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Research Article

Some New Remains of *Gazella* (Bovidae) Discovered from the Dhok Pathan Formation of the Siwaliks, Northern Pakistan

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ZS processed the samples. AMK supervised the research and drafted the manuscript. AI contributed in discussion and helped in identification of samples. MA collected the samples.

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Cetartiodactyla, Middle Siwaliks, Late Miocene, Early Pliocene.

Abstract | Newly discovered dental remains of a medium sized gazelle from the Dhok Pathan Formation in northern Pakistan, are described in this paper. The specimens comprise mandibular fragment and isolated teeth. The specimens are on the basis of rigorous comparison ascribed to *Gazella lydekkeri,* a late Miocene antelope. The Dhok Pathan Formation is late Miocene to early Pliocene in age.

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Introduction

Gazella is a genus in Subfamily Antilopini and Family Bovidae. Today it is represented by the species distributed in Asia and Africa (Gentry, 1964). There are nineteen living species of genus *Gazella* according to Integrated Taxonomic Information System (ITIS). These animals has a body weight of 12-75 Kg. The largest gazelle named as *Dama gazelle* has a height of 137-168 cm. Living gazelle has 30-40 meters per hour speed during its running. These animals also show stotting behavior. They are herbivores and typically leaves, grasses and shoots of the plants are the part of their diet. Pilgrim (1937) described the dental remains of *Gazella lydekkeri* from late Miocene deposits of the Siwaliks of India and Pakistan. The studied species shows similarities to the living gazelles for their small and slender skull. *Gazella lydekkeri* is basically a primitive species but shows a degree of hypsodonty, a more derived dental feature. In the fossil record, the genus *Gazella* is known from Eurasia and Africa and in the Siwaliks from the Middle Miocene to Early Pliocene deposits (Pilgrim, 1937; Chen, 1997; Bibi *et al.*, 2009; Khan *et al.*, 2013). Gazelles were rarely found in the early Pliocene in Europe for unfavorable cooler climate but they are well represented in the Middle East and Africa. The primitive member of the group found from Turkey is G. ancyrensis that can be distinguished from other member of genus *Gazella* by their small size and spiky horns (Kostopoulos, 2009). The primitive members of genus *Gazella* have low crowned teeth with long row of premolars and molars with lack of posterior lobe (Gentry, 1990).

Geological context

The village Dhok Pathan (Lat. 33° 07' N: Long. 72° 14' E) is located in the Chakwal district, northern Pakistan

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(Figure 1). The type area for the Dhok Pathan Formation is located at the Soan River about 75 km from Rawalpindi at Rawalpindi-Sargodha road and consists of substantial Neogene freshwater sedimentary rocks. It is situated in proximity to the Dhok Pathan Rest House close to the Soan River at an altitude of 1073 feet and the thickness of the sequence around this area is about 500 m (Barry *et al.*, 2002). The Dhok Pathan Formation consists of siltstone and sandstone, with some clays and lenses of conglomerate in the upper part. Near the village Dhok Pathan the sandstone is light gray in color and consists of fine to medium grained, medium bedded and cross bedded particles. To the northeast, buff sandstones are more common, the clay stone is primarily dark brown and orange red in color (Johnson *et al.*, 1985). The lower part of the Dhok Pathan Formation is dated to about 10.1-9.0 Ma and the upper part extends into the early Pliocene (Barry *et al.*, 2002). Pickford (1988) made an initial biochronological assessment of the formation. Paleomagnetic correlations provide a precise geochronology of the Mio-Pliocene Dhok Pathan Formation (Figure 1) (Barry *et al.*, 2002).

Here we describe the newly recovered dental remains of gazelle from near the Dhok Pathan Rest House. According to Khan *et al.* (2013), only a small number of fossils of gazelle have been described from the late Miocene Siwaliks since the beginning of the last century and there is no extensive and new gazelle data for this fossiliferous area. The only available records are those published by Pilgrim (1937), Khan (2007) and Khan *et al.* (2013).

Materials and Methods

The studied material was recovered from the late Miocene sediments at Dhok Pathan type locality, Punjab, Pakistan (Figure 1). The sample comprises a right mandibular fragment, isolated lower second molar, an isolated right upper first molar, an isolated right upper third molar, an isolated right upper second molar, right upper third and fourth premolars, and an isolated right lower fourth premolar.

The studied material is present in the palaeontological collections of the Zoology Department of Punjab University, Lahore. While cataloguing the specimen; a yearly index number as numerator and a serial list number as denominator are used in combination with the institutional abbreviation PUPC, which stands for Punjab University Palaeontological Collection (PUPC 13/60). Upper dentition is expressed by the capital letter (*e.g.* P, upper premolar; M, upper molar) and Lower dentition is denoted by small letters (*e.g.* p-lower premolar; m-lower molar).

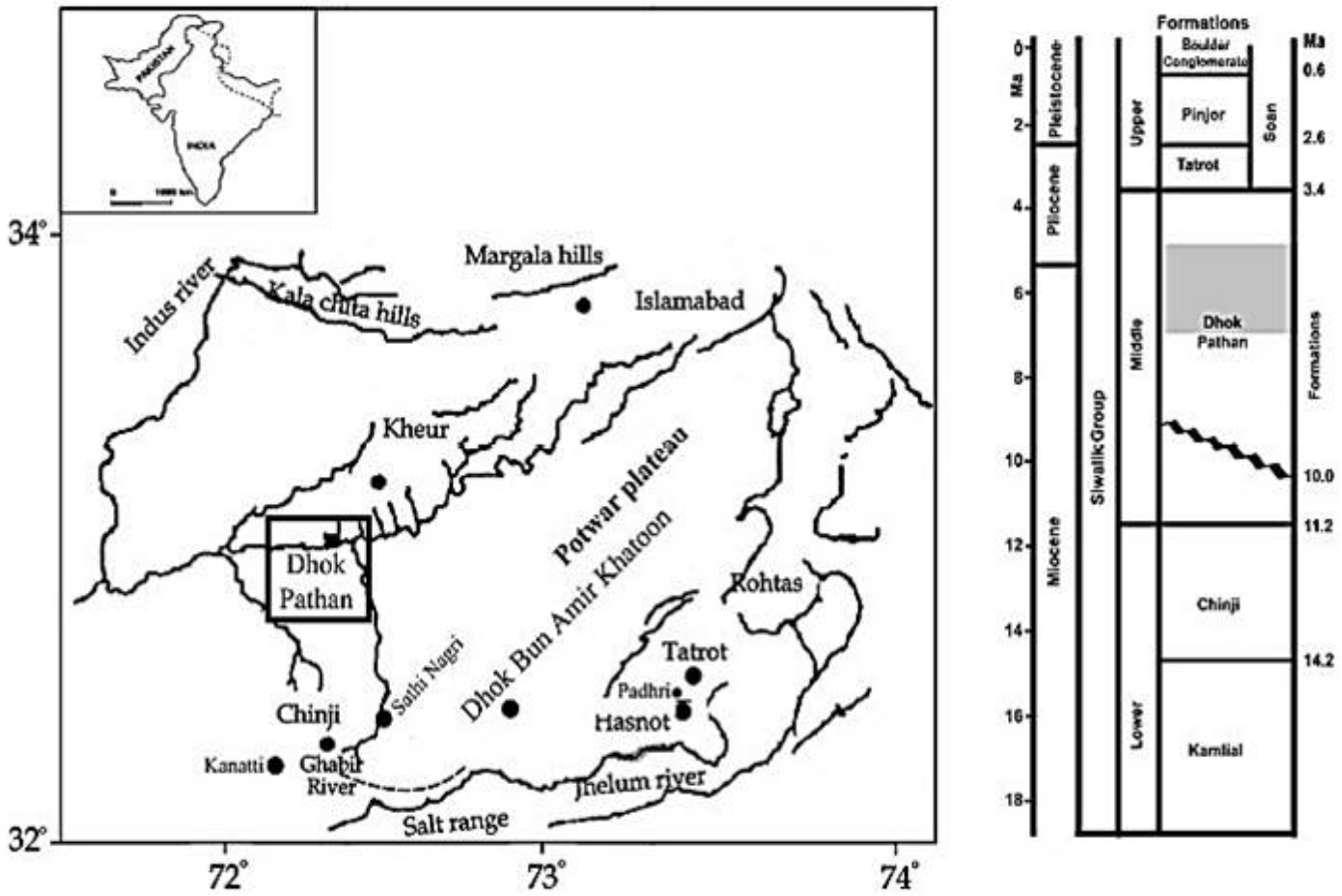

Figure 1: Map showing various Siwalik localities in the Potwar Plateau, Pakistan, with the temporal range of the study shaded (Behrensmeyer and Barry, 2005).

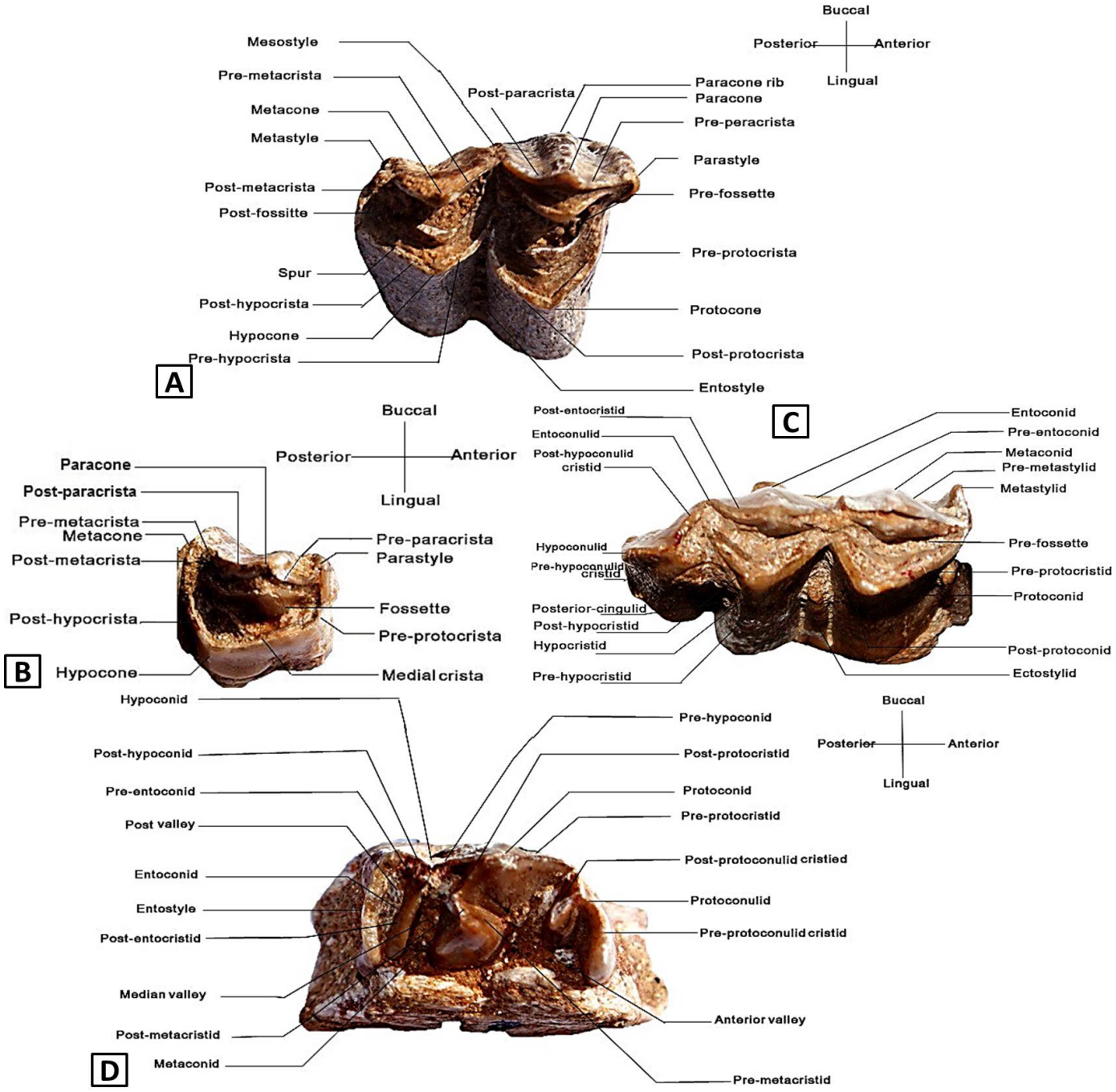

Figure 2: A, upper second molar (PUPC 13/59); B, upper third premolar (PUPC 13/57); C, lower third molar (PUPC 09/105); D, lower fourth premolar (PUPC 13/61). Terminology of dental remains of ruminants followed by Janis and Scott (1987) and Gentry (1994).

Systematic Paleontology

Family: Bovidae Gray, 1821
Subfamily: Antilopinae Gray, 1821
Tribe: Antilopini Gray, 1821
Genus: *Gazella* Blainville (1816)
Species: *Gazella lydekkeri* Pilgrim (1937)

Type locality

Dhok Pathan Formation district Chakwal, Pakistan (Pilgrim, 1937).

Stratigraphic range

The Middle Siwaliks.

Diagnosis

As described by Pilgrim (1937) and (1939).

New material

PUPC 09/105, a right mandibular fragment with m1-m3; PUPC 09/111, an isolated right M1; PUPC 13/57, right P3-P4; PUPC 13/58, an isolated right M3; PUPC 13/59, an isolated right M2; PUPC 13/60, an isolated right m2; PUPC 13/61, an isolated right p4. These specimens are all shown in Figure 3.

Description

Upper dentition: The upper dentition is represented

by premolars and molars (PUPC 13/57, PUPC 09/111, PUPC 13/58 and PUPC 13/59). The premolars are hypsodont with high crowned cusps. The paracone is slightly higher than the protocone and the parastyle is sharp and visible. The third premolar is asymmetric and semi-triangular. The third molar can be easily distinguished as the median rib is more prominent. The enamel extension connects the protocone to the hypocone. The median rib in the P3 is present in the middle unlike in the P4, and it is crescent shaped. The lingual cingulum is observed in the upper 2nd and 3rd premolar of the studied samples and in both the teeth it is moderately strong.

The molars are quadrate shaped and the cones are pointed and visible. The protocone is projected outwards which makes it appear V shaped and the hypocone is crescentic. The paraconus and metaconus ribs are visible. All of the styles can be seen and the transverse valley is present on the lingual side. The anterior and posterior interdental wear facet depressions distinguish the 2nd Molar from other molars.

Lower dentition: The lower dentition (PUPC 13/61, PUPC 13/60, and PUPC 09/105) is represented by premolars and molars. The teeth are rectangular in shape and have narrow crowns. The fourth premolar is pentaconid and the parastylid connected with the paraconid to form the anterior valley. The large protoconid and metaconid are connected with each other and the space between these two conids constitutes the median valley. The entoconid is connected to the protoconid labially and forms a posterior valley. The entostyle is present posterolingually.

The fossettes of the molars are relatively narrow and shallow. The molars have hypoconids that protrude bucally, which is characteristic of these teeth. The metaconid and entoconid are present on the lingual side, while protoconid and hypoconid are labial. An ectostylid is present in the transverse valley on the labial side. The studied specimen PUPC 09/105 is a part of right mandible, and a prominent hypoconulid is present at the posterior extent of the last tooth, which is a feature of the lower third molar. A well-developed goat folds is also present in the lower molars.

Comparison and Discussion

There is some morpho-metric variation within the known *Gazella* species from the Miocene Siwaliks of Pakistan; and various genera and species have been erected. Many of them are considered as probable synonyms of each other (Bibi and Guleç, 2008). The present material shows affinities with *Gazella lydekkeri* and observed dental characters are similar to the holotype of *Gazella lydekkeri* (AMNH 19663) described by Pilgrim (1937), from the Middle Siwaliks. After the boselaphines, the antilopine *Gazella lydekkeri* is the most abundant taxon in the middle Siwaliks stratigraphic sequence (Pilgrim, 1939; Barry *et al.*, 2002).

In our sample the presence of sharp median ribs and sharp styles with lack of median basal pillars in the upper molars and the presence of sharp median ribs and sharp styles with median basal pillars in the lower molars, conforms with the holotype of *Gazella lydekkeri* (Pilgrim 1937, 1939; Akhtar, 1992; Khan, 2008; Khan *et al.*, 2009).

The upper premolars are conical in shape (Figure 1A-C; Table I) with the pointed main cusps at the occlusal outline. The lingual cones are selenodont in shape but the paracone is higher as compared to the protocone. The hypocone and metacone are less prominent in the premolars.

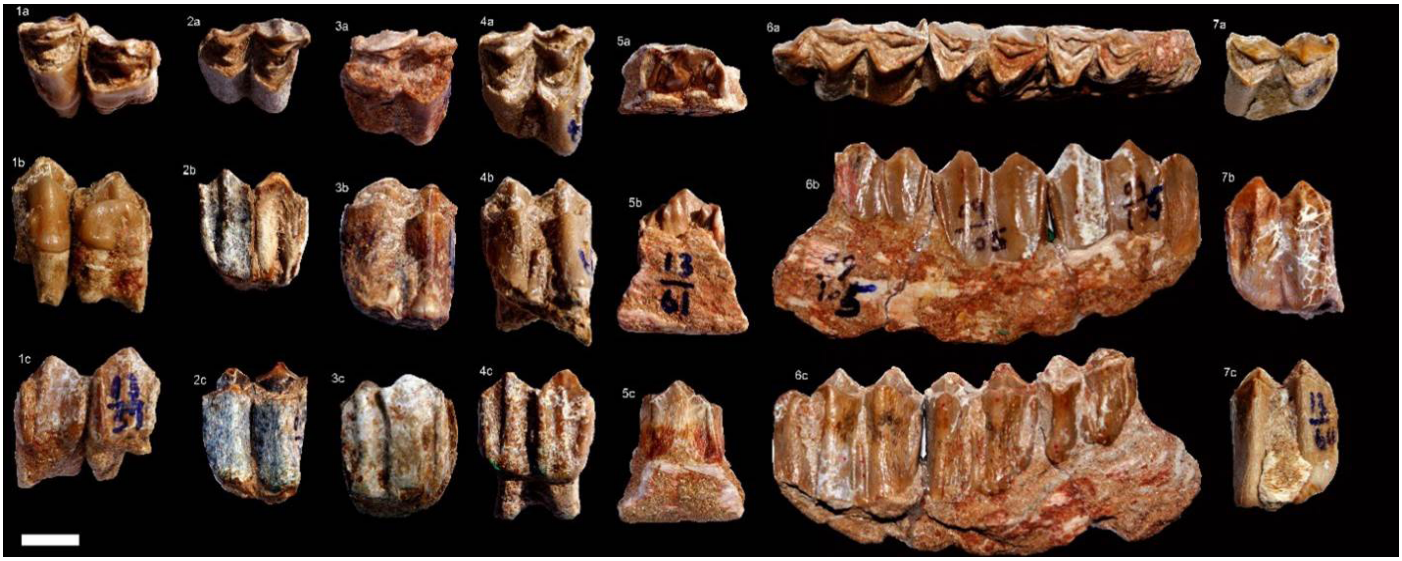

Figure 3: ***Gazella lydekkeri:*** **1, PUPC 13/57 – right P3-P4; 2, PUPC 09/111 – right M1; 3, PUPC 13/59 – right M2; 4, PUPC 13/58 – right M3; 5, PUPC 13/61 – right p4; 6, PUPC 09/105 – right m1-m3; 7, PUPC 13/60 – right m2. a, occlusal view; b, lingual view; c, labial view. Scale Bar=10 mm.**

In P3, the paraconus rib is more visible and is located towards the parastyle while in P4 the paraconus rib is present in the center of the teeth. P3 has a weak metastyle. In comparison with the dental features to *Gazella lydekkeri* reported from the Middle Siwaliks by Pilgrim (1937), Akhtar (1992), Khan *et al.* (2009) and (2013), PUPC 13/57 is consistent in having a long P3 relative to P4 and the presence of sharp parastyle and weaker metastyle in P3, with the anterobuccal paraconus rib.

Table I: Comparative measurement of the cheek teeth of *Gazella lydekkeri* (Pilgrim, 1937).

Specimen	Position	Length (mm)	Width (mm)	W/L ratio
PUPC 09/105*	rm1	16	9	0.5625
	rm2	18.5	10	0.5405
	rm3	25	10	0.4
PUPC 09/111*	rM1	17.5	12	0.6857
PUPC 13/57*	rP3	12	11	0.9167
	rP4	11	12.6	1.1454
PUPC 13/58*	rM3	18.5	14	0.7567
PUPC 13/59*	rM2	17.3	13	0.751
PUPC 13/60*	rm2	18	9	0.5
PUPC 13/61*	rp4	14.15	9.3	0.657
AMNH 19663[a]	rm1	10	12	1.2
	rm2	13	7.5	0.577
	rm3	17.5	7	0.4
	rM1	11	11	1
	rP3	8	7	0.875
	rP4	7	9	1.286
	rM3	15	11	0.733
	rM2	13.5	11.5	0.852
	rm2	13.5	7.5	0.555
PUPC 83/67[b]	rP4	9	9	1
	rM1	13.2	12	0.909
	rM2	14	11.5	0.821
	rM3	15.5	11	0.710
PUPC 86/76[b]	lM1	13.4	13	0.970
	lM2	15.4	12.5	0.812
	lM3	16.3	11	0.675
PUPC 98/101[c]	P4	9.6	9.7	1.010
	M1	14	13	0.929
	M2	14	12	0.857
	M3	14.2	12.5	0.880
PUPC 97/22[d]	lM2	13.5	13	0.963
PUPC 97/21[d]	lM2	12	12	1
PUPC 02/37[d]	rM2	14.5	9	0.621
PUPC 02/16[d]	rM3	22	10	0.454
PUPC 94/21[d]	rM3	21.5	8.5	0.395
PUPC 97/21	rM3	10	12	1.2

*Studied specimen. [a], Pilgrim (1937); [b], Akhtar (1992); [c], Khan *et al.* (2009); d, Khan (2008).

The upper molars are usually quadrate in shape (Figures 2A-C, 3A-C; Table I) with the pointed major cusps. The lingual cones are crescent shaped and the posthypocrista is longer as compared to the prehypocrista. The fossettes are selenodont, narrow and not very deep. The paraconus rib is sharper than the metaconus rib at their bases. The mesostyle is prominent but the transverse valley is surrounded by a small tubercle at the lingual side. The specimens show resemblance with *Gazella lydekkeri* in having; presence of well-developed median ribs, the rib of anterior lobe is stronger than that of the posterior lobe, absence of median basal pillar, and presence of narrow styles.

There are two reported species of genus *Gazella* in the Siwaliks of Pakistan. One is *Gazella lydekkeri* and other is *Gazella* sp. The absence of median basal pillar, strong ribs and strong stylids are the dental feature of *Gazella lydekkeri* that it share with other Siwalik species of genus *Gazella* but there is also dental morphological differences between the two species, entostyle are rudimentary in *Gazella* sp. but are slightly larger in *Gazella lydekkeri*.

Slight metric variation exists among our material in comparison with data provided by Pilgrim (1937). The specimens in the present study are slightly longer and broader but show similar morphology (Table I). The larger size of the studied sample may be due to intraspecific variations.

The isolated 4th lower premolar, the lower m_2 and the fragment of lower mandible with m_1-m_3, have identical morphology to the specimens described by Pilgrim (1937). According to Pilgrim (1937), the goat folds are prominent on the anterior side, and in our material, the goat folds are more prominent at the outer side than the inner side. The most prominent character is the presence of ectostylid which is only present on the lower molars. However according to Chen (1997) the acceptable range of individual interspecific variations among fossil taxa is yet need to be resolved.

Merceron *et al.* (2006) described the microwear of *Gazella* from Bulgaria. Their analysis indicates that these gazelles were usually browsers or mixed feeders. According to Khan *et al.* (2013), *Gazella lydekkeri* is abundantly found, second to the boselaphines, recorded from the Dhok Pathan and Hasnot areas. Remains exist in all the lithological deposits of the Middle Siwaliks (Pilgrim, 1937, 1939; Barry *et al.*, 2002). *Gazella lydekkeri* spanned the late Miocene and early Pliocene of the Dhok Pathan Formation in a seasonally humid environment (Barry *et al.*, 2002). *Gazella lydekkeri* may be considered as an important member of the ungulate fauna from the Dhok Pathan Formation including; Family Bovidae (*Selenoportax, Tragoportax, Pachyportax* and *Elachistoceras*), Family Tragulidae (*Dorcatherium* and *Dorcabune*), Family Anthracotheriidae (*Merycopotamus*), Family Giraffidae (*Giraffa* and *Bramatherium*), Family Elephantidae (*Stegolophodon*), Family Suidae (*Propotamochoerus, Hippohyus* and *Hip-*

popotamodon), Family Equidae (*Sivalhippus*) and Family Rhinocerotidae (*Brachypotherium* and *Alicornops*) (Pilgrim, 1937, 1939; Barry *et al.*, 2002; Bhatti *et al.*, 2012).

The faunal deposits of the Dhok Pathan Formation indicate a mixture of vegetation cover and forest condition. The artiodactyls in the late Miocene of the Dhok Pathan Formation suggest a variety of environments ranging from open woodland to riverine and forested settings. The assemblage of such taxa in the sedimentary area suggests an open environment with some grass, and may include a small amount of harsh vegetation (Janis *et al.*, 2002).

Conclusion

The fossils discussed in this paper have been identified as *Gazella lydekkeri*, a late Miocene antelope. They augment the currently recognized suite of gazelline fossils and will contribute to future studies of the evolutionary history of Antilopini in Pakistan.

Conflicts of interest

The authors declare no conflicts of interest.

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