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Gobius brevis (Agassiz, 1839), a gobiid fish with otoliths in situ (Pisces, Teleostei) in the Karpatian (Lower Miocene) of the Vienna Basin

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(With 4 figures and 3 table)

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Dedicated to our friend and colleague Ortwin Schultz for his 65th birthday.

Abstract

The occurrence of gobiid articulated skeletons is reported from the Karpatian of the Slovakian part of the Vienna Basin. They are characterized by a rather short vertebral column and somewhat small posterior dorsal and anal fins. The morphology of the otoliths, which are preserved in situ, demonstrates that these gobiid fishes belong to the species *Gobius brevis* (Agassiz) which was widely distributed in the freshwater and brackish environments of Central Europe from the uppermost Lower Miocene to the end of the Middle Miocene.

The monospecific fish fauna, characters of skeletons and lithological characters of rocks indicate that the final deposition of the Šaštín Sand in the studied area took place in a very shallow environment corresponding to a rather closed lagoon filled with brackish or oligohaline water, having a deficiency of oxygen on the bottom and being deprived of active bottom currents.

Keywords: Gobiidae, Teleostean fishes, Lower Miocene (Karpatian), Central Paratethys, Slovakia, otoliths, lagoonal palaeoenvironment.

Zusammenfassung

Eine Anhäufung von Gobiiden-Skeletten mit Otolithen in situ wird aus dem Karpatium des Wiener Beckens beschrieben. Die kurze Wirbelsäule und kleine Rück- und Analflossen sowie die Otolithenmerkmale sprechen für die Zugehörigkeit der Fischreste zu *Gobius brevis* (Agassiz), die in Süsswasser- und Brackwasser-Ablagerungen Zentral Europas vom jüngsten Untermiozän bis ins Ende des Mittelmiozän weit verbreitet ist.

Das monospezifische Vorkommen, die Einbettung der Skelette und lithologische Merkmale der Gesteine weisen eindeutig auf ein sehr seichtes Milieu einer geschlossenen Lagune mit brackischen oder oligohalinen Wasser, Mangel an Sauerstoff am Boden und Fehlen von Bodenströmungen hin. Diese Bedingungen herrschten am Ende der Sedimentation des Šaštín Sands im Závod-Gebiet.

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Schlüsselwörter: Gobiidae, Knochenfische, Unteres Miozän (Karpatium), Zentral-Paratethys, Slowakei, Otolithen, lagunares Milieu.

Introduction

In the Karpatian sediments of the Central Paratethys (uppermost Lower Miocene, Upper Burdigalian), isolated otoliths, teeth and scales dominate in the fish fauna, whereas articulated skeletons are rare and need a systematic revision. A recent general survey of the fish remains found in the Karpatian of this area is given in Brzobohatý et al. (2003).

A very interesting lithofacies with numerous gobiid skeletons exhibiting otoliths in situ was found in the Karpatian sediments of the Vienna Basin north of Malacky. The borehole Závod-72 (drilled by the Moravian Oil Industry, Hodonín) was situated at the western margin of the Slovakian part of the Vienna Basin near the village Závod (fig. 1). It crossed 4,180 m of Miocene sediments and stopped in the underlying Upper Triassic carbonates ("Hauptdolomit" facies of the Norian). The core Nr. 29 (3,751-3,754 m) contained many skeletons, some of them with otoliths in situ. A short report in Czech language on this fish fauna and its palaeogeographical significance was published by Brzobohatý (1991).

Otoliths were initially identified as gobiids belonging to a group of related species such as *Gobius multipinnatus* (von Meyer, 1852), *G.* cf. *multipinnatus* (von Meyer, 1852) and *G. praetiosus* Prochazka, 1893 (nomen dubium). Later, one skeleton determined by Gregorová as *G. multipinnatus* was figured (Brzobohatý et al. 2003: pl. 5, fig. 2). The purpose of the present paper is the revision of this material.

The material is kept in the collections of the Moravian Museum in Brno, Czech Republic (Catalogue Nr. Ge 29 793 to Ge 29 817).

Geological setting

The Vienna Basin, palaeogeographically the NW part of the Central Paratethys, is an intramontane basin lying at the Alpine-Carpathian-Pannonian junction. During the uppermost Lower Miocene (Karpatian, Upper Burdigalian) the tectonic regime of the basin has changed from the piggy-back into the pull-apart mechanism. There are two major transgressive/regressive cycles in the Karpatian of the Vienna Basin. The marine offshore Lakšárská Nová Ves Formation with nannoplankton indicating the NN4 Zone and the overlying Šaštín Sand represent the first cycle in the Slovak part of the basin. The Šaštín Sand, a sandy regressive part of the first cycle, is interpreted as a deltaic body sedimented in an environment in which local lagoonal depressions existed (e.g. Baráth et al. 2003).

In the Závod area, the Miocene deposition began during the Karpatian. The borehole Závod-72 drilled this stratigraphic level in depths between 3,749 and 4,181 m (Jiříček 1988). At the base the deposits are mostly barren, but in the interval 4,111-4,114 m (core Nr. 34) they contain an assemblage of foraminifers with *Uvigerina graciliformis* Papp & Turnovsky, *Semivulvulina pectinata* (Reuss), *Pullenia bulloides* (d'Orbigny),

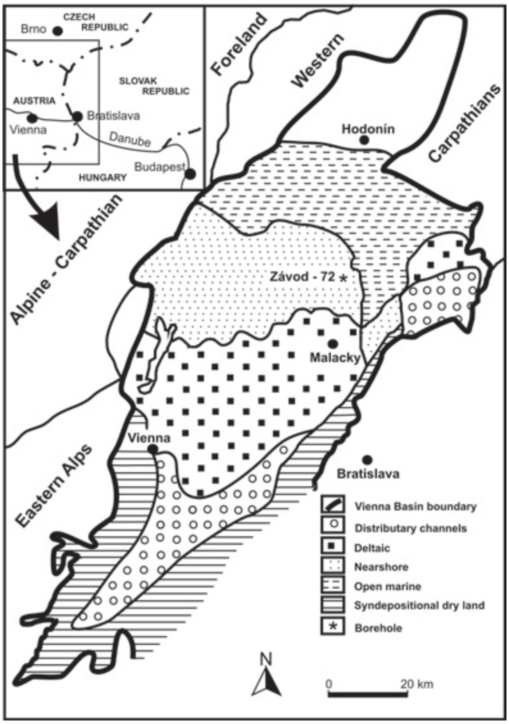

Fig. 1. Karpatian palaeogeography of the Vienna Basin showing the location of the borehole Závod-72, near Malacky (modified after BARÁTH et al. 2003).

Valvulineria arcuata (REUSS), *Bolivina dilatata* (REUSS), *B. scalprata muscosa* CICHA & ZAPLETALOVA, *Cribrostomoides columbiensis* CUSHMAN, etc. (HOLZKNECHT 1977). Higher up the faunal scarcity continues. However, numerous fish remains are preserved in the core Nr. 29 (3,751-3,754 m) situated at the top of the Šaštín Member. This core is constituted by a laminated dark grey, sandy, slightly micaceous, calcareous claystone. Occurrences of pyrite, mica farina and coalificated plant remains are very frequent on the bedding surfaces. The laminae do not alternate regularly and consist of dark gray pelitic and of green grey pelitic horizons (ŘEHÁNEK 1977). The fish skeletons and the coalificated plant remains are the only organic content of this core.

Fish remains are represented by articulated skeletons, some of them with otoliths in situ, sporadically by isolated bones and scales. The skeletons which occur in the dark gray pelitic laminae are generally crushed dorsal-ventrally or sometimes laterally like the skeletons of *Gobius francofurtanus* KOKEN in the *Corbicula* Beds of the Hanau Basin (WEILER 1961).

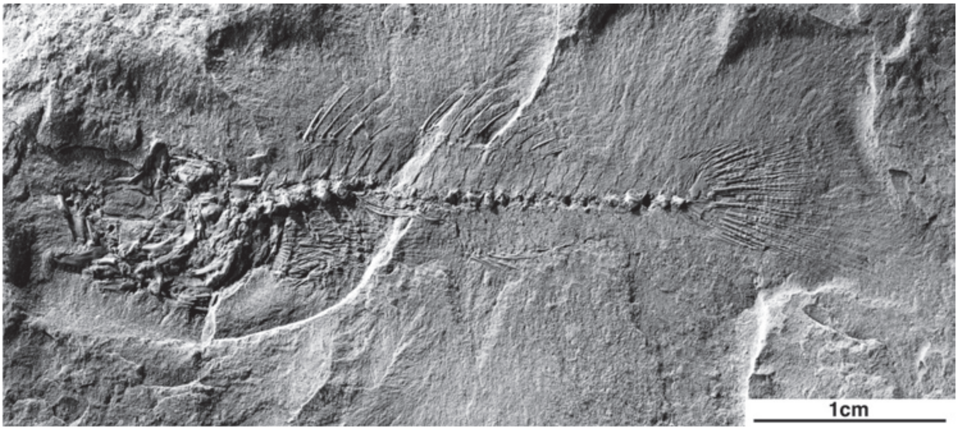

Fig. 2. *Gobius brevis* (Agassiz, 1839); general view of specimen Ge 29 817, borehole Závod-72: 3,751-3,754 m, Karpatian, Vienna Basin.

Systematic part

Order Perciformes Bleeker, 1859

Family Gobiidae Bonaparte, 1832

Genus *Gobius* Linnaeus, 1758 (s.l.)

Gobius brevis (Agassiz, 1839)

(figs 2, 3, 4)

* 1839	*Cottus brevis* Agassiz: 185; pl. 32, figs 2-4.
2003	*Gobius multipinnatus* (von Meyer, 1852) – Brzobohatý et al.: pl. 5, fig. 2 (non pl. 3, fig. 10, non von Meyer, 1852)
2007	*Gobius brevis* (Agassiz, 1839) – Reichenbacher et al.: 370; figs 2-4 [cum syn.].

Description:

The gobiids found in the borehole Závod-72 are small fishes having a standard length ranging from 22.5 to 53 mm (Fig. 2).

H e a d : The head, massive, is large: its length generally equals about 30 % of standard length (26.9 to 30.4 %). Its anatomy fits quite well with that of the other European Miocene freshwater gobiids. The frontals exhibit a characteristic morphology with their very narrow supraorbital region which contrasts with their very wide postorbital part (Nr. Ge 29 793 and Ge 29 810).

The mouth is rather long: the length of the lower jaw is slightly less than half the head length. The dentary is elongate. Its toothed oral process is slightly concave. The premaxillary has a rather narrow ascending process and a rounded articular process. Its rather

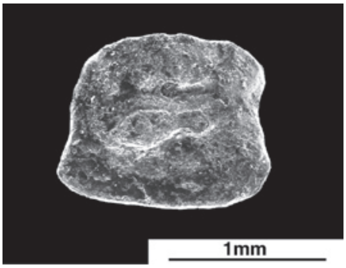

Fig. 3. *Gobius brevis* (AGASSIZ, 1839); right otolith, inner view, borehole Závod-72: 3,751-3,754 m, Karpatian, Vienna Basin.

large posterior process exhibits a triangular shape. The maxillary is long and narrow. The anterior part of the dermopalatine comprises a double articular process allowing an articulation both with the maxillary and the lateral ethmoid.

The triangular quadratum exhibits a large depression for the articulation of symplecticum between its main part and the posterior process.

The hyomandibular is massive: its vertical branch is reduced, in relation with the rather long symplecticum. The preoperculum is characterized by the great development of its horizontal branch which is approximately as long as the vertical one. The operculum is subtriangular; its maximum width equals the length of its anterior edge. The suboperculum which is also triangular exhibits a rather long articular process. The distal ceratohyal which is aliform shows a dilated distal part. The number of branchiostegal rays seems to have been small.

B o d y : The body is elongate: its maximum depth equals 15.1 to 18.3 % of standard length. There are 27 or 28 vertebrae: 11-12 abdominal and 15 or more frequently 16 postabdominal. All the postabdominal vertebrae have centra which are longer than high, supporting rather long straight neurapophyses and hemapophyses.

The caudal fin, which is paddle shaped is rather large: its length equals about 1/4 of standard length. It consists of 12 or 13 principal rays which are both articulated and branched. Additionally, about ten shorter unbranched rays are present both dorsally and ventrally.

The axial caudal skeleton consists of two components. Posteriorly, the triangular uroterminal centrum is fused with the upper triangular hypural plate. Beneath, a similar hypural plate articulates with the centrum. In front of it, the rather narrow parhypural takes place. The free preural centrum supports ventrally a long hemapophysis. Dorsally, above it, a unique epural is present.

The anterior dorsal fin begins slightly behind the head: the antedorsal distance ranges from 35 to 40 % of standard length. It consists of six slender spines, the length of which increases up to the third or fourth spine which is the longest one, whereas the last spines are shorter, although the distal end of the last spine reaches the origin of the posterior dorsal fin, partly because the distance between its base and that of the preceding spine is larger than that between the five first spines of the fin. The anterior dorsal fin is supported by six pterygiophores.

The posterior dorsal fin begins behind the middle of the body length: the antedorsal length equals 55-60 % of standard length. It is composed of one slender spine and 8-10 –

more frequently 9 – articulated rays. The second ray is the longest: its length is slightly less than the height of body mesured near its base. The length of the articulated rays regularly decreases backwards. The posterior doral fin is supported by 9 or 10 pterygiophores; their length progressively decreases backwards.

The anal fin generally begins behind the posterior dorsal fin: the anteanal distance equals 56-64 % of standard length. It consists of one slender spine and 7-8 articulated rays, the length of which is slightly less than that of the articulated rays of the posterior dorsal fin. It is supported by 8 pterygiophores.

The pectoral fins are rather large as the distal end of their longest rays almost reaches the origin of the anal fin. They consist of about 15 rays which articulate with four large radials.

The pelvic fins are inserted under the pectoral fins. They consist of one slender spine and 5 articulated rays.

The ctenoid scales are ornamented with a series of parallel longitudinal ridges.

O t o l i t h s (figs 3, 4): Altogether, 41 saccular otoliths in situ were found in skeletons or fragments of skeletons. This abundance is noteworthy. The otoliths are partially covered by bones and mostly visible from their outer side. They are also rather small (about 1 mm in length) but their size is well correlated with the fish size. For example an otolith

Table 1. Measurements in mm of three well preserved specimens of *Gobius brevis* (AGASSIZ, 1839) from the Závod-72 Borehole.

Measurements Sample	Nr Ge 29 793	Nr Ge 29 805	Nr Ge 29 817
Total length	—	—	42
Standard length	29	33.5	34
Maximum height of body	4.5	5.5	6.5
Head length	9.5	10	11
Distance to first dorsal fin	12	13.5	13
Distance to second dorsal fin	17.5	19	18.5
Distance to anal fin	18.5	18.5	21
Distance to pectoral fins	—	11	12
Distance to pelvic fins	—	—	—
Length of first dorsal fin	4	4	4
Length of second dorsal fin	4	5	5.5
Length of anal fin	4.5	4	4.5
Length of pectoral fins	6	7	8
Length of pelvic fins	—	—	—
Basal length of first dorsal fin	4	3.5	3.5
Basal length of second dorsal fin	4	5.5	6
Basal length of anal fin	3.5	4.5	4.5
Length of caudal pedicle	—	7.5	6.5
Height of caudal pedicle	—	3	3.5

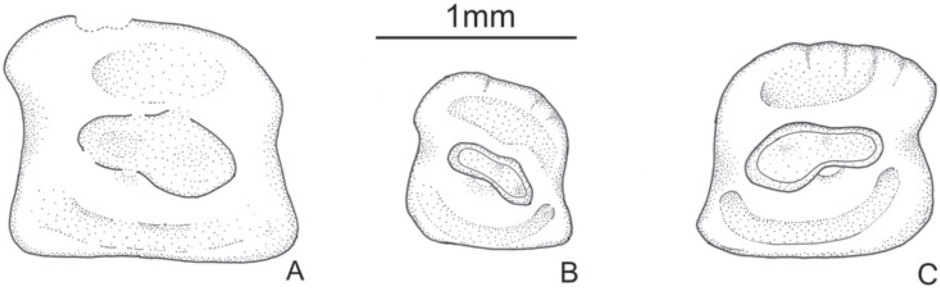

Fig. 4. *Gobius brevis* (AGASSIZ, 1839); left otoliths (A = Ge 29 806, B = Ge 29 816) and the right otolith, inner views, borehole Závod-72: 3,751-3,754 m, Karpatian, Vienna Basin.

length of about 2 mm corresponds to a skeleton as long as 60 mm. This agrees with both some recent and fossil gobiids (BAUZÁ-RULLÁN 1960; MALZ 1978).

The otolith length ranges from 0.7 mm to 2.1 mm and their height from 0.67 mm to 1.7 mm; the length-height ratio is 1.0-1.25. The otoliths are more or less rectangular, with a rounded or slightly ascending posteriorly dorsal rim, slightly incised upper part of the posterior rim, a slightly concave anterior rim and mostly straight ventral rim. The posterodorsal edge is rounded whereas the praeventral one is more pointed. Both sides of the otolith are convex. The sole-like sulcus has generally an anteriorly rounded ostium, but some small otoliths tend to have a pointed one (fig. 4B). The upper ostial rim varies between a pointed and a more rounded angle. A deep ventral line and a dorsal area are well developed.

A growth series of otoliths from small to adult specimens exhibits an ontogenetic variability pattern, showing an increasing length-height ratio related to the increasing age (length) of the fishes (see fig. 4). This fact is common in some gobiid groups (MALZ 1978). A certain growth allometry consisting in an increasing of the fish length versus otolith length ratio was also proved (tab. 2).

Table 2. Growth allometry of *Gobius brevis* (AGASSIZ, 1839) consisting in an increasing of the fish lenght versus otolith lenght ratio. Skeletons with otoliths in situ, borehole Závod-72: 3,751-3,754 m, Karpatian, Vienna Basin.

Total lenght (L) (in mm)		Fish L : Otolith L	Sample (Nr Ge)
Fish	Otolith		
17	0.7	24.2	29.806
18	0.77	23.4	29.807
32	1.2	26.6	29.814
35	1.23	28.4	29.807
42	1.65	25.5	29.817
43	1.43	30.0	29.805
48	1.34	35.8	29.803

D i a g n o s i s : Small elongate gobiids; standard length up to 53 mm. Maximum height of body 15-18 % of standard length. Number of vertebrae 27-28; 11-12 abdominal and 15-16 postabdominal. Caudal fin paddle shaped, feebly convex posteriorly. Anterior dorsal fin with 6 slender spines, the last one slightly distant from the preceding one. Posterior dorsal fin opposed to anal fin, composed of one slender spine and (8) 9 (10) rays. Anal fin with one slender spine and 7-8 rays. Otoliths varying from a quadrangular to rectangular shape, with a small but well-developed posterodorsal angle and a weak praeventral projection and generally with an anteriorly rounded ostium.

C o m p a r i s o n with other non marine gobiids from the Miocene of Central Europe: A new fossil material of gobiid fishes with otoliths preserved in situ was recently described from the Upper *Hydrobia* Beds (Late Burdigalian) of Edenkoben, in the Upper Rhine Graben (REICHENBACHER et al. 2007). The material from the Závod-72 borehole exhibits a great similarity with it and also with those from a Karpatian locality of Austria (Eibiswald, Late Burdigalian) and a Middle Miocene one of South-West Germany (Öhningen, Middle and Late Astaracian) (GAUDANT 1980, 2000).

Gobius brevis was originally described by AGASSIZ (1839) in the lacustrine Middle Miocene locality of Öhningen. It is a rather small slender species having a standard length not exceeding 50 mm and a maximum height of body ranging from 15 to 20 % of standard length. This species is also reported from the lacustrine Karpatian locality of Eibiswald where, like at Öhningen, the cyprinid genus *Palaeoleuciscus* OBRHELOVÁ is also present.

A comparison of the meristic characters of the skeletons from Öhningen, Eibiswald, Unterkirchberg, Edenkoben and Závod-2 Borehole shows that a great similarity exists between them (tab. 3), so that it is possible to include the skeletons under study in the species *Gobius brevis* (AGASSIZ).

On the contrary, *Gobius francofurtanus* (KOKEN) differs from *G. brevis* by its smaller anal fin which consists of one slender spine and 10 rays. In addition, otoliths of *G. francofurtanus* are longer with a more pronounced posterodorsal projection (e.g., REICHENBACHER et al. 2007) and a more undulated or crenated dorsal rim.

According to our own observations (GAUDANT, unpublished), a more important difference exists with *G. multipinnatus* (VON MEYER), a rather rare species from the Early Miocene (Late Burdigalian) of Illerkirchberg (Bavaria, Germany). In fact, this species has more vertebrae (29-30 vertebrae against 27-28), a larger posterior dorsal fin (one

Table 3. Comparison of the meristic characters of Lower and Middle Miocene populations of *Gobius brevis* (AGASSIZ, 1839).

Species	locality	vertebrae	postabdominal vertebrae	first dorsal fin (D1)	second dorsal fin (D2)	anal fin
G. brevis (AGASSIZ)	Závod-72	27-28	15-16	VI	I+(8) 9 (10)	I+7-8
G. brevis (AGASSIZ)	Öhningen	27-28	15-17	VI	I+9-10	I+7-8
G. brevis (AGASSIZ)	Eibiswald	26-27	16	VI	I+9-11	I+8-9
G. brevis (AGASSIZ)	Illerkirchberg	27-28	16	VI	—	I+8
G. brevis (AGASSIZ)	Edenkoben	28-29	(16) 17	VI	I+10-11	I+8

slender spine and 12-13 rays instead of, generally, one spine and 9 rays) and a larger anal fin (one spine and 10 rays instead of one spine and 7-8 rays). From this reason, the skeleton referred by GREGOROVÁ (BRZOBOHATÝ et al. 2003) to *G. multipinnatus* from the Karpatian of the Závod-72 borehole belongs to *G. brevis*. It should be noted that the skeleton from Illerkirchberg from which proceeds the sagitta figured by WEILER (1955, figs 5-6, 8) has a short, stocky-built, body, whereas *G. multipinnatus* (VON MEYER) is a more slender species. Additionally, the reexamination of the material described by WOODWARD (1901) as *G. multipinnatus* VON MEYER has shown that it only includes specimen of *G. brevis* (AGASSIZ) (GAUDANT, unpublished). Relations between otoliths of both species are recently interpreted in JOST et al. (2007).

Gobius serbiensis GAUDANT, from the Lower Miocene (?) of Serbia, differs from *G. brevis* in having generally one more ray in the anal fin and an otolith exhibiting a more expanded postero-ventral angle.

Another still undescribed species of gobiid fishes is present in the Badenian of the Rieskrater Lake (Bavaria, Germany). Although it was referred by DEHM (in DEHM et al. 1977) to the species *Lepidocottus* (= *Gobius*) *brevis* AGASSIZ, small differences exist in the composition of its posterior dorsal and anal fins.

Conclusions

Systematics

The analysis of the skeletons with otoliths in situ under study shows, that all identifiable fish remains from the Karpatian of the Závod-72 borehole belong to the species *Gobius brevis* (AGASSIZ, 1839). It is a species which was rather widespread in Central Europe during the uppermost Lower Miocene and the Middle Miocene. Its best known occurrences are in the lacustrine Karpatian of Eibiswald (Western Styrian Basin, Austria) and in the Middle Miocene of Öhningen (Baden-Würtemberg, Germany), where its articulated skeletons are preserved together with those of Cyprinid fishes. At Illerkirchberg – a Lower Miocene locality which was formerly called Unterkirchberg – articulated skeletons of *Gobius brevis* were found together with those of numerous clupeids, *Clupeonella humilis* (VON MEYER), living either in marine or brackish waters, fossil ambassids (*Dapalis* spp.), of undisputable marine fishes, *Solea kirchbergana* VON MEYER, and of rather scarce genuine freshwater fishes: *Palaeocarassius priscus* (VON MEYER) and *Palaeoleuciscus gibbus* (VON MEYER). One skeleton of *Gobius* cf. *brevis* was also found, together with skeletons of moronids in the brackish diatomites of Várpalota (Hungary), which are Late Badenian in age (GAUDANT 2005). On the contrary, the fish fauna of Edenkoben (Late Burdigalian, REICHENBACHER et al. 2007) is monospecific, the fish skeletons being fossilized in a marly laminated sediment which is rich in nannoplankton, especially *Coccolithus pelagicus*.

Isolated otoliths of *Gobius brevis* were also described as "*G. latiformis* REICHENBACHER" in the Upper Freshwater Molasse of Le Locle, Switzerland (uppermost Middle Miocene; REICHENBACHER & WEIDMANN 1992) and in lacustrine intercalations of the Upper Marine Molasse, Switzerland (uppermost Lower Miocene; REICHENBACHER 1993; JOST et al. 2007).

Palaeogeography

The fact that the material collected at the top of the Šaštín Sand in the Závod-72 Borehole is monospecific may be interpreted as suggesting the occurrence of brackish conditions during the deposition of the fossiliferous strata. The monospecific fish fauna (very low diversity, very high dominance), predominance of juvenile and subadult specimens, a lack of bottom biotas and zoo- and phytoplankton groups, a thin bedding and the occurrence of articulated skeletons (without a great transport and a rapidly gas rise in dead bodies, SCHÄFER 1962) and very abundant coalificated plant debris in claystones indicate a sedimentation in the very shallow environment of a rather closed lagoon with a deficiency of oxygen on the bottom and without active bottom currents. Lithological characters of the rocks (laminated claystones without bioturbation) are in agreement with that palaeoenvironmental conclusion. It is also consistent with the palaeogeographical interpretation that an archipelago existed in the Závod area separating the southern (lagoonal-deltaic) part of the basin from the northern (marine) part during the Late Karpatian (JIŘÍČEK 1988; BARÁTH et al. 2003). This lagoonal environment could have already been established during the final deposition of the Šaštín Sand.

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