

A charophyte flora from the Lower Pechelbronn Formation (?Upper Eocene/?Lower Oligocene) of Malsch south of Heidelberg (SW Germany)

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ABSTRACT - The Lower Pechelbronn Formation (?Upper Eocene/?Lower Oligocene) of Malsch (clay-pit 'Am Viehweg') yielded a moderately abundant charophyte assemblage. One new species, *Chara rhenana* sp. nov., is erected, two more species, *Harrisichara lineata* and *Nitellopsis (Tectochara)* cf. *wonnacotti*, are recorded in the Rhine Graben area for the first time. The Lower Pechelbronn Formation may be correlated to the *Stephanochara vectensis* zone (Riveline, 1986) and the mammalian level MP 20 (reference locality: St. Capraise; Schmidt-Kittler, 1987). The associated ostracod fauna clearly indicates a limnic depositional environment. *J. Micropalaeontol.* 13(2): 147–156, December 1994.

INTRODUCTION

The Palaeogene block of Malsch is situated between the Tertiary sediments covered by mighty Quaternary deposits of the Rhine Graben to the west and the Mesozoic sediments of the Kraichgau to the east (Barth, 1970a), about 20 km south of Heidelberg (Fig. 1). This uplifted block, whose structure had been recognized for the first time by Moos (1934) – Roter Septarientonplatte – is built up by Palaeogene sediments (Eocene Basal Clay, *Lymnaea* Marls, Pechelbronn Formation, Grey Marls Formation) with an overall thickness of 460 m maximum.

At the southern edge of this block, very close to the eastern peripheral fault of the Rhine Graben, several clay-pits are situated; in this area *Lymnaea* Marls and the Pechelbronn Formation are exposed at the surface. The first clay-pits had been laid out at the beginning of this century east of Federal Highway 3 (Heidelberg–Karlsruhe); these are currently refilled (clay-pits 'Guggen' and 'Dittmannstal'; Barth, 1970b). The latter was of particular interest for mammalian palaeontology since a well-dated fauna from the Lower Pechelbronn Formation had been described by Tobien (1949, 1968, 1987, 1988). West of Federal Highway 3 are located the clay-pits 'Reimschloch' and 'Am Viehweg'.

The first indication of an occurrence of charophytes in the clay-pits of Rot-Malsch was given by Wilser (1922). She cited *Chara petrolei* from strata of the clay-pit 'Guggen', erroneously assumed by her to be *Cyrena* Marls; this charophyte species, however, may not be interpreted with certainty (Schwarz & Griessemer, 1992).

The only further information referring to the subject is Barth (pers. comm.) who succeeded in isolating gyrogonites from samples of the clay-pits 'Reimschloch' and 'Am Viehweg'; these specimens were later determined by Dr K. Mädler (Hanover).

SAMPLING

The material for this paper was obtained from 15 samples taken by one of us (Th.G.) in 1988 from the clay-pit 'Am

Viehweg', excavated by the 'Ziegelwerke Bott-Eder GmbH' at Rauenberg. Due to the clay-extracting methods using a bulldozer, no detailed collecting could be carried out. Detailed collecting was carried out by Barth in the 1960s, however, when clay was extracted by bucket chain excavating.

GEOLOGY

The clay-pit 'Am Viehweg', origin of the charophytes subsequently described, has been exploited since 1962. The sediments, exposed at present, nearly 125 m in thickness, are exclusively of ?Upper Eocene/?Lower Oligocene age. According to Barth (1970a: fig. 2) the strike angle varies between 55° and 85°, and the dip angle between 22° and 40° to the NW. Thus, the age of the sediments decreases from SE (samples 1–3c) to NW (sample 13). The sampled sediments predominantly belong to the Lower Pechelbronn Formation, consisting of muds and calcareous muds with intercalated sandstones; only sample 13 may belong already to the overlying Middle Pechelbronn Formation, normally containing a rich ostracod and foraminiferal fauna.

The collected samples show olive-green to grey colours (1–3c, 7–12), while samples 4–6 came from red to 'beige'-coloured muds. At the NE edge of the pit, close to the 'g' of 'Viehweg' on the map (Fig. 1c), intense reddish-coloured muds with alabaster gypsum nodules can be observed. The stratigraphical position of these intense-coloured muds has not yet been clarified. There are indications that they may represent a special local type of facies somewhere within the sequence of the Lower Pechelbronn Formation. Alternatively, the aforementioned petrographic characters also allows one to regard them as the 'Rote Leitschicht'. This is a very important marker-level encountered by petroleum geologists in many borings in different oilfields in the middle part of the Rhine Graben. The 'Rote Leitschicht' is considered to be a separate stratigraphical unit underlying the Lower Pechelbronn

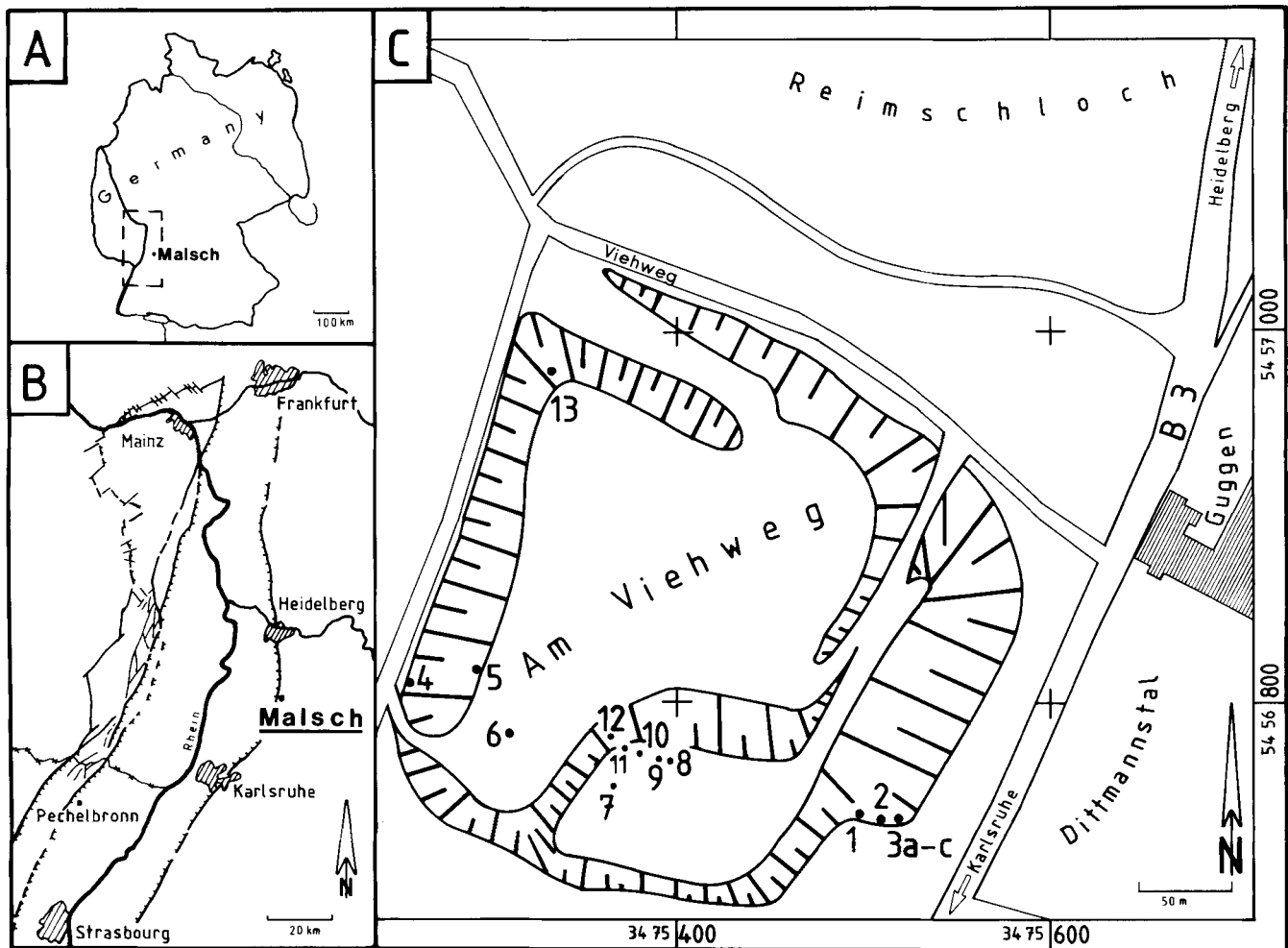


Fig. 1. Geographical position of the clay-pit 'Am Viehweg' (C) within the middle part of the Rhine Graben (A, B). The numbers refer to the samples taken.

Formation by some authors. Other geologists include it in the Lower Pechelbronn Formation, to represent the basal part of it, an opinion the authors of this paper would share.

MICROFAUNA

Besides the charophyte species, our knowledge about the palaeoecological demands of the accompanying microfauna is essential to the interpretation of the palaeoenvironment. Nearly all samples yielded a freshwater ostracod fauna, preserved in most cases with broken valves. The valves and fragments could be assigned to the following genera: *Heterocypris*?, *Herpetocypris*?, *Ilyocypris*, *Paralimnocythere*, *Stenocypris* and *Virgatocypris*. These genera are known to inhabit freshwater, salinity being less than 3‰. *Stenocypris* is regarded as a genus living in warm waters (Morkhoven, 1963: 55; Triebel, 1953: 12). Thus the whole fauna can be attached to the *Candona*-*Cypridopsis* assemblage (Keen, 1975), which lived in shallow lakes or lake edges. In addition, some internal moulds of snails have been found by picking the samples. The other fauna (Jurassic ostracodes, sclerites of sponges, columnalia of crinoids, spines of

echinids, Jurassic? foraminifera) is reworked from Mesozoic sediments forming the border of the Rhine Graben between Heidelberg and Karlsruhe. However, no further investigations on this fauna were undertaken; for distribution of this fauna see Fig. 4.

SYSTEMATIC DESCRIPTIONS

The material examined and figured is kept in the micropalaeontological collections (collection GRIESSEMER) of the Geological Survey of Rheinland-Pfalz at Mainz, Germany. From *Chara rhenara* sp. nov. some isotypes have been given to the British Museum (Natural History), London.

Division **Charophyta** Migula, 1890
 Class **Charophyceae** G. M. Smith, 1938
 Order **Charales** Richard, 1815
 Family **Characeae** Richard, 1815
 Genus **Chara** Vaillant, 1719
Chara rhenana sp. nov.

(Pl. 1, figs 1-4)

1992 *Chara* n. sp. Schwarz & Griessemer: 30, figs 11-12

Derivation of name. *Rhenanus* (latin), adjectival to Rhenus = Rhine, on account of the species' occurrence in the Rhine Graben.

Diagnosis. A medium-sized *Chara* species related to *Chara subcylindrica*; characteristic is the combination of a relatively low number of convolutions and the periaipically ± not modified spiral cells.

Holotype. Specimen figured on Pl. 1, fig. 1; no. 6717/12/1.

Isotypes. 3 figured specimens, Pl. 1, figs 2–4; nos 6717/12/2, 6717/12/3, 6717/12/4.

75 measured, completely preserved unfigured specimens used for preparing Fig. 2 (of those, 15 specimens are kept in the collections of the British Museum (Natural History), London under V.63725).

About 125 unmeasured, unfigured specimens with lost apical part (of these, 25 specimens are kept in the collections of the British Museum (Natural History), London under V.63726).

Type locality. Clay-pit 'Am Viehweg' (Ziegelwerke Bott-Eder GmbH), near Malsch south of Heidelberg, sample 12 (Fig. 1c); survey sheet 6717 Waghäusel.

Type stratum. Lower Pechelbronn Formation, ?Upper Eocene/?Lower Oligocene.

Depository. Geologisches Landesamt Rheinland-Pfalz, Mainz (Collection GRIESSEMER).

Material. About 200 gyrogonites.

Description. Oval to elliptic gyrogonites, as a rule constantly narrowed towards the base; gyrogonites thus occasionally with a somewhat conical appearance. Apical pole in general slightly depressed or even conspicuously flattened, not domed equally, as in the case of many *Chara* species. In a great number of specimens (70%) the apical centre has broken off, which is evidence for rather decreased thickness of the spiral cells in the apical periphery. Spiral cells usually slightly concave to almost flat, rarely markedly concave or even convex; in the apical region invariably concave. Intercellular ridges barely prominent, periaipical constrictions not, or at most poorly, discernible; apical ends of spiral cells, however, distinctly widened. Basal pore mainly within a shallow basal crateriform depression.

Dimensions. The most frequent values are given in parentheses; Fig. 2:

Length: 440–650 μm (475–600 μm)

Width: 330–490 μm (375–425 μm)

Number of convolutions: 8–10 (8–9)

Width of spiral cells: 50–80 μm (50–70 μm)

Diameter of basal pore: 20–40 μm (20–30 μm)

Isopolarity index: 120–171 (125–145).

Differential characters. (a) The characteristics of the apical structure of *Chara rhenana* sp. nov. prove a close relationship to *Chara subcylindrica*, described by Reid & Groves (1921) from the Lower Headon Beds. Being comparable to the latter species in length, the gyrogonites of *Chara rhenana* sp. nov. are nevertheless distinctively more voluminous (that means lower isopolarity values), moreover the number of convolutions is obviously lower. (b) The species *Chara tornata*, *Ch. cylindrica* and *Ch. elongata*, once grouped together under the generic name

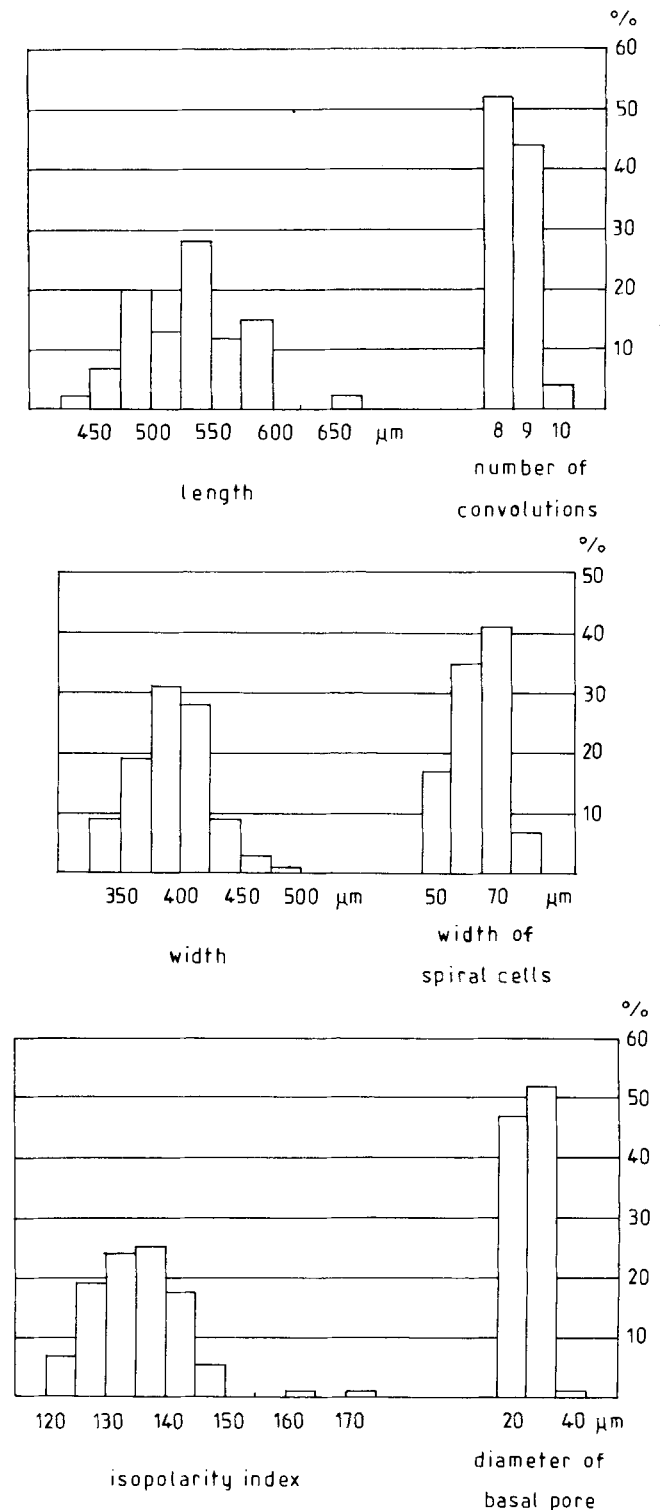


Fig. 2. Histograms of *Chara rhenana* sp. nov. $N = 75$ gyrogonites.

Grambastichara, differ from the new species firstly by the noticeably periaipically modified spiral cells, secondly by an ± equally domed apex and thirdly by an elevated number of convolutions.

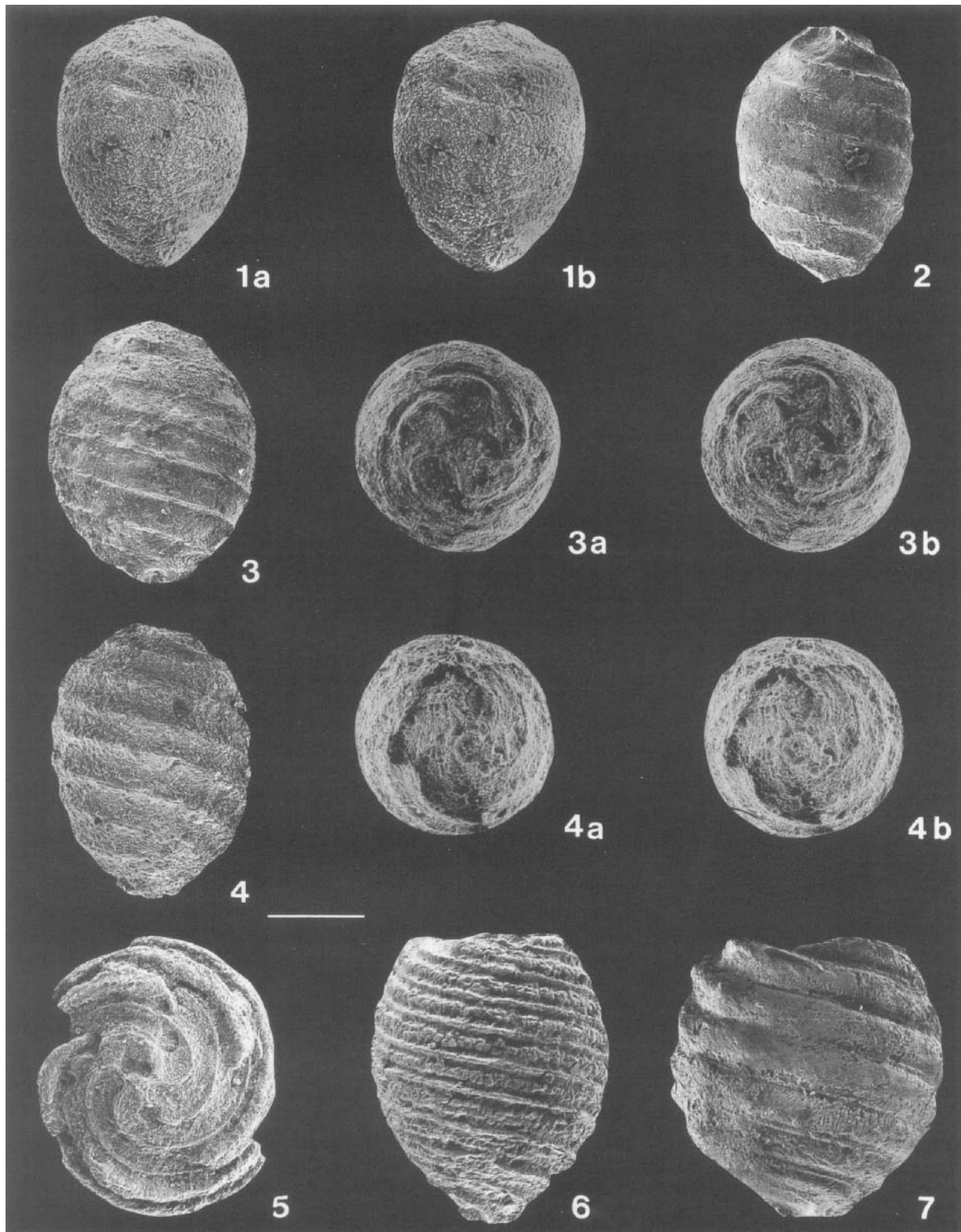


Plate 1

Remarks. Riveline (1986: 68) points out the strong morphological similarities that exist between the genera *Chara* Vaillant, 1719 and *Psilochara* Grambast, 1959 from the Upper Eocene onwards and thus the difficulties which can arise in the generic assignment of some species; as an example she refers to *Chara hamsteadensis*. Likewise in *Chara rhenana* sp. nov., peculiarities of both genera are combined: the oval, sometimes slightly conical shape of the gyrogonites points to the genus *Chara*, whereas the periaipically, barely modified, spiral cells as well as the somewhat flattened apical region, are to be found within the genus *Psilochara*. A future revision of both genera would be highly desirable, especially since the diagnosis of *Psilochara* does not sufficiently separate that genus from *Chara*.

Genus *Harrisichara* Grambast, 1957
Harrisichara lineata Grambast, 1957
(Pl. 1, figs 5–6)

1957 *Harrisichara lineata* Grambast: 349, pl. 6, figs 5–7.

Brief description. Gyrogonites roundedly oval to elliptic. Apical region subtruncate, rarely slightly domed. Base always clearly prolonged into a short column. Spiral cells slightly concave, in the apical periphery barely narrowed but conspicuously reduced in thickness (Pl. 1, fig. 5). As a rule, with ornaments in form of a more or less distinct median band. The ornamentation ceases abruptly before the basal tips of the spiral cells. Basal pore at the bottom of an indistinct crateriform depression.

Dimensions.

Length: approximately 630–650 μm ; not exactly determined since not all the gyrogonites are preserved undamaged.

Width: 500–590 μm

Number of convolutions: 9–10

Width of spiral cells: 70–90 μm

Diameter of basal pore: 20–30 μm .

Material. 8 fragmentary gyrogonites and debris respectively.

Genus *Sphaerochara* Mädlar, 1952, emend. Horn af Rantzien & Grambast, 1962

Sphaerochara parvula (Reid & Groves, 1921) Horn af Rantzien, 1959
(Pl. 2, figs 4–5)

1921 *Tolypella parvula* Reid & Groves: 188, pl. 6, figs 4–5.

1959 *Sphaerochara parvula* (Reid & Groves); Horn af Rantzien: 136, pl. 16, figs 10–13.

1986 *Sphaerochara parvula* (Reid & Groves); Breuer & Feist: 142, figs 3, 8.

1992 *Sphaerochara parvula* (Reid & Groves); Schwarz & Griessemmer: 32, fig. 18.

Brief description. Elliptical gyrogonites with rounded apical and basal poles. Spiral cells concave with distinct intercellular ridges, not modified in the apical periphery.

Dimensions.

Length: 350–380 μm

Width: 280–310 μm

Number of convolutions: 8–9

Width of spiral cells: 40 μm

Diameter of basal pore: 20–30 μm

Isopolarity index: 112–125

Material. 6 gyrogonites.

Sphaerochara pygmaea Schwarz & Griessemmer, 1992
(Pl. 2, figs 1–3)

1992 *Sphaerochara pygmaea* Schwarz & Griessemmer: 34, figs 4, 13–17.

Brief description. Roundedly oval to elliptic gyrogonites with apex and base generally well rounded; the basal region may be prolonged sometimes (e.g. specimens from sample 2; Pl. 2, fig. 3). Spiral cells concave to a varying degree, their width rarely reduced in the apical region. Basal pore fairly wide, superficial. Basal plug visible from the exterior.

Dimensions.

Length: 240–340 μm

Width: 180–280 μm

Number of convolutions: 8–10

Width of spiral cells: 20–40 μm

Diameter of basal pore: 20–40 μm

Isopolarity index: 109–150

Material. 64 gyrogonites.

Genus *Nitellopsis* Hy, 1889

Nitellopsis (Tectochara) cf. wonnacotti (Grambast, 1972)
Grambast & Soulié-Märsche, 1972
(Pl. 1, fig. 7)

1972 *Tectochara wonnacotti* Grambast: 22, fig. 9, pl. 7, figs 1–4.

1972 *Nitellopsis (Tectochara) wonnacotti* (Grambast); Grambast & Soulié-Märsche: 11.

The morphological features of this extremely rarely encountered species (one gyrogonite without apex, one apical fragment) are: gyrogonite of rounded shape; basal region largely rounded, not protruding; rather few convolutions (9). In spite of the somewhat low dimensions (length c. 920 μm , width c. 860 μm) the above-mentioned

Explanation of Plate 1

Scale bar for Figs 1–6 = 200 μm ; for Fig. 7 = 300 μm . All specimens are from the Lower Pechelbronn Formation from the clay-pit 'Am Viehweg'. They are deposited in the micropalaeontological collections (collection GRIESSEMER) of the Geological Survey of Rheinland-Pfalz at Mainz. **Figs 1–4.** *Chara rhenana* sp. nov.; sample 12: figs 1a, b, holotype, no. 6717/12/1, lateral view, stereo pair; fig. 2, specimen no. 6717/12/2, lateral view; fig. 3 specimen no. 6717/12/3, lateral view figs 3a, b, same gyrogonite, apical view, stereo pair; fig. 4 specimen no. 6717/12/4, lateral view figs 4a, b, same gyrogonite, basal view, stereo pair. **Figs 5–6.** *Harrisichara lineata* Grambast, 1957; sample 4: fig. 5, isolated apical portion of a gyrogonite (specimen no. 6717/4/2); the relief of the spiral cells ceases abruptly in the apical periphery, thus resulting in typical thinness of the apical centre; fig. 6, specimen no. 6717/4/1, lateral view, apical centre is broken off. **Fig. 7.** *Nitellopsis (Tectochara) cf. wonnacotti* (Grambast, 1972) Grambast & Soulié-Märsche, 1972; sample 4; specimen no. 6717/4/4, lateral view of a gyrogonite lacking apical centre.

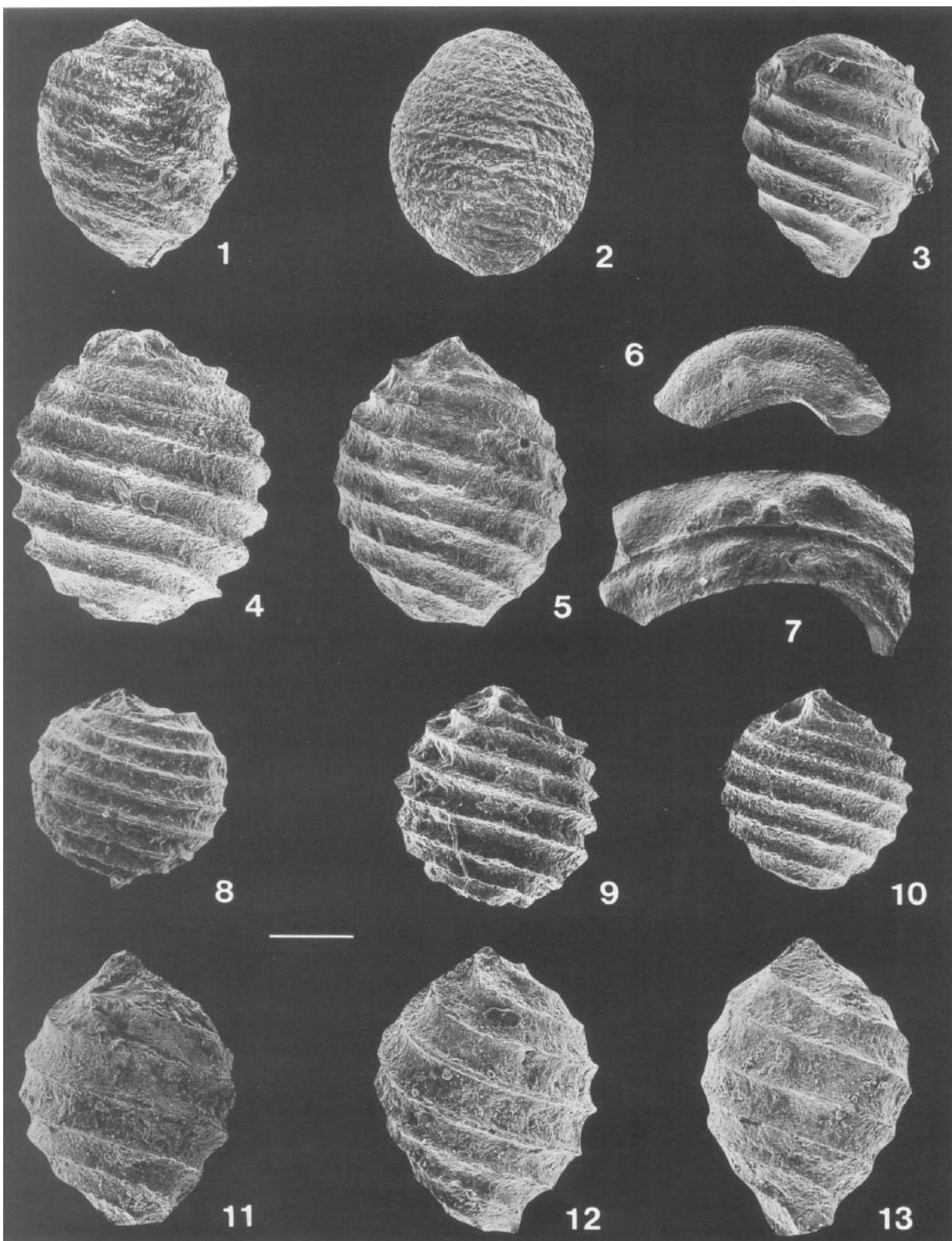


Plate 2

characters clearly indicate a close relation to *Nitellopsis wonnacotti* and not to the species complex around *Nitellopsis meriani*.

Genus *Gyrogona* Lamarck, 1804 ex Lamarck, 1822, emend. Grambast, 1956

Gyrogona sp.
(Pl. 2, figs 6–7)

Samples 4 and 10 yielded some isolated and fragmentary, flat to barely concave spiral cells of great width (up to 170 μm) and thickness. Such cells are characteristic of the genus *Gyrogona*. Specific assignments on the basis of spiral cells alone are, of course, always delicate, but it may be presumed with some certainty that they belong to *Gyrogona wrightii*.

Genus *Tolypella* Braun, 1849

Tolypella pumila Grambast, 1958
(Pl. 2, figs 8–10)

1958 *Tolypella pumila* Grambast: 198, figs 1–3.

1992 *Tolypella pumila* Grambast; Schwarz & Griessemmer: 35, figs 19–20.

Brief description. Minute, globular gyrogonites; apex centrally pointed, base rounded. Spiral cells few, slightly concave, without any periapical modifications.

Dimensions.

Length: 240–340 μm

Width: 200–260 μm

Number of convolutions: 6–8

Width of spiral cells: 30–40 μm

Diameter of basal pore: 20–30 μm

Isopolarity index: 102–125.

Remarks. Some of the gyrogonites originating from samples 5, 6 and 9 differ by having markedly concave spiral cells with strongly accentuated intercellular ridges.

Material. 23 gyrogonites.

Tolypella caudata Grambast, 1958

(Pl. 2, figs 11–13)

1958 *Tolypella caudata* Grambast: 199, figs 1–2.

1986 *Tolypella caudata* Grambast; Breuer & Feist: 142, figs 3, 9–10.

Brief description. Gyrogonites broadly globular to roundly oval. Apex with shortly pointed centre, in some specimens more protruding. Base gradually tapering, sometimes even distinctly prolonged. Basal pore quite small, superficial. Spiral cells slightly concave to flat,

united in the apical region without any modifications with regard to their width; intercellular ridges hardly discernible.

Dimensions. (Fig. 3):

Length: 280–390 μm (325–375 μm)

Width: 240–310 μm (250–300 μm)

Number of convolutions: 6–9 (7–8)

Width of spiral cells: 30–60 μm (40–50 μm)

Diameter of basal pore: 20–30 μm

Isopolarity index: 104–145 (110–140)

Material. 70 gyrogonites.

BIOSTRATIGRAPHY

The charophyte association from the Lower Pechelbronn Formation of Malsch comprises exclusively those species that also exist at other ?Upper Eocene/?Lower Oligocene localities in the Rhine Graben system (Schwarz, in prep.).

Decisive for the biostratigraphic position of the locality Malsch/'Am Viehweg' is the synoptic representation of the hitherto known maximum vertical extension of all involved taxa.

- *Chara rhenana* sp. nov. appears in the Rhine Graben from the *Lymnaea* Marls up to the Upper Pechelbronn Formation (Schwarz & Griessemmer, 1992) with increased density records from the Lower Pechelbronn Formation (Table 1).

- *Harrisichara lineata* is confined, in the Rhine valley, to the *Lymnaea* Marls and the Lower Pechelbronn Formation (pers. obs.). To date, this species has been described only from western Europe (Riveline, 1986); there, its stratigraphic levels extend from the 'Marinésien moyen' (*Chara friteli* zone) to the 'Ludien moyen récent à supérieur' (*Stephanochara vectensis* zone).

- *Sphaerochara parvula* exists in the Rhine Graben area from the *Lymnaea* Marls (including the Green Marls Formation) to the Upper Pechelbronn Formation (Breuer & Feist, 1986; Schwarz & Griessemmer, 1992). Its total vertical extension in western Europe covers all the interval between the 'Ludien inférieur' (*Gyrogona tuberosa* zone) and the 'Oligocène supérieur' (*Chara notata* zone) (Riveline, 1986).

- *Sphaerochara pygmaea*, a less frequently observed species, occurs in the Rhine Graben from the *Lymnaea* Marls up to the Upper Pechelbronn Formation (Schwarz & Griessemmer, 1992).

- *Nitellopsis* (*Tectochara*) cf. *wonnacotti*: a very few gyrogonites which are referable to this species have been

Explanation of Plate 2

Scale bar for Figs 1–5, 8–13 = 100 μm ; for Figs 6, 7 = 200 μm . All specimens are from the Lower Pechelbronn Formation from the clay-pit 'Am Viehweg'. They are deposited in the micropalaeontological collections (collection GRIESSEMER) of the Geological Survey of Rheinland-Pfalz at Mainz. **Figs 1–3.** *Sphaerochara pygmaea* Schwarz & Griessemmer, 1992: fig. 1, specimen no. 6717/4/5, lateral view; sample 4; fig. 2, specimen no. 6717/4/6, lateral view, apical region well rounded; sample 4; fig. 3, specimen no. 6717/2/1, lateral view, basal region extraordinarily prolonged; sample 2. **Figs 4–5.** *Sphaerochara parvula* (Reid & Groves, 1921) Horn af Rantzien, 1959: fig. 4, specimen no. 6717/4/3, lateral view; sample 4; fig. 5, specimen no. 6717/11/1, lateral view; sample 11. **Figs 6–7.** Isolated spiral cells of *Gyrogona* sp.; sample 4: fig. 6, specimen no. 6717/4/8, basal end of spiral cell; fig. 7, specimen no. 6717/4/7, spiral cells from the equatorial region of a gyrogonite. **Figs 8–10.** *Tolypella pumila* Grambast, 1958: fig. 8, specimen no. 6717/9/1, lateral view; sample 9; fig. 9, specimen no. 6717/5/1, lateral view; sample 5; fig. 10, specimen no. 6717/6/1, lateral view; sample 6. **Figs 11–13.** *Tolypella caudata* Grambast, 1958; sample 9: fig. 11, specimen no. 6717/9/2, lateral view; fig. 12, specimen no. 6717/9/3, lateral view; fig. 13, specimen no. 6717/9/4, lateral view.

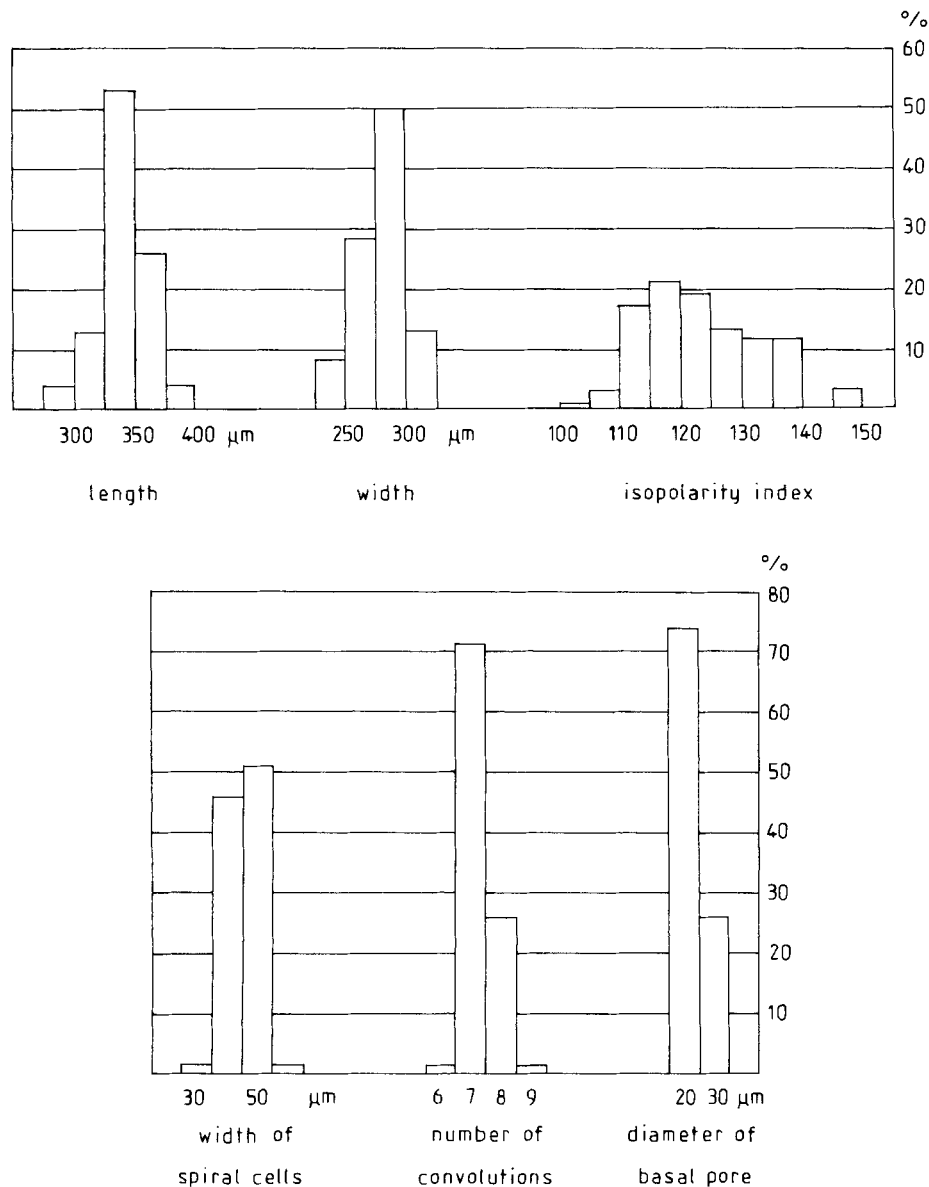


Fig. 3. Histograms of *Tolypella caudata* Grambast, 1958. $N = 70$ gyrogonites.

found in two more localities of the Rhine Graben: the wells Winden 4 and Lautersheim 1. Their exact stratigraphic position has yet to be clarified absolutely. From the samples in question only the charophytes have been studied to date; they indicate with certainty an ?Upper Eocene/?Lower Oligocene age.

Apart from this, *N. wonnacotti* has been described only from the west European Hampshire and Paris Basins. There it characterizes lithological units which are to be placed within the *Stephanochara vectensis* zone ('Ludien moyen récent et/ou supérieur') (Riveline, 1986).

• *Gyrogonia* sp.: possibly, the present fragmentary spiral cells may belong to *Gyrogonia wrightii*, a species with a vast vertical extension – 'Auversien supérieur' (*Raskyella pecki* zone) up to 'Stampien inférieur de faciès sannoisien' (*Stephanochara pinguis* zone) – according to Riveline (1986).

• *Tolypella pumila* is a quite rarely encountered species in the Rhine Graben, which occurs from the *Lymnaea* Marls to the Upper Pechelbronn Formation (Schwarz & Griessemer, 1992). In the Paris Basin it has been recorded from several localities in the Marnes bleues d'Argenteuil and the Calcaire de Brie (Cavelier *et al.*, 1972; Riveline, 1973).

• *Tolypella caudata* has been quoted from the *Lymnaea* Marls of the Rhine Graben by Breuer & Feist (1986). Originally, this species was described from the 'Tongrian' of Hoogbutsel (Belgium), but it also exists in the Paris Basin (Cavelier *et al.*, 1972; Riveline, 1973). In western Europe, *T. caudata* is, like *T. pumila*, typical for deposits belonging to the *Stephanochara vectensis* and *St. pinguis* zones.

By reason of too great a vertical extension, most of the species at hand are, as a result, of no particular significance

for the biostratigraphic interpretation of the sedimentary sequence studied here. The possibility of a more circumscribed correlation is offered solely by the two 'exotics' of the assemblage, *Harrisichara lineata* and *Nitellopsis (Tectochara) cf. wonnacotti*, occurring together in sample 4 (Fig. 4): *Stephanochara vectensis* zone (Riveline, 1986).

In the Hampshire Basin the *Stephanochara vectensis* zone covers the whole series of the Bembridge Beds (Bembridge Limestone and Bembridge Marls); in the Paris Basin it is represented by the Première Masse du Gypse and the Marnes supragypseuses (Riveline, 1986).

It may be deduced easily that within the charophyte zonation the Lower Pechelbronn Formation parallels the lower parts of both the Bembridge Marls and the Marnes supragypseuses (i.e. the Marnes bleues d'Argenteuil). This concept, although in contrast to the opinion of Breuer & Feist (1986; Table 1) in some aspects, would take into consideration equally well all data available for the mammal zonation; these data indicate concordantly an MP 20-age (reference locality: St. Capraise) for the following lithological units (Table 1):

- Lower Pechelbronn Formation: Tobien (1987, 1988).
- Bembridge Marls: Bosma (1974), Gad *et al.* (1990), Schmidt-Kittler (1987).
- Marnes bleues d'Argenteuil: Russell (1982).

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REFERENCES

- Barth, S. 1970a. Stratigraphie und Tektonik der Tertiärscholle von Rot-Malsch im Rheingraben. *Jahresberichte und Mitteilungen des Oberrheinischen Geologischen Vereins, Neue Folge* Stuttgart, **52**: 71–95.
- Barth, S. 1970b. Feinstratigraphische und lithofazielle Untersuchungen der Pechelbronner Schichten von Rot-Malsch (Obererzän/Unterobererzän des Rheingrabens). *Oberrheinische geologische Abhandlungen*, Karlsruhe, **19**: 43–60.
- Bosma, A. A. 1974. Rodent biostratigraphy of the Eocene–Oligocene transitional strata of the Isle of Wight. *Utrecht micropaleontological Bulletin Special Publications*, Utrecht, **1**.
- Breuer, R. & Feist, M. 1986. Biostratigraphisch bedeutsame Charophyten aus dem Alttertiär von Erdölfeldern des Oberrheingrabens. *Newsletters on Stratigraphy*, Berlin, Stuttgart, **16**(3): 139–147.
- Cavelier, C., Perreau, M., Riveline, J. & Turland, M. 1972. Contribution paléontologique (Characées et Mollusques) à la stratigraphie détaillée du Marinésien, du Ludien et du Stampien inférieur dans la région de Montereau (Seine-et-Marne). *Bulletin d'Informations des Geologues du Bassin de Paris*, Paris, **34**: 31–42.
- Gad, J., Martini, E., Rothausen, K. & Tobien, H. 1990. *Theridomys pseudosiderolithicus* (Rodentia, Mammalia) aus dem unteroligozänen Vorkommen von Bodenheim bei Mainz (Mainzer Becken), Neustadt, Kreis Marburg (Hessische Senke), der Isle of Wight (Hampshire Becken) und deren Beziehungen zur marinen Standard-Biostratigraphie. *Mainzer geowissenschaftliche Mitteilungen*, Mainz, **19**: 163–182.
- Grambast, L. 1959. Extension chronologique des genres chez les Charoïdeae. *Société des Editions Technip 1959*, Paris, 1–12.
- Keen, M. C. 1975. The palaeobiology of some upper Paleogene freshwater ostracodes. *Bulletins of American Paleontology*, Ithaca/NY, **65**(282): 271–283.
- Moos, A. 1934. Die Erdölbohrungen im nördlichen Rheintalgraben bei Bruchsal 1921–1926. *Schriften aus dem Gebiet der Brennstoff-Geologie*, Stuttgart, **9** Heft: Deutsches Erdöl II. Folge 12–76.
- Morkhoven, F. P. C. M. van. 1963. *Post-palaeozoic ostracoda. Their morphology, taxonomy, and economic use. Vol. II: Generic descriptions*. Elsevier, Amsterdam, London, New York.
- Reid, C. & Groves, J. 1921. The Charophyta of the Lower Headon Beds of Hordle (Hordwell) Cliffs (South Hampshire). *Quarterly Journal of the Geological Society of London*, London, **77**: 175–192.
- Riveline, J. 1973. Répartition des Characées dans les calcaires lacustres de l'Eocène terminal et de l'Oligocène basal du Sud-Est du Bassin de Paris. *Comptes rendus hebdomadaires des Séances de l'Académie des Sciences Paris, série D*, Paris, **277**: 2641–2643.
- Riveline, J. 1986. Les Charophytes du Paléogène et du Miocène inférieur d'Europe occidentale. Biostratigraphie des formations continentales. *Cahiers de Paléontologie*, Editions CNRS, Paris.
- Russell, D. E. (ed.) 1982. Tetrapods, of the Northwest European Tertiary Basin. International Geological Correlation Programme Project 124: The Northwest European Tertiary Basin. *Geologisches Jahrbuch*, Hanover, **A60**: 5–74.
- Schmidt-Kittler, N. (ed.) 1987. International Symposium on Mammalian Biostratigraphy and Palaeoecology of the European Paleogene – Mainz, February 18th–21st 1987. *Münchener Geowissenschaftliche Abhandlungen*, Munich, **(A)10**.
- Schwarz, J. & Griessemer, Th. W. 1992. Charophyten-Massenvorkommen aus den Oberen Pechelbronner-Schichten (Unterobererzän) von Merkwiller-Pechelbronn im Elsaß (Dépt. Bas-Rhin, Frankreich). *Paläontologische Zeitschrift*, Stuttgart, **66**(1/2): 23–37.
- Tobien, H. 1949. Säugetierpaläontologische Daten zur Altersbestimmung des tieferen Tertiärs im Rheintalgraben. *Berichte der naturforschenden Gesellschaft zu Freiburg im Breisgau*, Freiburg i. Br., **39**: 17–52.
- Tobien, H. 1968. Mammifères éocènes du Bassin de Mayence et de la partie orientale du Fossé rhénan. *Mémoires du B.R.G.M.*, Paris, **58**: Coll. sur l'Eocène, Paris, mai 1968: 297–307.
- Tobien, H. 1987. The Position of the 'Grande Coupure' in the Paleogene of the Upper Rhine Graben and the Mainz Basin. In Schmidt-Kittler, N. (ed.), International Symposium on Mammalian Biostratigraphy and Palaeoecology of the European Paleogene. *Münchener Geowissenschaftliche Abhandlungen*, Munich, **(A)10**: 197–201.
- Tobien, H. 1988. 4.8.2.2.3. France – The Federal Republic of Germany: The Rhine Graben and the Mainz Basin. In Vinken, R. (ed.), The Northwest European Tertiary Basin, Results of the IGCP No 124. *Geologisches Jahrbuch*, Hanover, **A100**: 395–398.
- Triebel, E. 1953. Genotypus und Schalen-Merkmale der Ostracoden-Gattung *Stenocypris*. *Senckenbergiana*, Frankfurt am Main, **34**(1/3): 5–14.
- Wilser, B. 1922. Cyrenenmergel (?) bei Rot-Malsch (Baden). *Jahresberichte und Mitteilungen des Oberrheinischen Geologischen Vereins Neue Folge* Stuttgart, **11**: 16–22.