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Holocene Environmental Changes In The Rif Mountains, Morocco

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ABSTRACT: After the last glacial period, the significantly increase of global temperature has dramatically impacted the ecosystems functioning. The aim of this study is to understand the impact of past climate change on vegetation especially on two emblematic species in Morocco which are *Cedrus atlantica* (Manetti ex Endl.) Carrière and *Abies maroccana* Trabut. Here we present the results of 8.5m fossil record collected in the western part of the Rif Mountains covering more than 9000 cal BP years. The age model is based on 10 AMS ^{14}C dates. Pollen content, charcoal remains, particles size, and some geochemical elements were analyzed. Besides the geological coring, a series of surface samples from Talassemtane National Park towards our coring site were collected to determine the range of pollen transport. The fossil record showed that Atlas cedar was strongly present since the early Holocene; however, after 6000 cal BP it declines aggressively due probably to a climate change and their replacement with more drought-tolerant evergreen species, then disappeared from the studied site at about 2000 cal BP. The Moroccan fir was not recorded during the Holocene except for few pollen grains during the last 1000 years probably transported from few fir populations that were present not far from the studied site. This hypothesis was confirmed by the modern samples showing that fir pollen is transported on very short distances. The overall data tend to suggest that the decline of Cedar forests in the Rif is probably related to natural factors rather than to anthropogenic activities.

Keywords: Holocene; Morocco; Rif; climate change; *Cedrus atlantica; Abies maroccana*

1 INTRODUCTION

Mediterranean forests are regarded as biodiversity hotspots with an important number of endemic species (Myers, et al., 2000; Bolle, 2003; Blondel, et al., 2010). They are highly heterogeneous because of the occurrence of different bioclimatic and geomorphologic factors. Mediterranean forests are also often fragmented either naturally or because of human activities (Barbero, et al., 2001; Quézel and Médail, 2003; Linares, et al., 2011). Morocco climate, as part of the Mediterranean biome, is influenced by the Atlantic Ocean, the Mediterranean Sea, and the southern Saharan climate (Fig. 1). Such multiple origins of climates have shaped Moroccan ecosystems and have probably contributed to maintain high species diversity over the past thousands of years.Environmental changes over the last few millennia in Morocco have been recovered from different proxies such as pollen (Reille, 1976, 1977; Lamb, et al., 1989, 1991, 1995, 1999, Cheddadi, et al., 1998, 2009; Muller, et al., 2014; Nour El Bait, et al., 2014) and geochemistry (Benkaddour, 1993; Zeroual, 1995; Rhoujjati, et al., 2010; Damnati, et al., 2012; Reddad, et al., 2013). These studies have focused mainly on the Middle and the High Atlas mountains. Two studies on the Holocene records are located in the Rif Mountains (Reille, 1977; Muller, et al., 2014). Muller, et al., (2014) revived the work of Reille (1977) with a new fossil core reaching 130cm deep and covering 5000 cal BP. They provide valuable information on ecosystem changes and species dynamics which may help defining key areas for conservation (Zanchetta, et al., 2013). Besides such weak historical information, the Rif Mountains harbor a high contingent of endemic species (Benabid, 1984) that largely rationalize new paths for environmental studies in this area. In fact, biodiversity hotspots are biogeographic zones with high biodiversity wealth and high endemism which are particularly threatened by human activity. Northern Morocco is part of the biodiversity hotspot areas identified in the world (Myers, et al., 2000). It has a prominent role in biological conservation (Brooks, et al., 2002). The Rif Mountains in Morocco fit the biodiversity hotspots criteria with two temperate conifer tree species: *Abies maroccana* Trabut (Moroccan fir) and *Cedrus atlantica* (Manetti ex Endl.) Carrière (Atlas cedar). Today, both species are considered as endangered according to the IUCN Red List (IUCN 2014). In Morocco, there are national parks and reserves such as Tazzeka in the Middle Atlas and Talassemtane in the Rif, to *in situ* long term protection and preservation of endangered species. However, some populations undergo multiple stresses, they are excessively exploited for their timber; their sprouts are grazed by cattle, in addition to the observed aridity (Till and Guiot, 1990) causing reduction of their natural range and even the full extinction of several populations in the Rif Mountains (Benabid, 1984, 1991). The time frame is an important element as it helps tracking environmental events over different periods which may provide evidences of a climate change (Sadori, et al., 2011). The low number of well dated fossil records from northern Africa prevents us from analyzing the spatial patterns and ultimately making comparisons with southern Europe and Middle East edges of the Mediterranean. In the Mediterranean basin the past environmental changes have been associated with either climatic trends or human activities (Di Rita and Magri, 2009; Finné, et al., 2011; Carrión, et al., 2004; Mercuri, et al., 2011; Damnati, et al., 2012). During the late Holocene, a progressive climate aridification was recorded, creating critical climate oscillations and an increasing ecosystem instability (Mercuri, et al., 2012; Sadori, et al., 2013). This has been strengthened by the more recent human activities (Sadori, et al., 2013; Muller, et al., 2014; Cheddadi, et al., 2015). Throughout the Mediterra-

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nean basin, networks of well dated fossil records would allow to depict potential delays and asynchronism between different areas (Carrión, et al., 2010). Broad scale vegetation changes have been synthesized from approximately 200 sites located in southern European covering 6000 cal BP (Collins, et al., 2012). This spatial reconstruction showed that at 6000 cal BP, *Olea*, *Fagus* and *Juniperus* had smaller distributions as today while *Abies*, *Cedrus* and *Quercus* (deciduous and evergreen) became less abundant following the mid-Holocene. After 6000 cal BP, cultivated olive trees spread over the Eastern and Northern edges (Besnard and Bervillé, 2000; Terral, et al., 2004; Breton, et al., 2006; Besnard, et al., 2007; Di Rita and Magri, 2009). In Morocco, the expansion of cultivated olives took place probably much later (Ballouche and Marinval, 2003). The aim of the present work is to analyze the environmental changes and their impact on the ecosystems from a very well dated, continuous and high resolution fossil record that was collected from the western part of the Rif Mountains. Several proxies were used for an optimal and synthetic analysis of the environmental changes over the Holocene.

2 Materials and methods

2.1 Site description

The studied site, dayet Bab El Karn (BEK) (Fig. 1; Fig. 2) is a mire outlet located in the south-west of Talassemtane National Park at 1178m of elevation, in the western Rif. It is located about 28 km south-east of Chefchaouen town and about 6 km south-west of the rural district of Bab Taza.

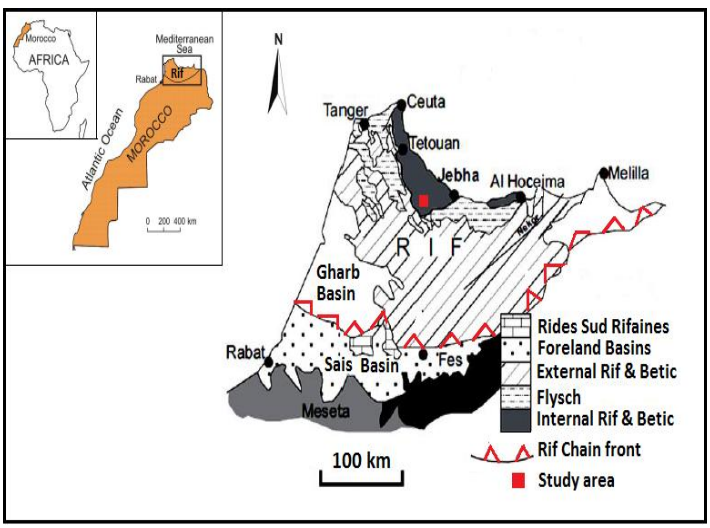

Fig. 1: *Map showing the Location of Morocco, the Rif Chain Mountain and the studied area*

The Rif Mountains form a part of the western segment of the Alpine belt formed under a convergence between the African and the Eurasian plates during the late Mesozoic. The Rif belt includes three major paleogeographic domains: the Internal domain called "Alboran domain" (García-Dueñas, et al., 1992; Negro, et al., 2006); the Maghrebian flysch domain (Guerrera, et al., 1993) and the External domain (Chalouan, et al., 2008). The studied site is located within the Alboran domain which is composed of calcareous complexes (Chalouan and Michard, 2004; Chalouan, et al., 2008). Such geological background helps interpreting the geochemical data of the fossil record. The Rif Mountain is characterized by a humid to sub-humid bioclimate. Nowadays, the average annual precipitation in the Rif's belt is about 600mm and it can reach locally 2100mm. Such amount of precipitation allows development and persistence of forest ecosystems with inner mires. The eastern part of the Rif that receives less rainfall is widely covered by *Pinus halepensis, Pinus pinaster* and *Tetraclinis articulata* (Atlas cypress) known to be more drought-tolerant species than firs and cedars. Around the BEK site, the catchment basin is covered by an oak forest with deciduous species (*Quercus pyrenaica* and *Quercus canariensis*). The sclerophullous *Q. ilex ssp. Rotundifolia and Q. coccifera* are much less abundant than other oaks. Evergreen oaks (*Quercus suber*) are very abundant in the region but present at lower altitude. The endemic *Abies maroccana* forms splendid landscape on the Limestone reliefs of Chefchaouen and Tazaot and it may be found at about 5 Km away from the studied site in the national parc of Talassemtane (Chefchaouen) where it is mixed with *Pinus* and with Atlas cedar on the mountain summits (Fig. 2; Fig. 3). In the BEK bog, we can enumerate many aquatic plant species such as *Sphagnum, Trifolium, Ranunculus, Geranium* and *Characeae.*

2.2 Coring, Laboratory and data analysis

In March 2012 we collected 8.5 meters coring in Dayet Bab El Karn (BEK) (Fig. 2) at 35° 01.364' N, 05° 12.412' W; 1178 m a.s.l using a Russian corer. At the same time, we collected eight surface samples along with a geographical transect from Talassemtane National Park where *Abies maroccana* dwells towards BEK site (Fig. 3). Ten samples of 1cm^3 were extracted from the sediment and dated with 10 AMS ^{14}C dates (table 1). The dated material varies depending on the core composition. The BEK core is mainly composed of bulk with peat deposition at many levels (e.g. 570-550 cm, 500-460 cm; 415-380 cm and 280-265 cm). The biggest piece of wood is found between 240 and 230 cm. the bottom of the core (from 750 to 850 cm) is composed by organic sand. The ^{14}C dating results were calibrated using CALIB 7.0 software (Stuiver, et al., 2013).

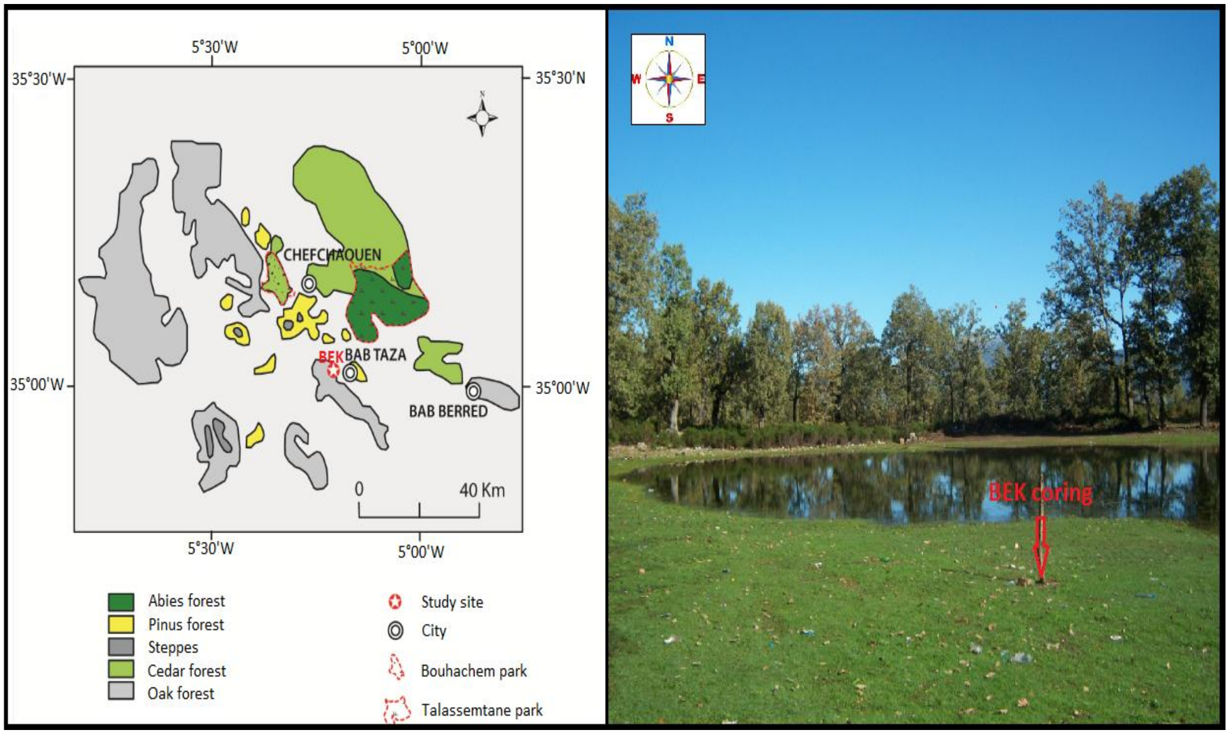

Fig. 2: *Phytoecological map and picture showing the location of the studied site (Bab El Karn) within Oak forest*

Fig. 3: Map showing the location of surface samples between the Talassemtane National Park in the fir forest (TA 01) and the studied area BEK (TA 08). These modern sample are not equidistant and their elevations are: TA01: 1563m a.s.l; TA02: 1498m a.s.l; TA03: 1350m a.s.l; TA04: 1284m a.s.l; TA05: 1142m a.s.l; TA06: 1150m a.s.l; TA07: 1043m a.s.l and TA08: 1178m a.s.l

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To establish a chronological framework for the sedimentary sequence we developed an age / depth model using the Clam software package (Blaauw, 2010) (Fig. 4). The Bab El Karn fossil record was used for analyzing pollen grains, micro-charcoals, sediment grain size and geochemical elements using XRF tool. We analyzed the pollen content of 92 samples. The pollen extraction was performed using the following procedure: HCl (10%) to remove carbonates, KOH (10%) in a water bath to remove soluble humic acids, zinc chloride ($ZnCl_2$, density between 1.7 and 1.8) to separate the organic fraction from minerals, acetolysis (1ml of sulfuric acid + 9 ml of acetic anhydride) in a water bath to destroy the remaining most resistant humic fraction (pollen grains are resistant to acetolysis when acetolysis does not exceed 2min), KOH and then ethanol to decrease the pH. The final residue is diluted in glycerine (usually 10%) for mounting microscope slides. The identification and counting of pollen grains was performed under an optical microscope (Leica DM750) using x40 magnification (x63 for accurate identification). The number of pollen grains counted exceeds 200 grains for fossil samples and 600 grains for modern ones (surface samples). Aquatic plants and *Cyperaceae* were excluded from the total pollen sum. The counting of micro-charcoals (10 to180µm) was performed on the same slides. Micro- and macro-charcoals allow reconstructing the history of fire at both regional (10 to 20 km) and local (10 to 103 m) scales (Clark, 1982; Reddad, et al., 2013). Results of these analyzes are presented in the form of a pollen diagram plotted with Tilia 1.7.16 software (Fig. 5; Fig. 6). The analysis of sediment grain size was performed at the Geosciences laboratory of Montpellier with a laser particle sizer (Coulter Beckman LS13 320) at each 5 cm interval. Samples were dissolved in distilled water to homogenize the sediment and then the solution is poured into an aqueous liquid module for determining the size of particles using diffraction by a laser light emitted by a spindle. A total of 170 samples were analyzed. This analysis is used to classify the particles into three categories: clay (0.375-2µm), silt (2-63 microns) and sand (63-2000 microns) (Fig. 7). In order to evaluate the geochemical composition of the sequence we used the technique of X-ray fluorescence spectrometry (XRF). The analysis was performed every 5cm interval on 170 samples. XRF analysis allowed us to obtain the concentrations of 23 elements: Si, Al, Fe, Mn, Mg, Ca, K, Ti, P, Cl, S, Ba, Nb, Zr, Sr, Rb, As, Pb, Zn, Cu, Co, Cr and V. Only concentrations of few elements (S, Ca, K, Fe, Al and Si) were used since they provide the most appropriate information for this study (Fig. 8).

3 Results

3.1 Modern data

The surface samples collected between Talassemtane National Park (Fig. 3: TA01) where fir forest (*Abies maroccana*) exist today with *Pinus* and the site BEK (Fig. 3: TA08), were gathered in a pollen diagram (except aquatic plants and pollen with very low percentages) (Fig. 5). Taking into account that the modern samples are not equidistant, the diagram shows that high pollen percentages of arboreal taxa such as *Abies maroccana*, *Quercus* (evergreen and deciduous) and *Pinus* are recorded in the fir forest (Talassemtane National Park) (TA01) which represent the Rif densest fir population, an exception is recorded for deciduous oaks for which the percentage is more important in the BEK site (TA08). Atlas cedar, not recorded in pollen sum, is located at altitudes slightly

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Table 1: *Radiocarbon ages for the Bab El Karn core. Calibrations were carried out using CALIB 7.0 software (Stuiver et al. 2013)*

Sample	Depth (cm)	Dated material	Lab. code	^{14}C ages (BP)	Calibrated age (Cal BP, 2 δ)	Cal BP (median probability)
BEK01	19	Bulk	Poz-46693	460 ± 30	483 - 537	513
BEK02	84,5	Bulk	Poz-46694	1225 ± 30	1065 - 1188	1154
BEK03	140	Bulk	Poz-46695	2570 ± 35	2695 - 2758	2719
BEK04	164	Bulk	Poz-46696	3320 ± 35	3464 - 3637	3545
BEK05	235	Wood	Poz-46699	3750 ± 40	3984 - 4184	4111
BEK06	257	Bulk	Poz-46700	4075 ± 35	4499 - 4649	4569
BEK07	387	Peat	Poz-46703	4240 ± 35	4805 - 4865	4826
BEK08	406	Peat	Poz-46704	4545 ± 35	5052 - 5190	5160
BEK09	516	Bulk	Poz-46706	6040 ± 40	6784 - 6997	6889
BEK10	845	Organic sand	Poz-54212	8140 ± 50	8997 - 9154	9085

higher and its dispersion is not large. For *Olea,* the pollen percentage increases when we move away from the national park together with the increase of both *Cistus* and *Cupressaceae* explaining the opening of the forest and the decrease of *Abies* and *Pinus*. The Pollen percentage of *Abies maroccana* decreases to disappear completely before reaching the BEK site. Pollen percentages of *Quercus* (evergreen and deciduous) are highly significant along the fir forest to the site BEK but it declines slightly in more opening landscapes.

3.2 Fossil data

The BEK pollen record (Fig. 6) spans the last 9000 cal BP. Twenty-nine trees, shrubs and herbs, and four aquatic taxa were identified. The most common tree taxa are Atlas cedar; evergreen and deciduous oaks (Fig. 6). The dynamic of these plant taxa and the cluster analysis allowed us to define four zones: from 848 to 620 cm / 9163 to 7000 cal BP (zone A), from 620 to 400 cm / 7000 to 5600 cal BP (zone B), from 400 to 125 cm / 5000 to 2500 cal BP (zone C) and from 125 to 0 cm / 2500 to present (Zone D).

Zone A (from 848 to 620 cm / 9163 to 7000 cal BP): Fossil pollen data showed that Atlantic cedar**;** evergreen and deciduous oaks were dominant in this period (Fig. 6), while *Cedrus atlantica* started to flourish after 8000 cal BP. The grain size analysis (Fig. 7) showed that the core bottom is composed essentially of sand (up to 65%), silts (25%) and clay (5%). Moving up the time frame, the Sand progressively was replaced by the silt. Most chemical elements were low except Potassium (K), iron (Fe) and Ca (Carbonate) that showed important values at the base of the sequence with a significant decrease after 8000 cal BP (Fig. 8). No micro-charcoal was detected in this period (Fig. 6).

Zone B (from 620 to 400 cm / 7000 to 5600 cal BP): Substantial expansions of *Cedrus atlantica* were observed with a peak at 6000 cal BP (up to 80%), before a sharp decline (Fig. 6). After 6000 cal BP, oaks are established and grew at the expense of *Cedrus atlantica*. Pollen of steppe vegetations were also recorded (*Asteraceae, Artemisia, Pistacia and Apiaceae*), while pollen of Aquatic species as *Ranunculus* and *Myriophyllum* totally disappeared from the studied site in this period. After

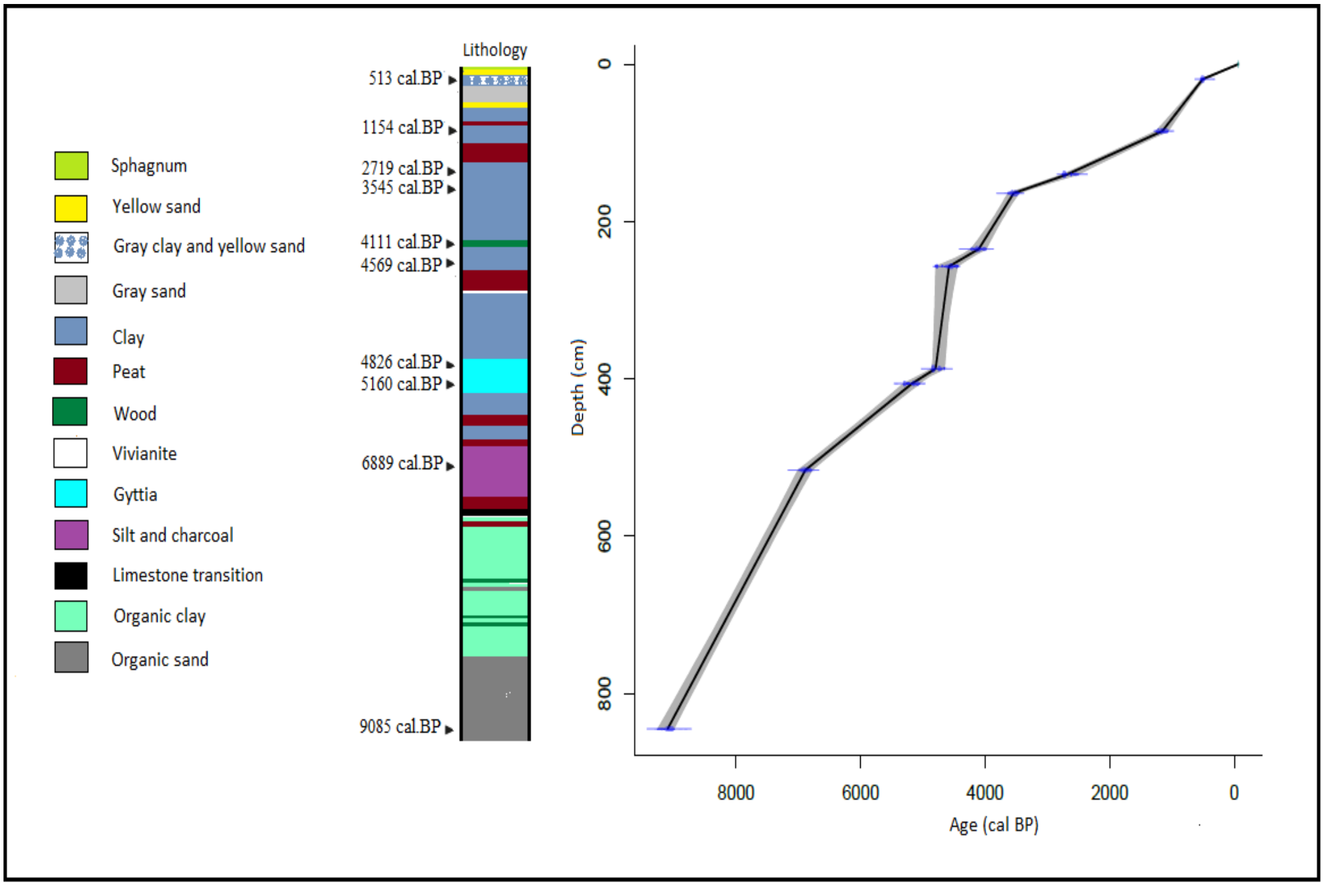

Fig. 4: *The age/depth model with a schematic stratigraphy of the coring*

6000 cal BP, some pollen of *Olea* appeared in the area (Fig. 6). Micro-charcoals were at low concentrations in the beginning of this period, and then increased synchronously with the regression of *Cedrus atlantica* and with the appearance of *Olea* (Fig. 6). Particle size showed important detrital silt input (Fig. 7) and the sediment composition becomes more organic with peat deposition at 6000 cal BP (Fig. 6).

Zone C (from 400 to 125 cm / 5600 to 2500 cal BP): *Cedrus atlantica* and oaks were stabilized within the levels of early Holocene (up to 20% for Cedar, 60% for deciduous oak and 30% for evergreen). *Olea*'s pollen was always present with a significant sharp peak at around 2900 years (Fig. 6). The Sediment composition was organic with peat deposition at around 4400 cal BP. Unlike the sandy fraction, silt and clay increased slightly (Fig. 7). Chemical elements tend to increase after 5000 cal BP; Sulfur showed noticeable peaks at around 5500 cal BP (Fig. 8) with a maximum value at 4000 cal BP when K, Ca, Al and Si showed noticeable peaks (Fig. 8). The micro-charcoals were abundant during this period especially between 4000 and 3000 cal BP when *Cistus* was also recorded (Fig. 6).

Zone D (from 126 to 0 cm / 2600 to present): The event characterizing this period was the disappearance of *Cedrus atlantica* (Fig. 6). Oaks (evergreen and deciduous) were abundant until now especially deciduous representing a percentage of 60% (Fig. 5). *Cistus was* substantially developed (Fig. 6). Except for Sulfur that did not showed any significant values, the other chemical elements were highly produced throughout this period (Fig. 8). Effectively, K showed several peaks from 2000 cal BP to the present day, while Fe, Si and Al reached their maximum at around 1000 cal BP and Ca reached it maximum at 2000 cal BP. After 2000 cal BP, sediment composition passed abruptly from small sized particles (clay and silt) to coarser sand (Fig. 7). Micro-charcoals were present with important concentrations until 500 cal BP, after this date no micro-charcoals were recorded (Fig. 6).

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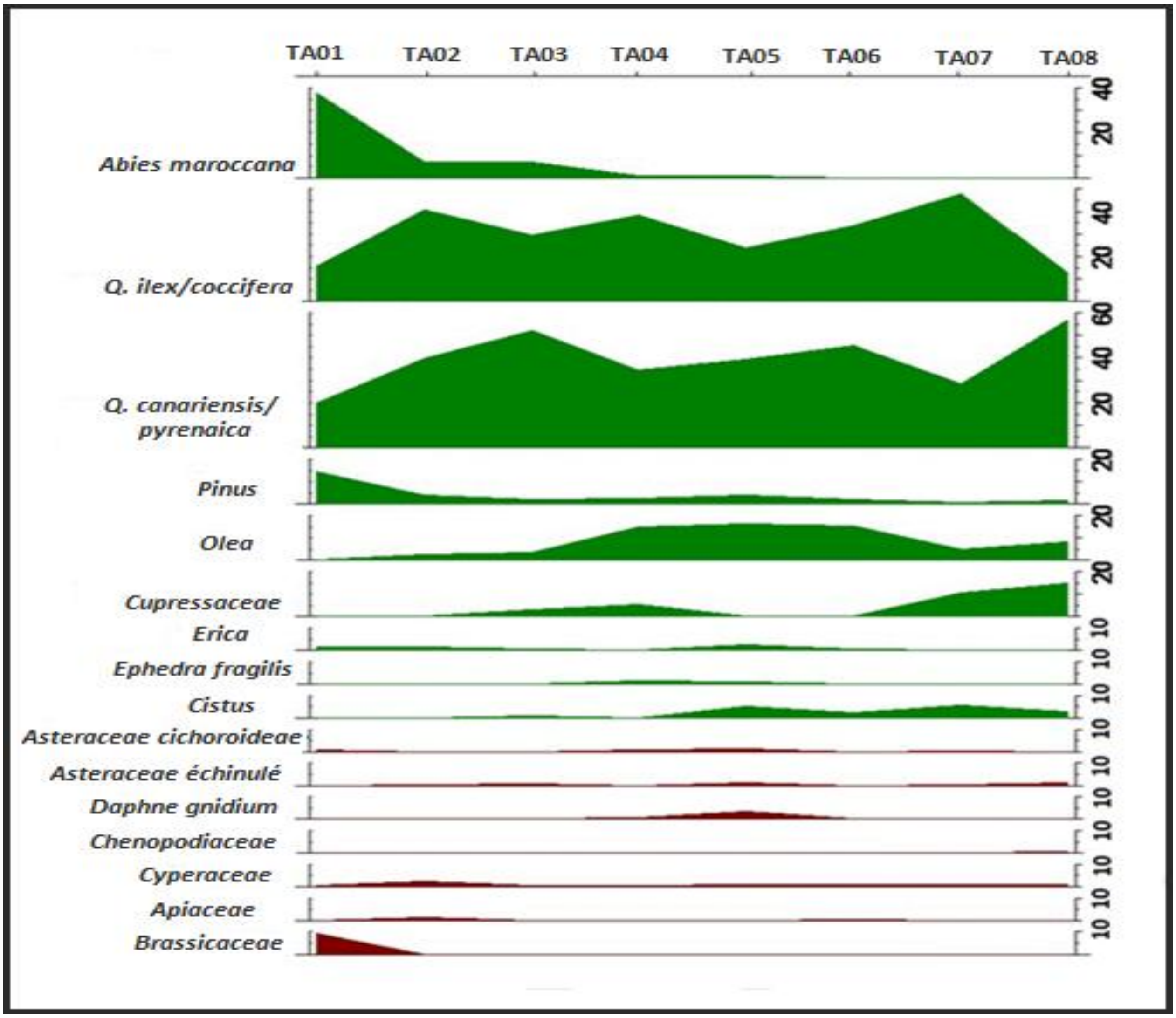

Fig. 5: *Diagram showing the percentage of main pollen taxa identified in the surface samples collected over a geographical transect between Talassemtane national park (TA01), from within the fir forest (Abies maroccana) and the site BEK (TA08). The distances between each surface sample are not equal*

4 Discussions

In order to improve the conservation policies and provide scientific sound basis for forest management actions, we need to better understand the relationship between the dynamics of *Cedrus atlantica* (Manetti ex Endl.) Carrière and *Abies maroccana* Trabut and their related past environments. In the present study we have explored the environmental impacts on the forests located in the western part of the Rif over the last 9000 years. The modern samples showed that fir pollen are not well wind transported as the pollen percentages decrease substantially over the first 2 km and are no longer found in more remote samples (Fig. 5). The pollen recorded in these remote samples corresponds to a very small population of *Abies maroccana* or to isolated trees suggesting that fir has never expanded beyond a range of 2 to 3 km during the Holocene. Fir pollen grains appear slightly only during the last 1000 years (Fig. 6). This may suggest that the isolated trees of *Abies maroccana* were not very far from the BEK site and the population of this species was denser than today and closer to the studied site. Nowadays, Bab el Karn is within a deciduous oak (*Q. pyrenaica*) forest and the closest Atlas cedar population may be found in the Bouhachem reserve at higher elevations. However, unlike fir, the high pollen input into the fossil record shows clearly that Atlas cedar forests were present around the site with probably a much more extended range during the Holocene than today (Fig. 5; Fig. 6). These cedar forests were mixed with both deciduous (*Q. pyrenaica, Q. canariensis*) and evergreen oaks most likely with *Q. ilex* (Fig. 6). The Algerian and Tunisian sites show an early Holocene dominated by deciduous oak (Ben Tiba and Reille, 1982; Salmani, 1993). Besides the strong presence of Atlas cedar and both deciduous (*Q. canariensis/ Q. pyrenaica*) and evergreen (*Q. ilex*-type) oaks throughout the Holocene (Fig. 6), we observe interesting changes in their proportions within the succession of pollen spectra through time and in the overall presence (and/or absence) of other taxa such as the aquatic plants (*Myriophyllum* and *Ranunculus*). These vegetation successions are accompanied by changes in the sediment texture and geochemical composition. Prior to 8000 cal BP, the sediment was composed of rather coarse particles such as sand (Fig. 7)

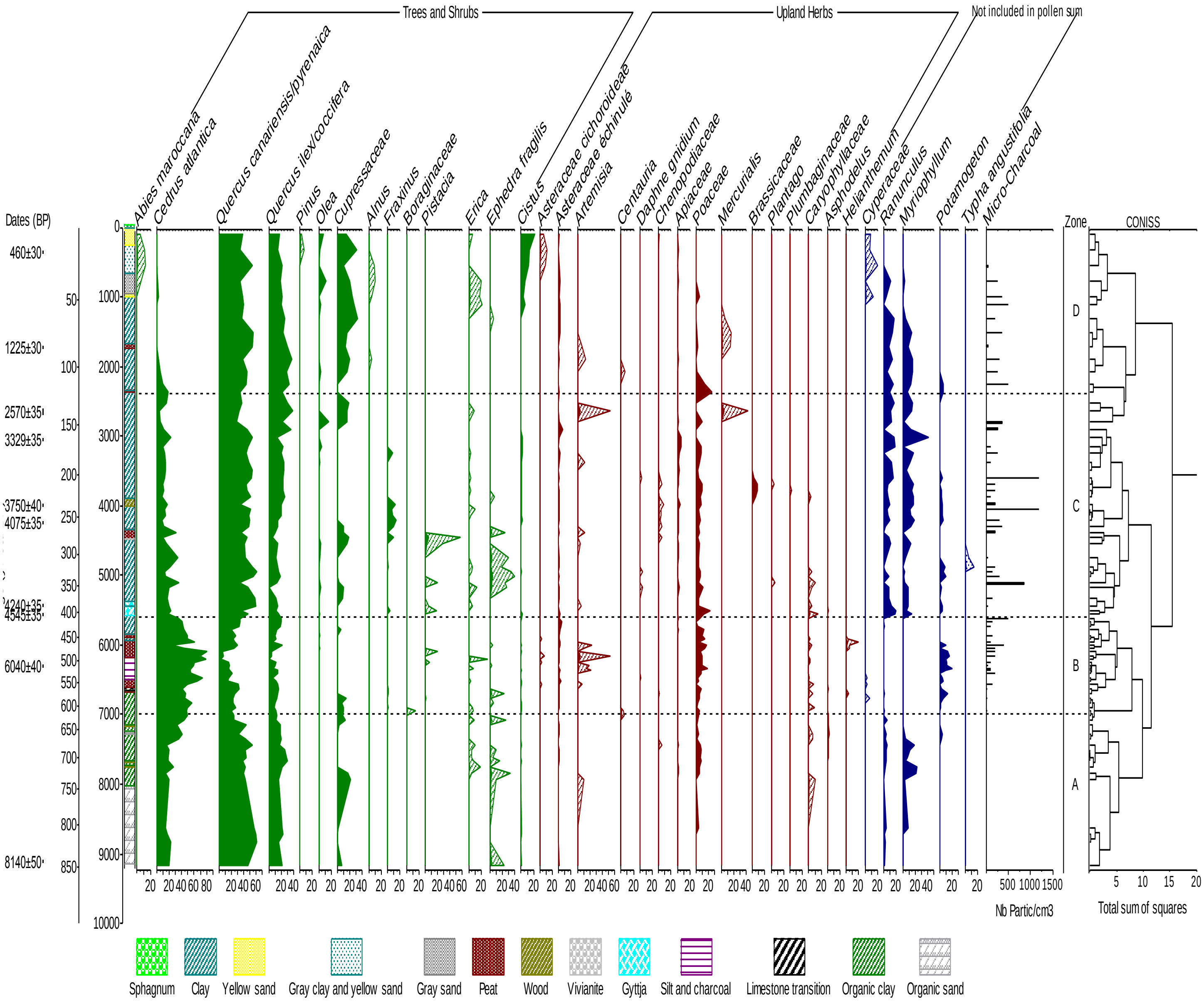

Fig. 6: *Diagram shows the percentages of the pollen taxa identified in the Bab El Karn record and the concentration of microcharcoals counted in the same slides containing pollen grains. An exaggeration (x 10) was applied for many species to be more visible: Alnus, Boraginaceae, Pistacia, Erica, Ephedra fragilis, Asteraceae cichoroideae, Artemisia, Centauria, Daphne gnidium, Chenopodiaceae, Mercurialis, Plantago, Plumbaginaceae, Caryophyllaceae, Asphodelus, Helianthemum and Typha angustifolia*

where iron (Fe) was one of the main geochemical elements (Fig. 8). These local environmental changes may be related to a stronger weathering of the catchment area, through an increase of the amount of rainfall, where the coarse and heavy particles are carried into the marsh. After 8000 cal BP a shift from sand to silt was observed (Fig. 7) and a decreasing trend of iron (Fig. 8) indicating a possible reduction of the terrigenous input due to the soil fixation favored by the expansion of *Cedrus atlantica* around 7500 cal BP.

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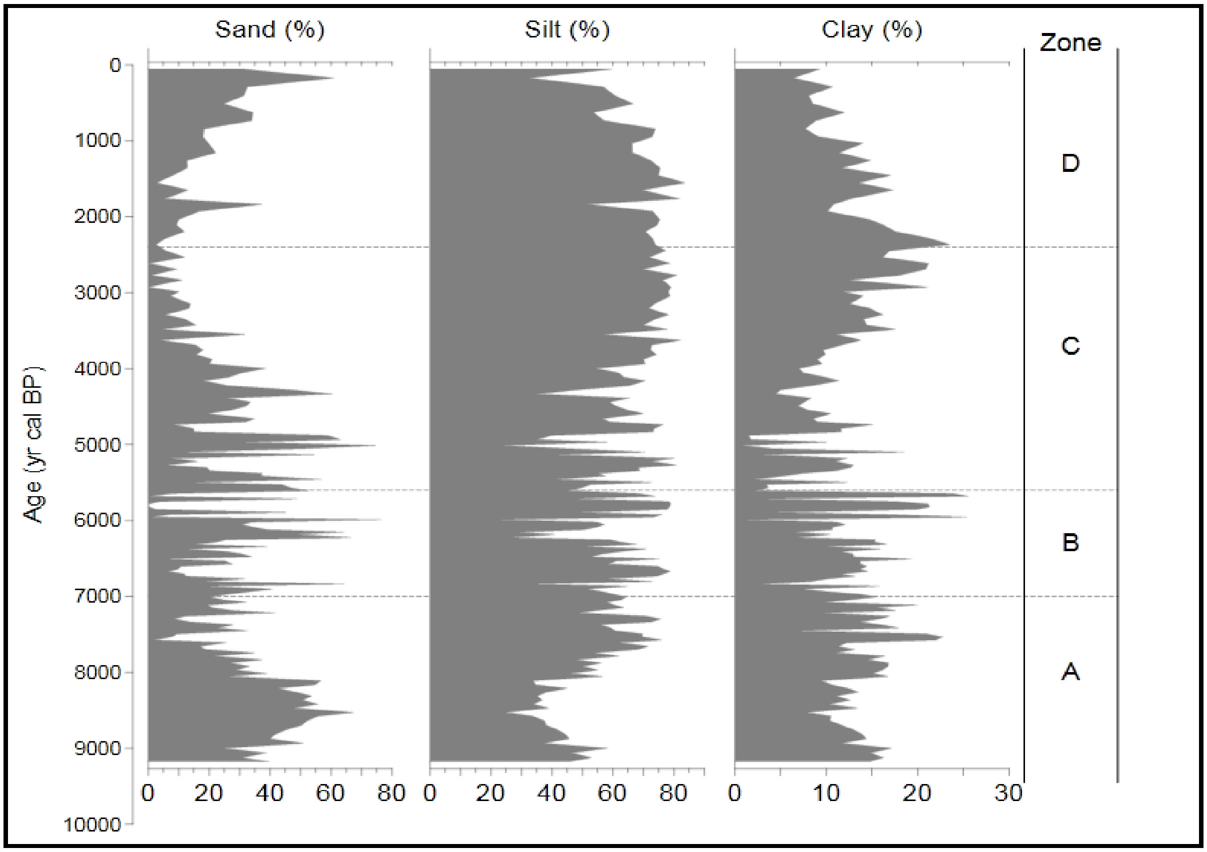

Fig. 7: *Grain size analysis showing the percentages of the main sediment fractions (clay, silt and sand), versus the coring age (years cal BP)*

The extension of *Cedrus atlantica* (Fig. 6), that may correspond to the highest population density around the site, reach their optimum around 6000 cal BP, then the oak forest expands. These changes in the forest composition between conifers, broadleaved deciduous and evergreen sclerophyllous trees in northeastern Morocco may be driven by different climate forcing. Thus, decline of the summer insolations after 8000 cal BP may be one factor causing a cooling trend with a decrease in the annual amount of precipitation (Lézine, 1989; Steig, 1999). The increase of microcharcoal (Fig. 6) suggests that the summer dryness led to local fires probably responsible for the replacement of *Cedrus atlantica* populations by evergreen and deciduous oaks. Indeed, fire can affect the forests directly by the degradation of the vegetation cover and indirectly by affecting the atmosphere through the carbon cycle perturbation once the fire is established, so it becomes a key element in climate change (Clark, et al., 1997). Roberts, et al., (2001) have suggested that the installation of the modern Mediterranean climate with warm and dry summers and frost free winters took place after 6000 cal BP. The Mediterranean climate with strong seasonal water availability had a strong impact on the lakes levels in the Mediterranean basin such for the Dead Sea which decreased steadily since 6500 cal BP (Robinson, et al., 2006) and the lake Eski Acigol in Turkey (Roberts, et al., 2001). Sediment composition becomes more organic with peat deposition at 6000 cal BP (Fig. 6) and minerals such as S and P (Fig. 8) with peaks after this date probably suggest a strong eutrophication potential of the lake. This may be related to human activities in the Rif where the Neolithic human presence has been detected between 8000 and 7000 cal BP (Ballouche and Marinval 2003) but at lower elevation compared to the BEK site. However, the BEK pollen record showed no appearance of any cultivated plants (e.g. *Olea* and *Linum*); this is probably due to the high altitude of the studied site that was not affected by a strong human impact on the environment. Thus, the regression of *Cedrus atlantica* after 6000 cal BP was mainly caused by an increase of aridity which started around 6000 cal BP, and then the forest degradation was strengthened by human activities such as local fires and wood collection. In the Mediterranean area, many complex societies emerged between 5000 and 3000 cal BP, and vegetation disturbance started to become clearly detected in pollen diagrams (Roberts, et al., 2004; Sadori, et al., 2004; Sadori and Giardini, 2007).

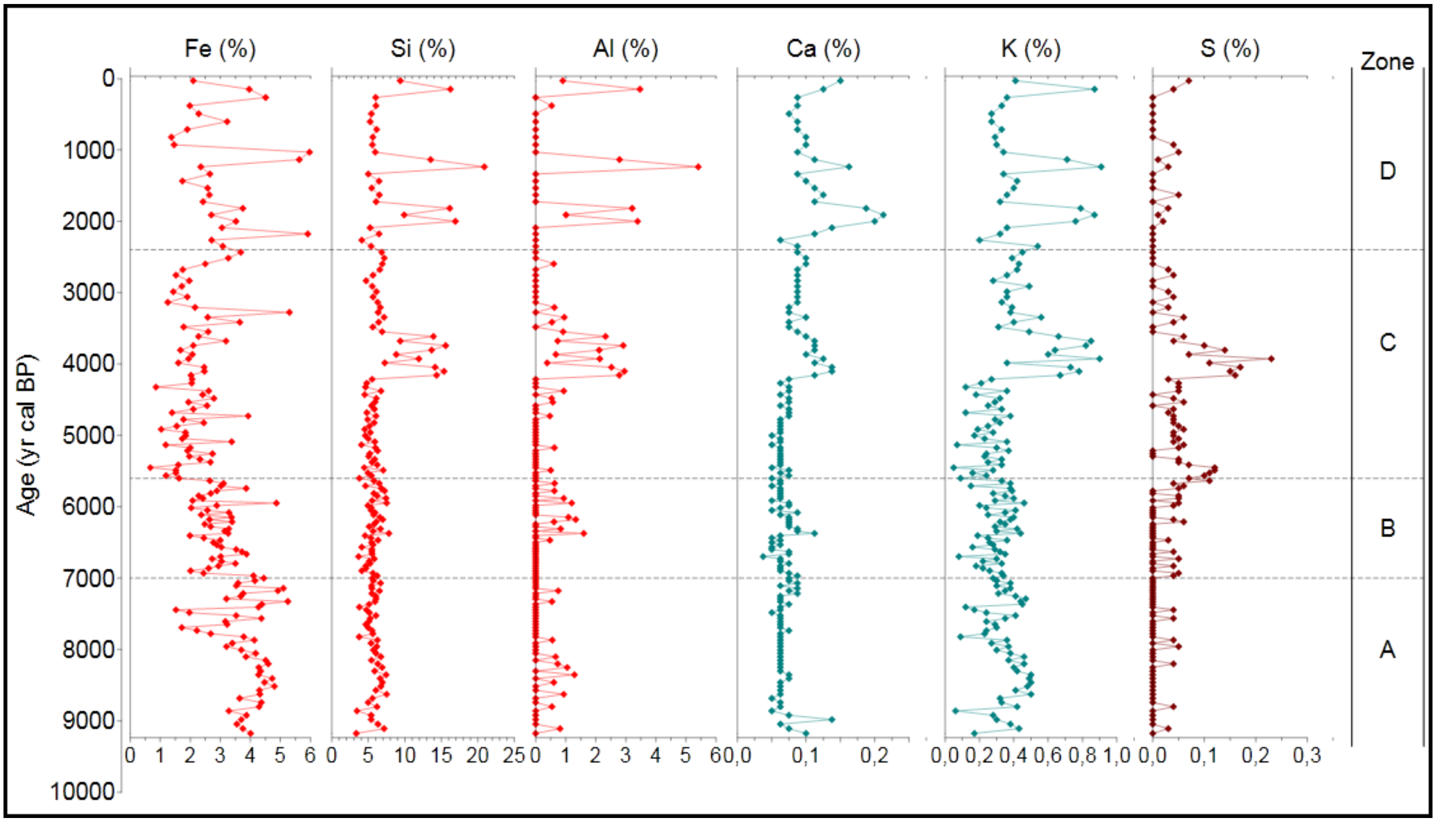

Fig. 8: *Evolution of the percentage of the main chemical elements versus the coring age (years cal BP), obtained by X-Ray-Fluorescence*

However, the lack of pollen markers of human activities in the BEK record and the absence of archaeological sites around the studied area do not allow us to confirm or reject a local human presence or their possible impact. While the BEK data shows a huge development of *Cedrus atlantica* after 7000 years BP on the Rif of Morocco, *Cedrus atlantica* was absent on Middle Atlas, and was recorded only after 6500 cal BP (Lamb, et al., 1995). *Cedrus atlantica* optimum was recorded around 6000 cal BP in the Rif, while almost all fossil records in Middle Atlas (Lamb and Van Der Kaars, 1995; Lamb, et al., 1995; Cheddadi, et al., 2009; Rhoujjati, et al., 2010) showed that the optimum of *Cedrus atlantica* is recorded around 4500 cal BP. However, Nour El Bait, et al., 2014 showed, in one and only one study, that *Cedrus atlantica* was present in Middle Atlas during the early Holocene and its optimum is recorded between 5700 cal BP and 1400 Cal BP. The authors explain this exception by a possible installation of a suitable microclimate due to the proximity of the site to permanent water sources. The late presence or the lack of expansion of cedar forests during the early Holocene around several lakes in the Middle atlas may be explained by the warmer and drier climate (between 10000 and 7000 cal BP). This explanation is supported by a climate reconstruction from Holocene pollen record (Cheddadi, et al., 1998). However, there is other fossil evidence that contradict this concept showing a rather higher moister availability than today during the interval 10000-6000 cal BP (Ritchie and Haynes, 1987). The mid Holocene in the Rif is characterized by a widespread of both evergreen and deciduous oak species. This was also recorded in other Mediterranean countries such as Italy and Balkans (Jahns and Van Den Bogaard, 1998; Jahns, 2005; Caroli and Caldara, 2007), Sicily (Sadori and Narcisi, 2001), Albania (Denèfle, et al., 2000; Fouache, et al., 2001) and Greece (Willis, 1992a, b). However, this expansion of *Quercus* forests in the Rif occurred at the same time than the spread of Cedar in the Middle Atlas (Lamb, et al., 1989; Lamb and Van Der Kaars, 1995; Cheddadi, et al., 2009), confirming the onset of moister climatic conditions in this period favorable to forest evolution (Cheddadi, et al., 1998; Lamb, et al., 1999). After 4000 cal BP, noticeable increase of chemical elements was observed (Fig. 8) especially i) Si and Al indicating a high detrital input of the watershed, ii) Ca resulting from the dolomite erosion and iii) K often associated with clay that can be leached by rain. In addition, high percentage of aquatic plants was also reported (Fig. 6). All these findings and factors suggest a significant increase in precipitation promoting the expansion of Oak forests. So, the fact that sediment composition becomes more organic with peat deposition at around 4400 Cal BP was probably due to the strong expansion of oak forest. In southeastern Spain, a dramatic decline in deciduous oaks occurred around approximately 4700 cal BP (Carrión, et al., 2001). In southern Italy, a temporary deforestation had occurred around 4400 cal BP (Sadori, et al., 2008). In North Africa, the increasing aridity forced North African savanna formations to move south reaching their present position around 3300 cal BP (Neumann, 1989). The final regression of *Cedrus atlantica* is recorded after 2000 cal BP while a rapid expansion of *Cistus* which is often accompanied the human disturbances (López-Sáez, et al., 2003) in addition to other mattoral indicators such as *Erica* and *Olea* recorded several hundred

years after this important event (Fig. 6). Also and in addition to the spread of *Cupressaceae* (*Juniperus* type) for which it's difficult to decide about its evolution during the Holocene because the known poor preservation capacity of its pollen grains. This means that the disappearance of *Cedrus atlantica* from this part of the Rif and from this altitude is the result of a climate change and not because of a human impact. The high content of Fe, Al, K and Si after 2000 cal BP (Fig. 8) would be linked to a very high detrital input in the watershed and the increased Calcium come from the erosion of the Dolomites. These may suggest that the watershed had an impact through the reduction of forest cover due to the *Cedrus atlantica* disappearance. Also, important values of Fe during the silty deposit may indicate a wind leaching. The increased human impact during the last millennia may correspond to the installation of several civilizations in Morocco, starting with the Phoenicians and their descendants (the Carthaginians). The ancient city of Lixus, settled by the Phoenicians date back to the 7th century BC then it was later annexed by the Carthaginians and Romans. The expansion of the Roman Empire across the Mediterranean enhanced the impact on the Mediterranean vegetation and particularly the conifer forests for heating, constructions and metal industry (Mather, et al., 1998). Many examples of these modifications induced by the Roman are located in many Southern Europe countries; where *Abies alba* and *Alnus glutinosa* are seriously affected. In the Middle Atlas (Lamb, et al., 1991; Nour El Bait, et al., 2014), the contemporaneous vegetation disturbances recorded in this period indicates that the populations have extensively exploited the forest and also installed industrial metallurgy.
In the Rif, the weak and discontinuous record of *Olea* suggests that the olive cultivation cited in archeological finding in the tangier region (Ponsich, 1964) did not extend to the EST of the Rif or at least did not extend to high altitudes. Also, the much lower human impact recorded during the periods of different civilizations arrived in north of Morocco suggests that the life style of people in the Rif was probably traditional and based on subsistence agriculture (Taiqui and Cantarino, 1997). Today, unlike *Cedrus atlantica*, oaks (mainly *Q. pyrenaica*) are present in our study area (Fig. 2; Fig. 5) as it was the case throughout the Holocene (Fig. 6), this confirms that oak forest have not been affected by serious anthropogenic activities in the Rif, a minor impact of Human on oak forests was also shown in Reille, (1977); Damblon, (1991) and Muller, et al. (2014) studies.

5 Conclusions

The Bab El Karn sequence offers through a multidisciplinary approach a clear picture of Holocene vegetation in the north western part of Morocco. According to the obtained data, the two emblematic species in the Rif mountains, *Abies maroccana* and *Cedrus atlantica* behaved differently; *Abies maroccana* does not reach the site of Bab El Karn during the Holocene, it has probably never persisted at altitudes lower than its current altitude of 1500m a.s.l while *Cedrus atlantica* was present during the early Holocene and even dominant between 8000 cal BP and 6000 cal BP. This period was cold enough and humid to promote maximum expansion of Cedar until 6000 cal BP, subsequently it was severely degraded probably because of a climate change characterized by warming and dryness giving priority to *Quercus* (mainly deciduous and some species of evergreen) to flourish. The recurrence of aquatic species and Oaks forest after 5500 cal BP may suggest that the climate became humid and warm. The total disappearance of *Cedrus atlantica* from the studied area occurs at about 2000 cal BP before the appearance of some anthropogenic disturbance signals. From our discussed data, we conclude that the deterioration of *Cedrus atlantica* is most likely related to a changing climate (warming) rather than human activities but the interference of this climate change with human pressure particularly during the last two millennia remains possible but not enough detected.

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