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Upper Eocene – Lowermost Miocene charophyte succession in the Ebro Basin (Spain). Contribution to the charophyte biozonation in Western Europe

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with 9 figures and 7 tables

Abstract. A charophyte succession has been established in nineteen sections and eight isolated outcrops from the Ebro Basin, ranging from the Priabonian to the Aquitanian. Most assemblages were recovered from continuous sections and their abundance and diversity allow to define a new zonal scheme for the Upper Eocene-Lower Miocene of Europe. The new zonation includes nine subdivisions, based on the distribution of thirty-two species and directly correlated with the mammal standard levels. Changes in diversity, occurring mainly in the Middle and Upper Oligocene, have been related to climatic variations. A new species, *Chara* sp. A. is also described and figured.

Résumé. Une biozonation basée sur les charophytes est établie dans le bassin de l'Ebre, à partir de 19 coupes et 8 gisements répartis du Priabonien à l'Aquitainien. Les associations représentées proviennent pour la plupart de coupes continues; l'abondance et la diversité floristiques observées permettent de définir une nouvelle biozonation, applicable à l'échelle de l'Europe pour l'intervalle Eocène supérieur-Miocène inférieur. Cette biozonation comprend neuf subdivisions, fondées sur la répartition de 32 espèces et comparées par corrélations directes avec les niveaux-repères standard des mammifères. Les changements affectant la diversité floristique à l'Oligocène moyen et supérieur sont corrélés avec des variations climatiques. Du point de vue de la systématique du groupe, une nouvelle espèce Oligocène, *Chara* sp. A, est décrite et figurée.

Zusammenfassung. An Hand von 19 Profilen und 8 zusätzlichen Fundstellen wird im Ebrobecken eine Biozonierung nach Charophyten vom Priabonium bis zum Aquitanium vorgenommen. Die Florenassoziationen stammen zumeist aus durchgehenden Profilen. Ihre Häufigkeit und Vielfalt erlauben, ein für Europa gültiges Zonierungsschema des Intervalles Ober-Eozän bis Unter-Miozän aufzustellen. Diese Biozonierung, die auf den Reichweiten von 32 Arten fußt, umfaßt neun Unterteilungen, die direkt mit dem Standard der Säuger-Leitniveaus korreliert sind. Fluktuationen in der Florendiversität im Mittel- und Ober-Oligozän werden auf Klimaschwankungen bezogen. Hinsichtlich der Systematik wird eine neue Art aus dem Oligozän, *Chara* sp. A, beschrieben und abgebildet.

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I. Introduction

During the Paleogene, predominantly nonmarine sediments accumulated in the eastern part of the Ebro Basin. The carbonate freshwater and brackish deposits have yielded abundant charophytes and the assemblages found in continuous sections show a florizonal succession from the Paleocene to the Lower Miocene. As a result of the stratigraphic studies carried out in the Paleogene sequences of the Ebro Basin (ANADÓN 1978; COLOMBO 1980, 1986; ANADÓN & FEIST 1981; CABRERA 1983; SÁEZ, 1987), it has been established that most of the studied charophyte assemblages are distributed through a number of continuous and correlable stratigraphic sequences (ANADÓN et al. 1989). This stratigraphic continuity and the quite large number of samples have enabled us to make a local charophyte biozonation. Moreover, this is one of the uncommon cases in which a charophyte biozonation established on a continuous nonmarine Upper Eocene – Lower Miocene stratigraphic sequence can also be referred to a local mammal biozonation based on more than thirty rodent assemblages (AGUSTÍ et al. 1987, 1988; ANADÓN et al. 1987). Our study focusses on the charophyte assemblages found in the sections spanning the Upper Eocene-Lower Miocene interval from the Eastern Ebro Basin, between the Llobregat Valley, to the East, and the Cinca and Ebro valleys, to the West (Fig. 1). These sequences are included between the top of the marine succession attributed to the Priabonian (FERRER 1971) and the bottom of the non-marine Neogene.

Charophytes from the Ebro Basin were first mentioned by DALLONI (1930) from the Sierra de Montclar and in the Santa Coloma de Queralt succession. Later, ROSELL et al. (1966) based the attribution of the nonmarine sequences at Igualada to the Upper Lutetian on a charophyte assemblage identified by L. GRAMBAST which also recognized *Harrisichara lineata* in the locality of El Parès (COLOM et al. 1970) which we will discuss below. Among these first records, the species quoted in the explanation of the geological maps of Calaf and Cardona (RAMÍREZ DEL POZO et al. 1975a & b) should be mentioned, although some of them they have not been rediscovered since. The first comprehensive study was by ANADÓN & FEIST (1981) who dated and subdivided the succeeding charophyte-bearing sequences of the central part of the Eastern Ebro Basin margin from Thanetian to Bartonian. Later, ANADÓN et al. (1983) demonstrated the correlation of the uppermost beds of the Pontils Group at the type section, containing *Raskyella vadaszi*, with the standard Mammal level of La Livinière and the NP17 Nannoplancton zone. These data have been taken into consideration in the Paleogene charophyte biozonation defined by RIVELINE (1986). The charophyte assemblages from the eastern part of the studied area have been partially analyzed by CHOI (1989).

II. Geological setting

The Tertiary Ebro Basin is the southern foreland basin of the Pyrenees. This basin is also bounded by the Catalan Coastal Ranges to the SE and the Iberian Chain to the SW. In the Eastern Ebro Basin (Fig. 1) the sedimentary evolution has been mainly influenced by two margins: the Pyrenees (a thrust – sheet belt, PUIGDEFÁBREGAS et al. 1986) and the Catalan Coastal Range which is mainly related to a Paleogene strike-slip fault system (ANADÓN et al. 1985). The Paleogene succession in the Eastern Ebro Basin, up to 2500 m thick, comprises two

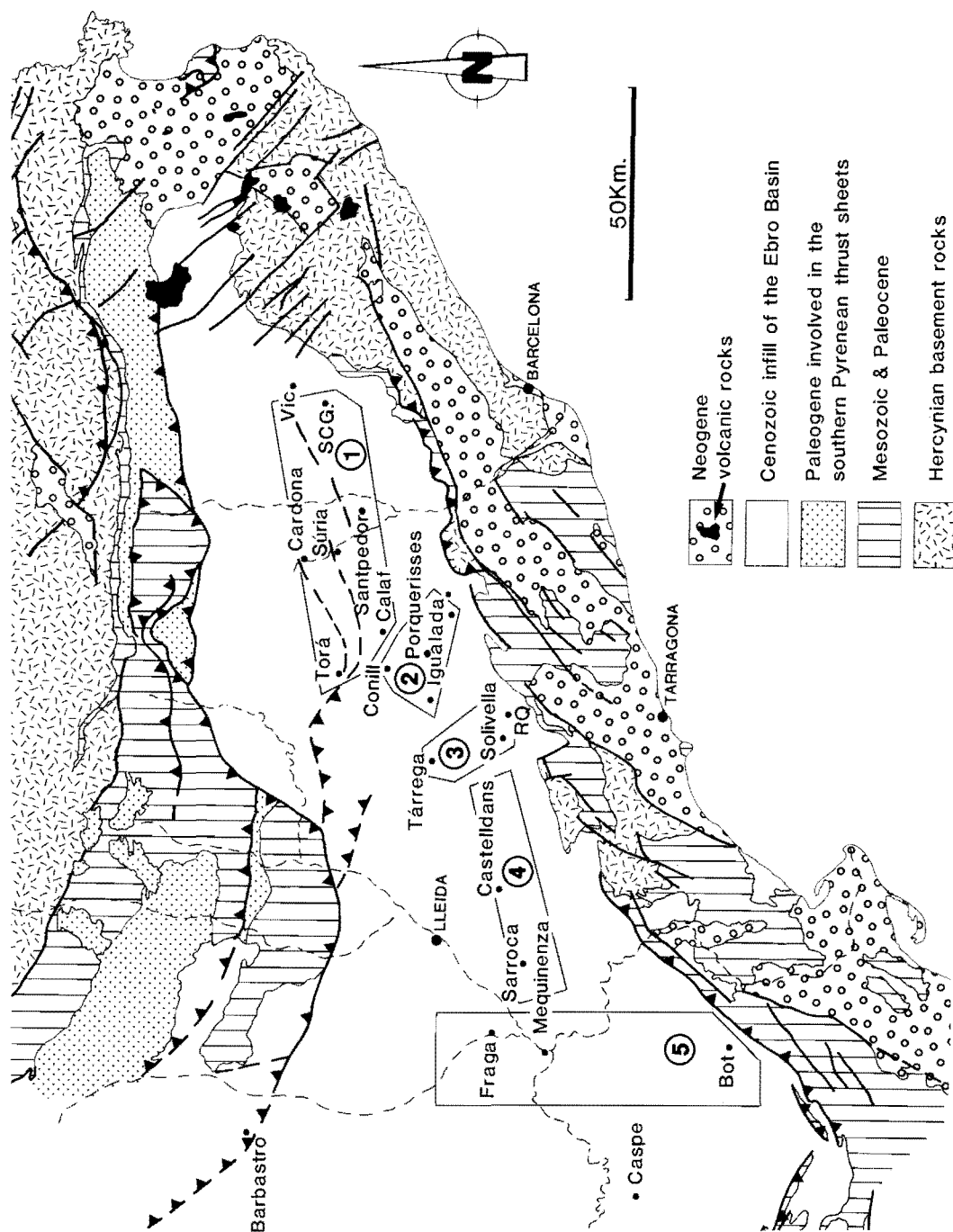


Fig. 1. The Eastern Ebro Basin map with areas used in this study.

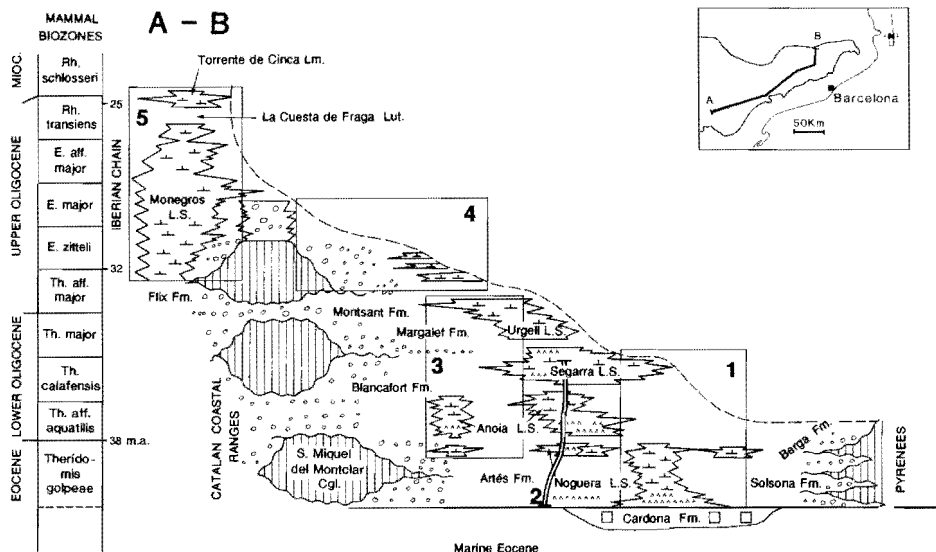


Fig. 2. Schematic stratigraphic cross section of the Upper Priabonian-Lower Aquitanian basin fill in the Eastern Ebro Basin.

important marine – non-marine cycles linked to two major transgressive maxima : Ilerdian (Early Eocene) and Bartonian (Middle – Late Eocene). In the northern areas of the Ebro Basin these two cycles are well recorded whereas in the southern areas non-marine sedimentation was continuous throughout the Paleogene. During the Late Eocene a rapid regression took place and non-marine conditions spread all over the Ebro Basin.

The Upper Eocene – Oligocene basin fill in the Eastern Ebro Basin consists of thick sequences formed in different lacustrine systems which developed in the inner basin zones. These lacustrine systems were fed by marginal alluvial systems. The deposits of the lacustrine systems comprise carbonates, mudstones, sandstones, evaporites and minor, coals. The alluvial deposits consist of proximal conglomerates that pass laterally, basinwards, into sandstone and mudstone dominated sequences. ANADÓN et al. (1989) have distinguished five lacustrine systems for the Upper Eocene to Upper Oligocene sequences of the Eastern Ebro Basin. The lacustrine systems must be regarded as “Depositional Groups” or “Depositional Systems” in the sense of FISHER & MCGOWEN (1969) and comprise several minor lithostratigraphic units with the range of Formation. Figure 2, based on ANADÓN et al. (1989) shows the schematic distribution of the lacustrine systems and their relationship with the alluvial systems in the Eastern Ebro Basin. In the present work, we will only mention the units related with the distribution of the charophytes or units with special stratigraphic interest.

The distribution of charophytes presented in this paper is based on samples referred to stratigraphic sections or mammal sites (Figs. 3–8) which have been correlated by mean of key beds in aerial photographs and geologic maps. The result of these lithostratigraphic correlations has been shown in Tables 1 to 5. The charophyte distribution of the sampled sections

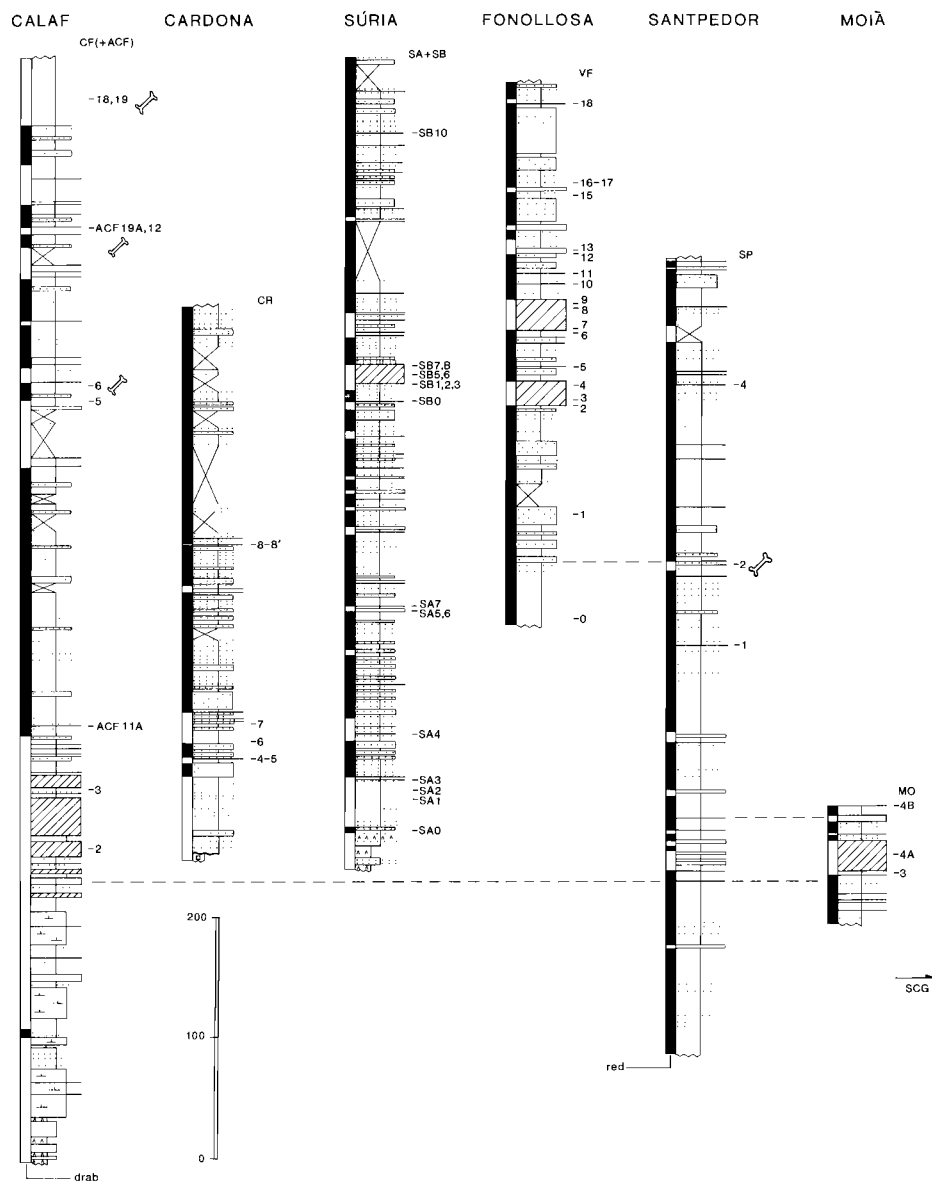


Fig. 3. Stratigraphic logs in the Upper Eocene-Lower Oligocene non-marine deposits of area 1. See Figs. 1 and 2 for location and stratigraphic position. See charophyte distribution in Table 1.

JORBA-LA PANADELLA

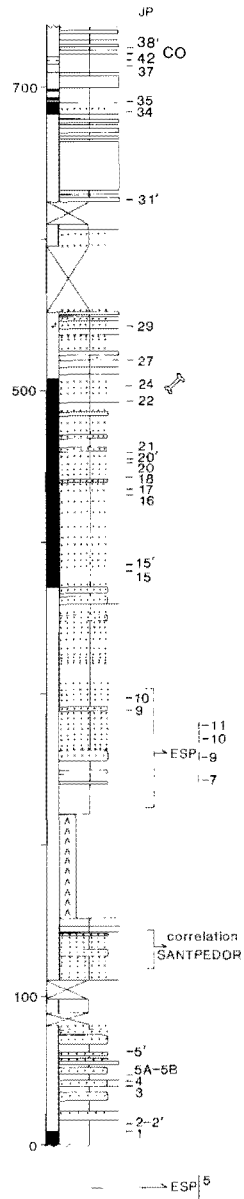


Fig. 4.

Fig. 4. Stratigraphic log of the Jorba-La Panadella section. Area 2 in Figs. 1 and 2. See charophyte distribution in Table 2.

FORÉS EL TALLADELL

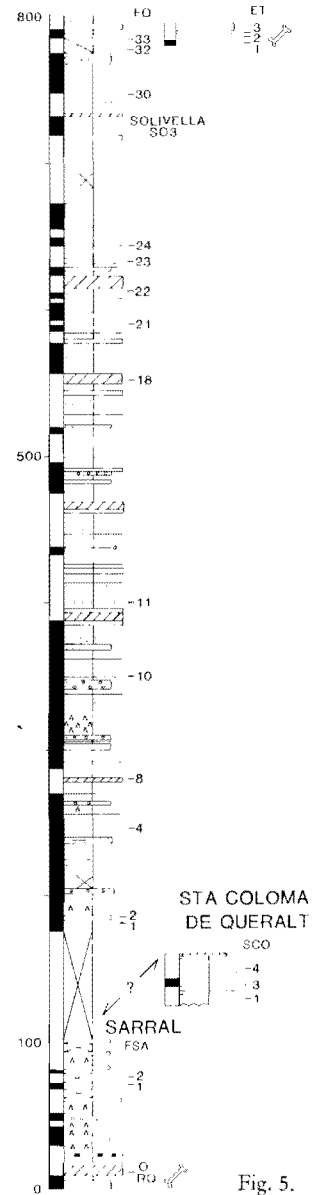


Fig. 5.

Fig. 5. Composite stratigraphic log of the Forés and SarraL sections. Correlation with El Talladell and Santa Coloma de Queralt logs are also shown. Area 3 in Figs. 1 and 2. See charophyte distribution in Table 3.

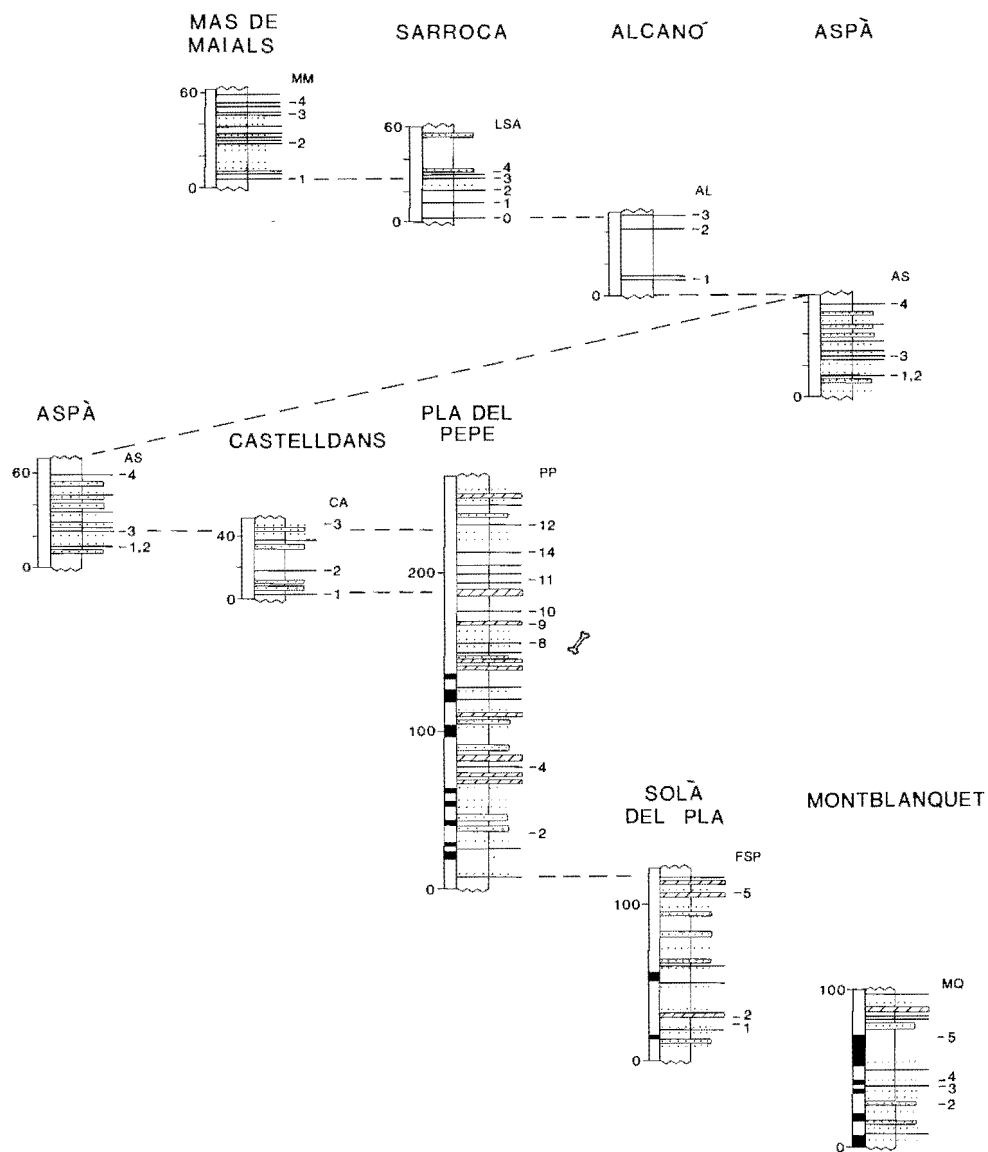


Fig. 6. Stratigraphic logs in the Oligocene deposits of area 4 (Figs. 1 and 2). See charophyte distribution in Table 4.

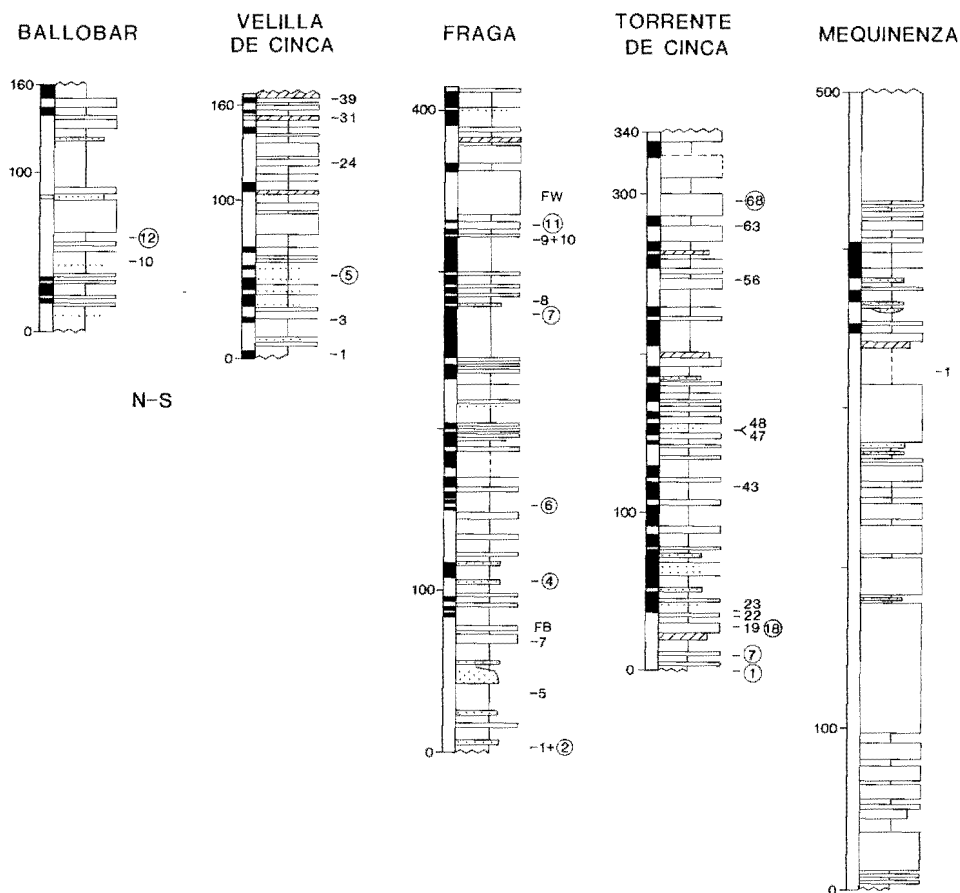


Fig. 7. Stratigraphic logs in the Upper Oligocene deposits of area 5 (Figs. 1 and 2). See charophyte distribution in Table 5.

have been grouped in 5 areas (Figs. 1 and 2) which correspond to stratigraphic record ranges that can be correlated among them. In some places, a certain degree of contemporaneity exists among these ranges.

III. The charophyte species

In the Upper Eocene – Lower Miocene sequences of the Ebro Basin, we have found thirty-two charophyte species. Most of these species have been reported previously from other areas in the numerous studies which have been carried out during the last two decades on the Cenozoic charophyte floras of Europe. In order to simplify the following report, we will frequently refer to the synoptic study of RIVELINE (1986) which sums up the papers prior to

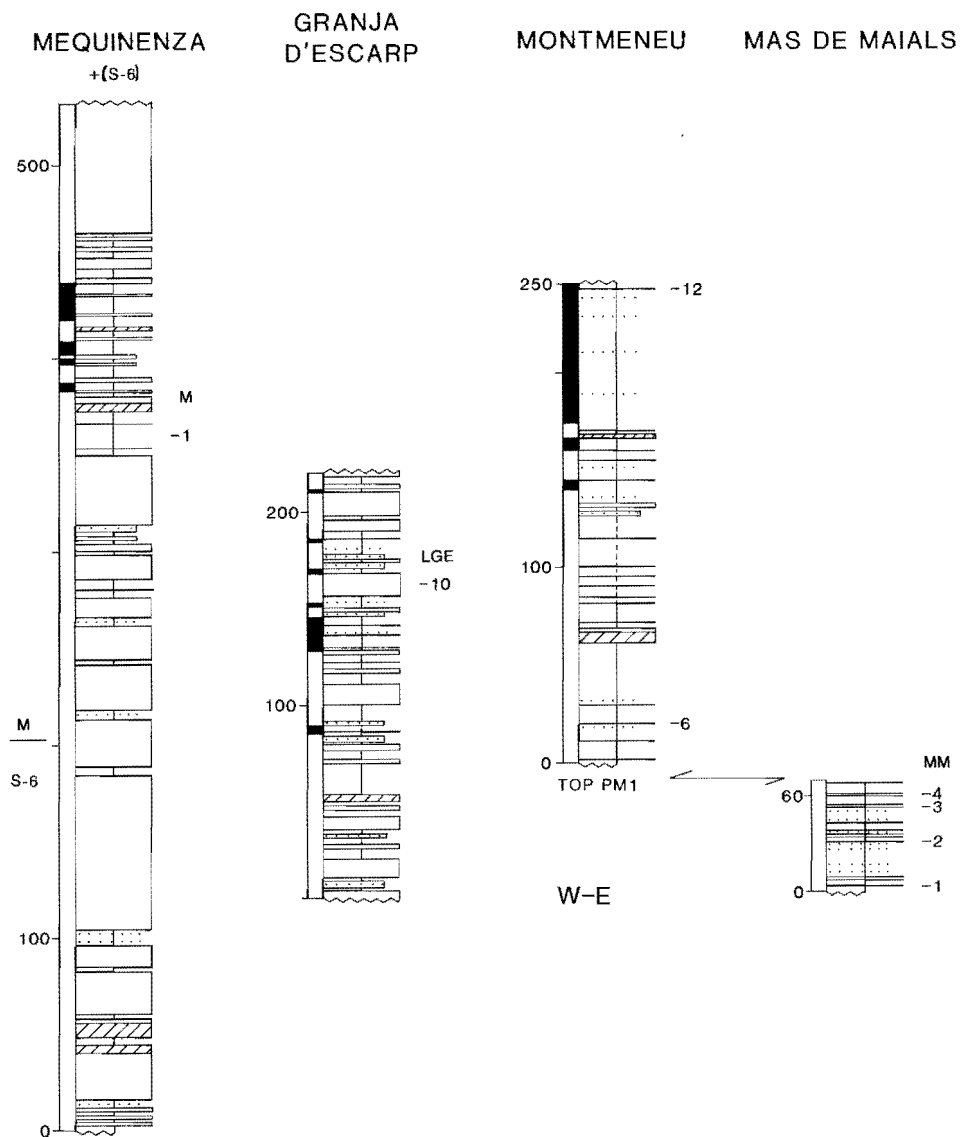


Fig. 8. Stratigraphic logs in the Upper Oligocene deposits of area 5. The correlation corresponds to an E-W cross section. This section links the correlation of profiles in Figure 6 with those in Figure 7.

1984. Moreover, we refer the Paleogene mammal local biozones to the work of AGUSTÍ et al. (1987) and to the correlation charts of the Paleogene European mammal reference levels of SCHMIDT-KITTLER (ed. 1987) abridged MP. The species recognized in the present study, documented below, all belong to the Characeae family.

1. *Harrisichara lineata* GRAMBAST 1957

Distribution and range in the Ebro Basin (area 1, Fig. 1): there is only one record of this species, at the locality of El Parès, in the Vic area (COLOM et al. 1970). *H. lineata* is represented there by more globular specimens and of higher dimensions than in the Paris Basin, but these differences are considered to be within the limits of variation of the species. The fossiliferous bed is placed in the lagoonal facies of the upper part of the Tossa Formation (Lower Priabonian; FERRER 1971), close to the lowermost beds of the non-marine Artés Formation. The species ranges from the Upper Bartonian *Raskyella vadaszi* zone to the Upper Priabonian *Sphaerochara labellata* zone, which is defined in this paper; in Saint-Cannat (Southern of France), that is its most recent locality, this species is associated with *H. tuberculata* (FEIST-CASTEL (1977b)).

Other occurrences: Upper Bartonian to Middle Priabonian of the Paris Basin and Southern of France (FEIST & RINGEADÉ 1977; RIVELINE 1986).

2. *Harrisichara tuberculata* (LYELL) GRAMBAST 1957

Distribution and range in the Ebro Basin (areas 1–3, Figs. 3–5, Tables 1–3): this species occurs abundantly in a number of horizons of Upper Priabonian and Lower Stampian age. The dating of the Calaf Formation is critical for the upper extension limit of the species and thus for the range of the Bembridge zone (CASTEL 1968), or *H. tuberculata* superzone (RIVELINE 1986).

The lowermost stratigraphic occurrence of this species is in the San Cugat de Gavadons mammal site (*Theridomys golpeae* local zone, MP 19); the uppermost occurrence is in the Conill section, stratigraphically located between the Porquerisses mammal site (*Th. calafensis* local zone, according to Anadón et al. 1987, MP 21–MP 22) and the Tàrraga mammal site (*Th. major* zone, MP 23).

Other occurrences: the species, widespread in Europe, has never been mentioned in localities more recent than Lower Stampian. In particular it is absent in the charophyte and mammal locality of Villebramar which is typical of the standard level MP 22 (SCHMIDT-KITTLER (Ed.) 1987). The extension of the species in the Isle of Wight, which is its type area, is also significant; *H. tuberculata* extends from the Bembridge Limestone to the Lower Hamstead Beds (FEIST-CASTEL 1977a), but it is absent in the superceeding Upper Hamstead Beds (*Cerithium* Beds, Bouldnor Clif, sample C. 300, University of Montpellier II). Outside of the Ebro Basin, the range of the species is thus restricted to the Upper Priabonian Lower – Stampian. However, its presence in the Calaf beds implies that it may extend higher, in the time interval corresponding to charophyte biozone 4, during which some endemic taxa occurred in the Ebro Basin, such as *Chara* sp. 2 and *Nodosochara jorbae* (Table 2).

3. *Harrisichara vasiformis-tuberculata*

This informal species name was proposed to designate the transitional forms from *H. vasiformis* to *H. tuberculata* (FEIST-CASTEL 1977a). These forms have been taken as index species for the establishment of a Late Eocene zone, due to their wide geographic distribution (RIVELINE 1986). This zone only covers the lower part of the species range.

Distribution and range in the Ebro Basin (area 1, Fig. 3, Table 1): the occurrence of the species in the Moia section, at the lower part of the Artès Formation, corresponds to its upper range, coexisting with the lowest occurrence of *H. tuberculata*.

Other occurrences: this form has been reported from the Isle of Wight, Paris Basin and South of France (see RIVELINE 1986). Its range corresponds to the Middle and Late Priabonian.

4. *Rhabdochara stockmansi* GRAMBAST 1957

Distribution and range in the Ebro Basin (areas 1–3; Figs. 3–5, Tables 1–3): the species has been collected in the Upper Eocene Rocafort de Queralt locality and in the upper part of the Calizas de la Panadella Formation at Conill. In addition, *R. stockmansi* occurs in the Solsona Formation, within the Fonollosa section. *H. tuberculata* is also present in Conill and its association with *R. stockmansi* is typical of the upper part of the *H. tuberculata* Superzone [RIVELINE 1986; corresponding to the previously defined Upper Bembridge zone (CASTEL 1968; FEIST & RINGEAD 1977)]. In Conill, the association of these two species with *Gyrogona medicaginula*, whose first occurrence is known to be in the Sannoisian Calcaire de Brie (GRAMBAST 1962), corresponds to a Lower Stampian or slightly younger age.

Other occurrences: the species has been reported from a great number of European localities (see RIVELINE 1986). Its range is the same as *H. tuberculata*, Upper Priabonian and Lower Stampian.

5. *Rhabdochara major* GRAMBAST & PAUL 1965

Distribution and range in the Ebro Basin (area 3, Fig. 5, Table 3): the species has been found in the Tàrraga Formation. Its lowest occurrence is in Solivella, below the El Talladell, also named Tàrraga mammal locality, referred to the *Th. major* zone (MP 23). The upper occurrence of this species is above the Pla del Pepe mammal site of the *Th. aff. major* zone (MP 25).

Other occurrences: *R. major* has been reported from Northern and Southern France, Switzerland and Germany (see RIVELINE, 1986). It spans the upper Lower Stampian and Upper Stampian.

6. *Rhabdochara praelangeri* CASTEL 1967

Distribution and range in the Ebro Basin (Fig. 1, area 5, Table 5): the species has been found in the Bot section, from beds of the Upper Oligocene Flix Formation which have been correlated lithostratigraphically with the Gandesa beds which are included in the *Eomys züteli* mammal zone (AGUSTÍ et al. 1987, MP 26).

Other occurrences: in addition to the type-locality near Marseille, the species has been reported from numerous localities in France, Germany and Switzerland. It ranges from the Upper Stampian to the Lower Aquitanian (FEIST-CASTEL 1977a; CHELLAI et al. 1982; RIVELINE 1986).

7. *Rhabdochara langeri* (ETTINGSHAUSEN) MÄDLER

Distribution and range in the Ebro Basin: (areas 4, 5; Figs. 6, 7; Tables 4, 5): the species is present in the Upper Oligocene sequences of the Margalef Formation and of the Granja d'Escarp Lutites, in the Mas de Maials and Aspà areas. Its lowest occurrence is in beds correlated from stratigraphical position with *E. major* zone (MP 27). The upper occurrence of the species is in beds referred to the *E. aff. major* zone, equivalent to the MP 27 and MP 28.

Other occurrences: *R. langeri* is widespread in Europe, in the Upper Chattian and Aquitanian (FEIST & RINGEADÉ 1977; RIVELINE 1986).

8. *Rhabdochara aff. altilis* FEIST-CASTEL 1977a

Specimens from the Ebro Basin designated under this name differ from the typical *R. altilis* in lacking a basal funnel and presenting a rounded, instead of truncated, apex (CHOI 1989).

Distribution and range in the Ebro Basin (area 1, Fig. 3, Table 1): this form is represented in the Artès Formation. Its lowest occurrence is in the lower part of the Calaf and Moia sections, in beds several tens of metres stratigraphically above the Sant Cugat mammal site (*Th. golpeae* zone) which can be referred indifferently to the *Th. golpeae* or to the *Th. aff. aquatilis* zones (MP 19/20 or MP 21). The upper occurrences of this form is in the Santpedor mammal locality attributed to the Lower Oligocene *Th. aff. aquatilis* zone (AGUSTÍ et al. 1987, MP 21). From Rodent evidence, this form extends, in the Ebro Basin, from the Lower Priabonian to the Lower Stampian.

Occurrences of *Rh. altilis*: typical representatives of the species have been reported from two localities of the Mormoiron Basin, in Southern France, both of Upper Priabonian age (FEIST-CASTEL 1977a).

9. *Rhabdochara aff. raibocarpa* FEIST-CASTEL 1977a

Close to *R. raibocarpa* in general shape and apical structure of the gyrogonites, the catalan form differs clearly in its smaller dimensions.

Distribution and range in the Ebro Basin (areas 1,2; Figs. 3,4; Tables 1,2): this form occurs abundantly in some levels of the Artès, Súria and Solsona Formations. Its lowest occurrence is stratigraphically located between the Sant Cugat de Gavadons and Santpedor mammal sites, respectively reported to the *Th. golpae* (MP 19) and *Th. aff. aquatilis* (MP 21) zones. The highest occurrence of the species is in the Fonollosa mammal site, referred to the *Th. calafensis* zone (MP 21–MP 22).

Occurrences of *R. raibocarpa*: The species has been reported only from the type locality, in the Mormoiron Basin (South of France).

10. *Stephanochara* aff. *vectensis* (GROVES) GRAMBAST in RIVELINE 1986

Two different forms are grouped under this denomination: a) In Bed 2 of the Forès section, specimens closely allied to *S. vectensis* but with a more conical shape and a slightly more prominent basal part; the dimensions do not differ significantly. b) In beds 0 and 1 of the Sarra section, the form represented differs from typical representatives of the species only by their distinctly smaller dimensions.

Distribution and range in the Ebro Basin (area 3, Fig. 5, Table 3): the lowest occurrence of *S. aff. vectensis* is in the Upper Priabonian Rocafort de Queralt mammal site, referred to the *Th. golpae* zone (MP 19). Its highest occurrence is above bed 2 in the Forès section, attributed the *Th. calafensis* zone (MP 21–MP 22).

Occurrences of *Stephanochara vectensis*: the species has been reported from the Upper Priabonian of the Paris Basin and from the uppermost Bembridge Marls of the Isle of Wight. Reexamination of material from the Bembridge Limestone did not confirm the presence of *S. vectensis*, notably the specimens collected by Professor D. CURRY at Hamstead Ledge (C. 313, Professor GRAMBAST charophyte collection, Montpellier University) and Gurnard Bay (C. 315). Further collectings at Whitecliff Bay (C. 2685c in FEIST-CASTEL 1977a) were also negative. The species is absent, too, in the Bembridge Oyster Beds, twelve metres above the Bembridge Limestone (C. 316). Our research has shown that the range of this form, which is the index-species of a charophyte biozone, is restricted, in the Isle of Wight, to the Insect Limestone of the Bembridge Marls (specimens V. 18335, Natural History Museum, London).

11. *Stephanochara* aff. *pinquis* GRAMBAST in RIVELINE 1986

The forms of the Ebro Basin allied to *S. pinquis* show similar general shape and dimensions but they differ in the less prominent apical nodules. This difference does not seem to be a result of a lower degree of calcification, as the spiral cells are clearly convex and thus well calcified.

Distribution and range in the Ebro Basin (area 3, Fig. 5, Table 3): *S. aff. pinquis* occurs in the Tàrraga Formation, in the uppermost beds of the Forès and El Talladel sections, attributed to the Upper Stampian *Th. major* zone (MP 23), on mammal evidence.

Occurrences of *S. pinquis*: this species is restricted to the Lower Stampian (RIVELINE 1986). In particular, in the Sierra Palomera (Teruel Province, Spain) it is associated with the Rodent *Theridomys aquatilis* (ADROVER et al. 1983), attributable to the MP 21.

12. *Stephanochara lychnothamnoides* FEIST in FEIST & RINGEADE 1977

Distribution and range in the Ebro basin (area 1, Fig. 3, Table 1): this species occurs only in the uppermost beds of the Calaf section which are attributed to the *Th. calafensis* zone (MP 21–MP 22).

Other occurrences: *S. lychnothamnoides* has previously been reported from the Upper Eocene of the Aquitaine Basin, France (FEIST & RINGEADE 1977) and from the Lower Oligocene of the Western Iberian Chains (ADROVER et al. 1983).

13. *Stephanochara* aff. *edwardsii* GRAMBAST in RIVELINE 1986

This form closely resembles typical representatives of the species, apart from its smaller dimensions. It shows little variation in its different occurrences in the Ebro Basin.

Distribution and range in Ebro Basin (area 1, Fig. 3, Table 1): *S.* aff. *edwardsii* occurs in several horizons of the Artès, Súria and Solsona Formations, notably in the Sant Cugat de Gavadons, Santpedor and Fonollosa mammal localities. It ranges from the *Th. golpeae* to the *Th. calafensis* zones (MP 19 to MP 21–MP 22), thus from the Upper Priabonian to the Lower Stampian and lower Upper Stampian.

Occurrences of *S. edwardsii*: the species was previously recorded only from the Paris Basin and from the Isle of Wight where its extension is restricted to the Lower Priabonian ("Lower Ludian"; RIVELINE 1986).

14. *Stephanochara ungeri* FEIST-CASTEL 1977b

Extension and range in the Ebro Basin (area 5, Fig. 7, Table 5): the species occurs in several sections of the Mequinenza area. Its lowest occurrence is in the Upper Oligocene Fraga B-7 locality, related to the *E.* aff. *major* zone (MP 27). The species extends into the Lower Miocene, deduced from the stratigraphic position of beds 24 to 39 in the Vellila de Cinca section, 20 to 40 m above the mammal site referred to the *Rhodanomys schlosseri* zone (MN 1).

Other occurrences: the species is widespread in the Upper Oligocene and Lower Miocene (FEIST-CASTEL 1977b) and, according to PAPP (1951), persists until the Tortonian. *S. ungeri* is recorded under its former invalid name "*Croftiella escheri*" by FEIST & KISSLING (in KISSLING 1974), from the Lower Chattian onward and by BERGER (1986) under the name "*gr. ungeri*" in the *S. ungeri* zone, parallelized with the Aarwangen Mammal zone, also referred to the MP 27. We thus see that the first appearance of *S. ungeri* occurs simultaneously in the Ebro Basin and in the Swiss Molassic Basin. This fact strengthens the value of the species as zonal indicator.

15. *Stephanochara berdotensis* FEIST in FEIST & RINGEADÉ 1977

Extension and range in the Ebro basin (area 5, Fig. 7, Table 5): the species occurs in several horizons of the Upper Oligocene sequences of the La Cuesta de Fraga Lutites and in the Lower Aquitanian Torrente de Cinca-68 mammal locality. The appearance of *S. berdotensis* slightly below the Upper Oligocene Fraga W-7 locality, referred to the *R. transiens* zone (AGUSTÍ et al. 1987, 1988; MP 30; SCHMIDT-KITTLER 1987) considerably extends its range, previously known as restricted to the Upper Aquitanian and thus the charophyte zone based on its lowest occurrence is no longer defined.

Other occurrences: this species was recorded previously from the Upper Aquitanian of the Aquitaine Basin, which is its type area, and from several localities of the same age in the Swiss Molassic and Paris Basins (see RIVELINE 1986).

16. *Lychnothamnus longus* CHOI 1989

Extension and range in the Ebro Basin (areas 1–3; Figs. 3–5; Tables 1–3): *L. longus* occurs abundantly in the Artès Formation and lateral equivalent successions as well as in the La

Panadella – Montmaneu Limestone, referred to the *Th. calafensis* one, but it does not persist in the overlying Tàrrrega Limestone. It thus occurs in the Upper Eocene and Lower Oligocene. The lowest occurrence of this species is in the lowest Calaf bed and in the Moià section. Both sites are placed stratigraphically between the Sant Cugat de Gavadons and the Santpedor mammal sites (*Th. golpeae* – *Th. aff. aquatilis* biozones; MP 19–MP 21). Its uppermost occurrence is situated between the Porquerisses and Tàrrrega mammal sites, referred to the *Th. calafensis* (MP 21–MP 22) and *Th. major* zones (MP 23), respectively.

Other occurrences: *L. longus* has not yet been recorded from elsewhere.

17. *Nodosochara jorbae* CHOI 1989

Extension and range in the Ebro basin (areas 1,2; Figs. 3,4; Tables 1,2): this species is well represented in the Artés Formation and lateral equivalent successions. It is particularly abundant in the *Th. aff. aquatilis* zone (MP 21). Its possible occurrence in the *Th. golpeae* (MP 19) and *Th. calafensis* (MP 21–MP 22) zones can not be disregarded.

Other occurrences: the species is presently known only from the Ebro Basin.

18. *Gyrogona caelata* (REID & GROVES) GRAMBAST 1956

Extension and range in the Ebro Basin (areas 1, 2; Figs. 3, 4; Tables 1, 2): the species is well represented in the Jorba La Panadella, Súria and Fonollosa sections as well as in the Artés Formation and equivalent sequences, until the base of La Panadella Limestone. Its lowest occurrence is situated between the mammal sites of Sant Cugat de Gavadons (MP 19) and Santpedor (MP 21). The uppermost occurrence of *G. caelata* in the upper part of the Fonollosa section referred to the *Th. calafensis* zone (MP 21–MP 22) extends its range a few higher than the Lower Stampian.

Other occurrences: *G. caelata* is widely distributed in Europe, from the Upper Lutetian (GRAMBAST 1958) to the Lower Stampian (FEIST-CASTEL 1971, RIVELINE 1986).

19. *Gyrogona medicaginula* LAMARCK

Extension and range in the Ebro Basin (area 2, Fig. 4, Table 2): this species has been found only in the locality of Conill. The Conill beds are stratigraphically located between the mammal sites of Porquerisses (*Th. calafensis* zone, MP 21–MP 22) and Tàrrrega (*Th. major* zone, MP 23). Thus, up to date the exact range of this species in the Ebro Basin remains uncertain in relation to the mammal biozones.

Other occurrences: The species was previously known from the Lower to Upper Stampian of the Belgium and Paris Basin (RIVELINE 1986) as well as from the Bavarian Untere Süsswasser Molasse (BAUMGARTNER 1985).

20. *Chara* sp. 1 CHOI 1989

Distribution and range in the Ebro basin (area 1, Fig. 3, Table 1): this form occurs scarcely in the Upper Eocene and Lower Oligocene beds of the Súria and Torà sections. The stratigraphic

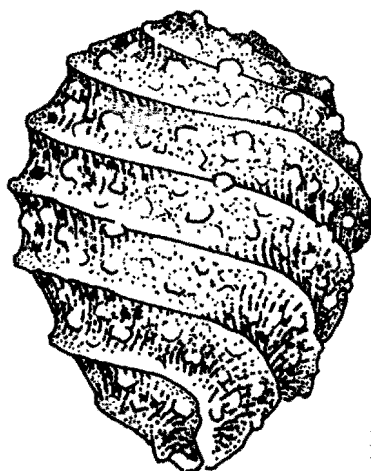


Fig. 9. *Chara* sp. A, lateral view, X80. From the Aspà section, bed 4; Upper Oligocene.

range of this species cannot be precisely determined due to its scarcity and its absence in well dated localities.

21. *Chara* sp. 2 CHOI 1989

Distribution and range in the Ebro Basin (areas 1, 2; Figs. 3, 4; Tables 1, 2): this form has been found in beds of the Artés and La Panadella Formations and lateral equivalent sequences. Its lowest occurrence is in levels stratigraphically situated between the mammal sites of Sant Cugat de Gavadons (*Th. golpeae* zone, MP 19) and Santpedor (*Th. aff. aquatilis* zone, MP 21). The uppermost occurrence is in beds overlying the Porquerisses mammal locality (*Th. calafensis*, MP 21–MP 22).

22. *Chara microcera* GRAMBAST & PAUL 1965

Distribution and range in the Ebro Basin (areas 3–5; Figs. 5–7; Tables 3–5): this species occurs in a number of localities, from the Upper Stampian to the Lower Aquitanian. Its occurrence in bed 3 of the Solivella section, referred to the *Th. major* zone (MP 23) extends its range, which was previously known as starting in the Heimersheim (MP 24) biozone (CHELLAI et al. 1982).

Other occurrences: *Chara microcera* is widespread in Europe, where it spans the Upper Oligocene and the Lower Miocene.

23. *Chara notata* GRAMBAST & PAUL 1965

Distribution and range in the Ebro Basin (areas 4, 5; Figs. 6, 7; Tables 4, 5): the species occurs in the upper sequences studied here, in the Late Oligocene and at the Oligocene-Miocene transition. Its lower occurrence is in the Aspà section, referred to the *E. major* zone (MP 27)

this fact resulting in a noticeable larger, lower extension of its range. Its uppermost occurrence is in the Velilla de Cinca Section, in beds corresponding to the Early Aquitanian *Rb. sclosseri* zone.

Other occurrences: this species is widespread in the Aquitanian and rarer in the Upper Oligocene. In the Swiss Molassic Basin, *C. notata* appears in the Rickenbach mammal horizon (BERGER 1986), attributed to the MP 29 standard level.

24. *Chara* sp. A (Fig. 9)

This form shows new conjunction of characters, but the diagnosis of a new species is not possible due to the small number of specimens found so far. The specimen represented (Fig. 9) shows a charoid apex and a pointed basal part that would characterize the genus *Hornichara* but, in addition to the fact that the spiral cells are provided with a *Chara*-like ornamentation, the population of *Chara notata* from the Aspà-4 bed includes specimens with a basal stalk and could be interpreted as transitional with the new form, that would question the validity of a new taxon.

Distribution and range in the Ebro Basin (area 4, Fig. 6, Table 4): *Chara* sp. A has been found in the Mas de Maials and Sarroca sections, in beds correlated with the Upper Oligocene *E. aff. major* zone (MP 27 and MP 28).

25. *Hornichara lagenalis* (STRAUB) HUANG & XU in WANG, HUANG, YANG & LEE 1978)

Distribution and range in the Ebro Basin (area 5, Fig. 7, Table 5): this species only occurs in some Upper Oligocene beds of the Mequinenza area. Its lowest occurrence is in bed Fraga B-5, that is placed few metres above the Fraga B-2 mammal site, attributed to the *E. major* zone (MP 26–27). The uppermost occurrence of *H. lagenalis* is in the Fraga W-4 mammal site, also included in the *E. aff. major* zone.

Other occurrences: *H. lagenalis* was reported from the Upper Oligocene and Lower Miocene of the Swiss and German molassic Basins (STRAUB 1952, FEIST-CASTEL 1977c) as well from Aquitaine (FEIST & RINGEADÉ 1977). However, previous Miocene records are now to be reconsidered and the species probably extends in fact from the Wynau (MP 27) to the Rickenbach (MP 29) mammal levels (BERGER 1986) and is thus restricted to the Oligocene, as it does in the Ebro Basin.

26. *Nitellopsis* (*Tectochara meriani*) (L. & N. GRAMBAST) GRAMBAST & SOULIÉ-MARSCHÉ 1972

Distribution and range in the Ebro Basin (areas 2, 4, 5; Figs. 4, 6, 7; Tables 2, 4, 5): the species is well represented, from the Lower Stampian onward. Its lowest occurrence is in bed 21 of the Jorba-La Panadella section, 40 m below the Porquerisses mammal site (bed 24, *Th. calafensis* zone, MP 22), which is 20 m below bed 27, containing the last representatives of *H. tuberculata*.

Other occurrences: *N. meriani* is widely distributed in Europe, from the Lower Oligocene to the Upper Tortonian. Its known lowest occurrences were reported by FEIST & RINGEADÉ (1977) from the mammal localities of Ruch and Pouquette, in the Aquitaine Basin, which are referred to the MP 21 standard level (RINGEADÉ 1987).

27. *Lamprothamnium* sp.

The presence of this genus is interesting in its palaeoecological significance; *Lamprothamnium* is a sure indicator of present and past saline lakes. Recent analogs of such environments in the Coorong area (south of Australia) are interpreted by BURNE et al. (1980) as being affected by seasonally varying salinities under semi-arid conditions.

Extension and range in the Ebro Basin (area 5, Fig. 7, Table 5): this form has been found in some beds of the La Panadella, Fraga and Torrente de Cinca sequences dated from the Upper Oligocene by other fossil assemblages.

28. *Sphaerochara subglobosa* (GROVES) HORN of RANTZIEN 1959

Distribution and range in the Ebro Basin (area 3, Fig. 5, Table 3): the species was only found in the lower part of the Forès section, attributed to the *Th. calafensis* zone (MP 21–MP 22).

Other occurrences: *S. subglobosa* was recorded from the Hampshire and Lower Saxonian Basins as well as from two localities in Southern France (see RIVELINE 1986). Taking in account the occurrences in the Ebro Basin, the species extends from the Upper Priabonian to the Lower Stampian.

29. *Sphaerochara* aff. *subglobosa*

Specimens incompletely calcified or not well preserved resembling *S. subglobosa* in their general shape, apex structure and ornamentation are doubtfully attributed to this species (CHOI 1989).

Distribution and range in the Ebro Basin (area 1, Fig. 3, Table 1): this form occurs in the Moia, Calaf and Fonollosa sections, from the Upper Priabonian to the Lower Stampian. Its lowest occurrence is stratigraphically placed between the Sant Cugat de Gavadons and Santpedor mammal localities (*Th. golpeae* and *Th.* aff. *aquatilis* zones), its uppermost occurrence in the uppermost Calaf mammal site (*Th. calafensis* zone).

30. *Sphaerochara labellata* FEIST in FEIST & RINGEADÉ 1977

Distribution and range in the Ebro Basin (area 3, Fig. 5, Table 3): the species is only represented in the Upper Priabonian mammal locality of Rocafort de Queralt attributed to the *Th. golpeae* zone (MP 19).

Other occurrences: *S. labellata* was previously recorded from the Baby-2 locality, in Aquitaine, attributed to the Upper Priabonian MP 20 mammal standard level (RINGEADÉ, 1987).

31. *Sphaerochara hirmeri* (RASKY) MÄDLER, emend. HORN of RANTZIEN & GRAMBAST 1962

Distribution and range in the Ebro Basin (areas 4, 5; Figs. 6, 7; Tables 4, 5): early representatives of the species occur in bed 4 of Pla del Pepe section, which is correlated with the *Th.*

aff. *major* zone (MP 25). The species was also found in bed 19 of the Torrente de Cinca section, just above the TC-18 mammal locality, referred to the *Eomys* aff. *major* zone (MP 27).

Other occurrences: *S. hirmeri* is widespread in the Upper Oligocene of the European Basins but according to RIVELINE (1986), the species occurs in the Late Eocene Bembridge Marls of the Isle of Wight and its persistence into the Miocene is doubtful. Apart from the isolated record of the species in the Late Eocene, its first occurrence is from the Upper Stampian locality of Saint-Vincent-de-Barbeyrargues (Languedoc; GRAMBAST 1962), referred to the MP 25 mammal standard level, thus quite simultaneously as in the Ebro Basin.

32. *Sphaerochara ulmensis* (STRAUB) GRAMBAST

Distribution and range in the Ebro Basin (areas 4, 5; Figs. 6, 7; Tables 4, 5): the lowest occurrence of the species is in Aspà-4, which is tentatively referred to the *E. major* zone (MP 27). Its uppermost occurrence is in parts of the Torrente de Cinca and Vellila de Cinca sections attributed to the *Rh. transiens* zone (MP 30). As reported below, records from other areas confirm this attribution.

Other occurrences: *S. ulmensis* was recorded, in Europe, from the Upper Stampian to Tortonian in Switzerland, from the Chattian and Aquitanian of Germany (MÄDLER 1955) and from the Aquitanian of Southern France (FEIST-CASTEL 1977a). The species is widely distributed as it was also reported from the Upper Oligocene of China (HUANG 1978, Pl. 9, Figs. 1–5). The lowest occurrences of the species is in the Aarwanger Molasse of Switzerland (HORN AND RANTZIEN 1959), referred to the MP 27 mammal standard level.

IV. Charophyte biozonation of the Upper Eocene-Upper Oligocene sequences

The wide geographical extension and relatively short ranges of charophyte species prevails on subdividing and correlating Cretaceous and Paleogene non-marine sequences. With regards to the Paleogene of Europe, after the pioneer studies of CASTEL (1968) and GRAMBAST (1972), RIVELINE (1986) defined 20 zones based on the first occurrences of charophyte index species and on their assemblages. Our study on Paleogene Mesogene floras gives us the opportunity to update this biozonation with defining new zones and delimitating others more precisely. We will first determine the succession of the local zones established in the Ebro Basin with the species represented (Table 6), then we will place them in the context of the whole Paleogene Zonal succession of the European Basins (Table 7), with the inferred modifications (Table 7).

A. Charophyte succession in the Ebro Basin

Local biozone 1

Definition: interval defined by the presence of *Harrisichara lineata*. This species occurs, in the Vic area (COLOM et al. 1970), at the upper part of the Lower Priabonian Tossa Formation (FERRER 1971, LUTERBACHER et al. 1973). The species ranging up to the Upper Priabonian *Sphaerochara labellata* zone, its datation cannot be established precisely.

Table 2 Charophyte distribution in the stratigraphic sections of Area 2 (Fig. 4).

LITHOSTRATIGRAPHIC UNITS			
JP: JORBA-LA PANADELLA CO: CONILL ESP: L'ESPELT	La Panadella-Montmeneu Limestone 38' 42' 37' 35' 34' 31' 29' 27' 22' 21' 20' 18' 17' 16' 15-15' 10' 9'	Artés Fm (s.l.) 5' 5.5A5B 4' 3' 2' 1-2' 11' 10' 9' 7' 5'	
<i>H. tuberculata</i> <i>St. aff. edwardsii</i> <i>L. longus</i> <i>N. jorbae</i> <i>G. caelata</i> <i>Chara</i> sp II (Choi 1984) <i>R. aff. raibocarpa</i> <i>N (T.) meriani</i> <i>Lamprothamnium</i> sp. <i>Rh. stockmansii</i> <i>G. medicaginula</i>			
LOCAL CHAROPHYTE ZONES	5 ?	4	3
FOSSIL MAMMAL SITES	?	JP 24] Porquerisses	CALAF SANTPEDOR
LOCAL MAMMAL BIOZONES	?		Th. aff. aquatilis biozone Th. calafensis biozone
STANDARD MAMMAL LEVELS		MP 21	MP 21 22

Local biozone 2

Definition: interval between the first occurrence of *Sphaerochara labellata* and the first occurrence of *Lychnothamnus longus* in the Ebro Basin. Early forms of *S. labellata* occur in the Rocafort de Queralt sequences exposed at the locality with the same name. This zone is also developed in the Moia and Sant Cugat de Gavadons sections.

Important species: *H. tuberculata* and *S. aff. vectensis* and *R. stockmansii* which appear simultaneously with *S. labellata*.

Zonal attribution: *Sphaerochara labellata* zone. This newly defined zone corresponds to the lower part of the *Stephanochara vectensis* zone of RIVELINE (1986). Correlation of *S.*

Table 3 Charophyte distribution in the stratigraphic sections of Area 3 (Fig. 5).

LITHOSTRATIGRAPHIC UNITS		LOCAL CHAROPHYTE ZONES		FOSSIL MAMMAL SITES		MAMMAL BIOZONES		STANDARD MAMMAL LEVELS	
Tàrraga Limestone	ET: EL TALLADELL SO: SOLIVELLA FSA :SARRAL FO: FORES SCQ: STA. COLOMA DE QUERALT	H. tuberculata L. longus G. caelata R. stockmansi S. labellata St. aff. vectensis Sphaer. subglobosa Ch. microcera Rh. major St. aff. pinguis	6 5 4 3 2	TÀRREGA FO-33	Th. major	MP 23			
Blancafort Fm. LP-M			?		Th. catalensis	21 22 MP			
Sarral Fm.			2	POCAFORT DE QUERALT	Th. galpaeae	19 MP			

LP-M = La Panadella-Montmaneu Limestone

Table 4 Charophyte distribution in the stratigraphic sections of Area 4 (Fig. 6).

LITHOSTRATIGRAPHIC UNITS		LOCAL CHAROPHYTE ZONES		FOSSIL MAMMAL SITES AND BIOZONES	
Granja d'Escarp Luites	3	MM: MAS DE MAIALS	8	[PP-8] Th. aff. major	MP 27
	1 2 3 4 0,1	LSA: SARROCA			MP 27 ?
	1 2	AL: ALCANO			
	3 2 4	AS: ASPA			
	12 14 11 10 9 8 4	CA: CASTELLDANS			
Tàrraga Limestone	5 4 3 2 1	PP: PLA DEL PEPE	6	[MO-2] Th. major	MP 24 ?
	5 4 3 2 1	FSP: SOLA DEL PLA			MP 23
Margalef Fm.	7 ?	MQ: MONTBLANQUET	5		
	6				
		N. (T) meriani Ch. microcera R. major Sphaerochara hirmeri Chara notata Rh. langeri Sph. ulmensis Chara sp A			

Important species: *N. jorbae*, which appears within local zone 3; *H. tuberculata*, *S. aff. vectensis* and *R. stockmansii* persist from local zone 2.

Zonal attribution: local zone 3 is correlable in its assemblage with the *Stephanochara vectensis* zone of RIVELINE (1986), which must be revised from new information on the range of the index species in the Isle of Wight. In the Ebro Basin, *S. aff. vectensis* shows the same range and distribution than *H. tuberculata*. Local zone 3 is identified in the Bembrige Marls of the Isle of Wight as well as in the Lower Molasse du Fronsadais, exposed at Baby-2 and Saint-Capraise localities of the Aquitaine Basin, which are referred to the MP 20 mammal standard level. In the Ebro Basin, the top of local zone 3, which is placed in the Lower Stampian MP 21–MP 22 standard levels, does not correspond to the upper limit of the *Stephanochara vectensis* zone that is restricted to the Late Eocene.

Table 5 Charophyte distribution in the stratigraphic sections of Area 5 (Figs. 7 and 8).

LITHOSTRATIGRAPHIC UNITS		LOCAL CHAROPHYTE ZONES		FOSSIL MAMMAL SITES		MAMMAL BIOZONES		STANDARD MAMMAL LEVELS	
Torrente de Cinca Limestone Cuesta de Fraga Lutites Mequinzenza Limestones Granja d'Escarp Lutites Flix Fm.		1 39 31 24 W10 W9 W8 W7 W6 W5 W4 W3 W2 W1 10 12 6 10 48 47 43 23 22 19 7 1 1 1	EL CAMPILLO BALLOBAR VELILLA DE CINCA FRAGA (B+W) TORRENTE DE CINCA M: MEQUINENZA MONTMENEU LGE: GRANJA D'ESCARP MM: MAS DE MAIALS COLL D'EN GRAU BOT	Lamprothamnium sp N. (T) meriani Ch. microcera Ch. notata Rh. praelangeri Sphae. ulmensis Stephan. ungeri Hornich. lagenalis Rh. langeri Chara sp. A Sph. himeri Steph. berdotensis	6 7 8 9	E. zittelli E. aff. major Rh. transiens Rh. schlosseri	MP 26 MP 26 MP 27 MP 28? MP 29? MP 30 MN 1	La Bagarella Mina Pilar Gandesa	E. zittelli E. aff. major Rh. transiens Rh. schlosseri

Local biozone 4

Definition: interval between the first occurrence of *Nitellopsis meriani* and last occurrence of *Harrisichara tuberculata*. Early forms of *N. meriani* occur in the Jorba-La Panadella section and the zone is developed in the Calaf, Súria, Fonollosa and Santpedor sections (Artès Formation). The base of zone 4 is placed within the *Th. calafensis* zone as it does in the Jorba-La Panadella section which includes its lowest occurrence.

Important species: early forms of *G. medicaginula*; last occurrences of *H. tuberculata*, *R. stockmansii*, *S. subglobosa*, *L. longus*, and *S. lychnothamnoides*.

Zonal attribution: local zone 4 corresponds in its assemblage to the *Stephanochara pinquis* zone of RIVELINE (1986). This zone can be referred to the MP 21 mammal standard level, by

correlation with mammal and charophyte associations of Soumaïlles, Ronzon and Hoogbutsel localities. The indexspecies has not been found in the Catalan localities. In the Ebro Basin, data from the Calaf mammal faunas imply the place the upper limit of the *S. pinquis* zone in the Mp21–MP 22. This attribution is not however consistent with the extension of the taxa which compose the assemblage of the *S. pinquis* zone, in particular the genus *Harrisichara*, which was never reported from the *Rhabdochara major* zone, correlated with the MP 22 standard level.

Undefined local biozone 5

Interval between the last occurrence of *Harrisichara tuberculata* and the first occurrence of *Chara microcera*. The uppermost part of the Jorba-La Panadella section, including bed 38, corresponds to this interval, which is also present in the Forès-Saral section.

Zonal attribution: *Rhabdochara major* zone (RIVELINE (1986).

Local biozone 6

Definition: interval between the first occurrences of *Chara microcera* and *Hornichara lagenalis*. Early forms of *C. microcera* occur in the Tàrraga Formation, in Solivella-3 and Montblanquet-3. The zone is also developed in the Forès and El Talladel sections.

Important species: *S. birmeri*; *R. major*, whose presence in this interval corresponds to the upper part of its range.

Zonal attribution: local zone 6 corresponds to the lower part of the *C. microcera* zone of RIVELINE 1986 with an earlier lower limit, the species appearing in an horizon referred to the MP 23 standard level, instead of MP 24 as previously known (CHELLAI et al. 1982). This newly redefined *C. microcera* zone is correlated with the Argiles des Milles and with the Argiles de Saint-André (South of France), the latter correlated with the MP 26 standard level.

Local biozone 7

Definition: interval between the first occurrences of *Hornichara lagenalis* and *Stephanochara ungeri*. Early form of *H. lagenalis* occur in the Flix Formation, in bed 5 of the Fraga B section, correlated with the *E. major* zone, attributed to the MP 27 mammal standard level. This zone is developed in the lower portion of the Mequinenza Limestone, appearing in the Fraga Section.

Important species: *Chara microcera*, persistent from zone 6.

Zonal attribution: *Hornichara lagenalis* zone corresponds to the Upper part of the *Chara microcera* zone previously defined by RIVELINE (1986). Out of the Ebro Basin, the new zone is identified in the Lower part of the “Molasse rouge” of the Geneva Basin (BERGER et al. 1986); thus in the SPM5 Borehole, the lowest occurrence of *H. lagenalis* is below the *S. ungeri* one, as reported in the Ebro Basin.

Local biozone 8

Definition: interval between the first occurrences of *Stephanochara ungeri* and *Stephanochara berdotensis*. Early form of *S. ungeri* occurs in the Fraga-7 horizon, referred to the *E. aff. major* zone, attributed to the MP 27 mammal standard level. This zone is represented in the Fraga, Velilla de Cinca and Mequinenza sections.

Important species: early forms of *R. langeri*, *Chara* sp. 1 and of *S. ulmensis* occur within local zone 8; *C. microcera*.

Zonal attribution: zone 8 corresponds to the *S. ungeri* zone of RIVELINE (1986) and BERGER (1986). Out of the Ebro Basin, this zone is identified in the Pelarda Formation, at the Vivel del Rio and Villanueva del Rebollar mammal localities (Teruel Basin; ADROVER et al. 1982), attributed to the MP 28 and MP 29, respectively; In Aquitaine, local zone 8 is developed in the upper part of the Molasse de l'Agenais, at the La Milloque locality (FEIST & RINGEADE 1977), referred to the MP 29; in the Swiss Molasse, from the Wynau to Rickenback mammal levels (KISSLING 1974; BERGER 1986), thus from MP 27 to MP 29.

Local biozone 9

Definition: base of zone 9 is based on the lowest occurrence of *Stephanochara berdotensis*. Early form of *S. berdotensis* occurs in bed 48 in the Torrente de Cinca section, referred to the *Rh. transiens* mammal zone, attributed to the MP 30. Top of zone 9 is not defined due to the, up to date, not recorded occurrence of the Lower Aquitanian markers (*Rantzieniella nitida* GRAMBAST, *Sphaerochara davidi* FEIST-CASTEL).

Important species: *Chara notata*, *R. langeri*, and *Chara* sp. A., persisting from lower levels.

Zonal attribution and resulting changes in the general biozonation: local biozone 9 is partially equivalent to the *Chara notata* biozone of RIVELINE (1986) which is no longer defined, due to the new range of the index-species determined in the Ebro Basin (see above, Part III, *Chara notata*); the *Rantzienella nitida* biozone, not identified in the Ebro Basin, will be placed over the *S. berdotensis* biozone, with its new definition.

B. Comparison of the Charophyte and Mammal successions

The charophyte-mammal correlations established in the European Basins are based on a number of common localities, from the Lower Eocene onward (CASTEL 1968; FEIST-CASTEL 1977a; FEIST & RINGEADE 1977; RIVELINE 1986; BERGER 1986; TAMBAREAU et al. 1989).

In the Ebro Basin, the identification of the Upper Priabonian *Sphaerochara labellata* and *Stephanochara vectensis* zones in the lower sequences is compatible with data from Vertebrate faunas. In contrast, some differences appear between the two groups with regard to the identification of the Lower Oligocene: the Eocene-Oligocene boundary based on the mammals is spanned without any change by the charophytes and the Lower Oligocene *Stephanochara pinquis* zone is developed in the *Theridomys calafensis* mammal zone, correlated with the Villebramar reference level. With regards to the previous charophyte records in this period, we admit that the *S. pinquis* zone may extend higher than its previous range,

restricted to the Ronzon-Hoogbutsel-Lower Hamstead level. With regard to the Middle Stampian, only undefined local zone 5, starting with the extinction of *H. tuberculata* and finishing with the first *Chara microcera*, could be referred to the *Rhabdochara major* zone. Charophyte and mammal indications are concordant for the Upper Stampian, Upper Oligocene and Lower Miocene sequences; the inability of charophytes in defining the basal Aquitanian is due to the local absence of stratigraphically significant markers.

C. The Ebro Basin Charophyte succession in the framework of the standard European biozonation (Table 7)

The zonation established in the Ebro Basin is based on continuous sections correlated one with each others inside a same area. The precision obtained in delimitating the species ranges and the composition of the successive assemblages leads to deeply modify the previous zonations. With regard with the more recent one, from RIVELINE (1986), the main changes consist in: 1) the suppression of two zones, which became invalid following the lengthen of the index species ranges; 2) a new definition of the *Stephanochara vectensis* and *Chara microcera* zones; 3) the adjonction of two new zones, the *Sphaerochara labellata* zone in the Lower Stampian and the *Hornichara lagenalis* zone in the Upper Stampian. On the other hand, data from micromammals lead to extend the range of the assemblage characterizing the *Stephanochara vectensis* biozone higher than the MP-20 (Saint Capraise) level and the *Stephanochara pinquis* zone higher than the Ronzon level, thus between the Ronzon and Villebramar mammal standard levels.

V. Oligocene extinction event in Charophytes

Table 6 shows that the charophyte assemblages succeed regularly in the Tertiary of the Ebro Basin. It is evident, however, that the species number varies from twenty for the three zones representing the Priabonian and Lower Stampian interval, corresponding to about five million years, to only twelve species for the whole younger zones during the same duration. Considering the assemblages represented in zone 4, we note that the extinctions of species are increasing in zone 4, from base to summit (Tables 1 and 2). These disparitions, not compensated by the recovery of new species, lead to a drastic impoverishment of the charophyte phylum during the Lower-Middle Oligocene transition.

The impoverishment of the group seems a general phenomenon derived from the extinctions occurring between the *Stephanochara pinquis* and *Rhabdochara major* zones. Charophytes being directly influenced by potential calcium carbonate precipitation, which is temperature-controlled, the Middle Oligocene cooling (KEIGWIN & KELLER 1984) may be evocated as major factor of extinctions. This hypothesis is supported by the contrasting event of speciation during the Upper Oligocene, coinciding with the general warming which seems to have occurred during this period (MILLER & FAIRBANKS 1985; VIANEY-LIAUD 1991).

VI. Conclusions

As a main result of the present paper, a new charophyte zonal scheme, based on the Ebro Basin succession, is proposed for the Upper Eocene-Lower Miocene interval. Most species

Table 6 Upper Eocene – Lower Miocene charophyte zones in the Eastern Ebro Basin and correlation with the standard mammal levels. (1) from AGUSTÍ et al. (1987) and SCHMIDT-KITTLER et al. (1987). (2) from HAQ et al. (1987).

										<i>Harrisichara lineata</i> <i>Sphaerochara labellata</i> <i>Harr. vasiformis-tuberculata</i> <i>Rhabdochara</i> aff. <i>atilis</i> <i>Harrisichara tuberculata</i> <i>Rhabdochara stockmansis</i> <i>Stephanochara</i> aff. <i>edwardsi</i> <i>Sphaerochara</i> aff. <i>subglobosa</i> <i>Stephanochara</i> aff. <i>vectensis</i> <i>Chara</i> sp.1 Choi <i>Lychnothamnus longus</i> <i>Nodosochara jorbae</i> <i>Rhabdochara</i> aff. <i>raibocarpa</i> <i>Gyrogonia caelata</i> <i>Chara</i> sp. 2 Choi <i>Sphaerochara subglobosa</i> <i>Stephanochara lychnothamnoides</i> <i>Gyrogonia medicaginula</i> <i>Nitellopsis meriani</i> <i>Lamprothamnium</i> sp. <i>Stephanochara</i> aff. <i>pinguis</i> <i>Rhabdochara major</i> <i>Chara microcera</i> <i>Sphaerochara hirmeri</i> <i>Rhabdochara praelangeri</i> <i>Chara notata</i> <i>Homichara lagenalis</i> <i>Rhabdochara langeri</i> <i>Sphaerochara ulmensis</i> <i>Chara</i> sp. A Feist <i>Stephanochara ungeri</i> <i>Stephanochara 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Table 7 Correspondence between the Ebro Basin charophyte zonation (4), the charophyte zonation (3) of RIVELINE (1986) and the proposed, new charophyte biozonation (7) for Western Europe (Late Eocene to Late Oligocene). This table also shows the correspondence of the RIVELINE (1986) charophyte biozonation with the mammal levels (2), the mammal local biozones for the Ebro Basin (5) based on AGUSTÍ et al. (1987) and the mammal reference levels (6) of SCHMIDT-KITTLER ed. (1987). Note the chronostratigraphic attribution of the RIVELINE (1986) zones (column 1) and the present chronostratigraphic attribution (8). The differences between the chronostratigraphic correspondences of the charophyte biozonations are due to changes in the chronostratigraphic attributions of several charophyte index species.

WESTERN EUROPE (Riveline, 1986)			EBRO BASIN (PRESENT PAPER)			NEW PROPOSAL FOR WESTERN EUROPE		
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being widely distributed, the new zonal scheme is applicable to the whole Western Europe. With distant areas, only broad correlations, based on rare common species, can be presently established. Notably, such correlations can be established with Asia (China, India).

On the other hand, the comparison of the charophyte and mammal zonations shows that, from the Lower Oligocene onward, the latter is twice more precise, in contrast with the previous periods: the number of Eocene zones is similar in charophyte and mammals zonations and, for the Cretaceous, eighteen zones subdivide the Cretaceous but none has been defined so far in the vertebrates, at least in the old world.

Finally, relations between the change in generic and specific diversity and the general climatic changes have been evidenced: decreasing diversity corresponding to the Middle

Oligocene cooling and, contrastingly, recovering of diversity during the Upper Oligocene warming phase. We expect, from current isotopic studies, more precise data on the temperatures that prevailed, during the Oligocene, in the Ebro Basin.

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