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Early Pliocene fishes from Priozernoe locality (Republic of Moldova)

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Abstract. This paper presents the results of study of the fossil fish remnants from the Early Pliocene strata of Priozernoe locality (Republic of Moldova). Nine species, belonging to seven genera, five families and five orders (Acipenseriformes, Cypriniformes, Siluriformes, Esociformes, and Perciformes) were identified. Most of the identified taxa are morphological analogues of extant forms. The investigated fish assemblage indicates freshwater to slightly brackish water environments.

Key words: sturgeons, bony fishes, MN 15, Pliocene, Priozernoe, Dniester Basin, Moldova.

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I. INTRODUCTION

History of the formation of the freshwater fish fauna in Eastern Europe during the Late Miocene and Pliocene is poorly known. In this case, information about the fish remnants from the Pliocene strata of the Republic of Moldova is important and deserving of special attention.

Locality Priozernoe (46°48′13″N, 29°55′39″E) is situated near the settlement of the same name, 20 km south-eastwards of Tiraspol (Fig. 1). It represents a sand pit on the high

Fig. 1. Location map of the Priozernoe locality.

fluvial terrace of Dniester River. The section reveals the strata of alluvial sediments divided into four layers (CHEPALYGA et al. 2011). The lower loamy-alluvial layer (thickness 2.0-3.5 m) is overlaid by yellow and yellow-grey sands (thickness 6.0-7.0 m) bearing the majority of fossil remnants (Fig. 2). The geological unit situated above is formed by sandy-loam sediment (thickness 1.0-2.5 m) and by modern soil (thickness 1.0-1.5 m). Priozernoe is the southernmost among the localities found in the Dniester River valley predominantly involving fossils belonging to the Kuchurgan faunal complex, which corre-

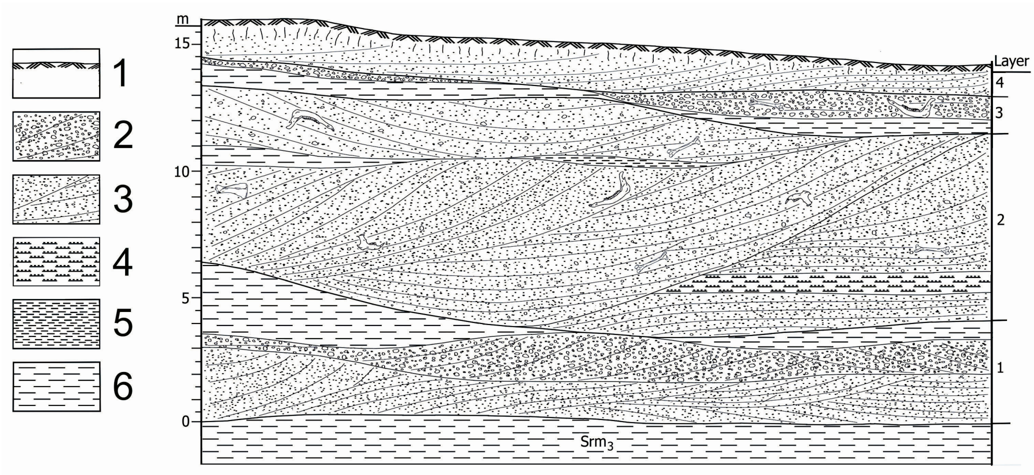

Fig. 2. Geological cross-section of the Priozernoe locality: 1 – modern soil; 2 – assorted cross- and diagonally-bedded sands and gravels; 3 – assorted cross-bedded sands; 4 – floodplain sandy loams; 5 – silts; 6 – clays.

sponds to the early Pliocene (Fig. 3). The tentative faunal list from Priozernoe comprises more than 40 taxa of vertebrates (CHEPALYGA et al. 2011; ZAKHAROV 2012; ZAKHAROV & REDKOZUBOV 2012). Information about the findings of the fish remains from this locality is still fragmentary. A preliminary list of taxa (*Acipenser* sp., *Rutilus frisii*, *Scardinius* sp., *Abramis* sp., *Tinca* sp., *Silurus* sp., and *Esox* sp.) is represented on the basis of the definition of systematic position, provided by E. K. SYTCHEVSKAYA (ZAKHAROV & REDKOZUBOV 2012). This paper is devoted to a detailed morphosystematic analysis of all available fish remains, as well as ecological characteristics of the studied area during the Early Pliocene.

II. MATERIAL AND METHODS

The present paper is based on the study of 50 isolated fish bones, 39 of which (78%) are determinable to species or to genus level. The collection of fossil fish from Priozernoe locality was obtained by screen-washing and is housed in the Geological and Paleontological Museum of the Transnistrian State University, Republic of Moldova. The material under study is represented by disarticulated bones, e.g. bones and pharyngeal teeth of carp fishes, visceral bones, teeth and fin rays of sturgeons, catfishes, pikes and zanders (Table 1).

The identity of the fossil remains was determined using diagnostic features. Recent fish bones, deposited in the National Museum of Natural History (NMNH) NAS of Ukraine and Schmalhausen Institute of Zoology NAS of Ukraine were used for comparison. Ichthyologic systematics in this paper follows NELSON (2006) and MOVCHAN (2011). Current correlation of the Eastern Paratethys stages with European Mammal Neogene Zones was taken from NESIN & NADACHOWSKI (2001). The specimens were measured with aid of a binocular microscope with an ocular micrometer. All measurements are taken accord-

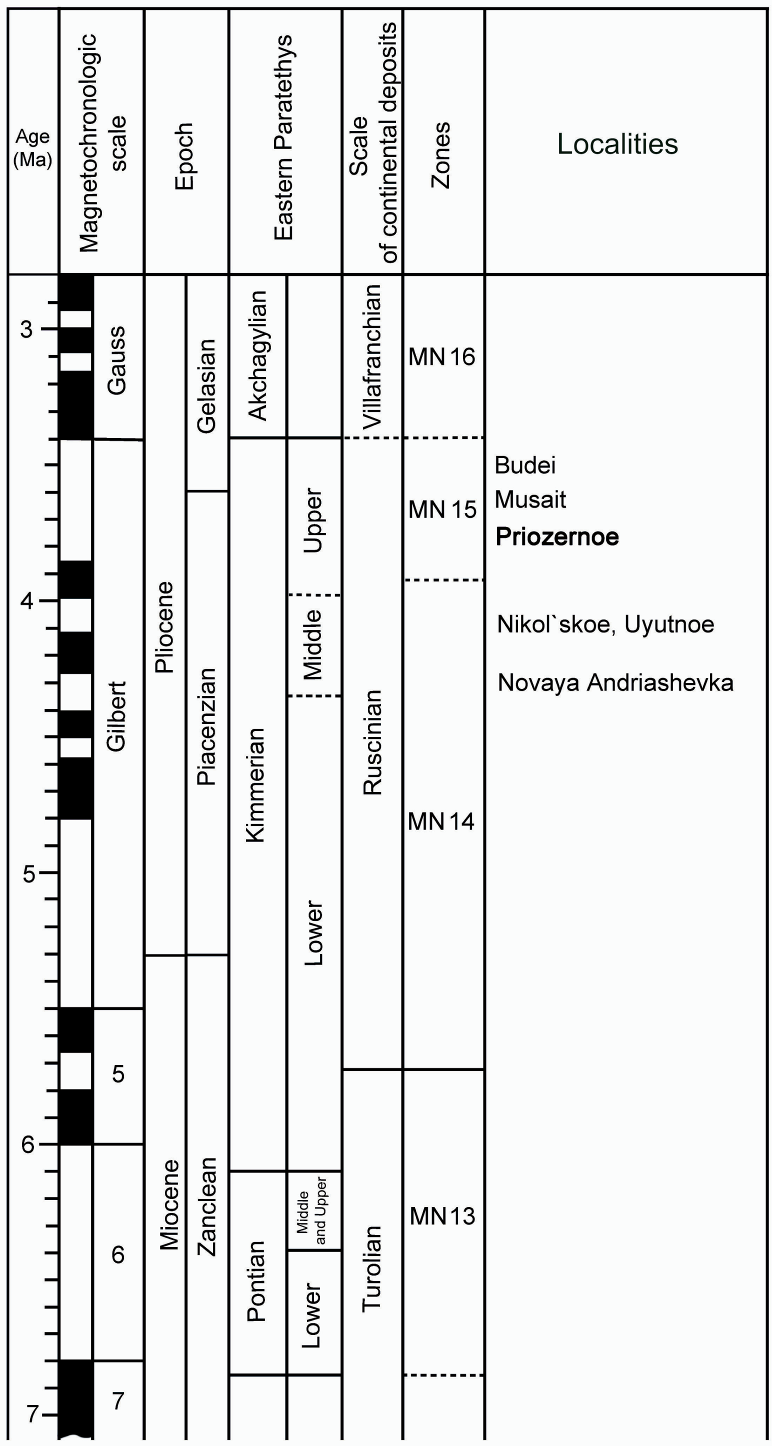

Fig. 3. Magnetochronologic and stratigraphic position of the Priozernoe locality (after VANGENGEIM et al. 1995, with modifications).

Table 1

List of identified fish remnants from Priozernoe locality

Fish	Species	Anatomical elements	Coll. No.
Stellate sturgeon	*Acipenser* cf. *stellatus*	3 opercular bones, 1 fin ray	Prz 10-1/1-4
Sturgeon	*Acipenser* sp.	2 opercular bones, 1 suboperculare, 1 supracleithrale, 1 cleithrum	Prz 10-1/5-9
Sturgeons	Acipenseridae gen. et sp. indet.	2 bone fragments	Prz 10-1/10-11
Roach	*Rutilus* sp.	1 pharyngeal bone, 2 isolated pharyngeal teeth	Prz 10-1/12-14
Barbel	*Barbus* sp.	2 isolated pharyngeal teeth	Prz 10-1/15-16
Common tench	*Tinca tinca*	1 pharyngeal tooth	Prz 10-1/17
Tench	*Tinca* sp.	1 opercular bone	Prz 10-1/18
Catfish	*Silurus* sp.	3 dentary fragments, 1 articulare, 6 spiny-like rays, 1 vertebra	Prz 10-1/19-29
Pike	*Esox moldavicus*	6 isolated teeth, 2 dentary fragments, 1 articulare	Prz 10-1/30-38
Zander	*Sander* cf. *lucioperca*	1 dentary fragment	Prz 10-1/39
Teleost fishes	Teleostei incertae sedis	1 supracleithrale, 1 praeoperculare, 2 vertebrae, 7 bone fragments	Prz 10-1/40-50

ing to the guidelines of MORALES & ROSENLUND (1979) and given in millimetres with 0.1 mm precision. Fish bone terminology follows RUTTE (1962), SYTCHEVSKAYA (1989), LEPIKSAAR (1994) and FINDEIS (1997).

Palaeoecological analysis of freshwater fish assemblages was conducted using ecotopic preferences of their recent analogues.

III. RESULTS AND DISCUSSION

Nine fish species, belonging to seven genera, five families and five orders (Acipenseriformes, Cypriniformes, Siluriformes, Esociformes, Perciformes), were identified in materials from the Pliocene strata of Priozernoe locality. Some of them are described under open nomenclature.

Order Acipenseriformes. Three fragments of opercular bones and one fin ray (pinna pectoralis I) are quite similar to those in *Acipenser stellatus* PALLAS, 1771 and identified here as *Acipenser* cf. *stellatus*. Length of the fin ray is 36.4 mm, width of its base – 12.2 mm (Fig. 4A).

Acipenser sp. from Priozernoe locality is represented by two fragments of opercular bones, one suboperculare, one supracleithrale, and also one cleithrum (Fig. 4B-D). Measurements of these bones are presented in Table 2. Besides these specimens, two small

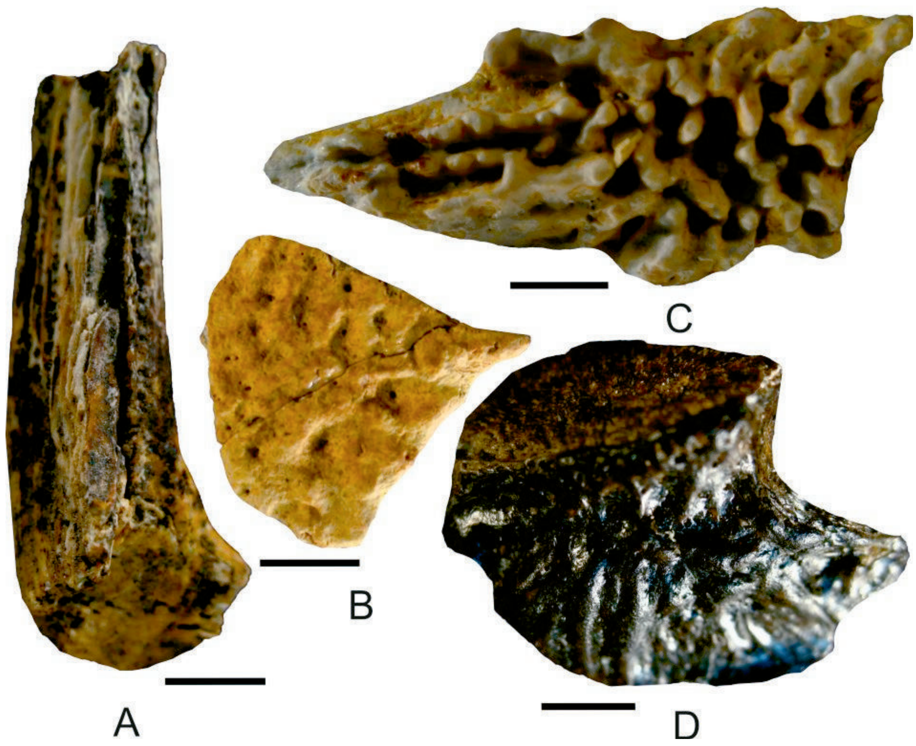

Fig. 4. Bones of sturgeon from Priozernoe locality: A – *Acipenser* cf. *stellatus*, pectoral fin ray; B-D – *Acipenser* sp., operculare (B), suboperculare (C), supracleithrale (D). Scale bar – 5 mm.

Table 2

Measurements (in mm) of the bones of *Acipenser* sp. from Priozernoe locality

Bone	n	Length	Width
Operculare	2	14.5; 14.6	12.0; 12.1
Suboperculare	1	36.0	13.9
Supracleithrale	1	25.3	19.8
Cleithrum	1	27.9	25.2

bones of sturgeons were found in the bonyferous layer, but due to the fragmentary nature they are described as Acipenseridae gen. et sp. indet.

Order Cypriniformes. There are four species, all belonging to family Cyprinidae FLEMING, 1822, in material from the Pliocene strata of Priozernoe locality: *Rutilus* sp., *Barbus* sp., *Tinca tinca* (LINNAEUS, 1758), and *Tinca* sp.

Rutilus sp. – This species is represented by the pharyngeal bone with one preserved tooth, and two isolated pharyngeal teeth (Fig. 5A-C). The ventral edge of the ceratobran-

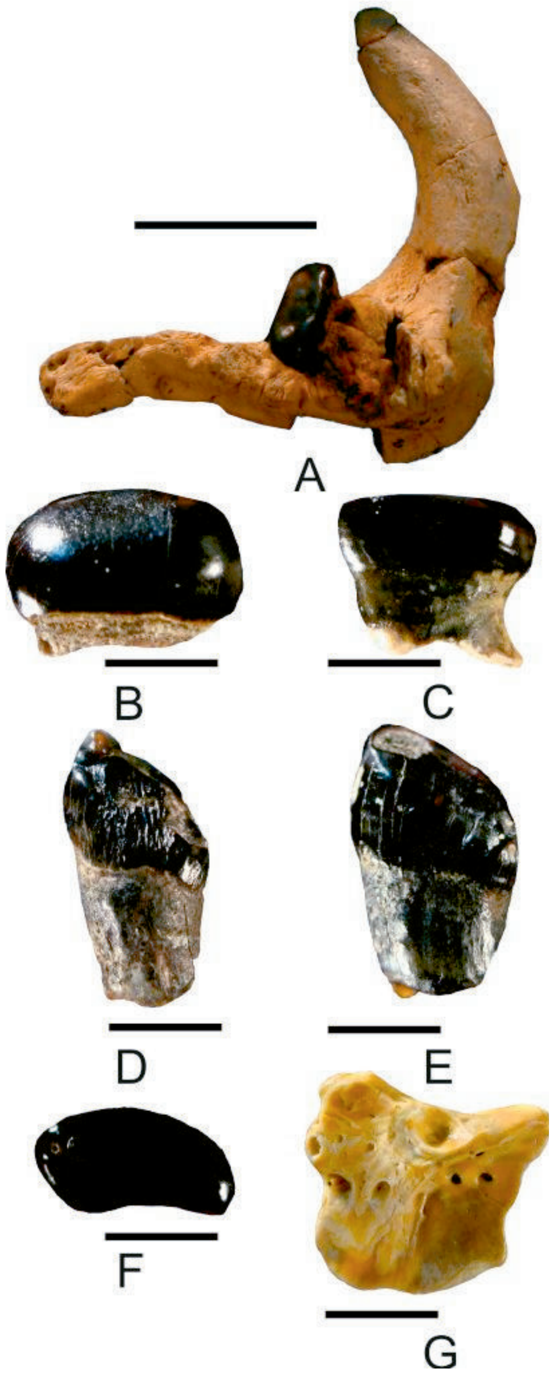

Fig. 5. Carp fish bones from Priozernoe locality: A-C – *Rutilus* sp., pharyngeal bone (A), scale bar – 2 cm; pharyngeal teeth (B-C), scale bar – 5 mm; D-E – *Barbus* sp., isolated pharyngeal teeth, scale bar – 5 mm; F – *Tinca tinca*, pharyngeal tooth, scale bar – 5 mm; G – *Tinca* sp., fragment of operculare (upper articulate part, inner side), scale bar – 5 mm.

chiale is almost straight to the front corner (Fig. 5A). Length of the bone is 62.0 mm, width – 21.7 mm, length of the cavernous surface – 27.4 mm, length of the dentiferous surface – 34.1 mm, height of the ceratobranchiale – 12.0 mm. Pharyngeal teeth are large with fungiform, laterally compressed crown and a distinct convex arcuate tooth back (Fig. 5B-C). Grinding surface is narrow and slightly convex. Pedicle is broken, oval in cross-section. Height of the pharyngeal teeth is 7.3 mm, width of the crown – 10.1 and 10.2 mm. Pharyngeal bone and teeth are quite similar to those in the *Rutilus frisii* (NORDMANN, 1840).

Barbus sp. – Two spatulate pharyngeal teeth have a flattened chisel crown (Fig. 5D-E). Pedicle is broad and cylindrical in cross-section. Tooth back is straight or slightly convex, with rounded belly and clearly expressed neck. Anterior part of the crown is convex; posterior is flattened and medially impressed. There is a weak hook at the tip. Grinding edge is bevelled towards the tooth belly. Grinding surface is narrow, with deep arcuate wrinkle. Height of the teeth is 11.5 and 12.1 mm (crowns – 5.7 and 6.1 mm), width – 7.6 and 8.4 mm. Presented teeth are similar to those in representatives of the *Barbus* CUVIER, 1816 and described here as *Barbus* sp.

Tinca tinca – One flattened pharyngeal tooth has a low crown (Fig. 5F). Pedicle is rounded and slightly deflexed. Tooth back is arcuate, belly is slightly convex. Grinding surface is narrow, laterally compressed, having a deep longitudinal wrinkle with slightly convex roller edges. Wrinkle on the lower edge of the grinding surface is jagged by transverse corrugations and forms a fin scroll on the posterior surface of the crown. Height of the tooth is 4.7 mm, width of the crown – 8.2 mm. Pharyngeal tooth is not different in size and morphology from those in extant *Tinca tinca*.

Tinca sp. – There is one fragment of the opercular bone from the Pliocene strata of Priozernoe locality (Fig. 5G). It is similar to those in *Tinca* CUVIER, 1816 and identified as *Tinca* sp.

Order Siluriformes. All catfish remains in material from Priozernoe (Fig. 6), represented by 11 isolated bones, are morphologically quite similar to those in the European catfish, and described there as *Silurus* sp.: three dentary fragments (Fig. 6A), one left articulare (Fig. 6B), two proximal and four distal fragments of spiny-like rays (Fig. 6C), and one vertebra with broken apophyses (Fig. 6D). Measurements of these bones are presented in Table 3. Diameter of vertebra is 14.0 mm.

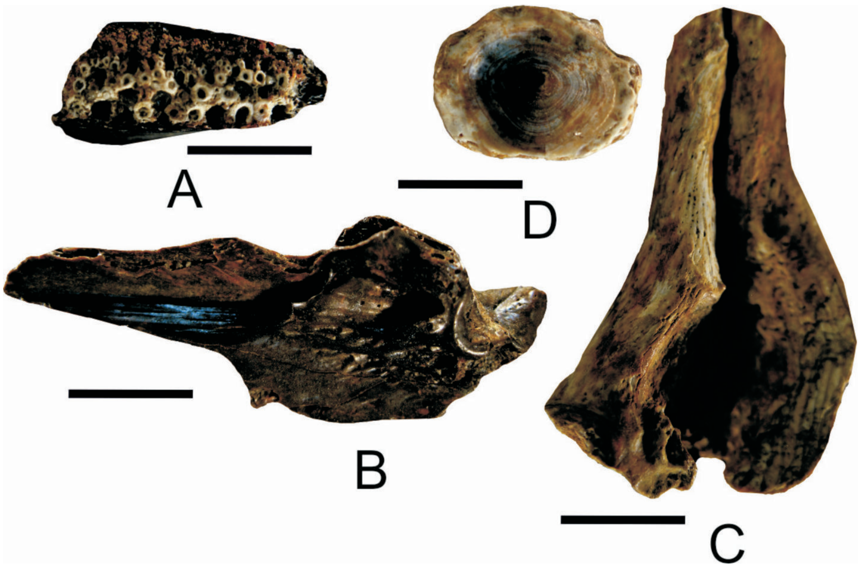

Fig. 6. Bones of *Silurus* sp. from Priozernoe locality: A – dentale; B – articulare; C – spiny-like ray; D – vertebra. Scale bar – 1 cm.

Table 3

Measurements (in mm) of the bones of *Silurus* sp. from Priozernoe locality

Bone	n	Length		Width	
		Range	Mean	Range	Mean
Dentale	3	13.6-23.1	18.8	5.4-19.7	10.8
Articulare	1	45.6	–	9.8	–
Spiny-like ray	6	11.0-42.8	24.8	11.0-25.4	18.2

Order Esociformes. Pike remnants from the Priozernoe locality are represented by nine bones, including six isolated teeth, two (left and right) dentary fragments, and one left articulare. The long, slender, pointed teeth have two sharp edges. Cross-sections of the teeth are interiorly smooth and exteriorly convex (Fig. 7A). Their measurements are presented in Table 4. Articulare has a high wall (near 70°) and narrow retroarticular process with a concave lower edge. There is a well-visible tongue notch at the articular facet. It is safe to say that this bone and dentale are completely similar to those in the extinct *Esox moldavicus* SYTCHEVSKAYA, 1974. Presented jaw teeth probably also belong to this species. In any case, the systematic position of the early described pike remnants from the Early Pliocene strata of the Republic of Moldova is questionable and needs verification (SYTCHEVSKAYA 1976).

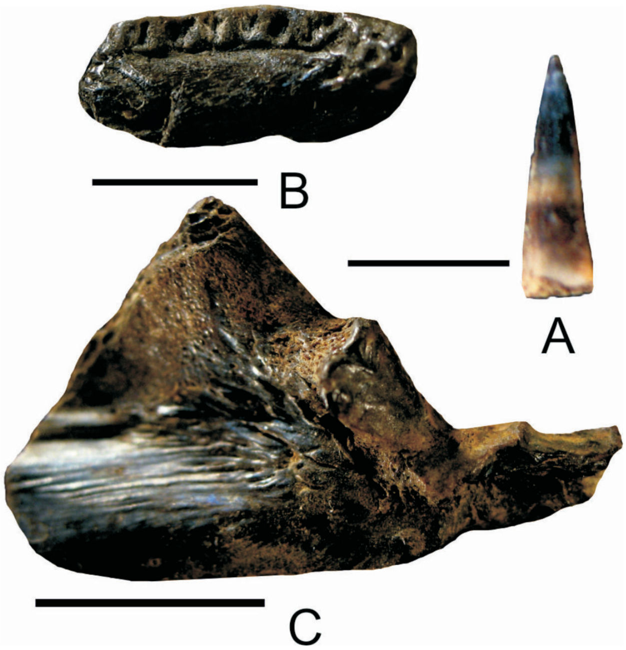

Fig. 7. Bones of *Esox moldavicus* from Priozernoe locality: A – isolated tooth; B – dentale; C – articulare. Scale bar – 1 cm.

Table 4

Measurements (in mm) of the bones of *Esox moldavicus* from Priozernoe locality

Bone	n	Length		Width	
		Range	Mean	Range	Mean
Tooth	6	3.2-8.6	5.7	1.9-3.1	2.5
Dentale	2	6.3; 9.2	–	N/A	N/A
Articulare	1	24.7	–	8.6	–

Order Perciformes. One left dentary fragment is morphologically similar to those in representatives of the *Sander* OKEN, 1817, and preliminary was identified as *Sander* cf. *lucioperca* (LINNAEUS, 1758). Length of the bone is 16.9 mm, height of the symphisis – 6.2 mm (Fig. 8).

Fig. 8. Dentary fragment of *Sander* cf. *lucioperca* from Priozernoe locality. Scale bar – 1 cm.

Teleostei incertae sedis. Some bones cannot be regarded to specific taxa in response to their fragmentary nature: one supracleithrale, one praeoperculare, two vertebrae, and seven bone fragments. It is safe to say that these remnants are belonging to teleost fishes.

The modern fish fauna of the Lower Dniester includes four species of the family Acipenseridae (including *Acipenser stellatus*), 18 species – Cyprinidae (with allowance of *Rutilus frisii*, *Barbus barbus* (LINNAEUS, 1758) and *Tinca tinca*), and also European catfish, Northern pike, and Zander (USATÎI et al. 2012). Thus, most of the identified taxa can be morphologically compared with analogous extant forms. From the point of view of the faunal composition, family Cyprinidae is most numerously represented by species (four) and genera (three), while only two species are determined as Acipenseridae, and one each as Siluridae, Esocidae and Percidae. The dominant fish taxa in the Priozernoe assemblage are *Silurus* sp. (11 bones), *Esox moldavicus* (nine bones) and representatives of the *Acipenser* genus (four and five bones).

It is important to focus on some ecotopic preferences of the extant analogues of the identified taxa that can help to separate their possible habitats in the paleo-Dniester. *Acipenser stellatus* is a typical benthic inhabitant of coastal waters in seas and the lowland sections of rivers (MOVCHAN 2011). For example, this species is common in the Lower Danube (HOLOSTENCO 2011) and Dniester (USATÎI et al. 2012; SICIU et al. 2013). It is an anadromous fish, which prefers warmer habitats (REINHARTZ 2002). *Acipenser* is recorded from the Pliocene strata of Romania (GARDINER 1984). The Pontic Roach, *Rutilus frisii*, prefers waters that are somewhat vegetated, because larval and young fish are protected by the vegetation and the mature fish can use it for food (MOVCHAN 2011). *Barbus* is a rheophylic and lithophilous fish (KOTLIK et al. 2004; BRITTON & PEGG 2011), which prefers flowing waters with sandy to gravelly bottom (RÜCKERT-ÜLKÜMEN & YIĞITBAŞ 2007). Physical habitat is an important component regulating barbel distribution and abundance. Adults are common in the mid-channel areas of relatively high flow (MOVCHAN 2011). Tench, *Tinca tinca*, is an omnivorous fish with a very broad diet and tends to feed in areas where there is a large supply of macrophytes (NORDSTROM 2011). This fish prefers standing to slowly flowing waters (RÜCKERT-ÜLKÜMEN & YIĞITBAŞ 2007) and muddy bottom with abundant vegetation (MORENO RENDÓN et al. 2003).

Catfish inhabits large and medium-sized lowland rivers and backwaters (KOTTELAT & FREYHOF 2007). It is known as an impressive predator with a wide range of food items (RÜCKERT-ÜLKÜMEN & YIĞITBAŞ 2007; COPP et al. 2009). Pike (*Esox*) is a cool water fish, which has a wide range of environmental tolerances (CASSELMAN & LEWIS 1996) and is characterized as a keystone piscivore that can shape the composition, abundance and distribution of fish assemblages (CRAIG 2008). It is found in shallow, moderately productive and vegetated waters (DIANA 1979; HARVEY 2009). *Sander* is generally a piscivorous fish (KOPP et al. 2009), which is well adapted to life in the slow-flowing, sparsely vegetated and murky waters. Zander needs plenty of oxygen and can be used as an indicator of eutrophication (KOTTELAT & FREYHOF 2007).

The investigated fish assemblage indicates freshwater to slightly brackish water environments. The diversity of the fish fauna indicates various habitats: 1) flowing water and a coarse-grained bottom; 2) slowly flowing to standing water and muddy bottom; and 3) a mainly standing-water habitat with seasonally stagnant conditions. Freshwater bony fish assemblages, similar to those from Priozernoe in faunal composition and taxonomic diversity, are known from the Pliocene strata of Kamenskoe, Kuchurgan and Kairy in Ukraine (TARASHCHUK 1962; TARASHCHUK 1965), Tchelopetchene 1 and Lozenets in Bulgaria (KAMENOV & KOJUMDGIEVA 1983), Willershausen in Germany (GAUDANT 1997), Ptolemais and Vorio in Greece (BÖHME & ILG 2003), and also Holu and Krivskaya Balka in Russia (NOVITSKAYA 1980).

IV. CONCLUSIONS

Based on a detailed study of fossil fish remains from Priozernoe locality their species composition was clarified, along with an attempt to reconstruct the palaeoecological conditions in the region during the early Pliocene. Nine species, belonging to seven genera (*Acipenser*, *Rutilus*, *Barbus*, *Tinca*, *Silurus*, *Esox*, and *Sander*), five families and five orders (Acipenseriformes, Cypriniformes, Siluriformes, Esociformes, Perciformes), were identified in materials from the Early Pliocene strata of Priozernoe locality. The family Cyprinidae is most numerously represented by species and genera, while others only by one or two species. Remains of *Rutilus* can belong to a new extinct Roach species based on its morphological distinction from closely related taxa (e.g., *Rutilus frisii*), but this assumption needs verification, as does the presence of *Esox moldavicus*.

Silurus sp., *Esox moldavicus*, *Acipenser* cf. *stellatus* and *Acipenser* sp. are dominant fish taxa in this assemblage (judging on the quantity of remains). Almost all identified taxa are morphological analogues of extant forms. The investigated fish assemblage indicates freshwater to slightly brackish water environments.

The faunal composition of Priozernoe locality is quite similar to other Pliocene complexes in Ukraine, Bulgaria, Germany, Greece and Russia. Formation of the freshwater ichthyocomplexes on the south of Eastern Europe during the Pliocene usually occurred in parallel with the transformation of the continental hydrographic network under the direct influence of the transgressions and regressions of the major ocean basins. Further study of the Pliocene fish fauna from the Republic of Moldova territories allows us to determine the dynamics and ways of formation of extant freshwater ichthyocomplexes in the Eastern Europe and conditions for their existence.

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