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Article

Fish otoliths from the Early Oligocene of Mangyshlak, Kazakhstan

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With 5 figures and 1 table

Abstract: Fish otoliths are described from the Uzunbas Formation (Rupelian) of the Karagie depression, Mangyshlak Peninsula, Western Kazakhstan. A total of 9 species are described, 3 as newly established (*Pterothrissus caspiensis* sp. nov., *Palaeogadus schwarzhansi* sp. nov., *Palimphyes stolyarovi* sp. nov.) and 2 in open nomenclature. This is the first record of Rupelian otoliths from Kazakhstan and the Turan Basin, which formed the eastward extension of the Paratethys during Late Paleogene. Expectedly, the fauna from Uzunbas shows considerable resemblance with the Rupelian fish faunas of the Caucasus, the Crimea, and Western Europe. Gadiform otoliths dominate the otolith association (*Raniceps tuberculosus*, *Palaeogadus schwarzhansi* sp. nov., *Palaeogadus germanus*, *Palaeogadus rarus*). The faunal composition indicates a marine, temperate palaeoenvironment within the neritic zone.

Key words: Teleostei, otoliths, Oligocene, Rupelian, taxonomy, palaeogeography, Mangyshlak, Kazakhstan.

1. Introduction

Fossils from the Rupelian deposits of the Mangyshlak Peninsula (Western Kazakhstan) have been described since the early 20th century. Among the first publications there was a study of Bajarunas (1912) dealing with fossil mollusks, followed by studies from Ilina (1960), Merklin (1960), Korobkov (1967), and Amitrov (1971, 1993). Foraminifera were studied by Morozova and Ter-Grigoryan (Merklin et al. 1960), shark teeth by Menner (1928), Glikman (1964), and Zhelezko & Kozlov (1999).

Stoliarov (1958) placed the Uzunbas, Kujulus and Kendzhalin formations of the Karagie depression (Fig. 1) in the Early Oligocene. The stratigraphic position was attributed to the Rupelian stage of International Stratigraphic Chart based on correlation of foraminifera, mollusks and sharks (Merklin et al 1960; Amitrov 1993; Popov et al 1993; Zhelezko & Kozlov 1999). The Uzunbas Formation was placed in the *Lenticulina hermani* benthic foraminifera zone (Merklin et al. 1960; Amitrov 1993). The mollusk association was interpreted as "typical Rupelian" by Amitrov (1993). The shark teeth were interpreted to represent the Selachian zone E17 (Early part of Ruppelian) by Zhelezko & Kozlov (1999).

The deposits of the Uzunbas Formation are nearly 24 m thick within the Uzunbas ravine (43º48'58" N, 51º44'22"E) at Northern Karagie. They overlay light greenish-grey marls of the Aday Formation of Priabonian age (NP21). Zhelezko & Kozlov (1999) distinguished the following levels of the Uzunbas Formation from bottom to top (Fig. 2):

Level 1: Marl, pale grey, with shark teeth; thickness = 0.6 m.

Level 2: Clay, greenish-grey, decalcified with shark teeth; thickness = 2.5 m.

Level 3: Clay, light green, carbonatic; thickness = 0.4 m.

Level 4: Clay, dark green, decalcified, with manganese layer; thickness = 1 m.

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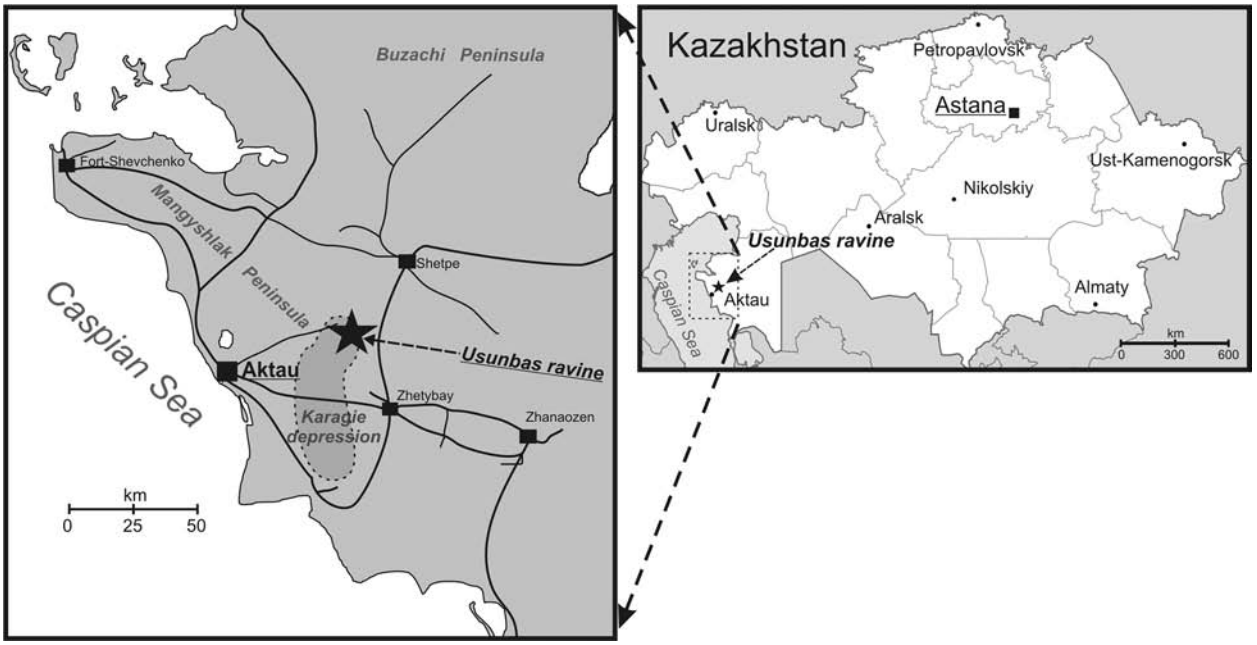

Fig. 1. Location map of the Uzunbas ravine, Karagie depression, Mangyshlak Peninsula, Western Kazakhstan.

Level 5: Clay, light green, carbonatic; thickness = 1.5 m.
Level 6: Clay, light green, carbonatic, with irregular manganese layers and siderite concretions. The upper part contains a layer of 0.1 m with shells of bivalves, gastropods, scaphopods, shark teeth, and otoliths; thickness = 0.4 m.
Level 7: Clay, light green, with iron-hydroxide stain, coarsely stratified, carbonatic, bioturbated; thickness = 0.5 m.
Level 8: Clay, dark brown, slightly carbonatic, with manganese layer; thickness = 0.6 m.
Level 9: Alternation of clay, greenish-grey, carbonatic and clay, pale grey, decalcified. The lower section contains a further manganese layer (0.2-0.3 m); thickness = 16 m.

The Uzunbas Formation is overlain by light yellow to yellow marls of the Kujulus Formation.

2. Material and methods

The Uzunbas Formation was sampled during field work in 2001 to 2005. About 250 kg of sediments were sieved (0.7 mm mesh) from the stratigraphic level 6 (Fig. 2). Despite the large amount of sediment processed, only 80 otoliths were obtained by this method. In addition, otoliths were picked directly from the weathered surface. This method was found to be much more effective, but of course led to an overemphasis of large-size shark teeth and otoliths in the collection. New taxa identified from shark teeth are *Squalus alsaticus* Andreae, 1892, *Lethenia vandenbroecki* (Winkler, 1880), *Cetorhinus parvus* (Leriche, 1908), and *Raja* sp.

The total number of otoliths collected amounts to 599 specimens. The description of the otoliths and the morphological terminology follow that of Koken (1884) and recommendations of Frizzel & Dante (1965) and Nolf (1985). The classification used follows Nelson (2006).

Abbreviations used here follow Schwarzhans (2012): OL = otolith length, OH = otolith height; OsH = ostium height, CaH = cauda height, OsL = ostium length, CaL = cauda length.

Each species is accompanied with a short description complementing the figures and with the aim to optimize future identification of similar collections. Specimens were coated with magnesium oxide before taking photographs. The photograph of Fig. 3H was taken by SEM "JEOL JSM-6490 LV".

All figured specimens and all type specimens are deposited at the geological museum of the Luhansk Taras Shevchenko National University, Ukraine, indicated with the prefix KUZU 2.

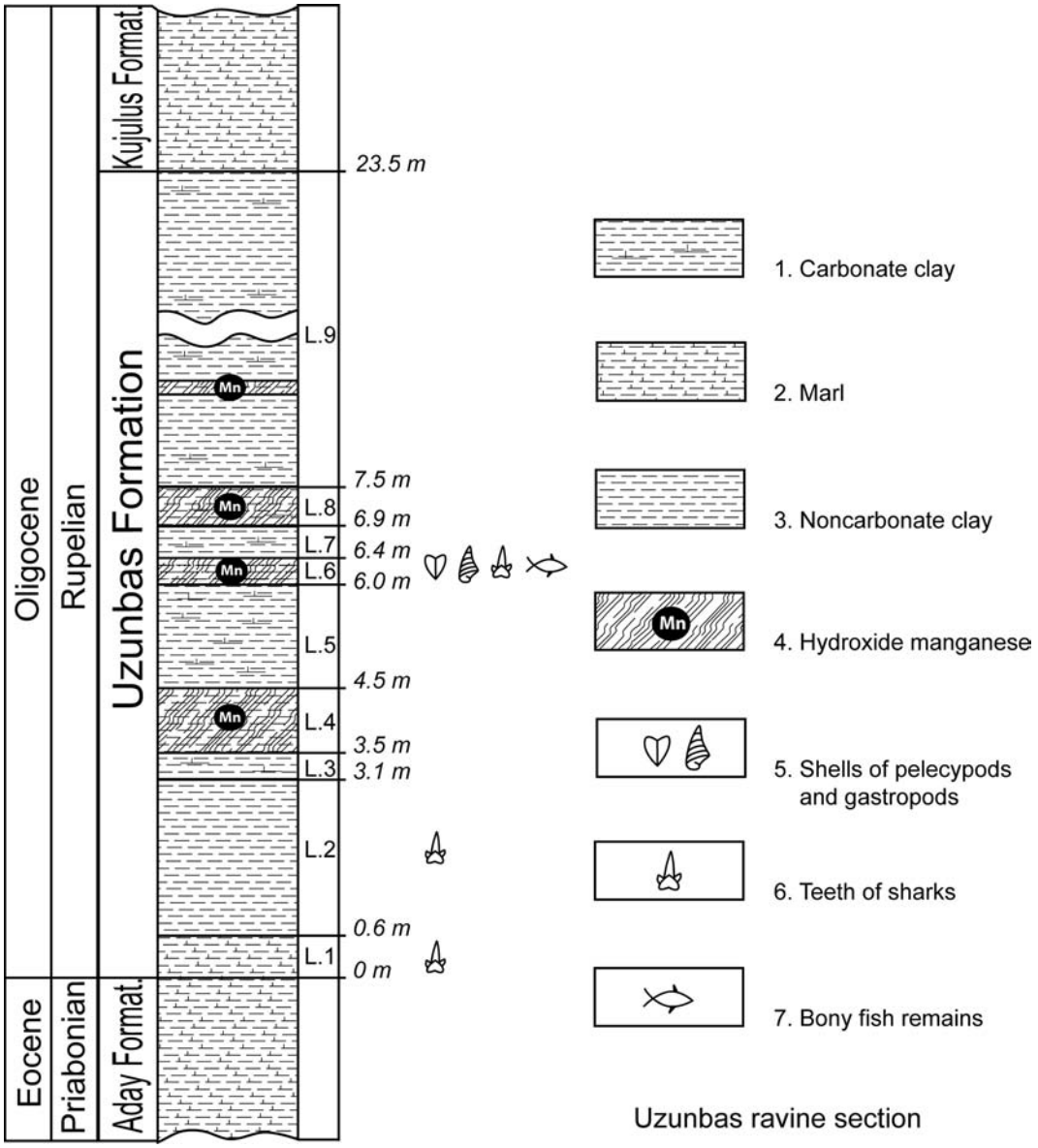

Fig. 2. Stratigraphic position of the Uzunbas Formation.

3. Systematic palaeontology

Class Actinopterygii Klein, 1885
Subclass Neopterygii Regan, 1923
Order Albuliformes Jordan, 1923
Family Pterothrissidae Gill, 1893
Genus *Pterothrissus* Hilgendorf, 1877

Type species: *Pterothrissus gissu* Hilgendorf, 1877; Enoshima, Japan, North Pacific Ocean.

Pterothrissus caspiensis n. sp.
Fig. 3A-G.

2011 *Pterothrissus* sp. 2. – Bratishko, p. 12.
2012 *Pterothrissus* sp. – Bratishko, p. 90.

Etymology: Named after the Caspian Sea.

Holotype: KUZU 2/018 (Fig. 3B).

Paratypes: Six specimens, KUZU 2/015 (Fig. 3A), KUZU

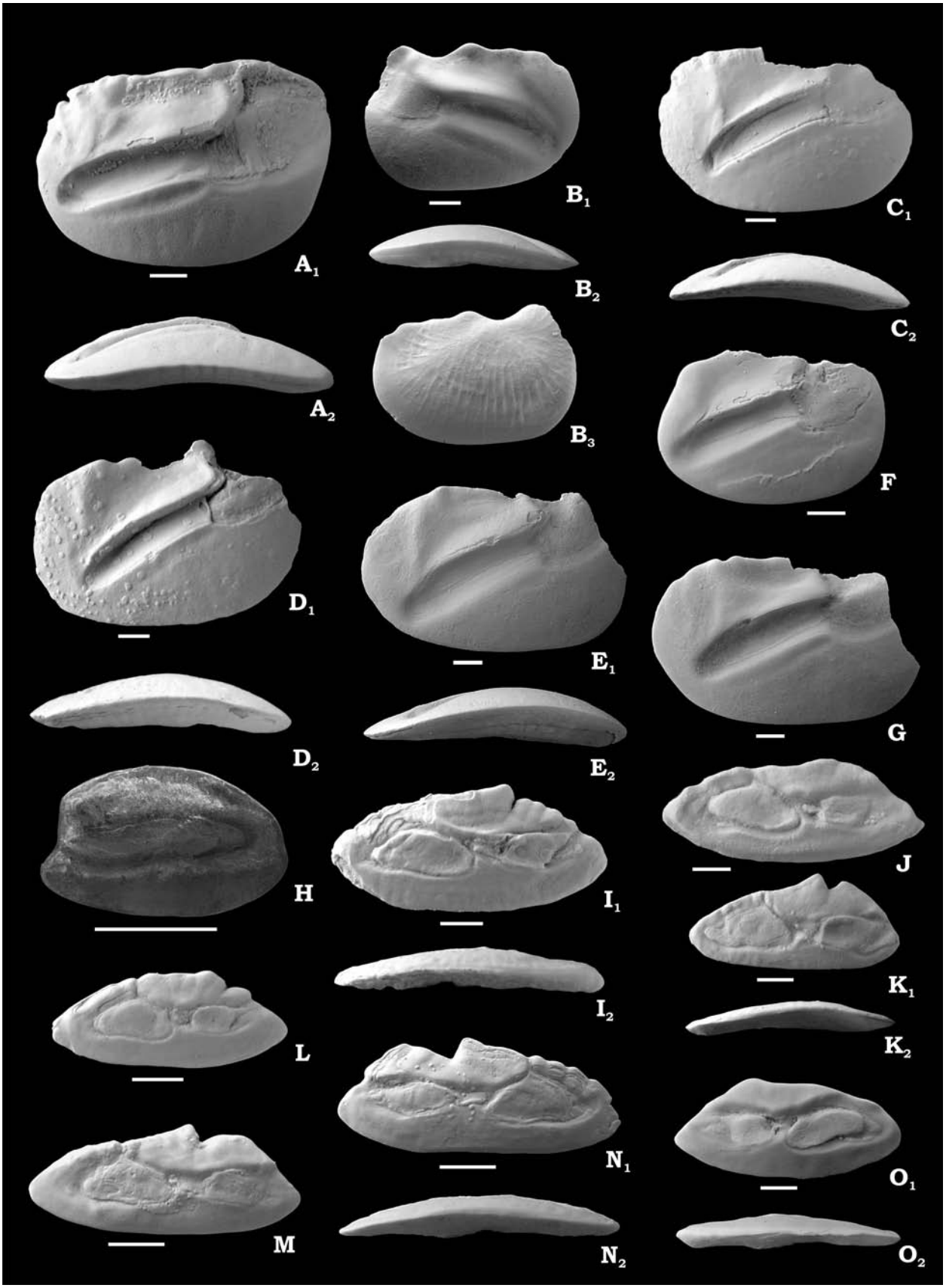

Fig. 3.

2/016 (Fig. 3C), KUZU 2/017 (Fig. 3D), KUZU 2/068 (Fig. 3E), KUZU 2/069 (Fig. 3F), KUZU 2/071 (Fig. 3G).

Further material: 14 otoliths.

Type locality: Uzunbas ravine, Northern Karagie, Mangyshlak Peninsula, Western Kazakhstan.

Type horizon: Uzunbas Formation (Early Rupelian).

Diagnosis: Outline of the otolith rectangular. Ventral and dorsal rims nearly straight. Dorsal rim undulating. Anterior and posterior rims obtusely rounded. Postdorsal angle well-pronounced. Inner face markedly convex; outer face slightly concave. Sulcus straight. The otoliths are thin.

Description: The otoliths are large, up to 19 mm in length, and show a rounded rectangular outline. OL (otolith length) : OH (otolith height) = 1.5-1.6; 1.4 in small specimens. The ventral and dorsal rims are straight, nearly horizontal; the dorsal rim is irregularly undulating. The anterior and posterior rims are blunt and rounded. The antero-dorsal angle is well-developed. The postdorsal angle is pronounced. All otolith rims are sharp. The inner face is markedly convex and smooth. The outer face is concave, often with notable growth rings. The diagonally oriented sulcus is straight and deep. The ostium opens to the antero-dorsal rim. The cauda shows a pointed posterior tip and is considerably narrower and longer than the ostium. OsH:CaH = 2.4-2.8; OsL:CaL = 0.6-0.8. The ostial colliculum is well-expressed and the caudal colliculum indistinct. The crista superior is well developed like the crista inferior below the cauda. A well-marked, but shallow dorsal depression is developed above the cauda. A ventral furrow is missing.

Comparison: The otoliths of *P. caspiensis* differ from *P. umbonatus* (Koken, 1884), a widespread species in the Oligocene of Europe, by the distinct rectangular outline, the well-expressed postdorsal angel and the concave outer face. It differs from *P. complanatus* (Nolf & Steurbaut, 2004) in being thinner, showing a well-expressed postdorsal angel and a concave outer face. *Pterothrissus caspiensis* differs from *P. balisticus* (Nolf & Steurbaut, 2004) in the rectangular outline, the concave outer face (vs convex) and a straighter cauda. In respect to outline and curvature of the inner and outer faces, the most closely resembling species is *P. conchaeformis* (Koken, 1891) from the Paleocene of northwestern Europe, the main difference being the wider ostium and shallower ventral rim in *P. caspiensis*. Thus the recognition of *P. caspiensis* proves the persistence of the *P. conchaeformis* lineage into Late Paleogene times.

Distribution: Rupelian of Kazakhstan.

Order Anguilliformes Regan, 1909
Family Heterenchelyidae Regan, 1912
Genus *Panturichthys* Pellegrin, 1913

Type species: *Panturichthys mauritanicus* Pellegrin, 1913; Eastern Atlantic.

Panturichthys sp.
Fig. 3H

Material: One otolith from the Uzunbas Formation.

Description: An oval, small otolith of nearly 2 mm length. OL : OH = 1.65. The dorsal and ventral rims are smooth and rounded. The rostrum is short and blunt. The exisura and antirostrum are indistinct. The inner face is flat and smooth, the outer face strongly convex and smooth. The undivided sulcus is straight and wide, with large colliculi and opening widely to the anterior rim.

Comparison: This otolith is similar to *Panturichthys subglaber* (Schubert, 1906) from the Neogene of Europe (Nolf 1985), but differs in showing now distinct postdorsal angle and a longer sulcus.

Distribution: Rupelian of Kazakhstan.

Order Gadiformes Goodrich, 1909
Family Merlucciidae Rafinesque, 1815
Genus *Palaeogadus* v. Rath, 1859

Type species: *Palaeogadus troschelii* v. Rath, 1859; Early Oligocene of Switzerland.

Fig. 3. Otoliths from the Rupelian of Mangyshlak, Western Kazakhstan. **A-G** – *Pterothrissus caspianensis* sp. nov. A: Paratype, KUZU 2/015, inner face (A_1), ventral view (A_2). B: Holotype, KUZU 2/018, inner face (B_1), ventral view (B_2), outer face (B_3). C: Paratype, KUZU 2/016, inner face (C_1), ventral view (C_2). D: Paratype, KUZU 2/017, inner face (D_1), ventral view (D_2). E: Paratype, KUZU 2/068, inner face (E_1), ventral view (E_2). F: Paratype, KUZU 2/069, inner face. G: Paratype, KUZU 2/071, inner face. **H** – *Panturichthys* sp., KUZU 2/004, inner face. **I-O** – *Palaeogadus germanus* Fedotov, 1970. I: KUZU 2/028, inner face (I_1), ventral view (I_2). J: KUZU 2/030, inner face. K: KUZU 2/054, inner face (K_1), ventral view (K_2). L: KUZU 2/029, inner face. M: KUZU 2/031, inner face. N: KUZU 2/047, inner face (N_1), ventral view (N_2). O: KUZU 2/052, inner face (O_1), ventral view (O_2). Scale bar = 2 mm, except for 3H = 1 mm.

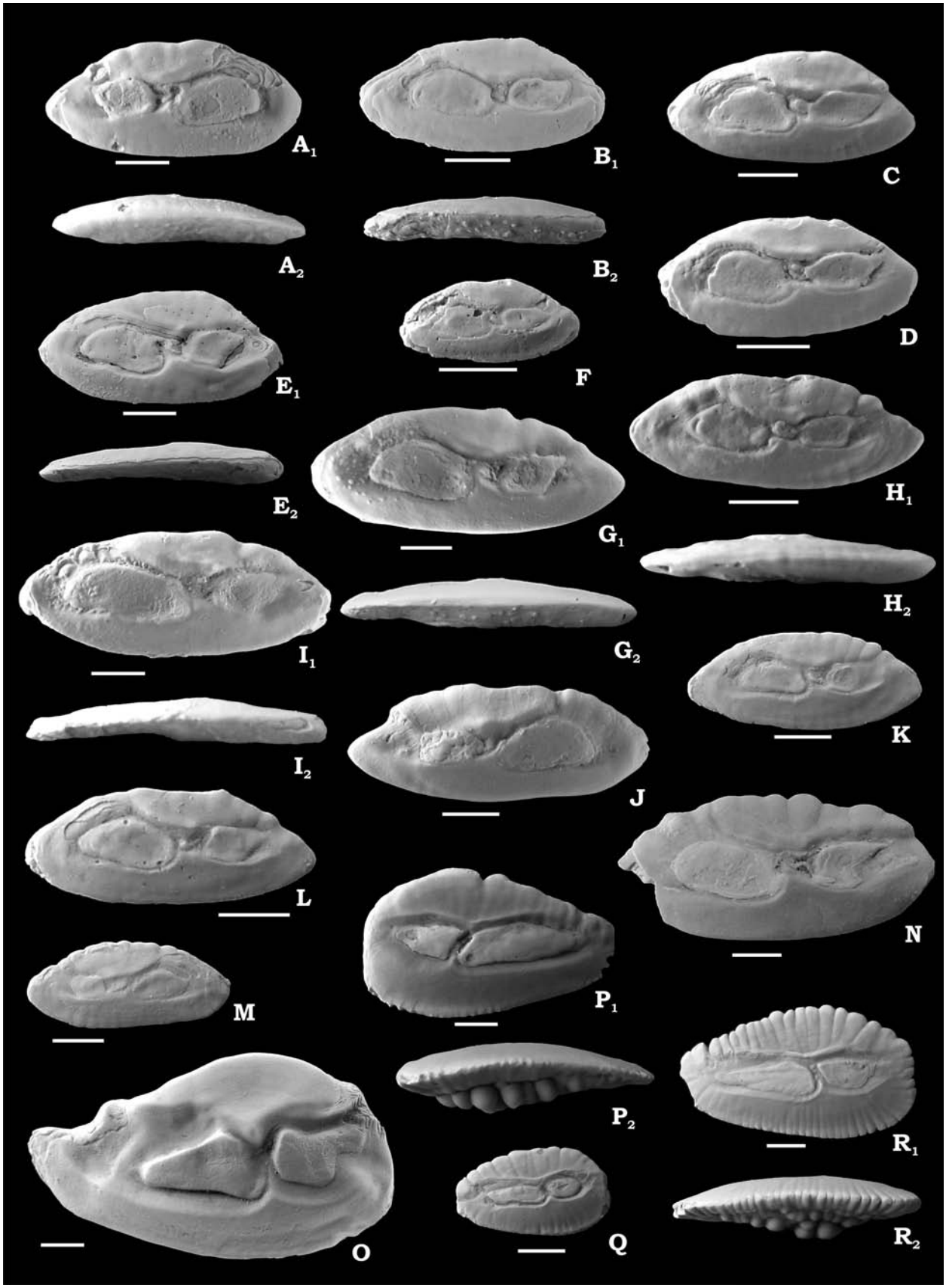

Fig. 4.

Palaeogadus germanus Fedotov, 1970
Fig. 3I-O

1970 *Palaeogadus germanus*. – Fedotov, p. 117, figs. 1-2 [skel.]
1976 *Palaeogadus germanus* Fedotov, 1970. – Fedotov, p. 20-23, figs. 6-7 [skel.], fig. 8 [otol.].
1985 *Palaeogadus germanus* Fedotov, 1970. – Nolf, p. 61.
1997 *Palaeogadus germanus* Fedotov, 1970. – Bannikov & Parin, p. 136.
2003 *Palaeogadus germanus* Fedotov, 1970. – Rozenberg, p. 62-64, fig. 5.5-5.8, 12, pl. 8, figs. 1-2.
2009 *Palaeogadus germanus* Fedotov, 1970. – Bannikov, p. 18.
2011 *Palaeogadus germanus* Fedotov, 1970. – Bratishko, p. 12.
2012 *Palaeogadus germanus* Fedotov, 1970. – Bratishko, p. 90.

Material: 60 otoliths from the Uzunbas Formation, Mangyshlak.

Description: The otoliths are elongated and fusiform in outline. The size of the otoliths is mostly not exceeding 5 mm. OL : OH = 2.2-2.4. The ventral rim is curved. The anterior and posterior tips are pointed. The dorsal rim is sometimes slightly indented and has a broadly lobate antero-dorsal angle. Some otoliths have a more round antero-dorsal lobe, whereas others show one or two pointed apexes at the dorsal rim.

The inner face of the otolith is slightly convex with a rather deep sulcus. The outer face is smooth or shows some furrows reaching from the dorsal rim to a distinct ridge along the horizontal axis of the otolith. Juvenile otoliths are more strongly ornamented than adults.

The sulcus is located in the middle of the long axis of otolith. The oval ostium opens to the anterior rim through, but is somewhat narrowed. The triangular cauda is longer and higher than the ostium. Cauda and ostium are filled with rather large colliculi. The crista superior is sharp, the crista inferior and the ventral furrow are indistinct. The collum is long, shallow and shows a small pseudocolliculum.

Comparison: *Palaeogadus germanus* differs from *P. emarginatus* (Koken, 1984) from the Oligocene of Europe (Gaemers & Hinsbergh 1978; Muller & Rosenberg 2003a; Shevchenko & Bratishko 2008) in the more compact shape of the otolith, the higher posterior-dorsal of the otolith and the wide triangular cauda. It has to be noted that certain specimens (KUZU 2/031 (Fig. 3M), KUZU 2/047 (Fig. 3N), KUZU 2/054 (Fig. 3K) et al.) are quite similar in the expression of the dorsal rim to otoliths of *P. emarginatus* from the collection of E. Koken (Gaemers & Hinsbergh 1978, pl. 4, fig 1), which indicates a considerably variable feature.

Distribution: Rupelian of the Caucasus and Mangyshlak (Kazakhstan).

Palaeogadus rarus Novitskaya, 1961
Fig. 4A-F

1961 *Palaeogadus rarus* sp. nov. – Novitskaya, p. 120-125, figs. 1-2 [skel.], 3a, b [otol.].
1976 *Palaeogadus rarus* Novitskaya, 1961. – Fedotov, p. 28-30, pl. 3, figs. 1, 12 [skel.].
1978 *Palaeogadus rarus* Novitskaya, 1961. – Gaemers & Hinsberg, p. 17.
1985 *Palaeogadus rarus* Novitskaya, 1961. – Nolf, p. 61.
2003 *Palaeogadus rarus* Novitskaya, 1961. – Rozenberg (diss.), p. 64-65, figs. 5.5.-5.7, 11, pl. 8, fig. 10.
2009 *Palaeogadus rarus* Novitskaya, 1961. – Bannikov, p. 18.
2011 *Palaeogadus rarus* Novitskaya, 1961. – Bratishko, p. 12.
2012 *Palaeogadus rarus* Novitskaya, 1961. – Bratishko, p. 90.

Material: 16 otoliths from the Uzunbas Formation, Mangyshlak.

Description: The otoliths are oval in shape and reach sizes of about 5 mm length. OL : OH = 2.1-2.2. The ventral rim is shallow and gently curved. The posterior tip is pointed, the anterior tip bluntly pointed below the ostium. The flat outer face is smooth or shows few furrows reaching from the dorsal rim to a well developed ridge along the horizontal axis of the otolith. The sulcus is located supramedian. The oval ostium is shorter and narrower than the cauda, which is ventrally extended. The sulcus is filled with large colliculi. The collum is long with a distinct pseudocolliculum. The crista superior is sharp, the crista inferior indistinct. The dorsal depression and the ventral furrow are indistinct, the latter running close to the ventral rim of the otolith.

Fig. 4. Otoliths from the Rupelian of Mangyshlak, Western Kazakhstan. **A-F** – *Palaeogadus rarus* Novitskaya, 1961. A: KUZU 2/023, inner face (A_1), ventral view (A_2). B: KUZU 2/040, inner face (B_1), ventral view (B_2). C: KUZU 2/025, inner face. D: KUZU 2/026, inner face. E: KUZU 2/038, inner face (E_1), ventral view (E_2). F: KUZU 2/037, inner face. **G-N** – *Palaeogadus schwarzhansi* sp. nov. G: Holotype, KUZU 2/033, inner face (G_1), ventral view (G_2). H: Paratype, KUZU 2/032, inner face (H_1), ventral view (H_2). I: Paratype, KUZU 2/034, inner face (I_1), ventral view (I_2). J: Paratype, KUZU 2/035, inner face. K: Paratype, KUZU 2/066, inner face. L: Paratype, KUZU 2/065, inner face. M: Paratype, KUZU 2/063, inner face. N: Paratype, KUZU 2/055, inner face. **O-R** – *Raniceps tuberculosus* (Koken, 1884). O: KUZU 2/008, inner face. P: KUZU 2/006, inner face (P_1), ventral view (P_2). Q: KUZU 2/077, inner face. R: KUZU 2/075, inner face (R_1), ventral view (R_2). Scale bar = 2 mm.

Comparison: The specimens from Uzunbas show a close resemblance to the otolith described from an *in situ* skeleton find in the holotype of *P. rarus* from the Rupelian of the Caucasus (Novitskaya 1961; Rozenberg 2003). Otoliths of *P. rarus* differ from those of *P. germanus* in being more compact and the lack of a distinct antero-dorsal lobe. *Palaeogadus rarus* is similar to *P. compactus* Gaemers, 1978 in the outline, thickness, proportions (*P. compactus* has an OL : OH of 2.1-2.3, rarely 2.4) and the shape of the ostium, but differs in the wider cauda and the smaller and rather indistinct dorsal depression.

Distribution: Rupelian of the Caucasus and Mangyshlak (Kazakhstan).

Palaeogadus schwarzhansi sp. nov.
Fig. 4G-N

2003 *Palaeogadus* sp. – Rozenberg, p. 65, pl. 8, figs. 6-7.
2011 *Palaeogadus latebrosus* Daniltshenko, 1960. – Bratishko, p. 12.
2012 *Palaeogadus* sp. – Bratishko, p. 90.

Etymology: In honour of Werner Schwarzhans (Hamburg) for his contributions to the knowledge of fossil and Recent fish otoliths.

Holotype: KUZU 2/033 (Fig 4G).

Paratypes: seven specimens, KUZU 2/032 (Fig. 4H), KUZU 2/034 (Fig. 4I), KUZU 2/035 (Fig. 4J), KUZU 2/066 (Fig. 4K), KUZU 2/065 (Fig. 4L), KUZU 2/063 (Fig. 4M), KUZU 2/055 (Fig. 4N).

Further material: 94 otoliths.

Type locality: Uzunbas ravine, northern Karagie, Mangyshlak Peninsula, Western Kazahstan.

Type horizon: Uzunbas Formation (Early Rupelian).

Diagnosis: Otoliths elongate with fusiform outline. OL : OH = 2.4-2.6. Ventral rim shallow and smooth. Dorsal rim gently curved and crenulated, with a low antero-dorsal angle which expands less than the postdorsal rim. Cauda higher and longer than ostium.

Description: The otoliths are elongate, fusiform and reach a size of about 5 mm length. The ventral rim is regularly curved and shallow. The dorsal rim is gently curved and crenulated, with a low antero-dorsal angle. Anterior and posterior tips are pointed. The inner face is slightly convex, the outer face smooth and concave with furrows reaching from the dorsal rim to a well developed ridge along the horizontal axis of the otolith. Adult otoliths are gently ornamented, juvenile specimens much more strongly. The crista superior is sharp, the crista inferior considerably less sharp. The long supramedian sulcus shows a wide, dorsally much extended cauda. The oval ostium is considerably narrower and shorter than the cauda. Juvenile specimens have a less expanded and more oval shaped cauda. The sulcus is filled with large colliculi. The collum is long with a small pseudocolliculum. The dorsal depression and ventral furrow are indistinct.

Comparison: *Palaeogadus schwarzhansi* shows a certain degree of similarity with an otolith figured from an *in situ* find of *P. latebrosus* Daniltshenko, 1960 by Fedotov (1976) from the early Oligocene of the Caucasus. Consistent differences are the low antero-dorsal angle, the wider cauda and the longer ostium. From *P. rarus* it is distinguished by the elongated form (OL : OH = 2.4-2.6 vs 2.1-2.2) and the low antero-dorsal angle, and from *P. emarginatus* (Koken, 1884) likewise by the shallow antero-dorsal angle and also the wide ostium and in particular the much wider cauda. From *P. germanus* finally it differs in the low antero-dorsal angle, even when considering a certain degree of variation of the shape of this antero-dorsal rim in that species. Rozenberg (2003) figured a number of otoliths in open specific nomenclature extracted from incomplete skeletons (collection number PIN 1417-765) from the Rupelian of the Caucasus, which are similar to the ones here described from Kazakhstan and are in deed considered to represent the same species.

Distribution: Rupelian of the Caucasus and Mangyshlak (Kazakhstan)

Family Ranicipitidae Markle, 1989
Genus *Raniceps* Oken, 1817

Type species: *Blennius raniceps* Linnaeus, 1758; lakes of Sweden.

Raniceps tuberculosus (Koken, 1884)
Fig. 4O-R

1884 *Otolithus* (Gadi) *tuberculosus*. – Koken, p. 540-541, pl. 11, fig. 1.
1977 *Raniceps tuberculosus* (Koken, 1884). – Nolf, p. 28, pl. 8, fig. 8.
1978 *Palaeoraniceps tuberculosus* (Koken, 1884). – Gaemers & Hinsbergh, p. 517, pl. 6, figs. 2-3.
1994 *Raniceps tuberculosus* (Koken, 1884). – Schwarzhans, p. 69-70, figs. 77-83.
1996 *Raniceps tuberculosus* (Koken, 1884). – Muller, p. 43, pl. 3, fig. 21.
2000 *Raniceps tuberculosus* (Koken, 1884). – Muller & Rozenberg, p. 85-86, fig. 7.8-7.12.
2003a *Raniceps tuberculosus* (Koken, 1884). – Muller & Rozenberg, p. 332, fig. 5.1-5.2.
2003b *Raniceps* ex. gr. *tuberculosus* (Koken, 1884). – Muller & Rozenberg, p. 368-369, fig. 5.20-5.21.
2008 *Raniceps tuberculosus* (Koken, 1884). – Muller, p. 75, pl. 8, fig. 21.
2008 *Raniceps tuberculosus* (Koken, 1884). – Girone & Nolf, p. 17, 19, 21.

2008 *Raniceps tuberculosus* (Koken, 1884). – Nolf & Girone, p. 153, fig. 9D.
2008 *Raniceps* sp. 1. – Shevchenko & Bratishko, p. 183, pl. 3, fig. 2.
2008 *Raniceps* sp. 2. – Shevchenko & Bratishko, p. 183, pl. 3, fig. 3.
2008 *Raniceps tuberculosus* (Koken, 1884). – Schwarzhans, p. 96, pl. 1, fig. A, B.
2011 *Raniceps tuberculosus* (Koken, 1884). – Bratishko, p. 10, 11, 12.
2012 *Raniceps tuberculosus* (Koken, 1884). – Bratishko, p. 90.

Material: 355 otoliths from the Uzunbas Formation, Mangyshlak.

Description: Oval, large otoliths, up to 20 mm length. OL : OH = 1.7-1.9. The ventral rim is gently curved with an antero-ventral angle, the dorsal rim with a broad medio-dorsal angle. The anterior tip is blunt, the posterior tip pointed. The posterior part of the otolith is narrowed. The otoliths are biconvex. The inner face is more convex than the outer face, and shows some radial furrows, becoming smoother in large specimens (more than 10-15 mm). The outer face is intensely ornamented with distinct tubercles (hence the name). All rims are finely crenulated, more intense so in smaller specimens. The sulcus is wide and supramedian with well defined colliculi. The colliculi occupy nearly the entire sulcus leaving only a narrow space for the collum. The cauda is slightly longer than the ostium, their width being approximately equal. Large specimens of more than 15 mm length exhibit a widened cauda. The crista superior is better expressed than the crista inferior. The ventral furrow and the dorsal depression are indistinct.

Comparison: *Raniceps tuberculosus* is very similar to *R. latisulcatus* (Koken, 1884). The distinction of the two species is being discussed in detail by Schwarzhans (2008). The comparison of the otoliths of *R. tuberculosus* from Mangyshlak with those of *R. latisulcatus* from the Priabonian of Dnepropetrovsk (Ukraine) shows the following differences: *R. tuberculosus* is slightly more compressed (OL : OH = 1.7-1.9 vs 1.9-2.1) and shows broad medio-dorsal and anterior-ventral angles, a less convex inner face (except for very large otoliths) and an only slightly widened cauda (vs cauda being considerably wider than the ostium in *R. latisulcatus*).

A very similar otolith has been figured by Novitskaya (1961) from an *in situ* recovery from the holotype of *Palaeogadus eximius* Novitskaya, 1961 from the Rupelian of the Caucasus. Rozenberg (2003) stated that he could not locate the otolith figured by Novitskaya and that it should be regarded as lost. He goes on arguing for a transfer of *P. eximius* to the genus *Raniceps* on the basis of the otolith figured by Novitskaya. This view is followed in Nolf (pers. comm.), who in an upcoming publication intends to figure otoliths from the Uzunbas Formation of Kazakhstan as *Raniceps eximius* (Novitskaya, 1961). It must be mentioned, however, that Novitskaya stated the presence of 12 rays in the first dorsal fin in the holotype of *Palaeogadus eximius*, while *Raniceps* has only 3, which is already the case in a species known from the Late Oligocene (*Pseudoraniceps sagus* Fedotov, 1974). We conclude that without a review of skeleton and (new) otolith material from Novitykaya's type locality it is impossible to adequately resolve the systematic position of *Palaeogadus eximius*. Furthermore, the relation of the otolith attributed to *P. eximius* with those of *R. tuberculosus* is problematic at this stage and we consider that both nominal species possibly represent a single species only.

Distribution: Priabonian, Rupelian of Ukraine, Rupelian of Kazakhstan, Early and Late Oligocene of Western Europe.

Order Ophidiiformes Berg, 1937
Family Ophidiidae Rafinesque, 1810
Genus *Palaeomorrhua* Gaemers & Schwarzhans, 1973

Type species: *Otolithus* (Gadi) *faba* Koken, 1884; Oligocene of Germany.

Palaeomorrhua faba (Koken, 1884)
Fig. 5A-D

1884 *Otolithus* (Gadi) *faba*. – Koken, p. 541-542, pl. 11, fig. 8.
1891 *Otolithus* (Morrhua) *söllingenensis*. – Koken, p. 94-95, pl. 3, fig. 1.
1978 *Palaeomorrhua faba* (Koken, 1884). – Gaemers & Hinsbergh, p. 22, pl. 8, fig. 1.
1985 "genus Neobythitinarum" *faba* (Koken, 1884). – Nolf, p. 67, fig. 51N.
1994 *Palaeomorrhua faba* (Koken, 1884). – Schwarzhans, p. 110, figs. 240-241.
2000 *Palaeomorrhua faba* (Koken, 1884). – Muller & Rozenberg, p. 92, fig. 10.19, pl. 3, fig. 5.
2003 *Palaeomorrhua faba* (Koken, 1884). – Rozenberg, p. 71, pl. 10, fig. 6.
2011 *Palaeomorrhua faba* (Koken, 1884). – Bratishko, p. 12.
2012 *Palaeomorrhua faba* (Koken, 1884). – Bratishko, p. 90.

Material: 6 otoliths from the Uzunbas Formation, Mangyshlak.

Description: The otoliths are oval, large (7-17 mm length), massive and thickened along the dorsal rim. They are nearly symmetrical along the horizontal and the vertical axes. OL : OH = 1.6-1.7. The ventral rim is deeply curved and smooth, the dorsal rim smooth too, but less strongly curved. The anterior and posterior tips are pointed. The inner face is strongly convex and smooth. The outer face is slightly concave with some tubercles. The sulcus is very wide and occupies a large part of the inner face. It is divided into nearly equally large ostium and cauda, the latter being slightly longer. The colliculi are at level with the inner face. The collum

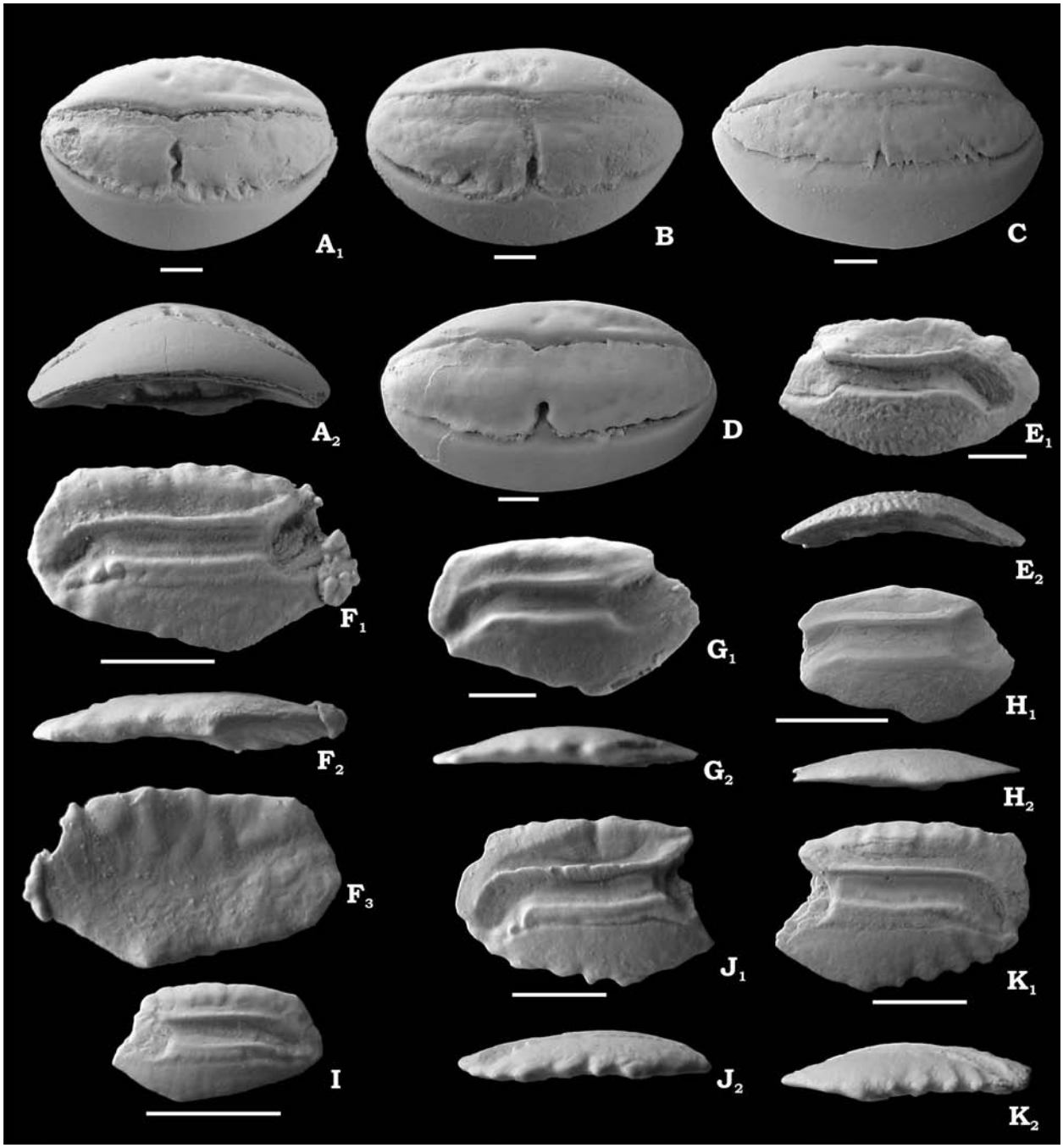

Fig. 5. Otoliths from the Rupelian of Mangyshlak, Western Kazakhstan. **A-D.** *Palaeomorrhua faba* (Koken, 1884). A: KUZU 2/013, inner face (A_1), ventral view (A_2). B: KUZU 2/014, inner face. C: KUZU 2/072, inner face. D: KUZU 2/073, inner face. **E** – *Erythrocles* sp. inner face (E_1), ventral view (E_2). **F-K** – *Palimphyes stolyarovi* sp. nov. F: Holotype, KUZU 2/022, inner face (F_1), ventral view (F_2), outer face (F_3). G: Paratype, KUZU 2/020, inner face (G_1), ventral view (G_2). H: Paratype, KUZU 2/086, inner face (H_1), ventral view (H_2). I: Paratype, KUZU 2/084 inner face. J: KUZU 2/088, inner face (J_1), ventral view (J_2). K: KUZU 2/087, inner face (K_1), ventral view (K_2). Scale bar = 2 mm.

is narrow with a clear, deep depression (less well-developed in small specimens).

Comparison: This species differs from *Palaeomorrhua thulei* Schwarzhans, 2004 form the Middle Paleocene of Greenland by the large, massive, thick and compact otoliths

and wider sulcus. The most similar species is *P. bulbus* (Nolf, 1978) ("genus Ophidiidarum" in Nolf) from the Late Paleocene of Belgium. Otoliths of *P. faba,* however, have a wider sulcus and smooth dorsal and ventral rims.

Distribution: Rupelian of Kazakhstan, Denmark; Rupelian and Chattian of Germany.

Order Perciformes Bleeker, 1859
Family Emmelichthyidae Jordan, 1923
Genus *Erythrocles* Jordan, 1919

Type species: *Erythrocles schlegelii* (Richardson, 1846); Indo-West Pacific.

Erythrocles sp.
Fig. 5E

2011 «genus Haemulidarum» sp. 2. – Bratishko, p. 12.
2012 «genus Serranidarum» sp. – Bratishko, p. 90.

Material: One otolith from the Uzunbas Formation, Mangyshlak.

Description: The otolith is large (nearly 9 mm) and elongate. The anterior tip is damaged. The ventral rim is smooth and deeply curved. The dorsal rim is almost straight, indistinctly undulating and shows a distinct postdorsal angle. The posterior tip is rounded. The otolith is thin, with a convex inner and a concave outer face. All otolith rims are sharp. The sulcus is wide, deep and straight except for the posterior part of the cauda which is bent downwards. The ostium has about a third of the length of the cauda and is twice as wide due to its dorsal and ventral expansion. The crista superior is sharp; the crista inferior is also distinct but less sharp. The ventral furrow is distinct, located at some distance from the ventral rim of the otolith. The dorsal depression is shallow and wide.

Comparison: This otolith resembles most *Erythrocles monodi* Poll & Cadenat, 1954 in outline and shape of the sulcus, as has been figured in Tuset et al. (2008). It differs, however, in being more compressed, the more deeply curved ventral rim and the wider sulcus. In the fossil record *Erythrocles ohei* Schwarzhans, 1994 from the Late Oligocene of Germany differs in the more compressed outline, the stronger postdorsal angle and the course of the dorsal rim. Two further otoliths probably representing the same species have been found in the Kyzyl-Dzhar Beds (Early Rupelian) of Crimea, Ukraine (unpublished data).

Distribution: Rupelian of Kazakhstan and Ukraine.

Family Euzaphlegidae Daniltshenko, 1960
Genus *Palimphyes* Agassiz, 1844

Type species: *Palimphyes longus* (Agassiz, 1844) (syn. *Clupea elongata* Blainville, 1818); Early Oligocene of Switzerland.

Palimphyes stolyarovi sp. nov.
Fig. 5F-K

2011 *Palimphyes* sp. – Bratishko, p. 12.
2012 *Palimphyes* sp. – Bratishko, p. 90.

Holotype: KUZU 2/022 (Fig. 5F).

Paratypes: six specimens, KUZU 2/020 (Fig. 5G), KUZU 2/021, KUZU 2/084 (Fig. 5I), KUZU 2/086 (Fig. 5H), KUZU 2/087 (Fig. 5K), KUZU 2/088 (Fig. 5J).

Further material: 14 otoliths.

Type locality: Uzunbas ravine, northern Karagie, Mangyshlak Peninsula, Western Kazakhstan.

Type horizon: Uzunbas Formation, Early Rupelian.

Etymology: In honour of A.S. Stolyarov (Moscov), who studied the stratigraphy of the Oligocene of Mangyshlak.

Diagnosis: Otolith elongate with flat dorsal rim, blunt posterior tip and ventral rim with a distinct angle slightly anterior of the middle. Sulcus straight, with an abruptly downward bent caudal tip and strong ventrally expanded ostium.

Description: The otoliths are elongate, thin, 3.5 mm to 6 mm in length. The dorsal rim is straight, gently undulating and with a distinct postdorsal angle. The ventral rim is deeply curved with a distinct obtuse angle slightly anterior of the middle. The posterior tip is blunt, the anterior tip short, with a rounded rostrum and a small exisura and antirostrum. The outer face is smooth and moderately concave, the inner face is convex and ornamented near the dorsal and the postventral rims. The sulcus is straight, deep and shifted dorsally. The ostium is considerably widened, particularly ventrally, and less than half the length of the cauda. The posterior part of the cauda is bent downwards and reaches close to the postventral rim. The crista superior and the crista inferior are distinct and sharp. The dorsal depression is narrow and distinct. There is no ventral furrow.

Comparison: *Palimphyes chadumicus* Daniltshenko, 1960 from the Early Oligocene of the Caucasus is the only species of the genus *Palimphyes* known from otoliths in situ (Rozenberg 2003). Otoliths of *Palimphyes stolyarovi* share with those of *P. chadumicus* the elongate shape, the distinct postorsal angle and the straight, supramedian sulcus. They differ in the distinct obtuse ventral angle, the wider sulcus and particularly the ventrally strongly widened ostium (vs slightly widened in *P. chadumicus*). Three otoliths of *P. stolyarovi* have also been found in the Kyzyl-Dzhar Beds (Early Rupelian) of Crimea, Ukraine (unpublished data).

Distribution: Rupelian of Kazakhstan and Ukraine.

3. Discussion

3.1. Biostratigraphic interpretation

In consideration of the small quantity of species obtained and since half of them are new to science only little can be said about their stratigraphic relevance (Table 1).

Raniceps tuberculosus dominates the otolith association by more than 60%. This species is also found widespread in Oligocene deposits of Western Europe and the Priabonian (Mandrikovka Beds) and Rupelian (Kyzyl-Dzhar and Zubakino Beds) of Ukraine (Müller & Rozenberg 2003a, 2003b; Shevchenko & Bratishko 2008). Other common species are: *Palaeogadus schwarzhansi* (more than 16%) and *P. germanus* (more than 10%). *Palaeogadus schwarzhansi*, *P. germanus* and *P. rarus* have been reported from *in situ* finds from the Early Oligocene of the Caucasus. *Erythrocles* sp. and *Palimphyes stolyarovi* sp. nov. are also known from Rupelian deposits (Kyzyl-Dzhar Beds) of the Crimea, Ukraine (unpublished data). The stratigraphic range of *Palaeomorrhua faba* does not contradict an Early Oligocene age of the Uzunbas Formation, as has been established by foraminifera, mollusks and sharks.

3.2. Paleogeographical and palaeoecological interpretation

Palaeogadus germanus, *P. rarus and P. schwarzhansi* indicate the existence of faunal interchange between the Mangyshlak and Caucasus basins during the Rupelian. *Raniceps tuberculosus*, *Erythrocles* sp. and *Palimphyes* sp. furthermore support a connection of the Crimean and Mangyshlak basins. The finding of *Raniceps tuberculosus* and *Palaeomorrhua faba* even indicates a faunistic connection with the North Sea Basin. Thus, the composition of the otolith association confirms the interconnection of the Turan Sea, Scythian Sea and North Sea during the Early Oligocene (Popov et al. 2009).

Most research of mollusks from the Uzunbas Formation indicates normally marine conditions at a palaeo-water depth in the range of not less than 100 m (Merklin et al. 1960; Amitrov 1971, 1993). However, Amitrov (1971) mentioned the absence of typical deep-sea and cold-water gastropods.

The composition of teleosts also indicates normal marine salinity. The dominance of gadiforms (*Raniceps* and *Palaeogadus*) may indicate cooler water. Recent *Raniceps* fishes are demersal and marine in temperate water of the neritic zone at a depth up to 100 m. The Mandrikovka Beds (Priabonian, Ukraine) represent the uncommon case of common *Raniceps* otoliths in a tropical to subtropical otolith association (Müller & Rozenberg 2003b; Girone & Nolf 2008). The other common gadiform species of the extinct genus *Palaeogadus* may be judged ecologically from the related Recent genus *Merlluccius*, which would again indicate rather cold water (Froese & Pauly 2013). Daniltchenko (1960) mentioned that *Palaeogadus* inhabited both shallow and deep water environments. The Rupelian association of Mallis (Germany) is rich in *Palaeogadus* and has been interpreted as deposited in about 100 m palaeo-waterdepth (Müller & Rozenberg 2000).

Schwarzhans (2008) considers *Raniceps tuberculosus* as a species of deeper, open marine environment in an analysis of Oligocene otolith assosiations of Western Europe. This observation is also corroborated in the deep-water deposits of the Zubakino Beds (Müller & Rozenberg 2003a; Shevchenko & Bratishko 2008), while the species is absent in the more shallow water environment of the Kyzyl-Dzhar Beds (unpublished data).

The presence of *Pterothrissus* otoliths further supports a comparatively deeper water palaeoenvironment. In the judgment of Daniltchenko (1960) the morphology of the skeleton of *Palimphyes* points to a deep-water (bathypelagic) habit of life. This species is very rare in the shallow water association of Kyzyl-Dzhar (unpublished data). Finally, *Palaeomorrhua faba* has been mostly reported from deepwater environments of Western Europe (Gaemers & Hinsbergh 1978; Müller & Rozenberg 2000).

Based on mollusk and fish-otolith data we therefore suppose that the fauna collected from the Uzunbas Formation was deposited in a marine, probably temperate environment in an outer neritic palaeobathymetric position.

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Table 1. Otolith species list from the Uzunbas Formation and correlation to other locations from literature. Dark grey = same species; light grey = related species.

	Priabonian	Rupelian			Chattian	Total
	Ukraine	W. Europe	Crimea	Caucasus	W. Europe	
Albulidae *Pterothrissus caspiensis*						12
Heterenchelyidae *Panturichthys*? sp.						1
Merlucciidae *Palaeogadus germanus*						60
Palaeogadus rarus						16
Palaeogadus schwarzhansi						94
Ranicipitidae *Raniceps tuberculosus*						355
Ophidiidae *Palaeomorrhua faba*						6
Emmelichthyidae *Erythrocles* sp.						1
Euzaphlegidae *Palimphyes stolyarovi*						14
Related species	1	3	2	2	3	599
Same species	1	2	3	3	2	
Degree of similarity	16%	38%	44%	44%	38%	

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