



First Record of *Eotragus noyei* from the Late Miocene Siwaliks of Pakistan

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ABSTRACT

The present paper reports the first record of *Eotragus noyei* from the late Miocene deposits of Dhok Pathan Formation, Chakwal, Pakistan. The sample comprises maxillary and mandibular fragments along with isolated upper and lower teeth. The morphometric analysis of the dental specimens led us to recognize the sample as belonging to *Eotragus noyei*, which has been considered as the smallest and the oldest bovid in the Siwaliks. *Eotragus noyei* is characterized by brachyodont teeth, finely rugose enamel, more inclined buccal walls of the molars and small lingual cingula. The inclination of the metaconal area has caused rotation of the metastyle in relation to the antero-posterior tooth axis and thus situated more lingually. The protocone in second upper premolar is well developed and situated posteriorly and also has an anterior lingual constriction. The metaconule in the third upper molar is smaller than the protocone. The dentition in *Eotragus noyei* is smaller in size as compared to *Eotragus sansaniensis* and *Eotragus lampangensis*. In *Eotragus noyei* the buccal walls in molars are more inclined while in *Eotragus sansaniensis*, they are less inclined. The genus *Eotragus* has been reported previously in the Lower Siwaliks of Pakistan; however, the recognition of the present sample as *Eotragus noyei* has extended the range of this species from Lower to the Middle Siwaliks of Pakistan.

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Authors' Contribution

AMK, MTW and HIN designed the study. AR, AI and RMA did the taxonomic identification. MTW and MA wrote the geological settings. MTW, HIN and AMK wrote the manuscript.

Key words

Boselaphini, Chakwal, Bovids, Dhok Pathan, Middle Siwaliks.

INTRODUCTION

Siwaliks has been found to be having artiodactyls in its Miocene and Pliocene sediments and they are found to belong to the Middle Siwaliks, the exact location of which is in the Potwar Plateau of Northern Pakistan (Barry *et al.*, 1982, 1985, 2002, 2013; Flynn *et al.*, 2016; Waseem *et al.*, 2016; Nawaz *et al.*, 2019). These artiodactyls are found to have outstanding material which shows high diversity of boselaphine bovids in between late Miocene and early Pliocene. Bovids constitute 56% of the recovered artiodactyls out of which 29.7% are boselaphine. During the Eurasian, African and the Siwalik late Miocene, and still today, these boselaphine remains were abundant (Bibi, 2007, 2009). This indicates that the niche was fully occupied by boselaphines rather than tragilaphines. These tragilaphines were found to be more diverse during late Miocene in Africa and due to which boselaphines became extinct (Haile-Selassie *et al.*, 2004). This is evidence for abolition of habitat of late Miocene boselaphines (Khan *et al.*, 2009; Badgley *et al.*, 2008). Dental microwear and mesowear analysis of *E. aff. clavatus* reported from the Calatayud-Daroca Basin of Spain, Göriach (Australia) and *Eotragus clavatus* from Sansan (France) showed that

both taxa were generalized browsers (Solounias and Moelleken, 1992). Extracted isotopes of oxygen and carbon from enamel of Mae Moh herbivores' tooth indicate that they occupied various habitats ranging from grasslands to woodlands. The carbon isotope values for Mae Moh herbivore community ranges from -12‰ to -8.4‰ indicating the appearance of grasslands close to open forests and woodlands. Exclusively, carbon isotope that is found in *E. lampangensis* sp. nov. ($\delta^{13}\text{C} = -8.4\%$) (Suraprasit *et al.*, 2014) shows that it lived in between grassland and forest habitat which express more close relationship with moderate brachyodonty. This paper reports the first occurrence of *E. noyei* from middle Dhok Pathan formation of the Siwaliks of Pakistan which extends the range of this species from late Middle Miocene to Late Miocene.

MATERIALS AND METHODS

The sample for the present study has been recovered from Dhok Pathan Rest House (33.12N, 72.34E), Dhok Pathan Formation, Chakwal, Pakistan. We assume that the sample belong to one individual. The complete magnetostratigraphic correlation with the section has been given in the Barry *et al.* (2002). The studied section comprised of multi storied sandstone more formally characterized as U-sandstone (Morgan *et al.*, 2009). The sample can be placed between the magnetozone 4An and

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4Ar.1r on the basis of U-sandstone interval (Behrensmeyer and Tauxe, 1982). The total height of the section is 150m at intervals it is 490m, while the samples for the current study has been recovered at the height of 90m. The correlation of section log and magnetic polarity given in Barry *et al.* (2002) allows us to place the sample between 8.5 Ma to 9 Ma. Biostratigraphically the recovered samples can be placed in *Hipparion* s.l. interval zone having an age of 9.5 Ma to 7.4 Ma (Barry *et al.*, 1982).

Studied material was collected during the field trip of April, 2015. The main technique which was used is the partial excavation by using fine needles, hammers, chisels, hand knives and brushes of the samples and exposed slightly. The samples were further washed and treated with weak bleach so the sample may be cleaned. All the measurements were taken by vernier calipers and reported in millimeters while photography was done by Canon EOS-350D using the lens 18-55mm. The collected specimens were catalogued and preserved in palaeontology laboratory of Zoology department for dental taxonomic study. The tooth width and length were measured on the occlusal side. The catalogue numbers are abbreviated as PUPC (Punjab University Palaeontological Collection). The terminology and measurements of the teeth follows Gentry (1994).

Systematic Palaeontology

Family: Bovidae (Gray, 1821)

Subfamily: Bovinae (Gray, 1821)

Tribe: Boselaphini (Knotnerus-Meyer 1907)

Genus: *Eotragus* (Pilgrim, 1939)

Included species

E. haplodon Thenius, 1952; *E. noyei* Solounias *et al.*, 1995; *E. sansaniensis* Lartet, 1851; *E. cristatus* Biedermann, 1873; *E. halamagaiensis* Ye, 1989 and *E. artensis* Ginsburg and Heintz, 1968.

Type species

Eotragus noyei.

Type locality

Dhok Pathan village, Chakwal district (Middle Siwaliks), Potwar Plateau, Pakistan.

Geographic distribution

Central Europe, China, Israel, Kenya, Libya, Pakistan and Spain.

Stratigraphic range

Lower Siwaliks to Middle Siwaliks.

Table I.- Comparison of morphological characters among the studied specimen and the different species of *Eotragus*.

Studied specimen	<i>E. noyei</i>	<i>Eotragus</i> sp.	<i>E. sansaniensis</i>	<i>E. lampangensis</i>
Selenodont morphology	Selenodont morphology	Selenodont morphology	Selenodont morphology	Selenodont morphology
Brachydont teeth	Brachydont teeth	Brachydont teeth	Brachydont teeth	Brachydont teeth
Finely rugose enamel	Finely rugose enamel	Finely rugose enamel	Finely rugose enamel	Finely rugose enamel
Narrow fossette	Narrow fossette	Narrow fossette	Narrow fossette	Narrow fossette
Small in size	Small size	Small in size	Very large size	Very large size
Buccal walls of the upper molar are more inclined	Buccal walls of the upper molar are more inclined	Buccal walls of the upper molar are more inclined	Buccal walls of the upper molar are less inclined	Buccal walls of the upper molar are less inclined
Parastyle is of medium sized	Parastyle is of medium sized	Parastyle is of medium sized		Parastyle is well developed
Mesostyle is of medium sized	Mesostyle is of medium sized	Mesostyle is of medium sized		Mesostyle is well developed
Paracone ribs are stronger than the metacone ribs	paracone ribs are stronger than the metacone ribs	paracone ribs are stronger than the metacone ribs		
A trace of cingulum present	A trace of cingulum present	Cingulum absent	Large cingulum	Cingulum absent
M ³ metaconule is smaller than the protocone	M ³ metaconule is smaller than the protocone		M ³ metaconule is larger than the protocone	M ³ metaconule is larger than the protocone
P ² protocone is well developed in the studied specimen and situated posteriorly	P ² protocone is well developed in the studied specimen and situated posteriorly			

Source: Gentry (1999), Solounias *et al.* (1995), Khan *et al.* (2009) and van der Made (2012).

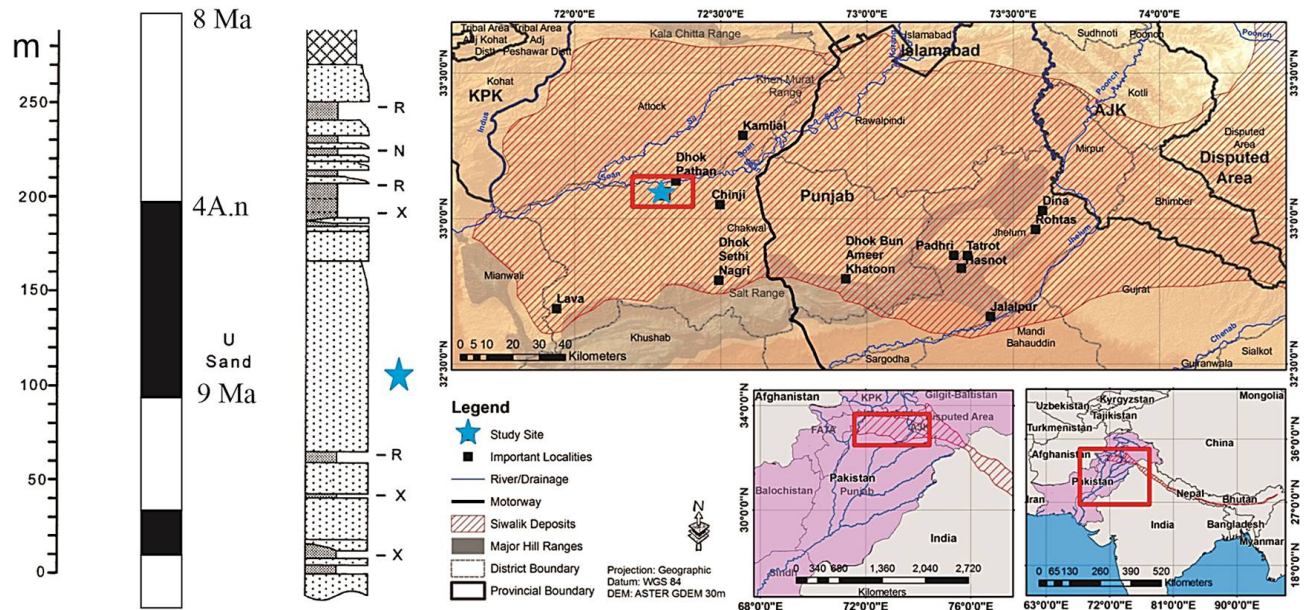


Fig. 1. Map of the Siwaliks of Pakistan with the studied locality and magnetostratigraphic chart (modified from Barry *et al.*, 2002; Morgan *et al.*, 2009).

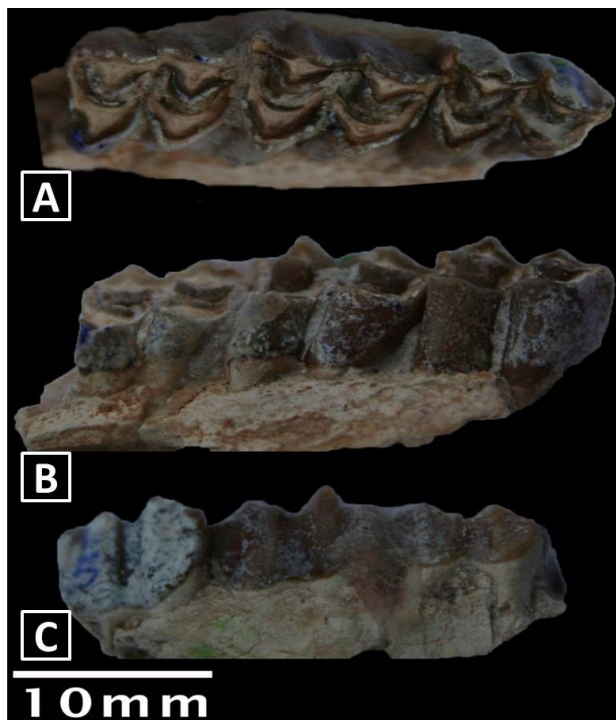


Fig. 2. *Eotragus noyei*. PUPC 16/353, left maxillary fragment having M^{1-3} . A, occlusal view; B, lingual view; C, buccal view.

Studied material

Upper dentition: PUPC 16/353, left maxillary

fragment having M^{1-3} ; PUPC 16/354, right maxillary fragment having P^2-M^3 ; PUPC 16/355, an isolated upper left second premolar (P^2). Lower dentition: PUPC 16/356, an isolated lower left third molar (m^3); PUPC 16/357, right mandibular fragment having p^4-m^3 .

Upper dentition

PUPC 16/353 (Fig. 2) is a left maxillary fragment having M^{1-3} . Its state of preservation is good. The molars are brachydont and quadrate in general appearance. A layer of cement is observed on the fragment. They have selenodont morphology and have finely rugose enamel. A piece of the palate is attached with the maxillary fragment. The buccal walls of the teeth do not align as the teeth are arranged obliquely. The anterior and posterior fossettes are rather narrow. The first molar is in the middle stage of wear. All the cusps are clearly visible and well developed while the styles are poorly developed. The protocone is more projected towards the lingual side. The teeth show the confluence of the premetacrista, postmetacrista and the postparacrista. Cingulum is absent on the fragment. The second molar is half worn causing the exposure of dentine of all the cusps. The protocone is isolated and slightly rounded. The posterior rib is weaker than the anterior rib. The size of parastyle, mesostyle and metastyle is medium. The lingual groove is not clearly visible due to middle stage of wear. The third molar has a comparable morphology to M^2 and almost equal in size to M^3 . In the third molar, the metaconule is smaller than the protocone. PUPC 16/354 (Fig. 3) have similar dental morphology to PUPC 16/353.

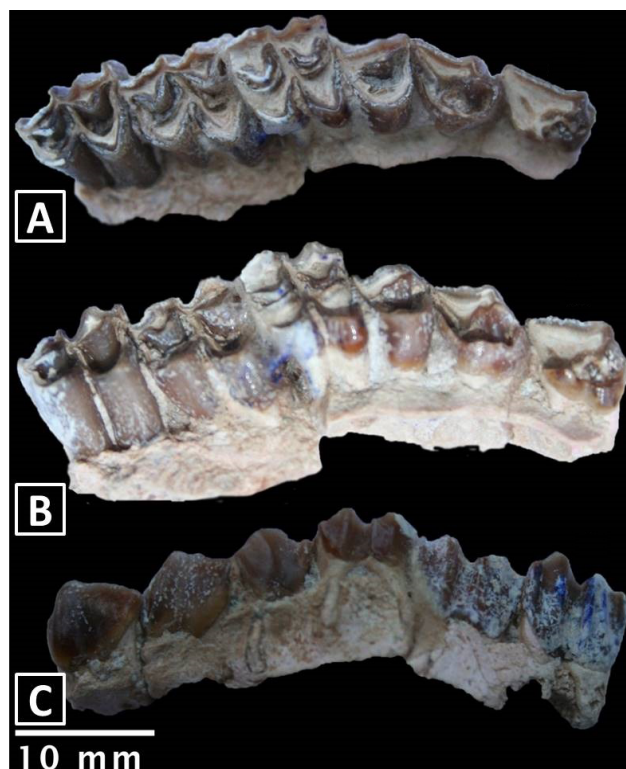


Fig. 3. *Eotragus noyei*. PUPC 16/354, right maxillary fragment having P²-M³. A, occlusal view; B, lingual view; C, buccal view.

PUPC 16/355 (Fig. 4A) is an isolated upper left second premolar. Its length is 8mm. It is well preserved. It is triangular in shape. It has well developed and clearly visible cusps. The protocone is well developed and located posteriorly and it has an anterior lingual constriction.

Lower dentition

PUPC 16/356 (Fig. 4B) is an isolated lower left third molar. It is moderately worn and has selenodont morphology. The enamel is finely rugose. The length of third molar is 12.5mm. It is rectangular by its appearance. A layer of cement is present on it. The protoconid is rounded and isolated. The mesostylid is less developed. The lower third molar has an additional cusp, known as talonid. The Central fossettes are isolated from the exterior. It has a weak metastylid. The posterior rib is weaker than the anterior one. All tooth features are well preserved and exhibit the confluence of protocristid, metacristid and the post metacristid.

PUPC 16/357 (Fig. 5) is a right mandibular fragment having P₄M₃ with a length of 39 mm. The state of preservation of the mandible fragment is average. It is rectangular in general appearance. Its buccal side is

more rugose than lingual side. The molar is brachyodont and narrow crowned. A thick layer of cement is present on the whole fragment. Cracks are present on the molars. On the buccal sides of molars, median basal pillars or entostyles are present in the transverse valley. The P₄ is elongated in shape and cones and styles are not visible. M₁ is not clearly visible. In M₂ stylids are less developed. The enamel is rugose especially on the buccal side of the mandible fragment. The lower right third molar, is moderately worn, dainty, with selenodont morphology and has a weak metastylid and anterior rib on its lingual wall. In the third a well-developed talonid is present. The cusp tips are rounded and sharp.

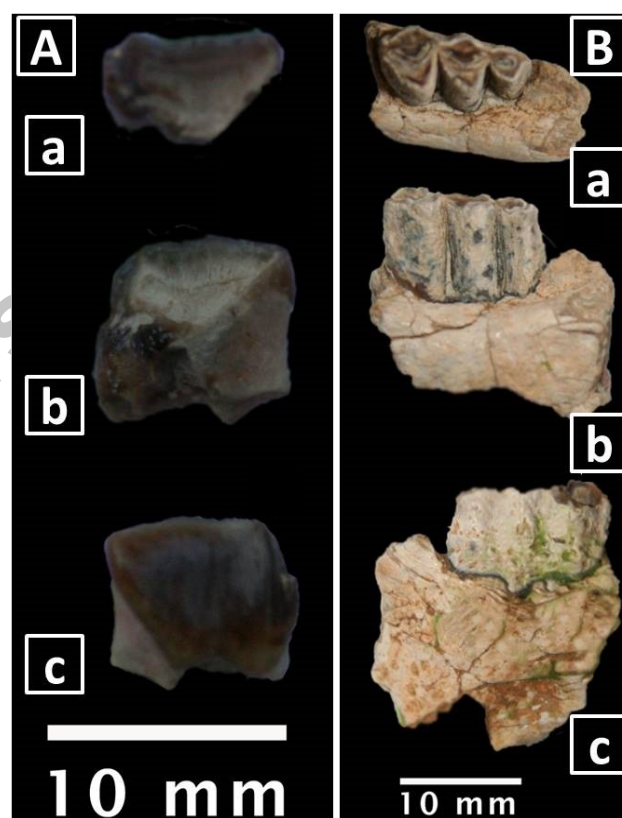


Fig. 4. A, *Eotragus noyei*. PUPC 16/355, upper left second premolar (P²). a, occlusal view; b, lingual view; c, buccal view; B, *Eotragus noyei*. PUPC 16/356, lower left third molar (m³). a, occlusal view; b, lingual view; c, buccal view.

Comparison

The studied specimens were collected from Dhok Pathan Formation is correlated with known specimens of genus *Eotragus* from various localities both of Pakistan as well as other regions of the globe. The morphometric measurements of the studied specimen are close to the

Eotragus sp. reported by Khan *et al.* (2009) and *E. noyei*, and large in *E. sansaniensis* and *E. lampangensis*. The size variation is observed among different species of the genus *Eotragus* based upon the dental size differences reported by Gentry (1999) and Solounias *et al.* (1995).

The studied specimens as well as comparable species have selenodont morphology and have brachydont teeth. The studied specimen resembles with the other species of the genus *Eotragus* in having finely rugose enamel. Fossettes are narrow in all the species of genus *Eotragus*. The buccal walls of the upper molar are more inclined in the studied specimens like *E. noyei* and *Eotragus* sp. while in the *E. sansaniensis* and *E. lampangensis* are less inclined. Parastyle and mesostyle are of medium size in the studied specimen as well as in the *E. noyei* and *Eotragus* sp. whereas well developed in *E. lampangensis*. In the studied specimen the paracone ribs are stronger than the metacone ribs like *E. noyei* and *Eotragus* sp. A trace of lingual cingulum is observed in the studied specimens like *E. noyei* but it is absent in *E. lampangensis* and *Eotragus* sp. of Khan *et al.* (2009) and large in *E. sansaniensis*. The M³ metaconule is smaller than the protocone in the studied specimen as well as in the *E. noyei*, whereas it is relatively larger in other *Eotragus* species. The P² protocone is well developed in the studied specimen and situated posteriorly like *E. noyei*. The P² of the studied specimen has an anterior lingual constriction like in *E. noyei*, but unlike in other species of *Eotragus*. In the studied specimen, the lower

molars have basal pillar which is clearly visible.

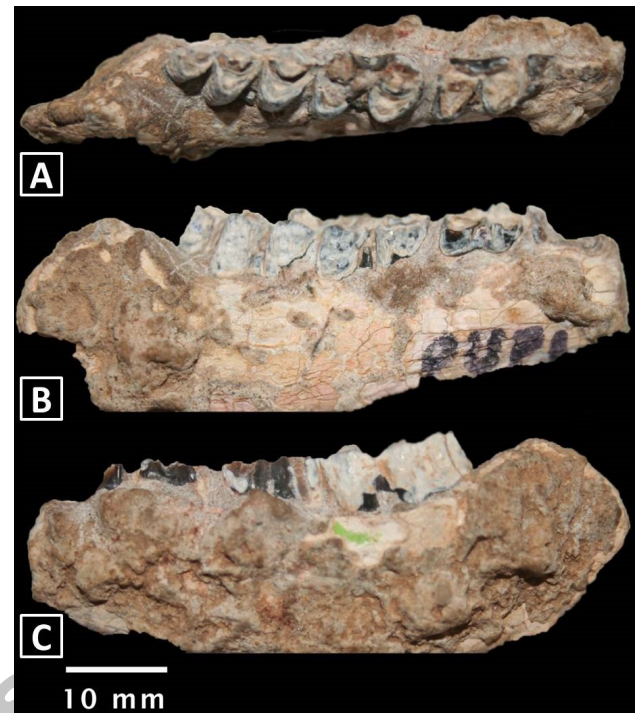


Fig. 5. *Eotragus noyei*. PUPC 16/357, right mandibular fragment having P₄M₃. A, occlusal view; B, lingual view; C, buccal view.

Table II.- Measurements of cheek teeth of studied material of *E. noyei* taken in mm.

Position		Studied specimen	<i>E. lampangensis</i>	<i>E. noyei</i>	<i>E. sansaniensis</i>	<i>Eotragus</i> sp.
p ⁴	L	8.0	11.24		*11.9	
	W	5.0				
m ¹	L	8.0	11.4	9.4	*12.2	8.0
	W	6.5		6.2		5.0
m ²	L	10.0		11.6	**10.7	8.0
	W	6.0		7.9	7.8	5.6
m ³	L	13.0	17.25	14.2	**15.0	11.7
	W	6.5		7.0	7.6	4.3
p ²	L	7.5	9.65	8.2		
	W	5.0		5.9		
p ³	L	8.0	9.7			
	W	7.0				
p ⁴	L	6.0		6.5		
	W	6.5		10.3		
M ¹	L	7.5		10.1		8.0
	W	8.0		10.5		7.0
M ²	L	8.0		10.7		9.0
	W	9.0				7.3
M ³	L	9.0	13.3	10.4	*12.5	9.0
	W	8.0		10.7		7.3

Thus, the described specimens have selenodont morphology, brachydont teeth, finely rugose enamel, small lingual cingula, third upper molar (M^3) metacone is smaller than the protocone, second upper premolar (P^2) protocone is located posteriorly and anterior lingual constriction, which indicate, that the specimen belong to the *E. noyei*.

DISCUSSION

The physical appearance of the studied specimen shows that they belong to the same individual. The described specimens are square and tetratuberculate, which is the characteristic of herbivorous mammals. The molars have selenodonty pattern which confirms its inclusion to the suborder Ruminantia of the order Artiodactyla. Several morphological features such as less bulky stylids and ribs; crests of the cusps jointed up in early wear; obliquely situated hypoconulid; confluence of the protocristid, metacristid, postmetacristid, and weak cingula are the characters, which represent *Eotragus* genus (Rössner, 2006; Gentry, 1999). Described morphological features of the specimen, for instance, finely rugose enamel, obliquely placed teeth without lined up buccal walls, small lingual cingula, $P2$ protocone is well formed which is situated posteriorly and possess an anteriorly placed lingual constriction, confluence of the protocristid, postmetacristid, and metacristid, brachydont teeth, medium sized parastyle and mesostyle allowed to include them in *E. noyei* (Alfarez *et al.*, 1980; van der Made, 2012).

Solounias *et al.* (1995) had been erected *E. noyei* from the Lower Siwaliks owing to their horn core, five postcranial specimens and a cranial specimen having a probable age between 18.0 and 18.3 Ma (Barry and Flynn, 1989). It is regarded as the smallest and oldest species of *Eotragus* genus. Morphologically and morphometrically, comparisons were made with specimen GSP-Y 41459 studied by Solounias *et al.* (1995), PUPC 69/272, PC-GCUF 08/01 studied by Khan (2008) from the Lower Siwaliks and with specimen PUPC 04/24, PUPC 05/11, PUPC 04/23 recovered by Khan *et al.* (2009) from the middle Siwaliks. The studied specimens have great resemblance to the specimen described by Solounias *et al.* (1995). Size of the studied specimen is slightly small as compared to the specimen which was recovered by Solounias *et al.* (1995) from the lower Siwaliks. The animal discovered in the Lower Siwaliks has bigger size in comparison to the animal present in the Middle Siwaliks (Khan, 2008; Solounias *et al.*, 1995). The *Eotragus* is known to be belonging to Europe's Late Early Miocene (15 Ma, MN6; Gentry, 1999; Mein, 1989), Pakistan (18–5 Ma; Khan, 2008; Khan *et al.*, 2009; Solounias *et al.*, 1995) and from China's Middle Miocene (16 Ma; Ye, 1989). The specimens recovered from Pakistan, belonging to the *Eotragus* sp. have reported to be from the Middle to Early Miocene Gaj Formation of Sindh (Thomas, 1984), the Early Miocene deposits from Dhok Bin Mir Khatoon (Khan, 2008) and the Late Miocene from the Dhok Bun Ameer Khatoon Formation of district Chakwal, mentioned a complete chronological range of 18.3–5.0 Ma from the Lower to Middle Siwaliks. Khan *et al.* (2009) reported the occurrence of *Eotragus* sp. firstly from the Middle Siwaliks. The new finding of *Eotragus* extends the stratigraphic area of the genus from Lower Siwaliks to Middle Siwaliks (18.3 Ma to 5.0 Ma).

CONCLUSION

New fossil remains that belongs to *E. noyei* are recovered from the Dhok Pathan Formation, Middle Siwaliks of the Potwar Plateau of Pakistan. The discovery of *E. noyei* from Dhok Pathan Formation considerably extends the geographic range of this taxon from the Lower Siwaliks to the Middle Siwaliks. The collected specimens consist of upper and lower premolars and molars. These specimens strengthen the existence of species in Dhok Pathan Formation of Middle Siwaliks at about 8.5–9 Ma. The diversity of Dhok Pathan fauna is very helpful in understanding and reconstructing the palaeoenvironment and palaeohabitat of animals that have ever been existed in locality of Dhok Pathan Formation. It is considered that *E. noyei* is the oldest and smallest species of the genus *Eotragus* as well as the oldest bovid found until then (Solounias *et al.*, 1995). The selenodonty of the ruminants may be interpreted for fibrous foods which may have been the swamp vegetation due to the depositional environment. The combined occurrence of such taxa in the Dhok Pathan locality proposes open but no grassy habitats, which includes some constituents of fairly abrasive vegetation like long grasses (Janis and Scott, 1988; Cerling *et al.*, 1997).

Statement of conflict of interest

The authors declare no conflict of interest.

REFERENCES

- Alfarez, F., Villalta, J.F. and de Moya, S., 1980. Primera cita en España del antelope mas antiguo de Europa, *Eotragus artenensis*, Ginsburg y Heintz, 1968 (Mammalia, Bovidae), Procedente del Orleaniense de Corcoles (Guadalajara). *Rev. COL-PA*, **36**, Editorial de la Universidad Complutense de Madrid, pp. 1-131.

- Badgley, C., Barry, J.C., Morgan, M.E., Velson, S.V., Behrensmeyer, A.K., Cerling, T.E. and Pilbeam, D., 2008. Ecological changes in Miocene mammalian record show impact of prolonged climatic forcing. *Proc. natl. Acad. Sci.*, **105**: 12145-12149. <https://doi.org/10.1073/pnas.0805592105>
- Barry, J.C., Behrensmeyer, A.K., Badgley, C.E., Flynn, L.J., Peltonen, H.A.N.N.E.L.E., Cheema, I.U., Pilbeam, D.A.V.I.D., Lindsay, E.H., Raza, S.M., Rajpar, A.R. and Morgan, M.E., 2013. The Neogene Siwaliks of the Potwar Plateau, Pakistan. In: *Fossil mammals of Asia: Neogene biostratigraphy and chronology*. Columbia University Press, New York, pp. 373-399. <https://doi.org/10.7312/columbia/9780231150125.003.0015>
- Barry, J.C., Johnson, N.M., Raza, S.M. and Jacobs, L.L., 1985. Neogene mammalian faunal change in southern Asia: Correlations with climatic, tectonic, and eustatic events. *Geology*, **13**: 637-640. [https://doi.org/10.1130/0091-7613\(1985\)13<637:NMFCIS>2.0.CO;2](https://doi.org/10.1130/0091-7613(1985)13<637:NMFCIS>2.0.CO;2)
- Barry, J.C., Morgan, M., Flynn, L., Pilbeam, D., Behrensmeyer, A.K., Raza, S., Khan, I., Badgley, C., Hicks, J. and Kelley, J., 2002. Faunal and environmental change in the Late Miocene Siwaliks of Northern Pakistan. *Paleobiology*, **28**: 1-72. [https://doi.org/10.1666/0094-8373\(2002\)28\[1:FAECIT\]2.0.CO;2](https://doi.org/10.1666/0094-8373(2002)28[1:FAECIT]2.0.CO;2)
- Barry, J.C. and Flynn, L.J., 1989. Key biostratigraphic events in the Siwalik sequence. In: *European Neogene mammal chronology* (eds. E.H. Lindsay, V. Fahlbusch and P. Mein). NATO ASI Series A 180, Plenum Press, New York, pp. 557-571. https://doi.org/10.1007/978-1-4899-2513-8_33
- Barry, J.C., Lindsay, E.H. and Jacobs, L.L., 1982. A biostratigraphic zonation of the middle and upper Siwaliks of the Potwar Plateau of northern Pakistan. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **37**: 95-130. [https://doi.org/10.1016/0031-0182\(82\)90059-1](https://doi.org/10.1016/0031-0182(82)90059-1)
- Behrensmeyer, A.K. and Tauxe, L., 1982. Isochronous fluvial systems in Miocene deposits of Northern Pakistan. *Sedimentology*, **29**: 331-352. <https://doi.org/10.1111/j.1365-3091.1982.tb01799.x>
- Bibi, F., 2007. Origin, paleoecology, and paleobiogeography of early Bovini. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **248**: 60-72. <https://doi.org/10.1016/j.palaeo.2006.11.009>
- Bibi, F., 2009. *Evolution, systematics, and paleoecology of Bovinae (Mammalia: Artiodactyla) from the Late Miocene to the recent*. Ph. D. thesis, Yale University, New Haven.
- Cerling, T.E., Harris, J.M., MacFadden, B.J., Leakey, M.G., Quade, J., Eisenmann, V. and Ehleringer, J.R., 1997. Global vegetation change through the Miocene/Pliocene boundary. *Nature*, **389**: 153-158. <https://doi.org/10.1038/38229>
- Flynn, L.J., Pilbeam, D., Barry, J.C., Morgan, M.E. and Raza, S.M., 2016. Siwalik synopsis: A long stratigraphic sequence for the Later Cenozoic of South Asia Synopsis Siwalik: longue succession stratigraphique du Cénozoïque moyen et tardif de l'Asie du Sud. *C. R. Palevol.*, **15**: 877-887. <https://doi.org/10.1016/j.crpv.2015.09.015>
- Gentry, A.W., 1994. The Miocene differentiation of Old World Pecora (Mammalia). *Hist. Biol.*, **7**: 115-158. <https://doi.org/10.1080/10292389409380449>
- Gentry, A.W., 1999. Fossil Pecorans from the Baynunah Formation, Emirate of Abu Dhabi, United Arab Emirates. In: *Fossil vertebrates of Arabia* (eds. P.J. Whybrow and A.P. Hill). Yale University Press, New Haven, pp. 290-316.
- Haile-Selassie, Y., Suwa, G. and White, T.D., 2004. Late Miocene teeth from Middle Awash, Ethiopia, and early Hominid dental evolution. *Science*, **303**: 1503-1505. <https://doi.org/10.1126/science.1092978>
- Janis, C.M. and Scott, K.M., 1988. The phylogeny of the Ruminantia (Artiodactyla, Mammalia). In: *The phylogeny and classification of Tetrapods*, Volume 2: *Mammals* (ed. M.J. Benton). Systematics Association Special Volume, Academic Press Systematics Association, London-New York, pp. 273-282.
- Khan, M.A., 2008. Fossil bovids from the Late Miocene of Padhri, Jhelum, Pakistan. *Pakistan J. Zool.*, **40**: 25-29.
- Khan, M.A., Iliopoulos, G. and Akhtar, M., 2009. Boselaphines (Artiodactyla, Ruminantia, Bovidae) from the Middle Siwaliks of Hasnot, Pakistan. *Geobios*, **42**: 739-753. <https://doi.org/10.1016/j.geobios.2009.04.003>
- Mein, P., 1989. Updating of the MN zones. In: *European Neogene mammal chronology* (eds. E.H. Lindsay and V. Fahlbusch). NATO ASI Series A 180, Plenum Press, New York, pp. 73-90. https://doi.org/10.1007/978-1-4899-2513-8_6
- Morgan, M.E., Behrensmeyer, A.K., Badgley, C., Barry, J.C., Nelson, S. and Pilbeam, D., 2009. Lateral trends in carbon isotope ratios reveal a Miocene vegetation gradient in the Siwaliks of Pakistan. *Geology*, **37**: 103-106. <https://doi.org/10.1130/G25359A.1>
- Nawaz, M.K., Abbas, S.G., Khan, M.A., Babar, M.A., Asim, M., Shahid, R. and Akhtar, M., 2019. Middle

- Miocene Suids from Chinji formation of Chabbar Syedan, Punjab, Pakistan. *Pakistan J. Zool.*, **51**: 1343-1353.
- Rössner, G.E., 2006. A community of Middle Miocene Ruminantia (Mammalia, Artiodactyla) from the German Molasse Basin. *Palaeontogr. Abteil. A*, **277**: 103-112.
- Solounias, N., Barry, J.C., Bernor, R.L., Lindsay, E.H. and Raza, S.M., 1995. The oldest Bovid from the Siwaliks, Pakistan. *J. Verteb. Paleontol.*, **15**: 806-814. <https://doi.org/10.1080/02724634.1995.10011263>
- Solounias, N. and Moelleken, S.M.C., 1992. Dietary adaptations of two goat ancestors and evolutionary considerations. *Géobios*, **25**: 797-809. [https://doi.org/10.1016/S0016-6995\(92\)80061-H](https://doi.org/10.1016/S0016-6995(92)80061-H)
- Suraprasit, K., Chaimanee, Y., Bocherens, H., Chavasseau, O. and Jaeger, J., 2014. Systematics and phylogeny of middle Miocene Cervidae (Mammalia) from Mae Moh Basin (Thailand) and a paleoenvironmental estimate using enamel isotopy of sympatric herbivore specie. *J. Verteb. Paleontol.*, **34**: 179-194. <https://doi.org/10.1080/02724634.2013.789038>
- Thomas, H., 1984. Les bovidés ante-hipparions des Siwaliks inférieurs (plateau du Potwar), Pakistan. *Mém. Soc. Géol. France*, **145**: 1-68.
- van der Made, J., 2012. *Eotragus clavatus* (Artiodactyla, Bovidae, Boselaphini) de Sansan. In: *Mammifères de Sansan* (eds. S. Peigne and S. Sen). *Mem. Mus. natl. Hist. Nat.*, **203**: 145-199. ISBN: 978-2-85653-681-0.
- Waseem, M.T., Sarwar, M.A., Ahmad, R.M. and Khan, A.M., 2016. Newly discovered fossil remains of *Selenoportax vexillarius* from Hasnot, locality of Siwaliks of Pakistan. *Punjab Univ. J. Zool.*, **31**: 53-58.
- Ye, J., 1989. Middle Miocene artiodactyls from the northern Junggar Basin. *Verteb. Palasiat.*, **27**: 37-52.