Pakistan J. Zool., vol. 52(5), pp 1955-1967, 2020 DOI: https://dx.doi.org/10.17582/journal.pjz/20181028131031

New Fossil Remains of Artiodactyla from Dhok Pathan Formation, Middle Siwaliks of Punjab, Pakistan

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ABSTRACT

New fossil remains of order artiodactyla have been recovered from Dhok Pathan Formation, northern Pakistan. The assemblage represents 16 specimens belonging to seven species of order artiodactyla which are *Selenoportax vexillarius, Pachyportax latidens, Dorcatherium minus, Dorcatherium majus, Gazella lydekkeri, Hippopotamodon sivalense* and *Propotamochoerus hysudricus*. The bovids are more prominent here as compared to all other artiodactyls. The suggested age of recovered species is Late Miocene to early Pliocene (7-5 Ma). The discovered specimens consist of upper and lower dentition which enhances our knowledge to the dental morphological features and palaeoenvironment of the described species.

Article Information
Received 28 October 2018
Revised 11 February 2019
Accepted 13 March 2019
Available online 21 May 2020

Authors' Contribution
SN, RY and XN presented the concept and designed the study. RMF, SA and ME helped in collection and preparation of fossils. KS, OD and MG drafted the manuscript.

Key words
Artiodactyla, Bovidae, Late Miocene, Early Pliocene, Siwaliks.

INTRODUCTION

Very rich vertebrate fossils fauna is present in Siwalik Hills as compare to all other parts of the world and fossils of artiodactyls are more prominent here (Colbert, 1935; Akhtar, 1992; Khan *et al*., 2008, Samiullah *et al.,* 2015). The Pliocene Siwalik artiodactyls are abundant here but their evolution and systematic are poorly known and outdated (Gentry and Hooker, 1988; Geraads and Gulec, 1999; Barry *et al.,* 2013; Gentry *et al.,* 2014). The sediments of Dhok Pathan Formation are highly fossiliferous and well known for the appearance of Tertiary fauna since 19th century (Matthew, 1929; Colbert, 1935; Pilbeam *et al*., 1977; Akhtar, 1992; Barry *et al.,* 2002; Khan *et al.,* 2010).

The village Hasnot (Lat. 32° 49′ N: Long. 73° 18′ E) is situated about 70 km away west of the district Jhelum, Punjab, Pakistan. The Hasnot village exposes the complete sequence of Siwalik fauna and yields diversified assemblage of the Dhok Pathan Formation (Farooq *et al.,* 2007 a-b, 2008; Khan *et al.,*2007, 2008, 2009, 2010; Samiullah *et al.,* 2015). The Hasnot Village consist of vertebrate fossils including the order Artiodactyla, Perissodactyla, Proboscidea and Primates (Ghaffar *et al.,* 2009; Iqbal *et al.,* 2009, 2011; Khan *et al.,* 2008, 2009, 2010, 2011, 2012). The bovids fossils are more prominent here as compare to all other texa. This paper reveals the taxonomic investigation of the Late Miocene to early Pliocene fauna of artiodactyls discovered from Hasnot Village, District Jehlum, Punjab, Pakistan and expose the richness by updating the taxonomy of fossil locality.

MATERIALS AND METHODS

The outcrops of the Hasnot village (Fig. 1) were explored thoroughly and samples were collected in 2015 from October to December. Surface collection was the primary mean of collection. The excavation was also done carefully where there was indication of embedded fossils. The hammers, chisels, fine needles, penknives and brushes were used for excavation. Cotton pieces and tissues were used to wrap the specimens for avoiding damages of transportation. Specimens were sensibly cleaned and washed in laboratory to remove the dust and sand particles. The broken leftovers of collected specimens were riposted by using different resins and gums like Elfy, Fixings and Magic Stone *etc*. The specimens were analyzed for morphological and taxonomic characteristics in the Palaeontology laboratory, Department of Zoology, GC University, Faisalabad, Pakistan.

To avoid equivocalness all the small morphological characters were carefully observed with the help of hand lens. Vernier caliper was used for measurements of specimens and scale was in millimeters (mm). The catalogue number PC-GCUF was assigned to the collected specimens who represented the serial number (numerator) and collection year (denominator) *e.g.*

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0030-9923/2020/0005-1955 $ 9.00/0

06/2015. For photographs canon DSLR camera was used and hard copies were prepared by using printer. Collected specimens were compared with the specimens of the Geological Survey of India (GSI), Geological Survey of Pakistan (GSP), American Museum of Natural History (AMNH), British Museum of Natural History (BMNH) and the specimens from the Paleontology laboratory of the Zoology department of the Punjab University, Lahore, Pakistan (PUPC). The studied specimens are stocked in the Paleontology laboratory of the Department of Zoology, Government College University Faisalabad, Pakistan.

SYSTEMATIC PALEONTOLOGY

Family Bovidae (Gray, 1821)
Subfamily Bovinae (Gill, 1871)
Tribe Boselaphini (Simpson, 1945)
Genus *Salenoportax* (Pilgrim, 1937)
Salenoportax vexillarius **(**Pilgrim, 1937)

Studied material

PC-GCUF 35/15, upper anterior part of left first molar M1; PC-GCUF 37/15, upper posterior part of left first molar M1; PC-GCUF 34/15, left second upper molar M2; PC-GCUF 36/15, right first lower molar m1.

Locality

Hasnot, district Jhelum, Punjab, Pakistan.

Diagnosis

Large sized species, teeth are extremely hypsodont, enamel is very rugose. Upper molars are quadrate in shape. Strong and divergent styles are present near the neck of the crown, ribs extremely large, ectostylid and entostyle strongly developed in molars. Fossetteeare simple in outline, transverse anterior goat folds are weekly developed at the front of lower molars.

Description

PC-GCUF 35/15 is left upper interior part of first molar. This specimen is at the middle stage of preservation and at the middle stage of wear (Fig. 2, 2a-c). The enamel is moderately thick. The protocone is less elongated and partially broken in the middle towards the lingual side. The paracone is narrow and comparatively more elongated

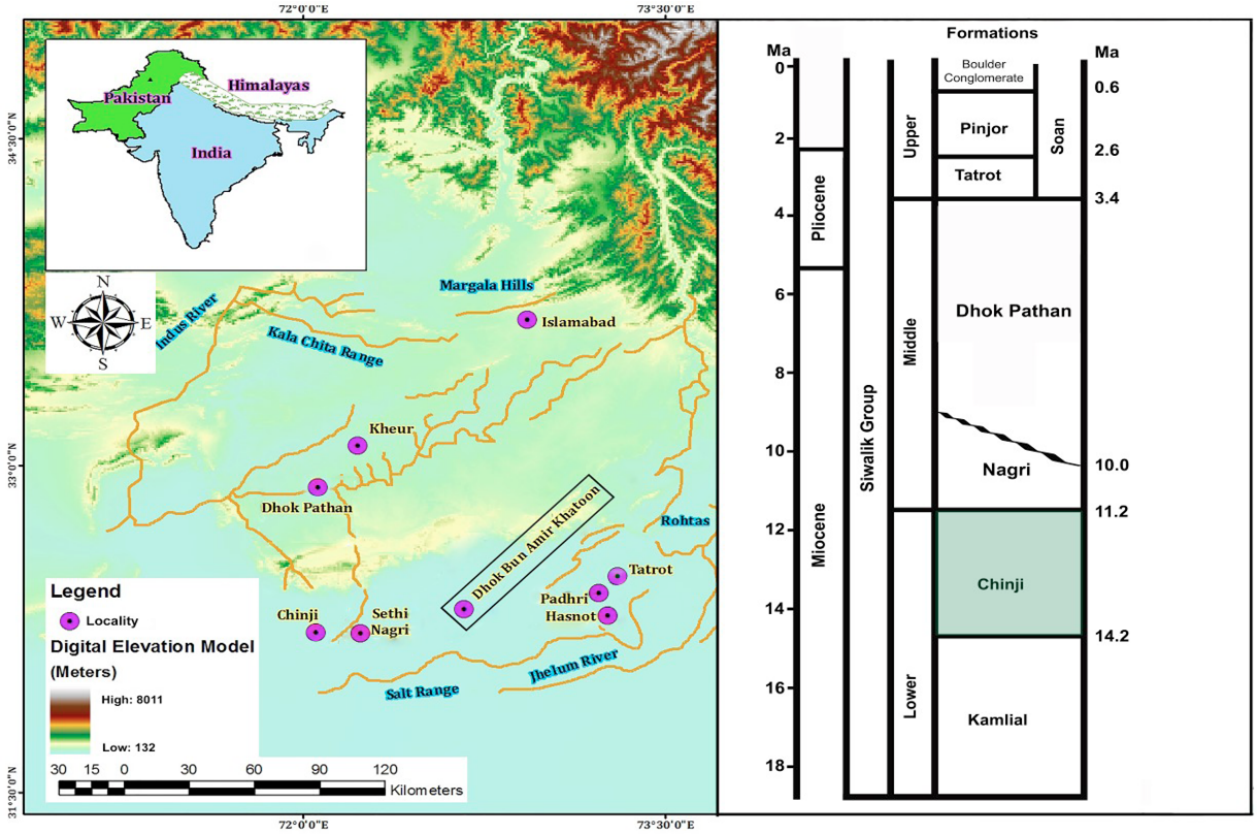

Fig. 1. Location map of Potwar Plateau in Northern Pakistan showing the fossil locality Hasnot in Jehlum district, Punjab, Pakistan (data from Johnson *et al*., 1982; Barry *et al*., 2002; Dennell *et al*., 2008; Nanda, 2008).

than protocone. PC-GCUF 37/2015 is an upper posterior part of first left molar. Both lingual and buccal sides are smooth. Protoconid is well preserved and less pointed. Paraconid is strongly pointed (Fig. 2, 4a-c). A deep median valley deposited with sandstone is present. Posterior part is completely absent. PC-GCUF 34/15 is an upper left second molar and is in the middle stage of preservation (Fig. 2, 1a-c). The dentine is clearly visible on the upper surface of the tooth. The enamel is very thick and more rugose. Metacone and paracone are extremely developed and elongated. The protocone and hypocone are well preserved. Posterior median rib is remarkably prominent than the anterior one. Parastyl and metastyl are strongly developed. Anterior and posterior median ribs are clearly visible. Cavities are narrow, elongated and filled deeply with sandstone. A well-developed, very sharp and strongly pointed median basal pillar is present in the transverse valley. PC-GCUF 36/15 is lower right first molar. It is excellently preserved and in the middle stage of wear. The buccal side is more rugose as compared to the lingual side. The central cavities are excellently preserved and these are narrow in the center and broad antero-posteriorly. Protoconid is well preserved (Fig. 2, 3a-c) while paraconid is flat in shape and mostly smooth in surface. Metaconid is slightly broken along its posterior side. Hypoconid is well preserved and pointed. Posterior median rib is sharply visible. Anterior median rib is not visible. Anterior median valley is less deep as compared to posterior median valley.

Comparison and discussion

Pilgrim (1937) first time described two large species of bovids which are *Pachyportax* and *Selenoportax* after a detailed study of their fossil remains of horn-cores and teeth. He differentiated these genera on the basis of their shape and size. Bibi (2007) considered these characters at which Pilgrim (1937) distinguished these genera are insufficient due to variation even within a single species. There is no any record of complete skull and horn cores from these deposits from previous seven decades. Previous collection clearly indicate that *Selenoportax* is only found from the Middle Siwaliks (Baker and Akhtar, 1985; Akhtar, 1992, 1995, 1996; Khan, 2007).

The prominent ribs, strong entostyle/ectostylid, divergent stylids/style and the features of crown in studied specimens reveal that they belong to large size Siwalik Boselaphini (Pilgrim 1937; 1939). The studied material is different from *Pachyportax* due to crown neck. The crown neck is absent in *Pachyportax* but it is present in *Salenoportax* (Khan *et al.,* 2007; 2009). There are two species of *Salenoportax* present in the Siwaliks such as *Salenoportax vexillarius* and *Salenoportax lydekkeri* (Pilgrim, 1937; Pilgrim, 1939). The cheek teeth of *Salenoportax lydekkeri* are larger than *Salenoportax vexillarius* (Akhtar, 1992; Pilgrim, 1939; Flynn and Qi, 1982). The morphology and dimension of studied material match with *Salenoportax vexillarius* which is described by moderate to large size with divergent and strong styles, high crowned and strongly developed median ribs. There is difference in size of dentition which are due to sex difference (Supplementary Table I).

Pachyportax (Pilgrim, 1937)

***Pachyportax latidens* (Pilgrim, 1939)**

Studied material

PC-GCUF 39/2015, upper right third premolar P3; PC-GCUF 74/15, left second upper molar M2; PC-GUCF 72/15, fourth left lower premolar p4; PC-GCUF 71/15, lower right third molar m3.

Locality

Hanot, District Jhelum, the Punjab province.

Diagnosis

A moderate to gigantic sized bovid, lower molars have thick and rugose enamel. Lower molars are hypsodont and have distinct ectostylid. Median ribs and stylids are intermediately developed. Crown is narrow at the apex and broad at the base. Upper molars are quadrate and strongly hypsodont. Entostyle relatively strong ribs, styles and more extended transversely.

Description

PC-GCUF 39/2015 is upper right third premolar. The specimen is at the middle stage of preservation and it is in the early stage of wear (Fig. 2, 5a-c). The protocone is strongly pointed and the paracone is broader. A deep slightly crescent shape cavity is present between protocone and paracone. Ecto and mesostyle are strongly developed. At the base of paracone a partial pillar like structure is present along its posterior side. PC-GCUF 74/15 is left second upper molar. It is in the middle stage of wear and middle stage of preservation. The enamel is moderately thick and darkish brown in colour. The protocone is V shaped and hollow internally (Fig. 2, 8a-c). The paracone is partially broken but at broken point a deep narrow valley like structure can be seen. The hypocone is less elongated. The metacone is also partially broken. The base of the metacone along buccal side is broken posteriorily. Median Basel pillar is present between the protocone and hypocone. PC-GUCF 72/15 is fourth left lower premolar. The specimen is well preserved and at the early stage of wear. The enamel is shiny. Lingual and labial sides are

smooth. The protoconid is slightly projected (Fig. 2, 7a-c) while paraconid is less projected. Behind the paraconid a rib like structure is present on the labial side. Between hypconid and entoconid a deep depression is present. The entoconid and hypoconid both are well projected. PC-GCUF 71/15 is lower right third molar. The specimen is well preserved. It is in the early stage of wear. The enamel is shine. Rugosity is more prominent at lingual side as compared to buccal side (Fig. 2, 6a-c). The protoconid is less pointed as compare to hypoconid. The entoconid is slightly flat. A depression is present at the posterior face of the hypoconid. The valleys are narrow. Mesostyle is present on the lingual side. Well preserved telonid is present at the posterior side of the specimen.

Comparison and discussion

The genus *Pachyportax* was first described by Pilgrim in 1937 and identified as *Pachyportax* which were identified by Lydekker in 1876 as *Cervus latidens*. He described two species *Pachyportax nagri* and *Pachyportax latidens*. He also described one subspecies *Pachyportax latidens dhokpathanensis*. Akhtar (1995) synonymized this species *Pachyportax latidens* with the subspecies *Pachyportax latidens dhokpathanensis* and added a new species *Pachyportax giganteus*. This genus mainly consists of large boselaphines of the Siwalik probably which were closer to ancestor of Bovini then *Tragoportax*. PC-GCUF 71/15 show similarities with PUPC 96/41 but in PUPC 96/41 ectostylid is broken anteriorly and the ectostylid is poorly developed. PC-GUCF 72/15 is quite similar with PC-GCUF 09/14 in both paraconid is well projected. In both specimens a furrow is present near paraconid. PC-GUCF 72/15 also shows similarities with PC-GUCF 10/74. PC-GCUF 79/15 shows great similarities with PC-GCUF 10/13 both specimens are triangular in shape. The enamel colour and rugosity is same in both specimens.

Boselaphines gave way to originate bovine like bovids at the end of late Miocene (Gentry *et al.,* 1999) although a complete skull of this species has not been recovered yet. The dental morphology of premolars of this species has not been well known yet but its molar morphology is well known today. The cheek teeth of *Pachyportax* are different with giraffid teeth because these teeth are so much hypsodont. Their ectostylids/entostyle is too much large and the Fossettes are isolated from the exterior as compare to giraffid. The studied material decidedly belongs to Boselaphines bovid because they are too large to place in *Tragoportax cyrenaicus*. The important character to identify the upper molar is the transverse extension of entostyle in some cases it may be slightly broader (Pilgrim, 1937). The roughness is also variable, in some specimens it is smooth while in some specimens it is rough. The studied specimens show all the basic features of genus *Pachyportax latidens*. Size of dental measurements is variable but it is too much insignificant as taxonomic point of view which may be due to the sex differentiation (Supplementary Table I).

Infraorder Tragulina (Flower, 1883)
Superfamily Traguloidea (Gill, 1871)
Family Tragulidae (Milne edwards, 1864)
Genus *Dorcatherium (*Pilgrim, 1937)
Dorcatherium minus (Lydekker, 1876)

Studied material

PC-GCUF 81/15, lower right third premolar p3; PC-GCUF 82/15 lower right second molar m2.

Locality

Hasnot, District Jhelum, the Punjab province.

Diagnosis

A small species of the genus *Dorcatherium* which molars have sub hypsodont and broad crowned. The Cingulam is well developed. Styles and ribs are moderately developed and vestigial ectostylids is present.

Description

PC-GCUF 81/15 is lower right fourth premolar. The premolar consists of three lobes. These lobes have similar in shape but they have variations in width, length and height. The anterior lobe is smaller than the posterior one but pointed (Fig. 2, 9a-c). The last lobe, at posterior end is biggest lobe of this specimen. The enamel is partially rugose and moderately thick. In lingual side the lobes look like W shape. PC-GCUF 82/15 is lower right second molar. The specimen is well preserved. The specimen is in early stage of wear. The enamel is darkly shined. Less rugosity is present at buccal side but lingual side is more rugose (Fig. 2, 10a-c). Hypoconid is well pointed. Protoconid is also pointed. Narrow depression is present between hypconid and Entoconid. Entoconid is partially broken at the base. The cavity present between protoconid and metaconid is completely filled with sand. The posterior cavity between hypconid and entoconid is deep but partially filled with sand.

Comparison and discussion

The genus *Dorcatherium* was discovered from the early Miocene sediments of east Africa (Pickford, 2001). This genus occurs in Pakistan in the Miocene sediments of upper part of Nagri Formation near the Dera Bugti. The specimens described here are limited to lower dentition. The studied specimens are not large enough to be including in *Dorcabune*. These two specimens are defiantly belonging

to genus *Dorcatherium* due to their well-developed ectostylids in lower molars. There are two known species of the genus *Dorcatherium* which is *Dorcatherium minus* and *Dorcatherium majus*. In *Dorcatherium majus* large animals are include but in *Dorcatherium minus* small sized animals are present. Morphologically the studied specimen belongs to the *Dorcatherium minus*. PC-GCUF 76/15 is characterized by the isolation of protocone, the anterior median rib and the presence of stylids. This specimen shows morphologically similarities with the PUPC 05/03. In both specimens the tooth is narrow crowned and hypsodont. The enamel is uniformly thick and this is finely rugose in all specimens. In both specimens a deep transverse valley is present between the hypconid and

Fig. 2. Salenoportax vexillarius: PC-GCUF 34/2015 (1), Upper left second molar; PC-GCUF 35/2015 (2), left upper interior part of first molar; PC-GCUF 36/15 (3), lower right first molar; PC-GCUF 37/2015 (4), upper posterior part of first left molar. Pachyportax latidens: PC-GCUF 39/2015 (5), right upper third premolar; PC-GCUF 71/15 (6), lower right third molar; PC-GUCF 72/15 (7), fourth right lower premolar; PC-GCUF 74/15 (8), left second lower molar. Dorcatherium minus: PC-GCUF 81/15 (9), lower right fourth premolar; PC-GCUF 82/15 (10), lower right second molar. Dorcatherium majus: PC-GCUF 73/15 (11), right second upper molar; PC-GCUF 76/15 (12), left first lower molar; PC-GCUF 77/15 (13), left second lower molar. Gazella lydekkeri: PC-GCUF 75/15 (14), lower left third molar. Hippopotamodon sivalense: PC-GCUF 83/15 (15), Right lower fourth premolar. Propotamochoerus hysudricus: PC-GCUF 79/15 (16), right upper fourth premolar. Views: a-occlusal, b-lingual, c-buccal.

protoconid. The studied specimen PC-GCUF 76/15 shows similarities with PUPC 04/13, PUPC 04/02, PC-GCUF 12/41, PC-GCUF 12/40 and PC-GCUF 12/39. However, the postmetacristed is present in PC-GCUF 12/40 but it is absent in specimen PUPC 04/13. PC-GCUF 81/15 the molar has low nonsymmetrical crown that is expended strongly in buccal side. The conids are very small not clearly visible. Due to low crown of the studied molar the styles and ribs are not clearly visible. On the basis of morphological character, the studied specimens are designated as *Dorcatherium minus.*

Dorcatherium majus

Studied material

PC-GCUF 73/15, right second upper molar M2; PC-GCUF 76/15, left first lower molar m1; PC-GCUF 77/15, right second lower molar m2.

Locality

Hasnot, district Jhelum, Province Punjab, Pakistan.

Diagnosis

This species is larger in size as compare to *Dracotherium minus* but size with equal to *dorcabune.* It is identified by well-developed mesostyle and parastyle. A well-developed cingulum present at upper molars. Strongly developed ectostylids is present in lower molars.

Description

PC-GCUF 73/15 is right second upper molar. The specimen is in the middle stage of wear and it is well preserved (Fig. 2, 11a-c). Paracone is extremely pointed in middle. Hypcone is clearly visible but its interior part partially filled with sand. Metacone is inclined at apex. Parastyle is well developed. Metastyle is also present but this is poorly developed. Poorly developed mesotyle is also present. Cingulam is also present. PC-GCUF 76/15 is left first lower molar. It is well preserved and narrow crowned. It is in early stage of wear. The enamel is thick and bright (Fig. 2, 12a-c). Rugosity is more present at buccal side as compare to lingual side. The hypoconid is pointed. The protoconid is less pointed. The paraconid is directed lingualy and triangular in shape. The entoconid is also lingualy directed. Between the hypoconid and protoconid a rudimentary ectostylid is present towards the lingual side. The median cavities are deep and narrow partially filled with sand. PC-GCUF 77/15 is right second lower molar. The specimen is in the early stage of wear and is well preserved. The enamel is thick and rugose at both lingual and labial sides. The teeth are selenodont (Fig. 2, 13a-c). The hypoconid is elongated and forwardly directed. The cavity present between protconid and entoconid is broader. Protoconid is slightly pointed. Metconid is slightly elongated than entoconid. Hypoconid and metaconid are slightly fused with each other. A deep but slightly broader valley is present along the protoconid and hypoconid at buccal side. The buccal conids are higher than the lingual conids.

Comparison and discussion

The important diagnostic feature of genus *Dorcatherium* is that the molar row is shorter than the premolars row. In the larger species of *Dorcatherium* the molar teeth are greatly bunoid and premolars length is greater than its breadth (Whitworth, 1958). A vestige ectostylid is present in lower molars. In upper molars the styles are well developed (Colbert, 1935). The genus *Dorcatherium* looks like the particular genus of tragulidae family which developed parallels with the recent African genus *Hyemoschus.* In *Dorcatherium* the cheek teeth are more hypsodont than those of *Hyemoschus*. The external styles of the upper molars of the *Dorcatherium* are more prominent than *Hyemoschus*. Ectostylid is also present in vestige from in lower molars. In the phylogenetic lineage the genus *Dorcatherium* is separated which eventually led to the African genus *Hyemoschus*.

Pilgrim (1910) described the second extinct genus *Dorcabune* from the Siwalik of Pakistan. The type species for this genus is *Dorcabune anthracotherioides.* This genus is different from *Dorcatherium* due to large size bunodont teeth. The upper molars have isolated mesostyles and parastyles rugose enamel and promienent cingulum. There are four species reported in Siwaliks. Three species are present in Pakistan and one reported from India. The species which reported from Pakistan are *Dorcatherium minimus, Dorcatherium majus* and *Dorcatherium minus* (Colbert, 1935; West, 1980). Later the species *Dorcatherium minimus* was synonymized to *Dorcatherium minus.* The Indian species is *Dorcatherium nagrii* (Gaur *et al*., 1983). However, *Dorcatherium nagrii* is rejected. So now a days there are two valid species of genus *Dorcatherium* which are *Dorcatherium minus* and *Dorcatherium majus.* Both species are mainly different in their size. *Dorcatherium majus* is larger than *Dorcatherium minus.* In *Dorcabune* crowns are broad, median ribs are well developed, molars are large, and the protoconid is pyramidal having posteriorly directed folds (Colbert, 1935). But all these characteristics are absent in described specimens so these specimens cannot be referred to genus *Dorcabune* so these specimens belong to *Dorcatherium majus.*

Family Bovidae (Gray, 1821)

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

Studied material

PC-GCUF 75/15, the lower left third molar m3.

Locality

Hasnot, district Jhelum, province Punjab, Pakistan.

Diagnosis

Upper molars are strongly hypsodont in which entostyle and basal pillars are absent. Lower molars are also extremely hypsodont. A small basal pillar is present in lower molars.in Lower molars well developed goat folds are also present. Enamel is moderately thick and rugose. Styles are strong and narrow. Anterior median rib is stronger as compared to the posterior median rib. The central cavities are deep and narrow which have moderately developed stylids. Premolar series are comparatively long.

Description

PC-GCUF 75/15 is lower left third molar. The specimen is excellent preserved. The enamel is bright and moderately thick. The specimen is in early stage of wear. The molars are extremely hypsodont (Fig. 2, 14a-c). The buccal side is more rugose as compare to lingual side. Hypoconid is well preserved and forwardly directed. Paraconid is also pointed. Protoconid is slightly crescent in shape. Moderately developed stylid is also present at the buccal side. The cingulum is absent. Lingual conids are more prominent than buccal conids. Median fossettes are deep and narrow.

Comparison and discussion

Morphological characters of the described materials revealed that *Gazella lydekkeri* is similar in size and appearance with the living *G. bennetti*. Shape and direction of horn cores, slender longer skull, lengthening of horns cores, acquisition of horns in females, shortening of nasals in hypsodonty, enlargement of bullae and reduction of premolar distinguish the living species *G. bennetti* from the extinct species *G. lydekkeri*. It is indicated that the living *G. bennetti* has been originated from *G. lydekkeri* (Pilgrim, 1937). In male gazelles the development of horn core is due to the competition for female partners. In the female *G. lydekkeri*, horn cores are absent which reveals the less competition among them. The teeth are weekly hypsodont in the *G. lydekkeri* as compare to *G. altidens*. The morphology of hypsodont teeth in *G. lydekkri* is very similar to *G. drocadoides*. *G. lydekkeri* is different from the *G. drocadoides* due to equally strong posterior and anterior median ribs (Kostopoulos, 2005). The length of Post canine teeth in *G. lydekkeri* is more than *G. capricornis*. Premolars of *G. lydekkeri* are narrower than those of *G. capricornis*. Small basal tubercles, quite flat metacone, fairly strong paracone and rib are the characters of *G. capricornis* (Bibi and Gulec, 2008). These are very similar to *G. lydekkri* but very weak in *G. pilgrimi and G. dorcadiodes*. PC-GCUF 75/15 and PC-GCUF 82/15 showed similarities with PUPC 04/2, PC-GCUF 11/180, PC-GCUF 11/175, PC-GCUF 10/53 and PUPC 96/6. All the basic morphological characters are quite similar as described in all these specimens. So, the studied specimens are assigned to *G. lydekkeri*. Due to sex difference, variation in size of dentition has been observed (Supplementary Table I).

Sub order Suiformes (Jaeckal, 1911)
Infraorder Suina (Gray, 1911)
Superfamily Suoidea (Gray, 1821)
Family Suidae (Gray, 1821)
Subfamily Suinae (Zittel, 1893)
Genus *Hippopotamodon* (Lydekker, 1877)
Hippopotamodon sivalense (Lydekker, 1877)

Studied material

PC-GCUF 83/15, Right lower fourth premolar p4.

Locality

Hasnot, district Jhelum, province Punjab, Pakistan.

Diagnosis

A species of genus *Hippopotamodon* in which the length upper molars row can exceeds 110 mm (Pickford, 1988).

Description

PC-GCUF 83/15 is approximately rectangular in shape. Partially cingulam is present at the anterior side of the specimen. Grooves are present in both lingual and buccal side but the groove of lingual side is deeper and broader then groove of buccal side (Fig. 2, 15a-c). The root of the anterior part is partially broken. Enamel is moderately rugose. The ribs are not visible due to sand sedimentation.

Comparison and discussion

The genus *Hippopotamodon* consists of comparatively large Siwalik suids. The morphology of tooth is similar

with *Microstonyx major* from Asia and Europe. Both genera share a lot of similar characters but the main difference is the reduced canines in *M. major* which is comparatively large in *Hippopotamodon sivalense*. Both these species range approximately to the beginning of the Pliocene. *Dicoryphochoerus timnoides* was recovered from the Dhok Pathan Formation near the Tatrot. It looks like *Microstonyx major*, due to this *Dicoryphochoerus timnoides* was synonym with *M. major* (Erdbrink, 1969). *M. antique* differ from *M. major* due to much reduced canines. However, many researchers described both *H. sivalense* and *M. Major* synonym because just on the base of size of canines they cannot be keep as separate species. This reveals that European and Siwalik fauna is similar with each other (Pickford, 1988).

Genus *Propotamochoerus* Pilgrim, 1926

Propotamochoerus hysudricus (Stehlin, 1899-1900)

Studied material

PC-GCUF 79/15, the right upper third molar M3.

Diagnosis

Diastema is absent in lower and upper molar rows. At the midline of M1 zygomatic arches leave is present, lower premolars deeply compressed with complex and long third molar (Colbert, 1935; Pickford, 1988).

Description

PC-GCUF 79/15 is right upper third premolar. The tooth is triangular in shape. The specimen is well preserved. It has middle stage of wearing (Fig. 2, 16a-c). The metacone is rounded in shape. The protocone is extremely broader and triangular in shape. The hypocone and paracone is slightly fused with each other. Cingulum is not visible on both labial and lingual side. The cavity present between protocone is widely broad.

Comparison and discussion

Many species of Suidae are present in Hasnot during the time of Late Miocene. *Hippopotamodon sivalense, Conohyus indicus, Lophochoerus nagrii, Tetraconodon magnus* and *Propotamochoerus hysudricus* are reported from the lower part of Late Miocene. *H. sivalense* and *P. hysudricus* are reported from the upper part of Late Miocene (Pickfold, 1988). These suid species are present in northern part of Pakistan with other group of artiodactyls like *Gazella, Tragoportax, Bramatherium, Dorcatherium, Pachyportax* and *Selenoportax* during the late Miocene to early Pliocene. *H. sivalense,* and *P. hysudricus* found only in late Miocene sediments of Siwalik and provide good evidence of the Late Miocene age (Pickford, 1988). In Hasnot, Dhok Pathan Formation the *Hippohyus lydekkeri, Hippohyus sivalensis* and *Sivahyus punjabiensis* were appeared first than *Hippopotamodon sivalense, and Propotamochoerus hysudricus*.

GENERAL DISCUSSION

Dhok Pathan Formation in Hasnot area have very rich mammalian fossils record particularly artiodactyls. The age of this type locality is 7 to 5 Million years late Miocene to early Pliocene. This region belongs to the upper part of the Dhok Pathan Formation (Barry *et al*., 2002; Pilbeam *et al*., 1977; Khan *et al.,* 2009). The order other than artiodactyls fossils present here are Proboscedia, Perissodactyla, Carnivora and primates (Barry *et al.,* 2002; Khan, 2007; Khan, 2008; Khan *et al.,* 2009; Khan *et al.,* 2012; Pilbeam *et al.,* 1977). The recovered studied material has been compared with the collections of Geological Survey of India (GSI), American Museum of Natural History (AMNH), Punjab University Paleontology Collection (PUPC) and Paleontology Collection of Government College University Faisalabad (PC-GCUF). The Hasnot fauna provides one of the good artiodactyl's fossils record (Table I). Its faunal elements are similar with faunal elements of Samos, Maragheh of Iran, Pikermi of Greece and East Africa (Pickfold, 1988; Thomas, 1977; Akhtar, 1992; Khan, 2007; Kostopoulos, 2009).

The tragulids (*Dorcatherium majus* and *Dorcatherium minus*) are recovered from the Late Miocene of Middle Siwaliks. The family Tragulidae is also reported from Greco-Iranian Province and Eurasia. It provides an evidence to concern the late Miocene Faunal interchange between Eurasia and Africa. *Dorcatherium* is commonly present in Dhok Pathan Formation and also in Nagri Formation. This genus fills up the major part of tragulid biodiversity in whole Siwalik (Farooq *et al.,* 2008; Khan *et al.,* 2012; Khan and Akhtar, 2013). *Dorcatherium* is evident from Miocene of Kenya, Moruorot and Sub-Saharan Mrica (Whitworth, 1958; Nakaya, 1994). The fossils of this genus also present in Southwest and central Europe, Sub-Paratethys and East Asia (Savage and Russell, 1983).

Bovids are geographically more diversified and widely distributed in all over the world (Nakaya *et al.,* 1984). In genus *Gazella* numerous species are recovered. The first fossil record of this genus has been reported from the Early Miocene of Gebel Zelten, North Africa (Hamilton, 1973). Later this genus was also reported from the middle Miocene of Fort Ternan (Gentry, 1978). This genus was present in East and North Africa, Sub-Parathys, Central and South west Europe, East Asia and Siwaliks during late Miocene sediments (Savage and Russell, 1983; Gentry, 1966, 1967, 1970, 1971, 1978, 1980).

Table I.- Comparison of Artiodactyl Fauna from Pakistan (Hasnot) and other related faunas from Europe and China.

Pakistan (Hasnot)	China	Europe
Bovidae:		
Tragoportax browni, T. salmontanus, T. perimense, T. punjabicus, Miotragocerus gluten, Proleptobos birmanicus, Gazella lydekkeri, G. padriensis, Perimia falconeri, Selenoportax vexillarius*, S. lydekkeri, Pachyportax latidens*, P. nagrii, P. giganteus, Elaschistoceros khauristanensis*	*Shaanxispira chowi, S. baheensis, S. linxiaensis, Plesiaddax depereti, Gazella gaudryi, G. paotehensis, G. dorcadoides, G. blacki*	*Prostrepsiceros houtumschindleri, Tethytragus koehlerae, Tragoportax amalthea, Gazella capricornis*
Giraffidae:		
Vishnutherium iravaticum, Bramatherium perimense, Giraffa punjabiensis, Hydaspitherium megacephalum, H. grande, H. magnum	*Palaeotragus microdon, Samotherium sinense,*	Decennatherium macedoniae, Palaeogiraffa macedoniae,
Tragulidae:		
Dorcabune anthracotherioides, D. nagrii, Dorcatherium majus, D. minus*, D. minimus*		*Dorcatherium naui, D. jourdani*
Suidae:		
Tetraconodon magnus, Propotamochoerus hysudricus , P. ingens, Hyosus punjabiensis, H. tenuis, Sivahyus punjabiensis, Hippohyus lydekkeri, H. grandis, Hippopotamodon sivalense*, H. vagus*	*Microstonyx major, Miochoerus youngi, Propotamochoerus wui, P. hyotherioides, Dicoryphochoerus medius, D. binxianensis, Hippopotamodon ultimus*	*Listriodon retamaensis, L. lockharti, L. splendens, L. latidens, L. lockharti, L. guptai, L. pentapotamiae, Eurolistriodon adelli, Lopholistriodon kidogosana, Bunolistriodon meidamon, B. akatikubas, B. guptai, B. lockharti, B. affinis, B. jeanneli, Kubanochoerus gigas, Libycochoerus jeanneli, Hippopotamodon antiques*
Family Cervidae		
Rucervus simplicidens, Cervus triplidens, C. sivalensis, C. punjabiensis	*Cervavitus novorossiae, C. shanxius, C. huadeensis, C. ultimus, C. fenqii, C. novorossiae, C. tarakliensis, C. demissus, C. shanxius, Cervocerus novorossiae, C. ultimus, C. huadeensis, Eostyloceros hezhengensis, Damacerus bessarabiae, Euprox grandis, E. furcatus, E. robustus, E. altus*	*Cervavitulus mimus, C. variabilis, Turiacemas concudensis, Procapreolus ucrainicus, Lucentia pierensis, L. iberica, Amphiprox anocerus, Procapreolus loczyi*

Data taken from Pickford and Molar, (2003); Liu *et al.,* (2004); Geraads *et al.,* (2005); Bibi and Gulec, (2008); Tao *et al.,* (2011); Azanza *et al.,* (2013); Deng *et al.,* (2014); Hua and Qun, (2014); Khan *et al.,* (2014); Shi *et al.,* (2014); Hou, (2015); Dong *et al.,* (2018); Hou *et al.,* (2018); Li *et al.,* (2018).

The abundant discovery of the genus *Gazella* has been recovered from the Hasnot, Dhok Pathan, Maragheh and Pikermi (Pilgrim, 1939; Akhtar, 1992; Khan, 2007; Kostopoulos, 2009; Samiullah *et al.,* 2015). The recovered species *Gazella lydekkeri* is morphologically similar at evolutionary stage with Eurasian species *Gazella capricornis* (Bibi and Gulec, 2008). The rich deposits of boselaphine are present in the Late Miocene sediments in Eurasia and Africa. In boselaphine genus *Selenoportax, Tragoportax* and *Pachyportax* are included. The recovered material of *Selenoportax vexillarius* is reported in the late Miocene to Pliocene of Siwaliks (Akhtar, 1992; Khan *et al.,* 2009; Barry *et al.,* 2002). Solounias (1981) described the horn core of the *Selenoportax* from the Pikermi but he also said that this material is not enough for the accurate determination. The genus *Selenoportax* is also recovered from the Lufeng of Chinese Miocene deposits, which has the age of 11.1-8.0 Ma (Qiu and Qiu, 1995; Steininger, 1999; Flynn and Qi, 1982).

The recovered material of genus *Pachyportax* is only present in Nagri and Dhok Pathan Formation in the Siwaliks. However, the French boselaphine which were reported from the early Pliocene of European Mammal zone MN14 shows similar morphology with described genus *Pachyportax* and due to this it is considered younger than *Pachyportax* (Mein, 1989). The described species *Pachyportax latidens* is also reported from the Baynunah formation in United Arab Emirates (UAE), which has

age 8-6 Ma (Gentry, 1999). So, 7.0 Ma is approximately measured age of *Pachyportax latidens* (Barry *et al*., 1991). In African Mpesida deposits has almost similar age with Hasnot 7-6 Ma, but genus *Pachyportax* and *Salenoportax* are absent here (Hill *et al.,* 1985; Nakaya, 1994; Kingston *et al.,* 2002). *Pachyportax* and *Salenoportax* are also absent from the same age localities such as Marageh dated 9.5-7 Ma and Afghani Localities Tagar dated 8.7-8 Ma (Sen *et al.,* 1997; Bernor, 1986). Overall the Hasnot has similar fauna with the fauna of Turolian Land Mammal age as described in North Africa, West Asia and Europe.

Palaeoenvironment

The major groups of artiodactyla present in the Hasnot are *Tragoportax*, *Pachyportax*, *Selenoportax, Dorcatherium* and *Gazella*, as in other Eurasian Late Miocene sites (Vrba and Haile-Selassie, 2006; Bibi *et al*., 2009; Khan *et al*., 2009, 2010, 2011, 2012; Gentry *et al*., 2014). The artiodactyls of the Hasnot are more diversified and were increased in the time of Early Pliocene and Late Miocene to cover the open niches. Forest may be deteriorated and open plains were originated (Pilgrim, 1937, 1939; Thomas, 1977; Akhtar, 1992; Bibi *et al*., 2009; Khan *et al*., 2009, 2010). If we observe the relationship between mass and habitat, it reveals that the large artiodactyls *Selenoportax* and *Pachyportax* occupied open land while other small artiodactyls like *Dorcatherium* inhabited closed environment (Kappelman *et al*., 1997). The studies revealed that arid paleoclimate was present in Hasnot and its surroundings during Late Miocene which supported the pockets of forest lands. The drier and changeable seasonal climate may be the reason of the extinct of these artiodactyls. The artiodactyls of Hasnot preferred relatively more open and drier mosaics of woodland while the presence of medium sized artiodactyls indicates that wooded-grassy savannas and grasslands were present there (Khan *et al.,*2015).

CONCLUSION

Seven species of artiodactyls *Salenoportax vexillarius, Pachyportax latidens, Dorcatherium minus, Dorcatherium majus, Gazella lydekkeri, Hippopotamodon sivalense,* and *Propotamochoerus hysudricus* are recognized from the Hasnot, Dhok Pathan Formation. *Salenoportax* ranged throughout the middle to late Miocene and are also found in the Central and Northern Asia. *Dorcatherium minus* and *Dorcatherium majus* were present in late Miocene and were different in size. *Dorcatherium majus* were compartivly larger in size as compare to *Dorcatherium minus*. *Hippopotamodon sivalense* and *Propotamochoerus hysudricus* were particularly present in late Miocene sediments of Siwaliks. So, their presence can be considered the good indicator of the late Miocene age.

ACKNOWLEDGEMENTS

The material described here was collected from the Dhok Pathan Formation in 2014-2015 under the project Higher Education Commission of Pakistan (HEC) funded project No. 20-1620/R&D/10 3347 entitled “Extinct Bovids from the Dhok Pathan Formation of Chakwal district in the Siwaliks of Northern Pakistan”. We are also indebted to Altaf Shah and Anar Khan for their help in the field.

Supplementary material

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.pjz/20181028131031

Statement of conflict of interest

The authors declare no conflict of interest.

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