



New Fossil Remains of Giraffids from the Lower Siwaliks of Punjab, Pakistan: Evolution, Systematics and Biogeography

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ABSTRACT

Taxonomic study from a late Miocene Fossil locality Dhok Bun Ameer Khatoon, Lower Siwalik Hills of Pakistan has been conducted. New fossil remains belong to family Giraffidae which include right and left maxilla, isolated upper premolars and molars. After morphological and comparative analysis, the collection is attributed to *Giraffokeryx punjabiensis* and *Giraffa priscilla*. Size variation in dentition is taxonomically important for vertebrate evolutionary point of view and this is the main reason to conduct this study at this specific site to add additional information about family Giraffidae. The fossil site has well exposed Chinji and Nagri Formation and has dated approximately 14.2-9.5 Ma. In this study, different aspects of evolution, taxonomy and biogeographic distribution as well as the relation of Giraffidae with Procerotidae have been discussed comprehensively. Palaeoenvironment, biostratigraphy and geology of the locality have also been discussed. The coexistence of *Giraffokeryx punjabiensis* with its mammalian paleo-community reveals the persistence of mosaics of diverse habitats ranging from tropical evergreen forest to subtropical ones, closed seasonal woodlands to wooded savannas during the deposition of the Dhok Bun Ameer Khatoon, Chinji Formation.

Article Information

Received 05 August 2018

Revised 29 May 2019

Accepted 05 November 2020

Available online 09 February 2021

Authors' Contribution

KS, RY and XN presented the concept and designed the study. AA, SA and SN helped in collection and preparation of fossils. KS and BR drafted the manuscript.

Key words

Miocene, Giraffidae, Lower siwaliks, Chinji formation

INTRODUCTION

The Siwalik Group, in the northern part of the Subcontinent, consists of thick sequence of terrestrial deposits which shows a relatively high degree of completeness over most of the Neogene's time (Flynn *et al.*, 1995; Flynn, 2003). The molasse-type sediments of Neogene and that of early Quaternary age occupied the forland basin of Siwaliks which is developed at the foothills of Himalayan mountain belt. The continental sedimentation as well as complete record of vertebrate fauna especially mammals is well preserved in the stratigraphic sequence of Siwaliks (Basu, 2004).

Dhok Bun Ameer Khatoon is a small village located about 16 Km from Chua Seydon Shah (North-East) in Chakwal district, Punjab, Pakistan. This locality (32° 47' 26.4" N, 72° 55' 35.7" E) mainly composed of Miocene deposits of Lower Siwaliks. Rich fossil fauna of vertebrate alongwith unique colored shale containing unweathered igneous minerals and notable amount of feldspar is a characteristic of this locality. This area, in the southern

Potwar Plateau, has exposed the most complete sequence of Siwalik group. The stratigraphic thickness varies from 2.0 to 2.5 Km that comprises all the five formations (Soan, Nagri, Dhok Pathan, Kamlial and Chinji) of Siwalik group. The lithological composition of this zone is almost identical with their respective stratotype areas (Samiullah *et al.*, 2011, 2015).

The Siwalik giraffid fauna was studied by Falconer and Cautley (1836), Falconer (1845), Forsyth-Major (1891), Pilgrim (1911), Bohlin (1926), Colbert (1933, 1935a), Lewis (1939), Churcher (1978), Akhtar *et al.* (1991), De Bonis *et al.* (1997), Franz-Odenaal and Solounias (2004), Samiullah (2011), Samiullah *et al.* (2011, 2012, 2015) and Tariq and Jahan (2014). The main aim of this study is to provide the knowledge of Giraffid fossils found in Dhok Bun Ameer Khatoon by highlighting the aspects of evolution, systematics and biogeographical distribution at specific level.

MATERIALS AND METHODS

The Miocene deposits of the Dhok Bun Ameer Khatoon were thoroughly investigated. Several field tours in 2014 and 2015 were carried out to the studied section and different fossils were collected. Surface collection was the

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0030-9923/2021/0001-0001 \$ 9.00/0
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primary method for fossil collection. Excavations were also conducted at some places, where dense concentrations of fossil bones occur in situ within sandstone. The embedded material was excavated by using chisels, penknives and geological hammers and fine needles and brushes. During excavation, disintegration of fossils was prevented by adopting careful measures. Each specimen was completely wrapped in cotton pieces which protect it from the shocks during transportation. Eventually the specimens collected from the site were brought to the Paleontology laboratory of Zoology Department, GC University Faisalabad for morphological and taxonomic analysis.

Dust particles were removed very carefully with the help of brushes which made the specimens clear for observation. Then the specimens were washed and cleaned with the help of citric acid. Clay and other adjoined sediments were removed by using GEMKA (engraving machine, BK industries, India) fine needles and brushes. Gums and resins like magic stone and elfy etc were used to rejoin the accidentally broken fragments of specimens. A magnifying lens (Triplet 10X18mm) was used for small and more ambiguous morphological characters. A digital vernier caliper was used for measurements that given in millimeters (mm). The catalogue number PC-GCUF 05/15 was allotted to the specimens that represent the serial number (numerator) and collection year (denominator). A digital camera was used to make photograph of the studied specimens and amended hard copies were prepared in the computer. Finally, the comparison was made with specimens from the Natural History Museum, London (BMNH), the American Museum of Natural History (AMNH), the Geological Survey of Pakistan (GSP), the Geological Survey of India (GSI), and the specimens from the Palaeontology laboratory of the Zoology Department of the Punjab University, Lahore, Pakistan (PUPC). The studied material was stored in the Palaeontology laboratory of the Department of Zoology, Government College University Faisalabad, Pakistan.

SYSTEMATIC PALEONTOLOGY

Order Artiodactyla Owen, 1848
Suborder Ruminantia Scopoli, 1777
Infraorder Pecora Linnaeus, 1758
Superfamily Giraffidea Gray, 1821
Family Giraffidae Gray, 1821
Subfamily Giraffinae Zittel, 1893

Genus *Giraffokeryx* Pilgrim, 1910

Type species: Giraffokeryx punjabiensis Pilgrim, 1910

Distribution

The genus *Giraffokeryx* is only known from the Lower to Middle Siwaliks (Pilgrim, 1910; Colbert, 1935).

Giraffokeryx punjabiensis Pilgrim, 1910

Type specimen

Lectotype GSI 502, a third molar M3 of right maxilla.

Locality

Chinji and vicinity, Salt Range Punjab.

Stratigraphic range

Lower Siwaliks, Chinji Formation and lower portion of the Middle Siwaliks.

Diagnosis

Giraffokeryx is a medium sized four horned giraffid, two at the frontal on anterior extremities and two on the fronto-parietal region. Posterior horn is hanging over the temporal fossae. Limbs and feet are certainly of medium length. Teeth are brachydont with prominent rugosity on enamel as in the other genera of Giraffidae (Pilgrim, 1910).

Distribution

The species are distributed in Lower Siwaliks as well as in Middle Siwaliks (Pilgrim, 1910; Colbert, 1935). The Lower Siwalik localities are Kamli and Chinji Formation, district Attock and Chakwal respectively, within the province of Punjab, Pakistan. The locality of the Nagri zone is in the Nathot, Jhelum District of Punjab, Pakistan.

Specimens examined

PC-GCUF 01/14, left maxillar ramus having P3-M3; PC-GCUF 02/14, an isolated right third upper molar; PC-GCUF 03/14, an isolated right third upper molar; PC-GCUF 04/14, an isolated left fourth upper premolar; PC-GCUF 10/15, broken left second upper molar having protocone and metacone.

Description

PC-GCUF 01/14

It is a left maxilla with P3-M3 (Fig. 1). The length of maxilla is about 110 mm. P3 is damaged from anterior lingual side but P4, M1, M2, and M3 is excellently preserved. In P3 protocones and metacone are absent. It is a narrow-crowned tooth without definite boundary between the major cones. The central cavity is not completely observed due to the broken anterior side which also makes dentine visible from anterior lingual side. Moderately developed mesostyles and parastyles

also observed. The P4 It is a low and broad crowned tooth having antero-posterior length slightly less than the transverse width. Rugosity can be observed on the lingual side. Cingulum is absent and central cavity is shallow and wide. Moderately developed parastyle and mesostyle with well developed metastyle is observed. All the chief cusps are preserved with outer cusps slightly taller than the inner ones. The antero-posterior length is little greater in the buccal side as compared to lingual side. Posterior side of the tooth is broken at the top. In M1 Median basal pillar and cingulum is absent. The outer cones are slightly larger in size as compared to the inner cones. The paracone is well developed and slightly broader in the middle having two sharp ridges running antero-posteriorly. Anterior ridge touches the parastyle while posterior ridge is united with anterior side of metacone. Parastyle is preserved. Metacone is excellently developed, slightly higher in size than paracone. Crescentic hypocone has anterior and posterior limbs. Para-, meso- and metastyles are weakly developed. The anterior median rib is well developed as compared to posterior one. Narrow and less shallow anterior cavity compared to posterior central cavity is also present. In M2 the protocone at the anterior lingual side is well developed having anterior limb slightly taller than the posterior limb. The paracone in the antero-buccal side is pointed towards the middle. It is connected to well develop metacone from posterior side. The mesostyle is well developed and anterior median rib is prominent but slightly broken from the top. The posterior median rib is almost disappeared. Parastyle is excellently developed. In M3 the wrinkles are more prominent on the lingual side compared to those of the buccal side. The median basal pillar is present but broken. The cingulum is absent. The major cones are very well developed and the outer cones are slightly taller than the inner cones. A well developed protocone is present on the antero-lingual side of the tooth and is rounded in the middle. The anterior limb is larger than the posterior. The paracone is medially pointed and is present at the antero-buccal side of the tooth. At the posterior side it is connected to the metacone which is well developed. The metacone is almost equal to the paracone. The mesostyle is well developed and broken. The slightly broken anterior median rib is more prominent than that of the posterior. The hypocone is present on the postero-lingual side of the tooth and is well developed, having no connection with the protocone. The parastyle is prominent.

PC-GCUF 04/14

The specimen is an isolated left fourth upper premolar (Fig. 1). It is in the excellent stage of preservation. It is a low and broad crowned tooth having antero-posterior length slightly less than the transverse width. Rugosity

can be observed on the lingual side. Cingulum is absent and central cavity is shallow and wide. Moderately developed parastyle and mesostyle with well developed metastyle is observed. All the chief cusps are preserved with outer cusps slightly taller than the inner ones. The antero-posterior length is little greater in the buccal side as compared to lingual side.

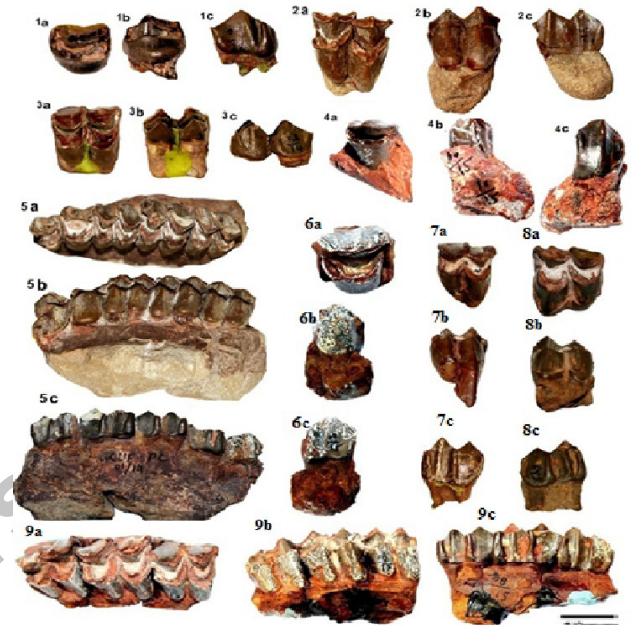


Fig. 1. *Giraffokeryx punjabiensis*: (1) PC-GCUF 04/14; left fourth upper premolar. (2) PC-GCUF 02/14; right third upper molar. (3) PC-GCUF 03/14; right third upper molar. (4) PC-GCUF 10/15; left second upper molar. (5) PC-GCUF 01/14; left maxilla having P3-M3, *Giraffa priscilla* (6) PC-GCUF 09/15; right fourth upper premolar. (7) PC-GCUF 01/15; right first upper molar. (8) PC-GCUF 02/15; left second upper molar. (9) PC-GCUF 08/15; right maxillary ramus with M1-M3. (a) Occlusal view, (b) Labial view, (c) Buccal view.

PC-GCUF 02/14

The tooth is an isolated right third upper molar in an excellent state of preservation (Fig. 1). It is brachyodont and narrow crowned. The enamel is very thick and rugose. The wrinkles are more prominent on the lingual side as compared to those of the buccal side. The median basal pillar is present but broken. The cingulum is absent. The major cones are very well developed and the outer cones are slightly taller than the inner cones. A well developed protocone is present on the antero-lingual side of the tooth and is rounded in the middle. The anterior limb is larger than the posterior. The paracone is medially pointed and is present at the antero-buccal side of the tooth. At the

posterior side it is connected to the metacone which is well developed. The metacone is almost equal to the paracone. The mesostyle is well developed and broken. The slightly broken anterior median rib is more prominent than that of the posterior. The hypocone is present on the postero-lingual side of the tooth and is well developed, having no connection with the protocone. The parastyle is prominent. The impression mark is absent on the posterior side of the tooth which confirms that the specimen under study is the last molar.

PC-GCUF 03/14

The tooth is in an excellent state of preservation. It is an isolated upper third molar (Fig. 1). It is brachyodont and narrow crowned. The enamel is very thick and rugose. The wrinkles are more prominent on the lingual side compared to those of the buccal side. The median basal pillar is present but broken. The cingulum is absent. The major cones are very well developed and the outer cones are slightly taller than the inner cones. A well developed protocone is present on the antero-lingual side of the tooth and is rounded in the middle. The anterior limb is larger than the posterior. The paracone is medially pointed and is present at the antero-buccal side of the tooth. At the posterior side it is connected to the metacone which is well developed. The metacone is almost equal to the paracone. The mesostyle is well developed and broken. The slightly broken anterior median rib is more prominent than that of the posterior. The hypocone is present on the postero-lingual side of the tooth and is well developed, having no connection with the protocone. The parastyle is prominent. The impression mark is absent on the posterior side of the tooth which confirms that the specimen under study is the last molar.

PC-GCUF 10/15

It is broken left second molar having prominent protocone and metacone (Fig. 1). Rugosity is observable in the anterior lingual side. Parastyle and mesostyles are also in preserved state. Median rib is developed.

Comparison

The specimens described here are of typical giraffid type showing almost all the basic features, such as crescentic cusps, deep enamel and its rugose sculpture, comparatively weak styles and median ribs. In *Giraffokeryx punjabiensis* the external folds are reasonably more developed in the premolars, and in the under study specimens, the styles and median ribs are not much pronounced which is a characteristic of *G. punjabiensis*. Specimen PC-GCUF 01/14 is a left maxillary segment having P3-M3. When compared with AMNH 19475, PUPC 08/33, PUPC 08/43

and PUPC 08/98, it is evident that the antero-posterior length and crown width can be compared favorably having narrow crown and the antero-posterior length of the teeth is almost equal to the transverse width (Table I). Median ribs are missing while the styles are weakly preserved which indicate that specimens under study belong to *G. punjabiensis*.

Table I. Comparative measurements of the cheek teeth of *Giraffokeryx punjabiensis* in mm.

Number	Position	Length	Width	W/L
PC-GCUF 01/14	P3	18.5	19.5	96.2
AMNH 19475	P3	20.5	20	97.5
PUPC 08/33	P3	23	21.5	93.4
PUPC 08/43	P3	16	13	81.2
PUPC 08/98	P3	23	20	86.9
PC-GCUF 01/14	P4	17.5	24	137.1
PC-GCUF 04/14	P4	20	21.5	107.5
AMNH 19475	P4	7.5	21	120
AMNH 19330	P4	17	23	135.5
PUPC 08/26	P4	18.5	21	113.5
PUPC 08/96	P4	13.5	19	140.7
PC-GCUF 01/14	M1	25	24	96
AMNH 19334	M1	24	24	100
AMNH 19311	M1	25.5	25	98
PUPC 08/105	M1	24	23	95.8
PUPC 94/07	M1	25	17	68
PUPC 02/157	M1	20.5	21	102.4
PC-GCUF 01/14	M2	27.5	27	98.1
AMNH 19472	M2	27	25	92.5
AMNH 19611	M2	26	27	96.2
AMNH 19320	M2	29	28.5	98.2
PUPC 08/18	M2	28.5	27	94.7
PUPC 08/28	M2	30	29	96.6
PUPC 69/137	M2	29	29	100
PC-GCUF 01/14	M3	25.5	26	101.9
PC-GCUF 03/14	M3	30.5	33	108.1
PC-GCUF 02/14	M3	29.5	31	105.5
AMNH 19325	M3	27.5	28	101.8
AMNH 19327	M3	23	23.5	102.1
AMNH 19475	M3	24.5	26	106
PUPC 08/117	M3	32.5	33	101.5
PUPC 66/95	M3	27	27	100

The specimens PC-GCUF 01/14 and PC-GCUF 04/14 are fourth upper left premolar that shows the striking resemblance with AMNH 19475, AMNH 19330, PUPC 08/26 and PUPC 08/96. All the teeth are broad crowned and show the typical morphology of this species. Moreover, crown width is slightly greater than the antero-posterior length. Further more, the antero-posterior length, transverse width and W/L ratio also closely related to the P4 of AMNH 19475 and others. In M1 of the specimen PC-GCUF 01/14, the median ribs along with styles are less pronounced and the measurements and tooth morphology resemble AMNH 19334, AMNH 19311, PUPC 08/105, PUPC 94/07 and PUPC 02/157. The specimen PC-GCUF 01/14, together with the M1 in the AMNH collections and PUPC are narrow crowned. The M2 of PC-GCUF 01/14 is comparable to AMNH 19320, AMNH 19472, AMNH 19611, PUPC08/18, PUPC 08/28 and PUPC 69/137 (Table I). The M3 of PC-GCUF 01/14, PC-GCUF 02/14, the right upper third molar and PC-GCUF 03/14, right upper third molar is comparable to AMNH 19325, AMNH 19327, AMNH 19472, AMNH 19475, PUPC 08/117 and PUPC 66/95 having almost similar antero-posterior lengths, crown widths and are narrow crowned. In the M3, the parastyle is more developed compared to the mesostyle and metastyle, while the posterior median rib is also missing (Colbert, 1935).

On the basis of tooth size, outline, enamel constriction and structure of crown, they resemble the species *G. punjabiensis*. The P3 measurements described here clearly resemble to those given for AMNH 19475. They all have narrow crown and their W/L ratio also resemble with the type specimen. In *Giraffokeryx*, the styles are weak, median ribs are absent or poorly developed and the crown is narrow. The teeth under study also show the resemblance with typical morphology of *G. punjabiensis*. Slight differences in the measurements obtained are due to intraspecific variation. Consequently, all the specimens under study referred to *G. punjabiensis*. Table II and Figure 2 show comparison of the studied specimens with the type specimens and already described collection of upper dentition.

Genus *Giraffa* Brisson, 1762

Type species

Giraffa camelopardalis Linnaeus 1758

Included species

G. sivalensis Falconer and Cautley 1849; *G. punjabiensis* Pilgrim, 1910; *G. priscilla* Mathew, 1929.

Distribution

The genus *Giraffa* is known from Lower, Middle and

Upper Siwaliks (Pilgrim, 1910; Mathew, 1929; Colbert, 1935). It is also found in Africa.

Giraffa priscilla Mathew, 1929

Type specimen

GSI B 511, a left M3.

Locality

Chinji, Salt range, Chakwal District, Punjab, Pakistan (Colbert, 1935).

Stratigraphic range

This species is only found in the Lower Siwaliks (Chinji Formation) of Pakistan.

Diagnosis

It distinguishes from *Giraffokeryx* by the broad and more brachyodont teeth, prominent styles (especially metastyle). Prominent anterior rib; in M3 the more oblique-set inner crescent, broad third lobe with strong accessory basal cusps in front of it, as well as shorter crown (Colbert, 1935).

Specimens examined

PC-GCUF 01/15, an isolated right first upper molar; PC-GCUF 02/15, an isolated left second upper molar; PC-GCUF 08/15, right maxilla having M1-M3; PC-GCUF 09/15, an isolated right fourth upper premolar.

Description

PC-GCUF 09/15

It is an isolated right fourth premolar and in an excellent preserved state (Fig. 1). Antero-posterior length is almost equal to the transverse width of the specimen. It is low and broad crowned tooth having rugose and thick enamel. Cingulum is absent. The central fossette is prominent towards the anterior side. Major cusps and styles are preserved well and develop properly. Well developed median rib is observed in the specimen.

PC-GCUF 08/15

GCUF-PC 08/15 is a right maxilla with M1-M3 (Fig. 1). The length of maxilla is about 81 mm. The M1 is low crowned first upper molar of right maxilla. It is extremely brachyodont broad crowned tooth having more prominent cingulum toward anterior side. The major cusps are fully developed in oblique angle to the axis of the tooth. The outer cusps are little higher vertically than the inner cusps. The crescentic protocone is present at the anterior lingual side. The metacone exists at the anterior buccal side of the tooth. The hypocone is well developed. The styles, meso-,

para-, and metastyles are prominent. The anterior median rib is well developed but posterior one is moderately developed. In M2 the protocone is crescent shaped and united with paracone with the help of a thin layer of enamel to form parastyle. The paracone is in good preserved state located at the anterior side of the tooth. It is pointed towards the middle with two sloping ridges running antio-posteriorly. The metacone is also preserved excellently pointed towards the middle with sloping ridges. Mesostyle is formed by the union of paracone and metacone. The hypocone is also well preserved. The parastyle is better preserved along with metastyle and mesostyle. The anterior median rib is prominent but broken at the top. The anterior central fossette is narrower than the posterior one. In M3 the Protocone is crescentric, joined with paracone to form parastyle. The paracone at the anterior side of the tooth is well preserved pointed towards the middle with two sloping antio-posterior running ridges. The metacone is preserved efficiently pointed towards the middle with sloping ridges. The paracone and metacone assembled to form a mesostyle. The hypocone is preserved well but broken at the posterior side. The parastyle, metastyle and mesostyle are all in better preserved state. The median ribs are not prominent. The anterior central cavity is narrower than the posterior one.

PC-GCUF 01/15

The specimen under study is low crowned first upper molar of right maxilla (Fig. 1). It is in good state of preservation. The enamel is moderately thick and rugose. The rugosity is more prominent towards the lingual side as compared to buccal side. It is in the late stage of wear. Since the teeth are completely worn, the teeth must belong to some old individual. It is extremely brachyodont and narrow crowned. The cingulum is more prominent toward anterior side. The length of the tooth is not in excess of the breadth. The major cusps are well developed. These are very oblique to the axis of the tooth. The outer cusps are slightly higher vertically than the inner cusps. The protocone is crescentic in shape and present at the anterior lingual side. The metacone located at the anterior buccal side. Due to late stage of wear, the metacone and paracone is connected to form a lope like structure. The hypocone is slightly damaged posteriorly. The styles are well developed. The median ribs are moderately developed.

PC-GCUF 02/15

It is an isolated upper low crowned second molar (Fig. 1). It is in late stage of wear. Its enamel is moderately thick and very rugose. Rugosity is more prominent towards the lingual side than buccal side. No cingulum and medial basal pillar in the transverse valley. Extremely brachyodont

and broad crowned. The length of the tooth is not in excess of the breadth. The major cusps are well developed. The outer cusps are slightly higher vertically than the inner cusps. Protocon is crescentric and joined with paracone through a thin layer of enamel to form parastyle. The paracone is well preserved. It is located at the anterior side of the tooth. It is pointed in the middle with two sloping antio-posterior running ridges. The metacone is slightly damaged posteriorly. It is pointed in the middle with sloping ridges. The paracone and metacone are connected to form a mesostyle. The hypocone is well preserved except posterior side which is missing. The parastyle is well preserved. The metastyle and mesostyle are slightly damaged. The median ribs are not prominent. The anterior central cavity is narrower than the posterior one. Small enamel is formed in the middle of the tooth due to late and advanced stage of wear.

Comparison and discussion

The described material comprises nine dental remains of giraffids from the Dhok Bun Amir Khatoon (Chinji Formation) of the Lower Siwaliks of Pakistan. Being squared and tetra tuberculated teeth; they all can be referred to some herbivorous mammalian group. Since the cusps are crescentic in outline, it can safely be included in the sub order ruminantia of the order artiodactyla. Since the enamel is strongly rugose, the tooth can be referred to the family giraffidae. General characters of giraffid teeth are: low crowned brachyodont teeth, enamel is moderately thick with prominent rugosity on the lingual side, absence of basal pillar in the transverse valley, outer cusps slightly higher as compare to inner ones, presence of all the major cones (protocone, paracone, metacone and hypocone) and of crescent shaped, anterior and posterior fossettes, median ribs may or may not prominent. All the specimens under study exhibit these characteristics. So, all belong to family Giraffidae.

Regarding size, giraffes can be placed into two forms (Sarwar and Akhtar, 1987). Small form includes the genera *Giraffokeryx* (Pilgrim, 1910) and *Giraffa* (Pilgrim, 1911) while the large one includes the genera *Bramatherium* (Falconer, 1845), *Hydasphtherium sivatherium* (Falconer and Cautley, 1845) and *Vishnutherium* (Colbert, 1935). Colbert (1935) gave the classification of Siwalik giraffes (Family Giraffidae) and divided it into three subfamilies i.e. Paleotraginae, Sivatheriinae and Giraffinae. Genus *Giraffokeryx* was placed in subfamily Paleotraginae, Sivatheriinae includes the *Sivatherium*, *Bramatherium*, *Helladotherium* and *Hydasphtherium* genera while *Giraffa* was placed in subfamily Giraffinae. The emergence of all these three subfamilies has occurred simultaneously but their migration took place at different times to the

Siwalik region. Sivatheriines came later to this region than Palaeotragines and Giraffines (Akhtar, 1996). Hamilton (1978) modified and added two new subfamilies in the above mentioned classification of family Giraffidae and divided it into five subfamilies i.e. Okapinae, Palaeotraginae, Sivatheriinae, Samotheriinae, Giraffinae and Palaeotraginae.

In genus *Giraffa*, styles and median ribs are strong and well pronounced and crown is slight broad while in *Giraffokeryx* weak styles, median ribs are absent and crown is slightly narrow. *Giraffa punjabiensis* is smaller species of genus *Giraffa* than *G. sivalensis* and *G. camelopardalis*. The upper premolars of this species are relatively smaller and narrow. *G. sivalensis* is larger than modern giraffe. The posterior half of third upper molar is reduced *G. sivalensis*. *Camelopardalis affinis* is similar to *G. sivalensis* in size but larger to the modern giraffe. In *G. Priscilla*, this broad and more brachyodont, prominent styles (especially metastyle), prominent anterior rib are observed. Parastyle is some what less developed as compared to the meso- and metastyle that are well developed. Posterior median rib is also present.

As characteristics mentioned above, it is evident that the specimens PC-GCUF 01/15, PC-GCUF 02/15, PC-GCUF 08/10 and PC-GCUF 09/15 belong to genus *Giraffa* and all the above mentioned feature sare comparable with type material GSI B 492 (described by Matthew, 1929), PUPC 02/99, PUPC 68/13 and GCUPC 1138/09 of the species *G. priscilla*. Therefore, it is concluded that, on the basis of above mentioned characters, the overall contour of the teeth, its size and enamel constriction and also the development of different crown structure, specimens are referred to species *G. priscilla*. Table II showing width/length indexes of cheek teeth of *G. Priscilla* and comparison of the studied specimens are also provided in Figure 2.

Table II. Comparative measurements of the cheek teeth of *Giraffa priscilla* in mm.

Number	Position	Length	Width	W/L
PC-GCUF 09/15	P ₄	23	22	95.6
PC-GCUF 01/15	M ₁	24	28	116
PC-GCUF 08/15	M ₁	29	28	96.5
PUPC 02/99	M ₁	24	24	100
PC-GCUF 08/15	M ₂	30	27	90
GCUF-PC 02/15	M ₂	28	29	103.5
PUPC 02/99	M ₂	25	28	112
PUPC 68/13	M ₂	25	27.5	110
GCUPC 1138/09	M ₂	25.2	28.6	113
PC-GCUF 08/15	M ₃	29	26	90

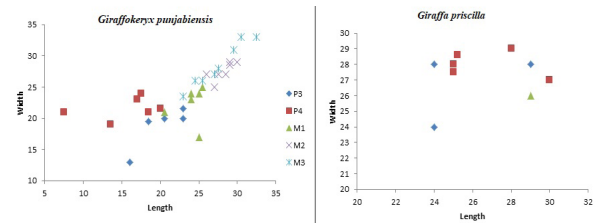


Fig. 2. Bivariate scattered graph showing of upper dentition of *Giraffokeryx punjabiensis* and *Giraffa Priscilla* with type specimen and already studied specimens.

Evolution of giraffids

Heintz (1975) gave the concept about the evolution and phylogenetic relationship of family giraffidae which was further modified by Mitchell and Skinner (2003). According to Heintz (1975), the evolution of giraffe started from deer. It was just after the *Eumeryx*. The *Climacoceras* were first giraffid to be appeared in very earliest Miocene. Then *Canthumeryx* appeared in very early Miocene, *Paleomeryx* and finally the short necked giraffids the “*Palaeotragus*” in early Miocene. This lineage through *Samotherium* (giraffes of late Miocene) split into a short necked *Okapia* having one species still alive and the modern long necked giraffes known as *Giraffa*. He arranged the evolution in following order: (1) *Canthumeryx*, (2) *Palaeomeryx*, (3) *Palaeotragus*, (4) *Samotherium*, (5) *Giraffa*.

Mitchell and Skinner (2003) modified the evolutionary concept of giraffe given by Heintz. They described that the okapi and giraffe (both have one extant species) have evolved from the Canthumerycids through the intermediate extinct forms of *Giraffokeryx*, *Palaeotragus*, *Samotherium* and *Bohlinia*. The order according to Mitchell and Skinner (2003) is thus: (1) *Canthumeryx* were the most primitive giraffes appeared about 22.8–11.2 million years before present (2a) *Giraffokeryx* lived 17.2–5.3 million years before present simultaneously with *Canthumeryx* (2b) *Palaeomeryx* lived about 15 Million years ago (3) *Palaeotragus* were appeared about 18–1.76 million years before present (4) *Samotherium* about 14.6–3.4 million years before present (5) *Bohlinia* about 11.2–5.3 million years before present (6) *Giraffa* about 12 million years to present (7) *Okapia* is a descendent from *Samotherium*, but according to Mitchell and Skinner *Okapia* is “the extant form” of *Palaeotragus* appeared about 18 million years to present.

Palaeoenvironment and feeding habits

Physical and ecological characteristics of habitat are directly related to the dietary habits of the animals (Kingston and Harrison, 2007). In Asia, warm tropical and

subtropical forest zones are represented in the Miocene period of Siwalik sequence (Northern Pakistan). The floral as well as faunal components of that period are quite comparable to the early Late Miocene of Europe (Barry *et al.*, 1985). The rainy humid environment was due to the persistency of the forested environment in Africa. The fauna of Dhok Bun Ameer Khatoon mainly contains of Artiodactyla (tragulids, bovids giraffids, suids and cervids) and Perissodactyla (rhinoceroses). In the present collection Giraffids were collected from the fossiliferous site. The association of Crocodilian skates and isolated teeth of *Gaiotherium browni*, *Deinotherium*, *Listriodon pentapotamiae*, *Dorcatherium minus*, *Dorcatherium majus*, *Giraffokeryx punjabiensis*, *Giraffa priscilla*, *Cervus punjabiensis*, and *Gazella lydekkeri* in the site, justifying that they probably had almost the same feeding resources at that time period (Samiullah, 2011).

The giraffid remains in this study justify the vegetation of Chinji Formation as seasonal woodland with riparian areas of forest. The presence of giraffids in Chinji to Nagri Formation indicates that the composition of the Siwaliks was change from seasonal woodland to tree savannas. *Giraffokeryx punjabiensis* was a mixed feeder and was better adapted to a life in savannas. They can with stand without drinking water for weeks and rely on dew drops in the morning and water contents of their food (Janis and Scott, 1987; Franz-odendaal and Solounias, 2004). It was thought that the diet of fossil Giraffids was to be similar to that of extant giraffes (committed browsers). Solounias (1988) studied the extinct giraffid *Samotherium boissieri* from the Miocene rocks of Greece (Samos) and declared it as a mixed feeder-grazer. This study had changed the notion that all Giraffids are browser. The heterogeneous diet of Giraffid fossils was further confirmed by tooth microwear analyses and premaxillary shape (Solounias and Moelleken, 1993). Among sivattheriinae the *Bramatherium megacephalum* and *Sivatherium giganteum* (Falconer and Cautley, 1836) were probably grazers but *Helladotherium duvemoysi* was a browser. The *Giraffokeryx punjabensis* (Pilgrim, 1910) was a mixed feeder where as *Palaeotragus primaevus* (Churcher, 1978) was a browser. Among the Giraffinae (Pilgrim, 1911) there are also browsing, grazing and mixed feeding taxas. In addition, Solounias and Semperebon (2002) found that the *Okapia johnstoni* (Selater, 1900), the second and rare extant species of Giraffidae, is not a browser but a fruit-dominated browser while the other extant species the *Giraffa camelopardalis* (Linnaeus, 1758) can be redefined as a leaf-dominated browser. Such dietary data suggest that the grazing in family Giraffidae was started before the expansion of C4 grasslands. Some giraffids were mixed feeders around 6 to 8 Ma (Cerling *et al.*, 1997; Harris and Cerling 1998), and they were feeding as such on C3

grasses, which were dominated in woodland environments in open meadows and near the margins of water.

Biostratigraphy

The Giraffokerycinae appeared sporadically in the Chinji beds of the Siwaliks (Bhatti *et al.*, 2007). *Giraffokeryx punjabiensis* has been documented from several localities of Siwalik late Middle Miocene (Bhatti, 2005), occupying a long geochronologic ranges from Western Europe to Indian subcontinent (Bohlin, 1926; Bosscha-Erdbrink, 1977; Gentry *et al.*, 1999). *G. punjabiensis*, in association with *Listriodon pentapotamiae*, *Conohyus indiensis*, *Gaiotherium browni*, *Brachypotherium fatehjangense*, *Sivapithecus* sp and *Deinotherium pentapotamiae* are considered to be zonal marker elements of Chinji Formation (Barry *et al.*, 2002). The Chinji fauna is in favour of Middle Miocene age because the comparison of the material with several representatives of the fauna indicates a Middle Miocene age (Pilgrim, 1937, 1939). The faunal assemblage contains elements significant enough to be compared with Astaracian of Europe and Greco-Iranian Province spanning from middle Miocene to earliest Late Miocene (Khan *et al.*, 2011). It shows overlapping of temporal ranges with that of the Chinji stratotype which correspond to the MN6 as well as MN7/8 (Colbert, 1935).

CONCLUSION

During the Late Miocene, the Lower Siwaliks were mainly characterized by the presence of two species of small-sized giraffids: *Giraffokeryx punjabiensis* and *Giraffa priscilla*. The presence of *Giraffokeryx* in the Late Miocene of the Siwaliks and the Greco-Irano-Afganian province implies at this time, the Himalayan Mountains did not act as a barrier in the dispersal of the fauna out of southern Asia. The range contraction of this species suggests that it occupied a wide territory from the Subcontinent to the Greco Irano-Afganian in Late Miocene of the Siwaliks. The paleoecology of studied taxon reveals the persistence of mosaics of diverse habitats ranging from tropical evergreen forests to subtropical ones, closed and seasonal woodlands to wooded savannas. The age of the fossils collected and studied from the Dhok Bun Ameer Khatoon is clearly later than the early Miocene, and also, they appear to be earlier than the Pliocene.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Akhtar, M., 1996. A new species of the genus

- Selenoportax* (mammalian Artiodactyla, Bovidae) from the Dhok Pathan, Chakwal district, Punjab, Pakistan. *Proc. Pak. Congr. Zool.*, **16**: 91-96.
- Akhtar, M., Sarwar, M., Saeed, M. and Khan, A.A., 1991. Vertical distribution of Siwalik Giraffids, *Acta Sci.*, **1**: 145-152.
- Barry, J.C., Johnson, M.N., 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., Morgan, M., Flynn, L., Pilbeam, D., Behrensmeyer, A.K., Raza, S.M., Khan, I., Badgely, C., Hicks, J. and Kelley, J., 2002. Faunal and environmental change in the Late Miocene Siwaliks of northern Pakistan. *Palaeobiology*, **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)
- Basu, P.K., 2004. Siwalik mammals of the Jammu Sub-Himalaya, India: an appraisal of their diversity and habitats. *Quart. Int.*, **117**: 105-118. [https://doi.org/10.1016/S1040-6182\(03\)00120-4](https://doi.org/10.1016/S1040-6182(03)00120-4)
- Bhatti, Z.H., 2005. *Taxonomy, evolutionary history and biogeography of the Siwalik giraffids*. Ph. D. thesis (unpublished), University of the Punjab, Lahore, Pakistan.
- Bhatti, Z.H., Qureshi, M.A., Khan, M.A., Akhtar, M., Ghaffar, A. and Ejaz, M., 2007. Individual variations in some premolars of species *Giraffokeryx punjabiensis* (Mammalia, Giraffidae) from Lower Siwalik (Chinji Formation) of Pakistan. *Contr. Geol. Pak. Proc. Pak. Geol. Cong.*, **5**: 261-272.
- Bohlin, B., 1926. Die Familie Giraffidae mit besondere Berücksichtigung der Fossilen Formen aus China. *Palaeontol. Sin. Ser. C*, **4**: 1-179.
- Bosscha-Erdbrink, D.P., 1977. On the distribution in time and space of three giraffid genera with Turolian representatives at Maragheh in N.W. Iran. *Proc. Koninkl. Nederl. Akad. Wetensch.*, **B80**: 337-355.
- 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**: 152-157. <https://doi.org/10.1038/38229>
- Churcher, C.S., 1978. Giraffidae. In: *Evolution of African mammals* (eds. V.J. Maglio and H.B.S. Cooke). Harvard University Press. pp. 509-535. <https://doi.org/10.4159/harvard.9780674431263.c26>
- Colbert, E.H., 1933. A skull and mandible of *Giraffokeryx punjabiensis* (Pilgrim). *Am. Mus. Novit.*, **632**: 1-14.
- Colbert, E.H., 1935. Siwalik mammals in the American Museum of Natural History. *Trans. Am. Phil. Soc.*, **26**: 1-401. <https://doi.org/10.2307/1005467>
- Colbert, E.H., 1935a. Distributional and phylogenetic studies in Indian fossil mammals. The classification and the phylogeny of the Giraffidae. *Am. Mus. Novit.*, **800**: 1-15.
- De Bonis, L., Koufos, G.D. and Sen, S., 1997. A Giraffid from the middle Miocene of the island of Chios, Greece. *Palaeontology*, **40**: 121-133.
- Falconer, H. and Cautley, P.T., 1836. *Sivatherium giganteum*, a new fossil ruminant genus from the valley of the Markanda in the Siwalik branch of the Sub-Himalayan mountains. *Asiatic Res.*, **19**: 1-24.
- Falconer, H. and Cautley, P.T., 1849. *Fauna antique sivalensis, being the fossil Zoology of the Siwalik hills, in the north of India*. London, pp. 1-9.
- Falconer, H., 1845. Description of some fossil remains of *Deinotherium*, giraffe, and other mammalia from Perim Island, Gulf of Cambay, Western Coast of India. *J. geol. Soc.*, **1**: 356-372. <https://doi.org/10.1144/GSL.JGS.1845.001.01.80>
- Flynn, L.J., 2003. Small mammal indicators of forest Paleo-environment in the Siwalik deposits of the Potwar Plateau, Pakistan. *Deinsea*, **10**: 183-196.
- Flynn, L.J., Barry, J.C., Morgan, M.E., Pilbeam, D., Jacobs, L.L. and Lindsay, E.H., 1995. Neogene Siwalik mammalian lineages: Species longevity, rates of change, and modes of speciation. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **115**: 249-264. [https://doi.org/10.1016/0031-0182\(94\)00114-N](https://doi.org/10.1016/0031-0182(94)00114-N)
- Forsyth Major, C.J., 1891. On the fossil remains of species of the family Giraffidae. *Proc. Zool. Soc. London*. **1891**: 315-326. <https://doi.org/10.1111/j.1096-3642.1891.tb01755.x>
- Franz-Odenaal T.A. and Solounias, N., 2004. Comparative dietary evaluations of an extinct giraffid (*Sivatherium hendeyi*) (Mammalia, Giraffidae, Sivatheriinae) from Langebaanweg, South Africa (early Pliocene). *Geodiversitas*, **26**: 675-685.
- Gentry, A.W., Rossner, G.E. and Heizmann, E.P.S., 1999. Suborder Ruminantia. In: *The Miocene land mammals of Europe* (eds. G.E. Rossner and K. Heissig), Verlag Dr. Friedrich Pfeil, Munchen, pp. 225-258.
- Hamilton, W.R., 1978. Fossil giraffes from the Miocene of Africa and a revision of the phylogeny of the Giraffoidea. *Philos. Trans. R. Soc. B*, **283**: 165-229.

- <https://doi.org/10.1098/rstb.1978.0019>
- Harris, J.M. and Cerling, T.E., 1998. Isotopic changes in the diet of Giraffids. *J. Vertebr. Palaeontol.*, **18**: 49A.
- Heintz, E., 1975. Origine, migration et paleobiogeographie des Paleotraginae (Giraffidae, Artiodactyla) Antevallesians de l'Ancien Monde. *Colloque Int. CNRS*, **218**: 723-730.
- Janis, C.M. and Scott, K.M., 1987. Grades and clades in hornless ruminant evolution: The reality of gelocidae and the systematic position of *Lophiomeryx* and *Bachitherium*. *J. Vertebr. Palaeontol.*, **7**: 200-216. <https://doi.org/10.1080/02724634.1987.10011653>
- Khan, M.A., Nasim, S., Ikram, T., Ghafoor, A. and Akhtar, M., 2011. Dental remains of early Bison from the Tatrot Formation of Upper Siwaliks. *Pak. J. Anim. Pl. Sci.*, **21**: 862-867.
- Kingston, J.D. and Harrison, T., 2007. Isotopic dietary reconstructions of Pliocene herbivores at Laetoli: Implications for early hominin paleoecology. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **243**: 272-306. <https://doi.org/10.1016/j.palaeo.2006.08.002>
- Lewis, G.E., 1939. A new *Bramatherium* skull. *Am. J. Sci.*, **237**: 275-280. <https://doi.org/10.2475/ajs.237.4.275>
- Linnaeus, C., 1758. *Systema Naturae per Regna tria Naturae, Secundum classes, ordines, Genera, species, cum characteribus, differentis synonymis, Locis*, 10 ed. Stockholm. <https://doi.org/10.5962/bhl.title.542>
- Mathew, W.D., 1929. Critical observations upon Siwalik mammals. *Bull. Am. Mus. Nat. Hist.*, **56**: 437-560.
- Mitchell, G. and Skinner, J.D., 2003. On the origin, evolution and phylogeny of giraffes, *Giraffa camelopardalis*. *Trans. Roy. Soc. S. Afr.*, **58**: 51-73. <https://doi.org/10.1080/00359190309519935>
- Pilgrim, G.E., 1910. Preliminary note on a revised classification of the Tertiary freshwater deposits in India. *Rec. Geol. Surv. India*, **40**: 185-205.
- Pilgrim, G.E., 1911. The fossil Giraffidae of India. *Palaeontol. Indica, N.S.*, **4**: 1-29.
- Pilgrim, G.E., 1937. Siwalik antelopes and oxen in the American museum of natural history. *Bull. Am. Mus. Nat. Hist.*, **72**: 729-874.
- Pilgrim, G.E., 1939. The fossil bovidae of India. *Palaeontol. Indica, N.S.*, **26**: 1-356.
- Samiullah, K., 2011. *Taxonomic studies of fossil even and odd-toed mammals from Miocene rocks of the Dhok Bun Ameer Khatoon, District Chakwal, Punjab, Pakistan*. Ph. D. thesis. University of the Punjab, Lahore, Pakistan.
- Samiullah, K., Akhtar, M., Ghaffar, A., and Khan, M.A., 2011. *Giraffokeryx punjabiensis* (Artiodactyla, Ruminantia, Giraffidae) from Lower Siwaliks (Chinji Formation) of Dhok Bun Ameer Khatoon, Pakistan. *J. Sci. Tech. MSU. Thailand*, **31**: 9-24.
- Samiullah, K., Akhtar, M., Khan, M.A. and Ghaffar, A., 2012. Fossil mammals (Rhinocerotids, Giraffids, Bovids) from the Miocene rocks of Dhok Bun Ameer Khatoon, District Chakwal, Punjab, Pakistan. *ARPJ. Sci. Tech.*, **2**: 69-108.
- Samiullah, K., Nasim, S., Jabeen, F., Yasin, R., Ahmad, S., Yaqub, S., Feroz, K. and Akhtar, M., 2015. *Gazella lydekkeri* from Dhok Bun Ameer Khatoon, Lower Siwaliks of Pakistan: evolution, taxonomy and biogeography. *Int. J. Biosci.*, **6**: 158-169. <https://doi.org/10.12692/ijb/6.5.158-169>
- Sarwar, M. and Akhtar, M., 1987. A new *Sivatherium giganteum* from Pabbi Hills of Potwar, Pakistan. *Kashmir J. Geol.*, **5**: 95-99.
- Slater, W., 1900. *The mammals of South Africa*. Vol. I. R.H. Porter, London, UK. <https://doi.org/10.5962/bhl.title.46403>
- Solounias, N. and Moelleken, S.M.C., 1993. Determination of dietary adaptations of some extinct ruminants determined by premaxillary shape. *J. Mammol.*, **74**: 1059-1071. <https://doi.org/10.2307/1382445>
- Solounias, N. and Semperebon, G., 2002. Advances in the reconstruction of ungulate ecomorphology and application to early fossil equids. *Am. Mus. Novit.*, **3366**: 1-49. [https://doi.org/10.1206/0003-0082\(2002\)366<0001:AITROU>2.0.CO;2](https://doi.org/10.1206/0003-0082(2002)366<0001:AITROU>2.0.CO;2)
- Solounias, N., Scott McGraw, W., Hayek, L.A. and Werdelin, L., 2000. The Paleodiet of the Giraffidae. In: *Antelopes, deer, and relatives* (E.S. Vrba and G.B. Schaller). Yale University Press. pp. 83-95.
- Solounias, N., 1988. Prevalence of ossicones in Giraffidae (Artiodactyla, Mammalia). *J. Mammal.*, **69**: 845-848.
- Tariq, M. and Jahan, N., 2014. Dietary evaluations and paleoecology of an extinct giraffid (*Giraffokeryx punjabiensis*) from siwaliks of Pakistan. *J. Anim. Pl. Sci.*, **24**: 1355-1365.