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New Fossils of *Giraffokeryx* (Mammalia: Cetartiodactyla: Giraffidae) from Chinji Formation, Pakistan

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Abstract.— This paper describes new fossils of *Giraffokeryx* originating from the Chinji Formation of northern Pakistan. The fossils, representing worth describing hemimandibles, are collected from the Middle Miocene outcrops of the Chakwal district, Punjab, Pakistan. A detailed description of the newly discovered fossils is being provided. The Chinji sample adds new information on the anatomical morphology of *Giraffokeryx* and conforms to an early distribution of the genus in the Middle Miocene of the Siwaliks.

Keywords: Palaeotraginae, giraffids, vertebrates, Middle Miocene, Siwaliks.

INTRODUCTION

Solounias (2007) noted that Giraffoidea comprises the following ranks: Palaeomerycidae, Climacoceridae, Canthumerycinae, Bohlininae, Okapiinae, Giraffokerycinae, Sivatheriinae, "Samotheriinae", "Palaeotraginae" and Giraffinae. In the Siwaliks, both large and small genera of Giraffidae are present (Pilgrim, 1910, 1911; Matthew, 1929; Colbert, 1935; Bhatti *et al.*, 2012a, b; Khan *et al.*, 2010, 2014). Four giraffid subfamilies are represented in the Siwaliks: Bohlininae, Giraffinae, Sivatheriinae and Giraffokerycinae (referred to the scheme in Solounias, 2007, p. 257). Bohlininae includes the genus *Progiraffa* (Solounias, 2007). The genus *Giraffa* is placed in the subfamily Giraffinae. The Siwalik Sivatheriinae includes the genera *Sivatherium*, *Bramatherium* and *Helladotherium* (Khan *et al.*, 2014). Giraffokerycinae comprises the genus *Giraffokeryx* (Solounias, 2007; Bhatti *et al.*, 2012a). Bohlininae is recorded from geologically older strata (Barry *et al.*, 2005). Giraffokerycinae and Giraffinae appear in the fossil record earlier than Sivatheriinae (Colbert, 1935).

The fossil remains of Giraffokerycinae described in this paper were recovered from the outcrops nearby the Dhok Bun Amir Khatoon

village (Lat. 32° 47' 26.4" N: Long. 72° 55' 35.7" E) and the Lava village (Lat. 32° 64' N: Long. 71° 95' E) of the Chakwal district, northern Pakistan (Fig.1). The outcrops are dominantly composed of bright red and brown orange siltstones interbedded with soft ash grey sandstones. The sediments were probably deposited in a fluvial environment leaving behind the fine-grained and fossil-bearing flood plains (Barry *et al.*, 2002; Khan *et al.*, 2011; Khan and Akhtar, 2011). Sandstone and reddish shale dominate the fossiliferous sites, which is the characteristics of the Chinji Formation of the Lower Siwaliks. The Formation consists of grey, sandy to muddy fluvial deposits (Barry *et al.*, 2002).

The genus *Giraffokeryx* founded by Pilgrim (1910) based on the type species *Giraffokeryx punjabiensis* comprised a low sample size. The aim of this paper is to document the newly recovered *Giraffokeryx* material. The collected hemimandibles and isolated dentitions enlarge our knowledge on the anatomic features of *Giraffokeryx punjabiensis*.

MATERIAL AND METHODS

The material is collected from the Middle Miocene sites of the Dhok Bun Amir Khatoon village and the Lava village in northern Pakistan. The measurements of the specimens were taken in millimeters (mm) with the help of a digital vernier caliper. The morphological and metrical characters of the specimens are described and their systematic determination is discussed. The catalogue number of

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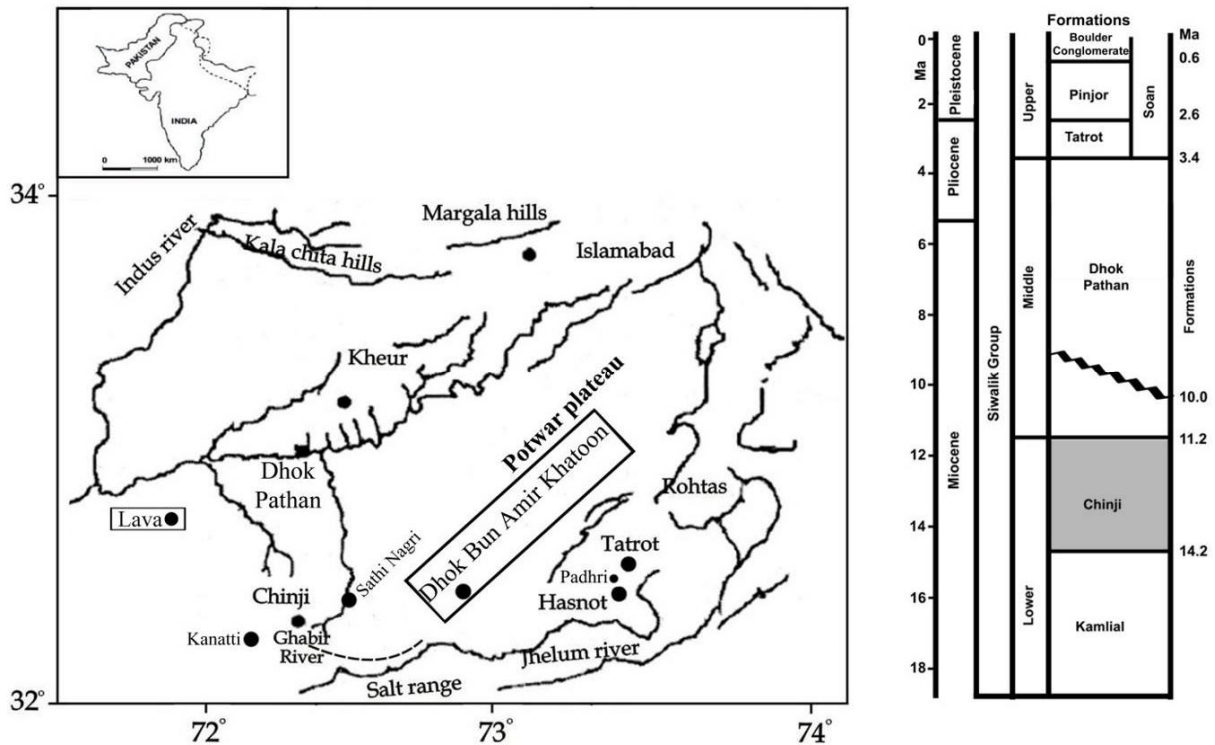


Fig. 1. The location of Dhok Bun Amir Khatoon and Lava fossil sites of the Chinji Formation, northern Pakistan, sites where the described material was found. Boundary dates are from Barry *et al.* (2002) and Nanda (2002, 2008).

the specimens consists of series *i.e.*, yearly catalogue number and serial catalogue number, so figures of the specimens represent the collection year (numerator) and serial number (denominator) of that year (*e.g.*, 09/12). Upper case letters with number stands for upper dentition (*e.g.*, M1) and lower case letters with number stands for lower dentition (*e.g.*, ml).

The studied material is the property of the Palaeontology laboratory of the Zoology Department of the Punjab University, Lahore, Pakistan. The taxonomy and terminology follows Hamilton (1973), Gentry (1994), Gentry *et al.* (1999) and Solounias (2007).

Abbreviations

AMNH, American Museum of Natural History, New York, USA; GSI, Geological Survey of India; PUPC, Punjab University Paleontological Collection, Lahore, Pakistan; DM, Deciduous

molar; P, Premolar; M, Molar; W/L, Width/Length ratio; r, Right; l, Left; mm, Millimeters.

SYSTEMATIC PALAEOLOGY

Suborder Ruminantia Scopoli, 1777
 Infraorder Pecora Linnaeus, 1758
 Superfamily Giraffoidea Simpson, 1945
 Family Giraffidae Gray, 1821
 Subfamily Palaeotraginae Pilgrim, 1911
 Genus *GIRAFFOKERYX* Pilgrim, 1910

Type species

Giraffokeryx punjabiensis Pilgrim, 1910.

Giraffokeryx punjabiensis Pilgrim, 1910

Lectotype

GSI B502, a third molar of the right maxilla.

Type locality

Chinji village (Lower Siwaliks), district Chakwal, Punjab province, Pakistan.

Known distribution

Indian subcontinent and Eurasia (Pilgrim, 1910; Colbert, 1935; Geraads, 1986; Janis, 1987; Gentry and Hooker, 1988; Bhatti, 2005; Khan *et al.*, 2010; Bhatti *et al.*, 2007a, b, 2012a).

Stratigraphic range

Lower Siwaliks and the lower portion of the Middle Siwaliks (Pilgrim, 1910; Colbert, 1935; Bhatti, 2005).

Abbreviated diagnosis

Larger than the other species of the genus. Upper molars comparatively large and subhypsodont. Parastyles and mesostyles well pronounced. Accessory column present blocking the transverse valley. The anterior rib more prominent than posterior one which is normally missing (Pilgrim, 1910; Colbert, 1935).

New material

PUPC 94/14, an isolated right deciduous third upper premolar (rDP3); PUPC 12/53, an isolated right third upper premolar (rP3); PUPC 12/54, an isolated right first upper molar (rM1); PUPC 69/37, an isolated second left upper molar (lM2); PUPC 09/93, an isolated second right upper molar (rM2); PUPC 02/13, an isolated second right upper molar (rM2); PUPC 09/88, a right hemimandible with premolars and molars (p2-m3); PUPC 09/117, a right mandible fragment with premolars and molars (p3-m3); PUPC 02/09, a left mandible fragment with partial m3.

Description

Isolated upper teeth: The teeth are highly rugose (Fig. 2). The major cusps are poorly developed in the deciduous tooth. The tooth is long, triangular and narrow. The anterior lobe is long with incomplete protocone. The parastyle is bulky than the mesostyle and the metastyle. The prefossette is elongated due to the extension of the anterior lobe. The prefossette is represented by two transverse crests and the postfossette by a spur. The third

premolar is of trapezoidal shape with a strong antero-lingual tubercle placed anteriorly. A weak lingual groove separates the protocone from the hypocone. The paracone rib is narrow and almost fused basally with well-distinguished parastyle. The less prominent metastyle is very thin and narrow.

The second upper molar is brachydont with rugose enamel. The entostyle is present. The cingulum is poorly developed. The major cusps are fairly developed. The praeparacrista is united with the parastyle whereas the postparacrista is just touching the praemetacrista. The parastyle is more developed than the meso- and metastyles. The paraconus rib is prominent whereas the metaconus rib is missing. The prefossette is narrower than the postfossette.

Mandible: PUPC 09/88 is an almost complete right hemimandible comprising the molar and premolar series, and the base of the ascending ramus (Fig. 3). The length of the hemimandible equals 274.7 mm. The complete cheek teeth series is 156.5 mm long. The mandible is labiolingually narrow. The depth of the mandible below p2 is 55 mm and 63 mm below m3. The length of the premolar series equals 63 mm and the molar series is 95.4 mm long. The diastema is broken. The ventral edge of the horizontal ramus is thick. The posterior edge of the angle of the mandible is thin (Fig. 3). PUPC 09/117 is a right hemimandible broken anteroposteriorly having a length of 169 mm (Fig. 4). The length of the premolar series is 61 mm and the molar series is 84.6 mm long. The diastema is missing.

Isolated lower teeth: The paraconid is separated from the parastyloid in the premolars (Fig.3). The anterior valley is open. The metaconid extends forward meeting the base of the paraconid. The crest joining the protoconid to the metaconid is oblique backwardly. The protoconid is connected to the hypoconid. Labially, separates the hypoconid is separated from the strong protoconid by a furrow (Fig. 3).

The molars are subhypsodont and narrow-crowned (Figs. 3, 4). The transverse valley seen in some molars represents the rudimentary ectostylid. The pre- and post-fossettids are deep. The praeprotocristid is longer than the postprotocristid. The anterior half of the protoconid is connected with the metaconid through a thin layer of enamel. The

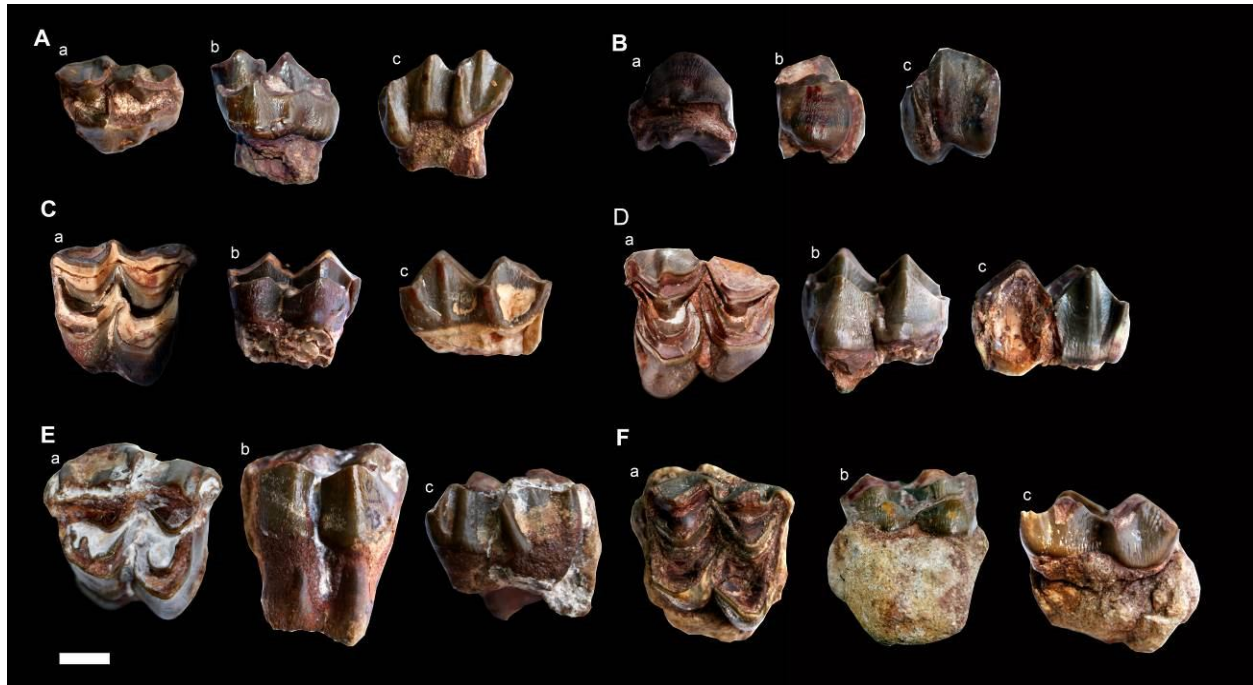


Fig. 2. *Giraffokeryx punjabiensis*: **A.** PUPC 94/14, right rDP3; **B.** PUPC 12/53, right P3; **C.** PUPC 12/54, left M1; **D.** PUPC 09/93, right M2; **E.** PUPC 02/13, right M2; **F.** PUPC 69/37, left M2. Views: a, occlusal; b, lingual; c, labial. Scale bar 10 mm.

postmetacristid touches with the praentocristid. The crescent-shaped hypoconulid is present posteriorly in the third molar. The postentocristid is joined with the hypoconulid. The lingual side of the hypoconulid is higher than the labial one. The stylids are weakly developed. The stylids are more prominent at the apex of the crown and less distinct to the base of the tooth. The paraconus rib is more prominent than the metaconus rib.

Comparison

The specimens exhibit typical giraffid features in representing rugose enamel and obliquely situated labial cusps (Pilgrim, 1911; Matthew, 1929; Colbert, 1935; Bhatti *et al.*, 2012a) (Figs. 2-4). The specimens under study are smaller in size so cannot be compared with the large taxa of the subfamily Sivatheriinae (*Helladotherium*, *Hydaspitherium*, *Vishnutherium*, *Sivatherium* and *Bramatherium*) (Khan *et al.*, 2010; Bhatti *et al.*, 2012a). They can be referred to the small giraffes of the subfamilies Palaeotraginae (*Propalaeomeryx* and *Progiraffa*), Giraffinae (*Giraffa*) and

Giraffokerycinae (*Giraffokeryx*). The specimens differ from Palaeotraginae in having a relatively higher degree of hypsodonty. The sample differs from Giraffinae in having less developed external folds (de Bonis *et al.*, 1997; Solounias, 2007).

The studied specimens present by the following characteristics: brachyodont with rugose enamel, weak styles/stylids and entostyles/ectostylids, and weak median ribs. The P3 is narrow crowned, with a crescent-shaped fossette. The upper third premolars are longer than the fourth premolars (Table I). In the upper molars, the parastyles and mesostyles are well differentiated, and the metastyles are weakly developed. The median ribs are incipiently developed and the entostyles are absent. These features associate the sample to the subfamily Giraffokerycinae and the genus *Giraffokeryx* (Pilgrim, 1911; Matthew, 1929; Colbert, 1935; Harris *et al.*, 2010; Bhatti *et al.*, 2012a). This taxon is distinguished by brachyodont to subhypsodont teeth with some degree of variability.

Teeth similar to the newly collected specimens



Fig. 3. *Giraffokeryx punjabiensis*: PUPC-09/88, a right hemimandible with p2-4 and m1-3. Views: a, occlusal; b, lingual; c, labial. Scale bar 30 mm.

described above, belonging to the species *Giraffokeryx punjabiensis*, are stored in collections of the American Museum of Natural History New York, USA, the Indian Museum, Kolkata, India, and the Zoology Department, University of the Punjab, Lahore, Pakistan (Figs. 2-4) (Pilgrim, 1910, 1911; Matthew, 1929; Colbert, 1935; Harris *et al.*, 2010;

Bhatti *et al.*, 2012a). The stylids and median ribs are less pronounced in the studied specimens, the feature of *Giraffokeryx punjabiensis*. Morphometrically, the specimens resemble the already described samples of *Giraffokeryx punjabiensis* (Figs. 2-5) and should be assigned to *Giraffokeryx punjabiensis*. The specimens are a

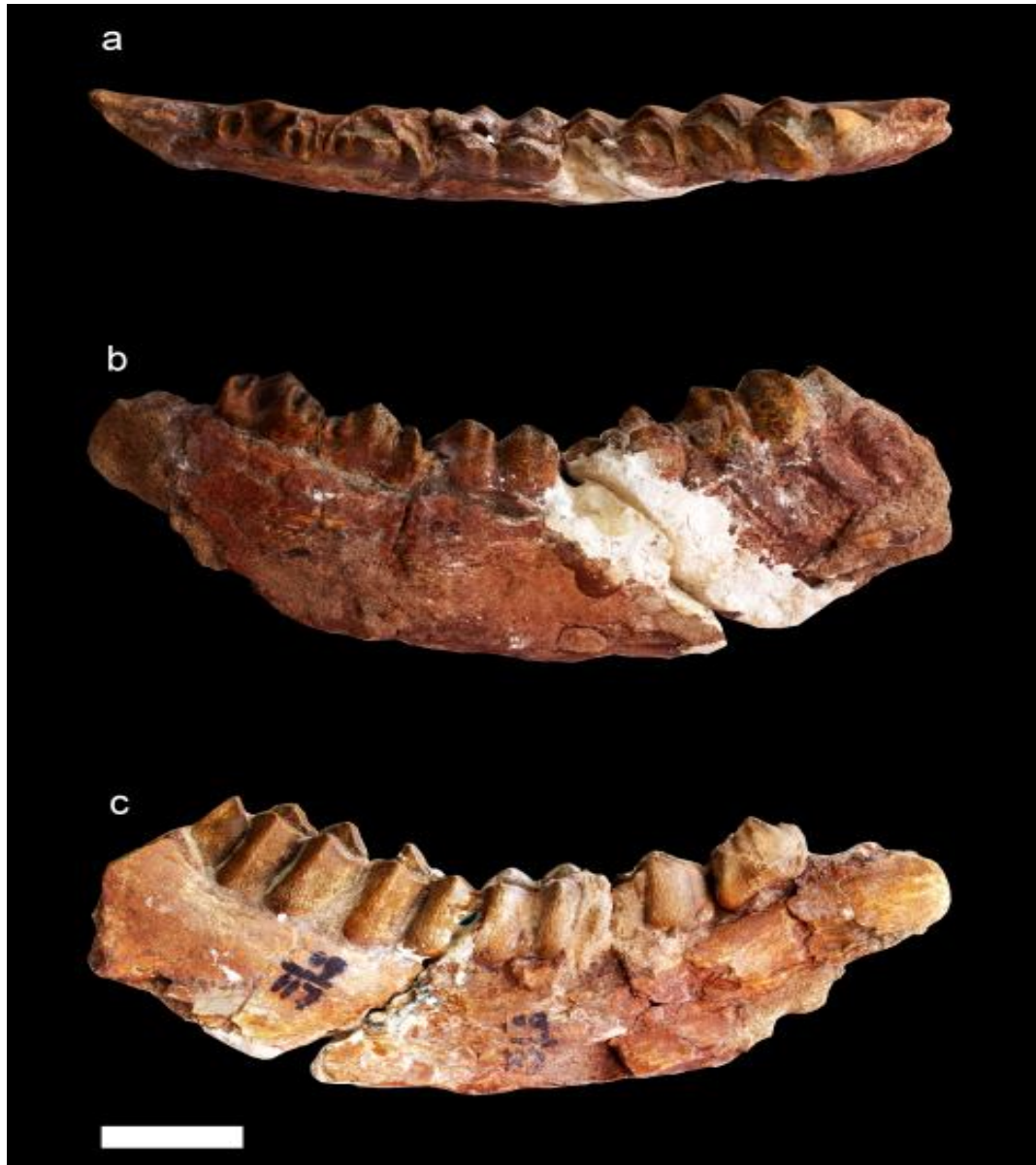


Fig. 4. *Giraffokeryx punjabiensis*: PUPC-09/117, right mandible fragment with p2-3 and m1-3. Views: a, occlusal; b, lingual; c, labial. Scale bar 30 mm.

pretty good match to *Giraffokeryx punjabiensis*, a small sized taxon of giraffids, found in the Middle Miocene of the Siwaliks.

DISCUSSION

During the Middle Miocene, the Lower Siwaliks were characterized by the presence of a Giraffokerycinae species: *Giraffokeryx punjabiensis*

(Pilgrim, 1911; Matthew, 1929; Colbert, 1935; Barry *et al.*, 2005; Khan *et al.*, 2010; Bhatti *et al.*, 2012a). In the Siwaliks, *Giraffokeryx punjabiensis* was identified as the single valid species of the genus *Giraffokeryx*, recorded from the Middle Miocene of the Siwaliks. The species is known from the Lower Siwaliks and the lower part of the Middle Siwaliks, which is the appearance datum of the Siwalik hipparionine (Matthew, 1929; Colbert,

1935; Barry *et al.*, 2002).

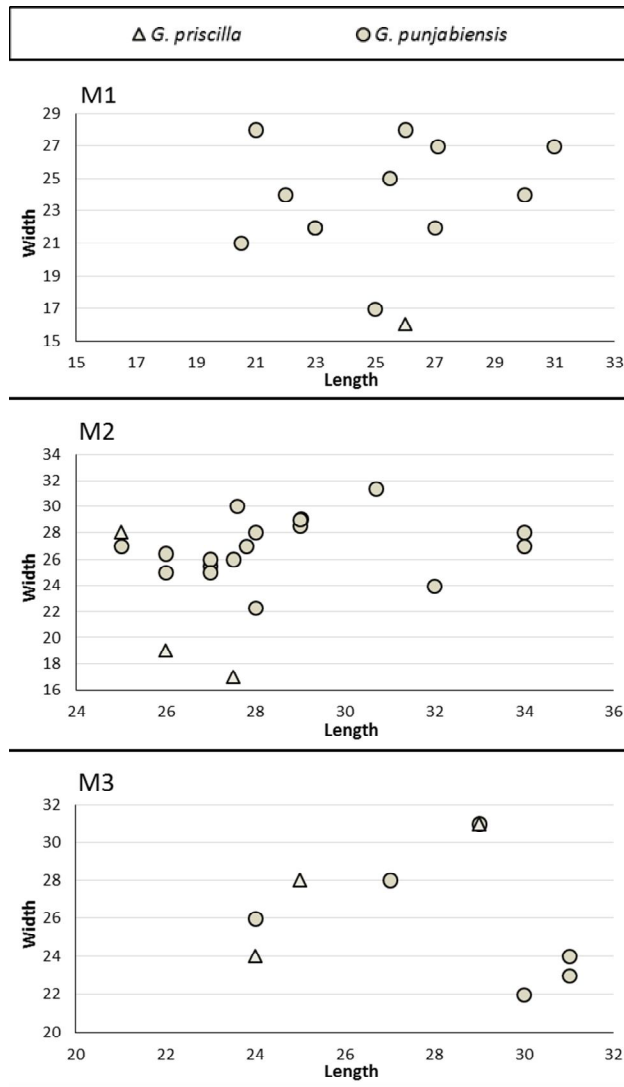


Fig. 5. Bivariate plot showing the size variation in the Middle Miocene giraffids of Pakistan.

Giraffokeryx punjabiensis has also been recorded from the Greco-Irano-Afganian province (Geraads *et al.*, 1995; Geraads and Aslan, 2003). The presence of *Giraffokeryx* in the Middle Miocene of the Siwaliks and the Greco-Irano-Afganian province implies that, at that 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 the Middle Miocene of the Siwaliks.

Table I.- Comparative measurements (mm) of the cheek teeth of *Giraffokeryx punjabiensis*. *the studied specimens. Referred data are taken from Pilgrim (1911), Colbert (1935), Gentry (1990), Barry *et al.* (2005), Samiullah *et al.* (2012) and Bhatti *et al.* (2012a, b).

Taxa	Number	Nature	L	W	W/L
<i>G. punjabiensis</i>	PUPC 94/14*	rDM3	24.8	19.0	1.30
	PUPC 12/53*	rP3	21.0	19.2	1.09
	PUPC 12/54*	IM1	27.0	27.0	0.99
	PUPC 09/93*	rM2	30.6	31.3	0.98
	PUPC 02/13*	rM2	27.5	30.0	0.92
	PUPC 69/37*	IM2	29.0	29.0	0.99
	PUPC 09/117*	rp2	12.9	6.01	2.15
		rp3	21.8	13.1	1.66
		rp4	21.7	13.2	1.64
		rm1	23.4	13.5	1.74
		rm2	25.0	16.0	1.56
		rm3	35.2	17.7	1.99
	PUPC 02/09*	m3	38.7	17.9	2.16
	PUPC 09/88*	p2	16.3	9.61	1.70
		p3	21.9	15.2	1.44
		p4	25.4	16.2	1.56
		m1	26.8	20.0	1.34
		m2	29.3	20.1	1.46
	m3	40.6	18.9	2.15	
AMNH 19475	M1	22.0	24.0	1.09	
	M2	25.0	27.0	1.08	
	M3	24.0	26.0	1.08	
AMNH 19334	M1	25.5	25.0	0.98	
AMNH 19311	M1	23.0	22.0	0.96	
AMNH 19593	M1	23.0	22.0	0.96	
AMNH 19472	M2	27.0	25.5	0.94	
AMNH 19320	M2	29.0	28.5	0.99	
AMNH 19611	M2	27.0	26.0	0.97	
AMNH 19587	P2	18.0	9.00	0.50	
	P3	20.5	12.0	0.58	
	P4	24.0	15.0	0.62	
PUPC 95/23	IP4	20.0	23.0	1.15	
	IM1	31.0	27.0	0.87	
	IM2	34.0	28.0	0.82	
PUPC 86/84	IM3	31.0	23.0	0.74	
	rM1	21.0	28.0	1.33	
	rM2	34.0	27.0	0.79	
GSI K13/349	rM3	31.0	24.0	0.77	
	P4	22.0	20.0	0.90	
	M1	30.0	24.0	0.80	
AMNH 19318	M2	32.0	24.0	0.75	
	M3	30.0	22.0	0.73	
	rP4	24.0	20.0	0.83	
GSI B182	rM1	27.0	22.0	0.81	
	rM2	26.0	25.0	0.96	
	M3	29.0	31.0	1.06	
PUPC 94/7	IM1	25.0	17.0	1.47	
PUPC 02/157	IM1	20.5	21.0	0.98	
PUPC 69/137	IM2	29.0	29.0	1.00	
PUPC 94/1	IM2	27.0	25.0	1.04	
PUPC 94/3	IM2	27.5	26.0	1.06	
PUPC 02/100	IM2	28.0	22.3	1.26	

	PUPC 94/2	rM2	26.0	26.4	0.98	
	PUPC 02/13	rM2	27.8	27.0	1.03	
	PUPC 66/95	lM1	26.0	28.0	0.93	
		lM2	28.0	28.0	1.00	
		lM3	27.0	28.0	0.96	
	PUPC 02/06	rp2	16.0	9.00	1.78	
		rp3	21.0	12.5	1.68	
		rp4	23.0	14.5	1.59	
	PUPC 02/12	rm3	34.0	18.0	1.89	
	PUPC 02/19	rm3	30.0	19.0	1.58	
	PUPC 02/15	lm3	29.5	17.5	1.66	
	AMNH 19317	m3	37.0	18.0	0.48	
	AMNH 19623	m2	29.0	14.5	0.50	
		m3	35.0	15.5	0.44	
<i>G. priscilla</i>	AMNH 19849	M1	26.0	16.0	0.61	
	PUPC 08/10	M2	27.5	17.0	0.62	
	PUPC 08/10	M2	26.0	19.0	0.73	
	PUPC 08/29	M3	25.0	28.0	1.12	
	PUPC 02/99	M3	29.0	31.0	1.06	
	GS1 B182	M3	24.0	24.0	1.00	
	PUPC 02/99	M2	25.0	28.0	0.89	

In the Chinji Formation of the Lower Siwaliks, the small sized giraffids associated with artiodactyls whereas perissodactyls associated with proboscideans (Matthew, 1929; Colbert, 1935; Khan *et al.*, 2011, 2013, 2014). The larger taxa, such as *Dorcatherium*, are likely to be dependent of grasses, associated with wet meadows, floodplains, or permanent drainage (Khan and Akhtar, 2013). The suids and giraffes are commonly found in open woodlands and presumed to have been mixed feeders. *Giraffokeryx punjabiensis* suggests the presence of woodland in the Dhok Bun Amir Khatoon and Lava regions at the time of deposition during the Middle Miocene.

CONCLUSIONS

Giraffokeryx punjabiensis, a Middle Miocene species of the Giraffidae, was recorded from the outcrops nearby the Dhok Bun Amir Khatoon and Lava villages of the Chinji Formation. *Giraffokeryx punjabiensis* had a taxonomic stability in Middle Miocene of the Siwaliks. The Dhok Bun Amir Khatoon and Lava localities are the richest Middle Miocene Siwalik localities in which *Giraffokeryx punjabiensis* was found. *Giraffokeryx punjabiensis* was common in the pre-hipparionine assemblages on the territory of northern Pakistan.

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