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SOME NEW PTEROPOD SPECIES FROM THE NORTH SEA BASIN CAINOZOIC (MOLLUSCA: GASTROPODA, EUTHECOSOMATA)

by

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Since the preparation of a paper on the overall systematics of NW European Cainozoic Euthecosomata had been considerably delayed, manuscript names were prematurely published as *nomina nuda* in the Final Report of I.G.C.P. project 124 (1988). These taxa, the names of which are circulating now, are formally described in the present preliminary paper: *Limacina ingridae* sp. nov. (Late Miocene), *L. irisae* sp. nov. (Late Miocene), *L. jessyae* sp. nov. (Middle Oligocene), *L. mariae* sp. nov. (Middle Oligocene), *L. wilhelminae* sp. nov. (Late Miocene), '*Creseis*' *berthae* sp. nov. (Middle Oligocene), *Clio blinkae* sp. nov. (Middle Oligocene), *C. irenae* sp. nov. (Middle Miocene), *C. jacobae* sp. nov. (Middle Oligocene) and *C. pauli* sp. nov. (Middle Miocene).

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CONTENTS

SAMENVATTING

Enkele nieuwe pteropodensoorten uit het Cainozoicum van het Noordzeebekken (Mollusca: Gastropoda, Euthecosomata).

Ernstige vertraging bij de voorbereiding van een samenvattende publicatie over de systematiek en de biostratigrafie van NW Europese pteropoden was er de oorzaak van dat een tiental namen voor nog onbeschreven soorten werd gepubliceerd in het eindrapport van I.G.C.P. project 124 (Janssen & King, *in*: Vinken, 1988). Omdat onvermijdelijk deze ongeldige namen (*nomina nuda*) nu langzamerhand in gebruik komen, worden in dit artikel de betreffende soorten formeel beschreven, vooruitlopend op een definitieve systematische beschrijving van alle bekende soorten uit het Cainozoicum van het Noordzeebekken, het Mainzer Bekken en het Bekken van Parijs. De oorzaak van de vertraging is vooral de grote hoeveelheid nieuwe gegevens die door onderzoek van nieuwe en bestaande collecties beschikbaar is gekomen.

De volgende nieuwe soorten worden beschreven: *Limacina ingridae* sp. nov., *L. irisae* sp. nov., *L. wilhelminae* sp. nov. (alle Laat Mioceen), *Clio irenae* sp. nov., *C. pauli* sp. nov. (Midden Mioceen), *Limacina jessyae* sp. nov., *L. mariae* sp. nov., *'Creseis' berthae* sp. nov., *Clio blinkae* sp. nov. en *C. jacobae* sp. nov. (alle Midden Oligoceen).

Het is niet geheel zeker, dat de soort *'Creseis' berthae* inderdaad tot de pteropoden (Gastropoda, Euthecosomata) behoort; het zou wellicht ook een annelide kunnen zijn.

De naam *Limacina antoniae* Janssen & King, 1988 (*nomen nudum*) blijkt niet te kunnen worden gehandhaafd. Het met deze naam aangeduide midden-oligocene materiaal werd inmiddels geïdentificeerd als *Limacina hospes* Rolle, 1861, een soort die tot op heden uitsluitend uit het Laat Oligoceen bekend was.

INTRODUCTION

In the early 1980s the well-known I.G.C.P. project 124 'The NW European Tertiary Basin' (subgroup 'Mollusca and other invertebrate mesofauna') included a study on a biostratigraphical zonation of Cainozoic strata in the North Sea and adjacent basins, based on planktonic molluscs ('Pteropoda'), by C. King and the present author. The subject came up rather late in the course of this project, at a time when studies of benthic molluscs were already in an advanced state.

The study of pteropods soon turned out to be very promising and a concentration of materials, together with a thorough study of available literature data, enabled the construction of a preliminary zonation based on this group of fossils. It was found that the study of fossil pteropods was a rather neglected subject and the occurrence of quite a number of undescribed species could be established.

Preliminary names were given to these undescribed taxa and these were incorporated into a manuscript to be published in the final report of I.G.C.P. 124. This paper was submitted to the editors in 1982. At that time it was known that publication of the final report was going to take at least several years. The inclusion of invalid taxa in the manuscript then seemed to be a justifiable action, as it was anticipated that the systematic paper in which these taxa were to be formally introduced would have come out before the publication of the final report. This, however, turned out to be wishful thinking. The paper in the final I.G.C.P. project 124 report has now been published (Janssen & King, *in* Vinken, 1988), but of the systematic paper not even a third has been completed so far. So here we are confronted with the undesirable fact that all names of new species given in Janssen & King (1988) are *nomina nuda*.

The main reason for the delay in completing the North Sea Basin systematic paper is the enormous number of new data that became available after submission of the manuscript of the I.G.C.P. 124 contribution. Some of these new data could still be incorporated during correction phase, but the bulk of the information had to be included in the systematic paper, which comprises for instance a detailed re-identification of pteropods from all boreholes studied by W. Hinsch (GLSH) over the years (NW Germany) and a revision of all data from boreholes in Denmark, as studied by the late T. Sorgenfrei and by L.B. Rasmussen (both DGU). A further reason for the delay is that very interesting pteropod material from outside the North Sea Basin had become available, leading to a better understanding of this group of fossils.

As the systematic paper will not reach completion within measurable time it was reluctantly decided to publish at least formal descriptions for all nomina nuda found in Janssen & King (1988), thus making them valid and prevęnting the possibility for the species concerned to be formally introduced with other names by other authors. This possibility is not unlikely, as the study of fossil pteropods is becoming increasingly popular. Formal introduction of the taxa will also preclude further errors and confusion, such as *e.g.* the rather embarrassing mix-up of the names *L. ingridae*/*L. wilhelminae* and *L. jessyae*/*L. mariae* in Janssen & King.

Seeing that the manuscript names are in wider use now, there is also the possibility, that they are validated unintentionally, as was almost the case with *Limacina ingridae* in Moths (1989); publication of a name accompanied by an illustration, however, is not a valid description [I.C.Z.N., art. 13 (e)].

Some of the data on the stratigraphic distribution of the pteropod species, given in the regional range charts by Janssen & King (1988), can now be demonstrated to be incomplete or even erroneous. Mr K.I. Schnetler (Stevnstrup, Denmark) supplied further information and material additional to Janssen & King's fig. 204, in which also pteropod zone no. 16 (of Chattian age) is wrongly situated. It should be placed at the level of the Velje Fjord and Branden Formations, and not in the upper part of the Viborg Formation.

NOTE ON THE ORIGIN OF THE NEW NAMES

Most of the new names in this paper were given to the species in 1980 or 1981, at a time when the present author was a member of the parent's governing body of the Montessori primary school at Alphen aan den Rijn. This school then faced a number of serious problems concerning the teaching staff, which eventually led to the headmaster's resignation. Participation in this committee had such a great impact on the author's daily life, that all new Euthecosomata species found during that time were named after members of the teaching staff or after fellow sufferers of the governing body. Thus two highly incompatible subjects were combined, in a way that was afterwards sometimes mildly criticised by colleagues, but which is not prohibited by the laws on zoological nomenclature.

ABBREVIATIONS USED IN THE TEXT

DGU	=	Danmarks Geologiske Undersøgelse, Copenhagen, Denmark
GLSH	=	Geologisches Landesamt Schleswig-Holstein, Kiel, F.R.G.
GMK	=	Geologisk Museum, Copenhagen, Denmark
RGD	=	Rijks Geologische Dienst, Haarlem, The Netherlands
RGM	=	Nationaal Natuurhistorisch Museum, Leiden, The Netherlands, (formerly the Rijksmuseum van Geologie en Mineralogie)
RT	=	rotary table
H	=	height of shell (in front view)
W	=	width of shell (in apical view).

ACKNOWLEDGEMENTS

I wish to express my gratitude to the following colleagues for their kind cooperation and/or for the donation of pteropod material to the RGM collections: Prof. Dr G.J. Boekschoten (Vrije Universiteit van Amsterdam, The Netherlands), Mr M. van den Bosch (Nationaal Natuurhistorisch Museum, Leiden, The Netherlands), Mr B. Christensen (Geological Survey of Denmark, Copenhagen, Denmark), Dr S. Floris (Geologisk Museum ved Københavns Universitet, Copenhagen, Denmark), Dr P.A.M. Gaemers (Nationaal Natuurhistorisch Museum, Leiden, The Netherlands), Dr W. Hinsch (Geologisches Landesamt Schleswig-Holstein, Kiel, F.R.G.), Mr K. Holm (Geological Survey of Denmark, Copenhagen, Denmark), Mr H.-J. Lierl (Geologisch-Paläontologisches Institut der Universität Hamburg, Hamburg, F.R.G.), Mr T. Meijer (Rijks Geologische Dienst, Haarlem, The Netherlands), Mr O.B. Nielsen (Odense, Denmark), Mr A. Piehl (Lauenburg, F.R.G.), Dr L.B. Rasmussen (Geological Survey of Denmark, Copenhagen), Mr K.I. Schnetler (Stevnstrup, Langå, Denmark), Mr B. Sliggers (Rijks Geologische Dienst, Haarlem, The Netherlands), Mr J. Timmers (Nationaal Natuurhistorisch Museum, Leiden, The Netherlands), Mr J. van der Voort (Ostercappeln-2, F.R.G.) and Mr F. Weinbrecht (Glücksburg, F.R.G.).

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Mr J.W.M. Jagt (Venlo, The Netherlands) spent a lot of time correcting the English text, for which I am most grateful indeed.

SYSTEMATIC PART

Phylum Mollusca
Classis Gastropoda
Ordo Thecosomata

Subordo Euthecosomata
Familia Limacinidae
Genus *Limacina* Bosc, 1817

Limacina antoniae Janssen & King, 1988 (nomen nudum) = **Limacina hospes** Rolle, 1861

. 1912 *Spirialis stenomphalus* n. sp., Gripp, pp. 21, 24, figs 5-7.
v. 1986 *Spiratella dilatata* — Janssen, p. 148, fig. 1 (non *L. dilatata* von Koenen).
v. 1988 *Limacina antoniae* sp. nov. — Janssen & King, p. 363, figs 188, 194 (nomen nudum).
v. 1988 *Limacina dilatata* — Janssen & King, fig. 188 (partim, only the Middle Oligocene specimens, non *L. dilatata* von Koenen).
v. 1988 *Limacina* ? *dilatata* — Janssen & King, fig. 194 (non *L. dilatata* von Koenen).

non:

1940 *Spirialis stenomphalus* Gripp sp. — Sorgenfrei, pp. 59, 60, 113 (= ? *Limacina valvatina*).

Remarks — A limacinid species from the Rupelian Boom Clay of Belgium was thought to represent an undescribed species by Janssen & King and was indicated as *Limacina antoniae* sp. nov. Now, with considerably more specimens being available, it must be concluded that this material is related to the Latdorfian species *L. dilatata* (von Koenen, 1892). Specimens from the same Boom Clay interval, identified as *L. dilatata* by Janssen & King can no longer be separated with any degree of certainty.

The Rupelian population, however, differs on average from typical (Latdorfian) *L. dilatata* (see von Koenen, 1892, p. 995, pl. 62, figs 3a-b, 4a-c) by a distinctly more depressed shell, resulting in a lower mean value for the H/W-ratio. It must be concluded that by this characteristic the Rupelian population approaches the (up to now) exclusively Late Oligocene species *Limacina hospes* Rolle, 1861 and, in fact, cannot be distinguished from it. *Spirialis stenomphalus* Gripp, 1912, also from Rupelian deposits, is a junior synonym. The relationship with *L. hospes* has not been recognised earlier, as most Rupelian specimens, being preserved as pyritic moulds, lack the reinforced apertural margin. The few specimens on which the widened lip is still present (Janssen, 1986, fig. 1) accidentally have a relatively high shell and were thus interpreted as *L. dilatata*. Such high specimens, however, are exceptional and therefore the entire Rupelian population is now considered to belong to *Limacina hospes*.

It is clear that the two species, *L. dilatata* and *L. hospes*, are part of one and the same evolutionary lineage. The exact morphological boundary between the two species is difficult to assess and will have to be defined by means of the H/W-ratio. This is not yet possible, as only very few specimens of Latdorfian *L. dilatata* are available. Also the syntypes of this species seem to be lost (Dr S. Ritzkowski, Göttingen, pers. comm.). Typical *L. dilatata* is about as high as wide, to somewhat higher than wide, whereas *L. hospes* is distinctly wider than high. In the Rupelian population the range of variation is rather wide; it includes a few specimens resembling *L. dilatata*, but on the other hand, many shells are present which are more depressed than typical *L. hospes*.

Up to now, Rupelian *L. hospes* is only known in a few specimens from the Bergedorf borehole, near Hamburg, F.R.G. (type locality of *Spirialis stenomphalus* Gripp, 1912) and from one locality in Belgium, viz. the clay-pit of Gralex N.V. at Kruibeke. The species is not rare in the Putte Member of the Boom Clay Formation, ranging from just below septaria level S 41 to S 70 (Vandenberghe

& Laga, 1986). The German specimens were collected from two depths in the Bergedorf borehole (294.8 and 302.1 m). From both samples (Gripp, 1912, table on pp. 19-21) *Limacina umbilicata* (Bornemann) was also recorded, together with the bivalves *Cyclocardia 'tuberculata'* Goldfuss and *Astarte kickxi* Nyst, indicating that the samples yielded mixed assemblages (van den Bosch *et al.*, 1975), presumably due to caving. The stratigraphical provenance of these specimens therefore cannot be indicated in any detail.

From higher parts of the Rupelian sequence in the North Sea Basin representatives of *L. hospes* are unknown, although pteropods have been found in certain intervals. The species reappears during the Chattian, from which interval it was originally described. These observations show *L. hospes* to be a rather long-ranging species, and, on the other hand, reduce the vertical range of *L. dilatata*. Still, it cannot be excluded that a future biometrical analysis of abundant material will lead to a three-fold subdivision of the *L. dilatata-L. hospes* lineage.

Limacina ingridae sp. nov.
Pl. 1, Figs 1-5; Pl. 5, Fig. 3; Text-Figs 1-2

. 1882 *Spirialis atlanta* Mörch sp. — von Koenen, p. 359, pl. 7, fig. 16a-d (non Mørch) (partim, not the material from Sylt = *Limacina atlanta*).

v. 1966 *Spiratella atlanta* (Mørch) — Rasmussen, pp. 229, 238, 276 (non Mørch) (partim, includes also *Limacina atlanta, L. irisae* and *L. wilhelminae*).

v. 1966 *Spiratella gramensis* nov. sp. — Rasmussen, p. 276 (nomen nudum) (partim, includes also *Limacina gramensis, L. irisae* and *L. valvatina*).

v. 1968 *Spiratella atlanta* (Mørch) — Rasmussen, p. 243 (non Mørch) (partim, includes also *Limacina atlanta, L. irisae* and *L. wilhelminae*) (non pl. 27, figs 8-10 = *L. atlanta*).

v. 1968 *Spiratella gramensis* nov. sp. — Rasmussen, p. 244 (partim, includes also *Limacina gramensis, L. irisae* and *L. valvatina*) (non pl. 27, figs 4-7 = *L. gramensis*).

v. 1969 *Limacina* B — Boekschoten, p. 44, pl.3, fig. 4a-b (partim, comprises also *Limacina irisae* and *L. atlanta*).

v. 1972a *Spiratella atlanta* (Morch) — Hinsch, pp. 39, 40 (non Mørch) (partim, includes also *Limacina wilhelminae*).

v. 1972b *Spiratella atlanta* (Mørch) — Hinsch, p. 69 (non Mørch) (partim, includes also *Limacina wilhelminae*).

v. 1973a *Spiratella atlanta* (Mørch) — Hinsch, tab. 5 facing p. 59, p. 66 (non Mørch) (partim, includes also *Limacina valvatina*).

v. 1975 *Spiratella atlanta* (Mørch) — Hinsch, p. 395 (non Mørch) (part of the material could not be traced in coll. GLSH).

v. 1979 *Spiratella atlanta* (Mørch) — Hinsch, p. 42 (non Mørch) (partim, includes also *Limacina irisae* and *L. wilhelminae*).

v. 1983 *Spiratella atlanta* (Mørch) — Hinsch, p. 16 (non Mørch).

v. 1986 *Spiratella wilhelminae* — Hinsch, p. 369, tab. 5b (nomen nudum) (partim, includes also *Limacina atlanta* and *L. wilhelminae*).

v. 1987 *Limacina* sp. — Hinsch, p. 130, tab. 2, p. 131, fig. 2 (partim, includes also *Limacina irisae, L. valvatina* and *L. wilhelminae*).

v. 1988 *Limacina ingridae* sp. nov. — Janssen & King, figs 188, 202, 203 (nomen nudum).

v. 1988 *Limacina wilhelminae* (*sic* !) — Janssen & King, pp. 366, 367.

. 1989 *Limacina* sp. — Moths, p. 112.

. 1989 *Limacina* sp. (*Limacina ingridae* A.W. Janssen) — Moths, pl. 23, fig. 123a-c (nomen nudum).

Holotype — Pl. 1, Fig. 1a-d, coll. RGM 229 551.

Locus typicus — Groß Pampau (F.R.G., Schleswig-Holstein), Ohle gravel-pit, 'lower level'.

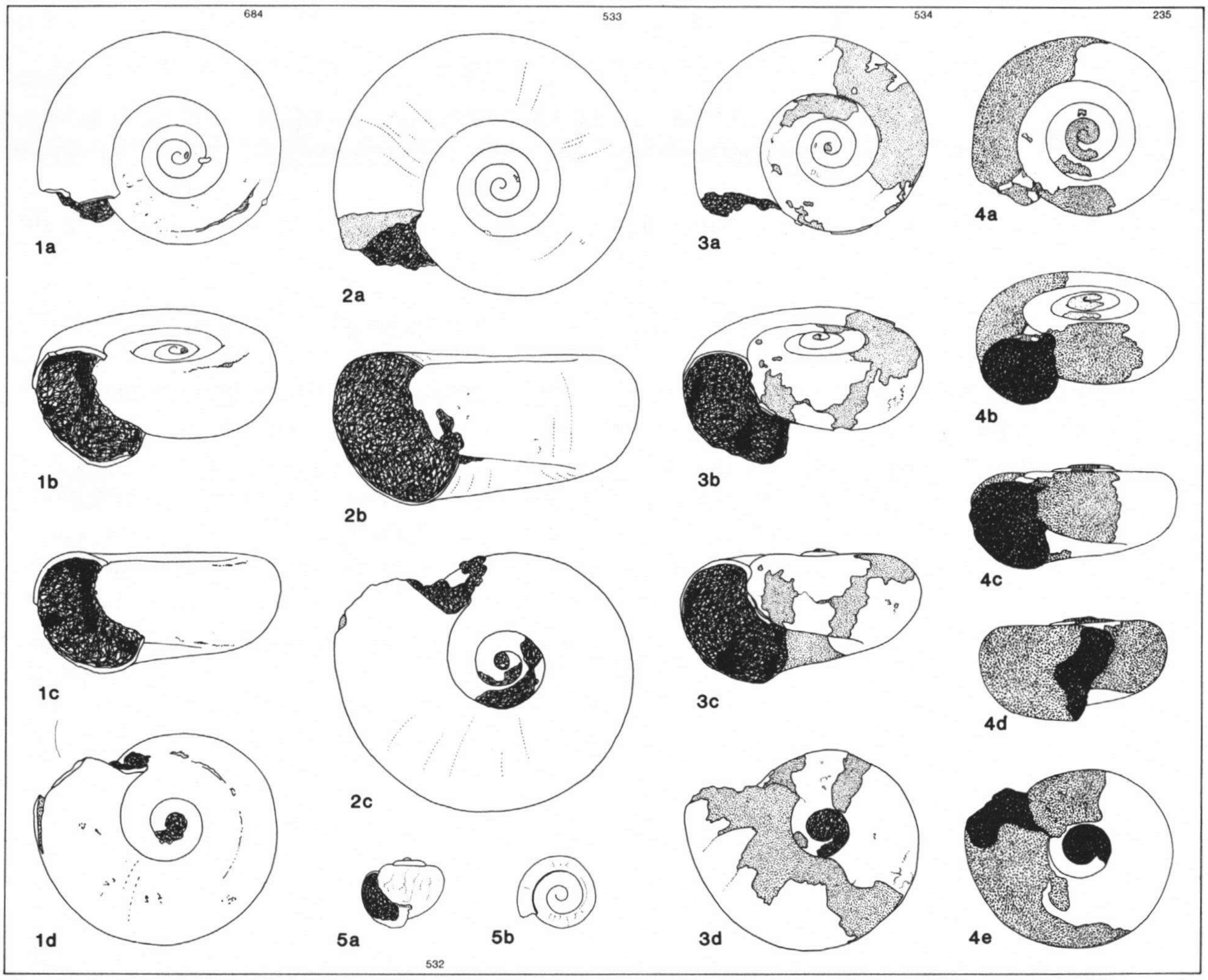


Plate 1

Limacina ingridae sp. nov., holo- and paratypes.

Fig. 1a-d. Holotype. Groß Pampau (F.R.G., Schleswig-Holstein), Ohle gravel-pit, 'lower level'. Miocene, Langenfeldian s.str., Eidelstedt Formation. Leg. A.W. Janssen, 1985, coll. RGM 229 551.
a: apical, b: oblique frontal, c: frontal, and d: umbilical view.

Fig. 2a-c. Paratype. Schönberg (F.R.G., Schleswig-Holstein), borehole, depth 96-97 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Coll. GLSH.
a: apical, b: frontal, and c: umbilical view.

Fig. 3a-d. Paratype. Schönberg (F.R.G., Schleswig-Holstein), borehole, depth 88-89 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Coll. GLSH.
a: apical, b: oblique frontal, c: frontal, and d: umbilical view.

Fig. 4a-e. Paratype. Hamburg-Langenhorn (F.R.G., Hamburg Area), borehole 1955, depth ± 99 m. Miocene, Langenfeldian s.str., Eidelstedt Formation. Don. G.J. Boekschoten, coll. RGM 229 556.
a: apical, b: oblique frontal, c: frontal, d: right lateral, and e: umbilical view.

Fig. 5a-b. Paratype, juvenile. Adelbyer Meierei (F.R.G., Schleswig-Holstein), borehole III, depth 128-138 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Coll. GLSH.
a: frontal, b: apical view.

Magnification of all drawings × 25.

Stratum typicum — Eidelstedt Formation (Late Miocene, Langenfeldian s.str.).

Derivatio nominis — This species is named after Mrs I. Castelijn of Alphen aan den Rijn.

Description — Shell sinistral, very small (the largest specimen has a width of 1.9 mm), discoidal, almost twice as wide as high, with a flattened apical side and a slightly produced, distinctly umbilicate base. Starting from the small nucleus the whorls increase slowly and very regularly in diameter, resulting in a very even spiral of the rather shallow suture line and a very gradual increase of the width of the whorls (apical view). The width of the visible upper parts of the whorls is rather variable in the many specimens available and therefore the suture line is more or less tightly twined. This results in a wide variability of the number of whorls, related to the width of the shell (Text-Fig. 2).

The upper junction of each whorl lies far above the periphery of the preceding one, in such a way that the upper parts of the subsequent whorls together form an almost flat, or only very slightly convex or concave apical plane. In specimens with a concave upper side the 1½-2 initial whorls frequently form a depressed cone in the centre of the apical plane. In flat or slightly convex specimens the apical whorls do not protrude. The lower junction of the whorls lies somewhat more adaxially and far below the periphery on the base of the preceding whorls, resulting in a somewhat oblique position of the crescent-shaped aperture (front view), the lower part of which protrudes distinctly beyond the base of the penultimate whorl. The basal part of the whorls is less wide than the upper part, therefore the curvature of the apertural lip is strongest in its most abapical part, rather regularly convex in juvenile specimens, but in larger ones the transitions to the apical plane and the base are very slightly angular, giving the shell (in front view) a mildly rectangular appearance.

The aperture is simple, apparently without any reinforcements of the apertural margin. Practically all available specimens, however, are filled with pyrite or preserved as pyritic moulds.

The width of the umbilicus is very variable, ranging from 15 to almost 35% of the shell's diameter. Measurements (Text-Fig. 1) demonstrate a distinct allometry of this value, becoming relatively higher in larger specimens. Within the gradually deepening umbilicus two or three of the preceding whorls are usually visible. The growth lines are very vague, frequently even completely indistinct. From the upper suture they run slightly backwards.

Material — **Miocene, Reinbekian (Hodde Formation) (downhole contamination from Langenfeldian Eidelstedt Formation)**: F.R.G., Schleswig-Holstein, borehole Bargfeld, depth 342-348 m (3 specimens, coll. GLSH, not mentioned in Hinsch, 1979, p. 42).

Do.: do., borehole Klein Hansdorf, depth 345-348 m (2 specimens); depth 333-339 m (1 specimen); depth 327-333 m (1 specimen) (coll. GLSH, not mentioned in Hinsch, 1979, p. 42).

Miocene, Reinbekian, Levensauian (Eidelstedt Formation) (downhole contamination from overlying Langenfeldian deposits ?): F.R.G., Schleswig-Holstein, borehole Kiel-Levensau Süd 1, depth 74.5-76 m (? 1 specimen, coll. GLSH, mentioned in Hinsch, 1987, p. 130, tab. 2 sub nomine *Limacina* sp.).

Miocene, Langenfeldian, Lüneburgian (Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Kiel-Levensau Süd 1, depth 64-65.5 m (1 specimen, coll. GLSH, mentioned in Hinsch, 1987, p. 130, tab. 2 sub nomine *Limacina* sp.).

Do.: F.R.G., Hamburg Area, borehole Hamburg-Eidelstedt (Nordgetränke), depth 248-251 m (1 specimen, coll. GLSH, mentioned in Hinsch, 1986, p. 369, tab. 5b sub nomine *Limacina wilhelminae*).

Miocene, Langenfeldian s.str. (Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Kiel-Levensau Nord 3, depth 69.3-70 m (? 1 specimen); depth 68-69 m 3 specimens) (coll. GLSH, mentioned in Hinsch, 1987, pp. 130, 131 sub nomine *Limacina* sp.).

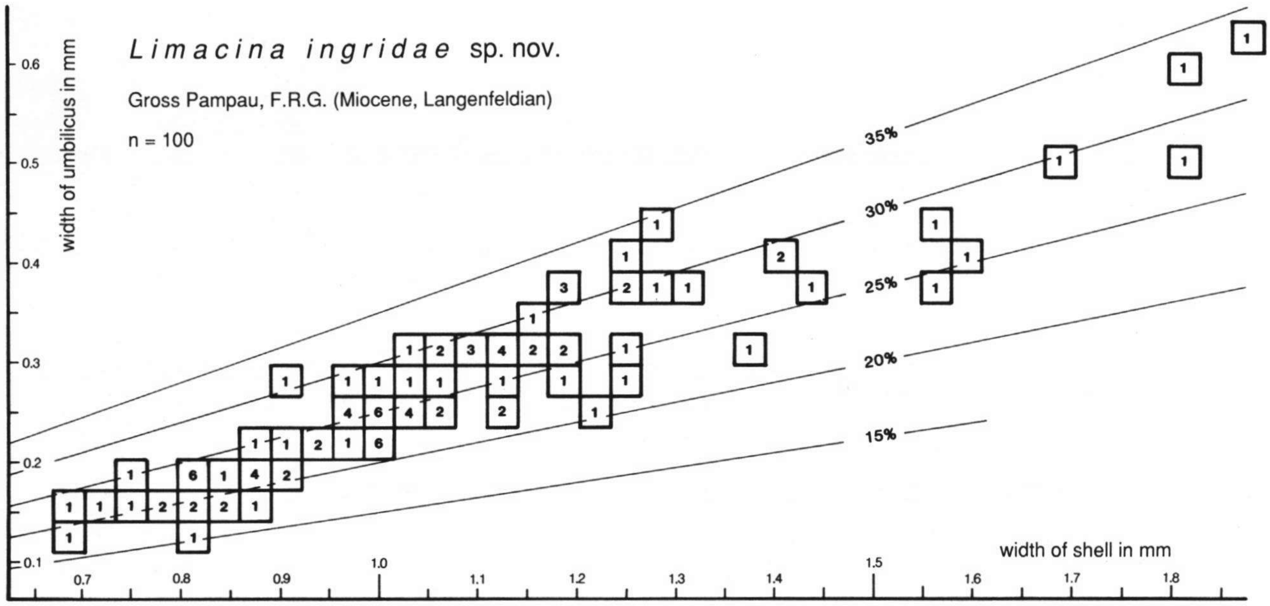


Fig. 1. *Limacina ingridae* sp. nov.
Relation between the width of the shell and the width of the umbilicus. Figures in squares denote the number of specimens. Coll. RGM 229 554.

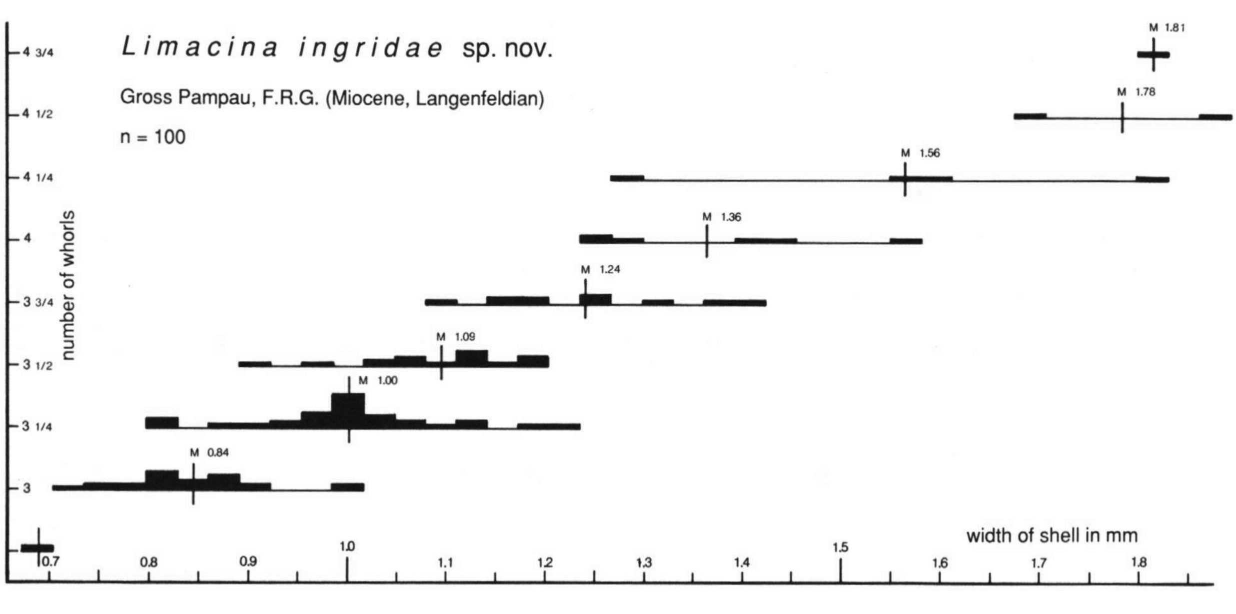


Fig. 2. *Limacina ingridae* sp. nov.
Variation in width of shell, related to the number of whorls. Coll. RGM 229 554.

Do.: do., borehole Kiel-Levensau Süd 1, depth 57-58 m (12 specimens, coll. GLSH); depth 56-57 m (4 specimens, coll. RGM 229 578, don. GLSH); depth 55-56 m (3 specimens, coll. GLSH); depth 54-55 m (4 specimens, coll. GLSH); depth 53-54 m (3 specimens, coll. RGM 229 579, don. GLSH); depth 49-50 m (1 specimen, coll. GLSH) (all samples mentioned in Hinsch, 1987, p. 130, tab. 2 sub nomine *Limacina* sp.).

Do.: do., Groß Pampau, Ohle gravel-pit, 'lower level' (1600 specimens, leg./coll. H.-J. Lierl, 1986; 1 specimen, holotype, Pl. 1, Fig. 1a-d, coll. RGM 229 551, 1095 specimens, coll. RGM 229 552, leg. A.W. Janssen, 1985); do. 'upper level' (658 specimens, leg./coll. H.-J. Lierl, 1986; 671 specimens, coll. RGM 229 553, leg. A.W. Janssen, 1985); do., level not indicated (1033 specimens, leg./coll. H.-J. Lierl; 100 specimens, measured for Text-Figs 1 and 2; coll. RGM 229 554, leg./don. H.-J. Lierl, 1986; 55 specimens, leg./coll. A. Piehl, reg. nos 66.16, 66.22, 66.26f and 66.26h).

Do.: F.R.G., Hamburg Area, borehole Hamburg-Eidelstedt (Nordgetränke), depth 220-222 m (3 specimens); depth 217-218 m (1 specimen); depth 216-217 m (4 specimens); depth 215-216 m (1 specimen); depth 214-215 m (2 specimens); depth 203-204 m (2 specimens); depth 202-203 m (1 specimen); depth 200-201 m (1 specimen); depth 199-200 m (1 specimen); depth 197-198 m (2 specimens); depth 179-180 m (1 specimen) (coll. GLSH, all specimens mentioned in Hinsch, 1986, p. 369, tab. 5b sub nomine *Spiratella wilhelminae*).

Do.: do., borehole Hamburg-Langenhorn, 1955 (see Boekschoten, 1969, p. 9), depth ± 99 m (4 specimens, RGM 229 555; 1 specimen, Pl. 1, Fig. 4a-e, coll. RGM 229 556; one specimen illustrated in Boekschoten, 1969, pl. 3, fig. 4a-b sub nomine *Limacina* B, coll. RGM 229 557), depth 102-108 m (18 specimens, coll. RGM 229 558), depth 114 m (12 specimens, coll. RGM 229 559), all specimens donated by G.J. Boekschoten.

Miocene, Langenfeldian s.lat. (Gram Clay): Denmark, Jylland, borehole Gram DGU 141.277, depth 21.50-22 m (6 specimens); depth 21-21.50 m (8 specimens); depth 20.50-21 m (18 specimens, one of which is in fact unidentifiable); depth 20-20.50 m (13 specimens; 1 specimen, paratype of *Limacina gramensis*); depth 19-19.50 m (3 specimens, transitional forms *L. ingridae/wilhelminae*); depth 18.50-19 m (4 specimens); depth 18-18.50 m (1 specimen); depth 17.50-18 m (3 specimens); depth 17-17.50 m (4 specimens); depth 16.50-17 m (4 specimens) (coll. DGU, all samples mentioned in Rasmussen, 1966, p. 276 and 1968, p. 244 sub nomine *Spiratella atlanta* or *S. gramensis*).

Do.: do., borehole Tvaermose DGU 85.381, depth 21-25 m (2 specimens, coll. DGU, mentioned in Rasmussen, 1966, p. 238 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Miocene, Langenfeldian s.lat. (Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Adelbyer Meierei III, depth 128-138 m (1 juvenile specimen, Pl. 1, Fig. 5a-b, coll. GLSH, mentioned in Hinsch, 1972b, p. 69 sub nomine *Spiratella atlanta*).

Do.: do., borehole Bargfeld, depth 297-303 m (1 specimen, coll. GLSH); depth 285-291 m (1 specimen, coll. GLSH); depth 267-273 m (1 specimen, coll. RGM 229 561, don. GLSH); depth 261-267 m (3 specimens, coll. RGM 229 562, don. GLSH); depth 250-255 m (1 specimen, coll. RGM 229 563, don. GLSH); depth 237-243 m (1 specimen, coll. RGM 229 564, don. GLSH); depth 231-237 m (1 specimen, coll. RGM 229 565, don. GLSH); depth 225-231 m (1 specimen, coll. RGM 229 566, don. GLSH); depth 213-219 m (1 specimen, coll. RGM 229 567, don. GLSH); depth 207-213 m (2 specimens, coll. RGM 229 568, don. GLSH); depth 201-207 m (3 specimens, coll. RGM 229 569, don. GLSH); depth 195-201 m (7 specimens, coll. RGM 229 570, don. GLSH); depth 180-186 m (1 specimen, coll. RGM 229 571, don. GLSH) (all specimens mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Bünningstedt, depth 222-228 m (2 specimens); depth 216-222 m (1 specimen); depth 210-216 m (1 specimen); depth 198-204 m (2 specimens); depth 192-198 m (2 specimens); depth 180-186 m (5 specimens); depth 156-162 m (3 specimens); depth 150-156 m (1 specimen); depth 144-150 m (5 specimens) (coll. GLSH, all specimens mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Forst Steinburg, depth 159-162 m (1 specimen, coll. GLSH, mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Forst Tremsbüttel, depth 318-327 m (1 specimen); depth 300-309 m (2 specimens); depth 282-291 m (2 specimens); depth 264-273 m (5 specimens); depth 255-264 m (3 specimens); depth 246-255 m (2 specimens); depth 237-241 m (8 specimens); depth 228-237 m (4 specimens); depth 219-228 m (8 specimens); depth 210-219 m (9 specimens); depth 201-210 m (1 specimen) (coll. GLSH, all specimens, except 318-327 m, mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Hindorf Br. III, depth 133-134 m, (3 specimens, coll. RGM 229 560; 1 specimen, Pl. 5, Fig. 3a-c, coll. RGM 229 660; both samples don. GLSH).

Do.: do., borehole Höltenklinken, depth 351-357 m (2 specimens); depth 345-351 m (1 specimen); depth 339-345 m (1 specimen); depth 327-333 m (2 specimens); depth 312-321 m (1 specimen); depth 306-312 m (1 specimen); depth 255-261 m (1 specimen); depth 246-249 m (4 specimens); depth 237-243 m (4 specimens) (coll. GLSH, all specimens mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Hüls, depth 504-510 m (2 specimens); depth 492-498 m (3 specimens); depth 486-489 m (1 specimen), depth 480-486 m (1 specimen); depth 459-465 m (1 specimen); depth 453-459 m (1 specimen); depth 429-435 m (1 specimen); depth 423-429 m (2 specimens); depth 411-417 m (6 specimens); depth 405-411 m (6 specimens); depth 399-405 m (5 specimens) (coll. GLSH, all specimens mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Kiel (Städtisches Krankenhaus), depth 96-99 m (? 1 specimen); depth 87-90 m (? 1 specimen) (coll. GLSH, mentioned in Hinsch, 1973a, tab. 5 facing p. 59 sub nomine *Spiratella atlanta*).

Do.: do., borehole Klein Hansdorf, depth 297-303 m (2 specimens); depth 279-285 m (1 specimen); depth 273-279 m (2 specimens); depth 231-237 m (3 specimens); depth 225-231 m (1 specimen); depth 219-225 m (1 specimen); depth 213-219 m (2 specimens); depth 207-213 m (6 specimens); depth 201-207 m (7 specimens); depth 189-195 m (8 specimens) (all samples coll. GLSH); depth 183-189 m (21 specimens, coll. RGM 229 580, don. GLSH); depth 177-183 m (13 specimens, coll. RGM 229 572, don. GLSH) (all specimens mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Langenklint, depth 56 m (32 specimens, among which some transitional forms *L. ingridae/wilhelminae*, coll. RGM 229 573, don. GLSH); depth 51.8 m (39 specimens, coll. RGM 229 574, don. GLSH) (all specimens mentioned in Hinsch, 1972a, pp. 39-40 sub nomine *Spiratella atlanta*).

Do.: do., borehole Schachtholm, depth 52-56 m (2 specimens, coll. GLSH, mentioned in Hinsch, 1983, p. 16 sub nomine *Spiratella atlanta*).

Do.: do., borehole Schmachthagen, depth 132-138 m (2 specimens, coll. GLSH, mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Schönberg/Lbg., depth 96-97 m (1 specimen, Pl. 1, Fig. 2a-c); depth 90-91 m (3 specimens); depth 89-90 m (1 specimen); depth 88-89 m (1 specimen, Pl. 1, Fig. 3a- d) (all samples coll. GLSH); depth 82-83 m (1 specimen, coll. RGM 229 575, don. GLSH) (all specimens mentioned in Hinsch, 1975, p. 395 and 1979, p. 42 sub nomine *Spiratella atlanta*, but the depth indications in these two papers do not coincide; apparently not all specimens were traced in coll. GLSH).

Do.: do., borehole Schulensee XII, depth 136-137.5 m (1 specimen, according to Hinsch, 1973a, p. 56 possibly downhole contamination); depth 92.5-96 m (7 specimens) (coll. GLSH, specimens mentioned in Hinsch, 1973a, tab. 5 facing p. 59 sub nomine *Spiratella atlanta*).

Do.: do., borehole Westerland, Sylt, 1959 (see Boekschoten, 1969, pp. 10ff), depth 296.10 m (1 specimen, don. G.J. Boekschoten, coll. RGM 229 576).

Miocene, ? Langenfeldian (Breda Formation, foram zone FC2): The Netherlands, province of Limburg, borehole Nederweert 58A/62 (PH/15), depth 480.00 m (1 specimen, coll. RGD).

Miocene, ? Gramian (Gram Clay): Denmark, Jylland, borehole Aulum DGU 74.321, depth 11.40-12.40 m (? 1 defective specimen, coll. DGU, mentioned in Rasmussen, 1966, p. 229 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Gram DGU 141.277, depth 16-16.50 m (? 1 specimen, coll. GLSH, mentioned in Rasmussen, 1966, p. 276 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Miocene, ? Gramian (? Gram Formation, see 'discussion' below): F.R.G., Schleswig-Holstein, borehole Bargfeld, depth 150-156 m (1 specimen, coll. RGM 229 577, don. GLSH, mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Discussion — The present species connects with *L. wilhelminae* through transitional forms; it is sometimes difficult to identify a certain specimen. The main distinguishing feature is the complete regularity of the suture spiral in *L. ingridae*, whereas in *L. wilhelminae* the middle whorls are distinctly more tightly coiled (and therefore narrower in apical view) than the initial and the later ones.

From the available samples it appears that *L. wilhelminae* developed from *L. ingridae* during the Early Langenfeldian. In the very large populations from Groß Pampau (F.R.G., see list of material above) only very few transitional specimens to *L. wilhelminae* are present. Typical *L. wilhelminae* is still absent, indicating that the Groß Pampau sediment is apparently of Early Langenfeldian age. (Note that the names *L. ingridae* and *L. wilhelminae* were unfortunately mixed up in Janssen & King, 1988, pp. 366, 367 and fig. 196).

Since distinct transitional forms between *L. wilhelminae* and *L. atlanta* (Mørch, 1874) (see below) are also known, these three species probably form together an evolutionary lineage, which is also supported by their vertical distribution. *L. irisae* is also related to this species complex and may represent a parallel branch that developed either from *L. wilhelminae* or directly from *L. ingridae.*

Limacina ingridae seems to be a typical index fossil for Langenfeldian deposits. The two Gramian specimens from Denmark (Aulum and Gram boreholes, see above) are poorly preserved and therefore uncertain. The only German specimen from a sample of Gramian age (Bargfeld borehole, see above) was collected from the lowermost Gramian sample, which therefore might have included some sediment of Langenfeldian age.

Plate 2

Limacina irisae sp. nov., holo- and paratypes.

Fig. 1a-d. Holotype. Klein Hansdorf (F.R.G., Schleswig-Holstein), borehole, depth 177-183 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Don. GLSH, coll. RGM 229 589.
a: apical, b: frontal, c: right lateral, and d: umbilical view.

Fig. 2a-b. Höltenklinken (F.R.G., Schleswig-Holstein), borehole, depth 237-243 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Coll. GLSH.
a: apical, and b: frontal view.

Fig. 3. Kiel-Levensau (F.R.G., Schleswig-Holstein), borehole 3, depth 57-58 m. Miocene, Langenfeldian s.str., Eidelstedt Formation. Coll. GLSH.
Frontal view.

Fig. 4a-b. Bünningstedt (F.R.G., Schleswig-Holstein), borehole, depth 144-150 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Coll. GLSH.
a: apical, and b: frontal view.

Fig. 5a-b. Hüls (F.R.G., Schleswig-Holstein), borehole, depth 480-486 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Coll. GLSH.
a: apical, and b: frontal view.

Fig. 6a-c. Hindorf (F.R.G., Schleswig-Holstein), borehole III, depth 133-134 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Don. GLSH, coll. RGM 229 587.
a: apical, b: frontal, and c: right lateral view.

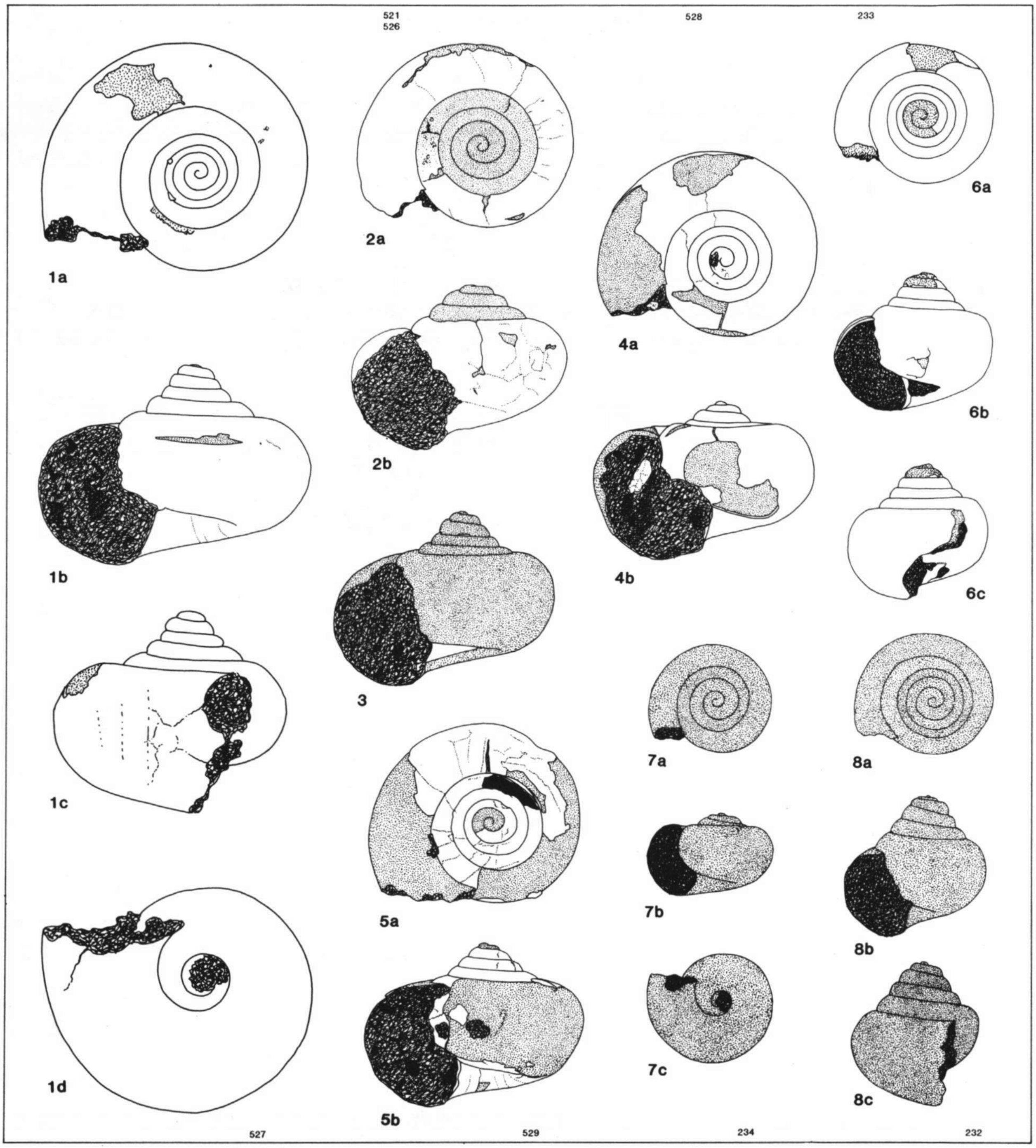


Fig. 7a-c. Westerland, Sylt (F.R.G., Schleswig-Holstein), borehole 1959, depth 246.30 m. Don. G.J. Boekschoten, coll. RGM 229 594.
a: apical, b: frontal, and c: umbilical view.

Fig. 8a-c. Hamburg-Langenhorn (F.R.G., Hamburg Area), borehole 1955, depth 96 m. Miocene, Langenfeldian s.lat., Eidelstedt Formation. Leg. G.J. Boekschoten, coll. RGM 229 597.
a: apical, b: frontal, and c: umbilical view.

Magnification of all drawings × 25.

Limacina irisae sp. nov.
Pl. 2, Figs 1-8; Text-Figs 3-5

v. 1966 *Spiratella atlanta* (Mørch) — Rasmussen, p. 276 (non Mørch) (partim, includes also *Limacina atlanta, L. ingridae* and *L. wilhelminae*).
v. 1966 *Spiratella gramensis* nov. sp. — Rasmussen, p. 276 (nomen nudum) (partim, includes also *Limacina gramensis, L. irisae* and *L. valvatina*).
v. 1968 *Spiratella atlanta* (Mørch) — Rasmussen, p. 243 (non Mørch) (partim, includes also *Limacina atlanta, L. ingridae* and *L. wilhelminae*) (non pl. 27, figs 8-10 = *Limacina atlanta*).
v. 1968 *Spiratella gramensis* nov. sp. — Rasmussen, p. 244 (partim, includes also *Limacina gramensis, L. ingridae* and *L. valvatina*) (non pl. 27, figs 4-7 = *Limacina gramensis*).
v. 1969 *Limacina* B — Boekschoten, p. 44 (partim, includes also *Limacina ingridae and L. atlanta*).
v. 1979 *Spiratella atlanta* (Mørch) — Hinsch, p. 42 (non Mørch) (partim, includes also *Limacina ingridae* and *L. wilhelminae*).
v. 1979 *Spiratella gramensis* (Rasmussen) — Hinsch, p. 42 (non Rasmussen)(partim, includes also *Limacina gramensis*).
v. 1979 *Spiratella valvatina* (Reuss) — Hinsch, p. 42 (non Reuss) (partim, includes also *Limacina valvatina*).
v. 1987 *Limacina* sp. — Hinsch, p. 130, tab. 2 (partim, includes also *Limacina ingridae, L. valvatina* and *L. wilhelminae*).
v. 1988 *Limacina irisae* sp. nov. — Janssen & King, figs 188, 202, 203 (nomen nudum).

Holotype — Pl. 2, Fig. 1a-d, coll. RGM 229 589.

Locus typicus — F.R.G., Schleswig-Holstein, borehole Klein Hansdorf, depth 177-183 m below surface (see Hinsch, 1979).

Stratum typicum — Eidelstedt Formation (Langenfeldian, Late Miocene).

Derivatio nominis — This species is named after Mrs I.S. de Jong of Alphen aan den Rijn.

Description — Shell sinistral, very small (the largest specimen has a width of 1.8 mm), conical, with a variably elevated spire, resulting in a wide range of the H/W-ratio: from about equally high as wide to almost twice as wide as high. There is a clear allometric tendency in the H/W-ratio: juvenile shells are on average relatively higher than full-grown ones. Large specimens have up to 5 3/4 convex whorls, the early ones slowly, the later ones more rapidly increasing in diameter. The number of whorls, related to the width of the shell, is very variable (Text-Fig. 5). The suture line is distinct and deeply impressed, forming a regular spiral in apical view. Quite typical of this species is the fact that the tangents of the spire part of the shell are concave, caused by an increasing sideward expansion of the whorls.

The body whorl is relatively large, with an evenly rounded periphery and very slightly flattened base which is distinctly umbilicate. The width of the umbilicus varies with the size and the H/W-ratio of the shell, from less than 15 to over 35% of the width of the shell. Measurements demonstrate also in these respects a distinct allometry (Text-Figs 3 and 4). The upper part of the apertural margin is attached above the periphery of the preceding whorl, the more so when the shell has a depressed form. The aperture is reniform, apparently without any reinforcements of the apertural margin. Practically all available specimens, however, are filled with pyrite or preserved as pyritic moulds. The shell's surface is smooth with growth lines hardly visible or not at all.

Material — **Miocene, Langenfeldian s.str. (Eidelstedt Formation):** F.R.G., Schleswig-Holstein, borehole Kiel-Levensau Süd 1, depth 57-58 m (1 specimen, Pl. 2, Fig. 3, coll. GLSH, mentioned in Hinsch, 1987, p. 130, tab 2, sub nomine *Limacina* sp.).

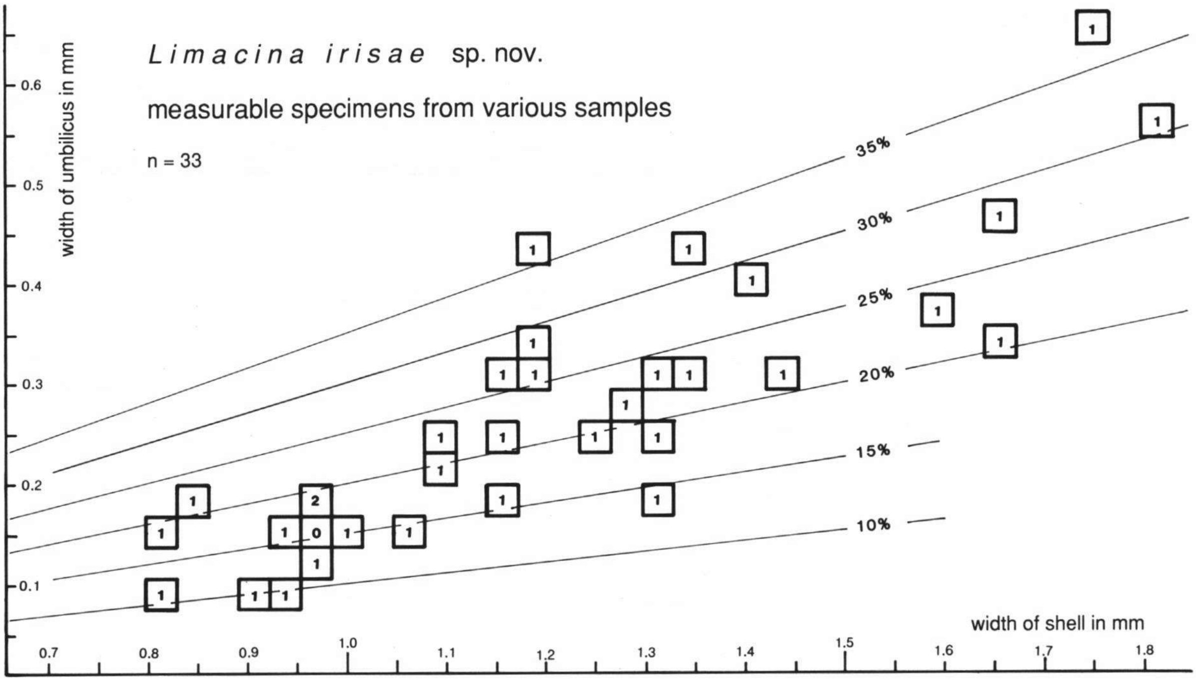


Fig. 3. *Limacina irisae* sp. nov.
Relation between the width of the shell and the width of the umbilicus. Figures in squares denote the number of specimens. Data of all measurable specimens from various localities.

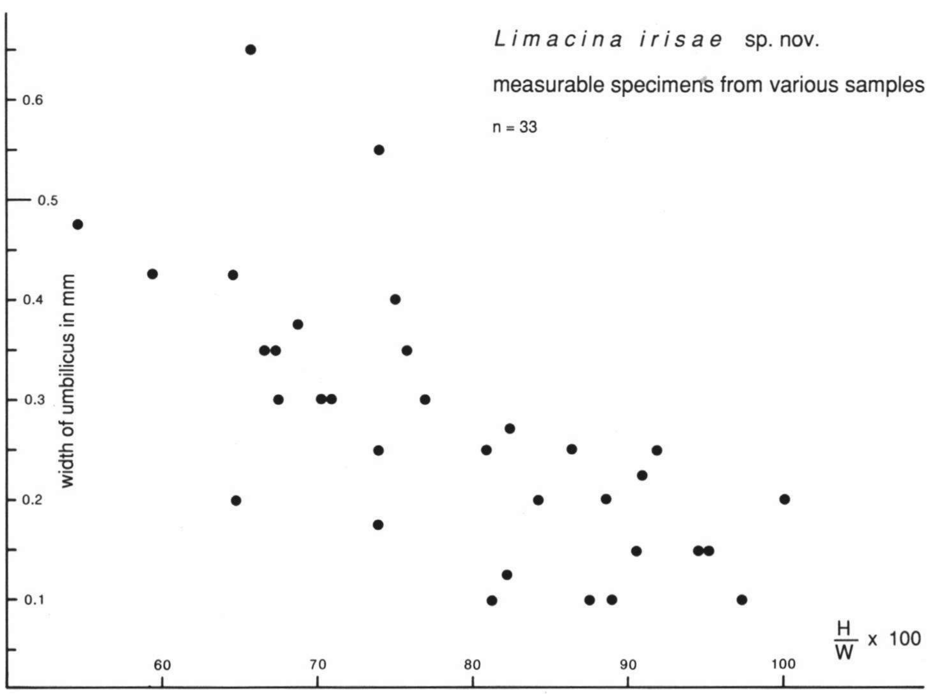


Fig. 4. *Limacina irisae* sp. nov.
Relation between the width of the umbilicus and the H/W-ratio of the shell. Data of all measurable specimens from various localities.

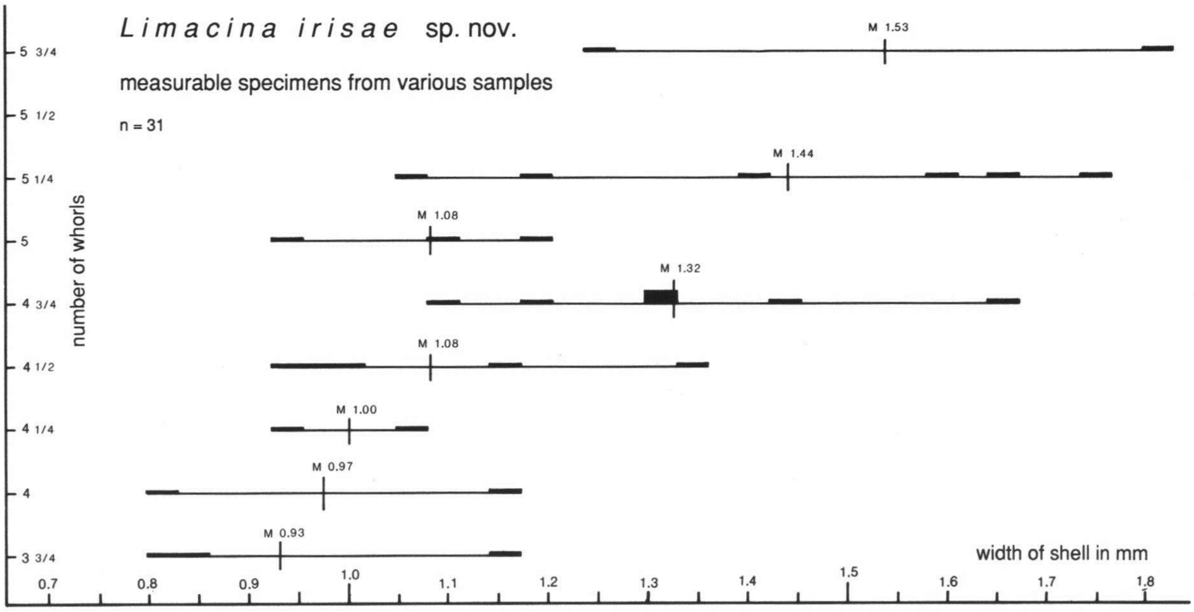


Fig. 5. *Limacina irisae* sp. nov.
Variation in width of shell, related to the number of whorls. Data of all measurable specimens from various localities.

Miocene, Langenfeldian s.lat. (Gram Clay): Denmark, Jylland, borehole Gram DGU 141.277, depth 20-20.50 m (2 specimens, depressed form; 3 specimens, paratypes of *Limacina gramensis*); depth 19.50-20 m (1 specimen, paratype of *Limacina gramensis*); depth 18.50-19 m (1 specimen, depressed form); depth 18-18.50 m (2 juvenile specimens, paratypes of *Limacina gramensis*) (coll. DGU, specimens mentioned in Rasmussen, 1966, p. 276 and 1968, pp. 244-245 sub nominibus *Spiratella atlanta* and *S. gramensis*).

Miocene, Langenfeldian s.lat. (Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Bargfeld, depth 255-261 m (1 specimen, coll. RGM 229 581); depth 225-231 m (1 specimen, coll. RGM 229 582); depth 213-219 m (1 specimen, coll. RGM 229 583); depth 195-201 m (1 specimen, coll. RGM 229 584); depth 186-195 m (3 specimens, coll. RGM 229 585); depth 174-180 m (1 specimen, coll. RGM 229 586) (all samples don. GLSH, mentioned in Hinsch, 1979, p. 42 sub nominibus *Spiratella atlanta* and *S. gramensis*).

Do.: do., borehole Bünningstedt, depth 210-216 m (1 specimen); depth 198-204 m (1 defective specimen); depth 186-192 m (1 juvenile specimen); depth 156-162 m (1 specimen); depth 144-150 m (1 specimen, Pl. 2, Fig. 4a-b) (coll. GLSH, all specimens mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Hindorf Br. III, depth 133-134 m, (1 specimen, coll. RGM 229 587, Pl. 2, Fig. 6a-c, don. GLSH).

Do.: do., borehole Höltenklinken, depth 237-243 m (1 specimen, Pl. 2, Fig. 2a-b); depth 219-225 m (1 specimen) (coll. GLSH, specimens mentioned in Hinsch, 1979, p. 42 sub nominibus *Spiratella atlanta* and *S. valvatina*).

Do.: do., borehole Hüls, depth 480-486 m (1 specimen, Pl. 2, Fig. 5a-b) (coll. GLSH, mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Klein Hansdorf, depth 183-189 m (11 specimens, coll. RGM 229 588); depth 177-183 m (1 specimen, holotype, Pl. 2, Fig. 1a-d, coll. RGM 229 589, 6 specimens, coll. RGM 229 590); depth 171-177 m (2 specimens, coll. RGM 229 591) (all samples don. GLSH, mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Ladelund, depth 105-108 m (1 specimen, coll. RGM 229 592, don. GLSH).

Do.: do., borehole Westerland, Sylt, 1959 (see Boekschoten, 1969, pp. 10ff), depth 281.20 m (4 specimens, coll. RGM 229 593), depth 246.30 m (1 specimen, Pl. 2, Fig. 7a-c, coll. RGM 229 594) (don. G.J. Boekschoten).

Do.: F.R.G., Hamburg Area, borehole Hamburg-Langenhorn, 1955 (see Boekschoten, 1969, p. 9), depth 228.50 m (downhole contamination, 1 specimen, coll. RGM 229 595), depth 96 m (1 specimen, coll. RGM 229 596; 1 specimen, Pl. 2, Fig. 8a-c, coll. RGM 229 597), all specimens donated by G.J. Boekschoten.

Discussion — The H/W-ratio of this species is remarkably variable (compare Pl. 2, Figs 7b and 8b) and some comparatively high specimens may therefore approach the somewhat older species *Limacina valvatina* (Reuss, 1867) in their H/W-ratio. They differ, however, by the concave tangents of the spire, the convex whorls, separated by deep suture lines, and the considerably wider umbilicus.

Relatively depressed specimens approach the more or less contemporaneous species *Limacina ingridae* and *L. wilhelminae*, a close relationship between these species is assumed. *L. irisae* differs from both, however, by the spatial spiral of at least the first three whorls and the concave tangents. Later whorls may be almost entirely involute. In relatively higher specimens the resemblance (in apical view) with *L. wilhelminae* is sometimes striking (Pl. 2, Fig. 1a), but usually the sutural spiral is more regular, as in *Limacina ingridae*. See also the discussion following the description of *L. ingridae*.

Limacina jessyae sp. nov.
Pl. 3, Figs 1-3; Pl. 4, Fig. 1

v. 1988 *Limacina mariae* sp. nov. — Janssen & King, p. 362, figs 188, 204 (nomen nudum) (partim, includes also *L. mariae*).

v. 1988 *Limacina jessyae* sp. nov. — Janssen & King, p. 362, figs 188, 196 (nomen nudum) (partim, includes also *L. mariae*).

Holotype — Pl. 4, Fig. 1a-d, coll. RGM 229 600.

Locus typicus — Borehole Opende-1 of the Nederlandse Aardolie Maatschappij B.V. (The Netherlands, province of Groningen), depth 520-525 m-RT.

Stratum typicum — 'Rupel Formation' or unnamed unit (Oligocene, Rupelian/Latdorfian).

Derivatio nominis — This species is named after Mrs J. la Faille of Alphen aan den Rijn.

Description — Shell sinistral, small (the largest specimen has a width of 2.95 mm), planorboid, discoidal, almost twice as wide as high. The largest specimens have 5 1/4 whorls. The first whorl has a slightly oblique position and therefore it seems to be somewhat wider than the second whorl (straight apical view). All further whorls increase slowly and very regularly, forming a distinctly concave apical plane.

The aperture is reniform, about twice as high as wide. The upper and lower junctions with the preceding whorl lie at the same distance from the shell's axis and therefore the umbilicus is just as wide and deep as the concave apical plane. Both the upper and lower part of the whorls are very slightly angular because of the presence of a weak carina, especially well visible on the body-whorl, making the shell somewhat rectangular in frontal or lateral view. On the base of the shell the position of the carina causes a gradual transition into the umbilicus. All preceding whorls, but for the initial one, are visible in the umbilicus. The aperture is simple, apparently without any reinforcements of the apertural margin. All available specimens, however, are filled with pyrite or preserved as pyritic moulds.

The suture is deep and distinct on both sides of the shell, as a result of the convexity of the upper and lower parts of the whorls. On only very few specimens traces of incremental lines are visible.

Material — **Oligocene, Rupelian/Latdorfian ('Rupel Formation' or unnamed unit):** The Netherlands, province of Groningen, borehole NAM Opende-1, depth 510-515 m-RT (1 specimen, coll. RGM 229 598); depth 515-520 m-RT (6 specimens, coll. RGM 229 599); depth 520- 525 m-RT (1 specimen, holotype, coll. RGM 229 600, Pl. 4, Fig. 1a-d; 3 specimens, coll. RGM 229 601); depth 525-530 m-RT (4 specimens, 2 defective specimens, coll. RGM 229 602); depth 534- 539 m (2 specimens, coll. RGM 229 603); depth 539-543 m-RT (2 specimens, coll. RGM 229 604); depth 553-558 m-RT (1 specimen, coll. RGM 229 605).

Do. (from samples interpreted as Eocene, downhole contamination): depth 567-571 m-RT (1 specimen, coll. RGM 229 606); depth 571-576 m-RT (2 specimens, coll. RGM 229 607); depth 576-580 m-RT (1 specimen, coll. RGM 229 608); depth 590-595 m-RT (1 specimen, 1 fragment, coll. RGM 229 609); depth 604-609 m-RT (1 specimen, coll. RGM 229 610); depth 609-614 m-RT (1 specimen, coll. RGM 229 611); depth 614-617 m-RT (1 specimen, coll. RGM 229 612); depth 617-627 m-RT (1 specimen, coll. RGM 229 613); depth 711-720 m-RT (1 specimen, coll. RGM 229 614) (all samples leg. M. van den Bosch).

Oligocene, Rupelian/Latdorfian (base of Viborg Clay): Denmark, Jylland, O/lst, FIBO clay-pit (1 specimen, Pl. 3, Fig. 3a-d, 10 specimens, coll. RGM 229 615-616, leg. O. B. Nielsen, don. K.I. Schnetler).

Eocene, Bartonian (Asse Clay Member, downhole contamination from Rupelian/Latdorfian deposits): The Netherlands, province of Drente, Ruinerwold, borehole De Wijk XML/NAM, depth 309-314 m-RT (1 specimen, Pl. 3, Fig. 2a-c, 3 specimens, coll. RGM 229 617- 618, leg. M. van den Bosch).

Eocene, Lutetian/Ypresian (downhole contamination from Rupelian/Latdorfian deposits): The Netherlands, province of Overijssel, borehole IJsselmuiden-1, depth 710.6-715 m (1 specimen, coll. RGM 229 619); depth 776-781 m (1 specimen, Pl. 3, Fig. 1a-e, coll. RGM 229 620) (all samples leg. P. A. M. Gaemers).

Discussion — *L. jessyae* may be distinguished from the accompanying *L. mariae* by its relatively flatter shell and much wider umbilicus, which is very similar to the concave apical plane in shape and width. In a transverse section the whorls are relatively higher, resulting in a less expanded aperture. The whorls increase relatively slowly in diameter and therefore the number of whorls at a given shell

Plate 3

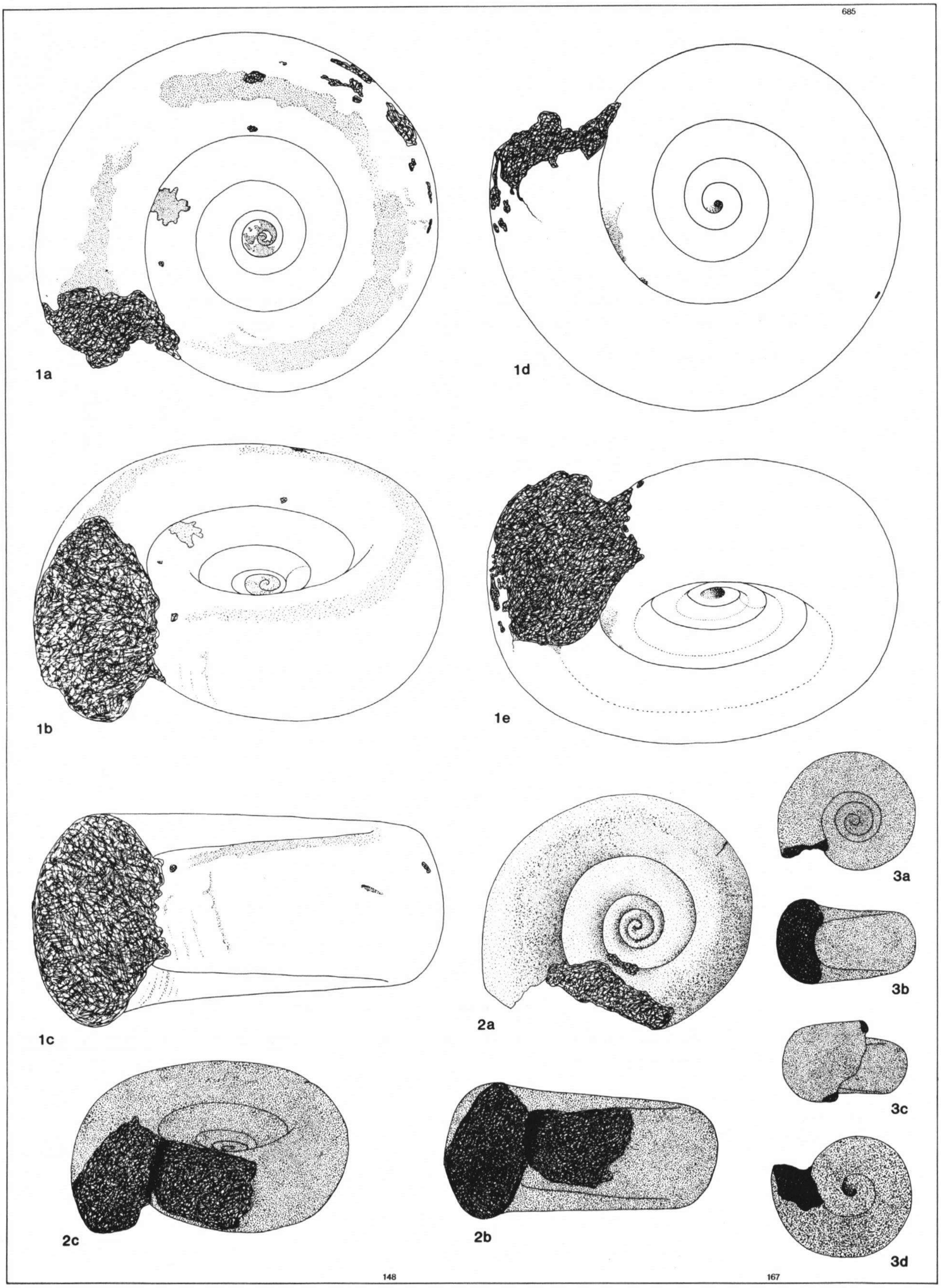
Limacina jessyae sp. nov., paratypes.

Fig. 1a-e. IJsselmuiden-1 (The Netherlands, province of Overijssel), borehole, depth 776-781 m. Eocene, Lutetian/Ypresian (downhole contamination from Rupelian/Latdorfian deposits). Leg. P. A. M. Gaemers, coll. RGM 229 620.
a: apical, b: oblique frontal, c: frontal, d: umbilical and e: oblique umbilical view.

Fig. 2a-c. Ruinerwold (The Netherlands, province of Drente), borehole De Wijk XML/NAM, depth 309-314 m-RT. Eocene, Bartonian (Asse Clay Member, downhole contamination from Rupelian/Latdorfian deposits). Leg. M. van den Bosch, coll. RGM 229 617.
a: apical, b: frontal and c: oblique frontal view.

Fig. 3a-d. Ølst (Denmark, Jylland), FIBO clay-pit. Oligocene, Latdorfian (base of Viborg Clay). Leg. O. B. Nielsen, don. K. I. Schnetler, coll. RGM 229 615.
a: apical, b: frontal, c: right lateral and d: umbilical view.

Magnification of all drawings × 25.


685
1a
1d
1b
1e
1c
2a
3a
3b
3c
3d
2c
2b
148
167

diameter is lower in *L. mariae* than in *L. jessyae*. In *L. mariae* the initial whorl has usually (but not always !) a straight position, whereas it is somewhat obliquely situated in *L. jessyae*, making the first whorl wider than the second one (straight apical view), causing also a slight irregularity in the gradual spiral of the suture.

Stratigraphical notes — At Ølst, Denmark, the present species was encountered co-occurring with *Limacina mariae* (not yet recognised in Janssen & King, 1988). The sample was collected from the base of the Viborg Clay Member, which according to Köthe (1988, p. 282) in the Aarhus-area belongs to nanno-zone NP 21 (NP 22 not entirely excluded, see his fig. 139) and therefore of Latdorfian age.

In the same sample from Ølst a single specimen of the pteropod *Praehyalocylis*, probably *P. cinctus* (von Koenen) was found, a species up to now also exclusively known from the Latdorfian. Both pteropod species *L. jessyae* and *L. mariae*, however, are absent in the well-known Latdorfian deposits in the Latdorf type area and in Belgium (Grimmertingen Sands). The Ølst sample yielded also some otoliths, which Dr P.A.M. Gaemers identified as *Ensigadus ensiformis* (Steurbaut & Herman) and *Palaeogadus compactus* Gaemers & van Hinsbergh. These two species are exclusively known from NP 22 and NP 23 sediments and do not occur in the Grimmertingen Sands. For these reasons it seems doubtful if the base of the Viborg Clay Member at Ølst indeed belongs to zone NP 21 (see also Gaemers, 1988, fig. 229).

Limacina jessyae was recorded in the Opende borehole from the interval 510-720 m-RT. The upper boundary of the Eocene Dongen Formation was established at 558 m-RT (Bor, 1985, fig. 3). The interval between 510 and 558 m-RT has to be indicated, according to the current lithostratigraphy for this part of The Netherlands, as 'Rupel Formation' (Nederlandse Aardolie Maatschappij & Rijks Geologische Dienst, 1980), but a closer inspection of the sediments might reveal possibilities for a more detailed lithostratigraphic interpretation.

In the sample 515-520 m-RT the species *Praehyalocylis ? cinctus* is present in two specimens. From 520 m-RT downward *L. jessyae* is accompanied by the species *L. mariae* (see below). The greater part of these specimens, however, must be considered to represent downhole contamination, which is a well-known feature in boreholes drilled with the straight flush method. Casing was placed to a depth of 506.70 m-RT, which is somewhat below the base of the Rupelian Boom Clay (determined on the basis of the lithology, especially the occurrence of calcareous matter, M. van den Bosch, pers. comm.). Therefore contamination from this unit or younger deposits can be excluded. Typical Boom Clay pteropods, such as *Limacina umbilicata* (Bornemann, 1855) or *Praehyalocylis maximus* (Ludwig, 1864) were not encountered in the available samples.

In the sample 534-539 m-RT the gastropod *Ectinochilus planus* (Beyrich, 1854) was found. The same species, together with the bivalve *Lentipecten corneus* (Sowerby, 1818), was present in the sample 553-558 m-RT. These observations indicate that Latdorfian sediments, equivalents of the Belgian Grimmertingen Sands, are present from at least this depth, but possibly already from about 515 m. Latdorfian deposits have also been recognised on the basis of bony fish otoliths (Dr P.A.M. Gaemers, pers. comm.). The first undoubtedly Lutetian pteropod is present in the sample 590- 595 m-RT, which agrees with the interpretation of the Eocene part of the Opende-1 section (Bor, 1985, p. 79, fig. 3).

In the interval from at least 506.70 to 534 m-RT sediments of Early Rupelian and Late Latdorfian age can be expected. In the Opende borehole this part of the sequence comprises exclusively heavy clays. In other, presumably more near-coastal sections, however, the same time interval is usually represented by more sandy deposits [*e.g.* the so-called Berg Sand Member and the Ratum Member (see Nederlandse Aardolie Maatschappij & Rijks Geologische Dienst, 1980, p. 51, fig. 13) in The Netherlands, and a variety of mainly sandy sediments in Belgium (Borgloon, Zelzate and Bilzen Formations, compare Maréchal & Laga, 1988)]. The age of this interval in the Opende borehole is indicated here as Rupelian/Latdorfian.

Considering the data given here the few specimens from the Ruinerwold and IJsselmuiden boreholes are considered to be of the same age as those from Opende.

Limacina mariae sp. nov.
Pl. 4, Figs 2-5

v. 1988 *Limacina mariae* sp. nov. —Janssen & King, p. 362, figs 188, 204 (nomen nudum) (partim, includes also *L. jessyae*).
v. 1988 *Limacina jessyae* sp. nov. —Janssen & King, p. 362, figs 188, 196 (nomen nudum) (partim, includes also *L. jessyae*).
v. 1988 *Limacina plana* —Janssen & King, p. 361, figs 188, 194 (partim, non Tembrock, only the specimens from Belgium).

Holotype — Pl. 4, Fig. 2a-c, coll. RGM 229 622.

Locus typicus — Borehole Opende-1 of the Nederlandse Aardolie Maatschappij B.V. (The Netherlands, province of Groningen), depth 525-530 m-RT.

Stratum typicum — 'Rupel Formation' or unnamed unit (Oligocene, Rupelian/Latdorfian).

Derivatio nominis — This species is named after Mrs M.I. van Vliet of Alphen aan den Rijn.

Description — Shell sinistral, very small (the largest specimen has a width of 2.6 mm), planorboid, about 1½ times wider than high. Large specimens may reach 4 3/4 whorls. The apical side of the shell is practically flat during the first whorls, but later whorls may rise above the earlier ones, thus forming a slightly concave or flat apical plane. The whorls increase rather rapidly in diameter.

The aperture is about 1½ times higher than wide. Its lower junction with the preceding whorl lies clearly more adaxially than the upper one. Therefore the umbilicus is much narrower than the concave apical plane. The transition of the base into the umbilicus is slightly carinated and therefore rather abrupt. In straight umbilical view the carina is situated on the inner half of the whorls, being more accentuated on the youngest whorls. In the umbilicus 2 or 3 of the preceding whorls are visible. The aperture is simple, apparently without any reinforcements of the apertural margin. All available specimens, however, are filled with pyrite or preserved as pyritic moulds.

The suture is moderately deep. The sutural spiral is usually completely regular, but in a few specimens the initial whorl has a somewhat oblique position, causing a slight irregularity in the gradual increase of width of the visible part of the whorls. Growth lines are indistinct. From the upper suture they run perpendicularly downwards, turning slightly forwards on the periphery and still more so in the umbilicus.

Material — **Oligocene, Rupelian/Latdorfian ('Rupel Formation'):** The Netherlands, province of Groningen, borehole NAM Opende-1, depth 520-525 m-RT (7 specimens, coll. RGM 229 621); depth 525- 530 m-RT (1 specimen, holotype, Pl. 4, Fig. 2a-c, 9 specimens, coll. RGM 229 622-623); depth 530-534 m-RT (7 specimens, coll. RGM 229 624); depth 534-539 m (8 specimens, 1 fragment, coll. RGM 229 625); depth 539-

543 m-RT (4 specimens, 2 defective specimens, coll. RGM 229 626); depth 543-548 m-RT (4 specimens, coll. RGM 229 627); depth 548-553 m-RT (4 specimens, 2 fragments, coll. RGM 229 628); depth 553-558 m-RT (3 specimens, coll. RGM 229 629) (all samples leg. M. van den Bosch).

Do. (from samples interpreted as Eocene, downhole contamination): depth 567-571 m-RT (6 specimens, coll. RGM 229 630); depth 571-576 m-RT (3 specimens, coll. RGM 229 631); depth 576-580 m-RT (5 specimens, coll. RGM 229 632); depth 580-585 m- RT (4 specimens, coll. RGM 229 633); depth 585-590 m-RT (4 specimens, coll. RGM 229 634); depth 590-595 m-RT (6 specimens, coll. RGM 229 635); depth 595-599 m-RT (5 specimens, coll. RGM 229 636); depth 599-604 m-RT (2 specimens, coll. RGM 229 637); depth 609-614 m-RT (2 specimens, coll. RGM 229 638); depth 614- 617 m-RT (2 specimen, coll. RGM 229 639); depth 627-637 m-RT (5 specimens, coll. RGM 229 640); depth 637-645 m-RT (1 specimen, coll. RGM 229 641); depth 669-674 m-RT (1 specimen, coll. RGM 229 642); depth 674-683 m-RT (1 specimen, coll. RGM 229 643); depth 683-692 m-RT (1 specimen, coll. RGM 229 644); depth 711-720 m-RT (1 specimen, coll. RGM 229 645); depth 748-757 m-RT (2 specimens, coll. RGM 229 646); depth 757-766 m-RT (1 specimen, coll. RGM 229 647); depth 766-776 m-RT (2 specimens, coll. RGM 229 648); depth 942-952 m-RT (1 specimen, coll. RGM 229 649).

Oligocene, Rupelian/Latdorfian (Zelzate Formation, Ruisbroek Sand Member): Belgium, province of Antwerpen, temporary outcrop in construction-pit for Rupel and Rupel Canal tunnel (3 specimens, Pl. 4, Figs 3a-c, 4a-b, 5a-c, 45 specimens, coll. RGM 229 652-655, leg. A.W.Janssen).

Oligocene, Rupelian/Latdorfian (base of Viborg Clay): Denmark, Jylland, Ølst, FIBO clay-pit (27 specimens, coll. RGM 229 650, leg. O.B. Nielsen, don. K.I. Schnetler).

Eocene, Bartonian (downhole contamination from Rupelian/Latdorfian deposits): The Netherlands, province of Overijssel, borehole IJsselmuiden-1, depth 657.8-662.5 m (2 specimens, coll. RGM 229 651, leg. P.A.M. Gaemers).

Discussion — This species differs from the accompanying *L. jessyae* by its relatively higher shell form and by its apical plane being flat or only slightly concave when adult. The more downwards produced

Plate 4

Limacina jessyae sp. nov., holotype.

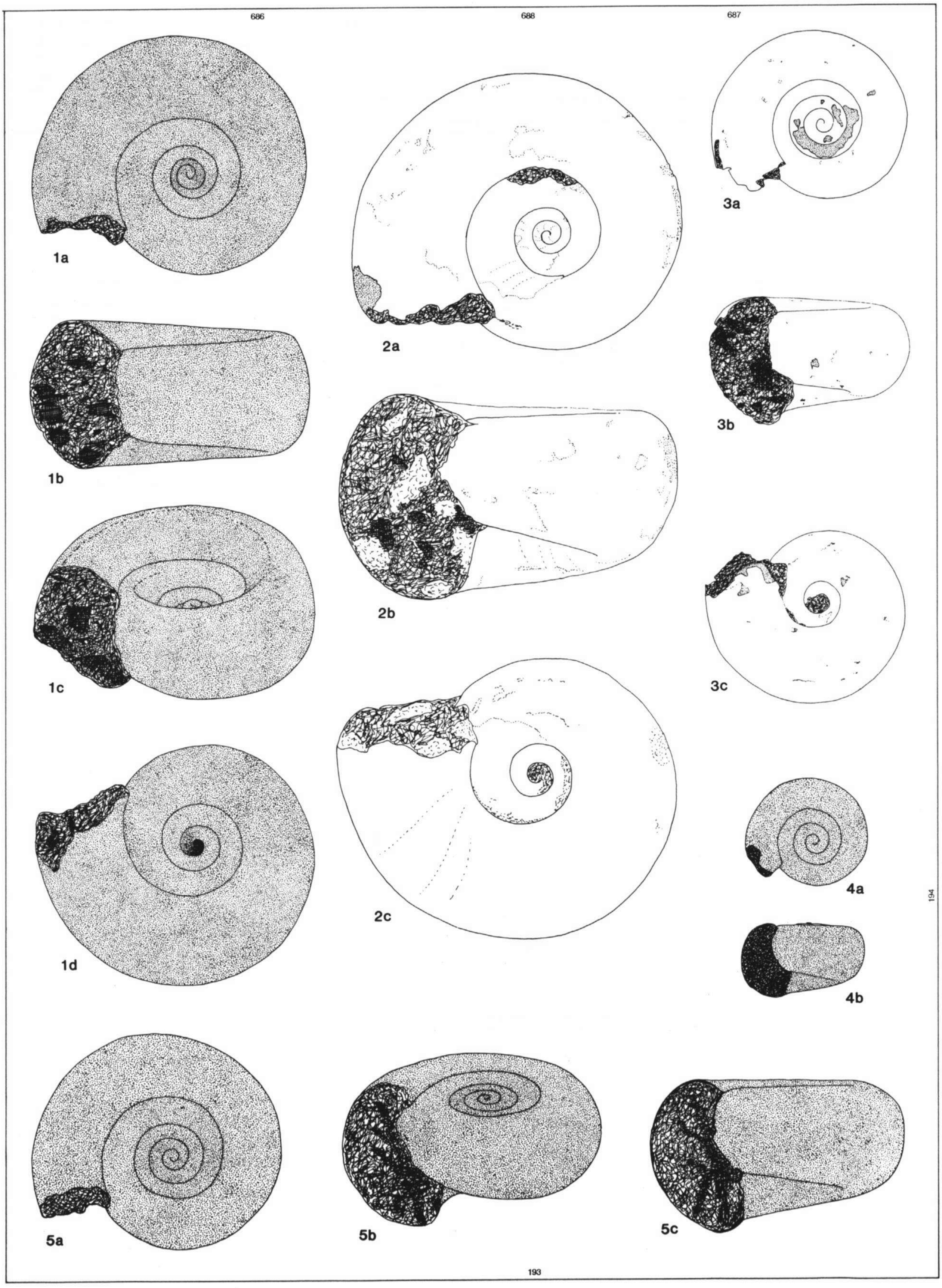
Fig. 1a-d. Opende (The Netherlands, province of Groningen), borehole NAM Opende-1, depth 520-525 m-RT. Oligocene, Rupelian/Latdorfian ('Rupel Formation'). Leg. M. van den Bosch, coll. RGM 229 600.
a: apical, b: frontal, c: oblique frontal and d: umbilical view.

L. mariae sp. nov., holo- and paratypes.

Fig. 2a-c. Holotype. Opende (The Netherlands, province of Groningen), borehole NAM Opende-1, depth 525-530 m-RT. Oligocene, Rupelian/Latdorfian ('Rupel Formation'). Leg. M. van den Bosch, coll. RGM 229 622.
a: apical, b: frontal and c: umbilical view.

Figs 3a-c, 4a-b, 5a-c. Ruisbroek (Belgium, province of Antwerpen), temporary outcrop in construction-pit for Rupel and Rupel Canal tunnel. Oligocene, Rupelian/Latdorfian (Zelzate Formation, Ruisbroek Sand Member). Leg. A.W. Janssen, coll. RGM 229 652-655.
3a, 4a, 5a: apical views; 3b, 4b, 5c: frontal views; 3c: umbilical view, 5b: oblique frontal view.

Magnification of all drawings × 25.


686
688
687
1a
2a
3a
1b
3b
2b
1c
3c
2c
1d
4a
194
4b
5a
5b
5c
193

whorls and the more adaxial position of the weak carina on the basal part of the whorls make the umbilicus in *L. mariae* narrower and steeper than in *L. jessyae*. The whorls also increase more rapidly in diameter: at an identical shell width the number of whorls is higher in *L. jessyae*. Usually the initial whorl of the shell has no oblique position, making the spiral of the apical suture completely regular.

The specimens from Ruisbroek (Belgium) initially were identified as *Limacina plana* (Tembrock), but additional material has clearly demonstrated that this latter species differs by its much smaller dimensions and the reinforced apertural margin.

Stratigraphical notes — The reader is referred to the discussion following the description of *L. jessyae* (above) for some important notes on the stratigraphical interpretation of the Opende and IJsselmuiden borehole sections. In the Opende-1 borehole the highest record of *L. mariae* (520 m-RT) was observed ten metres below that of the distinctly less common species *L. jessyae* (510 m-RT). This might indicate that the material of these species does not originate from the same level. Still, the sample from Ølst, Denmark, indicates that they do co-occur (in nanno-zone NP 21 or NP 22, see above).

At Ruisbroek, Belgium, *Limacina mariae* was the only pteropod species found in the so-called Ruisbroek Sand Member. This unit, belonging to zone NP 22 (at least the part from which the pteropods were collected), is considered to be an equivalent of the Oude Biesen Sand and Marl Member (Gaemers, 1984; Steurbaut, 1986). Its age was indicated as 'Tongrien supérieur' by Glibert & de Heinzelin (*in*: Denizot, 1957), but up to now it has not yet been decided whether this unit should be included in the Rupelian or in the Latdorfian. Therefore the age of the material from Ruisbroek is indicated here as Rupelian/Latdorfian.

Berggren *et al.* (1985, fig. 5) abandoned the Latdorfian concept and included both the greater part of NP 21 and NP 22 in the Rupelian, together with, as usual, NP 23). Dropping the Latdorfian, however, as a stage does not seem to be advisable for the North Sea Basin. Definitions for the Latdorfian/Rupelian boundary are urgently needed.

Limacina wilhelminae sp. nov.
Pl. 5, Figs 1-6; Pl. 6, Fig. 1-2

v. 1958 *Spiratella atlanta* (Mørch) — Sorgenfrei, p. 352 (non Mørch) (partim, includes also *Limacina miorostralis*).
v. 1966 *Spiratella atlanta* (Mørch) — Rasmussen, pp. 231-235, 238-240, 242, 244, 249, 252, 259, 266, 267, 276, 278-280 (non Mørch) (partim, includes also *Limacina atlanta, L. ingridae* and *L. irisae*).
v. 1968 *Spiratella atlanta* (Mørch) — Rasmussen, p. 243 (non Mørch) (partim, includes also *Limacina atlanta, L. ingridae* and *L. irisae*) (non pl. 27, figs 8-10 = *Limacina atlanta*).
v. 1972a *Spiratella atlanta* (Morch) — Hinsch, pp. 39, 40 (non Mørch) (partim, includes also *Limacina ingridae*).
v. 1972b *Spiratella atlanta* (Mørch) — Hinsch, p. 69 (non Mørch) (partim, includes also *Limacina ingridae*).
v. 1979 *Spiratella atlanta* (Mørch) — Hinsch, p. 42 (non Mørch) (partim, includes also *Limacina ingridae* and *L. irisae*).
v. 1983 *Spiratella* sp. — Hinsch, p. 16.
v. 1986 *Spiratella wilhelminae* — Hinsch, p. 369, tab. 5b (nomen nudum)(partim, includes also *Limacina atlanta* and *L. ingridae*).
v. 1987 *Limacina* sp. — Hinsch, p. 130, tab. 2, p. 131, fig. 2 (partim, includes also *Limacina ingridae, L. irisae* and *L. valvatina*).

v. 1988 *Limacina ingridae* sp. nov. — Janssen & King, fig. 188 (nomen nudum).

non:

v. 1988 *Limacina wilhelminae* — Janssen & King, pp. 366, 367 (= *Limacina ingridae*).

Holotype — Pl. 5, Fig. 1a-d, RGM 229 658.

Locus typicus — Borehole Hindorf Br. III (F.R.G., Schleswig-Holstein), depth 133-134 m.

Stratum typicum — Eideltstedt Formation (Miocene, Langenfeldian).

Derivatio nominis — This species is named after Mrs W.M. Meeus of Alphen aan den Rijn.

Description — This species strongly resembles *Limacina ingridae* sp. nov., as described above. Size and general shell form are entirely similar, but *L. wilhelminae* differs distinctly by the form of the suture spiral. The visible part of the first whorl (or the first 1½ whorls) is always wider than the subsequent one or two and these are also narrower than the next whorls. The result is that the sutural spiral starts widely, then becomes narrower and ends widely again. The transitions between these different parts of the spiral are gradual. They originate in changes in the position of the junction between the upper part of the whorl and the preceding one. The visible part of the preceding whorl becomes increasingly narrower, when the whorl is more highly attached.

A further small difference with *L. ingridae* is to be found in the form of the apical plane. In *L. wilhelminae* the first whorl is frequently a little elevated, forming a depressed cone on the apical plane. The youngest whorls may or may not rise above this central cone (frontal view). In *L. ingridae* the initial whorl is conical only in specimens with a concave apical plane.

Material — **Miocene, Hemmoorian (Arnum Formation) (downhole contamination from overlying Late Miocene sediments):** Denmark, Jylland, borehole Arnum DGU 150.25b, depth 104.3-107.5 m (1 specimen, coll. DGU, mentioned in Sorgenfrei, 1958, p. 352 sub nomine *Spiratella atlanta*).

Miocene, Reinbekian (Hodde Clay) (downhole contamination from overlying Langenfeldian or Gramian deposits): Denmark, Jylland, borehole Lillelund DGU 73.88, depth 62-69.5 m (? 1 specimen, strongly disintegrated, coll. DGU, from sample mentioned in Rasmussen, 1966, p. 27).

Miocene, Reinbekian (Hodde Formation) (downhole contamination from the Langenfeldian Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Schachtholm, depth 88-92 m (1 specimen, coll. GLSH, mentioned in Hinsch, 1983, p. 16 sub nomine *Spiratella* sp.).

Miocene, Langenfeldian, Lüneburgian (Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Kiel-Levensau Nord 3, depth 76-77 m (1 specimen, Pl. 5, Fig. 6a-c, coll. GLSH, mentioned in Hinsch, 1987, pp. 130, 131 sub nomine *Limacina* sp.).

Miocene, Langenfeldian s.str. (Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Kiel-Levensau Süd 2, depth 45.1-45.5 m (1 specimen, coll. GLSH, mentioned in Hinsch, 1987, p. 130, tab 2 sub nomine *Limacina* sp.).

Do.: do., Hamburg Area, borehole Hamburg-Eidelstedt (Nordgetränke), depth 215-216 m (1 specimen); depth 214-215 m (2 specimens) (coll. GLSH, specimens mentioned in Hinsch, 1986, p. 369, tab. 5b), depth 201-202 m (1 specimen, coll. RGM 229 656, don. GLSH).

Miocene, Langenfeldian s.lat. (Gram Clay): Denmark, Jylland, borehole Gram DGU 141.277, depth 20-20.50 m (1 specimen); depth 19-19.50 m (3 specimens, transitional forms *L. ingridae/wilhelminae*); depth 18.50-19 m (8 specimens); depth 18-18.50 (4 specimens); depth 17.50-18 m 36 specimens); depth 17-17.50 m (68 specimens); depth 16.50-17 m (35 specimens) (coll. DGU, mentioned in Rasmussen, 1966, p. 276 and 1968, p. 243 sub nomine *Spiratella atlanta*).

Do.: do., borehole Tvaermose DGU 85.381, depth 21-25 m, 1 specimen, coll. DGU, mentioned in Rasmussen, 1966, p. 238 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Miocene, Langenfeldian s.lat. (Eidelstedt Formation): F.R.G., Schleswig-Holstein, borehole Bargfeld, depth 195-201 m (1 specimen, don. GLSH, coll. RGM 229 657; mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Do.: do., borehole Flensburg (Mühlenstrasse), depth 114-125 m (1 specimen, coll. GLSH, mentioned in Hinsch, 1972b, p. 69 sub nomine *Spiratella atlanta*).

Do.: do., borehole Flensburg (Fuchskuhle) S 1, depth 141-142 m (1 specimen, Pl. 5, Fig. 5a-d, coll. GLSH, mentioned in Hinsch, 1972b, p. 69 sub nomine *Spiratella atlanta*).

Do.: do., borehole Hindorf Br. III, depth 133-134 m, (1 specimen, holotype, Pl. 5, Fig. 1a-d, coll. RGM 229 658; 1 specimen, Pl. 5, Figs 2a-d, coll. RGM 229 659; 12 specimens, coll. RGM 229 661; all samples don. GLSH).

Do.: do., borehole Ladelund, depth 105-108 m (1 specimen, don. GLSH, coll. RGM 229 662).

Do.: do., borehole Langenklint, depth 59.2 m (1 juvenile specimen, coll. GLSH, not mentioned in Hinsch, 1972a, p. 40); depth 56 m (7 specimens, don. GLSH, coll. RGM 229 663); depth 51.8 m (12 specimens) (don. GLSH, coll. RGM 229 664, mentioned in Hinsch, 1972a, pp. 39, 40 sub nomine *Spiratella atlanta*).

Do.: do., Lower Saxony, borehole Wursterheide, depth 218.5- 219 m (1 specimen, transitional form to *L. atlanta*, don GLSH, coll. RGM 229 665).

Miocene, ? Langenfeldian (Gram Clay): Denmark, Jylland, borehole Gjødstrup DGU 85.861, depth 57 m (1 specimen, coll. DGU, mentioned in Rasmussen, 1966, p. 239 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Kodal-Fjaldene DGU 84.1749, depth 22.55-23.55 m (2 specimens); depth 20.55-21.55 m (5 specimens; 6 specimens, transitional forms to *Limacina atlanta*); depth 19.55-20.55 m (8 specimens, transitional forms to *Limacina atlanta*) (coll. DGU, mentioned in Rasmussen, 1966, p. 233 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Plate 5

Limacina wilhelminae sp. nov., holo- and paratypes.

Fig. 1a-d. Holotype. Hindorf (F.R.G., Schleswig-Holstein), borehole III, depth 133-134 m. Miocene, Langenfeldian, Eidelstedt Formation. Leg. GLSH, coll. RGM 229 658.
a: apical, b: frontal, c: oblique frontal, and d: umbilical view.

Fig. 2a-d Locality data as in Fig. 1. Coll. RGM 229 659.
2a: apical, 2b: frontal, 2c: oblique frontal, 2d: umbilical view.

Fig. 4a-b. Hesselho (Denmark, Jylland), borehole DGU 113.121, depth 50-56 m. Miocene, Gramian, Gram Clay. Coll. DGU.
a: apical, and b: frontal view.

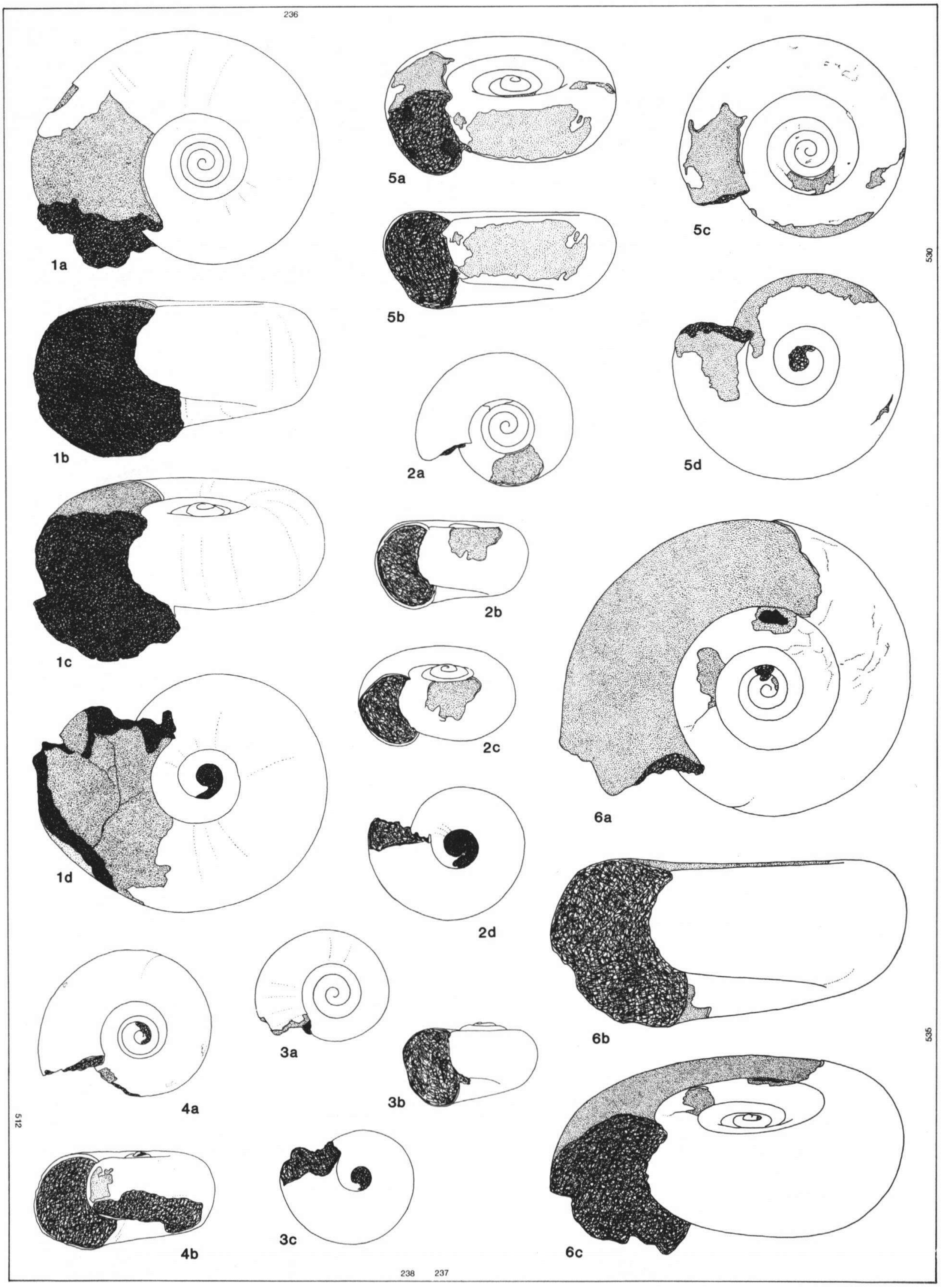
Fig. 5a-d. Flensburg-Fuchskuhle (F.R.G., Schleswig-Holstein), borehole S 1, depth 141-142 m. Miocene, Langenfeldian, Eidelstedt Formation. Coll. GLSH.
a: oblique frontal, b: frontal, c:apical, and d: umbilical view.

Fig. 6a-c. Kiel-Levensau (F.R.G., Schleswig-Holstein), borehole Nord 3, depth 76-77 m. Miocene, Langenfeldian, Lüneburgian, Eidelstedt Formation. Coll. GLSH.
a: apical, b: frontal, and c: oblique frontal view.

Limacina ingridae sp. nov., paratype

Fig. 3a-c. Locality data as in Fig. 1. Coll. RGM 229 660. a: apical, b: frontal, c: umbilical view.

Magnification of all drawings × 25.


236
1a
5a
5b
5c
530
1b
2a
5d
1c
2b
2c
6a
1d
2d
6b
535
3a
4a
3b
512
3c
4b
6c
238
237

Do.: do., borehole Videbaek DGU 84.1748, depth 23.95-24.95 m (4 specimens; 2 specimens, transitional forms to *Limacina atlanta*); depth 22.95-23.95 m (5 specimens, transitional forms to *Limacina atlanta*) (coll. DGU, mentioned in Rasmussen, 1966, p. 234 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Miocene, Langenfeldian/Gramian (Gram Clay): Denmark, Jylland, borehole Odderup DGU 103.150, depth 20-21 m (2 defective specimens; 7 specimens, transitional forms to *Limacina atlanta*) (coll. DGU, mentioned in Rasmussen, 1966, p. 249 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Videbaek DGU 84.441, depth 1.90-11 m (1 specimen, coll. DGU, not mentioned in Rasmussen, 1966, 1968).

Miocene, ? Gramian (? Gram Formation): F.R.G., Schleswig-Holstein, borehole Bargfeld, depth 150-156 m (1 specimen, don. GLSH, coll. RGM 229 666, mentioned in Hinsch, 1979, p. 42 sub nomine *Spiratella atlanta*).

Miocene, Gramian (Gram Clay): Denmark, Jylland, clay-pit of Brande Teglvaerk (1 specimen, transitional form to *Limacina atlanta*, coll. DGU, mentioned in Rasmussen, 1966, p. 242 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Brejning Kro DGU 83.197, depth 40.50 m (1 specimen, transitional form to *Limacina atlanta*, coll. DGU, mentioned in Rasmussen, 1966, p. 231 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Brodersmark DGU 166.351b, depth 22.6-24 m (5 specimens; 9 specimens, transitional forms to *Limacina atlanta*) (coll. DGU, mentioned in Rasmussen, 1966, p. 280 and 1968, p. 244 sub nomine *Spiratella atlanta*) (considering the species distribution in the lower samples of this borehole the sample 22.6-24 m is likely to be either incorrectly labelled or mixed up with another sample from a lower part of the Gram Clay !).

Do.: do., borehole Drantum DGU 104.1241, depth 51.4-51.8 m (1 specimen, transitional form to *Limacina atlanta*, coll. DGU, mentioned in Rasmussen, 1966, p. 244 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Frølund DGU 85.383, depth 9.2-17.9 m (2 specimens; 5 specimens, transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 238 and 1968 p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Gjødstrup DGU 85.861, depth 55 m (1 specimen, transitional form to *Limacina atlanta*); depth 54 m (4 specimens, transitional forms to *Limacina atlanta*); depth 53 m (2 specimens, transitional forms to *Limacina atlanta*) (coll. DGU, mentioned in Rasmussen, 1966, p. 239 and 1968, p. 244 sub nomine *Spiratella atlanta*).

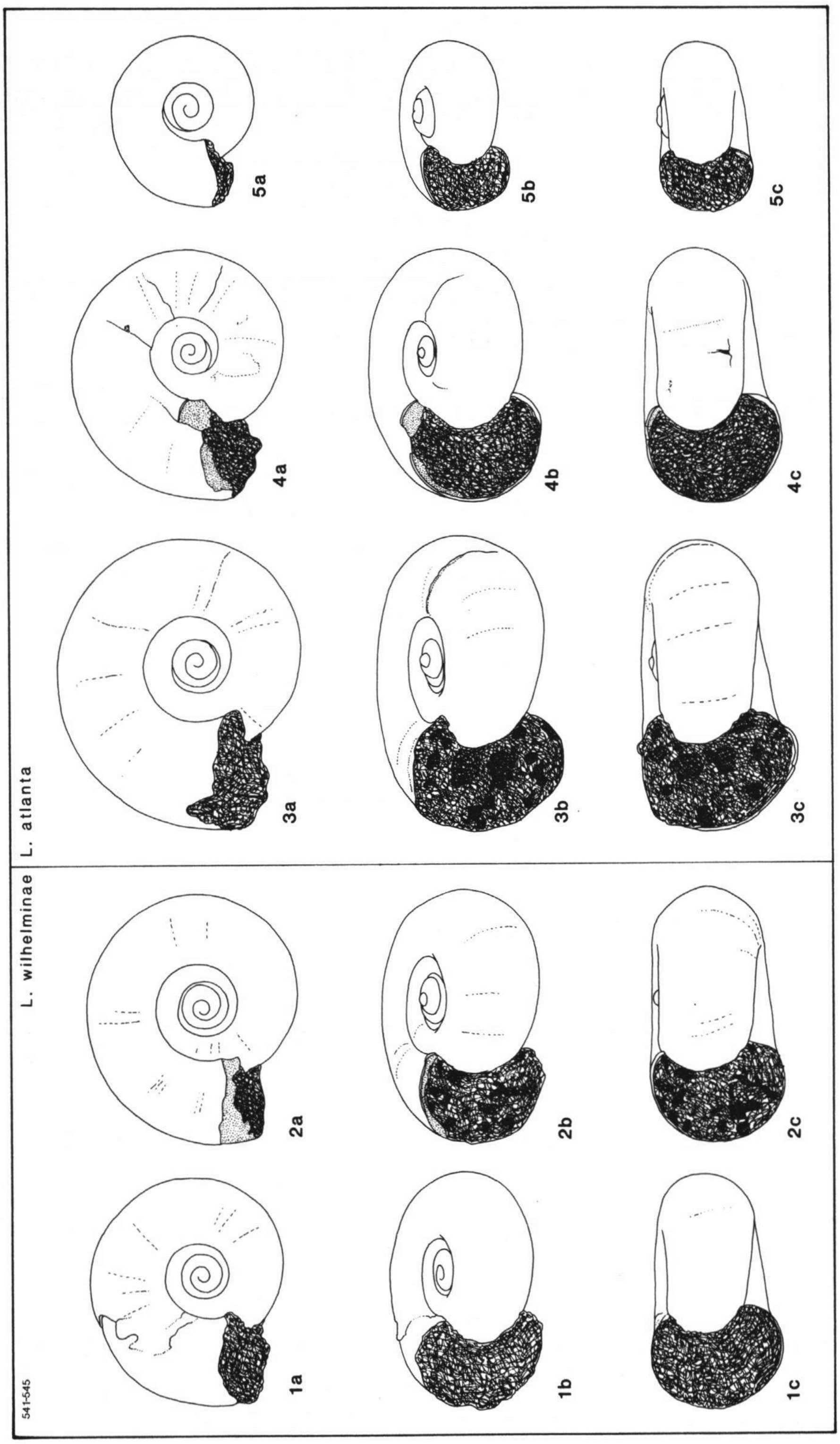
Do.: do., borehole Gram DGU 141.277, depth 16-16.50 m (23 specimens; 27 specimens, transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 276 sub nomine *Spiratella atlanta*). Note: during my visit to the DGU in 1987 I did not consider the possibility that *L. wilhelminae* might also occur

Plate 6

Transition from *Limacina wilhelminae* to *L. atlanta* (Mørch, 1874).

Fig. 1a-c. *Limacina wilhelminae* sp. nov., typical form (regular sutural spiral). Coll. RGM 229 669.
Fig. 2a-c. *Limacina wilhelminae* sp. nov., transitional form to *L. atlanta* (irregular sutural spiral, but all whorls visible). Coll. RGM 229 670.
Fig. 3a-c, 4a-c, 5a-c. *Limacina atlanta* (3: less than half a whorl invisible; 4-5: more than half a whorl invisible). Coll. RGM 229 671-673.
1-5a: apical view, 1-5b: oblique frontal, and 1-5c: frontal views

All specimens from one and the same piece of 'Flensburger Gestein' (boulder F), Hüllerup near Flensburg (F.R.G., Schleswig-Holstein), leg. H. Tüxen, don. F. Weinbrecht. Magnification of all drawings × 25.


541-545
L. wilhelminae
L. atlanta
1a
1b
1c
2a
2b
2c
3a
3b
3c
4a
4b
4c
5a
5b
5c

above the Langenfeldian/Gramian boundary, situated in the Gram borehole at approximately 16 m; therefore it still has to be checked if the samples from the higher part of this section also include some specimens of that species, in addition to *L. atlanta*.

Do.: do., borehole Hesselho DGU 113.121, depth 56-65 m (2 specimens); depth 50-56 m (1 specimen, Pl. 5, Fig. 4a-b) (coll. DGU, mentioned in Rasmussen, 1966, p. 252 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Kodal-Fjaldene DGU 84.1749, depth 15.55-16.55 m (2 specimens, transitional forms to *Limacina atlanta*); coll. DGU, mentioned in Rasmussen, 1966, p. 233 and 1968, p. 244 sub nomine *Spiratella atlanta*.

Do.: do., borehole Lille Torup DGU 85.379, depth 16.8-20 m (7 specimens, including some transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 238 and 1968 p. 244 sub nomine *Spiratella atlanta*).

Do.: do., Maade Teglvaerk, eastern clay-pit (2 specimens, coll. RGM 229 667, leg. L.B. Rasmussen, don. G. Spaink); do., 'new digging zone' (1962, "sample of clay") (6 specimens, transitional forms to *Limacina atlanta*; 7 further, very small specimens are too small to allow a sound distinction between *Limacina wilhelminae* and *L. atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 259 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Mjuldberg DGU 83.1006, depth 8-9 m (1 specimen, transitional form to *Limacina atlanta*); depth 6-7 m (1 specimen, transitional form to *Limacina atlanta*); depth 5-6 m (1 specimen) (coll. DGU, all samples mentioned in Rasmussen, 1966, p. 232 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Rødding DGU 141.75, depth 16.75-25.60 m (2 specimens, transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 267 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Rødding DGU 141.76, depth 37.15-42.40 m (2 specimens, transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 267 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Snejbjerg DGU 85.775, depth 29.35-30.25 m (1 specimen, coll. DGU, mentioned in Rasmussen, 1966, p. 240 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Sønder Hygum DGU 141.260, depth 12-40 m (5 specimens, transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 266 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Sønder Hygum DGU 141.261, depth 13-19 m (3 specimens, transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 266 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Spandet DGU 150.184, depth 33-37.1 m (5 specimens; 4 specimens, transitional forms to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 278 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Spjald DGU 83.127, depth 2.60-15 m (1 specimen, transitional form to *Limacina atlanta*; coll. DGU, mentioned in Rasmussen, 1966, p. 231 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Tønder DGU 166.398, depth 58.85-59 m (12 specimens; 11 specimens, transitional forms to *Limacina atlanta*; coll. DGU, samples mentioned in Rasmussen, 1966, p. 279 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Do.: do., borehole Videbaek DGU 84.358, depth 7.20-15.10 m (2 specimens, coll. DGU, mentioned in Rasmussen, 1966, p. 235 and 1968, p. 244 sub nomine *Spiratella atlanta*).

Age unknown (material from boulders, or reworked): F.R.G., Schleswig-Holstein, Hüllerup near Flensburg, gravel-pit Lorenzen, „Flensburger Gestein", leg. H. Tüxen, boulder A (9 specimens, transitional forms to *Limacina atlanta*, coll. F. Weinbrecht); boulder B (3 specimens, including transitional forms to *L. atlanta*, coll. F. Weinbrecht); boulder C (25 specimens, including some transitional forms to *L. atlanta*, coll. F. Weinbrecht; 17 specimens, coll. RGM 229 668); boulder D (9 specimens, transitional forms to *L. atlanta*, coll. F. Weinbrecht); boulder F (13 specimens, including transitional forms to *L. atlanta*, coll. F. Weinbrecht; 2 specimens, Pl. 6, Figs 1-2, coll. RGM 229 669- 670); boulder U (4 specimens, coll. F. Weinbrecht); boulder V (8 specimens, including transitional forms to *L. atlanta*, coll. F. Weinbrecht); boulder W (11 specimens, including some transitional forms to *L. atlanta*, coll. F. Weinbrecht); boulder X (7 specimens, transitional forms to *L. atlanta*, coll. F. Weinbrecht); composite sample Z (219 specimens, including transitional forms to *L. atlanta*, coll. F. Weinbrecht), boulder Z1 (23 specimens, including transitional forms to *L. atlanta*, coll. F. Weinbrecht), boulder Z2 (17 specimens, including transitional forms to *L. atlanta*, coll. F. Weinbrecht).

Note — The ,,Flensburger Gestein'' yields a typical Gramian mollusc fauna. This age assignment is confirmed by the bony fish otoliths (Dr P.A.M. Gaemers, pers. comm.). In the boulders Z1 and Z2 the bivalve *Astarte gleuei* Wollemann is present, which species was up to now considered to be restricted to faunas of Langenfeldian age).

Discussion — Specimens in which the point of attachment skips one whorl and attaches one whorl higher are easily recognised by the fact that in straight apical view part of a whorl seems to be missing because it is hidden below the next whorl. Such specimens are typical *Limacina atlanta* (Mørch). Transitional forms between *L. wilhelminae* and *L. atlanta* are common in the Langenfeldian and early Gramian. Specimens in which the spire is completely visible in straight apical view already are considered to be *L. wilhelminae*; they are indicated as 'transitional forms to *L. atlanta*', if a part of the spire, usually about half a whorl, tends to disappear below the next whorl. Specimens in which only a small part of a whorl is hidden in straight apical view are considered to belong to *L. atlanta*. The transition between *L. wilhelminae* and *L. atlanta* is illustrated on Pl. 6.

Transitional forms are also known between *Limacina ingridae* and *L. wilhelminae*. In *L. ingridae* the visible part of the whorls increases regularly in width towards the aperture, whereas in *L. wilhelminae* one or more of the middle whorls are comparatively narrow.

It is concluded that the species *L. ingridae, L. wilhelminae* and *L. atlanta* form together an evolutionary lineage, developing during the Langenfeldian. Apparently *L. irisae* is a further offshoot of this complex; it may have developed either directly from *L. ingridae*, or from *L. wilhelminae*. Its main characteristic is the elevated apex, combined with distinctly concave tangents of the spire. Especially in apical view it may closely resemble *L. wilhelminae*. *L. ingridae* and *L. irisae* are restricted to Langenfeldian sediments, whereas *L. wilhelminae* occurs during the Langenfeldian and the (early ?) Gramian; the youngest stage of the lineage, *L. atlanta*, is known to almost reach the upper boundary of the Pliocene. It is also the only species of this complex known to occur outside the North Sea Basin (Late Miocene and Pliocene of northern Italy and SE France, RGM collection).

Familia Cavoliniidae
Subfamilia Creseinae
Genus *Creseis* Rang, 1828

'Creseis' berthae sp. nov.
Pl. 7, Figs 1-7

. 1940 *'Tentaculites' maximus* Ludw. — Staesche & Hiltermann, p. 21, pl. 51, fig. 11-14 (non Ludwig).
v. 1969 *Tentaculites maximus* Ludwig — Boekschoten, p. 45, pl. 3, fig. 6 (non Ludwig).
v. 1988 *''Creseis'' berthae* sp. nov. — Janssen & King, p. 362, 363, figs 188, 195, 197 (nomen nudum).

Holotype — Pl. 7, Fig. 1, coll. RGM 229 675.

Locus typicus — Mol (Belgium, province of Antwerpen), shaft for Study Centre of Nuclear Energy, depth 216-217 m below surface.

Stratum typicum — Boom Clay Formation, upper part of Putte Clay Member (Oligocene, Rupelian).

Derivatio nominis — This species is named after Mrs B.P.H. Mellema at Alphen aan den Rijn.

Description — Very small, slender and completely straight, tube-shaped shells, very slowly increasing in diameter. The transverse section is circular. The outer surface is covered with numerous, rather prominent and regular annulations, which become weaker to almost absent on the shell parts with the smallest diameter. The interspaces of the annulations are somewhat wider than the annulations themselves and are relatively wider in juvenile shells. In the available material no specimens with embryonal shell parts were found.

Material — **Oligocene, Rupelian (Tonmergelstufe):** F.R.G., Schleswig-Holstein, borehole Vaale (see Boekschoten, 1969, p. 6), depth 284-285 m (1 specimen, illustrated in Boekschoten, 1969, pl. 3, fig. 6, coll. RGM 229 674, don. G.J. Boekschoten).

Oligocene, Rupelian (Boom Clay Formation, Putte Clay Member, upper part): Belgium, province of Antwerpen, shaft for Study Centre of Nuclear Energy, depth 216-217 m (sample A) (1 specimen, holotype, Pl. 7, Fig. 1, coll. RGM 229 675; 2 specimens, Pl. 7, Figs 2-3, coll. RGM 229 676-677; 4 specimens, coll. RGM 229 678).

Do.: do. (sample B) (1 specimen, Pl. 7, Fig. 4, coll. RGM 229 679; 7 specimens, coll. RGM 229 680); all samples leg./don. P.A.M. Gaemers.

Oligocene, Rupelian (Brinkheurne Formation, upper part of Woold Clay Member): The Netherlands, province of Gelderland, Winterswijk, borehole 41E.3-230, depth 63.19-64.23 m (1 specimen, Pl. 7, Fig. 5, leg. M. van den Bosch, coll. RGM 229 681).

Plate 7

'Creseis' berthae sp. nov., holo- and paratypes.

Fig. 1. Holotype. Mol (Belgium, province of Antwerpen), shaft for Study Centre of Nuclear Energy, depth 216-217 m (sample A). Oligocene, Rupelian, Boom Clay Formation, Putte Clay Member. Leg/don. P.A.M. Gaemers, coll. RGM 229 675, × 25.

Figs 2-3. Same locality data. Coll. RGM 229 676-677, × 25.

Fig. 4. Same locality data (sample B). Coll. RGM 229.678, × 25.

Fig. 5. Winterswijk (The Netherlands, province of Gelderland), borehole 41E.3-230, depth 63.19-64.23 m. Oligocene, Rupelian, Brinkheurne Formation, upper part of Woold Clay Member. Leg. M. van den Bosch, coll. RGM 229.681, × 25.

Figs 6-7. Winterswijk (The Netherlands, province of Gelderland), clay-pit complex 'De Vlijt'. Oligocene, Rupelian, Brinkheurne Formation, upper part of Woold Clay Member. Leg. A.W. Janssen, coll. RGM 229 686-687, × 25.

Clio blinkae sp. nov., holo- and paratypes.

Fig. 8a-c. Holotype. Schelle (Belgium (province of Antwerpen), Damman clay-pit. Oligocene, Rupelian, Boom Clay Formation, Waasland Clay Member, base of Bed no. 21 (Vandenberghe, 1978), leg. A.W. Janssen, 1976, coll. RGM 220 828, × 6.
a: ventral, b: right lateral and c: dorsal view.

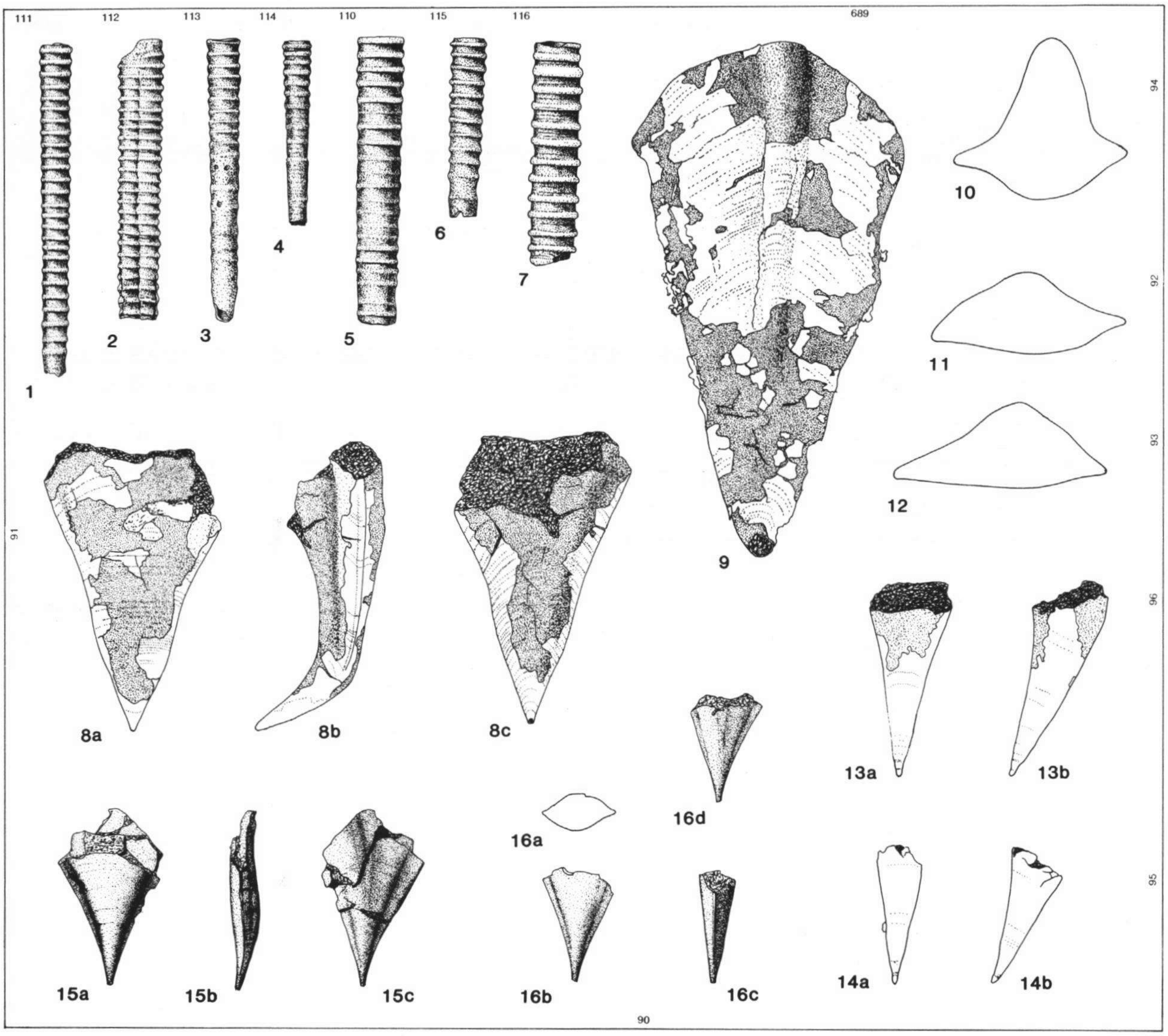


Fig. 9. Kruibeke (Belgium, province of Antwerpen), Gralex clay-pit, Rupelian, Boom Clay Formation, Waasland Clay Member, base of Bed no. 21 (Vandenberghe, 1978), leg. A.W. Janssen, 1988, coll. RGM 229 713 (on slab of clay), x 5.

Figs 10-12. Transverse sections of various specimens. Locality data as in Fig. 8. Coll. RGM 229 693-695, x 6.

Figs 13a-b, 14a-b. Juvenile specimens. Locality data as in Fig. 1. Coll. RGM 220 827 (Fig. 13) and 229 696 (Fig. 14).
a: ventral, and b: right lateral view, x 12½.

Clio jacobae sp. nov., holo- and paratype.

Fig. 15a-c. Holotype. Ruinerwold (The Netherlands, province of Drente), borehole De Wijk XML/NAM, depth 242.5-250 m-RT. Oligocene, Rupelian, Rupel Formation. Leg. M. van den Bosch, coll. RGM 229 720, x 6.
a: ventral, b: left lateral, and c: dorsal view.

Fig. 16a-d. Same locality data. Coll. RGM 229 719, x 6.
a: apertural, b: ventral, c:left lateral, and d:dorsal view.

Do.: do., borehole 41E.3-291, depth 7.00-8.00 m (1 specimen, coll. RGM 229 682), depth 8.00-9.00 m (2 specimens, coll. RGM 229 683), depth 9.00-10.00 m (1 specimen, coll. RGM 229 684), depth 10.00-11.00 m (1 specimen, coll. RGM 229 685) (all samples leg. M. van den Bosch).

Do.: do., clay-pit complex 'De Vlijt' (2 specimens, Pl. 7, Figs 6-7, coll. RGM 229 686-687 resp.; 2 specimens, coll. RGM 229 688; leg. A.W. Janssen).

Oligocene, Rupelian (basal bed of Winterswijk Member, but probably reworked from upper part of Woold Clay Member): The Netherlands, province of Gelderland, Winterswijk, clay-pit complex 'De Vlijt' (2 specimens, leg. A.W. Janssen, coll. RGM 229 689).

Discussion — This species has been mixed up in literature with *Praehyalocylis maximus* (Ludwig, 1864), also of Rupelian age, which has, however, a considerably larger shell and a different form with a much wider apical angle.

'Creseis' berthae sp. nov. is hesitatingly considered to be a euthecosomatous gastropod. It cannot be excluded (the apparent absence of a protoconch might support this) that it belongs to an entirely different animal group, *e.g.* the Annelida. A study of the aragonite crystal structure by SEM might reveal its relationship, but this has not yet been possible. This species shows a certain resemblance to the genus *Creseis*, especially with the Recent *C. acicula* (Rang, 1828), which has similar size and shell form, but differs by the absence of the significant surface sculpture. Because of the uncertain systematic place of the fossil species its generic position is provisionally indicated as *'Creseis'*, instead of introducing a new genus as well.

'Creseis' berthae sp. nov. co-occurs with *Limacina umbilicata* (Bornemann), but at least in the Winterswijk area its vertical distribution is apparently restricted to the upper part of the range of *L. umbilicata*.

Subfamilia Clioinae
Genus *Clio* Linné, 1767

Clio blinkae sp. nov.
Pl. 7, Figs 8-14

v. 1986 *Clio* sp. nov. — Janssen, p. 148, fig. 8.
v. 1988 *Clio blinkae* sp. nov. — Janssen & King, pp. 361, 363, figs 188, 194.

Holotype — Pl. 7, Fig. 8a-c, coll. RGM 229 692.

Locus typicus — Schelle (Belgium, province of Antwerpen), Damman clay-pit.

Stratum typicum — Boom Clay Formation, Waasland Clay Member, base of bed no. 21 (Vandenberghe, 1978) (Oligocene, Rupelian).

Derivatio nominis — This species is named after Mrs T.D.M. Euverman-Blink of Alphen aan den Rijn.

Description — Shell bag-shaped, bilaterally symmetrical, with a dorsally curved apical shell part. This curvature is not gradual, but rather abrupt and starts at a transverse diameter of about 1-1½ mm. The shell has an apical angle of some 22-24°, slightly increasing during growth.

The protoconch is somewhat higher than wide, slightly pointed and separated from the younger shell parts by a distinct constriction. There is no trace of an apical spine. Between the protoconch and the point of strongest curvature of the shell the transverse diameter is circular. Near the curvature two lateral carinae develop and the cross-section of the shell changes gradually to triangular, with an almost flat to only slightly convex ventral side and a distinctly swollen dorsal side. In this latter respect the species is very variable: in some shells the dorsal convexity is gradual, in others the central part of the dorsal side is produced, with the lateral parts more or less concave, thus accentuating a central dorsal ridge, which is in some cases accompanied by vertical grooves. In some of the largest specimens a further, weak radial fold is present on the dorsal side along the margins.

The carinae are rather pronounced, but rounded, sharper in apertural direction, not doubled. In frontal view the side lines of the shell are not straight, but somewhat flexuous, with usually a slight broadening at the place of the strongest curvature. The growth lines are rather distinct, but only visible if the aragonitic shell is preserved, which is only rarely the case. On the central part of the ventral side they are straight, curved adapically near the lateral margins. On the dorsal side the growth lines are distinctly and strongly curved in apertural direction, demonstrating that the dorsal apertural margin protrudes, in a rounded triangular shape, far beyond the ventral one.

Material — **Oligocene, Rupelian (Ratum Formation; but possibly downhole contamination from the Brinkheurne Formation, Kotten Member):** The Netherlands, province of Overijssel, borehole Haaksbergen (Schietbaan) 34G.2-8, depth 25-26 m (1 juvenile specimen, coll. RGM 229 690), depth 21.95-23 m (1 juvenile specimen, coll. RGM 229 691) (leg. M. van den Bosch, July 1982).

Oligocene, Rupelian (Boom Clay Formation, Waasland Clay Member, base of bed no. 21, see Vandenberghe, 1978): Belgium, province of Antwerpen, Schelle, Damman clay-pit (1 specimen, holotype, Pl. 7, Fig. 8a-c, coll. RGM 229 692; 1 juvenile specimen, Pl. 7, Fig. 13a-b, coll. RGM 220 827; 3 specimens, Pl. 7, Figs 10-12, coll. RGM 229 693-695 resp.; 200 specimens, coll. RGM 220 828, 8 slabs of clay with abundant specimens, coll. RGM 220 836-843; leg. A. W. Janssen, 1975). Do (1 juvenile specimen, Pl. 7, Fig. 14a-b, coll. RGM 229 696, 11 juvenile specimens, coll. RGM 221 104, 148 specimens, coll. RGM 221 103, 10 slabs of clay with abundant specimens, coll. RGM 221 108-113, 221 115-118; leg. A.W. Janssen, 1976).

Do.: do., Terhagen, clay-pit (15 specimens, coll. RGM 229 697, leg. A.W. Janssen, 1980).

Do.: do., Kruibeke, Gralex clay-pit (17 specimens, leg. A.W. Janssen, 1980, coll. RGM 229 722) (19 slabs of clay with abundant specimens, coll. RGM 229 699-717, 1 specimen on slab RGM 229 713 illustrated Pl. 7, Fig. 9, leg. A.W. Janssen, April 1988); sample 3.00-3.50 m (36 specimens, coll. RGM 229 698; leg. A.W. Janssen, from section measured in April 1988).

Discussion — No fossil species is known to the author in any way to resemble the present Oligocene species closely. Among the very few contemporaneous species, *Clio chadumica* Korobkov, 1966, described from the Rupelian (Khadumski Horizon) of the Pre-Aral area in the U.S.S.R. (Korobkov, 1966, p. 91, pl. 3, figs 10-18) has the general outline of the Recent species *C. polita* (Pelseneer, 1888), apparently a straight or only very slightly curved shell, distinctly separated lateral carinae and growth lines that are curved, both ventrally and dorsally, in apertural direction. Báldi (1986, p. 30, tab. 6) mentioned two *Clio* species from the more or less contemporaneous Kiscell Clay in Hungary. These two taxa were neither described nor illustrated.

The Recent *Clio polita* (Pelseneer, 1888) differs in many respects from *C. blinkae*. First of all the Recent species is much more slender, with a smaller apical angle. Furthermore the difference between the dorsal and ventral side in *C. blinkae* is much more accentuated. In *C. polita* the dorsal side is only slightly more convex than the ventral side. Also the protoconchs are different. In *C. polita* it is more globular than in *C. blinkae* and separated from the younger shell parts by a distinct ridge, which is absent in *C. blinkae*. The strong curvature of the shell reminds one of the Recent *Clio cuspidata* (Bosc, 1802), in which, however, the curvature is gradual. Furthermore the shell of this species has a completely different shape.

Clio blinkae might also be compared with *C. distefanoi* Checchia-Rispoli (1922, p. 20, figs 10, 10a-c), described from the Miocene of Monte Gargano, Italy. In this species, however, the apical angle is smaller, the ventral side has a considerably swollen central zone, and also the dorsal side has a very convex central part, separated from the margins by concave zones; no central ridge is present. Finally, the shell of *C. distefanoi* is less strongly curved dorso-ventrally.

Clio blinkae occurs in the North Sea Basin in a very restricted stratigraphical interval. In Belgium the species is only known from several localities in the Rupelian type area, south of Antwerp in Belgium. Here it is abundant in a level with a maximum thickness of some 5 cm, at the base of bed no. 21 (the so-called 'pink bed' of Vandenberghe, 1978, p. 26). This very restricted vertical distribution might be explained by a temporary (but massive !) invasion of this species from the Atlantic Ocean into the North Sea Basin. The short interval makes this pteropod a very useful tool for local correlations.

Two specimens from the eastern part of The Netherlands (Haaksbergen borehole, see 'material' above) are recorded from a level which is older than the horizon in the Belgian Boom Clay. It might very well be, however, that these two specimens have to be considered downhole contamination: the borehole was drilled using the straight-flush method, and the level corresponding with the Belgian horizon was indeed penetrated in the Haaksbergen section (Brinkheurne Formation, Kotten Member; compare van den Bosch, 1984, p. 109, fig. 4 for a correlation of the Dutch and Belgian Rupelian deposits).

Clio irenae sp. nov.
Pl. 8, Figs 1-3

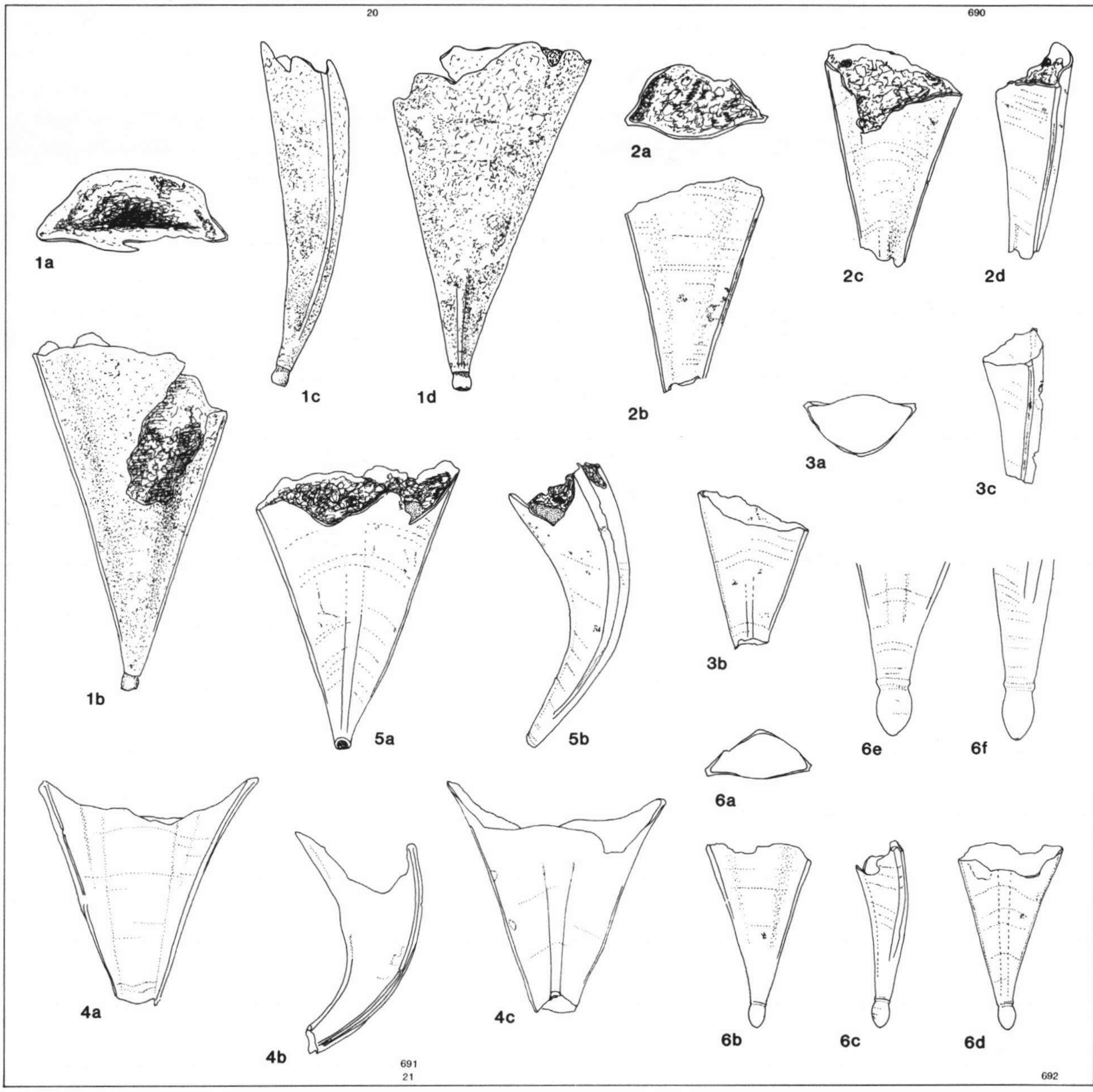
v. 1907 *Cleodora* sp. — Ravn, p. 370, pl. 8, fig. 18a-c.
v. 1915 *Cleodora deflexa* v.K. — Gripp, p. 29 (partim, only the specimens from Varde).
v. 1984 *Clio* sp. 1 — Janssen, p. 382, pl. 20, fig. 9a-c.
v. 1988 *Clio irenae* sp. nov. — Janssen & King, p. 365, figs 188, 197, 205 (nomen nudum).

Holotype — Pl. 8, Fig. 1a-d, coll. RGM 225 676.

Plate 8

Clio irenae sp. nov., holo- and paratypes.

Fig. 1a-d. Holotype. Winterswijk, Miste (The Netherlands, province of Gelderland), temporary outcrop. Miocene, Hemmoorian, Oxlundian, Aalten Member, Miste Bed. Leg. A.W. Janssen, 1971, coll. RGM 225 676, × 12½.
a: apertural, b: ventral, c: right lateral, and d: dorsal view.
Fig. 2a-d. Same locality data. Leg./coll. J. van der Voort, × 12½.
a: apertural, b: ventral, c: dorsal, and d: right lateral view.
Fig. 3a-c. Same locality data. Leg. A.W. Janssen, 1971, coll. RGM 229 718, × 12½.
a: apertural, b: dorsal, and c: right lateral view.



Clio pauli sp. nov., holo- and paratypes.

Fig. 4a-c. Holotype. Same locality data. Leg. A.W. Janssen, 1971, coll. RGM 225 677, × 12½.
a: ventral, b: right lateral, and c: dorsal view.

Fig. 5a-b. Gram, Enderupskov (Denmark, Jylland), from boulder of Holsteiner Gestein. Leg. A.W. Janssen, coll. RGM 229 721, × 12½.
a: dorsal, and b: right lateral view.

Fig. 6a-f. Arnum (Denmark, Jylland), borehole DGU 150.25b, depth 62.7-62.9 m. Miocene, Hemmoorian, Arnum Formation. Coll. DGU., 6a-d: × 12.5, 6e-f: × 25.
a: apertural, b: ventral, c and f: right lateral, d and e: dorsal view.

Locus typicus — Winterswijk, Miste (The Netherlands, province of Gelderland), temporary outcrop (see Janssen, 1984, p. 15, fig. 1), about 2 to 3.75 m below surface.

Stratum typicum — Aalten Member, Miste Bed; lower part of *Astarte radiata* Acme Zone or *Hiatella arctica* Acme Zone (Miocene, Hemmoorian, Oxlundian).

Derivatio nominis — This species is named after Mrs I. F. J. Beetsma-Vogels of Alphen aan den Rijn.

Description — Shell bag-shaped, bilaterally symmetrical, slightly curved dorso-ventrally in the apical part. Outline triangular, with an apical angle of 30-35°.

The protoconch is only partly preserved in the holotype. Its apical part is missing, but it seems to have had a more or less globular form; it may have had a pointed or a rounded apex. The width of the protoconch is about 0.20 mm. The boundary with the teleoconch is sharp and visible as a distinct constriction.

The teleoconch starts, just after the boundary with the protoconch, with a circular transverse section. Almost immediately, however, two strong lateral carinae develop, giving the shell a triangular cross section, with a flattened ventral and a convex dorsal side. The carinae are squarish and continue to the aperture, almost without curvature, giving the shell straight, diverging sidelines. The ventral side has two lateral depressions, enclosing a central convex field, which is about twice as wide as the lateral depressions. The dorsal side has a rounded central carina, which is present for a short distance only, starting just behind the boundary of the larval shell and gradually disappearing at a transverse diameter of about 0.75 mm. More anteriorly the dorsal side has a rather strongly convex central part, accompanied by slightly concave lateral zones, accentuating the lateral carinae.

The growth lines are horizontal and almost straight on the ventral side and curved in apertural direction on the dorsal side, indicating that the dorsal apertural margin protrudes strongly beyond the ventral one.

Material — **Miocene, Hemmoorian (Arnum Formation):** Denmark, Jylland, borehole Varde, depth 311' to 312' (1 defective specimen, illustrated in Ravn, 1907, pl. 8, fig. 18a-c, coll. GMK, registration no. MMH 565).

Miocene, Hemmoorian, Oxlundian (Aalten Member, Miste Bed): The Netherlands, province of Winterswijk, Winterswijk, Miste, temporary excavation (see Janssen, 1984, fig. 1) (holotype, Pl. 8, Fig. 1a-d, coll. RGM 225 676; 1 defective specimen, Pl. 8, Fig. 2a-d, coll. RGM 229 718; leg. A.W. Janssen, 1971); do. (1 defective specimen, Pl. 8, Fig. 2a-d, leg./coll. J. van der Voort).

Discussion — This species differs from the related and accompanying species *Clio pauli* sp. nov. (see below) by its smaller apical angle, the lesser degree of curvature and the distinctly less swollen dorsal side, on which the central carina disappears much earlier.

The specimen described by Ravn (1907) originally had its protoconch preserved. The shell, however, was apparently filled with pyrite, which has now partly disintegrated, thereby completely destroying the apical part. The still visible parts compare very well with the few specimens from Winterswijk and there is no doubt that it belongs to the same species. In the Varde borehole *C. irenae* is accompanied by *Limacina miorostralis* (Kautsky, 1925), which is mentioned in Ravn (1907, p. 369, pl. 8, fig. 16) with the erroneous name *Valvatina atlanta* Mørch. The illustrated specimen of this latter species is still present in the GMK collection (registration no. MMH 568). The same species (as well as several other pteropods) is also present at the Winterswijk-Miste locality.

Clio jacobae sp. nov.
Pl. 7, Figs 15-16

v. 1988 *Clio jacobae* sp. nov. — Janssen & King, p. 362, figs 188, 196 (nomen nudum).

Holotype — Pl. 7, Fig. 15a-c, coll. RGM 229 720.

Locus typicus — The Netherlands, province of Drente, Ruinerwold, borehole De Wijk XML/NAM, depth 242.5-250 m-RT.

Stratum typicum — Rupel Formation (Oligocene, Rupelian).

Derivatio nominis — This species is named after Mrs J.B. Samsom of Boskoop.

Description — Only two pyritic internal moulds are available. The species is bag-shaped, bilaterally symmetrical, only very slightly curved dorso-ventrally in the apical shell-part. Initially the sidelines are somewhat concave, but later they are almost straight, enclosing an apical angle of some 47-48°.

The protoconch is not preserved, the scar where it is broken off has a diameter of 0.15 mm. The teleoconch has a triangular outline and a lenticular transverse section with apparently very sharp lateral carinae. The ventral side of the shell is hardly less convex than the dorsal one, which has a very weakly developed central ridge. On both sides of the shell the carinae are accompanied by slightly concave zones, which are distinctly wider on the ventral side, occupying somewhat less than a quarter of the shell width. The growth lines are almost invisible on either of the internal moulds.

Material — **Oligocene, Rupelian (Rupel Formation):** The Netherlands, province of Drente, Ruinerwold, borehole De Wijk XML/NAM, depth 257.5-265 m-RT (1 specimen, Pl. 7, Fig. 16a-d, coll. RGM 229 719); depth 242.5-250 m-RT (1 specimen, holotype, Pl. 7, Fig. 15a-d, coll. RGM 229 720) (all samples leg. M. van den Bosch).

Discussion — *Clio (Nudiclio) nuda* Korobkov, 1966, introduced from the Late Eocene of the Pre-Aral area (U.S.S.R.), differs by its much smaller apical angle, the completely straight side-lines without a concave apical part, and the absence of a central ridge and concave marginal zones.

The Italian Miocene species *Clio bellardii* Audenino (1895, p. 104, pl. 5, fig. 5a-d) has a much more convex dorsal side with wider lateral concave zones. Its ventral side has a strong central ridge, subdivided by a median groove.

Clio pauli sp. nov.
Pl. 8, Figs 4-6

v. 1916 *Cleodora deflexa* v.Koen. — Nørregaard, pp. 38, 49, pl. 3, fig. 14a-d (non von Koenen).
v. 1958 *Clio* sp. — Sorgenfrei, p. 354.
v. 1966 *Clio deflexa* (v. Koenen) — Rasmussen, p. 201 (non von Koenen).
v. 1984 *Clio* sp. 2 — Janssen, p. 383, pl. 20, fig. 10a-c.
v. 1988 *Clio pauli* sp. nov. — Janssen & King, p. 365, figs 188, 197, 205 (nomen nudum).

Holotype — Pl. 8, Fig. 4a-c, coll. RGM 225 677.

Locus typicus — Winterswijk, Miste (The Netherlands, province of Gelderland), temporary outcrop (see Janssen, 1984, p. 15, fig. 1), about 2 to 3.75 m below surface.

Stratum typicum — Aalten Member, Miste Bed; lower part of *Astarte radiata* Acme Zone or *Hiatella arctica* Acme Zone (Miocene, Hemmoorian, Oxlundian).

Derivatio nominis — This species is named after Mr P. van Tilburg of Alphen aan den Rijn.

Description — Shell bag-shaped, bilaterally symmetrical, strongly curved dorso-ventrally, with the point of strongest curvature at a transverse diameter of about 1.5 mm. Apical angle initially between 35 and 40°, in the largest specimen widening to almost 45°.

The protoconch is ovoid, with a pointed apex; there are no traces of an apical spine. Measurements of the larval shell (2 specimens measured, ventral view): H 0.30 mm, W 0.20 mm.

The teleoconch starts as a conical tube with a circular cross-section. At a width of about 0.4 mm two strong, squarish lateral carinae develop rapidly, together with a rounded central ridge on the (concave) dorsal side. These carinae change the transverse section from circular to distinctly triangular. At a width of some 2.5 mm the ventral carina disappears gradually, the lateral ones persist to the apertural margin.

The ventral side has a very slightly convex central zone, initially separated from the narrower lateral zones by superficially incised grooves, but later without a sharp boundary. On the dorsal side the zones in between the central carina and the lateral ones are almost flat, undivided, somewhat concave close to the lateral carinae and thus accentuating them. In the largest specimens these concave zones become wider and more significant.

The growth lines are relatively well visible. On the ventral side they are only slightly curved in apertural direction, but on the dorsal side they are triangularly shaped with the bending-point on the central carina. Where this carina disappears on the younger shell portions the central part of the growth lines is more gradually and strongly curved in apertural direction, becoming straight, to even somewhat curved apically towards the sides, indicating that the dorsal ventral margin is protruding far beyond the ventral one. In the largest specimens there is a slight tendency for the development of transverse undulation.

Material — **Miocene, Hemmoorian (Arnum Formation):** Denmark, Jylland, borehole Arnum DGU 150.25b, depth 62.7-62.9 m (1 specimen, Pl. 8, Fig. 6a-f; 1 specimen, 2 defective specimens, coll. DGU, mentioned in Sorgenfrei, 1958, p. 354 sub nomine *Clio* sp.).

Do.: do., borehole Gram, Enderupskov, DGU 141.196, depth 54 m (2 specimens, coll. DGU, mentioned in Rasmussen, 1966, p. 201 sub nomine *Clio deflexa* von Koenen).

Miocene, Hemmoorian, Oxlundian (Aalten Member, Miste Bed): The Netherlands, province of Winterswijk, Winterswijk, Miste, temporary excavation (see Janssen, 1984, fig. 1) (1 defective specimen, holotype, Pl. 8, Fig. 4a-c, coll. RGM 225 677; leg. A.W. Janssen, 1971).

Age unknown (from boulders of Holsteiner Gestein): Denmark, Jylland, Maade near Esbjerg, washed ashore on the beach (2 specimens, illustrated in Nørregaard, 1916, pl. 3, fig. 14a-d, coll. GMK, registration no. MMH 1925).

Do.: do., Gram, Enderupskov, sand-pit (1 specimen, Pl. 8, Fig. 5a-b, leg. A.W. Janssen, coll. RGM 229 721).

Discussion — *Clio pauli* is closely related to the Recent species *Clio cuspidata* (Bosc, 1802), as unequivocally indicated by the general shell form, the embryonal shell, the squarish lateral carinae, etc. See for good illustrations of complete adult specimens (very rare !) of *C. cuspidata* for example Boas (1886, pl. 1, fig. 2 and pl. 2, fig. 13; dorsal and right lateral views) and van der Spoel (1967, fig. 66A-B; ventral and left lateral views).

There are, however, obvious differences between *C. cuspidata* and the Miocene *C. pauli* sp. nov. The protoconch of *C. cuspidata* is relatively broader, more globular, and has a sharp apical spine. Its lateral carinae develop later, at a shell width of some 0.8-1.0 mm, and they are strongly curved sidewards. The central carina of the dorsal side appears still later, at a shell width of about 2 mm; it does not disappear on the more anterior shell portion, but persists and protrudes on the apertural margin as a long spine. Although no completely adult specimens of *C. pauli* are available it may be supposed that in this species only the lateral carinae form spines on the apertural margin.

In *C. cuspidata* the zones on both sides of the dorsal carina are subdivided by a weak longitudinal depression, which is absent in the fossil species. Finally, a distinct and regular transverse sculpture is seen on the younger parts of *C. cuspidata*. In *C. pauli* only a slight tendency is present in this respect in those shell parts in which the sculpture is already well-developed in *C. cuspidata*.

Clio deflexa (von Koenen, 1882), to which the present species was assigned by Nørregaard and Rasmussen, is very different. It is a species from the Holsteiner Gestein, with a ventrally and dorsally almost equally convex shell, with a wider apical angle, without a central carina on the dorsal side and with a much better developed radial and transverse sculpture.

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