CLIMATIC AND HYDROLOGIC CHANGES IN MOROCCAN MIDDLE ATLAS DURING THE HOLOCENE

EL HAMOUTI[1] Najib
(1) University Mohamed I – F. P. Nador (Morocco)
n.elhamouti@ump.ma

Abstract.
The Middle Atlas represents an ideal location for testing hypotheses about the Holocene environmental responses to climate change. The Holocene also represents the period in which humans have become a dominant influence on the Earth System.
Two cores (marginal and central) have been sampled in *Tigalmamine* lake and dated by ^{14}C. Diatoms from this cores show new data for some species of *Cyclotella* genera and give valuable information concerning the hydroclimatic changes in middle Atlas.
At *Tigalmamine*, from 18 Ka BP. to present-day, a succession of three species related to hydroclimatic changes has been found: *Cyclotella* sp. type 1 and *Cyclotella* sp.type 3 characterizing shallow water conditions from 18 to 7 ka B.P.; the type 3 is likely to be associated with severe climatic conditions about 18-16 (?) Ka B.P., 10.3-10 Ka B.P., and 8-7 Ka B.P. *Cyclotella azigzensis,* which became dominant from 10-9 Ka B.P. to present-day time, shows more wet and warm conditions, particularly between 7 ka B.P. and present-day. The water level of lake *Tigalmamine* deduced from diatom study (El Hamouti, 1989, 1991, 2003, 2012) and charophytes (Lamb et al., 1995) supported by radiometric data are interpretable in terms of fluctuations in regional water balance.
This work shows the arid abrupt events are identified at 10.3 ka BP, 10 ka BP, 6.9-6.8 ka BP, 3-2.8 ka BP, 4.5-4.4 ka BP and 1.9-1.7 ka BP. This chronology suggests that arid episodes have occurred approximately every 2-3 kyr during the Holocene. The first one event is synchronous with the Young Dryas chronozone. Other causes have to be sought, however, to explain the events which affect *Tigalmamine* independent of the monsoon. The ages and durations of arid events identified especially during the Holocene are of immediate importance for the prediction of future climatic and hydrologic changes for the better management of water resources in our country who suffered from severe droughts over the past two decades.

Keywords: Morocco, Middle-Atlas, lake, *Tigalmamine*, Diatoms, *Cyclotella,* Plaeoclimatology, Holocene.

1. INTRODUCTION

The Middle Atlas of Morocco and the *Tigalmamine* site (Figure 1) which is under the influences of the Mediterranean, Atlantic and Saharan climates represent a privileged area for the understanding of hydrological and climatic changes in Morocco during the Quaternary. Tigalmamine site (32° 54'N, 5° 21' W, Figure 2) located in the southwestern part of the Middle Atlas of Morocco is a small catchment of 3.5 km. It is a group of three small solution lakes in Lower Lias dolomite bedrock. The climate of the area is strongly seasonal: mean

annual precipitation of 930 mm; mean annual air temperature of 10°C. Evergreen oak (*Quercus rotundifolia)* and Atlas Cedar (*Cedrus atlantica*) dominate the forest vegetation. Lake Tigalmamine, thus, represents an exceptionally favorable context, compared to most paleolakes in North Africa, as this site allows comparing the fossil remains to those living now. The site had been the subject of a 16 m long core taken in the center of the central lake under 16 m of water. The section represents the total of the Holocene from 10,200 BP to present (El Hamouti et al., 1991; Lamb et al., 1995).
A paleolimnological study can be particularly accurate in situations where the Diatoms from this sites species found in the sediments have persisted in the same lake and can provide a direct modern analogue for interpretation and for palaeoenvironmental and palaeoclimatic reconstruction.

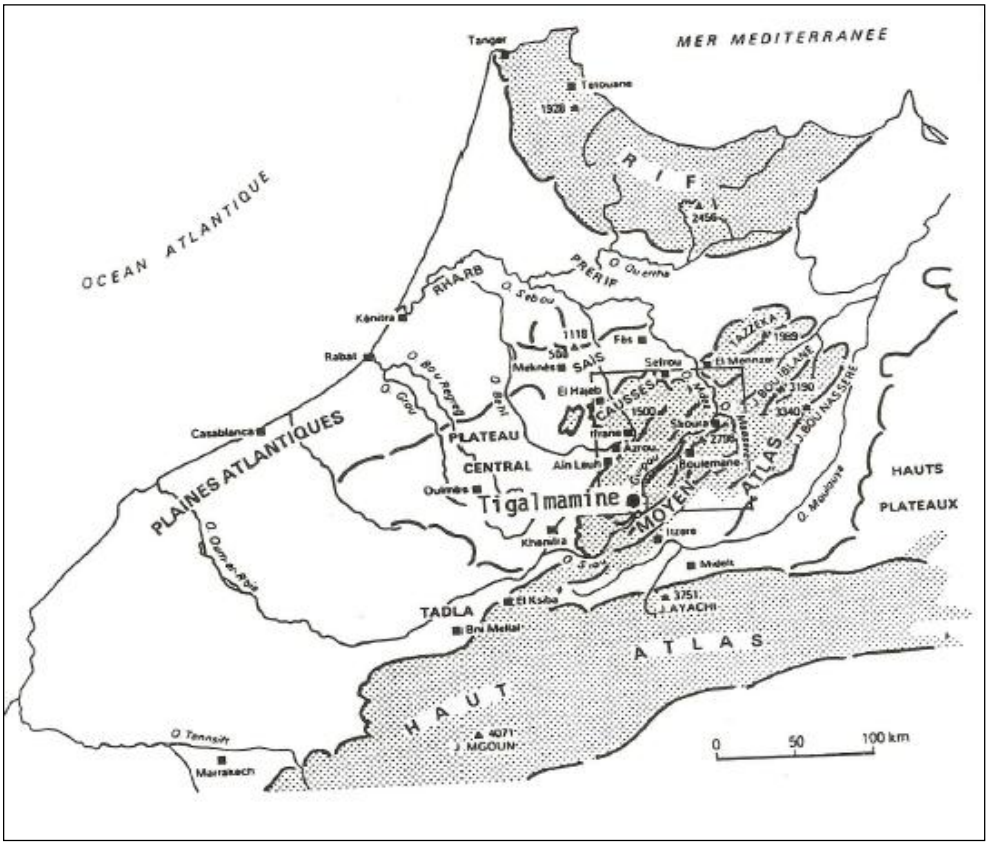

Figure 1 – Geographical location of *Tigalmamine* site.

2. MATERIALS AND METHODS

Four cores (Figure 2) taken from the Tigalmamine site reveal a rich and varied flora of diatoms but dominated by the genus *Cyclotella*. Sediments consist of marl and calcareous silts rich in diatoms, alternating with calcareous sands poor in biological remains. Diatom analyses (El Hamouti, 2003), supported by ^{14}C dates, of four cores from this site give information on the water-level fluctuations changes in water temperature and water chemistry. High frequencies (≥ 50%) of the following species were identified in this study:

Cyclotella sp. aff. *comensis* Grunow type 3 (Figure 4) is a planktonic species. It is abundant in the Sidi Ali lake (2080 meters sea level, depth 15m) (El Hamouti, 2003), and it is

associated with type1. Is growing in alkaline water (pH: 9.1) with conductivity of 1200 to 1600 µScm-^{1}.

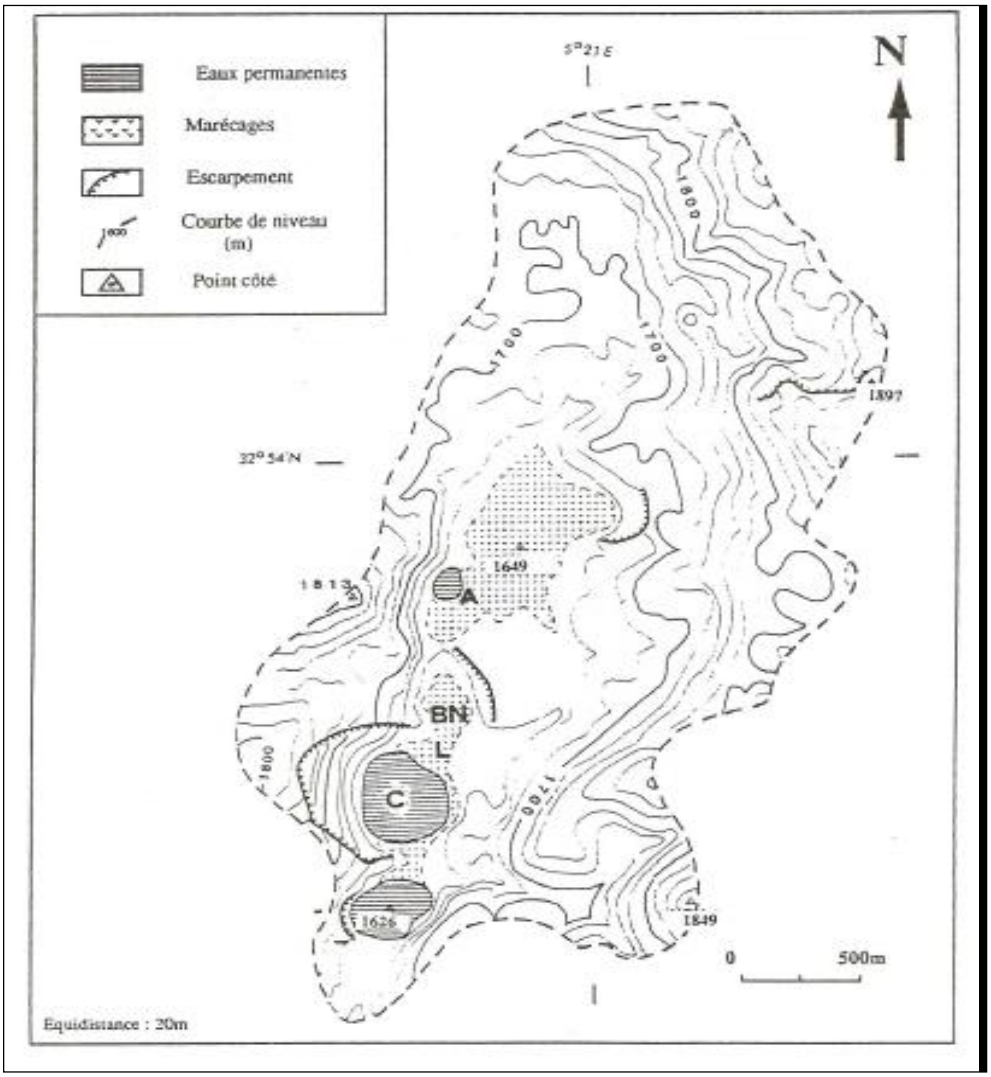

Figure 2 – *Tigalmamine* site

A : Admer core,

BN : Bassin Nord core,

L : Littoral core,

C : Central core.

Cyclotella sp. aff. *Comensis* Grunow type1 (Figure 5) dominates in the plankton from Aguelmane de Sidi Ali (2080m, depth 15m) (El Hamouti, 2003). The ecological data of *Cyclotella comensis* Grunow deduced from the literature are not in perfect agreement with the ecological data distribution of type1 in Middle Atlas. In the investigated area, *Cyclotella* sp. aff. *comensis Grunow type 1* is growing in alkaline water (pH : 9.1) with conductivity of 1200 to 1400 µScm^{-1}.

Cyclotella azigzensis Flower, Gasse & Hakansson (Figure 6), a fresh water species, dominates in the plankton and sediment samples from many lakes in the Middle Atlas. The species is abundant (50%) in Tigalmamine lake (El Hamouti 2003) where it lives in fresh (water) to slightly oligosalines (conductivity 600-840 μScm^{-1}), alkaline (pH 8.8), bicarbonate type water, rich in calcium and magnesium (El Hamout, 1991). Optimal condition(s) for the development of *Cyclotella azigzensis* are: pH: 8.02 and conductivity: 420 μScm^{-1} (Gasse et *al.* (1995).

Mastogloïa smithii and *lacustris* variety: (Figure 7) is littoral species oligohaline to mesohaline water forms developed during regressive stages at Tigalmamine site, about 6.9-6.8, 4.5-4.4 and 3.2-3 Ka B.P, as a result of evaporit concentration of dissolver salt. They are found in waters high in chlorides, carbonates, and/or sulphides.

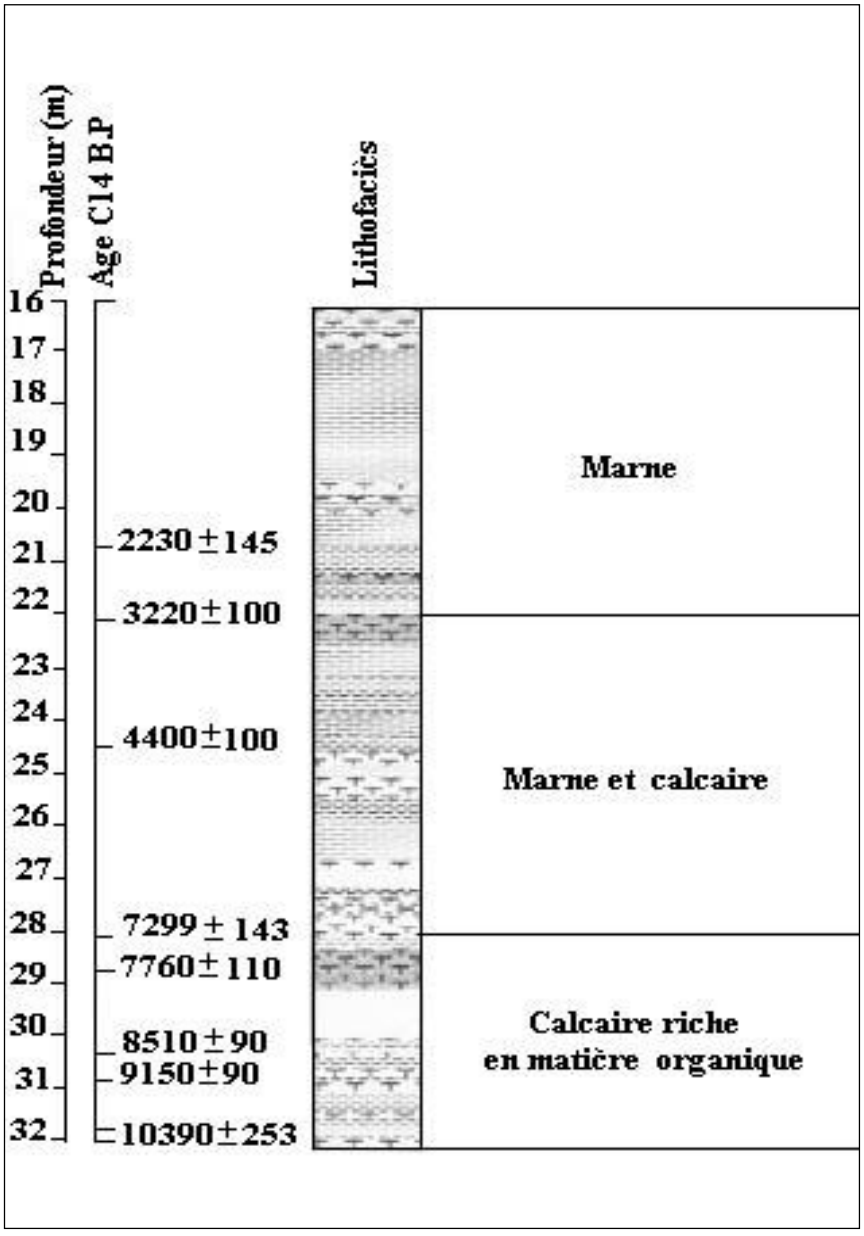

Figure 3 – Central core of Tigalmamine lake

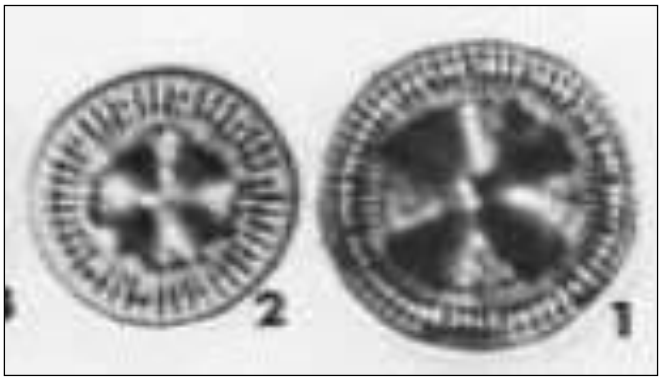

Figure 4 – *Cyclotella* sp. aff. *comensis* Grunow type 3

Figure 5 – *Cyclotella* sp. aff. *comensis* Grunow type 1

Figure 6 – *Cyclotella azigzensis*

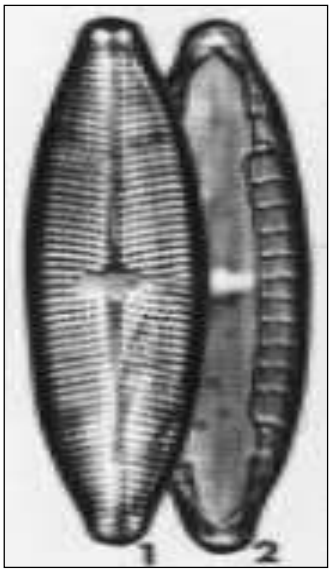

Figure 7 – *Mastogloïa smithii*

3. TIGALMAMINE LAKE

Tigalmamine lake (area 6 ha, Figure 8) is the largest of a group of three solution lakes, at 1.628 m above sea level in the Middle Atlas. The maximum depth lake is 14 meters. Two lines of paleoshoreline are marked on the ground: one located at 1-2 meters from the current level of the lake and the second to 6 meters. The vegetation of the catchment and the lake margins protect the lake from coarse detrital inputs. The lake is fed by ground water, local surface, winter runoff and karstic circulations.
The fresh water (conductivity 700 $uScm^{-1}$; pH 8.3) is of the calcium magnesium bicarbonate type. The planctonic diatom flora is dominated by the genus *Cyclotella,* as many lakes in the central Middle Atlas of Morocco (El Hamouti, 1991). Two piston-cores have been collected from the lake margin (marginal core; 21.25 m deep) and from the lake centre (under 16 m of water; central core; 16 m deep) respectively.

Figure 8 – Tigalmamine lake.

4. HYDROLOGICAL EVENTS

Diatoms analysis of central (fig. 9) and marginal cores from the main lake shows that hydrologic events at Tigalmamine are recorded by species changes of Cyclotella genera and give valuable information concerning the climatic history. Example: a succession of three species related to hydroclimatic changes has been found:
Cyclotella sp. aff. *comensis* type1 and *Cyclotella* sp. aff. *comensis* type3 characterizing from 18 to 7 ka B.P. a shallow water body, oligotherme, oligosaline and alkaline water. The type3 is likely to be associated with severe climatic conditions about 18-16 (?) Ka B.P., 10.3-10 Ka B.P., and 8-7 Ka B.P. *Cyclotella azigzensis,* which became dominant from 10-9 Ka B.P., shows more wet and warm conditions, particularly between 7 ka B.P. and present-day.
These three species of ultrastructure different show a morphology close *comensis* Grunow, they are observed in different events and concern three ecologic entities.

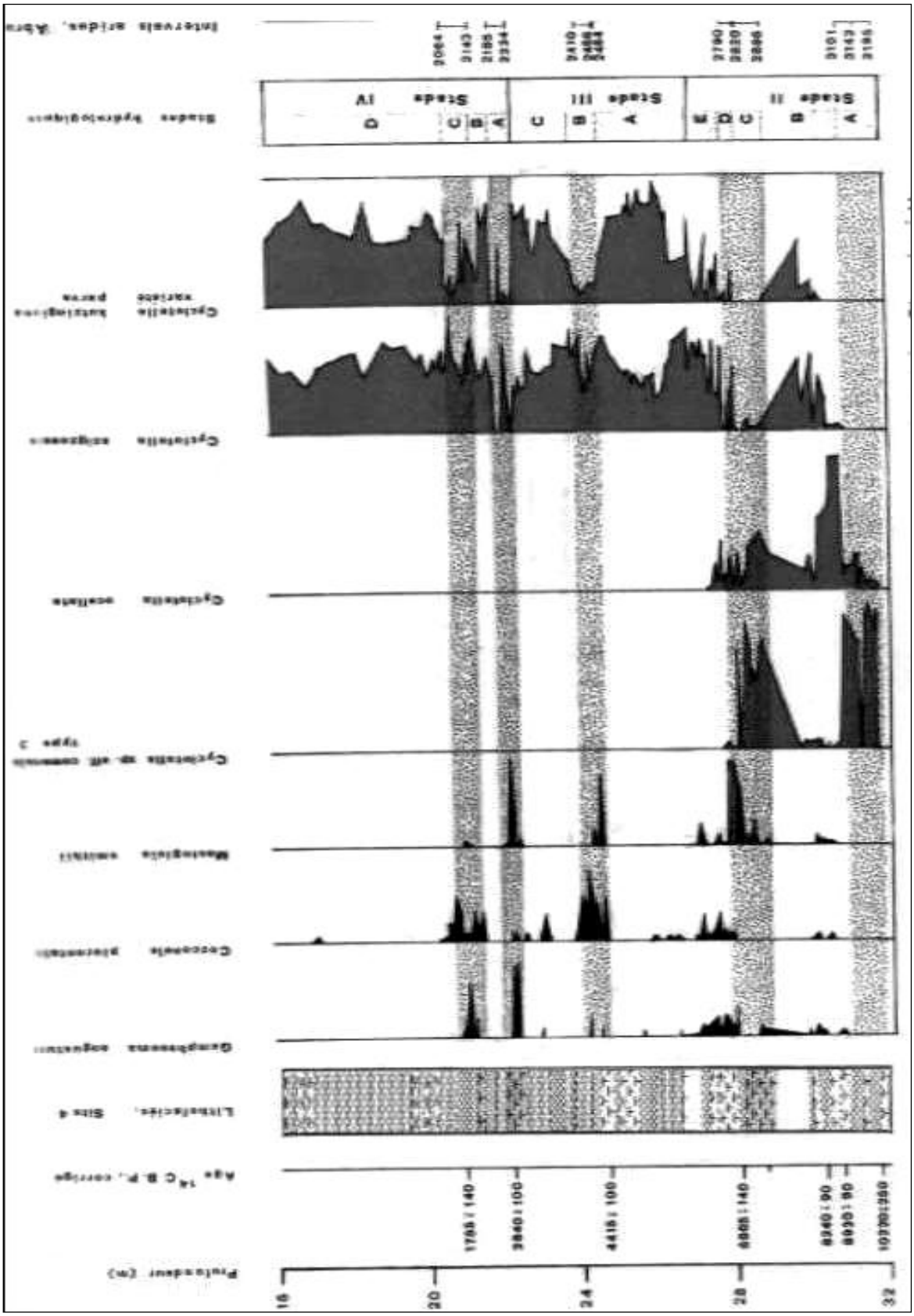

Figure 9 – Fluctuations in major diatoms species in central core.

5. CONCLUSIONS

The water level of Lake Tigalmamine deduced from diatoms study (El Hamouti, 2003) and charophytes (Lamb et al., 1995) supported by radiometric data are interpretable in terms of fluctuations in regional water balance.
This work shows arid abrupt events (table I) are identified at 10.3-10 ka BP, 6.9-6.8 ka BP, 3-2.8 ka BP, 4.5-4.4 ka BP and 1.9-1.7 ka BP. This chronology suggests that arid episodes have occurred approximately every 2-3 kyr during the Holocene. The first one event is synchronous with the Young Dryas chronozone. Other causes have to be sought, however, to explain the events which affect *Tigalmamine* independent of the monsoon. The ages and durations of arid events identified especially during the Holocene are of immediate importance for the prediction of future climatic and hydrologic changes for the better management of water resources in our country who suffered from severe droughts over the past two decades.

Ages and durations of arid events at *Tigalmamine* :
10.000 ans B.P., stade IIA1 : niveau 3142 no diatom/50 ans
6.900-6.800 ans B.P., stade IID : layer 2820.5-2811 *Mastoglïa* /100 ans
2.950-2.800 ans B.P., stade IVA2 : niveau 2219 *Mastoglïa* 50/ans
4.500-4.400 ans B.P., stade IIIB1 : niveau 2456 *Mastoglïa* /50 ans

Table I - *Tigalmamine*, ages and durations of abrupt arid events.

Acknowledgments: This study was supported by the Leverhulme Trust, by UK Naturel Environment Research Council and by Moroccan University Mohamed Premier Oujda.

References.

EL HAMOUTIN. (2012) - Climatic and hydrologic changes in Moroccan Middle Atlas. *Quaternary International, Volumes 279–280, 16 November 2012, Page 130*

EL HAMOUTI N. (2003) – Changements Hydrologiques et Climatiques dans le Moyen Atlas marocain depuis 18 Ka BP. Doctorat ès Sciences de l'Université Mohamed I, pp 300, 23 Pls.

LAMB H. F., GASSE F., BENKADDOUR A., EL HAMOUTI N., VAN DER KAARS S., PERINS W.T., PEARCE N. J., & ROBERTS N. (1995) - Relation betwen Century Scale Holocene Arid intervals in tropical and temperate zones, *Nature,*373

GASSE, F., JUGGINS S., & BEN KHELIFA L. (1995) – Diatom-based transfer functions for interring past hydrochemical characteristics of African lakes. *Palaeogeography, Palaeoclimatology, Palaeoecology* 117, 31-54.

EL HAMOUTI N. (1991) - Changements Hydroclimatiques Abrupts dans le Moyen Atlas marocain depuis le Dernier Maximum Glaciaire. *C. R. Académie Sciences* Paris, 313, Série II, pages 259-265.

EL HAMOUTI N. (1989) - Contribution à la Reconstitution de la Paléohydrologie et de la Paléoclimatologie du Maghreb et du Sahara au Quaternaire supérieur à partir des Diatomées. Thèse de Doctorat en Sciences de l'Université de Paris Sud XI, 300 page.