# Fish Otoliths from the Middle Miocene of Kienberg at Mikulov, Czech Republic, Vienna Basin: their paleoenvironmental and paleogeographic significance

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## Abstract

Sixty-three otolith-based species were recorded in the Kienberg-vineyard section (northwestern part of the Vienna Basin), ten of which are new for the Central Paratethys. The assemblage contains the first fossil records of the extant species *Scorpaena notata* and *Spondyliosoma cantharus*. It correlates with the survey of the foraminifera in the present study, implying a Late Langhian (uppermost Lower Badenian and the Middle Badenian) age for the Kienberg Section. The section provides the richest and most diverse otolith association of that age for the Vienna Basin. Actualistic analysis of the otoliths indicates open marine, open infralittoral sedimentary conditions varying between 30 and 80 m depth with sandy-muddy/sandy bottoms and possibly seagrass beds, in a subtropical climate with gradual upwards cooling. This cooling is documented by the markedly higher diversity of gadoids in contrast with the lowest Badenian of the Central Paratethys and may reflect the decline of the so-called climatic optimum in the Miocene of Middle Europe. The dominance of Atlantic and Atlantic-Mediterranean taxa indicates an open communication with these domains and confirms the idea of the still functioning trans-dinaride corridor.

**Keywords**: Teleostei, otoliths, Central Paratethys, Wiener Becken, Late Langhian (Middle Badenian), paleogeography.

## Résumé

L'étude des otolithes a permis d'identifier soixante trois espèces de téléostéens dans la coupe des vignobles du Kienberg (République tchèque, partie nord-ouest du Wiener Becken), dont dix étaient inconnues de la Paratethys centrale. Les espèces actuelles *Scorpaena notata* et *Spondyliosoma cantharus* sont reconnues ici pour la première fois à l'état fossile. Cette association indique un âge Langhien (Badenien inférieur terminal et Badenien moyen), ce qui est confirmé par l'étude des foraminifères. Il s'agit de l'association la plus riche que l'on connaît de ce niveau du Wiener Becken. Une analyse de l'écologie actuelle des taxa représentés indique un environnement marin infralittoral à salinité normale, vers une profondeur entre 30 et 80 m, avec un sol sableux à boueux, et peut être des herbiers, sous un climat subtropical. Un refroidissement progressif est observé en montant dans la coupe. Ce refroidissement est indiqué par une diversité des Gadoides nettement plus haute que ce que l'on connaît du Badenien inférieur de la Paratethys centrale et pourrait refléter le déclin de ce qu'on appelle l'optimum climatique du Miocène moyen d'Europe centrale. La prépondérance de taxa à répartition actuelle atlantique et atlantico-méditerranéenne indique une communication ouverte vers ces domaines et confirme l'idée d'un corridor trans-dinaride toujours ouvert.

**Mots-clefs**: Teleostei, otolithes, Paratethys central, Wiener Bekken, Langhien terminal (Badenian moyen), paleogeographie.

## Introduction

The small field ridge of Kienberg, which is well marked in the landscape about 3.5 km E of Mikulov (Czech Republic, Southern Moravia, 48° 48. 370′ N; 016°41. 140′ E), is one of the most important and best known fossiliferous localities within the Vienna Basin. The locality is cited in the literature under different German and Czech transcriptions: Kienberg, Kienberk, Kinberk, Kimberk and Kimberg. The first German transcription is the original and most widely accepted one. The ridge is generally oriented to the NW/SE and Badenian (Langhian) deposits are exposed in an abandoned sandpit and in small outcrops in terraces of a vineyard on the western slope (Fig. 1). In the 1990s, many new temporary excavations were carried out in a section on the western slope aiming at recovering and preserving new mollusc material (these were private activities of O. KROUPA). At the same time rich shark tooth, bryozoan and otolith associations were discovered using a 0.4 mm mesh. The present study deals with otoliths sampled in the levels S1, S3, and S8 as well

Fig. 1 — General view of Kienberg Hill (author: Z. STRÁNÍK, June 2006); position of samples numbered as in the text.

as with otoliths from earlier investigations in the same stratigraphic positions (R. BRZOBOHATÝ, P. HOLEC, C. SVITÁK, R. MARQUET). Total weight of the investigated sediments exceeded 5 t.

## Geological and paleontological setting

During the Badenian regiostage, the Vienna Basin (paleogeographically the NW part of the Central Paratethys, Fig. 2) was controlled by a pull-apart tectonical regime. Underlying and marginal nappes of the Outer Flysch Belt units in southern Moravia were finally placed and subsidence in the basin followed allong NE-trending sinistral faults (e.g. STRÁNÍK et al., 1999). The Early Badenian was characterized by a far-reaching transgression and by connections of the Central Paratethys with the Mediterranean and Atlantic realms in the SW ("Transtethyan-Trench-Corridor" in Slovenia) and probably with the Indo-Pacific realm in the E. A shortening and emerging of the Slovenian connection and a widening of the connection with the Eastern Paratethys Konka Basin is proposed in the Late Badenian (RÖGL, 1998 *inter alii*). However, ILYINA *et al.* (2004) also consider the Slovenian corridor as a question mark in the Late Badenian (Middle Serravallian, Konkian).

The Lanžhot Formation in the northwestern part of the Vienna Basin, represented by calcareous clays, was deposited in the Lower Badenian. Higher up variegated beds, sands and algal sandstones and limestones of the Hrušky Formation (Middle and Upper Badenian) transgressively overlap the underlying Lanžhot Formation (ŠPIČKA, 1966). The Hrušky Formation outsteps with a clearly angular nonconformity on the Flysch Ždánice Unit at the northwestern margin of the basin (e.g. E of Mikulov).

In the vicinity of the Kienberg locality, the deposition (Fig. 3) begins with a chaotic coarse sand and block
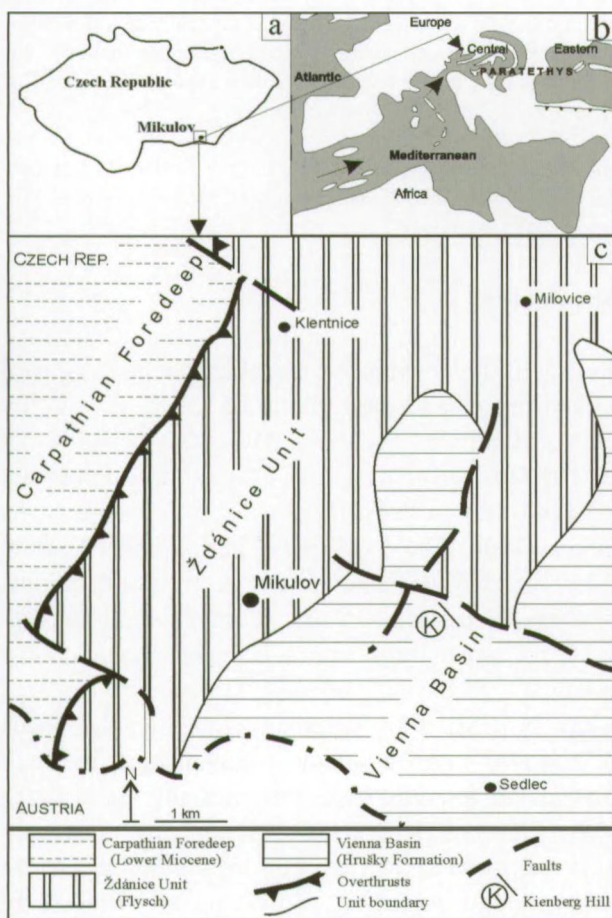


Fig. 2 — Geographical (a), paleogeographical (b – Middle Badenian, after RÖGL, 1998, modified), and geological (c – after STRÁNÍK *et al.*, 1999) position of Kienberg at Mikulov.
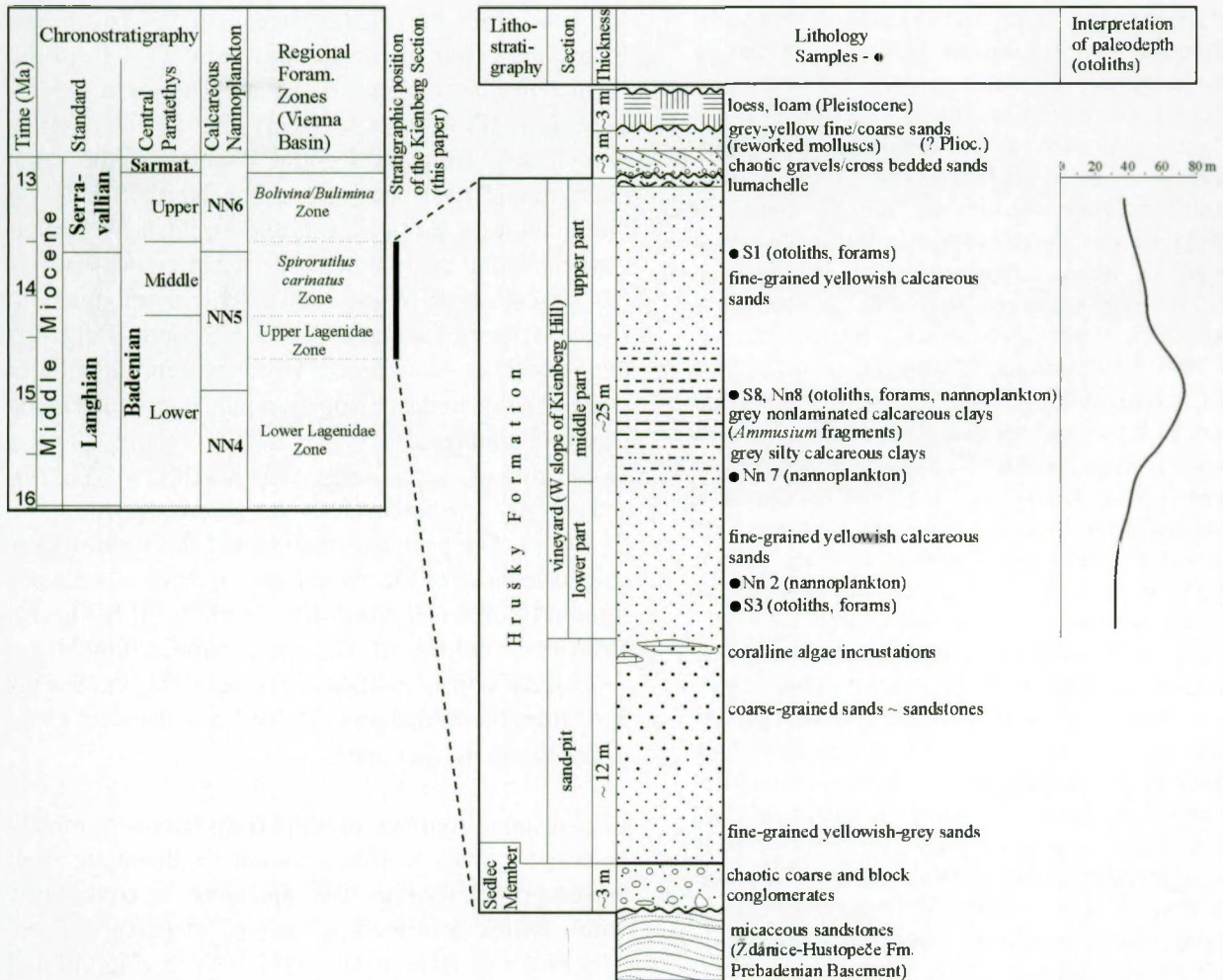
Fig. 3 — Middle Miocene chronostratigraphy and biostratigraphy (after GRADSTEIN *et al.*, 2004; KOVÁČ *et al.*, in press) – left. Stratigraphic position, lithostratigraphy and lithology of the Kienberg section, position of samples, and interpretation of paleodepth based on otoliths – right.

conglomerate of the Sedlec Member (ČTYROKÝ, 1993). Sands of the Hrušky Formation have been exploited in the previously mentioned sandpit crossing the southern part of Kienberg Hill. The base consists of fine-grained sands with *Chlamys flava* (DUB.), *Linga collumbella* (LM.) and *Corbula gibba* (OL.), higher up these alternate with coarse-grained sand and sandstone concretions containing *Glycymeris, Flabellipecten, Ostrea, Diloma, Ancilla,* and at the top with coralline algae sandstones alternating with "oyster and *Pecten* layers" (TEJKAL, 1968). The deposits in the sandpit have been variously considered to be Middle Badenian (TEJKAL, 1968; ČTYROKÝ, 1993) or Upper Badenian (BRESTENSKÁ & JIŘÍČEK, 1978) in age. The vertically and horizontally variable section continues in the western slope of the hill. Generally, the following succession of deposits prevails: in the lower part there are fine-grained yellowish calcareous sands rich in *Megacardita jouanneti* (BASTEROT) and other molluscs. They pass upward to sandy and silty grey calcareous clays

and finally to nonlaminated calcareous clays with mollusc fragments (*Amusium*) and sporadically with gypsum. In the upper part, the sandy component again increases into a fine-grained calcareous sand containing abundant molluscs. A lumachelle of mollusc fragments is locally developed at the top of the sands terminating the Badenian sedimentation. Chaotic gravels alternating with cross-bedded coarse/fine sands rest unconformably on the marine section. They contain only reworked molluscs (TOMAŠTÍK, 1981). The marine section in the vineyard of the western slope was considered to be Upper Badenian in age (STRÁNÍK *et al.*, 1999).

## Historical review

REUSS (1848) and HOERNES (1856, 1870) presented the Kienberg locality as a series of rich paleontological sites. TEJKAL (1956) summarized the early research history and

published a taxonomical study and synopsis of 98 bivalve species from the Kienberg sandpit. TEJKAL (1968) gave a revised list of the most abundant gastropods characteristic of the locality. According to TEJKAL, the sands in the sandpit "were deposited in an euhaline environment, which was well-aerated and generally of the aphytal shallow sublitoral zone, not very far from flat coast". In the following decades, the Kienberg fossils were described or depicted in many stratigraphical or taxonomical studies (e. g. STEININGER et al., 1978; ŠVAGROVSKÝ, 1981; TOMAŠTÍK, 1981 – Mollusca; BRESTENSKÁ & JIŘÍČEK, 1978 – Ostracoda; ZÁGORŠEK et al., 2004 – Bryozoa; KROH, 2005 - Echinoidea). ZÁGORŠEK et al. (l.c.) report 23 bryozoan species and very rare calcareous nannoplankton, represented by Coccolithus pelagicus and C. reticulofenestra, which may have been resedimented from the slope of the Kienberg Hill (presented under the name "Mikulov"). Bryozoans with encrusting growth forms support an interpretation of the original environment as shallow, warm seawater with normal salinity.

Otoliths from Kienberg were both taxonomically and environmentally evaluated by SCHUBERT (1902, 1905, 1906) based on museum collections and without a precise location in the field. SCHUBERT (1906) summarized 24 nominal taxa and interpreted the depositional environment of the locality as coastal, in which abundant sciaenid otoliths indicate the estuary of a great river. NOLF's (1981) taxonomical revision of SCHUBERT's material validated only 12 taxa. During recent investigations, "genus Sciaenidarum" fuchsi SCHUBERT, 1906 was not recorded again. This species, still accepted as valid in NOLF (1981, 1985) is here considered as dubious because of the very strong erosion affecting the holotype.

## Remarks on taxa requiring comments

### Material and abbreviations

A list of all otolith-based taxa from Kienberg and their distribution in the section is given in Table 1. The abbreviation "aff." in the binomen was used in the cases of well preserved material where specific identity could not be unequivocally determined. The abbreviation "cf." was inserted in cases where the poor preservation of otoliths did not allow an adequate specific identification. Thirteen species appear in open nomenclature due to too limited or too poorly preserved material. All identified species are pictured on the plates 1-9.

*Diaphus*. – Otoliths of this genus are rare in the Kienberg section, with only two species. *D. taaningi* NORMAN, 1930 represents the extant pseudo-oceanic species often found over shelves. Its fossil otoliths (Pl. 1, Figs 1-2) are relatively common in the European

Miocene from the Mediterranean to the North Sea Basin and occur in the Central Paratethys from the Karpatian till the Upper Badenian. The fossil species *D. kokeni* (PROCHAZKA, 1893) (Pl. 1, Figs 3-4) is known only from the Central Paratethys (the same stratigraphic distribution) and the North Sea Basin (Hemmoorian, Reinbekian), and could have similar environmental requirements as the previous species (BRZOBOHATÝ & NOLF, 2000). Other myctophid and *Diaphus* species are abundant in the Early Badenian deposits. They were probably not present in the later Badenian due to the paleogeographic conditions in the Central Paratethys.

*Gaidropsarus* cf. *vulgaris* (CLOQUET, 1824). – The only specimen lacks the anterior portion (Pl. 2, Fig. 1). The posterior portion and the ventral view resemble those of the present-day species *G. vulgaris* figured by NOLF & STEURBAUT (1989, Pl. 6, Fig. F). However, otoliths of *G. acuticaudatus* GAEMERS, 1973 mentionned by RADWAŃSKA (1992, Pl. 8, Figs 3, 4) from the Badenian of Poland, are also very close to the Kienberg specimen.

*Chelon* sp. – Fourteen otoliths from Kienberg mostly belong to juvenile fishes. Some of them are well preserved (Pl. 3, Figs 8-9) and may be conspecific with otoliths described as "genus Mugilidarum" sp. 1 by NOLF & STEURBAUT (1979, Pl. 5, Fig. 1) and "genus Mugilidarum" sp. by STEURBAUT (1984, Pl. 30, Fig. 11) from the Serravallian of the Aquitaine Basin. A good specific diagnosis is not possible on the basis of young specimens only. *Chelon* otoliths have not yet been reported from the Central Paratethys. However, in the Western Paratethys, a *Chelon* species is present in the terminal Oligocene (REICHENBACHER & WEIDMANN, 1992).

*Tylosurus wetzelsdorfensis* (WEINFURTER, 1952). – The Kienberg specimen (Pl. 3, Fig. 13) is very well preserved and completes our knowledge of the otolith morphology of the species, which was hitherto based on the relatively eroded holotype (WEINFURTER, 1952, Pl. 2, Fig. 6). The otolith is ellipsoidal in shape becoming increasingly elongate anteriorly. All rims are finely undulated or crenated. The sulcus runs medially with a not clearly divided colliculum, the cauda is three times as long as the nearly U-shaped ostium and closes near the posterior rim. The entire sulcus and the slightly deepened dorsal portion of the inner face bear fine groves and small tubercules. The inner face is convex, the outer face is deeply concave, slightly thickened anteriorly and posteriorly. This

| Families | Taxa<br>**bold** = extant species<br>\* = extant species documented by fossils otoliths for the first time | Iconography | Kienberg vineyard<br>Number of specimens | | |
|---|---|---|---|---|---|
| | | | Lower part (S3) | Middle part (S8) | Upper part (S1) |
| HETERENCHELYIDAE | *Panturichthys subglaber* (SCHUBERT, 1906) | Pl. 1, Figs 6-8 | 1 | 1 | 10 |
| CONGRIDAE | *Rhynchoconger pantanellii* (BASSOLI & SCHUBERT, 1906) | Pl. 1, Fig. 5 | 1 | 1 | 8 |
| ARIIDAE | *Arius* sp. | Pl. 1, Fig. 10 | | | 1 |
| SYNODONTIDAE | *Saurida germanica* (WEILER, 1942) | Pl. 1, Figs 12-13 | 3 | | 6 |
| MYCTOPHIDAE | *Diaphus kokeni* (PROCHAZKA, 1893) | Pl. 1, Figs 3-4 | 1 | 1 | 5 |
| | ***Diaphus taaningi* NORMAN, 1930** | Pl. 1, Figs 1-2 | | 3 | 5 |
| BREGMACEROTIDAE | *Bregmaceros albyi* (SAUVAGE, 1880) | Pl. 1, Fig. 9 | | 1 | |
| MORIDAE | *Physiculus* aff. *huloti* POLL, 1953 | Pl. 1, Fig. 11 | 5 | | 6 |
| LOTIDAE | *Gaidropsarus* cf. *vulgaris* (CLOQUET, 1824) | Pl. 2, Fig. 1 | | | 1 |
| PHYCIDAE | ***Phycis blennioides* (BRÜNNICH, 1768)** | Pl. 2, Fig. 4 | | | 1 |
| | *Phycis musicki* COHEN & LAVENBERG, 1989 | Pl. 2, Fig. 3 | 3 | | 1 |
| MERLUCIIDAE | *Merluccius* aff. *merluccius* (LINNAEUS, 1758) | Pl. 3, Fig. 14 | 5 | | 2 |
| GADIDAE | *Gadiculus labiatus* (SCHUBERT, 1905) | Pl. 2, Fig. 2 | | 1 | 1 |
| | *Micromesistius* cf. *arcuatus* RADWANSKA, 1992 | Pl. 2, Fig. 5 | | | 1 |
| | *Trisopterus sculptus* (KOKEN, 1891) | Pl. 3, Figs 3-7 | 27 | 7 | 77 |
| CARAPIDAE | *Carapus* aff. *acus* (BRÜNNICH, 1768) | Pl. 3, Figs 10-12 | 13 | 10 | 49 |
| | *Echiodon* sp. | Pl. 3, Fig. 2 | | | 2 |
| BYTHITIDAE | *Grammonus* sp. | Pl. 3, Fig. 1 | | | 1 |
| MUGILIDAE | *Chelon* sp. | Pl. 3, Figs 8-9 | 3 | | 11 |
| ATHERINIDAE | *Atherina austriaca* SCHUBERT, 1906 | Pl. 3, Figs 16-17 | 2 | | 1 |
| BELONIDAE | *Tylosurus wetzelsdorfensis* (WEINFURTER, 1952) | Pl. 3, Fig. 13 | 1 | | |
| HEMIRAMPHIDAE | *Hemiramphus miocenicus* (WEINFURTER, 1952) | Pl. 3, Fig. 15 | 2 | | 2 |
| HOLOCENTRIDAE | *Sargocentron* sp. | Pl. 4, Figs 1-2 | | 6 | 16 |
| MYRIPRISTIDAE | *Myripristis* aff. *verus* STEURBAUT, 1979 | Pl. 4, Fig. 3 | | 3 | 20 |
| SCORPAENIDAE | *\*Scorpaena notata* RAFINESQUE, 1810 | Pl. 4, Figs 5-6 | | 1 | |
| PERISTEDIIDAE | *Peristedion* cf. *cataphractum* (LINNAEUS, 1758) | Pl. 4, Fig. 4 | | 1 | |
| Percoidei inc. sed. | "genus Percoideorum" *tietzei* (SCHUBERT, 1906) | Pl. 4, Fig. 12 | 1 | | 1 |
| MORONIDAE | *Morone* sp. | Pl. 4, Fig. 14 | 1 | | 2 |
| PRIACANTHIDAE | *Pristigenys rhombicus* (SCHUBERT, 1906) | Pl. 4, Fig. 13 | 7 | | 17 |
| MALACANTHIDAE | "genus Malacanthidarum" *postdorsalis* (STEURBAUT, 1979) | Pl. 4, Fig. 16 | | | 1 |
| HAEMULIDAE | *Brachydeuterus speronatus* (BASSOLI, 1906) | Pl. 5, Figs 7-10 | 63 | 4 | 15 |
| | *Pomadasys* aff. *incisus* (BOWDICH, 1825) | Pl. 5, Fig. 11 | | | 11 |
| SPARIDAE | ***Boops boops* (LINNAEUS, 1758)** | Pl. 5, Figs 15-16 | | 7 | 17 |
| | ***Dentex gibbosus* (RAFINESQUE, 1810)** | Pl. 5, Figs 17-18 | 24 | 3 | 57 |
| | *Dentex* aff. *maroccanus* VALENCIENNES, 1830 | Pl. 5, Figs 12-14 | 17 | 4 | 66 |
| | *Diplodus* cf. *puntazzo* (CETTI, 1777) | Pl. 6, Fig. 1 | | | 1 |
| | *Diplodus* sp. | Pl. 6, Fig. 4 | 2 | | 3 |
| | ***Lithognathus mormyrus* (LINNAEUS, 1758)** | Pl. 6, Figs 6-7 | 8 | 5 | 23 |
| | *Oblada* aff. *chainei* STEURBAUT & JONET, 1982 | Pl. 6, Figs 13-14 | 2 | | |
| | *Pagrus* sp. | Pl. 6, Fig. 5 | | | 5 |
| | *Pagellus* cf. *acarne* (RISSO, 1806) | Pl. 6, Figs 2-3 | | 3 | |
| | ***Pagellus erythrinus* (LINNAEUS, 1758)** | Pl. 6, Figs 8-9 | | 1 | 1 |
| | *\*Spondyliosoma cantharus* (LINNAEUS, 1758) | Pl. 6, Figs 10-12 | 118 | 16 | 209 |
| SCIAENIDAE | ***Argyrosomus regius* (ASSO, 1801)** | Pl. 7, Figs 1-2 | 1 | | 5 |
| | *Sciaena* cf. *irregularis* (KOKEN, 1884) | Pl. 7, Fig. 4 | | | 1 |
| | *Sciaena rybnicensis* RADWANSKA, 1992 | Pl. 7, Fig. 3 | | | 2 |
| | *Umbrina* cf. *cirrosa* (LINNAEUS, 1758) | Pl. 7, Fig. 6 | | | 8 |
| | *Umbrina* aff. *ronchus* VALENCIENNES, 1843 | Pl. 7, Fig. 5 | | | 1 |
| CEPOLIDAE | ***Cepola rubescens* LINNAEUS, 1766** | Pl. 7, Figs 7-8 | 11 | 4 | 20 |
| CARANGIDAE | *Trachurus* aff. *picturatus* (BOWDICH, 1825) | Pl. 7, Figs 13-15 | 5 | 3 | 2 |
| TRACHINIDAE | ***Trachinus draco* LINNAEUS, 1758** | Pl. 7, Fig. 9 | | 1 | 4 |
| URANOSCOPIDAE | *Uranoscopus* sp. | Pl. 8, Fig. 1 | | | 2 |
| GOBIIDAE | *Deltentosteus telleri* (SCHUBERT, 1906) | Pl. 8, Figs 2-5 | 3 | 4 | 23 |
| | *Gobius multipinnatus* (VON MAYER, 1852) | Pl. 8, Figs 6-8 | 205 | 88 | 513 |
| | *Lesueurigobius* aff. *vicinalis* (KOKEN, 1891) | Pl. 8, Figs 12-14 | 566 | 152 | 1088 |
| | *Oxyurichthys* sp. | Pl. 8, Fig. 15 | 22 | 8 | 43 |
| | *Priolepis* sp. | Pl. 8, Figs 9-11 | | | 12 |
| SPHYRAENIDAE | *Sphyraena* aff. *sphyraena* (LINNAEUS, 1758) | Pl. 9, Fig. 7 | | | 9 |
| CITHARIDAE | *Citharus lusitanicus* (JONET, 1973) | Pl. 9, Figs 8-9 | 1 | | 1 |
| BOTHIDAE | *Arnoglossus* sp. | Pl. 8, Fig. 16 | | | 2 |
| SOLEIDAE | *Buglossidium frequens* STEURBAUT, 1984 | Pl. 9, Fig. 11 | 1 | | |
| | ***Dicologlossa hexophthalma* (BENNETT, 1831)** | Pl. 9, Fig. 10 | | | 1 |
| | *Solea* sp. | Pl. 9, Fig. 12 | | | 1 |
| E = | 63 | | 1125 | 339 | 2494 |

Table 1 — List of teleost species represented by otoliths in the Badenian of the Kienberg section.

specimen is very close to otoliths of the present-day *T. crocodilus crocodilus* (PÉRON & LESUEUR, 1821) – see SMALE *et al.* (1995, Pl. 38, Figs D1-3). It differs in the more rounded outline and the very short rostrum and antirostrum. *T. wetzelsdorfensis* has only been reported from the Lower Badenian of the Styrian Basin. Some other very rare belonids were described from the Badenian of southern Poland (RADWAŃSKA, 1992). *Tylosurus* sp. from the Lower/Middle Miocene of Catalunya has a very high posterior portion (HOEDEMAKERS & BATLLORI, 2005). Also, there is a certain affinity to the holotype of "Otolithus (*Rhombus* ?) *minor*" SCHUBERT (1906, Pl. 19, Fig. 36), from the Badenian at Vöslau. SCHUBERT's specimen is slightly eroded and was accepted by NOLF, 1981, Pl. 2, Fig. 3) as "g. Hemiramphidarum" *minor*.

*Sargocentron* sp. – Pl. 4, Figs 1-2. More then twenty otoliths are poorly preserved, but undoubtedly conspecific with the specimen described by BRZOBOHATÝ (1994) as *Sargocentron* sp. from the Badenian (Upper Lagenidae Zone) at Gainfarn. These otoliths seem to be different from present-day and fossil species of the genus known to us. The insufficient material does not allow for any more precise systematic conclusions.

*Myripristis* aff. *verus* STEURBAUT, 1979. – Myripristid otoliths are usually poorly preserved in the fossil material. In the Kienberg collection, the myripristids are relatively abundant (twenty-three specimens) albeit mostly broken. Their ventral portion and dorsal rim (Pl. 4, Fig. 3) however, are closely related to those of the *M. verus* reported from the Badenian of Poland (RADWAŃSKA, 1992) and differ markedly from the other Paratethys species "g. Myripristinarum" *banaticus* (WEILER, 1950).

*Scorpaena notata* RAFINESQUE, 1810. – Two otoliths (Pl. 4, Figs 5-6) are compatible with those of the present-day species (Pl. 4, Figs 7-11). Their ventral rim is very regular and not as oblique as is the case with *S. edegemensis* GAEMERS, 1973, also known from the Badenian of Poland (RADWAŃSKA, 1992, Fig. 77, Pl. 16, Figs 1, 2). *Scorpaena* sp., also known from Gainfarn, is represented only by juvenile eroded specimens (BRZOBOHATÝ, 1994, Pl. 3, Figs 13, 14). Furthermore, skeletons of *S. prior* HECKEL in HECKEL & KNER,1861 and "*S. ensiger*" (JORDAN & GILBERT, 1919) are known from the Badenian at St. Margarethen (Burgenland, Austria) and from the Badenian at Pinczów (Poland) respectively (*fide* SCHULTZ, 1993).

*Peristedion* cf. *cataphractum* (LINNAEUS, 1758). – The Kienberg otolith figured in Pl. 4, Fig. 4 shows a juvenile morphology and is not very diagnostic. It is comparable with young otoliths of the present-day species (see HUYGEBAERT & NOLF, 1979, Pl. 4, Figs 24-26). This species lives in coastal waters as a juvenile before migrating into deeper waters as an adult. Fossil *P. cataphractum* otoliths occur e.g. in the Middle Miocene of Belgium (HUYGHEBAERT & NOLF, l. c.) and in the Tortonian at Monte Gibbio, Italy (NOLF & STEURBAUT, 1983). *Peristedion* otoliths are extremely rare in the Paratethys Miocene. Only one specimen of *P. cataphractum* was found in the Lower Badenian of the Carpathian Foredeep in Moravia (unpublished data).

"genus Malacanthidarum" *postdorsalis* (STEURBAUT, 1979). – This species was defined on the basis of a single otolith from the Saubrigues Marls (Langhian, Aquitaine). No other specimens were found during subsequent research in the Saubrigues Paleocanyon (NOLF & BRZOBOHATÝ, 2002). The Kienberg specimen (Pl. 4, Fig. 16) is well preserved and smaller than the holotype. However, diagnostic features such as the shape and division of the sulcus, the colliculi, the outline of the otolith and inner and ventral views correspond with the Saubrigues specimen. Only the caudal end of the holotype is more curved posteroventrally (STEURBAUT, 1979, Pl. 7, Fig. 11). A comparison with the present day species *Caulolatilus cyanops* POEY, 1866 (Fig. 7: O) justifies the placement of the fossil species within the family Malacanthidae. Furthermore, otoliths of *Branchiostegus doliatus* (CUVIER, 1830) – see SMALE *et al.* (1995, Pl. 68, Fig. F1) – are also very similar to the Kienberg specimen. Fossil otoliths of this family seem to be extremely rare in the Paratethys. Skeletons of malacanthids have already been recorded from the Middle Eocene of Northern Caucasus (e.g. BANNIKOV, 1997).

*Brachydeuterus speronatus* (BASSOLI, 1906). – A comparison between the *Brachydeuterus* otoliths from Kienberg (Pl. 5, Figs 7-10; more than one hundred well preserved specimens) and those from Mediterranean and Aquitaine localities (Pl. 5, Figs 1-6, Sallespisse, Aquitaine Basin) shows the same variability throughout the ontogeny. The typical "*speronatus*" morphology of the posterodorsal portion appears only in some large specimens from Aquitaine. This is a solid basis for synonymizing *B. speronatus* and *B. latior* (SCHUBERT, 1906), as allready presumed by NOLF & STEURBAUT (1983). The paper of BASSOLI

(1906) being anterior to the one of SCHUBERT (1906), *B. speronatus* is the prioritary name to be used. There is only one extant *Brachydeuterus* species, *B. auritus* (VALENCIENNES, 1832), which lives benthopelagic in tropical brackish and marine waters of the Eastern Atlantic from Morocco to Angola. The fossil species seems to have a wider climatic range.

*Oblada* aff. *chainei* STEURBAUT & JONET, 1982. – Two poorly preserved otoliths (Pl. 6, Figs 13-14) from Kienberg may belong to *O. chainei*. They differ from the nominal species in a less prominent anterodorsal portion. *Oblada* otoliths seem to be very rare in the Paratethys Miocene. Only one problematic specimen has been reported from the Badenian at Gainfarn (BRZOBOHATÝ, 1994).

*Trachurus* aff. *picturatus* (BOWDICH, 1825). – RADWAŃSKA (1992) reported relatively abundant otoliths of *T. elegans* JONET, 1973 from the Badenian of Poland. *Trachurus* otoliths from Kienberg (Pl. 7, Figs 13-15) differ from this fossil species in the morphology of the dorsal rim and the missing posterocaudal trough and notch. They more correspond to otoliths of the Recent *T. picturatus* (Pl. 7, Figs 10-12). However, the adult specimens are mostly eroded (Pl. 7, Fig. 13). Otoliths of *T.* aff. *picturatus* from the Redonian (LANCKNEUS & NOLF, 1979, Pl. 3, Figs 7-9) are shorter. Additional and better preserved material is required to make a more precise comparison.

*Oxyurichthys* sp. – The otoliths are relatively high with an undulated dorsal rim and prominent posterodorsal angle (Pl. 8, Fig. 15). The posterior rim is markedly concave, the anterior undulated, the smooth ventral field is bordered by a deep ventral furrow, running parallel to the slightly convex ventral rim. The sulcus is footprint-like with a small collicular swelling situated near the cauda/ostium division. The outer face is markedly convex and thickened in the ventral portion, the inner face slightly convex with a rather deep dorsal depression. The features mentioned show a marked affinity to those of the present-day species *O. papuensis* (VALENCIENNES, 1837) – see SMALE *et al.* (1995, Pl. 129, Fig. F1) – which can be distinguished by the lack of a collicular swelling. *O. papuensis* lives in the Indo-West Pacific region including the Red Sea. The Mediterranean record must be considered as a lessepsian immigrant. The genus *Oxyurichthys* has not yet been reported from the Central Paratethys.

*Priolepis* sp. – These otoliths (Pl. 8, Figs 9-11) are approximately quadrangular in shape with a markedly concave posterior rim and a slightly concave anterior rim, a highly rounded dorsal rim ending in a prominent posterodorsal projection. The sulcus is elliptic in shape and angled slightly antero-ventrally with an undivided single colliculum. No collicular swelling is visible. The inner face is slightly convex and smooth, the outer face is markedly convex, smooth and thickened in the ventral portion. The sulcus undoubtedly refers the otoliths to *Priolepis*. Otoliths of the present-day *P. cincta* (REGAN, 1908) – see SMALE *et al.* (1995, Pl. 129, Fig. H1) – a species also known from the Red Sea, are very similar. Fossil otoliths can be distinguished from those of the present-day species by a more prominent anterodorsal portion and a more convex dorsal rim. Otoliths described as *Gobius* sp. 6 from the Badenian at Gainfarn (BRZOBOHATÝ, 1994, Pl. 6, Fig. 17, non Figs 18-20) and *Gobius praetiosus* PROCHAZKA, 1893 from the Lower Badenian of the Transylvanian Basin (WEILER, 1950, pl. 4, Figs 27, ? 25; non PROCHAZKA, 1893) are conspecific with the Kienberg species.

*Sphyraena* aff. *sphyraena* (LINNAEUS, 1758). – In Kienberg deposits, sphyraenids are mainly represented by fragments of otoliths, lacking the anterior portion. A single well preserved specimen (Pl. 9, Fig. 7) resembles otoliths of the present day species *S. sphyraena* (see Pl. 9, Figs 1-6). It differs because of a more prominent anterodorsal angle, the straight dorsal rim and the right-angled ostial/caudal division in the crista superior. There are two other species mentioned in the Paratethys Badenian: *S.* aff. *afra* PETERS, 1884 represented by eroded or fragmentary specimens (RADWAŃSKA, 1992, with synonymy; BRZOBOHATÝ, 1994) and *S. hansfuchsi* SCHUBERT (1906, Pl. 18, Fig. 40) defined on the basis of a single subadult lectotype. Moreover, the *S.* cf. *hansfuchsi* otolith mentionned by WEINFURTER (1952, Pl. 2, Fig. 5) also concerns a juvenile specimen. For this reason the problem of the relationships between all the referred species could not be unequivocally resolved. Furthermore, teeth of *S. substriata* (MÜNSTER, 1846) are reported from the Badenian Korytnica Clay of Poland (SCHULTZ, 1979) and some other localities of the Vienna Basin (SCHULTZ *in* BRZOBOHATÝ & SCHULTZ, 1978).

## Stratigraphy

The interpreted stratigraphic position of the Hrušky Formation at Kienberg oscillates between Middle and Upper Badenian in older publications (see Introduction). Therefore, new samples of nannoplankton and foraminifers were collected (Fig. 3).

*The nannoplankton (processed by L. ŠVÁBENICKÁ)*: Sample Nn2 (clayey intercalation in the sands of the lower part of the section) yielded abundant and reasonably preserved nannofossils. In addition to Upper Cretaceous, Paleogene, and particularly Oligocene redepositions, the assemblage contains *Helicosphaera ampliaperta* (15), *H. mediterranea* (2), *H. vedderi* (2), *H. carteri, H. scissura, H. euphratis, Sphenolithus moriformis, Pontosphaera discopora, P. multipora, Braarudosphaera bigelowii* (10), *Reticulofenestra pseudoumbilicus, R. minuta, Cryptococcolithus mediaperforatus, Calcidiscus premacintyrei, Discoaster deflandrei, D. exilis, Coronocyclus nitescens, Syracosphaera sp., Rhabdosphaera* cf. *poculii* and *Umbilicosphaera rotula*. The *H. ampliaperta, C. premacintyrei* and *D. exilis* association suggests the upper part of the NN4 Zone, probably *S. heteromorphus* paracme.

Sample Nn7 (sandy clays from the boundary between the lower and middle part of the profile) contained identifiable nannofossils (ca 30 individuals/ 1 visual field of the microscope). The autochthonous component (cca 20% of the oryctocoenosis) is characterized by the relatively abundant species *H. carteri, R. pseudoumbilicus* and *C. premacintyrei*, also present are *Helicosphaera ampliaperta* (15), *H. mediterranea* (5), *H. scissura, H. euphratis, H. intermedia, Coronocyclus nitescens, C.* cf. *macintyrei, Umbilicosphaera rotula, Pontosphaera multipora, P. discopora, Sphenolithus moriformis, Triquetrorhabdulus carinatus* (reworked from the NN1-NN2), *Rhabdosphaera* cf. *poculii, Discoaster exilis* (1), and *Reticulofenestra minuta*. The *H. ampliaperta, C. premacintyrei* and *D. exilis* association confirms the upper part of the NN4 Zone, probably *S. heteromorphus* paracme.

Sample Nn8 (calcareous clays from the middle part of the profile in the well S8) yielded a more abundant assemblage (ca 20-30 individuals/1 visual field of the microscope), the nannofossils are poorly preserved. The autochthonous component represents about 50% of the oryctocoenosis. The species *H. carteri* (38), *D. exilis* (20) and *C. premacintyrei* (43) are abundant, whereas *H. ampliaperta* (2) is

rare. Fragments of *Micrantholithus* cf. *vesper* occur and moreover the species *Pontosphaera discopora, P. multipora, H. mediterranea* (1), *H. vedderi, H. euphratis, H. scissura, Coronocyclus nitescens, Calcidiscus leptoporus, Umbilicosphaera rotula, Braarudosphaera bigelowii* (1), *Reticulofenestra pseudoumbilicus*, and *Sphenolithus* ? *heteromorphus* (a poorly preserved specimen with a broken distal spine) appear.

The association with abundant *D. exilis* and rare *H. ampliaperta* confirms the upper part of the NN4 Zone, up to the boundary NN4/NN5. The MNN4b is correlated with the lower part of the Middle Miocene (Lower Langhian) by FORNACIARI *et al.* (1996). The first occurrence of *Helicosphaera waltrans* in the Carpathian Foredeep in South Moravia (the lower part of the horizon with *H. waltrans* sensu ŠVÁBENICKÁ, 2002) was observed in the interval paracme *Sphenolithus heteromorphus* MNN4b (probably in its upper part). *H. waltrans* was not ascertained in the studied assemblage.

As far the NN6 Zone is concerned, it can be identified by the absence of *S. heteromorphus* (the base of NN6 is defined by the last occurrence of *S. heteromorphus*). The abundant *H. ampliaperta* can then be interpreted as the redeposition from the Lower Miocene, NN2-NN4 Zones interval. But *H. walbersdorfensis* and small reticulofenestras are absent in the assemblage. In contrast the abundance of *H. carteri, D. exilis* and *C. premacintyrei* can even be characteristic for communities from the lower part of the NN6 Zone (Lower Serravallian).

*Foraminifera*: The sands of the lower (S3) and upper (S1) parts of the section contain a stratigraphically inconclusive and very poor assemblage (see Paleoenvironmental evaluation). The middle part (S8) yielded a rich assemblage with the species *Spirorutilus carinatus* (d'ORBIGNY), *Semivulvulina deperdita* (d'ORBIGNY), *Textularia gramen gramen* d'ORBIGNY, *T. mariae* d'ORBIGNY, *T. laevigata* (d'ORBIGNY), *Adelosina schreibersi* (d'ORBIGNY), *Quinqueloculina boueana* d'ORBIGNY, *Q. buchiana* d'ORBIGNY, *Globigerina bulloides* d'ORBIGNY, *Globigerinoides trilobus* (REUSS), *Globoquadrina altispira* (CUSMAN & JARVIS), *Orbulina suturalis* BRÖNNIMANN, *Ammonia beccarii* (LINNAEUS), *Amphistegina mammilla* (FICHTEL & MOLL), *Cancris auriculus* (FICHTEL & MOLL), *Elphidium fichtelianum* (d'ORBIGNY), *Fursenkoina acuta* (d'ORBIGNY), *Glandulina ovula* d'ORBIGNY, *Heterolepa dutemplei* (d'ORBIGNY), *Lobatula lobatula* (WALKER & JACOB),

*Nonion commune* (d'ORBIGNY), *Pappina parkeri* (KARRER), and *Pullenia bulloides* (d'ORBIGNY). *Orbulina suturalis* and the absence of praeorbulinas confirm that this part of the section is younger than the base of the M6 Zone of planktonic foraminifers. From the perspective of the regional ecostratigraphy of the Vienna Basin it can be correlated with the Upper Lagenidae Zone or with the *Spirorutilus carinatus* Zone. The boundaries of these zones are not usually very well defined in the marginal conditions of the Vienna Basin. Nevertheless, the benthic part of the assemblage has already the character of the *S. carinatus* Zone (ŠPIČKA & ZAPLETALOVÁ, 1965). In the most recent publications by Austrian authors, these local levels are correlated with the middle and upper parts of the NN5 Zone (e.g. DAXNER-HÖCK *et al.*, 2004).

*Otoliths*: The otolith associations in the Kienberg-vineyards section are rather uniform with only ecologic variations. But the general character of the assemblage seems to be very similar to the otolith assemblage from Baden-Sooss and Gainfarn (Austrian part of the Vienna Basin), correlated with the Upper Lagenidae Zone of the regional stratigraphy (BRZOBOHATÝ, 1978, 1994).

Because of the uncertainties in the interpretation of nannoplankton associations, we prefer to focus on the presence of *Orbulina suturalis* and affinities of the otolith association, and therefore accept a correlation of the section discussed with the Upper Lagenidae Zone up to the *Spirorutilus carinatus* Zone of the Vienna Basin's regional biostratigraphic zonation (Fig. 3).

**Results**

Notice: The classical locality Kienberg–sandpit is long abandoned and its lower section has been filled in since the 1950s. Early finds of otoliths were not precisely located. New investigations in coarse-grained sands underlying the red algal sandstones provided only a very poor otolith association: *Trisopterus sculptus, Brachydeuterus speronatus, Dentex* aff. *maroccanus, Spondyliosoma cantharus* and *Argyrosomus regius*. These taxa are among the most abundant species of the overlying strata in the vineyard section. The association is conditioned by taphonomic influences (the type of sediments) and does not allow for an unequivocal geological interpretation. The bulk of the otoliths comes from the samples in the vineyard section (Table 1). They are evaluated below and in Table 2.

*Paleoenvironmental evaluation*

The frequency histogram of individual taxa (Fig. 4, >1%) is broadly identical throughout the whole studied section showing only slight fluctuations in sedimentary conditions. Gobiids are strongly dominant in all associations. Schooling fish such as *Lithognathus mormyrus, Spondyliosoma cantharus, Boops boops*, representatives of the genus *Dentex* and the holothurian commensal *Carapus* aff. *acus* occur regularly. Gadoids are most common and most diversified in the upper part of the profile.

*Lower part of the section (S3)*: This sample provided 32 taxa, 5 species of them extant. Demersal and benthopelagic taxa (90% of the species and 99% of all the otoliths) dominate in absolute terms (Table 2), pelagic fishes (*Diaphus, Tylosurus*), and fishes living in lagoons or estuaries (*Atherina*) and near the reefs (*Pristigenys*) occur sporadically only.

From a climatic point of view, tropical-subtropical, subtropical and subtropical-temperate taxa (66% and 65%) predominate. Only the genus *Brachydeuterus* is restricted to tropical waters today. Its single Recent



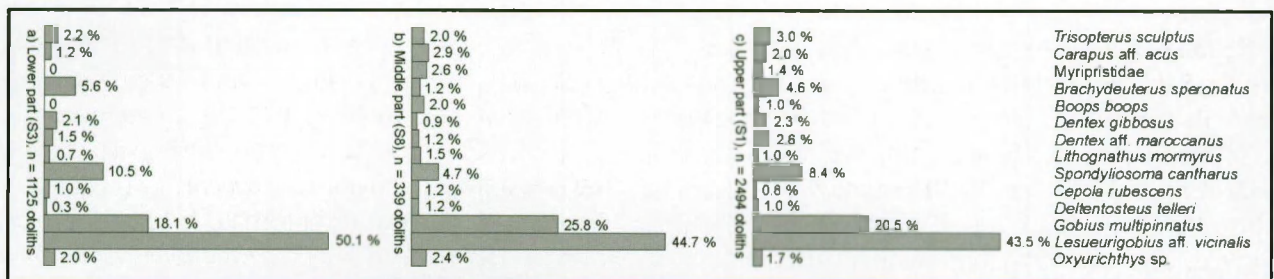| a) Lower part (S3), n = 1125 otoliths | b) Middle part (S8), n = 339 otoliths | c) Upper part (S1), n = 2494 otoliths | |
|---|---|---|---|
| 2.2 % | 2.0 % | 3.0 % | *Trisopterus sculptus* |
| 1.2 % | 2.9 % | 2.0 % | *Carapus* aff. *acus* |
| 0 | 2.6 % | 1.4 % | Myripristidae |
| 5.6 % | 1.2 % | 4.6 % | *Brachydeuterus speronatus* |
| 0 | 2.0 % | 1.0 % | *Boops boops* |
| 2.1 % | 0.9 % | 2.3 % | *Dentex gibbosus* |
| 1.5 % | 1.2 % | 2.6 % | *Dentex* aff. *maroccanus* |
| 0.7 % | 1.5 % | 1.0 % | *Lithognathus mormyrus* |
| 10.5 % | 4.7 % | 8.4 % | *Spondyliosoma cantharus* |
| 1.0 % | 1.2 % | 0.8 % | *Cepola rubescens* |
| 0.3 % | 1.2 % | 1.0 % | *Deltentosteus telleri* |
| 18.1 % | 25.8 % | 20.5 % | *Gobius multipinnatus* |
| 50.1 % | 44.7 % | 43.5 % | *Lesueurigobius* aff. *vicinalis* |
| 2.0 % | 2.4 % | 1.7 % | *Oxyurichthys* sp. |

Fig. 4 — Histogram of the most abundant species (>1% of otoliths) in the Kienberg-vineyard section (a = lower part, S3; b = middle part, S8; c = upper part, S1).

| Genera Species | Environment | | | | | | | | Climate | | | Distribution | | | Biology | | | | | Notice |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Bottom | | | | | |
| | Demersal | Benthopelagic | Pelagic | Oceanodromous | Amphidromous | Marine | Brackish | Fresh | Tropical | Subtropical | Moderate | Eastern Atlantic | Mediterranean | Western Indian Ocean | Mud | Sand | Rock | Reef-associated | Hreharious | |
| | D | Bp | P | O | A | M | B | F | T | S | M | A | M | I | M | S | Ro | Ra | G | |
| Panturichthys | D | | | | | M | | | (T) | S | | A | M | | M | | | | | |
| Rhynchoconger | D | | | | | M | | | T | S | | | M | I | M | | | | | |
| Arius | D | | | | A | M | B | F | | S | | A | M | I | M | S | Ro | | | + mangrove |
| Saurida | D | | | | A | M | | | T | S | | A | | I | M | S | | Ra | | |
| Diaphus taaningi | | | P | | | M | (B) | | | S | | A | | | | | | | | pseudo-oceanic |
| Bregmaceros | | | P | | | M | | | T | S | M | A | | I | | | | | | |
| Physiculus huloti | | Bp | | | | M | | | T | (S) | | A | | | | | | | | |
| Gaidropsarus vulgaris | D | | | | | M | | | | | M | A | M | | M | S | Ro | | | + graves, non migratory |
| Phycis blennioides | | Bp | | O | | M | | | | | M | A | M | | M | S | | | | |
| Merluccius merluccius | D | | | | | M | | | | | M | A | M | | | | Ro | | | |
| Gadiculus | | | P | | | M | | | | | M | A | M | | M | S | Ro | | | |
| Micromesistius | | | P | O | | M | | | | | M | A | M | | | | | | | at night - demersal |
| Trisopterus | | Bp | (P) | O | | M | B | | | | M | A | M | | | | | | | non-migratory |
| Carapus acus | D | | | | | M | | | | S | | A | M | | | | | | | commensal |
| Echiodon | D | | | | | M | | | | S | | A | M | | | | | | | |
| Grammonus | | | | | | M | | | (T) | S | | A | M | | | | Ro | | | caves (during the day) |
| Chelon | D | | | | A | M | B | F | | S | | A | M | | | | | | | occasionally migrates |
| Atherina | | | | | | M | B | F | | S | | A | M | | | | | | | lagoon, estuaries |
| Tylosurus | | | P | O | | M | B | | T | S | | A | M | I | | | | Ra | | |
| Hemiramphus | | | | | | M | B | F | | S | | A | | I | | | | Ra | | + Red Sea |
| Sargocentron | (D) | | | | | M | | | | S | | A | | I | | | | Ra | | + Red Sea |
| Myripristis | (D) | | | | | M | | | T | S | M | A | | I | | | | Ra | | |
| Scorpaena notata | D | | | | | M | | | | S | | A | M | | | | Ro | | | |
| Peristedion cataphractum | D | | | | | M | | | T | (S) | | A | M | | M | | Ro | | G | |
| Morone | D | | | O | | M | B | F | | S | | A | M | | M | S | Ro | | | |
| Pristigenys | | | | | | M | | | T | S | | | | I | | | Ro | Ra | G | |
| Brachydeuterus | D | Bp | | | | M | B | | T | | | A | (M) | | M | S | | | | |
| Pomadasys incisus | D | | | | | M | B | | | S | | A | M | | | S | Ro | | | |
| Boops boops | D | | | O | | M | | | | S | | A | M | | M | S | Ro | | G | |
| Dentex gibbosus | | Bp | | | | M | | | | S | | A | M | | | (S) | Ro | | | |
| Dentex maroccanus | D | | | | | M | | | | S | | A | M | | (M) | S | (Ro) | | | |
| Diplodus puntazzo | | Bp | | O | | M | | | | S | | A | M | | | | Ro | | G | |
| Lithognathus mormyrus | | Bp | | | | M | | | | S | | A | M | I | M | S | | | G | |
| Oblada | | | | O | | M | | | | S | | A | M | | | | Ro | | G | + Zostera |
| Pagrus | | | | O | | M | | | | S | | A | M | | | S | Ro | Ra | | |
| Pagellus acarne | | Bp | | O | | M | | | | S | | A | M | | (M) | S | (Ro) | | | + seagrass beds |
| Pagellus erythrinus | | Bp | | | | M | | | | S | | A | M | | M | S | Ro | | | |
| Spondyliosoma cantharus | | Bp | | O | | M | | | | S | | A | M | | | S | Ro | | G | + seagrass beds |
| Argyrosomus regius | | Bp | (P) | O | | M | B | | | S | | A | M | | M | S | (Ro) | | | |
| Sciaena | D | | | | | M | B | | | S | | A | M | | | S | Ro | | | +caves, + reefs |
| Umbrina cirrosa | D | | | | | M | | | | S | | A | M | | | S | Ro | | | |
| Umbrina ronchus | D | | | | | M | B | F | | S | | A | M | I | | S | Ro | | | |
| Cepola rubescens | D | | | | | M | | | | S | | A | M | | M | S | | | | + burrows |
| Trachurus picturatus | | Bp | | O | | M | | | | S | | A | M | | | | Ro | | G | |
| Trachinus draco | D | | | | | M | | | | | M | A | M | | M | S | | | | + burrows |
| Uranoscopus | D | | | | | M | | | | S | | A | M | | M | S | | | | + burrows |
| Deltentosteus | D | | | | | M | | | | S | M | A | M | | M | S | | | | + seagrass beds |
| Gobius | D | | | | | M | B | F | T | S | M | A | M | | M | S | | | | + seagrass beds |
| Lesueurigobius | D | | | | | M | | | | S | | A | M | | M | S | | | | |
| Oxyurichthys | D | | | | | M | B | | T | S | (M) | | ? | I | M | S | | | | + Red Sea, + burrows |
| Priolepis | D | | | | | M | B | | T | S | M | A | M | I | | | Ro | Ra | | + Red Sea |
| Sphyraena sphyraena | | | P | | | M | | | | S | | A | M | | | | | | | |
| Citharus | D | | | | | M | | | | S | | A | M | | M | | | | | |
| Arnoglossus | D | | | | | M | | | | S | | A | M | | M | (S) | | | | |
| Buglossidium | D | | | | | M | | | | S | | A | M | | | S | | | | |
| Dicologlossa hexophthalma | D | | | | | M | | | | S | | A | M | | M | S | | | | |
| Solea | D | | | O | | M | B | (F) | | S | | A | M | | M | S | | | | + burrows |

representative *B. auritus* is found in the eastern part of the Atlantic Ocean between Angola and Morocco and is absent from the Mediterranean. But we can presume a slightly broader climatic tolerance for the fossil *B. speronatus* by taking into consideration the relatively numerous otoliths of this species in the Badenian of the Korytnica Basin in Poland (RADWAŃSKA, 1992), in the Serravallian of the Aquitaine Basin (STEURBAUT, 1984) and in the Tortonian of the Mediterranean (NOLF & STEURBAUT, 1983). Seven percent of the taxa, representing only 3% of all otoliths, are fishes today restricted to the moderate belt (*Trisopterus*, major part of the *Merluccius* species).

As for salinity, purely marine taxa predominate (61%). Only 23% of the taxa also occur in brackish waters and only 16% are euryhaline from marine to freshwater conditions. With the exception of the genus *Gobius*, euryhaline taxa are represented only by sporadic otoliths. No characteristic brackish and freshwater taxa were identified.

Fishes from sandy bottoms prevail markedly. Together with quite tolerant groups, they represent above all a significant portion of the otolith number (48% of taxa and 94% of all otoliths). The high number of *Spondyliosoma cantharus* otoliths (10.5%) even indicates the possibility of seagrass bed environments. Taxa restricted only to muddy bottoms do not represent even one percent of the otoliths; taxa preferring rocky bottoms (*Merluccius* aff. *merluccius*, *Pristigenys*, *Diplodus*, *Oblada*, *Trachurus*) constitute 2% of all the otoliths. The number of possibly reef-associated taxa (*Saurida*, *Tylosurus*, *Hemiramphus*, *Pristigenys*) is also significant.

The paleobathymetric analysis (Fig. 5) indicates sedimentation depths around 30-40 m. Purely shallow water fishes characteristic of the first tens of meters are represented only by sporadic otoliths (*Chelon*, *Atherina*, *Hemiramphus*), the same is true for taxa from outside the shelf (Myctophidae). The asymmetric diagram with the gradual decrease of intervals to the depth of 200 m provides evidence for nearby deeper water environments.

This analysis indicates that the lower part of the Kienberg-vineyard section (S3) accumulated in subtropical conditions in an open marine environment of a shallow sublittoral with depths between 30-40 m and with a sandy or vegetated bottom without the influence of fresh or brackish waters, and possibly near bioherms or environments imitating reefs.

This corresponds with the lithology of the studied part of the section and of its basinal vicinity. The foraminiferal assemblage from this level is very poor – *Ammonia beccarii* (LINNAEUS), *Elphidium crispum* (LINNAEUS), *Lobatula lobatula* (WALKER & JACOB) and *Nonion commune* (D´ORBIGNY) – and is also in agreement with such environmental conditions.

*Middle part of the section (S8)*: In this part of the section, 27 otolith-based fish taxa, 9 species of them still extant, were recensed. The overwhelming majority consists of demersal and benthopelagic taxa (85% of the taxa and 98% of all otoliths). The rest (15% and 2%) represents mesopelagic (*Diaphus* – two species, *Gadiculus*) or epipelagic fishes (*Bregmaceros*). Climatic requirements of this otolith association are similar to those of the association from the lower part of the profile. The fishes from tropical-subtropical, subtropical or subtropical-temperate waters still dominate (63% and 65%). The number of eurythermal taxa has increased (22% and 31%), whereas the
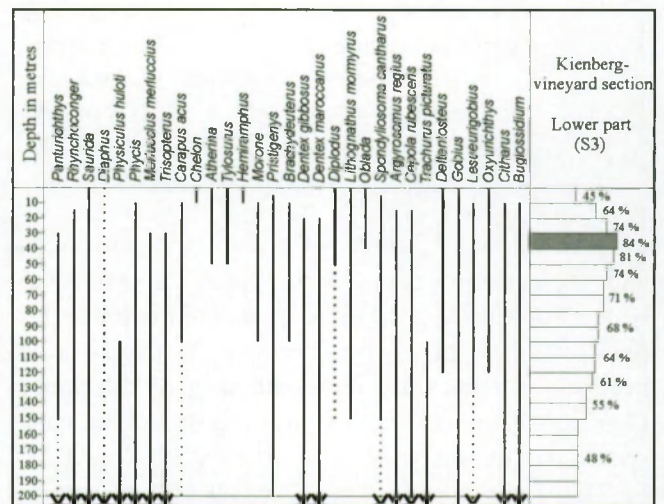


Fig. 5 — Present-day bathymetric range of taxa represented in the lower part (S3) of the Kienberg-vineyard section. Dotted lines indicate the nightly occurence near the surface of the mesopelagic species (*Diaphus*) or occasional presence of the species at the depth interval in question. For each 10 m interval, the graph shows the potential presences, expressed as a percentage of the total number of taxa used in the analysis. Data after QUÉRO (2003), and FROESE & PAULY (2005).

Table 2 — (opposite page) Ecological data (QUÉRO 2003, FROESE & PAULY 2005) of the extant genera and species reviewed in the List of taxa (see Table 1).
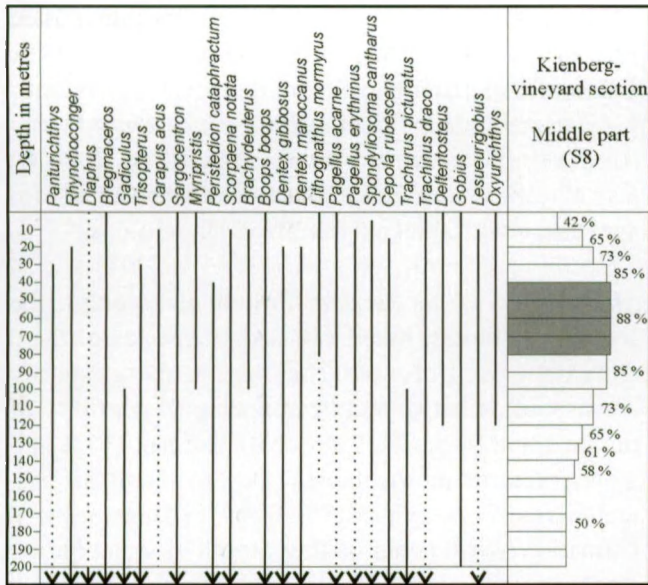
Fig. 6 — Present-day bathymetric range of taxa represented in the middle part (S8) of the Kienberg-vineyard section. Dotted lines indicate the nightly occurence near the surface of the mesopelagic species (*Diaphus*) or occasional presence of the species at the depth interval in question. For each 10 m interval, the graph shows the potential presences, expressed as a percentage of the total number of taxa used in the analysis. Data after QUÉRO (2003), and FROESE & PAULY (2005).

number of taxa characteristic for temperate (11% and 3%) and tropical (? *Brachydeuterus* – see above) waters remained the same. Stenohaline marine fishes represent 78% of all taxa, only 18% also tolerate brackish waters. Only representatives of the genus *Gobius* (4% of taxa) can live in fresh waters but most species are marine.

The same distribution of taxa with a bottom preference corresponds fully with the lithological shift toward sandy clays/clays. Fifty-seven percent of the taxa (83% of all otoliths) are represented by groups requiring or tolerating muddy bottoms. Typical sandy-bottom taxa are completely absent and taxa requiring hard substrates are represented only insignificantly (7% and 1%). The presence of other groups (sandy/rocky bottom, reef-associated) is relatively high (36% and 16%).

The paleobathymetric analysis indicates a non-sharply specified sedimentation depth between 40 – 80 m and the asymmetric diagram is characterized by relatively high percentages for the deeper intervals (– 150 m) and the scarcity of taxa living only in the shallowest waters (Fig. 6).

An evaluation of this part of the section using the requirements of individual fish groups indicates an open subtropical marine environment with normal salinity, in the lower parts of the interval 40-80 m on a muddy bottom with a distinct influence of the pelagic realm. The presence of taxa requiring different bottom types (sand-rocky, rocky) and of reef-associated fishes (*Sargocentron, Myripristis*, 2.6% of the otoliths) indicates nearby bioherms or reefs-imitating environments. The influence of the pelagic environment is also suggested by the foraminifers (see Stratigraphy).

*Upper part of the section (S1)*: This part of the section offers a highly diversified otolith association: fifty-three taxa, eleven species of which are still extant. Demersal and benthopelagic fishes are again dominant (82% of the taxa and 98% of all otoliths). The influence of purely pelagic groups decreased again, roughly approaching the level of the lower parts of the section (10% and 1%). Only *Micromesistius* cf. *arcuatus*, represented by one specimen and *Sphyraena* aff. *sphyraena* representing not even one percent of the otoliths appear in this group. Lagoonal elements (*Atherina*) or mangrove-preferring species (*Arius*) occur only sporadically.

The quantitative representation of fishes by their climatic requirements changed slightly. Subtropical fishes still dominate, representing 76% of the taxa and 68% of all the otoliths, together with tropical-subtropical and subtropical-temperate waters groups. The number of taxa preferring temperate waters and tending towards cool waters in Recent biota increased markedly (14% and 4%). Seven species of gadoids (families Lotidae, Phycidae, Merlucciidae and Gadidae) and the species *Trachinus draco* may indicate slightly cooler influences than in previous sedimentation periods. Such a high gadoid diversity is known neither from the Lower Miocene nor from the lowest Badenian (lowest Middle Miocene) of the Central Paratethys. It appears only in the clays of the Korytnica Basin in Poland (RADWAŃSKA, 1992) correlated with the Lower Lagenidae Zone (lowest Badenian) (HARZHAUSER et al., 2003). They interpret the absence of the most thermophile molluscan taxa in these northern regions as a consequence of a probably climatic-controlled gradient along the Central Paratethys, stretching N-S. If the stratigraphic correlation of the Korytnica section with the Lower Lagenidae Zone is correct, this gradient may also be supported by the decreasing diversity of the cool-water gadoids in a N-S direction (Fig. 7) in the Central
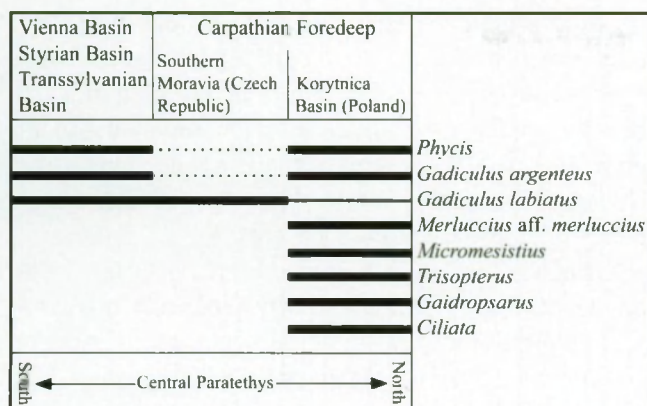
| Vienna Basin Styrian Basin Transsylvanian Basin | Carpathian Foredeep | | |
|---|---|---|---|
| | Southern Moravia (Czech Republic) | Korytnica Basin (Poland) | |

*Phycis*
*Gadiculus argenteus*
*Gadiculus labiatus*
*Merluccius* aff. *merluccius*
*Micromesistius*
*Trisopterus*
*Gaidropsarus*
*Ciliata*

South ◄————Central Parathethys————► North

Fig. 7 — Distribution of gadoids in the Central Paratethys during the Early Badenian, Lower Lagenidae Zone (SCHUBERT, 1906; WEILER, 1950; WEINFURTER , 1952; RADO 1965, 1969, 1981; RADWAŃSKA, 1992; BRZOBOHATÝ – unpublished data). Stratigraphic position of the Korytnica Clay after HARZHAUSER *et al.*, 2003.

Paratethys (Korytnica Basin, Poland: 8 species, RADWAŃSKA, 1992; Carpathian Foredeep, Southern Moravia: *Gadiculus* only [unpublished data]; Vienna, Transylvanian and Styrian basins: two genera, *Phycis* and *Gadiculus*, SCHUBERT, 1906; WEILER, 1950; WEINFURTER, 1952; RADO, 1965, 1969, 1981). In the more southern parts of the Central Paratethys, the higher diversity of gadoids can only be observed in the Upper Lagenidae Zone (Lower/Middle Badenian) of the Vienna Basin and the Carpathian Foredeep in southern Moravia. It is documented from the localities Baden-Sooss, Gainfarn (BRZOBOHATÝ, 1978, 1994), Vöslau, Möllersdorf, Grinzing (SCHUBERT, 1906); in all cases it is marked by abundant *Trisopterus sculptus* in addition to other species. It is also recorded at many localities in the Carpathian Foredeep (lacking *T. sculptus*, see BRZOBOHATÝ, 1997). Their appearance can be correlated to the decline of the so-called climatic optimum, which ends at the Middle/Upper Badenian boundary in Central Europe (e. g. BÖHME, 2003) and at the Langhian/Serravallian boundary in the Mediterranean (SUC *et al.*, 2005). Even the cool Mi-3 event defined on the basis of foraminifers and isotopic studies in the Mediterranean is placed before the LO *Sphenolithus heteromorphus*, which corresponds with the uppermost Middle Badenian in the sense of the Central Paratethys (IACCARINO *et al.*, 2005). JIŘÍČEK (1983) also established a rapid appearance of cool-water ostracodes since the Middle Badenian of the Central Paratethys. The gradual appearance of cool-water fish species connected with a distinct gadoid

increase is even mentioned in the Chokrakian (=Late Langhian) of the Eastern Paratethys (DANILTSHENKO, 1980).

The same type of otolith fauna continues even into the Upper Badenian as observed in sections from the Slovak part of the Vienna Basin near Devínská Nová Ves and Rohožník (SCHUBERT, 1906; HOLEC,1973, 1975, 1978; HORÁK, 1981; HUTYROVÁ, 2001), where the cooling trends are manifested for example by calcareous dinoflagellates (BANASOVÁ & REHAKOVÁ, 2005).

As for the salinity, 66% of all taxa represented in the upper part of the section belong to purely marine groups. 21% of taxa usually live in marine and brackish waters and 13% of the taxa tolerate marine, brackish and freshwater environments. Purely freshwater elements were not identified.

A complicated picture is indicated by the bottom requirements of individual taxa. Six percent of taxa (1% of otoliths) require purely muddy bottoms, 12% of taxa (1% of otoliths) purely rocky bottoms. Groups preferring sandy bottoms (e.g. muddy-sandy, muddy-sandy-rocky, sandy-rocky ones) dominate. In total, they represent 60% of all taxa and 91% of all otoliths. Thus, this assemblage structure corresponds with the fine-grained sands from where the material was collected. This environment is further confirmed by the frequency of gregarious fishes: *Boops boops, Lithognathus mormyrus* and most importantly *Spondyliosoma cantharus*. Apart from the gobiids representing a substantial portion of otoliths in Neogene shallow water sediments, *S. cantharus* accounts for 8.4% of all otoliths in the upper part of the section (Fig. 4). This species, associated with seagrass beds, and the abundant representatives of the genera *Gobius* and *Deltentosteus* indicate the possible presence or even proximity of this sedimentary environment.

The paleobathymetric analysis (Fig. 8) indicates sedimentation depths between 40-50 m. The diagram is slightly asymmetric with a slower decrease of depthwards intervals, again indicating rather the proximity of deeper shelf.

Based on these data, the upper part of the section accumulated in open marine conditions with a normal salinity, at depths between 40-50 m and on a sandy bottom or on a bottom with seagrass beds, in times of a gradual cooling. A scarce foraminiferal fauna represented by the species *Ammonia beccarii* (LINNAEUS), *Elphidium crispum* (LINNAEUS), *Amphistegina* sp. and *Globulina gibba* D'ORBIGNY is not in conflict with this interpretation.
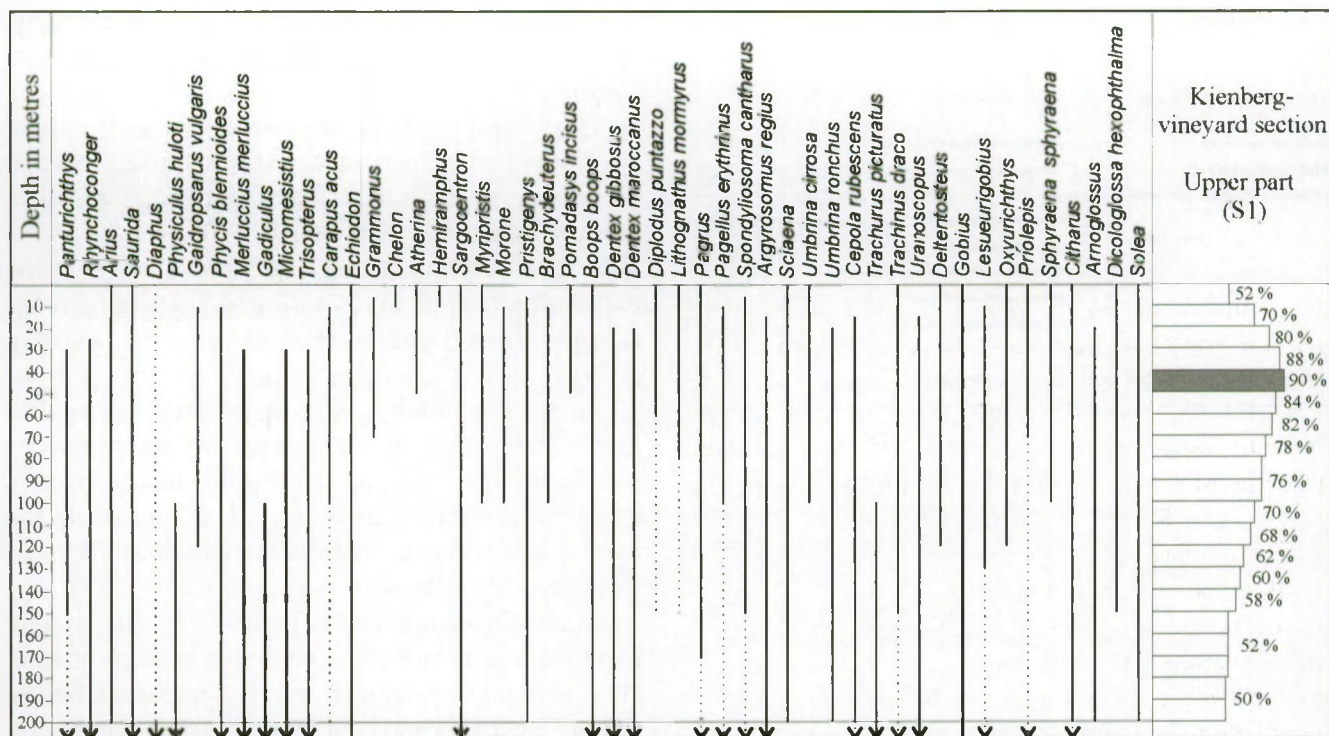
Fig. 8 — Present-day bathymetric range of taxa represented in the upper part (S1) of the Kienberg-vineyard section. Dotted lines indicate the nightly occurence near the surface of the mesopelagic species (*Diaphus*) or occasional presence of the species at the depth interval in question. For each 10 m interval, the graph shows the potential presences, expressed as a percentage of the total number of taxa used in the analysis. Data after QUÉRO (2003), and FROESE & PAULY (2005).

## Paleogeographical affinities

Taxa representing the Atlantic domain or the Eastern Atlantic-Mediterranean region dominate the whole section. *Physiculus huloti* and *Brachydeuterus* are purely Eastern Atlantic taxa, absent from the Recent Mediterranean. But the fossil species *Physiculus* aff. *huloti* and *Brachydeuterus speronatus* are an ususal component of Miocene faunas from the broader Mediterranean. The same is true for taxa of the Atlantic-Mediterranean area found at Kienberg with the exception of *Gaidropsarus* cf. *vulgaris*, *Scorpaena notata*, *Priolepis* sp. and *Sphyraena* aff. *sphyraena* that had earlier not been identified in the fossil record. *Boops boops* and *Diplodus puntazzo* are known from the Pliocene of Portugal and the Pleistocene of Italy respectively. An exception is the genus *Oxyurichthys* which is now found living only in the Indopacific realm, including the Red Sea. *O. papuensis* (VALENCIENNNES, 1837) is mentioned from the Turkish coast as a lessepsian immigrant. This otolith fauna confirms a close relation and rather good communication with the Atlantic. Thus, together with the association of deep-water macrourids in

the uppermost Middle Badenian at Walbersdorf (BACHMAYER & WEINFURTER, 1965; BRZOBOHATÝ, 1995), it confirms the idea of a still functioning trans-dinaride corridor (RÖGL, 1998) between the Central Paratethys and the Mediterranean in Slovenia.

In the Aquitaine Basin the above mentioned higher diversity of gadoids was ascertained only since the Serravallian (eight species including the genera *Micromesistius, Trisopterus, Raniceps* and *Merluccius* – STEURBAUT, 1984; NOLF & BRZOBOHATÝ, 2002). In the Mediterranean, relevant data on otoliths from the Langhian and Serravallian levels are lacking. The more synoptic data thus far published from this area from the Lower Miocene (REICHENBACHER & CAPPETTA, 1999; NOLF & BRZOBOHATÝ, 2004), from Burdigalian/Langhian boundary sediments (HOEDEMAKERS & BATLLORI, 2005), and from the Lower Langhian (STEURBAUT, 1983) confirm the otolith associations without gadoids or with only a sporadic presence of the more pelagic genera *Phycis* and *Gadiculus*. In the Tortonian however, the presence of these cool-water elements is distinctly higher (five species including the genera *Micromesistius* and *Merluccius* - NOLF & STEURBAUT, 1983).

## Conclusions

In the Kienberg-vineyard section, 63 otolith-based taxa were identified, ten of which are recorded for the first time in the Central Paratethys. Among the 12 extant species, *Scorpaena notata* and *Spondylisoma cantharus* are identified as fossils for the first time.

Based on an actualistic analysis of the otoliths, the sedimentation in the studied section occured in open infralittoral conditions without the influences of brackish or fresh waters, in a subtropical climate with gradual cooling upwards. Sands from the lower part of the profile overlying the algal sandstones accumulated at depths of 30-40 m, then the bottom dropped to a maximum of 80 m and the deposition of calcareous clays took place. In the upper part of the section, the otolith association again indicates shallowing (40-50 m) accompanied by the re-establishment of a sandy sedimentation. A bottom area with seagrass beds and bioherms or rocky bottoms can be supposed in the immediate neighbourhood of the studied depositional environment, which agrees with the facies diversity of Middle Badenian sediments documented from boreholes (ŠPIČKA & ZAPLETALOVÁ, 1965; ŠPIČKA, 1966).

The studied otolith association is most similar to otolith associations from the Upper Lagenidae Zone of the Vienna Basin, including the Gainfarn and Vöslau localities. It differs from the shallow-water assemblages of the Lower Lagenidae Zone in its markedly higher diversity of cool-water gadoids. In the stratigraphic equivalents of the Lower Lagenidae Zone, the latter are characteristic only of northern localities in the Korytnica Basin of the Polish part of the foredeep. Southwards, the presence and frequency of gadoids in the otolith associations is visibly decreasing. This is in agreement with a decrease of thermophilic molluscs in the opposite direction. Their higher diversity from the Middle Badenian even within the Vienna Basin may reflect both the decline of the so-called climatic optimum period in Central Europe and the gradual cooling documented at the end of the Langhian in the Mediterranean and in the Chokrakian of the Eastern Paratethys.

In the Upper Badenian, otolith associations remain very similar. Those from the Slovak part of the Vienna Basin are similar but markedly poorer than the one of Kienberg. The calcareous clays from the localities Děvínská Nová Ves and Rohožník, correlated with the regional *Bolivina-Bulimina* Zone (Upper Badenian, Early Serravallian), contain 23 taxa (four of them gadoids) and only *Umbrina cirrhosoides* (SCHUBERT,

1902), "g. aff. *Umbrina*" *kokeni* (SCHUBERT, 1902), "g. Cepolidarum" *vadaszi* (SCHUBERT, 1912), "g. Pleuronectiformorum" *tenuis* (SCHUBERT, 1906) and clupeids (fragments of otoliths) were not collected in the Kienberg associations.

The obvious dominance of Atlantic and Atlantic-Mediterranean taxa with a high number of pelagic and benthopelagic elements indicates good communication with these realms during the sedimentation of the studied interval. Thus, together with the association of deep-water macrourids in the uppermost Middle Badenian at Walbersdorf, it supports the idea of the still functioning "Transtethyan-Trench-Corridor" between the Central Paratethys and the Mediterranean in Slovenia.

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## Explanation of the plates

All figured specimens are deposited in the collections of the Institut Royal des Sciences Naturelles de Belgique (IRSNB). The fossil otoliths bear numbers of the collection of types and figured fossil fish specimens of the IRSNB. The Recent otoliths are part of the reference collection of Recent otoliths at the same institution. The latter collection is arranged in systematic order without numbering; therefore, such specimens, when figured, bear only the notation "coll. IRSNB". The abbreviations F and R in the upper right corner of each compartment of the plates indicate if the figured specimens in that compartment are fossils (F) or Recent (R). Recent species occuring as fossils are labeled with ([F]). The annotations a, b and c are used to indicate respectively ventral, inner (=mesial) and posterior views. Figures with only numbers and no letter show inner views. In the captions, L stands for left otolith and R for right otolith.

### PLATE 1

| | | |
|---|---|---|
| Figs 1-2 | — | *Diaphus taaningi* NORMAN, 1930, L (IRSNB P 8121 - P 8122). |
| Figs 3-4 | — | *Diaphus kokeni* (PROCHAZKA, 1893), R (IRSNB P 8123 - P 8124). |
| Fig. 5 | — | *Rhynchoconger pantanellii* (BASSOLI & SCHUBERT, 1906), R (IRSNB P 8125). |
| Figs 6-8 | — | *Panturichthys subglaber* (SCHUBERT, 1906), L (IRSNB P 8126 - P 8128). |
| Fig. 9 | — | *Bregmaceros albyi* (SAUVAGE, 1880), L (IRSNB P 8129). |
| Fig. 10 | — | *Arius* sp., (IRSNB P 8130). |
| Fig. 11 | — | *Physiculus* aff. *huloti* POLL, 1953, L (IRSNB P 8131). |
| Figs 12-13 | — | *Saurida germanica* (WEILER, 1942), L (IRSNB P 8132 - P 8133). |

### PLATE 2

| | | |
|---|---|---|
| Fig. 1 | — | *Gaidropsarus* cf. *vulgaris* (CLOQUET, 1824), R (IRSNB P 8134). |
| Fig. 2 | — | *Gadiculus labiatus* (SCHUBERT, 1905), L (IRSNB P 8135). |
| Fig. 3 | — | *Phycis musicki* COHEN & LAVENBERG, 1989, R (IRSNB P 8136). |
| Fig. 4 | — | *Phycis blennioides* (BRÜNNICH, 1768), R (IRSNB P 8137). |
| Fig. 5 | — | *Micromesistius* cf. *arcuatus* RADWAŃSKA, 1992, L (IRSNB P 8138). |
| Figs 6-11 | — | *Micromesistius arcuatus* RADWAŃSKA, 1992, R, Rybnica, Southern Poland, Langhian (= Lower Badenian, Central Paratethys), (IRSNB P 8139 - P 8144). |

### PLATE 3

| | | |
|---|---|---|
| Fig. 1 | — | *Grammonus* sp., L (IRSNB P 8145). |
| Fig. 2 | — | *Echiodon* sp., L (IRSNB P 8146). |
| Figs 3-7 | — | *Trisopterus sculptus* (KOKEN, 1891), L (IRSNB P 8147 - P 8151). |
| Figs 8-9 | — | *Chelon* sp., 8 = L, 9 = R ( IRSNB P 8152 - P 8153). |
| Figs 10-12 | — | *Carapus* aff. *acus* (BRÜNNICH, 1768), L (IRSNB P 8154 - P 8156). |
| Fig. 13 | — | *Tylosurus wetzelsdorfensis* (WEINFURTER, 1952), L (IRSNB P 8157). |
| Fig. 14 | — | *Merluccius* cf. *merluccius* (LINNAEUS, 1758), R (IRSNB P 8158). |
| Fig. 15 | — | *Hemiramphus miocenicus* (WEINFURTER, 1952), R (IRSNB P 8159). |
| Figs 16-17 | — | *Atherina austriaca* SCHUBERT, 1906, R (IRSNB P 8160 - P 8161). |

PLATE 4

Figs 1-2    —    *Sargocentron* sp., R (IRSNB P 8162 - P 8163).
Fig. 3      —    *Myripristis* aff. *verus* STEURBAUT, 1979, R (IRSNB P 8164).
Fig. 4      —    *Peristedion* cf. *cataphractum* (LINNAEUS, 1758), L (IRSNB P 8165).
Figs 5-11   —    *Scorpaena notata* RAFINESQUE, 1810, 5 = L, 6 = R (IRSNB P 8166 - P 8167), 7-11 = L, Recent, 7-8 = off the Azores, 8-9 = coll. CHAINE, locality unknown, 10-11 = Mediterranean, off Cassis (coll. IRSNB).
Fig. 12     —    « genus Percoideorum » *tietzei* (SCHUBERT, 1906), R (IRSNB P 8168).
Fig. 13     —    *Pristigenys rhombica* (SCHUBERT, 1906), R (IRSNB P 8169).
Fig. 14     —    *Morone* sp., R (IRSNB P 8170).
Fig. 15     —    *Caulolatilus cyanops* POEY, 1866, L, Recent, (coll. IRSNB).
Fig. 16     —    „genus Malacanthidarum" *postdorsalis* (STEURBAUT, 1979), R (IRSNB P 8171).

PLATE 5

Figs 1-10   —    *Brachydeuterus speronatus* (BASSOLI, 1906), 1-6 = L, Sallespisse, Carè, Aquitaine, France, Serravallian (P 8172- P 8177), 7- 10 = R, Kienberg (IRSNB P 8178 - P 8181).
Fig. 11     —    *Pomadasys* aff. *incissus* (BOWDICH, 1825), L (IRSNB P 8182).
Figs 12-14  —    *Dentex* aff. *maroccanus* VALENCIENNES, 1830, L (IRSNB P 8183 - P 8185).
Figs 15-16  —    *Boops boops* (LINNAEUS, 1758), 15 = L, 16 = R (IRSNB P 8186 - 8187).
Figs 17-18  —    *Dentex gibbosus* (RAFINESQUE, 1810), L (IRSNB P 8188 - P 8189).

PLATE 6

Fig. 1      —    *Diplodus* cf. *puntazzo* (CETTI, 1777), L (IRSNB P 8190).
Figs 2-3    —    *Pagellus* cf. *acarne* (RISSO, 1806), L (IRSNB P 8191 - P 8192).
Fig. 4      —    *Diplodus* sp., L (IRSNB P 8193).
Fig. 5      —    *Pagrus* sp., L (IRSNB P 8194).
Figs 6-7    —    *Lithognathus mormyrus* (LINNAEUS, 1758), R (IRSNB P 8195 - P 8196).
Figs 8-9    —    *Pagellus erythrinus* (LINNAEUS, 1758), 8 = R, 9 = L (IRSNB P 8197 - P 8198).
Figs 10-12  —    *Spondyliosoma cantharus* (LINNAEUS, 1758), L (IRSNB P 8199 - P 8201).
Figs 13-14  —    *Oblada* aff. *chainei* STEURBAUT & JONET, 1982, R (IRSNB P 8202 - P 8203).

PLATE 7

Figs 1-2    —    *Argyrosomus regius* (ASSO, 1801), 1 = R, 2 = L (IRSNB P 8204 - P 8205).
Fig. 3      —    *Sciaena rybnicensis* RADWAŃSKA, 1992, L (IRSNB P 8206).
Fig. 4      —    *Sciaena* cf. *irregularis* (KOKEN, 1884), R (IRSNB P 8207).
Fig. 5      —    *Umbrina* aff. *ronchus* VALENCIENNES, 1843, L (IRSNB P 8208).
Fig. 6      —    *Umbrina* cf. *cirrosa* (LINNAEUS, 1758), L (IRSNB P 8209).
Figs 7-8    —    *Cepola rubescens* LINNAEUS, 1766, R (IRSNB P 8210 - P 8211).
Fig. 9      —    *Trachinus draco* LINNAEUS, 1758, R (IRSNB P 8212).
Figs 10-12  —    *Trachurus picturatus* (BOWDICH, 1825), L, Recent, (coll. IRSNB).
Figs 13-15  —    *Trachurus* aff. *picturatus* (BOWDICH, 1825), L (IRSNB P 8213 - P 8215).

PLATE 8

Fig. 1      —    *Uranoscopus* sp., R.  (IRSNB P 8216).
Figs 2-5    —    *Deltentosteus telleri* (SCHUBERT, 1906), R (IRSNB P 8217- P 8220).
Figs 6-8    —    *Gobius multipinnatus* (von MAYER, 1852), L (IRSNB P 8221 - P 8223).
Figs 9-11   —    *Priolepis* sp., R (IRSNB P 8224 - P 8226).

Figs 12-14  —  *Lesueurigobius* aff. *vicinalis* (KOKEN, 1891), L (IRSNB P 8227 - P 8229).
Fig. 15     —  *Oxyurichthys* sp., L (IRSNB P 8230).
Fig. 16     —  *Arnoglossus* sp., L (IRSNB P 8231).

## PLATE 9

Figs 1-6    —  *Sphyraena sphyraena* (LINNAEUS, 1758), L, Recent, coll. Chaine, locality unknown (coll. IRSNB).
Fig. 7      —  *Sphyraena* aff. *sphyraena* (LINNAEUS, 1758), R (IRSNB P 8232).
Figs 8-9    —  *Citharus lusitanicus* (JONET, 1973), L (IRSNB P 8233 - P 8234).
Fig. 10     —  *Dicologlossa hexopthalma* (BENNETT, 1831), L (IRSNB P 8235).
Fig. 11     —  *Buglossidium frequens* STEURBAUT, 1984, L (IRSNB P 8236).
Fig. 12     —  *Solea* sp., L (IRSNB P 8237).

1a

1 mm

1b

1 mm

2

*Diaphus taaningi*
NORMAN, 1930

3a

1 mm

3b

4

*Diaphus kokeni*
(PROCHAZKA, 1893)

5a

5b

*Rhynchoconger pantanellii*
(BASSOLI & SCHUBERT, 1906)

6a

6b

*Panturichthys subglaber*
(SCHUBERT, 1906)

7

8

1 mm

9a

9b

1 mm

*Bregmaceros albyi*
(SAUVAGE, 1880)

10a

10b

1 mm

*Arius* sp.

11a

11b

1 mm

*Physiculus* aff. *huloti*
POLL, 1953

12a

12b

13

1 mm

*Saurida germanica* (WEILER, 1942)

PLATE 1

(F)

1a

1 mm

1b

*Gaidropsarus* cf. *vulgaris*
(CLOQUET, 1824)

F

2a

2b

1 mm

*Gadiculus labiatus*
(SCHUBERT, 1905)

F

3a

1 mm

3b

*Phycis musicki* COHEN & LAVENBERG, 1989

(F)

1 mm

4a

4b

*Phycis blennioides* (BRUENNICH, 1768)

F

5a

5b

1 mm

*Micromesistius* cf. *arcuatus* RADWANSKA, 1992

F

6a

6b

7

8

9

10

1 mm

11a

11b

*Micromesistius arcuatus* RADWANSKA, 1992

PLATE 2

F
1a
1b
1 mm
*Grammonus* sp.

F
2a
2b
1 mm
*Echiodon* sp.

3a
3b
4
1 mm
*Trisopterus sculptus* (KOKEN, 1891)

F
5
6
7

F
8a
8b
9a
9b
1 mm
*Chelon* sp.

(F)
10a
10b
10c
11a
11b
11c
12
1 mm
*Carapus* aff. *acus* (BRUENNICH, 1768)

F
13a
13b
1 mm
*Tylosurus wetzelsdorfensis*
(WEINFURTER, 1952)

(F)
1 mm
14
*Merluccius* cf. *merluccius*
(LINNAEUS, 1758)

1 mm
15a
*Hemiramphus miocenicus*
(WEINFURTER, 1952)

F
15b

16a
16b
F
17
1 mm
*Atherina austriaca* SCHUBERT, 1906

PLATE 3

*Sargocentron* sp.

*Myripristis* aff. *verus*
STEURBAUT, 1979

*Peristedion* cf. *cataphractum*
(LINNAEUS, 1758)

*Morone* sp.

*Scorpaena notata* RAFINESQUE, 1810

*Caulolatilus cyanops*
POEY, 1866

"genus Percoideorum" *tietzei*
(SCHUBERT, 1906)

*Pristigenys rhombica*
(SCHUBERT, 1906)

"genus Malacanthidarum"
*postdorsalis* (STEURBAUT, 1979)

PLATE 4

*Brachydeuterus speronatus* (BASSOLI, 1906)

*Dentex* aff. *maroccanus*
VALENCIENNES, 1830

*Pomadasys* aff. *incisus* (BOWDICH, 1825)

*Boops boops* (LINNAEUS, 1758)

*Dentex gibbosus* (RAFINESQUE, 1810)

PLATE 5

(F)

1a

1b

1 mm

*Diplodus* cf. *puntazzo* (CETTI, 1777)

F

4a

4b

1 mm

*Diplodus* sp.

(F)

6a

6b

1 mm

7

*Lithognathus mormyrus* (LINNAEUS, 1758)

(F)

2a

2b

3

1 mm

*Pagellus* cf. *acarne* (RISSO, 1806)

F

5a

5b

1 mm

*Pagrus* sp.

9

1 mm

8a

8b

*Pagellus erythrinus* (LINNAEUS, 1758)

(F)

10a

10b

11

12

1 mm

*Spondyliosoma cantharus* (LINNAEUS, 1758)

F

13a

13b

14

1 mm

*Oblada* aff. *chainei* STEURBAUT & JONET, 1982

PLATE 6

(F)

1 mm

1a

1b

2

*Argyrosomus regius* (ASSO, 1801)

(F)

5a

1 mm

5b

*Umbrina* aff. *ronchus* VALENCIENNES, 1843

(F)

1 mm

9a

9b

*Trachinus draco* LINNAEUS, 1758

F

3a

1 mm

3b

*Sciaena rybnicensis*
RADWANSKA, 1992

(F)

6a

1 mm

6b

*Umbrina* cf. *cirrosa*
(LINNAEUS, 1758)

R

10a

10b

1 mm

11

12

*Trachurus picturatus*
(BOWDICH, 1825)

F

4a

1 mm

4b

*Sciaena* cf. *irregularis* (KOKEN, 1884)

(F)

7a

1 mm

7b

8

*Cepola rubescens* LINNAEUS, 1766

(F)

13a

13b

1 mm

14

15

*Trachurus* aff. *picturatus*
(BOWDICH, 1825)

PLATE 7

*Uranoscopus* sp.

*Deltentosteus telleri*
(SCHUBERT, 1906)

*Gobius multipinnatus*
(VON MAYER, 1852)

*Priolepis* sp.

*Lesueurigobius* aff. *vicinalis*
(KOKEN, 1891)

*Oxyurichthys* sp.

*Arnoglossus* sp.

PLATE 8

R

(F)

1a

1b

7a

7b

1 mm

*Sphyraena* aff. *sphyraena* (LINNAEUS, 1758)

2

F

3

8a

4

8b

5

1 mm

9a

6

9b

1 mm

1 mm

*Sphyraena sphyraena* (LINNAEUS, 1758)

*Citharus lusitanicus* (JONET, 1973)

(F)

1 mm

F

1 mm

F

1 mm

10a

11a

12a

10b

11b

12b

*Dicologlossa hexophthalma*
(BENNETT, 1831)

*Buglossidium frequens*
STEURBAUT, 1984

1 mm      *Solea* sp.

PLATE 9