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BOROGOVIA GRACILICRUS GEN. ET SP. N., A NEW TROODONTID DINOSAUR FROM THE LATE CRETACEOUS OF MONGOLIA

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A new theropod dinosaur *Borogovia gracilicrus* gen. et sp. n. assigned to Troodontidae is described, based on fragmentary hind limbs of one individual from the Upper Cretaceous Nemegt Formation of Gobi Desert, Mongolia. A unique feature of *B. gracilicrus* is a straight ungual in the second, specialized toe of the pes. The known skeletal elements of all troodontid species are listed (Table 1). Taxonomic status of *Saurornithoides junior* is considered.

Key words: Dinosauria, Theropoda, Troodontidae, osteology, taxonomy, Cretaceous, Mongolia.

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INTRODUCTION

The Cretaceous theropod dinosaur family Troodontidae Gilmore, 1924 is known from very rare and mostly fragmentary remains (Table 1) found in the Upper Cretaceous deposits (?Upper Santonian — ?Lower Maastrichtian) of Asia and North America. The only Early Cretaceous (?Albian) troodontid specimen known (see: Barsbold *et al.* 1987) comes from Mongolian People's Republic, but the preserved fragments do not provide enough diagnostic features for a specific and generic assignement of this specimen. Nevertheless, its troodontid characters are evident.

Since 1974, the family name Saurornithoididae Barsbold has been widely accepted. However, recently Currie (1987) has demonstrated that *Stenonychosaurus inequalis* Sternberg, 1932 is a junior synonym of *Troodon formosus* Leidy, 1856 and Troodontidae Gilmore, 1924 is the valid family name, which has priority over the Saurornithoididae Barsbold, 1974.

Until now, two genera have been generally recognized within this family: the Mongolian *Saurornithoides* Osborn, 1924, with two species — *S. mongoliensis* Osborn, 1924 and *S. junior* Barsbold, 1974, and the Canadian *Troodon* Leidy, 1856 (= *Stenonychosaurus* Sternberg, 1932; comp. Currie 1987), with one species *T. formosus* Leidy, 1856. Two other genera

Table 1

Preserved skeletal elements in the troodontid species

Bones \ Name and number of individuals per species	*S. mongoliensis*	*S. junior*	*B. gracilicrus*	PIN 551—224	troodontid indet.	*T. formosus*
	1	2	1	1	1	ca 16
Skull	nearly complete, with teeth	nearly complete, with teeth	–	–	Bo, Bs, Q, Op	Bo, Bs, Fr, Pf, P, Pm, L loose teeth
Mandible	complete, with teeth	dentary with teeth	–	–	fr. dentary with teeth	dentary with teeth
Vertebrae						
cervicals	–	–	–	–	fr. 5	–
dorsals	fr. 4	–	–	–	–	fr. 1
sacrals	fr. 6	fr. 6	–	–	–	–
caudals	fr. 4	14	–	–	–	fr. 6
Scapulocoracoid	–	–	–	–	–	–
Pelvis						
ilium	–	fr. +	–	–	–	–
ischium	fr. +	fr. +	–	–	–	–
pubis	fr. +	fr. +	–	–	–	–
Fore limb						
humerus	–	–	–	–	–	–
radius	–	–	–	–	–	fr. +
ulna	–	–	–	–	–	+
manus						
Mtc I	–	–	–	–	–	+
Ph I_1	–	–	–	–	+	fr. + ?
Ph I_2	–	–	–	–	fr. + ?	fr. + ?
Mtc II	–	–	–	–	+	–
Ph II_1	–	–	–	–	+	–
Ph II_2	–	–	–	–	fr. +	–
Ph II_3	–	–	–	–	+ ?	–

Mtc III	–	–	–	–	+	–
Ph III_1	–	–	–	–	–	–
Ph III_2	–	–	–	–	–	–
Ph III_3	–	–	–	–	–	–
Ph III_4	–	–	–	–	+ ?	–
Hind limb						
femur	+ prox.	–	–	–	–	+ shaft
tibiotarsus	–	+ dist.	+	–	–	+ dist.
fibula	–	+ dist.	+ prox.	–	–	+ dist.
pes						
Mtt I	+ dist.	–	–	–	+	+
Ph I_1	+	–	–	–	+	+
Ph I_2	+	–	–	–	–	+
Mtt II	+ dist.	+ prox.	+ dist.	+	+ dist.	+
Ph II_1	+	–	+	–	+	+
Ph II_2	+	–	+	–	+	+
Ph II_3	+	–	+	–	+ prox.	+
Mtt III	+ dist.	+ prox.	+ dist.	+	+ dist.	+
Ph III_1	+	–	+ dist.	–	+	+
Ph III_2	+	–	+	–	+	+
Ph III_3	+ prox.	–	+	–	+	+
Ph III_4	–	–	+	–	+ ?	+
Mtt IV	+ dist.	+ prox.	+ dist.	+	+ dist.	+
Ph IV_1	+	–	+	–	+	+
Ph IV_2	+ prox.	–	+	–	–	+
Ph IV_3	–	–	+	–	–	
Ph IV_4	–	–	+	–	–	+
Ph IV_5	–	–	+	–	+ ?	+
Mtt V	–	–	–	–	–	fr. +
Other elements	chevrons	chevrons, sacral ribs, dist. tarsals	—	—	—	chevrons, thoracic ribs, dist. carpal bloc, gastralia
Stratigraphic distribution	Djadochta F-tion, ?Late Santonian/ ?Early Campanian	Beds of Bugeen Tsav, ?Late Campanian/ ?Early Maastrichtian	Nemeget F-tion, ?Late Campanian/ ?Early Maastrichtian	Nemegt F-tion, ?Late/ Campanian/ ?Early Maastrichtian	Barunbayanskaya Svita,? Aptian-?Albian	Judith River F-tion, Late Campanian
Locality	Bayn Dzak, Omnogov, MPR	Bugeen Tsav, Bayankhongor, MPR	Altan Ula IV, Omnogov, MPR	Nemegt, Omnogov MPR	Khamareen Us, Dornogov, MPR	Red Deer River, Alberta, Canada

Abbreviations: *Bo* basioccipital, *Bs* basisphenoid, *dist.* distal part, *F* frontal, *fr.* fragmentary, *Ls* laterosphenoid, *P* parietal, *Pf* prefrontal, *Pm* premaxilla, *prox.* proximal part. *Q* quadrate, *Op* opisthotic.

and species, based only on isolated teeth have been provisionally assigned to the Troodontidae by Carpenter (1982): *Pectinodon bakkeri* Carpenter, 1982, and *Paronychodon lacustris* Cope, 1876. Of the two, *P. bakkeri* teeth differ very significantly from the known teeth of the troodontids (*in: S. mongoliensis* and *S. junior*) and cannot be assigned to the Troodontidae. *Paronychodon lucustris* is a dubious taxon (Currie, personal communication). Neither species is considered here to be assignable to the Troodontidae.

The distal portions of some tibiotarsi from the Maastrichtian of Romania, described originally as the avian species *Bradycneme draculae* Harrison et Walker, 1975, and *Heptasteornis andrewsi* Harrison et Walker, 1975, represent theropods and may be, even troodontids. These genera and species cannot be, however, considered valid because the distal portions of tibiotarsi are very alike in all troodontid species in which they were found (*S. junior*, *T. formosus* and in the here described *Borogovia gracilicrus* gen. et sp. n.), and do not provide any reliable diagnostic feature.

Borogovia gracilicrus gen. et sp. n., described in the present paper, was found in 1971 by the Polish-Mongolian Palaeontological Expedition in the deposit of the Nemegt Formation at Altan Ula IV locality (Nemegt Basin, Omnogov, Mongolian People's Republic). The specimen is stored in the Institute of Paleobiology, Polish Academy of Sciences, Warsaw (ZPAL). Other abbreviations used:

AMNH, American Museum of Natural History, New York;
NMC, National Museum of Natural Sciences, National Museum of Canada, Ottawa;
PIN, Paleontological Institute of the USSR Academy of Sciences, Moscow;
SPS, Stratigraphy and Paleontology Section of the Geological Institute, Mongolian Academy of Sciences, Ulan Bator.

ON THE TAXONOMIC STATUS OF *TROODON* AND *SAURORNITHOIDES JUNIOR*

Some authors (Russell 1969, Barsbold 1974, Carpenter 1982, Paul 1984) suggested that the North American *Troodon* (= *Stenonychosaurus*) and the Asian *Saurornithoides* are synonymous. If this really is the case, it is extremely difficult to prove it at the moment, taking into account that remains of troodontids are very fragmentary and many skeletal elements found in the *Saurornithoides* species are unknown in *Troodon formosus* (Table 1). Lately Currie (1985, 1987) also considered *Saurornithoides* as a separate genus.

It seems that the troodontid pes provided some generic characters and a more or less complete pes is the most commonly preserved part of troodontid skeletons. The pes in *T. formosus* is completely preserved and displays a slender, but moderately long metatarsus (Sternberg 1932; Russell 1969). The metatarsi in all Mongolian species are incomplete, being preserved either distally (*S. mongoliensis*, *Borogovia gracilicrus* gen. et sp. n. and troodontid indet.; see: Barsbold *et al.* 1987) or proximally (*S. junior*). The only complete Mongolian metatarsus is that of an unidentified troodontid specimen in the PIN collection (PIN 551—224). The latter, however, is very different from *T. formosus* in being very slender and long. The PIN specimen comes from the Nemegt Formation which also yielded the remains of *B. gracilicrus*. *S. junior* comes from the Bugeen Tsav beds, which are the age equivalent of the Nemegt Formation. The three localities, where the PIN specimen (Nemegt), *B. gracilicrus* (Altan Ula IV) and *S. junior* (Bugeen Tsav), were found, are not far from one another lying within about 100 km (see: Gradziński *et al.* 1977: fig. 1) and they are more or less contemporaneous. If it appears in the future that the PIN 551—224 metatarsus should be assigned to *S. junior*, which is, as it seems, very close to the type species of *Saurornithoides* (*S. mongoliensis*) this latter genus should be considered valid. It is equally possible that the PIN metatarsus represents *B. gracilicrus*, which will not help in elucidating the taxonomic status of *Saurornithodes*. Still another possibility exists, that all three forms: *S. junior*, *B. gracilicrus* and the PIN metatarsus are conspecific; this again will be evidence in favor of separating *Troodon* and *Saurornithoides* on the generic level, although then *B. gracilicrus* would become the junior synonym of *S. junior*.

There exists, however, still some further complication. According to some authors (e.g. Carpenter 1982), *S. junior* is conspecific with *S. mongoliensis*. As far as the preserved skeletal elements allow one to judge, the only morphological difference between the two forms concerns the number of maxillary *versus* dentary teeth: 17—18 and 27—28 respectively in *S. mongoliensis* while 19—20 and 33—35 in *S. junior*. However, there is a size difference between the two compared skulls with mandibles, that of *S. mongoliensis* being the smaller and, possibly, ontogenetically younger. Thus the feature cannot be used with complete confidence owing to the poor sample size and may be indicative of an allometric factor. On the other hand, the final conclusion concerning the taxonomic status of *S. junior* cannot be drawn without knowledge of the pes (metatarsus!), and preferably also of the manus structure in the latter and *S. mongoliensis*. The features of the pes and manus are generally of great taxonomic importance within Theropoda. *S. mongoliensis* is stratigraphically older (?Late Santonian or ?Early Campanian, zone of *Protoceratops andrewsi* and *Velociraptor mongoliensis*) than *S. junior* (?Late Campanian or ?Early Maastrichtian, zone of *Tarbosaurus bataar* and *Saurolophus angustirostris*). Each of these troodontid species occurs in a different vertebrate faunal assemblage. The asemblage of the Djadochta Formation which yielded *S. mongoliensis*, lacks megavertebrates approaching the size of tarbosaurus, hadrosaurs or sauropods except for some rare teeth of these dinosaurs). There occurs, however, a ceratopsian species (*Protoceratops* *andrewsi*) that is the dominant dinosaur in this assemblage. In the Bugeen Tsav beds, that produced *S. junior* the giant dinosaurs are common (Gradziński *et al.* 1977, tables 3, 4; Osmólska 1980) but ceratopsians are absent. Also, the sediments that yielded the *S. mongoliensis* and *S. junior* specimens are different, reflecting different depositional environments in the two sites. Those of the Djadochta Formation at Bayn Dzak were deposited under conditions of hot, semi-arid climate and the sedimentation took place in eolian dunes and small lakes (Berkey and Morris 1927; Lefeld 1971). The Bugeen Tsav beds at Bugeen Tsav are lithologically similar to the co-eval sediments of the Nemegt Formation; Gradziński *et al.* (1977: 279) suggested that they even represent the same formation, which according to Gradziński (1970) was deposited in a fluvial environment. However, according to Sochava (1975: 180) the Bugeen Tsav beds formed in a large lake and marshes. Whether the first or the second interpretation of the sedimentary environment is chosen does not matter in this respect, as both indicate that the environmental conditions at the Bugeen Tsav site (which yielded *S. junior*) during Nemegt time were certainly different from conditions at Bayn Dzak (the site of *S. mongoliensis*) during Djadochta time. Until more *Saurornithoides* skulls are found, as well as complete mani and pedes, stratigraphic and paleoecological factors are considered here most relevant for distinguishing the two *Saurornithoides* species: *S. mongoliensis* and *S. junior*.

SYSTEMATICS

Family **Troodontidae** Gilmore, 1924

Genus *Borogovia* nov.

Derivation of the name: borogove — the name of a fantastic creature from "Alice in Wonderland" by Lewis Carroll.

Genus monotypic, stratigraphic and geographic range as for the type species *Borogovia gracilicrus* sp. n.

Borogovia gracilicrus gen. et sp. n.

(pls. 53, 54; figs. 1—4)

1982. *Saurornithoides* sp., Osmólska, 445.

Holotype: fragments of hind limbs ZPAL MgD-I/174 including: incomplete left and right tibiotarsi; proximal portion of fibula; of the left pes — distal parts of metatarsals II and IV, second digit with phalanx II-2 damaged, third digit including only distal end of phalanx III-1 and slightly damaged phalanx III-3, almost complete fourth digit with proximal part of ungual lacking; of the right pes — distal portions of articulated metatarsals II, III and IV, complete second digit, but phalanx II-2 lacking ventrodistal "heel", third digit with preserved distal end of phalanx III-1, phalanx III-2 dorsodistally with some damage and phalanx III-3 ventrodistally with some damage, ungual with damaged dorsal edge, complete fourth digit with ungual somewhat damaged at the dorsal edge; pls. 53, 54; figs. 1—4.

Type locality: Altan Ula IV, Nemegt Basin, Gobi Desert, Mongolia.

Type horizon: Nemegt Formation, zone of *Tarbosaurus bataar* and *Saurolophus angustirostris*, ?Late Campanian or ?Early Maastrichtian.

Derivation of the name: *gracilis* (Lat.) — slender, *crus* (Lat.) — shin, because of very long and slender shin.

Dimensions see table 2.

Diagnosis. — Troodontid of medium size with very slender and long tibiotarsus; second toe with very short phalanx II-2 and straight ungual; third toe much thinner and weaker than the second and fourth toes.

DESCRIPTION

Material. — Only the holotype (ZPAL MgD-I/174) is known which consists of incomplete hind limbs.

Tibiotarsus (pl. 53: 9; fig. 1). — The tibia is fragmentary but it is very slender, thin-walled and must have been long. Preserved portion of the right tibiotarsus is 170 mm long. Its shaft circumference is 51 mm, least diameter — 12 mm and distal width of tibia — 27 mm. The left tibiotarsus is crushed and its preserved length is 233 mm. Besides these two fragments there is preserved also a proximal portion of the tibia which is 113 mm long with a proximal part of the fibula attached which is 90 mm long. This latter fragment of the tibia-fibula is, however, so badly crushed and distorted that it is impossible to state whether it is from the right or left leg. The combined length of this fragment plus the left tibiotarsus would be at least 346 mm which seems rather improbable, thus the fragment is here arbitrary considered as coming from the right leg: it would still make the tibiotarsus at least 280 mm long.

Along the anterolateral edge of the distal half of the tibia is a very faint, narrow groove for the fibula. Of the tarsus, only the somewhat damaged astragalus is preserved in both legs, which displays the shape typical of the troodontids (comp.: Russell 1969, fig. 11; Barsbold 1974, fig. 4), it has very well pronounced condyles separated by a deep intercondylar groove and a comparatively deep transverse depression on the anterior face of the bone separating the condylar portion from the very high ascending process. Judging from an impression preserved on the right tibia, the astragalar ascending process rises about 60 mm above the distal astragalus surface.

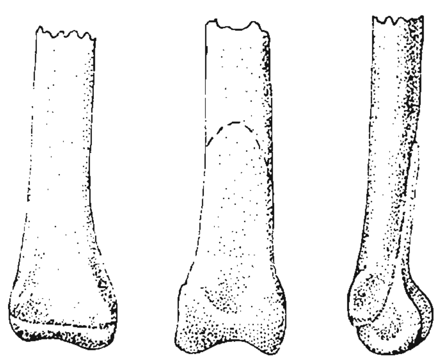

Fig. 1. *Borogovia gracilicrus* gen. et sp. n., ZPAL MgD-I/174, holotype. Distal end of the right tibiotarsus: *A* posterior, *B* anterior and *C* lateral, views, ×0.5.

Metatarsus (pls. 53: 1; 54). — Only distal parts of the metatarsals II, III and IV are known and together they form a very compact metatarsus, typical of the troodontids. Metatarsal II is the shortest; the preserved portion of its shaft is compressed mediolaterally and is very thin for most of its preserved length; the distal articular surface is normally developed, unreduced and almost as wide and deep as are these surfaces in metatarsals III and IV; anterodistally it is not divided, but posteriorly it displays two condyles, the lateral larger, which are separated by a deep and broad depression; the lateral face of the distal end is deeply concave, the concavity continuing dorsally in the form of a groove close to and parallel with the posterolateral edge of the bone. Metatarsal III has a shaft which is triangular in cross-section distally, displaying anteriorly a flattened surface and posteriorly a keel

Table 2

Dimensions (in mm) of the right pes of *Borogovia gracilicrus* gen. et sp. n. (ZPAL MgD-I/174)

Metatarsus	
preserved length	63
distal width (measured above articular surface of Mtt II)	20
Metatarsal II	
width of distal end	11,7
Metatarsal III	
width of distal end	11
Metatarsal IV	
width of distal end	12
Digit II	
total length (extended)	62
phalanx 1, length	32
proximal width	10
„ depth	14
least diameter	7
phalanx 2, length	13
proximal width	9
„ depth	13 e
least diameter	8
phalanx 3, length	31
proximal width	7
„ depth	12.5
Digit III	
phalanx 1, preserved length	12
distal width	9
„ depth	8
least diameter	5.5?
phalanx 2, length	23
proximal width	9
distal depth	7
least diameter	4.8
phalanx 3, length	22
proximal width	6
distal depth	6
least diameter	4.5
phalanx 4, length	15
proximal width	5
proximal depth	6.8

Digit IV		
total length		73
phalanx 1, length		18
	proximal width	10.8
	,, depth	14
	least diameter	8.8
phalanx 2, length		17
	proximal width	11
	,, depth	12
	least diameter	8.3
phalanx 3, length		15
	proximal width	9
	,, depth	10
	least diameter	8
phalanx 4, length		16
	proximal width	8.8
	,, depth	10
	least diameter	7.2
phalanx 5, length		21.5
	proximal width	7.3
	,, depth	9.2

which becomes sharp proximally; the medial and lateral sides of the shaft are flat and some distance above the articular surface they closely adhere to metatarsals II and IV; the distal articular surface is faintly concave in the middle; posteriorly, the articular surface is prolonged upwards in the form of a symmetric triangular tongue; medial and lateral sides of the distal end are concave, with foveae ligamentosae, the lateral one smaller but somewhat deeper. Metatarsal IV is almost as long as metatarsal III; it has a very thick shaft which is subquadrate in cross-section along the portion contacting the metatarsal III; the distal articular surface is divided posteriorly into two condyles, the lateral shorter vertically and narrower transversely; just above the medial condyle the bone is depressed for some distance upwards along its medial edge; dorsal to this depression begins a zone of close contact with the adjoining metatarsal III; the lateral surface of the distal end is irregularly and weakly concave and the medial surface bears a large and deep fovea.

Toes (pls. 53: 1—5, 54: 1; figs. 2—4). — The first toe was not found. The second toe is differently specialized in *B. gracilicrus* gen. et sp. n. than it is in other representatives of the family, its ungual being straight and the penultimate phalanx extremely short. Phalanx II-1 is long; it is also deep especially proximally; the proximal end bears a concave, undivided, subrectangular articular surface; the ventromedial corner of this surface is somewhat elongated posteriorly and slightly thickened; it should have entered the posterior intercondylar depression on metatarsal II during maximum flexion as indicated by the directions of the corresponding articular surfaces; the shaft has a sharp ventrolateral edge and narrows toward the

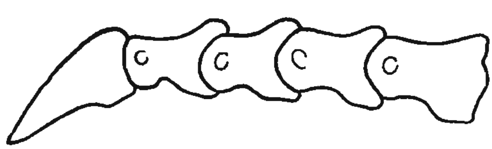

Fig. 2. *Borogovia gracilicrus* gen. et sp. n., ZPAL MgD-I/174, holotype. Fourth digit of the left pes, lateral view, ×1.

distal end; its articular surface is distinctly ginglymoid, with a deep groove between asymmetrical condyles, the lateral of which is larger; the lateral fovea ligamentosa is somewhat larger and deeper. Phalanx II-2 measured dorsally is very short, only a third the length of the preceding phalanx; the ventroposterior "heel" (Russell 1969) is broken off in both left and right phalanges II-2; however, judging from the size of the breakage surface, the "heel" was small and shallow; the central part of the proximal end extends distinctly posteriorly when viewed dorsally, invading far backwards onto the dorsal articular groove of the preceding phalanx. The ungual of the second toe is almost straight and not very strongly compressed lateromedially; the flexor tuber is very weak; the proximal end of the ungual is dorsoposteriorly extended in the mid-line comparable to the penultimate phalanx; there is no corresponding ventral extension; the proximal articular surface has a sharp articular ridge; the distal end is sharply pointed.

The third toe is incomplete; of the proximal phalanx only the distal end is preserved in the left and right pes. Remaining phalanges display also some minor damages. The striking character of this toe is its slenderness: it is the thinnest in the

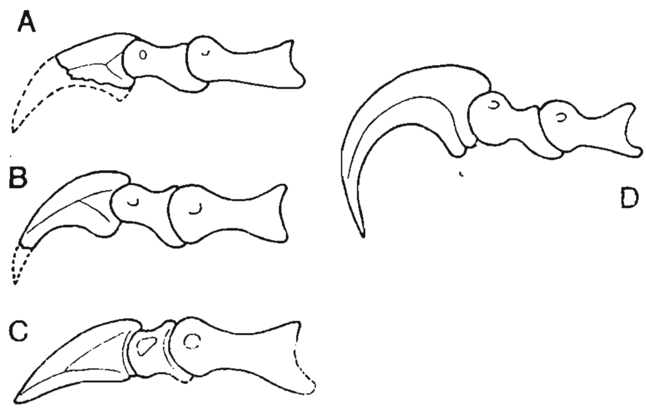

Fig. 3. Comparison of second pedal digits in: *A* troodontid indet., *B Troodon formosus*, *C Borogovia gracilicrus*, *D Deinonychus antirrhopus*. Not to scale. After: Barsbold *et al.* 1987 (*A*), Russell 1969 (*B*), Ostrom 1969 (*D*).

pes; its length is not known, however the combined length of the articulated phalanges III-2, III-3 and III-4 is 55 mm; thus the total length of the toe might have been between 73 mm and 83 mm which is as long, or somewhat longer, than the fourth toe.

Phalanx III-1 is preserved only distally and has an articular surface which lacks a groove and which is only slightly concave transversely; the foveae ligamentosae are large and deep. Phalanx III-2 has a damaged dorsoproximal part; it distinctly narrows towards the base of the distal articular end; the proximal articular surface, as far as can be observed, is undivided; on the ventral side the proximal end is somewhat concave transversely and has a more pronounced medial edge; the distal articular surface is also not grooved but is more deeply concave at the middle than is the preceding phalanx. Phalanx III-3 has a damaged ventroproximal part; it is uniformly slender, the articular ends being only somewhat wider than the shaft; the proximal articular surface is not ridged but the distal surface is distinctly ginglymoid. The ungual is dorsally and laterally damaged; it is comparatively narrow, has a flattened ventral side, weak flexor tuber, and a rather indistinctly ridged articular surface, which is astonishing taking into account the strong ginglymus on the distal end of the preceding phalanx.

The fourth toe has phalanges which are stout, short and generally subequal in length. They are much stronger than the phalanges of the third toe and their relative depth is striking. Both articular surfaces of all these phalanges, except the distal one in phalanx IV-4, are neither ridged (the proximal) nor grooved (the distal). Phalanx IV-1 displays a proximal end which is much deeper than wide,

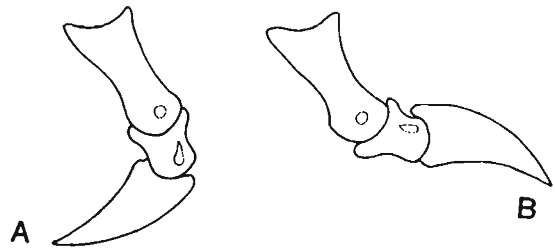

Fig. 4. *Borogovia gracilicrus* gen. et sp. n., ZPAL MgD-I/147, holotype. Second digit of the pes showing maximum flexion (*A*) and maximum extension (*B*).

with a concave articular surface of which the dorsal boundary is not extended posteriorly; the ventromedial corner of the proximal end is extended somewhat posteriorly what causes the posteroventral edge of the phalanx to be incised; this latter feature is found also to a lesser or greater extent in other phalanges of the fourth toe, except the ungual. The distal articular surface of phalanx IV-1 is somewhat concave transversely, so that there are no distinct condyles; the same is true for other phalanges (except the IV-4) but the concavity progressively deepens in the more distal phalanges. Proximal articular surfaces of phalanges IV-2, IV-3 and IV-4 are very deeply concave when viewed from the lateral side, slightly less so when viewed from the medial side; the posterodorsal border of the surface is elongated tongue-like posteriorly, invading comparatively far onto the dorsal part of the distal articular surface of each preceding phalanx. Such a structure resulted in a very strong articulation between the phalanges of the fourth toe. This contrasts with their apparently weak ligamental binding, as may be judged from the rather shallow foveae ligamentosae, much shallower that those on the phalanges of the slender third toe. The ungual of the fourth toe is damaged dorsally; it is comparatively small, asymmetrically flattened ventrolaterally, and has a weak flexor tuber; the articular surface is almost flat, with an indistinct articular ridge, even weaker than that on the ungual of third toe; again this is astonishing, because the distal end of preceding phalanx IV-4 ends by a ginglymus; the posterodorsal tongue is developed in this ungual, corresponding to those in other phalanges of the fourth toe.

DISCUSSION

Comparisons. — Lengths of the pedal phalanges in *Borogovia gracilicrus* (ZPAL Mg-D-I/174) and *Saurornithoides mongoliensis* (AMNH 6516) indicate that their pedes were of approximately similar sizes, that in *S. mongoliensis* being only slightly larger (comp.: Russell 1969, Table 7 and in the present paper, Table 2). A complete tibiotarsus has never been described in any troodontid and the fragments preserved in *B. gracilicrus* constitute the largest shin portion know in this family. Russell (1969) estimated the length of tibia in *S. mongoliensis* type specimen as 243 mm, basing mainly upon the impression of that bone in the rock. The presumed minimum length of the tibiotarsus in *B. gracilicrus* (280 mm) still exceeds by 13% that in *S. mongoliensis*, although the pes in the latter is slightly larger.

Incompleteness and scarcity of relevant material cause that it is difficult to judge whether the very long and slender tibiotarsus in the here described species deviates from the proportions typical for the troodontids. The tibiotarsus in *B. gracilicrus*, as compared with those of some other theropods (Table 3), is the longest and most slender; it is the closest in the respects to the tibiotarsus in *Microvenator celer*, although still relatively longer.

Table 3

Comparative dimensions of tibiae of *Borogovia gracilicrus* gen. et sp. n. and some selected theropods
(in mm)

Species, specimen	Length L	distal width W	least diameter D	ratios W/L	ratios D/L
Borogovia gracilicrus					
ZPAL MgD-I/174*	280 e	27	12	0.096 e	0.043 e
Microvenator celer					
AMNH 3941**	157	22.3	8	0.142	0.050
Gallimimus bullatus					
ZPAL MgD-I/94***	306	45	18	0.147	0.058
MgD-I/1	390	58	25	0.148	0.064
Deinonychus antirrhopus					
AMNH 3015****	324	63	18	0.194	0.055

e — estimated
data after: * — this paper; ** — Ostrom 1970; *** — Osmólska *et al.* 1972; **** — Ostrom 1969.

One of the most striking differences between the pes of *B. gracilicrus* and those of other troodontid species concerns the third digit (the axial one in the foot!) which is the thinnest of three functional toes in the pes.

Contrary to the slenderness of third toe, the fourth seems to be stronger than it is in *Troodon formosus* (Sternberg 1932: pl. 3a), the only other troodontid in which this digit is complete (comp. Table 1). It has its phalanges more firmly articulated with each other by means of deeply concave articular surfaces (fig. 2). Non-ridged articular surfaces of these phalanges are like the surfaces of the phalanges of third digit. The third digit displays non-ginglymoid distal ends and non-ridged proximal surfaces of the phalanges not only in *B. gracilicrus* but also in other troodontids which I have examined and in the ornithomimids. This feature seems to be related to the fact that structural axis of the foot passed through third digit in these theropods. Characters of the articular surfaces of the phalanges of fourth digit in *T. formosus* were not commented on either by Sternberg (1932) or Russell (1969); judging by Sternberg's illustration (1932: pl. 3A) there are no tongue-like elongations of posterodorsal borders of proximal ends of the phalanges such as are characteristic of *B. gracilicrus*. Metatarsal IV is extremely strong in all troodontids, constituting somewhat more than a half of the metatarsus thickness. Thus, the massive fourth digit is correlated evidently with thick metatarsal IV, and it was probably also strong in other troodontid species in which it has not been reported so far.

Other differences to remaining troodontid species are displayed in the structure of second pedal digit in *B. gracilicrus* (fig. 3). One of them is very short phalanx II-2, relatively much shorter than in the Early Cretaceous troodontid indet. (Barsbold *et al.* 1987), the Late Cretaceous *T. formosus* and *S. mongoliensis* (*fide* Russell 1969: Table 7). Another difference concerns the shape of the second ungual which is straight with an almost non-existant flexor tuber, whereas it is more or less strongly curved and provided with a distinct flexor tuber in all othe representatives of the family.

Functional aspects of hte pes. — Due to the broadly rounded distal articular ends of metatarsals II, III and IV in *B. gracilicrus* (and in other troodontids) the corresponding digits were allowed some mediolateral movements. Directions and shapes of the articular surfaces at the digit II — metatarsal II joint caused that digit to be directed medially during maximum flexion. At the same time, the ginglymus of phalanx II-1 rotated somewhat laterally, towards third digit. The maximum extension of phalanx II-2, allowed by dorsal extent of the distal articular surface of phalanx II-1, situated it about 130°—135° (measured anteriorly) to the long axis of the latter (fig. 4). The long axis of the ungual was aligned with the long axis of the penultimate phalanx during maximum extension. This arrangement hardly allowed *B. gracilicrus* to keep the ungual above the ground during progression. Maximum flexion possible brought the ungual at about 100°—110° (measured posteriorly) to the long axis of phalanx II-1.

Exceptional thinness of third digit in *B. gracilicrus*, unique among theropods, causes that explanation how the foot functioned is very difficult. Although the axis of symmetry of the pes passed through third digit, its seems that much reduced in thickness metatarsal III and digit III were not the main supporting elements. This role had to be played by thick metatarsals IV and II, which had major shares in the metatarsus structure, and by fourth and second digits. Evidently the latter digit redeveloped its supporting role in the foot (assuming that it was lost in the predecessors of *B. gracilicrus*, which remains to be proved), which seems to be reflected in the straight shape of its ungual and the decreased amount of extension possibile of phalanx II-2.

However, certain increase in thickness and associated firm articulation between the phalanges of fourth digit speak in favor of the supposition that some circumstances might occur during life of the animal which caused that the stress on the foot was distributed asymmetrically. Sharpness of the ungual might indicate that it was used occasionally in other functions than support, e.g. in a courtship behavior.

Troodontid — dromaeosaurid relationship. — The second pedal digit in the troodontids exposes specialization comparable to that in the dromaeosaurids. This was the main reason of the assignment of troodontid genera either within the Dromaeosauridae Matthew et Brown (Ostrom 1969) or within Deinonychosauria Cobert et Russell as a separate family — the Troodontidae Gilmore (Barsbold 1974, 1977; Osmólska 1982). It should be added that some authors (Sues 1978) maintained separation of these two families (Dromaeosauridae and Troodontidae) without explicit statement whether they should be placed in a common suprafamilial unit.

Barsbold (1983) excluded the Troodontidae from Deinonychosauria and assigned them within Coelurosauria Huene. Exclusion of troodontids from Deinonychosauria seems justified. Colbert and Russell (1969) were the first to recognize basic differences in the structure of similarly specialized second pedal digits in *Saurornithoides* and *Troodon* from one side, and *Dromaeosaurus*, *Velociraptor* and *Deinonychus* — from the other. These differences concern, among others, proportions of phalanges. Phalanx II-1 is distinctly longer than phalanx II-2 in the troodontids, while both are equal in length in the dromaeosaurids. The ventral and dorsal extent of the distal articular surface in phalanx II-1 is smaller and the ungual is usually less curved in the troodontids. The ungual length (measured between the posterodorsal extremity and the tip) is always less than twice the minimum length of phalanx II-1; the ungual length in the dromaeosaurids is at least twice the length of phalanx II-1, except for *Adasaurus mongoliensis* Barsbold, 1983 in which both equal in the length (*fide* Barsbold 1983: fig. 27A).

Colbert and Russell (1969) emphasized also the difference in formation of the distal ends of metatarsals II and III which are nonginglymoid in the troodontids in contrast to grooved surfaces in the dromaeosurids. The ginglymus is present in metatarsal III of some other theropods, e.g. in *Allosaurus fragilis* (Madsen 1976) and *Compsognathus longipes* (Ostrom 1978); ginglymoid distal end of metatarsal II is much more rare, being found, to my knowledge, only in the dromaeosaurids and *Compsognathus longipes* (Ostrom 1978). It is not possible to state for sure which of the two types of metatarsal distal ends is plesiomorphic for theropods without re-examination of their earliest representatives, It seems rather more probable that ginglymoid metatarsals are more primitive within this group, and that the broadly rounded distal metatarsal surfaces may be apomorphic for troodontids. The relatively long phalanx II-1 of the troodontids seems to reflect plesiomorphic theropod condition. Troodontid metatarsus as a whole is a very advanced structure, strongly convergent with that in the ornithomimids, but incomparable to the rather short and broad metatarsus in the dromaeosaurids which seems close to the primitive theropod condition.

It follows that the specialized second pedal digit might have developed convergently in the two families. It is also most probable that its function was different in saurornithoidids and dromaeosaurids as I have argued earlier (Osmólska 1982).

Among common features of troodontids and dromaeosaurids are: 1. manus with short metacarpal I and reduced in thickness the third metacarpal and digit, 2. carpus with a semilunate distal element, 3. ungual of second pedal digit much larger, and usually with more extensive possibility of dorsoventral rotation, than those on the remaining toes. The two first mentioned characters are found also in the Oviraptoridae (Barsbold 1983) and *Archaeopteryx* (Ostrom 1976) and may be plesiomorphic for the troodontids and dromaeosaurids and evidence a remote relationship (Maniraptora of Gauthier 1986); the last seems to be a convergence, as was argued above.

Several festures of particular importance put the Troodontidae and Dromaeosauridae widely apart: e.g., inflated parasphenoid capsule, peculiar middle ear cavity, periotic sinuses (Currie 1985) — in the troodontids and opisthopubic pelvis, very long caudal prezygapophses — in the dromaeosaurids. In result, the Troodontidae are neither more nor less close to the Dromaeosauridae than they are to, e.g., the Oviraptoridae, which also have periotic sinuses (personal observation), or may be, the Coeluridae. This latter family is, however, rather insufficiently defined and its members (*Coelurus*, ?*Ornitholestes*) need proper descriptions. Consequently, the status of the infraorder Coelurosauria seems, at the moment, unclear. For that reason I consider Barsbold's (1983) assignment of the Troodontidae within Coelurosauria as premature. Judging by the diagnosis (Barsbold 1983: 86), this assignment was based on the plesiomorphic characters (prepubic pelvis, teeth) and the unimportant ones (small, rarely moderate in size).

Recently Gauthier (1986: 47) also doubted the monophyly of the Deinonychosauria.

REFERENCES

BARSBOLD, R. 1974. Saurornithoididae, a new family of small theropod dinosaurs from Central Asia and North America. *In*: Z. Kielan-Jaworowska (ed.), Results Pol.-Mong. Palaeont. Expeds., V, — *Palaeont. Polonica*, **30**, 6—22.

— , OSMÓLSKA, H. and KURZANOV, S. M. 1987. On a new troodontid (Dinosauria, Therepoda) from the Early Cretaceous of Mongolia. — *Acta Palaeont. Polonica*, **32**, 1—2, 121—132.

BERKEY, C. P. and MORRIS, F. K. 1927. Geology of Mongolia. Natural History of Central Asia, 2. Amer. Mus. Nat. Hist., 475 pp. New York.

CARPENTER, K. 1982. Baby dinosaurs from the Late Cretaceous Lance and Hell Creek formations and a description of a new species of theropod. — *Contr. Geol.*, **20**, 2, 123—134.

CURRIE, P. J. 1985. Cranial anatomy of *Stenonychosaurus inequalis* (Saurischia, Theropoda) and its bearing on the origin of birds. — *Can. J. Earth Sci.*, **22**, 1643—1658.

— 1987. Bird-like characteristics of the jaws and teeth of troodontid theropods (Dinosauria, Saurischia). — *J. Vert. Paleont.*, **7**, 1. 72—81.

GAUTHIER, J. 1986. Saurischian monophyly and the origin of birds. *In*: K. Padian (ed.), The Origin of Birds and the Evolution of Flight. — *Mem. Calif. Ac. Sci.*, **8**, 1—55.

GRADZIŃSKI, R. 1970. Sedimentation of dinosaur-bearing Upper Cretaceous deposits of the Nemegt Basin, Gobi Desert. *In*: Z. Kielan-Jaworowska (ed.), Results Pol.-Mong. Palaeont. Expeds., II. — *Palaeont. Polonica*, **21**, 147—229.

— , KIELAN-JAWOROWSKA, Z. and MARYAŃSKA, T. 1977. Upper Cretaceous Djadokhta, Barun Goyot and Nemegt formations of Mongolia, including remarks on previous subdivisions. — *Acta Geol. Polonica*, **27**, 3, 281—318.

LEFELD, J. 1971. Geology of the Djadokhta Formation at Bayn Dzak (Mongolia). *In*: Z. Kielan-Jaworowska (ed.), Results Pol.-Mong. Palaeont. Expeds., III. — *Palaeont. Polonica*, **25**, 101—127.

MADSEN, J. H., Jr. 1976. *Allosaurus fragilis*: a revised osteology. — *Bull. Utah Geol. Min. Surv.*, **109**, 1—163.

OSBORN, H. F. 1924. Three new Theropoda, *Protoceratops* Zone, Central Mongolia, — *Am. Mus. Novitates*, **144**, 1—22.

OSMÓLSKA, H. 1980. The Late Cretaceous vertebrate assemblages of the Gobi Desert, Mongolia. — *Mém. Soc. géol. France, N.S.*, **59**, 139, 145—150.

— , RONIEWICZ, E. and BARSBOLD, R. 1972. A new dinosaur *Gallimimus bullatus* n. gen., n. sp. (Ornithomimidae) from the Upper Cretaceous of Mongolia. *In*: Z. Kielan-Jaworowska (ed.), Results Pol.-Mong. Palaeont. Expeds., IV. — *Palaeont. Polonica*, **27**, 103—143.

OSTROM, J. H. 1969. Osteology of *Deinonychus antirrhopus*, an unusual theropod from the Lower Cretaceous of Montana. — *Bull. Peabody Mus. Nat. Hist. Yale Univ.*, **30**, 1—165.

— 1970. Stratigraphy and paleontology of the Cloverly Formation (Lower Cretaceous) of the Bighorn Basin area, Wyoming and Montana. — *Ibidem*, **35**, 1—234.

— 1978. The osteology of *Compsognathus longipes* Wagner. — *Zitteliana*, **4**, 73—118.

PAUL, G. S. 1984. The archosaurs: a phylogenetic study. *In*: W. E. Reif and F. Westphal (eds.), Third Symposium on Mesozoic Terrestial Ecosystems, short papers. 175—180.

RUSSELL, D. A. 1969. A new specimen of *Stenonychosaurus* from the Oldman Formation (Cretaceous) of Alberta. — *Can. J. Earth Sci.*, **6**, 4, 595—612.

STERNBERG, C. M. 1932. Two new theropod dinosaurs from the Belly River Formation of Alberta. — *Can. Field-Naturalist*, **46**, 99—105.

[SOCHAVA, A. V.] СОЧАВА, А. В. 1975. Стратиграфия и литология верхнемеловых отложений Южной Монголии. Палеогеография Южной Монголии в позднемеловое время. В: Стратиграфия Мезозойских Отложений Монголии. — *Тр. Совм. Сов.-Монг. Науч.-Исслед. Геол. Експед.*, **13**, 178—182.

SUES, H.-D. 1978. A new small theropod dinosaur from the Judith River Formation (Campanian) of Alberta, Canada. — *Zool. J. Linn. Soc.*, **62**, 381—400.

HALSZKA OSMÓLSKA

BOROGOVIA GRACILICRUS GEN. ET SP. N., NOWY PÓŹNOKREDOWY PRZEDSTAWICIEL DINOZAURÓW TROODONTIDAE Z MONGOLII

Streszczenie

Opisano nowy gatunek drapieżnego dinozaura, *Borogovia gracilicrus* (Theropoda, Troodontidae), oparty na niekompletnych kończynach tylnych. Gatunek ten charakteryzuje bardzo znaczne skrócenie przedostatniego paliczka i prosty pazur w drugim palcu stopy, a także prawdopodobnie, znaczna długość i smukłość podudzia. Podudzie było dotychczas znane tylko bardzo fragmentarycznie u jednego gatunku Troodontidae. W związku z tym nie można z całą pewnością stwierdzić czy jego proporcje u *B. gracilicrus* odbiegają od typowych w tej rodzinie. Porównanie z podudziem u innych przedstawicieli dinozaurów drapieżnych (Theropoda) wskazuje, że podudzie *B. gracilicrus* jest niezwykle długie i smukłe.

Z zakresu ruchomości wysepcjalizowanego drugiego palca stopy wynika, że pazur nie mógł być unoszony tak wysoko jak u innych przedstawicieli Troodontidae, u których jest on silnie zakrzywiony; jego funkcja u *B. gracilicrus* była, zatem, zupełnie inna.

Troodontidae są bardzo rzadkim elementem w późnokredowych zespołach dinozaurów Azji i Ameryki Północnej; nieznane są także w tej rodzinie kompletne szkielety. W pracy załączono tablicę 1, na której podano, przez jakie fragmenty szkieletowe reprezentowane są poszczególne gatunki dotychczas opisane w tej rodzinie. Stwierdzono, że na podstawie tych fragmentarycznych materiałów nie można rozstrzygnąć z całą pewnością czy *Saurornithoides junior* jest młodszym synonimem *S. mongoliensis*, jak to sugerowali ostatnio niektórzy autorzy (Paul 1985, Carpenter 1982). Biorąc pod uwagę, że oba gatunki występują w różnych poziomach stratygraficznych i w różnych zespołach fauny, jest bardziej prawdopodobne, że nie są to formy konspecyficzne.

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EXPLANATIONS OF PLATES 53 AND 54

Plate 53

Borogovia gracilicrus gen. et sp. n.

1. Fragmentary right pes, in: *a* dorsal, *b* ventral, views; ZPAL MgD-1/174, holotype, ×0.5.
2. Phalanx II-1 of the left pes, medial view; same specimen, ×1.
3. Ungual of left second pedal digit, ventral view; same specimen, ×1.
4. Phalanx III-3 of the left pes, lateral view; same specimen, ×1.
5. Phalanges IV-1 to IV-4 of the left pes, lateral view; same specimen, ×1.
6. Distal portion of right metatarsal III, posterior view; same specimen, ×1.
7. Distal portion of left metatarsal IV, medial view; same specimen, ×1.
8. Distal portion of left metatarsal II, lateral view; same specimen, ×1.
9. Right tibiotarsus, *a* distal portion and *b* proximal portion with fragment of the fibula attached, posterior views, *c* distal portion, anterior view, *d* distal portion, lateral view; same specimen, ×0.5.

Nemegt Formation, ?Late Campanian or ?Early Maastrichtian, Ultan Ula IV, Nemegt Basin, Gobi Desert, Mongolia

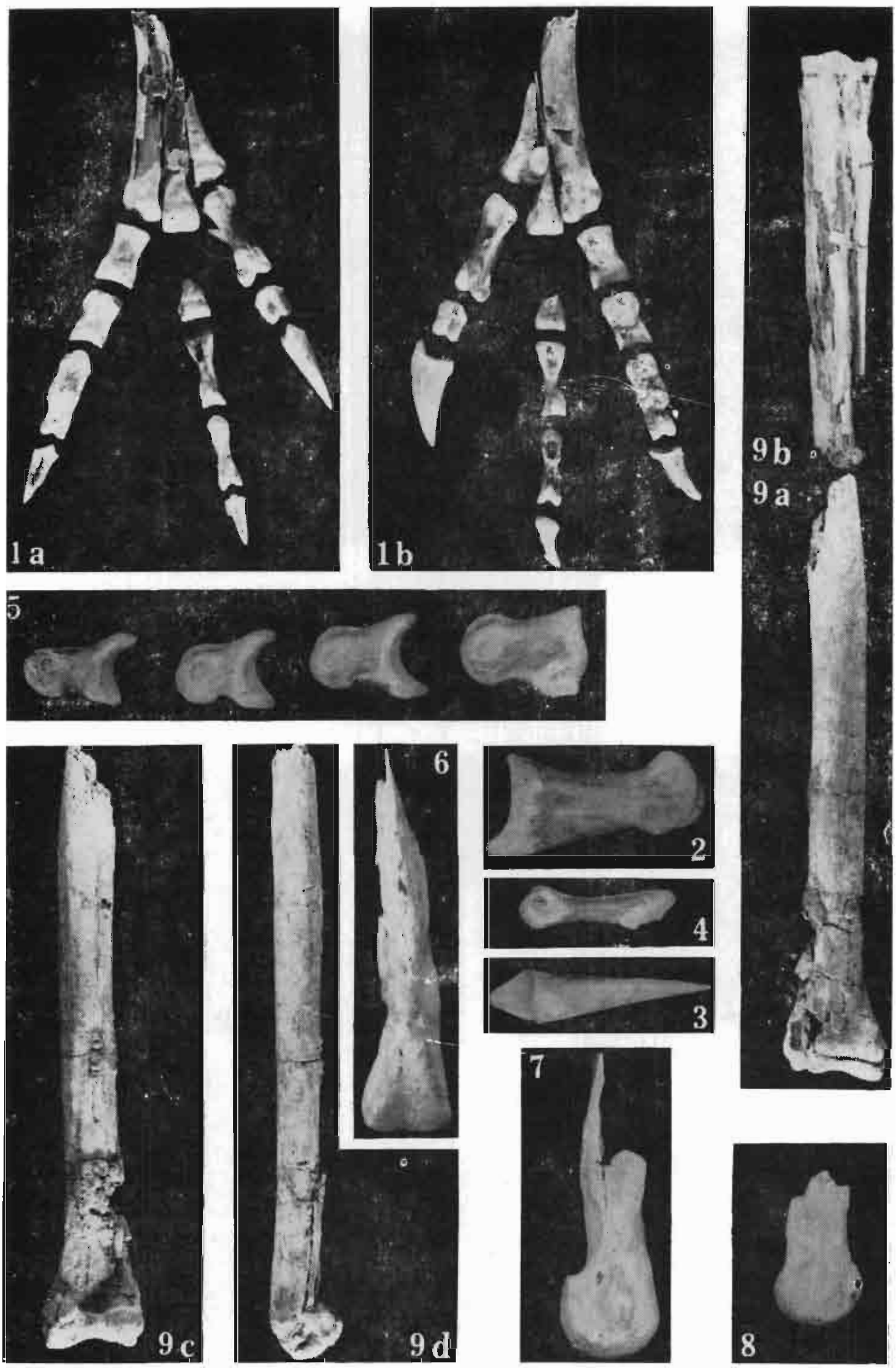
Plate 54

Borogovia gracilicrus gen. et sp. n.

1. Reconstruction of the right pes in dorsal view; first digit not reconstructed; proportions of the metatarsus based arbitrary on the metatarsus of an unidentified PIN 551—224 troodontid specimen (courtesy of Dr. S. M. Kurzanov).
2. Distal portion of the right metatarsus, posterior view; ZPAL MgD-I/174, holotype.
3. Distal portion of right metatarsal III, posterior view; same specimen.
4. Distal portion of left metatarsal II, lateral view, same specimen.
5. Distal portion of metatarsal IV, medial view; same specimen.

Nemegt Formation, ?Late Campanian or ?Early Maastrichtian, Ultan Ula IV, Nemegt Basin, Gobi Desert, Mongolia

Scale-bar equals 3 cm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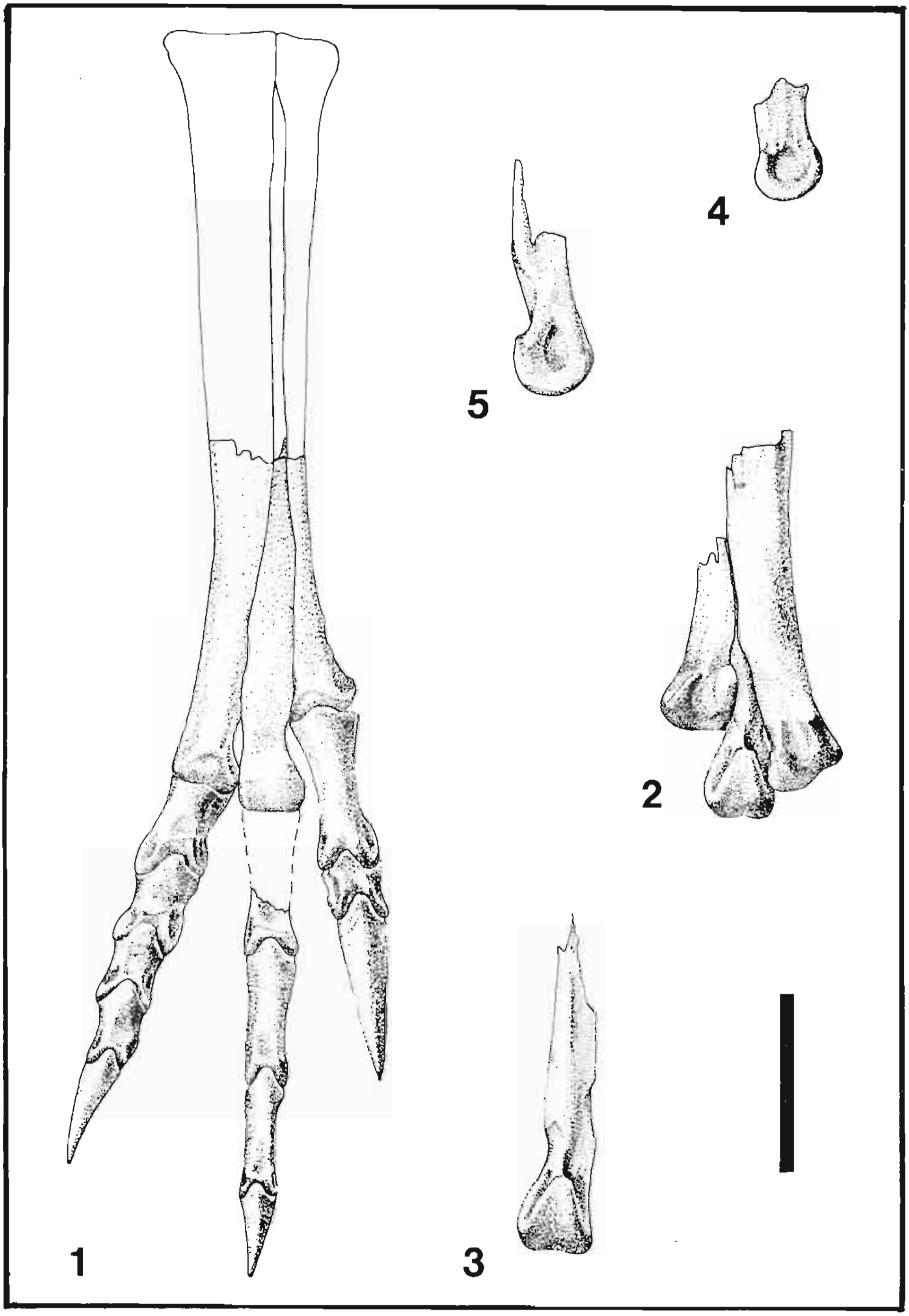
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