Simbirskiasaurus and Pervushovisaurus reassessed: implications for the taxonomy and cranial osteology of Cretaceous platypterygine ichthyosaurs

Valentin Fischer1,2, Maxim S. Arkhangelsky3,4, Darren Naish5, Ilya M. Stenshín6, Gleb N. Uspensky7 and Pascal Godefroit8

1Département de Géologie, Université de Liège, Liège, Belgium
2Operational Direction ‘Earth and History of Life’, Royal Belgian Institute of Natural Sciences, Brussels, Belgium
3Ecology Department, Ecological Faculty, Saratov State Technical University, Saratov, Russia
4Ecology Department, Geological Faculty, Saratov State University, Saratov, Russia
5Ocean and Earth Science, National Oceanography Centre, University of Southampton, Southampton, UK
6Ulyanovsk Regional Museum of Local Lore named after I.A. Goncharov, Ulyanovsk, Russia
7Natural Science Museum, Ulyanovsk State University, Ulyanovsk, Russia

ABSTRACT

The ichthyosaur fossil record is interspersed by several hiatuses, notably during the Cretaceous. This hampers our understanding of the evolution and extinction of this group of marine reptiles during the last 50 million years of its history. Several Cretaceous ichthyosaur taxa named in the past have subsequently been dismissed and referred to the highly inclusive taxon Platypterygius, a trend that has created the impression of low Cretaceous ichthyosaur diversity. Here, we describe the cranial osteology, reassess the stratigraphic age, and evaluate the taxonomy and phylogenetic relationships of two Cretaceous ichthyosaurs from western Russia: Simbirskiasaurus birjukovi from the early Barremian and Pervushovisaurus bannovkensis from the middle Cenomanian, both formerly regarded as nominum dubia, and allocated to Platypterygius sp. and Platypterygius campylodon, respectively. We show that Simbirskiasaurus birjukovi and Pervushovisaurus bannovkensis are valid platypterygiine ophthalmosaurids, notably characterized by a peculiar narial aperture. The cranial anatomy and phylogenetic relationships of these taxa illuminate the evolution of narial aperture anatomy in Cretaceous ichthyosaurs, clarify the phylogenetic relationships among platypterygines, and provide further arguments for a thorough revision of Platypterygius.

ADDITIONAL KEYWORDS: Barremian; Cenomanian; external naris; platypterygiinae; Platypterygius.

INTRODUCTION

The extensive stratigraphic range of ichthyosaurs, extending from the Lower Triassic to the beginning of the Upper Cretaceous (Bardet, 1992; Motani, 2005), is interrupted by numerous hiatuses, most notably during the Middle Jurassic (e.g. Fernández & Talevi, 2014) and the Cretaceous (e.g. Bardet, 1994; Fischer et al., 2011a); however, the taxonomic diversity of Cretaceous ichthyosaurs has recently increased, with the recognition of several new taxa in the Albian of North America (Maxwell & Caldwell, 2006b, 2006a; Druckenmiller & Maxwell, 2010; Maxwell & Druckenmiller, 2011) and the Early Cretaceous of Eurasia and the Middle East (Fischer et al., 2011b, 2012, 2013, 2014a). Our knowledge of Cretaceous ichthyosaur diversity is still poor (Zammit, 2012), however, especially outside the better-known intervals of the latest Jurassic-earliest Cretaceous ('Volgian'; e.g. Fernández, 1997; Arkhangelsky, 1998a; Efimov, 1999; Fernández, 2007b; Druckenmiller et al., 2012) and the late Early Cretaceous (Albian; e.g. Maxwell & Caldwell, 2006a; Maxwell & Caldwell, 2006b; Fischer et al., 2014b). As a result, their final extinction, which occurred at the end of the Cenomanian (Bardet, 1992), is poorly understood (Fischer et al., 2014b).

Several taxa have been named from the Hauterivian-Barremian and Cenomanian strata of Europe, Russia, and South America; most were, however, regarded as nominum dubia or subjective junior synonyms referable to the cosmopolitan genus Platypterygius Huene, 1922 in the reviews of McGowan (1972), Maisch & Matzke (2000), and McGowan & Motani (2003; but for an account on Platypterygius hauthali Huene, 1927, see Fernández & Aguirre-Urreta 2005). Similarly, for the Cenomanian material from Eurasia has been referred to Platypterygius campylodon Carter, 1846, by default (e.g. McGowan, 1972; Buffetaut, 1977). This taxonomic decision implies low ichthyosaur diversity during this part of the Cretaceous (but see Bardet, 1989). Note that the status of Platypterygius is subject to debate: Fischer (2012) demonstrated that this genus, which - as presently conceived - spans more than 35 million years, and is known from nearly all continents (McGowan & Motani, 2003), is a wastebasket taxon. Kear & Zammit (2014), however, proposed 'classic' diagnostic features for this
entity (all of which are present in other ophthalmosaurid taxa; Fischer et al., 2011b; Fischer, 2012). A solid
taxonomic background is therefore needed to better understand how ichthyosaurs diversified and became extinct
during the Cretaceous. Notably, the status and morphology of the taxa that have been referred to *Platypterygius*
in the past must be thoroughly reassessed under a modern taxonomic framework. Material from North America
(Maxwell & Caldwell, 2006a; Maxwell & Kear, 2010; Adams & Fiorillo, 2011), South America (Fernández &
Aguirre-Urreta, 2005), and Australia (Kear, 2005; Zammit, Norris & Kear, 2010; Zammit, 2011) attributed to
*Platypterygius* has recently been re-assessed, but the Eurasian material, which constitutes the most diverse and
taxonomically complex assemblage (e.g. McGowan, 1972), needs to be thoroughly revised (Fischer, 2012).

In this article, we describe the cranial osteology, reassess the taxonomy and stratigraphic age, and test the
phylogenetic relationships of two Cretaceous ichthyosaurs from two poorly sampled intervals: the early
Barremian *Simbirskiasaurus birjukovi* Ochev & Efimov, 1985 and the middle Cenomanian *Pervushovisaurus
bannovkensis* Arkhangelsky, 1998b. These taxa are frequently used for comparative purposes when Cretaceous
taxa are discussed (e.g. Sirott & Papazzoni, 2002; Druckenmiller & Maxwell, 2010; Fischer, 2012), despite their
poorly known and controversial osteology (Maisch & Matzke, 2000) and taxonomy (McGowan & Motani,
2003). As explained here, these taxa clarify the evolution of the narial aperture and the phylogenetic
relationships of derived platypterygiine ichthyosaurs, provide valuable data points in inadequately known
periods of ichthyosaur evolution, and add further support for the view that *Platypterygius* hides a mostly
unappreciated diversity of Cretaceous ophthalmosaurids.

**MATERIAL AND METHODS**

**INSTITUTIONAL ABBREVIATIONS**

CAMSM, Sedgwick Museum of Earth Sciences, Cambridge University, Cambridge, UK; IRSNB, Royal Belgian
Institute of Natural Sciences, Brussels, Belgium; NHMUK, Natural History Museum, London, UK; RGHP, Réserve
detable géologique de Haute-Provence, Digne-les-bains, France; SSU, Geological Museum, Saratov
State University, Saratov, Russia; YKM, Ulyanovsk Oblastnoi Kraevedcheskiia Museum I.A. Goncharova
(Ulyanovsk Regional Museum of Local Lore named after I.A. Goncharov), Ulyanovsk, Ulyanovsk Region,
Russia.

**GEOGRAPHY, STRATIGRAPHY, AND RESEARCH HISTORY**

**Ulyanovsk area**

The Ulyanovsk area has yielded two important Barremian ichthyosaur remains: YKM 65119, the holotype of
*Simbirskiasaurus birjukovi*, and IRSNB R269, the holotype of *Sveltonectes insolitus* Fischer et al., 2011b. Few
papers on the stratigraphy of this region are available; therefore, both specimens have been re-dated using *in situ*
fossils. The holotype specimen of *Sveltonectes insolitus* has been dated using palynomorphs and is late
Barremian in age (Fischer et al., 2011b). Ochev & Efimov (1985) considered that the preservation style of the
bones and presence of the bivalve *Astarte porrecta* (most likely to be *Astarte* sp.) with YKM 65119 (the
holotype of *Simbirskiasaurus birjukovi*) were indicative of a Hauterivian age. Although this evidence is scant, it
was the only stratigraphic data available at the time; however, microconchs of the ammonite *Aconeceras* sp.
were found within the skull during further preparation (I.A. Shumilkin, pers. comm., 2012). Blagoveschensky &
Shumilkin (2004) described the Barremian section in the northern part of Ulyanovsk and determined that
*Aconeceras* sp. occurs in the *Praeoxephytus pugio* Stolley 1925 belemnite zone, which is early Barremian in age
(Baraboshkin & Mutterlose, 2004). Accordingly, *Simbirskiasaurus birjukovi* should be regarded as originating
from lower Barremian strata.

Although their age is now constrained, the precise place where both holotypes were discovered is unclear
because the Hauterivian and Barremian strata of this area are tabular, and crop out along a stretch of the Volga
River bank that extends over several kilometres. Ochev & Efimov (1985: 87) stated that the holotype of
*Simbirskiasaurus birjukovi* ‘was discovered several years ago on the right bank of the Volga River, 25 km above
the town of Ulyanovsk, between the Zakhar'yevskoye mine and the children's sanatorium', but this is unlikely as
no Barremian strata are found in this area (I.V. Blagoveschensky pers. coram., May 2013). Blagoveschensky &
Shumilkin (2004) described a nearby Barremian section, between Ulyanovsk and Polivno, with abundant
*Aconeceras* specimens, hence providing a possible source locality for YKM 65119. This corroborates the
account of an eyewitness of the discovery (S.E. Biryukov, pers. coram., May 2013).

The taxonomic status of *Simbirskiasaurus birjukovi* has been debated. It was erected by Ochev & Efimov
(1985); however, these authors described the skull before adequate preparation had been completed, and
comparison of their drawings with the fossil in its current state indicates that both the narial and orbital regions
were still covered by matrix when they described it. As a consequence, they interpreted artefacts as diagnostic features. They also noted the presence of basicranial bones without describing them. Maisch & Matzke (2000) considered Simbirskiasaurus a junior subjective synonym of Platypterygius, but regarded the species Simbirskiasaurus birjukovi as a valid taxon. McGowan & Motani (2003) went further and proposed that the holotype was not diagnostic, and hence referred YKM 65119 to Platypterygius sp.

Saratov area

The holotype of Pervushovisaurus bannovkensis (SSU 104a/24) was found near Nizhnaya Bannovka village, Krasnoarmeisk District, Saratov Region, along the right bank of the Volga River (Arkhangelsky 1998b). The specimen was discovered in shales of the local Lingulogavelenella globosa Broten, 1945 zone, which constitutes the upper part of the middle Cenomanian of the Melovatskaya Formation, according to Zozyrev (2006). The specimen was studied by Arkhangelsky (1998b), who made it the type specimen of both a new subgenus and species within the genus Platypterygius: Platypterygius (Pervushovisaurus) bannovkensis. McGowan & Motani (2003) considered these taxa invalid: they regarded Pervushovisaurus as a subjective junior synonym of Platypterygius, and treated Platypterygius bannovkensis as a nomen dubium, with its material referrible to Platypterygius campylodon. As for Simbirskiasaurus birjukovi, these taxonomic opinions were not substantiated by direct observations of the material.

PHYLOGENETIC ANALYSIS

We coded Simbirskiasaurus birjukovi and Pervushovisaurus bannovkensis in the largest data set devoted to ophthalmosaurusids yet compiled (the data set from Fischer et al., 2014a, which is a slightly updated version of that of Fischer et al., 2012), using the morphological data from our reassessment alone, not the initial descriptions (except for character 23: posterior dorsal/anterior caudal centra of Simbirskiasaurus birjukovi, coded using Ochev & Efimov, 1985; see Appendix SI). The resulting matrix contains 52 characters and 20 taxa. Only 23.07% (12/52) and 13.46% (7/52) of the characters can be coded for Simbirskiasaurus birjukovi and Pervushovisaurus bannovkensis, respectively, because of missing material in their postcranial skeletons. We modified one character (character 6: descending process of the nasal on the dorsal border of the nares) to reflect our new observations on the external nares of some derived platypterygiine ophthalmosaurusids; we added a new state (6.2) for ichthyosaurs having a complete division of the external nares, regardless of the reduction of its anterior part (see Appendix SI). As in Fischer et al.’s (2012; 2014a) original analyses, some characters were treated as ordered (characters 17, 39, and 45). Running the analyses with all characters unordered did not modify the topology or length of the consensus trees; it slightly improved the statistical support of the topology arising from the analysis of the full data set, but slightly decreased the statistical support of the topology arising from the analysis of the pruned data set (see below). We used the exact parsimony searches of TNT 1.1 (Goloboff, Farris & Nixon, 2010) to analyse the character matrix (exact algorithm, 10 000 trees in memory) and calculate the Bremer support, Jacknife (removal probability of 36, with 1000 replications), and bootstrap (standard, 1000 replications) values.

As this data set incorporates numerous taxa known from fragmentary remains (eight taxa out of 20 have more than 50% missing data), the statistical support for the topology is moderate to low (see Results, below). We therefore ran a second analysis where all taxa with more than 50% of data missing were excluded, with the exception of Simbirskiasaurus birjukovi and Pervushovisaurus bannovkensis. The following taxa were therefore excluded in the second analysis: Stenopterygius cayi (Fernández, 1994), Arthropterygius chrisorum (Russell, 1993), Mollesaurus perialis Fernández, 1999, Maiaspondylus lindoei Maxwell & Caldwell, 2006b, Athabascasaurus bituminus Druckenmiller & Maxwell, 2010, and Leninia stellans Fischer et al., 2014a. The resulting matrix contains 52 characters and 14 taxa. The data set and the analytical procedure are otherwise identical to the first analysis. We optimized the phylogenetic trees using WINCLADA 0.9 (Nixon, 1999; detailed character state distribution in all optimizations are available in Figs S1-S6).

SYSTEMATIC PALAEONTOLOGY
ICHTHYOSAURIA BLAINVILLE, 1835
OPHTHALMOSAURIDAE BAUR, 1887
PLATYPTERYGIINAE ARKHANGELSKY, 2001 (SENSU FISCHER ET AL., 2012)
SIMBIRSKIASAURUS OCHEV & EFIMOV, 1985

Diagnosis and occurrence
As for the type and only species, S. birjukovi.
SIMBIRSKIASAURUS BIRJUKOVI OCHEV & EFIMOV, 1985

Simbirskiasaurus birjukovi Ochev & Efimov, 1985: 88-91, figs 1, 2 (original description).
Platypterygius birjukovi Maisch & Matzke, 2000: 82 (new combination).

Holotype
YKM 65119, a partial skull preserved in three dimensions. Storrs, Arkhangelsky & Efimov (2000: table 11.2) incorrectly cited 'SGU 104a/22' as the holotype specimen.

Emended diagnosis
Platypterygiine ophthalmosaurid characterized by the following autapomorphies: external naris divided by a nasomaxillary pillar; posterior opening of the narial complex with anteroposteriorly constricted dorsal extension; deeply interdigitating prefrontal-lacrimal suture [reminiscent of the basal neichthysaurian Temnodontosaurus platyodon (Conybeare, 1822); see Godefroit, 1993].

Simbirskiasaurus birjukovi is also characterized by the following unique combination of features: subnarial process of the premaxilla reaches the posterior margin of the external naris (shared with Cryopterygius kristiansenae Druckenmiller et al., 2012); elongated anterior process of the maxilla, reaching anteriorly the level of the nasals [unlike in Aegirosaurus leptospondylus Bardet & Fernandez, 2000 and Sveltonectes insolitus (Fischer et al., 2011b)]; presence of a supranarial process of the premaxilla [shared with Platypterygius australis (McCoy, 1867), see Kear, 2005, and possibly Pervashovisaurus bannovkensis (Arkhangelsky, 1998b)].

Occurrence
Praeoxyteuthis pugio zone, Lower Barremian, Lower Cretaceous of the Ulyanovsk area, probably on the right bank of the Volga River, in between the north of Ulyanovsk and Polivno (see Material and methods, above), Ulyanovsk Region, Russia.

DESCRIPTION

Premaxilla
The fossa praemaxillaris is deep and narrow anteriorly (Fig. 1), becoming wider and shallower at the level of the emergence of the nasals. The premaxilla has a slight overhang dorsal to the fossa praemaxillaris. The labial wall of the dental groove is markedly thickened. The premaxilla decreases in height continuously after the emergence of the nasals, but a processus supranarialis is present, as it also is in Platypterygius americanus (Nace, 1939), Ophthalmosaurus icenicus Seeley, 1874, Brachypterygius extremus (Boulenger, 1904), Aegirosaurus leptospondylus, Platypterygius australis, and Caypullisaurus bonapartei Fernandez, 1997 (see Romer, 1968; Kirton, 1983; Bardet & Fernandez, 2000; Kear, 2005; Fernandez, 2007b, respectively). The premaxilla forms the anterior and ventral edges of the anterior opening of the narial complex. Posteroventrally the premaxilla forms an elongated subnarial process covering the maxilla and lacrimal; the posterior end of this process is broken off, but a well-delineated facet textured by ridges and furrows is present on the lacrimal and the maxilla, indicating the subnarial process reached the posterior margin of the external naris, as it does in Cryopterygius kristiansenae (see Druckenmiller et al., 2012).

Maxilla
The maxilla has an elongated anterior process, as in many platypterygiines [Fig. 1; e.g. Platypterygius americanus, Brachypterygius extremus, and Platypterygius hercynicus (Kuhn, 1946); see Kuhn, 1946; Romer, 1968; Kirton, 1983; Fischer, 2012], and is peculiar in having a developed narial lamella forming a broad nasomaxillary pillar that divides the external naris in anterior and posterior openings (Fig. 2). The posterior opening of the narial complex has a slightly undulated ventral margin. There is no evidence for a posterior ascending process, such as that seen in Athabascasaurus bitumineus (see Druckenmiller & Maxwell, 2010), although this may be overlapped by the lacrimal.
**Nasal**

The nasal forms the dorsal edge of the naris and participates in the nasomaxillary pillar, although the relative contributions of the nasal and the maxilla to this pillar are uncertain (Fig. 1). The dorsal edge of the anterior opening of the narial complex is gently concave, whereas the dorsal surface of the posterior opening of the narial complex forms a deep ventral notch on the lateral surface of the nasal, giving the posterior opening of the narial complex an ‘hourglass’ shape (Figs 1, 2). The posterodorsal margin of the external naris of *Cryopterygius kristiansenae* slightly resembles the condition seen in *Simbirskiasaurus*. Unlike in *Platypterygius australis*, *Acamptonectes densus* Fischer et al., 2012, and *Pervushovisaurus bannovkensis* (see Kear, 2005; Fischer et al., 2012; and this work, respectively), there is no trace of a lateral wing on the nasal. As in *Athabascasaurus bitumineus* and many other ophthalmosaurids (e.g. Druckenmiller & Maxwell, 2010), the nasal forms a bony ridge at the junction between its narial and medial lamellae; however, this ridge becomes narrower and wider posteriorly in YKM 65119, forming a crest over the posterior part of the prefrontal. The excavatio internasalis is present but shallow, as it is in *Platypterygius hercynicus* and *Pervushovisaurus bannovkensis* (see below; Fischer, 2012), but unlike the condition in *Platypterygius australis* (V.F. pers. observ. on un-numbered specimens housed in the NHMUK).
**Figure 2.** Simbirskiasaurus birjukovi, Ochev and Efimov, 1985, holotype (YKM 65119). Detail of the left narial region in lateral view: A, annotated photograph; B, interpretation (the colour scheme is the same as that used in Figure 1). C, basioccipital in anterolateral view. Note the ball-like basioccipital lacking an extracondylar area, which is typical of platypterygine ophthalmosaurids.

![Diagram of narial region and basioccipital](image)

**Lacrimal**

The lacrimal participates in the posterior edge of the posterior opening of the narial complex, unlike in *Platypterygius australis* and *Athabascasaurus bitumineus* (see Kear, 2005; Druckenmiller & Maxwell, 2010, respectively), but over a short distance (Fig. 1). Posteriorly, the lacrimal forms a complex interdigitating suture with the prefrontal. The interdigitating bony processes are much larger than those reported in *Ophthalmosaurus icenicus*, *Athabascasaurus bitumineus*, and *Mollesaurus periallus* (see Kirton, 1983; Druckenmiller & Maxwell, 2010; Fernández & Talevi, 2014), and are set more ventrally, at a point relative to mid-height of the orbit. In many other ophthalmosaurids, the suture appears smooth and straight (e.g. *Brachypterygius extremus*, *Platypterygius australis*, *Caypullisaurus bonapartei*, *Sveltonectes insolitus*, and *Cryptopterygius kristiansenae*; see Kirton, 1983; Kear, 2005; Fernández, 2007b; Fischer *et al.*, 2011b; and Druckenmiller *et al.*, 2012, respectively).

**Prefrontal**

Unlike in *Aegirosaurus leptospondylus* and *Sveltonectes insolitus* (see Bardet & Fernandez, 2000; Fischer *et al.*, 2011b, respectively), the prefrontal does not participate in the narial aperture (Fig. 1). The position of the suture between the prefrontal and postfrontal is unclear because the surface of the bone is broken off in this area.

**Postfrontal**

The anterior part of the postfrontal is separated into wide medial and narrow lateral processes by the posterolateral process of the nasal. This condition is seen in many platypterygines, including *Platypterygius*...
hercynicus and Sveltonectes insolitus (Fischer et al., 2011b; Fischer, 2012, respectively), but contrasts with the situation present in ophthalmosaurines (Ophthalmosaurus spp., see Gilmore, 1905; Kirton, 1983; and Leninia stellans Fischer et al., 2014a).

**Figure 3.** Simbirskiasaurus birjukovi, Ochev and Efimov, 1985, holotype (YKM 65119), in posterior view: A, photograph; B, interpretation. Note that the frontal likely forms the anterior margin of the supratemporal fenestra, a feature frequently found among platypterygiine ophthalmosaurids. Abbreviations: Bf, basisphenoid facet of the basioccipital; Ef, exoccipital facet of the basioccipital; Ffm, floor of the foramen magnum; Of, opisthotic facet of the basioccipital; Sf, stapedial facet of the basioccipital.

**Frontal**

The anterior part of the left frontal is preserved. Its dorsal surface appears extensively exposed, unlike in Athabascasaurus bituminus (Druckenmiller & Maxwell, 2010). A long and concave area of smooth finished bone on the posterior edge of the frontal suggests that the frontal participates to the anterior margin of the supratemporal fenestra (Fig. 3), as it does in platypterygiine ophthalmosaurids (e.g. Aegirosaurus leptospondylus, Platypterygius australis, Sveltonectes insolitus, and Platypterygius hercynicus; see Bardet & Fernandez, 2000; Kear, 2005; Fischer et al., 2011b; Fischer, 2012, respectively), with the exception of Athabascasaurus bituminus (see Druckenmiller & Maxwell, 2010). The poor preservation of this region of the skull prevents unambiguous description on this feature, however, accordingly, we scored this character as unknown for Simbirskiasaurus birjukovi.
Jugal

The anterior part of the jugal forms a thin lamella that covers the posteroventral surface of the maxilla via an extensive well-delineated facet, textured by ridges and furrows (Fig. 1). This facet indicates that the anterior part of the jugal forms an acute process. Posteriorly, the jugal thickens and, together with the overlain maxilla, buttresses the posteroventral process of the lacrimal. There is no evidence for a premaxilla-jugal contact, unlike in Brachypterygius extremus (see Kirton, 1983).

Sclerotic ring

One large element of the sclerotic ring is preserved (Fig. 1). Both the internal (i.e. with respect to the pupil) and the external margins of the sclerotic ring are striated.

Basioccipital

The basioccipital (78 mm wide; Figs 2, 3) is partly freed from the matrix; only its posterior and right posterolateral surfaces are embedded. The basioccipital has no excentrally rounded area and lacks a peripheral groove, as is also the case in Arthropterygius chrisorum (see Maxwell, 2010; Fernández & Maxwell, 2012), platypterygiine ophthalmosaurids (Fischer et al., 2012), and possibly Palvennia hoybergeti Druckenmiller et al., 2012 (for which a single poorly preserved basioccipital is known). Among platypterygiines, the basioccipital of Simbirskiasaurus birjukovi is very similar to that of both some Platypterygius specimens (e.g. an unnumbered specimen in Bardet, 1989) and Brachypterygius extremus (CAMS J68516; McGowan, 1976), lacking the raised opisthotic facets seen in Sveltonectes insolitus and Fischer et al., 2014 (Fischer et al., 2011b; Fischer et al., 2014b, respectively; Fig. 3). The anterior surface is flat and lacks dorsoventral grooves. There is a minute foramen on the left side, ventral to the exoccipital facet. The opisthotic facet is flat and its anterior edge is confluent with the condylar area, unlike in ophthalmosaurines, in which a groove separates the condyle from the body of the basioccipital (Fischer et al., 2012, 2014a). The condyle is markedly convex. The exoccipital facet is deep and elliptical. The floor of the foramen magnum is raised and narrow, and lacks the distinctive median structure present in Acamptonectes densus, where it is divided by a longitudinal ridge (Fischer et al., 2012).

Stapes

The medial surface of the occipital head of the left stapes is preserved (Fig. 3); this surface is quadratic in medial view. The opisthotic facet is relatively large and flat. A hyoid process is present, but this feature appears to be intraspecifically variable among ophthalmosaurids (Fischer et al., 2012).

Dentition

Numerous teeth are preserved (Fig. 1). The apex is pointed and the crown is elongated (the largest crown is 19 mm in length); it is also robust and textured with numerous apicobasal ridges. The acellular cementum is smooth. The root forms only half of the height of the tooth. Its peripheral surface bears apicobasal ridges and its cross section is squared, as is typical for platypterygiine ophthalmosaurids (Fischer et al., 2012), but it lacks the prominent and sharp angles seen in some Platypterygius specimens (Bardet, 1990; Fischer et al., 2014b).

Although relatively larger than in Aegirosaurus leptospondylus (see Bardet & Fernandez, 2000), the shape and robustness of the teeth and the lack of specialized features suggest that Simbirskiasaurus birjukovi also occupied a 'generalist' feeding guild (see the scheme developed in Fischer et al., 2011a; Fischer et al., 2014b). Too few tooth apices are preserved to allow for the quantitative analysis of the wear pattern, but most crown apices are slightly polished and there is at least one broken-off tip with a polished broken surface; a very similar condition to that in the Aegirosaurus sp. specimen studied by Fischer et al. (RGHP LA 1; Fischer et al., 2011a).

Pervushovisaurus Arkhangelsky, 1998B

Diagnosis and occurrence

As for the type and only species, Pervushovisaurus bannovkensis.

Pervushovisaurus bannovkensis

Arkhangelsky, 1998B

Platypterygius (Pervushovisaurus) bannovkensis Arkhangelsky, 1998b: 611-615, figs 1, 2 (original description).

Holotype

SSU 104a/24, a complete rostrum.
Emended diagnosis

Platypterygiine ophthalmosaurid characterized by the following autapomorphies: presence of foramina along the ventral premaxillary-maxillary suture; presence of a semi-oval foramen on the lateral surface of the premaxilla, anteroventral to the external nares; presence of lateral ridges on the maxilla; presence of wide supranarial 'wing' of the nasal (a similar structure, although much smaller, is present in *Platypterygius australis* and *Acamptonectes densus*; see Kear, 2005; Fischer *et al.*, 2012, respectively); robust splenial markedly protruding from the external surface of the mandible.

*Pervushovisaurus bannovkensis* is also characterized by the following unique combination of features: secondarily closed naris surrounded by foramina [as in *Platypterygius sachicarum* and *Platypterygius australis* (see Paramo, 1997 and Kear, 2005, respectively), and in *Simbirskiasaurus birjukovi*, although the 'anterior' naris is still present in this taxon (Maisch & Matzke 2000; this work)]; elongated anterior process of the maxilla, reaching anteriorly the level of the nasal [unlike in *Aegirosaurus leptospondylus* (see Bardet & Fernández, 2000) and *Sveltonecetes insolitus* (see Fischer *et al.*, 2011b)]; root cementum forming prominent 90° angles (as in *Platypterygius campylodon*; see Fischer *et al.*, 2014b).

Occurrence

Middle Cenomanian, probably from the Melovatskaya Formation, Upper Cretaceous (Pervushov, Arkhangelsky & Ivanov, 1999) of the Nizhnaya Bannovka locality, Krasnoarmeisk District, Saratov Region, Russia.

Note

According to the principle of coordination (article 43.1 of the International Commission on Zoological Nomenclature, ICZN), Arkhangelsky (1998b) created *Pervushovisaurus* as a name of the 'genus group'; therefore, this name already exists at the generic rank and can readily be used as a genus-level taxon.

**Figure 4.** *Pervushovisaurus bannovkensis* Arkhangelsky, 1998b, holotype (SSU 104a/24), in dorsal view: A, photograph; B, interpretation. Note the elongated nasal, the premaxillary, and narial foramina, and the peculiar external naris. Abbreviations: An, angular; Dg, dental groove; Dt, dentary; Ex. int. na., excavatio internasalis; Fd, fossa dentalis; Lw, lateral 'wing' (lamella) of the nasal; Mc, Meckelian canal; Mx, maxilla; Na, nasal; Na f., nasal facet on the premaxilla; Na for., narial foramen; Nar, naris; Pmx, premaxilla; Pmx for., premaxillary foramen; Ri, lateral ridges of the maxilla; Sa, surangular; Sp, splenial.
**DESCRIPTION**

**Premaxilla**

The premaxilla is elongated (Fig. 4) and appears slightly bent ventrally as is also the case, though to a lesser degree, in *Platypterygius americanus* and *Platypterygius sachicarum* Paramo, 1997 (Romer, 1968; Paramo, 1997, respectively). The fossa praemaxillaris is deep, wide, and nearly continuous. In the anteriormost 100 mm of the rostrum, it forms a small series of aligned foramina. As in some other ichthyosaurs (e.g. *Aegirosaurus*; see Bardet & Fernández, 2000; Fischer et al., 2011a), there are multiple lateral foramina at the anterior extremity of the rostrum, which are not necessarily aligned with the fossa praemaxillaris. The dental groove is deep along the whole of its length (around 35 mm deep at the level of emergence of the nasal). As in *Athabascasaurus bitumineus* and *Svletonectes insolitus*, the dorsal edge of the premaxilla is strongly bent ventrally anterior to the narial aperture (Drucknemiller & Maxwell, 2010; Fischer et al., 2011b, respectively), but the premaxilla is incomplete and the presence of a supranarial process cannot be assessed unambiguously (Fig. 5). Unusually, there is a large semi-oval foramen ventral to the narial aperture (Fig. 5). Arkhangelsky (1998b) regarded this as a fenestra between the premaxilla and the maxilla; however, this foramen belongs to the premaxilla because no suture can be seen around it; furthermore, the premaxillary-maxillary suture is actually located ventral to it. Although the evolutionary origin and function of that foramen remains unclear, its presence is regarded as autapomorphic for *Pervushovisaurus bannovkensis*.

**Nasal**

The nasal is markedly elongated anteriorly, but unlike that of *Platypterygius hercynicus*, it is mostly hidden beneath the premaxilla (Fischer, 2012). This is clearly indicated by the presence of a well-defined contact zone, medial to which the nasal thickens abruptly, forming the dorsomedial portion of the rostrum (Fig. 4). The nasal emerges about 515 mm posterior to the tip of the premaxilla. Posteriorly, the nasal forms a subtle excavatio internasalis; there, the dorsal and lateral surfaces of the nasal meet perpendicularly via a thickened ridge. As in *Platypterygius australis* and *Acamptonectes densus* (see Kear, 2005; Fischer et al., 2012, respectively), the nasal lamella forms a lateral 'wing' overhanging the narial area, but this structure appears much more developed in *Pervushovisaurus bannovkensis* (Figs 4-6). A small foramen is present dorsal to that 'wing', 375 mm posterior to the emergence of the left nasal, and is present on both nasals (Figs 4-6). The right nasal is shifted medially by 90° and is dorsoventrally compressed; its nasal lamella faces dorsally whereas its medial lamella faces ventrally (Figs 4, 7). The nasal forms a small and semicircular notch with a thickened rim, which we interpret as the nasal contribution to the right narial aperture. The narial aperture is small, anteroposteriorly short, and deeply enclosed in the ventral edge of the nasal, as reconstructed on the left-hand side by Arkhangelsky (1998b), when the specimen was more complete. The external naris therefore appears similar to that of *Platypterygius australis*, as noted by Maisch & Matzke (2000: 92).

**Maxilla**

The anterior process of the maxilla is markedly elongated (Figs 4, 5, 8), emerging laterally at the same level as the nasals, in contrast to the condition in *Ophthalmosaurus icenicus, Aegirosaurus* sp., *Svletonectes insolitus*, and *Acamptonectes densus* (see Andrews, 1910a; Bardet & Fernández, 2000; Fischer et al., 2011a; Fischer et al., 2011b; Fischer et al., 2012). Posteriorly, a series of ridges extend along its lateral surface (Fig. 5). These may represent the articular facet for the jugal, but this is unlikely because this area is located anterior to the level of the narial aperture; this would imply an extremely elongated jugal, extending much farther anteriorly than the anterior edge of the external naris. The maxilla is dentigerous, but unlike in *Ophthalmosaurus icenicus* and *Platypterygius australis* (see Andrews, 1910b; Kirton, 1983; Kear, 2005), there are no individual pseudo-alveoli for maxillary teeth (Fig. 8). Anteriorly, the maxilla is a thin lamella lying on the medial surface of the labial wall of the premaxillary dental groove; the maxilla then progressively thickens and expands dorsally, then medially, as the dentigerous part of the premaxilla reduces. Approximately 710 mm posterior to the tip of the rostrum, the maxilla emerges medioventrally and forms the lingual wall of the dental groove. At that point, the medioventral part of the rostrum flattens and widens. There, the maxilla forms an oblique suture with the premaxilla, with two foramina that do not correspond to the internal naris.

**Dentary**

The dentary closely resembles the premaxilla. In lateral view, the tip of the rostrum is rounded, unlike the 'beaked' tip of *Platypterygius australis* (see Kear, 2005). Posteriorly, the ventral and lateral components of the dentary are replaced by the splenial, the angular, and the surangular, successively; at this level, the dentary is reduced to a thin lamella covering the surangular (Fig. 7).

**Surangular and angular**

The surangular is thick and slightly T-shaped in cross section; the dorsal surface of the angular bears two deep
grooves (Fig. 7). A fossa surangularis is present, unlike in Sveltonectes insolitus (see Fischer et al., 2011b) and embryonic Platypterygius australis (see Kear & Zammit, 2014).

**Splenial**

The splenial emerges ventrally 361 mm posterior to the tip of the mandible, and the symphysis is 695 mm in length. At the end of the symphysis, the splenial rapidly widens and thickens, forming a prominent ridge with a semicircular cross section, which is a unique feature of Pervushovisaurus bannovkensis (Figs 7, 8).

**Dentition**

The teeth are robust, although only a few are preserved. The largest one is 60 mm in total length, which is bigger than in most specimens of Platypterygius (55 mm, according to Bardet, 1990; Fig. 9). This appears small, however, relative to the skull size (anteorbital length ~1 m). The crown is conical, robust, and ridged along its entire height. The acellular cementum ring is smooth. As is the case in some specimens referred to Platypterygius campylodon, the roots of middle-snout teeth are thickened and form prominent 90° angles, although these are not as sharp and prominent as they are in Platypterygius campylodon (see Fischer et al., 2014b). This results in a markedly quadrangular cross section. The cross section is, however, rectangular rather than squared in the largest teeth, unlike in most specimens of Platypterygius campylodon, although this may partly result from diagenesis: one tooth (second from left in Fig. 9) is compressed labiolingually the crown being flattened on one side, and another one of similar size (left-most tooth in Fig. 9) possesses a squared cross section. Subtle apico-basal ridges texture the labial and lingual surfaces of the root. Posterior teeth (the two on the right in Fig. 9) are smaller and have rounder, more bulbous roots.

*Figure 5. Pervushovisaurus bannovkensis Arkhangelsky, 1998b, holotype (SSU 104a/24), in left lateral view: A, photograph; B, interpretation. Note the premaxillary and nasal foramina, and the ridges on the lateral surface of the maxilla. The nasal is disarticulated from the premaxilla, as shown in Figure 4.*
Figure 6. *Pervushovisaurus bannovkensis* Arkhangelsky, 1998b, holotype (SSU 104a/24), detail of the right narial region. Note the anteroposteriorly short external naris profoundly notching the nasal.

Figure 7. *Pervushovisaurus bannovkensis* Arkhangelsky, 1998b, holotype (SSU 104a/24), in ventral view: A, photograph; B, interpretation. Note the premaxillary-maxillary foramina and the thick splenials. Abbreviations: Fsa, fossa surangularis; Int. dt, interdentary suture; Int. pmx, interpremaxillary suture; Pmx-Mx for., premaxillary-maxillary foramina; for all other abbreviations, see Figure 5.
Figure 8. Pervushovisaurus bannovkensis Arkhangelsky, 1998b, holotype (SSU 104a/24), in posterior view: A, photograph; B, interpretation. Abbreviations: An f., angular facet of the surangular; Prf, prefrontal; for all other abbreviations, see Figure 5.
RESULTS

PHYLOGENETIC ANALYSIS

We recovered two most parsimonious trees in our unpruned analysis (of 103 steps, with a consensus tree of 104 steps; consistency index, CI = 54; retention index, RI = 67; Figs 10, S1-S6). The aim of this analysis is to provide a broad context to analyse the phylogenetic positions of Simbirskiasaurus birjukovi and Pervushovisaurus bannovkensis; the data set therefore incorporates numerous highly incomplete taxa. As a result, the general support of the tree topology is moderate to low. The topology is similar to that of previous analyses, finding Ophthalmosauridae to form two distinct clades: Ophthalmosauroidae and Platypterygiinae (Fischer et al., 2012, 2014a). The significant details of the topology for platypterygiines are discussed below.

The phylogenetic analysis of the pruned matrix yielded two most parsimonious trees (of 89 steps, with a consensus tree of 93 steps; CI = 61; RI = 68) with a topology similar to that of the unpruned analysis, except that the removal of Stenopterygius/Chacaicosaurus cayi from the data set created a polytomy at the base of Thunnosauria, and that Brachypterygius is recovered as a basal platypterygiine. The statistical support is, however, substantially increased (Fig. 10).

As in other morphological (Fischer, 2012) and phylogenetic (e.g. Druckenmiller & Maxwell, 2010; Fischer et al., 2012) analyses, the genus Platypterygius, as currently defined, is paraphyletic. We ran constrained analyses in TNT, forcing the monophyly of Platypterygius in both the full and pruned matrices; the shortest trees recovered were respectively one (104 steps) and three (92 steps) steps longer than the most parsimonious solutions; these topologies are therefore suboptimal. Whereas the precise interrelationships of platypterygiine ichthyosaurs are still poorly supported, our current analyses found support for a derived clade of platypterygiine ichthyosaurs comprising Simbirskiasaurus birjukovi, Pervushovisaurus bannovkensis, and Platypterygius australis, all of which share narial aperture division (Fig. 10).
**Figure 10.** Phylogenetic relationships of Simbirskisaurus birjukovi and Pervushovisaurus bannovkensis. A, strict consensus of the two most parsimonious trees (each of 103 steps; consensus tree of 104 steps; consistency index, CI = 54; retention index, RI = 67) arising from the cladistic analysis of the 'full' data set, with significant support values (Bremer support > 1; bootstrap and jacknife values > 50%). B, strict consensus of the two most parsimonious trees (each of 89 steps; consensus tree of 93 steps; CI = 61; RI = 68) arising from the cladistic analysis of the 'reduced' data set, with significant support values (Bremer support > 1; bootstrap and jacknife values > 50%). Abbreviations: Br, Bremer support; Bt, bootstrap value; Jk, jacknife value.

**DISCUSSION**

**DIFFERENCES WITH THE ORIGINAL DESCRIPTION OF SIMBIRSKIASAURUS BIRJUKOVI**

Ochev & Efimov (1985) considered that YKM 65119 represents a new taxon belonging to the family Ichthyosauridae, and noted that this taxon is characterized by a very peculiar naris surrounded by four foramina. Subsequent preparation of the external naris indicates that these foramina are actually a large posterior opening of the narial complex, separated from the anterior one by a nasomaxillary pillar. This also revealed the presence of a large narial lamella of the maxilla beneath the lacrimal. These new observations permit a better understanding of the peculiar nares in some other derived platypterygines, such as Pervushovisaurus bannovkensis and Platypterygius australis (see below). Besides minor differences in the interpretation of the dorsal surface of the skull roof and the extension of the maxilla, we found no evidence for a 'quadratic orbit', considered by Ochev & Efimov (1985) as a diagnostic feature. The postcranial material (sacral centra, ribs, and
neural arches) mentioned in the original publication is apparently lost.

YKM 65119 represents a valid taxon; given the peculiarities of its cranial anatomy and its stratigraphic age, we argue that Simbirskiasaurus birjukovi should be reinstalled as a valid genus and species of Cretaceous ichthyosaur that requires removal from the wastebasket taxon Platypterygius. It represents an additional taxon in the Barremian of the Ulyanovsk area, probably with an ecological niche distinct from that of the smaller, more gracile Sveltonectes insolitus (see Fischer et al., 2011b). These taxa have not been found in close association, however: the holotype of Simbirskiasaurus is early Barremian, whereas the holotype of Sveltonectes is late Barremian.

**The peculiar osteology and validity of Pervushovisaurus bannovkensis**

Pervushovisaurus bannovkensis is based on a single skull described by Arkhangelsky (1998b). Despite numerous intriguing features initially described in this taxon (including a foramen at the premaxillary-lacrimal suture, an extremely long lacrimal, and a reduced naris), McGowan & Motani (2003) regarded it as a nomen dubium, referring the material to Platypterygius campyloodon. Maisch & Matzke (2000) retained the species Platypterygius bannovkensis as provisionally valid, pending reassessment. Since the original description was published, the posterior part of the skull roof has been lost. Nevertheless, it is still possible to investigate the peculiar osteology of this specimen and evaluate the validity of the original description. The foramina on the premaxilla, maxilla, and nasal are genuine, although their functional significance is unclear; the peculiar narial shape is also genuine, and is actually present in other platypterygiine ophthalmosauroids, as discussed below.

Despite the incompleteness of the remains, Pervushovisaurus bannovkensis possesses numerous unique features, such as the numerous cranial foramina, the lateral ridges on the maxilla, the extensive supranarial wing, and the prominent splenial; moreover, the characters uniting this species to Platypterygius, such as the quadrangular cross section of the root, actually diagnose Platypterygiinae (see Fischer et al., 2012). Thus, Pervushovisaurus bannovkensis should be regarded as a valid taxon: its proposed inclusion within the genus Platypterygius was made by default, and has never been demonstrated. Our reasoning is as follows. (1) The type and only specimen of the type species of Platypterygius, Platypterygius platydactylus (Broili, 1907), is an immature ichthyosaur that was destroyed during World War II (McGowan & Motani, 2003; Kear & Zammit, 2014). Contrary to some published accounts (e.g. McGowan, 1972; McGowan & Motani, 2003), Platypterygius platydactylus is a lower Aptian taxon; indeed, Broili (1907) mentioned the associated presence of the ammonite Hopлитes deshayesi (= Deshayesites deshayesi d’Orbigny 1841), which is lower Aptian in age (Lehmann et al., 2009). (2) Additionally, phylogenetic analyses (e.g. Druckenmiller & Maxwell, 2010; Fischer et al., 2011b; Fischer, 2012; this work) repeatedly recover Platypterygius as paraphyletic; most of the previous features regarded as autapomorphic for Platypterygius are more widespread, and actually diagnose the diverse ophthalmosaurid clade Platypterygiinae (quadranular root section, basioccipital with extremely reduced exaracodalvær, large humeral trochanters; Fischer, 2012; Fischer et al., 2012). Therefore, we argue that Cretaceous ophthalmosaurid taxa should not be attributed to the genus Platypterygius by default, as has been the case since the revision of McGowan (1972), especially for middle Cenomanian material, which is about 20 million years younger than Platypterygius platydactylus (using the numerical ages from Kuhnt & Moullade 2007 and Gradstein et al., 2012). As we propose in the Discussion, below, the name Platypterygius should be restricted to its type species for the time being. (3) Platypterygius platydactylus and Pervushovisaurus bannovkensis share no overlapping remains; with the current state of knowledge, there is thus no solid ground to refer the latter to the genus Platypterygius. For these reasons, we use the available genus rank name Pervushovisaurus for reception of the species Pervushovisaurus bannovkensis. Being middle Cenomanian in age, Pervushovisaurus bannovkensis represents one of the youngest valid ichthyosaur taxa known so far.

**The complex taxonomy of Platypterygius**

Our new data on Simbirskiasaurus birjukovi and Pervushovisaurus bannovkensis provide a further step towards the re-evaluation of Platypterygius and the true taxonomic diversity of Cretaceous ichthyosaurs. According to recent phylogenetic analyses (Druckenmiller & Maxwell, 2010; Fischer et al., 2012; Fischer et al., 2013; this work), there are three possible ways in which the name Platypterygius can be applied: (1) as the name for the most inclusive clade that contains all species referred to Platypterygius included here in our cladistic analyses; (2) as the name for the Cretaceous platypterygiine clade that contains Pervushovisaurus bannovkensis, Platypterygius australis, and Simbirskiasaurus birjukovi (all of which share a peculiar narial aperture); (3) or as restricted specifically to the type species of Platypterygius - Platypterygius platydactylus - or to another type species that should be selected via a formal ICZN proposal. It should be noted that V.F and D.N. have prepared such a proposal; however, informal contact made with various colleagues prior to the submission of this work...
revealed the lack of a consensus on this issue and, in fact, a significant diversity of opinion.

Option 1 would require that Simbirskiasaurus and Pervushovisaurus are recognized as valid species within Platypterygius, as argued by Maisch & Matzke (2000), but would invalidate the early Tithonian genus Caypulliasaurus and the Albian genus Athabascasaurus. This particular taxonomic option would also result in a concept of Platypterygius that requires a near-global distribution as well as a stratigraphic range extending from the beginning of the Tithonian to the end of the Cenomanian, i.e. 58.2 Myr (using the timescale from Gradstein et al., 2012). This would make Platypterygius even more morphologically disparate and long-lived than as currently conceived. Although the concept of such a widespread, long-lived genus is not impossible, we consider it undesirable to interpret Platypterygius in this way in view of the alternatives.

Option 2 would include three species that are or have been referred to as Platypterygius, including the well-known Platypterygius australis, for which numerous descriptions and specimens are available (e.g. Wade, 1984; Wade, 1990; Kear, 2005; Zammit, 2010; Zammit et al., 2010; Maxwell, Zammit & Druckenmiller, 2012b); however, we conclude that this option is not advisable, predominantly because it would restrict the name Platypterygius to a clade that probably excludes the current type species, Platypterygius platydactylus, creating even more confusion. Furthermore, the application of the name Platypterygius to this clade would, like option 1, result in an unusual longevity for this taxon (early Barremian-middle Cenomanian, i.e. more than 30 Myr).

Figure 11. Schematic depiction of narial aperture evolution in parvipelvian ichthyosaurs. The narial aperture of many ophthalmosaurids is notched by a nasal process; the condition seen in the clade Simbirskiasaurus birjukovi + Pervushovisaurus bannovakensis + Platypterygius australis may therefore be derived from this common ophthalmosaurid configuration. External narial apertures not to scale. Basal neoichthyosaurian: Temnodontosaurus eurycephalus (NHMUK PV R1157, holotype; V.F., pers. observ.). Basal baracromian: Sienopterygius cf. quadriscissus (no specimen number, redrawn from Maisch & Ansorge, 2004). General ophthalmosaurid: based on photographs of Ophthalmosaurus icenicus (and Andrews, 1910a; Kirton, 1983), Ophthalmosaurus nutans (see Gilmore, 1905; Gilmore, 1906), Aegirosaurus leptospondylus (see Bardet & Fernández, 2000), and Cryopterygius kristiansenae (see Druckenmiller et al., 2012); Sveltonectes insolitus (IRSNB R 269, holotype; redrawn from Fischer et al., 2011b); Simbirskiasaurus birjukovi (YKM 65119, holotype; this work); Platypterygius australis (AM F98273; redrawn from Kear, 2005).

Given the paraphyly and absence of autapomorphic features of Platypterygius as currently defined (Fischer, 2012), we propose that the name Platypterygius should be restricted to its type species, Platypterygius platydactylus (or, perhaps less preferably, to a newly elected type species, left to be designated); this is option 3. Despite the numerous issues surrounding the holotype of Platypterygius platydactylus, many authors have pointed to unique or rare features present in this taxon, such as a fusion between the atlas, axis, and third cervical centrum, elongated posterior caudal centra, a peculiar quadrate, and more than two preaxial digits (e.g. Broili, 1907; Kolb & Sander, 2009; Maxwell & Kear, 2010). It cannot, therefore, be unambiguously considered a nomen dubium, and erection of a new type species is highly problematic, in part because it could require the renaming of Platypterygius platydactylus. For the purposes of taxonomic stability, this newly restrictive version of the name Platypterygius would require a detailed redefinition of the name Platypterygius; however, this alternative is (in our opinion) superior to the existing model in which the name is applied to a broad diversity of taxa: in the same way that the now abandoned name Leptopterygius was previously applied to diverse Early Jurassic taxa (see McGowan, 1996), the inclusive use of Platypterygius as currently conceived has persisted.
through social inertia. We feel that revision is needed, and that an adherence to the 'conventional' use of this name is confusing communication and stifling the appreciation of Cretaceous ophthalmosaurid diversity. This task is, however, beyond the scope of the present work, and will be dealt with in another article. Regardless of these taxonomic issues, it is clear from both recent morphological and cladistic analyses on Cretaceous ichthyosaurs that *Platypterygius* as conventionally conceived conceals a substantial diversity of Cretaceous ichthyosaurs.

**NARIS REDUCTION IN A DERIVED PLATYPTERYGIINE CLADE**

The phylogenetic analysis indicates the existence of a clade of derived platypterygiines containing *Simbirskiasaurus birjukovi, Pervushovisaurus bannovkensis*, and *Platypterygius australis*. *Simbirskiasaurus* extends the origin of this clade back to the early Barremian. In addition to being the youngest ichthyosaur clade to undergo radiation (the other parvipleian clades arose prior to the Cretaceous; Fischer et al., 2012; Fischer et al., 2013), it also contains one of the youngest ichthyosaur species known: *Pervushovisaurus bannovkensis* from the middle Cenomanian. A complete division of the external naris into distinct anterior and posterior openings, as a result of the formation of a nasomaxillary process, characterizes this clade; it appears that the anterior section of the narial complex subsequently became reduced to one or a series of small foramina, except in *Simbirskiasaurus*. Maisch & Matzke (2000: 92) previously noted the substantial similarities of narial aperture present among these taxa.

Our new observations on *Simbirskiasaurus birjukovi* and *Pervushovisaurus bannovkensis* therefore corroborate Maisch & Matzke's (2000) hypothesis that the foramina anterior to the external naris in some Cretaceous ichthyosaurs represent pleuric segments of the anterior part of the external naris. In fact, many ophthalmosaurids, including *Ophthalamosaurus* spp., *Platypterygius americanus*, *Aegirosaurus leptospondylus*, *Acamptonectes densus*, *Cryopterygius* *christiansenae*, and possibly *Brachypterygius* *extremus* (see Gilmore, 1905; Romer, 1968; Kittson, 1978; Bardet & Fernando, 2000; Druckenmiller et al., 2012; Fischer et al., 2012), possess a ventral process of the nasal that protrudes inside the narial aperture to produce a kidney-like shape. This process is elongated and hook-like in *Svelstonecites insolitus*, although the maxilla of this taxon lacks a corresponding process; its naris is not, therefore, entirely divided. The situation seen in *Simbirskiasaurus birjukovi, Pervushovisaurus bannovkensis, Platypterygius* *australis*, and probably *Platypterygius* *sachicarum* (see Paramo, 1997) could therefore be regarded as an elaborate version of a feature otherwise widespread among ophthalmosaurids, thereby indicating a trend towards reduction of the narial aperture in these ichthyosaurs, especially notable when compared with the large, oval, and often elongated nares of more basal neocichthyosaurs [Fig. 11; e.g. *Leptonectes moorei* McGowan & Milner 1999; *Leptonectes cf. tenuirostris*; *Eurhinosaurus longirostris* (Mantell, 1851); *Temnodontosaurus platyodon* (Conybeare, 1822); *Hauffiopteryx typicus* (von Huene, 1931); *Stenopterygius quadricissus* (Quenstedt, 1856); *Stenopterygius triscissus* (Quenstedt, 1856); see McGowan, 1979; McGowan, 1994; McGowan & Milner, 1999; Maisch & Matzke, 2003; Caine & Benton, 2011; Maxwell, 2012]. Interestingly, the external naris of the Aalenian taxon *Stenopterygius aalenensis* Maxwell, Fernando & Schoch, 2012 appears slightly kidney-shaped (Maxwell et al., 2012), possibly representing a prelude to the ophthalmosaurid condition. Such narial aperture reduction may appear counterintuitive given that ichthyosaurs apparently had a well-developed sense of smell, as suggested by the developed olfactory lobes of their brains (Maisch & Matzke, 2000). However, the derived platypterygiines *Caypullisaurus bonapartei* and *Platypterygius hercynicus* appear to have nares with convex dorsal margins (Fernandez, 2007b; Fernandez, 2007a; Fischer, 2012), indicating that this trend towards narial aperture reduction was not universal among ophthalmosaurids.

**CONCLUSION**

*Simbirskiasaurus birjukovi* and *Pervushovisaurus bannovkensis*, from the early Barremian and middle Cenomanian of Russia, respectively, are represented by diagnostic remains and are valid platypterygiine ophthalmosaurids. These taxa permit a re-evaluation of the peculiar narial aperture morphology encountered in other Cretaceous ophthalmosaurids, such as *Platypterygius australis* and possibly *Platypterygius sachicarum*, indicating the existence of a clade of platypterygiine ophthalmosaurids characterized by a reduction of the anterior part of the narial complex, following a complete division by a nasomaxillary process. Phylogenetic analysis indicates that *Simbirskiasaurus, Pervushovisaurus*, and *Platypterygius* *australis* form a clade, known to have persisted from the Barremian to the Cenomanian. Our phylogenetic analyses again indicate that the species currently referred to the widespread, long-lived genus *Platypterygius* are not close relatives: maintenance of this name as a catch-all for Cretaceous ophthalmosaurids is obscuring views on ophthalmosaurid diversity and disparity, and we therefore propose that the name should, for now, be restricted to the type species, *Platypterygius platydactylus*. 

*Status: Postprint (Author's version)*
ACKNOWLEDGEMENTS

We thank the SSU and YKM staff for removing the glass lids protecting the specimens and for making our study as easy as possible. We also thank J. Falconnet (Muséum national d'Histoire naturelle, Paris, France) for his helpful advice on complex nomenclatural issues. Finally, we warmly thank J.M. Pardo Pérez, J.E. Martin, and an anonymous reviewer for their thorough and insightful reviews. V.F. was a recipient of a grant from the Fonds de la Recherche Scientifique-FNRS when this research was conducted.

REFERENCES

Adams TL, Fiorillo A. 2011. Platypterygius Huene, 1922 (Ichthyosaurus, Ophthalmosauridae) from the Late Cretaceous of Texas, USA. Palaeontologia Electronica 14: 19A.


Carter J. 1846. Notice of the jaws of an Ichthyosaurus. From the chalk in the neighbourhood of Cambridge. Reports of the British Association for the Advancement of Science 1845: 60.


SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site:

**Figure S1.** Strict consensus of the two most parsimonious trees arising from the cladistic analysis of the 'full' data set, in unambiguous optimization.

**Figure S2.** Strict consensus of the two most parsimonious trees arising from the cladistic analysis of the 'full' data set, in fast optimization (ACCTRAN).

**Figure S3.** Strict consensus of the two most parsimonious trees arising from the cladistic analysis of the 'full' data set, in slow optimization (DELTRAN).

**Figure S4.** Strict consensus of the two most parsimonious trees arising from the cladistic analysis of the 'reduced' data set, in unambiguous optimization.

**Figure S5.** Strict consensus of the two most parsimonious trees arising from the cladistic analysis of the 'reduced' data set, in fast optimization (ACCTRAN).

**Figure S6.** Strict consensus of the two most parsimonious trees arising from the cladistic analysis of the 'reduced' data set, in slow optimization (DELTRAN).

**Appendix S1.** Codings and nexus of the two phylogenetic analyses.