Cryptogamie, Algol., 2004, 25 (2): 175-188

Recent environmental changes at Sidi Bou Rhaba Lake (Morocco) inferred from fossil Charophyte gyrogonites

*Najat ELKHIATI[a**], Ingeborg SOULIE-MÄRSCHE[b], Pierrette GEMAYEL[b], Roger FLOWER[c] and Mohammed RAMDANI[d]*

[a] Faculté des Sciences Aïn-Chock, km 8, Route d'El Jadida, BP 5366, Casablanca, Maroc

[b] ISE-M, Laboratoire de Paléobotanique, Université Montpellier II, CP 062, Place E. Bataillon, 34095 Montpellier-Cedex 5, France

[c] ECRC, Dept. of Geography, University College of London, 26 Bedford way, London, WCIH OAP, UK

[d] Institut Scientifique, Département Zoologie & Ecologie Animale, BP 703, Rabat-Agdal, Maroc

(Received 12 June 2003, accepted 11 March 2004)

Abstract — In order to reconstruct Holocene climatic changes in Sidi Bou Rhaba, sediment records of the Charophyte populations dynamics were examined. A 120 cm long core was collected from the southern zone of the lake and analysed for charophyte remains. Sediment samples revealed the presence of thousands of oospores. However, all spores were empty and devoid of starch, showing that they had lost their ability to germinate. The determinable fossil and viable subfossil remains consisted of calcified gyrogonites. These were attributed to four Charophyte taxa: *Lamprothamnium papulosum* (Wallroth) J. Groves, *Chara aspera* Detharding *ex* Willdenow, *C. connivens* Salzmann *ex* A. Braun and *C. baltica* Bruzelius. The palaeoecological significance of these species is relevant to inferring past environmental conditions for Sidi Bou Rhaba. Two of the species, *L. papulosum* and *C. baltica*, have never been recorded living in this site. They are typically indicative for a brackish water habitat. Their past presence was likely a response to higher water salinity than present and can be interpreted as corresponding to a series of dry years. On the contrary, *C. connivens* marked a period of dilution, indicating more humid years. *Chara aspera* is oligohaline, and can tolerate a range of salinity from freshwater to up to 12 $g{\cdot}l^{-1}$, whereas *C. baltica* is adapted to more brackish water up to a salinity of ca 15 $g{\cdot}l^{-1}$. The quantitative changes in the abundances of the remains of these taxa throughout the sediment core indicate that the salinity of Sidi Bou Rhaba has fluctuated during the past century.

brackish water environment / *Chara* / Charophytes / Gyrogonites / Lake Sidi Bou Rhaba / *Lamprothamnium* / Morocco / palaeolimnology

Résumé — Les changements environnementaux récents dans le lac de Sidi Bou Rhaba (Maroc) déduits à partir des gyrogonites fossiles de Charophytes. Dans le but de reconstituer les changements climatiques durant l'Holocène dans le lac de Sidi Bou Rhaba, en suivant la dynamique des populations de Characées, un carottage de 120 cm de profondeur

* Correspondence and reprints: nelkhiati@hotmail.com
Communicating editor: Pierre Compere

a été réalisé dans sa partie sud. L'observation des échantillons du sédiment a révélé la présence de milliers d'oospores et de nombreuses gyrogonites (fructifications femelles calcifiées des Characées). Les oospores étaient toutes vides et mal conservées, ce qui signifie qu'elles ont perdu leur pouvoir de germination. Les gyrogonites fossiles et subfossiles ont été attribués à quatre taxons de Charophytes : *Lamprothamnium papulosum* (Wallroth) J. Groves, *Chara aspera* Detharding *ex* Willdenow, *C. connivens* Salzmann *ex* A. Braun et *C. baltica* Bruzelius. Deux de ces espèces, *L. papulosum* et *C. baltica* n'avaient jamais été signalées à l'état vivant dans ce lac. Elles sont typiques pour un milieu d'eau saumâtre. Leur présence est considérée comme une réponse à une salinité supérieure à celle qui règne aujourd'hui et interprétée comme signe d'une période d'années sèches. *Chara connivens*, au contraire, marque une diminution de la salinité, indiquant, de ce fait, des années plus humides. *Chara aspera*, espèce oligohaline, supporte des taux de salinité allant jusqu'à 12 $g \cdot l^{-1}$, alors que *C. baltica* est adaptée à de l'eau saumâtre où la teneur en sels peut aller jusqu'à 15 $g \cdot l^{-1}$. Les changements quantitatifs des restes de ces taxons dans les différentes profondeurs du sondage montrent que la salinité du lac de Sidi Bou Rhaba a subi d'importants changements au cours du dernier siècle.

***Chara* / Charophytes / eau saumâtre / Gyrogonites / lac de Sidi Bou Rhaba / *Lamprothamnium* / Maroc / paléolimnologie**

INTRODUCTION

Sidi Bou Rhaba Lake is one of the last natural permanent standing water bodies on the north-west coast of Morocco, most of the other hydrosystems of the Gharb plain having been drained and dried. Its biological wealth was recognised by the International Office of Researches of the Sauvagine (BIRS) in 1964. Since 1975, a large part of the lake has been made a Natural Reserve by the international RAMSAR program. Human impacts are now much diminished. A reduction in grazing and the yearly cutting of rushes by residents has contributed to the large development of helophytes (*Phragmites gigantea* and *Typha angustifolia*) at the site. These plants constitute dense and extensive monospecific stands around the lake. The absence of grazing also encourages some other graminae species, e.g. *Panicum repens*, to proliferate. Sidi Bou Rhaba was recognised for the importance of its avifauna (Bayed *et al.,* 1997; Dakki & Elagbani, 1997). The environmental characteristics of the lake were assessed previously (Ramdani & Elkhiati, 2000; Ramdani *et al.*, 2001a, 2001b, 2001c).

Because of the variety of natural biotopes present in this wetland complex (freshwater, brackish water, temporary, permanent), Sidi Bou Rhaba is particularly interesting for palaeolimnological and palaeobotanical studies.

The Charophytes can provide a reliable fossil record in the form of their calcified reproductive organs (termed gyrogonites). A previous ecosystem analysis, based on a core (RHAB2) taken in the central, permanent part of the lake, mentioned the presence of *Chara*-type oospores (Birks *et al.*, 2001). An earlier core (RHAB1) has been studied in detail for its diatom contents (Flower *et al.*, 1989). The present study focuses on the Charophyte remains recovered from an additional core (RHAB3) taken in the temporary southern part of Sidi Bou Rhaba. The species assemblages of the Charophytes are highly sensitive to water quality, especially to salinity changes, and can be interpreted in terms of paleolimnological characteristics (Soulié-Märsche, 1989, 2002). The aim of this study is to compare the fossil charophytes from core RHAB3 to the known extant flora, in order to understand the recent environmental history of the lake.

SITE DESCRIPTION

Sidi Bou Rhaba is a flooded depression situated on the NW Atlantic coast of Morocco (N 34°24', W 06°67'), located 10 km South of Kenitra and 1 km inland from the coast. It is limited to the North by the Sebou estuary, to the South by the Marabout of Sidi Bou Rhaba, to the East by fossilised dune system and to the West by Quaternary mobile dunes. The lake is oriented NNE-SSW and is ca 5.5 km long and 100-350 m wide (Fig. 1). The biological reserve of Sidi Bou Rhaba

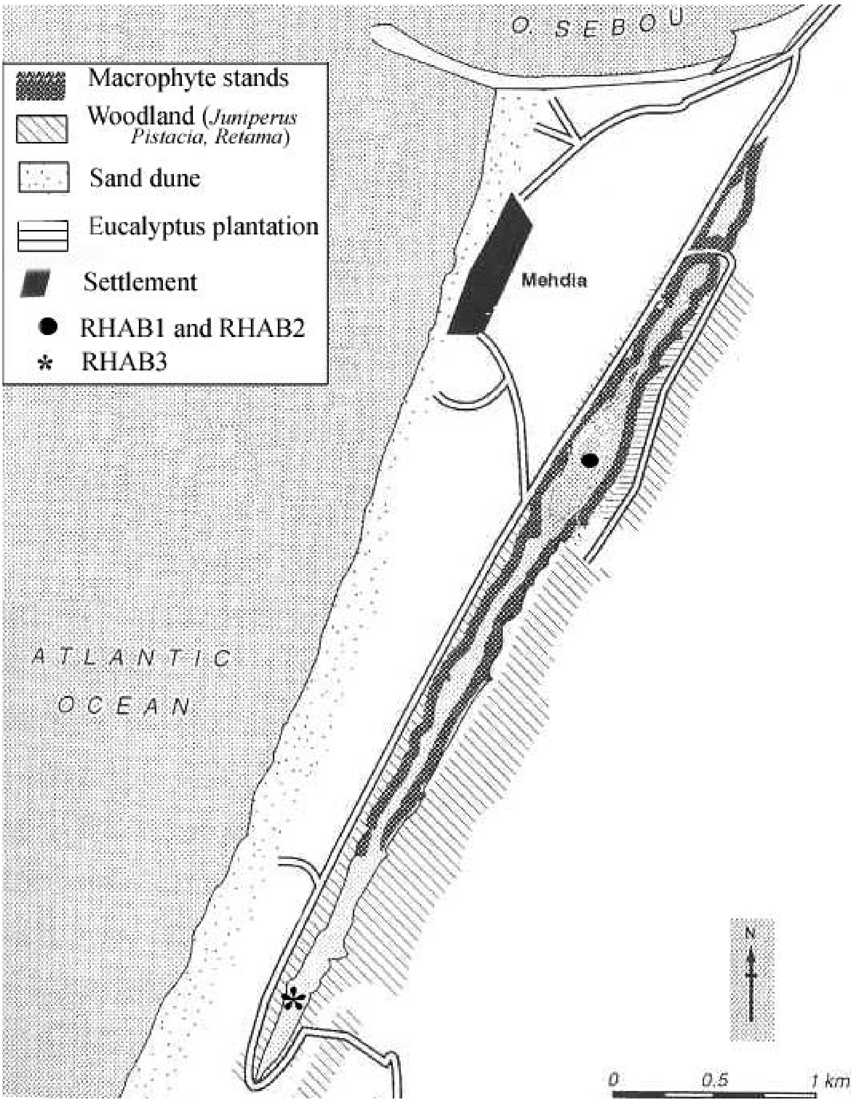


Fig. 1. Site map and core sampling location (RHAB1 and RHAB2 refer to previous studies; RHAB3 was analysed in the present paper).

is surrounded by slopes covered with trees. Most of the dense vegetation is composed of *Juniperus phoenicea*, *Olea europea, Pistacia lentiscus,* and *Myrthus communis*. *Populus alba* dominates on the southwest slope. The wetland vegetation is established where the slope is very gentle (Fig. 2). The western dunes can reach

Fig. 2. View to the south end of Sidi Bou Rhaba in a dry state (September 2000).

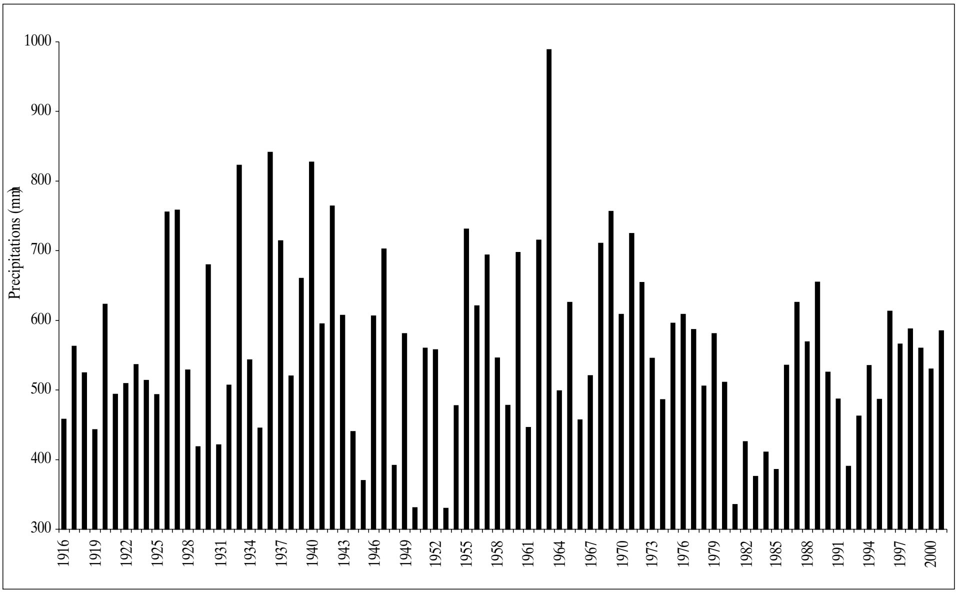


Fig. 3. Annual rainfall registered at Kenitra (1916-2000); data from the meteorological station at Mehdia-Kenitra.

20-30 m in height and separate the continental and coastal domains. This mobile dune system is formed by the accumulation of beach elements (shells, sands and silts) brought mainly by erosion. Consolidated paleodunes, ca 50 m high, form a rim east of the lake. The large depression separating the two dune systems is partly occupied by the Sidi Bou Rhaba Lake and is underlain by a deposit of red sand of continental origin (the Soltanian red silts). The lacustrine sediments consist in grey and black clays, silts, carbonates containing from 20 to 60 % of organic matter (Ramdani, 1981). Sidi Bou Rhaba is a low saline brackish water ecosystem disconnected from the ocean. Salinity measurements during the last decades recorded changes from 2 to 12 $g{\cdot}l^{-1}$ (Ramdani, 1981; Elkhiati, 1987, 1995). The lake level depends on both local rainfall and on supply by the fresh groundwater aquifer (Margat, 1961; Le Coz, 1964). Average local rainfall from 1975-1980 was 597 mm/year, followed by a series of dry years from 1981-1990 that registered an average rainfall of 483 mm/year (Fig. 3). In recent years, the southern part of the lake has dried out every summer; in the northern part the water depth has fluctuated by between 1.60 to 2.30 m. The hydrological balance is marked in winter by a period of high lake level with low salinity and, during the dry season, by a period of low water level with a strong increase in salinity due to evaporation (Ramdani, 1981; Elkhiati, 1987). Water quality features were measured in the frame of the multidisciplinary program Cassarina and revealed alkaline, brackish water, strongly mineralised and very productive with high content of dissolved oxygen (Ramdani & Elkhiati, 2000) (Table 1). This water quality supports a high diversity of aquatic life, including charophytes and other macrophytes. The extant flora has been determined previously at species level (Gayral, 1954; Guerlesquin 1978; Elkhiati, 1987). Living Charophytes were also collected in March 2003 when the Sidi Bou Rhaba depression was completely submerged.

Table 1. Seasonal range of variability of key parameters of Sidi Bou Rhaba Lake between 1997-99.

Parameters	*April 1997*	*January 1998*	*May 1998*	*September 1998*	*December 1998*	*May 1999*
Colour	Brown-green	green	green	green	green	Brown-green
Depth (cm)	200	195	203	163	172	200
Transparency (cm)	50-55	40-50	30	5	8	35-40
T°C air	24.1	18	24.8	25.8	17.8	25.5
T°C water	21.5	14.8	21.8	28	14.9	22.9
Dissolved oxygen ($mg{\cdot}l^{-1}$)	8.54	8.24	7.92	6.88	8.22	7.46
pH	8.21	7.84	8.63	8.90	8.03	8.34
Alkalinity ($mg{\cdot}l^{-1}$)	21.96	138.06	61.02	54.92	278.95	224.46
Salinity ($g{\cdot}l^{-1}$)	5	4.50	5.20	8.10	7.40	5.2
Conductivity (µMhos)	8 000	6 500	8 730	13 400	10 800	9 550
Chl “a” (µg/l)	15	8	8.4	5.7	8.1	9.6
M.E.S.T. (mg/l)	240	310	254	545	315	468

MATERIAL AND METHODS

A core of 120 cm length and 8 cm diameter, designated as RHAB3, was collected with a rod operated piston corer from the southern part of the lake in September 2000. This part of the lake was then dry (Fig. 2). The core was then sectioned at the laboratory into slices from 0-3, 3-5 and 5-10 cm and then sampled at 10 cm intervals. Samples of ca 100 g each were deflocculated for 24 hours in water containing sodium bicarbonate and hydrogen peroxide, then washed and sieved through 250 and 177 µm meshes. Thousands of oospores floating at the surface of the water were recovered by filtering; the gyrogonites were isolated under a stereomicroscope.

A second set of samples of 10 cm^3 was washed separately for counting of gyrogonites. Biometric parameters used for the determination are length, width and shape of gyrogonites usually expressed as the length/width ratio × 100 (termed Isopolarity index - ISI). The measurements were completed by observation of the morphology of the apical and basal poles of the gyrogonites. Photographs were taken with the Scanning Electron Microscope, type JSM-6300F after Pt metallization of 150Å, at the University of Montpellier. The material is kept under label SBG in the collections of the Laboratory of Paleobotany, University Montpellier II.

RESULTS

The sediment core consisted throughout of light grey marl and no significant lithological changes were noted from top to ca 120 cm depth. Despite the presence of sand dunes near the lake, the sediments were poor in clastic elements. Vegetative remains of the Charophytes, consisting typically of a calcitic central tube surrounded by a number of small tubes, were absent throughout the core. The fossil Charophyte remains consisted of two types of material: i) oospores, i.e. the ripe fertilised egg-cell surrounded by an organic cell wall of dark brown or black colour; ii) gyrogonites, a term applied to oospores that have a supplementary envelope of calcite formed by intracellular calcification. This envelope is true bio mineralization and displays features that allow determination at species level. Oospores were extremely abundant in all the samples but were poorly preserved, either compressed or broken. In contrast to the oospores, which showed few distinctive features, the gyrogonites were well preserved and displayed a larger number of characteristics that enabled reliable species identification (Soulié-Märsche, 1989; 2002).

Figs 4-12. *Chara* species from Sidi Bou Rhaba (core RHAB3); Scales = 100 µm. — Figs 4-6. *Chara aspera*, various morphological types of gyrogonites. — Fig. 7. *Chara connivens*, gyrogonite. — Fig. 8. *Chara baltica*, gyrogonite. — Fig. 9. *Chara connivens*, basal view of the gyrogonite. — Figs 10-12. Oospores isolated from inside the gyrogonites. — Fig. 10. *Chara aspera*. Fig. 11. *Chara connivens* with basal plug attached. Fig. 12. *Chara baltica*.

▶

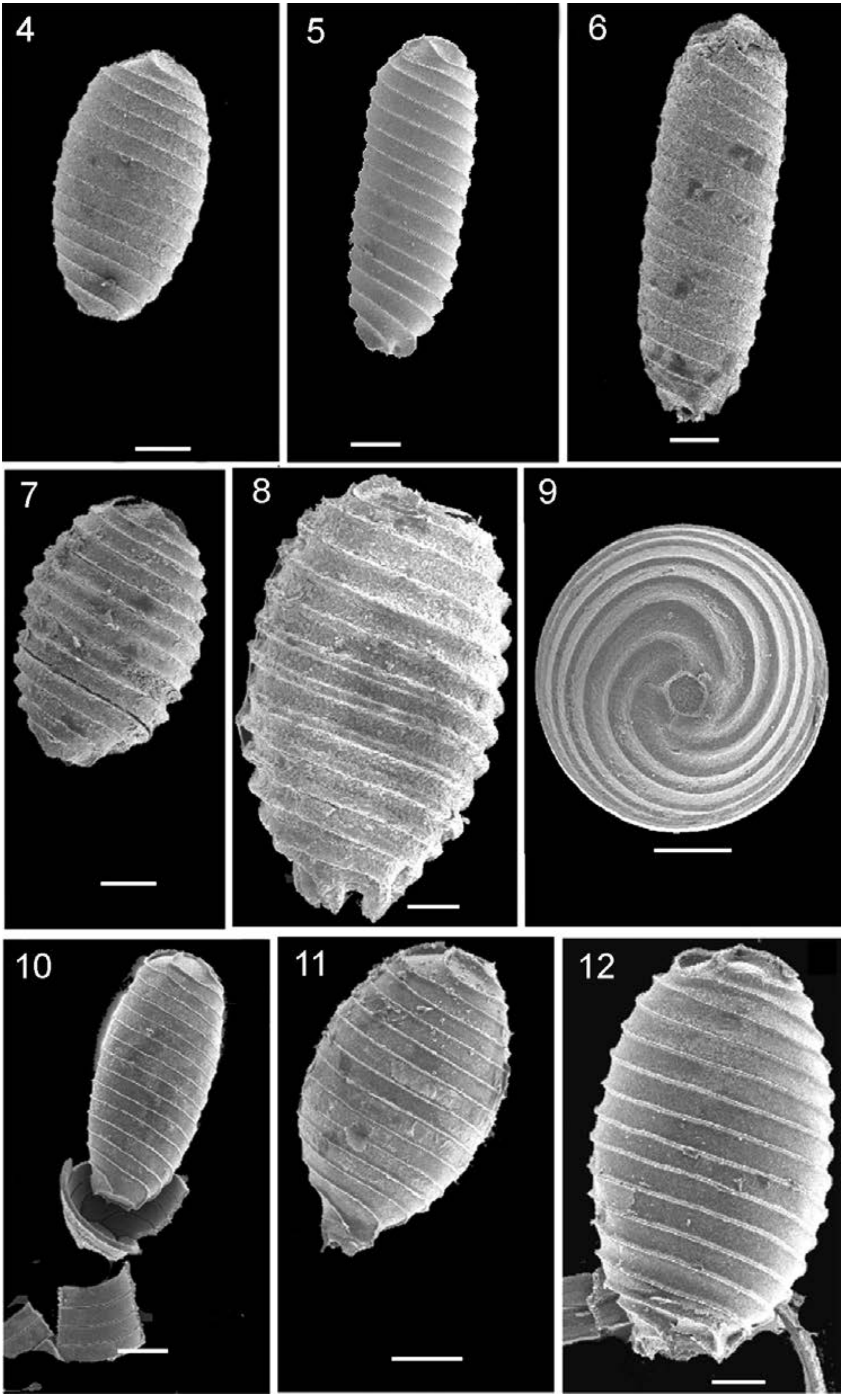
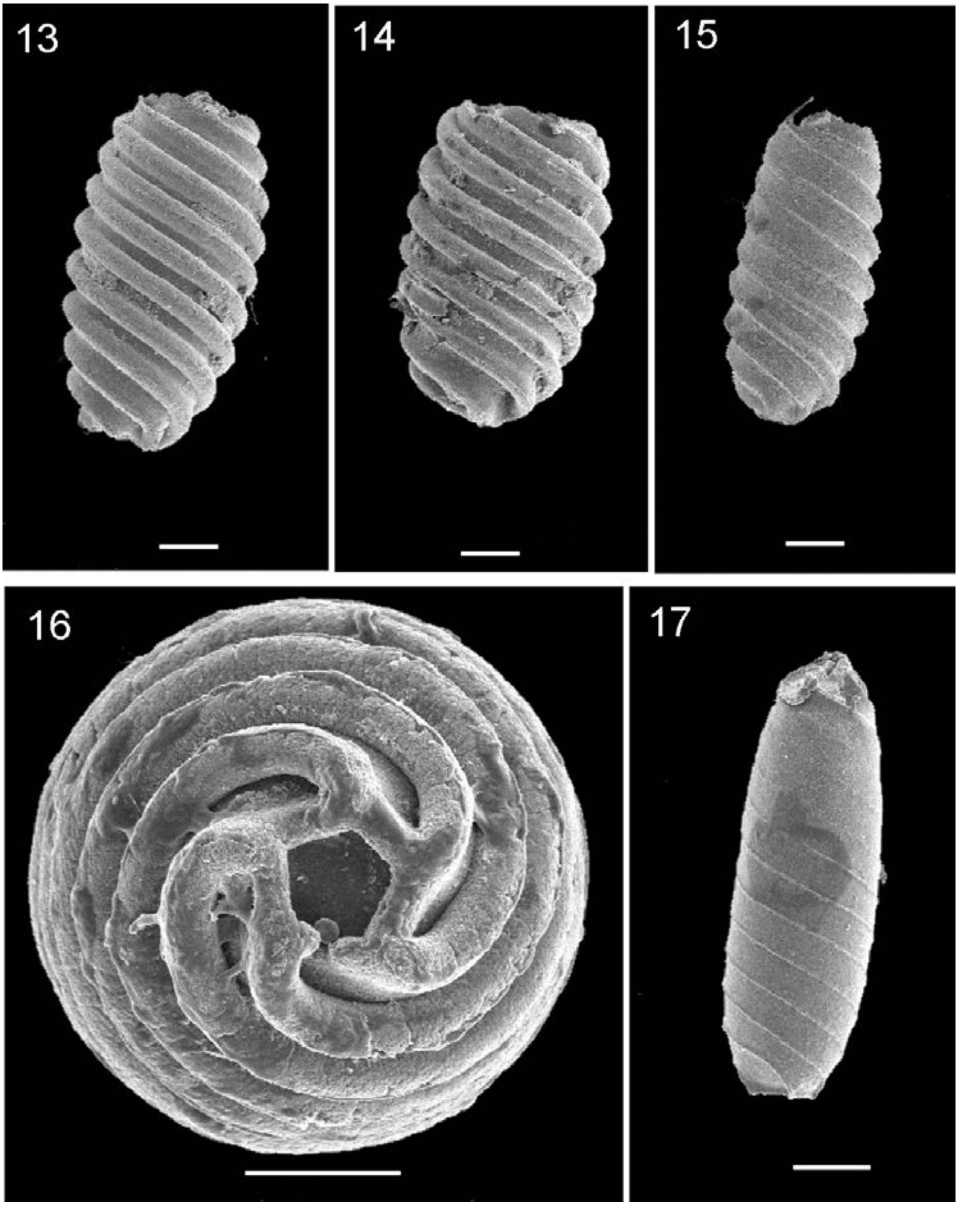

4
5
6
7
8
9
10
11
12

Table 2. Principal morphological features of the Charophyte gyrogonites from Sidi Bou Rhaba (core RHAB3).

Species	*Size and shape*	*Spires and apex*	*Basis and basal pore*	*Calcification*
Chara aspera Detharding *ex* Willdenow 1809	Length: 425-650µm. width: 125-300µm. Ovoidal to very elongate, often cigar- shaped.	11-15, mostly 12-14 spiral convolutions visible in lateral view; spires weakly concave or flat. Apical tips widened and often concave.	Truncate in lateral view, often weakly stretched. Basal opening pentagonal, basal plug visible.	Very slender and fragile, only some µm thick.
Chara connivens Salzmann *ex* A. Braun 1835	Length: 550-675 µm width: 350-450 µm Regularly ellipsoidal.	13 spiral convolutions visible in lateral view; spires strongly concave. Apex rounded, apical tips not modified.	Regularly rounded. Basal opening simple pentagonal, diameter: 75µm closed by the basal plug, visible at outer level.	Rather weak.
Chara baltica Bruzelius 1824	Length: 800-925 µm width: 575-600 µm. Ovoidal to ellipsoidal.	12-13 spiral convolutions visible in lateral view; spires concave. Apex rounded or weakly prominent in lateral view.	Basal zone rounded or stretched and truncate. Basal opening about 50 µm in diameter with basal plug incompletely calcified.	Incomplete in the present material, lime spirals strongly concave.
Lamprothamnium papulosum (Wallroth) J. Groves 1916	Length: 650-750 µm width: 300-450 µm. Cylindrically elongate.	8-10 spiral convolutions visible in lateral view, concave separated with protruding sutures. Apex mostly dehiscent.	Basis rounded or truncate, with thickened sutures around the basal pore. Basal opening pentagonal rather wide with basal plug visible at outer level.	Sutural crests well developed and thick, showing the typical fan-like calcification structure.



Figs 13-17. *Lamprothamnium papulosum* from Sidi Bou Rhaba (core RHAB3). Scales = 100 µm. — Figs 13-15. Various morphological types of the gyrogonites showing thickened calcification along the sutures. — Figs 16. Basal view of gyrogonite. — Fig. 17. Oospore with slightly undulated sutural crests.

Based on the gyrogonite morphology, the fossil remains of the core RHAB3 were identified as four taxa (Table 2): *Chara aspera* Detharding *ex* A. Braun showed a wide range of variation, from ovoid to cylindrically elongate (Figs 4-6). They were very similar to the gyrogonites collected from modern populations in South France (Soulié-Märsche, 1989). *Chara connivens* Salzmann *ex* A. Braun was characterised by relatively broad gyrogonites with strongly concave spiral turns (Fig. 7). The sutural crests were somewhat thickened around the basal cell with basal plug visible at outer level (Fig. 9). *Chara baltica* Bruzelius was present with very large ovoid gyrogonites (Fig. 8). The oospores of these three species differed also in size, as illustrated in Figs 10-12. A further very distinct morphological type of gyrogonite could be identified as *Lamprothamnium papulosum* (Wallroth) J. Groves by a comparison with modern gyrogonites of that species (Soulié-Märsche, 1989). The gyrogonites were characterised by very thick sutural crests and flattened apical pole (Figs 13-16). The thick calcification of the gyrogonite shapes the calcified fructification very differently from the organic oospores inside, which in contrast show a protruding apical pole. Figure 17 shows the oospore isolated from a gyrogonite similar to the specimen of Fig. 13, and illustrates that the determination criteria for oospores cannot be applied to the gyrogonites. The vertical distribution of the Charophytes down the core shows *Chara aspera* as the dominant species, with the three other species concentrated in different sections of the core (Fig. 18). Many specimens of the diatom *Campylodiscus clypeus* were also recovered from the residues. This mesohaline species had also been found previously in the open water and in the sediments of Sidi Bou Rhaba. In core RHAB2, it was abundant between 10-50 cm sediment depth (Flower,

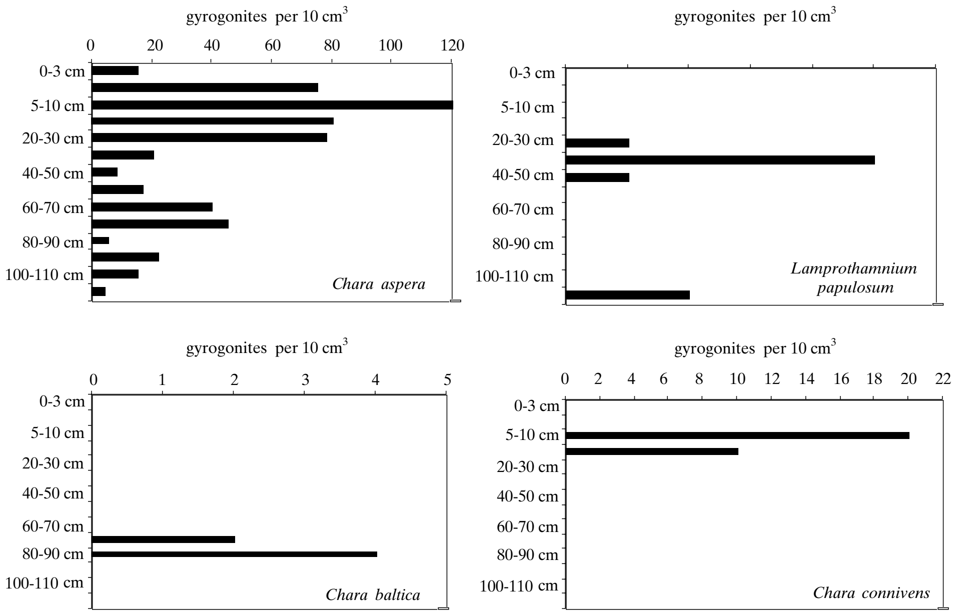


Fig. 18. Frequency and vertical distribution of the Charophyte gyrogonites at Sidi Bou Rhaba (core RHAB3).

2001). *Lamprothamnium papulosum* was abundant between – 30 and – 40 cm and rare between – 110 and – 120 cm depth. *Chara aspera*, present in all levels, increased markedly towards the top except for the uppermost surface sample at – 3 cm. *Chara connivens* was recovered from between – 5 and – 20 cm and *C. baltica* solely in level – 80 to – 90 cm.

Given the salinity tolerance of the taxa, as known from recent ecological data, the palaeoecological significance of these species is relevant to inferring past environmental conditions for Sidi Bou Rhaba. Thus, the past presence of *L. papulosum*, the most halotolerant species among the living Characeae, must be considered a response to higher water salinity at Sidi Bou Rhaba than present. *Chara connivens*, an occasional halophilous species, marked a period of dilution. *Chara aspera* is oligohaline, and can tolerate a range of salinity from freshwater to up to 12 $g \cdot l^{-1}$, whereas *C. baltica* is adapted to more brackish water up to a salinity of ca. 15 $g \cdot l^{-1}$.

DISCUSSION

The aim of this study was to examine the fossil Charophytes of Sidi Bou Rhaba and to compare this with the known extant flora to infer the recent environmental history of the lake. One of the more striking of our results was the presence of *Lamprothamnium papulosum*, a species that indicates significantly higher saline conditions than observed recently. Indeed, *L. papulosum* has never been recorded living in Sidi Bou Rhaba, despite the aquatic plants of Sid Bou Rhaba having been studied repeatedly over the last 50 years. Five species of living Charophytes were recorded at Sidi Bou Rhaba: *Chara aspera* var. *brevispina, C. canescens, C. connivens, C. galioides* and *C. imperfecta* (Feldmann, 1946, 1953; Gayral, 1954; Guerlesquin, 1974, 1978). Most of these previous collections were localised in the daya of Sidi Bou Rhaba, which is an adjacent temporary pond located north of the main water body. The submersion time there is shorter and the salinity remains oligohaline with a maximum of only 2 $g \cdot l^{-1}$.

Only two of the previously recorded taxa, *C. aspera* and *C. connivens* were identified among the fossil gyrogonites in RHAB3, whereas two additional species, *L. papulosum* and *C. baltica* were present in the sediment core. Both have never been recorded as living plants at Sidi Bou Rhaba. These two species are typical brackish water plants and indicate periods when the salinity of the lake water was of meso- to polyhaline conditions. In particular, *Lamprothamnion papulosum*, the most salt tolerant species among the Charophytes, displays its reproductive phase (evidenced by the presence of its characteristic gyrogonites, see Figs 13-17) at salinity rates between 20 and 40 $g \cdot l^{-1}$ (Soulié-Märsche, 1998). The salt tolerance of *Chara baltica* covers the range from 2 $g \cdot l^{-1}$ to 15 $g \cdot l^{-1}$ (Krause, 1997).

Changing environmental conditions are thus successively recorded in the core sediments (Fig. 18): the sedimentary record begins with a period including, at least, seasonal phases of relatively high salinity indicated by some gyrogonites of *L. papulosum* at a depth of – 110 – 120 cm. The lake water became slightly diluted at the time of deposition of *C. baltica*, between – 70 and – 90 cm depth. The significant presence of the halophilous *L. papulosum* in level – 30 cm can be attributed to a period of severe drought followed by a return to less salty conditions in the lake. The sediments between – 5 and – 20 cm depth, with *C. connivens* and very abundant *C. aspera*, correspond to conditions similar to the present, with salinity below 10 $g \cdot l^{-1}$.

Surveys of ecological conditions in the south part of Sidi Bou Rhaba during the years 1978 and 1979 recorded variable salinity, from 2.05 $g \cdot l^{-1}$ in February to 12.2 g $g \cdot l^{-1}$ before temporary drying out (Ramdani, 1981). Complementary studies during the years 1984-85 and 1990-93 measured salinity range from 3 to 8.10 $g \cdot l^{-1}$ (Elkhiati, 1987, 1995). At that time, *C. aspera, C. canescens* and *C. galioides* were collected in the southern part of the lake, where RHAB3 was sampled. In spring 2003, a large surface of shallow water (up to 1 m depth) around the core site was again densely covered by *C. aspera* and *C. canescens.* The latter taxon was not identified from the gyrogonites in the core because *C. canescens* never forms gyrogonites. The remains of this species are probably included in the thousands of indeterminable, uncalcified oospores.

The age of the sediments of core RHAB3 may be approximated by comparison with the previous core RHAB2, collected in April 1997. This earlier core was from the permanent part of the lake and was radiometrically dated using ^{137}Cs and ^{210}Pb (Appleby *et al.*, 2001). The core can be divided into two phases of sedimentation (Fig. 19): from 1860 to 1940, the average sedimentation rate was *ca* 0.5 cm per year. From about 1940 onwards, the sedimentation rate accelerated with an estimated yearly mean of *ca* 1.16 cm for the last sixty years. The base of the core RHAB2 at 1 m depth was dated to 1860 AD. Inferring dates for RHAB3 from RHAB2 is problematic. However, we can infer that the sedimentation rate might have been higher near the border of the lake (RHAB3) than in the centre. Thus, sediments from similar depth should be younger in RHAB3. The sediments at – 40 cm were dated to ~1970 AD in core RHAB2 and this depth could well correspond to the years around 1980 in the core RHAB3. The level containing *L. papulosum* could thus be correlated with the years 1981-83, for which the meteorological data registered a severe drought. Due to the recent low saline conditions, no gyrogonites of *L. papulosum* were found in the uppermost part of the core.

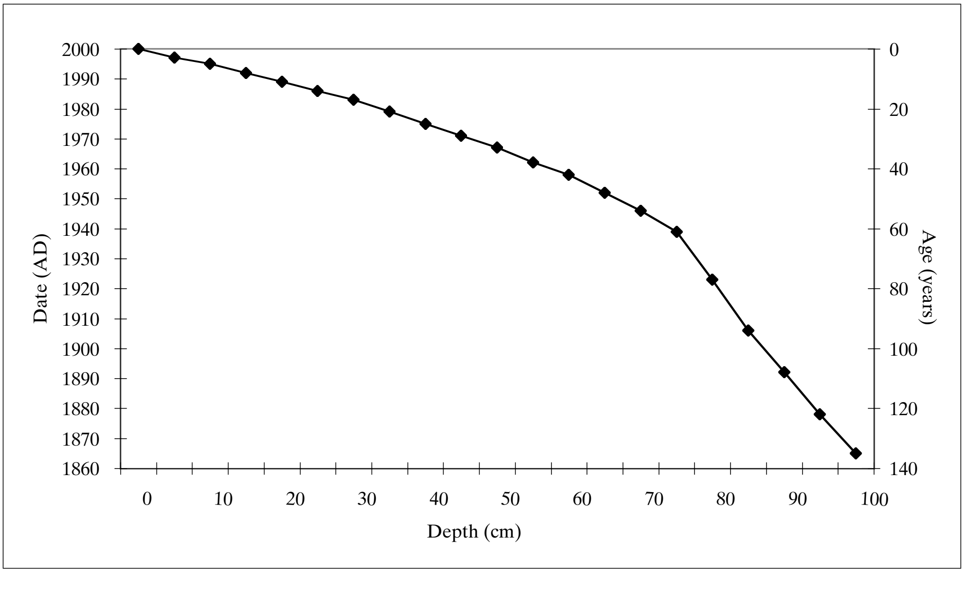


Fig. 19. Chronology of core RHAB2 (after data from Appleby *et al.*, 2001).

CONCLUSION

The study of the fossil and sub-fossil Charophytes in the sediments of Lake Sidi Bou Rhaba indicates that changes in salinity occurred during the last century. The presence of *L. papulosum*, not recorded previously in this lake, indicates that higher salinity conditions than at present have occurred in the recent past. These conditions probably corresponded to a period of dry years, as attested by meteorological data to have prevailed in this area about 1980 AD.

The vertical distribution of the Charophyte gyrogonites, belonging to four species with different salinity tolerances, points to an unstable environment in terms of salinity in Sidi Bou Rhaba. Climate change is thought the most likely cause of this instability. Two major phases of increased salinity, reaching more than 20 $g \cdot l^{-1}$, can be deduced from the presence of *L. papulosum*. These are likely indicative of low winter precipitation and strong evaporation occurring in spring followed by a long phase of summer desiccation. This summer period is likely the time of substantial increase in lake salinity. Contributions to lake salinity from underground saltwater can probably be excluded because the saline aquifer is known to be some 140 m below the interdunal freshwater lens (Margat, 1961; Le Coz, 1964). Humid periods with abundant winter precipitation and with a relatively wet spring favoured the development of low saline or even freshwater Charophyte species. The results of this study confirm that Charophytes can be a useful bio-indicator tool for palaeolimnological studies, particularly for inferring climate change effects on lake ecosystems at the decadal time-scale.

Acknowledgments. This collaborative work was facilitated by support from the *Comité Mixte Inter-Universitaire Franco-Marocain* (C.M.I.F.M.), research project A.I. 00/220/STU. This publication is number 2003-119 of the Montpellier Institute of Evolutionary Sciences (ISE-M).

REFERENCES

APPLEBY P.G., BIRKS H.H., FLOWER R.J., ROSE N., PEGLAR S.M., RAMDANI M., KRAIEM M.M., & FATHY A.A., 2001 — Radiometrically determined dates and sedimentation rates for recent sediments in nine North African wetland lakes (the CASSARINA Project). *Aquatic Ecology* 35 (3-4): 347-367.

BAYED A., BAZAIRI H.A., BENHOUSSA A., & QNINBA A., 1997 — La pêche à Merja Zerga. *MedWet2*, *Séminaire sur les zones humides*. Septembre 1997, 3 p.

BIRKS H.H., PEGLAR S.M., BOOMER I., FLOWER R.J., RAMDANI M., with contribution from APPLEBY P.G., BJUNE A.E, PATRICK S.T., KRAIEM M.M., FATHY A.A. & ABDELZAHER H.M.A., 2001 — Paleolimnological responses of nine North African lakes in the CASSARINA Project to recent environmental changes and human impact detected by plant macrofossil, pollen, and faunal analysis. *Aquatic Ecology* 35 (3-4): 405-430.

DAKKI M. & ELAGBANI M., 1997 — Diversité, fonction et valeurs des zones humides du Maroc. *MedWet2, Séminaire sur les zones humides*. Septembre 1997, 5 p.

ELKHIATI N., 1987 — *Les Characées (macroalgues) du Maroc : biotypologie dans les eaux continentales et production dans les dayas*. Thèse 3e cycle, Marseille I, 115 p.

ELKHIATI N., 1995 — *Biotypologie et biogéographie des Charophycées du Maroc. Contribution à l'étude des peuplements d'algues et de macrophytes de l'hydrosystème de Tamaris (Meseta occidentale)*. Thèse d'Etat, Fac. Sci. Semlalia, Marrakech, 155 p.

FELDMANN G., 1946 — Les Charophycées d'Afrique du Nord. *Bulletin de la Société d'Histoire Naturelle de l'Afrique du Nord* 37: 64-118.

FELDMANN, G., 1953 — Les Charophycées marocaines. *Bulletin de la Société des Sciences Naturelles et Physiques du Maroc* 33: 13-22.

FLOWER R.J., 2001 — Change, Stress, Sustainability and Aquatic ecosystem Resilience in North African wetland lakes during the 20th century: an introduction to integred biodiversity studies within CASSARINA Project. *Aquatic Ecology* 35 (3-4): 261-280.

FLOWER R.J., STEVENSON A.C., DEARING J.D., FOSTER I.D.L., AIREY A., RIPPEY B., WILSON J.F.F. & APPLEBY P.G., 1989 — Catchment disturbance inferred from paleolimnological studies of three contrasted subhumid environment in Morocco. *Journal of Paleaolimnology* 4: 279-292.

GAYRAL P., 1954 — Recherches phytolimnologiques au Maroc. *Travaux de l'Institut Scientifique Chérifien, Série Botanique*, 4: 1-308.

GUERLESQUIN M., 1974 — *Nouvelle contribution à l'étude des Charophycées du Maroc occidental*. CNRS, Travaux R.C.P. 249 (II): 187-207.

GUERLESQUIN M., 1978 — *Nouvelle contribution à l'étude des Charophycées du Maroc nord-occidental (II)*. CNRS, Travaux R.C.P. 249 (IV): 109-137.

KRAUSE W., 1997 — Charales (Charophyceae). *In*: ETTL H., GÄRTNER G., HEYNIG H. & MOLLENHAUER D. (eds), *Süsswasserflora von Mitteleuropa* 18. Stuttgart, G. Fischer, 202 p.

LE COZ J., 1964 — *Le Rharb. Fellahs et colons*. Doct. d'Etat, Rabat, 2t., 481 p.

MARGAT J., 1961 — Les eaux salées au Maroc. Hydrogéologie et hydrochimie. *Notes & Mémoires du Service Géologique, Maroc*, n° 151, 137 p.

RAMDANI M., 1981 — Recherches hydrobiologiques sur la merja Sidi Bou Rhaba (littoral atlantique du Maroc) : étude physico-chimique et analyse faunistique. *Bulletin de l'Institut Scientifique (Rabat)* 5: 37-137.

RAMDANI M. & ELKHIATI N., 2000 — *Description of the Moroccan sites, vegetation transects analysis, water chemistry analysis, zooplankton analysis in open water, zooplanktonic and benthic fauna analysis of the primary sediment cores from the 9 CASSARINA lakes*. London, CASSARINA final report, 121 pp.

RAMDANI M., FLOWER R.J., ELKHIATI N., KRAIEM M.M., FATHI A.A., BIRKS H.H. & PATRICK S.T., 2001a — North African wetland lakes: Characterization of nine sites included in the CASSARINA Project. *Aquatic Ecology* 35 (3-4): 281-302.

RAMDANI M., ELKHIATI N., FLOWER R.J., WITH CONTRIBUTIONS FROM KRAIEM M.M., FATHI A.A, BIRKS H.H. & PATRICK S.T., 2001b — Open water zooplankton communities in North African wetland lakes: the CASSARINA Project. *Aquatic Ecology* 35 (3-4): 319-333.

RAMDANI M., FLOWER R.J., ELKHIATI N., BIRKS H.H., KRAIEM M.M., & FATHI A.A., 2001c — Zooplankton (Cladocera-Ostracoda) Chironomidae and other benthic faunal remains in sediment cores from nine wetland lakes: the CASSARINA Project. *Aquatic Ecology* 35 (3-4): 389-403.

SOULIÉ-MÄRSCHE I., 1989 — *Etude comparée de gyrogonites de Charophytes actuelles et fossiles et phylogénie des genres actuels*. Millau, Imprimerie des Tilleuls, 237 p, 45 pl. [Thèse d'Etat, USTL, Montpellier, 1979, édition révisée].

SOULIÉ-MÄRSCHE I., 1998 — Fossil *Lamprothamnium papulosum* (Charophyta), a biomarker for seasonal rainfall in northern Mauritania. *Paleoecology of Africa* 25: 65-76.

SOULIÉ-MÄRSCHE I., 2002 — Les Charophytes comme biomarqueurs pour la reconstitution des paléoenvironnements lacustres. *In*: MISKOVSKY J.C. (éd.), *Géologie de la Préhistoire: Méthodes, Techniques, Applications*. Paris, GEOPRE, pp. 751-768.