

## A BIOZONATION BASED ON GADIDAE OTOLITHS FOR THE NORTHWEST EUROPEAN YOUNGER CENOZOIC, WITH THE DESCRIPTION OF SOME NEW SPECIES AND GENERA

by

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With the aid of five Gadidae lineages, viz. those of *Gadichthys*, *Colliolus*, *Pseudocolliolus*, *Trisopterus* and *Merlangius*, and the species *Phycis praecognatus*, the time interval Early Oligocene - Holocene is divided into 17 biozones (see table 1).

Two biozones represent time intervals of which the existence could not be demonstrated before: the *Colliolus johannettae* Lineage-zone as the youngest part of the Early Miocene (in the Edegem Sands) and the *Pseudocolliolus cuykensis* Range-zone as the youngest part of the Late Miocene. Two other biozones can be predicted on the ground of the evolution of the genus *Colliolus*: the *Colliolus* sp. 1 Lineage-zone as the youngest part of the Rupelian, and the *Colliolus* sp. 2 Lineage-zone as the middle part of the Early Miocene.

The Gadidae otolith biozones can be used for biostratigraphic correlations of normal shelf deposits in the northwest European younger Cenozoic (North Sea Basin and surroundings).

Two new genera, viz. *Pseudocolliolus* and *Ensigadus*, and three new species, viz. *Colliolus minutulus*, *Pseudocolliolus cuykensis* and *Palaeoraniiceps gramensis* are described.

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## SAMENVATTING

Met behulp van vijf evolutielijnen van de familie der Gadidae, namelijk van de genera *Gadichthys*, *Colliolus*, *Pseudocolliolus*, *Trisopterus* en *Merlangius*, en de soort *Phycis praecognatus*, kan het tijdsinterval Vroeg-Oligoceen - Holoceen worden onderverdeeld in 17 biozones (zie tabel 1).

Twee biozones vertegenwoordigen tijdsintervallen waarvan het bestaan nog niet eerder kon worden aangetoond: de *Colliolus johannettae* Lineage-zone als het jongste gedeelte van het Vroeg-Mioceen (aangetroffen in de Zanden van Edegem) en de *Pseudocolliolus cuykensis* Range-zone als het jongste gedeelte van het Laat-Mioceen. Twee andere biozones kunnen worden voorspeld op grond van de evolutie van het geslacht *Colliolus*: de *Colliolus* sp. 1 Lineage-zone als het jongste gedeelte van het Rupelien, en de *Colliolus* sp. 2 Lineage-zone als het middelste gedeelte van het Vroeg-Mioceen.

De biozones gebaseerd op otolieten van Gadidae kunnen worden gebruikt voor biostratigrafische correlaties van normale platzee-afzettingen in het jongere Caenozoicum van noordwest-Europa (Noordzeebekken en omgevende gebieden).

Twee nieuwe genera, namelijk *Pseudocolliolus* en *Ensigadus*, en drie nieuwe soorten, namelijk *Colliolus minutulus*, *Pseudocolliolus cuykensis* en *Palaeoranceps gramensis* worden beschreven.

## INTRODUCTION

For two reasons Gadidae otoliths are particularly suited for a biozonation of the younger Cenozoic in the North Sea Basin and surrounding areas. In the first place Gadidae are free living fishes which are less restricted to specific environments than benthonic organisms, so that they have a large horizontal distribution. In the second place the Gadidae family is an important and mostly even dominating group of fishes in northwestern Europe in sediments from the Early Oligocene up to the present. This is caused by the fact that they were and are numerous in the area in question, but also by the fact that Gadidae possess relatively large otoliths compared with the total length of the fishes. Investigations of otoliths from (sub)recent sediments have shown that those species which are small and which have relatively large otoliths are overrepresented in the fossil record (Gaemers, 1977, 1978). Thus especially the otoliths of the smaller codfish species occur in large numbers in the sediments.

Gadidae otoliths are never as numerous in the sediments as molluscs, but their frequency is often high enough to find them not only in (large) samples from exposures but also in relatively small boring samples. This is of course essential for biostratigraphic applications. A rich sample of 1 kg of sediment (dry weight) contains 5 to 10 or even more specimens. Naturally larger samples of some kilograms or more are a better guarantee for a more precise age determination, but also samples of these sizes can be obtained from borings.

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## BIOZONATIONS BASED ON GRADUAL EVOLUTION

One of the most reliable ways of distinguishing biozones, if not the most reliable way, is using the gradual evolution within lineages. When the evolution of a certain group of organisms is sufficiently known, it is possible to use the boundaries between succeeding species as boundaries for the biozones. The advantage of using such boundaries is that their places are fixed and so the precise stratigraphic ranges of species can be determined. In those cases the unpleasant situation is avoided that the stratigraphical range of a key species may prove to be longer when more data become available, which makes necessary considerable changes in the existing conception. Therefore I agree completely with Hedberg (1976, p. 59) who states that 'In theory, a system of overlapping zones based on several lineages offers one of the best assurances of reliable time-correlation on a biostratigraphical basis'. The evolution of the Gadidae offers a good opportunity to build up such a system.

The only possibility to distinguish different species within a gradually evolving lineage is to draw arbitrary boundaries. Properly speaking the different phylogenetic stages of such a lineage which can be distinguished in this way are no real species because of the gradual transitions in the course of time, but it is customary among palaeontologists to work with the binomial names as if it were real species. Natural history has an imperfect system of classification for the organic world, viz. the Linnaean system, but there has not yet been found a better one, which is more adapted to the evolution theory.

In order to define the boundaries of the biozones as exactly as possible the most effective way is the application of arbitrary boundaries between succeeding species, based on the stratigraphical mean of measurable evolving characteristics of populations. Because of the allometric growth in otoliths it is necessary to use non-linear curves representing the mean of the length-height and length-thickness ratios (Gaemers, 1976a). There, however, some difficulties arise. It is not easy to find the mathematical formulas which describe all these curves for it seem to be rather complicate functions. Therefore I prefer to use the ontogenetic handdrawn curves as the mean lines through clouds of points, until a clear mathematical circumscription of these curves can be given.

Because of the gradual changes in the evolving lineages the boundaries are in fact not sharp timelines. When we use the 95% reliability level, as is customary in statistics, the boundary falls within a time interval of a certain length. The duration of this interval is; however, not long; it is so many times shorter than the time interval represented by a biozone that it may be neglected.



## DEFINITION OF THE BIOZONES OF GADIDAE OTOLITHS (table 1)

### Zone 1. *Phycis praecognatus* Range-zone.

By definition this biozone is characterized by the 'outermost limits of known occurrence anywhere of specimens of the taxon whose range is to be represented by the zone. Thus the limits are those of the origin and extinction of the taxon insofar as these are known' (Hedberg, 1976).

*Phycis praecognatus* Schwarzhans, 1977 occurs in the fossiliferous parts of the Early Oligocene (Lattorfian) Grimmertingen Sands (province of Limburg, Belgium), in the lower part as well as in the uppermost part of these deposits (Nolf, 1974, and unpublished data); furthermore it is known from the Early Oligocene of Hückelhoven (Nordrhein-Westfalen, Federal Republic of Germany) (Schwarzhans, 1977).

Other Gadidae otoliths occurring together with *P. praecognatus* are *Gadidarum altus* [syn. *Raniceps altus* Nolf, 1974; *Palaeogadus altus* (Nolf) in Schwarzhans, 1977]. *Gadidarum* sp. (the otoliths of this poorly known species resemble those of *Gadichthys* and *Gadiculus* ver much), and *Palaeogadus* sp.

### Zone 2. *Colliolus minutulus* Lineage-zone.

The lower boundary of this biozone is defined by the appearance of *Colliolus minutulus* n.sp. and the upper boundary by the transition of this species into its descendant, *C. parvus*. We may also call this zone the *C. minutulus* Range-zone.

The key taxon is known from the lower part of the Middle Oligocene Boom Clay in Belgium, from the lower part of the Brinkheurne Member (Septaria Clay or Boom Clay) province of Guelders in the Netherlands and from the Middle Oligocene Nucula Clay in Belgium.

Gadidae species accompanying the key species are *Trisopterus elegans* (Koken, 1884) (this species occurs in the Nucula Clay in the province of Limburg, Belgium), and *Palaeoraniceps tuberculosus* (Koken, 1884) (in the lower part of the Boom Clay at Steendorp and Terhagen, Belgium; Steurbaut & Herman, 1978). Probably also *Palaeogadus emarginatus* (Koken, 1884), *Ensigadus ensiformis* (Steurbaut & Herman, 1978) and ? *Gadiculus* sp. Steurbaut & Herman, 1978, occur within the range of the key taxon.

### Zone 3. *Colliolus parvus* Lineage-zone.

The lower boundary of this zone is defined by the transition of *Colliolus minutulus* into the key taxon, the upper boundary by the transition of the key taxon into a still unknown intermediate form between *C. parvus* and *C. sculptus*. We may also call this zone the *C. parvus* Range-zone.

*Colliolus parvus* Gaemers, 1976, is known from the upper part of the Middle Oligocene Boom Clay in Belgium (Steurbaut & Herman, 1978) and from the upper part of the Brinkheurne Member and the lower part of the Winterwijk Member (both Middle Oligocene in age) in the province of Guelders in the Netherlands (Gaemers & van Hinsbergh, 1978). This species certainly has a much larger geographical distribution, for it has also been found by A. Müller (Leipzig) in the Democratic Republic of Germany (pers. comm.).

Other Gadidae occurring together with the key species are ? *Gadichthys altus* Gaemers & van Hinsbergh, 1978, *Trisopterus elegans*, *Palaeogadus emarginatus*, *P. compactus* Gaemers & van Hinsbergh, 1978, and *Palaeoraniceps tuberculosus*.

#### Zone 4. *Colliolus* sp. 1 Lineage-zone.

The existence of this zone has not yet been demonstrated but it can be predicted on the ground of the evolution of the *Colliolus* lineage. There is namely a large difference in size between the otoliths of *Colliolus parvus* and *C. sculptus*. A species with medium otoliths thus can be expected as a transitional form between them.

In fact a thick sediment packet mainly consisting of heavy clays and occurring in the eastern part of the Netherlands above the Winterswijk Member as described by van den Bosch et al. (1975) is very likely to represent this predicted biozone. The sediments in question are only known from borings and reach thicknesses of at least 130 m at places where hardly or no erosion has taken place (pers. comm. Mr. M. van den Bosch). Unfortunately faunas are not yet known from these deposits. Not long ago Mr. Van den Bosch has sampled the upper part of these deposits from a research boring at Lievelede (province of Guelders, the Netherlands). It will be highly interesting to see what fauna occurs in these clays.

#### Zone 5. *Colliolus sculptus* - *Gadichthys undosus* Concurrent-range-zone.

The lower boundary of this zone is defined by the transition of a still unknown *Colliolus* species (intermediate between *C. parvus* and *C. sculptus*) to *C. sculptus* (Koken, 1891), the upper boundary by the transition of *Gadichthys undosus* Gaemers, 1976, to *G. spatulatus* (Koken, 1891). This biozone is in fact a combination of two types of biozones defined by Hedberg (1976), viz. the Concurrent-Range-Zone and the Lineage-Zone. Therefore it is perhaps better to call this type of biozone the Evolutionary-Concurrent-Range-Zone.

The occurrence of *Colliolus sculptus* and *Gadichthys undosus* is known from the Late Oligocene (Chattian) deposits of northwestern Germany (Gaemers, 1973). In other parts of the North Sea Basin these deposits have often been completely or largely removed by erosion. Up to now there is not much known in detail about the Late Oligocene in countries around Western Germany.

Other Gadidae accompanying the key species are *Merlangiogadus decorus* Gaemers, 1973, *Trisopterus* sp. and *Palaeoraniceps supraoligocaena* (Weiler, 1942).

#### Zone 6. *Gadichthys spatulatus* - *Colliolus sculptus* Concurrent-range-zone.

The lower boundary of this zone is defined by the transition of *Gadichthys undosus* to *G. spatulatus*, the upper boundary by the disappearance of *Colliolus sculptus*. It is presupposed that the latter species gradually evolved into a still unknown *Colliolus* species which in its turn is connected by a gradual transition with *C. johannettae*. Thus this biozone can be considered to be an Evolutionary-Concurrent-Range-Zone.

The concurrence of the two key species is known from the latest Late Oligocene 'Sternberger Gestein' (Gaemers, 1976a) occurring in northern Germany, and from the Early Miocene (Vierlandian) of northwestern Germany (pers. comm. H. Menzel). The 'Sternberger Gestein', known from erratic boulders, thus belongs to a younger part of the Late Oligocene than most other Chattian deposits in northwestern Europe. In these boulders moreover the following Gadidae have been found (according to Martini, 1968): *Merluccius obtusus* Koken, 1891; *Palaeogadus emarginatus*, *Phycis simplex* (Koken, 1891), *Raniceps latisulcatus* (Koken, 1884) and *R. planus* (Koken, 1884) and *Gadus elegans* (Koken, 1884). Both *Raniceps* forms presumably should be reckoned to *Palaeoraniceps supraoligocaena* (Weiler, 1942) and the otoliths of *G. elegans* probably belong to *Trisopterus kasselensis* Schwarzhans, 1974.

Unfortunately much less is known of the Vierlandian and its otolith fauna. This stage is repre-

sented by marine clayey sediments in northwestern Germany and Denmark. In most parts of northwestern Europe they seem to have been eroded completely, if marine deposits were formed at all.

#### Zone 7. *Colliolus* sp. 2 Lineage-zone.

This zone can be predicted on the ground of the evolution of the *Colliolus* lineage. The general pattern of the Gadidae lineages namely consists of four phylogenetic stages (Gaemers, 1976a) of which stage 3 is still missing in the *Colliolus* lineage. Transitional forms can also be expected in the *Trisopterus* lineage between *T. kasselensis* and *T. concavus*. If these hypothetical species of the genera *Colliolus* and *Trisopterus* do exist, a separate biozone can be expected in the middle part of the Early Miocene.

#### Zone 8. *Colliolus johannettae* Lineage-zone.

The lower boundary of this biozone is defined by the appearance of *C. johannettae* Gaemers, 1976, which is supposed to be the descendant of a still unknown *Colliolus* species and which is supposed to be connected with this species by transitional forms. The upper boundary of the biozone is defined by the transition of the key species to *C. friedbergi*.

*C. johannettae* is known from the Edegem Sands in the Antwerp region (Belgium). I consider these sands to represent the latest part of the Early Miocene. The key species occurs also in equally old glauconitic sands found in boring 42B.20-3 at Haamstede, Isle of Schouwen-Duiveland, province of Zeeland, the Netherlands, at depths between 132 - 155 m (van den Bosch, 1978). The otolith fauna of these sands will be described at a later date. Deposits belonging to this biozone are unknown up to now from other places in northwestern Europe.

Other Gadidae occurring together with the key species are *Gadicthys antwerpiensis* (Gaemers, 1971), *Trisopterus concavus* Gaemers, 1976, *Merlangiogadus* aff. *cognatus*, *Merlangius bifurcus* Gaemers, 1973, *Gaidropsarus acuticaudatus* Gaemers, 1973, *Phycis elongatus* Posthumus, 1923, and *Palaeoraniceps regularis* Gaemers, 1976.

#### Zone 9. *Colliolus friedbergi* Interval-zone.

The lower boundary of this biozone is defined by the transition of *C. johannettae* to the key taxon, the upper boundary by the appearance of *Trisopterus spectabilis* (Koken, 1891). The species after which the zone has been named is not confined to this zone.

The boundary between *C. johannettae* and *C. friedbergi* (Chaine & Duvergier, 1928) is supposed to coincide with the Early Miocene - Middle Miocene boundary. The biozone comprises the complete Middle Miocene. Unfortunately it is not yet possible to divide this time interval into more biozones, although the Middle Miocene otolith faunas belong to the richest and best known faunas.

Gadidae accompanying *C. friedbergi* in this biozone are: *C. schwarzhansi* Gaemers, 1976, *Trisopterus concavus*, *Gadiculus ellipticus* (Schubert, 1905), *Merlangiogadus* aff. *cognatus*, *Merlangius bifurcus*, *Merluccius merluccius* (Linnaeus, 1758), *Phycis elongatus*, *Molva primaeva* Gaemers, 1976, and *M. izukai* Nolf, 1976.

*Colliolus schwarzhansi* is only known up to now from the younger part of the Middle Miocene (Reinbekian). If it can be proven that this species did not exist in the older part of the Middle Miocene (Hemmoorian), two biozones can be established for the Middle Miocene. We have to keep in mind that the boundary between the Hemmoorian and Reinbekian may not always be a time line, but may sometimes be a diachronous facies boundary (van den Bosch et al., 1975).

**Zone 10. *Trisopterus spectabilis* - *Trisopterus concavus* Concurrent-range-zone.**

The lower boundary of this zone is defined by the appearance of *T. spectabilis*, the upper boundary by the transition of *T. concavus* to *T. luscus* Linnaeus, 1758. *T. spectabilis* is supposed to have originated from *T. concavus*. This biozone can be considered to be an Evolutionary-Concurrent-Range-Zone.

The concurrence of the two key species is known from the earliest Late Miocene (Langenfeldian = Langenfelde-Stufe). Deposits of this age are wide-spread in northern Germany and Denmark (Hinsch, 1974, and many older publications of this author) and could also be demonstrated in a boring near Oploo in the Peel region, province of North-Brabant, the Netherlands (Gaemers, 1976a, p. 17).

Other Gadidae occurring together with the key species are *Trisopterus capelanus* (Lacepède, 1800), *Colliolus friedbergi*, ?*Gadichthys venustus* (Koken, 1891), *Merlangiogadus cognatus* (Koken, 1891), and *Boreogadus minusculus* (Schubert, 1906). The Late Miocene deposits of Hohen Woos, Democratic Republic of Germany (Heinrich, 1969) most likely belong to the Langenfeldian (Gaemers, 1976b). If this indeed should be the case, also *Gadichthys miocenicus* (Heinrich, 1969), *Trisopterus incognitus* Gaemers, 1976, *Micromesistius tenuis* (Weiler, 1942) and *Brosme heinrichi* Gaemers, 1976, are accompanying species in this biozone.

**Zone 11. *Trisopterus luscus* - *Trisopterus spectabilis* Concurrent-range-zone.**

The lower boundary is defined by the transition of *T. concavus* to *T. luscus*, the upper boundary by the transition of *T. spectabilis* to *T. angustus* Gaemers & Schwarzhans MS. This biozone is an Evolutionary-Concurrent-Range-Zone.

The concurrence of the two key species is known from the Late Miocene Gramian (= Gram-Stufe). Deposits of this age are wide-spread in Denmark and northern Germany (Hinsch, 1974) and occur also in the Antwerp region (the Deurne Sands belong to the Gramian; see Gaemers, 1976a, p. 17), and in the subsurface of the Netherlands.

Other Gadidae occurring together with the key species are *Trisopterus capelanus*, *Colliolus friedbergi*, ?*Gadichthys venustus*, *Boreogadus minusculus*, *Merlangiogadus cognatus*, *Gadidarum deurnensis* Gaemers, 1976, and *Palaeoraniceps gramensis* n.sp.

**Zone 12. *Trisopterus angustus* - *Pseudocolliolus syltensis* Concurrent-range-zone.**

The lower boundary of this zone is defined by the transition of *Trisopterus spectabilis* to *T. angustus* Gaemers & Schwarzhans MS, the upper boundary by the transition of *Pseudocolliolus syltensis* Gaemers & Schwarzhans MS to *P. cuykensis* n.sp.. This biozone is an Evolutionary-Concurrent-Range-Zone.

The concurrence of the two key species is known from the Late Miocene Syltian (= Sylt-Stufe). Up to now deposits of this age have only been found on the Isle of Sylt, northwestern Germany. The otolith fauna from the type locality of the Morsum Kliff at Sylt will soon be published by Gaemers & Schwarzhans.

Other Gadidae occurring together with the key species are *Colliolus friedbergi*, *Neocolliolus pliogenicus* (Gaemers & Schwarzhans, 1973), *Micromesistius schwarzhansi* Holec, 1976, *Boreogadus minusculus*, *Merluccius miocenicus* (Koken, 1891), *Ciliata fitchi* Gaemers & Schwarzhans MS, *Enchelyopus* sp., *Phycis elongatus*, and *Raniceps longissimus* Gaemers & Schwarzhans MS.



Zone 13. *Pseudocolliolus cuykensis* Range-zone.

The lower boundary of this zone is defined by the transition of *Pseudocolliolus syltensis* to *P. cuykensis*, the upper boundary by the disappearance of *P. cuykensis*. This biozone can change into a Lineage-Zone if the descendant of the latter species will be discovered in the future, supposing it to have existed.

The key species is known from depths between 78 and 94 m in boring 46A/147 at Cuyk, the Netherlands, and from 'Bed 1' (the so-called 'laag 1' of van den Bosch, 1967) in Borgerhout, suburb of Antwerp, Belgium. Van den Bosch (1967) already supposed rightly that 'Bed 1' was younger than the Late Miocene Deurne Sands and older than the Early Pliocene Kattendijk Sands. He found a typical chondrosteian fauna in this bed. He was, however, not able to situate it more exactly in the stratigraphy at that moment. De Meuter et al. (1976) did not distinguish this 'Bed 1' from the Kattendijk Sands in their sections of the Neogene deposits at Borgerhout.

According to the foraminifera the depth interval 78 - 140 m of the boring at Cuyk belongs to the FC2 zone, which is Late Miocene in age (Doppert, RGD internal reports nrs. 1259 and 1310). With the present state of knowledge the Late Miocene cannot be divided into more than one foraminiferal zone.

Spaink, who studied the molluscs (RGD internal report nr. 1121), places the depth interval 78 - 100 m of this boring in the Langenfeldian. This is, however, not possible on the ground of the assemblage of Gadidae otoliths. One of the otoliths has distinctly a different colour and was apparently reworked. It is a specimen of *Trisopterus spectabilis* which is only known from the Langenfeldian and the Gramian. This is an indication that also some of the molluscs may be reworked.

The biozone of which *P. cuykensis* is the key species represents a time interval that was not yet distinguished in the North Sea Basin before. It therefore does not fit in the conventional stage division of northwestern Europe.

Gadidae accompanying *P. cuykensis* in its type locality are *Colliolus friedbergi*, *Trisopterus luscus*, *T. angustus*, *Boreogadus minusculus*, *Merlangiogadus* aff. *cognatus* and a Gaidropsarinae sp. The otolith fauna as a whole (which will be described at a later date) has much more affinities with Miocene than with Pliocene faunas and therefore this biozone has been placed in the Miocene.

Zone 14. *Gadichthys benedeni* Range-zone.

The lower boundary of this zone is defined by the appearance of *G. benedeni* (Leriche, 1926), the upper boundary by the transition of this species to *G. verticalis*. This biozone may change into a Lineage-Zone, if the forerunner of *G. benedeni* will be discovered in the future.

The key species occurs as an autochthonous element in the Early Pliocene Kattendijk Sands in the Antwerp region. From borings these sands are also known to occur in large areas in the subsurface of the Netherlands.

Other Gadidae which occur together with *G. benedeni* in the Kattendijk Sands (see Gaemers & Schwarzhans, 1973) are: *Trisopterus luscus*, *Neocolliolus pliogenicus*, *Colliolus friedbergi* (autochthonous ?), *Merlangius pseudaeaglefinus* (Newton, 1891), *Micromesistius hochti* Gaemers & Schwarzhans, 1973, *Boreogadus similis* Gaemers & Schwarzhans MS, *Merluccius miocenicus* Koken, 1891 (syn. *M. triangularis* Weiler, 1942) and *Enchelyopus asper* (Gaemers & Schwarzhans, 1973) (syn. *Oncocottus asper*).

Zone 15. *Gadichthys verticalis* Range-zone.

The lower boundary of this zone is defined by the transition of *G. benedeni* to *G. verticalis*, the

upper boundary by the disappearance of the latter species. Possibly the key species evolved into the recent species *G. thori* (J. Schmidt, 1914). In that case we may call this zone a Lineage-Zone.

The key species occurs in many Late Pliocene deposits. In the Antwerp region it has been found in the Luchtbal and Oorderen Sands (Gaemers & Schwarzahans, 1973; the latter deposits used to be called Kallo Sands). In boring 42H.19-4 (A.40) at Ouwkerk, Isle of Schouwen-Duiveland, province of Zeeland, the Netherlands, it occurs in the Luchtbal and Merksem Sands (Gaemers & Schwarzahans, 1973; Gaemers, 1974). De Meuter & Laga (1976) included these three deposits with the Kruisschans Sands and Zandvliet Sands in their Lillo Formation.

Gadidae accompanying the key species in the Luchtbal Sands are *Trisopterus luscus*, *Neocolliolus pliocenicus*, *Merlangius pseudaeaglefinus*, *Melanogrammus conjunctus* Gaemers & Schwarzahans, 1973, *Pollachius* sp. and *Merluccius miocenicus*. In the Oorderen Sands the key species occurs together with *Trisopterus luscus*, *T. minutus*, *Micromesistius hochti*, *Melanogrammus conjunctus*, *Pollachius virens* Linnaeus, 1758, *Raniceps raninus* Linnaeus, 1758 and *Enchelyopus asper*. In the Merksem Sands the key species occurs together with *Trisopterus luscus*, *Melanogrammus conjunctus* and *Merlangius pseudaeaglefinus*.

#### Zone 16. *Merlangius pseudaeaglefinus* Interval-zone.

The lower boundary of this biozone is defined by the disappearance of *Gadichthys verticalis*, the upper boundary by the transition of *M. pseudaeaglefinus* to *M. merlangus*. The species after which the zone is named is not restricted to this zone.

To this biozone the Early Pleistocene deposits of the Maassluis Formation in the Netherlands (formerly called marine Icenian) are reckoned. Not much is known as yet of the otolith faunas in this biozone. The exact stratigraphic position of the upper boundary of the biozone is not yet known because otoliths from younger Pleistocene deposits were hardly found up to now.

Next to *M. pseudaeaglefinus* the following Gadidae have been found in boring Ouwkerk: *Gadus morhua* Linnaeus, 1758, *Trisopterus luscus* and *Pollachius virens*.

#### Zone 17. *Merlangius merlangus* Lineage-zone.

The lower boundary of this zone is defined by the transition of *M. pseudaeaglefinus* to *M. merlangus*, the upper boundary has not yet been reached because the key species is still a living one.

To this biozone Eemian (Late Pleistocene), Holocene and Recent deposits can be reckoned and presumably also somewhat older Late Pleistocene deposits. Otoliths are always extremely rare in Eemian deposits of the Netherlands, but I know of one find of the key species in these deposits.

Holocene Gadidae known from bottom samples taken in the North Sea are: *Gadus morhua*, *Melanogrammus aeglefinus* Linnaeus, 1758, *Merlangius merlangus*, *Micromesistius poutassou* (Risso, 1810), *Neocolliolus esmarki* (Nilsson, 1855), *Trisopterus minutus* (Linnaeus, 1758), *Gadichthys thori* (J. Schmidt, 1914), *Merluccius merluccius*, *Molva molva* (Linnaeus, 1758) (only teeth) and *Enchelyopus cimbrius* (Linnaeus, 1766) (see Gaemers, 1977, 1978).

Remark - For descriptions and pictures of the key species one is referred to the original descriptions of these species, of which the relevant literature can be found in the references. Additional information, for example photographs of lectotypes, is sometimes necessary. For *Gadichthys spatulatus* and *Trisopterus spectabilis* this can be found in Gaemers (1976b); see for *Gadichthys benedeni* and *Merlangius pseudaeaglefinus* also Gaemers & Schwarzahans (1973); for *Colliolus sculptus* see Gaemers (1973).

## COMPARISON OF OTOLITH BIOZONATION WITH BIOZONATIONS BASED ON OTHER FOSSIL GROUPS.

### Foraminifera

The planktonic foraminifera biozonation of Banner & Blow (1965) covering the time interval Late Oligocene - Holocene counts 23 biozones. This is more detailed than the Gadidae otolith biozonation but it is primarily based on circum-equatorial areas of the world. At higher and lower latitudes not all of these biozones are recognizable. Furthermore most of the Tertiary and Quaternary deposits of northwestern Europe have been formed in shelf environments in which planktonic foraminifera are rare or absent. So we have to rely mainly on benthonic foraminifera. Doppert (1975) gives a biozonation based on these foraminifera for the time interval Paleocene - Early Pleistocene which consists of 10 biozones; two of these can be subdivided into 2 or 3 subzones respectively. This biozonation is less detailed than the otolith biozonation. On the other hand von Daniels & Spiegler (1977) have divided the Hemmoorian - Gramian interval into 7 zones based on species of the genus *Uvigerina*, whereas only 3 biozones can be recognized with otoliths for the same interval up to now. The *Uvigerina* zonation, however, is essentially not based on lineages and therefore we may not expect that all these zones are recognizable outside their type area (viz. northwestern Germany), because of changing palaeoecological and palaeogeographical conditions. In several cases the stratigraphic ranges of the *Uvigerina* species may certainly be more extensive than found by von Daniels & Spiegler.

### Nannoplankton

In the North Sea Basin and surrounding areas calcareous nannoplankton assemblages are usually poor in species. Reworking frequently occurs and makes stratigraphical interpretations even more complicated (Martini & Müller, 1973). Rich nannoplankton assemblages allowing detailed biozonations are only known from the Danian (Early Paleocene) (pers. comm. Mrs. S. E. van Heck).

In the younger part of the Cenozoic continuous data are not yet available. In a preliminary report Martini & Müller (1973) have published six Miocene and one Pliocene nannoplankton assemblages, which represent only fragments of the Miocene and Pliocene. These assemblages can be correlated only partly with the Standard Nannoplankton Zones of Martini (1971). This standard zonation is very detailed: it has 26 biozones for the interval Early Oligocene - Holocene. Several of these zones can even be subdivided into subzones, thus providing even more detail (pers. comm. Mrs. S. E. van Heck).

The same difficulty as for the planktonic foraminifera applies to the nannoplankton namely the shallowness of the basin. Rich nannoplankton assemblages may only be expected in areas which are in good connection with the open ocean.

### Molluscs

For two reasons benthonic molluscs are not very suitable for biostratigraphic correlations. Firstly the evolutionary rate of most groups is low and secondly they are in a much higher degree tied to specific environments than planktonic organisms or fishes. In the Cenozoic of northwestern Europe molluscs are the most numerous fossils and that is the reason why they originally were used as guide fossils more than other groups. Zones based on molluscs are almost without exception based on ecological successions and therefore they have to be used with caution for biostratigraphic purposes. Only within restricted areas such zones may be regarded more or less as synchronous units. The

Early Pliocene - Early Pleistocene mollusc zones of Spaink (1975) are an example of this type of biozones.

#### MOST IMPORTANT RESULTS OBTAINED BY MEANS OF THE OTOLITH BIOZONES

1. The Rupelian is divided into three biozones; the youngest one can be predicted on the ground of the evolution of the *Colliolus* lineage. Sediments with a thickness of at least 130 m, known from the subsurface of the Netherlands probably belong partly or completely to this biozone.

2. Within the Chattian two biozones are distinguished. The so-called 'Sternberger Gestein' belongs to the younger one, most or all of the other Late Oligocene deposits in northwestern Germany belong to the older zone.

3. The Early Miocene belongs to three biozones. The upper part of the oldest one corresponds with the Vierlandian, the youngest one with the Edegem Sands. An intermediate biozone of which nothing is known at this moment can be predicted on the ground of the evolution of the *Colliolus* lineage.

4. The Late Miocene can be divided into four biozones. The youngest one (zone 13) represents a not earlier recognized time interval between the Syltian and the Kattendijkian. The key species of this biozone occurs in 'Bed 1' in Borgerhout, Belgium, and in the boring at Cuyk, the Netherlands, at depths between 78 and 94 m.

#### SYSTEMATICAL PART

Phylum PISCES  
Superclassis TELEOSTOMI (OSTEICHTHYES)  
Classis ACTINOPTERYGII  
Subclassis TELEOSTEI  
Ordo GADIFORMES  
Familia GADIDAE  
Subfamilia RANICEPSINAE  
Genus *Palaeoraniceps* Gaemers, 1976

*Palaeoraniceps gramensis* n. sp.

Plate 1, fig. 1a - d

*Holotype* - Plate 1, fig. 1a - d, coll. Geological Museum Copenhagen MGUHVP 2800.

*Locus typicus* - boring at Gram, Denmark.

*Stratum typicum* - Glauconite Clay, Gram Clay Formation, Gramian, Late Miocene, sample 51, depth 23.50 - 24.00 m below surface. The Glauconite Clay in the boring at Gram is a 3 metres thick deposit found at a depth of 25.50 to 22.50 m. 'Genetically it seems best to consider it the basal layer of the Gram Clay. The very few fossils known from the Glauconite Clay do not go against this' (Rasmussen, 1966).

*Derivatio nominis* - Named after the type locality.

*Diagnosis* - A very thick and compact *Palaeoraniceps* species (as far as adult otoliths are concerned).

No angles. Outline egg-shaped (oval). Dorsal rim irregularly and coarsely knobbed. Sulcus clearly bent toward ventral side.

*Description of holotype* - Otolith strong and medium-sized. Outline egg-shaped (oval) without angles. Ventral and dorsal rims rather thin. Regularly bent ventral rim with many small and low knobs. Irregular dorsal rim with fewer, much larger knobs. Caudal and rostral ends rounded.

Inner surface slightly convex. Sulcus acusticus inframedial, wide, shallow and rather short; clearly bent toward ventral side. Shape of sulcus and colliculi typical for *Palaeoraniceps*: rims of cauda nearly straight, rims of ostium curved; ostial and especially caudal colliculum angular near collum. Collum narrower than ostium and cauda; it is a groove with a uniform width. Crista superior sharp and high, especially the middle part of it. Crista inferior low and wide, but nevertheless distinct. Large and deep area intersected by long but vague furrows. Ventral furrow indistinct. Small furrows coming from ventral rim do not traverse ventral furrow.

Outer surface strongly convex; in general markedly sculptured. Caudal and rostral ends less sculptured. Slightly behind the middle a large and high cluster of mainly oval knobs. Peripheral knobs perpendicular to the rims.

*Material* - Only 1 sagitta, the holotype. L: 6.97 mm; H: 4.20 mm; T: 2.07 mm.

*Distribution* - Late Miocene, Gramian.

*Discussion* - This species is the most thickset form of the *Palaeoraniceps* lineage known up to now. It fits well in the general pattern of the evolution of lineages of codfish otoliths and probably represents the last part of phylogenetic stage 4 of the *Palaeoraniceps* lineage. Therefore we may expect that the L/H and L/T diagrams shows retrograde (i.e. concave) curves (Gaemers, 1976a). This means that juvenile otoliths of this species presumably are distinctly more slender and thinner. Thus it is quite possible that the juvenile otolith described below as *Palaeoraniceps* sp. also belongs to *P. gramensis*. Unfortunately this idea can not yet be proven, because no intermediate ontogenetic stages of this species are available at this moment.

The new species is the fourth known from the *Palaeoraniceps* lineage; the other species are the Middle Oligocene *P. tuberculosus* (Koken, 1884), the Late Oligocene *P. supraoligocaena* (Weiler, 1942) and the Early Miocene *P. regularis* Gaemers, 1976.

*Palaeoraniceps* sp.

Plate 1, fig. 2a - d

*Description* - One small juvenile otolith. Outline oblongly pear-shaped with pointed rostral and caudal angles. Ventral rim rounded, thick, regularly bent, and with some distinct knobs. Dorsal rim almost completely smooth, rather sharp, and much thinner than ventral rim. Dorsal rim regularly bent, most strongly in the anterior part.

Inner surface slightly convex. Sulcus acusticus supramedial, wide and shallow; bent toward ventral side. Rims of cauda and ostium straight or only slightly bent. Collum relatively wide. Crista superior well-developed, crista inferior less pronounced and more rounded, but nevertheless distinct. Deep area occupying complete dorsal part of inner surface. Middle part of ventral furrow distinct, to the front changing into a relatively large depression. Some small furrows clearly traverse ventral furrow.

Outer surface strongly convex; anterior and posterior parts nearly smooth, middle part markedly sculptured. Patterns of furrows mainly perpendicular to the long axis of the otolith. Thickest part

of otolith at the ventral side.

*Material* – 1 juvenile sagitta, Gram Clay Formation, boring at Gram, Denmark, sample 22, depth 9.50 - 9.90 m below surface, coll. Geological Museum Copenhagen MGUHVP 2801. L: 2.75 mm; H: 1.32 mm; T: 0.72 mm.

*Distribution* – Late Miocene, Gramian.

*Discussion* – The sulcus is not yet completely developed in the juvenile specimen and therefore it can not be used for an exact genus identification. The shape of the outline had definitely more resemblances with *Palaeoraniceps* than with *Raniceps*.

#### Subfamilia GADINAE

Genus *Colliolus* Gaemers & Schwarzahns, 1973

*Colliolus minutulus* n.sp.

Plate 1, fig. 3a - d – 6a - b

≪ genus *Gadidarum* ≫ *parvus* (Gaemers, 1976) forme trapue. – Steurbaut & Herman, 1978, p. 308, pl. 3, fig. 7 - 12 (registration numbers P.2649 - P.2654).

non ≪ genus *Gadidarum* ≫ *parvus* (Gaemers, 1976) forme typique. – Steurbaut & Herman, 1978, p. 308, pl. 3, fig. 1 6 (registration numbers P.2497, P.2500, P.2501, P.2503 - 2505).

*Holotype* – Plate 1, fig. 3a - d, 4a - b, coll. RGM 176 192, coll. M. van den Bosch.

*Paratypes* – from the type locality: Plate 1, fig. 5a - b, coll. RGM 176 193; Plate 1, fig. 6a - b, coll. RGM 176 195, coll. M. van den Bosch. Paratypes from the Nucula Clay at Vliermaal: coll. RGM 176 196, coll. A. W. Janssen.

*Locus typicus* – Willinkbeek at Ratum near Winterswijk, province of Guelders, the Netherlands, coordinates X = +96.075, Y = -19.620; locality nr. 41F.3-94.

*Stratum typicum* – Middle Oligocene; lower part of the Brinkheurne Member, ca. 2.50 m above its base.

*Derivatio nominis* – *minutulus* (Latin) = very small. Named after the very small size of the otoliths.

*Diagnosis* – A very small, thickset and barely sculptured *Colliolus* species. Colliculi small and of the same size, lying closely together. Postdorsal angle well-developed. Junction of ventral and dorsal rims at caudal end always forms a large angle. Caudal and rostral ends more or less rounded, never pointed. Ventral and dorsal rims slightly sculptured. Not bent along long axis.

*Description of holotype* – Otolith thick, very small and compact. Outline pear-shaped. Ventral and dorsal rims slightly sculptured, especially in the middle part. Both rims rounded and rather thick. Ventral rim regularly bent. Dorsal rim more strongly bent than ventral rim. Postdorsal angle well-developed; anterior part of dorsal rim regularly bent. Caudal and rostral ends more or less rounded. Junction of ventral and dorsal rims at caudal end forms a large angle of ca. 60°. Thus caudal end seems to be truncated.

Inner surface convex. Sulcus acusticus rather long and narrow, and slightly bent with convex side to dorsal rim. Widest parts of sulcus at the places where the colliculi are situated. Crista inferior and caudal part of crista superior well-developed. Cauda only slightly longer than ostium. Cauda slightly bent with convex side to dorsal rim. Ostium straight. Collum small. Sharp and deep groove below collum. Distinct oval colliculi fill only about half of the surface of the sulcus; they are small and of the same size and lie closely together in the centre of the inner surface. Rather distinct, triangular area. Ventral furrow indistinct, somewhat more pronounced at the posterior part. Weak

small furrows and knobs, especially along ventral rim.

Outer surface slightly convex along long axis, clearly convex along height axis; distinctly sculptured in the middle, smooth at the ends. Some relatively large knobs and clear furrows form an irregular pattern.

*Material* - 11 sagittas, lower part of Brinkheurne Member (ca. 2.50 m above its base), Willinkbeek at Ratum near Winterswijk, province of Guelders, the Netherlands (a short distance W of boring 41F.3-65), coll. RGM 176 192 - 176 195, coll. M. van den Bosch; 6 sagittas, Nucula Clay, 0.30 - 1.80 m above its base, sandpit Mommen, Vliermaal, province of Limburg, Belgium, coll. RGM 176 196, coll. A. W. Janssen. L: 1.68 mm, H: 0.94 mm, T: 0.43 mm (holotype); L: 1.61 mm, H: 0.92 mm, T: 0.41 mm (Willinkbeek); L: 1.60 mm, H: 0.89 mm, T: 0.35 mm (Willinkbeek); L: 1.23 mm, H: 0.69 mm, T: 0.31 mm (Vliermaal); L: 1.12 mm, H: 0.62 mm, T: 0.26 mm (Vliermaal); L: 1.06 mm, H: 0.62 mm, T: 0.26 mm (Vliermaal); L: 0.74 mm, H: 0.43 mm, T: 0.18 mm (Vliermaal).

*Distribution* - Lower part of Middle Oligocene (Rupelian) deposits.

*Variation* - A predorsal angle can be present and can be as strongly developed as postdorsal angle. The angle which is formed by the junction of ventral and dorsal rim at the caudal end can be distinctly smaller or larger than 60°, but is never smaller than ca. 50°. The angle which is formed by the junction of the rims at the rostral end can also vary considerably. The part of the dorsal rim between postdorsal angle and caudal end mostly is straight; it is often concave when the postdorsal angle is strongly developed. The sculpturing which is usually weak, can sometimes be strong, especially on the dorsal part of the inner surface.

*Discussion* - There are many clear and constant differences between the otoliths of *Colliolus parvus* and this new species. The shape and size of the colliculi, the L/H-ratio and the maximum size of the otoliths seem to be the most important characters in this respect. The differences between the two species are certainly not as small as suggested by Steurbaut & Herman (1978).

Moreover, both forms always occur at different stratigraphical horizons: *C. minutulus* occurs in the lower part of the Rupelian Boom Clay and *C. parvus* in the upper part of it (see also Steurbaut & Herman, 1978; Gaemers & van Hinsbergh, 1978). According to Steurbaut & Herman one specimen of the typical form of *C. parvus* occurs in an older stratum (Steendorp 26) than the otoliths which I describe here as the new species *C. minutulus*. Unfortunately they do not give a picture of this specimen, but there is a good probability, I think, that it belongs to the latter species.

Without doubt it can be concluded from the different stratigraphic range that the otoliths of *C. parvus* and *C. minutulus* belonged to different populations of fishes as Steurbaut & Herman suggest, but I can not agree with their interpretation that these populations belonged to the same species. In my opinion *C. minutulus* is the forerunner species of *C. parvus* and it fits completely in the evolutionary pattern of the *Colliolus* lineage.

#### Genus *Pseudocolliolus* n. gen.

*Type species* - *Pseudocolliolus cuykensis* n. sp.

*Diagnosis* - A genus of the subfamily Gadinae with relatively thin otoliths which are not or only slightly bent along the long axis. Outline pear-shaped or oblongly pear-shaped, with a rounded rostral end and a pointed caudal end. Predorsal angle is most pronounced angle. Postdorsal angle more weakly developed or absent. Sulcus acusticus shaped as in the genus *Colliolus*. Ventral and

dorsal rims are about equally thick and sharp; thickest part of otoliths on the average situated medially; the latter characteristics also occur in the genera *Gadichthys* and *Gadiculus*.

*Derivatio nominis* - Named *Pseudocolliolus* because of the resemblance with the genus *Colliolus*.

*Distribution* - Late Miocene: Syltian and latest Late Miocene. *Pseudocolliolus syltensis* (Gaemers & Schwarzahans MS) Syltian. *Pseudocolliolus cuykensis* n.sp. latest Late Miocene.

*Discussion* - No recent representatives of this genus are known to exist. Some characteristics of this fossil genus are in common with *Colliolus*, others with *Gadichthys* and *Gadiculus*. Therefore it is difficult to decide from which older genus it has descended. If we may consider the sulcus to be the most important characteristic in this respect, *Pseudocolliolus* is more closely allied to *Colliolus* than to *Gadichthys* and *Gadiculus*. Yet there is another possibility. *Gadidarum venustus* (Koken, 1891) namely has most characteristics in common with the two *Pseudocolliolus* species, and it seems also to be an intermediate form between *Colliolus* on the one hand and *Gadichthys* and *Gadiculus* on the other hand. Thus it is quite possible that *G. venustus* belongs to the forerunner lineage of *Pseudocolliolus*.

It is sure now that *G. venustus* is a good species, for I have seen adult otoliths of this species from the same boring at Gram from which the two above described *Palaeoranceps* specimens originate. This disproves my former idea (Gaemers, 1976a, p. 513) that the small specimens of *G. venustus* might belong to *Gadichthys miocenicus* (Heinrich, 1969) of which only adult otoliths are known to me.

*Pseudocolliolus cuykensis* n. sp.

Plate 1, fig. 7a - d, 9a - d, 10a - b

*Holotype* - Plate 1, fig. 7a - d, coll. RGM 176 197, leg. RGD.

*Paratypes* - see section Material.

*Locus typicus* - boring 46A/147 (RGD boring), Cuyk, on the road to Beers, 1 km east of Cuyk (coordinates X = 187,500, Y = 415,940), province of North-Brabant, the Netherlands.

*Stratum typicum* - latest Late Miocene, sample 69, depth 83 - 84 m below surface.

*Derivatio nominis* - Named after the type locality.

*Diagnosis* - A slender and large *Pseudocolliolus* species with distinct allometric growth. Adult otoliths are much more slender and thinner than juvenile ones. The larger specimens are strongly sculptured.

*Description of holotype* - Otolith rather fragile and medium-sized. Outline oblongly pear-shaped with a rounded rostral end and a pointed caudal end. Entire outline clearly knobbed. Highest part of the otolith far to the front. Anterior part of ventral rim regularly and strongly bent, posterior part straight. Distinct predorsal and postdorsal angles (predorsal angle most strongly pronounced). Parts of dorsal rim between dorsal angles and caudal and rostral ends straight. More and smaller knobs along dorsal rim than along ventral rim. Both rims are about equally sharp and thick.

Inner surface only slightly convex. Sulcus acusticus medial and nearly straight, formed as in the genus *Colliolus*: rather narrow and deep, and with a long collum; below the collum a sharp and deep furrow. Crista superior well-developed above cauda and collum. Crista inferior rounded and much less pronounced. Large area completely intersected by long sharp furrows. Ventral furrow rather distinct; especially in the anterior part far from the ventral rim. Small, sharp furrows from ventral rim traverse ventral furrow.



Outer surface slightly concave in length direction, concave in height direction. A medial ridge forms the thickest part of the otolith. Entire outer surface strongly sculptured except for the medial ridge. The furrows and knobs are oriented mainly perpendicular to the rims.

**Material** – All sagittas but one from boring 46A/147, 1 km east of Cuyk: 1 sagitta, sample 64, depth 78 - 79 m, coll. RGM 176 198; 5 sagittas, sample 66a, depth 80 - 81 m, coll. RGM 176 199; 16 sagittas, sample 67, depth 81 - 82 m, coll. RGM 176 200, 176 201 (broken), 176 202; 20 sagittas, sample 68, depth 82 - 83 m, coll. RGM 176 203 - 176 206; 29 sagittas, sample 69, depth 83 - 84 m, coll. RGM 176 197, 176 207 - 176 211; 15 sagittas, sample 70, depth 84 - 85 m, coll. RGM 176 212 - 176 215; 34 sagittas, sample 72, depth 86 - 87 m, coll. RGM 176 216 - 176 220; 20 sagittas, sample 73, depth 87 - 88 m, coll. RGM 176 221 - 176 224; 3 sagittas, sample 75, depth 89 - 90 m, coll. RGM 176 225 - 176 226; 5 sagittas, sample 76a, depth 90 - 91 m, coll. RGM 176 227; 3 sagittas, sample 79, depth 93 - 94 m, coll. RGM 176 228; 1 sagitta, 'Bed 1', temporary exposure for the construction of the E3 motorway (Kleine Ring), Foorplein, Borgerhout, Antwerp, Belgium, coll. RGM 176 229, coll. M. van den Bosch. L: 4.35 mm, H: 2.13 mm, T: 0.75 mm (holotype); L: 4.31 mm, H: 2.17 mm, T: 0.75 mm; L: 4.13 mm, H: 2.00 mm, T: 0.75 mm; L: 3.47 mm, H: 1.72 mm, T: 0.58 mm; L: 3.10 mm, H: 1.59 mm, T: 0.55 mm; L: 2.47 mm, H: 1.35 mm, T: 0.44 mm; (L: 6.04 mm), H: 3.10 mm, T: 1.14 mm.

**Distribution** – Latest Late Miocene.

**Variation** – Equally long specimens can vary rather much in their L/H and L/T ratios. Predorsal and postdorsal angles can be much less developed than in the holotype. Sometimes both angles are even missing. In large specimens the postdorsal angle is often poorly developed or absent. The predorsal angle is sometimes more strongly pronounced than in the holotype. The rostral end is usually well-rounded, but sometimes it is pointed. The highest part of the otolith can be situated somewhat more to the front or to the back; this seems to be correlated with the strongest bend in the ventral rim. The caudal end which is usually pointed may be slightly truncated in juvenile specimens.

**Ontogeny** – The ontogeny of this species shows distinct allometric growth. Adult specimens are clearly more slender than juvenile ones.

? Familia GADIDAE

Genus *Ensigadus* n. gen.

**Type species** – *Ensigadus ensiformis* (Steurbaut & Herman, 1978) (Plate 1, fig. 8a - d).

**Diagnosis** – An extinct genus with elongated, nearly flat otoliths. Ventral rim is a sharp edge, dorsal rim rounded. Ventral rim weakly twisted along the long axis. Dorsal rim with only one (middorsal) angle which probably developed out of a postdorsal angle. Sulcus acusticus supramedial, especially in the anterior part. Ostium and cauda closely together and not clearly separated. Anterior part of ostium narrowed.

**Derivatio nominis** – *Ensis* (Latin) = sword. Named after the sharp ventral rim.

**Distribution** – Middle Oligocene (Rupelian), lower part of the Boom Clay.

**Discussion** – No known genus of the recent Gadinae possesses a sharp ventral rim. For this reason it is obvious that *E. ensiformis* belongs to an extinct genus. Up to now only one other fossil genus is known to have a sharp ventral rim, viz. *Protocolliolus* Gaemers, 1976, which is represented by the species *P. eocenicus* (Frost, 1925). The outline of *Protocolliolus* however resembles closely that of *Colliolus*. The outline of *Ensigadus* otoliths and the sulcus are much more like the genus *Merlangius*.

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Plate I

- Fig. 1a - d *Palaeoraniceps gramensis* n. sp. Holotype.  
Late Miocene, Gramian, Glauconite Clay, boring at Gram, depth 23.50 - 24.00 m.  
Coll. Geol. Mus. Copenhagen MGUHVP 2800. 10 x.
- Fig. 2a - d *Palaeoraniceps* sp.  
Late Miocene, Gramian, Gram Clay, boring at Gram, depth 9.50 - 9.90 m. Coll.  
Geol. Mus. Copenhagen MGUHVP 2801. 15 x.
- Fig. 3a - d, *Colliolus minutulus* n. sp. Holotype.  
4a, b Middle Oligocene, Rupelian, lower part of Brinkheurne Member, Willinkbeek at  
Ratum. Coll. RGM 176 192. 15 x.
- Fig. 5a, b *Colliolus minutulus* n. sp. Paratype.  
Middle Oligocene, Rupelian, lower part of Brinkheurne Member, Willinkbeek at  
Ratum. Coll. RGM 176 193. 15 x.
- Fig. 6a, b *Colliolus minutulus* n. sp. Paratype.  
Middle Oligocene, Rupelian, lower part of Brinkheurne Member, Willinkbeek at  
Ratum. Coll. RGM 176 194. 15 x.
- Fig. 7a - d *Pseudocolliolus cuykensis* n. sp. Holotype.  
Latest Late Miocene, sample 69, depth 83 - 84 m, boring 46A/147 at Cuyk. Coll.  
RGM 176 197. 10 x.
- Fig. 8a - d *Ensigadus ensiformis* (Steurbaut & Herman, 1978). Holotype.  
Middle Oligocene, Rupelian, Bed 15, Steendorp. Coll. IRSNB - P. 2661. 10 x.
- Fig. 9a - d *Pseudocolliolus cuykensis* n. sp. Paratype.  
Latest Late Miocene, sample 67, depth 81 - 82 m, boring 46A/147 at Cuyk. Coll.  
RGM 176 201. 15 x.
- Fig. 10a, b *Pseudocolliolus cuykensis* n. sp. Paratype.  
Latest Late Miocene, sample 73, depth 87 - 88 m, boring 46A/147 at Cuyk. Coll.  
RGM 176 222. 10 x.

Plate I

