PRÉCIS OF THE CRETACEOUS PALEONTOLOGY, BIOSTRATIGRAPHY AND SEDIMENTOLOGY AT DZHARAKUDUK (TURONIAN?–SANTONIAN), KYZYLKUM DESERT, UZBEKISTAN

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ABSTRACT: Middle Asia encompasses newly independent countries that have produced Upper Jurassic through Upper Cretaceous vertebrates. Paleontologic work by Russians in Middle Asia dates from the last century. The most intensive work began in the late 1970's by Nessov. Collaborative research between Western, Russian, and local paleontologists has intensified since independence of the countries in Middle Asia. Joint field projects beginning in 1994 and 1997 in the Cretaceous of Uzbekistan hold great promise for the study of vertebrates. Most exploration has concentrated on sites in the vast Kyzylkum Desert in Uzbekistan, arguably the second largest desert in the world. The 1997 season concentrated on occurrences at Dzharakuduk. The 100 m of exposure includes nearshore marine rocks at the bottom, fluvial rocks in the middle, and marine rocks above. Earlier assessments suggest the sequence ranges in age from Turonian through Campanian (some 90–75 mya). Collections of over 80 species of invertebrates, as well as sharks from the overlying marine units, give a very preliminary date of Coniacian or Santonian (about 85–80 mya), suggesting the underlying fluvial rocks that bear terrestrial vertebrates are a minimum of 80 my old, but almost certainly older. Vertebrate fossils are locally very abundant, but quite fragmentary, as are contemporary fossils from North America. Unlike in North America, however, fossil vertebrate remains at Dzharakuduk sometimes preserve exquisite detail. Partial limb bones and vertebrae of pterosaurs, very fragile mammal jaws, and detailed parts of small dinosaur crania are not uncommon. Fossils were buried once and never disturbed, as is common in many fluvial settings. The faunal composition at Dzharakuduk is similar to that along coastal plains in North America during the Late Cretaceous. For example, hadrosaurid and tyrannosaurid fragments are very common, with rarer deinonychosaurs, oviraptorids, ankylosaurids and ceratopsids. Unlike the central and northern North America Cretaceous, sauropods are also relatively common. Some of these differences extend to other vertebrates. The mammalian fauna shows notable differences. In the North American Late Cretaceous, rodent-like multituberculates, marsupials, and placentals are almost equally abundant, while at Dzharakuduk there are very rare marsupials and multituberculates, and placentals are dominated by a group of early ungulate precursors that are rare in North America. Although present, lizards are relatively rare, while among amphibians, both salamanders and frogs are extremely abundant.

INTRODUCTION

During the Cretaceous, we see the appearance of taxa that subsequently underwent major radiations in the Tertiary (e.g., placental mammals and flowering plants), as well as taxa that reach their greatest ecological diversity (e.g., non-avian dinosaurs). Although molecular studies are starting to provide a framework as to when some of the major divergence events may have occurred in the Cretaceous (e.g., Hedges et al., 1996), it is only through the fossil record that we can provide tie points for such studies. It is also only through the fossil record that we can attempt to know what these biotas were like.

For the Cretaceous, the record of vertebrates remains patchy. In North America, we have reasonably good, if somewhat fragmentary vertebrate faunas in the later Late Cretaceous (Campanian–Maastrichtian: e.g., Lillegraven and McKenna, 1986), and somewhat less complete records from the earlier part of the Late Cretaceous (Cenomanian–Turonian: e.g., Cifelli, 1990; Eaton, 1995). In Asia, the best known vertebrate faunas are those from the Gobi Desert (mostly Campanian), that have produced some of the most exquisite material (e.g., Norell et al., 1994). Some new and important Late Cretaceous vertebrate faunas have been described from South America, Europe, Madagascar, Australia, etc. (e.g., Gayet et al., 1991; Gheerbrant and Astibia, 1994), but it is almost entirely from sites in North America and the Gobi that we have some reasonably good idea about the entire vertebrate assemblage. This began to change as word spread about the very important early Late Cretaceous vertebrate faunas that the late Dr. Lev Nessov (St. Petersburg, Russia) was recovering from the southwestern portion of Asia (usually referred to as "Middle Asia"). Because of both language and political barriers, information concerning these faunas has been slow to spread.

PREVIOUS WORK, PRESENT WORK, AND PALEOECOLOGIC SETTING

Middle Asia encompasses a number of newly independent countries that have produced Late Jurassic through Late Cretaceous dinosaurs and other vertebrates. Although paleontological work by Russian researchers in Middle Asia dates back to the late 19th century, the most intensive work began only in the late 1970's when the late Lev A. Nessov, along with colleagues and students, began an intensive program of field exploration. Nessov worked in Uzbekistan without benefit of field vehicles, relying instead upon local transport. This of necessity limited access to some more remote regions, but even then, the results of the work undertaken by Nessov have been nothing short of remarkable. Shorter papers and a few longer synoptic catalogues on various aspects of the vertebrate faunas, the biostratigraphy, stratigraphy, biogeography, and sedimentology have appeared (e.g., Nessov, 1995). With a few exceptions, these papers were published in Russian, with the unfortunate consequence that many western paleontologists are only vaguely familiar with the emerging results of this research. With the opening of the former Soviet Union and the establishment of new countries formed from the Soviet republics, such as Uzbekistan, we now have a great opportunity for cooperation between the Russians who first developed the paleontological resources of the region, the newly independent Uzbeks, and Western scientists.

Collaborative field research between Western, Russian, and local paleontologists has intensified since the independence of countries in Middle Asia. Joint field projects beginning in 1994 and continuing through 1997 in the Cretaceous of Uzbekistan hold great promise for the continued study of dinosaurs and other vertebrates. Most exploration has concentrated on sites in the vast Kyzylkum Desert in Uzbekistan, arguably the second largest desert in the world. The most important or at least most diverse vertebrate fauna occurs in the Kyzylkum Desert (Fig. 1).

The 1997 field season concentrated at Dzharakuduk (Fig. 1, circled 2), which means "well by the escarpment" in Kazakh. The 100 m of exposure includes nearshore marine rocks at the bottom, fluvial rocks in the middle, and marine rocks above. Earlier assessments suggest the sequence ranges in age from Turonian to Campanian (some 90–75 mya). Collections of over 80 species of invertebrates as well as sharks from the overlying marine units give a very preliminary date of Coniacian or Santonian (about 85–80 mya), suggesting the underlying fluvial rocks that bear terrestrial vertebrates are a minimum of 80 million years old, but almost certainly older.

There is no question that the localities in Uzbekistan are yielding the richest Cretaceous vertebrate faunas, not just in Middle Asia, but for all of Eurasia, with the very obvious exception of the sites in the Gobi Desert of Mongolia. The vertebrate faunas of the Kyzylkum and of the Gobi show some similarities, but are very different in other aspects, especially in paleoecology. Some of the faunal components, notably the mammals, are very different, with the Kyzylkum and Gobi assemblages sharing few taxa. In fact, the Uzbek sites are more similar to those in the North American Late Cretaceous. Unlike Mongolia in the Late Cretaceous, which was more inland and xeric, the sites in Uzbekistan and the western United States were on low coastal plains. Thus, because of the considerable paleoecological parallels between the Late Cretaceous sites in these latter two countries, it will be possible to examine paleobiogeographic differences with paleoecological differences held as more or less a constant.

The vertebrate fossils from the fluvial rocks at Dzharakuduk are locally very abundant, but are quite fragmentary, as are the contemporary vertebrate fossils from North America. Unlike North America, however, the fossils at Dzharakuduk are often very delicate and sometimes preserve exquisite detail. Partial limb bones and cervical vertebrae of pterosaurs, very fragile mammal jaws, and partial crania of small dinosaurs are not uncommon. This is probably the case because the fossils were buried once and never reworked, as is common in many fluvial depositional settings.

In many ways, the faunal composition at Dzharakuduk is very similar to that along the coastal plains during the Late Cretaceous in North America. For example, among dinosaurs, hadrosaurid and tyrannosaurid fragments are very common, with rarer deinonychosaurs, oviraptorosaurs, ankylosaurs, and ceratopsids. Unlike the central and northern North American Cretaceous, sauropods are also relatively common. Some of these differences extend to other vertebrates. The mammalian fauna shows notable differences. In the North American Late Cretaceous, the rodent-like multituberculates, marsupials, and placentals are almost equally abundant, whereas, at Dzharakuduk, there are no marsupials, multituberculates are extremely rare, and the placentals are dominated by a group of early ungulate precursors that are very rare in North America. Although present, lizards are relatively rare, whereas both salamanders and frogs are extremely abundant. Localities such as Dzharakuduk, which have only recently become known to western scientists, show that we still have much to learn about the latter days of the "Age of Dinosaurs."

The richest vertebrate locality at Dzharakuduk is CBI-14, from the middle of the Bissekty Formation (Fig. 2). This locality has yielded the greatest percentage of vertebrates found to date at Dzharakuduk. The locality is a 20 x 60 m, sand-covered slope that was cleared of brush and rock by Nessov and his crews over several field seasons. Although some small-scale screening was

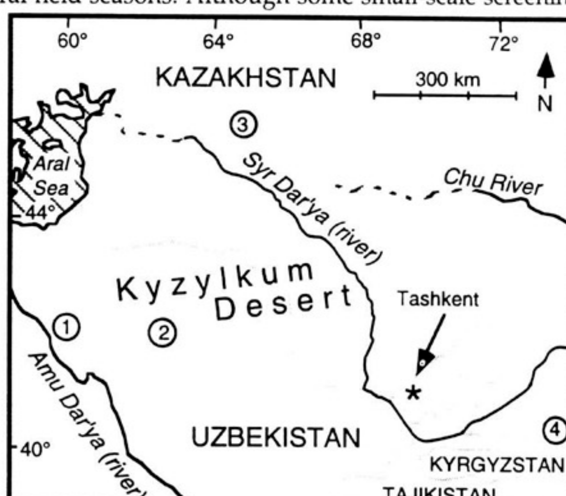

FIGURE 1. Map of the Kyzylkum Desert in western Uzbekistan showing the very productive Dzhyrakuduk area (2) as well other important areas that provide the chronostratigraphic framework in Figure 3. These other areas are: **1**, Sultanvais Ridge, northwestern Uzbekistan; **2**, Dzhyrakuduk area, central Kyzylkum Desert; **3**, Tyulkeli Hill and Zhalmauz well areas, Dzhalagash region, southern Kazakstan; **4**, Fergana region, southwestern Kyrgyzstan (after Nessov etal., 1998).

done using small hand screens, most collecting was done by crawling the surface. This yielded some well-preserved specimens, including delicate mammalian and pterosaur postcrania, but the process is particularly labor-intensive. It takes five experienced collectors almost two weeks to cover the majority of the locality's exposure.

In 1997, we continued this process, but with an added objective. For example, some 95% of the mammal specimens that we recovered in 1997 at CBI-14 came from an area measuring about 3 x 9 m. We spent two and one-half days dry screening this smaller area. Using Ward's techniques we screened 2.4 metric tons over about 2.5 days. We recovered almost as much material as had been found in the previous two weeks of surface crawling. An easy demonstration of this is the mammals. Four to five people crawling the surface found 15 mammal specimens in about 12 days. The same number of people recovered 10 mammal specimens in 2.5 days of intensive dry screening. The yield for mammals was about one specimen per 240 kilos of matrix. Although somewhat difficult to place in a larger context, this is about average for Cretaceous sites.

Some of the material found in screening is exceptionally delicate (e.g., very common complete frog limb-bones, complete salamander vertebrae, etc.); some of which is almost unknown (e.g., a nearly complete mammalian ischium) from most Late Cretaceous sites (the Gobi localities again being an obvious exception). Although the material can be very delicate, our pace of screening seems to leave many intact specimens. Fortunately, because of the sediment size, dry screening is a very easy (if dusty) and quite rapid process. Mammals are emphasized in this example, but parts of many other, often rare taxa (e.g., lizards and pterosaurs) were recovered during screening. From our experimentation with collecting techniques during 1997, it is clear that in future field seasons we will be able to dry-screen and sort large amounts of matrix.

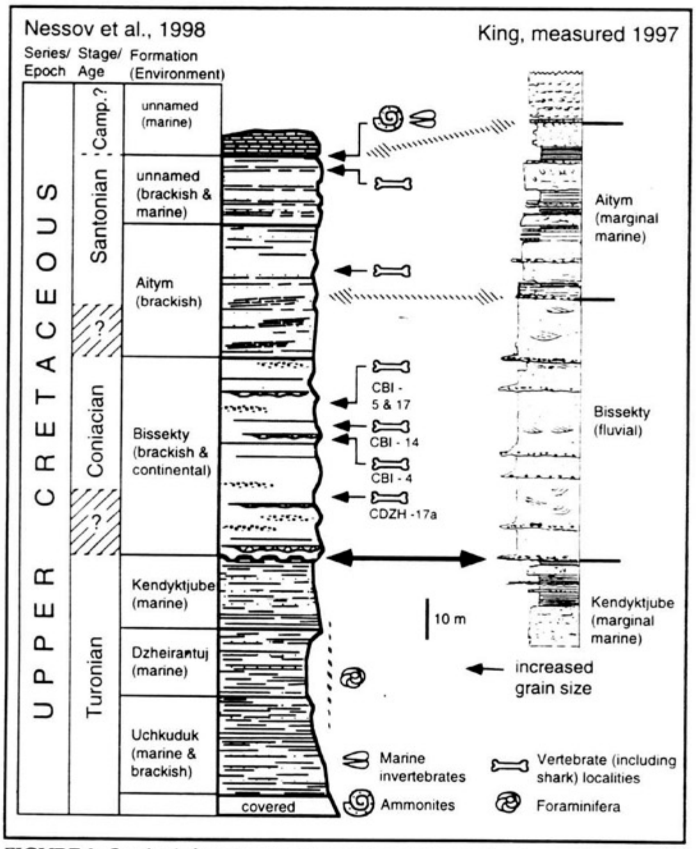

FIGURE 2. On the left is the stratigraphic column and paleoenvironmental interpretation modified after Nessov et al. (1998). On the right is much of the same section as measured and interpreted by Chris King during our field season in 1997. Both sections are at nearly the same scale. The major differences are the recognition of the Bissekty–Aitym and the Aitym–unamed unit contacts higher in the section on the right (note arrows with hatching), and the reinterpretation of the Bissekty as completely fluvial with no brackish influence. The placements of vertebrate fossil localities are nearly the same in both sections. The lags in the Bissekty Formation discussed in the text are units showing notable grain size increase in King's section.

BIOSTRATIGRAPHY AND SEDIMENTOLOGY

Prior to the independence of countries such as Uzbekistan at the beginning of this decade, the geology and paleontology of Middle Asia was not well known to scientists outside of the Soviet Union. Although some classic field research was conducted by Soviet researchers (Pyatkov et al., 1967; Martinson, 1969; Schultz, 1972), little of it was known to western science because of language and political barriers. The late Lev Nessov published brief Russian-language synopses of the biostratigraphic framework for his sites. In 1994, he published a more extensive biostratigraphic framework of the Cretaceous of Middle Asia in English with French colleagues (Nessov et al., 1994). It was not until 1997, however, that a more complete framework was published in English, explaining the basis for correlating Cretaceous vertebrate sites in Middle Asia (Fig. 3). This was the result of earlier geological work at Dzharakuduk as well as work done by Nessov. Although there was an attempt to correlate sections at Dzharakuduk with elsewhere in Middle Asia and outside of the Soviet Union, this correlation was somewhat limited by the previous restrictions of the Soviet system.

One of the goals for our 1997 field season was to begin re-examining geologic sections at Dzharakuduk and elsewhere in Uzbekistan so that correlations to other regions could be done more confidently. To this end, one of our crew members in 1997, Chris King, took on the task of examining the sections, notably at Dzharakuduk. During the 1997 season, three, detailed 200 m sections through the exposures of Dzharakuduk were completed. The overall stratigraphic interpretation presented in Nessov et al. (1997) remains basically correct, but there are some important reinterpretations of the marine faunas, the depositional and paleoecological settings, and placement of formational boundaries (Fig. 2). The description of the section is complete, but the age determinations are preliminary. The following description of the stratigraphic and depositional setting at Dzharakuduk is largely the work of Chris King with some input from other field-party members.

The lower 60 m of sediment at Dzharakuduk (Kendyktjube, Dzheirantuj and Uchkuduk formations) have previously been identified as Turonian in age (Fig. 2). The highest 25 m of the lower part of the section are well-exposed in places (as in King's section, Fig. 2); they consist of laminated clays, thinly interbedded fine sands and clays, with some bioturbation, and several thick units (up to 6 m) of bioturbated silty sands and sandy silts. The bioturbated sands and silts may be shallow marine or bay sediments; in the absence of glauconite or marine fossils, a bay environment seems more probable but not certain. The age interpretation as Turonian (Figs. 2–3) given in Nessov et al. (1998) was based on correlations to Kazakstan using comparisons of early Turonian foraminiferans (Pyatkov, 1967), the ammonite *Proplacenticeras kharesmense* and the pelecypod *Mytiloides labiatus* from 80 km east of Dzharakuduk (Vereshchagin, 1979). These correlations may well be correct, but no fossils were found in this interval in 1997 to justify the previous dating attempts. The problem is that the whole of the region is quite low, about 100–300 m above sea level, and that erosion rates, especially for finer-grained sediments appear to be quite slow. Thus, such units are often very deeply weathered and frequently riddled with gypsum minerals that add to the destruction of fossils. We will redouble our efforts in future field seasons to recover macro- and microinvertebrates from this lower interval.

Fieldwork in 1997, notably by King, agrees with Nessov et al. (1998) that the base of the vertebrate-producing Bissekty is unconformable on the underlying, presumably marine units. The placement of the upper boundary of the Bissekty as shown by Nessov et al. (1998), however, is probably not the best choice. A better placement of the upper boundary is at the top of the cross-stratified beds as seen in the stratigraphic columns in Figure 2. This appears to be a major depositional (but not temporal) break,

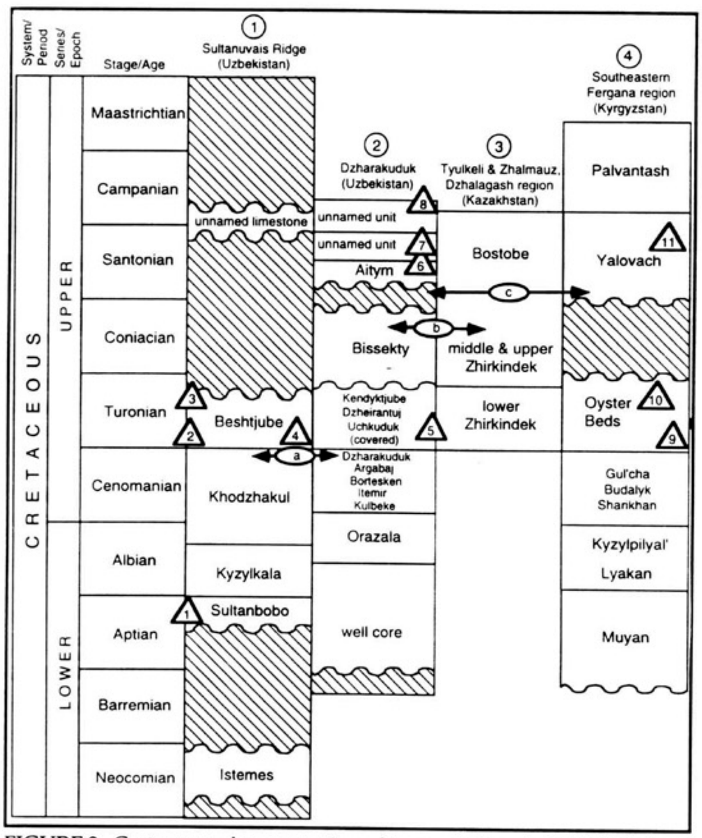

FIGURE 3. Cretaceous chronostratigraphic correlations in Middle Asia as given in Nessov et al. (1998). The locations of the four geological columns are shown in the map in Figure 1. The numbered triangles are biostratigraphic age estimates, and the numbered ellipsoids are correlations taken from Nessov et al. (1998). They are based upon a variety of marine invertebrates (ammonites, foraminiferans, pelecypods, gastropods), marine vertebrates (sharks, rays), nonmarine vertebrates (turtles, hadrosaurids, crocodiles, turtles), and plants (angiosperms). Note the placement of the Bissekty Formation (stippled) in the Dzharakuduk region that has produced the vertebrate fauna discussed in the text (after Nessov et al., 1998).

from the underlying, cross-stratified fluvial beds of the Bissekty Formation to the overlying, horizontal beds of the marine Aitym Formation. The Bisskety is 67 m thick in the gorge in which locality CBI-14 is located; this is the best exposure of the formation. It is dominantly (> 95%) medium- to coarse-grained sand, mostly uncemented, either apparently structureless or with trough cross-bedding. Current directions are broadly unidirectional. These are interpreted as fluvial channel sediments, on the basis of their lithology, sedimentary structures, absence of bioturbation and (locally) terrestrial fauna.

Nessov had argued for some brackish-water component in the Bissekty Formation (see paleoenvironmental interpretation for the Bissekty in the left column of Fig. 2), which was largely based on the occurrence of marine elasmobranchs at the richest sites (notably CBI-14) in the middle of the formation. As just noted, however, King argued that the Bissekty Formation is completely fluvial on sedimentological grounds. Thus, the occurrence of both freshwater and marine sharks at such sites as CBI-14 presented a paradox. The list of sharks included the hornshark *Heterodontus* and the carpet shark *Cantioscyllium*, both currently unknown from freshwater deposits. This necessitated a rather complicated (and unlikely) paleoenvironmental interpretation of marine and freshwater influences, which was at odds with the sedimentological findings made in 1997. These marine species had been collected on the surface at CBI-14 by Nessov and his colleagues. By sieving *in situ* material we were able to demonstrate that the more marine sharks, including *Heterodontus* and *Cantioscyllium*, were probably not present. In September, 1997, we discovered a hitherto unrecognized marine horizon in the overlying Aitym Formation, yielding abundant shark teeth, and concluded that contamination from this horizon was responsible for the mixed assemblage. The remaining species, including *Hybodus*, *Polyacrodus* and *Hispidaspis*, are known to be freshwater-tolerant. This simplified matters, eliminating the need for complicated paleoenvironmental scenarios.

The base of the Bissekty is sharply defined, almost planar, but slightly erosional, with a thick basal lag of ironstone and clay pebbles, that represents a major depositional break. Similar lags, usually containing variably abraded dinosaur bones and, at some levels, pieces of silicified wood and quartz pebbles, occur at about five other levels through the formation. As far as can be determined, they have approximately planar bases and may be followed for distances of at least 2 km. These are interpreted as erosional lag deposits left behind during lateral migration of fluvial channels. Mammal bones and teeth, associated with other vertebrate bone debris, mostly fragile and often unabraded, occur within the sands between the fourth and fifth lags (Fig. 2). These are interpreted as either primary deposits or reworking directly from contemporaneous land surfaces during fluvial channel migration. The much more abraded bones in the lag deposits may have been through several cycles of reworking and redeposition. Except possibly at the eastern end of the exposures, there is no suggestion of floodplain deposits. This is probably caused by the fact that Bissekty exposures run east to west. Any floodplain exposures to the south have long ago been eroded, while those to the north remain buried under the overlying marine units such as the Aitym Formation.

Most importantly for the purposes of this study, the middle portion of the Bissekty Formation produces the vast majority of vertebrate material. The most fossiliferous sediments are cross-stratified, laterally discontinuous units a meter or less thick, composed of poorly sorted, fine sands and silts. There are often clay-ball conglomerates at base of the units. Usually the more poorly sorted the unit, the richer it is in vertebrate remains. It is intriguing that given this depositional regime, the fossil material can be so fresh and fragile. This is not unlike the vast majority of vertebrate-producing sites throughout the Western Interior of North America, yet the North American sites never preserve such delicate material. We as yet have no definitive explanation for this apparent enigma. Nessov suggested that a superabundance of phosphates helped preserve the bones. Another possibility is that unlike in North America where bones appear to have been reworked through several cycles of erosion and deposition, the bones in the Bissekty sites were buried only once with no or very little reworking. The sites may have been closer to the sea or were part of a system that was more rapidly aggrading.

As noted above, the Bissekty Formation is overlain by the Aitym Formation, a 45-m-thick interval of laminated clays, interbedded sands and clays, bioturbated sands and localized cross-stratified sands. There appears to be no major depositional break at the base of this interval, rather a rapid environmental change. The sediments of the Aitym Formation resemble in many respects those in the interval underlying the Bissekty Formation, and are likewise interpreted as mainly or wholly marginal marine sediments. Lateral variability is probable but is difficult to assess on the basis of the current database. Several thin horizons with reworked ironstone and clay clasts, quartz pebbles and small phosphate pebbles, occur within this interval. They are usually sharp-based, and are interpreted as transgressive surfaces marking marine incursions. Where not leached by weathering, they contain numerous, well-preserved shark teeth and molluscs (mainly oysters). One member of the field party, David Ward, is only just beginning his study of the some 12–15 species of elasmobranchs from this horizon, but a Coniacian or perhaps Santonian age is likely. Depending upon the outcome of his study, he may be able to provide a more precise age. The elasmobranchs also offer an assessment of the environment, which was nearshore marine with a water depth of no more than about 20 m within the photic zone.

The Aitym Formation is capped by a thin (30 cm) glauconitic calcareous sandstone, forming the crest of the escarpment for long distances. It has a sharp base penetrated by *Thalassinoides* burrow networks. This unit preserves an abundant and diverse assemblage (some 80+ species) of macroinvertebrates, including a rich gastropod fauna, very rare ammonites and nautiloids, numerous pelecypods, corals, bryozoans, crabs, etc. It contains the most fully marine fossil assemblage in the Cretaceous succession at Dzhyrakuduk, and is interpreted as a marine, transgressive unit. Age assessments by Nessov (e.g., Nessov et al., 1998) suggested a Santonian or possibly Campanian age for this unnamed fossiliferous unit (see Fig. 2). Preliminary results for our 1997 season suggest a late Coniacian or early Santonian age for this invertebrate fauna. Two fragmentary ammonites collected in 1997 from this unit were identified by W. J. Kennedy (pers. comm. to King) as *Placenticeras* sp. (Albian–Late Campanian). Intraspecific variation in this genus is high, but the morphology of the specimens is consistent with identification as *P. kysylkumense* Archangelsky, 1916. Originally regarded as Turonian, this species occurs in association with latest Coniacian–early Santonian bivalves (inoceramids) elsewhere in Middle Asia. Nessov et al. (1998) also reported the recovery of an ammonite referable to this species from the same horizon. They noted a Santonian age for the ammonite. In Nessov et al. (1998: fig. 4), the position of the ammonite was incorrectly placed in the overlying unnamed unit, but this has been corrected in our Figure 2. Thus, the underlying units at Dzharakuduk, including the important vertebrate-producing Bissekty Formation, are very unlikely to be younger than Santonian. The possible late Turonian through Coniacian age for the Bissekty vertebrate fauna suggested by Nessov (Fig. 2) remains a reasonable age assessment.

The 30-cm-thick unit capping the Aitym Formation is followed by about 12 m of silts and fine sands, mostly poorly exposed on the top of the escarpment, with several shelly sandstone beds containing oysters and other molluscs. Again, the faunas are entirely marine, and these are interpreted as inner neritic nearshore sediments with the shell beds resulting from periodic pauses in sedimentation (parasequence boundaries). Above this, there is an interval with very poor exposures of unconsolidated sands. A Tertiary section follows, with its base about 10 m above the last Cretaceous sandstone bed.

COMMENTS ON THE FAUNA

Although Nessov published extensively in Russian on the Dzharakuduk fauna, our program of extensive dry screening will certainly recover new taxa and extensive new material. Thus, what is presented here is a very incomplete sketch of the faunal work that is only beginning to extend the earlier work of Nessov.

Invertebrates—Some 80+ species of invertebrates were recovered from the limestone at the top of the Dzharakuduk escarpment (Fig. 2). Although highly preliminary, the results (as noted above) suggest a Santonian or even Coniacian age, thus supporting Nessov's earlier assessment of minimum age of Coniacian for the underlying vertebrate fauna from the Bissekty Formation.

Elasmobranchs—Although extensive collections of elasmobranch material were made throughout the Dzharakuduk section in 1997, two particularly rich samples are noteworthy—one from the important vertebrate locality in the middle of the Bissekty Formation (CBI-14), and the other from the very rich shark locality some 10 m below the capping, invertebrate-rich limestone. The alpha-level analysis of the elasmobranchs involves, first, the sorting of large samples of teeth, and second, the arranging of these teeth into replacement series as they presumably occurred in the animal. The amount of potential variation in a tooth series dictates this painstaking procedure. These series will be used for both systematic studies and paleoecologic assessments, and may provide some biostratigraphic data. We are fairly optimistic that biostratigraphic information will be provided by the sharks. As discussed in the section on stratigraphy and sedimentology, the sharks are providing important paleoecologic assessments.

Turtles—Knowledge of Mesozoic turtles from the territories of the former USSR was increased significantly by the work of Nessov. He not only described many new taxa, but also described previously unknown turtle assemblages dating from the Late Jurassic (Callovian) to Late Cretaceous (Campanian) (Nessov, 1984). Through this work he increased the known diversity of Mesozoic turtles in Middle Asia to close to that known in Mongolia. Turtles are among the most common larger vertebrates at Dzharakuduk and are under study by one of the field-party members, Igor Danilov. Although rather fragmentary, the specimens are well-preserved. Separate shells, limb bones, vertebrae, and fragments of skulls have been collected. Because such large collections have been made, they permit detailed morphological studies that were not possible when Nessov first described these animals. Some important specimens were collected by our expedition in 1997. Based on this material it will be possible to study some of the Kyzylkum turtles in more detail. Some of the problems that should be solved based upon this material are: (1) assessment of the phylogenetic relationships of *Shachemys* (?Adocidae) and *Tienfucheloides* (?Sinemydidae); (2) determination of the status of some closely related species from various assemblages from Middle Asia, notably comparisons of *Shachemys baibolatica ancestralis* and *Lindholmemys elegans* (Coniacian) with *Shachemys baibolatica baibolatica* and *Lindholmemys gravis* (Santonian), respectively; (3) comparisons of related species from Middle Asia and Mongolia, notably *Mongolemys occidentalis* (Cenomanian) from Middle Asia with *M. elegans* (Maastrichtian) of Mongolia (which is part of Danilov's dissertation); and (4) comparative study of the skull of lindholmemydid turtles (*Lindholmemys* and *Mongolemys*) and the phylogenetic relationships of testudinoids (again part of Danilov's dissertation), because one hypothesis posits that Lindholmemydidae is the sister-group of Testudinoidea.

Dinosaurs (Including Birds) and Pterosaurs—Numerous taxa of dinosaurs, under study by Hans-Dieter Sues, are represented by excellently preserved, but isolated bones and teeth at Dzharakuduk. By far the most common taxon is a basal hadrosaur similar to *Gilmoreosaurus*, which is represented by cranial and postcranial bones referable to individuals ranging from post-hatchling to adult growth stages. Theropods are represented by numerous isolated teeth and bones. They include a tyrannosaurid, a dromaeosaurid, a caenagnathid, and a possible therizinosauroid. The holotype and only known specimen of the ?dromaeosaurid *Itemirus medullaris* Kurzanov, 1976, an excellently preserved braincase, was collected at Dzharakuduk, rather than "Itemir" as claimed in the original description (Nessov, 1995). Birds are represented by numerous well-preserved postcranial bones representing several taxa, including probable Enantiornithes. Sauropod dinosaurs are represented by isolated dorsal and caudal vertebrae as well as pencil-like tooth crowns from Dzharakuduk. The structure of the caudal vertebrae and of the teeth suggest titanosaurid affinities for this material, but this identification requires additional data. Wilson and Sereno (in press) have recently reassigned Opisthocoelocaudia from the Upper Cretaceous of Mongolia, first described as a camarasaurid, to the Titanosauridae.

Nessov (1995) described and figured skeletal remains of a small ceratopsian from Dzharakhuduk, which he considered referable to the Ceratopsidae. If correctly identified, this would represent the first record of this group from Asia. Dodson (1996), however, has questioned this identification, and additional material is needed to substantiate Nessov's identification. The dinosaurs from the Upper Cretaceous of the Kyzylkum are of great interest as they represent lowland flood-plain communities similar to those from the Upper Cretaceous of western North America. They are thus potentially more suitable for paleogeographic comparisons than the dinosaurian faunas of the more arid settings preserved in Mongolia and Nei Mongol (China).

Pterosaurs are represented by the azhdarchid *Azhdarcho longicollis* Nessov, 1984, which is known from numerous, often excellently preserved bones representing a variety of ontogenetic stages. Although isolated and fragmentary, the skeletal remains are, for the most part, uncrushed and three-dimensionally preserved, and thus are important for elucidating the anatomy of these unusual flying reptiles.

Mammals—Mammals from Dzharakuduk are being studied by David Archibald and Alexander Averianov. The most abundant mammals at Dzharakuduk are the so-called "zhelestids." The name comes from one of the included genera, *Zhelestes*, which means "wind thief," an appropriate name for fossil mammals from the windswept Kyzylkum Desert. This is a paraphyletic grouping of 15 named species from Asia (eight species), North America (four species), and Europe (three species) that collectively appear to be the sister taxa to the later Ungulata. Ungulata first appear near the K/T boundary in North America. Ungulata includes a host of extinct mammals such as the "condylarths" as well as at least six orders of living ungulates (Artiodactyla, Cetacea, Proboscidea, Sirenia, Perissodactyla, Hyracoidea). This collaborative work culminated in a 48 page monograph (Nessov et al., 1998) that provides a detailed, alpha-level description of the Asian "zhelestids," comparisons to non-Asian "zhelestids", and a species-level phylogenetic analysis of "zhelestids" and other Late Cretaceous placentals. The monographic study also provided the basis for a redefinition of Ungulata and the establishment of an even higher level taxon, Ungulatomorpha (Archibald, 1996). Relationships of mammals above the ordinal level are still a matter of considerable debate (e.g., Novacek, 1992), but our studies of "zhelestids" provide one of the most convincing cases using fossils of superordinal groupings of mammals extending well into the Cretaceous (to about 85 mya). These "zhelestids" also show the dental trends leading away from carnivory and insectivory towards ominvory and herbivory (Archibald, 1996), notably the squaring of the molar crowns, reduction in vertical shear, and the beginning trend towards moving the mandibular condyle above the tooth row as seen in most mammalian herbivores.

The placental mammals from Dzharakuduk are also providing a major breakthrough in our understanding of the evolution of the postcanine dental formula. A variety of studies (Lillegraven, 1969; Clemens, 1973; Kielan-Jaworowska and Dashzeveg, 1989) have shown that a few latest Cretaceous and late Early Cretaceous placentals had five premolars rather than the usual count of four. This has led some (McKenna, 1975) to suggest that this is the primitive formula for placental mammals. To date, *all* placental mammals (not just "zhelestids") from the intermediately aged (mid Late Cretaceous) Dzharakuduk that preserve the anterior portion of the maxilla or dentary have five premolars (Archibald and Averianov, 1997). Further, in *all* such species the middle premolar (P3) is small, suggesting this was the first premolar position lost in placentals. Some larger, presumably "zhelestid" dentaries do show that the third premolar position was lost later in ontogeny, leaving an obvious bone plug in its place. Even further, we can suggest that P2, P4, and P5 had both deciduous as well as replacement teeth, while P1 and P3 may have only retained one generation of tooth, probably the first.

Another joint project dealing with the mammals from Dzharakuduk involves the study of the postcrania. Nessov loaned Dr. Fred Szalay some 66 skeletal elements mostly from Dzharakuduk. Subsequently, some 21 additional elements have been recovered. Although almost always isolated and sometimes incomplete, most of the postcrania preserve quite delicate structures. In 1997 alone, we recovered one humeral head, two distal humeri, three proximal ulnae, one proximal caudal vertebra, an ischium, and a fused distal tibia/fibula. These nine specimens, along with 11 found in 1993 and 94, plus the 66 already in Szalay's possession, will make a very good assemblage for beginning the study of the postcrania of the mammals from Dzharakuduk. With the exception of the beautifully preserved mammalian skeletal remains from the Gobi, we have no other Late Cretaceous sites in the world that are yielding such a wealth of postcrania. Based on size alone, we are certain that some of the larger specimens are "zhelestids." Although the specimens have not been studied in any detail, some of the elements suggest the pronation/supination of both the fore and hindlimbs was probably restricted (e.g., the distal fusion of the tibia/fibula, the oval shape of the radial head, the semilunar notch of the distal humerus and the proximal ulna indicating that full rotation was limited).

Other Vertebrates—In addition to those specifically mentioned, various bony fishes, amphibians, and crocodilians are abundant, while lizards are rare components of the Dzharakuduk fauna.

CONCLUDING REMARKS

Our very preliminary studies and expansion of Nessov's work demonstrate that the vertebrate faunas from Dzharakuduk have and will continue to be important in elucidating major biostratigraphic, biogeographic, and phylogenetic questions of not just Late Cretaceous vertebrates but Cenozoic taxa as well. The pioneering work of Nessov opened up an entirely new region for the study of vertebrate evolution, but the task of using his discoveries to understand these faunas is only beginning.

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REFERENCES

Archibald, J. D., 1996, Fossil evidence for a Late Cretaceous origin of "hoofed" mammals: Science, v. 272, p. 1150–1153.

Archibald, J. D. and Averianov, A. O., 1997, New evidence for the ancestral placental premolar count: Journal of Vertebrate Paleontology, v. 17 (supplement to no. 3), p. 29A.

Cifelli, R. L., 1990, Cretaceous mammals of southern Utah, III. Therian mammals from the Turonian (early Late Cretaceous): Journal of Vertebrate Paleontology, v. 10, p. 332–345.

Clemens, W. A., 1973, Fossil mammals of the type Lance Formation, Wyoming: Part III. Eutheria and summary: University of California Publications in Geological Sciences, v. 94, p. 1–102.

Dodson, P., 1996, The horned dinosaurs: Princeton, Princeton University Press, 346 pp.

Eaton, J. G., 1995, Cenomanian and Turonian (early Late Cretaceous) multituberculate mammals from southwestern Utah: Journal of Vertebrate Paleontology, v. 15, p. 761–784.

Gayet, M., Marshall, L. G. and Sempere, T., 1991, The Mesozoic and Paleocene vertebrates of Bolivia and their stratigraphic context: A review: Revista Tecnica de Yacimientos Petroliferas Fiscales Bolivianos, Santa Cruz, v. 12, p. 393–433.

Gheerbrant, E. and Astibia, H., 1994, Un nouveau mammifère du Maastrichtien de Laño (Pays Basque espagnol): Comptes Rendus de l'Académie des Sciences, Paris (Série II), v. 318, p. 1125–1131.

Hedges, S. B., et al., 1996, Continental breakup and the ordinal diversification of birds and mammals: Nature, v. 381, p. 226–229.

Kielan-Jaworowska, Z. and Dashzeveg, D., 1989, Eutherian mammals from the Early Cretaceous of Mongolia: Zoologica Scripta, v. 18, p. 347–355.

Lillegraven, J. A., 1969, Latest Cretaceous mammals of upper part of Edmonton Formation of Alberta, Canada, and review of marsupial-placental dichotomy in mammalian evolution: Paleontological Contributions, University of Kansas, v. 50 (Vertebrata 12), p. 1–122.

Lillegraven, J. A. and McKenna, M. C., 1986, Fossil mammals from the "Mesaverde" Formation (Late Cretaceous, Judithian) of the Bighorn and Wind River basins, Wyoming, with definitions of the Late Cretaceous North American land-mammal "ages": American Museum Novitates, no. 2840, p. 1–68.

Martinson, G. G., 1969, Biostratigraphy and fauna of the Cretaceous continental deposits of the Tajik Depression, Kyzylkum Desert and Pritashkentshie Chuli; *in*, Martinson, G. G., ed., Continental deposits of the eastern regions of Middle Asia and Kazakhstan (lithostratigraphy and biostratigraphy): Leningrad, Nauka Press, p. 18–51.

McKenna, M., 1975, Toward a phylogenetic classification of the Mammalia; *in*, W. P. Luckett, W. P. and Szalay, F. S., eds., Phylogeny of the Primates: A multidisciplinary approach: New York, Plenum Press, p. 21–46.

Nessov, L. A., 1984, Data on late Mesozoic turtles from the USSR: Studia Geologica Salmanticensia. Studia Palaeocheloniologica, v. 1, p. 215–223.

Nessov, L. A., 1995., Dinosaurs of northern Eurasia: New data about assemblages, ecology and paleobiogeography. Saint Petersburg, Publishing House of the University of Sankt Petersburg, 156 pp.

Nessov, L. A., Archibald, J. D. and Kielan-Jaworowska, Z., 1998, Ungulate-like mammals from the Late Cretaceous of Uzbekistan and a phylogenetic analysis of Ungulatomorpha: Bulletin of the Carnegie Museum of Natural History, v. 34, p. 40–88.

Nessov, L. A., Sigogneau-Russell, D. and Russell, D. E., 1994, A survey of Cretaceous tribosphenic mammals from middle Asia (Uzbekistan, Kazakhstan and Tajikistan), of their geological setting, age and faunal environment: Palaeovertebrata, v. 23, p. 51–92.

Norell, M. A., Clark, J. M., Demberelyin, D., Rhinchen, B., Chiappe, L. M., Davidson, A. R., McKenna, M. C., Altangerel, P. and Novacek, M. J., 1994, A theropod dinosaur embryo and the affinities of the Flaming Cliffs dinosaur eggs: Science, v. 266, p. 779–782.

Novacek, M. J., 1992, Mammalian phylogeny: Shaking the tree: Nature, v. 356, p. 121–125.

Pyatkov, K. K., Pyanovskaya, I. A., Bukharin, A. K. and Bykovskij, Yu. K., 1967, Gyeologichyeskoye stroyeniye Tsyentral'nykh Kyzylkumov [Geological structure of the Central Kyzylkum]: Tashkent, Uzbekistan, Izdatyel'stvo Fan [Fan Press], 177 pp.

Schultz, S. S. Jr., 1972, Gyeologichyeskoye stroyeniye zony sochlyenyeniya Urala i Tyan'-Shanya [Geological structure of the contact zone of Ural and Tyan Shan' Mountains]: Moscow, Izdatyel'stvo Nyedra [Nedra Press], 207 pp.

Vereshchagin, V. N., ed., 1979, Stratigrafichyeskii slovar' SSSR. Trias. Yura. Myel [Stratigraphic Dictionary of the USSR. Triassic, Jurassic, Cretaceous]: Leningrad, Izdatyel'stvo Nyedra [Nedra Press], 592 pp.