Proceedings of the Zoological Institute RAS
Vol. 320, No. 1, 2016, pp. 50–65

УДК 595.752.3(471.324)

THE TURANIAN BASIN IN THE EOCENE: THE NEW DATA ON THE FOSSIL SHARKS AND RAYS FROM THE KYZYLKUM DESERT (UZBEKISTAN)

T.P. Malyshkina[1]* and D.J. Ward[2]

[1]*Institute of Geology and Geochemistry UB RAS, Akademika Vonsovskogo Str. 15, 620016 Ekaterinburg, Russia; e-mail: prionace@yandex.ru*

[2]*Department of Earth Sciences, The Natural History Museum, Cromwell Road, London SW7 5BD, UK; e-mail: david@fossil.ws*

ABSTRACT

Geological fieldwork to investigate the stratigraphic context of Dzheroy-2, fossil shark and ray location in the Kyzylkum desert (Case et al. 1996), resulted at the discovery of the new location, Dzheroy-3, consisting of three fossiliferous horizons, at different stratigraphic levels: in the base of Suzak Formation, in the middle of the Alay and at the base of Turkestan Formation. A total of over 450 shark and ray teeth were collected by a combination of surface prospecting and bulk sampling. From the lithology and the faunal composition of the individual assemblages it was possible to deduce the age and depositional environments of the new fossil fish-bearing horizons. Faunal analysis indicated full marine conditions of the including sediments with bottom-anoxic conditions of the two lower levels and more oxygenated in the upper one. All sequence of beds with fossil elasmobranches including Dzheroy-2 demonstrates a succession of sea shallowing. The vertebrate locality Dzheroy-2 has been placed in a stratigraphic context with its maximum age as NP16 – Late Middle Eocene, upper Lutetian or Bartonian. Lithostratigraphic description of the Dzheroy Sand Member is given.

Key words: Dzheroy, Elasmobranchii, Eocene, Kyzylkum, paleoenvironment, stratigraphy

ТУРАНСКИЙ БАССЕЙН В ЭОЦЕНЕ: НОВЫЕ ДАННЫЕ ПО ИСКОПАЕМЫМ АКУЛАМ И СКАТАМ ИЗ ПУСТЫНИ КЫЗЫЛКУМ

Т.П. Малышкина[1]* и Д.Дж. Уорд[2]

[1]*Институт геологии и геохимии УрО РАН, ул. Академика Вонсовского, д. 15, 620016 Екатеринбург, Россия; e-mail: prionace@yandex.ru*

[2]*Отдел наук о земле, Музей естественной истории, шоссе Кромвеля, Лондон SW7 BD, Великобритания; e-mail: david@fossil.ws*

РЕЗЮМЕ

Геологическое полевое исследование стратиграфического контекста местонахождения ископаемых акул и скатов Джерой-2, расположенного в пустыне Кызылкум (Case et al. 1996), привело к открытию нового местонахождения, Джерой-3, состоящего из трех нижележащих слоев на разных стратиграфических уровнях: в основании сузакской свиты, в средней части алайской свиты и в основании туркестанской свиты. Было собрано более 450 зубов акул и скатов путем просеивания породы и ручного сбора с поверхности. Исходя из литологии и фаунистического состава отдельных сборках можно определить возраст и условия осадконакопления новых костеносных горизонтов. Фаунистический анализ свидетельствует о полноценных мор-

**Corresponding author / Автор-корреспондент*

ских условиях образования вмещающих отложений, а также об аноксичных придонных условиях в двух нижних горизонтах и более насыщенной кислородом обстановке в верхнем. Вся последовательность слоев с ископаемыми эласмобранхиями, включая вышележащий Джерой-2, демонстрирует процесс постепенного обмеления бассейна. Местонахождение позвоночных Джерой-2 помещено в стратиграфический контекст с максимальным возрастом NP16 – верхи среднего эоцена, верхний лютет или бартон. Приводится литостратиграфическое описание Джеройской песчаной пачки.

Ключевые слова: Джерой, эласмобранхии, эоцен, Кызылкумы, палеообстановки, стратиграфия

INTRODUCTION

The marine vertebrate faunas from the Eocene of Uzbekistan are poorly represented in the scientific literature. What literature there is, tends is generally brief, poorly illustrated, often restricted to faunal lists with a paucity of stratigraphic information.

Brief references to the occurrence of shark teeth in the Eocene deposits of Uzbekistan are included in the papers of Korobkov and Makarova (1964), Minakova (1964) and Morozov et al. (1988). Some papers on fossil fish (Glickman 1964; Glickman and Stolyarov 1966; Glickman and Zhelezko 1985; Nessov and Udovichenko 1986) contain fauna lists but with poor illustrations.

A Fossil vertebrate locality, situated in the Tamdy district of the Navoi region of Uzbekistan, named Dzheroy (Dzheroi or Jeroy, the spelling varies), subsequently Dzheroy-1, was discovered in a temporary sand pit by Lev Nessov in 1985 and published two years later. This locality yielded 16 species of shark and ray, as well as reptile and bird remains. It was determined to be late Middle Eocene in age based on the shark assemblage (Nessov et al. 1987).

On a return to the region in 1987, a second and much larger locality was discovered, in the form of a commercial white sand quarry referred by Issmatov et al. (1973). This quarry exposed about 16 meters of sediment of which 7 to 10 meters were white to yellowish cross-bedded sands with different degree of bioturbation and layering and was rich of different vertebrate fossils such as turtles, snakes, selachians. The shark and ray fauna of this locality, named in this paper Dzheroy-2, coordinates: N41°38´59´´, E064° 41´30´´, approximately 30 km NNW of Dzheroy-1, was published by Case et al. (1996) and amounted to 34 nominal species. The age was given as Middle Eocene (Lutetian) based on the vertebrate assemblage as there were no diagnostic invertebrates present. The white sand body was termed "The White Mountain Formation" based on its proximity to the Aktau (White Mountain in Uzbek). As no geological or geographic context was given, this must be regarded as an informal stratigraphic unit and has been redefined as the Dzheroy Sand Member below. The turtles and snakes from this site, termed Dzheroy-2 were published by Averianov (2002, 2007).

Our paper concerns the locality named Dzheroy-3, wich was discovered during fieldwork carried out as part of a series of multinational expeditions to the Kyzylkum desert, Qyzylqum in Uzbek, between 2002 and 2004 (Archibald et al. 1998; Archibald and Averianov 2005). In 2002 the site Dzheroy-2 was briefly visited by the authors with the assistance of Noel Morris and Chris King. In an attempt to gain some stratigraphic context, the party followed a dry river channel to the west of the Dzheroy-2 sand pit. The ravine cut through approximately 40m of Cenozoic sediments before reaching the Paleozoic basement. These sediments were logged and identified as (from the base up) Suzak, Alay and Turkestan formations. Three vertebrate bearing phosphorite levels, one in each formation, were located and their outcrops surface collected and bulk sampled and sieved to 500 microns for vertebrates. A series of samples for were taken by Chris King to obtain stratigraphically useful microfossils to attempt to date the formations independently from the vertebrates.

This site, referred to as Dzheroy-3, was revisited in 2003 and 2004. The results of the micropalaeontologic samples were published by Janssen et al. (2011) and are partially reproduced in Fig. 1. A brief account of the elasmobranch fauna was published by T. Malyshkina (2015). This paper describes the shark and ray remains in each of the three horizons sampled (Ph-1, Ph-2 and Ph-3) and their stratigraphic context.

Geological and stratigraphic settings. In the Eocene, the central Kyzylkum, was in north-eastern part of the Turan basin with the waters of normal

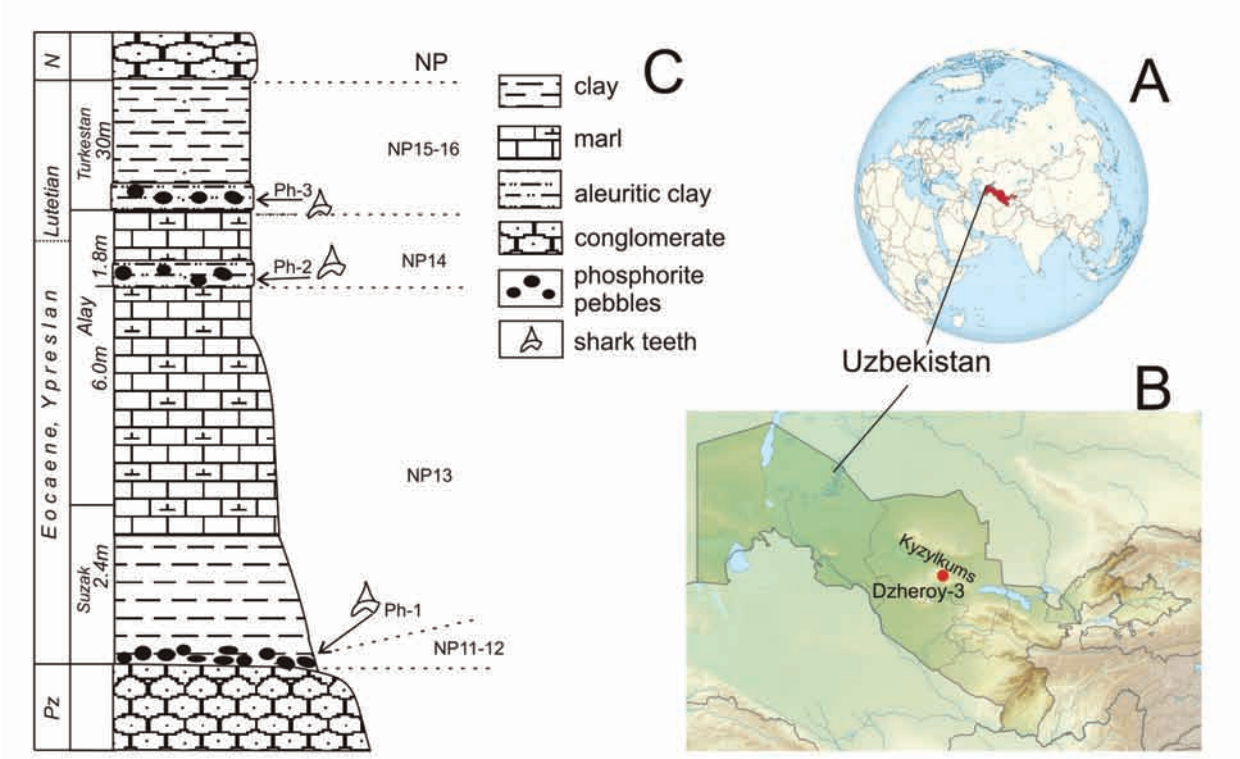

Fig. 1. General location map of the study area: A – Uzbekistan on the World map; B – the physical map of the Uzbekistan with the Dheroy-3 locality (circle); C – the section of the Dheroy-3 locality with the legend. NP data taken from Janssen et al. (2011).

salinity (Morozov et al. 1988). Six lithostratigraphic "horizons" or formations in different authors are recognized, Suzak, Alay, Turkestan, Rishtan, Isphara and Hanabad.

The Suzak Formation in the region is composed of sandy-clays and marls. It contains the nannoplankton of the NP11 and NP12 zones and making it early Eocene in age (Morozov et al. 1988).

The marls and limestones of the Alay Formation are characterized by a rich invertebrate fauna including foraminiferans, radiolaria, bivalves, gastropods, echinoids, crustaceans, fishes, and nannoplankton of zones NP13 and NP14. An abundance of *Pteria elytracea* Rom. suggests a correlation between the Alay and Tasaran formations of the North Aral Sea Region.

Fig. 2. Representatives of the Orectolobiformes from Dzheroy-3: A–C – *Eostegostoma angustum*, anterior tooth, Ph-1, NHMUK PV P73712; D, E – Orectolobiformes indet., lateral tooth, Ph-2, IGG P Dzh001. Scale bar = 2 mm.

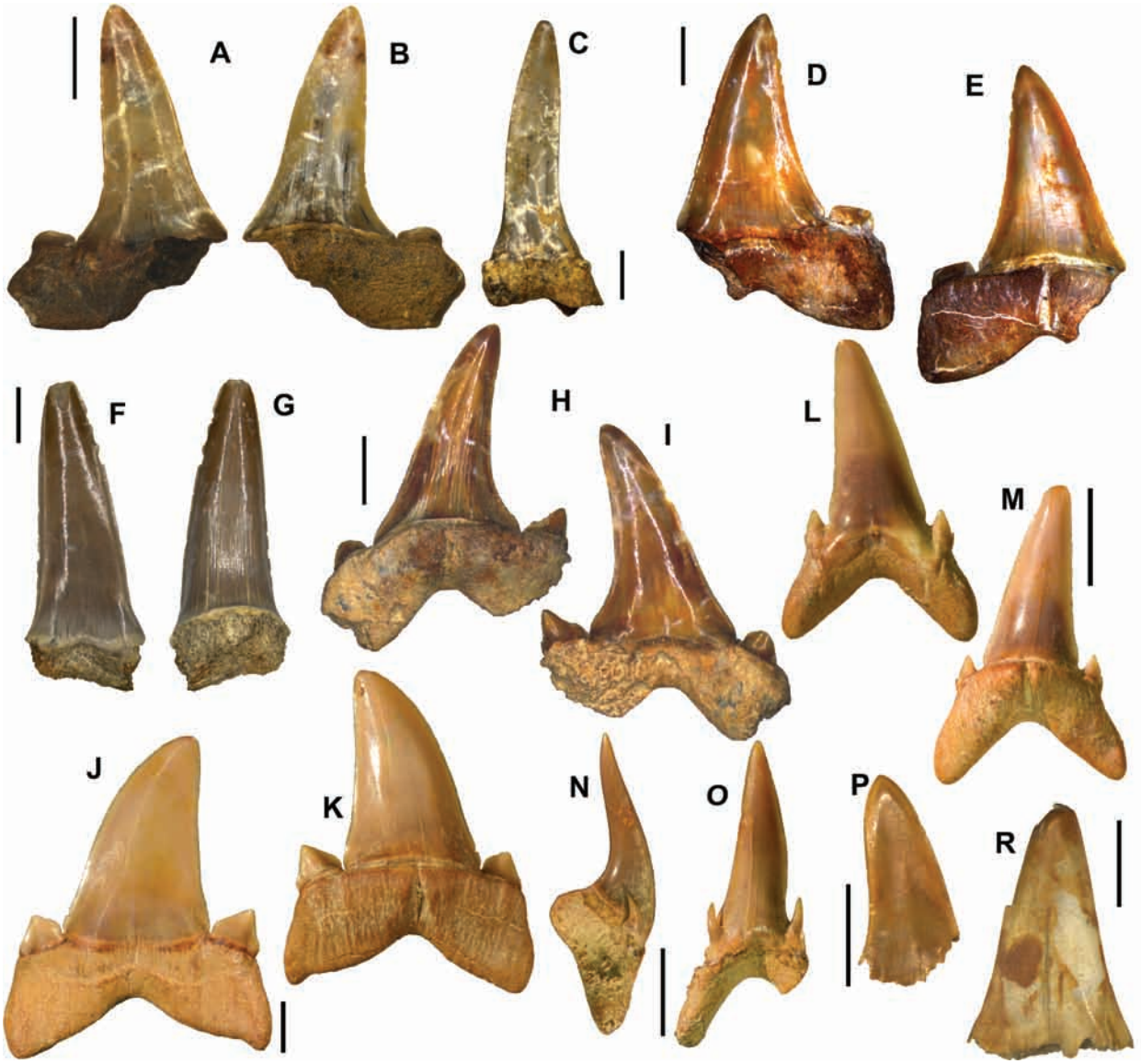

Fig. 3. Representatives of the Lamniformes and "Odontaspididae" from Dzheroy-3: A–E, J–K – *Striatolamia macrota*; A, B – upper lateral tooth, Ph-1, IGG P Dzh002; C – upper anterior tooth, Ph-1, IGG P Dzh003; D, E – lower lateral tooth, Ph-3, IGG P Dzh004; J, K – lower lateral tooth, Ph-2, NHMUK PV P73713; F–I – *Striatolamia* sp. 1, F, G – upper anterior tooth, Ph-2, IGG P Dzh005; H, I – 1st or 2nd upper lateral tooth, Ph-3, IGG P Dzh006; L–M – *Hypotodus verticalis*, lower lateral tooth, Ph-2, NHMUK PV P73714; N, O – *Odontaspis winkleri*, right lower (?) 1st anterior tooth, Ph-2, NHMUK PV P73715; P, R – *Jaekelotodus robustus*, fragments of teeth, Ph-3; P – IGG P Dzh007; R – IGG P Dzh008. A, C, D, F, I, J, L, O–R – labial view; B, E, G, I, K, M – lingual view; N is in profile. Scale bar = 5 mm.

The Turkestan Formation in the Central Kyzylkum contains nannoplankton of the NP14 zone: *Discoaster sublodornis* Braml. et Sull., *D. deflondre* Braml. et Reid. which correlate with beds with *Acarinina bulbrooki* and *Globorotalia caucasica* of the Northern Caucasus, Crimea and West Europe (Morozov et al. 1988).

Rishtan Formation or Horizon in the region has different construction and thickness and mainly consists of two parts of interbedding clays and limestones; faunas of molluscs and foraminifera let to correlate low part with Saksaul Formation of North Aral Sea Region and Kuma Horizon of the south

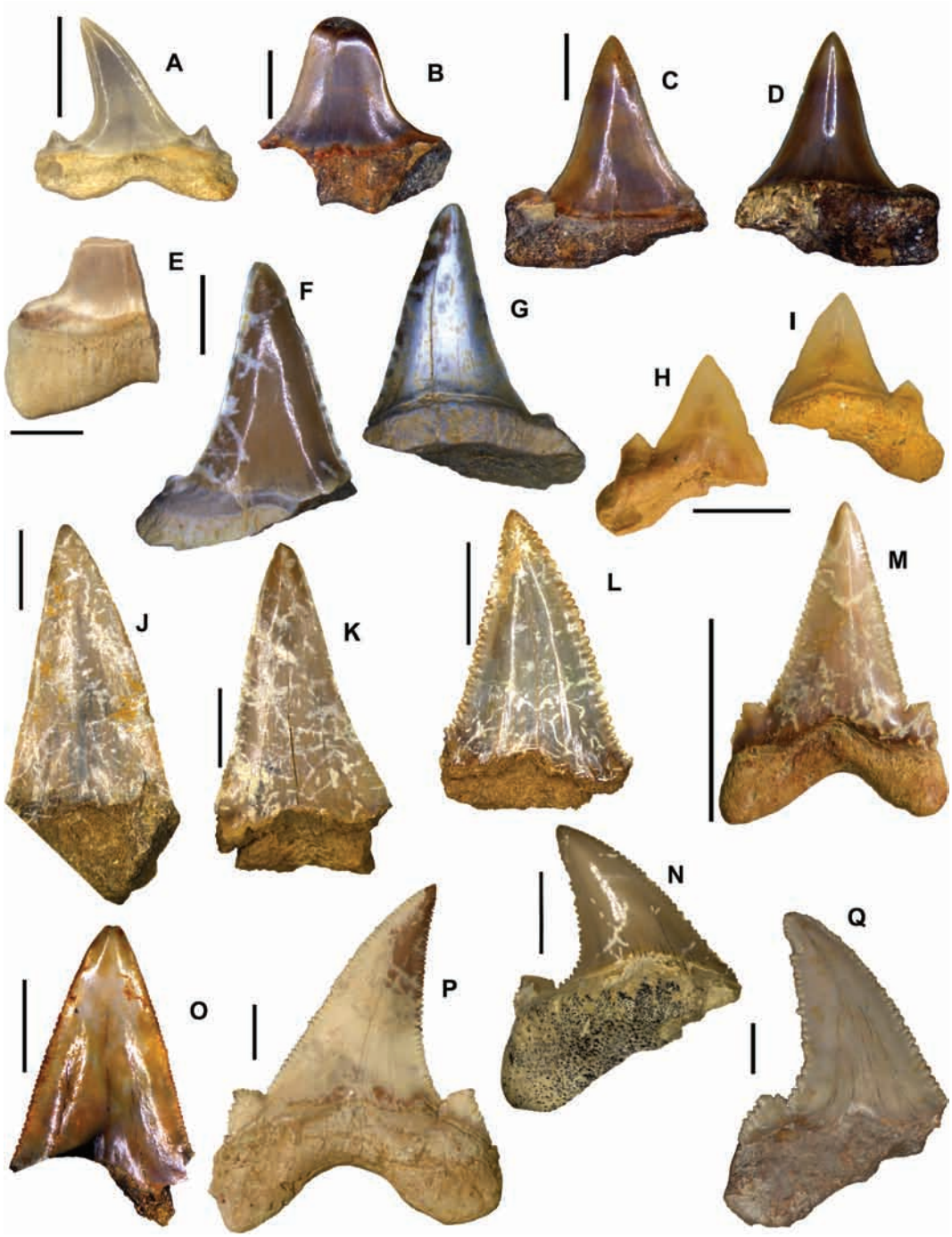

Fig. 4. Representatives of the Lamniformes Lamnidae and Otodontidae from Dzheroy-3. Lamnidae and Otodontidae: A – *Isurolamna inflata*, upper lateral tooth, Ph–1, IGG P Dzh009; C, D – *Macrorhizodus nolfi*, lower lateral tooth, Ph–3, IGG P Dzh010; B, E – *Macrorhizodus praecursor,* B – fragment of lateral tooth, Ph–3, IGG P Dzh011.; E – fragment of lateral tooth, Ph–3, NHMUK PV P73716; F, G – *Karaisurus* sp., lower lateral tooth, Ph–3, IGG P Dzh012; H, I – *Trigonotodus* cf. *T. tusbairicus,* lower lateral tooth, Ph–1, NHMUK PV P73717; J – *Otodus obliquus,* broken anterior tooth, Ph–1, IGG P Dzh013; K – *O. aksuaticus*, Ph–1, IGG P Dzh014; M–O, N–Q – *O. auriculatus,* M – Ph–2, NHMUK PV P73718; O – Ph–3, IGG P Dzh015; N – Ph–2, IGG P Dzh016; Q – Ph–1, NHMUK PV P73719; P – *O. sokolovi*, Ph–3, NHMUK PV P73720. A, B, C, E, F, H, J–P, Q – labial view; D, G, I, N – lingual view. Scale bar = 5 mm for A–I; 1cm for J–Q.

Table 1. The occurrence of the Dzheroy-3 species in other localities of Early and Middle Eocene Turan Basin. Ph-1, Ph-2 and Ph-3 – refer to the phosphatic horizons at the Dzheroy-3 locality described in this paper; Sb 5 – Sarbatyr locality, Central Kyzylkum, Early Eocene, phosphatic bed in the base of Suzak Formation, Early Ypresian (Malyshkina and Ward 2014); Sb 7 – the same locality, phosphatic bed in the base of Alay Formation, Ypresian (Malyshkina and Ward 2014); D1 – Dzheroy-1 locality, phosphatic beds into Alay Formation (Nessov et al. 1987); D-2 – Dzheroy -2 locality, sand pit, Middle Eocene (Case et al. 1996); AKT – Levels 1–5, Aktulagay, Eastern Pre-Caspian region, Western Kazakhstan, Ypresian (King et al. 2013). The numbers in the first column refer to taxonomic notes.

Note	Species	Ph-1 Suzak	Ph-2 Alay	Ph-3 Turk.	Sb 5 Suzak	Sb 7 Alay	Dzh-1	Dzh-2	AKT –
1	*Eostegostoma angustum* Nolf et Tavern., 1977	1	1			+	+	+	
	Otodus obliquus (Agassiz, 1943)	3				+			+
2	*Otodus aksuaticus* (Menner, 1928)	4			+	+			+
	Otodus auriculatus (Agassiz, 1943)	4	3	4		+	+		+
	Otodus sokolowi (Jaekel, 1894)			1				+	
	Alopias denticulatus Cappetta, 1981			4					
	Usakias sp.			1					
3	*Striatolamia macrota* (Agassiz, 1843)	3	34	67		+		+	+
4	*Striatolamia* sp.		1	3					
	Odontaspis winkleri Leriche, 1905		1			+		+	
	Hypotodus verticalis (Agassiz, 1843)		3	1			+	+	+
5	*Isurolamna inflata* (Leriche, 1905)	6	20	24		+	+		+
6	*Macrorhizodus nolfi* (Zhelezko, 1999)	3	6	4			+		+
6	*Macrorhizodus praecursor* (Leriche, 1905)		1	1				+	
7	*Karaisurus* sp.			1					
8	*"Cretalamna" twiggsensis* (Case, 1981)			1					
9	*Jaekelotodus* cf. *robustus* (Leriche, 1921)		1	2					
	Xiphodolamia ensis Leidy 1877	27				+			+
10	*Trigonotodus* cf. *T. tusbairicus* Kozlov, 1999	1							
11	*Physogaleus* sp.			2					
11	*Physogaleus secundus* (Winkler, 1874)	10	26	6	+	+	+	+	+
12	Triakidae *incertae sedis*		2						
	Pachygaleus lefevrei (Daimeries, 1891)	1				+			
12	*? Galeorhinus* sp.	1	1						
	Abdounia aff. *beaugei*	1	3	1		+	+	+	
	"Myliobatis" raouxi Arambourg, 1952	5	1	1		+	+	+	+
	Rhinoptera cf. *R.sherborni* White, 1931		10	26		+	+	+	
13	*Burnhamia* sp.	1	6	2		+	+	+	+
	TOTALS	75	120	149					

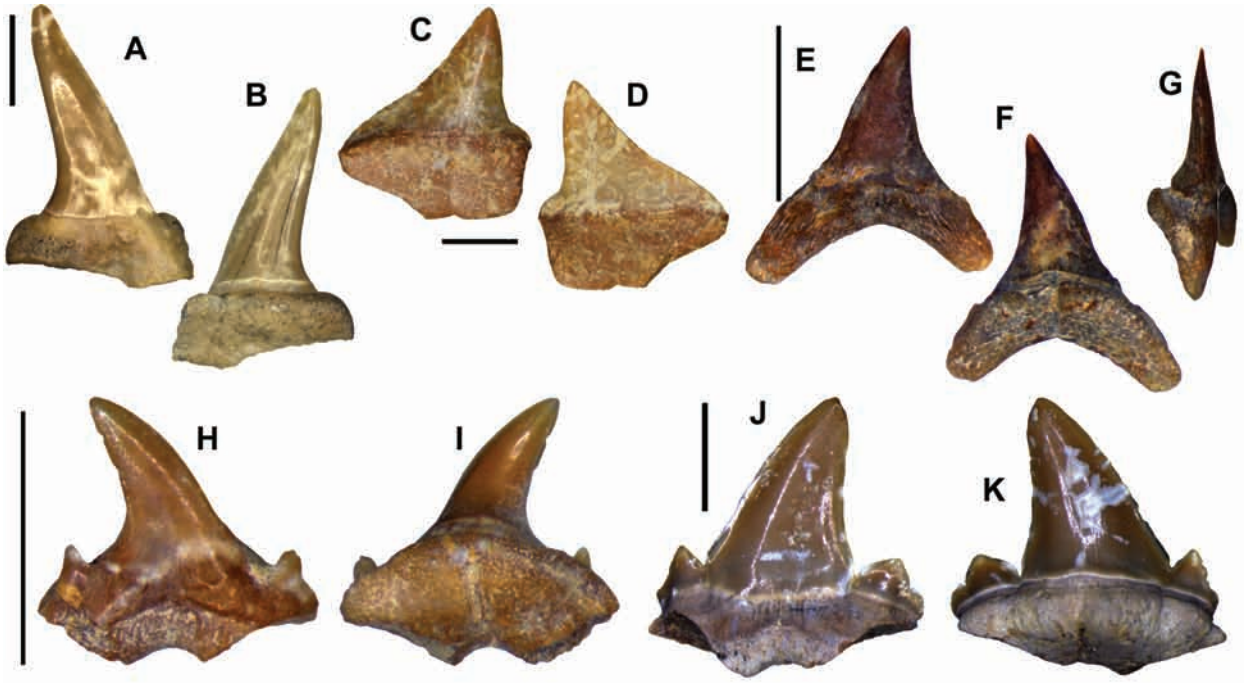

Fig. 5. Representatives of the Lamniformes from Dzheroy-3. Xiphodolamiidae, Alopiidae, "Odontaspididae": A, B – *Xiphodolamia eocaena*, A–B – anterior tooth, Ph–1, IGG P Dzh017.; C–D – lateral tooth, Ph–1, NHMUK PV P73721; E–G – *Alopias* cf. *denticulatus*, lateral tooth, Ph–3, IGG P Dzh018; H, I – *Usakias* sp., upper lateral tooth, Ph–3, IGG P Dzh019; J, K – *"Cretolamna" twiggsensis*, upper lateral tooth, Ph–3, IGG P Dzh020. A, D, E, H, J – labial view; B, C, F, I, K – lingual view; G – side view. Scale bar = 5 mm.

Russia and the Ukraine. Near Tamdytau and Bukantau these sediments are overlain by white to yellow unfossiliferous quartz cross-bedded sands (Mirzaev and Chinikulov 2015; Morozov et al. 1988). The upper part of Rishtan is non-calcareous and can be correlated with the Aday Formation of Mangyshlak on the base of radiolarian data (Morozov et al. 1988). The Rishtan Horizon is extremely diachronous over its depositional range because dinoflagellate data shows the age of Saksaul Formation varies geographically from Late Ypresian to Late Lutetian whereas the Kuma Horizon is dated as Bartonian (Vassilyeva 2014).

At Dzheroy-3, coordinates N41°38´60´´, E064°39´44´´, the Suzak Formation is 2.4 meters thick, overlying a lithified Paleozoic conglomerate. The basal 0.6m is a ferruginized glauconitic phosphatic conglomerate (Ph-1overlain by 0.8m of grey calcareous clays (Fig. 1).

The Alay Formation is a light grey marly limestone 8.8m thick with a 0.25m thick phosphatic pebble conglomerate about 1.8m below the top (Ph-2). The sediments below Ph-2 are dated as, NP13 and those above NP14a, both late Ypresian (Janssen et al. 2011).

The Turkestan Formation at Dzheroy-3 is a heavily weathered grey-green sandy marl about 30m thick. The base is erosive and heavily burrowed with complex *Thalassinoides* systems. The lowest 0.10m is a phosphatic pebble bed in a weathered matrix (Ph-3). The base of the Turkestan Formation is dated as mid Lutetian, being in the lower part of NP15 with the upper parts Late Lutetian to Bartonian; NP15/16 (Janssen et al. 2011). The absence of sediments of NP14b age, Early Lutetian, implies a hiatus at the Alay/Turkestan junction of about 1.3my (Janssen et al. 2011).

MATERIAL AND METHODS

The material described below was surface picked from the air-weathered slopes or bulk sampled on the northern slopes of the Dzheroy-3 ravine. The bulk samples were initially dry screened through a 500 micron sieve to remove most of the fine weathered sediment, then soaked in water and wet sieved to

Fig. 6. Representatives of the Carcharhiniformes from Dzheroy-3. Triakidae: A, B – *Pachygaleus lefevrei*, Ph–1, NHMUK PV P73722; C, D – Triakidae inc. gen. 1, lateral tooth, Ph–2, IGG P Dzh021; E, F – Triakidae inc. gen. 2, lateral tooth, Ph–2, IGG P Dzh022; G, H – ?*Galeorhinus* indet., lateral tooth, Ph–2, NHMUK PV P73723. A, C, E, G – labial view; B, D, F, H – lingual view. Scale bar = 5 mm.

disaggregate the remainder. Because of the limited water supply, the bulk samples were restricted to about 30 kg per horizon.

The fossil assemblages were sorted and identified and studied at the Institute of Geology and Geochemistry UB RAS, in Ekaterinsburg, Russia and at the Natural History Museum, London, UK.

Specimens with the prefix IGG P, are housed in the collections of the Institute of Geology and Geochemistry UB RAS, Ekaterinburg, Russia. They were photographed with a Leica digital acquisition system DFC 295 mounted on a Leica M80 binocular microscope.

Those with the prefix NHMUK VP are housed in the Department of Earth Sciences at the Natural History Museum, London UK. They were imaged with a Nikon D7200 digital camera with 105mm Nikkor micro lens or a Dino-Lite AM4815ZTL USB microscope.

RESULTS

Significant collections of shark and ray teeth were obtained from each of the three phosphatic horizons, both by surface collecting and bulk sampling and sieving. Surface collecting proved to be more cost effective than bulk sampling because of the low number of teeth in the samples combined with large number of phosphatic pebbles. Nevertheless, sieving was the only practical way to obtain some of the smaller taxa. In all over 450 teeth were collected from at least 25 species (Figs 2–8).

Table 1 lists the species and the number of determinate teeth obtained alongside those from other localities within the Turan Basin.

Taxonomic notes

1. *Eostegostoma angustum* figured by Case et al. (1996: pl. 11, figs. 204–208) under the name *Palaeorhincodon wardi* Herman, 1974. *Eostegostoma angustum* generally has an anaulacorhize root vascularisation whereas *Palaeorhincodon* has an open root groove, i.e. holaulacorhize.

2. Menner's type series of *Carcharodon toliapicus* Agassiz mut. *ak-suatica* are poorly illustrated (Menner 1928: 321 pl. XI, figs. 7–10 [7–11 in plate explanation]). Detail of the crown serration in figs. 7, 9 and 11 is indistinct but in figs. 8 and 10 the crown serration is seen to be irregular and diminishes in size apically. This is the character we used in identifying the species *Otodus aksuaticus* in our samples.

3. *Striatolamia macrota*. Teeth of Early Eocene members of *S. macrota* (Agassiz, 1843) differ in size and morphology from those of Middle Eocene age. Those from the Early Eocene have been referred to

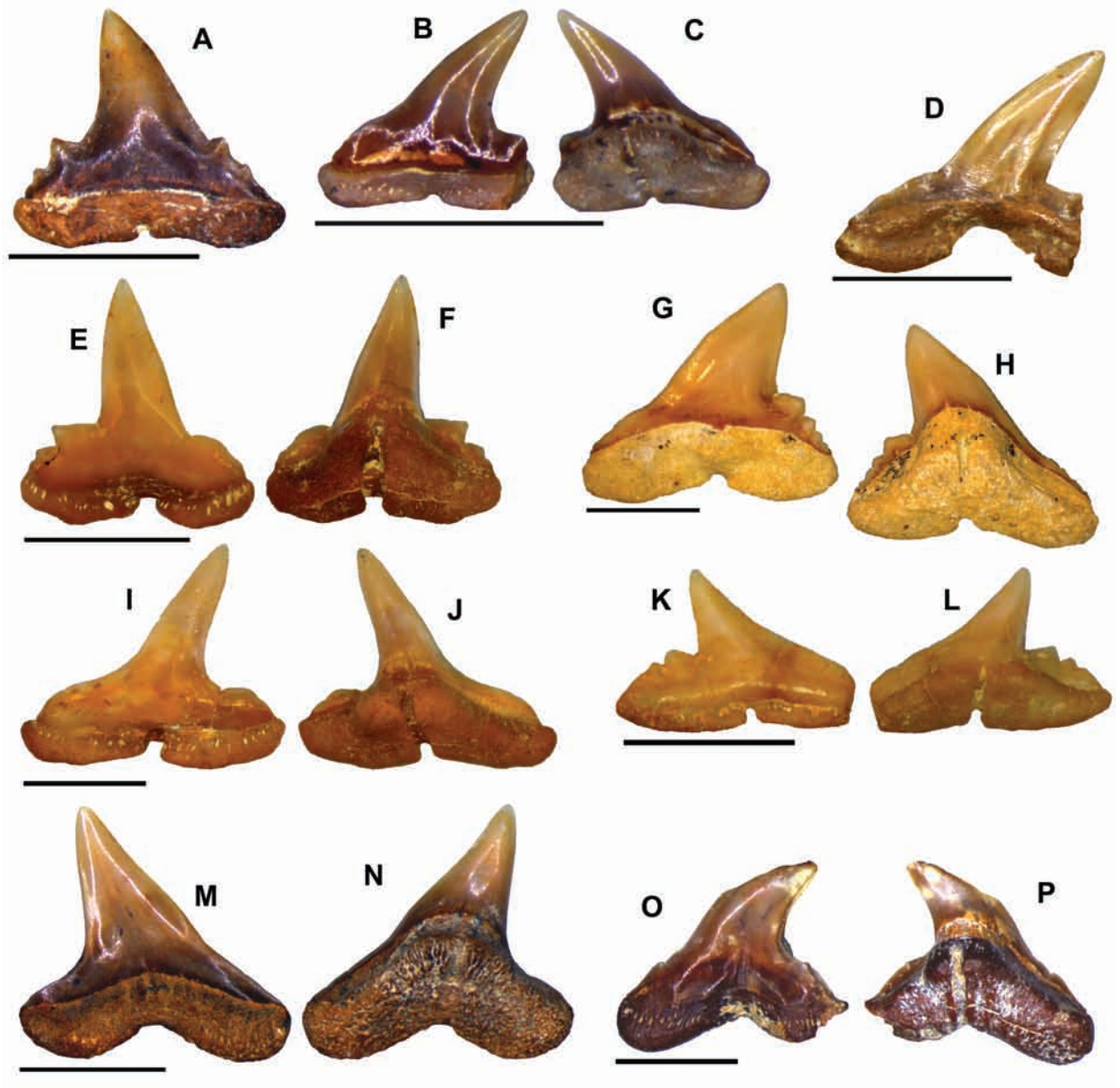

Fig. 7. Representatives of the Carcharhiniformes from Dzheroy-3. Carcharhinidae: A–C – *Abdounia* aff. *beaugei*: A – lower lateral tooth, Ph–3, IGG P Dzh023.; B, C – upper lateral tooth, Ph–3, IGG P Dzh024; D–L – *Physogaleus secundus,* D – second upper anterior tooth, Ph–2, IGG P Dzh025; E, F – upper anterior tooth, Ph–2, NHMUK PV P73724; G, H – upper lateral tooth, Ph–2, NHMUK PV P73725; I, J – lower anterior tooth, Ph–2, NHMUK PV P73726; K, L – lower lateral tooth, Ph–2, NHMUK PV P73727; M–P – *Physogaleus* sp., M, N – upper lateral tooth, Ph–3, IGG P Dzh026; O, P – ?second upper anterior tooth, Ph–3, IGG P Dzh027. A, B, D, E, G, I, K, M, O – labial view; C, F, H, J, L, N, P – lingual view. The scale bar = 5 mm.

as *Striatolamia striata* or *S. elegans* (White, 1931: 38; Casier, 1966: 69; Arambourg 1952: 62). Zhelezko and Kozlov (1999) designated a series of species and subspecies of *Striatolamia* spanning the late Paleocene to the Late Eocene, distinguished by characters on the upper lateral teeth. These were principally adult size, crown shape, degree of separation of the lateral cusps and the amount and nature of the labial crown striation. The Ypresian representative in this series was *Striatolamia elegans*, with two subspecies; *S, elegans*

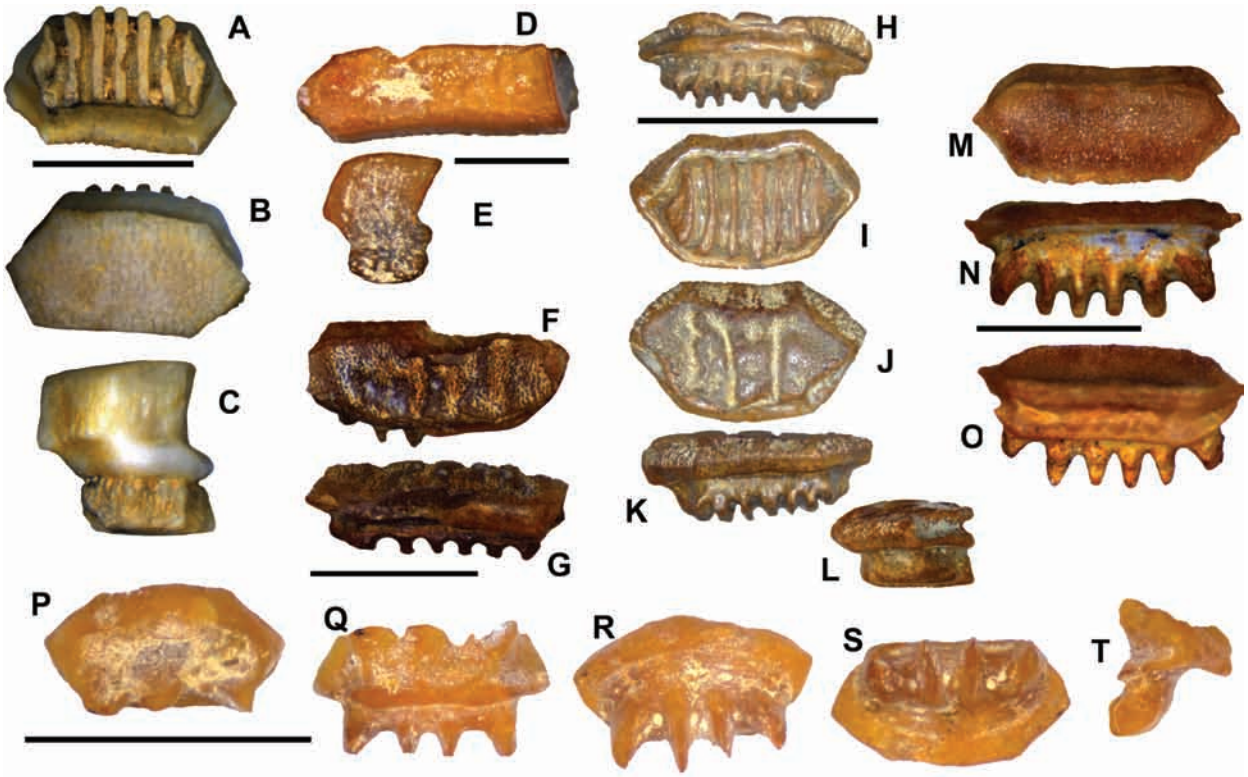

Fig. 8. Representatives of the Myliobatiformes from Dzheroy-3: A–E – *Rhinoptera* cf. *sherborni*: A–C – tooth of lateral series, Ph–2, IGG P Dzh031; D–E – tooth of medial series Ph–2, IGG P Dzh028; F–G – "*Myliobatis rauoxi*", tooth of medial series, Ph–3, IGG P Dzh029; H–L – tooth of medial series, Ph–2, NHMUK PV P73727; M–T – *Burnhamia* sp., M–O – tooth of ?female, Ph–2, IGG P Dzh030; P–T – tooth of ?male, Ph–1, NHMUK PV P73729. A, I, S – basal view, B, D, F, J, M, P – occlusal view, C, E in profile, G, K, N – labial view, H, O, Q – linqual view, R – linqualo-basal view. Scale bar = 3 mm for A–G, M–O; 5 mm for H–L, P–T.

naja in the early Ypresian and *S. elegans elegans* for the late Ypresian. Lacking formal descriptions, both subspecies are *nomena nuda*.

In describing *S. elegans*, Agassiz (1843: 289) did not designate a holotype. Of his nine syntypes, six are from the Lutetian (Middle Eocene) Calcaire Grossier of the Paris Basin, two are from the Ypresian London Clay of Sheppey, England and one is unknown. This weakens the biostratigraphic argument for the use of *S. elegans*. However, the fact still exists that globally, the Early Eocene population differs considerably from that of the Middle Eocene population. A systematic revision of *Striatolamia* is beyond the scope of this paper so we have chosen leave the Early Eocene representatives of this lineage as *S. macrota*.

4. Several incomplete anterior teeth of *Striatolamia* differ from typical *S. macrota* An incomplete tooth similar to that in Fig 3F, G was figured by Adnet (2006, pl. 20 fig. 4a, 4b).

5. *Isurolamna inflata* is regarded as the senior synonym of *I. affinis*. Teeth recorded from Dzheroy-2 by Case et al. (1996, pl. 7, figs. 126, 127) are those of *I. bajarunasi* (Glickman et Zhelezko, 1985) not *Brachycarcharias lerichei*.

6. *Macrorhizodus nolfi* is known from Ypresian deposits of Western Kazakhstan (Zhelezko and Kozlov 1999) and separated from *M. praecursor* by the presence of distinct lateral cusps which are reduced or absent in *M. praecursor*. The dividing line between the two species is uncertain. This is first record of the species in the Lutetian.

7. *Karaisurus* sp. This genus *Karaisurs* Kozlov in Zhelezko and Kozlov, 1999, known from a single species, *K. demidkini* Kozlov 1999), is currently only recorded from Shorym Formation (Bartonian) of Mangyshlak Peninsula, Western Kazakhstan. The single incomplete lateral tooth from Ph-3 differs from those of *K. demidkini* in having a more convex labial

crown which lacks a basal ledge. With such limited material it is not possible to determine whether these differences are specifically significant.

8. "*Cretalamna" twiggsensis*. This and several similar species undoubtedly belong in a separate genus.

9. *Jaekelotodus* cf. *robustus*. These records are based on large incomplete lamniform crowns and must be regarded as tentative.

10. *Trigonotodus* cf. *T. tusbairicus*. This is the first recorded occurrence in the Ypresian of the species recorded in Bartonian (Shorym Formation) of Mangyshlak Peninsula, Western Kazakhstan.

11. *Physogaleus secundus*. This "species" displays a great measure of heterodonty and may represent several separate species.

12. Triakidae and "*Galeorhinus*". Tentative determinations.

13. *Burnhamia* sp. Teeth of this taxon rarely possess more than six root lobes as opposed to the 10 plus seen in medial row teeth seen in *B. daviesi* (Woodward, 1889).

14. *Abdounia* aff. *beaugei*. The lateral cusplets are not quite like the type material of *A. beaugei* (Arambourg, 1952).

DISCUSSION

The assemblage from Ph-1, Suzak Formation, a ferruginized glauconitic phosphatic conglomerate was particularly interesting. The overall condition of the teeth was poor with most specimens having undergone a degree of post-mortem abrasion. It contained teeth of three members of the *Otodus* lineage, *Otodus obliquus, Otodus aksuaticus* and *Otodus auriculatus*.

The presence of nannofossils in the Suzak Formation in the Central Kyzylkums indicating an NP11 and NP12 age was reported by Morozov et al. (1988). Morozov et al. (1988) indicate an NP11 and NP12 age for the Suzak Formation in the Central Kyzylkum. At Dzheroy-3, where NP data from the Suzak Formation is absent, the same age is supported by the occurrence of teeth of *O. obliquus* and *O. aksuaticus*. However, at Aktulagay *O. aksuaticus* ranges up into NP13 with the first appearance of *O. auriculatus* several meters higher in the succession (King et al. 2013). This implies that age of the condensed deposit occupies the whole of the time span of NP12 and some NP13 which indicate a period of non-deposition of about 2.3 million years. It also means that the overlying Suzak Formation at Dzheroy-3 is, at the oldest, NP13 in age.

The abundance of *Xiphodolamia* is indicative of a highly productive, outer neritic environment, as does the high faunal diversity. The lack of any obligate bottom-feeding sharks and rays, may be a taphonomic artifact but more likely indicates anoxic or dysoxic bottom waters. There is a very close similarity between the Ph-1 assemblage and that of Aktulagay beds 1–5 (King et al. 2013: 192).

Ph-2 is a phosphatic band within the Alay Formation, level D1 of Janssen et al. (2011: 72) who suggest that it represents a pause in sedimentation of about 100,000 years. The elasmobranch assemblage shows an increased in the proportion of large and medium-sized predators, *O. auriculatus, Isurolamna* and *Physogaleus* as well as the sand shark *Striatolamia*. These along with the absence of *Xiphodolamia* suggest a shallower environment, probably near island shore. Morozov et al. (1988) state that in the central Kyzylkum, during the Alay Formation, there was a marine transgression with the sea covering all but islands formed by mountain massifs such as Tamdytau. King in Janssen et al. (2011:72) envisage an outer to inner neritic environment. The virtual absence any bottom-feeding sharks and rays again suggests anoxic bottom water conditions.

Ph-3 is a pelletal phosphate in a weathered sandy marl at the base of the Turkestan Formation. It has a relatively more diverse fauna, dominated by sand sharks and rays. This suggests shallow coastal waters. Nessov in Nessov et al. (1987) mentions that the phosphate horizons of Dzheroy-1 are pelletal indicating high oceanic productivity. This also raises the possibility that Dzheroy-1 is placed stratigraphically at the base of the Turkestan Formation. The brief fauna list from Dzheroy-1 in Nessov et al. (1987) does not contradict this possibility.

Table 2a, b compares the shark and ray assemblage from Dhzeroy-3 with the fauna from Dhzeroy-2 listed by Case et al. (1996). Those marked with an asterisk have been reidentified based on material collected by the authors from Dzheroy-2. The comparison let to see alteration of selachan fauna in the restrict territory in Eocene and changing of species in some lineages by the time.

Tables 3 and 4 indicate the stratigraphic and geographic ranges of the shark and ray material from Dzheroy-3.

Table 2a. An integrated faunal list of the Dzheroy-3 phosphatic horizons Ph-1, Ph-2 and Ph-3 and of Dzheroy-2 (Dzheroy Sand Member). Hexanchiform, Squaliform, Heterodontiform, Orectolobiform and Lamniform sharks.

	Ph-1 Suzak	Ph-2 Alay	Ph-3 Turk.	Dz-2 Turk
HEXANCHIFORM SHARKS				
Notorynchus kempi Ward, 1981				+
SQUALIFORM SHARKS				
Squalus sp.				+
Isistius trituratus (Wink., 1874)				+
SQUATINIFORM SHARKS				
Squatina prima (Wink., 1874)				+
HETERODONTIFORM SHARKS				
Heterodontus vincenti (Ler.,1905)				+
ORECTOLOBIFORM SHARKS				
Eostegostoma angustum N.et Tr., 1977	+	+		+*
Palaeorhincodon wardi Herm., 1975				+
LAMNIFORM SHARKS				
Xiphodolamia ensis Leidy, 1877	+			
Trigonotodus tusbairicus Kozl., 1999	+			
Striatolamia macrota (Ag., 1843)	+	+	+	+
Otodus obliquus (Ag., 1843)	+			
Otodus aksuaticus (Menn., 1928)	+			
Otodus auriculatus (Blain., 1818)	+	+	+	
Otodus sokolovi (Jaek., 1895)			+	+
Alopias denticulatus Capp., 1981			+	
Usakias sp.			+	
Isurolamna inflata Ler., 1906	+	+	+	
Isurolamna bajarunasi(Gl.et Zh.,1985)				+*
Macrorhizodus nolfi Zh,. 1999	+	+	+	
Macrorhizodus praecursor (Ler.,1905)		+	+	+
Karaisurus sp.			+	
"Cretalamna" twiggsensis (Case,1981)			+	
Brachcarcharias lerichei (Cas., 1946)				+
Odontaspis winkleri Ler., 1905		+		
Carcharias acutissima (Ag., 1843)				+
Hypotodus verticalis (Ag., 1843)		+	+	+
Jaekelotodus cf. *robustus* (Ler., 1921)		+	+	
Jaekelotodus trigonalis (Jaek., 1895)				+
Mennerotodus glueckmani Zh., 1994				+

Table 2b. An integrated faunal list of the Dzheroy-3 phosphatic horizons Ph-1, Ph-2 and Ph-3 and of Dzheroy-2 (Dzheroy Sand Member). Carcharhiniform sharks and batoids.

	Ph-1 Suzak	Ph-2 Alay	Ph-3 Turk.	Dz-2 Turk.
CARCHARHINIFORM SHARKS				
Premontrea gilberti (Cas. 1946)				+
Scyliorhinus sp.				+
Galeorhinus sp.	+	+		+
Triakidae inc. gen.		+		
Pachygaleus lefevrei (Daimer. 1891)	+			
Foumtizia pattersoni (Cap. 1976)				+
Abdounia aff. *beaugei* (Aramb. 1952)	+	+	+	+
Abdounia lapierrei Cap. et N. 1981				+
Abdounia sp.				+
Galeocerdo latidens (Ag. 1843)				+
Physogaleus secundus Wink. 1876	+	+	+	+
Physogaleus sp.			+	
Rhizoprionodon sp.				+
Mustelus sp.				+
BATOIDS				
Rhinobatos bruxelliensis Jaek. 1894				+
Rhinobatos steurbauti Cap. et N. 1981				+
Dasyatis sp.				+
Hypolophodon sylvestris (Wh. 1931)				+
Coupatesia sp.				+
Anoxypristis sp				+
Coupatezia woutersi Cap. 1982				+
Aetobatus irregularis Ag. 1843				+
Aktaua kyzylkumensis Case *et al* 1996				+
Myliobatis sp.				+
Myliobatis raouxi Aramb. 1952	+	+	+	+
Rhinoptera cf. *R. sherborni* Wh.1926		+	+	+
Archeomanta melenhorsti Herm. 1979				+
Burnhamia sp.	+	+	+	+

Table 3. The stratigraphic distribution of Dzheroy-3 species in the Palaeogene.

	Selandian	Thanetian	Ypresian			Lutetian		Bartonian	Priabonian
				Ph-1	Ph-2	Ph-3			
Eostegostoma angustum		■	■	■	■	■	■	■	
Otodus obliquus		■	■	■					
Otodus aksuaticus			■	■					
Otodus auriculatus			■	■	■	■			
Otodus sokolovi						■	■		
Alopias denticulatus						■		■	
Usakias sp.						■			
Striatolamia macrota				■	■	■	■	■	■
Striatolamia sp.					■	■			
Odontaspis winkleri		■	■		■		■		
Hypotodus verticalis		■	■		■	■	■		
Isurolamna inflata			■	■	■	■	■		
Macrorhizodus nolfi				■	■	■			
Macrorhizodus praecursor						■	■		
Karaisurus sp.						■			
"Cretalamna"twiggsensis						■			■
Xiphodolamia ensis			■	■	■	■	■		
Trigonotodus tusbairicus				■				■	
Physogaleus sp.					■	■			
Physogaleus secundus			■	■	■	■	■	■	■
Triakidae inc. gen.					■		■	■	■
Pachygaleus lefevrei		■	■	■					
? Galeorhinus sp.				■					
Abdounia beaugei			■	■	■	■	■	■	
Myliobatis raouxi				■	■	■			
Rhinoptera cf. *sherborni*					■	■			
Burnhamia sp.				■	■	■	■	■	

Dzheroy-2 is a large commercial sand quarry exposing about 12 metres of sand. This is heavily bioturbated cross-bedded sands indicating its close proximity to the palaeoshoreline. Cross-bedding if sands was a result of underwater currents which have place in the Central Kyzylkum part of basin in the Eocene near islands (Morozov et al. 1988; Mirzaev and Chinikulov 2015). This is supported by the prevalence of teeth of small sting rays and guitar fish, *Dasyatis* and *Rhinobatos*, both bottom-feeding predators characteristic of shallow and well oxygenated bottom conditions. The vertebrates were collected from a series of localized lag deposits. Their abundance is a partial reflection of the large extent of wind-ablated surfaces to surface collect from and the ease of sieving.

It was not possible to log a continuous section between the Ph-1 to Ph-3 localities to the Dzheroy-2 sandpit, a distance of over 2 km. However, it was estimated that the Dzheroy-2 sand body overlay 25 to 30 metres of Turkestan Formation silty marls. No evidence was seen to suggest the deposit was a chan-

Table 4. The paleogeographic distribution of the of the Dzheroy-3 species in the Eocene of the World.

Species	Kyzylkum desert	North Aral Sea Region and Turgai	Trans-Urals	West Kazakhstan	Europe	North Africa	North America
Otodus obliquus	■	■	■	■	■	■	■
O.aksuaticus	■	■		■	■	■	■
O. auriculatus	■	■		■	■	■	■
Xiphodolamia ensis	■	■	■	■	■	■	■
Striatolamia sp.	■						
Striatolamia macrota	■	■	■	■	■	■	■
Isurolamna inflata	■	■	■	■	■	■	■
Karaisurus demidkini	■	■					
Cretalamna sp.	■						
Macrorhizodus nolfi	■			■	■		
Jaekelotodus robustus	■	■			■		
Alopias aff. denticulatus	■	■	■		■		
Abdounia beaugei	■	■	■	■	■	■	■
Physogaleus secundus	■	■	■	■	■	■	■
Carcharhinidae inc.gen.	■						
Triakidae inc. gen.	■						
Myliobatis raouxi	■	■				■	
Burnhamia sp.	■	■	■	■	■	■	■

nel fill as the sand body appears to lie conformably on Turkestan Formation marls. Janssen et al. (2011) place the bulk of the Turkestan Formation in nannofossil zone NP15/16. This places the base of overlying Dzheroy-2 sands in the latest Lutetian or Bartonian.

In the central Kyzylkum, the lower part of the Rishtan Formation (Horizon) contains a sand body at the top (Morozov et al. 1988: Mirzaev & Chinikulov, 2015). These could possibly be the same sands quarried at the Dzheroy-2. An alternative hypothesis is that the Dzheroy-2 sands represent a local local body within the Turkestan Formation overlies Turkestan clays.

The upper age limit of Dheroy-2 sands is Bartonian due to presence of sharks absent from younger deposits, e.g. *Macrorhizodus praecursor*, *Abdounia beaugei* and *Hypotodus verticalis*. Teeth of *M. praecursor*, *Isurolamna bajarunsi*, and *Galeocerdo* were recorded from the Kuma horizon (Bartonian) in the Crimea and Northern Caucasus (Malyshkina et al. 2013). Most of lamniform species of Dzheroy-2 were recorded from the Shorym Formation of Mangyshlak (Zhelezko and Kozlov 1999).

Below the description of Dzheroy sand body is provided. It has been redescribed because the original description (Case et al. 1996) omitted almost all of the criteria required by the International Commission on Stratigraphy when defining a new stratigraphic unit (http://www.stratigraphy.org/index.php/ics-stratigraphicguide). Additionally, the term "White Mountain Formation" is preoccupied by the early Miocene White Mountain Formation of Western Australia (Lloyd 1968). Mirzaev and Chinikulov (2015) give a lithological description of the Dzheroy sands without determination in the separate lithostratigraphic unit but they do not give biostratigraphic characters and erroneously refer the age to Upper Eocene.

Lithostratigraphic description of the Dzheroy Sand Member

Name: Dzheroy Sand Member.

Formation: Rishtan Horizon.

Synonymy: The White Mountain Formation of Case et al. (1996).

Lithology: White to yellow medium to fine cross-bedded and bioturbated quartz sand. Detailed description see in Mirzaev and Chinikulov (2015).

Thickness: Between 10 and 15 metres.

Stratigraphic relationships: With a break overlies clays of the Turkestan Formation and is overlain by 3.8m of sandstone and clays of unknown age.

Geographic extent: Currently restricted to the Type Locality.

Depositional environment: Shallow coastal marine.

Age: Middle Eocene, Late Lutetian or Bartonian.

Type Locality: Dzheroy Sand Quarry.

Coordinates: N41°38´58.6´´, E064°41´29.4´´.

Fauna: Contains abundant teeth and bones of fishes (Case et al. 1996 and this paper, see Table 2a, b), as well as reptile and bird remains (Averianov 2002, 2007).

CONCLUSIONS

The age of the Suzak formation at Dzheroy-3 has been determined by a combination of sharks of the Otodus lineage (*O. obliquus* and *O. aksuaticus*) as being Early Eocene spanning nannofossil Zones NP11, NP12 and part of NP13.

The depositional environments of the Suzak, Alay, Turkestan formations at Dzheroy-3 have been determined with the use of their respective shark and ray faunas. All three formations are fully marine and show evidence of high productivity.

All three beds with a selachian fauna in the Dheroy-3 section are part of a shallowing-upward sequence in the transgressive-progressive succession of the region.

There is a strong probability of anoxic/disoxic bottom waters at levels Ph-1and Ph-2 but only slightly disoxic in Ph-3 as supported by the presence of *Thalassinoides* burrows.

The vertebrate locality Dzheroy-2 has been placed in a stratigraphic context with its age as most late Lutetian or Bartonian.

The stratigraphic and geographic ranges of *Trigonotodus, Macrorhizodus nolfi* and *Karaisurus* have been extended.

The relationships between Eocene geological formations in the Central Kyzylkum area as well as their palaeontological characters requires further research.

ACKNOWLEDGMENTS

Authors wish to thank Dr Galina Aleksandrova, Geological Institute of RAS and Dr Charlie Underwood, Brickbek College University of London, for thoughtful comments that improved the paper. We are grateful Prof. David Archibald, San-Diego State University, for giving the authors the opportunity to visit this locality as members of the URBAC expedition team. Dr Noel Morris and the late Dr Chris King assisted in the field work. We would also like to thank the Institute of Zoology, Uzbek Academy of Science, especially its Director, Dr D.A. Azimov for permission to conduct fieldwork in the Kyzylkum desert. Dr David Ward would like to thank Miss Emma Bernard (NHMUK) for curating the specimens housed in Natural History Museum, London, UK. Dr Tatiana Malyshkina is grateful to Drs Alexander Borodin, Maria Fomynykh, Evgenia Markova and Sergey Zykov, Institute of Plant and Animal Ecology UB RAS, for the opportunity to use of their photographic equipment.

REFERENCES

Agassiz L.J.R. 1833–1844. Recherches sur les Poissons fossiles. T. 3 contenant l'histoire des placoïdes. Petitpierre, Neuchâtel and Soleure, 422 p.

Arambourg C. 1952. Les Vertebres Fossiles des Gisements de Phosphates (Maroc–Algerie–Tunesie). *Notes et Mémoires. Service des Mines et de la Carte Géologique du Maroc Paris,* **92**: 1–372, 44 pls.

Archibald J.D., Sues H.-D., Averianov A. O., King C., Ward D.J., Tsaruk O.A., Danilov I.G., Resvyi A.S., Veretennikov B.G. and Khodjaev A. 1998. Précis of the paleontology, biostratigraphy, and sedimentology at Dzharakuduk (Turonian? – Santonian), Kyzylkum Desert, Uzbekistan. In: Kirkland J.I. and Lucas S. (eds.) Lower to Middle Cretaceous Terrestrial Ecosystems. *New Mexico Museum, Natural History and Science Bulletin*, **14**: 21–28.

Archibald J. D. and Averianov A.O. 2005. Mammalian Faunal Succession in the Cretaceous of the Kyzylkum Desert. *Journal of Mammalian Evolution*, **12**(1/2): 9–22, figs 1–4.

Averianov A.O. 2002. Review of Mesozoic and Cenozoic Sea Turtles from the former USSR. *Russian Journal of Herpetology,* **9**(2)**:** 137–194.

Averianov A.O. 2007. A New Sea Turtle (Testudines, Cheloniidae) from the Middle Eocene of Uzbekistan. *Paleontological Journal,* **39**(6): 646–651.

Case G.R., Udovitchenko N.I., Nessov L.A., Averianov A.O. and Borodin P.D. 1996. A Middle Eocene Selachian Fauna from the White Mountain Formation of the Kizylkum Desert, Uzbekistan, C.I.S. Palaeontographica Abt. A. Stuttgart, 242 p.

Casier E. 1966. Faune ichthyologique du London Clay. London: British Museum (Nat. Hist.), 496 p.

Glickman L.S. 1964. Sharks of Paleogene and their stratigraphic significance. Nauka, Moscow, 229 p. [In Russian].

Glickman L.S. and Stolyarov A.S. 1966. Stratigraphy of the Upper Eocene of the Mangyshlak Peninsula based on the paleoichthyological data. *Izvestija Akademii Nauk SSSR. Serija geologicheskaja*, **11**: 130–138. [In Russian].

Glickman L.S. and Zhelezko V.I. 1985. Paleogene sharks of the Mangyshlak Peninsula and the Eocene/Oligocene boundary. *Bjulleten' Moskovskogo obshhestva ispytatelej prirody. Otdel geologicheskij*, **60**(5): 86–99. [In Russian].

Issmatov A.A., Karzhauv T.K., Gafurdzhanov S. and Issmatova M.Yu. 1973. Quartz sands in the Dzheroy deposit as a raw material used in production of glass, Uzbekistan. *Doklady Akademii Nauk Uzbekskoy SSR,* **4**: 44–45. [In Russian].

Janssen A.W., King C. and Steurbaut E. 2014. Notes on the systematics, morphology and biostratigraphy of fossil holoplanktonic Mollusca, 21. Early and Middle Eocene (Ypresian–Lutetian) holoplanktonic Mollusca (Gastropoda) from Uzbekistan. *Basteria*, 75(4–6): 71–93.

King C., Iakovleva A., Steurbaut E., Heilmann-Clausen C. and Ward D. 2013. The Aktulagay section, west Kazakhstan: a key site for northern mid-latitude Early Eocene stratigraphy. *Stratigraphy*, **10**(3): 171–209.

Korobkov I.A. and Makarova R.K. 1964. To the stratigraphy and fauna characteristic of the Palaeogene deposits of the Kyzylkums and South Pre-Aralie. *Trudy of VSEGEI. Leningrad. Novaya seria,* **102**: 236–252. [In Russian].

Lloyd A.R. 1968. Possible Miocene marine transgression in Northern Australia. *Bureau of Mineral Resources, Australia, Bulletin*, **80**: 85–103.

Malyshkina T.P. 2015. New data on the Eocene ichthyofauna of the Central Kyzylkum. Recent problems of the Palaeontology. Materials of the LXI session of the Palaeontological Society at RAS (13–17 April 2015, Saint Petersburg). Saint Petersburg, 160–162. [In Russian].

Malyshkina T.P. and Ward D.J. 2014. New records of Early Eocene Elasmobranchs from the Kyzylkum desert, Uzbekistan. Program and Abstract Book. Erin Maxwell, Jessica Miller-Camp, Eds. 74th Annual Meeting of Society of Vertebrate Paleontology (November 2014, Berlin, Germany), 176.

Minakova N.E. 1964. On the stratigraphy of the Upper Eocene and Oligocene sediments of the Kyzylkum. Common problems of the stratigraphy and Palaeogeography of the Turgay and Middle Asia. *Trudy VSEGEI. Novaya seriya,* **102**: 40–52. [In Russian].

Mirzaev A.U. and Chinikulov X. 2015. The role of breaking undersea flows for the forming of the locality of quarz sands "Jeroy" (Uzbekistan). Deposits of gemstone and nonmetallic raw materials of different geodynamic conditions (XVI Papers in memory of academician A.N. Zavaritsky). Ekaterinburg: IGG UrO RAN, 83–88. [In Russian].

Morozov S.D., Rasulov U.M., Boiko V.S. and Troitskyi V.I. 1988. Geology of the Paleogene deposits of the South-Eastern Kyzylkums. FAN, Tashkent, 139 p. [In Russian].

Nessov L.A. and Udovitchenko N.I. 1986. New findings of the fossil vertebrates remains of the Cretaceous and Palaeogene of the Middle Asia. *Voprosy paleontologii,* **9:** 129–136. [In Russian].

Nessov L.A., Shabanina N.V., Udovichenko N.I. 1987. New findings of the vertebrate remains in the phosphorites of the Middle Eocene of the Central Kyzylkum and conditions of the forming of the grained phosphorites. *Uzbekskiy geologicheskiy zhurnal*, **4**: 72–77. [In Russian].

Vassilyeva O.N. 2014. Eocene zonal dinocyst succession in southern part Turgay hollow (Chelkar depression, Kazakhstan). *Lithosphera,* **6:** 132–140. [In Russian].

White E.I. 1931. The Vertebrate Faunas of the English Eocene. 1. From the Thanet Sands to the Basement Bed of the London Clay. BM(NH), London, 123 p.

Zhelezko V.I. and Kozlov V.A. 1999. Elacmobranches and Biostratigraphy of the Palaeogene of the Trans-Urals and Middle Asia. *Materialy po stratigraphii i palaeontologii Urala,* Ekaterinburg: UrO RAN, **3**: 324 p. [In Russian].

Submitted January 25, 2016; accepted March 23, 2016.