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Discovery of a crocodyliform tooth from the upper Eocene Ergilin Dzo Formation, Mongolia

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Although the distribution of Asian crocodyliforms was extended northwards during the Paleocene–Eocene greenhouse world, the fossil record in northern Asia becomes scarce towards the end of the Eocene. We here report the first crocodyliform (an isolated tooth) from the upper Eocene Ergilin Dzo Formation of southeastern Mongolia, the mammalian fauna of which defines the Ergilian Asian Land Mammal Age. The conical non-recurved crown, the near complete root with the central resorption facet, and its late Eocene age suggest the crocodyliform affinity of the tooth. The current finding represents one of the northernmost occurrences of crocodyliforms in the upper Eocene of Asia (paleolatitude ca. 49°30' N), and demonstrates that SE Mongolia probably met thermal requirements of crocodyliforms during the late Eocene.

Introduction

The early Cenozoic, before the abrupt climate deterioration at ca. 34 Ma during the Eocene–Oligocene transition, was characterized by higher mean global temperature and reduced latitudinal temperature gradient (Zachos et al. 2001; Cramer et al. 2009), and crocodyliforms were extended into middle and even high latitudes over North America, Europe and Asia (Estes and Hutchison 1980; Markwick 1998, 2007; Mannion et al. 2015). In northern Asia, several crocodyliform taxa were reported from the late Paleocene through late Eocene (Mook 1940; Dong 1974; Efimov 1976, 1982, 1983, 1988, 1993; Snetkov 2011; Skuchas et al. 2015; Ni et al. 2016). However, the fossil record becomes poorer in younger formations, and only eastern Kazakhstan and northwestern China yielded late Eocene crocodyliforms (Dong 1974; Efimov 1988; Lucas et al. 2012; Stidham and Ni 2014). Here, we report an isolated crocodyliform tooth from the upper Eocene Ergilin Dzo Formation of southeastern Mongolia. Crocodyliformes is considered as a biological climate proxy (Markwick 1998, 2007; Mannion et al. 2015; Tennant et al. 2016), and its occurrence can help discuss the regional paleoclimate of Mongolia during the late Eocene.

Institutional abbreviations.—MPC, Institute of Paleontology and Geology (= formerly Mongolian Paleontological Center), Mongolian Academy of Sciences, Ulaanbaatar, Mongolia.

Systematic palaeontology

Eusuchia Huxley, 1875

Crocodyliformes Hay, 1930

Crocodyliformes gen. et sp. indet.

Fig. 2.

Material.—MPC-MX 1/108, an isolated tooth. This specimen was collected by one of the co-authors, TC, during the paleontological expedition on 4th September, 2008 (Tsubamoto et al. 2010) from Ergilin Dzo (= Ardyn Obo) located in the southern part of Dornogobi Aimag (eastern Gobi Desert), southeastern Mongolia (43°19'40''N, 109°07'42''E, map datum: WGS84; Yanovskaya et al. 1977; Dashzeveg 1993; Tsubamoto and Tsogtbaatar 2008; Fig. 1: 1) in Ergilin Dzo Formation (= Ardyn Obo Formation by Berkey and Granger 1923; Ergilin Dzo svita/suite by Yanovskaya et al. 1977 and Dashzeveg 1993); late Eocene (Ducrocq 1993; Meng and McKenna 1998; Tsubamoto et al. 2004, 2008).

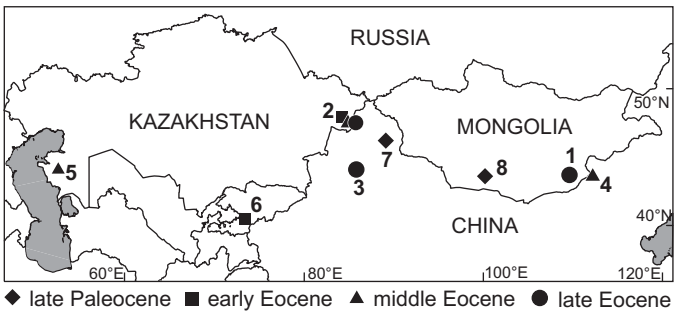

Fig. 1. Locality map of the Paleocene–Eocene crocodyliforms in northern Asia. 1, Ergilin Dzo, southeastern Mongolia (ca. 49°30' N in the late Eocene); 2, Zaysan Basin across eastern Kazakhstan and northwestern China (ca. 48°18' N, 49°54' N, and 50°55' N in the early, middle, and late Eocene, respectively; after Efimov 1982, 1988; Lucas et al. 2012; Stidham and Ni 2014; Skuchas et al. 2015); 3, upper reach of Manasi River, southern Junggar Basin, Xinjiang, China (ca. 48°18' N in the late Eocene; Dong 1974); 4, near Erenhot, Inner Mongolia, China (ca. 50°06' N in the middle Eocene; Mook 1940); 5, Mangyshlak Peninsula of western Kazakhstan (ca. 41°00' N in the middle Eocene; Snetkov 2011); 6, Osh, Kyrgyzstan (paleolatitude incomputable; Efimov 1982); 7, northeastern Junggar Basin, Xinjiang, China (ca. 46°06' N in the late Paleocene; Ni et al. 2016), 8, Tsagan Hushu, southern Mongolia (ca. 46°18' N in the late Paleocene; Efimov 1976, 1983). Paleolatitudes of the crocodyliform localities in the late Paleocene (58 Ma) and the early, middle, and late Eocene (50, 45, and 35 Ma, respectively) were calculated using the paleolatitude calculator (van Hinsbergen et al. 2015).

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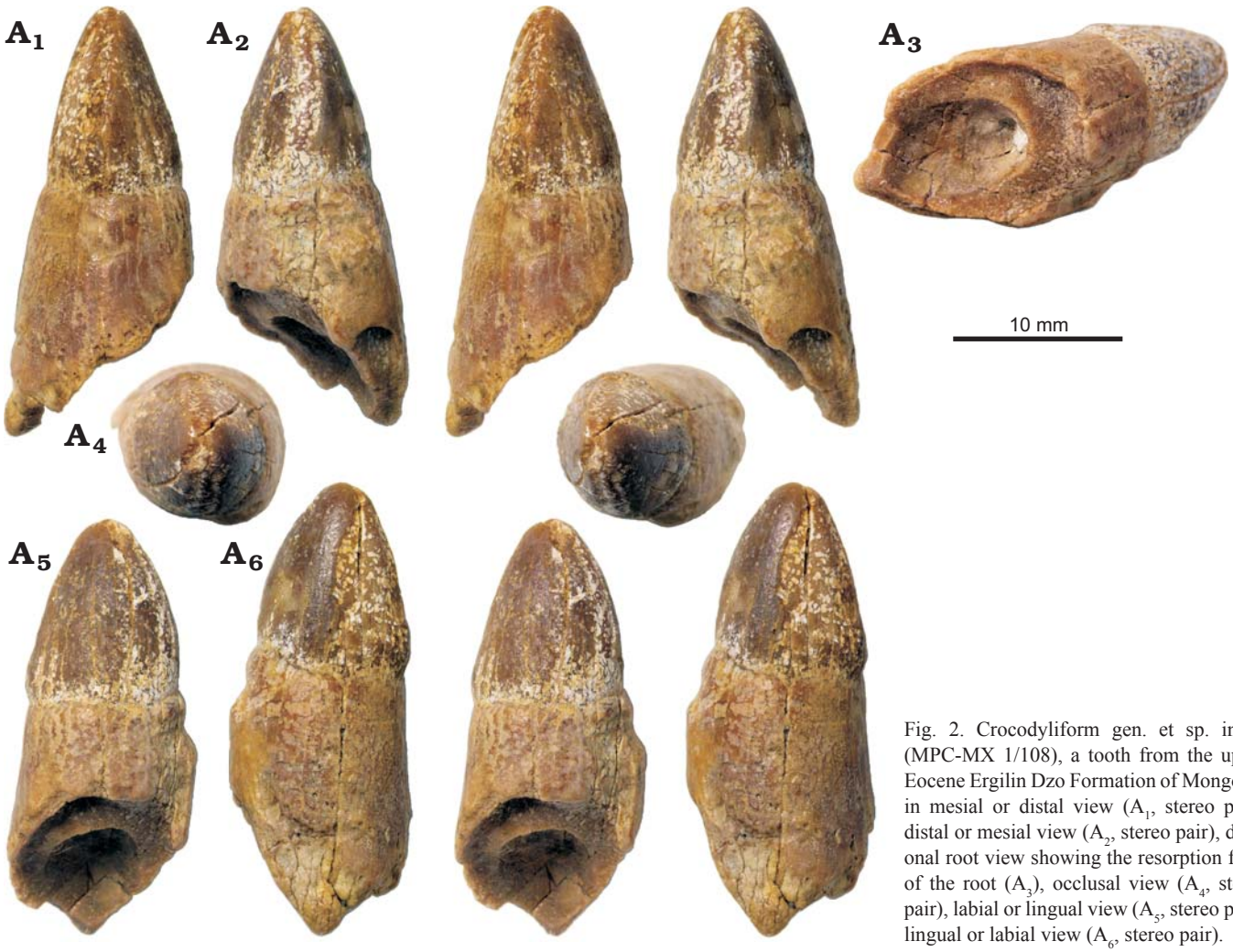

Fig. 2. Crocodyliform gen. et sp. indet. (MPC-MX 1/108), a tooth from the upper Eocene Ergilin Dzo Formation of Mongolia; in mesial or distal view (A_1, stereo pair), distal or mesial view (A_2, stereo pair), diagonal root view showing the resorption facet of the root (A_3), occlusal view (A_4, stereo pair), labial or lingual view (A_5, stereo pair), lingual or labial view (A_6, stereo pair).

Measurements.—Crown height = 11.9 mm; mesiodistal crown width at the base = 9.3 mm; labiolingual crown width at the base = 8.2 mm.

Description.—The isolated tooth (Fig. 2) preserved with its root and representing a functional tooth. The blunt-tipped conical crown without apparent recurvature suggests it is a posterior maxillary or dentary tooth. The crown surface is badly worn and neither carinae nor striation is observed. The crown-root boundary is slightly waisted, and the root flares towards the base. The presence of the resorption facet in the root (Fig. $2A_3$) indicates the root resorption by the next generation. The root neck shows uniform thickness.

Remarks.—The presence of the resorption facet (Fig. $2A_3$) characterized by a uniformly thin neck, and its late Eocene age suggest the crocodyliform affinity of the tooth (Frey and Monninger 2010). The near complete root suggests the postmortem tooth loss, which is common in crocodyliforms and mammals, but rare in other tetrapods (Brand et al. 2003; LeBlanc and Reisz 2013). The non-recurved, conical crown excludes the possibility of a mammalian canine. The lack of distinctive features in the tooth precludes the diagnosis at a lower taxonomic level (i.e., Crocodylia). Because basal crocodyliforms (putative dyrosaurids) were reported from the Paleogene of China and Myanmar (Buffetaut 1978; Ni et al. 2016), the possibility of a non-crocodylian crocodyliform cannot be excluded.

Discussion and conclusions

MPC-MX 1/108 is the first crocodyliform from the Ergilin Dzo Formation, and demonstrates that a crocodyliform inhabited in southeastern Mongolia during the late Eocene. The Ergilin Dzo Formation is interpreted as fluvial deposits (Saneyoshi et al. 2010) and is dated as the late Eocene on the basis of its fossil mammalian fauna (Ducrocq 1993; Meng and McKenna 1998; Tsubamoto et al. 2004, 2008). The formation yields many vertebrate fossils including amiiform and siluriform fishes, amphibians, chelonians, lacertilians, avians, and more than 80 species of mammals (e.g., Kurochkin 1976; Yanovskaya et al. 1977; Russell and Zhai 1987; Dashzeveg 1993; Tsubamoto et al. 2006, 2008, 2011a, b, 2012, 2013a, b; Tsubamoto and Tsogtbaatar 2008; Egi et al. 2009, 2016; Tsubamoto 2010; López-Torres and Fostowicz-Frelik 2018; and references therein). The mammals from this formation define the type fauna of the Ergilian Asian Land Mammal Age (Ergilian ALMA) (Russell and Zhai 1987; McKenna and Bell 1997; Meng and McKenna 1998). Despite

such richness and importance of the vertebrate taxa and specimens in the Ergilin Dzo Formation, crocodyliforms have never been reported so far even in the comprehensive faunal lists of the formation (e.g., Yanovskaya et al. 1977; Devyatkin 1981). Efimov (1983, 1988) and Skuchas et al. (2015) reviewed and newly described many fossil crocodyliforms from Mongolia and the former Soviet Union; in these papers, no crocodyliform was reported from the Ergilin Dzo Formation (= Ergilin Dzo suite).

In northern Asia, several crocodyliform taxa were reported from the upper Paleocene through upper Eocene, although most of which need taxonomic revisions. In Central Asia, *Pristichampsus birjukovi*, *Pristichampsus kuznetzovi*, *Asiatosuchus zajsanicus*, and *Tomistoma borisovi* from the lower to upper Eocene of the Zaysan Basin, eastern Kazakhstan (Efimov 1982, 1988), and *Ferganosuchus planus* from the lower Eocene Alay beds of Osh, Kyrgyzstan (Efimov 1982; Fig. 1: 2, 6) were known. The Zaysan Basin of Kazakhstan (Aksyir Formation) also produced numerus crocodylian coprolites (Lucas et al. 2012). Additionally, the upper part of the Irtysh River Formation (late Eocene) in the Zaysan Basin across the border of China, Xinjiang, yields a crocodylian (Stidham and Ni 2014). In East Asia, *Dzungarisuchus manacensis* from the upper Eocene of Xinjiang, northwestern China (Dong 1974; Fig. 1: 3), and *Asiatosuchus grangeri* from the earlier middle Eocene Erdin Manha Formation of Inner Mongolia, northern China (Mook 1940; age based on Meng and McKenna 1998; Tsubamoto et al. 2004; Fig. 1: 4) were known. Many other fragmentary materials of indeterminate crocodyliforms were also reported from the upper Paleocene to upper Eocene of northern Asia (Efimov 1976, 1983; Skuchas et al. 2015; Ni et al. 2016; Fig. 1: 5, 7, 8). However, crocodyliform records become scarce towards the end of the Eocene in northern Asia, and only eastern Kazakhstan and northwestern China have yielded the late Eocene crocodyliforms (Dong 1974; Efimov 1988). To our knowledge, Ergilin Dzo is the third crocodyliform bearing locality in the upper Eocene of northern Asia (Fig. 1).

During the late Eocene (at 35 Ma), the Ergilin Dzo fossil locality (approx. 43°20'N at present) was likely located at ca. 49°30'N according to the paleolatitude calculator (van Hinsbergen et al. 2015). Together with the Zaysan Basin across Kazakhstan and China (located at ca. 50°55'N; Efimov 1988; Lucas et al. 2012; Stidham and Ni 2014) and southern Junggar Basin, Xinjiang, China (located at ca. 48°18'N; Dong 1974), Ergilin Dzo represents the northernmost locality for the late Eocene crocodyliforms in Asia (paleolatitudes according to van Hinsbergen et al. 2015). Crocodyliforms are ectothermic animals, and the distribution of living crocodylians suggests that temperatures (coldest month mean temperature of at least 5.5°C, mean annual temperature of at least 14.2°C, relatively lower mean annual range of temperature) as well as the presence of standing water are important factors for their survival (Markwick 1998). Therefore, southeastern Mongolia (northern part of East Asia; estimated paleolatitude ca. 49°30'N) most likely met the thermal requirements of crocodyliforms during the late Eocene (Ergilian ALMA); thereafter, crocodyliforms were increasingly constrained to lower latitudes around the world (Markwick 1998, 2007).

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