第53卷 第3期 古 脊 椎 动 物 学 报 pp. 238-244
2015年7月 VERTEBRATA PALASIATICA figs. 1-2

New material of the Eocene marine bird *Kievornis* Averianov et al., 1990 and a reassessment of the affinities of this taxon

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Abstract New specimens of the Eocene bird *Kievornis* Averianov et al., 1990 are described. It is shown that this taxon existed in the Middle Eocene of the Tethys Sea, from the early Lutetian to the early Bartonian, and in an area spanning at least from Kiev in central Ukraine to Ikovo in the eastern part of the country. We tentatively refer *Kievornis* to the Procellariiformes. However, although the taxon exhibits features characteristic of the Procellariiformes, it also, and perhaps plesiomorphically, lacks some derived features of these birds.

Key words Ukraine, Tethys, Middle Eocene, Procellariiformes, *Kievornis*

1 Introduction

In 1873, a partial humerus and an ulna of a small bird were collected in the Eocene "blue brick clay" of Kiev vicinity in Ukraine. They were first identified as "*Scolopax*?" (Rogovich, 1875), and more than a century later, they were described as the new species *Kievornis rogovitshi* and tentatively referred to the charadriiform family Graculavidae by Averianov et al. (1990). In 2012 and 2013, three incomplete ulnae which closely resemble that of the holotype of *K. rogovitshi* and which are referred to *Kievornis* in this paper, as well as two carpometacarpi, were collected by two of the authors (EZ and LG) in the gravel sands of the Ikovo locality in eastern Ukraine. One of the carpometacarpi (SMF Av 593) was mentioned in a short communication by Mayr et al. (2013), who did, however, not assign the fossil to a particular avian taxon. The new material extends the known stratigraphic and geographic range of *Kievornis*, and here we also reassess the affinities of this taxon. Comparisons with the extant taxa of waterbirds are based on specimens in the osteological collection of NMNH-P. The osteological terminology follows Baumel and Witmer (1993).

Institutional abbreviations IRSNB, Royal Belgian Institute of Natural Sciences,

收稿日期：2015-02-01

Brussels, Belgium; NMNH-P, Department of Vertebrate Palaeozoology of the National Museum of Natural History at the National Academy of Sciences of Ukraine, Kiev, Ukraine; SMF, Forschungsinstitut Senckenberg, Frankfurt am Main, Germany; ZIN, Zoological Institute of Russian Academy of Sciences, St. Petersburg, Russian Federation.

2 Systematic paleontology

?Procellariiformes Fürbringer, 1888

Kievornis Averianov et al., 1990

Type species *Kievornis rogovitshi* Averianov et al., 1990.

Age and distribution Marl-clayish part of Kiev Formation, Middle Eocene (late Lutetian or early Bartonian), Kiev vicinity, Ukraine (type species, see Discussion) and Ikovo near Novopskov, Luhansk Province, Ukraine (new material; Udovichenko, 2009); quartz sands and sandstones, Middle Eocene (early Lutetian).

Kievornis sp.

Referred specimens NMNH-P Av-85 (Fig. 1A, C, E; left ulna missing olecranon and small adjacent part of the bone); NMNH-P Av-45 (Fig. 1G; distal end of right ulna); NMNH-P Av-86 (distal end of right ulna); SMF Av 593 (left carpometacarpus missing processus extensorius and os metacarpale minus); NMNH-P Av-47 (Fig. 2G, H; right carpometacarpus missing processus extensorius, os metacarpale minus, processus pisiformis and central part of os metacarpale majus).

Locality and horizon Ikovo near Novopskov, Luhansk Province, Ukraine; quartz sands and sandstones, Middle Eocene (early Lutetian; Udovichenko, 2009).

Measurements (in mm) NMNH-P Av-85: length as preserved, 49.9; dorsoventral width of extremitas proximalis, 4.5; craniocaudal width of extremitas distalis, 5.3. NMNH-P Av-45: craniocaudal width of extremitas distalis, 5.5. NMNH-P Av-86: craniocaudal width of extremitas distalis as preserved, 4.5. SMF Av 593: length as preserved, 28.2. NMNH-P Av-47: length as preserved, 28.6.

Description and comparison The ulnae are comparable to the holotype of *Kievornis rogovitshi* (ZIN PO 3926) in morphology and size, with the length of the latter specimen being 54.4 mm, versus 49.9 mm in NMNH-P Av-85 (in which the olecranon is broken). As far as the features are preserved, the Ikovo specimens exhibit all features considered to be diagnostic for the ulna of *K. rogovitshi* by Averianov et al. (1990): 1) cotyla ventralis and cotyla dorsalis (especially the dorsal rim of the latter) significantly projected cranially; 2) cranioventral part of cotyla ventralis not rounded; 3) incisura radialis deep, bordered by ridges, which run from the tuberculum bicipitale towards it; 4) impressio brachialis relatively wide; 5) tuberculum ligamenti collaterale ventrale very narrow and elongate, almost not raised; 6) tuberculum carpale separated from condylus ventralis by a deep notch; 7) incisura tendinosa notch-like. We also observe that 8) the depressio radialis is shallow. Unlike in the holotype, papillae remigales

are absent in the new Ikovo specimens, which may, however, well be due to intraspecific variability. Because of this difference and the fragmentariness of the material, we refer the Ikovo specimens to *Kievornis* sp.

The ulna of *Kievornis* differs from that of the slightly larger gaviiform taxon *Colymbiculus*, also from the Ikovo locality (Mayr and Zvonok, 2011, 2012; Mayr et al., 2013), in that the cotyla ventralis is not rounded, the shaft is more slender, the tuberculum carpale projects strongly distoventrally and is separated from the condylus ventralis by a deep notch, and in that the depressio radialis is shallower (Fig. 1).

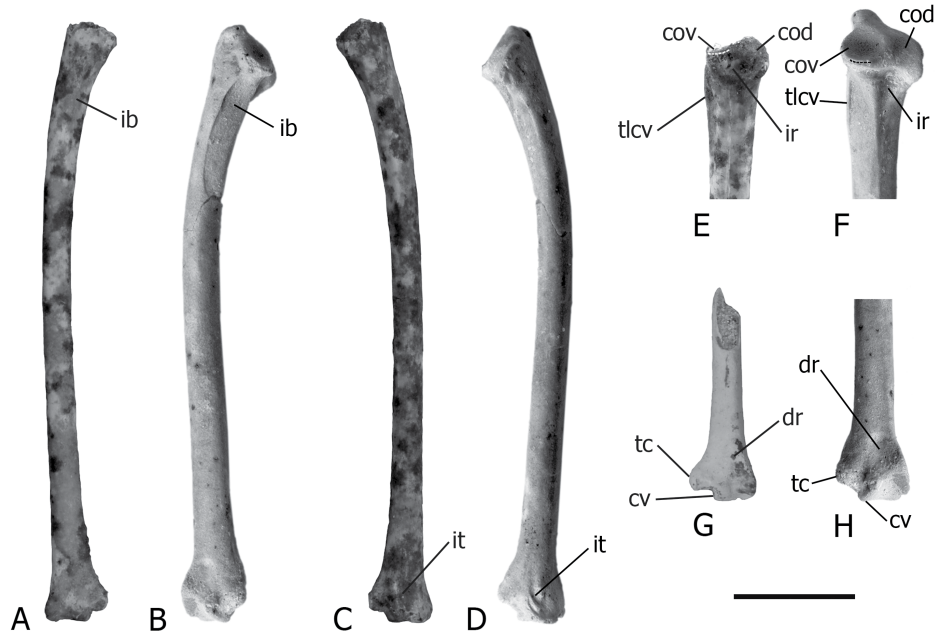

Fig. 1 Ulnae of *Kievornis* sp. and *Colymbiculus udovichenkoi* from the Middle Eocene Ikovo locality
A, C, E. *Kievornis* sp., left ulna (NMNH-P Av-85) in ventral (A) and dorsal (C) view; E. cranial view of proximal end (cranial rim of cotyla ventralis is highlighted); G. *Kievornis* sp., distal end of right ulna (NMNH-P Av-45) in ventral view; B, D, F, H. *Colymbiculus udovichenkoi*, right ulna (SMF Av 548) in ventral (B) and dorsal (D) view; F. cranial view of proximal end (cranial rim of cotyla ventralis is highlighted); H. ventral view of distal end (B, D, and F are mirrored images)
Abbreviations: cod. cotyla dorsalis; cov. cotyla ventralis; cv. condylus ventralis; dr. depressio radialis; ib. impressio brachialis; ir. incisura radialis; it. incisura tendinosa; tc. tuberculum carpale; tlcv. tuberculum ligamenti collaterale ventrale. Scale bar equals 10 mm

There are two incomplete carpometacarpi among the new specimens from Ikovo, which we also assign to *Kievornis*. These bones are smaller than what has to be expected for *Colymbiculus* and also differ from Gaviiformes in morphological features (Mayr et al., 2013). They correspond with *Kievornis* in size and are tentatively assigned to this taxon here, because – other than the loon *Colymbiculus* – small birds are very rare at the Ikovo locality, and because the carpometacarpi exhibit features found in taxa of Aequornithes (the “waterbird” clade): the fovea carpalis caudalis is deep like in Gaviiformes, Pelecanidae, Suliformes and

Phaethontiformes; the ventral rim of the trochlea carpalis continues with the caudal edge of the minor metacarpal like in Procellariiformes and Phaethontiformes; the symphysis metacarpalis proximalis is proximodistally short, and, also like in Procellariiformes and Phaethontiformes, it does not extend much beyond the facet for the alular digit distally.

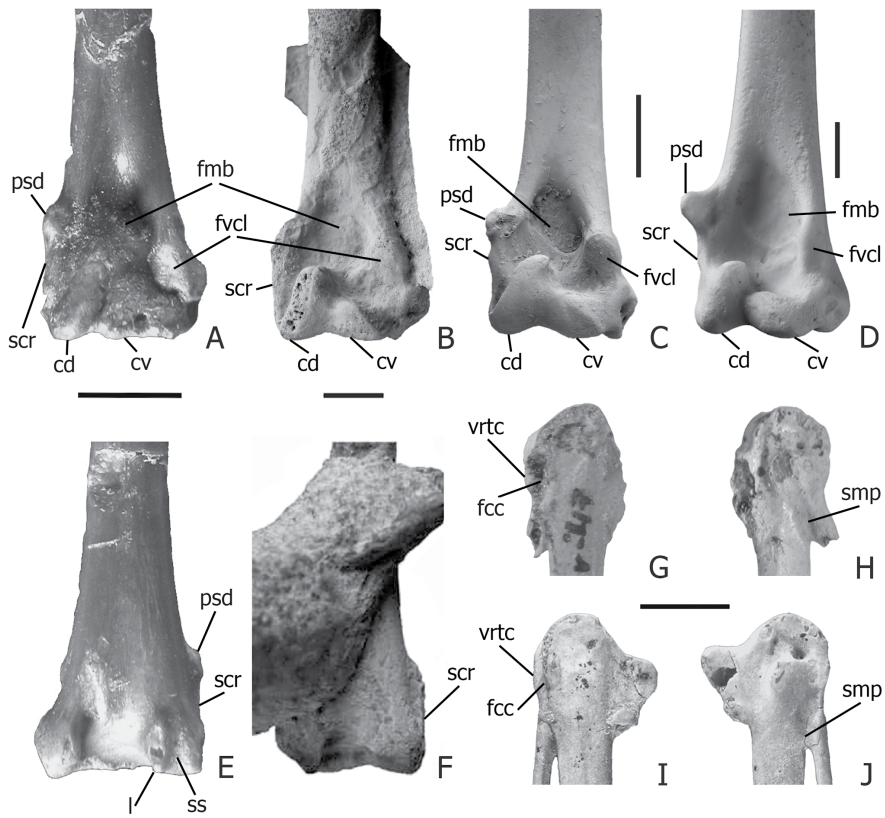

Fig. 2 Humeri and carpometacarpi of *Kievornis* and Procellariiformes

A, E. *Kievornis rogovitshi*, distal end of right humerus (ZIN PO 3926) in cranial (A) and caudal (E) view; B, F. *Makahala mirae*, distal end of right humerus (SMF Av 603) in cranial (B) and caudal (F) view; C. *Rupelornis definitus* (Diomedeoididae), distal end of left humerus (IRSNB Av 102a, reversed) in cranial view; D. *Fulmarus glacialis* (Procellariidae), distal end of right humerus (SMF 6317) in cranial view; G, H. *Kievornis* sp., proximal end of right carpometacarpus (NMNH-P Av-47) in dorsal (G) and ventral (H) view; I, J. *Murunkus subitus,* left [erroneously identified by Panteleyev and Nessov (1993) as right] carpometacarpus (ZIN PO 5113, mirrored image) in dorsal (I) and ventral (J) view

Abbreviations: cd. condylus dorsalis; cv. condylus ventralis; fcc. fovea carpalis caudalis; fmb. fossa musculi brachialis; fvcl. facet for the ventral collateral ligament; l. ledge on the caudal surface of the humerus; psd. processus supracondylaris dorsalis; scr. supracondylar ridge; smp. symphysis metacarpalis proximalis; ss. sulcus scapulotricipitalis; vrtc. ventral rim of the trochlea carpalis. Scale bars equal 5 mm

3 Discussion

The new *Kievornis* specimens show that this taxon inhabited the Tethys Ocean in an area spanning at least from Kiev in central Ukraine to Ikovo in the eastern part of the

country. The holotype of *Kievornis rogovitshi* was considered to be of Late Eocene age by Averianov et al. (1990). However, it was found in the "blue brick clay" (the marl-clayish part of Kiev Formation) of the Kiev vicinity (Rogovich, 1875), which is well dated and belongs to the middle/upper part of the nannoplankton zone NP 16 and the lowermost part of NP 17 (Ryabokon, 2002). The *K. rogovitshi* holotype is therefore from the Middle Eocene (late Lutetian to early Bartonian), whereas the *Kievornis* remains from the Ikovo locality are from the early Lutetian (Udovichenko, 2009) and therefore are slightly older.

The recognition of *Kievornis* sp. in the Ikovo locality increases the diversity of seabirds known from this marine locality. It is the sixth bird species from this fossil site, in addition to the gaviiform *Colymbiculus udovichenkoi*, two species of Pelagornithidae and two indeterminate gruiform- and galliform-like birds (Mayr and Zvonok, 2011, 2012).

Averianov et al. (1990) referred *Kievornis* to the family Graculavidae. However, Graculavidae was already recognized as an artificial assemblage ("form-family") by Olson and Parris (1987) and the true affinities of *Kievornis* remained elusive. Based on the published figures of the fossils, Mayr (2009a) considered *Kievornis* to be more similar to the Procellariiformes or Phaethontiformes than to the Charadriiformes.

In addition to an ulna, the *K. rogovitshi* holotype also includes a partial humerus, which is clearly distinguished from that of charadriiform birds. The condyli ventralis and dorsalis, for example, extend distally approximately to the same level in *K. rogovitshi*, whereas in Charadriiformes the condylus ventralis always extends further distally. The shaft of the *Kievornis* humerus is also straighter in cranial and caudal view. In Charadriiformes, by contrast, the distocaudal surface of the humerus is more angular in dorsal-ventral view.

Kievornis shares two characteristic features with Procellariiformes and the phaethontiform Prophaethontidae, which were widespread on the Northern Hemisphere from the Late Paleocene to Middle Eocene (Thanetian to Lutetian; Bourdon et al., 2008), that is, a craniocaudally compressed humeral shaft and a deeply excavated fossa musculi brachialis. *Kievornis* exhibits the following features that distinguish the taxon from Phaethontiformes and are characteristics of Procellariiformes: 1) the presence of a ridge along the dorsal surface of the distal end of the humerus, which forms a straight margin as in *Makahala* from the Priabonian or Rupelian of North America (Mayr, 2015), the Diomedeoididae from the Oligocene of Eurasia, and in some extant procellariiforms (Fig. 2A-F), and 2) a sharply protruding ledge on the caudal surface of the distal humerus as in *Makahala*, Diomedeoididae, and extant Oceanitidae (Fig. 2E, F; Mayr et al., 2002; Bourdon et al., 2008; Mayr and Smith, 2012; Mayr, 2015). The very wide facet for the ventral collateral ligament differs from phaethontiforms and most waterbirds, and resembles that in *Makahala*, Diomedeoididae, and in some extant procellariiforms (Fig. 2A-C; pers. obs.). On the other hand, *Kievornis* is distinguished from all Procellariiformes by the presence of a sulcus scapulotricipitalis (Fig. 2E) and a more strongly curved ulna (Fig. 1A, C). The last two features most likely are plesiomorphic for Procellariiformes because the presence of a sulcus scapulotricipitalis is

common for non-procellariiform birds and a curved ulna occurs in other taxa of Aequornithes, such as Gaviidae and most “Ciconiiformes” (pers. obs.). Compared to procellariiform birds, *Kievornis* resembles the Diomedeoididae and the Oceanitidae (Mayr et al., 2002; Mayr, 2009b; de Pietri et al., 2010; Mayr and Smith, 2012) in the weakly developed processus supracondylaris dorsalis, but differs from them by the above-mentioned features that are absent in procellariiform birds. *Kievornis* differs from *Makahala* (Mayr, 2015) in the presence of a shallow processus supracondylaris dorsalis. It differs from the putatively procellariiform *Primodroma* Harrison & Walker, 1977 from the Ypresian of England (Harrison and Walker, 1977) in that the supracondylar ridge is more straight, whereas this ridge is longer in another possible procellariiform, *Tytthostonyx* Olson & Parris, 1987 from the Maastrichtian-Danian of North America (Olson and Parris, 1987).

The new carpometacarpi also support procellariiform affinities of *Kievornis*, except that the fovea carpalis caudalis is deeper, which may, however, also be a plesiomorphic feature for Procellariiformes, because a deep fovea also occurs in many other waterbirds (pers. obs.).

Acknowledgements We thank A. O. Averianov for providing photos of the *Kievornis* holotype, M. S. Komar for financial support for the excavation in the Ikovo locality, N. V. Zelenkov for photos of the Murunkus holotype, and Wang Min for translating the Chinese abstract. We further thank Wang Min and an anonymous reviewer for comments, which improved the manuscript.

始新世海鸟基辅鸟(*Kievornis* Averianov et al., 1990)新材料及其亲缘关系的重新评估

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摘要：描述了始新世基辅鸟类新标本。研究表明基辅鸟类生活在特提斯海中始新世早路特期至早巴顿期，分布范围至少包括乌克兰东部的伊克夫到中部的基辅地区。暂时将基辅鸟归入鳽形目。虽然基辅鸟具有一些鳽形目的典型特征，但缺少鳽形目的衍生特征，或许代表了近祖状态。

关键词：乌克兰，特提斯海，中始新世，鳽形目，基辅鸟

中图法分类号：Q915.865 **文献标识码**：A **文章编号**：1000-3118(2015)03-0238-07

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