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NEW RECORDS OF LATEST CRETACEOUS NEOSUCHIAN CROCODYLIFORMS FROM THE MAASTRICHTIAN TYPE AREA (SOUTHERN LIMBURG, THE NETHERLANDS)

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Abstract—A small collection (leg. Leendert de Heer) of isolated skeletal elements of neosuchian crocodyliforms, made at the Nekami quarry (now 't Rooth, near Bemelen), and at the former Curfs quarry (Geulhem, southern Limburg) in the 1960s is described and illustrated. In view of the fact that the material was picked from conveyor belts by local workmen, data on exact provenance are lacking. However, the stratigraphy of the levels quarried at Bemelen and Geulhem in those days is well known. In addition, small quantities of matrix (biocalcarenite) from the bones contain exclusively late Maastrichtian microfossils that are indicative of the middle and upper levels of the Maastricht Formation (Schiepersberg, Emael, Nekum and Meerssen members). The collection comprises an incomplete left humerus, a fragmentary left femur and two osteoderms. In general, remains of neosuchians are rare in the Maastrichtian type area. From overlying strata, of early-middle Danian (Early Paleocene) age, isolated teeth of *Thoracosaurus* are known, of the kind also recorded from New Jersey, eastern Denmark, southern Sweden and eastern Poland.

INTRODUCTION

Strata of late Maastrichtian age (69.3-66 Ma) exposed in the type area of that stage in southern Limburg (The Netherlands) and adjacent regions in Belgium and Germany (Fig. 1) are renowned worldwide for their well-preserved faunas of large marine reptiles, such as mosasaurid squamates and chelonioid turtles. These medium- to coarse-grained biocalcarenites document shallow-marine settings immediately prior to the Cretaceous-Paleogene (K/Pg) mass extinction event at 66 Ma. In the second half of the eighteenth century, the mosasaur remains played an important role in the emergence of modern paleontology, because they paved the way to grasping the reality of extinct life forms (Mulder, 2004). In recent decades, a renewed interest in the vertebrate faunas from these strata has become apparent. In addition to new finds of partial skeletons of medium- to large-sized mosasaurs, there are numerous records in particular of neoselachian and teleost fishes and occasional examples of elasmosaurid plesiosaurs, neosuchian crocodyliforms and dinosaurs, including birds (see e.g., Mulder, 2003; Dyke et al., 2008; Jagt et al., 2008; Jagt, 2015). Even a marsupial tooth has been described (Martin et al., 2005).

Unambiguous records of crocodyliforms comprise notably isolated teeth from the Maastricht Formation (upper Maastrichtian) and from the overlying Geulhem Member of the Houthem Formation (lower-middle Danian) (Table 1; Jagt et al., 2013), and a few loose vertebrae from the Nekum or Meerssen members (Mulder, 1998; Mulder et al., 1998). The latter are morphologically indistinguishable from those of the gavialoid neosuchian *Thoracosaurus neocesariensis* (DeKay, 1842) from the upper Maastrichtian and lower Paleocene of New Jersey (Gallagher, 1993, 2015). This illustrates the trans-Atlantic latest Cretaceous distribution of "thoracosaurs," to which other data from across southern and northeast Europe have been added subsequently (Denton et al., 1997; Machalski, 1998; Żarski et al., 1998a, b; Hartstein et al., 1999; Brochu, 2004; Schein et al., 2006; Damholt et al., 2010; Martin and Delfino, 2010; Carbot-Chanona et al., 2013; Gravesen and Jakobsen, 2013; Schwarz-Wings et al., 2014; Puértolas-Pascual and Canudo, 2015; Puértolas-Pascual et al., 2015).

Here we describe new neosuchian records from the Maastrichtian type area, based on material already collected in the 1960s. This lot comprises an incomplete left humerus, a fragmentary left femur and two osteoderms.

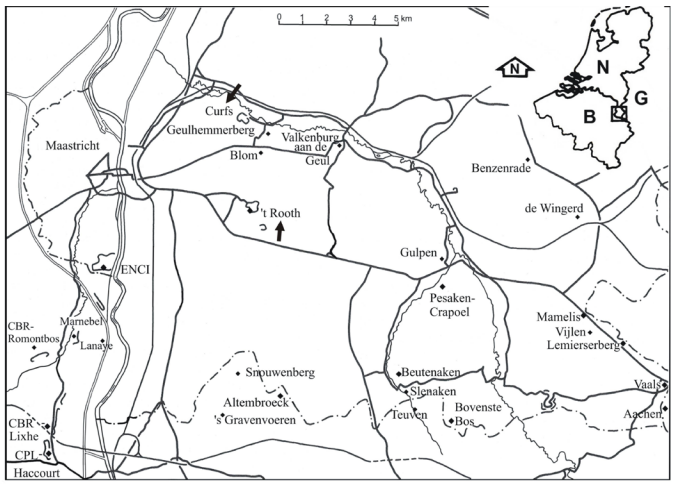

FIGURE 1.The extended type area of the Maastrichtian Stage in southern Limburg (The Netherlands) and contiguous areas in northeast Belgium and Germany, showing principal cities and towns (modified from Jagt and Jagt-Yazykova, 2012, fig. 1). The localities of Bemelen ('t Rooth, formerly Nekami) and Geulhem (former Curfs quarry) are marked by arrows.

INSTITUTIONAL ABBREVIATIONS

To denote the repositories of material referred to and illustrated in the text, the following abbreviations are used: **NHMM** –Natuurhistorisch

TABLE 1. Lithostratigraphy of Upper Cretaceous (early Campanian-latest Maastrichtian) and lower Paleogene (early-middle Danian) strata in the type area of the Maastrichtian Stage (southeast Netherlands, northeast Belgium). The Cretaceous-Paleogene (K/Pg) boundary equates with the Berg enTerblijt Horizon in the uppermost part of the Meerssen Member (for details see Jagt&Jagt-Yazykova [2012] and Jagt et al. [2013]).

Houthem Formation	**Geleen** Member
	Bunde Member
	Geulhem Member
Maastricht Formation	**Meerssen** Member --- K/Pg boundary ---
	Nekum Member
	Emael Member
	Schiepersberg Member
	Gronsveld Member
	Valkenburg Member
GulpenFormation	**Lanaye** Member
	Lixhe 1-3 members
	Vijlen Member
	Zeven Wegen Member
	Benzenrade Member
VaalsFormation	**Terstraten** Member
	Beusdal Member
	Vaalsbroek Member
	Gemmenich Member
	Cottessen Member
	Raren Member

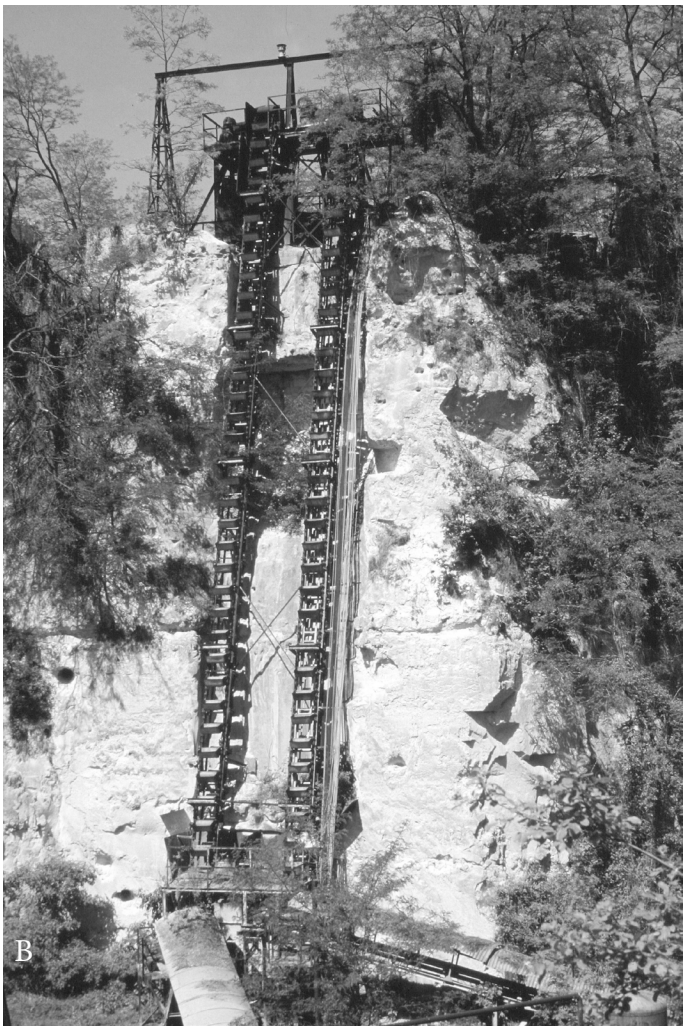

FIGURE 2. Quarrying activities at the Nekami quarry, Bemelen (now Groeve 't Rooth). **A,** during the period 1970-1975 (photograph courtesy of Sibelco-Europe, Maastricht). **B,** Post-1975 (archives of Geologisch Bureau Heerlen, Afdeling Kartering; now at Natuurhistorisch Museum Maastricht, Maastricht).

Museum Maastricht (Maastricht, The Netherlands); **RMNH** –Naturalis Biodiversity Center (Leiden, The Netherlands; formerly Rijksmuseum van Natuurlijke Historie). Leendert de Heer's Collection has been transferred from the Museum Natura Docet/WonderryckTwente (Denekamp, The Netherlands) to the Natuurhistorisch Museum Maastricht in recent years.

STRATIGRAPHY

Labels associated with the specimens merely state the locality, date and surname of the collector, but details on stratigraphic provenance are lacking. The material was picked from conveyor belts and sieving tables by local quarry men (Fig. 2), who subsequently presented it to Leendert de Heer, who visited the area every summer. However, the litho- and biostratigraphy of the levels excavated at the quarries near Bemelen and Geulhem in those days are well known. At the former Curfs quarry, the upper part of the Nekum Member, the entire Meerssen Member (both Maastricht Formation) and the Geulhem Member (Houthem Formation) were quarried. The last-named unit comprises grayish-green glauconitic biocalcarenites; glauconite is not known from the underlying Meerssen and Nekum members. At the 't Rooth quarry, only the middle and upper portions of the Maastricht Formation are exposed.

We have removed very small quantities of matrix (biocalcarenite) from the bones; these contain exclusively late Maastrichtian

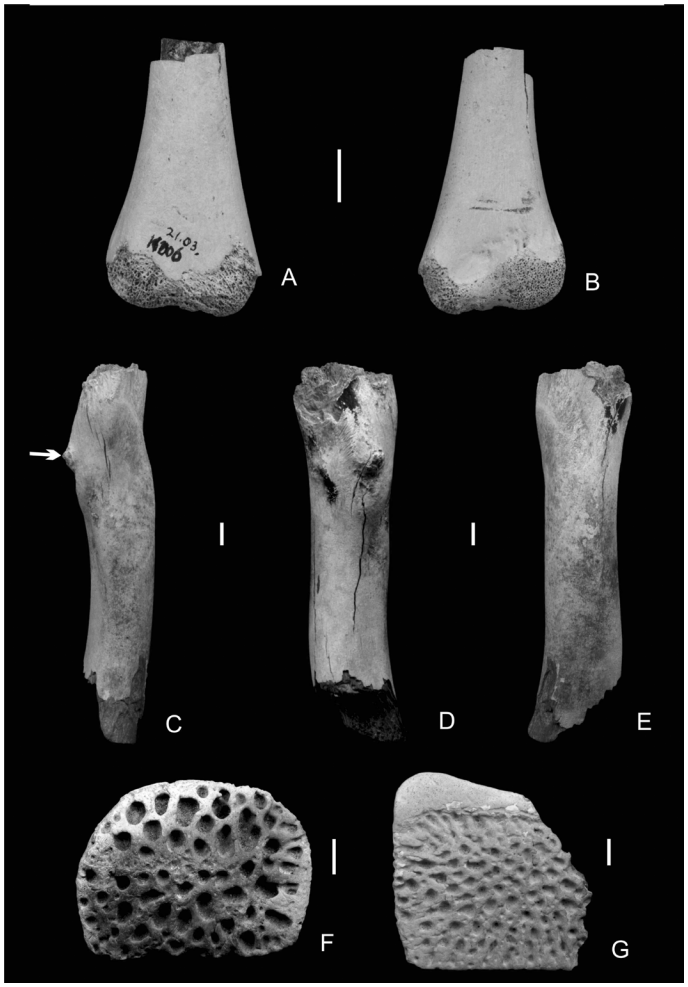

FIGURE 3. Isolated skeletal elements of neosuchian crocodyliforms from the Maastrichtian type area. All scale bars equal 10 mm. **A, B,** Incomplete (distal portion) left humerus (NHMM K 21.03.006); upper Maastricht Formation (Nekum or Meerssen members), former Curfs quarry, Geulhem, southern Limburg, The Netherlands, in dorsal and ventral view, respectively, the latter revealing close-set, parallel grooves that apparently represent mechanical damage rather than indications of scavenging. **C-E,** Fragmentary right femur (NHMM K 21.03.953); unknown level within Maastricht Formation, quarry 't Rooth, Bemelen, southern Limburg, The Netherlands, in posterior (arrow denoting fourth trochanter), dorsal and ventral views, respectively. **F,** Abraded osteoderm (NHMM K 21.03.920); unknown level within the Maastricht Formation, quarry 't Rooth, Bemelen, southern Limburg, The Netherlands. **G,** Fragmentary osteoderm (NHMM K 21.03.921); unknown level within the Maastricht Formation, quarry 't Rooth, Bemelen, southern Limburg, The Netherlands.

microfossils that are indicative of the middle and upper levels of the Maastricht Formation (Schiepersberg, Emael, Nekum and Meerssen members; Table 1). Ostracods, echinoid/ophiuroid ossicles and benthic foraminifera have been noted. The last-named comprise a few *Cibicides*- and *Gavelinella*-type forms (see Hofker, 1966; Witte and Schuurman, 1996), but no representatives of the families Orbitoididae, Lepidorbitoididae and Calcarinidae that are so typical of the Nekum and Meerssen members (Renema and Hart, 2012; Hart et al., 2016). However, this may simply be a matter of the small size of benthic foraminifera recognized in this limited sampling.

DESCRIPTION AND DISCUSSION OF MATERIAL

Specimen NHMM K 21.03.006, from the former Curfs quarry, Geulhem (leg. Saar; August 17, 1961), represents the distal portion of a left humerus; about 40 per cent of the original bone is preserved (Fig. 3A-B). The length, as preserved, is 51.6 mm; the width, across the distal condyle, is 28.5 mm, while the greatest diameter of the shaft is 14.5 mm. It illustrates general crocodyliform morphology and is indicative of a small-sized individual in comparison with RMNH.RENA.39580, a 323-cm-long skeleton of *Crocodylus niloticus* Laurenti, 1768, that we have recently studied. Ventrally, the present humerus reveals two close-set, parallel running grooves (Fig. 3B), which appear to represent mechanical damage rather than indications of scavenging.

Specimen NHMM K 21.03.953, from quarry 't Rooth, Bemelen (leg. Heutz; May 3, 1969), filled in with plaster to ensure stability, is a fragmentary right femur, of which the head and distal end are missing (Fig. 3C-E). As preserved, the length is 167 mm. As far as general habitus and the slightly S-shaped curvature in dorsolateral view are concerned, this femur clearly is of crocodilian affinity. In fact, it compares well with that of RMNH.RENA.39580. However, with median diameters of 31.1 mm and 26.5 mm (anterioposteriorly and dorsoventrally, respectively), the present specimen is larger and more robust, representing an animal of at least 4 meters in overall length. A prominent fourth trochanter (Fig. 3C) is present; the bone also reveals close-set scratch marks (?scavenging) of the *Linichnus*-type of Jacobsen and Bromley (2009).

Specimens NHMM K 21.03.920 (Fig. 3F) and NHMM K 21.03.921 (Fig. 3G), both from quarry 't Rooth, Bemelen (leg. Neederlants; May 2, 1969 and leg. Fransen; May 3, 1969, respectively), are incomplete osteoderms (dermal scutes). The former (greatest length and width 62 and 48 mm, respectively) is slightly abraded; most probably it was originally rectangular in shape. Along its midline, as far as can be observed, NHMM K 21.03.920 shows a slight elevation, which may represent an eroded keel.The sculpture of this scute is coarser than that of NHMM K 21.03.921 (greatest length and width 71 and 70 mm, respectively), the osteodermal pits being deeper and the ridges between them wider (compare Fig. 3F and 3G). NHMM K 21.03.921 is unkeeled and rectangular, bears a broad anteromedial process and may represent a midline dorsal element.

CONCLUSIONS

Meager as they may be, the above records confirm that, "crocodiles appear to show no effects of the general extinction that overtook so many other reptiles at the end of the Cretaceous" (Carroll, 1988, p. 283; see also Martin and Delfino, 2010; Puértolas-Pascual et al., 2015). The slender-snouted "thoracosaurs" (i.e., Thoracosaurinae Nopcsa, 1928) had a trans-Atlantic distribution during the Late Cretaceous, occurred mostly in marginal marine (proximal) settings and survived perturbations across the Cretaceous-Paleogene (K/Pg) boundary (Gallagher, 1993, 2015; Denton et al., 1997; Mulder, 1998; Martin and Delfino, 2010; Carbot-Chanona et al., 2013; Hastings et al., 2014; Puértolas-Pascual et al., 2015). Phylogenetic relationships among the various forms remain unresolved for now; Brochu (2004) noted that North American taxa presented a paraphyletic grade at the base of the Gavialoidea. "Thoracosaurs" either represent a single, widely distributed species, *Thoracosaurus neocesariensis* (which has no antorbital fenestra), or several, closely related taxa such as *Th. macrorhynchus* (de Blainville, 1855), with records from northwest and eastern Europe (France, northern Spain, eastern Denmark, southern Sweden, eastern Poland and Crimea; see Laurent et al., 2000; Martin and Delfino, 2010; Puértolas-Pascual et al., 2015).

Various neosuchian taxa, among which are "thoracosaurs" and dyrosaurids, co-occur in Maastrichtian and Paleocene rock units in the North Atlantic region, despite the undoubtedly fierce competition from other marine reptiles and medium- to large-sized neoselachians. Isolated tooth crowns are known from both the upper and lower portions of the Geulhem Member at the former Curfs quarry, Geulhem (Jagt et al., 2013), and these appear to be conspecific with Danish and Swedish material. Apparently, crocodiles benefitted from the demise of other marine reptiles across the K/Pg boundary (Gallagher, 2015; Mannion et al., 2015).

A final note on the alleged presence of *Th. macrorhynchus* in the Maastrichtian type area is needed, as it was apparently accepted as such by Martin and Delfino (2010, table 1) and Puértolas-Pascual et al. (2015, table 1). The skull described by Koken (1888), currently housed in the collections of Naturalis Biodiversity Center (Leiden, The Netherlands), has been completely freed from the original matrix, and mounted on a block of biocalcarenitic sediment of unknown origin. In view of the uncertainties over the exact geographic and stratigraphic provenance, we propose to strike this species from the faunal list for the type Maastrichtian until material collected *in situ* is forthcoming (see also Mulder et al., 1998).

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