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DEINOCHEIRIDAE, A NEW FAMILY OF THEROPOD DINOSAURS

(Plates I—V)

Abstract. — A new carnosaurian dinosaur, *Deinocheirus mirificus* n. gen., n. sp., is described from the Upper Cretaceous of the Gobi Desert. The material consists of a shoulder girdle, fore limbs and fragmentary ribs. The fore limbs are about 240 cm long and tridactyl, all the digits being equally developed and terminating in powerful claws. Carnosaurian fore limbs of such large size have not been previously reported. The gigantic size of the fore limbs appears ample justification for establishment of a new family, Deinocheiridae, within Carnosauria.

INTRODUCTION

During the course of the Polish-Mongolian Palaeontological Expedition of 1965, an unusual, incomplete skeleton of a gigantic carnosaurian dinosaur was recovered. This skeleton was found by Prof. Z. KIELAN-JAWOROWSKA at Altan Ula III locality, Nemegt Basin, Gobi Desert, Mongolian People's Republic, in the Upper Cretaceous sandstones, designated by GRADZIŃSKI *et al.* (1968/69) as Upper Nemegt Beds; its exact location is given by GRADZIŃSKI *et al.* (*l. c.*, Text-fig. 6; see also KIELAN-JAWOROWSKA & DOVCHIN, 1968/69, p. 24, Pl. 4, Fig. 1).

The specimen in question, consisting of a shoulder girdle, fore limbs and other incomplete bone fragments, is described in the present paper as *Deinocheirus mirificus* n. gen., n. sp.

Because of its extreme dimensions and the unreduced tridactyl structure of the manus, the new genus cannot be assigned to any known family of theropod dinosaurs. Consequently, a new family Deinocheiridae is erected for it, within the superfamily Megalosauroidea Walker, *faute de mieux*, infraorder Carnosauria (non Megalosauroidea sensu MALEYEV, 1968). It should be mentioned that the only carnosaurian dinosaurs, previously described from the Upper Nemegt Beds of the Nemegt Basin (MALEYEV, 1955*a*, 1955*b*), belong to the superfamily Tyrannosauroidea WALKER and are regarded by ROZHDESTVENSKY (1965) as representing a single genus and species *Tarbosaurus bataar* (MALEYEV).

The specimen of *Deinocheirus mirificus* was found on a small hill in the very poorly cemented sandstone. The bones of the fore limbs were only slightly disarranged (Text-fig. 1), and the articular relationships were partly preserved. The rest of the skeleton apparently was destroyed by the erosion. Plastic casts of the preserved bones were made, with the missing parts (i.e. the distal end of the scapula and the antero-ventral edge of the coracoid) restorted, according to data obtained from the literature on other carnosaurian skeletons. The restoration shown here (Pl. I) is composed of those casts.

Use of the humero-femoral index, H:F (widely accepted in the descriptions of carnosaurs), and determination of the degree of reduction of the fore limbs, was not possible. Instead,

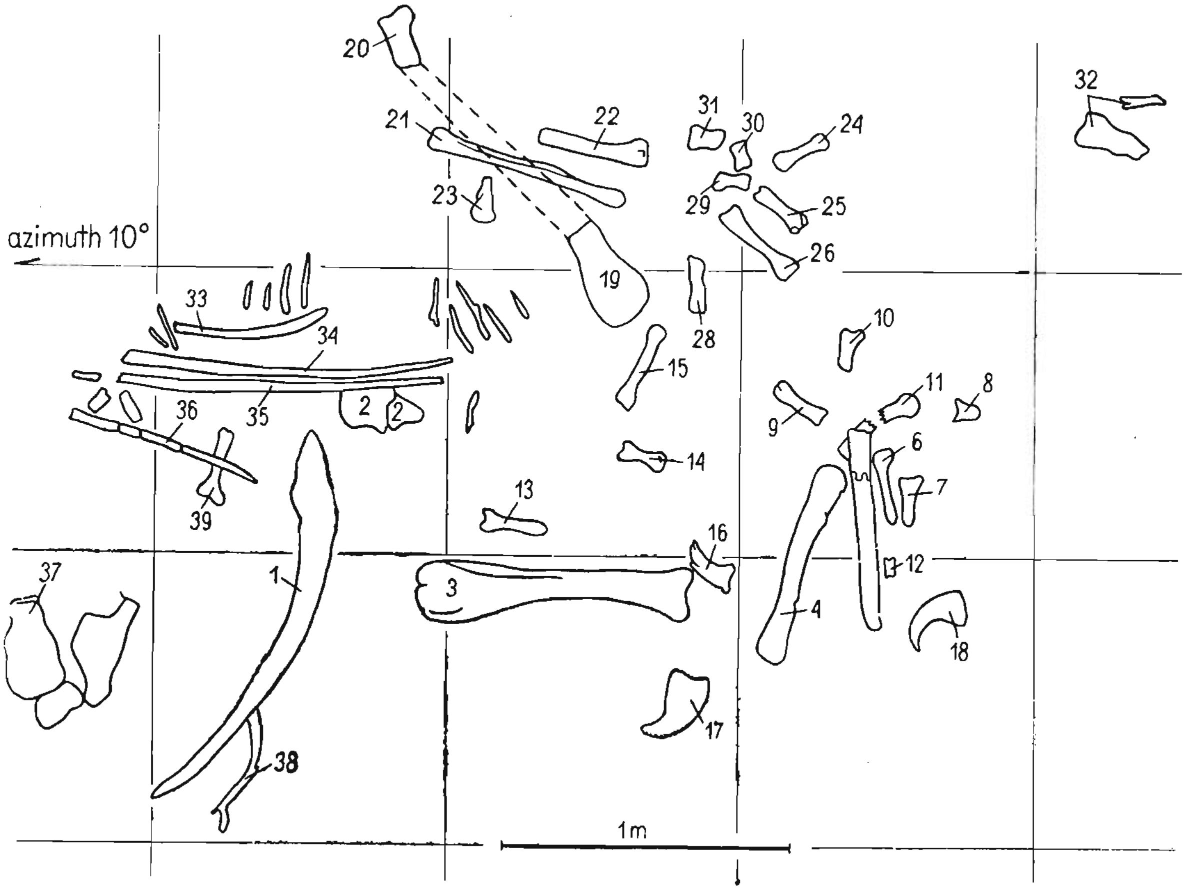

Fig. 1

Plan of the skeletal remains of *Deinocheirus mirificus* n. sp. as found in the field: *1* left scapulocoracoid, *2* fragments of the right scapula (other parts situated outside the plan, next to *32*), *3* left humerus, *4* left unla, *5* left radius, *6* left metacarpal II, *7* phalanx 3 of the left digit III, *8* phalanx 2 of the left digit III, *9* phalanx 3 of the right digit III, *10* phalanx 1 of the left digit II, *11* left metacarpal III, *12* phalanx 1 of the left digit III, *13* phalanx 2 of the left digit II, *14* left metacarpal I, *15* phalanx 1 of the left digit I, *16* ungual of the left digit III, *17* ungual of the left digit II, *18* ungual of the left digit I, *19* and *20* right humerus, *21* right radius, *22* right ulna, *23* right metacarpal I, *24* right metacarpal II, *25* phalanx 2 of the right digit II, *26* phalanx 1 of the right digit I, *28* right metacarpal III, *29* phalanx 1 of the right digit II, *30* phalanx 2 of the right digit III, *31* phalanx 1 of the right digit III, *32* undetermined bone fragments, *33-35* right dorsal ribs, *36* left dorsal rib, *37* fragments of the vertebrae and undetermined skeletal remains, *38* supposed ceratobranchial, *39* fragment of the dorsal rib, thin and long bones perpendicular to dorsal ribs (*33*) and bones right (to *34*) represent gastralia.

the humero-scapular index, H:S, is here introduced, which to some degree provides similar information.

The interpretation of muscle attachments is based on ROLLESTON (1870), FÜRBRINGER (1875), BRONN (1890) and ROMER (1956).

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DESCRIPTIONS

Order SAURISCHIA
Suborder THEROPODA
Infraorder CARNOSAURIA
Superfamily **MEGALOSAUROIDEA** WALKER, 1964 *(faute de mieux)*
Family **DEINOCHEIRIDAE** n. fam.

Diagnosis. — Gigantic carnivorous dinosaur with long, slender scapula and long fore limbs; manus with three, uniformly developed fingers, ending in strong, large claws.

Genus assigned: *Deinocheirus* n. gen., monotypic family.

Geographical and stratigraphical range. — Gobi Desert, Mongolian People's Republic Upper Nemegt Beds, Upper Cretaceous.

Discussion. — The structure of the shoulder girdle and fore limbs indicates that *Deinocheirus* n. gen. can only be assigned to the Theropoda. Judging from length of the scapulocoracoid and of the ribs, estimated size of the animal was about that of the biggest known *Tyrannosaurus*. Characters such as the gigantic size, hollowed limb bones and fore limbs adapted for grasping rather than locomotion, are the principal evidences for this assignment. The gigantic size and thick-walled limb bones dictate an assignment to the infraorder Carnosauria rather than to the Coelurosauria. However, the structure of the manus and humerus strongly resembles that of *Ornithomimus*, but to what extent this is due to convergence or reflects true phyletic relationships, cannot be determined at present. Nevertheless, in the present authors' opinion, this fact, as well as the fact that the structure of the manus is, in some respects (p. 18), more primitive than that of the Jurassic Megalosauridae, indicate that the family Deinocheiridae had its origin early in carnosaurian history and continued throughout the Jurassic and Cretaceous, in parallel with the Megalosauridae. The possibility that this family constitutes a link between Carnosauria and Coelurosauria cannot be excluded.

The systematic division of Carnosauria accepted here is that of WALKER (1964). He proposed a separation of tyrannosaurids, establishing a new superfamily Tyrannosauroidea and grouping the remaining carnosaurs in the superfamily Megalosauroidea. The family Deinocheiridae is tentatively assigned to the latter superfamily, since the only known representative, *Deinocheirus*, is in many respects distinct from all known megalosaurids (p. 16). On the other hand, it is closer to the megalosaurids than to tyrannosaurids in the apparently insignificant reduction of the fore limbs.

Genus **Deinocheirus** n. gen.

Type species: *Deinocheirus mirificus* n. sp.

Derivation of the name: Gr. *deinos* = horrible, *cheir* = hand; because of the large fore limbs and strong claws.

Diagnosis. — As for the species. Genus monotypic.

Stratigraphical and geographical range. — Known only from the type horizon and locality of the type species.

Deinocheirus mirificus n. sp.

(Pls. I—V; Text-fig. 2)

Type specimen: Shoulder girdle and fore limbs (Z. Pal. No. MgD-1/6); Pls. I—V; Text-fig. 2.

Type horizon: Upper Cretaceous, Upper Nemegt Beds, zone of *Tarbosaurus bataar* (MALEYEV), *Saurolophus angustirostris* ROZHDESTVENSKY and *Dyoplosaurus giganteus* MALEYEV.

Type locality: Altan Ula III, Nemegt Basin, Gobi Desert, Mongolian People's Republic.

Derivation of the name: Lat. *mirificus* = unusual, peculiar; because of the unusual structure of the fore limbs.

Diagnosis. — Scapula long and slender; coracoid large; fore limbs long, slender; humerus straight, twisted, with a pronounced, triangular deltopectoralis crest; length of humerus equal to about three fourths that of scapula; radius slightly longer than half humeral length; manus only slightly shorter than humerus, with three equally developed digits terminated in claws; metacarpus comparatively long; digits long.

Material. — The material consists of right and left scapulocoracoids, both of which are damaged at the dorsal extremities of the scapular blade and at the acromion; complete left humerus; right humerus crushed along the shaft; entire left ulna; the right ulna which is damaged near the proximal end; left and right radius; complete left and right metacarpus; and all phalanges, excluding the unguals of the right manus. Also found were two supposed ceratobranchials, four or five right dorsal ribs and one or two left ribs, all with proximal and distal ends broken off, numerous fragments of abdominal ribs, fragments of three vertebrae and several unrecognizable bone fragments.

In addition to these bones which undoubtedly belong to the same skeleton, a nearly complete astragalus of carnosaurian type, 105 mm long *(tr.)* was found. This seems too small to be assigned to this specimen, however, and most probably belongs to a tarbosaur.

For the arrangement of bones in the field — see Text-fig. 1.

Dimensions — see Table 1.

Description. — *General remarks.* The surfaces are covered in many places by distinct, rough areas and impressions, some of which may be interpreted as places of attachment of known muscles of the shoulder region and fore limbs. These rugosities consist of irregular, longitudinal striations. However, the determination of such muscle attachments is uncertain, as no Recent reptiles are fully bipedal and consequently none of them have the peculiar structure of the scapulocoracoid found in most Theropoda. Thus, homologies between some of these muscles and their origins and insertions in living reptiles and in bipedal dinosaurs can hardly be established. Besides the attachments mentioned above, longitudinal striations occur over the circumference of these bones, near the articular surfaces. These are interpreted as impressions of ligaments uniting the joints. Such pronounced sculpture of the bone surfaces indicates the presence of powerful limb muscles.

The majority of the articular surfaces are deeply and irregularly furrowed. This indicates the presence of a thick pad of articular cartilage, which was destroyed during fossilization (thus the term "articular surface", as used here and in other palaeontological papers on fossil reptiles, should not be understood as a proper articular surface; the latter very often must have been completely different in shape from its bone base). Especially strongly furrowed are the articular surfaces of the glenoid cavity, the head and distal end of the humerus, the olecranon and head of the ulna. This may indicate that the cartilaginous pads were very thick in these joints. The remaining articular surfaces of antebrachium, as well as the bases of metacarpals are much less furrowed. The distal ends of the metacarpals and the articular surfaces of the phalanges do not display this character at all.

Table 1

Deinocheirus mirificus n. sp. (Z. Pal. No. MgD-I/6) — measurements (in mm)

	Length	Width		Circumference
		proximal end	distal end	
Scapula	L, R 1190	?	100	
Coracoid	L, R 340	—	—	
Sc. + Cor.	L, R 1530	—	—	
Humerus	L 938	L 221 R 245	L 164	L 290
Ulna	L 688	L 112	L 92 R 100	L, R 185
Radius	L, R 630	L, R 96	L, R 72	L, R 168
Manus	L 770 (along digit II)	—	—	—
Mtc. I	L 214 R 220	L 92 R 90	L 68 R 64	L 163 R 165
Mtc. II	L 230	L 68	L 71 R 66	L 155 R 153
Mtc. III	L 246 R 245	L 70 R 73	L 60 R 61	L 137 R 140
Dig. I, Ph. 1	L, R 320	L, R 79	L, R 76	L 164 R 170
Dig. II, Ph. 1	L, R 140	L, R 77	L 60 R 63	L, R 168
Ph. 2	L 226 R 229	L 64 R 66	L, R 51	L, R 152
U	L 196 (323 along upper curve)	—	—	—
Dig. III, Ph. 1	L 110 R 105	L 71 R 72	L 59 R 63	L 195 R 185
Ph. 2	L 104 R 100	L 66 R 64	L, R 54	L 180 R 173
Ph. 3	L 186 R 182	L 54 R 58	L 46	L 160 R 150

Scapulocoracoid (Pl. II; Pl. IV, Fig. 1). The scapula is curved, tall and narrow, and is fused with coracoid. The scapular blade is of equal width for most of its length, becoming somewhat expanded dorsally and persistently expanded ventrally, where it is strongly thickened. The acromial process was present, however it is not completely preserved. Scapulocoracoid suture is provided with distinct incurvature convex dorsally.

The coracoid is large, moderately convex and extends behind the glenoid. The postero-ventral part of the coracoid develops an apex, which is strongly curved inwards. The coracoid foramen on the outer surface is round, but on the inner surface it is elongate and prolonged into the scapular blade in the form of a deep groove. The glenoid cavity is shallow and faces slightly outwards. The rim surrounding the glenoid is somewhat pronounced. A supraglenoid buttress is present in the form of a weak swelling.

Comparison of the coracoids reveals some differences in their shape and in the development of some parts (Pl. IV, Fig. 1). The left coracoid is somewhat narrower across its ventral half. The anterior edge of this part is strongly curved inwards. The bone is distinctly thickened along the line of this bend. The outer surface of this curved area is very rough, contrary to its inner surface which is smooth. The corresponding part of the right coracoid is developed differently, being devoid of the above mentioned bend. Its outer surface is smooth, but a rugose area of the same shape and size occurs on the inner surface. This particular development of the corresponding edges of coracoids suggests that it is the result of overlapping. This may be due to abnormal development, or it may represent an example of arcifery, a phenomenon reported in some living reptiles. Overlapping of coracoids has not been reported previously in any group of archosaurs, *Deinocheirus mirificus* apparently being the first example. It may be that overlapping of the coracoids was a common condition among dinosaurs. For instance, the shape of the supposed sternal bones reported by LAMBE (1917, p. 44, Figs. 29, 30) in *Gorgosaurus libratus* LAMBE, 1914, may indicate that the sternum articulated only with the posteromedial edges of the coracoids. In such a situation, the coracoids would be in contact along the medial line.

The dorsal extremity of the scapula consists of thin bone which probably extended into a cartilage peripherally. It seems highly probable that this part formed an area for the insertion of the levator scapulae, serrator profundus and serrator superficialis muscles. A ridge extends along the posterior edge of the anterior half of the scapular blade. A comparison of the shoulder muscle of a crocodile (FÜRBRINGER, 1875, Pl. 26, Figs. 91, 92) suggests that this might be the marginal boundary of the insertion of m. serratus superficialis.

A small, oval, rough area is present on the posterior edge of the scapula, above the glenoid. This may be interpreted as the origin of one of the heads of triceps, or the insertion of the teres minor. A ridge, nearly perpendicular to the long axis of the scapular blade, extends across the external surface of the proximal part of the scapula. This forms the dorsal boundary of a large depression, situated opposite the glenoid, which extends onto the adjoining part of the coracoid. A gentle convexity occupies the coracoid plate separating the ventral part of the coracoid from rest of the scapulocoracoid. Two shallow muscle fields are developed on this part: a medial one, which is the smaller and probably representing the origin of the biceps, and a lateral muscle field, that is larger and probably represents the origin of the coracobrachialis muscle. At the posterior edge of the coracoid, below the glenoid cavity, is an elongate triangular area, that is separated from the mentioned lateral muscle field by a ridge.

On the internal surface, the scapulocoracoid is greatly thickened between the glenoid cavity and the coracoid foramen. This thickening is very rugose and probably is part of the area of origin of the m. subscapularis. Antero-ventrally, this thickening passes into a broad subcoracoid cavity, the attachment site of the m. subcoracoides.

Humerus (Pl. III, Pl. IV, Fig. 2). The humerus is long and decidedly twisted, the distal end being at 30° to the proximal end. Proximal end is more expanded than the distal end.

Proximal end. The head slightly overhangs the posterior face of the humerus. The articular surface is divided into two parts: a medial part, which is broadly rounded, and the lateral area, that is narrow. Medial to the head, a distinct triangular process is present (processus medialis). Both anterior and posterior surfaces of this process are striated longitudinally, marking the areas for insertion of m. subscapularis and m. scapulo-humeralis. The area for attachment of the two muscles cannot be distinguished. A striated area exists on the anterior side of the proximal expansion, below the lateral part of the articular surface. This feature is smaller on the left humerus, than on the right. This area may represent the insertion of coracobrachialis muscle. On the posterior side, just below the medial part of articular surface, several deep pits are present in the area, corresponding to the probable insertion of m. deltoides scapularis superior.

The deltopectoral crest is triangular and high. Its summit is situated about one fourth of the humeral length from the head. The crest lowers gradually distally, disappearing before reaching mid-length of the shaft. The area for the insertion of pectoralis muscle is smooth. On the lateral surface of the crest, an extensive depression is present, which probably provided an area for the attachment of m. deltoid scapularis inferior (insertion) and m. humero-radialis (origin). This depression is situated near the lower end of the crest and occupies only the basal part of the deltopectoralis triangle, passing onto the adjacent part of the shaft. The lower boundary of the depression is quite deep and rough, but shallows towards the proximal end of the bone. The shaft is long, comparatively slender and somewhat triangular in cross-section.

Distal end. Articular surface is divided into two condyles, the medial one being somewhat larger. Small epicondyles are present, the medial one of which is prolonged upwards by a short condyloid crest. Above the articular surface, there is a centrally situated depression, which shallows distally. The olecranon fossa is very faintly depressed.

Ulna (Pl. IV, Fig. 3). The ulna is slender, long and slightly expanded at the extremities. The bone is slightly curved, convex outwards. The proximal end has a well developed olecranon process. Anterior to the latter, there are two distinct surfaces separated by a ridge, the medial one is the larger and is inclined ventrally. On the internal surface, a broad fossa is present, which shallows downwards. A thickened crest runs downwards from the articular surface, along the medial edge of the bone. The attachment of m. brachialis inferior is distinct. The shaft is triangular in cross section, but several low crests extend obliquely along the internal surface.

Distal end is weakly expanded and the articular surface is slightly convex. Its outline is in the form of a triangle, strongly elongated backwards. The radial face of the ulna is slightly convex for articulation with the radius. On the lateral surface of ulna, at the margin of the articular surface, there is a comparatively well developed tuberosity, which is much less well developed on the left ulna. This may be an insertion for some of the extensor muscles of the carpus.

Radius (Pl. IV, Fig. 3). The radius is slender, noticeably thinner than the ulna, and curves anteriorly. Its proximal end is slightly expanded and flattened, with a flat articular surface. The part of the proximal expansion, next to the ulna, has stronger longitudinal striations than that of the opposite side. A slight expansion at the medial edge of the proximal end indicates the attachment site of the m. biceps. In cross-section, the proximal part of the shaft is flattened antero-posteriorly, while at mid-length it is flattened in a plane perpendicular to the former one. The cross-section near the distal end is nearly round.

The distal end consists of a subtriangular articular head. The surface facing ulna is flat. A prominent tuberosity is present on the lateral surface, slightly above the articular head.

The carpus is unknown.

Manus (Pl. V, Fig. 1; Text-fig. 2). The manus is isotridactyl and provided with three strong claws. All digits are equally developed and about the same length; digit I is somewhat divergent. The phalangeal formula is 2, 3, 4. The metacarpus is comparatively long in relation to the digits (see Table 2).

Table 2

Skeletal indices of the shoulder girdles and fore limbs of some theropod dinosaurs

Index	*Deinocheirus mirificus*	*Ornithomimus altus*	*Ornithosuchus longidens*	*Eustreptospondylus oxonnensis*	*Antrodemus valens*	*Gorgosaurus libratus*
H:S	0.78	0.92	1.01	0.78	0.47	0.37
R:H	0.66	0.73 (UR:H)	0.84	0.58	0.71	0.48
Man:R	1.2	1.3 (Man:UR)	—	—	1.8	1.8 (estim.)
H:R:Man	1.5:1:1.2	1.8:1:1.3(estim.)	—	—	1.4:1:1.8	2:1:1.8 (estim.)

H — humerus U — ulna Man — manus (along digit II)
R — radius UR — ulno-radius S — scapula

The metacarpals fit closely together proximally, forming a weakly arched metacarpus. Spatia interossea are large, the one between metacarpals I and II being larger than the other. The articular surfaces between metacarpals I and II are very close fitting and longer than those between metacarpals II and III. The distal ends of metacarpals I and II are more spaced than those of metacarpals II and III. Foveae for ligamenta palmaria are comparatively deep and broad.

Metacarpal I is the shortest and stoutest of the three metacarpals, is flattened dorso-ventrally and triangular in cross-section. The basal articular surface is divided into two parts, the medial one smaller and slanting externally. Ventral to it, is situated a deep fossa, which may represent the attachment of the tendon of m. flexor carpi radialis. The surface for articulation with metacarpal II is deep and hollowed. The caput of metacarpus I is strongly asymmetrical, divided by a deep groove with a small medial condyle shifted ventrally, and a larger lateral condyle, which is very strongly convex transversely. Fovea ligamentosa on the radial side of the caput is deep, while that on the ulnar side is shallow and in the form of a groove directed dorsally.

Metacarpal II is slender and slightly longer than metacarpal I. Proximal articular surface is divided by a transversely oriented shallow depression. The articular surface for metacarpal I is tuberculous; that for articulation with metacarpal II is slightly concave. The shaft is nearly quadrangular in cross-section. The caput is convex, with a shallow, broad depression, which is situated close to metacarpal I and faces ventrally. The condyles are weakly developed and situated on the ventral side of caput. Foveae ligamentosae — medial and lateral — are moderately deep and groove-like.

Metacarpal III is slender and the longest of the three metacarpals. The base is triangular, with a flat articular surface. The surface for articulation with metacarpal II is in the form of a shallow depression, elongated dorso-ventrally. The shaft is nearly round in cross-section. The lateral condyle is larger than the medial one, and the fovea ligamentosa on the medial side of the caput is shallow.

Digit I is the strongest. Phalanx 1 is long and slender and is expanded proximally. The articular surface of the base is concave and nearly funnel-like, with two shallow depressions for the condyles of metacarpal I. On the ventral side of the base are two tubercles for ligamenta collateralia. The shaft is nearly round in cross-section. The caput is symmetrically divided by a comparatively deep sulcus sagittalis. Foveae ligamentosae are extremely deep. On the ventral side of the caput there is a centrally situated fossa. Ungual phalanx of digit I is the largest of all and has the same shape as the ungual of digit II (the latter is the best preserved, thus it is the only described here).

Digit II. Phalanx 1 is short and stout and is expanded proximally. The articular surface of the base is concave, with a deep pit centrally located. There are on the ventral side of base, below the articular surface, two tubercles with a shallow depression between them. The shaft is quadrangular in cross-section. The caput is nearly symmetrically divided by a deep and broad groove. On both sides of the caput there are very shallow foveae ligamentosae. Phalanx 2 is thinner and about one third longer than phalanx 1. The articular surface of the base is divided by a prominent crest, and at the edges of the ventral side of base, two tubercles for the ligamenta collateralia are visible. Centrally, on the dorsal side of the base, there is a prominent eminence for the tendon of m. extensor digitorum profundus. Shaft is rounded in cross-section. The condyles of the caput are symmetrical, with a deep sagittal groove. Foveae ligamentosae are extremely deep. On the ventral side of the caput, there is a round depression centrally situated. The ungual phalanx, which is somewhat smaller than that of digit I, is triangular in cross-section. It is strongly curved, pointed and laterally compressed. A groove occurs on each side of the ungual, which deepens distally. Within the groove, two elongate pits are present. The proximal end of the ungual is formed of an oval articular surface, divided by a sagittal ridge. A very prominent tuber for the tendon of m. flexor profundus is situated ventral to this articular surface, only very short distance from it. On the dorsal edge of the ungual, near the articular surface, an oval rough area is present, which may represent an attachment site of extensor tendons. On both sides of the proximal part, tubercles for ligamenta collateralia are present. Small foramina are visible on the surface of ungual, especially along the dorsal edge of distal part.

Digit III. Phalanx 1 is very short and stout. The proximal articular surface is shallowly concave, and within this concavity there is a pronounced short fossula, which is directed towards the ventro-medial angle of the articular surface. On the ventral side, the tubercle for ligamentum collaterale is more strongly developed at the medial side, than that at lateral edge. Foveae ligamentosae are shallow. The caput is symmetrically divided by a deep sagittal groove. Phalanx 2 is somewhat shorter and thinner than phalanx 1. The proximal articular surface has a prominent sagittal crest and the tubercles and foveae for ligamenta collateralia are weakly developed. The caput is comparable to that of phalanx 1. Phalanx 3 is slender and as long as the two preceding phalanges together. Base with a sagittal crest is developed, the tubercles for ligamenta collateralia are weak. The shaft is rounded in cross-section and the caput is nearly symmetrically divided by a sagittal groove. Foveae ligamentosae are extremely deep. On the ventral side, near the caput, is a centrally situated, round depression. The ungual is somewhat smaller than that of digit II.

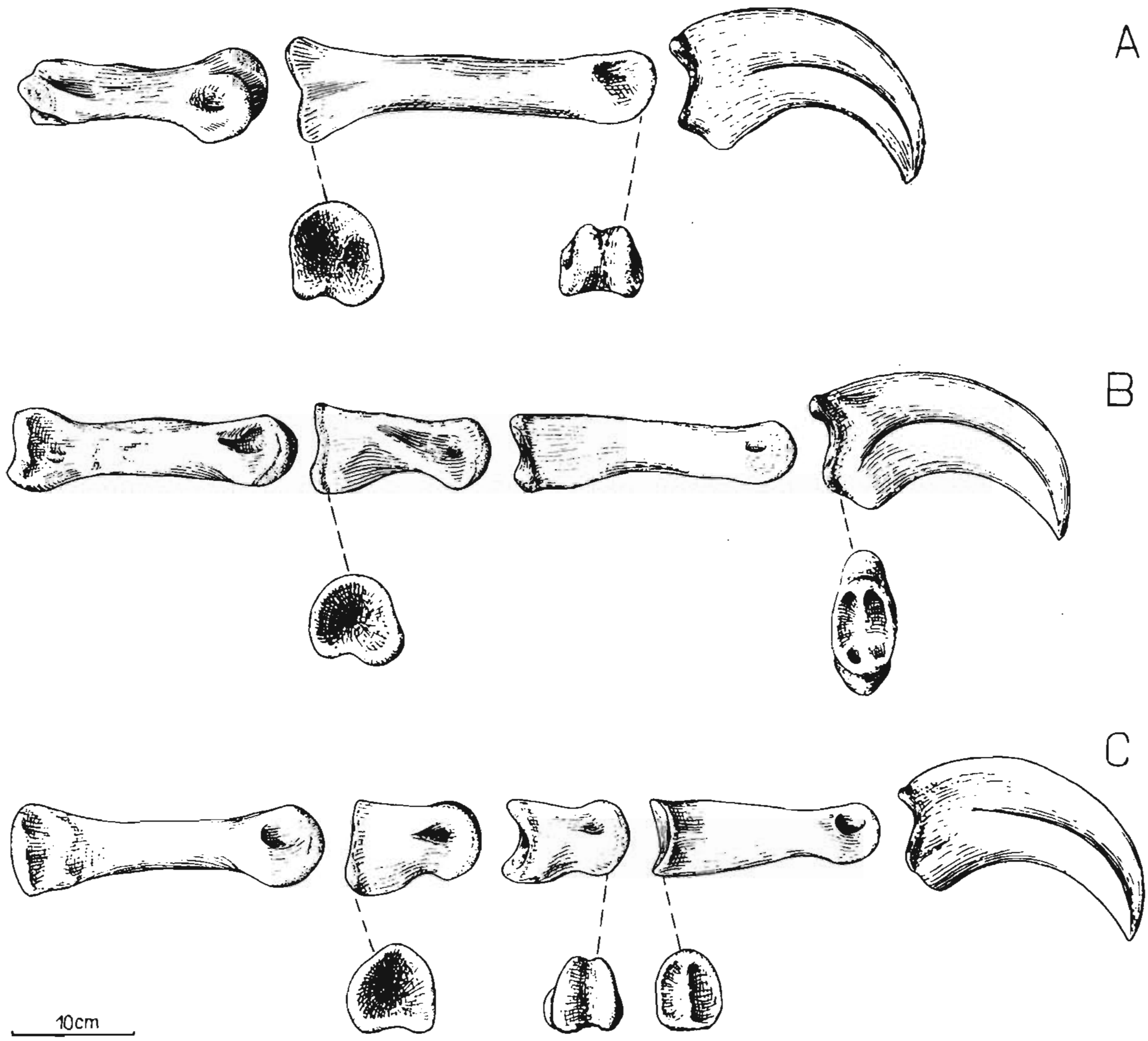

Fig. 2
Digits of the left manus of *Deinocheirus mirificus* n. sp. in medial aspect, with some articular surfaces of their bases and caputs: *A* digit I, *B* digit II, *C* digit III.

Abnormalities. In the left manus, the phalanx 1 of digit III has the mark of an injury on the outer margin of the medial condyle, in the form of a deep pit. On the corresponding surface of the base of phalanx 2, there is also a trace of injury in the form of a groove. Both injury scars mentioned have rounded edges. Doubtless, these two injuries resulted from the same cause, i.e. damage to the joint. Moreover, this damage probably caused changes in the normal arrangement of ligaments and muscles. As evidence of this, there is an abnormally enlarged area of roughness on the medial side of phalanx 2, in the part adjacent to the wounded joint. In addition on the palmar side of phalanx 2, there occurs a round and somewhat swollen rough area, situated centrally, which was also apparently caused by the abnormal changes, mentioned in the musculature of the left hand. It is worth mentioning that this damage occurred in the area of ligamentum collaterale.

Other skeletal elements. In the assemblage above described, there are two paired elements which may represent the ceratobranchials (Pl. V, Fig. 2). They are bent at an angle of about 40°. One of them, representing perhaps the right ceratobranchial, is more completely preserved. Its length is 420 mm (along the curve). It is flattened along two thirds of its length, then becomes narrower and rounded in cross-section. The maximum width is attained at the angle of the bent, at one third of the total length, and amounts to about 25 mm, while the diameter of the narrower extremity is 8 mm. On the supposed inner surface of the broader end, just at its extremity, remains of the articular surface can be seen. At mid-length, a thin branch of bone originates and is directed to the main bone. The free extremity of this branch is broken off. The thin end of the supposed right ceratobranchial is twisted somewhat screw-like and covered with longitudinal striations, suggesting the presence of ligaments.

The possibility exists that the above described two bones may represent abdominal ribs. However, should this be the case, they are completely different from those, found together with the *Deinocheirus* skeleton, which are far thinner, as well as from the abdominal ribs so far known of other theropods. It should be mentioned that these elements differ also from the known ceratobranchials, i.e. in *Gorgosaurus lancensis* GILMORE, 1946 (GILMORE, 1946) or in *Ornithosuchus longidens* (HUXLEY, 1877), (see WALKER, 1964), where the ceratohyals are more or less equal in width at both ends.

Among the other bones, found together with the above described elements, are several badly damaged fragments of vertebrae. The most complete centrum is 145 mm high and preserves an articular surface that is slightly concave. Fragments of four right and two left ribs were also found. The longest fragments is 1050 mm long, being 90 mm wide at the proximal extremity and 30 mm wide at the opposite end (Pl. V, Fig. 4).

Numerous fragments of abdominal ribs (gastralia) are preserved. Some of these fragments are flat and on an average 20 mm in diameter (Pl. V, Fig. 3).

Discussion. — The fore limbs of *Deinocheirus mirificus* n. gen., n. sp. are characterized by the slenderness of all their elements. The longest is the stylopodium, next in length is the autopodium, while the zeugopodium is the shortest, although it too is long (see Table 2). The proximal articular surface of the humerus is so long *(tr.)* and so insignificantly expanded backwards, that retractile or backward movements were probably limited. In the zeugopodium the flexory surface is comparatively concave, perhaps indicating that the flexion movements were significant. The arch of the metacarpus is rather flat and the manus, as a whole, is comparatively broad and strong. From analysis of the flexion and extension movements in the metacarpo-phalangeal and interphalangeal joints (Text-fig. 3), one may judge that it is not a manus of purely grasping type: the pre-ungual phalanges are very long, digits have a limited range of movements, digit III having the greatest range. The pollex can hardly be regarded as an "opposable" digit, being directed only slightly outwards from the other digits and having the possibility of some rotary movements. During the maximum flexion permitted by the articular surfaces, which occurs mainly in the metacarpo-phalangeal joint, each digit forms a different arch. This condition seems to be unfavourable for a prehensile manus. Such a manus, together with the length of the fore limbs, which presumably could easily reach the ground, may suggest that they could have been used in tearing dead or weakly agile prey asunder.

The length and size of the fore limbs of *Deinocheirus mirificus* set it aside from the other theropods (Text-fig. 4). Nevertheless, several representatives of this group are comparable in some details, i.e. in the structure of the manus or in the proportions of limbs to the rest of the skeleton.

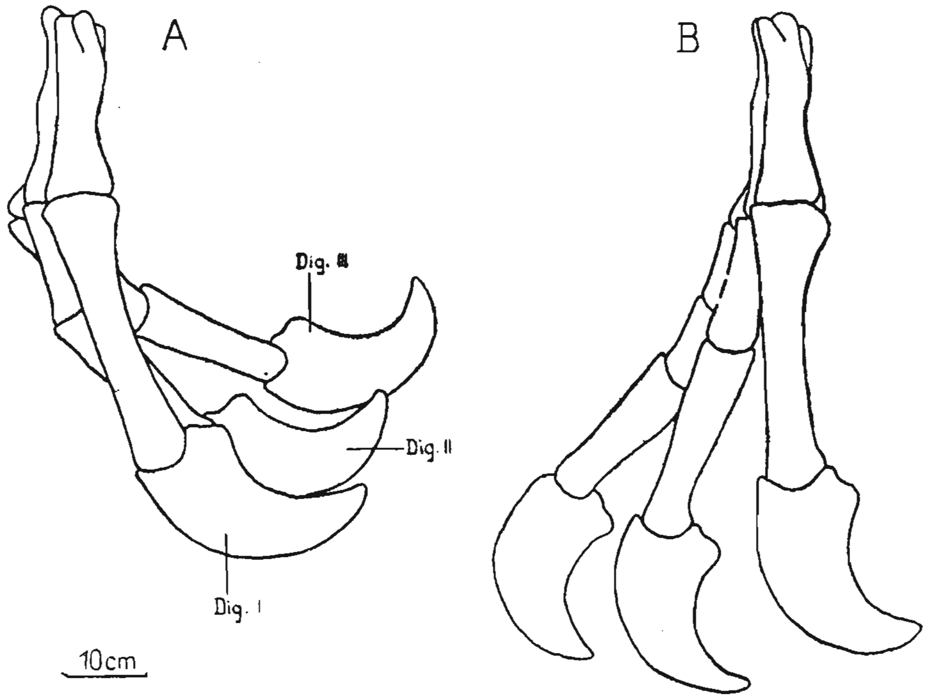

Fig. 3
Right manus of *Deinocheirus mirificus* n. sp., medial aspect: *A* maximal flection, *B* maximal extension of digits.

Certain resemblances in the manus, as well as in the relative length and proportions of parts of fore limbs, are found in a representative of the Coelurosauria — *Ornithomimus*, but some differences should be mentioned between these two genera. In *Deinocheirus*, the scapula is relatively much more slender, the glenoid cavity is shallower, the apex of the coracoid is less pointed and not expanded so far backwards; the humerus, although of similar shape (see OSBORN, 1916), is in relation to the scapula much shorter (Table 2). A very distinct difference exists in the humerus head. In *Ornithomimus* there is a strongly rounded, projecting portion, that is decidedly twisted backwards (see OSBORN, 1961, Figs. 7, 8). This character, without any doubt, affected the degree of mobility in the shoulder joint, with the result that in *Ornithomimus* the backward movements of the brachium were greater than in *Deinocheirus*. In addition, the deltopectoral crest of the humerus in *Deinocheirus* is better developed and shifted distally. The manus in *Deinocheirus* is broader than in *Ornithomimus*, and the tuber for the tendon of m. flexor profundus on its unguals is situated just below the articular surface, while in the *Ornithomimus* it is shifted far forwards (see OSBORN, *l. c.*, Fig. 3). This could mean that the manus of *Ornithomimus* was more effective in its "grasping" function than was the manus of *Deinocheirus*.

Within the Megalosauroidea, only *Antrodemus* invites a close comparison, having a tridactyl manus and powerful fore limbs. However, its fore limbs are much more reduced than in *Deinocheirus*, although, they are relatively much stouter than in the latter. Moreover, fore limbs of these two genera differ from each other in the development of all their elements, with the exception of the scapulocoracoid, which is similar in both cases (see GILMORE, 1920). The humerus in *Antrodemus* is sigmoid in shape and more twisted than in *Deinocheirus*. It has a prominent, hemispherical tuber on the medial side of the proximal articular surface, with a high deltopectoral crest situated near the proximal end; condyles on the distal end are strongly

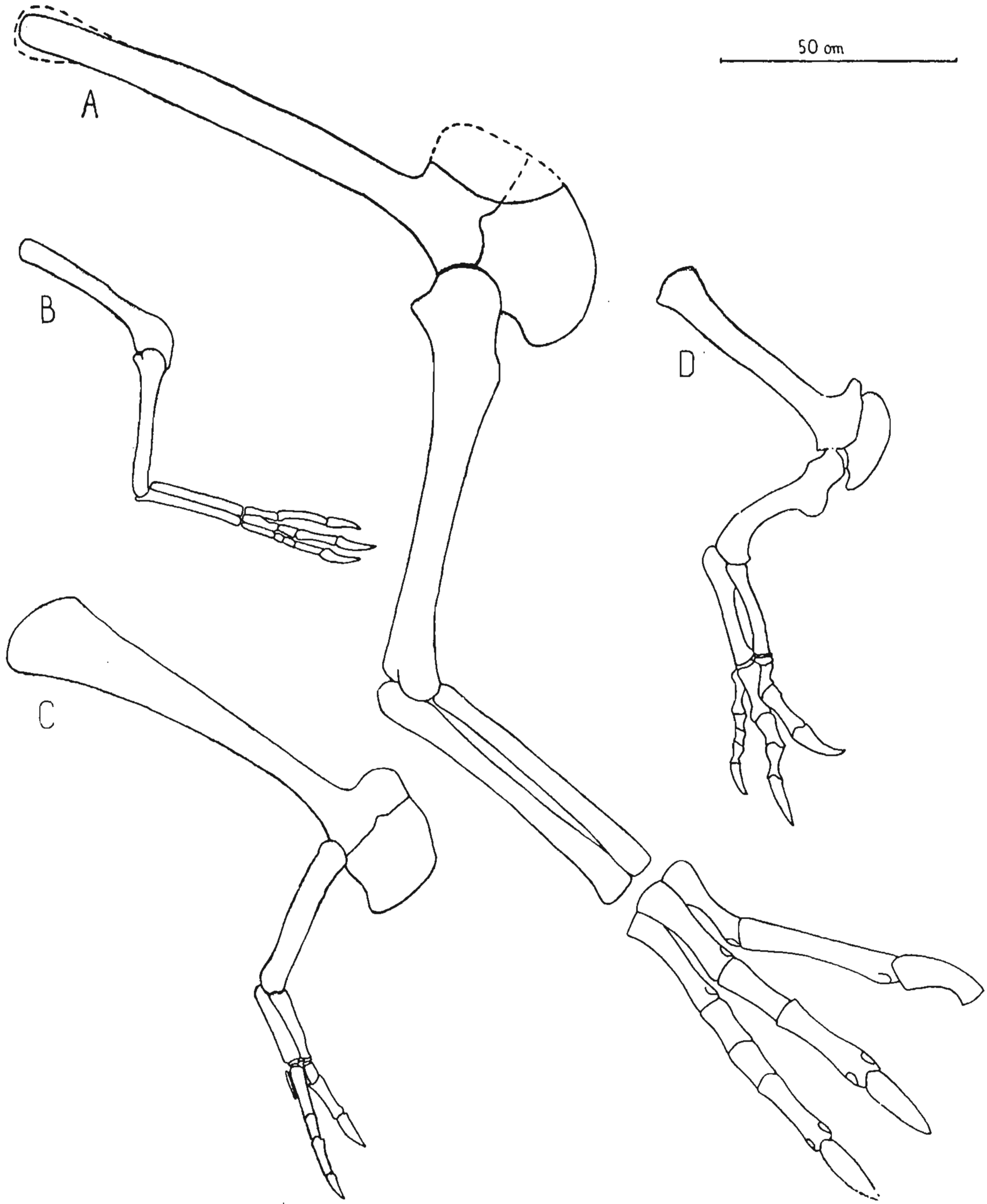

Fig. 4

Comparison of the relative sizes and proportions of the fore limbs: *A Deinocheirus* n. gen., *B Ornithomimus* (after OSBORN, 1916), *C Gorgosaurus* (after LAMBE, 1917), *D Antrodemus* (after GILMORE, 1920); all in the same scale.

developed. The ulna and radius are much more expanded at their extremities, the olecranon is stronger.

There are additional differences between these two genera in the structure of the manus. The most striking of these is the development of the third digit, which in the Jurassic *Antrodemus* is much thinner than the first and second digits, thus relatively more reduced than digit III in *Deinocheirus*, where it is subequal in thickness with the other. Metacarpal I is only about half the thickness of metacarpal II. Another important difference is in the structure of the proximal articular surface of the phalanx 1 of the digit I, which in *Deinocheirus* is undivided, funnel-like, while in *Antrodemus* and in some other carnosaurians (e.g. *Tarbosaurus*, *Gorgosaurus*) it is divided centrally by a vertical ridge. This character indicates that in *Deinocheirus* the first digit has a greater degree of mobility than in other carnosaurians (the same character is present in the *Ornithomimus* sp. found in the Nemegt Basin by the Polish-Mongolian Expedition in 1964).

Table 2 gives some indices illustrating the proportions of the shoulder girdle and the fore limbs in several theropods. One of these indices, humero-scapular (H:S), gives approximate information about the reduction of fore limbs (p. 2). An H:S index, corresponding to that of *Deinocheirus*, was calculated for the Jurassic megalosaurid — *Eustreptospondylus oxonnensis* WALKER. For the Cretaceous coelurosaurid — *Ornithomimus*, the H:S index is greater than in *Deinocheirus*, being approximately the same as for the primitive Triassic carnosaur — *Ornithosuchus longidens* (HUXLEY). Thus, of two contemporaneous "long armed" theropods — *Deinocheirus* and *Ornithomimus* — the first is already more advanced in the reduction of the fore limbs.

Though *Deinocheirus* seems to be a very peculiar theropod with very little reduction of the fore limbs, one should mention that unusually large unguals of fore limbs, associated with a long humerus, have been found in the Cretaceous deposits of China (*Chilantaisaurus tashuikouensis* SHOW-YUNG; see SHOW-YUNG, 1964). The humerus, however, in comparison with that of *Deinocheirus*, is much stouter and has a more prominent deltopectoral crest, that is nearly rectangular and shifted distally. OSTROM (1969) described a new genus and species of theropod dinosaur — *Deinonychus antirrhopus* OSTROM, 1969, which he assigned to Dromeosauridae MATTHEW & BROWN, 1922 (nom. trans. OSTROM, 1969). This lightly built animal is characterized a. o. by not reduced fore limbs and tridactyl manus. Contrary to the structure of the manus in *Deinocheirus mirificus* n. gen., n. sp. the third digit is here distinctly thinner than others, the second digit being also much longer than the remaining ones.

Claws, about three times as large as those of *Deinocheirus*, were already described by MALEYEV (1954) from the Upper Cretaceous deposits of Nemegt Basin. He classified them, together with long ribs and a metacarpal, as a new genus and species of the "turtle-like" reptile, *Therezinosaurus cheloniformis* MALEYEV. It seems, however, more probable that the claws belong to a carnosaur. Also a large ungual of a manus has been found by TAQUET (see DE RICQLÈS, 1967) in *Gadoufaoua* beds (Lower Cretaceous) in Niger, Africa. Apparently gigantic theropods were represented during the Cretaceous by several forms with unreduced or slightly reduced fore limbs. They cannot be included in any of the known families of the Megalosauroidea, but whether they all can be assigned to the Deinocheiridae or should form another separate unit, cannot be determined at present.

Palaeozoological Institute
of the Polish Academy of Sciences,
Warszawa, November 1967

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PLATES

Palaeontologia Polonica, No. 21, 1969

H. OSMÓLSKA & E. RONIEWICZ: DEINOCHEIRIDAE, A NEW DINOSAUR FAMILY

PLATE I

Upper Cretaceous (Upper Nemegt Beds), Altan Ula III, Nemegt Basin, Gobi Desert

(see also Plates II—V)

Fore limbs mounted from the plaster casts, with the missing parts restorted. Type specimen (Z. Pal. No. MgD-I/6); $\times 0.1$.

Photo: W. Skarżyński

H. Osmólska & E. Roniewicz: Deinocheiridae, a new dinosaur family

H. OSMÓLSKA & E. RONIEWICZ: DEINOCHEIRIDAE, A NEW DINOSAUR FAMILY

PLATE II

Upper Cretaceous (Upper Nemegt Beds), Altan Ula III, Nemegt Basin, Gobi Desert

(see also Plates I, III—V)

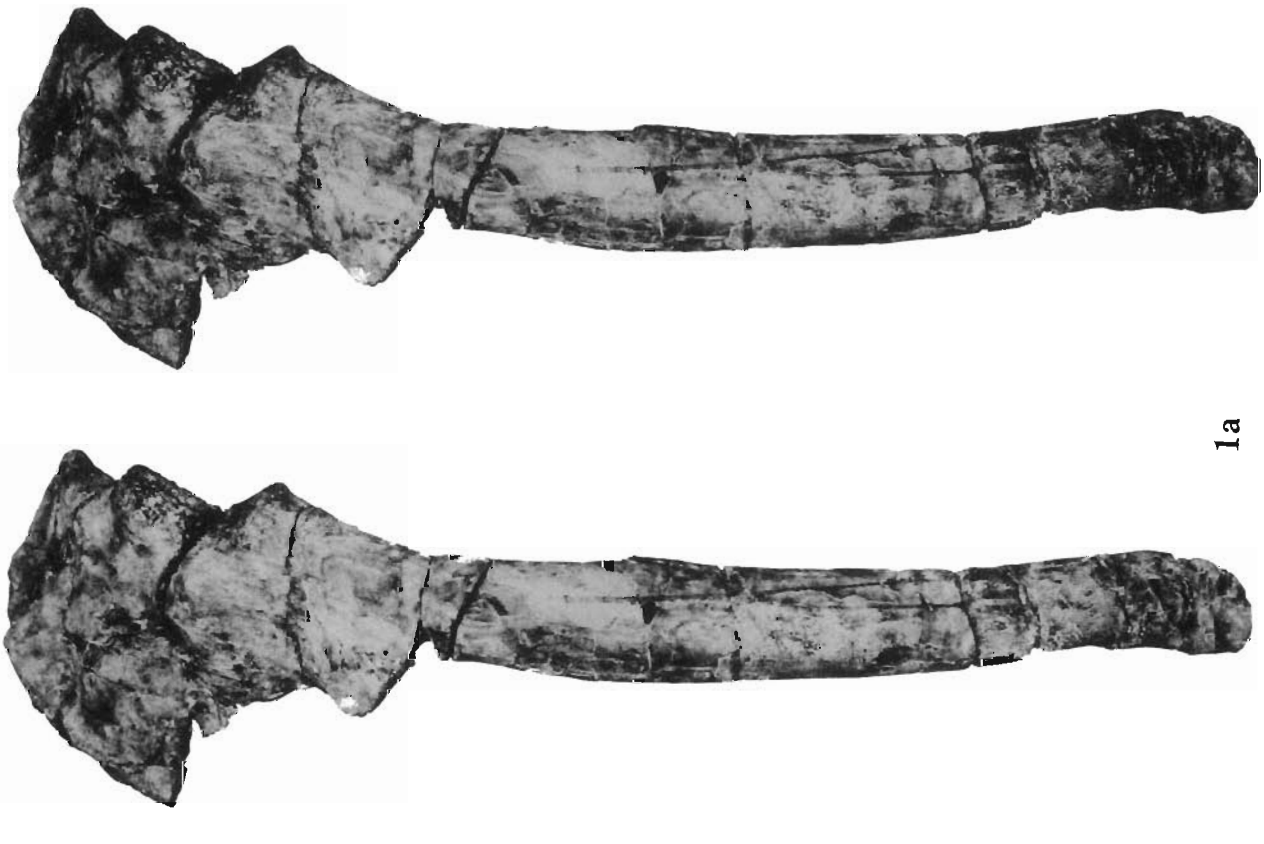
Fig. 1*a*. Stereo-photograph of the right scapulocoracoid, external view; × 0.11.
Fig. 1*b*. The same specimen, posterior view; × 0.11.
Fig. 1*c*. The same specimen, internal view; × 0.11.

Z. Pal. No. MgD-I/6

Photo: J. Błaszyk & W. Skarżyński

1c

1b



1a

H. OSMÓLSKA & E. RONIEWICZ: DEINOCHEIRIDAE, A NEW DINOSAUR FAMILY

PLATE III

Page

Deinocheirus mirificus n. gen., n. sp. 8

Upper Cretaceous (Upper Nemegt Beds), Altan Ula III, Nemegt Basin, Gobi Desert

(see also Plates I, II, IV, V)

Fig. 1. Stereo-photograph of the left humerus: *a* anterior view, *b* posterior view (Z. Pal. No. MgD-I/6); × 0.15.

Photo. W. Skarżyński

1b

1a

H. OSMÓLSKA & E. RONIEWICZ: DEINOCHEIRIDAE, A NEW DINOSAUR FAMILY

PLATE IV

Upper Cretaceous (Upper Nemegt Beds), Altan Ula III, Nemegt Basin, Gobi Desert

(see also Plates I—III, V)

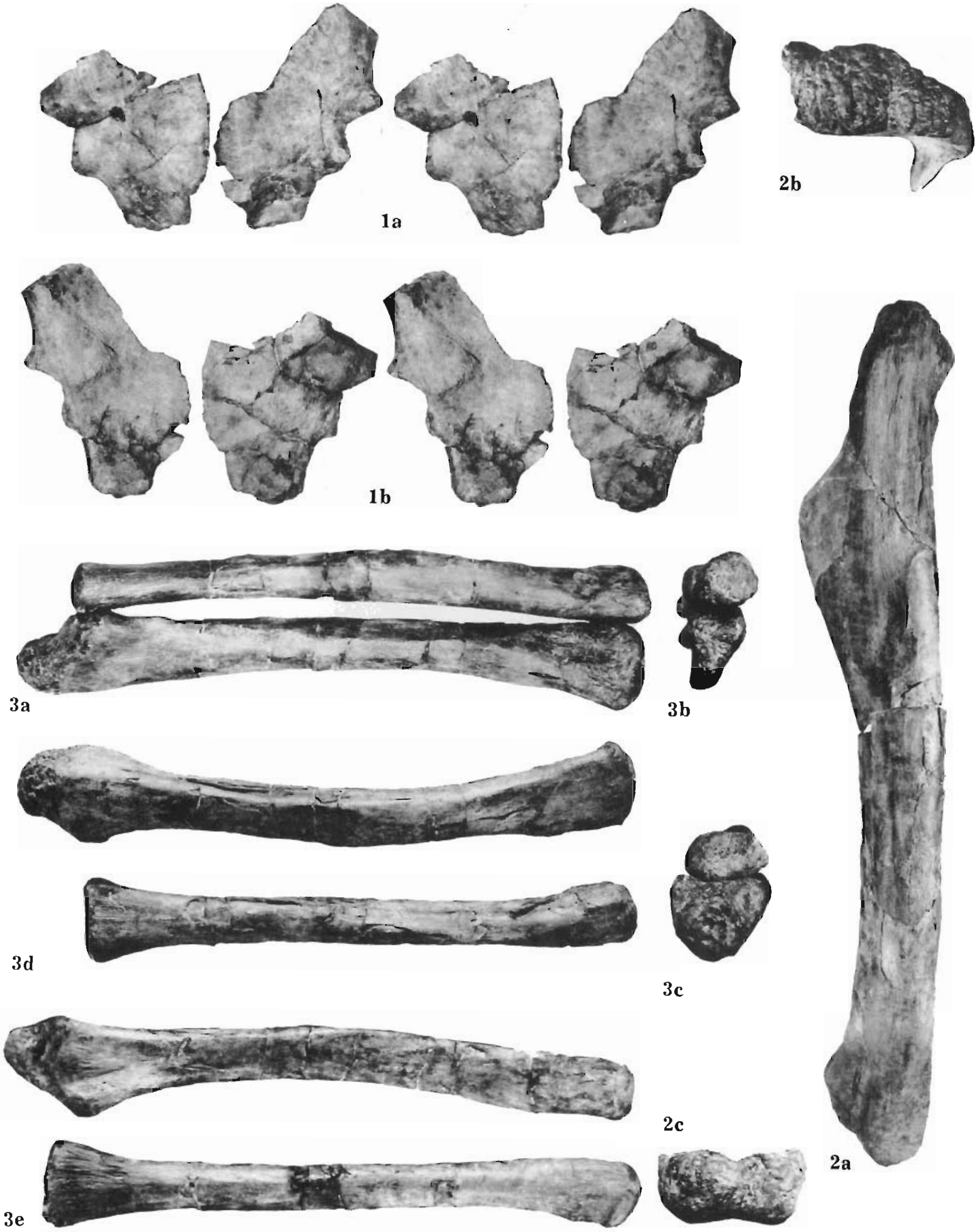
Fig. 1. Stereo-photograph of the coracoids and the adjoining parts of the scapulae: *a* external view, *b* internal view; × 0.07.

Fig. 2. Left humerus: *a* lateral view, *b* proximal view, *c* distal view; × 0.15.

Fig. 3. Left ulno-radius: *a* medial view, *b* distal view, *c* proximal view, *d* posterior view of the ulna and anterior view of the radius, *e* internal view of the ulna and internal view of the radius; × 0.15.

(Z. Pal. No. MgD-I/6)

Photo: J. Błaszyk & W. Skarżyński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2b
1b
3a
3b
3d
3c
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2a
3e

Palaeontologia Polonica, No. 21, 1969

H. OSMÓLSKA & E. RONIEWICZ: DEINOCHEIRIDAE, A NEW DINOSAUR FAMILY

PLATE V

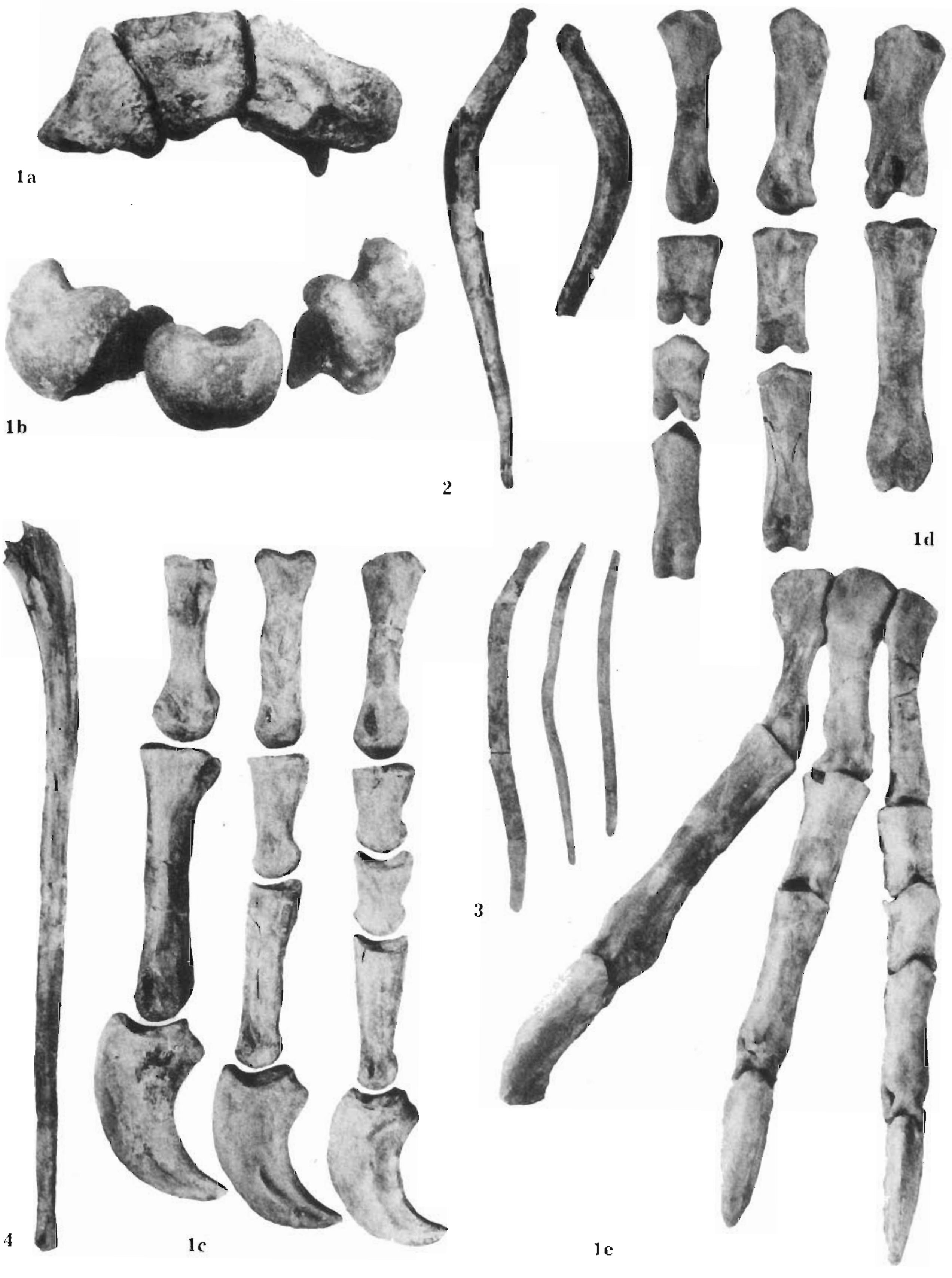
Upper Cretaceous (Upper Nemegt Beds), Altan Ula III, Nemegt Basin, Gobi Desert

(see also Plates I - IV)

Fig. 1. *a* Left metacarpus, proximal articular surfaces,
b the same, distal articular surfaces, × 33,
c left manus, digits and metacarpals, lateral view,
d the same (without unguals), palmar view,
e the same, dorsal view; × 0.15.
Fig. 2. Supposed ceratobranchials, dorsal view; × 0.22.
Fig. 3. Abdominal ribs; × 0.22.
Fig. 4. Right dorsal rib, posterior view; × 0.12.

(Z. Pal. No. MgD-I/6)

Photo: J. Błaszyk & W. Skarżyński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