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Theropod dinosaurs from Late Cretaceous deposits in the northeastern Aral Sea region, Kazakhstan

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Abstract

Seven theropod taxa (Tyrannosauridae indet., Ornithomimidae indet., Therizinosauroidea cf. *Neimongosaurus* sp., Therizinosauroidea indet., Caenagnathidae indet., Dromaeosaurinae indet., and Velociraptorinae indet.) have been identified from the Santonian Bostobe Formation, and four taxa (Tyrannosauridae indet., Ornithomimidae indet., Therizinosauroidea indet., and Dromaeosauridae indet.) are known from the underlying Turonian Zhirkindek Formation of the northeastern Aral Sea region in Kazakhstan. These theropod faunas are similar in composition to faunas from the Turonian Bissekty Formation of Uzbekistan, Santonian Yalovach Formation of Tajikistan, and Turonian–Santonian Irendabasu and Bayanshiree (upper part) formations of northern China and southern Mongolia. The therizinosauroid cf. *Neimongosaurus* sp., known from an isolated femur, is the only theropod taxon from Kazakhstan currently identifiable to generic level. A therizinosauroid similar to *Neimongosaurus* is reported here for the first time; this genus was known previously from the Irendabasu Formation of northern China.

Keywords: Dinosauria; Theropoda; Bostobe Formation; Zhirkindek Formation; Late Cretaceous; Kazakhstan

1. Introduction

Upper Cretaceous continental to marginal marine deposits are widespread on the Lower Syr-Darya or Dzhusaly Uplift in the northeastern Aral Sea region of central Kazakhstan. Several dinosaur localities in this region have been discovered since1956, the majority of which are in the Bostobe Formation (Fig. 1). Rozhdestvensky (1968) provided a detailed description of the skull and postcranial elements of the hadrosaurine *Aralosaurus tuberiferus* Rozhdestvensky, 1968 from this unit at the Shakh-Shakh locality, and Shilin and Suslov (1982) described a possible lambeosaurine *Arstanosaurus akkurganensis* Shilin and Suslov, 1982 from the Akkurgan locality. Based on fragmentary maxilla, the latter taxon is now considered a nomen dubium (e.g., Norman and Kurzanov, 1997; Horner et al., 2004). Blade-like theropod ungual phalanges from Shakh-Shakh were described in detail by Suslov (1982). Preliminary identifications of other dinosaurs from the Bostobe Formation were published by Nurumov (1964), Rozhdestvensky (1964, 1970a,b, 1976), Rozhdestvensky and Khozatsky (1967), and Nessov (1995). Nessov and Udovichenko (1986), Nessov (1988, 1997), Nessov and Khisarova (1988), and Kordikova et al. (2001) provided some data on microvertebrates from the formation recovered by screenwashing. Dyke and Malakhov (2004) published on several isolated theropod, sauropod, ornithopod, and ceratopsian teeth from three unspecified sites in the Bostobe Formation. The single supposed ceratopsian tooth, identified by these authors as "Ceratopsidae incertae sedis" (Dyke and Malakhov, 2004, fig. 4E), is more likely to be an unidentifiable bone fragment, rendering the presence of ceratopsids in the Bostobe Formation dubious.

Here I describe isolated theropod bones and teeth from various sites in the Zhirkindek and Bostobe formations, most of which were collected by L.A. Nessov in 1980 and 1982.

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Fig. 1. Schematic map of the northeastern Aral Sea region, Kazakhstan, with positions of Upper Cretaceous dinosaur localities (asterisks): 1, Tyul'kili; 2, Shakh-Shakh I and II; 3, Buroinak I and II; 4, Akkurgan; 5, Baibishe; 6, Egizkara.

1.1. Measurements

Teeth: BW, basal width; DSDI, denticle size difference index; FABL, fore-aft-basal length; TCH, tooth-crown height. Femur: L, length (from greater trochanter to lateral distal condyle); PW, width of proximal end (from greater trochanter to head); HD, anteroposterior diameter of head; MW, mediolateral width at midshaft; DW, width of distal end. All measurements are in mm.

1.2. Geographic and stratigraphic terms

For local Kazakh place names I use transliterations of the Russian spelling of these names as they appear on the maps of the General Staff of the Soviet Army, which are the most reliable geographic maps currently available for the region. Some of these geographic terms may have new Kazakh spellings that are not yet well established and may vary between sources. For transliteration of stratigraphic terms I follow the recommendation of Russian geological journals translated into English using geographic place names that form the basis for designations of stratigraphic units without the Russian adjective derivational suffix. Thus I use "Bostobe Formation" (as in Kordikova et al., 2001) rather than "Bostobynskaya Formation" used by Dyke and Malakhov (2004). For Mongolian stratigraphic terms and locality names I follow the transliteration recommended by Benton (2000).

1.3. Institutional abbreviations

CCMGE, Chernyshev's Central Museum of Geological Exploration, Saint Petersburg, Russia; IZK, Laboratory of Palaeobiology, Institute of Zoology, National Academy of Science, Alma-Ata, Kazakhstan; ZIN PH, Palaeoherpetological Collection, Zoological Institute, Russian Academy of Sciences, Saint Petersburg, Russia.

2. Dinosaur localities

Tyul'kili [=Kankazgan]. An isolated hill about 80 km north of Dzhusaly [=Zhosaly, =Jhosaly] station. Grey clays and sands of the Zhirkindek Formation. Local sites TUL-5, -7v, -7g and -15. Dinosaurs: Tyrannosauridae indet., Ornithomimidae indet., Therizinosauroidea indet., Dromaeosauridae indet., Sauropoda indet., and Hadrosauridae indet.

Shakh-Shakh I and II [=Baibolat, =Zhalmauz]. A nearly continuous series of outcrops located about 70 km northeast of Dzhusaly station. Grey clays and reddish sands of the Bostobe Formation. Local sites Shakh-2, -3, KAD-3, -5, and -7. Dinosaurs: Tyrannosauridae indet., Ornithomimidae indet., Therizinosauroidea indet., Caenagnathidae indet., ?Troodontidae indet., Dromaeosauridae indet., Sauropoda indet., *Aralosaurus tuberiferus* (Hadrosaurinae), and Ankylosauridae indet.

Buroinak I and II. A low mountain ridge 110–120 km north-northeast of Dzhusaly station. White and red clays and sands of the Bostobe Formation. Local site BOR-7. Dinosaurs: Tyrannosauridae indet., Therizinosauroidea indet., Sauropoda indet., Hadrosauridae indet., and Ankylosauria indet.

Akkurgan [=Akkurgan-Boltyk]. An isolated hill about 130 km north of Dzhusaly station. Grey sands in the upper part of the Bostobe Formation. Local site AKK-3. Dinosaurs: Tyrannosauridae indet. and ?Lambeosaurinae indet. [=*Arstanosaurus akkurganensis*, nomen dubium].

Baibishe. Series of isolated hills some 120 km north-northwest of Dzhusaly station. Red sands of lower or middle part of the Bostobe Formation. Local sites BAI-3 and -3k. Dinosaurs: Tyrannosauridae indet., cf. *Neimongosaurus* sp. (Therizinosauroidea), Therizinosauroidea indet., Dromaeosauridae indet., Sauropoda indet., and Hadrosauridae indet.

Egizkara. An escarpment 2–3 km northeast of the isolated hill Egizkara, about 105 km north of Dzhusaly station. Grey clays and reddish sands in the upper part of the Bostobe Formation. Dinosaurs: Hadrosauridae indet.

In a recent review of dinosaur distribution (Weishampel et al., 2004, p. 594), three Upper Cretaceous dinosaur-bearing units were listed for Kzyl-Orda Province [=Qyzylorda Oblysy] of Kazakhstan: (1) Beleuta Svita, (2) Bostobe Svita, and (3) ''Manrakskaya'' Svita. In fact, 1 and 2 refer to the same stratigraphic unit, the Bostobe Formation. The Beleuty [sic, named after Beleuty River] Formation was established for Upper Cretaceous continental deposits with plant remains in the Chu-Sarysu Depression, east of the Lower Syr-Darya Uplift (Nikiforova, 1960), and this term has since been abandoned (Lobacheva, 1979). The name was sometimes incorrectly applied to the dinosaur-bearing beds of the Lower Syr-Darya Uplift (e.g., Nikiforova, 1960; Rozhdestvensky, 1964, 1968; Bazhanov, 1972), which were referred to initially as the Bostobe Formation by Samodurov (1958; see also, e.g., Martinson et al., 1966; Geology of the USSR, 1970; Martinson and Nikitin, 1978; Nessov and Khisarova, 1988; Martinson, 1990; Nessov, 1995, 1997; Kordikova et al., 2001). The Manrak Formation is not found in Kzyl-Orda Province, but in the Zaisan Depression of Eastern Kazakhstan Province, where the Taizhuzgen locality has produced dinosaur eggs (Bazhanov, 1961; Nessov, 1995). The review by Weishampel et al. (2004), as well as its earlier version (Weishampel, 1990), contains numerous other mistakes concerning dinosaur localities in the former Soviet Union and should be used with caution.

3. Systematic palaeontology

Dinosauria Owen, 1842
Saurischia Seeley, 1888
Theropoda Marsh, 1881
Tyrannosauridae Osborn, 1905

Tyrannosauridae indet.
Fig. 2

[= Tyrannosauridae indet.: Nessov, 1995, pp. 105, 107; = large tyrannosaurid theropod (cf. *Alectrosaurus*): Dyke and Malakhov, 2004, fig. 4A]

Material. ZIN PH 10/49, tooth (KAD-7, 1980). ZIN PH 11-14/49, tooth fragments (KAD-3, 1980). ZIN PH 15/49, tooth fragment (TUL-7g, 1982). ZIN PH 16/49, tooth (Shakh-3, 1982). ZIN PH 17/49, tooth fragment (Shakh-Shakh). ZIN PH 18/49, tooth fragment (BAI-3, 1982). ZIN PH 19-22/49, tooth fragments (AKK-3, 1982). ZIN PH 5/49, neural spine from dorsal vertebra (TUL-5, 1982).

Description. A number of isolated, usually incomplete tooth crowns are referable to the Tyrannosauridae. The most complete tooth (Fig. 2A–C) lacks the apical portion and would have exceeded 80 mm when complete. All measured tooth fragments ($n = 11$) are large, with FABL ranging from 22.1–27.7 mm, $M = 24.65 \pm 0.56$ and BW 9.6–13.4 mm, $M = 11.39 \pm 0.36$. The crowns are recurved, distinctly flattened labiolingually, and have serrated mesial and distal carinae. The labiolingual flattening as expressed by the BW/FABL index is 0.38–0.57, $M = 0.46 \pm 0.02$, $n = 11$. Denticles can only be measured on ZIN PH 10/49, where there are 17 denticles per 5 mm mesially and 13 denticles per 5 mm distally.

A fragment of neural arch and spine from a dorsal vertebra (Fig. 2D–F) is also referable to Tyrannosauridae on the basis of its strong similarity with definitive tyrannosaurid remains (e.g, Lambe, 1917; Brochu, 2003). The neural spine is robust, trapezoidal in lateral view, and only slightly expanded posteriorly. The spine is higher anteriorly than posteriorly, suggesting that it comes from a posterior dorsal vertebra (Brochu, 2003). It has extremely rugose surfaces along much of the length of the anterior and posterior grooves for insertion of interspinous ligaments. These grooves separate the zygapophyses. The widest transverse part of the neural spine is some distance ventral to its tip.

Discussion. The teeth are similar in size to the largest teeth of tyrannosaurids from the Turonian Bissekty Formation in Uzbekistan (Sues and Averianov, in prep.). The difference in the BW/FABL index between these two samples (0.41–0.70, $M = 0.51$, $n = 77$ for the Bissekty sample) is not significant at $p < 0.10$. The DSDI can be calculated only for the single specimen, ZIN PH 10/49, where it is 1.308. This value is notably higher than in other tyrannosaurids, which have this index around 1.0 (Rauhut and Werner, 1995). However, the taxonomic significance of this character for the Shakh-Shakh tyrannosaurid could be tested only on the larger sample. The absence of smaller tyrannosaurid teeth from the northeastern Aral Sea region sample is apparently owing to a collecting bias. Nessov (1995) referred labiolingually compressed tyrannosaurid teeth from the Bissekty Formation and various other Upper Cretaceous sites in Uzbekistan to *Alectrosaurus* sp. This identification was followed by Dyke and Malakhov (2004, fig. 4A), who referred isolated tyrannosaurid teeth from an unspecified site in the Bostobe Formation to cf. *Alectrosaurus* sp. However, the original material of *Alectrosaurus olseni* Gilmore, 1933, from the Irendabasu Formation in northern China, consists of hindlimb and pelvic elements (Gilmore, 1933; Mader and Bradley, 1989). A more complete skeleton, including a skull, from the Bayanshiree Formation in

Fig. 2. Tyrannosauridae indet. Localities Shakh-Shakh, Bostobe Formation (A–C) and Tyul'kili, Zhirkindek Formation (D–F), northeastern Aral Sea region, Kazakhstan. A–C, ZIN PH 10/49, tooth, in labial or lingual (A), distal (B), and basal (C) views. D–F, ZIN PH 5/49, dorsal neural spine, in posterior (D), lateral (E), and anterior (F) views. Scale bar represents 10 mm.

Mongolia that was referred to the same taxon by Perle (1977) has not yet been described in detail and is not definitely referable to *Alectrosaurus* (Holtz, 2004). Blade-like lateral teeth from the Upper Cretaceous of Kazakhstan, Uzbekistan, and of "*Alectrosaurus*" from Mongolia, appear to exhibit the plesiomorphic morphology for Tyrannosauridae and cannot be identified more precisely. In more derived, Campanian–Maastrichtian tyrannosaurids, the teeth are much more incrassate, with a BW/FABL index close to or greater than 1.0 (Holtz, 2004).

Ornithomimosauria Barsbold, 1976
Ornithomimidae Marsh, 1890

Ornithomimidae indet.
Fig. 3

[= Ornithomimidae [indet.]: Rozhdestvensky and Khozatsky, 1967, p. 87; Nessov and Khisarova, 1988, p. 5; Nessov, 1995, p. 105]

Material. ZIN PH 6/49, anterior caudal (Shakh-Shakh). ZIN PH 8/49, anterior caudal (KAD-5, 1980). ZIN PH 7/49, posterior caudal (KAD-3, 1980). ZIN PH 9/49, posterior caudal (KAD-5, 1980). ZIN PH 36/49, posterior caudal (TUL-15, 1982). ZIN PH 40/49, posterior caudal (Shakh-Shakh). ZIN PH 2/49, right metacarpal III (Shakh-Shakh). ZIN PH 3/49, manual ungual (Shakh-2). ZIN PH 26/49, fragment of juvenile left tibia (Shakh-Shakh). ZIN PH 23/49, distal fragment of juvenile right second metatarsal (KAD-7, 1980). ZIN PH 4/49, right pedal phalanx IV-1 (KAD-7, 1980).

Description. On anterior caudals (Fig. 3A–E), the centrum is elongated, laterally compressed, constricted at the middle, and bears subcircular anterior and posterior articular surfaces. The ventral surface of the centrum has either a distinct ventral keel (ZIN PH 8/49) or triangular depressions at the anterior and posterior margins that incise these margins ventrally (ZIN PH 6/49). The transverse processes are either thin and blade-like, with wide bases more or less level with the neural canal (ZIN PH 6/49), or are small spur-like projections closer to the posterior end (ZIN PH 8/49). The prezygapophyses extend slightly beyond the anterior end of the centrum (ZIN PH 8/49, broken in ZIN PH 6/49). The prezygapophyseal articular surfaces are elongate and face dorsomedially. The neural spine is relatively tall (ZIN PH 6/49, broken in ZIN PH 8/49). The anterior interspinous recess is long and cleft-like, with a well-developed floor.

On posterior caudals (Fig. 3F–I) the centrum is less constricted at mid-length, with the anterior and posterior articular surfaces laterally (ZIN PH 9/49) or dorsoventrally (ZIN PH 7/49) compressed. The ventral surface of the centrum is flat, with remnants of the ventral keel present in ZIN PH 9/49, or with a complete longitudinal groove, as in ZIN PH 7/49. There are no transverse processes. The neural spine is long and quite low. The prezygapophyses are triangular in cross-section. The anterior interspinous recess is shorter than on the anterior caudals and has a floor.

Metacarpal III (Fig. 3J–O) has a triangular proximal articular surface and a proximal shaft that is triangular in cross-section. At the proximal end, the medial and lateral surfaces are slightly concave and the ventral surface is slightly convex. The distal articular end is symmetrical and triangular in

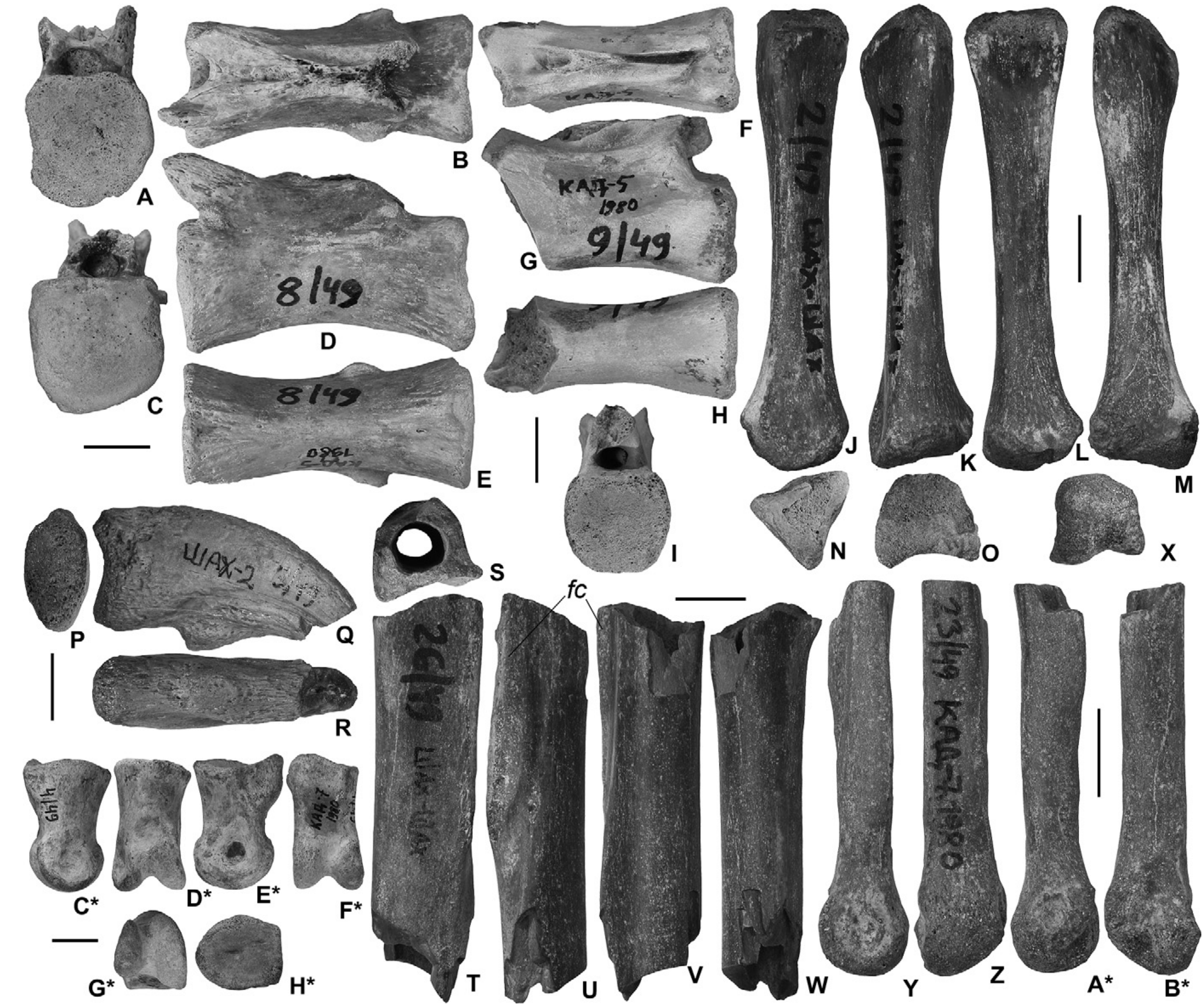

Fig. 3. Ornithomimidae indet. Locality Shakh-Shakh, Bostobe Formation, northeastern Aral Sea region, Kazakhstan. A–E, ZIN PH 8/49, anterior caudal, in anterior (A), dorsal (B), posterior (C), lateral (D), and ventral (E) views. F–I, ZIN PH 9/49, posterior caudal, in dorsal (F), lateral (G), ventral (H), and posterior (I) views. J–O, ZIN PH 2/49, right metacarpal III, in lateral (J), anterior (K), medial (L), posterior (M), proximal (N), and distal (O) views. P–R, ZIN PH 3/49, manual ungual phalanx, in proximal (P), lateral or medial (Q), and ventral (R) views. S–W, ZIN PH 26/49, juvenile left tibia fragment, in proximal (S), anterior (T), lateral (U), posterior (V), and medial (W) views. X–Z, A*, B*, ZIN PH 23/49, right metatarsal II distal fragment, in distal (X), lateral (Y), anterior (Z), medial (A*), and posterior (B*) views. C*–H*, ZIN PH 4/49, right pedal phalanx IV-1, in lateral (C*), anterior (D*), medial (E*), posterior (F*), distal (G*), and proximal (H*) views. Abbreviation: fc, fibular crest. Scale bar represents 10 mm.

outline. The lateral distal condyle is only slightly larger than the medial proximal condyle. The intercondylar groove is broad and shallow. The lateral collateral ligament pit is shallow, and the medial one is indistinct. The greatest length of metacarpal III is 69.7 mm.

The manual ungual phalanx (Fig. 3P–R) is moderately curved and flattened mediolaterally. Its proximal articular surface is symmetrical in proximal view and divided by a low ridge. A well-developed ventral flexor tubercle is situated distal to the proximal end at a distance equivalent to about one-third the length of the ungual. Lateral grooves extend distally from the region of the flexor tubercle. The ventral rims of these grooves protrude slightly laterally.

A fragment of tibia represents the proximal portion of the bone bearing most of the fibular crest, though lacking the proximal end (Fig. 3S–W). The preserved shaft is hollow and straight, as in other ornithomimids. The anterior side of the shaft is flat or slightly concave whereas the remaining sides are convex. Along the anteromedial edge at the proximal end, the elevated base of the cnemial crest is preserved. Most of the anterolateral edge is occupied by the proximally incomplete fibular crest. It is straight and of even height, continuing distally as a low ridge. On the lateral side there is an oblique, shallow trough for the fibula that is restricted by the fibular crest anteriorly and by a much lower parallel ridge posteriorly. At the distal end of the fibular crest, opposite the parallel low ridge, there are two nutrient foramina.

Metatarsal II is represented by a distal end (Fig. 3X–Z, A*, B*). It is a straight bone that is not deflected laterally at its distal end. Its shaft is rectangular in cross-section, with flat lateral, anterior, medial and posterior surfaces. A prominent ridge extends along the posteromedial edge of the bone some distance proximal to the distal end. The distal articular surface is oblique in anteroposterior view, with its lateral condyle projecting further distally. In distal view, the distal articular surface is almost symmetrical; the lateral condyle is slightly larger than the medial. The condyles are separated by a shallow posterior groove. The collateral ligament fossa is large and shallow laterally, but small and deeper medially. The mediolateral width of the distal articular surface is 11.1 mm.

The proximal phalanx of pedal digit IV (Fig. 3C*–H*) is short (maximum length 28.4 mm). Its proximal articular surface is oval in outline (with its long axis orientated anteroposteriorly), concave, and divided posteriorly into two unequal parts by a notch, corresponding to the shape of the distal condyle of metatarsal IV. The phalanx is anteroposteriorly constricted at its distal condyle. The distal articular end is ginglymoid and asymmetrical, with a distinctly larger medial condyle. The collateral ligament fossa is deeper on the medial side.

Discussion. The anterior and posterior caudals ZIN PH 8 and 9/49 come from the same locality and are similar in size and preservation; they may pertain to the same individual. The posterior caudal ZIN PH 7/49 belongs to a considerably larger individual (Table 1), approximately 35% larger than adults of *Gallimimus bullatus* Osmólska et al., 1972 from the Maastrichtian of Mongolia (Osmólska et al., 1972).

The metatarsal II from Shakh-Shakh is straighter at its distal end than that of *Gallimimus* (Osmólska et al., 1972, pl. 49); this may be a juvenile character.

The tibia from Shakh-Shakh differs from that of *Gallimimus* (Osmólska et al., 1972) and the ornithomimid from the Bissekty Formation, Uzbekistan, in that it is of constant height along its length, and has a lower and less sharp fibular crest that extends further proximally than the distal end of the cnemial crest. In Mongolian and Uzbek ornithomimids, the proximal end of the fibular crest is approximately level with the distal end of the cnemial crest, and the fibular crest is higher at mid-length than at either end. A trough for the fibula, with a distinct posterior crest paralleling the fibular crest, is present in ZIN PH 26/49 and *Gallimimus* (Osmólska et al., 1972, pl. 47), but not in the Uzbek ornithomimid.

There are two nutrient foramina on the tibia fragment from Shakh-Shakh, whereas in other ornithomimids (Osmólska et al., 1972) and theropods there is a single foramen (tibial foramen of Naish, 1999). This could represent individual variation.

The ornithomimid postcranial skeleton is generally regarded as conservative (Osmólska et al., 1972; Russell, 1972), but detailed descriptions are available for only few taxa. The aforementioned difference in the tibial structure of the Shakh-Shakh ornithomimid suggests its attribution to a distinct taxon, which, however, cannot be adequately diagnosed without additional materials.

Table 1
Measurements of caudal vertebrae of Ornithomimidae indet. from Shakh-Shakh (Bostobe Formation) and Tyul'kili (Zhirkindek Formation), Kazakhstan

Specimen	Measurements				
	ACH	ACW	CL	PCH	PCW
Shakh-Shakh					
ZIN PH 6/49	—	—	—	20.6	22.5
ZIN PH 8/49	19.5	—	44.3	19.7	20.1
ZIN PH 9/49	—	—	—	15.1	16.2
ZIN PH 7/49	16.4	24.3	54.0	16.4	23.6
ZIN PH 40/49	12.1	19.7	—	—	—
Tyul'kili					
ZIN PH 36/49	7.4	8.3	21.1	7.0	8.1

ACH, anterior centrum height; ACW, anterior centrum width; CL, centrum length (ventral); PCH, posterior centrum height; PCW, posterior centrum width.

Therizinosauroidea Maleev, 1954
Neimongosaurus Zhang et al., 2001

cf. *Neimongosaurus* sp.
Fig. 4

[= *Tarbosaurus* sp.: Nessov, 1995, p. 40, pl. 10, fig. 1; Nessov, 1997, pl. 58, fig. 7]

Material. CCMGE 601/12457, right femur (BAI-3k, 1982).

Description. The femur is complete and apparently belongs to an adult (L, 512; PW, 134; HD, 55; MW, 76; DW, 116). It is only slightly bent in the anteroposterior plane. The lateral margin is remarkably straight and the anterior surface is flat. The head is medially directed. The head and greater trochanter are separated by a shallow groove dorsally. The greater trochanter is a low rounded ridge, approximately level with the head, and expands posteriorly 1.5 times farther than the head. The anterior trochanter is broken off, but, judging from its base, it was spine-like. The base of the anterior trochanter is level with the distal margin of the femoral head. The shaft is columnar and barely constricted at midshaft. The fourth trochanter forms a low, posteromedially located ridge about one-third of the total element length distal from the head. The lateral distal condyle does not protrude laterally beyond the lateral margin of the shaft. It is directed almost ventrally while the medial condyle is directed ventromedially. The distal end is U-shaped in distal view, incised by a deep intercondylar fossa that separates the lateral and medial condyles posteriorly; the anterior groove separating the condyles is extremely shallow. The lateral condyle is distinctly narrower mediolaterally than the medial condyle and has a pointed posterior edge (tibiofibular crest).

Discussion. Nessov (1995) referred CCMGE 601/12457 to *Tarbosaurus* sp. He did not provide a rationale for this

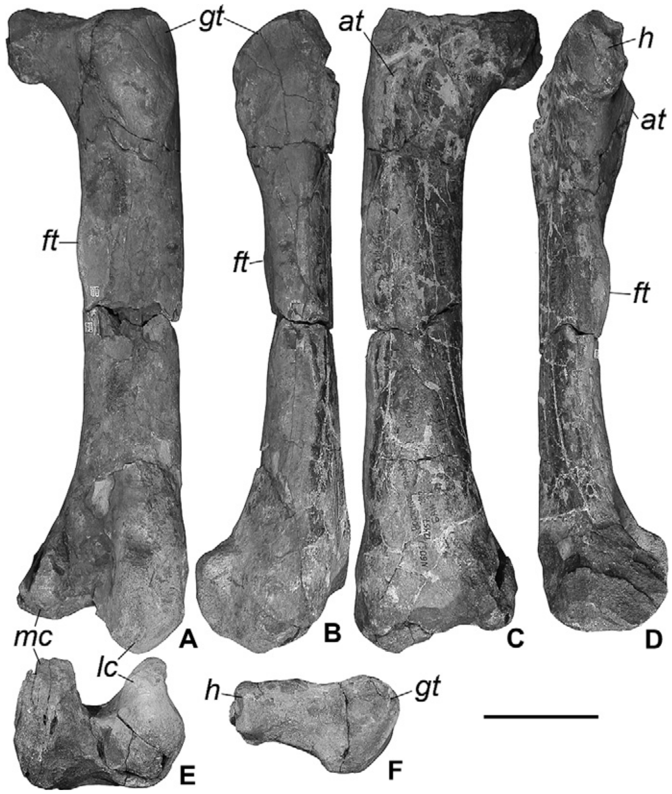

Fig. 4. cf. *Neimongosaurus* sp. Locality Baibishe, Bostobe Formation, northeastern Aral Sea region, Kazakhstan. CCMGE 601/12457, right femur in posterior (A), lateral (B), anterior (C), medial (D), distal (E), and proximal (F) views. Abbreviations: at, anterior trochanter; ft, fourth trochanter; h, femoral head; lc, lateral condyle; mc, medial condyle. Scale bar represents 100 mm.

identification, but it was apparently based on the similarity of this bone to the femur of *Tarbosaurus bataar* (Maleev, 1955) from the Maastrichtian of Mongolia (Maleev, 1974, figs 40, 41). Indeed, these bones are quite similar. However, the anterior trochanter is leaf-like in *Tarbosaurus*, as in other tyrannosaurids, as well as ornithomimids (Brochu, 2003; Carr et al., 2005), rather than spine-like as in CCMGE 601/12457. The fourth trochanter forms a low ridge in CCMGE 601/12457 and *Tarbosaurus*, but it is prominent and acuminate in other tyrannosauroids (Brochu, 2003; Carr et al., 2005). The distal lateral condyle projects laterally beyond the shaft in *Tarbosaurus* and *Tyrannosaurus rex* Osborn, 1905 from the Maastrichtian of North America (Brochu, 2003), but not in either CCMGE 601/12457 or the basal tyrannosauroid *Appalachiosaurus montgomeriensis* Carr et al., 2005 from the Campanian of the USA (Carr et al., 2005, fig. 16A). In *Appalachiosaurus*, however, the femoral lateral condyle is greatly reduced, which might be an autapomorphy of that taxon. In all tyrannosauroids, the lateral and medial distal condyles are separated by a distinct groove anteriorly, whereas a comparable groove is nearly absent in CCMGE 601/12457, rendering the distal end of the femur U-shaped in distal view. These differences are sufficient to rule out attribution of CCMGE 601/12457 to the Tyrannosauridae. On the other hand, such characteristics as a low and rounded greater trochanter, spine-like anterior trochanter, straight lateral margin with little or no lateral expansion of the lateral condyle, and low crescentic fourth trochanter are found among therizinosauroids (Russell and Dong, 1994; Xu et al., 1999, 2002; Zhang et al., 2001; Sues and Averianov, in prep.). In particular, except for being larger and more robust, CCMGE 601/12457 is virtually indistinguishable from the femur of *Neimongosaurus yangi* Zhang et al., 2001 from the Irendabasu Formation of northern China (Zhang et al., 2001, pp. 38, 39, pl. 3L) and is thus referred here to cf. *Neimongosaurus* sp. CCMGE 601/12457 differs from the therizinosauroid femur from Buroinak (Fig. 5L–P) described below, which has a dorsomedially projecting head that is distinctly higher than the greater trochanter, and an anteroposteriorly less expanded greater trochanter. This indicates the presence of at least two therizinosauroid taxa in the Bostobe Formation.

Therizinosauroidea indet.
Fig. 5

[= Therizinosauridae indet.: Rozhdestvensky, 1964, p. 229; 1970a, fig. 2b; 1976, fig. 2b; = cf. *Alectrosaurus*: Rozhdestvensky and Khozatsky, 1967, p. 87; Rozhdestvensky, 1970b, p. 51; = Dromaeosauridae incertae sedis: Suslov, 1982, p. 8, figs 2–4]

Material. ZIN PH 35/49, tooth (BAI-3k, 1982). ZIN PH 32/49, juvenile sacral centrum (TUL-5, 1982). ZIN PH 1/49, left metacarpal III lacking proximal end (TUL-7v, 1982). ZIN PH 24/49, proximal fragment of left femur (BOR-7, 1982). ZIN PH 37/49, proximal fragment of left femur (BAI-3k, 1982). ZIN PH 38/49, proximal fragment of left femur (TUL-14, 1982). ZIN PH 39/49, proximal fragment of left femur (TUL-4, 1982). ZIN PH 25/49, left(?) preungual(?) pedal phalanx of digit III or IV (BAI-3, 1982).

Description. The tooth is small (Fig. 5A, B; FABL, 2.2; BW, 1.2), with a bulbous crown that is distinctly wider mesiodistally than its root. The crown is almost symmetrical in labial/lingual view, labiolingually compressed, with one side (labial?) more convex than the other. The denticles are heavily worn. Apparently the denticles were larger on one (distal?) side.

A juvenile sacral centrum (Fig. 5C–F; centrum length 43.9 mm) is spool-shaped, with elongate, shallow lateral depressions. The anterior and posterior articular surfaces are platycoelous, with circular ventral and straight dorsal margins. The anterior articular surface is larger than the posterior. The ventral side of the centrum is flat, lacking ridges or grooves. At the neurocentral suture, close to the anterior end, there is an oval parapophysis.

Metacarpal III (Fig. 5G–K) is rather long, gracile, and slightly curved in mediolateral plane. Its shaft is triangular in cross-section proximally but becomes more circular towards the distal end. The lateral surface is flat and the medial surface is slightly convex. The distal articular end is mediolaterally narrow and parallelogram-shaped, with oblique dorsal and ventral margins. The lateral distal condyle is missing but

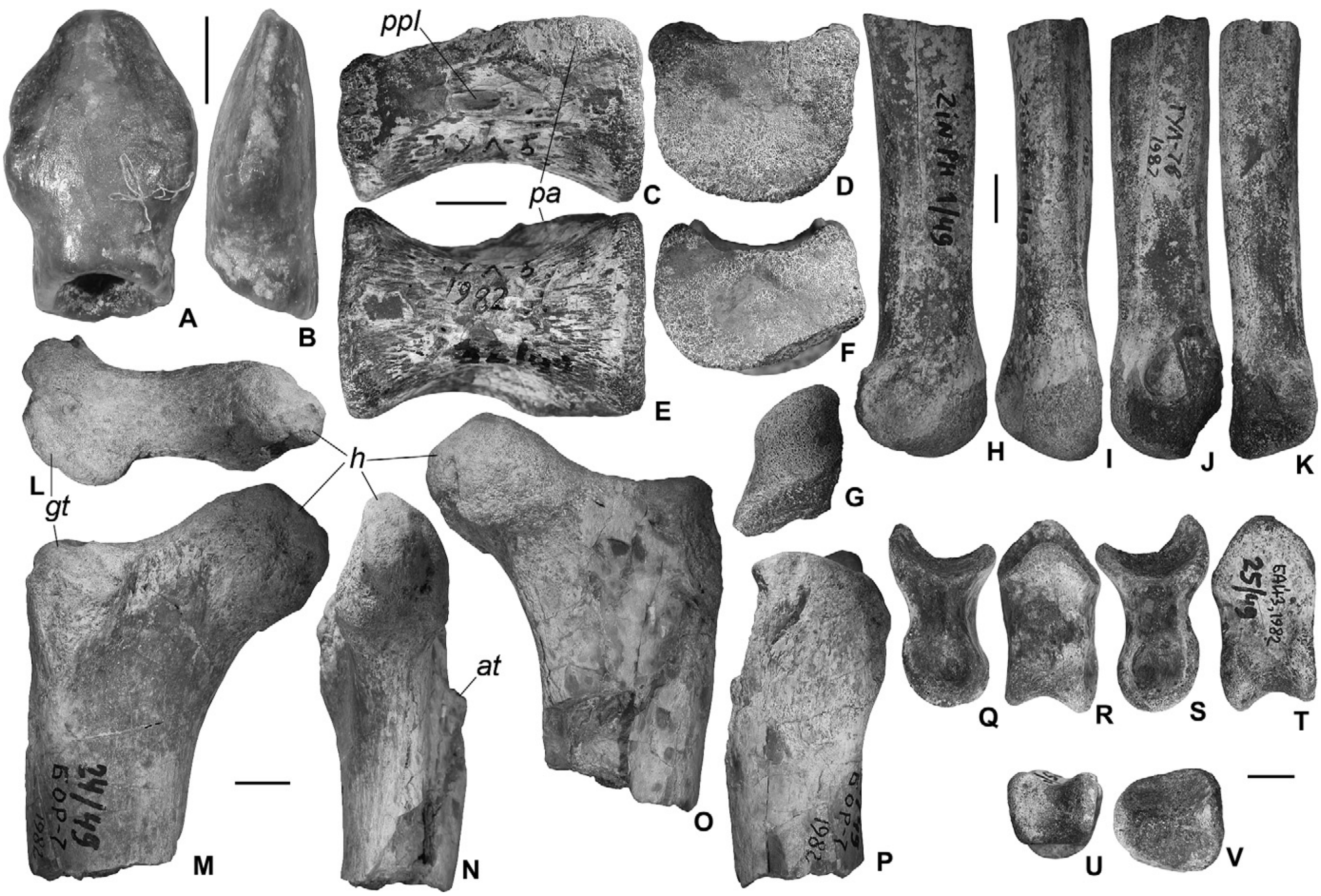

Fig. 5. Therizinosauroidea indet. Localities Baibishe (A, B, Q−V), Buroinak (L−P), Bostobe Formation, and Tyul'kili (C−K), Zhirkindek Formation, northeastern Aral Sea region, Kazakhstan. A, B, ZIN PH 35/49, tooth, in labial? (A) and distal? (B) views. C−F, ZIN PH 32/49, juvenile sacral centrum, in lateral (C), anterior (D), ventral (E), and posterior (F) views. G−K, ZIN PH 1/49, left metacarpal III distal fragment, in distal (G), medial (H), anterior (I), lateral (J), and posterior (K) views. L−P, ZIN PH 24/49, left femur proximal fragment, in proximal (L), posterior (M), medial (N), anterior (O), and lateral (P) views. Q−V, ZIN PH 25/49, left? preungual? phalanx of pedal digit III or IV, in medial? (Q), anterior (R), lateral? (S), posterior (T), distal (U), and proximal (V) views. Abbreviations: at, anterior trochanter; gt, greater trochanter; h, femoral head; pa, parapophysis; ppl, pseudopleurocoel. Scale bar represents 1 mm in A, B; 10 mm in C−V.

evidently was similar in size to the medial condyle. The medial distal condyle is deflected medially. The intercondylar groove is shallow. The lateral collateral ligament fossa is deep and well delimited, but the medial one is almost absent. The minimum mediolateral width of the distal articular end is 15.5 mm.

The femur is represented by four proximal fragments of similar morphology (Fig. 5L−P). The largest is ZIN PH 37/49 with PW = 124, HD = 53. The proximal end is hourglass-shaped in proximal view, with a saddle-shaped proximal surface. The head, capping a well-developed neck, projects medially and dorsally relative to the level of the greater trochanter. The articular surface of the head bears a large posteromedial tubercle that is bounded by notches anteriorly and posteriorly. The greater trochanter is ridge-like and obliquely orientated. The anterior trochanter is greatly reduced, spine-like, much smaller than the greater trochanter, and situated far distal to the latter. It is separated from the greater trochanter by a distinct notch.

A preungual phalanx, possibly belonging to pedal digit III or IV, is also known (Fig. 5Q−V). It is moderately elongate (greatest length is 42.2 mm). The proximal articular surface is deeply ginglymoid, with almost symmetrical proximal articular facets, a distinct dorsal lip, and an even more prominent ventral heel. The ventral and dorsal margins are concave in side view. The distal articular end has well-developed and slightly asymmetrical condyles. The collateral ligament fossa is better developed on one side (lateral?).

Discussion. The sacral centrum and third metacarpal from Tyul'kili, the femora from Buroinak, Baibishe, and Tyul'kili, and the tooth and pedal preungual phalanx from Baibishe are indistinguishable from the same elements known from therizinosauroids from the Turonian Bissekty Formation at Dzharakuduk, Kyzylkum Desert, Uzbekistan. At Dzharakuduk, at least two therizinosauroid taxa are present, differing from each other in the structure of some postcranial elements (Sues and Averianov, in. prep.), but only one morphology of femur is present, similar to ZIN PH 24/49 and different from the femur of cf. *Neimongosaurus* sp. from Baibishe described above (Fig. 4). The dorsomedially projecting head of this type of femur is similar to that of *Erliansaurus bellamanus*

Xu et al., 2002 from the Irendabasu Formation of China (Xu et al., 2002). An identical therizinosauroid femur is also known from the lower Santonian Yalovach Formation at the Kansai locality, Tajikistan (PIN collection).

The tooth ZIN PH 35/49 is very similar to the dentary teeth of *Erlikosaurus andrewsi* Perle, 1981 from the Bayanshiree Formation of Mongolia figured by Clark et al. (1994, fig. 12).

Therizinosauroids are identified here from the Baibishe locality for the first time (Nessov, 1988, 1995, 1997). Therizinosauroids were first identified from the Shakh-Shakh locality by Rozhdestvensky (1964) based on a giant manual ungual phalanx about 20 cm in length. Later (Rozhdestvensky, 1970b; Rozhdestvensky and Khozatsky, 1967), he re-identified this phalanx as cf. *Alectrosaurus*, based on its similarity to an ungual phalanx from the Irendabasu Formation in Inner Mongolia, China referred to that taxon by Gilmore (1933: fig. 9A). Rozhdestvensky (1970a, 1976) referred *Alectrosaurus* to the Therizinosauridae, but it has now been established that this taxon was based originally on a mixed assemblage of bones, some of which (including the lectotype hind foot) pertain to a tyrannosaurid while others, such as a humerus and manual phalanges, including the aforementioned large ungula phalanx, belong to a therizinosauroid (Mader and Bradley, 1989). Suslov (1982: figs 2–4) described and figured other blade-like therizinosauroid unguals from Shakh-Shakh, which he identified as dromaeosaurid manual and pedal unguals.

Of the three unguals figured by Suslov, one was considered a manual ungual (IZK 2/1) while the other two were regarded as pedal unguals (IZK 2/2 and 2/3). The ostensible manual ungual differs from the others by being more mediolaterally flattened, having a lip dorsal to the proximal articular surface, and in having a more strongly developed flexor tubercle. If the pedal unguals are correctly identified, the Shakh-Shakh therizinosauroid belongs to an advanced subclade, characterized by blade-like pedal unguals that would include *Erlikosaurus* Perle, 1981, *Segnosaurus* Perle, 1979, *Nanshiungosaurus* Dong, 1979, and *Therizinosaurus* Maleev, 1954 (Zhang et al., 2001).

Dromaeosauridae Matthew and Brown, 1922
Dromaeosaurinae Matthew and Brown, 1922

Dromaeosaurinae indet.
Fig. 6A–I

[= dromaeosaur: Dyke and Malakhov, 2004, fig. 4D]

Material. ZIN PH 27/49, tooth (KAD-7, 1980). ZIN PH 28/49, tooth (KAD-5, 1980). ZIN PH 29/49, tooth (KAD-7). ZIN PH 30/49, tooth (KAD-3, 1980). ZIN PH 31/49, tooth fragment (KAD-3). ZIN PH 33/49, tooth (BAI-3k, 1982).

Description. The teeth from Shakh-Shakh are thick-crowned, with FABL ranging from 9.1-16.7, $M = 13.44 \pm 1.44$, BW 7.2-9.5, $M = 12.4 \pm 1.01$ and BW/FABL 0.54-0.86, $M = 0.72 \pm 0.05$ ($n = 5$). The mesial carina is shifted to the lingual side of the crown. There are 14 denticles per 5 mm on the mesial carina and 15–17 denticles per 5 mm on the distal carina (ZIN PH 27/49 and 28/49).

The single dromaeosaurid tooth from Baibishe is much smaller (FABL, 3.1; BW, 1.5; BW/FABL, 0.48) and apparently from a juvenile. The crown is strongly curved distally (Fig. 6H). The mesial carina is lingually displaced and worn smooth. If it bore any denticles, they would have been very small. The distal carina bears six denticles per 1 mm, all of which are significantly worn. On the lingual side there are two poorly differentiated vertical ridges. The enamel is wrinkled.

Discussion. The dromaeosaurine teeth from Shakh-Shakh are similar to those described by Dyke and Malakhov (2004), which apparently were collected from the same locality, and to dromaeosaurine teeth from the Turonian Bissekty Formation in Uzbekistan (Sues and Averianov, in prep.). However, the DSDI value (0.875) is significantly low for dromaeosaurids, where it is always more than 1.0 (Rauhut and Werner, 1995). The possibility that the thick-crowned theropod teeth from Shakh-Shakh with lingually displaced mesial carina actually represent anterior dentary or maxillary dentition of a tyrannosaurid cannot be completely excluded.

Dromaeosaurines are identified here for the first time from the Baibishe locality (Nessov, 1988, 1995, 1997). Weak ridges on the lingual side of ZIN PH 33/49 make this tooth similar to those referred to *Paronychodon* Cope, 1876, which have been interpreted as belonging to juvenile deinonychosaurs (dromaeosaurids and troodontids) by Sues and Averianov (in prep.). The serrated distal carina of this tooth suggests that it belongs to a later growth stage than that characterized by adenticulated *Paronychodon* teeth. Based on its relatively small and closely packed distal denticles, ZIN PH 33/49 is referable to Dromaeosauridae rather than to Troodontidae, and based on its relatively slightly labiolingually compressed crown and lingually displaced mesial carina, it can be referred to the Dromaeosaurinae rather than the Velociraptorinae.

Velociraptorinae Barsbold, 1983

Velociraptorinae indet.
Fig. 6J

Material. ZIN PH 34/49, tooth (BAI-3k, 1982).

Description. The single tooth is very small (FABL, 2.1; BW, 0.80); its broad base suggests that it comes from the posterior part of the jaw. The crown is strongly compressed labiolingually (BW/FABL, 0.38). Both mesial and distal carinae lie in the same plane. The mesial carina is worn, but close to the broken apical end there are remnants of several very small denticles. The distal denticles are U-shaped and much larger, with about seven denticles per 1 mm.

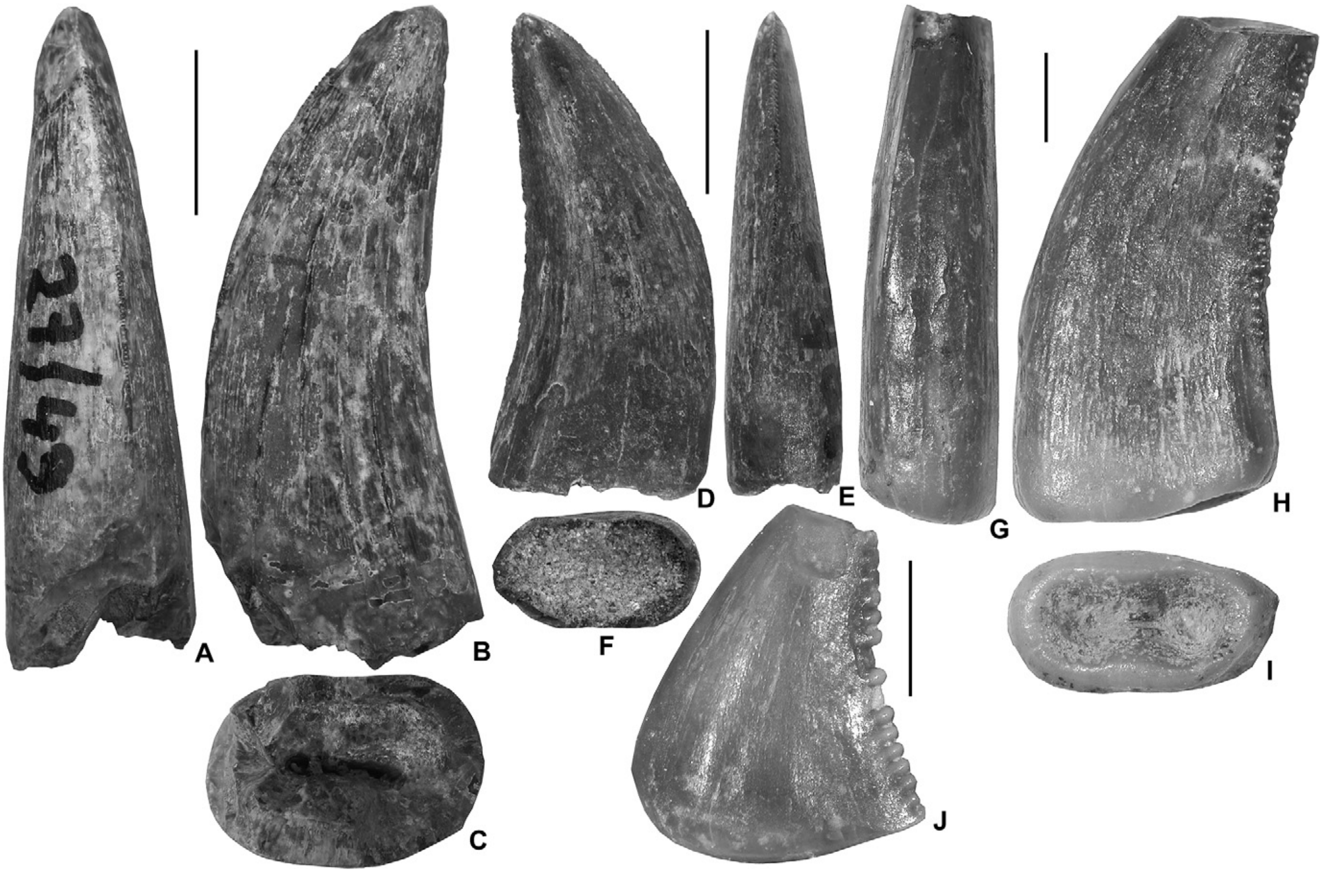

Fig. 6. Teeth of Dromaeosaurinae indet. (A–I) and Velociraptorinae indet. (J). Localities Shakh-Shakh (A–F) and Baibishe (G–J), Bostobe Formation, northeastern Aral Sea region, Kazakhstan. A–C, ZIN PH 27/49, in mesial (A), lingual (B), and basal (C) views. D–F, ZIN PH 28/49, in lingual (D), mesial (E), and basal (F) views. G–I, ZIN PH 33/49, in mesial (G), labial (H), and basal (I) views. J, ZIN PH 34/49, in labial or lingual view. Scale bar represents 10 mm in A–F; 1 mm in G–J.

Discussion. ZIN PH 34/49 is referred to Velociraptorinae because of its strong labiolingual compression, great disparity in size between the mesial and distal denticles, and lack of lingual displacement of the mesial carina (Currie et al., 1990; Baszio, 1997). This is the first record of the group from the Cretaceous of the northeastern Aral Sea region.

4. General discussion

Table 2 summarizes the distribution of theropod dinosaurs in the principle Upper Cretaceous vertebrate faunas of Uzbekistan, Tajikistan, and Kazakhstan. Altogether, 11 theropod taxa are currently known from this region, though they are unevenly distributed. This distribution pattern, however, is heavily affected by the sampling techniques employed. The most common taxon is Tyrannosauridae indet., identified mostly from isolated teeth, which are easily found during surface collecting. The large bones of therizinosauroids and ornithomimids are also common in the surface collections. Much smaller dinosaur teeth, such as those of therizinosauroids, troodontids, and *Paronychodon* sp., are more likely to be found in samples collected during large-scale screen-washing, which was employed at only a few localities (Sheikhdzheili, Dzharakuduk, Kansai, and Baibishe). Nessov (1995) reported troodontids from Shakh-Shakh, but this occurrence has not been confirmed by examination of the material. Similarly, the presence of dromaeosaurids in the Zhirkindek Formation at Tyul'kili is based only on the preliminary, unpublished data presented by Kordikova et al. (2001) and remains to be substantiated. Caenaganathids are a rare group in the Dzharakuduk fauna, known only from a few specimens, and their absence from other faunas apart from at Shakh-Shakh is not surprising: it, too, may reflect a sampling bias. At Shakh-Shakh caenagnathids are known from a single dentary that was originally attributed to a turtle (Nessov and Khisarova, 1988, fig. 5; Currie et al., 1994, p. 2267). Another rare taxon is *Richardoestesia* Currie et al., 1990, known from several dozen teeth in the Dzharakuduk fauna and the Khodzhakul Formation. The absence of the medium-sized teeth of *Richardoestesia* in other Central Asian faunas is also possibly owing to a sampling bias (lack of screen-washing of adequate matrix samples), to judge from the better study of this taxon in Campanian–Maastrichtian faunas of North America (e.g., Estes, 1964; Currie et al., 1990; Baszio, 1997; Sankey, 2001; Sankey et al., 2002).

Taking into account the assumptions outlined above, the Late Cretaceous theropod fauna of Central Asia appears to be quite homogenous and dominated by basal tyrannosaurids,

Table 2
Distribution of theropod dinosaurs in various Late Cretaceous vertebrate faunas in Uzbekistan, Tajikistan and Kazakhstan

Taxa	Formations/Localities							
	Khodzhakul Fm	Bissekty Fm	Yalovach Fm	Zhirkindek Fm	Bostobe Fm			
	various localities	Dzharakuduk	Kansai	Tyul'kili	Shakh-Shakh/Baibolat	Buroinak I and II	Akkurgan	Baibishe
Tyrannosauridae indet.	+	+	+	+	+	+	+	+
Ornithomimidae indet.	+	+	+	+	+			
cf. *Neimongosaurus* sp.								+
Therizinosauroidea indet.	+	+	+	+	+	+		+
Caenagnathasia martinsoni		+						
Caenagnathidae indet.					+			
Troodontidae indet.	+	+	+		?			
Itemirus medullaris		+						
Dromaeosauridae indet.	+	+	+	+	+			+
Paronychodon sp.	+	+						
Richardoestesia asiatica	+	+						

ornithomimids, and therizinosauroids. A similar association of theropods and other dinosaurs is known from the Irendabasu and Bayanshiree formations in China and Mongolia, respectively (e.g., Currie and Eberth, 1993; Nessov, 1995, 1997; Norman and Kurzanov, 1997; Averianov, 2002). The ages of these stratigraphic units are controversial and sometimes discussed without any clear arguments. Currie and Eberth (1993, p. 140) considered the age of the Irendabasu Formation to be early Senonian, but noted that it may be "as young as Campanian". This assessment was based on the identification in the formation of the troodontid *Saurornithoides* Osborn, 1924, the dromaeosaurid *Velociraptor* Osborn, 1924 and the avimimid *Avimimus* Kurzanov, 1981, which are also known from the Campanian Djadokhta Formation in Mongolia. However, the identification of *Velociraptor* in the Irendabasu Formation was based only on isolated teeth, and the report of *Saurornithoides* from this unit was based solely on isolated third metatarsals in which "the distal articulation extends onto the posterior surface of the bone in a broad tongue" (Currie and Eberth, 1993, p. 136). Although this feature is characteristic of derived troodontids, it was discovered later to be absent in *Saurornithoides*. Thus, the Irendabasu troodontid "cannot be identified further without additional material" (Currie and Dong, 2001, p. 1764). This conclusion was overlooked by Makovicky and Norell (2004, pp. 192, 193), who reiterated the claim that the Chinese material is referable to the Mongolian *Saurornithoides mongoliensis* Osborn, 1924 while referring to the same paper by Currie and Dong (2001). *Avimimus* material from the Irendabasu Formation was said to be indistinguishable from the type material of *Avimimus portentosus* Kurzanov, 1981 (Currie and Eberth, 1993, p. 137), but these remains have not yet been described and their attribution to the same taxon has yet to be demonstrated. Later, Currie (2000, p. 443) stated that "whether these two earlier occurrences [of *Avimimus* in the Irendabasu and Bayanshiree formations] represent the same species [*A. portentosus*] or not cannot be determined at this time." Thus, there currently exists no compelling evidence to suggest a Campanian age for the Irendabasu Formation, contrary to assignments in the recent literature (e.g., Weishampel et al., 2004).

According to the magnetostratigraphic data presented by Hicks et al. (1999), the age of the Bayanshiree Formation is not younger than latest Santonian. Nessov (1995, 1997) distinguished two levels within the Bayanshiree Formation: a lower, Cenomanian–early Turonian, level that produced the carettochelyid turtle *Kizylkumemys* Nessov, 1977 (Shine Us Khudag, Khar Hötöl, Baishin), and an upper, late Turonian–Santonian, level that produced the basal testudinoid turtle *Lindholmemys* Riabinin, 1935 (Bayan Shiree, Amtgai, Usheen Khudag, Shireegiin Gashuun; see also Sukhanov, 2000; Danilov and Sukhanov, 2001). A similar change in the composition of the turtle communities also occurs at the lower/upper Turonian boundary in Central Asia (Nessov, 1995, 1997). Here, *Lindholmemys* is common in the upper Turonian Bissekty Formation and Santonian Yalovach and Bostobe formations (Riabinin, 1935; Nessov and Khozatsky, 1980; Nessov, 1997). The Irendabasu Formation, which produces *Lindholmemys* sp. (Currie and Eberth, 1993), can be correlated with the upper part of the Bayanshiree Formation in Mongolia and with the Bissekty and Bostobe formations in Central Asia and Kazakhstan. The record of the therizinosauroid cf. *Neimongosaurus* sp. from the Bostobe Formation reported in this paper, which is similar to *Neimongosaurus* from the Irendabasu Formation, further supports this correlation. Thus the age of the Irendabasu Formation can be more confidently pinpointed as late Turonian–Santonian.

In Central Asia, terrestrial deposits with dinosaur remains are sometimes intercalated with marine strata containing orthostratigraphically important marine invertebrates that allow more precise dating of the terrestrial units (King et al., in press). Thus, the Khodzhakul Formation with its various dinosaurs and turtles, including *Kizylkumemys*, is dated as early Cenomanian, and the Bissekty Formation with similar dinosaurs but different turtles, as middle–late Turonian. Data from freshwater molluscs and plants, summarized by Nessov (1995, 1997; see also Martinson, 1965; Nessov et al., 1998; Kordikova et al., 2001), allows dating of the Yalovach Formation in the Fergana region as early Santonian and of the Bostobe Formation in Kazakhstan as late Santonian–early Campanian. The age of the Zhirkindek Formation, which underlies the Bostobe Formation, is well constrained by plant remains as late Turonian (e.g., Shilin, 1982, 1986, 1998).

In the future, Cretaceous terrestrial vertebrates from Central Asia and Kazakhstan, notably turtles and dinosaurs, may play an important role in more refined correlation of continental strata in Central Asia, including Mongolia and northern China, but much more detailed work on these taxa is needed.

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