaeological sites and four from natural deposits) in Oukaïmeden (Morocco) has shown sensitivity to both climatic and anthropogenic changes. The development of vegetation and fluctuations of component 2 of the analysis have revealed the existence of alternating wet and dry phases, along with two milder phases that favoured the development of relatively thick forests around 1970 years BP (50 calBC - 130 calAD) and after 1013 years BP (940-1160 calAD). A major factor in the growth of this vegetation was the high-altitude Mediterranean mountain climate, mainly dry. Human activity is revealed by the presence of charcoal, which acts on vegetation, as well as livestock pressure, detected through pollen. Nevertheless, it is possible to infer humidity fluctuations in five phases with a greater development of forests indicating more humid conditions in OK-IX, OK-VII, OK-V, OK-III and OK-I. In OK-V, a phase subsequent to 680 -880 calAD (1240 ± 30 years BP) should be noted. During this phase, forest development reached the maximum of the sequence with values close to 60%, along with significant diversity, with walnut trees as the dominant element of the forest.

Human activities around the site have been detected from the beginning of the sequence and they affected the territory either directly (deforestation) or indirectly (grazing, frequent use, etc.). Such practices increased after 1010-1210 calAD (947 ± 44 years BP), since most human-nitrophilous elements significantly increase from that time, while arboreal taxa curves are more discontinuous and irregular, indicating a gradual increase in forest withdrawal. Meanwhile, woody formations decreased significantly, which favoured the presence of open areas where formations of true grasses for grazing prospered, indicating greater grazing pressure from that time on. In addition, the pollen diagram shows human impact from the beginning and intensifying towards the end. This establishes the foundations of the landscape transformations that allow us to understand the current landscape of the studied area as a place highly valued for stockbreeding exploitation.

These conclusions are subject to evaluation. Nevertheless, they completely explain the anthracological data: we observed a progressive decrease in high mountain vegetation diversity with a progressive decrease of yew and holly tree, and a corresponding increase in *Juniperus*, which could correlate with the dominant and monospecific juniper forests present nowadays (Fromard and Gauquelin 1993). Also, the presence of deciduous elements associated with waterways is very well represented in the earliest phase of Oukaïmeden, which could correspond with one of the wet phases detected in the pollen sequence. Afterwards, this presence almost disappears from the rest of the phases represented in the anthracological sequence. This would have been complemented by a general decrease of holm oak forests and an increase in the amount and diversity of serial shrubs (some types of legume and cistaceae) associated mainly with the development of stockbreeding activities, proved with further evidence from pollen analysis.